Created in COMSOL Multiphysics 5.2a

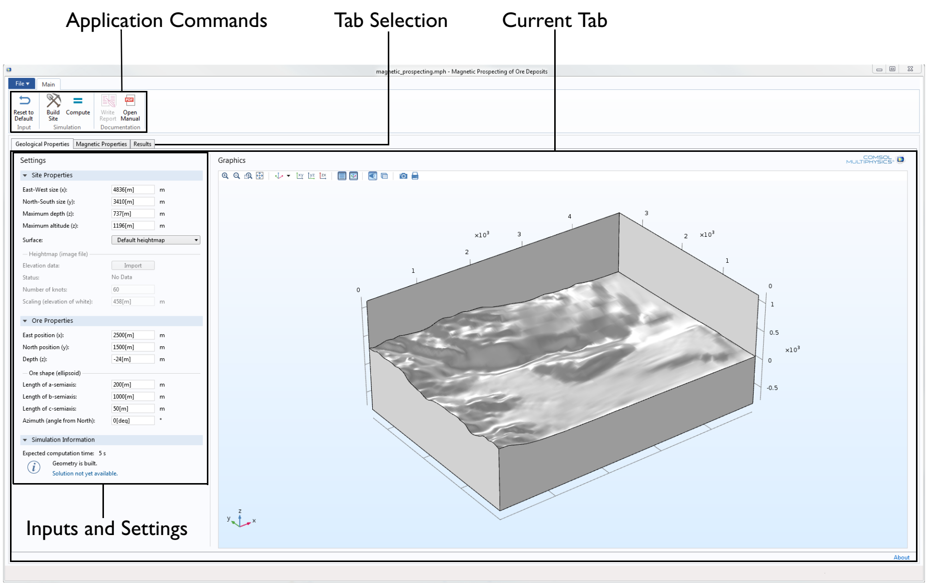
Magnetic Prospecting of Ore Deposits

About the Magnetic Prospecting of Ore Deposits Application

Magnetic prospecting is one of the methods of geological exploration applicable to certain types of iron ore deposits, in particular, those made up of magnetite and hematite. The method consists of measuring the magnetic anomalies (changes in the earth's magnetic field) due to the presence of magnetic ores.

The app models the effect of a deposit of magnetic ore on the earth's magnetic field and predicts the measured anomaly at specified measuring points on the surface.

USER INTERFACE



The buttons in the Ribbon can be used to control the application functionality.

- Click the **Reset Inputs** button to reset all of the values to the defaults and to reload the default heightmap.
- In the **Simulation** section, use the **Build Site** button to rebuild the 3D geometry of the site and the visualization of the geomagnetic field. Click the **Compute** button to compute the solution (and rebuild the geometry if necessary).
- In the **Documentation** section, click the **Write Report** to create a report containing the results of the simulation. This button is active only if a solution has been computde. Click the **Open Manual** button to open this documentation file.

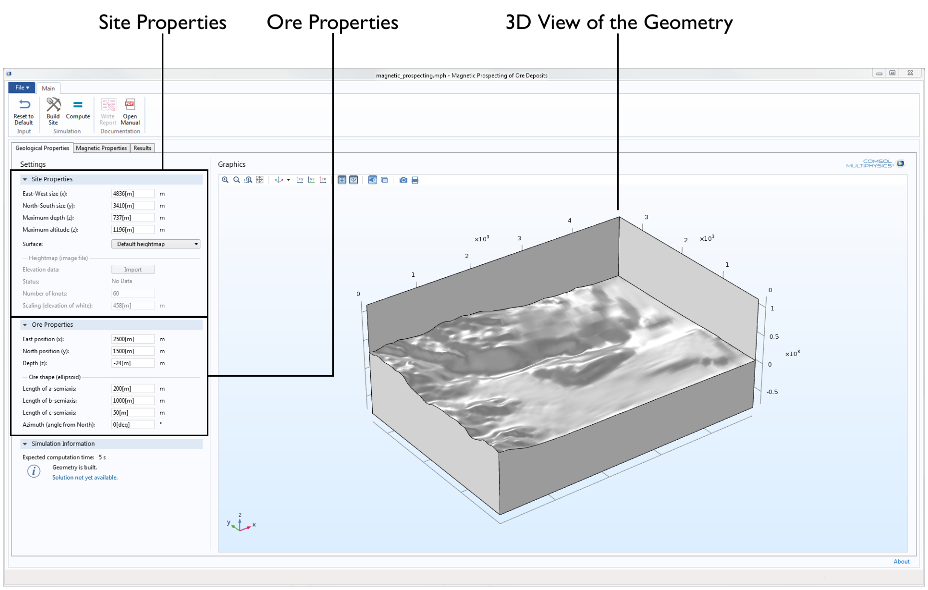
The Tabs

The user interface is organized in three tabs:

- The **Geological Properties** tab defines the size of the area under study, how the surface of the earth is represented, and the geometry of the ore deposit.
- The **Magnetic Properties** tab contains the input fields for the local geomagnetic field and the magnetic properties of the ore. The application can also download the geomagnetic field data from the Internet for any location. The magnetic properties of the ore can be specified using a mixture model and can account both for the magnetic permeability and the remanent magnetization of the magnetic portion of the ore.
- The **Results** tab shows a 3D plot of the computed anomaly of the geomagnetic field at the surface and the controls for the **Anomaly Probes**. Use these controls to specify the location of the probes on the surface and obtain numerical values for the anomaly at those locations.

The tabs also display a **Status** section that shows the current status of the geometry and the solution. Changes in the geometric parameters will require the geometry to be rebuilt (by clicking the **Build Site** button), while changes in the application inputs (including the geometry) will require the solution to be recomputed.

THE GEOLOGICAL PROPERTIES TAB



The model geometry consists of a simulation area oriented in the West-East (x) and South-North (y) directions. The origin is placed in the South-West corner of the area. The area extends a certain height above and a certain depth below a reference elevation level, identified by the level $z = 0$. The simulation area is partitioned by the surface of the earth in an aboveground (air) region and an underground region.

The surface of the earth is specified using the **Surface** list box:

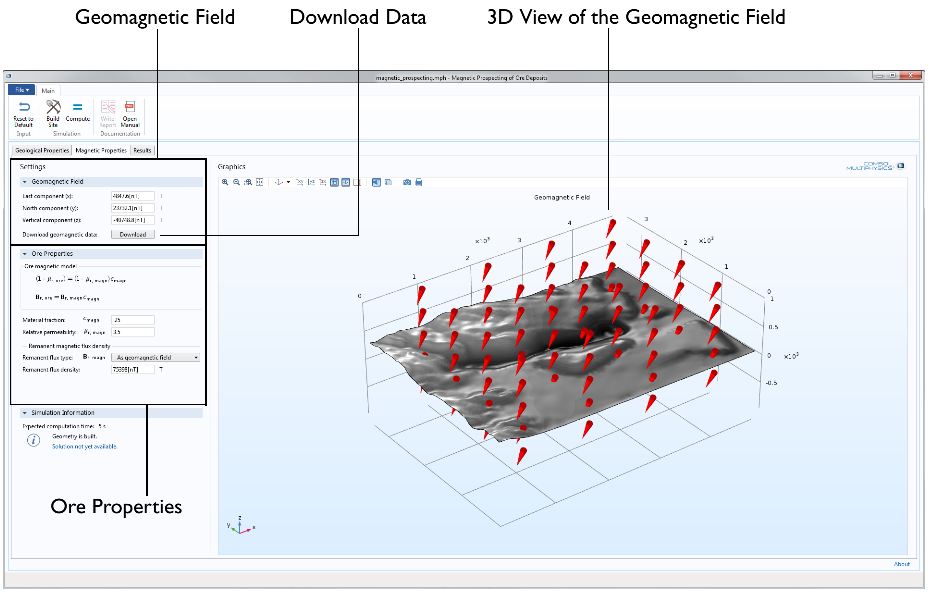
- Use **Flat** to specify a flat surface at z = 0.
- Use **Heightmap (image file)** to import an image representing the elevation profile. The image should be in greyscale, with darker tones representing lower elevations (with black pixels taken as $z = 0$) and brighter tones representing higher elevations. When this option is selected, you can enter a value for the **Scaling (elevation of white)** to specify the z-elevation of the white pixels in the image. The image is automatically scaled to the dimensions of the area.
- Use **Digital Elevation Model (DEM)** to import a file in the DEM file format, as defined by the United States Geological Survey. DEM files contain elevation data for the points placed on a regular grid. When this option is selected, you can enter the Reference elevation, which is the elevation taken as $z = 0$. The elevation grid is not scaled, but it is overlaid over the simulation area.
- Use **Default heightmap** to use the application's built-in heightmap, which represents the area around the Eagle Mountain Mine, a former Kaiser Steel Co. mining operation in Riverside County, California, USA.

When **Heightmap (image file)** or **Digital Elevation Model (DEM)** are selected, a Parametric Surface geometry feature is used to render a smooth surface from the discrete pixels or elevation grid. Specify the **Number of knots** to use to approximate the surface. A higher number of knots will increase the accuracy of the surface (especially for high-resolution images or fine grids) but will also require a longer processing time.

Ore Deposit

The ore deposit is modeled as a homogeneous ellipsoid. Use the input fields in the **Ore Properties** tab to specify size and position of the ellipsoid in the simulation area. The ellipsoid must be entirely contained in the simulation area and must be below the surface of the earth.

THE MAGNETIC PROPERTIES TAB



Use this tab to specify the geomagnetic field and the magnetic properties of the ore.

Geomagnetic Field

Enter the components of the geomagnetic field: **North** (y), **East** (x), and **Vertical** (z). A positive Vertical component is directed upwards. The geomagnetic field data for the current time can be downloaded automatically from the National Centers for Environmental Information website (Ref. 1). Click on the **Download** button to open the dialog and enter the coordinates (longitude, latitude, mean elevation) of the simulation area, then click on **Get Data**.

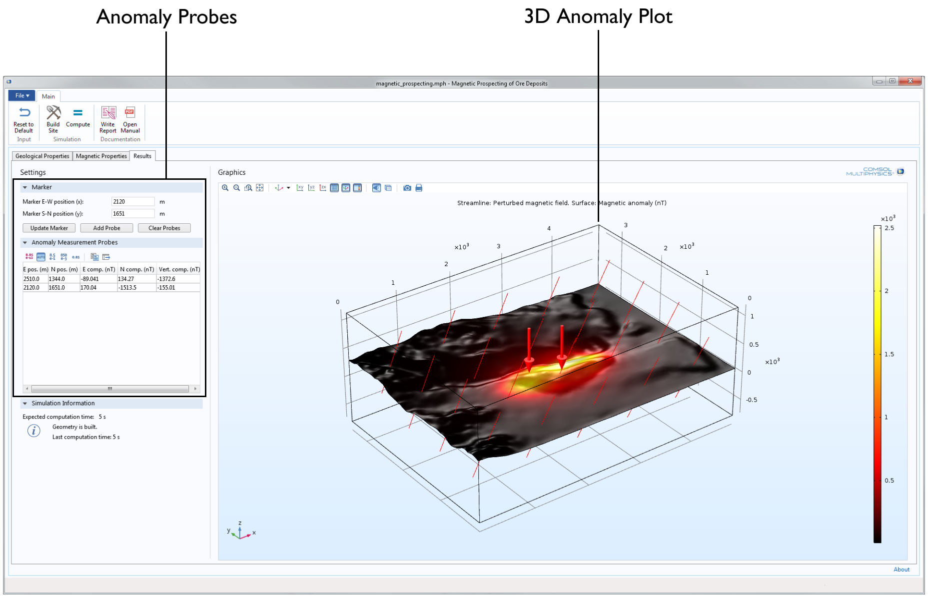
This functionality requires that access to network sockets is allowed in the **Security** settings. In the COMSOL Desktop, this setting can be reached from the **Preferences** window. To enable this security setting on COMSOL Server, contact your server administrator.

Ore Properties

For the magnetic ore, the app uses an averaging model. The ore is assumed to contain a magnetic material (e.g., hematite or magnetite) in concentration c_{magn}, with a relative permeability of μ_{mag} and remanent magnetic flux density of $\mathbf{B}_{\mathrm{magn}}$. The remanent magnetic flux density can be specified as parallel to the geomagnetic field, in which case it is necessary to enter the component along the field (a scalar value), or as a three-component vector. The material properties of the ore are then computed as:

$$(1-\mu_{\mathrm{ore}}) = c_{\mathrm{magn}}(1-\mu_{\mathrm{magn}})$$
$$\mathbf{B}_{\mathrm{ore}} = c_{\mathrm{magn}}\mathbf{B}_{\mathrm{magn}}$$

THE RESULTS TAB



After the computation is complete, postprocessing occurs in the **Results** tab. On the right is presented a 3D plot of the anomaly of the geomagnetic field at the surface and the total (perturbed) field as streamlines.

In this tab **Anomaly Probes** can be added to measure the anomaly at specified points of the surface. To add a probe and measure the anomaly, start by entering the desired location in the input fields in the **Marker** section and clicking **Update**. A blue marker is placed on the 3D plot on the right at the specified position. If the location is satisfactory, click **Add Probe** to create a probe at the location of the Marker.

The 3D plot will show a red arrow at the specified position and the data from the probe will be added to the **Anomaly Measurement Probes** table. The contents of the table can be exported or copied to the clipboard using the buttons in the toolbar.

If necessary, click the **Clear All Probes** button to remove all the added probes.

The Embedded Model

MODEL DEFINITION

The embedded model uses the **Magnetic Fields, No Currents** physics interface to solve a magnetostatic problem. The physics specify a uniform background magnetic field computed from the specified geomagnetic field and solves the equation for the reduced magnetic scalar potential:

$$\nabla \cdot (-\mu \nabla (V_{\mathrm{red}}) + \mathbf{B}_{\mathrm{r}} + \mathbf{B}_{\mathrm{ext}}) = 0$$

where $\mathbf{B}_{\mathrm{ext}}$ is the (background) geomagnetic flux density, $\mathbf{B}_{\mathrm{r}}$ is the remanent flux density, and μ is the magnetic permeability of the material. The size of the simulation domain is assumed large enough compared to the size of the ore deposit. The boundary conditions used on the exterior boundaries is **External Magnetic Flux Density**, which forces the reduced magnetic flux density to be tangential to the surface.

The embedded model is based on the Magnetic Prospecting of Iron Ore Deposits application in the **AC/DC Module > Magnetostatics** folder.

References

1. NOAA, National Centers for Environmental Information, http://www.ngdc.noaa.gov/geomag-web/

Application Library path: `ACDC_Module/Applications/magnetic_prospecting`