[PS]Geochemistry of Shallow Water Shales from the Virgin Limestone, Nevada, USA: Evidence for Periodic Shallow-Water Anoxia Following the Permian-Triassic Mass Extinction*

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Abstract

The end of the Permian (~252 My) was marked by a mass extinction that proved greater than any mass extinction of the past 600 million years, with an estimated loss of 85% of marine genera. Reconstructing environmental conditions after a mass extinction such as the Permian-Triassic event is key to understanding how and when recovery occurs following major biotic crises. The Spathian (uppermost Lower Triassic) Virgin Limestone at Ute, Nevada is comprised of interbedded red and green shales and limestone beds (primarily packstones and grainstones) that are fossiliferous, often oolitic, and commonly contain anachronistic facies (i.e., fabrics and features that were common in the Precambrian). The limestone units were previously examined in detail (Woods, in press); the purpose of this study was to determine paleoenvironmental conditions in shallow water environments during the Early Triassic via geochemical analysis of interbedded shales.

Twenty-five samples were analyzed using a Perkin-Elmer 7300 DV ICP-OES to measure major, minor and trace elements to reconstruct environmental conditions and the overall sedimentology of the shales. Vanadium, molybdenum, cobalt, chromium, and manganese values indicate that oxygen levels within the shale beds range from oxic to dysoxic, while low barium, copper, nickel, phosphorus, and zinc values suggest the efficient breakdown of organic matter in shallow environments. Overall, results suggest that in nearshore environments, the water was mostly oxygenated but was punctuated by occasional anoxic events that were likely short-lived based on the lack of preservation of organic matter. The close juxtaposition of dysoxic to anoxic shales and anachronistic facies supports previous hypotheses that suggest unusual Lower Triassic facies and fabrics are the result of the impingement of anoxic, alkaline deep waters onto the continental shelves (Woods, in press) that likely resulted in the long, slow biotic recovery from the Permian-Triassic mass extinction that has been previously documented in the southwestern United States (e.g., Schubert and Bottjer, 1992).

Selected Reference

J.K. Schubert, and D.J. Bottjer, 1992, Early Triassic stromatolites as post-mass extinction disaster forms: Geology, v. 20/10, p. 883-886.

Geochemistry Of Shallow Water Shales From The Virgin Limestone, Nv, Usa: Evidence For Periodic Shallow-Water Anoxia Following The Permian-Triassic Mass Extinction

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Abstract

The end of the Permian event (~252 My) was marked by an extinction that proved greater than any mass extinction of the past 600 million years. The Permian-Triassic mass extinction had an estimated loss of 85 percent of marine genera 70 percent of terrestrial genera. Understanding environmental conditions and the timing of the reestablishment of primary productivity after a mass extinction such as the Permian – Triassic crisis is key to understanding the recovery of many organisms. 25 samples were taken from the Spathian (uppermost Lower Triassic) Virgin Limestone (Moenkopi Formation), from Ute, Nevada for geochemical analysis. The Virgin Limestone at Ute is comprised of interbedded red and green shales and limestone beds (primarily packstones and grainstones) that are fossiliferous (primarily bivalves, gastropods and phylloid algae), often oolitic, and commonly contain so-called anachronistic facies (i.e., fabrics and features that are more common prior to the Ordovician). The limestone units were previously examined in detail (Woods, in revision), and the purpose of this study was to determine the relationship of the interbedded shales with the limestone units. Shale samples were analyzed using a Perkin-Elmer 7300 DV ICP-OES to determine specific trace elements contents and calculating the enrichment factors, which then can be used to better understand environmental conditions, primary productivity, and sedimentology during deposition. Vanadium, molybdenum, cobolt, chromium, and manganese values indicate that oxygen levels within the shale beds range from oxic to dysoxic , while barium, copper, nickel, phosphorus, and zinc values suggest that the oxic waters were associated with low productivity. Clay content relates to the aluminum, titanium, and zirconium. Clay content seems to relate the amount productivity, the lower the clay content the higher the productivity. Magnesium values are typically low, while calcium values are high indicating that the shales are rich in calcite as opposed to dolomite. Geochemical data analysis suggests that during the time of deposition on the shallow, near shore environment the water was mostly oxygenated with few anoxic events and low productivity during shale deposition. Little peaks in data below 1.0 on graphed data indicate low oxygen events. Low productivity in the shally layers could be a result of the shallow depth where sediment is being deposited, or organic material is not properly preserved in low oxygen events. As mentioned above, the oxic and anoxic shales are interbedded with fossiliferous limestones that often contain anachronistic facies. Anachronistic facies are often associated with the inorganic or microbial precipitation of calcium carbonate, which has been attributed to the upwelling of anoxic, alkaline deep waters and the results of this study support this hypothesis by demonstrating the close juxtaposition of anoxic waters and anachronistic facies with each other.

Site Description

The Virgin Limestone (Moenkopi Formation) was deposited on a shallow marine shelf on the western edge of the supercontinent of Pangea during the Spathian stage of the latest Early Triassic. The Virgin Limestone is comprised of interbedded shales and carbonates that often contain anachronistic facies, or features and fabrics that are more common prior to the Ordovician, and are rare since. Some of these facies include: flat pebble conglomerates, wrinkle structures, microbialites, and synsedimentary seafloor cements. The presence of these features indicates unusuall environmental conditions during the post-extinction period, specifically anoxic, alkaline deep waters that may have impinged into shallow water depositional environments.

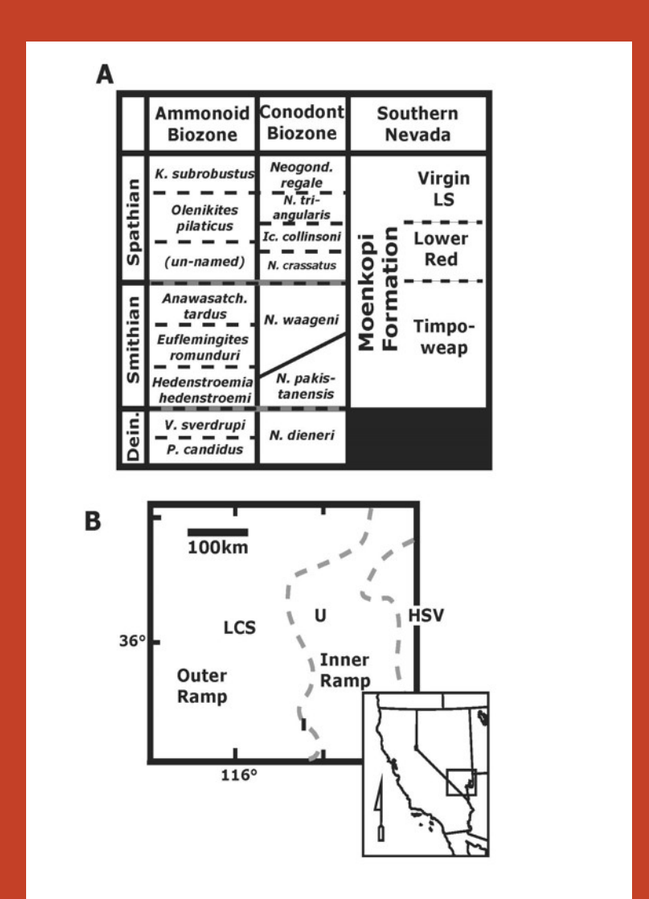


Figure 1. A) Chrono- and biostratigraphy of the Virgin Limestone; B) Locality map of the study section (U) at Ute, Nevada

Figure 2. The Virgin Limestone is comprised of interbedded shale and limestone at Ute, NV.

Figure 3. A closer view of the interbedded shales and limestone beds.

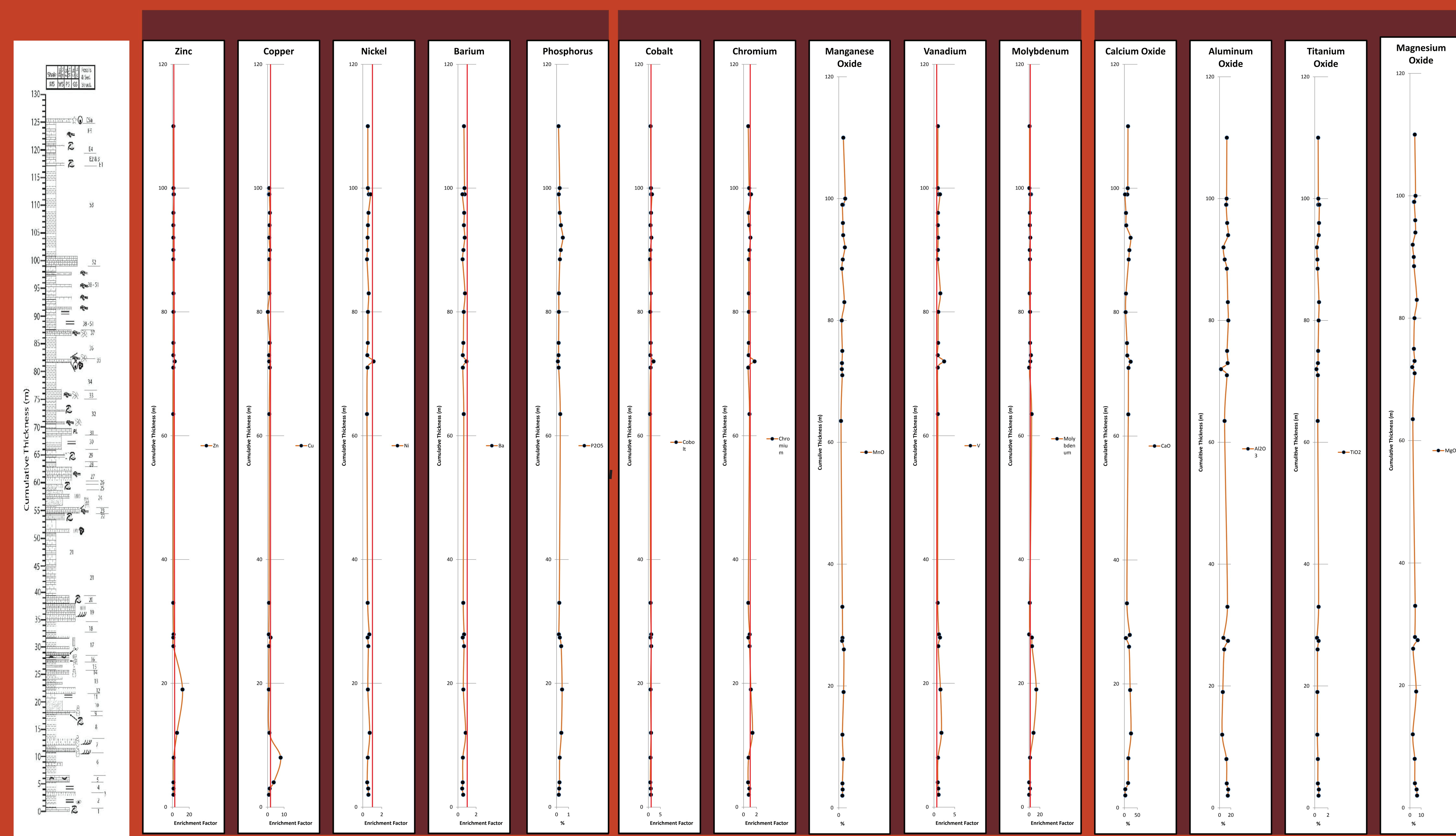
Research Problem

- Anachronistic facies are thought to have formed as the result of anoxic, alkaline waters flooding into shallow water environments. Interbedded shales and carbonates offer an excellent means to test if alkaline, anoxic conditions might have led to the growth of anachronistic facies.
- Trace element analysis was used to determine oxygenation of the shales, and can be used to infer alkalinity.

Methods

- Samples were prepared based on Ziegler and Murray (2007) Microwave digestion method
- Approximately 50 mg of sample was placed in a microwave digestion vessel along with a mixture of HNO3, HF, HCl, hydrogen peroxide, and boric acid.
- Vessels were placed in Multiwave 3000 Microwave Digestion System heated, digested, and diluted with ultrapure DI water to 50 ml.
- Samples were analyzed using Perkin-Elmer Optima 7300DV ICP-OES located in the Geology Department at CSU Fullerton.
- Data were plotted as % oxides, ppm, or as Enrichment Factors, which are normalized to Al contents and World Shale Averages (values >1 are considered enriched).

Productivity　Oxygen　Sedimentology



Interpretations

Oxygen Levels

Vanadium, molybdenum, cobalt, chromium and manganese contents are closely associated with paleoxygenation (Tribovillard, et al., 2006). In general, enrichment factors of V, Co, and Cr vary between slightly less than one (i.e., slightly depleted, and representing deposition under oxygenated conditions) and slightly more than one (i.e., slightly enriched, and representing deposition under reduced oxygenation). Mo values are indicative of deposition under euxinic conditions (Tribovillard, et al., 2006), and Mo enrichment factors are >1 through much of the study section, however, this likely is the result of a high degree in error in measuring Mo contents, since measured Mo values are near the detection limit of the ICP-OES. MnO levels are low, probably due to loss during diagenesis, as Mn is highly mobile under reducing conditions, and is typically only enriched near the redoxocline (Tribovillard et al., 2006). Slight enrichment of V, Co, and Cr is significant, and are indicative of the impingement of deeper, anoxic waters onto the shelf that were attenuated to dysxoic to oxic conditions by atmospheric mixing by waves.

Productivity

Barium, copper, nickel, phosphorus, and zinc are common elements associated with high primary productivity and burial of organic matter (Tribovillard et al,. 2006). All demonstrate low enrichment factors across the study section, except for Zn. Overall, the results indicate that the shales were not organic rich, which is to be expected given the shallow depositional environment.

Sedimentology

Al2O3 values, (average value = 11.467), are indicative of high of high clay contents while TiO2 values are low, (average value = .49903). values are low indicating a low concentration of detrital minerals other than clay. MgO values (average values = 4.2393), are typically low, while CaO values, (average values = 13.195), are muc that the shales were rich in calcium carbonate (likely in the form of cement and fine-grained micritic mud) as opposed to dolomite.

Conclusions

Paleoxygenation and Productivity

- Shale interbeds were deposited under oxic to dysoxic conditions.
- Organic matter was not preserved in the shales due to the shallow depositional environment.

Anachronistic Facies

- Oxic and anoxic shales are interbedded with fossiliferous limestones that often contain anachronistic facies. Anachronistic facies are associated with the inorganic or microbial precipitation of calcium carbonate, which has been attributed to the upwelling of anoxic, alkaline deep waters.
The presence of anoxic waters during deposition of the shales likely enhanced the precipitation of anachronistic facies at the Ute locality.
- Future analysis of shales from deeper-water facies will test the hypothesis that anoxic waters that may be responsible for enriched V, Co, and Cr values were

Acknowledgements

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