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3D WEB MAPPING – 3D GEOSCIENCE INFORMATION ONLINE

D. J. Beard[1], R. J. Hay[1], M. G. Nicoll[1] and D. O. Edge[1]

[1]Geoscience Australia

David.Beard@ga.gov.au

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ABSTRACT

Scientists within Geoscience Australia (GA) create complex models of 3D geological structures. These models are built using specialised 3D modelling software to which very few people outside of GA have access. To overcome this access problem, GA has developed 3D VRML (Virtual Reality Modelling Language) models, to display interactive 3D data using a web browser plug-in – hence '3D web mapping'. VRML is an open source standard for 3D graphics on the web. GA's 3D web mapping development is unique and has proved to be a very effective method for communicating large amounts of complex 3D geoscientific and geospatial information to a wide audience. GA has produced nearly 40 unique 3D VRML models during the last five years, some of which are available for online interaction on the GA web site. The next challenge for GA's visualisers is to move from VRML to X3D - the XML successor to VRML. This paper outlines the motivations for developing 3D VRML models, explains the technologies used, and takes a brief look at possible future developments.

BIOGRAPHY

David Beard attained a BSc. (Hons) in Resource and Environmental Management from the Australian National University in 1997. He commenced work with Geoscience Australia (then the Australian Geological Survey Organisation) in late 1997 and worked on several large GIS data compilation and map production projects. Whilst working for one of these projects he helped create GA's 3D web mapping pages. In 2003 he moved to the Visualisation Team in GA's Geospatial Applications and Visualisation unit (GAV) to help create and further develop 3D VRML models. He is currently the Visualisation Team Leader.

INTRODUCTION

In recent years scientists within Geoscience Australia have increasingly used 3D software to compile, display and interpret geoscience information and to build 3D models of geological structures. In the early stages of 3D development in GA there was realisation that it was critical to be able to communicate and share these 3D models with external users. However, many of GA's clients and stakeholders did not have access to the 3D applications used by GA, due to the high cost and niche nature of the software. Added to this was the government mandate to make information freely available and accessible to clients and the public. The question GA staff asked was 'Did the technology exist for GA to share 3D information in a free and widely accessible format?'

After some research it was determined that VRML provided a possible solution and GA visualisers subsequently embarked on the development of web-ready 3D VRML models ('3D web maps'). These models use free and open technologies – VRML, HTML and JavaScript – to display data within a web browser plug-in. The 3D information is created within other specialised software packages, exported to VRML and compiled to create the models. The models enable synthesis of, and interaction with, large amounts of 3D information within 3D space. Most of the 3D data types used by GA are supported by VRML. This development has allowed GA to distribute its 3D products to a very wide audience via the Internet, conferences and workshops, at no cost to the end users.

This paper is based on the experiences of GA staff - experiences working with 3D data and communicating 3D information to others. As such, it is largely based on personal observations and communication.

BACKGROUND

Advantages of 3D visualisation

Much of the data with which we work is 3D so it is best to display and interact with this data in 3D space where possible. Traditionally geoscientific and geospatial professionals have used 2D maps to display and interpret 3D data. We have used contours and cross-sections to summarise our knowledge of 3 dimensions into 2 dimensions. Now we have the ability to view and interact with this information in three dimensions – to observe the true spatial relationships between the features we are studying.

Clearly, when dealing with 3D data it is easier to communicate our understanding of the data with 3D displays, rather than 2D. This is especially so when communicating with people who are not spatial information specialists – 'non-mappers'. Those of us who work in the spatial information sciences interact with maps every day. We develop skills for interpreting 3D shapes from 2D maps, such as the shape of a landscape from a contour map or sub-surface information from a cross-section. For non-mappers this visualising of 3D shapes from 2D maps can be difficult. However, all sighted people understand 3D shapes, so we can communicate knowledge of 3D data more effectively if we display the data in a familiar form.

Further, moving from 2D interpretation of 3D data to 3D interpretation adds greater rigour to the interpretation. Scientists are forced to make their interpretations work in 3 dimensions. The relationships between features may look fine in 2D, but simply may not work within 3D space. The very act of creating a 3D dataset from 2D interpretations often raises this problem, forcing scientists to review their interpretations and therefore their understanding of the spatial relationships between features. The result is more robust and comprehensive interpretations [Korsch, pers. comm. 2005].

An example of the benefit of 3D visualisation to communication was GA's use of 3D VRML models and 3D flythroughs in Australia-New Zealand maritime boundary negotiations in the Norfolk/Three Kings Ridge region. From the late 1990s until 2004, Australia and New Zealand negotiated the location of the maritime boundary between the two nations throughout the Tasman Sea and Southern Ocean, including in Norfolk/Three Kings Ridge region. Negotiations revolved in part around the shape of the ocean floor, in particular the location of underwater ridges, troughs and plateaus that are connected to landmasses of Australia and New Zealand. Until 2001 the shape of the ocean floor was displayed using 2D maps – contour maps. The negotiating delegations included non-technical people such as lawyers and diplomats, who are generally not experienced in visualising and understanding the shape of the ocean floor from contour maps. Thus, during negotiations considerable time can be spent explaining the nature of the ocean floor, and increasing the trust of the non-technical delegation members in the scientists' explanations of the nature of ocean-floor features. From 2001 the Australian delegation started to use 3D VRML models of the ocean floor to communicate its shape and nature (Figure 1). These models, which were created by GA, were used in conjunction with 3D flythroughs of the ocean floor. The 3D models were most useful as they allowed interaction with the information. Users could vary the angle at which they viewed the ocean floor and turn boundaries on and off. With these 3D models and flythroughs the Australian delegation was able to reduce the communication problem. Non-technical people could now visualise the shape of the ocean floor and the location of various maritime boundaries. The information sharing was faster and more effective. This allowed the debate to move from describing the nature of various ocean-floor features to discussing the significance of the features to potential maritime boundaries – the real issue. The negotiators were therefore better informed to more readily achieve an agreed outcome [Symonds, pers. comm. 2005].

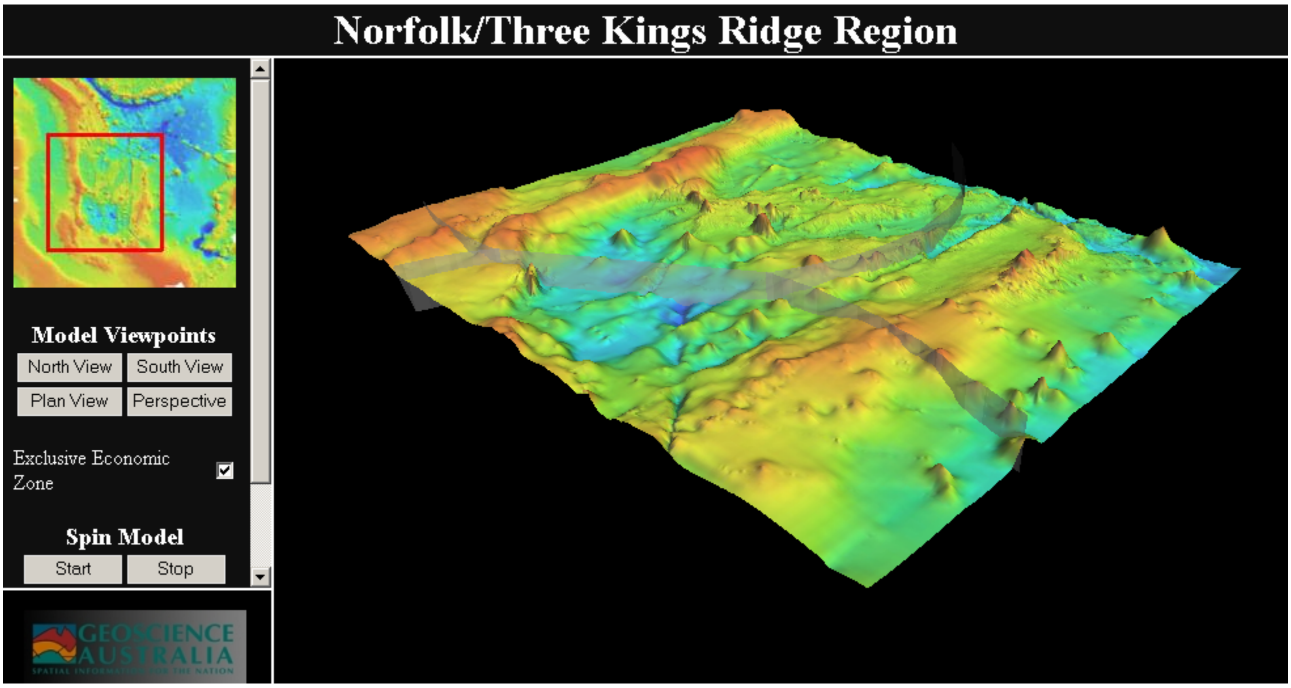

Figure 1. 3D VRML model of the ocean floor and Exclusive Economic Zone boundary in the Norfolk/Three Kings Ridge region.

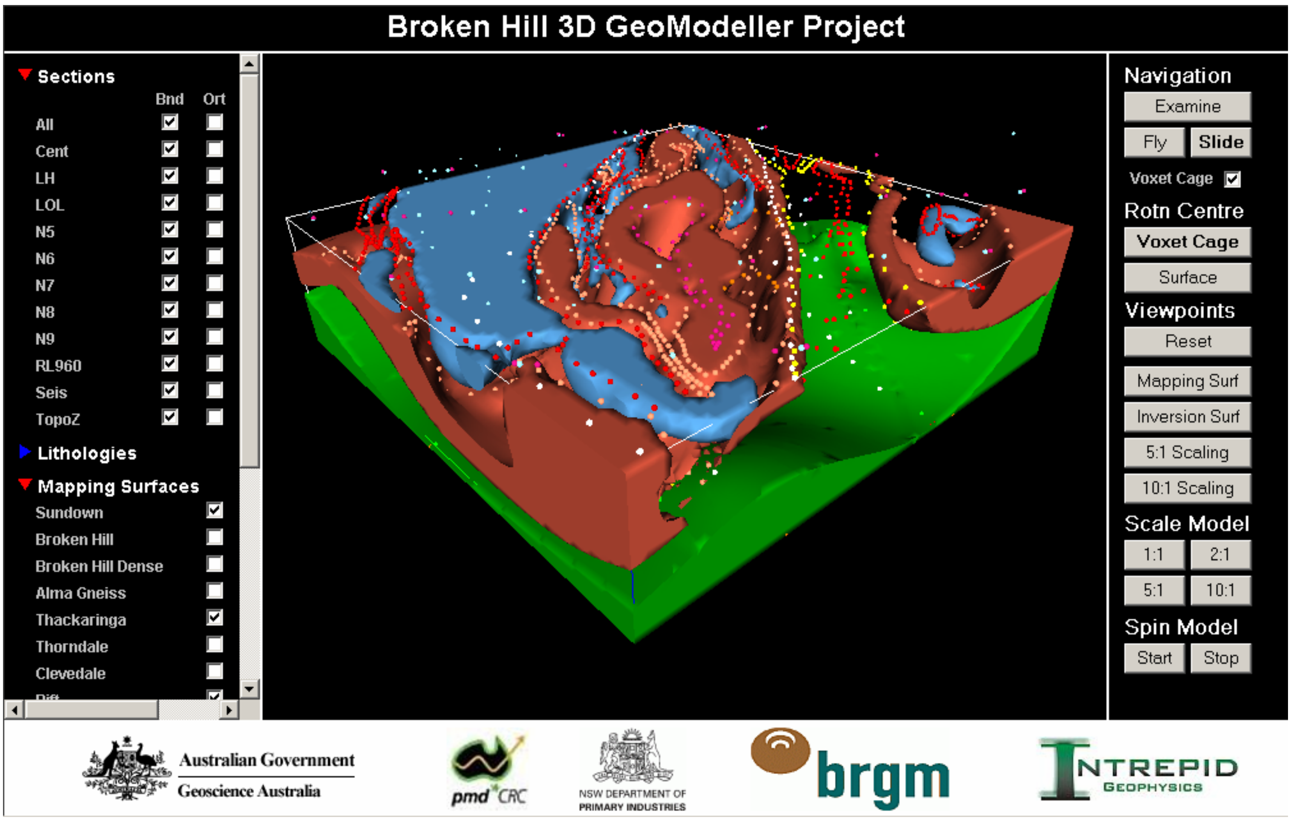

Figure 2. 3D geological model of the Broken Hill area, created using 3D Geomodeller, showing lithology volumes and source data points.

Another example involves using 3D VMRL models to communicate the processes within 3D geology modelling software. Scientists within GA recently started using 3D Geomodeller to automatically create 3D models of sub-surface geology. 3D Geomodeller was developed by BRGM (the French national geological survey). Intrepid Geophysics, an Australian company, is continuing the development, with assistance from GA and the state geological surveys. The output models are complete cubes, composed of discrete geological units. The models typically cover volumes 50 km by 50 km at the surface and up to 10 km below the surface. To communicate the output from 3D Geomodeller and the processes employed by 3D Geomodeller, GA creates 3D VMRL models from the 3D Geomodeller output (Figure 2). Prior to using the VRML models scientists required up to 20 minutes to explain the workings of 3D Geomodeller and even then the message may have been poorly understood by the audience. By using 3D VRML models scientists can explain the workings in only a few minutes and the audience gains a better understanding. This enables the audience to discuss important issues, such as the benefits and draw backs of the 3D Geomodeller approach or implications for understanding the geology of the modelled area [Lane, pers. comm. 2005].

History of 3D VRML model development in Geoscience Australia

GA first started exploring VRML in the late 1990's, exporting 3D data from Arc/Info 7, Petrosys (via Open Inventor), EVS and Gocad. This early work showed that graphics card performance lagged behind 3D file format development. Very few computers within GA had the graphics performance to display the VRML files. Also, only individual VRML files were created, rather than complex VRML models with multiple data layers.

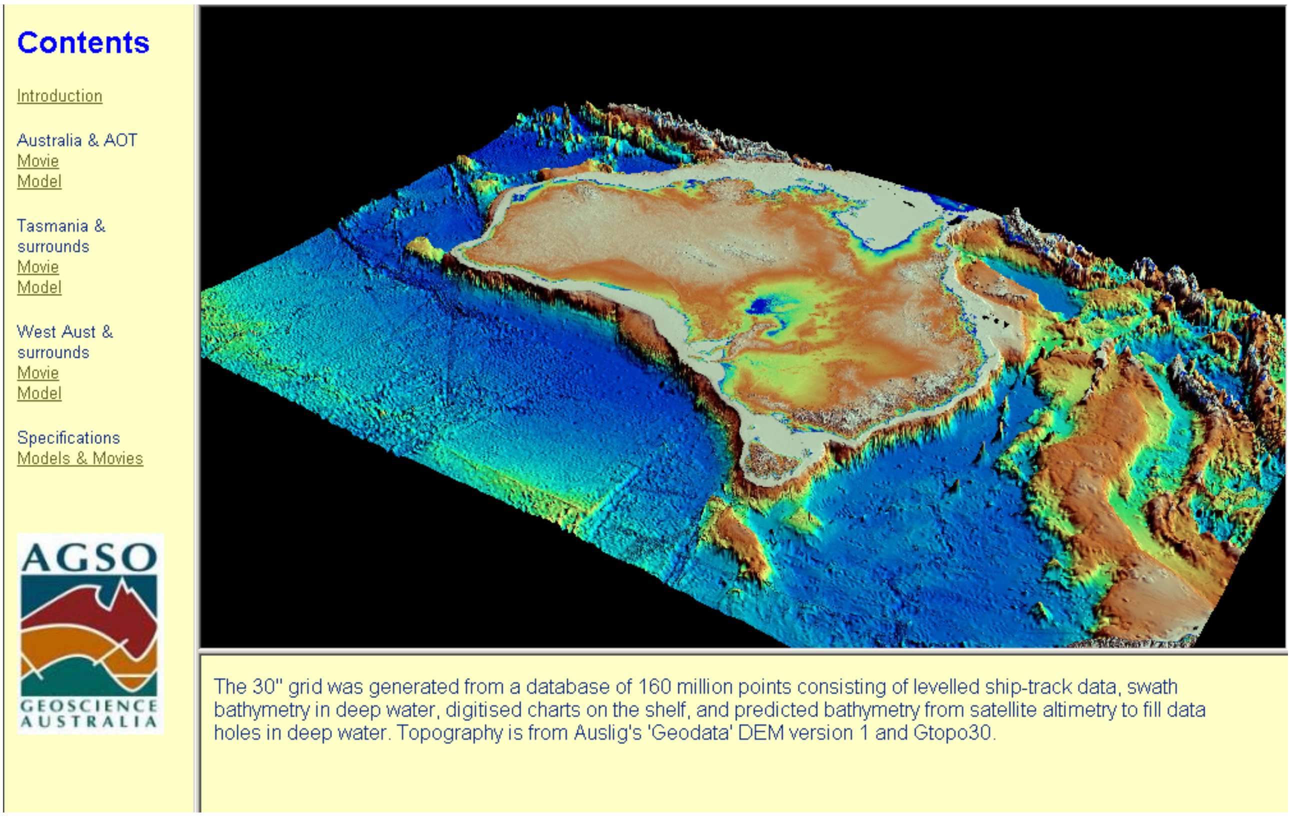

Figure 3. 3D VRML model of bathymetry in the Australian region. An early VRML model created by GA.

2001 was a watershed for 3D VRML models at GA. During this year the following complex 3D VRML models were created and used as communication tools by scientists at conferences.

- An integrated HTML, 3D VRML and 3D flythrough of Australian bathymetry was created for display at the Australian Society of Exploration Geophysicists Conference, 2001 (Figure 3). The product contained three VRML models and associated 3D flythroughs, showing the entire Australian Offshore Territory, the Tasmanian region and an area offshore from southwestern Australia. The data were exported from ERDAS Imagine VirtualGIS to VRML elevation grids. The models were still primitive, containing only one data layer and limited user interaction. They did however allow users to move the bathymetry surfaces within 3D space and enabled zooming in and out through numerous preset viewpoints.
- Complex 3D VRML models of geological structures were created for Australia, Tasmania, the Lachlan region (New South Wales) and the Rabaul Volcanic Caldera (Papua New Guinea). The models synthesised multiple

VRML files within a single interface, and allowed more interaction between users and the data, including turning layers on and off, automatic spinning and variable vertical exaggeration. The individual VMRL files were exported from Gocad.

The first model provided for online viewing on the GA web site was the Leonora-Laverton model, in 2002. Since then three other models have been added, with each new model containing improvements to the amount and range of data included and in user friendliness and functionality of the interface.

3D MAPS ON THE WEB

The GA web site currently houses four 3D models (see http://www.ga.gov.au/map/web3d) [Geoscience Australia, 2005]. The models are of Tasmania, the Gawler Craton (South Australia), the Leonora-Laverton region (Western Australia) and the Tanami region (Northern Territory and Western Australia). The Tanami model has been significantly updated twice and the Gawler model once. More models are planned for the near future. Models are optimised for web delivery and have user friendly interfaces (Figure 4).

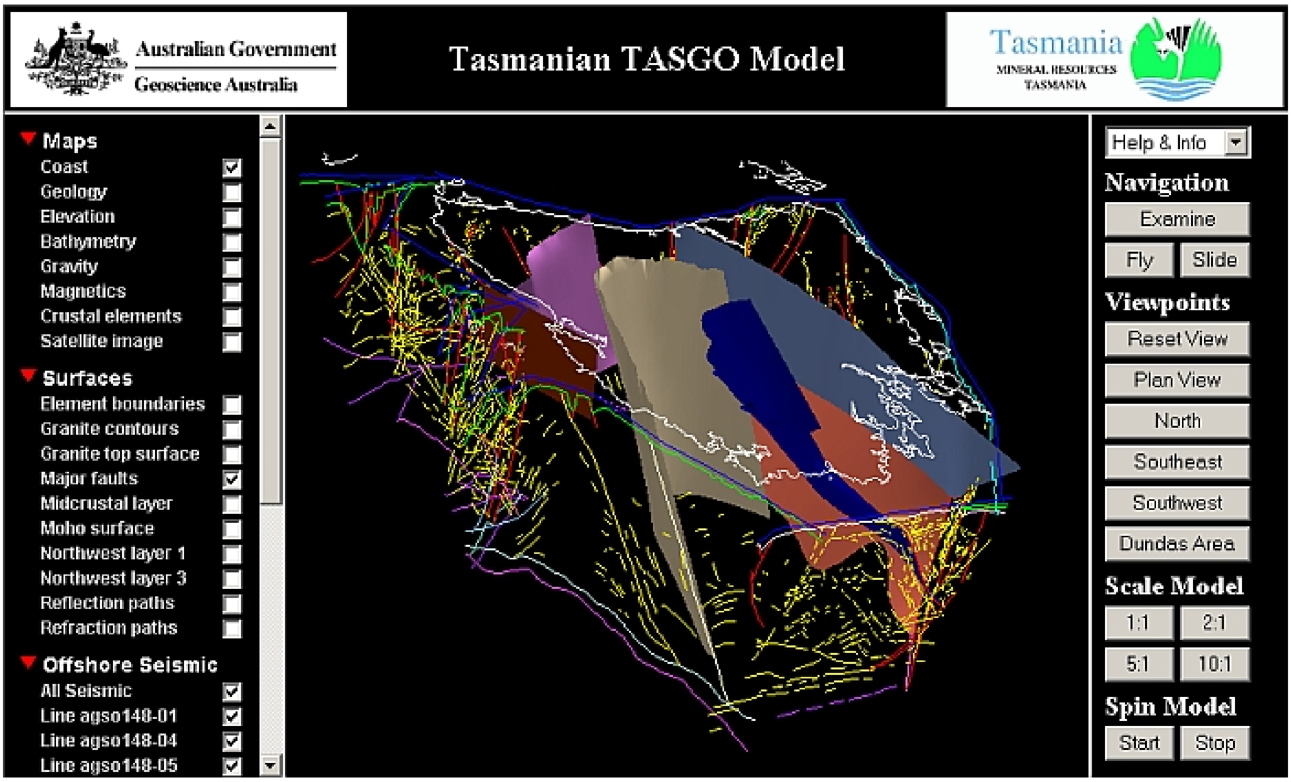

Figure 4. Tasmanian TASGO Model, from the GA web site, showing interpreted seismic data and major faults, within a user friendly interface.

The models 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), triangulated surfaces (DEMs, 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). The Gawler model alone contains over 2,600 VRML data files.

Attribute information is also provided for selected features, including fault names, mineral deposit names and commodities and geochronology ages. This information can be viewed by hovering the mouse over a feature (Figure 5). The Tanami model takes this attribute information further by including a live connection to GA's geochronology database, OZCHRON. Clicking on a sample site in the 3D model causes a query to be sent to the database, returning detailed attribute information.

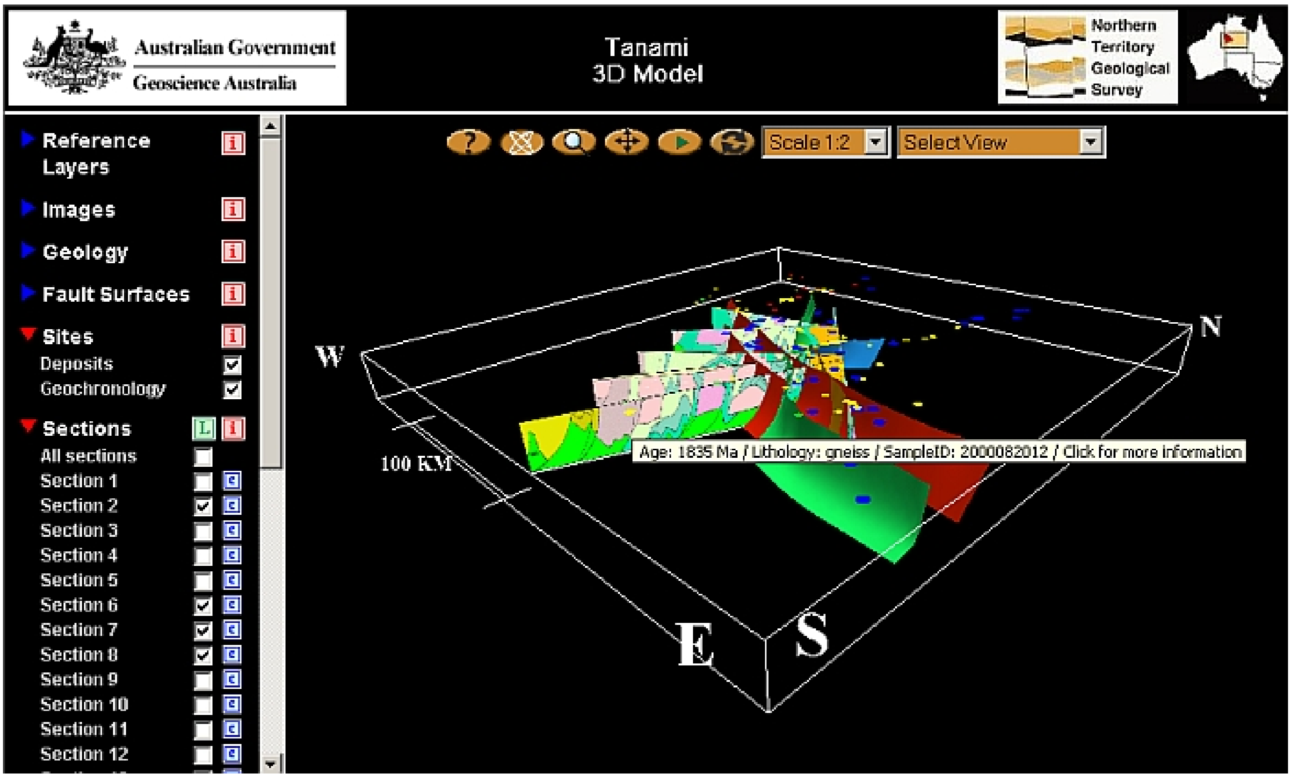

Figure 5. Tanami 3D Model, showing cross-sections, faults and geochronology sample sites with attribute information.

Delivering such large amounts of data over the Internet is a challenge, especially given GA's desire to make all web information suitable for delivery over a 56k modem. To meet this challenge, GA employs the following techniques.

- Advise scientists on appropriate size limits for 3D files.
- Use VRML editing software, 'Chisel', to optimise and zip VRML files for web delivery (see http://www.external.hrp.no/vr/tools/chisel/install.htm [Institutt for energiteknikk, 2005] for more information on Chisel). A triangulated surface VRML file containing 10,000 triangles can be zipped to approximately 100 KB, reducing the download time to about 20 seconds over a 56k modem.
- Use the most efficient geometric features for representing data. For example, draping JPG, GIF or PNG images over triangulated DEMs to represent surface images and maps. An alternative method involves colouring each triangle in the DEM to represent the image. However, the resulting files are larger and the representation is not improved.
- Ensure users only download the files they request. When the models are first accessed only the start-up files are downloaded, allowing users to start interacting with the model quickly. Other files are not downloaded until they are selected by the users. For example, the Gawler model has a total size of approximately 22 MB, yet the start-up download is only approximately 400 KB.
- Reuse files. Where many raster images are draped over a common DEM, the DEM is downloaded only once. When users select a different image to view only the raster image is changed. This is made possible by the fact that VMRL supports external manipulation of file content through Protos and External Protos.

Since these models are communication tools, GA has put much effort into creating user friendly interfaces and data views, which include the following features.

- Reference information within the models, including coordinate grids, scale bars and compass markers.
- Attribute information accessed by hovering over 3D features.
- Automatic spin around the centre point, or a selected point.
- Change the vertical exaggeration applied to the 3D model.
- Drag slices through 3D cubes of geophysical data.
- Buttons for changing between 3D navigation methods, and preset viewpoints.
- Simple cascading layer lists, and help and metadata information.
- 3D viewing area maximised within the interface.
- The ability to change from perspective to orthographic viewpoints. 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.

MORE THAN JUST THE WEB

GA's use of 3D VRML models as communication tools extends well beyond the Internet. Approximately 40 unique models have been created during the last five years. Models are displayed in-house, especially to visitors to the organisation, and used by GA scientists at external conferences, workshops and meetings.

Stereo 3D viewing

GA has purchased and implemented specialised equipment to view 3D data (including 3D VRML models) in 'true 3D', using stereo display techniques. Two separate stereo facilities exist within GA – an in-house 3D theatre, the 'EDGe' (for Enhanced Discovery of Geosciences), and a portable system for external displays.

The EDGe has been in operation since August 2003 and has two uses. Firstly, GA scientists use the room to view their 3D data in true 3D space, to help with data interpretation. Secondly, it is used to display the results of GA's 3D interpretation and modelling to visitors. A stereo-capable VRML viewer, BS Contact Stereo, is used within a web browser to view the VRML models (see 'Technical information' in the 'Addendum' of this paper (below) for more information about BS Contact Stereo).

The portable stereo system is a recent development. It was used for the first time in Hobart during March 2005, to present a new 3D model of Tasmanian geology to important stakeholders for Mineral Resources Tasmania (the state geological survey). Stakeholders included politicians, senior public servants and mining industry representatives. The system includes a high performance stereo-capable laptop, BS Contact Stereo, two small projectors with polarising filters, a stereo-capable silver screen and passive polarising glasses for the audience.

Combined products

To create even more useful communication tools, GA incorporates 3D VRML models with other information sharing and visualisation techniques, including 3D flythroughs, narration and music, and HTML education tutorials.

An example of a combined 3D VRML and 3D flythrough product was that created for GA's Law of the Sea project for use during Australia-New Zealand maritime boundary negotiations in the Norfolk/Three Kings Ridge region. In this product the 3D flythrough movie provided easy access to the information, but with no ability to interact with the information. The 3D VRML model allowed users to more readily interact with the information [Symonds, pers. comm. 2005]. This product is discussed in more detail in the "Advantages of 3D visualisation" section of this paper (above). GA's use of 3D visualisation to share information about Australia's marine zone is discussed more by Watford et al. [2005].

An example of VRML incorporated into a HTML education tutorial is a 3D regolith virtual world training module created in 2005 by GA for the Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME). In this product much information is delivered via text and graphics within a HTML interface. Six VRML models are used to add value to the tutorial by allowing students to interact with maps and geophysical images draped over DEMs.

An example of VRML combined with narration and music is an animated model of global datasets (including satellite imagery, weather, vegetation, topography and bathymetry and earthquake epicentres) created by GA during 2004. This product was created for public display at GA's 2004 Open Day. It has since been displayed to school groups visiting the GA Education Centre. The model uses VRML animation capabilities to rotate and zoom in and out on the globe, to view multiple global datasets. The global datasets include jpg images, mpg movies and 3D line and point data. The datasets are explained by recorded narration, with background music. The model is displayed in stereo using GA's in-house 3D theatre and portable system.

LIMITATIONS

3D VRML models are without doubt very effective tools for sharing complex 3D information with clients and stakeholders. However, they are not without limitations, including the following.

- **Dependency on particular VRML viewers**. GA's 3D VRML models only work with blaxxun Contact 5 and BS Contact VRML/X3D and Stereo. This is because the VRML specification does not define methods for external manipulation of VRML file content. Different viewers use different methods. GA chose to use blaxxun

Contact and BS Contact because the method used by these software is open and uses JavaScript. X3D, the XML successor to VRML, should overcome this dependency because the method for accessing the exposed fields is defined in the specification. Those creating X3D models need only ensure their models comply with the X3D specification, giving users greater choice of X3D viewers.

- **Lack of ease for users to add data**. The models created by GA are products, not software, so do not allow users to easily add their own data. Users with knowledge of VRML, HTML and JavaScript can add their own data by editing the code, but non-specialists cannot simply drop-in their own data. This problem will only be overcome by free and accessible software that replicates the capabilities of GA's VRML models and allows users to easily add their own data. Such software does not currently exist.
- **Some interactivity lacking**. GA's VRML models meet the interactivity needs of most users and data types. However, missing capabilities include: allowing users to select any point within the model area as the rotation point; returning the X, Y and Z location of selected points; and to interactively slice through 3D data. GA has overcome this first problem to an extent by providing users with a limited choice of rotation centre points within models. The third problem is partly overcome by providing cross-section slices through 3D voxet volumes.
- **Bandwidth**. Although GA optimises VRML models for viewing with a 56k modem, bandwidth is still a problem. Some 3D data files are very large and may take up to 2 minutes to download. GA's scientists often create 3D data files that are too large for online viewing. These files must be resampled for the web, thus compromising data quality in exchange for data access. This problem will only be overcome by an increased uptake of high bandwidth by GA's clients.
- **Sparse source data**. In areas of high data density it is possible to build very accurate 3D models. However, GA scientists often have to make do with sparse source data. In such cases the scientists employ their expert knowledge to create the most geologically plausible interpretation of the available data. However, users should remember that 3D models are interpretations. Also, those creating the models need to provide metadata to explain the quality of the source data. An outstanding question is how best to represent variable source data quality and density within a 3D model. One solution employed by GA for 3D triangulated surfaces is to include the source data points as layers in VRML models.

FUTURE DIRECTIONS

Future directions for continued development of this work within GA include the following.

- **X3D**. GA is likely to move from VRML models to X3D models in the near future. Promised improvements of X3D over VRML include easier interaction with other XML data formats and lack of dependency on particular viewers (as discussed above). More information on X3D is available from the Web3D Consortium web site: http://www.web3d.org [Web3D Consortium, 2005b].
- **Download models**. At present GA's online 3D VRML models are available for live online viewing, but not for download as a single product. GA plans to make models available for download as well as live online viewing. The advantage of providing a download facility is that users can run the models from their computer's hard disk, rather than over the Internet.

The recent release of Google Earth [Google, 2005] is a major leap forward for 3D web mapping, and indeed, for web mapping in general. It has redefined web mapping by providing users with easy access to a very large database of 3D information. It appears that Google Earth is just the beginning, with other players in this space, including World Wind [NASA, 2005], ImageAtlas 3D [GlobeXplorer, 2005] and ERDAS Imagine Virtual Delivery [Leica Geosystems, 2005]. However, Google Earth and these other players are currently limited to draping imagery over 3D terrains, plus 3D building models. They do not include subsurface data, nor the range or complexity of the 3D data included in GA's VRML models. In the near future there appears to be no obvious business driver for Google and others to include such data, so a need continues for tools such as VRML and X3D for specialist models like those created by GA. GA is watching these developments with interest, looking for new ways to share data with partners, clients, stakeholders and the public.

CONCLUSION

3D visualisation has become an integral part of Geoscience Australia's operations. The development of 3D VRML models in particular has proved to be very beneficial in enabling the organisation to share its 3D data and knowledge with others. These innovative models are effective tools for communicating complex 3D geoscience information and concepts to a very wide audience without the need for specialised software or systems. GA is continuing to develop the capabilities of these models, as well as looking for new fields in which to use the models and investigating new techniques for sharing 3D information with our clients and stakeholders.

Footnote: The innovative nature of GA's 3D VRML models was recognised by an award in Directions Magazine's Web Mapping Contest 2004. The Tasmanian TASGO model won an 'Oscar' for 'Best Eye Candy' [Directions Magazine, 2004]. Of more than 70 entries in the competition, GA's entry was the only truly 3D web map.

ADDENDUM

Technical information

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, 2005a]. 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 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/en/products/contact/index.html [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].

The 3D VRML models created by GA contain the following components: HTML frames interface; JavaScript code (for HTML to VRML interaction); and VRML objects. Each individual 3D object within the models is a single VRML file. These files are indexed within a parent VRML file. This parent file also defines 3D properties for the entire model, including the position of lighting within the 3D space, the location of preset viewpoints and animation of the 3D objects, such as changing the vertical exaggeration of objects or automatically spinning all the objects. For a more detailed discussion of this technical information see Hay [2003].

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