Noddy

Structural geophysical and geological modelling

Reference Manual

www.tectask.org

Noddy Development Team

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Noddy makes use of XVT, Microsoft, Symantec, Metrowerks, Far Bit Research an Micro System Options development libraries and source code.

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Introduction

1 Introduction

Noddy allows an integrated forward modelling of geological structures together with resulting gravity and magnetic anomalies. The program enables the complex structure of a poly-deformed area to be calculated via a sophisticated 3-dimensional structural modelling procedure.

Noddy allows a geoscientist armed with a reasonable understanding of the geology of an area to refine this understanding by interactive manipulation of the geometry and geophysical characteristics. It is a kinematic forward-modelling system that creates a three-dimensional geometry through addition of a sequence of deformation events on an initial stratigraphy. From the generated model, Noddy can calculate the gravity and magnetic responses for the structure. Noddy is based on two types of algorithms:

a) Those that deal with forward modelling of geology and
b) Those that deal with forward modelling of potential field geophysical responses.

The Noddy modelling system has been developed jointly with funding from the Australian Research Council, The Australian Geodynamics Cooperative Research Centre and AMIRA (Australian Mineral Industries Research Association) group of sponsors (Aberfoyle Limited, AGSO, BHP Minerals, Billiton Ltd, North Limited, MIM Exploration Pty Ltd, Newcrest Mining Limited, Pasminco Exploration, RGC Exploration Pty Ltd, Riotinto Exploration Limited. Mines and Energy of South Australia, Sumitomo Metal Mining Oceania Pty Ltd and Western Mining Corporation Ltd).

Geological Modelling

Geological modelling is achieved by superimposing a series of deformations, described as parameterised displacement equations acting on an initial stratigraphy.

The choice of deformation ‘events’ includes folding, faulting, unconformities, shear zones, dykes, plugs, homogeneous strains, tilts and importing geometries (e.g. voxel models). The events may be combined in any order or any number. The starting model not only represents geology, but also defines geophysical rock property stratigraphy. This combination allows the calculation of sophisticated geophysical behaviour such as alteration around faults or intrusives.

Geophysical Modelling

Geophysical modelling is accomplished by dividing the final geological structure into discrete ‘cubes’ or voxels. A modification of the fast Hjelt dipping prism equations are then used to compute and sum the potential field responses of the 3D volume. A Fourier domain calculation has also been implemented based on the same voxel model of the geology.

Using This Reference Manual

This Reference Manual describes the operation and features of Noddy. The manual has been written as a reference to Noddy and includes descriptions of the basic operations.

The information in this manual applies to Noddy Version 7.1 only.

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In addition to this Reference Manual, a printed and electronic version of the Noddy User’s Guide is available. The electronic version of this guide is supplied as a Portable Document File (PDF). This manual is supplied on the Noddy distribution CD-ROM and is accessible using the Adobe viewing software (Acrobat Reader) supplied with your installation version of Noddy. Also available as PDF files are tutorials which can provide a ‘hands on’ introduction to Noddy.

Help and Documentation

Obtaining Help

Technical Support and Updates Available

Using the Electronic Reference Manual

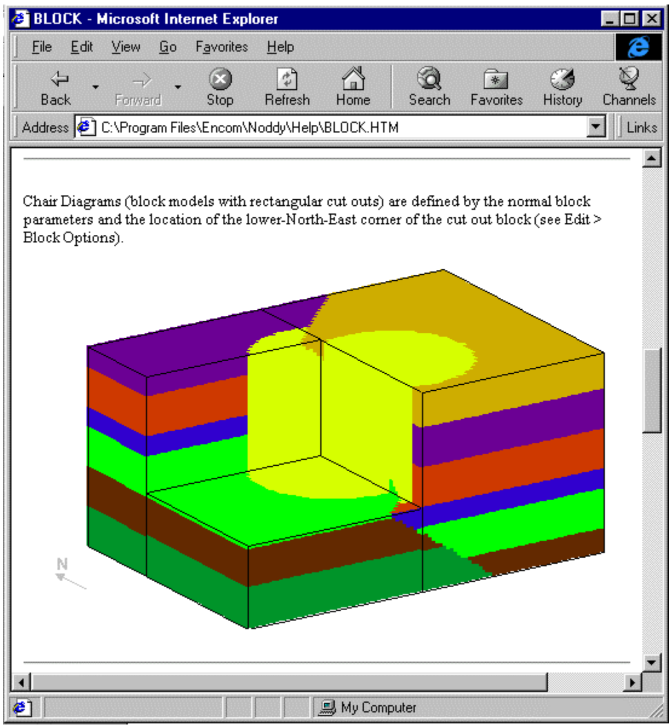
Using Adobe Acrobat Reader

2 Help and Documentation

Obtaining Help

Should difficulties or questions arise while operating Noddy there are three available sources of help. These are:

1. **Online Help -** a comprehensive subset of the main Noddy documentation is available while operating the software. This help can be initiated at any time by selecting the **Help** menu or from the various Help push buttons located in dialog screens. The help provided is categorized into a reference listing and an indexed or hyperlinked help. Noddy help uses the HTML document format for viewing. Refer to *Project Options* for information on the usage of a help browser viewing the help. An example of this help is provided below:



An example of the Help menu of Noddy

Detailed instructions on using Help can be found in the documentation of your preferred Web browser.

2. **Reference Documentation** provides a second form of help supplied with the software. This manual provides all the required information for the operation of Noddy.

3. **Noddy Tutorial** exercises often provide a valuable insight into the functionality and normal procedural use of the deformation event tools available in Noddy.

   We recommend that each user review the tutorial exercises as an aid to problem solving in Noddy.

Troubleshooting

Sometimes difficulties may arise in Noddy that you do not understand, or a display does not appear as you expect. These are not normal occurrences but if certain options are inadvertently set, or a history file with inappropriate parameters are read, the following situations may arise:

Situation 1
A block model has been requested (either from the **Geology>Block Diagram** option or the Preview window) and nothing but a coloured background is displayed.

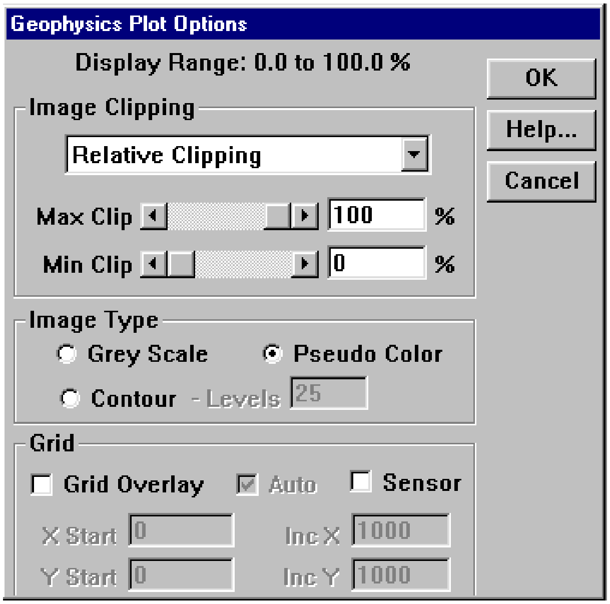
This problem is most likely to be due to an incorrect setting in the **Edit>Geology Display Options**. In particular, examine the Declination, Azimuth and Scale settings. These should be about 200, 25 and 100 for a starting, visible model. Within this option, you may also wish to check the background colour.

Refer to the *Geology Display Options* for additional information.

Situation 2
The geophysical computation (using the **Geophysics>Calculate Anomalies**) has been requested but when finished, the image displays for magnetics or gravity are black.

This situation can arise from two causes. Firstly, the geophysical response may be inappropriate or too small to be detectable. Secondly, the display settings may be incorrect and result in a dark image.

To test the geophysical response, open an edit dialog for the last event in the displayed history. In the Preview window, open the Block list and select say, Magnetics. If a valid geophysical response displays after computation, then it should in the **Geophysics>Calculate Anomalies** option. If no display is seen, click the right mouse button with the cursor in the image window.



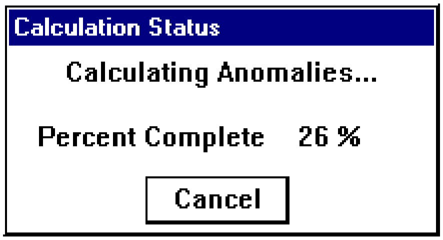
Ensure that the clipping level is appropriately set. Note that the Min Clip should be at 0 and Max Clip at 100% (unless otherwise set).

Situation 3
A geophysical or geological computation appears to take excessive time to result in a display.

Usually this situation is due to choosing too small a block or cube size in the **Edit>Block Options**. When too many cubes are required to be computed, the computer can be forced to swap memory and this can be inefficient. Given sufficient time, a result is usually obtained, but if the time taken is too long and computation is still continuing, you may need to Cancel Noddy processing to proceed. This circumstance stresses the importance of regularly saving History files. With a history created, the saved file can be re-loaded and processing recommenced with a larger cube size. You can reduce the cube size but refer to *Important Considerations When Modelling* for additional information.

Note

To halt any computing or display operation in Noddy, press the **Cancel** button as shown in the dialog below.



Situation 4
Geophysical response is segmented and unrealistic.

Two causes bring this situation about.

1. A large geophysical cube size (set using the **Edit>Block Options** menu item) will result in a blocky, segmented geophysical response. You can reduce the cube size, and refer to *Important Considerations when Modelling* for additional information.

2. The geophysical sensor (by definition) will measure responses at the surface of the block. If strongly magnetically susceptible or dense rock units exist close to the surface, their geophysical responses will be excessive. In reality, it is more often the case (at least for magnetics) that the sensor is located at a height above the block (flying height) and weathering beneath the surface will tend to deplete magnetically susceptible minerals. For this case, the height can be simulated with an offset available in the **Edit>Geophysical Survey Options** for airborne surveys.

Learning The Basics

4 Learning the Basics

Noddy is a relatively simple program to operate and use for data display and creating simple or complex geological simulations. A number of guidelines are provided below to assist in your operation of Noddy. These guidelines apply throughout the program.

Guideline 1
Data and models can be displayed in a number of windows at any one time. Only one window (the one with the highlighted banner at the top) is active. You are able to set display and object attributes only within the active window. To make a window active, move the cursor to the window and click the **left mouse button**.

Guideline 2
Alteration of the display appearance is ALWAYS controlled by pop-up dialog boxes. These are accessed by clicking the **right mouse button** while the cursor is in the relevant window. Usually a number of sub-options are presented.

Guideline 3
Configuring individual selectable objects such as events (and their icons) etc is done by double clicking on the event icon with the **left mouse button**. In all cases, this operation results in an edit dialog being presented. In the various option and event editing dialogs, pull-down or check box operation controls the settings.

Guideline 4
Standard Microsoft Windows keyboard usage applies for dialog list controls. This means that the **SHIFT** key in combination with the left mouse button can be used to select multiple list items. The **CTRL** key can also be used in combination with the left mouse button when selecting non-consecutive items in a list.

Guideline 5
The selection of single or multiple graphics objects can be controlled by using the **SHIFT** and **CTRL** keys. Select multiple graphics objects with the **SHIFT** key held down and multiple left mouse button selections.

Guideline 6
All of the window display types in Noddy present models as they are created and edited. As changes to events are made or new objects are added, each window is automatically updated to reflect that change.

Five basic window types exist in Noddy:

- Block models (including chair diagrams).
- Section displays through a block with cross-sections of geology.
- Map displays (of geology or geophysical response). Data can be presented as images or contours etc.)
- Legends, titles and borehole content displays are available.

Access To Tutorials

To assist in you in learning how to use Noddy we have provided you with a set of tutorials on your installation CD-ROM. Tutorials are composed of documents which explain the operation and steps to follow, plus data which are used in the tutorial exercise. All tutorials are based on real exploration situtations in which Noddy can be used to display, model and interpret potential field data.

The written tutorials are available as HTML documents that use a browser program such as Microsoft Explorer or Netscape for viewing.

The HTML files can be installed from the supplied CD-ROM or accessed directly from the \NODDY\HELP directory on the CD.

Tutorial data is available if the Noddy tutorials are installed from the CD-ROM. A total of 10 Mbytes of disk space is required to install the tutorial data. As you work through the tutorials, additional storage is required for data, model, grid and exported data.

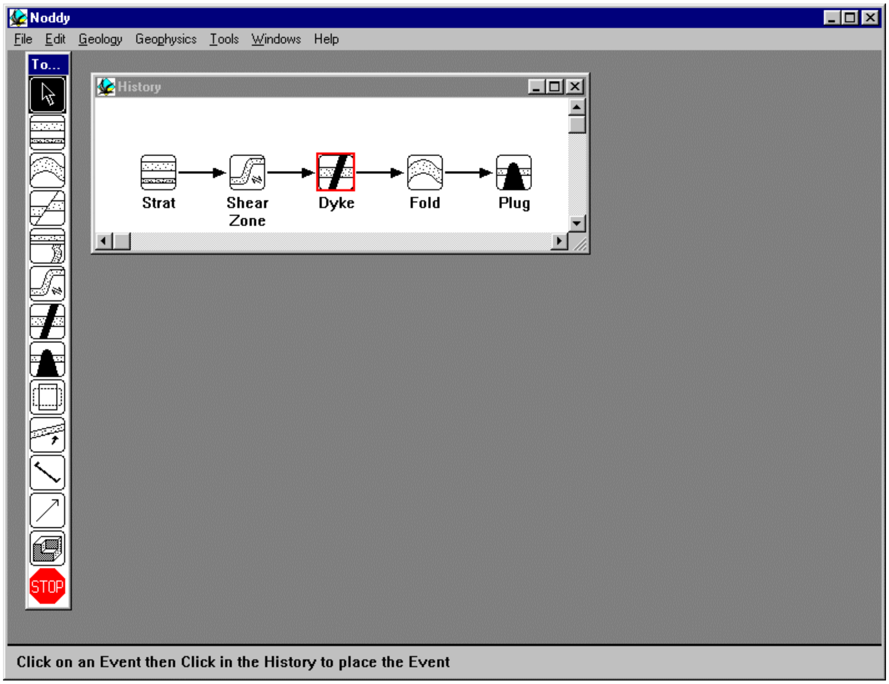
Starting and Quitting Noddy

You can execute Noddy in a number of ways but the two easiest methods are:

1. Select the Windows Start button and then choose the **Programs>Noddy >Noddy** option after the software has been installed.
2. During installation, a Noddy program icon is created on the Windows Desktop. Double clicking on the icon initiates the program.

Other methods of creating shortcuts to executables are available in the Windows environment. Refer to the *Users' Guide to Windows* and *Users' Guide to Office 97* for additional information.

After using one of the methods described above, executing Noddy displays a 'splash' screen, followed by a history and toolbar.



The main menu items of Noddy

The initial banner screen disappears after 10-12 seconds leaving the main Noddy screen with a grey background and a choice of icons.

The main menu items displayed are:

- **File -** File handling for geological histories is controlled using the options on this menu item. Setting of default directories, licensing, movies, printing and exiting are also available.
- **Edit -** Various Noddy option controls as well as standard Windows editing functions (cut, paste etc).
- **Geology -** Create displays of geology in various formats (blocks, maps, stratigraphic columns etc).
- **Geophysics** – Create displays of magnetic and gravity responses examine other images, differences and derivative data.
- **Tools** – Importing and saving block models and controlling the properties of stratigraphic rock units in a database.
- **Windows -** Control of the position and selection of windows and toolbars.
- **Help -** On-line help facility.

To exit Noddy, select the **File>Exit** option. You are given the chance of saving the current work in a history file. History files are useful as a rapid means of returning to the same processing session when next you use Noddy.

Program Guide

5 Noddy Program Guide

Introduction

In order to characterise the complex three dimensional structures that often cause geophysical anomalies, it is necessary to have some understanding of the structural history of an area. Noddy provides the ability to construct a complex geological history as a succession of relatively simple structural, sedimentary and igneous events. Each geological history is defined as a sequence of kinematic events, and each event is defined by a set of orientation, position and scaling parameters. The structural modelling used in this program were first written by Mark Jessell as part of an MSc at Imperial College, London University, in 1981, as an interactive map creation package.

The basic assumption of Noddy geology is to create an earth consisting of an infinite volume of rock. The displacement equations controlling events are defined explicitly or implicitly with respect to flat planes, so that the curvature of the earth is ignored. The displacement equations within Noddy are all **unary**, that is there is a one-to-one mapping of all points before and after each deformation event. These displacement equations need to be specified in both their **forward** (Lagrangian) forms and their **inverse** (Eulerian) forms. Since it does not matter whether the geology is deformed by complex equations which include terms for the orientation of the deformation, or by a separate rotation term and a simple equation, the latter approach was adopted, since this makes the development of new deformation styles much more straight forward.

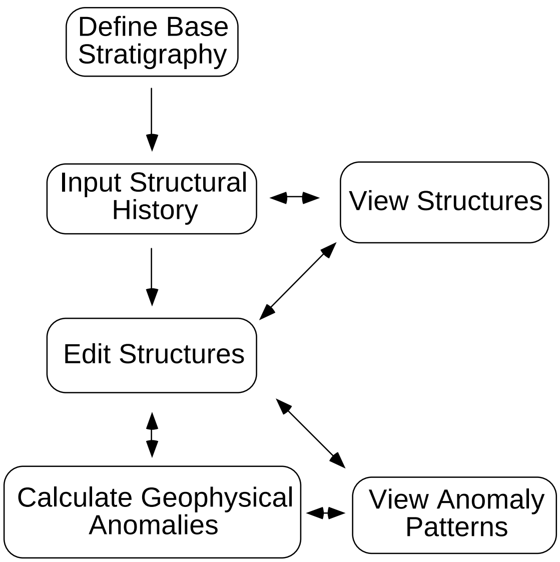
In Noddy, the metre is the unit of length. All planar features are defined by their dip and dip direction, all independent linear features are defined by their plunge and plunge direction, and all linear features on planes are defined by their pitch. The 000 direction is North, 090 is East etc.

Noddy Program Flow

The general flow of the Noddy program consists of:

1. The definition of an initial ‘layer cake’ stratigraphy
2. The interactive development of a structural history
3. The use of 2D and 3D visualization tools such as maps and block diagrams.
4. The calculation of 1D and 2D gravity and magnetic images.
5. The editing of the existing structural history and re-calculation of the anomalies to improve the match between real and calculated structure and geophysical response.

Since this program is completely interactive, the steps may be enacted in any order, apart from the initial definition of a base stratigraphy at Step 1.

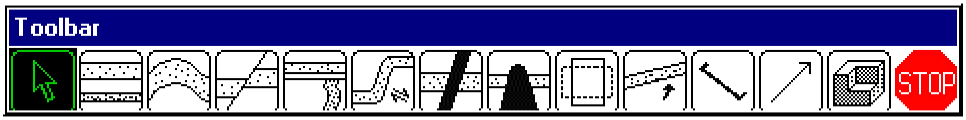


Getting Started

Creating a Structural and Geophysical Model

When you execute Noddy you are presented with three windows:

1. The **Toolbar**, which is a small window containing a set of icons for each deformation type.



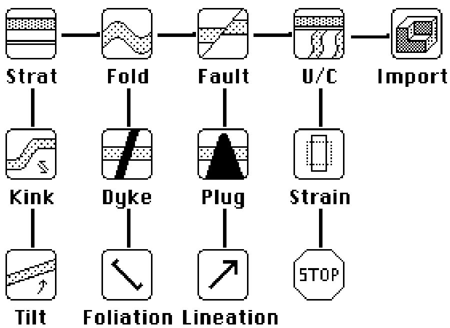
2. A **History** window, into which these deformation events may be placed, edited and moved.
3. A **Status Bar**, at the bottom of the screen providing status information.

The contents of the **History** window contains the currently defined event history, and is blank on start up, unless a file with defined events called 'DEFAULTS.HIS' is in the same directory as the executable binary.

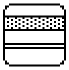
Tip

The orientation of the Toolbar can be cycled between three different shapes by holding down the SHIFT key and clicking the cursor icon with the left mouse button.

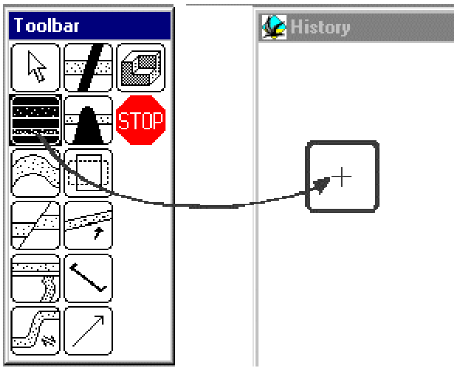
A complete set of icons and their meaning are shown below:



Defining the Base Stratigraphy

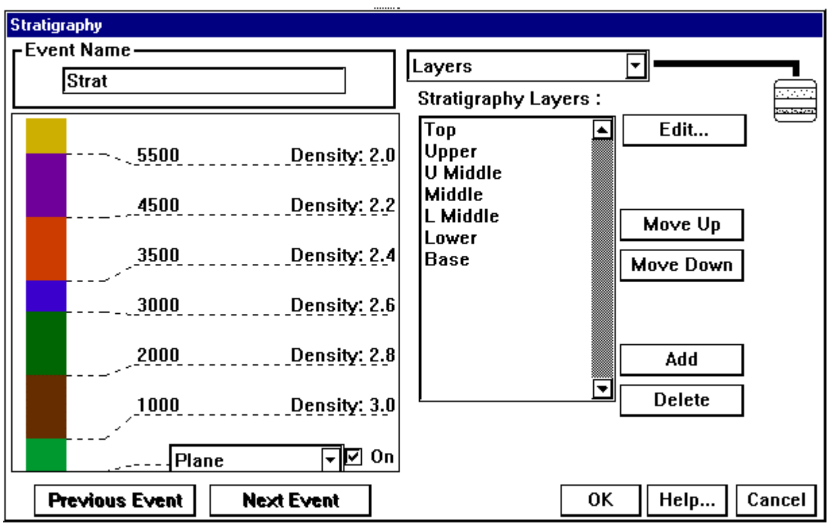


To define the Base Stratigraphy (which must be the first step in the construction of a history, unless a pre-existing history is read in from disk) click once on the Base Stratigraphy icon which then becomes highlighted. Move the cursor over the History window, a dashed square follows the cursor, and clicking in the History window 'drops' that icon in the window.



Placing an icon in the History window

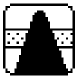
As soon as the icon is 'dropped', a new window opens that allows you to define a starting stratigraphy for your model.



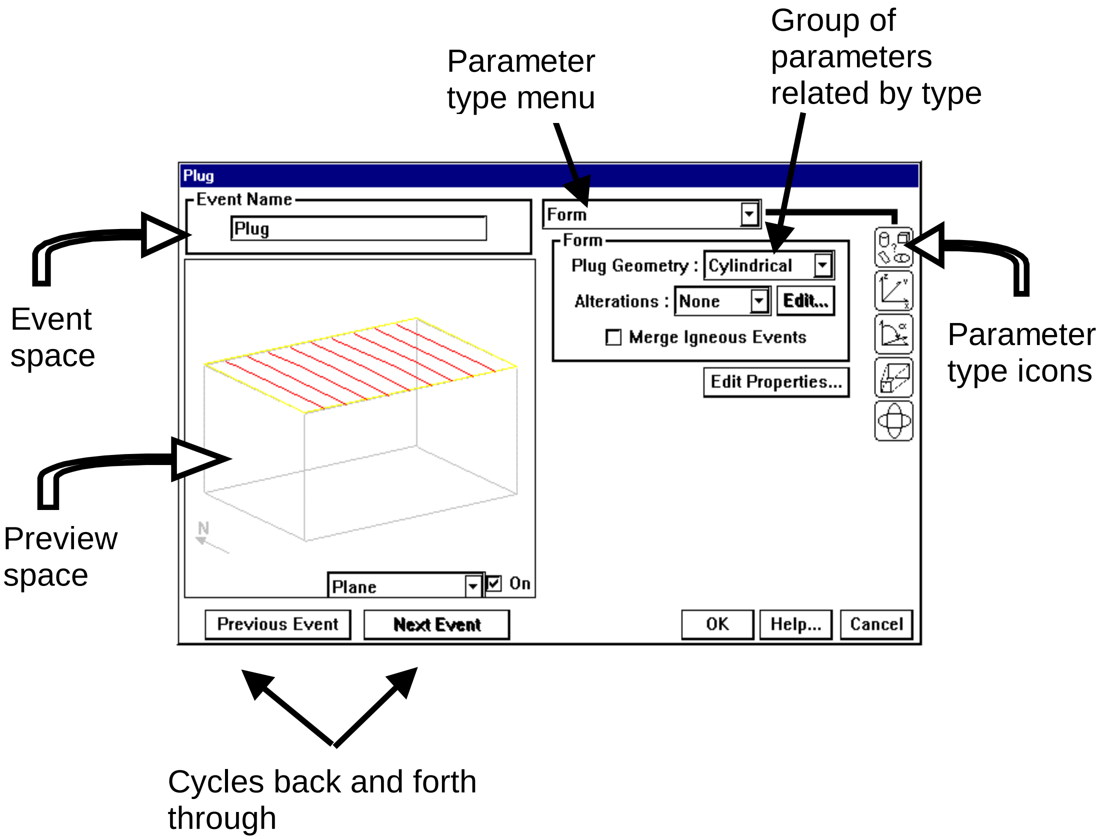
Stratigraphy Summary window

This window displays a summary of the stratigraphic column on the left hand side, and allows you to edit layers on the right hand side.

Defining a Deformation Event



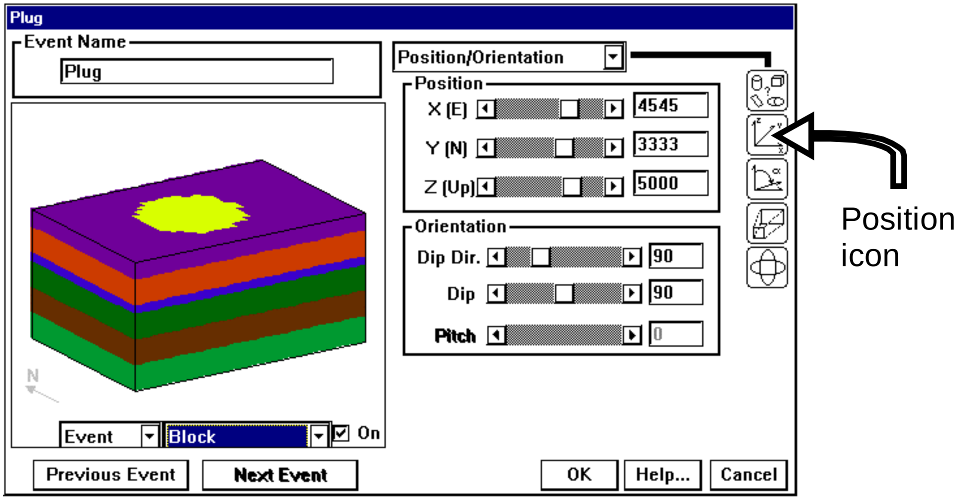
To add a granite plug to this model, first select the Plug icon, by clicking on it and dropping it to the right of the Base Stratigraphy icon in the History window. This opens up the plug definition window, which demonstrates the standard deformation event window capabilities:



Note in this example that the Plane option in the Preview Type pull-down list is used (at base of the block display area of the dialog). The Preview list has a number of options (refer to *Previewing Potential Field Anomalies*), but the Block option is the default.

Previewing an Event

To preview the effect of an event on the pre-existing geology (in this case the base stratigraphy), select **Block** from the Preview type menu (if not already selected). A Block diagram should now be drawn in the preview space.

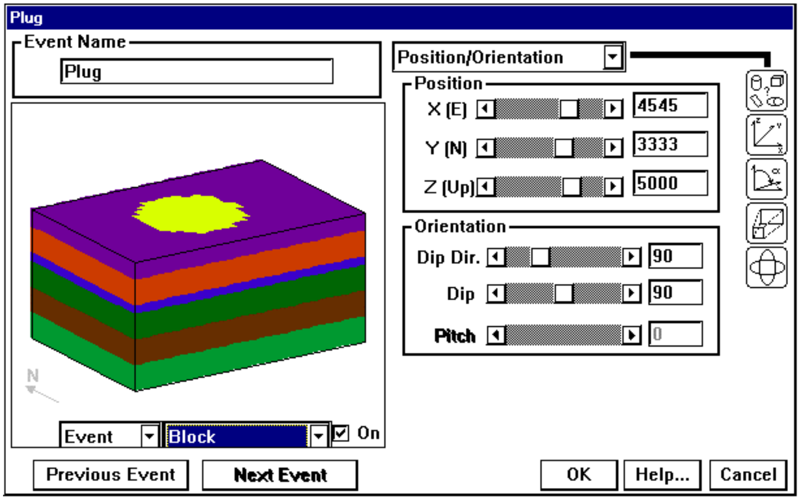


Editing the Position of an Event

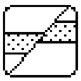
To alter the position of the (cylindrical) plug, select either the Position/Orientation menu item from the Parameter Type menu, or click on the Position Icon. A new set of parameters related to position and orientation appears. Alter the X and Y parameters that define the position of one point on the central axis of the cylinder.

Note

The preview of the block diagram changes to reflect any edited operations. If this display update is too slow, you can alter the Preview menu back to Plane and make all the changes before reselecting Block or deselect the **Preview On** check box.



When satisfied with the position of the plug, click **OK**.

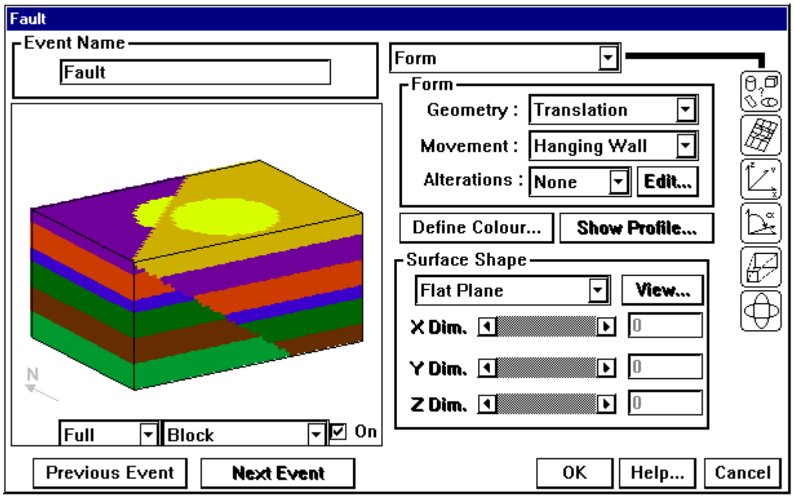


Adding Another Deformation Event

To add a fault, click on the Fault Icon from the Toolbar, and drop it to the right of the Plug Icon in the History window. A Fault definition window opens, where the Block Preview menu item is used initially.

Choose between **Event**, **History** or **Full** Block Previews, by selecting from the timing menu list that appears to the left of the Preview Type menu. The functions of these three options are:

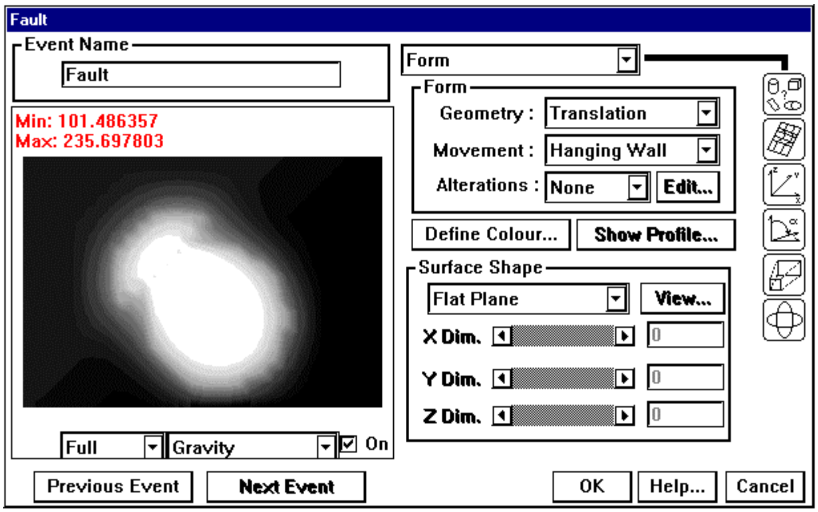
- **Event** timing shows only the effect of this one event on the Base Stratigraphy
- **History** timing shows the history up to and including the event currently being edited
- **Full** timing shows the effect of all events. In this case, Full and History blocks have the same effect as the youngest event, which is currently being edited.



Fault edit and control dialog.

Previewing Potential Field Anomalies

Just as geological models may be previewed, the gravity and magnetic images may also be previewed by selecting, for example, Gravity from the Preview Type menu. The gravity anomaly associated with the currently defined geology is now calculated (depending on the choice of Event/History/Full in that menu).



The preview edit window common to all edit dialogs.

When satisfied with this model, click **OK** to return to the History window.

Having previewed the geological and geophysical models, you can now make higher resolution and more complex visualizations by selecting menu items from the Geology and Geophysics menus. Alter the display choices by selecting the Options items of the Edit menu item.

Editing Deformation Events in the History W indow

Subsequent deformation event icons may be placed to the right, below, or between the existing icons. An icon placed below another icon indicates that it occurred after that icon, but before any icons to its right. Icons cannot be placed above other icons. Tie lines connect all the icons in the History window to make the age relationships easier to decipher, and any icon that is to be inserted between two other icons should be placed on top of these tie lines.

Tip The History window reads top to bottom and then left to right with respect to sequence. Therefore, the Base Stratigraphy must always be the top-left most icon.

Once a deformation history has been developed, the icons within the History window may be edited in two ways.

Editing Parameters

The parameters associated with a particular event may be edited by double clicking on the icon associated with that event in the History window. This brings up the Event Definition window.

Editing Event Timing

A number of controls are provided to enable the timing of structural events:

- **Undo -** There is a single level of undo available within the history window that allows any of the editing functions below to be reversed. An undo also removes the placement of an icon into the window.
- **Dragging -** The relative timing of events may be altered by dragging the icons around the window. Click on an icon, and move the cursor with the left mouse button depressed. A dashed rectangle follows the cursor. When the mouse button is released, the event is repositioned. As long as the Base Stratigraphy is the first event, any timing combination of the existing icons may be tried.

Tip Dragging an icon to the left of the History window is an easy way of deleting it.

- **Selecting -** Icons may be selected by clicking once on the icon, or dragging a rectangle around a group of icons. Multiple icons may also be selected by clicking on each icon in turn while holding down the SHIFT key. All the icons may be selected at the same time by choosing Select All from the Edit menu. Selected icons are outlined in red.
- **Cut -** Cutting deletes the selected event(s) but places it on a temporary clipboard.
- **Copy -** Makes a copy of the selected event(s) and places it on the clipboard
- **Clear -** Clearing deletes the selected event(s) without keeping a copy. Dragging an icon above or to the left of the title bar of the History Window is a short cut for clearing/deleting it.
- **Paste -** Pastes the last event(s) copied to the clipboard by a Cut or Copy action to the History window. The next click in the History window presents a drag rectangle which when positioned and left clicked again, drops the event icon(s).
- **Duplicate -** Makes a copy of the selected event(s) and immediately pastes it into the window. The next click in the History window drops the duplicated event(s). Note that the Duplicate process creates an exact copy of the selected event(s) including all parameter settings for the event(s).
- **Tidy Window -** Tidy Window does not alter the actual history, but compacts the display within the History Window to remove any unfilled spaces between icons.

Note

The length of the joining lines between icons has no impact on the geological model.

Structural Modelling

Base Stratigraphy Event

Folding

Faulting

Unconformity Event

Shear Zone Formation Event

Dyke Intrusion Event

Plug Intrusion Event

Tilting

Foliation Formation Event

Lineation Formation Event

Stop Sign

Parameter Groups

Previews in Event Definition Windows

Profile Window

Alteration Zone Definition

Rock Property Definition

Colour Definition

6 Structural Modelling

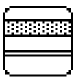
There are several basic elements in each of the Event Definition windows, and the behaviour of these elements is common to all the appropriate deformation events. Consequently, the events are described before specific deformation event definitions.

For each event, a table with the complete list of available options is presented. The name and detailed function of each item of an event option grouping is provided.

The first event in a structural history must always be the Base Stratigraphy Event. There is currently no extra significance to placing some icons in a column rather than as a horizontal sequence.

Tip The time sequence of icons in the history window is top to bottom then left to right.

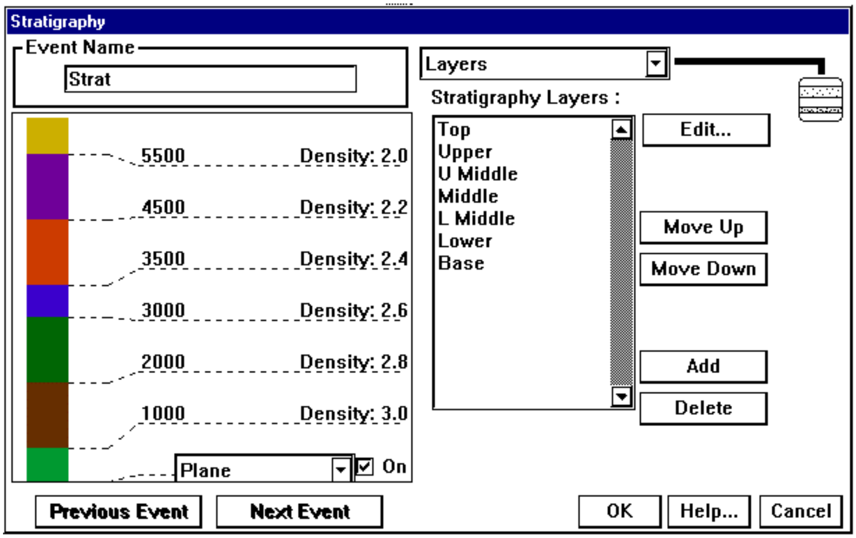
Base Stratigraphy Event



In order to define a Base Stratigraphy (which must be the first event in a history) place a Base Stratigraphy icon in the History window. You are then be provided with the Base Stratigraphy definition window.

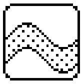
Group	**Name**	**Function**
Event Name	Name	Name of Stratigraphic sequence
Stratigraphic Layers		List of all layers currently defined for this stratigraphy
	Edit	Edit Rock Properties (e.g. thickness, density, name, colour etc) for currently highlighted layer
	Move Up	Move currently highlighted layer up in sequence
	Move Down	Move currently highlighted layer down in sequence
	Add	Add a new 1000 m thick layer above highlighted layer

	Delete	Delete highlighted layer

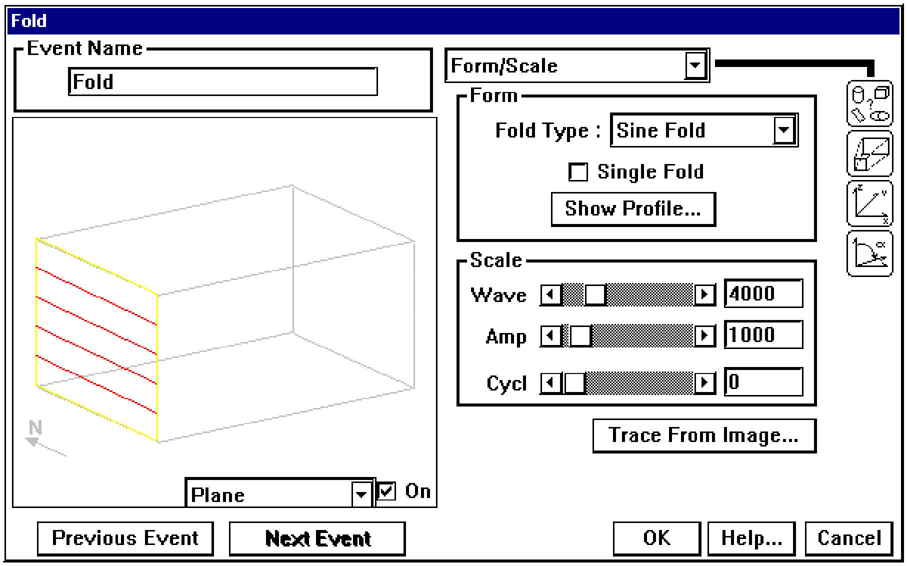


Base Stratigraphy Definition Window

Folding



In order to define a folding event place a Fold icon in the History window. You are then provided with the Fold definition window.



Fold definition dialog.

Note

All folds distort the existing geology by variable translation parallel to the fold axial plane. Fold events simultaneously generate an axial plane cleavage and a fold axis lineation.

As fold distortions occur parallel to the fold axial plane, introduction of a fold plunge must result from an additional Tilt event.

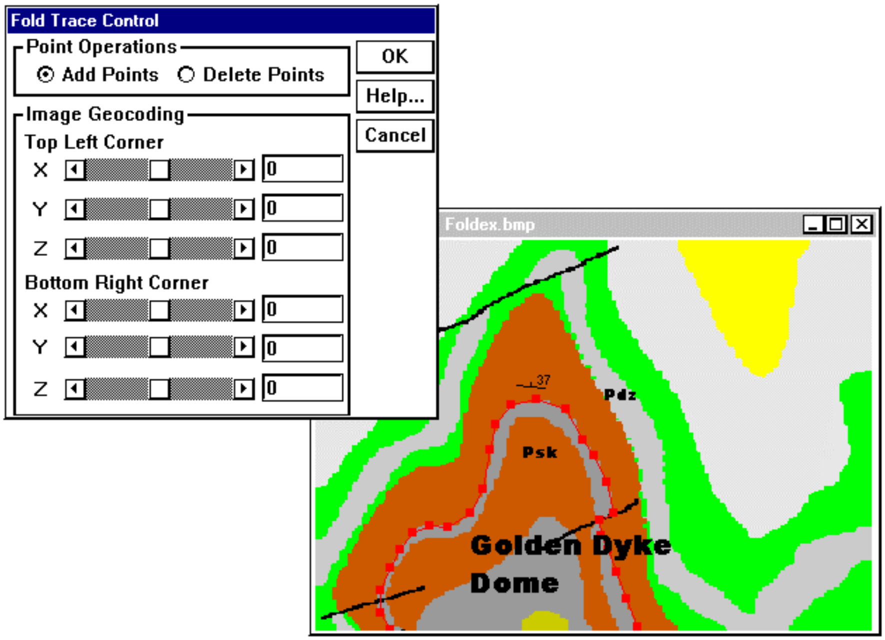
Group	Name	Function
Form	**Fold Type**	Select from Sinusoidal or User Defined fold profiles
	Single Fold	Only allow one fold train to develop
	Show Profile	Show and edit current fold profile

	Trace From Image	Trace fold profile over .BMP format image file
Position	**X**	Origin position in X direction of fold train
	Y	Origin position in Y direction of fold train
	Z	Origin position in Z direction of fold train
Orientation	**Dip Dir**	Dip Direction of Fold Axial Plane
	Dip	Dip of Fold Axial Plane
	Pitch	Pitch of Fold Axis in Axial Plane for cleavage and fold axis lineations
Scale	**Wave**	Wavelength of One Anticline/Syncline pair, or if User Defined, of one wave train as drawn
	Amp	Height of maximum fold displacement perpendicular to fold axis
	Cyl	Distance at which fold amplitude dies off 50% along fold axis (produces doubly plunging folds)

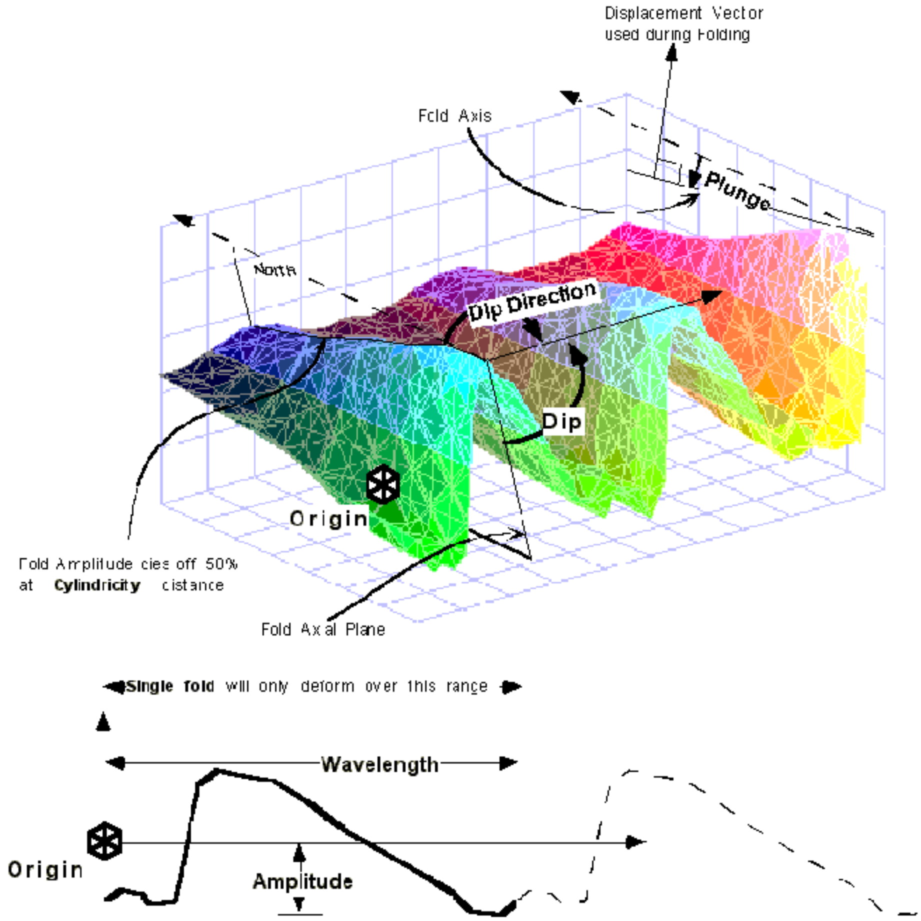
Tracing Fold Profiles Directly from Maps

When the **Trace From Image** button is selected, the program asks for a .BMP format file from which fold profiles can be directly traced. Digitizing from a loaded image can be used to calculate the fold wavelength, amplitude and position. The scaling of the profile is determined by the Fold Trace Control window, which determines the coordinates of the NW and SE corners. Points on the fold profile may be defined by clicking in the Image window, and edited by dragging them. To remove a point, select **Delete Points** and click on the unwanted point(s).

At present the fold profile tool only works for upright fold profiles, where the X values of the profile increase from left to right. The map image may need to be rotated before the tool can be used if the required fold outline is not upright.

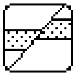


Tracing a fold trace from an imported bitmap.

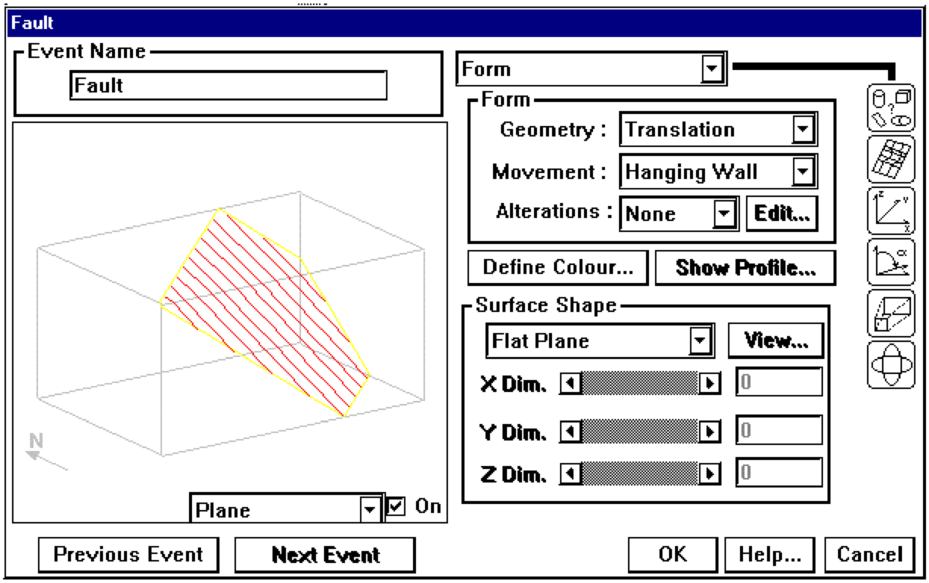


An example of a fold axis across a series of repetitive folds.

Faulting



In order to define a faulting event place a Fault icon in the History window. You are then provided with the Fault definition dialog.



Fault Definition Window

Fault surfaces can be planar or curved but the slip vector is always parallel across the plane. A fault plane is infinite in extent.

The X,Y,Z coordinates define any one point on the fault plane (and the centre of symmetry of ring, elliptical and curved faults). Most of the other parameters are normal structural definitions. Translational events implicitly generate fault slip vector lineations.

For DXF triangulated surface faults the DXF surface defines the fault plane shape, but is assumed flat and planar between defined points contained in the DXF. The slip vector is uniform in length parallel to the fault plane. The X,Y,Z coordinates in this case define the position of the top right corner of the surface, looking down on the plane.

Group	Name	Function
Form	**Geometry**	
	Translation	Simple planar translational faults
	Rotation	Simple planar rotational faults
	Elliptical	Elliptical fault plane, these faults displace material within an ellipsoidal zone defined by the long axes of the ellipsoid, with slip vectors dying off away from the centre of the ellipsoid.
	Curved	Curved fault plane, essentially an elliptical fault with a curved fault surface, which is defined by its profile, and the amount of decay of the curvature away from the plane of definition.
	Ring	Ring fault, producing a cylindrical volume of slipped material. Dip and Dip Direction are actually the to Plunge and Plunge Direction of central axis of ring fault.
	Movement	
	Hanging Wall	Hanging wall only movement on fault (hanging wall is inside of ring fault).
	Foot Wall	Foot wall only movement on fault (foot wall is outside of ring fault).
	Both	Both footwall and hanging wall. The total slip vector is divided into 50% movement in each direction.
	Alterations	
	None	No alteration halo associated with this event
	Top	Alteration halo on hanging wall side of fault

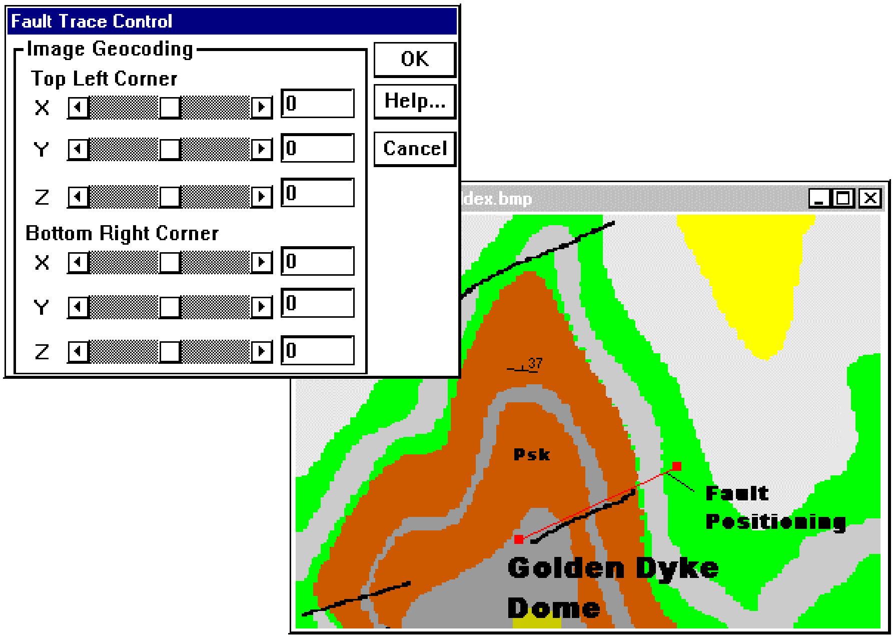
	Bottom	Alteration halo on foot wall side of fault
	Both	Alteration halo on both sides of fault
	Edit	Brings up Alteration Profile window
	Define Colour	Defines colour of fault plane for vector graphics displays
	Show Profile	Shows Profile Definition window for Curved Faults
Surface Shape	**Flat Plane**	Fault plane defined only by Geometries options (see above)
	DXF Surface	Part of fault plane defined by .DXF triangulated surface
	View	View grey scale image of DXF surface topography
	X Dim	Scaling factor for X direction of plane
	Y Dim	Scaling factor for Y direction of plane
	Z Dim	Scaling factor for Z direction of plane
Position	**X**	X position of one point on fault plane (centroid of elliptical and curved faults, centre of rotation of rotational faults, top right hand corner of DXF surface bounding rectangle)
	Y	Y position of one point on fault plane
	Z	Z position of one point on fault plane
Orientation	**Dip Dir**	Dip Direction of Fault Plane
	Dip	Dip of Fault Plane
	Pitch	Pitch of slip vector on fault plane

	Trace From Image	Allows orientation of fault to be traced directly from BMP format.
Scale	**Rotation**	Rotation of fault block in degrees, around normal to fault passing through X,Y,Z, anti-clockwise looking down rotation axis
	Slip	Displacement on fault parallel to slip vector
	Amplitude	Amplitude of curvature of fault, as defined on profile
	Radius	Radius of Ring Fault
	Cyl Index	Cylindricity index for decay of curvature of curved faults. Distance perpendicular to profile at which amplitude drops to 1/2 following a exponential drop-off
	Profile Pitch	Orientation of Curved Fault Profile (Independent of Slip Vector Pitch)

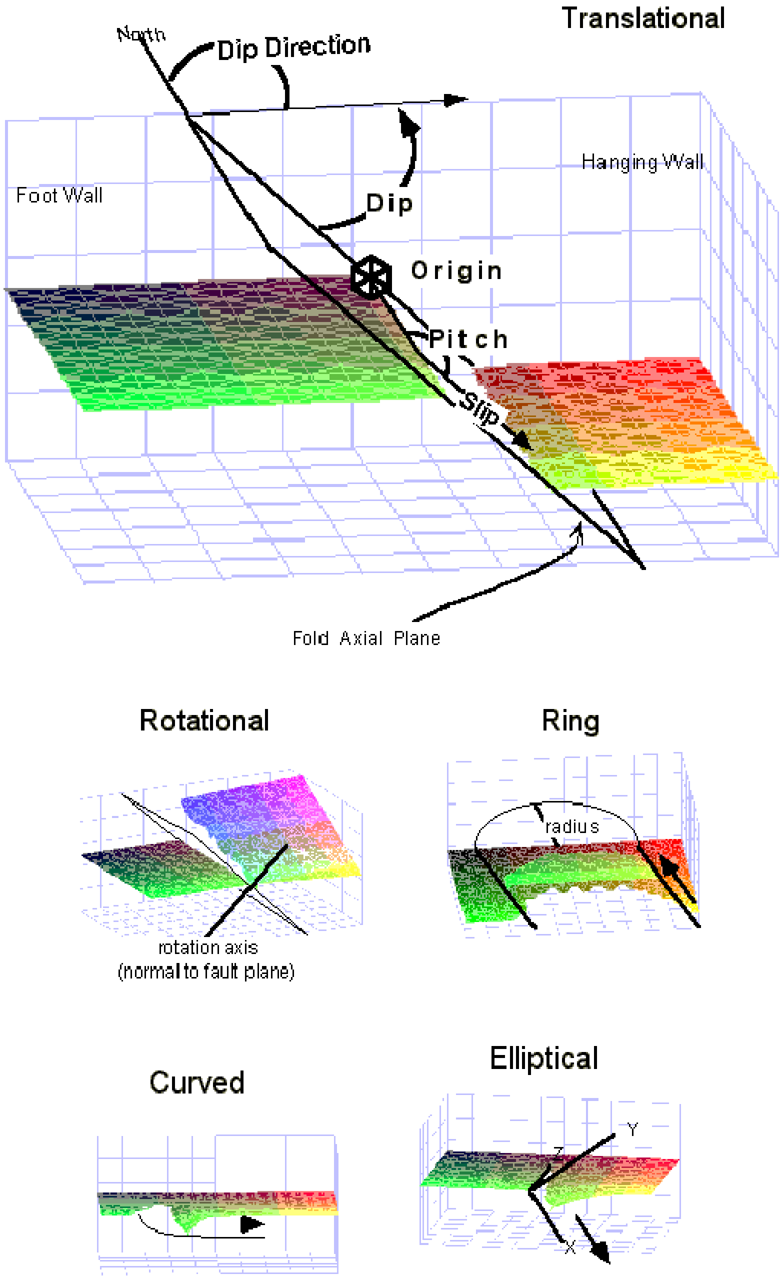
Scale (Ellipsoid)	**X Axis**	Long axes of ellipsoid for elliptical faults (X=slip direction, XZ plane = fault) The magnitude of the chosen slip vector must always be less than 45% of the X value.
	Y Axis	Magnitude of ellipsoid normal to fault plane
	Z Axis	Magnitude of ellipsoid normal to slip vector

Tracing Fault Orientations Directly from Maps

When the **Trace From Image** button is selected, the program asks for a bitmap (.BMP) format file from which fault trends can be traced directly. The scaling is determined by the Fault Trace Control window, which determines the coordinates of the NW and SE corners. Two points of a fault trace may be defined by clicking in the Image window. These may be edited by dragging them.

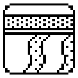


Fault trace entry from a bitmap.

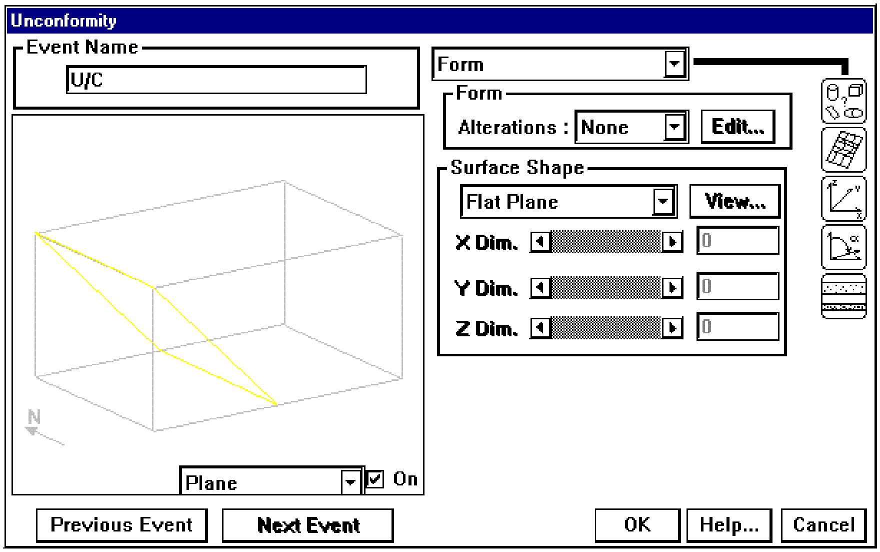


Schematic of fault forms.

Unconformity Event



In order to define an unconformity event, place an Unconformity icon in the History window. You are then provided with the Unconformity definition dialog.



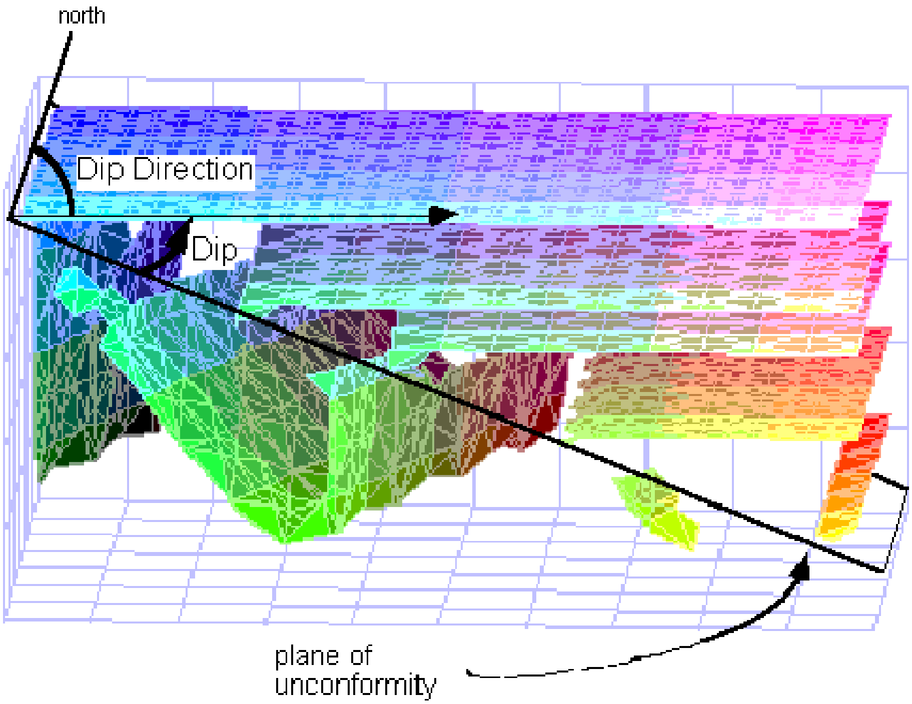
Unconformity editing dialog.

Unconformities are planar and infinite in extent. The X,Y,Z coordinates define one point on the plane of the unconformities (or the top right hand corner of the bounding rectangle of a DXF surface, if defined), and the other parameters are normal structural definitions.

A new stratigraphy above the unconformity also needs to be defined. Note that a stratigraphy icon appears on the right hand side of the dialog. Select this icon to define the stratigraphy above the defined unconformity. Refer to the *Base Stratigraphy* event for additional information.

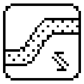
Group	Name	Function
Form	**Alterations**	
	None	No alteration halo associated with this event
	Top	Alteration halo on hanging wall side of fault
	Bottom	Alteration halo on foot wall side of fault
	Both	Alteration halo on both sides of fault
	Edit	Brings up Alteration Profile window
Surface Shape	**Flat Plane**	Flat planar unconformity
	DXF Surface	Part of unconformity plane defined by .DXF triangulated surface
	View	View grey scale image of DXF surface topography
	X Dim	Scaling factor for X direction of plane
	Y Dim	Scaling factor for Y direction of plane
	Z Dim	Scaling factor for Z direction of plane
Position	**X**	X position of one point on unconformity plane (top right hand corner of DXF surface bounding rectangle)
	Y	Y position of one point on unconformity plane(top right hand corner of DXF surface bounding rectangle)
	Z	Z position of one point on unconformity plane
Orientation	**Dip Dir**	Dip Direction of unconformity Plane

	Dip	Dip of unconformity Plane
Stratigraphy		Define the stratigraphic layers above the unconformable surface.

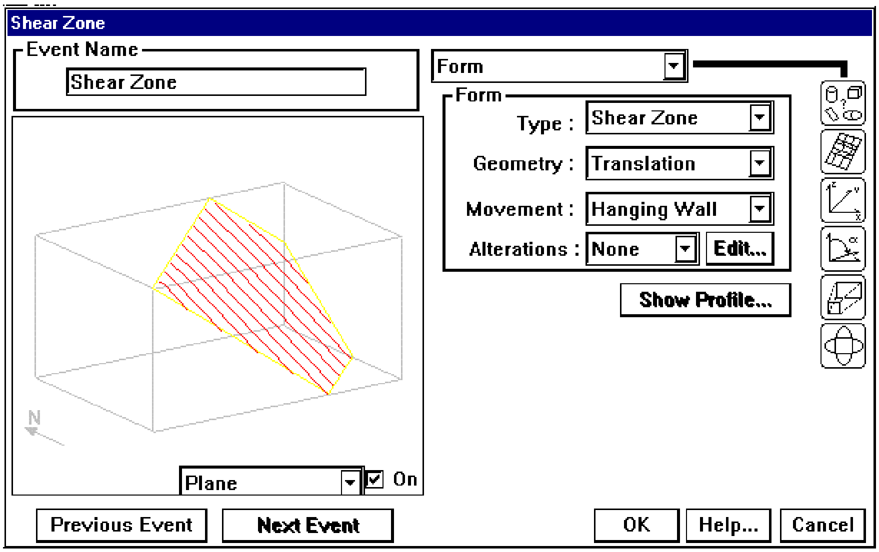


Schematic of unconformity.

Shear Zone Formation Event



In order to define a shear zone or kink event, place a Shear Zone icon in the History window. You are then be provided with the Shear zone definition dialog.



Shear Zone Definition Window

Shear zones and kinks are parallel sided zones of simple shear which share the same overall geometries as faults. The cross-sectional profile of the shear zone can either be sharp (kink) or smooth (shear zone).

A DXF file can be used to define a shear surface, similar to faults.

Group	Name	Function
Form	**Type**	
	Shear Zone	Smoothly varying displacements across shear zone
	Kink	Kink like displacement profile
	Geometry	
	Translation	Simple planar translational shear zones

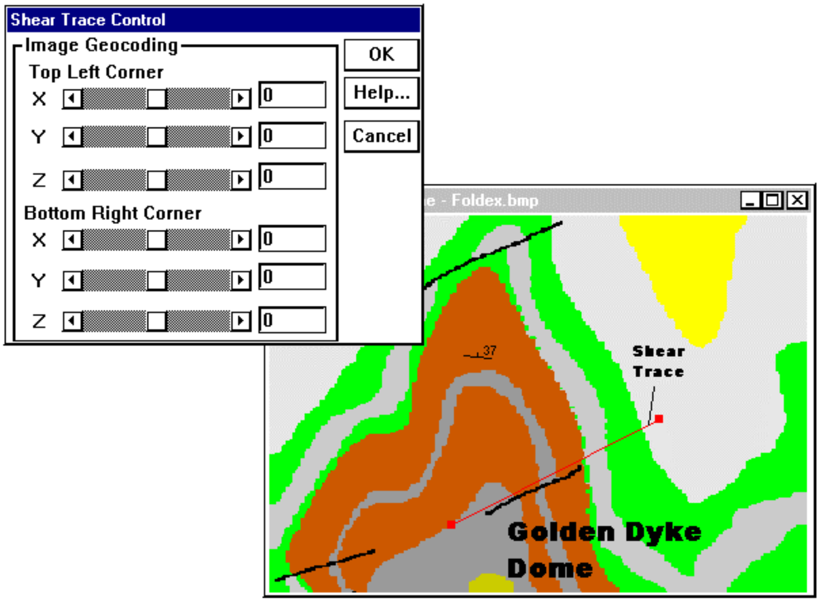
	Rotation	Simple planar rotational shear zones
	Elliptical	Elliptical shear zone plane, these shear zones displace material within an ellipsoidal zone defined by the long axes of the ellipsoid, with slip vectors dying off away from the centre of the ellipsoid.
	Curved	Curved shear zone plane, essentially an elliptical shear zone with a curved shear zone surface, which is defined by its profile, and the amount of decay of the curvature away from the plane of definition.
	Ring	Ring shear zone, producing a cylindrical volume of slipped material. Dip and Dip Direction are actually the to Plunge and Plunge Direction of central axis of ring shear zone.
	Movement	
	Hanging Wall	Hanging wall only movement on shear zone (hanging wall is inside of ring shear zone).
	Foot Wall	Foot wall only movement on shear zone (foot wall is outside of ring shear zone).
	Both	Both footwall and hanging wall. The total slip vector is divided into 50% movement in each direction.
	Alterations	
	None	No alteration halo associated with this event
	Top	Alteration halo on hanging wall side of shear zone
	Bottom	Alteration halo on foot wall side of shear zone
	Both	Alteration halo on both sides of shear zone
	Edit	Brings up Alteration Profile window

	Show Profile	Shows Profile Definition window for Curved Shear zones
Surface Shape	**Flat Plane**	Shear zone plane defined only by the Geometries options (see above)
	DXF Surface	Part of shear zone plane defined by .DXF triangulated surface
	View	View grey scale image of DXF surface topography
	X Dim	Scaling factor for X direction of plane
	Y Dim	Scaling factor for Y direction of plane
	Z Dim	Scaling factor for Z direction of plane
Position	**X**	X position of one point on shear zone plane (centroid of elliptical and curved shear zones, centre of rotation of rotational shear zones, top right hand corner of DXF surface bounding rectangle)
	Y	Y position of one point on shear zone plane
	Z	Z position of one point on shear zone plane
Orientation	**Dip Dir**	Dip Direction of Shear zone Plane
	Dip	Dip of Shear zone Plane
	Pitch	Pitch of slip vector on shear zone plane
	Trace From Image	Allows orientation of shear zone to be traced directly from BMP format.
Scale	**Rotation**	Rotation of shear zone block in degrees, around normal to shear zone passing through X,Y,Z, anti-clockwise looking down rotation axis
	Slip	Displacement on shear zone parallel to slip vector

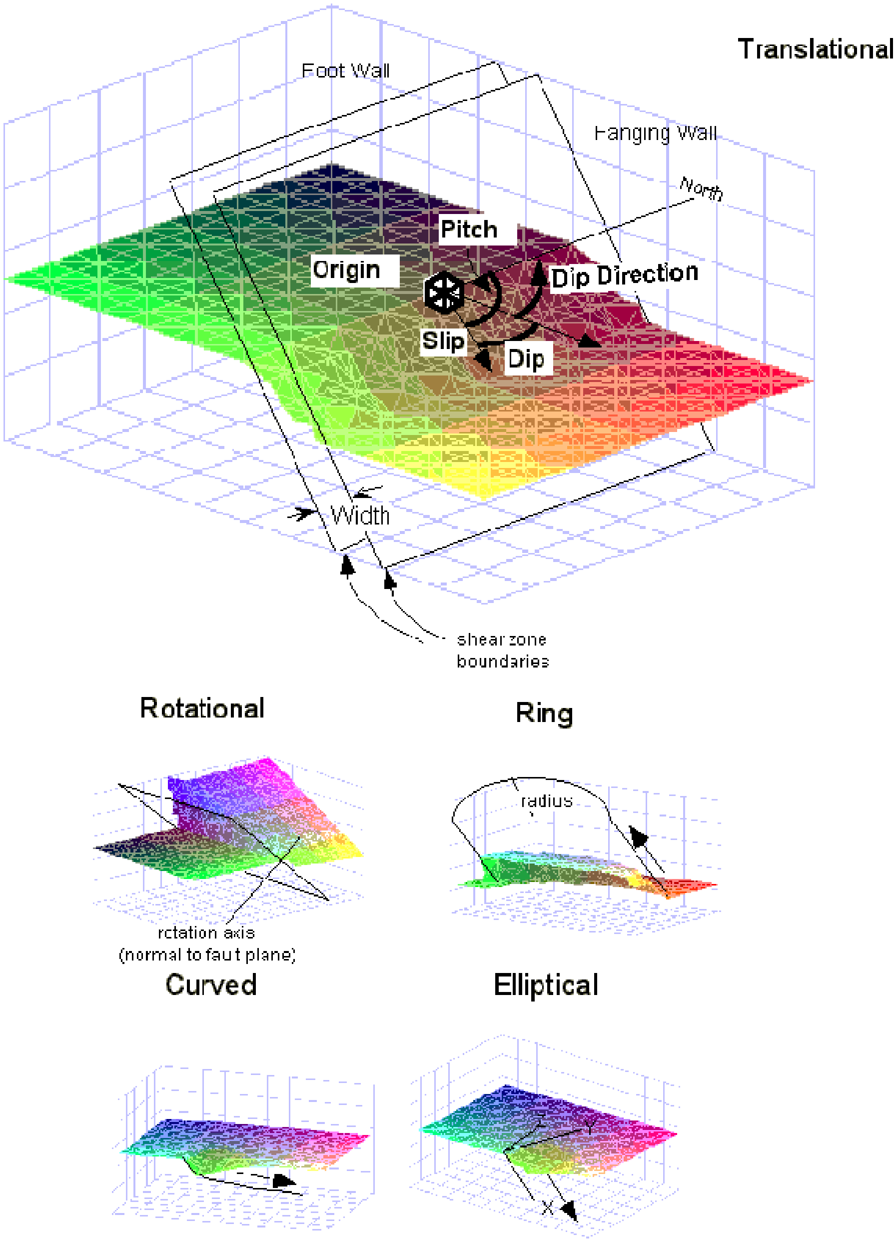
	Amplitude	Amplitude of curvature of shear zone, as defined on profile
	Width	Width of shear zone
	Radius	Radius of Ring Shear zone
	Cyl Index	Cylindricity index for decay of curvature of curved shear zones. Distance perpendicular to profile at which amplitude drops to 1/2 following a exponential drop-off
	Profile Pitch	Orientation of Curved Shear zone Profile (Independent of Slip Vector Pitch)
Scale (Ellipsoid)	**X Axis**	Long axes of ellipsoid for elliptical shear zones (X=slip direction, XZ plane = shear zone) The magnitude of the chosen slip vector must always be less than the X value.
	Y Axis	Magnitude of ellipsoid normal to shear zone plane
	Z Axis	Magnitude of ellipsoid normal to slip vector

Tracing Shear Zone Orientations From Maps

When the **Trace From Image** button is selected, the program asks for a .BMP format file from which fault trends can be traced directly. The scaling is determined by the Fault Trace Control window, which determines the coordinates of the NW and SE corners. The two points on the shear trace may be defined by clicking in the Image window. The shear points may be edited by dragging them.

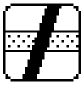


Shear trace creation from a bitmap.

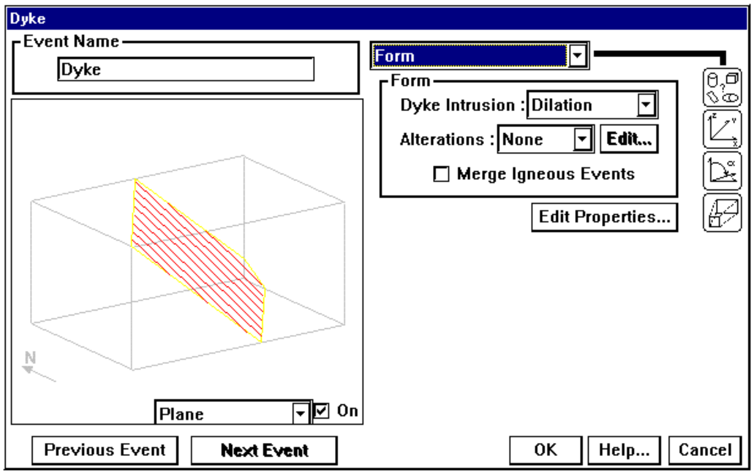


Schematic of shear trace forms.

Dyke Intrusion Event



In order to define a dyke event, place a Dyke icon in the History window. You are then provided with the Dyke definition dialog.



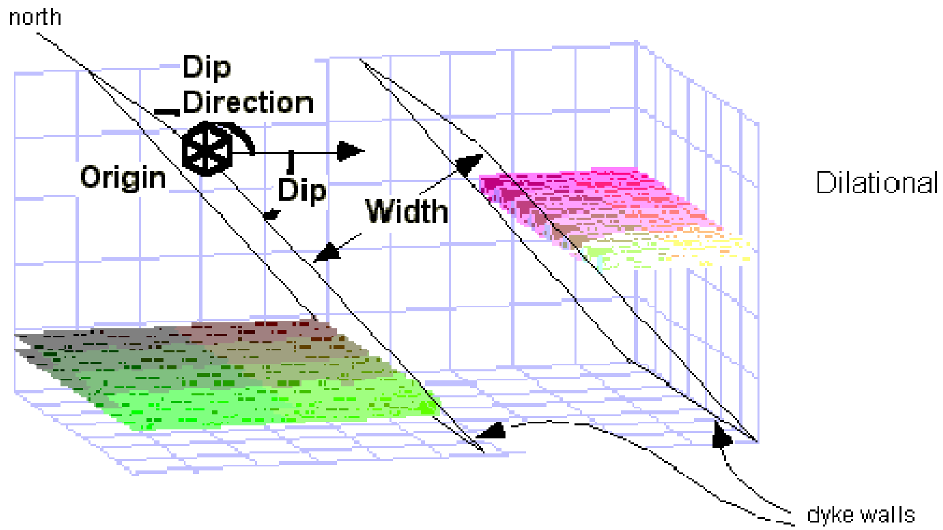
Dyke Definition Window

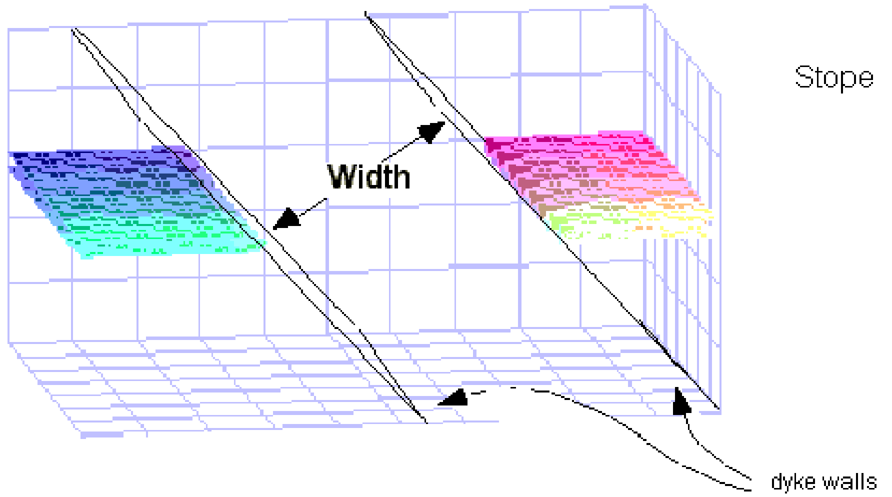
Dykes are parallel sided and are infinite in extent. The X,Y,Z coordinates define one point on the upper boundary of the dyke. The dyke can either be stope-like, where pre-existing material is replaced, or dilational, where the material on each side of the dyke is pulled apart to allow the dyke to form. In the latter case, an offset can be defined by the projected slip vector on the lower boundary. For dykes the name and geophysical properties have to be defined.

If you select the Merge Igneous Events option, Noddy forces all intrusive events such as dykes and plugs to merge in their timing and appearance.

Group	Name	Function
Form	**Dyke Intrusion**	
	Dilation	Dyke fills open space
	Stope	Dyke replaces existing rock
	Alterations	
	None	No alteration halo associated with this event
	Top	Alteration halo on 'hanging wall' side of dyke
	Bottom	Alteration halo on 'foot wall' side of dyke
	Both	Alteration halo on both sides of dyke
	Edit	Brings up Alteration Profile window
	Edit Properties	Editing window for geophysical properties of dyke rock
Position	**X**	X position of one point on lower contact of dyke
	Y	Y position of one point on lower contact of dyke
	Z	Z position of one point on lower contact of dyke
Orientation	**Dip Dir**	Dip Direction of dyke plane
	Dip	Dip of dyke plane
	Pitch	Pitch of slip of hanging wall for dilational dyke (leave at 90°)
Scale	**Rotation**	Rotation of shear zone block in degrees, around normal to shear zone passing through X,Y,Z, anticlockwise looking down rotation axis

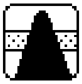
	Slip	Displacement of hanging wall of dyke (should be equal to Width)
	Width	Width of dyke



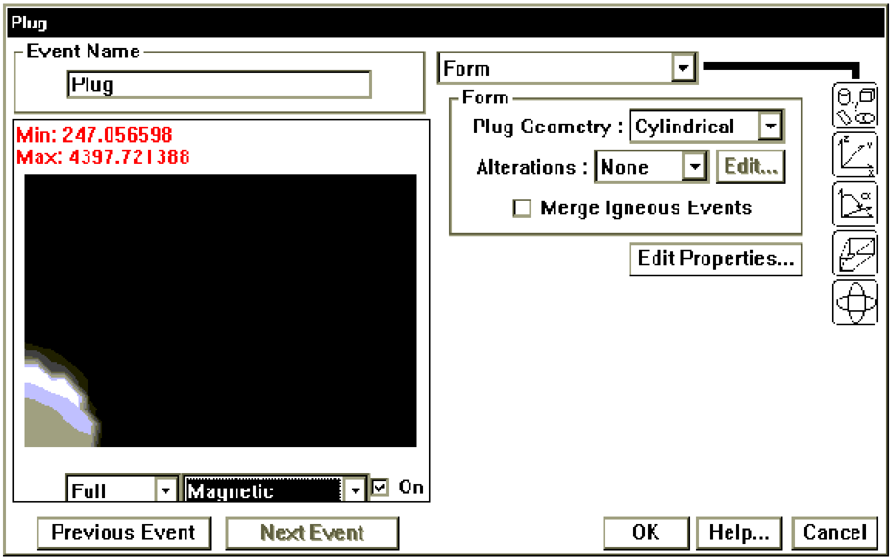


Schematic showing the various dyke forms.

Plug Intrusion Event



In order to define a plug event, place a Plug icon in the History window. You are then provided with the Plug definition dialog.



Plug Definition Window

Plugs can have a variety of shapes, but all have radial symmetry about an axis which is perpendicular to the defining plane (except for ellipsoidal plugs). The plugs can have four fundamental shapes:

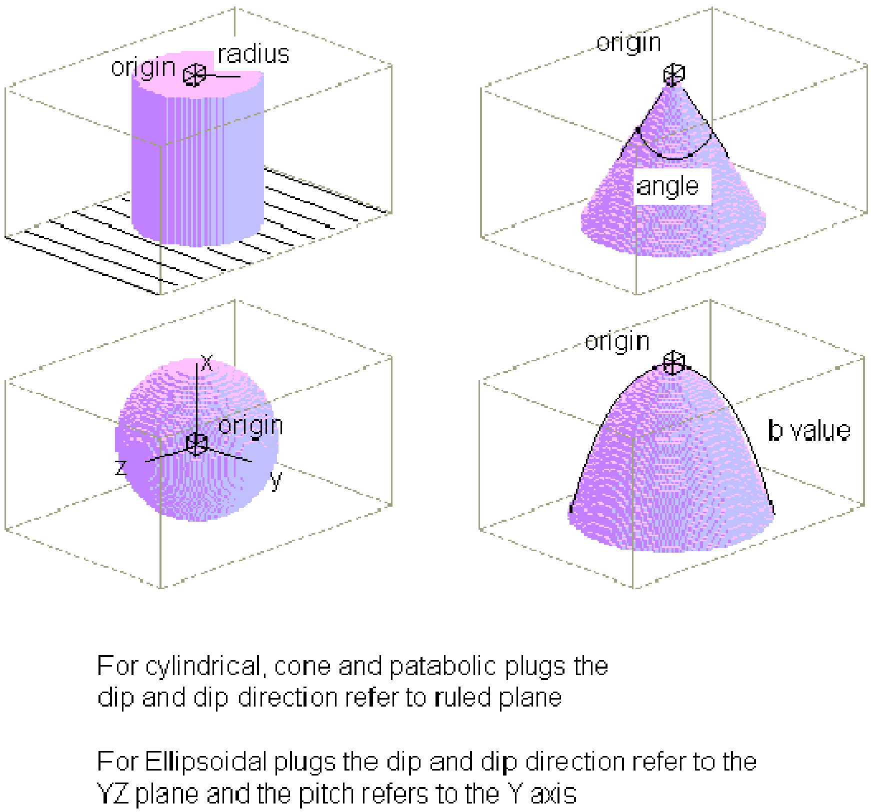
- Conic
- Parabolic
- Cylindrical
- Ellipsoidal.

The X,Y,Z coordinates define the apex of cone or parabolic plugs, one point on the central axis of cylindrical plugs (which are infinite in length) and the centre of symmetry of ellipsoidal plugs. The plug is always stope-like. The defining plane of plugs is perpendicular to the central axis of the conic, parabolic and cylindrical shape. For ellipsoidal plugs the defining plane is the XY central intersection of the shape.

If you select the Merge Igneous Events option, Noddy forces all intrusive events such as plugs and dykes to merge in their timing and appearance.

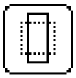
Group	Name	Function
Form	**Plug Geometry**	
	Cylindrical	Infinite cylinder
	Cone	Cone
	Parabolic	Parabaloid
	Ellipse	Ellipsoid
	Alterations	
	None	No alteration halo associated with this event
	Top	Alteration halo on hanging wall side of fault
	Bottom	Alteration halo on foot wall side of fault
	Both	Alteration halo on both sides of fault
	Edit	Brings up Alteration Profile window
	Edit Properties	Editing window for geophysical properties of dyke rock
Position	**X**	X position of one plug (one point on central axis of cylinder, apex of cone, apex of parabaloid, centre of ellipsoid)
	Y	Y position of one plug
	Z	Z position of one plug
Orientation	**Dip Dir**	Dip Direction of plane normal to cylinder, cone

		and parabaloid axes; and parallel to XY plane of ellipsoid
	Dip	Dip of plane normal to cylinder, cone and parabaloid axes; and parallel to XZ plane of ellipsoid
	Pitch	Pitch of X direction for ellipsoid
Scale	**Radius**	Radius of cylindrical plug
	Angle	Apical angle of cone shaped plug
	B Value	Width of plug at depth Z is defined by ($Z^{1/2}$ * B/10)
Scale (Ellipsoid)	**X Axis**	Length of X axis of ellipsoid for ellipsoidal plugs
	Y Axis	Length of Y axis of ellipsoid for ellipsoidal plugs
	Z Axis	Length of Z axis of ellipsoid for ellipsoidal plugs

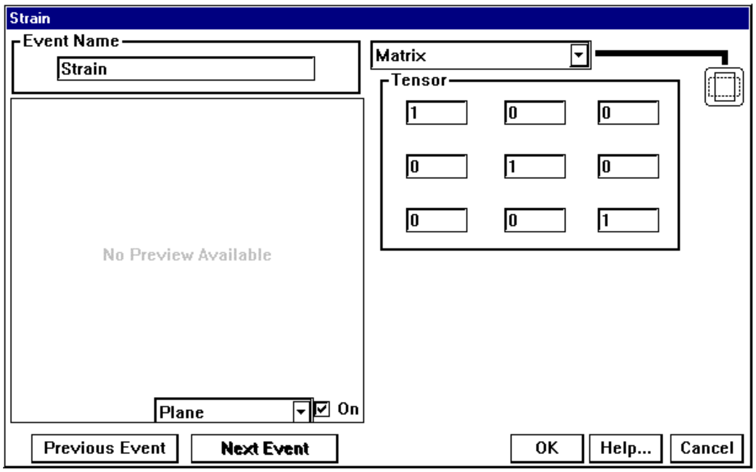


Schematic of the various plug/intrusive forms.

Strain Event



In order to define a Strain event, place a Strain icon in the History window. You are then provided with the Strain definition dialog.

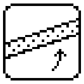


Strain Definition Window

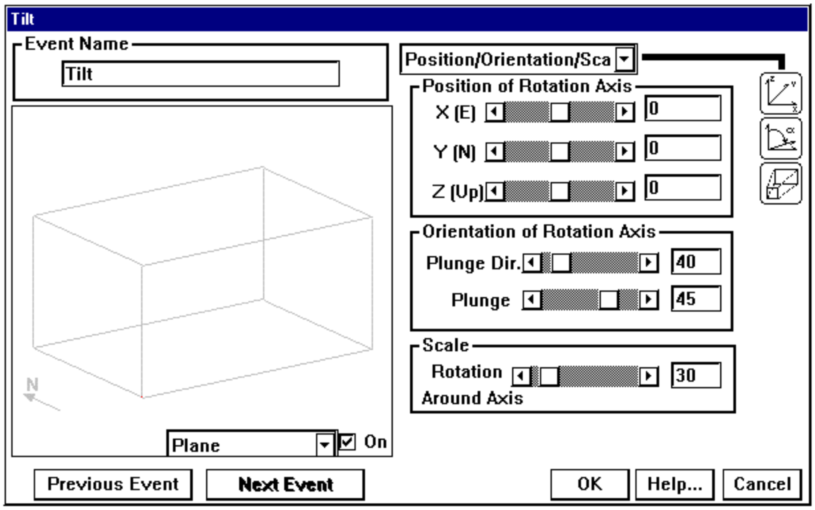
Strain allows strain tensors to be applied to previously defined geological events. The strain may be arbitrarily applied but is homogenous in its defined direction. Strains may not be volume preserving and may distort the internal volumes of layers and intrusives.

There is no Plane Preview for the Strain Definition window, however all other preview types operate.

Tilting



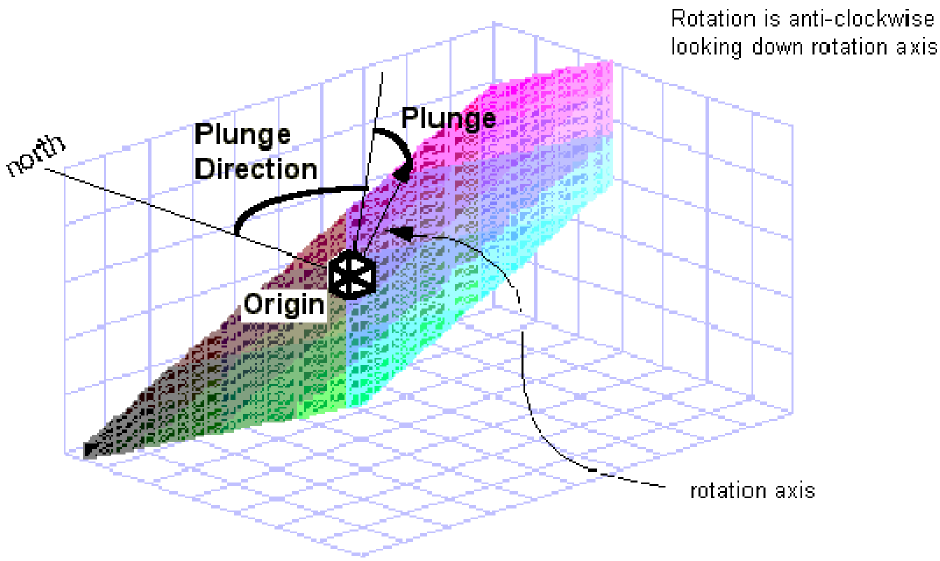
In order to define a Tilt event, place a Tilt icon in the History window. You are then provided with the Tilt definition dialog.



Tilt Definition Window

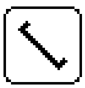
Tilt allows arbitrary uniform rotations to be used. The rotation is defined by a rotation axis, and a rotation about the axis in degrees, anticlockwise, looking down the axis.

Group	**Name**	**Function**
Position	**X**	X position of one point on rotation axis
	Y	Y position of one point on rotation axis
	Z	Z position of one point on rotation axis
Orientation	**Plunge Dir**	Plunge Direction of rotation axis
	Plunge	Plunge of rotation axis
Scale	**Rotation**	Rotation in degrees around axis, anticlockwise looking down axis

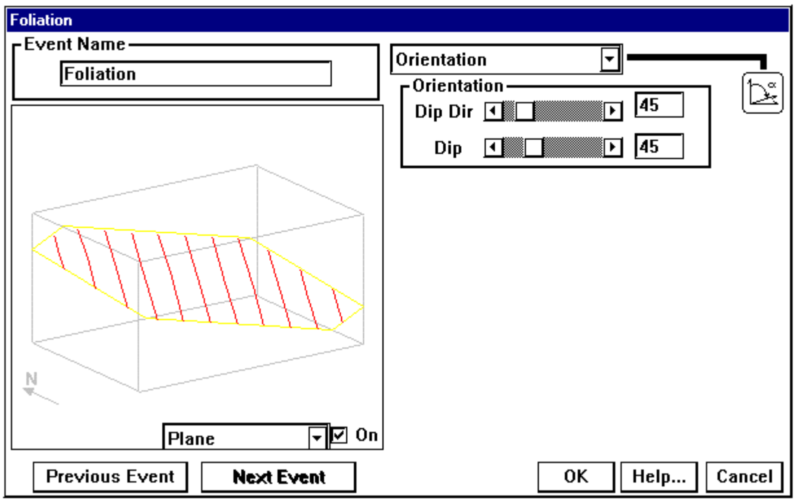


Schematic of tilt events.

Foliation Formation Event



In order to define a Foliation event, place a Foliation icon in the History window. You are then provided with the Foliation definition dialog.

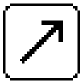


Foliation Definition Window

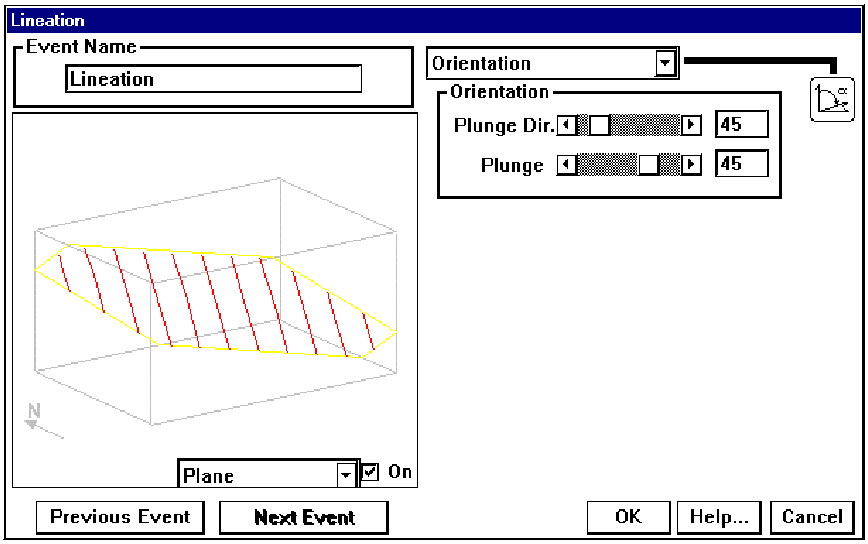
Foliation allows arbitrary penetrative foliations to be added to the geology. These foliations are not associated in any way with any other deformation, and do not displace the geology. They are available as extra planar orientation markers, and as such could be used to represent cross-bedding in a sandstone, or igneous layering or more typically a cleavage not otherwise associated with a deformation event.

Group	Name	Function
Orientation	**Dip Dir**	Dip Direction of foliation
	Dip	Dip of Foliation

Lineation Formation Event



In order to define a Lineation event, place a Lineation icon in the History window. You are then provided with the Lineation definition dialog.

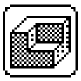


Lineation Definition Window

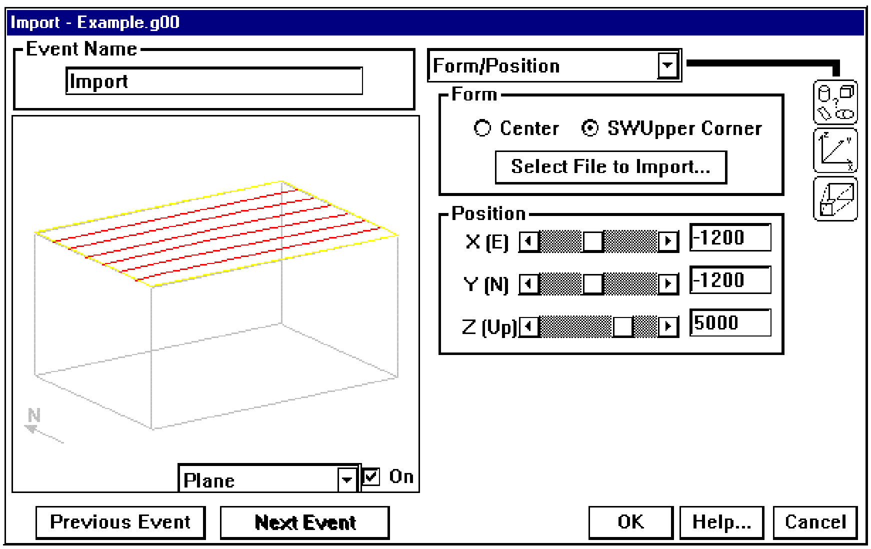
Lineations allows arbitrary penetrative lineations to be added to the geology. These lineations are not associated in any way with any other deformation, and do not displace the geology in any way. They are merely available as extra linear orientation markers, and as such could be used to represent flow directions in a sandstone or more typically a lineation not otherwise associated with a deformation event.

Group	Name	Function
Orientation	**Plunge Dir**	Plunge Direction of lineation
	Plunge	Plunge of lineation

Import Block Model Event



In order to Import an existing block model as an event, place an Import icon in the History window. You are then provided with a File Open window to select the block file (which has a default suffix of .G00). Once the file has been read in, a second window opens that allows you to alter the offset, the scale and other import parameters.



Import block edit dialog.

A block model is a three dimensional structure described as a regular voxel model, that is it is broken up into equal sized cubes. The format of the block model must be a standard indexed Noddy block model file set, with default suffix .G00. Various formats may be converted into Noddy block format, such as raw voxel models, old Noddy block model formats, and Vulcan regularized block models, via the Tools menu. Refer to the *Tools* section).

The geology in the rectangular volume defined by the block model is replaced by the content of the block model, with one exception if the transparency value for a particular voxel is zero. In this case the pre-existing geology remains. Using the **Scale Properties>Transparent Layers** option, multiple unconnected objects may be imported at one time, and objects may be hollow, or in fact have any complex structure desired.

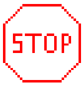
Internal boundaries defined by imported block models are not seen by the triangulation calculation (3D Layer view).

History files save the associated block model by absolute path name, hence if a history file and its block model are moved to a new file system, the block model may need to be re-imported.

Group	**Name**	**Function**
Form	**Centre**	Position parameters refer to centre of rectangular block
	SWUpper Corner	Position parameters refer to South West Upper corner of rectangular block
	Select File to Import	Allows new block model file to be imported
Position	**X**	X position of either centre or corner of block (see above)
	Y	Y position of either centre or corner of block (see above)
	Z	Z position of either centre or corner of block (see above)
Scale	**Block Size**	Size of cubes
Rock Properties	**Rock Properties**	Edit individual geophysical rock properties of imported block

	Transparent Layer 0+	All blocks with an index of 0 or this value are ignored, and the underlying geology ‘shows through’

Stop Sign



To temporarily halt the structural history calculation short of the complete sequence, the Stop Sign icon may be placed anywhere after the initial Base Stratigraphy. Any structural or geophysical calculations stop at the first Stop Sign found in the sequence.

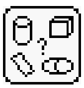
Tip Make sure to remove these icons when the full history is required again.

Parameter Groups

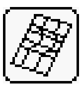
All structural modelling is kinematic and is based on the application of displacement equations or replacement zones of seven basic classes of parameters, viz **Form**, **Surface Shape**, **Position**, **Orientation**, **Scale**, **Ellipsoidal Scale** and **Stratigraphy**.

Parameter Group Icons

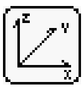
The deformation event definition windows are standardised so that the same basic window is used to define all event types. Parameters belonging to each class are grouped together. Each group may be selected by clicking on the appropriate icon on the right hand side of the window, or selecting the group from the menu above the groups of parameters. The parameter group icons (different combinations of which are present for different events) are:



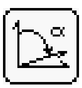
Form - The form parameter is generally defined by the program from a few set shapes, with the notable exception of folds, which can have any profile.



Surface Shape - For unconformities, faults and shear zones the defining surface can be read in as a DXF triangulated surface, and can be loaded, seen in plan view and re-scaled using parameters from this group.

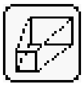


Position - The coordinate convention used in Noddy assumes X (EW) is positive towards the East, Y (NS) is positive towards the North and Z is positive up.

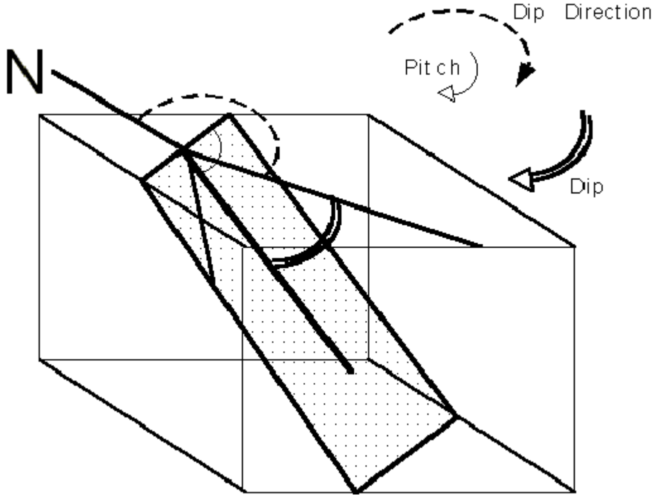


The default block is defined by a rectangular volume with opposite corners at 0,0,0 and 10000,7000,5000 metres X,Y,Z (W,N,Z) respectively, so that the top surface of the block is the ‘map area’. Events which are localized and defined to occur outside this block are only seen if the origin or scale of the block are altered or subsequent deformation brings them into view. An overriding XY offset may be defined to match the model to real world coordinate systems.

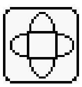
The scale and extent of the displayed block must be considered when an event, or its effect is not obvious when you feel it should be.



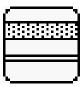
Orientation - Planar features are defined by their dip and dip direction, and independent linear features are defined by their plunge and plunge direction. Linear features associated with planes, such as slip vectors on faults or fold axes, are defined by their pitch.



Scale - The spatial dimension of all features is defined in metres.



Ellipsoid Scale - Ellipsoidal plugs and elliptical and curved faults require the dimensions of the ellipsoid to be defined.



Stratigraphy - This allows the definition of a stratigraphy, for the base stratigraphy and unconformities.

Previews in Event Definition Windows

In each structural definition window and some other option windows is a preview window that helps you to choose the correct parameters for each deformation event. Two distinct preview menus are provided which in combination allow many different previews of the geological or geophysical results of changing specific parameters.

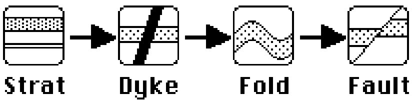
All types of previews update automatically whenever a parameter is altered in the event definition window. Alternatively, click in the Preview window. Some examples of the various preview combinations are shown below.

Block Previews

These provide a block diagram view of the effect of the current event on the geology. The Block Preview format is the default presentation type when event edit dialogs are initially displayed. Three types of Block Preview can be selected from the pull-down menu item that appears to the left of the Preview Type menu in the preview window. The three choices are:

- **Event -** Shows the effect of this event on the Base Stratigraphy.
- **History -** Shows the cumulative effect of events up to and including the event currently being edited.
- **Full -** Shows the effect of all the events defined in the History Window.

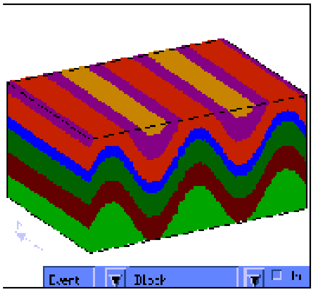
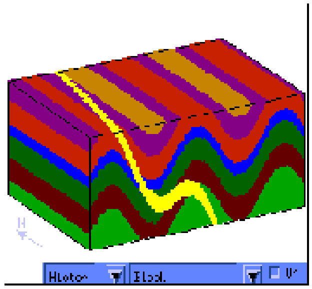
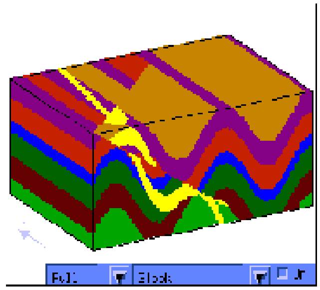
In the example history pictured below the fold event is currently being edited. Thus, **Block/Event** shows the effect of folding only, **Block/History** shows the effect of the dyke and the fold, and **Block/Full** shows the entire history.



The block diagram origin and scale are determined by the current **Edit>Block Options** settings and the resolution is 60% of the current **Geology Block Size** settings.

Note

The preview block diagram is not rotatable. It is quite possible for the block diagram to be unaffected by an event, depending on the choice of parameters.

Block/Event Preview *Block/History Preview* *Block/Full*
Preview

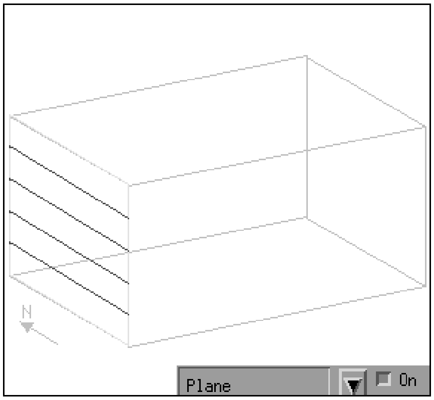
Plane Previews

Plane previews show the current orientation and position of the planar and/or linear features described for the particular event. In each Structural Definition window there is a small preview showing the current orientation and position of the planar and or linear features described for the particular event.

Within the rectangular volume, planar features are defined by a yellow outline, and linear features are defined by a set of red parallel rulings within the plane. The arrow of the block view points to North. The preview is sensitive to orientation settings such as dip, dip direction and pitch, as well as positional information in X,Y,Z form.

Note

If large or negative values are used for X,Y and Z the volume may be blank, as the plane is outside the field of view.



Plane Preview

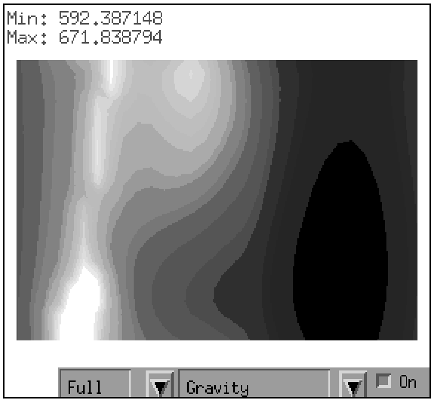
Gravity/Magnetics Previews

These show a preview of the geophysical fields resulting from the currently defined geology. As with **Block Previews**, three types of preview (**Event**, **History** and **Full**) may be selected from the pull-down menu that appears to the left of the Preview Type menu in the preview window.

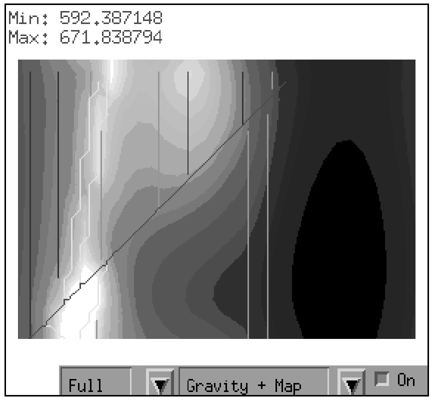
In addition, a line map of the geology may be overlain on the geophysical image by selecting **Gravity + Map** or **Magnetics + Map**.

The calculation origin and scale are determined by the current **Edit>Block Options** settings and the resolution is 60% of the current **Geophysics Block Size** settings.

Note If complex geology or fine cube sizes are chosen, previews are slow to display. It is often better to switch off the Preview, change a number of parameters, and then switch back to block or other computationally intensive previews.



Gravity/Full Preview



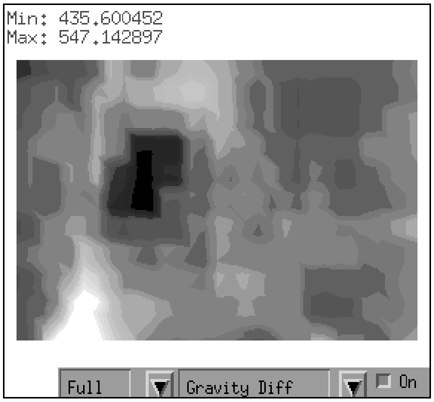
Magnetic+Map/History Preview

Difference Previews

Difference Previews show the arithmetic difference between the currently modelled gravity or magnetics and a previously defined reference dataset. As with other previews, three types of preview (**Event**, **History** and **Full**) may be selected from the pull-down menu that appears to the left of the Preview Type menu in the Preview window.

If no gravity or magnetics reference image has been loaded, this option is not able to function (see *Reference Datasets*).

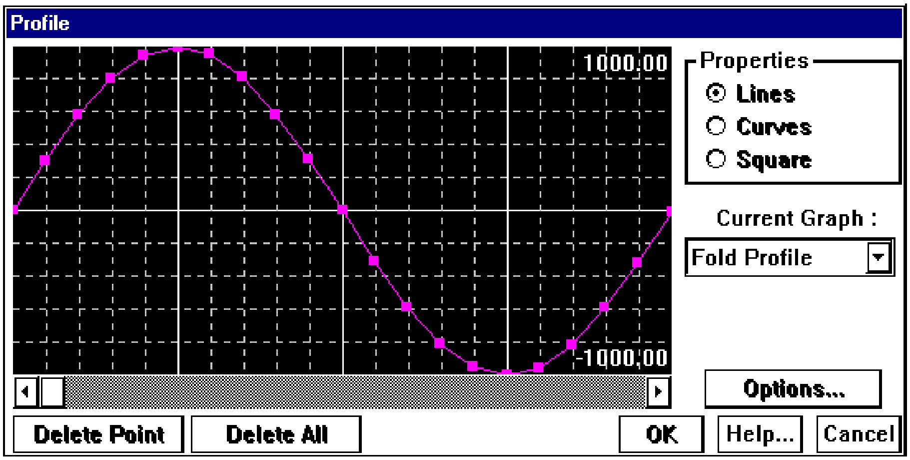
In order to convert another image format to Noddy geophysics .MAG or .GRV formats, first dump the other image out in ASCII tab-delimited or space-delimited format, then import using **Import Image>ASCII** from the Tools menu.



Gravity Difference Image Preview

Profile Window

When defining a geological event by profile (faults, shear zones, folds, alteration haloes) a standardized profile window appears:



The profile window for defining the control of faults, shears etc.

Three point based drawing modes are allowed in this window:

- **Lines -** Each point on the profile is joined by a straight line.
- **Curves -** The profile is defined by a Bezier Curve that does not pass through each entered point (except the end points)

- **Square -** A square waveform is defined by the points (mostly used for replacement zones)

Additional options are provided to:

- **Add points -** Individual points may be added to the profile by clicking in the window
- **Delete Points -** Individual points may be deleted from the profile by selecting them with the mouse and then clicking on the **Delete Point** button
- **Moving Points -** Individual points may be moved by dragging them around the window with the mouse.

For alteration zones, the scaling of the window may be altered by clicking on the **Options** button. Other properties can be individually varied by selecting from the **Current Graph** menu list.

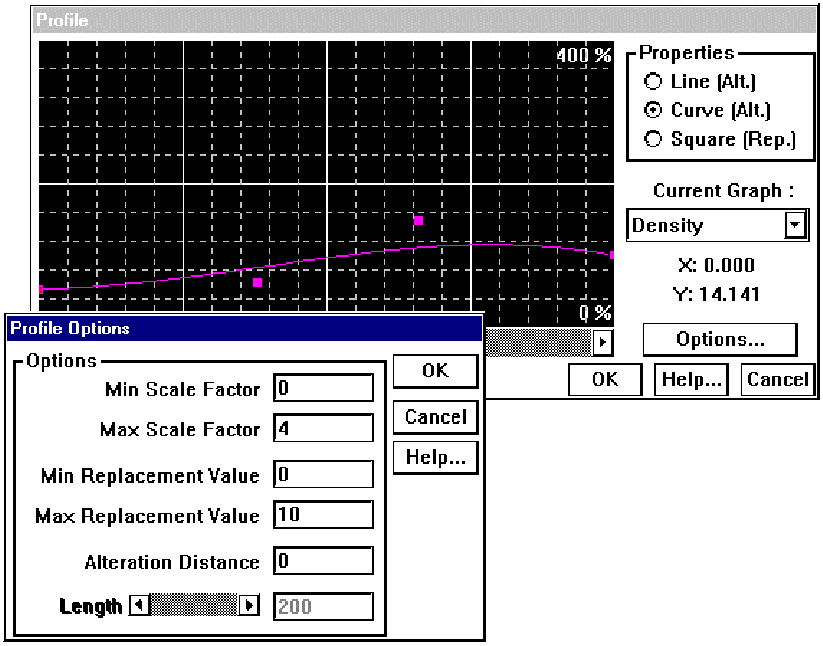
For deformation event profiles, scaling is accomplished using the normal scaling parameters, such as fold Amplitude.

Alteration Zone Definition

Alteration zones can be created around a number of structural features (faults, shear zones, plugs, dykes and unconformities). The zones are defined as either alteration haloes, where the pre-existing rock property values are enhanced or depleted, or as replacement zones, where the original rock property values are replaced without regard for the original values. In either case, the alteration profile varies as a function of distance from the structural feature. This uses a standard profile definition window, and where appropriate, can be defined as occurring above and/or below the defining surface. Beyond the Alteration Distance, the rocks simply maintain their original values.

Alteration Haloes

Rock properties in alteration haloes are defined by the product of the original rock property value and the alteration index. This index is defined as a function of distance using the Alteration Profile window, with the Properties value set to Line or Curve. The specific geophysical rock property profile being defined is selected from the Current Graph menu list, and the Options window supplies specific scaling parameters.



Alteration Haloes and Options Profile Window

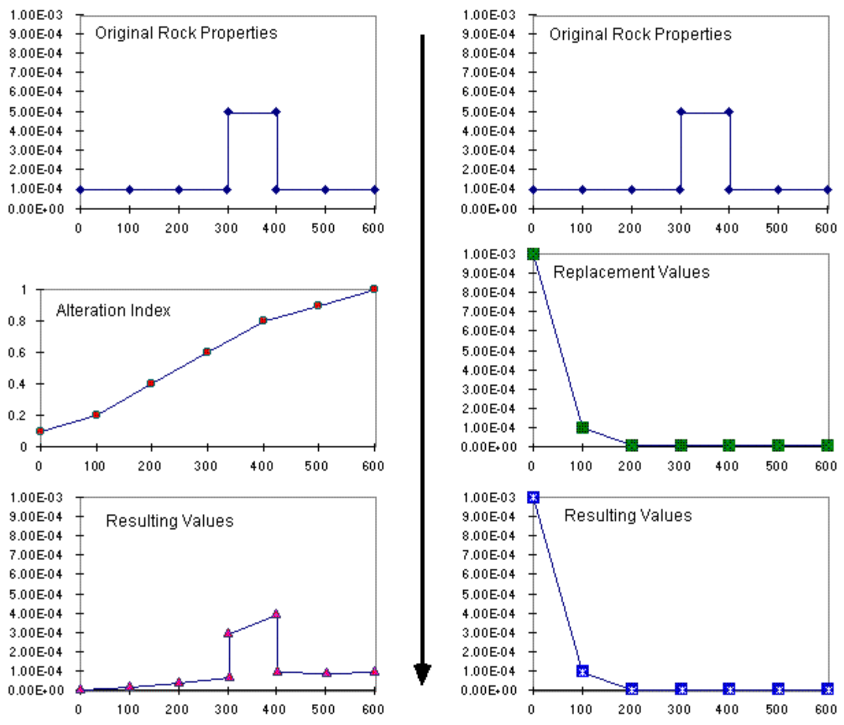
Replacement Zones

Rock properties in these zones are defined by their alteration value. With the Properties value set to Square, a replacement zone uses the alteration value applied (but varying as a step function) over the distance specified in the alteration profile window.

Comparing Alteration Versus Replacement Behaviour

As an example of how alteration haloes behave compared to replacement zones, the post alteration susceptibility values for these two modes are compared in table and graph form below. In the following table, the alteration profile values and the original susceptibility are shown as a function of distance away from a dyke with an Alteration Distance set to 600m.

Distance to Fault	Original Susceptibility	Alteration Halo Index	Resulting Susceptibility	Replacement Index	Resulting Susceptibility
0	1.0e-4	0.1	1.0e-5	1.0e-3	1.0e-3
100	1.0e-4	0.2	2.0e-5	1.0e-4	1.0e-4
200	1.0e-4	0.4	4.0e-5	1.0e-5	1.0e-5
300	5.0e-4	0.6	3.0e-4	1.0e-5	1.0e-5
400	5.0e-4	0.8	4.0e-4	1.0e-5	1.0e-5
500	1.0e-4	0.9	9.0e-5	1.0e-5	1.0e-5
600	1.0e-4	1.0	1.0e-4	1.0e-5	1.0e-5
601	1.0e-4	undefined	1.0e-4	undefined	1.0e-4



Alteration effects as a function of distance from fault

In order to turn on or off an anisotropic susceptibility and remanence within an alteration zone, an on-off control is required. The behaviour of the profile window for the **Anisotropy** and **Remanence** settings is to turn these types of behaviour on (non-zero Y axis values) or off (zero Y axis values). The easiest way to set these parameters is with the Square Profile option. The underlying colour of the profile changes to green when these controlling settings are turned on, and this colouration remains for all parameters that depend on the controlling profile.

Group	**Name**	**Function**
Properties	**Line**	Alteration Halo profile defined by straight line segments
	Curve	Alteration Halo profile defined by Bezier Curve
	Square	Replacement Zone profile defined by step function
	Current Graph	Currently selected rock property for profile definition
	Delete Point	Delete currently selected point from profile
	Delete All	Revert Profile back to default settings
	Options	Scaling Options for profile
Options	**Min Scaling**	Minimum Y axis value for alteration haloes
	Max Scaling	Maximum Y axis value for alteration haloes
	Min Replacement	Minimum Y axis value for replacement zones
	Max Replacement	Maximum Y axis value for replacement zones
	Alteration Distance	X axis distance on profile (distance beyond which alterations of either type have no effect)

Rock Properties Definition

This window can be accessed from the **Stratigraphy Definition** window or when defining an event that generates new lithologies (dykes, plugs and unconformities). Within this window you can define the name, alteration properties, geophysical properties and thickness of a given lithology.

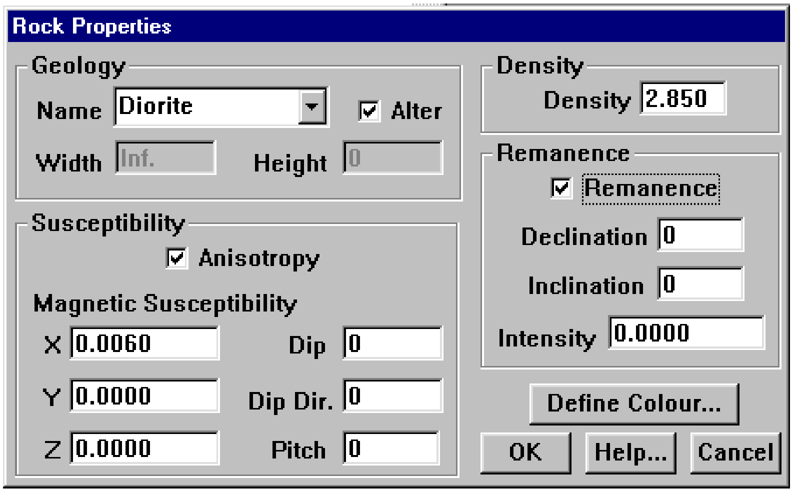
Stratigraphic Thicknesses

For stratigraphically defined units (that is, the base stratigraphy and unconformities, but not dykes or plugs), the thickness of the unit is defined (in metres) as follows:

a. The top-most unit extends infinitely upwards in the positive Z direction, and the base of this unit is defined by the Height parameter.

b. Middle units are defined by their Width (thickness).

c. The lowest unit extends down (in the negative Z direction) from the base of the unit above it to infinity.



Rock Properties Window

Group	Name	Function
Geology	**Name**	User Selectable name, also a menu for pre-defined rock properties from the Rock Property Database
	Width	Thickness of stratigraphically defined lithologies (Except topmost or lowermost unit in a sequence)
	Height	Level of base of topmost unit in a stratigraphically defined lithology
	Alter	Allows this unit's geophysical properties to be affected by alteration haloes, if not checked the original rock property values are retained during alteration events.
Susceptibility	**Anisotropy**	Defines susceptibility to be anisotropic
	Magnetic Susceptibility X	Magnitude of Anisotropy in user defined units in the X direction (or for all 3 directions if Anisotropy is not checked)
	Magnetic Susceptibility Y	Magnitude of Anisotropy in user defined units in the Y direction (only if Anisotropy is checked)
	Magnetic Susceptibility Z	Magnitude of Anisotropy in user defined units in the Z direction (only if Anisotropy is checked)
	Dip	Dip of XY plane of Anisotropy
	Dip Direction	Dip Direction of XY plane of Anisotropy
	Pitch	Pitch of X direction in XY plane of Anisotropy

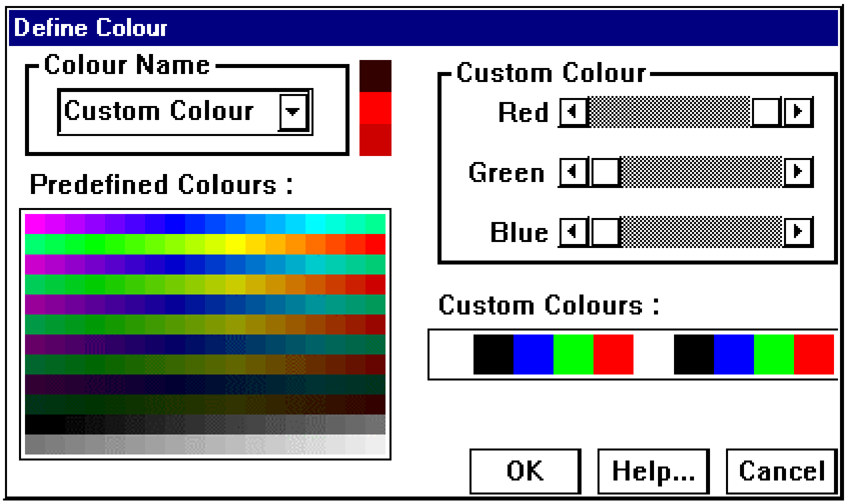
Density	**Density**	Density of lithology
Remanence	**Remanence**	Defines a remanent component of magnetization
	Declination	Declination of remanent vector
	Inclination	Inclination of remanent vector
	Intensity	Intensity of remanent vector
Define Colour		Allows colour of unit to be altered

Colour Definition

This window allows you to define the colour of lithological units and faults. Click on the colour you like, select it from the list of colour names, or select one of the Custom Colours and define your own colour.

Note

For 3D Voxel views, the program needs to find one darker colour and one lighter colour to match the colour chosen in order to simulate shaded lighting. For this reason, it is always better to choose medium brightness colours than darker or lighter ones. The three colours that are used are displayed to the right of the Colour Name menu.



Colour definition dialog.

Structural Visualizations

Block Diagrams

Maps

Topographic Maps

Sections

Boreholes

3D Topography

3D Triangulation

Stereographic Plots of Orientation Data

Kinematic Animations – Movies

Stratigraphic Columns

Geology and Geophysics Legend Window

7 Structural Visualizations

There are currently eight distinct visualization techniques available to display the geology of an area. These are:

- Block diagrams
- Voxel views of specific lithologies
- Surface maps of the geology
- Topography
- Vertical sections
- Boreholes
- 3D drapes of the geology over a topography
- 3D views of a single layer within the stratigraphy

The geology may be viewed for any volume or area of rock at any scale. The default block is a rectangular volume with diagonally opposite corners defined by 0,0,0 and 10000, 7000, 5000 metres X,Y,Z (North, East and Down) respectively.

Note By default each new display type, such as a block diagram, overwrites the contents of the previous window. A new window for each drawing may be made if the **New Window Each Time** option in the **Edit>Geology Display Options** window is selected.

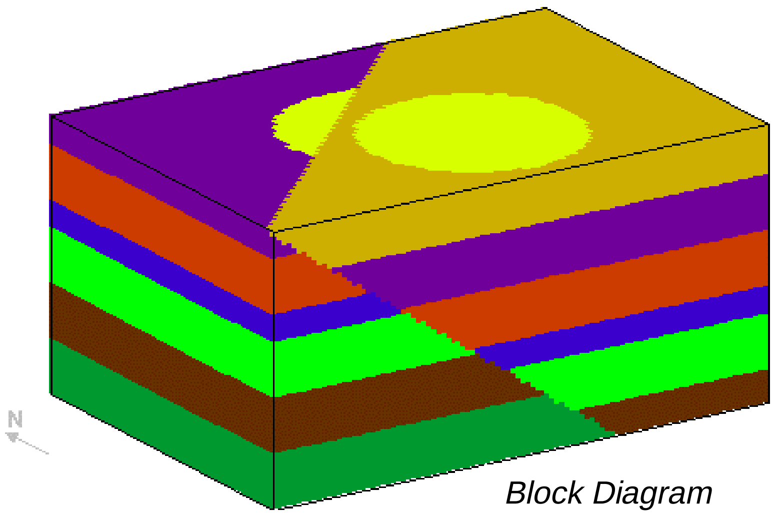
Block Diagrams

Block diagrams can be viewed as soon as the base stratigraphy has been defined, and selected by choosing Block Diagram from the Geology menu.

Note The scale and initial orientation of the block diagram can be defined in the **Edit>Geology Display Options** window.

The block view is an interactive view and the following actions change the displayed information:

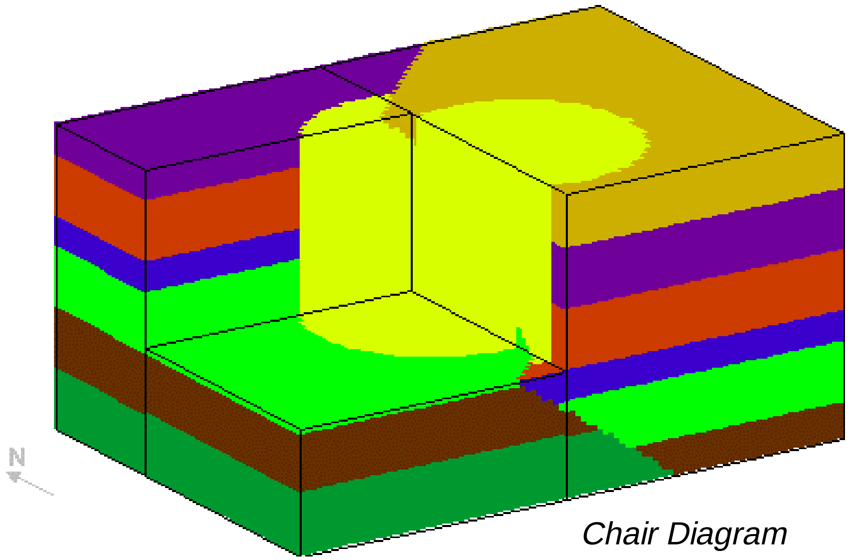
- Dragging the mouse in the window with the mouse button held down **rotates** the block in the window. The four side faces and the top face may be viewed from any angle.
- Holding the SHIFT key down while dragging the mouse in the window **re-scales** the block in the window.
- Resizing the window itself **re-scales** the block the next time it is rotated.
- Double clicking on a block face brings up a separate **map** or **section view**.
- Clicking with the right mouse button brings up a **3D Voxel view** selector window (see detail below).



Block Diagram

Chair Diagrams

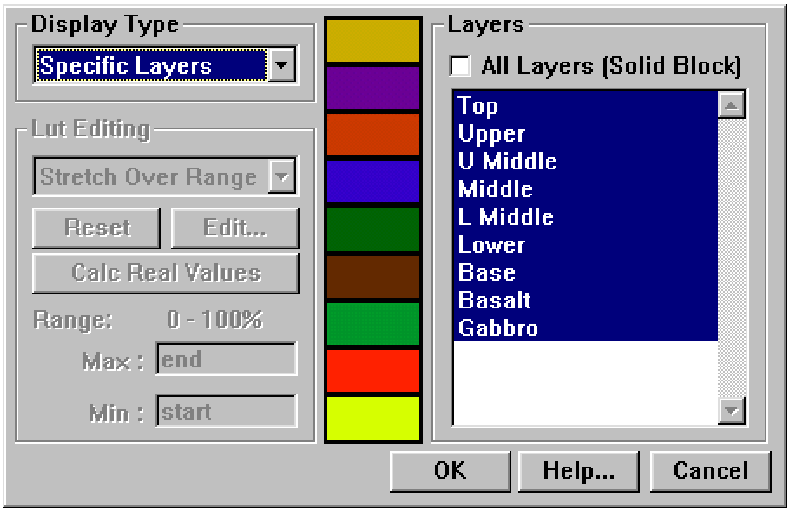
Chair Diagrams (block models with rectangular cut outs) are defined by the normal block parameters and the location of the lower-North-East corner of the cut-out block. Chair diagrams can be displayed by setting the Chair Diagram option in the **Edit>Block Options>Geology Display**.



Chair Diagram

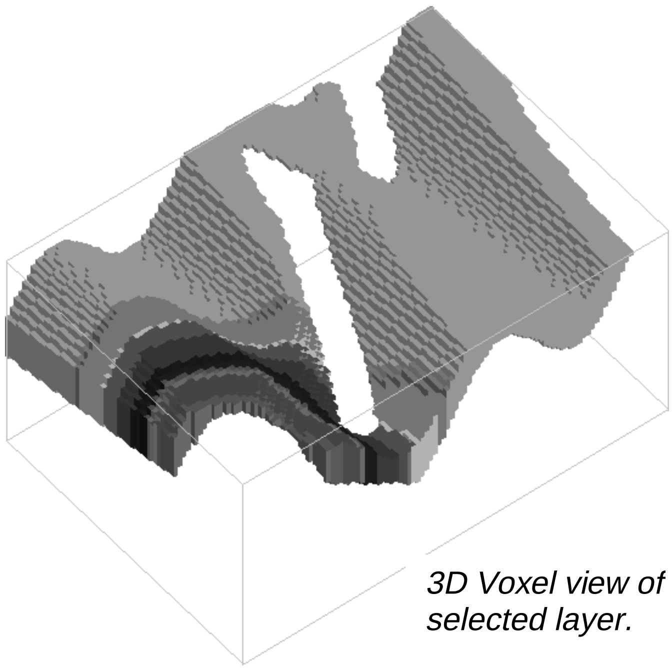
3D Voxel Views

Clicking in a block diagram with the right mouse button brings up a 3D Voxel view selector window, which allows you to display individual layers, and layers coloured according to geophysical rock properties (see *Block Diagram Defaults Window* for details).



Block Default Options window

Using this option, the specific layer variations (resulting from replacement adjacent to a cylindrical plug) can be viewed in 3D.



3D Voxel view of selected layer.

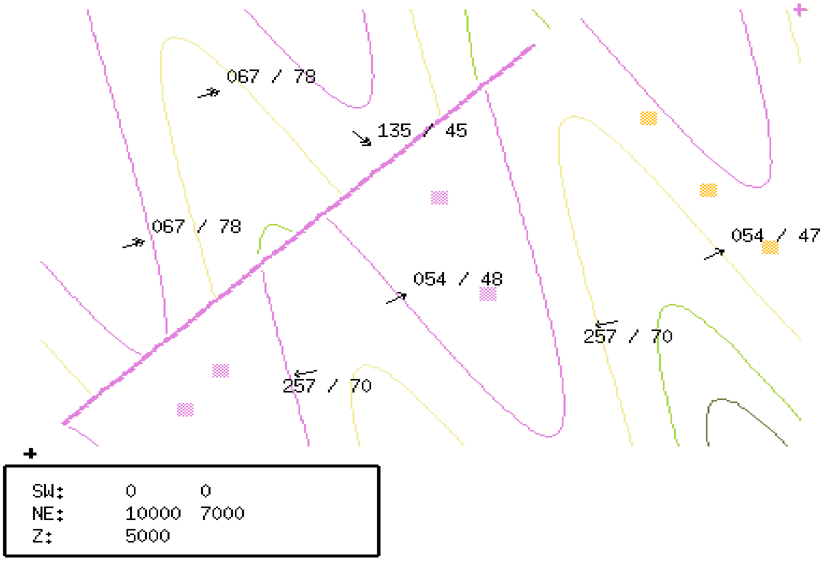
Maps

Maps can be viewed as soon as the base stratigraphy has been defined. The Maps option is available from the Geology menu.

There are two submenu options which produce two map types:

- Solid Colours - Solid colour maps of each layer/intrusive
- Line - Line maps which are easier to view orientation data and discontinuities such as faults

Maps show a plan view of the currently defined geology, with the line colours referring to the lower unit at the contact. The area is always the same as the top surface of the geology displayed in the Block Diagram.



Line map created from the Geology>Map>Line option.

If a digital terrain model of the geology has been loaded (by selecting the **Topography** button from the **Edit>Block Options** window) the geology displayed is the intersection geology for that land surface and the contours of the topography. The shape of the digital terrain model is fixed, so changing the XY scale of the map also changes the XY scale of the digital terrain model.

Plotting Orientation and Rock Type Information

Once a Map or Topographic Map has been displayed, you can interrogate the map for structural orientation information by clicking the mouse at any point on the map.

Note

You cannot interrogate the map for structural orientation information once you have altered any history parameters or geology plot options.

Orientations may only be measured up until the history is next edited. Once you edit the history, you change the structure, and therefore has to recalculate the Map or Topographic Map in order to redefine the structure.

Plotting Orientation Symbols on Maps

When a map is displayed and selected (that is, the window titlebar is highlighted) the Noddy main menu alters and add menu items to control events and symbols.

To plot a mapping symbol on a Line or Solid Colours map, choose the Symbol menu item and an event from the Event 1 and Event 2 menus, and then click anywhere within the area of the map with the mouse. The Symbols menu allows you to choose from:

- **Bedding** lots a symbol showing the dip and dip direction of the bedding at the position selected by mouse. This also gives dyke wall orientations.
- **Foliation** lots a symbol showing the dip and dip direction of the foliation chosen from the Event 1 menu, at the position selected by mouse. This option also calculates fault and unconformity surface orientation.
- **Lineation** lots a symbol showing the plunge and plunge direction of the lineation chosen from the Event 1 menu, at the position selected by mouse.
- **Bedding-Cleavage** intersection lineation – Plots a symbol showing the plunge and plunge direction of the intersection lineation defined by the foliation from the Event 1 menu and the local bedding orientation, at the position selected by mouse.
- **Cleavage-Cleavage** intersection lineation - Plots a symbol showing the plunge and plunge direction of the intersection lineation defined by the foliation from the Event 1 menu and the foliation from the Event 2 menu, at the position selected by mouse.

Some deformation events, such as folds and faults, have ‘inherent’ planar/linear features (for example, folds automatically generate penetrative fold axial planes and fold axis lineations).

In order to specify which foliation (or lineation) you wish to display, select an event from the Event 1 menu. For Cl-Cl intersection lineations only select a second foliation from the Event 2 menu. The orientation data can be saved as a text file for input to a plotting program by choosing Save Orientations from the File menu.

The orientation of layering of a dyke can be measured using the Bedding option.

The orientation of a fault can be measured using the Foliation option.

Interactively Defining Event XYZ Positions

While a map is the front window, the XYZ coordinates of the deformation defined by Event 1 can be redefined by selecting **Define XYZ Position** in the Define menu, and clicking in the Map window. The new XYZ position of the event is defined by the XY position of the mouse click and the Z level of the map. For further information on interactively defining an event location, refer to *Sections* and *Interactively Defining Section Event XYZ Positions*.

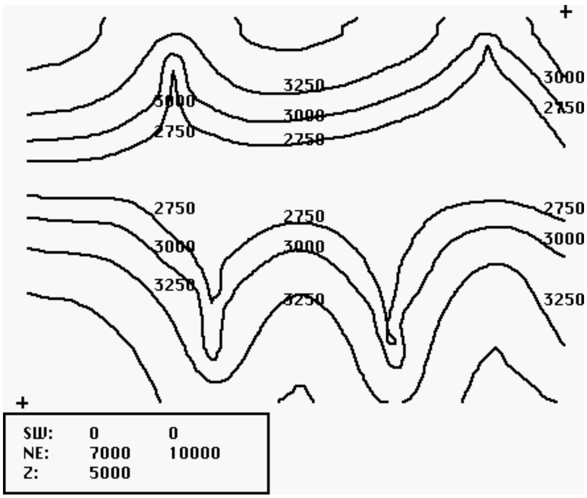
Topographic Maps

Topography Maps can be viewed by choosing Topography Maps from the Geology menu. This option displays a contour map of the topography.

Topographic maps are only available once a digital terrain model of the geology has been loaded, by selecting the **Topography** button from the **Edit>Geology Options** window. The shape of the digital terrain model is fixed, so changing the XY scale of the map also changes the XY scale of the digital terrain model. By default, the origin of the loaded topographic file is 0,0,0. The default block model uses this value (0,0,0) on the base of the block. The topographic surface is therefore required to be positioned relative to your block model top surface.

The scale of the topography and the contour levels are defined while the digital terrain model is being loaded in, to edit these values, reload the topography.

Controlling parameters for topographic maps are found in the **Edit>Block View Options** and **Edit>Geology Options** window.

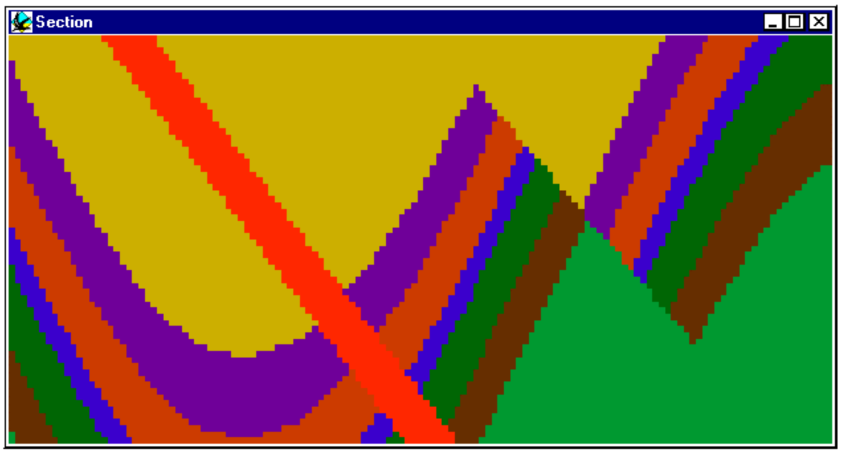


Topographic map output.

Sections

Sections can be viewed by choosing Section from the Geology menu. This option displays a vertical section through the geology.

The top left hand corner of the section is always the origin of the currently defined block diagram. The orientation of the section is defined by the Section Declination parameter in the **Edit>Geology Options** window.



Cross section with solid colour fill.

There are two submenu options - **Solid Colours** and **Lines** produces solid fill sections and line sections respectively.

Plotting Orientation Symbols on Sections

When a section is displayed and is the selected display window (the titlebar is highlighted) the Noddy main menu alters and adds menu items to control events and symbol plots.

To plot a mapping symbol on a Solid Colour or Line section, choose the symbol type and event from the Symbols menu and Event 1 and Event 2 menus, and then click anywhere within the area of the section with the mouse.

Note

In sections the symbols are oriented according to the true dip or plunge of the feature, and not the intersection angle with the section plane.

The Symbols menu allows you to choose from:

- **Bedding** lots a symbol showing the dip and dip direction of the bedding at the position selected by mouse. This also gives dyke wall orientations.
- **Foliation** lots a symbol showing the dip and dip direction of the foliation chosen from the Event 1 menu, at the position selected by mouse.
- **Lineation** lots a symbol showing the plunge and plunge direction of the lineation chosen from the Event 1 menu, at the position selected by mouse.
- **Bedding-Cleavage** intersection lineation - Plots a symbol showing the plunge and plunge direction of the intersection lineation defined by the foliation from the Event 1 menu and the local bedding orientation, at the position selected by mouse.
- **Cleavage-Cleavage** intersection lineation - Plots a symbol showing the plunge and plunge direction of the intersection lineation defined by the foliation from the Event 1 menu and the foliation from the Event 2 menu, at the position selected by mouse.

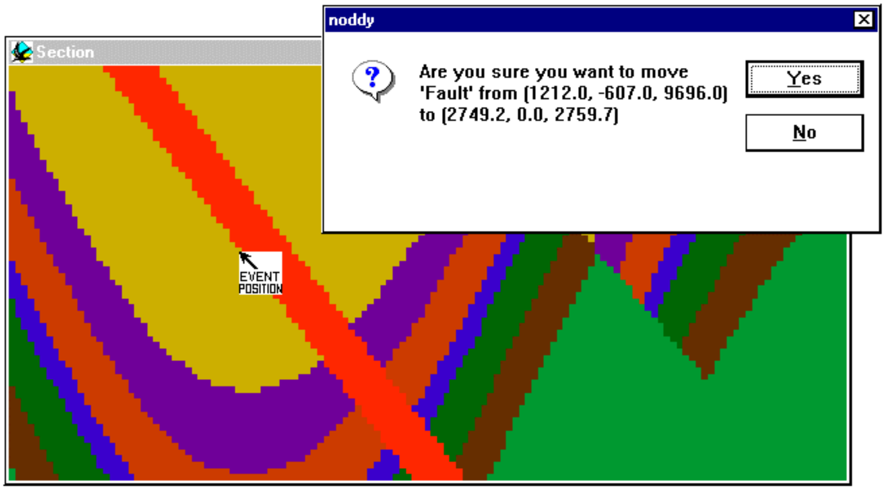
Some deformation events, such as folds and faults, have ‘inherent’ planar/linear features, for example folds automatically generate penetrative fold axial planes and fold axis lineations.

In order to specify which foliation (or lineation) you wish to measure, select an event from the Event 1 menu. For Cl-Cl **intersection lineations only** select a second foliation from the Event 2 menu. All of this orientation data can be saved as a text file for input to a plotting program by choosing **File>Save Orientations**.

The orientation of layering of a dyke can be measured using the Bedding option. The orientation of a fault can be measured using the Foliation option.

Interactively Defining Section Event XYZ Positions

While a section is the front window (that is, selected with the title bar highlighted), the XYZ coordinates of a deformation defined by Event 1 can be redefined. Select the Position of Event 1 option from the Define menu, and click in the section window. The new XYZ position of that event is defined by the XY location of the mouse click and the Z level of the section.



Interactively defining events in the section.

In the example below, the dyke can be interactively re-positioned by selecting **Event 1>Dyke** and then the **Define>Position** of Event 1 menu item.

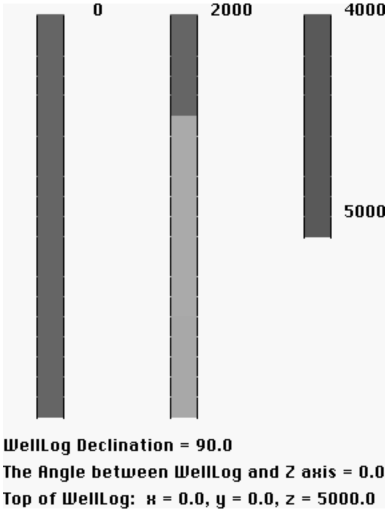
An arrowed 'Event Position' icon appears in the Section window. You can move the requested item of Event 1 by clicking on it and holding the left mouse button down while dragging it to a new location. When the mouse button is released, a dialog is displayed to confirm the new location of the event. After accepting the relocation you need to re-compute the Section window using the **Geology>Section** option.

Boreholes

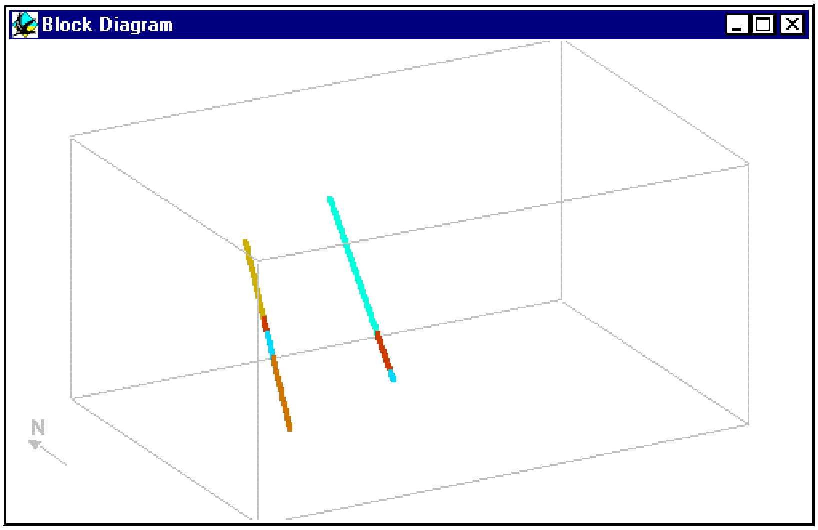
There are two types of borehole available:

- An internally generated straight borehole (using the **Edit>Geology Section/Borehole Options** item.
- An imported XYZ specification (using the Import option).

There are also two types of visualizations for boreholes, which can be viewed either as well-logs (Schematic option) or as 3D visualizations (3D option).



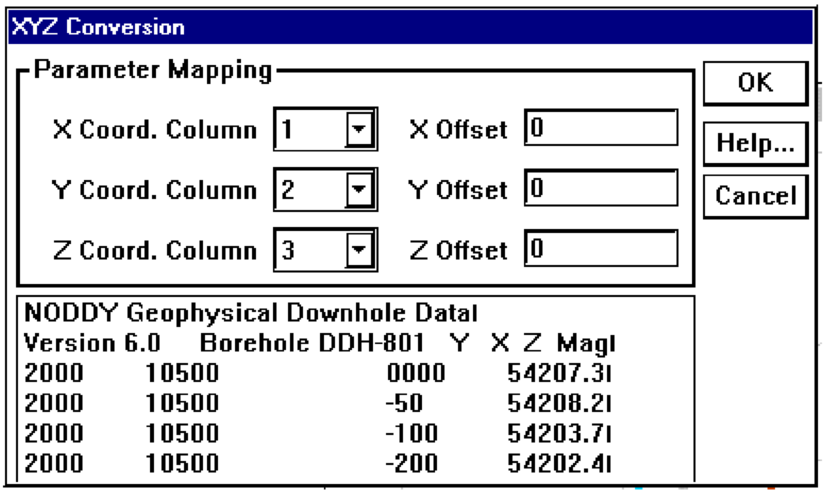
Schematic Borehole view



3D Borehole View

The **Geology>Borehole>Generate>Schematic** menu combination is equivalent to a Well-log view.

Pre-existing borehole positional information may be imported using the **Geology>Borehole->Import->3D** or **Geology>Borehole>Import>Schematic** menu items. Each option opens any plain ASCII column format data file and there is the opportunity to specify which columns refer to X, Y and Z. The area of the window below the Parameter Mapping section shows the first few lines of the file to aid in selecting the proper X,Y,Z columns.



Conversion of borehole survey data.

An example of an ASCII borehole .XYZ file follows:

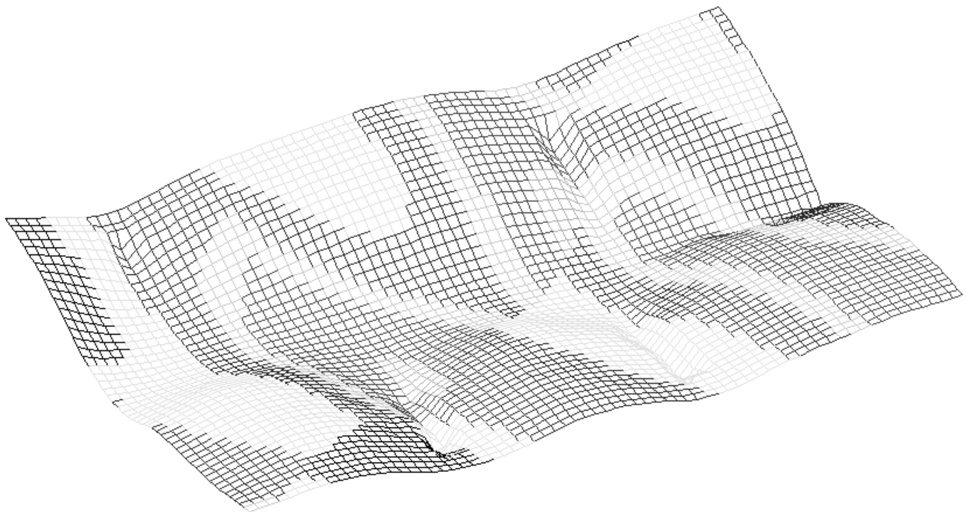
```
Noddy Example Borehole
Hole=DDH-1   X Y Z

2000      1050  0000
2000      1050  -50
2000      1050  -100
2000      1050  -200
2000      1050  -250
2000      1050  -300
2000      1050  -350
2000      1050  -400
2000      1050  -450
2000      1050  -500
```

Any input row starting with a number is considered to be data, and any other row is considered to be a comment.

Group	Name	Function
Parameter Mapping	**X Column**	Column containing X position data
	Y Column	Column containing Y position data
	Z Column	Column containing Z position data
	X Offset	Offset applied to input X position
	Y Offset	Offset applied to input Y position
	Z Offset	Offset applied to input Z position

3D Topography

A 3D view of the topography can be viewed by choosing 3D Topo from the Geology menu. This displays a wire-frame view of the geology draped over a three dimensional view of the topography.



3D topography view.

3D topography views are only available once a digital terrain model has been loaded by selecting the **Topography** button from the **Edit>Block Options** window. Information on the file format is provided in the *Topography File* section. The shape of the digital terrain model is fixed, so changing the XY scale of the map also changes the XY scale of the digital terrain model.

A topographic surface cannot be displayed as the uppermost surface of a block diagram. The geology of the block appears in the topographic display.

Note

The orientation of the view may also be altered interactively by dragging the mouse within the window containing the image. Dragging the mouse horizontally alters the Declination whilst dragging the mouse vertically alters the Azimuth.

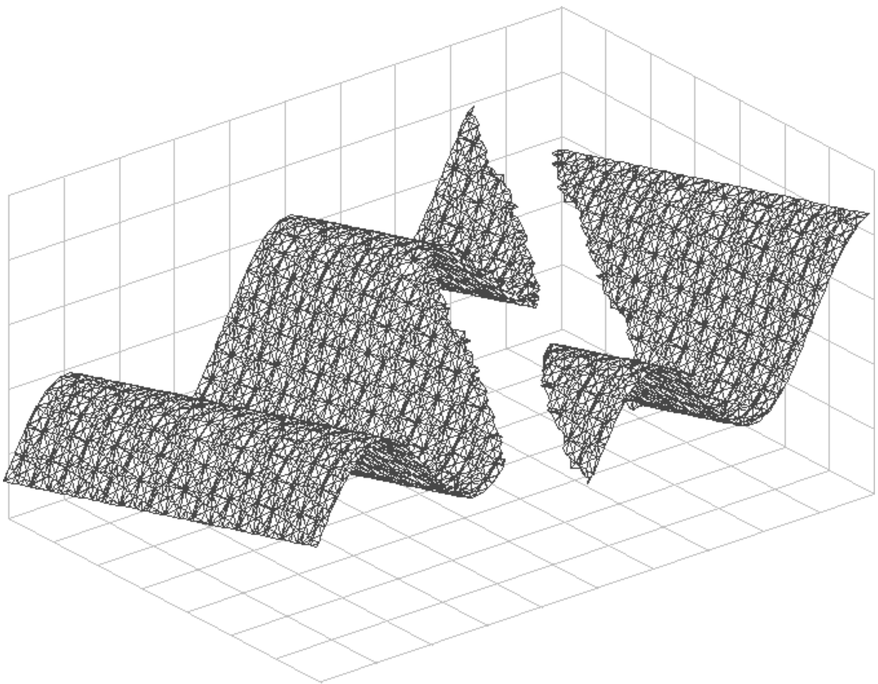
3D Triangulation

A 3D triangulated surface model of the geology can be viewed by choosing 3D Layer from the Geology menu. This displays a wire-frame view of the geometry of one or more stratigraphic, fault, unconformity or igneous contacts within the bounds of the current block diagram. Computation of this option can be slow for small cube size renderings.

Note

The model may be rotated by dragging the mouse in the window, and re-scaled by holding down the SHIFT key and dragging the mouse.

The triangulation may be saved to a file by changing the destination of the calculation via the **Edit>3D View Options** window.



3D triangulation of an event.

Stereographic Plots of Orientation Data

By selecting Plot Orientations from the File Menu, an equal area lower hemisphere stereographic projection of all data collected from the current line map is provided. The colour coding for each structural element is as follows:

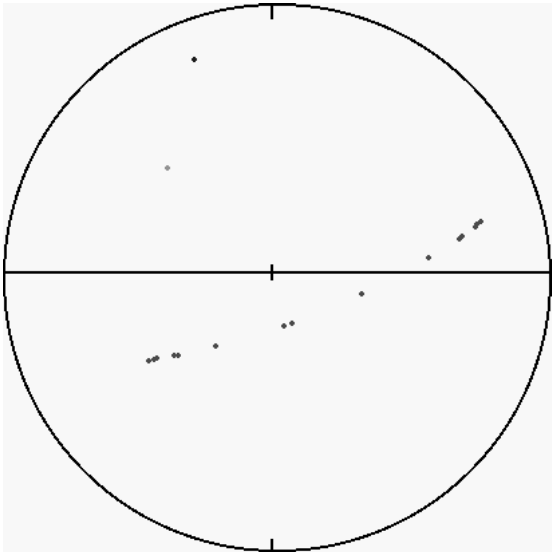
Red=Bedding

Green=Foliation

Blue=Lineation

Magenta=Bedding/Cleavage Intersection Lineation

Cyan=Cleavage /Cleavage Intersection Lineation



Stereographic plot of orientation data.

Note

Stereographic projections may also be found in the Legend window when a map or section with orientation information is selected

Kinematic Animations - Movies

An animated sequence of displays representing a geological history can be viewed by choosing Create Movie from the File menu. This feature displays a view of the geology or geophysics controlled by the current settings. The following visualizations are available as animations:

- Block Diagrams
- Maps (colour or line)
- Sections (colour or line)
- Well Logs
- 3D Layer
- Geophysics (image or contour).

Each frame of the movie is saved as a .BMP file. Multiple increments per deformation event are calculated by reducing the controlling parameters systematically. For example, dividing up a 30° rotation into 3 steps is achieved by calculating the deformation after 10°, 20° and 30° rotations, and playing them back in rapid succession. The more frames per event, the smoother the animation appears. The number of frames per event is defined by the Number of Frames parameter in the **Edit>Movie Options** menu item.

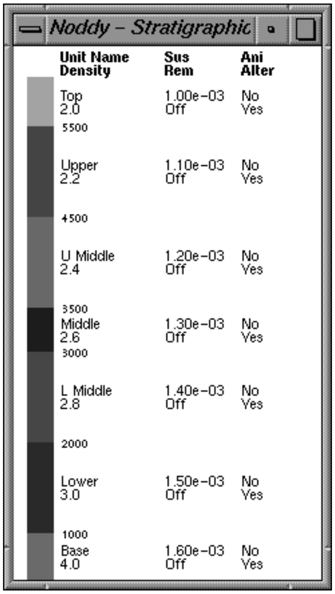
Note If a large number of frames are requested, a large number of BMP files are created and this can impact on disk storage.

Once an animation has been created, clicking in the window with the left mouse button moves the animation forward one frame Clicking in the window with the right mouse button moves the animation back one frame. If the SHIFT key and the left mouse button are clicked in the Display window, Noddy runs the entire animation at the frame rate specified in the Movie Options window (Slow-Fast) as defined by the speed of On-Screen Replay.

Once a movie window has been closed it can be re-opened by selecting the .NMV header file associated with the sequence of pictures (by selecting **Movie>Load** from the File Menu). In addition, there are a number of utilities available to turn sequentially numbered .BMP files into QuickTime or MPEG animation sequences.

Stratigraphic Columns

A summary stratigraphic column for all defined rock units can be displayed by selecting Stratigraphic Column from the Geology menu.



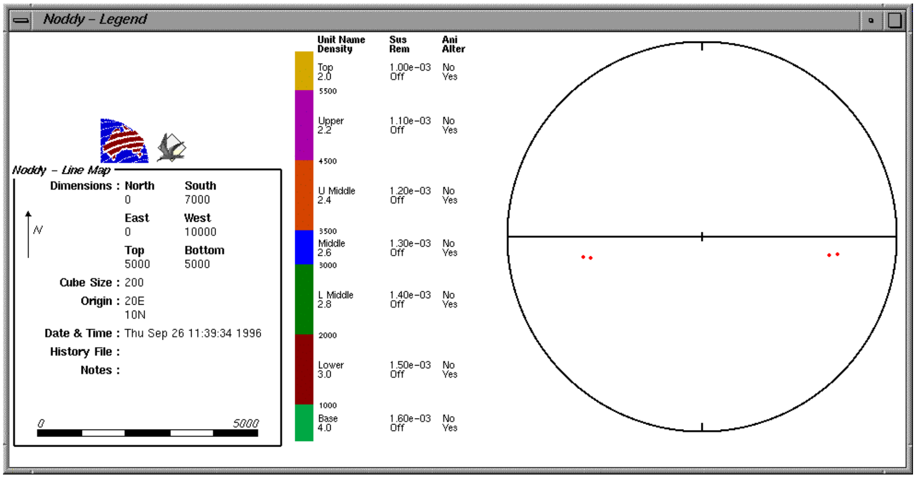
Stratigraphic Column

Geology and Geophysics Legend Window

This option, accessible from the Window menu, provides background information for all geological and geophysical visualizations, as well as providing a means of including a company logo within the title information. The nature of the information varies according to which displays are selected. It includes a variety of information such as the file used to create the visualization, the time and date, the current stereonet, stratigraphic column, look-up table and scale bar.

The Legend window updates automatically as each window is selected, and some information, such as the scale bar, are updated each time a change is made to the associated window (for example changing the size of a gravity image changes the length of the scale bar).

A company logo may be placed in the top left hand corner by placing a BMP format image named COMPLOGO.BMP in the same directory as the Noddy executable.



Legend window (example shown here for map)

Edit Options

8 Edit Options

The Edit options of the main menu provide a number of features for controlling displays, computations and modelling in Noddy. The Edit menu is divided into two separate groups of menu operations. In the top half, the items are used to select, manipulate and position events and icons that are presented in the History window. Using these edit commands also defines the order and timing in which deformation events occur.

In the second, lower portion of the menu list (beneath Tidy Window), the menu items are designed to set display and computation parameters which serve as defaults for ongoing processing. Note that most settings assigned in these options are retained if a history file is saved. Similarly, the defaults can be saved in a file called DEFAULTS.HIS which is used for defaults when Noddy is initiated from the same directory as the defaults file. This file is saved by selecting the **File>Save As Defaults** option.

The top portion Edit commands the events contained in the History window. The control selection, manipulation and the timing of structural events edit items are:

- **Undo -** There is a single level of undo available within the history window that allows any of the editing functions below to be reversed. An Undo also removes the placement of an icon into the window.
- **Dragging -** The relative timing of events may be altered by dragging the icons around the window. Click on an icon, and move the cursor with the left mouse button depressed. A dashed rectangle follows the cursor. When the mouse button is released, the event is repositioned. As long as the Base Stratigraphy is the first event, any timing combination of the existing icons may be tried.

Note

Dragging an icon above the title bar or to the left of the History window is an easy way of deleting it.

- **Selecting -** Icons may be selected by clicking once on the icon, or dragging a rectangle around a group of icons. Multiple icons may also be selected by clicking on each icon in turn while holding down the SHIFT key. All the icons may be selected at the same time by choosing Select All from the Edit menu. Selected icons are outlined in red.
- **Cut -** Cutting deletes the selected event(s) but places it on a temporary clipboard.
- **Copy -** Makes a copy of the selected event(s) and places it on the clipboard
- **Clear -** Clearing deletes the selected event(s) without keeping a copy. Dragging an icon above or to the left of the title bar of the History Window is a short cut for clearing/deleting it.
- **Paste -** Pastes the last event(s) copied to the clipboard by a Cut or Copy action to the History window. The next click in the History window presents a drag rectangle which when positioned and left clicked again, drops the event icon(s).
- **Duplicate -** Makes a copy of the selected event(s) and immediately pastes it into the window. The next click in the History window drops the duplicated event(s). Note that the Duplicate process creates an exact copy of the selected event(s) including all parameter settings for the event(s).
- **Tidy Window -** Tidy Window does not alter the actual history, but compacts the display within the History Window to remove any unfilled spaces between icons.

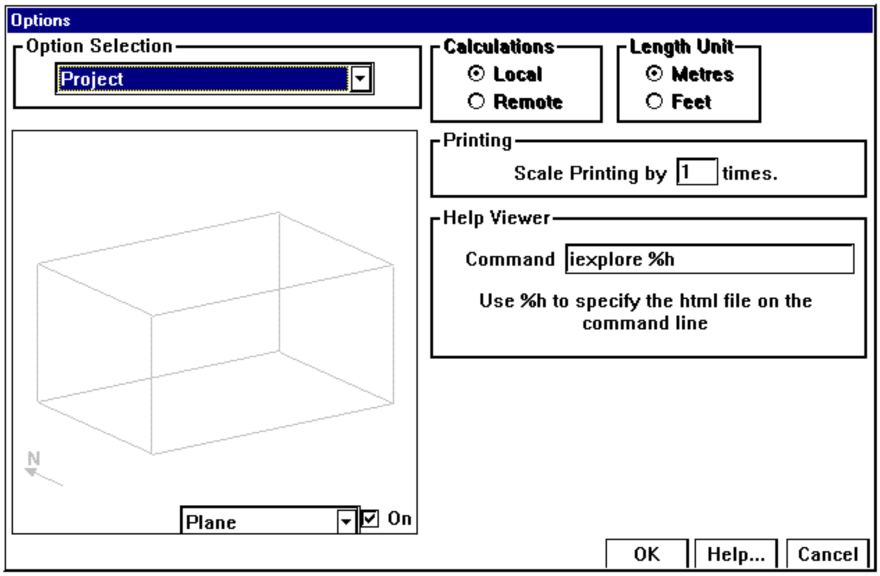
Note

The length of the joining lines between icons has no impact on the geological model.

The remaining (and lower Edit menu items) editing options which control display and computational defaults are described below. In all the Edit options described below, there is an Option Selection list box in the top left hand corner of the dialog. From this list box, all other editing options can be accessed without having to individually select the Edit menu item.

Project Options Window

This option, which may be accessed via the Project Options item in the Edit menu, provides some overall controls for the program.



Project Options Window

Group	Name	Function
Calculation Scheme	**Local**	Calculations are performed by currently active program
	Remote	Calculations are performed by currently remotely activated program
Printing	**Scale**	Multiplying factor to scale up printing to allow exact scaling of images, or when printer drivers don't behave

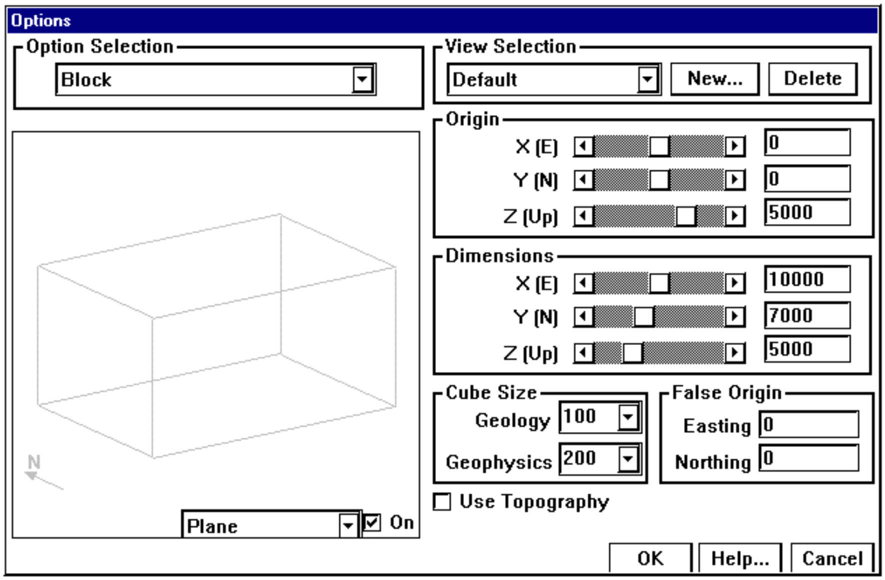
Note

Noddy uses on-line help from files in HTML format. To view these files an HTML browser is required. By default Noddy uses Microsoft Explorer

(IEXPLORE.EXE in the Help Viewer entry), however other browsers such as Netscape Navigator can also be used. If you wish to use an alternative browser, path and specify the executable name into the command line entry and add the ‘%h” specification. Refer to *On-Line Help* for an example of available help.

Block Options

This window provides access to options that control the resolution, position and shape of geological and geophysical calculations.



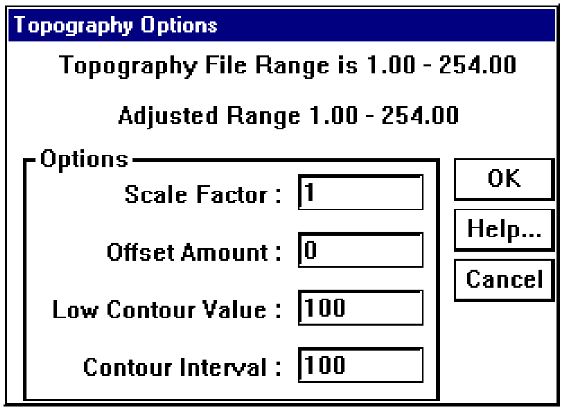
Block View Options Window

Group	Name	Function
View Selection	**Current**	Menu of named sets of distinct block parameters
	New	Add new view to list
	Delete	Delete currently selected view from list
Origin	**X**	X position of upper south west corner of block

	Y	Y position of upper south west corner of block
	Z	Z position of upper south west corner of block
Dimensions	**X**	X Dimension of Block in metres
	Y	Y Dimension of Block in metres
	Z	Z Dimension of Block in metres
Cube Size	**Geology**	Cube size for all geological visualizations
	Geophysics	Cube size for all geophysical calculations
False Origin	**Easting**	This value adds to ER Mapper and Geosoft format Easting (X) coordinates to provide allow real world coordinates to be used
	Northing	This value adds to ER Mapper and Geosoft format Northing (Y) coordinates to provide allow real world coordinates to be used
Use Topography		This check box causes a topography grid file to be loaded

Topography Scaling Window

If the **Use Topography** button is checked, the Topography Scaling window appears. This window allows the user to scale and offset the topography file as it is loaded. This window is accessed whenever the **Use Topography** check box is selected. Refer to the section on *Topography File* for additional information.



Topography Scaling Window

Group	Name	Function
Options	**Scale Factor**	Scales topography values to provide vertical exaggeration when viewing 3D.
	Offset Amount	Offset from the block origin for the topographic surface (0 is normally the base of the block)
	Low Contour Value	Lowest contour level for maps showing topographic contours
	Contour Interval	Contour interval for maps showing topographic contours

Movie Options

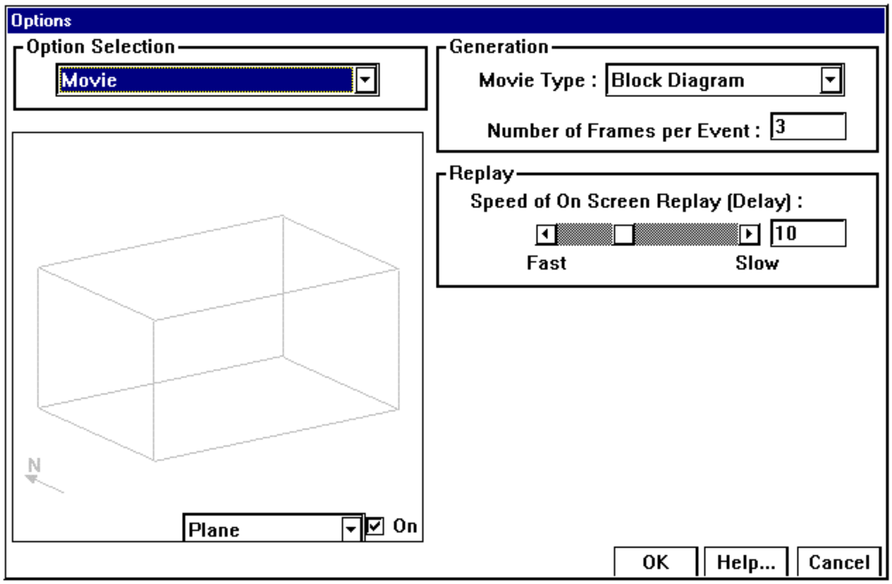
This window allows the user to define the parameters that control the creation of kinematic animations (movies). Access the option via **Edit>Project Options.**

Note

To load a movie (.NMV) file, you must have a history available. If the **File>Movie** option is not enabled, drag and drop a Base Stratigraphy icon into the History window. The **File>Movie** option should now be enabled. Select an appropriate movie file. The amount of time taken for a movie to load depends on the number of animation elements and BMP files to be re-played. Wait until the movie has accessed all files. The first scene of the animation should then be displayed.

- Clicking in the window with the left mouse button moves the animation **forward** one frame.
- Clicking in the window with the right mouse button moves the animation **back** one frame.
- SHIFT + left mouse click in the window runs the entire animation at the frame rate specified in the **Edit>Movie Options** window.

Animations can be read back from disk file by selecting **Movie>Load** from the File menu.



Movie Options Window

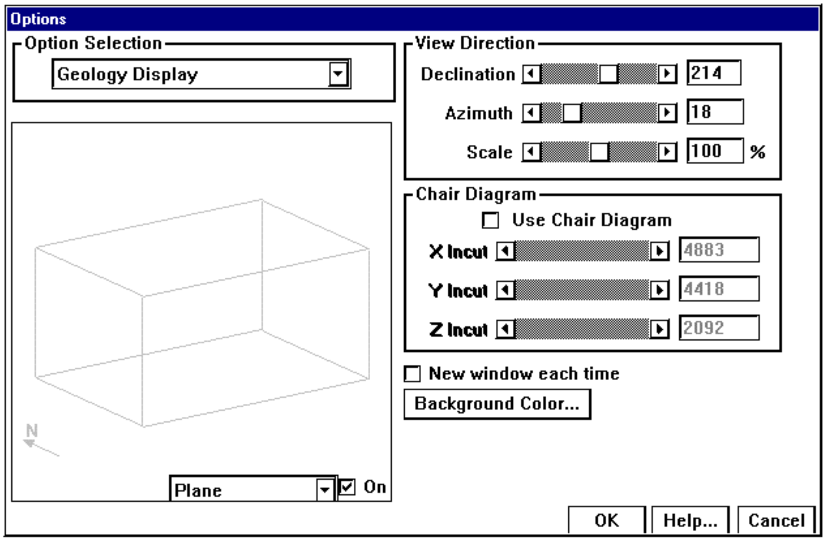
Group	Name	Function
Options	**Movie Type**	Type of geological or geophysical visualization to use for animation
	Number of Frames per Event	The number of intermediate frames for each deformation event
	Speed of On-Screen Replay	The relative speed of on screen replay of the movie

Geology Display Options

This window allows the user to define the parameters that control the specific viewing parameters for the 3 dimensional geological visualizations.

Note

It is also possible to interactively alter the viewing Declination and Elevation options by clicking and dragging the cursor within the Block Diagram, 3D Topo and 3D Triangulation windows. Dragging the cursor horizontally alters the Declination, whilst dragging the cursor vertically alters the Azimuth.



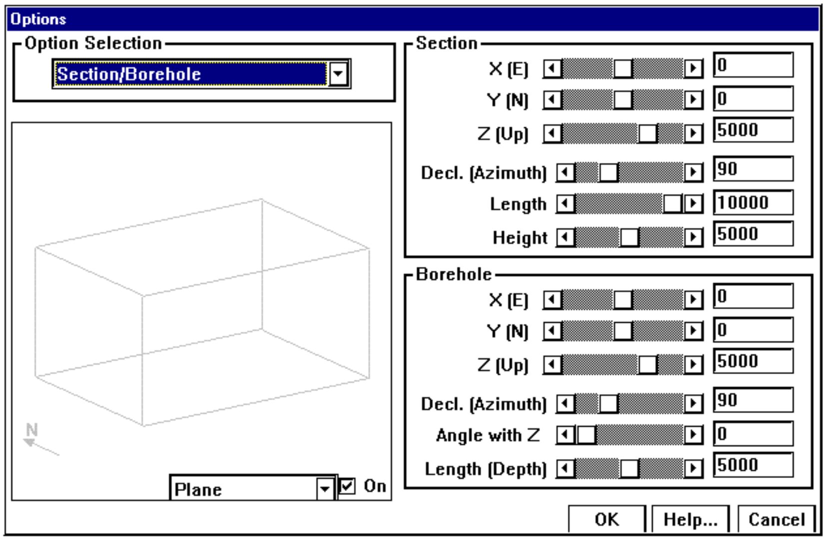
Options for display of geology block diagrams.

Group	Name	Function
Chair Diagram	**Use Chair Diagram**	Draw Block Diagrams with rectangular cutouts
	X	X position of lower north east corner of cut out
	Y	Y position of lower north east corner of cut out
	Z	Z position of lower north east corner of cut out

New Window Each Time		Create new display window each time a geological visualization is calculated (this happens automatically for geophysical visualizations)
View Options	**Declination**	Declination of viewer with respect to centre of model
	Azimuth	Azimuth of viewer with respect to centre of model
	Scale	Overall scaling function for model
Set Window Background		Brings up colour selector window to change background colour for all windows (black is good for the screen, white is good for printing)

Geology Section/Borehole Options

These options control the position, scale and orientation of sections and boreholes.



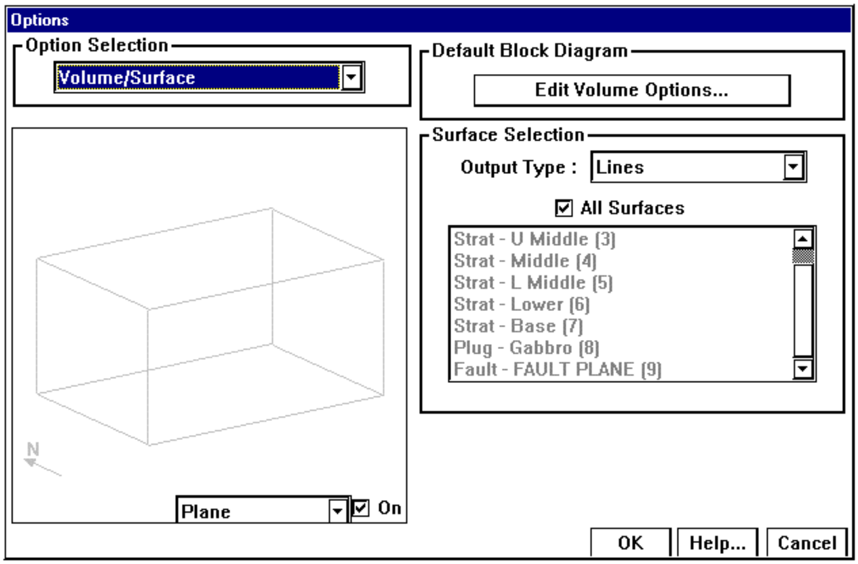
Section/Borehole Options Window

The settings defined in the Borehole section of the dialog creates a borehole using these parameters in the **Geology>Borehole>Generate** option.

Section	**X**	X position of start of section
	Y	Y position of start of section
	Z	Z position of start of section
	Declination	Orientation of section from origin of block, 000 is North, 090 is East
	Length	Length of section from X,Y,Z
Borehole	**X**	X position of top of borehole
	Y	Y position of top of borehole
	Z	Z position of top of borehole
	Declination	Orientation of borehole from origin of block, 000 is North, 090 is East
	Angle with Z-axis	Well Log orientation
	Length	Length of well log from X,Y,Z

Geology Volume/Surface Options

This window controls the appearance of 3D Triangulations and the default Block Diagram View.



Volume/Surface Options Window

Surfaces Displayed		For 3D triangulation visualizations, this allows the selective calculation for individual stratigraphic layers and discontinuities (such as faults) to be performed. To select multiple surfaces, use Alt-mouse click.
	All Surfaces	To select all layers, click in the All Surfaces check box
Calculation Type	**XYZ Colour**	An XYZ Colour plot colours surfaces according to their position in space.
	Shading	A Shading plot, uses a simulated Lambert shading on the surfaces.
	Lines	A Lines plot, colours the triangulation according to the layer colour, but leaves their interiors white.
	DXF 3dFace	A .DXF 3d Face file saves the surfaces as a DXF file using 3Dface objects.
	DXF Polyline Face	A DXF Polyline Face file saves the surfaces as a DXF file using Polyline objects.
	Vulcan	A Vulcan file saves the surfaces as an ASCII file using that can be converted into native Vulcan triangulations via utility routines.
Default Block Diagram		Controls the default view style for block diagrams, via the Block Diagram Options window

Block Diagram Defaults

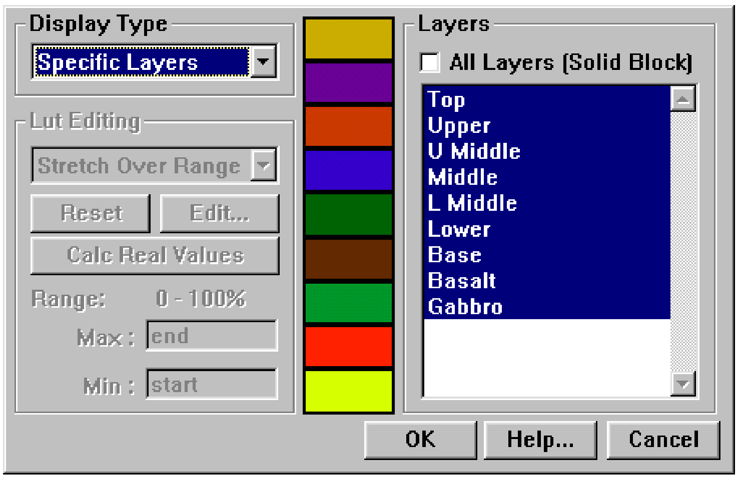
In the Volume/Surface Options dialog, the Block Diagram Defaults section controls the display behaviour of block diagrams. It controls the default display behaviour of all block diagrams. An alternative method of controlling the behaviour of individual block diagram windows is by clicking in the block diagram with the right mouse button (see diagram below).

Three types of display are available:

1. Solid Block that shows the outside surfaces of the block coloured according to rock type
2. Specific Lithologies allows layers de-selected in the Layers list to be made transparent
3. Rock Property displays voxels according to the magnitude of one of their rock properties

Specific Lithologies and Rock Property may be used in combination to show, for example, a block diagram which presents only the density variation within a single layer (all other layers being transparent).

The interactive method of controlling the display of layers in a block diagram is to right mouse click in the display window after it is initially presented.



Block Diagram Options Window

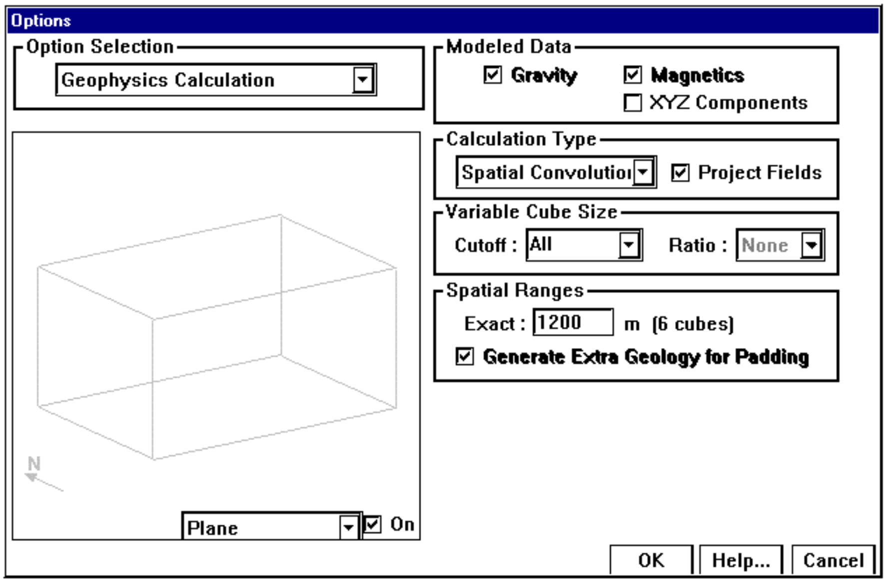
Alter the Display Type to Specific Layers and select the layers you require. Only the selected layers appears when you click **OK**. Note that you can use the

SHIFT and CTRL keys in combination with the mouse selections to nominate more than one layer.

Display Type		This menu controls the parameters used to define the colour and transparency of individual voxels in the model.
Layers	**All Layers**	When selected, it makes all layers visible, otherwise only selected layers are displayed
LUT Editing	**Stretch over Range**	Stretches range of look up table to match range of rock property values found in model
	Absolute Range	Allows user to define range of look up table to specific values, which is useful when comparing different models
	Reset	Resets look up table to complete range
	Calc Real Values	Calculates maximum and minimum values for rock property in model (performed automatically after first display of new model)
	Max	Maximum (as % or real values) to which look up table is clipped, clipping may also be performed interactively with mouse by clicking in look up table
	Min	Minimum (as % or real values) to which look up table is clipped, clipping may also be performed interactively with mouse by clicking in look up table

Geophysics Calculation Options

The **Edit>Geophysics Calculation Options** allows you to specify various parameters which alter the calculation scheme used for geophysical anomalies. Refer to the section on *Geophysics Calculations within Noddy* for additional information.



Geophysics Calculation Options Window

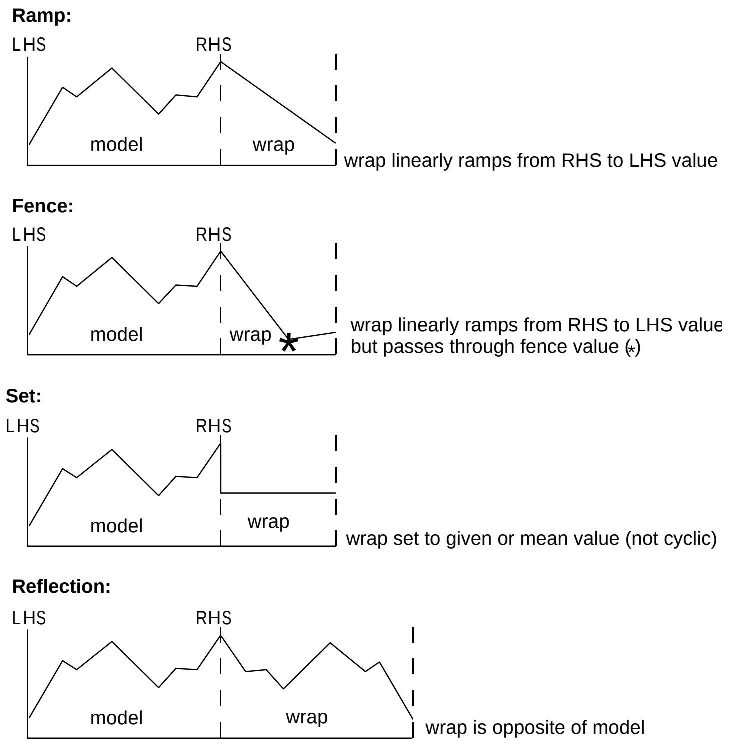
Additional parameters enable gravity, magnetics or magnetic component modelling.

Note

If you set the Spatial Range with a large 'padded' geology, it severely effects the speed of geophysical response computation. As a guide, it is optimal to set an upper limit of about 6-8 cubes around the modelled block. This limit ensures a reasonable response is created (with minimal edge effects in the response computation), but also provides reasonable speed of calculation.

Group	Name	Function
Calculation Type	**Spatial Convolution**	Calculations are performed in the spatial domain, and takes longer, produce clipped profiles for simple geology but can have less obvious edge effects
	Spectral	Calculations are performed in the spectral domain, and takes less time, produce better profiles for simple geology but can have more obvious edge effects
	Full Spatial	Calculations are performed in the spatial domain, and take into account every cube in the model, which makes the calculation very slow, but is the only really accurate means of calculating draped surveys
Spatial Calculation s	**Calculation Range (m)**	In order to limit the extent of the spatial domain calculations a Calculation Range needs to be defined, which serves as a horizontal cut-off distance beyond which the behaviour of the geology is ignored. This number is rounded off to whole numbers of cubes. The larger this value, the more accurate the far field calculation is.
Variable Cube Size	**Cutoff Level**	Cutoff height above which cube size as defined by Cube Size parameter takes effect. Select All for constant cube size with depth.
	Size Ratio	Ratio of cube size increase below cutoff level
Modelled Data	**XYZ**	Saves X, Y and Z components of magnetic field separately (as .MGX, .MGY and .MGZ suffix files)
Spectral Padding	**Type**	Defines padding scheme used to fill out rock properties in area around calculated geology (See below for details)
	Value	Fence and Set Value padding options require

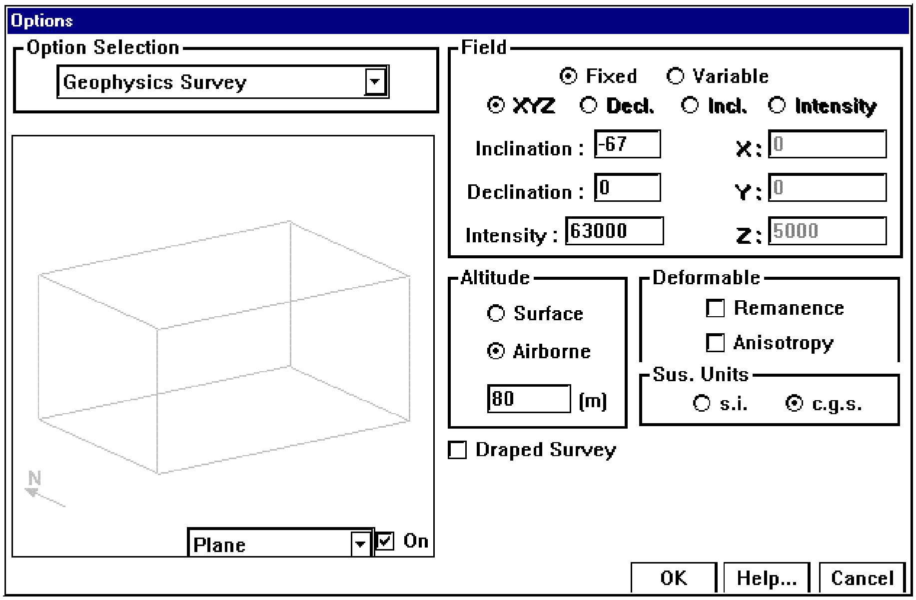
		specific values (as %) to be entered



Wrapping types for spectral geophysics calculations

Geophysics Survey Options

The **Edit>Geophysics Survey Options** allows you to specify various parameters which alter the survey and Earth's inducing magnetic field characteristics of geophysical calculations.



Setting the options for the Earth's magnetic field plus the geophysical survey parameters.

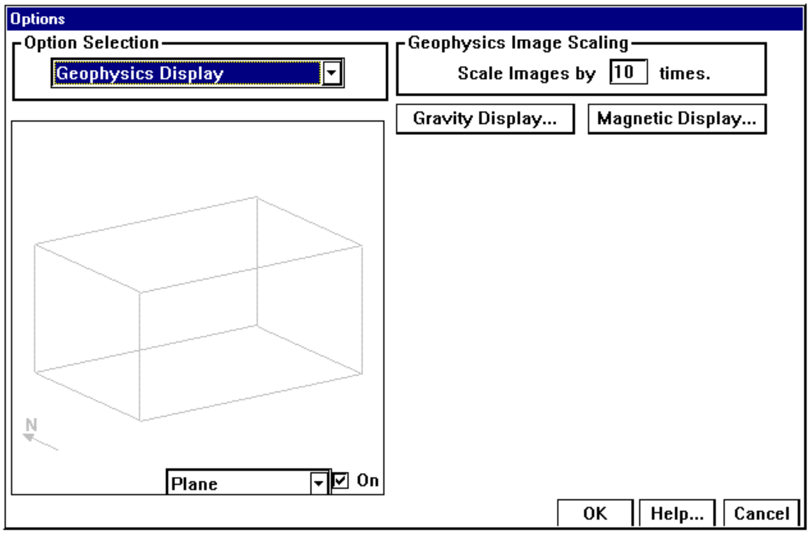
For more information on the application of the various survey types, remanence, anisotropy and measurement systems (SI or cgs) refer to *Advance Geophysical Calculations*.

Field	**Fixed**	Earth's Magnetic Field is uniform over survey area
	Variable	Earth's magnetic field (declination and/or inclination and/or strength) varies linearly over survey area
Fixed	**Inclination**	The inclination of the Earth's Magnetic Field at the location specified by XYZ coordinate in this window
	Declination	The declination of the Earth's Magnetic Field with respect to the North direction of the model at the location specified by XYZ coordinate in this window.
	Intensity	The intensity of the Earth's Magnetic Field at the location specified by XYZ coordinate in this window
	X,Y,Z	Location of local origin for variable inclination, declination or intensity
	Orient	Orientation of gradient in inclination, declination or intensity
	Change	Gradient in inclination, declination or intensity (in units of degrees per km or nT per km as appropriate)
Field	**Inclination**	The inclination of the Earth's Magnetic Field at the origin of the block.
	Declination	The declination of the Earth's Magnetic Field with respect to the North direction of the model.
	Intensity	The intensity of the Earth's Magnetic Field at the origin of the block
Calculation Altitude	**Surface**	Geophysical calculations carried out at the top surface of the block model
	Airborne/ Altitude	Geophysical calculations carried out for given altitude above the top surface of the block model

	Draped Survey	If a topography has been read into the model, a draped survey may be performed at the height specified by the calculation altitude above the selected topographic surface. If this option is not checked, but a topography has been loaded, a barometric survey is calculated. **This option is only available for Full Spatial calculations. You must set the upper north east corner Z value to the highest elevation of the topography for this option to function correctly!**
Deform Fields	**Remanence**	This option changes the way remanent vectors are treated. If the vectors are deformable, the remanent vector the user provides is the orientation provided when the rock is created, and the final vector orientation depends on the deformation history. If remanent vectors are not deformable, the vector orientation is uniform for a given rock unit regardless of the subsequent.
	Anisotropy	This option changes the way anisotropic susceptibility is treated. If the anisotropy is deformable, the anisotropic susceptibility the user provides is the orientation provided when the rock is created, and the final orientation depends on the deformation history. If anisotropic susceptibility is not deformable, the orientation is uniform for a given rock unit regardless of the subsequent deformation.
Sus Units	**c.g.s.**	c.g.s. units used for magnetic susceptibility
	SI	SI units used for magnetic susceptibility
Draped Survey		Calculates survey at constant terrain clearance above the topographic surface (should use Full Spatial calculations to get accurate solution)

Geophysics Display Options

This option allows you to alter the default display mode for geophysics images, or alter them once an image has been displayed.



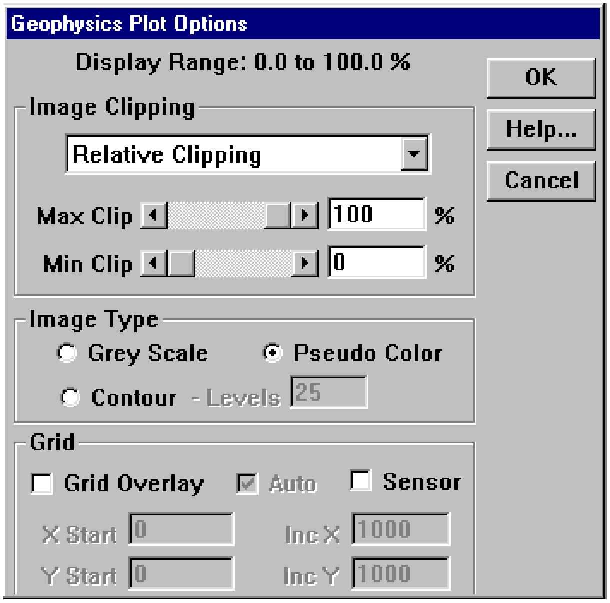
Dialog to control the display options of geophysical presentations.

Group	Name	Function
Geophysics Image Scaling		Sets scaling for bilinear interpolation of calculated data prior to display
Gravity Display		Opens up window with defaults for gravity image displays
Magnetics Display		Opens up window with defaults for magnetics image displays

Gravity/Magnetics Display Options

These items in the **Edit>Geophysics Display Options** allow you to alter the default display mode for geophysics images, or alter them once an image has been displayed.

Note The Gravity Display and Magnetics Display options may have their display contents altered individually when the right mouse button is clicked in a geophysics image window. When this is done, the following dialog is presented which enables data clipping, greyscale, pseudocolour or contour display formats.



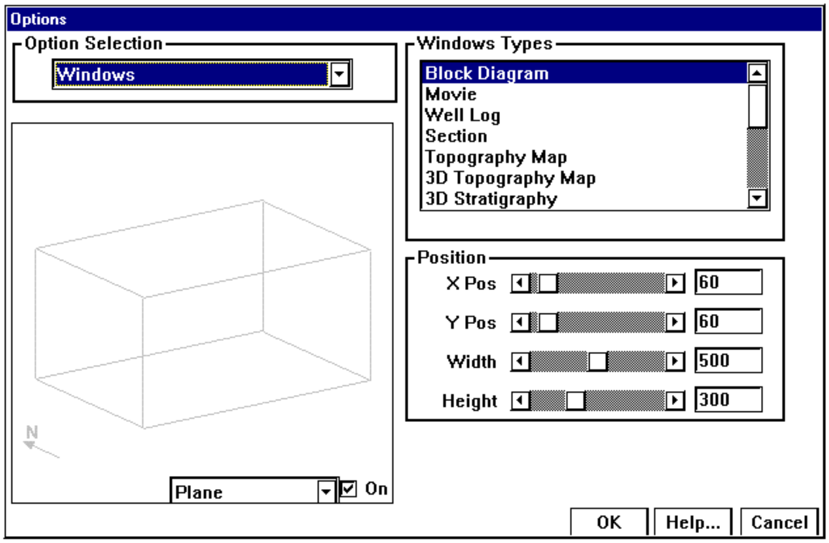
Controlling the geophysical display options.

Group	**Name**	**Function**
Image Clipping	**Relative Clipping**	Sets look up table clipping values relative to max/min within image
	Absolute Clipping	Sets look up table clipping values relative to absolute values (useful when comparing different models)
	Max Clip	Clips the upper range of the data
	Min Clip	Clips the lower range of the data
Image Type	**Grey Scale**	Displays image as grey scale raster
	Pseudo	Displays image as rainbow look up table raster

	Colour	
	Contour	Displays image as rainbow look up table contour map
	Levels	Range is divided evenly into this number of contour levels
Grid	**Grid Overlay**	Turns on vector overlay grid of grid intersections
	Auto	Uses automatic grid spacing (depends on image scale and shape)
	X,Y Start	Starting position of manually defined grid
	Inc X,Y	Grid increments in X and Y direction

Window Position Options

Each window type can have a user definable default size and screen position, which controls its initial appearance.



Window Positions Options

Group	Name	Function
Window Types		Window type
Position	**X**	Position in screen coordinates from left of the top left corner of the currently selected window type
	Y	Position in screen coordinates from top of the top left corner of the currently selected window type
	Width	Width of window in screen coordinates
	Height	Height of window in screen coordinates (not always independently definable)

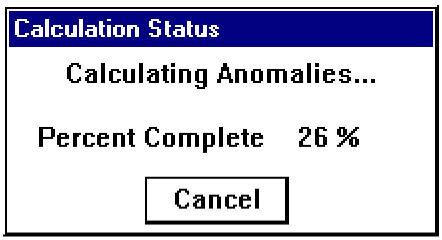
Geophysical Modelling

9 Geophysical Modelling

Noddy allows you to calculate the 2D anomaly patterns that arise from a 3D volume of geology. Once the volume of rock to be modelled has been specified from within the **Edit>Block Options** window, the calculations for gravity and magnetics are performed simultaneously by selecting **Geophysics>Calculate Anomalies**. The anomalies themselves are written out to file. A window opens that allows the user to provide the directory and prefix of the output files to be created. The directories are below the level of the location of the Noddy program. Once the calculation is completed, these files are loaded into the program as raster or contour images, depending on the settings of the **Edit>Geophysics Display Options**.

Several schemes are available for calculating gravity and magnetic responses. These fall into two groups - the Spatial Domain and Spectral Domain. To switch between these schemes select the appropriate option in the **Edit>Geophysics Calculation Options**.

Note When calculating the geophysical response for any combination of settings, the following status dialog is displayed.



If you wish to halt computations, press the **Cancel** button.

Geophysical Calculations within Noddy

There are three calculation schemes available within Noddy. These are the Spatial Convolution scheme, Spectral scheme and the Full Spatial scheme. Each scheme has advantages and disadvantages for particular settings, and not all calculation types are available for each scheme.

For all surveys the rock property of a cube is defined as the value at the centre of the cube, and for grid surveys (that is, not arbitrary surveys or borehole surveys) the field strength is calculated at the X,Y location above the centre of each cube.

The Total Magnetic Intensity value calculated for all schemes is actually the value projected onto the Earth's field, following the convention of many modelling schemes.

The gravity field calculated is for the Z component only.

Basic Calculation Schemes

The control of computation scheme and parameters to be used is provided in the **Edit>Geophysics Computation Options**. Three geophysical computational schemes are available in Noddy. The criteria as to which scheme should be used depends on required accuracy, speed and the various geological situations being modelled. A brief description of each scheme is provided below.

Spatial Convolution Scheme

This scheme works by calculating the summed response of all the cubes within a cylinder centred on the sensor, with a radius defined by the spatial range term. The calculation for each cube is based on the analytical solution for a dipping prism presented by Hjelt, 1972 and 1974. In order to calculate solutions near the edge of a block, extra geology is used to produce a padding zone around the block equal in width to the spatial range, so that there are no edge effects in this scheme. The scheme only provides exact solutions when the range is larger than the length of the model. For reasonably complex geology this limitation does not result in inaccurate models, however for idealized geometries using a range that is too small results in a kink in resultant profiles, which is accentuated by 1^{st} VD calculations. The spatial convolution scheme is slower than the Spectral scheme for medium ranges (10-20 cube ranges), but generally much faster than the Full Spatial Calculation. As long as the range is greater than the spacing between high density/susceptibility features, the inaccuracies associated with truncating the calculation is probably not evident. The draped survey and down-hole surveys have not been implemented for this scheme.

Spectral Scheme

This scheme works by transforming the rock property distributions into the Fourier domain, applying a transformed convolution, and then transforming this result back into the Spatial Domain. The calculation is performed for each horizontal slice through the geology, and the results are summed vertically. The Spectral scheme produces a different result than the other two schemes in terms of absolute numbers for three reasons:

a. The Fourier transform implies that the geology is infinitely repeating outside the calculation area. This produces edge effects when high susceptibility or density bodies are found near the edges of the survey area. This effect can be lessened by the choice of a suitable padding around the block, including over specified areas of interest, however it cannot be totally removed.

b. The calculation loses the absolute base line of the gravity or magnetic field, so even when comparisons are made for well padded Spectral and large range Spatial models, an overall offset is apparent between the two schemes. When trying to model real data this offset is not a problem as any regional is removed before the modelling process.

c. There is a high frequency component to the calculated field that is of the same wavelength as the cube size and are especially apparent when there are steep gradients in the values of the rock properties.

Occasionally, extremely regular geological models such as North-South trending sinusoidal folds, the spectral scheme produces very surprising results, such as markedly different anomaly amplitudes for identical fold structures.

Full Spatial Scheme

This is similar to the Spatial Convolution scheme except that all the cubes in the model are summed in order to calculate the response at any point. This calculation is effectively identical to the Mag3D program. It generally takes significantly longer to apply this calculation scheme than either of the other schemes. The only exception is when there is a relatively sparse geological model. In the extreme case where only one cube has non-zero values for both density and susceptibility, any cubes which have both zero density and susceptibility are ignored. This is the only scheme that can accurately calculate draped surveys, down hole surveys and arbitrarily located airborne surveys.

A table describing the available calculation abilities of the schemes is presented below.

Calculation	Spatial Convolution	Spectral	Full Spatial
Magnetics	√	√	√
Gravity	√	√	√
3 Component Magnetics	X	√	√
Remanence	√	√	√
Anisotropy	√	√	√
Draped Surveys	X	X	√
Exact XYZ airborne	X	X	√
Variable inclination	√	X	X
Exact XYZ downhole	X	X	√

Availability of specific calculations for each scheme

Advanced Geophysical Calculations

The required controlling parameters for the various advanced calculations can be specified in the **Edit>Geophysics Survey Options**.

Remanence Calculations

Remanence calculations have been implemented for all three schemes and do not alter the calculation time.

Anisotropy of Susceptibility

Anisotropy calculations have been implemented for all three schemes and do not alter the calculation time.

Barometric Surveys

Barometric Surveys have been implemented for all three schemes and do not alter the calculation time. The survey height is assumed to be the sum of the height of the top of the block plus the altitude of the plane specified in the **Edit>Geophysics Surveys** option. All cubes above the land surface are given zero densities and susceptibilities.

Note that in many circumstances this feature should be used to simulate geophysical responses which are more 'geophysically realistic'. The magnetometer sensor would normally be separated from the geologically susceptible units and intrusives by a combination of flying height and weathering depth. By using a sensor elevation (simulated by aircraft height), a separation between magnetically active rocks and the computed sensor location can be derived. This tends to smooth the geophysical response and simulate regolith and weathering effects. An alternative application of this option is for the use of computing upward continuations.

Draped Surveys

Draped surveys have only been implemented for the Full Spatial calculation, and thus take a considerable time to calculate. The survey height is assumed to be the height of the land surface plus the altitude of the plane. Finer cube sizes are obviously better able to preserve subtle variations in topography.

3 Component Surveys

3 Component calculations have been implemented for both the spectral and full spatial schemes.

1st and 2nd Vertical Derivatives

These are calculated in the Fourier domain, and in keeping with normal convention, assume Z is positive downwards (as opposed to the convention for the geological definitions where Z is positive up).

Note

Opposing Z conventions have been adopted as it is less confusing to produce ‘normal’ looking 1st VD images than to enforce a single axis convention.

Borehole Calculations

These calculations are provided only for the Spectral and Full Spatial schemes, and do not address the problem of the local distortion to the field caused by the borehole itself.

Variable Cube Size with Depth

This calculation can be used in conjunction with all three schemes to reduce the calculation time by increasing the cube size by a fixed factor below a threshold depth.

Arbitrarily Located Surveys

These surveys have been implemented for all three schemes, and can either be generated from within Noddy, or based on imported XYZ locations. Only the Full Spatial calculation gives precise values for the localities provided. The other two schemes both take the value of the nearest value calculated over the centre of a cube.

Calculation	**Preferred Scheme**	**Reason**
General Calculations	Spectral	Fastest scheme
Calculations where absolute numbers are required	Spatial Convolution	With reasonable range size, produces accurate numbers
Calculations which must be completely accurate	Full Spatial	Produces most accurate calculation
Models with high density/susceptibility features near edge	Spatial Convolution or Spectral padded out with extra geology	Extra padding slows down spectral scheme, so speed may be similar
Barometric Surveys	Spectral	Fastest scheme
Draped Surveys	Full Spatial	Produces most accurate calculation (cannot be performed with Spatial Convolution)
Borehole	Full Spatial	Produces most accurate calculation
3 Component Surveys	Spectral	Fastest scheme
Arbitrarily Located Surveys	Full Spatial	Calculates precise field values at locations provided
Surveys with varying inclination, declination or intensity	Spatial Convolution	Only scheme currently implemented

Recommended calculation scheme for specific cases

Important Considerations when Modelling

There are a number of factors that need to be taken into account when calculating the response of a particular structure:

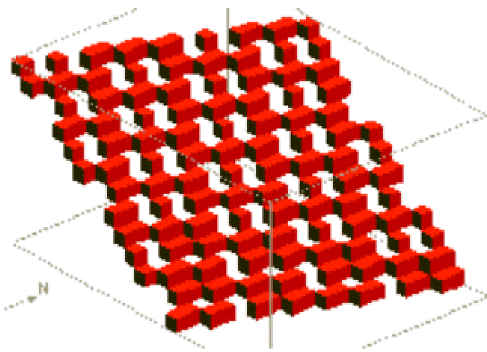
Resolution of Structural Detail

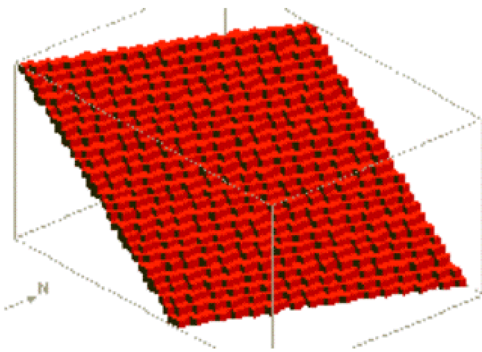
In order to accurately model a particular geological model, it is essential to make sure that the cube size is fine enough to resolve the individual units which make up the model. This generally means that if the lithological units (of geophysical interest), are of a given thickness, the cube size needs to be the same as that thickness. Care needs to be taken since deformation can result in thinning of units (such as a fault cutting through a dyke obliquely). A second problem with using coarse cubed models is that the position of the anomaly can be displaced by up half the cube size, since the body is made up of cubes on a regular grid.

The true test of the correct choice of cube size may be made by setting the Geological Cube Size to the same value as the Geophysical Cube Size.

Note The cube sizes are specified in the **Edit>Block Options** menu item.

As a check on the chosen cube style, make a Block Diagram with the only lithological units you wish to check made visible (by right mouse clicking in the block diagram - refer to *3D Voxel Views*). If the units look continuous in the resulting visualization then the geophysical calculations have the necessary detail. In the two figures below a 200 m thick dyke is represented with 400 m (left) and 200 m (right) cubes, with a significant loss of resolution seen in the coarser model.





Reducing the cube size significantly increases the calculation time. It is wise to develop the model using a larger cube size, so the positioning of the structures can be performed quickly. Only use a finer cube size for later stage geophysical calculations. To help in this process two separate cube sizes can be defined. Geological calculations are generally much quicker than geophysical calculations, so a finer value can be defined for the Geological Cube Size than for the Geophysical Cube Size.

Speed of Calculation

The speed of all calculations is dependent on three factors:

a) Model Volume

The larger the volume or area of the calculation, the longer the calculation takes. For a given volume, a reduction in the cube size (for both geological and geophysical models) quickly result in an increase of the computation time needed. Performing low resolution calculations during the preliminary stages of modelling assists in speeding up the model development process. A batch mode of operation for Noddy also exists. To run Noddy in batch mode for the most common case (performing a geophysical anomaly calculation), in a DOS window type:

```
noddy -h test.his -anom -o test.mag
```

where **test.his** is the name of the previously set up history file, and **test.mag** is the output file name.

Also be aware that the number of cells surrounding a block (used as padding to reduce the edge effects of calculations), also affects the volume of the model. Refer to *Geophysics Calculation Options* for further information.

b) The Type of Calculation

Some calculations inherently take longer than others. For example a deformable remanence calculation takes longer than a non-deformable remanence calculation.

c) The Choice of Geophysical Calculation Scheme

The three different calculation schemes all take different times to perform the same calculation. Typically, the slowest is the Full Spatial Scheme and the fastest is the Spectral, with the Spatial Convolution in-between, however there are exceptions. Within each calculation scheme there are different options that speed up the calculation:

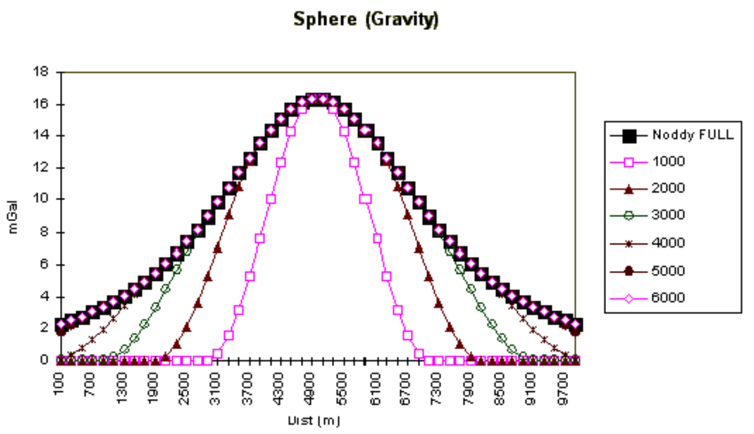
Spectral Scheme - The Spectral scheme works more slowly with the Reflective Padding Option set, so unless there is a need for this scheme related to the boundary conditions of the model, it is better to use, for example the Ramp padding Options.

Spatial Convolution Scheme - The larger the Spatial Range, the more accurate the calculation. The Spatial Range term in the Spatial scheme controls the calculation time and is proportional to the range squared, so smaller ranges can be used early in the modelling processes.

Full Spatial Scheme - The Full Spatial scheme only calculates the contributions of cubes whose density **or** susceptibility values are none zero. Consequently, if **both** are set to zero, and the model only contains one or two units with non-zero rock properties, the calculation time can be quite reasonable.

Absolute Anomaly Intensities

The absolute intensities of an anomaly are not preserved by the Spectral calculations. The shape, however, is preserved so that when comparing Noddy calculations with other modelling schemes an offset may be applied for this scheme. Another reason for variation between Noddy and other schemes is that the bodies defined are approximated by cubes. This means that the true volume of a 1000m radius sphere modelled by 200 m cubes is only 95% of the Noddy model version, so that the anomaly calculated in Noddy is approximately 5% larger than an analytical solution. Noddy also does not take into account self-demagnetization and this contributes to a Noddy-derived anomaly being of slightly higher amplitude.



Magnetic response of a sphere at various cell block sizes.

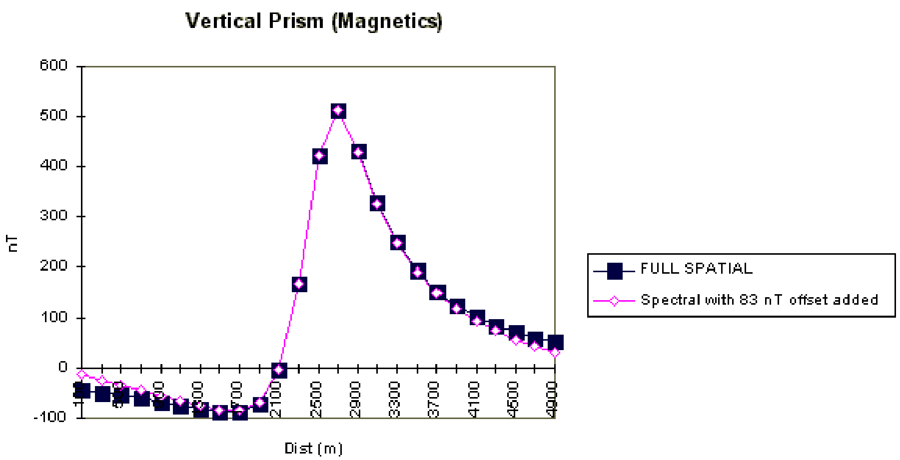
Anomaly Shapes

The shape of anomalies calculated by Noddy are correct with two provisions:

- For Spatial Convolution calculations, the anomaly due to a single body can only be correct up to the distance defined by the Spatial Range
- For Spectral Calculations, there is a spurious high frequency component that is particularly evident adjacent to high contrasts in rock properties.

Boundary Effects

Since a calculated anomaly for a model cannot take into account the geology of bodies outside the model bounds, so highly responsive bodies that intersect the edges of a model can result in edge effects. These effects can be reduced for both Spatial calculation schemes by using a large range term, which calculates 'extra' geology around the model bounds up to the Spatial Range distance. For the Spectral scheme, care has to be taken with bodies near the edge of the model, as the different padding options have different results. In the image below, which shows the arithmetic difference between a full spatial and a spectral magnetics calculation, notice the increased variation near the boundaries.



Magnetic boundary effects relating to a vertical prism.

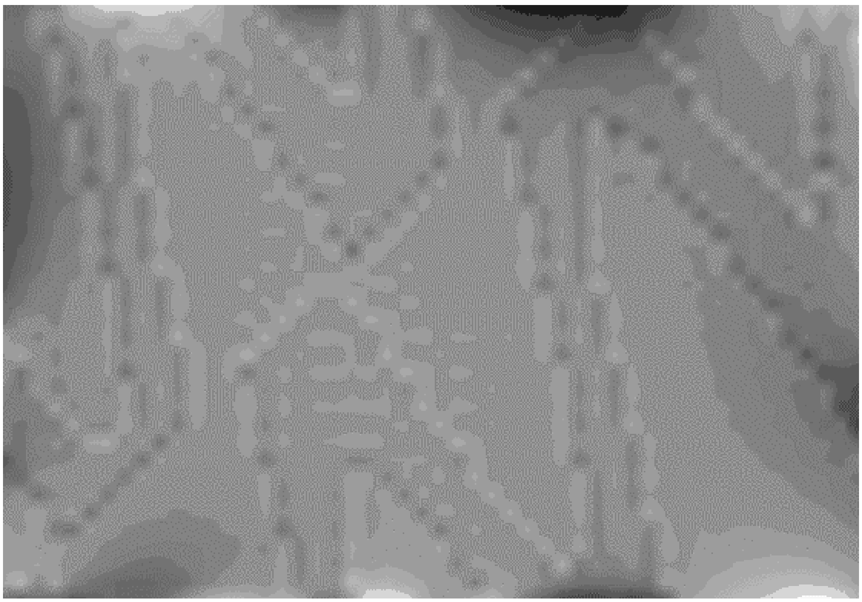
Anomaly Maps

There are three submenu options for the **Geophysics>Calculate Anomalies** menu that produces raster maps of the gravity and magnetic response, these are:

1. **Calculate Anomalies -** The default, this calculates the gravity and magnetic anomalies for the current history.
2. **Calculate Block and Anomalies-** Calculates the current anomaly patterns, but also saves out the geology in an XYZ ASCII block model form. The cube size is defined by the **Edit>Block Options>Geophysics Cube Size** parameter.
3. **Calculate Anomalies From Block -** Calculates the anomaly patterns for a given block model read in from file, and allows in principal the importing of models from other packages.

Note

The results of these calculations are displayed automatically as raster or contour images on completion.



Example of a raster image of an anomaly map.

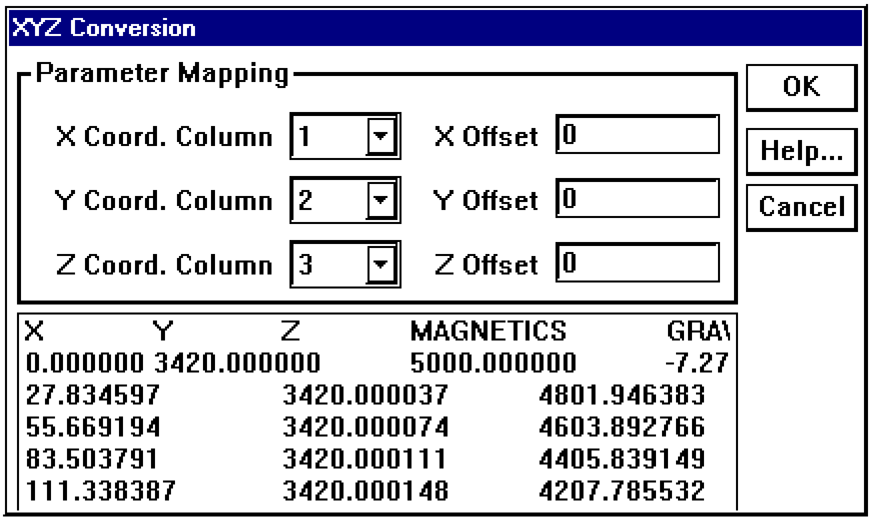
Borehole Response Calculations

There are two options for calculating downhole geophysical survey responses from internally generated or imported borehole specifications:

- **Geophysics>Calculate Anomalies>Borehole>Generated**
  This option calculates a downhole survey using the borehole specifications in the **Edit>Geology Section/Borehole Options** Window. The results can be are written out as an ASCII file with filename extension .GEO.

- **Geophysics>Calculate Anomalies>Borehole>Imported**
  This option calculates the response of a downhole survey using the borehole specifications imported from an ASCII three column XYZ data file. You have the opportunity to specify which columns refer to X, Y and Z. The area of the window below the Parameter Mapping section shows the first few lines of the file to aid in selecting the proper X,Y,Z columns. The results can be written out as an ASCII file.

Note Any input row starting with a number is considered to be data, and any other row is considered to be a comment.



Borehole survey and location control conversion.

Group	Name	Function
Parameter Mapping	**X Column**	Column containing X position data
	Y Column	Column containing Y position data
	Z Column	Column containing Z position data
	X Offset	Offset applied to input X position
	Y Offset	Offset applied to input Y position
	Z Offset	Offset applied to input Z position

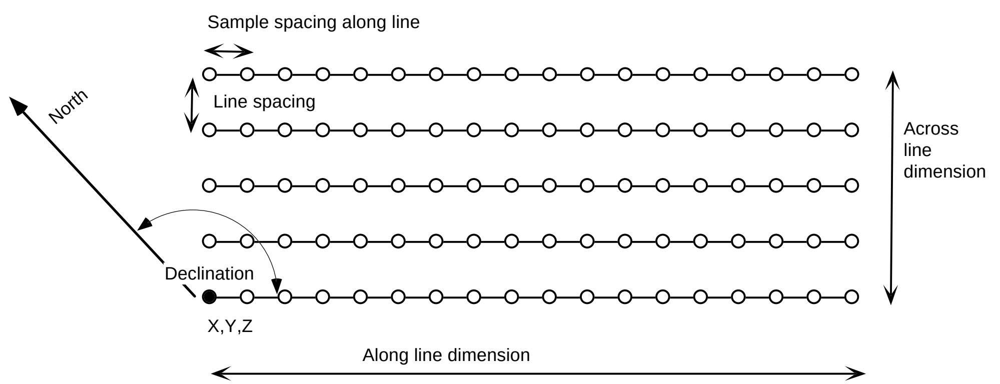
Flight Line Surveys

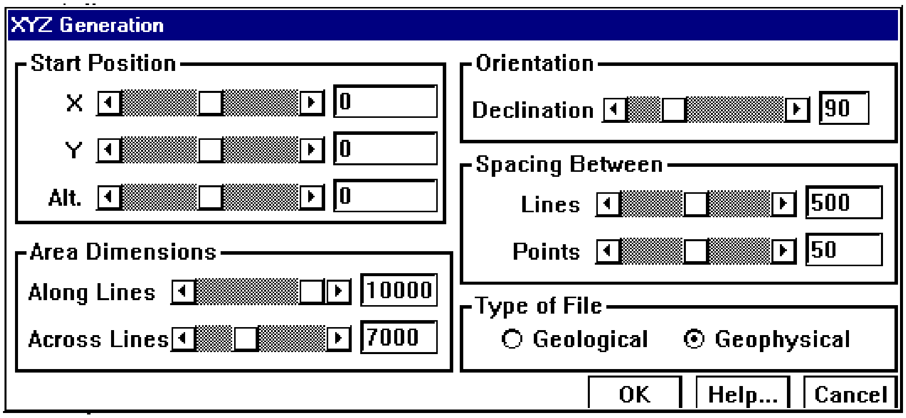
As an alternative to dense raster geophysical calculations, it is possible to calculate the geophysical response along real or synthetic flight lines.

Generated Surveys

A rectangular area is defined with arbitrary declination, and then the line spacing and sample spacing along lines can be defined. Use the **Geophysics>XYZ Point Data>Generate** option to create synthetic data points.

Flight Line Geometry



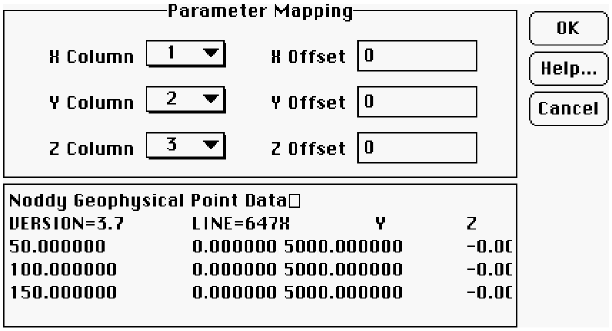


Dialog to control the creation of flight paths.

Group	Name	Function
Position	**X**	X Position of South West corner of survey
	Y	Y Position of South West corner of survey
	Alt	Altitude above South West corner of survey maintained over block
Orientation	**Declination**	Declination of flight lines
Area Dimensions	**Along Lines**	Total extent of survey along lines
	Across Lines	Total extent of survey across lines
Spacing Between	**Lines**	Spacing of flight lines
	Points	Spacing of samples along lines
Type of File	**Geological**	File stores a simple ASCII tab delimited file showing for each sample point the raw rock property information at the surface of the block.
	Geophysical	File stores the calculated gravity and magnetic measurements for each sample point.

Imported Flight Line Surveys

Pre-existing flight line positional information may be imported using the **Geophysics>Calculate Anomalies>XYZ Point Data>Import From File** menu item. This opens any plain ASCII column format data file. You have the opportunity to specify which columns refer to X, Y and Z. Once the calculations have been completed, two extra columns for TMI and Gravity are appended to a copy of the import file. The area of the window below the Parameter Mapping section shows the first few lines of the file to aid in selecting the proper X,Y,Z columns.



Any input row starting with a number is considered to be data, and any other row is considered to be a comment.

Group	Name	Function
Parameter Mapping	**X Column**	Column containing X position data
	Y Column	Column containing Y position data
	Z Column	Column containing Z position data
	X Offset	Offset applied to input X position
	Y Offset	Offset applied to input Y position
	Z Offset	Offset applied to input Z position

Vertical Derivative Calculation

Fourier domain first and second vertical derivatives of gravity and magnetics images may now be calculated from within Noddy by selecting **Geophysics>Vertical Derivatives>First or Vertical Derivatives>Second**. These two options both read in a .MAG or .GRV file from disk, perform the vertical derivative calculation, and then save the result back to file (again as .MAG or .GRV format files). The results of this calculation are also displayed in a normal geophysics image window on completion of the calculation.

Reference Datasets

These datasets are used to provide direct constraints on the modelling performed within Noddy. A reference image can be imported using **File>Load Reference Images** option.

Formats supported are the Noddy .MAG and .GRV formats, however you can use the conversion tool (**Tools>Import>ASCII**) to allow conversion to this format. Additional import capability is provided for ER Mapper (.ERS) and Geosoft (.GXF) grid formats.

Once loaded a reference image may be used in one of three ways:

1. For further modelling, by examining the loaded image, drawing profiles across it, or calculating the vertical derivative images.
2. In the Structural Definition options the Preview window provides Gravity Difference and Magnetics Difference menu items for calculating the difference between actual and modelled data.
3. High resolution difference images may be calculated using the Difference with **Reference>Gravity** or **Difference with Reference>Magnetics** options from the Geophysics menu.

Geophysical Visualizations

Geophysics Images and Profiles

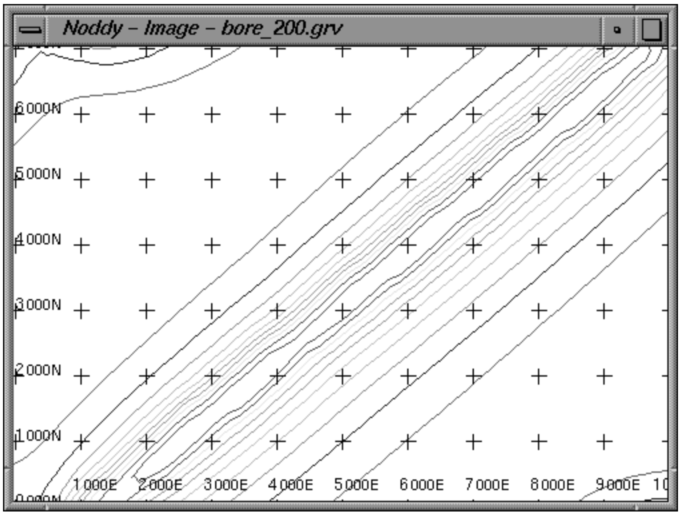
Difference Images

10 Geophysical Visualizations

As soon as a geophysics calculation is completed, the appropriate image(s) are displayed. The default form of these images may be preset (using the Edit options), and they may also be altered interactively.

Geophysics Images and Profiles

As soon as an anomaly map has been calculated, grey scale, contour or pseudocolour images of gravity and magnetic anomalies are automatically displayed. Images may also be loaded from previous calculations (and from ER Mapper (.ERS) or (Geosoft) .GXF format files using the Load Reference Images), using the Display Image menu items from the Geophysics menu. The spatial scaling of the image (including .ERS and .GXF formats) is dependent on the Geophysics Image Scaling Option from the **Edit>Geophysics Display Options**, and is performed using a bilinear interpolation.

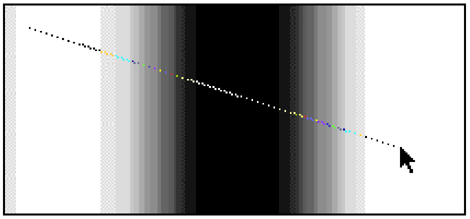


A contour map of a loaded gravity data grid.

This window allows the following interactive responses:

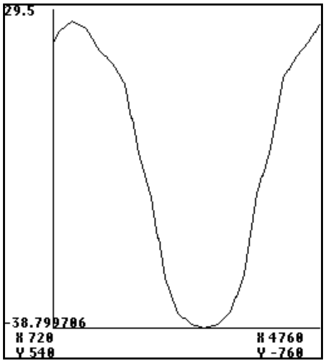
Profile Displays

In order to display a profile of any section within an image, click the left mouse button and drag while the cursor is over the image. This produces a 'rubber band' line showing the profile position.



Creating a profile trace.

Once the mouse button is released, a profile line is interpolated from the underlying file. These profiles are scaled to the currently selected image range.

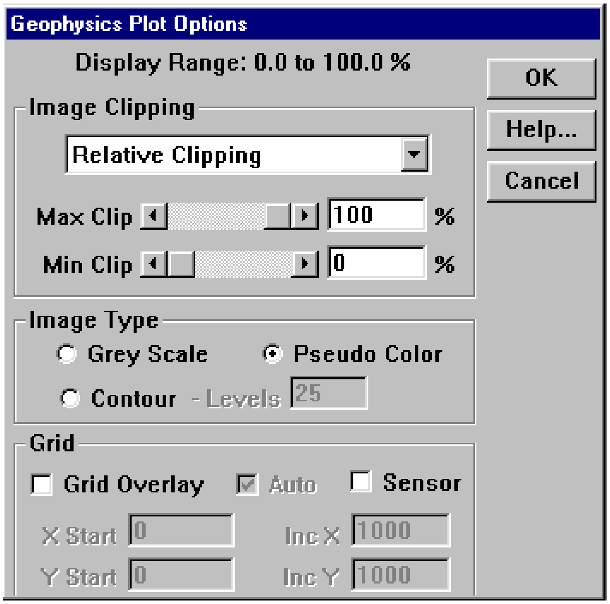


The profile data displayed in a horizontal track.

If the SHIFT key is held down during this operation the line defining the profile position is left on the image together with the number of the profile.

Image Display Options

If the right mouse button is clicked in an image display window, the Display Plot Options dialog appears, and the range and display type can be altered (grey scale, rainbow LUT or colour contour). LookUpTable scaling can also be switched between Absolute range limits and a Maximum-Minimum percentage (%) Clip.



Geophysics Plot Option control dialog.

Difference Images

These images show the arithmetic difference between the loaded reference image and a previously calculated potential field image.

The order of processing assumes the reference image is already loaded, so the image that is imported from file is the model image.

Once loaded, this is a normal geophysical visualization, so that the LUT of the image may be clipped or profiles may be drawn across the image as for normal image displays. Refer to *Reference Datasets* for information on importing these images.

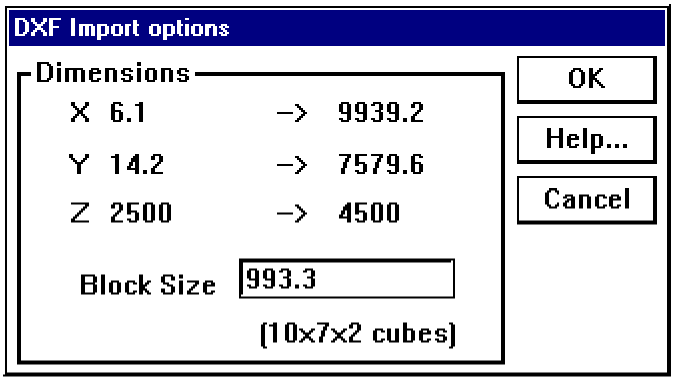
Tools

11 Tools

The tools described in this section are all accessed via the Tools menu. Tools control the various utility procedures, mostly related to converting internal Noddy formats to various external formats and vice versa.

Importing DXF Triangulations

Closed single or open multiple triangulated surfaces can be converted into the .G00 Noddy block model format (which can then be used via the **Import Deformation Event**). Once the triangulation file has been loaded, the resolution of the Noddy block model can be defined.



Importing a DXF triangulated data file.

Group	Name	Function
Block Size		Size of voxels used in converted file

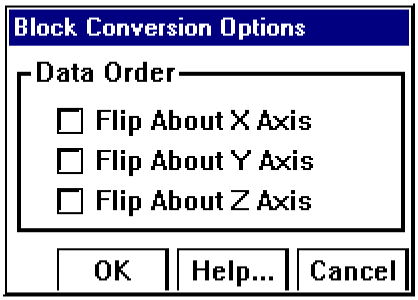
Importing Vulcan Regularized Block Models

The **Tools>Import Block>Vulcan** option allows Vulcan format block models to be converted to the .G00 series Noddy block model formats (which can then be used via the Import Deformation Event).

Vulcan can export a regularized block model with the following ASCII format, one line per voxel:

```
x_location y_location z_location x_voxel_size
y_voxel_size z_voxel_size rock_name_index density
mag_sus
```

The option converts the Vulcan file (default filename extension of .VUL) and provide an option to rotate the data.



Dialog to control block rotation and conversion.

After defining the axis rotation, Noddy requests the name of the .VUL file for import.

Importing Old Noddy Block Models

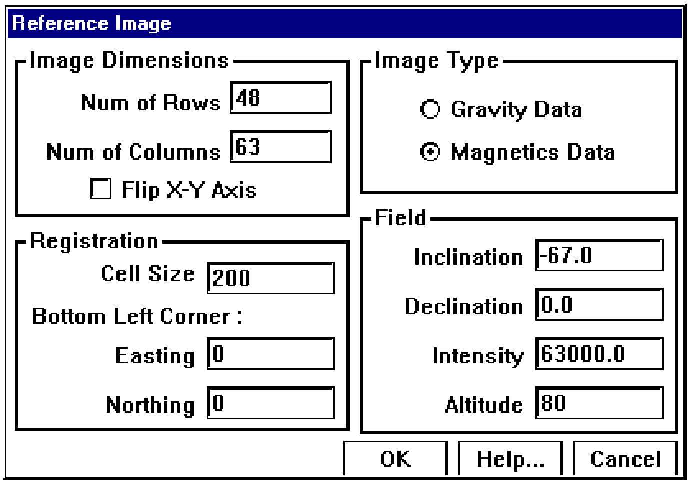
The **Tools>Import>Old Noddy** block option enables early (Noddy Version 3.0) .BLK block model history files to be loaded into Noddy.

Importing Potential Field Images

The **Tools>Import Image** menu item allows you to convert tab or space delimited ASCII text files into Noddy format .GRV or .MAG geophysics files. These files must represent evenly spaced rectangular gravity or magnetics sample points. This is useful:

1. To use Noddy for contouring or other display of raw geophysical data.
2. To use Noddy to calculate the 1st or 2nd vertical derivatives of some data.
3. To create a reference dataset.

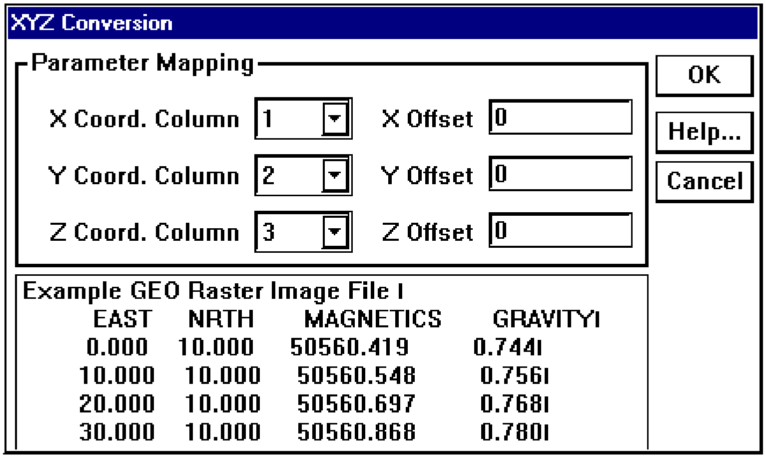
Image imports can be of two types. ASCII format data where the number of rows/columns and registration information is required. Information about the file and data contained in it needs to be known before this option can be used (see the Reference Image dialog below).



Control dialog for reference images.

Group	**Name**	**Function**
Image Dimensions	**Num of Rows**	Number of rows (Y direction) of data points in image
	Num of Columns	Number of columns (X direction) of data points in image
Image Type		Select data type of image (gravity or magnetics)
Registration	**Cell Size**	Dimensions of cells in metres
	Easting	Eastings of South West corner of Image
	Northing	Northings of South West corner of Image
Field	**Inclination**	Inclination of Earth's magnetic field in area of survey
	Declination	Declination of Earth's magnetic field in area of survey
	Intensity	Intensity of Earth's magnetic field in area of survey
	Altitude	Altitude of survey

A second image format of generalized multi-column type can also be imported from a .GEO file. The pre-existing positional information may be imported using the **Tools>Import Image>Column** menu item. This command opens any plain ASCII column format data file and there is the opportunity to specify which columns refer to X, Y and Z. The area of the window below the Parameter Mapping section shows the first few lines of the file to aid in selecting the proper X,Y,Z columns.



Conversion of a raster format file.

An example of an ASCII multi-column image file follows:

```
Example GEO Raster Image File
           EAST       NRTH        MAGNETICS         GRAVITY
          0.000     10.000        50560.419           0.744
         10.000     10.000        50560.548           0.756
         20.000     10.000        50560.697           0.768
         30.000     10.000        50560.868           0.780
         40.000     10.000        50561.067           0.794
         50.000     10.000        50561.300           0.807
         60.000     10.000        50561.575           0.822
         70.000     10.000        50561.904           0.838
         80.000     10.000        50562.300           0.854
         90.000     10.000        50562.785           0.872
```

Any input row starting with a number is considered to be data, and any other row is considered to be a comment.

Group	Name	Function
Parameter Mapping	**X Column**	Column containing X position data
	Y Column	Column containing Y position data
	Z Column	Column containing Z position data
	X Offset	Offset applied to input X position
	Y Offset	Offset applied to input Y position
	Z Offset	Offset applied to input Z position

Exporting Voxel Models in the Noddy Block Model Format

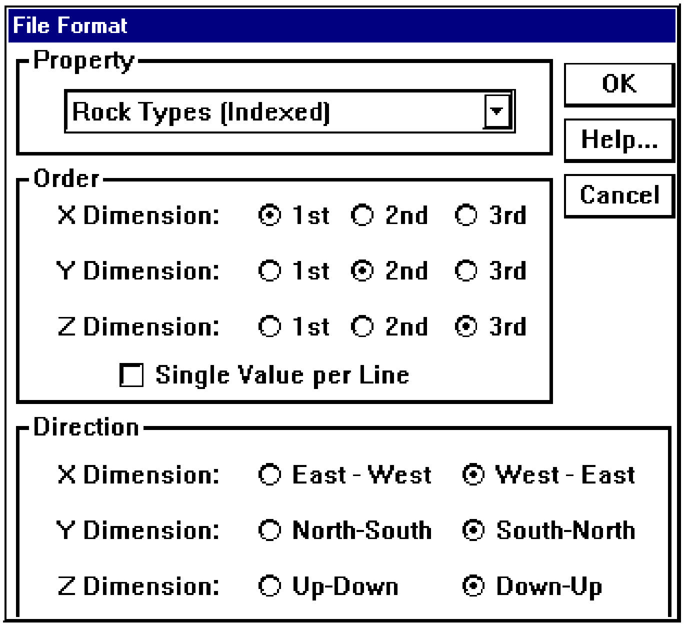
This option creates a Noddy format block model which consists of a header file with a .G00 suffix together with a variable number of voxel model files (numbered .G01 to .G12), depending on the **Edit>Geophysics Survey** and **Calculation** settings. This format may be loaded back into Noddy via the Import event.

Note The cube size is determined by the **Edit>Block options>Geophysics** cube size.

Exporting Voxel Models in Raw Format

This is an export file format (created from the **Tools>Export Block Model>Dicer Block Model** menu item) that contains a tab delimited ASCII voxel model of the either the rock type index or any one geophysical rock property, in whichever voxel order is specified by the File Format window which appears. This model may then be easily converted to BOB, VoxelGeo, Dicer or other voxel rendering package formats.

Note The cube size is determined by the Geophysics cube size.



File Format Window

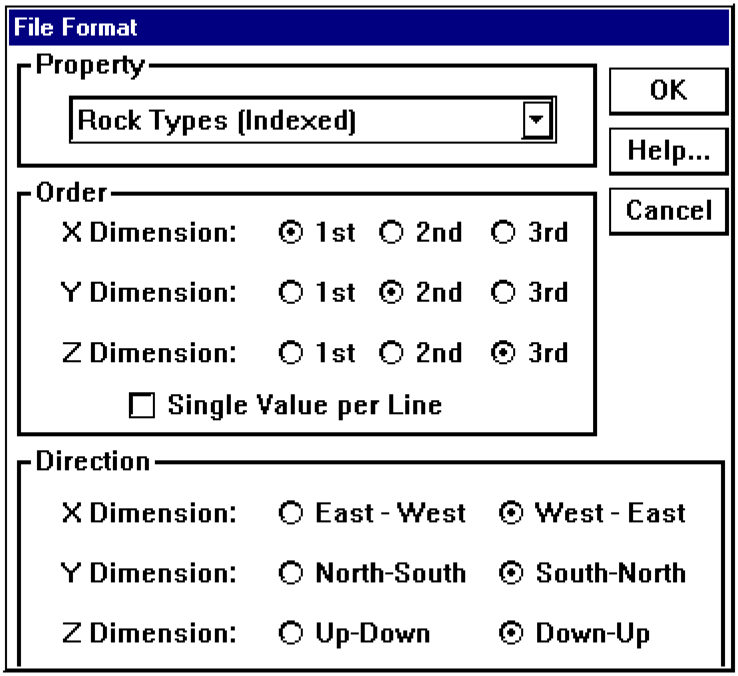
Group	Name	Function
Property		Selection of which property to export
Order	**X,Y,Z Dimension**	Loop order for writing out voxels (1st means outermost loop)
	Single Value per Line	File is written with one voxel per line (instead of whole row of voxels)
Direction	**X,Y,Z Direction**	Direction of writing out voxels East to West vs West to East etc for each index

Exporting Voxel Models in Tabulated Column Format

This option provides an export file format (created from the **Tools>Export Block Model>Tab Columns** item) that creates a tab delimited ASCII voxel model file of either the rock type index or any one of the geophysical rock properties. The File Format window provides voxel coordinate specification to account for the voxel order and direction. The default output file has a .TAB file extension.

Note

The cube size is determined by the Geophysics cube size (see the **Edit>Block Option>Geophysics** option).



File Format Window

Group	Name	Function
Property		Selection of which property to export
Order	**X,Y,Z Dimension**	Loop order for writing out voxels (1st means outermost loop)
	Single Value per Line	File is written with one voxel per line (instead of whole row of voxels)
Direction	**X,Y,Z Direction**	Direction of writing out voxels (East to West vs West to East etc) for each index

Exporting DXF Format Block Models

This option provides an export file format (created from the **Tools>Export Block Model>DXF - 3D Faces** or **Polylines** items) that creates a DXF ASCII voxel model file.

The ASCII DXF file may take one of two forms and these may contain triangulated surfaces of the same type as displayed in 3D Layer visualizations. Two types of definitions of three dimensional triangle objects are supported, as different CAD systems, such as MicroStation and Vulcan, is only read in one or other of the object types. The two types are 3D Faces, and Polylines. Each surface selected in the **Edit>Geology Display 3D Options** window is saved as a triangulated surface, with continuous surfaces saved within single 'DXF Layers'. If, for example a stratigraphic horizon is broken by a fault plane, two distinct DXF layers are created.

Further information on the DXF created file formats is provided in *DXF Triangulation Files*.

Exporting Vulcan Block Model Files

The menu item **Tools>Export Block Model>Vulcan** creates a .VUL format, Vulcan-specific block model file. From the file created using this option additional processing steps must be undertaken to make the model suitable for import into Vulcan. The necessary processing steps are described in *Vulcan Trangulation Files*.

Exporting Response and Vector Data in ER Mapper Formats

The **Tools>Export Image>ER Mapper** options allows Noddy computed geophysical responses (.GRV and .MAG suffix geophysics files) to be converted to .ERS ER Mapper format raster files. A sub-option allows either magnetics or gravity images .ERS files to be created.

The option (**Geology>Line Map**) also saves a vector map of the current geological history in .ERV ER Mapper vector file format. The ER Mapper format file can be read back into Noddy or ER Mapper at a later date.

Export Potential Field data in Geosoft Format

The **Tools>Export Image>Geosoft** (Gravity or Magnetics) options allows Noddy .GRV and .MAG suffix geophysics files and geophysical responses to be converted to .GXF Geosoft format raster files. The Geosoft format file may be read back into Noddy or Oasis Montaj© at a later date.

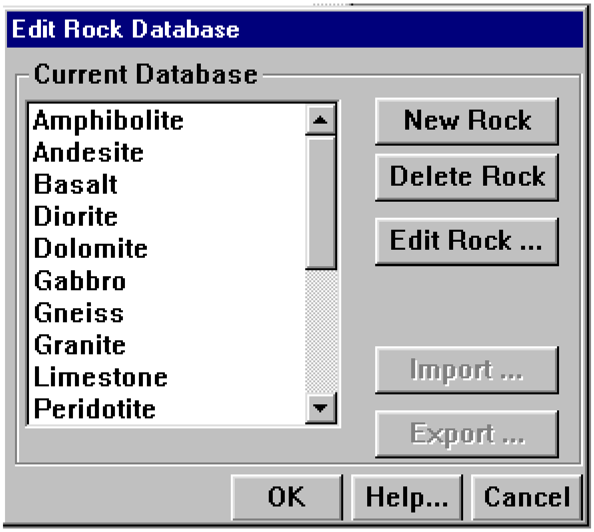
Editing the Rock Properties Database

A set of pre-defined rock properties contained in a rock property database can be built. Noddy comes with a default set of properties (Telford et al, 1981) which represent 'average' values of susceptibility and density for a number of different rock types. Since susceptibility values in particular show enormous regional variations, it is likely that you need to create your own database entries.

In order to edit the default database, a file is supplied called 'PROPERTY.ROX'. This file can be edited within Noddy using the **Tools>Edit Rock Database** option. This file is a global file that is loaded each time Noddy is executed, however history files written out from Noddy are not updated if the database if modified.

Once a rock properties database has been defined, clicking in the menu tag of the name of the rock in the Rock Property definition window allows the user to choose from a predefined list of rock types, and all of the rock property values (except the Height) are automatically loaded.

WARNING If SI units are specified in the **Edit>Geophysics Survey Options** window, the values entered must be in SI units, as they are converted to cgs units within the database.



Dialog to select, create or edit rock types in the database.

Group	Name	Function
	New Rock	Add new rock name to database (opens up rock property definition window)
	Delete Rock	Delete selected rock from list
	Edit Rock	Edit properties of existing rock

File Formats

12 File Formats

History File

The history file is an ASCII text file generated by the Save History menu item from the File menu. It contains a full summary of the stratigraphies defined to that stage, together with the current structural history, and all option settings for geology, geophysics and 3D views.

The history file format allows for full editing outside of the framework of the program, using any standard text editor, so that modified models can be created externally.

There are a number of conventions that must be obeyed in order for the file to retain a valid format when editing these files:

- **Comment lines -** Any line which starts with a # symbol is ignored when read by Noddy
- **Blank lines -** All blank lines are ignored when read into Noddy
- **Equals sign -** All lines with information to be read contain an equals (=) sign, and the information to be read follows the equals sign. Any value after an equals sign may be altered, however altering the number of stratigraphies, the number of layers within a stratigraphy, or the number of events has a trickle down effect requiring further editing. It is not recommended that this degree of editing be undertaken. It is better to manipulate the file from within Noddy.
- **Internal order** within thematic blocks of data must not be altered, and the order of block groupings must also be preserved, specifically the block groupings.

Block Groupings of History Files

The components of a Noddy history file (.HIS) are composed of:

1. **Header Information - File Type**

   Version number

2. **Stratigraphic Information -** Number of stratigraphies

   Number of layers in 1st stratigraphy
   Layer information of the first layer/1st stratigraphic height
   Density
   Magnetic Susceptibility
   Colour
   Layer information of the second layer/1st strat etc

3. **Deformation Information -** Number of events

   Event information for 1st event: Type information for that type
   Event information for 2nd event: etc

4. **Geology Options -** All options from Geology options window

5. **Geophysics Options -** All options from Geophysics options window

6. **3D Options -** All options from 3D view options window

7. **Icon positions -** The position of icons in the history window

8. **End of file check -** Test for correct reading of data file

Editing this file can be accomplished in two ways, either by changing the value of a parameter after an equals sign, or by changing the order of events by reshuffling entire event descriptions. The event numbers that are associated with each event type do not need to be altered as they are only for external reference.

Example History File

The example event file (.HIS) shown on the following page contains a base stratigraphy and one dyke event.

#Filename =		
mvis_noddyNS.his		
FileType = 111		
Version = 7.00		
	Name	
No of Events	Type	= 2
Event #1	Join Type	= ST
Num Layers	Graph Length	= 1
Unit Name	Min X	= Ba
Height	Max X	= -3
Density	Min Y Scale	= 0.0
Anisotripic Field	Max Y Scale	= 0
MagSusX	Min Y Replace	= 0.0
MagSusY	Max Y Replace	= 1.
MagSusZ	Num Points	= 1.
MagSus Dip		= 9.0
MagSus DipDir		= 9.0
MagSus Pitch		= 0.0
Remanent		
Magnetization	Name	= 0
Inclination	Type	= 30
Angle with the Magn.	Join Type	
North	Graph Length	= 30
Strength	Min X	= 1.
Color Name	Max X	= W
Red	Min Y Scale	= 24
Green	Max Y Scale	= 22
Blue	Min Y Replace	= 17
Name	Max Y Replace	= St
Event #2	Num Points	= DY
Type		= St
Merge Events		= 0
X		= 50
Y		= 30
Z	Name	= 51
Dip Direction	Type	= 90
Dip	Join Type	= 90
Pitch	Graph Length	= 9
Slip	Min X	= 2
Width	Max X	= 6
Alteration Type	Min Y Scale	= NO
Num Profiles	Max Y Scale	= 12
Name	Min Y Replace	= De
Type	Max Y Replace	= 2
Join Type	Num Points	= LI
Graph Length		= 20
Min X		= 0.0
Max X		= 50
Min Y Scale		= 0.0
Max Y Scale	Name	= 4.
Min Y Replace	Type	= 0.0
Max Y Replace	Join Type	= 10
Num Points	Graph Length	= 2

Min X
Max X
Min Y Scale
Max Y Scale
Min Y Replace
Max Y Replace
Num Points

Name
Type
Join Type
Graph Length
Min X
Max X
Min Y Scale
Max Y Scale
Min Y Replace
Max Y Replace
Num Points

Name
Type
Join Type
Graph Length
Min X
Max X
Min Y Scale
Max Y Scale
Min Y Replace
Max Y Replace
Num Points

Name
Type
Join Type
Graph Length
Min X
Max X
Min Y Scale
Max Y Scale
Min Y Replace
Max Y Replace
Num Points

Name
Type
Join Type
Graph Length
Min X
Max X
Min Y Scale
Max Y Scale
Min Y Replace
Max Y Replace
Num Points

Name
Type
Join Type
Graph Length
Min X
Max X
Min Y Scale
Max Y Scale
Min Y Replace
Max Y Replace
Num Points

Name
Type
Join Type
Graph Length
Min X
Max X
Min Y Scale
Max Y Scale
Min Y Replace
Max Y Replace
Num Points

Name
Type
Join Type
Graph Length
Min X

```
	Max X
	Min Y Scale
	Max Y Scale
	Min Y Replace
	Max Y Replace
	Num Points




	Unit Name
	Height
	Density
	Anisotropic Field
	MagSusX
	MagSusY
	MagSusZ
	MagSus Dip
	MagSus DipDir
	MagSus Pitch
	Remanent
Magnetization
	Inclination
	Angle with the Magn.
North = 30.00
	Strength
	Color Name = Plum2
	Red
	Green
	Blue
	Name

#GeologyOptions
	X
	Y
	Z
	Scale
	SectionDec
	WellDepth
	WellAngleZ
	topofile
	Topo Filename
	Topo Directory
	Topo Scale
	Topo Offset
	Topo First Contour
	Topo Contour Interval
	Chair Diagram
	Chair_X
	Chair_Y
	Chair_Z
	Linemap_X
	Linemap_Y
```

```
	Cube Resolution		= 50
	Cube Scale		= -5.
				= 5.(
#GeophysicsOptions		= -5.
	GPSCube			= 5.(
	GPSRange		= 2
	Declination		Poin
	X1			Poin
	Y1			Poin
	Z1			Poin
	X2			= Ba
	Y2			= 55
	Z2			= 3.(
	Inclination		= 0
	Intensity		= 1.(
	Altitude		= 1.(
	Airborne=		= 1.(
	Calculation Method	= 9.(
	Constant Boxing		= 9.(
Depth				= 0.(
	Clever Boxing Ratio
	Deformable		= 0
Remanence=			= 30
	Deformable
Anisotropy=
	Draped Survey=		= 1.(

#3DOptions			= 23
	Declination		= 17
	Elevation		= 23
	Scale			= Dy
	Offset X
	Offset Y
	Offset Z		=  0.
	Fill Type		=  0.
				=  0.
#ProjectOptions			= 10
	Susceptibility Units	= 90
	Geophysical		= 50
Calculation			=  0.
	Calculation Type	= FA
	Length Scale		=
	Printing Scale		= c:\
	Image Scale		=  1.
	New Windows		=  0.
	Internet Address	= 10
	Account Name		= 10
	Noddy Path		= FA
	Movie Frames Per	=  0.
Event				=  0.
	Movie Play Speed	= 50
	Movie Type		= 10
				= 70
```

Image Display Clip
Min = 0.000000
Image Display Clip
Max = 100.000000
Image Display Type
Image Display Num
Contour = 25

#Icon Positions
Num Icons
Row
Column
X Position
Y Position
Row
Column
X Position
Y Position
Floating Menu Rows
Floating Menu Cols
End of Status Report

Topography File

This is an import ASCII text file with a short header followed by an array of floating point or integer spot heights. Each number should be separated by a space, tab or carriage return. An example:

```
9876
51  71
0.0 0.0
10000.0   7000.0
254 254   253   253   252   252   249   247   243
253 253   252   251   249   248   246   243   239 etc
```

Where:

- The first line is a file ID flag and is always the same.
- The second line gives the rows and columns in the data.
- The third line gives the XY position of the SW corner of the topographic data
- The fourth line gives the XY position of the NE corner of the topographic data
- The array assumes that the first spot height is the lower left (SW) height in the map. Data order is Row1 Column 1; Row1 Column 2; Row1 Column 3; etc

Topography files are read in by selecting the **Topography** check box in the Block Options window (**Edit>Block Options>Topography**). A default file extension of .TOP is used.

Topographic data may be re-scaled and offset on input into the program using the Topography option from the **Edit>Block Options** window.

Orientations File

This is an export ASCII text file (tab delimited) which contains the orientation data for the current outcrop map. This file is created using the Save Orientations option from the File menu. The data provides information on orientation, feature type, and age of feature:

Dip/Plunge	DipDn/PlDn	Type	Feature	Age1	Age2
47	53	Plane	Bedding		
78	66	Plane	Foliation	1 Fold	
45	134	Plane	Foliation	3 Fault	
44	134	Line	Lineation	3 Fault	
17	340	Line	Lineation	1 Fold	
17	340	Line	Bedding-Cl	1 Fold	
44	144	Line	Cl-Cl	1 Fold	3 Fault

The default file extension for this file type is .ORI.

Orientation files may be opened up directly by spreadsheets such as Lotus 1-2-3, MS Excel for later processing.

Geophysics Grid File

These files include 2D anomaly file types with file extensions of .GRV, .MAG, .MGX, .MGY and .MGZ extensions. Note that the .MGX, .MGY and .MGY suffixes refer to files having magnetic component data.

These files are ASCII text files that have the following format:

```
333
0   51    36    25
-50.000000      0.000000    50000.000000
0.000000  0.000000    -5000.000000
10000.000 7000.000    0.000000
200.00000 0.400000
-13.61813 -13.5166    -13.61075   -14.06067   -14.92
-13.14149 -12.7782    -12.56127   -12.46823   -12.45
-12.51657 -12.0349    -11.65146   -11.35929   -10.34
11.82019  -11.2963    -11.10930   -10.58582   -10.12
-10.41911 -9.91104    -9.447624   -9.043615   -8.691
-9.76106  -9.272736   -8.820832   -8.384072   -7.958
etc.
```

Where:

- The first six lines provide the following header information:
- The first line anomaly file code 333=2D mag file or 444=2D gravity file<cr>
- The second line calculation range <tab> # rows <tab> # cols <tab> # layers <cr> 3rd line inclination <tab> declination <tab> intensity <cr>
- The fourth line lower south west corner: X <tab> Y <tab>Z
- The fifth line upper north east corner: X <tab> Y <tab>Z
- The sixth line cube size of discretisation <tab> height of survey above land surface
- Then the following #rows lines are a set of #cols to a line magnetic or gravity anomaly values. Note that these values are floating point, and scaling and clipping is performed before an image is displayed within the program.

To import an image into another package, skip the first 6 lines or 16 numbers and a simple ASCII array of data results.

Geophysics Profile File

This file is created when Save Profile is selected from the File Menu and an interactively drawn geophysical profile has been generated from a grey scale image. The format is similar to the .MAG and .GRV formats for 2D data, with the exception that there are only ever one line of data.

The first six lines provide the following header information:

- 1st line anomaly file code 555=1D mag file or 666=1D gravity file
- 2nd line calculation range <tab> # cols <tab> # rows <tab> # layers
- 3rd line inclination <tab> declination <tab> intensity
- 4th line start of profile: X <tab> Y <tab>Z
- 5th line end of profile: X <tab> Y <tab>Z
- 6th line always 0.0 <tab> always 0.0
- The 7th line contains the data.

```
555
031511
-67.000000      0.000000    63000.000000
280.000000      60.000000   5080.000000
6560.000000     -40.0000    5080.000000
0.000000        0.000000
-1261.585
-1261.687
-1262.585
-1263.462...
```

Noddy Block Model Files

The Noddy Block Model consists of a variable number of files all coordinated by a header file, with suffix '.G00'. Depending on whether deformable anisotropy and/or remanence are defined, files with suffixes up to '.G12' may be created by the **Tools>Export Block>Noddy Block Model** menu item. The individual suffices .G00 to .G12 contain column-row-layer (top layer first) ordered information as follows:

File suffix	File Type
.G00	Header file for Noddy Block Format
.G01	Density values for each voxel
.G02	Susceptibility values for each voxel
.G03	Remanence declination for each voxel
.G04	Remanence inclination for each voxel
.G05	Remanence strength for each voxel
.G06	Magnetic anisotropy dip for each voxel
.G07	Magnetic anisotropy dip direction for each voxel
.G08	Magnetic anisotropy pitch for each voxel
.G09	Magnetic anisotropy strength of x-axis for each voxel
.G10	Magnetic anisotropy strength of y-axis for each voxel
.G11	Magnetic anisotropy strength of z-axis for each voxel
.G12	Look-up table index of rock type (LUT in header file)

Not all files are generated by any given calculation. For example, if deformable remanence is selected, files .G00, .G01, .G03, .G04 and.G05 are created. If neither deformable remanence or anisotropy is selected, .G00, .G01 and .G12 are the only files created.

Voxel models from other packages may be imported by converting the format to Vulcan, which is simple but excessively large, or by directly creating a Noddy Block Model file set (.G00 and .G12 files only are required). The format for the .G00 header file is as follows, and can be easily copied and edited.

```
VERSION = 7.10
FILE PREFIX = manual
DATE = 01/01/90
TIME = 12:00:00
UPPER SW CORNER (X Y Z) = 0.0 0.0 5000.0
LOWER NE CORNER (X Y Z) = 10500.0 7500.0 10500.0
NUMBER OF LAYERS = 11
LAYER 1 DIMENSIONS (X Y) = 21 15
LAYER 2 DIMENSIONS (X Y) = 21 15
LAYER 3 DIMENSIONS (X Y) = 21 15
LAYER 4 DIMENSIONS (X Y) = 21 15
LAYER 5 DIMENSIONS (X Y) = 21 15
LAYER 6 DIMENSIONS (X Y) = 21 15
LAYER 7 DIMENSIONS (X Y) = 21 15
LAYER 8 DIMENSIONS (X Y) = 21 15
LAYER 9 DIMENSIONS (X Y) = 21 15
LAYER 10 DIMENSIONS (X Y) = 21 15
LAYER 11 DIMENSIONS (X Y) = 21 15
NUMBER OF CUBE SIZES = 11
CUBE SIZE FOR LAYER 1 = 500
CUBE SIZE FOR LAYER 2 = 500
CUBE SIZE FOR LAYER 3 = 500
CUBE SIZE FOR LAYER 4 = 500
CUBE SIZE FOR LAYER 5 = 500
CUBE SIZE FOR LAYER 6 = 500
CUBE SIZE FOR LAYER 7 = 500
CUBE SIZE FOR LAYER 8 = 500
CUBE SIZE FOR LAYER 9 = 500
CUBE SIZE FOR LAYER 10 = 500
CUBE SIZE FOR LAYER 11 = 500
CALCULATION RANGE = 0
INCLINATION OF EARTH MAG FIELD = -67.00
INTENSITY OF EARTH MAG FIELD = 63000.00
DECLINATION OF VOL. WRT. MAG NORTH = 0.00
DENSITY CALCULATED = Yes
SUSCEPTIBILITY CALCULATED = Yes
REMANENCE CALCULATED = No
ANISOTROPY CALCULATED = No
INDEXED DATA FORMAT = Yes
NUM ROCK TYES = 7
ROCK DEFINITION = 1
Density = 4.000000
Sus = 0.001600
ROCK DEFINITION = 2
Density = 3.000000
Sus = 0.001500
ROCK DEFINITION = 3
Density = 2.800000
Sus = 0.001400
ROCK DEFINITION = 4
```

```
Density = 2.600000
Sus = 0.001300
ROCK DEFINITION = 5
Density = 2.400000
Sus = 0.001200
ROCK DEFINITION = 6
Density = 2.200000
Sus = 0.001100
ROCK DEFINITION = 7
Density = 2.000000
Sus = 0.001000
```

DXF Triangulation Files

An ASCII DXF file in two forms may be created containing triangulated surfaces of the same type as displayed in 3D Layer visualizations. Two types of definitions of three dimensional triangle objects are supported, as different CAD systems, such as MicroStation and Vulcan, are only read in one or other of the object types. The two types are 3D Faces, and Polylines. Each surface selected in the 3D Options window is saved as a triangulated surface, with continuous surfaces saved within single 'DXF Layers'. If, for example a stratigraphic horizon is broken by a fault plane, two distinct DXF layers are created.

The naming convention for **stratigraphic** layer names is as follows:

```
S02040005
```

Where:

- The initial S indicates that this is a stratigraphic surface.
- The next two characters (02 in this example) refer to the stratigraphy number, showing that this is the second stratigraphy defined in the deformation history.
- The next two characters (04) refer to the surface number within this stratigraphy.
- The last four characters (0005) are an internally generated code which uniquely identify which contiguous volume this layer sits in the model.

Faults, unconformities, plugs and dykes all cut a geological model into discontinuous volumes, and each distinct volume, across which other surfaces are discontinuous, are labelled internally by the software.

The naming convention for **discontinuity** layer names is as follows:

```
B003006009
```

Where:

- The initial B indicates that this is a discontinuity surface (Fault, unconformity, plug or dyke).
- The next three characters (003 in this example) indicate event numbers of the discontinuity causing deformation event.
- The next three characters (036) indicate the internally generated contiguous volume code of the volume on one side of the discontinuity.
- The final three characters (009) indicate the internally generated contiguous volume code of the other side of the discontinuity.

The reason for adopting such a complex scheme is that it allows related surfaces to be grouped in one of two ways:

1. Stratigraphic or discontinuity surfaces can all be selected by their age
2. Individual contiguous volumes may be selected by their volume code, so that all the surfaces surrounding a particular contiguous volume may be identified easily. This approach allows simple triangulated 3D volumes to be created.

Vulcan Triangulation Files

The files generated by Noddy are not Vulcan files, however they may be converted into Vulcan triangulations using the following procedure:

1. Create .VUL file by selecting **Tools>Export Block>Vulcan** and then selecting the 3D Layer menu item from the Geology menu. The latter selection creates a .HED header file. This file may also be used to convert to other vector formats, as it consists of 4 line sets of Layer Name; vertex 1; vertex 2; vertex 3 in ASCII format, and is much easier to convert than a DXF file.
2. Where a file has been created (for example on a PC version of Noddy), but Vulcan is operating on a Unix platform, such as a Silicon Graphics computer, run the Parse utility, which converts .VUL file into two types of files:
    i. for stratigraphic surfaces, the files are complete,
    ii. for discontinuity surfaces, a further processing stage is required.

The command **Parse < filename.hed** enables step (ii).

3. Since discontinuity surfaces are quite irregular, a smoothing step may be introduced by altering the SMOOTH.PRF file, which contains an integer that specifies how many smoothing steps are applied to these surfaces. A value of 0 outputs the surfaces as calculated.

   When executed, the ASCII file with a smooth suffix created by Parse performs this step for all discontinuity surfaces.

4. The final step is to convert these files into native Vulcan format using the ASCII file with a load suffix. When executed, this file uses the **triload** Vulcan routine to convert the files to binary format.

You should now have a set of files with naming conventions to read in directly by Vulcan as triangulations.

Rock Property Database File

This ASCII file, called ‘PROPERTY.ROX’, contains a set of predefined rock property values, which can be called up from within Noddy. This file is read into Noddy on startup, however pre-existing histories are not updated. The file consists of a two line header and then copies the rock property format from a normal history file. The units of magnetic susceptibility in this file are always c.g.s, and are automatically converted to S.I. units within the program if those units are selected.

An example of PROPERTY.ROX follows.

```
Version = 7.10
Number of Rocks = 2

Unit Name = Dolomite
Height    = 0
Density   = 2.70e+00
Anisotropic Field     = 0
MagSusX   = 8.00e-06
MagSusY   = 0.00e+00
MagSusZ   = 0.00e+00
MagSus Dip      = 0.00e+00
MagSus DipDir   = 0.00e+00
MagSus Pitch    = 0.00e+00
Remanent Magnetization      = 0
Inclination     =  0.00
Angle with the Magn. North  =  0.00
Strength  = 0.00e+00
Color Name      = Light Sky Blue
Red = 135
Green     = 206
Blue      = 250

Unit Name = Limestone
Height    = 0
Density   = 2.55e+00
Anisotropic Field     = 0
MagSusX   = 2.00e-05
MagSusY   = 0.00e+00
MagSusZ   = 0.00e+00
MagSus Dip      = 0.00e+00
MagSus DipDir   = 0.00e+00
MagSus Pitch    = 0.00e+00
Remanent Magnetization      = 0
Inclination     =  0.00
Angle with the Magn. North  =  0.00
Strength  = 0.00e+00
Color Name      = Deepskyblue
Red = 0
Green     = 191
Blue      = 255
```

Menus and Printing/Saving Images

13 Menus and Printing/Saving Images

Overview of Menus

This program is completely menu and icon driven. On starting the program you are presented with one small Toolbar which contains deformation event icons and a History window. Menus are found in the main menu bar at the top of the Noddy opening screen. Access to all aspects of the program is via these icons and menus, and each menu performs a calculation, display a visualization or create or load a file.

The following pages show the complete menu options, followed by a brief description of the item.

FILE MENU	**Handles all file input/output and hardcopy**
New History	Clear memory and set defaults
Read History…	Read from file previously defined sequence of events
Save History	Write to file currently defined sequence of events with current history file name
Save History As...	Write to file currently defined sequence of events with new history file name
Save As Defaults	Write currently defined options and sequence of events as defaults file
Load Reference Images	
-> **Geological**	Loads geological image file (not implemented)
-> **Gravity**	Loads .GRV gravity image file as reference data for image difference calculations
-> **Magnetics**	Loads .MAG magnetics image file as reference data for image difference calculations

-> ER Mapper	Import a reference raster image dataset derived from ER Mapper (combined .ERS header and BIL format data file)
-> Geosoft	Import a Geosoft .GXF grid dataset as a reference image
Movie	Control, create and load a series of BMP files to replay a movie (kinematic animation)
-> Create	Display sequential images showing evolution of geology or geophysics to current state, and simultaneously save these images to disk.
-> Load	Read a .NMV movie file to import a series of .BMP images and replay them under user control.
Read Picture (BMP)…	Reads an existing .BMP format file into a new window. This is useful in order to import sections, geological maps, and geophysical images for comparison with the model results.
Save Picture (BMP)…	Saves front window to file in .BMP format.
Save Orientations	Saves as tab delimited text file all orientation data plotted on current line map.
Save Profile	Saves as text file profiles of geophysical data interactively calculated from image window
Page Setup	Alter the printer specifications
Print Page	Prints front window to printer
Licence	Install licensing and security.
Quit/Exit	Exit from program

EDIT MENU	Handles editing of program and desk accessories
Undo	Single level of undo available for all changes to contents of history window.
Cut	Cutting removes the event(s) but places it in a temporary clipboard
Copy	Makes a copy of the event(s) and places it in the clipboard
Paste	Pastes the last event(s) copied to the clipboard by a Cut or Copy edit to the History window, so that the next click in the History window drops the copied event(s).
Clear	Clearing removes the event(s) without keeping a copy,
Duplicate	Makes a copy of the event(s) and immediately pastes it into the window, so that the next click in the History window drops the duplicated event(s).
Select All	Selects all icons in History window
Tidy Window	Tidy Window does not alter the actual history, it merely compacts the display within the History Window to remove any unfilled spaces between icons.
Project Options...	Options for scaling printing, on-line help etc
Block Options	Options for block dimensions and resolutions. Geological block dimensions and origins plus use of topography is controlled by this option.
Movie Options	Select defaults for speed of replay of movies and the number of frames required to define geological events.

Geology Display Options	Controls the size, orientation and viewing direction of geological block models. Also controls chair diagram presentations and background colour.
Section/Borehole Option	For both sections and boreholes, this option controls the location, direction, height and size/length.
Volume/Surface Options	Options to control the presentation of surfaces or voxels in blocks and which layers are to be presented. Default output formats can also be set.
Geophysics Calculation Options	Define the geophysical computation scheme and the controlling parameters for these. Gravity, magnetic or magnetic components selection is also available.
Geophysics Survey Options	Airborne or Surface geophysics survey specifications and the Earth's Magnetic Field Inclination and Intensity. Units of measurement (SI or cgs) are also defined.
Geophysics Display Options	Viewing options for geophysics visualizations. Control over scaling and the default grey scale, pseudocolour or contour displays is contained.
Window Options	Default window size and location settings for all window and display types (defined in pixels).

GEOLOGY MENU	**Handles plotting of geology**
Block Diagram	Plot discretised block diagram of geology, size of block defined by Plot options window.
Map	Plot map of geology, overlying topographic base if specified. This map may be in turn overlain by orientation data by selection symbol type and event type.
->Solid Colours	Submenu creates solid colour maps

->Lines	Submenu creates line maps with no fill
Topo Map	Plot contour map of topography if specified. This map may be overlain by orientation data by selection symbol type and event type.
Section	Plot vertical oriented section through geology.
->Solid Colours	Submenu creates solid colour sections
->Lines	Submenu creates line sections with no fill
Stratigraphic Column	View all currently defined stratigraphic sequences
Borehole	Controls the creation and display of boreholes.
->Generate	
->3D	3D view of geology along internally generated borehole
->Schematic	Schematic view of geology along internally generated borehole
->Import	
->3D	3D view of geology along imported borehole
->Schematic	Schematic view of geology along imported borehole
3D Topo	3D visualization of geology draped over topography.
3D Triangulation	3D triangulation of stratigraphic layers/ discontinuities
Plot Orientations	Display orientation information on equal area stereo net.

GEOPHYSICS MENU	**Handles plotting and calculation of geophysical anomalies.**
Calculate Anomalies	Calculate gravity and magnetic anomalies according to currently defined geology and calculation options defined in Geophysics Options window.
-> Anomalies	Submenu for geophysical calculations from current history
-> Block and Anomalies	Submenu for geophysical calculations from current history together with block model of geology
-> Anomalies From Block	Submenu for geophysical calculations from previously saved geology block model
->Borehole	
->Generated	Calculate downhole geophysical response along internally generated borehole
->Imported	Calculate downhole geophysical response along imported borehole
XYZ Point Data	Calculate gravity and magnetic anomalies long one or more lines
->Import From File	Submenu for geophysical calculations from imported XYZ line data
->Generate Line	Submenu for geophysical calculations from internally generated XYZ line data
->Gravity	Calculate 1st vertical derivative from gravity image file

->Magnetics	Calculate 1st vertical derivative from magnetics image file
Vertical Derivatives	
->First	
->Gravity	Calculate 1st vertical derivative from gravity image file
->Magnetics	Calculate 1st vertical derivative from magnetics image file
->Second	
->Gravity	Calculate 2nd vertical derivative from gravity image file
->Magnetics	Calculate 2nd vertical derivative from magnetics image file
Difference with Reference	
->Gravity	Calculate the difference between loaded reference gravity image and previously calculated .GRV format gravity file
->Magnetics	Calculate the difference between loaded reference magnetics image and previously calculated .mag format magnetics file
Display Image	Display previously calculated gravity or magnetics image. The image is automatically linearly scaled to fit the calculated range of the data. It may be clipped if required.
->Gravity	Submenu for gravity files
->Magnetics	Submenu for magnetics files

->X,Y,Z Components	Submenu for magnetics component file
->ER Mapper	Load an ER Mapper .ERS image file and display it.
->Geosoft	Load an Geosoft .GXF grid file and display it.
Display Profile	Display previously calculated gravity or magnetics profile. The profile is automatically linearly scaled to fit the calculated range of the data.
->Gravity	Submenu for gravity files
->Magnetics	Submenu for magnetics files

TOOLS MENU	**Handles file conversion utilities**
Import Block	Converts voxel formats into Noddy block format
-> DXF	Read in and convert a .DXF file format into a Noddy block format.
->Dicer	Converts raw voxel model format into Noddy block format (not yet implemented)
->Vulcan	Converts Vulcan regularized block model format into Noddy block format
->Old Noddy Block	Converts Version 3 Noddy block format into Noddy block format
Import Image	Import images of various formats for display.
->ASCII	Converts ASCII Tab delimited data to Noddy .MAG or .GRV formats
->Column	Column definable files to Noddy .MAG or .GRV formats
Export Block	Export Noddy voxel block files in various formats

->Noddy Block Model	Standard G00 voxel block model
->Tabulated Columns	ASCII column delimited block voxel model
->DXF-3D Faces	Triangulated .DXF surfaces of block models
->DXF-Polylines	Outline triangulated .DXF surfaces
->Vulcan	.VUL standard Vulcan voxel block models
Export Image	Create output geophysical response images.
->ERMapper	Converts geophysics file to ER Mapper formats
->Gravity	Submenu for gravity files (.MAG to .ERS)
->Magnetics	Submenu for magnetics files (.GRV to .ERS)
->Line Map	Submenu to create line map of current geology in ERMapper vector format (Line Map to .ERV)
-> Geosoft	Converts geophysics file to Geosoft formats
->Gravity	Submenu for gravity files (.MAG to .GXF)
->Magnetics	Submenu for magnetics files (.GRV to .GXF)
Edit Rock Properties	Edit global rock properties database

WINDOWS MENU	**Handles positioning and selection of visualization windows**
Cascade	Tidy up window positions to form a single cascading
Tile	Tidy up window positions to fill available screen space
Default Size	Zoom window to default size
Remove All	Close all windows

History Menu etc.	List of all windows that belong to Noddy, which may be selected and brought to front by these menu items.

HELP MENU	**Provides access to help files.**
Contents	Access to on-line help
About	Licensing and copyright information.

Printing Windows

In order to send the contents of a window to a printer or plotter, select the relevant printer as a normal Windows® operation. Under Windows®95 and Windows NT®, print drivers (usually supplied by the printer manufacturer) need to be loaded. Refer to the printer's *Reference and Installation Manual* for additional information.

Select **File>Page Setup** to configure the page dimensions etc, and select Print Page from the File menu to send the contents of the window to the printer. Note that using standard Windows® printer configuration settings output can be saved to a print file if desired.

Specific scaling of the created print is not available. Size of the output print however can be controlled by the Printer Scaling option in **Edit>Project Options**.

Saving Windows to a File

To save the contents of a window to a screen resolution file, select Save Picture from the File menu. This saves the contents of the window to a .BMP raster picture format.

Overview of Calculations

Spectral Domain Potential Field Calculations

Spatial Domain Potential Field Calculations

Test of Spatial and Spectral Noddy Solutions

Displacement Equations used in Noddy Faults

Faults

Unconformities

Folds

Shear Zones

Dykes

Penetrative Foliations and Lineations

14 Overview of Calculations

Spectral Domain Potential Field Calculations

Code for computing magnetic and gravity fields is present in two distinct forms, spatial and spectral, each with its own advantages and drawbacks. In a spatial approach, one attempts to sum the effects, at each measurement point, of all the sources below. Now, as the output points comprise an image, and the rocks themselves are distributed in space, the required calculation is a five-fold one, beyond easy reach of present computing power. Noddy spatial code evades this limitation by taking account of just the sources nearest each output location. (This is done by means of the notorious ‘range’ parameter.) There are some curious consequences. For example, a field geologist would note the effect on a port- able magnetometer of a strongly magnetized dyke long before tripping over it, but there is no such indication in the Noddy results.

Use of the fast Fourier transform permits a simplification whereby a few point-wise multiplications replace the many sums and products required for the direct, spatial approach. While renovating the practice of forward geophysical modelling, as noted below this method entails some paradoxes of its own. The gravitational case is simplest to describe, while the magnetic one differs from it only in detail. To find the gravitational response for a given Noddy model, we imagine the block divided into horizontal layers, each layer comprising all the voxels at a particular depth. The individual layers can be considered as images of rock density distribution. The steps involved in computing the response of the entire block-model, as it would be measured on a horizontal plane above the sources, are then as follows:

1. Compute the Fourier transform, F say, of each density image (one per layer).
2. Multiply F pointwise by a real exponential factor to take account of the depth of the cur- rent layer below the plane of measurement.
3. Add the results for all layers.
4. Multiply the sum by a second factor, then perform inverse Fourier transformation. By varying the choice of second factor, we can obtain in this way images of the field components for each of the x, y and z directions.

These three images constitute the vectorial gravitational field, and may be used to derive further images, such as those for the magnitude of the field or its component in a specified direction. However, while such options may be useful future improvements, in its current release the program has been limited to returning just the vertical component of gravity. This, of course, is the main component of the terrestrial gravity field, though not necessarily of its anomalous (non-regional) part. In anticipation of possible further developments it may be noted that the spectral approach has here a peculiar limitation: it assigns mean values of zero to both horizontal field components. The true common mean value, if taken over the entire horizontal plane of measurement, is indeed zero (the force reverses direction, along a traverse across a massive body, being always towards the attractor). But there is sure to be disagreement, propagated also to the field-magnitude calculation, with results of the corresponding spatial calculations. For the vertical component of the gravitational field the same problem does not arise, the attraction being ‘downward’ everywhere.

Little need be added regarding the magnetic field calculations. Only the total field is returned, although it seems desirable to widen this choice, at least to include the component of field in the direction of the earth's field, and possibly all three directional components (presently computed but suppressed). Because Noddy is fully voxel-based, it is untroubled by the effects of deformation upon directions of remanence, each voxel's individual imprint being fully respected.

Two other effects complicate routine application of the Fourier method. The root of both problems is the periodicity of the functions used as the elements in Fourier representations. Give the Fourier program a rectangular brick and behaves as if dealing instead with a regular paving, by identical bricks, of the entire continent.

Taken separately, the two effects are:

1. Jump discontinuities in (for example) density between abutting bricks, i.e., between opposite faces of a single brick;
2. Unsolicited contributions to (say) the gravitational field of one brick from all the others.

Effect (a) is serious because, to model the wholly fictitious discontinuity, the Fourier representation must incorporate high-frequency terms with large amplitudes. Such terms respond unfavourably to the subsequent frequency-domain manipulations and produce at last images marred by unacceptable ‘ringing’ phenomena. One way to minimize the problem is to present the Fourier program with a composite brick, one made from four ordinary bricks arranged four-square such that the density distributions are mirrored symmetrically in the planes of contact. There is no density contrast between opposite ends in such a superbrick. This type of compensation is incorporated within the present release.

Effect (b) requires a little further discussion to avoid possible confusion when spatial and spectral results are compared. Its undesirability may seem self-evident. However, Noddy is intended to represent real-world lithology. In the absence of data external to the model, is the infinite replication imposed by the spectral approach any less realistic, as a surrogate for the unknown material, than suspension of the block in a vacuum, as is done in spatial modelling?

Certain models can nevertheless defeat superbricks derived by reflection. The type of discrepancy to be expected is illustrated by a two-layer model with sinusoidal folding (perhaps the result of east-west compression). Suppose that three crests and two troughs of the deeper, denser material fall symmetrically within the limits of the block. The spatial code generates a gravity field with three equal highs, situated directly over the denser crests. This pattern is incorrect because, for example, the two outsiders should actually be lower, in consequence of the infinite void beyond. In the spectral approach, on the contrary, they are actually much higher.

The paradox is resolved by visualizing the superbrick. The mirroring process puts two crests together, with no intervening trough, so the outside ones gain double strength. This, of course, indicates a failure of technique for dealing with the replication problem. Although we can never wholly eliminate the host of imaginary companions, in the present example we could lessen their effect by spacing them farther apart. That might be done by creating a new type of superbrick wherein, before Fourier transformation, the original one is effectively packaged, not with three reflections of itself, but with three fibreglass replicates. In the infinite tessellation by identical companions, the ‘genuine’ (that is, denser) companion bricks would at least have their influence attenuated by distance.

To provide for cases where the Fourier interpretation of a problem differs so markedly from the real problem as to preclude realistic solution, we have supplied a variety of such alternative remedies. Unfortunately, the need to choose between them means a further sacrifice of simplicity. Whenever the output from the spectral method seems odd, users should try to imagine the configuration of all the replicates, especially the ones immediately adjacent to the actual block. Their influence upon the field is just the same as if they were actually present and visible.

Spatial Domain Potential-Field Calculations

A general-purpose subroutine was written to compute the magnetic and gravity anomalies due to any arbitrary 2-D or 3-D structure that has been discretised onto a regular grid. That is, represented by small, equal-sized blocks of homogeneous physical properties.

The general approach consists of calculating the effects of each individual element and adding its contribution to the anomaly at the plane of observation. The basic element was defined to be a cube of material with homogeneous geophysical properties throughout, and of size equal to the selected grid size.

An alternative approach would have involved dividing the structure into a series of polyhedra and computing the combined anomaly by surface integration over each. This method was, however, not considered to be suitable because of the complexity of the associated numerical algorithms.

The starting point of the calculations is the evaluation of the geometric coefficients, which is the same for all elements at a particular level of observation. This was done by using the analytic solutions to the magnetic and gravity anomalies of dipping prisms developed by Sven-Eric Hjelt (1972,1974), which were simplified to the case of cubes. The numeric algorithms derived from these solutions are well established, and have been successfully implemented in numerous other modelling programs (for example, MAGMOD - Geosoft and ModelVision Pro - Encom). The values of the gravity and induced magnetic field strength are obtained by multiplying the coefficients with the respective susceptibility and density values of the element under consideration.

The initial approach was to add up the contribution of each element at every point on the grid. However, it became apparent that this introduced edge effects in the anomaly pattern that could not be compensated for. This is due to the fact that we are no longer dealing with isolated, homogeneous bodies immersed in an infinite half-space (as is commonly assumed in many modelling programs). If the model is treated as such, the resulting anomaly pattern highlights the differences between the continuum and the model as a whole, rather than the internal structure of the model itself. Ideally, in order to eliminate effects of the continuum, the model must be very large compared to the actual region of interest. This is very demanding in terms of computer time, as a large number of elements beyond the region-of-interest boundaries have to be included in the calculations to adequately compensate for edge effects.

A simple solution to this problem was found by reducing the area over which the contributions of each point were added to the anomaly (see *Figure 1*). This can be justified by the fact that the coefficients diminish rapidly in magnitude as the distance from the element increases. Thus, an area of the original area - calculation range around the boundaries is completely free of edge effects (see *Figure 2*). However, the overall magnitude of the anomaly is also diminished, depending on the calculation range, because smaller contributions from distant elements are ignored entirely.

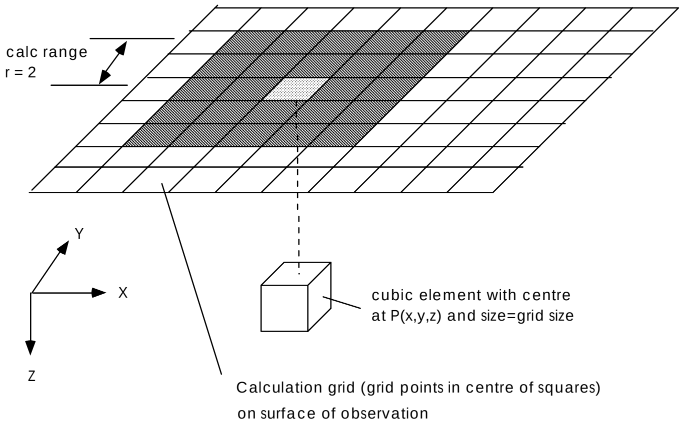


Figure 1 Method of Calculation. The shaded part is the coefficient matrix, superimposed onto the master grid covering the entire region of interest of the model. r is the calculation range (in cubes)

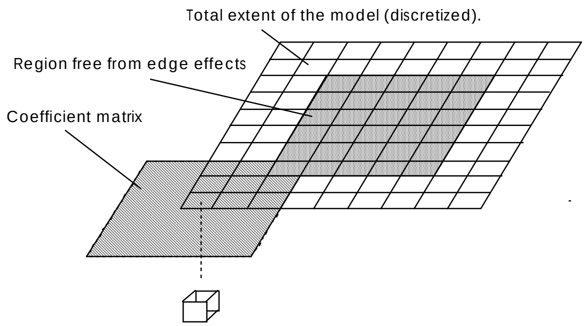


Figure 2 How the size of the coefficient matrix (calculation range=2 grid units in this example) affects the size of the distortion-free region.

The process of calculation can be summed up as follows:

1. **For a single layer**, the geometric coefficients of a single cubic element are computed, over a given calculation range, at the level of observation.
2. The individual contributions are summed up by centring the coefficient matrix over each element (that is, on its grid coordinates), multiplying the coefficients by the appropriate susceptibility and density values and mapping (adding) the result to the anomaly (which is stored in a matrix of grid values).
3. Steps 1 and 2 are repeated for the remaining layers until a specified depth has been reached. Calculation is from top to bottom.

Advantages of the method

- Fast, efficient calculation of the anomaly (no integrals require solving)
- Edge effects are completely eliminated over a reduced area of calculation edge. Effects are present in a region extending to 1 calculation range inwards from the edge of the grid
- Calculation time is independent of the complexity of the model, or the number of different rock types present
- The accuracy can be adjusted by selecting different cube sizes and calculation ranges

Disadvantages

- Reducing the range of calculation reduces the effective magnitude of the anomaly (diminished amplitude as compared to real anomalies).
- Using a square area of calculation rather than a spherical one introduces subtle effects of its own. The effects are visible only for coarse grids and small calculation ranges
- Slightly different weights are placed upon elements at different depth levels, as the lateral variation of the coefficients decreases with depth (which results in the broadening of the anomaly pattern). Therefore, deep bodies contribute less to the anomaly pattern than those closer to the surface of observation. This effect is mainly offset by the larger source distance.
- Very large objects (larger than the calculation range) have their contribution more severely diminished than small ones, as the calculation range cannot cover the whole body. The result is a complete flattening of the calculated profiles around the centre of the body. This is easily recognized, however.

Careful attention should be paid to the model at hand before deciding upon the calculation range and grid size. If ample computer time is available, the largest practicable range and smallest grid size should be favoured, especially, if quick preliminary runs do not yield good results.

Layer-by-layer calculation has the advantage, that the coefficients of previous layers can be discarded, thus saving on memory. Also, the speed of calculation is directly proportional to the depth extent, which is variable.

Test of Spatial and Spectral Noddy Solutions

1. Buried Sphere
Noddy Spatial Versus ModelVision and Analytical Solution

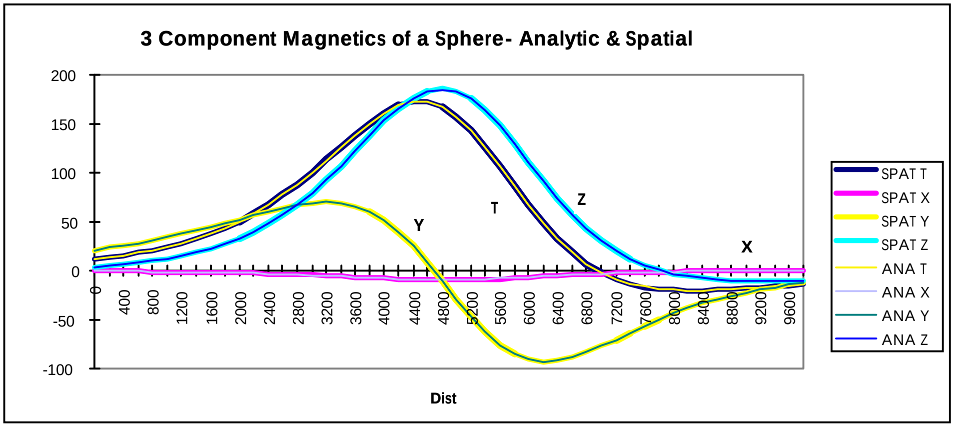
In this test is a comparison of the magnetic response of a sphere using Noddy and the analytical solution provided in Emerson et al. 1985, and the gravity response of a sphere using Noddy and ModelVision.

Model	sphere.his
Radius	1000 m
Depth to top of sphere	2000 m
Density of sphere	4.74
Density of Background	0
Magnetic Susceptibility of Sphere	$9.49x10^{-3}$ cgs
Magnetic Susceptibility of Background	0
Earth's Field Declination	0
Earth's Field Inclination	-67
Earth's Field Intensity	63,000
Remanence and Anisotropy	none
Cube size of Noddy Calculation	200 m
Calculation Scheme	Full Spatial

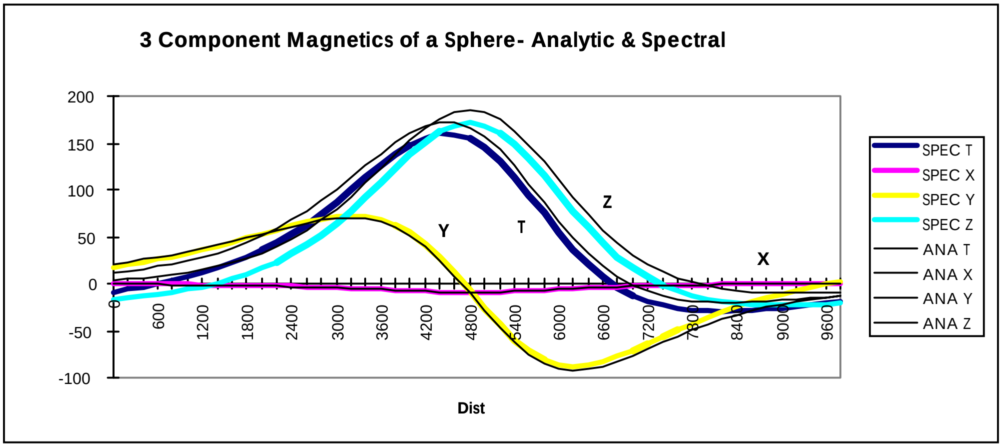
Note

The Noddy model produces a sphere whose actual volume is $4.42x10^9$ m^3 whereas the volume of a true sphere with a radius of 1000m is $4.19x10^9$ m^3. In order to compensate for this ~5% difference in modelled spheres we have increased the ModelVision sphere's rock properties by 5%, to a susceptibility of 10^{-2} and a density of 5 gm/cc.

The Noddy calculation was carried out using both the Full Spatial and Spectral options. Once we do this we can make a direct comparison between the models, for example along a NS axis the TMI and Gravity responses compare as shown in the graphs and table below. The two packages produce results within 0.1% of each other for both gravity and magnetics. The profile line used was one 100m to the west of the centre of the sphere, so the X component of the magnetics is non-zero.



Comparative model between analytic and spatial approaches.



3 Component magnetic comparison using analytic and spectral methods.

DIST	SPAT T	SPAT X	SPAT Y	SPAT Z	SPEC T	SPEC X	SPEC Y	SPEC Z	ANA T	ANA X	ANA Y	ANA Z
0	11.928185	-0.518866	21.483896	3.838931	-8.508938	-0.467457	16.954069	-16.440359	11.86241	-0.575229	21.459277	3.809959
200	13.728405	-0.591159	23.529456	4.92633	-5.978604	-0.529598	19.842205	-14.917444	13.656918	-0.652847	23.503691	4.894197
400	15.821924	-0.675191	25.785391	6.243058	-3.208822	-0.604008	22.833337	-13.178123	15.744233	-0.74276	25.758536	6.207389
600	18.258171	-0.77303	28.267921	7.835928	-0.147722	-0.695078	25.958269	-11.179119	18.173773	-0.847085	28.240077	7.796314
800	21.09417	-0.887104	30.991399	9.760797	3.264743	-0.802224	29.244241	-8.866764	21.002568	-0.968298	30.962722	9.716791
1000	24.395113	-1.020247	33.966608	12.08391	7.096627	-0.930887	32.712773	-6.176259	24.295838	-1.10927	33.937327	12.03504
1200	28.234618	-1.175736	37.198361	14.883198	11.424831	-1.081233	36.378446	-3.030254	28.12726	-1.273311	37.168798	14.828972
1400	32.694422	-1.357328	40.682215	18.249344	16.333974	-1.259982	40.244717	0.661711	32.578677	-1.464187	40.652803	18.18927
1600	37.863154	-1.56926	44.400066	22.286315	21.915876	-1.467992	44.300905	5.003921	37.738888	-1.686119	44.371372	22.219925
1800	43.833695	-1.816216	48.314422	27.110928	28.265767	-1.713378	48.515205	10.113328	43.701018	-1.943737	48.287167	27.037818
2000	50.698467	-2.103224	52.3612	32.850789	35.478951	-1.997324	52.829751	16.118033	50.557831	-2.241954	52.336269	32.770662
2200	58.541832	-2.435456	56.441053	39.639715	43.641991	-2.329127	57.149849	23.152266	58.394145	-2.585754	56.419497	39.55245
2400	67.428679	-2.817879	60.409533	47.609513	52.823608	-2.709161	61.337052	31.349453	67.275422	-2.979815	60.392545	47.515228
2600	77.388281	-3.254724	64.066923	56.87676	63.055676	-3.146813	65.194362	40.827841	77.231616	-3.427949	64.055788	56.77587
2800	88.392827	-3.748707	67.14936	67.523246	74.314553	-3.63887	68.462369	51.671858	88.235676	-3.932304	67.145371	67.416508
3000	100.330805	-4.299987	69.323931	79.569142	86.488584	-4.192255	70.806665	63.902154	100.176858	-4.492296	69.328274	79.457641
3200	112.976912	-4.904855	70.191675	92.939037	99.35495	-4.794974	71.833289	77.443896	112.83054	-5.103297	70.205318	92.824095
3400	125.962459	-5.554261	69.30344	107.423056	112.539755	-5.447894	71.087911	92.083747	125.82852	-5.755187	69.327075	107.306062
3600	138.753334	-6.232366	66.193807	122.638518	125.514481	-6.1223	68.120653	107.438509	138.63692	-6.430968	66.227928	122.520709
3800	150.645653	-6.915477	60.436705	138.001608	137.560328	-6.812038	62.485396	122.916675	150.551891	-7.105846	60.481892	137.883934
4000	160.791048	-7.571873	51.722035	152.722325	147.845896	-7.457837	53.962115	137.708434	160.725131	-7.747237	51.779409	152.605616
4200	168.261884	-8.163034	39.945153	165.837338	155.585596	-8.022239	42.380738	151.032549	168.22942	-8.316258	40.016788	165.722965
4400	172.159518	-8.64672	25.291552	176.29166	159.609807	-8.603602	27.745096	161.61676	172.167029	-8.771035	25.380398	176.182635
4600	171.7555	-8.981906	8.290951	183.069081	159.251902	-8.845146	10.925171	168.367586	171.810534	-9.071768	8.399902	182.971101
4800	166.639089	-9.13495	-10.186333	185.35396	154.332456	-9.035721	-7.373675	170.790697	166.749323	-9.186849	-10.056135	185.275564
5000	156.83182	-9.085701	-29.007551	182.688868	144.595804	-8.947976	-26.05752	168.144005	157.003038	-9.098691	-28.858449	182.640152
5200	142.829922	-8.831856	-46.925108	175.083315	130.79024	-8.718348	-43.723843	160.645093	143.063528	-8.807662	-46.763709	175.073427
5400	125.552649	-8.390132	-62.762676	163.036621	113.646938	-8.290254	-59.436997	148.691122	125.84383	-8.332826	-62.59912	163.07101
5600	106.204141	-7.79374	-75.591974	147.462883	94.441519	-7.704684	-72.009593	133.163859	106.541619	-7.709086	-75.437826	147.541454
5800	86.085136	-7.086819	-84.853701	129.537763	74.548144	-7.065975	-81.104265	115.412936	86.452807	-6.981496	-84.719266	129.65475
6000	66.405196	-6.317449	-90.395958	110.510805	54.870737	-6.197286	-86.499275	96.326216	66.78512	-6.198308	-90.288115	110.656388
6200	48.14016	-5.531062	-92.431896	91.532596	36.76657	-5.476398	-88.180813	77.372327	48.515715	-5.404533	-92.353254	91.695457
6400	31.958327	-4.765642	-91.441764	73.533007	20.80218	-4.707805	-86.924451	59.495942	32.316426	-4.63733	-91.391214	73.702681
6600	18.214381	-4.049267	-88.054102	57.16415	7.206282	-4.005299	-83.272719	43.17582	18.546286	-3.92372	-88.028137	57.332422
6800	6.99285	-3.399795	-82.936255	42.801124	-3.845664	-3.359339	-77.844971	28.865474	7.293856	-3.280424	-82.930351	42.962396
7000	-1.823001	-2.826046	-76.712259	30.582001	-12.486703	-2.796502	-71.285153	16.693707	-1.554458	-2.715171	-76.721874	30.732974
7200	-8.477917	-2.329762	-69.913363	20.466403	-18.946505	-2.305935	-64.113602	6.631885	-8.241259	-2.228746	-69.934477	20.605496
7400	-13.280807	-1.907738	-62.957505	12.296144	-23.537236	-1.89467	-56.75391	-1.479312	-13.074157	-1.817161	-62.98681	12.422923
7600	-16.556564	-1.553731	-56.149783	5.847784	-26.578736	-1.54847	-49.50653	-7.859811	-16.377368	-1.473584	-56.184675	5.962504
7800	-18.614229	-1.259979	-49.695444	0.872712	-28.381087	-1.26655	-42.576732	-12.759342	-18.459669	-1.189841	-49.733925	0.976014
8000	-19.729068	-1.018285	-43.718458	-2.875486	-29.215673	-1.034916	-36.082637	-16.422585	-19.596314	-0.957472	-43.759018	-2.782778
8200	-20.134949	-0.82072	-38.280921	-5.624518	-29.313723	-0.850901	-30.082352	-19.076075	-20.021308	-0.768406	-38.322427	-5.541511
8400	-20.02353	-0.660023	-33.400603	-7.57505	-28.860954	-0.702792	-24.587142	-20.916784	-19.926518	-0.615323	-33.442215	-7.500847
8600	-19.54739	-0.52979	-29.06545	-8.897954	-28.004665	-0.588528	-19.580037	-22.111936	-19.464763	-0.491824	-29.106548	-8.831689
8800	-18.825063	-0.424521	-25.244796	-9.735019	-26.85641	-0.499055	-15.023963	-22.798457	-18.75483	-0.392448	-25.284935	-9.675879
9000	-17.946666	-0.339581	-21.897611	-10.20156	-25.49945	-0.433536	-10.8718	-23.086798	-17.887072	-0.312625	-21.936475	-10.148791
9200	-16.97931	-0.271123	-18.978254	-10.389856	-23.992174	-0.385179	-7.070087	-23.063086	-16.928826	-0.248583	-19.015631	-10.342769
9400	-15.97194	-0.215987	-16.440321	-10.372778	-22.37385	-0.354311	-3.564245	-22.793143	-15.92924	-0.197237	-16.476077	-10.330745
9600	-14.959431	-0.171593	-14.239048	-10.207214	-20.667417	-0.335883	-0.299808	-22.325014	-14.923374	-0.156084	-14.273111	-10.16967
9800	-13.965946	-0.135852	-12.332716	-9.937122	-18.883476	-0.331186	2.775229	-21.692287	-13.935551	-0.123106	-12.365059	-9.903561

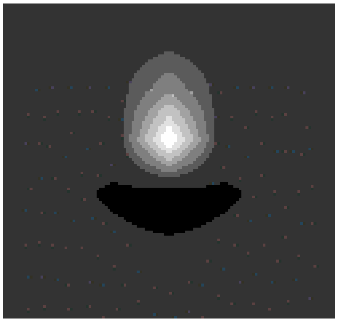
2. Single cube: Noddy vs Mag3D

In this test are compared the magnetic response of a single cube as modelled by Noddy and Mag3D.

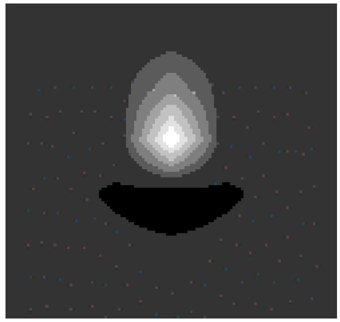
Model	**CUBE.HIS**
Dimension of sides of cube	200 m
Depth to top of cube	80 m
Density of cube	4.0
Density of Background	0
Magnetic Susceptibility of cube	10^{-2} cgs
Magnetic Susceptibility of Background	0
Earth's Field Declination	0
Earth's Field Inclination	-67
Earth's Field Intensity	63,000
Remanence and Anisotropy	None
Cube size of Noddy Calculation	200 m
Calculation Scheme	Spatial Convolution and Full Spatial

Note

Since the two modelling schemes use the same geometry to define the model, no corrections had to be applied. A representative sub-area with dimensions of 2200 m square is shown for comparison in the table, whereas the full 4000 m square is shown in the images. The two schemes produce results within 0.05% of each other.



Noddy



Mag3D

Noddy	TMI									
-15.0	-16.5	-16.2	-13.6	-9.7	-7.7	-9.7	-13.6	-16.2	-16.5	-15.0
-21.9	-25.4	-25.6	-18.5	-4.9	2.9	-4.9	-18.5	-25.6	-25.4	-21.8
-31.9	-40.9	-44.4	-25.5	30.9	72.2	30.9	-25.5	-44.4	-40.9	-32.0
-45.5	-66.1	-85.4	-45.3	240.5	574.1	240.5	-45.3	-85.4	-66.1	-45.5
-60.2	-99.9	-165.9	-170.4	1267.5	5997.1	1267.5	-170.4	-165.9	-99.9	-60.2
-70.3	-127.5	-257.6	-548.2	478.0	16755.5	478.0	-548.2	-257.6	-127.5	-70.3
-70.6	-128.9	-266.7	-645.3	-1731.4	-2993.9	-1731.4	-645.3	-266.7	-128.9	-70.6
-61.5	-105.5	-195.1	-383.0	-715.4	-948.3	-715.4	-383.0	-195.1	-105.5	-61.5
-48.3	-75.3	-120.5	-190.1	-272.4	-313.8	-272.4	-190.1	-120.5	-75.3	-48.3
-35.6	-50.7	-71.6	-97.3	-121.1	-131.2	-121.1	-97.3	-71.6	-50.7	-35.6
-25.6	-33.7	-43.5	-53.7	-61.9	-65.1	-61.9	-53.7	-43.4	-33.7	-25.6

Mag3D	TMI									
-15.0	-16.5	-16.3	-13.6	-9.7	-7.7	-9.7	-13.6	-16.3	-16.5	-15.0
-21.9	-25.5	-25.6	-18.5	-4.9	2.9	-4.9	-18.5	-25.6	-25.5	-21.9
-32.0	-40.9	-44.5	-25.5	31.0	72.3	31.0	-25.5	-44.5	-40.9	-32.0

-45.5	-66.2	-85.5	-45.3	240.8	574.7	240.8	-45.3	-85.5	-66.2	-45.5
-60.2	-100.0	-166.0	-170.5	1268.7	6002.9	1268.7	-170.5	-166.0	-100.0	-60.2
-70.4	-127.6	-257.9	-548.7	478.5	16771.9	478.5	-548.7	-257.9	-127.6	-70.4
-70.7	-129.1	-267.0	-645.9	-1733.1	-2996.8	-1733.1	-645.9	-267.0	-129.1	-70.7
-61.6	-105.6	-195.3	-383.4	-716.1	-949.2	-716.1	-383.4	-195.3	-105.6	-61.6
-48.3	-75.4	-120.6	-190.3	-272.6	-314.1	-272.6	-190.3	-120.6	-75.4	-48.3
-35.7	-50.7	-71.7	-97.4	-121.2	-131.4	-121.2	-97.4	-71.7	-50.7	-35.7
-25.6	-33.7	-43.5	-53.7	-62.0	-65.2	-62.0	-53.7	-43.5	-33.7	-25.6

Displacement Equations Used in Noddy

In order to simplify the formulation of the displacement equations used in this system we perform a transformation between the global (real world) reference frame and a local reference frame, which is used only for the displacement equations. This transformation consists of a translation followed by a rotation prior to the enactment of each displacement equation, followed by the inverse rotation and translation after it. In the following sections the displacement equations are given for the local reference frame, and only in the Lagrangian form. In most cases the Eulerian form of the equations may be easily derived from the Lagrangian form, however for curved and elliptical faults a Newton-Raphson iterative algorithm is used to calculate the Eulerian displacements.

Faults

Five different fault geometries are currently supported. These range from simple planar faults with uniform translation or rotation of one block relative to the other; to arbitrarily curved surfaces defined by a profile, where the translation vector is a function of position relative to the surface. These die off to zero outside the area of influence of the fault. In each case, the equations show the example of hanging wall only slip.

Translation Faults

In the local reference frame, the fault plane is the YZ plane, with slip in Y direction.

The kinematics are defined by:

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \begin{pmatrix} X \\ Y + s \\ Z \end{pmatrix} \textit{for} \quad X > 0$$

where s is the slip vector.

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \begin{pmatrix} X \\ Y \\ Z \end{pmatrix} \textit{for} \quad X \leq 0$$

Rotational Faults

In the local reference frame, the fault plane is the YZ plane, and the X axis is the rotation axis.

The kinematics are defined by:

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \end{pmatrix} \quad for \quad X > 0$$

where q is the rotation angle.

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \begin{pmatrix} X \\ Y \\ Z \end{pmatrix} \quad for \quad X \leq 0$$

Ring Faults

In the local reference frame, the tangent to the fault plane and the slip vector are always parallel to the Y axis.

The kinematics are defined by:

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \begin{pmatrix} X \\ Y + s \\ Z \end{pmatrix} \quad for \quad X^2 + Z^2 > R^2$$

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \begin{pmatrix} X \\ Y \\ Z \end{pmatrix} \quad for \quad X^2 + Z^2 \leq R^2$$

where s is the slip vector and R is the radius of the ring fault.

Elliptical Faults

The displacement equations for elliptical faults, where slip decays away from the centroid of the fault, are based on the empirical equations developed in Walsh and Watterson (1987). In the local reference frame, the fault plane is the YZ plane, with slip in Y direction.

The kinematics are defined by:
$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \begin{pmatrix} X \\ Y+s.p \\ Z \end{pmatrix} \text{for} \quad X>0$$
$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \begin{pmatrix} X \\ Y \\ Z \end{pmatrix} \text{for} \quad X\leq 0$$

where s is the maximum slip, and p is a function of position within the ellipsoid of deformed rock defined by:

$$d = \left(1 - X/_{Ex}\right)^2 + \left(1 - Y/_{Ey}\right)^2 + \left(1 - Z/_{Ez}\right)^2$$

where *Ex, Ey and Ez* are the principal axes of the ellipsoid

Curved Faults

The displacement equations for curved faults are similar to those used for elliptical faults. In these cases, slip decays away from the centroid of the fault, except when combined with curved fault surfaces. They require a term for the displacement of points perpendicular to the fault surface (parallel to local X), so that all points maintain a constant distance from the fault.

The kinematics are defined by:

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \begin{pmatrix} X+d \\ Y+s.p \\ Z \end{pmatrix} \text{for} \quad X>0$$
$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \begin{pmatrix} X \\ Y \\ Z \end{pmatrix} \text{for} \quad X\leq 0$$

where s is the maximum slip, d is the difference between a point and the fault surface before and after deformation, and p is a function of position within the ellipsoid of deformed rock defined by:

$$d = \left(1 - X/_{Ex}\right)^2 + \left(1 - Y/_{Ey}\right)^2 + \left(1 - Z/_{Ez}\right)^2$$

where *Ex, Ey and Ez* are the principal axes of the ellipsoid that encloses the faulted volume.

Unconformities

Unconformities do not imply any displacement, as they merely define a planar discontinuity.

Folds

A similar fold model currently supported is probably the weakest representation of its true counterpart, and does not allow upper crustal, flexural slip geometries.

The kinematics are defined by:

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \begin{pmatrix} X \\ Y \\ a.e^{\left(\frac{-Y^2}{c}\right)}.f(w.Z) \end{pmatrix}$$

where $f()$ is either a simple sinusoid function or a Fourier series, which allows arbitrary fold profiles to be generated, w is the fold wavelength, a is the fold amplitude, and c is a parameter that controls fold cylindricity.

Shear Zones

Shear zone kinematics are the same as those for faults, except that the slip is distributed continuously within a parallel sided shear zone, rather being concentrated on a discrete fault plane.

Dykes

Dykes are infinite parallel sided bodies which can either be stope-like, with the country rock replaced by dyke material, or dilatational, which implies the creation of a void space to be filled by the dyke material.

Dilatational Dyke

The kinematics are defined by:

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \begin{pmatrix} X + s \\ Y \\ Z \end{pmatrix} \mathit{for} \quad X > w$$

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \begin{pmatrix} X \\ Y \\ Z \end{pmatrix} \mathit{for} \quad X \leq 0$$

where w is the dyke width.

Plugs

Plugs can only be stope-like, with a replacement model for plug emplacement. Simple geometric forms can be defined (cylinders, paraboloids, cones and ellipsoids) or complex voxel geometries can be imported. In the future, the displacement equations described by Guglielmo (1993) could become the basis for a forced emplacement model.

Homogenous Strains

A strain tensor can be defined to homogenously deform the geology.

The kinematics are defined by:

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \begin{pmatrix} \varepsilon_{11} & \varepsilon_{12} & \varepsilon_{13} \\ \varepsilon_{21} & \varepsilon_{22} & \varepsilon_{23} \\ \varepsilon_{31} & \varepsilon_{32} & \varepsilon_{33} \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}$$

Tilts

A uniform tilt can be defined to rotate the geology.

The kinematics are defined by:

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \begin{pmatrix} j^2 + \left((1-j^2)\cos\theta\right) & jk(1-\cos\theta) + l\sin\theta & jl(1-\cos\theta) - k\sin\theta \\ jk(1-\cos\theta) - l\sin\theta & k^2 + \left((1-k^2)\cos\theta\right) & kl(1-\cos\theta) + j\sin\theta \\ jl(1-\cos\theta) + k\sin\theta & kl(1-\cos\theta) - j\sin\theta & l^2 + \left((1-l^2)\cos\theta\right) \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}$$

where j,k,l is the unit vector defining the axis of rotation, and q is the angle of rotation.

Penetrative Foliations and Lineations.

These deformation events are not explicitly associated with a volume change or strain, however they can be combined with homogeneous strains if needed. Some of the deformation events implicitly produce cleavages and lineations, for example folds produce an implicit axial plane cleavage and a fold axis lineation, whose orientation can be displayed symbolically on map views.

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15 References

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