Palaeogeography, Palaeoclimatology, Palaeoecology 323-325 (2012) 100–109

Contents lists available at SciVerse ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

Driftwood dropstones in Middle Miocene Climate Optimum shallow marine strata (Calvert Cliffs, Maryland Coastal Plain): Erratic pebbles no certain proxy for cold climate

Peter R. Vogt [a,b,*], Mary Parrish [b]

[a] Marine Science Institute, University of California at Santa Barbara, Santa Barbara, CA 93106, USA
[b] National Museum of Natural History, Smithsonian Institution, Washington, DC 20560, USA

ARTICLE INFO

Article history:
Received 1 August 2011
Received in revised form 21 January 2012
Accepted 27 January 2012
Available online 3 February 2012

Keywords:
Middle Miocene Climate Optimum
Ice-rafted detritus
Driftwood dropstones
Calvert Formation
Columbia River Flood Basalts
East Antarctic ice sheet expansion

ABSTRACT

Sparse lithic erratics (pebbles to cobbles) sampled from three shallow marine strata deposited during the Middle Miocene Climate Optimum (MMCO, ca. 16–14 Ma) along the western Atlantic margin (exposed in the Calvert Cliffs, Maryland) suggest transport and deposition not from ice but from the roots of trees uprooted during floods and carried out to sea. Evidence for driftwood transport includes carbonized wood in the same strata. More than half the ca. 225 erratics were quarried in the largely metamorphic Piedmont province (including a few from the Port Deposit Gneiss, still outcropping on the lower Susquehanna River). The lowest sampled bed (Parker Creek Bone Bed) is assigned to the ca. 15.7–15.5 Ma peak warmth of the MMCO, which we attribute in part to CO_2 from the coevally erupted Grande Ronde flood basalts (GRFB), the peak effusiveness episode of the Columbia River Flood Basalts (CRFB) The three sampled beds predate the ca. 13.9 Ma Antarctic cryosphere expansion, which may be recorded in the Calvert Cliffs by a unique buried channel.

1. Introduction and geological background

The world's sediment strata hold an enormous paleoenvironmental archive. Reading and interpreting this archive has for practical reasons focused on abundant microfossils and other fine sediment particles sampled by coring. However, sediments also contain paleoenvironmental information in the form of relatively large, sparse objects, such as vertebrate bones or wood, missed or destroyed by coring; their story may require extensive, eroding outcrops and years of collecting for meaningful interpretations. This paper deals with objects of this sort—widely dispersed lithic erratics, pebble to cobble size, occurring in three shallow Middle Miocene marine strata (hereafter referred to as beds), part of the ca. 18–8 Ma, fossil-rich Miocene deposits outcropping along the Calvert Cliffs on the western shore of the Maryland Chesapeake Bay. The three beds were laid down in a shallow, open embayment, called the Calvert Sea (Fig. 1), of the western Atlantic Ocean.

The erratics are here attributed to deposition from driftwood, not ice, during the Middle Miocene Climate Optimum. The age of the host strata and the nature and origin of the MMCO, when global temperatures may have been 3 °C higher than today (e.g., Tripati et al., 2009) is reevaluated. Our term "driftwood dropstones" denotes entrapment in the roots of trees, which were occasionally uprooted along river banks in floods, perhaps associated with transgressions, and carried out to sea. Erratic pebbles in marine sediments are often attributed to ice-rafting, and may become unchallenged cold-climate proxies. However, there are other ways to transport lithic erratics into the sea. Bennett et al. (1996) review 'dropstones' and caution against uncritical identification of dropstones as IRD (Ice-Rafted Detritus).

About 225 lithic erratics (pebbles and cobbles) were collected over more than a decade from Shattuck's (1904) "zones" #12, 13 and 14 (hereafter referred to as "beds", following Ward and Andrews, 2008). We also use some of the nomenclature introduced by Kidwell (1984, 1997): She designated units (packets) of two to three beds, as well as the disconformities at the base of these units, by a two-letter abbreviation for the formation or member (e.g., CT for Choptank Formation), followed by a digit indicating stratigraphic position. Thus, CT0 denotes the basal unit of the Choptank Formation, and also the disconformity at the base of the unit.

The Calvert Cliffs form a 50 km-long series of seacliffs, ca. 10–30 m high, along the western shore of the Maryland Chesapeake Bay (Figs. 1, 2). The three beds (Fig. 3), described in many papers (e.g., Kidwell, 1997; Ward and Andrews, 2008), belong to the upper Plum Point Member of the Calvert Formation. This member and the overlying Choptank Formation are traceable over a ca. 9000 km^2 area of the Maryland and Virginia coastal plain (Kidwell, 1984). The sampled beds are Langhian to perhaps early Serravalian in age, but more accurate direct dating (e.g., Browning et al., 2006) remains uncertain.

* Corresponding author at: Marine Science Institute, University of California at Santa Barbara, Santa Barbara, CA 93106, USA.
E-mail address: ptr_vogt@yahoo.com (P.R. Vogt).

0031-0182/$ – see front matter
doi:10.1016/j.palaeo.2012.01.035

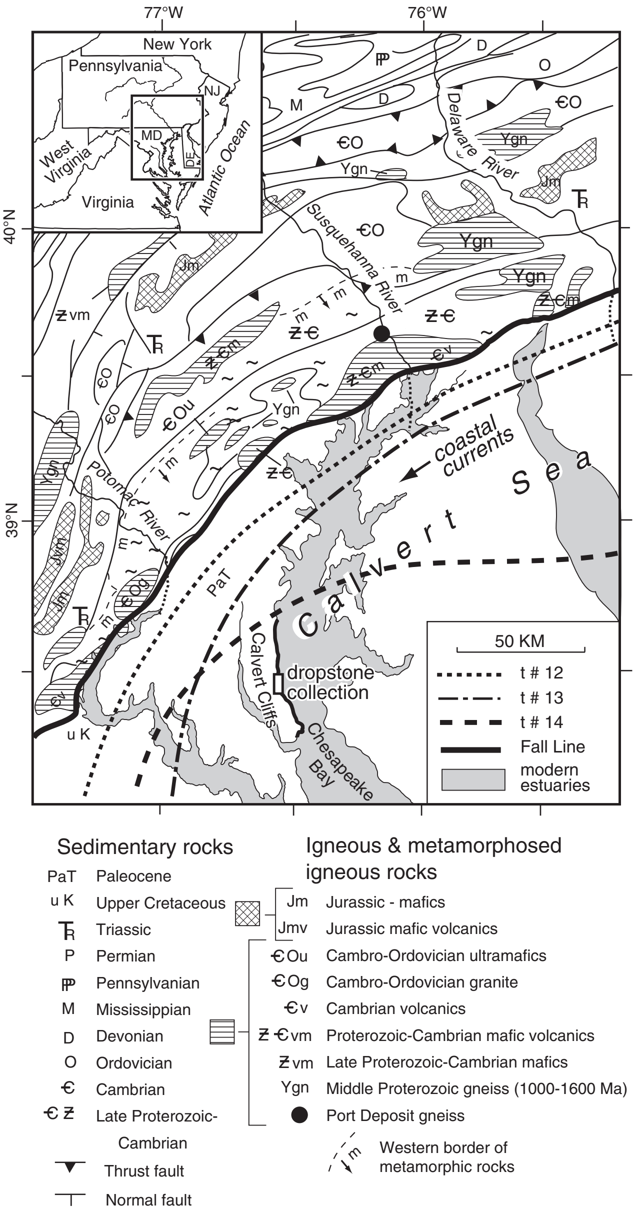

Fig. 1. Modern surface geology of probable erratic provenance area, (simplified from Reed et al., 2005), with estimated average paleoshoreline locations when beds 12, 13 and 14 were deposited (t#12, t#13, and t#3), and location of Calvert Cliffs and dropstone collection area. Fall Line marks the easternmost extent of Piedmont province, from which metamorphic and igneous erratics could have been eroded. Large dot locates Port Deposit Gneiss.

Using lithology and paleoenvironments, we propose relating the beds indirectly to glacioeustatic sea level fluctuations driven by volume changes in the Antarctic ice sheet. Although detailed age assignments differ among investigators (Kidwell, 1997; Section 5 in present paper), the three sampled beds were deposited during an anomalous and enigmatic interval of climate history: the ca. 16–14 Ma Middle Miocene Climate Optimum (MMCO; e.g. Tripati et al., 2009) and the 'Monterey' carbon isotope excursion, a period of anomalously high ^{13}C (16.4–13.6 Ma; Holbourn et al., 2007).

2. Lithology of beds 12–14

Beginning in the 19th century, many geologists have studied the Calvert Cliffs Miocene marine strata; the following summary is partly based on a recent review (Ward and Andrews, 2008):

Bed 12 (Parkers Creek Bone Bed) is a distinctive light chocolate brown, slightly muddy to clean sand unit ca. 30 cm thick (thickening updip), rich in disarticulated vertebrate remains, with a sparse, poorly preserved molluscan assemblage. Carbonized wood fragments and pebbles are present in low concentrations. The underlying Bed 11 is a blue-gray sandy clay, barren of macrofossils. The base of bed 12 is burrowed, but the burrows are short.

Bed 13 (*Glossus–Chione* interval of Kidwell, 1984) is a shell-poor, blocky, silty clay, ca. 1–2 m thick in the sampling area. Relatively well preserved vertebrate remains have been found. Ward and Andrews (2008) combine beds 12 and 13 into a single unit, with bed 13 the deeper-water part of a transgressive sequence. However, this is inconsistent with the diversity of planktonic foraminera (Gibson, 1983) and sedimentological analyses (Kidwell, 1989; 1997) that beds 11 and 12 were deposited in the deepest (40–50 m), furthest offshore, fully marine environment. A sediment-starved deep-shelf environment, in which the coastal current winnowed out clay and silt, would also explain the sandy character of Bed 12.

Bed 14 (Kenwood Beach Shell Bed of Kidwell, 1984) is a semiconsolidated, shelly fine sand–silt–clay mixture, its molluscan fauna moderately diverse. Up to four discrete shelly interbeds are locally present, separated by less fossiliferous layers of muddy fine sand, with burrowed discontinuities separating the units. The interbeds are not present further updip (Kidwell, 1984). The top of bed 13 is burrowed, suggesting a hiatus in deposition. Bed 14 is about 1–2 m thick in the sampling area, up to 4.5 m elsewhere. Widely scattered carbonized wood fragments, vertebrate remains, and pebbles/cobbles occur. Kidwell (1984, 1997) placed a disconformity at the bed 13–14 contact, but no basal lag deposits (e.g., pebbles or bone) or root fillings in bed 13 were observed in the pebble collection area. According to Kidwell (1997) bed 14 was deposited in a relatively shallow marine, but not littoral environment during a transgressive phase, with the overlying shell-poor bed 15, with relatively more clay, deposited in deeper water. However the general absence of barnacles on pecten shells, and the plentiful shark teeth and bones of large marine vertebrates are more consistent with deeper shelf water for bed 14 as well.

The mollusk shells in bed 14 and particularly in bed 12 are crumbly, apparently altered, especially in contrast with shells from the overlying Choptank Formation.

3. Dropstone characteristics

Bennett et al. (1996, p. 332) define a dropstone as a "clast of anomalous size and/or lithology, indicative of vertical or oblique introduction into the host sediment". The clasts discussed here are dropstones largely due to size (>1 cm, much larger than the surrounding matrix). The sea bed lacked bottom currents or wave action strong enough to move such clasts, as shown by the limited shell fragmentation, with many bivalves in life position (e.g., Kidwell, 1984) and widely scattered articulated cetacean skulls.

Of the ca. 225 dropstones collected to date from beds 12 to 14, 191 (Fig. 4A) were collected between 1982 and 1992 by Wallace A. Ashby along ca. 3 km of the Calvert Cliffs between the community of Governors Run and the mouth of Parkers Creek. While these beds crop out along a longer stretch of cliffs, they are only accessible from the beach in the study area. Within this area, bed 12 is only exposed above sea level along the northern 1 km portion, bed 13 is accessible along the northern 2 km, and bed 14 along the southern 2 km. Even within these outcrop sections, outcrops are missing at many ravine mouths, and at any time portions of the beds are obscured by vegetation or slide debris. The 191 clasts were described by J. Glaser, a field geologist (Glaser, 1971) with the Maryland Geological Survey. Glaser, most familiar with the geology of Maryland could best evaluate rock provenance. The exact clast location within each bed was unfortunately not recorded, but clasts appeared scattered throughout each bed, not concentrated as basal lags. The Ashby–Glaser clasts (Fig. 4A), ca. 5 to