

# THEORETIC CALCULATION OF ROCKS ELECTRICAL RESISTIVITY AND SOME EXAMPLES OF ALGORITHM'S APPLICATION

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## Abstract

At calculation of rocks resistivity some statistical formulas are frequently used, the best example is the Archie formula. In the present report calculations of rocks' resistivity are made on the basis of the exact physical-chemical theory. The merit of the exact theory application is that this approach allows understanding more directly the mechanism of rocks resistivity forming and the different factors' influence. The demerit is, that the algorithm requires a good knowledge of physics and chemistry and inputting additional information, which a practical geophysicist not always has. The main stages of rock' resistivity calculation are: electrical conductivity account for electroneutral solutions; calculation of electrical conductivity of a liquid in a double electric layer taking into account the electric properties of the solid phase, then calculation of rock's resistivity for definite lithology, porosity, humidity and grain size. On a series of examples the possibilities of such calculation and the influence of the different factors are shown. Most evidently the algorithm's opportunities are uncovered at resistivity calculation of sandy-clayish sediments. It is possible to use the algorithm at the inverse problem solution for resistivity method - for the estimation of rocks hydro-geological properties on their resistivity.

## Introduction

The different approaches of rocks' electric resistivity calculation are known. The Archie law, operating statistical connection of rock's resistivity with a pore water resistivity, rock cementation and pore tortuosity, is well known. For rock with uniform granularity the idealized calculation formulas like Maxwell formula for spheres or I.K.Ovchinnikov formula for ellipsoids are known. A.S.Semenov proposed to calculate rock resistivity of a multicomponent mixture by a method of series displacement, when resistivity of a mixture of two components is counted, then this mixture is considered as homogeneous substance and the third component is added, etc. A.Ryjov developed an algorithm for resistivity calculation, based on the exact physical-chemical theory (theory of weak solutions' conductivity, theory of a double electric layer conductivity and theory of rock's resistivity, which takes into account rock's porosity, humidity, clay content, etc.).

## Method of calculation

A.Ryjov proposed the algorithm of calculation based on the exact physical-chemical theory. First it was realized as a program for the small desktop computer in 1983, and then was transferred on IBM PC. The calculation is performed in three stages.

At the first stage a solution resistivity is counted. The electrostatic theory of weak solutions, developed by Debye and Hückel in 1923 and upgraded by S.Arrenius is utilized. The results of

calculations for some solutions are presented in fig. 1. The study held by A.Ryboj, demonstrated, that the connection of electrical conductivity with salt concentration dissolved in water is satisfactorily approximated by the next dependence:

$$\sigma = |z_+ z_-| CF (V_c + V_a) \exp [- C / (|z_+ z_-| n \cdot 1000)] \quad (1)$$

where  $\sigma$  - electrical conductivity, Sm/m;  $C$  - concentration, mole/m<sup>3</sup>;  $F$  - Faradey constant, coulomb / mole;  $V_c, V_a$  - mobility of cations and anions of the dissolved substance, m<sup>2</sup>/(s·V);  $n$  - hydration number, showing, how many moles of the solvent surround  $i$ -th ion in a solution, mole/m<sup>3</sup>;  $z_+, z_-$  - valence of cations and anions, accordingly.

For a temperature different from 20°C it is necessary to use a temperature correction and to compute electrical conductivity on the following formula:

$$\sigma(T) = \sigma_{293} [1 + \alpha (T - T_0)], \quad (2)$$

where  $\sigma_{293}$  - electrical conductivity of a solution calculated on the formula (1), for temperature  $T_0$ ;  $\sigma(T)$  - electrical conductivity of solution at temperature  $T$ ;  $\alpha$  - temperature factor equal to  $1,77 \cdot 10^{-2}, 1/^\circ\text{K}$ .

At the second stage the conductivity in a double electric layer (DEL) on the boundary between solution and solid phase with known parameters is calculated. Solution properties were determined at the first stage. Thus the DEL theory is used. For the first time quantitative DEL theory was offered in 1879 by Helmholtz. Then Gui (1910) and Chapman (1913) independently offered the DEL theory, which took into account ionic interaction of coulomb type in the area, close to phases' interface. They considered, that near to phases' interface a «cloud» of electrical charges – co-ions and gegenion is formed, which concentration depends on a distance up to a solid phase. With a progress of the theory of solutions some other theories more precisely reflecting a DEL structure were proposed by D.A.Fridrihsberg (1984), V.D.Sobolev and N.V. Churaev (1983), G.R. Kroit (1955).

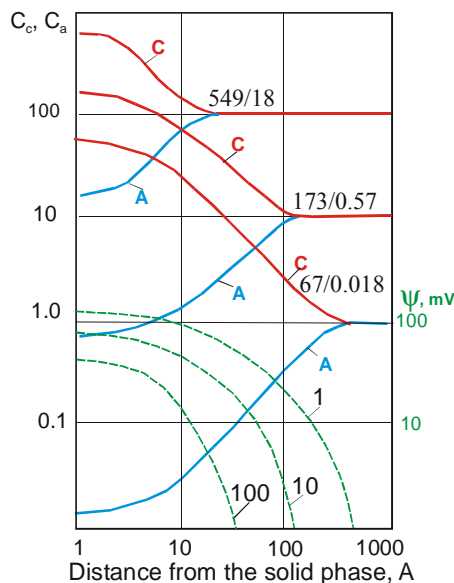


Fig. 2. Ions' distribution in DEL, depending on concentration of the electro neutral aquatic solution.  $C = 1; 10; 100$  mol/m<sup>3</sup>. Continuous lines - concentration of ions, dashed lines - electrical potential of a liquid, mV. Distance is in angstrom.

The examples of calculations are presented in fig. 2 and 3. The conductivity in a double electric layer is higher, than in a free solution, and the less is salt content in solution, the more this difference is (Fig. 3). In fig. 2 the DEL structure and its dependence from concentration of electro neutral solution is shown. In fig. 3 a variation of solution conductivity depending on the distance to a capillary wall (at different concentrations of electroneutral NaCl solution  $C = 0.059; 0.59; 1.18; 5.9$  g/l) is shown. (The distance is given in angstroms, 1 angstrom =  $10^{-10}$  m). From figure 2 follows, that at approach to a capillary wall the concentration of cations grows (on 1-1.5 order), and the

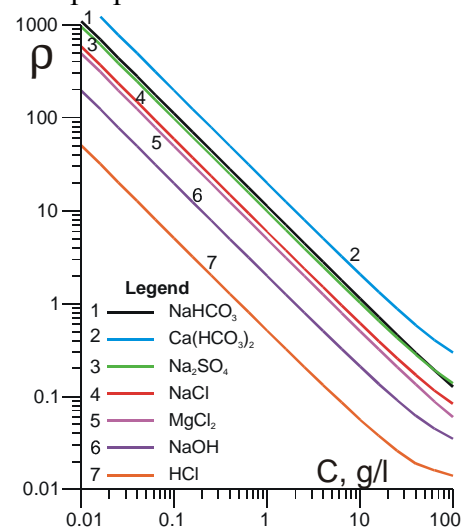


Fig.1. Dependence of resistivity from concentration for different solutions.

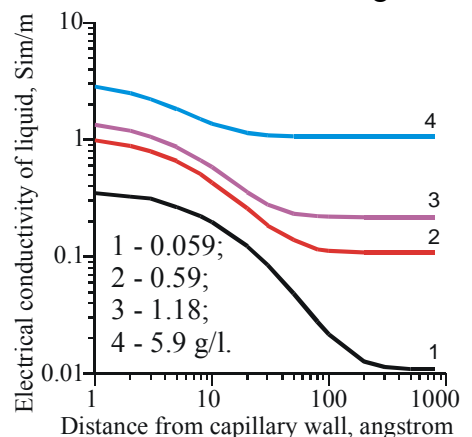


Fig.3. Conductivity in a double electric layer for NaCl solution.

anions' concentration decreases, that essentially breaks an electroneutrality of a solution near to solid - liquid interface. The significant concentration of free charges near to the interface essentially raises DEL electrical conductivity, in result electrical conductivity of a liquid with decreasing of capillaries' radius grows and essentially differs from electrical conductivity of an electroneutral solution. The DEL thickness (as a distance, on which the concentration changes in  $e$  times) decreases with concentration growth. In solutions with concentration more then  $100 \text{ mol/m}^3$  it is possible to neglect the DEL influence and use more simple formulas at account of rock's resistivity.

At the third stage the rock resistivity is calculated with taking into account the properties of pore fluid, DEL parameters, and also rock porosity and humidity. It is possible to calculate soil's properties, for example of sandy-clayish mixture, clayish limestone or any other mixture of rocks with different pore radii. For these calculations the following model of a capillary - porous medium is used.

### Model of a capillary - porous medium

The model consists of three components: - 1-st component (for example - sand) contains wide pores; - the second component (for example, clay) contains narrow pores, fluid in sand and clay is the third component. Generally pores of the 1-st and 2-nd components are not necessary completely filled with a liquid, the part of porous space can be filled with gas, in this case the model includes four components. The capillary walls in sand have a skeleton non-conducting electrical current -  $\text{SiO}_2$  grains, the capillary walls in clay also have a non-conducting skeleton – a silicate shell. Number of pores in sand and clay in a volume unit are  $N_s$  and  $N_c$ , accordingly. The total pore volume in sand and clay is possible to express through a porosity value, separately for each component - sand and clay. The model of a multicomponent mix is presented on fig. 4. It consists of two types of capillaries having different radii. Fig 4 includes:

- a) Model of parallel connection of sand and clay capillaries.
- b) Model of series connection of sand and clay capillaries.
- c) Model equivalent to model (a) for parallel connection of capillaries.
- d) Model equivalent to model (b) for series connection of capillaries.
- e) Model with series - parallel connection of capillaries.

As the conductivity of such model basically depends on conductivity of a liquid in pores of sand and clay, let's unite all non-conducting skeletons of sand and clay in separate volume  $V_1$ , all liquid in pores of sand also in the other united volume  $V_2$ , and liquid in pores of clay in third volume -  $V_3$ . Let's receive new model of a rocks' mix, which electrical conductivity is equivalent to initial model. So models 4a and 4c are equivalent to each other in resistivity, and models 4b and 4d, accordingly, are also equivalent to each other. On fig.4e the model, mixed of models 4c and 4d is presented, which shows a general case.

Model 1, transformed into the equivalent form, has a type, represented on fig.4c. This model we name as model with parallel capillaries. At complete filling of pores in sand and clay by a liquid the resistivity of model with parallel capillaries is equal:

$$\text{At } K_{ps} > C_{clay}$$

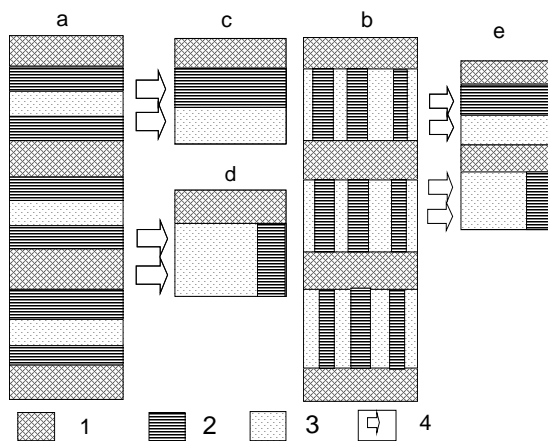


Fig. 4. Different rock models. 1 - Matrix non-conducting electrical current. 2. Thin capillaries (clay). 3. Thick capillaries (sand). 4. Equivalent models.

$$\rho_{prl} = \frac{1}{\sigma_{l,clay} K_{pclay} C_{clay} + \sigma_{l,s} (K_{ps} - C_{clay})}, \quad (3)$$

and at  $K_{ps} < C_{clay}$

$$\rho_{prl} = \frac{1}{\sigma_{l,clay} K_{pclay} C_{clay}} \quad (4)$$

where  $\rho_{prl}$  - resistivity of rock consisted of a sand - clay mix at parallel connection of capillaries;

$\sigma_{l,clay}$  –conductivity of a liquid in clay capillaries;

$\sigma_{l,s}$  - conductivity of a liquid in sand capillaries;

$K_{pclay}$  - clay porosity;

$K_{ps}$  - sand porosity;

$C_{clay}$  - volumetric clay content in a sandy-clayish mix.

The condition  $K_{ps} < C_{clay}$  means, that all capillaries of sand are filled with clay, hence, the conductivity of a mix in this case depends only on conductivity of a liquid in capillaries of clay, porosity index and volumetric clay content.

The conductivity of this model (with parallel capillaries' connection) is possible to calculate, as inverse value of its resistivity:

$$\sigma_{prl} = \frac{1}{\rho_{prl}} \quad (5)$$

The model of sandy-clayish mix with series connection of capillaries of sand and clay is represented on the same fig. 4b. Making similar transformations, we receive equivalent model of series connection of capillaries presented on fig.4d. This model we shall name as model with series capillaries. At series connection of capillaries the model has an electrical resistivity equal:

If  $K_{ps} > C_{clay}$ ,

$$\rho_{ser} = \left(1 - \frac{C_{clay}}{K_{ps}}\right) \frac{1}{K_{ps} \sigma_{l,s}} + \frac{C_{clay}}{K_{ps}} \cdot \frac{1}{K_{ps} K_{pclay} \sigma_{l,clay}} \quad (6)$$

If  $K_{ps} < C_{clay}$ ,

$$\sigma_{ser} = C_{clay} K_{pclay} \sigma_{l,clay}, \quad (7)$$

In nature generally the joint distribution of parallel and series capillaries is observed, that is in pores of sand some clay corks are available, but there are also capillaries in which clay is smeared on pore walls in sand. Therefore we consider, that the volumetric part of parallel capillaries in the mixed model of serial - parallel connection is equal to  $M$  and that for serial connection is equal to  $1-M$ . In this case the mixed model conductivity is possible to calculate under the following formula:

$$\sigma_{\Sigma} = \frac{M}{\rho_{prl}} + \frac{(1-M)}{\rho_{ser}}, \quad (8)$$

where  $\sigma_{\Sigma}$  - is specific conductivity of a mix of parallel and series connection of capillaries.

Such construction supposes a wide choice of rock models. For example, we can consider the model, in 25% of which wide capillaries clay is in corks, and in the other 75% of wide capillaries' volume - clay is smeared on their walls.

Actually model consists of two porous bodies. In

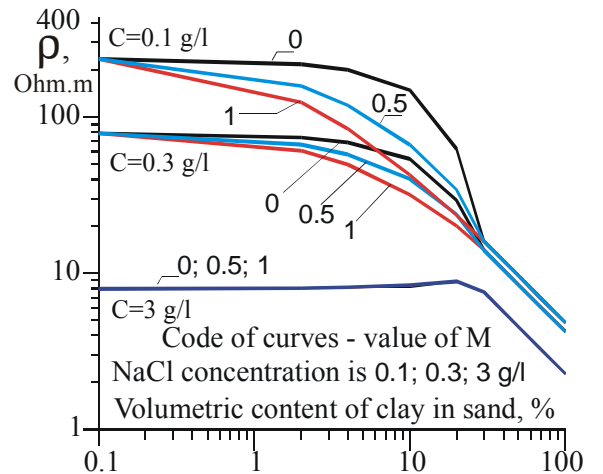


Fig.5. Dependence resistivity of sand and clay mix from  $M$  and volumetric clay content at various NaCl concentration.

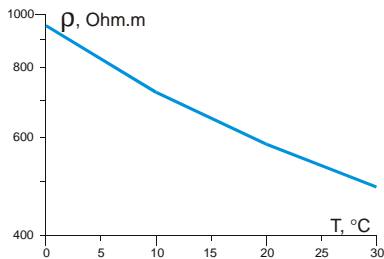


Fig. 6. Change of water-saturated soil's resistivity with temperature.

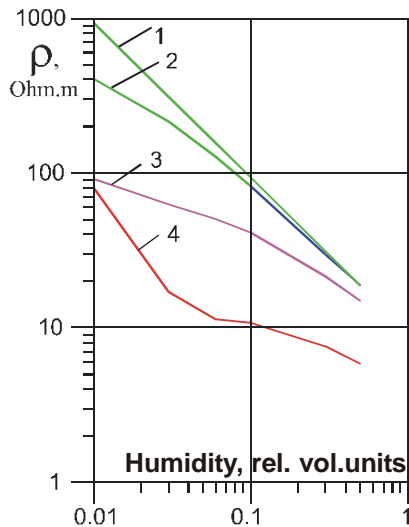


Fig. 8. Dependence of resistivity from humidity and capillary's radius. NaCl solution with  $C=0.63$  g/l. Porosity  $K_p = 0.5$ ;  $IEC = 0$ ;  $t = 20^\circ\text{C}$ . Capillary radii (in microns): 1 - 1000, 2 - 1; 3 - 0.1; 4 - 0.01.

changes of clay content in an interval from 1 up to 20 % practically have no effect on resistivity value, but sharply influence in interval 20 - 100%. In practice the clay is placed in sand in both forms - of the first and second type, as formula (8) reflects.

capillaries of the first porous body the second porous body is placed, which can be smeared on walls of capillaries of the first body or is in corks. The combination of these bodies gives variety of the structural forms of porous space of model and this flexibility allows calculating functional dependences of electrical

properties of rocks for many practical cases. The porous space can be or completely filled by liquid, or not completely. The part of porous space of capillaries, not filled with a liquid, can be filled with gas either non-conducting liquid (oil) or ice, which is the non-conducting electrical current body. Therefore, by setting incomplete saturation of capillaries by water, it is possible to calculate volumes of the first and second body, and electrical properties of rocks in frozen state.

On fig. 5 the dependence of resistivity of sand and clay mix is shown at constant concentration of salts (0.1; 0.3; 3 g/l) in aquatic NaCl solution at various percentage of capillaries with parallel connection (M value) and various degree of clay content. The dependences represented in fig. 5 were calculated under the formula (8) at the following parameters of sand and clay: for clay  $K_{p\text{clay}}=0.50$ , radius of clay pores -  $r_1 = 0.01$  microns; for sand  $K_{p\text{sand}}=0.25$ , radius of sand pores -  $r_1 = 0.1$  mm. Let's note, that at value  $M=1$ , all clay is allocated on walls of capillaries, and at  $M = 0$  - is concentrated in clayish corks.

When the clay is "smeared" on walls of capillaries in sandy rock, the small increase of clay content appreciably changes resistivity of mix (in logarithmic scale it is nearly inversely proportional dependence). In a case of clay "corks", on the contrary, the significant

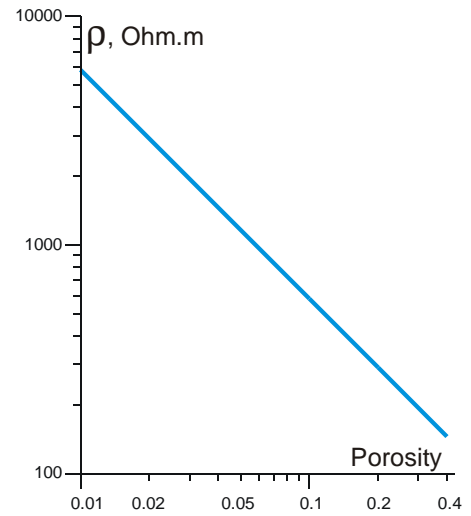


Fig. 7. Resistivity dependence of water-saturated soil from porosity (at the absence of DEL influence). NaCl content is constant and equal to 0.1 g/l.

## Examples of algorithm application

The results of calculations are shown on a series of figures reflecting influence of the different factors (temperature (fig. 6), porosity (fig. 7), humidity (fig. 8)).

### Resistivity Of Sandy - Clayish Mixture

To show the influence of a double electric layer on soil conductivity we calculated some resistivity graphs as function of water salinity for sand, clay (and pore fluid). The results of calculations for NaCl solution are shown in fig. 9, and for  $\text{Ca}(\text{HCO}_3)_2$  - in fig. 10. Let's compare these results. If to

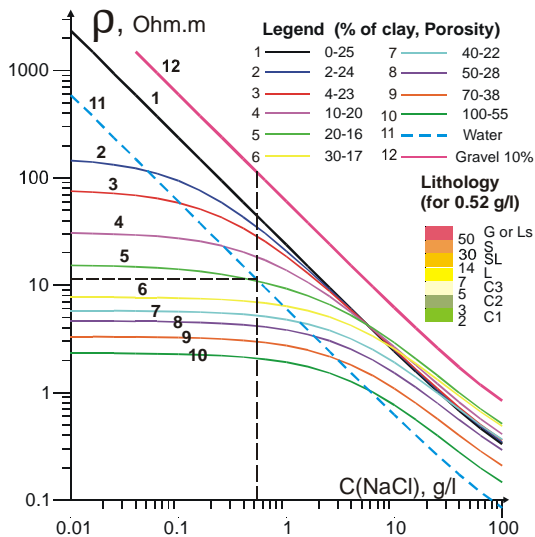


Fig. 9. Dependence of sand and clay mixture resistivity from NaCl concentration in aquatic solution. The code of curves - volumetric clay content and porosity.

divide sand resistivity value on water resistivity (at identical concentration), we receive a constant ratio, not depending on concentration and equal to sand porosity (Kps). The similar ratio between clay and water resistivity is not a constant and shows a more complex dependence. It is interesting to mark, that water-saturated sand has resistivity more, than resistivity of pore fluid, while the clay at high salt content has higher resistivity, and at low concentrations - lower resistivity, than pore fluid resistivity alone. Such complex dependence resulted from the influence of a double electric layer in capillaries; when those diameters are comparable with a DEL thickness. The difference between sand and clay resistivity values depends on salinity (and resistivity) of pore water, and it is greater at small salt content. There is a vertical line on fig.9, which cross water resistivity graph at 11 Ohm.m. For fixed water resistivity we can develop lithological legend, presented in the same figure. According to this legend and depending on rock resistivity we can call some rock as clay, sand, loam, etc.

There are following types of clays: kaolin, hydromica and montmorillonite. These clays differ on their physical-mechanical and structural characteristics. In particular pore width descends in a line kaolin, hydromica, montmorillonite. On our data based on clay resistivity measurements, mean pore size for kaolin is 0.05; hydromica - 0.01; montmorillonite - 0.005 microns. The clay porosity also depends on the type of clay. For example, typical porosity values are: for kaolin - 50 %; hydromica - 55 %; montmorillonite - 60 %.

The typical sand pores' width is in interval from 10 up to 100 microns, and sand porosity in natural condition is from 10 up to 30%.

### Resistivity Of Rock Without DEL Influence

To show the difference in resistivity changes as function of porous water mineralization at the absence of a double electric layer influence we calculated resistivity graphs for lavas with different porosity (fig.11) for NaCl solution. All curves are parallel to each other and to the curve of water resistivity.

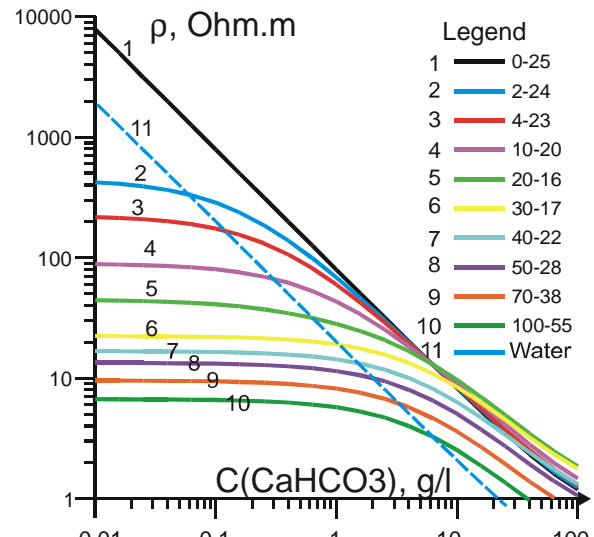


Fig.10. Dependence of sand and clay mixture resistivity from  $\text{Ca}(\text{HCO}_3)_2$  concentration in aquatic solution. The code of curves - volumetric clay content and porosity.

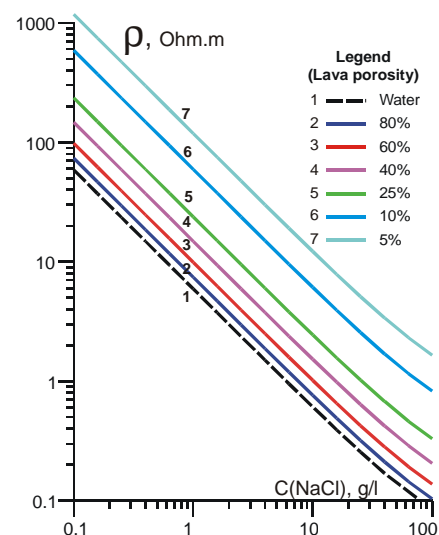


Fig.11. Dependence of lava's resistivity from NaCl concentration in pore water. The code of curves - lava's porosity.



## Frozen Rocks

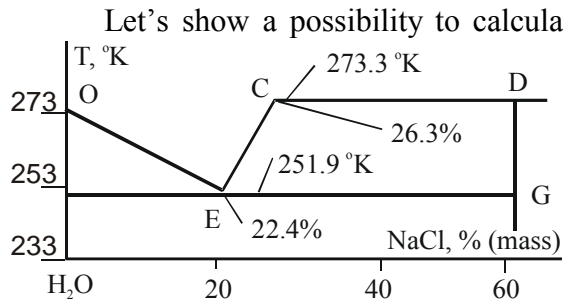


Fig. 12. Phase diagram of the system "water – sodium chloride".

Let's show a possibility to calculate water-physical properties of rocks at temperatures below 0°C. At the temperatures below 0°C some transformations of a liquid into solid state appear according to the phase diagram given at fig. 12. These transformations are exactly described in the theory of a thermodynamic equilibrium of solutions. According to this theory at achievement of temperature 251.9°K at pressure 1013 MPa in the system containing water and sodium chloride (NaCl), there are simultaneously crystals of ice, crystals NaCl·2H<sub>2</sub>O and saturated sodium chloride solution with 22.4% NaCl. From

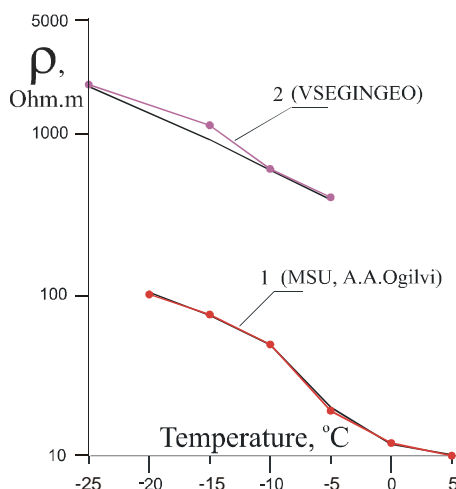
fig. 12 follows, that minimal temperature, at which water can be in a liquid condition at presence in it of the dissolved NaCl, is equal to 251.9°K. It means, what even in porous space of rocks at temperatures below specified there should be a complete freezing of water and, hence, the resistivity of rocks below this temperature (at pressure 1013 MPa) not changes and remains constant. It is possible, that in porous space of clay there is some amount of not frozen water, because the experimental data show that final resistivity of clay is about 100 Ohm.m, even at temperature -20°C (253°K). From this fact follows, that the phase equilibrium of system sodium chloride - water in a DEL space is a bit different, for example point of eutectic E is displaced in area of lower temperatures. From the diagram follows, that the condition of system liquid - solution of an electrolyte is appreciably determined by a thermodynamic equilibrium of solution, which is in turn determined by the temperature and content of salts in an electrolyte (and also by pressure in porous space). Therefore it is necessary to expect, that the frozen soil's resistivity depends in greater extent on temperature, than that for not frozen soil, due to a phase conversion at temperature below 0°C, when the porous water from a liquid condition transforms into ice.

The field and laboratory studies of frozen soils fulfilled in institute VSEGINGEO have shown, that the frozen soils' resistivity depends on conditions of their formation and the action of natural factors, those vary for different regions. For this reason many researchers resulted temperature dependences of soil resistivity, those differ from each other on an order and more. However, the general laws are revealed also, for example, frozen clay resistivity on 2 and more orders is lower, than that of frozen sand. The loam's resistivity is determined by the volumetric clay content, and its resistivity value is in a range between typical values for sand and clay.

For example, on fig.13 there are two different temperature dependences of clay resistivity. The temperature dependence for clay with layered cryotexture received in VSEGINGEO considerably differs on that for frozen clay, which was used in experiments of MSU (Geoecological inspection ..., 1999). Probably, such difference resulted from not only various cryotextures, but also from various content of a sandy fraction.

Despite of essential differences in resistivity values our calculations rather well approximate data on fig.13. In table 1 calculated and experimental resistivity values of both types of clay, and also their water-physical characteristics are shown. The amount of not frozen water is shown by water-content values. Let's note, that the differences in resistivity of two types of clay were found and in dynamics of their freezing. So for low-resistive clay (MSU) the phase conversion of water into ice was finished at temperature -15°C, below this temperature the amount of not frozen water remains constant and equal 7% of volumetric water-

Fig. 13. Changes of clay resistivity at low temperature. Circles show experimental data, lines – theoretical account.



content. For highly resistive clay (VSEGINGEO) taken from a borehole at 19 m depth in Nadim area of Tyumen region, the phase conversions were finished much earlier at temperature of  $-10^{\circ}\text{C}$ . The second clay differs and by amount of not frozen moisture - at temperature below than  $-10$  degrees its amount makes only 1.5% of volumetric water-content. Let's note also, that the observable increase of resistivity at the change of temperature from  $-15^{\circ}\text{C}$  and  $-10^{\circ}\text{C}$ , accordingly, is connected with the cooling of solution, instead of phase conversion. It is possible to make the conclusion, that the point of eutectic (at which solid and liquid phases exist simultaneously) in porous space of clay is observed at much higher temperatures, than in open system, represented at fig.12.

The graphs on fig. 14 reflect changes of sand resistivity with temperature. For comparison, MSU and VSEGINGEO resistivity values of are given here. The values of the water-physical characteristics for these sands are given in table 2.

In tables 1 and 2 water-content is considered as amount of not frozen water in rock pores, expressed in volumetric units.

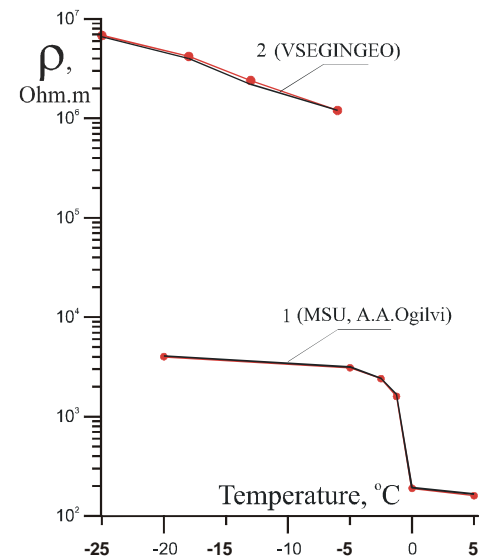


Fig. 14. Changes of sand resistivity with temperature. Circles show experimental data, lines – theoretical account.

Table 1. Water-physical characteristics of clay at low temperatures

T <sup>o</sup> C	Clay 1 (MSU)			Clay 2 (VSEGINGEO)		
	ρ (Exper), Ohm.m	ρ (Theor), Ohm.m	Volumetric humidity, %	ρ (Exper), Ohm.m	ρ (Theor), Ohm.m	Volumetric humidity, %
5	10	10.15	50			
0	12	11.77	50			
-5	19	20	30	400	386	1.75
-10	48	48.78	10	600	599	1.5
-15	75	74.31	7	1120	912	1.5
-20	100	106	7			
-25				2000	1949	1.5

Clay 1 (MSU) Porosity – 0.5; capillary radius– 0.05 micron; ionic exchange capacity – 1 g/l; NaCl concentration – 0.3 g/l. Clay 2 (VSEGINGEO) Porosity – 0.21; capillary radius – 0.05 micron; ionic exchange capacity – 0 g/l; NaHCO<sub>3</sub> concentration – 0.1 g/l.

Table 2. Water-physical characteristics of sand at low temperatures

T <sup>o</sup> C	Sand 1 (MSU):			Sand 2 (VSEGINGEO):		
	ρ (Exper), Ohm.m	ρ (Theor), Ohm.m	Volumetric humidity, %	ρ (Exper), Ohm.m	ρ (Theor), Ohm.m	Volumetric humidity, %
5	160	166	25			
0	190	193	25			
-1.25	1600	1665	3			
-2.5	2400	2417	2.17			
-5	3100	3154	1.18			
-6				$1.2 \cdot 10^6$	$1.2 \cdot 10^6$	$3.0 \cdot 10^{-3}$
-13				$2.4 \cdot 10^6$	$2.2 \cdot 10^6$	$1.8 \cdot 10^{-3}$
-18				$4.2 \cdot 10^6$	$4.0 \cdot 10^6$	$1.0 \cdot 10^{-3}$
-20	4000	4059*	1.18			
-25				$6.8 \cdot 10^6$	$6.6 \cdot 10^6$ **	$1.0 \cdot 10^{-3}$



Sand 1 (MSU): Capillary radius= $10^{-4}$  m; Porosity – 0.25; Concentration NaCl=0.2 g/l.  
 Sand 2 (VSEGINGEO): Capillary radius= $10^{-3}$  m, Porosity – 0.25; Concentration NaCl=0.2 g/l.

**Estimation Of Hydro-Geological Soil Properties On VES Data.**

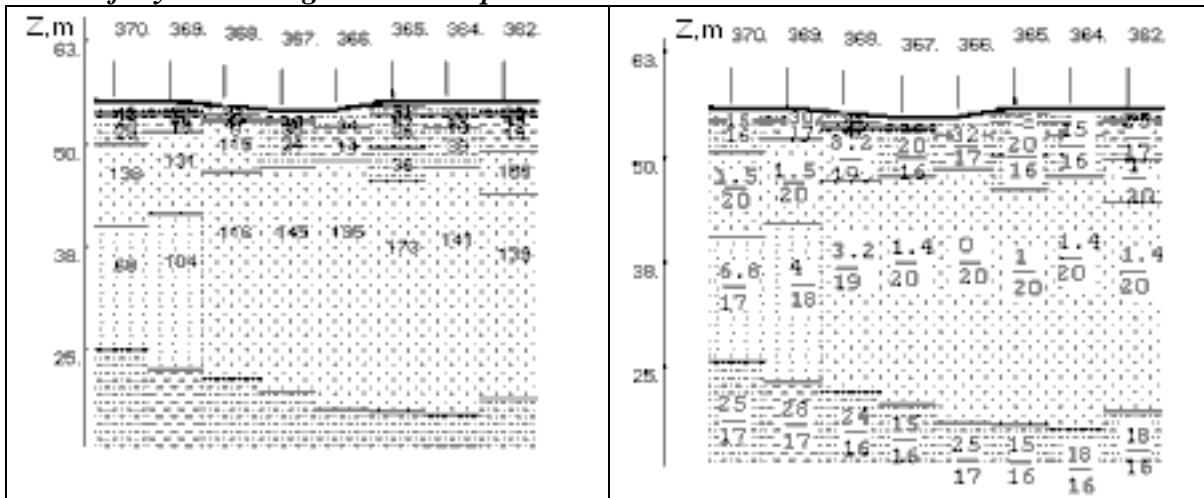


Fig.15. On the left there is a fragment of geoelectrical cross-section for Elabuga region. On cross-section resistivity values are shown. On the right there is the same fragment with estimated values of clay content (above fraction line) and porosity (below).

The functional dependence of sandy-clayish mixture's resistivity, shown on fig. 9, can be used for estimation of resistivity dependence from clay content. The resistivity dependence from clay content in a sandy - clayish mixture (at definitely known water mineralization) (fig. 16) can be used for estimation of clay content and porosity of soil. By using these calculations it is possible to estimate, for example, the clay content in sand for definite geoelectrical sections obtained from VES data interpretation (fig.15).

Analyzing the information represented on fig.15, it is possible to make the conclusion, that optimal place (from the point of view of maximal water discharge) is at interval between VES 368 and VES 362. The filter should be settle down in an interval from 28 up to 50 m, as here there is the greatest value  $k_m$  - product of percolation factor on aquifer thickness.

**Possible Ways Of Algorithm Application**

The algorithm is the effective tool for modeling electrical properties of solutions and rocks. It is realized as the program "Petrofiz" for personal computer and the base of knowledge (manual) illustrating the basic features of its application.

1. With the help of the program it is possible to calculate the resistivity of different types of soils and hard rocks, their mixtures and water solutions.

2. It is possible to study the influence of different factors on electrical properties of rocks: like temperature, water-content, porosity, clay content, porous water mineralization, etc.

3. At resistivity data interpretation the estimation of physical-mechanical and water-physical characteristics of rocks (for example, porosity and clay content) on their resistivity is possible. By virtue of multifactoriness of such

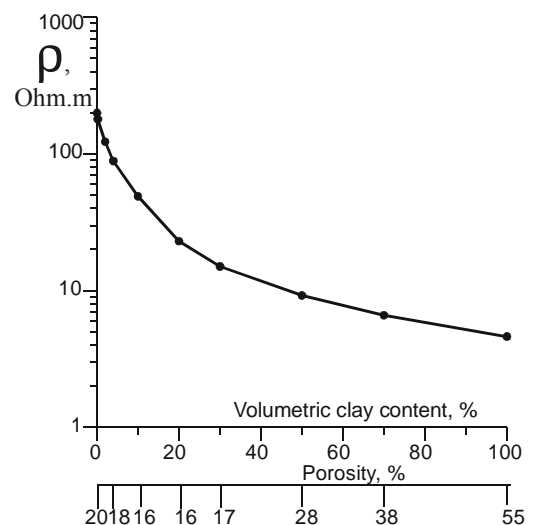


Fig. 16. Dependence of Quaternary sediments' resistivity from the volumetric clay content and porosity.

connections it is necessary to have a priori information for geological parameters estimations.

4. The program can help to understand better the formation of electrical resistivity and its connection with hydro-geological and engineering-geological parameters, transition from formal geometrical interpretation of resistivity data to more and more deep geological interpretation, that should increase geological effectiveness of resistivity method.

5. In the report (Shevnin, Ryjov et al., 2002), presented at this SAGEEP conference the program "Petrofiz" was used for theoretical calculations of soils' resistivity to separate non-contaminated and contaminated soils, as the properties of the last ones are changed.

## Conclusions

1. Theoretical calculation of rock resistivity with the program "Petrofiz" during 15 years proved its accuracy in different cases at comparison with both alternative theoretical accounts and experimental results.
2. The program "Petrofiz" can show the influence of different factors (like temperature, water salinity, type of salt, humidity, clay content, porosity, acting separately or together) on rock resistivity.
3. At application of additional information it is possible to calculate resistivity values for definite geological situation.
4. The program can be used for inverse problem decision - for estimation of hydro-geological parameters on resistivity values.

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