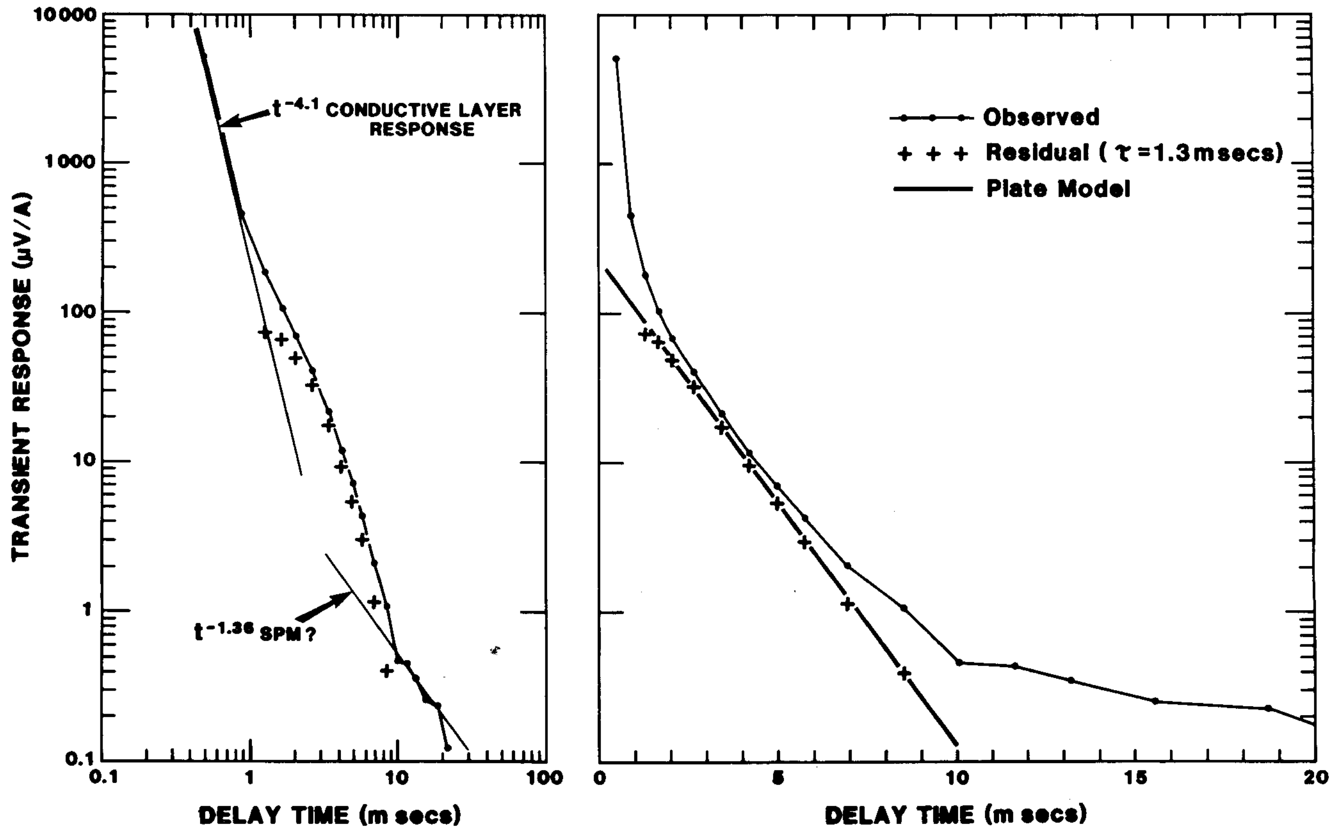

FIGURE 6
SIROTEM decay curves (200 m single loop) for station 8600E/8700N. Residual exponential decay due to Abra body is shown, compared with decay of plate model of conductance 17S.

Downhole EM surveys were completed in several holes using a large surface transmitter above the body, and a receiver coil profiling the hole. The results in general show a broad positive response through both stratabound and stringer zones, inferring that the whole body is uniformly weakly conductive. This is supported also by the layered earth interpretation of apparent resistivity soundings derived from the 200 m loop SIROTEM results, and from two EM-37 soundings over the deposit (Peacock & King, 1985).

Conclusions

The discovery of the Abra base metal deposit represents a significant case study of the application and integration of geophysical techniques in the search for deeply buried mineralized targets in arid terrain. Despite what would seem prohibitive depths for exploration, the careful application and interpretation of modern geophysical methods can provide the means for effective location and assessment of mineral resources in the future.

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A MODEL FOR THE CALCULATION OF EFFECTIVE THERMAL CONDUCTIVITIES OF MULTIPHASE-FLUID-SATURATED POROUS ROCKS

Stefan W. E. Nachtsheim and Eduard Oberaigner

Introduction

The calculation of effective thermal conductivities of porous rocks saturated with several fluid phases is problematic because of the large range of possible fluid phase distributions Another problem is the fact that the most important variable, the solid thermal conductivity, is not easily measured. The advent of advanced E&P technologies like enhanced oil recovery and similar advances in geothermics have increased the significance of the problem.

The accuracy of the effective thermal conductivity calculations has a pronounced effect on recovery forecasts arrived at by numerical reservoir simulation of nonisothermal displacements. The description of such systems in terms of the energy conservation equation hinges on the correct determination of the effective thermal conductivities of the inhomogeneously fluid-saturated porous rock. The best review of the traditional approach has been given by Woodside and Messmer (1961). For convenience in simulation the primary aim has always been to determine some equation that can be universally applied as a reasonable estimate of effective thermal conductivities. The traditional approach consisted of the selection of some equation developed for a specific phase distribution as a best estimate. The primary available candidates were the statistical (arithmetic, geometric, and harmonic) mean equations. Maxwell's dispersed-sphere equation and formulations like that developed by Somerton *et al.* (1974). The problem with all of these is that phase distribution does not appear explicitly in these formulations, resulting in the need to approximate large sets of highly variable data by just one equation. Another drawback of the traditional approach is that the dominant variable, i.e. the overall solid thermal conductivity, needs to be determined independently. The high degree of uncertainty associated with the measurement of this quantity makes it desirable to arrive at a method for calculating it back. This is accomplished in the present method.

The Basic Model

While other authors have recognized the desirability of accounting for phase distribution explicitly (see Woodside and Messmer; 1961), no overall consistent model has previously been presented. Such a model is described here.

The model, an application of the statistical method of spatial averaging of transport coefficients presented at several mathematical conferences (Nachtscheim, 1981, 1982, 1984) consists of a heuristic and a theoretical branch, linked by a simple transformation. Both branches are based on the explicit introduction of phase distribution in parametric form. The heuristic branch is a generalization of the statistical mean equations and affords easy calculability. The theoretical branch is a generalization of Maxwell's model and describes (via potential theory, here linear, i.e. Laplacian) dispersed ellipsoidal phase inclusions in an otherwise continuous, homogeneous matrix. We propose to use this branch as an interpretive and filing tool to classify results obtained by the heuristic branch in a geometrically meaningful manner. Both branches coincide at the physically admissable upper and lower bounds, the arithmetic and harmonic means respectively of the phase conductivities weighted by their volume fractions.

The theoretical (or geometrical) phase distribution parameter sweeps out the positive reals while its heuristic counterpart varies between negative and positive unity. Taking the multiplicative inverse of the theoretical parameter produces the same result as taking the additive inverse in the heuristic model. For progressively positive parameter values the flow model is one of increasingly parallel phase distributions.

The transformation linking the distribution parameters of our model branches has been analyzed for error generation in continuously varying scenarios of phase volume fractions, thermal conductivities and distributions.

The analysis indicates that results of one branch are approximated well by the other (within about 5% error) over roughly two orders of magnitude of phase conductivity contrasts. The range is wider for extreme distributions near the bounds, narrower around the central random distribution.

Our phase distribution parameters are closely related to the depolarization factor of dielectrics. This fact can be exploited in geophysical analyses of formations for which thermal conductivity values cannot be easily obtained but dielectric data are readily available. Conversely, the interrelationship is also useful in estimating dielectric properties from thermal conductivity measurements made in the laboratory.

Calculatory Procedure

For data sets such as that presented by Somerton *et al.* (1974), the following calculatory procedure is used:

Step 1:
Iterative calculation of pore geometry factors (solid-fluid distribution parameters) for the various formations from data obtained when pores are saturated with a single homogeneous fluid phase.

Step 2:
Calculation of the overall solid phase thermal conductivities of the individual formations.

Step 3:
Calculation of fluid phase distribution parameters for all multiphase data points.

Step 4:
Averaging of fluid phase distribution parameters and formulation of best estimate equation for each formation.

Step 5:
Interative optimization of input solid and fluid phase thermal conductivities. This is one of the most powerful tools of the present method.

Discussion and Conclusion

In following the above steps one develops an optimal effective thermal conductivity for each formation in terms of any occurring fluid saturations. Such an equation accounts for formation specifics and thus gives a more realistic picture of the physical situation than the global equations employed to date. The added advantage of optimizing the input values, particularly of the solid phase conductivities, has been stressed previously.

Presently ongoing research at several U.S. universities is aiming to establish best estimates for the heuristic distribution parameters associated with prominent types of formations. The stockastic analyses of field-scale hydraulic conductivity data (Gelhar, 1984) appear to indicate that near-random distributions are prevalent on that scale. Research at Stanford University, however, has shown microscopic pore geometry distributions to be much closer to parallel than their macroscopic counterparts (Aziz, 1986). This is not surprising in view of the fact that macroscopic heterogeneity has long been considered more important than the level of heterogeneity occurring in core-size samples.

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3D SEISMIC IMAGING WITHOUT STACK: A CASE HISTORY FROM THE IRISH SEA

P. Newman

Introduction

Conventional 3D marine seismic surveys usually employ high-fold Common Midpoint (CMP) stacking techniques, long streamers, and elaborate positioning systems to determine both the source and receiver array locations for every shot. It is inevitable that the reflection responses occurring in seismic profiles obtained through the CMP stack process are spatially averaged. Responses are further averaged over a range of reflection incidence angles in consequence of the various offset distances represented in the CMP gather. Whilst these effects may benefit the continuity of reflected events in a processed section, they detract from the potential resolution that could be achieved through subsequent 3D migration and obscure detail that might otherwise contribute to a more rigorous interpretation.

As an alternative approach we consider single-trace recording with minimal separation between seismic source and receiver. This geometry effectively yields normal-incidence reflection responses, ideally suited as input to dereverberation by predictive deconvolution, to a true-amplitude migration scheme that we shall describe, and for inversion to band-limited acoustic impedance. It is further expected that the 3D migration process will yield sufficient signal-to-noise enhancement to avoid the need for CMP stack for this purpose, as was indicated by physical model experiments described by Newman (1980).

In order to test the usefulness of such a radically simplified method a full-scale survey was conducted during the winter of 1984–85 at a particularly difficult location in the Irish Sea.

The Prospect Area

Figure 1 indicates the location of the experimental survey which covered an area of approximately 50 square km and lies some 30 km to the North of the Morecambe Bay gas field. Water depth is about 30 m and the tidal range almost 8 m with correspondingly strong currents. The area is characterised by a hard and irregular sea floor that results in severe back-scattered noise in conventionally processed seismic sections.

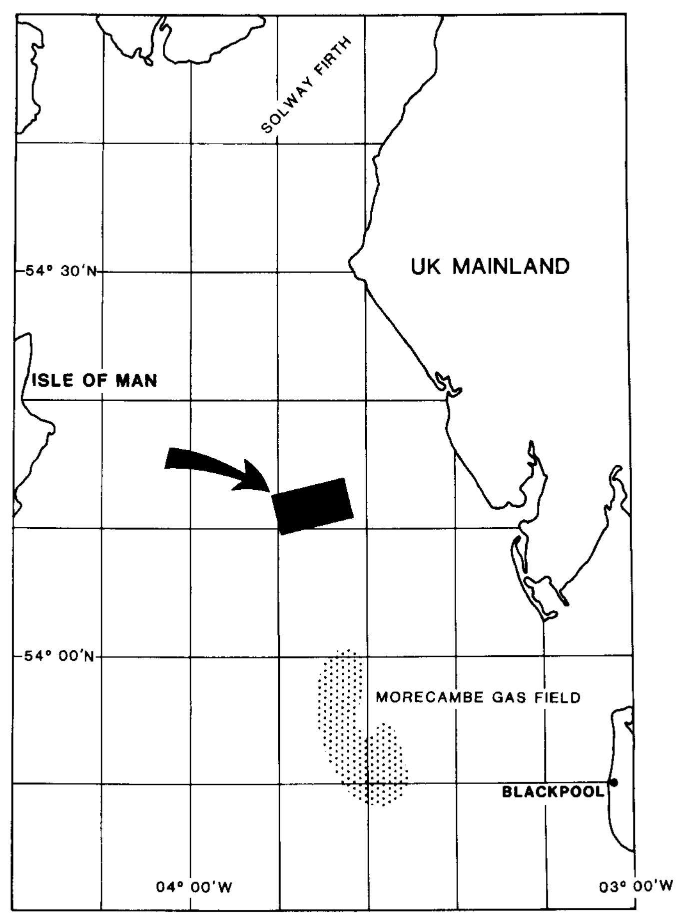

FIGURE 1
Location of experimental 3D survey in UK Block 113/22, Irish Sea. The surveyed area contained 221 lines of 9.5 km length with 25 m line spacing.