The paradigm change of hydraulic fracture stimulation is to artificially create reservoirs in unconventional source rocks, where production was previously unimaginable. Effective stimulation requires either the connection to existing natural fractures or the presence of geomechanical brittleness capable of supporting extensive induced fractures. As very few tight formations are thick, continuous and homogenous, so any given well can be uneconomic to the point of never paying out (negative cash flow). The variation between wells in economic ultimate recovery in these tight formations is due to the heterogeneity of stimulated fracture potential or fracability, porosity and saturation that are critical to mapping “sweeps” for development drilling and optimizing completion parameters. Consequently 3D, AVO and AVO variation with azimuth (AVAZ) to detect anisotropy due to fractures, stress or over-pressure are almost routinely applied for the development success of such plays.

The Wiki definition of fractures (http://en.wikipedia.org/wiki/Fracture_(geology)) is “any local separation or discontinuity plane in a geologic formation, such as a joint or a fault that divides the rock into two or more pieces. Fractures are commonly caused by stress exceeding the rock strength, causing the rock to lose cohesion along its weakest plane.” The simplicity of this definition confirms the tri-axial geomechanical models used in the description of the subsurface, thereby enabling azimuthal reflection seismic inversion to remotely sense fractures despite the usual undetermined condition of remote sensing methods. However excepting post-stack spatial volume attributes such as curvature, propagating seismic waves do not directly sense fractures, but instead the anisotropy arising from the directional heterogeneity of fractures or the differential stresses that produce them in the first place.

These controlling stresses are relatively simple consisting of normal and tangential components of a second order tri-axial tensor that determines various anisotropic symmetries. The seismic signature of these stresses can be measured through an anisotropic fourth order stiffness tensor composed of λ’s and μ’s relating stress to elastic strain in Hooke’s law. The anisotropy in these tensors are described as fractional relative changes in terms of Thomsen parameters $e_{\theta\theta}$, $e_{\phi\phi}$ and $\gamma$ as well as Schoenberg’s “linear slip model” $\Delta N$ and $\Delta T$ for a simple HTI medium, with $e_{\theta\theta}$, $e_{\phi\phi}$, $\Delta N$ and $\gamma$, $\Delta T$ being the respective natural extensions to the isotropic AVO attributes of $\lambda\rho$ and $\mu\rho$ from P-wave and S-wave impedance.

The three articles in this special RECOORDER edition on fractures describe and introduce the potential of interesting new methods such as 4D and AVO variation with azimuth (AVAZ) to detect anisotropy due to natural fractures or in-situ stress that would ideally corroborate the mapping of optimal fracture prone zones from the standard isotropic AVO.
of wave induced fluid motion between fractures and pores that result in complex elastic stiffness coefficients can produce measurable frequency-dependent attenuation. Based on this theory, spectral analysis of the seismic wavefield is used to obtain direct permeability estimates. The case study analyzes the time-lapse attenuation response from a 4D acquired before and after hydraulic fracturing to investigate the permeability within the stimulated zone. The results obtained from this analysis qualitatively confirm the microseismic observations and 4D seismic amplitude and travelt ime anomalies, indicating the presence of a permeable fault/fracture system that diverted the hydro-fracture energy from the treatment to re-stimulate isolated portions of the in-situ rock.

I would like to acknowledge and thank the primary authors for their contribution to this special RECORDER edition on fractures. All the articles are technically illuminating with a clear exposition of a complicated topic and also describe some novel methods that have progressed seismic applications to estimate fractures in the subsurface.