Fractured reservoir analysis using a continuous sequence stratigraphic framework, and attributes derived from seismic data and RGT model: method and examples

Nicolas Daynac, Eliis

In most of current workflows for faults and fractures imaging, post-stack seismic data are directly interrogated using structural gradients and artificial intelligence to enhance and recognize patterns of vertical and spatial displacements. Various methods of data filtering may strengthen those approaches, but the results still remain highly sensitive to noise, and mostly visualized on horizontal slices cutting through seismic reflectors, or on a few major horizons mostly based on key seismic reflections. The author hereby presents a method that aims at showing how seismic sample details can be stratigraphically correlated through an automation-assisted and amplitude-driven Relative Geological Time (RGT) model (Pauget et al, 2009), ultimately providing noise-free structural attributes and sub-sample stratal slices of any seismic and RGT-derived information, both in structural and Wheeler domains.

A first pass of fault imaging and extraction is performed from post-stack seismic data, by using an advanced algorithm of multi-trace attribute sum extrema called Fault Plane attribute. This process scans a seismic 3D gradient with a rotating and tilting window in every azimuth and for each dip angle. The output fault networks can afterwards be used to constrain the RGT modelling process. Every step of the fault extraction and RGT modelling remains automated and under the supervision of the geoscientist. The fault network can be filtered – dip, azimuth, size – and completed, and the RGT modelling can be refined by editing the auto-tracked and stratigraphically sorted seismic horizons in a discrete stratigraphic framework called 'Model-Grid'. A 3D interpolation of the discrete Model-Grid converts each seismic sample into relative geological time and delivers a continuous RGT model.

While traditional 3D gradients of seismic traces may partially or not at all emphasize low amplitude or noisy fault expressions (Figure b), RGT-driven attributes such as the Deepest Descent Gradient highlight them (Figure d) even within pre-salt layers. The RGT model moreover provides an output Fault Throw attribute which feeds the analysis of 3D fault behaviour and reservoir compartmentalization (Figure e and f).

This workflow has been successfully applied on a broad range of geological settings, including the difficult challenges of subtle fractures imaging and characterization, such as those driven by diagenetic and meteoric processes. Indeed, because seismic data processing typically tries to remove subtle discontinuities with weak amplitudes often appearing as noise, reflection-based attributes are less sensitive to the detection of reservoir scale fractures. However, a Diffraction Energy weighted stack – produced by using directional filters to remove the specular energy – enhances the appearance of fractures and karsts. When combined with the RGT workflow, it enables to stratigraphically visualize small magnitude diffraction events, establish facies and geometries hierarchies, and ultimately assess reservoir properties and drilling hazards.

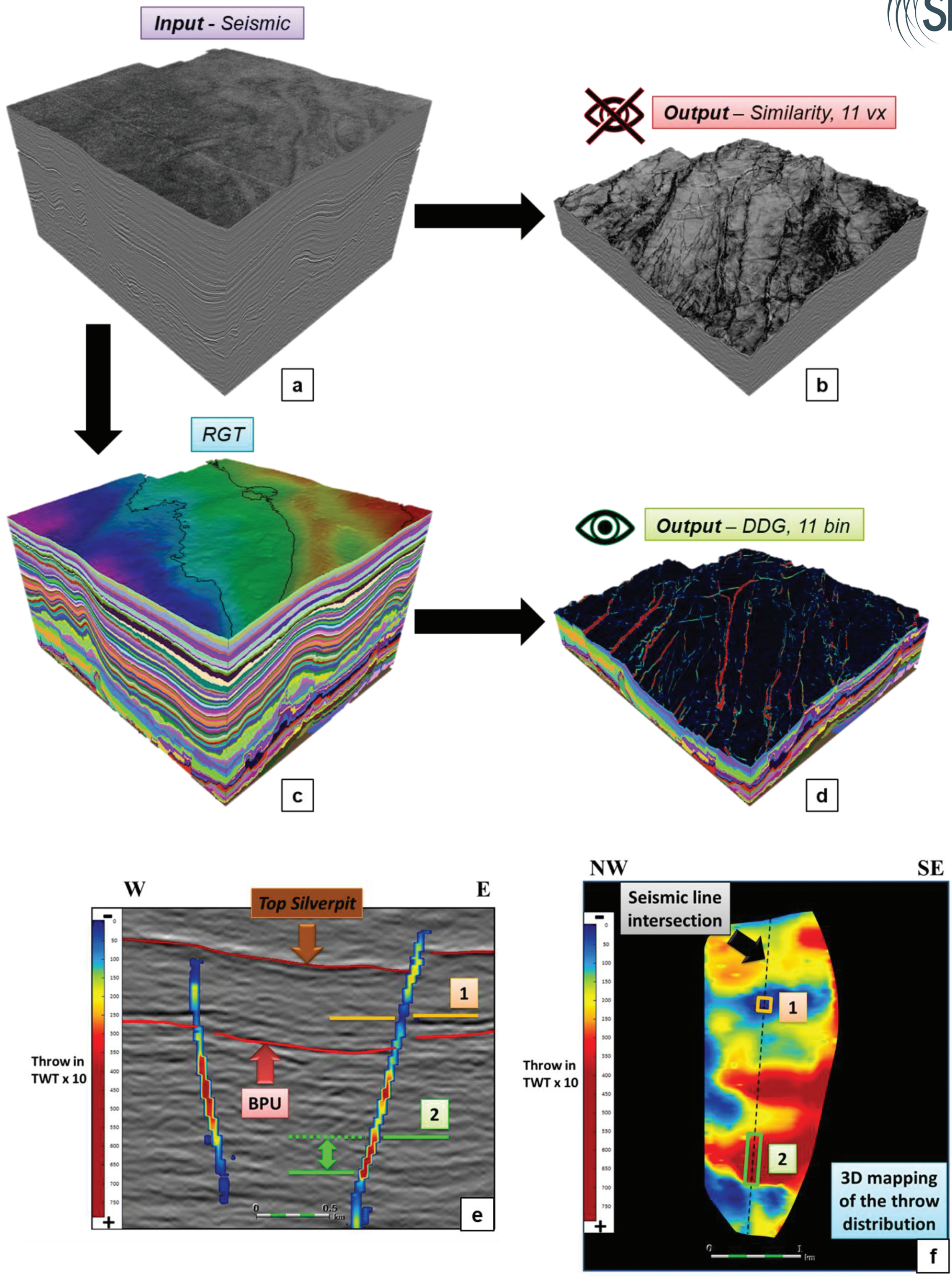

Figure: a. Seismic data, direct input of b and c; b. Stratal slice of Similarity attribute, a 3D gradient of seismic amplitudes; c. Relative Geological Time model, a continuous stratigraphic framework driven by the seismic amplitudes; d. Stratal slices of Deepest Descent Gradient attribute, a spatial gradient of the RGT; e. Fault Throw attribute derived from RGT, blended with seismic reflections within Carboniferous (source rock prone) and early Permian (reservoir and seal rock prone between Base Permian Unconformity 'BPU' and base Zechstein salt 'Top Silverpit') layers; f. 3D distribution of Fault Throw values along a chosen fault plane. *K05 3D seismic data, Dutch Cleaver Bank High province, offshore Netherlands, courtesy of TNO*