LIDAR-DERIVED DIGITAL ELEVATION MAPS OF MARYLAND, DELAWARE AND NEW JERSEY USED TO IDENTIFY CAROLINA BAY LANDFORMS

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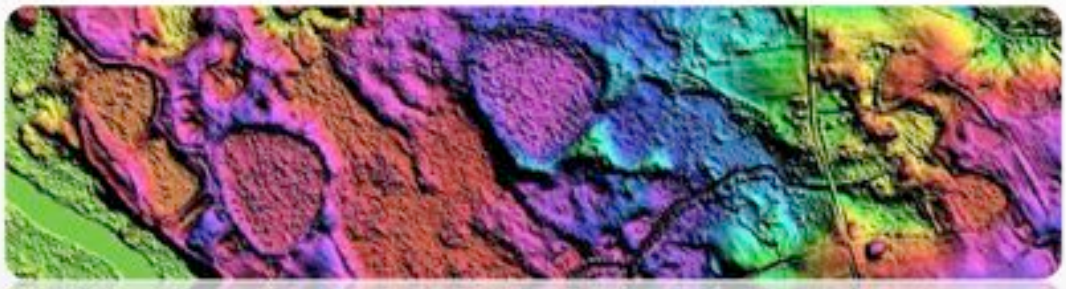
Michael E. Davias



Visualizing the Enigmatic Coastal Ponds

Greetings:
My objective this afternoon is to use LiDAR-derived high resolution digital elevation maps to survey the shallow, closed basins known to exist along the Coastal Plain of New Jersey and the DelMarVa Peninsula

Abstract

LIDAR-DERIVED DIGITAL ELEVATION MAPS OF MARYLAND, DELAWARE AND NEW JERSEY USED TO IDENTIFY CAROLINA BAY LANDFORMS

DAVIAS, Michael, Stamford, CT 06907, michael@cintos.org

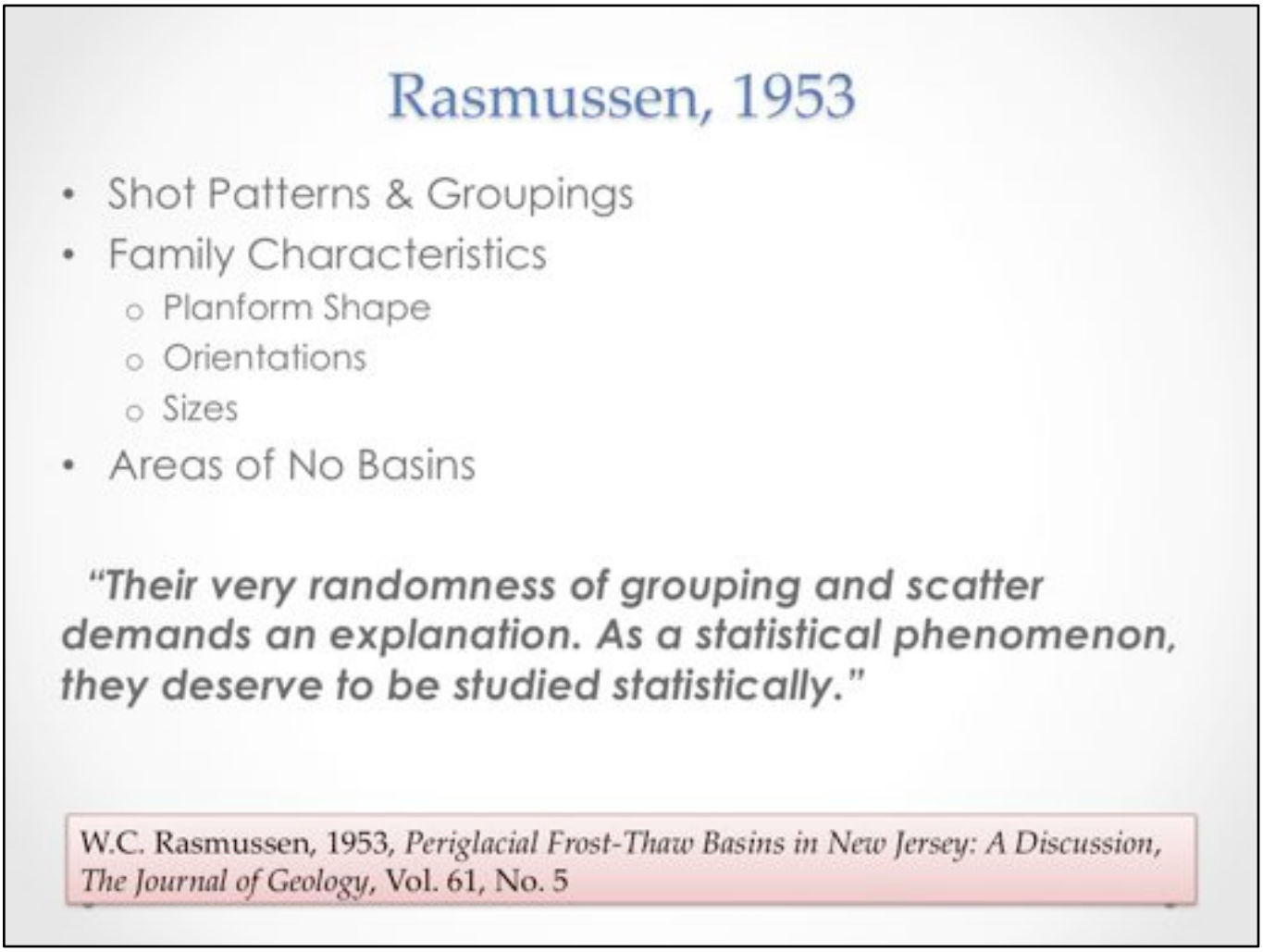
The existence of Carolina bay landforms in the Carolinas has been researched for decades, but their presence on the landscape across Maryland, Delaware, and New Jersey has been slowed by their smaller sizes and more circular presentation. Recent advances in digital elevation mapping using LiDAR (Light Detection And Ranging) technology offer a new perspective on the location and shapes of these shallow basins and their enigmatic circumferal rims. To support a geospatial survey of Carolina bay landforms within the northeastern Atlantic coastal plain, we generated hsv-shaded DEMs (Digital Elevation Maps) as KML-JPEG tile sets for visualization. A majority of these DEMs were generated with LiDAR data, while a small subset used USGA 1/3 arc second data. A gentle progression of planform shape is seen on these maps as the viewer moves from south to north. We demonstrate that the planform of most bays identified suggests a very robust correlation to one of two archetypical shapes. These two shapes were engineered into Google Earth overlay elements, which were placed over candidate basins; by manually adjusting the length, width and rotation from North, the shape of the circumferal bay rim can often be satisfactorily captured. The generic Carolina bay characteristics set includes a pervasive common orientation among neighboring bays. However, as we traverse the coastal plain towards the north, the bays' more-rounded presentation leaves this as a subjective assignment. Using LiDAR-derived imagery, we present our argument for the alignment suggestion that we imbedded in our archetype planform overlays. We demonstrate that when these archetype planforms are overlaid on the basins, their orientation varies systematically by latitude, in a gentle progression similar to that seen further south. The high fidelity LiDAR elevation maps also demonstrates the pervasiveness of the bay planforms against a backdrop of wind-driven sand sheets and parabolic dune formations across this landscape. All LiDAR maps referenced have been made available on the Internet to support independent research. Likewise, the geospatial database of metrics for 2,500 bays we examined in this region is available from an on-line Google Fusion Table:

http://www.google.com/fusiontables/DataSource?snapid=S226571Pxml

Called "Spungs", and "Delaware Basins", they are differentiated from sand dunes by their closed circumpheral rims. From that perspective, they have been associated with the enigmatic Carolina bays located further to the south, and their geomorphology has been debated for decades. Among proposed mechanisms are Periglacial frost-thaw basins, blowouts in sand sheets and kettle holes left behind by icebergs shoaling on the landscape. Age constraints suggest they were created during Pleistocene times.

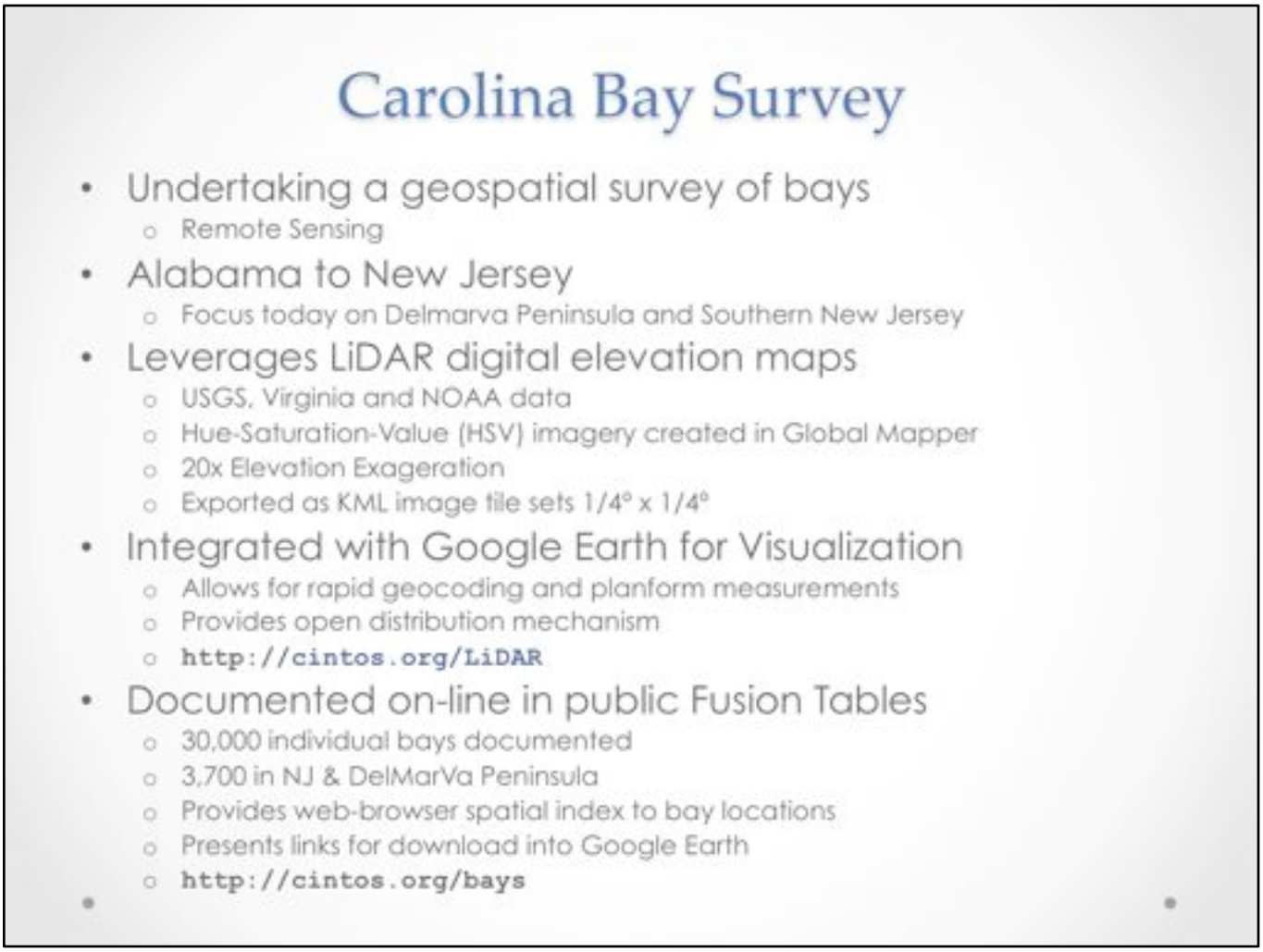
While "bays" in the Carolinas have been shown to present very robust oval shapes and pervasive northwest to southeast alignments of their major axis, the smaller basins discussed here are reported as being chaotic in both shape and orientation.

This afternoon, I will attempt to show how LiDAR brings a new perspective to this discussion, and hopefully document a stronger correlation between the two collections.

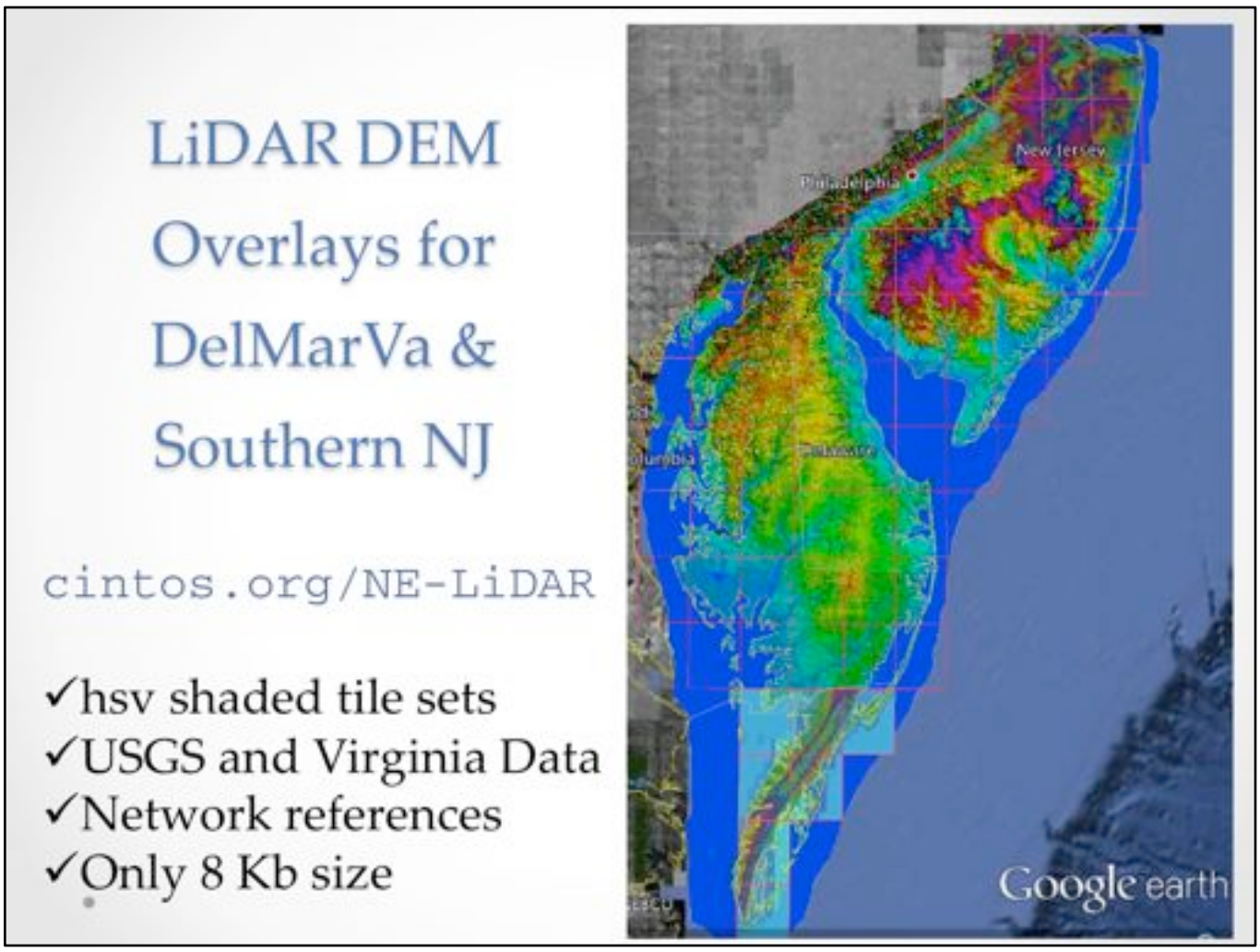


In his review of these basins, USGS Geologist William Rasmussen offers some motivation and direction. He observes some interesting patterns of distribution.

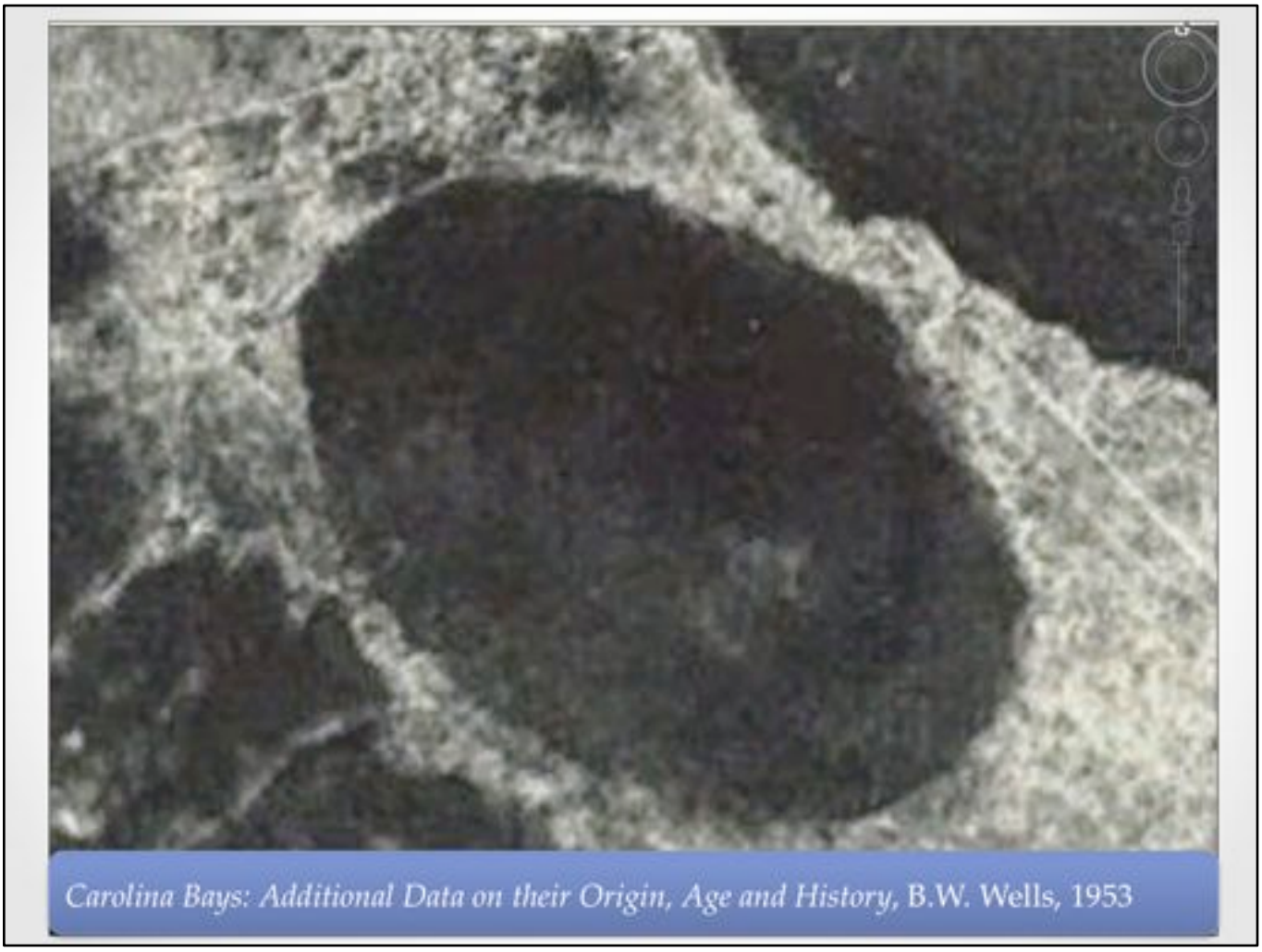
"Their very randomness of grouping and scatter demands an explanation. As a statistical phenomenon, they deserve to be studied statistically."



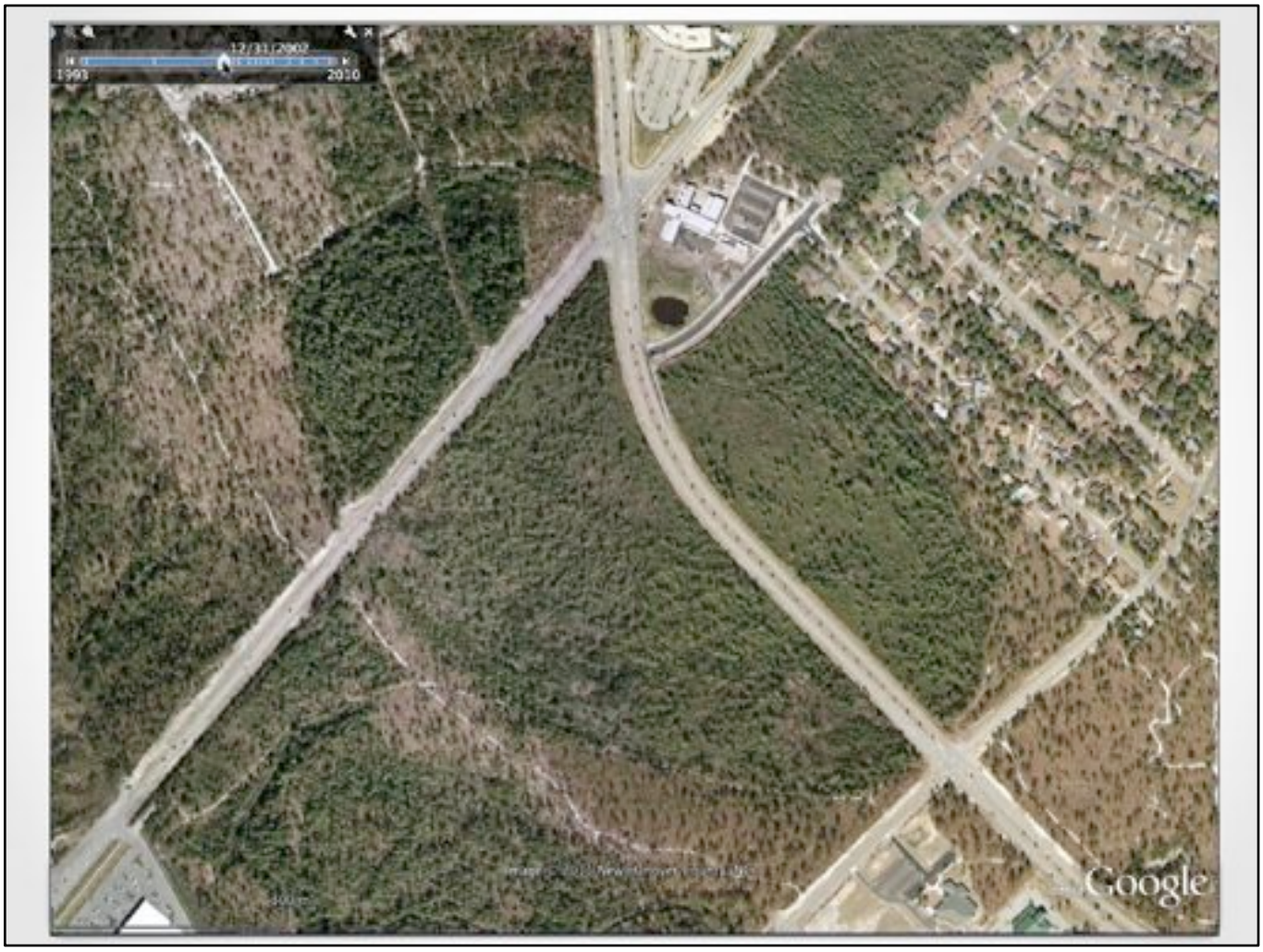
To do a statistical analysis, one needs data, so I undertook a remote sensing-based geospatial survey. To assist in visualizing and measuring the basins, I have generated digital elevation maps, using hue-saturation-value (hsv) coloration. These are viewable using the Google Earth virtual globe, where network links load only the appropriate imagery. All survey data are available through the Google Fusion Tables facility.



The url shown here links to a KML file, which opens in Google Earth displaying this image. DEM horizontal resolution is either 3 meter or 1.5 meter spacing, vertical resolution is typically in the centimeter range, depending on source



Lets take a look at a classic Carolina bay photographed from the air in 1938.
Here is a satellite image of the same bay, which is actually located within the Wilmington, NC city limits. The major axis is exactly 1 kilometer, so this is a significant structure.
Seen in LiDAR, the structure displays a strikingly geometric planform. Note that even the construction of major roadways across the “bay” has had minimal affect on the presentation of the actual landform.



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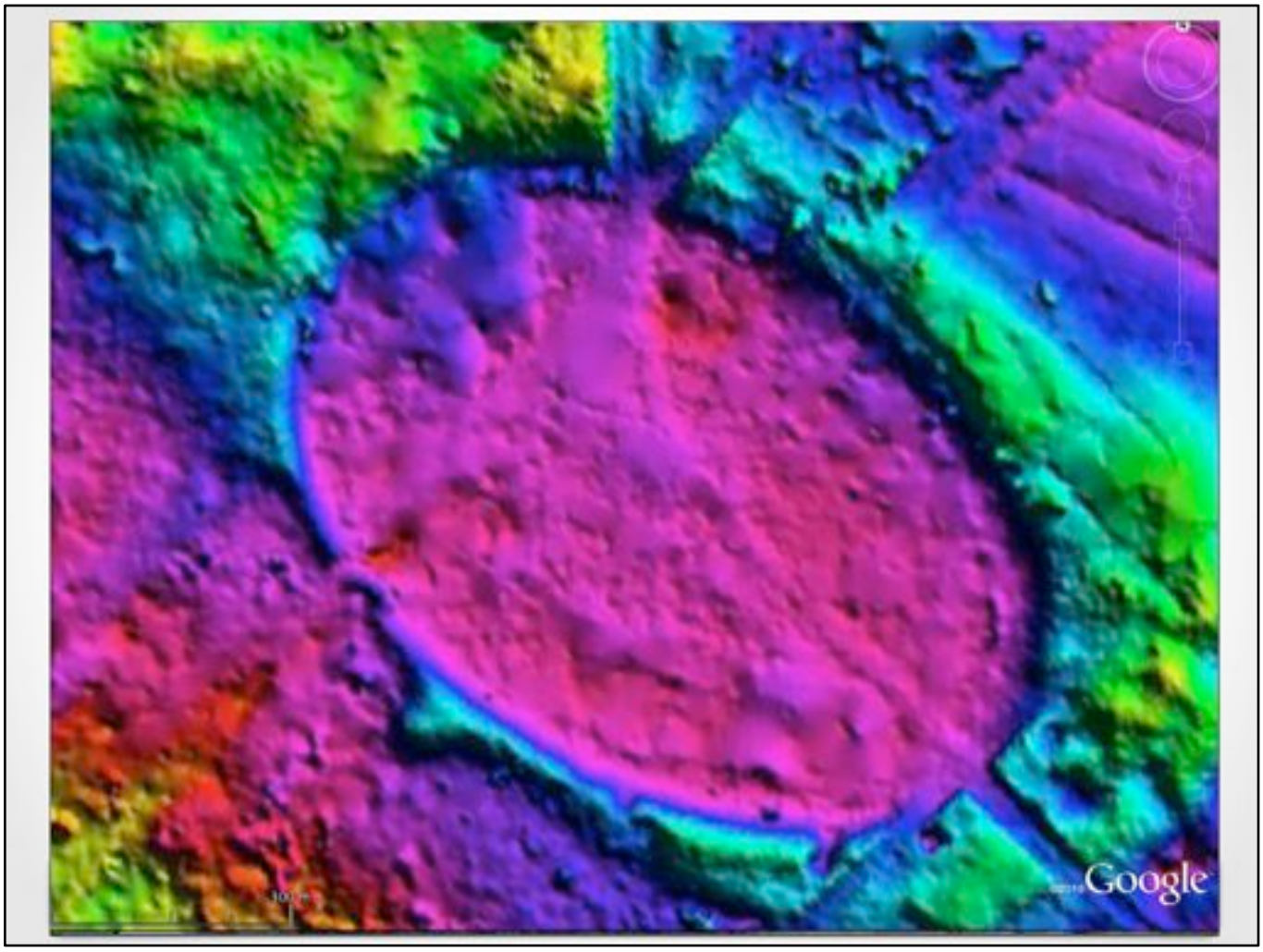

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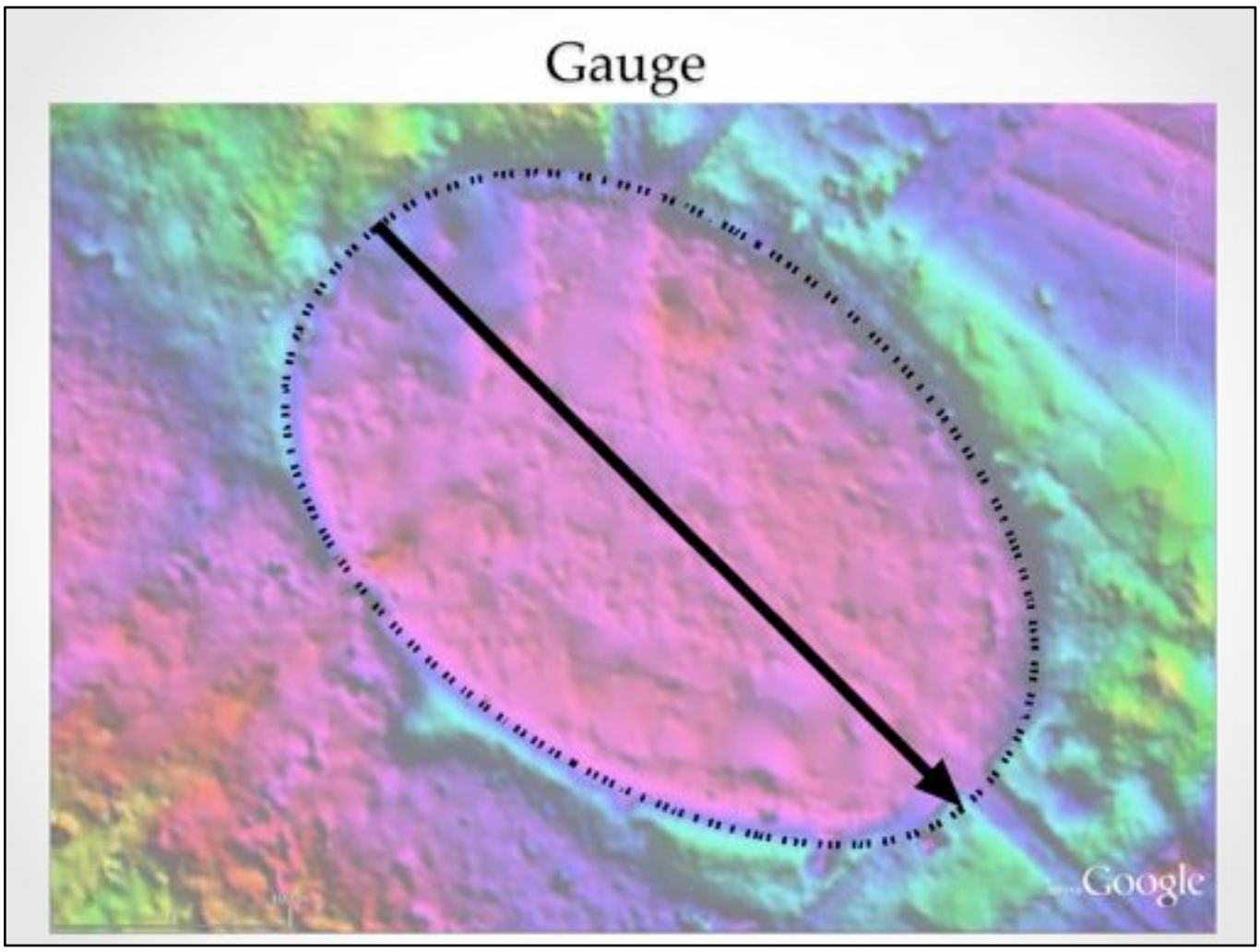
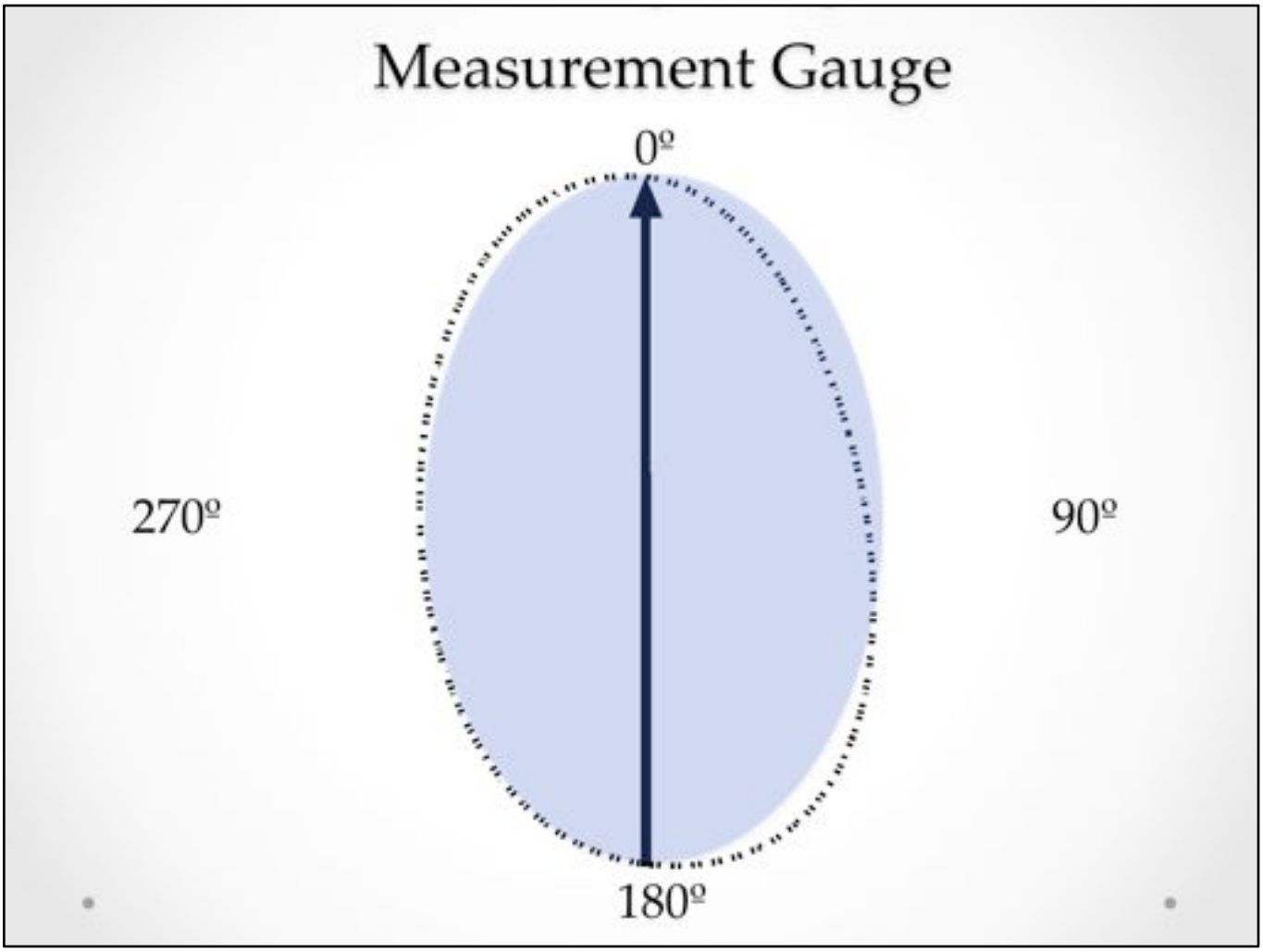
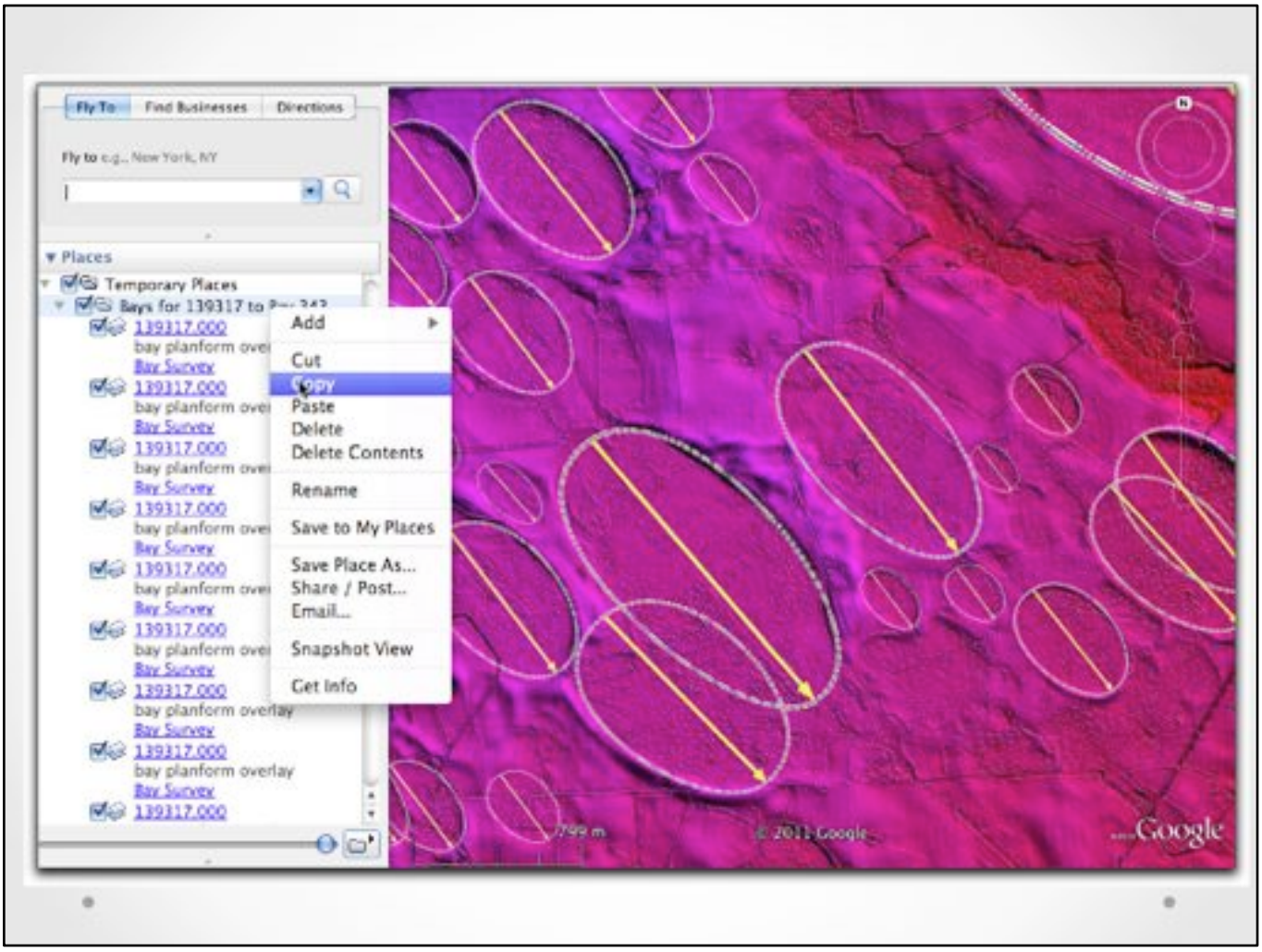


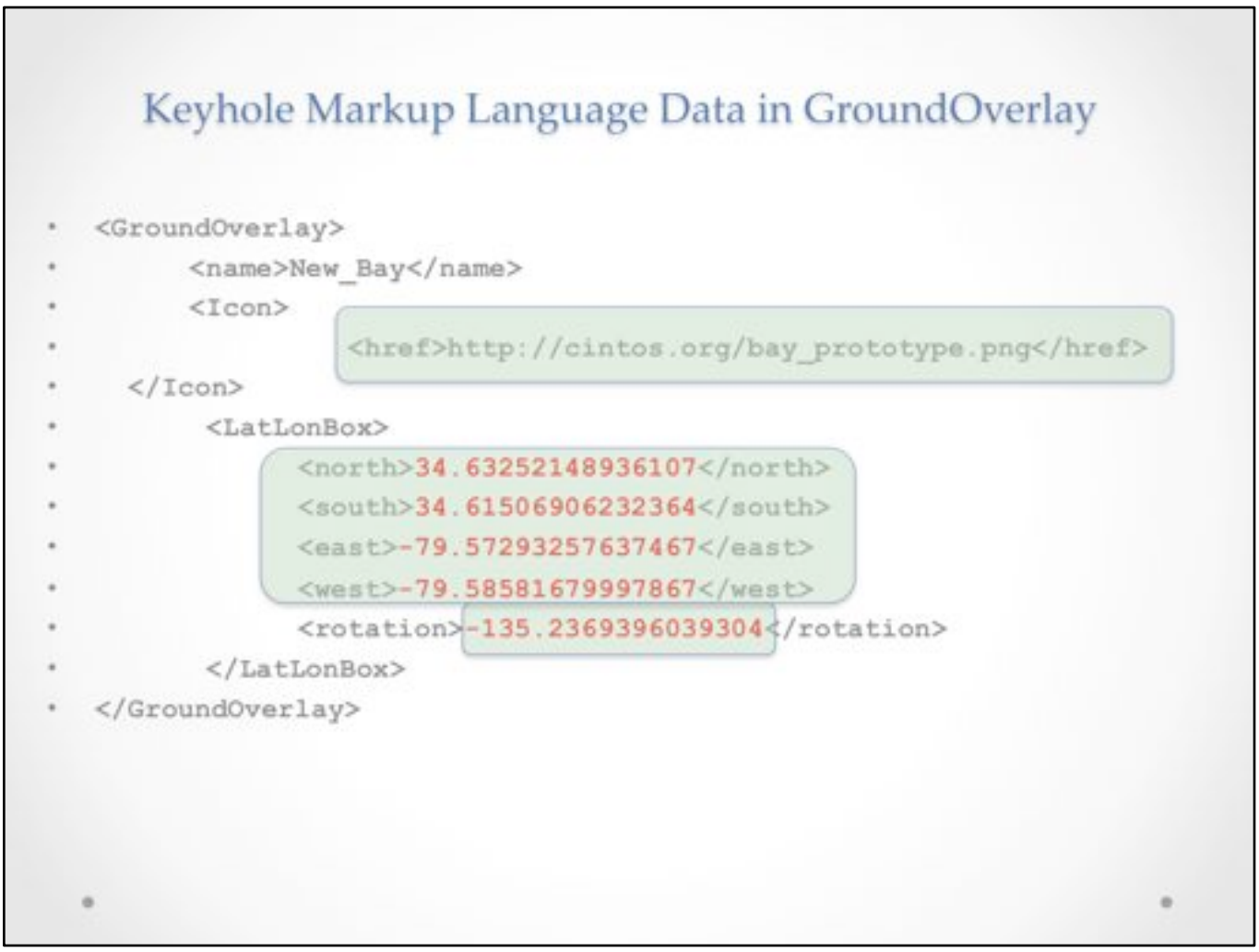
The survey uses a GroundOverlay element as a pattern matching device. We created this by tracing a typical bay's rim in a graphic program and Click generating a PNG image with transparency.



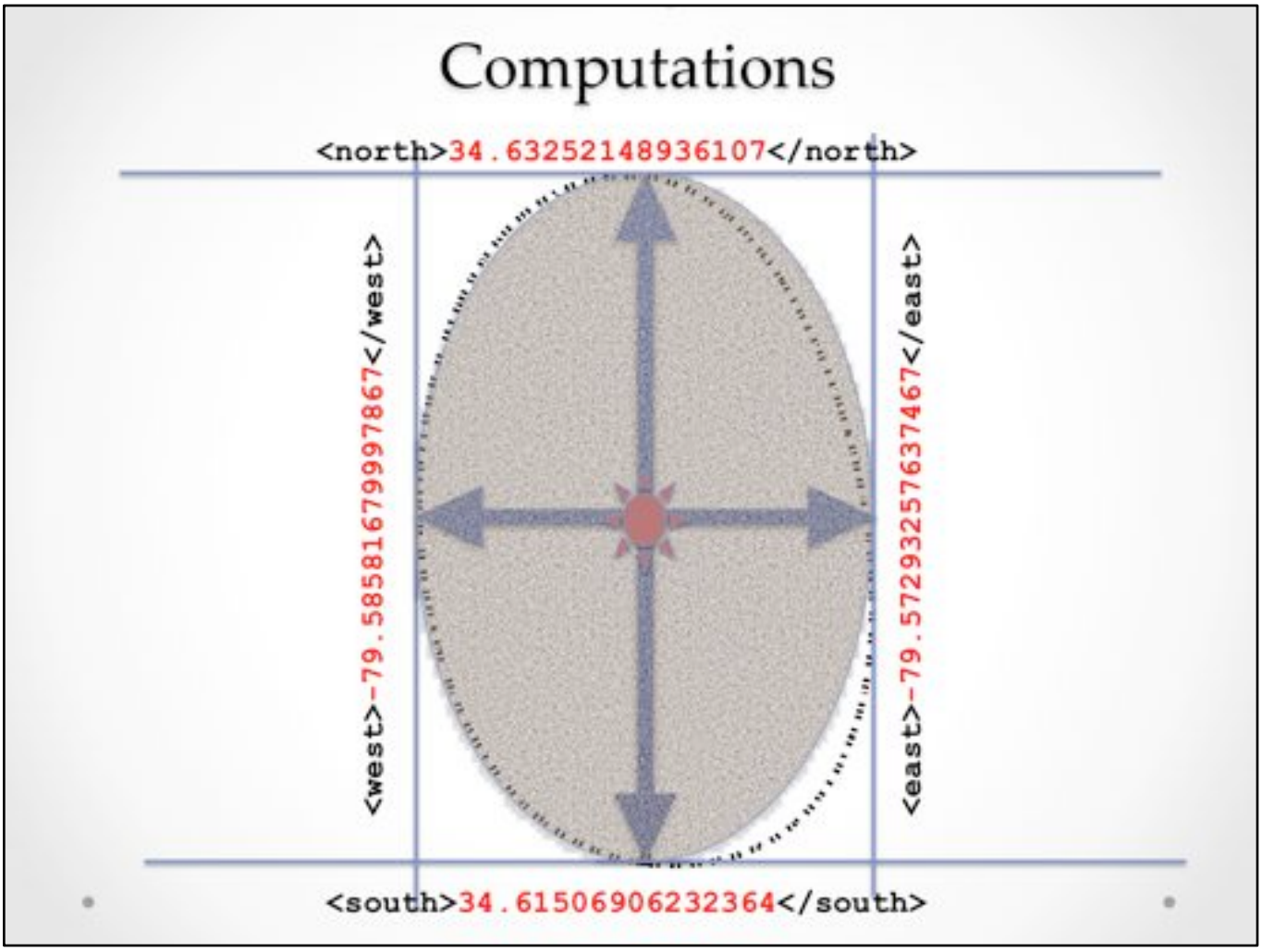
This is our Bay Archetype planform. When compared to a true oval, it is slightly “twisted”, or “skewed”. The orientation arrow is used to measure the rotation from north. Now, I don’t create an individual planform graphic for each bay, because they have been shown to be robustly repetitive.



Once an archetype planform is identified, we simply replicate the ground-overlay element, grab its center handle and drag it to another basin, adjusting the size and rotation in the process. Copy, drop, drag, roll, stretch, shrink, repeat. Trust me, after doing that for a few thousand times, one begins to get a sense of just how robustly similar these shapes are.

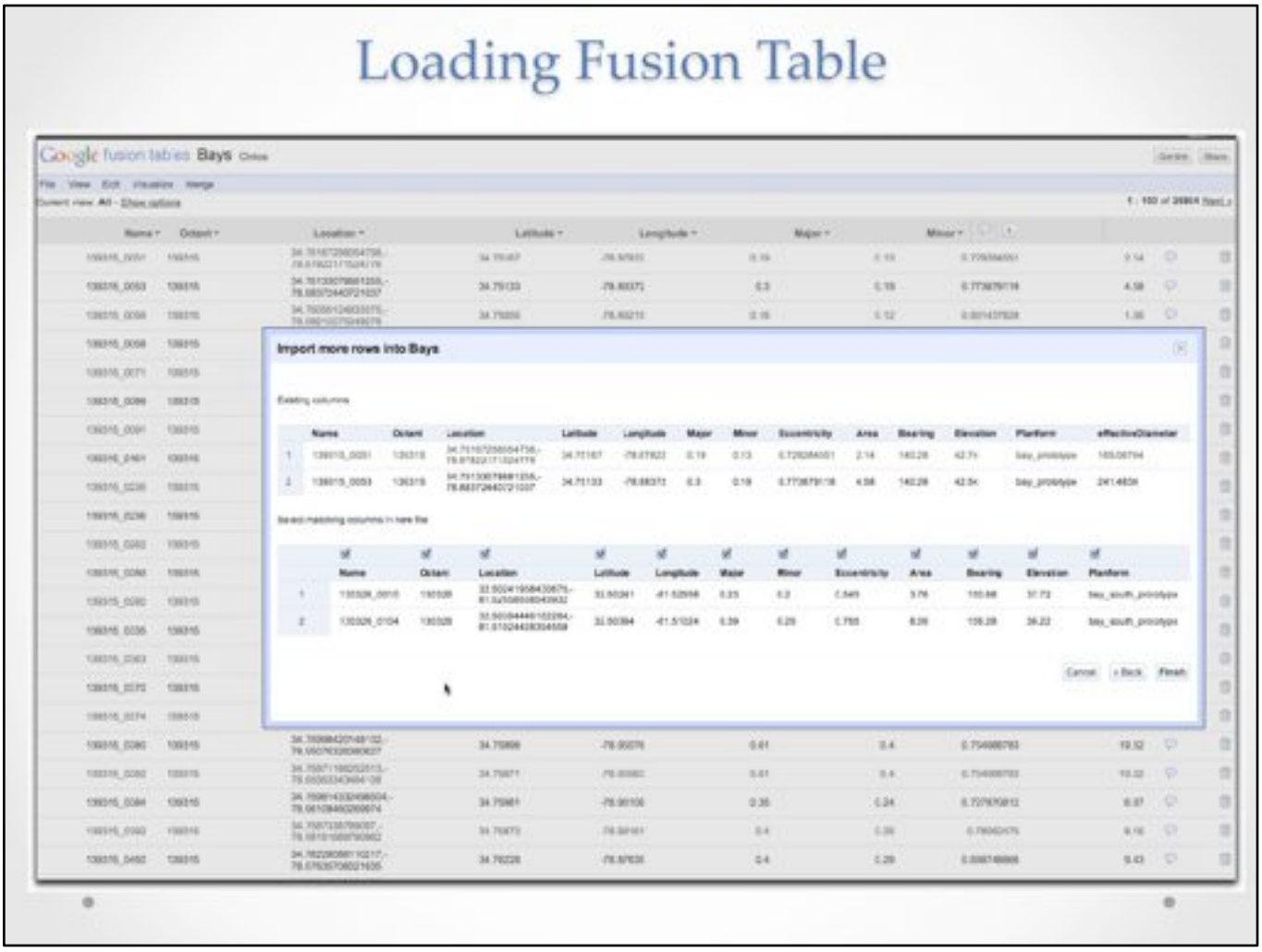


Now, a ground overlay element is not a graphic image – its text in the Keyhole Mark-up Language - KML . We can read this: The overlay's url is there, The rotation angle from due north reports the bay's orientation. The LatonBox coordinates…

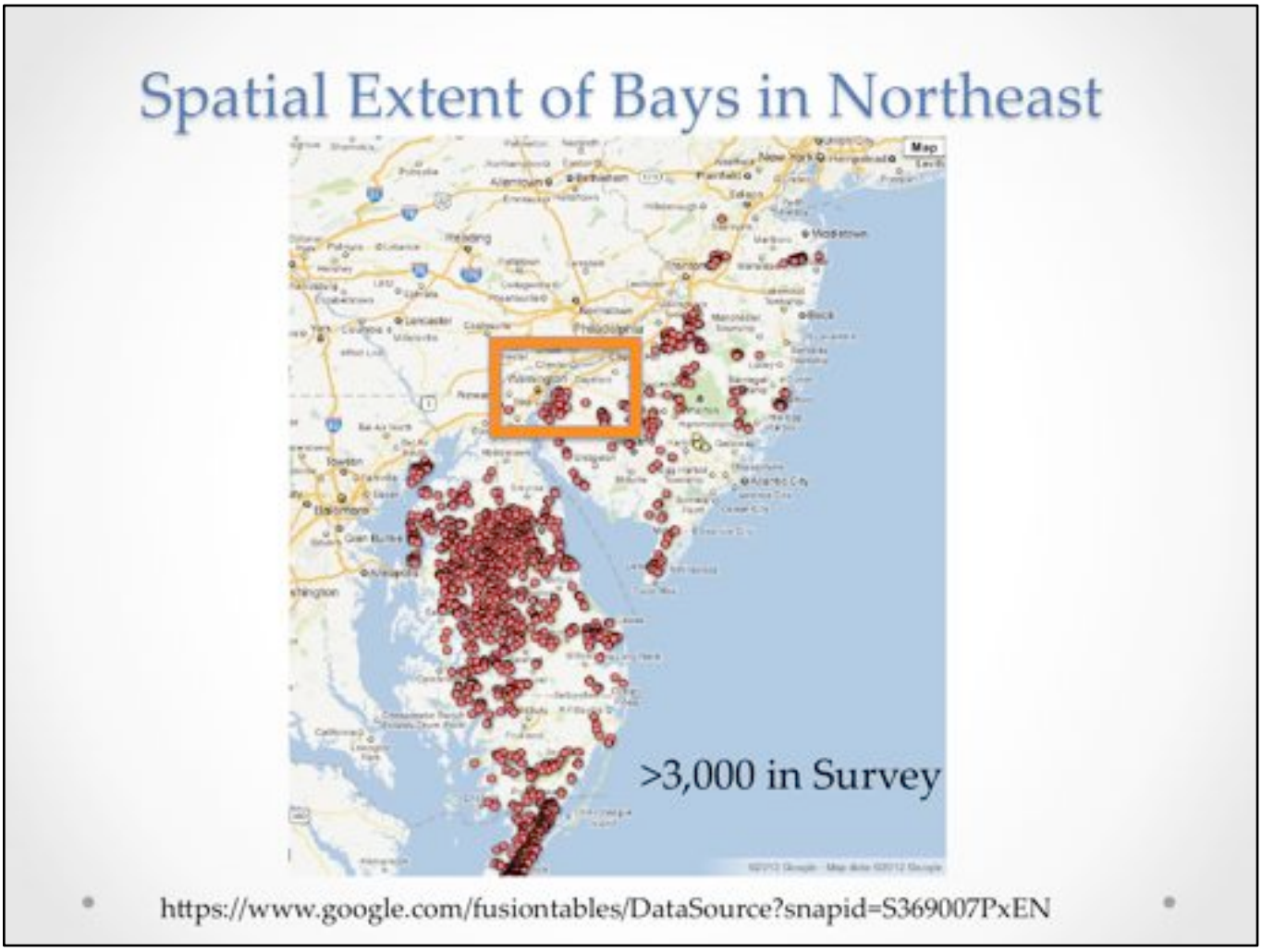


… create a bounding box that defines (with a bit of trig) the major and minor axis of the bay, a bay center, and an approximate surface area.

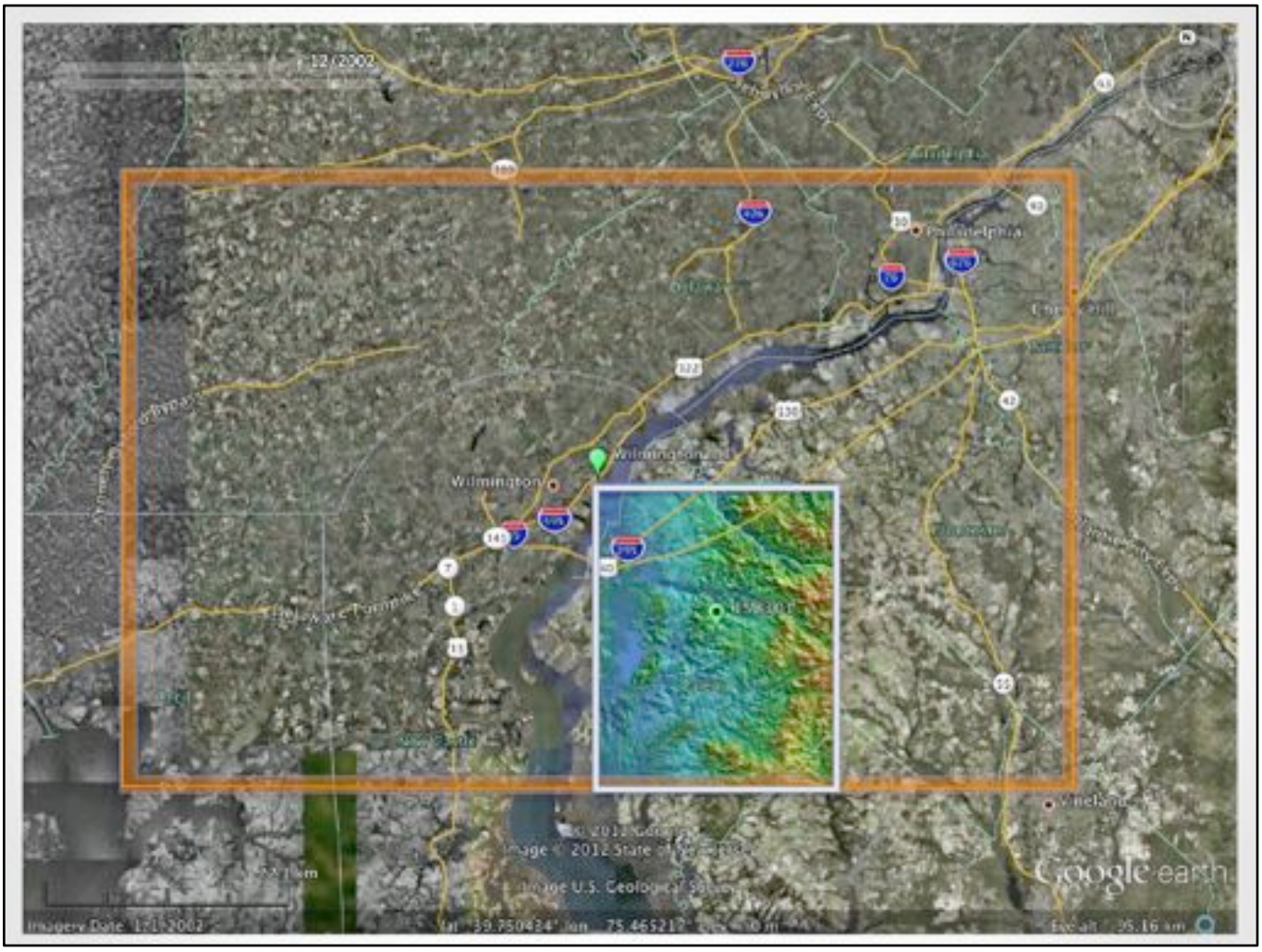
Loading Fusion Table



We developed a Java program to generate a tabular list of bay measurements from the KML and uploaded into a Google Fusion Table.



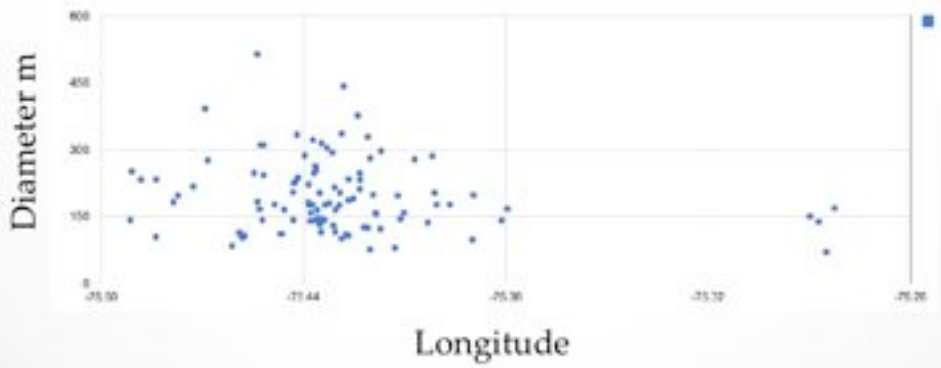
This is a screenshot of the live web browser Map created by the Fusion Table facility, which displays a placemark for each of the 37 hundred measured bays in the survey. Lets start reviewing them near the other Wilmington – Delaware.



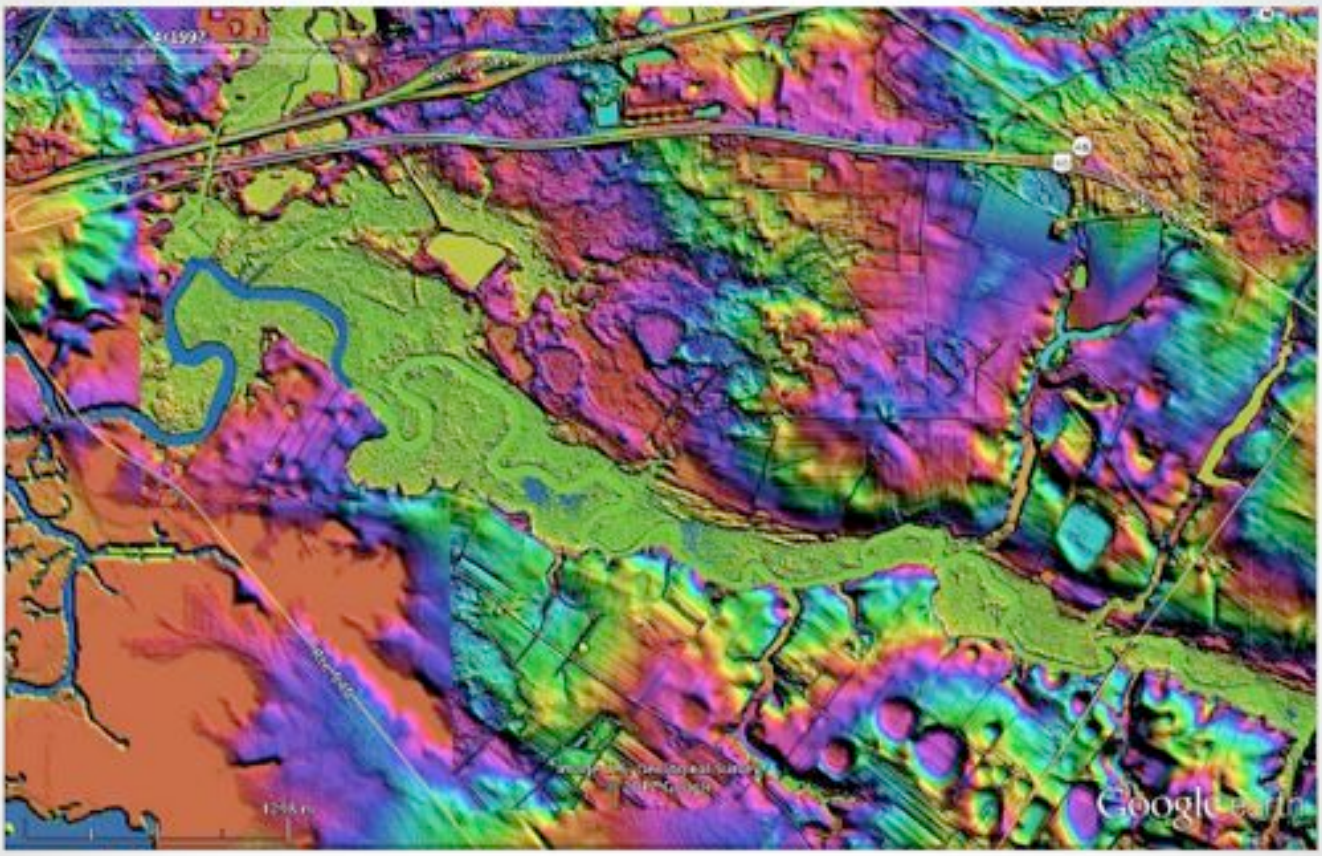
At the highest level, the survey is grouped within USGS 100K Quads. Outlined in orange is the Wilmington, DE Quad. My hsv-shaded LiDAR DEMs are created as quarter degree by quarter degree grid elements, and there are eight of these in a 100K Quadrant, so I nick-name them “Octants”. Each was given a numeric number, in the case of the area with the DEM turned on here - 158301.

Octant 158301

- Wilmington, DE 100k Quad
- East of Delaware River and south of Wilmington
- "bay bell" Planform
- 103 bays identified/measured
- Mean Bearing 118°
- Std dev 6.7°



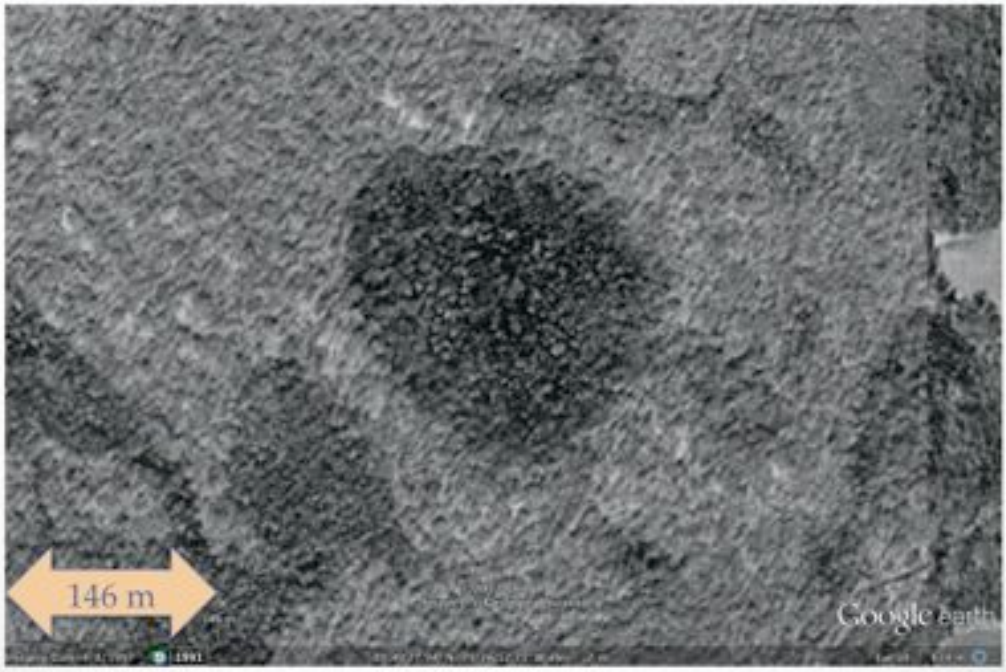
Here are some of the survey metrics for this Octant, showing that 103 basins have been measured within. The chart – generated as a Fusion Table visualization type – displays the distribution of basin diameters as a function of longitude.



Many of you are familiar with the locale shown here . It is immediately east of the Delaware Memorial Bridge. Top center is the Jersey Turnpike's barrier toll. US 40 runs directly below. If one looks close, subtle ovoid shapes can be seen on the landscape. It is almost pool-table flat to the naked eye on the ground – or from the bridge. But using a DEM with 20 x elevation exaggeration, an interesting landscape is revealed. Let me direct your eye to the center of the image, just above the fluvial channel, where several closed depression exhibiting a raised rim are present.

Local Planform

- Shape differs from the classic oval - Triangular
- Closed circumpheral rim
- Shape seen MD to NJ



This ovoid is visible in historical imagery – here from 1997. I often find these to be more informative. And the LiDAR confirms it is a basin. Note that the raised rim is more of a Triangle than an oval. Our survey entry provides a placemark for each measured bay. Clicking on the placemark icon will bring up the survey's metrics. A link will recover the overlay used to map the bay.

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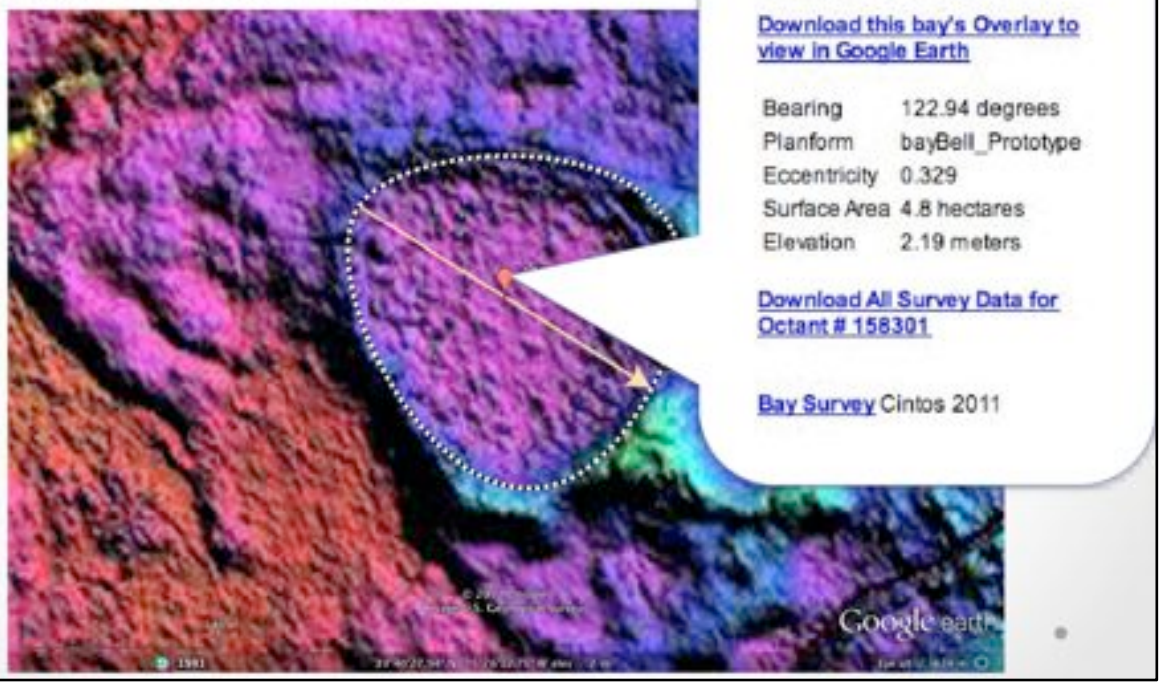

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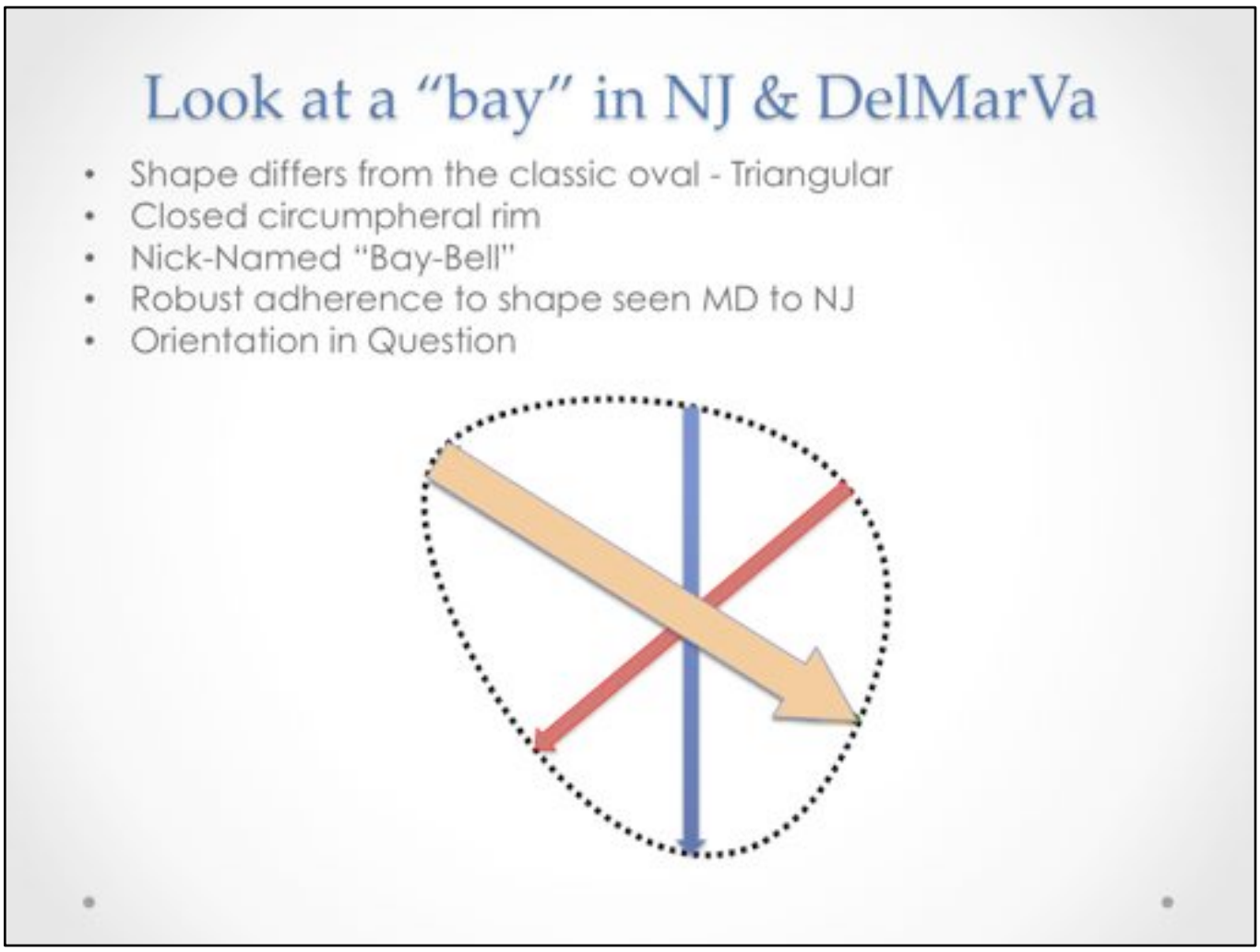
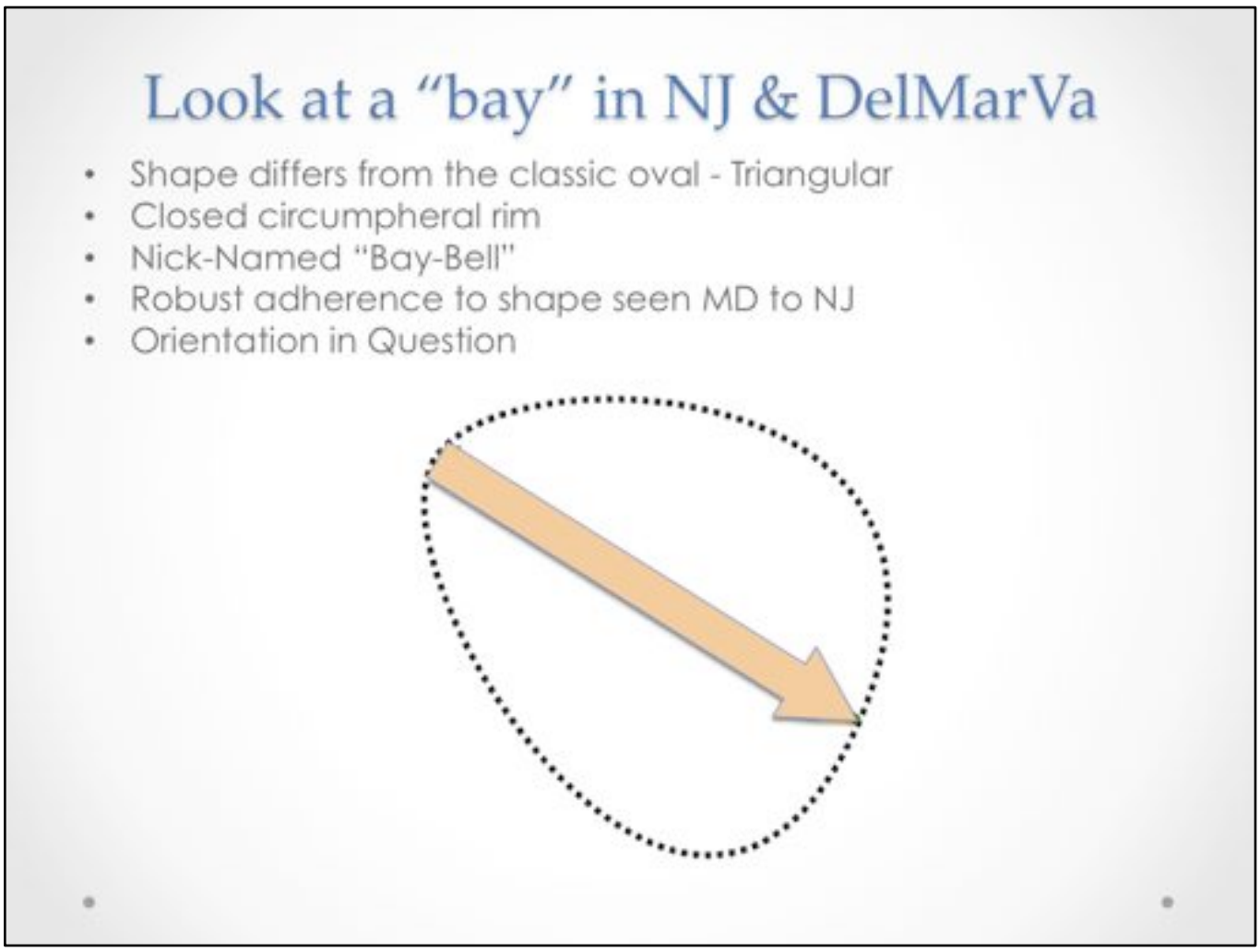


I have nick-named this shape "Bay-Bell", to differentiate it from the Archetype Bay Planform seen in the Carolinas. Let me foreshadow that we will be seeing many basins with this planform this afternoon. Our immediate challenge is how to deduce the orientation of such an object. Is the classic northwest-to-southeast alignment reasonable, or perhaps another? While the shape is robustly geometric, the orientation is questionable, supporting a chaotic or bi-modal orientation which has been reported by others. This afternoon, I will be attempting to justify applying this classic Carolina bay alignment.



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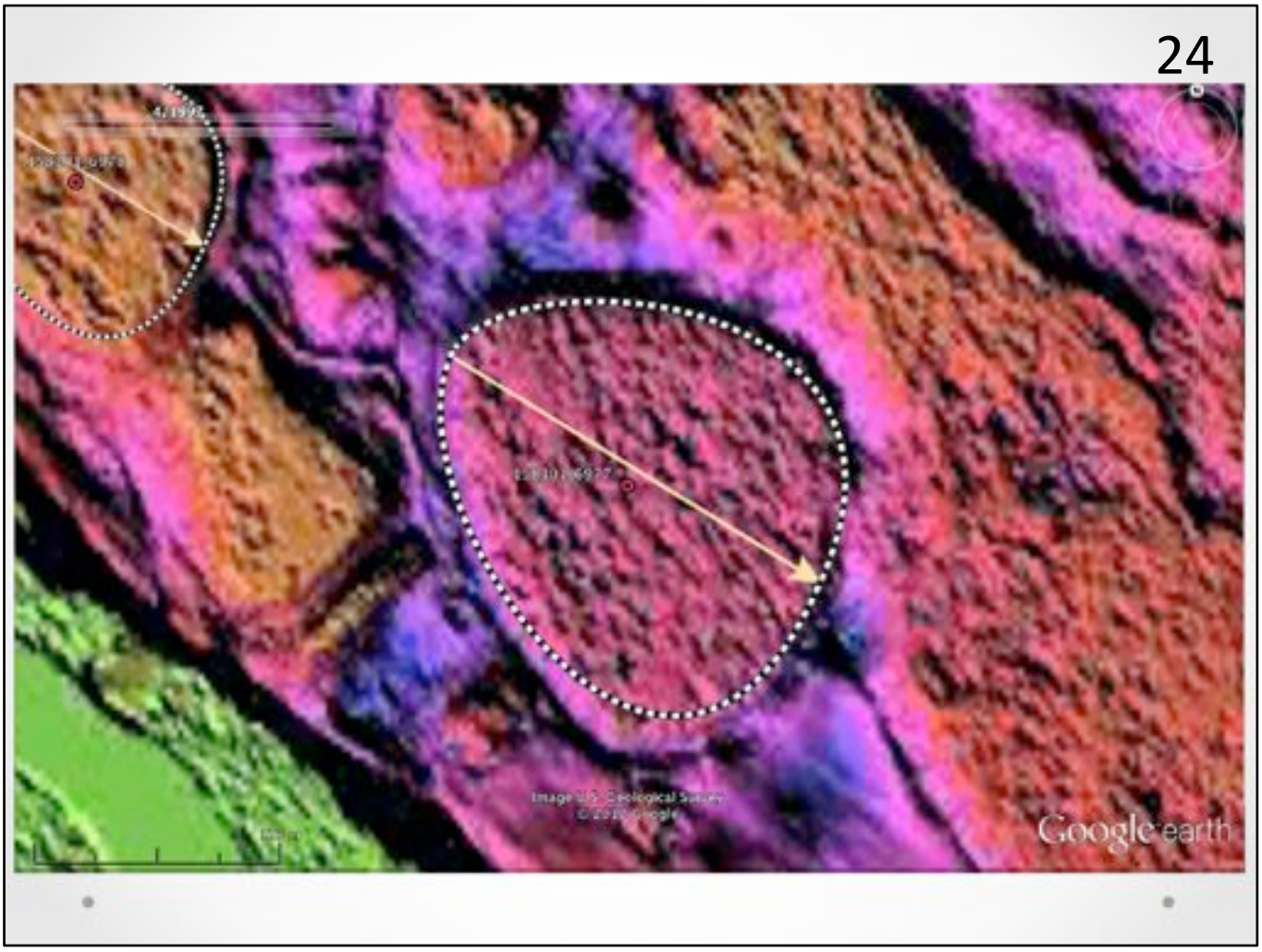
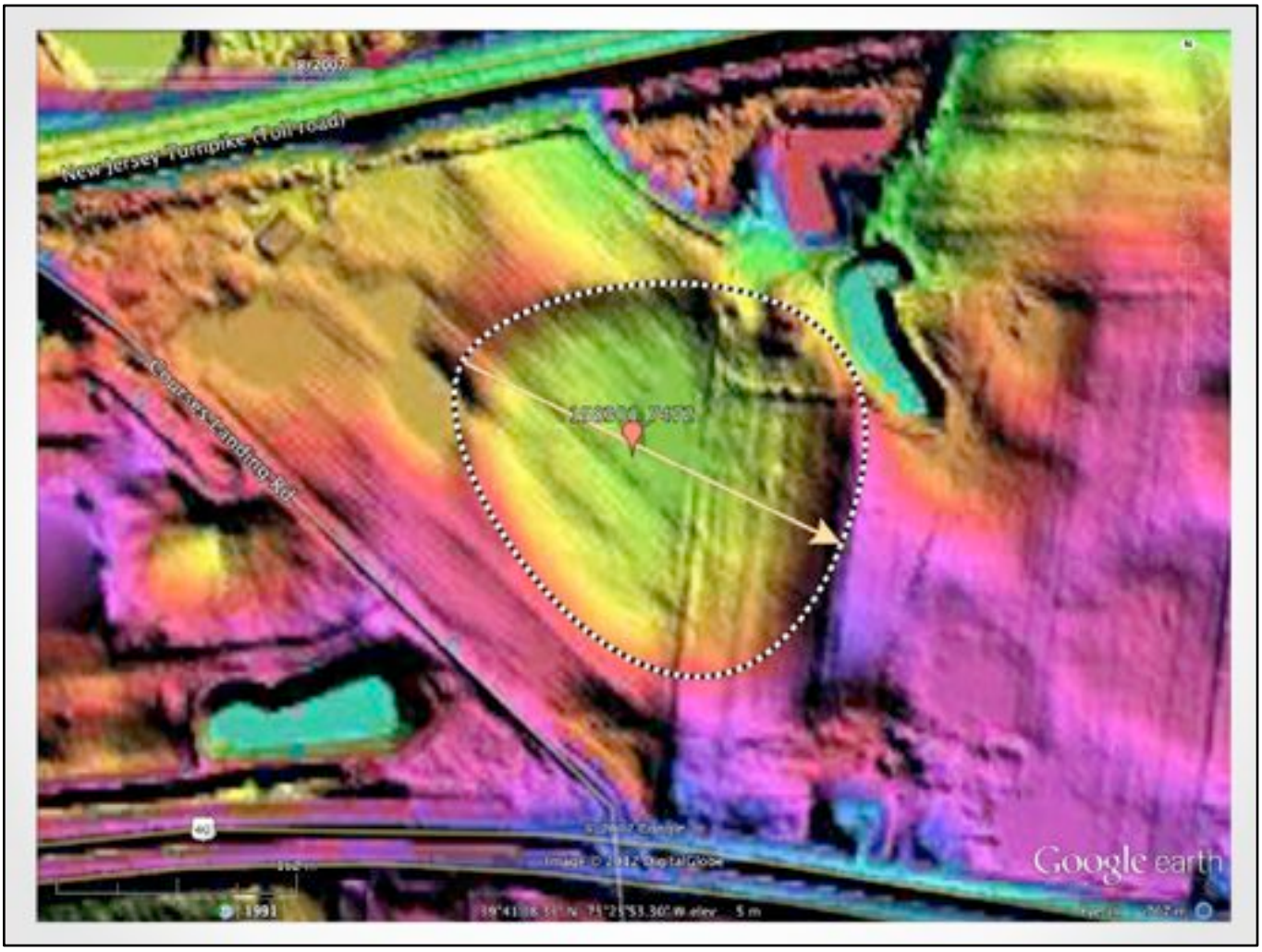
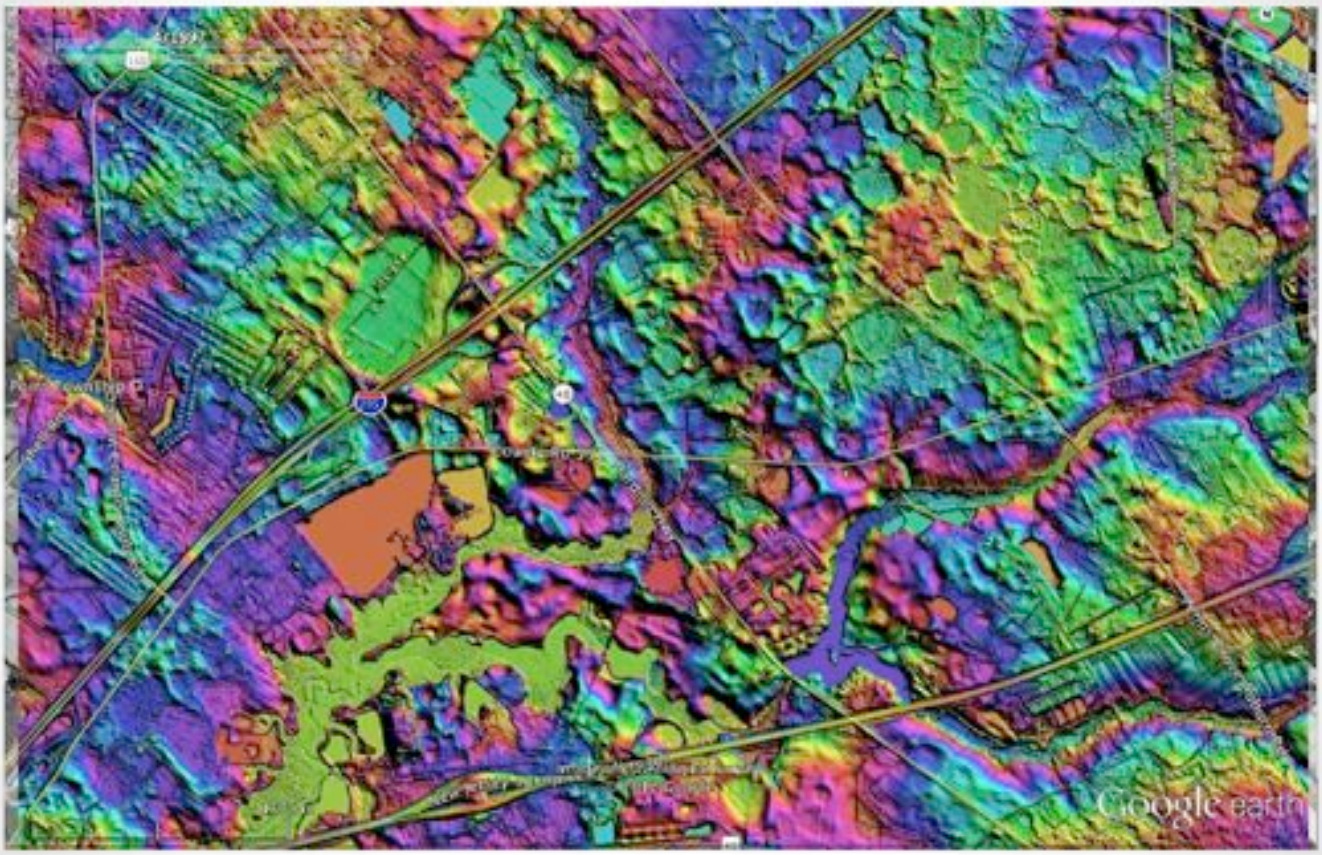


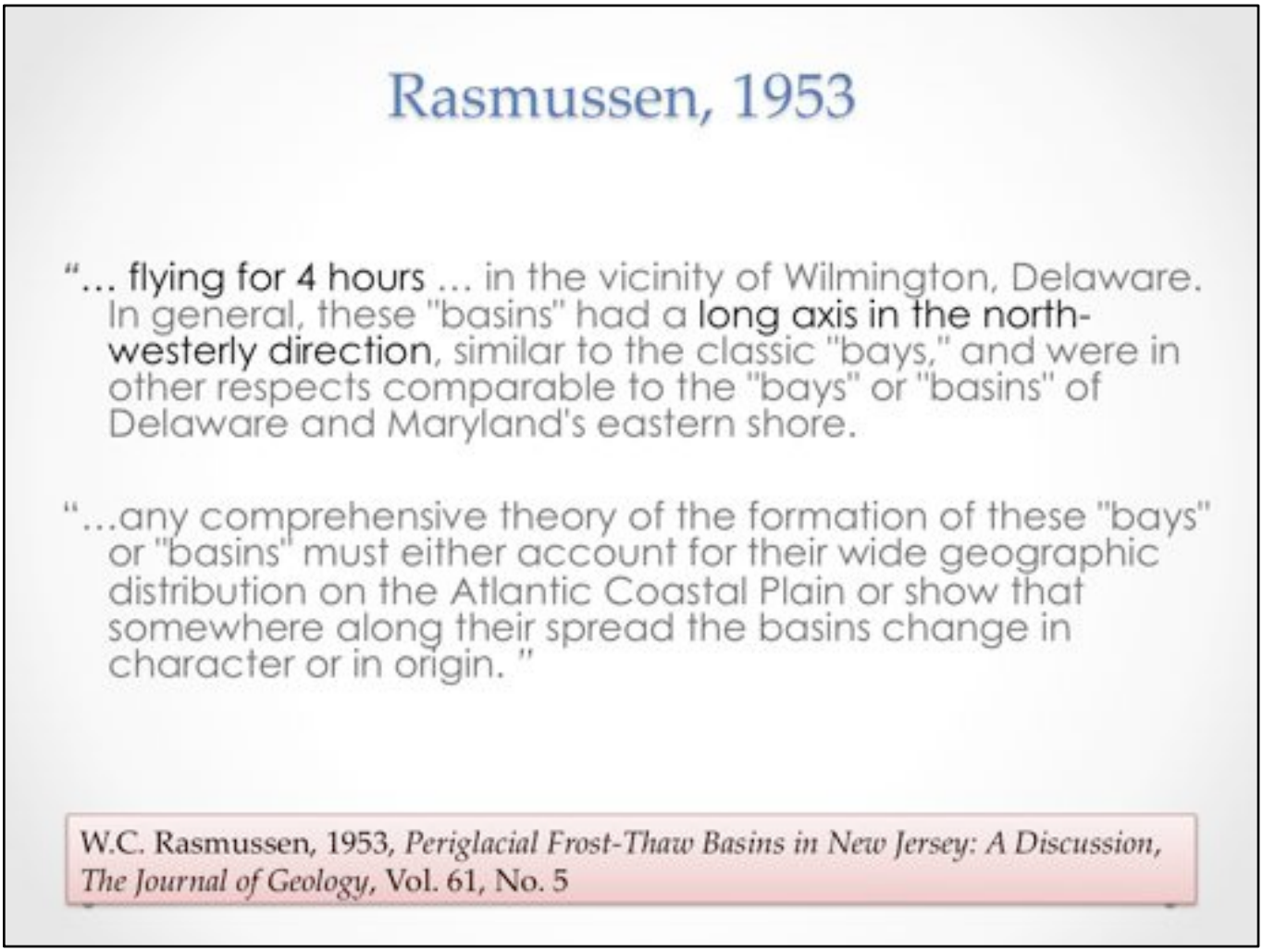
Here is another depression a few meters away.



In the narrow band between the Turnpike and US 40, we see this watermark on the landscape. In Lidar we note it is a well-developed depression. This landscape has seen some human modifications, and our measurement is subjective



How about all the other 3,700 bays in the region? Well if we zoom out we will see numerous basins to the north of the one just viewed, bottom center.



These are likely the same landforms seen by William Rasmussen from the air back in the early '50s. On the question "Are these Carolina bays", he provides a positive opinion. He goes on to challenge us to either find a universal mechanism for their creation, or show how they are in fact different in origin despite their common characteristics.


1991
Google earth

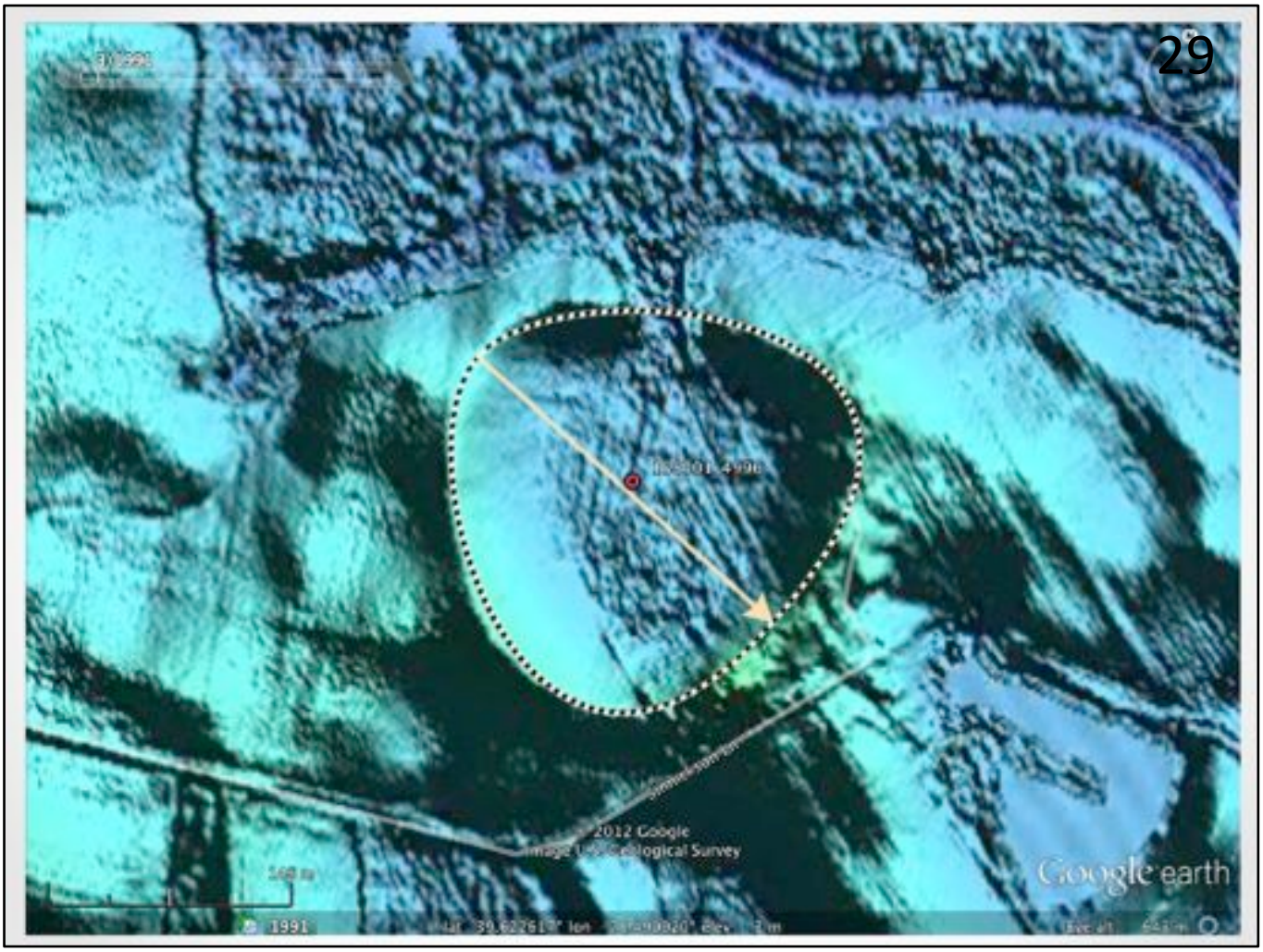

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Image U.S. Geological Survey
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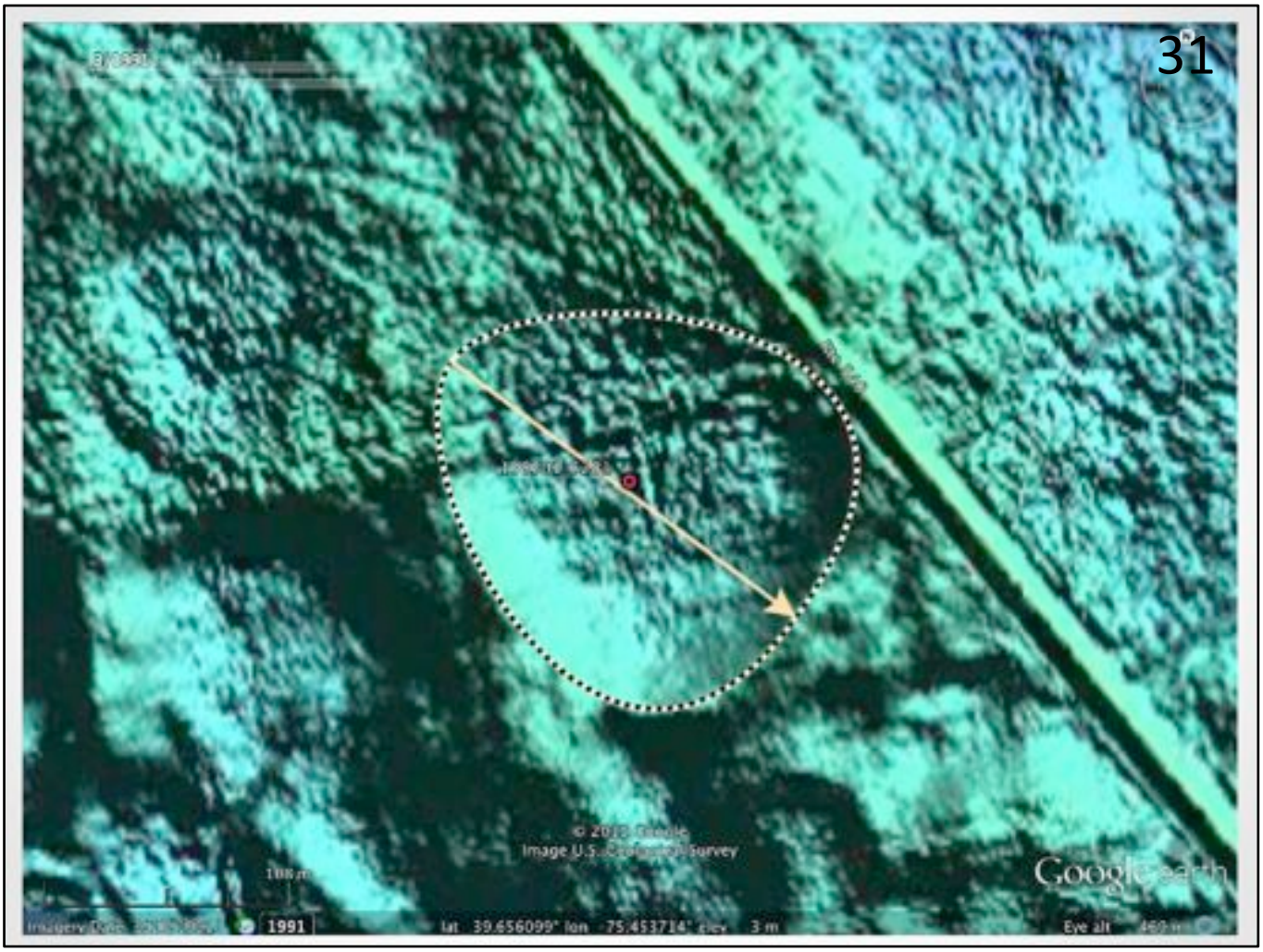
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Image U.S. Geological Survey
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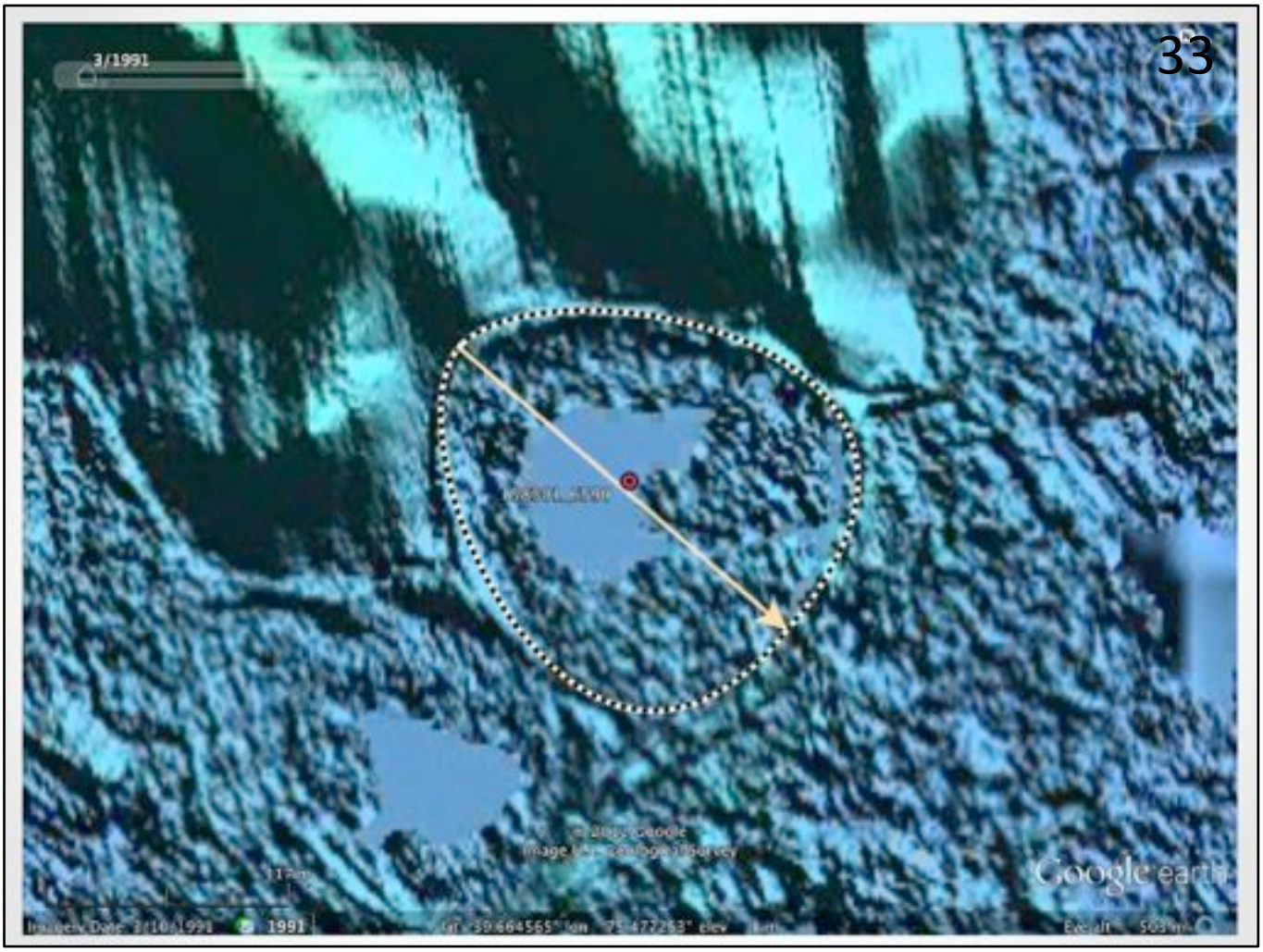
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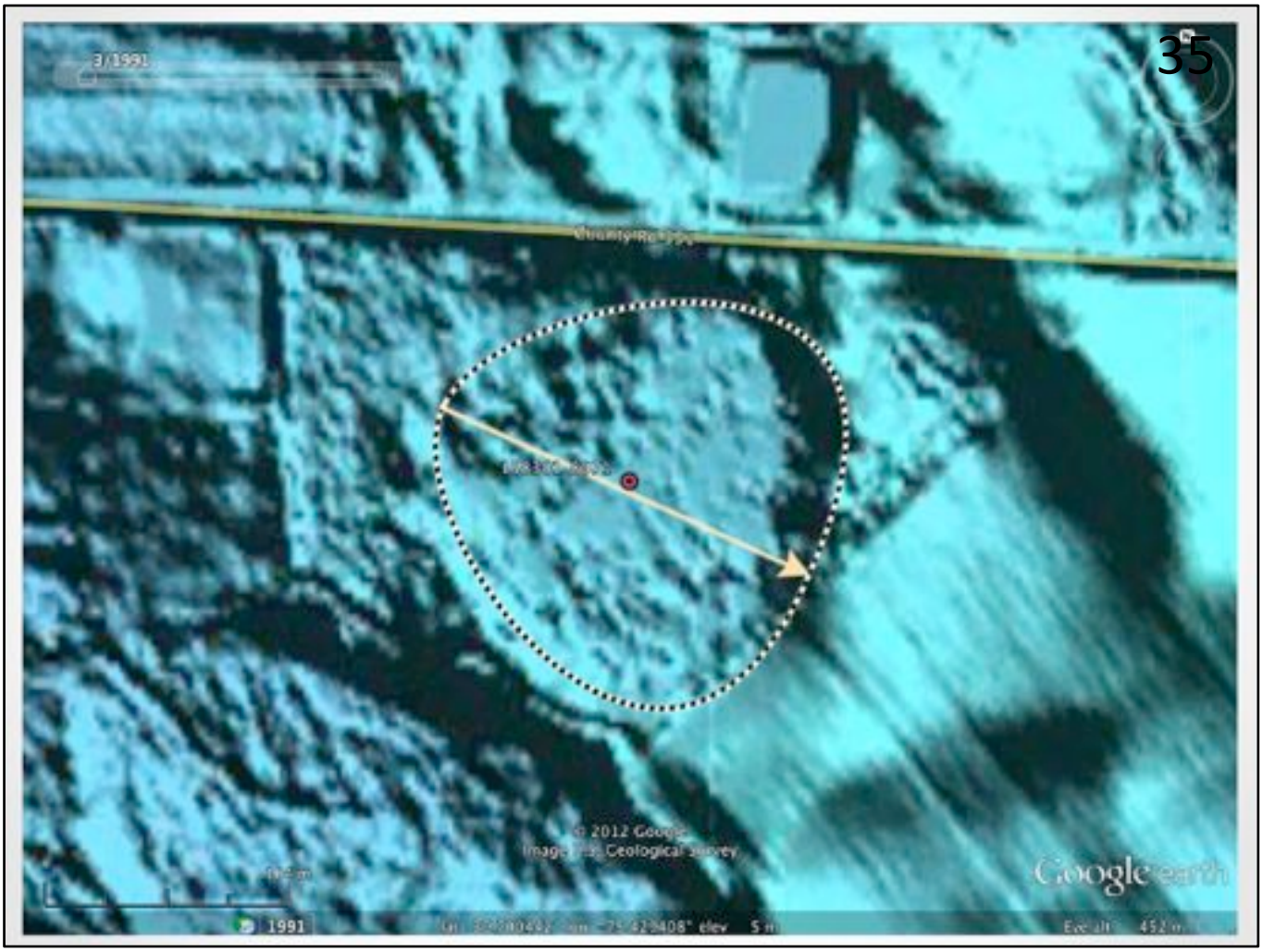
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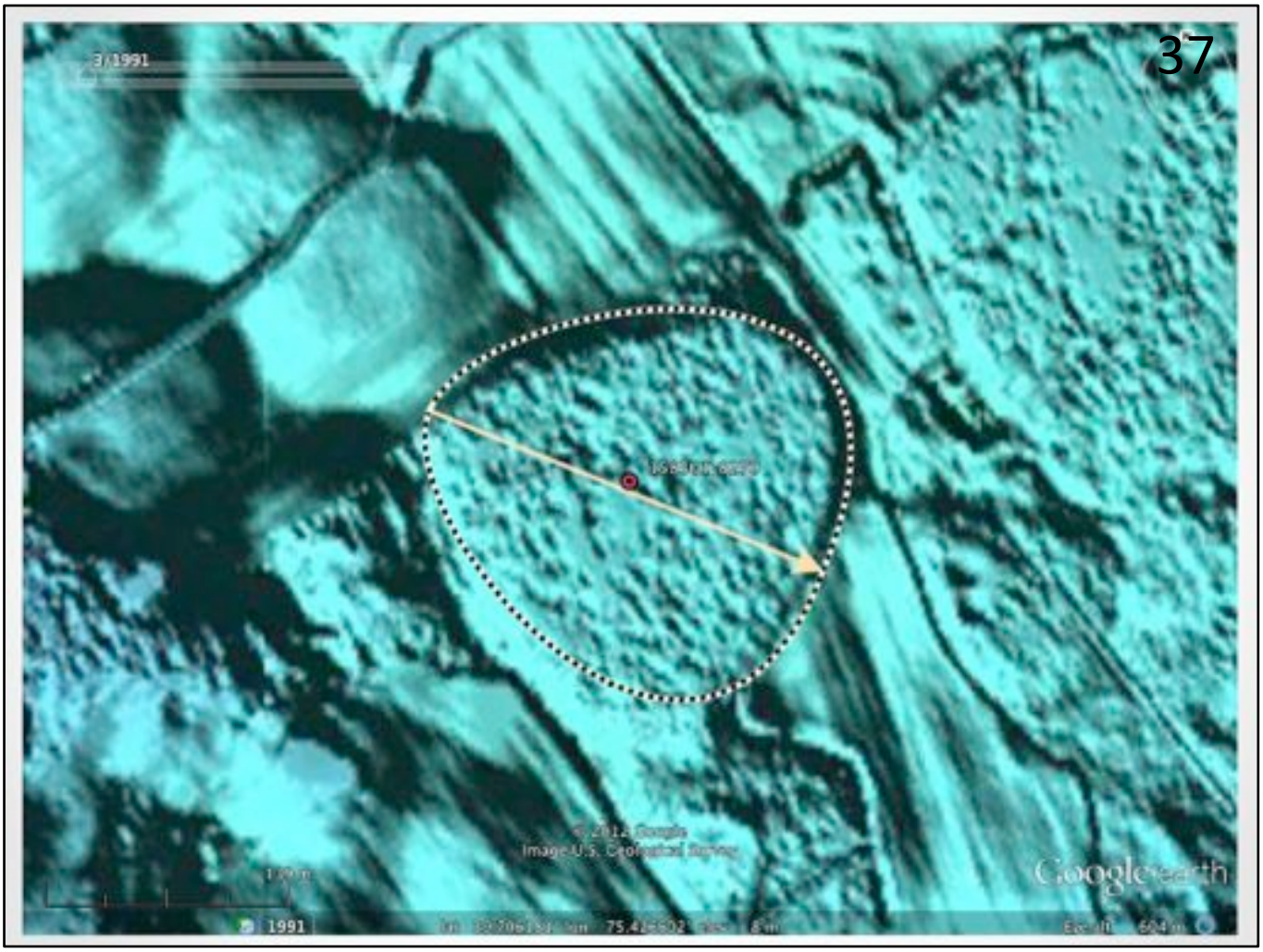
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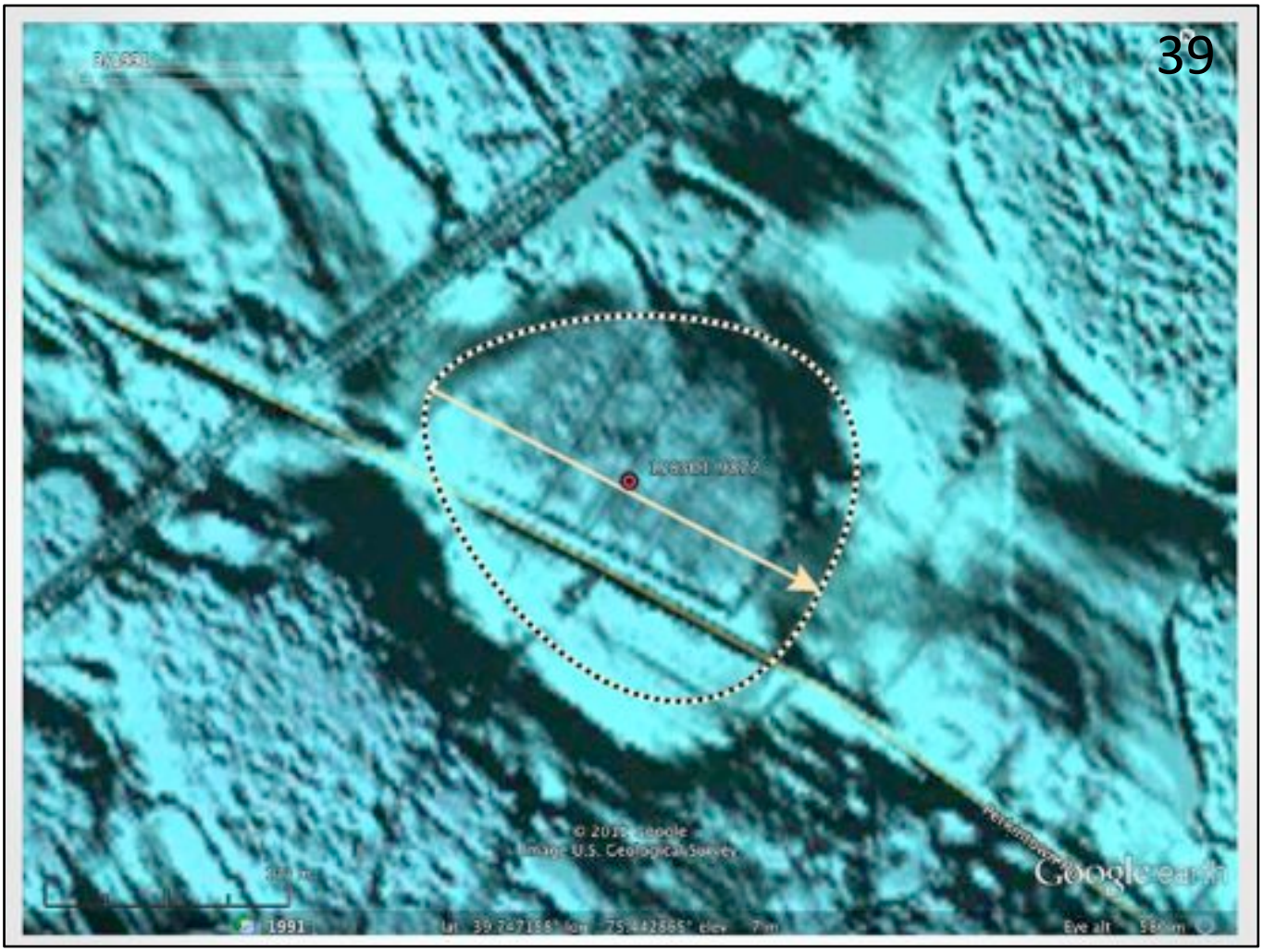
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Image U.S. Geological Survey
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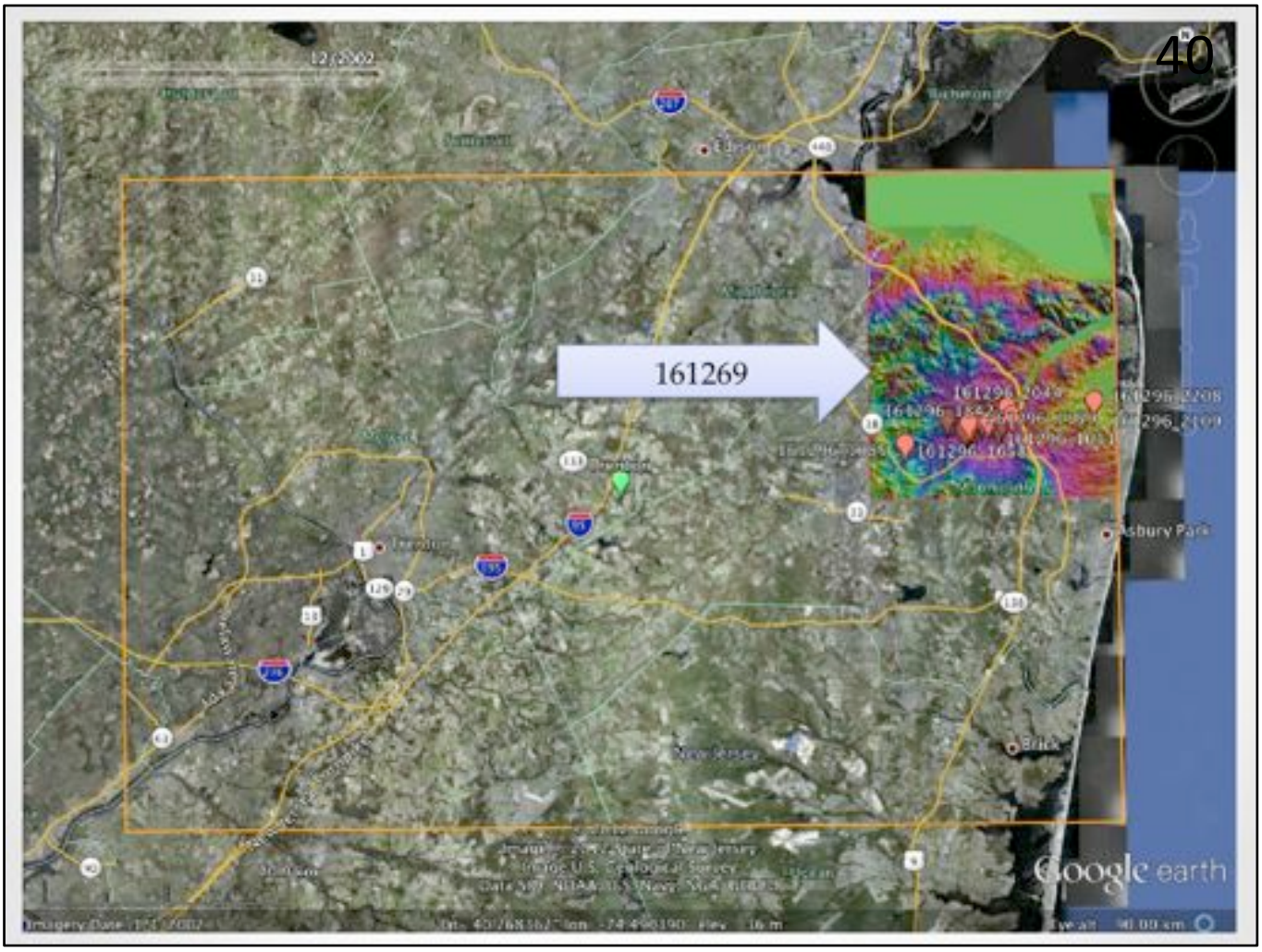


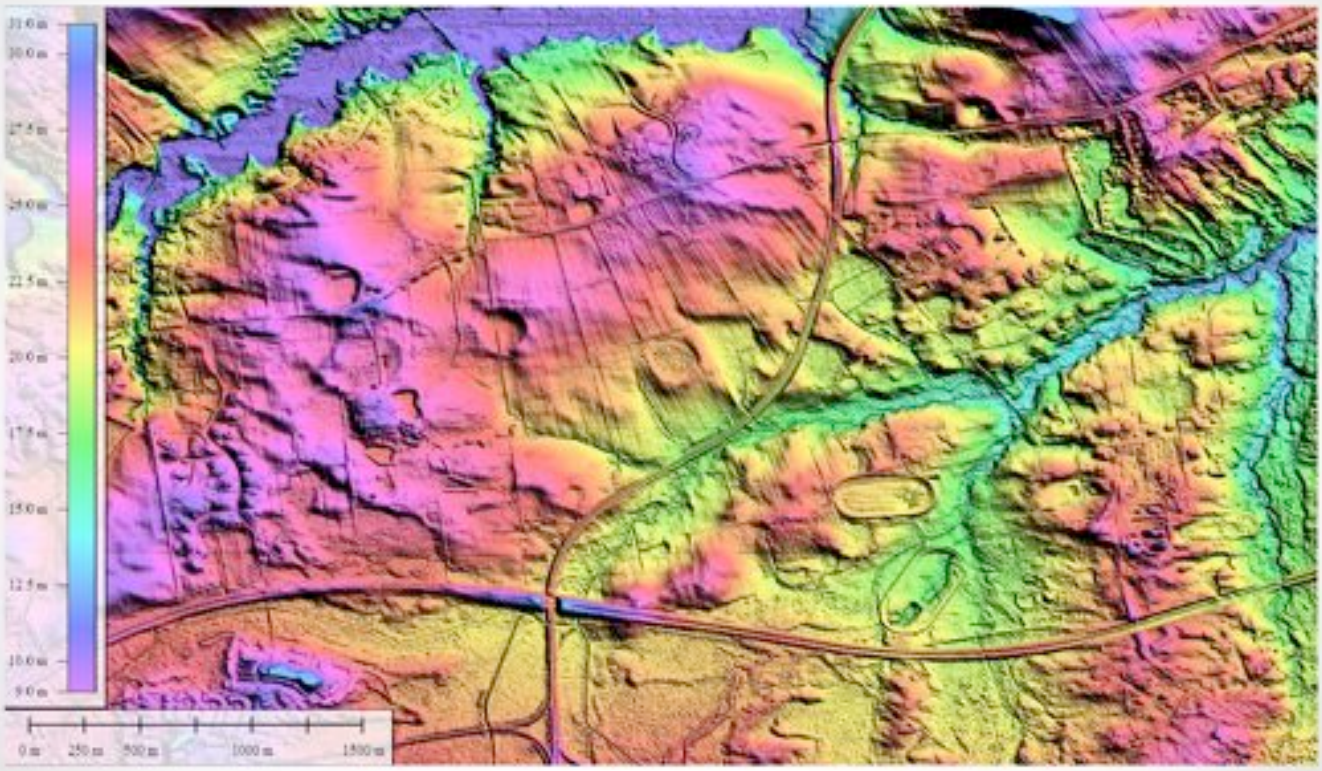
Now lets move closer to Hartford – Monmouth County, NJ. Octant 161269

Octant 161296

- Trenton, NJ 100k Quad
- Monmouth County / Eatontown
- "bay bell" Planform
- 31 bays identified/measured
- Mean Bearing 119°
- Std dev 6.7°

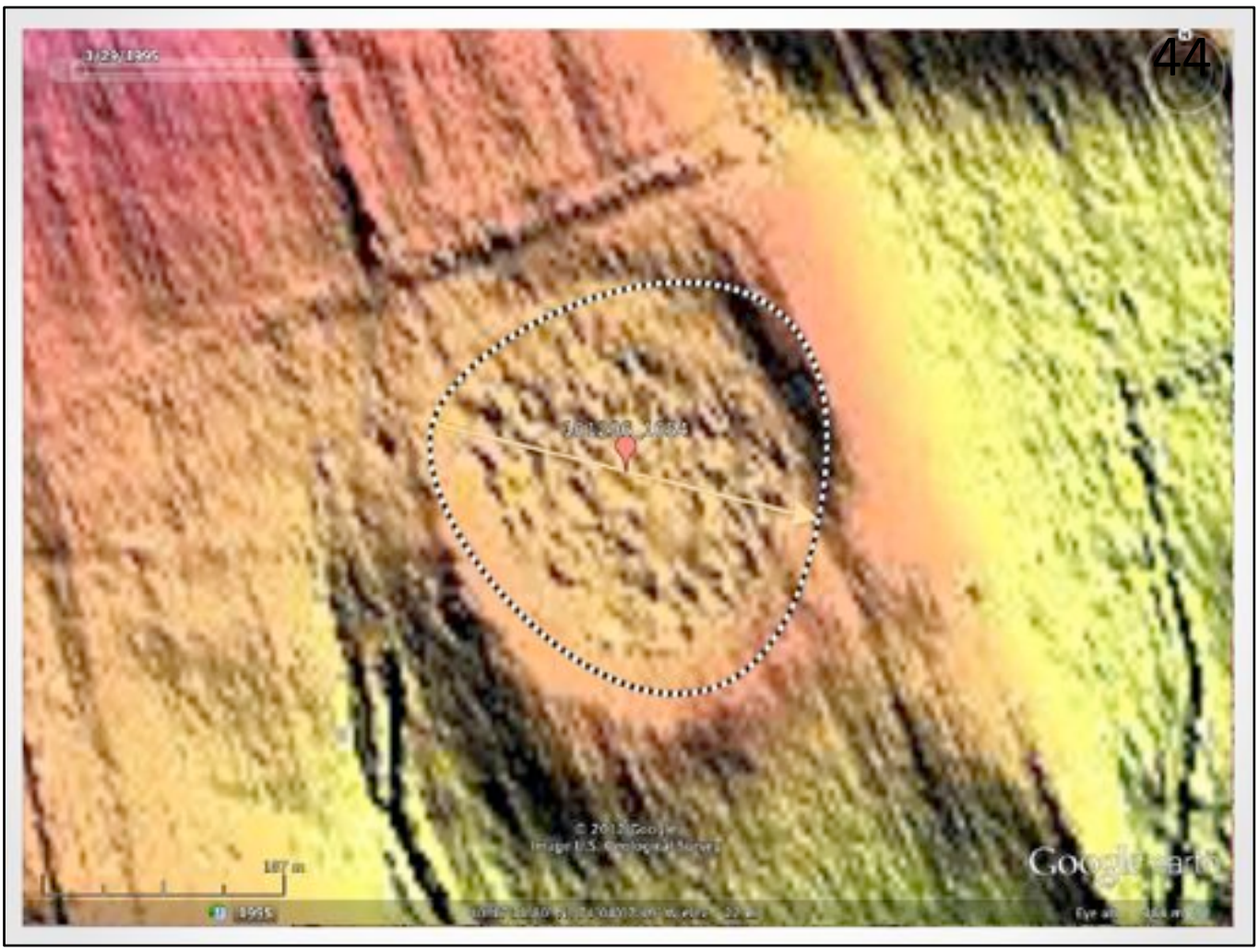
Now lets move closer to Hartford – Monmouth County, NJ. Octant 161269

Octant 161296



This is an annotated DEM created within the Global Mapper GIS program. Running north-south is the rail corridor between Weapons Station Earl and the docks on Raritan Bay. Note the numerous “bayBell” shaped depressions seen at different elevations. As seen in the Carolinas, elevation seems to have no control on basin morphology. Lets have a closer look.

Moving into southern Monmouth county, we are looking at a basin rendered using recently-distributed USGS LiDAR point cloud data, from which I extracted the bare earth component.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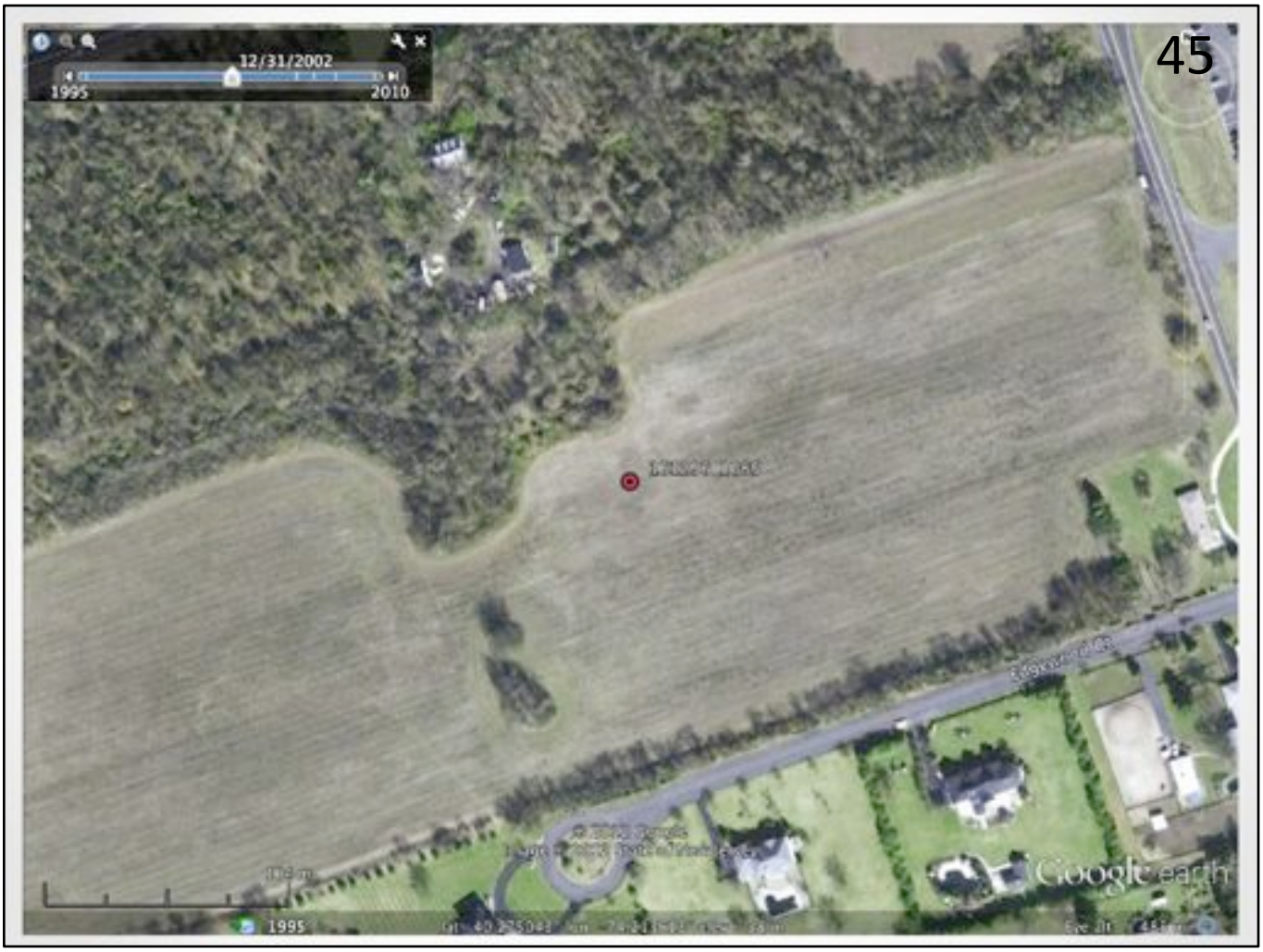
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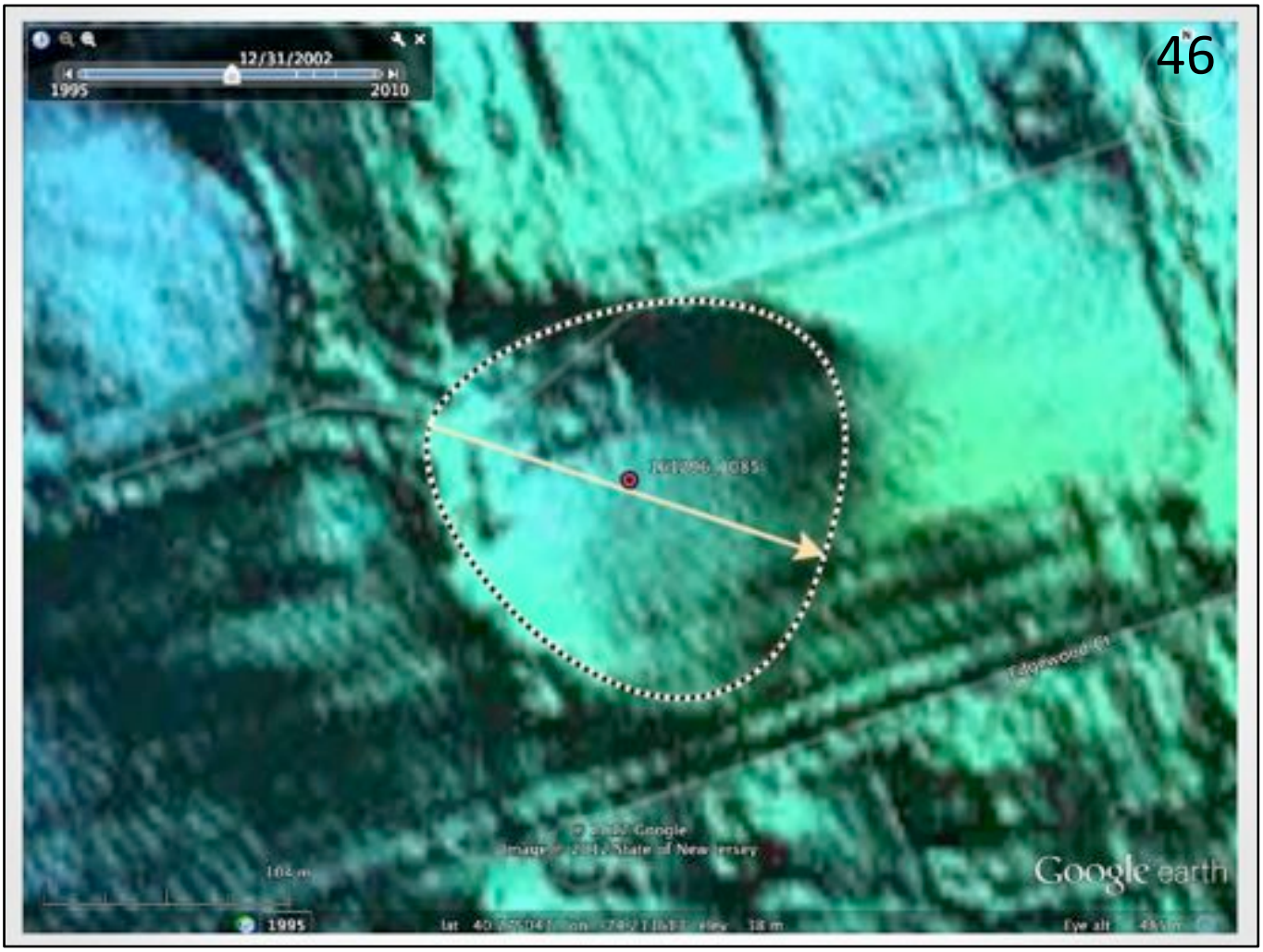
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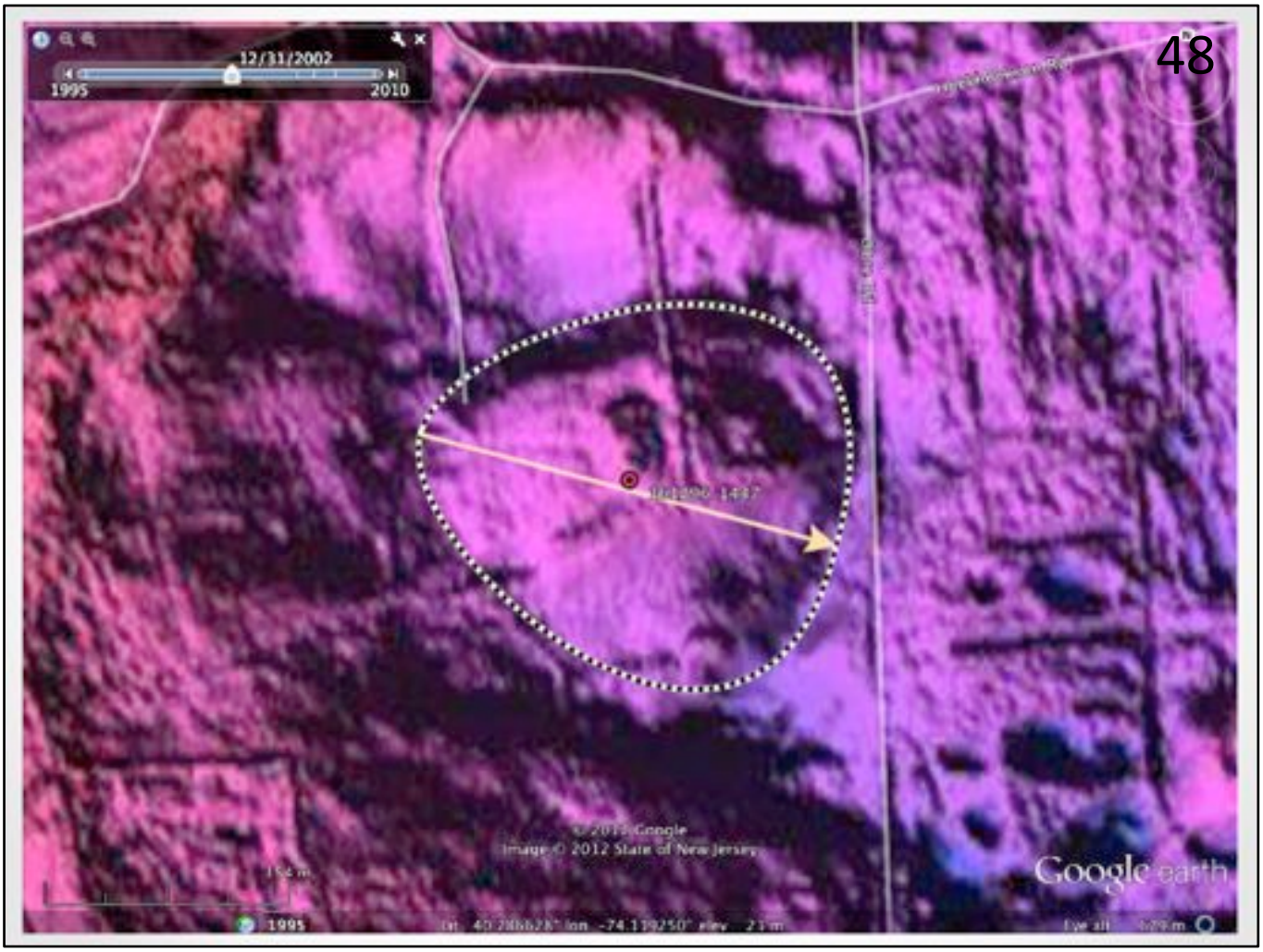
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Image © 2012 State of New Jersey
Google earth
1995

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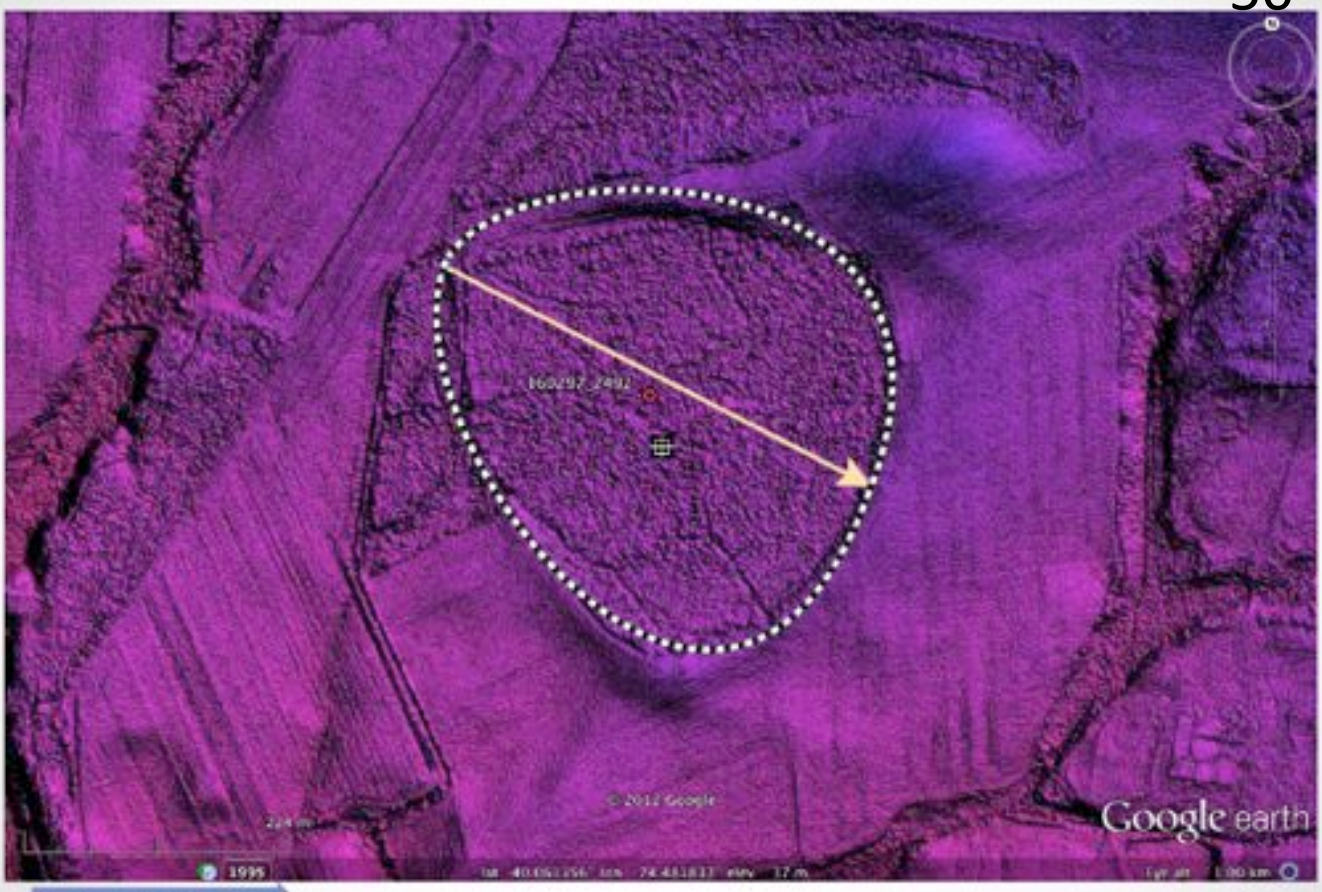
© 2012 Google
Google earth
1935
224 m


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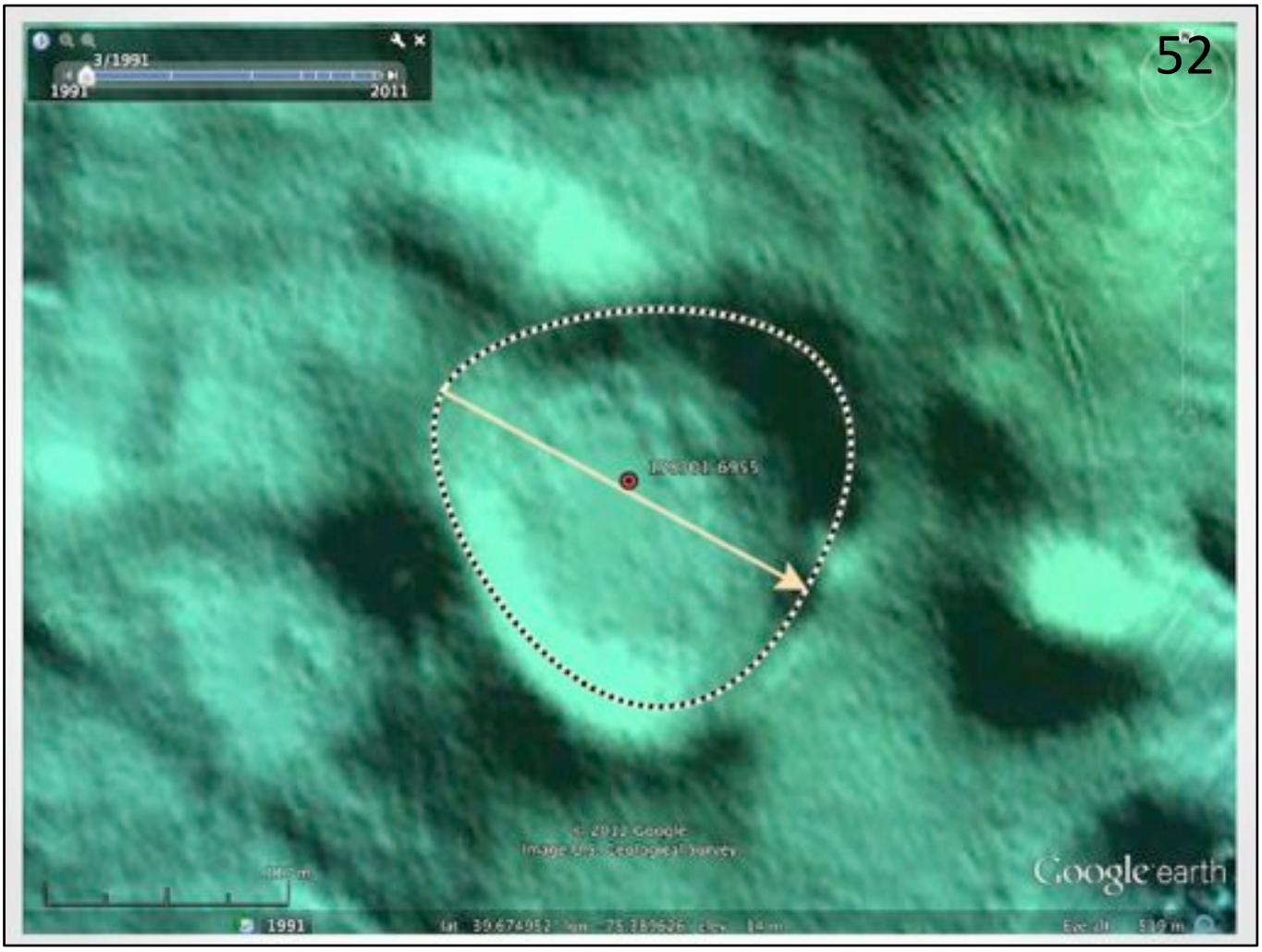

Moving into southern Monmouth county, we are looking at a basin rendered using recently-distributed USGS LiDAR point cloud data, from which I extracted the bare earth component.

This is near Beach Haven, NJ, on the Atlantic , and the higher resolution allows these 100 meter structures to be visualized.

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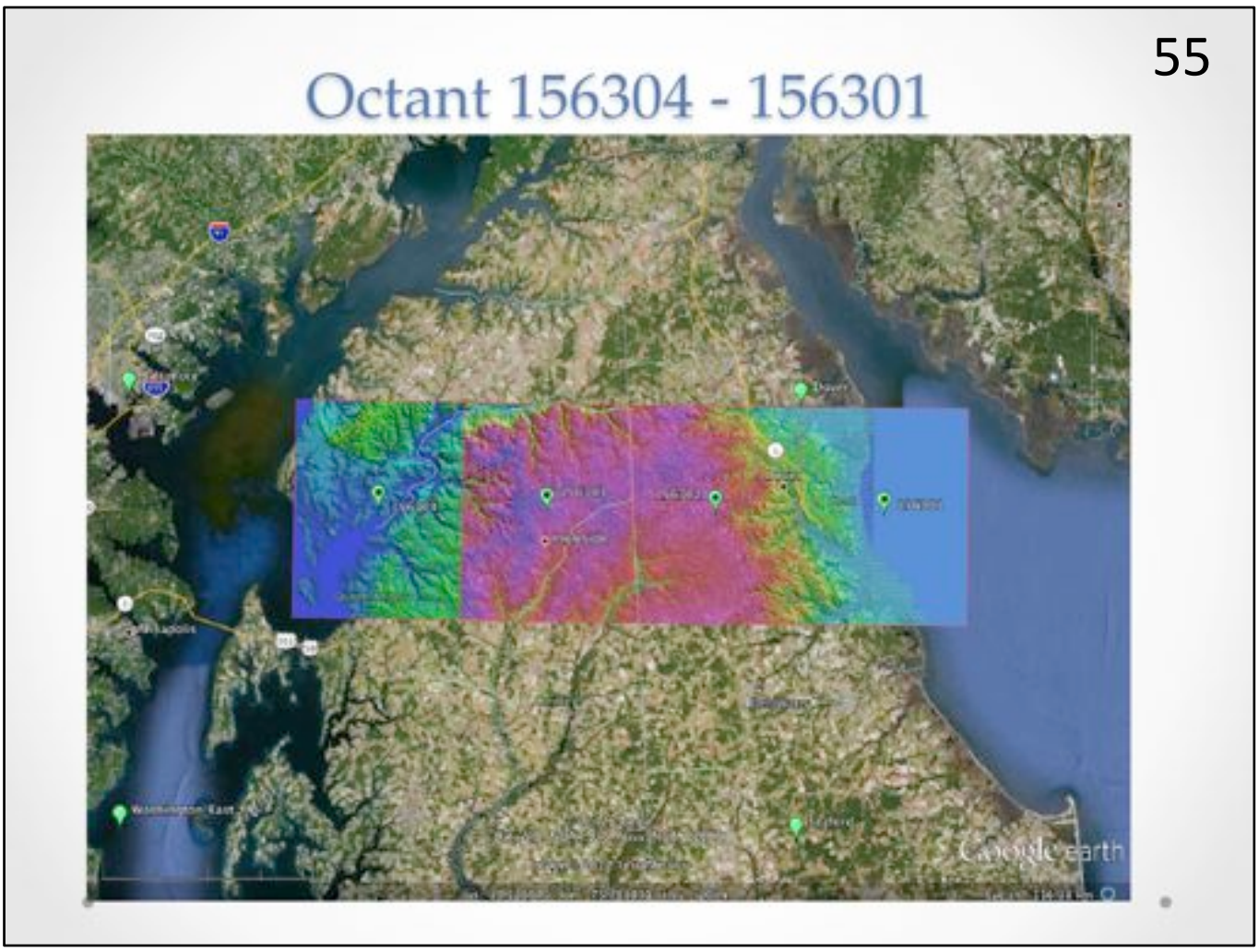
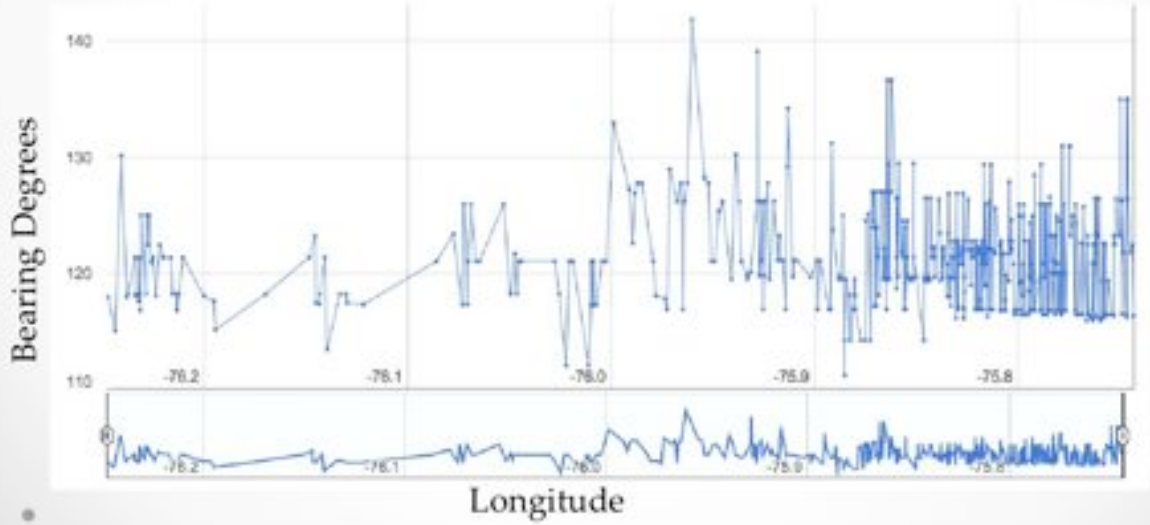


Now lets move south into a stripe of 4 Octants across upper DelMarva

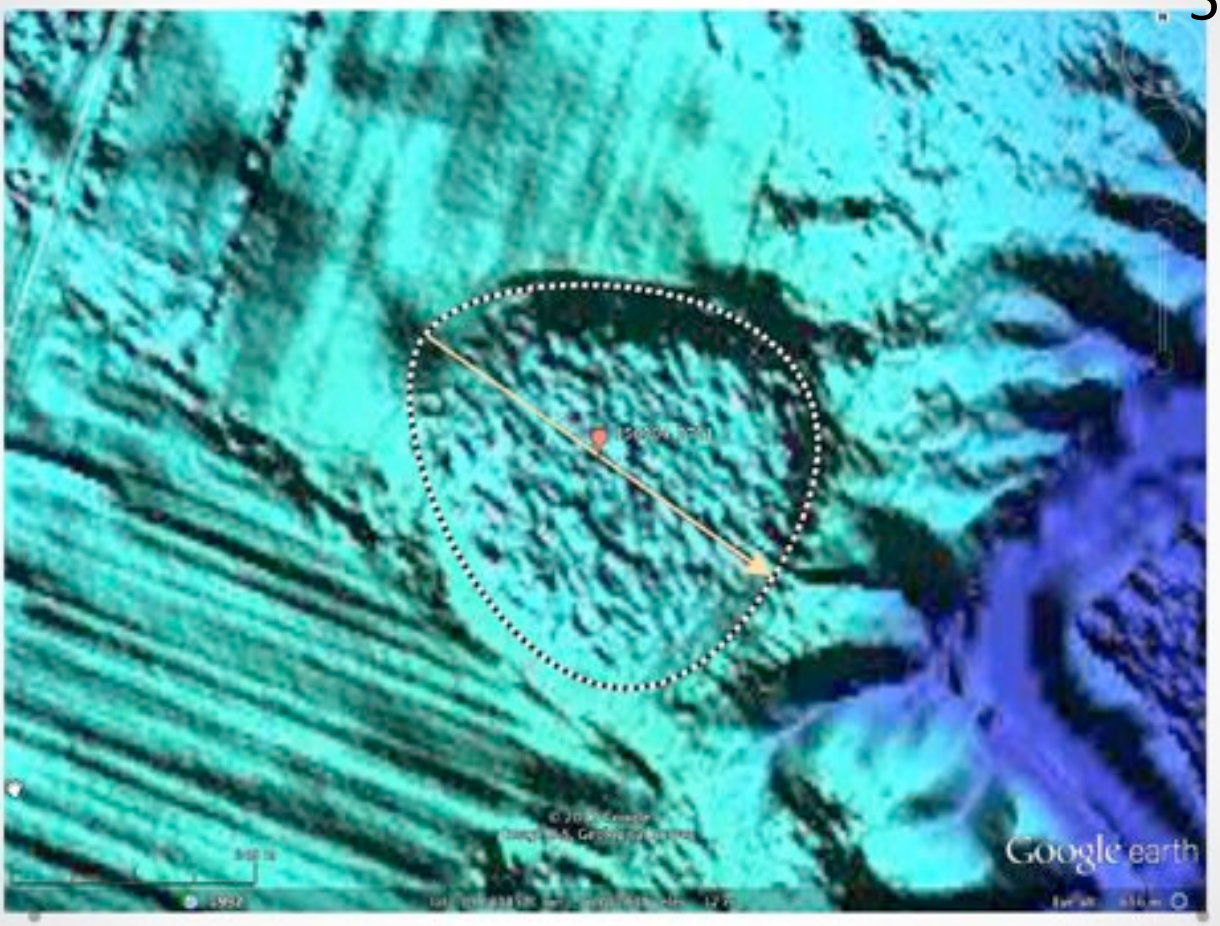
Octants 156304 - 156301

- Baltimore & Dover 100k Quad
- Across Central Maryland and Delaware
- "Bay Bell" Planform
- 1153 bays identified/measured



These four Octants host over 11 hundred bay-bell shaped basins. The graph displays bearing as a function of longitude. This is another Fusion tool for visualization of data in the table.

Basins on DelMarVa Peninsula



Basins on DelMarVa Peninsula

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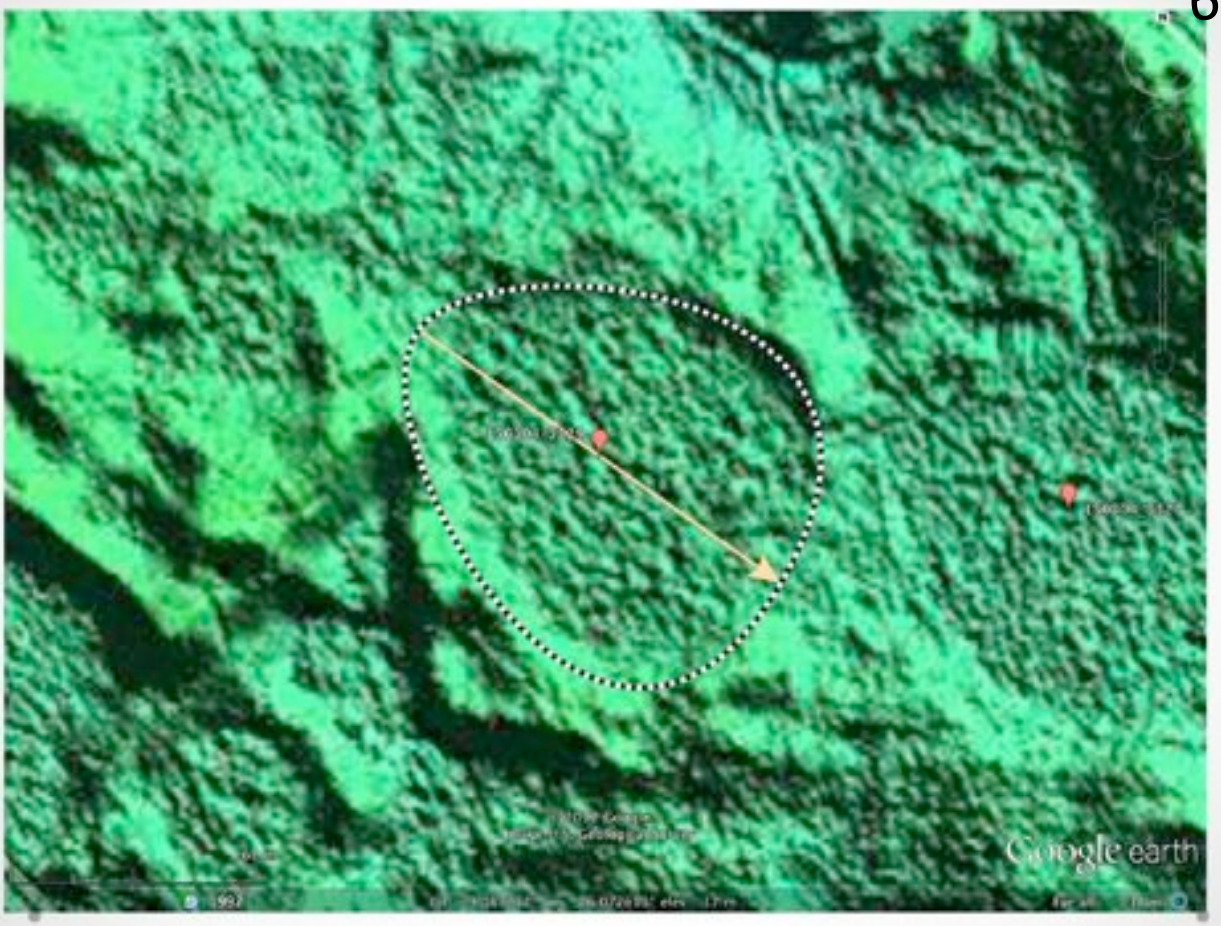

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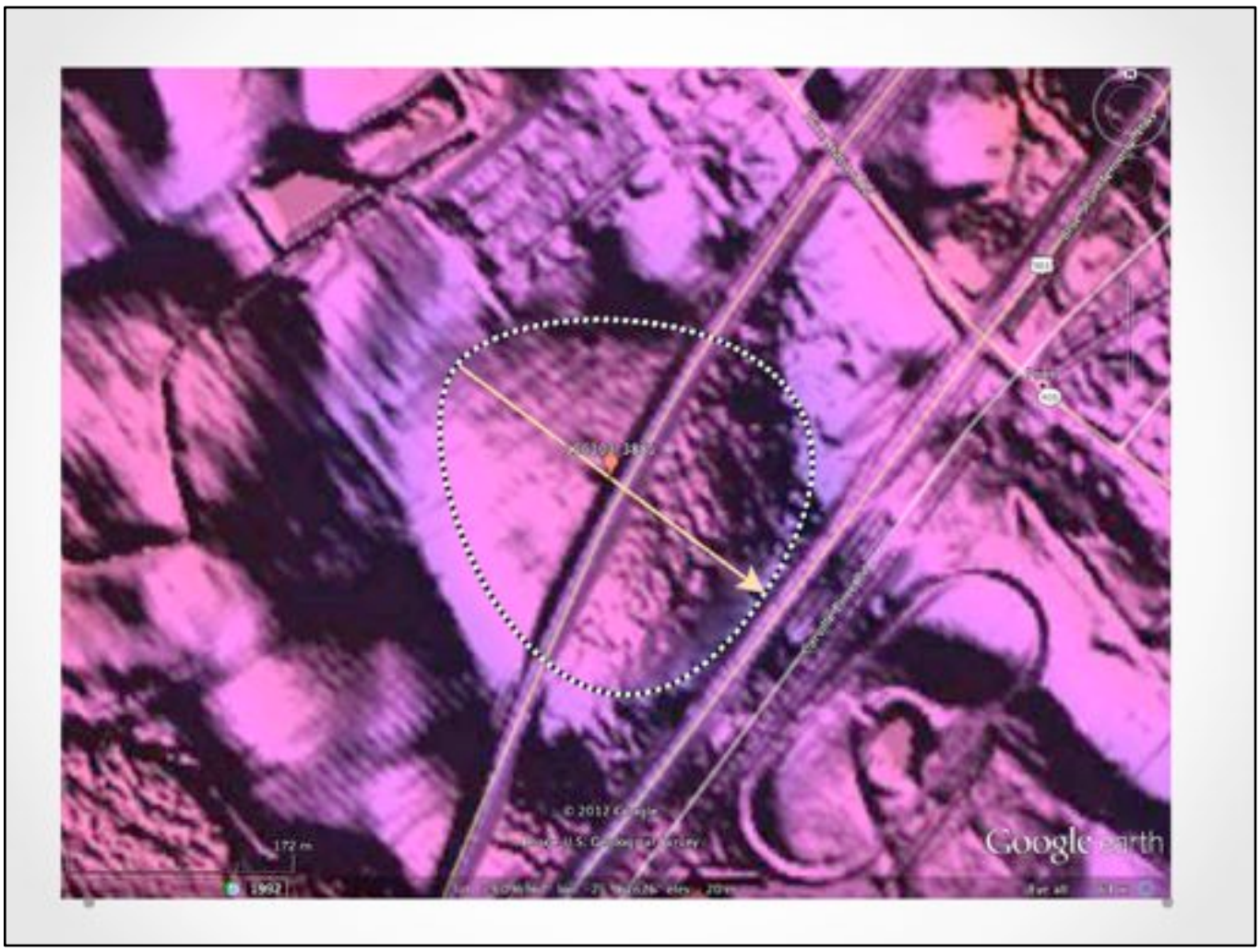

Basins on DelMarVa Peninsula

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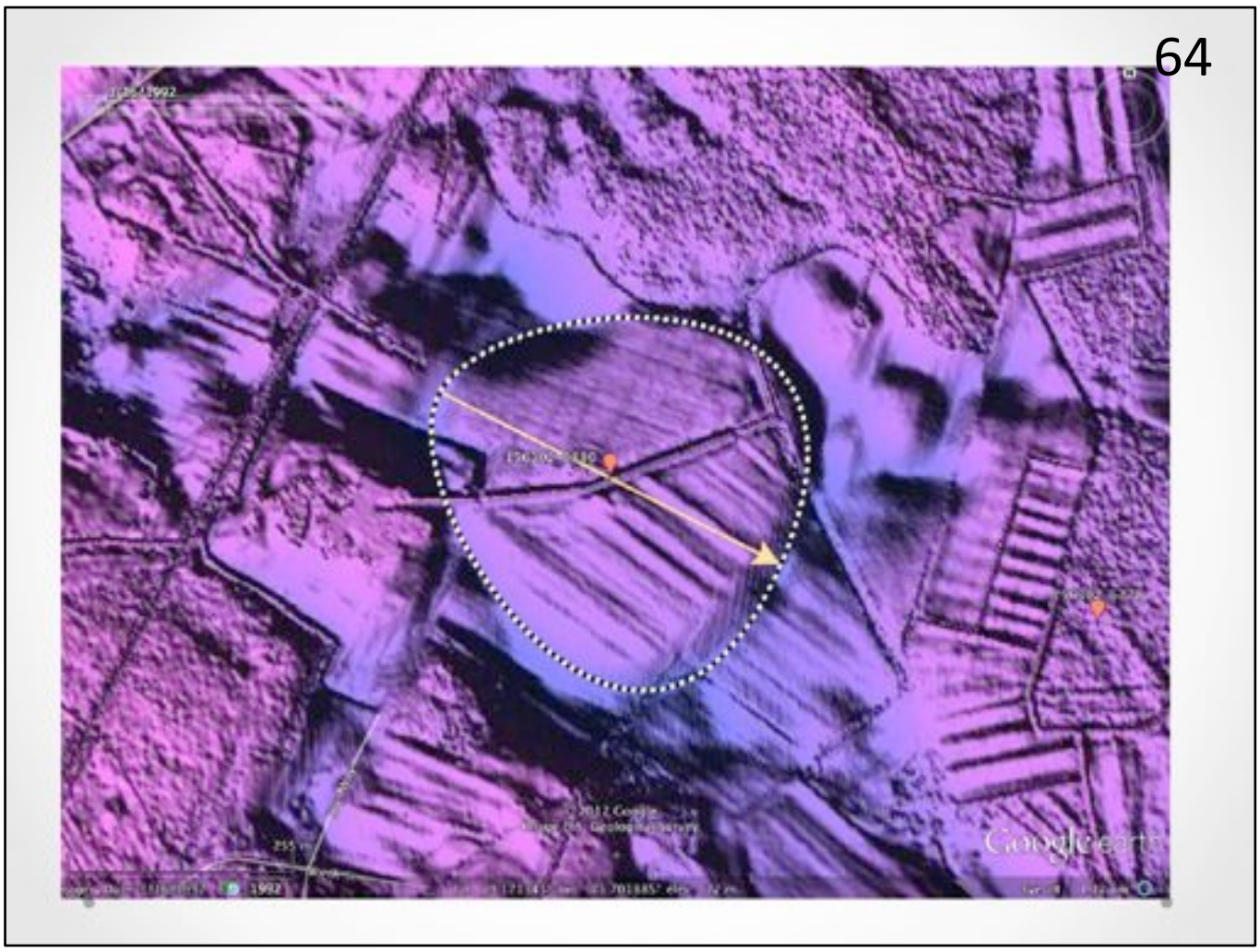

Basins on DelMarVa Peninsula

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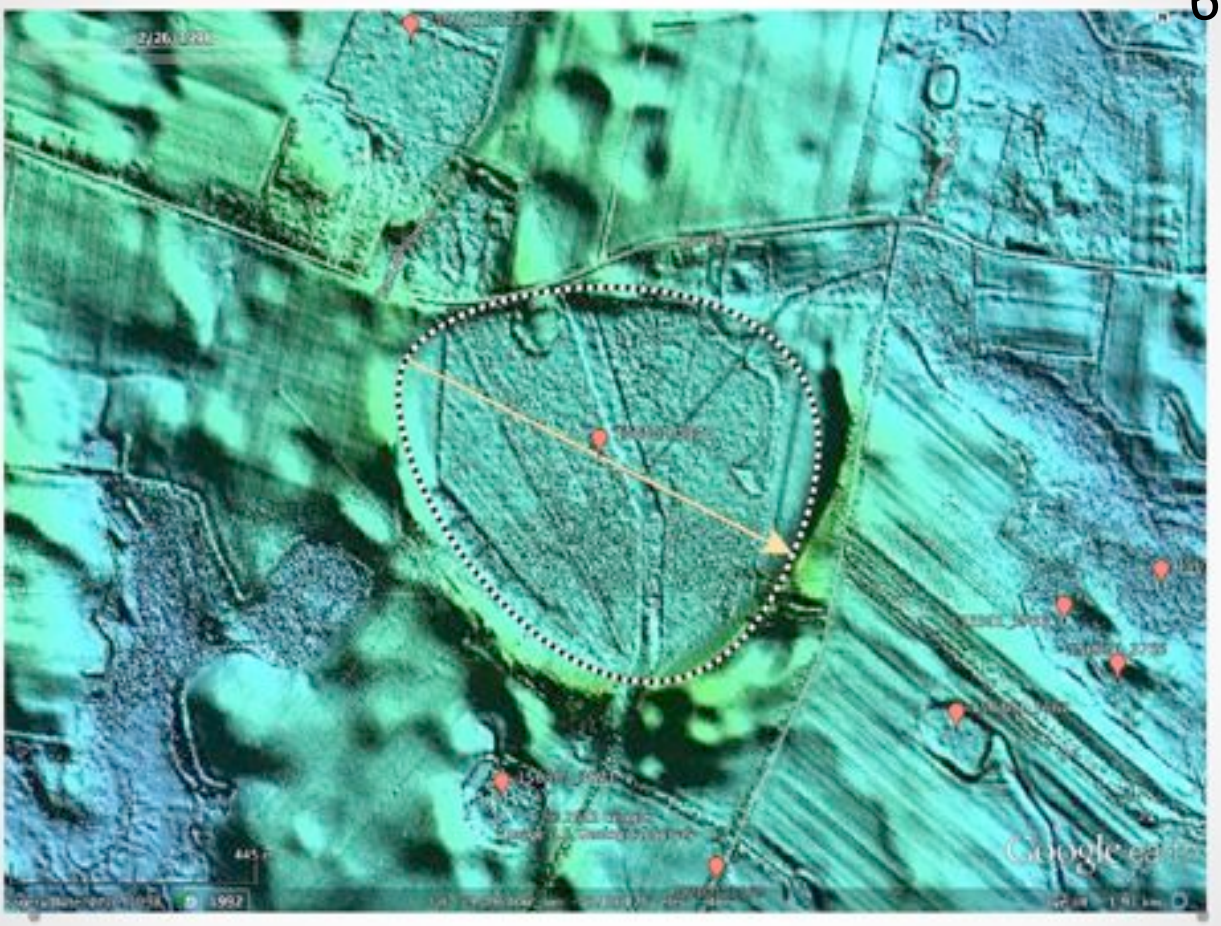
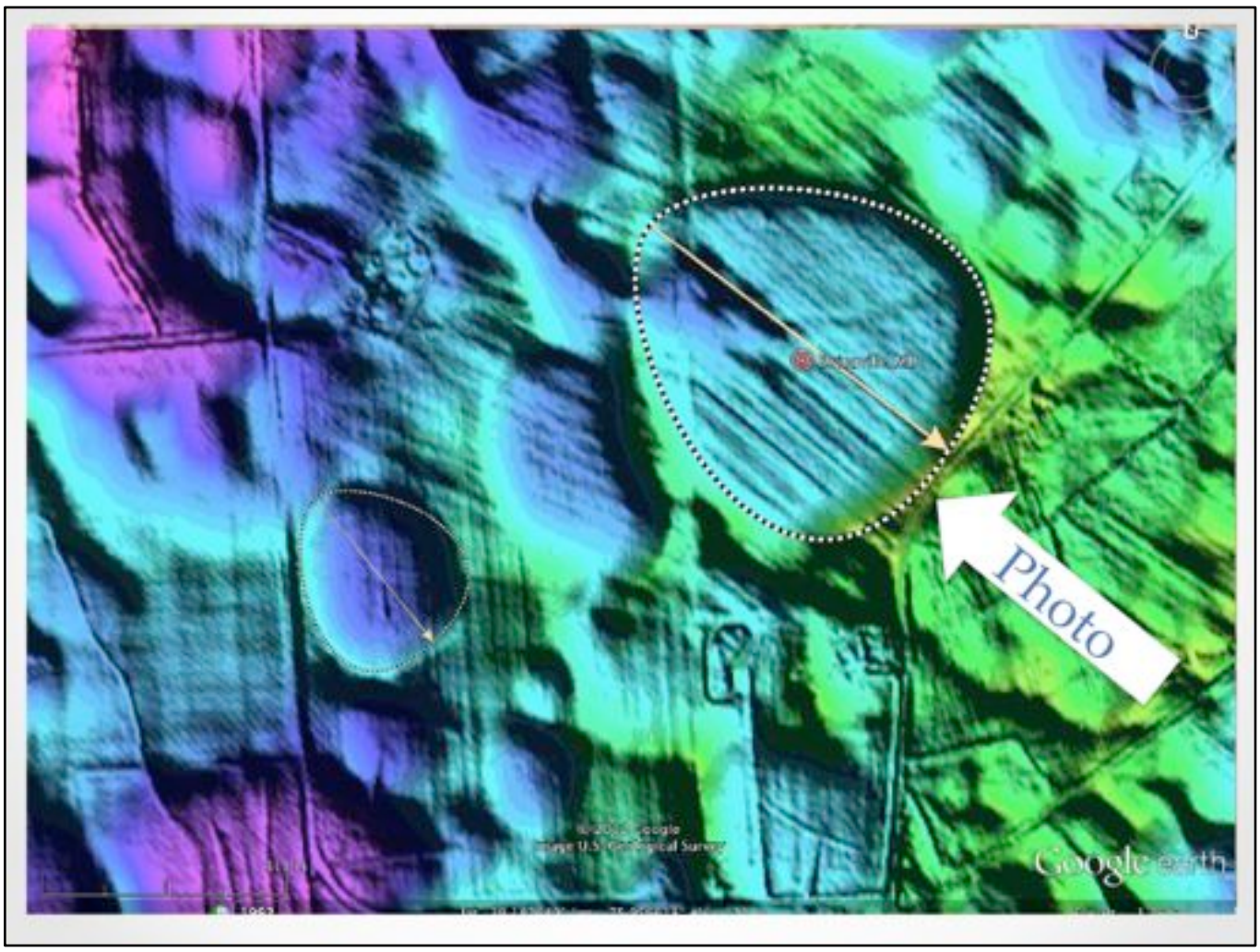


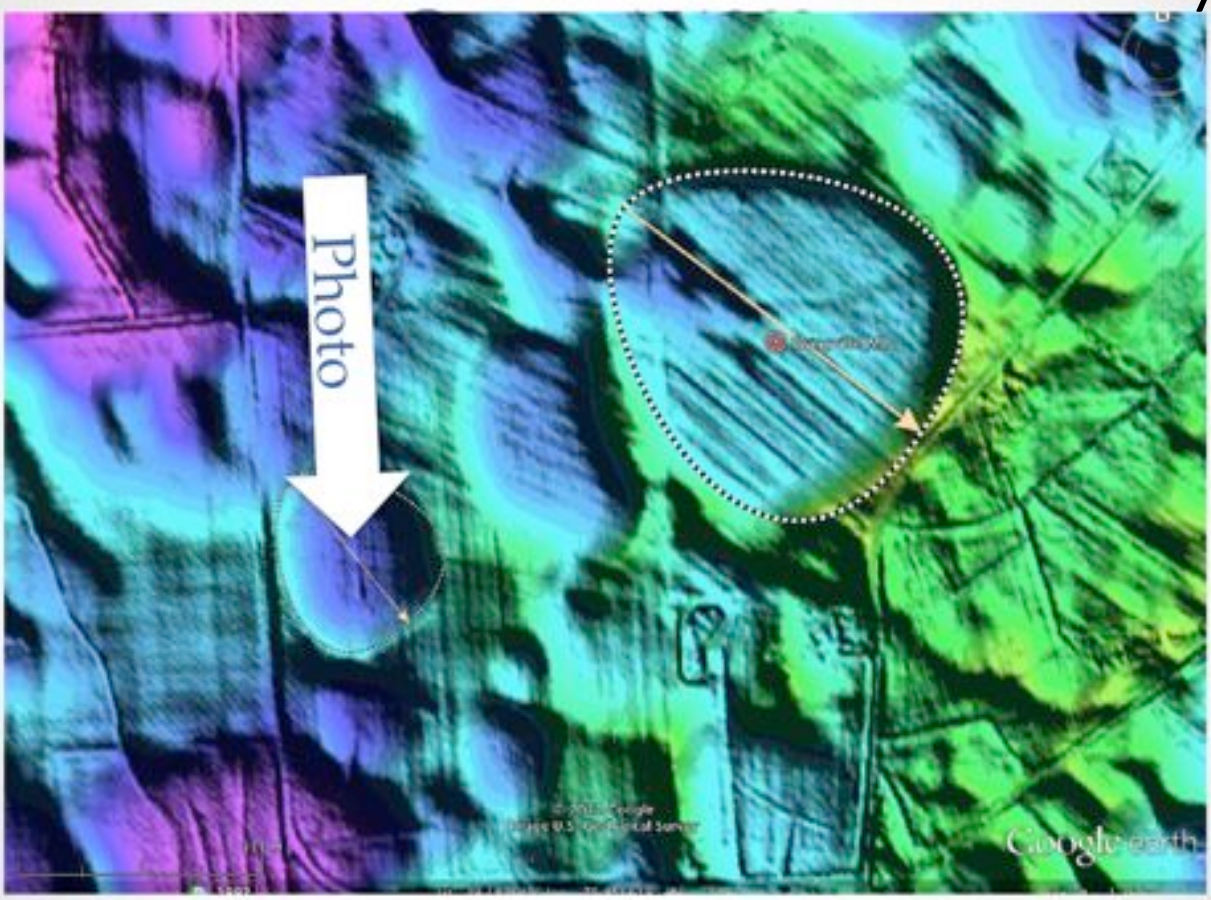
Basins on DelMarVa Peninsula

Basins on DelMarVa Peninsula, photographed from ground



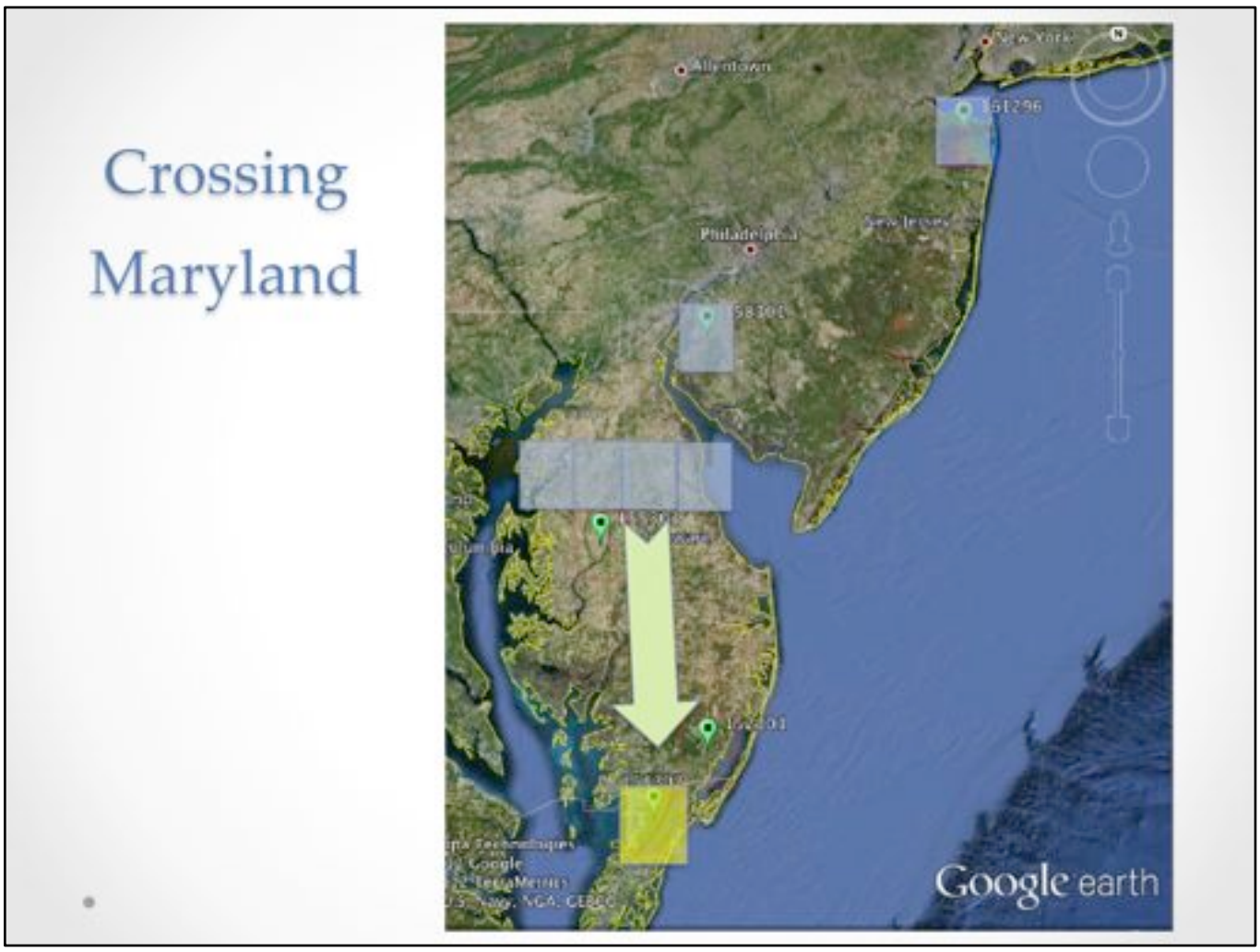
Basins on DelMarVa Peninsula, photographed from ground

Basins on DelMarVa Peninsula, photographed from ground. Gentle depression – hard to read the landform shape with the unaided eye. Crop cover aids view of dip.

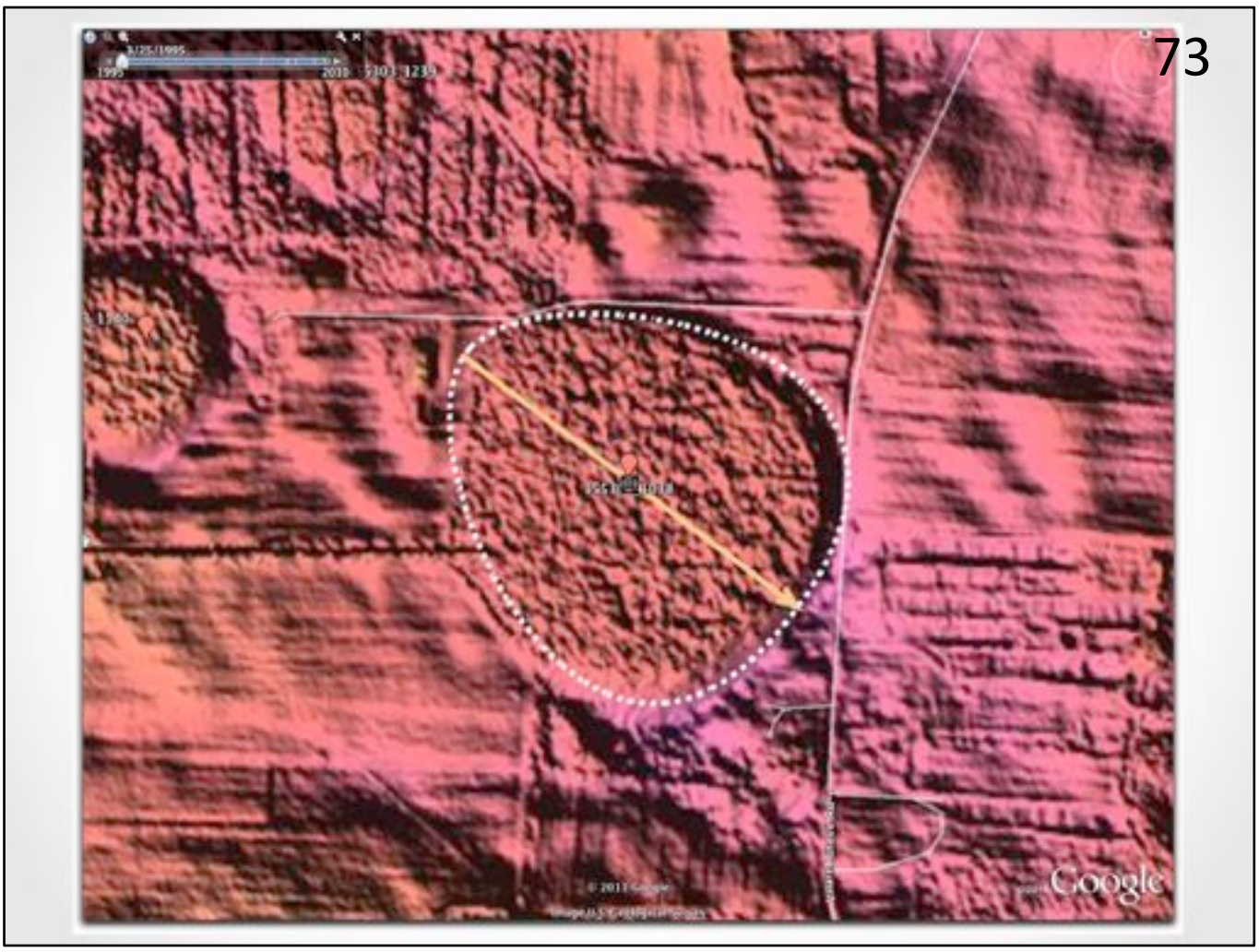


Basins on DelMarVa Peninsula, photographed from ground.

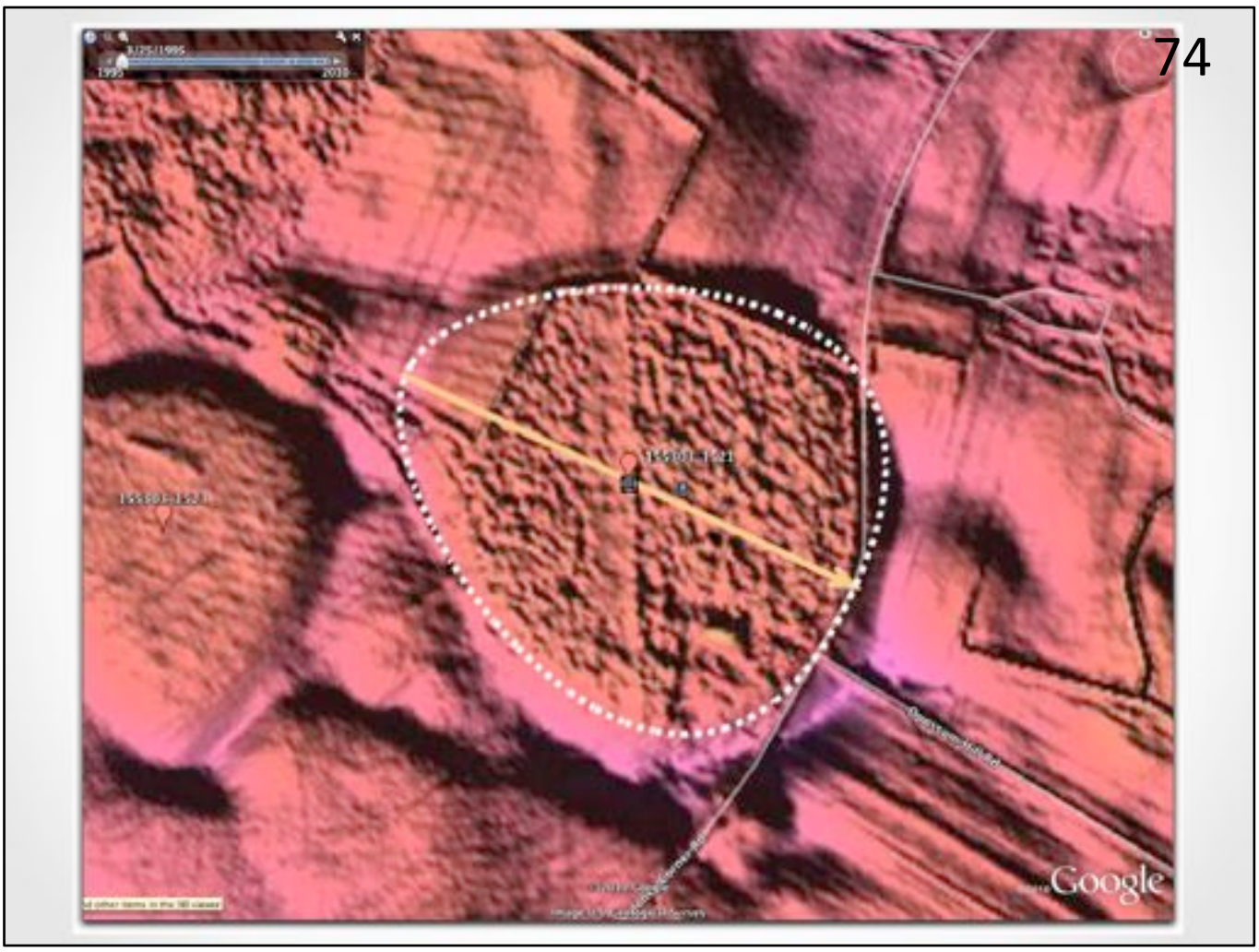
Basins on DelMarVa Peninsula, photographed from ground. Gentle depression from center looking south– hard to read the landform shape with the unaided eye. Corn stalk stubble aids in perceiving the rise to rim in distance.



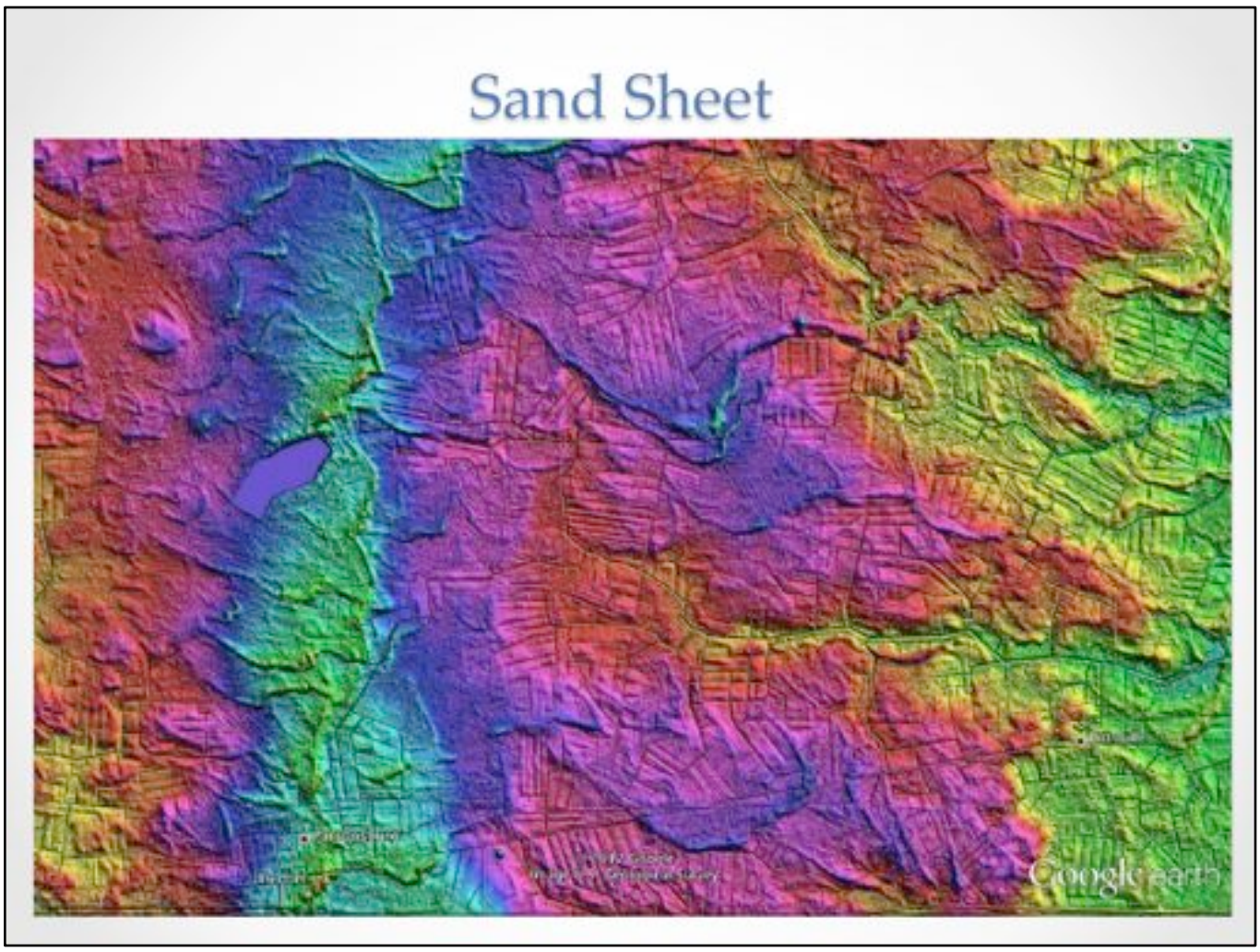
We cross DelMarva towards Virginia's Eastern Shore



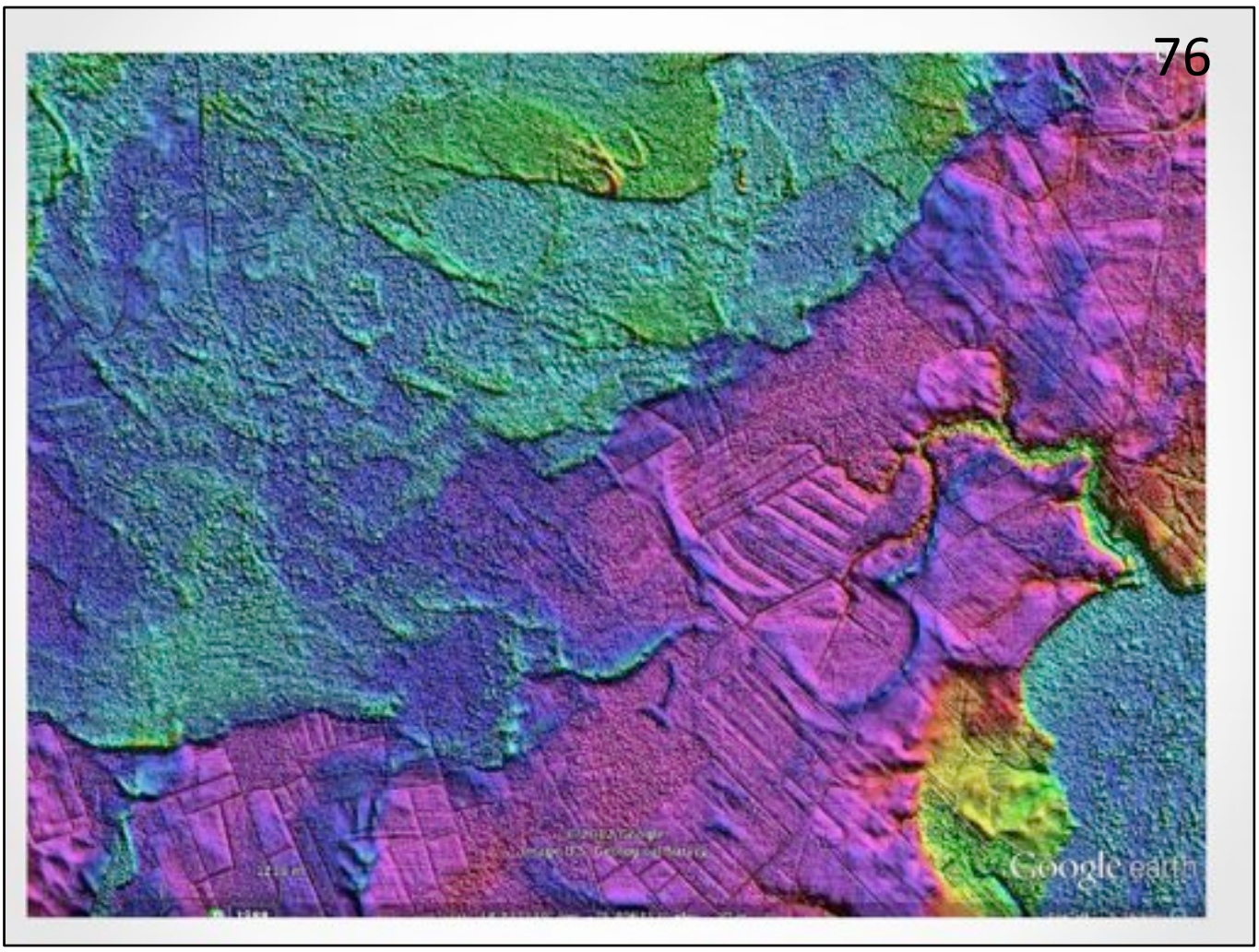
DelMarVa Bays



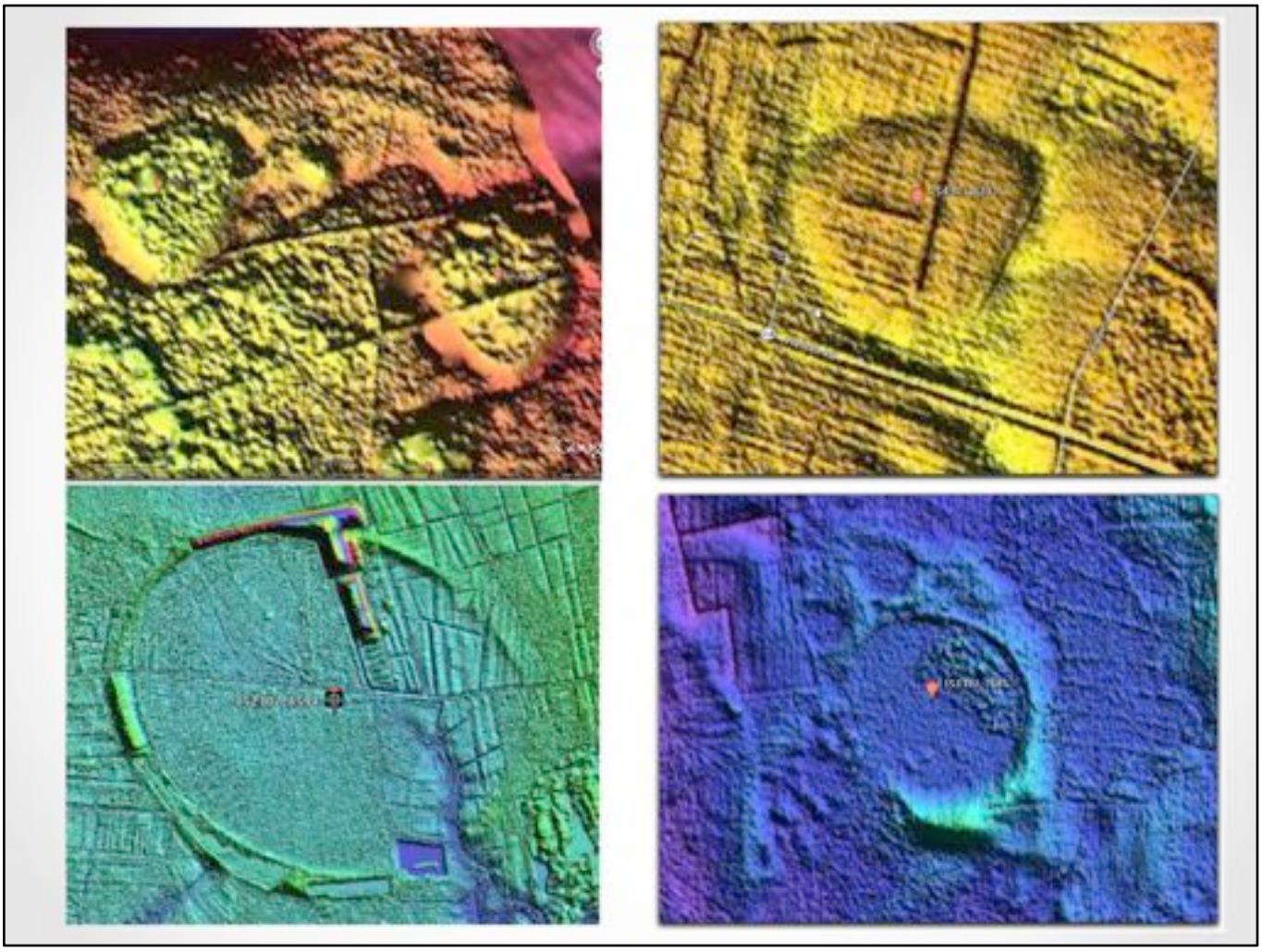
DelMarVa Bays



DelMarVa Sand Dune Sheets



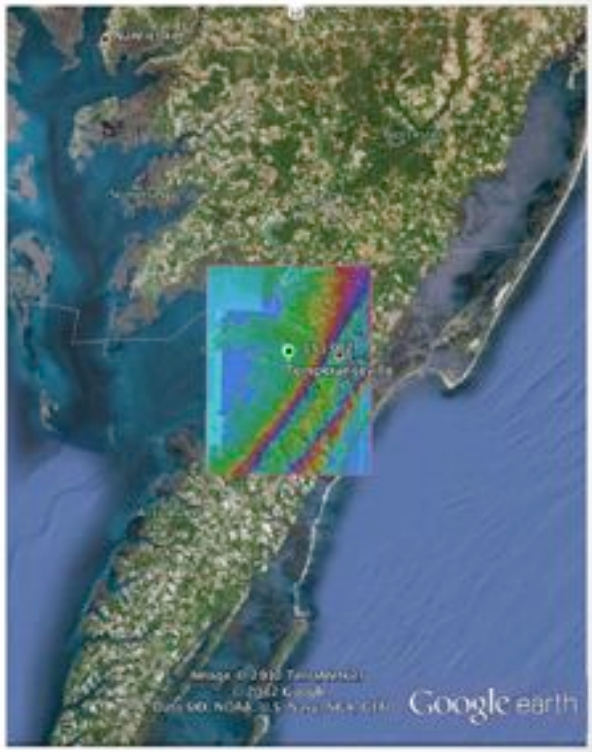
DelMarVa Sand Dune Sheets encroaching on basins



As we move further south, bays become more round

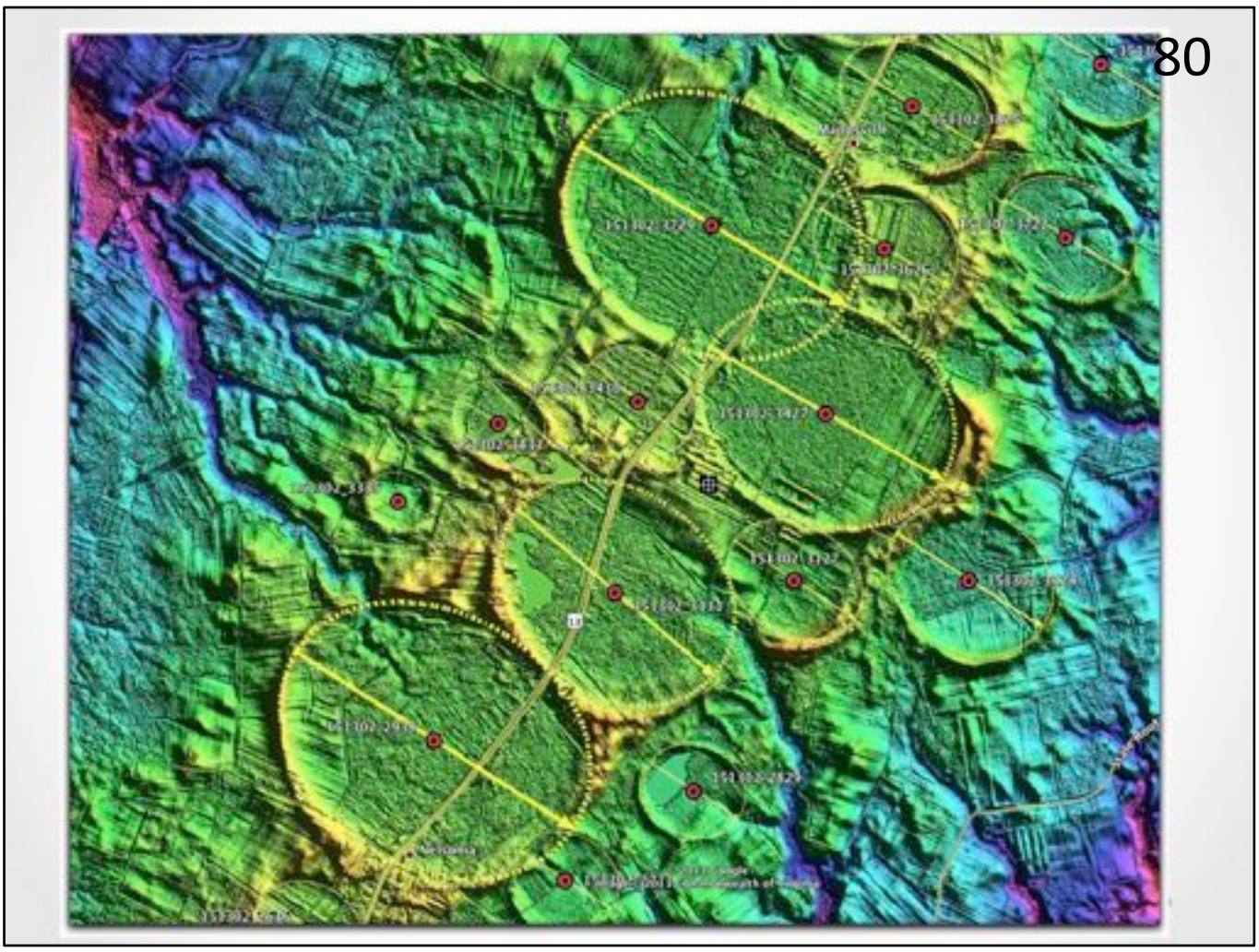
Octant 151302

- Chincoteague 100k Quad
- Eastern shore MD/VA line
- "Oval" Planform
- 227 bays measured
- Mean Bearing 121°
- Std dev 2.1°

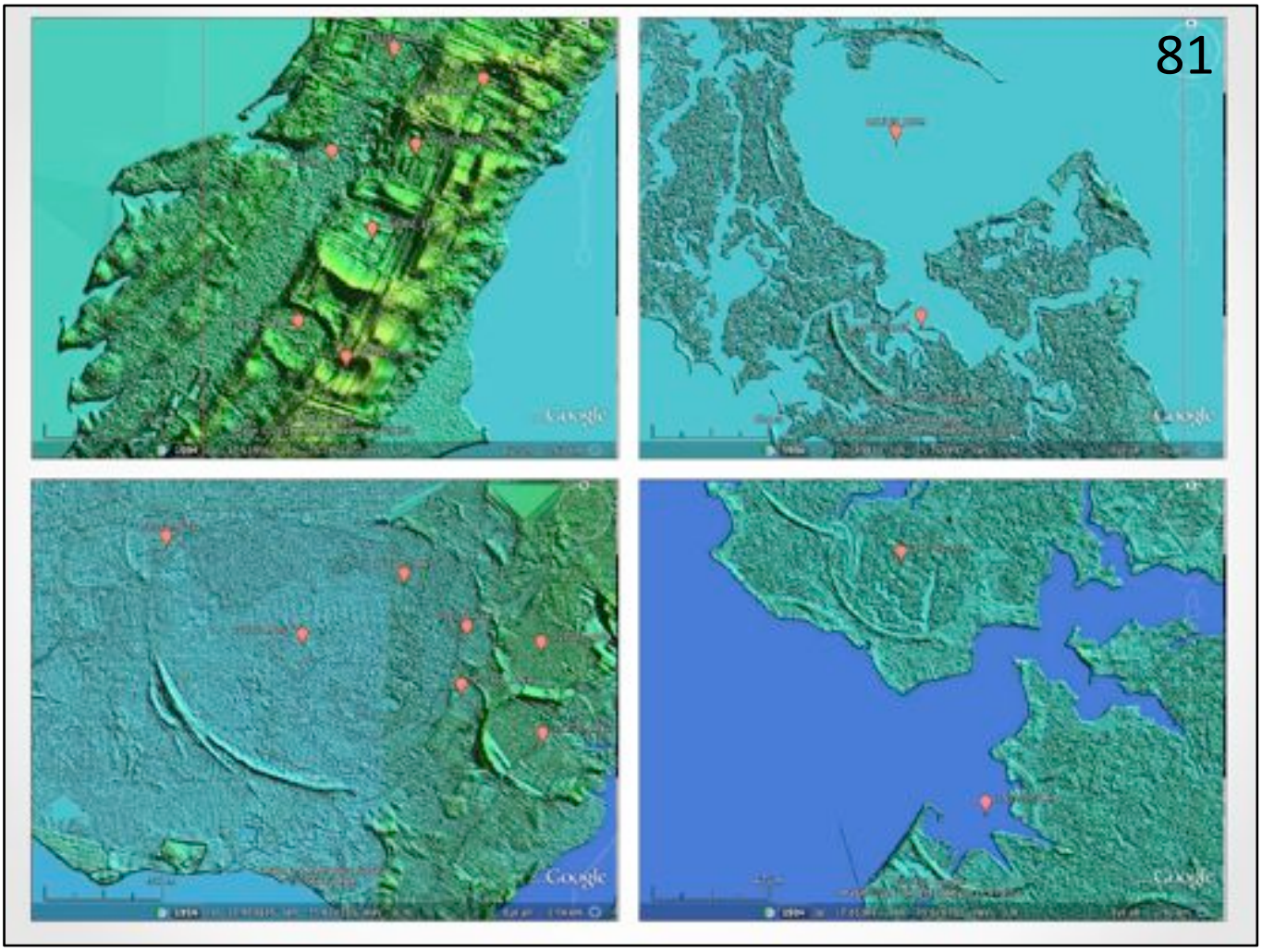


Immediately to the south, on Virgina's Eastern Shore, we see the oval shape become pervasive in octant 151302.

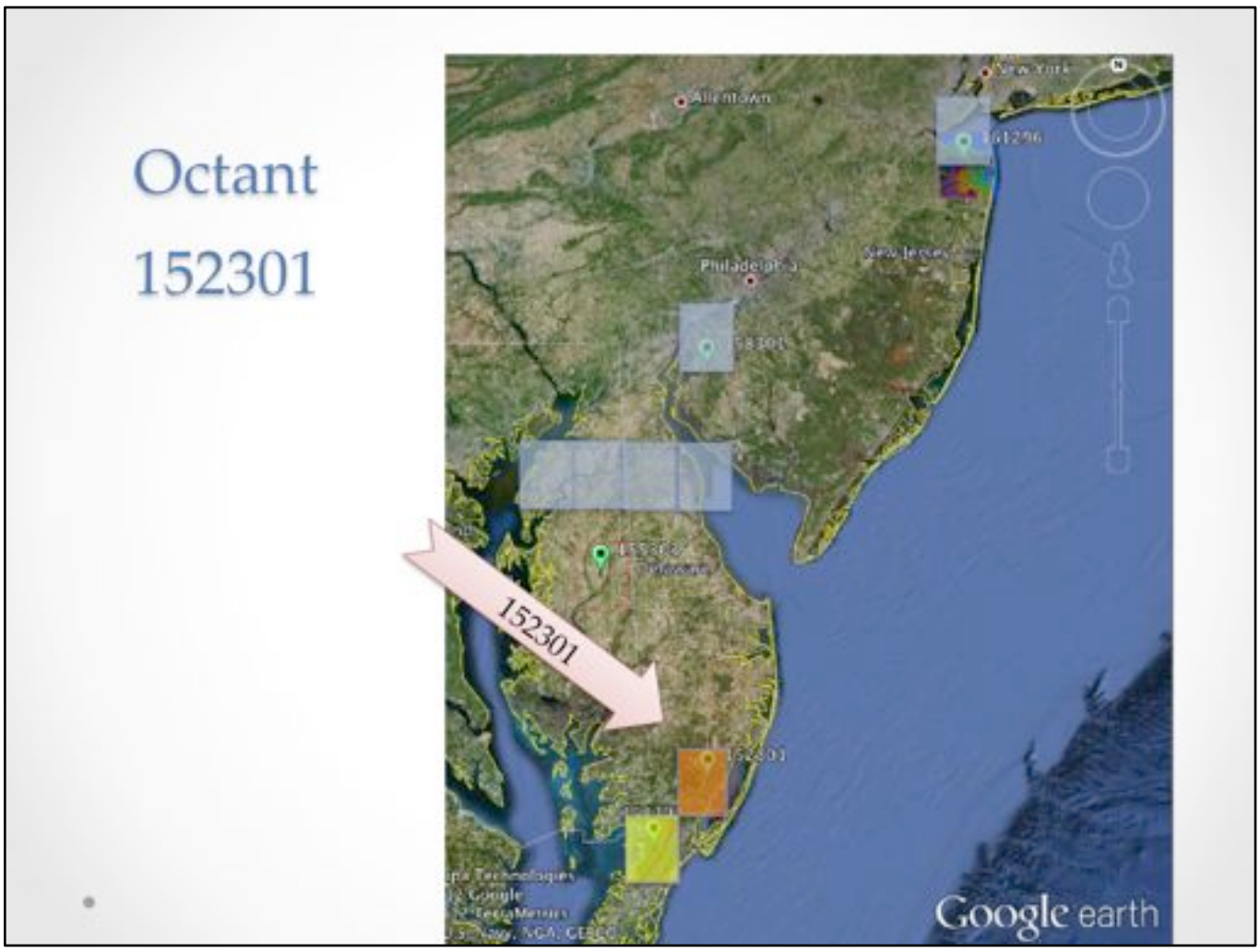
Hard to see – just watermarks on the landscape



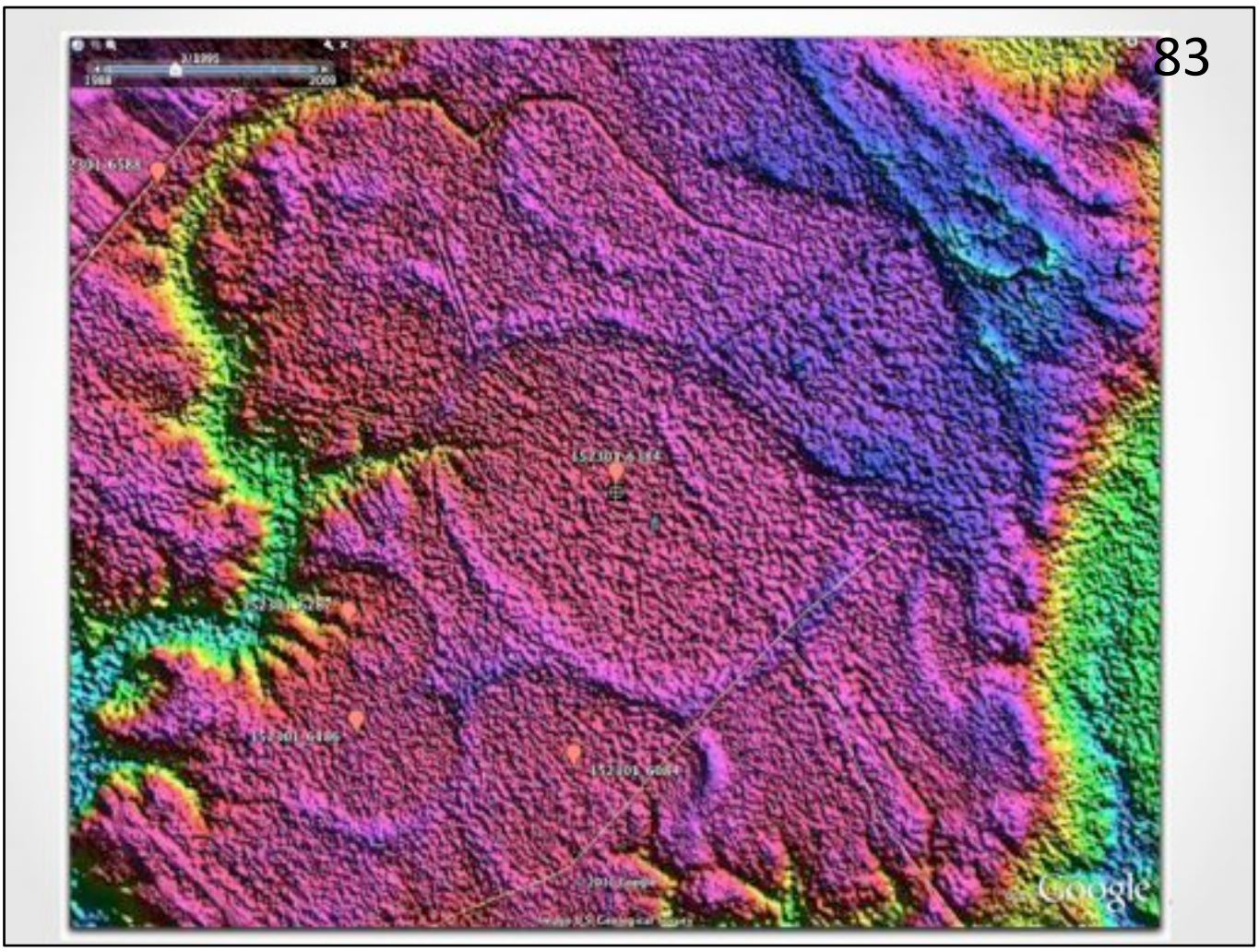
Bays see as are robustly oval in LiDAR , and oriented, with a defendable alignment.



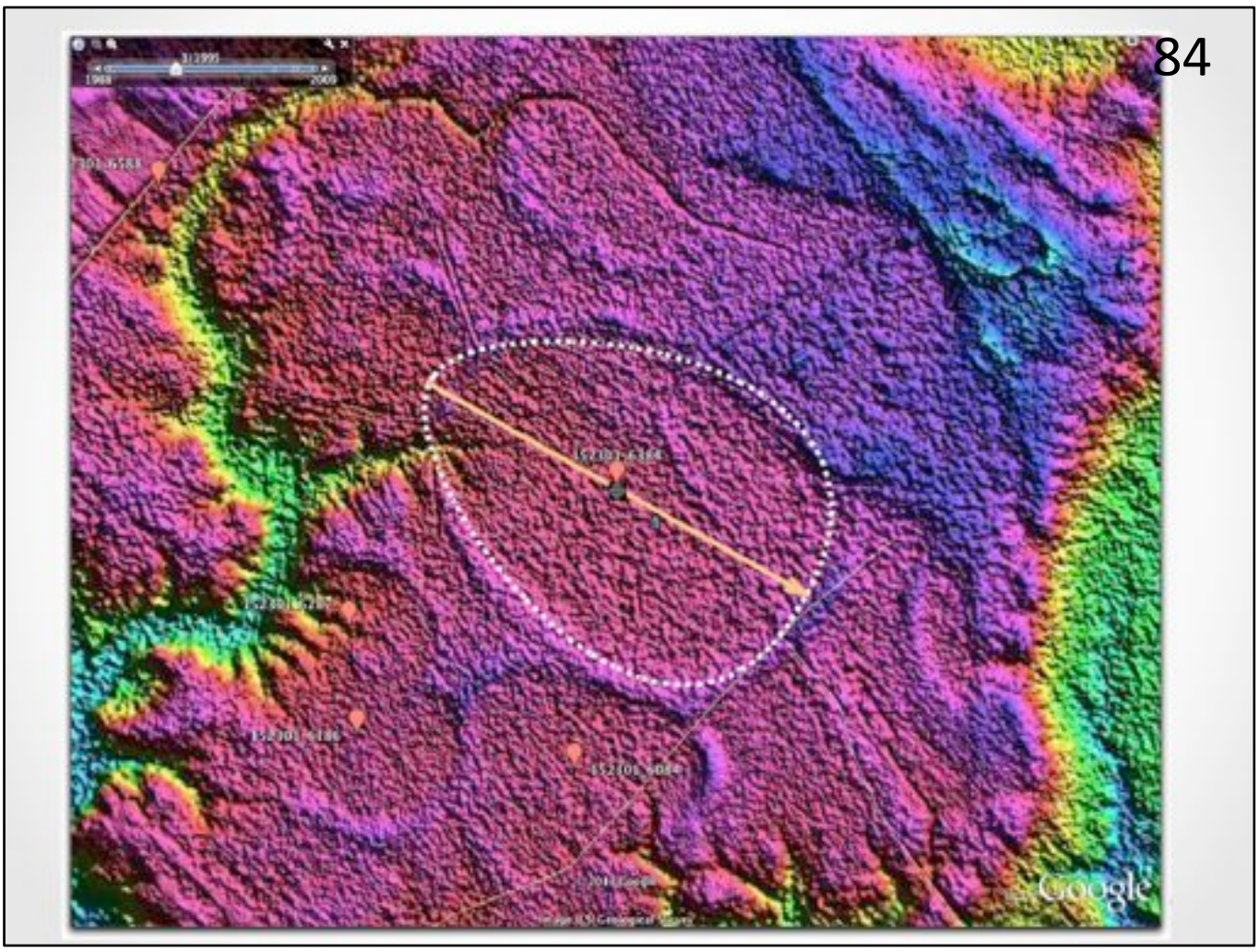
The ovals are seen along the barrier islands to the east and out in Chesapeake Bay marshlands to the west, at sea level.



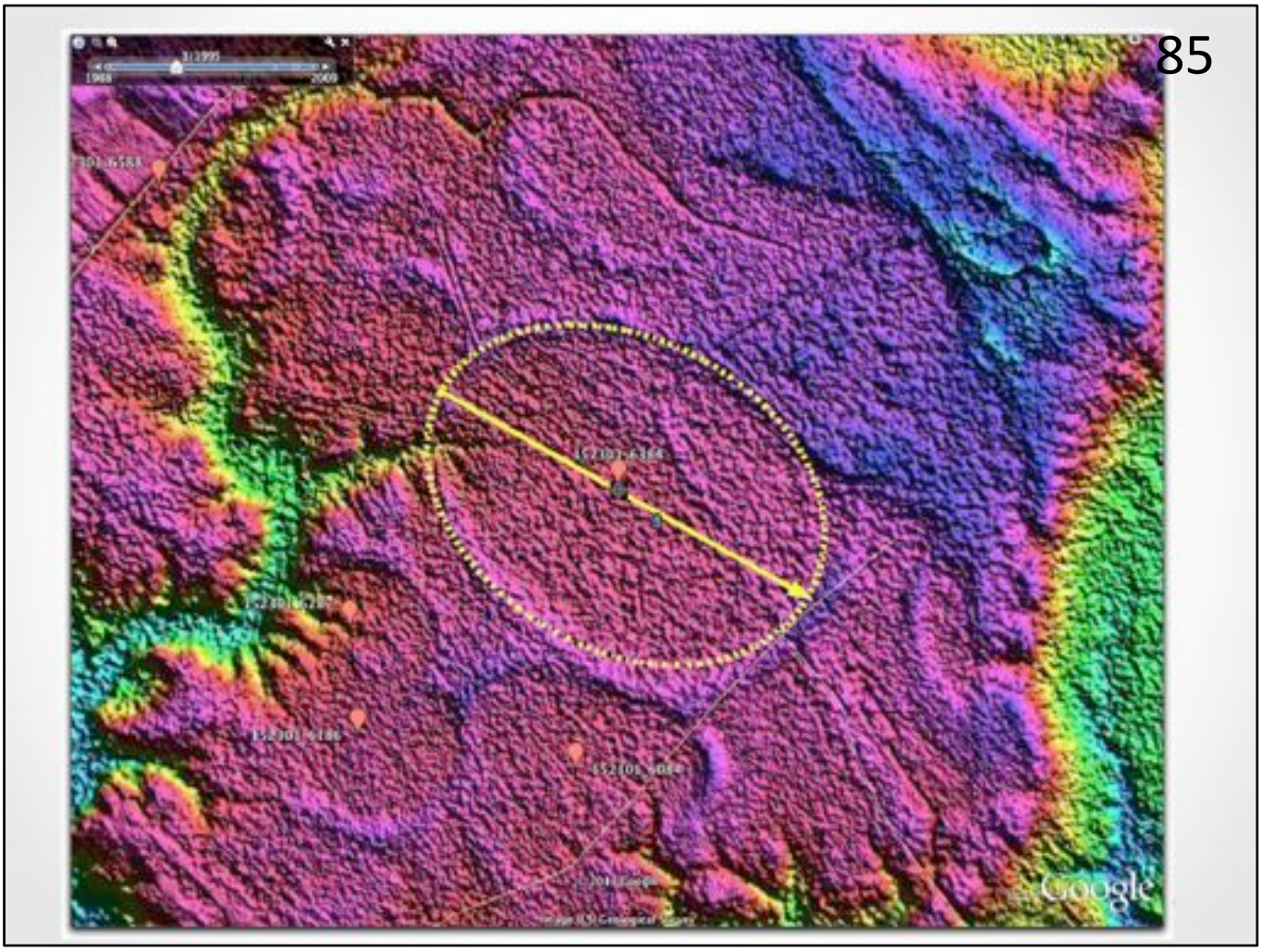
Moving back northward into Maryland



Bay 152301_6384 is my “Rosetta Bay”



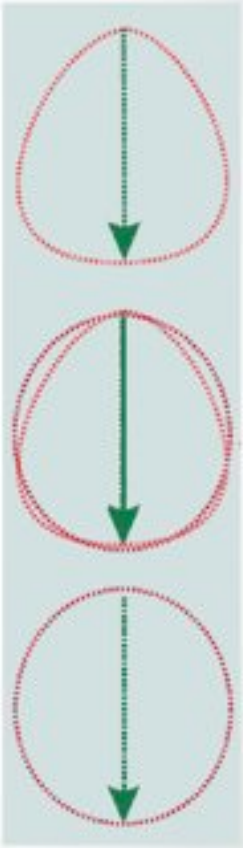
The bay-bell shape fits well, given a pointed tip to the north west, and a flat brow to the southeast.



But, a more oval shape fits also. This leads me to consider if a continuum of shape and hence orientation, has been suggested.

Planform Continuum

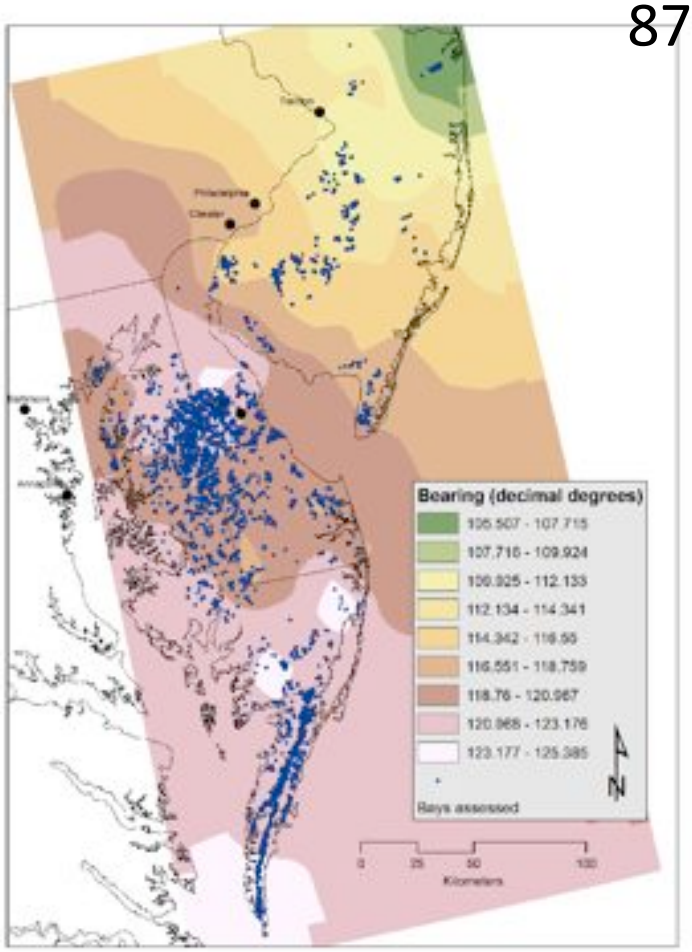
- Carolina bays seen in two Planforms
- Shape changes gradually from one into another
- Is this Continuum a Compelling Argument?
- Can diverse Geomorphologies be Supported?



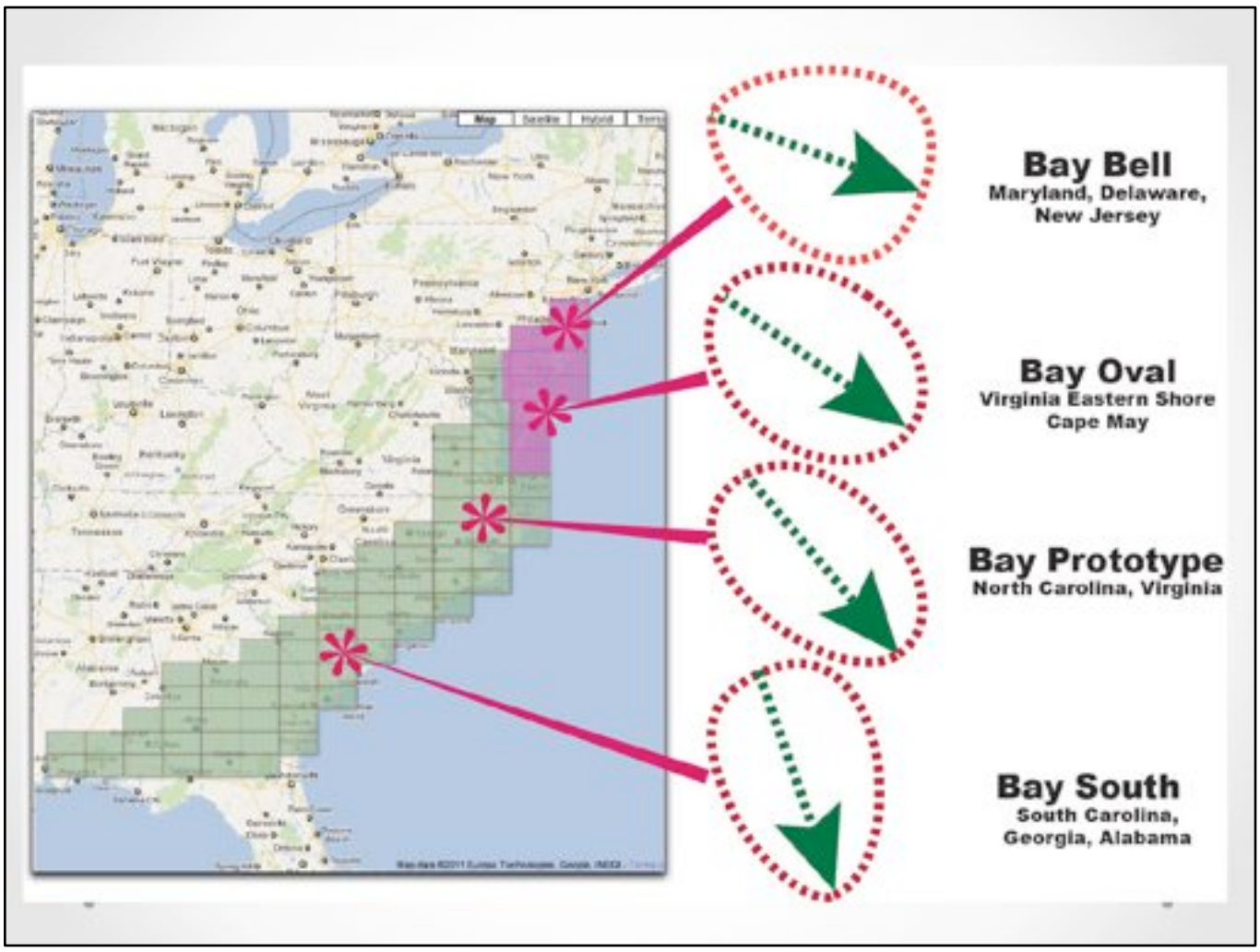
We see these two planforms, and by noting how they grade into each other, we interpret the orientation of the bay-ball shape to be northwest to southeast. With such a strong correlation, It seems improbable to me that they would have different geomorphologies.

Orientations

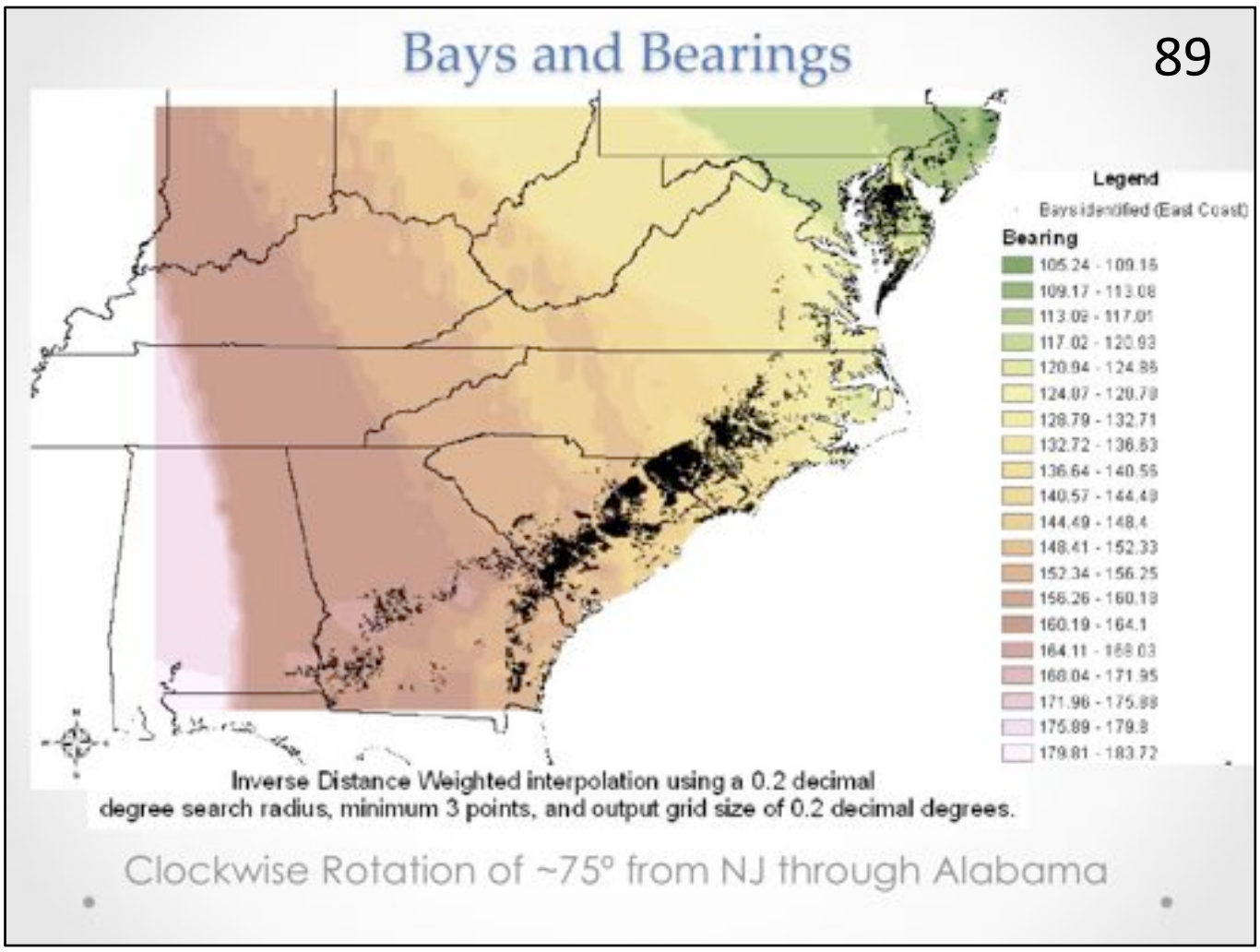
Rotates clockwise ~20° from NJ through Eastern Shore



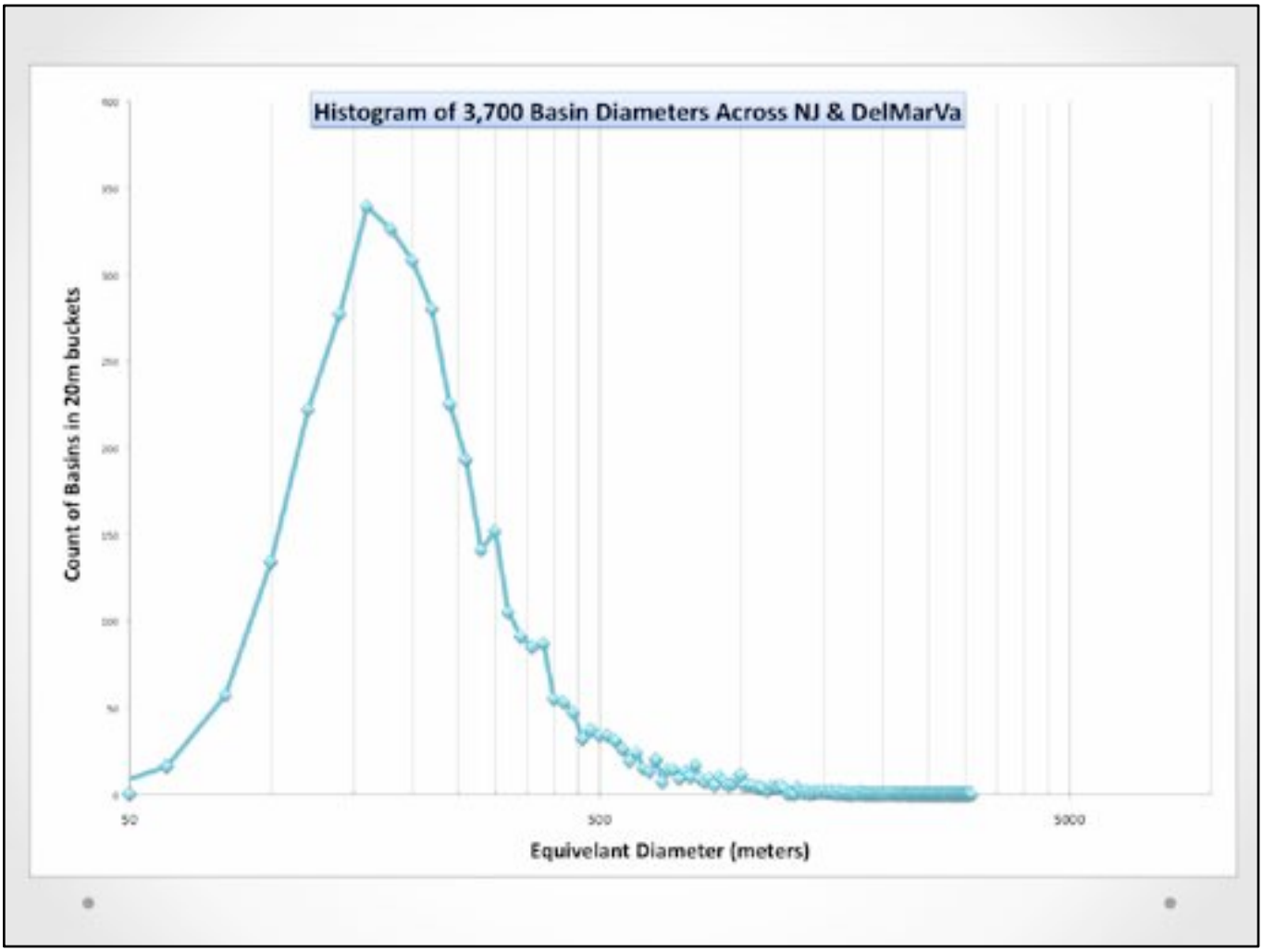
If we accept the northwest to southeast orientation across the northeastern coastal plains, this graphic presents the Inverse distance weighted Interpolation of the 3,700 measured bay's bearings. They rotate about 20 degrees clockwise moving from Monmouth County down to Cape Charles in a statistically significant manner.



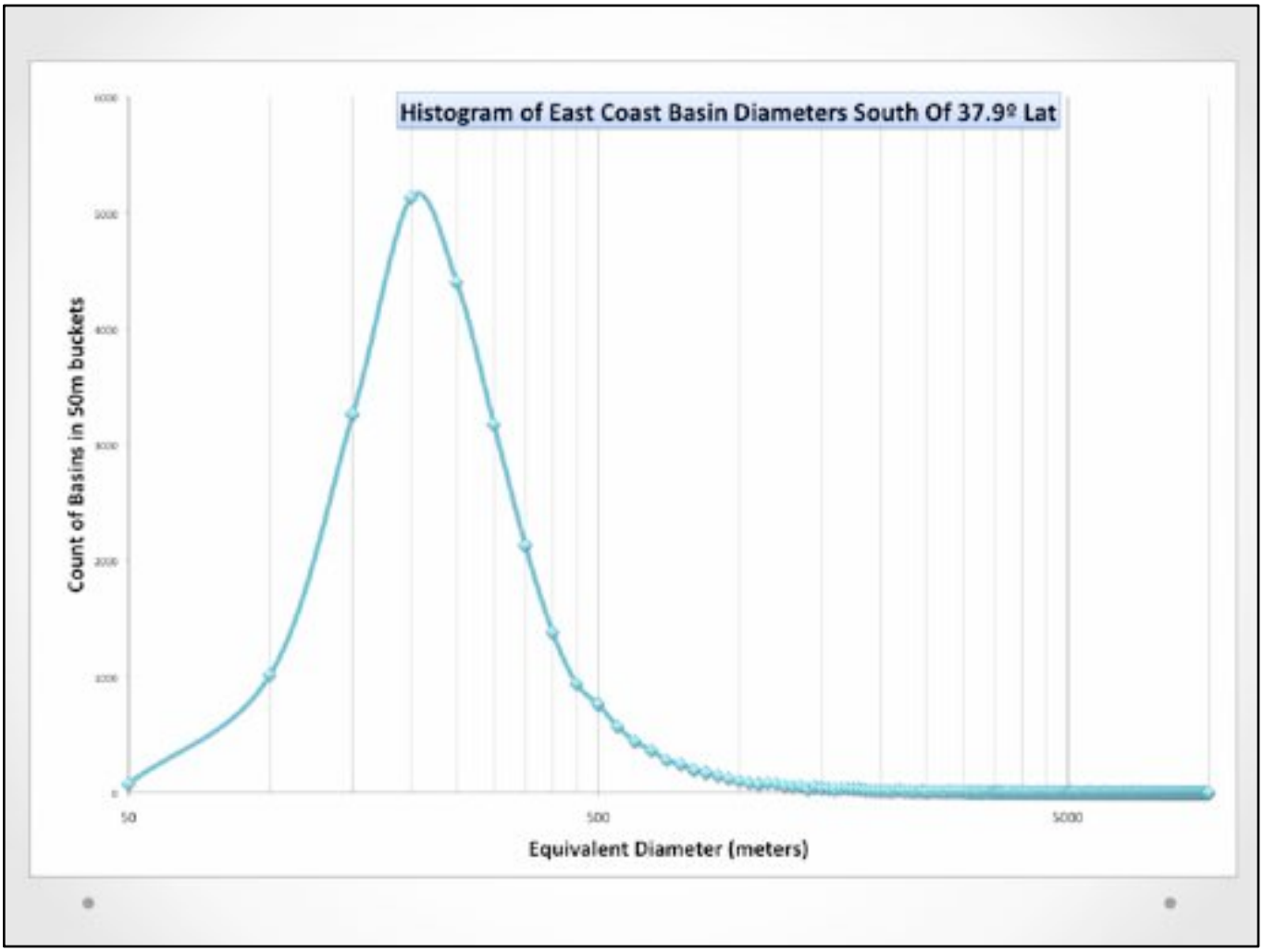
The planform shape continuum also extends across the extent of bays we have surveyed on the East Coast.



IDW map of 30,000 bays on East Coast, Systematic rotation of ~75 degrees is found.



I find this an intriguing statistical comparison. Here is the histogram of all 3,700 basin sizes from the northeast, displaying quite a nice log-normal distribution with a peak between 150 and 200 meters. Now, here is the same chart for all 30,000 bays in the survey, with virtually the identical distribution and a peak at 200 meters, although the tail does go out past 5 km vs only 4km for those in the northeast. The last chart shows the same histogram for bays south of Cape Charles, demonstrating that the northerly bays are not skewing the overall picture.



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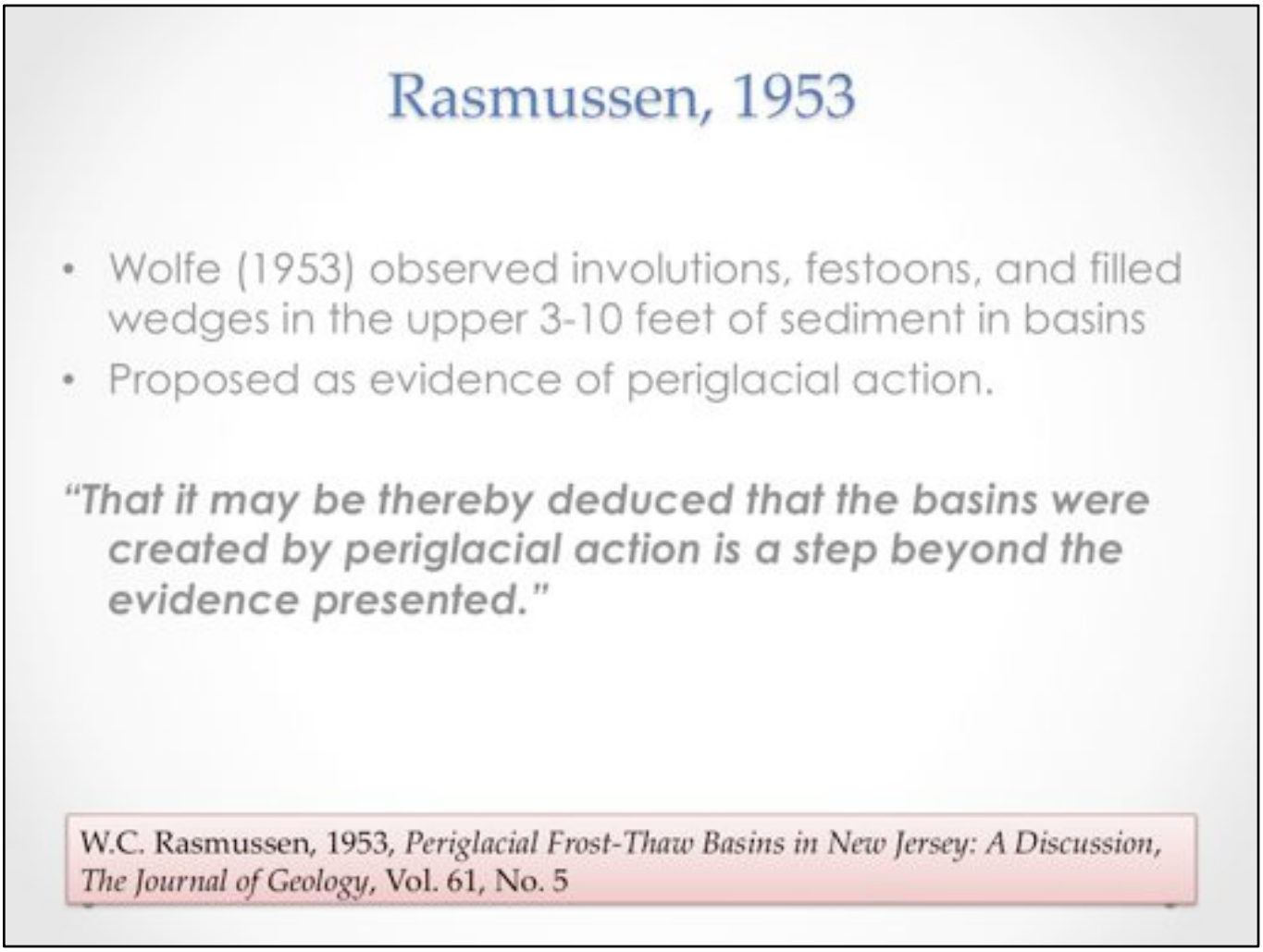
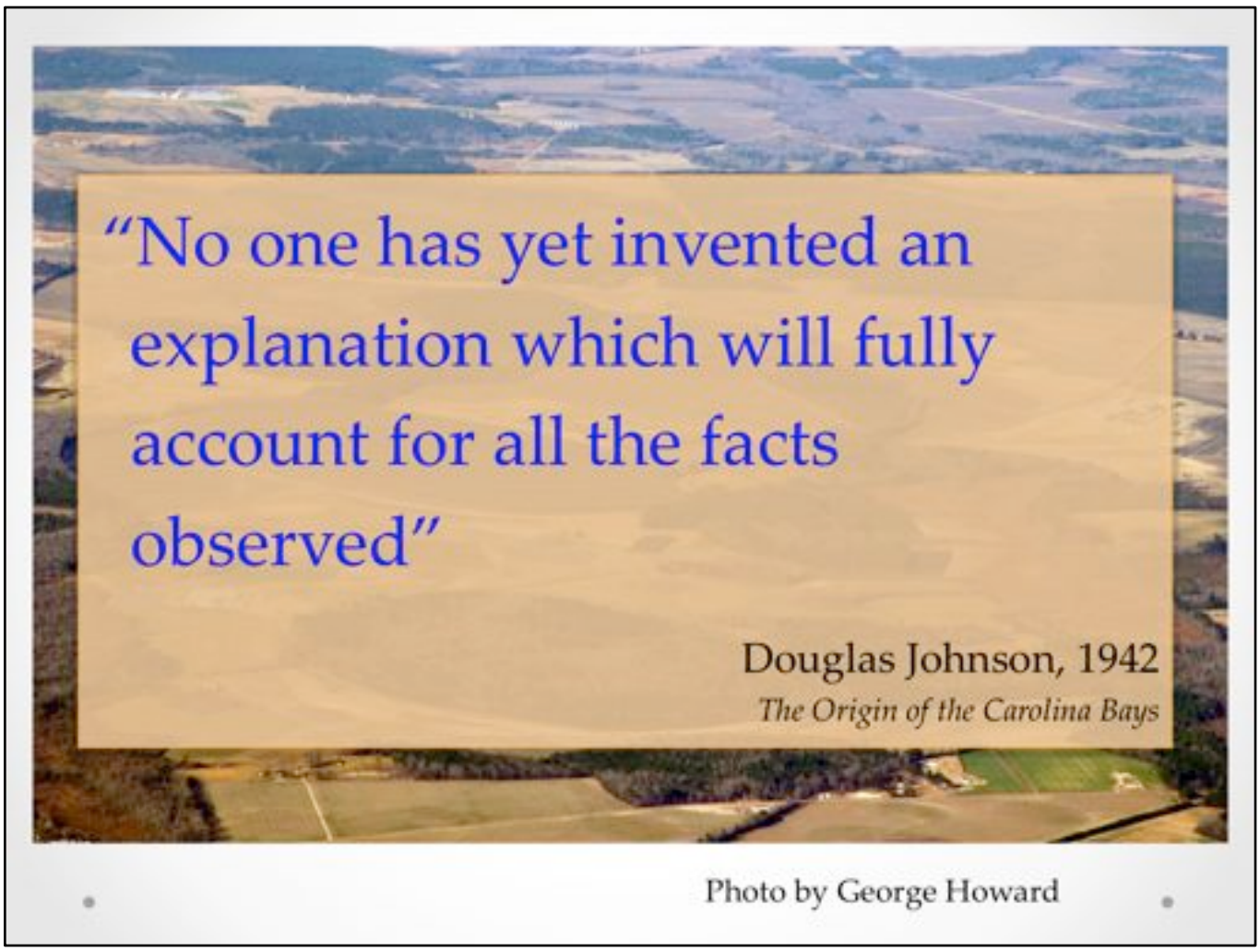
Conclusions

- "Carolina bays" related to "Coastal Ponds"
  - Slightly Different planforms which change on a continuum
  - Not as robustly cookie-cutter as more southerly bays
  - Few multi-km bays
  - Lower eccentricity
- Orientation Seen as NW to SE
- Demonstrate Systematic-by-Latitude Rotation
  - 20° Monmouth County to Cape Charles
  - 75° Monmouth County to Alabama
- Size Distribution Log-Normal
  - Identical statistically with distribution of entire 30,000 bay survey

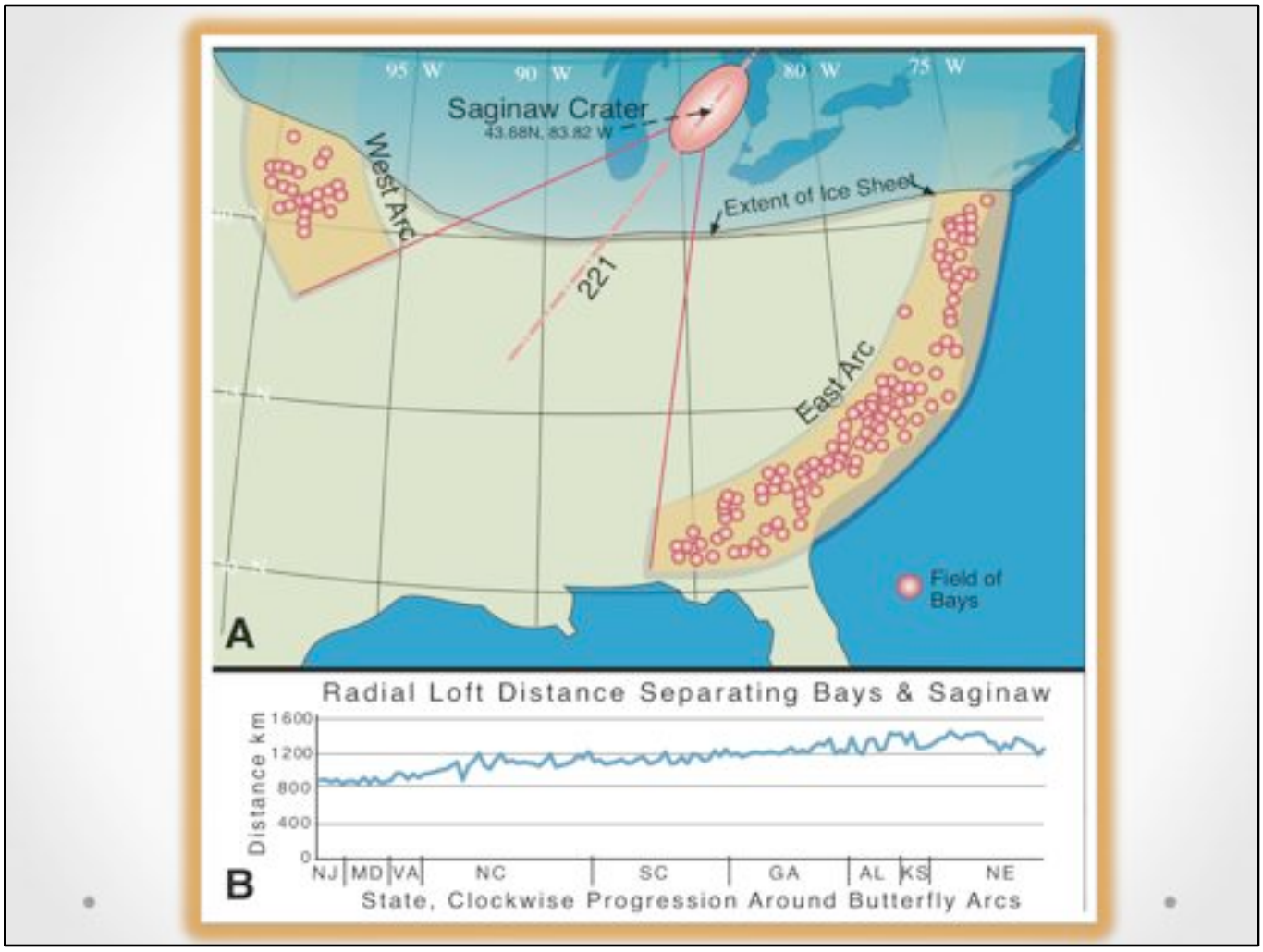


Current consensus seems to put Periglacial activity as the primary driver of the basins. I agree with Rasmussen that the evidence presented thus far could easily be interpreted as activity within an antecedent basin, not as the mechanism for its initial creation. In 1958 Rasmussen tendered a 500 page doctoral thesis. While he did not definitively identify a genesis for the basins, he soundly dismissed the Periglacial mechanisms.

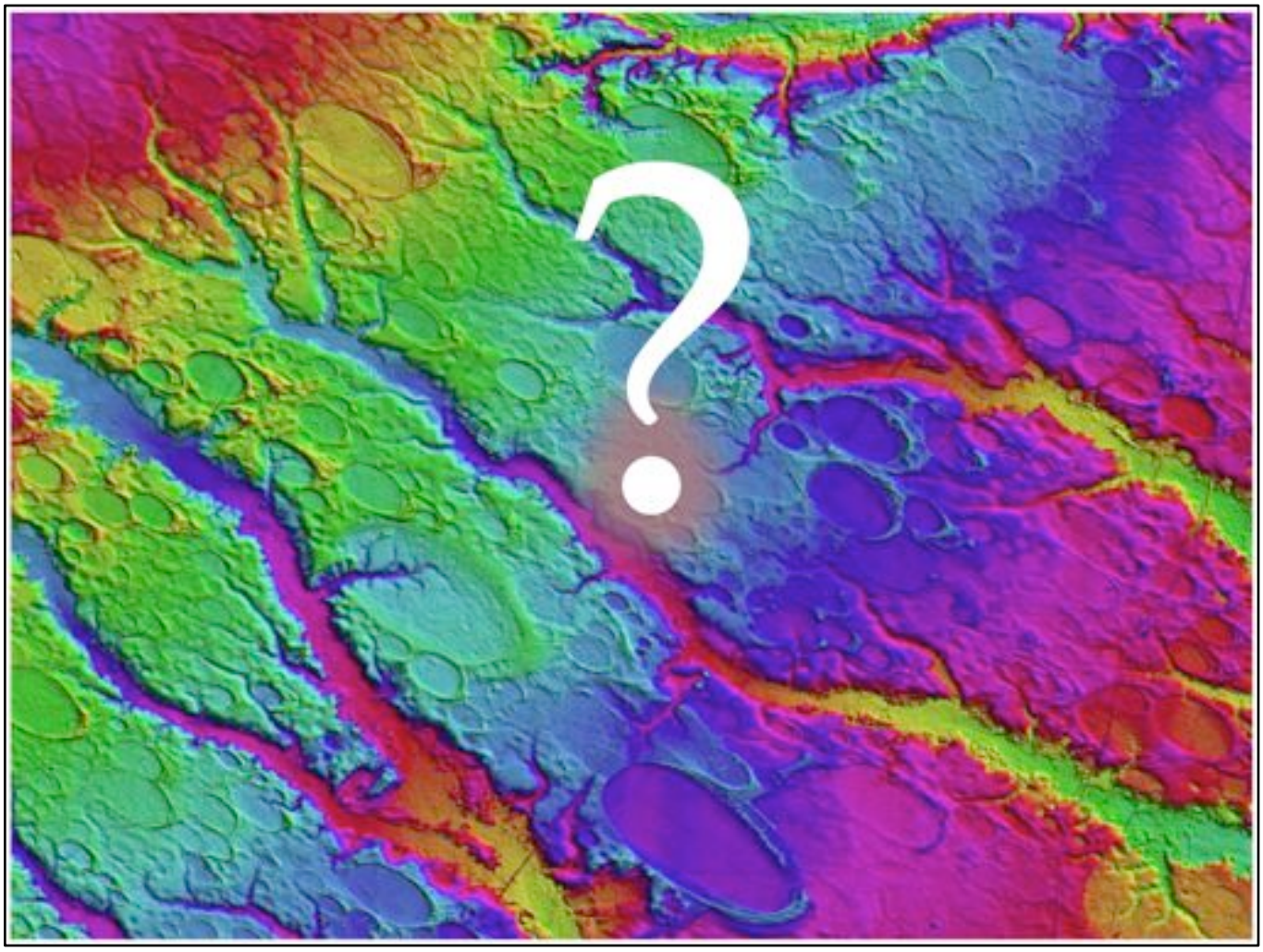


Dr. Johnson's well-phrased statement still has merit 70 years on. When pressed, geologists generally elicit a thin collage of wind and wave theory. I don't buy it, as it does not fully account for all the facts observed.

We speculate that the sand in the rims, as well as the matrix between the bays, is comprised of sand transported to the site in a foamy, frothy super-heated slurry of silicate and water. The bays are seen as voids in the distal sheet of sand, created by the deflation of gaseous (water vapor) inclusions in the ejecta curtain wall.



Triangulation sample suggesting a locus in the Saginaw Bay area of Michigan. This graphic created with data from an earlier survey of ~250 “fields” of bays. The current survey was undertaken to address a complaint that the ~250 sites represented a selection bias of sites which represented favorable alignments. Lower chart displays the distances of the bay sites from the Saginaw Locus.



Questions?

Abstract Geological Image category winner, Meeting's Photography Exhibition. This is displayed as the November 2012 image on the GSA 2012 Wall Calendar.