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BOOK OF ABSTRACTS

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POSSIBLE SOURCES OF AEOLIAN DEPOSITION IN THE AUGŠDAUGAVA SPILLWAY VALLEY DERIVED FROM INLAND DUNE SAND GEOCHEMISTRY

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The inactive inland dunes located in the Augšdaugava spillway valley, SE Latvia, have developed on the surface of river terraces, where aeolian deposition took place presumably during the late Pleistocene and Holocene. These landforms represent the evidence of past wind-driven geological processes and landscape changes during the transition from periglacial to post-glacial conditions, and later during human-affected disturbances in vegetation cover in this area. Recent geomorphological mapping and studies on grain-size characteristics have proved to be efficient tools for identifying the environmental conditions during the aeolian deposition. Together with reconstruction of efficient wind directions inferred from inland dune morphology and distribution, these data give insight into local atmospheric circulation and the main factors involved in the past aeolian activity.

However, the possible sources of unconsolidated fine sediments, their provenance, and pathways of transportation by wind remain insufficiently studied. In turn, it limits the understanding of substantial issues related to the formation and paleogeographic development of this part of Latvia. Additional data for the identification of sediment provenance can be derived from inland dune sand geochemistry. During the last decades, developments in X-ray fluorescence (XRF) spectrometry have led to the wide use of this analytical technique for obtaining high-resolution geochemical data for Quaternary sediments (Dunnington et al., 2018). Therefore, in this study data on aeolian sand geochemistry have been obtained by Olympus portable XRF (pXRF) instrument Vanta (M-Series).

From previously collected dune sand 192 samples, five samples were selected in each meander section for the pXRF analyses, hence providing 45 samples in total so that they representatively characterize the chemical composition of aeolian sediments (so-called geochemical signatures) throughout the entire Augšdaugava spillway valley. In addition, to compare dune sand geochemistry with possible sources of sand sediments, six alluvial sand and six glaciofluvial sand samples were collected from different localities in the valley.

Previously collected and air-dried samples were analysed following the modified procedure described by Chagué-Goff et al. (2012) and Williams et al. (2018). Representative subsamples were ground with an agate pestle and mortar and mixed to account for possible heterogeneity, then placed in cylindrical polypropylene containers, filling at least 12 mm thick layer of sand sample, and sealed by Prolene™ 6 µm film. The samples prepared in this way were placed in pXRF instrument and analysed.

In order to perform statistical processing of sample results and to exclude outlier values, for each sample analyses were repeated six times. To obtain full element spectra, each measurement was done using the standard GeoChem REE2 protocol which is included in the manufacturer's software and applying two scan modes. The first mode (4.5 keV to 18 keV beam) provided the detection of low-energy

elements, while the second mode (18 keV to 35 keV beam) allowed to identify high-energy elements. Each sample was analysed over 90 s for two beams. A NIST standard NIST2711A (2018) and Blank Silica, as well as OREAS standards (OREAS, 2019) were measured to verify the reliability of the concentrations reported by the pXRF analyzer.

The geochemical analysis points out that elemental composition is rather typical for aeolian sediments, determined by the mineralogical composition, i.e. the dominance of quartz and K-silicates. In addition, they exhibit moderate Fe oxides concentration associated with coating on the surface of sand grains. Ca, as a component of carbonate (calcite, dolomite) or silicate minerals (feldspar, amphibole), is presented in the aeolian sand fraction in rather high concentrations ranging from 690 ppm to 3680 ppm; whilst Mg is lacking, but it has been found in the glaciofluvial sediments. Among microelements, dune sediments are dominated by Ba and Zr with an average concentration >430 ppm and >140 ppm respectively, followed by Sr and Rb with average concentrations of <60 ppm. Among REE elements, only Y and Nb were identified in detectable concentrations. Similar geochemical signatures of dune sands across the valley and geochemical characteristics alike to glacioaquatic sediments, but different from alluvial sediments, suggest the provenance of aeolian deposits from one main source, possibly from glaciofluvial sediments which have been transported, sorted, and deposited by wind.

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V-SHAPED SUBGLACIAL VALLEYS AND COLD GLACIERS REVEALED IN THE SOUTHERN PART OF THE QAANAAQ ICE CAP, NW GREENLAND

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This study presents new results of ground-penetrating radar (GPR) and unmanned aerial vehicle surveys performed on the two southern outlet glaciers of the Qaanaaq Ice Cap following the methodology by Karušs et al. (2022a, b) and Lamsters et al. (2022). The ice cap is located on the Piulip Nunaa peninsula in Thule region of NW Greenland and is drained by the Qaanaaq and unnamed glacier to the SE from it among others. Due to remote location, the Qaanaaq glacier has been investigated only from 2012 despite being sensitive to global warming and having significant impact on local ecosystems and communities (Sugiyama et al., 2014).

The recorded GRP profiles show mainly radar transparent facies, which we interpret as cold ice. Inside cold ice, internal layering of annual ice layers is visible, and it is concave along the central axis of the studied glaciers. We find also scattering facies, which thickness increases towards the glacier's terminus. Due to the signal characteristics, we interpret them as debris within the ice indicating sub/englacial transport. Reconstructed subglacial topography clearly reveals V-shaped subglacial valley providing indications on the glacier thermal structure and glaciation history. We also compare our interpolated ice thickness with the ice thickness model from Millan et al. (2022) and find that, although the ice volume differs by 19.3% and 10% for the Qaanaaq and unnamed glacier accordingly, the difference of the maximum ice thickness reaches 89 m, and it is highly underestimated along the central axis of the valley in Millan et al. (2022) model. As this model has been further used by Carrivick et al. (2023) to reconstruct the glacier thermal structure today and during the Last Ice Age (LIA) assuming the ice thickness threshold of 90 m, we, however, note that the studied glaciers are completely cold despite reaching the ice thickness of up to 152 m, and had probably limited distribution of temperate ice and restricted glacial erosion in the past and also during the LIA allowing to sustain V-shaped valley.

Our study shows that the existing ice thickness models are not suitable for the reconstruction of ice thickness of small High Arctic valleys in narrow subglacial valleys, and also reveal that in such polar environment and due to specific conditions including glacier geometry and thermal structure, the common U-shaped glacial valleys do not develop.

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GLACIER THICKNESS AND VOLUME MODELLING, USING SHEAR-STRESS-BASED AND MASS-CONSERVING APPROACHES

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Glaciers, distinct from ice sheets, are considered prominent indicators of climate change due to their proximity to melting conditions. They are projected to be the largest contributors to 21st-century sea-level rise after thermal expansion (Hugonnet et al., 2021). Estimating the current ice thickness distribution is crucial, allowing for the assessment of potential cryosphere-related future environmental and socio-economic hazards. Present-day solutions to this problem tend to favour ice thickness modelling over geophysical measurements. However, the accuracy of these models remains in question (Farinotti et al., 2017).

In this study, spatially distributed ice thickness and volume was modelled using open-source models GlabTop2 (Frey et al., 2014) and OGGM v.1.53 (Maussion et al., 2019), which implement shear-stress-based and mass-conserving approaches, respectively. Additionally, volume and mean ice thickness were determined using a simple volume-area scaling relation. With both approaches distributed ice thickness was obtained twice to simulate different possible scenarios: (1) solely satellite data is available and tuning of model parameters is therefore not possible; (2) additional data is available, and model parameters can be calibrated accordingly. Model input data, e.g., DEM and glacier outlines, and detailed GPR data for assessing modelled thickness accuracy, were obtained from Karušs et al. (2022a; 2022b) studies, from Waldemarbreen and Irenebreen glaciers in Svalbard.

The obtained ice thickness distribution in scenario 1 shows significant discrepancies against GPR data (Figure 1). For the northern glacier, Waldemarbreen, the volume error is 7.1% with the GlabTop2 model and noticeably higher with the OGGM model - 39.2%. For the southern glacier, Irenebreen, the errors are 24.8% and 47.7%, respectively. Calibration of model parameters results in a slight decrease in error with GlabTop2 and an increase with OGGM. In scenario 2, the volume error for Waldemarbreen is 3.8% with GlabTop2 and 31.8% with OGGM. For Irenebreen, the errors are 26.5% and 70.1%, respectively. Using the volume-area scaling relation, the error for Waldemarbreen is 25.5%, and for Irenebreen, it is 2.2%.

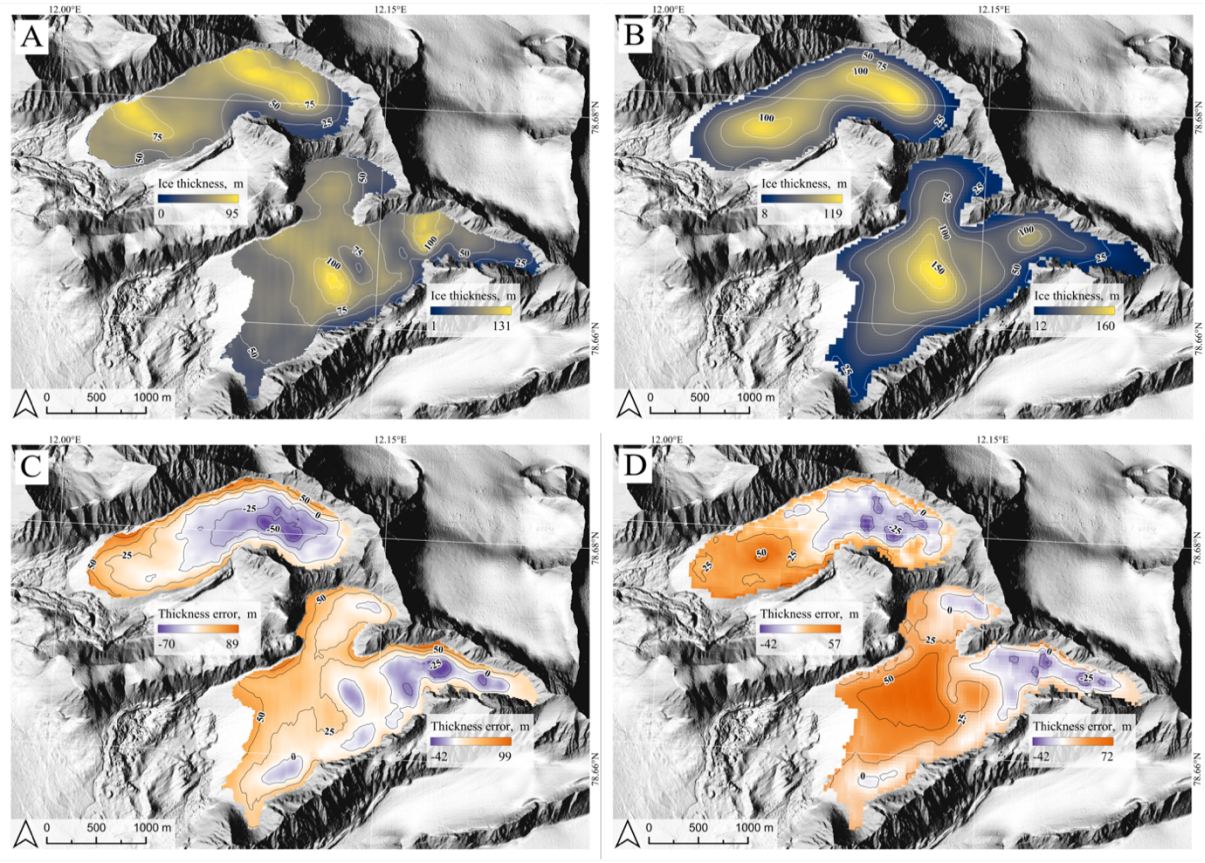

Figure 1. Spatial distributions of ice thickness and thickness error in scenario 1. (a) Ice thickness modelled by GlabTop2. (b) Ice thickness modelled by OGGM. (c) Difference in ice thickness between GlabTop2 and GPR measurements. (d) Difference in ice thickness between OGGM and GPR measurements.

The results exhibit variations both among glaciers and across different modelling approaches. Overall, models tend to overestimate glacier thickness and volume while also generating inaccurate spatial distributions of ice. The primary source of errors likely stems from theoretical assumptions. This leads to the conclusion that the current understanding of glacier geophysical processes is insufficient for developing mathematical models with the required level of precision, indicating a continued necessity for on-site geophysical measurements.

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SEDIMENTOLOGICAL CHARACTERISTICS OF ESKERS FORMED DURING THE SAALIAN GLACIATION IN POLAND

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Eskers are glaciofluvial forms, which originate in tunnels and channels, as a result of accumulation of meltwater sediments. Analysing their features provides invaluable information on the drainage system and allows to reconstruct the conditions and processes occurring in formerly glaciated areas. The aim of the study was to determine sedimentological characteristics of eskers formed during the Saalian Glaciation in Poland and to determine the conditions of their formation.

The research was conducted in exposures in seven selected eskers. It included lithofacial analysis, measurement of paleocurrent directions, analysis of grain size distribution, determining the roundness and shape of gravel clasts. Markov chain analysis was applied to investigate relations between lithofacies and to find potential modal sequences for each type of recognised esker succession.

Based on sedimentological profiles and deposit features, facies associations of three subenvironments were distinguished. The validity of the division was confirmed by Markov chain analysis. The subglacial tunnel facies (1) are the most diagnostic for the eskers. Sediments of this subenvironment are mainly composed of lithofacies of massive gravels and gravels with boulders, planar cross-stratified gravels and gravels with boulders, and horizontally stratified gravels. They often exhibit very poor sorting, widespread imbrication, strong orientation of gravel clasts consistent with the direction of water flow in tunnels, and the presence of intraclasts. In some eskers, a pseudoanticlinal macroforms were observed. The deposits were primarily accumulated during turbulent flow under hydrostatic pressure, but hyperconcentrated flows also played a significant role. The facies of tunnel with the crevasse (2) occurred in all analysed forms. Among its most typical deposits are trough cross-stratified and horizontally stratified gravels and sands. These deposits are characterized by varying sorting, strong orientation of clasts, the presence of outsized clasts, and the occurrence of deformations. The latter, are most commonly associated with the pressure of overlying layers, melting of buried ice blocks, and the collapse of the ice tunnel roof. Sediments were formed under atmospheric pressure. Turbulent flow of water with generally high energy predominated in this subenvironment. The facies of an open channel (3) are mainly composed of sandy lithofacies with horizontal, planar- and trough-stratification, as well as ripple-lamination. Sometimes, the deposits are intersected by layers of gravel or cut by channels filled with coarse-grained sediments. The deposits are characterized by weaker orientation of clast fabric and the presence of gravitational deformations associated with the disappearance of ice support. Water flow within the channel could occur across its entire width or take the form of migrating meltwater channels.

Esker deposits in the study area are diverse, and their formation was strongly influenced by local conditions such as the delivery of meltwater, sediment supply, tunnel geometry, the shape of the tunnel roof, and the deglaciation process. Despite

these factors, the repeatability of certain sedimentary successions has been documented, which was not observed in other glacial landforms.

MAPPING OF ESKERS IN LATVIA USING A 1-M RESOLUTION DIGITAL TERRAIN MODEL

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In the ice-sheet reconstructions, various landforms including deglaciation-related ones as eskers, are often used. However, in rather recent scientific studies within the context of various reconstruction models, there is an assumption that the presence of eskers in the Baltic states and the whole SE part of the Fennoscandian Ice Sheet (FIS) is rather rare due to the soft bed (sedimentary bedrock and Quaternary deposits) underneath the FIS (Stroeven et al. 2016). Additionaly, there have been two scenarios proposed regarding the evolution of subglacial drainage networks in the peripheral zone of the FIS. In the areas where the ice sheet moves on top of a sedimentary bedrock, the meltwater flow occurs through a distributed drainage system (canals and lined cavities etc.), while in the areas where the underlying substrate is made from crystalline bedrock, meltwater flow occurs through a channelized system facilitating the formation of eskers (Clark, Walder 1994). Therefore, it is assumed that subglacial or englacial tunnel drainage systems are not found in Latvia, nor the Baltic States. Such a perception of esker distribution presents a situation atypical for Latvia and other Baltic countries. As this information is incorporated into deglaciation models, we can conclude that assumptions about the retreat of the FIS in its SE part is incomplete. The identification and mapping of eskers in Latvia, as well as further research, is a significant contribution to the reconstruction of deglaciation processes in this region.

In Latvia, eskers have been mapped using mainly topographic, geological and geomorphological maps up to now (Putniņš, Celiņš 2011; Lamsters 2015; Zelčs et al. 2018), and digital terrain model (DTM) has been used only in specific areas and mainly in students' final thesis (Grīnbauma 2022, Šulcs 2022). Therefore, the most recent DTM with 1-m resolution provides an opportunity not only to significantly improve mapping accuracy but also to carry out the first mapping of eskers in Latvia using resources of significantly higher resolution. This study is a part of an ongoing project in which the mapping of eskers and the following research is carried out through collaboration with scientists from Estonia, Latvia, Lithuania, and Poland. That contributes greatly to the understanding of drainage and deglaciation of the SE part of the FIS.

The mapping in this study is done using the DTM with 1-m resolution, which is available in the map server of the Faculty of Geography and Earth Sciences (University of Latvia) (http://kartes.geo.lu.lv/karte/). The desired outcome is a map of eskers in Latvia and an attribute table portraying various morphological and morphometric features, such as the length and type of the esker ridge (main, tributary, distributary). Further, an analysis of esker distribution in Latvia will be carried out.

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STORMINESS AND FIRE EVENTS RECORDED IN THE SEACOAST PEATLAND NORTHWESTERN LATVIA OVER THE LAST 5400 YEARS

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Coastal peatlands are relatively new formations in the Baltic region due to the glacioisostasy land-uplift and the Baltic Sea development. Nevertheless, ombrotrophic bogs formed close to the sea serve as a valuable archive to seek information about the past storminess and fire episodes. In current study we identified quartz grains and macroscopic charcoal at 1-cm resolution from Bažu bog peat to reconstruct past storminess and fire events in northwestern Latvia. We established the chronology based on ^{14}C AMS dates on plant macroremains and age-depth modelling.

According to the ^{14}C AMS dates, Bažu peatland established 5400 years ago. Due to the close vicinity to the seashore (<2 km) we were expected to see rather frequent increased quartz grain record in peat. According to our estimated aeolian sand influx, we recognized at least 36 increased wind/storm episodes. Meanwhile, there were at least 30 fire events according to the macroscopic charcoal record. Mean fire return interval was 172 years (min 129 and 230 max). While there were no macroscopic charcoal recorded for the last ca 300 years, we used available fire-scar data to compliment fire event record. Mean storm return interval was estimated 145 years (min 30 and 345 max). Our statistical analyses (cross-correlation) did not show any significant correlation between storminess and fire events. Although, there were 15 fire events overlapping with strong wind/storms, we cannot confirm what these fire events were related to the storm nor that quartz grains were more easily brought from the catchment after the fire events. It is likely that due to the increase in shrub vegetation, there are more frequent fire episodes in the vicinity.

INLAND APPLICATION OF RELATIVE WATER SURFACE MODELS OF THE BALTIC SEA DEVELOPMENT STAGES: THE CASE OF LAKE BURTNIEKS

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The Baltic Sea region has undergone various development stages over time due to glacio-isostatic adjustment and global water level fluctuations. As a result, remnants of these ancient shores can now be found both underwater and above the current sea level. Although the ancient shore remnants may not be easily noticeable in the present terrain, they serve as useful spatiotemporal markers for relative sea levels in the region (Rosentau et al. 2021).

While the case of the development of Lake Burtnieks seemingly had been thoroughly conveyed by Eberhards with relatively detailed descriptions of several palaeolake Burtnieks shorelines (Eberhards 2006), the notion of glacio-isostatic adjustment not affecting the palaeolake shoreline configuration nowadays does not stand the test of the newest glacio-isostatic adjustment models, e.g., NKG2016LU (Vestøl et al. 2019). By analysing the relationship between the relative sea level markers and glacio-isostatic adjustment via regression analysis and implementing a previously developed free and open-source software workflow on a LiDAR-derived digital elevation model (Breijers et al. 2023), relative water surface models can also be applied to inland water bodies, where there is glacio-isostatic adjustment data coverage. Several relative water surface models have been applied to the palaeolake Burtnieks area to derive palaeolake shorelines over a period corresponding to the Ancylus Lake and Littorina sea stages.

During the 2023 archaeological survey near Lake Burtnieks, which took place from 18 to 24 September, one locality of the modelled palaeolake shorelines was verified. A visual surface survey of an arable field to the east of the Cieši swamp yielded 46 Silurian flint finds. Of the finds, six are reliably identifiable as flint scrapers, while at least 12 others are identified as flint knapping residues such as cores, flakes, and fragments of flakes, indicating that humans were present in the area during the Middle or Late Mesolithic period, between 8300-5400 BC. Since the distance to the nearest water body has often been set as a determinant of human activity during the Stone Age due to the availability of resources, and there are indications of human activity near the modelled shorelines, a thorough verification of the proposed approach is warranted.

The use of the relative sea level indicators and glacio-isostatic adjustment in relative water surface modelling beyond the coastal areas can broaden the understanding of the development of inland water bodies. There is also potential for spatiotemporal models, which could aid in settlement suitability modelling, and lead to discoveries in new localities.

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UNUSUAL CASE OF MOULTING IN TRILOBITE *ILLAENUS KUKERSIANUS* FROM ORDOVICIAN OF ESTONIA

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The arthropods are the most evolutionarily successful group, with about two million of species known to science today, representing more than 80% of all described animal species. One of the most important reasons for the success of arthropods is their rigid chitinous exoskeleton, which in several groups is saturated with minerals, mainly carbonates or phosphates, and the segmentation of the body, including the skeleton. The hard skeleton gives the strong structural support for muscles to attach, thus allowing fast and precise movements, and provides protection from predators, injuries and desiccation, which is essential for animals that spend time out of water, and even allows them to live permanently on land. The elements of the rigid exoskeleton form various appendages such as limbs, jaws, antennae, and wings, thus providing the ability to adapt to a wide variety of environments. On the other hand, the rigid exoskeleton restricts growth, so arthropods, like some other animals, need to have their shells replaced every so often. During a shell change called moulting (or ecdysis), the animal is vulnerable to predation, therefore individual usually needs to find shelter for exuviation. In the process of moulting, the new exoskeleton gradually hardens and, in some groups, becomes biomineralised. These include the trilobites, highly successful and diverse but completely extinct arthropods that existed from the Cambrian to the end of the Permian.

Trilobite fossil remains dominate Cambrian deposits, accounting for up to 75% of all fossils in a particular stratigraphic unit. They were also quite diverse in the Ordovician and Silurian periods, but gradually lost their dominant position from the Devonian onwards. Trilobites have a rich fossil record of carcasses and moults, or exuviae, and the majority could be moults (Drage, Daley 2016). Trilobites needed a quiet environment to complete ecdysis (Zong et al. 2016), thus it is not uncommon to find trilobite remains within the shells of nautiloid cephalopods (Davis et al. 2001).

The studied sample of cephalopod shell from the deposits of the Kukruse Regional Stage cropping in the Põhja-Kiviõli open-cast mine of the oil shale, northern Estonia, was found in 2019 by Eduards Desainis, a former BSc Geology student at the University of Latvia, who passed specimen to the author. During the preparation of this specimen represented by a partial living chamber and three chambers of phragmocone of *Orthoceras* sp., fossil remains of the enrolled trilobite *Illaenus kukersianus* Holm, 1866, were found within the living chamber. The trilobite shell remains are badly deformed, represented by a strongly curved head (cephalon), a relatively well-preserved but slightly deformed tail (pygidium), and seven pleura of thorax preserved; 10 pleura are characteristic of the family Illaenidae. Both cephalon and pygidium are with smooth surface; the pygidium almost unsegmented; the glabella poorly separated from the rest of the cephalon; eye situated not far from the lateral side, both eyes and free cheeks (librigena) are poorly visible. The cephalon and pygidium are situated close together, but the pleura of the thorax lye closer to the pygidium than to the cephalon and are hardly deformed. The cephalon is 25.9 mm long and 28.4 mm wide; the pygidium is almost similar in size being 26.8 mm long

and 29.0 mm wide. The cephalopod shell is slightly flattened *post mortem*, with an internal diameter of only 28-32 mm near the phragmocone; the internal diameter of reconstructed living chamber might reach approximately 42 mm near the aperture. The moulting of this trilobite took place in a very tight space, which casts doubt on the success of the process. This is evidenced by the similarity of the internal diameter of the cephalopod shell and the external dimensions of the trilobite, and by the rather strongly deformed exuvia. Of particular note is the relatively thick (1-2 mm) pyrite layer within the living chamber of the cephalopod shell, indicating the presence of a relatively large amount of unoxidised organic matter in the chamber after it was filled with sediments.

Observations from fossil material in previous studies have collected data on the moulting patterns of different trilobite groups (Daley, Drage 2016). Most trilobites moult by opening both of the facial sutures that run between the fixed cheek (or fixigena) and free cheek (or librigena), and the rostral suture. The eyes are very important organs, so the librigena are the first to separate from the skeleton. The trilobite then slipped through the resulting gap, often deforming the cephalon. Other trilobites are characterised by the detachment of the entire cephalon from the thorax. Statistical data show that the Corynexochida (Illaenidae belongs to this order) mostly moulted via disarticulation of librigena (Daley, Drage 2016). The studied case of trilobite moulting is therefore quite unusual for two reasons: it is the first case of *Illaenus kukersianus* exuvia found within the cephalopod *Orthoceras* sp. shell ever reported, and the configuration of moulting using cephalothoracic joint to moult is unusual for Illaenidae.

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CLIMATE CHANGE DURING THE EARLY FRASNIAN: INDICATIONS FROM DOLOCRETES OF THE AMATA REGIONAL STAGE, LATVIA

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The Amata Regional Stage (RS) is the upper unit in the Lower Devonian to lowermost Upper Devonian dominantly siliciclastic succession of the Baltic Devonian Basin (BDB). The following part of the Frasnian succession are mainly dolomites and mixed dolomitic-siliciclastic deposits. The reasons of changes from the dominantly siliciclastic to carbonate sedimentation in the BDB at the early Frasnian have not been well understood yet.

The Amata RS is composed of fine-grained sandstones and clayey deposits, considered as a transgressive unit (Kurshs 1992), and interpreted as tidally-dominated estuary deposits (Pontén, Plink-Björklund 2009). Dolocretes were documented in several levels in the upper part of the Amata RS. The dolocretes formed in soils, probably also in groundwaters (Pipira 2015), which show regressive development for the upper part of the Amata RS.

This study focuses on comparison of the dolocretes and their siliciclastic host rocks in four geological successions of the upper part of the Amata RS. All sections are located at both banks of the Amata River, in total distance of 2 km. Vizuļi Rock was documented by D. Pipira (2015), Īļaki Rock and Dolomites Cliffs by M. Meire-Kārkle (2020), but Ainavas Cliffs by G. Vasiļevska (unpublished data) and Ģ. Stinkulis. Ratios of stable isotopes $\delta^{18}O$ and $\delta^{13}C$ in 49 carbonate samples (25 from Īļaki, 13 from Dolomites, and 11 from Vizuļi outcrops) were analysed in the University of Tartu and in the Tallinn University of Technology. Dolocretes were documented in polished slabs and thin-sections, which all were made at the Faculty of Geography and Earth Sciences of the University of Latvia.

Fining-upwards of deposits take place in the upper 4-5 metres of the Amata RS. Fine-grained and very fine-grained cross-stratified sandstones upwards change to very fine-grained sandstones, siltstones, and clays; cross-bedding disappears, and the deposits are rather homogeneous. Dolocretes are in 3-5 levels in the upper 5 metres of the Amata RS. Some of them likely can be correlated both by lithological properties and by carbon stable isotope data.

The stable isotope data are typical for calcretes and dolocretes described in literature (e.g. Casado et al. 2014). The carbon stable isotope ($d^{13}C$) values are from -8.89 ‰ to -5.72 ‰, but the oxygen stable isotope ($d^{18}O$) values from -8,75‰ to -4,67‰ (Pipira 2015, Meire-Kārkle 2020). The carbon isotope values show several negative excursion trends at the intervals, where the most massive dolocretes are present.

Calcretes and dolocretes form in semi-arid, rarer in arid climates (Alonso-Zarza 2003). They are typical for monsoonal climate, as carbonate minerals accumulate in a soil (fractures, root channels) during dry seasons, and remains fixed in the soil during moister conditions (Driese and Mora 2001). The appearance of the dolocretes in the upper part of the Amata RS can be considered as an indication of climate change from moister to dryer, more arid conditions at the beginning of the Frasnian.

The same reason likely initiated the transition from siliciclastic to carbonate sedimentation in slightly later time (Pļaviņas RS).

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PATHOLOGIES IN THE FISH FOSSILS FROM THE MIDDLE DEVONIAN, GAUJA FORMATION DEPOSITS OF ESTONIA AND LATVIA

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The Gauja Stage is spread in almost all territory of Latvia and a restricted area in SE Estonia and consists of sandstones, clay and siltstones. Fossils coming from different parts of the Gauja Stage belong mainly to psammosteids, arthrodire and antiarch placoderms, and sarcopterygians (Lukševičs & Stinkulis 2018). Vertebrate remains of excellent preservation including fully articulated specimens as well as the oldest parasite fossils in the world have been found in the Lode Formation deposits in the Liepa clay pit (Upeniece 1999).

Pathologies - various bite marks and scratches on the fossil material of Devonian psammosteids were first observed by Obruchev and Mark-Kurik (Obruchev & Mark-Kurik 1965; Mark-Kurik 1966) however attention to pathologies in these remains has been given only recently. These include several perforations on the scale of *Psammolepis venyukovi* as well as scratches, deformations and bite marks accompanied by regenerational tissue on different psammosteid bone plates from the Gauja Formation deposits of Latvia and Estonia (Lebedev et al. 2009; Lukševičs et al. 2009). Traces of possible parasite activity on antiarch placoderm bone plates from the Gauja Formation and Lode Formation deposits of Latvia have also been reported however the studied material is very fragmentary (Alksnītis 2022).

The paleontological material in the geological collections of the University of Tartu and Tallinn University of Technology containing fossils from the Middle and Upper Devonian deposits Estonia and Latvia as well as the fossil material from the Museum of the University of Latvia has been thoroughly examined.

Pathologies that have been found in the material from the Gauja Formation deposits include small pits on the outer surface of the bones that could have been caused by ectoparasite activity on armour plates of placoderm *Asterolepis ornata* on specimens from Latvia and Jõksi müür outcrop, Estonia. Possible parasite attachment traces have been found for the first time on a clavicle of a coelacanth gen. indet. which are similar to those on scales of porolepiforms described before from the Upper Devonian Ketleri Formation (Lukševičs et al. 2009). The branchial plate of psammosteid *Placosteus alatus* from Jõksi müür displays small pits on the outer surface of the plate as well as a groove that is continuing into the deeper layers of the bone and has been filled with secondary dentine tubercles in a response to activity of a possibly migratory parasite. While traces of predatory action on heterostracans have been reported from different Devonian strata (Lebedev 2009; Randle& Sansom 2019), it is worth noting that that this is only the second specimen of a heterostracan that displays signs of parasite activity.

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MINERALOGICAL AND CHEMICAL COMPOSITION OF THE ORE OF THE STAICELE AND GARSENE IRON ORE DEPOSITS

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Magnetic anomalies have been known in Latvia for a long time and were studied in the 1960s and 1970s. The anomalies appeared to be caused by magnetite iron ore deposits located in the crystalline basement rock in the northern, southern and central parts of the country (Kuršs, 1997). In the 1980s, geophysical surveys and drilling works were carried out. Iron ore samples were collected from boreholes and data on iron deposits of Latvia such as depths, chemical composition, forecasted resources obtained. Voluminous information is included in V. Vetrennikov works (Vetrenikov, 1984).

The work is devoted to the study of chemical and mineralogical compositions of magnetite ores from two Proterozoic crystalline basement deposits in Latvia - Gārsene and Staicele. Powder X-ray diffractometry (XRD) was used. Also, energy dispersive X-ray fluorescence (EDXRF) to determine the composition of iron ore constituents, scanning electron microscopy (SEM) with EDX, and laser-induced breakdown spectroscopy (LIBS) methods were applied.

According to XRF and XRD data, the most abundant element in the ore samples is silicon (Si), which occurs as oxides - SiO_2 (quartz) and various silicates such as biotite - $K(Mg,Fe^{2+})_3(Al,Fe^{3+})Si_3O_{10}(OH,F)_2$ and annite - $K_{0,964}(Fe_{2,680}Al_{0,328})(Al_{1,34}Si_{2,66})O_{10}(OH)_2$, microcline - $(K_{0,94}Na_{0,06})(Al_{0,95}Si_{3,05}O_8)$ and albite - $Na(AlSi_3O_6)$. All of these silicates contain elements such as (Al, K, Mg, Na, Ca), which are also present in relatively high amounts in the samples studied by XRF, suggesting that the above silicates are also the source of this metal in the ore. The second most abundant mineral is magnetite. As regards non-metallic elements, both sulphur (S) and phosphorus (P) were found, which are particularly characteristic of the Garsene deposit and are associated with various iron sulphides and apatite. According to the X-ray fluorescence data, titanium (Ti) and manganese (Mn) are typical of all deposits of Latvia and are located in the magnetite crystalline lattice, forming their variants titanmagnetite and manganmagnetite. The ore also contains other useful impurities such as: chalcophile (Cu, Pb, Zn), siderophile (Cr, Co) and lithophile (Y, Ga, Zr).

Element oxides	Garsene Sample number, Nr.						Element oxides	Staicele Sample number, Nr.				
	1	2	3	4	5	6		1	2	3	4	5
	W, %							W, %				
SiO_2	51,1	33,7	35,6	64,4	57,3	78,6	SiO_2	77,9	51,9	66,9	59,5	53,1
Fe_2O_3	22,7	51,3	52,4	22,4	19,3	2,07	Fe_2O_3	3,31	36,0	16,9	25,8	27,3
MnO	0,02	0,05	0,03	0,02	0,02	0,03	MnO	0,77	5,17	3,54	3,44	6,65
Al_2O_3	12,6	6,29	3,49	7,26	9,25	13,6	Al_2O_3	10,6	5,01	9,64	2,97	5,29
MgO	8,07	6,25	3,43	4,22	2,30	3,30	MgO	2,73	-	-	6,96	5,13
CaO	0,69	0,50	1,94	0,62	1,51	0,35	Na_2O	1,55	-	-	-	-
K_2O	2,37	0,79	0,17	0,33	0,25	1,35	CaO	1,94	1,03	2,22	1,14	1,77
TiO_2	0,43		-	-	-	0,46	K_2O	0,74	0,65	0,27	0,08	0,42
SO_3	1,40	0,35	-	0,61	0,05	0,13	TiO_2	0,29	0,19	0,27	-	0,24
P_2O_5	0,55	0,50	2,72	-	1,62	-	SO_3	0,06	0,09	0,19	0,06	0,06
ZnO	0,005	-	-	-	-	0,002	Co_2O_3	-	-	-	-	0,053
ZrO_2	-	-	-	0,003	0,016	0,048	ZnO	0,007	0,014	0,006	0,009	0,013
SrO	0,003	0,005	-	0,002	0,002	0,001	ZrO_2	-	-	0,001	-	0,007
V_2O_5	-	0,171	0,197	0,045	0,081	-	SrO	0,006	0,006	0,013	0,002	0,005
Nd_2O_3	-	-	-	-	-	0,015	V_2O_5	-	-	-	0,015	-
Y_2O_3	-	-	0,008	0,003	0,008	0,006	Nd_2O_3	-	-	0,029	-	-
Rb_2O	-	-	-	-	-	0,006	BaO	0,15	-	-	-	-
Sm_2O_3	-	-	-	0,026	-	0,020	Ir_2O_3	0,005	-	-	-	-
CuO	-	0,024	0,023	-	-	0,008	PbO	0,003	-	-	-	-
Ga_2O_3	-	-	-	-	-	0,003	Y_2O_3	0,003	-	-	-	-
Ta_2O_5	-	-	-	0,018	-	-	Rb_2O	0,001	-	-	-	-

Figure 1. Oxide mass fractions of elements detected by XRF in ore samples ("-" - element not detected or below detection limit).

According to the results of the sample analysis, which are also confirmed by the LIBS data, the iron ore samples contained impurities of relatively rare metals (such as Ti, V, Co, Sm, etc.), which are present in the ore in small quantities. It follows that iron ores from deposits of Latvia can be used as a source of by-products of these metals. The ores of the Staicele deposit, on the other hand, contain an increased amount of manganese (from 0,77 to 6,65 % in oxide form, according to the results), which confirms the literature data on the possible extraction of this element in parallel with iron. According to old reserve estimates, the deposit contains at least 56.8 million tonnes of manganese oxide (Vetrenikov, 1991).

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A NEW SPECIES OF *HOLOPTYCHIUS* (SARCOPTERYGII, POROLEPIFORMES) FROM THE UPPER FAMENNIAN KETLERI FORMATION, LATVIA

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The Upper Devonian porolepiform *Holoptychius* Agassiz, 1839 is one of the most often founded Palaeozoic vertebrate's fossils. *Holoptychius* is one of the widespread dispersed sarcopterygian taxa, consistent with an abundant fossil record mostly represented by scales (Mondéjar-Fernández, Meunier 2020). Given that the majority of *Holoptychius* fossils are scales, species diagnosis has traditionally been based only on the scale morphology (Downs et al. 2013). Recently, most palaeontologists who study Devonian and Carboniferous fishes, agreed to the opinion that the structure of holoptychiid scales depends more on the location on the fish's body and individual's age than on belonging to a species (Cloutier & Schultze 1996; Downs et al. 2013). Because of that, many authors do not consider the *Holoptychius* species that were previously distinguished by scale morphology (e.g., Downs et al. 2013). Therefore, contrary to the traditional opinion, according to which up to 20 species belong to the genus *Holoptychius* (Vorobyova 2004), nowadays only four species are considered valid: *Holoptychius nobilissimus* Agassiz from the Famennian of Scotland, *H. flemingi* Agassiz from the Upper Devonian of Scotland, *H. jarviki* Cloutier et Schultze from the Frasnian of Quebec, Canada, and *H. bergmanni* Downs, Daeschler, Jenkins, Shubin, 2013 from the Frasnian of Arctic Canada.

Studied fossil remains of *Holoptychius* from the Ketleri Formation have been collected from two localities: the Pavāri locality at the left bank of the Ciecere River opposite the vanished farmhouse "Pavāri", and the Ketleri locality at the right bank of the Venta River close to the abandoned farmhouse "Ķetleri" (e.g., Lebedev, Lukševičs, 2018; Lukševičs et al. 2023). The material includes 49 bones or bones fragments and a large number of scales. The author participated in several excavations in the Pavāri locality and partially prepared the material under this study. Specimens were mechanically prepared under the optical microscope and photographed. Morphometrical analysis was performed to compare the studied material with the described one.

The most diagnostic and taxonomically valuable specimen is the parieto-ethmoidal shield with associated otic-occipital GM 290-22 from the Ketleri site. The occipital shield (partially fused occipital bones) is longer than wide, ratio maximum length/maximum width reaches 1.45; the shield reaches its maximum width about a third of its length from the anterior margin, thus differing in the proportions well from all the other species of *Holoptychius*.

Based on a comparative morphological analysis of this material with the described material from valid species, it can be concluded that the yet undescribed material could potentially represent a new species, which was previously reported as *Holoptychius nobilissimus* (Gross 1933), *Holoptychius* cf. *nobilissimus* (e.g. Lebedev, Lukševičs, 2018) or *Holoptychius* ex gr. *nobilissimus* (Lukševičs et al. 2023).

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VĒLĀ DRIASA IESTĀŠANĀS KOSMISKĀ ĶERMEŅA TRIECIENA HIPOTĒZES LIECĪBAS LIELĀ SVĒTIŅU EZERA NOGULUMOS

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Vēlais driass (VD) kā vēlā Vislas apledojuma kušanas fāzes pavēsināšanās laiks ir aprakstīts daudzos pētījumos, kā arī to saista ar pleistocēna megafaunas masveida izmiršanas sākumu. Par cēloni šādai pavēsināšanās epizodei kvartāra pētnieku vidū joprojām nav vienprātības. Virspusēji aplūkojot tendences zinātniskajās publikācijās var izdarīt secinājumus, ka šajā jautājumā pastāv viena izteikta pētnieku grupa, kas ir pārliecināta, ka VD izraisīja kāda kosmiskā ķermeņa trieciens Zemes virsmā, precīzāk, Laurentīdas ledus vairogā (Ziemeļamerika, Grenlande), un otra grupa, kas spītīgi pretojas šim apgalvojumam un cenšas ar jebkādiem argumentiem noraidīt kosmiskā ķermeņa trieciena hipotēzi, dažreiz pat aizejot līdz personisku apvainojumu līmenim.

VD kosmiskā ķermeņa trieciena hipotēze pieņem, ka lielas sairušas komētas vai asteroīda fragmenti radīja triecienu sēriju Zemes virsmā, pārsvarā uz ledāja, un eksploziju sēriju atmosfērā pirms aptuveni 12900 gadiem, kas kompleksā mehānismā izraisīja VD globālo klimata pavēsināšanos. Šie kosmisko ķermeņu triecienu produkti ir radījuši izteiktu un atpazīstamu izohronu nogulumu slāni (Ziemeļamerikā to dēvē par "*black mat*" – melnais paklājs), kurš bez oglēm un citiem organikas degšanas produktiem var saturēt tādus trieciena marķierus kā magnētiskas sferulas, skorijai līdzīgas daļiņas, fullerēnus, nanodimantus, īpaši augstas enerģijas apstākļiem raksturīgas formas kvarca graudus (lešateljereītu), kā arī platīna grupas elementu klātbūtni, kas īpaši raksturīga kosmisko ķermeņu triecienu pēdām.

Notiek pētījums, kurā tiek veikta izpēte par iespējamo VD kosmiskā ķermeņa trieciena hipotēzes marķieru identificēšanu Lielajā Svētiņu ezerā (Austrumlatvija), kurā uzkrājušies nogulumi pēdējo 15000 gadu laikā. Pētījumam nepieciešamie paraugi ņemti no Lielā Svētiņu ezera un tajos VD nogulumu joslās tiek meklētas iepriekš uzskaitītās kosmiskā ķermeņa trieciena liecības. Uzsvars laboratorijas pētījumos, pielietojot induktīvi pārotās plazmas masspektrometriju (ICP-MS), tiek likts uz platīna grupas elementu paaugstinātas koncentrācijas pazīmju meklēšanu VD nogulumos.

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