CHAPTER 11

THE STUDY OF THE PHYSICAL PROPERTIES OF ROCKS
SURROUNDING THE BOREHOLE

Of great importance in the study of the region around the borehole, in addition to mapping structures, is the study of the physical properties of rock which is essential for determining the geologic section, and particularly hydrocarbon and solid mineral deposits, as well as establishing physical foundations for assessing the section from surface observations. To this end, it is first of all necessary to study the effect of various heterogeneities on the parameters of the wave field. Such effects should be capable of making detectable any deposits of oil and gas penetrated by the borehole, which were not detected in the testing of the borehole (such instances have occurred), and should also help in outlining the deposits, in studying their extent and geometry as well as in controlling them in the process of exploitation.

The basic factors governing the application of seismic exploration at the exploration and exploitation stages of a field, are associated with studies of the physical properties of rock, and there is no doubt that in the coming years this trend will rapidly develop.

The determination of the physical properties of rock is to a large extent founded on the use of the dynamic properties of waves in addition to their kinematic properties. This sets special standards for the quality of field data that substantially affects the potential and the accuracy of such determinations. The conditions that field data will have to satisfy depend on the problems to be solved. Here we can discuss some general requirements only.

1. Conditions the Initial Data Must Satisfy

For dynamic processing one needs VSP data that provides stable information about the characteristics of the shape and intensity of the waves, primarily of the direct wave. This is especially important in the study of absorption.

The following may serve as criteria for the quality of the data:

- the facility to obtain records in a frequency band and with a dynamic range free whenever possible of various regular and irregular unwanted waves;
- the reproducibility of the record (of both amplitude and frequency) when repeated observations are made at a point;
- the reproducibility of conditions governing the variation of amplitudes and of spectra, when repeated observations are made in the same borehole (along the vertical profile) of waves excited from the same shotpoint;
- the validity of the data available for statistical processing.

The quality of the data is influenced by a number of factors associated both with the conditions of excitation and of reception.

Among the conditions of excitation, constancy and control are the chief factors. This is true in the first instance of excitation by explosives. With non-explosive excitation, it is easier to guarantee constancy, because the earth is less affected in this case. With
explosives, it is possible to achieve the required reproducibility for a great number of shots only if the excitation conditions are kept strictly constant. In particular, by exploding comparatively small charges at the same depth each time, and aligned in the borehole, it is possible to keep the excitation conditions constant and to carry out numerous explosions.

In addition to the constancy of such traditional parameters as the intensity and the spectral composition, the constancy of source directivity becomes a factor of essential importance for the solution of certain problems. In such cases directional excitation sources are usually employed.

To eliminate the effect of changing excitation conditions, particularly when absorption is to be determined, the pulses of the direct wave observed at great depths are frequently normalized with the aid of records of the same wave obtained at a comparatively shallow depth relatively close to the source. Such a normalization does not always improve the quality of the data, because the effect of various source excitation conditions on the direct wave near the source may be different from that at a great depth (as has been pointed out earlier in Chapter 5). One can prevent this by placing the monitor geophone at a depth where the shape of the direct wave has already stabilized. Sometimes better results can be obtained by using records from monitor geophones to reject low-quality data.

Reception conditions should guarantee undistorted recording in the specified dynamic range and frequency band at every point. To this end, the instrumentation should be calibrated, and the effects of the temperature and pressure, which vary along the vertical profile, should be eliminated. Recording should be performed in the frequency band corresponding to the problem being solved. For instance, to study absorption and its frequency dependence, a frequency band approximately from 5 to 500 Hz and a dynamic range up to 100 dB should be available.

Downhole measurement technology should exclude various mechanical parasitic resonances associated with the design of the borehole tool itself, its clamping to the borehole wall, and the cementation between the casing strings and between the casing and the earth, which may change from point to point along the vertical profile. The extension of the frequency band of the waves being studied necessitates a substantial increase in the force with which the borehole tool is clamped to the borehole wall. The possible effect of the cable remaining on the drum should also not be overlooked. The inductive reactance of the cable changes with its length, and this can affect the frequency response of the recording channel and thereby distort the results of the measurement. Such an effect can be assessed by recording calibrated electric pulses. All these effects merit special attention, because in several instances attempts have been made to determine physical parameters with the aid of wave dynamics, using data known to be low-grade (e.g., from records of a sliding-clamp or bowspring tool, or even worse, from a tool suspended by the cable, etc.), with completely erroneous results being the outcome.

When solving certain problems, e.g., when studying the mechanism of absorption, it is advisable to make special checks of the coupling conditions at every depth point, e.g., clamping reliability and casing cementation quality.

The observation system should require observations not at disconnected points, but at ones allowing a continuous correlated tracking of a wave, yielding an adequate amount