Abstract

In this thesis a method for the characterization of reservoirs in terms of their hydraulic properties is further developed, applied and numerically verified. The proposed method was partly derived already in the last few years. Basis of the method, which is called 'Seismicity Based Reservoir Characterization (SBRC)', is the analysis of fluid-induced microseismic events. Such events very often occur during fluid injection or extraction experiments in boreholes. The events can be localized up to several kilometers away from the borehole and the injection source. The mechanisms for the triggering of such microearthquakes are still not fully understood. In several studies and analyses the hypothesis is proposed, that fluids can play a fundamental role in the triggering of such microseismic events.

In the SBRC method used in this thesis, data of fluid-induced microseismicity are analysed in terms of their spatio-temporal evolution. The main hypothesis is, that a fluid-injection-induced pressure diffusion can be an significant and thus is possibly a main triggering factor for microseismic events. Based on the theory of poroelasticity (Biot [1956a]), equations are derived, which allow the estimation of hydraulic parameters like hydraulic diffusivity or permeability of rocks in 1D, 2D and 3D. The advantage of the proposed method is the estimation of hydraulic parameters of rocks not only locally (orders of centimeters or meters) but of a large spatial scale (cubic kilometer regime). Parameters like hydraulic diffusivity or permeability are of special interest in the industrial utilization of reservoirs, production or storage of oil and gas resources, storage of nuclear waste and in the optimal recovery of renewable energy sources.

The main topic of this thesis is the numerical simulation of the hypotheses proposed in the SBRC-method for the triggering of fluid-induced microseismic events. Such a numerical verification is of importance for the application, the validity and accuracy analysis of the method. So far, the SBRC method was solely applied to real data and never numerically verified. For this study, the two- or three dimensional time-dependent equation of diffusion is solved for different hydraulic models. The simulation of the process of pore pressure diffusion is then used to create synthetic microseismicity clouds. Therefore, following the main hypothesis of SBRC that microseismic events occur at points of the medium which are characterized by a critical state of stress, a criticality field is compared with the pore pressure distribution. At locations where pore pressure exceeds criticality, an event is defined. The signatures of the spatio-temporal evolution behaviour of such event clouds are then compared with those calculated by the SBRC-method and observed for real data from fluid injection experiments in geothermal or hydrocarbon reservoirs.

The computer-based simulations allow the systematic study of the hypothesis proposed in the SBRC for the triggering mechanism for the first time. The results show that the process of pore pressure diffusion can explain the spatio-temporal signatures of microseismic event clouds in many cases. Moreover, the study presented in this thesis confirms that fluid-injection-induced microseismicity can be used for the characterization of reservoirs in terms of hydraulic parameters and their large scale distribution.

Another main point in this thesis is the application of the SBRC-method to two data sets: of the German Continental Deep Drilling Site (KTB), and of a reservoir in tight-gas environment (Cotton Valley, USA). At the KTB microseismicity was induced at different depth levels during two fluid injection experiments. Such a data set allows the analysis of hydraulic diffusivity or permeability changes with depth at one single and unique location for the first time. The estimation of hydraulic parameters are compared with results of seismic reflectivity experiments. It turns out that pore pressure diffusion can explain the signatures observed and structural properties like faults or fractures affect the distribution of microseismic hypocenters to a large amount. The analysis of data obtained during experiments at a gas reservoir are of interest and of importance for application of the SBRC method. With the analyses and results presented in this thesis a step is done towards the cause study of microseismicity genesis and helps to understand the underlying physical processes.