Late Cretaceous marine arthropods relied on terrestrial organic matter as a food source: Geochemical evidence from the Coon Creek Lagerstätte in the Mississippian Embayment

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Background

The Upper Cretaceous Coon Creek Lagerstätte (Late Campanian–Maastrichtian, 72–71.5 ma; [1]) of Tennessee and Mississippi has yielded some of the best preserved Mesozoic decapod and mollusacan fossils in the world. Large, well-preserved brachyuran crabs are often fully articulated, while bivalves, cephalopods, and gastropods are typically pristine, retaining their aragonitic compositions.

Despite a long history of study, however, the depositional environment of this interval remains equivocal. The Coon Creek Formation has been variously interpreted as a deep–shallow mixing zone, marine shelf, low-energy nearshore marine, the front of a delta platform, and freshwater marsh or hypersaline estuary. Most recently, it has been interpreted as a nearshore, back bar environment with a bivalve fauna very similar to that of the modern Florida Keys [2].

We extend on previous geochemical studies by testing the carbon isotope composition of the decapod fauna and sediments of this Lagerstätte. Fossil and biomarker isotope results shed new light on the Coon Creek paleoenvironment and indicate that well-preserved marine fossil arthropod remains can provide biogenic isotopic data.

Geologic Setting

The Coon Creek Formation is exposed from west-central Tennessee through eastern Mississippi and southwestern Alabama, on the northern end of the Mississippi Embayment (Fig. 1). The unit overlies the Demopolis Chalk Formation and underlies the McNairy Sand Formation, and is composed primarily of unlithified glauconitic marl.

Study material came from the Coon Creek Formation type section, 1.6 km south of Enville, TN (Fig. 1). Well-preserved crabs (*Dakoticancer*) and mudshrimp (*Mesostylus*) remains (Fig. 2) are typically found lower in the section, in the Lagerstätte bed, either within concretions or free within the matrix. Only non-concretionary specimens were used in this study.

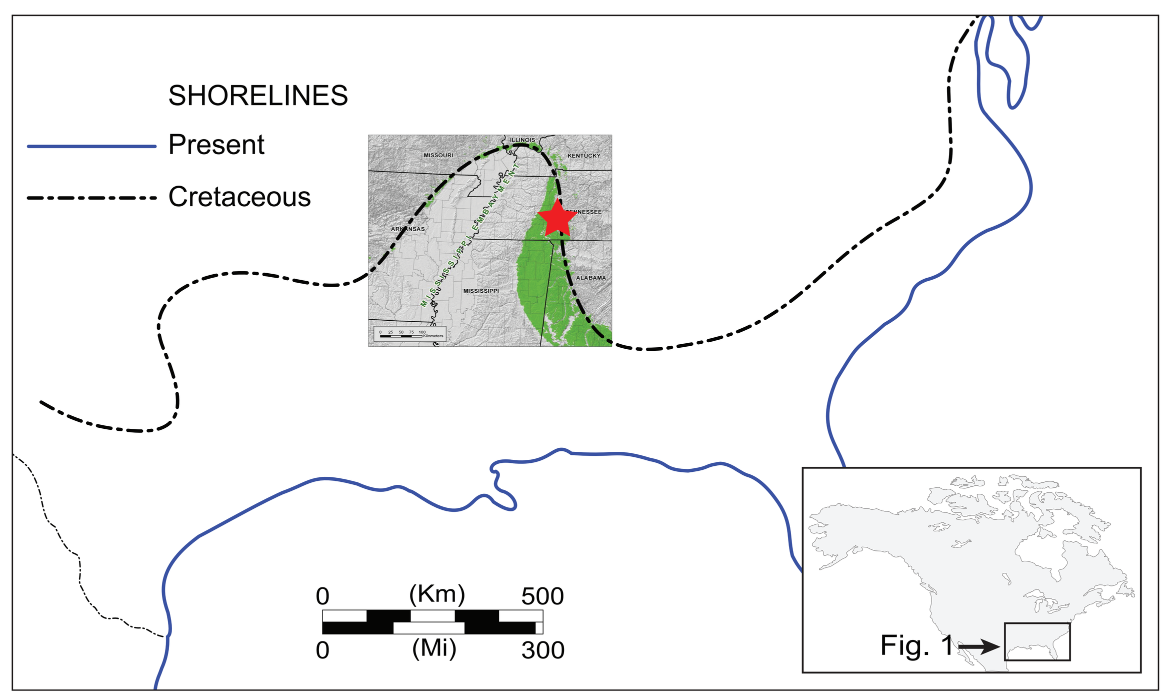

FIGURE 1—Regional map of the North American Mississippi Embayment and paleoshoreline. Green shaded area represents exposures of the Late Cretaceous Coon Creek Formation. The type section location at Enville, TN, is indicated by the star. Modified from NOAA (2004) and [2].

FIGURE 2—Decapods from the Coon Creek Formation, Enville, TN. Scale bars = 1 cm. Top, *Dakoticancer* with various associated bivalves; bottom, isolate *Mesostylus* appendage.

Methods

Isolation of fossil organics and bulk carbon isotope analysis

Fossil specimens were demineralized following the protocol described by Bierstedt et al. [3]. $\delta^{13}C$ and weight percent total C (wt. %) values of prepared specimens and lab chitin were determined on a elemental analyzer (EA) coupled to a isotope ratio mass spectrometer (IRMS).

Biomarker extraction, identification, and quantification

Biomarkers were solvent-extracted from Coon Creek sediment samples and identified and quantified with a gas chromatograph (GC)-mass selective detector (MSD) and flame ionization detector (FID). Compound-specific $\delta^{13}C$ values of the n-alkanes were determined by GC-combustion (C)- IRMS.

Raman Spectroscopy

Single fossil crab and mudshrimp specimens were analyzed using a Raman spectrometer and 244 nm laser excitation. The laser was focused to a spot size of ~2 µm and had a power at the sample surface of <1 mW. No evidence of alteration by the laser was detected.

Calculation of carbon sources and fluxes in the Coon Creek Fm.

Calculated terrestrial plant δ13C values are based on obtained δ13C values of the leaf wax n-C29 and n-C31 alkanes after conversion to leaf δ13C values. Marine phytoplankton $\delta^{13}C$ values and atmospheric $\delta^{13}C$ of CO_2 were calculated from previously published values obtained from inorganic aragonite and calcite from Coon Creek molluscs and Late Cretaceous forams, respectively.

Results

Results for bulk (EA-IRMS) and compound-specific (GC/MS-IRMS) isotope analysis, Raman spectroscopy analysis, and carbon isotope systematics are presented graphically in Figures 3–5 and Table 1.

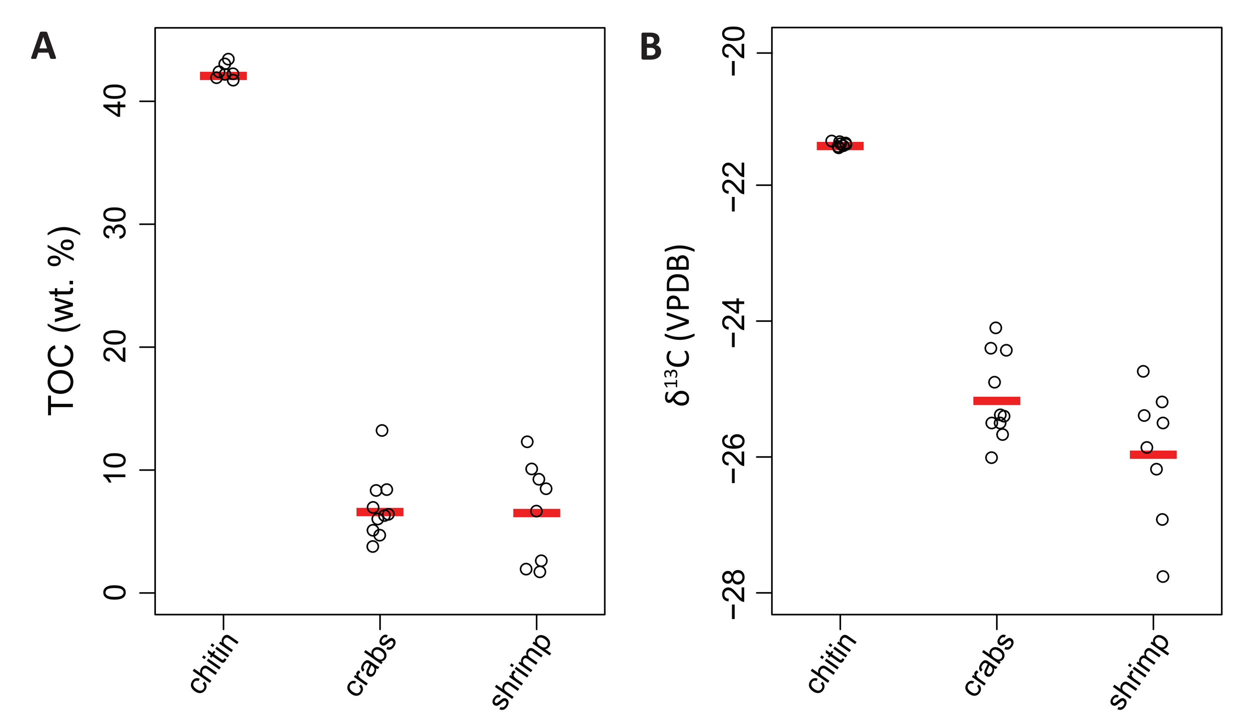

FIGURE 3—EA-IRMS results for commercial chitin (N = 8), and Coon Creek crabs (N = 10) and mudshrimp (N = 8). Sample means are indicated by red bar. A) Total organic carbon (TOC) based on weight percent; B) carbon isotope values. Isotopic precision = 0.05‰; accuracy = 0.04‰.

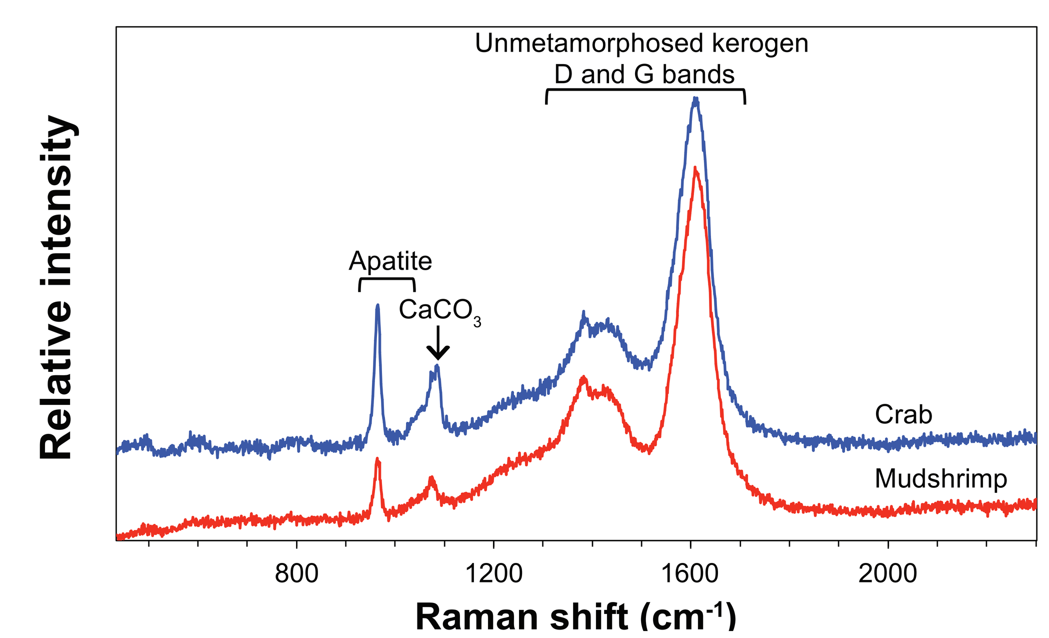

FIGURE 4—Raman spectra for a brachyuran crab and mud shrimp from the Coon Creek Formation, Enville, TN. Spectra represent the average of three spot analyses from different locations on each specimen. "D" and "G" bands confirm presence of organic carbon, as disordered and ordered kerogen, respectively. Apatite may represent diagenetic alteration of original inorganic $CaCO_3$ component of exoskeleton [4].

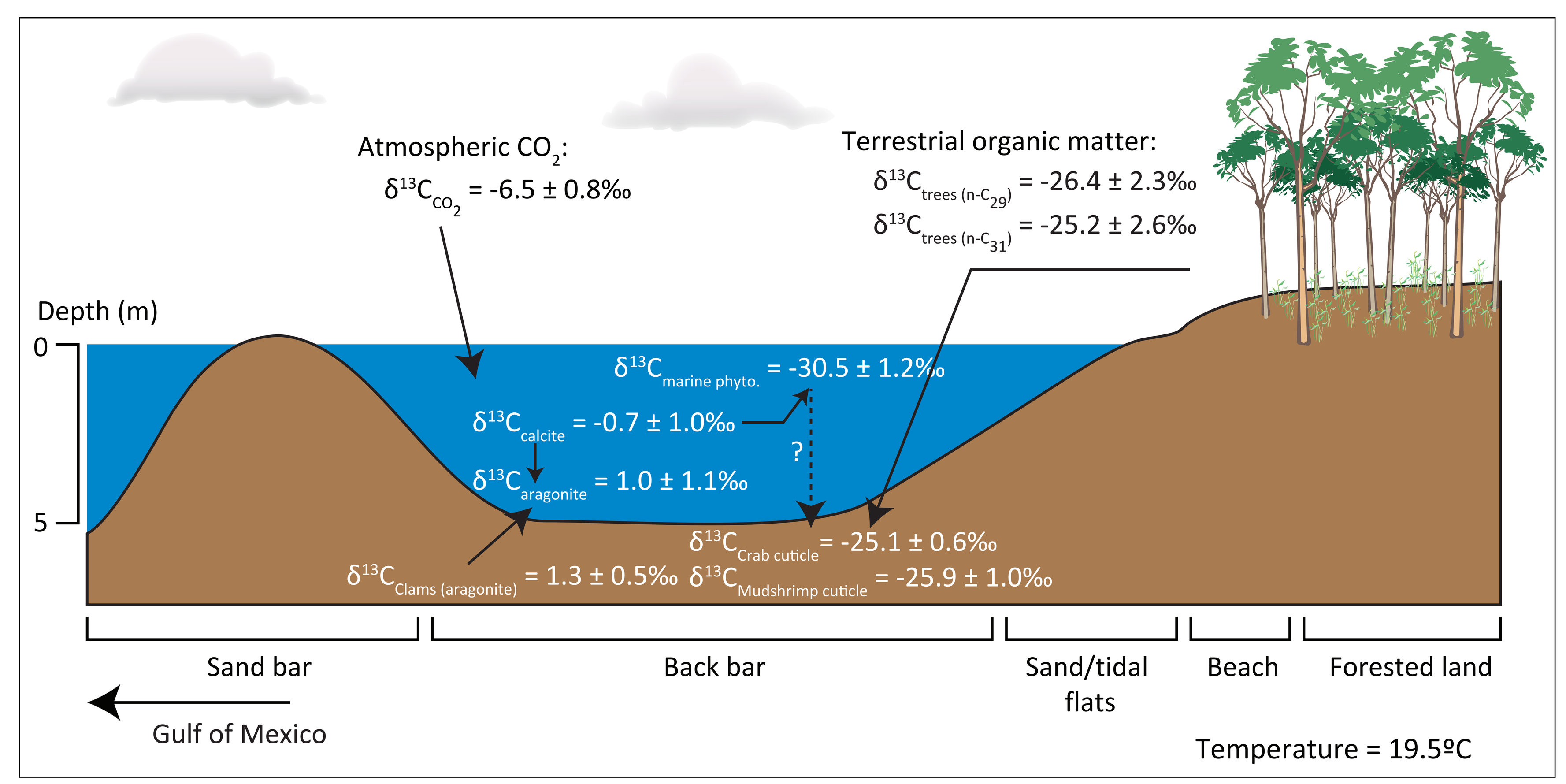

FIGURE 5—Carbon isotope systematics and interpreted environment of the Coon Creek Formation. In this model, decapod $\delta^{13}C$ values are closer to those calculated for terrestrial plants than those determined for marine organic matter. N.B. Exoskeletal chitin $\delta^{13}C$ values are typically enriched by ~1‰ relative to the food source.

TABLE 1. Results from GC/MS-C-IRMS analysis of Coon Creek Formation sediment (Enville, TN). The Carbon Preference Index (CPI) is obtained using the predominance of odd over even long-chain alkanes [cf. 5].

n-Alkane	ng/g	$\delta^{13}C$ (‰, VPDB)
C16 alkane	4.4	-30.2
C17 alkane	37.7	-30.0
C18 alkane	75.6	-30.0
C19 alkane	60.5	-30.3
C20 alkane	30.4	-30.3
C21 alkane	22.5	-30.3
C22 alkane	25.7	-30.1
C23 alkane	18.1	-
C24 alkane	8.9	-29.9
C25 alkane	4.2	-29.8
C26 alkane	2.6	-30.1
C27 alkane	2.6	-30.6
C28 alkane	1.8	-31.8
C29 alkane	2.7	-31.5
C30 alkane	1.3	-30.7
C31 alkane	2.2	-30.6
C32 alkane	0.7	-
C33 alkane	0.7	-30.4
C34 alkane	0.2	-
C35 alkane	0.2	-
C36 alkane	0.1	-
Carbon Preference Index		1.37
Pristane/Phytane ratio:		1.77
Thermal maturity: (Homohopane 22S/(22S+22R))		0.12

Discussion

Low Coon Creek decapod TOC values (Fig. 3A), compared to modern chitin, indicate that they have been degraded. Specimens are kerogenized (Fig. 4), but the CPI and thermal maturity index (Table 1) indicate low temperature burial conditions. Critically, decapod $\delta^{13}C$ values do not suggest significant microbial (or diagenetic) alteration (Fig. 3B), based on results from experimental degradation studies [6]. Integration of obtained bulk and compound-specific $\delta^{13}C$ values with published inorganic $\delta^{13}C$values also reveals that the C in the atmosphere-marine model system is in isotopic equilibrium.

From these results, we conclude that the decapod $\delta^{13}C$ values represent a biogenic isotopic signal that is reflective of original diet. Specifically, enriched $\delta^{13}C$ values suggest a largely terrigenous, plant-based diet, as opposed to marine-derived, and indicate that this environment received more terrestrial input than previously thought. Our results suggest, for the first time, that chitinous remains in the marine fossil record are a source of isotopic information that can be used in paleoenvironmental and paleoecological reconstruction.

References

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