Subject: Assessment of the Doctoral dissertation

Title: ***Imaging the East European Craton margin by reprocessing and interpretation of the PolandSPAN reflection seismic profiles supported by machine learning.***

By: ***Milosz Mezyk***

a) General Assessment of the PhD thesis.

The manuscript presented by Milosz Mezyk aims to be a short summary of the work carried out in order achieve all the requirements for the Degree of Doctor of Philosophy in the field of Geophysics. It is difficult to go over all the details concerning the knowledge, research achievements and/or the original work that the author has been able to developed over the few years that he has employed in pursuing this objective. This thesis volume has been developed within the framework of the ION Geophysical PolandSPAN seismic reflection data set. The data acquisition was designed to image the structure of the sedimentary basin down to the basement, thus the Vibroseis shot records once correlated reach down to 12 s. This control source (Vibroseis) dataset is used by the candidate to image beyond the base of the crust by applying an extended correlation processing scheme, building up on previous. The resulting images are used by the author to unravel the crustal structure of the Eastern European Craton (EEC) of Fennoscandian and Sarmatian affinity concealed under the thick Phanerozoic Cover. The main objective is to provide new knowledge on the exact character of the Paleozoic suture between both major crustal components which remain speculative as they were only based on earlier refraction and/or wide-angle seismic reflection data. Thus the candidate during the development of his degree has acquired the basic knowledge in Structural Geology, Control source seismic data acquisition, Digital signal processing, among other thematic areas, the general knowledge on these subjects has lead him to developed a number of new and original scientific contributions which have been published in international research journals. These include:

Mężyk, M., Chamarczuk, M., Malinowski, M. Automatic image-based event detection for large-n seismic arrays using a convolutional neural network, Remote Sensing, 2021, 13(3), pp. 1–18, 389

Mężyk, M., Malinowski, M. Multi-pattern algorithm for first-break picking employing open-source machine learning librariesJournal of Applied Geophysics, 2019, 170, 103848

Mezyk, M., Malinowski, M., Mazur, S. Imaging the East European Craton margin in northern Poland using extended correlation processing of regional seismic reflection profiles, Solid Earth, 2019, 10(3), pp. 683–696

Chamarczuk, M., M. Malinowski, Y. Nishitsuji, J. Thorbecke, E. Koivisto, S. Heinonen, S. Juurela, **M. Mężyk,** and D. Draganov, (2019), "Automatic 3D illumination-diagnosis method for large-N arrays: Robust data scanner and machine-learning feature provider," GEOPHYSICS 84: Q13-Q25.

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Mezyk, M., Malinowski, M. Deep Neural Network and Multi-pattern Based Algorithm for Picking First-arrival Traveltimes, 80th EAGE Conference and Exhibition 2018: Opportunities Presented by the Energy Transition, 2018

Dupuy, B., Torres, V.A.C., Ghaderi, A., Querendez, E., **Mezyk, M.** Constrained AVO for CO2 Storage Monitoring at Sleipner, Energy Procedia, 2017, 114, pp. 3927–3936

The first three journal contributions constitute the many body of the presented thesis volume. The fact that his work has been published in international leading edge journal, is evidence that his research is original, relevant and is of interest to the research community working within this area of knowledge. It is also important that these contributions have already been cited by a number of other research indicating that the candidate's results are useful and constitute solid evidences upon which new knowledge can rely.

It is relevant to point out that the full, complete analysis, processing and interpretation of the PolandSPAN data set has revealed unprecedented and unique high resolution images of the crust down and beneath the Moho of the EEC. These images are a result of new and original ideas the pursue of which required the design, development of new codes, new software tools that need to be implemented within processing flows. Work that the candidate carried out to obtain the results displayed in this thesis. This is evidence that the PhD. candidate has acquired the necessary knowledge and has develop the basis of new theoretical and practical skills.

The relevant issues within the work carried out by the PhD candidate include the new approach to processing the conventional industry seismic reflection data set to obtain constraints on the deep crust. This effort required the application of "an extended correlation scheme" to be able to obtain longer shot records that would provide a view of the deep crust, imaging reflection fabrics beyond the conventionally recorded time Extended correlation achieves this objective although the higher frequency signal is lost within the process. Futher outstanding contributions of Mężyk's research include the use of coherency filtering schemes combined with unsupervised machine learning to further emphasize the deep features in the seismic sections. The approaches and their convination are indeed original and new ideas that contribute to unravel the seismic fabrics that define critical tectonic features of the deep crust, down to the Moho and upper mantle of the EEC. Thus, Meźyk's PhD research contributes significantly to the advancement of the understanding og the geological structure and underlying lithospheric processes the characterize the EEC of Fennoscandian and Samaritian affinity that build up a large part of Poland and surrounding territory.

b) Specific Points

- Assessment for the Candidate's general theoretical knowledge in the discipline and the ability to independently carry out scientific research.

The PdD. Research summarized in Meźyk thesis aims to answer a number (4) of critical questions concerning theoretical approaches and interpretation analysis of control source seismic reflection imaging. The first one features the development of machine learning schemes to help determine the first-breaks in order to be able to design a highly effective

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"statics correction" within the conventional processing flow. He makes use of a number of statistical measurements treating the seismic trace (or better a window of the seismic trace around the first break to be able to accurately determine the starting time of the first energy burst that arrives at the geophone (seismic sensor). Within his work he developed the necessary software tools to be able to perform a binary classification to solve this picking problem. It is very important the research carried out in this part results in a fully automatic procedure to accurately identify the first breaks with minimum error.

The second question that the PhD thesis addresses is to be able to label, or better identify and classify reflection fabrics within a seismic section. This automatic process should enable the association of the seismic reflection signatures to specific tectonic structures aiding the interpretation of the seismic images. Meźyks is able to develop this by using the "seismic attributes" combined by unsupervised learning. This is the focus of chapter three. In it he fully demonstrate a broad knowledge of the theory behind, seismic reflection data as well as behind digital signal analysis.

Once the seismic fabrics are classified he aims to unravel the crustal structure, proposing geologic cross-section and analyzing similarities and differences with seismic images of other well constrained terranes. It is important to emphasize that the candidate at this point has fully re-processed the 950 km of the regional seismic profiles acquired within the PolandSPAN programme. The integrated interpretation of all the profiles results for the first time on a detailled crustal scale picture of the EEC. These images are unique as they were not possible with the original 12 s long shot records.
The seismic signatures obtained through the new processing are similar to the ones interpreted in transects acquired within the neighborhood, in particular to the BABEL and FIRE deep seismic research programmes acquired in the Baltic Sea and onshore Finland y respectively. The candidate's interpretation suggests a convergent setting with mid- to lower-crustal flow during the Svecofennian orogeny. This thickened lithosphere underwent a delamination process and asthenospheric ascent inducing partial melting of the lithospheric mantel material. Gabbroic melts ponded at the base of the crust. Such a model would be consistent with the seismic fabrics imaged by the candidate's new processing. The proposed interpretation is further supported by other structural and geodynamic studies indicating that the candidate has acquired the currently available and up to date geologic and tectonic knowledge.

The forth topic the candidate addresses is focalized on the nature, geometry and characteristics of the suture zone between the Fennoscandia and Sarmatian segments. This has been a controversial feature within the European plate geodynamic evolutiotn. Thus the candidate's work provides new information and seismic evidences on this topic.

In summary, the clear definition of the objectives, the structure of the thesis, jointly with his developments are indicative of the candidate's high degree of knowledge on the theoretical aspects of the research field. These also demonstrates the ability to carry out successfully independent research within the topic area.

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- The justification that the solution of the problem in the doctoral dissertation is original.

Meźeks contributions, as indicated in the general assessment of the Thesis, have been recognized as well supported and original research. His contributions have been published (and more importantly already cited) in internationally recognized first break research journals.

- Positive or negative opinion regarding the candidate's admission to the public defense of the doctoral dissertation.

I n my opinion Meźyks has acquired the necessary knowledge on the field, has developed original research with relevant results and implications. Therefore, he has accomplished all the necessary requirements to be able to be admitted for the public defense.

- The reviewer consider the doctoral dissertation outstanding, he may apply for its distinction, the requests and justification must be included in the text of the review.

Under my point of view this is an outstanding work the candidate should apply for this distinction. As it has been mentioned already he has developed new processing schemes and new ideas that undoubtedly contribute to the understanding of the structure, nature and geodynamics of the EEC beneath the Polish terranes.

Barcelona, August 1, 2021.

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