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Abstract

Full Text

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GEOPHYSICS

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ON THE USE OF TRANSVERSE WAVES IN STUDYING THE EARTH' S CRUST

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In deep seismic sounding (DSS), longitudinal waves of various types are analyzed –reflected, head waves, refracted waves, etc. ([2,4]) and others. In order to broaden the information on the structure of the Earth' s crust, it is expedient to make use of transverse and exchange waves. In particular, exchange waves from remote earthquakes have been used ([1,5]). A new direction is the application of transverse waves in DSS.

In the Urals, work by the Institute of Geophysics of the Ural Branch of the USSR Academy of Sciences has shown the effectiveness of using "Zemlya" stations* for recording elastic waves from industrial explosions in quarries and mines ([5]).

Fig. 1. Characteristics of the longitudinal and transverse waves reflected from the Conrad boundary (respectively $P^{K}_{4\,\mathrm{ref}}$ and $S^{K}_{4\,\mathrm{ref}}$). Distance 43 km

A brief characterization of these explosions is as follows (only charges weighing more than 5 tons were considered). In quarries, massive grouping of blast holes is carried out (up to 200 holes), arranged in several rows. In each row there are usually 10-20 holes. The distance between them is on the order of 5 m, between rows 10 m; the depth of the holes is 8-15 m. Mostly instantaneous explosions were used; the number of short-delay explosions (with a delay of about 35 msec) did not exceed 30%.

In the wave field recorded by the "Zemlya" station, the following features are noted (observations with filtering at 2-6.5 Hz). In the distance interval from 3 to 300 km, both longitudinal and transverse waves are distinguished. At the same time, because of the comparatively small angles of incidence of the transverse waves (which is due to the development of high-velocity rocks near the surface),

Fig. 2. Characteristics of head and reflected longitudinal and transverse waves from the Conrad and Mohorovičić boundaries. Distance 118.5 km

Figure 2: Fig. 2. Characteristics of head and reflected longitudinal and transverse waves from the Conrad and Mohorovičić boundaries. Distance 118.5 km

these waves have significant vertical components recorded by vertical instruments (Figs. 1 and 2). Similarly to the first arrivals of longitudinal waves, the corresponding hodograph of transverse waves has breaks at the same distances ([5]). As in the case of longitudinal waves, the character of the wave pattern of the transverse-wave field depends on the distance of the explosion source. Thus, the duration increases from 5 to 15 sec as the distance changes from 40 to 120 km (Figs. 1 and 2). The intensity of transverse waves is usually an order of magnitude greater than the intensity of longitudinal

* Developed at the All-Union Scientific-Research Institute of Geophysics under the direction of A. N. Mozzhenko.

near the explosion point, and 2–3 times greater at a distance of 40 km, and is commensurate with the intensity of the latter at a distance of 200 km (Fig. 1) (5).

Let us dwell on the characteristics of the field of longitudinal waves. For DSS in the Urals, relatively high-frequency (8–17 Hz) filtering is used (4). In this case, for distances of 0–90 km there is usually no dominant wave. In the precritical part, even the main waves reflected from the Conrad and Mohorovičić boundaries are distinguished with difficulty (respectively $P^K_{4\ \mathrm{refl}}$ and $P^M_{0\ \mathrm{refl}}$). Therefore, in order to increase the reliability of the interpretation here it is necessary to use special methods: densification of the seismic record, analogy with theoretical hodographs, etc. (3).

Fig. 2. Characteristics of head and reflected—longitudinal and transverse—waves from the Conrad and Mohorovičić boundaries. Distance 118.5 km

A different picture was obtained from industrial explosions with lower-frequency filtering. On the seismograms of the "Zemlya" station, owing to this, the waves $P^K_{4\ \mathrm{refl}}$ are distinguished confidently, usually already from 30 km, and $P^M_{0\ \mathrm{refl}}$ from 50 km (Fig. 1). This indicates, on the one hand, that industrial explosions in quarries are favorable for exciting relatively low-frequency oscillations, and, on the other hand, that the latter are also energetically more favorable for the formation of pronounced reflections and refractions from the principal boundaries in the Earth' s crust.

The investigations revealed three transverse waves dominant at the output, which are of interest for DSS. As already noted, the use of converted waves of distant earthquakes for studying the Earth' s crust is known. Converted waves from explosions are successfully used for studying the surface of the consolidated basement (6). In our investigations, at some points at distances of 55–

Fig. 3

Figure 3: Fig. 3

Fig. 4

Figure 4: Fig. 4

85 km, waves assigned to converted waves of the type PPS_2^K were identified (Fig. 4). In Fig. 3 one can see a repetition of the shape of the record of the first longitudinal wave (vertical instrument) by an oscillation on the horizontal seismograph, shifted in time, which is one of the criteria for identifying converted waves (1). The depth to the conversion boundary was determined as 5-6 km. By analogy with DSS on the nearby Sverdlovsk profile, it was identified with the surface of the granite-gneiss complex (4).

The most important element established as a result of analysis of the field of transverse waves should be considered the identification of transverse waves identified with waves from the Conrad and Mohorovičić surfaces (Figs. 1, 2, 4).* With the applied point system of observations, for the Conrad surface the most reliably recorded reflected wave

* One of the reasons for the identification of intense transverse waves may be the structure of the explosion—the confinement of it to the edge of a cavity, the side of a quarry (6).

$S^K_{4\,\mathrm{refl}}$. The head wave S_4^K has lower intensity and is traced in the first arrivals of the shear-wave field only at distances of 100–120 km (Fig. 2). The wave $S^K_{4\,\mathrm{refl}}$, however, is already distinguished from distances of 30–40 km (Fig. 1). The interval over which it is most reliably traced is 50–120 km, i.e., in the post-critical region (Fig. 2).

In an analogous way, the head and reflected shear waves associated with the Mohorovičić boundary, S_0^M and $S^M_{0\,\mathrm{refl}}$ (Figs. 2 and 4), are distinguished. The first of them is confidently recorded from distances of 100–110 km, where it is traced together with $S^M_{0\,\mathrm{refl}}$ (Fig. 2). Thereafter the waves separate, and already at a distance of 180 km S_0^M usually appears in the first arrivals

Fig. 3. Characteristic of the converted wave PPS_2^K. The record on the horizontal instrument is analogous to the longitudinal wave of the first arrivals (delay 0.73 sec). Conversion at the surface of the granite-gneiss complex. Distance 55 km

Fig. 4. Scheme of formation of the waves under consideration: the converted wave PPS_2^K and the shear waves $S^K_{4\,\mathrm{refl}}$ and $S^M_{0\,\mathrm{refl}}$. d_2^K is the surface of the granite-gneiss complex; d_4^K is the Conrad surface; d_0^M is the Mohorovičić surface

of the shear field (5). The wave $S^M_{0\,\mathrm{refl}}$ can be studied already from a distance of 50 km, since its intensity here is commensurate with that of the wave $S^K_{4\,\mathrm{refl}}$.

With increasing distance, the dynamic expressiveness of the shear wave reflected from the Mohorovičić boundary increases, and after 150 km it becomes dominant.

In identifying the shear oscillations considered with head waves and waves reflected from the Conrad and Mohorovičić boundaries, two principal criteria were used. First, their arrival times are $\sqrt{3}$ times greater than those of the corresponding longitudinal waves. In interpreting the latter, their correlation tie to the boundaries of the Sverdlovsk DSS profile was taken into account (4, 5). Second, in most cases the intensity of the shear waves correlates well with their analogues in the longitudinal-wave field: where anomalies occur for the longitudinal wave, an identical pattern is also observed for the shear wave.

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Note: Figure translations are in progress. See original paper for figures.