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Review

of the *member* of the dissertation council for the dissertation of **Gorbunov Ilia Aleksandrovich** on the topic: "Paleoproterozoic kinematic reconstruction in the Keivy Terrane, Northeastern Fennoscandian Shield", submitted for the degree of *candidate/doctor* of geological and mineralogical sciences in scientific specialty 1.6.1. General and regional geology. Geotectonics and geodynamics.

Summary evaluation.
My conclusion is that the dissertation clearly meets the standard for the award of the degree. The application of kinematics on the scale of an orogen is an important although challenging topic, especially since the Lapland-Kola belt is an ancient and deeply eroded orogenic belt. The dissertation represents a substantial body of work that employs appropriate methods of strain analysis and the recording and interpretation of kinematic indicators. This demonstrates the candidate's competence as a structural geologist. Many of the examples illustrated in the dissertation seem to be to be very difficult to interpret so that it is clear that the candidate has not had any easy task in investigating these rocks. Despite this, some of the work is highly innovative - especially the discovery, documentation and interpretation of the "spiral pods" (chapter 5), which the candidate has published as first author in the highly prestigious *Journal of Structural Geology*. For me, publication as first author in an international journal is one of the key criteria for the award of the degree.

While Chapter 5 is the most detailed part of the dissertation, other chapters, e.g. Chapter 4 are a little short on detail. In places I would like to have seen more of the raw data and observations upon which the interpretation and conclusions are based.

Detailed evaluation and questions for the candidate
Below, each chapter is reviewed in turn pointing out the strengths and weaknesses and posing questions (marked "**Q.**" below), which I look forward to hearing the candidate answer.

The dissertation is organized into eight chapters. The **introduction** sets out the scientific context as well as the aims of the study and concludes with a clear statement of the conclusions that the candidate will defend. The novelty and relevance of the work is also clearly explained and a list of the author's publications is provided.

Chapter 1 provides a concise review of the Fennoscandian Shield explaining the broader geological and tectonic context of the study. **Chapter 2** is a general review of the Keivy Terrane, including a summary of the various versions of the stratigraphy within the Keivy schist. The three study subareas (Serpovidny, Shuuruta-Yagelurta and Manyuk) in which detailed structural work has been carried out are identified. **Chapter 3** presents a study of strain and kinematics of the Serpovidny Synform (giant sheath fold). **Chapter 4** briefly discusses the kinematic reconstruction of the central and eastern parts of the Keivy Schist Belt focusing on the Shuururta-Yagelyurta and Manyuk areas. **Chapter 5** is a substantial document setting out an account of "spiral pods", a new

shear sense indicator discovered by the candidate. The content of this chapter is published in the Journal of Structural Geology. **Chapter 6** discusses the kinematics of the Keivy Schist Belt in a regional context. A final short chapter sets out the "conclusions" of the dissertation. A **reference list** is also provided. An **appendix** shows photographs of the cut slabs used in the strain study in Chapter 3. Sample 7 is missing from this appendix.

Chapter 3 is a substantial body of work detailing the results of a study of strain and kinematics of the Serpovidny Synform (giant sheath fold). This study makes use of observations within the Serpovidny Complex and also from the surrounding Keivcy Schists. The work is well documented especially in the Serpovidny fold itself. Unfortunately fewer locations are provided for the shear-sense observations made within the Keivy shists.

Q. Please explain why you consider the major Serpovidny structure to be thrust-related, i.e.. to be a compressional structure. What are the compelling arguments against this being an extensional feature?

> I ask this because the local kinematic indicators on both limbs of the Serpovidny fold indicate top to the south movements, i.e., DOWN-dip within the rocks of the Serpovidny Complex. Since the layering and foliation dip northwards, these movements would appear to be extensional not compressional and therefore are not thrust movements. Similar kinematics are shown within the Pestsovaya Tundra psammites.

Q. Related to this kinematic point, in the text (p. 181 under the heading "shear-sense indicators analysis"), you say that the shear sense indicators indicate northward directed transport. Can you please place this statement in context. Firstly where were these observations made; what is the general dip direction at these places and do they indicate compression or extension?

Q. At what stage in the tectonic development of the Keivy Schist did (a) the staurolite, (b) the kyanite and (b) cordierite grow?

Q. Please explain how you derive kinematic information from Fig. 3.18 C and D. Please also show on a map where this sample was located.

Q. Considering that the strain measurements higher up in the structure were made at four sub-localities (samples 3-6), what is the reason for not replicating the strain measurements near the base of the structure (sample 7 – whose photograph is unfortunately also missing from the Appendix)?

Q. Using figures 3.13 and 3.14, please explain your kinematic interpretations of sample 909-2, which apparently records three successive movement directions (e.g. as in Fig. 3.11).

Chapter 4 discusses the kinematic reconstruction of the central and eastern parts of the Keivy Schist Belt focusing on observations on shear sense indicators in the Shuururta-Yagelyurta and Manyuk areas. Near the beginning of the chapter, the Lebyazhka metavolcanics are mentioned but there is very little information beyond the fact that these rocks are sometimes deformed and sometimes not. It is claimed here as well as in Chapter 6 that the strain is higher in the Keivy schists than in the metavolcanics but this is not substantiated. There is more information about the Keivy schists but this aspect of the chapter is difficult to evaluate because although maps are provided showing the interpreted thrusting direction at the several localities, the various field photographs and photomicrographs are not located. It would appear that the candidate has worked mainly on the Chervurta Formation but this unit is not shown on Fig. 4.11. In general the candidate's conclusions are clearly shown (e.g. on Fig. 4.11) but the primary data are less well documented. For example, the lineations are not plotted on either of the maps (Figs 4.11, 4.12) and no structural information is provided on the map of the Manyuk area (Fig. 4.12 A) yet these data clearly exist (Fig. 4.12B). It is essential to know the location of the samples in order to evaluate the kinematic information independently. Kyanite lineations are said to be "generally N-S trending", i.e. towards the SSE (169) but there are a small number that plunge the other way. It is important to know where these measurements were made. I assume they were made over a representative area but it is impossible to know. Similarly it is important to know if these lineations are parallel to the layering and foliation.

Q. Given the apparent widespread devolvement of S-C fabrics in the Keivy Schists, which foliation plane is plotted on the maps (e.g. Fig. 4.11)? Is it S or C? What are the dip values?

Q. On a smaller (more local scale, e.g. Fig. 4.11) there is a substantial variation in the dip and strike of the foliation. In some cases the interpreted thrusting direction is associated with generally southward dipping layering/ foliation but elsewhere this is less clear. What is the shear sense in the places where the dip is towards the northeast or northwest (Fig. 4.11)?

Q. Why, in some cases, is the thrusting direction (Fig. 4.11) apparently at a high angle to the foliation plane rather than normal to it?

Q. In the Yagelurta Mt area, amphibolite bodies are present (Fig. 4.11). Are these also "rift-related" as in the Seropvidny area? Are they deformed? Does proximity to the amphibolites influence the strain and the kinematics within the Keivy Schist rocks? Which unit of the Keivy schist A map would also help to understand the geology in which these structures are developed

Q. Muscovite and kyanite lineations (data of Batieva) are plotted <u>together</u> in Fig. 4.3. At individual locations are these parallel to one another or if plotted separately, do they generally diverge? How is the muscovite lineation developed – is this due to the replacement of kyanite by muscovite? Where were Batieva's measurements made? – they seem to be very different from the candidate's.

Q. In general, S-C fabrics are probably best developed (and recognised) in homogeneous materials. Here, the C planes are said to be compositional banding planes – are these original or due to pressure solution?

Q. Was the angle between S and C measured and does it vary spatially?

Q. As illustrated (Fig 4.10), it would appear that the S planes meet the C plane abruptly rather than asymptotically. Is this the case? Please explain how these structures develop.

Q. Unfortunately it is hard to see the details of the individual mineral textures in the photmicrographs (Fig. 4.10). Which minerals define the S-planes, e.g. in Fig. 4.10B?

In contrast with the Yagelurta area, more stratigraphic detail is given for the Keivy schists in the Manyuk area (Fig. 4.12), but there is no structural information (no foliations or lineations) on the map.

Q. Is it possible that the high angle between the fold hinge lines and the lineations is due to successive deformations i.e. refolding?

Q. Why do you think kinematic indicators are apparently absent in the Manyuk area?

Chapter 5 sets out an account of "spiral pods", a new shear sense indicator discovered by the candidate. The content of this chapter is published in the Journal of Structural Geology. This paper has been thoroughly reviewed and is clearly an excellent piece of work.

Q. Please outline the circumstances in which spiral pods are likely to be found in nature. Are you aware of other examples?

Chapter 6 discusses the kinematics of the Keivy Schist Belt in a regional context.

Q. What is the evidence for the tectonic transport direction shown for the Manyuk area in Fig. 6.2?

Considering the above, I believe that **Ilia Aleksandrovich Gorbunov's** dissertation on the topic: "Paleoproterozoic kinematic reconstruction in the Keivy Terrane, Northeastern Fennoscandian Shield" meets the requirements of scientific specialty 1.6.1. General and regional geology. Geotectonics and geodynamics.

The dissertation is

A scientific qualification work that resolves a scientific problem important for the development of the relevant field of science *or* provides new science-based technical, technological or other solutions and developments vital for the national development.

No violations of paragraphs 9 and 11 of the Order No.11181/1 as of November 19, 2021 "On the Procedure for Awarding Academic Degrees at St. Petersburg State University" have been detected.

The dissertation meets the criteria of dissertations for the academic degree of candidate of sciences, established by the specified Order. The dissertation is recommended for the defense at St. Petersburg State University.

Member of the dissertation council
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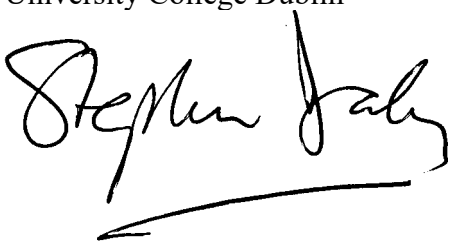

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