Geophysical Research Abstracts
Vol. 13, EGU2011-4765, 2011
EGU General Assembly 2011

Inversion of downhole streaming potentials to determine water front position

Jon Saunders and Matthew Jackson
Dept. of Earth Science and Engineering, Imperial College London, UK (jon.saunders@imperial.ac.uk)

Self-potentials are increasingly being used to characterise the Earth, and especially to investigate and determine the position and nature of fluids saturating porous rocks. Such potentials may include contributions from electrochemical and/or electrothermal sources, but it is often the electrokinetic contribution to the self-potential, the so-called streaming potential, which is of principal interest, as it is caused by, and is also therefore indicative of fluid(s) moving through the subsurface. In the monitoring of groundwater resources, volcanoes and in hydrocarbon reservoirs, the ability to detect and characterise moving fluids in a non-invasive and non-destructive manner sets self-potential methods apart from other geophysical techniques.

The theory of self-potentials is now fairly well understood for water-saturated porous media, although issues remain in the determination of critical physical parameters in partially-saturated conditions and in the presence of a second fluid phase. In recent years attention has turned to the inverse problem, namely the determination of the location and nature of the self-potential source given measurement of potentials at the Earth surface or downhole. Authors have focussed on locating the position of a saturation front within a porous body (e.g. the elevation of the water table), and have employed methods including Simplex-type optimisation, genetic algorithms and simulated annealing as well as global methods with regularisation and many of the techniques developed for resistivity inversion.

We have investigated the use of an inversion procedure for determining the position of a water front during oil production by water-flood. Following previous work which has suggested that significant streaming potentials may be measured downhole due to the movement of water towards the production well while the water is still up to 100m away, we have developed a method to determine the location of the water front during production, thereby allowing control actions to be implemented at the well with the aim of reducing water cut and maximising overall recovery. The method employs the Hooke and Jeeves algorithm which performs an efficient search for an optimum solution for the position and width of a discretised water front, minimising the mismatch between normalised observed and predicted potentials along the borehole and using multiple initial positions to maximise the likelihood of finding the global minimum of the error functional.

We present results from simple synthetic models which demonstrate the function and efficiency of the inversion algorithm. We then investigate a layered 3-dimensional field-scale model, and evaluate the impact of using control actions based on inversion results in comparison to an uncontrolled production regime. Previous work has shown that if reliable information can be extracted from a monitoring technology such as self-potentials then significant gains in productivity and reductions in cost may be achieved over the production cycle. This work makes the first link between the forward modelling of streaming potentials in a reservoir and the well control actions which turn their measurement into practical advantage.