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A non-destructive non-contact method of the sea-bottom structure investigation

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Abstract

The paper describes a nondestructive noncontact method for investigating the sea-bottom structure using hydroacoustic and laser radiation. A practical implementation of this method is also presented. The research complex incorporates a state-of-the-art low-frequency hydroacoustic radiating system and a system of coastal laser strainmeters arranged in the specially selected sea waters and coastal grounds. The hydroacoustic radiators are used to generate a seismic signal. Seismic superficial waves are recorded by the coastal laser strainmeters. Optical parts of the strainmeters are constructed as the unequal-path Michelson interferometer where the frequency-stable helium-neon lasers serve as emission sources. A preliminary model of the sea-bottom testing ground has been developed by application of geologic-geophysical procedures. The model-based analysis of the timing data of the recorded seismic waves was carried out. The prospectivity of the used method was proved.

Keywords: Sea bottom structure; Laser strainmeter; Shelf; Hydroacoustic transducer; Seismic signal.

1. Introduction

Over the past few years, the Laboratory of Geosphere Physics of the V.I. Il'ichev Pacific Oceanological Institute of the Far Eastern Branch of the Russian Academy of Sciences (POI FEB RAS) has carried out studies into the possibilities of determining the structure of the sedimentary layers of the Earth's crust in a sea shelf using systems of coastal laser strainmeters.

Laser strainmeters can detect the deformations of the Earth's crust with an accuracy up to 10^{-10}–10^{-12} (depending on the level of frequency stability of the laser used) over a wide frequency range and over an almost unlimited dynamic range when measuring natural processes. Various modifications of hydroacoustic transducers are used as signal sources for generating seismoacoustic waves.

The advances in this direction are due to the growing interest in the development of natural resources of the World Ocean (including in Russia) and the study of the Arctic shelf. The Arctic seas are covered with ice for the greater part of the year, so the above-described non-contact method, which does not destroy the ice cover, is highly important for environmental protection.

The capabilities of the method for detecting seismic surface waves with different acoustic properties

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that propagate along the boundaries of the geological layers of the Earth's crust were discussed in our earlier studies [1,2]. The experiments on detecting and processing complex phase-shift signals by coastal laser strainmeters laid the foundations for determining the structure and composition of the Earth's crust.

2. Experimental procedure

In order to develop the procedure for the study, a complex experimental project was accomplished in June 2016 that involved detecting acoustic signals by laser strainmeters with different angles of propagation of seismic signals on their path from the transformation point to the detection system, as well as at various distances from this point.

The experimental studies were carried out using the newest hydroacoustic low-frequency radiating transducer and a system of coastal laser strainmeters.

The system in question is located at the Schultz Cape experimental station of POI FEB RAS. The system consists of two laser strainmeters with a 52.5-m-long (NS (north–south)) and a 17.5-m-long (WE (west–east)) measuring arm. The strainmeters are located at the peninsula near the coast, at an altitude of 76 m above sea level. The optical parts of the strainmeters are constructed by the unequal-arm Michelson interferometer where frequency-stabilized helium-neon lasers are used as radiation sources. The sensory elements of the devices and the light guides are located in separate underground chambers isolated from the environmental effects. The measuring arms of laser strainmeters are almost mutually perpendicular (located at an angle of 92°). The principle of each measuring device is in synchronized detection of the changes in the phase shift of interfering laser beams passing through the measuring arms from the main interference node to the corner reflector and back.

The hydroacoustic radiating system is designed to generate various hydroacoustic signals in the frequency range from 19 to 26 Hz, with an acoustic power of 1 kW. In the course of this experiment, the emitter operated at a depth of one quarter of the wavelength with a frequency of 22 Hz. In this mode of operation, the emitter and its imaginary antiphase source form an antenna whose maximum directivity is oriented vertically downwards, and the minimum lies in the horizontal plane. In this case, the greater part of the hydroacoustic energy is transformed into bulk waves, and the remainder is transformed into surface waves that are then registered by laser strainmeters. The positioning, as well as the time characteristics of hydroacoustic radiation and its reception is registered using the GLONASS system.

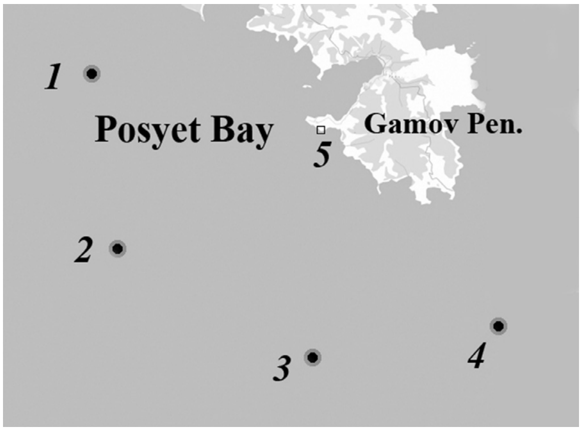

Fig. 1. Geometric layout of the experiment: radiation source stations (*1–4*), position of the signal-receiving system (*5*). The Maritime experimental station is located in the Primorsky Krai, at a distance of 84 km from Vladivostok.

Fig. 1 shows the geometrical layout of the experiment. The experimental design consisted in emitting the same series of hydroacoustic signals from each of the *1–4* stations, located at a distance of 10 km from the signal-receiving system *5*.

Since no drilling of the sea bottom was carried out within the test site in the Posyet Gulf, preliminary information on the structure of the bottom was obtained through geological sampling by corers and grab samplers, from the geological structure of the basement of the Furugelm Island and the Gamow Cape [3,4] and by geophysical results [5,6]. The sea bottom at the test site has a gently rolling topography, inclined to the south–south-east and complicated by shallow gullies and separate hills. Sedimentary waves (ripples) were detected in the low-frequency seismic profiles obtained by bathymetric survey in the sea bottom relief of the area under investigation [7].

3. Results and discussion

Based on all the available data, we have constructed a preliminary model of the floor structure for each of the signal propagation routes (Fig. 2). The Above Sea Level Elevation (ASLE) was plotted on the vertical axis of the graphs and distance was plotted on the horizontal axis.

According to the preliminary model, a basement made up of half-space IV, consisting of granitoids of the Late Permian period, and sedimentary layers is located along the signal propagation route: I–Late