INTRODUCTION

The optimization of production using advanced recovery programmes is critically dependent upon the detection of reservoir bodies, together with the distribution, alignment and density of heterogeneities on a variety of scales. Although standard seismic measurements are of value in inferring spatial variability, they can often lack sufficient detail to adequately resolve some important heterogeneities. and higher resolution is almost always desired for a greater definition of small-scale features. During the last decade, a new brand of data analysis has evolved which has changed our perspective on seismic resolution, and may provide a suitable alternative strategy in usual surveying. This takes advantage of seismic scattering from heterogeneities smaller than a fraction of a wavelength, for which an equivalent homogeneous anisotropic medium can produce the same wave behaviour. Using this concept we may gain insight into the geometry and density of the internal structure of the rock, fractures, facies units, sand channels, layering sequences in cross-bedding or reservoir compartments, but sacrifice some details on their exact spatial distribution and individual seismic expression within the group due to the averaging process. This powerful concept allows complicated geology to be analysed using processing tools for a homogeneous structure, whilst retaining the impact of the complexity and the level of description.

RESERVOIR HETEROGENEITY AND SEISMIC RESOLUTION

To place this equivalent medium theory in its proper context, the various features of reservoir architecture must be displayed together with the range of wavelengths (lcm to 1 km) used in most seismics (Figure 1). Traditional seismics image those heterogeneities with scalelengths (a) obeying the inequality $a/\lambda > 1/4$, with the interpretation relying predominantly on high frequency ray theory. Equivalent medium theory has a range of validity to the left of the operative seismic wavelength, current laboratory work suggesting $a/X < 1/8$. In principle it seems that the role of equivalent medium theory could be to fill the lower scalelength portion of the seismic resolution, and provide information on a complete spectrum of reservoir features, including the characteristic dimensions of many fundamental flow units. In practice the effectiveness of this concept is largely controlled by the heterogeneity strength (magnitude of departure from the background model), geometry, and the nature (physical manifestation as a change in velocity, density, impedance or some complicated boundary condition involving, for example, a fluid flow process).

WHAT CAN BE CURRENTLY ACHIEVED USING SEISMIC ANISOTROPY?

This equivalent seismic anisotropy is of immediate value in providing: (1) a powerful image of heterogeneity distributions with some degree of alignment, which are known to dominate the seismic data, such as fractures or layered sequences with particular lithological components; (2) a suitable mathematical framework for: (a) modelling of the excitation and propagation of the seismic wavefield in complicated heterogeneous reservoirs, especially when the scalelengths transcend many orders of magnitude; (b) processing seismic data for the effects of subseismic heterogeneities on moveout, in addition to understanding the disparity between well log velocities, VSP and surface seismic data.
Investigation is required to define the exact boundaries of scattering behaviour for the equivalent medium concept in relation to the magnitude and nature of the heterogeneity (MacBeth 1995). For a typical dataset the seismic anisotropy includes all heterogeneity distributions smaller than the shortest wavelength. It is essential to determine which heterogeneity groups, if any, dominate the effective medium response. This may also help to improve consistency between seismic measurements at different scales. The composite response depends upon the way each class of heterogeneity such as pores, fractures and facies units are organized within the medium, with the scalelength distribution of each group being critical. Consequently, it is essential that the detailed statistical character of each heterogeneity population be calibrated. This highlights a requirement to model more exactly the seismic interaction with realistic geological and petrophysical conditions, and necessitates a stronger cooperation between geophysicists, geologists, and reservoir engineers.

CONCLUSIONS

It is possible to use equivalent medium theory for seismics to resolve some of the reservoir features we initially thought unresolvable with standard data. Anisotropy is a valuable aid for estimating fracture details, layering sequences, modelling and processing seismic waves propagating through heterogeneous media, and a generally useful tool for simplifying complexity whilst not missing out on all the information. It has considerable untapped potential, and is still under-exploited in reservoir characterization.

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