Creating Three-Dimensional Displays With ArcScene

By Patrick J. Kennelly, Montana Bureau of Mines and Geology

ArcScene, the three-dimensional viewing application that is part of the ArcGIS 3D Analyst extension, allows earth scientists to create both traditional and unconventional three-dimensional displays from real-world data. Figures created from elevation and depth values are commonly used to reveal the earth's surface and expose its interior. Alternatively, other measures can represent a third dimension of earth-scientific data. Examples of creating three-dimensional displays with readily available elevation, magnetic field, and geologic time data are discussed and illustrated in this article.

Elevation Z-Values

Elevation data is the foundation for the creation of three-dimensional displays. Data in digital elevation model (DEM) format is commonly used for storing and displaying topographic surfaces. Also, points, lines, polygons, grids, and images can be positioned in three-dimensional space with information from underlying DEM data. Alternatively, a feature can be displayed in three-dimensions with a constant *z*-value or a *z*-value derived from an attribute of a feature. Two examples of such displays in earth science are geologic block diagrams and earthquake location figures.

Creating Geologic Block Diagrams

Geologists have a passion for illustratively dissecting the land to create block diagrams. These drawings show a perspective, cutaway view of surface and subsurface geologic features. The accompanying illustrations under "Block Diagrams" show the sequential development of Bighorn Canyon in southeastern Montana. The Montana Bureau of Mines and Geology (MBMG) created these block diagrams for an outdoor interpretive exhibit at the Bighorn Canyon National Recreation Area.

To create geologic block diagrams or the other types of three-dimensional data displays discussed in this article, the properties for each data layer in an ArcScene project must be set. Access the Layer Properties dialog box by right-clicking on an individual data layer in the table of contents. In the Layer Properties dialog box, the Base Heights and Extrusion tabs are used to specify the display of three-dimensional data. Set display properties for grid and vector data on the Base Heights tab. The Extrusion settings can only be applied to vector data. Extruding data—stretching it into the third dimension—creates lines from points, vertical surfaces from lines, and volumes from polygons.

In constructing the Bighorn Canyon block diagram, the DEM was drawn using its elevation values by choosing the Obtain Heights for Layer
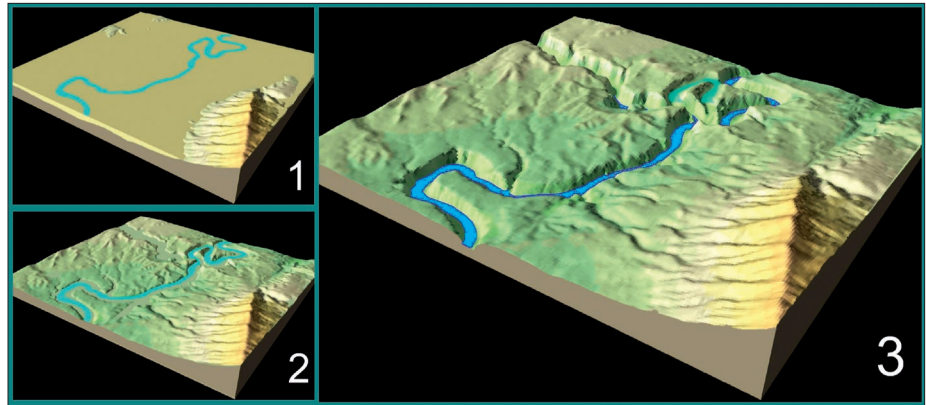

Block Diagrams

These three block diagrams, created by the MBMG for the National Parks Service, represent the sequential development of the Bighorn Canyon in southeastern Montana. At Time 1, a predecessor of the Bighorn River flows across flat lying Tertiary-age sediments (tan color) washed eastward from the Rocky Mountains across the Great Plains. At Time 2, the Tertiary deposits have been eroded away, leaving a superposed river that cuts across preexisting geologic structure. At Time 3 (present day), the river has cut down into the uplifted topography. The Natural Corrals area is highlighted in light blue and represents an old meander that was abandoned during downcutting as the river carved a more direct path downstream.

from Surface radio button on the Base Heights tab. A square, polygonal, vector data layer matching the extent of the DEM was created and added as two separate layers to the scene. Base heights for the first layer were obtained from the DEM and

diagram was copied from the original stream polygon and modified to overlie the abandoned meander. Its *z*-value, set to a constant value just above the top of the polygon, was extruded upward. For the second block diagram, the base
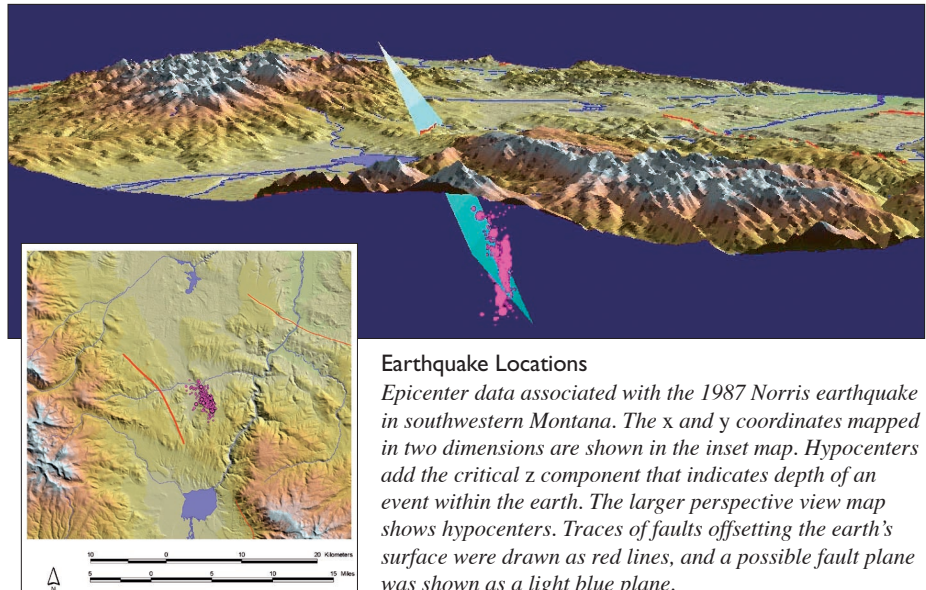

Earthquake Locations

Epicenter data associated with the 1987 Norris earthquake in southwestern Montana. The x and y coordinates mapped in two dimensions are shown in the inset map. Hypocenters add the critical z component that indicates depth of an event within the earth. The larger perspective view map shows hypocenters. Traces of faults offsetting the earth's surface were drawn as red lines, and a possible fault plane was shown as a light blue plane.

extruded upwards (i.e., given a positive extrusion value) and added to the feature's minimum height to form the tan-colored Tertiary-age sedimentary cover shown in the first block diagram. The DEM was also the source for the second polygon's base height but it was negatively extruded to form the block beneath the topography.

The light blue river shown in the first block

height of the modified river was lowered in an appropriate manner. For the third block diagram, the current dark blue river and a clipped portion of the modified light blue river derived their *z*-values from the DEM to properly locate the current waterway and the abandoned meander channel in the Natural Corrals area.
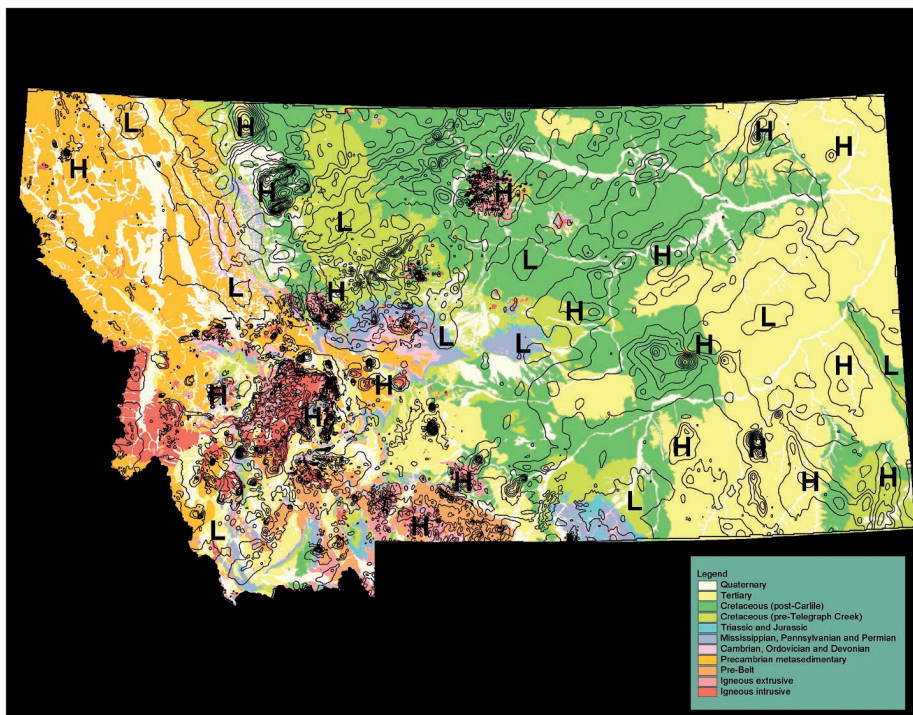
Magnetic Surfaces

In the upper image, contours of aeromagnetic intensity are overlain on a generalized geology map of Montana. This allows quantitative comparison of various magnetic anomalies but may not be as readily comprehended as the lower map, which uses the same data but drapes the geology over an aeromagnetic surface.
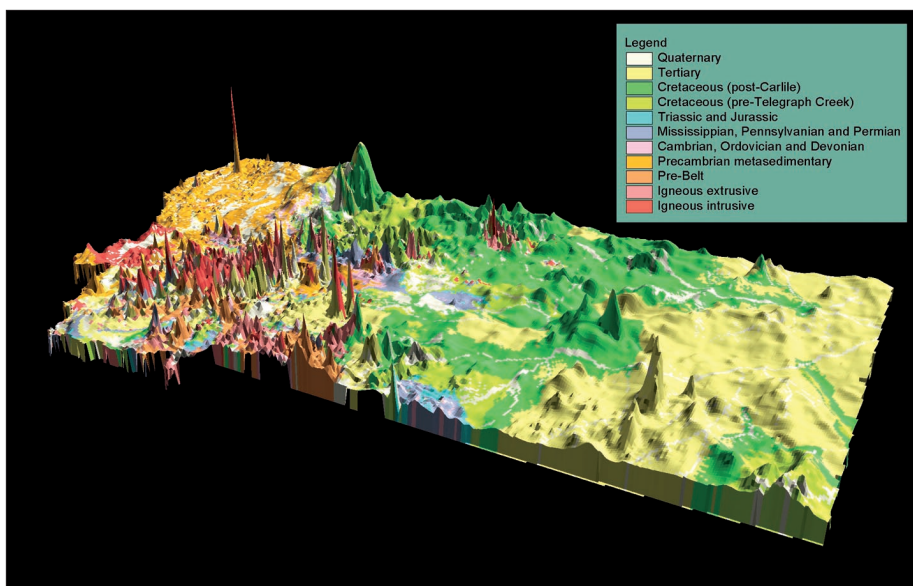
surfaces. Metrics can also change in a discrete fashion and are represented by constant values that change abruptly at boundaries. Three-dimensional displays are useful in representing and visualizing both types of geologic phenomena.

Understanding Magnetic Surfaces

While geologists find rocks aesthetically attractive, geophysicists are irresistibly drawn to them (in a magnetic sense). The strength of the earth's magnetic field is not constant; it has local variations associated with the mineralogy of near-surface rocks. Measurements of these variations are often gathered from aerial surveys. In Montana, the United States Geological Survey compiled 60 aeromagnetic surveys, conducted over a 40-year period, into a 500 x 500 meter grid. Sharp spikes in the aeromagnetic data can pinpoint locations of magnetic minerals.

Often, this type of data is displayed as contours of magnetic intensity overlain on a geologic map as shown in the first map under "Magnetic Surfaces." Although this allows quantitative comparison of various magnetic anomalies, this type of representation may be difficult for some to understand. Draping the geology over an aeromagnetic surface offers an alternative method for displaying this information that shows the obvious correlation between isolated, volcanic intrusives in red and spikes in the magnetic field.

To create this display, base heights were assigned to a generalized geologic polygon layer from the magnetic surface. These *z*-values are in nanoteslas (nT), a measure of magnetic intensity. In this instance, a vertical exaggeration of 30 *x*s, set by right-clicking on Scene Layers and choosing Scene Properties, was created although this is actually stretching vertical values in nanoteslas compared with horizontal values in meters.

More Information on Earthquake Locations

Seismologists are keenly interested in where earthquakes occur and will go to any length (or depth) to determine their locations. During the Norris earthquake swarm of 1987 in southwestern Montana, MBMG located nearly 600 aftershocks. While epicenters give *x* and *y* coordinates (i.e., surface locations) of earthquakes that are suitable for two-dimensional maps, hypocenters add the critical *z* component that indicates depth of an event within the earth. In an ArcScene view, each hypocenter can be represented by a sphere. The size of each sphere can be made proportional to the magnitude of the event.

The *z*-values for topography as well as the stream, lake, and fault trace layers for the perspective representation of the Norris earthquake swarm shown in the second of the two illustrations under "Earthquake Locations"
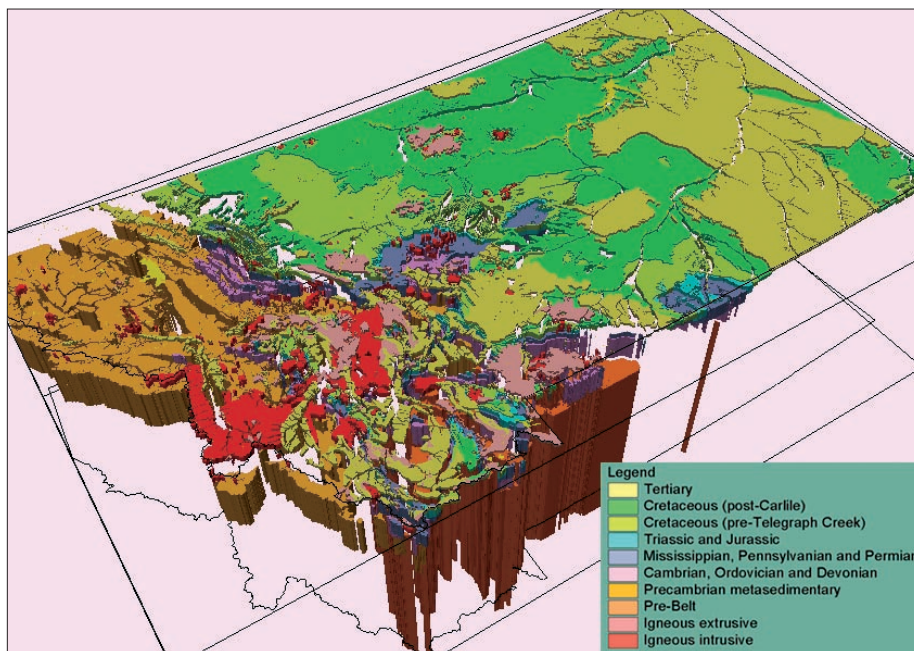
were obtained from a DEM. The hypocenter layer was created from a database containing *x, y* and depth information. The hypocenters are properly located for each individual point by first obtaining a height from the DEM and then adding an offset based on the earthquake's depth attribute. A first order polynomial fit to the hypocenters and points comprising the surficial fault trace in three dimensions define the fault plane. The complexity of the hypocenter cluster probably indicates a network of fault planes, as opposed to the single plane approximation shown.

Displaying Alternative Z-Values

Earth scientists measure numerous features that vary across the landscape and are unfazed by the fact that these metrics are often impossible to see or difficult to comprehend. Metrics that vary in a smooth manner can be represented as continuous
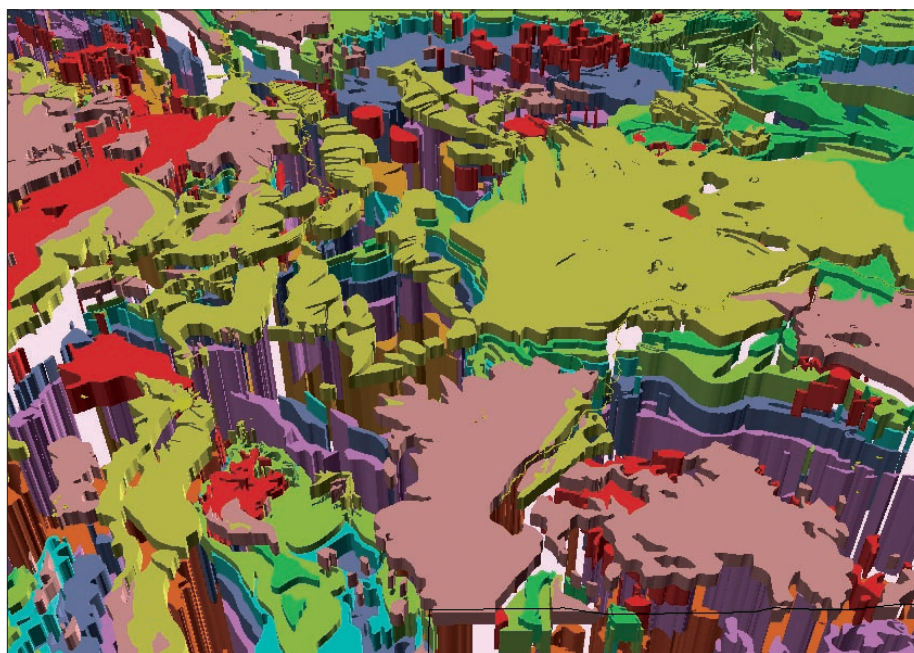
Creating Three-Dimensional Displays With ArcScene

Legend
- Tertiary
- Cretaceous (post-Carlile)
- Cretaceous (pre-Telegraph Creek)
- Triassic and Jurassic
- Mississippian, Pennsylvanian and Permian
- Cambrian, Ordovician and Devonian
- Precambrian metasedimentary
- Pre-Belt
- Igneous extrusive
- Igneous intrusive

Geologic Time

These geologic maps of Montana indicate the length of each geologic period along the z-axis. The top map gives a detailed three-dimensional display of both geology and time for an area north of Yellowstone National Park. Note the Precambrian rocks that comprise a large portion of the western part of the state. The lowest levels are shown in orange and brown. All other geologic units are 570 million years old or younger.

The lower map shows details of the area north of Yellowstone National Park. Topographic highs here are associated with uplift and erosion of older rock units, resulting in mountains of high elevation being transformed into canyons of deep time. In this example, a measure corresponding to one meter in the x or y direction is equivalent to 20,000 years in the z direction.

Summary

The figures accompanying this article are just a few examples of how earth science data can be displayed in three dimensions with ArcScene. As demonstrated by the surface and subsurface geologic and seismic data examples, *z*-values can be derived from elevation values. Alternatively, the *z*-coordinate can be derived from any measured value. These values can vary continuously and create a surface over which additional data may be draped or can be discrete and cause abrupt changes in *z*-values at boundaries. The flexibility of assigning *z*-values from various sources makes ArcScene a powerful tool for anyone who needs to show the quantitative variations in three-dimensional data.

For more information, please contact

Pat Kennelly, Assistant Professor
Earth and Environmental Science Department
CW Post Campus/Long Island University
720 Northern Boulevard
Brookville, NY 11548
Tel.: 516-299-2318
E-mail: patrick.kennelly.liu.edu

About the Author

Patrick Kennelly was an associate research professor and GIS manager at the Montana Bureau of Mines and Geology, a department of Montana Tech of the University of Montana. He is currently an assistant professor in the Earth and Environmental Science Department at the CW Post Campus of Long Island University. He has a doctorate in geography from Oregon State University, a master's degree in geophysics from the University of Arizona, and a bachelor of science in geology from Allegheny College.

Grasping Geologic Time

All geologists—from rough-hewn students to weathered professionals—struggle to comprehend the billions and billions of years that comprise the earth's history. The extinction of the dinosaurs occurred at the Cretaceous/Tertiary boundary. Although this occurred 65 million years ago, the interval represents a mere 1.4 percent of the earth's 4.6 billion-year history. The illustrations under "Geologic Time" are three-dimensional depictions of the span of geologic time.

These images begin with a polygonal geologic data layer. A geologic period attribute is added to the layer, polygons are assigned to the appropriate period, and the layer was dissolved on this attribute. New numeric attributes are added to the dissolved layer to store values representing the beginning and ending of each period as years before the present. Each polygon was assigned a constant height based on its ending age attribute and was extruded by its temporal extent as calculated from the attributes for beginning and ending years. Although deposition may not have spanned the entire time period, this simplified extrusion improved visual clarity. To further clean up the display, the most recent, and often unconsolidated, Quaternary deposits were removed.