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Carolina Bays And Aeolian Dunes: Playing Nice In The Sandbox?

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Introduction

The juxtaposition and interplay between elliptical Carolina bay basins and accompanying aeolian dune structures has been previously recognized across the USA's Atlantic Coastal Plain. Recent advances in 3D terrain visualization using LiDAR (Light Detection And Ranging) remote sensing technology allows for new insight into the nature of the bays' enigmatic elliptical circumferential rims and their spatial relationships with unambiguous aeolian sheets. In support of a survey to discover and elucidate the full geographic range of Carolina bay landforms, 500,000 km2 of hsv-hinted (hue-saturation-value) Digital Elevation Maps have been produced using publicly accessible LiDAR data (1).

Using examples from my geospatial survey of ~45,000 bays (2), hereinafter referred to as "the Survey", I share some observations about bay-dune relationships that appear pervasively in the data.

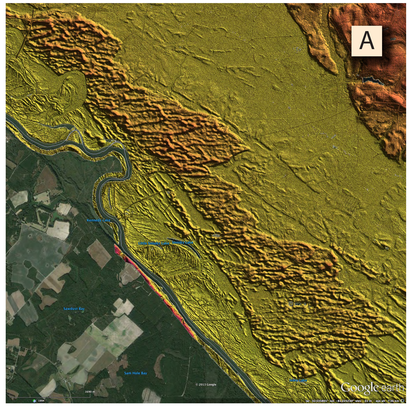
Instances of "secondary rims" are seen, where robust wave-like repetitions of bay rim structures are found rippling away from a Carolina bay's primary rim. Also of interest are bay planforms that have remained intact while the surrounding landscape has been resurfaced with extensive parabolic and longitudinal dune topography, differentiated from others where classic aeolian landforms have encroached into bay basins; intriguingly, cases exist where both outcomes are seen in close proximity.

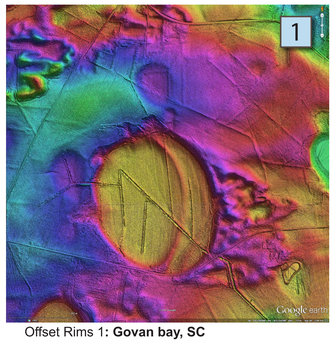
An established hypothesis holds that bay basins and their closed rims were generated by glacial-era katabatic winds passing perpendicular to the bay's major axis (3), yet inspection of classic wind-blown dunes in the vicinity of bays document long-term resultant sand drift directions which fail to correlate, perhaps suggesting entirely independent mechanisms were responsible for their presence in these topographies.

Detailed examination of these spatial relationships may illuminate Carolina bay geomorphology research and guide future OSL dating and chemical analysis activities to relevant locales.

Dunes A: **Savannah River Dunes Void of Carolina bays**

The Savannah River Terrace shown in Figure A has extensive parabolic dunes, yet shows no signs of Carolina Bay development. Swezey, et al (2011) reported OSL dates of 32-17 ka for these dunes, suggesting activation just prior too and during the last glacial maximum (LGM). Thus, Carolina bay development does not necessarily derive from dune development on the coastal plain, nor from cyclonic winds which have been proposed to exist across the continent at the LGM. Also apparent is that post-LGM over-bank flooding of the Savannah River is not responsible for the destruction of bays on this particular terrace. Soller (1988) reported that some older dunes in the Cape Fear River Valley (CFRV) might be contemporaneously with Carolina bays therein, whereas younger dunes greatly postdated the bays. He also noted that bays were also not present on the more recent terraces of the CFRV, again suggesting minimum bay ages of over 120,000 years therein.





Offset Rims 1: **Govan bay, SC**

This is a large landform, just shy of a kilometer in diameter. It consists of two baySouth (my taxonomy) archetype shapes offset slightly east-west from each other. The elevation profile map shows the bay floor to be over 8 meters below the surrounding terrain.

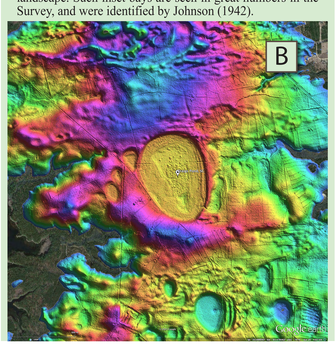
The intervening rim is very well expressed, compared to some co-joined bays where there is no dividing rim apparent. The LiDAR imagery suggests the area has been passed over by migrating parabolic dunes, yet Govan Bay's "baySouth" archetype shape is relatively unscathed. Two smaller bays are also seen in the LiDAR here, both presenting the same 156º orientation and baySouth shape.

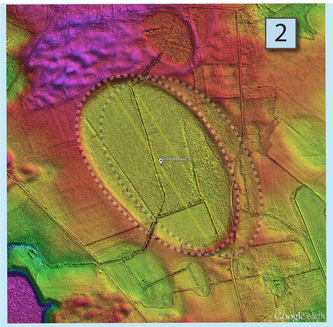
Dunes B: **Craigs Pond bay, SC**

Craigs Pond and Sarracenia Bay, a much smaller bay immediately to the west, are an associated pair of open water Carolina Bays, both of who's shape conforms to the baySouth archetype. The Survey has measured the alignment of both bays to be 157.3º.

Along with numerous other smaller bays nearby, Craigs Pond sets into an area with extensive tracks of wind blown sand. While dunes appear to be blowing off the eastern raised rim of several bays as surficial reworkings, there appears to be no indication of bay infilling by migrating dunes.

Craigs Pond has a free-standing eastern rim, but note that its neighboring bays are fully set into the surrounding landscape. Such inset bays are seen in great numbers in the Survey, and were identified by Johnson (1942).





Offset Rims 2: **Lizard Man bay, SC**

This basin and surrounding landscape is interpreted by me as being composed of two slightly offset templates, both of identical size, shape and orientation. This paired assembly has been seen on numerous times in the Survey. The situation has also been noted by others, who recognize that the eastern-most element has been overlaid by the more western of the two.

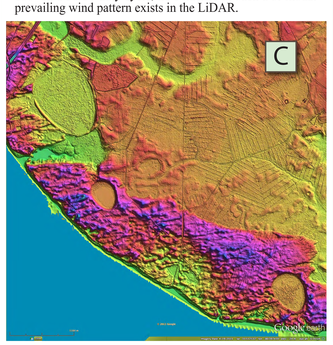
These mash-ups may provide some needed insight into the mechanisms which formed the bays.

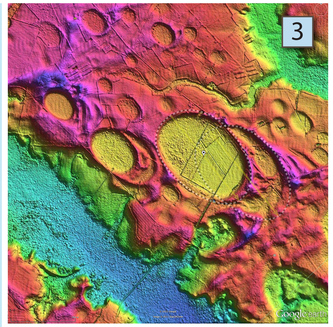
Dunes C: **Dingle and Goshing Pond bays, SC**

Dingle Pond (upper left in Figure C) and Goshing Pond (left center) are two of several perfectly-crafted baySouth Carolina bays located within an expansive dune field along the eastern bank of the Santee River Basin and the Lake Marion reservoir.

These bays and immediate surroundings are preserved as the Santee National Wildlife Refuge. There are no indications in the LiDAR that these closed depressions have been infilled by the migrating dunes.

The prevailing wind direction during dune formation does not appear to have been perpendicular to the bays' long axis, but rather off by 10º to 20º. This might indicate that prevailing sand drift direction during dune-building episodes varied from those during bay creation. Regardless, Kaczorowski's protocol (3) mandated winds which alternate 180º on a 50-50 duty cycle; no evidence of such a bi-modal prevailing wind pattern exists in the LiDAR.





Offset Rims 3: **Odessy bay, NC**

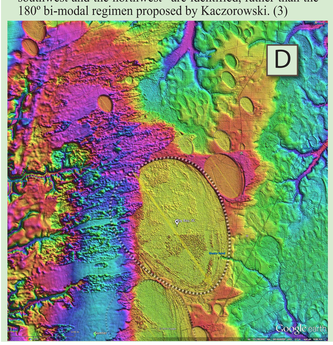
Many of the bays in the Survey have been informally named by me, and this is the case for Odessy bay. The name is taken from that of a small road which approaches the southern rim. Embedded in a matrix of dozens of bays on a 2 -3 km wide interfluvial, it presents a perfect "bayCarolina" (my taxonomy) archetype shape.

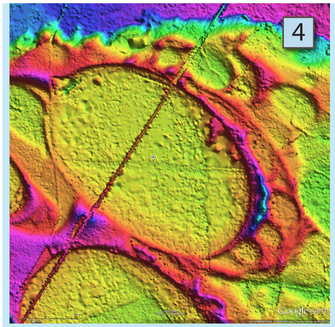
Of note here is the presence of a duplicate template rim offset to the south and east, presenting as a secondary rim. Within the landscape between the two rims are nascent bay forms, similar in appearance to the configuration at Glass Pond (Figure 4) immediately to the east.

Dunes D: **Big Bay,**

Based on dating of sediments and encroaching sand, Big Bay may be as old as the early Pliocene, as it is built upon Duplin Formation marine sediments (Brooks, 2001). Sheets of sand driven off the Wateree River basin have partially infilled Big Bay. OSL dates from the interface between the dune and the antecedent bay fill suggests the sheet migrated onto the pre-existing bay over 100 ka. Other bays seen with similar rim shapes and orientations have no sign of infilling. Perhaps bay infilling is only seen where the rim is broached by a natural drainage channel, allowing the bay floor to be dry enough for sand to accumulate as the dune migrates. Conversely, in bays which retain a circumpherial rim and therefore can hold water, the encroaching sand is distributed across the bay floor by wind and wave action.

Brooks states "wind direction was 18º more westerly for dunes than for bays", and that "paleowinds from both the southwest and the northwest" are identified, rather than the 180º bi-modal regimen proposed by Kaczorowski. (3)





Offset Rims 4: **Glass Pond Complex, NC**

Like many larger bays, Glass Pond has a wave-like secondary rim on its southeast "leading edge" The secondary rim can be recreated exactly using a copy of the main bay's archetype overlay, using the same 1.88 km length, and the same 136.71º orientation. In all such cases, the open bay is superimposed north and west of the secondary rim bay.

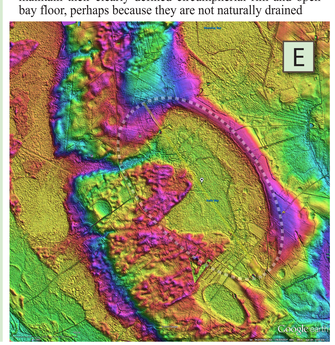
Along with a handful of other bays, the area between Glass Pond's primary and secondary rim is populated by small "toe"bays, which share the same 136.71º orientation and archetypal shape as the parent bay.

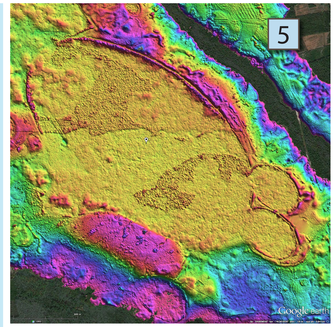
I speculate that an association might exist between the generation of these "toes" and that of the "daughter bubbles" produced by the folding of ruptured thin films. (Bird, 2010)

Dunes E: **Kelly bay, SC**

Kelly bay is among the largest, with a major axis of 3 kilometers, and an orientation of ~146º. It was created on the eastern banks of the Little Pee Dee River. Extensive parabolic sand dunes are visible in the LiDAR moving east from the adjacent flood plain. Similar to the situation at Big Bay (Figure G), the dunes are migrating onto the bay floor, but they do not significantly alter the manifestation of the bayCarolina archetype bay shape. Note that this bay has a major natural drainage channel penetrating into its floor, effectively restricting the creation of an open water lake.

As commonly seen, the prevailing winds driving the dunes are not perpendicular to the bay's major axis. Note that other local Carolina bays have withstood the encroachment and maintain their clearly defined circumpherial rim and open bay floor, perhaps because they are not naturally drained





Offset Rims 5: **Tussock Complex, NC**

The Tussock Bay Complex is located on the Penholoway terrace of the Cape Fear River Valley. Note that the first-generation LiDAR Elevation data from North Carolina is challenged when sensing through the very dense canopy in this area, often presenting the sandy un-vegitated rims as recesses in the canopy-driven elevation reading.

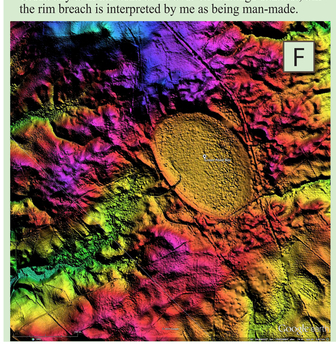
The primary bay here is known as Tussock bay. At 3.7 kilometers on the major axis, and is among the top 100 bays by size in the Survey. All three bays included in the Complex have the common bayCarolina shape. Numerous other large Carolina bays are seen in the LiDAR as having a cluster of small bays at the southeastern end of the bay, reminiscent of toes on a footprint. An understanding of the physical construction of such "toes" may offer a clue to refining the mechanisms responsible for Carolina bay generation.

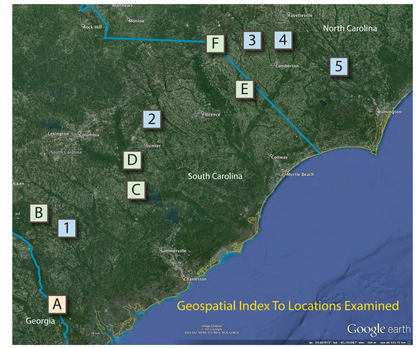
Dunes F: **Green Pond, NC**

Green Pond Bay is one of numerous Carolina bays in the Survey which exhibits a surprisingly narrow section of rim perched high above the surrounding landscape, presenting itself as a geometrically precise man-made reservoir. The "dam wall arc" here is over 1 kilometer in length, isolating the bay from an overfit drainage channel to the west.

The bay's location is at 79 MASL in the western-most tip of Scotland County, SC, 67 km NNE of Florence, SC. Green Bay stands alone on its ridge, surrounded by sand dune features which have not encroached on the bay.

A large assortment of bays exists immediately to the south. Green bay is at the head of an over-fit drainage channel, but the rim breach is interpreted by me as being man-made.





Discussion

Timothy D. Nifong, in his 1998 PhD thesis, noted that out of original estimates of hundreds of thousands of bays, "*fewer than 900 bay depressions with relatively unaltered site hydrologies remain within the study area.*"

The Survey's LiDAR and photo imagery of 45,000 bays suggests that Nifong was overly optimistic. I would be hard pressed to suggest as many as 90 remain unscathed by the hand of mankind today. In stark contrast to the bay's recognized fragile hydrology and ecology, the bay's densely packed sand rims and geometrically smooth shapes have proven to be robust in the face of geologic forces and human modifications. That aspect of their nature must be accounted for in any proposed geomorphic mechanisms.

Douglas Johnson, after reviewing the many then-current hypothesis for bay geomorphology and finding them lacking, made a pragmatic assessment:

"No one has yet invented an explanation which will fully account for all the facts observed".- Douglas Johnson (1942)

Dr. Johnson was able to convincingly rule out cosmic impacts. However, the persistent adherence of the Carolina bays to several archetype shapes and groupings needs to be better addressed than by purported hurricane-force winds exhibiting tightly constrained directionality during glacial maximums.

Visualizing the bays in high resolution LiDAR confirms their robust adherence to archetypal ovoid shapes. When co-located with commonly recognized sand dune landforms, I have identified no compelling examples of Carolina Bays emerging from those dunes, but rather interpret their interplay as nothing more than surface reworking over and around antecedent instances of bays. Studies of bay stratigraphy by others confirms the dune sands are significantly finer than the dense, coarse sand of the structural rims.

Bay infilling by migrating dunes may occur when bays drain through natural channels, whereas closed basins retain water adequate to distribute infilling sand, such that the dune can not gain a foothold on the bay floor

A persistent characteristic of the bay is the existence of "secondary rims" to the southeast of a primary bay. In the cases shown here, the secondary rim is well represented by a duplicate of the main bay's archetype overlay, shifted slightly eastward and southward. The juxtaposition is reminiscent of a standing fluid bow wave or shock wave emanating from the primary bay.

I speculate that the robustly repetitive Carolina bays may have been generated between 780 ka and 140 ka during a catastrophic mass-transport and deposition of high purity quartz particles, materialized as a surficial blanket of sand, spread chaotically over an antecedent terrain. The bays may be imperfections generated within the blanket while the sand was in a state of liquefaction, and preserved at lockup as a densely compacted stratum.

The imagery displayed here is a subset of the 45,000 bays in my publicly available Survey (2), but I maintain that the entire set supports these findings.

Footnotes & References

1) Digital elevation map source data: U.S. Geological Survey National Elevation Data, 1/9 arc-sec
2) Davias, (2009-2013), Carolina Bay Survey, http://Cintos.org/Survey
3) Kaczorowski, Raymond T., 1977; The Carolina Bays: A Comparison with Modern Lakes. [Ph.D. Thesis]
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Swezey, et al, 2011; Eolian Dunes Of Late Quaternary Age On The Floodplain Of The Savannah River, Jasper County, South Carolina, GSA Abstracts with Programs, Vol. 44, No. 4, p. 13