

## REVIEW REPORT

for a Ph.D. Thesis submitted to Saint Petersburg State University

**Title:** Joint detection, location and source mechanism determination of microseismic events

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The PhD thesis of Denis Anikiev is devoted to investigation of microseismic events which result from fracturing of rock layers during hydraulic stimulation of a natural gas reservoir. The signal of such induced earthquakes of a very small magnitude is passively recorded on the surface or in a borehole. The peculiarity of such corresponding seismic sources is that they are well described by the theory involving non-trivial seismic moment tensors in contrast to conventional active seismic prospecting. Appropriate complex radiation patterns lead to variations of amplitude polarity, that is, change of amplitude signs along the observation profile. Processing of such real data is a topical and challenging task.

The goal of the research is modification of existing numerical imaging methods based on stacking of waveforms intended to take into account source radiation patterns. The key aspects of the author's methodology are: a new algorithm of detection of microseismic events, a new algorithm of verification of reliability of the detection, and a new representation of results of a location procedure based on a likelihood distribution function. The suggested approach implies stacking of seismic data along diffraction traveltimes curves and allows efficient suppressing of noise while imaging of relatively weak microseismic events. Benchmarking of the proposed method against a reliable well-known method showed good agreement in derived locations and source mechanisms.

The author presented interesting results of real data processing. The studied dataset was recorded during the surface microseismic monitoring of hydraulic fracturing in a shale formation. Author's results demonstrate the feasibility of the proposed method in detection and location of real microseismic events. The thesis is well-written and undoubtedly demonstrates author's qualification in processing of seismic data. The list of publications is impressive (16 publications, whereas in 12 of them Denis is the first author). To conclude, I state that the PhD thesis submitted by Denis Anikiev should be accepted and PhD degree should be awarded to the author.

### Remarks:

1. The vertical bias of locations (shown in fig. 9, Section 3.4) determined by the proposed method as compared to locations found manually, in my opinion, deserves further discussion.
2. I would not expect too significant improvement of location accuracy from the scaling approach applied to likelihood function described in Section 2.1.5. As a possible further development, this approach should be discussed in more details.

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