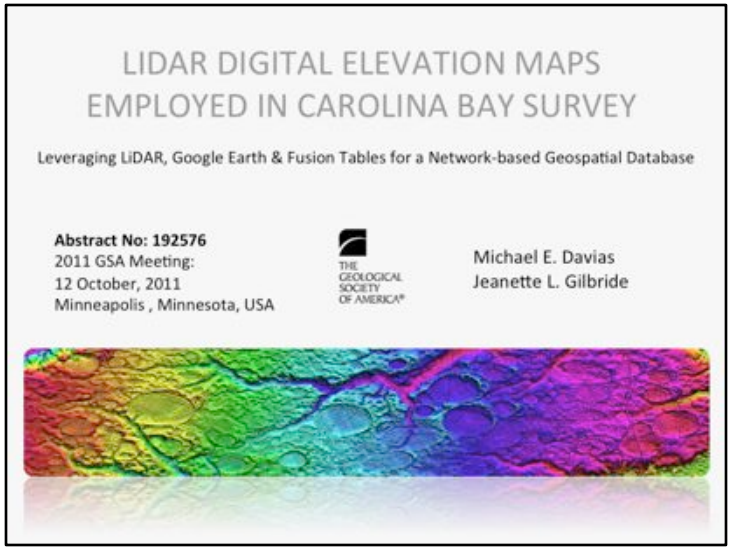
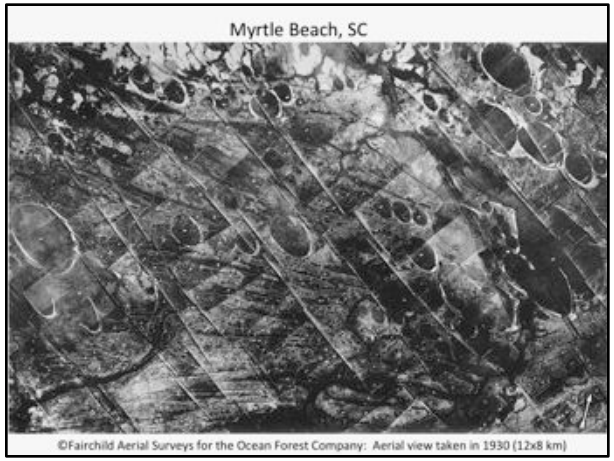
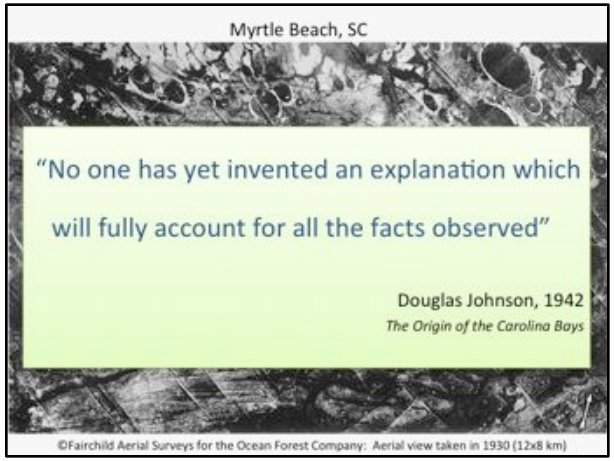


Greetings:

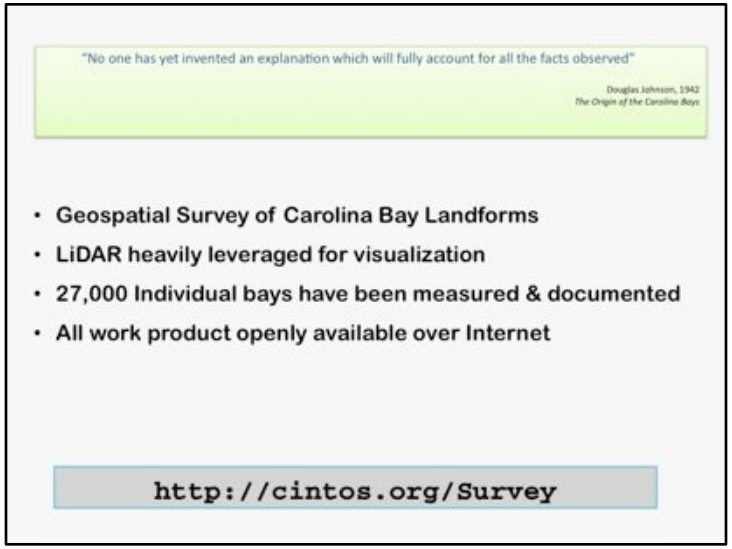
Now, many of you are likely fascinated with the fidelity of relief offered by today's LiDAR elevation data. Allow me to share with you some of the LiDAR resources and techniques we have applied in a geospatial survey of Carolina bay landforms. Along the way, I will be demonstrating the integration of LiDAR imagery with the Google Earth Virtual Globe. I'll also be sharing a few preliminary observations.



Since the “Carolina bays” were first visualized in aerial photography of Myrtle Beach in the 1930s, their presence on the landscape has generated controversy as to their geomorphology. These landforms are shallow depressions which exhibit a closed circumpheral rim.



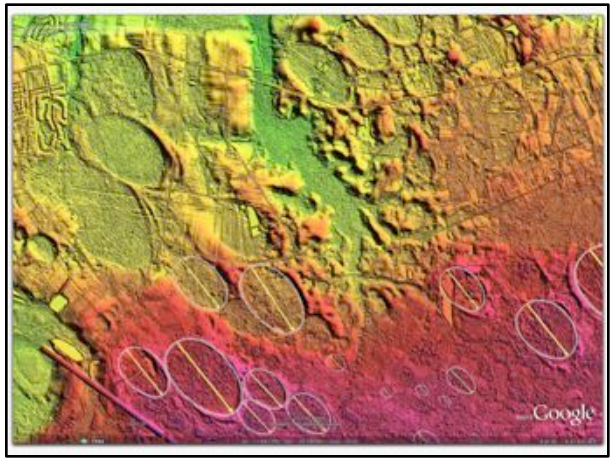
70 years on, Dr. Jonhson's observation still holds true. Many individual bays may be satisfactorily explained using various geomorphologies, but across the entire range of bays, no unifying solution has been accepted.



Our techniques, tools and database is available via our web site.

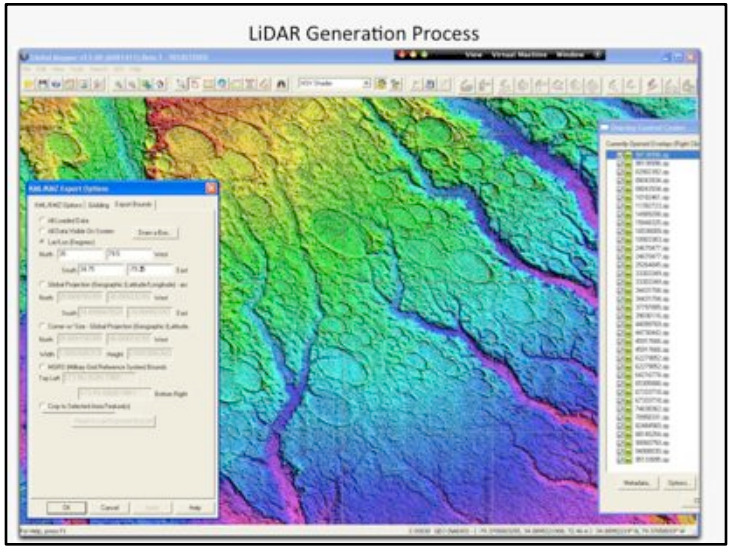
Here is a satellite image of the Myrtle Beach available in Google Earth. This is from historical imagery, as the older black & white images often show the bays and their rims in better contrast than today's color imagery. Urbanization and farming has taken a toll on the bay's visibility.

… in spite of this, we can still visualize some bays, and here we introduce our use of Image Overlays to highlight bay planforms. LiDAR just now becoming available for this area.

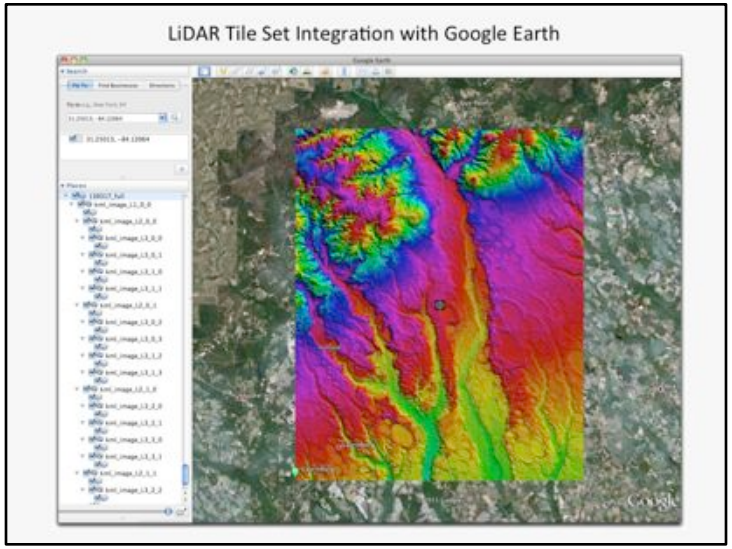


Suddenly, numerous additional bays are clearly visible. This DEM created using beta elevation data from the USGS, courtesy of G. Merrill. LiDAR captured across several South Carolina counties in 2009 are expected to be made available at year-end.

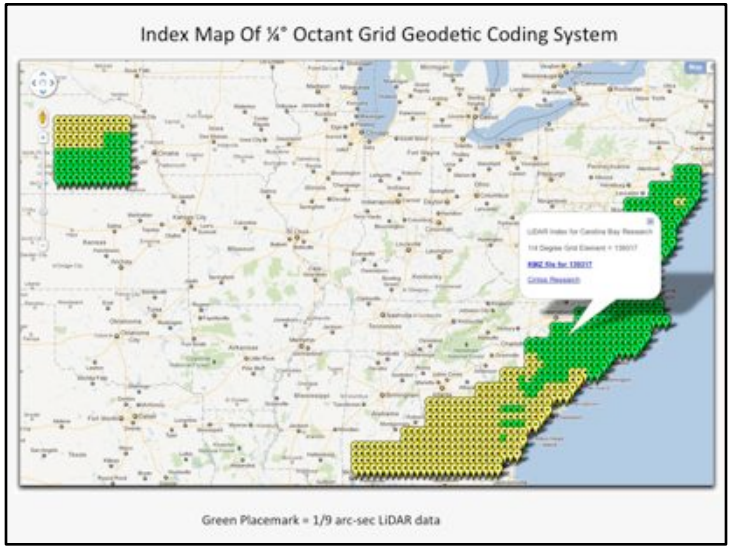
Several sources were tapped to obtain LiDAR-derived elevation data, which were processed in the Global Mapper and used to create KML-wrapped jpg images. Using various tools within Google Earth, we capture bay geospatial metrics. Google Fusion Tables are used to store this data in the cloud and source data to Google Earth using networked links.



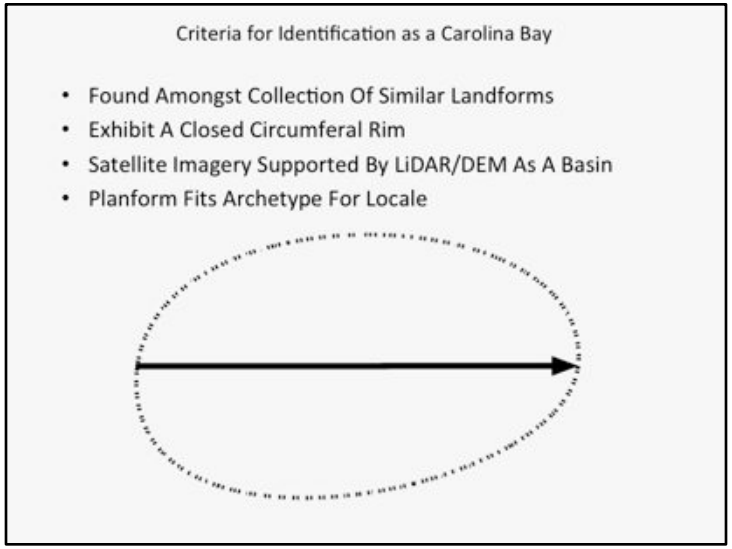
Here, we have loaded 32 USGS 24K Quad 1/9 arc second elevation data files into Global Mapper's interface. This covers one USGS 100K Quad. From this, we create eight ¼ degree tile sets as our basic grid element. I have nicknamed these as "Octants"



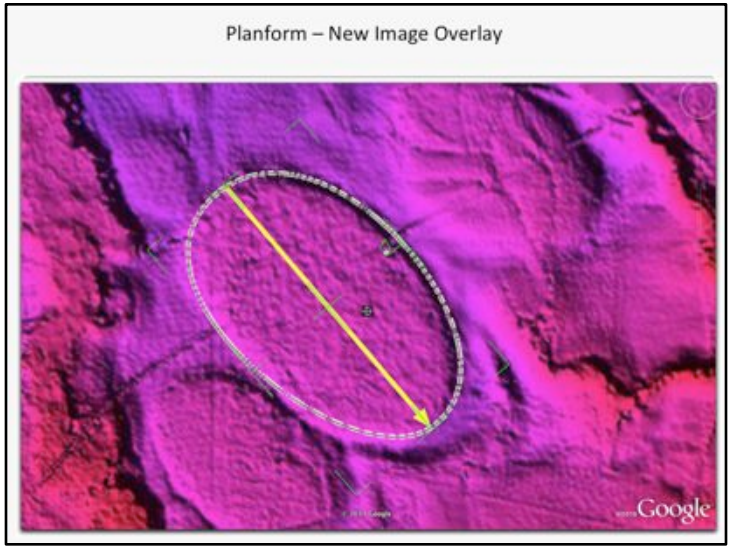
The exported octant's LiDAR tile set is opened in Google Earth, with the Image automatically positioned on the virtual globe. The tree of increasingly detailed image tiles is shown on the left. We are sourcing these tile sets using network links from our web server to minimize distribution bandwidth, as Google Earth will only load the appropriated data for the user's zoom level.



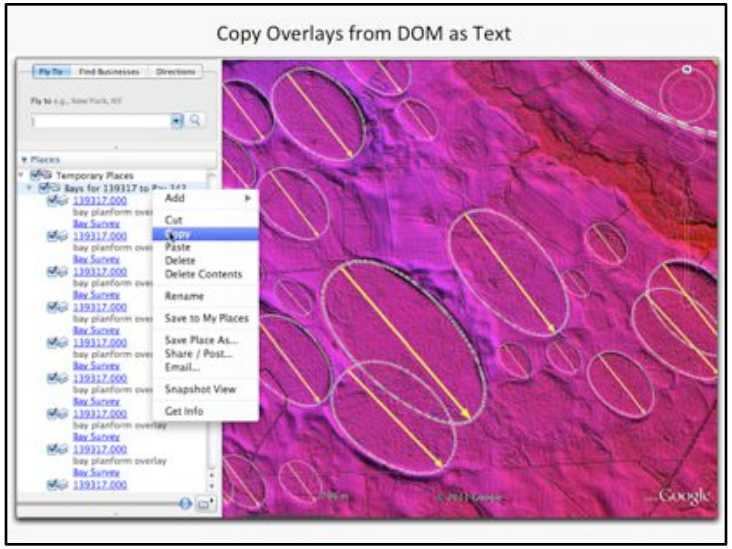
This is an example of a Fusion Table Visualization. Our survey encompasses ~800 quarter degree “Octants”. Green- 1/9 arc sec data available, with high resolution LiDAR overlay sets. Yellow=1/3 arc sec hsv shaded DEM/s, Each placemark’s popup includes a link to the survey data for that Octant. This is a screen shot from a web browser, and Fusion offers links to embed these visualizations in a web page.



There are some of our criteria for selecting a Carolina bay. They should not be singularities in the area, their rims should be closed, or at least a significant hint that a closed rim exists. And finally, it should conform to one of our planform overlays, such as the one shown here **Click** , which is the Archetype. It is not a true oval, but is slightly “twisted”, or “skewed”.



To facilitate our survey of bay metrics, we utilize a Google Earth Overlay element. The overlay is placed over the bay being measured and is rotated manually using the handle -

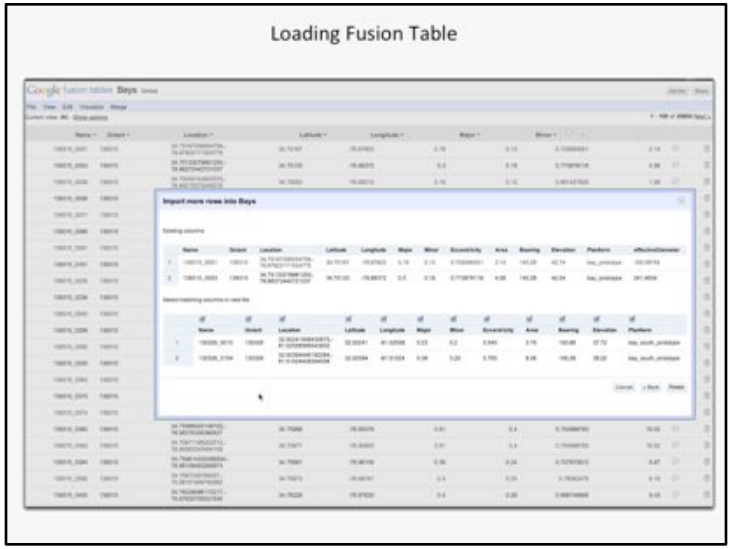


To facilitate our survey of bay metrics, we utilize a Google Earth Overlay element. The overlay is placed over the bay being measured and is rotated manually using the handle -

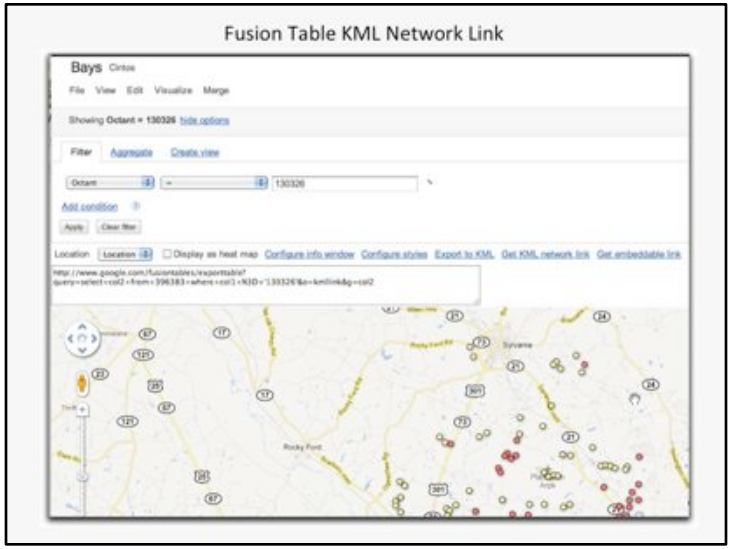
KML Meta Data in Overlay

```
<GroundOverlay>
  <name>New_Bay</name>
  <Icon>
       <href>http://cintos.org/bay_prototype.png</href>
  </Icon>
   <LatLonBox>
    <north>34.63252148936107</north>
    <south>34.61506906232364</south>
    <east>-79.57293257637467</east>
    <west>-79.58581679997867</west>
    <rotation>-135.2369396039304</rotation>
   </LatLonBox>
</GroundOverlay>
```

Pasting this in a text editor, we see the overlay format carries information: The bounding box's latitude and longitude yields the length of the major and minor axis and an estimate the bay's surface area. The rotation angle of the overlay from due north documents the bay's orientation.



We have engineered a Java tool to process the overlay KML text. The calculator produces a coma-separated-value (csv) formatted text list of each individual overlay's meta data. This is then uploaded into a Google Fusion Table.



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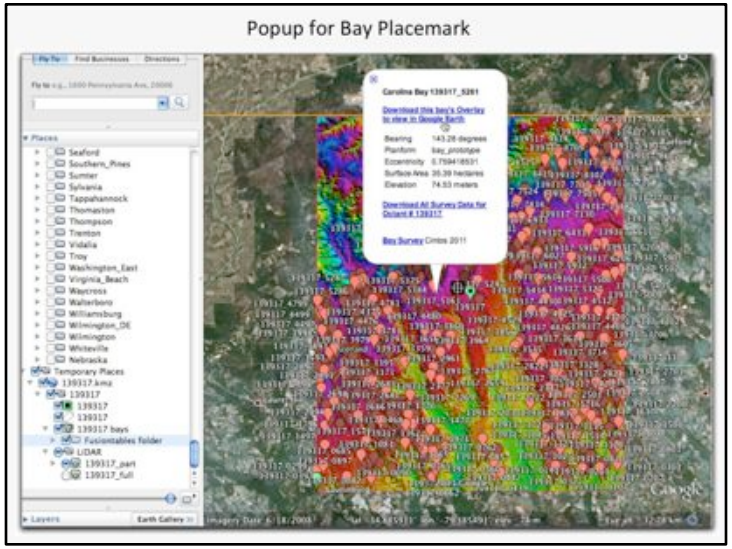
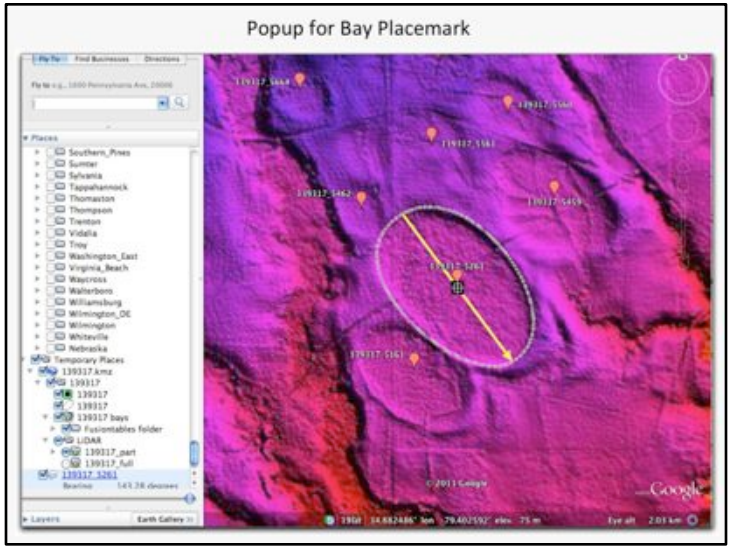
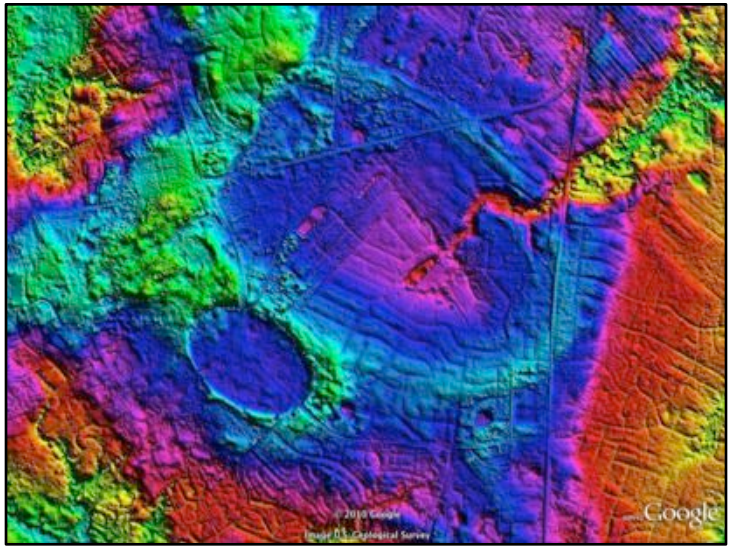


Here, we open in the Octant 139317.kmz file in Google Earth. On the left is the DOM which shows the elements we have created. The “Fusiontables Folder represents a listing of all bays in the survey, and they show up on the virtual globe as placemarks with attached metadata. When we click on any placemark, we get a popup displaying some of the survey measurements for that particular bay. Also present is a link to download the planform overlay used to measure the bay.



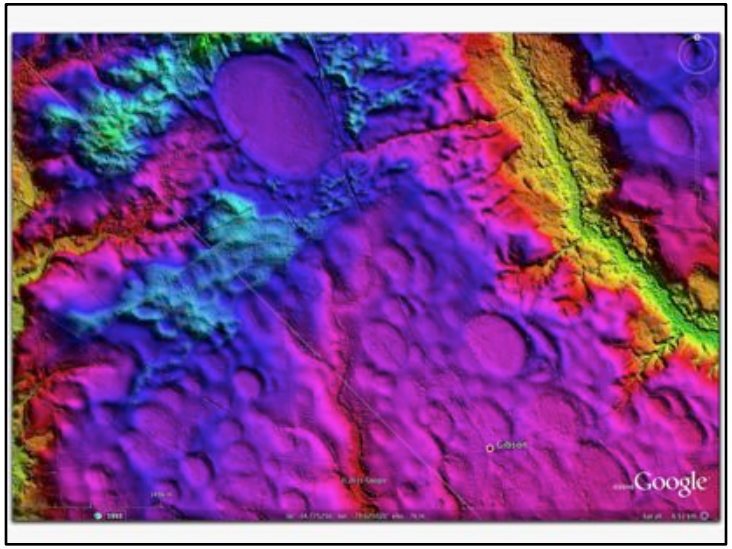
Viewing the overlay for bay 139317-5261, the user can assess the correctness of our interpretation. The first part of the name is the octant number, the remaining 4 digits declares one of 10,000 cells within the octant that contains the geometric center of the bay.

Here we are in Wilmington! In a this urban landscape, a bay in a park might be noticed – but that would be overlooking the big elephant in the room: **Blythe Ba**y

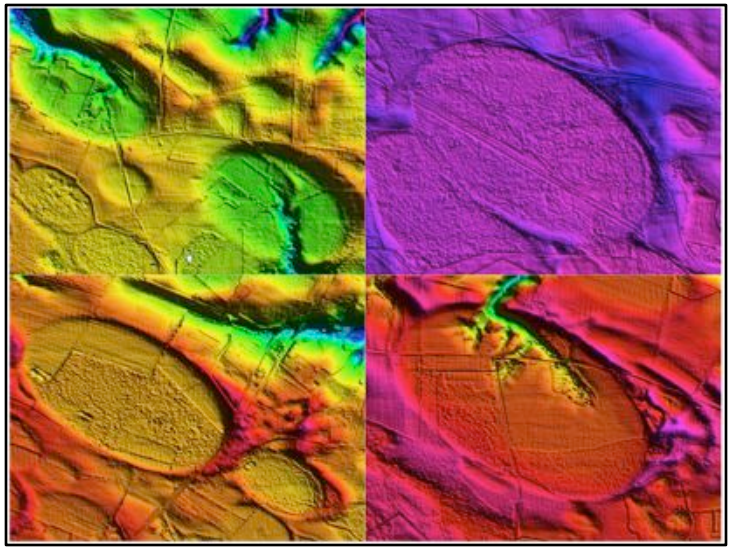


Here we are in Wilmington! In a this urban landscape, a bay in a park might be noticed – but that would be overlooking the big elephant in the room: **Blythe Ba**y

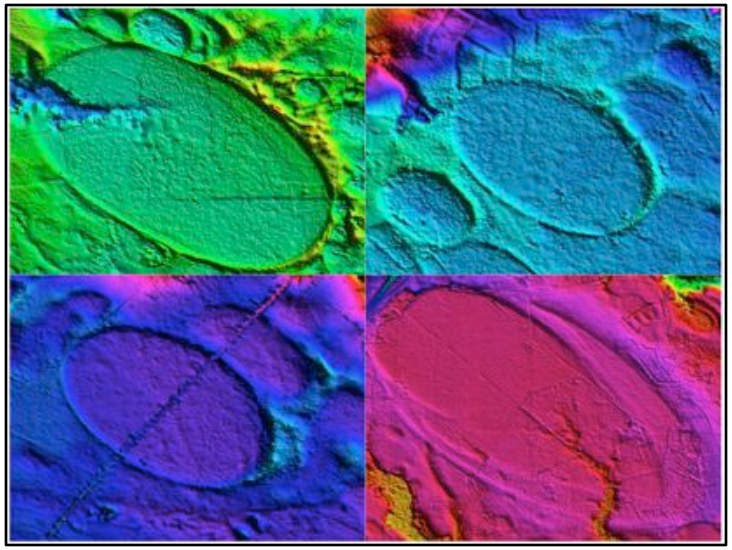
Gibson NC in Google Earth Imagery. Some bays are visible.



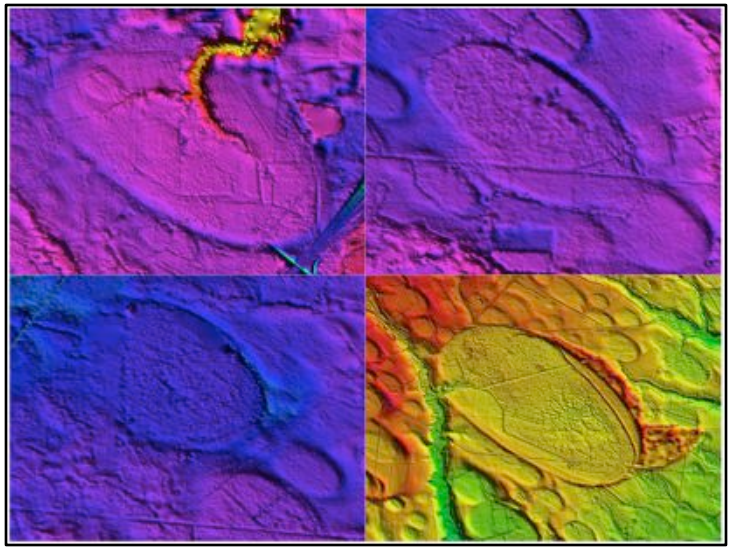
Gibson NC in LiDAR DEM. Bays are crisply represented, allowing for identification and measurement.



Detail of bays near Rex, NC. The next set of slides shows how robustly the archetype planform is maintained across thousands of bays.



Detail of bays near Rex, NC.



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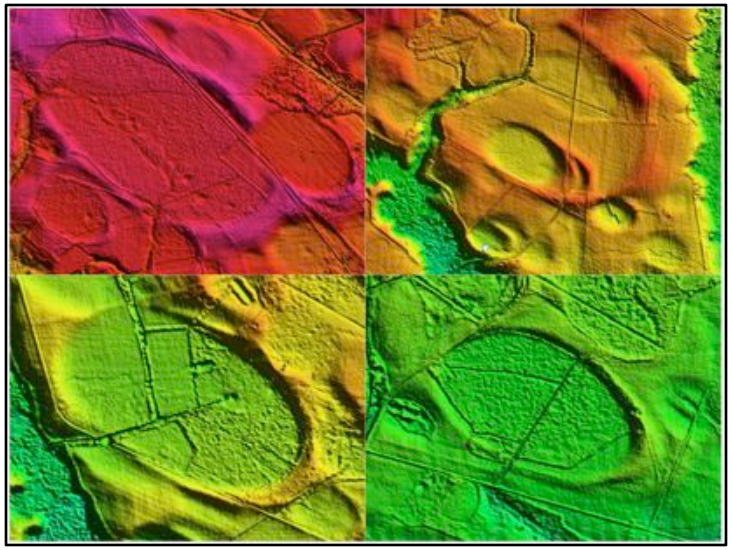
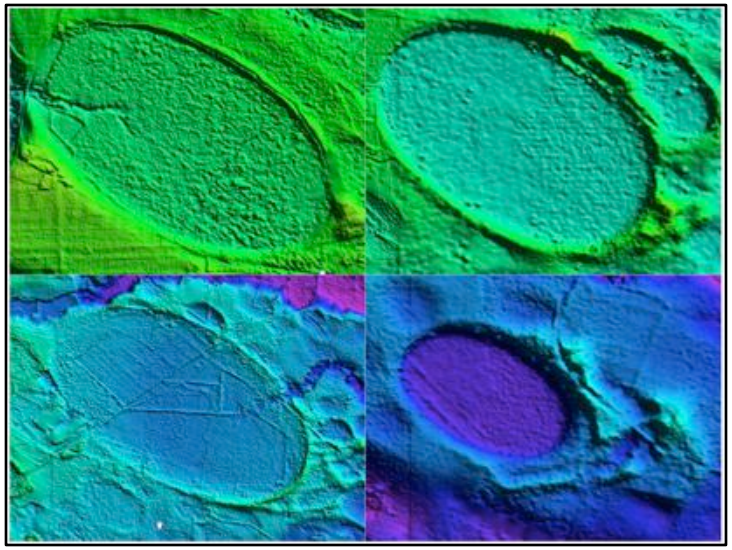


Detail of bays near Rex, NC.



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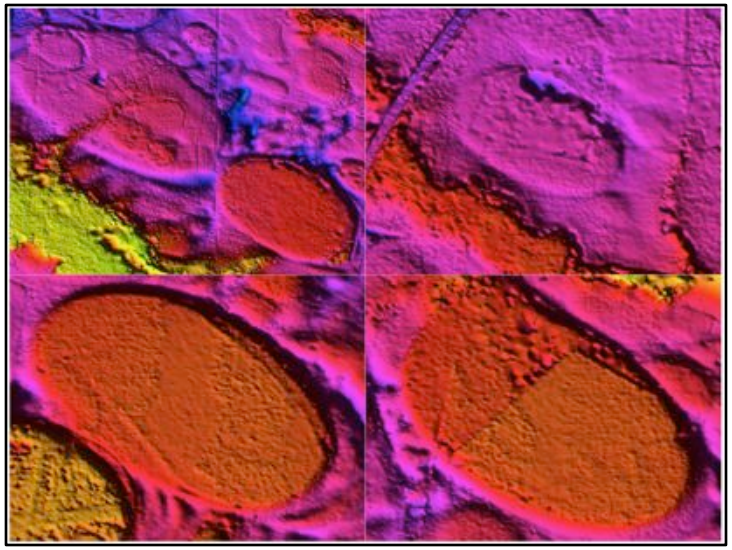

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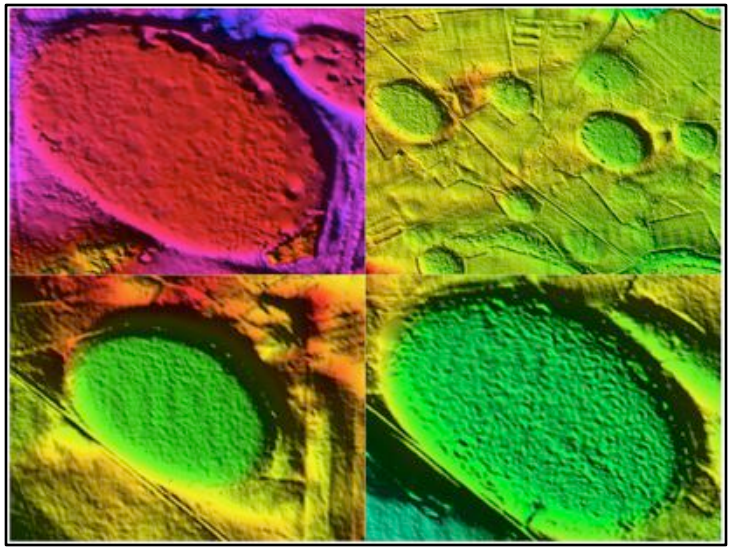

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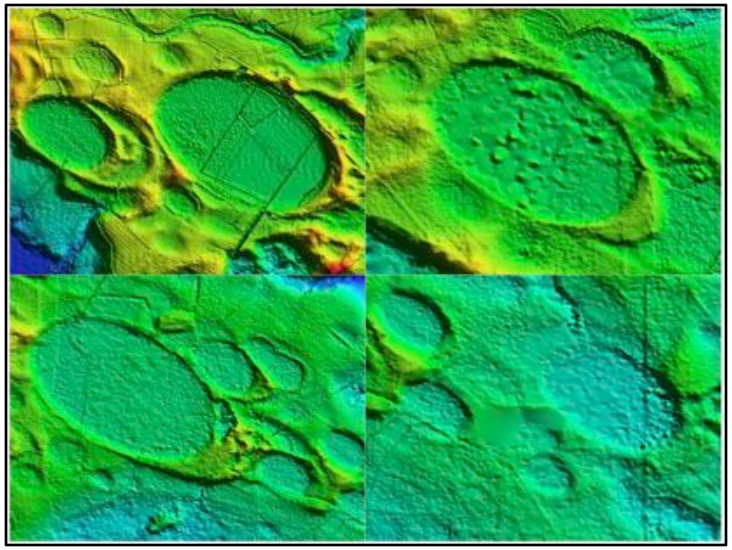

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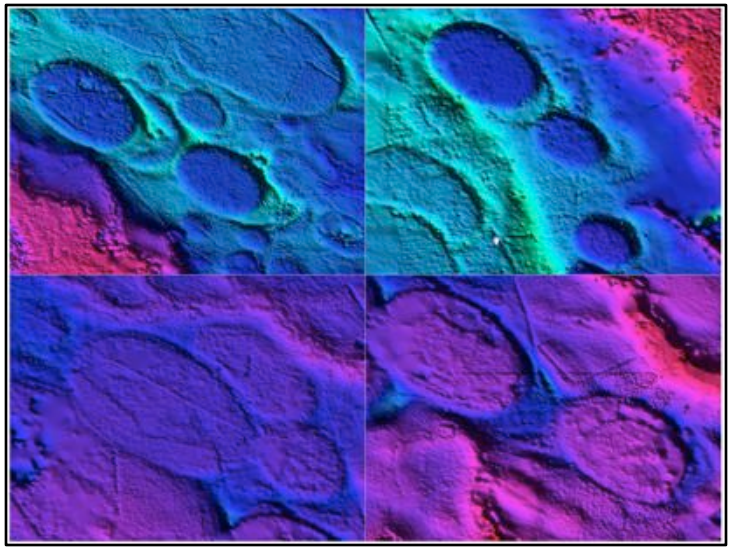
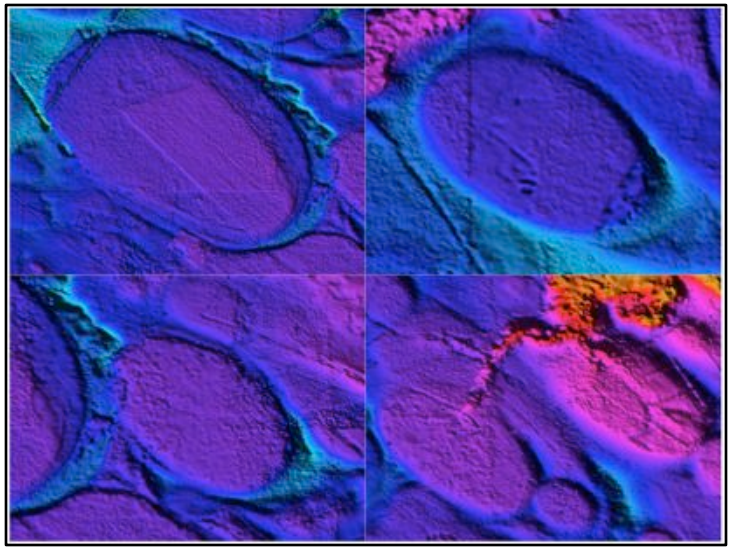


Detail of bays near Rex, NC.



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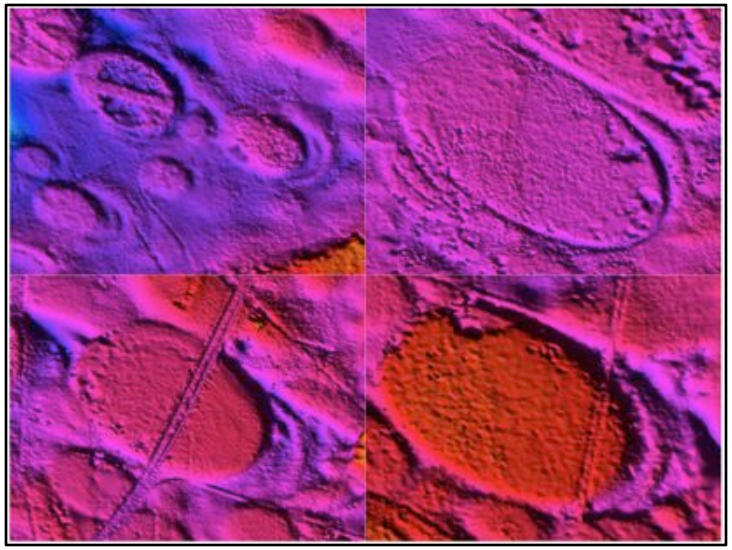

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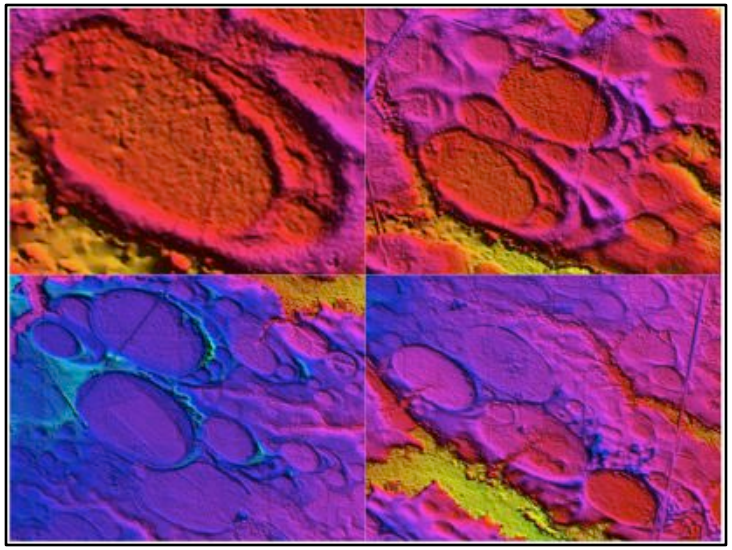

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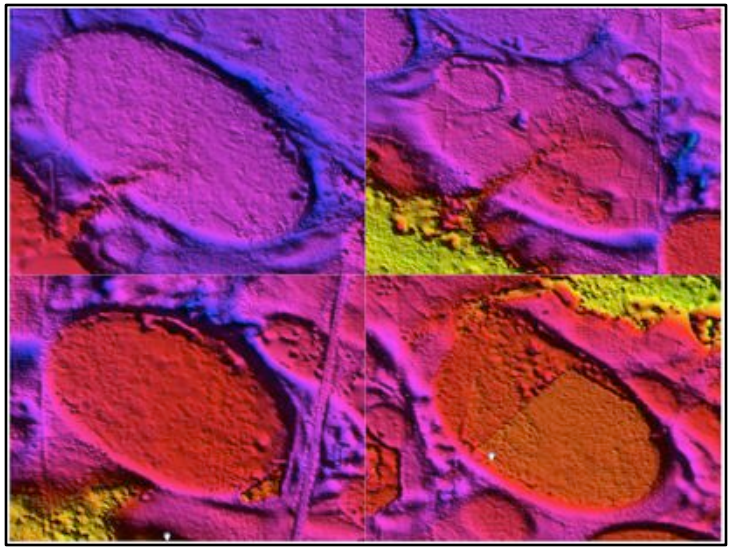

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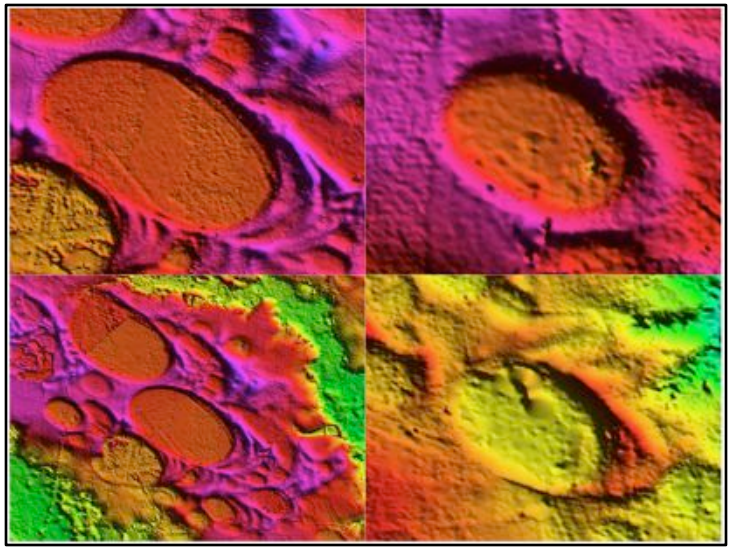

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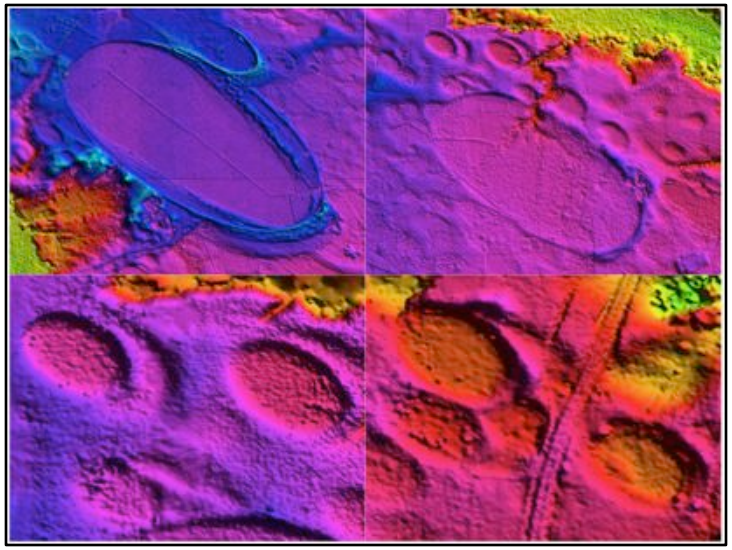

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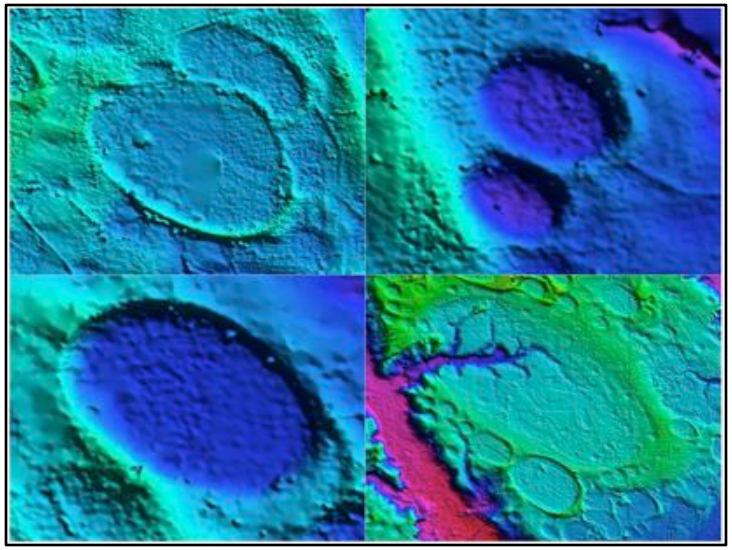

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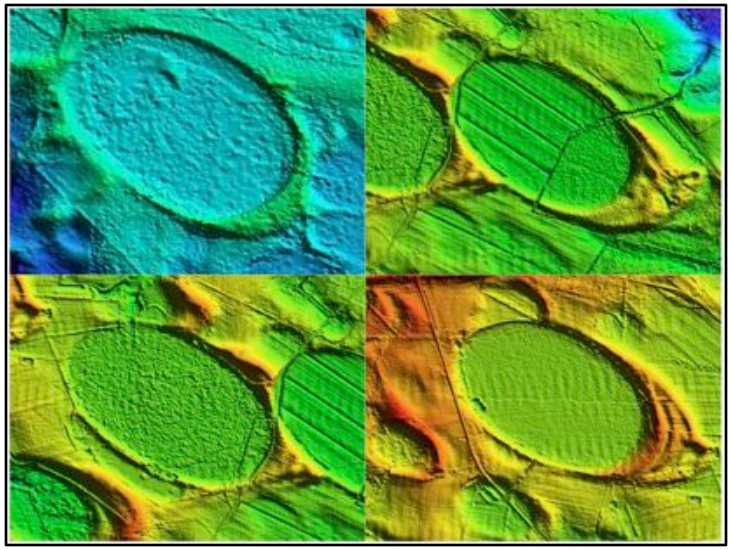

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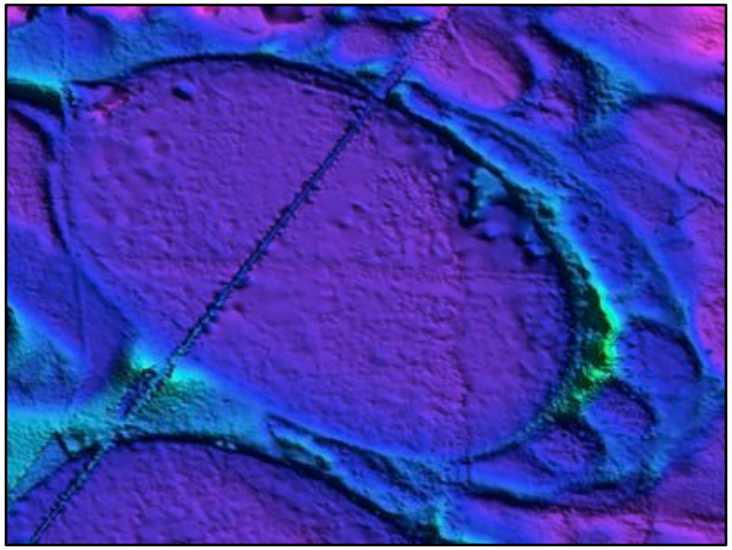
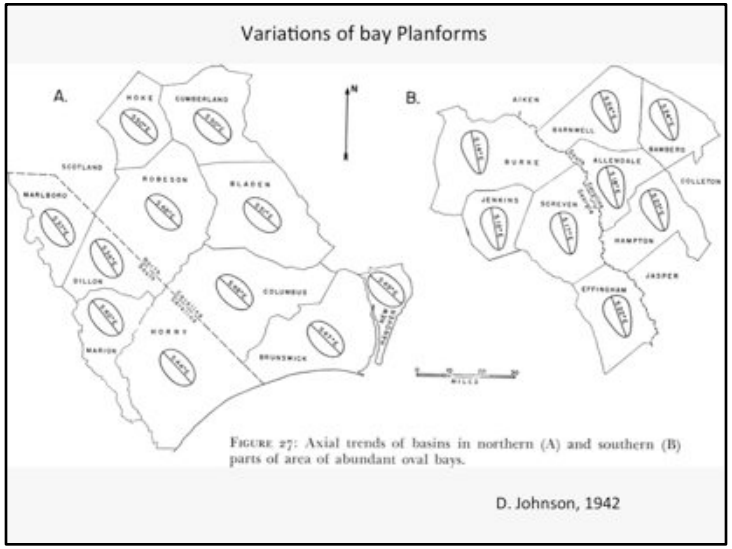
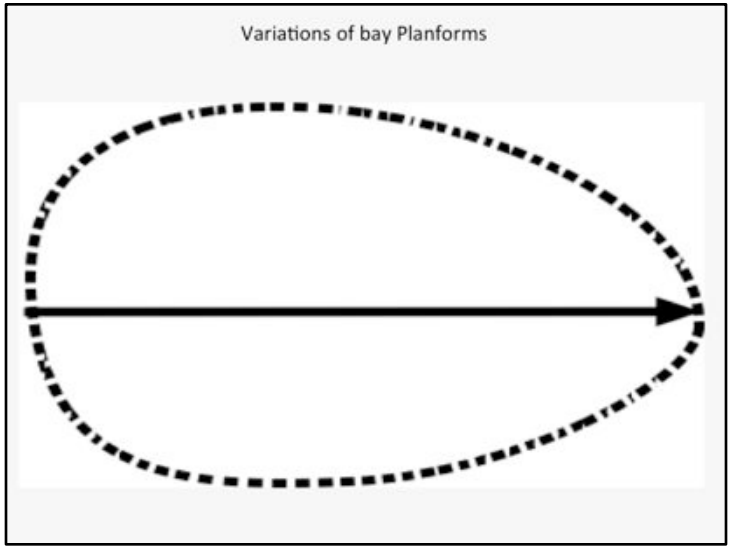


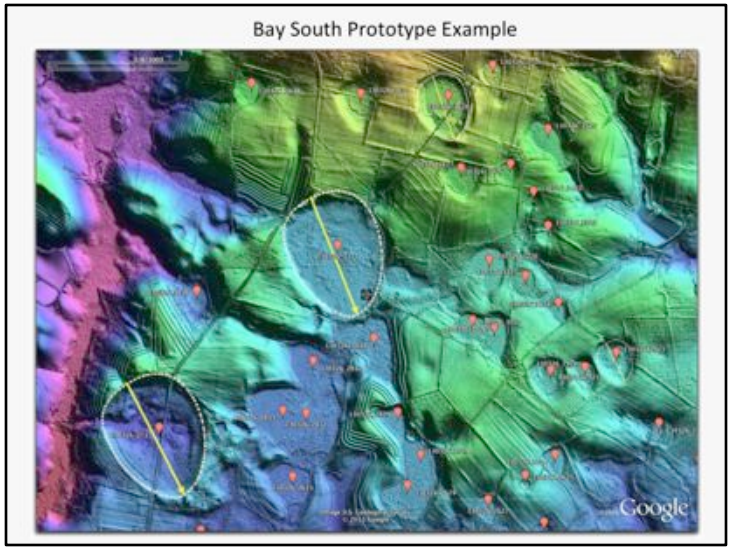
Detail of bays near Rex, NC. The juxtaposition of the large bay with the smaller bays clustered at the SE end are considered to be a “Daughter Bubble” scenario, where a large bubble collapses and new bubbles are formed by vapor entrained in the collapsing bubble wall.



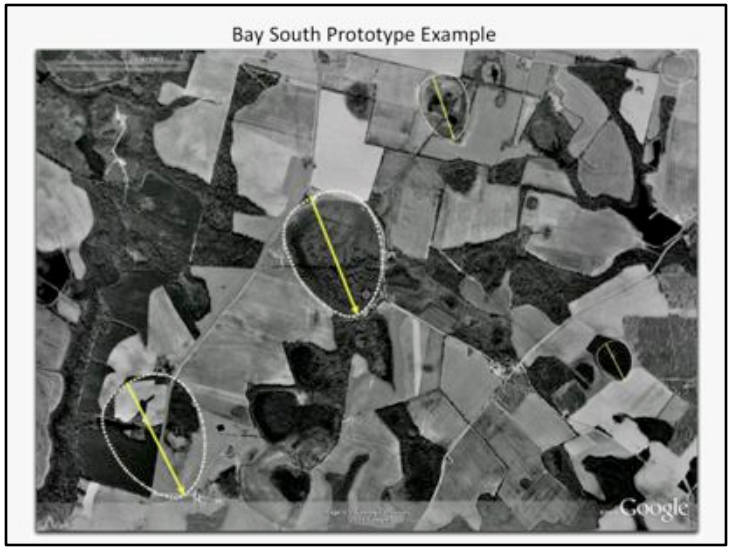
Douglas Johnson documented his version of these two bay types in his book *The Origins of the Carolina Bays*, and we note them in the same general areas. Obviously there is a gently transformation from one style to the other, as the bays are found to exists on a near-continuum across the region.



This is the “South” bay archetype. It presents a more pointed SE end, and a broader NW end.

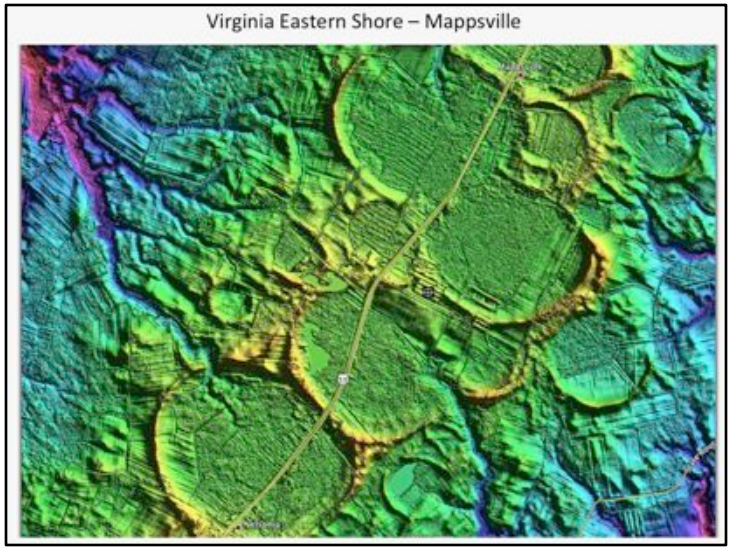


Bay South Prototype Example in LiDAR

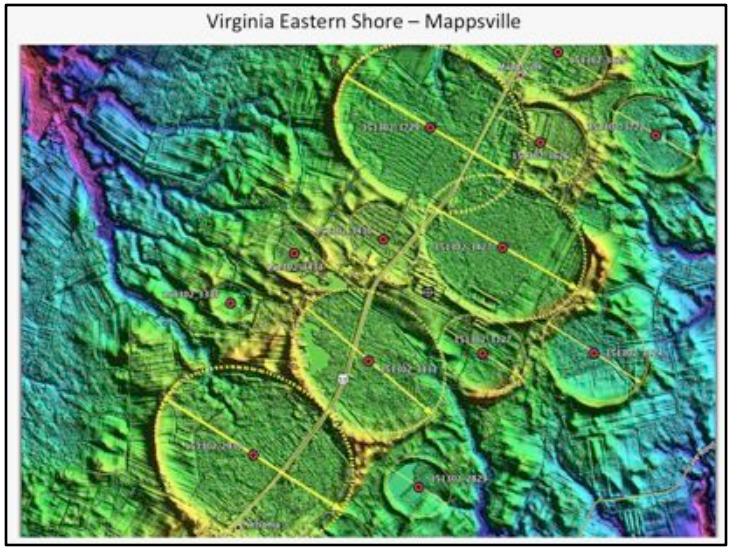


Bay South Prototype Example I Google Earth imagery

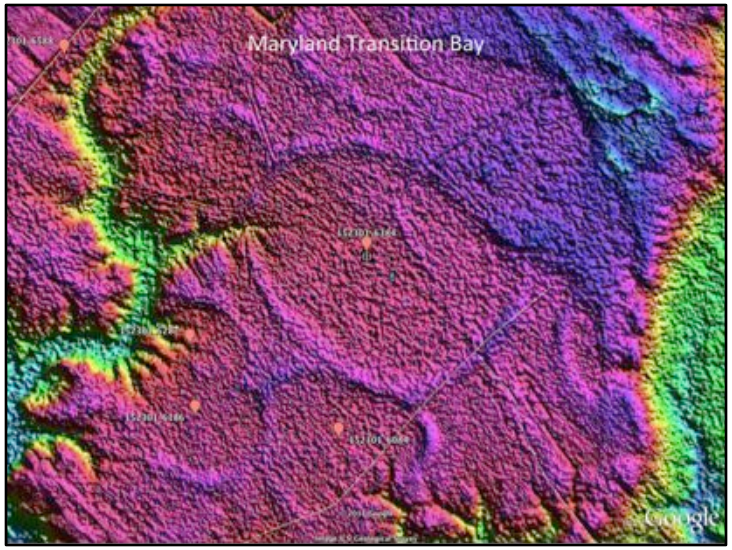
Oval Planform: Virginia Eastern Shore – Mappsville using Google Imagery



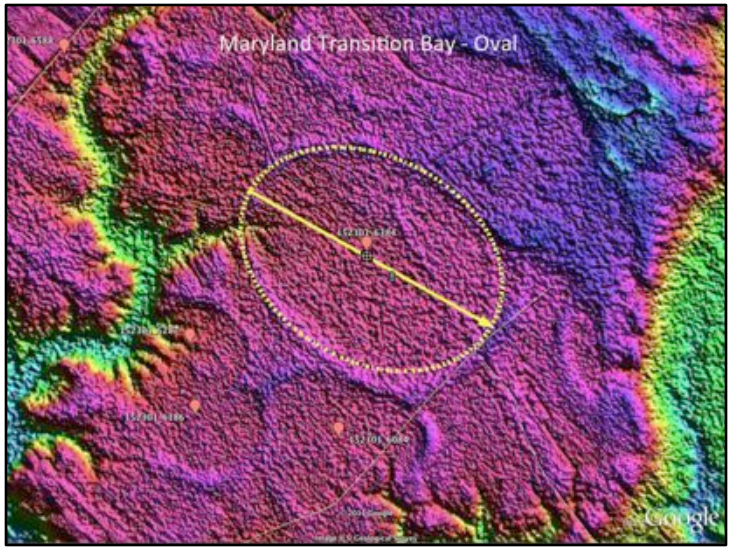
Oval Planform: Virginia Eastern Shore – Mappsville using LiDAR DEM created with recently released elevation data from College of William and Mary/



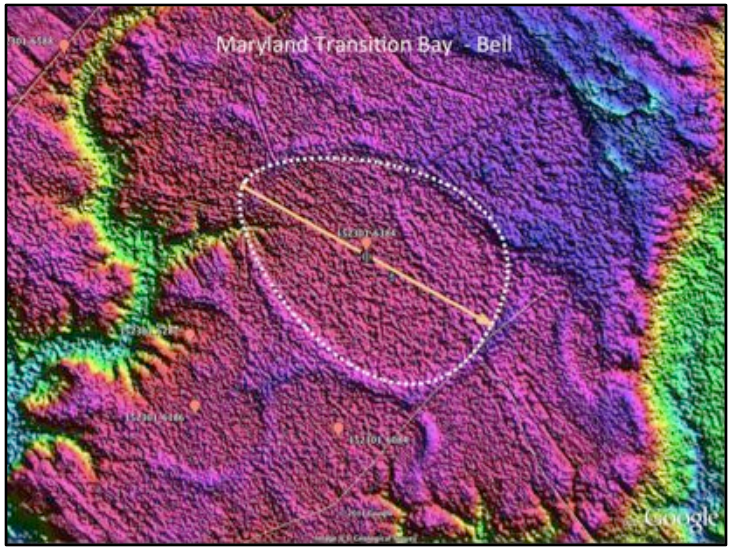
Oval Planform: Virginia Eastern Shore – Mappsville using LiDAR DEM with overlays in place for measuring bays.



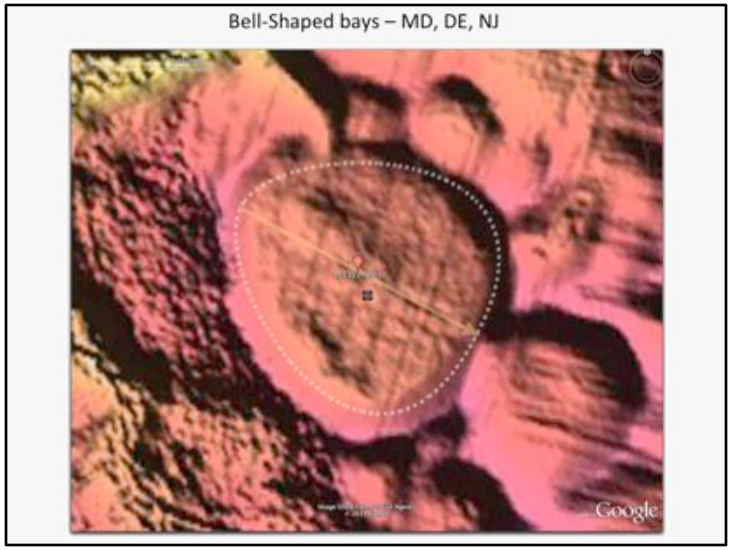
Further north into Maryland, another archetype appears.



If we place the oval overlay, we see it does not capture the broad SE end, nor the more pointed NW end.



Here is the “Bay Bell” Archetype seen robustly across Maryland, Delaware and New Jersey



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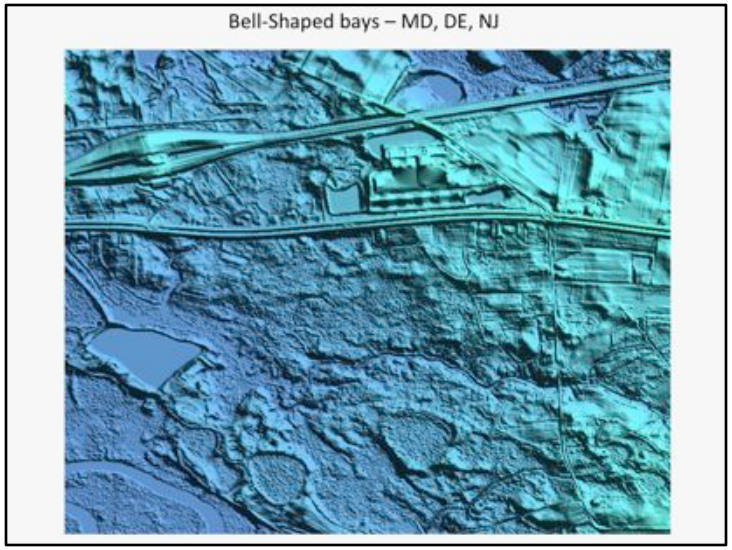
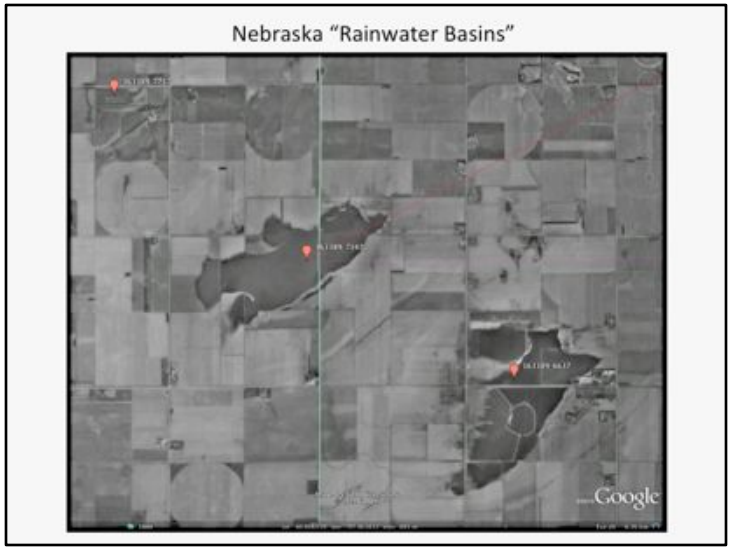
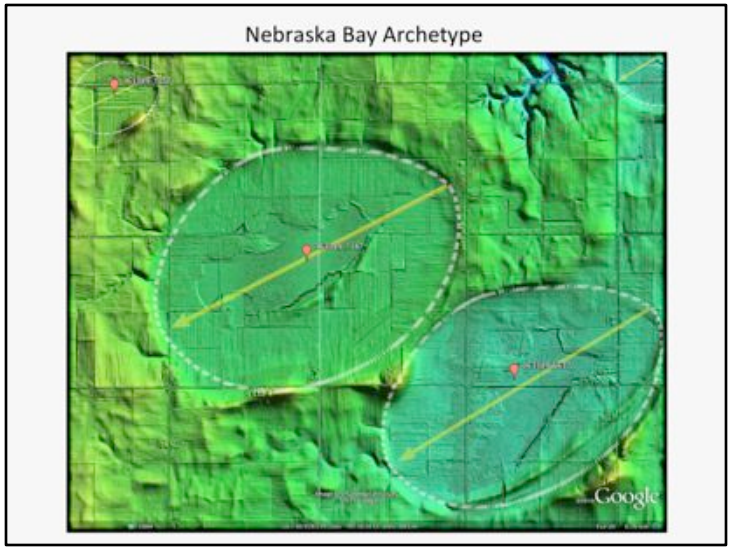


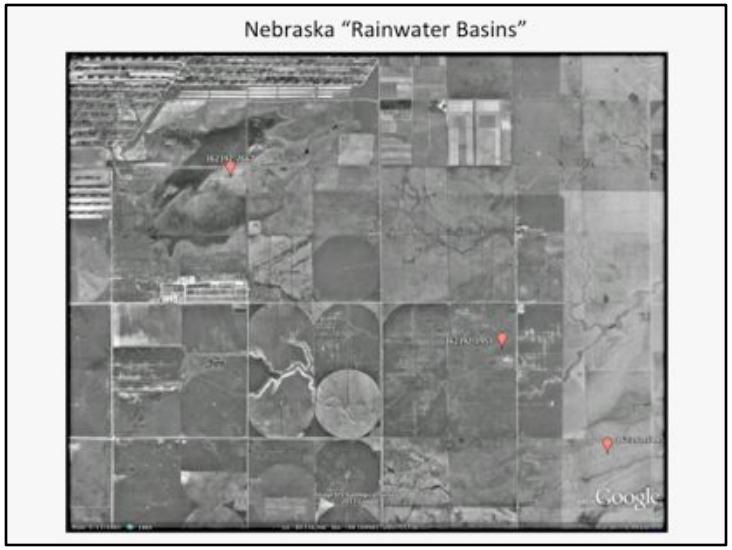
Here is the “Bay Bell” Archetype in New Jersej, just east of the Delaware Memorial Bridge. Note the farmed-over bay between TPK and US 40, upper right. In the Delaware River flood plain, 6 more bay bell planforms are seen in different sizes, all displayin



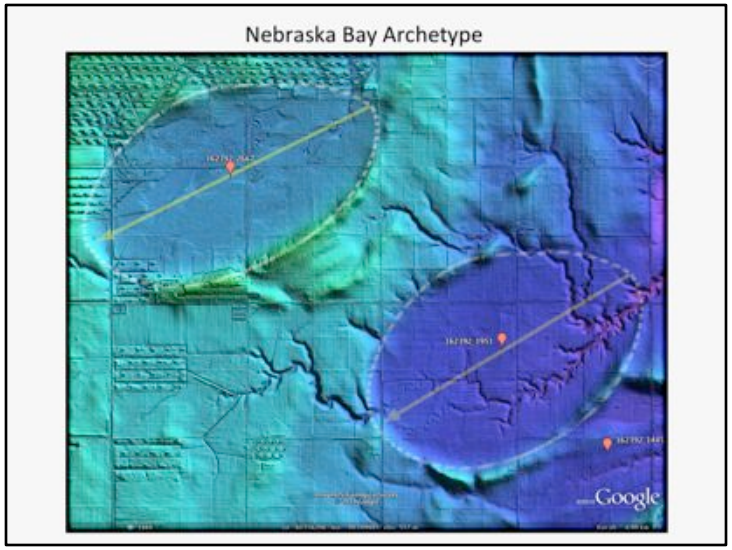
Nebraska “Rainwater Basins” seen in Satellite imagery



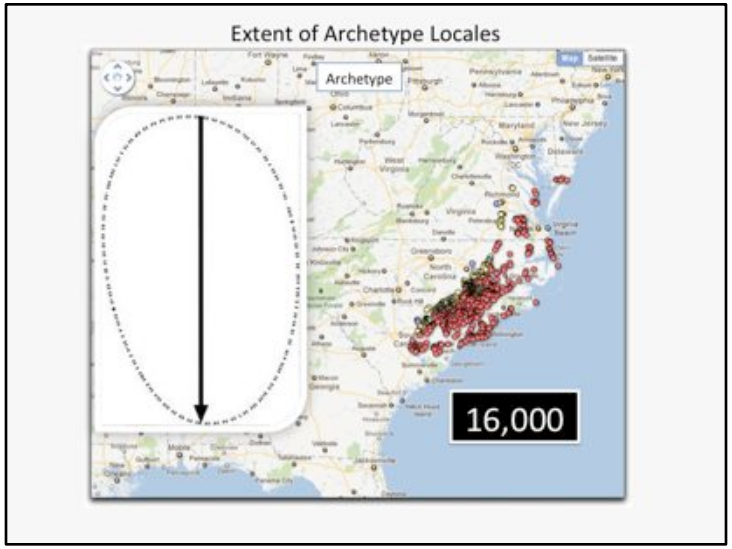
Nebraska “Rainwater Basins” seen in LiDAR imagery created with Nebraska DNR elevation data.



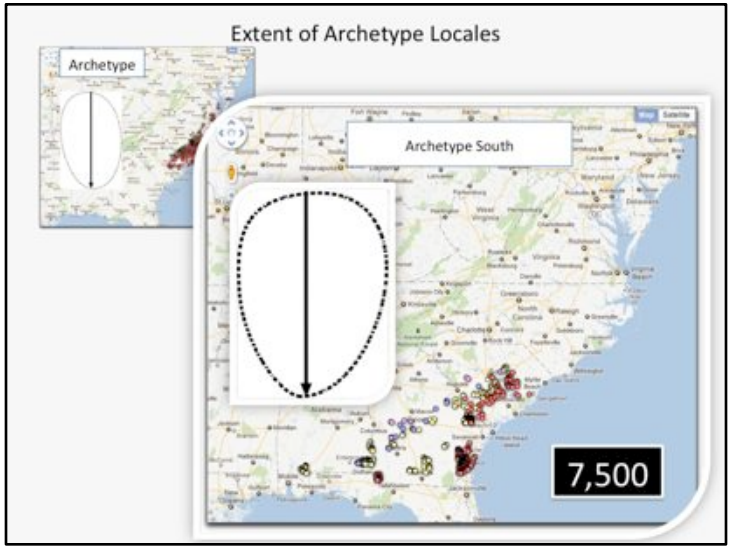
More Nebraska “Rainwater Basins” seen in Satellite imagery



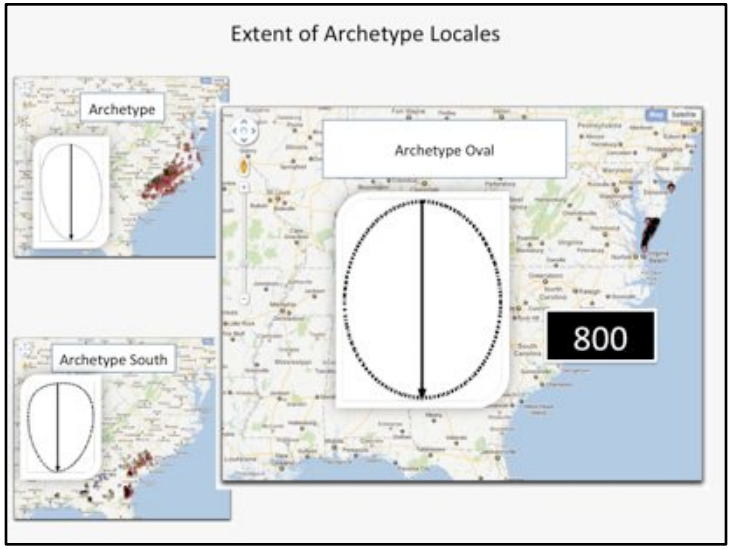
More Nebraska “Rainwater Basins” seen in LiDAR imagery – 0ver 500 such bays are identified an measured in the survey



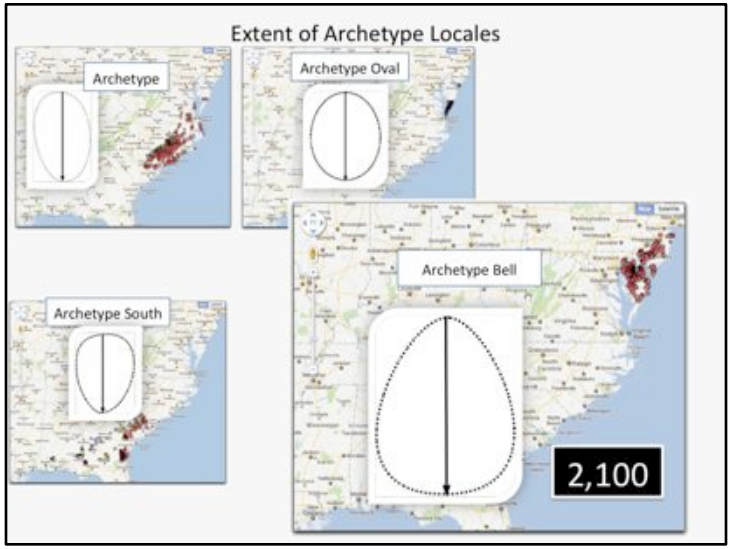
Spatial distribution of the central Carolina planform – 16,000 in survey. This is a Fusion Table map visualization, filtered by planform type .



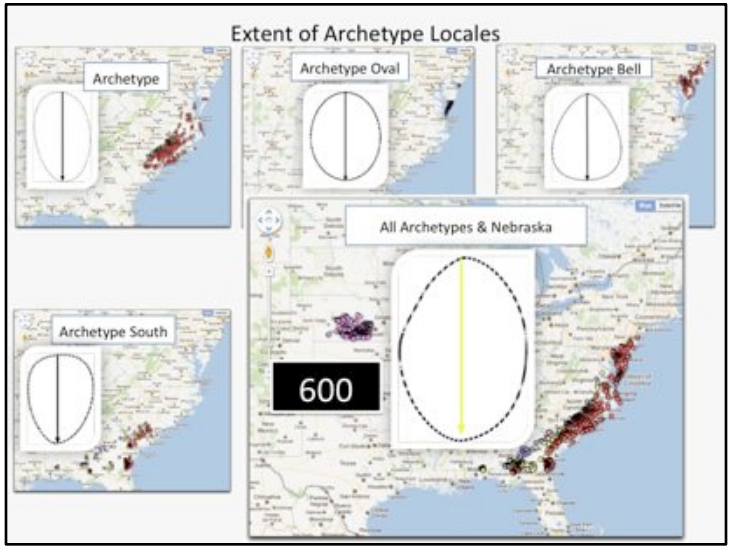
Spatial distribution of the “South” planform – 7,500 in survey. This is a Fusion Table map visualization, filtered by planform type .



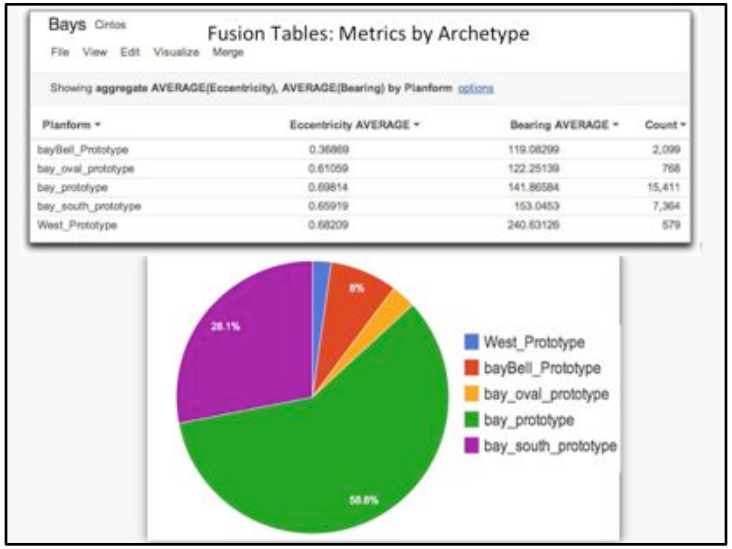
Spatial distribution of the “Oval” planform – 800 in survey. This is a Fusion Table map visualization, filtered by planform type .



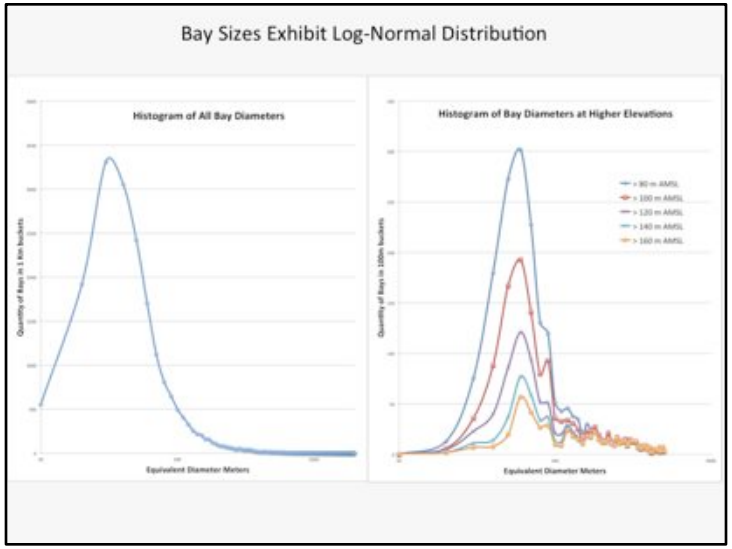
Spatial distribution of the “Bay Bell” planform – 2100 in survey. This is a Fusion Table map visualization, filtered by planform type .



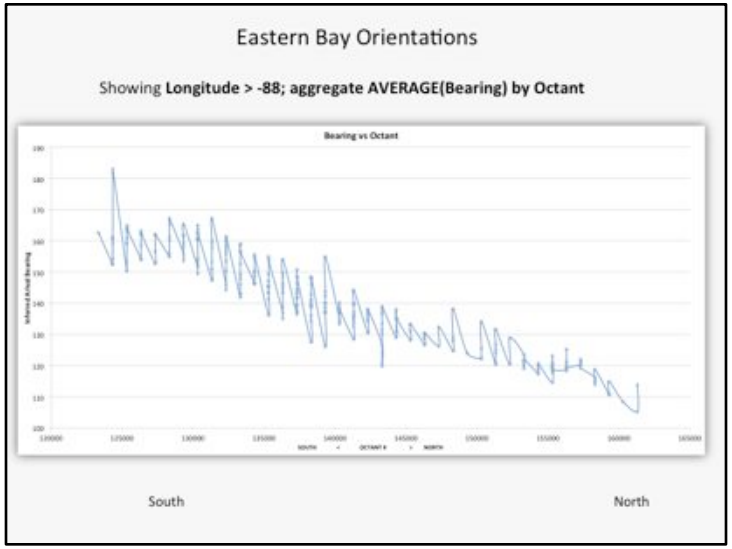
Spatial distribution of the “West” planform – 600 in survey. This is a Fusion Table map visualization, filtered by planform type, and also shows the distribution of all bays identified in the survey.



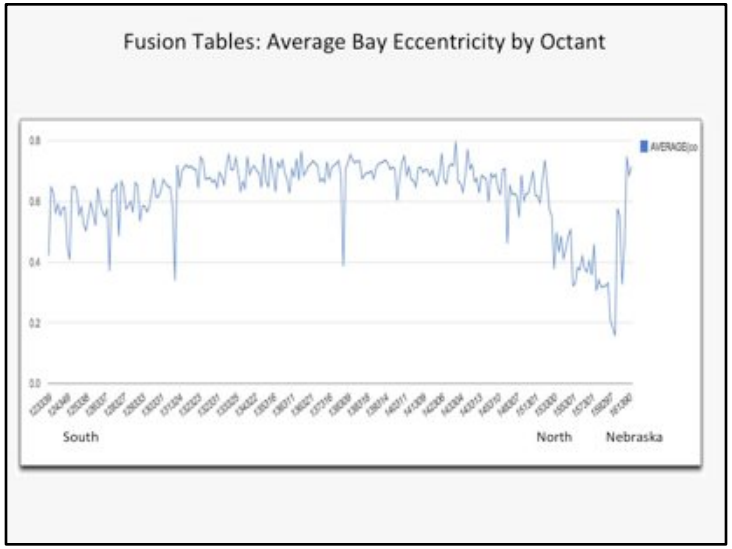
Two of the possible Fusion Tables visualization types. Table shows Eccentricity and Bearing aggregated by planform type. Pie chart shows count of bays in the 5 planform shapes.



On your left is a histogram of all bay sizes in the survey , exhibiting a classic log normal distribution. Contrasted on the right is the log-normal distribution of bays found above 80 m in five ranges. We suggest this statistically associates each of these groups with the main body of bays. i.e., one common geomorphology. And what is that exactly? Who knows!



Fusion Table chart visualization of average bearing aggregated by Octant. Facility only offers Averages, hopefully other statistical values such as means will be added to functionality. Reads from south to north as Octant value increases. Saw tooth driven by longitude variations at each latitude.



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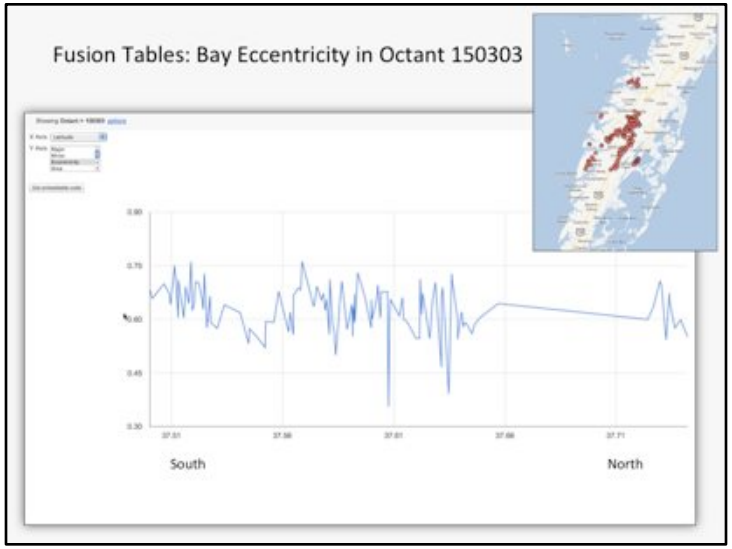

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Summary

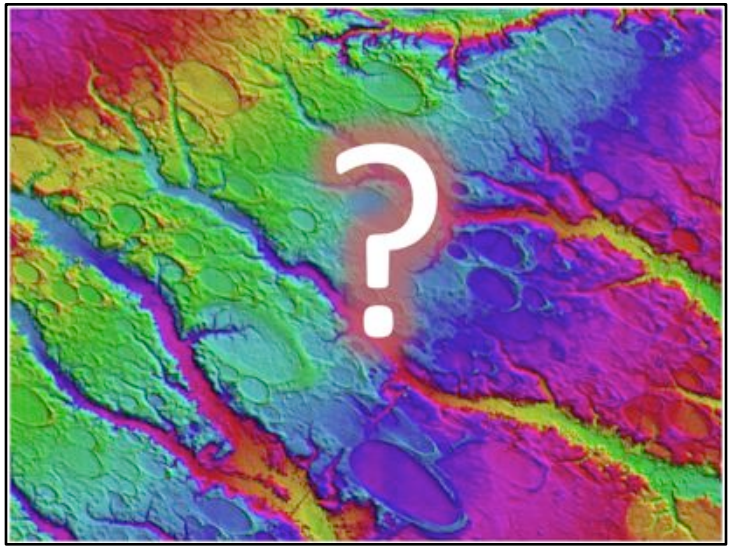
- Integrated thousands of LiDAR DEM images into Google Earth
- Identified and Documented ~ 27,000 Individual Bays
- Captured Individual bay Metrics
  - Location
  - Major & Minor Axis: yields Area & Eccentricity
  - Orientation
- Integrated data into Google Fusion Tables
  - Feeds Google Earth visualizations
- Observations
  - Bays exhibit tightly constrained planform shapes
  - Bays exhibit log-normal size distribution
- Survey is Remote Sensing Based Only
  - Ground-proofing efforts are non-existent

Open Questions

- How many bays exist? … 50,000?
- How were the bays were created?
  - … but we do speculate….
- Relationship between the various Archetypes
  - due to similar mechanisms?
- Do the orientations suggest a triangulation network focus?

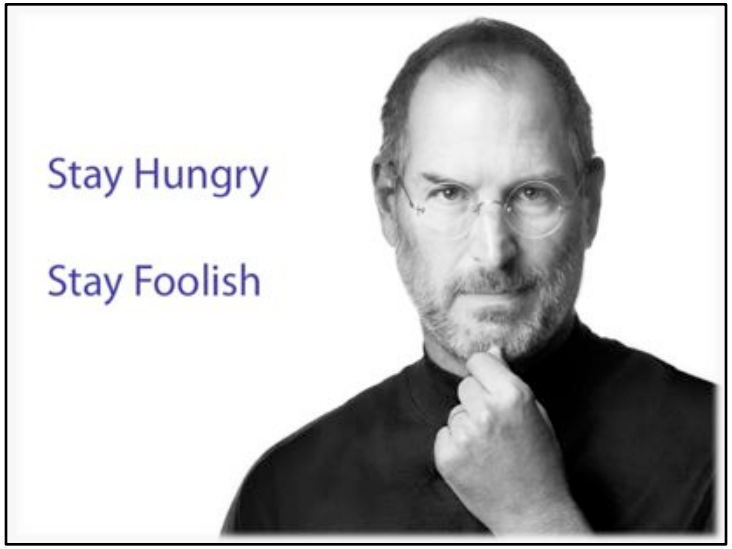
What You Can Do

- Access the Bays Survey, export a copy from **cintos.org/bays**
- Review individual bay planforms for voracity of identification
- Comment on quality of measurement based on your own observations
- Do statistical analysis on the orientations with a triangulation in mind



Questions?

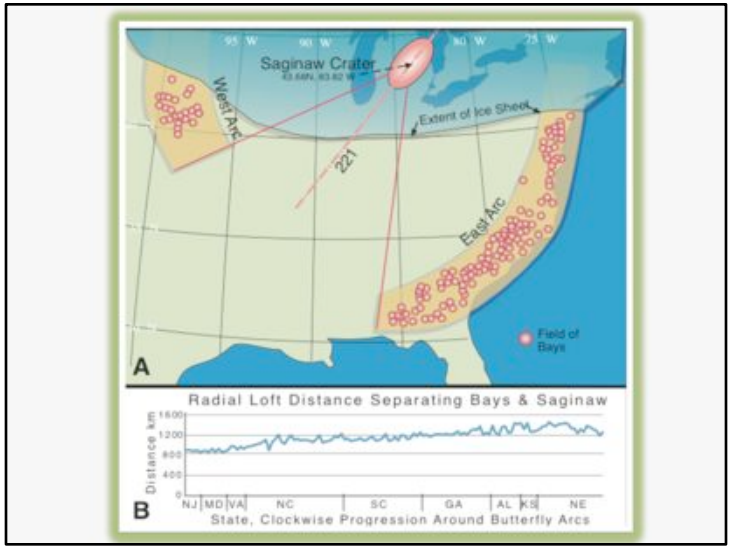
Abstract Geological Image category winner, Meeting's Photography Exhibition. This is displayed as the November 2012 image on the GSA 2012 Wall Calendar.



Steve Jobs
1955 - 2011

I’m hungry for the truth of bay genesis
And I’m foolish enough to pursue a catastrophic scenario

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.

Abstract

LIDAR DIGITAL ELEVATION MAPS EMPLOYED IN CAROLINA BAY SURVEY

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and GILBRIDE, Jeanette L., North Carolina State University, Raleigh, NC 27695

Aerial photographs of Carolina bays taken in the 1930's sparked research into their geomorphology, but revealed only part of their unique planforms. Digital Elevation Maps (DEMs), using LiDAR-derived data, accentuate the visual presentation of these shallow basins. To support a geospatial survey of Carolina bay landforms in the continental US, 400,000 km^2 of hsv-shaded DEMs were created as KML-JPEG tile sets for visualization on a virtual globe. A majority of these DEMs were generated with LiDAR data, while the remainder represents USGS 1/3 arc second data. We demonstrate the tile generation process and their integration into Google Earth for open public access over the Internet. While the generic Carolina bay planform is considered oval, we document regional variations. Using a small set of empirically derived planform shapes, we created Google Earth overlay elements to support the manual capture of individual Carolina bay shapes and orientations. The resulting overlay data element for each measured bay is extracted from Google Earth and programmatically processed to generate metrics such as geographic location, elevation, surface area and inferred orientation. When visualized in LiDAR, we document the robustness of a single planform shape across hundreds or thousands of basins within geographically large areas. We maintain that utilizing a virtual globe facility for data captures and extraction results in more reliable data sets compared to processes that reference flat map projections. This is especially true when capturing the geospatial shape and orientation of the bays, which can be skewed and distorted in the projection process. Using the process described, we have measured over 25,000 distinct Carolina bays, and have assembled their individual characteristics into a geographic information database. We examine the Google Fusion geospatial visualization facility, through which the database has been made publically accessible. Preliminary findings from the survey are briefly discussed, such as how bay surface area, eccentricity and orientation vary within and across ~700 ¼º x ¼º grid elements.

Session No. 165 - Seeing the True Shape of Earth: Quantitative and Qualitative Applications of Airborne LiDAR
Minneapolis Convention Center: Room 101DE, 8:00 AM-12:00 PM, Tuesday, 11 October 2011

Abstract text.