THE GEOLOGICAL SOCIETY OF AMERICA®
CONNECTS
2022
9–12 October
Denver, Colorado, USA
& Online Everywhere

GEOSPATIAL SURVEY OF HIGH PLAINS PLAYAS USING HIGH RESOLUTION TOPOGRAPHIC MODELS

Poster Session 164 : Booth #25

Michael E. Davias
michael@cintos.org

Abstract

The High Plains Playa basins found across wide areas of the western United States represent a class of water retaining, hydraulically closed, ovoid basins comparable to the Carolina bays of the Eastern US and Rainwater Basins of Nebraska. The playa are generally considered to have an eolian and karst geomorphology and are embedded within members of the Blackwater Draw Formation, whose sediments lie above the calcified caprock of the High Plains aquifer. The genesis of both the Playas and the surficial sediments they are found within are the subject of ongoing research. The presence of these closed basin on the High Plains may be the primary source of recharge to the regional aquifers. Playa are in constant pressure of anthropological alterations, making their continual existence an ecological and economic imperative. The establishment of the playa-dotted landscape may well have also moderated the climate of the region during the Quaternary by buffering open water subaerially. The advent of Light Detection and Ranging technology facilitated a new look at these landforms using High Resolution Topographic Models (HRTMs). A westward extension of a geospatial survey leveraging seamless HRTMs has encountered these gentle basins. Employing Google Earth as a freely available visualization platform, the facility discussed offers a unique perspective on their shapes, sizes, and spatial distribution. Access to the imagery is freely provided for non-profit use by accessing a cloud-based repository using a light-weight keyhole markup file. The implementation leverages techniques to minimize download bandwidth based on the user's viewport. Examples of the HRTM imagery is provided, along with a discussion of the GIS workflow from source datasets to displayed imagery.

Ovoid Basin Geospatial Survey

> ***"Their very randomness of grouping and scatter demands an explanation. As a statistical phenomenon, they deserve to be studied statistically."*** - William C. Rasmussen, 1953 [1]

A detailed geospatial survey (Survey) of shallow ovoid basins has been underway since 2010 [2]. Our motivation is to properly characterize a family of low-relief landforms (1-10 m topography) of significant size (100 m to multi km). Such data may encourage geoscientists to consider research into their geomorphology, history and relationships between family members.

The Survey data includes an Excel spreadsheet with one row per measured landform, and HRTM geospatial visualizations which leverage Google Earth's virtual globe. Survey work product is provided freely on the web.

The HRTM featured on this poster is a small extract from the actual Survey's dataset. This particular footprint can be viewed on SOAR.earth using the QR code in lower right of the image. The full geospatial Survey can be accessed using the url listed in the References panel.

Initially focused on the Carolina bays of the Eastern Atlantic Coastal Plain, the Survey has was extended to include basins along the Gulf Coast and interior areas. In 2011 the Rainwater Basins of Nebraska were added, and more recently the High Plains Playas found across New Mexico, Texas, Oklahoma, Colorado and Kansas have been under consideration.

Most of the High Plains region has been added to the HRTM deliverable, but the surveying effort for the Playa's ovoid aureole and catchments is only beginning. Only about 7,000 playas have been measured out of an expected 66,000 [3]. Those range in size sizes from 1 to 2500 hectares. The process is ongoing and results will be added to the cloud files.

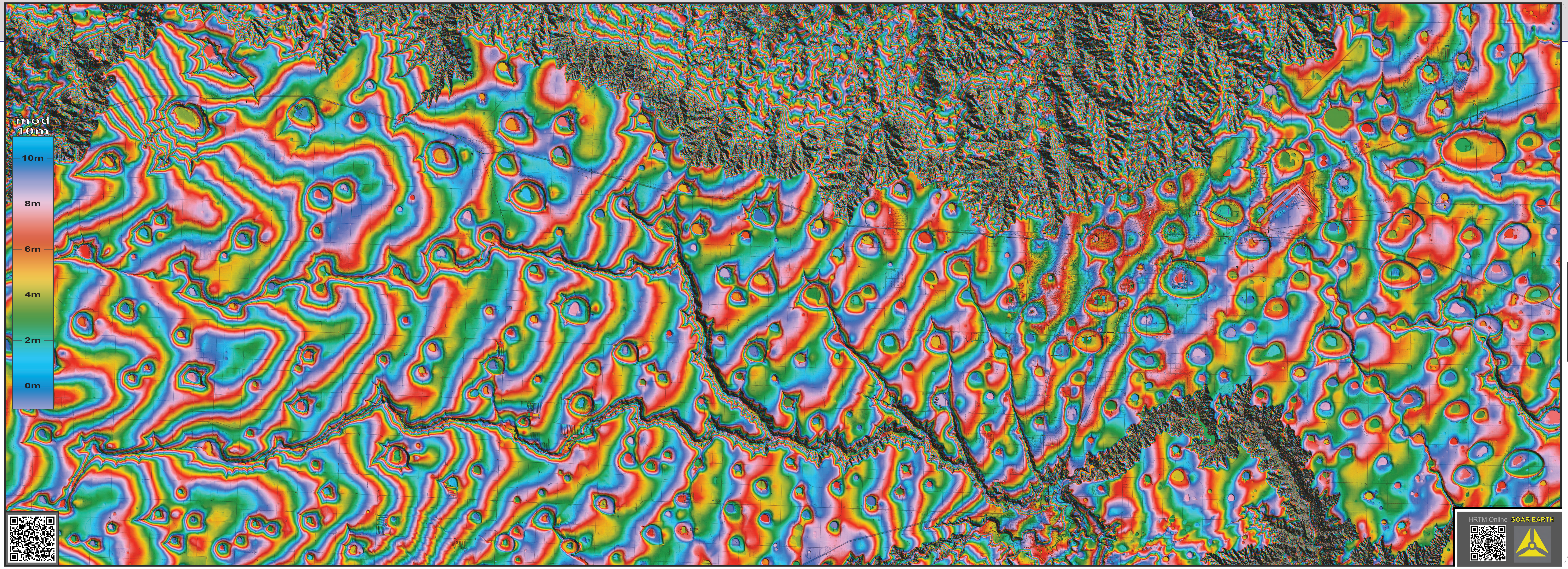
A benefit of HRTMs are their ability to identify anthropological alternations to the basins. In many places the basins are no longer hydrologically closed owing to ditching and draining efforts. Many playas have catchments dug to concentrate precipitation for agricultural or livestock use.

HRTM Generation Protocol

High Resolution Topographic Models are assembled from public LiDAR derived elevation data sets (USGS, State's DNR, NOAA) into seamless USGS-named 1ºx1º quadrangles using the commercial Global Mapper GIS. Artificial hill shading is applied with a 20x elevation exaggeration to pump up the fine rim topography, which would be lost given these shallow basin morphologies. Sun angle is 45º azimuth and 45º elevation

The color ramp employed, shown on the left of the main map, is a cyclic Perceptually Uniform Color Map engineered to enhance the visualization of subtle landforms. When implemented in Global Mapper, elevations values are mapped modulo 10 meters, such that elevation value of "0 m", effectively mean sea level, is mapped to the darkest blue hue. Elevation value "10m" is also mapped to that blue hue. Effectively each color in the pallet is repeated every 10 meters. The approach provides a persistent elevation index that is relevant anywhere the HRTM imagery is presented. It also provides an in situ set of contour lines. When running the Survey on Google Earth, the color scale is presented using a fixed screen overlay. Google Earth's elevation value provides the coarse elevation to refine with the scale. The 100-color mapping table was engineered after an example from Peter Kovesi's web site at colorcet.com.

For further organizational benefits, the 1ºx1º quadrangles are subset during kml export into sixteen (16) ¼º x ¼º (15 minute, 15') quadrangles using the location's 3-digit modulo ¼º offset north of the Equator and its 3-digit modulo ¼º offset west of the Grand Meridian as a six-digit name yyyxxx. Maps for each 15' quad are rendered down from LiDAR quality to a 150 or 120 cm spatial grid to reduce download bandwidth. Global Mapper generates "regionalized" tile sets, with indexing that retrieves image tiles from a network-based service at an optimum resolution for the current Google Earth field-of-view and monitor resolution.



Google Earth

Google Earth is essential to the geospatial nature of the Survey. As a freely-distributed platform for visualizing the surface of the Earth it meets the criteria that the work product can be distributed without restrictions. Being multi-platform, it offers a solution that imposes few restriction on required computing hardware and performance. Finally, the product is utilized by both scientists and citizens across the globe, providing a diverse audience for the work product.

Global Mapper integrates with Google Earth with the ability to create georectified imagery which is seamlessly and efficiently visualized on the virtual globe, replacing satellite imagery.

The NetworkLink facility in Google Earth offers the advantage of crafting a facility that requests the vast majority of required data (placemarks, text boxes, HRTMs) over an Internet connection. Considering that a typical user would only be presented with a vanishingly small fraction of the data, this lowers the bandwidth costs and improves the user experience by being more responsive and allows for distribution of updates.

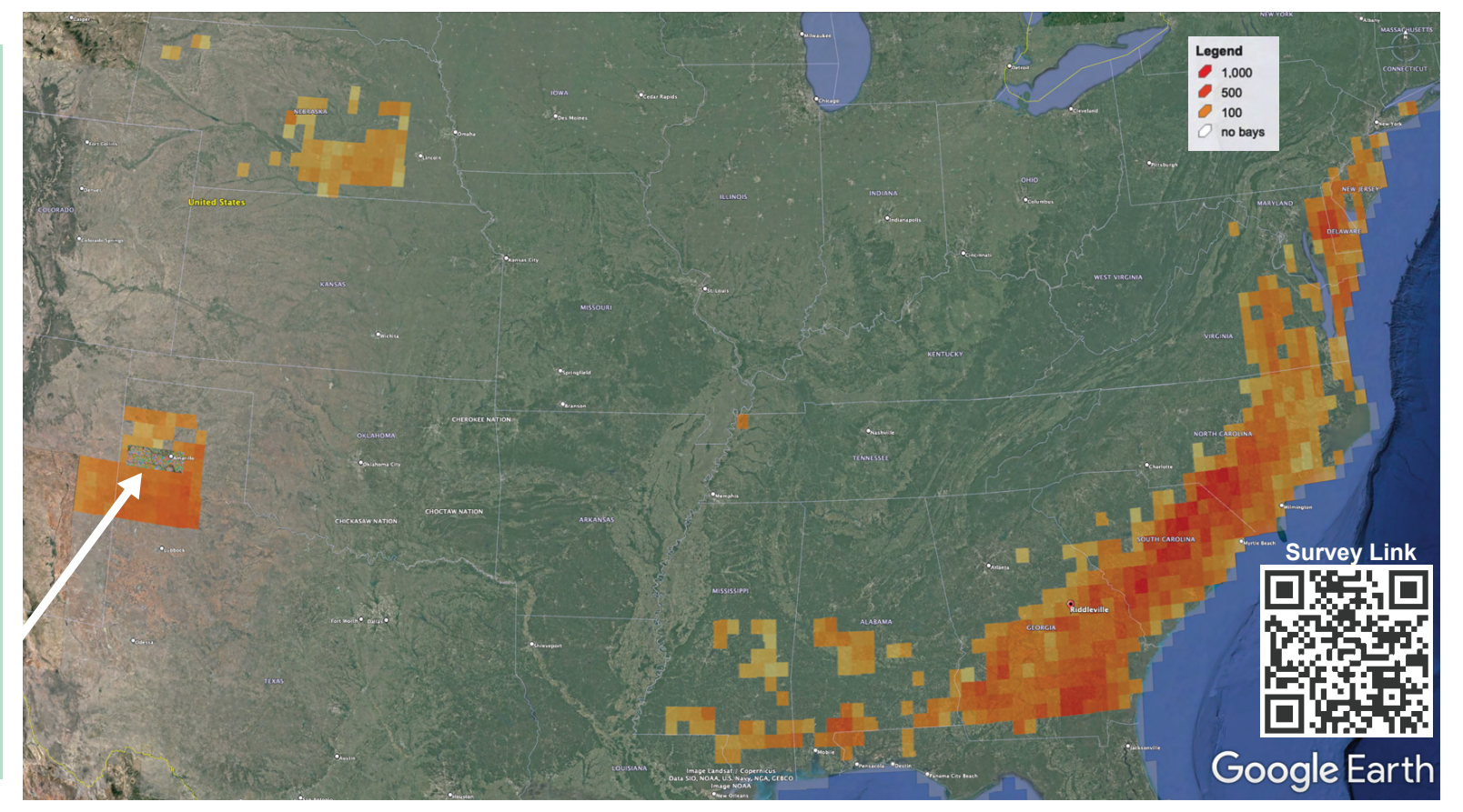
The GroundOverlay function is critical to the accuracy and reproducibility of the data capture aspect of the Survey, as discussed in the *Low Relief Planforms* section on the right.

Basins measured within a 15' quadrangle acquire a name based on the quadrangle's name, appended with a 4-digit index. This allows up to 10,000 basins to be indexed per 15' quadrangle in a format yyyyxxx-zzzz. Presentation of basins on Google Earth in the geospatial query mode is triaged by major axis to download the largest 10%, next largest 40% and smallest 50% based on field-of-view. This protocol avoids overloading Google Earth and network resources, while allowing spatial searches across the entire geographic span of the Survey.

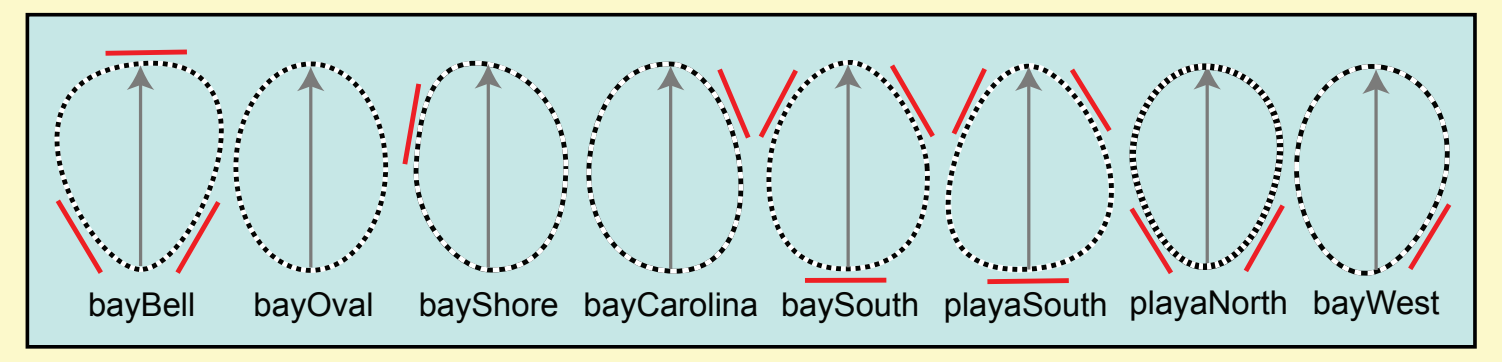
Access to the spatial data is enabled by a small file (2kb). The full dataset is currently ~450 Gbyte and is hosted in an Amazon S3 Bucket. The Survey's initialization file and the Excel database are downloadable from a links on a web page reached using the "Survey" url in the references or the QR code below.

A semi-transparent heat map is presented in Google Earth when fully zoomed out from the Survey's footprint. Using a color code, each 15 min quadrant that has measured basins provides a high-level indication of it's quantity of basins.

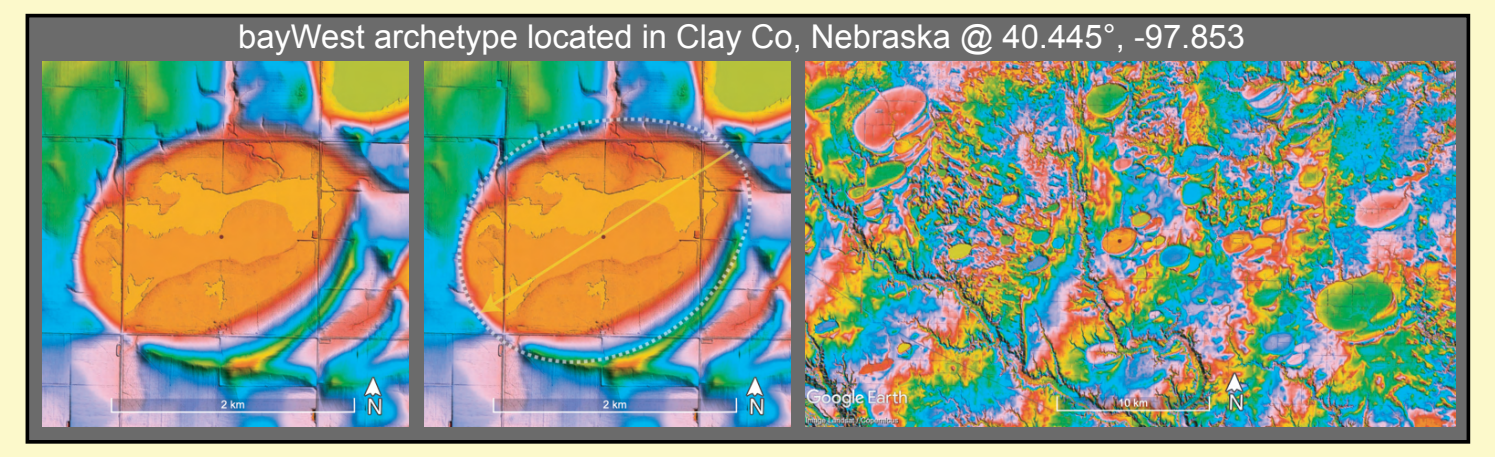
The location in Texas of the HRTM on the main panel above is indicated by the white arrow.



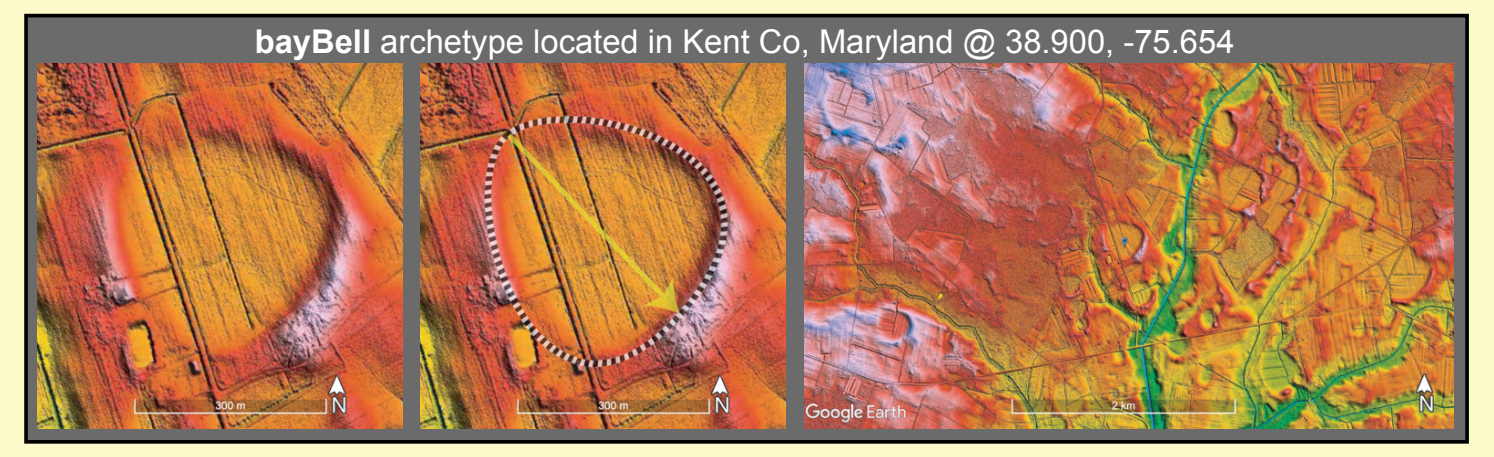
Low-relief Planforms



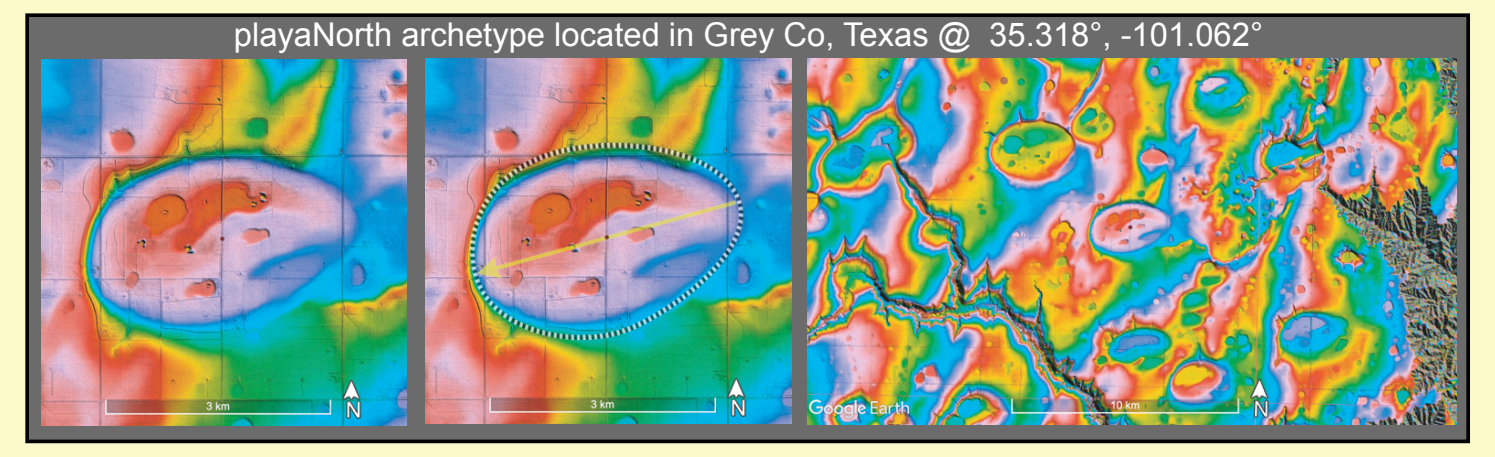
bayWest archetype located in Clay Co, Nebraska @ 40.445°, -97.853



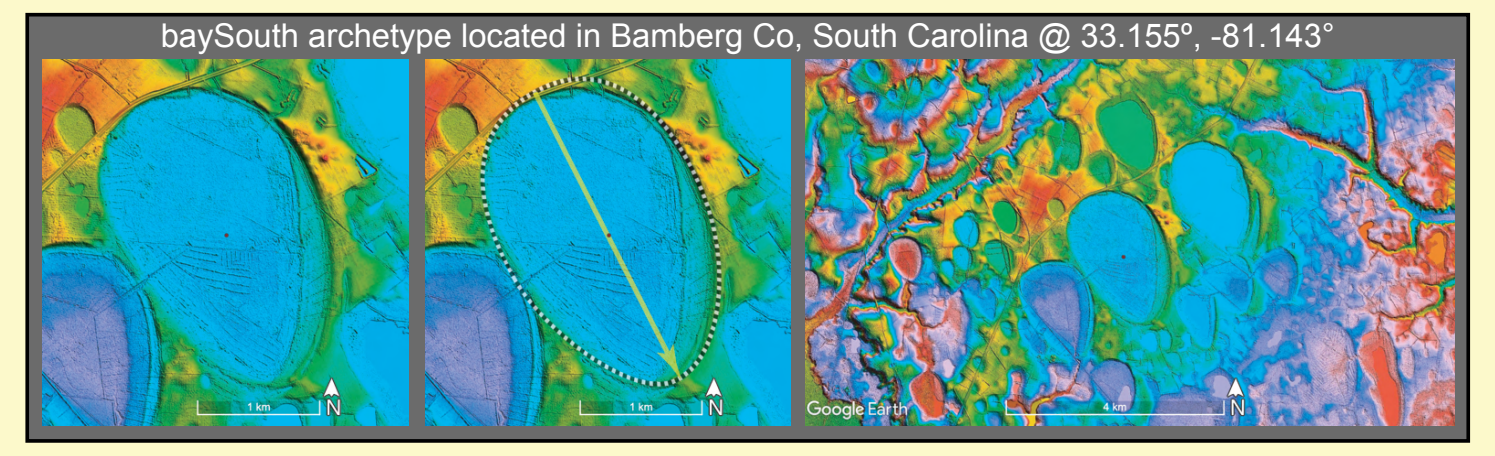
bayBell archetype located in Kent Co, Maryland @ 38.900, -75.654



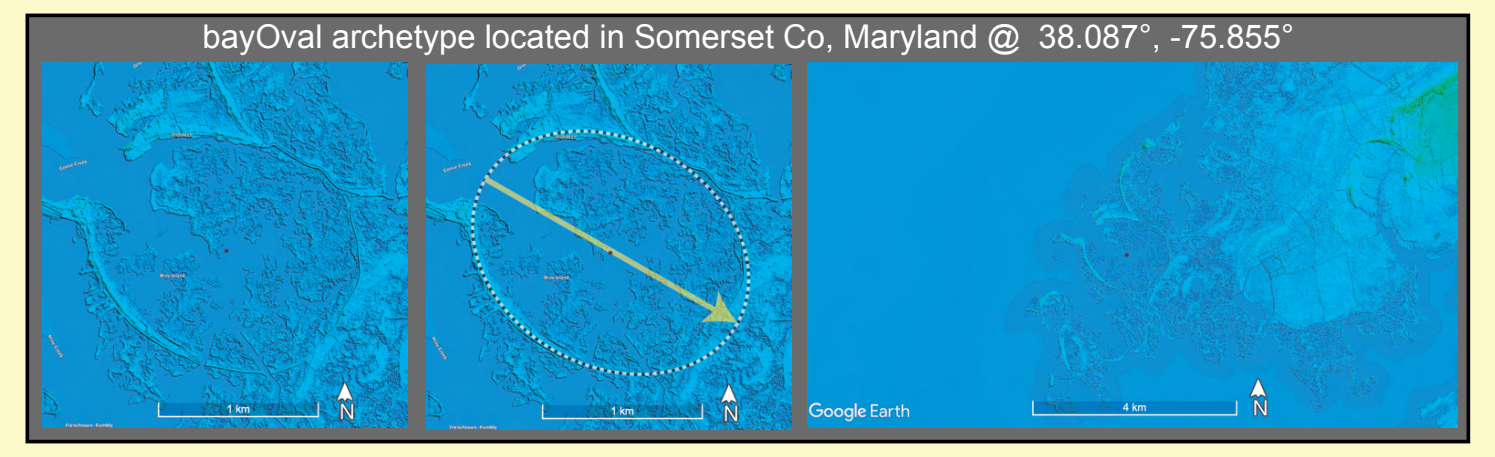
playaNorth archetype located in Grey Co, Texas @ 35.318°, -101.062°



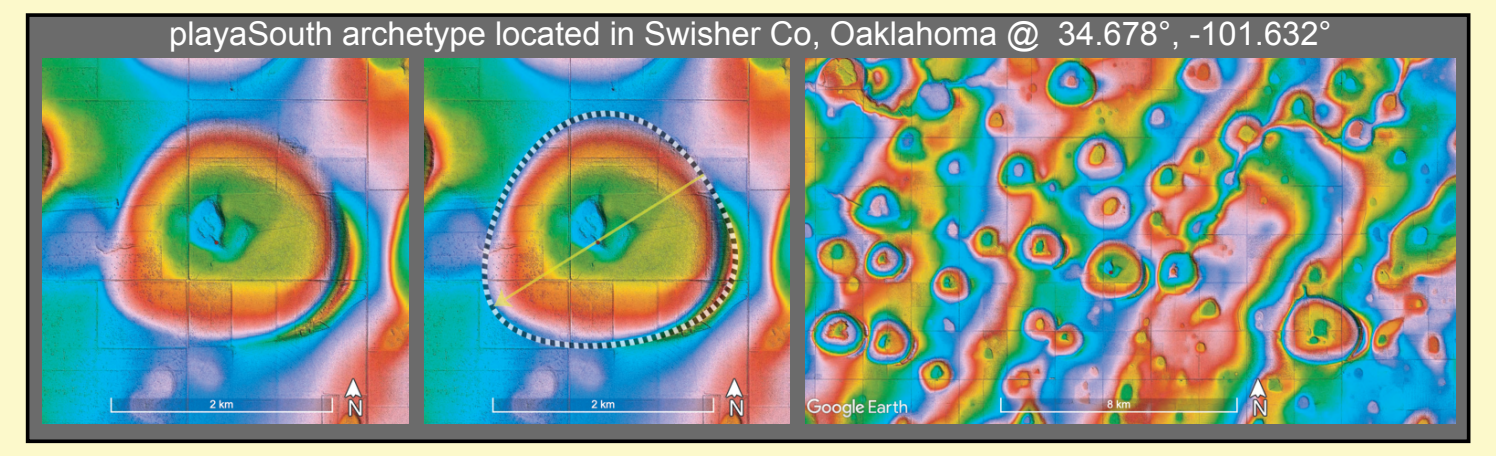
baySouth archetype located in Bamberg Co, South Carolina @ 33.155°, -81.143°



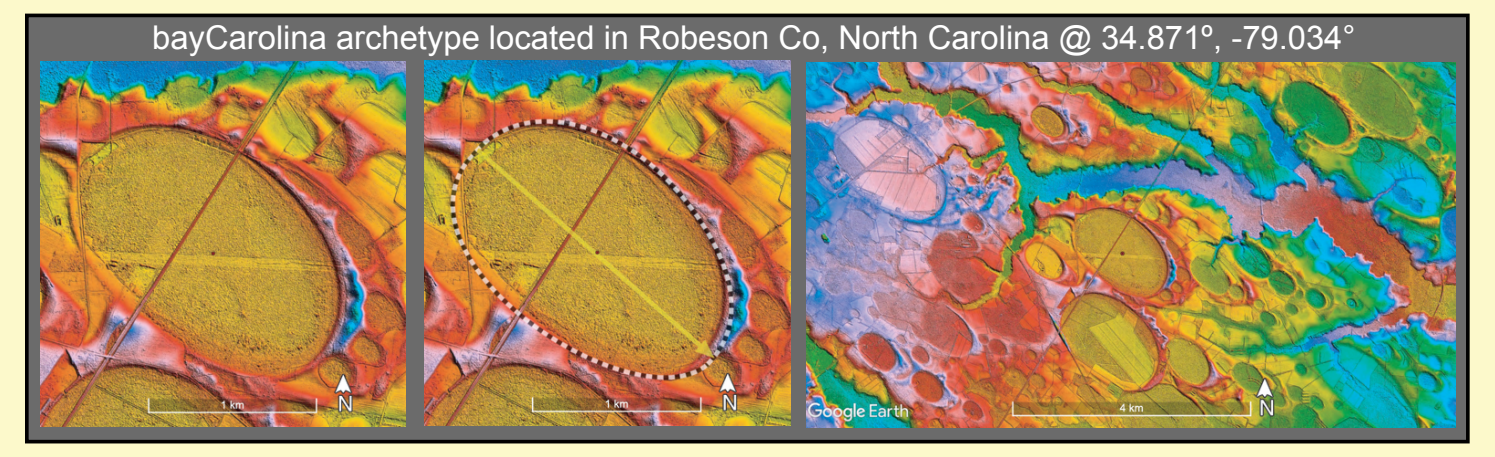
bayOval archetype located in Somerset Co, Maryland @ 38.087°, -75.855°



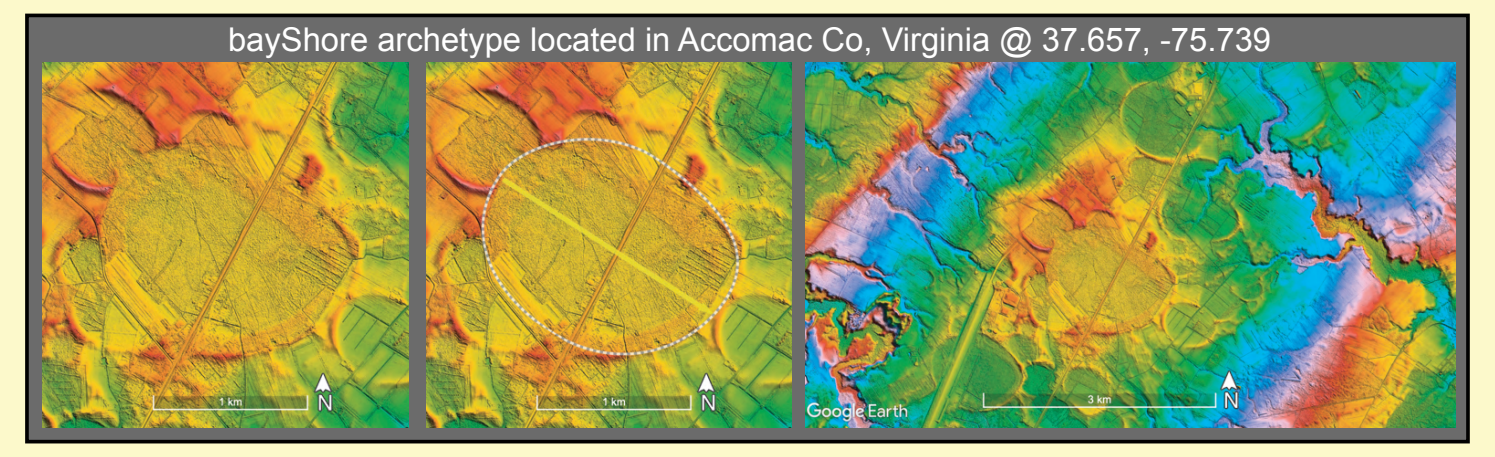
playaSouth archetype located in Swisher Co, Oaklahoma @ 34.678°, -101.632°



bayCarolina archetype located in Robeson Co, North Carolina @ 34.871°, -79.034°



bayShore archetype located in Accomac Co, Virginia @ 37.657, -75.739

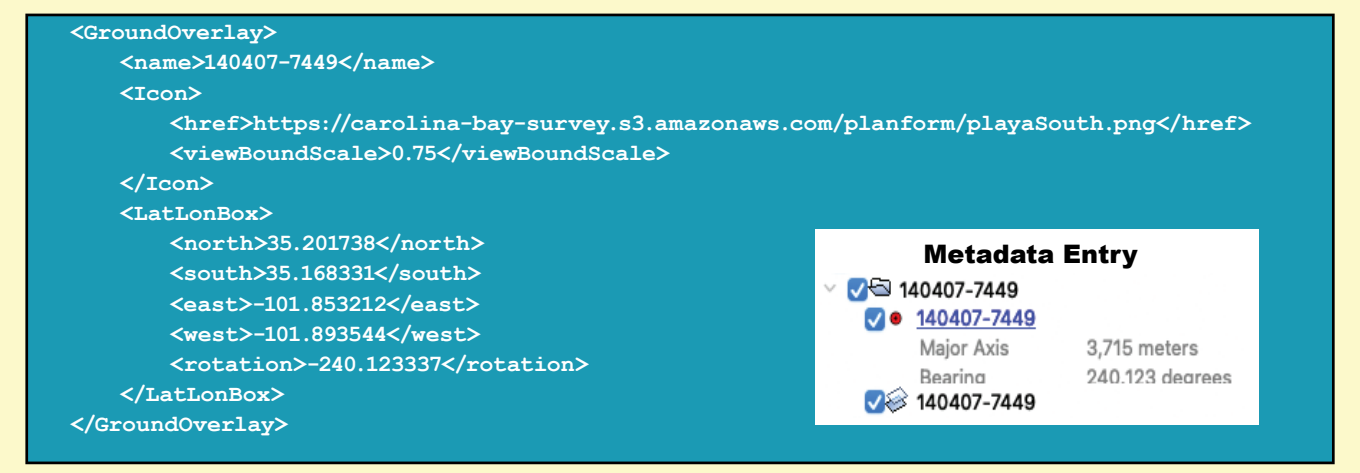


The Survey employs eight (8) archetype planforms to facilitate differentiation of subtly different low-relief landforms. Each planform type is associated in the Survey with an archetype template, created by subtly modifying a Bezier oval in Illustrator to track the basin's rim or drainage aureole as elucidated in an HRTM of the archetype. The modified Bezier ovoid is exported as a PNG image file with transparency, containing only pixels for the trace (black dotted line superimposed over white) to be employed as a measurement template.

To visualize the template on the virtual globe, a new GroundOverlay element is added, using a cloud-based url for the desired PNG file. The upper left image above shows the eight templates, annotated with red lines highlighting the divergence from a pure ellipse by subtle stylistic markers. Each archetype has been found to be applicable to a specific region of the basin distribution. Orientation is subjective.

The overlay is manually placed in Google Earth over a basin's HRTM and adjusted for scale and orientation. When matched to the basin's rim or aureole, the overlay's "Keyhole" markup language (kml) text is read from Google Earth. The LatLonBox's and the Rotation value are shown on the left in the copied text. The archetype's url is also relevant. From those data the basin's length (major axis), width (minor axis) and a location centroid lat/lon are computed using trig in a JAVA application. The application generates an identifying indexed name and a Google Earth placemark for the basin with a pop-up summarizing the metrics. A tab-separated text string is output for database ingest. The basin's input kml text is stored in the database record for provenience, allowing the original GroundOverlay to be re-created. The Java program generates custom kml to declare each basin in the Google Earth directory of metadata (DOM) panel.

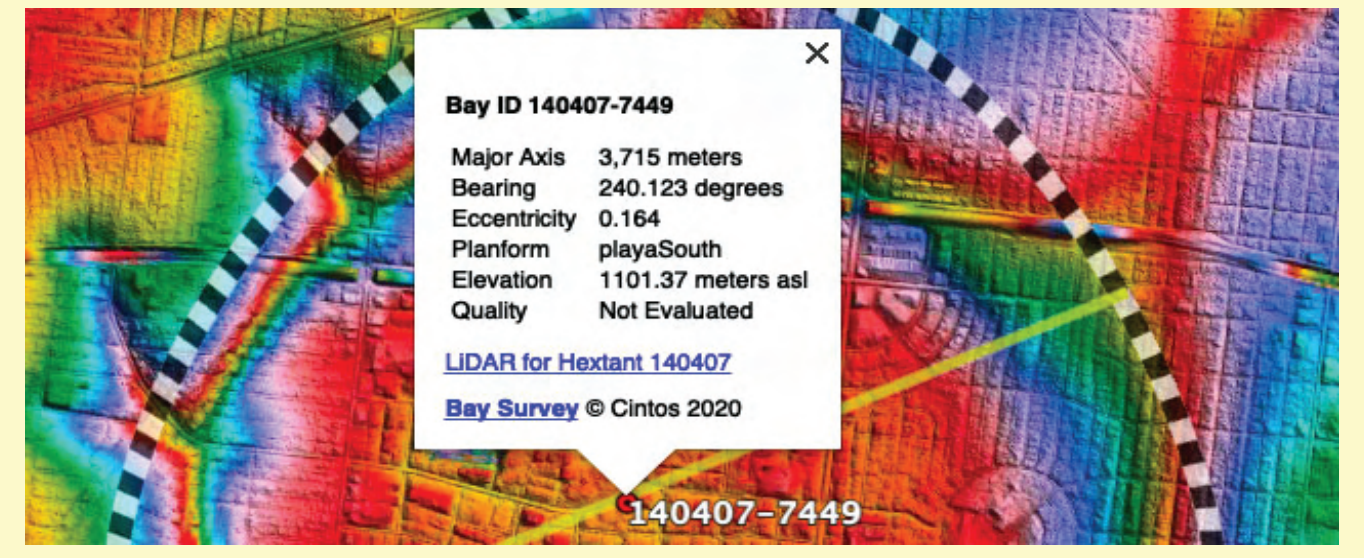
The eight templates are shown in use above. Each panel contains an HRTM of an example basin, the same HRTM with the archetype overlay applied, and an HRTM showing the regional context of the basin. Basin centroid latitude and longitude is also listed.



```
<GroundOverlay>
    <name>140407-7449</name>
    <Icon>
        <href>https://carolina-bay-survey.s3.amazonaws.com/planform/playaSouth.png</href>
        <viewBoundScale>0.75</viewBoundScale>
    </Icon>
    <LatLonBox>
        <north>35.201738</north>
        <south>35.168331</south>
        <east>-101.853212</east>
        <west>-101.893544</west>
        <rotation>-240.123337</rotation>
    </LatLonBox>
</GroundOverlay>
```

Metadata Entry

- ☑ 140407-7449
  - ☑ 140407-7449
    - Major Axis 3,715 meters
    - Bearing 240.123 degrees
  - ☑ 140407-7449



Bay ID 140407-7449

Major Axis	3,715 meters
Bearing	240.123 degrees
Eccentricity	0.164
Planform	playaSouth
Elevation	1101.37 meters asl
Quality	Not Evaluated

LiDAR for Hextant 140407

Bay Survey © Cintos 2020

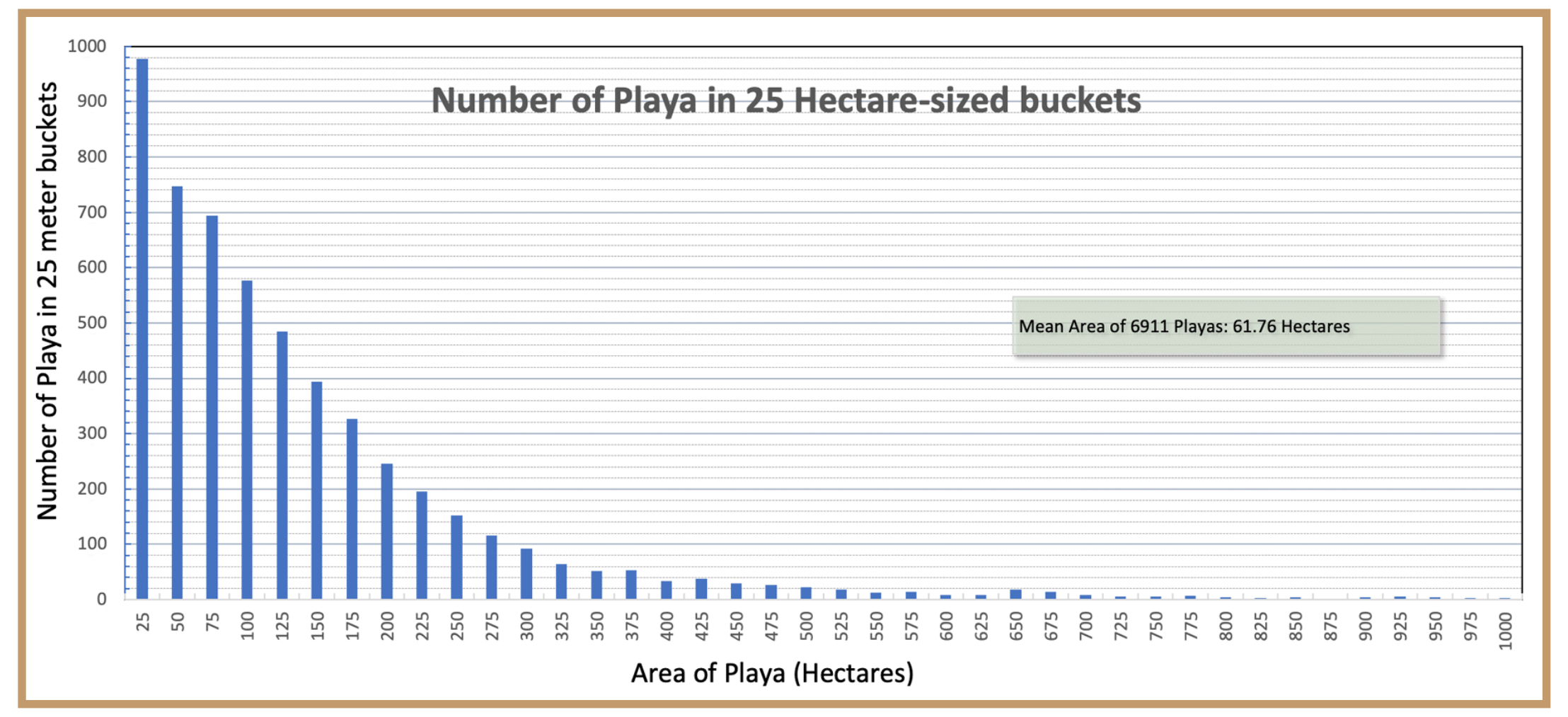
Results

The playa contents of six adjoining USGS 1ºx1º quadrangles were assessed using the Survey's HRTM presentation on Google Earth. The Quadrants were Tucumcari_W, Tucumcari_E, Amarillo_W, Clovis_W, Clovis_E and Plainview_W. These occupy the area between latitude 34º & 36º North and between longitude 101º and 104º West. These cover approximately 30,300 km^2 of Eastern New Mexico and Western Texas. The HRTM above represents 5,100 km^2, or ~17% of the assessed region.

At the center of most playas there does exist an area we interpret as representing the temporal wetland, since it presents as a single solid color and hence quite level across its expanse. While the playas rarely present "raised rims", the HRTM's 10 meter color ramp elucidates the presence of clearly defined aureoles surrounding the actual temporal wetland. We interpret that area as defining the zone in which the landform captures precipitation and effectively, the limits of the "basin".

6,909 basins were identified and measured within 5 the 6 USGS quads (none found in Tucumcari_W). The mean playa size was ~61 hectares. While there are great quantities of extensive playas as measured by their crisply defined drainage aureoles, there are over 1,500 small playas under 50 hectares that don't present aureoles. The histogram below relates the number of playas templated at within 25 hectare buckets up to 1,000 hectares, and presents a very orderly declining distribution with a long tail. Only 43 playas were larger than 1,000 hectares. The largest measured playa was ~2500 hectares; the 25 hectare buckets not plotted contained 4 or fewer playas.

We observe that the path of major drainage channels pass through large - but pirated - playas that seem to have been fully formed prior to the incursion and playa presence and planform remain distinct in the HRTM. Also recognized is overlap between playas while maintaining some of each playa's planform.



High Plains Aquifer

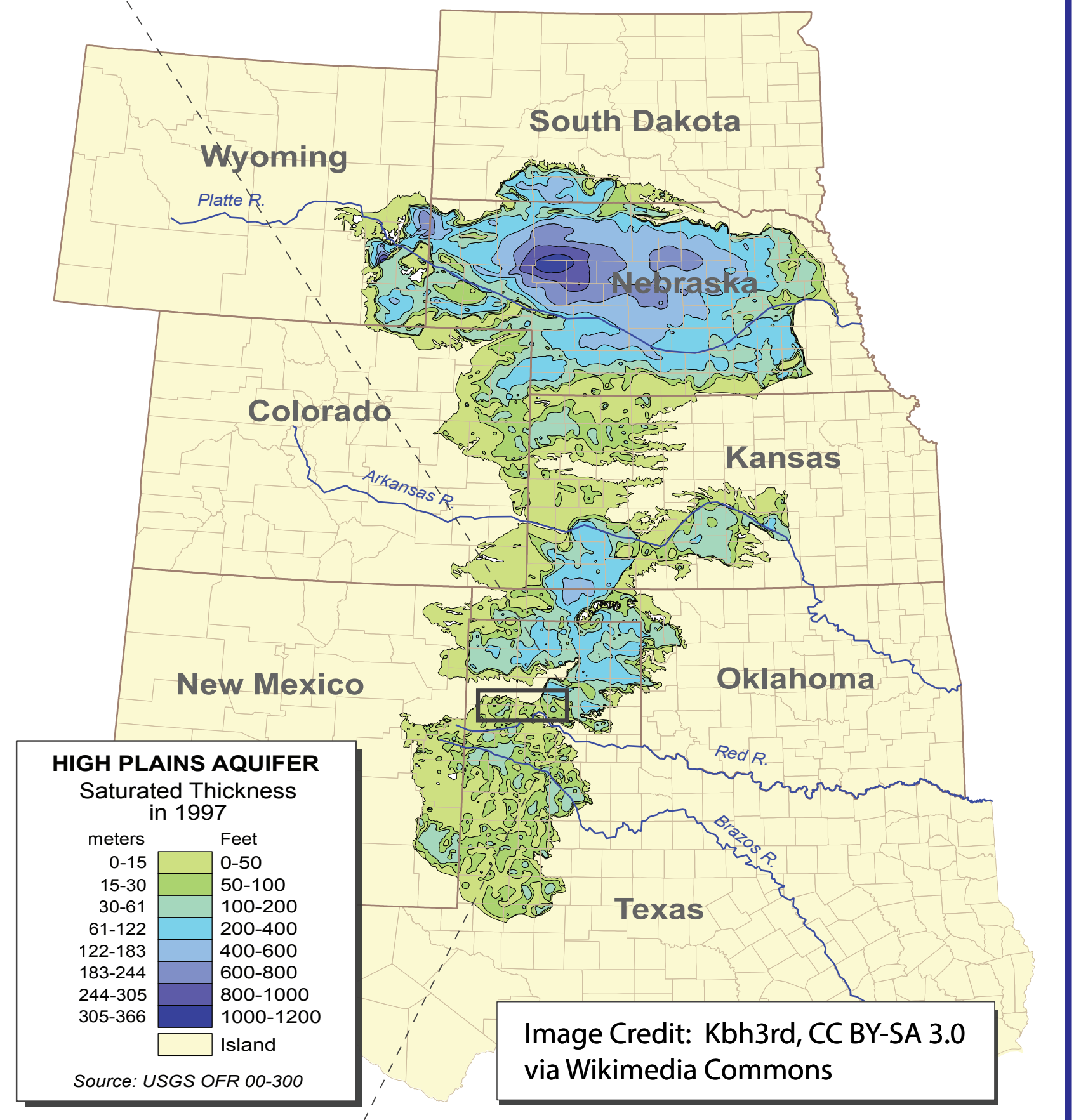
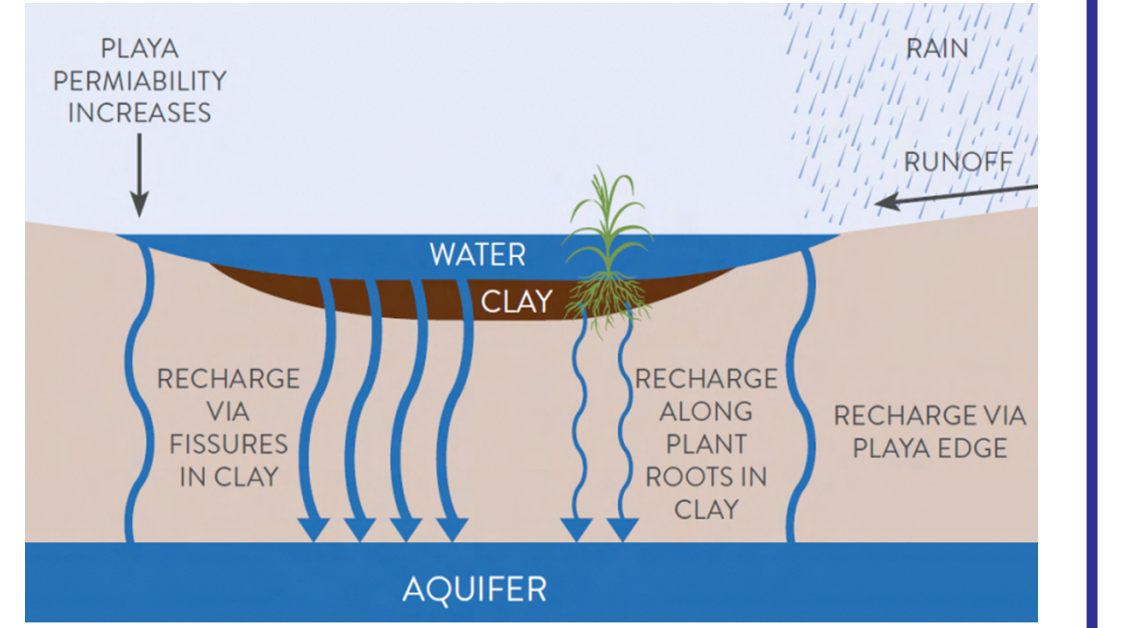


Image Credit: Kbh3rd, CC BY-SA 3.0 via Wikimedia Commons

The High Plains Aquifer is a primary source for fresh water across a great extent of the Midwest, pumped for potable water and agricultural irrigation. Approximately 90% of the surface area of the southern High Plains region has been identified as draining into playas, emphasizing the great role they play in focused recharge of the aquifer [4].

The cartoon here offers an explanation of the playa's role in delivering rain and runoff into regional aquifers. Tests have been undertaken to better understand the benefits or problems of removing accumulated fine silt and clays that create a semipervious seal across most playa wetlands found in an aureole's central basin.



Graphic credit: *Playa Lakes Joint Venture* `pljv.org`

Conclusions

The protocol shared may offer an alternative approach for extracting information from landform features which have proved difficult when referencing conventional remote sensing, including LiDAR using the common color ramp-to-elevation false-color shading. This is especially the case when local relief is on the order of 1 to 10 meters within regions of otherwise high relief.

The HRTM geospatial Survey for Google Earth visualization is freely available for non-commercial use. The geographic scope of the Survey is presently approximately 2/3 of the continental USA.

The Survey has revealed shallow ovoid basins arrayed along an annulus around the Great Lakes, USA. These landforms are not primary or secondary impact craters because of their shallow depth and for additional falsifications. The HRTM imagery suggests they may be products of a catastrophic event because of their robust adherence to crisply-defined ovoid planforms. The HRTM do show signs of gradualist geomorphology creating superficial artifacts such as dunes and lunettes on the downwind side of a small number of playas, perhaps attesting to their great age.

Future Work

We expect to continue the process of identifying and measuring tens of thousands of additional ovoid basins on the continent. This will require extending the footprint of the HRTM dataset to the continental level. We are actively encouraging an extensive geochronology program to better constrain the age of deposition of the deep surficial sediments these basins are formed within. We propose using cosmogenic nuclide dating such as $^{10}Be/^{26}Al$ burial dating of the underlying well dated strata [5].

Links

Survey:	`http://cbaysurvey.cintos.org`
Planforms:	`http://planform.cintos.org`

References

[1] Rasmussen, 1953, The Journal of Geology, Vol. 61, #5
[2] Davias & Gilbride, 2011, AGU FM EP52C-08
[3] Gurdak & Roe, 2009, http://pubs.usgs.gov/circ/1333/
[4] Nativ, 1992, doi: 10.1007/BF01740574
[5] Davias, Harris, 2022, doi: 10.1130/2021.2553(24)

This project is funded by the author.