Assessing the Impact of Diagenesis on Isotopic Composition of Paleosol Carbonates from the Chu Basin, Kyrgyzstan

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RESEARCH OBJECTIVE

Petrographically investigates paleosol samples to reconcile anomalous δ¹⁸O values and determine whether anomalous variance through time is due to changes in water composition at the time of deposition or related to post-burial diagene.

BACKGROUND

The Chu Basin lies in the northern foreland of the Tian Shan range of Central Asia. Neogene sedimentary rocks provide a temporal record of Tian Shan evolution and climate. Basin fill is composed of silicilastic sedimentary rocks with interbedded paleosols. Gypsum and carbonate are abundant, suggesting seasonal and arid conditions have existed. Paleosol carbonate samples were analyzed for δ¹⁸O with numerous samples showing anomalously negative values. These paleosol samples were investigated using petrographic techniques to better understand why anomalously negative δ¹⁸O values are present in some pedogenic carbonates. We hypothesize that post-burial groundwater interaction led to calcite cementation from fluids that do not reflect the environment at the time of deposition. Cementation is temperature-dependent; as water temperature increases, less δ¹⁸O relative to δ¹⁶O is incorporated into the carbonate crystal lattice as the energy in the system overwhelm mass differences. Reduced fractionation at high temperatures results in a carbonate with a more negative δ¹⁸O value. This research highlights the importance of distinguishing between primary cements closely associated with environmental conditions and later diageneric products from other fluid sources in studies of paleoclimate and paleosea.

RESULTS

Micritic Carbonate

Sparry Inclusions

Sparry

δ¹⁸O vs Sample Age

Increasing δ¹⁸O value & carbonate grainize

PETROGRAPHIC EXAMINATION

Samples with anomalously low δ¹⁸O values were more micritic than samples with more positive δ¹⁸O values.

- Samples with more negative δ¹⁸O values were more micritic and contain possible diageneric fluid-like microstructures (labeled above as FLM).
- Samples with average δ¹⁸O values (-10.57‰) were predominately composed of a silty silicilastic matrix with sparry carbonate inclusions.
- The sample with the most positive δ¹⁸O value, JBCB09 (-4.64‰), contained large gypsum crystals.

Sparry samples from JBCB09 were predominantly fine to silt sized quartz and angular feldspatic grains. The brown patches are rich in oxidized iron. JBCB12 (-10.01‰, δ¹⁸O) predominantly composed of silt-sized silicilastic grains with evidence of iron banded fluid-like microstructures in lower right quadrant. The dark brown circular nodules are iron-rich silicilastic features. JBCB03 (-13.93‰, δ¹⁸O) composed of silt-sized silicilastic grains and opalescent oxides. There are white, oblong, sparry inclusions in the upper sector. Iron banded fluid-like microstructures are prevalent throughout. JBCB06 (-11.09‰) poorly sorted silt to fine sized angular silicilastic lithics and rounded sparry carbonate grains. JBCB10 (-5.95‰, δ¹⁸O) is composed of a silty silicilastic matrix with sparry carbonate inclusions.

δ¹⁸O values, microstructures, and petrography indicate that anomalous negative δ¹⁸O values are not correlated to microbial activity or other diageneric processes.

METHODS

Thin sections were made from five samples with anomalously low δ¹⁸O values, four with average δ¹⁸O values, and one sample with a relatively positive δ¹⁸O value. The samples were investigated for the presence of secondary carbonate deposition, recrystallization of carbonate grains, bridged grains, fluid-like microstructures, and carbonate inclusions.

A Zeiss Sigma VP scanning electron microscope was used to explore the presence of biogenic indicators and Energy Dispersive Spectroscopy (EDS) was used to identify elemental composition of mineral grains.

DISCUSSION

Analysis reveals that groundwater infiltration during post-burial diagene likely plays a larger role in anomalous δ¹⁸O variance than does changes in water composition at the time of deposition.

Anomalously negative δ¹⁸O values could be explained by high temperature groundwater depositing carbonate as a micritic cement during post-burial diagene. The micritic nature of the carbonate in the anomalously negative samples could result from carbonate cement being replaced during the size of the pore space within the silicilastic rock (Figure 1). The timing of diagene is not well constrained.

Microbes have been shown to cause anomalously negative δ¹⁸O values in carbonates (Mortimer & Coleman, 1997). The lack of microbial evidence after SEM inspection implies that the anomalously negative carbonates are not related to microbes and are inorganic (Figure 2).

The sparry fabric of the most positive δ¹⁸O sample (JBCB09) does not show signs of recrystallization (Figure 4), suggesting that it is gypsum formed at the time of deposition. This is consistent with deposition in a lacustrine environment (Buck & Hoesen, 2005).

Excluding anomalously negative values, the mean δ¹⁸O value for all samples is about -10.57‰ VPDOS. The calcite clasts in these samples were likely formed from primary water with an isotopic composition of -13.13‰ to -8.55‰ VPDOS at 5-20°C respectively (O’Neill et al., 1990). Present day water in the region has an average isotopic composition of -10.7‰ VPDOS (Bershaw and Lechler, in review). This suggests that palaeoclimates in the Tian Shan foreland has been similar to modern since at least a temporal period. The lack of fluid-like microstructures in samples with δ¹⁸O values near the average is additional evidence that they are likely not altered.

Our findings contradict previous research that suggests secondary carbonates are likely to be sparry while primary carbonates are more likely to be micritic in terrestrial sedimentary basins. We suggest that evidence of fluid-like microstructures and anomalously negative δ¹⁸O values are more reliable indicators of diagene.

CONCLUSION

Petrographic investigation revealed that samples with anomalously low δ¹⁸O values were more micritic than samples with more positive δ¹⁸O values. For these samples, it is possible that post-burial groundwater interaction led to calcite cementation from fluids that do not reflect the environment at the time of deposition.

REFERENCES & ACKNOWLEDGMENTS


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