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# Electric Properties of Siliciclastic Rocks in the Baltic Cambrian Basin

*A. Shogenova[1], A. Jõeleht[2], K.Kirsimäe[2], S. Sliaupa[3], V. Rasteniene[3], A. Zabele[4]*
[1]Institute of Geology at TTU, 7 Estonia Avenue, Tallinn 13913, Estonia, alla@gi.ee, [2]Institute of Geology, TU, [3]Institute of Geology, Vilnius, [4]Latvian University

## Introduction

Electrical properties of 273 Cambrian quartz sandstones and siltstones sampled from 33 wells representing north (Estonia, depths 80-800 m), central (Latvia and central Lithuania, 1-1.8 km) and western (western Lithuania, 1.8-2.3 km) parts of Baltic Cambrian basin were studied together with porosity, density, chemical and mineralogical composition. Apparent resistivity measured on water-saturated samples and dielelctric constant measured on dry samples were analysed and compared in the different regions of the Cambrian basin. Lithology and cementation are the main factors controlling properties of the Cambrian rocks in the Baltic basin. Three dominant types of cement are documented in sandstones and siltstones, i.e. secondary quartz, clay and dolomite. Correlation between resistivity formation factor and porosity of the studied rocks was compared with theoretical correlation lines calculated using Archie equation for siltstones and sandstones in the three basin parts. Correlation lines between dielectric constant and density were calculated using the Olhoeft (1981) equation.

## Geological settings

The Cambrian deposits are represented by the triple alternation of marine siliciclastics which are sandstones, siltstones and claystones. Cambrian deposits lay transgressively on the crystalline basement or siliciclastics of the Vendian. It is covered by the Ordovician clayey and carbonate deposits. The Cambrian (the Lontova and Talsi regional stages) is exposed at the North-Estonian Klint and the Finnish Gulf. Thickness of the Cambrian changes from 10 m in the central Latvia up to 250 m in the West (Paškevicius, 1997). The Cambrian layers dip toward the Southwest and South down to 2200 m. This is associated with significant syn-depositional and essentially diagenetic variations across the basin. Cementation of the sandstones is strongly controlled by burial depth. The shallow basin flanks are dominated by dolomite and clay cement. The secondary quartz cement occurs in sandstones, which are located today deeper than ~1 km. It drastically increases in abundance below 1.8 km. Siltstones cemented there by clay and dolomite (Sliaupa *et al*., 2001). Sedimentary facies and diagenetic cementation are the primary factors controlling physical properties of the Cambrian rocks (Sliaupa *et al*., 2000).

Grain-size composition is similar in Estonia, Latvia and Lithuania. Two groups are defined. The first group is related to the basal part of the Cambrian and to the Upper Cambrian. Quartz/feldspar ratio there is usually >10 and is >25 in the Upper Cambrian. This group is represented by well, rarely moderately sorted fine- and medium-grained quartz sandstones that are weakly cemented by scarce clay, phosphates or dolomite. The second group is composed of variable lithologies reported mostly from the Lükati and Irbeni (Lower Cambrian) formations. Quartz/feldspar ratio does not exceed 10 and commonly is 3-5. The rocks are poorly sorted or unsorted. They are moderately cemented. The clay content in the matrix is commonly higher (Shogenova *et al*., 2001).

## Sampling and analytical methods

The rocks were sampled from 33 drill cores representing shallow (Estonia, depths 80-800 m), central (Latvia and central Lithuania, 1-1.8 km) and western (western Lithuania, 1.8-2.3 km) parts of Baltic Cambrian basin (Fig. 1). The samples that were sufficiently cemented, were cut into 24 mm cubes and studied by petrophysical, geochemical and other methods. Mineralogical and grain-size analysis were also made for 58 Estonian samples.

Chemical composition of rocks was determined by X-ray-fluorescence analysis in the All-Russian Geological Institute, St.-Petersburg. Mineral composition of the whole-rock samples was estimated by powder X-ray difractometry (XRD). Unoriented powder mounts were analyzed using the standard XRD technique on a DRON 3M diffractometer in the Institute of Geology, Tartu University.


Figure 1. Location of studied drill-cores.

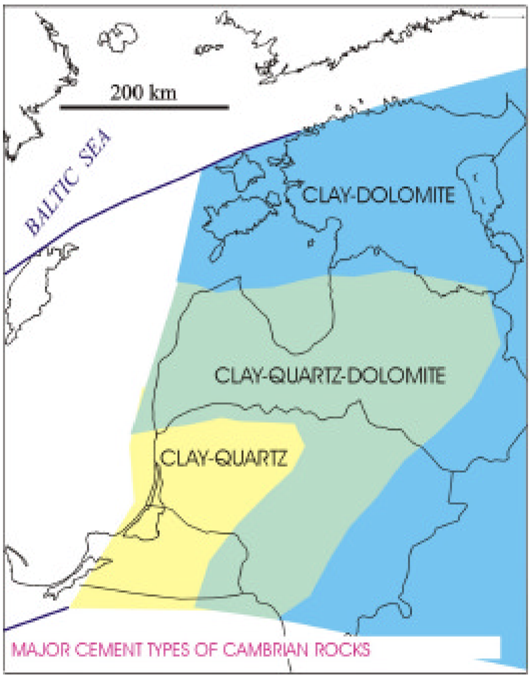



Figure 2. Major cement types of Cambrian siliciclastic rocks.

Grain-size analysis was made in the Institute of Geology at TTU. The studied samples were sieved using cooper screens into the following fractions: >2mm, 2-1mm, 1.0-0.5mm, 05-0.25 mm, 0.25-0.1mm, 0.1-0.05mm, 0.05-0.01mm, <0.01mm. Cemented samples were disaggregated using 3.5% HCl. For rock classification the grades were combined into the sand grade (>0.1mm), silt grade (0.1-0.01mm) and clay grade (<0.01). According to the grain-size data the following classification have been used: sand if rock included >50% of particles with size range over 0.1 mm, silt (>50% of particles with size range 0.1-0.01mm) and clay (>50% of particles with size range <0.01mm).

Petrographical description of 38 Estonian thin-sections prepared in the Institute of Geology at TTU was made using microscope with magnification 50 and 100 times.

Physical properties were measured in the Petrophysical laboratory of Research Institute of Earth's Crust of St.-Petersburg University using the methods described by Prijatkin and Poljakov (1983).

The dielectric constant ε was measured on the dry samples. The measurements of apparent resistivity $\rho_a$ were performed on the water-saturated samples. The electrical resistance of the samples (R) were measured by the two-electrode method with the help of a direct current Ohm-meter. Apparent resistivity of the rock was calculated by formula: $r_a$=R·S/l (Ohm·m), where R represents the sample resistance, S the contact area, and l the sample length (0.024 m).

To characterize the dielectric properties of the rocks, ε, the relative dielectric permittivity or dielectric constant (Schön, 1996) was studied. ε was measured using the Q-meter E 9-4 apparatus. Measurements of samples were performed in three directions and relative dielectric permittivity was calculated by the formula: $\varepsilon_x=4.75C_x+1$, where $C_x$ represents the measured capacitivity of the sample (24x24mm) in the X direction.

Density properties were measured in the following sequence. Samples were saturated with ordinary water for 7 days. The samples were then weighted in air ($P_w$) and water ($P_{ww}$). Then samples were dried at a temperature 100-110°C, and the weight of dry samples was determined ($P_d$). From the obtained measurements the following parameters were calculated: dry sample density $\delta_d=P_d/V=P_d/(P_w-P_{ww})$, where V represents sample volume; wet sample density $\delta_w=P_w/(P_w-P_{ww})$, grain density $\delta_g=P_d/(P_d-P_{ww})$, effective porosity $\Phi=(P_w-P_d)/(P_w-P_{ww})$.

## Results

*Composition*

Electric properties of the 273 studied rock samples were compared for the shallow, middle and deep parts of the Baltic Cambrian basin (Table 1), taking into account the present position of the rocks. The rocks were divided into two groups by $SiO_2$ content using correlation between mineralogical and chemical composition. The studied sandstones ($SiO_2$>90%) from the western Lithuania have the highest quartz and $SiO_2$ content (91.5-99.8%) and the lowest clay and carbonate content (average $Al_2O_3$ content is 0.95%, average CaO content is 0.19%). The rocks from Estonia have the lowest quartz and $SiO_2$ content (90-96%) and the highest clay and carbonate content (2.68% of $Al_2O_3$ and 0,54 of CaO). $SiO_2$ content is more or less in the same range (57-89%) in the all studied rocks with $SiO_2$<90% (on average 76-79%). The highest clay content in this group was in the deep rocks and the highest carbonate content was in the shallow rocks. The chemical data are in a very good agreement with available mineralogical and petrographical data of the studied rocks. Dolomite cementation prevailed in the Estonian rocks with $SiO_2$<90%, and west Lithuanian sandstones had quartz cementation.

Table 1. Properties and composition of siliciclastic rocks in the Baltic Cambrian basin.

| Location | Northern | | Central | | Western | |
|---|---|---|---|---|---|---|
| Depth | Shallow (80-800 m) | | Middle (1-1.8 km) | | Deep (1.8-2.3) | |
| Countries | Estonia | | Latvia, central Lithuania | | Western Lithuania | |
| Rock type | Sandstones | Siltstones | Sandstones | Siltstones | Sandstones | Siltstones |
| | Min-Max/Avg<br>Std.Dev. (N) | Min-Max/Avg<br>Std.Dev. (N) | Min-Max/Avg<br>Std.Dev. (N) | Min-Max/Avg<br>Std.Dev. (N) | Min-Max/Avg<br>Std.Dev. (N) | Min-Max/Avg<br>Std.Dev. (N) |
| Porosity, %<br>Φ | 1.5-39.8/21.5<br>7.3(26) | 1.9-25.5/16.4<br>7.1(34) | 8-22.5/14.4<br>3.3 (76) | 2.7-20.3/13.8<br>4.2(35) | 0.4-9.3/3.3<br>2.3(61) | 1.9-12.4/9.6<br>2.4(34) |
| Wet density<br>g/cm$^3$ | 2.09-2.6/2.2<br>0.11(26) | 2.07-2.68/2.3<br>0.17 (34) | 2.13-2.81/2.3<br>0.09(76) | 2.2-2.69/2.4<br>0.11(35) | 2.4-2.62/2.55<br>0.06 (61) | 2.45-2.64/2.52<br>0.05(37) |
| Grain density<br>g/cm$^3$ | 2.4-3/2.5<br>0.11(26) | 2.19-2.88/2.57<br>0.12(34) | 2.42-2.64/2.51<br>0.04(76) | 2.47-2.99/2.6<br>0.1(35) | 2.52-2.66/2.6<br>0.03(61) | 2.56-2.75/2.68<br>0.03(37) |
| Dielectric<br>constant, ε | 3.1-4.8/3.6<br>0.3(26) | 3.4-5.8/4.3<br>0.7(34) | 2.7-4.6/3.4<br>0.5(76) | 3.1-7.9/4.1<br>0.8(39) | 3.4-5-5/4.4<br>0.4(61) | 3.4-6/4.5<br>0.49(37) |
| Apparent<br>Resistivity $r_a$,<br>Ohm·m | 96-5760/456<br>1098(26) | 36-3600/466<br>744(34) | 70-430/159<br>65.5(76) | 40-580/135<br>102(35) | 170-2300/820<br>569(61) | 40-1130/147<br>175(37) |
| $SiO_2$, % | 90-96.9/92.8<br>1.7(26) | 62-88.6/76<br>8.8(34) | 90.2-99.4/96.4<br>2.2(76) | 57-89.9/79<br>8(39) | 91.5-99.8/97.7<br>2.2(61) | 61.1-88.7/76.5<br>5.8(37) |
| $Al_2O_3$,%<br>(as indicator of clay content) | 0.4-4.9/2.68<br>1.18(26) | 1-17.7/7.3<br>4.13(34) | 0.05-5.88/1.23<br>1.15(76) | 0.63-16.6/8.24<br>4.27(39) | 0.05-5.95/0.95<br>1.3(61) | 0.13-14.6/9.8<br>3.67(37) |
| CaO,%<br>(as indicator of carbo-nate content) | 0.03-1.8/0.54<br>0.58(26) | 0.03-16.5/3.5<br>4.2(34) | 0.03-2.48/0.34<br>0.45(76) | 0.05-11.1/1.16<br>2.2(39) | 0.03-1.42/0.19<br>0.33(61) | 0.11-6.4/1.47<br>1.5(37) |

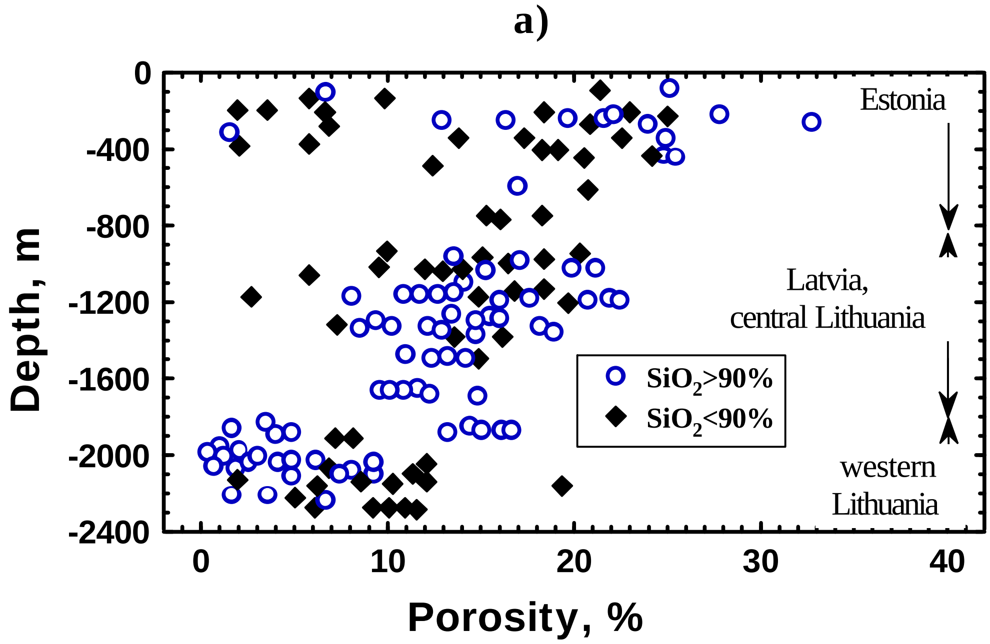
*Porosity and density*

As is known, electrical properties of rocks depend on their porosity and density. Porosity in the Baltic Cambrian basin generally decreases with depth (Fig. 3a), while wet density increases with depth (Fig. 3b). Porosity of the studied rocks depends on cementation and decreases with depth (Fig. 3a). That's why wet density of the rocks increases with depth and generally changes from 2.07 in the shallow part in the basin up to 2.62 g/cm$^3$ in the deep part (Fig. 3b, Table 1). The densest rocks from the western Lithuania cemented by secondary quartz have densities 2.45-2.64 g/cm$^3$.

The most considerable scatter of porosity values was stated for shallow reservoirs. Rocks sampled at the depths of 80-800 m, show porosity 22-26% (1 samples 32%). Increase of dolomite cement up to 18-28% leads to an attenuation of porosity to 2-10%. The minimum values were reported from rocks cemented by calcite and phosphate, where the pore space is reduced to 2%. Increase of clay content from 15 to 50% in rocks with quartz<50% causes an increase in porosity from 6 to 19-26%. Increase of K-feldspar content from 3-4% up to 20-35% causes an increase in porosity from 2 up to 19-25 % in the rocks with 50-75% quartz content.

At the depths of 1-1.8 km (Latvia and Lithuania) porosity of sandstones and siltstones systematically decreases to 8-20%, though locally reaching 22%. This reduction is accounted to mechanical compaction and occurrence of secondary quartz (Figure 2). There was not correlation of porosity with clay content in this basin part. However, correlation of porosity with K-feldspar was determined in the rocks with $SiO_2$<90% (quartz<95%). Increase of K-feldspar up to 13% causes an increase of porosity from 6-13% up to 14-20.5%. The porosity of several samples cemented by dolomite or clay is 2.7-8%.

The south-west-ward increase in the secondary quartz content (Latvia, Lithuania) associates with gradual decrease in porosity of Cambrian sandstones (Fig. 3a, Table 1). The latter drastically decreases to an average of 2-5% at the depths of 2-2.3 km (Fig. 3a). Bulk porosity of claystones changes from 16-20% at the depths of 0.6-0.8 km to 8-12% or even less (5-6%) in western Lithuania (Sliaupa *et al*., 2000, 2001). Porosity of quartz cemented sandstones here is less than the porosity of samples cemented by dolomite, but an increase in dolomite cementation in the rocks with $SiO_2$<90% caused a decrease of porosity. Increase in clay content generally increases porosity in western Lithuania.



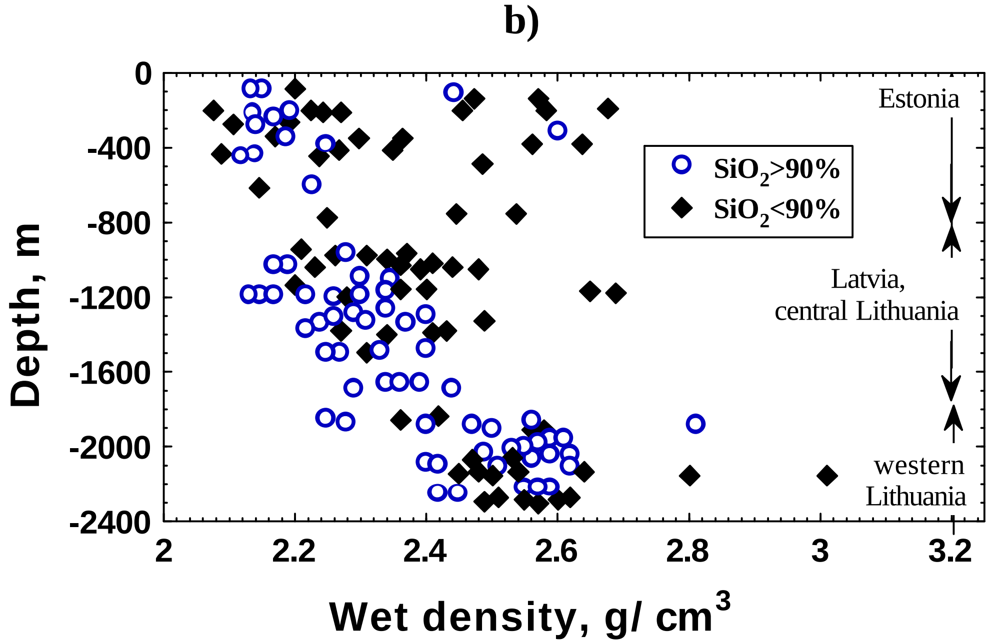




Figure 3. a) Porosity versus depth, b) wet density versus depth.

*Apparent resistivity*

The studied rocks have resistivities in the wide range of 40-5760 Ohm·m (Fig. 4-7, Table 1). Resistivity of sandstones increased with depth, but resistivity of rocks with $SiO_2$<90% decreased. This is explained by increase of quartz content in sandstones and by dolomite cementation of rocks with $SiO_2$<90% in the shallow setting. The resistivity range in the middle part of the basin (40-580 Ohm·m) (Fig. 4, 6, 7b), where porosity are ranged only from 2.7 to 22.5%. Apparent resistivity of quartz sandstones (200-2300 Ohm·m) in the western part of the basin is higher than for most of more silty rocks (40-210 Ohm·m). Two sandstones from the shallow part also had high resistivity (Fig. 4, 5a, 6, 7a). One of them included 93.9% of quartz and its $\rho_a$ was 6500 Ohm·m. The second one with 91% of quartz had $\rho_a$ 1080 Ohm·m. Samples from the shallow part with resistivity more than 1000 Ohm·m had more than 17% of dolomite cement or had calcite cement (Fig. 5a). Most of the other siliciclastic rocks had $\rho_a$ lower than 600 Ohm·m. Resistivity of siltstones from the shallow part of the basin increase with increasing dolomite content (Fig. 5a).

Resisitivity of rocks in log-decimal scale versus porosity in log-decimal scale had rather good correlation with porosity in different basin parts (Fig. 6). As is known the correlation between apparent resistivity of the water saturated rock $\rho_0$ and porosity was introduced in the famous work of Archie (1942) as

$$\rho_0 = F \cdot \rho_w \tag{1}$$

where F is “formation resistivity factor” and $\rho_w$ is electrical resistivity of the brine. A graphic presentation of the logarithm of the formation factor F versus the logarithm of porosity φ results approximately in a straight line with the slope *m*

$$\lg F = -m \cdot \lg \Phi, \tag{2}$$

$$m = -\lg F / \lg \Phi, \tag{3}$$

and the “first Archie equation” is

$$\rho_0/\rho_w = F = 1/\Phi^m \tag{4}$$

where *m* is empirical quantity called “cementation exponent” for siliciclastic rocks and reflects the porosity geometry (tortuosity of the pore network) for carbonates (Doveton, 1986, Shön, 1996). The value of *m* exponent determines the slope of formation resistivity factor-porosity correlation line. Therefore, if correlation lines have the same slope, but different position, then rocks have the same cementation, but different pore space structure. Usually “cementation factor” changes from 1.3 for unconsolidated sands to 2-2.2 for highly cemented sands (Doveton, 1986). A complicated pore system usually gives higher *m* in carbonate rocks. Taking into account an occurrence of carbonate cementation in the studied siliciclastic rocks, we can call *m* for the studied rocks as the “cementation-tortuosity exponent”.

Formation factor was calculated for the studied rocks where the measurements of the apparent resistivity were made with non-mineralized water with an apparent resistivity equal to 1 Ohm·m. Calculation of *m* from the studied data using equation (3) gave us the following results (Table 2, Fig. 7). The value of *m* increased from the deeper part of the basin to its shallow part. The highest values of *m* were calculated for the sandstones and siltstones from Estonia (Fig. 7a). It may be explained by dolomite cementation of Estonian siltstones from one side and by high tortuosity of pore space of Estonian rocks with very wide range of porosity. The lowest *m* for both sandstones and siltstones and the best fit of data to theoretical correlation lines were determined in the western Lithuania (Fig.7c). For the samples with the low porosity 1-3% the following equation was used

$$F=a/\Phi^m \qquad (5)$$

where *a* is the second empirical parameter.

The best fit to these data was found using a=1.4 and m=1.58 suggested for metamorphosed sedimentary rocks with less than 4% porosity (Keller 1989). This equation did not fit the data with porosity less than 1%.

In the central part of the basin the *m* was higher than in the western Lithuania, but lower than in Estonia (Fig. 7b). Two parallel groups of sandstones with different formation factor may be interpreted as rocks with different pore space structure.

Generally the significant fit of practical data to theoretical correlation lines using calculation by the formula (2) and empirical parameter *m* was found only for the deep part of the basin.

Table 2. Empirical parameters calculated for Archie and Olhoeft equations.

| Location | Northern | | | Central | | Western | |
|---|---|---|---|---|---|---|---|
| Depth | Shallow (80-800 m) | | | Middle (1-1.8 km) | | Deep (1.8-2.3) | |
| Countries | Estonia | | | Latvia, central Lithuania | | Western Lithuania | |
| Rock type | Sandstones | Siltstones | Clay.Sitst | Sandstones | Siltstones | Sandstones | Siltstones |
| Exponent *m* in Archie equation (4) | 3.5 | 3.2 | 2.59 | 2.58 | 2.38 | 2.0 | 1.79 and 1.58 (a=1.4) |
| A, ($E=A^d$), d-bulk density, Olhoeft equation (6) | 1.76 | 1.86 | 1.93 | 1.60-1.93 | 1.86-1.93 | 1.66-1.93 | 1.76-1.93 |

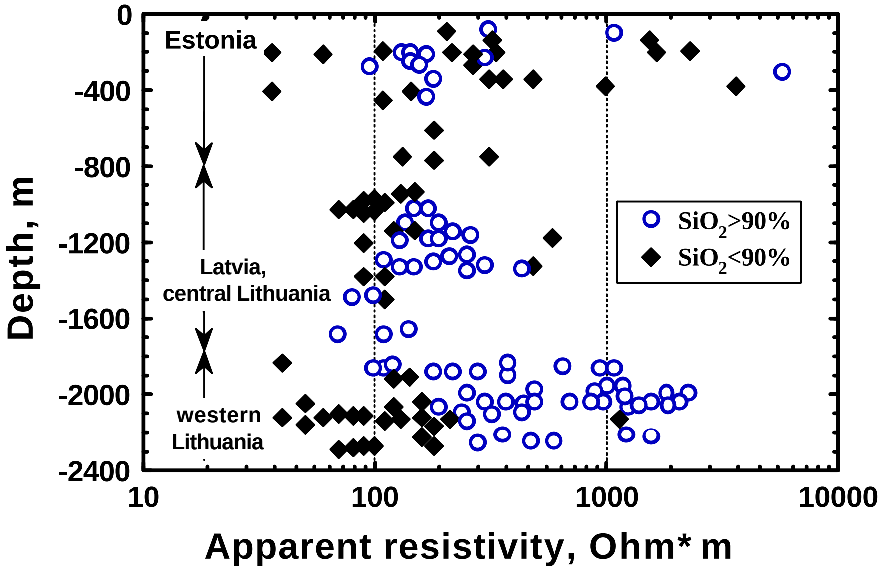



Figure 4. Apparent resistivity in log-decimal scale versus depth in the Baltic Cambrian basin.

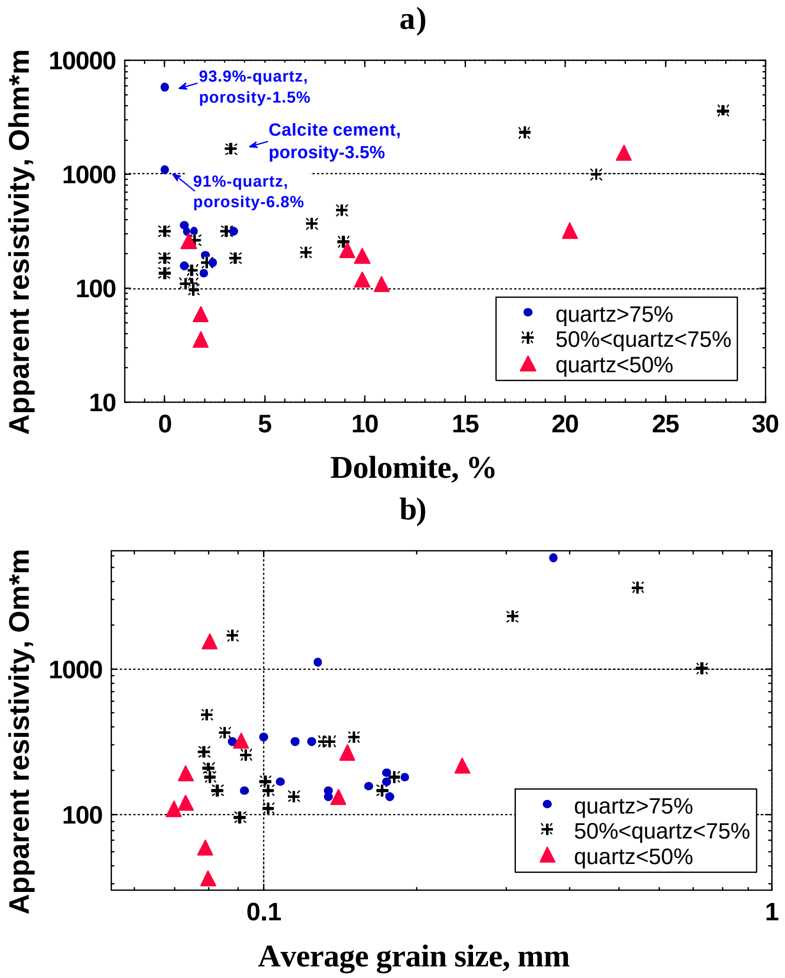



Figure 5. Apparent resistivity in log-decimal scale in the shallow part of the basin (Estonia) versus: a) dolomite content, b) average grain size. Filled circles are sandstones, crosses are siltstones and filled triangles are clayey siltstones (claystones).

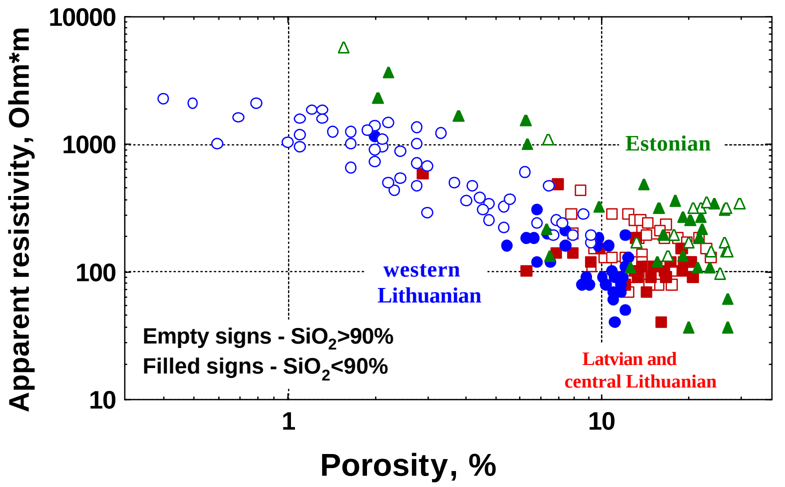



Figure 6. Apparent resistivity in log-decimal scale versus porosity in the Baltic Cambrian basin. Empty green triangles are rocks with $SiO_2$>90% and filled green triangles are rocks with $SiO_2$<90% from Estonia (depth 80-800m); empty red squaires are are rocks with $SiO_2$>90% and filled red are are rocks with $SiO_2$<90% from Latvia and central Lithuania (depth 1-1.8 km); empty blue circles are are rocks with $SiO_2$>90% and filled blue circles are are rocks with $SiO_2$<90% from the western Lithuania (depth 1.8-2.3km).

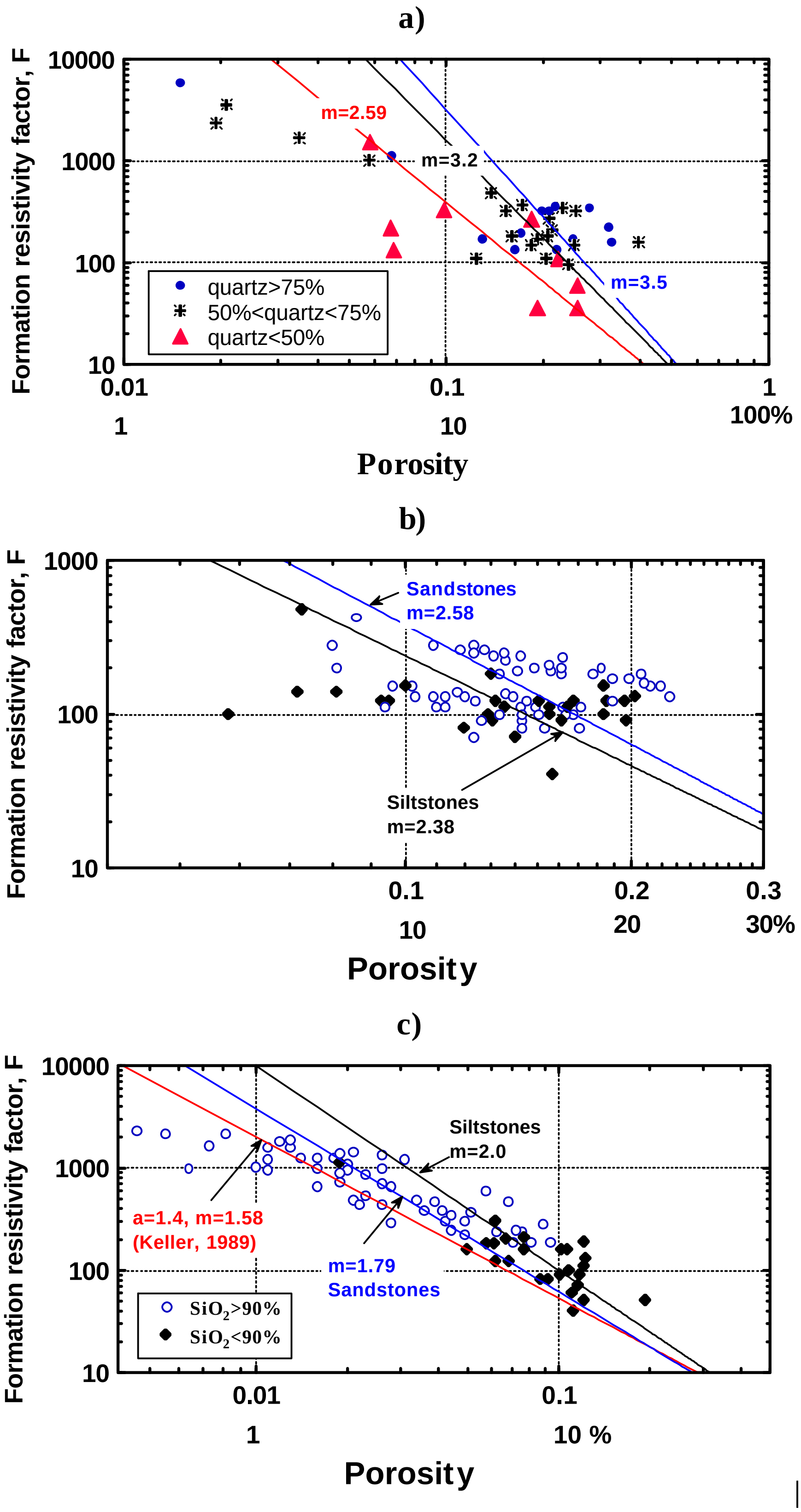



Figure 7. Formation factor versus porosity with correlation lines calculated from Archie equation $F=1/\Phi^m$, where *m* is cementation factor for the rocks from: a) Estonia (depth 80-800m); b) Latvia and central Lithuania (depth 1-1.8 km); c) the western Lithuania (depth 1.8-2.3km).

*Dielectric constant*

The dielectric constant of the studied rocks ranged from 2.7 to 7.9 (Table 1, Fig. 8). The dielectric constant of rocks (E) usually has a negative correlation with porosity. Therefore the highest dielectric constant in sandstones (3.4-5.5) were measured in the samples from the western Lithuania. The dielectric constant of siltstones was higher than that of sandstones in the shallow and central parts of the basin. This difference between dilelectric constant of siltstones and sandstones was not very significant in the western Lithuania, while on the graph of dielectric constant versus porosity they make two more or less separate groups with parallel correlation lines. This makes it possible for discrimination of sandstones and siltstones using E - porosity relation in the western Lithuania. Such discrimination is not possible in the shallow and central parts.

The dielectric constant of the feldspatic quartzose sandstones and siltstones from Estonia showed negative dependence on porosity, and most of them positively correlate with dolomite and total iron content (Fig. 9a, b). There are seven samples out of range from positive correlation of E with dolomite cementation (Fig. 9a). These out of range samples have relatively high dielectric constant (4.6-5.5) and low dolomite content (0-3.4%). One of them has high quartz content (93.9%) and low porosity (1.5%), another cemented by calcite (3.5%) and has a porosity of 1.5% and one of the sample includes 3.7% of appatite (phosphate cement) and 24% of clay minerals. Three samples have high content of clay minerals (36.6-53.4%) and another one includes 1.5% of pyrite and in total 9.5% of iron. This demonstrates that the dielectric constant of Estonian samples show a positive correlation with all cementation materials, which are dolomite in most of the samples and in some cases it is clay, calcite and appatite.

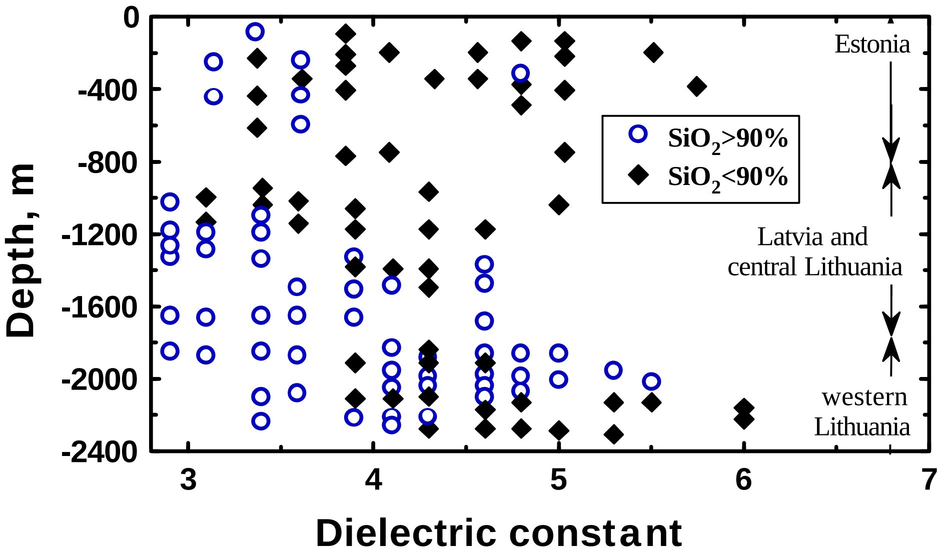
A remarkable correlation of relative permittivity (dilectric constant) with the bulk density was found by Olhoeft for silicates:

$$E=(1.93 \pm 0.17)^d \qquad (6),$$

where d is the bulk density of rocks. Using this empirical equation we calculated equations for the studied rocks more or less coinciding with Olhoeft equation (Fig. 10). It was found that the different rock types from the shallow part of the basin fitted to three different correlation lines calculated using following equations: $E=1.76^d$ for sandstones, $E=1.86^d$ for siltstones and $E=1.93^d$ for clayey siltstones.

In Latvia and central Lithuania all samples were between two correlation lines $E=1.6^d$ and $E=1.93^d$ with average correlation line $E=1.86^d$. In the western Lithuania most of the samples were between correlation lines $E=1.76^d$ and $E=1.86^d$ and only some samples fitted to correlation lines $E=1.66^d$ and $E=1.93^d$. There was no discrimination between sandstones and siltstones in these central and western basin parts.

a)




b)

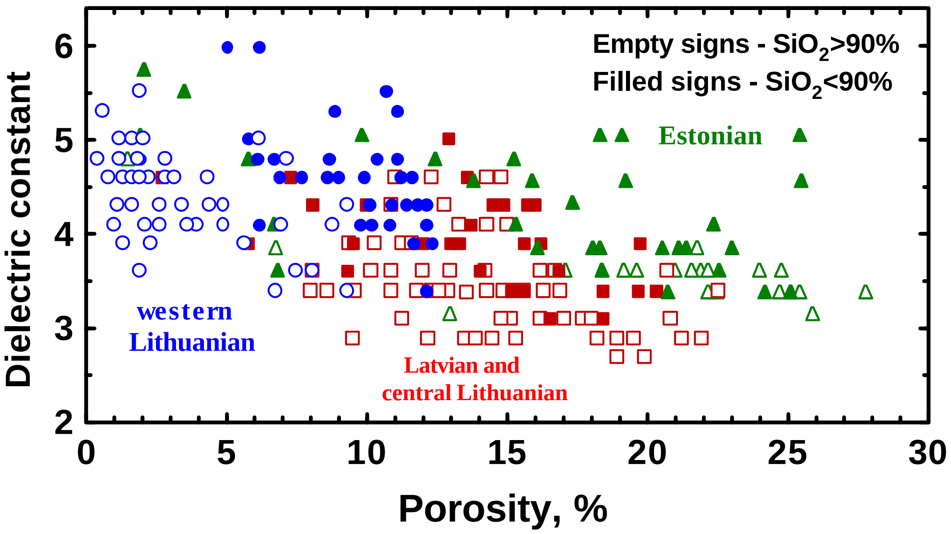



Figure 8. Dielectric constant in the Baltic Cambrian basin versus a) depth (empty circles are sandstones, filled diamonds are siltstones); b) porosity (empty green triangles are sandstones and filled green triangles are siltstones from Estonia (depth 80-800m); empty red squaires are sandstones and filled red are siltstones from Latvia and central Lithuania (depth 1-1.8 km); empty blue circles are sandstones and filled blue circles are siltstones from the western Lithuania (depth 1.8-2.3km)). Rocks with $SiO_2$ content >90% are called here sandstones, and rocks with $SiO_2$ content less than 90% are called siltstones.

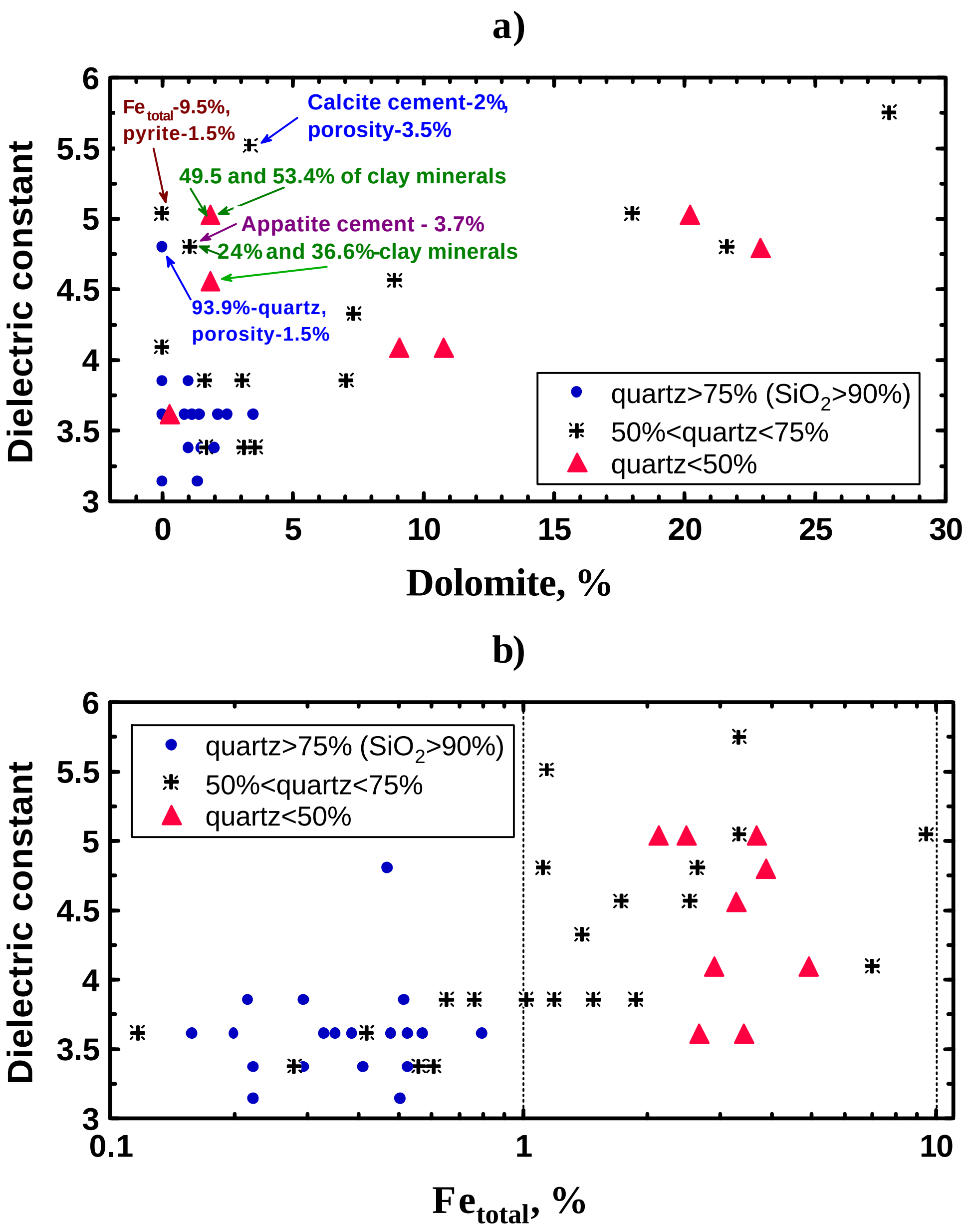



Figure 9. Dielectric constant in the shallow part of the Baltic basin (Estonia) versus a) dolomite content, b) total iron content. Filled circles are sandstones, crosses are siltstones and filled triangles are clayey siltstones (claystones).

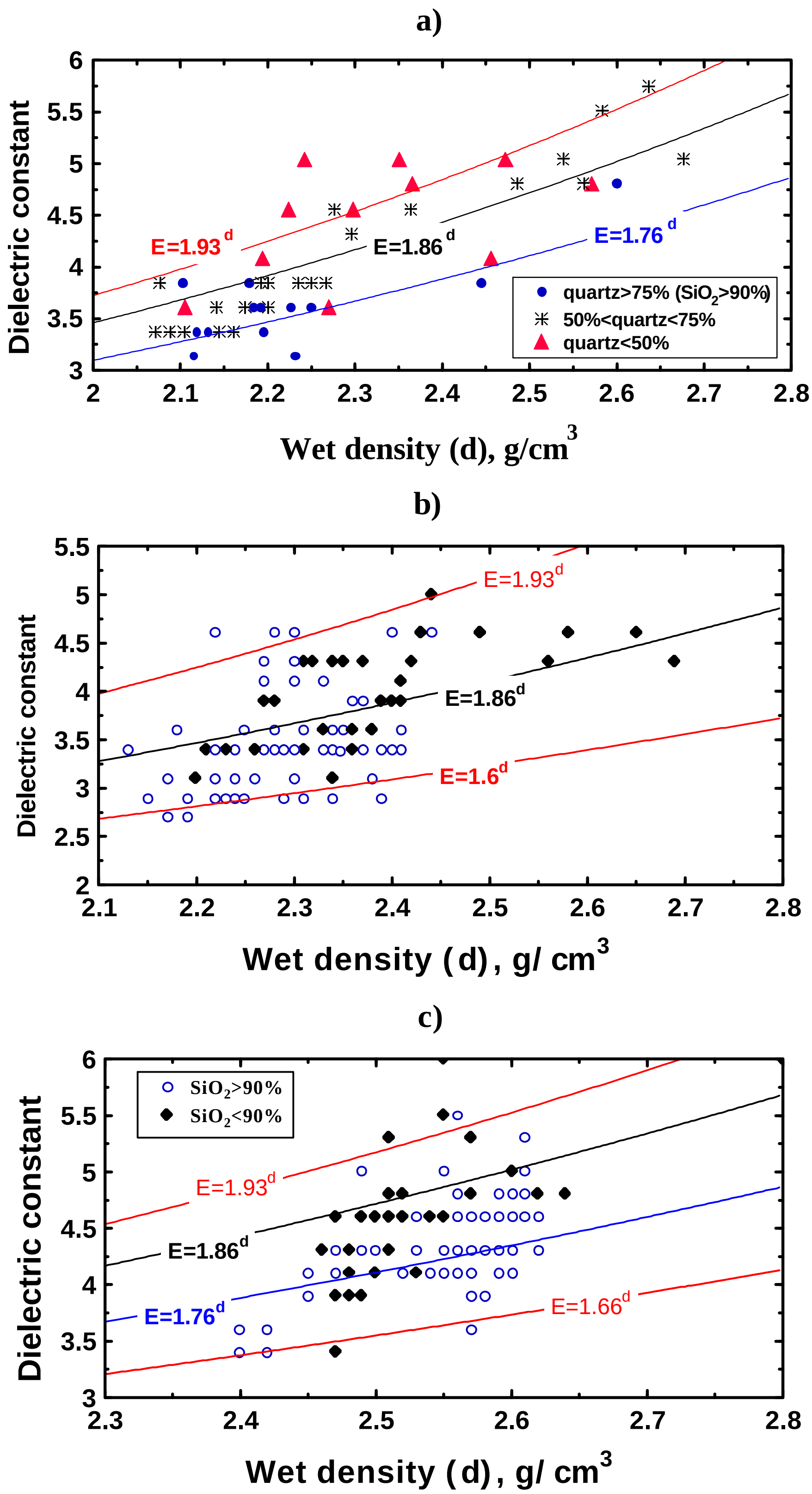



Figure 10. Dielectric constant versus wet density with correlation lines calculated according Olhoeft $E=(1.93\pm0.17)^d$ for the rocks from: a) Estonia (depth 80-800m); b) Latvia and central Lithuania (depth 1-1.8 km); c) the western Lithuania (depth 1.8-2.3km).

## Conclusions

Sandstones and siltstones from the different regions of the Baltic basin are characterized by the different ranges of apparent resistivity and dielectric constant. They depend on porosity, pore space structure, lithology, cementation and grain size.

Resistivity of rocks with $SiO_2$>90% were the highest and resistivity of rocks with $SiO_2$<90% were the lowest in the western Lithuania, where Cambrian rocks now occur in their deepest position. The highest values of dielectric constants for both goups of rocks were also found there. The electrical parameters versus porosity have good discrimination for the studied rocks in this basin part. The best fit of theoretical correlation lines (calculated using Archie equation) with practical data were also obtained in this region. The calculated exponent *m* was lowest here owing to low porosity and low tortuosity of the pore space.

Resistivity of rocks with $SiO_2$>90% (sandstones) from the shallow and middle basin parts was lower than in the deep part. The dielectric constant in these two parts was lower than in the deep part, and the dielectric constant of rocks with $SiO_2$<90% was higher than of rocks with $SiO_2$>90%. This permitted more or less satisfactory discrimination of lithological rock types using the dielectric constant-porosity relation in these regions of the basin. The highest cementation exponent *m* for rocks with $SiO_2$<90% (feldspatic quartzose sandstones and siltstones) was found in Estonia where the rocks had the highest tortuosity. The fit of data to the "first Archie equation" was not very good in the shallow and middle parts of the basin. The empirical dielectric constant-bulk density relation by Olhoeft had significant fit to our data and some discrimination between rock types only for Estonian samples.

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## References

Archie, G.E., 1942. The electrical resistivity log as an aid in determining some reservoir characteristics. Trans. Americ. Inst. Mineral. Met., 146, 54-62.

Doveton, J.H., 1986. Log analysis of subsurface geology, John Wiley & Sons, New York.

Keller G.V., 1989. Electrical properties, in: Practical handbook of Physical Properties of Rocks and Minerals Carmichael, R.S. (Ed.), CRC Press, 1989, Boca Raton.

Olhoeft, G.R., 1981. Electrical properties of rocks, in: Physical Properties of Rocks and Minerals, Y.S. Toulokain, W. R. Judd, R.F. Roy (eds.), McGraw Hill, New York.

Paškevicius, J., 1997. The geology of the Baltic Republics, Vilnius, 387.

Prijatkin, A.A., Poljakov, E.E., 1983. Petrophysical investigations of rocks, (in Russian), Leningrad University.

Schön, J.H., 1996. Physical properties of rocks: fundamentals and principles of petrophysics, Pergamon, 583.

Sliaupa, S., Shogenova, A., Rasteniene, V., Zabele, A., Lashkova, L., Bitjukova, L., Kirsimäe, K., Jõeleht, A., Eihmanis, E., 2000. Collector properties of the Cambrian reservoir in the Baltic Basin – Estonia, Latvia, Lithuania, Extended Abstracts Volume 2, 62nd EAGE Conference and Technical Exhibition, Glasgow, Scotland, 29 May - 2 June, European Association of Geoscientists & Engineers, P- 08, 4pp.

Shogenova, A., Bitjukova, L., Jõeleht, A., Kirsimäe, K. and Mens, K., 2001. Petrophysical properties of siliciclastic Cambrian rocks, Estonia, In: Nordic Petroleum Technology Series: V, Research in Petroleum Technology, Ida L. Fabricius (Ed.), Nordisk Energi-Forskningsprogram, Ås, Norway, 123-148.

Sliaupa S., Rasteniene V., Lashkova L., Shogenova A. 2001. Factors controlling petrophysical properties of Cambrian Siliciclastic Deposits of Central and Western Lithuania. – In: Nordic Petroleum Technology Series: V, Research in Petroleum Technology, Ida L. Fabricius (Ed.), Nordisk Energi-Forskningsprogram Ås, Norway, 157-180.