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16. Abstract

Characteristics of physical properties of rocks in the crystalline mass of the Voronezh anteclise are studied. It is found that the physical properties of the rocks are closely related to their composition and origin. Petrographic properties of the rocks help to solve the problem of identifying the rocks with a certain complex.

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STUDY OF THE PHYSICAL PROPERTIES OF CRYSTALLINE ROCKS IN THE SOUTHEAST VORONEZH ANTECLISE

By V. S. Dmitriyevskiy, N. S. Afanas'yev and S. M. Frolov /247*

Study of the physical properties of rocks is very important for improving geological efficiency of geophysical methods for mapping crystalline rocks in the foundation and exploring different geological objects associated with the crystalline foundation, covered by the sedimentary mantle. In addition, studying the physical properties of rocks allows us to solve many questions involving genesis, interrelationship, metamorphism, and so forth.

Complicated rock complexes differing in age, genesis, degree of metamorphism, substance composition and physical properties have been established by now by drilling and geophysical work in the southeast Voronezh anteclise territory. Deeply metamorphized rocks of the gneiss type, amphibolites and their migmatites (gneiss complex), and comparatively weakly metamorphized sandy, aleurite and phyllite-like shales (shale complex) have been found here. However, granitoid rocks, predominantly of palingenic and metasomatic genesis are widespread. Bodies of basic and ultrabasic rocks extended in a chain mainly along the Losevsko-Mamonskiy zone of tectonic dislocations occupy a considerable place in the crystalline foundation structure. Finally, sheet deposits of paleobasalts are intersected in the sedimentary deposits of the Devonian in a number of places by wells.

Brief characteristics of the physical properties of rocks in the crystalline mass of the foundation (and partially the mantle) of the Voronezh anteclise are presented in the summary table, which gives the value of their density (g/cm^3), magnetic susceptibility (10^{-6} CGSM), residual magnetization caused by polarization and the rate of spread of ultrasound in them (m/sec). Measurements of all physical properties were made according to the existing techniques.

*Numbers in margin indicate pagination in original foreign text.

TABLE. TABLE OF PHYSICAL PROPERTIES FOR CRYSTALLINE ROCKS OF THE SOUTHEAST VORONEZH ANTECLISE

	Плотность (1)		Магнитная восприимчивость (2)		Остаточная намагниченность (3)			(4) Поляризуемость, %		(5) Скорость ультразвука			
										V_p		V_s	
	(6) средн. (от—до)	(7) колич. обр.	(6) средн. (от—до)	(7) колич. обр.	(6) средн. (от—до)	(7) колич. обр.		(6) средн. (от—до)	(7) колич. обр.	(6) средн. (от—до)	(7) колич. обр.	(6) средн. (от—до)	(7) колич. обр.
	1	2	3	4	5	6	7	8	9	10	11	12	13
quartzites, alkali-amphibole-magnetite	3,41 3,29—366	20	92000 58000—13500	19						5200 4850—5750	8	4850 3950—5700	8
shales, biotite-quartz, biotite-sericite-quartz	2,71 2,57—2,92	240	25 2—510	252						5550 4500—6800	166	5500 450—6200	178
metasandstones, hornfels, biotite-plagioclase-quartz	2,72 260—284	112	20 4—160	132						5450 4550—6200	62	5500 4600—6050	94
gneisses, biotite-hornblende-plagioclase with garnet	2,80 2,64—3,21	77	450 2—5500	77						5000 3400—5000	52	4000 3800—5950	53
gneisses, biotite-muscovite-plagioclase	2,75 2,61—2,95	64	55 0—590	64				3,2 0,7—10,85	6	5200 3950—6100	18	5300 3400—6350	17
migmatites, hornblende-biotite-plagioclase, biotite-feldspar	2,67 2,60—2,80	234	1650 0—5700	234	700 2250—3000	22	0,5—0,8			5500 5100—6300	44	5500 4250—6250	50
granodiorites, biotite-hornblende	2,80 2,73—2,90	38	1300 10—6150	39						5150 44—5800	44	5950 4100—550	16
plagiogranites, biotite-hornblende-plagioclase	2,73 2,61—2,83	60	70 5—720	59						5500 4500—6100	13	5500 4400—6600	49
granosyenites, biotite-hornblende-microcline	2,67 2,60—2,73	61	2250 10—6300	60			0,5—0,9			5350 4300—6600	48	5250 3600—6000	53
granites, biotite-hornblende-plagio-microcline	2,64 2,58—2,78	227	1100 10—7500	220			0,3—0,9			5250 400—6400	110	4850 3200—6100	147
granites, biotite-microcline	2,63 2,59—2,67	46	500 18—1350	37						5450 4900—6400	23	5350 4300—5900	23
hornblendites, orthoamphibolites	3,18 2,90—3,38	23	20000 4500—58000	23	2500 1200—5800	8	0,2—0,5			4250 3700—5700	14	5100 3600—5800	20

(Table continued on next page)

TABLE. Continued:

1	2	3	4	5	6	7	8	9	10	11	12	13
pyroxinites, slightly amphibolized												
3,09 2,87—3,31	193	350 10—1800	194	650 <200—2600	83	2—5			6150 4100—7300	103	6250 4300—7300	126
peridotites, serpentinized												
2,90 2,60—3,25	317	3000 40—32500	315	4100 <80—17500	296	0,7—2,5	12 0,34—81	81	5400 2400—6550	140	5400 3750—6650	154
amphibolites, apopyroxenite and apoperidotite												
2,91 2,68—3,20	135	600 20—4200	130	2300 130—4600	47	2—5			5250 3550—6650	57	5450 3400—6600	68
serpentinites, apoperidotite												
2,66 2,31—2,90	807	4300 20—21000	786	4500 130—62000	616	1—3	4,4 0,41—31,1	64	4500 1950—6450	325	4500 230—6650	417
serpentinites, apoolieinites												
2,46 2,06—2,68	335	5250 25—26600	387	1400 65—15300	345	0,2—0,8	12,9 0,17—55,5	81	3400 1650—5700	157	3400 1400—5500	270
gabbro, hornblende, melanocrat												
3,03 2,90—3,20	85	8000 35—12160	78	2350 140—8200	26	0,5—2,8			530[illegible] 4[illegible]—67[illegible]	33	[illegible] [illegible]	37
gabbro-norites, gabbropyroxene and olieino-pyroxene												
2,93 2,76—3,20	314	950 20—12200	286	6550 200—28400	210	5—45			5500 5000—70[illegible]	137	5500 3700—6[illegible]	14[illegible]
gabbro-pyroxinites to pyroxinite, amphibolized												
2,98 2,68—3,14	99	30 10—360	97						6700 5700—7200	78	6750 6250—7300	73
gabbro-diabases, gabbro-diorites, amphibolized												
2,88 2,60—3,02	108	1250 10—6100	108	1450 140—8200	37				5250 4550—[illegible]	54	5[illegible] 47[illegible]—6500	[illegible]
diorites, biotite-hornblende												
2,82 2,69—3,05	117	50 9—650	117						5850 4850—6400	53	5850 5[illegible]—6500	7[illegible]
paleobasalts (D_3)												
2,84 2,67—2,95	92	2100 390—3800	91	1750 1100—2800	17				4850 4400—[illegible]	17	4950 [illegible]—5700	20

Key:

1. density
2. magnetic susceptibility
3. residual magnetization
4. polarizability
5. ultrasound velocity
6. average (from-to)
7. number of samples

The table includes data that refer to fresh (nonweathered) rocks (see table).

The characterized types of rocks have considerable fluctuations and different ratio in the examined properties.

The density of crystalline formations of the Precambrian and paleobasalts of the Devonian have a very broad range of average values, from 3.43 g/cm^3 for ferruginous quartzites to 2.60 g/cm^3 for pigmetites.

In the group of basic and ultrabasic rocks, the hornblendites of the Sergeyevskiy complex have the highest density properties: /250
in the region of Belgor'ye 3.30 g/cm^3, and somewhat less, 3.17 g/cm^3 in the region of Sergeyevka and Kodintsovka, 30.05 g/cm^3. The average density of the pyroxenites is 3.09 $g/c,^3$, and the peridotites 2.90 g/cm^3.

In the shale group, the densities are 2.64 - 2.77 g/cm^3. Of them the biotites of keratinized analogs have high values, and sericites have low, which is also linked to their mineralogical features and the degree of metamorphism.

Magnetic susceptibility of the studied rocks fluctuates in very broad limits, not only from group to group, even within one variety of a definite type of rock. These fluctuations are primarily determined by the presence or absence of ferromagnetic minerals, the ratios of the latter, conditions of their isolation, secondary changes and other factors. The highest magnetic susceptibility is in ferruginous quartzites of the Kodintsovka section (average value 92,000 x 10^{-6} CGSM) with magnetite content up to 40%; it is somewhat lower (from 18,150 to 33,000) in the orthoamphibolites of the Sergeyevka and Belogor'ye sections which have up to 20% magnetite.

Severe fluctuations in magnetic susceptibility are noted in all types of gabbroids from the first units to 10,000 - 12,000. In this case the low values are generally found in the differences, almost devoid of ore mineral or containing it in single grains. The gabbro-pyroxinites have very low magnetic susceptibility, 30×10^{-6} (average) and the melanocrat pyroxene-hornblende gabbros of the Razdorenskiy massif have the maximum reaching 8,000 units. It has been established that even within one massif one can encounter both magnetite and nonmagnetite differences of gabbroids, which creates definite difficulties for mapping them by magnetic exploration.

In the granitoid rocks, the magnetic properties are also exposed to sharp fluctuations (from zero to 7500). Their minimum values are in pegmatites, zero - 7 units, higher in fine-grained and leucocratic differences (average 560) and maximum (2250) in porphyraceous granosyenites in the central band of the region. In this case, both as in the gabbro, the magnetic susceptibility of the granitoid rocks /252 on the whole is determined by the content of ore mineral (primarily magnetite), whose quantity sometimes rises to 5%.

Granites of the Kodintsovka , and in the overwhelming majority of the Sergeyevka sections, by the way, which almost do not contain ore mineral, are essentially nonmagnetic. High values of magnetic susceptibility of granitoids in the central band of the region (Pavlovsk, Basovka, Shkurlat) are apparently due to the fact that these granitoids develop through the rocks with considerable content of dark-colored components in the composition. Recently amphibolites, gabbro-amphibolites and others which differ in shape and body size have been established in this region. Granitization of these rocks is accompanied by release of magnetite and other ore minerals.

Amphibolites, gneisses, and migmatites, like the granitoids, have variable magnetization. Its maximum value is found in migmatites, 1650×10^{-6}, as well as those confined to the central band of the region. It has been established that at a definite stage of migmatization of gneisses, especially amphibolites, magnetic susceptibility reaches a certain maximum. The magnetic properties decline with further development of the process. The gneisses and migmatites, in the same way as the granites on the sections of Sergeyevka and Kodintsovka are essentially nonmagnetic or slightly magnetic. Considerable magnetization is only found during migmatization of the hornblendites (wells 185, 186).

Rocks in the shale complex are usually nonmagnetic (up to the first dozen units). However several shale samples on the Kodintsovka section associated with ferruginous quartzites that have magnetic susceptibility to 13,700 x 10^{-6} have been noted.

Paleobasalts containing 5 - 7% ore mineral (titanium-magnetite) have stable magnetic susceptibility, 2100 x 10^{-6} (average).

Magnetic susceptibility of peridotites and pyroxinites fluctuates from 350 to 3000 units, serpentinites 1300 - 5250 units, and apopyroxinite amphibolites 600 units. Fluctuations in magnetic susceptibility in rocks of the pyroxinite-peridotite-serpentinite complex are due to a series of factors, of which the primary are: composition of primary ore mineralization, degree of substitution of sulfide mineralization by allometamorphic, and partially autometamorphic magnetite, the degree of auto- and allometasomatic reprocessing of the primary rocks, and the appearance of veined mineralization.

Residual magnetization (I_r) and the Q factor (ratio J_r/I_i) of crystalline formations of the southeast Voronezh anteclise have the most diverse values for individual rock groups. Their maximum quantities are noted in the gabbro-norites and the olivine-pyroxene gabbros: 6500 x 10^{-6}, residual magnetization, from 5 to 40, Q factor. High parameters of I_r and Q indicate thermal magnetization of the rocks at high temperatures (above the Curie point of magnetite) [2, 3, 4, 5]. Residual magnetization and the Q factor of pyroxene-hornblende gabbros are 2350 x 10^{-6} and 0.5 - 0.8. In all probability, isolation of the ore mineral (magnetite) here occurred during substitution of pyroxene by the hornblende at temperatures below the Curie point. Low values of residual magnetization and the Q factor are noted for hornblendites, 2500×10^{-6} and 0.2 - 0.5, and very low for amphibolites, gneisses, migmatites and granites, which also indicates relatively low temperatures for the formation of ferromagnetics of these rocks.

Among the ultrabasites of the Mamonskiy complex, maximum residual magnetization (in absolute value) is found in the peridotites and apoperidotite serpentinites, 4100 and 4500×10^{-6}. With ratio J_r/I_i equal to 1 - 3, the Q factor of pyroxinites reaches 5 with relatively low magnetic properties (350 magnetic susceptibility and 650 residual magnetization). With noticeable manifestation of hydrothermal reprocessing of the serpentinites (carbonatization, chloritization, talc formation, substitution of sulfides by allometamorphic magnetite) and with considerable rise in magnetic susceptibility, the Q factor drops to 0.2 - 0.8 (here the magnetite is clearly low-temperature). The induced polarization was measured on a small number of samples mainly for peridotites and serpentinites. Its increased values are noted in zones with noticeable sulfide impregnation. The nature of the bond, polarizability and content of different ore minerals (including magnet) in the rock are not yet clear. Work in this area has been started and is underway. /253

Rate of ultrasound spread in its absolute values is characterized by comparatively close quantities (averaging 5200 - 5700 m/sec) for the majority of rocks in the region, excluding gabbros, pyroxinites, where these quantities reach the maximum (6750 m/sec), as well as serpentinites and palobasalts, where they are the minimum and are 4350 - 4550 m/sec for the first and 4950 m/sec (average) for the second. Reduced rate of ultrasound spread in the serpentinites is due to their composition, and primarily the crystalline structure of the serpentine. Differences in serpentinites and the original rocks in ratio of ultrasound spread rate can be used in seismic exploration.

Analysis of the material presented above allows us to draw the following conclusions:

1. Rocks in the crystalline foundation are sharply differentiated in the ratio of parameters of physical properties (density, magnetic susceptibility, residual magnetization induced by polarization, and rate of ultrasound spread).

2. The physical properties of the rocks are closely related to their substance composition and genesis.

3. The petrographic properties of the rocks often make it possible to unequivocally solve the question of affiliation of the rock to a certain complex.

4. Study of the physical properties, including study of magnetic properties in strong fields needs to be done only in close relationship to the petrographic, chemical, x-ray and other methods of study.

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