Review report

of the PhD Thesis submitted to St. Petersburg State University

Title: Joint Detection, Location and Source Mechanism Determination of Microseismic Events

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Nowadays technology of hydraulic fracturing is widely used in seismic prospecting. It is conditioned by exhaustion of gas and oil reservoirs and exploitation of shale fields. Injection of water to rocks results in microfracturing which improves productivity of wells. Information on location, magnitudes and mechanisms of the fractures is important for evaluation of the effectiveness of hydraulic fracture stimulation and for identification of active faults and estimation of bypassed reserves. Thus a relevance of the author's studies is beyond doubt.

Difficulty of the problem is that signals from microearthquakes are lower than noise level. Stacking of a large number of records from receivers covering a wide range of offsets widely used in seismic prospecting for increasing signal/noise ratio cannot be applied for solving this problem because of non-uniform radiation from microearthquakes sources, which results in summation of signals in different phases. In such a case it is necessary to correct the records for phases, i.e. for radiation pattern of source. In other words, it is necessary to estimate the source radiation (moment tensor) not only as a final goal, but in the procedures of signal detection and source location. The problem of moment tensor determination is well developed in seismology, but in seismology it is easier because of high level of signals from earthquakes and of known source locations. But even in such a case the estimates of source mechanisms usually differ.

An important point in the proposed method is the so-called semblance analysis. In contrary to other works the author suggested to involve semblance for amplitudes corrected due to event radiation patterns rather than only for the sign. This aspect enhance signal-to-noise ratio of semblance function and allows detection of weaker events.

The algorithm developed by the author (DSMTI) was automated and tested on real data. Up to present detection of signals from microearthquakes was done manually by picking first arrivals. The great achievement of the author is that his algorithm is fully automated and can be used in processing of field data.

The remark about the thesis is a lack of analysis of noise-immunity of the algorithm and of its stability in conditions of imperfect information. Indeed, the data used for estimation of the moment tensor always cover a limited range of angles of departure of the rays from a source – it depends on an array size and on a source depth. In such a case the source mechanism solution becomes non-unique, especially in presence of observation errors. Of course, a statistical analysis of noise is very complicated, for simple illustration of the observation errors it would be desirable to adduce examples of residuals between experimental amplitudes and calculated for the estimated moment tensor.

Evaluation

The results reported in the PhD thesis are novel and important in current state of seismic prospecting. They demonstrate a high level of professionalism of the author. The thesis written and submitted by Denis Anikiev can be accepted, and the PhD degree can be awarded to the author

Questions

1. The author explains a vertical shift of sources in DSMTI (fig.9) by an attenuation effect. Why this effect is not revealed in TML?
2. Are the inferences about numerical values of thresholds (0.17 for semblance and 2 for STA/LTA) universal, or they are valid only for the given example? If the former, then it is necessary to prove this statement by statistical analysis. If the latter – how to select the criterion in other cases?
3. If the vertical shift of sources is due to attenuation then is it possible to take into account decrease of frequency in the algorithm?

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