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Stratigraphic, Hydrologic, and Climatic Influences on the Formation and Spatial Distribution of Carolina Bays in Central Delaware

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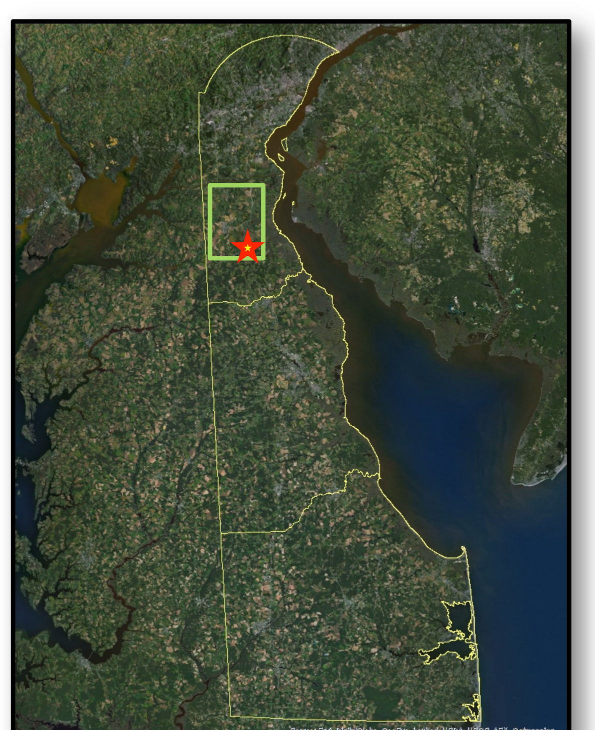
Introduction

There are many theories concerning the origin of Carolina Bays, from meteorite impacts to buffalo wallows. The general consensus is that they were the result of interaction between periglacial winds, groundwater levels, and an exposed water table (Stolt and Rabenhorst, 1987; Sharitz, 2003; Tiner, 2003), but the exact mechanism remains unknown. Limited evidence in Delaware indicates that these features are late Pleistocene in age. Radiocarbon dates from three Carolina Bays in northern Delaware show deposition prior to 11,000 yrs B.P., followed by a depositional hiatus. Deposition resumed by about 6,000 yrs B.P. (Webb, 1990).

The occurrence of thousands of these enigmatic features at the land surface in northern Delaware presents an interesting mapping challenge. Carolina Bays are difficult to recognize in the field and on topographic maps due to their low relief. On average, from base to rim top is less than 1.5 m and the bays are typically less than 500 m in diameter. The recent availability of high-resolution LiDAR (Light Detection And Ranging) reveals these features in greater detail than ever before. In this study we compare the currently available LiDAR to two historical topographic maps (1955 and 1993). The results of the survey shed new light on possible underlying geologic controls for the formation of Carolina Bays in Delaware.

Study Area



Location map. Clayton Quadrangle is boxed in green. Star shows location of images to the right.

Delaware is located on the Delmarva Peninsula between the Chesapeake and Delaware Bays. The majority of the state (94%) lies in the Atlantic Coastal Plain; the remainder is in the Piedmont Province. Delaware's Coastal Plain topography is subdued and flat; much of the state lies less than 100 ft above sea level. Due to the paucity of outcrops, we rely on shallow subsurface borings and well data for surficial geologic investigation. Stream incision is relatively shallow and the water table generally occurs within 20 ft of land surface.

The study area, the Clayton Quadrangle, is ~30 mi south of the Delaware's circular arc boundary with Pennsylvania. Depth to basement is approximately 1,600 ft. The majority of the Coastal Plain sediments (~1,000 ft) is comprised of the nonmarine Cretaceous Potomac Formation overlain by 300 ft of Late Cretaceous-age marine deposits. These deposits are overlain by 200 ft of Paleogene marine deposits. The uppermost portion of the study area is composed of the late Miocene marine Calvert Formation and is overlain by less than 50 ft of surficial fluvial (Beaverdam and Columbia Fms) and estuarine (Lynch Heights Fm) deposits (Ramsey, 2005). The surficial deposits have a Pleistocene periglacial overprint of numerous (up to 35 per km^2) Carolina Bays, which have sandy rims and commonly have a thin (<5 ft) muddy fill of Holocene sediments.

Literature Cited

Ramsey, K.W., 2005, Geologic Map of New Castle County, Delaware: Delaware Geological Survey Geologic Map Series No. 13, scale 1:100,000.

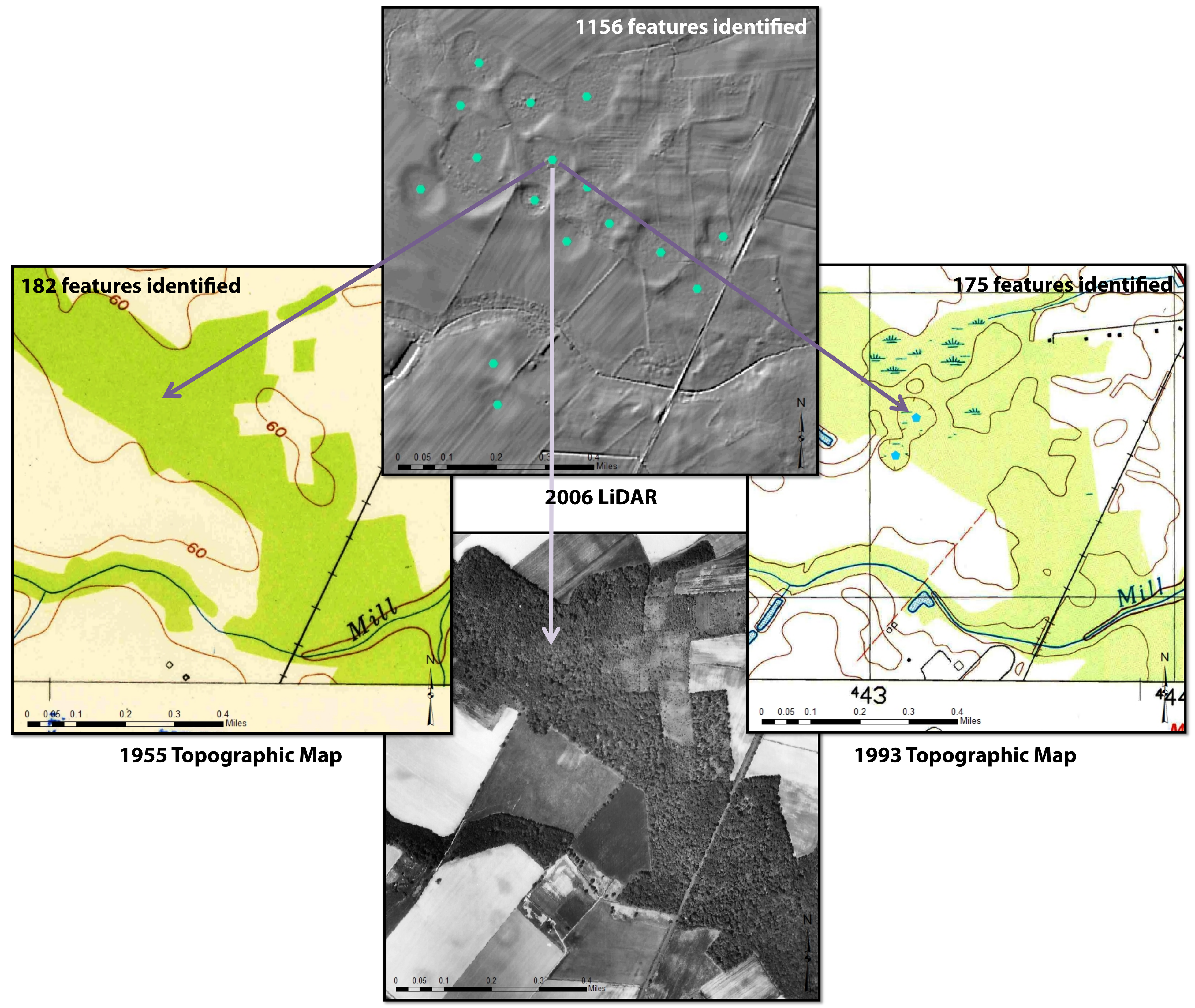
Sharitz, R.R., 2003, Carolina Bay Wetlands: Unique Habitats of the Southeastern United States: Wetlands, v. 23, p. 550-562.

Stolt, M.H., and Rabenhorst, 1987, Carolina Bays on the Eastern Shore of Maryland: II. Distribution and Origin: Soil Science Society of America Journal, v. 51, p. 399-405.

Tiner, R.W., 2003, Geographically Isolated Wetlands of the United States: Wetlands, v. 23, p. 494-516.

Webb, R.S., 1990, Late Quaternary Water-Level Fluctuations in the Northeastern United States: Ph.D. Dissertation, Dept. of Geological Sciences, Brown University, 347 p.

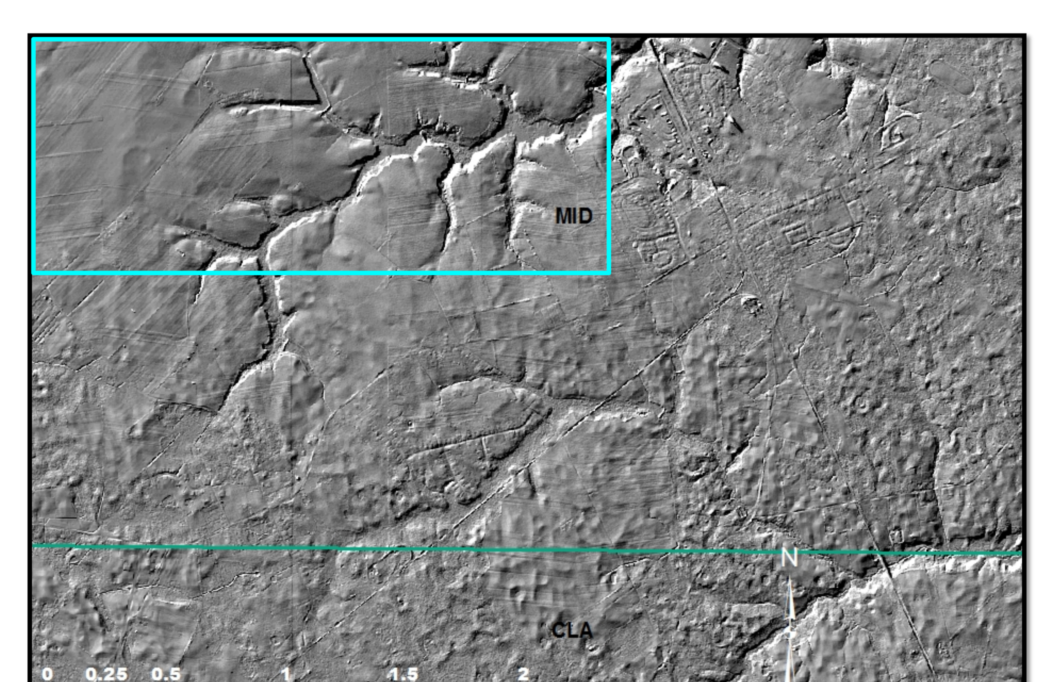
Methods and Results



- Individual Carolina Bays in the Clayton Quadrangle were identified on a hillshade DEM generated from 2005 LiDAR in GIS and were marked as a point in a layer file.
- 1955 (10-foot contour interval) and 1993 (5-foot contour interval) 1:24,000 topographic maps were georectified and individual Carolina Bays were identified and marked with a point in GIS.
- Only closed depressions on the topographic maps were counted as Carolina Bays.
- Closed circular or elliptical contour lines without depression indicators were considered "highs", and therefore were not counted.
- Semi-circular contour lines were not counted.

	1955 Topo	1993 Topo
Carolina Bays	182	175
Scale	1:24,000	1:24,000
Contour interval	10-foot	5-foot
Data source	1:62,500 Smyrna Quad, 1951 aerial photos	1989-1990 aerial photos
Datum	Mean Sea Level	Ntl Geodetic Vertical Datum of 1929
Magnetic declination	8º	11.5º

Number of Carolina Bays identified in the two topo maps and a comparison of the map details. 1156 Carolina Bays were identified in the LiDAR image of the study area.



A survey of the LiDAR revealed a sharp boundary between densely-spaced Carolina Bays in the Clayton and southern Middletown quadrangles and the nearly complete absence of these features to the north (boxed area).

Conclusions

Topographic maps vs. LiDAR

- 2006 LiDAR: 1156 Carolina Bays were identified.
- 1955 topographic map (10-ft contour interval): 182 (15.7%) of the Carolina Bays were identified.
- 1993 topographic map (5-ft contour interval): 175 (15.1%) of the Carolina Bays were identified.
- Using topographic maps alone, extensive field investigation would have been necessary to map the majority of Carolina Bays in northern Delaware.

LiDAR Survey

- In northern Delaware, Carolina Bays occur in a belt roughly parallel to the strike of the subsurface Neogene and Paleogene deposits.
- The spatial density of the Carolina Bays increases abruptly from north to south from <1 per square kilometer to >30 per square kilometer.
- The transition zone parallels the strike of the Cretaceous to Miocene units that subcrop beneath the surficial units (Beaverdam, Columbia, Lynch Heights, and Scotts Corners Formations).
- No correlation between the surficial unit lithology (sand-dominated) or thickness (10-40 ft) and the spatial density of Carolina Bays was found.
- The change in Carolina Bay density coincides with the intersection of the updip limit of the Calvert Formation (Miocene).

Highest Carolina Bay density → underlain by silty clays to clayey silts (Calvert Formation)

Lowest Carolina Bay density → underlain by glauconitic sands (Manasquan (Eocene) and Vincentown and Hornerstown Formations (Paleocene))

The exact nature of the influence of the Calvert muds is undetermined. We hypothesize that when the Carolina Bays were forming (radiocarbon dates from the study area yield an age range of 13,060-1,520 yrs B.P., with initial formation occurring before ~11,000 yrs B. P.), the presence of the muddy beds beneath the surficial deposits contributed to localized higher groundwater levels during a time of a regionally low sea level. Exactly how elevated groundwater contri-buted to the formation of the Carolina Bays is unknown. It is possible that the features began as inderdunal lows or dune blowouts (Stolt and Rabenhorst, 1987) or as periglacial patterned ground later modified by wind into circular features aided by ponding in the lows. We will continue to investigate these features on future mapping projects.

Acknowledgements

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