REMOVAL OF SURFACE LAYER ANOMALY EFFECTS

BACKGROUND OF THE INVENTION

This invention relates to seismic exploration and more particularly to the removal of distortion produced by surface layer anomalies.

In seismic exploration, seismic energy from a source is reflected from subsurface layers and detected to produce seismograms which represent the subsurface layering. One type of seismic exploration which is particularly prevalent is referred to as common depth point (CDP) exploration. Seismograms produced in this manner are particularly useful because they can be stacked, or composited, to enhance the signal to noise ratio. Before stacking, it is necessary to normal move-out correct seismic traces. In order to do this, it is necessary to determine the velocity of the subsurface layers. The velocity used to normal move-out correct the traces before stacking is often referred to as the "stacking velocity".

Determination of the correct stacking velocity is described, for example, in "SEISMIC VELOCITIES FROM SUBSURFACE MEASUREMENTS", C. H. Dix, GEOPHYSICS, Vol. 20, pages 868–886, 1955.

Prior to stacking, groups of seismic traces beyond a certain source receiver offset distance and having a record times less than a minimum time are muted or nulled. This operation eliminates noise, refractions and nonlinear distortion from the resulting summed output. This muting of the seismic common depth point records also determines the effective spread length and trace distribution with distance. However, it results in a variable number of traces with time, and this introduces time variant distortions in the resulting summed set of seismic traces representing the stacked cross section. One particularly troublesome time variant distortion results from surface layer velocity gradients or thickness changes. This problem is discussed in Lucas, A. L. et al., "The Calculations Of Laterally Varying Time Delays From Stacking Velocity Anomalies" SEG, October 1975; Booker, A. H. et al, "Long Wavelength Static Estimation" SEG, October 1975; and Booker, A. H. et al, "Long Wavelength Static Estimation Geophysics", 41, No. 5, pp. 939–959. An example of a surface layer anomaly which produces time variant distortion is a depression in the ocean bottom. The stacking velocity, as determined from the seismograms, is distorted by this change in the depth of the water layer. Similarly, a change in the velocity characteristics of a uniform surface layer distorts the stacking velocity in land exploration. Other layer anomalies introduce such distortion. These include irregular surface elevation along the seismic profile, layer anomalies due to thickness or velocity, and changes where the layer occurs at any level in the section. This distortion is particularly difficult to remove because it changes with record time, i.e., it is time variant. It is not possible to introduce a static time shift into the seismograms which will correct this type of distortion. The time distortion diminishes with record time, but it also spreads horizontally across a field section with record time. Therefore, it is necessary to determine the time correction for all record times and for all horizontal distances from the shot point.

The present invention is directed to a method which can be used to successfully correct seismograms for the distortion introduced by anomalous layers.

SUMMARY OF THE INVENTION

In accordance with the present invention, distortion introduced by layer anomalies is removed from seismograms by a technique which includes generating a seismic depth section having the anomaly, and generating another seismic section which does not have the anomaly. From these depth sections, records are produced of the reflections to the various subsurfaces. The differences between these reflections are a set of time corrections. These time corrections are determined for each trace of the seismograms and for each subsurface. These time corrections are applied to the seismograms at the correct record times to remove distortion in a time variant manner.

The foregoing and other objects, features and advantages of the invention will be better understood from the following more detailed description and appended claims.

DESCRIPTION OF THE DRAWINGS

FIG. **1** depicts the distortion removal process of this invention;

FIG. **2A** depicts a seismic field system recording over a surface layer thickness anomaly;

FIG. **2B** depicts seismograms from a reflecting subsurface below the surface layer with and without the thickness anomaly of FIG. **2A**;

FIG. **3** depicts a model depth section with a surface layer thickness anomaly and ray paths to reflecting subsurfaces;

FIg. **3A** shows a model seismic trace obtained from the depth section of FIG. **3**;

FIG. **4A** shows a depth section of a surface anomaly;

FIG. **4B** is a seismogram of the reflections beneath the anomalous surface layer of FIG. **4A**;

FIG. **5A** is a depth section of a desired surface layer without the anomaly;

FIG. **5B** is a seismogram of reflections beneath the desired surface layer of FIG. **5A**;

FIG. **6** shows corrections applied to field traces of a seismogram whose source and receiver locations are positioned over the field anomaly;

FIG. **7** depicts a velocity anomaly which produces distortion similar to the surface layer anomaly of FIG. **3**;

FIG. **8** shows the reflections from subsurfaces on a CDP stacked seismic section which has not been corrected for time variant distortion; and

FIG. **9** depicts the reflections from subsurfaces on the same CDP stacked seismic section which has been corrected in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Before describing the invention as depicted in FIG. **1**, the problem of distortion introduced by an anomalous layer will be discussed.

FIG. **2A** depicts a typical marine seismic exploration system which has a source S and receivers R_1, R_2 . . . R_6 which are towed along a line of exploration. The water bottom **10** has an anomaly which is the depression **11**. This depression causes time differences in the times of reflections from subsurface interface **12** as detected at the different receivers.