The correlation of the carbonate facies of the lower Silurian in Lithuania: carbon isotope and the cross-recurrence plot

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The facies of the lower Silurian deposits vary from shallow lagoon in east Lithuania to open deep shelf in the west. The fauna of eastern Lithuania is rare and correlations with deep facies are difficult. Sometimes, the solution to these problems is using stable carbon isotope chemostratigraphy.

The Ledai-179 borehole is located in the central part of Lithuania, and Wenlock geological section is composed of dolomitic marl of the Paprieniai Formation in the lower part, nodular limestone of the Birštonas Formation in the middle and dolostone of the Nevėžis Formation on the top. Two positive carbon isotope excursions were established in the investigated interval of the Ledai-179 borehole. The first one is identified as the Ireviken Carbon Isotope Excursion and linking to Paprieniai formation of the Jaani Regional Stage. The second one is the Mulde Carbon Isotope Excursion linking it to the Nevėžis Formation of the Gėluva Regional Stage. The Jočionys-299 well is located in the eastern part of Lithuania and contains sediments of a lagoonal environment. The geological succession consists of various conditions of dolomite with gypsum interbeds of the Paprieniai, Jočionys and Verknė formations. The Ireviken Carbon Isotope Excursion is identified in the Paprieniai and Jočionys formations (Jaani Regional Stage) in the Jočionys-299 borehole. The Mulde Excursion is absent there and is associated with a stratigraphic gap. So, the problem is how to correlate the geological section of the Jaagarahu Regional Stage.

For the purpose of this study, we employed stable carbon isotope data and the cross-recurrence plot (CRP) to compare two time series in a data-point-wise manner. The obtained 2D Heaviside-filtered binary matrix was then used as a field for searching for the most expensive continuous path from its starting to the finishing corner, i.e., the dynamic time warping (DTW) algorithm. The path obtained is referred to as a line of synchronisation (LOS), i.e., correlation. There are numerous paths with similar cost coming through laminar states, although many of them pass through narrow joints between laminar states where the confidence of the correlation is the highest.

The recurrence plot results indicate the presence of two stratigraphic gaps in the Jočionys-299 borehole. The first one was determined at the boundary of Paprieniai and Jočionys formations (stable zone of Ireviken CIE). This occurrence seems to be somewhat questionable, especially because the core interval related to the stable zone of Ireviken CIE in the Jočionys-299 well is missing.

The second stratigraphic gap was identified in the middle part of the Verknė Formation, indicating its probable occurrence. In conclusion, cross-recurrence plot analysis represents a valuable tool for correlating geological sections.

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