Chapter 16: Recognizing craters from their mascons

Abstract

Recognizing craters by the low gravity, expansional release-ring, inside the high gravity, compressional shock-ring is referred to as the energy envelope of a crater. Using this transition to define the Uncompahgre Crater's Open ring, and the gneissic, monoclinic Uncompahgre Plateau as an up-thrusting mascon with its ends limited by the release valley of the Open ring. Using the Uncompahgre Plateau the characteristics of mascons are established and additional examples are searched for in California through the Rocky Mountains. The Sierra Nevada Mountains in the Sequoia Crater, Owens Release Valley in the Owens crater, the Bering Sea linears in the Blowout Mountain crater, and the Ipojuca linears in the Mormon Basin crater are recognized.

Introduction

Chapter 12 defined an energy signature as evidence of movement from extreme high energy to extreme low energy by way of an adiabatic conversion, where the excess energy contributed by the shock wave is dispersed through work as a means to get to the low energy of the release wave. Chapter 13 demonstrated how to locate craters using this sudden energy drop as a visual clue on the moon. Chapter 5 emphasized that we can find continued expression of at least the largest craters by their CGRS globally. And, Chapter 9 showed how the mascons, mass concentrations in lunar craters, can be traced back to CGRS from distant craters occurring in the crater's raised center. Putting all of this together, we can locate some craters in the western half of the USA.

Paradox Basin and Uncompahgre Plateau

The Four Corners area of the USA is where Utah, Colorado, Arizona, and New Mexico meet. It is also the location of a very prominent sedimentary basin, the Paradox Basin. Like many sedimentary basins, it is a half-circle in shape, the redder area in Figure 16.1A. The Uncompahgre Plateau lies in the middle of a dark band that diagonally crosses that image, cutting off the Paradox Basin, and suggest a drastic change in the geology. The Uncompahgre Plateau, and the peaks to its east, are part of the Front Range of the Rocky Mountains. ("Front Range" because the earlier settlers were coming from the east and they got to it first.)

Over the past hundred years the geology of this area has generated a lot of discussion as they have tried to explain the basic structural questions by processes they see happening today. Questions like: Why is the Paradox Basin, like many basins in the area of the greater Rocky Mountains, only half a circle? Why does the Uncompahgre Plateau rise up so suddenly without any foothills? Why are the valleys in the Rocky Mountains so steep and deep? Why does this highest topographical area have some of the thinnest crust (Rosenberg et al, 2014) in North America? They try to make the Uncompahgre Plateau the remnant of an Ancestral Rocky Mountains that has eroded away to fill the Paradox Basin, but that does not work. Finding some of the answers will change how we interpret geology. No longer can we interpret the structures by the processes seen at work today, and we learn to understand the cratering that put the present structures here.

We first need to familiarize ourselves with the two primary map forms we will use. We are familiar with the general topographic map like Google Earth's photographed surface of the earth from satellite, Figure 16.1A. The two NASA missions that were used to acquire these images were Landsat and Copernicus. I will use Landsat to refer to this map image. Figure 16.1B is Global Gravity Anomaly (Scripps 2014) which was also acquired from satellite data, which I will refer to as simply gravity map. While areas of high gravity do not necessarily correlate with high topography, they do so enough that we can orientate ourselves recognizing mountain peaks and valleys. While we generally think of "roots" below the mountains, they do not show up in gravity. The deepest blue can be thought of as very *deep roots to some of the valleys*.

Looking for circular shapes that might indicate craters. The larger circular shape shows up in gravity, Figure 16.1C, but most give no hint in Landsat. By contrast, several small shapes that may be circles show up in Landsat, Figure 16.1D, suggesting more investigation need to be done. This illustrates an important principle, the larger circles, the drawn one is ~430 km wide (~270 miles), can be seen more clearly in gravity, while smaller circles, the green one is ~160 km wide (~100 miles), are seen in Landsat, resolution does matter. Again the reader is encourages to use Google Earth on his/her computer to pan up and down. Seeing circular lineaments often depends on resolution of details and field of view. Sometimes we cannot see the linears resolve into a lineament until we see the linears at close view and the lineaments at regional or gravity view, Chapter 2.

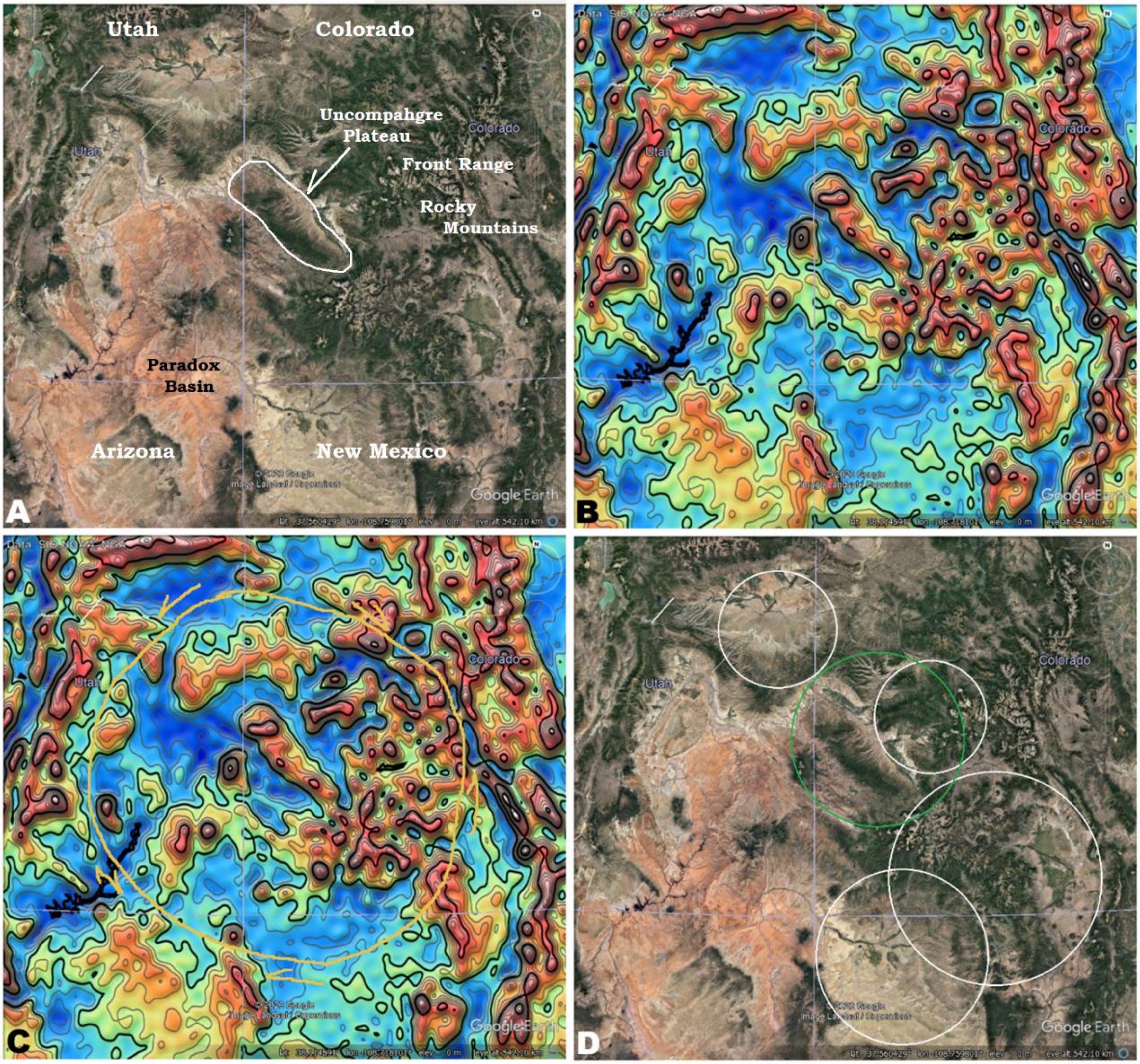

Figure 16.1: The Paradox Basin area. (A) Landsat/Copernicus image on Google Earth. (B) Exact same area in Global Gravity Anomaly (Scripps 2014). Blue to green areas represent low gravity and yellow to red represent high gravity. (C) The circular shape seen as most prominent in the gravity image. Three sets of arrows indicate the segments of circular shape seen most prominently. (D) Some of the smaller circular shape seen in Landsat. The green one contains the Uncompahgre Plateau.

Which circle to interpret as a crater? Figure 16.2A (choice "A") has the larger red circle with a lot of blue adjacent inside. That would agree with my appraisal of the shock wave circle with a release wave valley just inside it. It also takes advantage of two of the edge linears indicated in 14.1C, on the west and southwest, but it leaves the blue linear on the northeast outside the circle. Since I recognize the commonality of the release wave being inside the chock wave, Figure 14.2B (choice "B") takes this into account. This seems like a good option but it pushes the rim into the other portions of edge linears on the west and southwest.

A second area of comparison is the smaller, inner circle. On "A" it tightly wraps both ends of the Uncompahgre Plateau. If mountains have to do with being pushed up in crater rims, why would this isolated chunk of mountain be sitting here all alone? Chapters 9 and 10 made the connection between CGRS and mascons on the moon. If this was the earthly equivalent to a lunar mascon we would expect it to be sitting out by its self in the middle of a crater. And, the tight wrap is the same as Mare Orientale's (Figure 11.2) and Moscoviense Basin's (Figure 11.8) wrap of the Open ring on their mascons. One minor difference visible between Figures 11.2 and 11.8 and the Uncompahgre Plateau is the blue area that almost completely wraps the plateau, separating it from the hills that would constitute the Open ring. They do not touch as they do on the moon. That may reflect differences in the structure of the crust on both spheres.

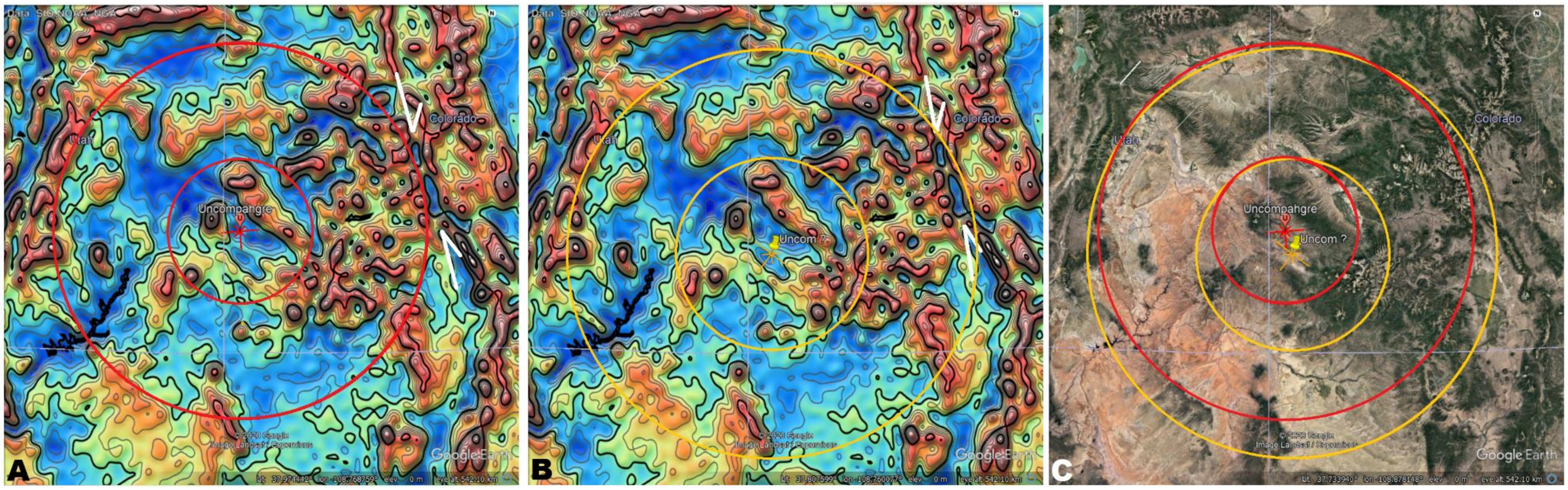

Figure 15.2: Possible circles for the Uncompahgre crater. (A) Following the circle drawn in 14.1C, excluding the blue areas between the white arrows. (B) The possible circle including the blue areas. (C) Both seta of circles showing the difference in Landsat.

So, how to decide between choices “A” and “B”? The Paradox Basin is a popular hydrocarbon drilling site and much mapping has been done from well logs. The Cutler Undivided is the most common fill for the Paradox Basin, and Figure 14.3 shows thickness contours for it. The thickness also reflect the general shape of the basins bottom. Basin Depth is also included for the San Juan Basin and it is noted that includes some Cutler Undivided at its deepest, north end. Above that, the San Juan is topped with the same upper lithologies as the Paradox Basin, showing that the two basins were parts of the same depositional system. The two basins are presently separated by the Four Corners Uplift.

The Cutler Shelf shows the bottom topography of a half bowl shape with several irregularities. The Four Corner Uplift is prominent as a high topography, but the roughly parallel low to the northwest is also interesting. It corresponds with the gravity low in 14.2A and the present path of the Colorado River, but it does not make any difference to the thickness of the Cutler Undivided. This suggest it was not a valley but an area that dropped as a result of a contained release valley at its roots. As both the high and low was present when the Uncompahgre impactor arrived I would propose they are both CGRS already present and the cratering process truncated the high and added depth to the low.

As the small ring of choice “A” is more symmetrical to both drawings of the basin’s interior, I would recognize the Uncompahgre crater is more likely to be “A.” In making this decision, I recognize when I am looking for a mascon on Earth to show some low gravity ring before the high gravity of the Open ring, but that it will generally be restricted by the Open ring. Also, the OCR will be an up-thrusting ring that has a release wave valley inside it, but it may show a smaller release wave in front of any given upthrust ring, possibly leftover from the display of the next shock wave annulus. Additionally, I must never forget any crater on earth will have multiple underlying and overlying energy patterns from larger and smaller craters. Making that choice leads me to propose, both of the CGRSs, the Uncompahge Plateau and Four Corners Uplift, were thrusting upward in the cratering process, which would require they were put in place in a few minutes to hours.

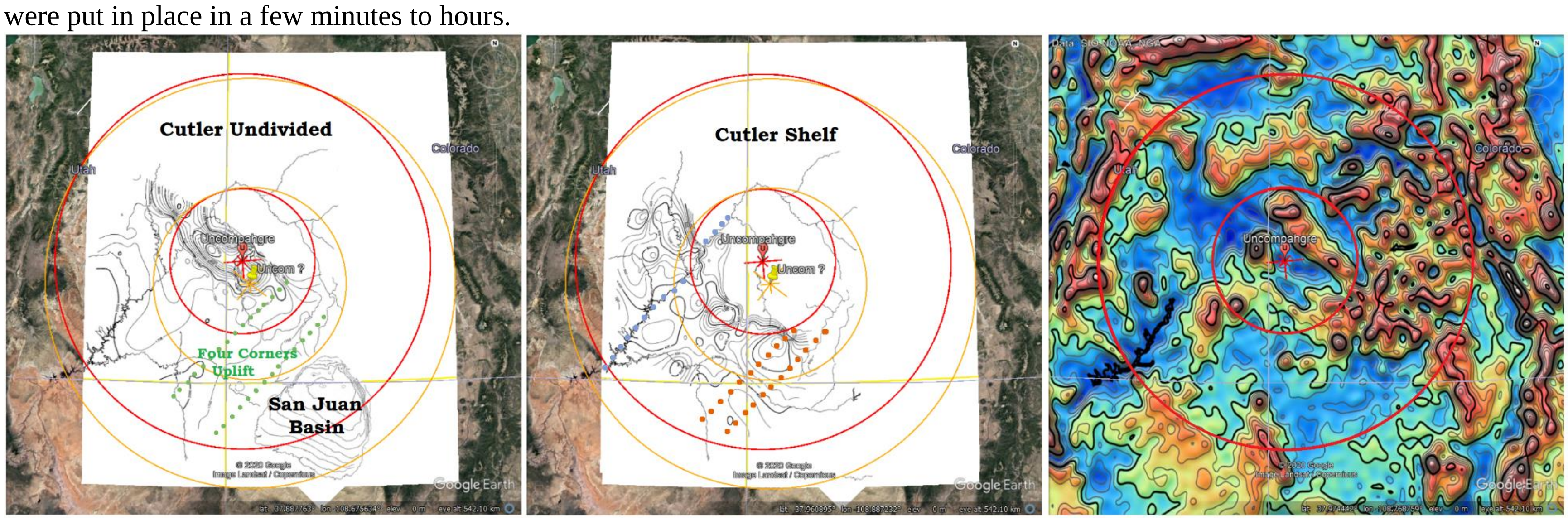

Figure 16.3: Choices of “A” and “B” compared to Cutler Undivided and Cutler Shelf contour drawings. Gravity map of choice “A.” (Image credits: All diagrams redrawn from Condon 1997, overlaid on Google Earth.)

Having established that “A” is the crater, how do we recognize the Uncompahgre Crater from its energy envelope? If the energy signature is the evidence of movement from extreme high to extreme low energy by way of an adiabatic conversion, we want to see great sudden movement from high to low gravity. Figure 16.4A shows many points on the OCR where that sudden change from the shock high in the red ring drops to the low of the blue ring. Additionally, B shows the same for the Open Ring’s red ring dropping to the low of the blue ring. But, there are also several exception that show other CGRS are interacting.

Figure 16.4B suggest an interesting connection of the energy peak of the Monument Valley Uplift, Abajo Mountains, and the Rico Mountains across the Paradox Basin. The red dotted line is a possible inferred linear that connects them into a highly fragmented energy high. Henry (2009, page 575) observed, “Topography is a first-order indicator of geology…. Understanding the character and evolution of topography is fundamental to understanding a region’s tectonic evolution,” and I will agree with him completely. When we understand the origin of these mountains and basins in their craters and the specific portion of the shock or release energy they contributed to the CGRS, we are prepared to understand more of their energy history and the form of their minerals, including oil, coal, and gold.

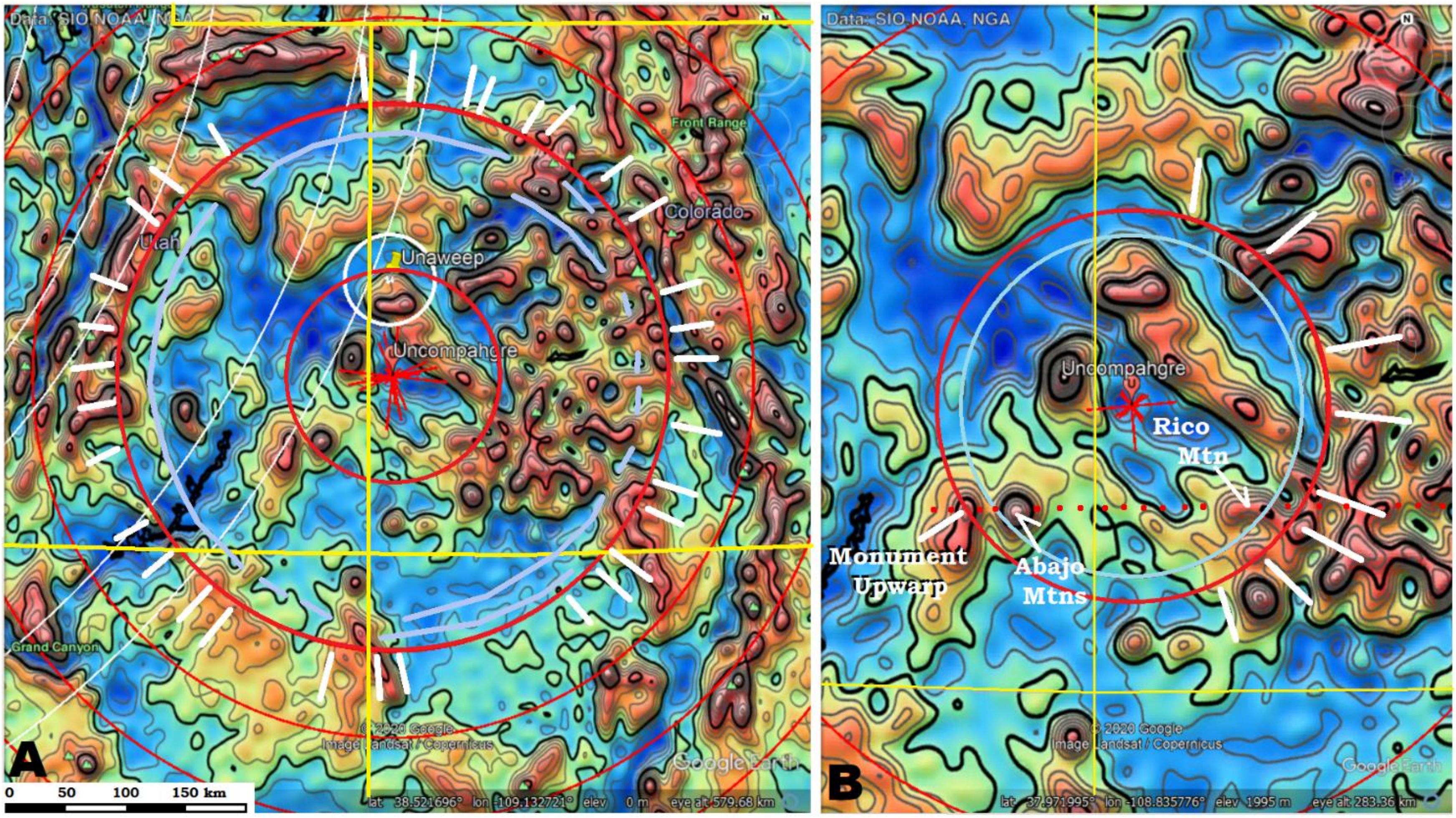

Figure 16.4: (A) Uncompahgre crater in Global Gravity Anomaly showing the OCR and Open rings (~175 km (108 miles) diameter, OCR ~460 km (285 miles) diameter). Short lines point out spots where the high gravity, red, made a sudden drop to blue, low gravity. The long pale blue arcs indicate the concentric, following low gravity valley. (B) Uncompahgre Plateau within the Open Ring with its shock-side shown in red and the release-side shown in blue. White lines point to sudden change points from high to low gravity. Red dotted linear may follow a shock-high that connects Monument Uplift and Abajo Mountains with Rico Mountains. (Image credit: Scripps 2014 overlaid on Google Earth.)

The heavy red arc in Figure 16.5 defines several highs on the Tavaputs Plateau moving to the high on the north end of the Uncompahgre Plateau, to the La Sal Mountains, to the Abajo Mountains, to the Monument Upwarp. This CGRS belongs to Blowout Mountain center in northern Nevada and may be its OCR ring. The energy from this CGRS was added to by the Open ring from the Uncompahgre crater’s shock ring but was then overridden and divided by the release valley that formed between the Monument uplift on the west and the Abajo Mountains on the east by the release portion of the Uncompahgre’s Open ring.

The La Sal Mountains have a curious energy history. The heavy red CGRS was not able to override the short (blue) release valley just southwest of the Uncompahgre Plateau, but was able to override it further south in the La Sal Mountains. I would propose this was accomplished with a another CGRS ring portion that crossed at that exact point (the Arenosa craters OCR ring, Figure 16.14), adding its positive energy push, and thereby prevented the release valley from swallowing the energy as it did just to the north.

In Figure 16.5 the sudden movement from high under the Uncompahgre Plateau, thrusting it up, between sudden lows on both sides illustrates the movement from low to high back to low occurring in a CGRS’s energy pattern. The three linears of blue correspond to CGRS from the Tasmanian Sea center. The appearance of the short blue linear, release wave valley, immediately southwest of the Uncompahgre Plateau and its lighter blue separation from the longer blue linear further southwest suggest there are other significant contributing CGRS in that area. The suddenness of the change on *both side* of the Uncompahgre Plateau strongly suggest an adiabatic event.

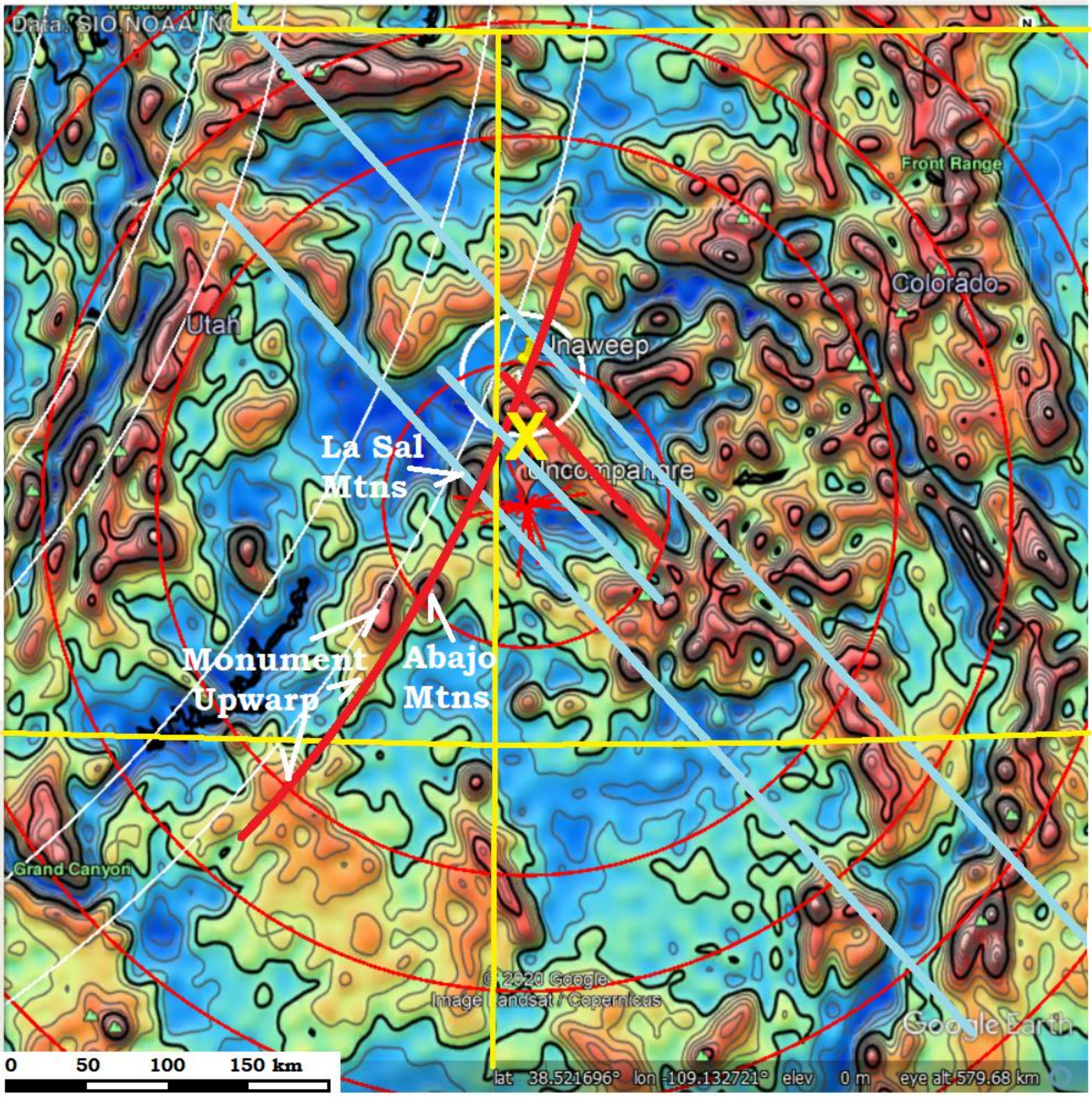

Figure 15.5: Three Release Valley CGRS that define the northeast side of the Uncompahgre Plateau, centered in the Tasmanian Sea. Yellow X marks Moore et al (2008) research area.

Uncompahgre's monoclonal dome

The Uncompahgre Plateau is classed as a monocline because its top primarily slopes in only one direction, to the northeast, Figure 16.6B. The oldest rock in the dome is a complexly folded and interlayered feldspathic gneiss, amphibole gneiss, and porphyroblastic microcline gneiss of high grade and is intruded by dikes and plutons of at least four separately identifiable units of granodiorite, quartz monzonite, amphibolite, and plagioclase (Case 1992). These intrusions with the basal dome structure reflect at least five distinct energy pulses in the uplift.

It is thought to be the remaining remnant of the Uncompahgre Highland which tilted up at the Uncompahgre Fault (Figure 16.6A), and was the primary source for the Cutler Undifferentiated formation that filled the Paradox basin (Condon 1997, Rønnevik et al. 2017.). The Uncompahgre fault spans the entire plateau, Figure 16.6A) and separates the Precambrian gneiss of the plateau from the Cutler's alluvial sandstone. Most sources assume the fault was active for the entire deposition period of the Cutler, but Moore et al (2008, with agreement from Trudgill 2009 and Arbuckle 2009) could find no evidence of any fault in their study area (yellow X in Figure 16.5) near Gateway and the west end of Unaweep Canyon. Instead, their Figure 10 shows the two formations grew up together with heat welding of the sedimentary layers to the gneiss and granite without evidence of post deposition thrusting or brecciation. Moore et al documents continuous deposition of the Cutler on-laps the top edge of the southwestern edge of the gneiss.

If there was "heat welding" between the gneiss and the alluvial sandstone, the Cutler was not being eroded at ambient temperatures and redeposited at the surface of the Earth by water processes. Additional difficulty comes when the drainage divide is identified in the monocline, Figure 16.6B. It is significantly towards the southwest edge, and would not be expected to deliver most of the sediments from erosion of a supposed Uncompahgre Highlands in that direction to form the Cutler formation on that side of the plateau. I would reinterpreted the gneiss and granite as forming a rolling contact with the Cutler, like a highly viscus liquid would make clinging and moving up through fine breccia at high temperature.

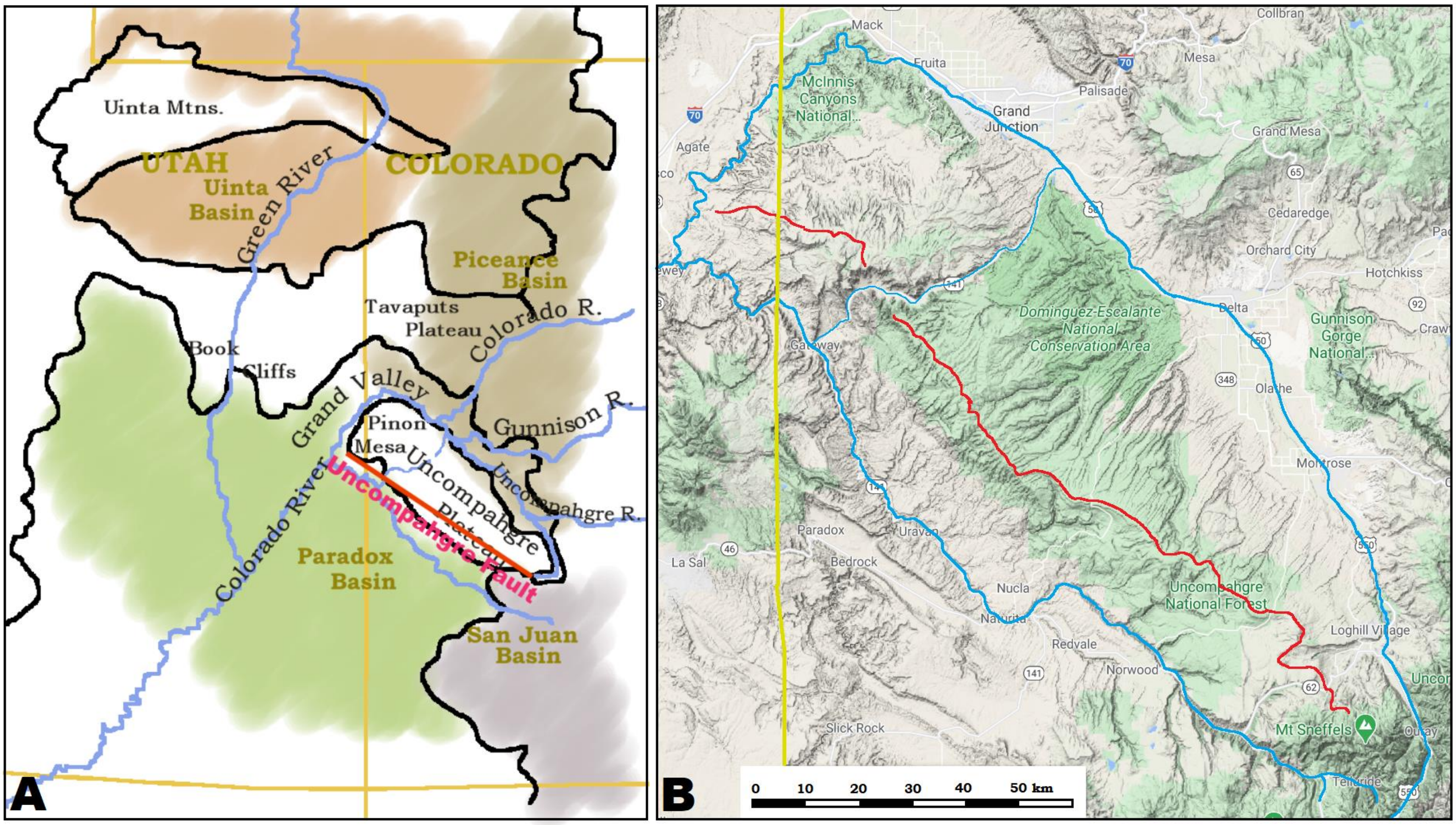

Figure 16.6: (A) Location of the Uncompahgre Fault along with other locations in this chapter. (B) The plateau defined by the rivers surrounding it and location of the drainage divide indicated in red. (Image credit: (B) ©Google Maps 2020, Terrain.)

Uncompahgre Plateau as a Mascon

The linear of the gneiss-Cutler contact does not follow the same angle of the Tasmanian Sea CGRS already identified, but a CGRS from the Irminger center south of Greenland in the Irminger Sea, Figure 14.7. Not only does the Irminger Sea linear extend through the Uncompahgre Plateau, but it crosses the Grand Valley and through the western end of the Tavaputs Plateau and then through the northern Book Cliffs. A third CGRS identified belongs to the Great Bight center south of Australia. The three together account for the triangular shape of the uplifted plateau. If they identify five major energy pulses, and I have identified only 3 CGRS, I will leave it to future researchers to locate the other major CGRS involved.

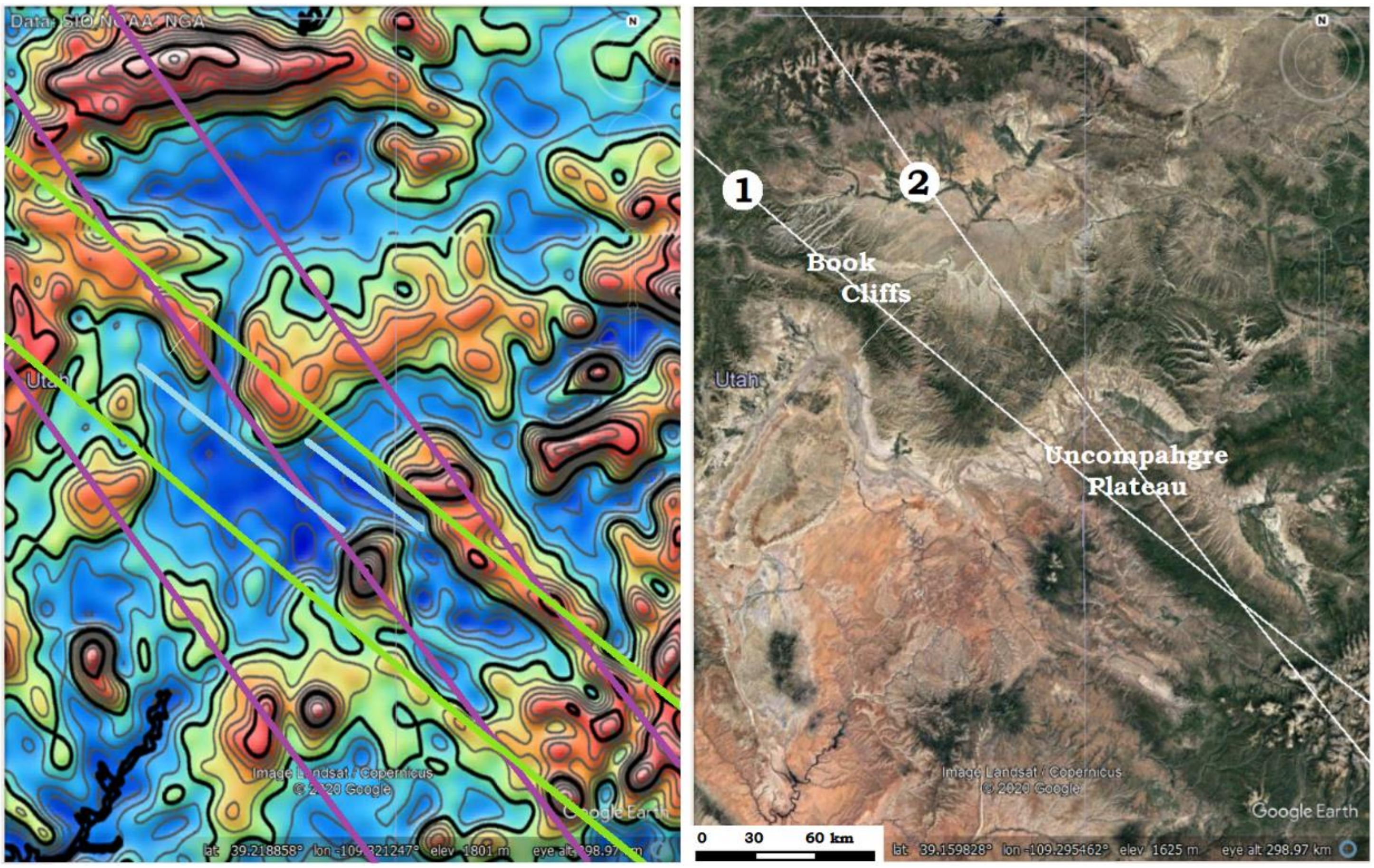

Figure 16.7: A) Landsat, and B) Global Gravity Anomaly showing major CGRS determining location of Uncompahgre Plateau. Green (1), CGRS from Irminger crater, Purple (2), CGRS from Great Bight crater, south of Australia. (Image credit: Google Earth with Global Gravity Anomaly overlay, Scripps 2014)

The monoclinal shape, Figure 16.8.3, has a distinctive high on the southwest side roughly running parallel to the drainage divide. It along with much of the Rocky Mountains is modeled to have formed in the Laramide Orogeny from contraction along preexisting weaknesses that resulted in en echelon folds and arches (Erslev and Koenig, 2009). The plateau aspect of its structure is seen in the relatively level top in the A-A' section, from section C northwest, the portion affected by the Unaweep crater. The Uncompahgre fault contact of gneiss and Cutler sandstone plunges back towards the northeast at ~35-45º (Moore et al 2009) as shown in 16.8.3E and I propose a direction of thrust from the Irminger CGRS as shown with the red arc in the cross sections, but recognize that if multiple thrust are involved it would produce the varied folding patterns typical of gneiss domes and migmatite. It identifies gneiss domes as the expression of multiple CGRS's provides the thrust and energy needed for multiple episodes of rapid uplift, each with partial melting.

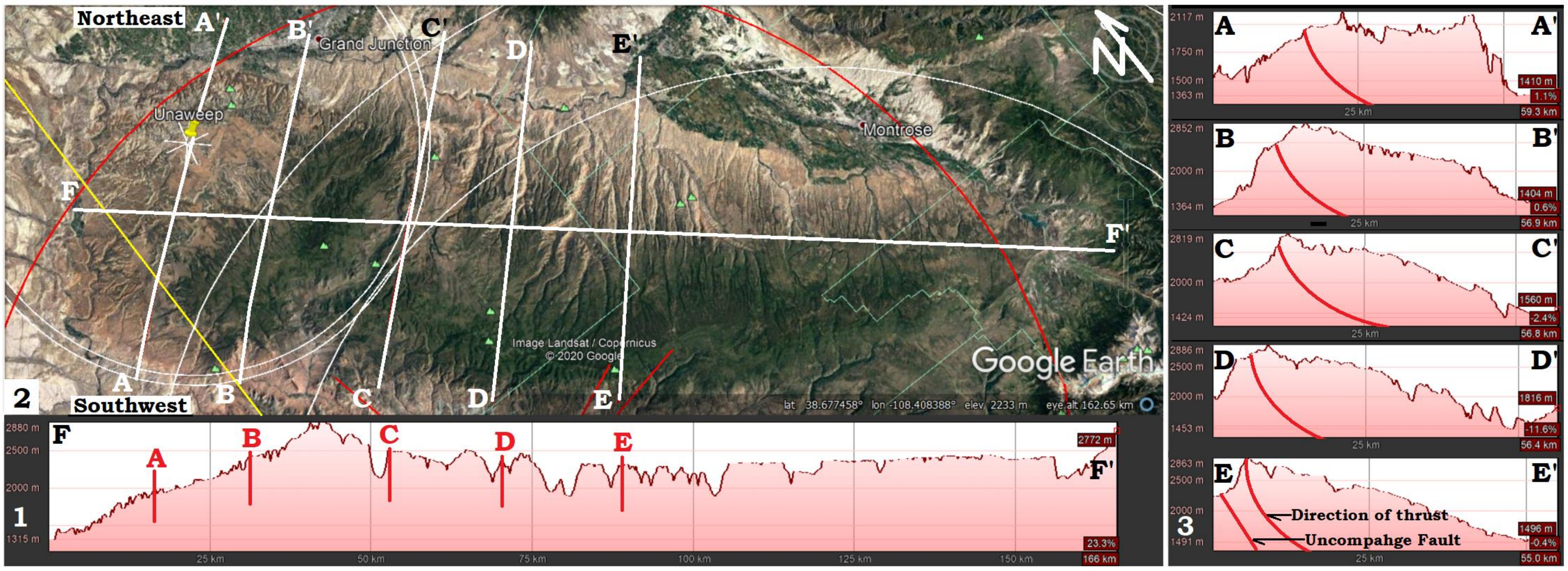

Figure 16.8: Linear section through the Uncompahgre Plateau parallel to the Irminger CGRS shown in Figure 14.7A. 3E shows the angle of the so called Uncompahgre Fault and how it conforms to the direction of thrust consistent with the Irminger center. (Image Credit: Google Earth elevation.)

While the only portion of the plateau that is thrust above the present surface is that of the Uncompahgre, most geology exploration has recognize the structure extends far beyond the plateau region through the western end of the Tavaputs Plateau and through the Book Cliffs to the north and into the San Juan Mountains to the south where it would be just west of Uncompahgre Mountain, Figure 16.9.

The section in Figure 16.9 follows the ring of the Irminger crater's CGRS. While the section overall is not nearly so flat as Figure 16.8, it shows the energy of many more CGRSs have come into play, but the cross sections of B-B' and C-C' (Figure 16.10) still retain their monoclinic form, down to the northeast.

If the roots of the plateau extend beyond the Open Ring of the Uncompahgre crater, this suggest two alternatives: either the original upthrust extended much more distance and was mascon for a much larger crater, or the roots for CGRS extend far beyond the portion of up-thrust that shows. Since there is no evidence for these extended roots in gravity maps, I would tentatively look for a much larger crater for an extended display of the CGRS.

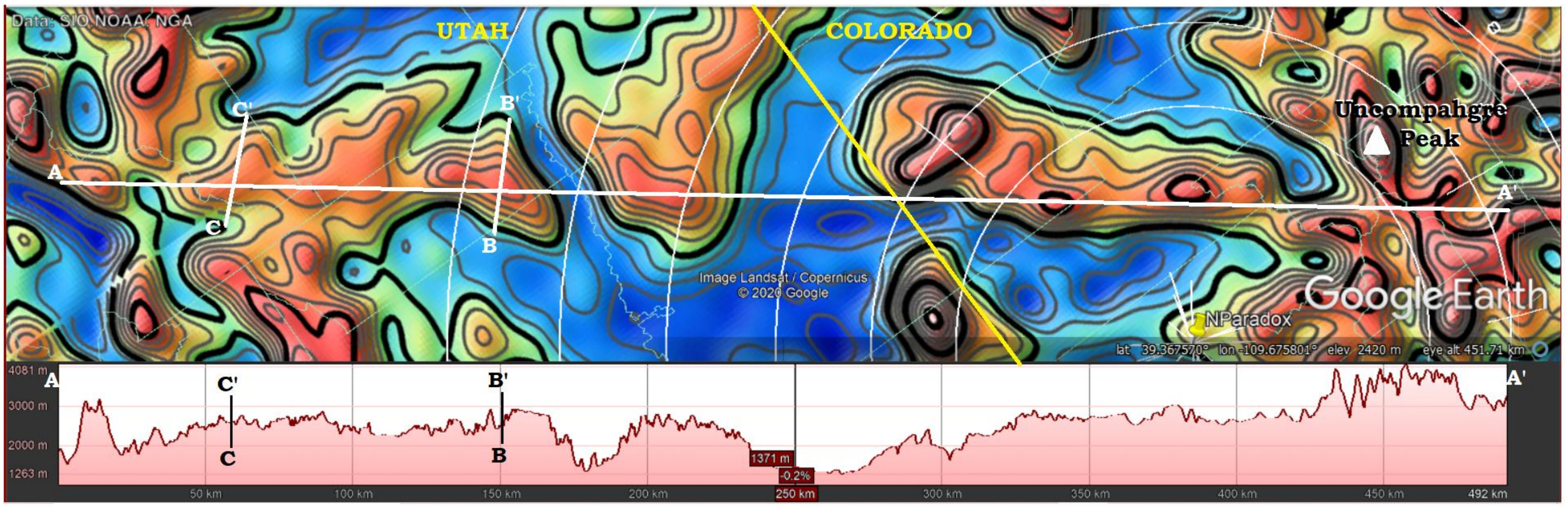

Figure 16.9: Topographic elevation section through the northern Book Cliffs, west end of the Tavaputs Plateau and west side of the Uncompahgre Plateau into the San Juan Mountains following the CGRS from the Irminger center. (Image Credit: Google Earth with gravity overlay, Scripps 2014.)

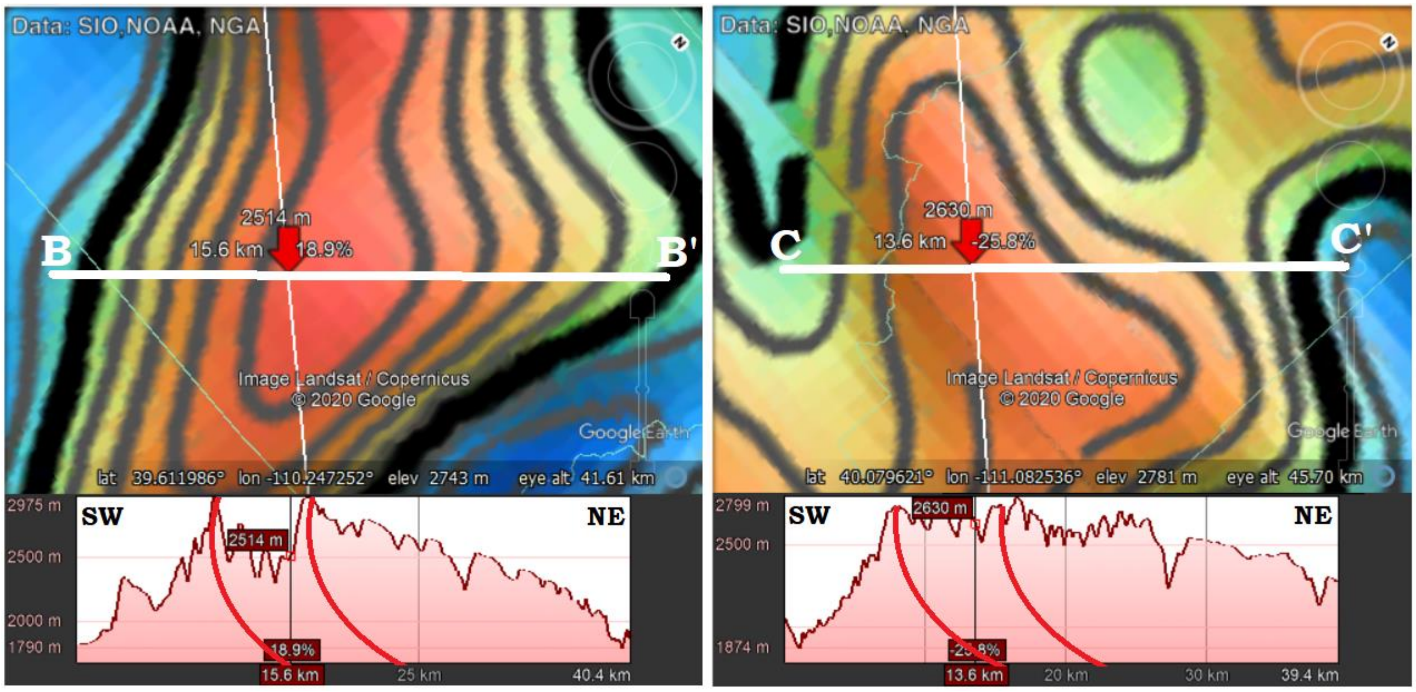

Figure 16.10: Detail of Figure 14.9 showing section through B-B' and C-C'. (Image Credit: Google Earth elevation, GGA, Scripps 2014)

Understanding the association between gneissic and granitic domes and CGRS and Open rings of craters, can it help us identify more crater rims?

Using Mascons on Earth in identifying craters

Carefully examining the Uncompahgre Plateau's image of gravity maps for clues as to the characteristic of a Mascon on Earth, there is three that are evident, Figure 16.11. 1) The CGRS distinctly shows the energy envelope with both the compression shock-ring and the expansion release-ring. The Uncompahgre Plateau is high gravity while each side is low gravity release valleys. 2) The CGRS is distinctly cut off at each end, and the south end (3) shows the distinction of a thin release valley. One of the most significant distinctions of mascons, the location of their ends defines two points on the crater's Open Ring.

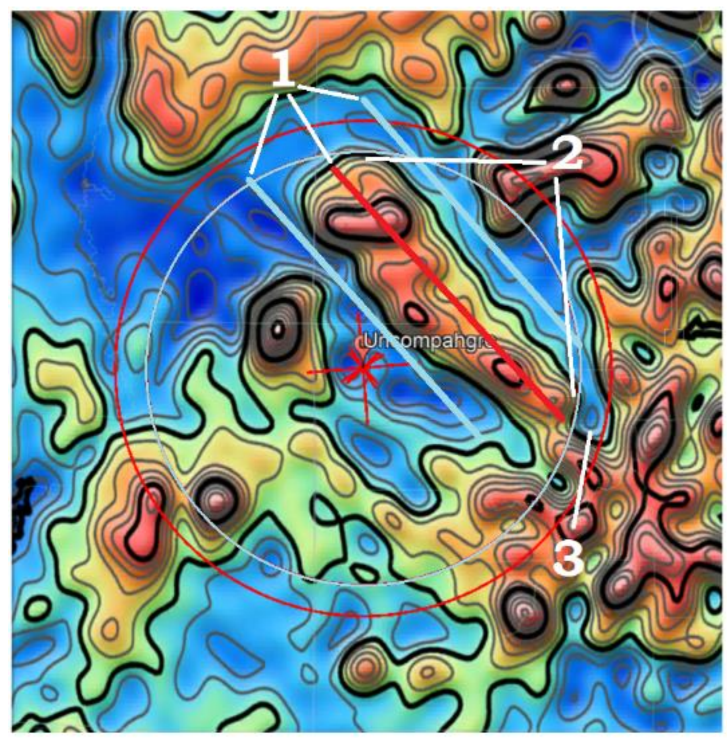

Figure 16.11: Detail of the gravity image of Uncompahgre Plateau showing the three distinctions indications of the map.

Sequoia crater and its mascon, Sierra Nevada Mountains

One of the longest and most distinctive linear mountain ranges in North America is the Sierra Nevada Mountains of California, a major historic source of placer and hard-rock gold. Extending from Mount Shasta Volcano on the North, over 600 miles (970 km) to north of Los Angeles on the south (Wakabayashi and Sawyer 2001) or 1500 km (930 miles), well down into Baja California (Bateman 1968), it has engendered much discussion about its origin.

In the more recent view its geology started with the freely moving Sierra Nevada microplate, a portion of the supposedly broader Pacific Plate, moving into place confronting the Basin and Range province of Nevada along the Walker Lane fault belt which roughly follows the diagonal line of the California-Nevada border. The San Andreas Fault, nearer the California coast, is thought to form the western edge of that micro plate. The collision with accompanying volcanism and metamorphism is credited with thrusting up the mountains. A number of individual Paleozoic and Mesozoic plutons of feldspar and granite compose the larger batholith with scattered remnants of metamorphic rocks pinched between them, At least three episodes of intrusion, left abundant evidence of wall and roof rock being pushed aside by the intrusion so it is thought to have moved in discreet burst of energy. Abundant faulting and glaciation are thought to have taken place prior to a late volcanic episode on its eastern edge, when there was a final fourth episode of tilting with or without additional lifting. Cassel et al 2009, by contrast feels most of the uplift was restricted to the Late Cretaceous and early Cenozoic.

Viewing Figure 16.12 shows a crater encompassing all of California and most of the western states in its OCR ring. Centering at 36.1445° latitude and -118.4634° longitude in the Sequoia National Forest of the southern Sierra Nevada Mountains, the Sequoia crater is based on the location of the Sierra Nevada Mountains as a mascon of that crater.

Viewing the Sierra Nevada Mountains in a section extending across most of California, Figure 16.12, the mountains are sandwiched between the release valley low of the Central Valley and the topographic low of the Owens Valley. The Owens Valley does not follow the same linear as the Sierra Nevada Mountains and therefore cannot be related to the same CGRS. Figure 16.13 shows I have placed the eastern release wave valley further east in a primarily blue/low gravity area. The sectional view shows the mountain's sectional form is the same of the Uncompahgre Plateau as a monocline facing to the west, (Figure 16.8). This would fulfill the first distinction of a mascon.

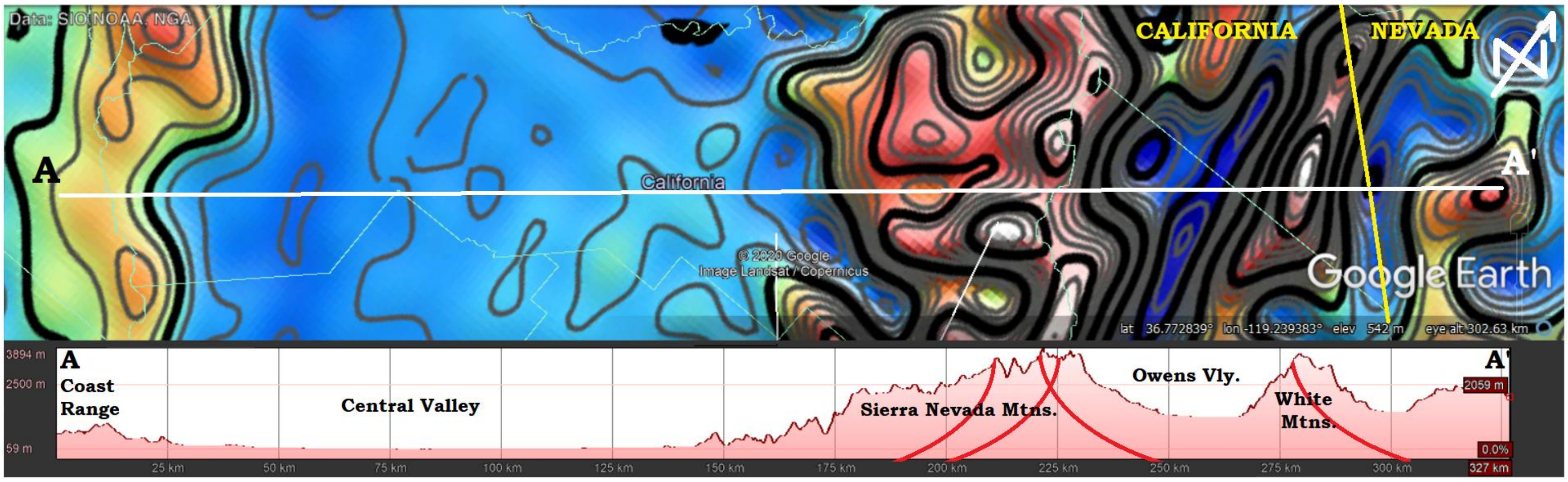

Figure 16:12: Section from the Coastal Range through the Central Valley of California through the Sierra Nevada Mountains, Owens Valley, and White Mountains. (Credit image: Global Gravity Anomaly Scripps 2014, and elevation profile from Google Earth.)

Within the northern red ring, a distinct blue/low gravity band separates the Sierra Nevada Mountains from the ring containing Mount Shasta. This short linear of low gravity corresponds to the dark green linear on B that extends from Redding to Aden. This low gravity linear definitely ends the northern end of the Sierra Nevada Mountains although other mountains completely surround the occurrence. Low gravity linears extends in a broken ring around about half of the circle, from the continental shelf of the Pacific to the middle of Arizona. This semicircle of blue defined the Open ring.

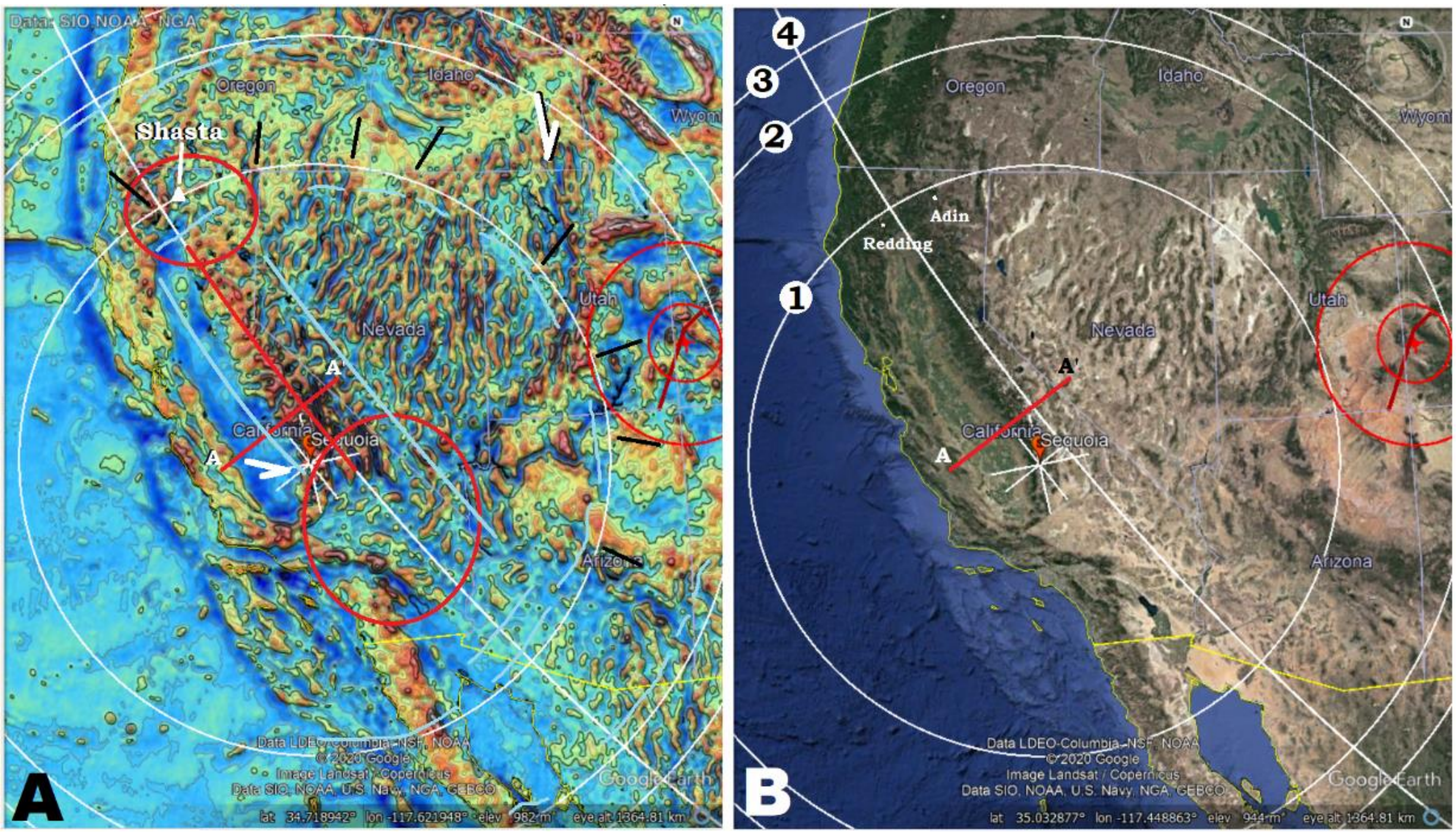

Figure 16.13: Sequoia crater showing the energy signature of its rings. 1) Open ring at 1,330 km, (820 miles) diameter, 2) OCR ring at 1,940 km (1200 miles) diameter, 3) Second ring at 2,200 km (1,370 miles) diameters. 4) CGRS from Great Bight center provides one source of uplift. (Image credit: (A) Global Gravity Anomaly, Scripps 2014. (B) Google Earth.)

In the area of the southern red ring, we would expect to see a continuation of the Sierra Nevada Mountains, but it does not exist there. Instead, a low gravity arced linear from the northeast, marked with white arrows at its ends, cuts them off. We will see that this linear is part of the Blowout Mountain Open ring. While the exact cause of the mountain's termination cannot be decided at this time, two alternatives are offered in Figure 16.14. 14A shows four smaller craters that occur in the area of the missing Sierra Nevada Mountains and probably contributed to its obscuring inside the Open ring. But I would prefer 14B which shows a possible Arenosa crater which being larger would likely have preceded the Sequoia crater and have left its low gravity energy imprint on the lithology. Sorting out the sequence needs much more research.

With the Sierra Nevada Mountains having a parallel low gravity linear on both sides, and the northern end terminating with a distinct narrow low gravity release valley prior to the upthrust of the Open Ring. As that ring structure continuing over 180º, I am comfortable recognizing the size of the Sequoia crater’s Open ring, and identifying the Sierra Nevada Mountains as an incomplete mascon.

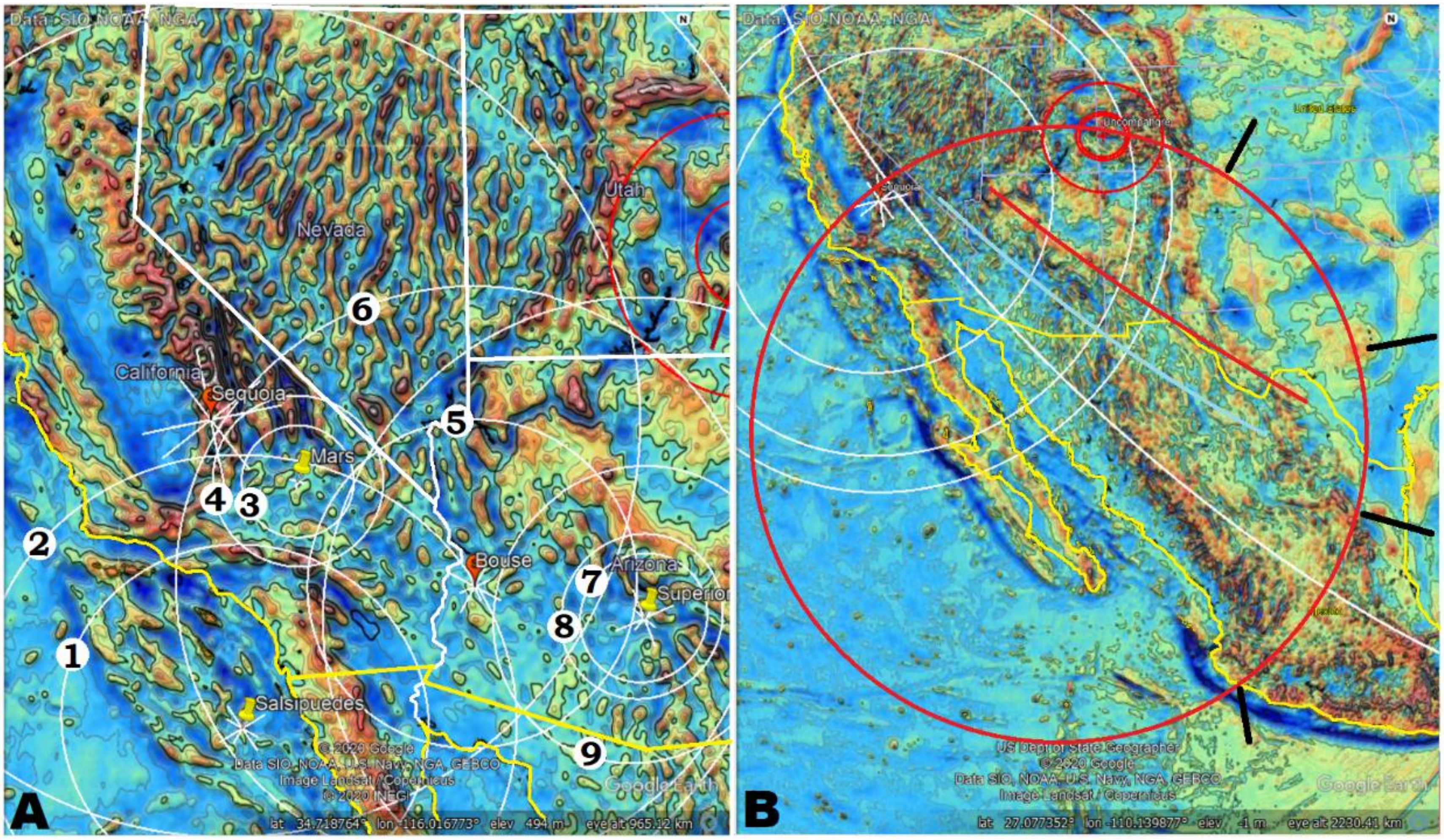

Figure 16.14: (A) Some of the crater rings found southeast of the Sierra Nevada Mountains that might have affected the expression of the CGRS. Salsipuedes crater: 1) Open ring, 580 km (360 miles) diameter, 2) OCR ring, 850 km (530 miles) diameter. Mars crater: 3) Open ring, 170 km (100 miles) in diameter, 4) OCR ring, 260 km (160 miles) in diameter. Bouse crater: 5) Open ring, 505 km (319 miles) in diameter, 6) OCR ring, 920 km (570 miles) in diameter. Superior AZ crater: 7) Open ring, 200 km (125 miles) in diameter, 8) One ring, 265 km (165 miles) in diameter, 9) OCR ring, 475 km (300 miles) in diameter. (B) Sketch of the Arenosa crater which would have proceeded the Sequoia crater, based on larger craters generally coming first, ~2260 km (1,400 miles) diameter. This circle is based on the southern end of the Sierras and the points indicated by black lines. Red and blue linears would be the remnant of a mascon from a CGRS of the Irminger center. (Image Credit: Google Earth and Global Gravity Anomaly, Scripps 2014.)

Other Crater Recognized from Mascons

Can other distinctly terminated sections of CGRS be identified within the general reach of the Sequoia crater? The most obvious one is the Owens Valley which cuts across the southeast edge of the Sierra Nevada Mountains and separates them from the White Mountains.

The Owens Valley would be the release valley portion of a CGRS and the shock wave thrust that proceeded it would have been lost in the high energy of the up-thrusting Sierra Nevada Mountains, Figure 16.15A. I identify the angle of the CGRS as originating in the Bermuda crater, which I would also credit with providing much of the upthrust for the Appalachian Mountains. The energy signature of the Open ring of the Owens crater provides a nearly complete low gravity ring just inside the high gravity ring under the circle. The OCR ring shows a similar low gravity ring. Inside the two red ellipses the distinct release valley prior to the shock expression of the ring is significantly expanded at both ends. I propose the expanded gravity reading at the ends is a result of dealing with the release wave and not the upthrust portion of this CGRS. The release valley is expanded by the definitive low gravity valley before the high gravity ring.

Blowout Mountain and Mormon Basin

Two other Mascon defined craters are the Blowout Mountain and Mormon Basin craters. Both are well defined by the blue ring just inside the shock produced ridge. The blue ring is most obvious in the southeast quadrant of the Blowout Mountain Open ring, but can be traced around most of the rings. The mascons of the Blowout Mountain is three ridges of the Bering Sea crater. Linear 7 is the most obvious because of its lowered gravity, yellow, in the eastern red ellipse and just south of it. That linear exits the continent at San Francisco Bay, within the western red ellipse, and contributed to the low gravity release valley under the bay. Just as high gravity shock waves often contribute to topographic high elevations, low gravity release waves often contribute to topographic low elevations. All three of the Bering Sea mascons show blue cut-offs inside the shock wave ring as is consistently seen in mascons.

The Mormon Basin crater shows four clear rings of blue, release valleys inside four shock wave rings. Linear 9 is obvious along the California coast having a very obvious exit from the continent in both Washington State and California. But, Linear 10 seems to be the Open ring because it defines the ends of the Ipojuca mascon CGRS within both red ellipses at their ends.

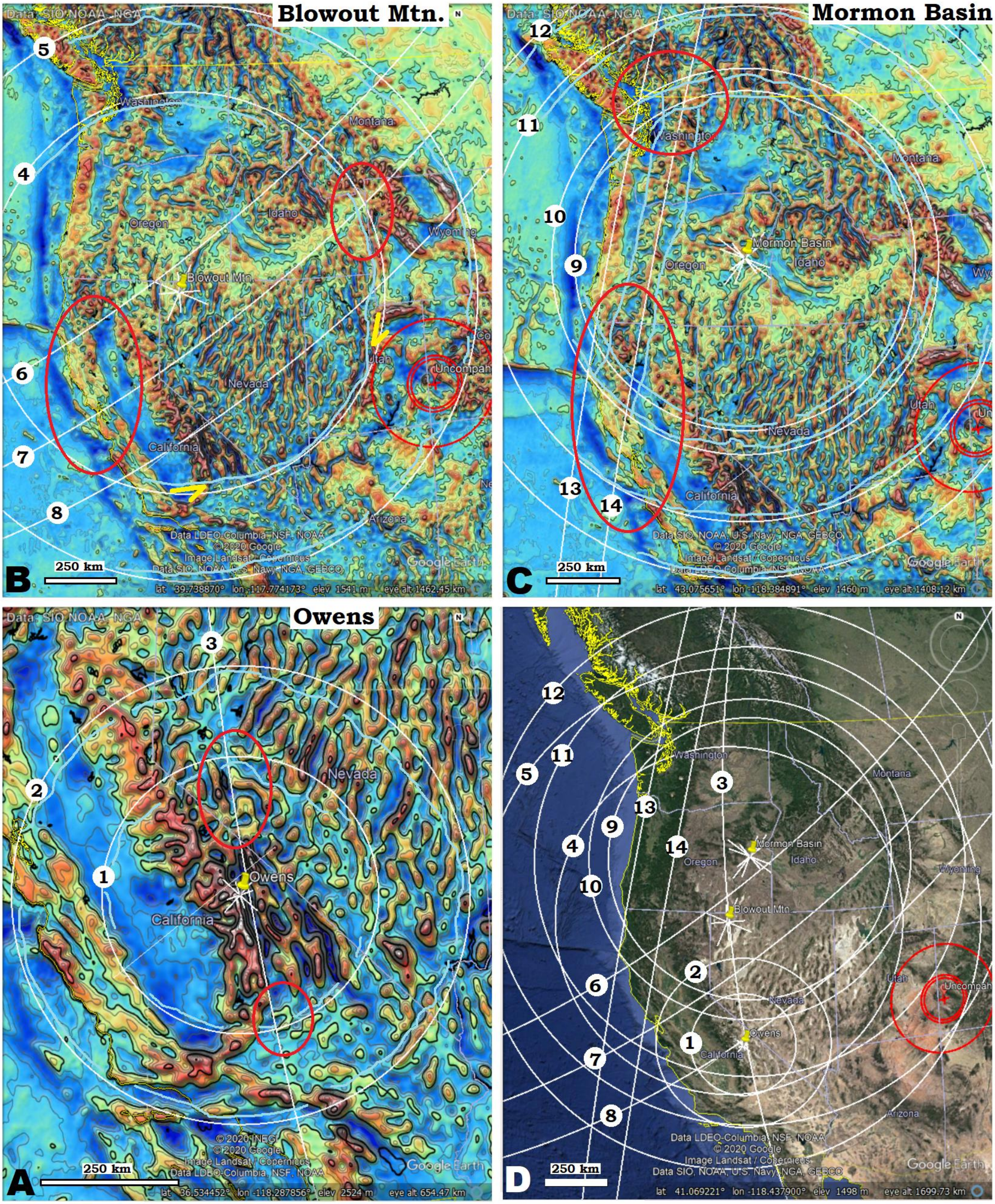

Figure 16.15: Energy signature of other large craters in the area. (A) Owens crater: 1) Open ring at 425 km (260 miles) in diameter, 2) OCR ring at 710 km (440 miles) in diameters. 3) CGRE from Bermuda center. (B) Blowout Mountain crater: 6) Open ring at 1,430 km (885 miles) in diameter, 5) OCR ring at 2,100 km (1300 miles) in diameter. 6, 7, 8) CGRS from Bering Sea center. (C) Mormon Basin crater: 9) Open ring at 1,150 km (720 miles) in diameter, 10) 1b ring at 1,300 km (800 miles) in diameter, 11) OCR at 1800 km (1120 miles) in diameter, 12) 2 ring at 2,230 km (1400 miles) in diameters. 13-14) CGRS from Ipojuca center. (D) All of the linears shown on Google Earth to see spatial relationship.

Yin (1991) presents a series of gneissic domes in the lower Colorado valley, near the border of Arizona and California. He interprets them as the repeated expression of antiforms (up folds) and synforms (down folds) as a result of a Laramide type crustal contraction. I find a direct correlation with his antiformal and synformal forms and rings I relate to the Owens crater, Figure 14.16. The difference in angle I would ascribe to where he took his angle reading on individual linears which he thought was straight, and I assume are curved. If these are annulus rings on a crater, they would be en echelon upthrust rings (CGRS) rather than antiformal and synformal forms.

While the Uncompahgre Plateau is not one of a series of folds, when discussing the Laramide Orogeny Ersley and Koenig (2009) try fitting all of the folds and arches of the Rocky Mountains into five groups. My CGRS model for those same folds and arches would expect en echelon expression from >10 major and >25 minor preexisting centers globally to be expressed in the greater Rocky Mountain area. Some of the folds and arches are original crater rims (OCR) and some are from more distant annuli (CGRS). If CGRS are regularly expressing in gneissic to granitic lithology, it suggest the waves are traveling through the mantle, some closer to the surface and erupting as gneiss and others deeper erupting as granitic.

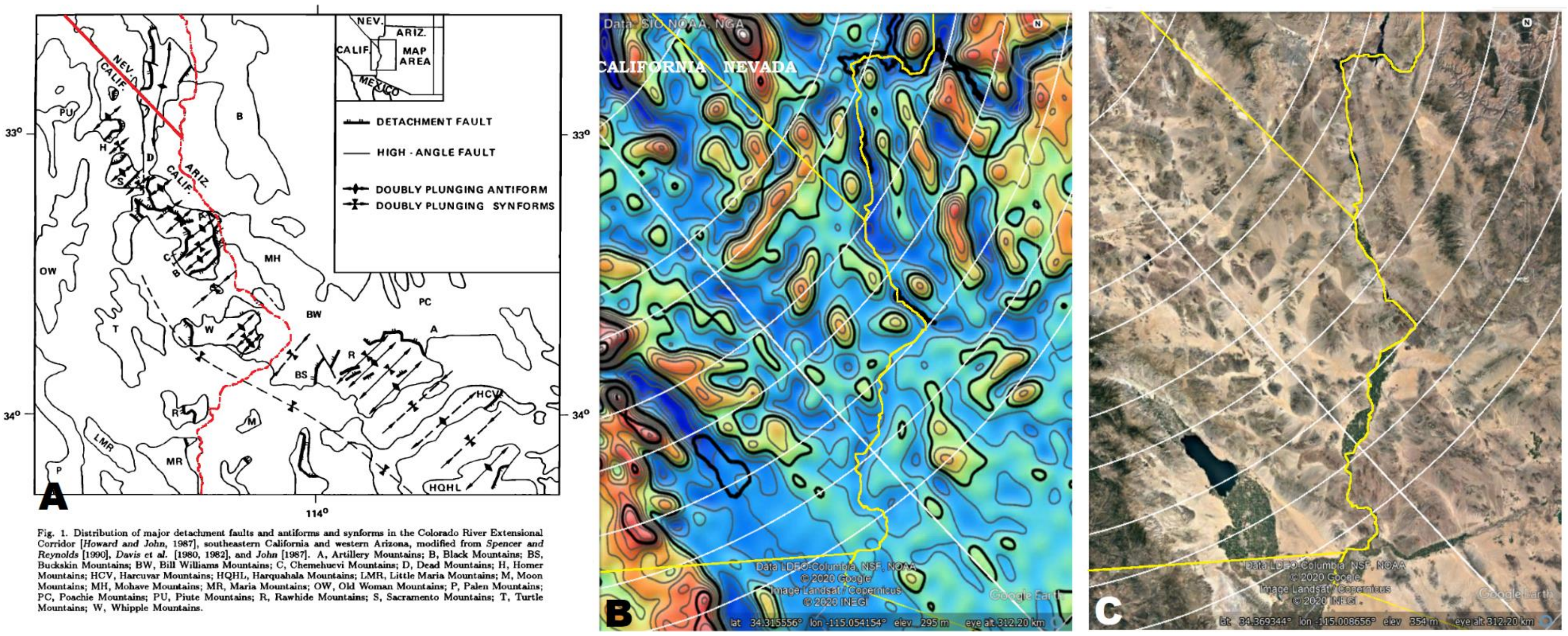

Figure 15.16: (A) Yin's Figure 1 showing his identification of antiforms and synforms. While his identification was on the ground, the annulus from the Owen crater correspond across the same land surface as charted in gravity patterns, and would suggest almost constant wave expression in the surface lithology. (Image credit: (A) Yin 1991, his Fig. 1 (B) Global Gravity Anomaly, Scripps 2014, (C) Google Earth)

Blowout Mountain crater

A second crater with a mascon is Blowout Mountain, Figure 16.15B. Centering in the northwest corner of Nevada, it leaves some of the most prominent linears in gravity across the Rocky Mountains. With its Open Ring at over 1400 km (870 miles), it is larger than the Sequoia Open ring and I will assume earlier. The portion of the Sierra Nevada Mountain mascon that exist is entirely contained within that Open ring, and I will attribute part of the termination of that mascon to Blowout Mountain crater's energy signature.

CGRS from the Bering Sea center form the mascons in Blowout Mountain's Open ring. Figure 16.15B shows three relatively distinct shock ridges, but only 7 shows a well-developed release valley behind it. Linear 7 shows a distinct yellow portion just west of the east red oval. Yellow results from lowering the gravity in that area. Evidence of that lowering is still visible when Linear 7 exits the continent through San Francisco Bay, which shows as a blue low gravity area. Actually, all three linears leave the continent with extra blue valleys in their paths.

Looking at the eastern red ellipse, all three linears also demonstrate a distinct low gravity valley between the end of the mascon and the shock ridge of the Open ring.

Mormon Basin crater

Mormon Basin, Figure 16.15C, was recognized because the linears of CGRS from the Ipojuca center did not quite fit into the Open ring of the Blowout Mountain crater. After trying several methods to justify their non-fit, it was evident that another Open ring was being dealt with. If the two rings are compares in Figure 16.15D, Blowout Mountain's Open ring, Linear 4, and Mormon Basin's Open Ring, Linear 9, in western Washington crossing Puget Sound, within the northern red ellipse. Figure 16.15C, there is seen to be much irregular areas of low gravity breaking up the Ipojuca OCRS. I would attribute that to the release valley linears from these crossing Open rings.

In the geology of the Sierra Nevada Mountains, four episodes of up-thrusting and tilting were cited. Bateman (1968) offers a model that recognizes three. While Figure 16.17 allows me to use Bateman's basic structure showing the three to four up-thrust, with the final one coming from the Bermuda center and resulting in the Owens Release Valley. I would suggest the Great Bight was the second or third, but more research is needed before a complete models for this mascon is proposed.

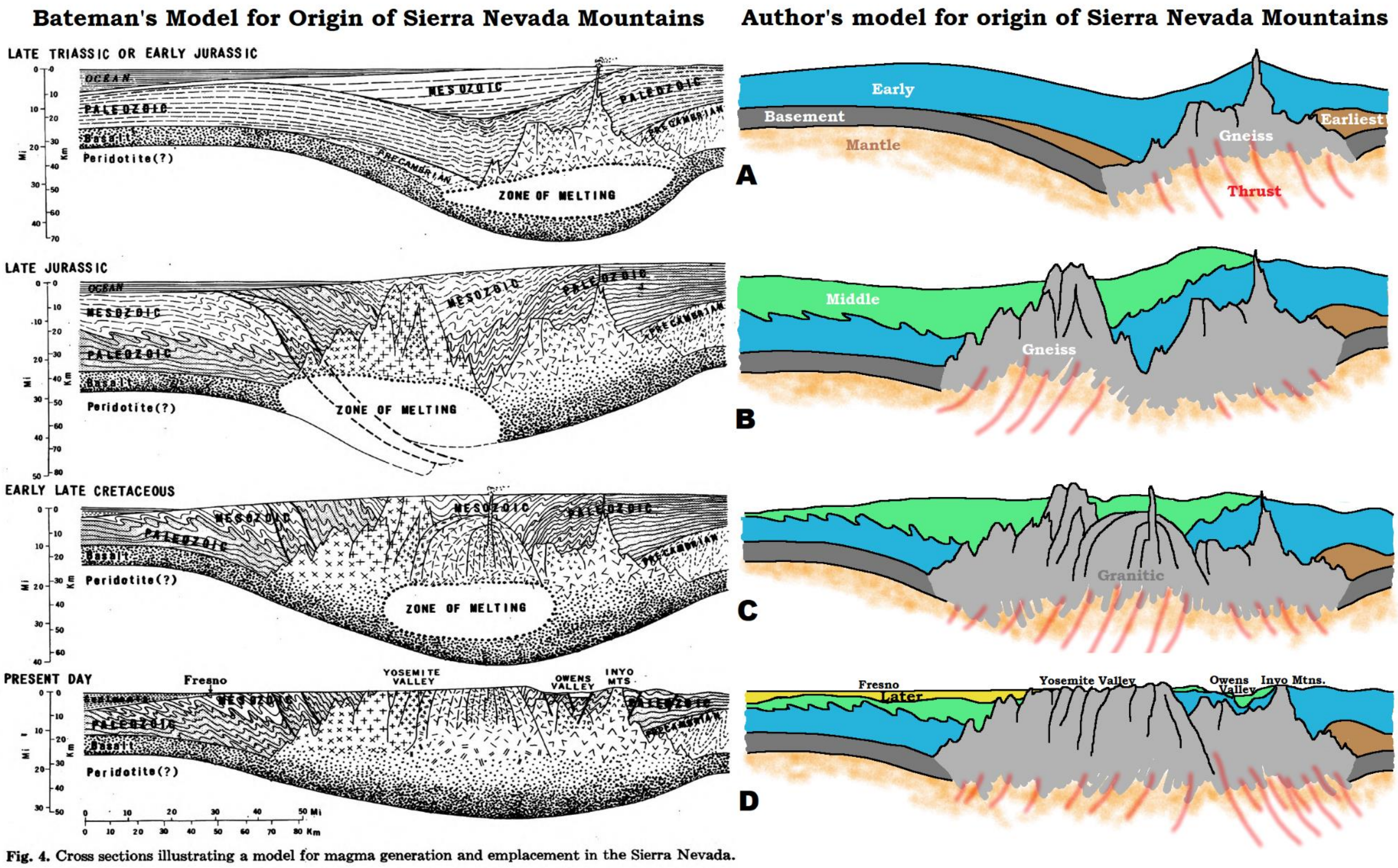

Figure 15.17: Models for origin of the Sierra Nevada Mountains. In Author's model vertical exaggeration varies. "Early, Middle and Later" denote relative period of time, hours to days. Likely less than two weeks total.

Conclusion

While a single circular bowl shaped depression may not be enough pattern to recognize an impact craters, the expression of the shock and release wave pair, with indication of the adiabatic transition between them, here referred to as the energy signature, gives positive proof of a shock wave, and the size of these shock waves could have no other known cause other than an impact. Equating isolated monoclonal mountain forms with mascons on the moon, and finding these early mascons relate extremely distinctively with the shock rings makes an impact origin more likely.

A major advantages of recognizing the energy signature of a crater or CGRS, we have so much more information as to how the form, mineralogy, and lithology got to any geographical location. It topography and the related lithology of a location is a primary source of information on the geology of that location, and both of those can be related to impacts, we are much further on our understanding how our resources got to where they are. As we continue to study these geographical location, we learn less has happened out of sight, deep in the mantle, and the key to understanding is recognizing the energy signature expressed at the surface of the crust where we can examine it.

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