Paper C7

The Evolving Role of Geophysics in Exploration. From Amplitudes to Geomechanics

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Over the last 25 years, geophysical analysis of seismic data has greatly evolved. However, in the routine utilization and daily workflows of many exploration and development teams, geophysical technology is at a standstill.

The purpose of this paper is to review a few of the major milestones of geophysical innovations, as we see them. The aim is to provide insight into how geophysics has evolved and provide a glimpse into the direction of the technology and its application to improving exploration and production solutions.

In school we – geologists, engineers, and geophysicists - learned how reflectivity equations provide us with the basics for what is needed to interpret seismic data. It gives us an understanding of the time required for a seismic impulse to travel to and through a reservoir. It also gives us some understanding of the amplitude we should expect to record by way of acoustic impedance properties encountered by the traveling seismic wave.

This has been the status quo for more than 40 years. Seismic amplitudes were revolutionary in the 1960's (see e.g. Schneider, 1971). Many exploration teams still rely solely on time structure and horizon amplitude maps to present their exploration prospects to management or drilling engineers.

The first innovation came through the simplification of the work of Zoeppritz (1919) by Aki and Richards (1980) and particularly by Shuey (1985). At the same time, Ostrander (1982) observed that seismic amplitudes changed with offset in the presence of gas. The Zoeppritz equations provide an explanation for this effect, especially through the use of the simplifications introduced by Aki and Richards, and Shuey. Castagna et al (1985) started to quantify this effect with their development of the "Mudrock Line" (Figure 1). This effect was further quantified with the "Fluid Factor" of Smith and Gidlow (1987). The importance of this innovation was the ability to evaluate fluid properties from seismic data.

With the evaluation now focusing on angles, the shear wave component to the seismic ray path came under scrutiny. This brought rock physics into play – the next great innovation. Backus et al. (1993) describe the incorporation of petrophysics and borehole properties into seismic interpretation. A further extension of this was the work by Goodway et al (1997) who incorporated these principles with his paper on rock properties - Lambda-Mu-Rho (LMR). This innovation provided for more direct estimation of lithologies and fluids from seismic data. (Figure 2).

Thomsen (1985) simplified the concept of seismic anisotropy, the variation of physical properties in different directions, by introducing the concept of weak anisotropy. Lynn et al (1996) showed that these effects could be seen in seismic data and Gray et al (1999) showed that fractures could be detected using 3D wide-azimuth seismic data– the next innovation. This was done by examining the shear wave component, which is affected differently depending whether it is traveling parallel or perpendicularly to the fracture system due to its anisotropy.

The impact of this was that engineering decisions could now influenced directly by seismic recordings. Geophysics was not strictly regulated to geologic interpretations.

So where are we now? By incorporating the concepts of stress and stain into the anisotropic calculations, we are now deducing Geomechanical properties from seismic data (Figure 3). Young's Modulus and Poisson's ratio, although present in geophysical algorithms for years for fluid calculations, they are also parameters the engineering teams use for well planning and frac'ing.

Modern geophysicists should consider themselves a partner in the drilling and development of the field. We are no longer just producing structural maps. We now have the capability of providing key links between geology and engineering through the use of seismic data. Expensive drilling decisions can be influenced in a positive way with the use of these seismic techniques.

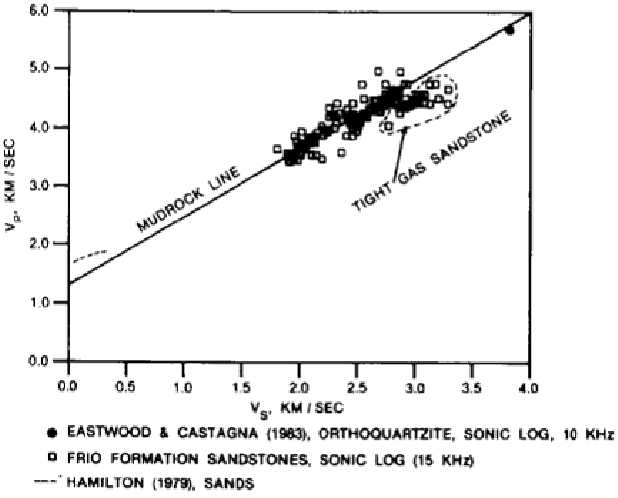

Figure 1: Sonic Log Velocities in Sandstone (Castagna et al, 1985).

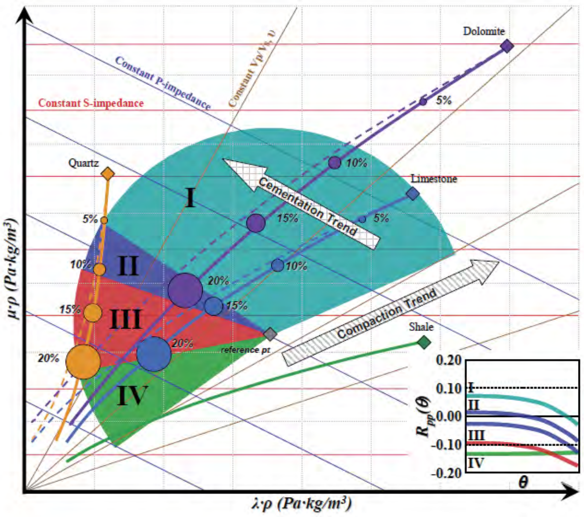

Figure 2: LMR crossplot showing effects of lithology, porosity and fluids. Hoffe et al (2008).

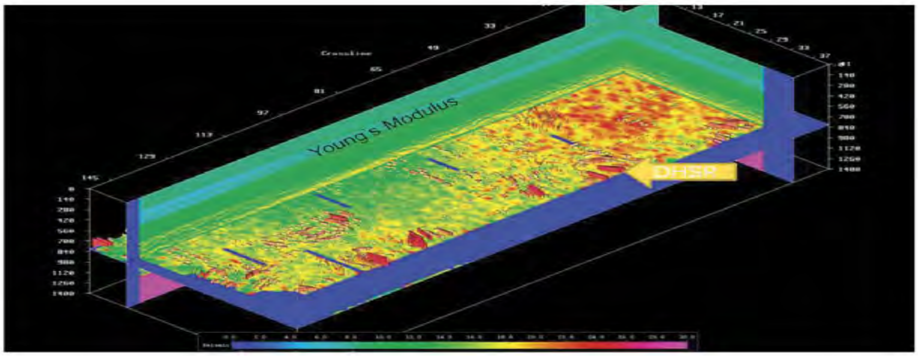

Figure 3: Young's Modulus Cube (Gray, 2010)

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