Focal-time estimation: A new method for stratigraphic depth control of induced seismicity

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ABSTRACT

In this paper we describe a novel method for focal-depth determination of induced seismic events. Our approach involves joint interpretation of microseismic and induced-seismicity waveform observations along with multicomponent surface seismic data. The method operates using parallel workflows for processing induced-seismicity data and P-P and P-S data. The output is a set of calibrated P-P times for the microseismic events, which thereby enables the events to be co-rendered and visualized with the seismic data, thus providing stratigraphic control on source locations. The method requires Vp and Vs time-depth control from coincident multicomponent seismic data and is achieved by registration of P-P and P-S reflections from equivalent horizons. Hypocenter vertical locations are initially expressed as the zero-offset focal time (2-way P-P reflection time) and then converted to depth by leveraging methods available for time-depth conversion of the surface seismic data, as well as well ties using synthetic seismograms. Application of this method requires high-quality P- and S-wave picks for microseismic events, which are extrapolated to zero offset. This approach avoids the necessity to build and calibrate a 3-D velocity model for hypocenter location, nor determination of accurate absolute origin times. This method also implicitly accounts for factors that are often ill-constrained for most velocity models, e.g. velocity anisotropy, since these factors similarly affect both the induced seismicity and the 3-D seismic travel times. We apply our new method to an induced seismicity dataset with events up to M_L3.6, recorded using a shallow-well monitoring array in Alberta, Canada. Reconciling the seismic processing datum with the microseismic datum was found to be a critical, but not insurmountable, challenge. The inferred focal depths place most induced events at, or above, the treatment depth.

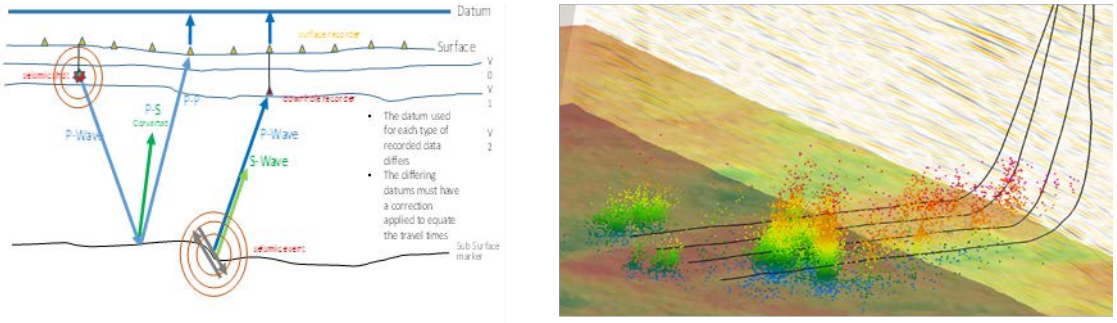

FIG 1. Illustration of the relationship between recorded seismic data and microseismic recording. Reflection seismic data is corrected to an artificial datum, above the highest elevation. The Dark arrows represent PP (reflection), P direct, the grey arrows represent P-S (reflection) and S direct (microseismic). The reflection seismic data is time-adjusted downward to match the microseismic data. The 3-D rendered image shows the calculated hypocenter depths with the well trajectories, inserted into the depth-converted 3-D volume.