Europa: seismic geophysics

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Abstract

- The Europa has a rich content of geophysical tasks. The ways of solution some from it list are next: modern geomorphology, nonlinear seismology, knowledge of extreme state of Europe ice crust. In accordance of geomorphology search the ice crust is homogeneous matter, original seismicity is absent or very weak, faults are straight and formed by tidal forces; core is small. Exogenous seismicity has high level in compared for example Earth. Simultaneously search of Anthracitic seismicity and seismogram from polar station show that the ice crust thickness will be able to define possibly by seismic methods after one day recording of seismic waves fields by seismometer. The property of Europa ice has peculiarity which formed few broads into inner crust massif which has a nature of phase – pass of second kind. Other main property of ice crust is that all phase broads and beside ice surface water generate high frequency acoustic and seismic noises and electric magnetic radiation which are a source information too.

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Continue

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§ 2. Europa Geomorphology

- **Nonlinear Seismic on Impact Cratering: Information Content.** Historically, craters were first found out element of structure of a surface of the Moon and further till now remain a basic element of geomorphology of other planets and large bodies of Solar system which it is persistent draws attention of researchers in the course of a 4 centuries. After almost 3 centuries this problem "has returned" to the Earth and only now crater forming process is a subject of steadfast studying of several sections of natural sciences. Besides obvious problems existence of a certain secret which disclosing unexpectedly will result in new quality of knowledge in this area is looked through.
- **Parameters of processes for formed craters.** Type of an impact body forming a crater may be single or complicated, its density and the form (extent for complicated); speed of a collision for an impact body-surface. Dominant type of seismic waves at the upper structures of heavenly body; Makh numbers M for all stages of wave and hydrodynamic processes of crater forming. Physical and thermodynamic characteristics and features of crater forming medium and more deep structures: density, lamination; structural (block) and integral parameter of nonlinearity of medium and more deep structures. Thickness and extent of the fused and softened layer of outside of a crater substance on a day surface; shock waves and a complex wave field of a crater forming zone. Shock and seismic-radiative stress forms of excavation of a crater medium; the central hill and multiring structures.

- **Seismic-radiative stresses or forces - the important part of wave model or the crater forming mechanics.** Stages of contact and compression, shock excavation and adjournment of emissions are full enough presented by H. J. Melosh [1]. More correct description of laws of similarity for craters, the conditions of the crater central zone forming (the hill, diameter of a complex of the central hills or more complex structures - failures in case of Mars) demand to account for occurrence and existence of a field of powerful seismic-radiative forces manifesting as acoustic current or pressure in other sections of wave physics [2, 3]. As a result of viscoelastic properties of a crater forming zone and deeper structures instead of acoustic currents it is more correct to consider seismic-radiative forces or pressure (stress) [4].
- Seismic-radiative stress is proportional to coefficient of nonlinearity n and square of Mach seismic number (M). The record of the stresses was made using radiation of the vibrator for different experimental conditions. During the intense excitation directly under the plate of vibrator the observed values of quasi-steady radiative stresses (QSRS) (100-200 kPa) correspond to unloading of preliminary loading of the soil. The initiation of quasi-steady deformations of day surface under intense excitation by vibrator is recognized in experiments on measuring a inclination of day surface near working vibrator. This additional inclination disappears at lockout of vibrator. The nonlinear seismic effects are found according to the Feynman equation describing nonlinear response of absorbing medium. In geological media irrespective of the mechanism of absorption the sufficiently strong seismic waves leads to production of the QSRS which are a correct experimental analogue of radiative stress or forces.

- **The mapping of planet internal structure into structures of craters and astroblems.** Conditions of effective mapping are determined by several factors. The following concern to the most essential. An extent and spatial distribution of bodies of crushing impactor, forming at surface impact, are one or several long train-packages of flat seismic waves with number of Mach M≈10-2. Occurrence of a piston mode of radiation trains - bunchs of high-frequency seismic waves in an impact zone. For this wave bunch the subsequent preservation of wave train form and conditions 10-3 < M < 10-2 after passage and/or its reflection from geological border of a planet (minus losses). As a direction of vectors of seismic - radiative stresses and a gradient of density of the geological medium are opposite, the occurrence of the central hill is the elementary consequence of this fact. Diameter of the crater with such hill corresponds to the minimal cross section of a wave bunch at a piston mode radiation of seismic waves. As is known, minimal diameter of craters with the central hill for the Earth, Mars and the Moon is of about 5 km. With other things being equal formation of a wave bunch is determined by velocity of seismic waves in besides surface structures of a planet crust, therefore for more densities of Mercury medium the minimal diameter of craters with the central hill exceeds 5 km. Reflected from the removed borders of a planet (a crust - a mantle, a mantle - an external corn etc.) the wave bunch tests a geometrical divergence because a reflecting surface is a spheroid form. Accordingly seismic-radiative stress or force of wave packages of the reflected beam at its output on a day surface operates on the area with diameter exceeding an initial crater, and forms an external ring. If reflections of a wave bunch from more removed borders are powerful enough and also create a field of seismic-radiative stresses or forces the multiring structure is formed around of external border of an initial crater in fused and/or the softened ground. Thus, the geomorphology of impacted craters and astroblems, beginning from craters with the elementary central hill before complex multiring formations, contains the information on an internal structure of a planet, first of all about borders and it is possible about an internal corn.

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- There is on the Europa picture crater contents one ring and broad crater. The distance between them is long. It is a case when small core and capacity crust.
- **The conclusion.** Purposeful study of astroblems as objects of nonlinear seismology, natural and physical model, the computer analysis and also cartographical researches of shock craters of Solar system bodies will allow create algorithm of the specified structures decoding. For specification of an internal structure experimentally it is necessary to determine velocities of seismic waves in a crust.
- **References.**

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About the Key for the Research of In Homogeneity and Deformation of the Planet Crust

- **The Earth. The decoding cosmic photographs of geological structures and the catastrophe theory.** Seismic wave dynamic and strain field picture in case of inhomogeneous crust are described by the theory of catastrophes. Isoseismic curves and seismic caustic curves are connected with elementary catastrophe of wave fronts. In seismically turbid environment occurrence of caustic curves (or caustic) is inevitable. Concentration of seismic wave energy is come about in forms caustic. Energy can surpass background many times over and to form on a day time caustic surface, as well as in optical systems, original structure. The day surface of the formed caustic structure will have deformed geological medium. Loss of stability and destruction (transformation) of the geological structure is one of objects of research of the theory of catastrophes. If geological structure with areas of instability influences of an intensive seismic wave train forms in its volume one of figures of catastrophes. So the new defect (fault) reflecting the form seismic caustic appears. According to properties of the seismic environment and waves these caustics can be formed and are classified. Considering a terrestrial surface as the projection of the three-dimensional structures which are cut off by destructed processes, allows reveal caustic pictures for case at various the original of cartographical and photographic materials (cosmic photo). Tested work was carried out on geological and geomorphologic areas of Pamirs, Tan`-Shan`, Pamirs-Altai and other territories. Thus the following was found out. All images are easily decoded not only on space pictures of M 1: 2.5 000.000 and 1: 5 000.000, but also under initial tectonic both topographical circuits and maps. The sizes of figures of elementary catastrophes on district are from first tens up to hundreds kilometers. Decoding of various forms is variably and depends on the geological structure of region. So we know after examination of the cosmic region picture new information about inhomogeneous geological medium and deformation fields.

- **The planets of terrestrial group.** If planet is tectonic active the previous case has a place. The Moon is typical tectonic non-active object and the cosmic region pictures have few peculiarities.
- **The Moon.** On first look on the Moon crust has in general only craters surface because tectonic activity is absent. Therefore only crater appears after new meteoroid impact. These imagine is very simple. Really part of Moon surface is covered by thin layer of regolith and a dust. Seismic waves in the moment of meteoroid impact and after it which emerge from lithosphere on surface form the caustic figures. Seismic wave field from moonquake is existing long time and forms figures likeness acoustic Khladney pictures on day surface. Unlike acoustic case these pictures will be instable, because next impact will destroy it.
- The **Europa** & **Venus.** Gold age for geomorphology or exogeomorphology is time receiving generalized maps of planet when the inside structure, faults and tectonic activity are cheaply defined. This epoch is appears for Europa and it is overpass (bygone) for Venus for which had made generalized maps. So new maps and detailed pictures of day surface of Venus will not help because in present stage of development only clever mind can find new solution using generalized maps and not detailed pictures.

§3

- **The Polar seismic station seismograms in Antarctica: thickness and capacity of an ice cover**

- One of key geophysical tasks at research of Europa is definition of parameters of an ice crust and thickness and capacities of it. The most perspective and authentic method is seismic. As own seismicity of Europa cannot be significant on capacity and frequency of events, and conditions of stay of landing station on a surface is rigid at reliable performance of seismic experiment two circumstances should be taken into account: insignificant duration of functioning of the equipment and rare weak seismic events. Really the picture can be more optimistically, as constantly there is an induced seismicity because of powerful tidal forces and influences of meteoroids and gas dust streams. Comparative representation exogenous acting is submitted as analogue of processes in orbits of Europe and the Moon (see Table 1).

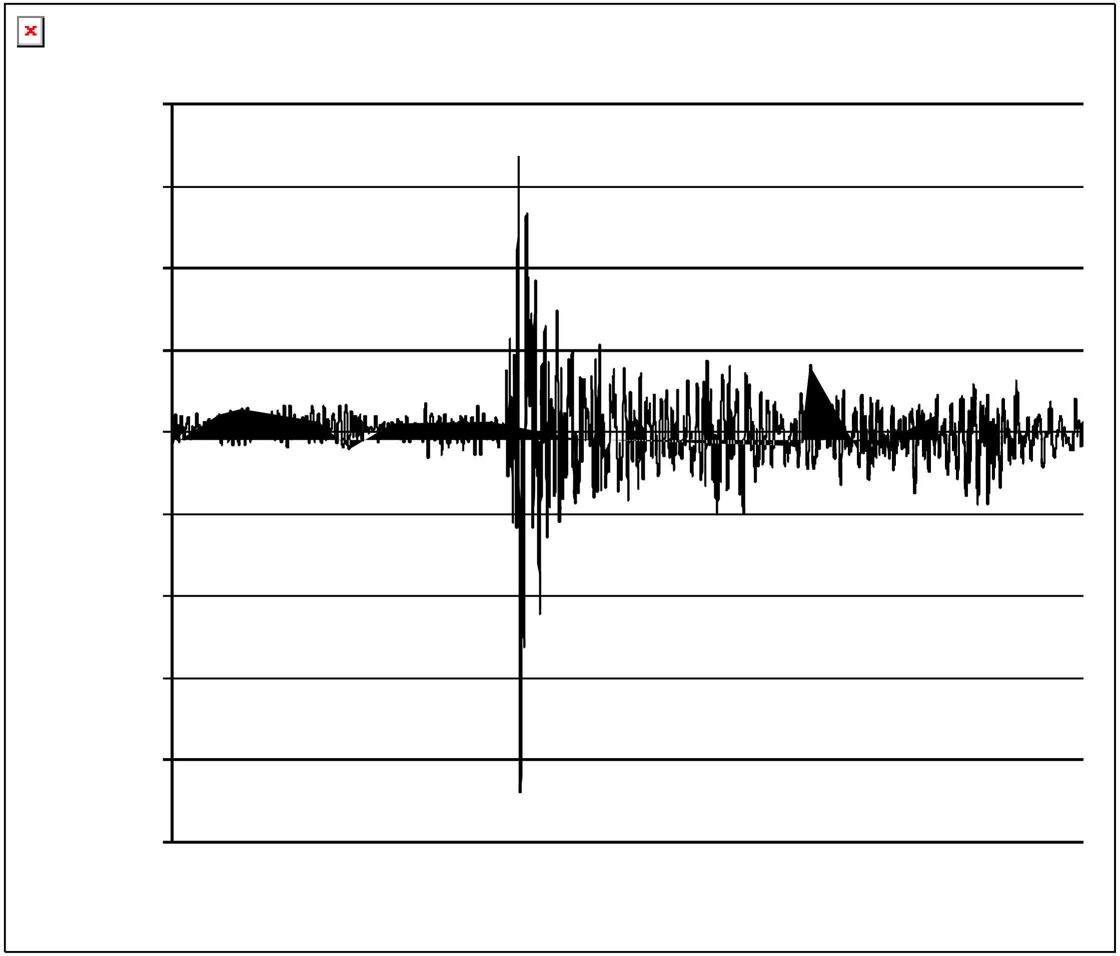
- External influences on a lunar surface and Europa

Source	*Pmin*, Pa	*Pmax*, Pa	P_{md}, Pa	Stream of energy, W/m2	Σ *P max* × *S*, N	
					The Moon	The Europa
Pressure of solar light			$4.8\cdot10^{-7}$	$1.4\cdot10^{-1}$	$5\cdot10^{6}$	$2.5\cdot10^{6}$
Solar wind	$1\cdot10^{-9}$	$1\cdot10^{-7}$	$2.5\cdot10^{-9}$	$1.3\cdot10^{-3}$	$1\cdot10^{6}$	$4\cdot10^{4}$
Gas dust stream of Solar system	$1\cdot10^{-8}$	$1\cdot10^{-6}$	$2\cdot10^{-8}$	$2.5\cdot10^{-5}$	$1\cdot10^{7}$	$5\cdot10^{7}$
Gas dust a stream of other stars	$5\cdot10^{-9}$	$1\cdot10^{-7}$	$1\cdot10^{-8}$	$2.5\cdot10^{-3}$	$5\cdot10^{6}$	$5\cdot10^{6}$
Short-wave radiation of the Sun, flash	$>1\cdot10^{-7}$	$>1\cdot10^{-5}$	$2.5\cdot10^{-8}$	$1.2\cdot10^{-2}$	$1\cdot10^{7}$	$5\cdot10^{5}$
Pulsar, γ, Re-pulses	$<1\cdot10^{-10}$	$1\cdot10^{-9}$	$2.5\cdot10^{-11}$	$1.2\cdot10^{-3}$	$5\cdot10^{6}$	$5\cdot10^{6}$
Close double stellars, Re	$1\cdot10^{-8}$	$1\cdot10^{-6}$	$1\cdot10^{-7}$	$2.5\cdot10^{-2}$	$5\cdot10^{7}$	$>1\cdot10^{7}$

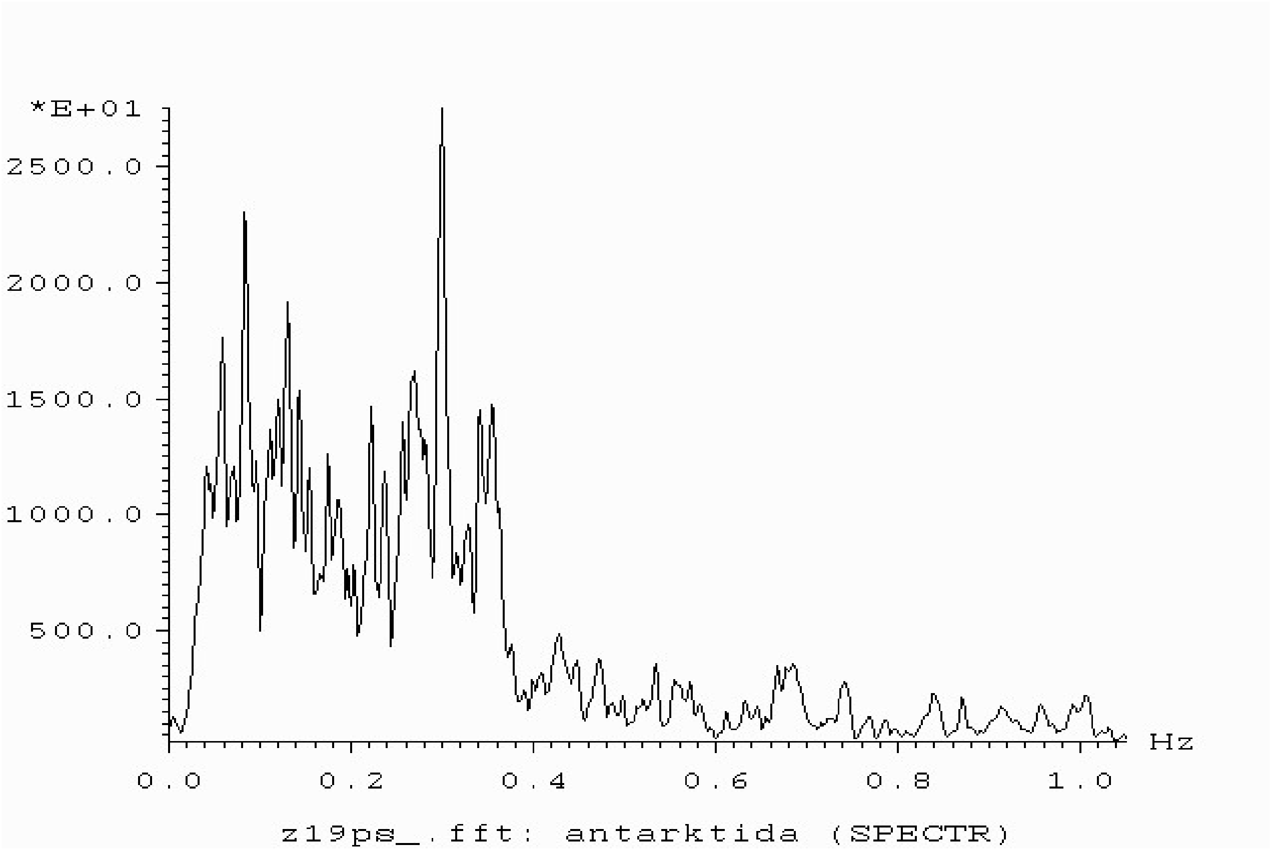
Note: *P* - pressure; *Pev.* - average value of pressure; *E* - a stream of energy, *ΣPmax × Sm, E* - the total maximal force acting on a hemisphere of the Moon or Europe.

- As seismic noise of Europa is supposed significant that it allows to apply modulated method and to receive an independent estimation of capacity of a crust. As there is an opportunity of check its on the data of Polar station (USA) in Antarctica where thickness of an ice cover is close to the minimal estimations of capacity of a crust of Europa. For this purpose seismograms have been analyzed of two removed earthquakes (A1; A19) and records of seismic noise (microseism). First earthquake A1 has taken place 24 December 1991y. in 4hours 6min. 1.4sec. UT near to Southern islands Sandviches
- with magnitude M = 6.2, on the distance of 34.12 degrees. Second earthquake A19 has taken place on February, 13 1992y. in 1hour 29min. 15.5sec. near to islands Vanuatus with magnitude M = 6.1, on the distance of 74.19 degrees. The example of record Z components of earthquake A19 is shown on Fig. 1.

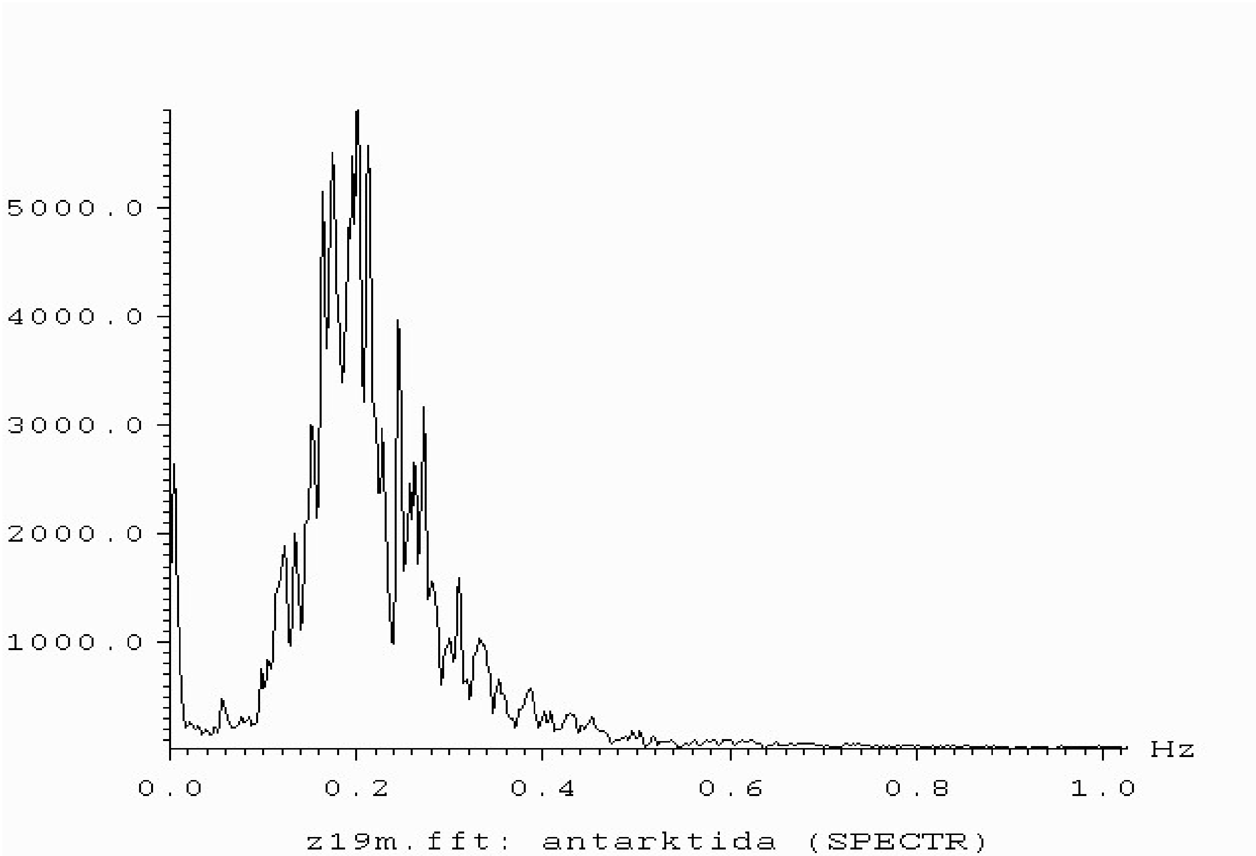
Seismogram A19 earthquake. Records storm of мmicroseisms before the introduction P - waves record storm (from 0 up to 6000), group P - waves (from 6000 up to 9000) and S waves are visible



Examples of spectra earthquakes A19 (Z-components)



A spectrum storm microseisms before the seismic P-waves introduction of earthquake A19.



Conclusion

- On the basis of the submitted data their spectral characteristics in the assumption have been received, that its are caused not only features of occurrence of seismic waves in a seismic source but also a geological structure of environment in a point of reception in particular by thickness of an ice cover polar areas (before slides). These results confirm an opportunity of reception of the information on an ice crust at use only one seismic station on Europa.

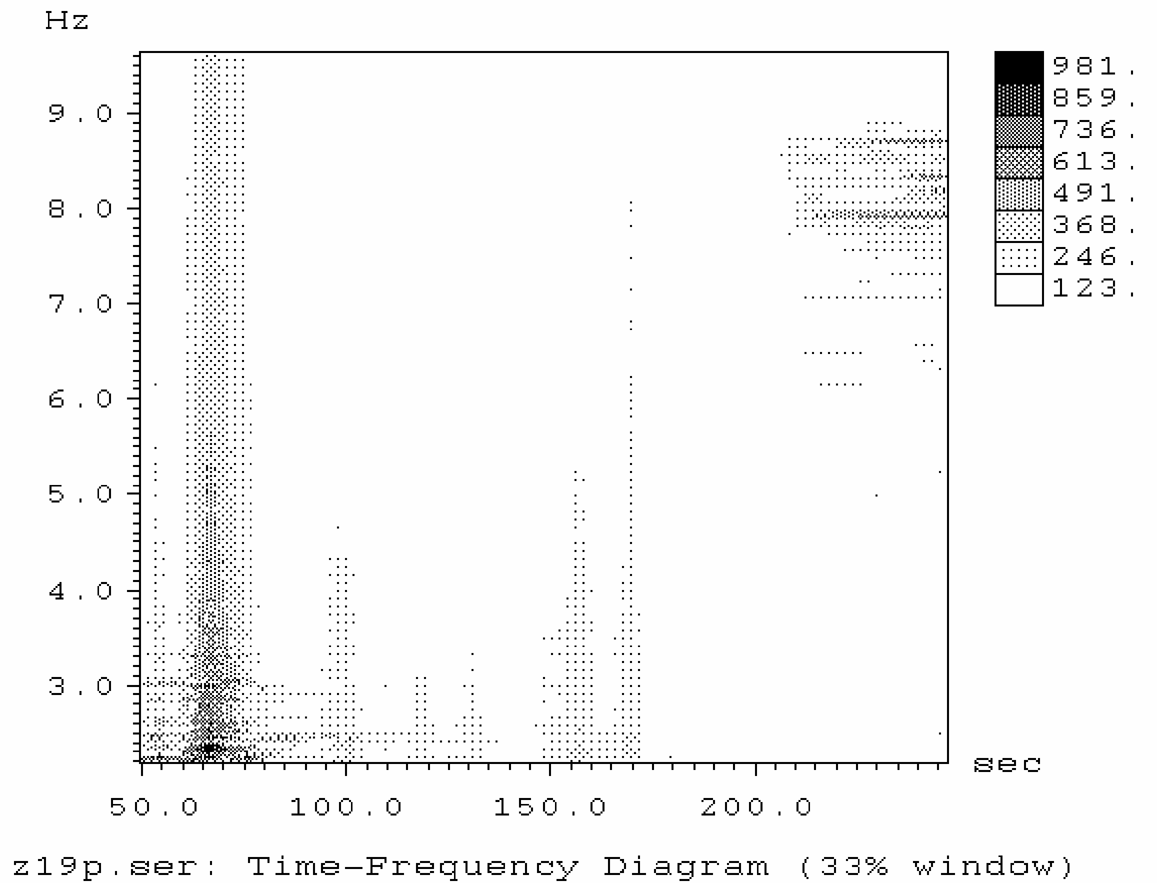
The processing technique of a seismogram analyzing

- **The processing technique of a seismogram consists in the following.** Three-componential records seismogram were derived into three parts: 1st is microseism or seismic noise before seismic event which is a wind and sea storm origin; 2nd is record of group of P-waves and 3d is record of group of S-waves. Further at processing each of realizations (parts) received their spectra or spectrum temporal representations (STR). Further values of significant spectral peaks have presented at Table. (Were used seismograms of events A1 and A19). See results submitted in tables.
- In the first column of Tables is the name of an analyzed part: Z record of a vertical component, X and Y horizontal components (the North - South, the West - East) of seismograms, in columns 2 - 9 significant (P> 0.95) spectral peaks are in seconds, in column 10 is in Hz.; a Z m-vertical microseism component.

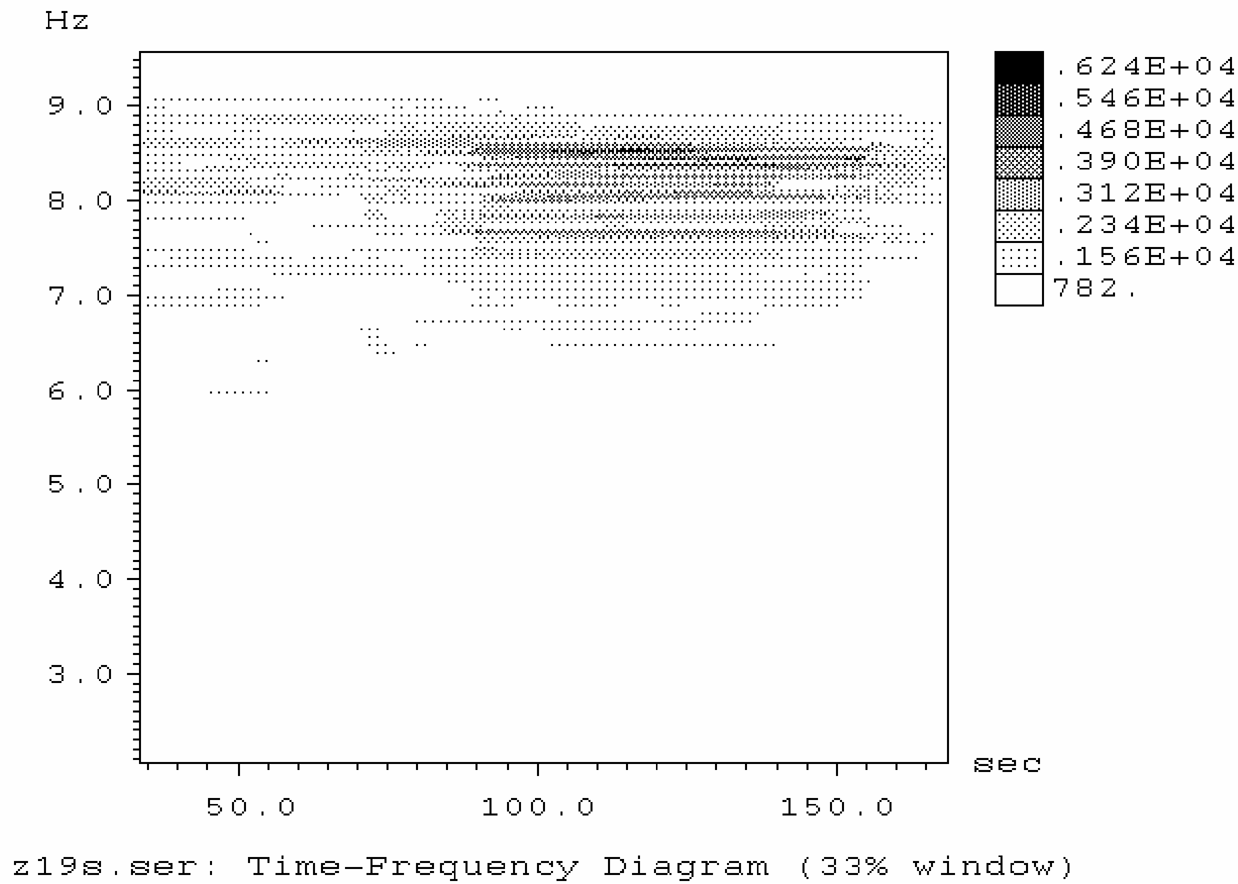
Spectral peaks earthquakes A1 seismogram

1	2	3	4	5	6	7	8	9	10/Hz
Zm	137	14-16	4.4	3.8	3.6	3.15	2.8		6-9
Z**p**		13.7	5.3		3.45	2.9	2.7	2.3	
Zs	29.4	10.2	7.1	6.0	4.4	3.2	2.3	2.0	>7
Xm		15.8	10.7						6-9
Xp		9.5-14	5.4		3.3	2.9	2.7	1.7	1.5
Xs	20.5	10.8	7.9	6.6	5.4-4.7	2.3-3.2		2.1-1.8	7,8
Ym	58.4	10.8	7.3	5.4	4.5				6-9
Yp		13.7	7.4	5.4		2.6	1.7	1.5	**1.3-1.4**
Ys	22.7	12-9.7	7.1	5.5		2.6			>7

Spectrum - temporal diagram of event A19 in a range of frequencies from 2 up to 10Hz. P - waves group



Spectrum- temporal diagram of event A19 in a range of frequencies from 2 up to 10Hz for S-waves group



Common comments

- Attentively examination of data STD has revealed occurrence of rather high-frequency seismic noise in a range of 7-9 Hz approximately through 200s from arrival of group P - waves. These noise already considerably amplify and also exist on all time. This effect is known as seismic acoustic emission. That is occurrence of these noise is result of processes of destruction in ice under a place of registration and in essence confirms propensity of an ice massif to the induced seismic emission. Delay in occurrence (200 seconds) from the moment of arrival P - waves can change depending on amplitudes and kind of seismic waves. Besides, as P - waves have considerably outstripped S - waves seismic acoustic emission at S - waves arises practically without a time delay.

Continue

- Knowing thickness of ice and speed of passage P waves (3000m/s) and S waves (1700 – 1800m/s), it is possible to estimate roughly the spectral component corresponding to thickness of ice under formula T =2 H/C where: T is the observable spectral period, H - thickness of ice, C is velocity of a sound in ice.For P waves in ice Cp = 3000m/s and H = 3-4km it is received Tp = 2*3000/3000 = 2s (on a spectrum - 2.67s). At S waves in ice Cs = 1700m/s it is received Ts = 3.5 - 4.7s. In this range of the periods peaks in seismogram spectra of earthquakes in Antarctica (A1 also, A19) for P - and S – waves are observed. Usual low-frequency peaks in a range of tens seconds are observed also. The reason of their occurrence demands more in-depth study. Peaks of the same range of the periods are observed and without earthquakes on spectra of seismic noise.
- **Conclusion.** The received results allow estimating roughly necessary time of registration of seismic signals for Europa which is guaranteeing definition of capacity of an ice crust. At capacity in 5-10km necessary duration of recording will require 1-3 hours; at 60-600km - 1-1.5 day.