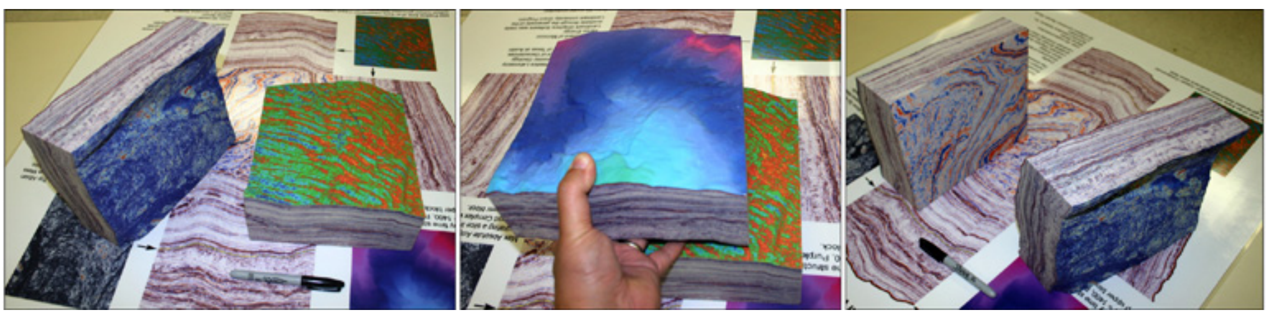
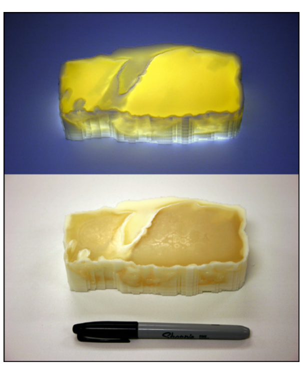
Cyber Techniques used to Produce Physical Geological Models

Reuben Reyes, Jerome A. Bellian, Dallas B. Dunlap, and Rachel A. Eustice
Jackson School of Geosciences, Bureau of Economic Geology,
The University of Texas at Austin, Austin, TX

Computer applications used for producing and displaying digital 3D models are complex and require many hours of training to use. Because of this, we explored using different digital techniques to produce 3D physical models. These models can be used independently or can be used to enhance virtual models. The models we produced represent real geological data from seismic, X-ray computed tomography, and point cloud lidar sources. For each data set, a different 3D physical technology was used to produce the model. The seismic data is represented by an interlocking color model, with each color used to show a different seismic attribute. A translucent 3D model showing cavities and vugs within a limestone was produced from X-ray computed tomography data. The last model represents cave geometry and was produced by replicating a lidar point cloud in clear crystal glass. All three physical models or replicas accurately portray the complex data, yet are scaled so they are small enough to hold. New advances in 3D printing and computer technology allow scientists to produce 3D models from a wide variety of geological data rapidly to use for teaching and research. These new techniques allow a fast turn around time between gathering geological data and producing a 3D physical model.



Color 3D model made from seismic data.

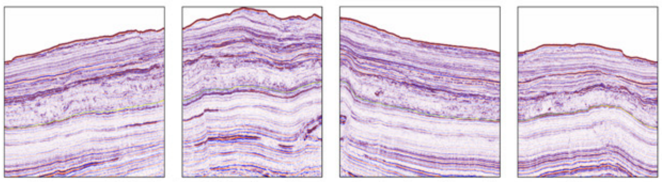


Translucent 3D model made from X-ray computed tomography data (left) and cave point cloud data in a clear crystal glass (right).

Cyber Techniques used to Produce Physical Geological Models

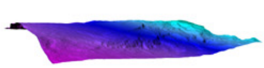
Purpose: To create a color 3D model from seismic data in order to show different attributes across multiple horizons. This model can be used with or without computers.

Problem: Converting Landmark data file types into color VRML files for use with a Zcorp color 3D printer. Several horizons and seismic sections are needed to make a working VRML file. A specific VRML file must be use to create a 3D print.

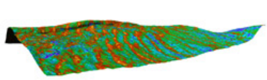


Walls of the model are output as seismic vertical section images. Each adjacent section is perpendicular, making the four walls of the model. Each image needs to be scaled and converted into a 3D file format. A center horizon divides the model into sections, top and bottom.

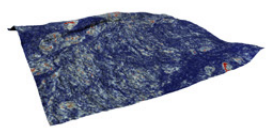
The model is divided into two blocks stacked on top of one another.



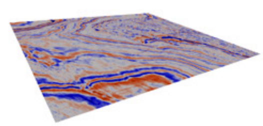
Top of the model represents bathymetry and is a two-way time structural map of seafloor.



Upper section of bottom model represents the seismic maximum peak amplitude of a Cenomanian deepwater deposit.

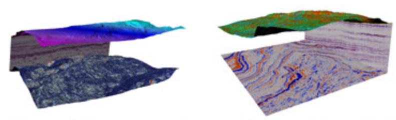


Bottom section of top model is a map of the maximum absolute amplitude above the Top Albian, illustrating a slice through a large End Cretaceous Mass Transport Complex.

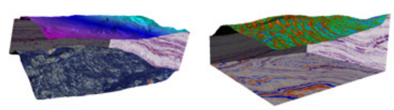


Base of model is a horizontal seismic slice.

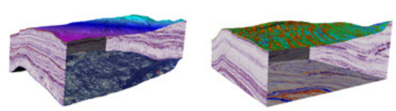
Three horizons and the base are output each with xyz information and color.



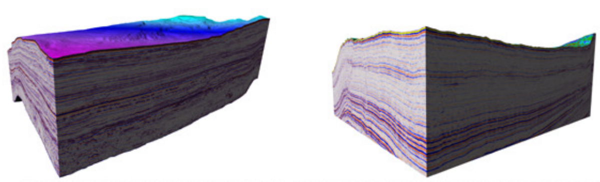
Top and bottom sections with one side added.



Top and bottom sections with two sides added.



Top and bottom sections with three sides added.



Complete digital 3D model with all four seismic sides and two top and bottom horizons in standard VRML format ready for color 3D printer.

Zcorp Spectrum
Z 510 3D color printer.

Color 3D model after printing. Top and bottom sections can be stacked one on top of the other and are small enough to hold.

Solution: We wrote several computer programs to extract and reformat data structures from Landmark data files. Horizon color attributes and geometry were converted to fit a specific file type. We worked with Zcorp to find the correct VRML format for the Z 510 3D color printer.

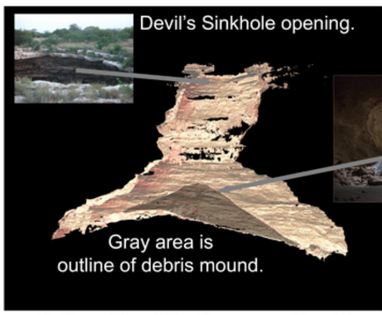
Acknowledgments: Warmer Brown, Allan B. Cobb, Eric Hepburn, James W. Jennings, Raymond Keller, Jay Kipper, Jerry F. Lucia, Lorena Moscardelli, Stephen Ruppel, Ruben Ruckman, Scott W. Tinker, Lesli J. Wood, CrystalProtine.com, Devil's Sinkhole Society, Landmark Graphics, Technical Laboratory Systems Inc, Texas Parks and Wildlife Dept., Texas Cave Management Association, UTCT High-Resolution X-ray Facility, and Z Corporation.

Cyber Techniques used to Produce Physical Geological Models

Purpose: To utilize lidar point-cloud data of Devil's Sinkhole cave in order to embed them in a glass crystal so that the 3D structure of the cave can be viewed.

Problem: Unprocessed lidar point-cloud scans contain a large number of data. More than 150 million xyz points with intensity values must be reduced intelligently to preserve cave-wall detail.

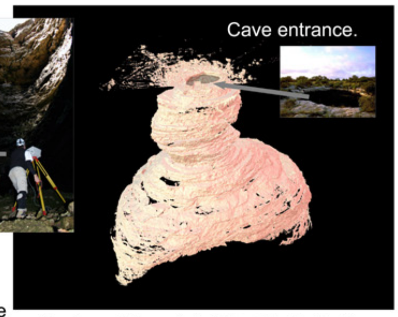
Devil's Sinkhole is located close to Rocksprings, Texas. It is a vertical cavern with an opening approximately 12 by 18 meters and a vertical drop to the main cavern of about 42 meters. The main cavern is circular and reaches a total depth of 107 meters.



Surface 3D model with cross section of Devil's Sinkhole cave to show interior.

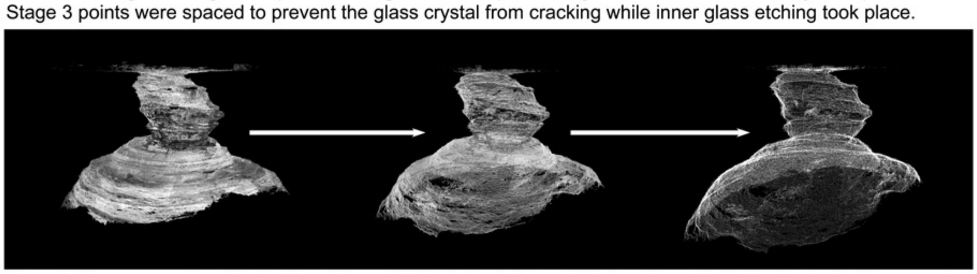
Debris mound inside cave.

Jerry Bellian taking lidar scans inside cave. Photographs taken inside Devil's Sinkhole by Allan B. Cobb.



Surface 3D model of Devil's Sinkhole. Solid surface makes it difficult to view inside.

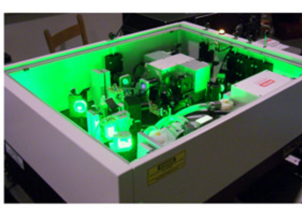
Three stages of digital processing were used on the lidar-point cloud data. Stage 1 consisted of a mosaic of overlapping lidar scans. So that the high concentration of points could be reduced in overlapping areas, points were fit into a grid. The gridded points in Stage 2 needed processing to remove or relocate adjacent points. In Stage 3 points were spaced to prevent the glass crystal from cracking while inner glass etching took place.



Stage 1: Unprocessed point cloud with overlapping scans contains more than 150 million points.

Stage 2: Point-cloud data gridded to fit area within glass crystal is reduced to 1.1 million points.

Stage 3: Point cloud with the corrected spacing and reduced down to 655,184 points is ready to be etched into glass.



A Green Nd:YAG laser similar to the one pictured here was used to create points in glass crystal.

Each point in the glass crystal is a microfracture (.1 mm) created by a focused pulsed laser beam.

Computer-controlled mirrors and motors insure accuracy of each point to .025 mm.

Solution: Unprocessed lidar data were gridded into an array, reducing the points significantly. Statics were used either to remove or spread out points in order that the risk of the crystal collapsing or cracking was reduced. The resulting data set was sent to a service bureau, and within one week, a completed crystal with an image of Devil's Sinkhole embedded in glass arrived by mail.

Acknowledgments: Warmer Brown, Allan B. Cobb, Eric Hepburn, James W. Jennings, Raymond Keller, Jay Kipper, Jerry F. Lucia, Lorena Moscardelli, Stephen Ruppel, Ruben Ruckman, Scott W. Tinker, Lesli J. Wood, CrystalProtine.com, Devil's Sinkhole Society, Landmark Graphics, Technical Laboratory Systems Inc, Texas Parks and Wildlife Dept., Texas Cave Management Association, UTCT High-Resolution X-ray Facility, and Z Corporation.

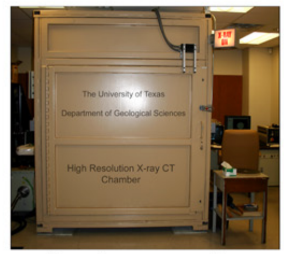
Cyber Techniques used to Produce Physical Geological Models

Purpose: To create a translucent physical 3D model of a limestone block so that complex internal structures can be viewed.

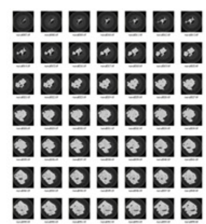
Problems encountered: How can different geometry file types be converted without losing key attributes and retaining detail to match the resolution of the 3D printer?

Limestone rudist reef block (Glen Rose Formation) collected near Pipe Creek, Texas.

Limestone block sample showing cut and exposed sides.



Limestone scanned in a high-resolution X-ray CT facility.



Series of 16 bit 2D slices.

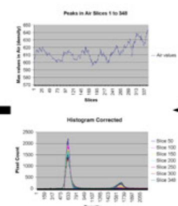
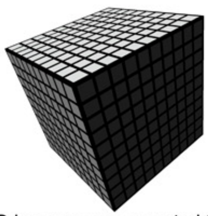
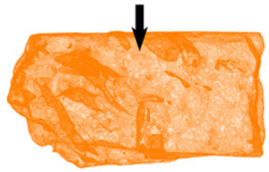


Image processing and thresholding of 2D images.

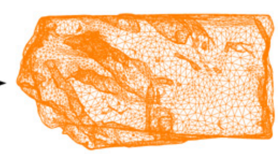


2D images are converted to 3D data block of voxels.

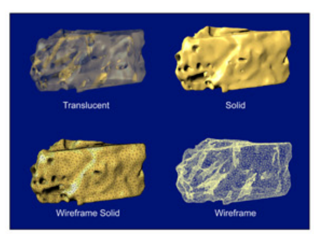


Surface is created from 3D data block with 320,000 facets.

3D surface is reduced in size to speed up processing before sending to 3D printer.



3D surface is decimated down to 20,000 facets.



Computer model is digitally cleaned up and made water tight. Problem areas within the surface mesh are fixed, and bad facets are removed.

Computer model is converted to digital stereolithography format (STL) and transfered via network to a 3D Systems Invision SI2 printer. Print time was about 2 hours.

Physical 3D model is built with solid material Acrylate Thermo Polymer and white matrix wax in cavities and outer surface.

Solution: Trial and error established a way of solving file-type incompatibilities so that we could create a physical 3D model. Understanding the limits and capabilites of computers + persistance helped us create the model. We used translucent material in the model to view internal structures, although some internal structures were not visible in the translucent material. To solve this problem, we created cross-section halves to be included with the full 3D physical model. Physical models can be used with or without computers when complex internal stuctures are being investigated.

Acknowledgments: Warmer Brown, Allan B. Cobb, Eric Hepburn, James W. Jennings, Raymond Keller, Jay Kipper, Jerry F. Lucia, Lorena Moscardelli, Stephen Ruppel, Ruben Ruckman, Scott W. Tinker, Lesli J. Wood, CrystalProtine.com, Devil's Sinkhole Society, Landmark Graphics, Technical Laboratory Systems Inc, Texas Parks and Wildlife Dept., Texas Cave Management Association, UTCT High-Resolution X-ray Facility, and Z Corporation.