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CORRELATING AN IMPACT STRUCTURE WITH THE CAROLINA BAYS

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We propose that the Carolina bays are depositional artifacts in the surface of a ~10 meter-thick sheet of distal ejecta, spread differentially from a cosmic impact. The lack of a correlated impact structure in North America is challenging, however. Using the alignments of 40 fields of Carolina bays in the East and the Mid-West, we generated great circle paths for visualization in Google Earth. This yielded a fuzzy triangulation locus centered at 43.5 N, 89.5 W. Our analysis implies this triangulation would yield an erroneous impact location, offset to the west due to Earth rotation of .25 degrees of arc every clock minute of flight time. Adjustment of the crater eastward along the 43.5º N Parallel should direct us towards the actual impact site. We examined geological depressions found along that transit, selecting the Saginaw area of Michigan.

It is generally understood that glacial activity removed vast quantities of softer strata from around the Michigan Basin's periphery (i.e., Lakes Michigan, Huron and Erie), however the ice sheet was unsuccessful in breaching proximal cuestas encircling the basin with one major exception: Saginaw Bay.

We propose a low-density hydrated silicate impactor, likely cometary, impacting the Earth on a shallow angle. Remote sensing shows that approximately 5% of all craters are created during such oblique impacts, creating an oval shaped crater and a butterfly ejecta pattern. The mechanism for removal of terrestrial material is seen as shearing rather than compression, thus many of the classic impact markers (such as shocked quartz) are not expected. We note that the Saginaw region exhibits a geometrically oval shaped depression, oriented SW to NE, which correlates well with the Carolina bay distribution seen across North America as an ejecta butterfly pattern.

Recent studies suggest that oblique impacts into solid surfaces protected by a layer of low impedance materials produces structures that differ from classic crater planforms. In our specific case, we invoke the Wisconsinan ice shield as a low-impedance layer protecting the sedimentary strata of the Michigan basin. The ice sheet offers a rationale for the relatively shallow "crater" seen in the area today. Implicating the ice sheet also provides a vehicle to re-distribute the local crater ejecta across a wide area as "glacial till".

An Impact and Distal Ejecta Hypothesis

The aligned oval basins known as "Carolina bays" are rimmed by distinctive deposits of siliciclastic sands. This stratotype is notable for its lack of terrigeneous detritus, leptokurtic coarse-skewed size-frequency grain distribution, hummocky cross-stratification, and invariant mineral composition at any given locale. Gradualistic processes are commonly held accountable, although this specific combination of traits is challenging for eolian, fluvial or marine depositional mechanisms.

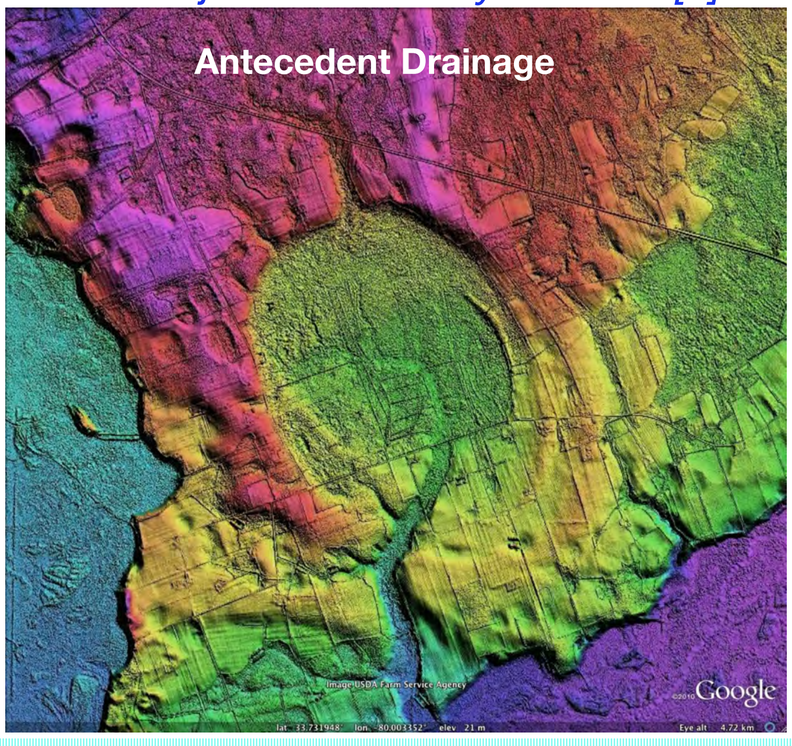
In his 1942 scholarly examination of numerous then-current hypotheses for the genesis of Carolina bays, Douglas Johnson stated: “No one has yet invented an explanation which will fully account for all the facts observed”. 70 years later, the geomorphology of these ovoid basins continue to challenge. Their sheer numbers, bedding in an anomalous stratum of homogeneous sand, distinctly geometrical circumpheral rims, variety of sizes, and common alignments across significant relief in any one area are seen by us as enigmatic. We view the bays collectively as a geological singularity, justifying a non-classical solution. Although it is possible that future models and/or observations may solve this enigma, it has motivated us to explore a potential independent solution.

Rim Cross Section: Photo by G. Howard

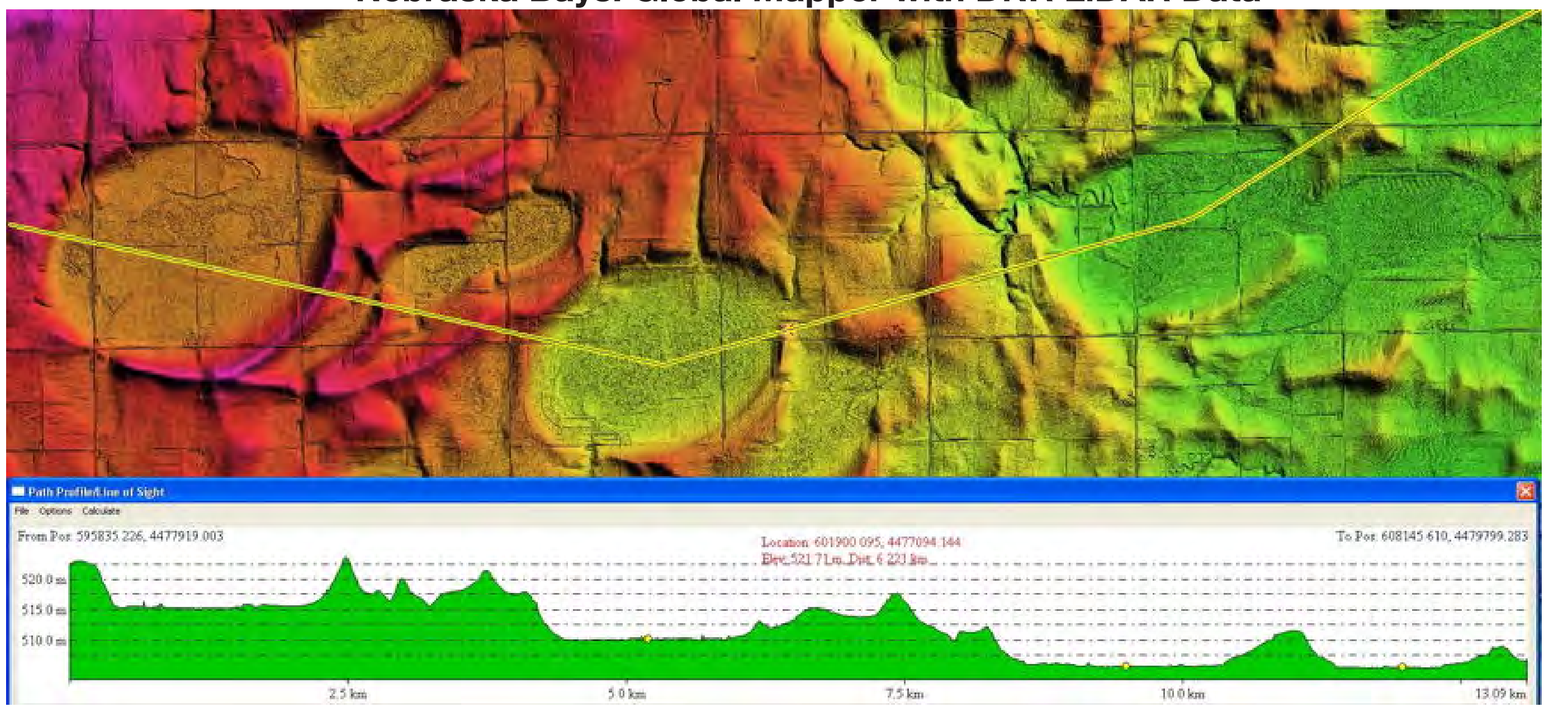
Researchers generally consider the bays to be formed within or excised from pre-existing strata through impact or by eolian, fluvial or marine (or combinations) processes. In direct contrast to all previous work, we propose that the bays are surface features within a blanket of ballistically deposited ejecta, draped conformably over antecedent topography and creating a palimpsest upon which much geological history has been written in the form of lacustrine and eolian development within and about those basins. We maintain that observations dismissing an impact scenario can be viewed as supportive of a blanket deposition:

- ◊ *Homogeneity of characteristics of rim & surrounding pediments (single stratum)*
- ◊ *Challenging lack of terrigeneous detritus in the stratum*
- ◊ *Rim material is not derived from underlying strata (nor do they deform them)*
- ◊ *Overprinting of pre-existing drainage channels*

No variation in the heavy mineral suite was found along a traverse of the major axis of one Carolina bay, even though samples were taken from the bay floor, rim and the adjacent non-bay terrace. [1]

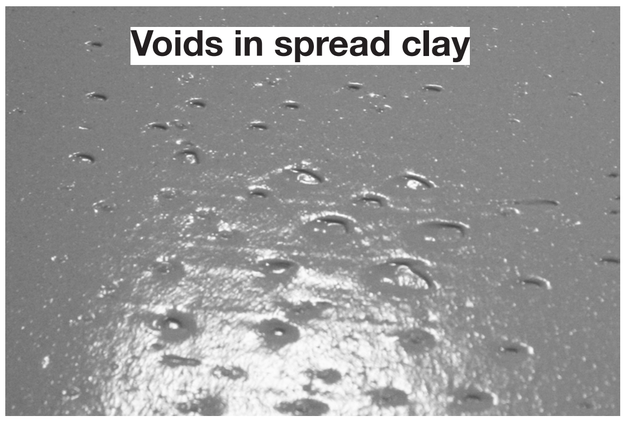


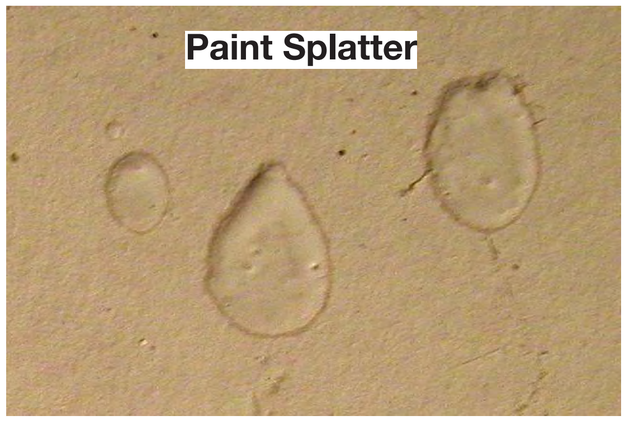
Nebraska Bays: Global Mapper with DNR LiDAR Data

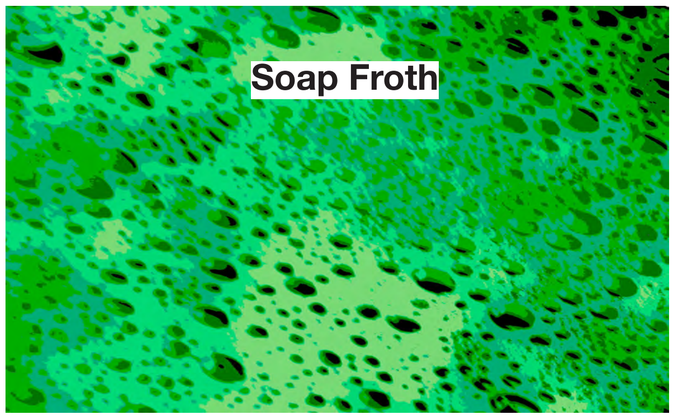


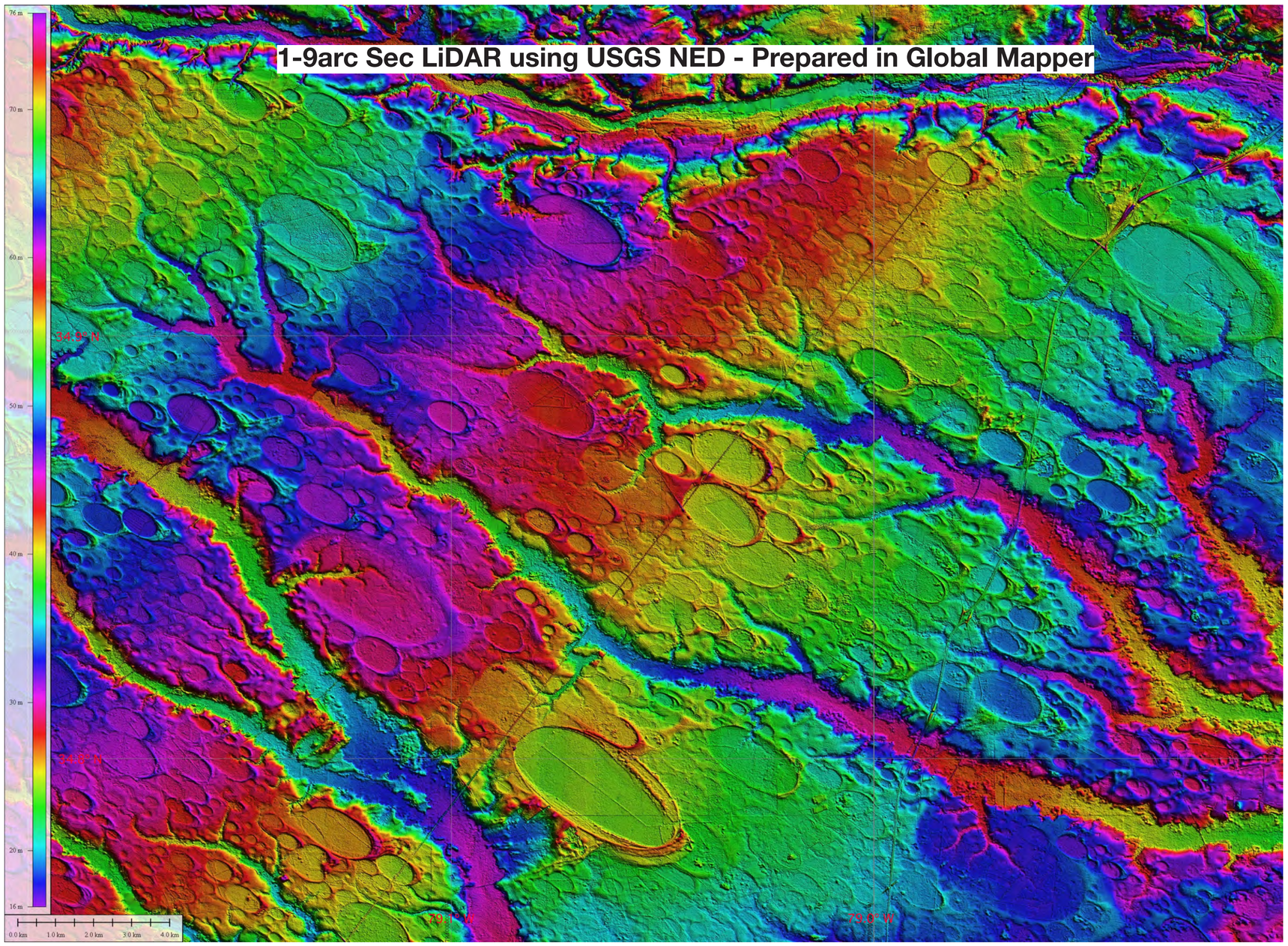
Carolina bays Interpreted as Depositional Artifacts in a Veneer of Ejecta

The hypothesis holds that glacial ices, excised sedimentary strata, and elements of the impactor shattered into small particles during the cosmic impact and intermixed in the ejecta curtain wall. The resulting 1-10 meter-thick layer of distal ejecta was spread differentially across North America, primarily within an annulus located at 900 to 1400 km from impact. We posit that relatively shallow basins were created as surface features during the energetic deflation of steam inclusions in the ejecta blanket; effectively “popped bubbles”, often manifested as a void in the blanket. This high-temperature, high-pressure emplacement created an unconsolidated rim stratum that has maintained its structural integrity over time. We see the planform and spatial distribution of the bays as being similar to voids and bubbles in various experiments with hydarated slurry deposited enegertically.The authors believe this interpretation explains the bays' geophysical characteristics, such as companion bays across a continuum of elevations, occasionally intersecting or overlaying one another.

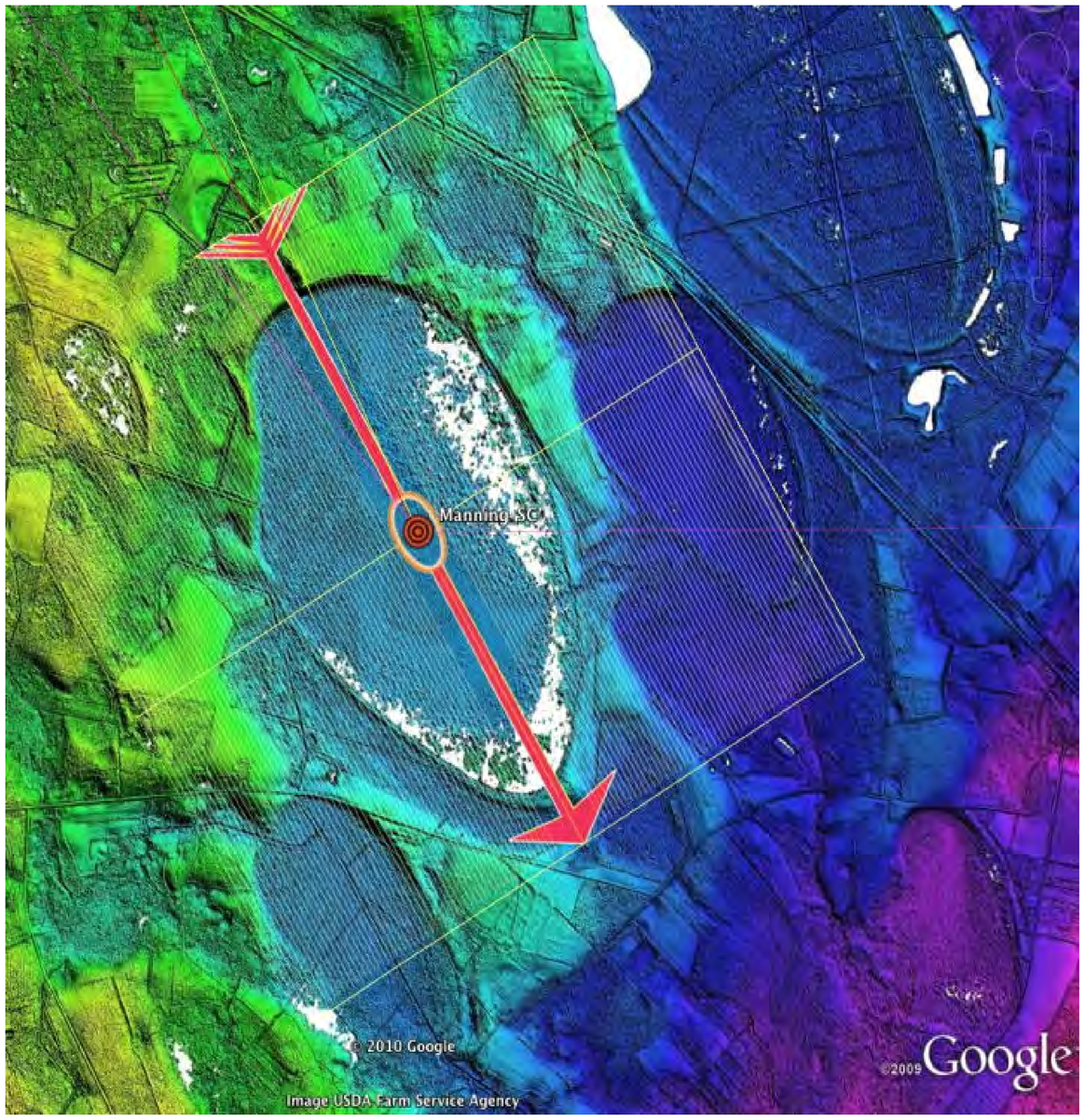


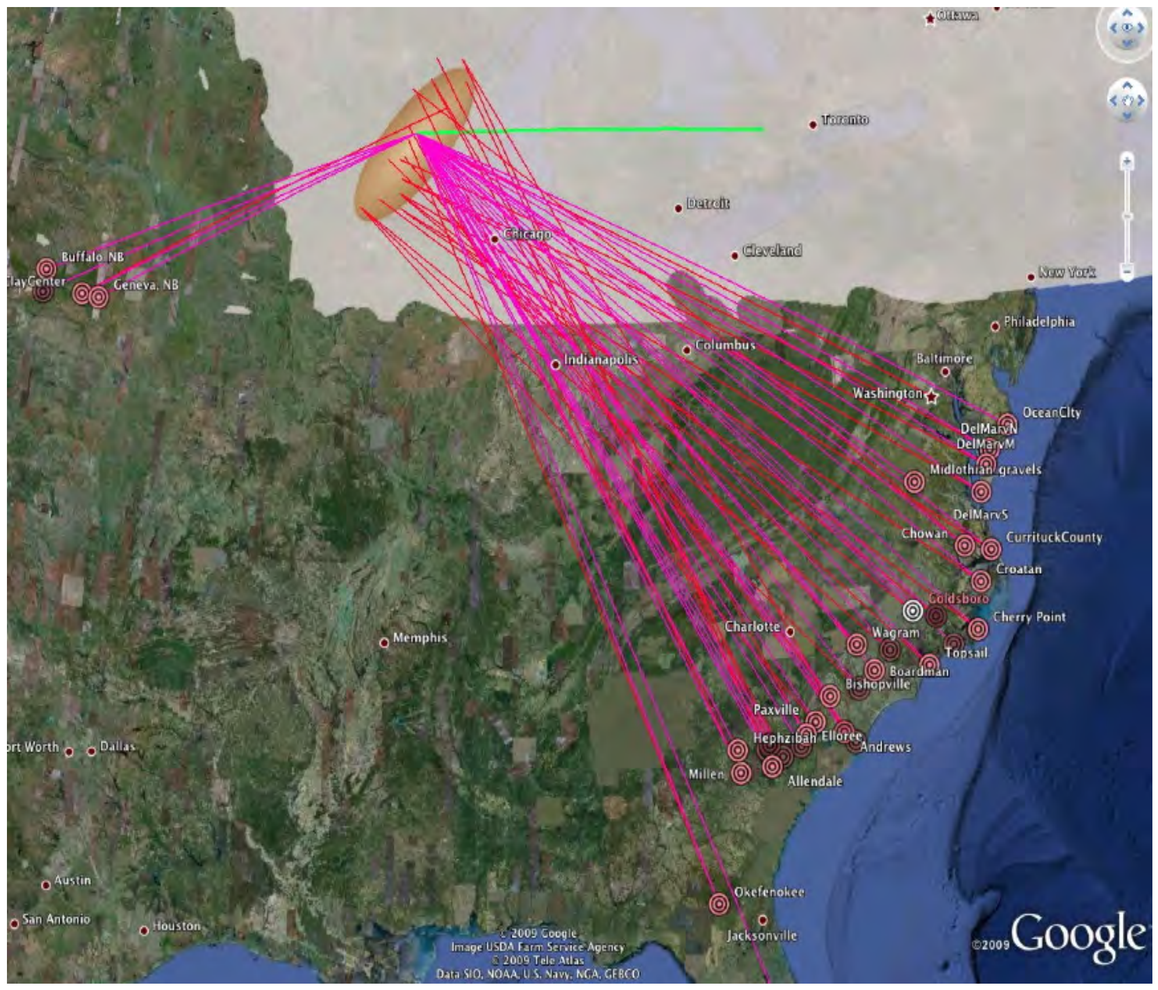






Crater Hunt





Using the facilities and satellite imagery of the Google Earth GIS, augmented with high resolution LiDAR imagery, a survey was undertaken to catalogue the extent of Carolina bays, indexed as localized “fields”. The Global Mapper GIS application was used to generate LiDAR HSV-Shaded image overlays for visualization in Google Earth, using 1/9 and 1/3 arc-second DEM data from the United States Geological Survey, and 1/9 arc-second DEM data from the Nebraska Department of Natural Resources.The survey resulted in a catalogue of ~220 fields of Carolina bays, managed in a spreadsheet database and in a Keyhole Markup Language (kml) metadata file.

Our working hypothesis that Carolina bays represent depositional features in an ejecta blanket leads to a corollary that the arrival bearing is a momentum artifact, aligned along the bays's major axis. To measure the bays and capture this alignment, we employ calibrated overlays on Google Earth's virtual globe. The overlays are rotated and scaled so that it aligns with the user's interpretation of orientation and planform size; the rotational value is captured in the overlay's metadata, along with the bay’s latitde, longitude and dimensions.

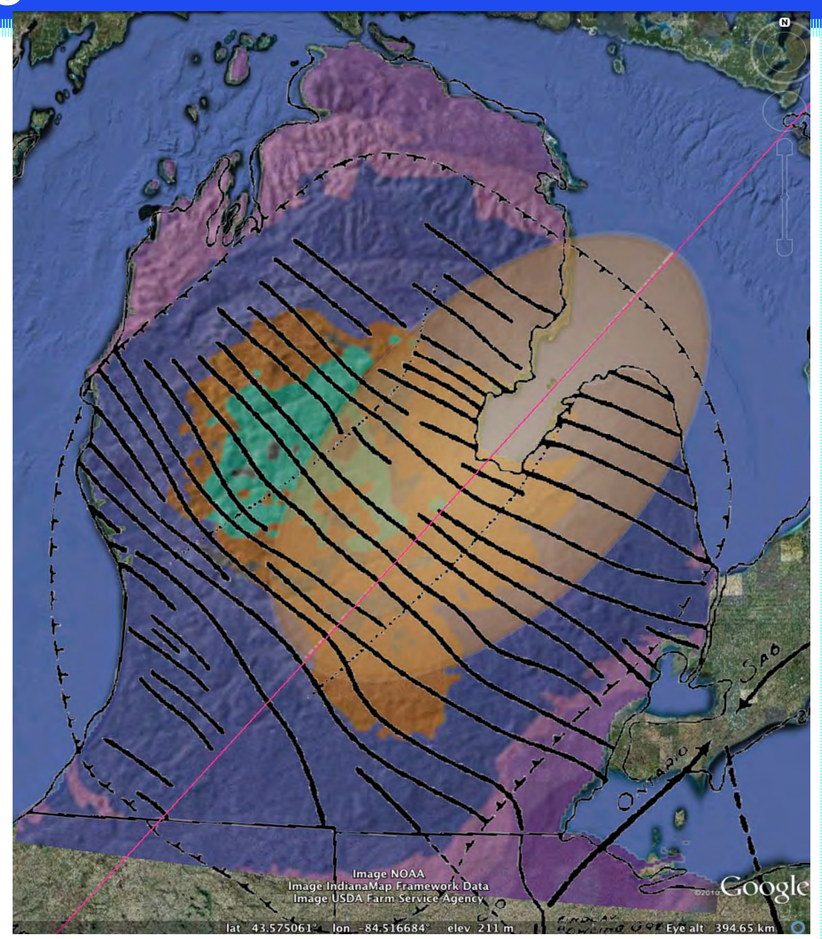
Using the measured alignments of an initial 40 Carolina bay fields, we generated great circle paths for visualization in Google Earth. This yielded a fuzzy triangulation locus centered at 43.5 N, 89.5 W. Our analysis implies that a great circle triangulation would yield an erroneous “surrogate” impact location, offset to the west. A flight-time adjustment of the crater eastward along the 43.5ºN Parallel (taking into account the Earth rotating .25 degrees of arc every clock minute) directs us towards the impact. We heuristically examined various geological depression found along that transit, and selected the Saginaw area of Michigan's Lower Peninsula for further analysis.

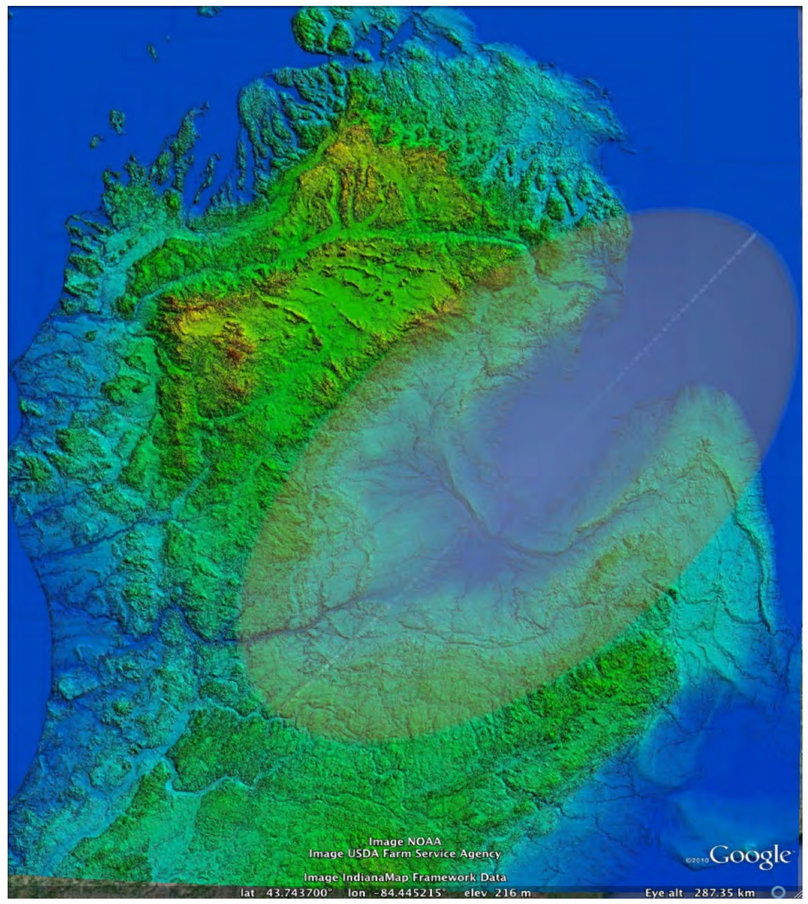
Saginaw Impact Structure

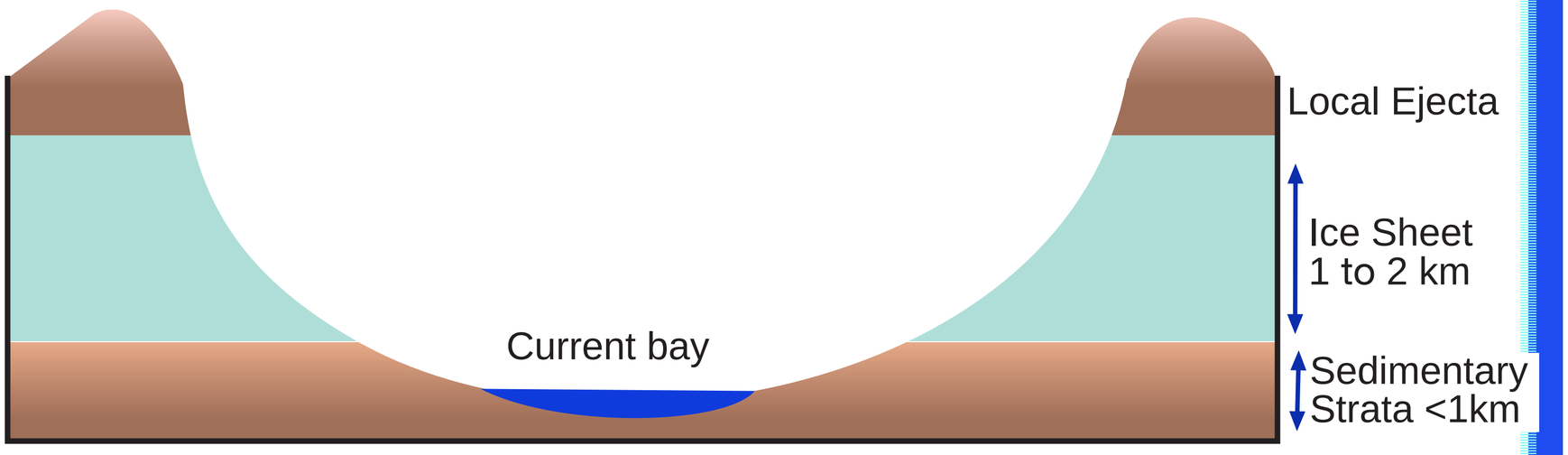
Our hypothesis holds that the impacting object was a massive low-density hydrated silicate object, likely a cometary body, which impacted the Earth on a shallow angle, nearly tangential to the Earth's surface. Remote sensing has show that approximately 5% of all craters are created during such oblique impacts, creating a set of recognizable characteristics: oval shape, butterfly ejecta pattern, “no-fly” ejecta area up field, and “blow-out” rim down field. Recent studies suggest that impacts into solid surfaces protected by a layer of low impedance materials produces structures that differ from classic planforms (Schultz, 2007; Schultz and Stickle, 2009). In our specific case, we invoke the Wisconsinan ice shield as a low-impedance layer protecting the sedimentary strata of the Michigan basin. The mechanism for removal of terrestrial material is seen as shearing rather than compression, thus many of the classic impact markers (such as shocked quartz) are not expected.

Using remote imaging tools, we note that the Saginaw region exhibits a geometrically oval shaped depression, oriented SW to NE, which correlates well with the ejecta symmetry. Research by others utilizing remote sensing tools (Herrick and Hessen, 2003) have shown oblique impact craters often display the deepest excavation at the up range end of the crater, which here falls in the northeast end of our proposed Saginaw crater, where one of the deepest areas of Lake Huron exists - the Bay City Basin. Another attribute of oblique impact planforms is a ridge - likely rebound strata - down the center of the structure. Here, the Charity Islands exist along the oval's centerline.

We expect that the Huron lobe of the Ice sheet would have advanced into the excavated crater from the Huron basin, bulldozing the collapsed ice crater ramparts, leaving the present-day terminal moraines behind as it deglaciated. Research has indicated that the Saginaw lobe was absent from southern Michigan while the Lake Michigan, Huron-Erie, and Erie lobes continued to advance during the latter part of the Wisconsinan glaciation.







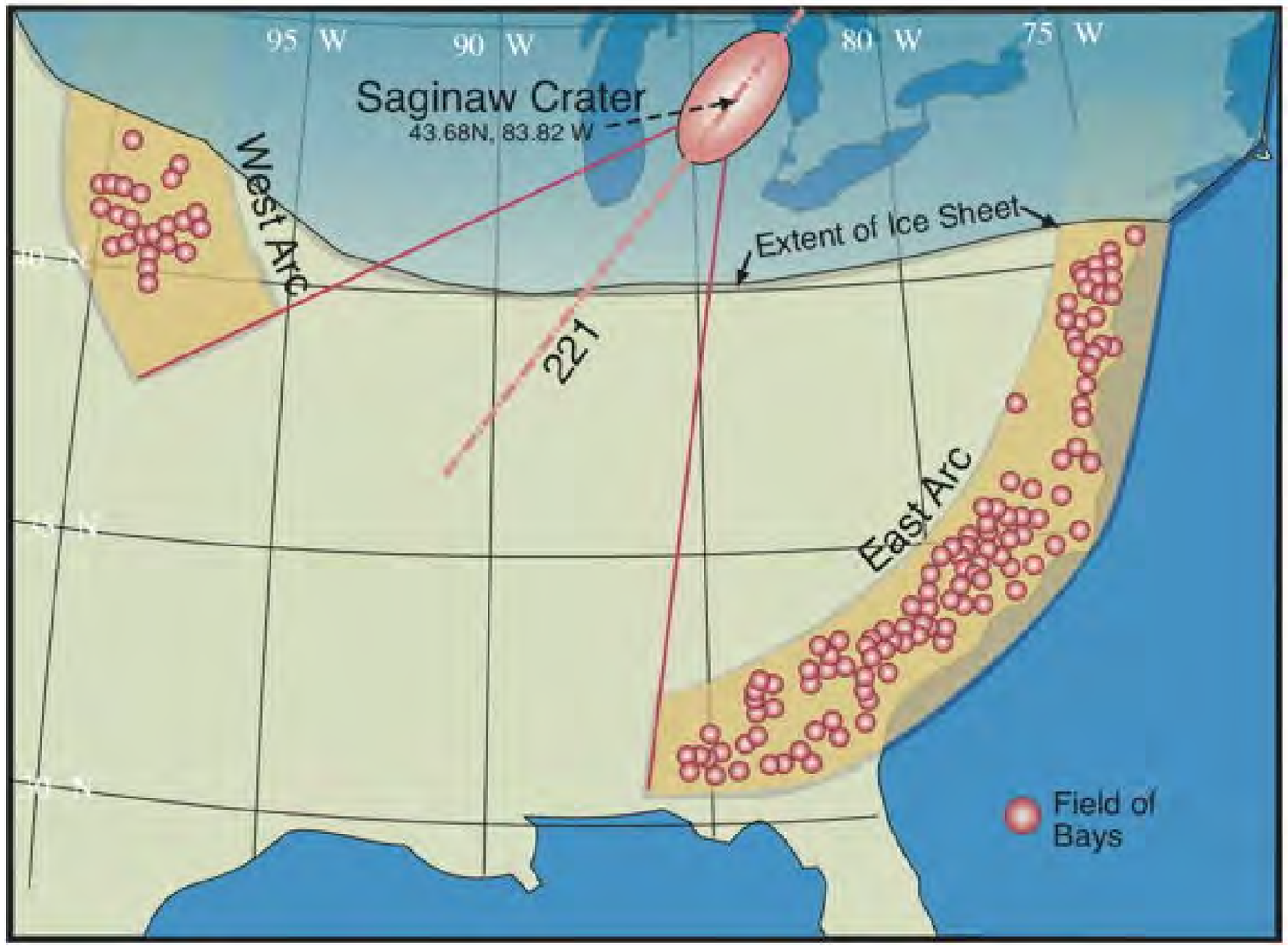
Cross-Section View of Saginaw Crater - Elevation Not To Scale

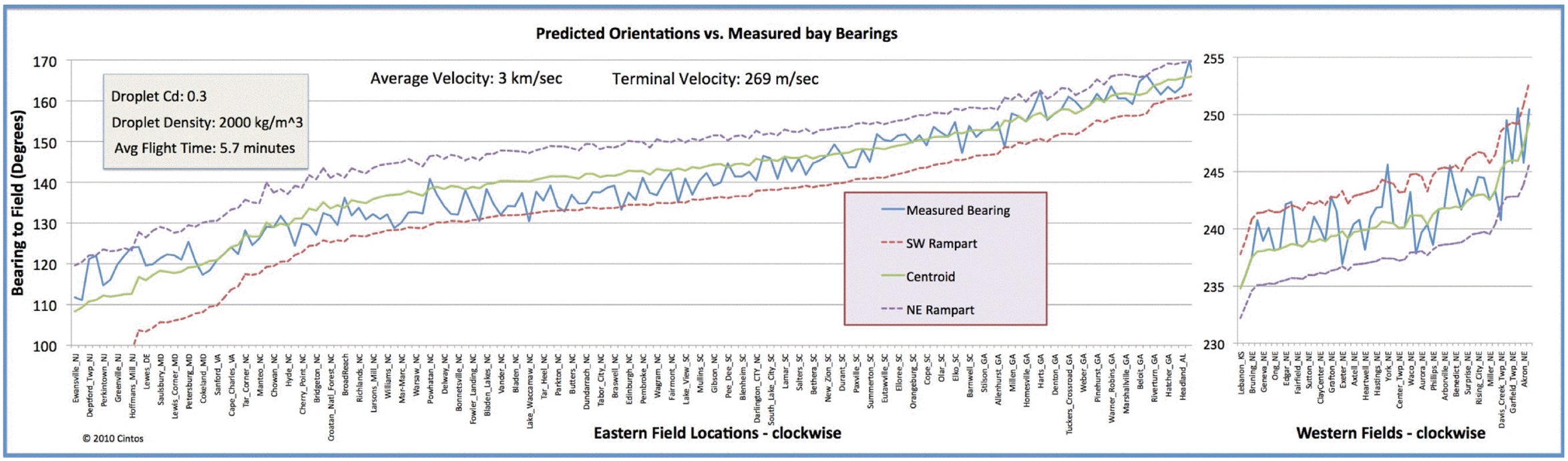
Correlating Carolina bay Orientations

Attempts by others to correlate bays' orientations across their extent have failed (Eyton, J.R. and Parkhurst, J.I., 1975), as they typically were accomplished by drawing straight lines on flat-earth maps. We propose that satisfactory correlation can be obtained by applying several physical aspects of planetary-scale ejecta trajectories, a process not considered as relevant by previous workers. First, the impact may have generated ejecta from a broad geographic extent. Secondly, a planetary body rotates during any realistic ejecta flight-time. Third, the west-to-east ground-velocity between the ejection site and the landing site differs, and the difference will be resolved as the ejecta re-enters the atmosphere and strikes the Earth.

We developed a model for an ejecta curtain wall radiating outward from an impact site that represents the adjustments made for ballistic trajectories over a rotating sphere, heuristically engineered to predict Carolina bays' orientations. It was our intent to only address first-order magnitude effects, given the expected chaotic distribution of ejecta velocities, densities and directions.

A Java calculator was developed specifically to interface with the Google Earth virtual globe. Using the Google Earth "Placemark" metadata element, the location's latitude and longitude are captured and annotated. The calculator processes the placemark and returns a set of Google Earth elements that represent the numerical model's predicted ejecta arrival vector. The model is heuristically focused on the latitude and longitude of the proposed Saginaw crater's three control points (NE, Centroid and SW); the calculator returns predictions for ejecta emanating from those three locations.





Carolina bays' Gensisis as Distal Ejecta Blanket ~41 kya

This poster is a necessarily brief overview of an extensive hypothesis, which holds that an oblique cosmic impact into the Wisconsinan ice sheet spread a blanket of distal ejecta across North America along a broad annulus. We propose that shallow basins were created during the energetic deflation of gas inclusions in those superheated hydrous ejecta. The resulting paleobasins have persisted over the intervening millennia as "Carolina bays", "Rainwater Basins", "Maryland Basins", etc, while being overlain with loess and subjected to reworking by water and wind erosion. Using numerous constraints, we have set the impact date ca 41 ka, coinciding with the Laschamp excursion.

To test the hypothesis, an analytical model was engineered based on several fundamental considerations of ejecta movement around a planetary-scale rotating sphere that hosts a dense atmosphere. The model has been shown to successfully predict trajectories and emplacement orientations of the ejecta blanket and the surficial bays assuming only the source impact location and bay locations on the sphere. While we demonstrate the accuracy of the model using constants for all other parameters, variable sensitivity testing has shown that satisfactory predictions can be obtained by perturbing the two physically relevant parameters (ejecta average and terminal velocities) over a realistic range. The model can be inverted to identify a causal impact crater location using a triangulation network. We also note that the distribution of bays is highly symmetrical around the proposed impact's azimuth.

The correlations identified demonstrate the existence of a unique geospatial relationship between all known Carolina bays and the Saginaw region, and can be seen as validation of the model's algorithm and lending support for the distal ejecta blanket hypothesis introduced here. It is our hope that the presented argument will add a new perspective to the geomorphologic nature of the Carolina bays and Michigan's Lower Peninsula, thus warrant future research and investigation.