Artificial Silica Deposits from Pauzhetkoe Geothermal Field: Petrophysical Properties and Possibility of Utilization (South Kamchatka, Far East, Russia)

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Abstract: This report describes a composition, pore space structure and petrophysical characteristics of artificial silica deposits in Pauzhetskoe geothermal field (South Kamchatka, Far East, Russia) which are formed from waste thermal water disposed after steam separation. The possibilities of their utilization in industry, cosmetology and balneology are discussed.

Key words: artificial silica deposits, petrophysical properties, Pauzhetskoe geothermal field

Pauzhetskaya GeoPP has been operating since 1967. Steam in production wells is separated from the water at the surface (Figure 1a) and is then used to power a turbine/generator unit. The remaining thermal water (pH~8,5, $T \leq 100\ ^{0}C$) is directly disposed of into creeks results in formation of thick layers of artificial deposits on the bed (Figure 1b,c).

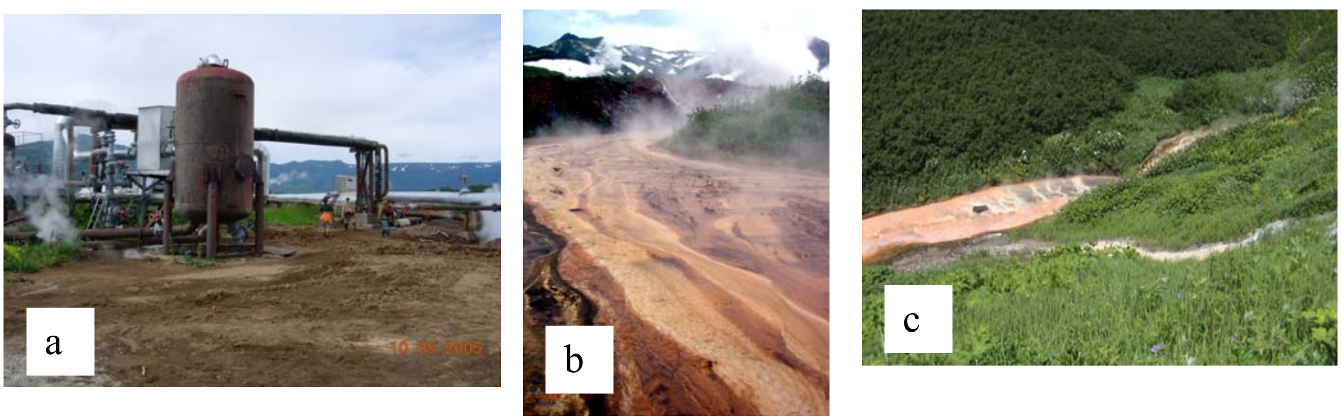

Figure 1. The process of thermal water disposal into the creeks: a – Steam separator at production well GK-3; b, c – Silica covers on the bed of creeks

Figure 2. Artificial silica deposits: a – Thermohyll alga; b – Silica-gel; c – Solid silica material

During summer field works in 2005 we investigated and collected deposits of three creeks. Sampling was made along and across the creeks and accompanied by pH and temperature measurements. Generally, vertical section of deposits is composed from three parts: thermophyll alga, silica-gel layer (~ 15-20 cm) and solid silica material (Figure 2).

The deposits are several hundreds meters length, tens meters width and 0,5-1 m thick. This research emphasizes on solid material structure and properties. Field observations reveal that silica rocks are highly porous and have layered structure forming by alternation of lamellar and large-cellular layers (Figure 3). Type of microstructure is mainly controlled by regime of thermal flow, firstly speed and temperature. Large-cellular or spongeous structure with the highest porosity is formed in quiet places, whereas lamellar, relatively dense structure is typical for races places.

Figure 3. Types of silica structure. 1 - Cellular or spongeous structure; 2 - Dense lamellar structure

Lab investigations of composition, structure and properties (physical, mechanical, thermal, magnetic) are carried out. X-ray analysis confirms amorphous silica composition of deposits. Electronic microscope allows describe microstructure in detail. SEM images illustrate an alternation of porous and dense layers (Figure 4a). Large magnitude image illustrates that porous layer consists of silica globules (diameter is about 0,5-2 μm), which form fibers 0,1-0,2 mm length (Figure 4b,c). Dense layer consists of amorphous homogeneous material. Its microstructure is invisible even in large magnitude (Figure 4 a).

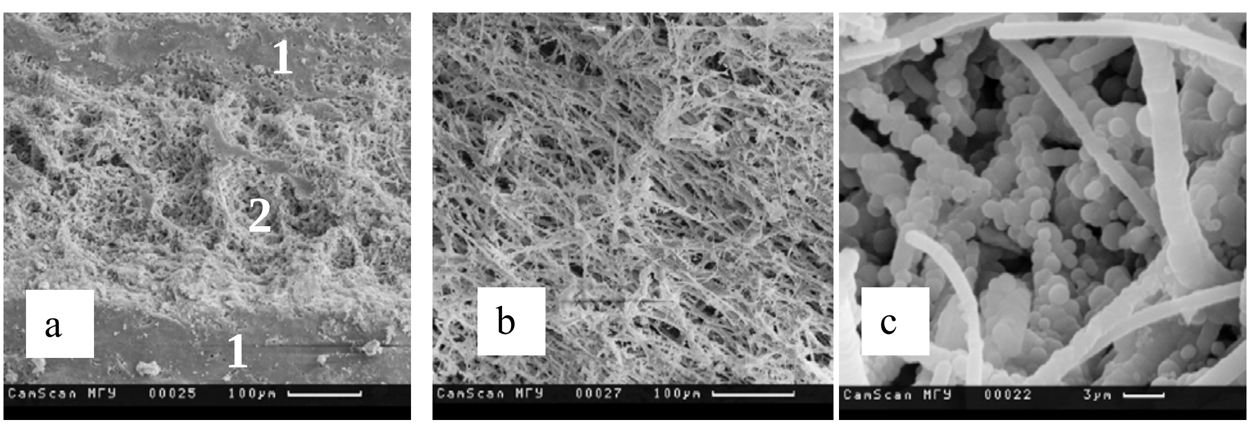

Figure 4. SEM micrographs. Microstructure of silica deposits: a – Alternation of dense (1) and porous (2) layers; b - Felty microstructure; c – High magnitude image of silica globules

Table 1 shows main petrophysical characteristics of silica rocks. Studied rocks are extremely low dense (ρ=0,3-1,3 g/cm^3) with specific density varying in interval 2,13-2,29 g/cm^3, that coincides with density of opal (1,9-2,5 g/cm^3). They are highly porous (n=40-87%). Effective porosity by water (n_o) is lower changing from 20 up to 73%. The ratio n_o /n is characterized the pore-space structure and portion of pores which is open for water flow. For some samples the ratio n_o/n~0,9-1 indicates that almost all pore are connected to common network opening for flow. In other samples the ratio n_o/n~0,3-0,4 shows on prevalence of isolated pores.

Due to high porosity sonic velocity (V_p) is characterized by low values. It is important to note that layered rocks are strongly anisotropic. V_p values along layering 1,5-2 times higher than cross layering. Coefficient anisotropy reaches 2,35. The rocks are weak: uniaxial strength (R_c) is characterized by low values (prevalence values < 5 MPa) so that material can be easy crushed into powder. Strength depends on porosity and pore size. A scatterplot (Figure 5) shows that rocks with the highest porosity (65-87%) and large pore size are the weakest among others (R_c<1 MPa). Less porous rocks (60-70%) with fine pores are characterized by strength in order 2-7 MPa. And relatively the strongest rocks (5-17 MPa) are visually dense types with porosity 40-50%.
Specific surface is measured as 120-145 m^2/g. The material is characterized by excellent thermal insular properties; it is non-magnetic (magnetic susceptibility $\chi \sim 10^{-5}$-10^{-4}SI) (Table 1).

Table 1. Petrophysical properties of silica deposits

Property	Number of measurements	Mean	Min	Max
Density, g/cm^3	33	0,79	0,29	1,31
Sp. density, g/cm^3	5	2,20	2,13	2,29
Hygroscopy, %	5	2,7	1,7	3,4
Porosity, %	33	64	40	87
no/n	33	0,66	0,31	0,98
$V_{p\perp}$	33	1,9	1	2,5
$V_{p\,II}$	33	2,7	2,05	3,6
K anisotropy	33	1,47	1	2,35
Strength, MPa	33	3,6	0,03	17
χ*10^{-3} SI	33	1,3	0,03	27
Sp. surface, m^2/g	3	132	122	145

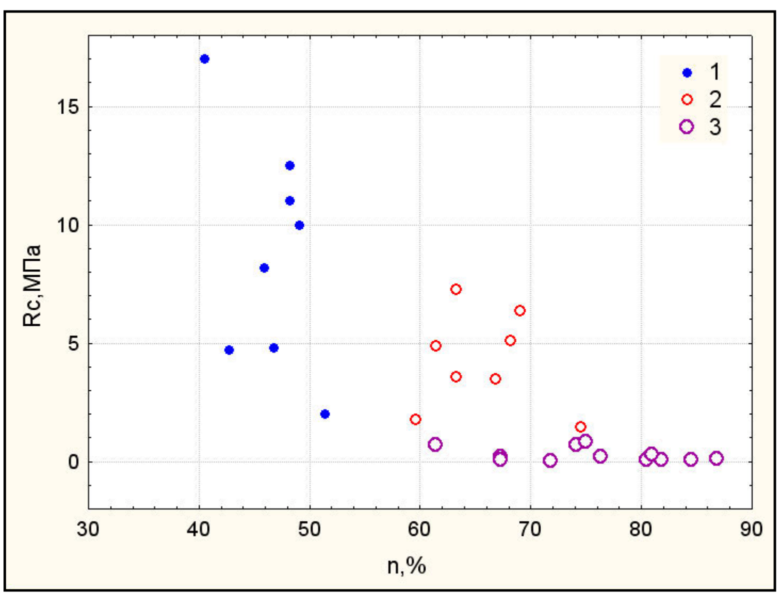

Figure 5. The scatterplot POROSITY (n) – UNIAXIAL STRENGTH (R_c). 1 – Visually dense rocks; 2 – Fine-porous rocks; 3 – Large-porous rocks

No certain tendency in properties change is observed across or along silica covers. A comparison of silica deposits from three wells is revealed on boxplots (Figure 5). Two wells (R-120 and K-20) have similar properties of silica rocks whereas rocks from well GK-3 are distinguished by higher density and lower porosity. The explanation is that in silica cover from well GK-3 prevail visually dense rocks (group 1 in figure 5). They are formed in race condition. Silica deposits from wells R-120 and K-20 are mostly characterized by fine-porous or large-porous structure forming in quiet flow conditions.

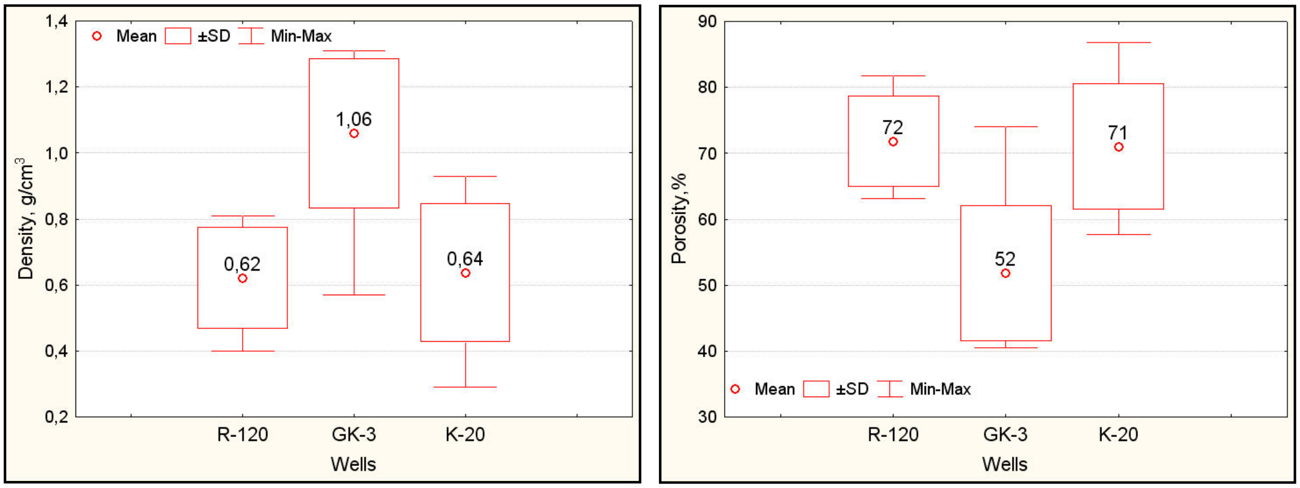

Figure 6. Comparison of silica rocks from three wells. Boxplots: a – Density; b – Porosity

Conclusion

To our opinion it has to consider different possibilities of silica deposits utilization in industry (as sorbents, catalizators, filters, thermal insulators, composite materials), cosmetology (as the component for perfume) and balneology. In depend on type of utilization artificial amorphous silica can be used in different ways:

1) "Direct use" of silica rocks. The negative agent is inclusions of terrigenous material (sand, gravel, soil) and organic remains, which lead to deterioration of silica rock quality.
2) Crushing of weak silica rocks into powder.
3) Drying of silica-gel (using geothermal energy)
4) Precipitation from hydrothermal fluids silica material with standard predictable properties, certain structure and pore size favorable for utilization.

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