THE EFFECT OF VARIATIONS IN CHEMICAL COMPOSITION ON THE VELOCITY OF SEISMIC WAVES IN CARBONATE ROCKS

by

CARL KISSLINGER, B. S., M. S.

Dissertation Presented to the Faculty of the Graduate School of Saint Louis University in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

1952

INTRODUCTION

Purpose of Investigation.

A knowledge of the velocity with which elastic waves are propagated through the materials that make up the solid body of the earth is either an essential tool or the final direct result of all phases of the analysis of seismic records. In seismic prospecting by the reflection method, some assumption must be made as to the variation of wave velocity with depth below the surface if the times of arrivals of reflections are to be converted into depths to the reflecting rock horizons. Interpretation of the data obtained in the refraction seismic method requires knowledge of wave velocity in all strata between the earth's surface and the level of deepest penetration of the waves (68, p.243).*

All direct evidence as to the internal constitution of the earth obtained from the investigation of earthquake data is in terms of wave velocities at all depths from the earth's surface to its center(67). These velocities, especially when combined with density information gained from astronomic and geodetic obser-

---

*For this and other references to authors and their works, see Bibliography.

vations, can indeed be given a likely interpretation in terms of actual constituent materials.

As will be discussed further, the distinct possibility of using the great amount of seismic velocity information that has been accumulated as an aid to stratigraphic correlation of rock units has been increasingly recognized by geologists. It has at the same time been recognized that the full realization of this possibility rests on the fuller understanding of the variable properties of rocks that influence the velocity.

Thus it is apparent that there are ample reasons, both purely scientific and commercial, for the numerous efforts which have been made to formulate the principles which govern the velocity of seismic waves in rocks. The general law yielding the velocity of seismic waves in a homogeneous and isotropic elastic solid in terms of the elastic constants and the density of the solid has long been known. The earth as a whole is certainly not homogeneous, as is made evident first by the fact that its average density is considerably higher than the observed average density of surface materials, and secondly, by even the casual inspection of a typical well log or exposed vertical rock section.

Further, as far as observable surface materials are concerned, within a given section of rock that may appear quite homogeneous in its physical properties, the substance is not isotropic, as measurements of wave velocities parallel and perpendicular to the bedding planes of sedimentary strata have shown (33).

Nevertheless, it has often been useful to treat the earth's solid body, at least in relatively thin layers, as if it did exhibit this ideal behavior, and thus gain an approximate notion of wave velocities in terms of elastic properties and density, and more important for present knowledge of the earth as a whole, some insight into the properties of the substances from velocities (67, p. 221). This approximation seems to have worked well for the materials lying deep within the earth's interior.

Limits of Investigation.

In this investigation, attention will be limited to the sedimentary layers that form the outer portion of the earth's solid body over most of the exposed continental areas, and which are the principal object of interest in seismic exploration. It is within these layers that very striking departures from ideal behavior are found. Because of this, the approach to the problem of determining the laws governing seismic velocities in sediments has been largely an empirical one.

Of the two types of elastic waves that can be propagated through the interior of an elastic solid, condensation-rarefaction, or dilatational, and shear, or distortional waves (67,p.220-221), only the former will be considered in this investigation. There are several reasons for this, the most important of which is that the method of gathering field data practically limits the observations to those of the higher velocity dilatational wave. Further, this wave is the one that is observed in both reflection and refraction seismic prospecting, so that chief interest has always been in it. Lastly, under rather restrictive assumptions as to the elastic properties of the material, the shear wave velocity can be predicted from a knowledge of the dilatational wave velocity (67, p.221). It is not suggested that the results obtained here be immediately applied to shear waves by making these assumptions, but a trend in the behavior of the one should most likely be paralleled, at least roughly, by a trend in the other. In all cases in the following pages, the expressions "seismic wave velocity", or "wave velocity" will mean the dilatational wave velocity.