ΑΡΙΣΤΟΤΕΛΕΙΟ
ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΕΣΣΑΛΟΝΙΚΗΣ

ARISTOTLE
UNIVERSITY OF THESSALONIKI

ΣΧΟΛΗ ΘΕΤΙΚΩΝ ΕΠΙΣΤΗΜΩΝ
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PhD Thesis review

Candidate: Monika Staszek

Title: Joint multiplet and static stress drop analysis for enhanced characterization of reservoir undergoing fluid injection

Supervisor: dr hab. Lukasz Rudzinski, prof. PAN

The human need for clean energy sources has led to the exploitation of geothermal fields. Several techniques have been developed for this purpose, with fluid injection among them being widely used. However, this procedure is related to induced seismicity that sometimes triggers even destructive earthquakes. Although surface geological mapping or seismic or other geophysical surveys can provide information on the existing faults, there are several drawbacks, that make the use of the local seismicity a more advanced tool. The properties of the local events to occur in multiplets and the evolution of the static stress drop have proven to be a powerful tool for the study in this field and consequently, for seismic risk mitigation.

From the text and the published papers, it is deduced that the candidate has gained knowledge on the induced seismicity and the related aspects. She has comprehensively

applied modern methods and techniques showing that she is efficient to carry out scientific research in the field of induced seismicity.

The work of the candidate has been published in three international scientific journals. These are:

Staszek, M., Orlecka-Sikora, B., Leptokaropoulos, K., Kwiatek, G., & Martínez-Garzón, P. (2017). Temporal static stress drop variations due to injection activity at The Geysers geothermal field, California. Geophysical Research Letters, 44(14), 7168–7176. https://doi.org/10.1002/2017GL073929.
(18 citations in Scopus)

Leptokaropoulos, K., & Staszek, M. (2019). Temporal response of magnitude distribution to fluid injection rates in The Geysers geothermal field. Acta Geophysica, 67(1), 327–339. https://doi.org/10.1007/s11600-018-0215-1.
(2 citations in Scopus)

Staszek, M., Rudziński, Ł., & Kwiatek, G. (2021). Spatial and temporal multiplet analysis for identification of dominant fluid migration path at The Geysers geothermal field, California. Scientific Reports, 11(1), 23908. https://doi.org/10.1038/s41598-02103267-y.
(8 citations in Scopus)

In the first paper (Staszek et al., 2017) the authors examined the influence of injection rates, moment magnitudes, focal mechanisms, hypocentral depths and hypocentral distances from the injection wells on the static stress drop changes. For this work a group of 322 earthquakes from the NW part of the Geysers geothermal field was used. It was found that static stress drop variations are statistically significant and they are inversely related to injection rate fluctuations. The authors conclude that static stress changes depend on the effective normal stress and strength of the medium. The dependence of stress change on the operational phase could be utilized in seismic hazard assessment.
In the second paper (Leptokaropoulos and Staszek 2019), a method for assessing the statistical significance of static stress changes with various types of b value estimation was performed. Significant positive correlation was found between b values and the

second derivative of the injection volume (slope rate of injection). This dependence is attributed to the dynamic reservoir response in the increasing pore pressure. A statistically significant difference was also found between b values of events corresponding to increasing and decreasing periods of injection rate. Positive linear correlation follows the injection rate changes with time lags of 0–15 days. The authors could not identify a statistically significant relation between the static stress changes and the b values. However, in the second chapter of the PhD draft it is stated that the significant positive correlation between b-value and injection rate, implies an existence of potential relationship between static stress drop and b-value in the area.

In the third paper, (Staszek et al., 2021) multiplets accurate location by using double difference technique and waveform cross correlation, as well as their spatial and temporal migration, are used to define the reservoir response to fluid injection and verify the hypothesis for aseismic behavior of the reservoir. The biggest number of event repetitions was observed close to the injection well where pore pressure was the highest. All multiple events were relocated using the precise travel time differences determined from signal cross correlation. The spatial and temporal distribution of the multiple and single events was the mean to interpret the mechanism leading to reservoir behavior.

The candidate participated in two more scientific papers with relevant subject, published in peer reviewed journals:

Orlecka-Sikora, B., Rudziński, Ł., Staszek, M., Lizurek, G., & Mizerski, K. (2023). Seismic swarms as intermittent quasi-static ruptures driven by pore pressure variations due to the water reservoir impoundment. Tectonophysics, 863, 230005. https://doi.org/10.1016/j.tecto.2023.230005.

Leptokaropoulos, K., Staszek, M., Lasocki, S., Martinez-Garzón, P., & Kwiatek, G. (2018). Evolution of seismicity in relation to fluid injection in the North-Western part of The Geysers geothermal field. Geophysical Journal International, 212(2), 1157-1166. https://doi.org/10.1093/gji/ggx481.

The five scientific papers have been published between 2017 and 2023. She is the first author in four abstracts presented in four international scientific meetings either orally

(three) or as poster (one). She also has participated or participates in four research projects, in two of them as principal investigator.

The results obtained in this Thesis, prove that it is possible to recognize significant variations of static stress drop of the earthquakes related with induced seismicity in geothermal reservoirs. Thus, static stress drop could characterize the reservoir and its response to the injection process contributing to the seismic hazard assessment. The study of multiple and single events properties, demonstrate that it is possible to identify seismogenic structures which determine the reservoir behavior. The consistency of the results obtained by the analysis of microseismicity properties and the static stress drop changes provide strong evidence of the validity of the present thesis.

In summary, from the PhD text and the published papers in scientific peer reviewed journals, it is deduced that the candidate exhibits scientific expertise on both theoretical knowledge and applications. In addition, her participation in research projects, particularly in those as principal investigator, evidence that she can independently carry out scientific research. The publication of PhD results in scientific peer reviewed journals, as well as the international recognition shown by the citations that the papers have received, show the originality of the research. Based on all the above I am positive, and I strongly support the admission of the candidate for public defense of the doctoral dissertation.

Thessaloniki, 08 January 2025

Vasileios Karakostas
08.01.2025 21:53

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