A New Hydrostratigraphic Framework Model (HFM) of Pahute Mesa, Nevada - 2
Lava Flow Aquifers (LFAs).

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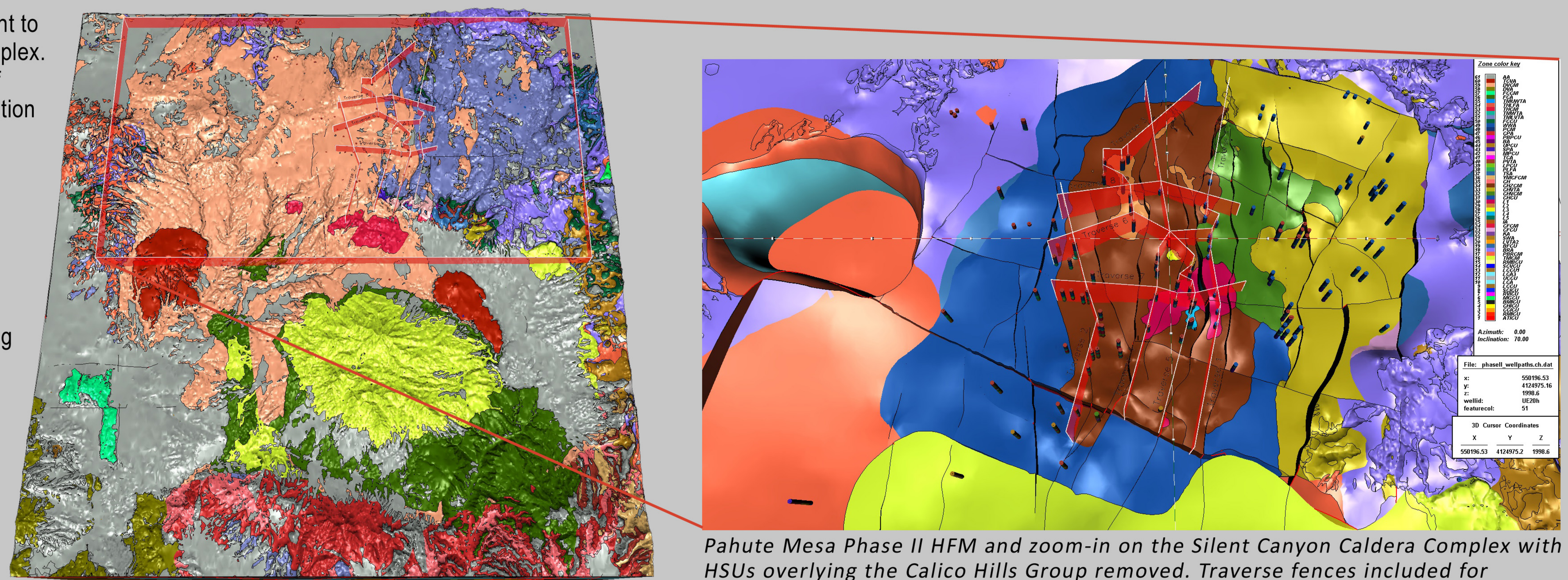
ABSTRACT

The new Pahute Mesa HFM incorporates five sub-HSU LFAs believed to be significant to groundwater flow and contaminant transport through the Silent Canyon Caldera Complex. The LFAs are individual lava flows that were subsequently surrounded by deposits of volcanic tuff. All five LFAs and the surrounding tuff are part of the Calico Hills Formation (CH). Reasonably incorporating the LFAs in the HFM was challenging because the features are not continuous and are irregularly shaped 3D lenses or volumes. To address these problems, a modeling approach was developed that describes each LFA as well as four mineralogic zones within the surrounding tuff as a series of indicator properties. Nine datasets were defined for five LFAs and four mineralogic zones describing the presence or absence of the respective features as ones and zeroes at borehole contacts and along interpretive cross-sections supplied by the field geologists. A 3D indicator grid was then developed for each dataset. Comparing the 3D grids and selecting the feature with the highest indicator value at each grid node provided a single pseudo-probabilistic grid ofthe lateral and vertical extent of the LFAs and mineralogic zones. That grid was then used to subdivide the Calico Hills. The result of this work is a model framework that includes both the faulted HSU thicknesses as well as key sub-HSU zonations that can be updated rapidly and exported for use in groundwater flow and contaminant transport modeling.

LOCATION MAP

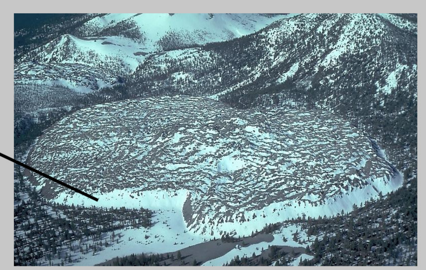


Pahute Mesa Phase II HFM and zoom-in on the Silent Canyon Caldera Complex with HSUs overlying the Calico Hills Group removed. Traverse fences included for reference that show where interpretive cross-section data were digitized by NSTec Geologists.

Lava Flow Aquifers

As conceptualized in the Calico Hills Lava Flow Aquifers component of the Pahute Mesa HFM, the LFAs simulate rhyolitc lava flows emanating from low-relief fissure-type vents, similar to what can be seen in the Mono-Inyo Craters area in the Long Valley Caldera region on the East Side of the Sierra in Central California.

Rhyolitic lava flow domes exhibiting high angled slopes at distal edges.



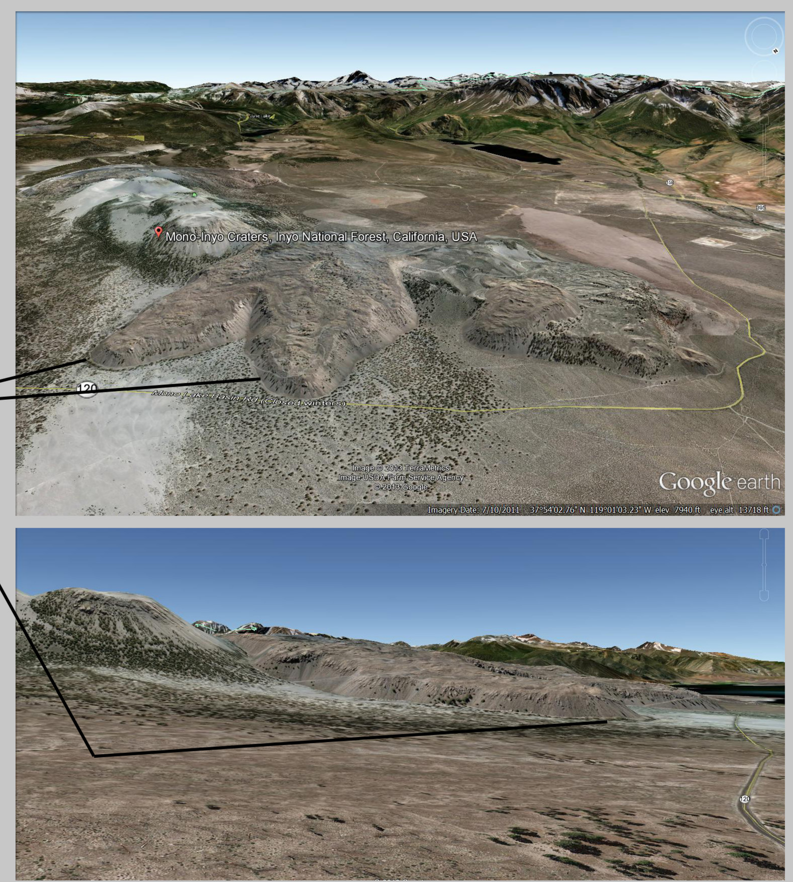
Aerial view of Obsidian Flow near Inyo Craters, Long Valley, CA.

Wilson Butte Dome, a viscous rhyolitic lava flow, Long Valley, CA

Aerial view of Obsidian Flow and Inyo Craters.

Inyo / Mono craters provide a modern day example of rhyolitic lava domes originating from fissure-type vents. The geologic features shown in these images provide examples of potential conditioning information on the shape and lateral extents of Calico Hills lava flows. Note the high relief of the domes and steep truncation at the distal edges of these geologic features that have formed in recent millenia.

Extent of silicic lava flows

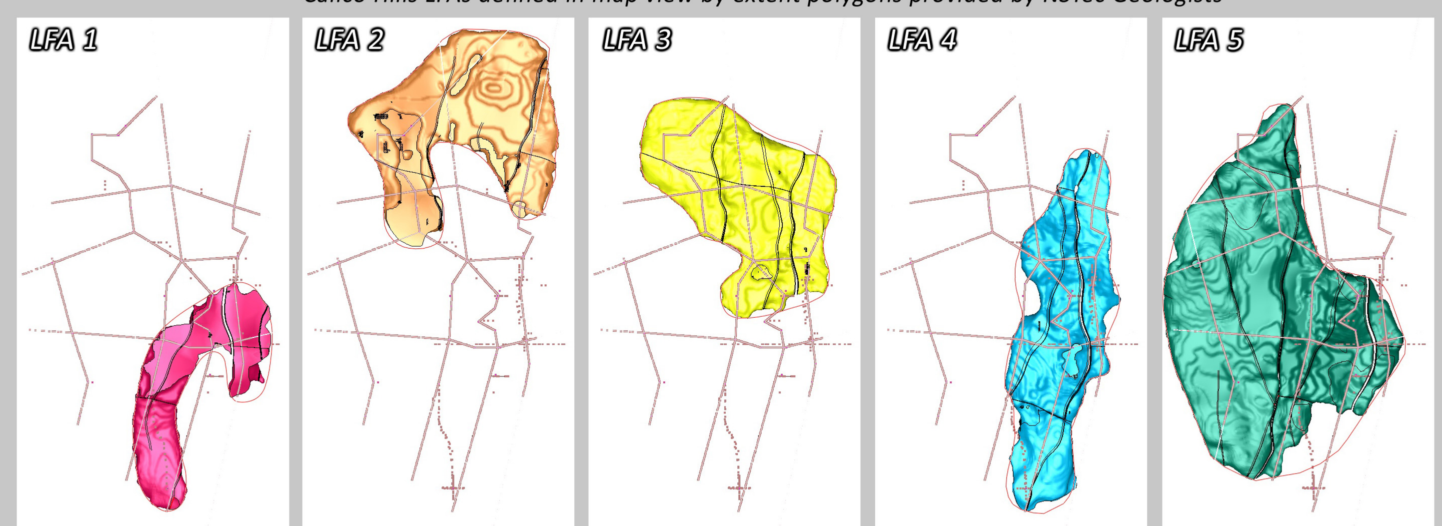


Views of Mono Craters produced in Google Earth highlighting the vertical relief and topographic expression produced by high viscosity silicic lava flows.

Images courtesy of United States Geological Survey
http://volcanoes.usgs.gov/volcanoes/long_valley/long_valley_gallery_1.html

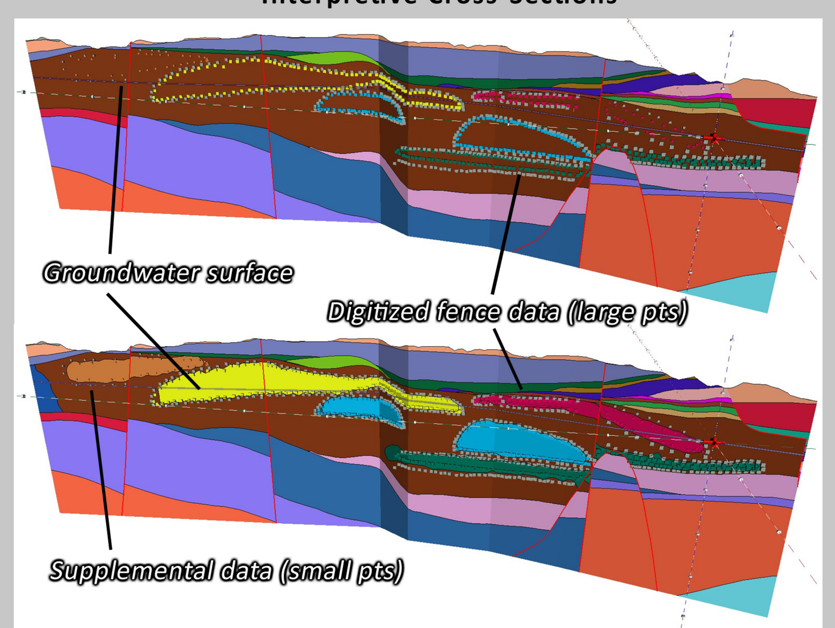
Model Construction - Data

Calico Hills LFAs defined in map view by extent polygons provided by NSTec Geologists



Polygons were provided by NSTec geologists delineating the extent of each LFA in map view, shown above. These polygons, outlining the footprint of each LFA, were incorporated into the model building process to truncate the fill zone, CHZCM, outside of the boundary of each individual flow zone. Also shown are the traverses used to extract fence diagrams to be used as digitization planes by NSTec Geologists to define the extent of LFAs in 3-D.

Interpretive Cross-Sections

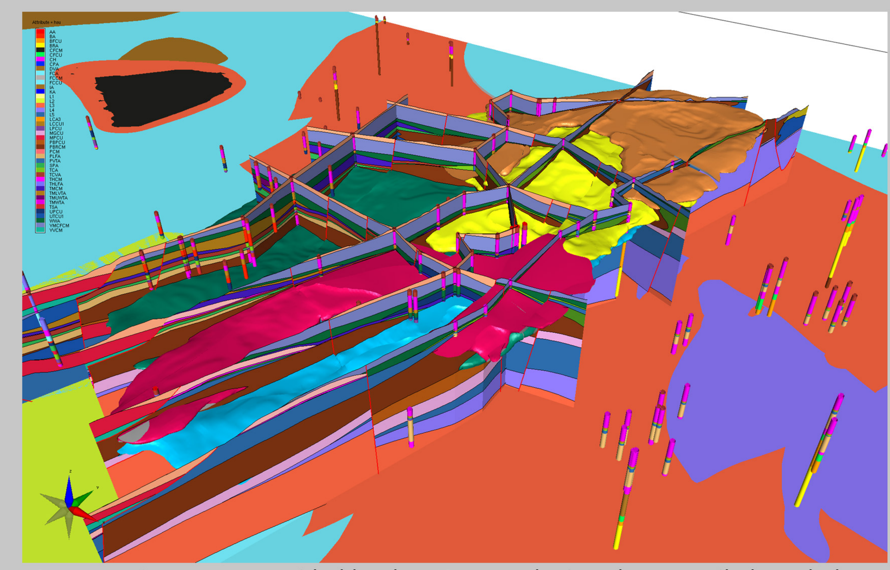


Interpretive cross-section data were provided by NSTec Geologists to provide guidance on the distribution of LFAs in 3-dimensions. A set of traverses were provided to extract fence diagrams from the base PM Phase II HFM, shown in the top fence cut on the left. The fence diagrams were made available to the Geologists, who digitized the shape of the LFAs as shown by the data points in the top figure. Using these digitized data points along the 8 fence diagrams along with the plan view guidance, the preliminary LFA volumes were generated in Earthvision.

The second fence cut, below left, shows the resulting fence diagram with the LFAs included. Supplementary data points were digitized to fill in gaps and refine the extents based on exchange of information between the modelers and the geologists. In both of the adjacent fence cuts, the larger data points represent the preliminary data set, the smaller data points have been subsequently added to more precisely delineate the conceptualized lava flows.

The groundwater surface trace in the adjacent images were derived from the volcanics groundwater contours in the USGS Professional Paper: 1771, Groundwater Flow Systems at the Nevada Test Site, Nevada: A Synthesis of Potentiometric Contours, Hydrostratigraphy and Geologic Structures. 2010, Fenelon, Joseph M,; Sweetkind, Donald S.; Laczniak, Randell J.

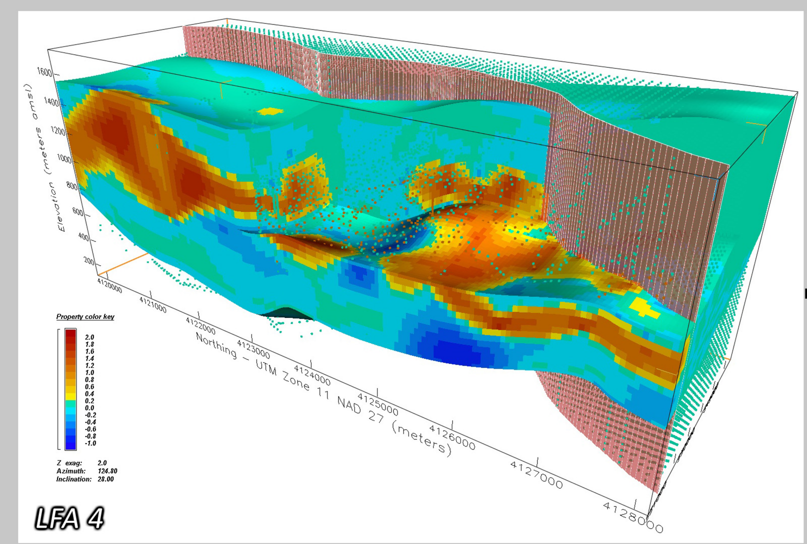
Model Construction - Data (Cont.)



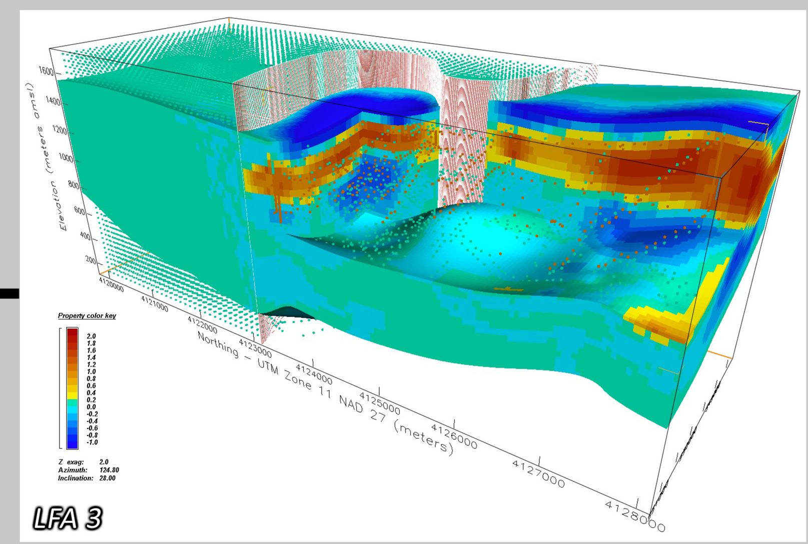
Cross-sections were provided by the NSTec geologists that compile knowledge gained from the field, boreholes and nearby analogs to interpret the most probable configuration of the LFAs within the Calico Hills Group. Shown above are the 8 fence diagrams used to digitize interpretive cross sections of the LFAs.

Model Construction - Process

Initial Pseudo-Probability Distribution Gridding

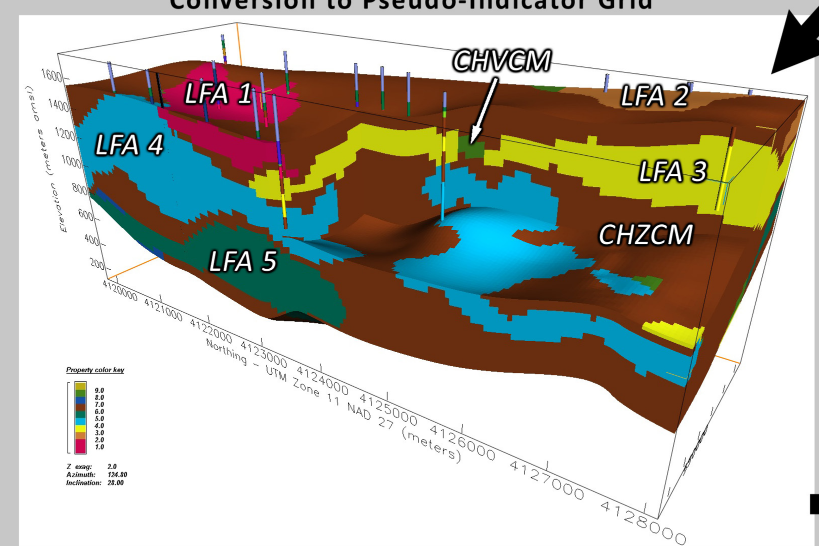


LFA datasets are converted to individual binary indicators: 1 for LFA present, 0 for LFA absent, and an individual dataset was created for each LFA.



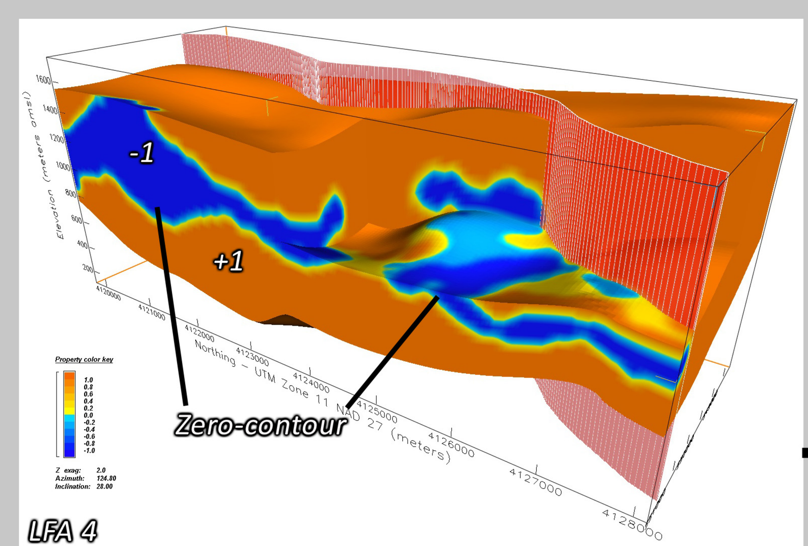
Initial Psuedo-Probability Grids are produced by gridding the parsed datasets using the EarthVision minimum tension gridding algorithm in 3-D.

Conversion to Pseudo-Indicator Grid

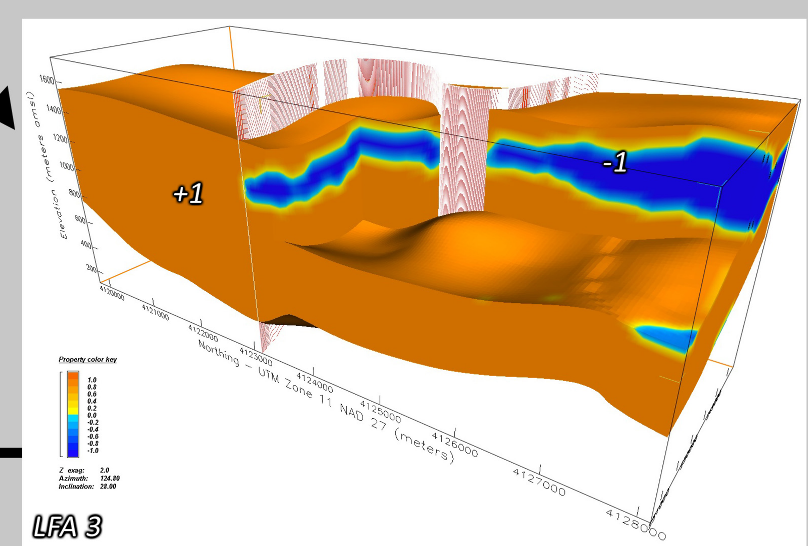


The range of values in each of the initial psuedo-probability grids was modified slightly to accomodate an integer label (0 - 1 was changed to 0.001 - 0.999). The integer label was then assigned to corresponded to the stratigraphic order of the LFA occurrence. For example, the value at a datapoint marking the presence of lava 4 (LFA 4) in the LFA-4 grid became 4.999, while the value at the same location in the LFA-3 grid became 3.001. The psuedo-probability components of the grid values (value after the decimal point) for each of the LFA grids were then programatically compared at each grid cell. The integer with the highest value was then assigned to the respective grid node to create a composite pseudo-indicator grid.

As an example, consider a scenario with 5 volumes with grid values at a single i,j,k grid cell in each initial grid defined as: L1 = 1.355, L2 = 2.882, L3 = 3.019, L4 = 4.227, and L5 = 5.538. In this example, the L2 volume would “win” the comparison, and the corresponding i,j,k value in the composite psuedo-indicator grid would be set to 2.



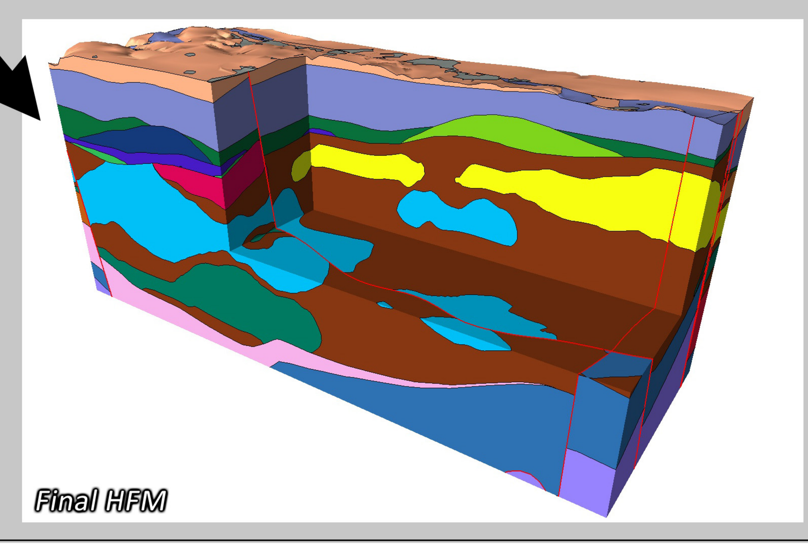
This example shows the pseudo-indicator grid of Lava 4 for a single fault block in the final HFM.



This example shows the pseudo-indicator grid of Lava 3 for a single fault block in the final HFM

After the composite grids were produced, individual pseudo-indicator grids were extruded as shown above. The automated process cycles through each of the volumes, and assigns a -1 where the corresponding integer occurs in the composite indicator grid and a 1 where the integer is absent. These grids became inputs to the final HFM. The respective LFAs occur in the HFM where the pseudo-indicator grid contains negative values, and the zero contour of the input grid defines both the unit surface and extent of the LFA volume.

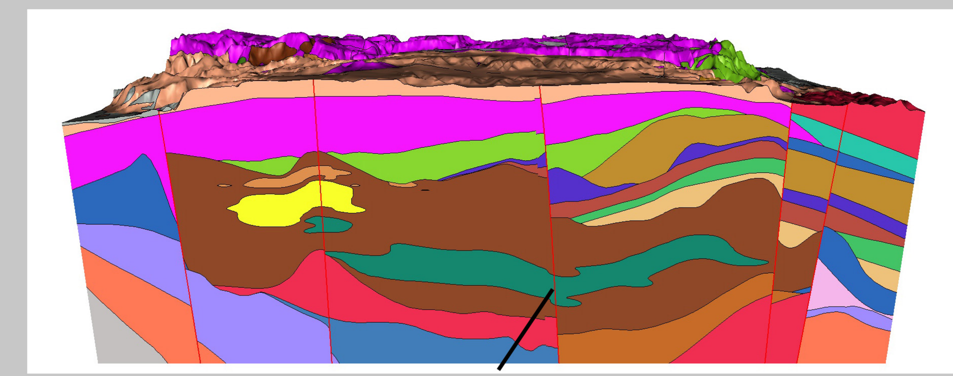
The process produced volumetric models of the LFAs that conform to both the hard data (borehole contacts) and the geologist’s interpretations of shape and extent, and the entire process was automated such that the LFA volumes could be modified easily to adapt to evolving interpretations.



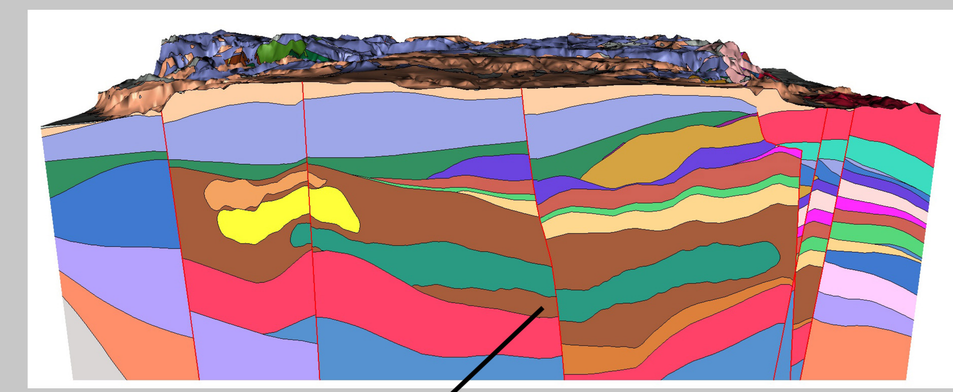
Model Construction - Process (Cont.)

Conformal vs. Non-Conformal Gridding

Earthvision offers several property gridding options and the ability to fine-tune the appearance and continuity of the grids relative to the containing zone. Conformal gridding can be applied as top-conformal, bottom-conformal or both, meaning that the grid conforms to the top or bottom of the surface of the containing zone and fault offsets. In the non-conformal option, the property is contoured with no consideration to the containing surfaces.



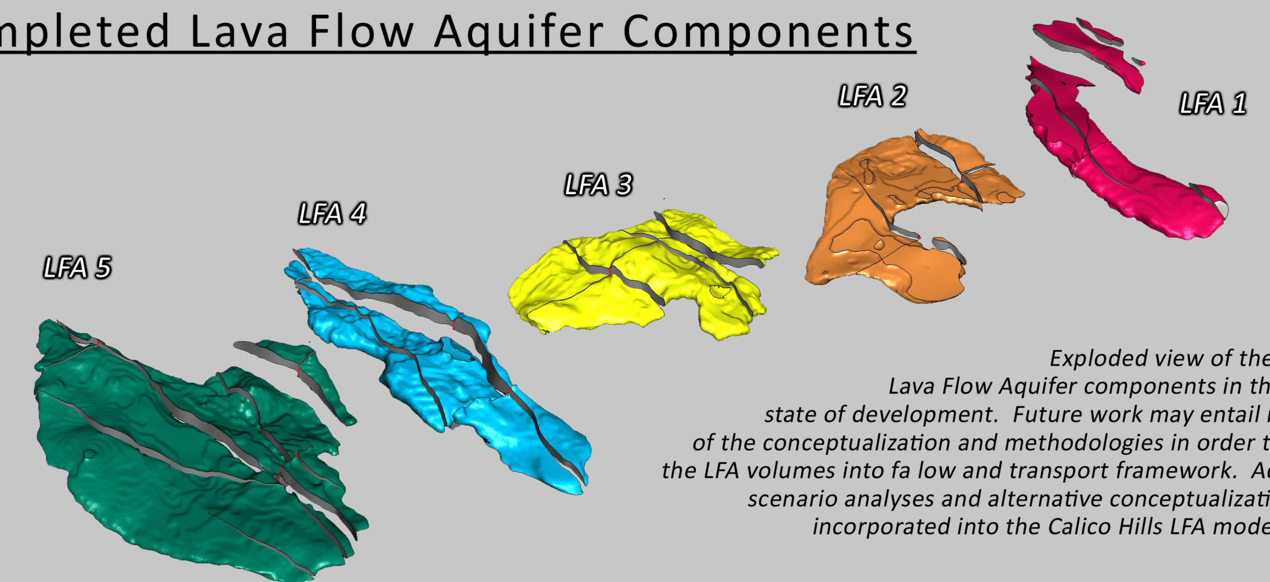
Fault offset is not preserved in the Phase I HFM non-conformal example.



Conformal gridding preserves fault offsets in the Phase II HFM example.

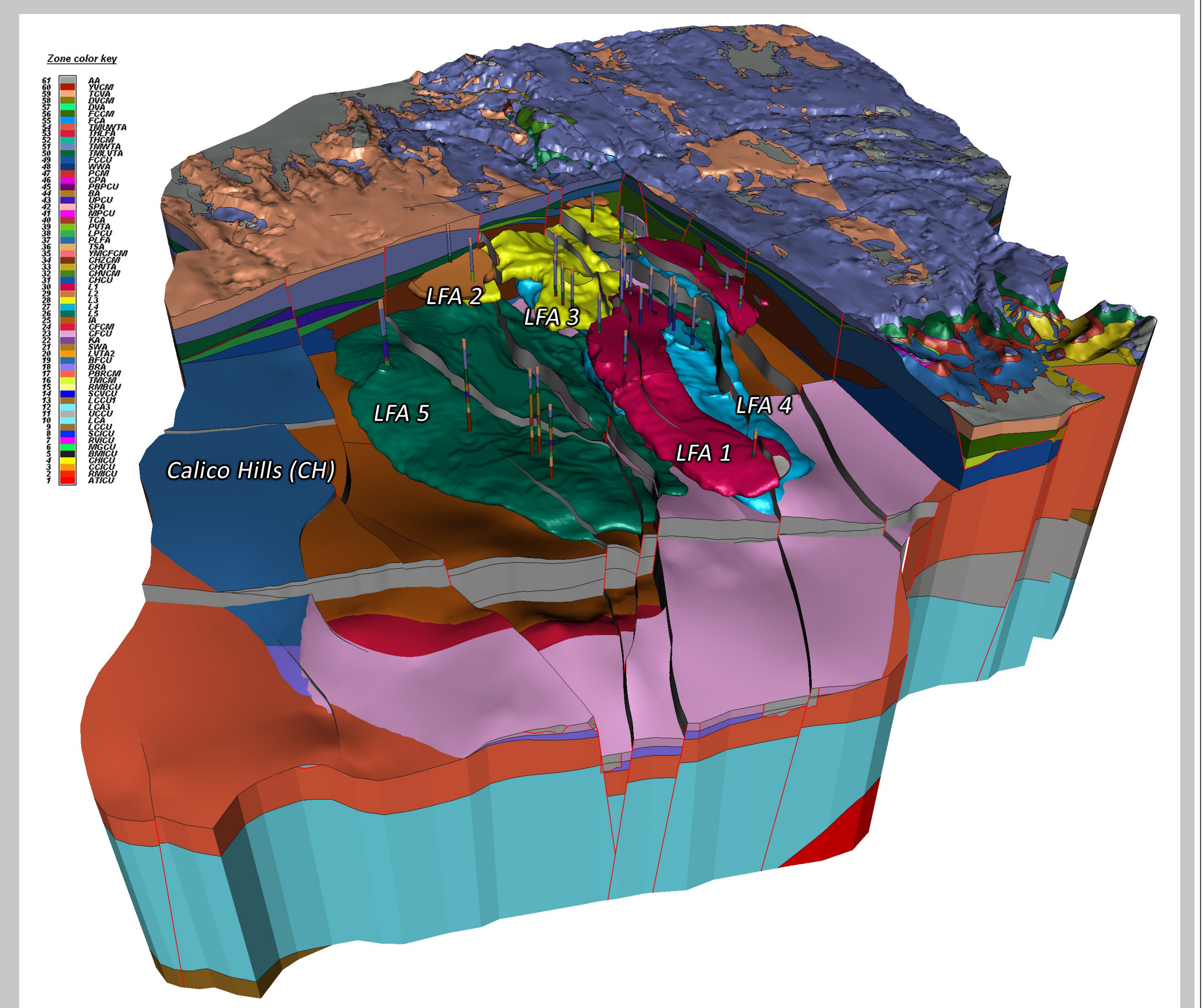
After reviewing many different possible configurations of gridding options, it was determined that the most realistic rendering of the LFA volumes was produced by using the top and bottom conformal gridding scheme with a grid spacing of 50 meters in the x- and y- directions, 4 meters in the z- direction, and a z-influence of 0.05, which enhanced lateral continuity.

Completed Lava Flow Aquifer Components



Exploded view of the individual Lava Flow Aquifer components in their current state of development. Future work may entail refinement of the conceptualization and methodologies in order to translate the LFA volumes into fa low and transport framework. Additionally, scenario analyses and alternative conceptualizations will be incorporated into the Calico Hills LFA modeling effort.

Completed Hydrostratigraphic Framework Model with LFAs



Reference

Slate, J.L. and Oters, 1999. Digital geologic map of the Nevada Test site and vicinity, Nye, Lincoln, and Clark Counties, Nevada, and Inyo County, California. U.S. Geological Survey, Open-File Report 99-554-A. Prepared in cooperation with the Nevada Operations Office, U.S. Department of Energy, Interagency Agreement DE-AI08-96NV11967.