Yu.V.Marapulets(1), V.A.Gordienko(2), A.O.Tsherbina(1)

RESEARCH OF THE ANISOTROPY GEOACOUSTICAL SIGNAL ON THE KAMCHATKA POLYGON BY VECTOR-PHASE METHODS

Institute of Cosmophysical Research and Radio Wave Propagation
Far Eastern Branch of Russian Academy of Sciences (1)
Russia, 684034, Kamchatka Region, Paratunka, Mirnaya str., 7,
Tel.: (41531) 33-193; Fax: (41531)33-718, Email: marpl@ikir.kamchatka.ru
Moscow State University, Physical Faculty (2)
Russia, 119991, Moscow, GSP-1, Leninskie Gory,
Tel.: (495) 939-2969; Fax: (495) 932-5602, E-mail: vgord@list.ru

Research of anisotropy was carried out by combined acoustic receiver installed in a natural reservoir (Mikizha lake) in 28 kms in the south to the west of Petropavlovsk-Kamchatsky. It is establishe, that geoacoustical signal represents to a sequence of shock pulses in the frequency range 5-10000 Hz, with the a medial expansion up to 200 msec and amplitude of 0.1-1 Pa. In the capacity of the quantitative performance of an estimate of an anisotropy of signals was used the frequency of recording of impulses from directions in a horizontal plane with a pitch in 1 degree. In the report was presented the results of research of the anisotropy geoacoustical signal in seismically calm periods and at the final stage of earthquake preparation.

For a detailed study of geoacoustic radiation anisotropy at different stages of seismic activity a directional operation receiving system was installed in Lake Mikizha, in Kamchatka, at the depth of 5 miters; it allowed us to determine the direction of arrival of acoustic wave energy and to analyze the character of movement of media particles in it using vector-phase methods. A combined receiver (CR), worked up at ZAO “Geoacustika” under FGUP VNIIFTRI, was used as an acoustic receiving device; the CR register simultaneously acoustic pressure and tree mutually orthogonal projections of its gradient in the frequency range 5-11000 Hz [1, 2]. A special software-hardware complex was developed to register geoacoustic signals. The hardware includes a PC, an electric signal amplifier and an IBM compatible computer with 2 sound cards which provide synchronous data channeling. The software included special programs for real time registration and detailed analysis of the registered signal in the conditions of the laboratory.

The analysis of geoacoustic data showed that the broadband signal from the hydrophone is a sequence of shock pulses with the amplitude of 0.1-1 Pa [1-3]. It was determined that he pulse repetition frequency depends on relative deformation and changes within a wide range from single pulses at a time slot of several seconds during background interval up to tens and even hundreds of impulses per second during deformation changes. As an example, 3-minute record of acoustic signal is shown in the upper part in Fig.1 and a single pulse of this record is in the lower part.

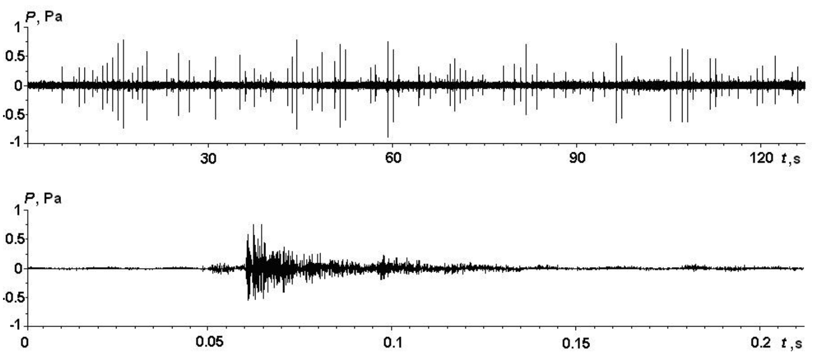

Fig.1. Part of a broadband record of geoacoustic emission signals (upper part) and a single pulse of this record (lower part), P - pressure.

In order to analyze an acoustic signal from the CR we used its hodograph in polar coordinates which, in particular, allows us to determine the direction to the source of impulse generation. The software for processing automatically finds and determines pulses in the recorded data. In the result a file-list is formed; it contains all the determined pulses with the description of the main characteristics:

registration time and an angle of arrival with 1 degree discreteness. Than we determine space distribution of *geoacoustic activity* $N'(\alpha) = \frac{dN(\alpha)}{dt}$ – dependences of the number of impulses registered per time unit from every direction, and graph it. To analyze geoacoustic signal anisotropy a CR was in operation on Kamchtka testing ground in autumn 2004 – spring 2005, than it was stopped and started up again in October, 2006. The second place of installation is 10 miters to the south-east from its first location. Estimation of spatial characteristics of geoacoustic activity during calm (background) period was carried out on the days without clear continuous high-frequency acoustic anomalies determined by the increased activity of deformation process or weather conditions (wind, rain). As an example of such a period Fig.2 illustrates the graph of acoustic signal behaviour on November 15, 2004. The analyzed value is 4-second total value of acoustic pressure P_s in the most informative frequency range of 2 – 6.5 kHz [3].

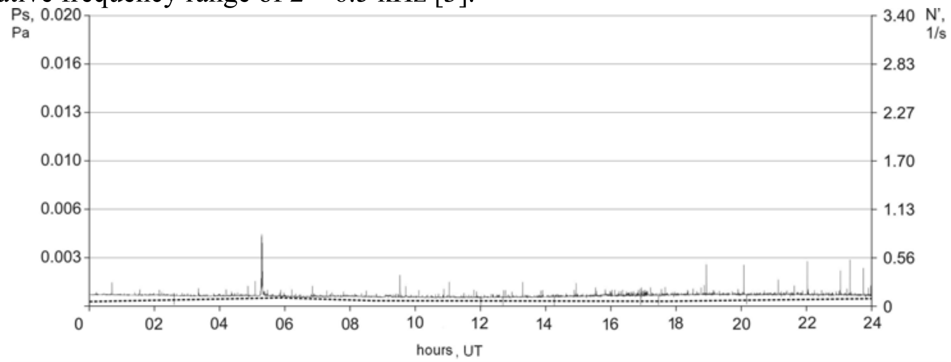

Fig.2. Signals of geoacoustic emission registered in Lake Mikizha on November 15, 2004.

Dashed line on the graph shows the level of *geoacoustic activity* $N' = \frac{dN}{dt}$ (right scale of Y-axis). There are only accidental acoustic emissions with considerable calm periods between them.

In the result of processing of background data the averaged graphs of geoacoustic activity were plotted for the following periods: autumn 2004 (Fig.3, a) and winter 2007 – winter 2008 (Fig.3,б).

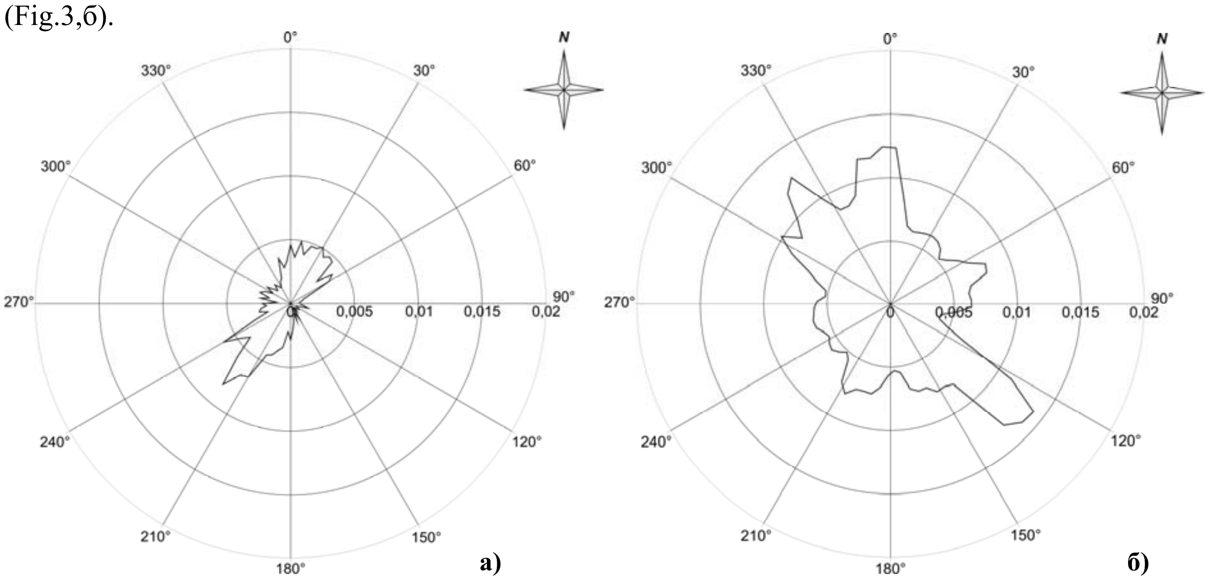

Fig. 3. Averaged graphs of geoacoustic activity $N'(\alpha)$

From the diagram for 2004 it is clear that there are active areas at the place of registration; they are located at 0°–60° and symmetrically to it at 180°–240°; they emit acoustic pulses the most intensively. The diagram for 2007-2008 differs considerably both in the spatial distribution of the direction of signal arrival and in the activity value. Perhaps, these changes are the result of the longer period of data acquisition (1 year) which entailed the influence of seasonal factors or they may be the result of quite a long period between the operation of the device (change of seismotectonic process activity in the region).

Nevertheless, it should be noted that in every case the mechanism of formation of diagrams of background period pulse activity is associated with acoustic signals generated mainly by local inhomogeneities located in the immediate vicinity of the place of CR installation. The main factor which determines the presence of such regions is the peculiarity of the geological structure of the territory close to the lake.

But before an earthquake, in about one day interval, at the background of these signals the CR also regularly registered anomalous disturbances in the behavior of AE determined by deformation changes in the near-surface sedimentary rocks and associated with the source of a future earthquake. Such phenomena were observed in the absence of strong wind and precipitation and that is why they may not be connected with meteorological factors. Previously such disturbances of AE were repeatedly observed by a weakly directed receiving system on the base of hydrophones which was installed in Lake Mikizha in 2001 [3]. For example, on November 10, 2004 at 21:47 UT a 9.1 class earthquake occurred at a distance of 15 km in the direction of 107° relatively the measuring system. In spite of a quite low class of the event a considerable increase of average power of acoustic signal was observed from 04 to 11 o'clock, and simultaneously with it the increase of pulse repetition frequency was noted. (Fig. 4). There are the same parameters in Fig.4 on the ordinate axes as in Fig.2. Such an active reaction of AE is likely to be determined by the closeness to the earthquake epicenter.

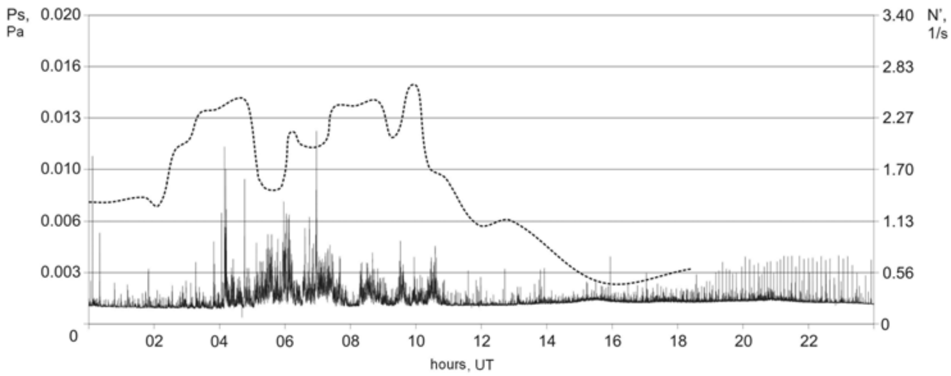

Fig.4 Acoustic emission of Lake Mikizha on November 10, 2004

In the figure one can clearly see the correlation of the level of acoustic signal in the range of 2-6.5 kHz and the activity of geoacoustic pulses. Their simultaneous increase is observed only on the whole. The details of the processes in the general case differ. For example, at about 6 UT the increase of acoustic emission level is observed simultaneously with a small decrease of pulse activity. It is determined by a complicated nature of the registered signal which consists of not only a pulse component but more complicated in form signals which are not shown up by the automatic pulse recognition system. In Fig.5,a there is a graph of spatial distribution of geoacoustic activity $N'(\alpha)$ for this period at the background of averaged activity (bold type) for autumn 2004. In Fig.5,б an analogous phenomenon is shown; it was registered on December 14, 2007 at the background of averaged activity (bold type) for December, 2007. This 7-hour disturbance (from 03 to 10 UT) was registered before a high-class earthquake (11,6), which occurred on December 15, 2007 at 9:00 UT at the epicentral distance of 175 km in the direction of 114°.

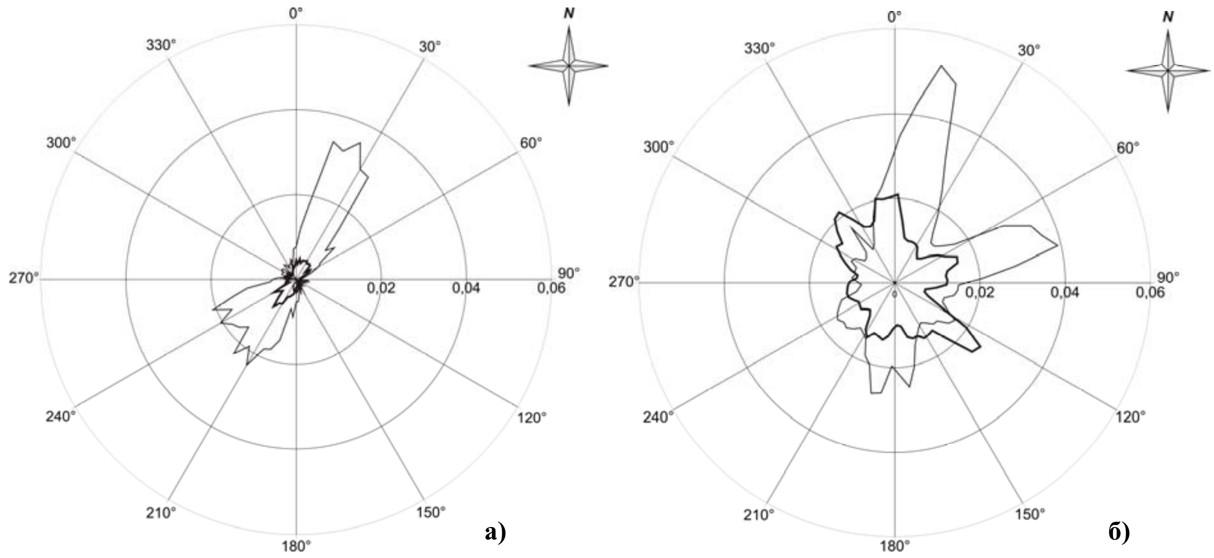

Fig.5. Graphs of geoacoustic activity $N'(\alpha)$

In spite of the fact that the both earthquakes occurred in the direction of about 110° relatively the observation site, one day before the event the anomalous increase of pulse activity was registered form the directions close to 15°-30°, though the diagrams slightly differ. Analysis of geological structure of the area shows [4], that there is a "new relief-forming, possibly, seismoactive fault hidden by overlying loose sediments" at the distance of several hundreds of meters in the direction of 15°-30° in the north-east of Lake Mikizha. The two mentioned earthquakes occurred in the plane of this fault. It should be noted that during 2007 two more cases were observed when earthquakes occurred in the direction close to 110° (on May 2, 2007 at 12:00 UT, class 12.1; August 19, 2007 at 18:06 UT, class 11.5). In the day interval a sharp increase of geoacoustic emission was observed in the direction of 15°-30°. One may suppose, that anomalous increase of geoacoustic activity appear in a day interval before an earthquake during preparation stage of a seismic event in the fault plane located close to Lake Mikizha (angle range 100°-120°) from the directions corresponding to the shortest directions to this fault.

R E F E R E N C E S

1. Gordienko V.A., Gordienko T.V., Kuptsov A.V., Larionov I.A., Marapulets Yu.V., Rutenko A. N., Shevtsov B.M. Geoacoustic location of earthquake preparation areas. // Doklady Akademii Nauk, 2006, Vol. 407, No. 5, pp. 669–672. (in Russian)
2. Gordienko V.A., Gordienko T.V., Krasnopistsev N.V., Kuptsov A.V., Larionov I.A., Marapulets Yu.V., Rutenko A.N., Shevtsov B.M. Об особенностях векторно-фазовой структуры поля высокочастотных геоакустических предвестников землетрясений. // Akusticheskii Zhurnal, 2008, Vol. 54, No. 1, pp. 97–109. (in Russian)
3. Kuptsov A.V., Larionov I.A., Shevtsov B.M. Singularities of geoacoustic emission at preparation of the Kamchatka earthquakes // Vulkanologiya i Seismologiya, 2005, No. 5. pp. 45-59. (in Russian)
4. Sereshnikov A.I. The report about results of hydro-geological re-analysis with engineering – geological and geoecological research and map-making of a scale 1:200 000 carried out in territory of sheet N-57-XXVII in 1991-1996. //Kamchatnedra, 2000. (in Russian)