Fast-linearized methods for hypocentre location, magnitude estimation and site amplification effects of seismic events induced in conventional and unconventional gas fields

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Microseismic monitoring is an essential tool required to better understanding the induced-seismicity processes observed in multiple oil and gas, and geothermal projects during fluid-injection or extraction operations. The data obtained from a seismic monitoring program, as the location and magnitude of the observed induced events, can be integrated with the near-surface conditions (represented by the average shear-wave velocity of the shallowest 30 meters - Vs30) to assess the ground motions generated by these events at surface, and its impact to local infrastructure. However, its reliability strongly depends on the implemented methods for hypocentre location, where most of the conventional methods rely on a pre-defined velocity model. For magnitude estimation, most of the conventional methods rely on the availability of broadband sensors, even though most microseismic monitoring programs are acquired with short-period geophones as those used in seismic reflection exploration surveys. As an alternative, an epicenter location method based on the linearized normal moveout (NMO) equation is proposed to locate events without the need of a velocity model, together with a magnitude estimation method based on the duration of the coda wave which can me measured in seismic data acquired with short-period sensors. These methods are applied to locate and estimate the magnitude of some induced seismic events reported during a multi-stage hydraulic fracturing stimulation in the Duvernay shale formation in western Canada, and in the Groningen gas field in the Netherlands. Both case studies were monitored with a dense shallow-borehole array that also allows a reliable measurement of seismic velocities of the near surface in the location of each shallow-borehole station, where the Vs30 can be calculated and integrated with a subsequent ground motion analysis of the same events.

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