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Impact Trajectory Fracture Comparisons
In Glass and Rock Samples

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Impact Trajectory Fractures - James D. Byous

Abstract

Samples of projectile impacts in glass on a micro scale are studied and compared to bolide impacts on earth. Using 5mm soda lime glass as a target material for 5mm steel balls at low velocity, 150 to 250 fps impact features are studied for direct and indirect fracturing.

Using aerial and satellite photos for reference, images of micro fractures in glass were laid side by side with those of bolide impacts on earth. The terrestrial samples consist of astroblemes around the globe. Included is one suspected impact structure in West Texas, USA. The samples were studied for features that would indicate patterns created when the target material was forced beyond elastic and plastic tolerances.

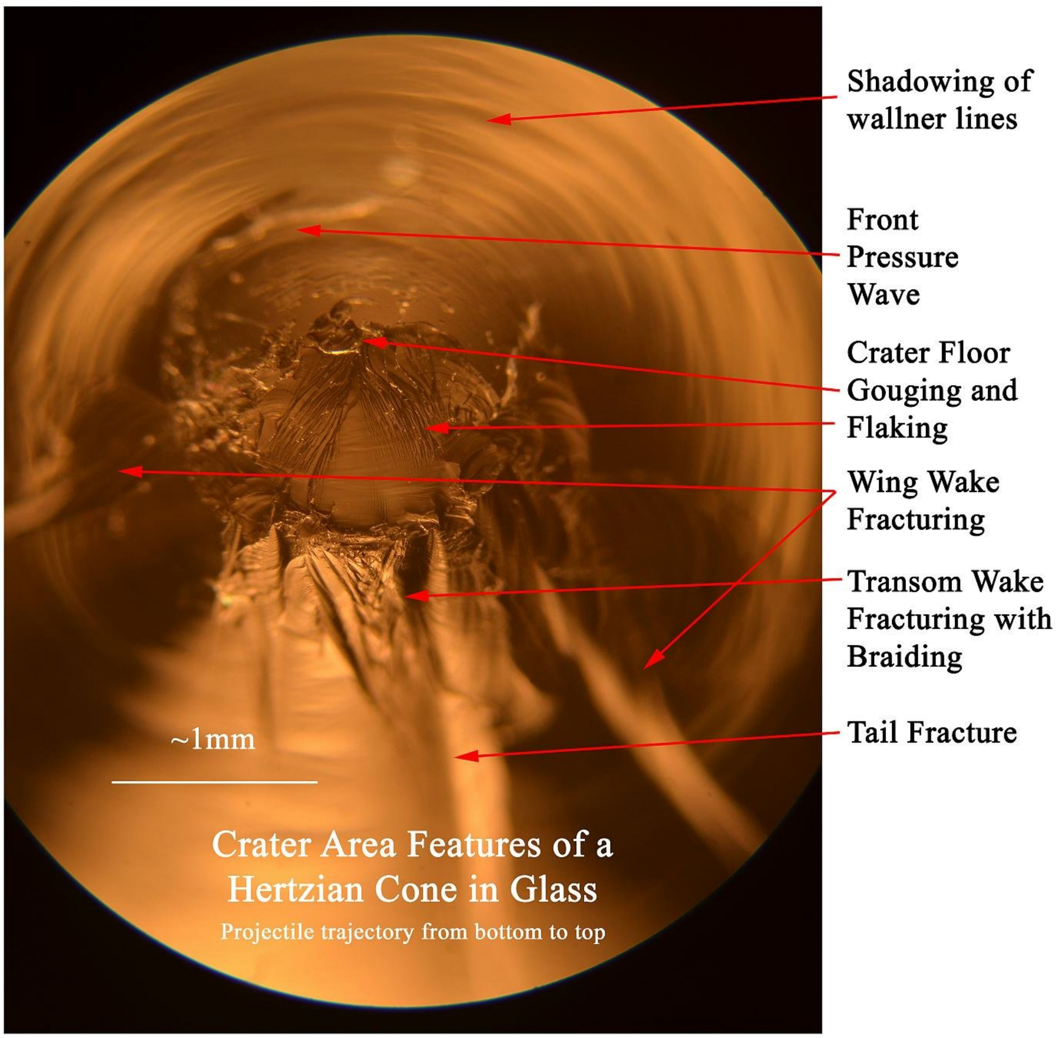

Figure 1 *Details of the area surrounding the crater of a Hertzian fracture in glass.*

The Study

Here samples of glass impacts along with nineteen known (and one suspected) impact craters showing similar features to those on and around impact craters in glass. Those shown included crater floors, pressure waves, wings, braided-transom wakes and tail fractures, names that are covered in earlier papers on Hertzian fractures and cones as described in Hertzian Fractures and Related Terms – A Glossary.[1]

This paper is a study in the nature and physicalities of Hertzian fractures and how they may be applied to determine the angles of origin for terrestrial impacts. Admittedly it creates more questions than answers. What is know is that when a projectile strikes a brittle material with enough force a Hertzian fracture and cone will result. They are evident in glass plates, windows, and windshields around the world. They are found in laboratory impact tests in rock samples. They are evident in ballistic studies of glass, ceramics, metal and muscle tissue. They should be suspected in bolide impacts on planetoids and planets as well.

Fractures in rock erode at a greater rate than does the surrounding material. By viewing the water-shed associated with impact craters we can deduce possible correlations between the drainage-route angles, the crater and the impact trajectory. When a brittle material is pushed beyond its plastic limits it will fracture. The cone section of a Hertzian fracture appears to be stretched in the same manner as when one pulls a finger across a gelatin surface. In glass the "stretch marks" appear in fracture lines. Forward pressure and the spin of a projectile can also influence the slope of the surface and influenced the tilt of the surrounding plane. This result can be seen as a bulge in the cone's upper profile to the right of the crater floor in figures 2 and 3 where front spin had an influence on the tilt of the directed energy than was the forward motion.

Low angle trajectories of steel balls can create cones in glass that tilt slightly away from the point of origin.[2] However, if the projectile is spinning forward, backward or to axially clockwise or counter-clockwise the shape of the cone and the direction of the fractures can be twisted from the line of trajectory in the same manner as english on a billiard ball.[3]

Following are samples of Hertzian fractures and cones in glass with similar featured impact structures. The red lines mark the general locations of possible fracture courses.

A KMZ file is available for a more detailed viewing on Google Earth at www.dowdresearch.org.

Figure 2 *The picture at top is of a Hertzian fracture mold as seen through the edge of a 5mm glass plate. In the lower image is the matching Pap-styled Hertzian cone that was removed from the void. Pap cones are named for like-named and similarly-shaped hills found in Scotland. The detached crater floor and impact area wing fractures visible are highlighted in figure 3.*

[1] Downloads with terms and descriptions are available at http://www.dowdresearch.org.

[2] Sliding contact fatigue damage in layered ceramic structures, JW Kim, JH Kim, VP Thompson, Y. Zhang Department of Biomaterials and Biomimetics, New York University College of Dentistry 2007, http://jdr.sagepub.com/content/86/11/1046.short.

[3] Hertzian Fractures and Related Terms – A Glossary, JD Byous, A.T. Dowd Research, AATR Publishing, 2013.

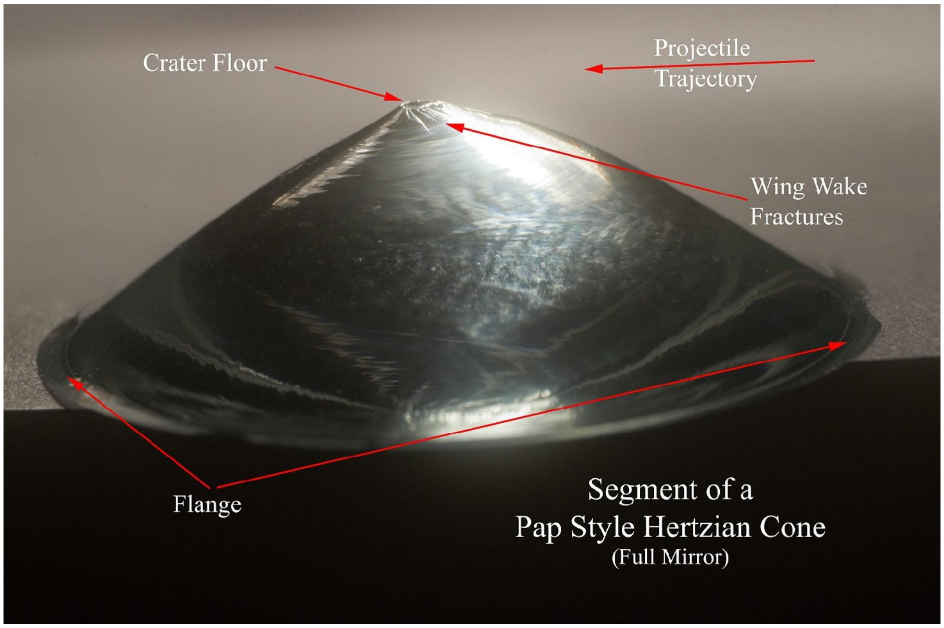

Figure 3 *A larger view of the cone section shown in figure 2 displays the projectile trajectory, crater floor, wing wake fractures and the flange section of the Pap-style Hertzian cone. The projectile was forward spinning along the trajectory causing a mound or bulge to the right of the crater.*

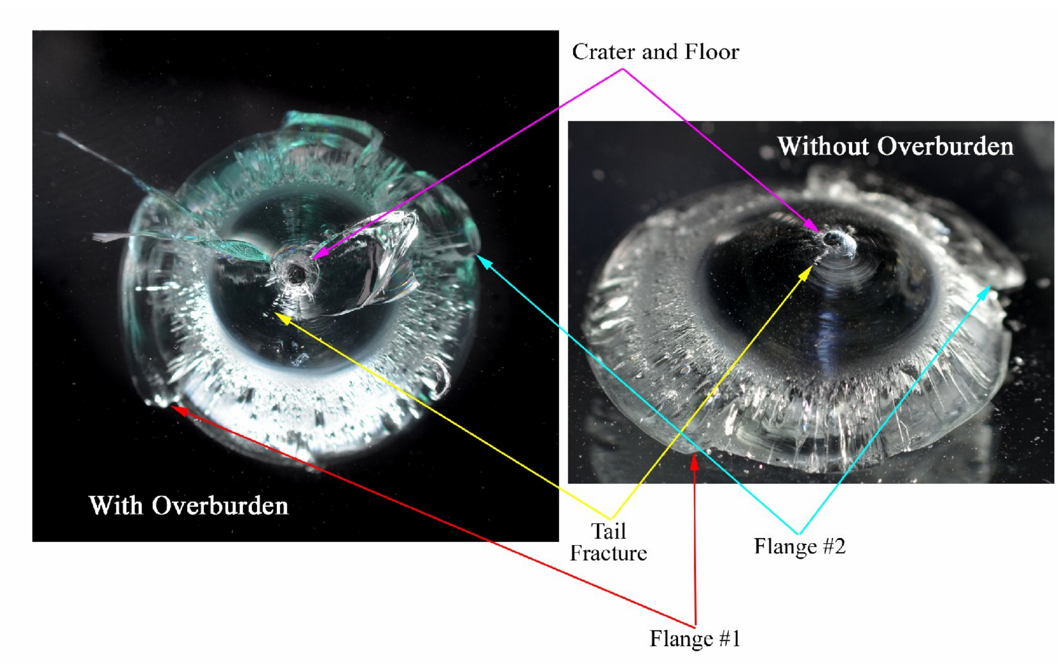

Figure 4 *Above is an example of a Hertzian fracture with and without the glass-plate overburden. The crater floor can be seen at the center of both images. At left is the cone seen through the glass plate and has longer wing-like fracturing spanning most of the ~20mm in diameter fracture. In the image on the right the cone is detached from the glass plate with the crater floor at the apex. In both examples the short wing and tail fractures, ~1.5mm, are evident around the crater. In the left photo the projectile trajectory was from the bottom left of the frame while in the right the projectile came from the left.*

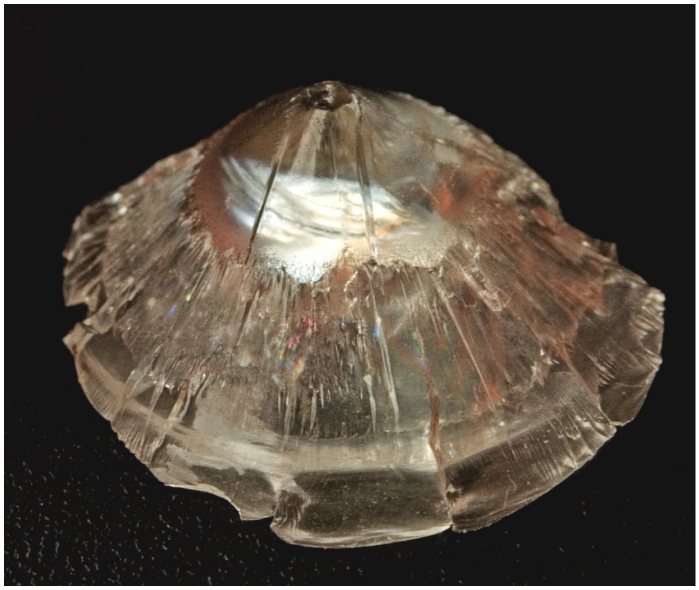

Figure 5 *This cone displays wing wakes that are longer than other examples. The fractures reach from the crater edges to the mist section and indicate that the trajectory of the projectile was from the bottom of the frame to the top.*

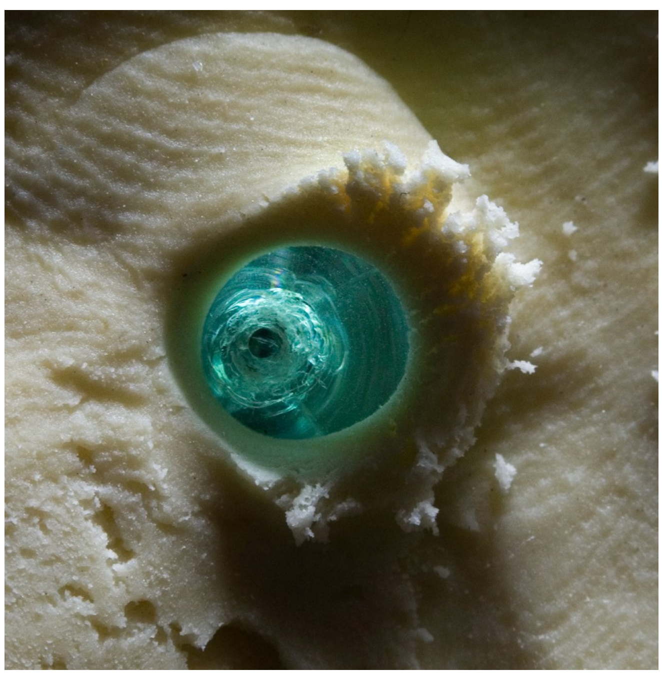

Figure 6 *Here a coating of clay was placed over a 5mm glass plate to act as a "crust." The projectile trajectory was from left to right. Upon impact it created a Hertzian cone below the surface while creating an overturned lip on the crater.*

Shoemaker Crater, AU

Shoemaker Crater in Australia displays features that closely resemble fractured segments surrounding the crater floor areas around Hertzian cones in 5mm glass plates. In the latter, projectile trajectories ran from the bottom of the frame to the top and suggests that like terrestrial features should have similar trajectories.

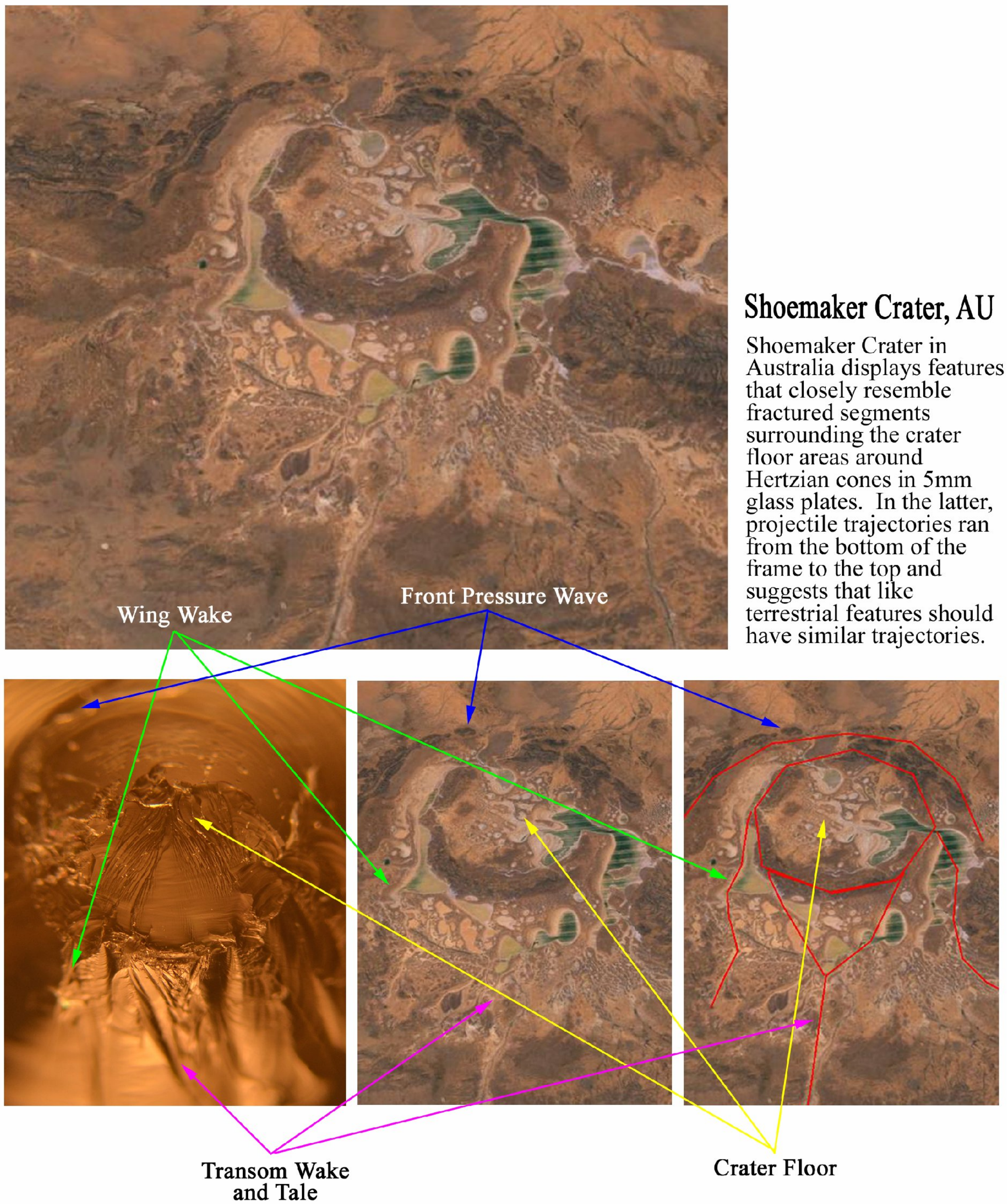

Figure 7

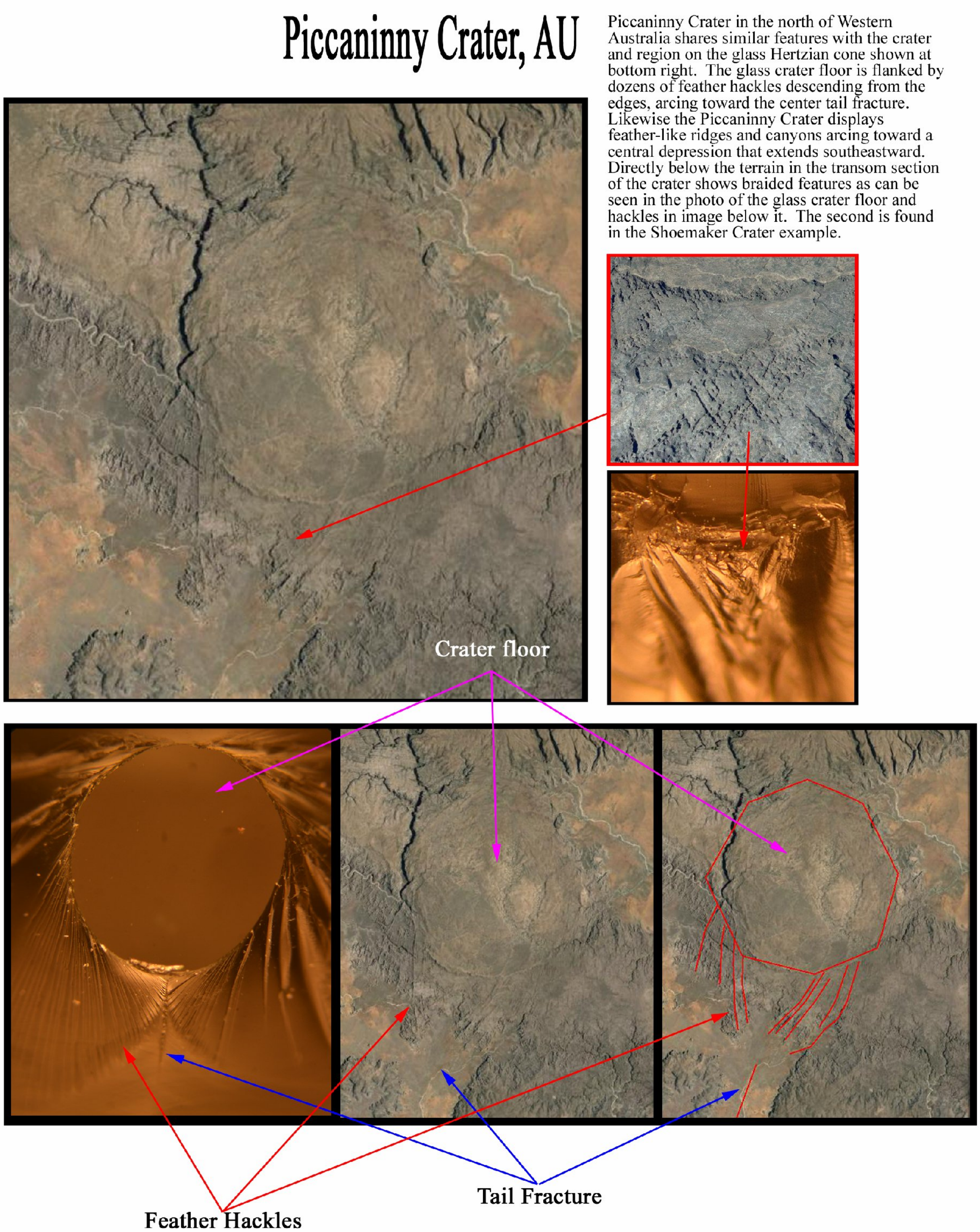
Piccaninny Crater, AU
Piccaninny Crater in the north of Western Australia shares similar features with the crater and region on the glass Hertzian cone shown at bottom right. The glass crater floor is flanked by dozens of feather hackles descending from the edges, arcing toward the center tail fracture. Likewise the Piccaninny Crater displays feather-like ridges and canyons arcing toward a central depression that extends southeastward. Directly below the terrain in the transom section of the crater shows braided features as can be seen in the photo of the glass crater floor and hackles in image below it. The second is found in the Shoemaker Crater example.
Crater floor
Tail Fracture
Feather Hackles

Figure 8

Examples

Below are samples of craters that have features discussed above. The prominent characteristic for most examples is the Tail Fracture which, in most, is displayed in a straight or near straight line. Red-line marks are general area locators for terrestrial features. For a detailed look use the KMZ file.

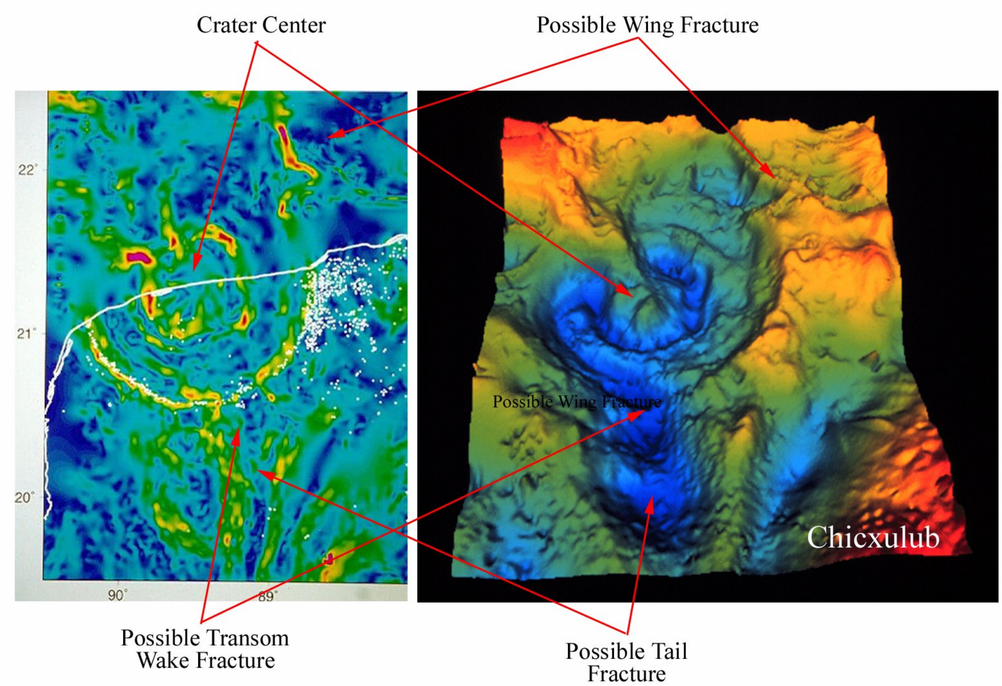

Figure 9 *Above are computer-generated gravity maps of Chicxulub Crater displaying anomalies that imply wing, tail and transom-wake fracturing as displayed in glass Hertzian-cone crater samples. The bolide traveled from slightly right of the bottom of the frames to the top.*
Images: Geographic Survey of Canada, left, NASA, right. All other crater examples, Google Earth.

Figure 10 *Based on studies of rotating-projectile impacts in glass the fracture lines at Upheaval Dome, Utah suggests that the crater was created by a clockwise-spinning bolide with a south-southeast trajectory.*

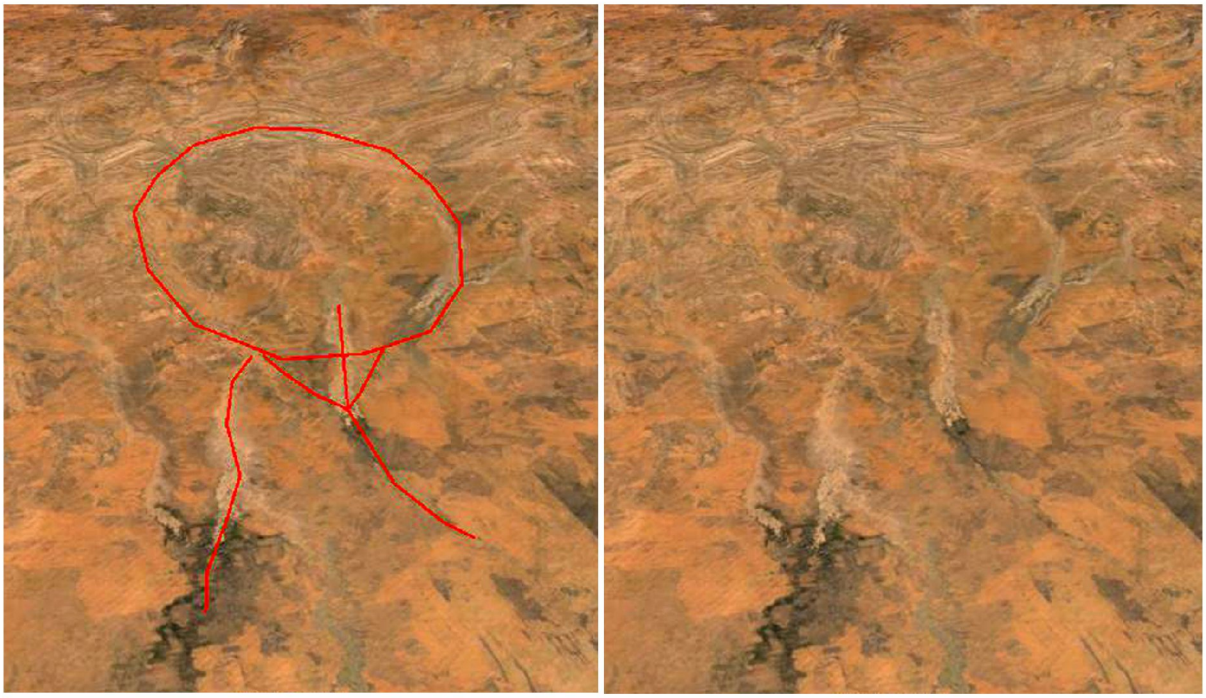

Figure 11 *Amelia Creek Crater, Australia.*

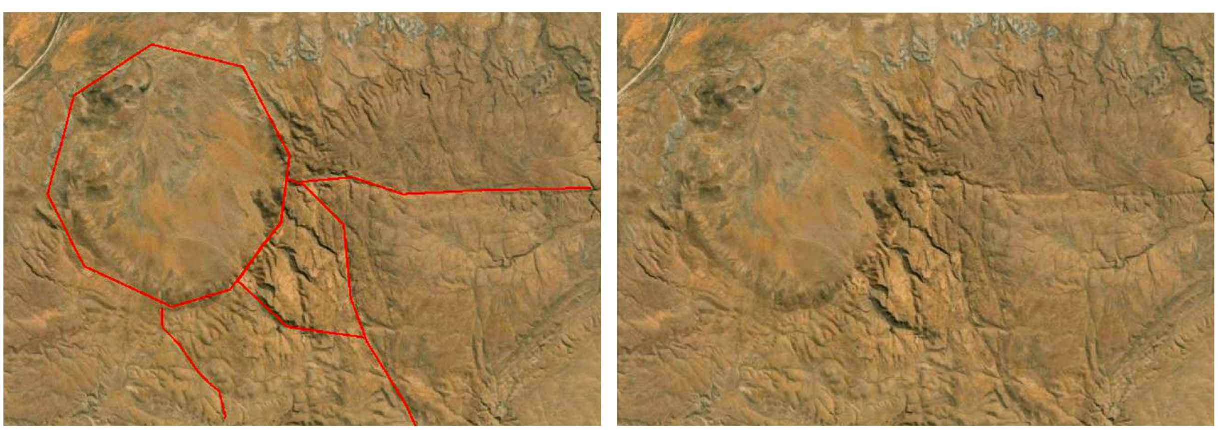

Figure 12 *Goat Paddock Crater, Australia.*

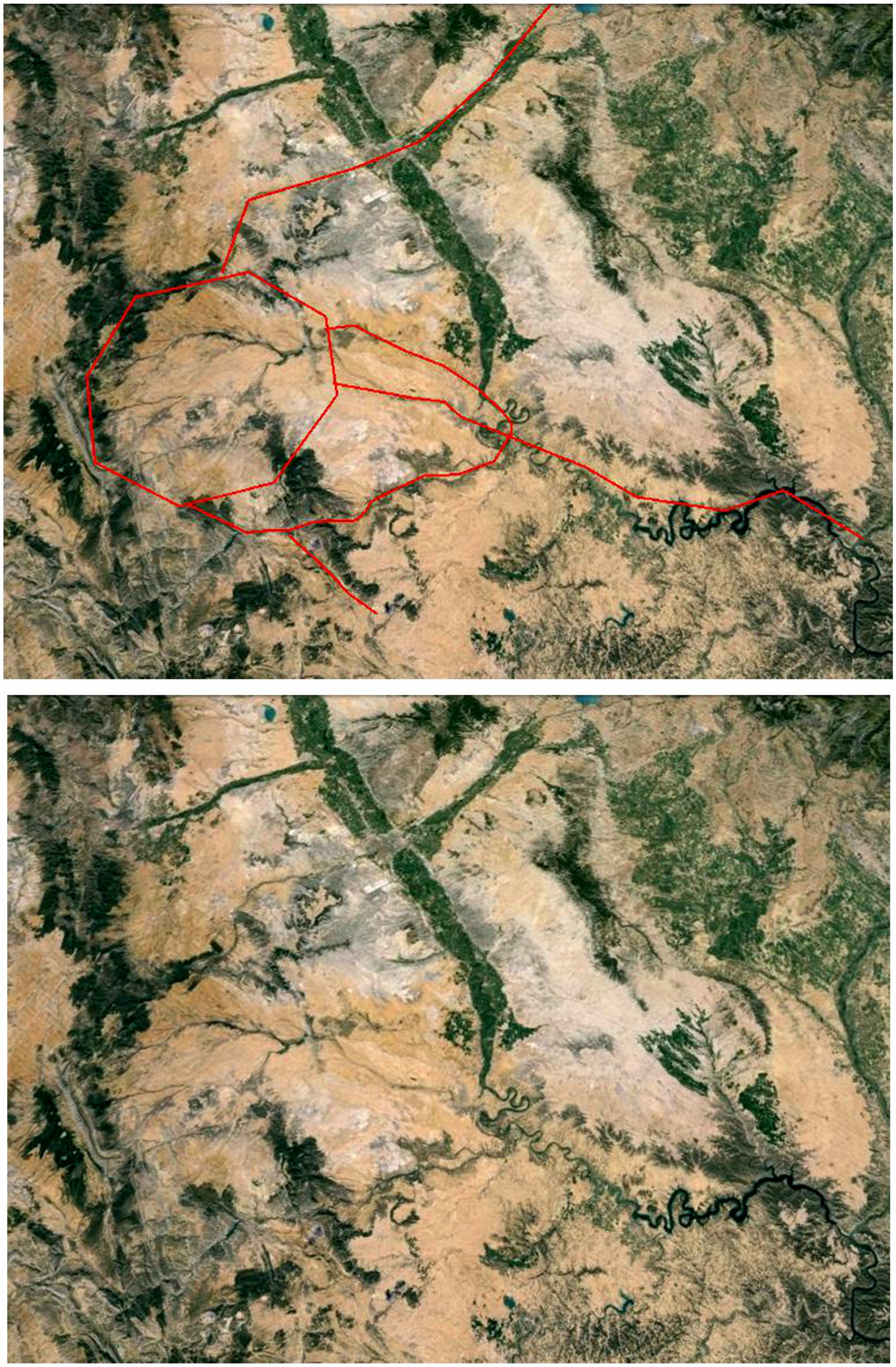

Figure 13 *Azuara Impact Structure, Spain.*

Figure 14 *Carswell Crater, Canada.*

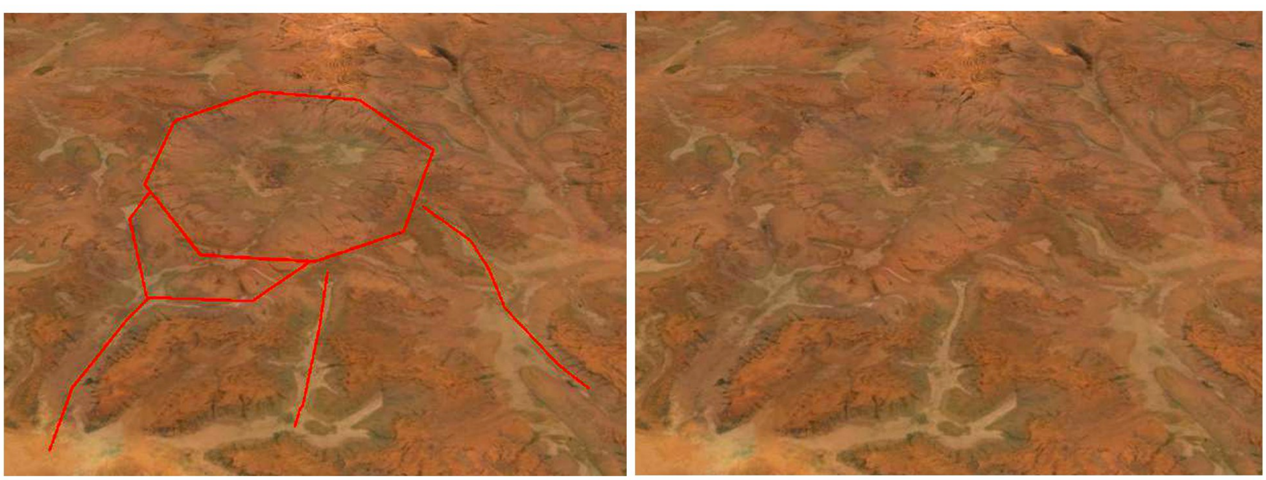

Figure 15 *Connolly Basin Crater, Australia.*

Figure 16 *Houghton Impact Crater, Canada.*

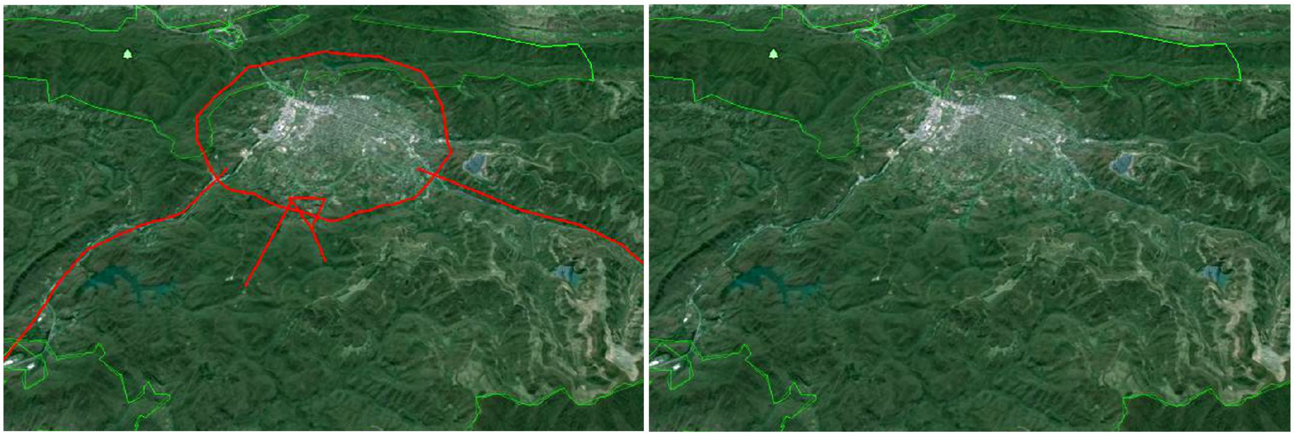

Figure 17 *Middlesboro Crater, Kentucky.*

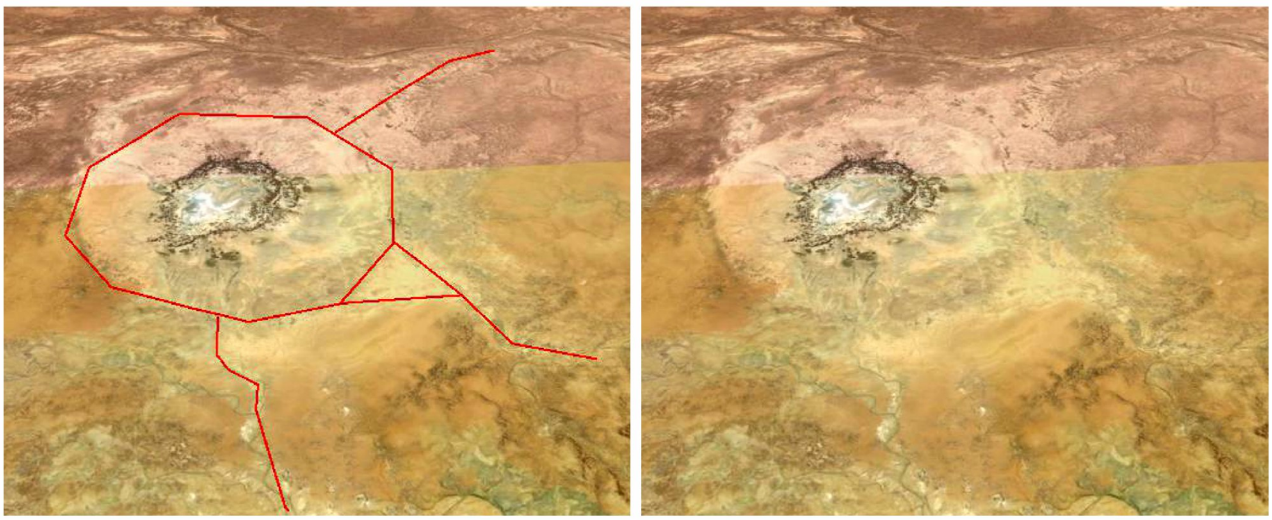

Figure 18 *Mt Toondina, Australia.*

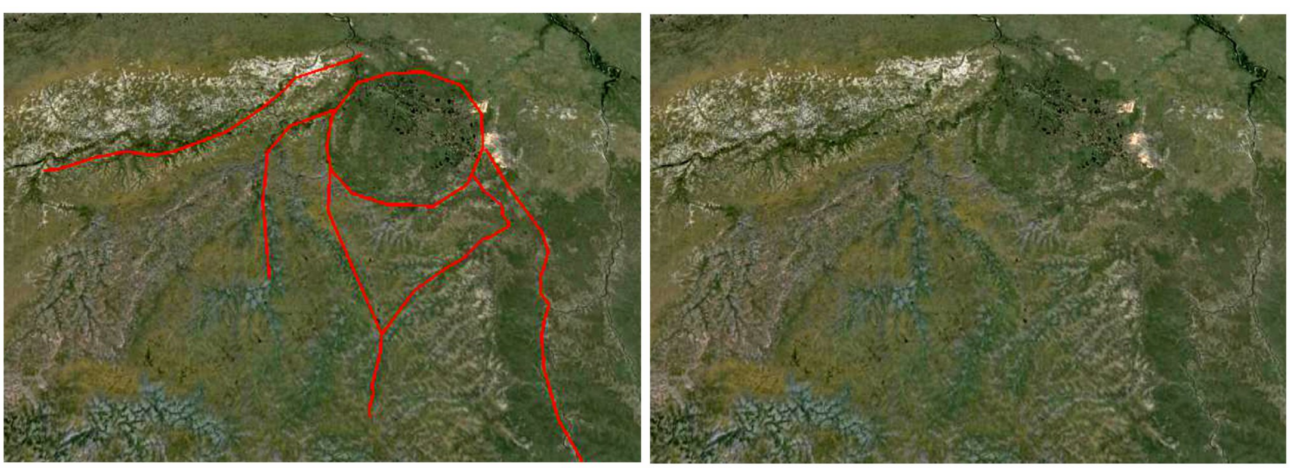

Figure 19 *Popigai Crater, Russia.*

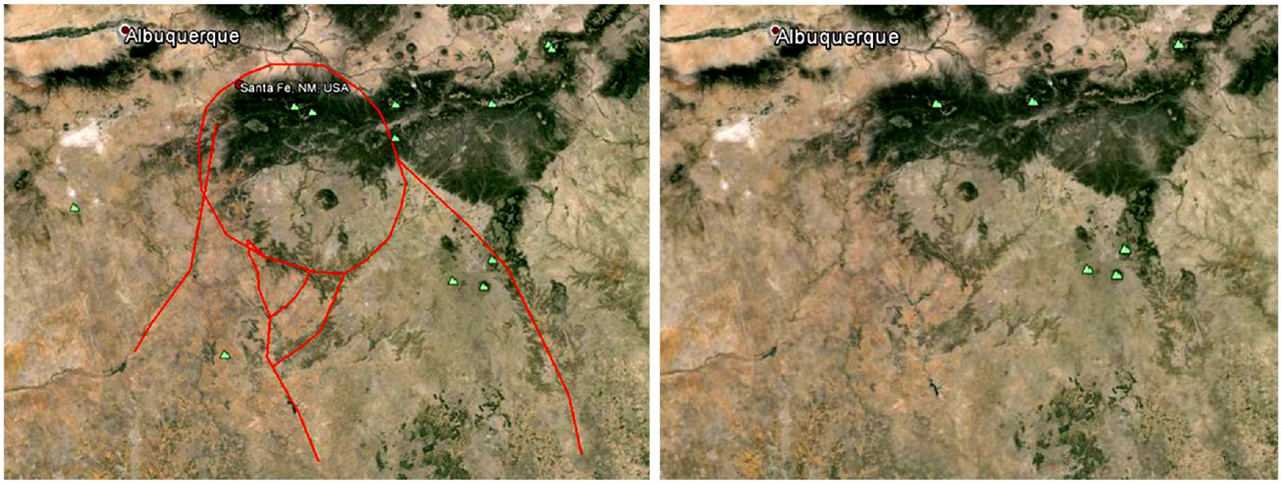

Figure 20 *Santa Fe Impact Structure, New Mexico.*

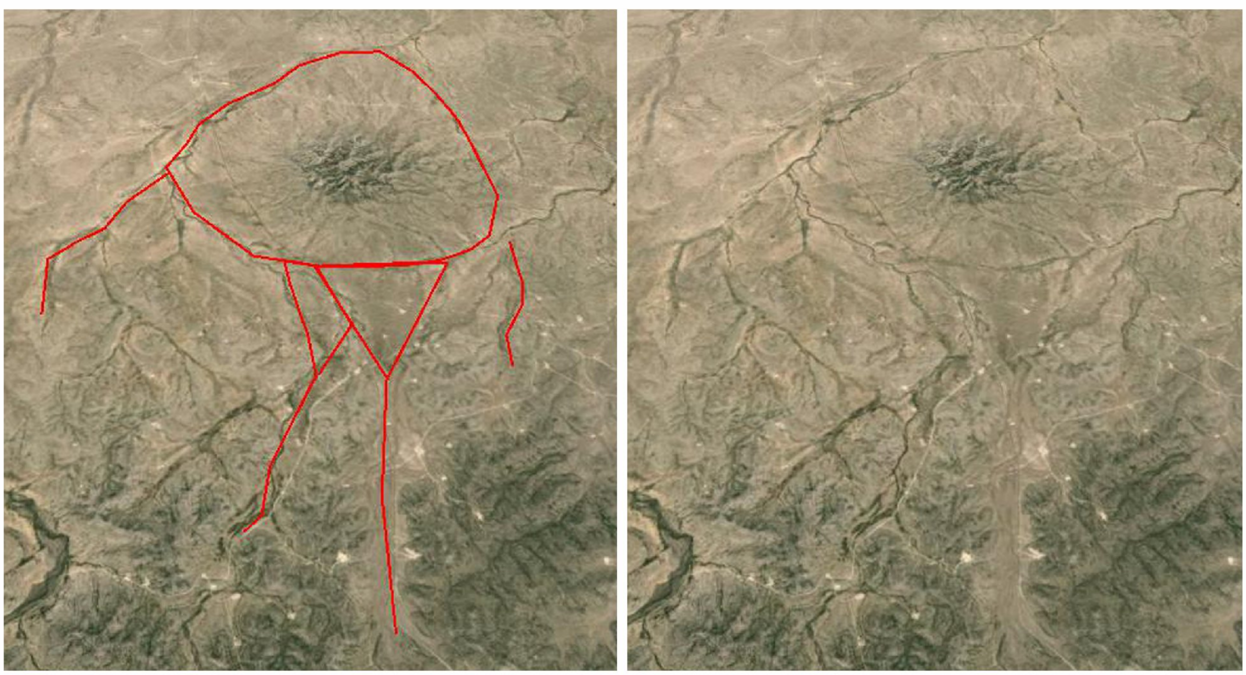

Figure 21 *Sierra Madera Astrobleme, Texas*.

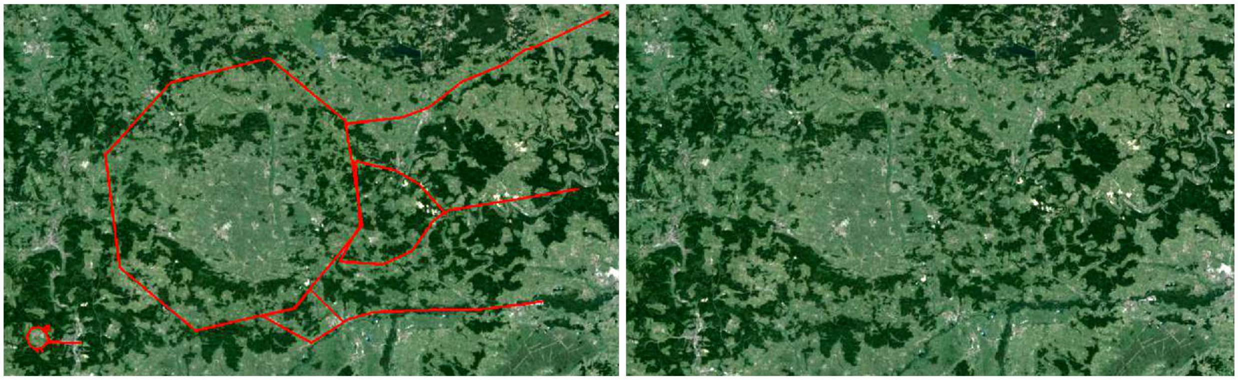

Figure 22 *Nördlinger Ries Crater, Germany. For a better view of the terrain use the KMZ file mentioned above.*

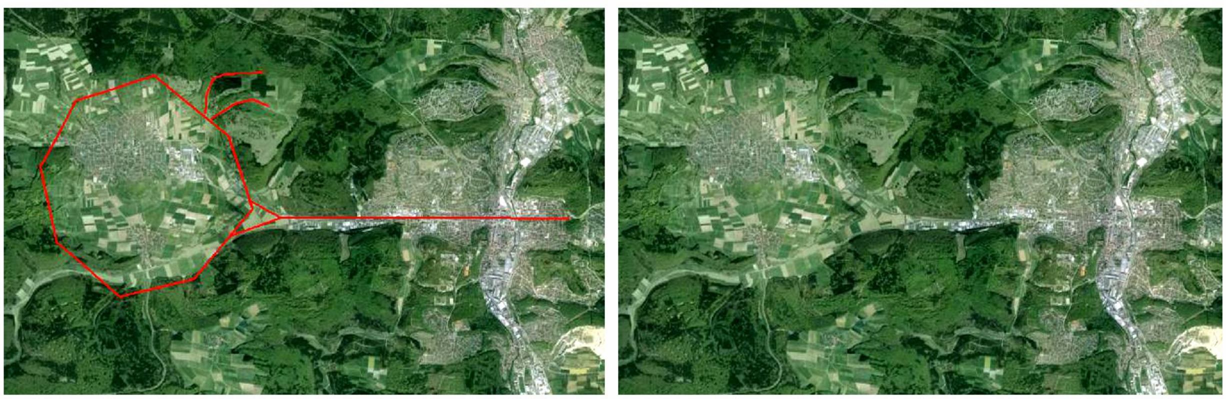

Figure 23 *Steinheim Crater, Germany.*

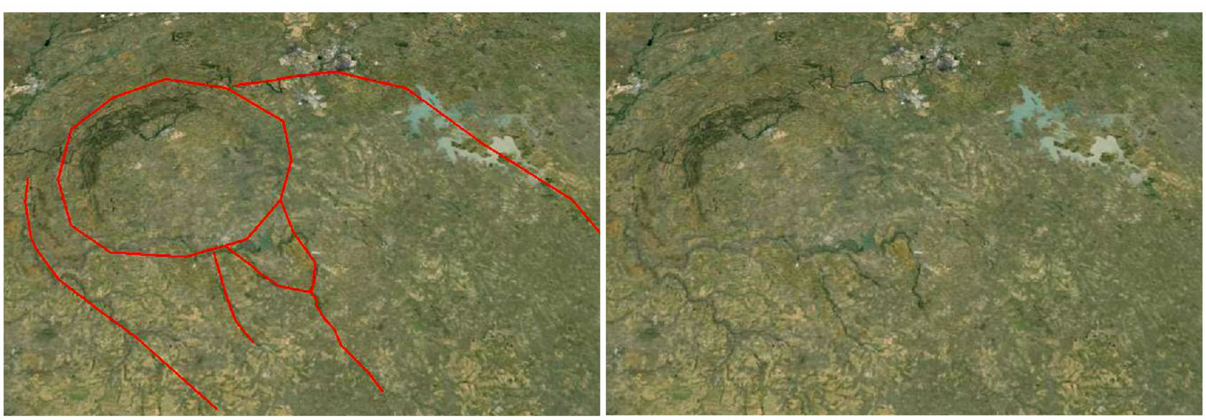

Figure 24 *Vredefort Crater, South Africa.*

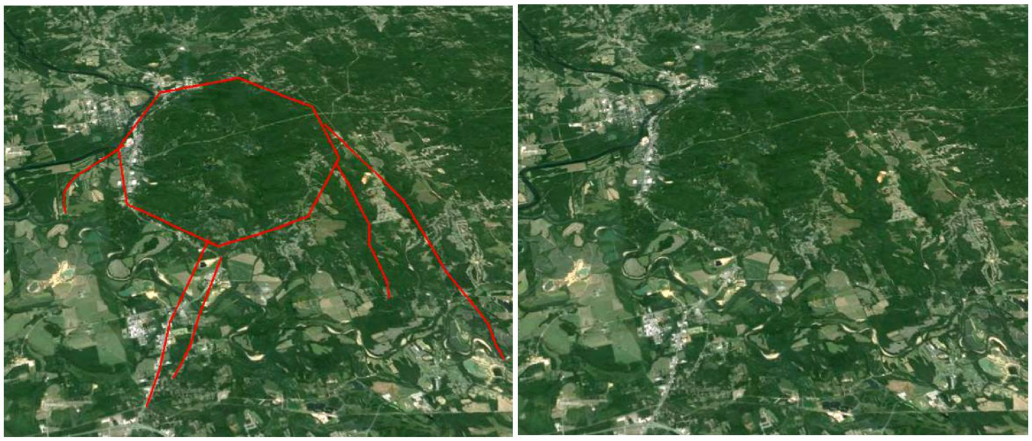

Figure 25 *Wetumpka Crater, Alabama.*

Figure 26 *Yarrabubba Crater, Australia.*

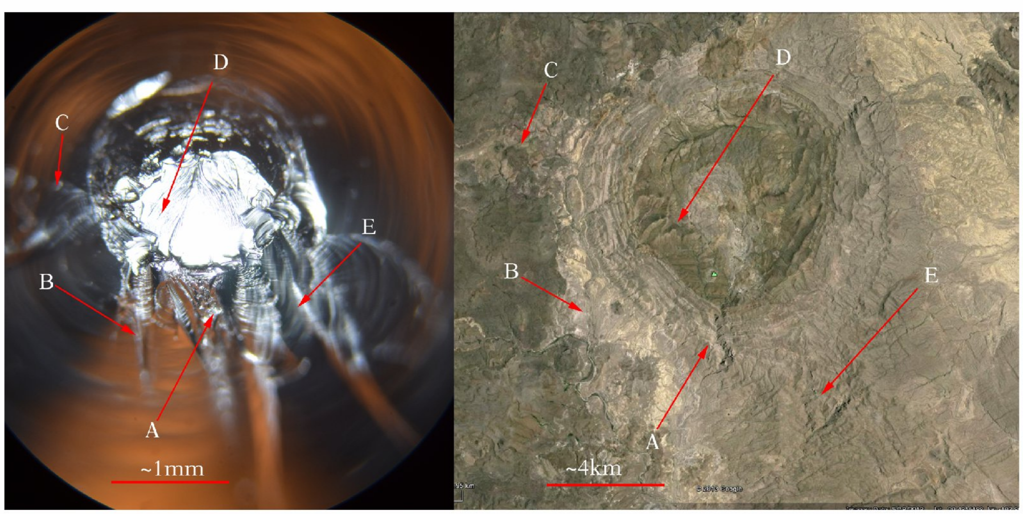

Figure 27 *El Solitario Structure in west Texas at right has many similarities to the impact crater in glass on the left. The glass crater and rock structure share the following features in like locations:*
A *- Transom Wake.* ***B*** *– Wing fracture.* ***C*** *– Upper Wing fracture.* ***D*** *– Flaking and crater floor tilt.*
E *– Lower Wing Fracture with Wake-Like disruption.*[4]

[4] Hertzian Fractures and Related Terms – A Glossary.