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Tectonics of detached middle crust in the north-eastern foreland of the Palaeoproterozoic Lapland-Kola collisional orogen, north-eastern Baltic Shield

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Abstract. The Serpovidny Ridge Fold is located in the north-western Keivy Terrane situated in the north-eastern foreland of the Palaeoproterozoic Lapland-Kola Collisional Orogen, north-eastern Baltic Shield. Its isoclinal core is composed of Palaeoproterozoic rift-related rocks and displays sheath-like morphology (8 × 2 km in size on the surface). Sedimentary structures that indicate the polarity of bedding suggest that this fold is a synformal anticline, with its axial surface dipping northwards. The lower (southern) limb of the fold is strongly thinned (the X/Z ratio up to 25) whereas the upper (northern) limb is almost undeformed. Kinematic indicators suggest that this super-large sheath fold resulted from north-directed movements under amphibolite-facies conditions at the boundary between the middle and lower crust. The core of the Serpovidny Ridge Sheath Fold composed of Palaeoproterozoic rift-related rocks is interpreted as an outlier of a Helvetic-type nappe that came from the Imandra–Varzuga Rift-Belt located *ca*. 50 km south of the study area. This tectonism is classified as tectonics of detached middle crust in foreland of the Lapland–Kola Collisional Orogen. It seems to be a counterpart of thin-skinned tectonics in foreland of Phanerozoic collisional orogens which operates in the upper crust.

Аннотация. Складчатая структура хр. Серповидного находится в северо-западной части Кейвского террейна, расположенного в северо-восточном форланде палеопротерозойского Лапландско-Кольского коллизионного орогена (северо-восток Балтийского щита). Ее изоклинальное ядро (размером 8 × 2 км на поверхности) сложено палеопротерозойскими рифтогенными породами и обнаруживает колчановидную морфологию. Осадочные текстуры, являющиеся индикаторами кровли и подошвы слоев, указывают на то, что эта складка представляет собой ныряющую (синформную) антиклиналь, осевая поверхность которой падает к северу. Нижнее (южное) крыло складки сильно пережато (отношение X/Z до 25), тогда как верхнее (северное) крыло почти не деформировано. Кинематические индикаторы указывают на то, что эта сверхкрупная колчановидная складка возникла в результате направленных к северу движений в условиях амфиболитовой фации на границе между средней и нижней корой. Ядро колчановидной складки хр. Серповидного, сложенное палеопротерозойскими рифтогенными породами, интерпретируется как останец тектонического покрова гельветского типа, который пришел из рифтогенного пояса Имандра-Варзуга, расположенного примерно в 50 км к югу от района исследований. Это проявление тектоники классифицируется как тектоника сорванной средней коры в форланде Лапландско-Кольского коллизионного орогена. Она, по-видимому, является эквивалентом тектоники сорванного чехла в форланде коллизионных орогенов фанерозоя, которая имеет место в верхней коре.

Key words: Palaeoproterozoic, Lapland-Kola Orogen, collision, detached middle crust, Helvetic-type nappe, sheath fold
Ключевые слова: Палеопротерозой, Лапландско-Кольский ороген, коллизия, сорванная средняя кора, покров гельветского типа, колчановидная складка

1. Introduction

Palaeoproterozoic plate tectonics is identical to the Phanerozoic plate tectonics in their principal operating mechanism (*Helmstaet, Scott*, 1992; *Lahtinen et al*., 2005). The Palaeoproterozoic Lapland-Kola Collisional Orogen (hereafter LKO) is located in the north-eastern part of the Baltic Shield and is deeply eroded. Nevertheless, it also displays all of geotectonic elements critical for Phanerozoic fold-thrust belts resulted from intercontinental collision (*Balagansky et al*., 2006; *Daly et al*., 2006). At the same time the north-eastern foreland of this orogen remarkedly differs from the foreland of Phanerozoic collisional orogens in tectonic style though the orogenic core of the LKO is very similar to those of younger collisional orogens.

In the middle Palaeoproterozoic (from *ca*. 2.1 Ga to *ca*. 1.9 Ga) the north-eastern Baltic Shield was a locus of a Red Sea type oceanic separation. Subsequent subduction resulted in generation of Palaeoproterozoic juvenile crust, and intercontinental collision formed the LKO, a collisional belt traceable across the Atlantic to Greenland and Labrador (*Bridgwater et al*., 1992; *Melezhik, Sturt*, 1994; *Mints et al*., 1996; *Balagansky et al*., 1998; *Daly et al*., 2006). The LKO is separated from the Karelian Craton to the south-west by the SW-dipping Palaeoproterozoic Northern Karelia suture and from the Murmansk Craton to the north by a NE-dipping Neoarchaean suture reactivated during Palaeoproterozoic collision (*Mints et al*., 1996, and references therein). It consists of (i) the orogenic core, which is composed mainly of Palaeoproterozoic juvenile crust metamorphosed under conditions of granulite to amphibolite facies, and (ii) the south-western and north-eastern margins (foreland) composed of both Archaean and Palaeoproterozoic rocks (the latter are subordinary; Fig. 1A). The Keivy Terrane is a key tectonic unit in the north-eastern foreland and is crucial, along with the orogenic core, for an understanding of Palaeoproterozoic collision in the LKO.

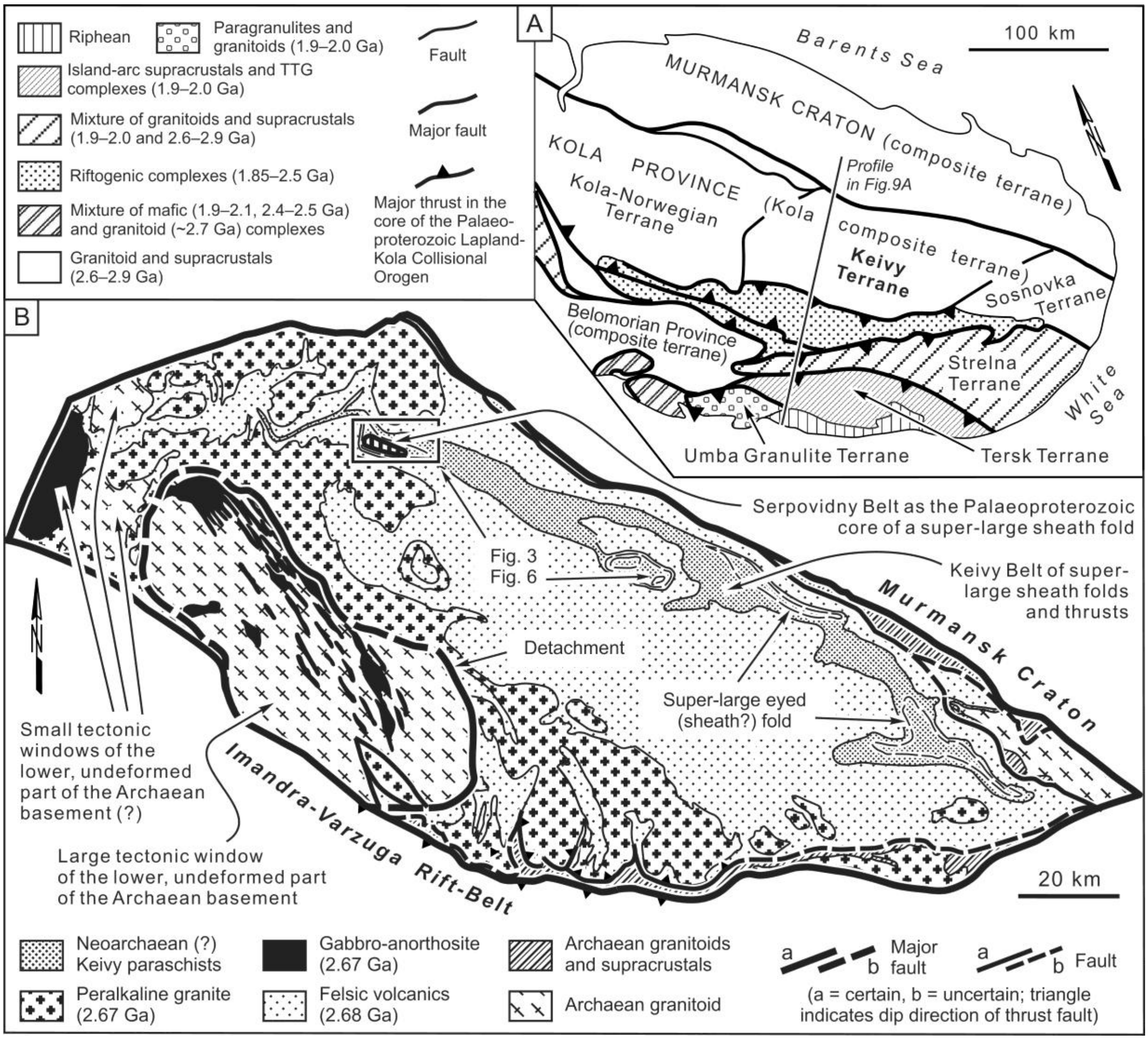

Fig. 1. (A) Tectonic map of the Kola Peninsula (*Balagansky et al*., 2006) and (B) schematic geological map of the Keivy Terrane (*Balagansky et al*., 2011)

Unambiguous Palaeoproterozoic lithologies occur only in the north-western Keivy Terrane where they make up the core (8 × 2 km in size on the surface) of the Serpovidny Ridge Fold (Fig. 1B). This core is surrounded by Keivy muscovite-biotite, muscovite-quartz, garnet, kyanite, and staurolite metasedimentary schists of uncertain age (Neoarchaean or Palaeoproterozoic) which are also deformed into the same fold (Fig. 1B). The Palaeoproterozoic core was interpreted as an ordinary WNW-trending syncline, with its keel reaching a depth of 500 m or less, and the thickness of the Palaeoproterozoic rocks was estimated at *ca*. 200 m (*Bel'kov*, 1963). Later on, *Belolipetsky et al.* (1980) reported that the southern limb of the Palaeoproterozoic core was cut off by a thrust resulted from south-directed movements, and an estimate of the thickness was 875 m. They mentioned an antiformal shape of this structure; nevertheless they classified it as "a false anticline" and had no doubt about its synclinal character. However, data on the polarity of bedding which could confirm the synclinal character of the Serpovidny Ridge Fold have not been reported. Then *Milanovsky* (1984) suggested that the entire Serpovidny Ridge Fold represents a collage of tectonic lenses and sheets. V.Z. Negrutsa (*Negrutsa, Negrutsa*, 2007) supposed that the Palaeoproterozoic fold core is an outlier of a nappe that came from the Palaeoproterozoic Imandra–Varzuga Rift located *ca*. 50 km south of the Serpovidny Ridge. After all, *Balagansky et al.* (2011) reported magnetic data and poor field observations that favour a synformal character of the fold core and suggest its sheath-shaped morphology. The length of the sheath is estimated at *ca*. 4-5 km.

Our study has focused on the following main aims: (i) deciphering the internal structural pattern of the Palaeoproterozoic core, which is called hereafter the Serpovidny Belt, based on detailed magnetic survey, geological mapping and field observations; (ii) reconstructing the shape of the Serpovidny Ridge Fold from orientation data; (iii) determining the polarity of bedding in metasedimentary rocks of the Serpovidny Belt in order to identify it as a syncline, a synformal anticline or a normal anticline; (iv) studying kinematic record in Palaeoproterozoic and the surrounding Keivy metasedimentary rocks, and (v) measuring bulk strain in deformed amygdaloidal metabasalts.

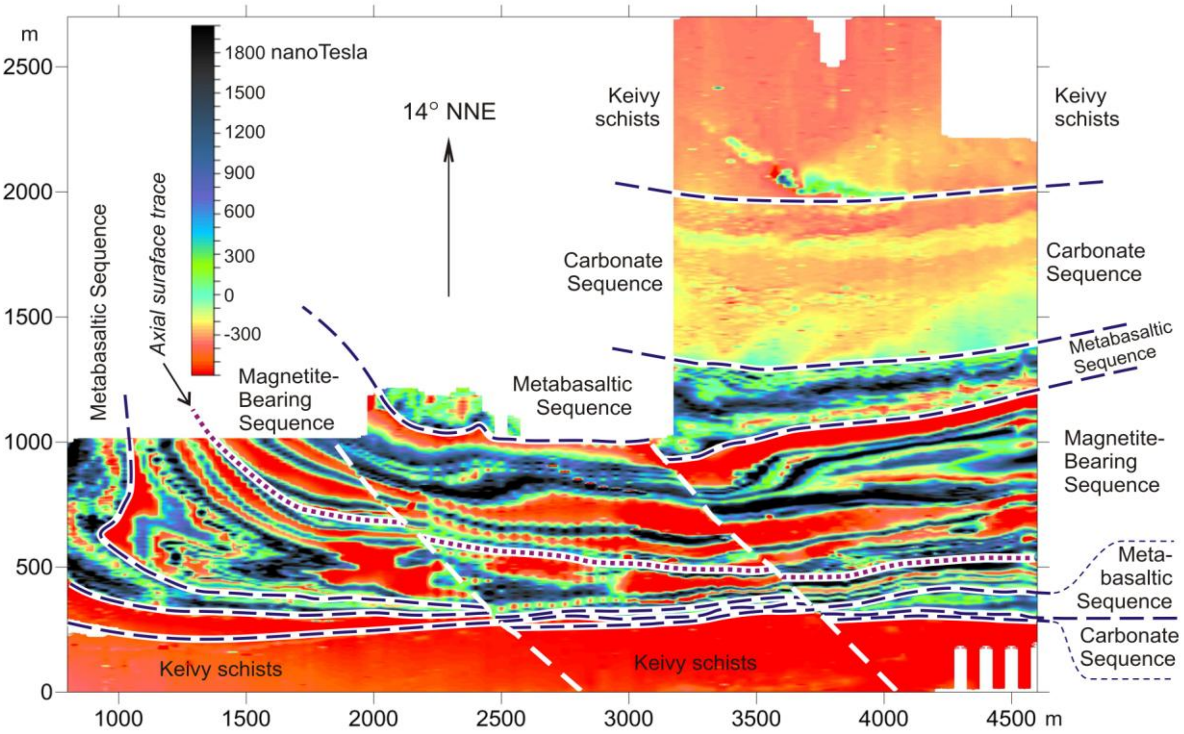

Fig. 2. Map of local magnetic anomalies of the central and south-western parts of the Serpovidny Belt as the core of the Serpovidny Ridge Fold

2. General structural pattern of the study area

A detailed magnetic survey combined with geological mapping, like an X-ray investigation, has revealed the structure of the central and south-western parts of the Serpovidny Belt in detail (Fig. 2). First, it has confirmed that the Serpovidny Belt consists of three sequences: Metasedimentary Carbonate-Bearing, Metabasaltic and Metasedimentary Magnetite-Bearing (respectively, the Northern, Middle and Southern sequences in *Balagansky et al*., 2011). These are deformed into an eyed isoclinal fold, the axial surface of which dips northwards at an intermediate angle (Fig. 3). Second, it has shown that the structural pattern of the Magnetite-Bearing Sequence is rather complicated. This sequence is deformed into tight to isoclinal folds of different orders, meso-scale *s*-shaped structures, pinches and swells. The development of these structures was accompanied by faults (sub)parallel to bedding (Fig. 2). Third, it has revealed that the southern limb of the Serpovidny Belt is extremely thinned rather than cut off by a fault, and this is the most important conclusion. The visible thickness of the Carbonate-Bearing Sequence of the belt is *ca*. 700 m in the northern, almost undeformed limb whereas it is 15-20 m in the southern limb (Figs. 2 and 3). In the southern limb rocks of all types are extremely lineated and sheared, which along with very poor exposures did not allow us and many precursors to correlate them with their undeformed counterparts in the northern limb before the present work.

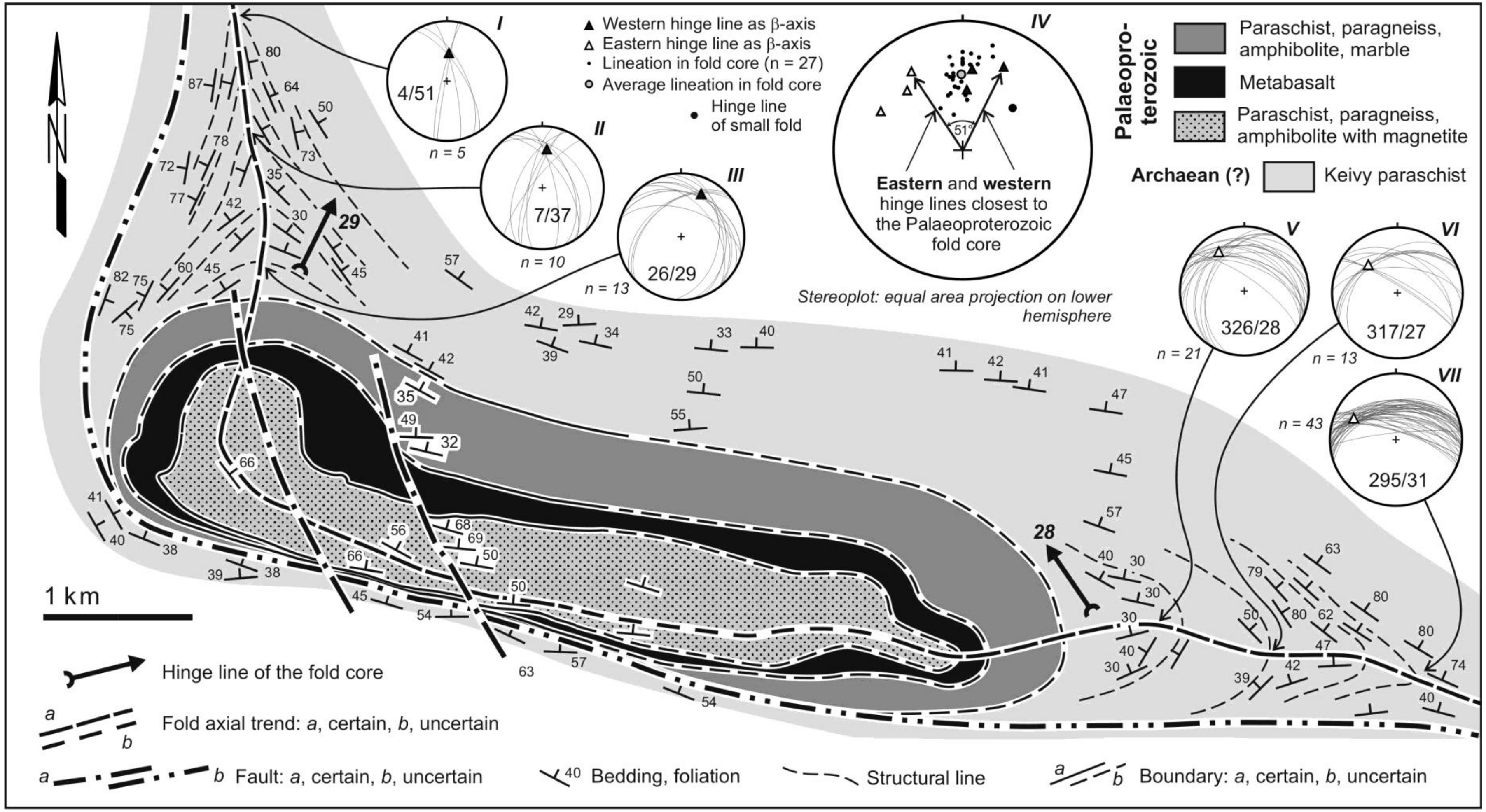

Fig. 3. Geological map of the Serpovidny Belt based on authors' magnetic data and field observations (a few orientation data taken from the state geological maps)

3. Fold morphology

The western and eastern hinges of the Palaeoproterozoic Serpovidny Belt (the core of a large fold) are not exposed. In contrast, the western and eastern closures of Keivy muscovite-biotite schists that envelop Palaeoproterozoic rocks and together with them are folded into the Serpovidny Ridge Fold are exposed enough for establishing the morphology of this fold (Fig. 3). Geometrical analysis of orientation data for relic bedding and foliation, parallel to each other in almost all exposures, has shown that a hinge line in the eastern closure of Keivy metasedimentary schists near to the hinge of the Palaeoproterozoic core plunges to the NW at an angle of 28° (Fig. 3, plot V), which defines this closure as centroclinal at the E-W trend of its axial surface. In the western closure the hinge line plunges to N–NE at the same angle (Fig. 3, plot III), defining the closure as periclinal at the N-S trend of its axial surface. The angle between these hinge lines is 51°, and a stretching lineation plunging northwards subdivides this angle into two almost equal parts (Fig. 3, plot IV). A structural pattern of this type is nearly identical to that for mesoscopic sheath folds in the core of a mega-sheath fold in the Oman Mountains (*Searle, Alsop*, 2007). These orientation data unambiguously indicate a sheath-like shape of the Serpovidny Ridge Fold. Metres-scale sheath folds also have been observed in the Keivy Metasedimentary Belt.

Judging from the orientation data, we estimate the length of sheath composed of Palaeoproterozoic rocks to be a few kilometres, which is consistent with an estimate calculated from magnetic data (*Balagansky et al*., 2011). Based on the attitude of the calculated hinge lines, we conclude that the axial surface of the Serpovidny Ridge Sheath Fold should dip northwards at an angle of 35-40°.

4. Sedimentary structures

Parallel bedding is typical for all Palaeoproterozoic metasediments. Sedimentary structures that indicate the polarity of bedding have been observed only in seven exposures in the northern limb and in one exposure in the southern limb. They are represented by cross-bedding, graded bedding, and erosion surfaces. All these types of bedding occur together in one and the same exposure of magnetite-bearing quartzitic gneisses (Fig. 4A). Unambiguous graded bedding in garnet-muscovite-biotite-quartz schists has been observed only in one exposure.

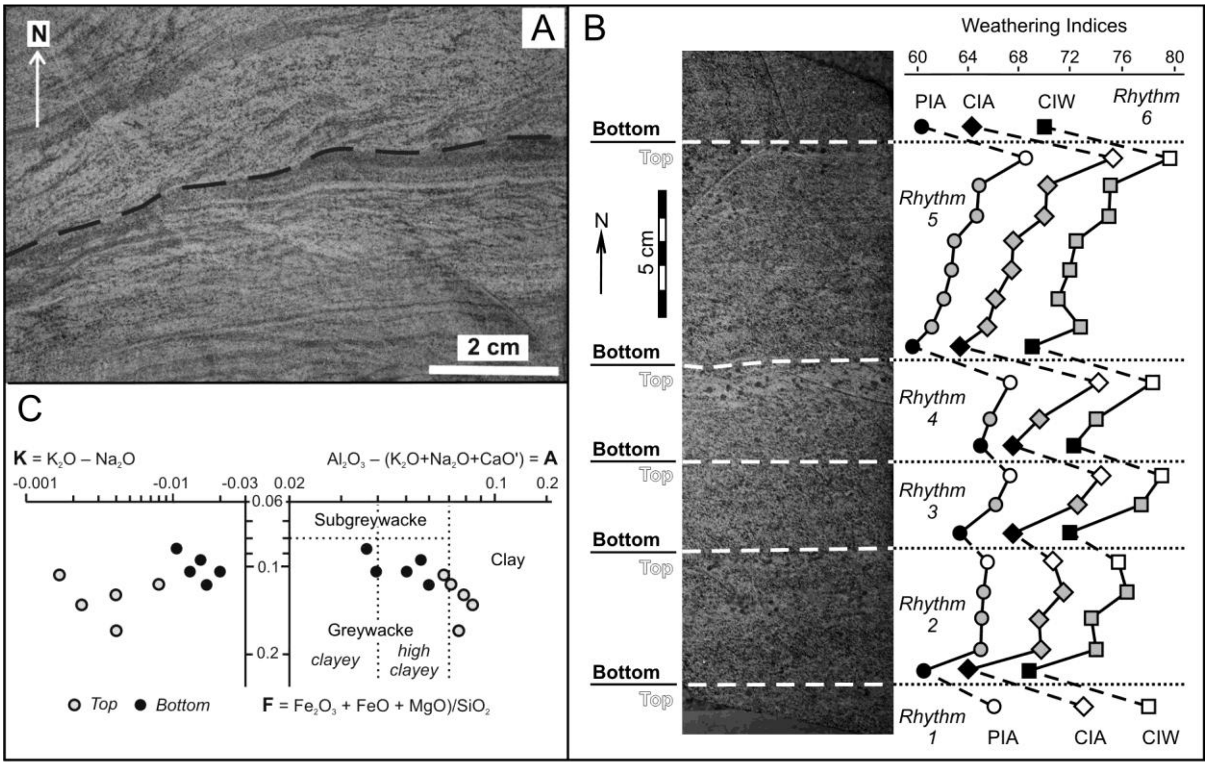

Fig. 4. (A) Parallel and cross-bedding, and erosion surface (dashed) in a magnetite-bearing quartzitic gneiss (dark = mainly magnetite, grey = quartz). (B) Graded bedding, dipping steeply northwards, and weathering indices for its lower, intermediate and upper parts in a garnet-muscovite-biotite-quartz schist from the Magnetite-Bearing Sequence of the Serpovidny Belt (PIA = Plagioclase Index of Alteration, *Fedo et al*., 1995; CIA = Chemical Index of Alteration, *Nesbitt, Young*, 1982; CIW = Chemical Index of Weathering, *Harnois*, 1988). (C) FAK plot (*Predovsky*, 1980; molar proportions) for top and bottom of graded bedding in the schist shown in (B)

In this exposure layers have rather sharp boundaries with both underlying and overlying layers. The lower part of each layer is composed of biotite, quartz and minor garnet and muscovite, and is gradually changed into the upper part of the layer, which consists of garnet, muscovite, quartz and minor biotite. The chemical composition of bottom, intermediate and top parts of layers of this type is well consistent with the given grading: the weathering degree within a layer increases from its bottom to top (Fig. 4B). Sedimentary protoliths of the top are reconstructed as clay and of the bottom as clayey and high clayey greywacke (Fig. 4C). All these data indicate the normal polarity of bedding in the northern limb of the Serpovidny Belt (fold core) built up by Palaeoproterozoic rocks. The only observation of graded bedding in the southern limb suggests the reverse polarity. Therefore, the Serpovidny Belt is a synformal anticline.

5. Kinematic indicators

Numerous centimetres-scale structures displaying the monoclinic symmetry have been found in Palaeoproterozoic rocks of the Serpovidny Belt and high-alumina schists of the Keivy Metasedimentary Belt (Fig. 5). Structures of this kind are widely used as kinematic indicators in sheared rocks (σ- and δ-structures, *c–s*-mylonites, *Ramsay, Huber*, 1987; *Hanmer, Passchier*, 1991). Three deformational events have been established in rocks of the Serpovidny Belt. The earliest deformational structures have been observed only in a few thin-sections as relics and are interpreted to have been formed by top-to-the-north movements. Younger structures suggest top-to-the-south movements and, like the earliest ones, were formed under conditions of amphibolite facies. The youngest structures are formed by chlorite, developed under greenschist-facies conditions and indicate top-to-the-north movements.

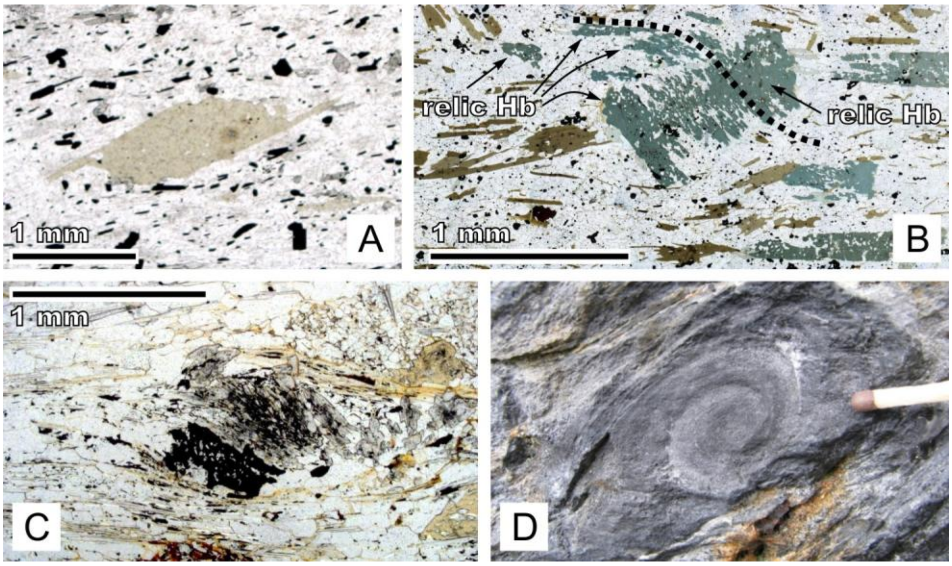

Fig. 5. Monoclinic structures in rocks of the Serpovidny (A-B) and Keivy Metasedimentary belts (C-D). (A) A biotite porphyroblast in a magnetite-biotite-muscovite-quartz paraschist. (B) A bent relic of older hornblende (Hb) in a chlorite-biotite-amphibole paraschist. (C) A bent kyanite grain in a staurolite-kyanite-quartz paraschist. (D) A rotational structure in the matrix of a staurolite-kyanite-quartz paraschist. (A-C) Thin-sections (transmitted light) parallel to stretching lineation and normal to foliation (the XZ plane of the finite strain ellipsoid). (D) Vertical erosion surface of an exposure almost coinciding with the XZ plane. All of these structures suggest top-to-the north movements (in the modern geographic coordinates)

In Keivy schists that surround the Serpovidny Belt from the north (muscovite-biotite-quartz schists and muscovite-quartzitic schists), we have observed kinematic indicators suggesting only top-to-the-north movements. In kyanite-bearing schists of the Keivy Metasedimentary Belt nearly all of kinematic indicators are formed by kyanite, locally along with staurolite. Furthermore, the overwhelming majority of kyanite crystals display a prominent lineation which plunges northwards, i.e. it is parallel to the lineation in the Serpovidny Belt. Data available now for the Keivy Metasedimentary Belt suggest top-to-the-north movements that occurred under amphibolite-facies conditions.

Sheath folds also are kinematic indicators. The general morphology of the Serpovidny Ridge Sheath Fold strongly suggests that it resulted from north-directed movements, and its dimensions indicate a rather considerable displacement (not less than tens of kilometres). The fact that the Serpovidny Sheath Fold is a synformal anticline is well consistent with movements to the north. All of small sheath folds found in the

Keivy Metasedimentary Belt (Fig. 6) also suggest only top-to-the-north movements. Finally, we conclude that the north-directed movements developed under amphibolite-facies conditions (kyanite-bearing assemblages in Keivy paraschists and relic hornblende-bearing in the Serpovidny Belt) were responsible for the formation of the Serpovidny Ridge Sheath Fold as a component of the Keivy Belt of super-large sheath folds and faults established by *Balagansky et al.* (2011).

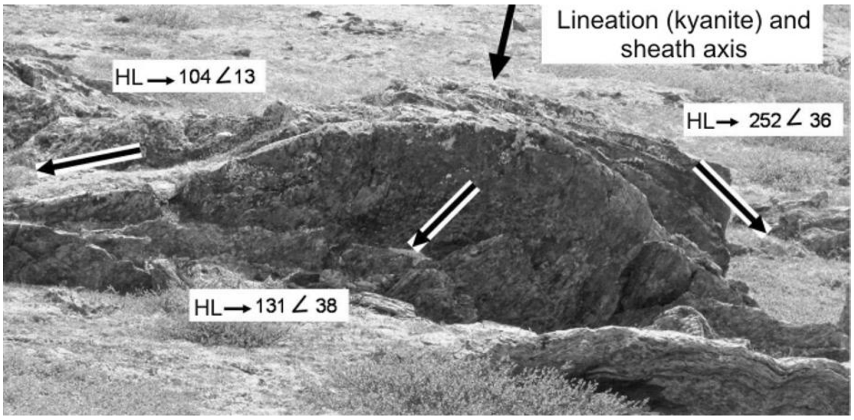

Fig. 6. A sheath fold in a kyanite-bearing schist of the Keivy Metasedimentary Belt; the height of exposure is *ca*. 3 m (HL, hinge line; Kolokol'naya Mountain, Central Keivy Highlands)

6. Strain analysis

Metabasalts have been chosen for the strain analysis. Undeformed varieties of these rocks in the northern limb of the Serpovidny Belt often contain almost isometric amygdales filled with calcite and epidote whereas amygdales in deformed varieties in the southern limb are strongly flattened and stretched (Fig. 7). Presence of these amygdales makes rocks suitable for the strain analysis. First results show that the X/Z ratio in deformed metabasalts located as far as 100 and 10 m from a contact of the southern, lower limb with the underlying Keivy schists (the central part of the belt) is *ca*. 13 and *ca*. 25, respectively. Strain ellipsoids are prolate and plotted into the apparent constriction field on the Flinn graph. It should be pointed out that practically undeformed rocks are widely spread already at a distance of *ca*. 400 m from the contact.

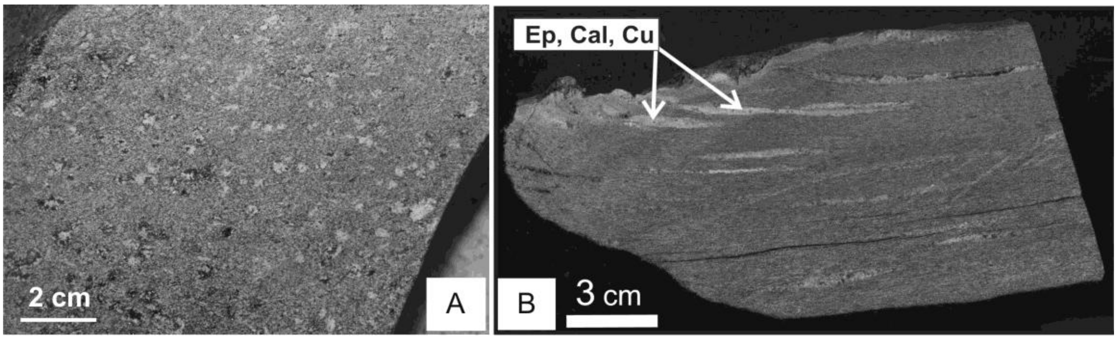

Fig. 7. (A) Isometric and (B) flattened amygdales filled with calcite and epidote in metabasalts from the northern and southern limbs of the Serpovidny Belt, respectively (Ep, epidote; Cal, calcite; Cu, native copper)

7. Discussion and conclusions

Foreland of Phanerozoic collisional orogens provides spectacular evidence for significant horizontal shortening and displacement of upper portions of crust composed of sedimentary rocks. Two tectonic styles of deformation can be observed in the foreland, and these are defined by a reaction of a depositional crystalline basement to horizontal shortening: thin- and thick-skinned deformation (*van der Pluijm, Marshak,* 2004). If the former occurs (thin-skinned tectonics), total deformation is accommodated within a sedimentary cover, and thrusts, ramps, thrust-related folds and structures develop above a basal detachment that separates the deformed cover from its undeformed basement (Fig. 8A). But if the latter takes place (thick-skinned tectonics), both a sedimentary cover and its basement are deformed. In this case a structural pattern of the sedimentary cover becomes more complicated because the basement is broken into tectonic blocks, and horizontal shortening uplifts these basement blocks along reverse faults and cause monoclinal drape folds to develop in the sedimentary cover (Fig. 8B). In foreland of younger fold-thrust belts a combination of thin- and thick-skinned tectonics is common: thick-skinned deformation begins at later stages of thin-skinned tectonics, when reverse faults inherit pre-orogenic normal faults in a basement (*Tozer et al.*, 2002; *Molinaro et al.*, 2005; *Scrocca et al.*, 2005; *Madritsch et al.*, 2008). In spite of that the structure of terrains experienced both thin- and thick-skinned deformation is rather complex, their structural pattern are specific and can be easily recognized.

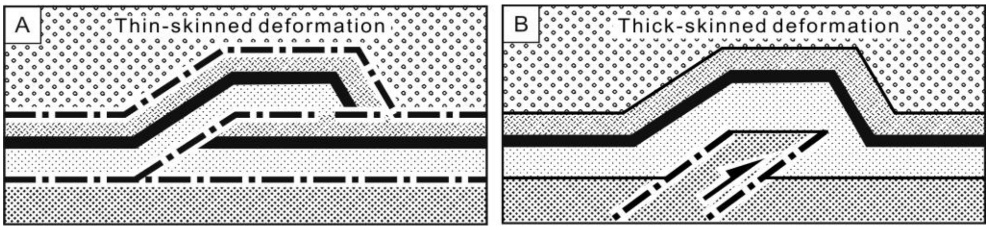

Fig. 8. (A) Thin-skinned deformation resulted from horizontal shortening of sedimentary cover and (B) thick-skinned deformation caused by horizontal shortening of this cover and the underlying basement

Further, we should take into account that by the onset of the Lapland–Kola Orogeny the Keivy Terrane had consisted of the Archaean crystalline basement, Neoarchaean (?) platform cover (the Keivy Belt of quartzitic and high-alumina sediments), and the overlying Palaeoproterozoic rift-related sequences (*Zagorodny, Radchenko*, 1983; *Mitrofanov et al.*, 1995). The lower part of the basement was built up mainly of granitoids while the upper part was composed of the Lebyazhka felsic volcanics and peralkaline granites. These supracrustal rocks underwent amphibolite-facies metamorphism and coeval deformation only in the Palaeoproterozoic at $T = ca.\ 600°$ and P = 6-7 kbar (*Glazunkov, Petrov*, 1990), which corresponds to a depth of 20-25 km. It is this depth that is related to a detachment that separates rocks undergone Palaeoproterozoic collisional deformation and rocks free of this deformation (*Balagansky et al.*, 2011).

A schematic section across the Keivy Terrane and adjacent tectonic units based on data given above and taken from the literature (*Mints et al.*, 1996; *Daly et al.*, 2006) is presented in Fig. 9A. It can be seen easily that this section displays both principal distinction from and similarity to those shown in Fig. 8. The main similarity is that there is an association of strongly deformed rocks and the underlying undeformed ones in both the Keivy Terrane (the north-eastern foreland of the LKO) and foreland of Phanerozoic collisional orogens on a regional scale (for example, see Fig. 18.3 in *van der Pluijm, Marshak*, 2004). This similarity has resulted from a considerable horizontal shortening that detached supracrustal rocks from a basement avoided this deformation.

The first main distinction is that supracrustal sequences consisting of the Keivy metasedimentary schists and the Palaeoproterozoic rocks have not experienced conventional both thin- and thick-skinned deformation in spite of that these sequences were detached from the Archaean undeformed basement. *Balagansky et al.* (2011) referred faults parallel to boundaries between layers in the Serpovidny Belt to thin-skinned deformation but a newly mapped part of the belt has provided evidence that these faults are better interpreted in terms of accommodation of deformation within the core of the Serpovidny Ridge Sheath Fold rather than thin-skinned tectonics. The Lebyazhka felsic metavolcanics and peralkaline granites that make up the upper part of the Archaean basement compose large sheet-like bodies structurally concordant to the Keivy Metasedimentary Belt rather than uplifted tectonic blocks which could have caused drape folds to develop in the Keivy schists (see Figs. 1B and 9). The second main distinction is the depth of development of the basal detachment below which the crust was not deformed. Both thin- and skinned tectonics are limited by the upper crust (its thickness is 10-12 km; *Rudnick, Fountain*, 1995) whereas shearing and lineazation caused by the development of the Serpovidny Ridge Sheath Fold took place at a depth of 20-25 km, which corresponds to the transitional zone between the middle and lower crust. At last, the third distinction is connected with a specific structure of the detached middle crust, which is defined by super-large sheath folds which are recumbent as a whole. Similar kilometre-scale recumbent sheath folds have been described in orogenic complexes of the Alps (*Lacassin, Mattauer*, 1985) and the Oman Mountains (*Searle, Alsop*, 2007) where they are tightly connected with large-scale thrusts and transport direction.

We believe that the Serpovidny Ridge Sheath Fold could be compared with the Helvetic nappes in the Alps (Fig. 9). These nappes are represented by giant recumbent folds separated from the undeformed basement by a basal thrust. The lower limbs of these folds are thinned while the upper limbs display very weak or no deformation. The most striking fact is that noses of many Helvetic fold-nappes, like the nose of the Wadi Mayh Mega-Sheath Fold in Oman, present synformal anticlines. Shape of the sheath folds in question strongly reflects kinematics of movements that forced the folds to develop.

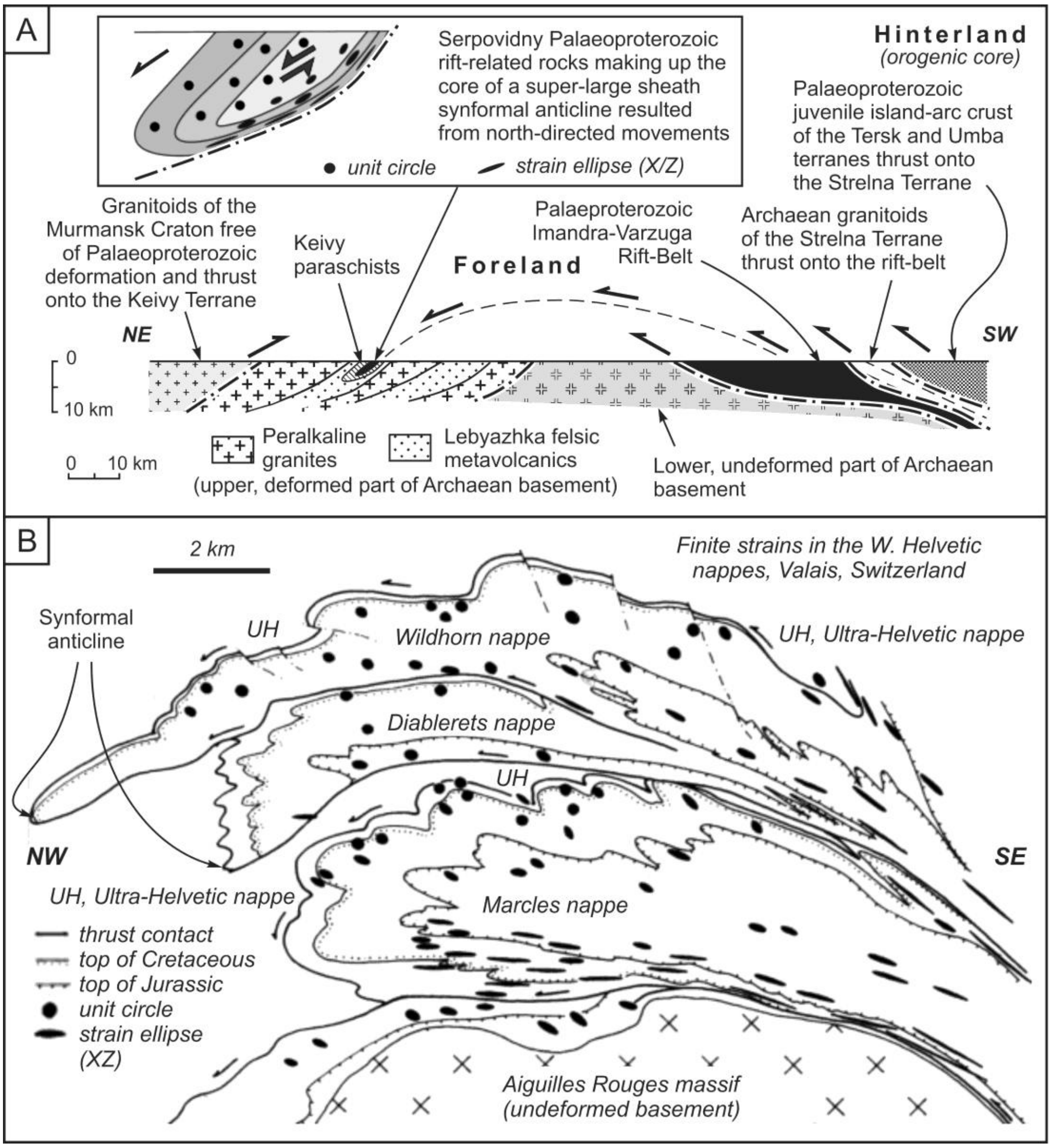

Fig. 9. (A) Schematic profile section across the Keivy Terrane and major structural features of the Palaeoproterozoic core of the Serpovidny Ridge Sheath Fold. (B) Profile section showing the shapes of the XZ principal plane strain ellipses in the Helvetic nappes in the Alps (*Ramsay, Huber*, 1983)

All of these peculiarities are typical for the Serpovidny Ridge Sheath Fold (Fig. 9A), which allows us to conclude that the Serpovidny Belt as the fold core represent an outlier of a Helvetic-type nappe that came from the Palaeoproterozoic Imandra-Varzuga Rift-Belt located *ca*. 50 km south of the Serpovidny Ridge. We suppose that the Lebyazhka felsic metavolcanics and peralkaline granites belonging to the upper part of the Archaean basement make up tectonic sheets which underlie the Helvetic-type nappe. These Archaean metavolcanics and granites are weakly deformed but their most marginal parts are strongly sheared and lineated coevally with the Keivy schists and Palaeoproterozoic rocks. These tectonic sheets could be classified as Penninic-type nappes, which overlie granitoids of the lower part of the Archaean basement exposed in the south-western part of the Keivy Terrane (Fig. 1B) and free of Palaeoproterozoic deformation. This part of the basement is considered as a tectonic window 90 × 20 km in size.

The north-oriented dip of rocks in frontal parts of nappes near the Murmansk Craton could be explained by both a specific internal structure of Helvetic-type nappes (see Fig. 9B) and south-directed thrusting of the Murmansk Craton onto the Keivy Terrane (*Mints et al.*, 1996). If so, the Keivy Belt of super-large sheath folds and thrusts should have been a locus in which tectonic sheets came from the south and north and were stacked there during collision. The change in dip of thrusts is established in the Himalayas, and mechanisms leading in this change (*Coward*, 1983) also could be implied in the Keivy Terrane, but this idea needs a further study.

The Palaeoproterozoic deformation and the tectonic position of the Keivy Terrane are consistent with a spatio-temporal succession of tectonic processes according to which a Palaeoproterozoic supercontinent, a fragment of which is the Baltic Shield, was formed (*Balagansky et al*., 2011). This succession had started with tectonics of detached middle crust in the Keivy Terrane in the north-eastern Kola Region *ca*. 1.97 Ga ago. The tectonics of detached middle crust heralded the onset of the Lapland–Kola Collisional Orogeny the peak of which occurred 30 Ma later in the orogenic core located south-south-west of the Keivy Terrane. Collision was intercontinental and resulted in amalgamation of the Archaean Kola and Belomorian provinces and the intervening Lapland, Umba and Tersk terranes, composed of Palaeoproterozoic juvenile crust (*Daly et al*., 2006). It was later followed by collision of microcontinents with the supercontinent just south-west of the Belomorian Province at 1.92-1.89 Ga (the Lapland-Savo Orogeny as the earliest event of the complex Svecofennian Accretionary Orogeny) and then by accretion of island-arc terranes farther to the south-west and south at 1.87-1.84 Ga and 1.83-1.80 Ga (Fennian and Svecobaltic orogenies, respectively; *Lahtinen et al*., 2008).

So, we deal with a specific horizontal tectonics in the north-eastern foreland of the Palaeoproterozoic Lapland–Kola Collisional Orogen. In contrast to Phanerozoic collisional orogens, this tectonics differs in that horizontal shortening resulted in development of a basal detachment at the boundary between the middle and lower crust rather than between the upper and middle crust, and formation of the Keivy Belt of super-large sheath folds and thrusts (*Balagansky et al*., 2011). The upper tectonic sheets have been represented by Helvetic-type nappes, which have been completely eroded, apart from the Serpovidny Ridge Outlier 8 × 2 km in size. We classify this specific Palaeoproterozoic foreland tectonism as tectonics of detached middle crust, which seems to be a counterpart of thin-skinned tectonics that occurs in the upper crust of foreland of Phanerozoic collisional orogens. Differences between Palaeoproterozoic tectonics of detached middle crust and Phanerozoic thin-skinned tectonics appear to reflect some irreversible changes in the operating mechanism of the plate tectonics that have occurred since the Palaeoproterozoic when the Earth had more energy and its interior was hotter (*Tolstikhin, Kramers*, 2008).

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