Sea Level and Climate History of the Delmarva Peninsula Over the Past 40,000 Years: A Radiocarbon Date Perspective

Kelvin W. Ramsey, Delaware Geological Survey, Univ. of Delaware, Newark, DE

Abstract

Radiocarbon (RC) dates from organic sediments in coastal deposits have been used to estimate sea levels over the past 40,000 years including the Holocene rise. The Delaware Geological Survey Radiocarbon Database contains 474 radiocarbon dates from the Delmarva Peninsula Region collected from offshore, coastal, and upland depositional environments. Examination of geographic distribution, depositional environment, and sample elevation paired with pollen data allow for the following observations regarding Holocene and late Pleistocene sea level and climate history of the Delmarva Peninsula: 1.) Organic sedimentation was relatively continuous in the region throughout the last 40,000 yrs., but was geographically variable as follows (observations 2-4). 2.) RC dates from coastal and offshore deposits show the Holocene rise of sea level since 12,000 yrs BP, no dates between 12,000 and 22,000 yrs BP and dates scattered over an 80 ft elevation range between 22,000 and 40,000 yrs BP. 3.) Periglacial organic deposition on the uplands in the Cypress Swamp Fm and adjacent to modern streams was active between 15,000 and 40,000 yrs BP, was less active between 10,000 and 15,000 yrs BP, and was not active between 10,000 and 4,000 yrs BP. The period of non-deposition may coincide with a period of dry conditions during the early Holocene documented elsewhere in North America. 4.) Modern swamp deposition in the uplands began about 4,000 yrs BP and continues to the present.

Data and Methodology

The Delaware Geological Survey (DGS) Radiocarbon Database contains 474 radiocarbon dates from unpublished DGS data, published data (including Belknap, 1975; Kraft, 1976; and Ramsey and Baxter, 1996) and other unpublished technical reports, theses and dissertations. Dates other than in the abstract are reported as ka (ka=1,000 yrs) BP (before present). Dates considered to be dead to carbon (>40 ka) were not used except where laboratory results indicate that they are viable, leaving a total of 398 dates (Figure A).

Figures A-D show the elevation of the top of the sampled interval from which the date was obtained versus the conventional radiocarbon age of the sample. Conventional radiocarbon age was used rather than a calibrated age because many of the dates were collected prior to widely available calibration programs and have not yet been calibrated.

Each date (Figures B-D) was assigned a geographic/geomorphic region (Figure E) from which the geologic sample was collected. By plotting the sample elevation relative to age from geomorphic regions, features such as sea-level rise or periods of time lacking deposition of organic material within the region become evident. The plots are visual representation of the data and have not undergone statistical or other (e.g. Bayesian) analyses. The conclusions presented are preliminary.

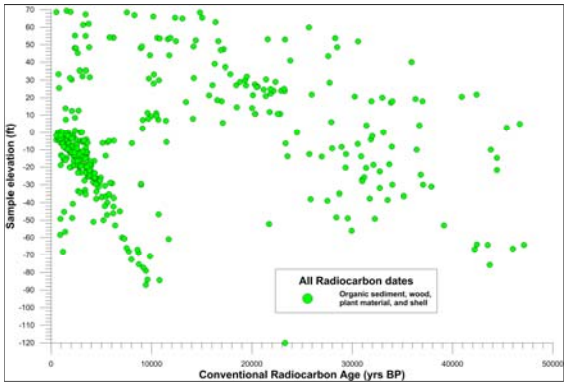


Figure A. All radiocarbon dates: The graph above contains 398 radiocarbon dates. The spread of dates across the entire time range suggests that organic deposition has been continuous somewhere in the Delmarva Peninsula region during the last 40 ka. Sample locations for this and all the other plots are shown in Figure E.

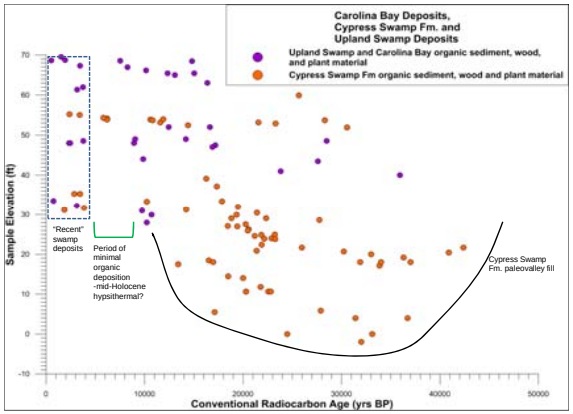


Figure B. Carolina Bay, Cypress Swamp Fm. and upland swamp dates: Carolina Bays (Figure E inset) are circular features whose formation is likely related to periglacial climate. They are most abundant in a belt across Maryland into central Delaware along the Kent-New Castle County border above the subcrop of the lower Calvert Fm. (Tomlinson and Ramsey, 2014). The Cypress Swamp Fm. is located in south-central Sussex County, Delaware and northern Wicomico County, Maryland. The Cypress Swamp Fm. (Andres and Howard, 2000; Ramsey and Tomlinson, 2014) consists of swamp and sphagnum bog deposits interbedded with stream and eolian sand deposits that fill a paleovalley and grade into a sheet of sand and peat sediments on the adjacent uplands. Upland swamp deposits include "recent" swamps along streams and wetlands in Carolina Bays. Note that there is a gap in organic deposition in the Carolina Bays and upland swamp deposits between 4 ka and 7 ka, limited deposition between 7 ka and 9 ka, and only two dates during that period in the Cypress Swamp Fm. Another apparent gap in Carolina Bay dates occurs between 18 and 23 ka. It is unknown if this due to a lack of sampling of older deposits or an actual period of non-deposition.

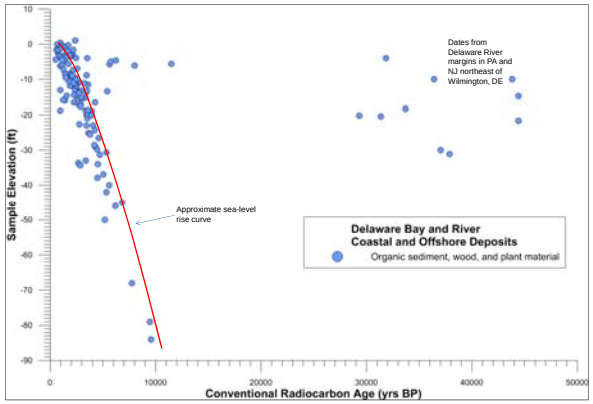


Figure C. Delaware Bay and River Coast and Offshore deposits: Samples from the marshes adjacent to Delaware Bay and offshore estuarine deposits in Delaware Bay show the Holocene rise of sea level (red line), a lack of dates between approx.10 ka and 30 ka, and a cluster of samples between present sea level and -30 ft below sea level between 30 ka and 40 ka. Three dates at approx. 45 ka may or may not be viable dates. All of the older dates come from the margins of the Delaware River near Chester, PA and north of Woodbury, NJ.

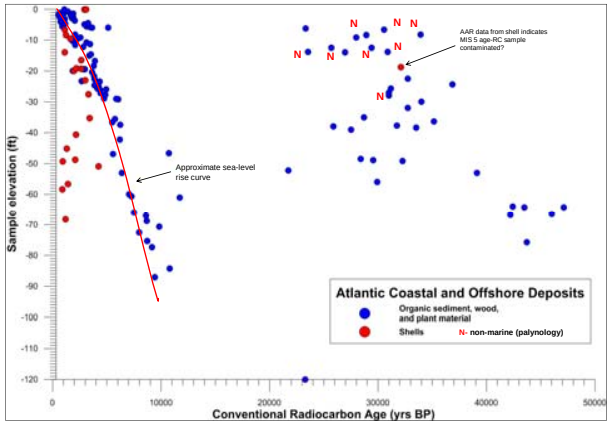


Figure D. Atlantic Coastal and offshore deposits: Samples from the marshes adjacent to the Atlantic Ocean and offshore marine deposits show the Holocene rise of sea level (red line), a lack of dates between approx.10 ka and 24 ka, and a cluster of samples between present sea level and -60 ft below sea level between 24 ka and 40 ka. Another group of samples between 40 ka and 50 ka either are not viable dates or are deposits related to the MIS-3 highstand of sea level. Radiocarbon dates of shell material plot off the sea-level rise curve and indicate that the mollusks lived on the seafloor at a water depth within +/- 10 ft of their sample elevation. Dates between 24 ka and 40 ka have previously been considered to be estuarine or marine (Finkelstein, 1986) and have been a point of controversy regarding MIS 3 sea levels in the Delmarva region (Finkelstein and Kearney, 1989; Colman et al., 1989). Pollen from some of the samples (N on graph; Weigle, 1974; Finkelstein, 1986) however, indicate that they are non-marine and similar in environment to the Cypress Swamp Fm. (e.g., sphagnum bog or open wetland) deposited in cool-cold climate conditions (Groot and Jordan, 1999). The pollen data support a MIS-3 sea-level highstand lower than present sea level in the Delmarva region, not near or above present sea level.

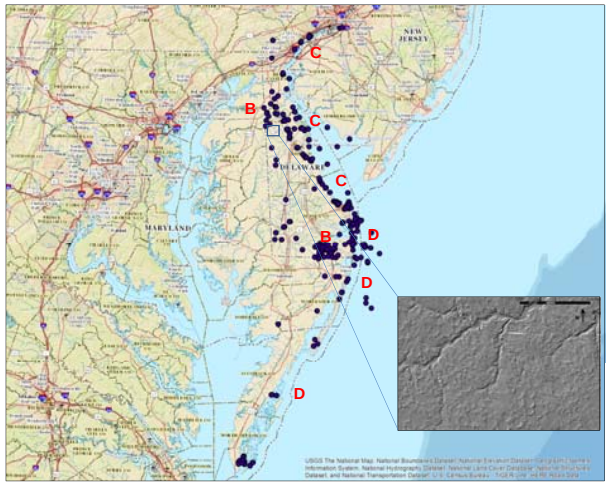


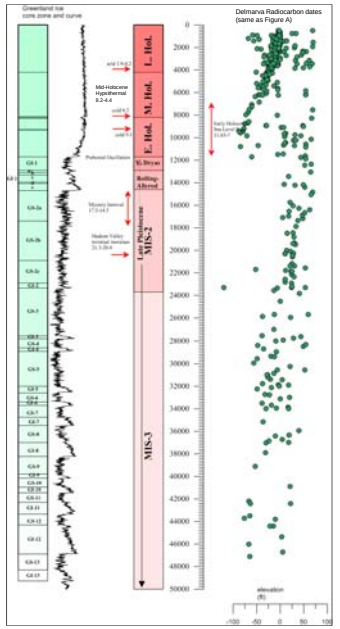
Figure E. Sites from which organic material was sampled for radiocarbon dating. Red letters refer to geographic regions in Figures B-D. Map scale 1:1,500,000. Carolina Bays (circular features) west of Dover, DE shown in inset (2014 Lidar DEM).

Discussion and Conclusions

Figure F shows a plot of all the radiocarbon dates (same data as **A**) relative to the late Pleistocene to Holocene time scale, marine isotope stages (MIS), and the Greenland ice core records. ka=1,000 yrs BP

1. The Holocene rise in sea level appears in the region at about 11ka and continues until the present.
2. Late Pleistocene (MIS-2 to MIS-3) RC dates along the Atlantic Coast and offshore previously considered to be marine deposits (Finkelstein and Kearney, 1988) are likely nonmarine and represent periglacial bog deposition (based on pollen data) across a range of elevations on a subaerial landscape when sea level was much lower than present. Similar age deposits have not been found in the area of Delaware Bay.
3. Organic bog deposition occurred on the Delmarva uplands (Carolina Bays, Cypress Swamp Fm.) during MIS-3 and MIS-2 (Figures B, F). These bog deposits, along with eolian sands, filled a paleovalley with Cypress Swamp Fm. sediments (Figure B) by the glacial maximum (approx. 20.4 ka; Braun et al, 2008; Stanford 2010). Organic deposition continued on the uplands as the glaciers retreated to the north between 20 ka and 12 ka.
4. Between approx. 10 ka and 8 ka, organic deposition on the uplands becomes less common, and in the area of Cypress Swamp ceases until approx 4 ka. Stinchcomb et al (2012) document between 8 and 5 ka to be a period of floodplain erosion and deposition of coarse-grained floodplain sediments between 8 and 6 ka, incision between 6 and 5 ka, and a paucity of organic material compared to the early and late Holocene on the Delaware River in central PA. They attribute their observations to a period of warm and wet climate followed by a shift to warm and dry at about 5.5 ka. Rather than the region being warm and wet, a mid-Holocene hypsithermal (warm and dry) event in eastern North America (Tanner et al, 2015; Mullins et al, 2011) better fits the lack of organic deposition during the early to middle Holocene on the Delmarva uplands. In the Carolina Bays and the Cypress Swamp area, wetlands present during the late Pleistocene dried up and only became wetlands again as wetter conditions returned during the late Holocene.
5. Modern organic deposition in wetlands and swamps on the uplands began about 4 ka.

Figure F. Late Pleistocene and Holocene time scale. NGRIP Ice Core data 2010-11-19 GICCO5modelext.xls; Holocene subdivisions from Walker and others (2012)



References cited

Andres, A.S., and Howard, C.S., 2000, The Cypress Swamp Formation, Delaware: Delaware Geological Survey Report of Investigations No. 62, 13p.

Belknap, D.F., 1975, Dating of late Pleistocene and Holocene relative sea levels in coastal Delaware; M.S. Thesis, Univ. of Delaware, Newark, DE, 95 p.

Braun, D., Ciolkosz, E., Drohan, P., and Sevon, W., 2008, The Pleistocene record in the middle to lower Susquehanna River Basin and the longer term evolution of the Susquehanna Basin landscape: 20th Biennial American Quaternary Association guidebook, 58 p.

Broecker, W. and Putnam, A.W., 2012, How did the hydrologic cycle respond to the two-phase mystery interval?: Quaternary Science Reviews, v. 57, p. 17-25.

Colman, S.M., Mixon, R.B., Rubin, M., Bloom, A.L., Johnson, G.H., 1989, Comments and reply on "Late Pleistocene barrier-island sequence along the southern Delmarva Peninsula: implications for middle Wisconsin sea levels"; Geology, v. 17, p. 84-88.

Finkelstein, K., 1986, The late Quaternary evolution of a twin barrier-island complex, Cape Charles, Virginia: Ph.D. Dissertation, Virginia Institute of Marine Science, College of William and Mary, Williamsburg, Va., 284 p.

Finkelstein, K., and Kearney, M.S., 1988, Late Pleistocene barrier-island sequence along the southern Delmarva Peninsula: implications for middle Wisconsin sea levels: Geology, v. 16, p. 41-45.

Groot, J.J., and Jordan, R.R., 1999, The Pliocene and Quaternary deposits of Delaware: palynology, ages, and paleoenvironments: Delaware Geological Survey Report of Investigations No. 58, 36 p.

Kraft, J.C., 1976, Radiocarbon dates in the Delaware coastal zone: Univ. of Delaware Sea Grant Publication No. DEL-SG-19-76, 20 p.

Mullins, H.T., Patterson, W.P., Teece, M.A., and Burnett, A.W., 2011, Holocene climate and environmental change in central New York (USA): Journal of Paleolimnology, v. 45, p. 243-256.

NGRIP Ice Core Data, obtainable from https://www.ncdc.noaa.gov/data-access/paleoclimatology-data/datasets/ice-core

Ramsey, K. W., and Tomlinson, J.L., 2014, Geologic Map of the Millsboro and Whaleysville Quadrangles, Delaware: Delaware Geological Survey Geologic Map No. 20, scale 1:24,000.

Ramsey, K.W., and Baxter, S.J., 1996, Radiocarbon dates from Delaware: a compilation: Delaware Geological Survey Report of Investigations No. 54, 18 p.

Stanford, S.D., 2010, Onshore record of Hudson River drainage to the continental shelf from the late Miocene through the late Wisconsinan deglaciation, U.S.A.: synthesis and revision: Boreas, v 39, p. 1-17.

Stinchcomb, G.E., Driese, S.G., Nordt, L.C. and Allen, P.M., 2012, A mid to late Holocene history of floodplain and terrace reworking along the middle Delaware River valley, USA: Geomorphology, v. 169, p. 123-141.

Tanner, B.R., Lane C.S., Martin, E.M., Young, R, and Collins, B., 2015, Sedimentary proxy evidence of a mid-Holocene hypsithermal event in the location of a current warming hole, North Carolina, USA: Quaternary Research, v. 83, p. 315-323.

Tomlinson, J.L., and Ramsey, K.W., 2014, Stratigraphic, hydrologic, and climatic influences on the formation and spatial distribution of Carolina Bays in central Delaware: Geological Society of America Abstracts with Programs, v. 46, no. 2. p. 71

Walker, M.J.C., Berkelhammer, M., Bjorck, S., Cwynar, L.C., Fisher, D.A., Long, A.J., Lowe, J.J. Newnham, R.M., Rasmussen, S.O., and Weiss, H., 2012, Formal subdivision of the Holocene Series/Epoch: a discussion paper: Journal of Quaternary Science, v. 27, p. 649-659.

Weigle, J.M., 1974, Availability of fresh ground water in northeastern Worchester County, Maryland,: Maryland Geological Survey Report of Investigations 24, 64 p.

Acknowledgements

Some radiocarbon dates were funded by the Delaware Geological Survey, STATEMAP (a program component of the USGS National Cooperative Geologic Mapping Program), and BOEM Marine Minerals Program (Bureau of Ocean Energy Management Hurricane Sandy Cooperative Agreement with the Delaware Geological Survey). Jaime Tomlinson and Trevor Metz of the Delaware Geological Survey assisted in the collection and preparation of samples for radiocarbon dating and in management of the data.