Conodont biostratigraphy and chemostratigraphy of the Grove Creek Member of the Snowy Range Formation, northwestern Wyoming and southwestern Montana

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INTRODUCTION

It has been suggested that sea level changes can be linked to carbon isotopic variations in sediments as well as to conodont and other biozone boundaries (Hilbrecht et al., 1996; Ripperdan et al., 1992). $\delta^{13}C$ minima correspond with regressive sea level events, while $\delta^{13}C$ maxima appear to be related to sea level rises and anoxia events. Ripperdan et al. (1992) suggest that a possible mechanism for the correlation is climate change. They proposed that climate change simultaneously induces sea level changes and conodont assemblage zone boundaries at the Cambrian-Ordovician boundary interval at Black Mountain, Australia. Geochemical signatures of sea water may also be linked to climate change, as suggested by correlations to $\delta^{13}C$.

The study of links between carbon isotopes, conodont biozones, and sea level is relatively new. Further study is necessary in order to put together a more global picture of system dynamics and feedback mechanisms. The objective of this study is to determine if such links exist for Cambrian-Ordovician rocks in northwestern Wyoming and southwestern Montana. It will provide additional evidence for understanding global sea level changes. Based on the results from samples collected from the Grove Creek Member of the Snowy Range Formation (Upper Cambrian-Lower Ordovician), this study will provide evidence for global correlation in an effort to create a picture of physical and biological evolution during the Lower Paleozoic.

GEOLOGIC SETTING

The Grove Creek Member is the uppermost member of the Snowy Range Formation which consists of three units. The bottom unit is the Dry Creek Shale, overlain by the Sage Limestone-Pebble Conglomerate which is beneath the Grove Creek Limestone (Grant, 1965). In the field area for this study, the Snowy Range Formation is disconformably overlain by the Ordovician Bighorn Dolomite. Beneath the Grove Creek Limestone lies the Pilgrim Limestone , a cliff-forming oolitic formation.

The two sites from which samples were collected include Cathedral Cliffs, located along the Chief Joseph Highway southeast of Cooke City, MT in the Clarks Fork Valley of Wyoming, and the type section for the Grove Creek Member at North Grove Creek located about five miles southeast of Red Lodge, MT.

SEDIMENTOLOGY

The Grove Creek Member of the Snowy Range Formation at the North Grove Creek and Cathedral Cliffs sections is composed of interbedded shale, grainstone and intraformational flat pebble conglomerate. A typical stratigraphic column (Fig 1) shows the variation in lithologies and bed thicknesses throughout the sections, as well as some of the detailed sedimentary features. There are no significant changes in the facies patterns throughout the sections. This consistency leads me to believe that any changes in biostratigraphy throughout the section is independent of any facies variations.

METHODS

Bed-by-bed measurement of 16 meters at the North Grove Creek section and 8 meters at the Cathedral Cliffs section was completed an drafted. Each bed was drawn and described thoroughly, including its lithological composition, and internal sedimentary structures.

Twenty-four 5-10 kg samples were collected at every 1-2 meters for conodont study. A combined 45 samples were collected at every 0.5 meter interval for geochemical analysis. Powder were prepared using a Spex 4200 Jaw Crusher and Shatter Box, and then sieved through a 200μ mesh sieve. Each sample was run through the X-ray Diffractometer. Dolomite mole percentages were determined by X-ray diffraction.

Lab work was completed in the Sable Isotope Laboratory at The University of Tennessee, Knoxville. $\delta^{13}C$ values for carbon isotopes and $\delta^{18}O$ values for oxygen isotopes were determined for each sample by analyzing them in the form of CO_2 gas, which was run through a Finnigan MAT Delta plus mass spectrometer. A vacuum line was used to collected CO_2 gas produced during the reaction of carbonate sediment with phosphoric acid. Dissolution times for carbonates with less than 30% dolomite were 24 hours and for those with greater than 30% dolomite were 48 hours.

DISCUSSION

Carbon isotopes have been favored variables of study because of its relative insensitivity to post-depositional processes. This is because the volume of carbon in carbonate rock is far greater than that in the pore-water reservoir (Scholle and Arthur, 1980). Increases and decreases in $\delta^{13}C$ values are reflections of changes in geochemical cycling of marine carbon. During times of high organic productivity, ^{12}C is preferentially incorporated into organic matter, taking ^{12}C out of the sea water. Thus there the sea water in ^{13}C-rich. At these times there is an increased amount of organic carbon burial due to an increased rate of productivity. $\delta^{13}C$ values recorded in carbonate sediment deposited from sea water at these times are relatively high. Relatively depleted $\delta^{13}C$ values are the result of the combination of rapid ocean turnover, involving the mixing of surface water with bottom water depleted in ^{13}C; oxygenation and efficient recycling of nutrients; and a decrease in the rate of organic carbon burial. A decrease in productivity causes ^{12}C to remain in sea water, thus making the $\delta^{13}C$ values of precipitated carbonate relatively low (Scholle and Arthur, 1980)

Extinction events are recorded by boundary sections for certain fossils such as conodonts and trilobites. These boundaries have been shown to correlate in cases with $\delta^{13}C$ minima. This is supported by the understanding that at times of extinctions there is less organic burial and less productivity resulting in the enrichment of ^{12}C in the sea water. This correlation between boundary zones horizons and $\delta^{13}C$ variations is pictured in figure ??.

It has been suggested that sea level change correlates with extinction events and $\delta^{13}C$ variations. Transgression is proposed to correlate with $\delta^{13}C$ maxima, while regression correlates with $\delta^{13}C$ minima.

RESULTS

Biostratigraphy Conodonts were reasonably abundant at the North Grove Creek section. A few were found at the Cathedral Cliffs section, but only a very poor fauna in one sample of flat pebble conglomerate. Several samples of graptolites found, mainly in float at Cathedral Cliffs. All samples are of the order *Dendroidea* including *Dictyonema*, *Dendrograptus*, *Reticulograptus* and *Inocaulis.*

The majority of the conodont in the North Grove Creek section are consistent with a warm water, carbonate platform environment. These conodont subzones range from the *Cambrooistodus minutus* Subzone of the *Eoconodontus* Zone to the *Clavohamulus elongatus* Subzone of the *Cordylodus proavus* Zone.

Miller (1984) has suggested that a possible horizon for the placement of the Cambrian-Ordovician boundary lies at the base of the *Cordylodus proavus* zone. This zone is represented in the North Grove Creek section. Based on this suggestion it is possible that the Grove Creek Member contains evidence for the Cambrian-Ordovician boundary. Results from the Cathedral Cliffs section were inconclusive due to the composition of the rock at that location. Dissolution was not successful in conodont study and XRD analysis showed the samples to contain numerous extraneous minerals besides calcite and dolomite.

Conodont biostratigraphy is listed Table 1 with possible locations of unconformity determined through conodont analysis. When comparing the biostratigraphy and the stratigraphic columns it is clear to see that biostratigraphic changes were relatively independent of facies changes.

Chemostratigraphy - $\delta^{13}C$ analysis Figure 2 shows the plot of $\delta^{18}O$ versus $\delta^{13}C$. It is important to notice the lack of a linear trend in this relationship which would indicate diagenetic resetting of the carbon isotope values. Oxygen isotopes, contrary to carbon isotopes, are highly sensitive to post-depositional processes. This difference is shown by the scattered character of the plot.

Figure 3 represents the $\delta^{13}C$ curve with a moving average. The curve shows the positive and negative $\delta^{13}C$ shifts throughout the section. The most significant change in the curve corresponds with the base of the *Cordylodus proavus* zone at 8.11 meters. This interval could represent the Cambrian-Ordovician boundary in the North Grove Creek section. When this interval of the curve is compared with other data from Black Mountain Australia (Ripperdan et al., 1992) there is striking similarity lending support to the global usefulness of this study.

$\delta^{18}O$ analysis $\delta^{18}O$ values in marine limestone of Recent age vary between +28‰ and +30‰ compared with SMOW. Due to the effects of lithification on isotopic compositions, $\delta^{18}O$ values decrease with increasing geologic age to about +20‰ for rocks of Cambrian age (Faure, 1977). My results for $\delta^{18}O$ from North Grove Creek show values compared with the PDB standard (Faure, 1977) to be typical marine values showing little alteration. They are consistent with typical values of Cambrian time. The range is between -7‰ and -9‰ (vs. PDB) which is about +22 to +24 SMOW. $\delta^{18}O$ values for North Grove Creek show little variation throughout the section while the $\delta^{13}C$ values fluctuate. I conclude that the $\delta^{13}C$ values Represent the isotopic signature of the sea water at these times due to the consistency of $\delta^{18}O$ values. The consistency shows that there was little water-rock interaction causing fluid disturbance of the sediment which would cause fluctuation in $\delta^{18}O$ values.

CONCLUSIONS

The Grove Creek Member of the Snowy Range Formation at the North Grove Creek section contains evidence for the Cambrian-Ordovician boundary. This study proves to have global significance because of its similarity to other Cambrian-Ordovician boundary sections around the world. This similarity is based on a significant negative $\delta^{13}C$ shift at 8.11 meters which corresponds with a well-documented shift at the base of the Cordylodus *proavus* Zone elsewhere. I have concluded that biostratigraphic changes in conodont zonation do not depend upon facies changes, due to the lack of significant lithologic variation in the stratigraphic columns. The results can be interpreted in regard to sea level changes as well. At times of relatively high $\delta^{13}C$ values there may have been a rise in sea level while at times of relatively lower $\delta^{13}C$ values there may have been regression.

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TABLE 1. CONDONT BIOSTRATIGRAPHY

meters	conodont zone/subzone
0.50	*Cambrooistodus minutus* Subzone
0.98	*Cambrooistodus minutus* Subzone
2.07	*Eoconodontus notchpeakensis* Subzone, (poor fauna)
3.05	*Cambrooistodus minutus* Subzone
4.00	*Cambrooistodus minutus* Subzone
4.91	*Cambrooistodus minutus* Subzone
6.20	*Cambrooistodus minutus* Subzone
(unconformity)	
8.11	*Cordylodus proavus* Zone
(Possible Cambrian-Ordovician boundary)	
8.90	*Hirsutodontus hirsutus* Subzone
(unconformity)	
10.33	*Clavohamulus elongatus* Subzone
11.70	*Clavohamulus elongatus* Subzone
12.13	*Clavohamulus elongatus* Subzone not as clear as below
13.50	*Clavohamulus elongatus* Subzone
14.18	*Clavohamulus elongatus* Subzone
14.97	*Clavohamulus elongatus* Subzone

Figure 1. Stratigraphic column from North Grove Creek

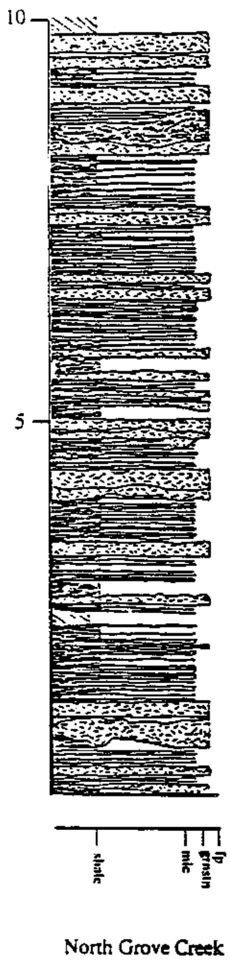
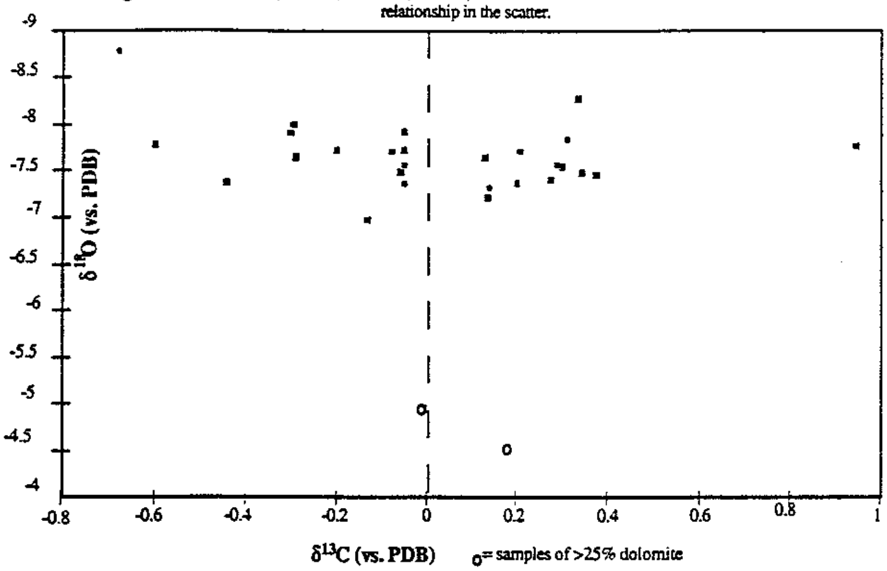


Figure 2. Plot of $\delta\ ^{13}C$ (vs. PDB) vs. $\delta\ ^{18}O$ (vs. PDB) for North Grove Creek. Note the lack of linear relationship in the scatter.



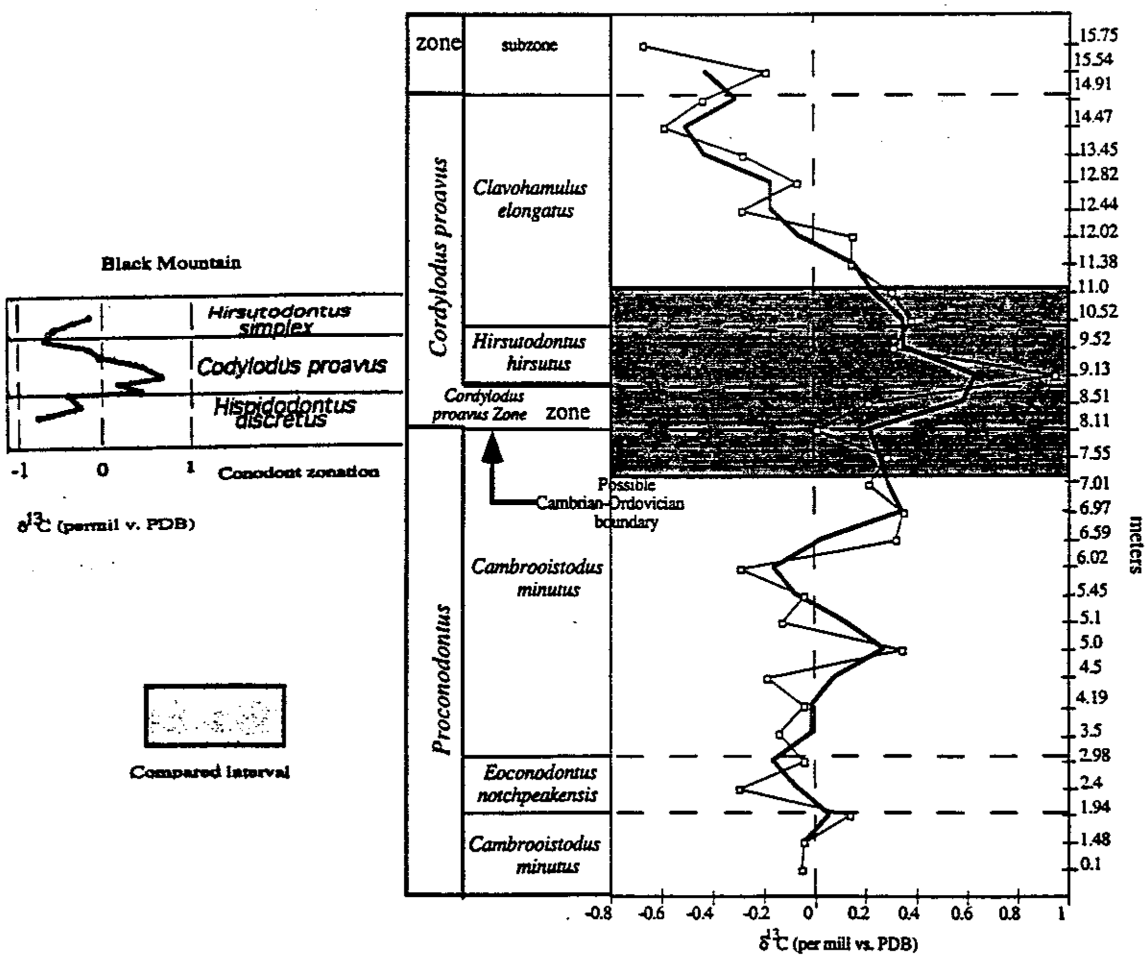


Figure 3. Stratigraphic plot of carbon isotope values from North Grove Creek correlated to conodont boundaries. (Heavy line represents moving average). Compared interval based on data from Ripperdan et al. (1992).