

An analysis of the canyons in the Toutle River.

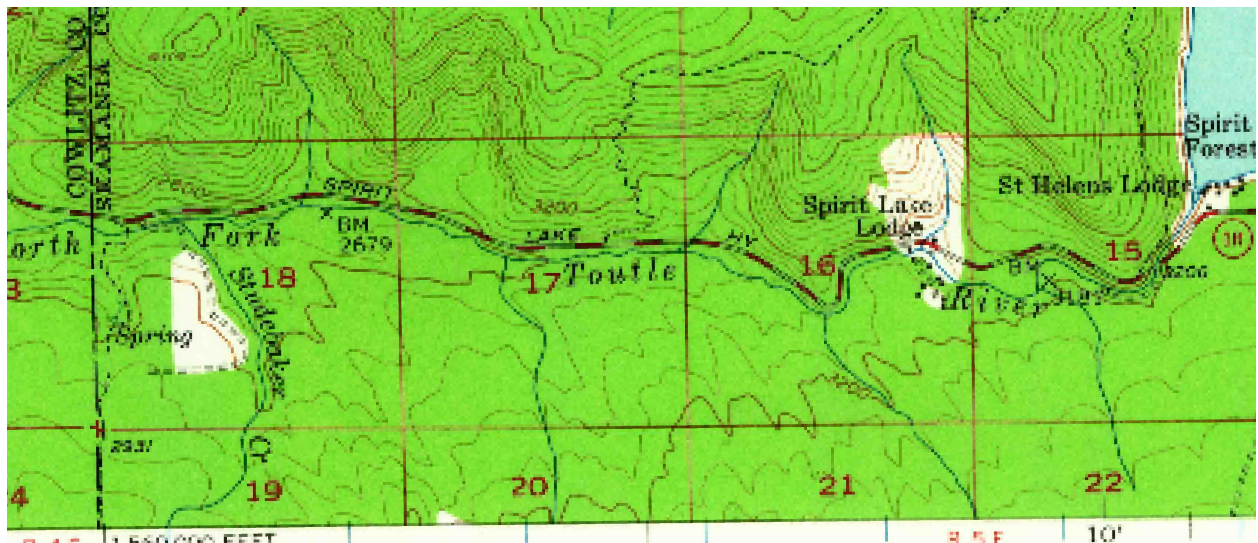
by Edmond W. Holroyd, III, Ph.D.

My background includes a B.S. in astrophysics, Ph.D. in atmospheric science, and continuing education in geology. I have been teaching graduate courses in remote sensing since 1999.

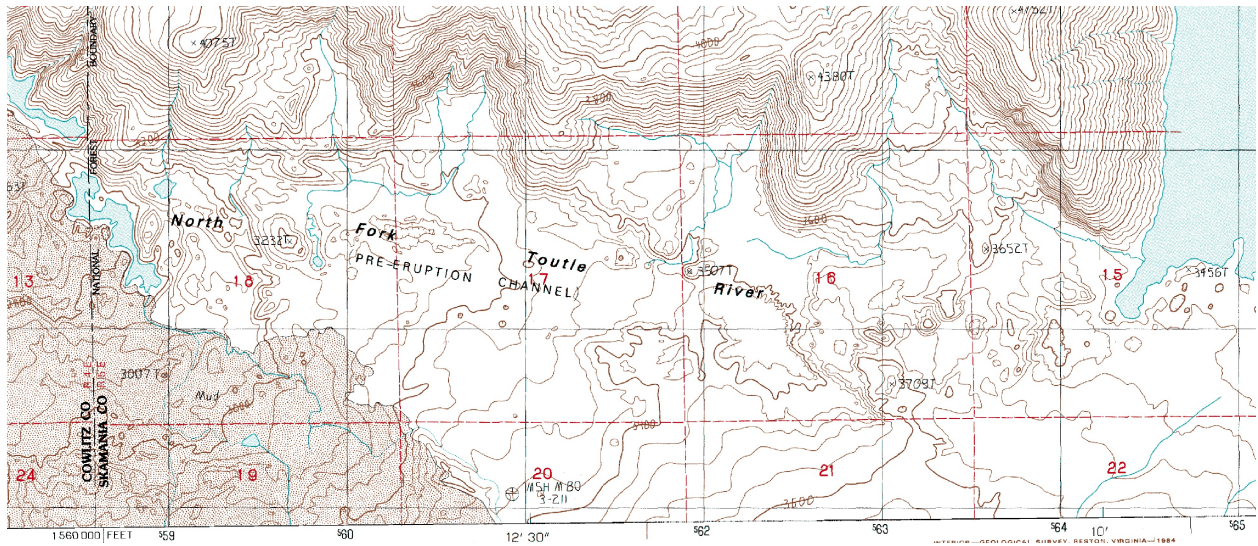
I was asked by Bob Enyart to examine comments related to his web site regarding Mt. St. Helens. I was provided a long set of comments from “Keith” and a short comment by “David”. I was also provided the GSA Field Guide 15 (2009) by Steven A. Austin and his Hiking guide of August 4, 2012. I skimmed those sources initially to see the general questions. Then I accumulated maps and remote sensing imagery to become familiar with the headwaters of the Toutle River where canyons were formed in 1982.

I defined an area of interest (AOI) 3 x 7 km in size extending between UTM zone 10N coordinates from 5122 to 5125 km North and from 558 to 565 km East. (NAD83 datum). For some image products I used 1 meter resolution within this area for the analyses. Many products were downloaded from Internet sources, such as USGS web sites. The topographic quadrangles were named Spirit Lake and Spirit Lake West.

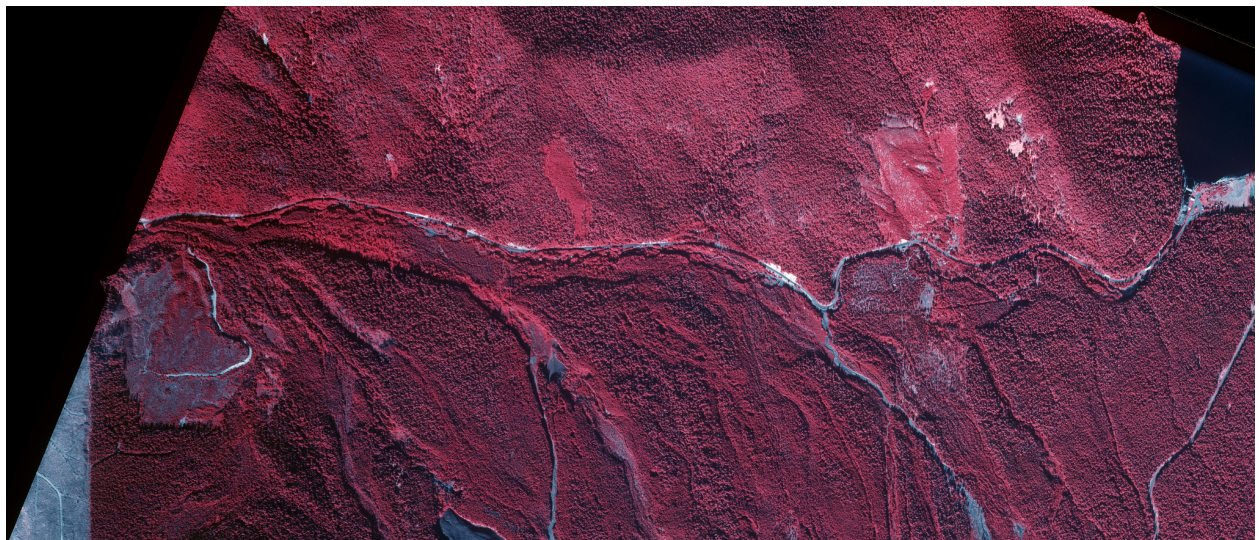
The 1957 topographic quadrangle was based on 1952 aerial photography, field checked in 1957. Its scale was 1:62,500 and the contour interval was 80 feet. The contours were traced and converted into a digital elevation model (DEM) using the TNTmips software to compare elevation differences. The AOI looked like this:



The 1984 provisional topographic quadrangle was based on 1980 aerial photography, field checked in 1981. Its scale was 1:24,000 and the contour interval was 40 feet. The contours were traced and converted into a digital elevation model (DEM) using the TNTmips software to compare elevation differences. The AOI looked like this, though more detail is visible in the original:



Aerial photography of 3 October 1973 was obtained as scanned stereo imagery by USGS, originally on 9 x 18 inch film at scale 1:31,000. The scanned resolution was 0.43 m. That view:

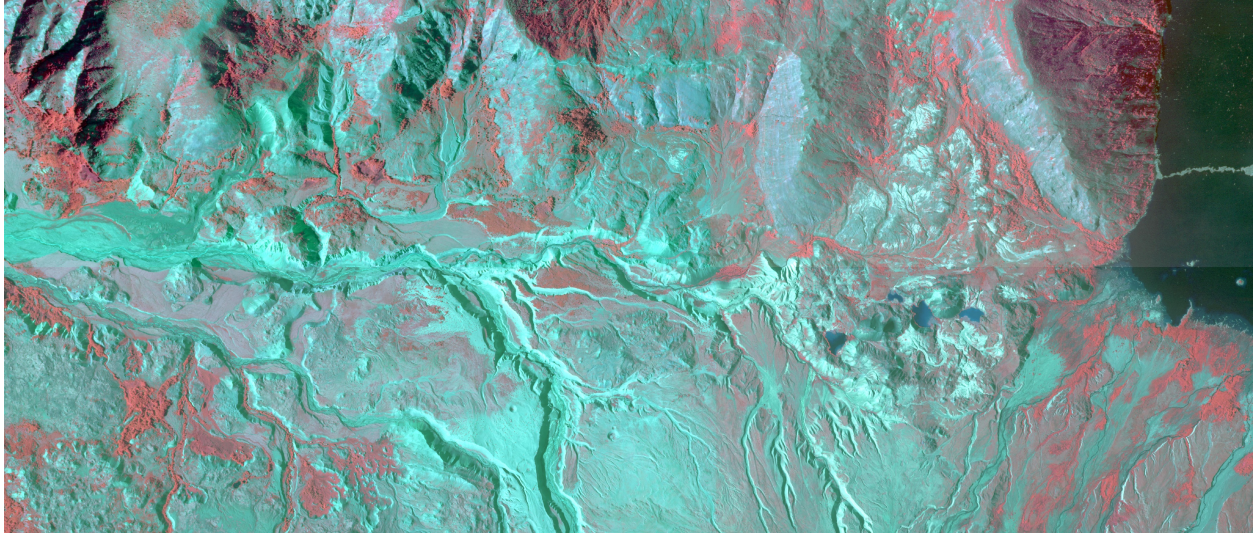


This is false-color infrared imagery. Red tones indicate healthy green vegetation. The black at the left and in the extreme upper right are beyond the photo frame edges. Otherwise the black in the upper right is the old Spirit Lake. The stream channels are visible along with some roads.

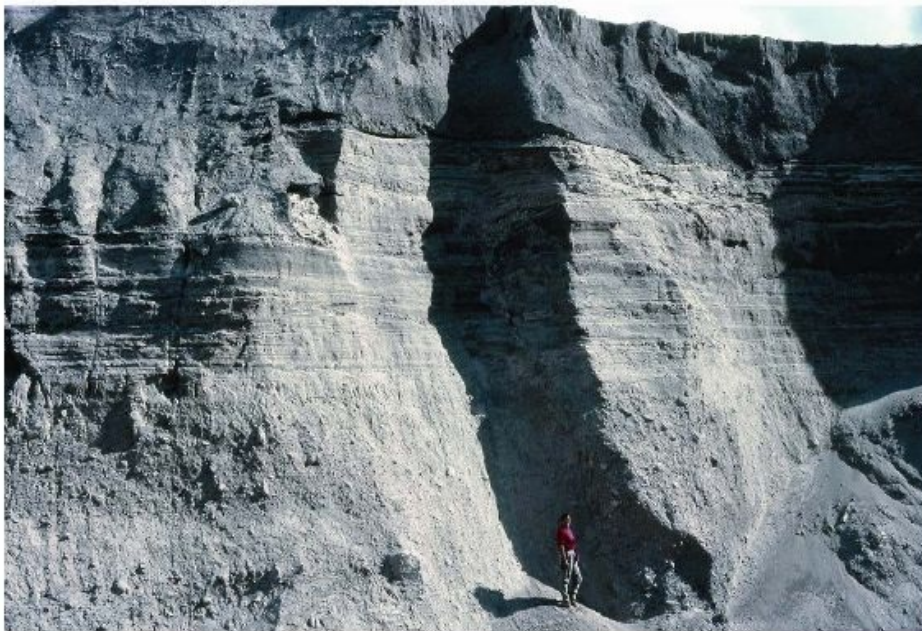
The first objection of Keith and David is about “solid rock” being eroded quickly. Keith uses the words “loosely consolidated” and quotes “unconsolidated”. David refers to Attenborough’s demonstration that the surface is “simply ash and dust” “which he can easily carve with one hand”. David says that the demonstration intent was to show that “plants have a tough time getting started in such a surface, since it’s too loose for their roots to get much of a grip”.

The entire AOI was blanketed with volcanic ash and rock debris to a significant depth, so plant regrowth in the lowlands would not be coming up from roots and seeds that existed before the first eruption. Any plant growth on deep deposits had to start at or near the new surfaces. The

next image shows the regrowth pattern in the AOI as of about 16 August 2011 from false color infrared orthoimage aerial photography obtained from USGS. There is some apparent tree and shrub regrowth in areas receiving only thin coatings of volcanic ash. There is much pink tone in the lowlands showing new plant growth on top of the new surfaces. So the concern about roots not getting much of a grip is invalid. The cyan (light blue) areas are barren.



On page 7 of Austin's Hiking guide is this illustration and caption:



Strata within "Little Grand Canyon" at the top of the western wall at Station 7. Lower third is the air-fall tephra from May 18, 1980. Middle third is pyroclastic flow deposit of June 12, 1980. Upper third is mudflow deposit of March 19, 1982.

Note the nearly vertical cliffs of the three deposits. The materials have significant structural integrity. The lower layers had nearly two years for the materials to settle and compact before the top layer was added and the canyon was cut. Precipitation draining through these layers likely contributed to rearrangements of sediment grains, resulting in increased

stability. The fresh ash materials may have started alterations from weathering processes and some silicate binding of grains may have begun during the nearly two years.

Nowhere in Austin's articles is "solid rock" mentioned. He does mention in the Field Guide that "stability is also enhanced by the armoring of the bed by accumulation of coarse particles resulting in part through winnowing of finer sediment."

In July of 2010 and 2011 I was stationed at Xining, capital of Qinghai Province in western China. The region has loess deposits exceeding a kilometer in thickness. The material is easily crumbled by hand and eroded by water, yet would be considered to be "solid rock". Here is a photo showing a white pebble layer within the deposit. The front surface has been carved by mechanized equipment, resulting in the vertical scratches. The surfaces on the left were carved by natural stream erosion and soil creep from precipitation. The consistency of the materials in this deposit may have similarities to the volcanic ash. Terracing is needed for agricultural activities in this area to limit further erosion.



Sugar comes in several forms: grains, cubes, hard candies.



While the Toutle River deposits are not hard rock in the sense of the hard sugar candies they are firm like the sugar cubes

and not loose grains like those in the teaspoon. There has been some consolidation of the volcanic material. It appears that the two critics are properly reacting against a "solid rock" description that they have found somewhere, being analogous to the hard candies. They err in the other direction by appearing to describe the deposits as having a consistency like the sugar grains in the teaspoon.

Keith refers to soil layers in the stratigraphic record. They do not apply to the Toutle River deposits. The discontinuities are clean and distinct.

Keith tries to minimize the depths of the erosion channels. Of course the plateau areas have had minimal erosion during the 1982 event as the canyons were being carved. He attributes the erosion of Engineers Canyon to the pumping of water from Spirit Lake. Austin writes that the pumping was from November 1982 to April 1985. So the "single day" for the formation of Engineers Canyon is unlikely to be correct. However, it could be correct for all of the other canyons in the system. They resulted from the mudflows starting March 19, 1982.

An aerial overview of the canyon system, looking westward, is in Austin's Field Guide:

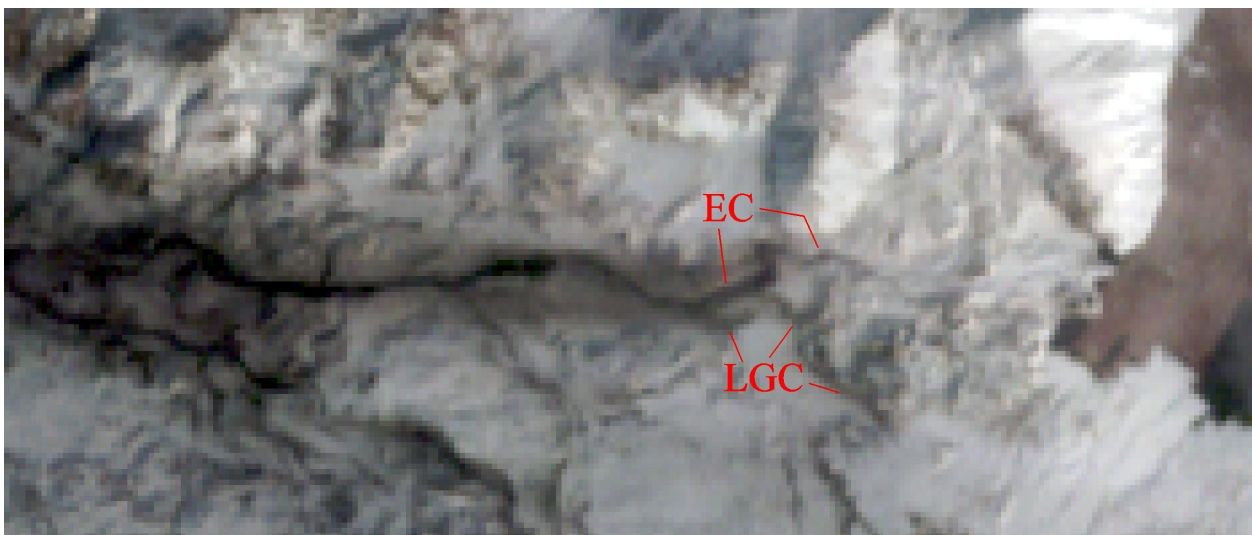


Engineers Canyon is represented by the two 9s at the center right. What Austin calls the “Little Grand Canyon”, 1/40 scale, is represented by the two 8s at the left, draining through the 7 in the middle. Canyon 8 has a different water source from Engineers Canyon and therefore cannot be attributed to the 2.5 years of pumped water from Spirit Lake.

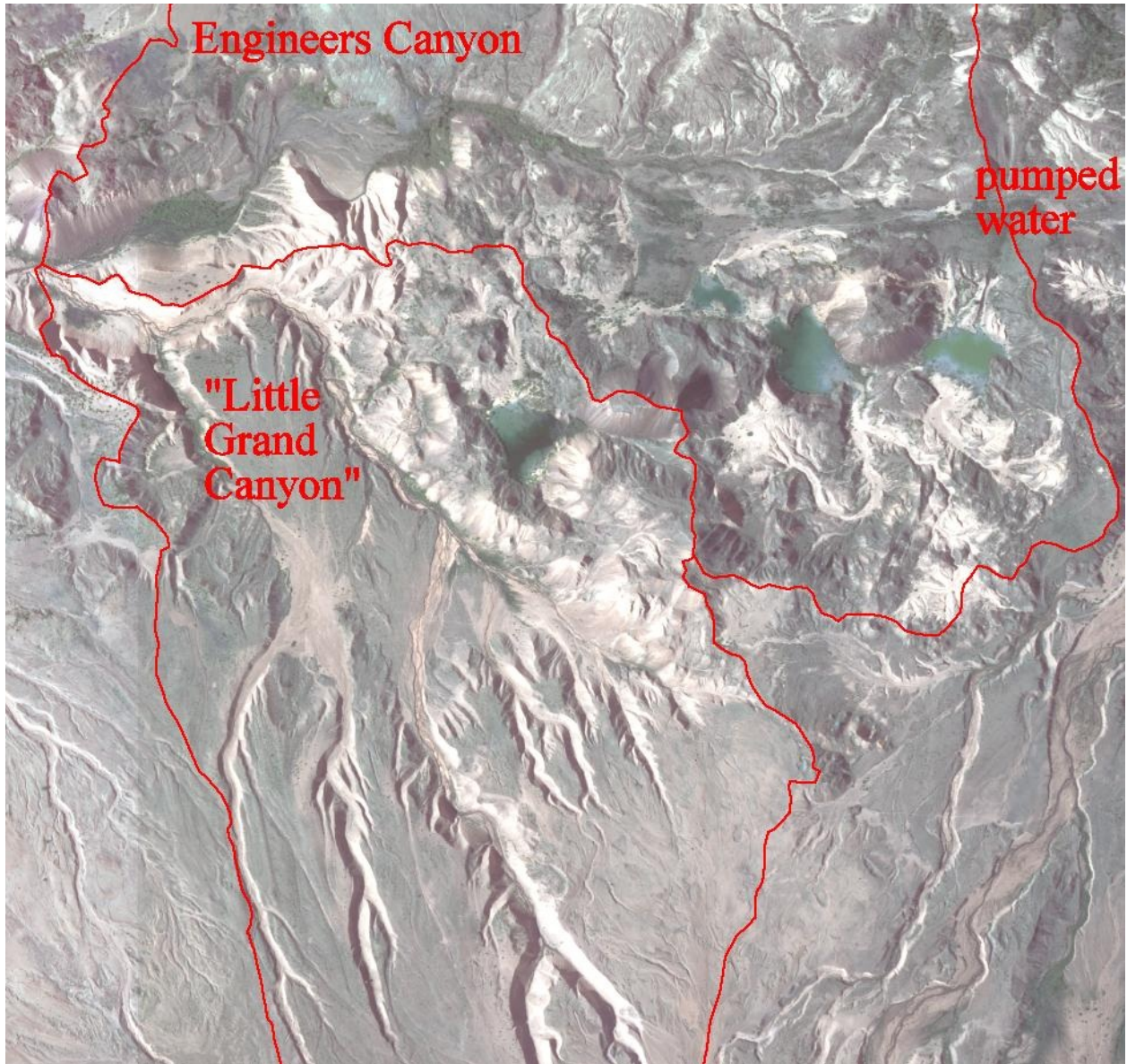


Figure 7. Oblique, low-altitude aerial photo directly above Breached Explosion Pit Overlook (Stop 2, Feature 16) looking westward through the breach. Annotations are explained in the text. Photo by John Pike, September 2008.

A DEM (digital elevation model) was obtained from USGS via the Internet. The data are the finest resolution available, based on 2004 lidar measurements. The natural color version of the 2011 orthophoto image was used for illustration. The TNTmips watershed algorithm was used to compute water flow paths and basin boundaries. The boundaries for the Engineers Canyon watershed and that for the “Little Grand Canyon” are traced in red on the natural color background (next page). The Engineers Canyon watershed extends to the crest of the hills to the north, out of view. That for the other canyon extends towards Mt. St. Helens to the south. A likely location for the pumping pipe crossing of the watershed crest into Engineers Canyon is indicated at the right. The pipe outlet is not known to me. This confirms that the two canyons had different

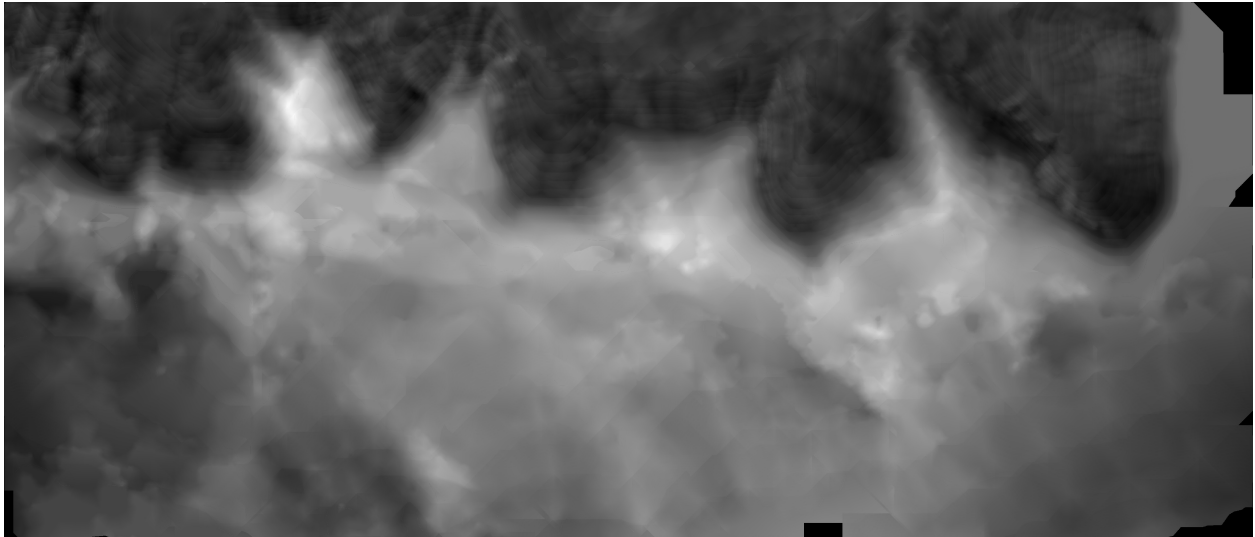


watersheds and that the Spirit Lake water did not carve the southern “Little Grand Canyon”.

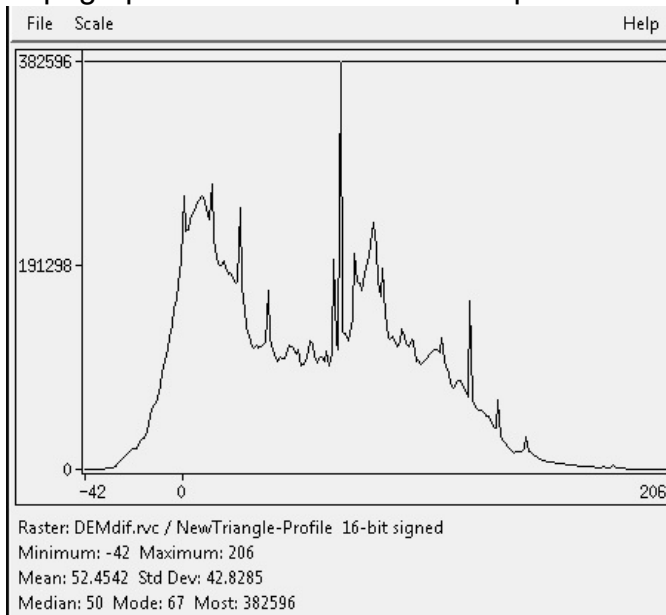


On the previous page is the view of the AOI from Landsat-4 on 29 December 1982. This is the first good view of the area after the March 1982 eruption. Snow covers much of the area. The Engineers Canyon (EC) and “Little Grand Canyon” (LGC) locations are marked. These already existed at the time of this image, and so the continued pumping through 1985 did not carve these canyons, but may have enlarged Engineers Canyon.

The topographic maps from before the main eruption and from before the 1982 eruption were each converted to a DEM for comparison with each other and with the detailed lidar measurements of 2004. The elevation difference resulting from the 1980 eruption was calculated by subtraction of the DEMs based on the topographic maps. The result is presented next as a gray shade image where dark is little elevation change and bright is greatly increased elevation.

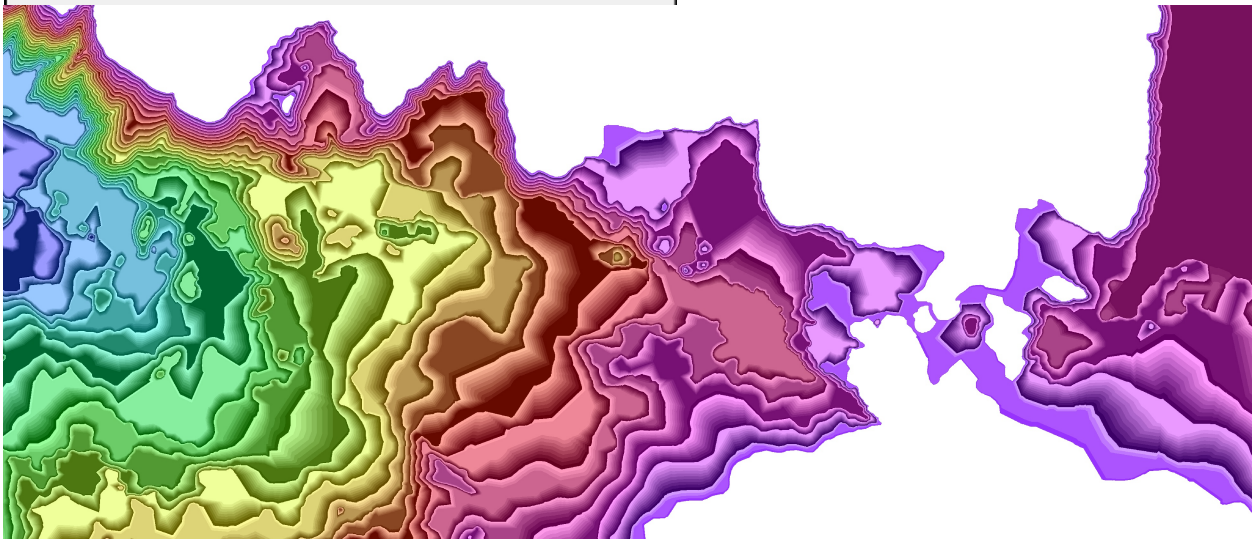


Topographic difference from ash deposits from the 1980 eruption. White is thickest.



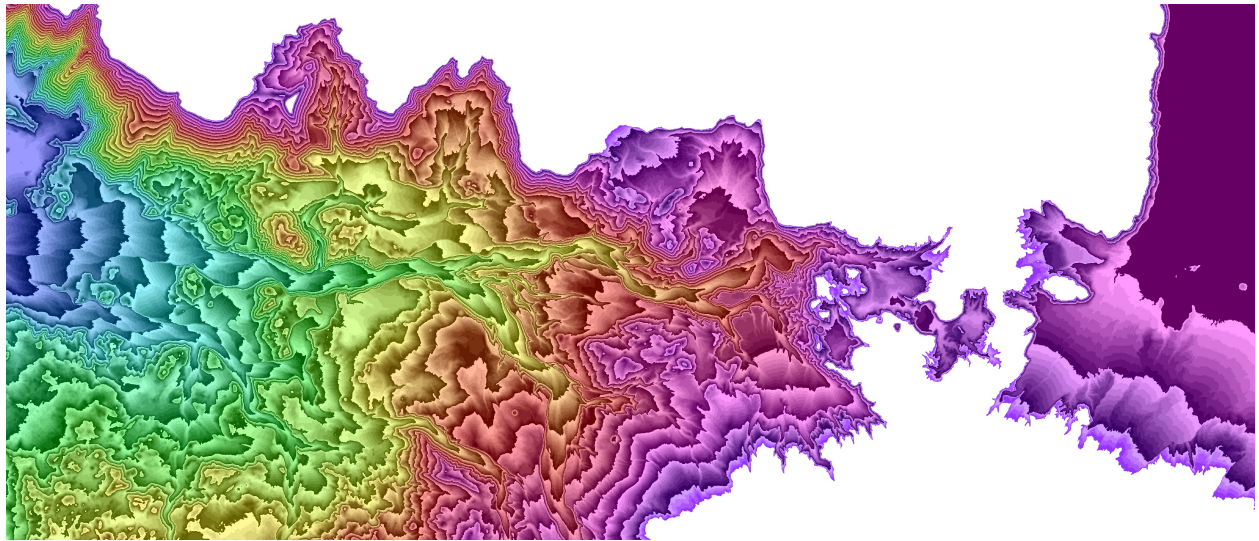
This graph shows the distribution of elevation differences between the two topographic maps. Most of the depth increases are less than 150 meters. The tall spike in the middle is for the Spirit Lake elevation change. The negative values come from the resolution differences between the two maps and the coarse, 80 and 40 foot, contour intervals. The depth increases in the Toutle River valley were great enough so that the 1982 canyon carvings would not reach down to the original surface and any old hard rock layers.

The DEM for the topographic map after the



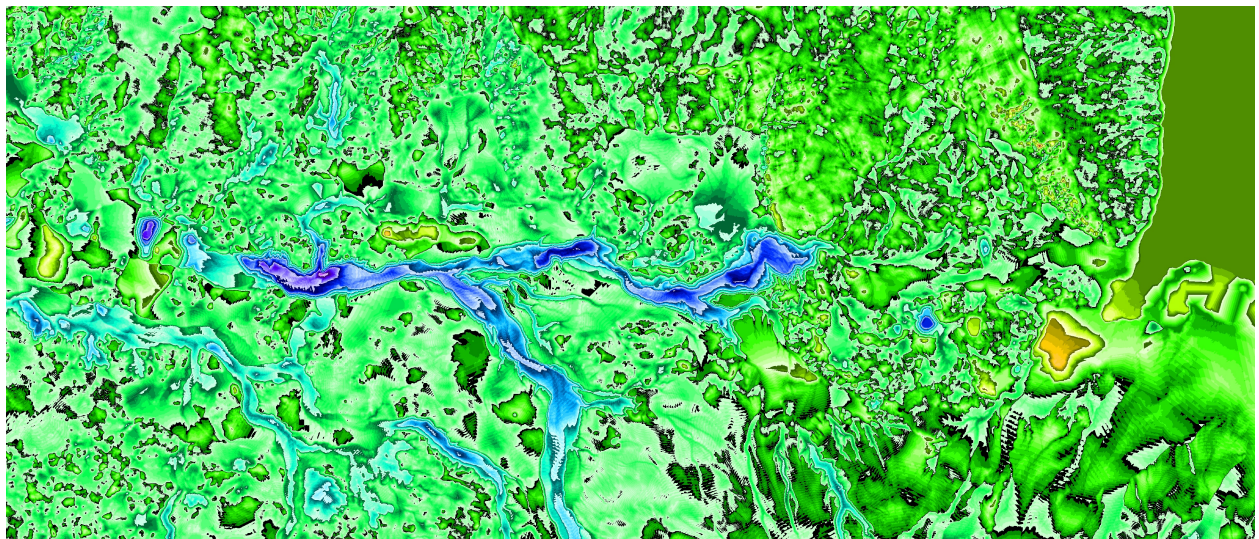
Post 1980 elevations in AOI region, ignoring higher elevations (white); 10 m steps.

1980 eruption has been colorized in the next figure with higher elevations left white. The color intensity steps are 10 m. It shows no canyon development. The DEM from the 2004 laser survey was similarly colorized and shows the canyon positions and much finer detail.

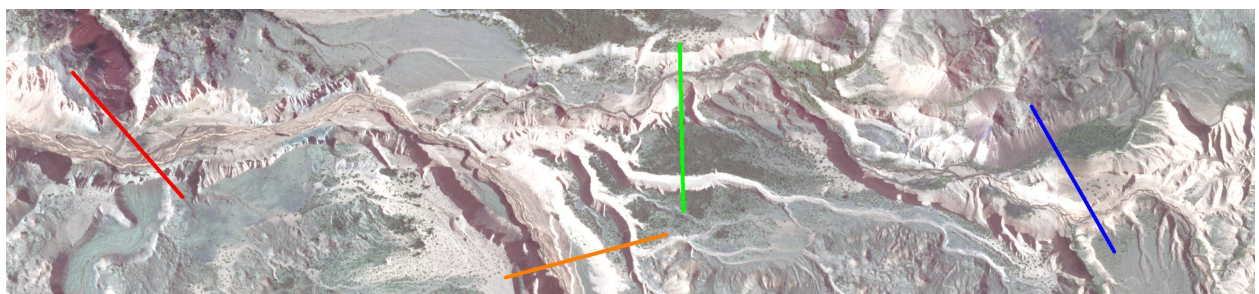


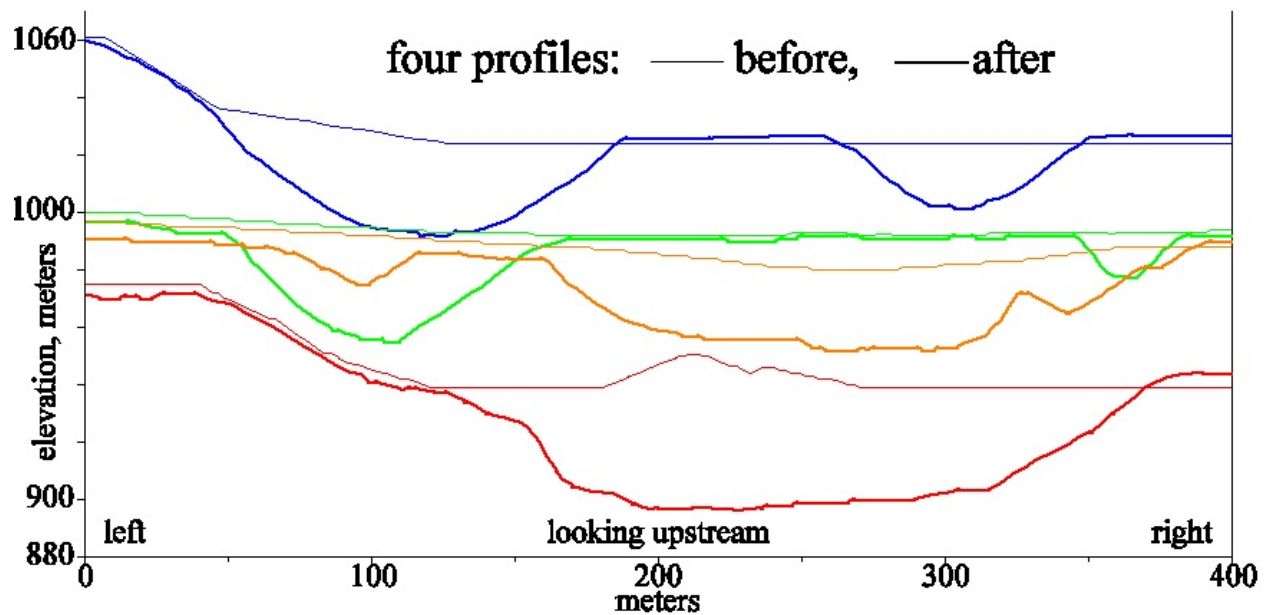
2004 Lidar elevations, ignoring higher elevations. 10 m color intensity steps.

Subtracting the two DEMs gives this map where the blue tones are the new canyons and black is for zero change.



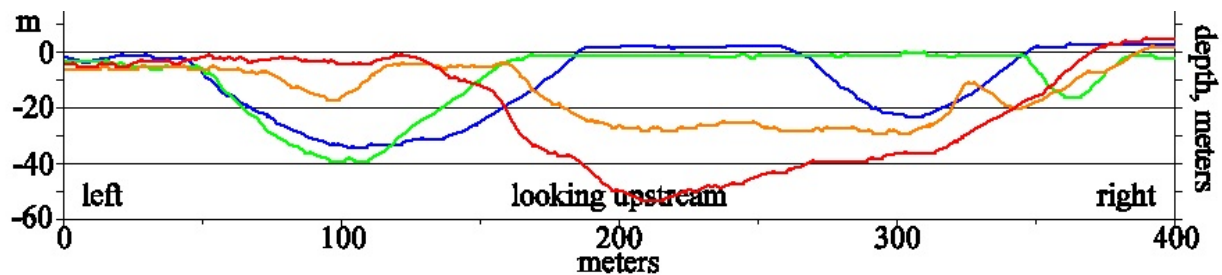
400 m long vertical cross sections of the canyons were made at 4 locations indicated by the colored lines. The following graphs show the profiles in the upstream viewing directions. The thin lines are for the initial elevations and the thick lines are for after the canyons were made.





Small elevation differences are not significant and result from the differing resolutions of data used for the DEMs. Any vertical cliffs are not visible because of the spacing of lidar observation points and subsequent smoothing of the data. Even so, an approximate angle of repose in the lidar elevations (thicker lines) is evident.

The difference in elevations between the two data sets at the profile locations is shown in the next graph.



In the blue location the left canyon (Engineers Canyon) depth exceeded 30 m. The right canyon (part of “Little Grand Canyon” section) depth exceeded 20 m. In the green location the left canyon (possibly affected by the Spirit Lake pumping through Engineers Canyon) reached a depth of 40 m while the independent minor canyon at the right cut down about 15 m. At the orange location the mudflow channels coming down from Mt. St. Helens cut down nearly 30 m. Far downstream at the red location the canyon was cut down about 50 m.

Keith was correctly claiming that depth changes on the plains did not exceed 2 m. However, he minimized the channel depths by claiming only 5 to 11 m cuts in contrast to the creationists claims of 30 to 45 m. These four profiles show that Keith and the reference he quotes are incorrect regarding channel depths.

Overall, Austin’s descriptions in the Field Guide and Hiking guide are accurate. The unknown

creationist being quoted by the critics may have a misconception about “solid rock”, but that depends on the understanding of “solid”. The critics are incorrect in attributing the deposits to loose powder because there was structural integrity in the deposit which allowed near-vertical cliffs at the canyon sides. The speed of canyon development of a “single day” quoted from a creationist source may not apply to Engineers Canyon if it was eroded by water pumped from Spirit Lake, but that canyon already existed within a half year of the 1982 eruption. The other canyons all resulted from the mud flows of March 1982 and a time scale of days is certainly appropriate for them. The critics are incorrect about the depth of the channel cuts, giving values that are too small.

Ed Holroyd, 10 December 2012