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

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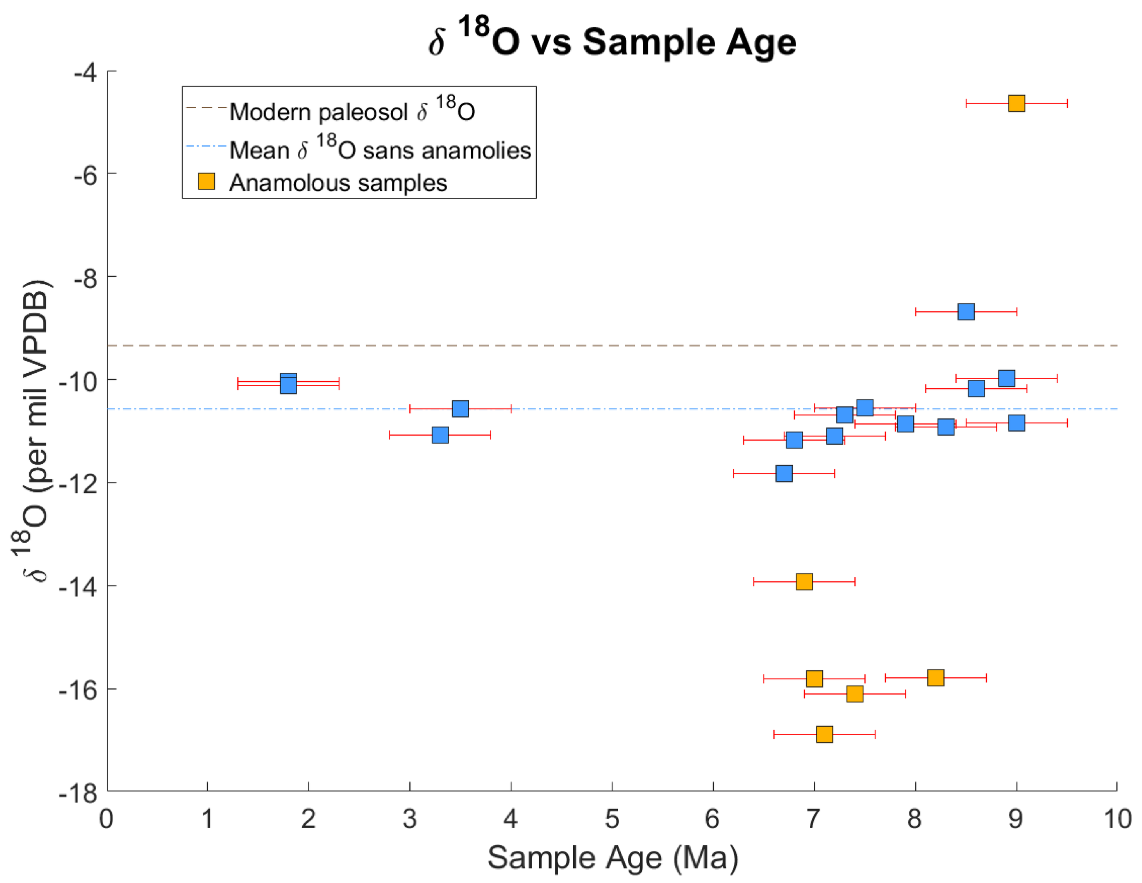
RESEARCH OBJECTIVE

Petrographically investigate paleosol samples to reconcile anomalous $\delta^{18}O$ 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 diagenesis.

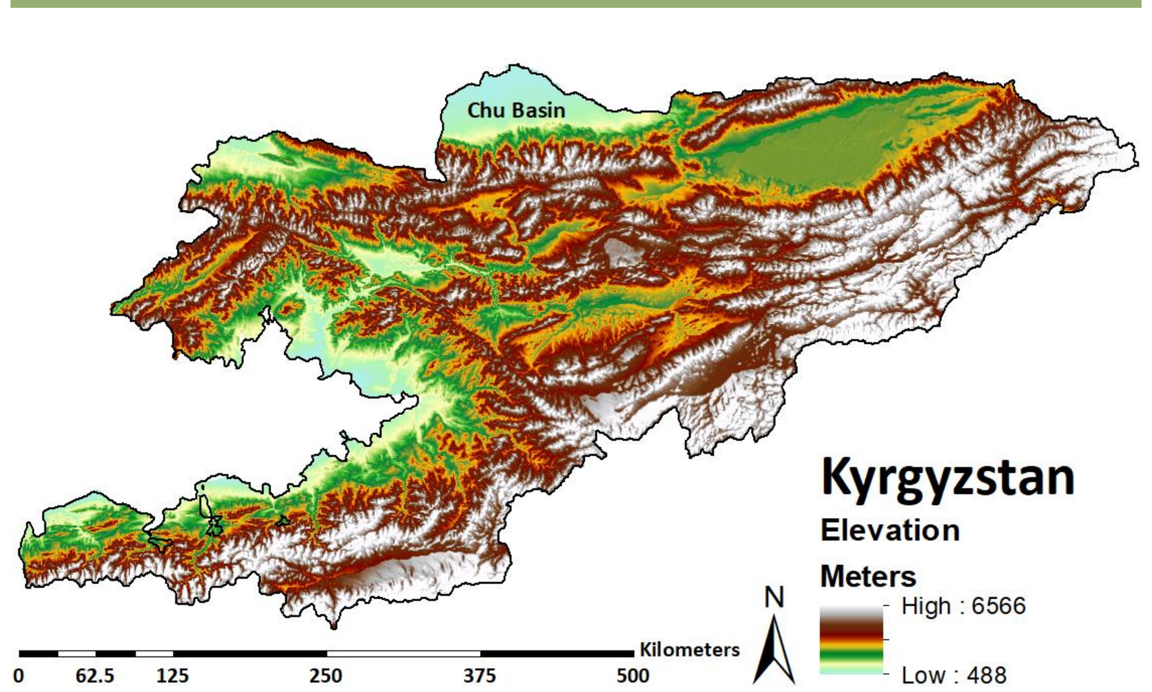
BACKGROUND

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 siliciclastic sedimentary rocks with interbedded paleosols. Gypsum and carbonate are abundant, suggesting seasonally arid conditions have existed.

Paleosol carbonate samples were analyzed for $\delta^{18}O$ with numerous samples showing anomalously negative values. These paleosol samples were investigated using petrographic techniques to better understand why anomalously negative $\delta^{18}O$ 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. Carbonate precipitation is temperature-dependent; as water temperature increases, less ^{18}O relative to ^{16}O is incorporated into the carbonate crystal lattice as the energy in the system overwhelms mass differences. Reduced fractionation at high temperatures results in a carbonate with a more negative $\delta^{18}O$ value. This research highlights the importance of distinguishing between primary cements closely associated with environmental conditions and later diagenetic products from other fluid sources in studies of paleoclimate and paleoaltimetry.

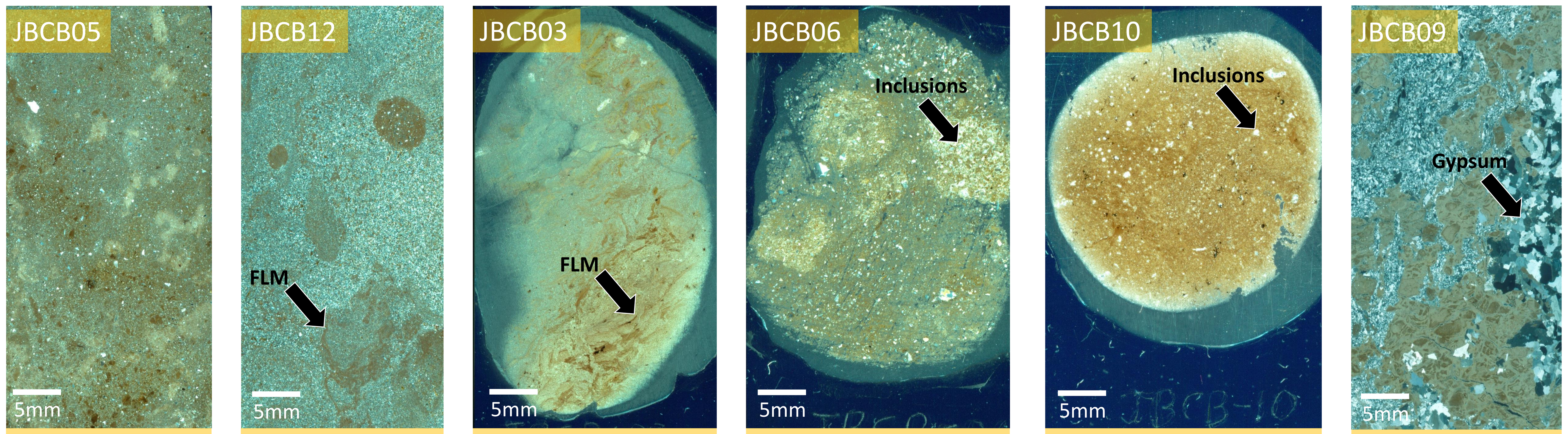


TECTONIC SETTING



RESULTS

Micritic Carbonate | Sparry Inclusions | Sparry



JBCB05	JBCB12	JBCB03	JBCB06	JBCB10	JBCB09
-16.90‰ $\delta^{18}O$	-16.10‰ $\delta^{18}O$	-13.93‰ $\delta^{18}O$	-11.09‰ $\delta^{18}O$	-10.68‰ $\delta^{18}O$	-4.64‰ $\delta^{18}O$

Increasing $\delta^{18}O$ value & carbonate grainsize

Petrographic examination revealed that samples with anomalously low $\delta^{18}O$ values were more micritic than samples with more positive $\delta^{18}O$ values.

- Samples with more negative $\delta^{18}O$ values were more micritic and contain possible diagenetic fluid-like microstructures (labeled above as FLM).
- Samples with average $\delta^{18}O$ values (-10.57‰) were predominantly composed of a silty siliciclastic matrix with sparry carbonate inclusions.
- The sample with the most positive $\delta^{18}O$ value, JBCB09 (-4.64‰), contained large gypsum crystals.

JBCB05 (-16.90‰ $\delta^{18}O$) predominantly fine to silt sized quartz and angular feldspathic grains. The brown patches are rich in oxidized iron.

JBCB12 (-16.10‰ $\delta^{18}O$) predominantly composed of silt-sized siliciclastic grains with evidence of iron banded fluid-like microstructures in lower right quadrant. The dark brown circular nodules are iron-rich siliciclastic features.

JBCB03 (-13.93‰ $\delta^{18}O$) composed of silt-sized siliciclastic grains and opaque oxides. There are white, oblong, sparry inclusions in the upper sector. Iron banded fluid-like microstructures are prevalent throughout.

JBCB06 (-11.09‰ $\delta^{18}O$) poorly sorted silt to fine sized angular siliciclastic lithics and rounded sparry carbonate grains.

JBCB10 (-10.68‰ $\delta^{18}O$) rounded sparry calcite clasts 250 – 1000µm supported in silty siliciclastic matrix.

JBCB09 (-4.64‰ $\delta^{18}O$) Large gypsum crystals coating pedogenic clay features. Gypsum crystals are up to 2mm in size.

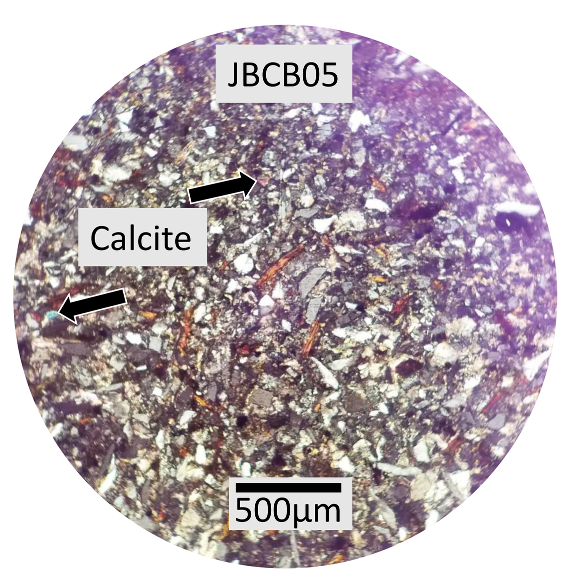


Figure 1. Petrograph of JBCB12 (xpl). Arrows indicate micritic calcite with fourth-order interference colors in a matrix of angular siliciclastic silt.

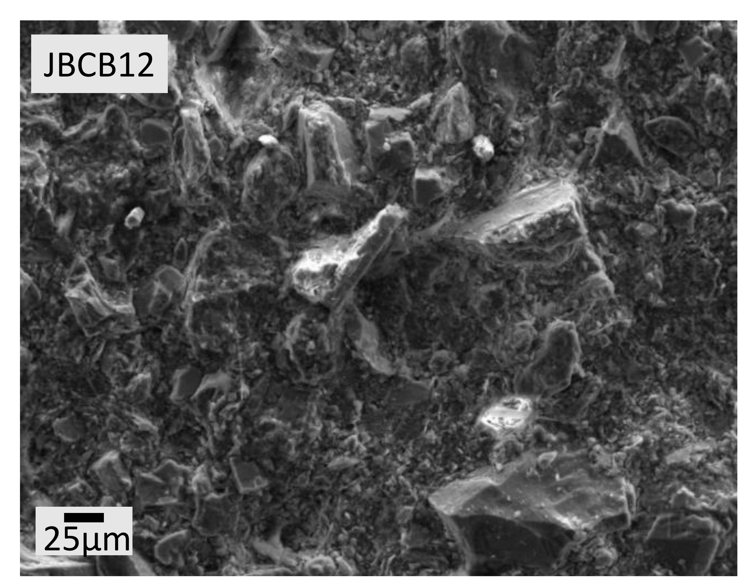


Figure 2. Scanning electron photomicrograph of JBCB12. No microbial evidence was located, so the negative $\delta^{18}O$ value is likely not due to preferential biogenic fractionation; implying that the carbonate is inorganic.

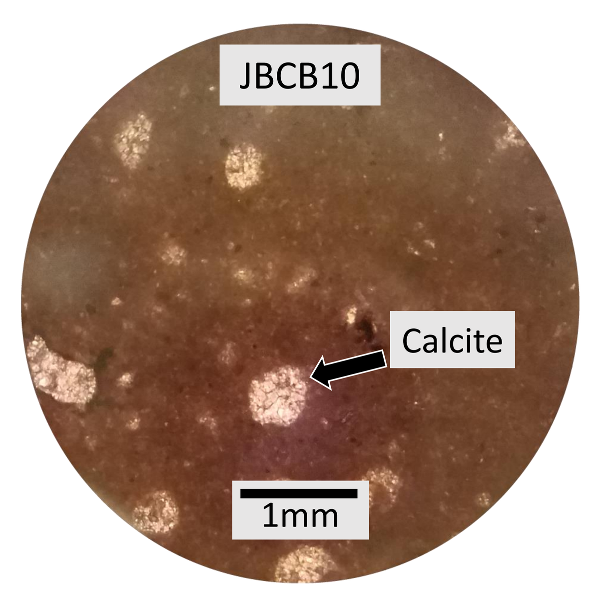


Figure 3. Petrograph of JBCB10 (xpl). Calcite clasts supported in a siliciclastic matrix.

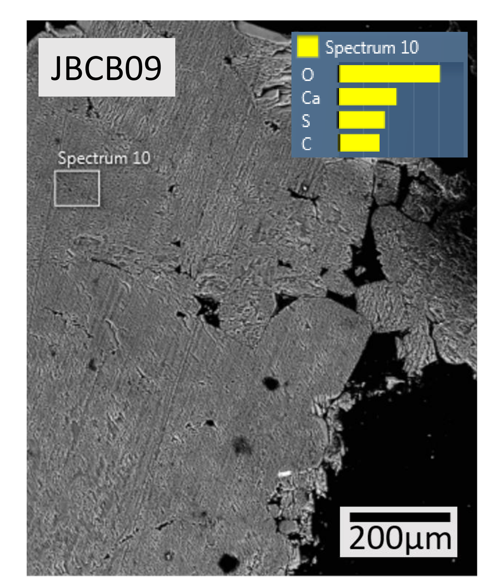


Figure 4. Scanning electron photomicrograph of the gypsum fabric from JBCB09. Energy Dispersive Spectroscopy was used to confirm the sparry fabric as gypsum (Spectrum 10).

METHODS

Thin sections were made from five samples with anomalously low $\delta^{18}O$ values, four with average $\delta^{18}O$ values, and one sample with a relatively positive $\delta^{18}O$ value. The samples were investigated for the presence of: secondary carbonate deposition, recrystallization of carbonate grains, bridged grains, fluid-like microstructures, and carbonate infillings.

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 diagenesis likely plays a larger role in anomalous $\delta^{18}O$ variance than does changes in water composition at the time of deposition.

Anomalously negative $\delta^{18}O$ values could be explained by high temperature groundwater depositing carbonate as a micritic cement during post-burial diagenesis. The micritic nature of the carbonate in the anomalously negative samples could result from carbonate cement being restricted to the size of the pore space within the siliciclastic rock (figure 1). The timing of diagenesis is not well constrained.

Microbes have been shown to cause anomalously negative $\delta^{18}O$ 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 $\delta^{18}O$ 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 $\delta^{18}O$ value for all samples is about -10.57‰ VPDB. The calcite clasts in these samples were likely formed from primary water with an isotopic composition of -13.13 ‰ to -8.55‰ VSMOW at 5-20 °C respectively (O'Neil et al, 1969). Present day water in the region has an average isotopic composition of -10.7‰ VSMOW (Bershaw and Lechler, in review). This suggests that paleoclimate in the Tian Shan foreland has been similar to modern since at least the late Miocene (9 Ma). The lack of fluid-like microstructures in samples with $\delta^{18}O$ 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 $\delta^{18}O$ values are more reliable indicators of diagenesis.

CONCLUSION

Petrographic investigation revealed that samples with anomalously low $\delta^{18}O$ values were more micritic than samples with more positive $\delta^{18}O$ 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.

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Many thanks to Dr. John Bershaw and Dr. Steven Bachtel for advising me on this project and to Dr. Richard Hugo for allotting time to investigate the samples during his SEM class at Portland State University.