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LiDAR Elevation Data Provides New Insight Into The Bon Air Gravel And Attendant Carolina Bays

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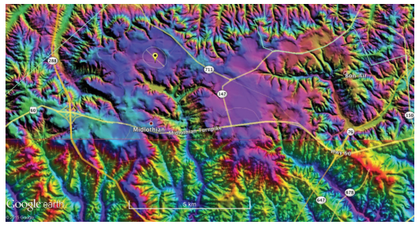
Abstract

The Bon Air Gravel paves ~50 km^2 of a relatively undissected upland terrace which unconformably overlies Piedmont province bedrock in the vicinity of Midlothian, Virginia. Previous workers have considered these upland gravels to be fluvial deposits of Middle Miocene or older, and may represent a remnant of a formerly more expansive terrace. The Midlothian surface grades gradually from ~120 to ~100 meters above mean sea level (mamsl), west to east. Although referred to as a gravel, this unit is commonly subdivided into a lower gravel member and an upper quartzose loam member, and is correlated with the similarly subdivided gravel/loam Upland Deposits (formerly Brandywine) located at lower elevations to the east. As a curiosity, numerous aligned elliptical depressions have formed on this surface and have been considered “Carolina bay” landforms by many workers over the past 50 years. Here, we interrogate these bays' shape and orientation utilizing new digital elevation maps created from LiDAR data acquired in 2014. The new LiDAR additionally elucidates numerous Carolina bays established to the east on the adjacent gravel/loam sequence. Our findings suggest that these landforms adhere robustly to the “bayCarolina” archetypical ovoid planform found extensively (>22,000) in our Carolina Bay Survey, and have major axis orientations at 132º ± 2º rotation from north. When compared to bays we have documented to the north and south, this orientation is consistent with the systematic-by-latitude rotation noted in studies over the last 70 years. Studies by others indicate that the Midlothian bay rims are built solely within the massive loam member, whereas the loam member is absent within the basin proper and the gravel member remains intact throughout. The existence of bays on this surface is unexpected, since classic Carolina bay geomorphology considers them to be hosted above thick antecedent units of un-consolidated siliciclastic sediments. Furthermore, the uniformity of the gravel member beneath the bays adds to observations elsewhere that Carolina bays are created as voids in a unit of quartzose loam without disturbing the underlying surface. Their presence here is consistent with our Survey’s discovery of dense clusters of Carolina bays on isolated terrace remnants located west of the Coastal Plain up to 200 mamsl.

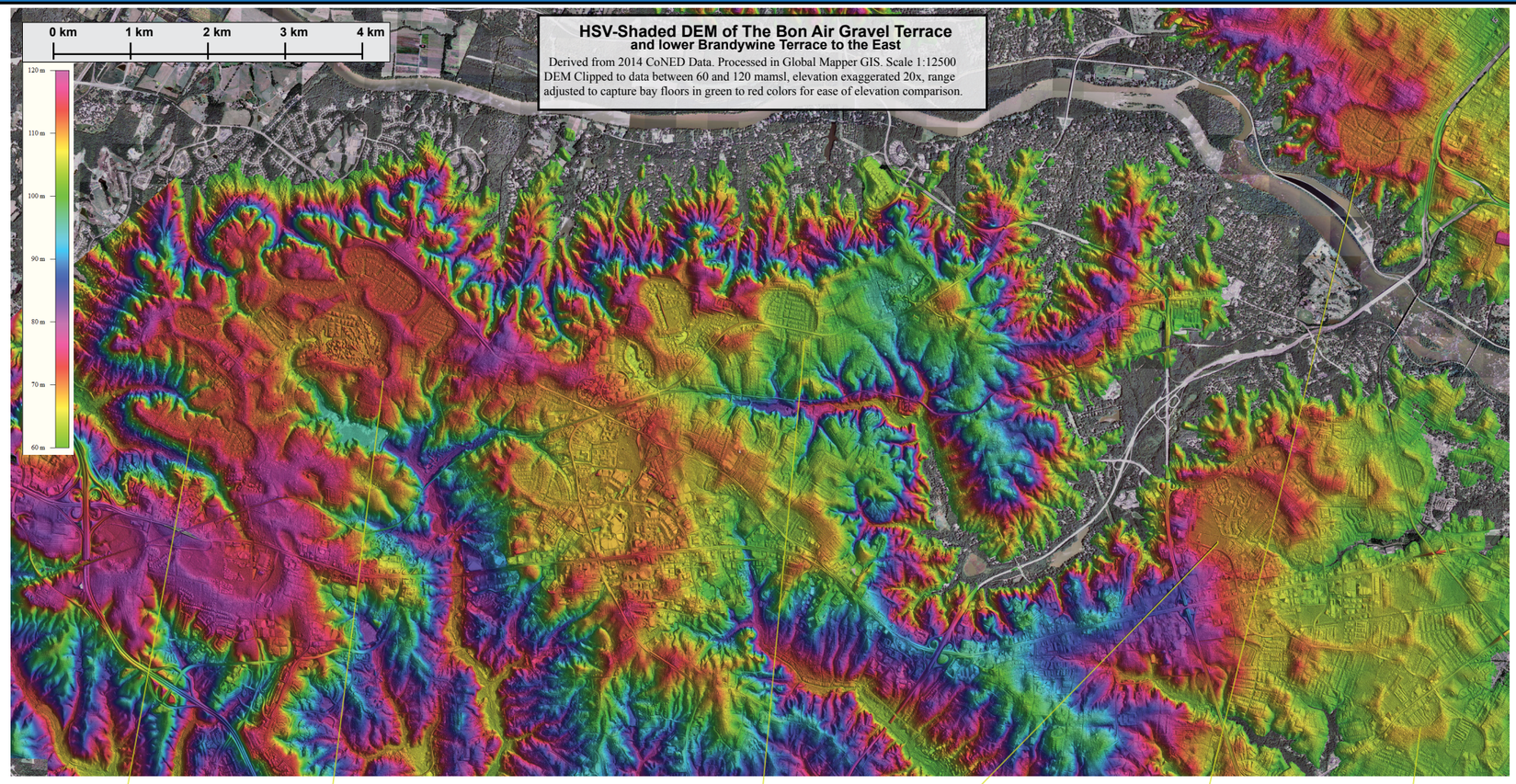
Development of Elevation Fidelity

Prior to the acquisition of LiDAR in 2014, the best available elevation data was 10-meter USGS NAD. Below is the Bon Air region of bays rendered in a hsv-shaded DEM using that data. Elevation values are exaggerated 20x to pump up the relief. The terrain is relatively flat as seen in photo, below right, across Kings Lynn Bay (15010-1259), featured as CBoD for 12/18/2014 (1). It is ~1 km on the major axis, outlined below in the *bayCarolina* template.



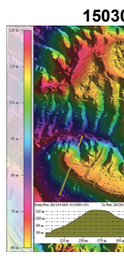
What we can see even in the 10 m data, above

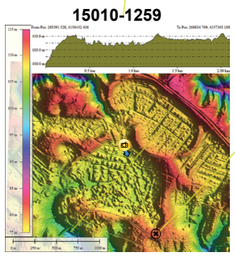
Despite the low resolution, the presence of numerous bays is apparent, and the Carolina Bay Survey had measured ~ a dozen in the area. We consider the terrace to have been far more extensive at the time of bay creation, with additional bays having been since destroyed by erosion as the terrace undergoes dissection. The rims appear to be more resistant to the headward erosion, as seen along the northern edge of the terrace, where the James River channel has been widening as it erodes immediatly west of the fall line. These examples of bay rim preservation support the concept that Carolina bays are quite robust. Authors of earlier explorations of these depressions (2,3,4,5) considered them to be associated with the Carolina bay morphology.

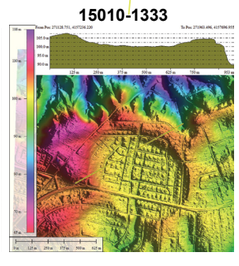


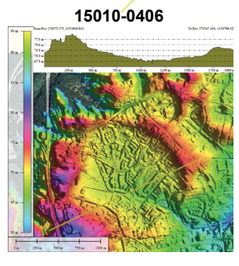
HSV-Shaded DEM of The Bon Air Gravel Terrace and lower Brandywine Terrace to the East

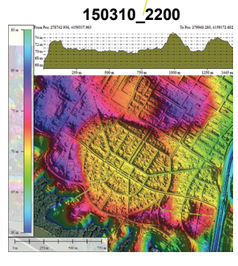
Derived from 2014 CoNED Data. Processed in Global Mapper GIS. Scale 1:12500 DEM Clipped to data between 60 and 120 mamsl, elevation exaggerated 20x, range adjusted to capture bay floors in green to red colors for ease of elevation comparison.

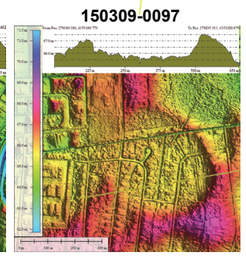












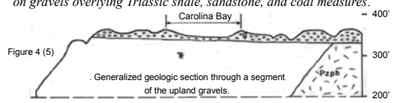
The 2014 LiDAR Data

During 2014, the USGS executed series of LiDAR data flights in support of the Coastal National Elevation Database (CoNED) Project. In the state of Virginia, the acquisition covered the counties of Spotsylvania, Caroline, Hanover, Henrico, Chesterfield, Dinwiddie, Sussex, Richmond City, Hopewell City, Colonial Heights City, Orange, Louisa, Amelia, Nottoway, Prince Edward as well as Petersburg City. The project acquired almost 60 billion classified data points on sub-meter spacing. The image to the left was generated by selecting only the last-return (bare earth) results within the area of interest, and processed down to a 1m x 1m grid. The resulting 155 cm x 80 cm DEM represents ~ 1 m per pixel; 8 cm = 1 km (1:12500). To emphasis the detail of the bays, which are found between 60 m and 120 m, the elevation data was clipped between those values, and integrated with a photographic view of the area. Selected bays’ elevation profiles included at bottom, center.

Subsurface Sucture of the Terrace

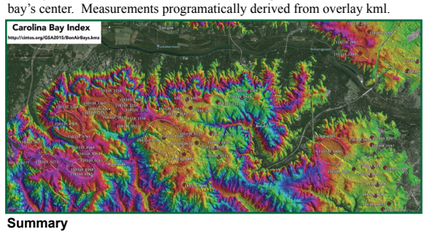
The Bon Air statigraphy was discribed by Goodwin & Johnson (5) as:

Apparently the development of the bays is in no way related to the Piedmont bedrock which underlies the Midlothian gravels. Some of the bays have formed on gravels overlying granite, and some have developed on gravels overlying Triassic shale, sandstone, and coal measures.



Bay Index[http://cintos.org/GSA2015/BonAirBays.kmz]

55 bays identified within the 1m DEM. Naming index based the lat-lon of bay’s center. Measurements programatically derived from overlay kml.



Summary

The collection of bays on the dissected terrain continues uninterrupted from the 120-100 m Bon Air terrace down onto the 75-60 m Brandywine terrace to the east and northward across the James River into Richmond. All bays here conform to the common *bayCarolina* planform, oriented ~132º. The bays are distributed in a log normal range of sizes but are shallow depressions, regardless of girth. Many of the bays are breached by headward erosion and no longer represent hydrologically closed depressions; their persistence speaks to the robustness of the landform. If the underlying bedrock surface is indeed of Miocene age or older, a mid-Pleistocene age or older (~800+ ka) for the gravel/sand members and attendant bays would not be inappropriate based on the extensive erosion visible in the LiDAR. We also call attention to the robustness of the bay rims, as seen along the northern limit of the terrace, where bay rims present an impediment to erosion from the James River. The outcome might be due to the durability of compacted angular quartz-rich loam comprising the bay rims, compared to more easily mobilized sediments elsewhere. Future efforts will be directed towards acquiring 10Be/26Al burial dating for the differentiated gravel and loam members of the Bon Air Gravels.

Footnotes & References

1) Carolina Bay of the Day (CBoD) 12/18/2014 https://goo.gl/qLbXTj
2) Johnson, G.H., and Goodwin, B.K., 1967, Elliptical depressions on undissected high level gravels in northern Chesterfield County, Virginia (abs.): Virginia Journal of Science, v. 18, p. 186
3) Johnson, G.H., Goodwin, B.K., Ward, L.W., and Ramsey, K.W., 1987, Tertiary and Quaternary Stratigraphy across the Fall Zone and western Coastal Plain, Southwestern Virginia, in Geological Excursions in VA and NC: Guidebook, Field Trips No 1-7, Geological Society of America, Southeastern Section, p. 87-144
4) C.R. Berquist, Jr. and Bruce K. Goodwin, Guidebook No 5. Dept. of Geology, College of William and Mary, 21st Annual Meeting of the Virginia Geological Field Conference, September 1989
5) Bruce K. Goodwin and Gerald H. Johnson, Guidebook To The Geology Of The Upland Gravels Near Midlothian, Virginia, 11th Annual Field Conference, Atlantic Coastal Plain Geological Association ,10/1970