A Stratigraphic Test of the Terrestrial Carbon-isotope Record of the Latest Albian OAE from the Dakota Formation, Nebraska

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Abstract

Recently, the Albian–Cenomanian boundary was identified in a terrestrial sequence at Rose Creek Pit (Gröcke et al. 2006) using carbon-isotope stratigraphy of bulk sedimentary organic matter and charcoal. However, within terrestrial sequences there are inherent difficulties associated with correlating from one section to another. In this study, we tested the stratigraphic reproduction of the negative carbon-isotope excursion in bulk sedimentary organic matter ($\delta^{13}C_{org}$) from a short core adjacent to the Rose Creek Pit and another from ~2.6 km from Rose Creek Pit. In each of these cores, a significant negative $\delta^{13}C_{org}$ excursion is recorded that is directly comparable to that produced from Rose Creek Pit and published in Gröcke et al. (2006). Although there are subtle differences in the absolute $\delta^{13}C_{org}$ value of bulk sedimentary carbon between the stratigraphic sections, this has not disguised the overall shape of the curve. Hence, high-resolution bulk sedimentary $\delta^{13}C_{org}$ records can be used to correlate not only global stratigraphies, but also locally complex stratigraphies in terrestrial environments.

Introduction

The ability with which to correlate marine and terrestrial stratigraphies has in the past proved problematic, or at least not very conducive to provide high-resolution comparisons. More recently, the use of carbon-isotope ratios ($\delta^{13}C$) from terrestrial organic matter has shown their ability in producing high-resolution stratigraphic correlations (e.g., Gröcke et al., 1999; Hesselbo et al., 2000, 2003; Hasegawa et al., 2003). Gröcke et al. (2006) reported a $\delta^{13}C$ curve for bulk terrestrial organic matter and charcoal from the quarry exposures at Rose Creek Pit and compared that to a high-resolution record produced from planktonic foraminifera (Wilson and Norris 2001). Previous palynology of the Rose Creek Pit suggested the section covered the Albian–Cenomanin interval and thus the latest Albian oceanic anoxic event (OAE) and its related isotopic perturbations. The terrestrial curve revealed the negative $\delta^{13}C$ excursion prior to the Albian/Cenomanian boundary, but did not record the subsequent positive $\delta^{13}C$ excursion. The Albian/Cenomanian boundary is concurrent with the D2 sequence boundary of Brenner et al. (2000). The D2 surface unconformably separates deposits of the underlying Upper Albian Muddy Cycle ("J" Sandstone) from the overlying Cenomanian–Turonian Greenhorn Cycle ("D" Sandstone) (Weimer, 1987). Gröcke et al. (2006) estimated based on the isotopic curve and using the timescale in Wilson and Norris (2001) the minimum duration of the D2 sequence boundary at Rose Creek Pit would be on the order of ~0.5 Myr.

The subtle depositional changes associated with terrestrial sequences inextricably are strewn with gaps and therefore, the carbon-isotope curve generated from Rose Creek Pit may not be reproducible from one section to another in the Dakota Formation. In order to test the reproducibility of this curve and its application, two separate cores were investigated: (1) a short core (~2.5 m) within several meters of the Rose Creek Pit quarry face – RC upper; and (2) a longer core (12 m) approximately 2.6 km SSW of RC upper –13A05. Neither of these cores was analyzed for palynology.

Geological Setting and Methodology

The Rose Creek Escarpment (Joeckel et al., 2005) of southern Jefferson and Thayer counties, Nebraska, exposes the classic midcontinent mid-Cretaceous succession of the Dakota Formation, Graneros Shale, and Greenhorn Limestone. These and other gently, westward-dipping (~2.0 m/km) Cretaceous strata cropping out across central to northern Kansas and into southernmost Nebraska produce conspicuous east-facing escarpments with relief exceeding 100 m. Escarpment topography disappears abruptly northward into southeastern and south-central Nebraska, where Cretaceous rocks are, for the most part, buried by thick Pliocene-Pleistocene loess, glacial till, and fluvial sediments. The Rose Creek Escarpment is, in essence, the northern limit of the Smoky Hills of Kansas (cf. Chapman et al., 2001), and it is one of the best field areas for the study of the midcontinent Cretaceous succession in the northern part of the eastern margin of the Western Interior basin.

As part of U.S. Geological Survey's STATEMAP cooperative geologic mapping project and associated research on Cretaceous bedrock geology and the regional mineral resources (particularly brick clays and limestone), the University of Nebraska-Lincoln Conservation and Survey Division drilled multiple shallow boreholes into the Greenhorn Limestone, Graneros Shale, and Dakota Formation on the Rose Creek Escarpment during 2004–2005 (fig. 1). These boreholes were drilled more-or-less along strike. One of these cores (13A05)

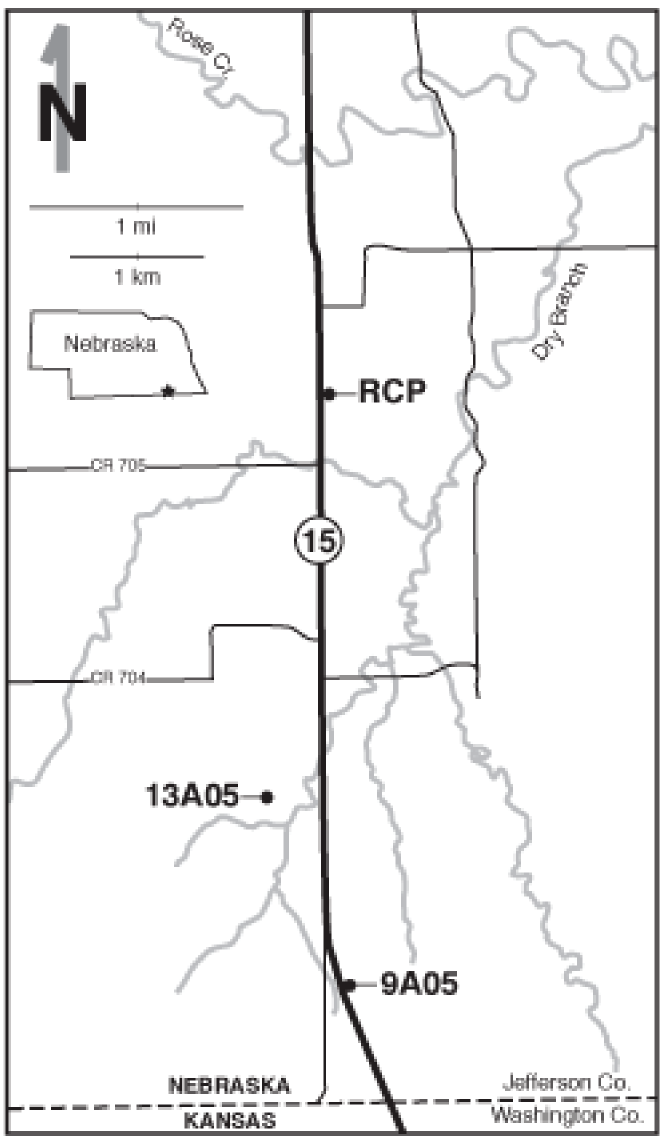

Figure 1. Geographic position of the three cores drilled in Jefferson County, Nebraska, as part of the involvement of the University of Nebraska–Lincoln Conservation and Survey Division in the U.S. Geological Survey's STATEMAP cooperative geologic mapping project. RCP = Rose Creek Pit. Core 9A05 will not be discussed in this study.

was drilled through the upper to middle part of the Dakota Formation in the SW NW NW sec. 26, T. 1 N., R. 2 E., at a new brick clay pit operated by Endicott Clay Products (Endicott, Nebraska). Core 13A05 (~ 12 m) penetrates cross-cutting tidally influenced fluvial-estuarine channel fills consisting largely of gray mudstones, dark lignitic mudstones, and sandstones (fig. 2 for stratigraphic key; fig. 3). This core reached red-mottled kaolinitic mudstones, more typical of lower Dakota Formation strata, at the bottom of the hole. The land-surface elevation of the borehole site is about 1,460 ft (445 m) MSL, or about 40 ft (12.2 m) below the "X"-bentonite marker bed in the Graneros Shale.

Another cored borehole (9A05), not discussed in this report, was drilled at a land-surface elevation of 1,540 ft (469.4 m) MSL about 2.2 km SSE (SW SW NE sec. 35, T. 1 N., R. 2 E.), and penetrated the Graneros Shale and uppermost Dakota Formation to a depth of some 60 ft (18.3 m) (fig. 1). The bottom of core 9A05 is slightly above the top of core 13A05.

A third, shorter core (RCP upper; fig. 1) was drilled approximately 2.6 km NNE of 13A05 into thin sandstones, lignitic mudstones, and gray mudstones in the highwall of the Rose Creek Pit (DeBoer property) in the SW NW SE sec. 14, T. 1 N., R. 2 E., at a land-surface elevation of approximately 1,440 ft (438.9 m) MSL (fig. 3). Cores RCP upper and 13A05, then, sample partially overlapping stratigraphic sections around the level of the Albian/Cenomanian boundary.

Bulk-sediment samples of ~1cc were ground to a fine powder and then chemically treated with 3 mol/L HCl. All carbon-isotope measurements were performed on a COSTECH Elemental Analyzer connected to a ThermoFinnigan DeltaPlus XP mass spectrometer. Carbon-isotope values are reported in the standard delta (δ) notation relative to VPDB with analytical precision of 0.1‰ on international and internal standards. Reproducibility on replicate bulk sediment samples was better than 0.3‰.

Results and Discussion

$\delta^{13}C_{org}$ analyses of bulk sediment were performed on the lower part of core 13A05 in order to capture the trend of the curve prior to the lignitic horizon (fig. 3). The $\delta^{13}C_{org}$ curve for core 13A05 shows a distinct trend from –25‰ to –24‰ in the lower part, followed by a rapid negative excursion of ~2.4‰ within the white sandy siltstone at ~9.8 m. $\delta^{13}C_{org}$ values remain relatively stable at ~ –26‰ to 8 m where they trend back towards an average value of ~ –24.5‰ (fig. 3). Within the Rose Creek Pit upper core, a similar $\delta^{13}C_{org}$ record is produced (fig. 4), with an offset in absolute values compared to core 13A05. $\delta^{13}C_{org}$ values at the base of the RCP upper core shift from ~24.4‰ to –23‰, and then rapidly to more negative values of ~ –25‰; which occurs within the middle of the lower lignitic horizon. From this point $\delta^{13}C_{org}$ values trend steadily to less negative values of ~ –22.3‰ before rapidly decreasing to ~ –25.4‰, after which the values fluctuate around –25.6‰ (fig. 4). The negative shift in the RCP upper core also occurs within a lithological unit (sandstone at ~1 m). This would suggest that the negative $\delta^{13}C_{org}$ excursion is not controlled by lithofacies, and in fact represents a significant shift in the isotopic value of the organic matter being inputted. What becomes apparent in these two datasets is the trend to less negative values that is interrupted by a rapid negative $\delta^{13}C_{org}$ excursion, a similar feature to that reported by Gröcke et al. (2006) for the Rose Creek Pit quarry.

Figure 5 depicts the carbon-isotope curves from core 13A05 and the RCP upper core compared to the original dataset produced in Gröcke et al. (2006) for the Rose Creek Pit quarry. All the $\delta^{13}C_{org}$ curves have been stratigraphic-tied to the Rose Creek Pit quarry data where the rapid negative shift is recorded. No stratigraphic heights have been adjusted as might be expected for changes in sedimentation rates—a definite possibility for these respective stratigraphic sections. The trend from negative $\delta^{13}C_{org}$ values to less negative values in the lower segments of core 13A05 and RCP upper are clearly evident. The only difference between these datasets is the absolute $\delta^{13}C_{org}$ value, which may in fact be related to different organic carbon inputs and/or preservation biases in organic matter between the two sites. This is unlike the study by Hesselbo et al. (2003) who reported a shift in $\delta^{13}C_{org}$ compared to $\delta^{13}C$ charcoal, in which they related this to the change in abundance of terrestrial versus marine organic matter. Although the Dakota Formation sediments in this region have intermittently been influenced by marine incursions, we suspect that these minor differences in $\delta^{13}C_{org}$ are not controlled by changes

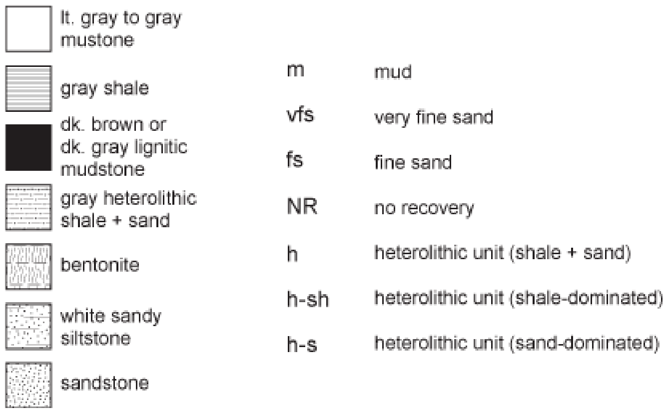

Figure 2. Key to the stratigraphic sections provided in figs. 3 and 4. lt. = light; dk. = dark.

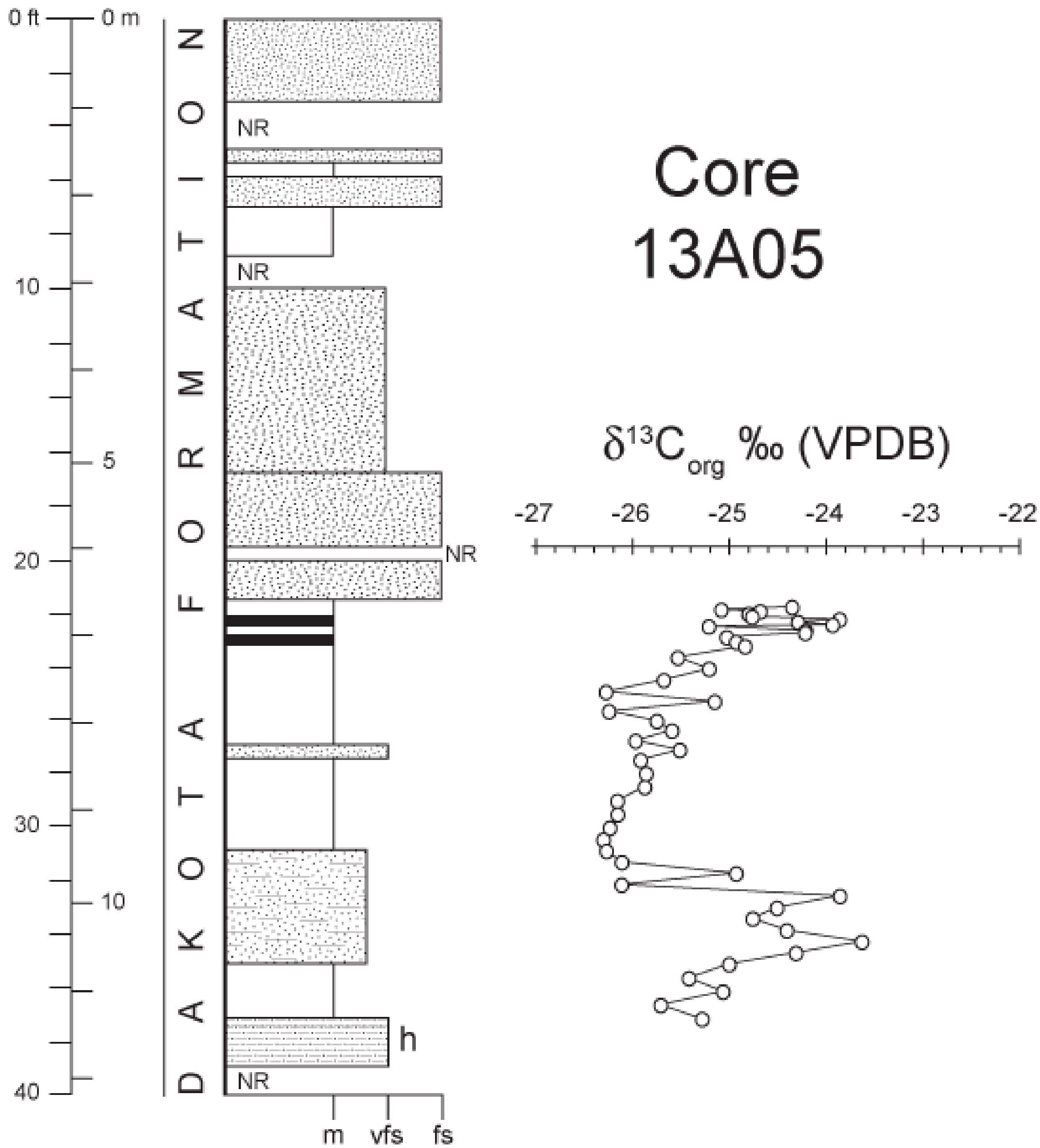

Figure 3. Stratigraphic section and $\delta^{13}C_{org}$ record of core 13A05 spanning the upper part of the Dakota Formation, Nebraska. The $\delta^{13}C_{org}$ curve was only produced for the lower segment of this core: see text for details. See fig. 2 for key.

in terrestrial versus marine organic matter in the bulk sediment. However, as noted in Gröcke et al. (2006), the delayed shift in $\delta^{13}C$ charcoal from the Rose Creek Pit may be influenced by a lack of sampling during the critical interval, because it is only one sample (at ~0.9 m; fig. 5) that does not support the negative $\delta^{13}C_{org}$ record. This sample (fig. 5, arrow) may also be a reworked fragment, a charcoal from older sediments, which is always a possibility when dealing with terrestrial sediments. Having said that, it is interesting to note that the trend back towards less negative $\delta^{13}C_{org}$ values in core 13A05 from ~2.3 m follows very nicely the charcoal record from the Rose Creek Pit quarry (fig. 5).

In conclusion, the construction of a bulk sedimentary $\delta^{13}C_{org}$ record from terrestrial sequences can be used to stratigraphically correlate sections. Although there will be inherent difficulties associated with this technique, it is recommended that high-resolution curves from multiple sections will resolve many of this issues. In addition, to avoid any biasing of the $\delta^{13}C_{org}$ record through preservation and input changes, future work should involve compound-specific analyses to confirm any significant shifts in $\delta^{13}C$ that may be associated with larger, global events, such as the oceanic anoxic event in the latest Albian.

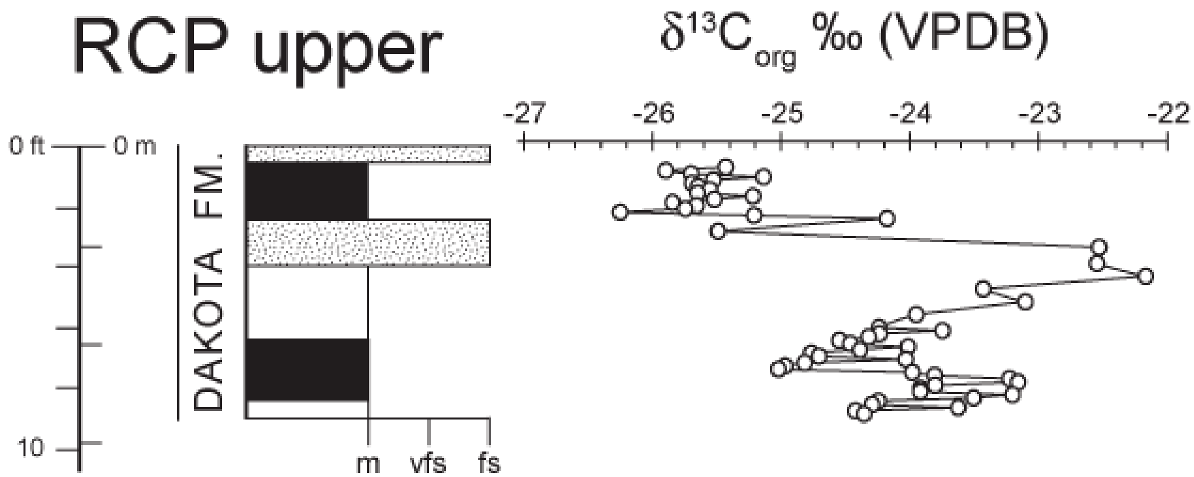

Figure 4. Stratigraphic section and $\delta^{13}C_{org}$ record of the Rose Creek Pit upper core spanning a brief segment of the upper part of the Dakota Formation, Nebraska. This core was taken close to the quarry wall and thus is directly comparable to the Rose Creek Pit quarry record produced in Gröcke et al. (2006). See fig. 2 for key.

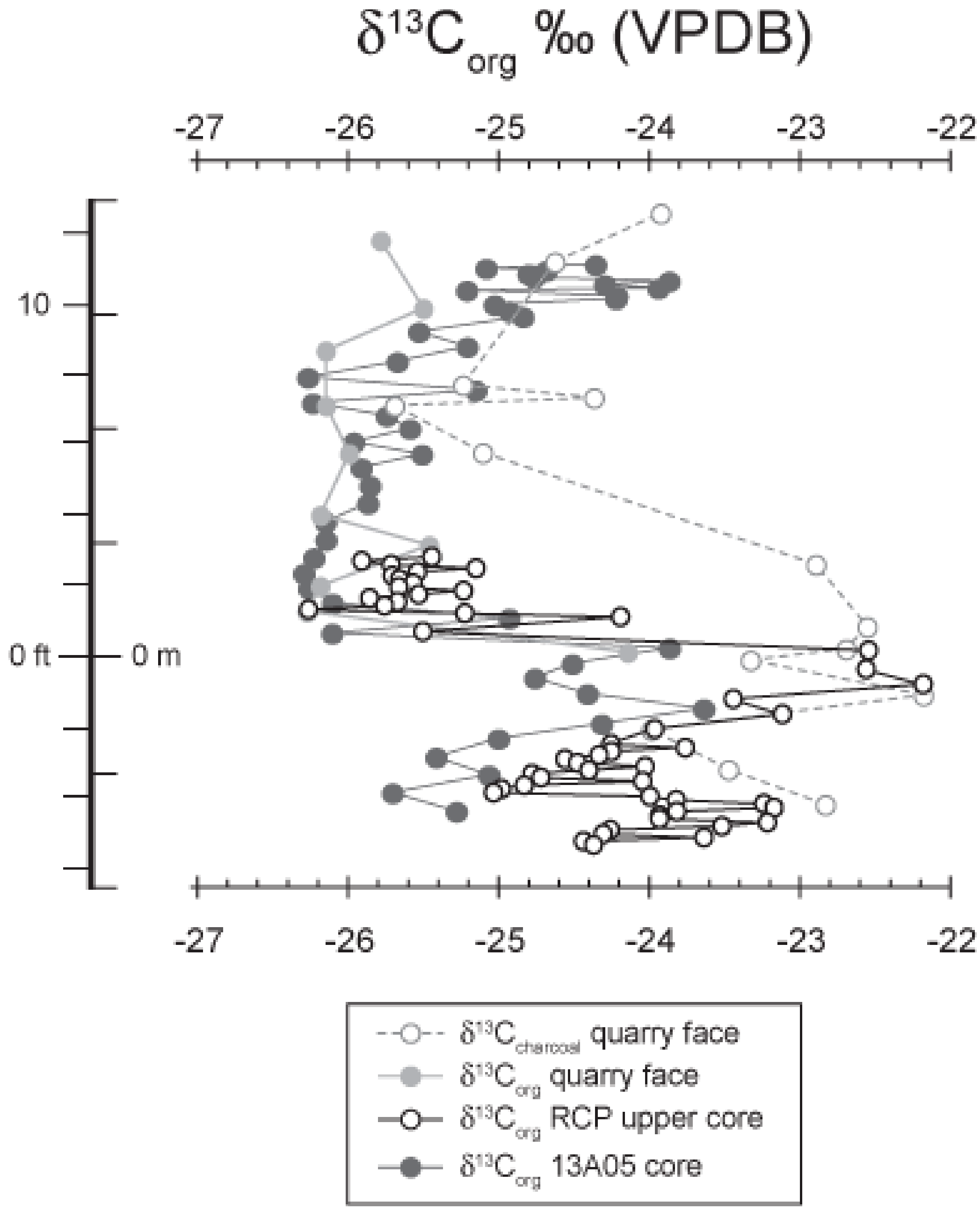

Figure 5. Stratigraphic comparison of the $\delta^{13}C_{org}$ records from the Rose Creek Pit quarry and the two cores, 13A05 and RCP upper. Included in this record is the $\delta^{13}C$ charcoal record from Gröcke et al. (2006). Each stratigraphic section has been fixed by the negative $\delta^{13}C_{org}$ excursion at 0 m.

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