Using VRML to Share Large Volumes of Complex 3D Geoscientific Information via the Web

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Abstract

Scientists within Geoscience Australia (GA) create complex 3D models of geological structures, using specialised 3D modelling software. Very few people outside GA have access to this specialised software. To provide clients and stakeholders with access to 3D information GA has developed VRML-HTML-JavaScript interfaces. These interfaces allow GA to share large volumes of complex 3D geological information via the Web, with data volumes up to 22 MB. A number of methods are employed to allow users to interact with such large amounts of data. The geometric features within VRML are used to represent a wide range of geological features. The interfaces are user friendly and provide users with a high level of interaction with the complex information.

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1. Introduction

Geoscience Australia (GA) is the Australian Government's national geoscience agency, tasked with producing geoscientific information and knowledge, to enable the government and the community to make informed decisions about resource exploration, environmental management and safety of critical infrastructure for the benefit of all Australians [Geoscience Australia 2005a].

GA uses the Virtual Reality Modelling Language (VRML) to publish 3D geoscientific models on the Web. The unique features of these models are the large volumes of data provided, the range of complex geoscientific features represented and the interactivity provided for users within an easy to use interface.

GA started publishing complex 3D VRML models on the Web in 2001, with the Leonora-Laverton model, which presents a 3D view of surface and sub-surface geological structures under the Leonora-Laverton region, Western Australia. Data includes a digital elevation model, surface geophysical and geological images, 3D fault planes and rock volumes, mineral deposit and geochronology sites [Geoscience Australia 2005b]. The website (http://www.ga.gov.au/map/web3d) now houses this model plus three more - Tasmania, Gawler and Tanami - covering regions of Tasmania, South Australia, Western Australia and the Northern Territory respectively. GA, in cooperation with the Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management (Coastal CRC), has also published three other models on the OzEstuaries website (http://www.ozestuaries.org/projects/3D_index.jsp) – Sydney Harbour, Woody Island and Keppel Bay and Fitzroy River Area – focussing on coastal data for regions of New South Wales, Western Australia and Queensland. GA plans to publish more models on the web in the near future.

Development of 3D VRML models within GA was driven by a need to share 3D information with a broad audience. For some time now scientists within GA have used specialised 3D modelling software to compile, view and interpret 3D information. However, many of GA's peers, stakeholders and clients do not have access to this 3D modelling software, due to the high cost and niche nature of the software. Another driver was the Australian Government's mandate to make information freely available and accessible to clients and the public via the Web. To meet this need to share 3D information via the Web, GA chose to use open and free technologies that are easily viewed with Web browsers and free plug-ins – hence the development of VRML-HTML-JavaScript models (VRML models). Since 2001 more than 40 models have been created, mostly for distribution at conferences and workshops, rather than via the Web. For more information on the use of VRML models within GA see Beard et. al. [2005].

3D VRML models are very effective communication tools, enabling users to easily explore complex scientific ideas. As an example, scientists within GA use VRML models to explain processes within and output from *3D Geomodeller* – new 3D modelling software for automatically creating sub-surface geology models. Results from *3D Geomodeller* are compiled into VRML models to explain how the software works. Using VRML models reduces explanation time and, more importantly, provides audiences with a good understanding; enabling discussion of important issues, including the benefits and draw backs of *3D Geomodeller's* methods and implications for understanding the geology of the modelled area [Beard et. al. 2005, Lane, pers. comm. 2005].

Others have also used VRML to share 3D geoscientific information via the Web, including Gill et. al. [2004], McCann [2002 and 2005] and Thurmond et. al. [2005]. This paper does not review this other work, since it is a description of GA's application of VRML to displaying geoscience data, rather than a research paper.

2. Model structure and creation

GA's 3D VRML models use VRML, HTML and JavaScript. The basic structure is a parent HTML with frames for the model title,

navigation controls, layer list and 3D display (see Figures 1 and 2). This parent HTML also contains the JavaScript functions for externally interacting with the VRML files and for all other interactivity.

The structure of the VRML files is a single parent file that references many individual data files, one for each 3D object (geological feature). The parent file uses *Switch* and *Inline* nodes to reference the individual data files and to enable each individual file to be turned on and off in the 3D display frame. The parent file also contains navigation, lighting, viewpoint and animation information for the entire model. The animation allows users to change the vertical exaggeration (Z axis stretch) of the model and to automatically spin the model around the centre point.

Some of the user interactivity requires changes within the individual VRML files. These changes are made by using external protos to pass information from the JavaScript functions through the parent VRML file to the individual VRML files. Individual files also use protos to create new nodes (such as discs with attached attribute information) and to reduce file sizes in cases where many similar objects are used.

The VRML files contained within GA's models have two sources. Many files are exported from 3D modelling applications (including *Gocad*, *Virtual GIS* and *3D Geomodeller*), while others are created by reformatting data from digital text files, often using *GAWK* to automate the process (*GAWK* is a pattern scanning and processing language good for reformatting digital text files [Open Source Technology Group 2006]). The files exported from applications are manually edited to remove unnecessary information (such as standard viewpoints created by the applications), then automatically edited with *Chisel* to remove data duplication and default values and in some cases to reduce the coordinate precision of the data (*Chisel* is a free VRML optimisation tool [Institutt for energiteknikk 2006]). For web delivery, all VRML files are zipped, again using *Chisel*. The parent VRML and HTML files are all created manually.
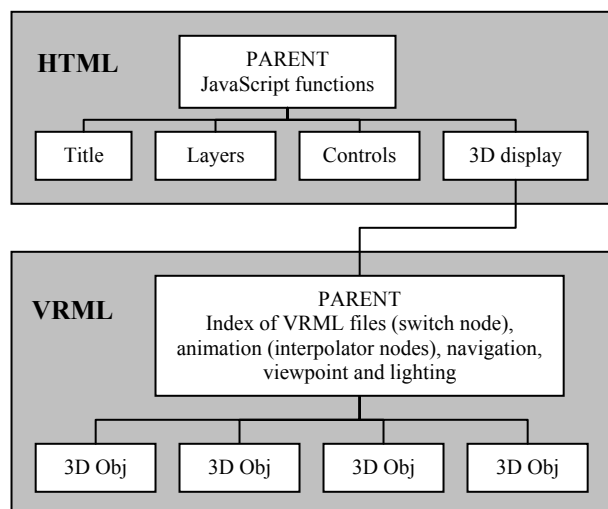

Figure 2. HTML and VRML structure of GA's models.

Since each model uses the same VRML-HTML-JavaScript template, new models are easily created by taking this template, adding the new VRML files and editing the parent VRML and HTML files.

For more information on how GA creates VRML models see Hay [2003].

3. Sharing large volumes of 3D data via the Web

The online 3D models contain large volumes of data, as illustrated by the Gawler model, which contains over 2600 VRML data files. Even when zipped these files total more than 22 MB, yet users can successfully view and interact with this model over a 56 kbps modem connection.

It is necessary for the models to work over a 56 kbps modem connection because GA has a policy of making online data as accessible as possible to all members of the Australian community. This policy is driven by Australian Government web accessibility guidelines [Australian Government Information Management Office 2003] and by the slow uptake of broadband Internet within Australia – especially in remote regions with limited infrastructure for Internet access. Some of GA's clients are in these remote regions. At the end of March 2005 only 30% of Australia's 5.98 million Internet subscribers were using broadband connections; where broadband is defined as an 'always on' connection with access speed equal to or greater than 256 kbps. However, uptake of broadband is increasing, from only 9% of subscribers at the end of March 2003 and 16% at the end of March 2004 [Australian Bureau of Statistics 2005]. This increasing uptake may influence how GA supplies 3D information over the Web in the future. For example, we are currently developing models that provide users with the ability to choose between lower and higher resolution representations of the same data. Users with fast Internet connections will be able to choose the higher resolution representations and those with slow connections will be able to choose the lower resolution representations.

A number of methods are used to optimise the sharing of such large volumes of data over the Web, including on-demand download, file re-use, efficient geometric features, compression, low and high resolution data alternatives, warnings for users and advice to scientists [Beard et. al. 2005].

3.1 On-demand download

On-demand download means users only receive the files they request. In the case of the Gawler model the initial download is not 22 MB, but only 400 kB - the HTML interface and a small number of VRML files. All other VRML files are downloaded when selected from the layer list by the user. As a result users are able to start interacting with the model far sooner than they would if they had to wait for the entire model to download.

3.2 File re-use

In some models large VRML files are used to represent more than one geological feature. In these cases the VRML files are downloaded once only and external protos are employed to re-use the VRML files. For example, many of the models created by GA include a single large indexed faceset VRML file to represent terrain. Images that display terrain information (such as height above sea level, satellite images, geological maps and geophysical images) are draped over the indexed facesets. External protos are used to switch between the draped images so that only one indexed faceset file is required for the many images.

3.3 Efficient geometric features

To reduce VRML file sizes the most efficient geometric features are used to represent geological data. For example, terrain models can be represented by *IndexedFaceSets* or *ElevationGrids*. In most cases GA's models use *IndexedFaceSets*, as they result in smaller file sizes, since they allow small and dense triangles in areas of complex terrain and large and sparse triangles in areas of less complex terrain. *ElevationGrids* on the other hand require a dense grid across the entire terrain.

3.4 Compression

We use the VRML editing software *Chisel* to optimise and compress VRML files. Optimisation is used to remove duplicate data and default values and to reduce coordinate precision. Compression is used to convert the files from ASCII to binary.

3.5 Low and high resolution alternatives

A number of models that are soon to be released on the GA and OzEstuaries Web sites provide users with multiple versions of some data layers – lower resolution versions for users with low speed Internet connections and higher resolution versions for users with high speed connections. The different versions are clearly identified in the layer lists.

3.6 Warnings for users

All the models available on the GA and OzEstuaries Web sites contain start-up warnings, stating that some files are large and estimating maximum download times for these files over non-broadband connections. In the Gawler model large files are clearly identified by warning signs against the layer names in the layer list.

3.7 Advice to scientists

The process of ensuring file sizes are acceptable for online viewing starts with the creation of source 3D information, by advising scientists of methods for limiting the final VRML file sizes. Advice includes limiting the number of triangles in triangulated surfaces. For example, a file with 10 000 triangles will be approximately 100 kB when compressed, which will take approximately 20 sec to download on a 56 kbps modem connection. Scientists are also advised to filter vertices from source line data, as there are often many unnecessary vertices.

4. Using VRML to represent complex geological features

The models created by GA contain large amounts of complex geoscience data, represented by points (sample sites, mineral deposits, earthquake epicentres), lines (boundaries, seismic interpretations), planes (cross-sections, seismic sections), indexed facesets (terrain, bathymetry and fault surfaces), volumes (complex 3D rock volumes, 3D cubes of geophysical data), 3D objects such as cylinders (drill hole paths), and images (raster maps, satellite images) (see Figure 3) [Beard et. al. 2005]. This paper will now discuss some of the innovative methods used to convey information about some of these geoscientific features.

4.1 Slicing through 3D cubes of data

Some models use 2D planar slices to represent 3D grids or cubes of data – two vertical planes and one horizontal plane. Each slice contains an *IndexedFaceSet* rectangle with a raster image of the data, created in specialist software (*Gocad*) by slicing 3D grids at regular intervals. Users are able to drag these slices through the cube and add multiple slices. *PROTOs* and *ROUTEs* and *PlaneSensor* and *Script* nodes are used to enable this interactive slicing. Figure 4 shows slices from the Gawler model.

4.2 Attribute information

The models provide attribute information via tooltips and live connections to databases, using *Anchor* and *TouchSensor* nodes. A tooltip displaying attribute information is shown in the 3D display frame in Figure 1. In the Tanami model VRML features link to large amounts of attribute information contained within one of GA's Web visible databases. The VRML features are extruded discs, representing locations for geochronology (geological age dating) samples. Clicking on these discs causes PHP requests to be sent to the database, returning HTML tables of attribute information about the sites.

5. Interactive user interface

We ensure the models are effective communication tools by creating user friendly interfaces that allow users to interact with the 3D information. The following interactive capabilities are provided for users and are built with standard HTML and JavaScript tools, including buttons, check boxes, radio buttons, drop-down lists and cascading lists (see Figures 1 and 4).

- Add and remove 3D objects from the display, allowing users to compare and contrast the 3D spatial relationships between many different data types.
- Change the VRML navigation method.
- Automatically spin the 3D objects.
- Select from a number of centre rotation points.
- Refresh the 3D display – useful for when users become lost in models.
- Vary the vertical exaggeration (Z axis stretch) applied to the 3D objects. This helps users to see patterns and spatial relationships within the data in the Z axis, since many models have relatively small Z dimensions in comparison to the X and Y dimensions.
- Select viewpoints, to display selected data from optimum viewing angles. Available viewpoints include perspective views and orthographic views. Perspective views provide a natural view of depth within the 3D space. However, with these views it is not possible to compare horizontal relationships between features at different heights, due to perspective distortion. Orthographic views remove this distortion.
- View reference 3D objects, such as coordinate grids, scale bars and compass markers.
- Access attribute information by hovering over 3D features.
- Access more detailed attribute information via live database connections.
- Drag slices through 3D cubes of geophysical data.
- Access help information and metadata on the geological properties of the 3D objects in the display.

Our user interface is also discussed by Beard et. al. [2005].

6. Solutions to limitations

GA's 3D VRML models are very effective communication tools, but they do have limitations, so we have developed solutions to mitigate the impact of some of these limitations.

The models only work with *blaxxun Contact 5* and *BS Contact 6* VRML viewers, since they use an external authoring interface (EAI) and different plug-ins use different methods for external authoring. We chose to use *blaxxun Contact* and *BS Contact* because the method used by these plug-ins is open and uses JavaScript. Moving to X3D should overcome this dependency, since the EAI is better defined in the X3D specification [Hay, pers. comm. 2005].

GA's VRML models meet the interactivity needs of most users and data types, but not all. For example, users are not able to select any point as the rotation centre point, gather X, Y and Z coordinates for selected points, nor interactively slice through 3D data. We have partly overcome the first problem by providing users with the ability to select a small number of rotation centre points. The third problem is partly overcome by providing cross-section slices through 3D grids.

Our VRML models are optimised for viewing with 56 kbps modems, but bandwidth is still a problem. Some 3D data files are very large (up to 1.4 MB) and may take up to 5 minutes to download. Files that are too large for online viewing must be resampled, thus compromising data quality in exchange for data access. This problem will be partly overcome by the increased uptake of broadband Internet by our clients, as discussed in Section 3 of this paper.

Some of our clients and stakeholders would like to add their own data to the models by simply pressing a button, since they lack the required scripting knowledge. This problem will only be overcome by free and accessible software that replicates the capabilities of the VRML models and allows users to easily add their own data. Such software does not currently exist.

In areas of high data density it is possible to build very accurate 3D models, however many geoscience datasets have sparse source data, meaning scientists apply their expert knowledge to create geologically plausible interpretations. To explain the quality of the source data for our models we provide detailed metadata. We also provide some graphical views of data quality, such as VRML layers showing the points used to create triangulated surfaces.

These solutions to limitations are also discussed by Beard et. al. [2005].

7. Future directions

GA intends to continue improving Web delivery of 3D models by migrating from the VRML file format to the X3D format. A number of the enhancements of X3D over VRML should improve GA's 3D models. First, since X3D is an XML (eXtensible Markup Language) format it should enable better management and exchange of 3D data, through easy interaction with other XML formats. Second, X3D models should operate on all X3D viewers, unlike VRML models which are tied to particular players. Third, the X3D binary format promises much greater file compression than is possible with zipped VRML files [Web3D Consortium 2005a].

We also intend to continue improving the functionality of the model interface. For example, models currently under development contain multiple versions of some data layers (lower and higher resolution versions), allowing users to choose between downloading smaller and larger files.

GA also plans to provide users with the capacity to download whole models, in addition to online viewing of files on-demand (the current status). Downloading whole models will allow users to run models from their hard disk, improving model performance [Beard et. al. 2005].

8. Conclusion

The VRML-HTML-JavaScript models developed by GA have proved to be very effective communication tools. They make it possible to share large amounts of 3D geological information with wide audiences, via the Web. The large range of *geometric* features available within VRML enable representations of many different *geoscientific* features. GA continues to develop these models and is especially looking to X3D for future development.

Addendum – further technical information

From Beard et. al. [2005].

The Virtual Reality Modelling Language (VRML) is a file format for 3D graphics for the Internet. It was developed by the VRML Consortium and the VRML moderated email list and formalised into an international standard (ISO/IEC 14772) by these groups and the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). The VRML specification is available from the following Web site: http://www.web3d.org/x3d/specifications/vrml [ISO/IEC 1997].

This ISO/IEC standard is version 2 of VRML, known as VRML 2.0 or VRML 97. It was published as a standard in 1997. The first version (VRML 1.0) was published in 1994. VRML 1.0 specified static 3D objects and scenes. VRML 2.0 extends VRML 1.0 by adding movement – enabling 3D objects to move within the 3D worlds and users to interact with the objects [Carey and Bell 1997]. For more information on the history of VRML see Carey and Bell [1997]. Much information on VRML, including tutorials, is available from the Web3D Consortium web site: http://www.web3d.org/x3d/vrml/index.html [Web3D Consortium 2005b]. The 3D VRML models developed by GA use VRML 2.0.

VRML files can be viewed within web browsers. However, VRML viewer plug-ins must be installed. Numerous free plug-ins exist. One downfall of the VMRL specification is that it fails to clearly define external interactions with VRML files. Consequently, different plug-ins use different methods to perform these interactions, so VRML worlds will not work with all plug-ins. The 3D VRML models developed by GA work with the blaxxun Contact 5 and BS Contact VRML/X3D and BS Contact Stereo plug-ins. Blaxxun Contact 5 is available from the blaxxun technologies Web site: http://www.blaxxun.com/home/index.php?option=com_frontpage&Itemid=1 [blaxxun technologies 2005]. BS Contact VRML/X3D and BS Contact Stereo are available from the Bitmanagement Software GmbH web site: http://www.bitmanagement.com [Bitmanagement Software GmbH 2005].

X3D is an Open Standards XML-enabled 3D file format. It is the next generation of VRML, in XML (eXtensible Markup Language) format [Web3D Consortium 2006a]. Much information on X3D is available from the Web3D Consortium Web site: http://www.web3d.org [Web3D Consortium 2006b].

Acknowledgements

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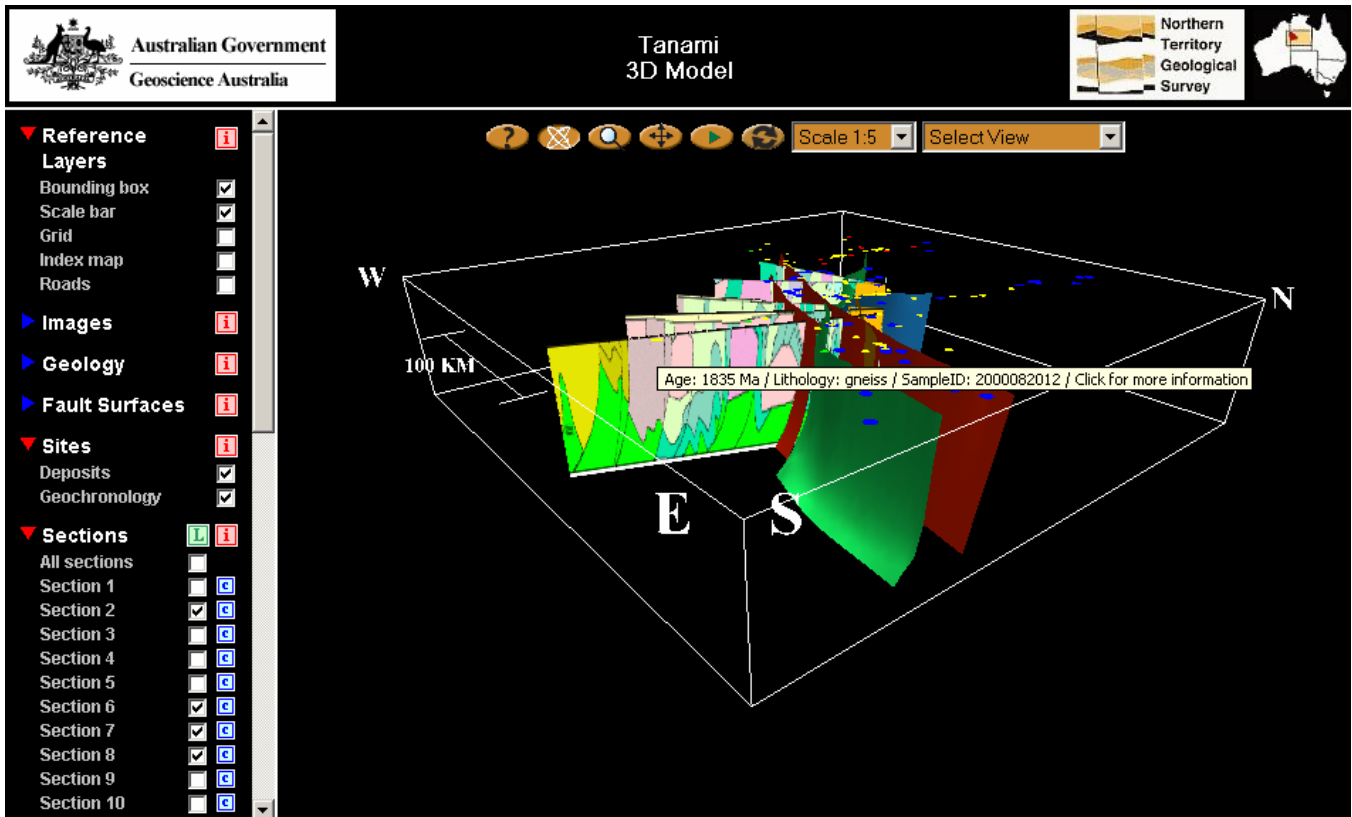
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Figure 1. Tanami 3D Model interface with HTML frames for the title, layers, controls and 3D display. Attribute information and reference scale and compass markers are also shown.
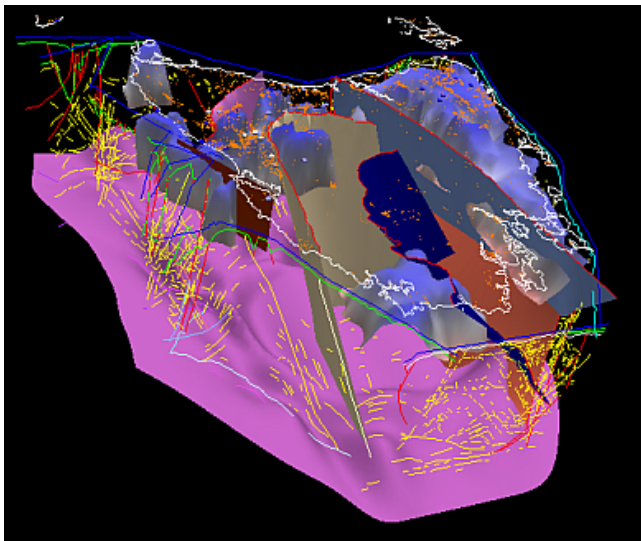

Figure 3. Indexed facesets (fault planes and geological boundaries), lines (coastline and interpreted seismic) and points (gold localities) in the Tasmanian model.
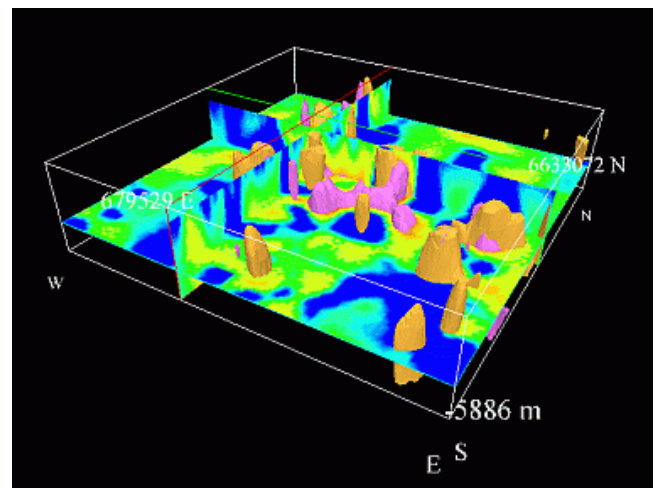

Figure 4. Slices through a 3D grid of geophysical data from the Gawler model. 3D indexed faceset volumes and reference coordinates and compass markers are also shown.

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