C053 PARAMETERISATION OF DETAIL IN MACRO MODELS

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Introduction

Inspection of both well and seismic measurements reveals a subdivision of the earth's subsurface into a few stratigraphic sections. The trend in and throughout these intervals gives information on the depth dependent compaction properties of the subsurface. The remaining detail gives information on the different rock and pore properties of the individual geologic layers (within the resolution of the measurements).

The seismic response, measured at the surface, represents a mixture of propagation and reflection information (see Figure 1). It is nowadays common seismic practice to attribute the propagation effects to the macro layering in the subsurface and the reflection behaviour to the detail (Berkhout and Wapenaar 1990). The main objective of this paper is to account for the influence of detail on the propagation (denoted by the dotted arrow (1) in Figure 1).

Additional information on the stratification in a macro layer has to be included in the conventional macro model in order to describe the propagation effects properly. Considering a geologic section as statistically stationary leads to a formulation defined by only two parameters, the values of which depend on the geology of the macro layer.

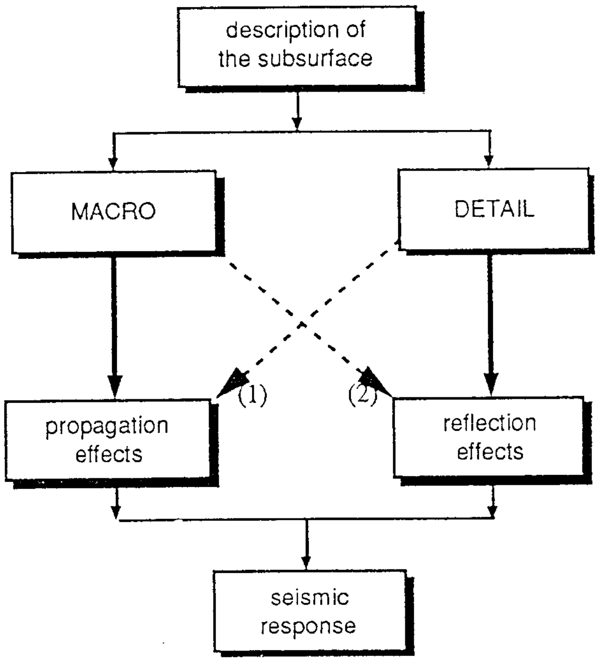

Figure 1 description of the seismic response
(1) influence of detail on the propagation
(2) influence of macro information on the reflectivity

Wave propagation in 1-D media

Attention will be paid to the main features of wave propagation in finely layered 1-D media first. The signature of a plane wave, incident on a stack of many horizontal layers with layer thicknesses smaller than the prevailing wavelength, changes due to a complex system of multiple internal reflections. This process results in a frequency dependent amplitude and phase behaviour which arises from the gradual transformation of primary arrivals into a train of delayed internal multiples.

The properties of the exact "generalised primary" (Resnick 1985), i.e. the ensemble of the primary and its first multiples, are primarily determined by the autocovariance function of the medium parameters. Successive approximations on the exact modelling scheme lead to propagation operators defined in terms of the causal part of the autocovariance function of the reflection coefficient sequence.

Now the main question is how to characterise this autocovariance function by only a few parameters.

Stochastic subsurface modelling

The reflection coefficient sequence in each macro layer will be regarded as a realisation of a stochastic process. The shape of "the generalised primary" converges, as it travels through a specific stratigraphic section, to a form which is specific for the statistical properties of that layer (Burridge 1989). This enables a wave propagation formulation in terms of statistical expectations of the detail. Hence, detailed information of the individual layers is not longer necessary.

In this paper Fractal Brownian Motion (FBM) is used as a stochastic model for the detail in each macro layer (Mandelbrot 1985; Walden and Hosken 1985). It provides an analytical description together with a tool to generate synthetic well-logs. The proposed Gaussian process is an extension of the commonly known AR(1) or Markov process and quantifies the degree of irregularity of the medium parameters. This irregularity is described by the fractal dimension which is related to the slope of the power spectrum, i.e. the Fourier transform of the autocovariance function of the detail.

FBM does not posses a characteristic size imposed by a fixed correlation length, and has the same statistical properties on every scale range. This non-scaling behaviour, within certain physical bounds, is conform the characteristics of many geological features.

The behaviour of a reflection coefficient sequence strongly depends on the fractal dimension and can be divided in two main classes: the correlated and anticorrelated. The latter category displays, in a statistical sense, a strongly alternating sign for the reflection coefficients which results in a substantial reinforcement of the "generalised primary" in the seismic frequency band. Estimation results of the slope of the power spectrum from real well-logs often belong to the anticorrelated category.

Extended macro model

The subsurface can, on geological grounds, be subdivided into a few major sections. A macro model reflects this subdivision and focusses primarily on the traveltimes of the waves propagating through the earth.

Contemporary seismic processing techniques increasingly depend on true amplitudes. It is therefore of great importance to find a macro parameterisation for the amplitude and phase characteristics of the seismic signal.

The combination of the proposed stochastic model and the approximate propagation operators leads to the definition of an extended macro model. This model consists in the acoustic 1-D case of the conventional macro quantities and two additional parameters, namely the variance and slope of the power spectrum of the detail in each macro interval.

A first order approximation for the effects of detail in 2-D or 3-D subsurface configurations can be obtained by considering the statistics of the medium fluctuations along the raypaths. For higher order approximations more research has to be conducted on the definition of 2-D or 3-D versions of the stochastic model for the medium fluctuations. Also the fact that the interfaces may not longer be smooth functions requires additional attention.

Conclusions

The effects of detail in the earth's subsurface can be accounted for by including a priori information in the macro model for each geologic interval. To be more specific, this prior information consists of two extra parameters, the variance and slope of the power spectrum of the detail in each macro layer. This information can be captured from well-logs or other geologic sources and amounts to a better treatment of the amplitudes and traveltimes of the seismic wavefield.

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