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Crusta: Visualizing High-resolution Global Data

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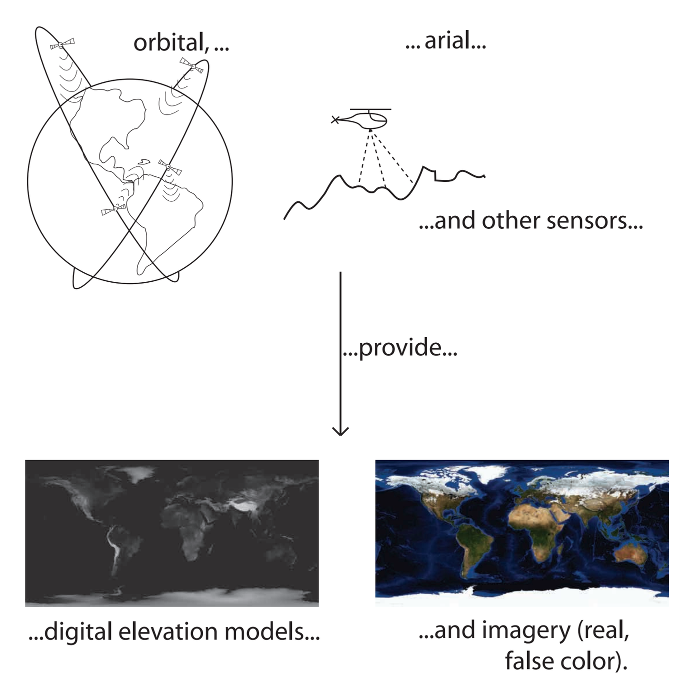
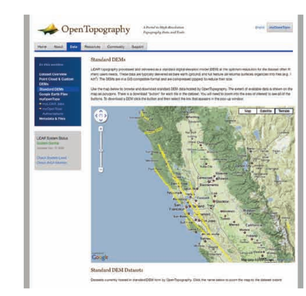
UC DAVIS KECKCAVES W.M. Keck Center for Active Visualization in the Earth Sciences

1 Motivation

(A) High-quality surface data is acquired

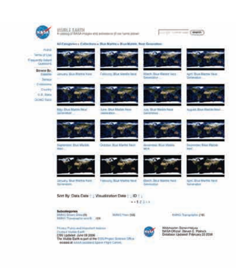


(B) Data is quickly and easily available



OpenTopography Portal:
- 0.5m and 1m resolution DEM
- regional extent
- active data recovery missions

NASA Visible Earth Portal:
- 30 arcsecond DEM
- 15 arcsecond true color images
- global extent



(C) We need a virtual globe that can:
1. Easily integrate global digital terrain data
2. Provide fast and powerful visualization

Main features of Crusta and GoogleEarth

Crusta:	GoogleEarth:
- custom **topography**	- global data
- custom imagery	- high resolution imagery
- high resolution	- pre-loaded GIS data
- fast navigation	- area mapping
- dynamic surface shading	- easy measurement

W.M. Keck **Center for Active Visualization in the Earth Sciences**

KECKCAVES

What is KeckCAVES?

Goals: Use interactive visualization to:

www.keckcaves.org

Accurately delineate features in remotely acquired data
- Interactively map small structures over large spatial scales
- Characterize complex structures

Integrate diverse datasets into models
- Develop a Virtual California for earthquake forecasting
- Precisely represent dynamic processes in the deep Earth

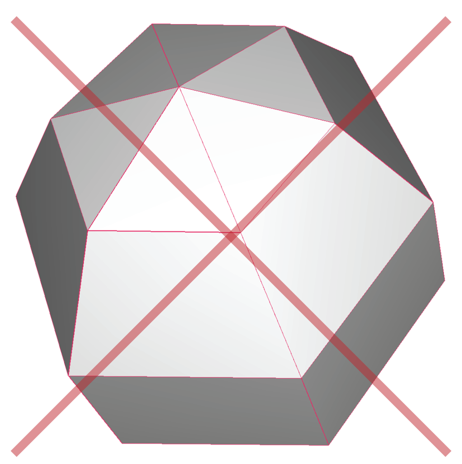
Interact with dynamic models
- Simultaneously adjust, run and visualize numerical experiments
- Interactively explore rare events

Create complex boundary and initial conditions for models
- Build crystal structures
- Reconstruct the morphology of microbial communities
- Build models of faults

The centerpiece of KeckCAVES is a Mechdyne CAVE immersive visualization system that was installed in the UC Davis Department of Geology in April 2005. It has been fully functional since before the installation team left. We currently have several highly interactive visualization applications for a variety of earth science problems, and are in the process of developing more.

2 Global data representation

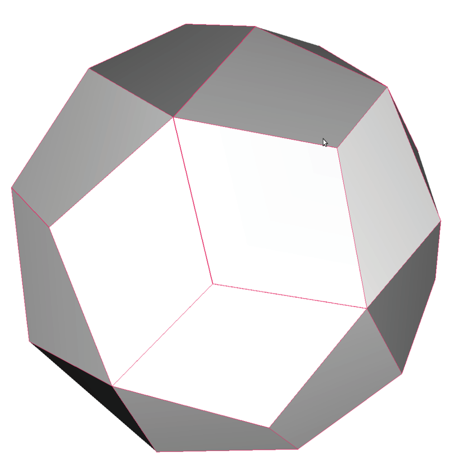
(A) Chose appropriate globe approximation



30 Lat/Lon cells. as 5 latitude divisions and 6 longitude divisions. Longitude lines converge at the poles.

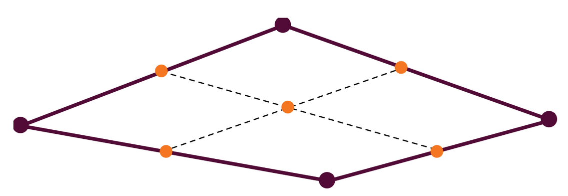
For efficient, real-time data visualiztion on a global scale the underlying data representation should provide following characteristics:
- A globe parametrization that *avoids singularities* (e.g. poles).
- A parametrization that *minimizes distortion*.
- A data structure that accommodates a *wide range of data resolutions* and *sparse coverage*.
- Efficient *localized* data access.

We chose a base Polyhedron with 30 equal-area and same-shaped faces, the rhombic triacontahedron. It drastically reduces the effect of distortions. The four-sided faces are amenable to quadtree refinement. The acute angles are 63.43 degrees on a face, thus, each quad can be split into two almost equilateral triangles for rendering.

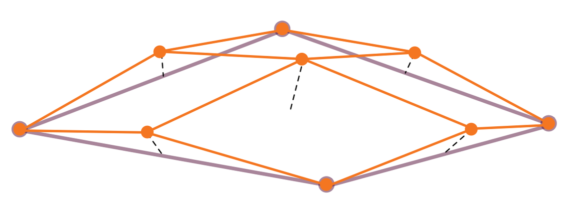


30 rhombic faces of the triacontahedron.

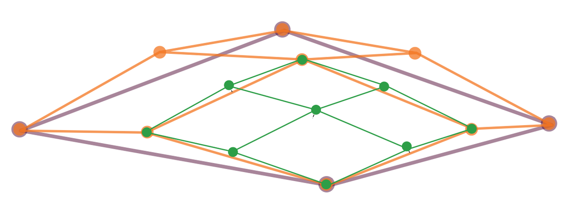
(B) Support a wide range of data resolutions



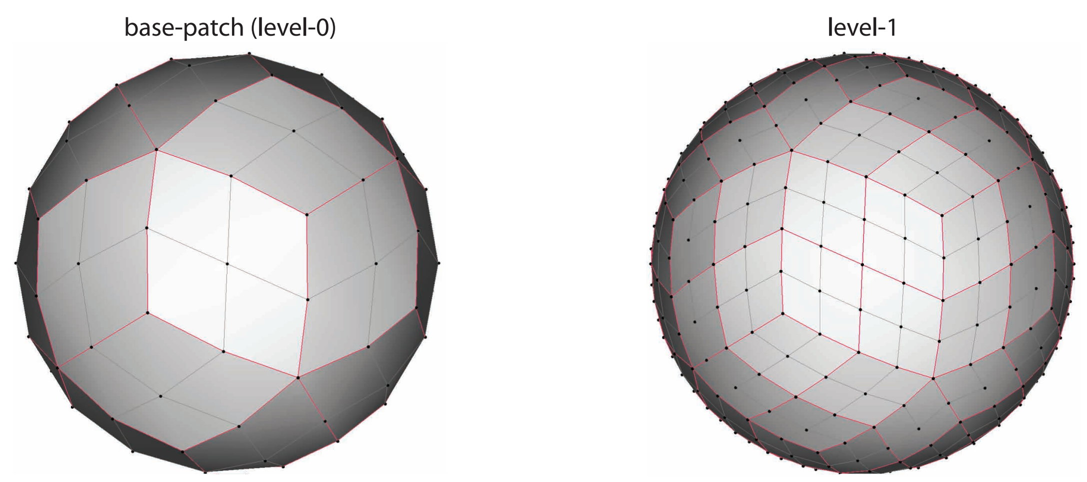
We start with the four vertices of a parent tile. The new vertices of the four child tiles are computed as the linear mid-points between each pair of edge-vertices and the centroid.



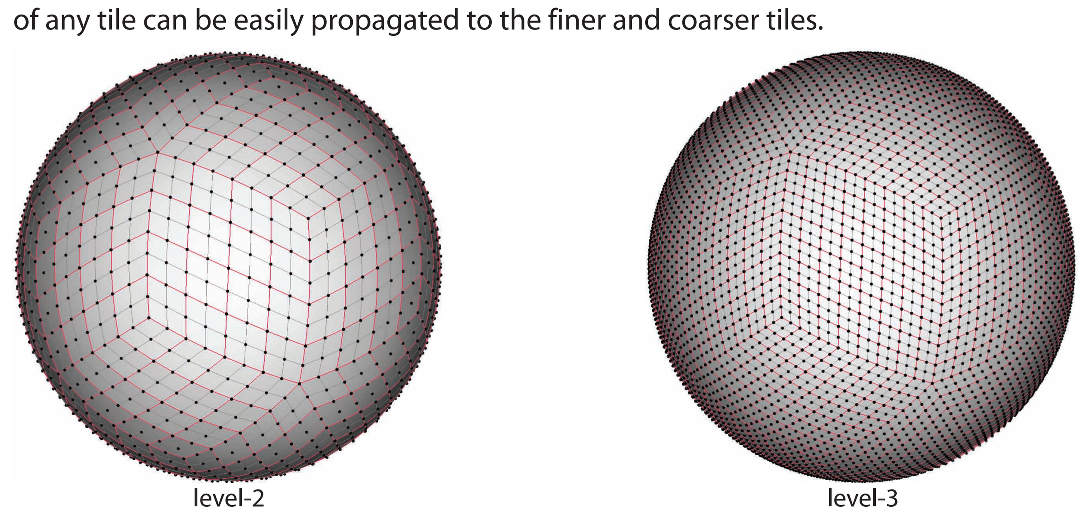
The new vertices are then projected onto the surface of the spherical globe by means of radial extrusion. The vertices of the parent tile can be directly used as a corner in each child tile



The process can be recursively applied to the newly created tiles, increasing the surface sample desnsity with each step. Any tile in the hierarchy can be independently refined, enabling a localized, sparse, multi-scale data representation.

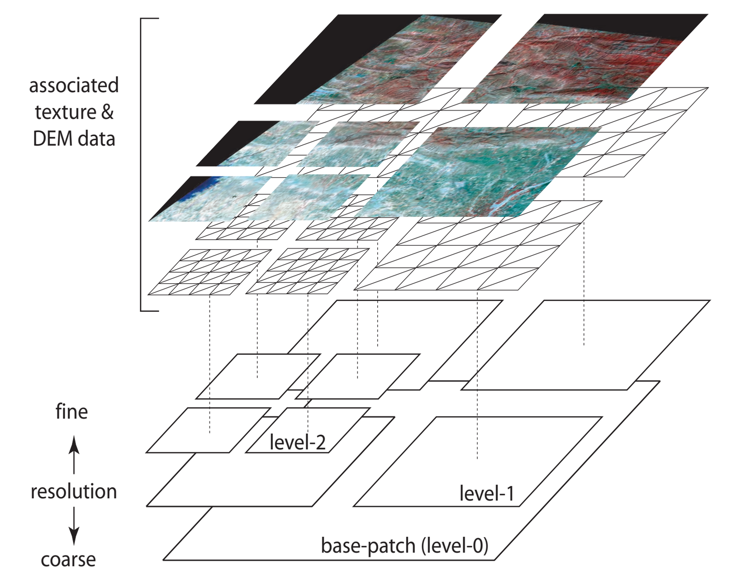


The refinement, here with a 3x3 sample sample resolution per tile, is a recursive scheme that can easily be computed on-demand. The hierarchies are fully determined by the sample resolution and the vertices of the base-patches. Coverage between different Crusta data hierarchies is, thus, implicitely defined independently of the data resolution of the specific hierarchies.
Within the parametrization of a base-patch tree, the relation between the samples of a parent tile (coarser) and a child tile (finers) is straight-forward. Updates to the data of any tile can be easily propagated to the finer and coarser tiles.



(C) Map data onto base-patch hierarchies

Digital terrain data is typically resolved at a given resolution. To map it to the multi-scale crusta globe we:



Multiresolution terrain representation within a base patch

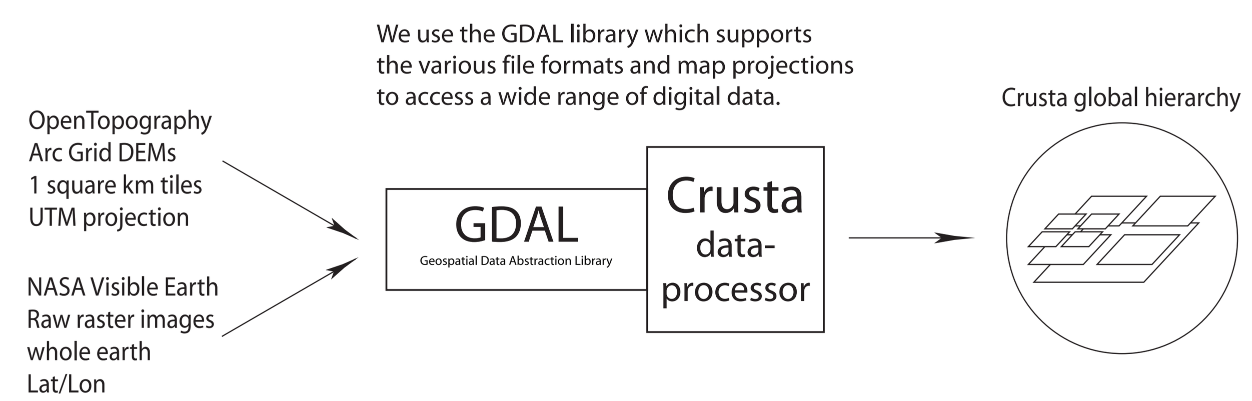
1 Determine covered base-patches. These are the roots (coarsest resolution) of affected hierarchies.

2 Refine base-patches. Each patch is refined until the spacing of the surface sample points can properly resolve the data.

3 Map finest tiles. Each sample of the finest resolved tiles is mapped into the data domain and the corresponding value is recorded.

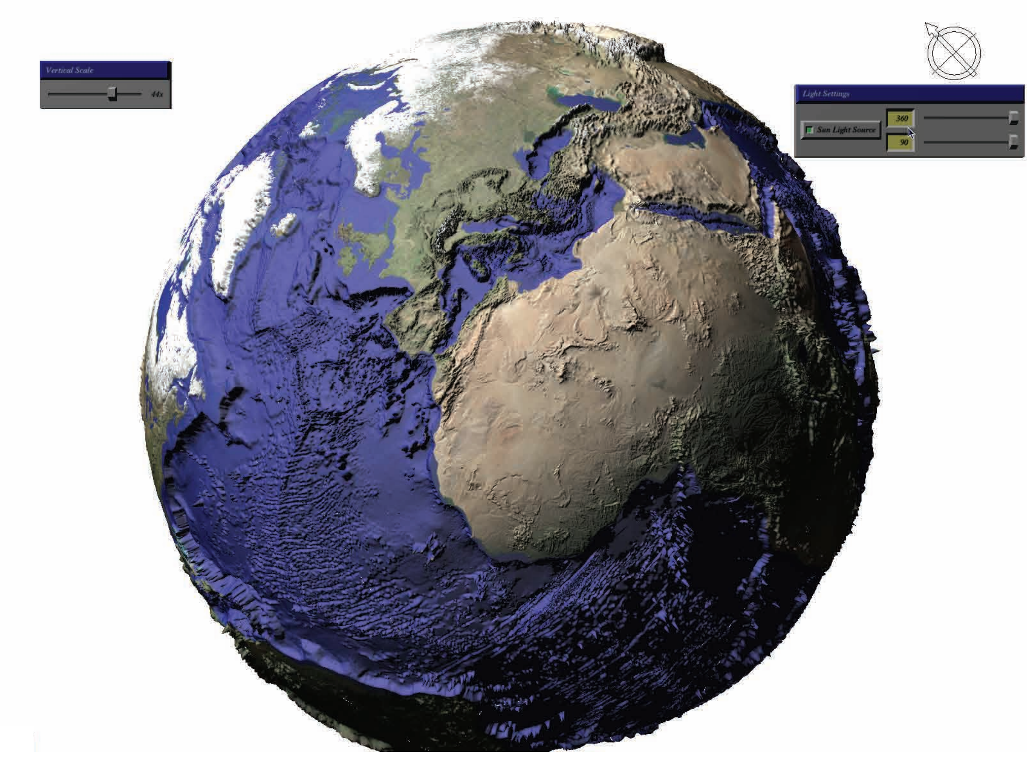
4 Subsample fine tiles. Combine the data of four fine tiles to produce the half-resolution data needed for the parent. Recursively, this step populates the coarser tiles with the appropriate data.

(D) Easily incorporate digital data



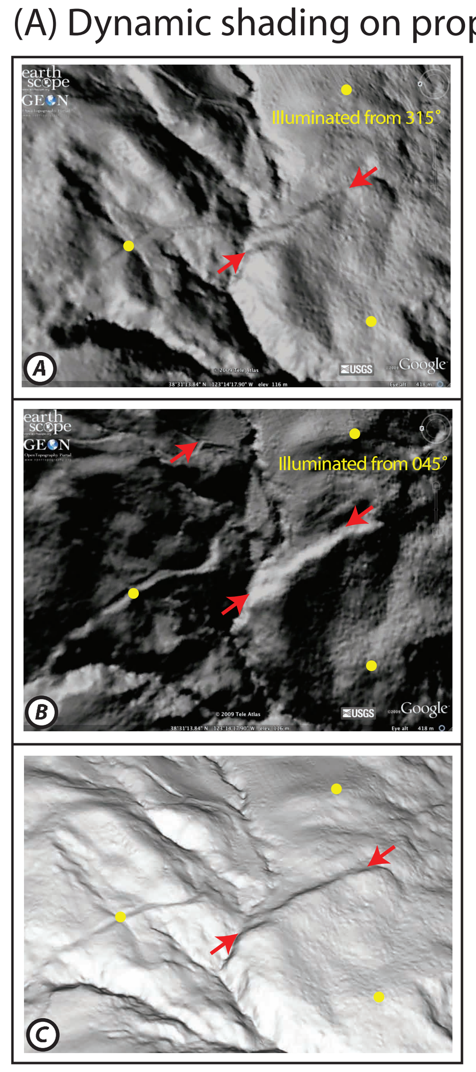
(E) Visualize using vertical exaggeration and shading

Exploiting the multi-scale representation of the data, approximations of the terrain are produced based on the viewing parameters to enable the real-time visualiztion.
We enhance the visualization further by allowing the terrain mesh to be distorted (vertically exaggerated) as well as shaded on-the-fly. We've found these features to greately enhance the perception of shape.



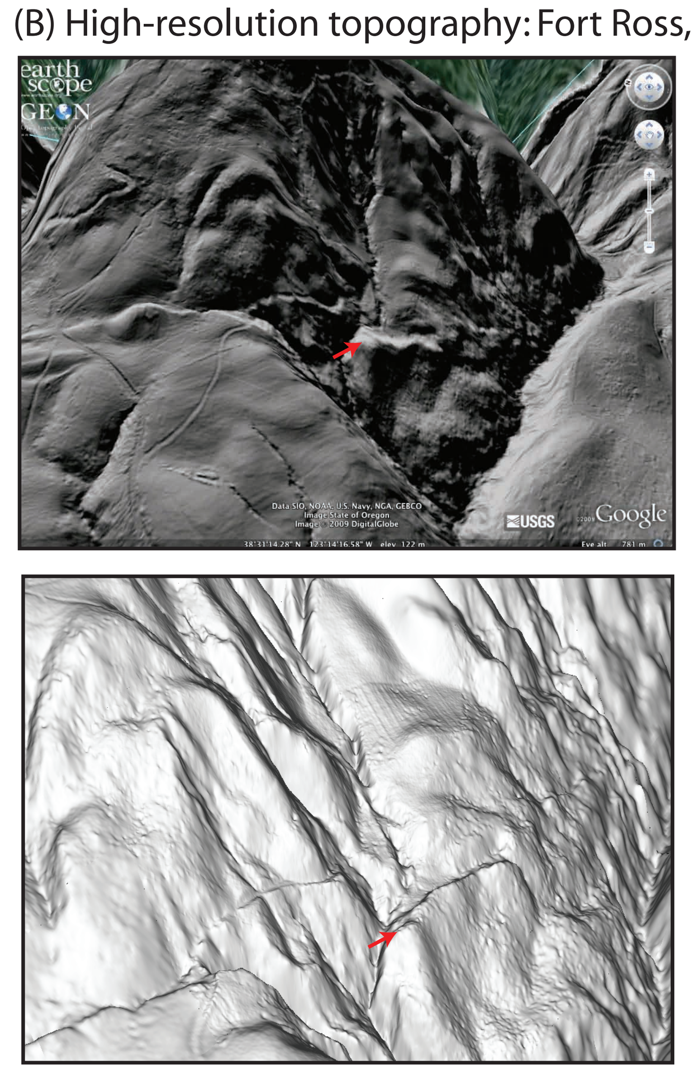
3 Using Crusta: visualizing high-resolution GeoEarthScope LiDAR digital elevation models (0.5m to 1m pixel resolution)

(A) Dynamic shading on properly resolved topography: Fort Ross, California



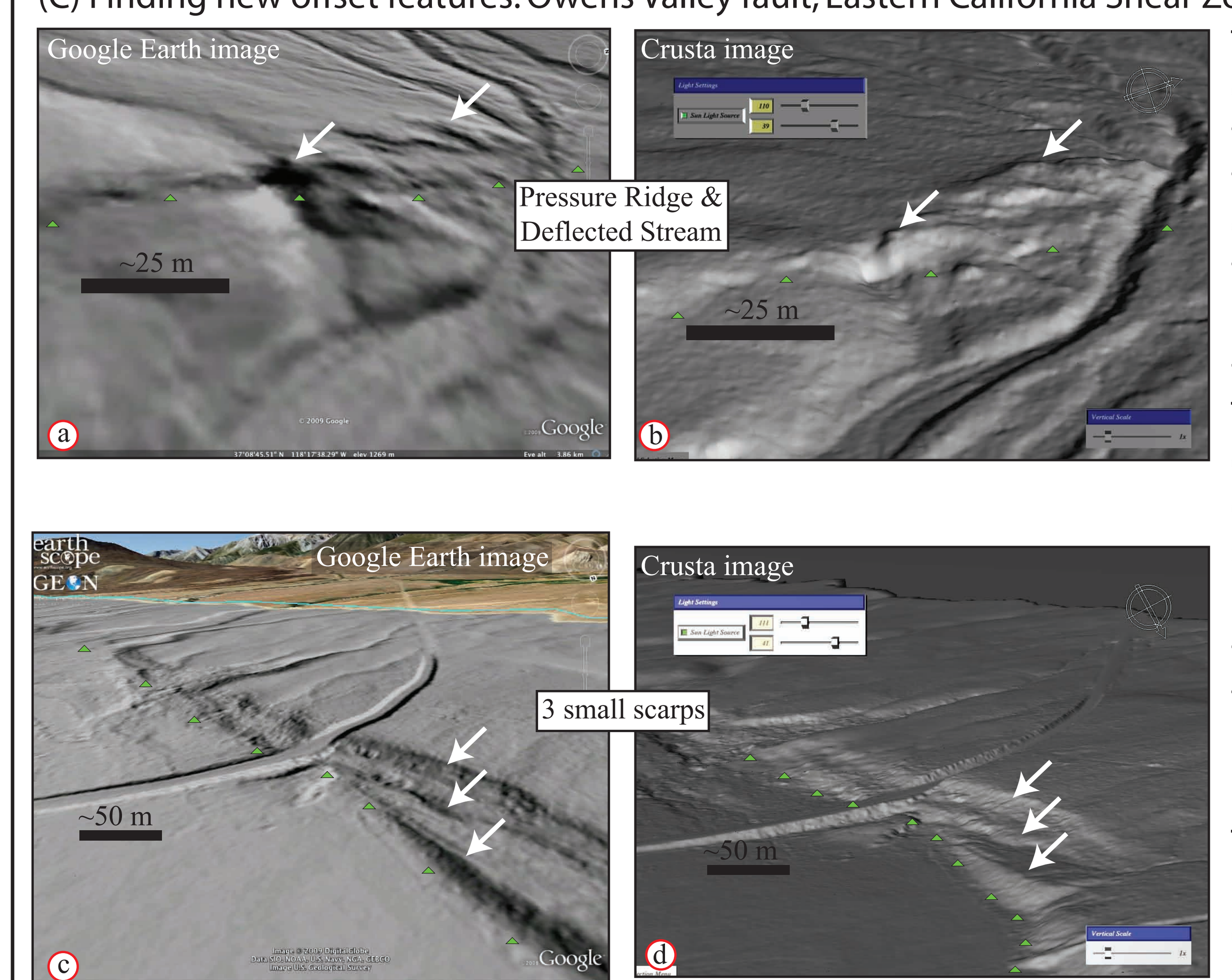
The screenshots reveal an uphill-facing scarp that defines the active trace of the San Andreas fault in this area. It is useful to note that it is on the basis of geomorphic details such as this scarp that neotectonic geologists identify and map active faults. In detail the figure provides a comparison of the preprocessed hillshade images draped over a lower-resolution digital elevation model in Google Earth (A and B) with the visualization of the true elevation data with a dynamic lighting source provided by Crusta (C). As the illustrations demonstrate, it is considerably easier to locate and map the trace of the fault using the Crusta visualization. Besides the dominant scarp, it is also much easier to see subtle topographic features within Crusta for two reasons. First, features are not hidden by shadows, as they are in static relief-shaded images. Second, the surface in Crusta is not a texture draped over lower-resolution topographic data as in Google Earth, but rather a dynamically lit surface that is created directly from the high resolution topographic data.

(B) High-resolution topography: Fort Ross, California



The same area as in (A) except with a three-fold vertical exaggeration in both Google Earth and Crusta. Because of the low-resolution of the underlying topographic data in the Google Earth visualization, the uphill-facing scarp becomes diffuse at this scale. The texture that is draped over the digital elevation model is also stretched out which could result in misleading interpretation. By contrast, because Crusta uses the high-resolution digital elevation model, the scarp becomes a prominent feature when it is vertically exaggerated, allowing it to be more clearly distinguished.

(C) Finding new offset features: Owens Valley fault, Eastern California Shear Zone



The Owens Valley fault is an active dominantly right-lateral fault with a component of oblique normal slip. Of interest is the contrast between the recorded geodetic rates of ~2 to ~7 mm/yr and the geologically determined slip rates of ~1 to ~4 mm/yr. Finding new offset features and corresponding geologic slip rates may help explain the discrepancy between the geodetic and geologic slip rates.

(a) and (b) reveal a probable pressure ridge and deflected stream along the fault with 1x vertical exaggeration in both Crusta and Google Earth. The feature is obvious in Crusta, but within Google Earth there are no recognizable features that suggest a pressure ridge besides the shadow outline. The prominent drainage that is easily distinguished in (b) is obscure and hard to recognize in (a).

In (c) and (d) three small (< 5m) scarps record the normal movement of the fault. Again, the shadow outlines are the only distinguishing marks for these features in the Google Earth display (c); there are no clear breaks in slope. In comparison, the Crusta display (d) reveals obvious breaks in slope and scarps are easily identified.

The comparison illustrates how the dynamically shaded visualization using Crusta readily exposes such features critical in researching evidence of previous ruptures along the Owens Valley fault.