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Chemostratigraphic characterization and correlation of lower Silurian (Llandovery) strata across the Baltic Basin

Dr. Seth A. Young, Dept. of Earth Ocean & Atmospheric Science,
Florida State University

Over the duration of year-1 of this DNI project we have had two successful field campaigns to sample drill cores from Estonia in July of 2017 and Sweden in August of 2018. In July of 2017 myself and a Masters student of mine, traveled to Estonia to meet with colleagues in the Institute of Geology at Tallinn University of Technology (TUT) and collected 462 samples from three separate drill cores (Aizpute-41, Ohesaare, and Kirikukula). In August of 2018 a PhD student and I collected 642 samples from separate drill cores in southern Sweden (Röstånga-1, Röstånga-2, Grönnhögen-2015, Lerhamn, and Krapperup). Over the last year since the first field season in 2017 my Masters student along with an undergraduate assistant have made detailed lithologic descriptions, prepared, and analyzed a subset of ~ 200 samples from the early Silurian (Llandovery) parts of the Aizpute-41 and Röstånga-1 drill cores. A wide variety of detailed geochemical analyses have been carried out on these samples (Fig. 1 & 2) including: $\delta^{13}C_{org}$, $\delta^{34}S_{pyr}$, Fe-speciation, and trace metal concentrations (e.g., [Mo], [Cr], [V]), [U]). From these early data sets we can see robust signatures of two globally recognized carbon burial events (i.e., they have been documented outside of the paleocontinent of Baltica), the Late Aeronian carbon isotope excursion (CIE) and the Valgu CIE. The sulfur isotope data support these two CIE's as being the result of carbon burial under increased anoxic marine conditions globally as we see >10‰ shifts in pyrite sulfur isotopes that indicate enhanced pyrite burial was also occurring at the same time. Furthermore, the local paleoredox proxy Fe-speciation data (Fe_{HR}/Fe_{T} > 0.22) from both cores demonstrate that anoxic marine conditions spread from deeper basinal environments to distal shelf settings during the Aeronian Stage of the early Silurian. These iron speciation data suggest that while anoxic conditions during the Aeronian may have been more wider spread they were largely not euxinic (anoxic + sulfidic conditions). When this data is integrated with the trace metal data, regional paleogeography, and sea level records we find good evidence for these sediments have been deposited under an oxygen minimum zone (OMZ) and that these reducing conditions within the OMZ likely expanded during the Aeronian Stage in the Silurian. These results thus far have allowed us relate our geochemical signatures from ancient marine sediments (~ 440 Ma) to modern day geochemical and microbial processes that have been documented in OMZ's off the coasts of Peru, Argentina, and Namibia (e.g., Algeo et al., 2009; Hardisty et al., 2018; Scholz, 2018). By comparing our new geochemical data sets to geochemical data sets from modern day OMZs it has allowed my research group to broaden the impact of our findings in these ancient marine sediments, by utilizing uniformitarianism concepts we are now beginning to reconstruct early Silurian paleoceangraphic conditions on the margin of the Baltic paleocontinent and demonstrate physical and chemical oceanographic conditions that operated in early Paleozoic oceans.

More broadly, this project will allow the one Masters student working on two of the Silurian drill cores mentioned above to complete her degree by Spring/Summer 2019, giving her valuable geochemical skill sets that she may apply in future jobs or academic pursuits potentially. More broadly these research projects that both graduate and undergraduate students have worked on have given them real laboratory experiences, experiences operating state-of-the-art equipment at the National High Magnetic Field Lab (NHMFL), and experiences in time management, project deadlines, working in teams, and communicating their findings to their peers at conferences. Additionally, the field work and samples more recently carried out by my PhD student will allow him to collect preliminary data that can be used to submit graduate research proposals to AAPG and GSA. These new data forthcoming in the next year will allow me to submit full NSF and NASA-Exobiology research proposals to continue this type of geochemical work into Ordovician age organic-rich black shales from Sweden where we will be utilizing the above mentioned geochemistry in addition to a new novel proxy, thallium isotopes, for global ocean oxygenation to test the hypotheses and new models put forth about oxygen's role in Earth's second largest radiation of marine life, the Great Ordovician Biodiversification Event (GOBE). These forthcoming projects on Ordovician graptolitic black shales from Sweden and the United Kingdom will involve new collaborations with researchers from FSU, Lund University (Sweden), and several universities within the U.K. Over the next year of the project I anticipate that the one Masters student will defend her thesis successfully and a manuscript on the early Silurian paleoredox reconstructions in the Baltic Basin will be submitted to a high-quality peer reviewed journal during the summer of 2019. The pilot geochemical data from the Ordovician black shales will be collected and proposals written and submitted to obtain funds to continue more detailed work within the Ordovician graptolitic black shales of both Baltica and Avalonia (modern day U.K.). Lastly, this project thus far has allowed me and my research group to develop new geochemical skill sets and methods in our laboratory here at FSU and the NHMFL, solidify good working relationships colleagues here at FSU, Lund University and TUT, and to be able to gain valuable experiences mentoring the next generation of geoscientists at both the graduate and undergraduate levels.

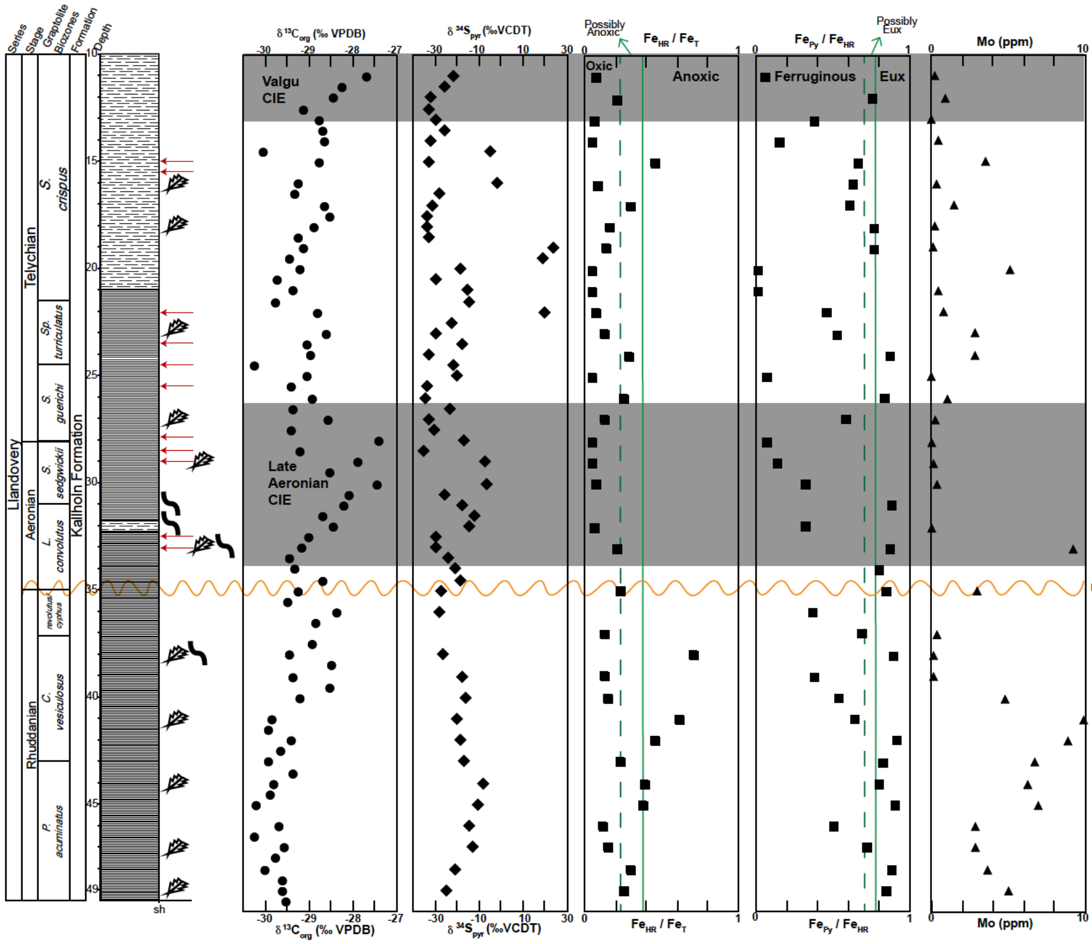

Figure 1, Geochemical data from the early Silurian interval of the Röstånga-1 drill core. Eux, euxinic and ferruginous = Fe^{2+}-rich.

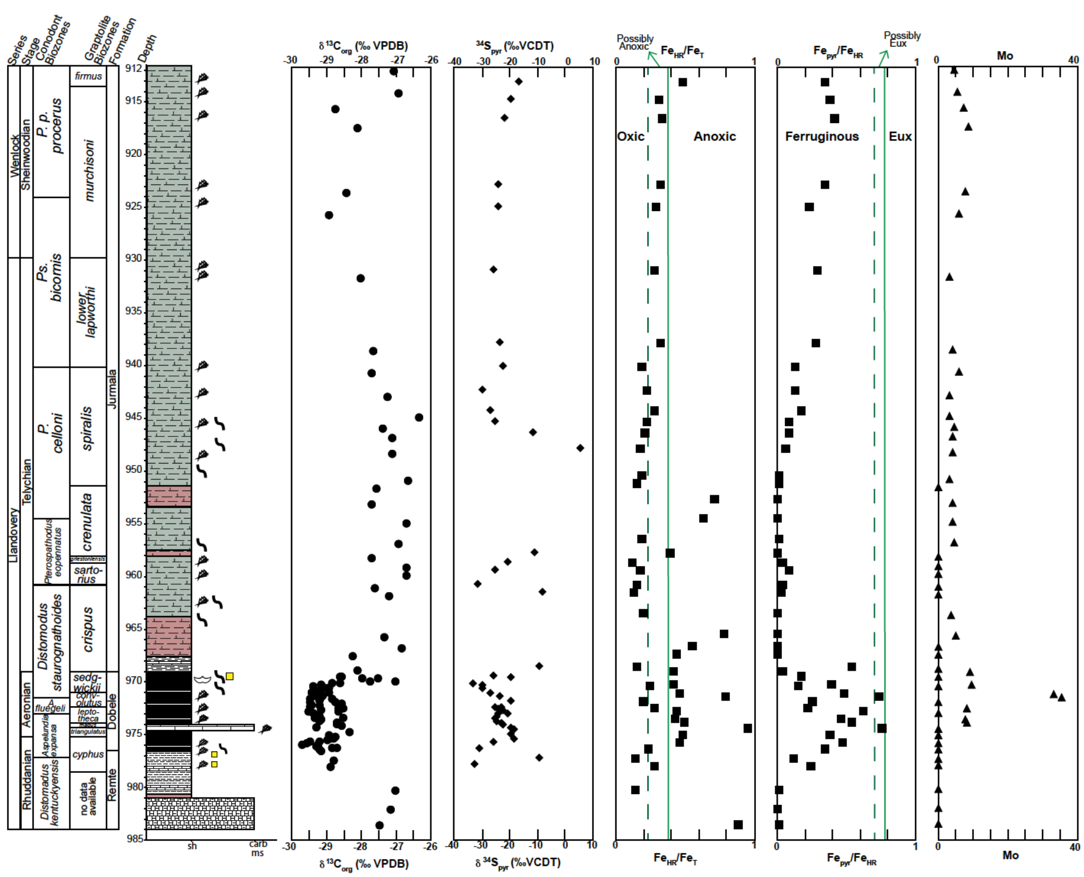

Figure 2, Geochemical data from the early Silurian interval of the Aizpute-41 drill core.