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Technogenic Precipitation in the Structures of Mutnovsky Geothermal Power Complex (South Kamchatka)

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ABSTRACT

Mutnovsky geothermal power complex was created on the basis of Mutnovsky deposit of hydrotherms. The capacity of this biggest in the Russian Federation geothermal power complex is 62 MWt. At present the complex consists of two geothermal power stations – Verkhne-Mutnovskaya (12 MWt) and Mutnovskaya (50 MWt). Verkhne-Mutnovskaya power station was built as a pilot power object for base service of operation technologies and testing new engineering designs. It was of importance to gain experience of building and operation of complex power plants under harsh climatic and geological conditions of the region having no any infrastructure. The station has three turbogenerators, 4 MWt each. It was built by a block-module method and launched in 2000. The main module of the complex – Mutnovskaya geothermal station with capacity of 50MWt – started to generate electricity in 2002. The area of Muntovskoe deposit of hydrotherms is about 80 km2 (according to isotherm 150^0 C). Geothermal reservoirs of the deposit are of composite shape, they are located at depths from 300 down to 2000 meters from the surface. Temperatures of these geothermal reservoirs vary from 240 up to 300^0 C. Geothermal heat carrier (steam-water mixture) is carried to the work area of the power complex by wells. Composition of this steam-water mixture varies depending on the structural location of the well. While operating, at metal constructions of different elements of manufacturing equipment there takes place precipitation of various minerals and compounds. The following ones have been identified among them: oxides and hydroxides of Fe, sulphides of Fe, Cu, Zn, Pb, silicates, native silicon. Aggregates of amorphous SiO_2 and native silicon form nanoparticles of ideal spherical shape. Clarification of conditions of technogenic precipitation accumulation is of important practical and theoretical significance. It will enable to make power complex equipment life longer. Knowledge of parameters, by which nanoparticles of amorphous SiO_2 and native silicon are formed, is of great importance for perfection of synthesis technologies of composite materials.

1. INTRODUCTION

The Mutnovsky geothermal energetics is a most prospective line of economic development of Kamchatka (**Fig. 1**). The first in Russia Pauzhetka geothermal power station with initial power of 5 MWt was put in operation in 1966; its power increased up to 11 MWt in 1979. Three geothermal power stations successfully function in Kamchatka at the present time. In addition to the Pauzhetka station, the Verkhne-Mutnovsky pilot station (12 MWt) started to work in December 2000 and the Mutnovsky main station (50 MWt), in September 2002 (**Fig. 1-4**). The new stations have been built at the Mutnovsky geothermal deposit of the North Mutnovsky high-temperature geothermal system, a largest geothermal system of Kamchatka. The energy resources are estimated as $71.28 \cdot 10^{18}$ J.

Figure 1: Panorama of the Mutnovsky main geothermal station (50MWt).

The Mutnovsky geothermal field is situated 70–75 km southeast of the city Petropavlovsk-Kamchatsky on the volcanic plateau at elevations of 700–900 m and localized in the central part of this system. The Mutnovsky geothermal system (Mutnovsky geothermal district, after Okrugin, 1995) is extremely diverse as concerns the present-day volcanic and postvolcanic activity. Three field groups are recognized: (1) fumarolic fields of the active Mutnovsky and Gorely volcanoes, (2) thermal fields and water-vapor springs of the North Mutnovsky volcanotectonic zone, and (3) thermal fields and ascending hot springs in river valleys (Okrugin, 1995; Kiryukhin, 1998). The largest heat occurrences: Dachny, North Mutnovsky, and Perevalny contain the main heat carrier resources and are localized within the North Mutnovsky volcanotectonic zone. This zone is a graben-like basin controlled by a large meridional fault (Lonshakov, 1979; Kiryukhin, 2002). A combination of meridional zone of tectonic dislocations with diagonal NW and NE faults and latitudinal faults along with lithological screens provide favorable conditions for hot water and vapor accumulation (Okrugin et. al 2003).

Figure 2: New Drillhole Geo-2

2. TECHNOGENIC PRECIPITATION

Steam hydrotherms Mutnovsky deposit located in the southern region Mutnovskii geothermal reserves and provided Mutnovskaya high geothermal system - one of the largest in Kamchatka. On the basis of this field for several years operated Upper Mutnovskaya Mutnovskaya and geothermal power capacity of 12 and 50 MW, respectively (**Fig. 3,4**). As a result of the operation of these plants significantly improved electricity Petropavlovsk-Elizovo agglomeration. Geothermal power plants are operated in difficult climatic and mining conditions , which naturally affects the features of the technology cycle and operating conditions of the equipment. To one of the main factors complicating the work equipment, the chemical composition refers coolant. It is characterized by relatively high mineral content, which in turn leads to precipitation of mineral growths on the details of the equipment, the walls of the separators and pipelines (**Fig. 5**).

Figure 3: Location of the Verkhne-Mutnovskaya (pilot, 12 MWt) geothermal power station

Figure 4: Location of geothermal power plants Mutnovskaya GPS, 50 MWt.

The aim of our research - the study of mineral growths are deposited in different parts of the technological cycle geothermal power plants. Research Methods: - full-scale: sampling mineral growths of various nodes of technological equipment (from the walls of the column and filter one of the wells, separator , pipe line reinjection Pilot and Main stations): testing coolant and getting out of it by a series of wells precipitation (**Fig. 5**); - classic mineralogical; - XRF, XRD, EPMA,SEM and ICP.

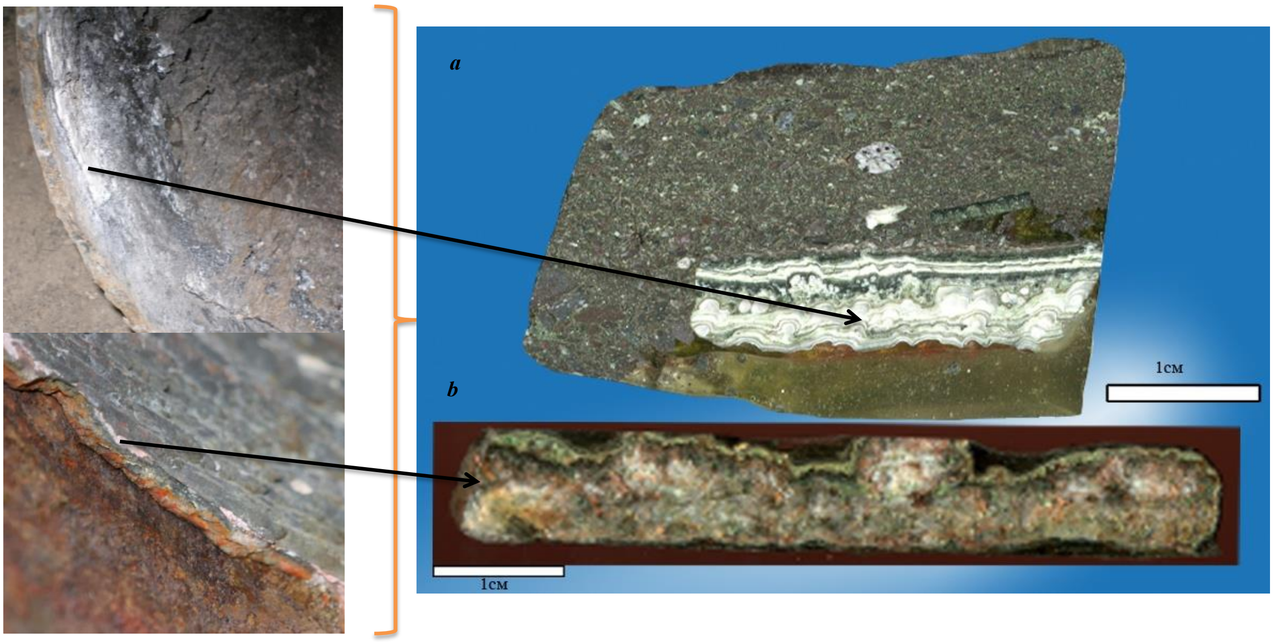

Figure 5: The two types of precipitations: a - first type of deposits - sulfide (troilite, marcasite, pyrite) border on the outer layer of SiO_2 into pipe wall; b - the second type of deposits - deposits with a large range minerals

Figure 6: Aggregates of amorphous SiO_2 are precipitated from steam (T 237^0 C).

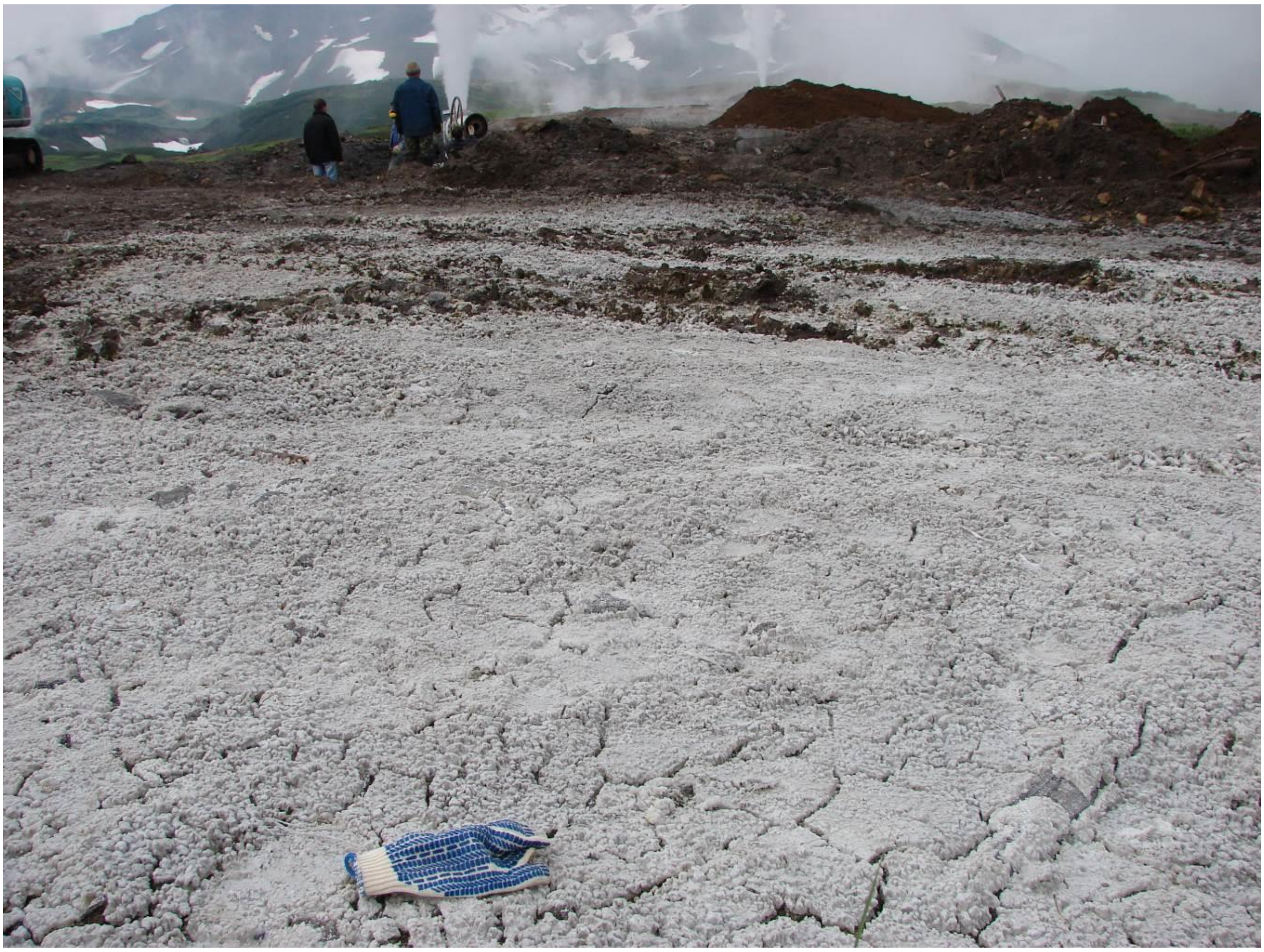

Figure 7: Technogenic Precipitation, South Range of Mutnovsky geothermal deposits (aggregates of amorphous SiO_2 + NaCl +Na_2SO_4).

Among diagnosed ore minerals pyrite, troilite, chalcopyrite , sphalerite, oxides and hydroxides of iron and of nonmetallic - minerals, and silica compounds , carbonates, adularia (Table 1).

Table 1 **Material composition of precipitations which was collected in the several constructions of geothermal power complex**

Quartz	SiO_2
Tridymite,	SiO_2
Chalcedony	SiO_2
X-ray amorphous	SiO_2
X-ray amorphous	Si (?)
Adularia	$KAlSi_3O_8$
Albite	$NaAlSi_3O_8$
Magnetite	$FeFe_20_4$
Iron hydroxide	$FeOxnH_2O$
Pyrite	FeS_2
Marcasite	FeS_2
Pyrrhotite	FeS
Sphalerite	ZnS
Chalcopyrite	$CuFeS_2$
Chalcocite	Cu_2S
Halite	NaCl
Galotrihit	$FeAl_2(SO_4)_4*22H_2O$
Gypsum	$CaSO_4^*2H_2O$
Native gold	Au
Complex oxides and hydroxides containing Cu, Zn, As, Sb, Fe	

Table 2 **Mineral composition of deposits of thermal waters sampled from the lower parts of the "boiling zone" boreholes (wells at depth 1000 - 1500 m, abs. elev. 200-250 m**)

Halite	NaCl
Thenardite	Na_2CaSO_4
Gypsum	$CaSO_4{}^{*}2H_2O$
Rhodochrosite	$MnCO_3$
Siderite	$FeCO_3$
Calcite	CaCO3
Zeolites Wairakite	$(CaAl_2Si_4O_{12}*2H_2O)$
Quartz	SiO_2
Adularia	$KAlSi_3O_8$
Albite	$NaAlSi_3O_8$
Magnetite	$FeFe_20_4$
Pyrite	FeS_2
Marcasite	FeS_2
Pyrrhotite	FeS
Arsenopyrite	FeAsS
Sphalerite	ZnS
Galena	PbS
Chalcopyrite	$CuFeS_2$
Chalcocite	Cu_2S
Native gold	(Au?)

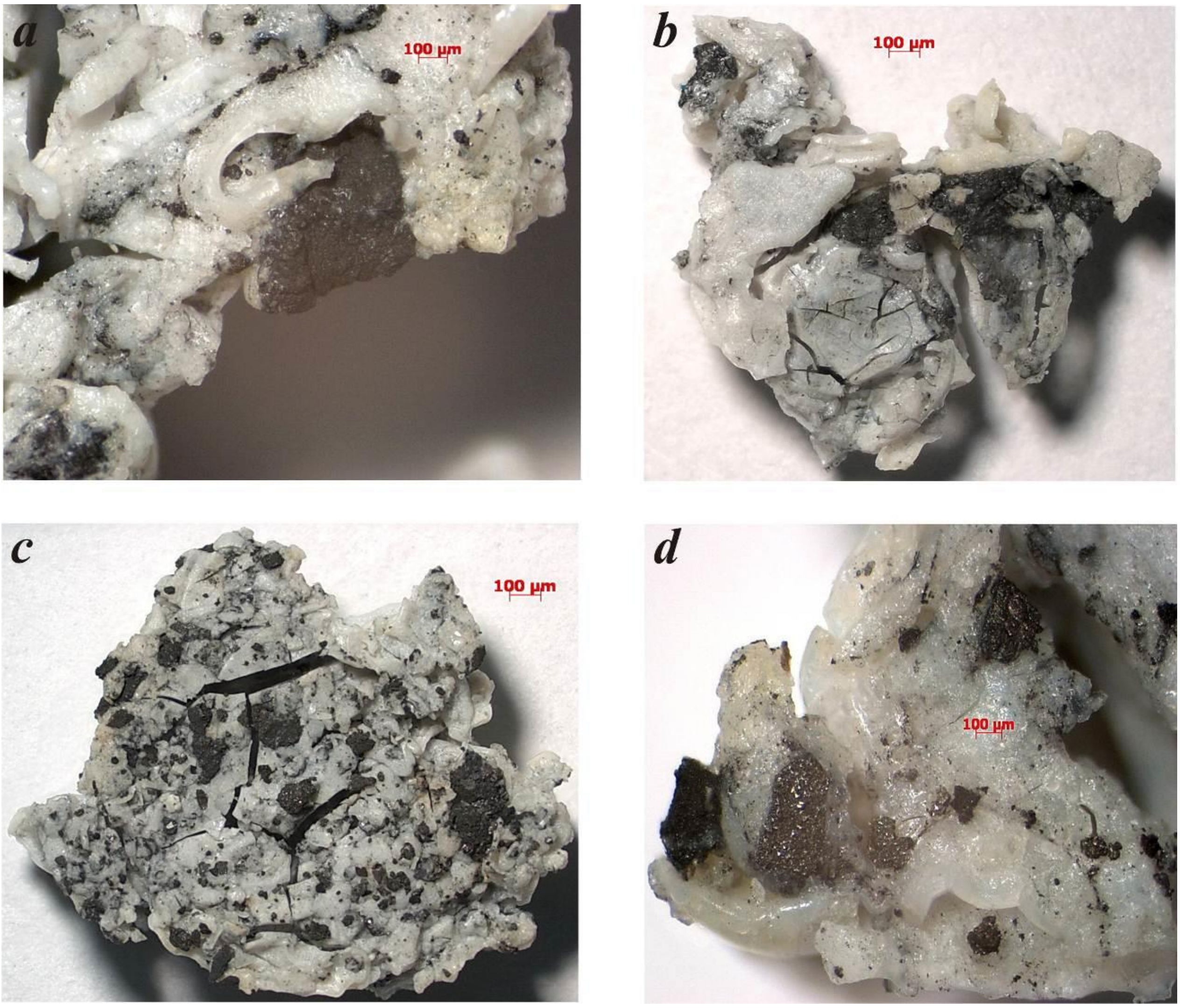

Figure 8: Aggregate of SiO_2, NaCl, Na_2SO_4, FeS_2, ZnS (a,b) and SiO_2, NaCl, Na_2SO_4, FeS_2, ZnS, CuFeS2, FeAsS(c,d).

Established a variety of forms of silica - 6 of amorphous (opal - chalcedony), crystalline (quartz) to spherical silica nanoparticles and possibly pure silicon (**Fig. 9 a, b**).

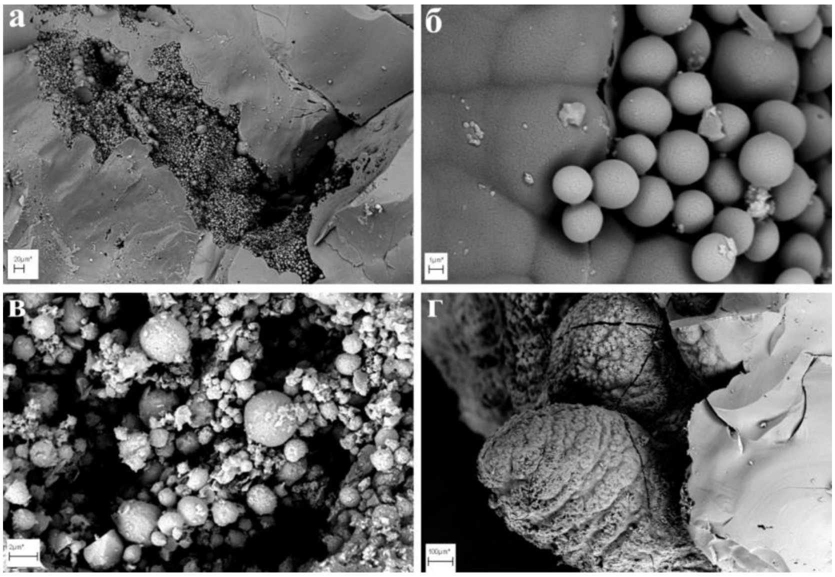

Figure 9: SEM micrographs of technogenic deposits Mutnovsky geothermal power complex: a – globular grains of silicon dioxide (SiO_2) and troilite (FeS); b - the nanoparticle SiO_2; c - fragments microtecture technological neoplasms; d - the micromorphology of sulfide aggregates.

The chemical composition variations due to a wide range of different items - from light to heavy and toxic, in some cases, similar to the composition of modern sediments fluid.

Technological cycle geothermal complex is comparable to the chemical reactor, synthesizing various compounds.

Detailed mineralogical and geochemical characteristics of the sediments , the knowledge of the C-P -T synthesis parameters may allow the development of measures to slow down the reaction rate of accumulation of some (bad) phases and other large-scale production (silica nanoparticles) .

3. CONCLUSIONS

1. Technological system Mutnovskii energy complex (producing wells communication station - reinjection) complex is chemical reactor.

2. Process of converting electrical energy in the coolant is accompanied by synthesis of various chemical compounds, which lead to premature wear of the process equipment.

3. A special variety of different forms of a silicon dioxide (quartz, chalcedony, tridymite) .

4. During such synthesis, the formation of nanoparticles of silica are used in the world in the production of tires.

5. Detailed mineralogical and geochemical characteristics and knowledge of the C-P -T synthesis parameters can afford to develop measures to slow reaction rates of some deposits (harmful) phases and other large-scale production (silica nanoparticles) .

The scope and efficiency of the use of geothermal water depends on their energy potential, the total flow rate and reserve wells, chemical composition, mineralization, corrosive water, the presence of the consumer, etc.

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