Forum Comment

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Mid-latitude terrestrial climate of East Asia linked to global climate in the Late Cretaceous

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Gao et al. (2015) recently reported mid-latitude terrestrial oxygen-carbon isotope data from presumably pedogenic carbonates in Upper Cretaceous core SK-1 from the Songliao Basin, northeast China. In that paper, the authors interpreted the negative $\delta^{18}O$ excursion as a result of decreasing temperature and/or strengthened westerlies, and modeled the negative $\delta^{13}C$ excursion at ca. 66 Ma as a result of enhanced primary productivity due to the increasing temperature and precipitation. The paper provides valuable high time-resolution subsurface O and C isotope data, and new insights into the terrestrial O-C isotopic evolution in a mid-latitude region during the Late Cretaceous. However, without details about the origin of the calcrete described in the main text and supplemental data, I question the interpretation of the C and O isotopic variations as paleoclimatic signals.

Gao et al. describe the calcrete as of pedogenic origin. However, the paleosols, the host of calcretes, are introduced in a simple citation only "...... by distinctive calcareous horizons and carbonate nodules, slickensides, mottled colors, and fossil root traces (Cheng et al., 2009; Huang et al., 2013)". No detailed paleosol observations are presented in those two references or by Gao et al. As we know, terrestrial calcretes can be formed in various different environments, including paleosols, lakes, swamps, and phreatic zones (e.g., Alonso-Zarza, 2003; Alonso-Zarza and Wright, 2010), and therefore detailed information about the origin of the calcrete is crucial for the interpretation of processes causing the isotopic variations.

An aerially exposed depositional environment favors pedogenesis. According to the lithofacies analysis of two formations recovered in the SK-1 core (Cheng et al., 2009), the sublithofacies (overbank, crevasse splay, and flooding) of the alluvial plain lithofacies with most common paleosols is developed in intervals (e.g., at 1012–1000, 905–810, and 342–290 m below the surface), which only account for <20% of the total thickness. Almost half of the calcretes occur in a lacustrine facies, some associated with fossil mollusks (Cheng et al., 2009, their figure 3), indicating an aquatic origin of these calcretes. The microfacies of some calcretes show circumgranular cracks cemented by microsparite (see Huang et al., 2013, their figure 4C), confirming a palustrine origin (refer to Alonso-Zarza, 2003). Frequently fluctuating lake levels (Cheng et al., 2009) could have led to either the formation of phreatic calcretes or the modification of earlier-formed paleosol calcretes.

The recognition of pedogenic calcretes based on the short-term, high-frequency cyclicity of the 'pedogenic' sequence is questionable. According to Gao et al.'s supplemental data (GSA Data Repository item 2015101), the 741.78-m-thick strata contain 121 paleosol layers (samples) with an average spacing of 6.13 m between two neighboring layers. The studied succession represents 10.398 m.y., so that the average duration of the cycles would be ~0.0859 m.y., which does not fit any Milankovitch periodicity. The thickness of a paleosol BK horizon is generally <0.5 m, so that a short-term cycle represented by the paleosol sequence is <0.007 m.y. (0.5 m / 6.13 m × 0.0859 m.y.); i.e. <7000 yr. Such a short-term paleosol cycle is extremely rare and suspect in geohistory.

The Sifangtai and Mingshui Formations were deposited in environments alternating between arid-semiarid and humid-semihumid conditions, based on sediment color, O-C isotopes of ostracod valves, spore-pollen fossil association, and plant fossils (e.g., Cheng et al., 2009). Calcretes formed in a humid-semihumid climate are not of pedogenic origin. Gao et al. did not distinguish pedogenic calcretes from those formed in humid-semihumid climates, raising questions about the pedogenic origin of the calcretes, particularly for those in greenish and grayish sediments, which account for about half of the studied calcretes.

From Gao et al.'s supplemental data, the covariance of C and O isotope values is R = 0.559 (R^2 = 0.3128) for the linear regression ($\delta^{13}C = -0.8883\delta^{18}O - 16.797$), and R = 0.613 ($R^2$ = 0.3759) for the multinomial regression [$\delta^{13}C = -0.2663\ (\delta^{18}O)^2 - 5.0376\delta^{18}O - 32.541$]. The high covariance and mirror pattern of the coupled C-O isotopes (Fig. 1B) may indicate either diagenetic imprints and/or a palustrine/lacustrine origin, or even phreatic groundwater modification of calcretes. Unfortunately, neither Huang et al. (2013) nor Gao et al. (2015) discussed diagenetic changes in isotope composition.

If all the calcretes are pedogenic, as suggested by Gao et al., the O and C isotope data would present a paleoclimatic problem. The $\delta^{18}O$ values decrease by ~3‰ (from ~10‰ to –13‰), indicating a decline in temperature of ~8 °C, as estimated by Gao et al., whereas the $\delta^{13}C$ values of pedogenic(?) calcretes are from –7.0‰ to –6.0‰ over the same interval, which would correspond to a high pCO_2, based on the equation of Ekart et al. (1999) for the early Maastrichtian (Gao et al., 2015, compare their figures 2B, 2E, and 2F). A similar relationship is present in material from the late Campanian through the Maastrichtian. Such a long-term relation presents a problem, because it means that atmospheric temperature would have increased while pCO_2 decreased, with CO_2 a known greenhouse gas. On the other hand, this observation may imply that some O-C isotope data were not related to paleoclimate.

In summary, the Late Cretaceous O-C isotopes from borehole SK-I in the Songliao Basin may come from several kinds of calcretes formed in different depositional environments, due to a lack of analyses of petrofacies, diagenesis, hydrology, and the covariance of coupled O-C isotope values. In other words, some isotope data presented by Gao et al. were probably not related to paleoclimate, and thus cannot be used to interpret atmospheric paleoclimate.

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