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USSR Report

EARTH SCIENCES

(FOUO 4/80)

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USSR REPORT

EARTH SCIENCES

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I. METEOROLOGY

UDC 551.510.42

MONOGRAPH ON EXPERIMENTAL STUDIES OF ATMOSPHERIC AEROSOL

Leningrad EKSPERIMENTAL'NYYE ISSLEDOVANIYA ATMOSFERNOGO AEROZOLYA (Experimental Studies of Atmospheric Aerosol) in Russian 1979 signed to press 13 Apr 79 pp 2, 263-264

[Annotation and table of contents of monograph by O. P. Petrenchuk, Gidrometeoizdat, 264 pages]

[Text] Annotation. This monograph presents the results of study of the physicochemical characteristics of aerosol particles, clouds and precipitation, constituting the subject of research in a new direction in meteorology -- atmospheric chemistry. The author describes the methods and instruments for their determination. Using a great volume of experimental data, the book gives the patterns for the entry of salt particles into the atmosphere and their propagation along the coasts of different seas and the characteristics of change in the chemical composition of precipitation in relation to meteorological conditions and the advection of air masses and cloud water, collected in different regions of the USSR, in dependence on the synoptic situation and type of clouds. The author evaluates the contribution of clouds and the washing-out of admixtures from the layer beneath the clouds in formation of the chemical composition of precipitation. On the basis of data from investigation of the chemical composition of cloud water and precipitation a global evaluation is made of the intensity of different sources of aerosols and a model of the cycling of sea salts in the atmosphere is presented. An investigation of the influence of marine aerosols on the corrosive activity of the atmosphere on sea coasts is given as an important practical application. The book is intended for specialists in the field of physics and chemistry of the atmosphere and other related disciplines.

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PAPERS ON ACTIVE AND PASSIVE RADAR IN METEOROLOGY

Leningrad TRUDY GLAVNOY GEOFIZICHESKOY OBSERVATORII: METODY AKTIVNOY I PASSIVNOY RADIOLOKATSII V METEOROLOGII (Transactions of the Main Geophysical Observatory: Methods of Active and Passive Radar in Meteorology) in Russian Issue 411, 1978 signed to press 19 Dec 78 pp 2, 126

[Annotation and table of contents of collection of papers edited by V. D. Stepanenko and G. G. Shchukin, Gidrometeoizdat, 126 pages]

[Text] These papers give the results of theoretical and experimental investigations of meteorological characteristics of the cloudless atmosphere, clouds and dangerous weather phenomena associated with them by the methods of electromagnetic sounding of the atmosphere (active and passive radar) carried out during 1976-1977. The collection includes methodological studies on improvement in methods for radar observations of hydrometeors in the network of meteorological radars. The problems involved in constructing radiophysical apparatus are considered. The collection is intended for scientific workers and engineers concerned with problems relating to physics of the atmosphere, radiophysics and radio engineering. It can also be recommended for graduate students and students in advanced courses in the corresponding fields of specialization.

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MONOGRAPH ON REMOTE METEOROLOGICAL INSTRUMENTS

Leningrad DISTANTSIONNYYE METEOROLOGICHESKIYE USTROYSTVA, IKH MONTAZH I EKSPLUATATSIYA (Remote Meteorological Instruments, Their Installation and Operation) in Russian 1979 signed to press 19 Oct 79 p 2, 385-392

[Annotation and table of contents of monograph by D. L. Bronshteyn, A. N. Bystramovich and A. A. Makarenko, Gidrometeoizdat, 392 pages]

[Text] Annotation. This monograph gives descriptions of instruments and the principles for operation of automatic meteorological instruments used at the present time in the network of hydrometeorological stations (UATGMS-4M, KRAMS, ARMS). The authors examine the design and operation of remote meteorological instruments used in measuring individual meteorological elements (M-54-1, AM-29, M-63M-1, M-49, IVO-1, RDV-3). Information is given on the installation, operation, technical servicing and very simple repair of remote meteorological instruments. The book is intended as an academic aid for students at hydrometeorological technical schools. It can be useful to specialists concerned with the servicing and operation of meteorological instruments.

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METEOROLOGICAL AND ACOUSTIC EFFECTS FROM ARTIFICIAL HEATING OF THE TROPOSPHERE BY ELECTROMAGNETIC RADIATION

Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 248, No 3, 1979 pp 577-580

[Article by V. P. Dokuchayev and Corresponding Member of the USSR Academy of Sciences V. S. Troitskiy, Gor'kiy Scientific Research Radiophysics Institute, submitted for publication 21 Jun 79]

[Text] Currently to stimulate certain meteorological phenomena artificial heating of small volumes of the earth's atmosphere is used [1]. Several methods are based on heating of air during combustion of chemical fuel. For example, the unit "Meteotron" consists of gas burners arranged on the earth's surface [2]. Another device uses streams of hot gases emerging from jet engine nozzles [1]. Solar energy is also used for heating; a section of the earth's surface is covered with good light absorbers and space heating is implemented with the release of absorbing aerosols into the atmosphere.

In this respect the use of electromagnetic radiation of the optic and especially the radio range for heating the troposphere is of undoubted interest. This radiation is noticeably absorbed by the atmosphere. It is resonance with well-pronounced bands of strong absorption separated by windows of transparency [3]. The achievements of high-power electronics in the problem of superhigh frequency wave generation open up an effective method of artificial heating of the tropopshere that is significantly superior in its potentialities to all the listed methods. In fact, millimeter range radio waves, especially close to the oxygen absorption lines at wave 5 mm make it possible to heat the troposphere in the space of the antenna projector zone. The base area of the vertical air column to be heated is regulated by the number and aperture of the antennas, and its length--by the frequency selection; it can be altered in limits from a hundred meters to several kilometers. One can essentially create any shape of volume to be heated. The temperature gradients in the heated area generate convective movements of the air masses, i.e., affect the meteorological processes in the atmosphere.

An important and new quality of volumetric electromagnetic heating is its low time lag, i.e., the possibility of rapid changes in the absorbed power by amplitude and frequency modulation of the superhigh frequency oscillations. This opens up the possibility of creating a new atmospheric emitter of sonic, infrasonic and internal waves. In fact, absorption of electromagnetic waves is accompanied by instantaneous heat release that leads to warming of the atmosphere and espansion of the heated area. The pressure gradients forming here yield sonic effects. For example, with rapid engagement of the generator a sonic impulse occurs that is analogous to thunder during a lightning disbharge. The electromagnetic heating will also permit the more effective resolution of a number of other practical problems, in particular, dispersal of fog above sections of the earth's surface where it is undesirable. We note that anomalous absorption of electromagnetic waves in the high frequency range is used for modification of parameters and heating of the ionospheric plasma [4].

This work examines meteorological and acoustic phenomena that accompany absorption of electromagnetic radiation in continuous and amplitude-modulated generation patterns. For simplicity we will examine the case where the air temperature in the absence of radiation is constant in the limits of the antenna projector zone. Disturbances in the temperature T_1, density ρ_1 and pressure p_1 induced by radio wave absorption are assumed to be small as compared to the udnisturbed amounts T_0, ρ_0, and p_0. In this case it is convenient to obtain the following system of equations for disturbances in pressure and temperature from the equations of gas dynamics of a viscous and heat-conducting medium [5]:

$$(1) \quad \rho_0 c_p \frac{\partial T}{\partial t} - \frac{\partial p}{\partial t} = \rho_0 c_p \chi \Delta T + q(\mathrm{R}, t),$$

$$(2) \quad \left(\frac{\partial^2}{\partial t^2} - \nu\Delta\frac{\partial}{\partial t}\right)(p - \rho_0 RT) = \gamma^{-1} c_s^2 \Delta p;$$

here $\gamma = c_p/c_V$ is the ratio of specific heat with constant pressure c_p and volume c_V, R--gas constant, χ--coefficient of temperature conductivity; $\rho_0\nu = (\zeta + 4\eta/3)$, here η, ζ --coefficients of first and second viscosity, Δ--Laplace operator, c_s--speed of sound, q(R,t)--distribution of heat sources in space averaged for high frequency. The q sources are governed by the absorption of electromagnetic waves in the atmosphere, and their density equals the product of intensity times the absorption coefficient. We will examine only the sources that are governed by cylindrical axisymmetric beams directed along the vertical:

$$(3) \quad q = \alpha \exp(-\alpha z)[W_0 + W_\sim \cos \Omega t]\, F(r)/\pi a^2,$$

where α--mean absorption coefficient, a--radius of beam of electromagnetic waves; W_0--mean power of radiation; $W_\sim$--power of radiation linked to amplitude modulation of acoustic frequency Ω; r and z--cylindrical coordinates with axis z directed along the vertical. Here it is assumed that $\alpha z_0 \gg 1$, $\alpha c \gg \Omega$, where z_0--altitude scale of uniform atmosphere, c--speed of light, $F(r)$--function that describes the distribution of intensity over the beam section.

At first we will examine the atmospheric disturbances in a continuous operating pattern of the transmitter where $W_\sim = 0$ in (3). It follows from (1)-(3) that the processes of establishing the steady-state condition in the atmosphere with instantaneous engagement of the transmitter are completely finished in the time $t_s \simeq (4\chi\alpha^2)^{-1}$ on the condition $\alpha a \ll 1$ and the Prandtl number $Pr = \nu/k \sim 1$. Assuming $\alpha = 4$ km^{-1} the coefficient of turbulent temperature-conductivity $\chi = 5$ m^2/s we obtain $t_s \approx 50$ min.

The temperature distribution T_1 in the medium with $t > t_s$ is described by the equation that follows from (1) and (3),

$$\frac{\partial^2 T_1}{\partial r^2} + \frac{1}{r}\frac{\partial T_1}{\partial r} + \frac{\partial^2 T_1}{\partial z^2} = -\frac{\alpha W_0}{\pi a^2 \kappa} e^{-\alpha z} F(r), \tag{4}$$

where $k = \rho_0 c_p \chi$ --coefficient of heat conductivity. We assume that the beam is uniform over the section, i.e., $F(r)=1$ with $r \leq a$, $F(r)=0$ with $r > a$. The solution to (4) that diminishes with $z \to +\infty$ looks like*

$$T_1(r, z) = -\frac{W_0}{2a\kappa} e^{-\alpha z} \begin{cases} (2/\alpha a) + N_1(\alpha a) J_0(\alpha r), & r \leqslant a, \\ J_1(\alpha a) N_0(\alpha r), & r \geqslant a; \end{cases} \tag{5}$$

here J_0, J_1, N_0 and N_1--functions of Bessel and Neumann of zero and first order. From (5) we find the temperature distribution T in the atmosphere on the beam axis with the condition $\alpha a \ll 1$:

$$T(0, z) = T_0 + \frac{\alpha W_0}{2\pi\kappa} \ln\left(\frac{2}{\alpha a}\right) \exp(-\alpha z). \tag{6}$$

Thus, absorption of electromagnetic waves is accompanied by warming of the atmospheric gases in the volume of the beam $r_H \simeq a$, $z_H \simeq \alpha^{-1}$. To evaluate ΔT it is convenient to assume $\ln(2/\alpha a) = 2\pi$, while we select altitude z such that $\alpha z \ll 1$. Here from (6) we obtain the correlation $\Delta T = T - T_0 \simeq \alpha W_0/\kappa$, which also follows from the theory of dimensionality. If one assumes the coefficient of turbulent heat conductivity $k = 40$ w/cm$\cdot$K, $\alpha = 4$ km^{-1}, we obtain $\Delta T = W$, K where W should be taken in megawatts, i.e., with $W_0 = 1$ Mw, $\Delta T = 1$ K. For estimates we took the maximum value k, which apparently with neutral and stable stratification of the atmosphere is 10-100 times smaller than this amount. In these cases a lower power, 10-100 kw is required for heating the air by 1 K. The temperature gradient in the heated area $(dT/dz) < 0$ and for the values adopted above α, k_T and W_0 on the axis of the cylinder has the magnitude -4K$\cdot$km^{-1}. In gas dynamics and meteorology it is well known that if $(dt/dz) < -g/c_p = -10$ K$\cdot$km^{-1} then the atmosphere becomes convectively unstable.

*With the condition $\max(a, r) < 2\chi/V_0$ the calculation of wind in the atmosphere with velocity V_0 has little effect on an evaluation of the amounts T_1 and dT_1/dz.

Consequently, artifical heating with superhigh-frequency radiation must significantly affect the nature of the free and forced convection in the troposphere. This is determined by the fact that in the heated area the density disturbances $\Delta\rho \simeq -\rho_0(T_1/T_0)$ result in the appearance of Archimedes' force that, in turn, induces movements of air masses in the heated area and its environs. Even with $dT/dz \gtrsim -g/c_p$ a laminar flow is formed in the heated region due to the horizontal temperature and pressure gradients. From the theory of dimensionality we find the velocity in these flows $w \simeq (gW_0/kT_0)^{\frac{1}{2}}$. For the values indicated above W_0 and k_T $w \sim 3$ m/s. However, in a complete analysis of convection it is necessary to examine the nonlinear equations of gas dynamics with regard for the gravity force. We note that the dependence of k_T on the altitude and boundary conditions on earth for $T_1(0,r)$ will alter the appearance of solution (5), but will not significantly affect the estimates of T_1 and dT_1/dz with $r<r_H$ and $z \leq \alpha^{-1}$.

In the case of electromagnetic radiation modulated according to the amplitude of the sonic frequency Ω, quadratic detection occurs in the area of absorption since the thermal sources of acoustic disturbances are proportional to the power of the electromagnetic wave, i.e., the square of the electrical field. By ignoring the absorption of sound waves as a consequence of viscosity and heat conductivity, we obtain the acoustic equation from (1)-(3)

$$(7) \qquad \Delta p_a - \frac{1}{c_s^2}\frac{\partial^2 p_a}{\partial t^2} = \frac{i(\gamma-1)\alpha\Omega W_\sim}{\pi a^2 c_s^2} F(r)\exp(-\alpha z + i\Omega t).$$

We note that this mechanism for sound wave generation by laser beam with its absorption in a liquid has been examined in [7, 8]. Solution (7) with boundary condition $\partial p_a/\partial z=0$ with $z=0$ (i.e., for the flat earth surface) is found by standard method. In the case of the Gaussian intensity distribution over the beam section $F(r)=\exp(-r^2/a^2)$ the acoustic pressure p_a on the earth's surface in the far zone of the emitter $r > \alpha^{-1} \gg \max(a, \lambda_s)$ is determined by the expression

$$(8) \qquad p_a = [(\gamma-1)\Omega M_\sim \mathcal{L}/4rc_s^2]\exp[i\Omega(t-r/c_s)-(k_s a/2)^2],$$

$$\mathcal{L} = \sigma\{1-2c(\sigma)-i[1-2S(\sigma)]\}\exp(i\pi\sigma^2/2),$$

where $\sigma = \alpha(r/\pi k_0)^{1/2}$ --acoustic wave parameter [9], C and S--Fresnel's integrals, $k_s = \Omega/c_s$--sonic wave number. The value $\mathcal{L}$ significantly depends on σ. In the Fraunhofer zone $\sigma \gg 1$, $\mathcal{L} \simeq 2\pi^{-1}$, $p_a \sim r^{-1}$, and in Fresnel's zone $\sigma < 1$, $\mathcal{L} \simeq (1-i)\sigma$ and $p_a \sim r^{-\frac{1}{2}}$, i.e., the wave is cylindrical. We evaluate the pressure amplitude p_a with $W_\sim = 1$ mw, $\alpha=4$ km^{-1}, $a = 1$ m at a distance $r=1$ km from the axis of the electromagnetic beam. We select the frequency $\Omega = 2c_s/a = 680$ s^{-1} with $c_s=340$ m/s. Finally we find the amount $p_a=0.02$ N/m^2 which is an order greater than the threshold of audibility for the frequency f=100 Hz. Thus, the beams of electromagnetic waves that are strongly absorbed by the atmosphere can be used to generate sound.

The authors are grateful to V. N. Ivanov, L. Kh. Ingel' and A. V. Troitskiy for valuable notes.

BIBLIOGRAPHY

1. Kachurin, L. G., "Fizicheskiye osnovy vozdeystviya na atmosfernyye protsessy" [Physical Principles for Modification of Atmospheric Processes], Leningrad, Gidrometeoizdat, 1978.

2. Dessens, J. NATURE, Vol 193, No 4810, 1962, 15.

3. Zhevakin, S. A.; and Naumov, A. P. IZV. VYSSH. UCHEBN. ZAVED., RADIOFIZIKA, Vol 10, No 9, 1967, 1213.

4. Gurevich, A. V.; and Shvartsburg, A. B. "Nelineynaya teoriya rasprostraneniya radiovoln v ionosfere" [Nonlinear Theory of Radio Wave Spread in the Ionosphere], Moscow, Nauka, 1973.

5. Landau, L. D.; and Lifshits, Ye. M. "Mekhanika spolshykh sred" [Solid-State Mechanics], Moscow, Tostekhizdat, 1954.

6. Tverskoy, P. N. "Kurs meteorologii" [Course in Meteorology], Leningrad, Gidrometeoizdat, 1962.

7. Bunkin, F. V.; and Komissarov, V. M. AKUSTICH. ZHURN., Vol 19, No 3, 1973, 305.

8. Kasoyev, S. G.; and Lyamshev, L. M. AKUSTICH. ZHURN. Vol 23, No 2, 1977, 35.

9. Gorelik, G. S. "Kolebaniya i volny" [Oscillations and Waves], Moscow, Fizmatgiz, 1959.

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II. OCEANOGRAPHY

FIFTIETH ANNIVERSARY OF THE BLACK SEA HYDROPHYSICAL STATION

Moscow OKEANOLOGIYA in Russian Vol 19, No 6, 1979 p 1142

[Article by V. N. Yeremego]

[Text] The fiftieth anniversary of formation of the Black Sea Hydrophysical Station was marked in April 1979. In our country it is the oldest scientific research institute oriented on solution of fundamental and practical problems in physical oceanology. Founded in the Crimea in 1929 by Academician V. V. Shuleykin, the hydrophysical station later served as the base organization in creating the Marine Hydrophysical Institute USSR Academy of Sciences (1948), into whose makeup it entered as an independent structural and scientific unit -- the Black Sea Division. In 1961 the Marine Hydrophysical Institute was rebased from Moscow to Sevastopol' and was transferred to the Ukrainian Academy of Sciences, and its division in the village of Katsiveli came to be called the Experimental Division of the Marine Hydrophysical Institute Ukrainian Academy of Sciences.

During 50 years of scientific activity the body of professional hydrophysicists at Katsiveli has written more than a few glorious pages in the history of development of Soviet investigations of the world ocean. There, in the laboratories of the hydrophysical station, in experimental polygons and in the first Black Sea expeditions in the 1930's-1940's, the basis was laid for a new direction in modern oceanology -- marine physics.

The favorable natural conditions at Katsiveli made it possible to organize long-term systematic observations of the development of coastal currents and wind-induced level changes, sea waves, and also to carry out specialized field experiments for the purpose of investigating processes of small-scale interaction between the atmosphere and the sea, study of heat balance components, hydrooptical characteristics and electromagnetic phenomena in the waters of the shelf zone. The V. V. Shuleykin aerohydrodynamic channel was constructed (1953) for the modeling of wind waves with strictly determined and monitorable external influences of the medium. Its use made possible a considerable supplementation and development of the results of field investigations, and in the long run, to obtain the necessary experimental material for formulating a new theory of sea waves. The fundamental results of these investigations are used extensively in the practice of shipbuilding, port construction, marine instrument making and navigation.

V. V. Shuleykin and his students have carried out a great volume of research on the year-to-year variability of oceanological fields, determined by variations in large-scale interaction between the oceans and the atmosphere, including autooscillatory processes in the complex natural ocean-atmosphere-continents system. The study of the mechanisms of year-to-year variability of oceanological fields is of great importance for creating methods for long-range weather forecasting on the continents and hydrometeorological conditions in the expanses of the world ocean used by man.

The studies of V. V. Shuleykin and other scientists in the division devoted to investigations of the processes of formation, development and attenuation of tropical hurricanes have gained wide fame among specialists. These studies can be regarded as the first stage on the way to creation of methods for the prediction of the development of destructive sea cyclones.

During its 50-year history more than 40 Doctors and Candidates of Sciences have been prepared in the Experimental Division of the Marine Hydrophysical Institute Ukrainian Academy of Sciences. Its specialists have twice been awarded USSR State Prizes; their scientific studies have received a high evaluation both in our country and abroad.

Continuing the glorious traditions of the Black Sea Hydrophysical Station, the scientists of the division at the present time are successfully carrying out investigations within the framework of international and national oceanographic programs in timely directions in modern physics of the ocean.

[180-5303]

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PROBLEMS IN THREE-DIMENSIONAL GEOPHYSICAL RESEARCH IN THE OCEAN

Moscow VESTNIK MOSKOVSKOGO UNIVERSITETA, SERIYA 4, GEOLOGIYA in Russian No 6, 1979 pp 93-100

[Article by A. V. Kalinin and A. G. Gaynanov, Geophysics Department, Moscow University, submitted for publication 19 May 1979]

[Text] Multisided geophysical investigations in the waters of the world ocean even now have their history and major achievements, the practical and scientific significance of which is well known [4]. These investigations were a powerful stimulus for improvements (of both a technical and theoretical nature) of virtually all geophysical methods. At the basis of the achievements in this work it is easy to see the need for carrying out observations in continuous movement, that is, by a method fundamentally different from that which is basic for investigations on the land.

For example, a major achievement was the creation of a theory of gravity measurement from a moving base and the development of specialized sea gravimeters adapted to work under conditions of a high level of disturbing accelerations. To a considerable degree the needs for marine research dictated the rapid development of proton and quantum magnetometers. Precisely in connection with the problems of marine seismic research there was vigorous development of nonexplosive methods for the excitation of elastic oscillations, now also extensively used on the land. An exceptionally important role in the successes of seismic investigations at sea was played by the development of detectors which were essentially new in comparison with those used on the land -- towed strings of piezodetectors with fluid filling. Also directly related to successes in the field of nonexplosive sources of elastic waves was the development of such specifically marine modifications of seismic prospecting as different types of continuous seismic profiling, realizing the possibilities of seismic prospecting principles in the range from the first tens of Hz to several hundred Hz -- in a range incomparably broader than on the land.

The improvement in the technical means in all geophysical methods was constantly accompanied by an increase in the rate of movement of the vessel in the process of carrying out the complex of geophysical observations.

At the present time when carrying out seismic profiling, the method imposing the principal restrictions on a ship's speed, a speed of approximately 20 knots, that is, 37 km/hour, has been attained. The possibility of obtaining such a volume of data in a month's time which when working on the land would require several years, makes completely understandable the striving for increasing more and more the speed of the ship, which at first glance completely determines the productivity of the investigations as a whole.

Without discussing, for the time being, the matter of the relatively direct relationship between the ship's speed and work productivity, we note that in comparing the productivity of work on the land and in the ocean it is necessary to bear the following in mind. With the presently existing approach to the problem of geophysical investigations in the waters of the world ocean there is no fundamental difference between the results obtained on the land and in the ocean: in both the first and second cases the measurements are made only in a single plane, that is, are superficial. However, whereas under land conditions the tie-in to the surface is of a fundamental character, under oceanic conditions there are no fundamental restrictions in this respect and therefore the created situation can more properly be related to factors of the psychological inertia type.

According to the traditions which have developed, all the investigations carried out in the ocean are readily divided into two groups: those carried out in movement, reconnaissance investigations, and work at stations, when the vessel is at anchor. Up until recently, at the stations only thermal observations were carried out among the geophysical methods. Within the framework of this tradition, investigations at stations are regarded as a direct interference with highly productive reconnaissance methods. This occurs because the principal parameter determining the final productivity of geophysical investigations is assumed to be the number of kilometers in which observations are made in the plane of the water surface.

At the present time more than a million kilometers have been covered in all by surface geophysical methods and from the regional point of view the ocean can no longer be regarded in the geophysical sense as a "white spot." It goes without saying that this fact in no way means that the volume of surface observations now carried out makes it possible to reduce the rates of study by the mentioned methods. Moreover, in continuing further investigations with the developed geophysical complex -- gravimagnetic and seismic investigations of the continuous profiling type -- in our opinion it is necessary to look differently on the entire problem of geophysical investigations in the ocean.

The physical basis for the new approach to the considered problem is the possibility of making use of the fundamental differences between land and ocean investigations not used at the present time. These differences have a dual nature. On the one hand, the mean depth of the water in the world ocean is 3,700 m, which is equivalent to a removal of all the studied objects by a distance of 3,700 m from the observation plane. On the land the studied objects very frequently are at depths less than 1000-2000 m from the observation surface. This difference leads to a loss in resolution applicable to all the geophysical methods employed in reconnaissance work, and in this respect the water layer can be regarded as a hindering factor. On the other hand, due to the easy permeability of the intermediate water layer for all geophysical instruments, we obtain a possibility for free movement in the z-coordinate, investigating the gradients of the magnetic field and the gravity field and obtaining completely new conditions for seismic observations. The high uniformity (from the geophysical point of view) of the intermediate layer and accessibility for penetration at any stipulated point to depths of three or more kilometers creates a situation fundamentally different from that which is characteristic for the land. If we add to this the circumstance that measurement of the heat flow requires observations at the surface of the ocean floor, we obtain a new picture in the relationships between primarily geophysical observations of the reconnaissance type and observations at stations considered primarily hydrogeological and geological. Observations at stations must become a highly important type of complex geophysical investigations making it possible to obtain a three-dimensional picture of the anomalous magnetic and gravitational fields in combination with data on heat flow and fine structure and the properties of sediments, whose study is impossible within the framework of reconnaissance investigations. With such an approach to the problem observations at stations will play the role of reference, standard points relative to reconnaissance surface observations.

Now we will briefly examine some of the consequences following from the new approach to geophysical observations at stations.

Seismic investigations. Applicable to seismic investigations in the ocean there is a sharp narrowing of the possibilities of one of the most informative methods in seismic prospecting -- the reflected waves method. This pertains, in particular, to study of the velocity characteristic of the studied deposits, and as a result, also the density characteristics. The essence of the difficulties arising here essentially involves the following.

With a mean depth of the world ocean of 3,700 m the mean speed of sound in the two-layer model -- water - sedimentary rocks - acoustic basement -- is determined by the expression

$$\frac{\Delta v_{cp}}{v_0} = p\,\frac{1-n}{1+np},$$

where

$$n = \frac{v_0}{v_1}, \quad p = \frac{h_1}{h_0}, \quad \Delta v_{cp} = v_{cp} - v_0,$$

[cp = mean]

h_0, h_1, v_0, v_1 is the thickness of the water layer and the sedimentary rocks and the speed of sound in them respectively. For p = 0.2, n = 0.8, which is typical for the considered situation, we obtain $\Delta v_{mean}/v_0 \approx 3.5\%$.

In the case of a great water depth or a lesser thickness of the sedimentary deposits the situation becomes still worse. Precisely this circumstance predetermines the infeasibility of multichannel seismic profiling and brings to the forefront methods for continuous seismic profiling (CSP) in the central ray variant. However, in this variant as well the fundamental limitations are not removed. Regardless of the method employed for the reflected waves method, substantial limitations also arise in the case of a purely kinematic approach to interpretation of the results as a result of the decrease in the spatial resolution. For example, with a water depth of 4000 m and a wavelength corresponding to the maximum and the excitation spectrum at a frequency of 100 Hz, the diameter of the area forming the reflection is 700 m for the central ray method. This means that the relief details of the reflecting discontinuity, in plan having dimensions less than those indicated above, become indistinguishable. The situation is substantially worsened if the central frequency of the excitation spectrum lies near 40-50 Hz, as is characteristic for pneumatic sources of elastic waves, whereas the reflecting discontinuities lie 1000-2000 m below the bottom level. In a case when

$$\rho < \frac{1}{H}, \qquad (1)$$

where ρ is the local radius of relief curvature, H is depth to the reflecting discontinuity, the CSP travel curve becomes a multivalued function of coordinates; loops appear on the travel-time curve which create the "cobblestone" picture well known to researchers in the CSP field. The reflecting boundary is manifested only integrally, on the basis of the complex form of the wave field.

In a case if

$$\frac{1}{8H} < \rho < \frac{1}{H}, \qquad (1a)$$

the CSP travel-time curve remains an ambiguous function of coordinates, but the dynamics of the reflected waves will not conform to the laws of geometrical seismics, that is, the reflection coefficient loses a clear sense, becoming a frequency-dependent parameter whose value is determined by the form of the reflecting discontinuity, in essence being a random value. Thus, in a number of cases the use of the dynamic parameters of reflected waves for the purposes of determining the coefficient of reflection from the bottom or discontinuities beneath the bottom becomes impossible, although the absence of multiple and reverberation waves in the interval of the useful record creates the prerequisites for such determinations. Moreover, under conditions of more or less complex relief precise kinematic determinations also become difficult. The sole reason for difficulties of the considered type is the great depth of water in the world ocean. However, even for relief of the "quiet" type the use of the dynamics of reflected waves for precise evaluations is difficult due to the fact that the shape of the sounding pulse is subject to rigorous monitoring only when there is a "quiet" water-air discontinuity. With waves of three-four units considerable fluctuations of intensity and the shape of the sounding pulse begin, making impossible a definite approach to the dynamics of the reflected waves. Thus, within the framework of reconnaissance investigations seismic investigations can give information in the best case on the geometric structure of the studied section and with a reasonable choice of the speed of sound in sediments make it possible to determine the thickness of these deposits with an error of about 10-20%.

Data of such a type unquestionably are of independent value in solving important problems in theoretical and practical geology. However, their role can be considerably broader. Here, in particular, we should note the interesting possibilities for the use of information on the thickness of sediments for the introduction of corrections for the sedimentary layer into gravimetric data, which makes it possible to increase the effectiveness of gravimetry as a whole. Such use of CSP data assumes that with a sufficiently high accuracy both the thickness of the sedimentary rocks and their density are known. Information on the thickness of the sedimentary deposits and their properties, and also data on the relief of the acoustic basement are essentially necessary also for study of the distribution of temperatures (heat flow) in the basement rocks. The considerations cited above relative to the possibilities of CSP show that when carrying out these investigations in the form as is now done, data on the speed of sound and density cannot be obtained. The situation changes essentially if there is a changeover to observations at stations with the use of vertical measurement apparatus similar to that which is used in vertical seismic profiling in boreholes. Despite the similarity in the technology of observations, here, it is true, there is a fundamental difference in that the medium in which the measurement apparatus is situated from the seismic point of view is ideally uniform, and the thickness of the intermediate (water) layer on the average considerably exceeds the thickness of the studied sedimentary deposits. The latter circumstance means that by means of a corresponding deepening of the source of elastic waves and detector (detectors) it is possible to avoid completely the influence of the free water surface, that is, realize conditions corresponding to a case when the water layer is equivalent to a half-space. Moreover, having a measurement apparatus at a stipulated distance from the bottom it is possible to ensure satisfaction of the conditions (1, 1a), impaired in the case of surface observations.

Now we will consider some possibilities afforded with such an approach to the problem [7].

We will visualize a measurement apparatus consisting of a source of elastic waves and a receiver situated on the same vertical at the distance Δz from one another. If the duration of the excited pulse is τ_{pulse} and $v_0 \tau_{pulse} < \Delta z$, in each excitation - registry cycle we obtain all the parameters of the incident pulse, which is registered by the detector first, and the sequence of pulses reflected from the bottom and subsequent discontinuities. If the distance from the detector to the bottom Δh_0 satisfies the condition $2\Delta h_0 > \Delta z$, the incident pulse will be registered without interference and a possibility is created for using the dynamics of reflected waves for determining the reflection coefficients and the absorbing properties of the studied deposits.

Now we will visualize a more complex measurement apparatus consisting of a source of elastic waves and two detectors, situated, as before, on the same vertical. The distance between the source and the first detector will be denoted Δz; between the first and second detector -- by z, the thickness of the deposits -- by h_1, and the distance between the source and bottom -- by h_0.

If the relief of the reflecting discontinuities satisfied the smoothness conditions, as can always be ensured by an appropriate choice on the basis of CSP data, it is possible to use the laws of geometrical seismics. Then for a wave reflected from one and the same reflecting discontinuity, but registered in different channels, the expressions for amplitudes will be given by the expressions:

$$A_1(\Delta t_1) = \frac{A_0}{2h_0 - \Delta z + 2h_1 v_1/v_0},$$
$$A_2(\Delta t_1) = \frac{A_0}{2h_0 - z - \Delta z + 2h_1 v_1/v_0},$$
$$A_1/A_2 = q = \frac{2 - (z + \Delta z)/h_0 + 2(\Delta t_1/t_0)p^2}{2 - \Delta z/h_0 + 2(\Delta t_1/t_0)p^2},$$
$$1 - q = \mu = \frac{z/h_0}{2 - \Delta z/h_0 + 2\alpha p^2}, \tag{2}$$

where

$$t_0 = \frac{2h_0}{v_0};\ \Delta t_1 = \frac{2h_1}{v_1};\ p = \frac{v_1}{v_0};\ \alpha = \frac{\Delta t_1}{t_0}.$$

The t_0 and Δt_1 values are determined directly from the records in the first or second channels. Since z is a known parameter of the apparatus, and h_0 is determined from the t_0 value and the speed of sound in water, by having the μ value it is also possible to determine v_1. If the section has a multilayer structure, in place of α and p it is necessary to substitute the value

$$p_{э\phi} = \frac{v_{э\phi}}{v_0};\ \alpha = \frac{\sum_i h_i/v_i}{t_0}.$$

[$э\phi$ = ef = effective]. Then on the basis of the observed μ values it is possible to determine the effective velocity v_{ef}. Since, as in the case of an apparatus of the first type we have a possibility for registry of the incident wave in "pure" form, in principle it becomes possible to determine absorption, the distribution of the speed of sound with depth, and finally, the reflection coefficients. A knowledge of the latter also makes it possible to ascertain the density distribution with depth. Thus, the use of vertical measurement apparatus when making observations at stations, in combination with surface reconnaissance observations, ensures the possibility of continuous determination of the necessary parameters of the sedimentary deposits. Reconnaissance observations are now necessary for the purposes of interpolation between reference observations at stations. In turn, the speedy analysis of CSP data makes possible a sound selection of points for observation at stations and the density of such observations. The close interrelationship and interdependence of surface reconnaissance observations and observations at stations are obvious.

Gravimetric investigations. Successes in the development of the theory of gravity measurement on a moving base and the designing of automated on-board gravimetric apparatus are now making it possible to carry out continuous measurements of gravity aboard research vessels with an accuracy to ±1 mgal if there is corresponding navigational support. However, as a result of the distance of the studied objects from the observation surface there is a marked decrease in the resolution of on-board gravimetric measurements. The gravitational influence of the discontinuity (two-dimensional problem) can be estimated using the formula [2]

$$\Delta g = 2\pi f \sigma e^{-\frac{2\pi h}{l}} (z_2 - z_1), \tag{3}$$

where f is the gravitational constant, σ is the difference in densities at the discontinuity, h is the mean depth of the discontinuity, z_2 and z_1 are the maximum and minimum depths to the discontinuity, e is the "period" of the curve.

For example, with a water depth of 4000 m the gravitational influence exerted on the ocean surface by unconsolidated sedimentary deposits with a density 1.6-1.7 g/cm^3 and a thickness of 500 m, lying on rocks of the acoustic basement with a density 2.6-2.7 g/cm^3, with transverse dimensions 5 km ("period" - 10 km), will be less than 4 mgal. At a depth of 2000 m from the ocean surface the gravitational influence of this structure increases to 12 mgal, that is, can be reliably registered by modern sea gravimeters. If the measurements are made at a depth of 3500 m, that is, at a distance of 500 m from the ocean floor, the influence of the above-mentioned structure attains 30 mgal. The approach of the discontinuity to the observation level seemingly makes it possible to "focus" the influence of the discontinuity, to achieve a clearer and sharper manifestation of the effect of this discontinuity in the observed field. For this purpose it is possible to carry out analytical continuation of the anomalous field to some horizontal plane situated between the observation plane and the discontinuity responsible for the presence of the investigated gravitational anomalies. However, in the analytical continuation of anomalous fields into the lower half-space there inevitably will be errors which with the low accuracy of sea measurements of the anomalous gravitational field can be extremely significant. Observation of the anomalous gravitational field at different levels makes it possible not only to obtain a sharper manifestation of the influence of different anomalous sources in the observed fields, but also to obtain data on the distribution of the anomalous gravitational field in space.

In a quantitative interpretation a knowledge of the nature of the distribution of anomalous fields in space considerably increases the reliability of the interpretation results [2, 3].

In the Soviet Union specialists have developed a damped float apparatus for measuring gravity at different depths from the ocean level (Nemtsov, 1977). The tests indicated that the accuracy of measurements with the float apparatus is several times greater than the accuracy of on-board measurements of gravity with modern sea gravimeters due to a marked decrease in the influence of the disturbing accelerations of waves within the damped float apparatus, submerged to a depth of 30-50 m.

Magnetometric investigations. Despite the fact that the error for modern proton and quantum magnetometers does not exceed ±(1-2) gamma, the accuracy of magnetic surveys in the ocean usually does not exceed ±(10-20) gammas. This is attributable for the most part to the fact that with low speeds of towing of magnetometers (10-30 km/hour) it is impossible to filter out the diurnal variations from the anomalous field due to the fact that their spectra overlap [6]. A high survey accuracy can be attained by the placement of buoy variation stations or by simultaneously measuring the total magnetic field and the gradient using a magnetometer - gradient meter. The intensity of the magnetic anomalies in the case of observations near the ocean floor increases more sharply than in the case of gravitational anomalies [1]. The strengths of the anomalous magnetic field at different levels obtained in this case make it possible to obtain the vertical derivative of the anomalous magnetic field. The use of the higher derivatives of the anomalous magnetic field is important both for localizing individual anomalies and for determining the parameters of the sources of anomalies.

Thermal investigations are possible only in the case of observations at stations. Under conditions when observations at stations are used for many-sided geophysical investigations, the carrying out of such investigations can no longer be regarded as interference in the carrying out of the main types of work.

In our opinion, the successful further use of thermal observations will require measurements of temperatures in the water layer near the bottom and temperatures in the ground at several levels.

A determination of heat flow alone is inadequate for study of the heat field in the section. With the availability of data on the thickness of sedimentary deposits and relief of the acoustic basement data on temperature in the layer adjacent to the sediments can be scaled downward into the region of basement rocks and this will make it possible to study the structure of the heat field in its relationship to deep structure. Since the temperature regime of the bottom deposits is essentially dependent on water filtering processes in this layer, the problem arises of evaluating the intensity of filtration processes as a component part of thermal investigations at stations. In such a formulation thermal measurements are considerably complicated and require the development of new methods and special apparatus. The combination of reconnaissance investigations and observations at stations forms a geophysical complex of an operational character in which it is already possible to note a definite hierarchy: reconnaissance investigations have a high productivity, but yield information in a reduced volume. In this sense the collected volume of information can be regarded as adequate for investigations of the reconnaissance type, on the basis of which the points for the stations must be selected. In this case observations at stations will represent the second stage in multi-sided geophysical investigations.

Proceeding on the basis of the considerations presented above, it can be stated with assurance that:

1) the idea that there is an identity in the rate of carrying out reconnaissance geophysical investigations and the productivity of geophysical investigations as a whole cannot be considered correct;
2) there must be a new approach to the problem of many-sided geophysical investigations in the world ocean in which observations at stations become an indispensable part of the full geophysical complex;
3) the combination of reconnaissance (route) observations and observations at stations makes possible a considerable increase in the information content of geophysical investigations and an increase in the reliability of the geological interpretation of geophysical data as a whole;
4) the planning and carrying out of geophysical investigations in the ocean must be carried out with adherence to stages: reconnaissance, point (at stations), polygon;
5) serious attention must be devoted to the development of an instrument base for carrying out geophysical investigations using the entire water layer and deep-water bottom observations.

BIBLIOGRAPHY

1. Vak'yev, V., GEOMAGNETIZM V MORSKOY GEOLOGII (Geomagnetism in Marine Geology), Leningrad, 1976.

2. Andreyev, B. A., Klushin, I. G., GEOLOGICHESKOYE ISTOLKOVANIYE GRAVITATSIONNYKH ANOMALIY (Geological Interpretation of Gravitational Anomalies), Moscow, 1962.

3. Logachev, A. A., MAGNITORAZVEDKA (Magnetic Reconnaissance), Moscow, 1968.

4. Sokolov, B. A., Gaynanov, A. G., Nesmyanov, D. V., Seregin, A. M., NEFTEGAZONOSNOST' MOREY I OKEANOV (Presence of Petroleum and Gas in the Seas and Oceans), Moscow, 1973.

5. Nemtsov, L. D., et al., "Gravimetric Prospecting," MORSKIYE GEOFIZICHESKIYE ISSLEDOVANIYA (Marine Geophysical Investigations), Moscow, 1977.

6. Uglov, B. D., "Magnetic Prospecting," MORSKIYE GEOFIZICHESKIYE ISSLEDOVANIYA, Moscow, 1977.

7. Kalinin, A. V., Kalinin, V. V., Azimi, Sh. A., "A Method for Seismic Exploration in Sea-Ocean Areas," AUTHOR'S CERTIFICATE No 325573, 12 October 1971.

[145-5303]

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MONOGRAPH ON MEASURING SPEED OF SOUND IN OCEAN

Leningrad IZMERENIYE SKOROSTI ZVUKA V OKEANE (Measurement of Speed of Sound in the Ocean) in Russian 1979 signed to press 9 Feb 79 p 3

[Table of contents from monograph by G. N. Seravin, edited by Corresponding Member USSR Academy of Sciences V. V. Bogorodskiy, Gidrometeoizdat, 136 pages]

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CSO: 1865

UDC 550.83:551.351.2

MONOGRAPH ON MARINE GAMMA-SPECTROMETRIC SURVEYING

Moscow MORSKAYA GAMMA-SPEKTROMETRICHESKAYA S"YEMKA (Marine Gamma-Spectrometric Surveying) in Russian 1979 signed to press 12 Oct 79 pp 2, 147-148

[Annotation and table of contents of monograph by V. V. Kostoglodov, Izd-vo "Nauka," 1979 148 pages]

[Text] Annotation. This monograph deals with theoretical problems, physical and geochemical prerequisites and possibilities of practical application of the method of a continuous underwater gamma-spectrometric and radiometric survey intended for rapid study of the surface layer of sea sediments. The author points out the high effectiveness and advantage of this method in comparison with traditional methods and the methods for studying bottom sediments widely used in marine geology. The monograph is intended for specialists in the field of marine geology and geophysics. Tables 15, figures 40, bibliography of 103 items.

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III. TERRESTRIAL GEOPHYSICS

UDC 553.98.061.43:001.18

COLLECTION OF ARTICLES ON PREDICTION OF PETROLEUM AND GAS

Leningrad KRITERII PROGNOZIROVANIYA TRESHCHINNYKH KOLLEKTOROV NEFTI I GAZA V RAZLICHNYKH GEOLOGICHESKIKH USLOVIYAKH (Criteria for the Prediction of Petroleum and Gas in Fissured Collectors Under Different Geological Conditions) in Russian 1978 signed to press 18 Apr 78 pp 2, 3-4

[Annotation and table of contents of collection of articles edited by Candidate of Geological and Mineralogical Sciences M. Kh. Bulach, VNIGRI, 146 pages]

[Text] Annotation. This collection of articles deals with different problems involved in the prediction of fissured collectors under different geological conditions. The authors discuss the criteria for evaluating the influence of post-sedimentation processes on the formation of porosity in calcareous rocks and the patterns of distribution of the collectors (in the example of Ciscaucasia). The collection also contains data on the role of disjunctive dislocations in the formation of calcareous collectors (in the example of the Baltic area and the Vuktyl'skoye deposit) and the relationships among the collector properties of the latter and the cyclicity of sedimentation. Also examined are the problems relating to the modeling of a fissured collector, terminology and classification. The book is intended for specialists engaged in investigations and prediction of calcareous (fissured) petroleum and gas collectors.

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UDC 550.83

COLLECTION OF ARTICLES ON EXPLORATORY GEOPHYSICS

Moscow RAZVEDOCHNAYA GEOFIZIKA (Exploratory Geophysics) in Russian No 86, 1979 signed to press 17 Jan 79 p 163

[Table of contents from collection of articles edited by V. Yu. Zaychenko, et al., "Nedra," 168 pages]

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UDC 550.34

COLLECTION OF PAPERS ON EARTHQUAKE PREDICTION AND STRUCTURE OF EARTH

Moscow VOPROSY PROGNOZA ZEMLETRYASENIY I STROYENIYA ZEMLI, VYCHISLITEL'NAYA SEYSMOLOGIYA in Russian Issue 11, 1978 p 2, 180

[Annotation and table of contents from collection of articles edited by Doctor of Physical and Mathematical Sciences V. I. Keylis-Borok, Izdatel'stvo "Nauka," 1978 184 pages]

[Text] Annotation. The authors of these papers examine the results of search for the precursors of strong earthquakes, employing an electronic computer for investigation of various kinds of seismological data (earthquake catalogues, bulletins from the network of seismic stations). The articles describe the results of application of a number of statistical and heuristic algorithms to the problems involved in detecting the locations of possible strong earthquakes, migration of seismic foci and determining the mechanism of earthquakes. This includes theoretical investigations of some direct and inverse problems in seismology: stability of the inverse problem in geometrical seismics, asymptotic methods in the theory of characteristic oscillations of the earth and wave propagation in stratified porous media. New modifications of spectral analysis are proposed and investigated. A method for the practical interpretation of surface waves is described. New approaches are found for the designing of long-period digital registry apparatus and calibration of earthquakes on the basis of long-period records. This particular collection of papers is of interest for a broad range of specialists in the field of global and regional geophysics, general and shot seismology and seismic prospecting.

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UDC 550.348

VARIATIONS IN ACTIVITY OF WEAK CRUSTAL EARTHQUAKES WITH DIFFERENT FOCAL DEPTHS

Moscow IZVESTIYA AKADEMII NAUK SSSR, FIZIKA ZEMLI in Russian No 12, 1980 pp 23-35

[Article by Yu. M. Teytel'baum and V. S. Ponomarev, Institute of Physics of the Earth, submitted for publication 26 April 1979]

Abstract: On the basis of materials on the seismicity of the Garm region in Tadzhik SSR the authors make a detailed study of the temporal changes in the activity of weak ($K \geqslant 7$) crustal earthquakes with different focal depths. It was found that the variation in temporal changes is substantially different in different layers. Near-surface earthquakes, constituting about 85% of the total number of earthquakes, determine the differences of regime in individual parts of the region. The regime of relatively deep earthquakes (deeper than 10 km) is uniform over the entire area of the region. The temporal changes in activity of deeper earthquakes reveal a close correlation with the occurrence of strong earthquakes ($K = 13$-14). It is manifested in brief increases in the activity level over the entire area of the region 1 1/2 years before the appearance of a strong earthquake. Prolonged tendencies in change in activity level for deeper earthquakes can be used for long-term evaluations of the total change in seismic danger over the area of the region.

[Text] Materials. This study makes use of materials from seismological observations in Garm region from 1955 through 1976. The location of the seismic stations is shown in Fig. 1. The earthquake coordinates were determined with an accuracy of the classes A (±1-2 km), B (±2-5 km) and C (±5-10 km). The accuracy in determining coordinates worsens with increasing distance from the network of seismic stations [1]. Therefore, the principal investigations were carried out over an area of about 10^4 km^2, which in Fig. 1,a has been defined as the area S_p. In the overwhelming majority of cases the coordinates in this area were determined with the accuracy of classes A and B. The energy classification of earthquakes was determined using the T. G. Rautian scale [1]. In this investigation we used earthquakes with $K \geqslant 7$. They are registered representatively over the entire area of the region.

The position of the epicenters of the most significant earthquakes occurring in the region during the observation period (K = 13-14) is noted in Fig. 1,a. Here, on the basis of data from Leonov [2], we have also shown the position of the pleistoseist region of the Khaitskoye earthquake of 1949.

In the Garm region it was possible to define three regions differing substantially with respect to seismic regime, regions of dynamic coherence -- RDC [3]. In Fig. 1a they are designated by Roman numerals. The principal differences in the seismic regime include the different level of seismic activity and the nature of the prolonged trends in change of activity. The regions coincide with the most significant inhomogeneities in the geological structure of the region: region I coincides with the structures of the Southwestern Tien Shan, region II -- with structures of Petr I Range, region III -- with structures of the Darvaz-Karakul'skiy fault zone. These geological structures differ with respect to the gradients of vertical movements [4]. In this study the examination of seismological data is made for the S_p area as a whole and separately for regions of dynamic coherence.

Spatial Structure of Seismically Active Volumes

The distribution of the relative number of earthquakes by depth is illustrated in Fig. 2. The data in the histograms are given in percent of the total number of earthquakes during the period from 1955 through 1976. As the gradation of depth of hypocenters we used an interval of 5 km. The mean position of the seismic stations -- 1350 m above sea level -- was used as the zero level surface.

Some idea concerning the volumetric distribution of weak earthquakes is given by the maps and sections of the density field of weak earthquakes (Figures 1 and 3). By the density n of weak earthquakes is meant the number of weak earthquakes n of the energy classes K = 7-12, normalized in area and time. The number of epicenters for 1955-1970 in the averaging areas was calculated for each layer for constructing the density maps. The areas used measured 6' x 6' (about 100 km^2). They were laid out with an interval of half the linear dimension of the area. The mean annual values n of the numbers of earthquakes in the averaging areas were assigned to the centers of the areas. The dimensionality of the n values adopted in this study was (100 $km^2 \cdot year)^{-1}$. In constructing the density isolines the assumption was made that there is a linear change in the n values from area to area. Density maps were constructed for the first three 10-km layers. Earthquakes with foci deeper than 30 km are indicated by their epicenters in Fig. 1. Sections, examples of which are given in Fig. 3, were obtained using the density maps. They reflect the distribution of weak earthquakes in meridional and latitudinal zones with a width of 6'. The n values were assigned to the middles of 10-km layers with 5-km intervals. The axial lines of the sections are indicated in Fig. 1.

The cited materials show that the foci of weak earthquakes for the most part (85%) are concentrated in the upper 10-km layer of the earth's crust. With an increase in depth their number decreases sharply and deeper than 35 km only individual earthquake foci are registered.

The density field in the surface layer has a complex structure. With an increase in focal depth the field structure becomes simpler and the foci of the deepest earthquakes are concentrated in the central part of the region. On the quantitative side the decrease in the number of earthquakes deeper than 10 km is virtually identical in all three RDC, despite the difference in their geological structure and in the type of seismic regime. Appreciable differences in the distributions are noted only in the upper 10-km layer.

Table 1 gives the values of the angular coefficient of the graph of frequency of recurrence γ, computed using data for 1955-1976. The table shows that the γ values experience considerable fluctuations both vertically and horizontally. However, the cited data do not exhibit any significant pattern in the changes in values with an increase in depth.

Table 2 gives data on the change (with depth) of the mean values of the coefficient of grouping of earthquakes $\bar{\gamma}_\delta$, determined for the "north" (RDC I) and "south" (RDC II and III) areas of the region. The method for determining $\bar{\gamma}_\delta$ was described in detail in [5]. The cited table shows that the grouping of earthquakes in the "north" of the region virtually does not change with depth: the values here are close to 0.1. In the "south" of the region the degree of grouping is relatively great in the upper layers ($\bar{\gamma}_\delta = 0.25$) and with an increase in depth decreases, tending to the value 0.1. In [5] the γ_δ coefficient is regarded as a characteristic of properties of the medium. From this point of view the observed effect can be attributed to the fact that the high values of the grouping coefficient in the "south" characterize rocks of the sedimentary cover of the Tadzhik depression, whose thickness attains 10-13 km. In the "north" of the same region, where the rocks of the crystalline basement emerge at the surface, the values are identical in the entire depth range.

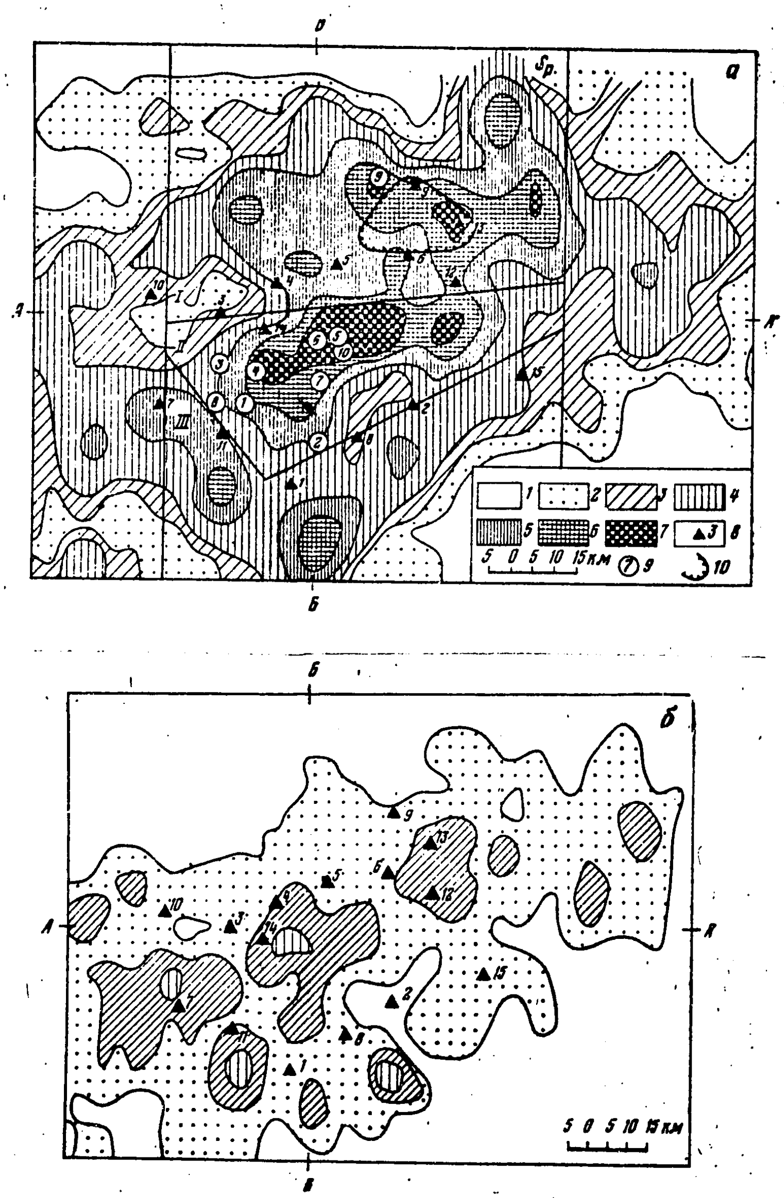

Fig. 1a,b

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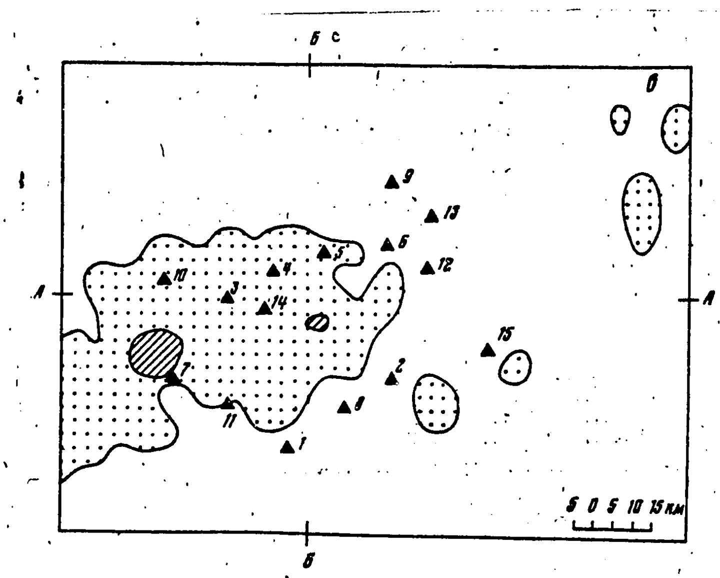

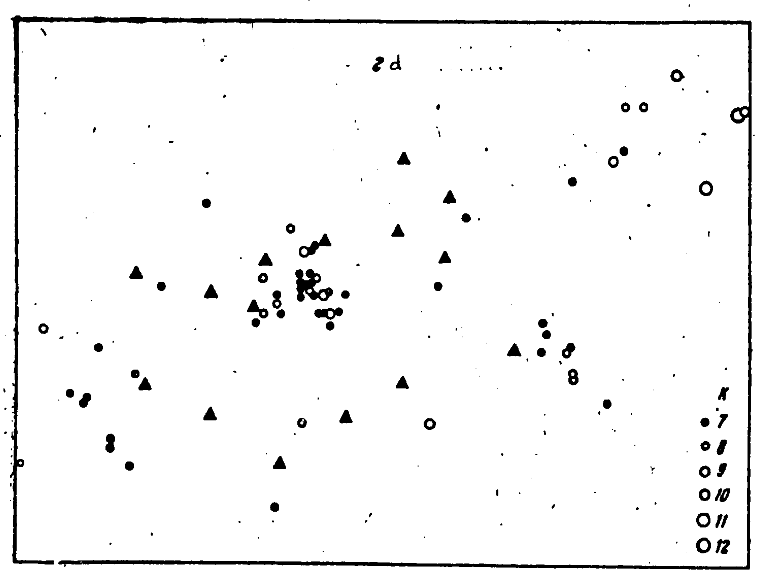

Fig. 1. Map of seismicity of Garm region (caption on next page).

Caption for Fig. 1. Density of earthquake epicenters: a) with focus in layer 0-10 km; b) 11-20 km; c) 21-30 km; d) epicenters of earthquakes with focal depth greater than 30 km. The density of epicenters is expressed in (100 km^2·year)$^{-1}$; 1) 0-0.24; 2) 0.25-0.99; 3) 1-1.99; 4) 2-4.99; 5) 5-9.99; 6) 10-14.99; 7) 15 or more; 8) seismic station; 9) epicenters of earthquakes with K⩾13 (1955-1976); 10) focal zone of the Khaitskoye earthquake.

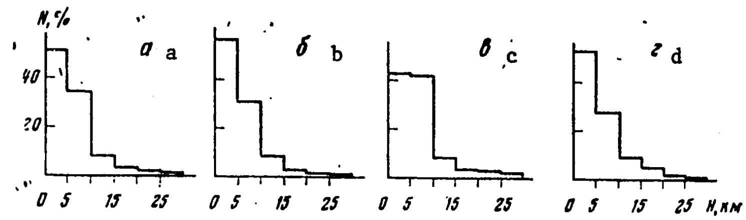

Fig. 2. Distribution of relative number of weak earthquakes (K⩾ 7) with depth. a) over area of Garm region; b, c, d) over areas of RDC I, II, III respectively.

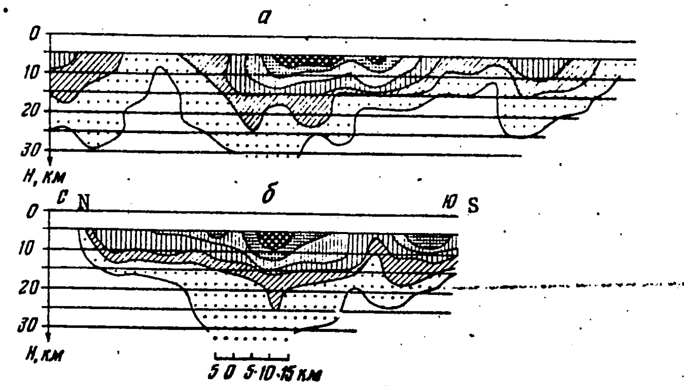

Fig. 3. Sections. a) along A-A; b) along B-B.

Changes in Activity of Weak Earthquakes With Time

A study of temporal variations of the activity of weak earthquakes was made using time series of the annual sums of earthquakes with K⩾7. The sampling of earthquakes for their construction was carried out over the area of the region (S_p) and over the areas of regions of dynamic coherence. Table 3 gives the cross-correlation coefficients computed in a paired comparison of time series obtained separately for a group of earthquakes with focal depths 0-5, 6-10, 11-15, 16-20, 21-25 and more than 25 km. The time series were obtained using data for the period from 1955 through 1976. Correlation coefficients differing significantly from zero with a confidence level P = 0.9 are underlined in the table.

Table 1

Angular Coefficient of Graph of Frequency of Recurrence of Earthquakes ($-\gamma$)

Focal depth, km	Garm region	RDC I	RDC II	RDC III
0-5	0.50	0.51	0.47	0.53
6-10	0.46	0.50	0.43	0.47
11-15	0.48	0.49	0.44	0.44
15	0.47	0.56	0.53	0.43

KEY:
1. Focal depth, km
2. Garm region
3. RDC

Table 2

Mean Grouping Coefficients

Focal depth, km	"North" (RDC I)	"South" (RDC II + RDC III)
0-10	0.1	0.25
6-15	0.102	0.252
11-20	0.106	0.184
16-25	0.124	0.138
21-30	0.13	0.133

KEY:
1. Focal depth, km
2. "North" (RDC I)
3. "South" (RDC II + RDC III)

Table 3

Cross-Correlation Coefficients of Time Series of Annual Sums of Earthquakes With Different Focal Depth

Focal depth, km (Глубина очагов, км)	0—5	6—10	11—15	16—20	21—25	>25
0-5	×	−0,1	−0,33	−0,11	0,15	−0,24
6-10		×	0,66	−0,37	−0,3	0,64
11-15			×	0,7	0,58	0,8
16-20				×	0,64	0,69
21-25					×	0,41
>25						×

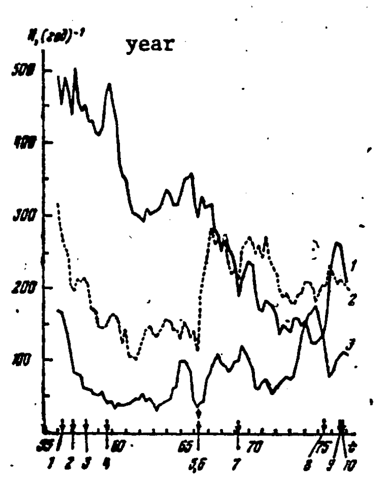

Fig. 4

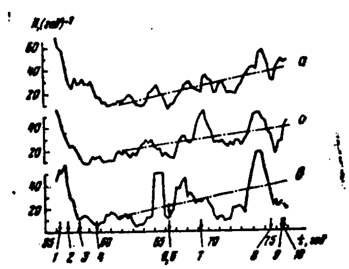

Fig. 6

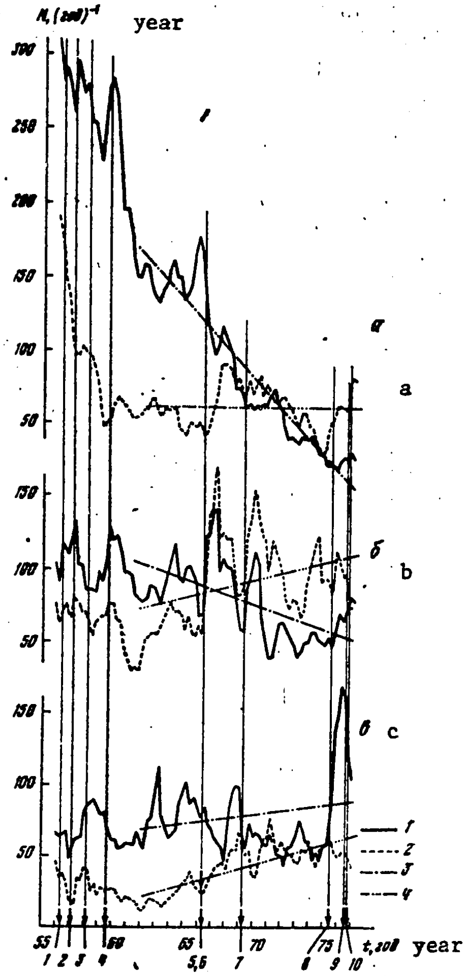

Fig. 5

Fig. 4. [Top left] Graph of change in annual sums of weak earthquakes in Garm region. Focal depths: 1) 0-5, 2) 6-10, 3) >10 km.

Fig. 5. [Right] Graphs of change in annual sums of weak earthquakes in regions of dynamic coherence I (a), II (b) and III (c). Focal depths: 1) 0-5, 2) 6-10 km. Averaging straight lines for foci: 3) 0-5, 4) 6-10 km

Fig. 6. Graphs of change in annual sums of weak earthquakes with foci deeper than 10 km in RDC I (a), II (b) and III (c).

Table 4

Cross-Correlation Coefficients of Time Series of Annual Sums of Earthquakes (K = 7), Selected from Regions of Dynamic Coherence of Region in Different Depth Layers

Сопоставляемые объемы Compared volumes		0–5 км			6–10 км			10 км		
		I^1	II^1	III^1	I^2	II^2	III^2	I^3	II^3	III^3
0–5 км	I^1	×	0,63	−0,15	0,48	−0,48	−0,63	−0,14	−0,42	−0,21
	II^1		×	0,07	0,3	0,02	−0,61	−0,28	−0,32	−0,51
	III^1			×	−0,68	−0,64	0,08	0,11	−0,14	−0,24
6–10 км	I^2				×	0,05	0,04	0,41	0,1	0,14
	II^2					×	0,58	0,27	0,43	0,22
	III^2						×	0,51	0,59	0,31
10 км	I^3							×	0,67	0,55
	II^3								×	0,60
	III^3									×

Table 5

Cross-Correlation Coefficients of Time Series of Annual Sums of Earthquakes ($K \geqslant 7$) With Exclusion of Long-Term Tendencies

Сопоставляемые объемы Compared volumes		0–5 км			6–10 км			10 км		
		I^1	II^1	III^1	I^2	II^2	III^2	I^3	II^3	III^3
0–5 км	I^1	×	0,09	0,28	−0,25	−0,32	−0,29	−0,17	−0,3	0,24
	II^1		×	0,18	0,29	0,58	−0,2	0,32	0,24	0,3
	III^1			×	0,04	−0,26	−0,27	−0,03	−0,37	−0,1
6–10 км	I^2				×	0,41	0,33	−0,2	0,09	−0,17
	II^2					×	0,33	0,05	0,19	0,01
	III^2						×	−0,07	0,24	−0,11
10 км	I^3							×	0,44	0,33
	II^3								×	0,4
	III^3									×

Table 3 shows that the temporal changes in the activity of weak earthquakes in the layer 0-5 km are uncorrelated with activity variations in the deeper layers. The cross-correlation coefficients in layers deeper than 10 km are positive and considerably different from zero, that is, the changes in seismicity in these layers have a similarity. The temporal variation of changes in the layer 6-10 km are uncorrelated with changes in the layer 0-5 km and are partially correlated with changes in the deeper layers. Accordingly, thereafter we compared the behavior of the three principal sets of crustal earthquakes: surface (0-5 km), intermediate (6-10 km) and relatively deep (deeper than 10 km). The time series of annual sums with such a subdivision are given in Fig. 4. The annual sums of earthquakes are shown on the graphs with a three-month interval.

Figure 4 shows that in the changes of each of the time series there is a systematic component or long-term trend. Prolonged trends are expressed differently in different layers: whereas the activity of surface earthquakes successively decreased up to 1975, the general decrease in the activity of intermediate earthquakes ended much earlier -- by 1961, and for relatively deep earthquakes -- by 1960. Later, for the two deeper layers there was a tendency to an increase in activity, so that in the second half of the observation period the direction of the long-term changes in the layer 0-5 km was opposite the direction in the deeper layers.

The time series of annual sums of earthquakes with $K \geqslant 7$, relating to different RDC, are given in Fig. 5 (surface and intermediate earthquakes) and Fig. 6 (relatively deep earthquakes). The cross-correlation coefficients for the mentioned time series are given in Table 4. Coefficients considerably different from zero with a confidence level P = 0.9 are underlined. Different samples are denoted in the following way: Roman numerals are employed in designating the regions -- I, II, III, the superscripts denote the depth of the layer. For example, I^1 is a sample of earthquakes from RDC I with foci in the interval 0-5 km, II^3 is a sample of earthquakes from RDC II with foci deeper than 10 km, etc.

Using the data from Table 4, it is possible to compute the mean correlation coefficients $\bar{r}$ between the time series relating to different depths, but within the limits of one RDC (vertically), and at one depth, but in different RDC (horizontally). Their values are: vertically -- $\bar{r}^I = 0.25$ (RDC I), $\bar{r}^{II} = 0.04$ (RDC II), $\bar{r}^{III} = 0.05$ (RDC III), horizontally -- $\bar{r}^1 = 0.14$ (0-5 km), $\bar{r}^2 = 0.22$ (6-10 km), $\bar{r}^3 = 0.61$ (deeper than 10 km).

The cited data show that the nature of the changes in the activity of weak earthquakes in the case of a layer-by-later examination in each RDC is different. Any similarity in changes in the layer 0-5 in different RDC is also lacking. However, this similarity is manifested deeper than 5 km and becomes significant at a depth greater than 10 km.

It can be seen from the figures, in which the time series are represented, that the values of the cross-correlation coefficients are dependent to a considerable degree on the long-term trends observable in these series.

It is therefore of interest to examine the cross-correlation coefficients of the time series using these same samples, but with the exclusion of long-term trends.

In order to exclude the trends the time series during the period from 1961 through 1976 were approximated by a straight line obtained by the least squares method. Henceforth in computing the cross-correlation coefficients we took into account only the deviations of the individual values of each series from the approximating straight line. The values of the cross-correlation coefficients of the "short-period" oscillations obtained in this way are given in Table 5, which was prepared the same as Table 4.

The mean values of the correlation coefficients obtained from these data have the following values: vertically $\overline{r}^{I} = -0.21$, $\overline{r}^{II} = 0.34$, $\overline{r}^{III} = 0.16$, horizontally -- $\overline{r}^{1} = 0.18$, $\overline{r}^{2} = 0.36$, $\overline{r}^{3} = 0.39$. The relatively high value of the coefficient $\overline{r}^{II} = 0.34$ is attributable, as can be seen from Table 5, exclusively to the high correlation coefficient between layers 1 and 2 in RDC II ($r = 0.58$). Such a high value can be attributed to the influence of earthquakes with $K = 13\text{-}14$ arising in this part of the region (their aftershocks and the seismic calms preceding them). In general, however, the cited data also indicate that with depth the regime of weak earthquakes becomes more uniform, although this phenomenon is not expressed so clearly as when long-term trends are taken into account.

The totality of the examined data in general leads to the conclusion that the differences in the regions of dynamic coherence with respect to the regime of change in the activity of weak earthquakes with time for the most part are fixed by the seismicity of the upper part of the earth's crust. With an increase in depth the differences in regime become less conspicuous, but in the layer deeper than 10 km the regime of weak earthquakes is virtually identical over the entire area of the region.

Correlation Between Strong Earthquakes and Variations in the Activity of Weak Earthquakes

In the Garm region no earthquakes whose energy exceeded 10^{14} J occurred during the observation period. Therefore as strong earthquakes we arbitrarily used those with $K = 13\text{-}14$. The position of their epicenters is indicated in Fig. 1,a. In Figures 4-6 the sequence numbers of the epicenters correspond to the arrows, which indicate the moments of occurrence of these earthquakes.

The correlation between short-period variations of activity and strong earthquakes was determined on the basis of observational data for 1961-1976, that is, using that part of the time series in which long-term trends in all the samples with some approximation can be considered linear. The variations of each curve relative to the straight line approximating it were compared with the moments of occurrence of strong earthquakes.

The correlation coefficient of the qualitative criteria [6] is determined by the expression

$$Q = \frac{(AB)(\alpha\beta) - (A\beta)(\alpha B)}{(AB)(\alpha\beta) + (A\beta)(\alpha B)},$$

where the following are used as qualitative criteria: A is the particular value of the time series, not less than the moving average, α is the particular value of the series, less than the moving average, B is the presence of an earthquake with K = 13-14 in a one-year time period, β is the absence of such. The time series ended with an interval of three months and the number of groups of criteria participating in the computation of Q was reckoned. The computed values were used in ascertaining the $Q(\tau)$ functions, cited in Fig. 7. They have the sense of cross-co elation functions [7], where one of the functions is a time series reflecting the change in activity of weak earthquakes, whereas the other corresponds to the moments of occurrence of strong earthquakes. The argument of the function $\tau = 0, \pm 0.5, \pm 1 \ldots$ is the lag time. Since the correlation between the preliminary values of the activity variations with the subsequent occurrence of strong earthquakes is of the greatest interest, the series of positive delay time values was selected long (up to +2.5 years). Figure 7 shows that the correlation of earthquakes K = 13-14 with changes in the activity of weak earthquakes is expressed differently at different depths. On the whole, over the area of the region in the two upper layers there is a significant positive correlation (Q about +0.7 or more) in the region of negative time delay values, that is, with the aftereffects of strong earthquakes. The seismic activity excited by these earthquakes is localized in the upper two layers, as is indicated by the low value of the correlation coefficients (Q = +0.2), computed for the layer deeper than 10 km in the region of negative delay time values. However, seismicity in the upper two layers is weak and reacts at different times to the preparation of large earthquakes, whereas in the lower layer there is a strong positive correlation (Q = +0.8). This indicates that 1-2 years before the appearance of major earthquakes the activity in the layer deeper than 10 km increases considerably, which is qualitatively conspicuous also in Figures 4, 6. As can be seen from Fig. 7, this type of precursor activation is clearly manifested almost simultaneously in all three sectors of the region. Figure 7 also shows that the maximum Q values are attained in the layer 0-10 km with lesser τ values than in the deeper layers. The aftereffect of earthquakes with K = 13-14 has a local character and exerts a brief effect on the form of the time series. It is natural to assume that both the area and the duration of the effect should increase with an increase in the energy of large earthquakes. Thus, the already noted prolonged tendency to a dropoff in seismic activity, evidently, is attributable to the aftereffect of the Khaitskoye earthquake of 1949 (M = 7.4). This is supported by the fact that the tendency to a decrease in the activity of surface earthquakes lessens with increasing distance from the focal region of the Khaitskoye earthquake: in RDC I in 22 years it decreased by a factor of 10, in RDC II -- by a factor of 2, in RDC III, at more 50 km from the epicenter the influence of the Khaitskoye earthquake cannot be traced on the basis of the data for the observation period.

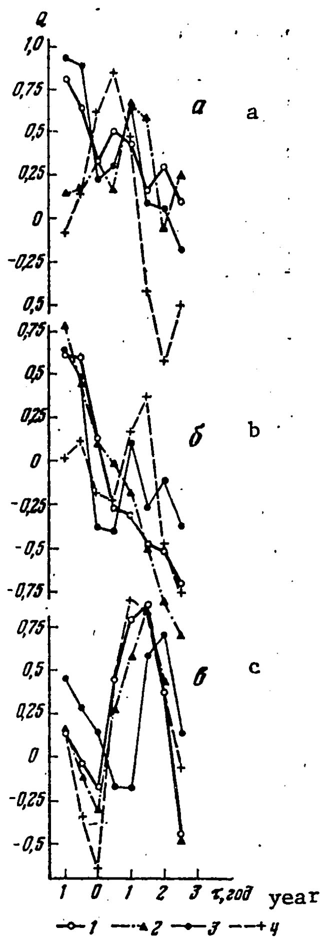

Fig. 7. Correlation function for time of occurrence of strong earthquakes (K = 13-14) with brief variations in change in activity of weak earthquakes. Averaging areas: 1) Garm region, 2) RDC I, 3) RDC II, 4) RDC III. Focal depths: a) 0-5, b) 6-10, c) > 10 km

It is interesting to note that as for earthquakes with K = 13-14, the influence of the Khaitskoye earthquake is also limited vertically: in RDC I, that is, in the near-focal region of the Khaitskoye earthquake, the decrease in the activity of weak earthquakes in the layer 6-10 km persists only up to 1959. Later it becomes indistinguishable against the background of brief oscillations (Fig. 5). With respect to the layer deeper than 10 km, here both at the beginning of the observation period and later the activity changes were synchronous and virtually identical in value in all three RDC (Fig. 6), from which it can be assumed that these changes were caused by other factors. In general, the form of the long-term tendencies in change in activity of weak earthquakes during the course of the observation period seemingly was determined by the interaction of two factors: the aftereffect of the Khaitskoye earthquake, manifested primarily in the upper layer of the earth's crust, and the influence of some more general factor, being manifested primarily in the activity changes of deeper earthquakes. As a result, the course of the temporal changes in different layers was different up to and including oppositely directed changes.

Discussion of Results

The results show that the overwhelming majority of the foci of weak earthquakes in the Garm region are concentrated in the upper layer of the earth's crust with a thickness of about 10 km. Therefore, the pattern of manifestations of weak seismicity, examined in the entire group without separation by depth, for the most part reflects processes transpiring in the upper layer of the earth's crust. Moreover, the behavior of seismicity vertically differs extremely significantly: in the upper layer the changes in the activity of weak earthquakes have a similarity only within the limits of one RDC [3], whereas in the layer deeper than 10 km the similarity is manifested over the entire area of the region. It is obvious from this that more local factors exert an influence on changes in activity near the surface. Evidently, this phenomenon reflects the usually observed complication of geological structure of the earth's crust from the deep layers to the surface (for example, see [8]). It is not impossible that here there is reflection of the course of those processes which form the indicated complication of structure.

The idea of a difference in the conditions for formation of geological structures vertically has been examined, for example, in [9]. According to this study, the differences are determined by the dependence of the mechanical properties of the rocks on temperature and pressure; with an increase in the latter the capacity of rocks to flow increases. Therefore, first, the rocks near the surface are more brittle, and second, the lifetime of structural inhomogeneities decreases with depth. In agreement with such ideas it can be assumed that the marked increase in the activity of weak earthquakes in the layer 0-10 km is associated with increased brittleness of the rocks in this layer, whereas the greater uniformity of the regime of earthquakes deeper than 10 km reflects the greater uniformity of this structure of deep layers of the earth's crust. Since the relaxation time of stresses at relatively great depths is relatively small, the structure of the medium here is more uniform and the changes in the level of activity of weak earthquakes at this depth more closely follow the changes in the level of tectonic stresses than the changes in the activity of earthquakes in the less deep layers.

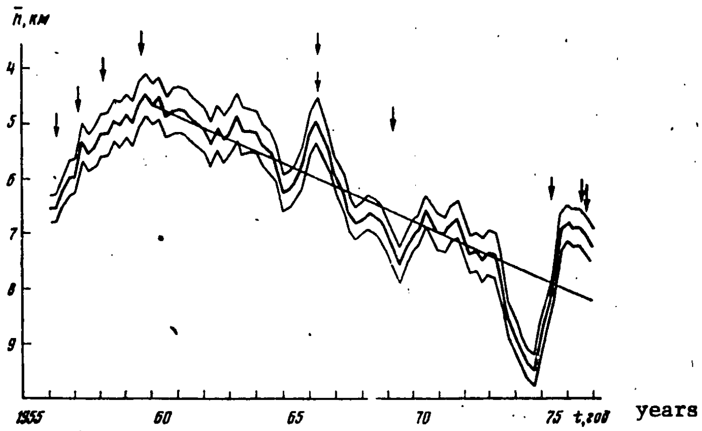

Fig. 8. Graph of temporal change in mean annual values of focal depths of earthquakes in the Garm region.

Disturbances in the field of activity of weak earthquakes, caused, for example, by the appearance of major earthquakes, are expressed more intensively in the near-surface layer and last far longer. This, in particular, can explain the different direction of changes in the activity level of weak earthquakes in the layer 0-5 km and in the deeper layers, caused by the aftereffect of the Khaitskoye earthquake (particularly well expressed in RDC I). This sort of local effects, strongly and persistently expressed in the upper layer of the earth's crust, mask the general changes transpiring at great depth. However, the latter, in all probability, reflect more important, more general changes in the level of tectonic stresses in the region, which in the last analysis also determine the appearance of major earthquakes. For example, it follows from Fig. 6 that brief increases in activity in the layer deeper than 10 km after approximately 1 1/2 years resulted in the appearance of the strongest earthquakes in the region. A prolonged increase in the activity level, beginning in the early 1960's, was accompanied at the end of the observation period by a series of earthquakes with K = 13 which followed one another with unusual frequency. Five such earthquakes occurred in the region (in the area S_p) during the period 1975 through 1978, and in the immediate neighborhood of the region (first tens of kilometers) -- two. Such an intense seismicity was not observed in the region after the Khaitskoye earthquake of 1949 and its aftershocks.

It was demonstrated in [10] that active and inactive periods alternate in the life of the main seismic zones of the world. In particular, in the Alps seismic zone (where the Garm region is situated) seismic activity changes almost simultaneously through the entire zone. It is not impossible that the prolonged changes in the activity level of relatively deep earthquakes which we examined characterize not only the seismic conditions in the Garm region, but also are related to the development of strong earthquakes over a far greater area. Thus, in the near-lying part of the Central Asian seismic region a series of major earthquakes occurred in recent years, among them the Markansuyskoye earthquake of 1974, the earthquakes at Gazli in 1976, the Isfarinskoye earthquake of 1977, the earthquake of 1978 in the Alayskaya valley. Another, earlier period of activation of large earthquakes in this part of Central Asia, lasting about 15 years from 1934 to 1949, was represented by such earthquakes as the Argankul'skiye earthquakes of 1934-1935, the Garmskoye earthquake of 1941, the Fayzabadskoye earthquake of 1943 and the Khaitskoye earthquake of 1949. Earthquakes of the same intensity in the intervals between these two periods, and also long before the period 1934-1949, did not occur here. It is noted in [10] that the "existence of active and inactive periods in the main seismic zones of the world is one of the fundamental problems in long-range forecasting of seismic activity." The cited data show that in the considered part of the Central Asian region there is a distinct alternation of active and inactive periods. In the light of what has been said, prolonged changes in the activity level of weak, relatively deep earthquakes appear promising as an indicator by means of which it is possible to predict the alternation of such periods, and what is especially important, to predict an increase in seismic danger in the region prior to the development of major earthquakes.

To what extent are the patterns noted in the behavior of relatively deep earthquakes manifested in the total group of earthquakes? Figure 8 gives an answer to this question. This figure is a graph of $\bar{h}$ -- the temporal changes in the mean annual values of focal depths in the region and the confidence intervals of the $\bar{h}$ values with a confidence level P = 0.95. In computing the $\bar{h}$ values all the hypocenters for a year interval of summation in each 5-km layer (0-5, 6-10,...,20-25 km) were reduced to the middle of the corresponding layer; earthquake foci deeper than 25 km were related to a depth of 27.5 km.

Figure 8 shows that the mean annual focal depth decreases from 1955 to 1959 from $\bar{h} \approx 6.5$ to $\bar{h} \approx 4.5$ km. Then there is a change in the direction of the trend, which retains its sign virtually to the end of the observation period. It is evident that at the beginning of the observation period the form of the time series was greatly influenced by the high activity of relatively deep weak earthquakes, associated with the Khaitskoye earthquake, and rapidly decreasing after it. After 1959 in the entire group of earthquakes it became possible to trace a tendency to a systematic increase in $\bar{h}$. Against a long-term increase in mean focal depth one could see brief "plungings" of the hypocenters, after which earthquakes with K = 13-14 developed. Such an effect was observed before some earthquakes with $M \approx 5$ in Central California [11]. In order to evaluate the correlation of earthquakes with K = 13-14 and brief oscillations of $\bar{h}$, the already described method was used in computing the function $Q(\tau)$ (for the period 1959-1976). It was found that the effect of an increase in the mean focal depth of weak earthquakes gives a maximum value Q = +0.93 1 1/2 years before the appearance of a strong event. Thus, the information which is contained in variations of mean focal depth is essentially the same as in variations of change in activity of only relatively deep earthquakes.

We also note the following. As indicated by the cited data, each brief active period begins with a marked activation in the relatively deep layers of the earth's crust and affects the entire seismically active area. Then activation begins in layers with a lesser depth. This, in particular, is evidence that if extraterrestrial factors also exert an influence on the change in the level of tectonic stresses, their influence nevertheless is first reflected in the earth's deep layers and the activity of the earthquakes is propagated from the deep layers to the surface, as if it was caused by endogenous factors. The process of activation of earthquakes in the surface layer seems to be sort of secondary relative to variations of activity at a greater depth.

In general, it follows from the content of this study that the appearance of brief maxima in the number of relatively deep earthquakes or brief "plungings" in the mean depth of hypocenters can be used in predicting earthquakes with K = 13-14 for about 1 1/2 years in advance; the form of the long-term trends in the change of these characteristics can be used in long-term evaluations of seismic danger.

BIBLIOGRAPHY

1. METODY DETAL'NOGO IZUCHENIYA SEYSMICHNOSTI (Methods for Detailed Study of Seismicity), TR. IFZ AN SSSR (Transactions of the Institute of Physics of the Earth USSR Academy of Sciences), No 9, Moscow, Izd-vo AN SSSR, 1960.

2. Leonov, N. N., "Khaitskoye Earthquake of 1949 and the Geological Conditions for its Occurrence," IZV. AN SSSR, SER. GEOFIZ. (News of the USSR Academy of Sciences, Geophysical Series), No 3, 1960.

3. Lukk, A. A., Ponomarev, V. S., "Temporal Tendencies in Change in the Seismic Background," IZV. AN SSSR, FIZ. ZEMLI (News of the USSR Academy of Sciences, Physics of the Earth), No 5, 1972.

4. Gzovskiy, M. V., Krestnikov, V. N., Nersesov, I. L., Reysner, G. I., "Comparison of Tectonics and Seismicity of the Garm Region in the Tadzhik SSR," IZV. AN SSSR, SER. GEOFIZ. (News of the USSR Academy of Sciences, Geophysical Series), No 8, 12, 1958.

5. Ponomarev, V. S., Teytel'baum, Yu. M., Tret'yakova, N. V., "Peculiarities in the Spatial Distribution of Seismicity in Places of Occurrence of Major Earthquakes," ISSLEDOVANIYA PO FIZIKE ZEMLETRYASENIY (Investigations of Earthquake Physics), Moscow, "Nauka," 1976.

6. Yule, G. E., Kendall, M. G., TEORIYA STATISTIKI (Theory of Statistics), Moscow, Gosstatizdat, 1960.

7. Box, G., Jenkins, H., ANALIZ VREMENNYKH RYADOV (Analysis of Time Series), Moscow, "Mir," 1974.

8. Belousov, V. V. OSNOVY GEOTEKTONIKI (Principles of Geotectonics), Moscow, "Nedra," 1975.

9. Sherman, S. I., FIZICHESKIYE ZAKONOMERNOSTI RAZVITIYA RAZLOMOV ZEMNOY KORY (Physical Patterns of Development of Faults in the Earth's Crust), Novosibirsk, "Nauka," 1977.

10. Mogi, K., "Patterns in the Spatial and Temporal Distribution of Strong Earthquakes and Earthquake Prediction," POISKI PREDVESTNIKOV ZEMLETRYASENIY (Search for Earthquake Precursors), Tashkent, "Fan," 1976.

11. Bufe, Ch. G., Pfluke, J. H., Wesson, R. L., "Premonitory Vertical Migration of Microearthquakes in Central California -- Evidence of Dilatancy Biasing?" GEOPHYS RES. LETT., 1, No 5, pp 221-224, 1974.

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MANUAL ON PROCESSING OF EARTHQUAKE RECORDS

Moscow RUKOVODSTVO PO OBRABOTKE ZAPISEY ZEMLETRYASENIY, ZAREGISTRIROVANNYKH NA STANTSIYAKH INZHENERNO-SEYSMOMETRICHESKOY SLUZHBY (Manual on Processing Records of Earthquakes Registered at Stations of the Engineering-Seismometric Service) in Russian 1977 signed to press 12 Jul 77 p 3

[Foreword and table of contents of unsigned manual, Stroyizdat, 36 pages]

[Text] This manual describes the method for primary processing of the records of earthquakes registered at stations of the engineering-seismometric service situated in different seismic regions of USSR territory.

The manual contains information on the seismic instruments installed at stations in the engineering-seismometric service and also the general requirements on the quality of seismograms and the rules for their primary processing and reduction to digital form for data input into electronic computers.

The manual was prepared at the Central Scientific Research Institute of Construction Parts imeni V. A. Kucherenko USSR Gosstroy (Doctor of Technical Sciences S. V. Polyakov, Candidates of Technical Sciences B. Ye. Denisov, Ye. Ye. Zhukov, G. V. Mamayev, O. I. Ponomarev).

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We ask that comments and proposals with respect to the content of the manual be sent to the address: 109389, Moskva, 2-ya Institutskaya Ul., d. 6, TsNIISK, Laboratoriya Inzhenerno-Seysmometricheskoy Sluzhby (Laboratory of the Engineering-Seismometric Service).

CONTENTS

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NEW SYSTEM OF TECTONIC CONSTRUCTIONS FOR THE TERRITORY OF SIBERIA

Moscow VESTNIK AKADEMII NAUK SSSR in Russian No 10, 1979 pp 84-87

[Article by Professor K. V. Bogolepov]

[Text] On the initiative of scientists of the Institute of Geology and Geophysics Siberian Department USSR Academy of Sciences, supported by the administration of the Ministries of Geology USSR and RSFSR, in 1978 major interdepartmental work began on compilation of the ATLAS TEKTONICHESKIKH KART I OPORNYKH PROFILEY SIBIRI (Atlas of Tectonic Maps and Reference Profiles of Siberia). Participating in this work are geologists and specialists in tectonics and geophysics of institutes of the Siberian Department USSR Academy of Sciences, branch scientific research institutes of the USSR Geology Ministry and Siberian territorial geological administrations and trusts of the RSFSR Geology Ministry.

In working up the program and method for compiling the atlas the initiators of this work proceeded on the assumption that the long-range support of the national economy of the USSR with raw material and mineral resources, including power resources, is dependent to a considerable degree on the reserves contained in the territory of Siberia. Its territory, occupying more than 10 million square kilometers, that is, approximately 45% of the area of the entire country, is exceedingly diversified in geological structure and composition of already known raw material deposits. The scientific prediction and detection of new deposits of petroleum and gas, ferrous and nonferrous metals and chemical raw materials, hidden below the earth's surface, require a clear knowledge of the present-day structure of the earth's crust -- the spatial relationship of the geological bodies making it up, formed by different rock formations, including those bearing ores.

The era of discovery of new mineral deposits at the surface, even in the least studied regions of the enormous territory of Siberia, is approaching an end. In order to predict hidden deposits and at the end of the current century and at the beginning of the future century to exploit successively ever-deeper parts of the crust and its power and other raw material resources it is necessary to have additional information on the surface geological structure. Approximate qualitative structural maps of deep layers prepared on the basis of existing tectonic mapping methods also do not meet scientific and practical needs. It is necessary to create three-dimensional quantitative models based on specific data on mineralogical composition, structure, geometrical relationships and geological age of bodies which are discriminated in the form of layers, tectonic lenses, blocks, complexes, etc., depths, degree of dislocation and metamorphic transformations. The prototype of such tectonic models, which should cover the earth's crust as a whole or a part of it to some stipulated depth, is the constructions employed in practical geological practice in determining the structure of ore fields and in calculations of the mineral reserves. In these models the size and properties of bodies are determined from the vertical coordinate in the same system of measurements and with the same accuracy as from the horizontal coordinate.

The creation of quantitative tectonic models, reflecting really existing natural situations, will have far-reaching scientific consequences. These models are extremely necessary as a basis for the reconstruction of geodynamic systems of the geological past, revision of global tectonic hypotheses, formulation of a general theory of structure of the earth and its evolution.

The system of constructions planned in work on the atlas is the first such undertaking in world practice and therefore it requires the formulation and solution of a number of exploratory theoretical and practical problems. Among these a key place should be occupied by the creation and improvement of methods for correlating geological and geophysical criteria for the discrimination of geological bodies. Among the geological criteria which are established visually and which at present are only predicted in depth, proceeding on the basis of structural and historical geology data, the most important are mineralogical (rock) composition and the internal structure of geological bodies. The geophysical criteria, determined by instrumental remote methods, include a complex of interrelated characteristics -- density (velocity), magnetic susceptibility, conductivity. They are dependent on the above-mentioned geological properties, but their correlations with the structure and composition of the mineral masses, found under different natural thermodynamic conditions, have not been determined. It is difficult to expect that in the years immediately ahead in compilation of the atlas there will be complete solution of the problem of detecting and correlating geological boundaries by means of geophysical methods. However, it is of very great importance for the further development of geotectonics, petrology and mineral science, and key groups of scientists must be directed to its solution.

Thus, the purpose of compiling the atlas is the creation, for the first time for the territory of Siberia, of a three-dimensional model of the present-day structure of the earth's crust. The implementation of this objective provides for:

-- synthesis of present-day data on the mineralogical composition, structure and age of the geological bodies making up the surface parts of the earth's crust and on their geophysical parameters;

— systematic knowledge concerning the deep geological structure of the earth's crust and determination of deep bedding conditions of geological bodies both discriminated at the surface and hidden below it, by means of improvement in methods for correlation of structural-mineralogical and physical criteria and multisided geological-geophysical modeling;
-- detection of spatial and genetic relationships in the development of geostructural regions (geosynclinal folded systems, platforms, orogens) in the course of individual tectonic epochs, that is, analysis of lateral series of simultaneously forming structural elements;
-- determination of the general patterns of formation and evolution of the earth's crust in Siberia, its mineralogical composition and structure.

In general form the continental crust is a system of discontinuous shells (they are conveniently called megacomplexes), of different age, superposed on one another, corresponding with respect to time of formation to large -- planetary or subplanetary -- tectonic eras: Prekarelian, Karelian, Baykalian, Caledonian, etc. The internal structure of the megacomplexes is determined by the combination of geological bodies of the next, lower rank. In accordance with the existing tectonic nomenclature, these are geosynclinal, protoorogenic (epigeosynclinal), platform (shield) and deuteroorogenic (including intracontinental rift) complexes. Within the megacomplexes they replace one another both in the vertical stratigraphic section and in the lateral direction. Their regularly constructed, interrelated vertical and horizontal series reflect the dynamics of formation of new and transformation of the already continental crust in the course of a tectonic era. The units of the next ranks, into which the complexes are subdivided, are structural stages, substages and the geological formations making them up. The latter serve as the principal indicators in determining where the complexes belong in the classification.

The boundaries of the megacomplexes usually correspond to the largest structural "reorganizations," expressed in deformations (including displacements and faulting) of the earlier consolidated crust, the formation of new systems of geosynclinal, platform and deuteroorogenic downwarps, the formation of extensive interregional surfaces of structural and stratigraphic disconformities. In geosynclinal folded regions the base of the sections of the megacomplexes coincides with the bottom of the geosynclinal formations of the corresponding tectonic era, frequently lying in zones of parting in a crust of the oceanic type, and the top of the sections -- with the top of epigeosynclinal (protoorogenic) strata or rocks associated with them which were formed during the stabilization of orogens prior to deformations, marking the onset of a new tectonic era. But there are also more complex combinations when geosynclinal formations within one and the same megacomplex are underlain by rocks belonging to platform (shield) and deuteroorogenic complexes. There are also cases of disrupted stratigraphic sequence, when the ancient megacomplexes or their component elements, as a result of displacements and shifts along subhorizontal surfaces, lie on younger formations. Also common are structural "spikes" of megacomplexes associated with "through" identical development of geosynclinal, platform and similar complexes from one tectonic era to the next. These different structural relationships are exceedingly complex, but precisely they predetermine the principal patterns of distribution of minerals.

The work program on the atlas provides for the compilation of 11 maps of tectonic and geophysical content, including individual tectonic maps of megacomplexes: Karelian (including more ancient Archean formations), Baykalian, Caledonian, Early and Late Hercynian, Mesozoic-Paleogene and Neogene-Quaternary (most recent tectonics). In addition, specialists will compile the following: summary tectonic map for the entire system of megacomplexes, map of relief of the surface of the folded basement of platform regions, map of the deep structure of the earth's crust and upper mantle, map of the present-day state of the earth's crust (stresses, heat flows, seismicity, recent movements), and also a series of reference geological-geophysical profiles intersecting the principal geostructural regions of Siberia.

The compilation of individual maps for each megacomplex will make it possible, making extensive use of the possibilities of geological-geophysical modeling, to analyze the spatial dissemination, thickness, depth and structure of vertical and lateral series of component elements of megacomplexes not only within the limits of their outcropping at the surface, but also under a cover of younger platform and geosynclinal folded formations. In this case it is possible to expect the detection of new and extremely significant patterns.

The complex of planned studies not only will afford a possibility for solving a number of theoretical problems in geotectonics; it will serve as a basis for predicting and searching for mineral deposits in structural stages of the earth's crust in Siberia of different age, including ore deposits, whose distribution is governed by geosynclinal prehistory and repeatedly occurring deuteroorogenesis.

Within the limits of the Western Siberian Platform the carrying out of these studies will ensure the determination of the limits of occurrence and volumes of potentially petroleum- and gas-bearing deposits of Paleozoic platforms and orogenic downwarps, underlying the Mesozoic cover. In the territory of the Siberian Platform it will be possible to make a more precise determination of the morphology and spatial relationships of Riphean-Paleozoic structural stages and define regions which are of the greatest interest for detecting commercial resources of petroleum and gas, potassium salts, copper-nickel and iron ores, etc. Within the limits of the folded structures framing present-day platforms, in addition to establishing the tectonic prerequisites for the formation and distribution of stratum and stratiform deposits, analysis of the distribution of folded and disjunctive dislocations and their position in depth in different structural stages will make it possible to determine more precisely the possibilities of detecting zones and centers of concentration of ore deposits both at the surface and in depth.

An important practical problem of the work which has begun, whose implementation will in large part be dependent on the broad participation of production organizations of the USSR and RSFSR Geology Ministries, is the compilation, using a unified method and with standard legends, of a set of detailed tectonic maps for the territories of activity of geological administrations. Constituting first compilations for the atlas, these maps at the same time must be working maps, systematically being supplemented by new factual material and serving territorial geological administrations and trusts as a permanent basis for detailed metallogenetic prediction and the drawing-up of long-term plans for specialized and geological prospecting studies.

Work on compilation of the atlas is proceeding. At the interdepartmental working conferences held in October 1977 and May 1978 at Novosibirsk, the program was adopted, a general draft of the legends and methodological recommendations were approved. An editorial board, headed by Academician A. L. Yanshin was formed, which included leading scientists and specialists of the Siberian Department USSR Academy of Sciences and the USSR Geology Ministry. Map compilation groups for individual territories of Siberia were organized. They are headed by leading specialists in the field of regional tectonics.

In accordance with the prepared calendar plan for work on atlas compilation, it is proposed that the collective monograph TEKTONIKA I EVOLYUTSIYA ZEMNOY KORY SIBIRI (Tectonics and Evolution of the Earth's Crust in Siberia) be completed in 1983. This work is part of a complex superprogram for exploitation and preservation of natural resources in Siberia, developed at the present time by the Presidium Siberian Department USSR Academy of Sciences with the participation of interested organizations.

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IV. PHYSICS OF THE ATMOSPHERE

UDC 550.385

MONOGRAPH ON GEOMAGNETIC VARIATIONS AND STORMS

Novosibirsk GEOMAGNITNYYE VARIATSII I BURI (Geomagnetic Variations and Storms) in Russian 1979 signed to press 13 Sep 79 pp 2, 245-248

[Annotation and table of contents of monograph by A. D. Bazarzhapov, M. I. Matveyev and V. M. Mishin, Izdatel'stvo "Nauka," 248 pages]

[Text] Annotation. This monograph contains a review of methods for potential analysis of the fields of geomagnetic variations and storms together with a mathematical description of these fields and their dynamics. The authors set forth a theory of electric fields and currents in the earth's quiet plasmosphere and phenomenological models of magnetospheric substorms. The monograph describes a new class of geomagnetic δ-fields, each of which is a response of the earth's magnetic field to a change in one of the parameters of the solar wind. Methods for computing three-dimensional systems of electric currents in the geomagnetosphere are given using surface data and the first results of their use. The book is intended for geophysicists, space physicists and students in the corresponding fields of specialization.

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CSO: 1865

STUDIES OF PROCESSES IN THE AURORAL IONOSPHERE BY ARTIFICIAL MODIFICATION METHODS

Apatity ISSLEDOVANIYA PROTSESSOV V AVRORAL'NOY IONOSFERE METODAMI AKTIVNOGO VOZDEYSTVIYA (Studies of Processes in the Auroral Ionosphere by Artificial Modification Methods) in Russian 1978 signed to press 13 Dec 78 p 119

[Table of contents of collection of articles edited by Doctor of Physical and Mathematical Sciences O. M. Raspopov, Kola Affiliate USSR Academy of Sciences, 1978 126 pages]

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UDC 551.521.12+551.593+551.510.534

COLLECTION OF ARTICLES ON ACTINOMETRY, ATMOSPHERIC OPTICS AND OZONOMETRY

Leningrad TRUDY GLAVNOY GEOFIZICHESKOY OBSERVATORII: AKTINOMETRIYA, ATMOSFERNAYA OPTIKA I OZONOMETRIYA (Transactions of the Main Geophysical Observatory: Actinometry, Atmospheric Optics and Ozonometry) in Russian Issue 406, 1978 signed to press 1 Dec 78 pp 2, 125

[Annotation and table of contents from collection of papers edited by Doctor of Technical Sciences G. P. Gushchin, Gidrometeoizdat, 126 pages]

[Text] Annotation. This collection of articles includes papers on the methods used and the results of measurement of components of the radiation balance, atmospheric spectral transparency and aerosol, range of visibility and total content of atmospheric ozone. The collection of articles is intended for scientific workers and specialists in the field of atmospheric physics.

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V. ARCTIC AND ANTARCTIC RESEARCH

UDC 550.83(98)

PAPERS ON GEOPHYSICAL EXPLORATION METHODS IN THE ARCTIC

Leningrad GEOFIZICHESKIYE METODY RAZVEDKI V ARKTIKE (Geophysical Exploration Methods in the Arctic) in Russian 1978 signed to press 24 Aug 78 pp 2, 3-5

[Annotation and table of contents of collection of papers edited by G. I. Gaponenko, et al., Scientific Research Institute of Arctic Geology, 165 pages]

[Text] Annotation. This collection of articles continues the publication of materials related to the problems involved in the methods, technology and economy of marine geophysical studies on the shelf of arctic and eastern seas of the USSR and in individual regions of the world ocean. The authors analyze problems relating to the physical geology and interpretation methods in the geomagnetic and geoelectric study of the bottom section of oceanic and shelf regions. The papers give the results of joint analysis and computer processing of magnetic and gravitational fields of the northeastern part of the Siberian platform and also data on study of variation of the geomagnetic field on the shelf and experimental formulation of electric prospecting work done while the ship is in movement. Also discussed are the problems relating to the methods for carrying out highly precise aeromagnetic surveys. The principal methodological procedures for the interpretation of these materials are characterized and described. Attention is given to further investigation of the possibilities of the spectral-spatial method for separation of the anomalous magnetic field. A number of articles are devoted to the method for marine seismic investigations on the shelf and work on the problems involved in their interpretation. Included are materials relating to the mathematical support (for programming purposes) of solution of the problem of constructing a seismic discontinuity in an inhomogeneous medium and also relating to individual problems in the processing and interpretation of gravitational data and explaining the geological reasons for the seismological activity of individual sectors of the shelf.

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