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Provenance and stratigraphy of the oldest sediments at the western slope of the East European Craton (Volyn-Orsha Rift, SE Poland) – constraints from detrital zircon geochronology

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Abstract

The Volyn-Orsha Rift (VOR) extends NE-SW, from the interior of the East European Craton (EEC) to its western margin. The basin is filled the oldest non-metamorphosed deposits in the craton, mainly with continental reddish to variegated sandstone of the Paliessie Group. It contains no stratigraphic indexes, therefore, its age remains ambiguous. Detrital zircon ages (SHRIMP) were investigated for sandstone from the lowermost part of the Polish Polesie formation in Kaplonosy IG 1 borehole to constrain the timing of its deposition and detritus provenance. Two dominant populations have been identified: yielding ²⁰⁷Pb/²⁰⁶Pb ages of ~1850–1750 Myr, interpreted as derived from denudation of the late Svecofennian proximal basement of the northern flank of the basin, and in a range of 1560–1450 Myr, typical of anorogenic within-plate granitoid batholiths, widespread in the Fennoscandia in the direct vicinity of the NW margin of the VOR. The remaining zircons (ages ~1290–1050 Myr) are interpreted as derived from the common Sveconorwegian-Grenville orogenic belt, in the Neoproterozoic riming the EEC from the west. The youngest six detrital zircons with ²⁰⁷Pb/²⁰⁶Pb age in the range of ~1082–1048 Myr, provide a new constraint on the possible deposition time. The true depositional age of this unit is probably younger (at least ~100 Myr) interpreted here as Neoproterozoic, due to an intracratonic position of VOR basin within the assembled Rodinia.

Key words: Volyn-Orsha Rift, Polesie formation, Neoproterozoic, detritus provenance, Pb-Pb dating on zircon

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1. INTRODUCTION

The oldest non-metamorphosed sedimentary cover of the western slope of the East European Craton is the Paliessie Group, composed of continental clastic red-beds and shallow marine deposits (Juskowiakowa, 1974; Makhnach et al., 1978, 2001; Wichrowska, 1992; Mikhnytska, 2013). This sediment is a fill of a large system of tectonic grabens of the Volyn-Orsha Rift (VOR), extending NE-SW, from the interior of the East European Craton (EEC) to the western margin of the EEC (Fig. 1; Bogdanova et al., 1996; Poprawa and Paczeńska, 2002; Mikhnytska, 2013).

The stratigraphic age of this group is, therefore, of high significance for understanding the evolution of the sedimentary cover of the EEC, palaeogeography, and chronology of regional-scale tectonic processes. However, the Paliessie Group contains no indexes fossils, and its stratigraphic age remains ambiguous. It unconformably covers the metamorphic complexes and igneous belts adjacent to the suture of Fennoscandia and Sarmatia, generally not younger than 1.8 Gyr, being pierced by the anorthosite-mangerite-charnockite-granite (AMCG) suite at ~1.5 Ga (Fig. 2; Bibikova et al., 2009; Krzemińska et al., 2017).

In the Polish part of the VOR, the Paliessie Group is represented by an informal lithostratigraphic unit traditionally named the Polesie formation (Areń, 1974, 1982; Juskowiakowa, 1974) and is covered by the uppermost Ediacaran clastic and volcanic complex of the Żuków, Sławatycze and Teremiski Formations, from which it is divided by a large hiatus (Fig. 2; Paczeńska, 2014). The U-Pb dating of zircons from tuffs within the Sławatycze Formation, being the component of the Volyn Large Igneous Province, allowed determination of its age as no older than ~580-570 Myr (Shumlyanskyy et al., 2016; Poprawa et al., 2020; Krzemińska et al., 2022).

The above-mentioned data on the stratigraphy of the basement of the Polesie formation and the base of its overburden are highly unsatisfactory as constraints on the age of the formation's deposition, indicating that this process occurred over an extensive time span of nearly the entire

Meso- and Neoproterozoic, i.e., nearly 1 Ga. To narrow it down, we investigated Pb-Pb ages of detrital zircon for sandstone from two core samples, aiming to assess the maximum deposition age of the formation. This was supported by similar data from the Belarusian and Ukrainian parts of the VOR (Paszowski et al., 2019; Shumlyanskyy et al., 2023; Zaitseva et al., 2023).

The other purpose of our U-Pb dating of detrital zircons from the Polesie formation sandstone is to determine detritus provenance. We regard it as key data for revealing the Proterozoic palaeogeography of the western EEC, detritus routing systems, and configuration of plates and orogenic belts in the direct vicinity of the EEC, thus, possibly having significance broader than regional.

2. GEOLOGICAL SETTING

2.1. Regional perspective

The Volyn-Orsha basin is a Precambrian abandoned rift extending through the western and central EEC from the NW to SE (Fig. 1).

It is referred to as the Volyn-Orsha Rift (this study), the Volyn-Orsha Aulacogen (e.g. Bogdanowa et al., 2008), the Volyn-Orsha basin or depression (Shumlyanskyy et al., 2015, 2023), or the Volyn-Orsha Palaeotrough (Zaitseva et al., 2023). The sedimentary fill of its western part is composed mainly of continental reddish to variegated sandstone, mudstone, and nearshore claystone and mudstone of the Paliessie Group, the thickness of which reaches ~800-900 m in the depocentre in central part of the Volyn-Polesie Depression (Mikhnytska, 2013). It developed along the former suture of Fennoscandia and Sarmatia and Volgo-Uralia, being three once autonomous crustal segments together composing the EEC (Bogdanova et al., 1997, 2008). The crystalline basement of the western VOR is mainly the Osnitsk-Mikashevichi igneous belt (2.0–1.95 Ga), as well as the surrounding Okolovo terrane (2.0–1.9 Ga) and the Belarus-Podlasie granulite belt (1.9–1.85 Ga) (Bibikova et al., 2009; Shumlyanskyy et al., 2015; Krzemińska et al., 2017).

In the western EEC, the VOR is buried beneath a succession of younger sedimentary basins, including the upper Ediacaran-lower Paleozoic, the Devonian-Carboniferous, and the Permian-Mesozoic ones (e.g. Modliński et al., 2010; Poprawa, 2019). Therefore, the deposits of Polesie formation is available for research only as core samples from the deep boreholes. Prior to the late Ediacaran, the VOR was a subject for long-lasting denudation, therefore, the youngest part of its sedimentary fill is not preserved.

The VOR is directly covered by the sedimentary succession of the Lublin-Podlasie Basin (Poprawa and Paczeńska, 2002), part of an extensive system of the Ediacaran and/or lower Paleozoic basins of the SW slope of the EEC (Gareckij et al., 1987; Sliupa et al., 2006; Poprawa et al., 2018; Poprawa, 2020). The development of the Lublin-Podlasie Basin was initiated with magmatic activity of the Volyn Large Igneous Province (Shumlyanskyy and Andréasson, 2004; Nosova et al., 2008; Środoń et al., 2019), interpreted as a synrift magmatism related to the break-up of the Rodinia/Pannotia supercontinent (Poprawa et al., 1999, 2020; Krzemińska et al., 2022).

Up-section, the Volyn flood basalts, agglomerates, and pyroclastics are replaced by continental to shallow marine clastic sediments of the uppermost Ediacaran to middle Cambrian (Fig. 2; Moczyłowska, 1991; Paczeńska, 1996, 2006, 2010; Jaworowski, 1997), deposited during a transgressive to regressive cycle in the post-rift basin at the passive continental margin (Paczeńska and Poprawa, 2005). The Lower and Middle Ordovician overlie the Cambrian with a hiatus and are composed of sandstone, shale, and limestone (Modliński, 1982; Modliński and Szymański, 2008). The Upper Ordovician and Silurian are represented by a facially monotonous complex of marine mudstone, claystone, and marl, partly bituminous, characterised by high thickness reaching several hundred metres (Fig. 2; Modliński and Szymański, 2008; Porębski and Podhalańska, 2019; Poprawa, 2020), deposited in the Caledonian foredeep basin related to the Avalonia-Baltica collision (Poprawa et al., 1999, 2018; Poprawa and Paczeńska, 2002).

Age of the overlying and underlying rocks makes broad constraints on the Polesie formation stratigraphic age.

The Lower Devonian is a marine shelf, fine-grained, clastic sediment, passing up-section into alluvial clastic deposits, while the Middle and Upper Devonian are dominated by carbonates, locally with evaporite and clastic interbeds (Fig. 2; Miłaczewski and Radlicz, 1974; Miłaczewski, 1981; Narkiewicz et al., 1998). During the Mississippian time, the development of the basin was interrupted by tectonic deformation, uplift, and denudation, terminated with intensive alkaline magmatism covering the area between the Lublin and Baltic regions (Poprawa et al., 2024; Krzemińska et al., 2025). The subsequent Carboniferous basin accumulated shallow shelf, deltaic, and fluvial sediments (Waksmundzka, 1998), in the lower part mostly carbonate and fine-grained clastics, while in the upper

part mostly sandstone and mudstone, with a characteristic contribution of hard coal (Fig. 2; Żelichowski, 1972; Porzycki and Zdanowski, 1995).

Following the late Variscan tectonic deformation, uplift, and denudation, an early Permian episode of magmatic activity took place in the study area (Krzemińska et al., 2021). In the Late Permian and throughout the Mesozoic, this area became the eastern flank of the Polish Basin, characterised by the presence of common hiatuses, covering a significant part of late Permian and Mesozoic time span (Dadlez and Marek, 1997). The Cenozoic is an unconsolidated, clastic sedimentary cover of low thickness (Piwocki and Kramarska, 2004).

2.2. The Polesie formation

The oldest, unmetamorphosed sediments were deposited on eroded Paleoproterozoic crystalline basement rocks as the siliciclastic Polesie formation (Areń, 1982; Juskowiakowa, 1974). They were accumulated mainly within a narrow, NE-SW elongated tectonic graben, thus they were recognized locally in SE Poland, e.g. in the Kaplonosy IG 1, at depths ranging from 1811 m to 1877 m and Busówno IG 1 boreholes, from a depth of 4082.0 m to the borehole end at 4154.5 m (Fig. 3 A-B). The sedimentary rocks rest on a thin zone of weathered rock, the nature of which indicates mechanical weathering and basement disintegration, with the formation of a small layer of weathered clays. In Busówno IG 1, it is a red-coloured, fine-grained, quartz sandstone, with interbeds of fine-grained grey sandstone. Although macroscopically rather monotonous (Fig. 4 A-B), they sometimes contain thin clay layers. They are considered to be epicontinental or continental and marginal-marine deposits (Wichrowska, 1992; Paczeńska, 2007) dominated by quartz arenites with minor constituents of mud and coarser sediments. These rocks are characterized by a weak to sub-angular rounding of grains and a variable degree of sorting. They are composed mainly of sand-sized (0.0625 to 2 mm) silicate grains (quartz: 50 to 60%), accompanied by alkali feldspar (orthoclase and microcline) and plagioclase feldspar (albite). Mica grains occur as random tiny fragments or elongated flakes (ranging between 1-3%). The heavy minerals, like zircon, rutile, and/or tourmaline, occur only in traces (Fig. 4A-B), but their concentration increases towards the top. The sandstones of the Polesie formation are cemented with silica, carbonate, or hematite.

The Polesie formation is the westernmost part of a significant lithological complex the Paliessie Group which has broad regional lithostratigraphical significance in the VOR. In the chronostratigraphical framework this lithostratigraphical unit is an equivalent of the Paliessie regional stage or horizon (Makhnach et al., 2001; Zaitseva et al., 2023). Deposits of Paliessie Group filled of most tectonic grabens of the VOR. The thickness of Paliessie Group reaches 170 m in northern Byelarus in the Orsha sub-basin of VOR (Makhnatsch et al., 2001) and maximum 900 m in the Volyn-Polesie sub-basin of VOR in a centre of the Volyn-Polesie Depression in the Ukraine (Mikhnytska, 2013). At the most area of the VOR the Paliessie Group covers crystalline rocks of lower Proterozoic basement of EEC represented by 1.2 Gyr gneisses and granitoids and 1-1.1 Gyr gabbro intrusions (Makhnach et al., 2001; Mikhnytska, 2013). Locally, in the Orsha Depression it lies on the deposits of older Sherovici Group. The sedimentary cover of Paliessie Group is composed of red-beds mainly of fine-, rarely coarse-grained sandstone with hematite intercalated with grey to brown siltstone or clay and thin beds of conglomerate. Sediments of Paliessie Group originated in the broad spectrum of sedimentary environments mainly in the very shallow epicontinental basins with reduced salinity. Part of these sediments were deposited on the wide alluvial plain with deposition in the braided river channels and streams periodically flooded by a short duration marine ingressions (Makhnach et al., 2001).

3. ANALYTICAL METHODS

3.1 Zircon separation and sample preparation

In the sandstone collected from the lowermost part of the Polesie formation, depth of 1875.0 m, a change in the colour of the sediment was observed from dominant red to grey (Fig. 3A). For this reason, this fragment of the drill core was cut into two separate pieces (Fig. 4B-C). The zircon separation procedure for each of them was carried out separately. This resulted in two individual samples designated as Kap-1875j, a grey part, and Kap-1875c, a reddish part.

For the separation of detrital zircons, the cut pieces of the drill core were crushed using a jaw crusher. The samples were further pulverized using a ring mill and then filtered through a few sieves up to 63 µm. Heavy minerals were obtained from the particles separated using water panning and heavy liquids. The magnetic minerals were removed using a hand magnet. The remainder underwent a series of magnetic separations by Frantz barrier separator. All detrital zircons were individually

isolated manually using a binocular microscope. An epoxy resin megamount of 35 mm diameter disc for U–Pb analysis was prepared together with the separated detrital zircons and the reference zircon grains.

The grain-rows of each sample were photographed in transmitted light and reflected light using the optical NIKON microscope with ECLIPSE LV100POL system. To identify the internal structures of the detrital zircons, back-scattered electron (BSE) and cathodoluminescence (CL) images were obtained using a scanning electron microscope (Hitachi Su 3500) installed at the Polish Geological Institute-National Research Institute. Analytical points were mainly selected as rims of detrital zircons, while fractures, mineral inclusions, inherited cores, and metamorphic overgrowth parts were eliminated after the CL and BSE image observation.

3.2. U–Pb analysis

All detrital zircon U–Pb age determinations were performed using a Sensitive High-Resolution Ion Microprobe (SHRIMP IIe/MC) at PGI-NRI. The diameter and current of the O₂⁺ primary ion beam were ~20–23 µm and 3.0–4.0 nA, respectively. The reference zircon 91500 was used for quantitative calibration of U concentration (78 ppm; Wiedenbeck et al., 1995; Williams, 1998). U–Th–Pb ratios were determined relative to the TEMORA2 (416.8 Myr, $^{206}\text{Pb}^*/^{238}\text{U} = 0.06683$) reference zircon (Black et al., 2003) analyzed repeatedly during the analytical session. Data acquisition for zircon during each session involves analysis of the TEMORA2 reference zircon, performed after every three sample analyses. A supplementary table 1 contains the full analytical dataset from SHRIMP comprising analyses of the reference TEMORA 2 grains.

Details of the analytical procedures can be found in Williams (1998). The SHRIMP data reduction was handled using SQUID 2.5 (Ludwig, 2009). All uncertainties are quoted at the one-sigma level. To construct the concordia curve and determine the concordia age, as well as probability plots showing an age distribution, the Isoplot 3.71 (Ludwig, 2008) was applied.

Individual corrected ratios and dates are reported with 1σ precision estimates. U–Pb concordia ages and weighted mean age diagrams were calculated using the program Isoplot/Ex 3.0 of Ludwig (2003). Age calculations are based on IUGS recommended values for U decay constants (Steiger and Jäger, 1977). The statistical coherence of calculated means is assessed using the mean square of weighted deviation (MSWD; McIntyre et al., 1966).

Following common practice, the SIMS $^{207}\text{Pb}/^{206}\text{Pb}$ ages were used directly for zircons older than 1 Ga, but $^{206}\text{Pb}/^{238}\text{U}$ ages for those younger, although the exact cut-off values vary considerably in the literature (e.g., 1.2 Gyr - Spencer et al., 2016). In this case, the choice was more aligned with earlier publications that were used for correlation.

The final detrital zircon data processing encompassed an evaluating the difference between samples using objective methods, a non-parametric statistic test to recognize a dissimilarities of the matrix, including Multi-Dimensional Scaling (MDS) map for zircon populations calculated using both Wasserstein and Kolmogorov-Smirnov distance. The results were visualised on the Multidimensional Scaling (MDS) plots (Vermeesch, 2012, 2013), generated using Isoplot R toolkit (Vermeesch, 2018).

4. RESULTS

4.1. SHRIMP detrital zircon ages and populations

The analyzed detrital zircon crystal morphologies ranged from euhedral to anhedral. Both samples (Kap-1875j and Kap-1875c) of the Polesie formation are characterized by a diversity of detrital grain forms, including rounded and angular (Fig. 4C), with colours ranging from almost clear to reddish or light brownish. The size of the grains ranged between ~40–150 µm. As a detrital cargo of this sample, a less rounded grains, and those that have rougher surfaces were also identified. There are no significant differences between the grain collections from both subsamples. Cathodoluminescence (CL) images of representative detrital zircon grains (Fig. 5) disclose, that a most grains have clear oscillatory zoning that is indicative of a magmatic origin, whereas others have weak or banded oscillatory zoning of mafic magmatic or metamorphic origin. The CL images of individual detrital zircons from the youngest populations of mostly prismatic crystals are shown separately (Fig. 5C) to demonstrate their various (mostly simple) oscillatory zoning and no inherited material.

A total of 84 and 82 analysis points were measured in zircons from each sample for the U–Pb ages. The U–Pb age data for the detrital zircon grains are given in Supplementary Material (Tab. S1).

Most analyses were concordant or nearly concordant (Fig. 6A, C), within analytical uncertainty. The few exceptions showed evidence of significant loss of radiogenic (Tab. S1). Consistent with their common detrital origin, the analysed zircons had a wide range of U–Pb isotopic compositions, with the most concordant $^{207}\text{Pb}/^{206}\text{Pb}$ ages ranged from 1972 Myr to 1080 Myr (Kap-1875j) and from 1987 Myr to 1067 Myr (Kap-1875c) (Fig. 6A, C). The detrital zircons is dominated by two clusters (Fig. 6B, D) of the Orosirian age, with peaks on a density probability plot at 1807 or 1802 Ma, and the Calymmian age, with peaks at 1515 or 1514 Myr. There is also a minor group of the Stenian grains. There is no Archean or early Paleoproterozoic (i.e. Siderian and Rhyacian) detritus. Apart from the youngest group, the age distribution of the population seems to be bimodal. The age peaks seem to be analogous. This small diversity led to the use of the Unimix age isoplot tool to better define the peaks and clusters. This shows that both parts of the sandstone that differ in colour contain almost identical detrital zircon groups (Tab. 1).

To constrain the maximum depositional age of the Paliessie Group, which was one of the main purposes of this study, the analysis was preferentially performed on transparent euhedral detrital zircon grains with simple oscillatory zoning that are thought to have the youngest age and origin. The age of the youngest detrital zircons for both samples (tab.S1) ranges between ~1080 (+0%disc)–1048 (-16%disc.) Myr (two grains) and 1082 (-6%disc) –1059 (-3%disc) Myr (four grains). Thus, each sample shows relatively similar ages of the youngest cluster (Tab. 1). Due to this similarity and the uneven content of the few youngest zircons, for the calculation of the concordia age (c.a.) and the weighted average (w.a.) data for both samples were combined. A merged data are showed on the Wetherill and Tera-Wasserburg concordia plots (Figs. 7F, 8D).

Apart of the $^{207}\text{Pb}/^{206}\text{Pb}$ detrital zircon age spectra (Fig. 7), Th/U values of analysed grains were used to discriminate between metamorphic origin (Th/U < 0.1) and magmatic origin (Th/U > 0.1), for this purpose all analysed zircons were used (Tab. S1). The grains with Th/U < 0.1, typical of metamorphic crystallisation, are rare within all compared samples (Fig. 9).

5. DISCUSSION

5.1 Characterizing a potential provenance areas

The provenance of sedimentary material can be assessed by comparing its detrital zircon ages with geochronological characteristics of the potential source areas. The detrital zircons from the lowermost part of the Polesie formation can be split by age peaks into three major groups, including the late Paleoproterozoic (Orosirian) group with the age peaks at 1807 and 1802 Myr, the early Mesoproterozoic (Calymmian) group, with the age peaks at 1515 and 1514 Myr, and the Mesoproterozoic (Stenian) group with relatively smaller number of grains, indicating that both late Paleoproterozoic and Mesoproterozoic magmatic activity was intense in the provenance region. The crystalline basement with that age pattern extends over a vast area of central Fennoscandia from the southern Baltic offshore (Amberland Domain) to the edge of the EEC (Bogdanova et al., 2006, 2015; Krzemińska et al., 2017; Skridlaite et al., 2021). This age range is typical of the syn- to late-orogenic intrusions in the Svecofennian orogen, that constitute most of the south-western Fennoscandia. (Bogdanova et al., 2015; Skridlaite et al., 2021; Krzemińska et al., 2021). The centre of Fennoscandia hosted an episodic Mesoproterozoic (~1.53–1.50 Gyr) continental magmatism of the anorthosite-mangerite-charnockite and granite (AMCG) suites extending from central Sweden and Finland to Poland (e.g. Bingen et al., 2008; Wiszniewska and Krzemińska, 2021). All emplaced between the 1.55–1.53 Ga (Salmi suite), 1.65–1.61 Ga (Wiborg suite), 1.59–1.56 Ga (Åland suite), and 1.53–1.50 Ga (Mazury Complex). reflect an intracontinental extensional setting. The age pattern with two major age peaks well corresponds to the time of formation of the crystalline basement located directly to the north of the Kaplonosy IG 1 borehole. A relatively proximal source type are would also be indicated by the presence of the significant number of poorly rounded zircons and other detrital components (Fig. 4). Despite a fine-grained fraction of the sediment, no particularly exotic material from distant sources has been identified here. The characteristics of detrital material obtained from sample Kap-1875.5 almost unequivocally indicate dominance of a local type of source (i.e. > 85% grains), represented by ~1.8 Gyr and ~1.5 Gyr zircons (Fig. 6), that must have come from the eroded topographic highs, exposing the late Svecofennian (1.85–1.74 Ga) basement of the EEC intruded by the AMCG (1.53–1.48 Ga) massifs (Krzemińska et al., 2017; Wiszniewska and Krzemińska, 2021; Grabarczyk et al., 2023). The very similar detrital zircon cargos were also noted in younger layers, e.g. Ediacaran, in clastic rocks, including pyroclastic rocks accompanying the Sławatycze Formation (Poprawa et al., 2020). The peaks at 1.5 Gyr and 1.8 Gyr in detritus have for a long time constituted a legible signature of the basement at the SW margin of EEC (Żelaźniewicz et al., 2020).

Similarly a local source has been concluded for quartz rich sediments of the Orsha sub-basin (Zaitseva et al., 2023; Shumlyanskyy et al., 2023), on the basis detrital zircon age pattern, and for sedimentary fill of the Volyn sub-basin where a relatively poorly-sorted, poorly-rounded, subarcotic detritus was recognized.

A simple comparison of the detrital zircon age distribution (Fig. 7A-F) between VOR sediments revealed a significant differences of the age patterns, which can be explained by a differences in the age of the eroded local basement i.e. a specific crustal units within the EEC. A common feature of the detrital fill remains however a deposition of the material younger than 1.2 Gyr. All of the sediments from VOR listed in the diagrams are characterized by the presence of late Mesoproterozoic zircons.

This also applies to the results of the Kap-1875.5 (Fig. 7E) sample, where almost bimodal detrital age pattern is accompanied, with the third, lesser group represented by $n=12/166$ (12.6%) grains yielding $^{207}\text{Pb}/^{206}\text{Pb}$ ages of $\sim 1.29\text{--}1.05$ Gyr (peak at 1133 ± 45 Myr). The source of these youngest zircons was the Sveconorwegian orogenic belt in the NW part of the EEC (Fig. 10), active $\sim 1.14\text{--}0.96$ Ga (Bingen et al., 2008, 2021; Bogdanowa et al., 2008; Slagstad et al., 2013). The youngest zircon grains, clustering at $\sim 1044\text{--}1079$ Ma may be regarded as of the Sveconorwegian orogen affinity, i.e., derived from the NW part of the EEC (Fig. 1) e.g. N Denmark, SW Sweden, S Norway. The Sveconorwegian orogeny at $1.15\text{--}0.9$ Ga (corresponding to the Grenville orogeny in North America) amalgamated the youngest Precambrian crust to Baltica in the southwest (Bingen et al., 2008, 2021), forming ~ 550 km wide orogenic zone covering south Norway and southwest Sweden and one of the components of Rodinia supercontinent (Li et al., 2008). A post-orogenic relaxation was accompanied with extensional tectonism that facilitated the creation of a sedimentary basins. A subsequent processes between of the end-Mesoproterozoic and the beginning of the Neoproterozoic included a gradual peneplanation until the break-up of Rodinia at ~ 600 Ma. Intracratonic type basins comprise mainly Mesoproterozoic and some Neoproterozoic sediments. According to synthesis of Cawood et al. (2007) the detrital zircon record of Mesoproterozoic to early Paleozoic sedimentary successions along the eastern margin of Laurentia and Baltica are characterized by a remarkably similar pattern for ages of the main sediment pulses from the late Archaean (~ 2.7 Ga), late Paleoproterozoic ($2.0\text{--}1.75$ Ga), early Mesoproterozoic (~ 1.5 Ga), and late Mesoproterozoic to earliest Neoproterozoic ($1.2\text{--}0.95$ Ga) consistent with derivation from the cratonic interior Baltica or Laurentia.

This also applies to one of the small Neoproterozoic rift basin in southern Sweden, running NNE-SSW along the Lake Vättern consists of deltaic sandstone and marine shale, of the Visingsö Group. The recent studies of these post-Sveconorwegian sediments provided a detrital zircon age patterns of a large group of samples from a few locations (Moczyłowska et al., 2017; Ahrenstedt, 2018; Pulsipher and Dehler et al., 2019).

The comparison (Fig. 8) between representative sample of Visingsö Group (Ahrenstedt, 2018) and sample of Kap-1875 disclosed a very similar range of detrital zircon ages, including youngest population, however a peaks distribution shows some shifts. The age groups from Visingsö are present throughout the region of the central Sweden and can be tied to several specific stages of Svecofennian belt ($2.0\text{--}1.75$ Ga), the Transscandinavian igneous belt TIB ($\sim 1.86\text{--}1.66$ Ga), the Gothian orogeny ($1.66\text{--}1.52$ Ga), Hallandian event ($1.47\text{--}1.38$ Ga), the Eastern Segment and Idefjorden regions ($1.21\text{--}1.37$ Ga), the Telemarkia Terrane (1.16 Ga) and the Sveconorwegian orogeny ($1.14\text{--}0.90$ Ga), indicating derivation from sources in the relative vicinity of the basin (Ahrenstedt, 2018). Also for other samples of Visingsö Group within Baltica source was concluded (Ahrenstedt, 2018; Pulsipher and Dehler et al., 2019).

Despite age similarity, the comparison of VOR detrital zircon dataset (Fig. 9) using the Th/U vs age diagram suggests a subtle differences of Th/U values between coeval zircons. They may indicate (1) method dependent bias (i.e. La-ICP MS vs SHRIMP analysis) or (2) a real differences of the melt characteristics suggesting that the source rocks were coeval but not the same, although some projections in each age group overlap. Moreover a most Kap-1875.5 zircons exhibited Th/U ratios >0.3 , supporting the assertion that detrital grains have an igneous origin, consistent with the CL findings (Fig. 5). The fluctuated Th/U ratios in Kap.-1875.5 zircons exhibit a general trend of increase during $1600\text{--}1500$ Ma (consistent with AMCG type source), which is followed by a decrease of youngest cluster

The range of $\sim 1.2\text{--}0.90$ Gyr, has become a characteristic indicator of the crust formed during Sveconorwegian or / and Grenvillian orogeny within the belt (Fig. 10), developed upon the continent-continent collisions related to the assembly of the supercontinent Rodinia. Thus for late Mesoproterozoic zircon age component reported from the eastern part of VOR the Grenvillian orogen ($1250\text{--}980$ Ma) or/and Sveconorwegian ($1140\text{--}960$ Ma) has been discussed as a potential source area (Shumlyanskyy et al., 2023; Zaitseva et al., 2023).

Detrital zircons from the Polesie formation contain only a small population yielding $^{207}\text{Pb}/^{206}\text{Pb}$ ages of ~1290–1050 Myr (Figs. 6, 7E-F), but they are much common for the samples representing Polytsi Formation lateral equivalents of the Polesie formation in Ukraine (Figs. 7C-D, 10; Shumlyanskyy et al., 2015, 2023) and Rudnya Formation in the Orsha sub-basin or Pinsk Formation in Volyn-Polesie sub-basin in the Belarus (Figs. 7A-B, 10) (Zaitseva et al., 2023).

The Visingsö Group sediments deposited closest to the potential source area (e.g. Sveconorwegian orogenic belt), the detrital zircons of ~1250–950 Myr are most abundant in the lower part formation (Moczyłowska et al., 2017).

5.2. Characterizing populations heterogeneity

The observed detrital zircon age spectra are influenced by proportion of zircons available in the source area for incorporation into basinal deposits and the efficiency of erosion. Although the probability plots and histograms (Figs. 6-8) can indicate a main crustal forming events, which provided a detrital material from eroded rocks, it is difficult to properly visualize the proportions within different age groups. Therefore, a cumulative probability plots (CPPs) are introduced in this study (Fig. 11A, C, E). They allow by percentiles to compare different data distributions. Proximity between CPP or overlapping of lines implies similar detrital zircon age populations, suggesting a common source for the zircons. However a review of available detrital zircon ages from the VOR basin (Paszowski et al., 2019; Shumlyanskyy et al., 2023; Zaitseva et al., 2023) and Visingsö post-Sveconorwegian basin (Ahrenstedt, 2018) on the CPPs diagram highlight a differences in proportions of detrital ages distribution, including that between from the Volhynian and Orsha zones of the VOR (i.e. Korma -519, Vilchi vs #70/106.5) previously concluded by (Shumlyanskyy et al., 2023).

Compared data shows a strong similarity of detrital zircon age distribution of the Orsha sediments (samples Vilch and Korma-519). This independently confirms a leading input of the same detrital material, that was available in the eroded proximal basement. The (CPPs) samples reveal two distinct curve groups (Fig. 11C vs E), one of which represents the input of detritus from the crust of the western Sarmatia (Fig. 11C) but the other (Fig. 11E) from the central and southern Fennoscandia.

To further confirm the division observed in the CPPs two-dimensional MDS diagrams (Fig. 11B,C) .of statistical metrics like the Kolmogorov - Smirnov (K-S) and Wesserstein-2 (W-2) were applied. The MDS plots capture the relative differences of populations. They are rather intuitive for visualizing the relationship between the detrital age distributions, where greater distances between sample plots represented a greater degree of dissimilarity between them. The K-S is defined as the maximum vertical distance between two empirical cumulative distribution functions, but the W2 distance is a function of the horizontal distances (i.e. age differences) between analyses set of samples.

The MDS diagram for all detrital zircon ages (Fig. 11A) shows that (1) the detrital zircon population of Korma-519 is very similar to that of the Vilchic siliciclastic rocks, both belonging to Orsha Zone; (2) there is a similarity between the Kap-1875.5 of the Polesie formation and the Visingsö Group detrital zircon populations; and (3) there is a certain degree of dissimilarity between the above pairs.

The #70 clastic rock being linked to Volynian zone shows a tenuous connection with both siliciclastic rocks groups. Both the Kolmogorov-Smirnov (K-S) Test and Wesserstein-2 Test (Fig 11 BD) produce an analogous record of sample dissimilarity, supporting the indications identified by other diagrams, that provenance for the clastic rocks deposited within the VOR can be as different as the nearest eroded basement units (including available detritus on this basement).

All samples are characterized by multimodal patterns with grain contributions from a broader age range, including shifts towards older age components, that is characteristic for divergent/passive margin settings (Cawood et al., 2012).

5.3 Characterizing a maximum deposition age versus youngest detrital zircon grains

Presented detrital zircon dataset and their MDS models used here represent: (1) shales and siltstones deposits of the Visingsö Group that belong to the Neoproterozoic (i.e., Tonian) beds, as defined by microfossils that provided a minimum age of ~740 Myr (Moczyłowska et al., 2017); sedimentologically they are consistent with the few remaining evidences from this time period in Sweden, and (2) the VOR basin sediments of the Polesie formation with unknown deposition age, but considered previously as a possibly lower Stenian (1.2–1.0 Gyr) age (Bogdanova et al., 2008).

For expected stratigraphic correlation (Fig. 12) between different sampling sites (Fig. 1) within a single sedimentary basin or different basins, the age of deposition remains a most important and critical parameter. A youngest cluster of detrital zircon U-Pb dataset is routinely used to approximate an age of deposition as a so called maximum depositional age (MDA). There are at least three methods of

calculating the MDA (Dickinson and Gehrels, 2009) using U-Pb ages. The most common are based on calculated ages of either the youngest single grain (YSG), the youngest grain cluster composed of three or more grains that overlap at 2σ (YGC 2σ), using the weighted mean age of the youngest ($n>3$) zircons with $\pm 2\sigma$ age overlap, or concordia age as well as the youngest graphical peak (YPP). However, as has been recently emphasized by numerous works (Gehrels, 2014; Coutter et al., 2019; Sharman, Malkowski, 2020), that MDA detrital zircon may be older, even much older, than the true depositional age (TDA), usually in the passive or and amagmatic setting. This is because passive margins do not have a strong component of syndepositional magmatic activity. In case of the VOR tectonic context i.e. Rodinian intracratonic/rift and passive margin basin (see Cawood et al., 2007) the use of the youngest zircons from obtained data set as a MDA limit is rather impermissible. It may contribute to misinterpretation (Andersen, 2005). In the intracratonic basins, characterized by a lack input from syndepositional magmatic activity, resulting in an increasing gap between a real age of sediment accumulation and the youngest detrital grain.

The importance of this problem i.e. using youngest zircons to constrain the TDA within intracratonic setting may be explained by case studies of sediments from the central Fennoscandia, preserved as down faulted remnants within the vicinity of the Lake Vättern basin in southern Sweden (Fig. 1), known as the Visingsö Group. The detrital zircon provenience study from several samples and locations (Moczyłowska et al., 2017; Ahrenstedt, 2018; Pulsipher and Dehler et al., 2019) in this exceptional case was supported by biostygraphic dating. A comparison of both the age cathegories reveals a difference of at least 100–150 Myr between the youngest detritus and the biostratigraphic age of the strata. U-Pb detrital zircon study by Moczyłowska et al., (2018) reported a youngest zircons as MDA of 886 ± 9 Myr. The studies of another sandstones of the Visingsö Group sampled on the eastern shore of Lake Vättern (Pulsipher and Dehler, 2019) provided youngest ages in range from 941 ± 12 to 1227 ± 31 Myr (based on $n=5$ youngest grains per sample) or 919.4 ± 25.1 to 1197.2 ± 22.2 Myr (based on youngest single grain per sample). The upper range together with the middle Visingsö Group defined on microfossils (acritarchs of the *Cycliocyrtium simplex* assemblage) indicates the time span of ~788–740 Ma (Moczyłowska et al., 2018), which shows a gap of at least 140–150 Myr between youngest zircon grains and biostratigraphic indications. Consequently, by combining the age obtained by U-Pb dating of younger detrital zircons with the minimum age obtained from biochronological results, the deposition age was constrained to a broad range of 146 Myr between ≤ 886 –740 Ma (op cit.).

U-Pb SHRIMP dating on detrital zircons of Kap-1875.5 m (Figs. 6, 7) allowed to recognize a youngest detrital cluster in the westernmost part of the VOR at ~1073 Myr to 1044 Myr. The youngest detrital zircon clusters of $n=3$ grains from the sample Korma -519 (Zaitseva et al., 2023) yielding a concordia age of 952 ± 10 Myr.

The ages of 977 ± 6 Myr and 1056 ± 4 Myr (defined as MDA) have been constrained for samples Vilch-6A and Vilch-7A, respectively (Paszkowski et al., 2019), represented the Orsha Suite and Vilchitsy Series. They are somewhat younger to that result from sample #70), i.e. the weighted mean age of 1079 ± 8 Myr was explained as deposition age but finally the MDA was concluded in range ~1000-950 Myr (Shumlyanskyy et al., 2023).

The sandstones of the Sherovichi series in Belarus (Fig. 12) contain a relatively large amount of zircon grains from 948 to 1030 Myr in age (Korma-519) but other nearby ones don't. These differences were explained by the complex block structure of the palaeotrough bottom, which influenced the ways of transport of terrigenous material (Zaitseva et al., 2023). In the Visingsö Group, Southern Sweden, where more samples from one sedimentary sequence was investigated the stratigraphically lowest sample contained a youngest zircons. This illogical pattern in case of the deltaic sandstone and marine shale, debris-flow marine sandstone may indicate either (i) increasingly older rockswere being unroofed and eroded, or (ii) an expanding depositional system covered younger, more locally derived material with older, more distal detritus (Moczyłowska et al., 2018) or/and deposition in a tectonically dynamic intercontinental basin (Pulsipher and Dehler, 2019).

The sediments from several locations within the VOR (Fig. 1) undoubtedly differ in the abundance of the youngest group. A representative pie charts are introduced in Figure. 13 to depict the percentage for different age groups, including those related to Sveconorwegian/Grenvillian sources .

This set of diagrams indicates a relatively poor population of only 12.5% of relatively the oldest zircons recognized in this group in Kap-1875.5 sample of Polesie formation (Fig. 13). These results from cratonic sandstones of lower part of deposits (Fig. 12) implying an input of slightly younger material, than in Kap-1875.5 sample but not mark out the TDA for the each of them.

The lag time between zircon crystallization and deposition related to amagmatic tectonic setting (Cawood et al., 2012) however does not allow for precise recognition of the real maximum age of deposition (MDA) or/and precise correlation different sampling sites. The observed variations in detrital

zircon age spectra relatively well-correlate with the geological heterogeneity of the local basement, within distinct parts of the VOR. However, low-n single grains datasets compared here still remain not fully decisive. It has been recently emphasized (Zametzner et al., 2025), that detrital zircon age variations fall within typical facies variability at a single stratigraphic level when analyzing ~240 grains, but fall within the typical variability of geological formations when analyzing only ~70 grains using a representative selection strategy.

5.3 Stratigraphic position

The upper limit of the Polesie formation is defined by the overlying upper Ediacaran flood basalts of Sławatycze Formation or clastic sediments of Żuków Formation, presumably not older than 580 Ma (Poprawa et al., 2020; Krzemińska et al., 2022). These constraints leave a very broad time interval for deposition of the Polesie formation (>400 Myr), covering at least the lower and/or middle Neoproterozoic. This might be narrowed down by tectono-facies arguments. The development of the Volyn-Orsha basin, being a large-scale rift structure (e.g. Bogdanova et al., 1996; Poprawa and Paczeńska, 2002), should fit on a regional scale with phases of extensional tectonics. In our opinion, VOR developed in a framework of the break-up of the supercontinent Rodinia, the main phase of which took place between 800 and 650 Ma (Bogdanova et al., 2008; Scotese, 2009; Kheraskova et al., 2015). Previously, the lower part of the VOR sedimentary fill was considered to be of the Ectasian (1.4 Ga–1.2 Ga) and possibly lower Stenian (1.2–1.0 Ga) age (Bogdanova et al., 2008). This was, however, based on the imprecise K–Ar and Rb–Sr dating of mafic sills cutting sedimentary rocks of the adjacent Valday/Krestsy graben (~1.3 to 1.1 Ga; Aksenov, 1998). Due to the low precision of these geochronological data, the uncertain correlation of the sedimentary fill of the Valday/Krestsy graben and VOR, and the clear incompatibility with the U–Pb detrital zircon geochronology (Shumlyanskyy et al., 2023; Zaitseva et al., 2023), the concept of the Ectasian and/or lower Stenian age of the VOR is rejected here. The Neoproterozoic age of the Polesie formation and thus the Volyn-Orsha rifting is supported by detrital mica and feldspar K–Ar ages of 815–700 Myr and whole-rock ages of 980–880 Myr (Semenenko, 1968; Makhnach et al., 1976; Chebanenko et al., 1990). Due to these constraints on the maximum deposition age, the age of the sedimentary fill of the VOR was tentatively assigned to the late Cryogenian or Ediacaran (Poprawa, 2006).

The Precambrian continental sandstone and mudstone of the red beds type of Polesie formation, which is the sedimentary fill of the Polish part of the western Volyn-Orsha Rift basin contains no stratigraphic indexes, therefore its age remained poorly defined for a long time. Our study on U–Pb SHRIMP geochronology of detrital zircons from lowermost part of this formation brings new and strong constraints towards its deposition time. The $^{207}\text{Pb}/^{206}\text{Pb}$ ages of the youngest zircons cluster at 1060 Myr to 1073 Myr. The youngest detrital grains define the Concordia age of $\sim 1067 \pm 16$ Myr. The extensional tectonic regime governing the development of the Volyn-Orsha Rift is related here to the Neoproterozoic break-up of the supercontinent Rodinia (Cawood et al., 2007). Its main phase took place between 800 and 650 Ma (Bogdanova et al., 2008; Scotese, 2009; Kheraskova et al., 2015). The new observations (Callegari et al., 2023) from northern Sweden (Seve Nappe Complex) provided recently a critical age record of the Early Neoproterozoic (Tonian) break-up event manifested by metagabbro, metagranite, which coupled with bulk rock major and trace element geochemistry, suggests an unsuccessful rifting across Rodinia at 870–830 Ma. This event indicates continental-scale tectonic extension. It cannot be ruled out that the Volyn-Orsha early rifting might be of similar age, because in the intracratonic extensional to rift basins, with a lack of syn-depositional magmatic activity, the gap between a real age of sediment deposition and the youngest detrital grains cluster, increases. The Polesie formation is, therefore, younger than ~1 Gyr, while due to the age of overlying strata, it is older than 580 Myr, and is interpreted here as of the lower and/or middle Neoproterozoic age.

6. CONCLUSIONS

The Precambrian continental sandstone and mudstone of red beds type of the Polesie formation, which is the sedimentary fill of the Polish part of the intracratonic VOR basin, contains no biostratigraphic indexes. The U–Pb dating of detrital zircons of the lowermost deposits (Kap-1875.5m) of the western sub-basin reflect the erosional unroofing history of the adjacent late Svecofennian orogenic and AMCG related suites.

Our study on U–Pb SHRIMP geochronology of detrital zircons from this formation brings new constraints on its time of deposition age based on youngest grains.

The youngest (n=3) detrital zircons define an age of $\sim 1067 \pm 16$ Myr (concordia age), interpreted as pre-depositional in this amagmatic setting. It indicates deposition after this age as the rock must be younger than its component.

Due to the intracratonic position of VOR basin where the gap between age of sediment accumulation and the youngest detrital grain occurs and the newly recognized age of the youngest detrital zircon cluster (1067 ± 16 Myr), the late Mesoproterozoic stratigraphic position is questioned.

The development of the Volyn-Orsha Rift was governed by the extensional tectonic regime related here to the Neoproterozoic break-up of the supercontinent Rodinia. Its earliest episode of continental-scale extension took place between 870–830 or 800 Ma, thus, the Volyn-Orsha rifting might be initiated coevally. The Polesie formation is presumably, younger than ~1 Gyr, while due to the age of overlying strata, it is older than 580 Myr, and is interpreted here as of the early and/or middle Neoproterozoic age.

The main source of detritus in the western part of the VOR was located to the north and north-west of the basin. This is represented by the two major populations of zircon grains. that yields Pb-Pb ages in a range of ~1.56–1.45 Gyr (41%) with a well-defined peak at 1500.5 ± 2.5 Myr, and of ~1.85–1.75 Gyr (46% of zircon grains) with a peak at 1807 ± 1.4 Myr. This detritus represents an influx of relatively proximal north westerly derived cratonic detritus originated from the anorogenic AMCG suite common in the direct vicinity of the NW margin and supplied from the denudated Svecofennian basement of the NW surrounding of the basin.

The youngest zircon grains, clustering at ~1044–1079 Myr could be regarded as of the Sveconorwegian–Grenvillian affinity, i.e. derived from the NW part of the EEC (N Denmark, SW Sweden, S Norway).

The early Neoproterozoic siliciclastic deposits from a VOR compared in this contribution revealed a different detrital zircon age patterns. The prominent feature remains a presence of the youngest detritus cluster derived from denudation of the Sveconorwegian/Grenvillian rocks. Among these youngest sources those related to the -Sveconorwegian/Grenvillian source, increase from 13% in Kaplonosy sedimentary rock (E Poland) to more than 40% in #70 sandstone sample (W Ukraine) and to 43.6% in Korma sandstone sample (W Belarus), which reach a dominant percentages comparable to the Svecofennian source (43%) in E Poland.

These results determine not only the differences in the proximal source of detrital material, i.e. distinct local basement, but most likely reflect progressive shift or greater influence of the Sveconorwegian-Grenvillian material.

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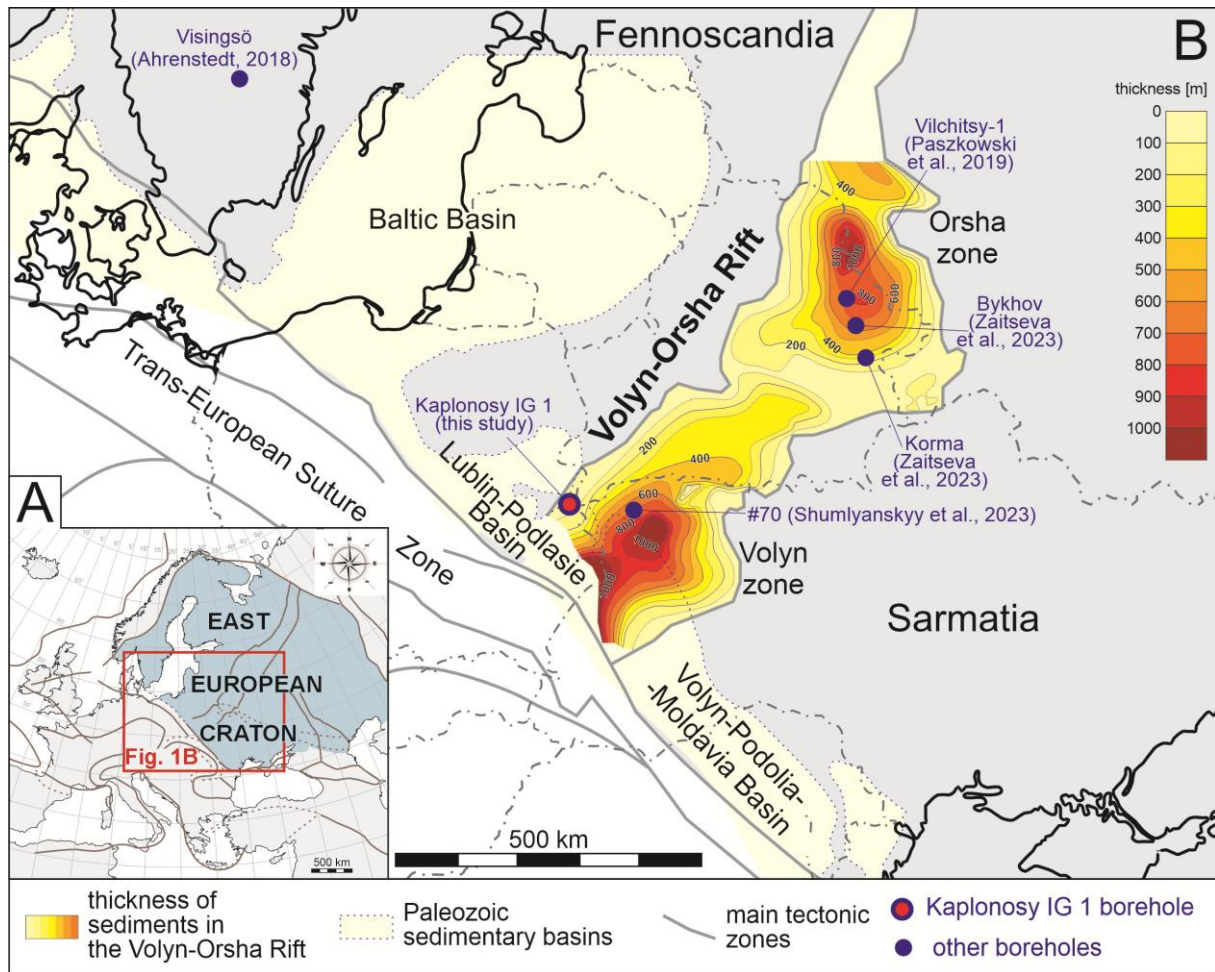


Fig. 1. Location of the Volyn-Orsha Rift and its relation to (A) the East European Craton (EEC) and (B) Lublin-Podlasie Basin (after: Poprawa, 2019, 2020; Krzemińska et al., 2024), together with the location of the studied Kaplonosy IG 1 borehole ($N51^{\circ}37'13,42''$, $E23^{\circ}21'24,47''$). B – the thickness map of the Polesie formation (Poland), in Belarus, including the Pinsk, Orsha, and Lapici formations, is compiled from the data of Gareckij et al. (1987) and Wichrowska (1992). The location of boreholes for which similar U-Pb dating on detrital zircon from the Polissia Group were conducted (Paszowski et al., 2019; Shumlyanskyy et al., 2023; Zaitseva et al., 2023) and Neoproterozoic Visingsö Group of southern Sweden (Moczyłowska et al., 2017; Ahrenstedt) are also indicated.

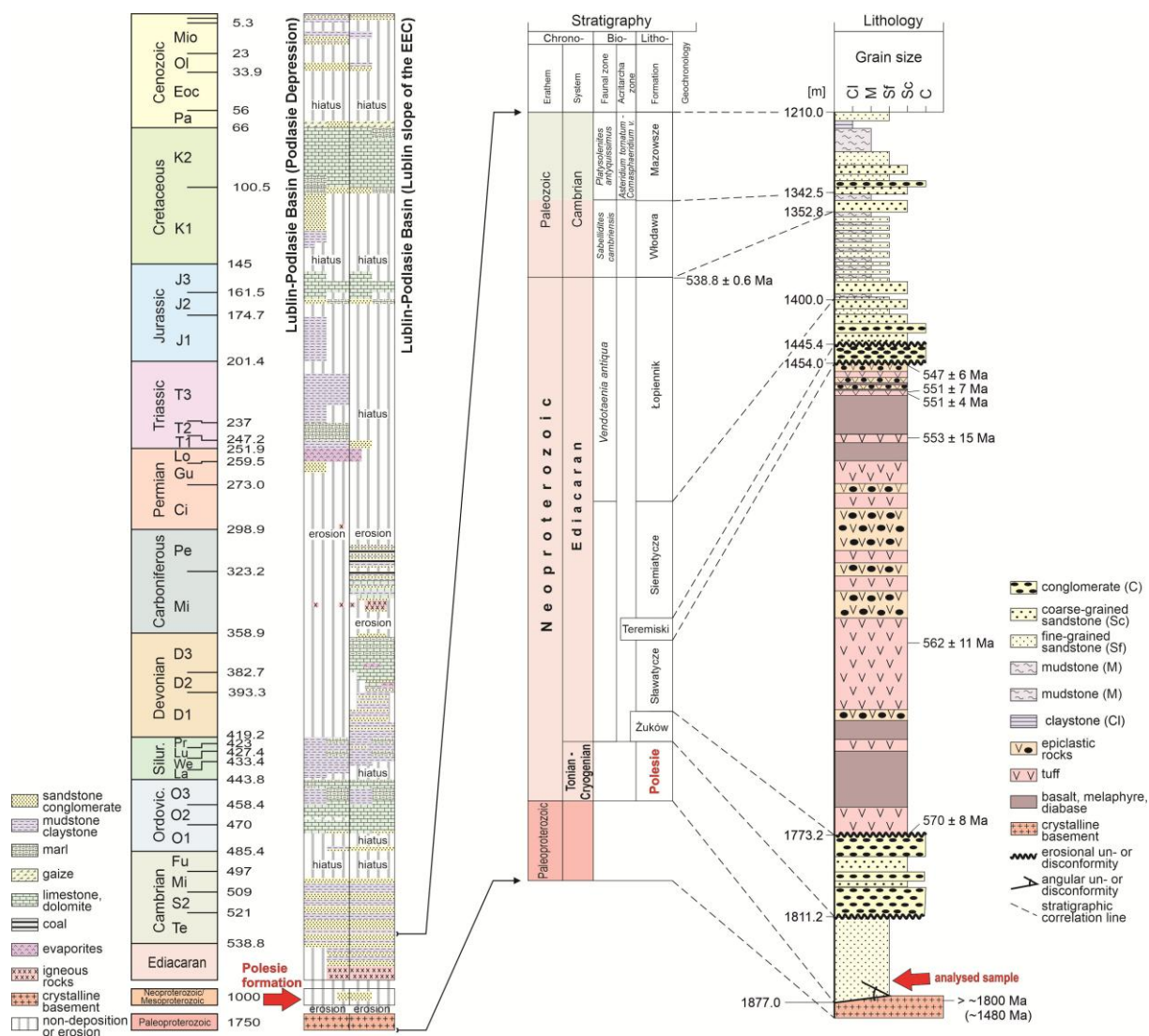


Fig. 2. Lithostratigraphic section of the Lublin-Lviv Basin with position of the Polesie formation (after Moczyłowska, 1991; Paczeńska, 2010, 2014; Poprawa, 2019; Poprawa et al., 2020; Krzezińska et al., 2022; supplemented and modified). Age of the overlying and underlying rocks gives broad constraints on the Polesie formation stratigraphic age.



Fig. 3. The drill core samples showing a typical feature of arcose sandstones from the Polesie formation: (A) Large – scale cross-bedded fine-grained sandstone with very thin coarse- grained sandstone intercalations. Busówno IG 1 borehole, depth 4146. 4 m (B) Kaplonosy IG 1 borehole, depth 1875.5 m (the bottom part of the formation) collected for detrital zircon age study. (divided into two sub-samples; (C) Sample Kap-1875.5 j and (D) sample Kap-1875.5c.

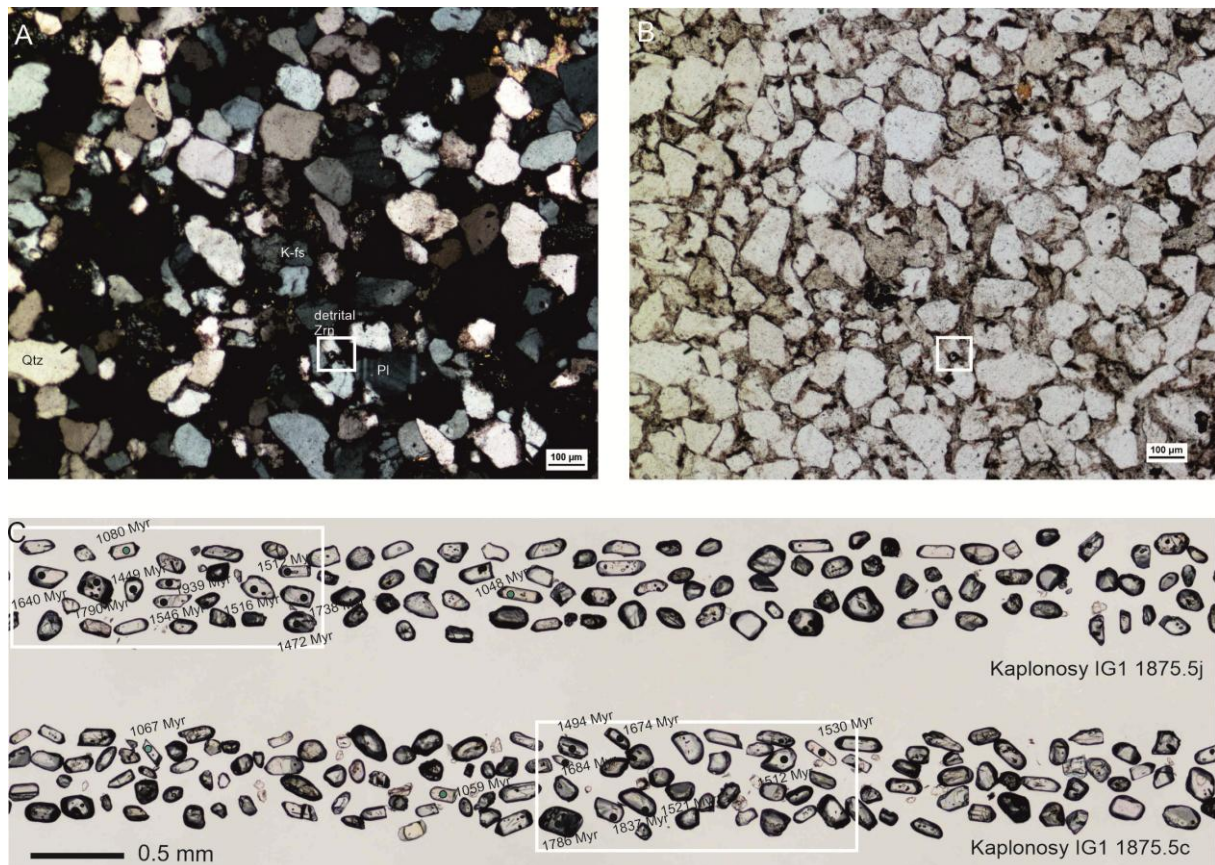


Fig. 4. Photomicrographs of the sandstone sample (thin-section) from the lower part of Polesie formation (Kaplonosy IG 1 borehole) showing: A-B) a mineral assemblage with sub-rounded grains dominated by quartz, feldspars, and zircons as an accessory phase including zircon, indicated by a white frame. (C) Transmitted light image of zircon grains morphology from both subsamples, with locations of some SHRIMP analyses. The position of the representative CL zircon images presented in Fig. 5 is marked with the white frame. Photographs were taken: (A) under crossed polars, (B, C) plane polars, transmitted light, including the image of detrital zircon grains (Kap-1875.5j and Kap-1875c) selected for age study. Scale bar is 100 μm for A, B and 500 μm for C.

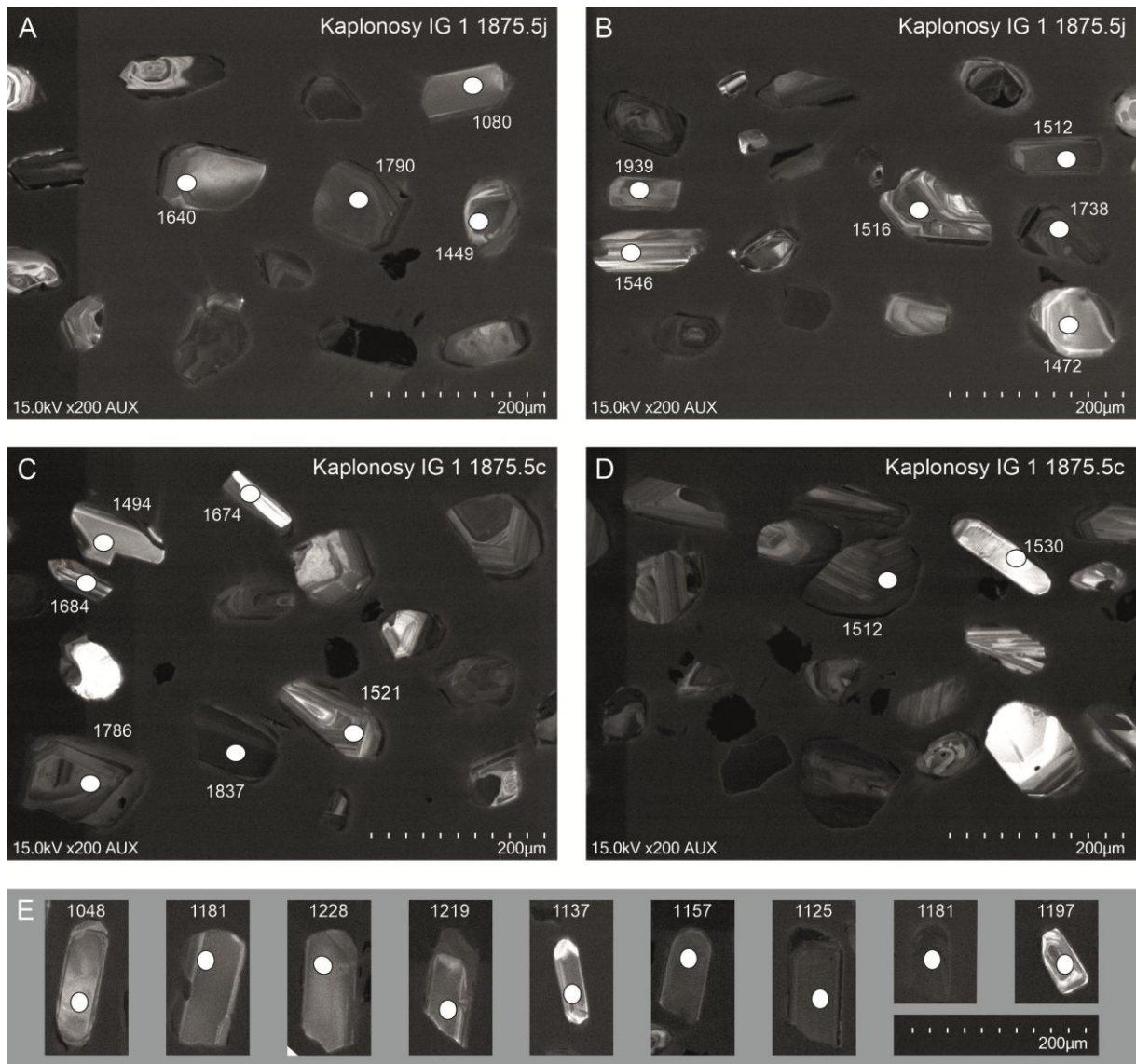


Fig. 5. The characteristics of representative detrital zircon grains disclosed by cathodoluminescence imaging CL, accompanied with selected images of single zircons representing a relatively youngest age group. The morphology of some grains is visible in the transmitted light photos. SHRIMP analyses are located and labelled with their $^{207}\text{Pb}/^{206}\text{Pb}$ ages.

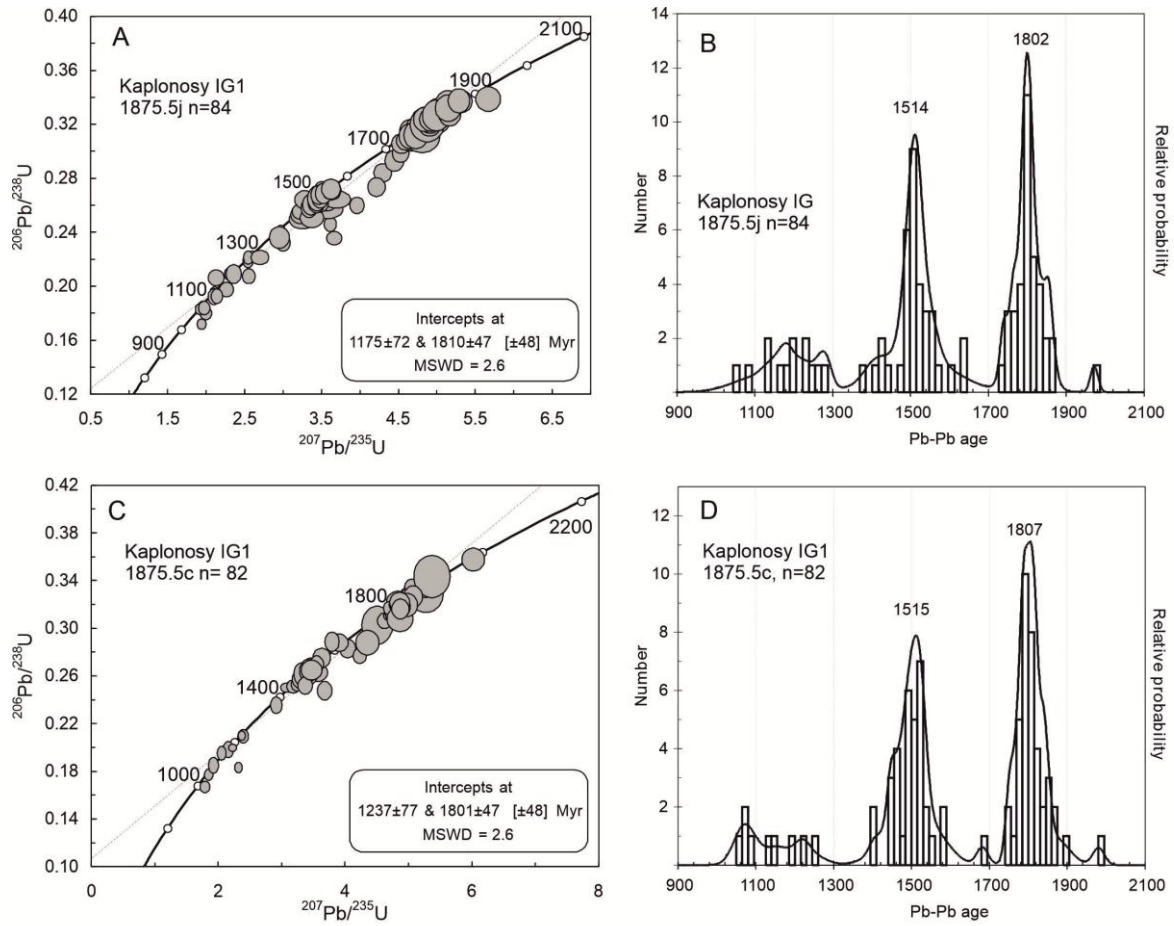


Fig. 6. Results of the SHRIMP U-Pb dating of detrital zircons of the Polesie formation Kap-1875.5 Concordia diagrams and Probability density plot (PDP) diagrams, displaying ages from the main zircon populations in the analyzed sub-samples.

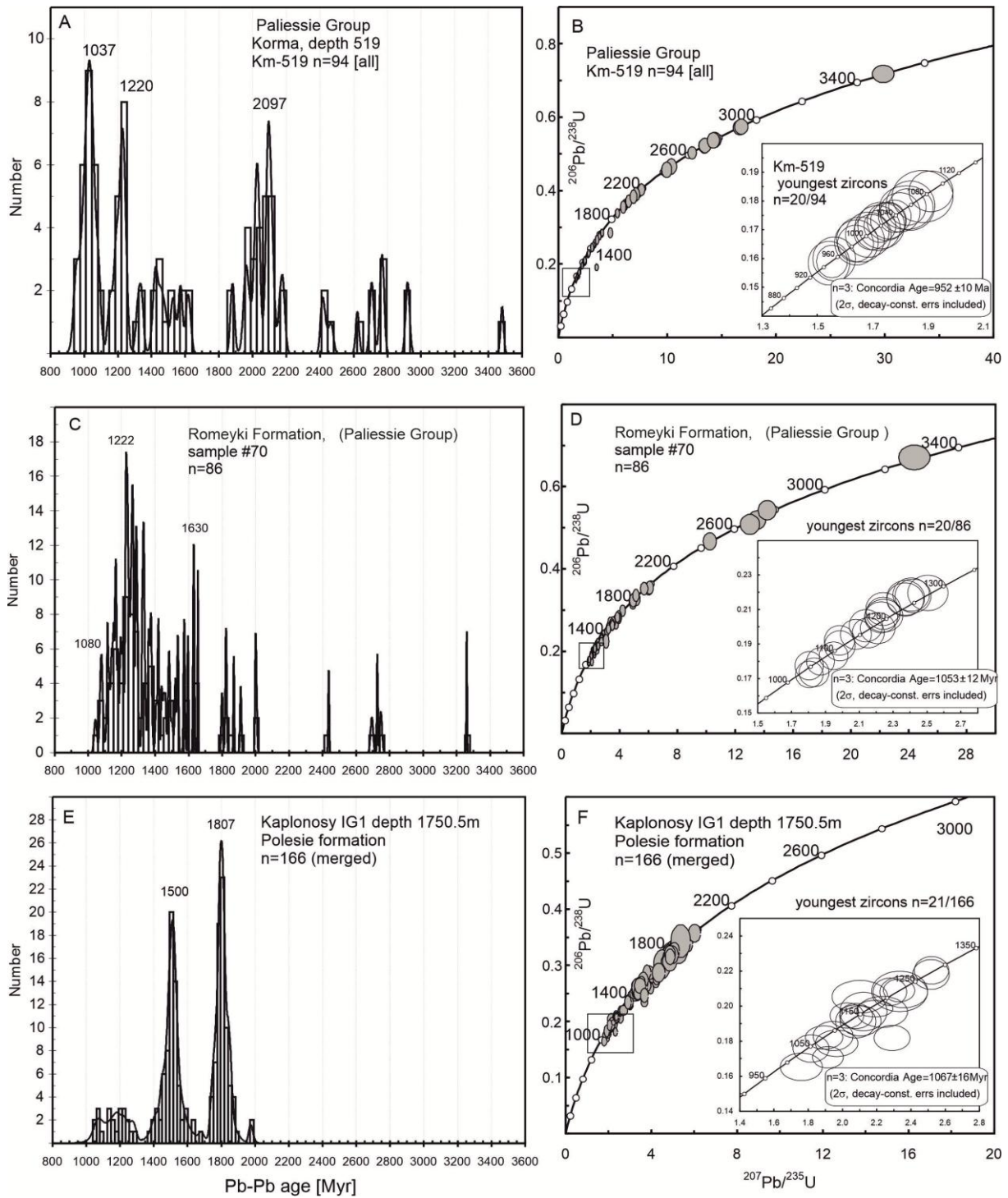


Fig. 7. The Polesie formation detrital zircons characteristics compared with the data for its lateral equivalents: (A-B) Sample Korma -519 Rudnya Formation in Belarus (after Zaitseva et al., 2023); (D,E) Sample #70, Romeyki Formation in Ukraine (after Shumlyanskyy et al., 2023); Sample Kap-1875.5 merged (this study).

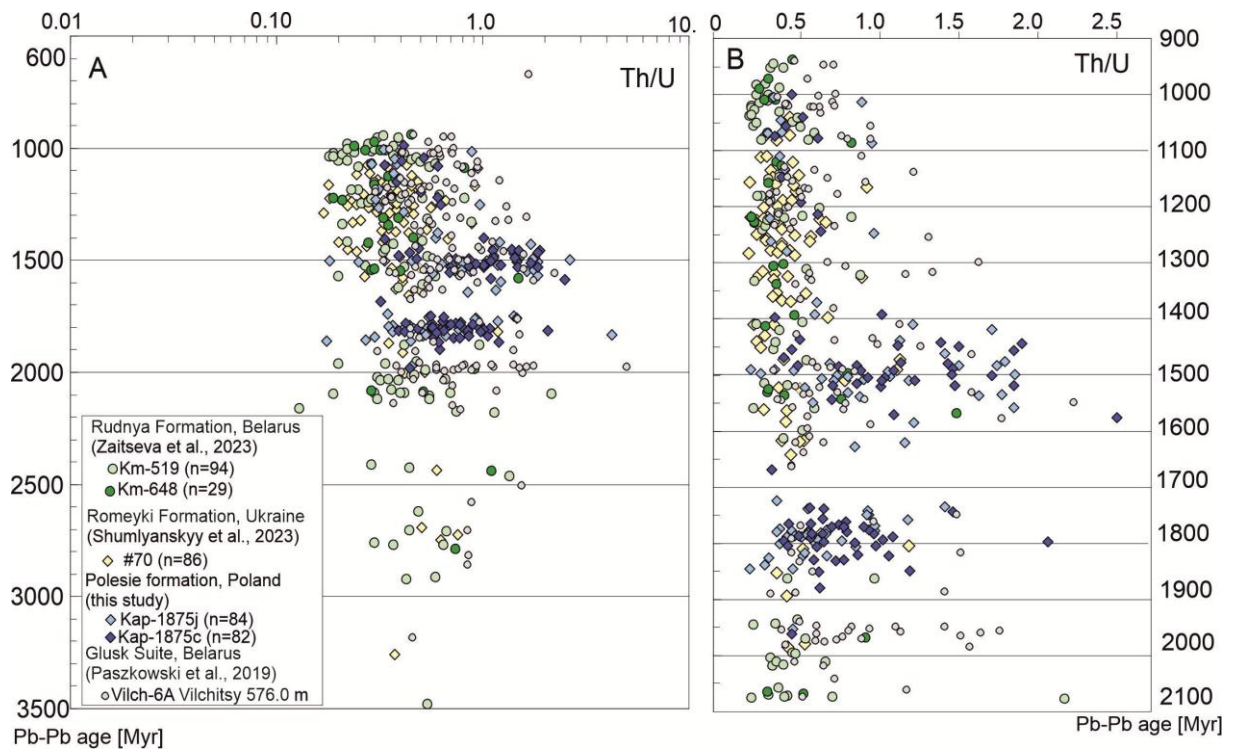


Fig. 8 The Polesie formation detrital zircons characteristics compared to Late to post-Sveconorwegian sediments of the Visingsö Group, southern Sweden sample #312 after Ahrenstend, 2018.

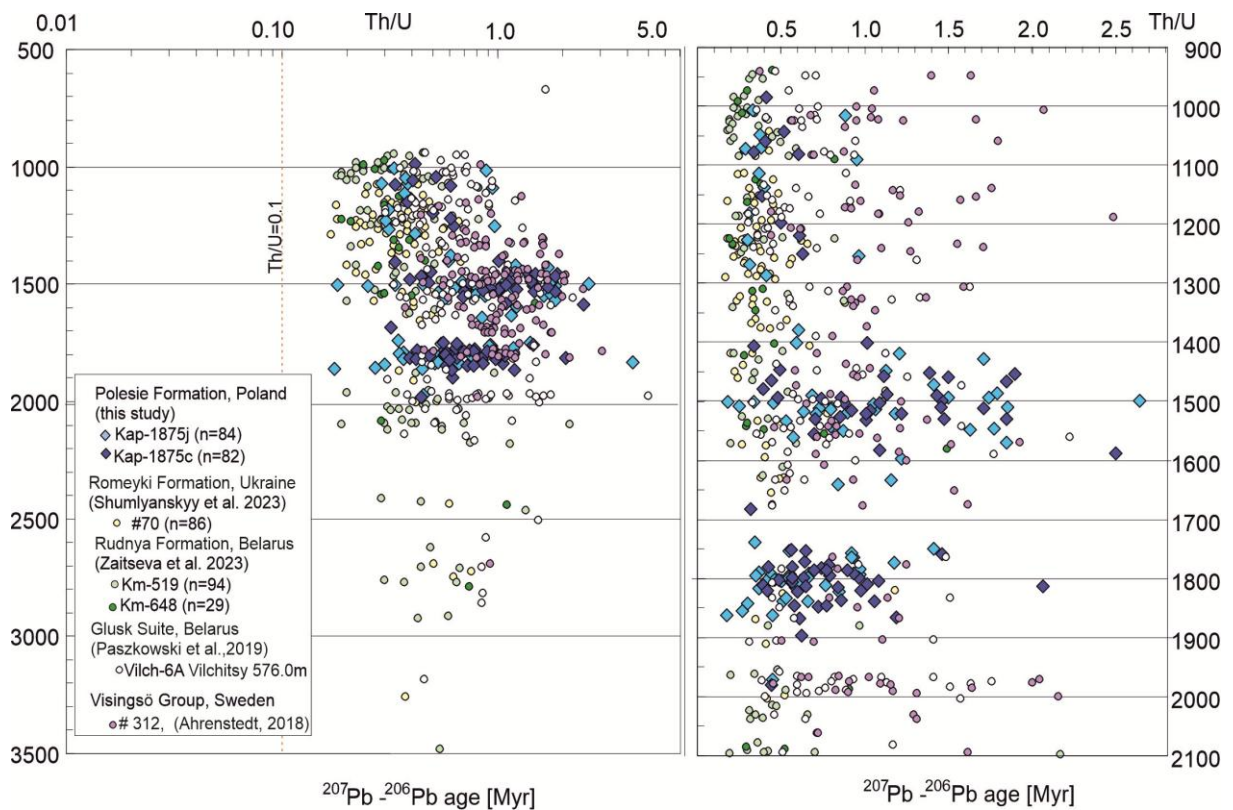


Fig. 9. Comparisons of detrital zircon ages and Th/U parameter based on data from this study and data taken from Ahrenstend (2018); Paszkowski et al. (2019); Zaitseva et al. (2023); Shumlyanskyy et al. (2023)

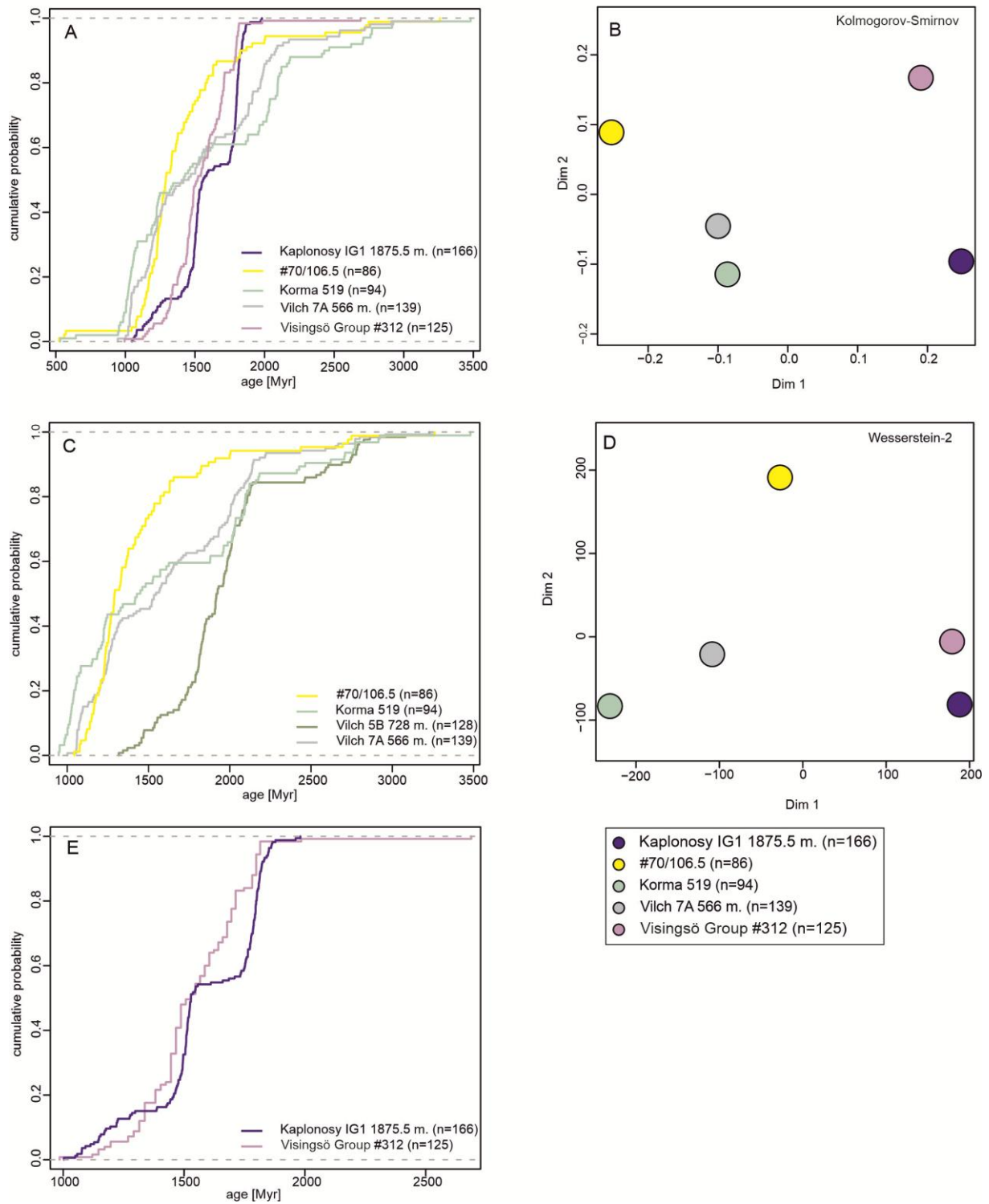


Fig. 10. Cumulative age distribution and associated multidimensional scaling (MDS) plots of detrital zircon age spectra characterizing compared samples deposited within VOR and Central southern Sweden; data taken from Ahrenstendt (2018); Paszkowski et al. (2019); Zaitseva et al. (2023); Shumlyanskyy et al. (2023)

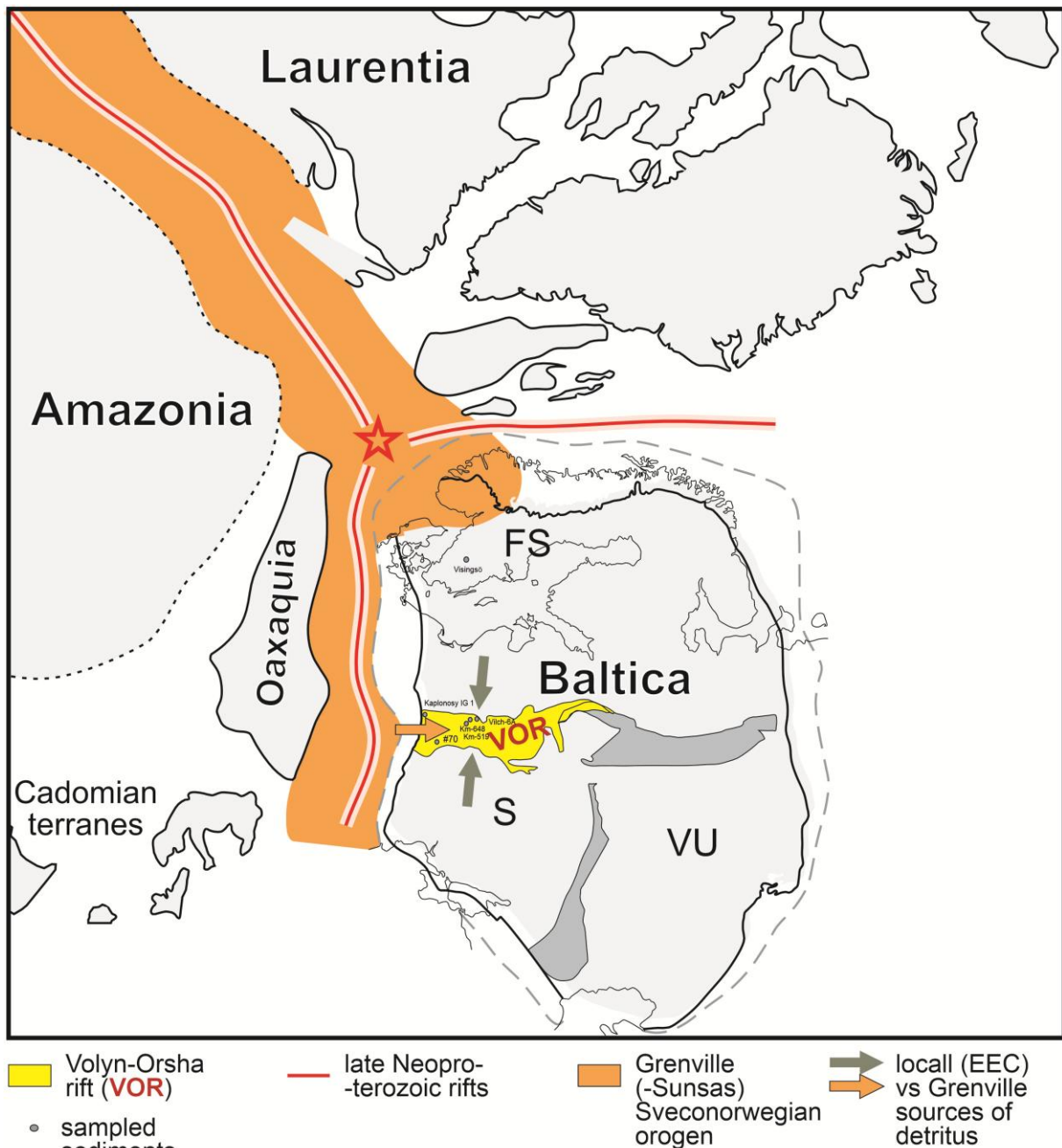


Fig. 11. Supposed palaeogeographic position of source areas of detritus for the Polesie formation relative to the position of the Orsha-Volyn Rift. The basin was supplied with detritus from both the Grenville-Sunas-Sveconorwegian orogen to the west of the Baltica, and the local cratonic sources. FS: Fennoscandia, S: Sarmatia, VU: Volgo-Uralia blocks.

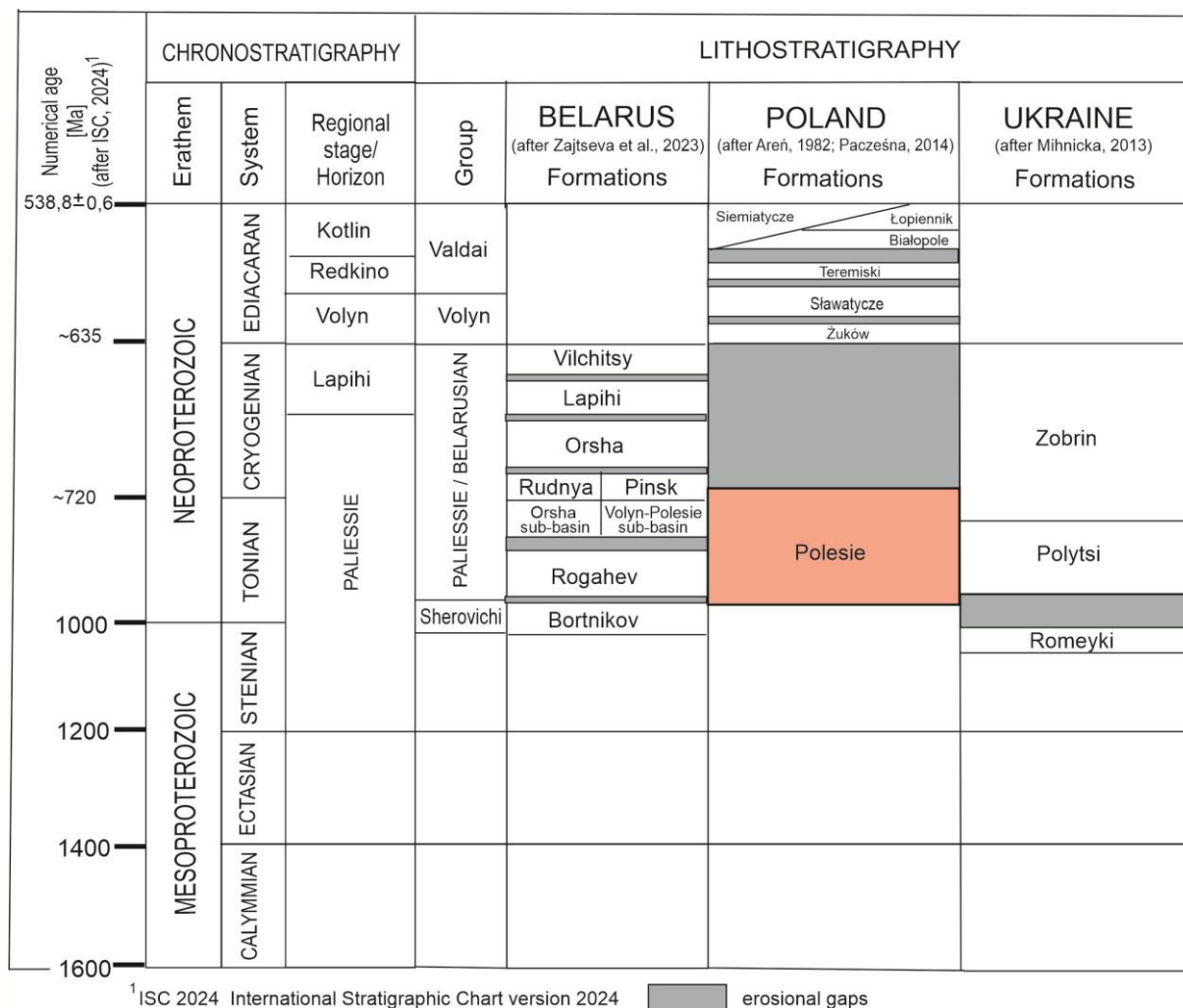


Fig. 12. Correlative scheme of the regional stratigraphical units in the Belarusian, Polish and Ukrainian part of the Volyn-Orsha Rift basin.

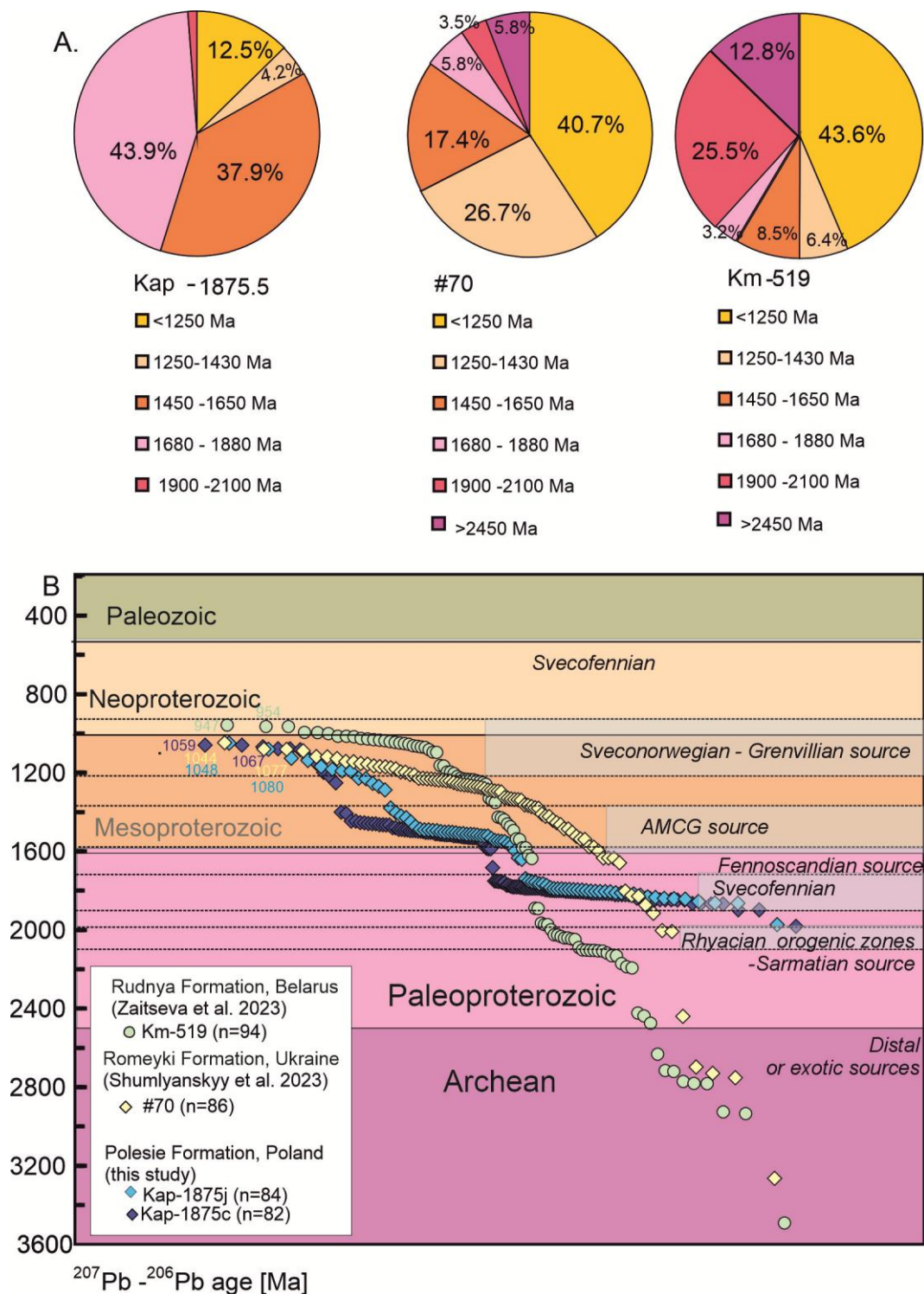


Fig. 13. Schematic diagram including a comparison of detrital zircon ages of the early Neoproterozoic cratonic sandstones from lower part of VOR: (A). pie chart graphics showing the proportion of the zircon Pb-Pb ages according to the time frames matched to the source areas and rocks; B. Linearized-probability plot diagram showing a distribution of detrital components within distinct parts of VOR; Generalized potential source areas and rocks are indicated. Data after Zaitseva et al. (2023) - sample Km-519; after Shumlyanskyy et al. (2023) - sample #70; Sample Kap-1875.5 merged (this study).

Table 1

The summary of the U-Pb detrital zircon age results obtained for the lowermost part of Polesie formation in Kaplonosy IG 1 borehole, depth 1875.5 m.

Sample ID	n=	Range [Ma]	Group I [%]	Group II [%]	Group III [%]	Pb-Pb age [Ma] youngest grains (YSG),
Kap-1875j	84	1080 1972	1811.8±4 [43%]	1511.6±7 [41%]	1144.3±11 [15%]	1080, 1048
Kap-1875c	81	1067 1981	1800.9±4 [49%]	1487.6±7 [40%]	1103.3±17 [11%]	1067, 1082, 1059, 1078
Kap-1875.5 merged	166	1067 1981	1807±1.4 [46%]	1500.5±2.4 [41%]	1133±4.5 [13%]	1067±16 (c.a) 1071 ±11 (w.a)

Supplementary data

Table S1

The U-Pb SHRIMP analytical data for zircon grains from Kaplonosy IG 1 subsamples Kap-1875.5j and Kap-1875.5c

Table S1 U-Pb detrital zircon age data

Kaplonosy IG1 depth 1875.5m sample Kap_1875.5 c

youngest zircon age

	Spot	204Pb /206Pb	±%	207Pb /206Pb	±%	208Pb /206Pb	±%	206Pb /238U	±%	% 206Pb _c	ppm U	ppm Th	4-corr ppm 206Pb ⁺	4-corr ppm 208Pb ⁺	232Th /238U	±%	(1) 206Pb /238U Age	(2) 206Pb /238U Age	(3) 206Pb /238U Age	(1) 207Pb /206Pb Age	Dis- cor- dant	% 7corr 208Pb ⁺ /232Th	(1) 238U /206Pb ⁺	±%	(1) 207Pb ⁺ /206Pb ⁺	±%	(1) 207Pb ⁺ /235U	±%	(1) 206Pb ⁺ /238U	±%	err corr				
Kap_1875c.4.1	8,6E-5	58	0,076	1,2	0,192	0,79	0,41	1,0	0,156	77	38	11,6	2,2	0,52	0,30	1044	18	1043	18	1027	19	1067	31	+2	0,064	2,6	5,69	1,8	0,075	1,5	1,8	2,4	0,176	1,8	0,76
Kap_1875c.8.1	---	---	0,089	0,9	0,129	0,73	0,65	0,4	0,000	76	25	15,2	2,0	0,33	0,29	1358	24	1354	26	1339	25	1407	16	+4	0,086	3,8	4,27	2,0	0,089	0,9	2,9	2,2	0,234	2,0	0,92
Kap_1875c.9.1	----	---	0,095	0,8	0,373	1,30	0,68	1,3	0,000	75	73	16,3	6,1	1,01	0,59	1451	23	1444	25	1397	28	1531	15	+6	0,091	2,5	3,96	1,8	0,095	0,8	3,3	2,0	0,253	1,8	0,92
Kap_1875c.5.1	2,5E-5	100	0,092	1,0	0,400	0,55	0,44	1,3	0,045	87	94	19,6	7,9	1,11	0,30	1493	26	1496	29	1440	32	1458	21	-3	0,095	2,4	3,84	2,0	0,092	1,1	3,3	2,2	0,261	2,0	0,88
Kap_1875c.3.1	1,1E-4	58	0,095	1,2	0,328	1,36	0,68	1,8	0,203	39	32	8,7	2,8	0,86	0,50	1497	26	1498	28	1445	30	1494	30	-0	0,099	2,9	3,82	1,9	0,093	1,6	3,4	2,5	0,261	1,9	0,77
Kap_1875c.11.1	-4E-5	100	0,097	2,1	0,426	0,69	0,72	1,1	-0,072	36	38	8,1	3,5	1,09	0,47	1500	26	1492	28	1421	31	1583	41	+6	0,100	2,7	3,82	1,9	0,098	2,2	3,5	2,9	0,262	1,9	0,66
Kap_1875c.1.1	-4E-5	71	0,093	0,8	0,540	0,42	0,64	1,8	-0,063	87	124	19,8	10,8	1,46	0,30	1514	26	1516	29	1426	34	1498	17	-1	0,098	2,2	3,78	1,9	0,094	0,9	3,4	2,2	0,265	1,9	0,91
Kap_1875c.2.1	-2E-5	100	0,103	0,8	0,123	1,86	0,77	1,6	-0,030	65	20	15,8	2,0	0,32	1,58	1603	26	1594	28	1581	27	1682	15	+5	0,098	5,3	3,54	1,8	0,103	0,8	4,0	2,0	0,282	1,8	0,91
Kap_1875c.6.1	-3E-5	71	0,110	0,7	0,234	0,49	0,79	1,7	-0,047	74	46	19,6	4,7	0,64	0,28	1727	27	1717	31	1687	30	1799	13	+5	0,107	3,1	3,26	1,8	0,110	0,7	4,7	1,9	0,307	1,8	0,93
Kap_1875c.7.1	4,4E-5	100	0,109	1,2	0,292	0,83	0,85	1,7	0,079	32	25	8,9	2,6	0,78	0,53	1796	31	1798	36	1743	35	1776	25	-1	0,121	3,4	3,11	2,0	0,109	1,4	4,8	2,4	0,321	2,0	0,82
Kap_1875c.10.1	1,7E-5	71	0,122	0,8	0,155	0,48	0,72	1,3	0,031	149	64	45,7	7,1	0,44	0,22	1971	30	1969	36	1947	32	1981	15	+1	0,123	5,4	2,80	1,8	0,122	0,9	6,0	2,0	0,358	1,8	0,90
Kap_1875c.30.1	-6,4E-5	100	0,0763	1,78	0,128	1,42	0,35	1,5	--	39	16	5,5	0,7	0,41	0,92	986 ±18		980 ±18		984 ±19		1126 ±42		+13	0,0465	4,3	6,05	1,9	0,0772	2,11	1,76	2,9	0,165	1,9	0,68
Kap_1875c.42.1	4,8E-5	58	0,0920	0,82	0,545	1,97	0,66	1,0	0,08	64	118	10,0	5,5	1,90	1,11	1076 ±16		1057 ±17		1093 ±23		1454 ±18		+8	0,0480	2,8	5,50	1,6	0,0914	0,93	2,29	1,9	0,182	1,6	0,87
Kap_1875c.27.1	-2,8E-5	100	0,0751	1,18	0,186	0,79	0,48	1,4	--	70	41	11,6	2,2	0,61	0,33	1146 ±16		1149 ±17		1143 ±17		1082 ±26		+6	0,0622	2,3	5,14	1,5	0,0755	1,29	2,03	2,0	0,195	1,5	0,76
Kap_1875c.34.1	-9,3E-5	50	0,0769	1,08	0,115	0,91	0,47	2,0	--	76	28	12,9	1,5	0,38	1,04	1158 ±24		1158 ±26		1156 ±26		1152 ±27		-1	0,0611	3,9	5,08	2,3	0,0782	1,36	2,12	2,7	0,197	2,3	0,86
Kap_1875c.48.1	-2,5E-4	30	0,0765	1,14	0,145	0,87	0,51	3,9	--	67	32	11,4	1,8	0,50	0,57	1167 ±10		1165 ±11		1165 ±11		1197 ±34		+3	0,0597	2,2	5,04	1,0	0,0800	1,71	2,19	2,0	0,198	1,0	0,49
Kap_1875c.45.1	-1,3E-4	50	0,0803	1,24	0,186	0,86	0,59	0,8	--	35	22	6,3	1,2	0,63	0,71	1218 ±20		1216 ±21		1216 ±21		1250 ±32		+3	0,0620	2,8	4,81	1,8	0,0822	1,65	2,36	2,4	0,208	1,8	0,73
Kap_1875c.54.1	-6,0E-5	50	0,0801	0,83	0,184	0,58	0,54	1,2	--	74	44	13,4	2,5	0,61	0,47	1223 ±14		1223 ±15		1220 ±15		1219 ±19		-0	0,0642	2,0	4,79	1,3	0,0809	0,98	2,33	1,6	0,209	1,3	0,79
Kap_1875c.39.1	2,6E-4	38	0,0924	1,27	0,354	4,08	0,45	5,5	0,42	58	57	12,4	4,3	1,01	1,47	1435 ±13		1438 ±14		1404 ±19		1400 ±39		-3	0,0862	4,6	4,01	1,0	0,0888	2,03	3,05	2,3	0,249	1,0	0,46
Kap_1875c.50.1	1,1E-4	38	0,0929	1,54	0,417	1,45	0,69	1,2	0,19	53	71	11,4	4,7	1,39	2,26	1439 ±18		1438 ±20		1435 ±24		1453 ±32		+1	0,0743	3,2	4,00	1,4	0,0913	1,70	3,15	2,2	0,250	1,4	0,64
Kap_1875c.20.1	1,1E-4	41	0,0942	0,86	0,117	0,79	0,63	1,1	0,18	56	21	12,2	1,4	0,39	0,66	1450 ±19		1448 ±21		1451 ±20		1480 ±21		+2	0,0709	3,6	3,96	1,5	0,0926	1,12	3,22	1,9	0,252	1,5	0,80
Kap_1875c.17.1	----	---	0,0919	1,29	0,492	2,26	0,63	0,5	--	31	56	6,9	3,4	1,85	0,65	1473 ±26		1472 ±26		1512 ±35		1466 ±24		-1	0,0685	3,2	3,90	2,0	0,0919	1,29	3,25	2,4	0,257	2,0	0,84
Kap_1875c.24.1	----	---	0,0950	1,90	0,553	0,92	0,72	1,4	0,00	33	59	7,3	4,1	1,85	0,34	1483 ±25		1479 ±27		1475 ±33		1529 ±36		+3	0,0766	2,4	3,87	1,9	0,0950	1,90	3,39	2,7	0,259	1,9	0,70
Kap_1875c.41.1	----	---	0,0943	0,80	0,319	2,05	0,70	2,0	--	61	61	13,6	4,4	1,03	1,49	1484 ±12		1481 ±13		1474 ±15		1515 ±15		+2	0,0789	2,8	3,86	0,9	0,0943	0,80	3,37	1,2	0,259	0,9	0,75
Kap_1875c.46.1	1,5E-5	58	0,0912	0,46	0,133	0,39	0,69	1,1	0,03	179	85	39,9	5,3	0,49	0,32	1486 ±13		1489 ±14		1493 ±14		1446 ±9		-3	0,0729	1,9	3,86	1,0	0,0910	0,48	3,25	1,1	0,259	1,0	0,90
Kap_1875c.49.1	5,3E-5	50	0,0926	0,73	0,131	0,63	0,70	1,0	0,09	69	30	15,4	2,0	0,44	0,54	1486 ±18		1488 ±19		1486 ±19		1465 ±16		-2	0,0778	2,8	3,86	1,3	0,0919	0,84	3,28	1,6	0,259	1,3	0,85
Kap_1875c.43.1	1,3E-4	38	0,0934	0,87	0,428	0,47	0,66	1,3	0,21	51	74	11,4	4,9	1,50	0,96	1494 ±32		1497 ±35		1506 ±41		1459 ±22		-3	0,0747	2,9	3,83	2,4	0,0916	1,17	3,29	2,7	0,261	2,4	0,90
Kap_1875c.16.1	-3,4E-5	58	0,0946	0,67	0,210	0,47	0,68	1,1	--	95	65	21,4	4,6	0,70	0,90	1496 ±17		1493 ±18		1491 ±18		1530 ±14		+2	0,0768	2,1	3,83	1,2	0,0951	0,72	3,43	1,4	0,261	1,2	0,87
Kap_1875c.59.1	2,3E-5	71	0,0933	0,69	0,334	0,41	0,66	2,9	0,04	79	87	17,8	6,0	1,13	0,40	1503 ±17		1505 ±18		1504 ±20		1488 ±14		-1	0,0776	1,6	3,81	1,2	0,0930	0,73	3,37	1,4	0,263	1,2	0,86
Kap_1875c.44.1	4,7E-5	50	0,0947	0,68	0,407	1,40	0,51	0,7	0,08	116	164	26,6	10,9	1,46	0,83	1520 ±16		1521 ±17		1520 ±16		1510 ±14		-1	0,0743	2,1	3,76	1,2	0,0941	0,76	3,45	1,4	0,266	1,2	0,84
Kap_1875c.60.1	3,6E-5	71	0,0942	0,84	0,266	0,55	0,66	1,1	0,06	55	46	12,5	3,3	0,88	0,53	1522 ±20		1524 ±22		1518 ±23		1503 ±17		-1	0,0812	2,1	3,75	1,5	0,0937	0,93	3,44	1,7	0,266	1,5	0,85
Kap_1875c.40.1	2,9E-5	100	0,0935	1,10	0,483	0,40	0,66	2,2	0,05	33	46	7,6	3,7	1,43	9,61	1525 ±24		1528 ±27		1479 ±52		1490 ±22		-3	0,0908	11,7	3,75	1,8	0,0931	1,19	3,43	2,2	0,267	1,8	0,84
Kap_1875c.63.1	1,4E-4	38	0,0965	0,87	0,291	0,55	0,49	1,9	0,22	68	67	15,6	4,5	1,01	0,50	1526 ±19		1527 ±21		1533 ±22		1521 ±22		-0	0,0762	2,0	3,74	1,4	0,0946	1,18	3,48	1,8	0,267	1,4	0,77
Kap_1875c.38.1	4,5E-5	58	0,0944	0,77	0,326	0,46	0,66	0,9	0,07	66	69	15,5	5,1	1,09	0,47	1563 ±19		1559 ±22		1553 ±22		1501 ±26		-5	0,0842	1,8	3,64	1,4	0,0938	0,87	3,55	1,6	0,274	1,4	0,84
Kap_1875c.61.1	-4,5E-6	100	0,1104	0,39	0,171	0,36	0,69	1,2	--	200	109	47,4	8,2	0,36	0,31	1572 ±21		1549 ±23		1568 ±23		1807 ±7		+15	0,0658	2,9	3,62	1,5	0,1104	0,40	4,21	1,6	0,276	1,5	0,97
Kap_1875c.37.1	-6,3E-5	38	0,0935	0,60	0,285	0,99	0,66	2,2	--	100	89	23,8	6,9	0,92	0,38	1576 ±16		1582 ±18		1565 ±18		1515 ±13		-5	0,0886	1,8	3,61	1,2	0,0943	0,69	3,60	1,3	0,277	1,2	0,86
Kap_1875c.56.1	-2,6E-4	33	0,0945	1,07	0,757	0,54	0,64	1,2	--	43	103	10,5	8,1	2,50	2,38	1628 ±27		1597 ±41		1632 ±27		1587 ±30		-3	0,0884	3,0									

Kap_1875j.18.1	-1,9E-5	71	0,083	0,64	0,16	0,76	0,56	0,9	--	164	66	30,7	4,9	0,41	0,20	1271 ±18	1270 ±20	1251 ±20	1286 ±13	+1	0,082	2,5	4,59	1,6	0,084	0,68	2,52	1,7	0,218	1,6	0,92
Kap_1875j.9.1	----	---	0,083	0,73	0,12	0,63	0,60	1,9	--	109	33	20,6	2,5	0,31	0,23	1284 ±17	1285 ±18	1268 ±18	1268 ±14	-1	0,085	2,8	4,54	1,5	0,083	0,73	2,52	1,6	0,220	1,5	0,89
Kap_1875j.11.1	2,9E-4	41	0,092	1,41	0,22	0,97	0,44	1,7	0,52	45	26	8,5	1,8	0,60	0,42	1285 ±19	1278 ±20	1267 ±20	1379 ±46	+8	0,072	2,9	4,53	1,6	0,088	2,41	2,67	2,9	0,221	1,6	0,55
Kap_1875j.14.1	4,0E-5	58	0,113	1,06	0,18	1,02	0,37	1,6	0,07	179	88	36,1	6,4	0,51	0,21	1360 ±18	1317 ±19	1345 ±19	1839 ±20	+29	0,047	4,5	4,26	1,4	0,112	1,10	3,64	1,8	0,235	1,4	0,80
Kap_1875j.48.1	-2,1E-5	50	0,106	0,44	0,15	1,13	0,69	3,4	--	184	61	38,7	5,9	0,35	0,27	1414 ±18	1384 ±19	1383 ±19	1738 ±8	+21	0,072	3,3	4,08	1,4	0,106	0,45	3,60	1,5	0,245	1,4	0,95
Kap_1875j.13.1	-1,3E-4	100	0,093	2,29	0,38	1,28	0,39	1,9	--	18	19	3,9	1,5	1,06	0,65	1431 ±24	1424 ±26	1382 ±29	1514 ±55	+6	0,087	3,0	4,02	1,9	0,094	2,92	3,23	3,5	0,249	1,9	0,54
Kap_1875j.49.1	2,1E-4	50	0,095	1,52	0,53	3,19	0,58	1,5	0,38	25	34	5,4	2,8	1,41	2,76	1449 ±22	1447 ±24	1366 ±33	1472 ±43	+2	0,093	4,6	3,97	1,7	0,092	2,25	3,21	2,8	0,252	1,7	0,60
Kap_1875j.6.1	-8,7E-5	50	0,093	0,94	0,69	1,44	0,69	0,9	--	49	88	10,6	7,4	1,85	1,26	1451 ±20	1446 ±22	1333 ±30	1509 ±21	+4	0,093	2,5	3,96	1,5	0,094	1,13	3,27	1,9	0,253	1,5	0,80
Kap_1875j.17.1	1,8E-5	100	0,096	0,83	0,60	0,40	0,65	0,4	0,03	64	101	14,0	8,4	1,63	0,30	1461 ±20	1367 ±26	1453 ±21	1548 ±16	+6	0,091	1,7	3,93	1,5	0,096	0,87	3,37	1,7	0,254	1,5	0,86
Kap_1875j.43.1	1,8E-4	28	0,094	1,26	0,41	1,56	0,47	1,3	0,32	136	148	29,8	12,2	1,13	1,51	1463 ±19	1464 ±21	1408 ±24	1449 ±29	-1	0,092	2,8	3,93	1,5	0,091	1,51	3,20	2,1	0,255	1,5	0,70
Kap_1875j.47.1	-1,3E-5	100	0,094	0,73	0,27	1,49	0,53	1,4	--	99	70	21,8	5,9	0,73	1,11	1472 ±19	1469 ±21	1435 ±22	1512 ±14	+3	0,093	2,7	3,90	1,5	0,094	0,75	3,33	1,6	0,257	1,5	0,89
Kap_1875j.26.1	-3,8E-4	50	0,095	1,95	0,43	1,05	0,59	0,8	--	13	15	2,9	1,3	1,16	0,66	1474 ±25	1458 ±27	1396 ±30	1633 ±59	+11	0,093	2,7	3,89	1,9	0,100	3,15	3,56	3,7	0,257	1,9	0,51
Kap_1875j.28.1	----	---	0,095	0,64	0,20	1,87	0,73	2,2	--	84	43	18,5	3,7	0,53	1,49	1476 ±19	1471 ±21	1447 ±21	1533 ±12	+4	0,093	3,3	3,89	1,5	0,095	0,64	3,38	1,6	0,257	1,5	0,92
Kap_1875j.1.1	5,6E-6	100	0,110	0,44	0,18	0,67	0,76	1,1	0,01	187	90	41,6	7,5	0,50	0,18	1486 ±20	1453 ±21	1464 ±22	1804 ±8	+20	0,066	3,0	3,86	1,5	0,110	0,44	3,94	1,6	0,259	1,5	0,96
Kap_1875j.25.1	7,3E-5	58	0,094	0,99	0,65	0,49	0,52	1,4	0,13	63	109	14,1	9,2	1,79	0,32	1494 ±23	1494 ±25	1393 ±33	1487 ±22	-1	0,094	2,0	3,83	1,7	0,093	1,19	3,34	2,1	0,261	1,7	0,83
Kap_1875j.51.1	-2,7E-4	38	0,095	1,23	0,44	0,66	0,51	0,8	--	49	57	10,9	5,0	1,22	0,73	1496 ±21	1486 ±23	1425 ±26	1596 ±34	+7	0,094	2,1	3,83	1,6	0,099	1,85	3,55	2,4	0,261	1,6	0,65
Kap_1875j.45.1	-1,1E-4	50	0,094	1,03	0,67	0,54	0,71	1,4	--	39	67	8,8	6,0	1,77	0,42	1499 ±21	1494 ±23	1371 ±29	1546 ±24	+3	0,098	1,8	3,82	1,6	0,096	1,27	3,46	2,0	0,262	1,6	0,77
Kap_1875j.33.1	2,8E-5	58	0,094	0,62	0,17	1,24	0,60	3,8	0,05	132	58	29,8	5,2	0,45	0,73	1502 ±23	1502 ±25	1474 ±24	1503 ±13	+0	0,101	3,1	3,81	1,7	0,094	0,66	3,39	1,8	0,262	1,7	0,93
Kap_1875j.37.1	-4,2E-5	41	0,093	0,84	0,09	0,54	0,64	1,1	--	143	34	32,2	3,1	0,25	0,19	1503 ±21	1502 ±23	1489 ±21	1509 ±17	+0	0,099	4,5	3,81	1,5	0,094	0,88	3,40	1,8	0,263	1,5	0,87
Kap_1875j.2.1	1,8E-4	50	0,092	1,35	0,44	0,71	0,75	1,1	0,32	24	28	5,4	2,4	1,21	0,50	1507 ±22	1516 ±25	1444 ±28	1419 ±38	-7	0,098	2,2	3,80	1,7	0,090	1,98	3,26	2,6	0,263	1,7	0,65
Kap_1875j.7.1	3,1E-5	71	0,095	0,79	0,29	1,11	0,73	1,1	0,06	66	51	14,9	4,4	0,80	0,55	1510 ±23	1509 ±26	1469 ±27	1513 ±16	+0	0,096	2,6	3,79	1,7	0,094	0,85	3,43	1,9	0,264	1,7	0,90
Kap_1875j.40.1	-4,8E-4	35	0,094	1,57	0,30	0,96	0,38	1,2	--	39	32	8,8	2,8	0,84	0,45	1510 ±22	1497 ±24	1461 ±25	1640 ±51	+9	0,093	2,7	3,79	1,7	0,101	2,73	3,67	3,2	0,264	1,7	0,52
Kap_1875j.30.1	2,2E-5	71	0,094	0,65	0,12	1,86	0,77	1,4	0,04	83	27	18,8	2,3	0,33	1,38	1513 ±21	1514 ±23	1497 ±22	1502 ±13	-1	0,098	4,1	3,78	1,6	0,094	0,69	3,42	1,7	0,264	1,6	0,92
Kap_1875j.46.1	-1,6E-5	71	0,094	0,57	0,24	0,38	0,75	1,1	--	104	64	23,6	5,7	0,64	0,21	1515 ±22	1515 ±24	1477 ±24	1516 ±11	+0	0,100	2,2	3,77	1,6	0,094	0,59	3,45	1,7	0,265	1,6	0,94
Kap_1875j.22.1	1,2E-4	52	0,095	1,74	1,01	0,83	0,71	2,1	0,21	33	84	7,5	7,7	2,64	0,41	1526 ±22	1288 ±40	1499 ±38	1529 ±24	-2	0,103	1,9	3,74	1,6	0,094	1,99	3,44	2,5	0,267	1,6	0,62
Kap_1875j.50.1	----	---	0,093	1,18	0,64	0,56	0,53	0,5	0,00	46	77	10,7	6,9	1,74	0,38	1545 ±21	1550 ±24	1433 ±30	1493 ±22	+4	0,101	1,8	3,69	1,6	0,093	1,18	3,48	2,0	0,271	1,6	0,80
Kap_1875j.41.1	1,1E-4	33	0,111	0,65	0,13	1,06	0,53	0,3	0,20	113	40	27,4	3,5	0,37	0,64	1609 ±23	1588 ±25	1595 ±24	1790 ±15	-11	0,074	4,9	3,53	1,6	0,109	0,81	4,28	1,8	0,283	1,6	0,90
Kap_1875j.19.1	----	---	0,110	0,41	0,18	0,36	0,72	3,6	--	278	149	70,0	12,8	0,55	0,76	1655 ±26	1638 ±29	1640 ±28	1793 ±7	+9	0,083	3,5	3,42	1,8	0,110	0,41	4,42	1,8	0,293	1,8	0,97
Kap_1875j.12.1	-3,4E-5	58	0,109	0,63	0,35	0,39	0,69	1,9	--	81	76	20,9	7,4	0,97	0,25	1682 ±22	1668 ±24	1626 ±25	1794 ±12	+7	0,102	2,0	3,35	1,5	0,110	0,67	4,51	1,6	0,298	1,5	0,91
Kap_1875j.32.1	7,4E-5	58	0,108	0,94	0,20	0,73	0,75	2,0	0,13	40	21	10,5	2,1	0,54	0,38	1719 ±23	1714 ±26	1690 ±25	1754 ±20	+2	0,106	3,3	3,27	1,6	0,107	1,09	4,52	1,9	0,306	1,6	0,82
Kap_1875j.36.1	7,3E-5	35	0,110	0,56	0,24	1,34	0,61	1,7	0,13	160	106	42,3	10,0	0,68	0,72	1728 ±26	1720 ±29	1699 ±29	1789 ±12	+4	0,101	3,2	3,25	1,7	0,109	0,65	4,64	1,8	0,307	1,7	0,93
Kap_1875j.27.1	1,5E-4	35	0,110	0,80	0,34	0,51	0,83	2,2	0,27	52	47	13,7	4,7	0,93	0,34	1729 ±23	1724 ±26	1673 ±27	1765 ±19	+2	0,109	2,2	3,25	1,5	0,108	1,06	4,58	1,9	0,308	1,5	0,82
Kap_1875j.15.1	-1,6E-4	71	0,110	1,66	1,51	1,14	0,59	2,4	--	17	71	4,6	7,1	4,22	1,32	1742 ±37	1271 ±121	1730 ±42	1831 ±38	+6	0,110	3,1	3,22	2,4	0,112	2,10	4,79	3,2	0,310	2,4	0,76
Kap_1875j.21.1	4,4E-5	45	0,110	0,55	0,15	0,48	0,50	1,2	0,08	195	83	52,7	8,1	0,44	0,68	1760 ±25	1756 ±29	1741 ±27	1793 ±11	+2	0,104	3,9	3,18	1,7	0,110	0,61	4,74	1,8	0,314	1,7	0,94
Kap_1875j.24.1	3,1E-5	71	0,110	0,74	0,35	0,47	0,68	1,1	0,06	78	73	20,9	7,3	0,97	0,29	1761 ±23	1758 ±26	1705 ±27	1784 ±15	+1	0,111	2,2	3,18	1,5	0,109	0,80	4,72	1,7	0,314	1,5	0,88
Kap_1875j.39.1	----	---	0,107	0,97	0,48	0,54	0,62	1,0	--	46	62	12,3	6,0	1,41	0,37	1763 ±29	1765 ±33	1697 ±36	1749 ±18	-1	0,108	2,4	3,18	1,9	0,107	0,97	4,64	2,1	0,315	1,9	0,89
Kap_1875j.16.1	-2,1E-5	58	0,110	0,50	0,17	0,87	0,78	1,3	--	136	61	37,0	6,3	0,46	0,64	1772 ±25	1768 ±28	1745 ±26	1803 ±9	+2	0,111	3,6	3,16	1,6	0,110	0,52	4,81	1,7	0,316	1,6	0,95
Kap_1875j.38.1	1,3E-4	35	0,109	0,75	0,33	2,59	0,80	0,8	0,23	54	48	14,7	4,8	0,92	2,63	1778 ±23	1729 ±29	1729 ±29	1757 ±17	-1	0,114	4,3	3,15	1,5	0,107	0,95	4,71	1,8	0,318	1,5	0,85
Kap_1875j.29.1	-5,4E-5	58	0,109	0,79	0,13	0,74	0,90	1,4	--	47	16	13,0	1,7	0,35	0,35	1799 ±28	1774 ±29	1796 ±16	1796 ±16	-0	0,123	5,0	3,11	1,8	0,110	0,87	4,87	2,0	0,322	1,8	0,90
Kap_1875j.44.1	-1,2E-4	35	0,111	0,73	0,24	2,14	0,86	1,3	--	51	33	14,2	3,6	0,66	2,03	1801 ±28	1795 ±32	1755 ±32	1839 ±16	+2	0,117	4,3	3,10	1,8	0,112	0,88	5,00	2,0	0,322	1,8	0,90
Kap_1875j.3.1	-7,2E-5	45	0,110	0,71	0,21	0,54	0,77	1,8	--	74	42	21,0	4,6	0,59	0,29	1833 ±24	1836 ±26	1795 ±26	1815 ±15	-1	0,123	3,0	3,04	1,5	0,111	0,80	5,03	1,7	0,329	1,5	0,88
Kap_1875j.20.1	9,7E-6	100	0,110</																												