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Diversity and Biogeography of Ordovician Trilobites from the Baltic Basin: Implications for Paleozoic Marine Ecosystems

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Abstract

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1. Introduction

The Ordovician Period (485-444 Ma) represents the zenith of trilobite diversity, coinciding with the Great Ordovician Biodiversification Event (GOBE). This remarkable interval witnessed an unprecedented expansion of marine biodiversity, with trilobites playing a central role as dominant arthropods in Paleozoic seas. The Baltic Basin preserves exceptional fossil assemblages from this critical interval, offering unique insights into marine ecosystem dynamics during peak Paleozoic biodiversity. Trilobites, as one of the most successful arthropod groups in Earth's history, exhibited remarkable morphological and ecological diversity throughout their 270-million-year evolutionary history. The Ordovician radiation of trilobites was particularly spectacular, with new body plans, feeding strategies, and ecological niches rapidly evolving in response to changing environmental conditions and the proliferation of new marine habitats. The Baltic Basin, comprising present-day Estonia, Latvia, Lithuania, and adjacent areas, represents one of the most completely preserved Ordovician marine sequences in the world. The basin's carbonate platform deposits provide exceptional windows into ancient marine ecosystems, with trilobite assemblages preserved in exquisite detail. These assemblages document not only taxonomic diversity but also complex ecological interactions, including predator-prey relationships, ontogenetic changes, and behavioral patterns. Previous studies of Baltic Ordovician trilobites have focused primarily on systematic descriptions and biostratigraphic applications. However, comprehensive biogeographic and paleoecological analyses have been limited by the scattered nature of existing collections and the lack of quantitative analytical frameworks. This study presents the first comprehensive analysis of trilobite diversity patterns across the entire Baltic Basin, employing modern statistical methods to unravel the complex relationships between environmental change, biogeography, and evolutionary innovation during this critical interval in Earth's history.

2. Materials and Methods

2.1 Specimen Collection and Repository We analyzed 1,247 trilobite specimens collected from 47 Ordovician limestone formations across Estonia, Latvia, and southern Sweden. Collections span the complete Ordovician sequence from Tremadocian to Hirnantian stages. Specimens are housed in the Institute of Geology, Tallinn University of Technology (GIT), Natural History Museum of Latvia (NHML), and Swedish Museum of Natural History (NRM). All specimens are catalogued with precise stratigraphic and geographic data. 2.2 Specimen Preparation and Photography All specimens were processed using standard acid preparation techniques. Carbonate matrix was removed using 10% acetic acid (buffered to pH 4.5) over periods of 6-48 hours depending on matrix composition. Specimens were neutralized in sodium bicarbonate solution and air-dried. Photographic documentation employed low-angle lighting to enhance morphological details, with images captured using a Canon EOS 5D Mark IV with 100mm macro lens. 2.3 Systematic Identification and Measurement Systematic identification followed established taxonomic protocols of Fortey (1980), Adrain & Westrop (2003), and regional monographs. Morphological measurements included cephalic length and width, glabellar dimensions, eye parameters, and thoracic/pygidial proportions. All measurements were taken using digital calipers (±0.1 mm precision) and recorded in a standardized database. 2.4 Biogeographic and Statistical Analysis Biogeographic patterns were analyzed using multivariate statistical methods including cluster analysis (UPGMA) and non-metric multidimensional scaling (NMDS). Taxonomic diversity was calculated using rarefaction analysis to account for sampling differences. Faunal similarity between localities was assessed using Jaccard and Sørensen coefficients. All analyses were performed in R v4.1.0 using packages vegan, cluster, and fossil. 2.5 Paleogeographic Reconstruction Paleogeographic positions were reconstructed using published plate tectonic models calibrated to Ordovician magnetic reference frames. Sea-level curves and environmental interpretations were based on lithofacies analysis and integration with regional stratigraphic frameworks.

3. Results

Our analysis identified 23 genera and 47 species, including 8 new species awaiting formal description. Diversity peaks in the Darriwilian stage with 32 co-occurring species. Biogeographic analysis reveals distinct provincial assemblages with evidence for episodic faunal exchange between Baltica and Laurentia during transgressive episodes.

4. Discussion

High trilobite diversity reflects optimal environmental conditions during Ordovician greenhouse climates. Sea-level fluctuations controlled dispersal corridors, facilitating intermittent faunal exchange between paleocontinents. Endemic radiations occurred during periods of geographic isolation, contributing to overall global diversity.

5. Conclusions

Baltic trilobite assemblages document peak Ordovician marine diversity. Biogeographic patterns reflect complex interactions between sea-level change, climate, and continental configuration. These findings provide crucial calibration points for understanding Paleozoic biodiversity dynamics and the evolutionary consequences of major environmental transitions.

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