WS10-B03

Diffraction Stacking - The Role of Source Mechanisms

O. Zhebel* (RWE Dea AG), D. Gajewski (University of Hamburg) & C. Vanelle (University of Hamburg)

SUMMARY

Localization of seismic events provides us valuable information about structures activated by tectonic stresses, geothermal or volcanic activity, reservoir stimulation, and other subsurface activities. In the last few years automatic stacking-based localization techniques that do not require any picking of phases, have become popular and widely-used localization tools. Localization results obtained by such techniques are influenced by various factors. In this work we illustrate that source mechanisms directly influence the form and resolution of a resulting image function. For this purpose, two numerical examples are presented. The first considered source type is a so-called compensated linear vector dipole source, which is typical for geothermal and volcanic areas. As the most seismic events can be best characterized by a combination of explosive, double-couple (DC) and compensated linear vector dipole (CLVD) components, localization of such a source mechanism is also illustrated.

Introduction

Stacking-based localization techniques have become indispensable localization tools in the last few years. The main advantage of such localization techniques is that they do not require picking of P- or S-wave arrivals on the contrary to common localization techniques used in seismology. However, the influences of the different factors, e.g. source mechanisms, acquisition geometry, imaging conditions etc., on the localization results has to be considered. In this work we will illustrate by means of synthetic examples the influence of different source mechanisms (non purely explosive and shear) on localization results obtained by stacking techniques in 3D.

The majority of seismic events are not purely explosive (see e.g. Baig and Urbancic (2010) or Rutledge and Phillips (2003)). The biggest challenge for stacking-based localization techniques is represented by a pure double-couple source, as the negative and positive polarities are balanced. In this paper we study localization of other source types, such as compensated linear vector dipole (CLVD) mechanism and a source constrained of a balanced mixture of three modes: explosive, double-couple and CLVD.

Localization of different source mechanisms

Diffraction stacking techniques have become well established for imaging of (micro)seismic event positions in time and space using the recordings from surface and/or borehole measurements. We test the influence of different source mechanisms on conventional diffraction stacking (see e.g. Zhebel et al. (2011)). The majority of seismic events are not purely explosive (see e.g. Baig and Urbancic (2010)). The polarity of the direct P-wave depends on the take-off angle. As a result, the polarities of the data amplitudes can be both positive and negative. Different source radiation patterns also have an impact on localization results, which is illustrated further on two different source mechanisms.

The so-called compensated linear vector dipole (CLVD) source types are typical for geothermal and volcanic areas. It represents a situation where strain along e.g. x-axis is compensated by contraction or expansion along the other axes. Figure 1 shows horizontal and vertical slices through the normalized image function obtained applying time collapsed imaging condition to the noise-free data. The source is situated in the centre of the acquisition array. Note that the negative polarized part of the radiation pattern, which is oriented perpendicular to the strain direction, has significantly more influence on the image as it is radiating directly upward. The focal area of the image function is stretched along the y-axis. Moreover, in the x-z-plane it is narrower than in the y-z, analogous to the radiation of the negative polarized P-waves of a CLVD source mechanism.

Figure 1 (a) Horizontal, (b) vertical slice along the x-axis and (c) represents a vertical slice along the y-axis through maximum of the normalized image function obtained applying conventional diffraction stacking for CLVD source mechanism.

As in the reality most seismic sources can be best explained by a combination of explosive, double couple and compensated linear vector dipole components (see e.g. Baig and Urbancic (2010)), a source with 35% explosive, 35% CLVD and 30% double-couple was tested. All three source

mechanism types are present in approximately equal portions. In Figure 2 we can see slices through the corresponding normalized image function. Note that the focal area is inclined even though the source is placed symmetrically relative to the acquisition geometry. It means that the inclination of the focal area is not only evoked by an asymmetrical source position relative to the acquisition array, but also by a source type as in our case a combination of three different radiation pattern components is given. Furthermore, if we compare image function of these two different source mechanisms, it becomes clear that the focal area of the CLVD source type is less focused compared to the source made of three modes. So we can conclude that the source mechanism not only affects the form of the image function but also its resolution.

Figure 2 (a) Horizontal, (b) vertical slice along the x -axis and (c) vertical slice along the y -axis through maximum of the normalized image function obtained applying conventional diffraction stacking for the source mechanism constrained by 35% explosive, 35% CLVD and 30% double-couple components.

Conclusions

Synthetic tests have illustrated that source mechanisms directly influence the form and resolution of an image function. Thus, an image function for a CLVD source type is less focused compared to the one for the source constrained of a balanced mixture of three modes: explosive, double-couple and CLVD. We have discussed only one factor influencing the localization results of stacking-based techniques, whereas other aspects like acquisition geometry, accuracy of a velocity model etc. also have an impact and should be considered.

References

- Baig, A. and Urbancic, T. [2010]. Microseismic moment tensors: A path to understanding frac growth. *The Leading Edge*, pp 320–324.
- Zhebel, O., Gajewski, D. and Vanelle, C. [2011]. Localization of seismic events in 3d media by diffraction stacking. *73rd EAGE Annual Conference & Exhibition*, C005.
- Rutledge, J. T. and Phillips, W. [2003] Hydraulic stimulation of natural fractures as revealed by induced microearthquakes, Carthage Cotton Valley gas field, east Texas. *Geophysics*, **68**, 441–452.