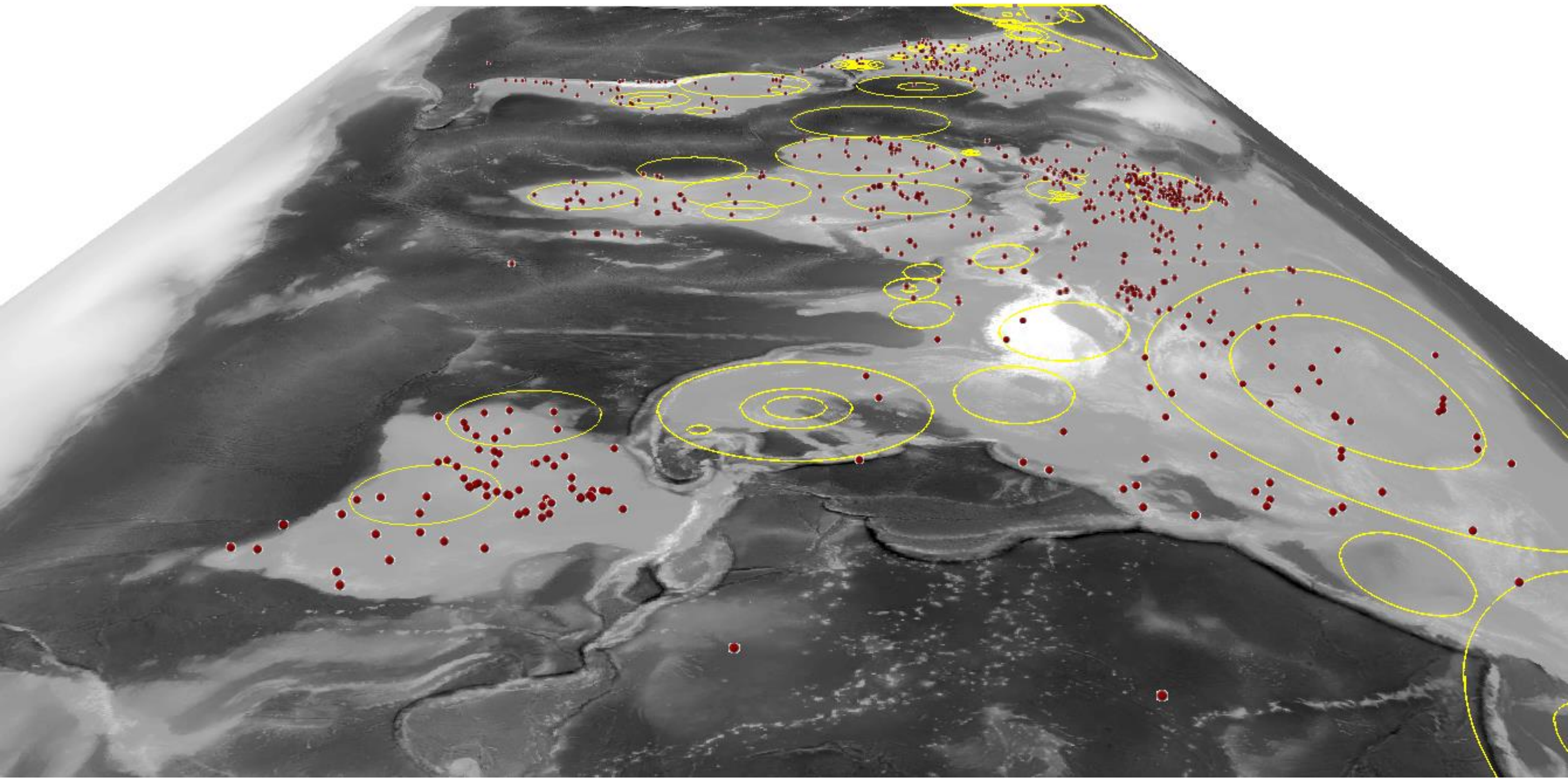
Terrestrial Multi-Ringed Impact Structures as Petroleum Traps

Grand Valley State University AAPG Student Chapter
Spring 2021 Virtual Speaker Series
D. Buthman 4/2/2021

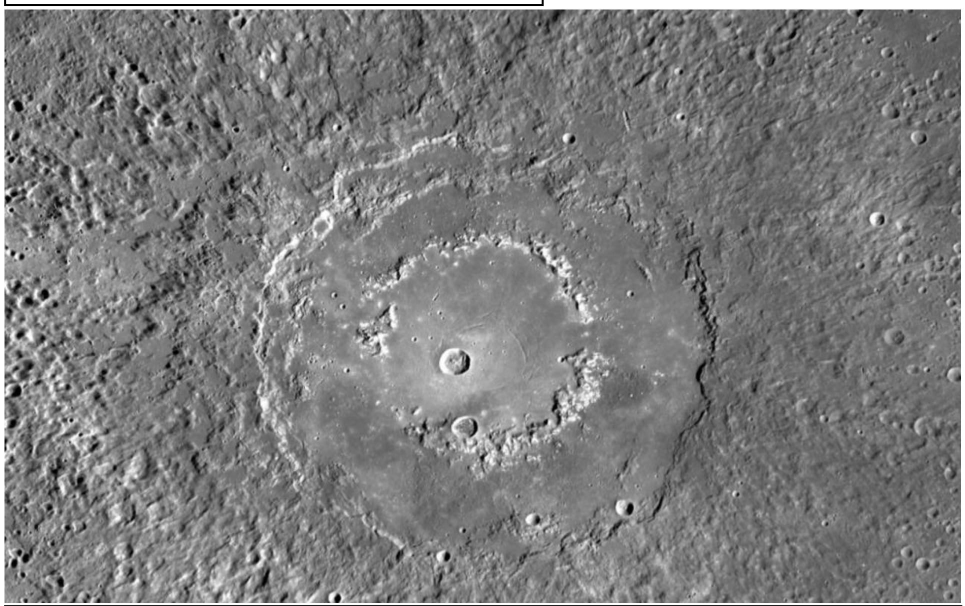
- 3 Dimensional Global Index Maps
- Abundances of multi-ringed impact basins in our Solar System
- **Possible**, Probable, Proven (Entrepreneur to Industry to Academy)
- Predictive Math
- Crustal-Mantle Earth Models
- Mid-Atlantic Ridge
- Thermal Effects: Volcanics, Meltrock, Source Rocks
- Oil and Gas Basins Analyses

The Problems with Projections: Representing 3D in 2D

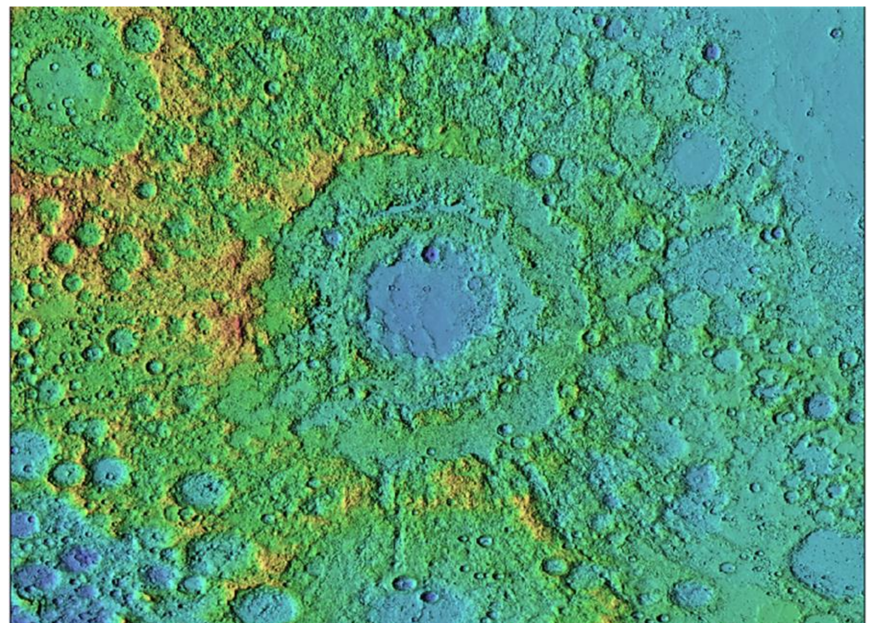


Simple crater, Earth, **1200 meter** diameter

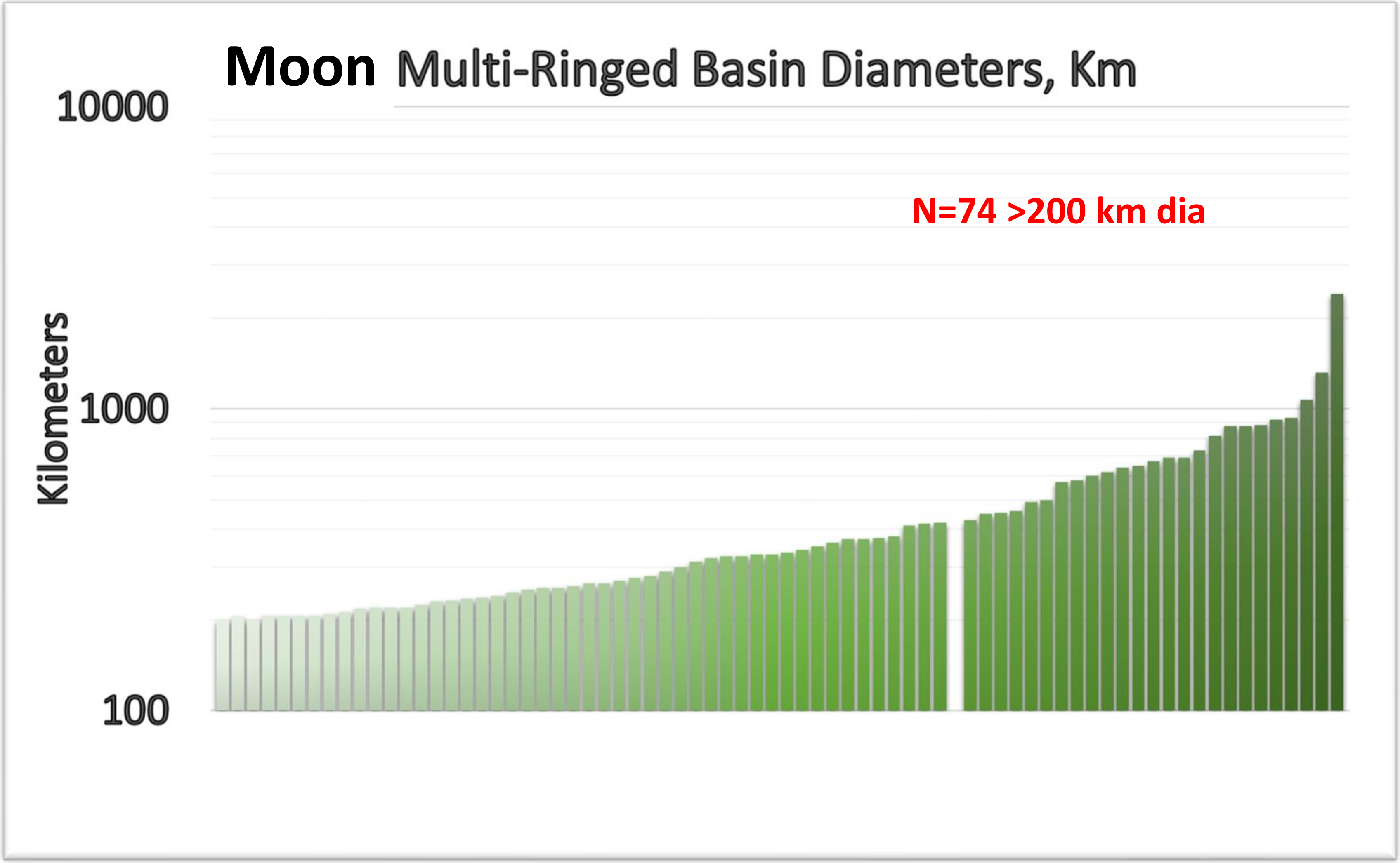
Complex peak ring or multi-ringed crater, Mars, **50 km** diameter



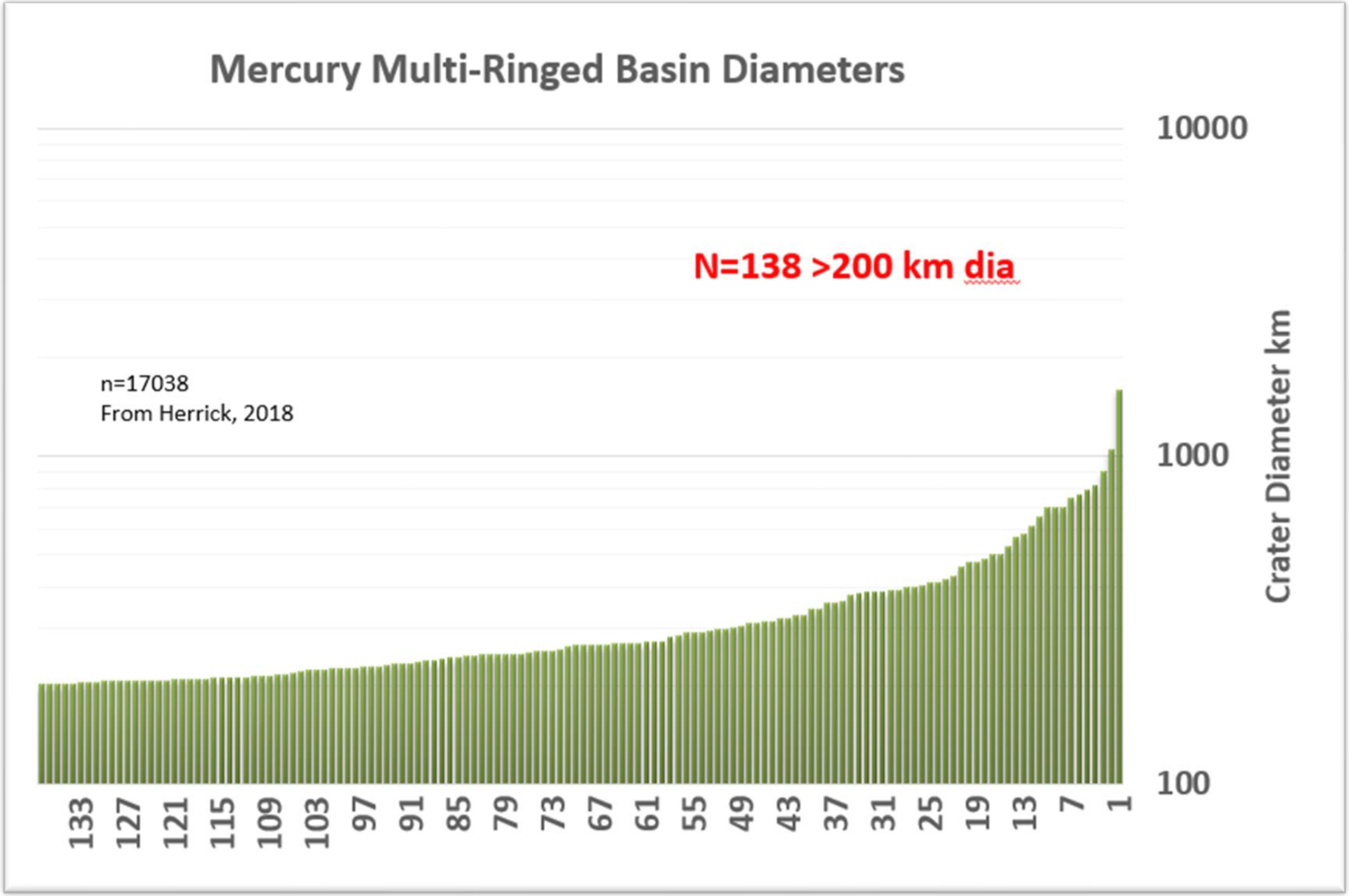
Raditladi peak-ring basin, Mercury. Mercury dual imaging system (MDIS) Crater diameter is **258 km**. NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washingston, 4/16/2015.



Mare Orientale multi-ringed crater basin. Innermost ring is 340 km diameter, outer rim is **962 km** diameter.



Lunar multi-ringed basin diameters based on a combination of topography and bouguer gravity from NASA's lunar gravity field laboratory mission (From Neumann, 2015). Data shows there are 74 multi-ringed basins on the Moon with main ring diameters of greater than 200 kilometers (124 miles). The Moon is 1/3rd the size of the Earth. Is it believable that a planet three times the size of the moon only has 2 impact craters equal to or larger than 200 km in diameter?



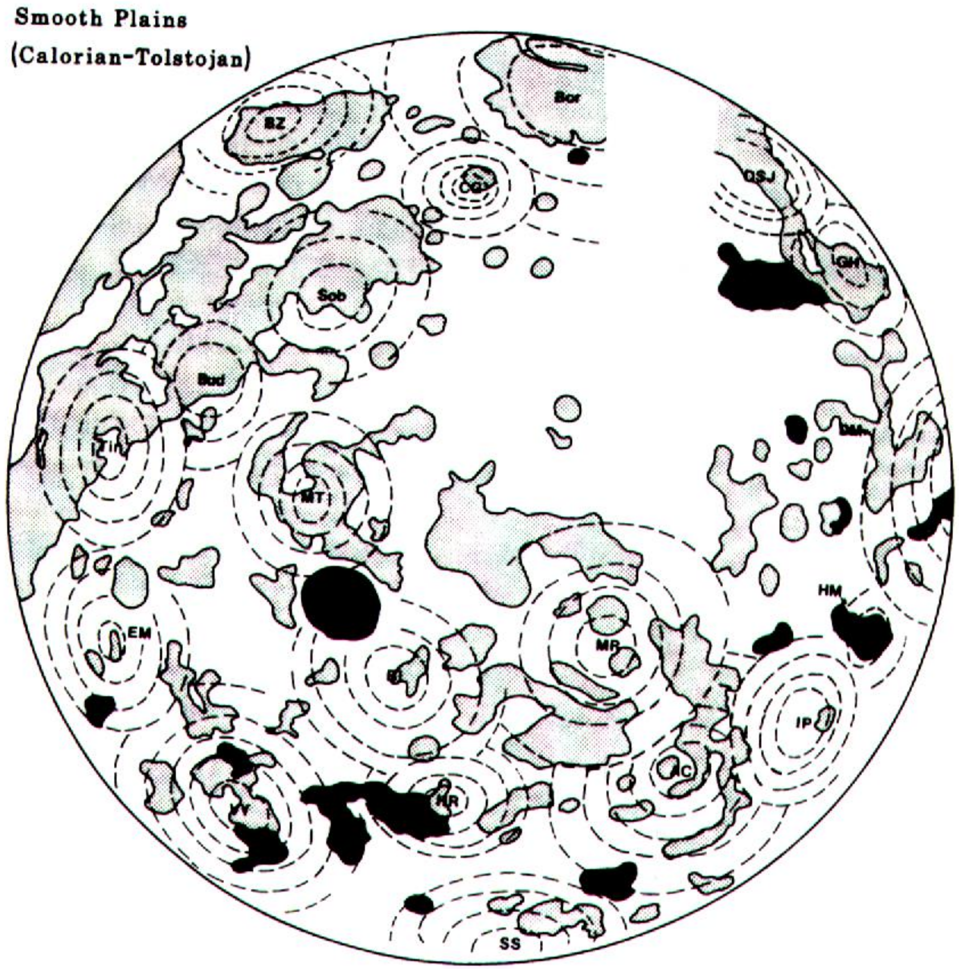
Mercury 4878 km diameter, approximately the size of the continental United States. It is 2/5ths the size of the Earth. The Earth's diameter is 12,742 km (Herrick, 2018; total 17,038 craters)

MOON: 3,475 km dia → 74 >200 KM

MERCURY: 4,878 km dia → 138>200 KM

EARTH: 12,742 km dia → 1-2>200 KM (?)

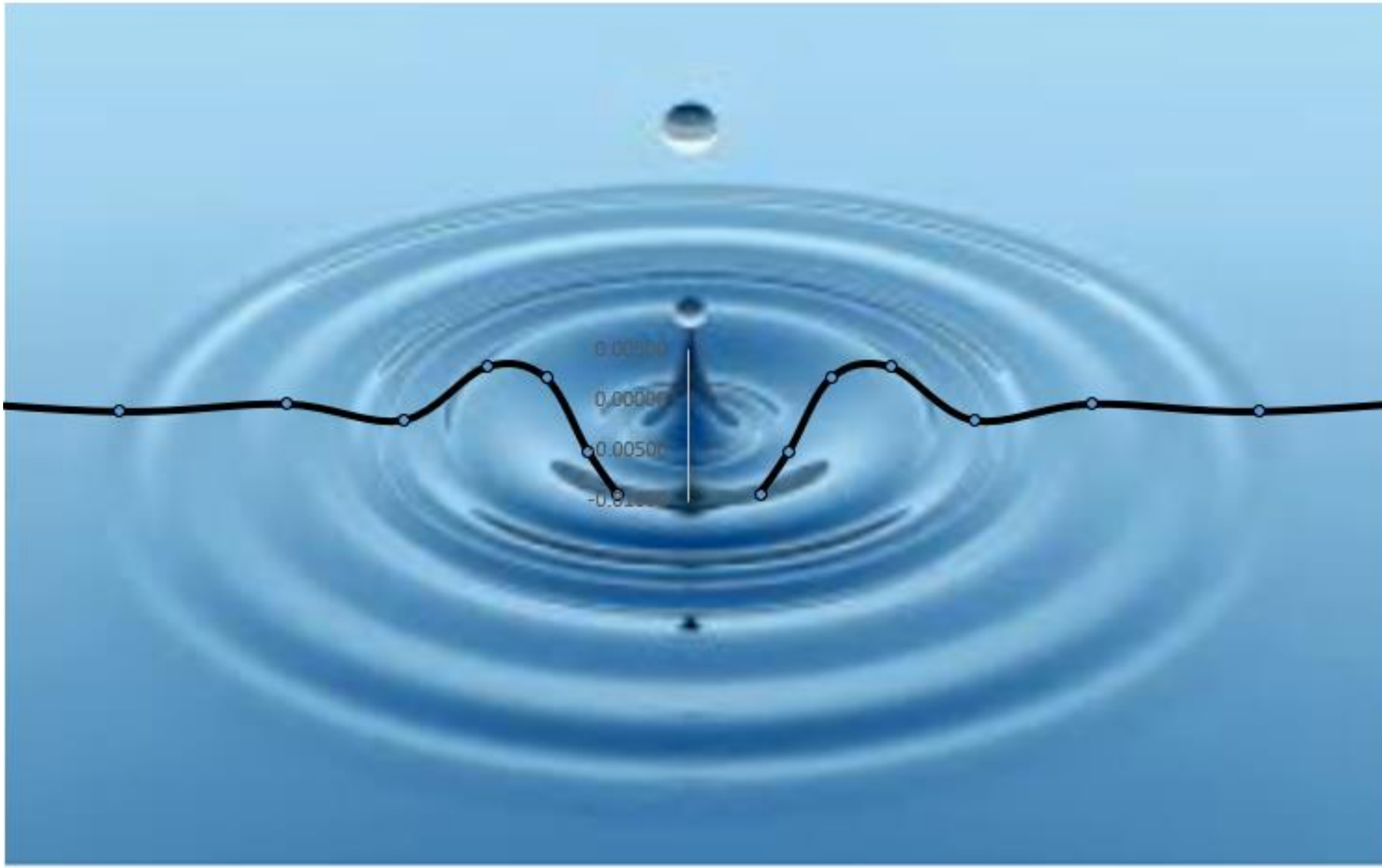
Multi-ringed Crater Basin Analysis



√D=ring spacing

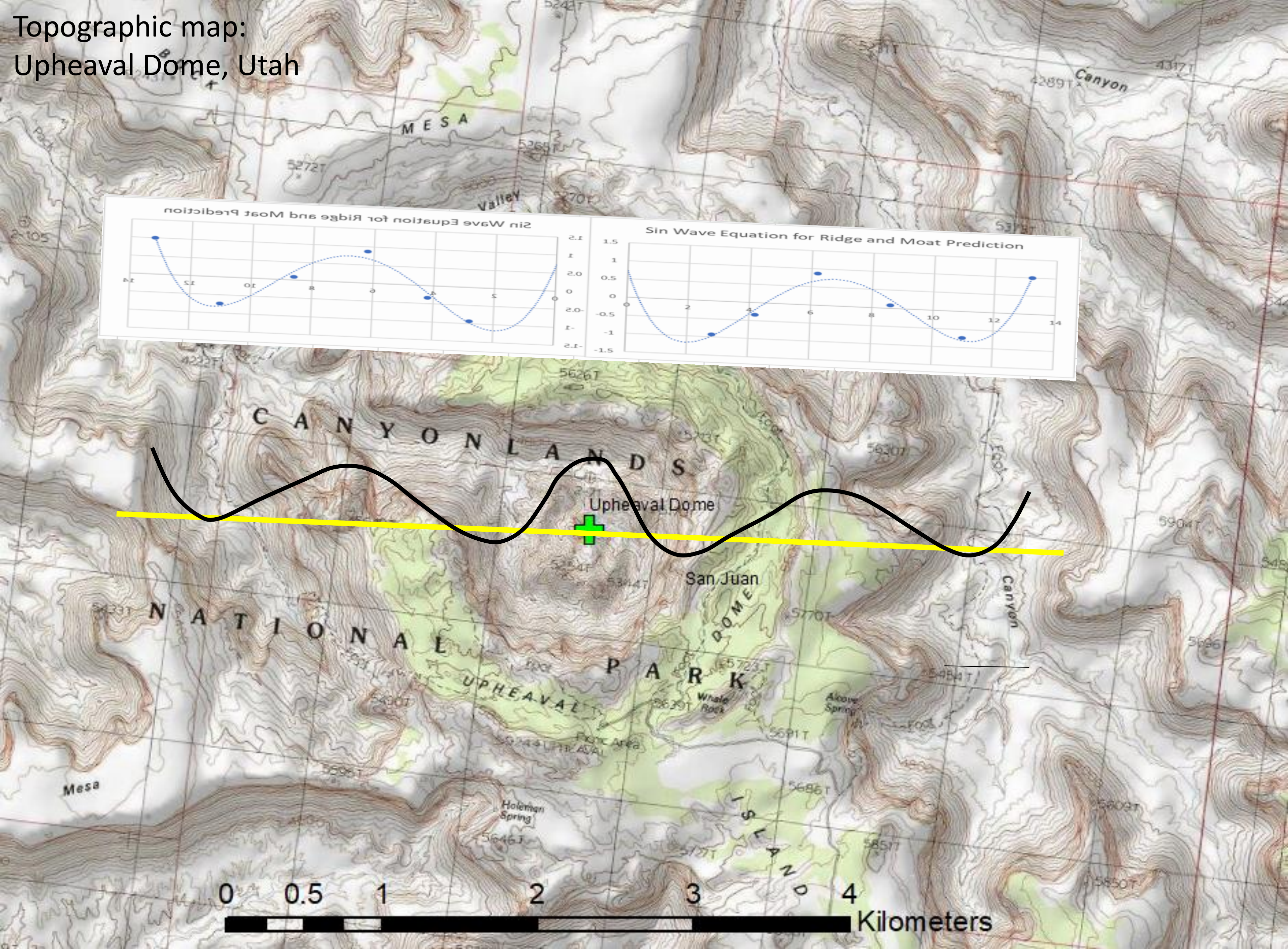
But what's a ring?

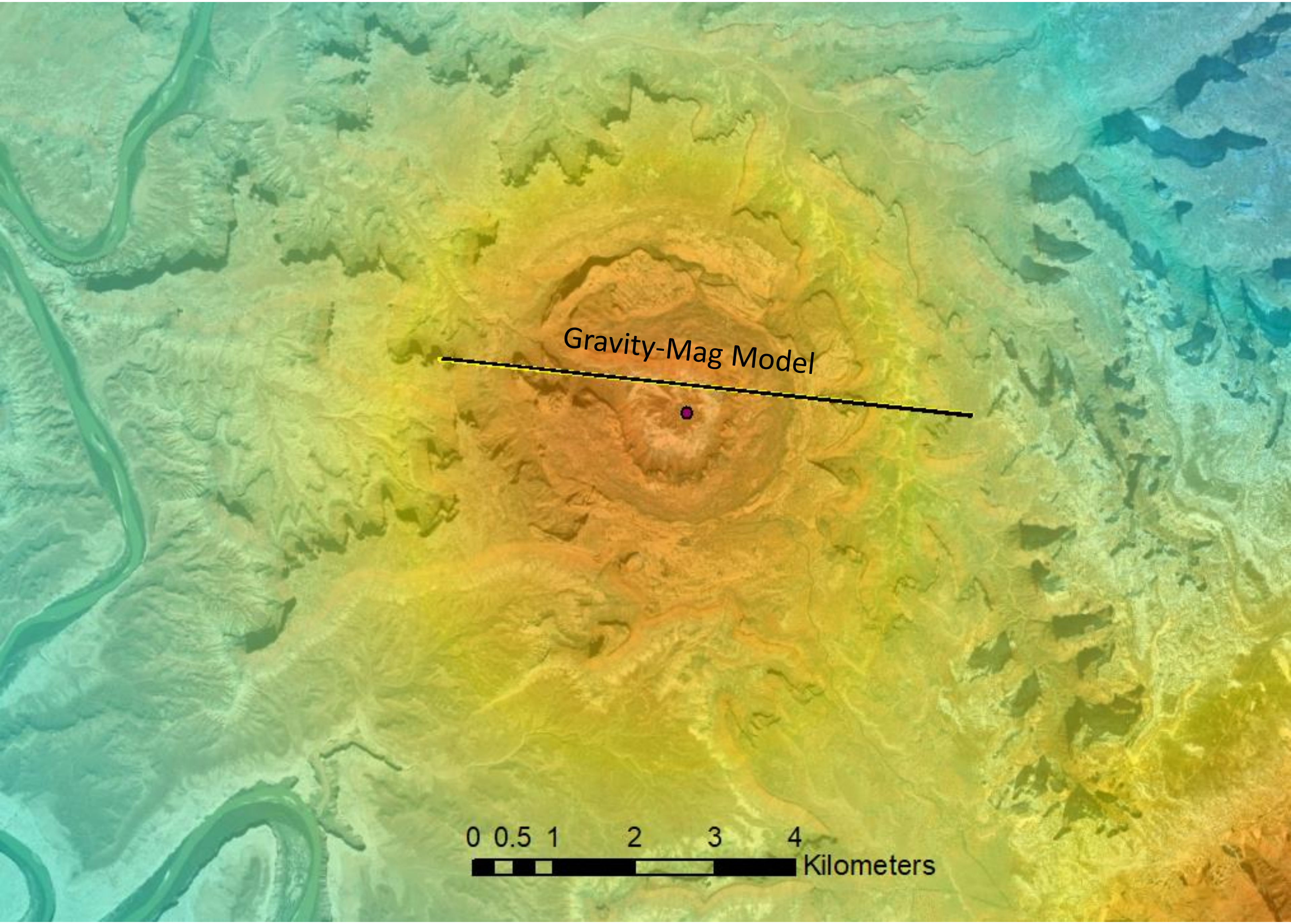
Lambert equal-area projection showing the distribution of smooth plains and multiringed basins on Mercury (Moore, 1981; Spudis, 1993√). On both Mercury and the Moon, basins control the distribution of volcanic units.



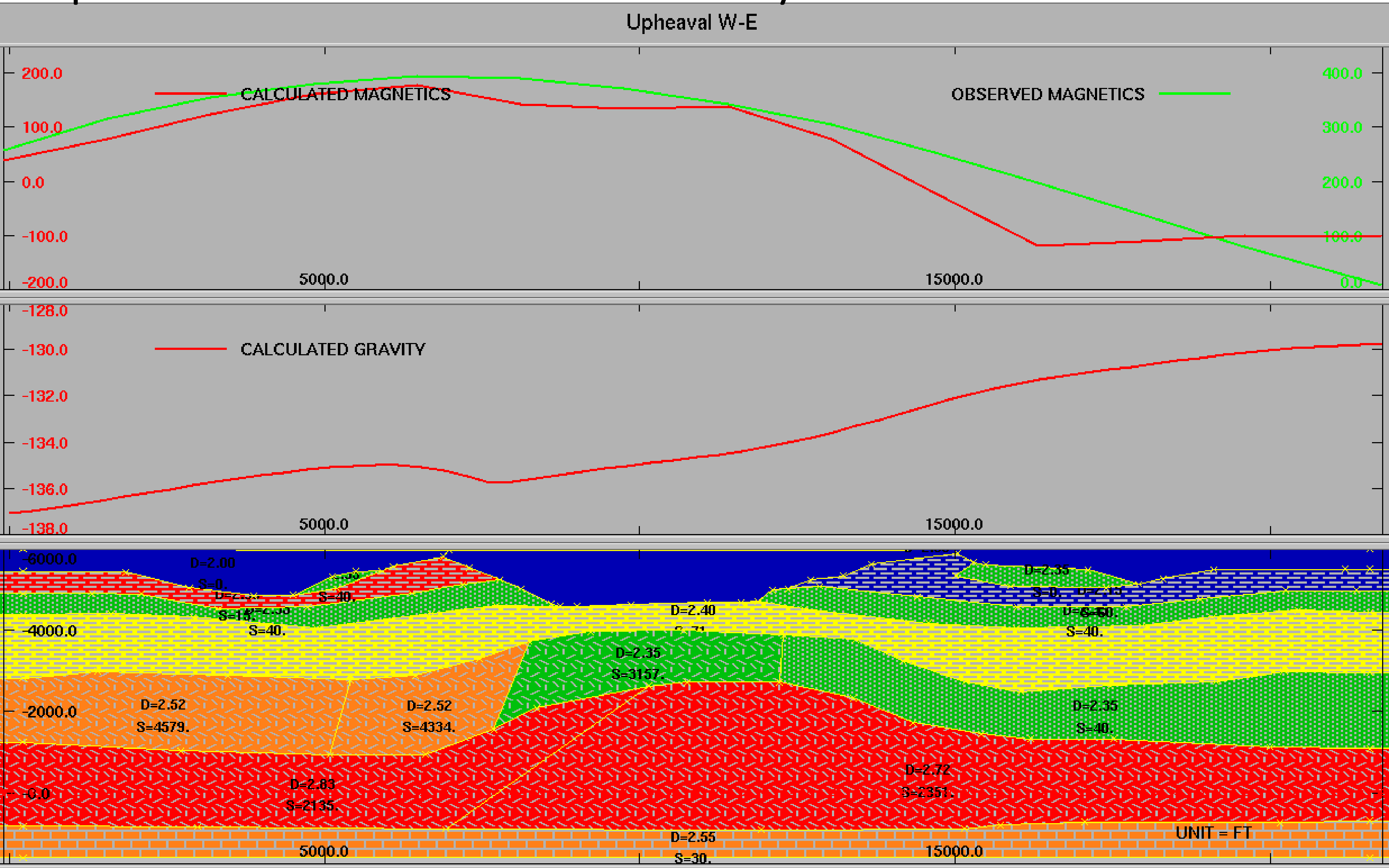
The function ***sin(x)/x*** describes the rippling waves in water, and with adjustment factors, with meteoritic impact on our Earth. The harmonics describe multiple rings, circular ridges and encircling moats, with a central peak and its peak ring. Multiringed features propagated in water: the proverbial pebble dropped in the pond.

Topographic map:
Upheaval Dome, Utah

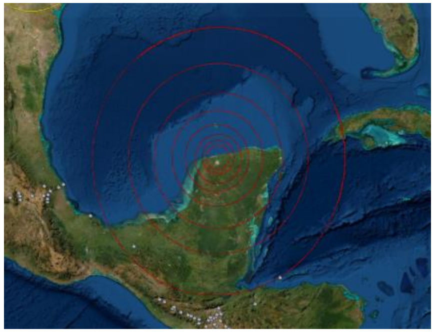



Gravity-Mag Model
0 0.5 1 2 3 4
Kilometers

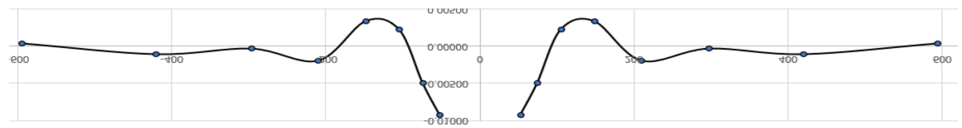
Upheaval Dome Earth Model: Definitively *Not* Salt Cored



"It's embarrassing to relate that it took me another 34 years to finally realize that Upheaval Dome is the world's best exposed impact structure." -Gene Shoemaker

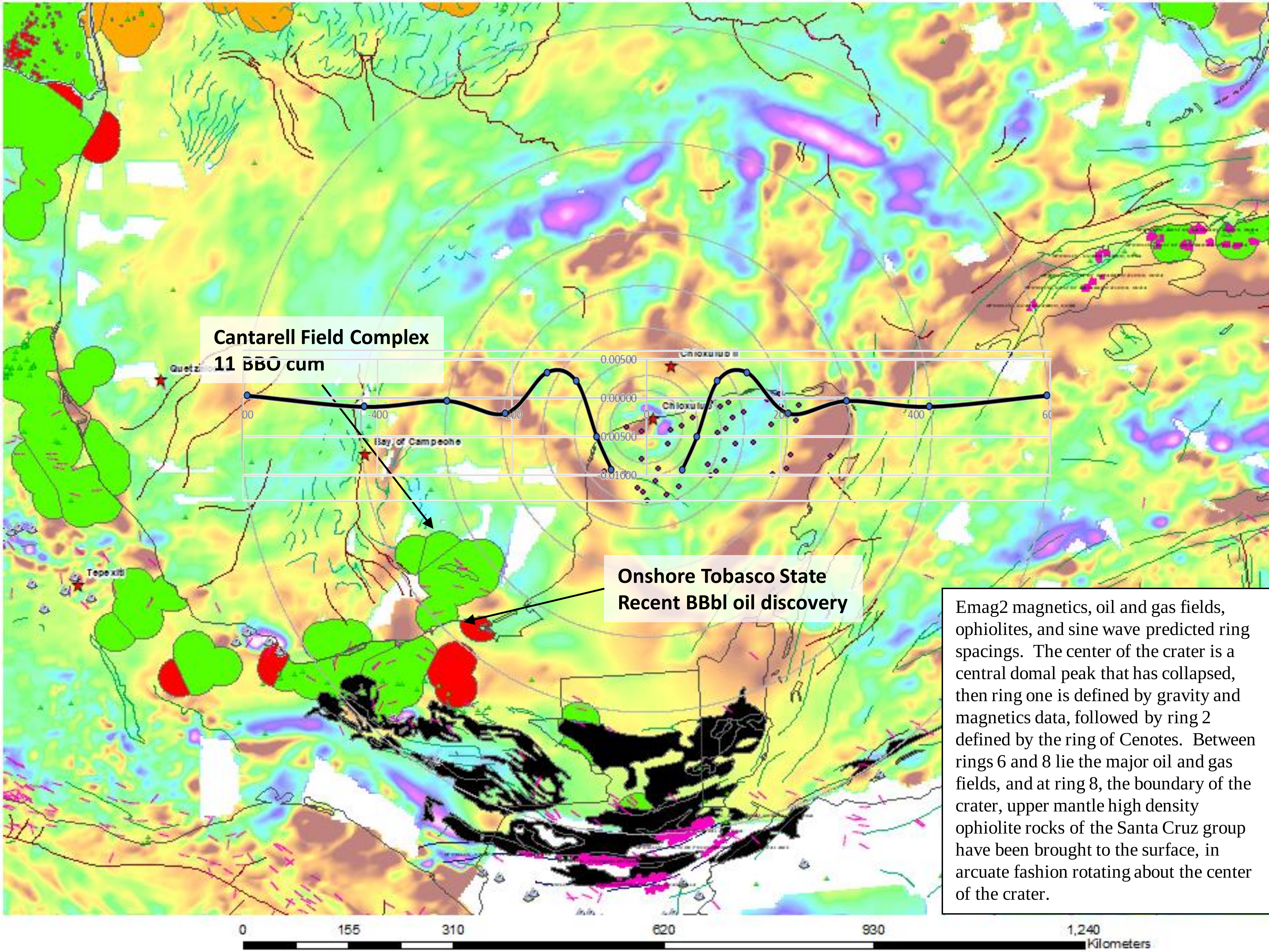


Chicxulub sin(x)/x

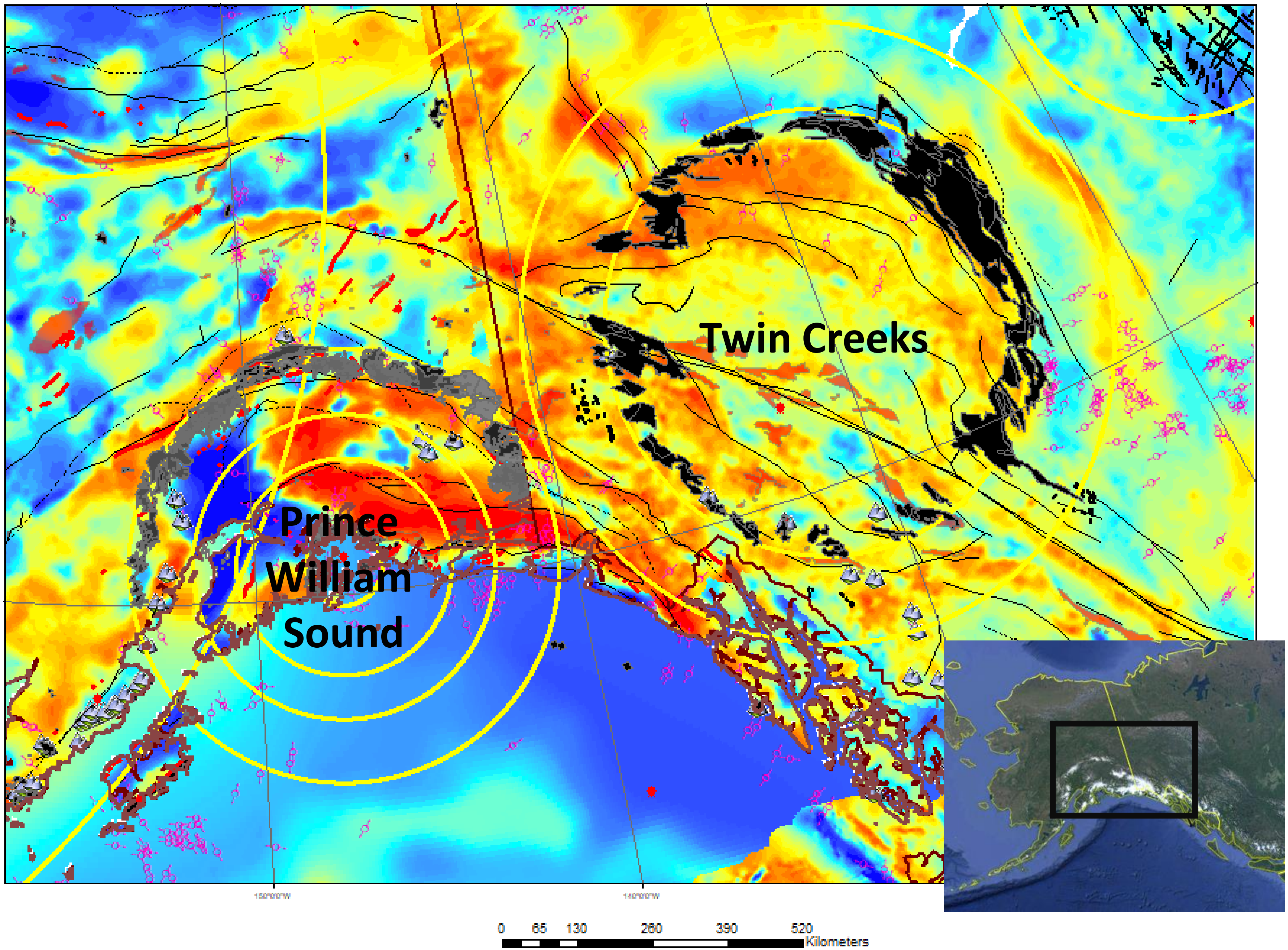


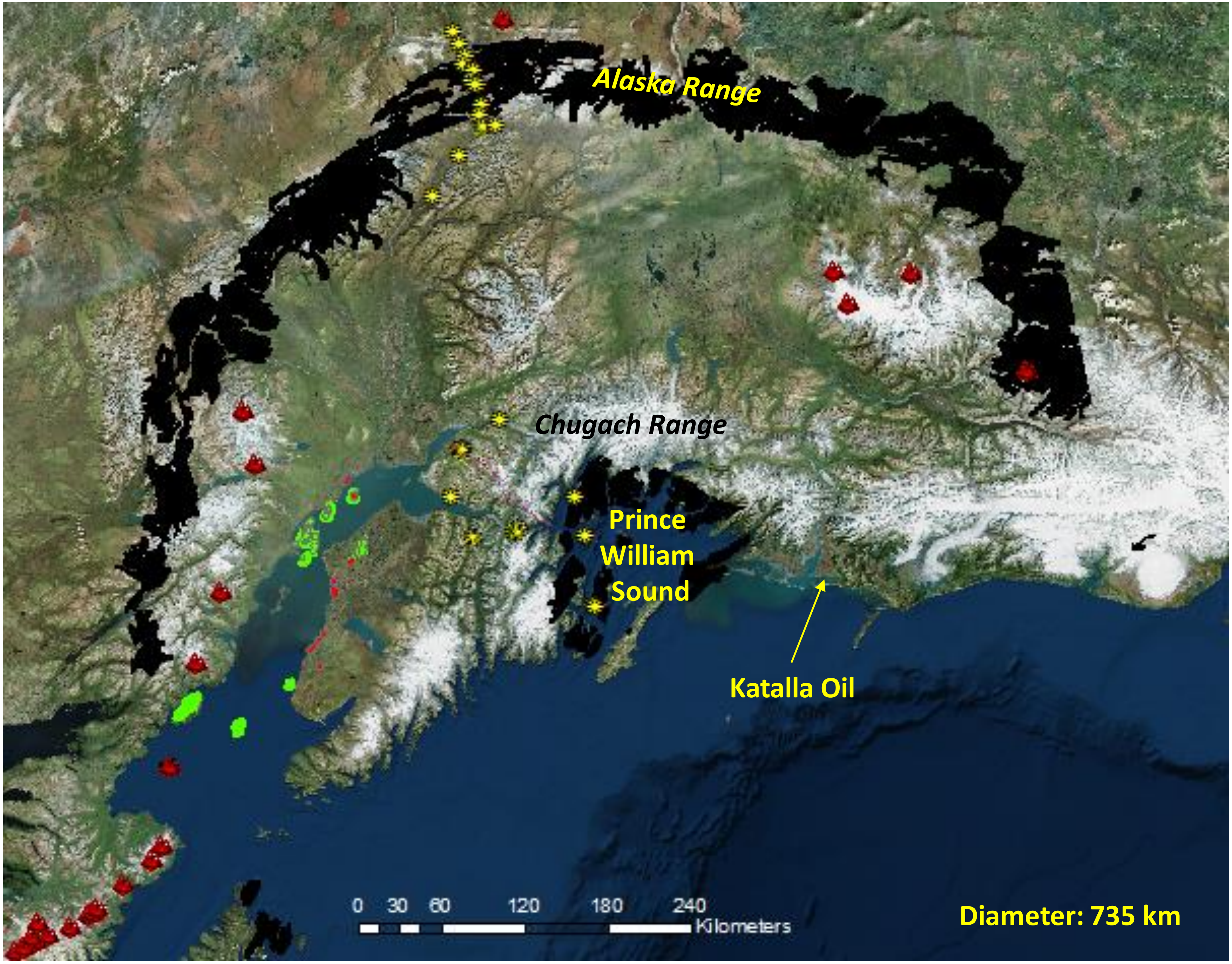
Ring Number	Actual Diameter, km	Spacing Rule Diameter, km	Spacing Rule Radius	Sin(x)/x	Diagnostic Element	Deformation Depth (IFF Ring = D	Earth Layer
12		-4752	-2376	0.00021			upper mantle
11		-3360	-1680	-0.00030			upper mantle
10		-2376	-1188	0.00031			upper mantle
9		-1680	-840	0.00041	Santa Cruz Ophiolite belt		upper mantle
8		-1188	-594	0.00034	Saline_Comalcalco Basin oil fields		upper mantle
7		-840	-420	-0.00111	Cantarell Complex Rings 6-7		asthenosphere
6		-594	-297	-0.00035	Cantarell Complex Rings 6-7		asthenosphere
5		-420	-210	-0.00197			asthenosphere
4		-297	-148	0.00335			lithosphere
3		-210	-105	0.00223			lithosphere
2	154	-148	-74	-0.00500	Cenote Ring; published diameter		lithosphere
1	105	-105	-53	-0.00924			contl crust
0			0		Center Chicxulub		oceanic crust
1	105	105	53	-0.00924		20	contl crust
2	154	148	74	-0.00500	Cenote Ring; published diameter	29	lithosphere
3		210	105	0.00223		43	lithosphere
4		297	148	0.00335		63	lithosphere
5		420	210	-0.00197		92	asthenosphere
6		594	297	-0.00035	Cantarell Complex Rings 6-7	135	asthenosphere
7		840	420	-0.00111	Cantarell Complex Rings 7-7	198	asthenosphere
8		1188	594	0.00034	Saline_Comalcalco Basin oil fields	289	upper mantle
9		1680	840	0.00041	Santa Cruz Ophiolite belt	424	upper mantle
10		2376	1188	0.00031		620	upper mantle
11		3360	1680	-0.00030		908	upper mantle
12		4752	2376	0.00021		1330	upper mantle

Chicxulub ring diameters predicted and forecast using the square root of 2 ring spacing rule. The deformation depth calculation corresponds to rheological layers of the Earth, from Crust to Upper Mantle.



Emag2 magnetics, oil and gas fields, ophiolites, and sine wave predicted ring spacings. The center of the crater is a central domal peak that has collapsed, then ring one is defined by gravity and magnetics data, followed by ring 2 defined by the ring of Cenotes. Between rings 6 and 8 lie the major oil and gas fields, and at ring 8, the boundary of the crater, upper mantle high density ophiolite rocks of the Santa Cruz group have been brought to the surface, in arcuate fashion rotating about the center of the crater.

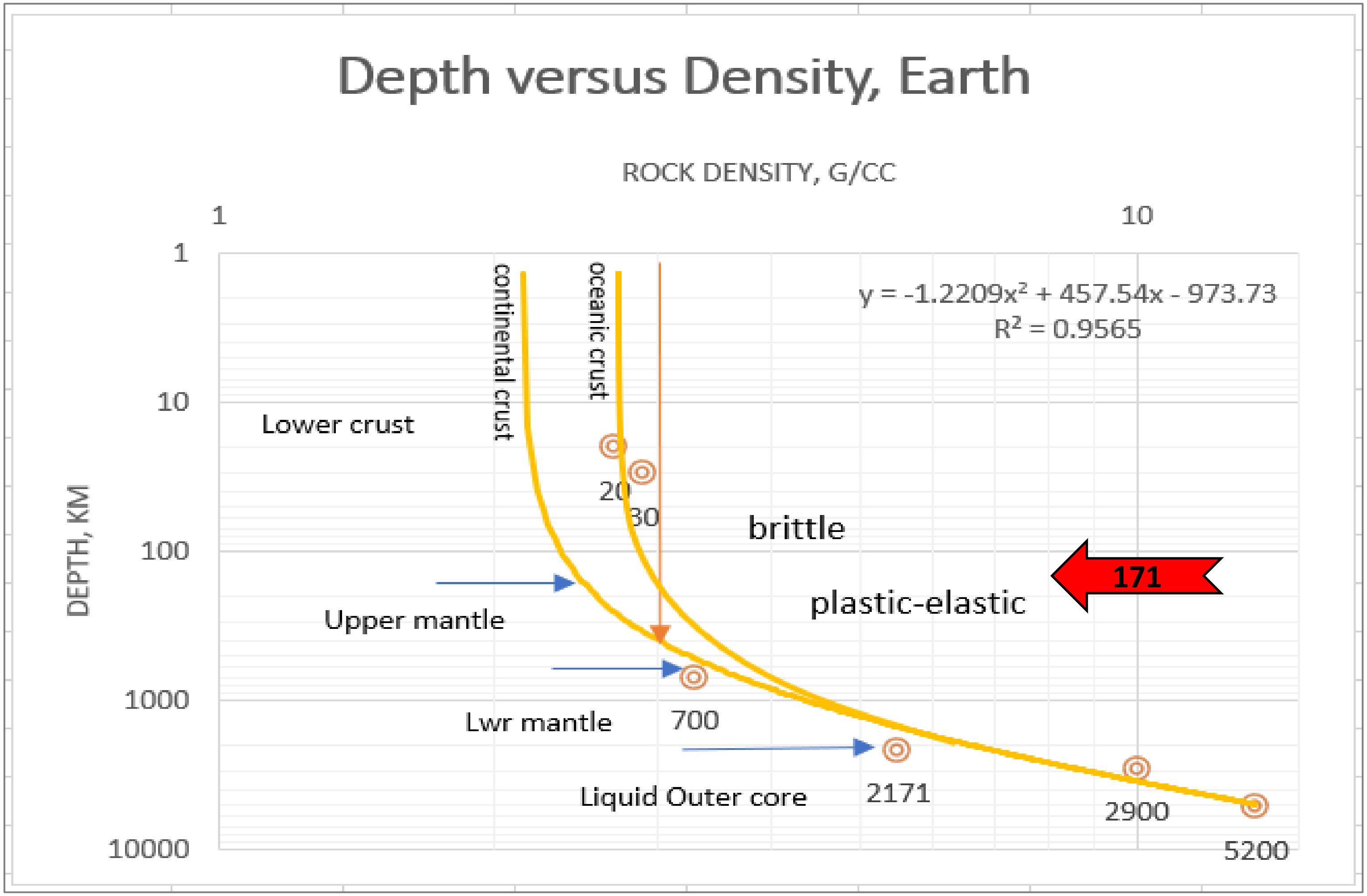

Twin Creeks
Prince William Sound
0 65 130 260 390 520
Kilometers


Alaska Range
Chugach Range
Prince William Sound
Katalla Oil
0 30 60 120 180 240
Kilometers
Diameter: 735 km

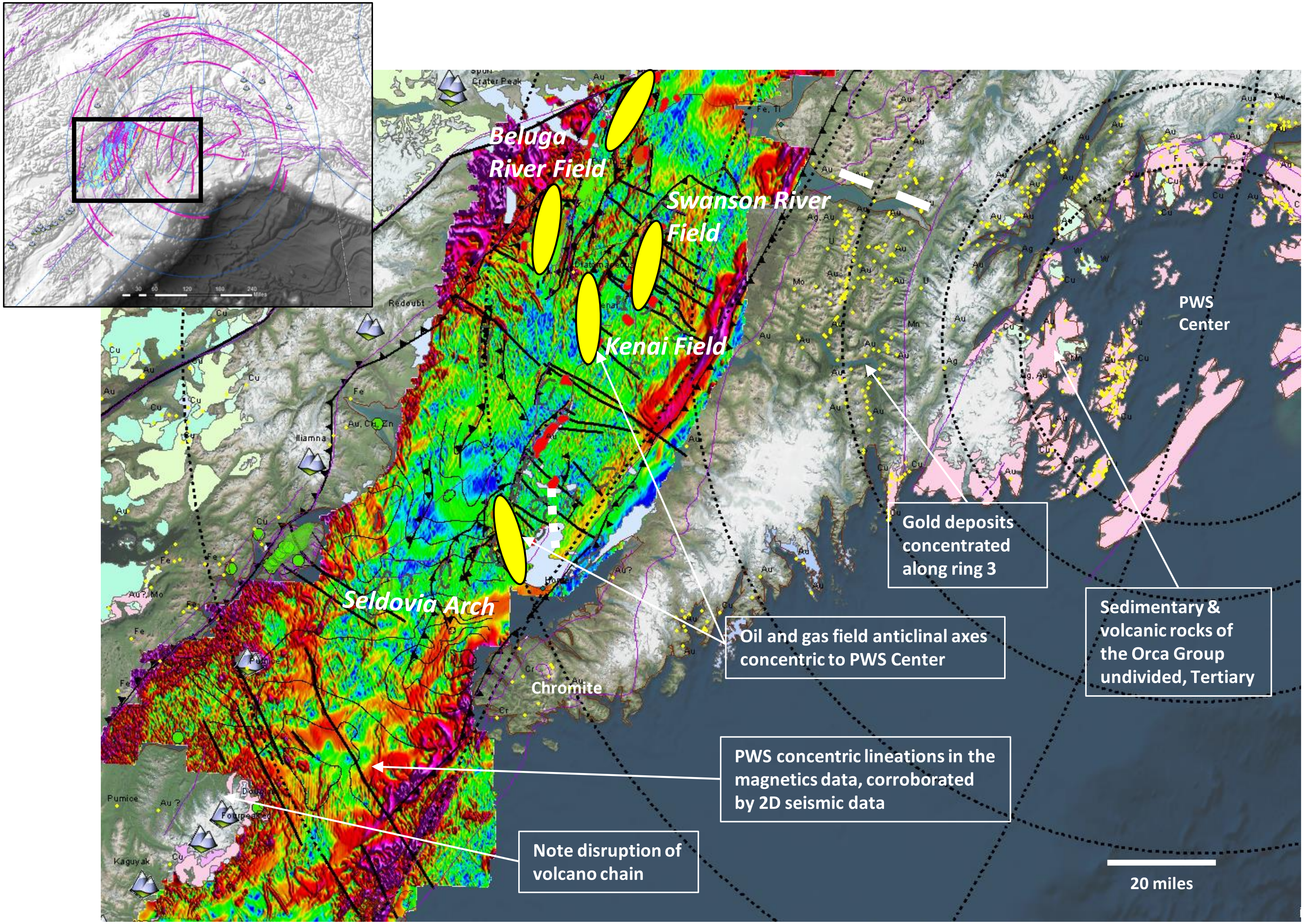
PWS Ring spacing predictions, possible multi-ringed crater basin

Spacing Rule Diameter km	Spacing Rule Radius	Sin(x)/x	Diagnostic Element	Deformation Depth (IFF Ring = D	Earth Layer
736	-368	0.00104	McKinley Park volcanics	171	reverberation, volcanics
520	-260	-0.00169	syncline	117	asthenosphere
368	-184	-0.00114		80	lithosphere
260	-130	0.00197	Bird Creek to Katalla oil seeps	54	lithosphere
184	-92	0.00531		37	lithosphere
130	-65	-0.00741	Whittier	25	lithosphere
92	-46	-0.00847		17	lithosphere
65	-33	0.01272		12	lithosphere
0	0		Center PWS	0	oceanic, volcanics
65	33	0.01272		12	lithosphere
92	46	-0.00794		17	lithosphere
130	65	-0.00715	Whittier	25	lithosphere
184	92	0.00543		37	lithosphere
260	130	0.00263	Bird Creek to Katalla oil seeps	54	lithosphere
368	184	-0.00035		80	lithosphere
520	260	-0.00192	syncline	117	asthenosphere
735	368	0.00035	McKinley Park volcanics; anticline	171	reverberation, volcanics

=2*(0.06*Dia^1.1)



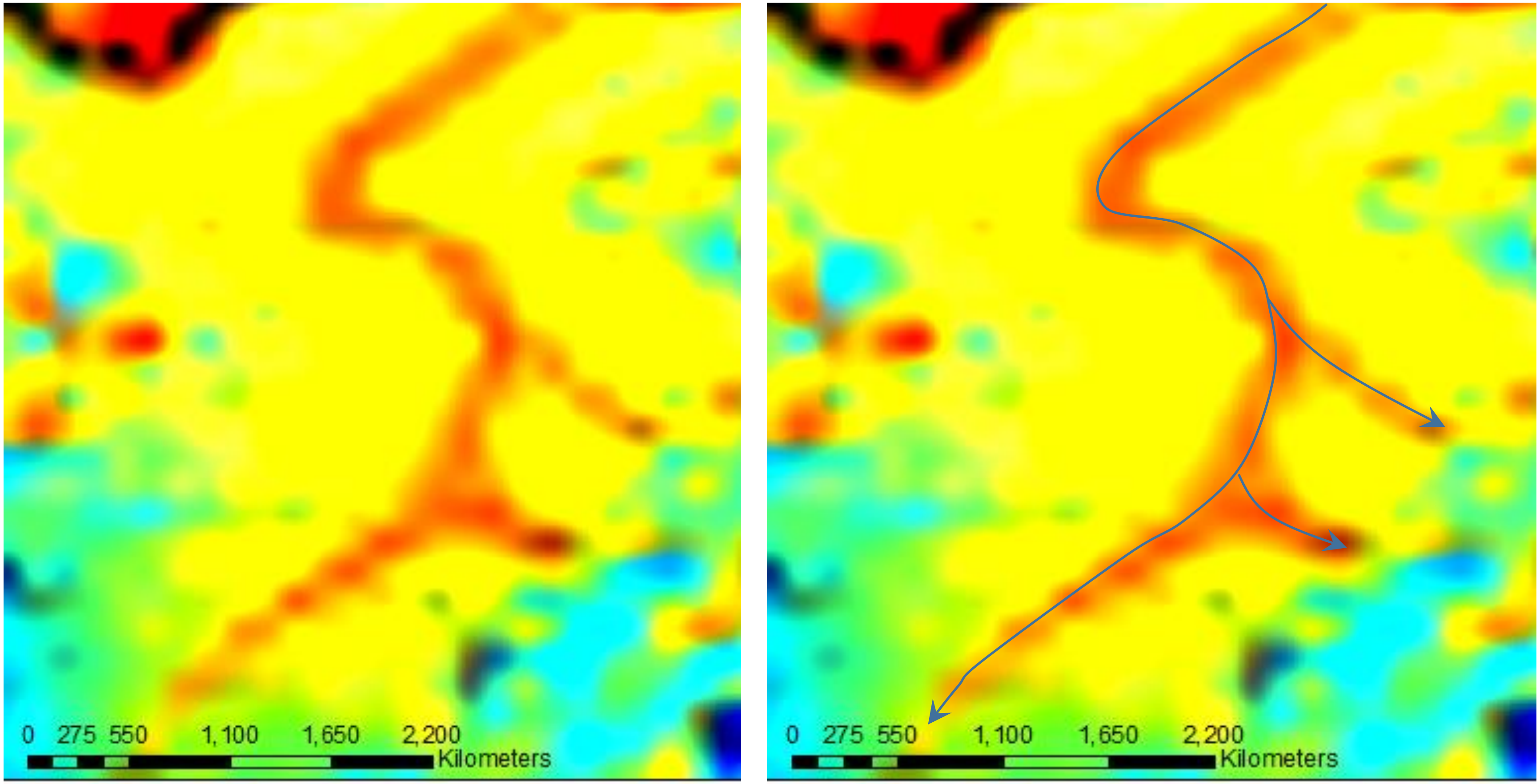
Specific gravity, used synonymously with density, versus depth for the Earth. The rheological properties and layer designations are indicated. As an example, given a dunnite with a specific gravity of 3.0 g/cc, we follow the x-axis to where it intersects the oceanic crust curve, which indicates the rock came from the upper mantle a) 150 km deep if on oceanic crust, and b) 400 km deep if on continental crust.

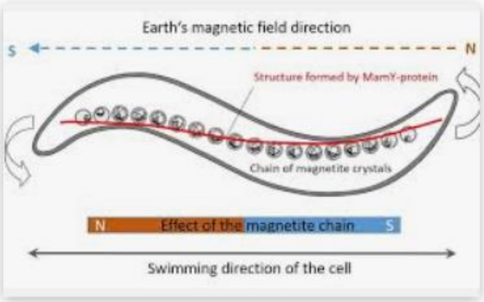


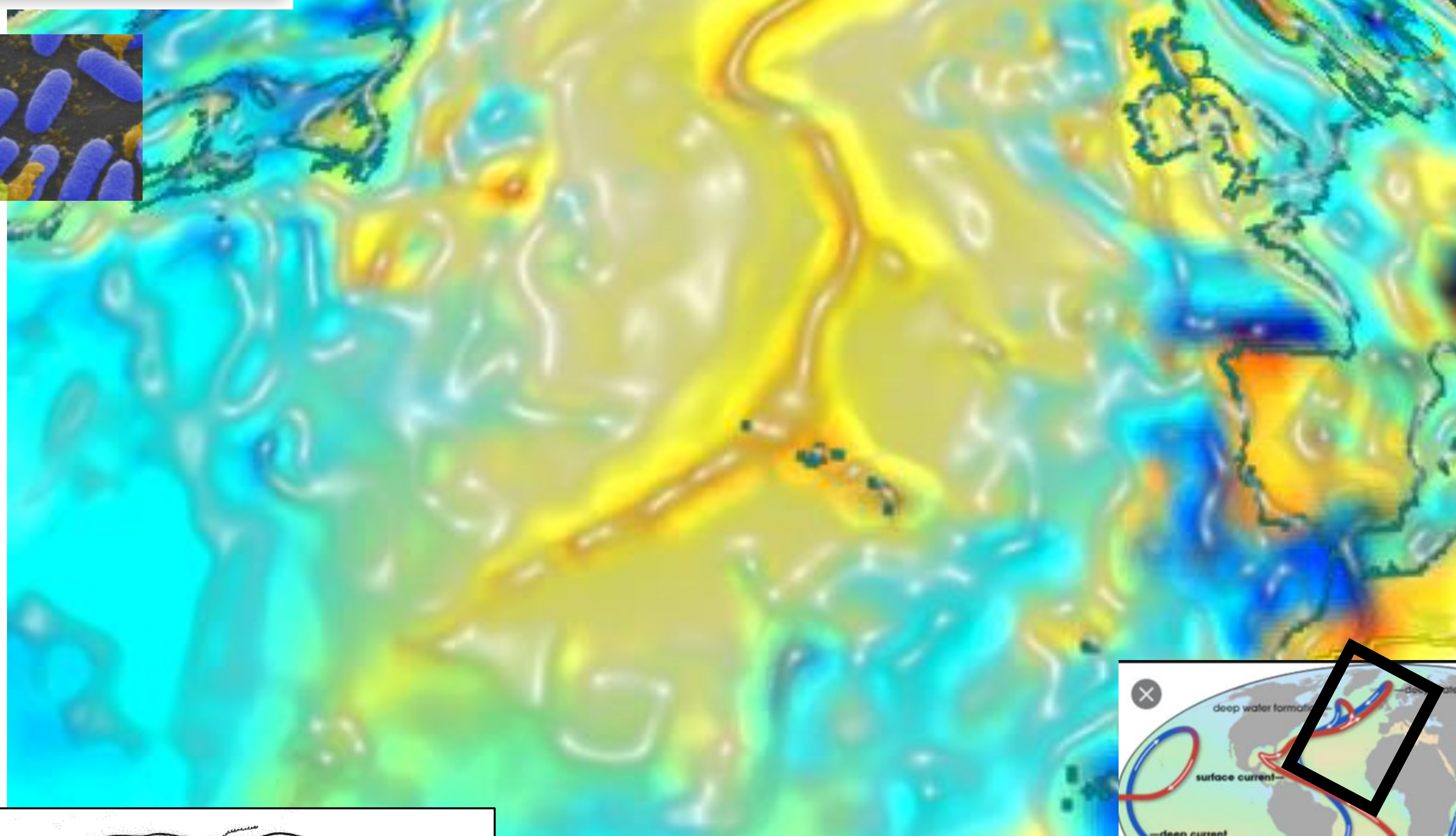
Prince William Sound Copernican, Multi-Ring Analysis, Alaska

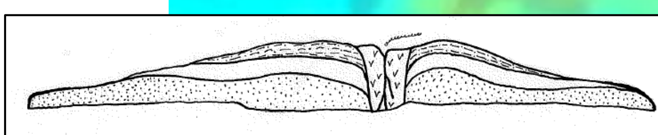
D. Buthman 8/23/2018

What is this?


0 275 550 1,100 1,650 2,200
Kilometers
0 275 550 1,100 1,650 2,200
Kilometers

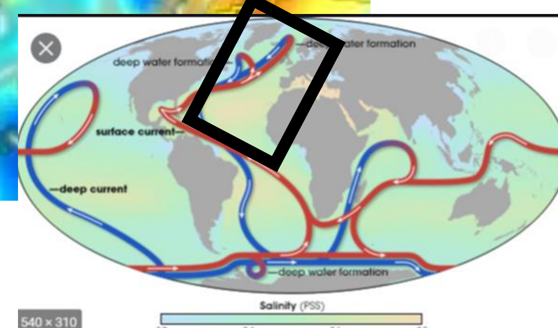




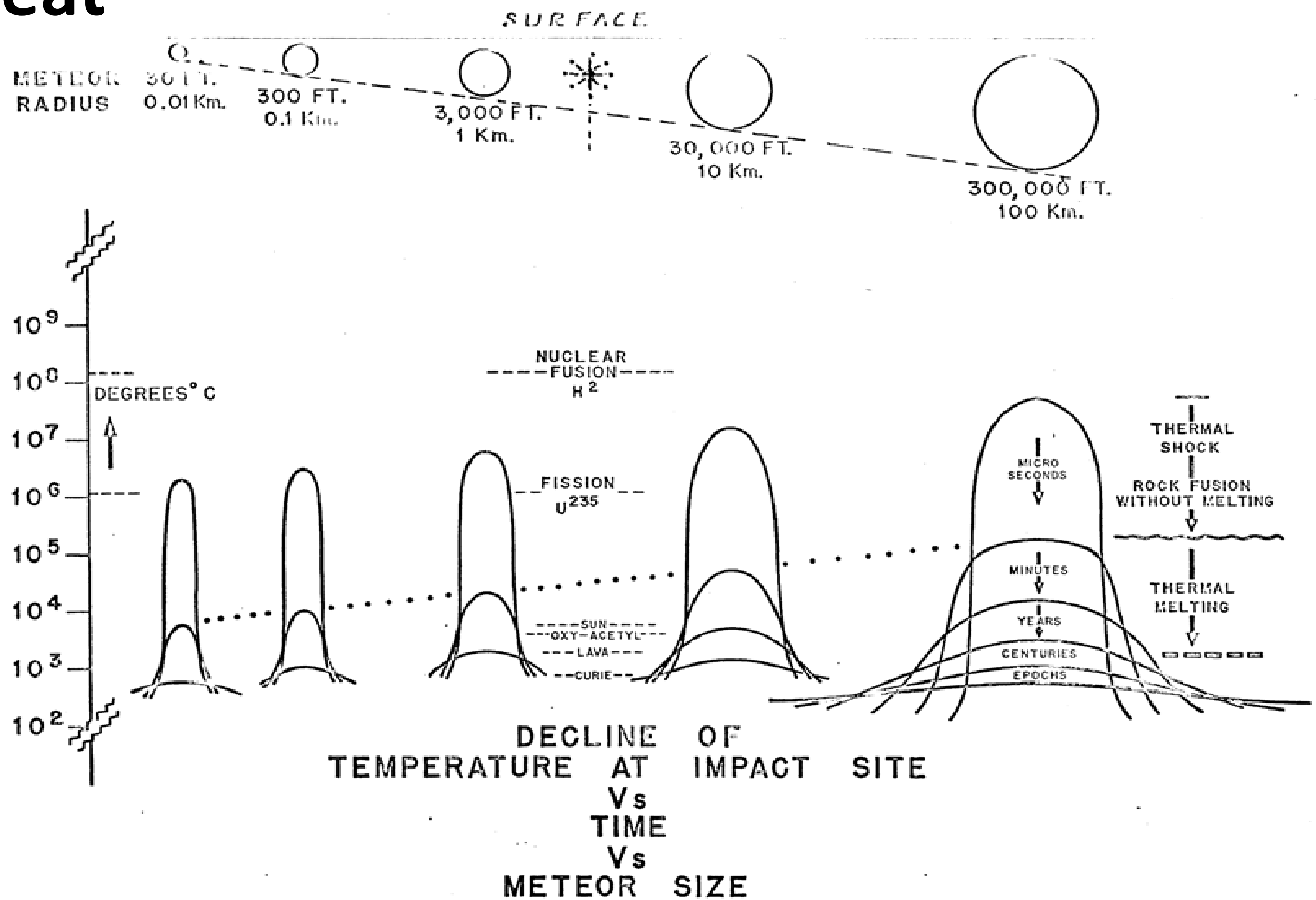


Sinuous deepwater channel showing symmetry of older levees away from central channel, which is the youngest deposition.

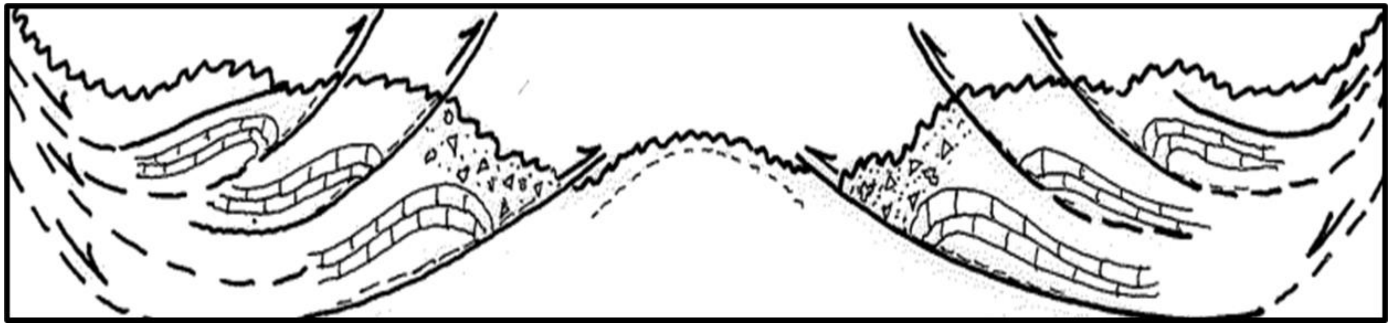
An Earth crack?
A deepwater current?
Critters feasting on smokers?



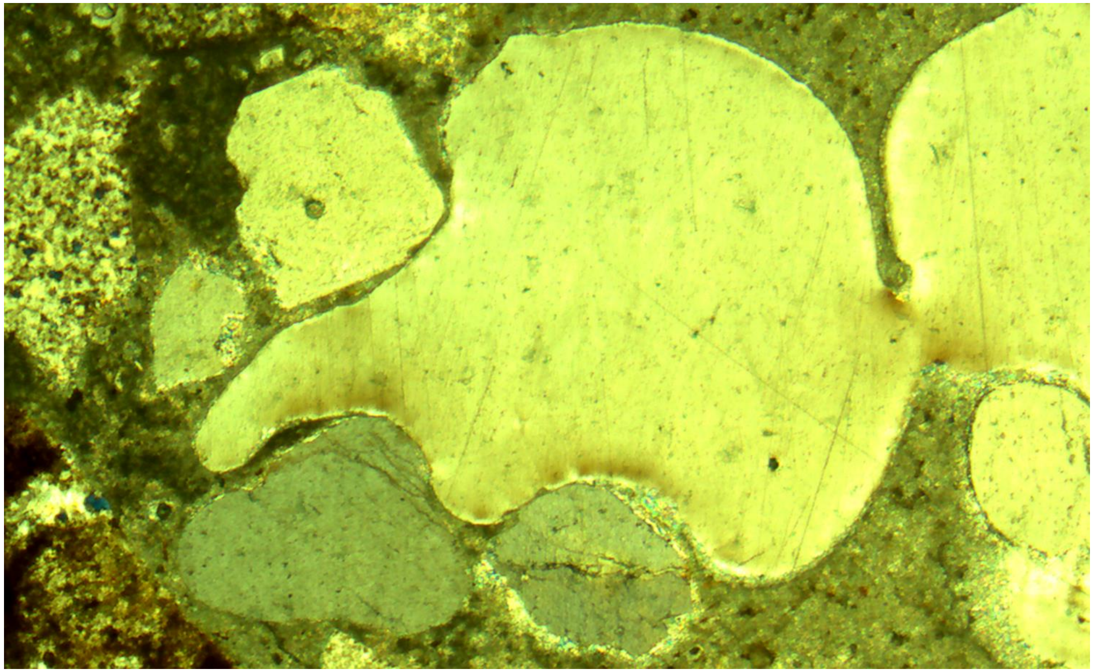
Heat



Geoloic time scale, temperature effects, and size of meteors and craters. From Mark Butler, 1998, personal communication & files. The y-axis shows the temperature generated in degrees C, and the x-axis shows the size of the meteorite. The graph shows the decline of temperature at impacts sites, versus time, versus meteor size.



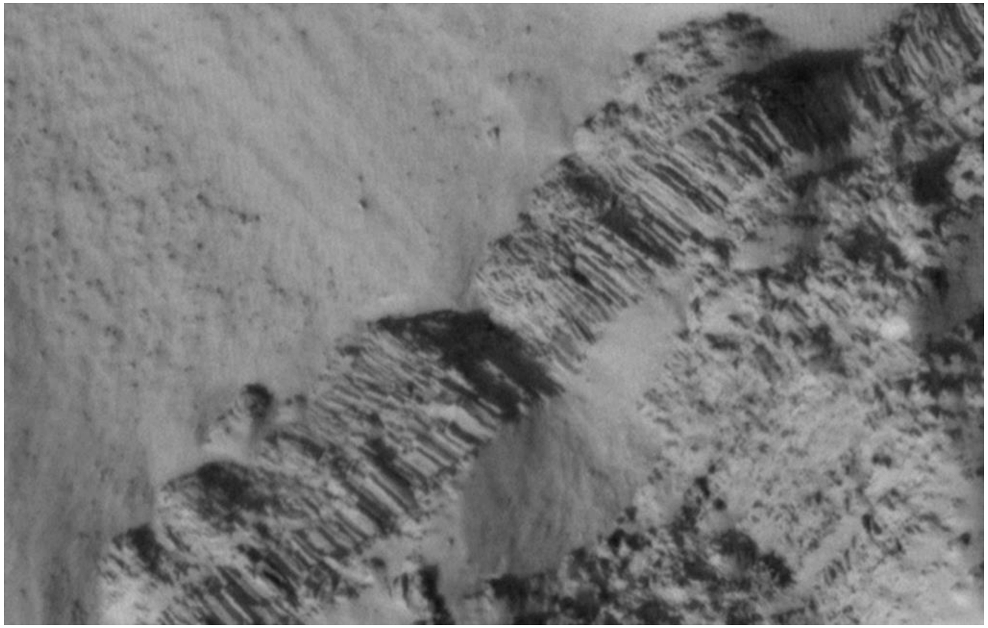
Right side is west to east sketch of Highway 5 outcrop, with mirror image on the left, showing recumbent folds sliding on slick green shale glide planes that culminate in the development of the ring structure.



Heat

40 x magnification, Thin Section CC-1, Crooked Creek meltrock, showing flow sand melt structures.

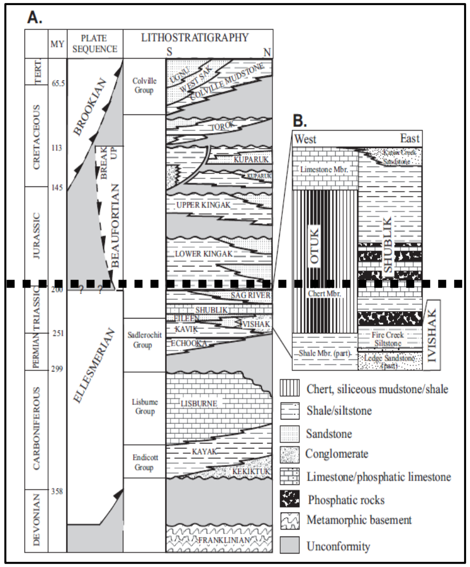
Southern cliff face of Discovery Hill, 80 m tall, shows columnar jointed impact melt on west shore of Mistastin Lake (Grieve, 1975). Paradigm would be that these are columnar basalt flows. Instead, it's impact melt rock.



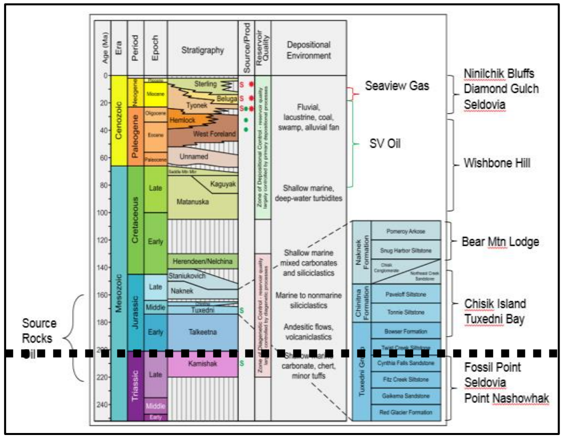
Columnar basalt or impact melt rock (?), Marte Vallis, Mars (https://earthobservatory.nasa.gov/images/38904/mars-and-earth-columnar-jointing)

Heat

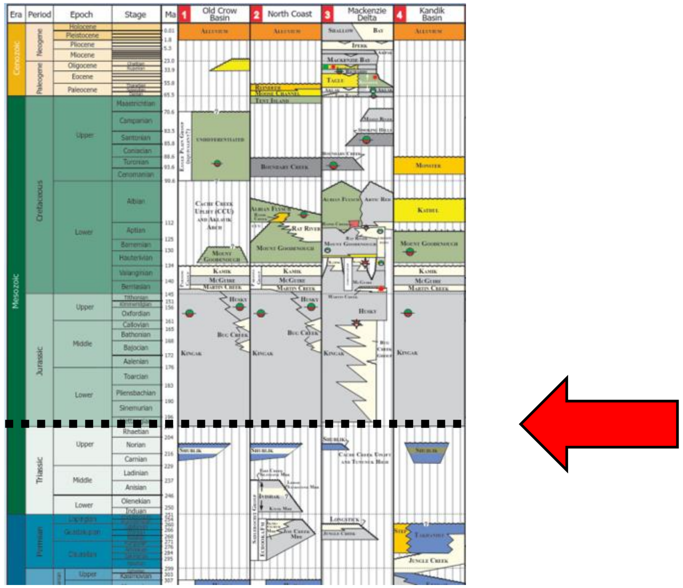
Alaska Basins: Oil Source Rocks: UT-MJr



Shublik Formation source rocks, N. Slope

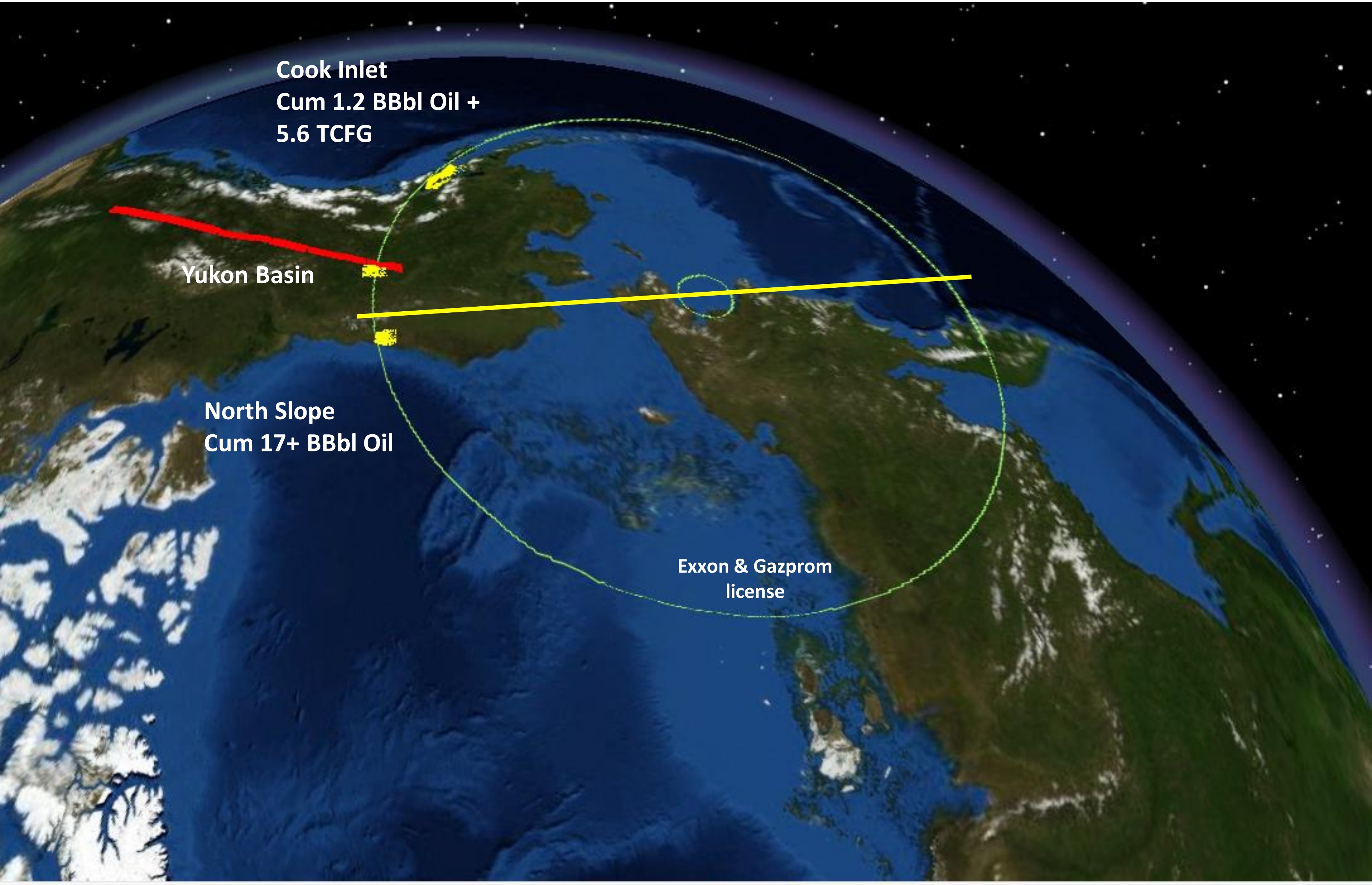


Tuxedni Formation source rocks, Fossil Point, Tuxedni Bay.

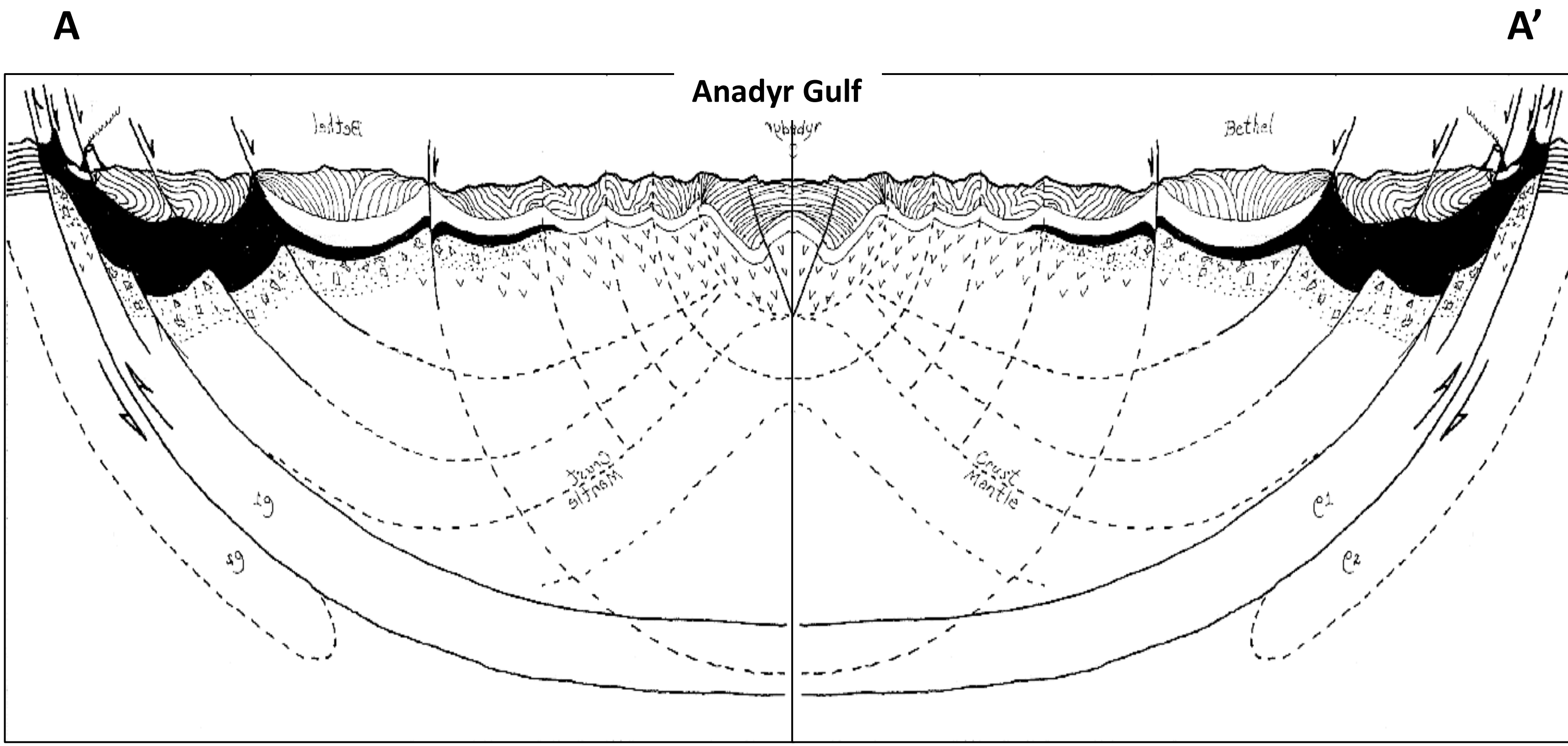


Oil source rock distribution for Upper Triassic-Lower Jurassic (~Glenn Shale).

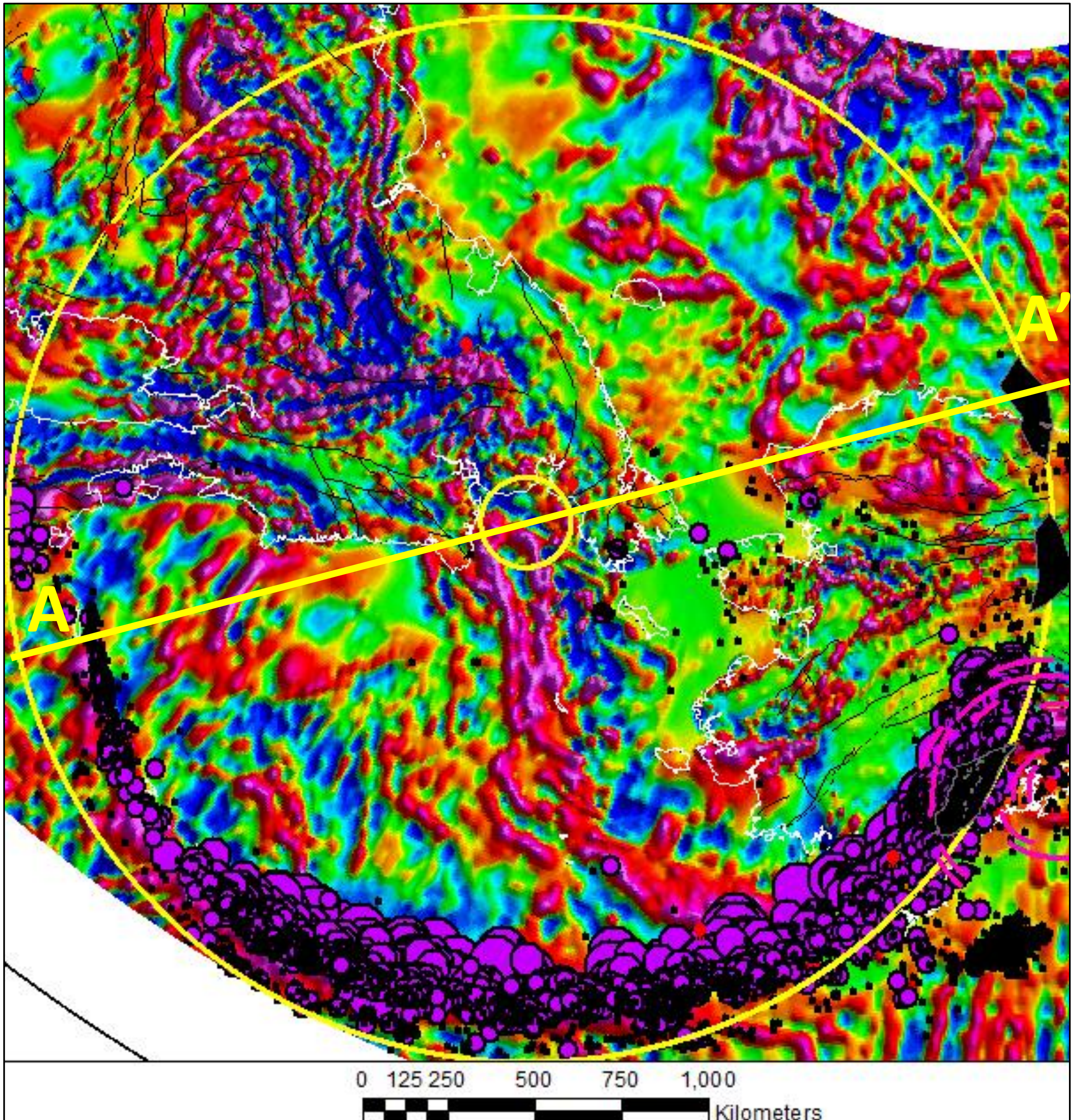
Anadyr-Aleutian Arc & Source Rx



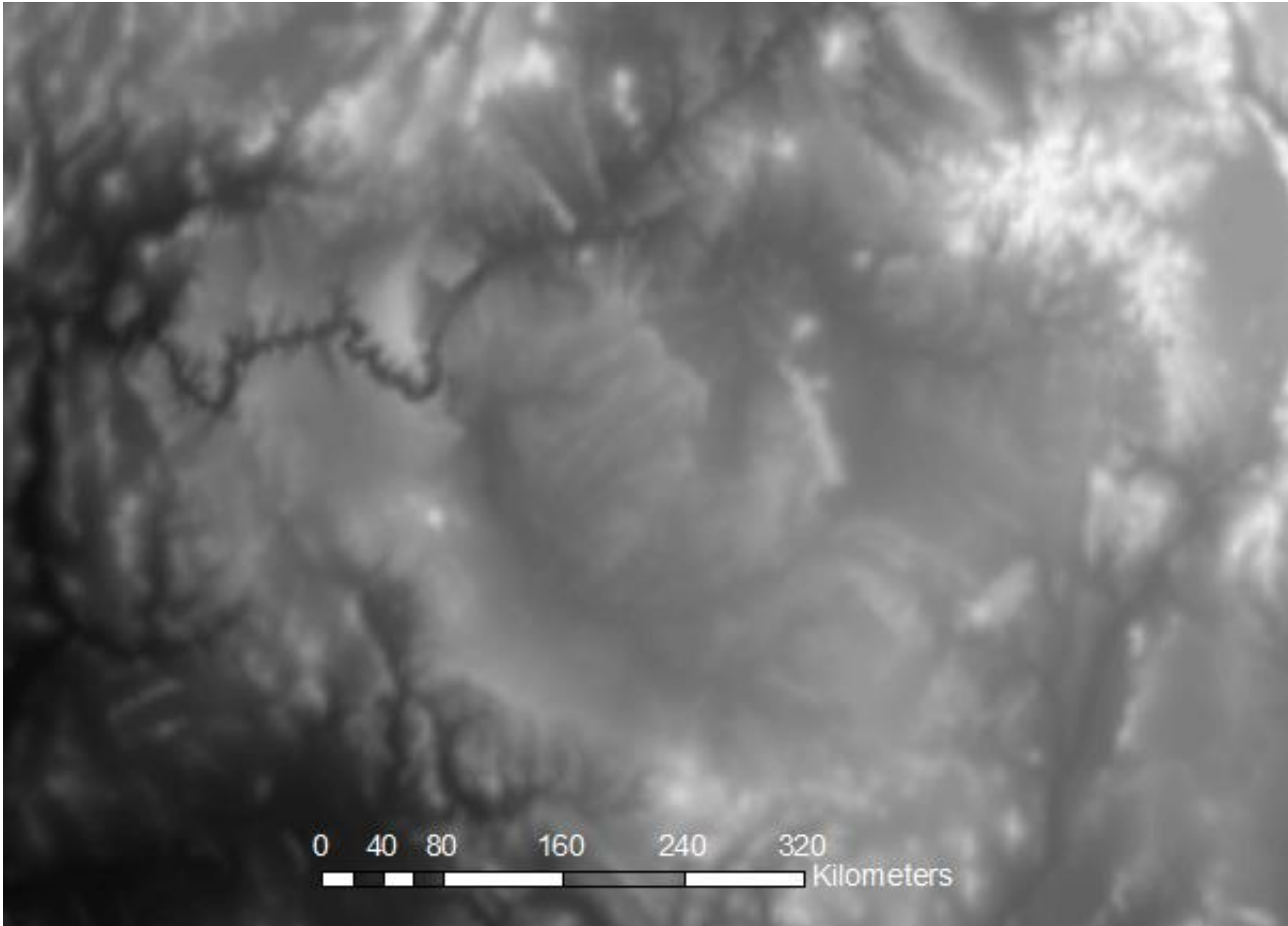
Upper Triassic to Middle Jurassic Sc Rx

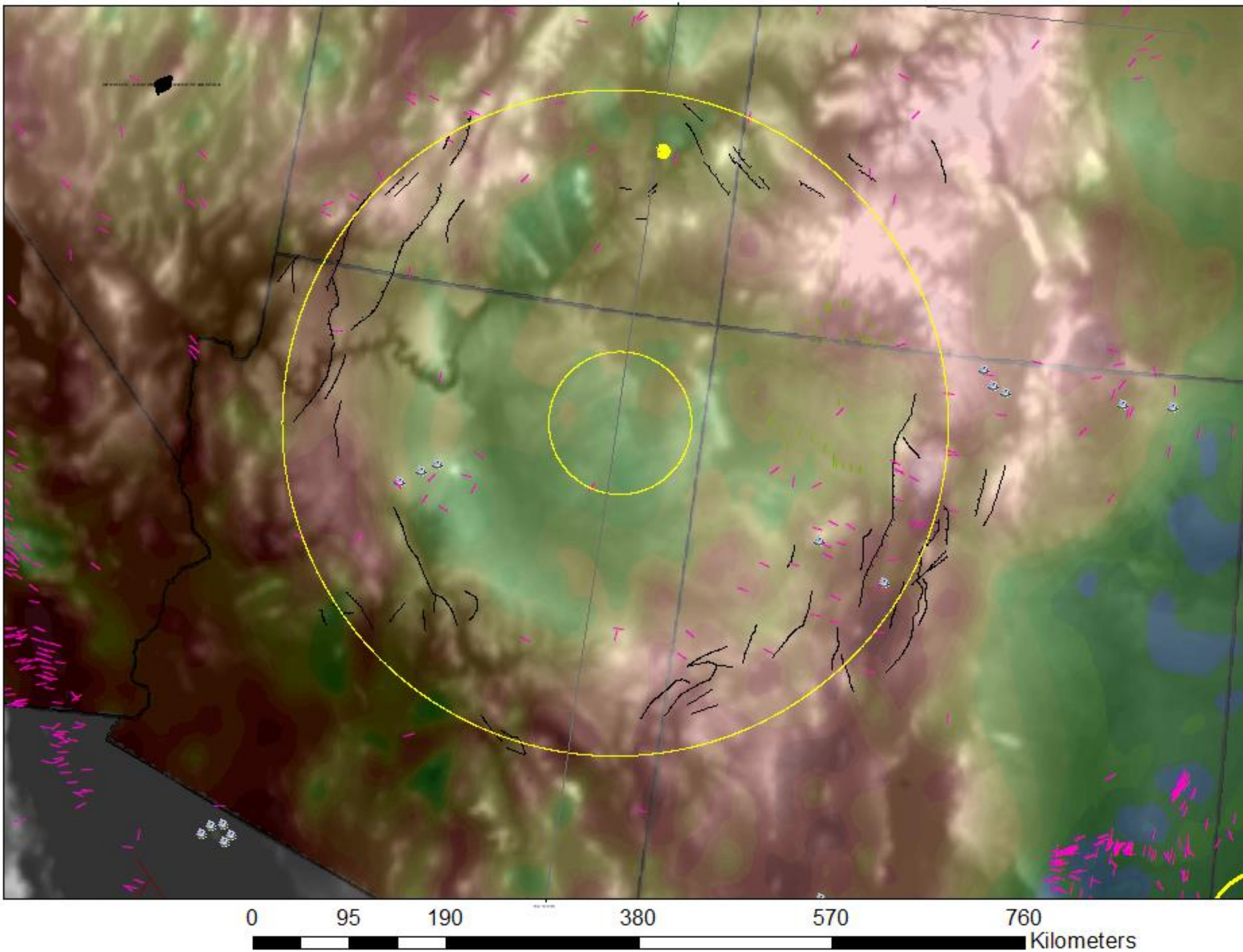


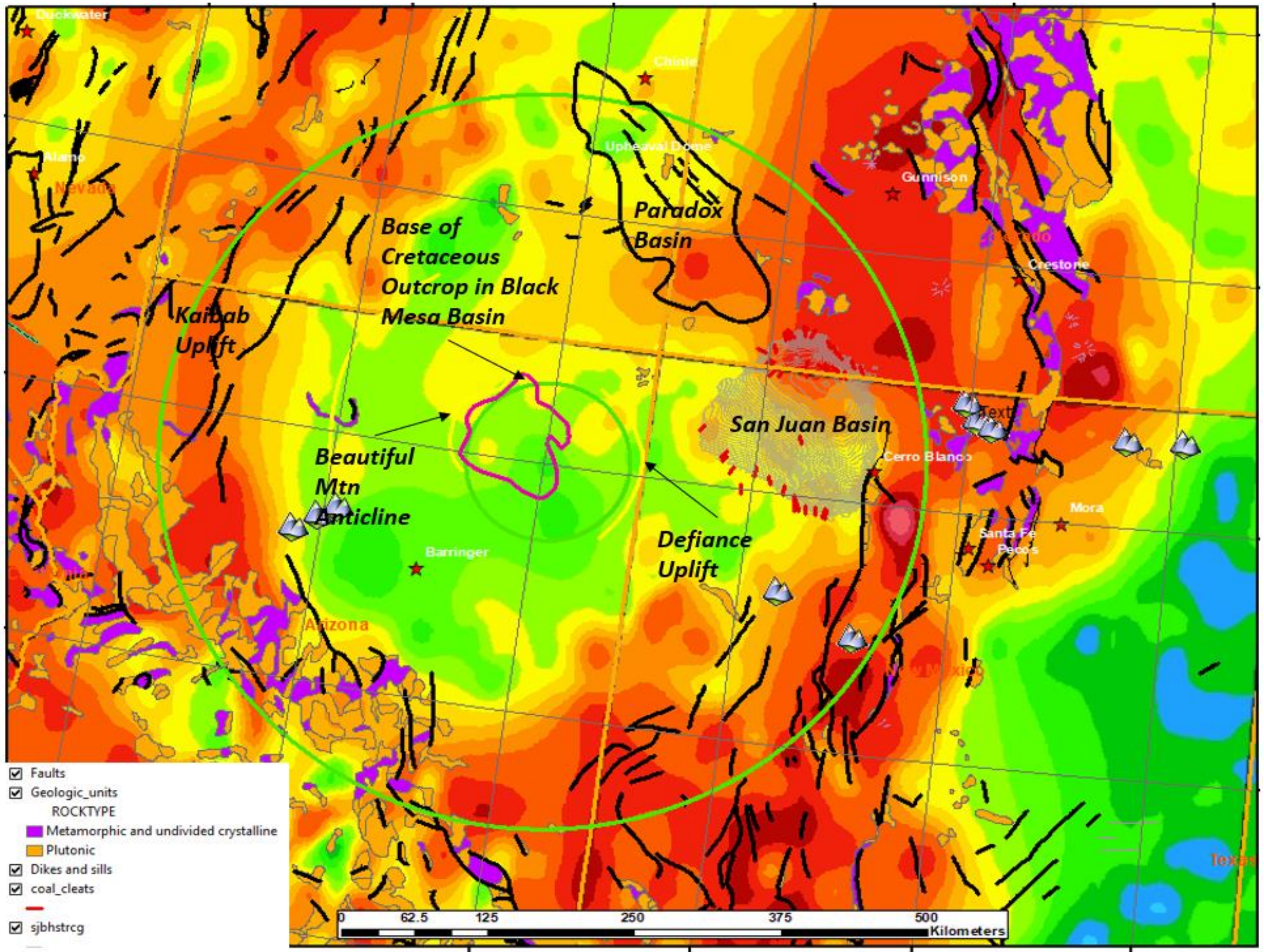
Petroleum source rocks in outer margin rift terraces for the proposed Anadyr-Aleutian crater basin.



Anadyr-Aleutian Chain, Alaska, Bering Sea, to East Siberia. Emag2 colorfill contours, multi-ringed crater analyses, and bubble symbols representing earthquake epicenters. The deeper the earthquakes, the larger the bubble. The earthquakes show a bowl-shaped depression deepening toward the center of the basin, at Anadyr. Note characteristic wheel and spoke symmetry.

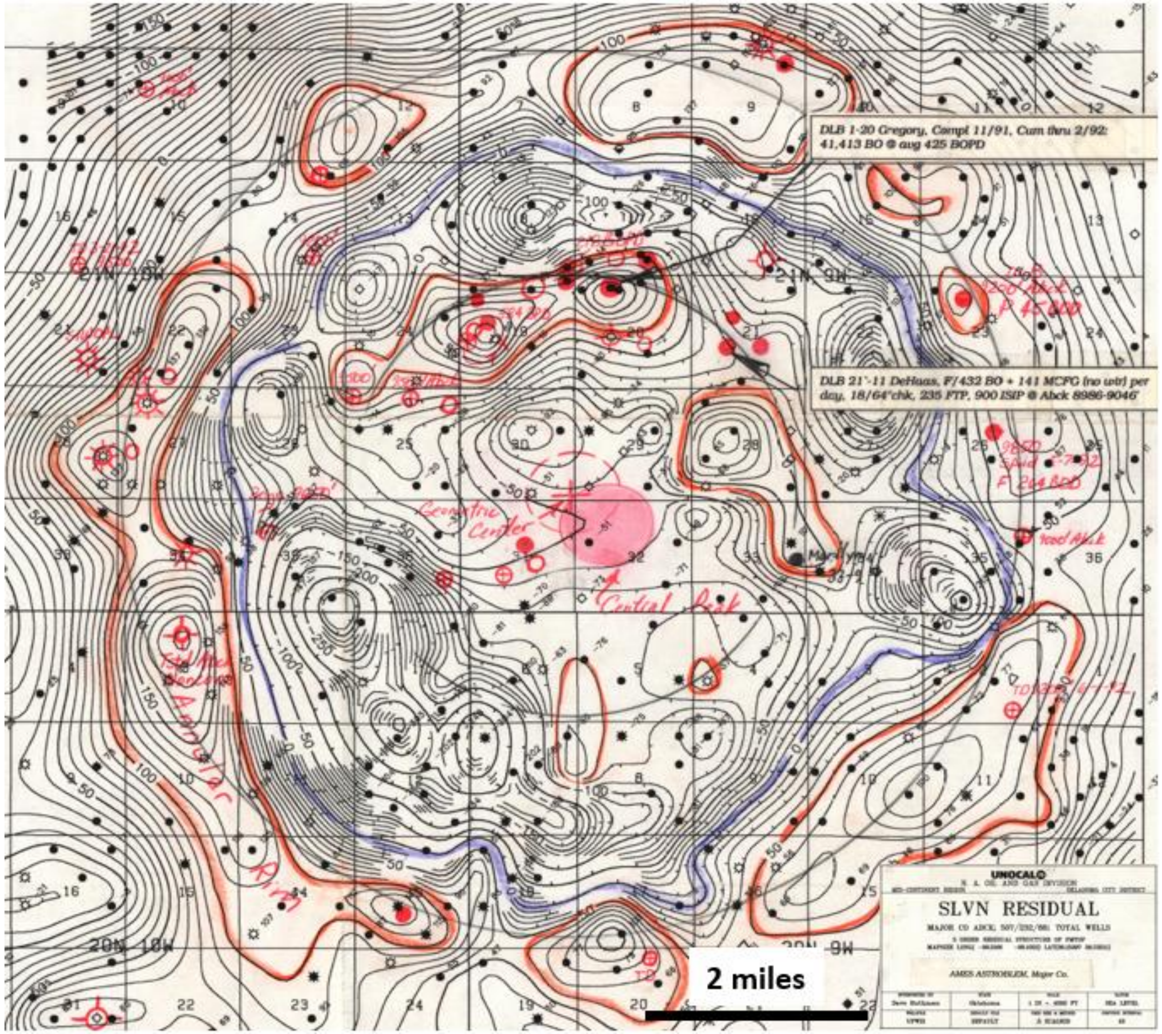

0 40 80 160 240 320
Kilometers


0
95
190
380
570
760
Kilometers



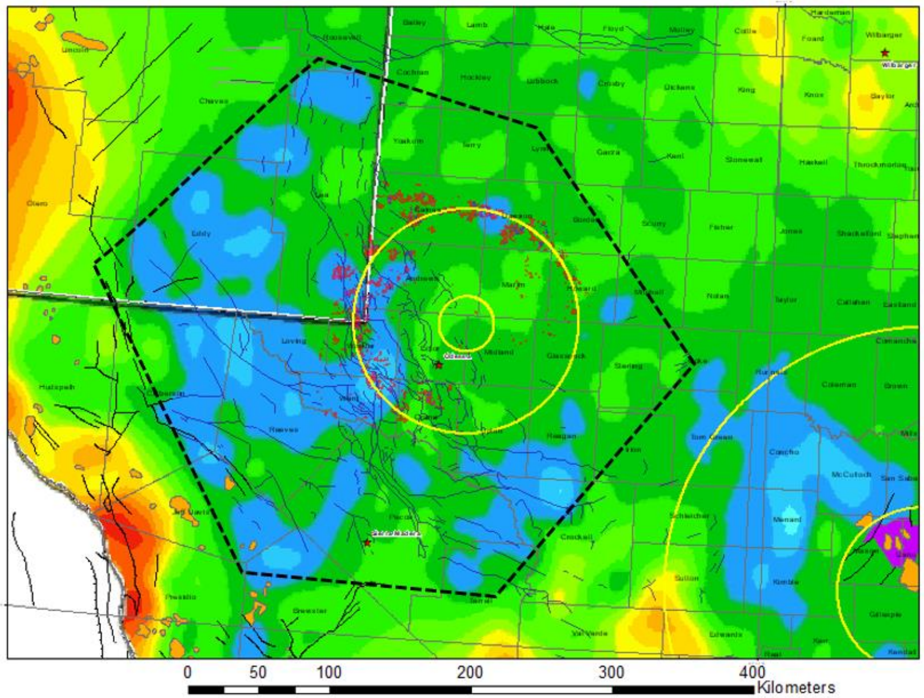
Four corners area, USA, on US Heat Flow map (SMU, 2011). Note the relative cool within the crater, and the high heat flow coincident with the crater's rim. The small red lines along the southern border and within the San Juan Basin are the strikes of regional fractures (Whitehead, 1997). These formed in response to compressive stress originating outside the basin, and coincidentally lie concentric to the hypothesized Four Corners crater basin.. Cum gas 43 TCFG + 381 MMBO.

Oil and Gas Traps in Multiple Rings

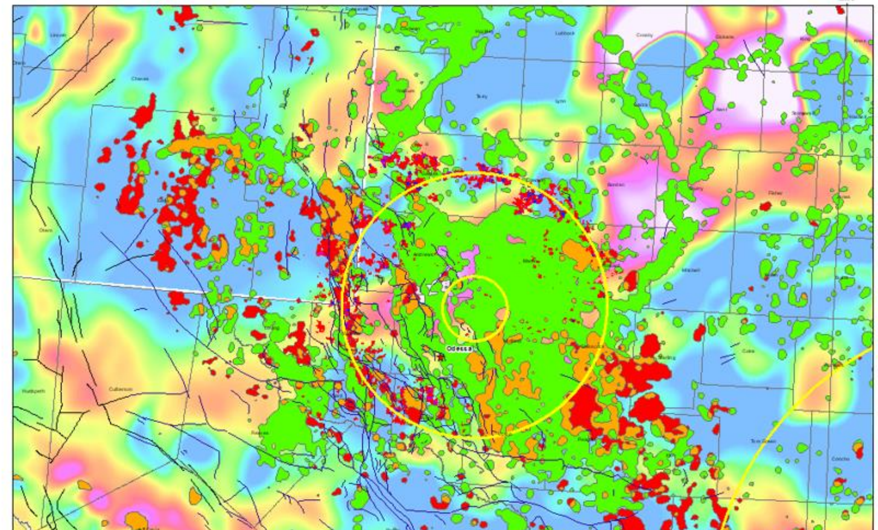


Ames Astrobleme Sylvan Shale residual map. 4/10/1992, D. Buthman

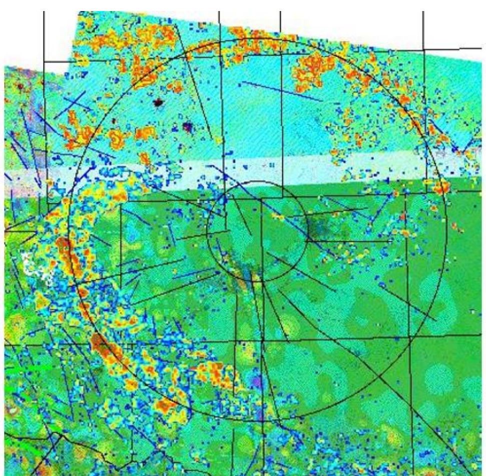
Cum 11 MMBO + 12 BCFG from Arbuckle in 1991 from ~60 wells (thru 2006).



West Texas heat flow (SMU, 2011), Hexagonal polygon suggests crustal involvement, and may indicate the direction of impact from the east.

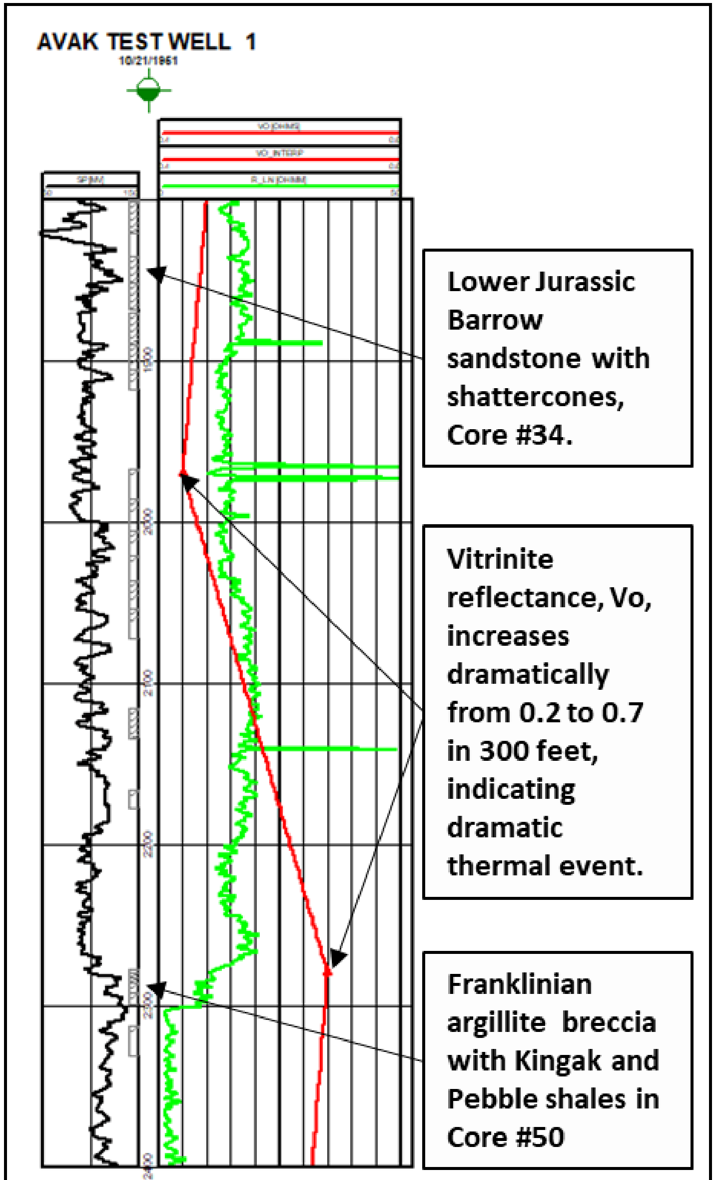


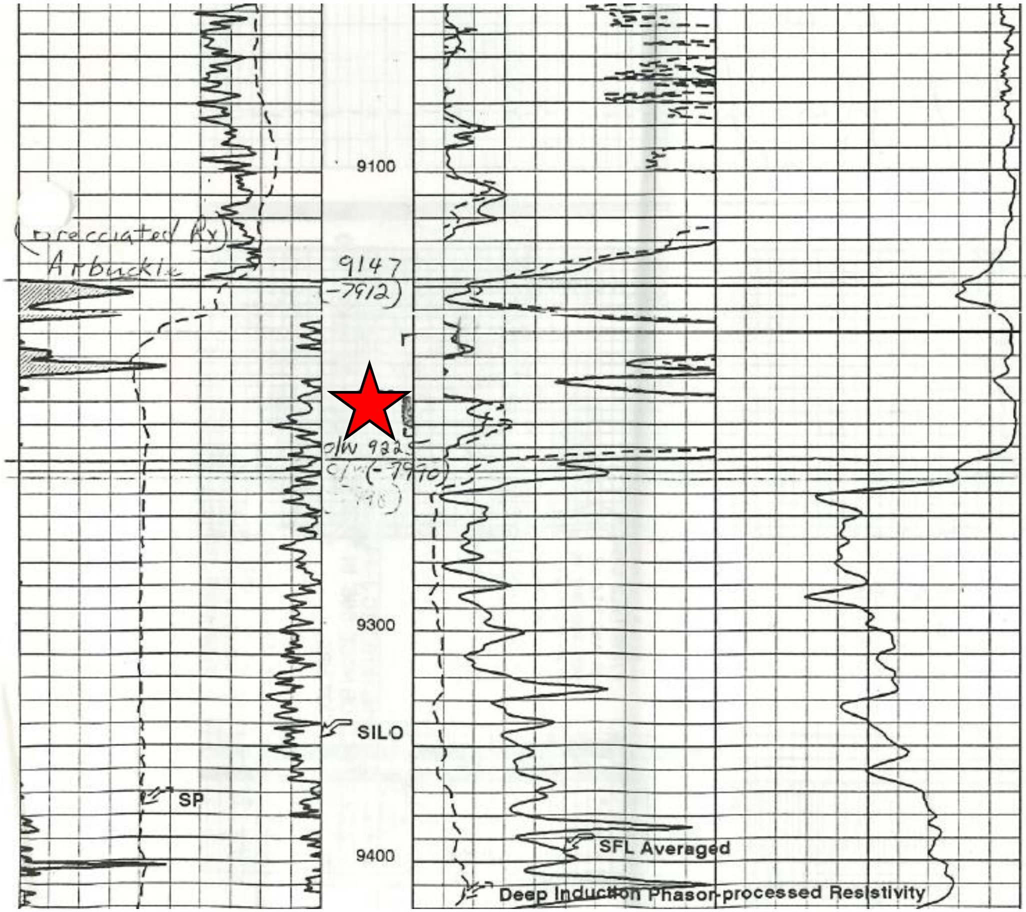
West Texas Bouguer gravity, oil and gas fields, Woodford faults, and crater interpretation. Cum 29 BBbls oil + 75 TCFG.



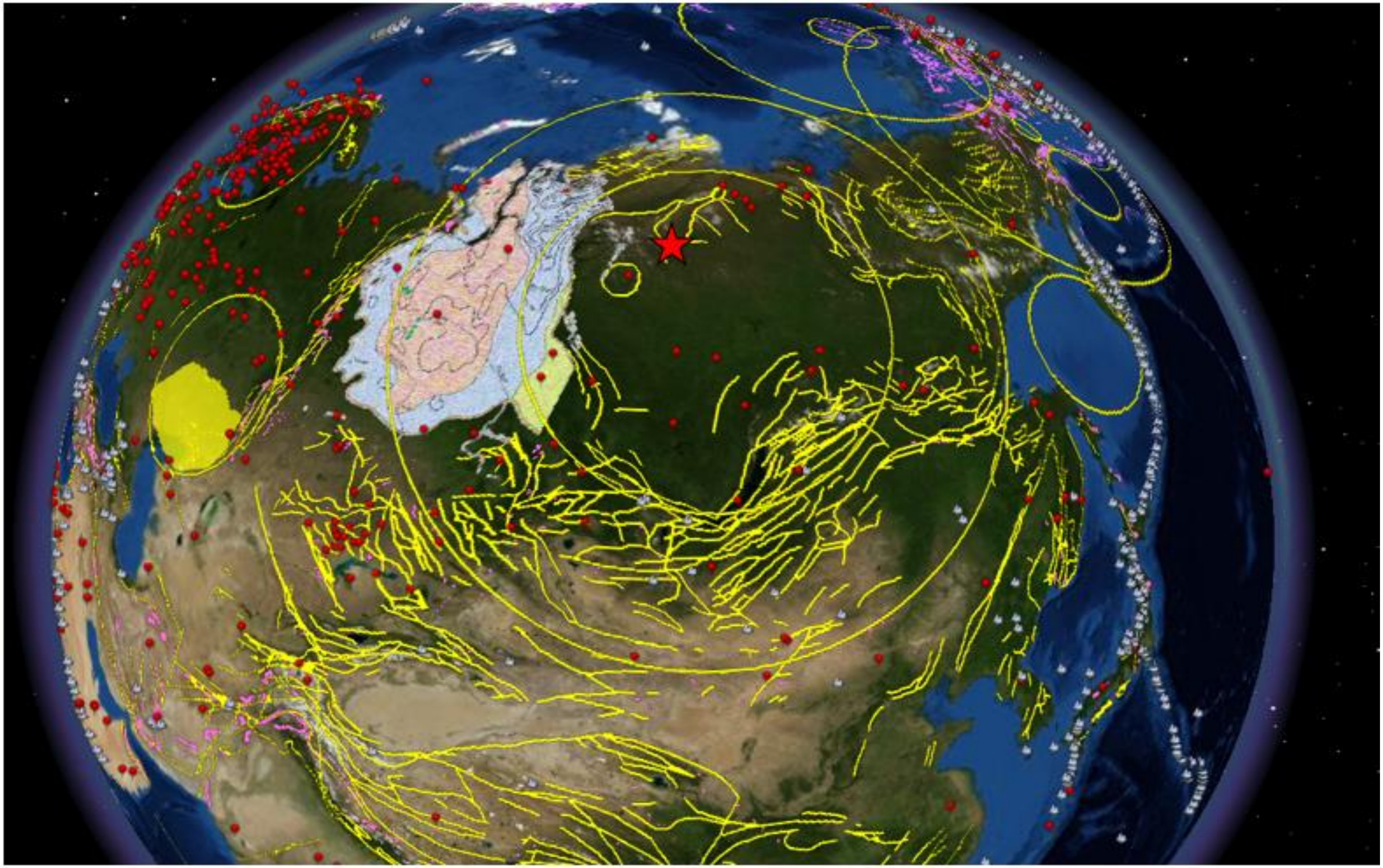
Experiment of 45-degree impact from lower right to upper left.

Heat

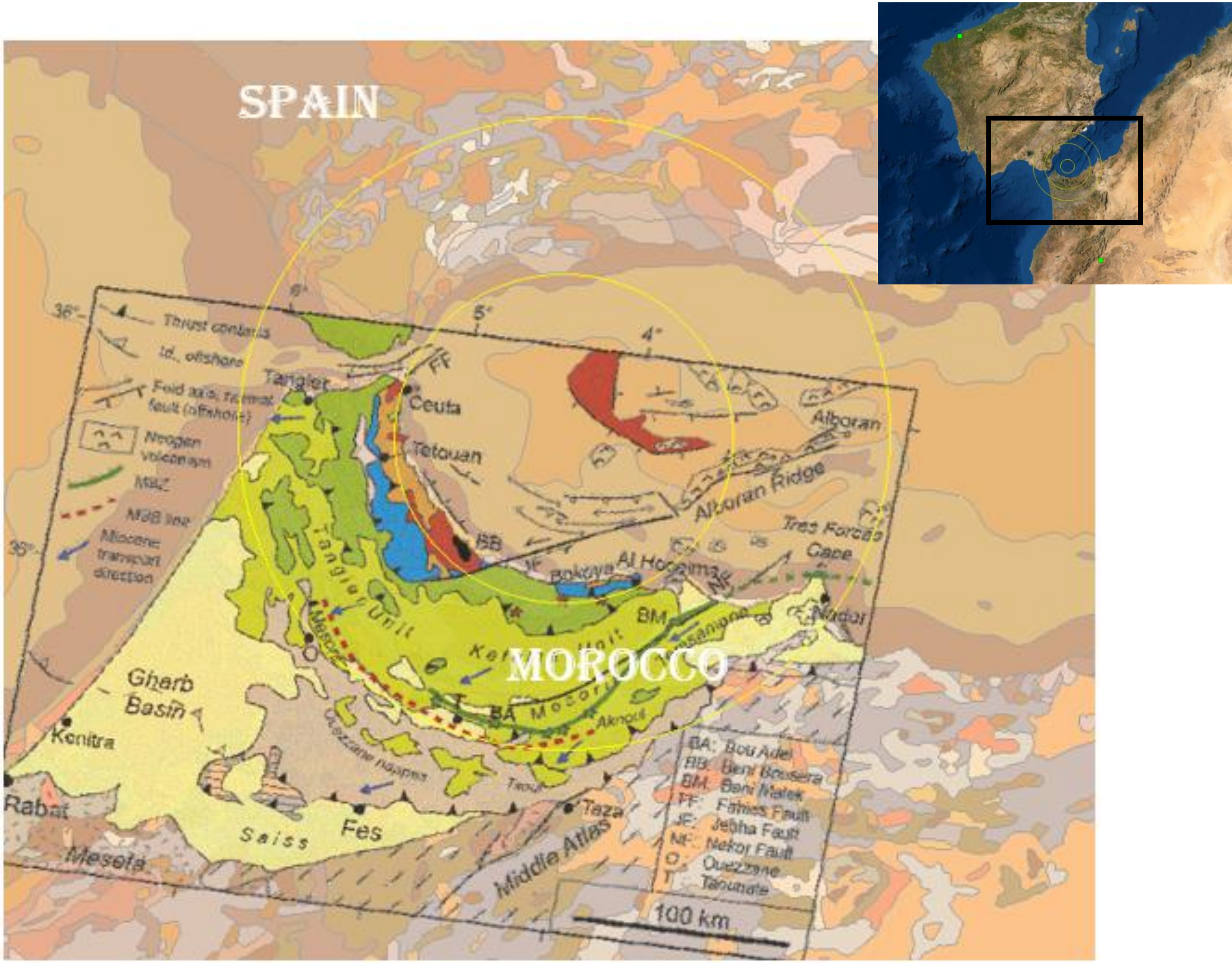




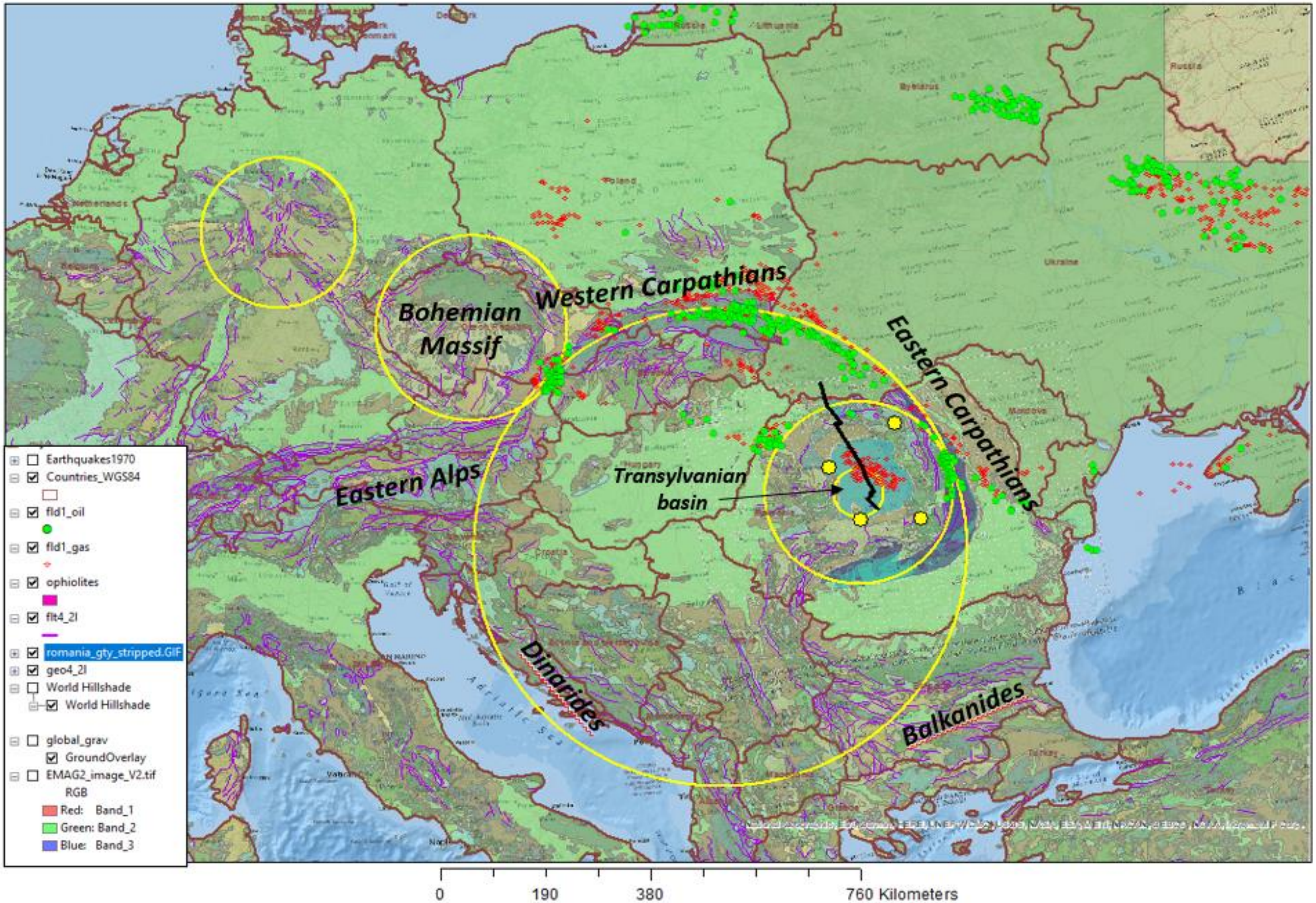
DLB 33-9 Marilyn, Ames Impact Crater reservoir, Major County, Oklahoma. The red star is the depth at which the well flow commercial oil rates. Curves are: left track = gamma ray, depth track in center, right tracks deep resistivity and far right track conductivity. flowed at a rate of **4,234 BOD + 2.2 MCFGD** and no water.



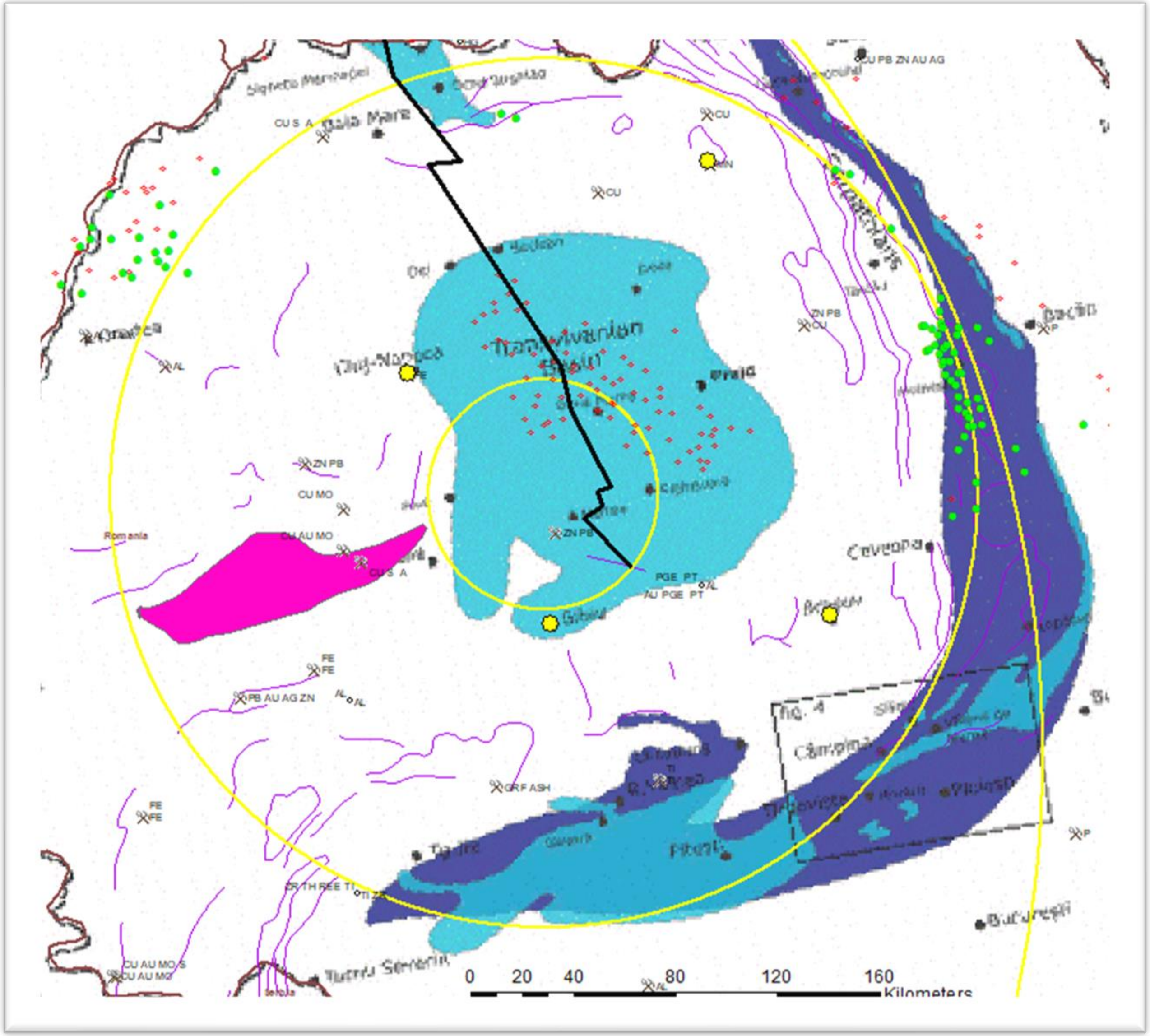
West Siberian Basin crater interpretation, with Bazhenov Shale (petroleum source rocks) isopach and facies (Ulmishek, 2003). The inner diameter measures 2324 km, and the outer ring measures 4077 km in diameter. Red pushpins are listed impact craters (Rajmon, 2018). Yellow lineations are faults, tectonic boundaries, and steppes (from Finko). The red star is the recently proposed 200-km diameter Kotuykanskaya impact crater (Klokocnik, et. al, J., 2020). World's largest petroleum basin, with world's largest remaining oil reserves. Discovered: **144 BBbl oil + 1,300 TCFG**.



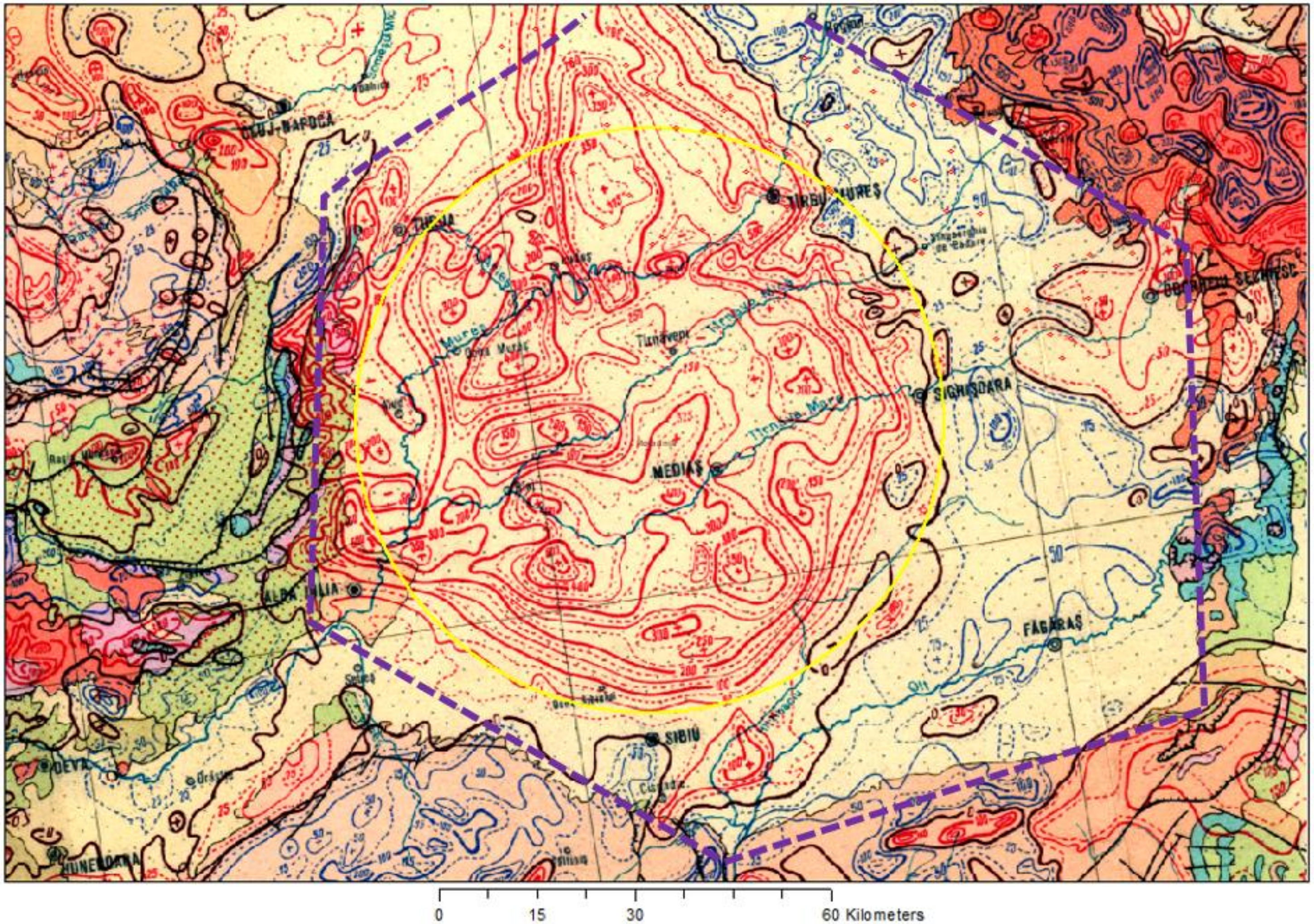
Rif of Morocco: fusion of surface geologic maps that illustrate the pronounced circular outline (Michard, et al, 2018).



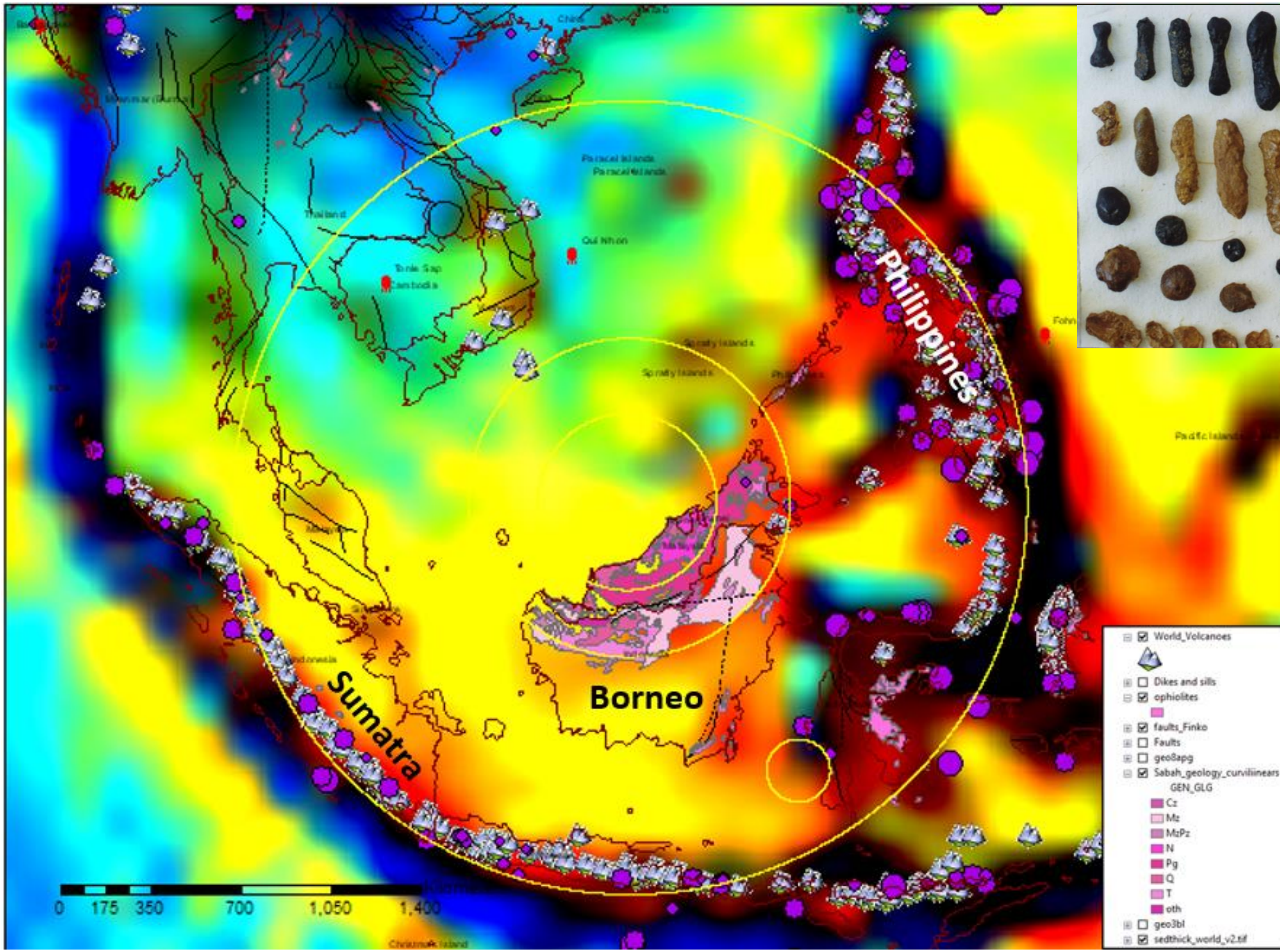
Regional crater interpretation in Romania, Czechia, Germany, Austria, Hungary, Croatia, Slovenia, and Poland. Diameters are: 340 km for the Bohemian Massif, for the Serbian Copernican the diameter is 883 km, and the diameter of the Transylvania Basin is 340 km.

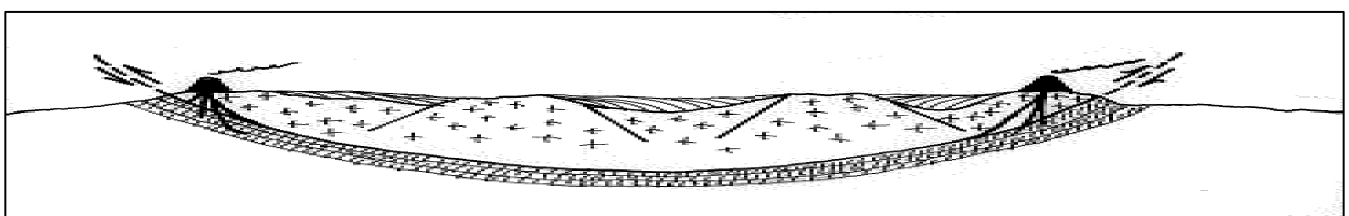


Distribution of lower and upper salt formations in Romania’s Transylvania Basin (Tamas, Et. al, 2018). Cumulative production: 30 TCFG.   Oil production to east and northwest: 5 BBbls.

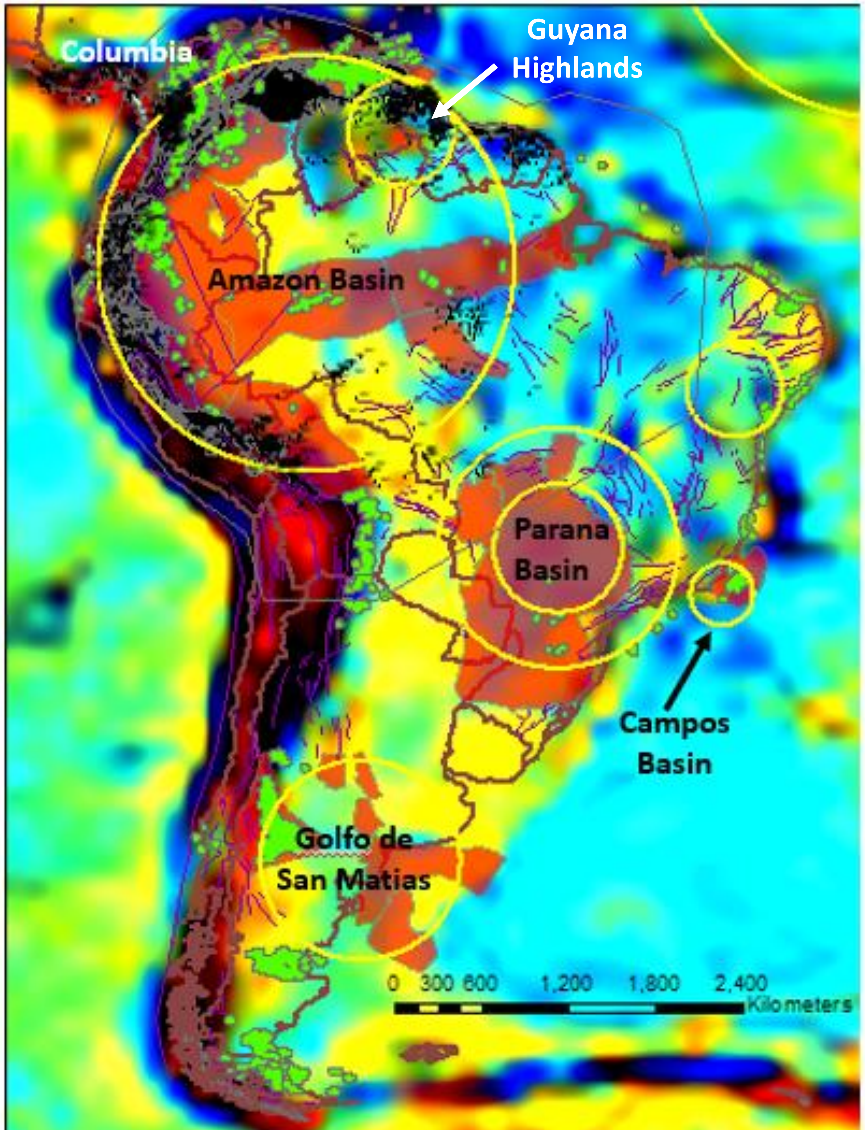


Transylvanian Basin, magnetics (red contours). The central crater dome, thus, is outlined in yellow, with a diameter of 89.7 km, and the hexagonal polygon outside of that defines the area where pre-Miocene strata is absent. This hexagonal ground is common where meteoritic or asteroidal impact has occurred on thin oceanic crust; and may be due to basalt, or impact melt, seeking entropy at 120-degree angles for most efficient cooling, or some fractal reproduction of silica's hexagonal crystal class.

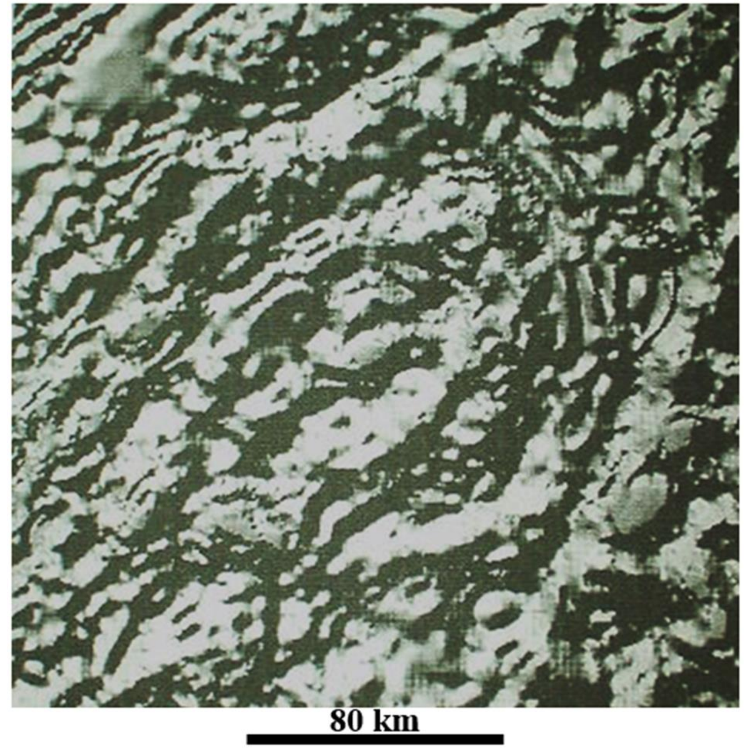




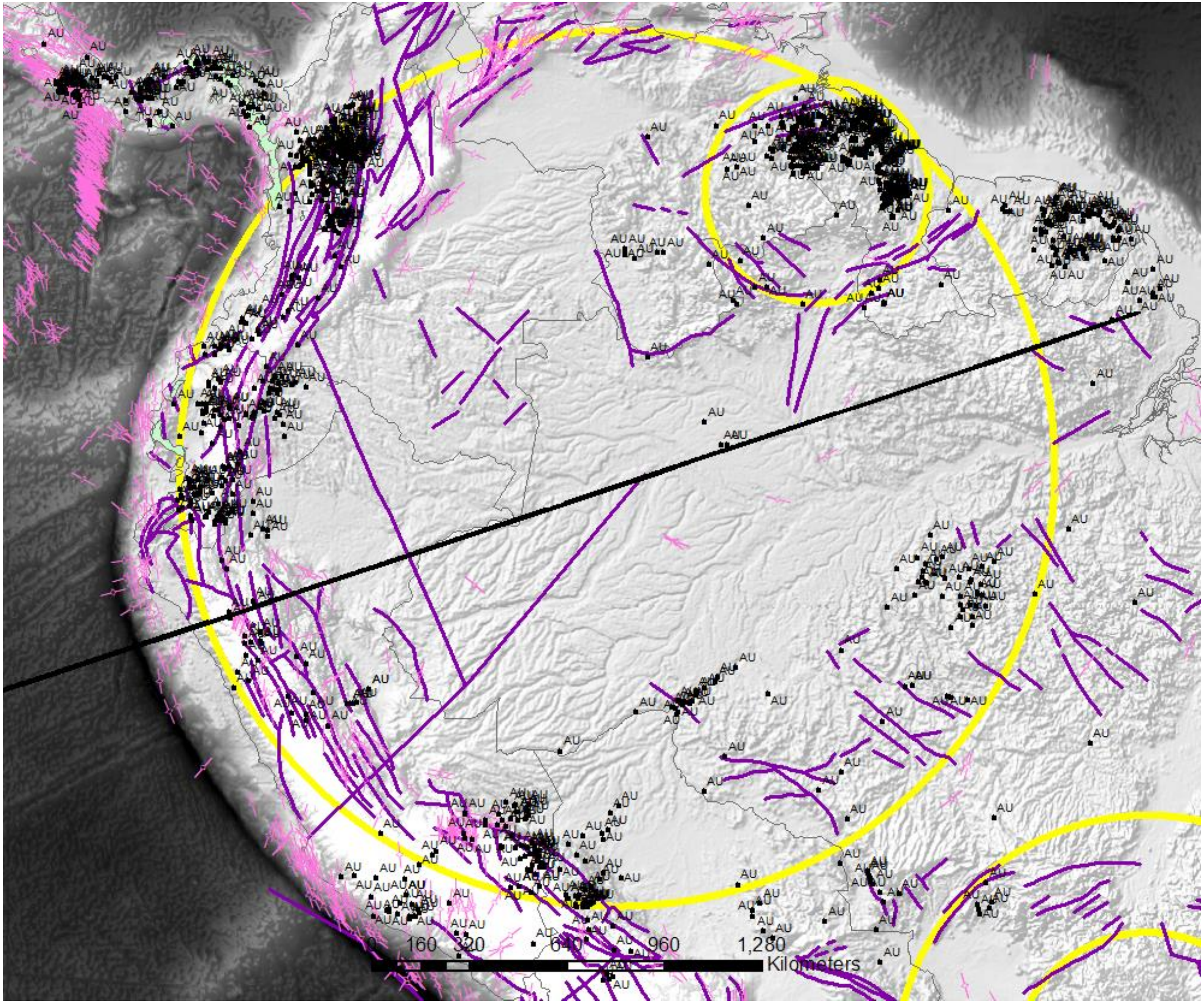
Global gravity, volcanoes, earthquakes, onshore curvi-linear geology on the island of Borneo, with crater interpretations. Major structural disruptions occur on the northwesternmost and southeasternmost Sumatra volcanic arcs, and also to the north-northwest and southern eastern margins of the Emden Deep trench east of the Philippines.

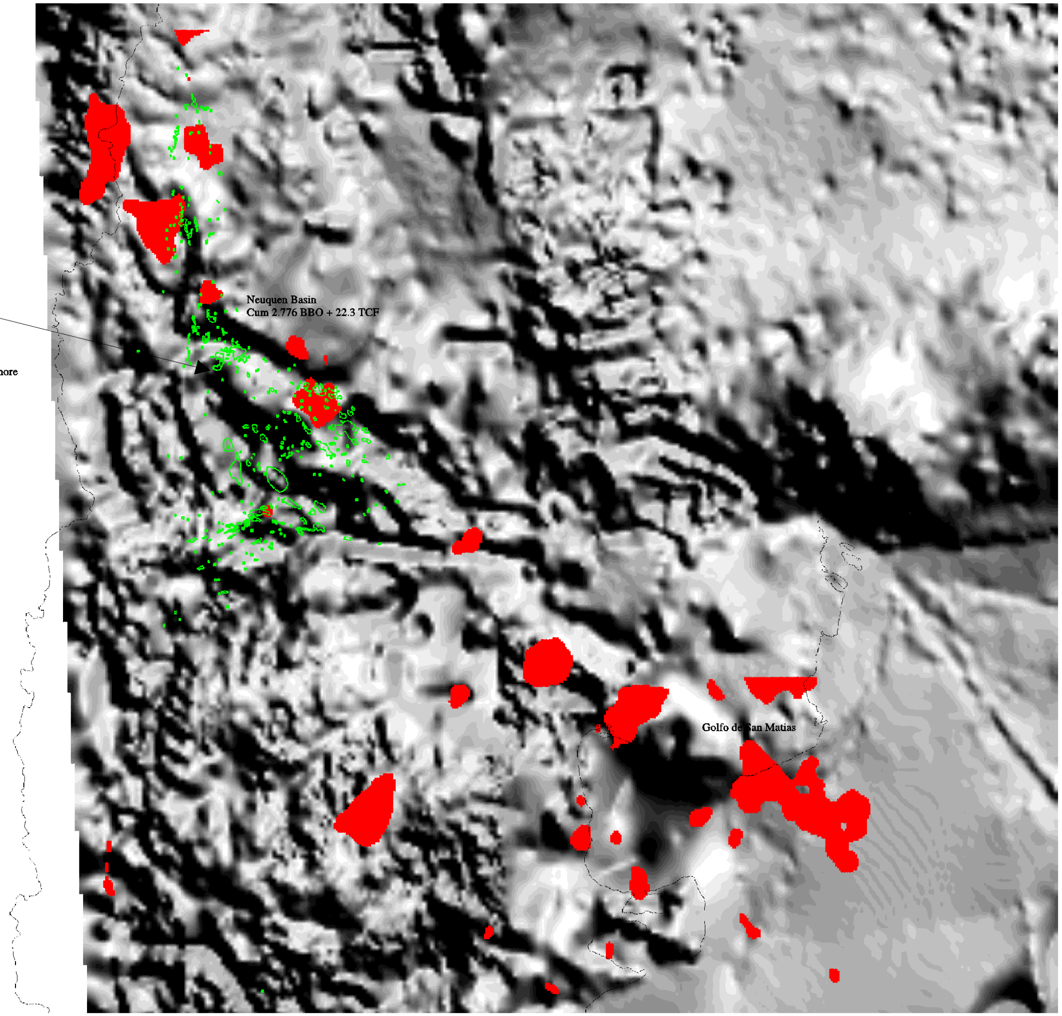


South America gravity color-filled contours, cratons, oil fields (green), volcanoes, faults, world stress vectors (pink) along with interpreted (possible) crater basin.



Shaded relief magnetics, showing circular geometric pattern. When Unocal Chief Geologist John Baines saw this map he declared, “Now that’s an impact crater!” When I commented that this was the oil-prolific deepwater Campos Basin, offshore Brazil, he exploded. “You’re full of @##$!” I escaped the layoff axe by a narrow margin that time. The Campos Basin magnetics exhibits clear circular, multiple rings, encircling a center. The majority of the oil production is within the rings.


AU
0 160 320 640 960 1,280
Kilometers



Virtual dataset 1: Seepdensity>0.01 per 15' cell and Satellite Gravity 14K bandpass <20, else null.

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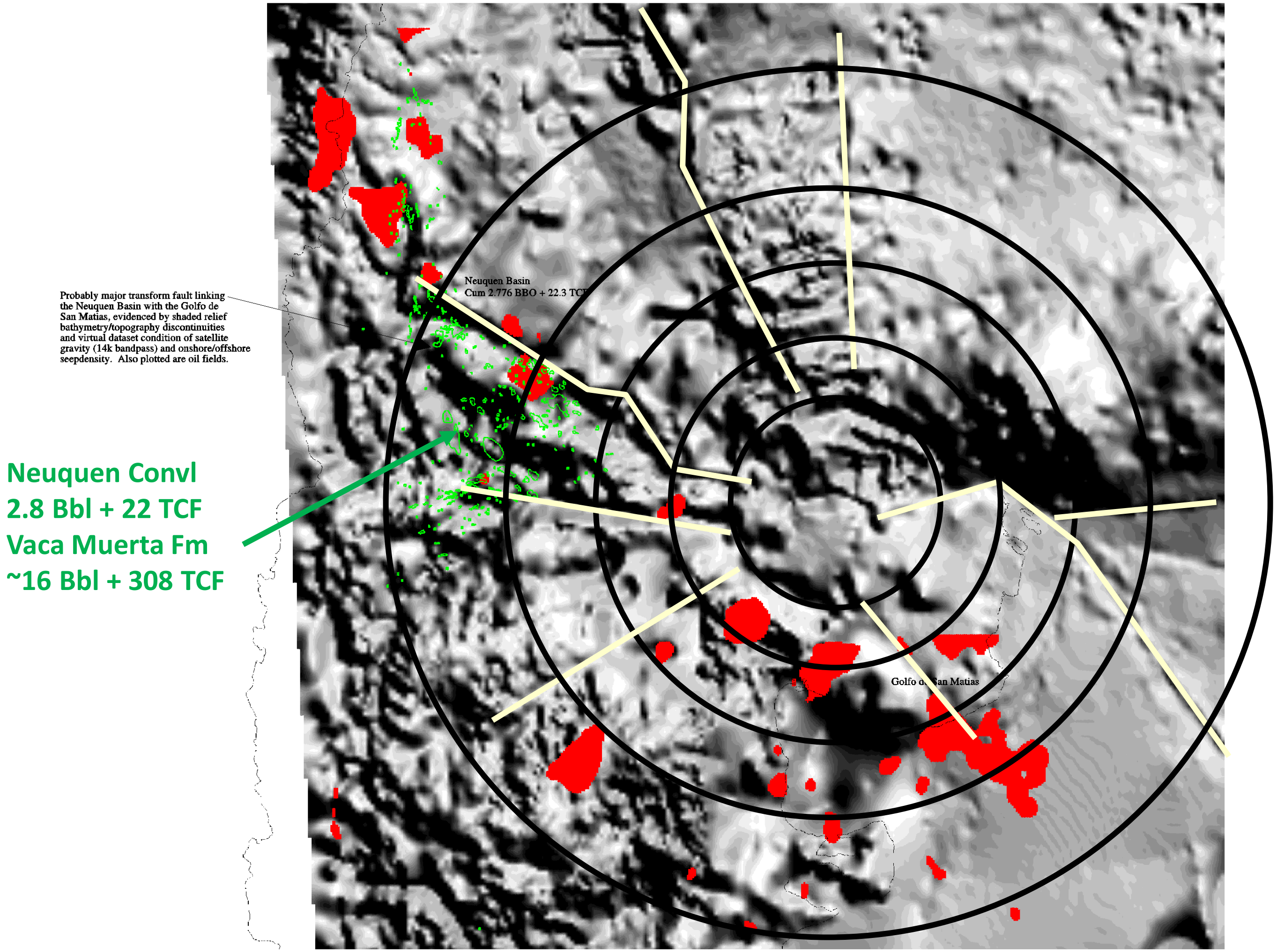
SAR ARGENTINA

Projection Information: Transverse Projection, Spheroid Southamerican1969, scale factor 1.0, longitude of central meridian -66:0:0, latitude of origin 0:0:0, false easting 3500000, false northing 10002288.34, units meters.

File: /home/epcodbb/argentina/virtual_srtopo_121498.cgm/alg
GIS Team / D. Buthman 12/14/98

DB '99



Scale 1:1,500,000

Virtual dataset 1: Seepdensity>0.01 per 15' cell and Satellite Gravity 14K bandpass <20, else null.

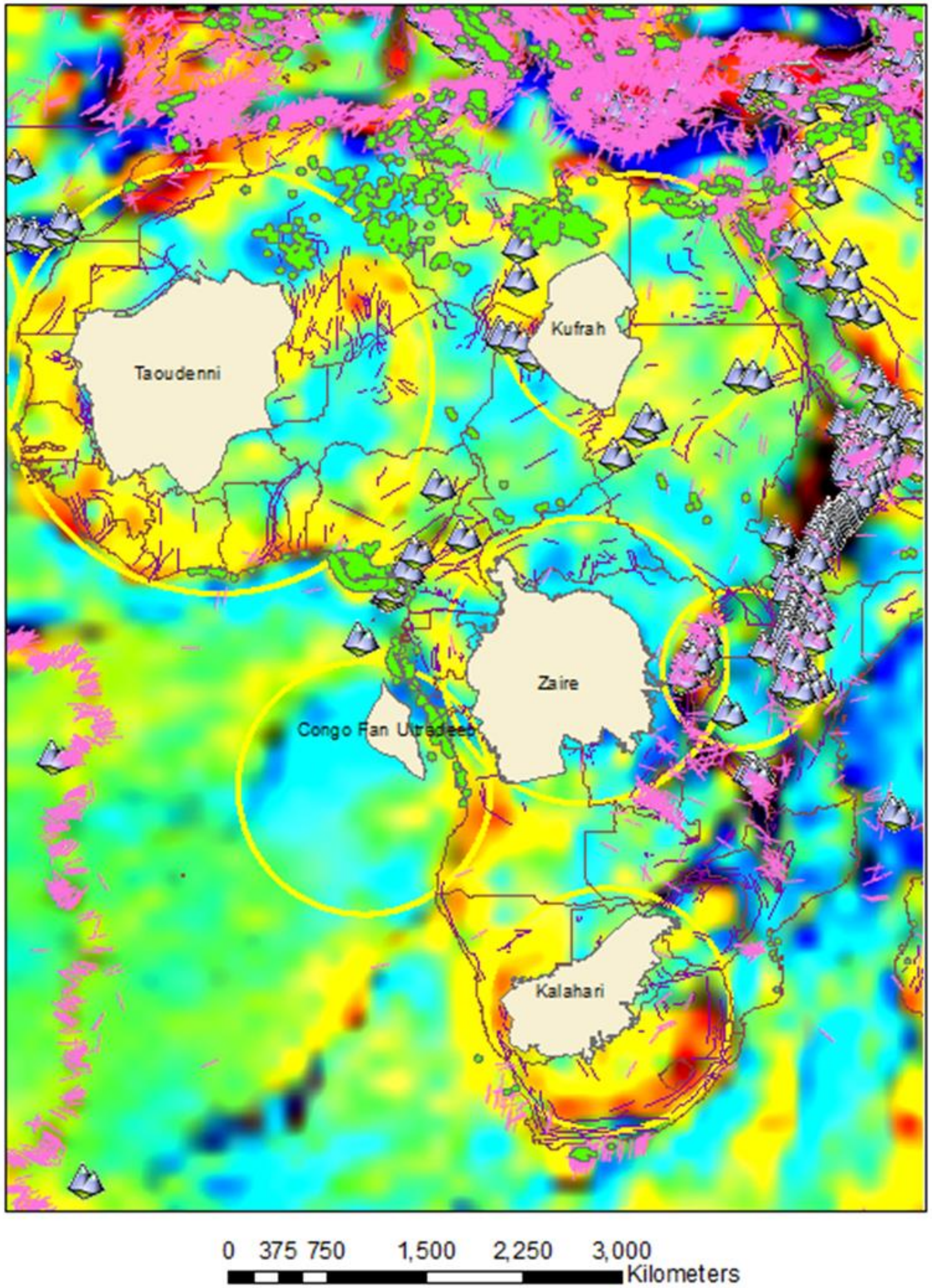
Unocal
SAR ARGENTINA

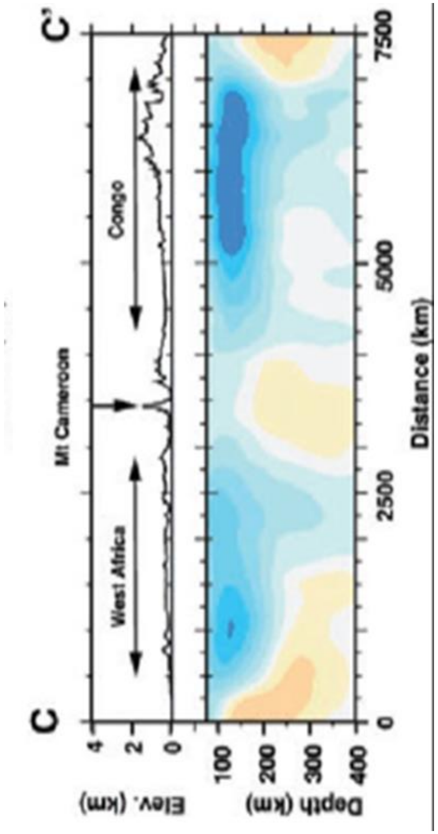
Projection Information: Transverse Projection, Spheroid Southamerican1969, scale factor 1.0, longitude of central meridian -66:0:0, latitude of origin 0:0:0, false easting 3500000, false northing 10002288.34, units meters.

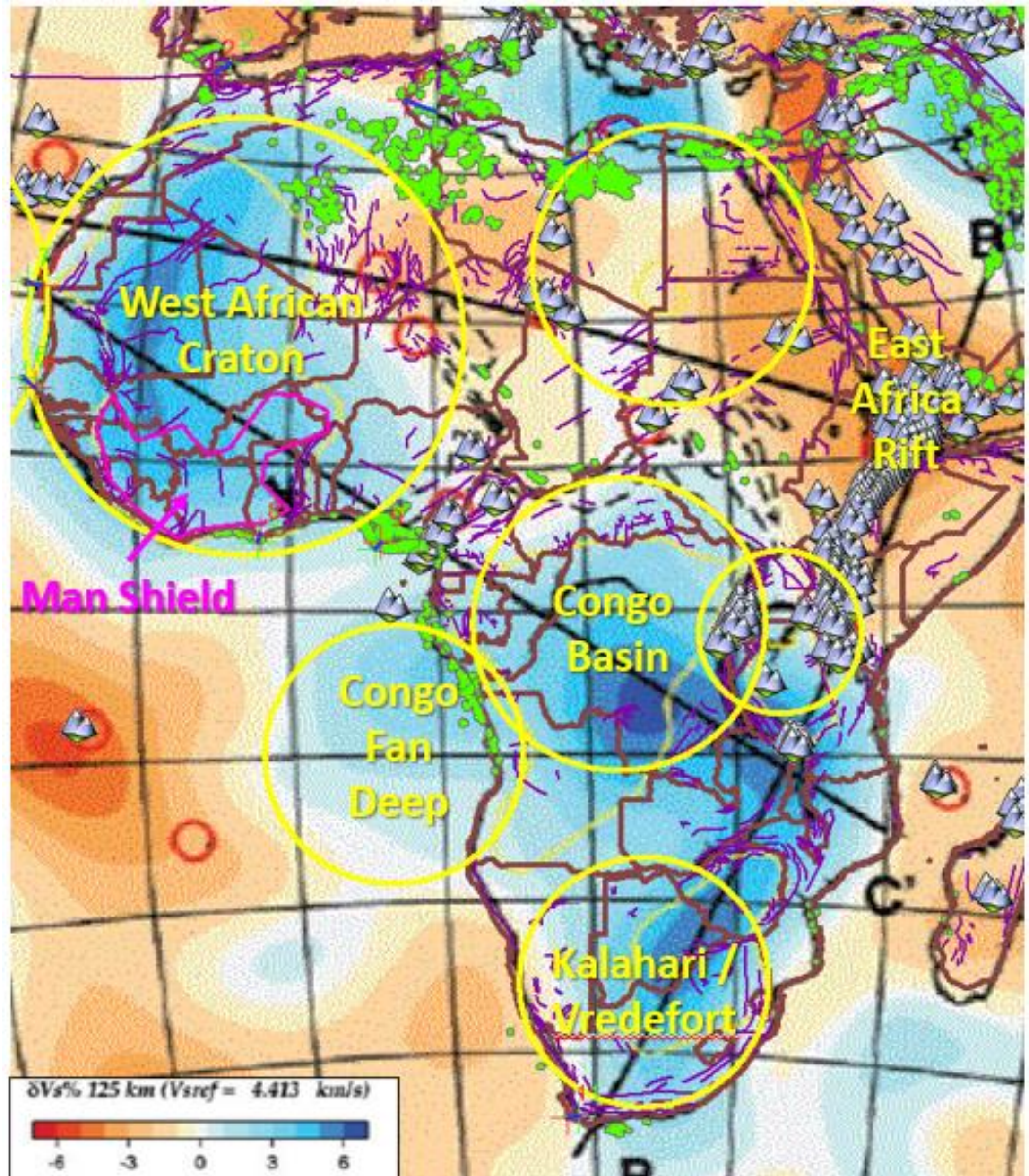
File: /home/epcodbb/argentina/virtual_srtopo_121498.cgm/alg
GIS Team / D. Buthman 12/14/98

Multibasin crater geometric analysis, Neuquen and San Matias Basins, Argentina, Shaded relief topography and bathymetry with gravity / SPT-SAR seepdensity virtual GIS query.

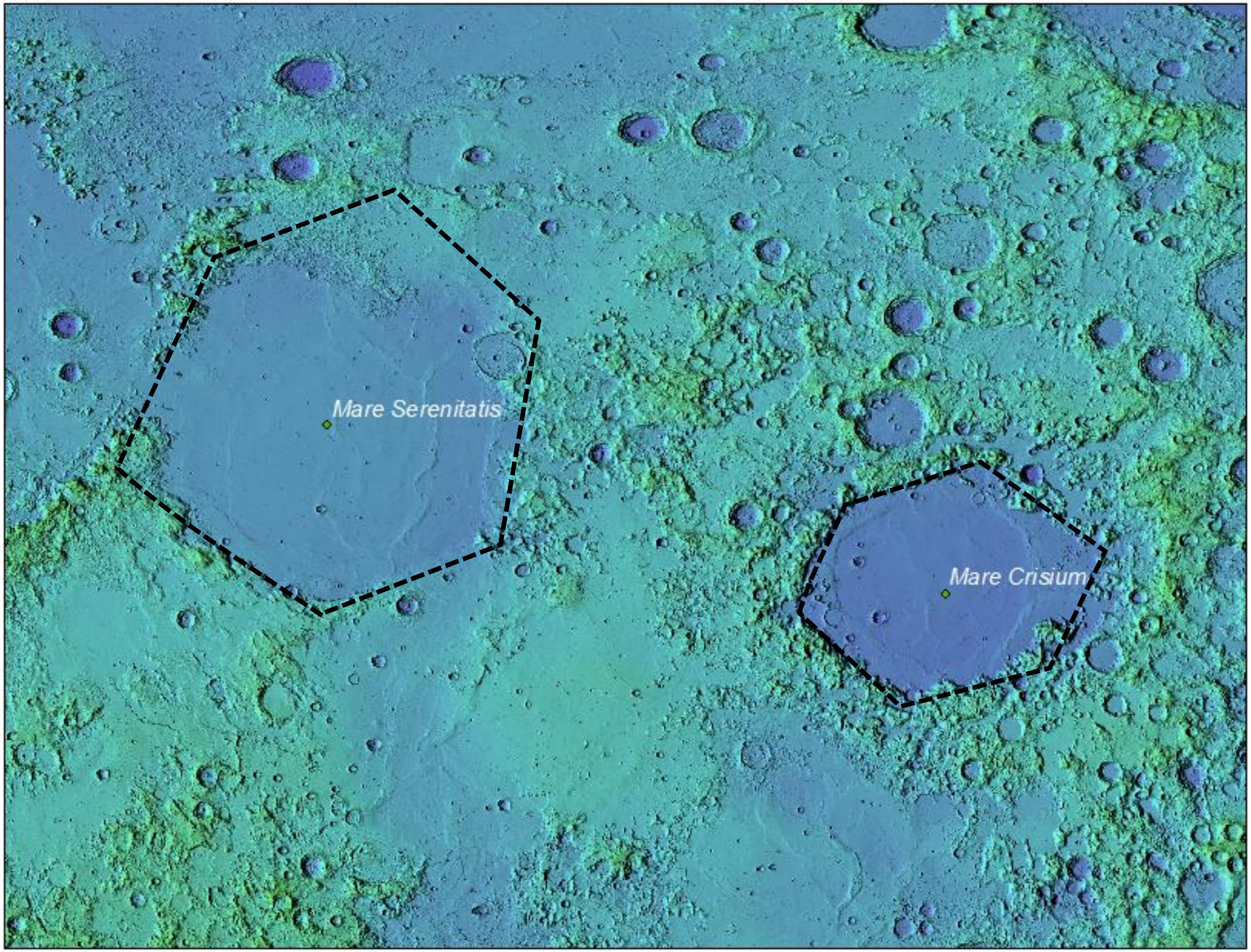
DB '99


Taoudenni
Kufrah
Zaire
Congo Fan Ultradeep
Kalahari
0 375 750 1,500 2,250 3,000
Kilometers

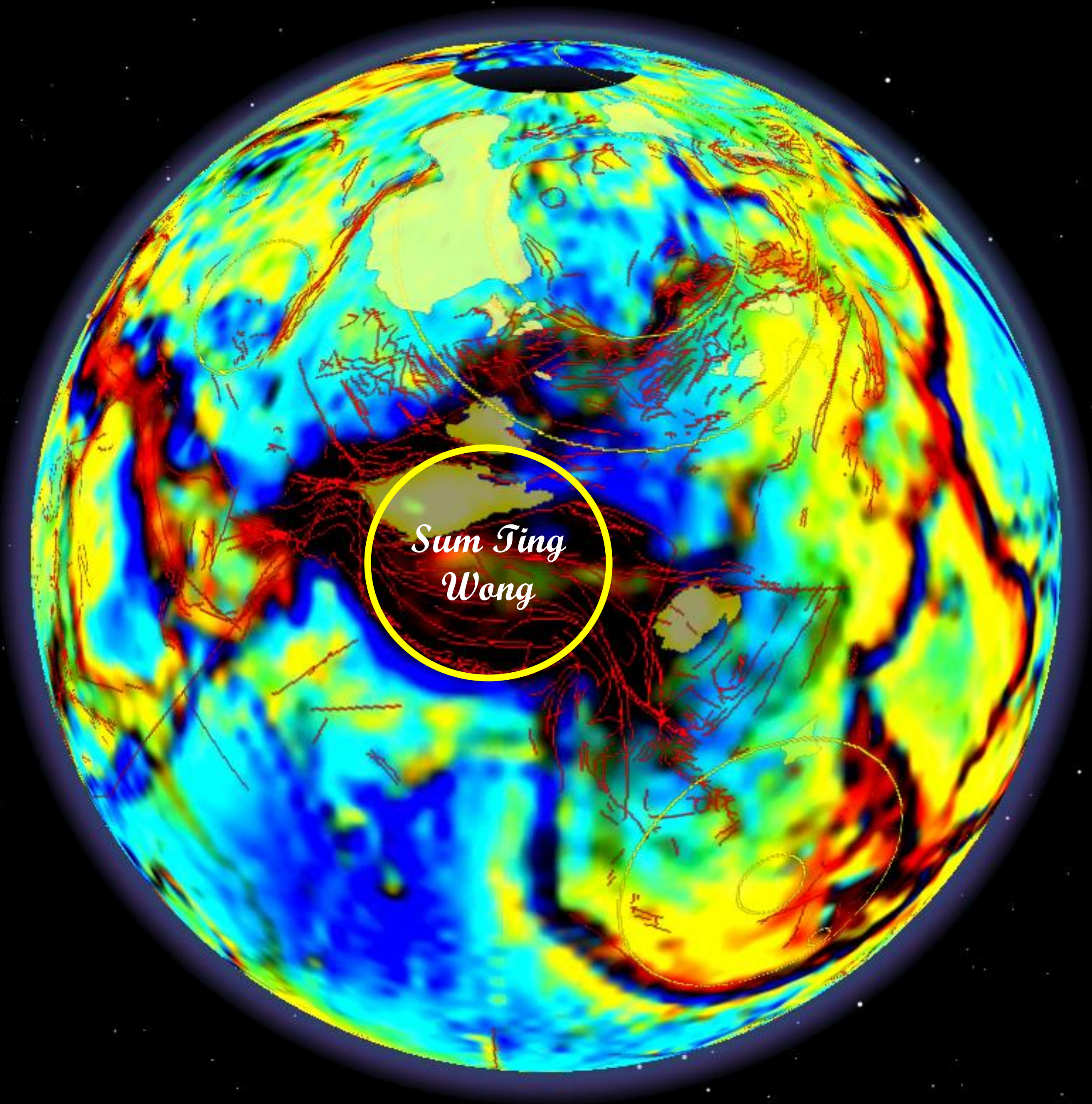




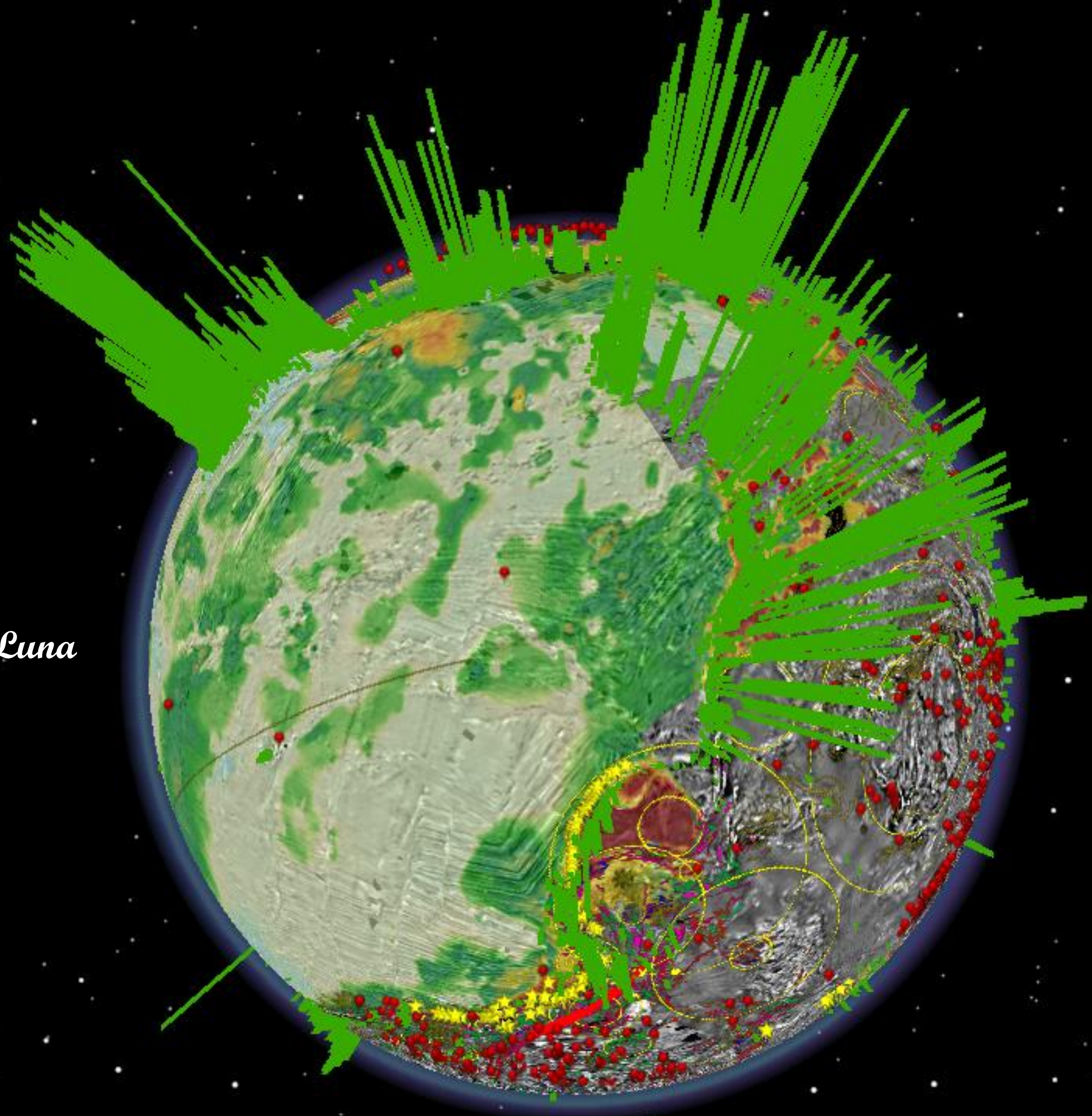
Mantle shear models developed for Africa indicate anomalous high velocity shear anomalies coincident with four of the six possible crater basins proposed here (Priestley, et.al, 2008).



Mare Serenitatis
Mare Crisium


Sum Ting
Wong

Le Luna



Summary

- Recognize Hypotheses
- Demand Multiple Working Hypotheses
- Mindset
  - All maps are wrong
  - Some make you money

- Acknowledgements
  - Hilcorp
  - Dr. John Weber

Presentation: 50 minutes, 15 minutes for questions:

- J. Weber asked:
  - 1. Haedian Period early bombardment—(following up on C. Koerbls question) how do large multi-ringed crater basins with such young ages line up with those graphs?
  - 2. Age distribution of Lunar craters?
  - 3. crater diameter is 20x the diameter of the impactor
    - How do these diameters line out with your hypotheses, given the good empirical data?
- Students asked:
  - Have you seen where the thermal effects of impact have preferentially matured source rocks to gas in the center and oil in the outer rings where cooler?
- Talk was recorded, will get permission to give to folks.