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Minerals in Bacterial Mats from the Transbaikalia Mud-Volcanic Deposits

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Abstract

The necessary condition of mineral genesis-is rather high level of geo chemical accumulation by bacterial communities from the water not only the more important for life chemical elements (C, H, N, S, P and Cl) and necessary for life components: ions Na, K, Ca, Mg, transition ((Fe, Cr, Ni, Cu, Zn at al.) and precious metals, lantanoids in biochemical classifications, also referred to biophily elements. Cooperative interaction of various types and groups microorganisms, making local oxidizing and alkaline geochemical barriers provides selective character of chemical elements bioaccumulation processes from water medium. Normally, high content starting level of micro-components in waters of alkaline mineral sources, soda and salt lakes quite meets the need of bacteria in the transition metals. In case of latter deficit in water, the resource of these elements are the enriched by them the rests of water and ground vegetation, decomposed and oxidized by bacteria-destructors (saprophytes and cellulitics).

Keywords: Bacteria; Mud volcanism; Minerals; Mineral resources; Lakes; Associations biomaterials; Gas-oil fluids

Introduction

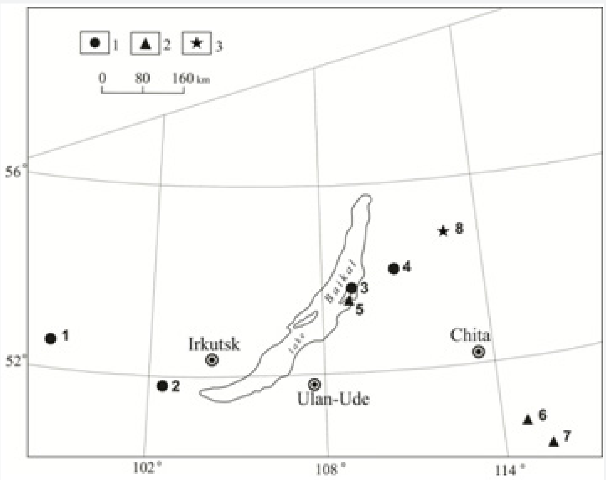

Figure 1: Research objects location layout 1 – water lightly mineralized (fresh) and mineral resources (1 – Hoyto-Gol, 2 – Arshan, 3 – Zmeiniy (Snake), 4 – Garga); 2 – lakes (5 – Kuliniye swamps, 6 – Hilganta, 7 – Zun-Torey); 3 – mud micro-volcano structure (Aunik river).

Water medium of the Transbaikalia mud-volcanic origin - a bacterial communities habitat is represented by griffon ground and underwater lightly mineralized (fresh) and mineral resources and lakes of the different mineralization (M) degree, the alkalinity.

Our research covered a variety of aquatic ecosystems objects of mud volcanoes (Figure 1), the purpose of which is the study of bacterial mineral formation processes, of element composition, of crystallization mechanisms and conditions, of separate micro - and nano-minerals, their associations [1,2]. The most attention was paid to mineral phase diagnostics, formed by micro-elements available in rather small concentrations in water, but necessary for life: transition metals (Mn, Fe, Cr, Ni, Cu, Zn and other) [3,4] as well as related to biophily, the lanthanides, noble metals and other elements in the periodic table [5,6]. Discovered mineral phases belong to group of meta-biogenic minerals [2] so as they were fixed under an electron microscope in dried biomats fragments, i.e. in the dead bacterial mass. On the one hand, they can substitute, recrystallize orthobiogenic phases, inheriting living organisms protein crystals forms, and on the other hand-be manifested on geochemical barriers by accumulating on living and dead biofilms, individual mats fragments.

Associations of Bacterial Minerals from Mud Volcanic Deposits Ground Water Resources

Table 1: Characteristic (typomorphic) associations of bacterial micro- and nanominerals from mud volcanic deposits of the Transbaikalia region ground water resources.

Aquatic ecosystems (main parameters of micro-organisms habitat)	Research objects	Mineral associations
Low-moderate temperature (7-44 °C) griffon waters (M=2.0-4.5g/l, pH=6.1-6.6)	Resource Arshan	Pyrite, Galena, magnetite, ilmenite, hematite, goethite, smectite, hydromica
Modrate temperature (26-36 °C) griffon waters (M=0.5-0.6g/l, pH=7.1-9.1)	Resource Hoyto-Gol	Native S, Si, Ni and Al, intermetallic compounds Fe-Cr-Ni, Cr-Cu-Fe, Cr-Cu, Zn-Cu, Zn-Ce pyrrhotite, sphalerite, covellite, eskolaite, goethite, periclase, lime, corundum, wustite, manganosite, tenorit. cuprite, sylvite, halite, fluorite, calicinet, nahcolite, calcite, dolomite, siderite, magnesite, rhodochrosite, malachite, gypsum, smolnica, melanterite, epsomite, anhydrite, thenardier, salts, lasso, keseric, butit, monazite, vitlacit, hydroxyl-Apatite
Average temperature (53 °C) griffon waters (M=0.3g/l, pH=8.9-9.1)	Resource Zmeiniy (Snake)	Native S, pyrite, goethite, sylvite, lawrencite, hydrophillic, chloraluminite, calcite, siderite, magnesite, calicinet, nahcolite, alunogen, glauberite, Apatite, albite, quartz
High temperature (73-75 °C) griffon waters (M=0.5-1.08g/l, pH=7.7-8.4)	Resource Garga	Pyrite, Galena, magnetite, ilmenite, hematite, goethite, smectite, hydromica

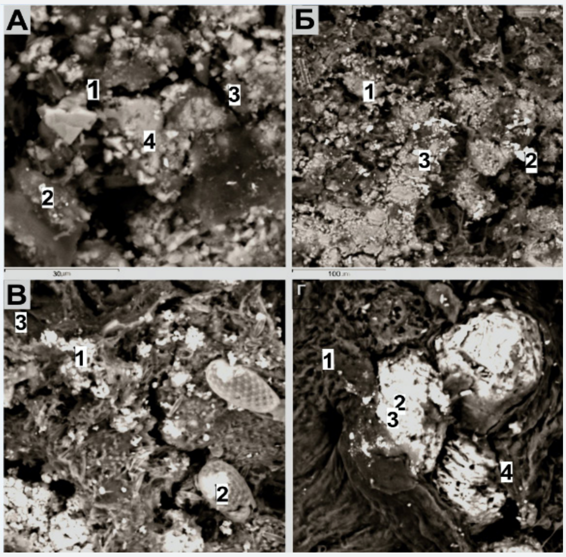

Figure 2: Native elements, intermetallic compounds, and other minerals in bacterial biofilms of Hoyto-Gol resource (A, light yellow film of sulfur bacteria; B, C, yellowish-green film of sulfur bacteria; D, film of purple bacteria). Minerals at analysis points (%): A: 1, native Ni (43.2), eskolaite (16.4), quartz (6.3), pyrite (1.2); 2, calcite (22.6), quartz (7.4), melanterite (6.9), gibbsite (2.2), sylvite (1.0), rutile (0.7), kalicinite (0.3), sulfur (0.2); 3, Fe–Cr–Ni alloy (47.2), calcite (26.6), gypsum (4.9), quartz (4.4), gibbsite (2.1); 4, lime (32.4), calcite (22.9), quartz (1.0); B: 1, calcite (86.5), gypsum (1.8), quartz (1.2); 2, Cr–Cu alloy (80.0), lime (7.2), hematite (6.7), quartz (3.7); 3, Cr–Cu alloy (78.3), lime (8.2), cuprite (6.9), quartz (5.0), hematite (1.6); C: 1, Cu–Cr–Fe alloy (74.2), calcite (12.1), quartz (10.9), szmolnokite (2.8); 2, calcite (6.8), quartz (1.7), gypsum (0.9); 3, quartz (11.1), calcite (11.0), gypsum (4.4); D: 1, mirabilite (3.1), quartz (1.3), nahcolite (1.2), kalicinite (0.7); 2, Zn–Ce intermetallic compound (78.0), calcite (19.6), sphalerite (2.4); 3, Zn–Ce intermetallic compound (84.6), calcite (10.0), quartz (2.9); 4, monazite (49.4), hydroxyl-apatite (10.9), quartz (4.9).

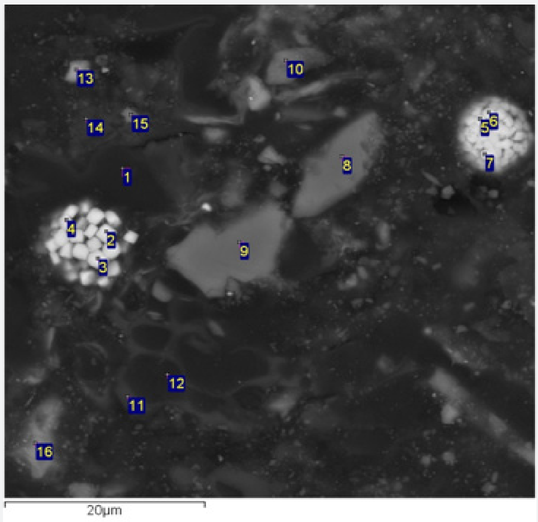

Figure 3: Pyrite framboids in bacterial mat of the resource Zmeiniy. 1 – quartz (2.0%), chloraluminite (0.8%), lavrencic (0.7%), alunogen (1.0%), sulfur (0.3%); 2-7 – pyrite; 8-9 – albite; 10 – K-feldspar (29.4%), quartz (23.4%), corundum (9.6%), anortite (5.7%), goethite (5.6%), magnesite (4.2%), gacela (0.8%); 11 – quartz (6.6%), calcite (5.8%), thenardier (1.8%), sylvite (1.2%), Mercalli (0.4%), nahcolite (0.4%); 12 – hydrophillic (0.9%), calcite (0.2%); 13 – wollastonite (65.9%), calcite (10.3%), magnesite (1.7%), gibbsite (1.0%), siderite (0.9%), sylvite (0.6%); 14 – calcite (6.4%), albite (3.1%), glauberite (2.5%), siderite (2.2%), Apatite (1.9%), magnesite (1.7%), kalicinite (0.6%), nahcolite (0.3%); 15 – calcite (31.3%), albite (3.9%), melanterite (.3%), nahcolite (1.9%), Apatite (1.3%), Mercalli (0.8%), sylvite (0.7%), gibbsite (0.5%), calicinet (0.2%); 16 – K-feldspar (59.0%), albite (33.6%), quartz (2.0%), calcite (1.1%), siderite (0.7%).

Table 1 shows the characteristic bio-minerals associations, generated by bacterial communities functioning in the waters

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of the ground resources, which have different parameters. It follows from their analysis:

– the minimum types number of micro - and nanominerals is proper to microorganisms at living in the most mineralized waters but low and high temperature resources with lower pH values (Arshan and Garga). Their associations are mainly represented by ore minerals (sulfides of Fe and Pb, oxides of Fe and Ti)

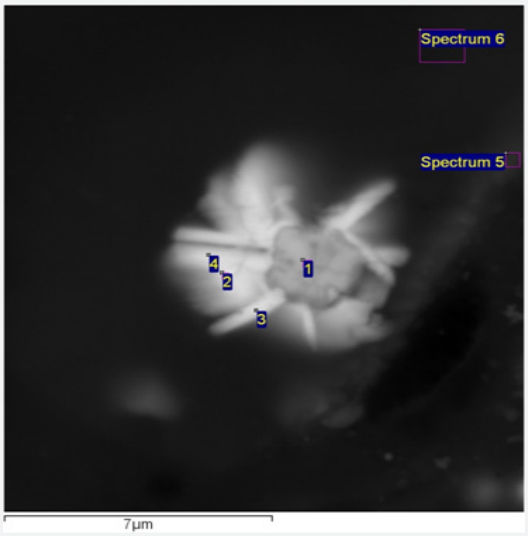

Figure 4: Radial-rayed pyrite-sulphate micro-aggregate in bacterial mat of the resource Zmeiniy. In the center (1 m) – pyrite (57.1%) with carbonate minerals: witherite (9.6%), siderite (9.4%), strontianite (4.7%), nahcolite (1.7%), calcite (1.3%), calcinite (1.0%). The outer sulphate zone of radial-rayed structure (2-4): 2 – barite (51.5%), Celestine (29.9%), melanterite (3.8%), gypsum (1.8%), sulfur (1.0%); 3 – barite (44.9%), Celestine (19.4%), melanterite (7.3%), Mercalli (0.6%), sulfur (0.4%); 4 – barite (45.3%), Celestine (19.4%), melanterite (3.1%), gypsum (2.9%), sulfur (3.1%).

– the greatest number of mineral species are identified in the bacterial mats, films , most low-mineralized moderate - and average temperature water ground sources, with high levels of the alkalinity (Hoyto-Gol, Zmeiniy). Noteworthy is the appearance in these conditions, a significant number of native elements and a variety of intermetallic compounds. There are also widely spread in association with them, carbonates and sulfates (Figure 2-4)

Associations of Bacterial Minerals from Lakes Deposits with Underwater Springs and Micro-Volcanoes Gas-Water Pulp

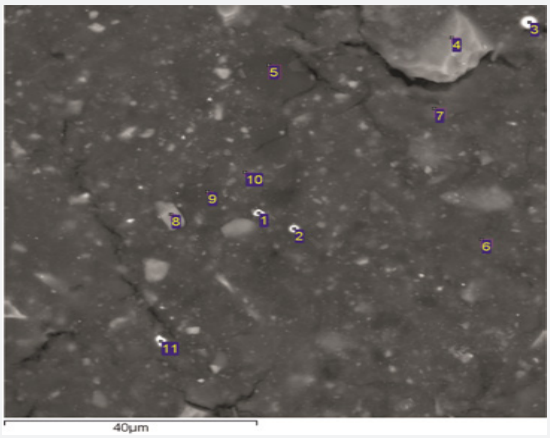

Figure 5: Bacterial film fragment with trace mineral particles, appeared from mud volcanic fluids
1-galenite (60%), partially replaced by cerussite (5%) and with inclusions of standard nanominerals (Fe-Ca carbonate–4%, quart–2%, kaolinite-1%); 2-wuestite (53%) with nanoinclusions of regulatory naccolite (7%), kalkinskit and cerite (5%); 3- wuestite; 4 -native Si with quartz (11%); 5- carbonic matrix with standard nanophases of anorthite (0.8%), tugarinovite (0.7%), calcite (0.5%) and quartz (0.3%); 6 - carbonic matrix with standard nanophases of corundum (15%), anhydrite (6%), garnet with 21% of pyrope minal (5%), halite (2%), anorthite (1%), quartz (1%); 7-carbonic matrix with standard nanophases of quartz (8%), anhydrite (6%), potassium feldspar (6%), sideroplesite (2%), kaolinite (1%); 8 – moissanite (55%) with inclusions of standard nanophases of quartz (11%), calcite (1%) and siderite (1%). The concentration of Corg=32%; 9-arbonic matrix with regulatory nanophases of kaolinite (5%)m goethite (3%), gypsum (1%); 10 – carbonic matrix with standard nanophases of carbonates (magnesite – 11%, calcite - 4%, calcinite - 1%, nahcolite - 1%), boehmite (6%), kaolinite (5%), gypsum (3%), halite (1%); 11 – native Pb (34%) with inclusions of standard nanophases of calcite (2%), sylvite (1%) and goethite (1%). Concentration of Corg =62%.

Table 2: Characteristic (typomorphic) associations of bacterial micro- and nanominerals from lakes deposits with underwater thermal springs and mud micro-volcanoes gas-water pulp.

Aquatic ecosystems (main parameters of micro-organisms habitat)	Research sites	Mineral associations
Low mineralized lakes with high temperature (65-71°C) water alimentation source (M=0.3-0.6g/l, pH=7.5)	Kuliniye swamps	Native S, Ag, with an uranium mixture, Au, Pt, Pd, intermetallic compounds Cu-Sb, pyrite, bereit, Argentina, tetrahedrite, corundum, Ca-Mg carbonates, bismutite, Apatite, mica
Alkaline salt lakes (M=25-230g/l, pH=8.6-9.5)	Hilganta Zun-Torey	Native Au, Ag, Pd, Au-Ag alloy, pyrite, ilmenite, magnetite, hematite, calcite, barite, Celestine, Apatite, chlorite
Gas-water pulp from mud micro volcanoes griffons	Aunik river valley	Native Si, Pb, Al, moissanite, Galena, wustite, goethite, rutile, girokastra, corundum, bemit, magnesite, calcite, siderite, nahcolite, calcite, calcinskite, cerite, anhydrite, barite, gypsum

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In the low mineralized lake Kuliniye swamps with high temperature underwater springs (Table 2), unlike aquatic media formed by ground resources, among native elements, formed by bacteria, the leading position is occupied by the noble metals, sulfides Sn, Ag, Bi appear and the intermetallic compounds Cu-Sb too.

The crystallization of the noble metal particles is also associated with the cyanobacterial mats of the salt lake Hilganta, but the formation of the above-mentioned sulphides is not seen. The bacterial minerals are related in particular group (Figure 5), formed in ground conical structures of actual mud micro-volcanoes during the small portions ejection of a gas-water pulp.

Table 3: Micro- and nanomineral associations in bacterial communities films and mats of resource Hoyto-Gol.

Functional Groups Of Bacterial Communities	Featured Micro- and Nanominerals Associations
Sulfur bacteria (T=33.5 oC, pH=7.5)	The native S, Si, Ni, and Al, intermetallic compounds Fe-Cr-Ni, Cr-Cu-Fe, Cr-Cu, pyrrhotite, pyrite, eskolaite, rutile, periclase, wustite, manganosite, tenorit, cuprite, corundum, lime, sylvite, halite, fluorite, nahcolite, siderite, magnesite, rhodochrosite, smolnica, melanterite, epsomite, anhydrite, thenardier.
Purple bacteria (T=32.9 oC, pH=8.2)	The intermetallic Zn-Ce, sphalerite, covellite, manganite, lime, siderite, magnesite, malachite, thenardier, salts, monazite, vitlacit, hydroxyl-Apatite.
Cyanobacteria (T=31.4-31.8 oC, pH=8.3-8.8)	Intermetallics Cr-Cu, Zn-Cu, sylvite, halite, dolomite, lasso, salts, melanterite, keseric, butit, monazite
Common minerals	Goethite, calcite, calicinete, gypsum

On the example of the resource Hoyto-Gol bacterial communities it is established that (Table 3) the different functional micro-organism groups have not similar ability for mineral formation. Cooperative interaction of various microorganism kinds and groups, making local alkaline and oxidative geochemical barriers, provides selective nature of chemical elements bioaccumulation processes from the water medium. Typically, a high initial level of micro-component contents in the alkaline waters of mineral springs, soda and salt lakes, meets the bacteria need in the transition metals. In case of latter deficit in the water the source of these elements are the enriched with them remains of water and ground vegetation, decomposed and oxidized by bacteria-destructors (saprophytes and cellulitics). Bacteria-the organic matter destructors, create a favorable environment for bacteria life support of other functional groups (resource Hoyto-Gol), making available to absorb trace components extracted from the phytomass.

Note: In brackets - the parameters of the water habitat microorganisms. Sulfer bacteria -Thiothrix sp, Beggiatoa sp; purple bacteria, closed to Rhodopseudomonas palustris, Rhodobacter capsulatus, Thiocapsa sp, Chlorobium sp; cyanobacteria - Oscillatoria, Phormidium, Anabaena.

Conclusion

Table 4: Bacterial micro- and nanominerals associations formed at the bacterial mats intersections by the gas-oil fluids microchannels.

Research Objects	Mineral Associations
Resource Zmeiniy	Native Fe, Ag, Au, Pb, intermetallics Fe-Cr-Ni, pyrite, sphalerite, bereit, bismuthic with native Fe, barite
Resource Garga	Native Cr, C (graphite), Au, intermetallics Ti-Cr, Ti-Cr-Fe, pyrite, rutile, calcite, barite, hydromica, xenotime, kyanite
Kuliniye swamps	Native Fe, Au, sulfur, intermetallics Fe-Cr-Ni, pyrite, Galena, cinnabar, tetrahedrite with a mixture of Zn and Ag, the carbonates of the rare earths, calcite, ankerite, anglesite, barite, barite-Celestine
Resource Arshan	Native Fe, Zn, Ag, C (graphite), pyrite, Galena, bismuthine, Argentina, fahlores, ilmenite, rutile, wolframite, hematite, massicot, xenotime

The most important factor of micro- and nanominerals crystallization in bacterial mats - is an evaporative geochemical barrier. In the course of drying, the bacteria, to survive, deliberate themselves from elements-catalyst (transition, partially noble metals) converting them into mineral form of native elements, intermetallic compounds (Fe-Cr-Ni, Cr-Ni, Cr-Cu, Cu-Zn, Zn-Sn, Cu-Sn), oxides, sulphides, carbonates and sulfates (wustite, hematite, magnetite, ilmenite, powellite, cassiterite, sphalerite, Galena, pyrite, covellite, malachite, zinkosite etc.). Elements -catalysts ions, initially in varying degrees, are accumulated primarily by polymer macromolecules of proteins, nucleic acids and polysaccharides, being a part of bio-organic crystals. The latter one, in the dehydration process, is transformed into mineral solid crystalline phases, which use structured biogenic organic matrix as samples and "patterns" [1].

Most part of Au, Ag, Pt, Pd in dried bacterial films is in the form of organometallic compounds and only 10-15% is in the form of native elements and intermetallic compounds. The most widely spread in the dried bacterial mats and films are quartz, carbonates, Ca, Fe, Mg and Mn, sulphates (Fe, Ba, etc.) and chlorides, the quantitative ratio of which is determined by macro-components content values in the microorganisms water habitat.

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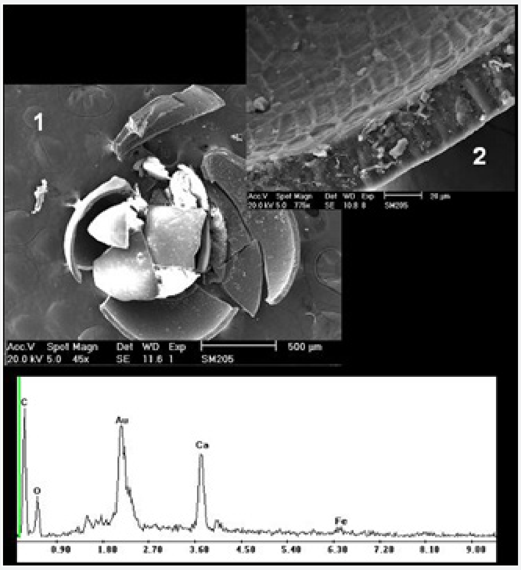

Figure 6: Carbonaceous hollow microspherule of gas-oil origin (pyrolysis product) from sand-silt depositions of thermal spring Zmeiny 1 - a fragment of shattered spherule; 2 - microstructures of the spherule fragment: on the inner wall - net-like, in the-cross section - columnar. Carbon contains nanoparticles of gold.

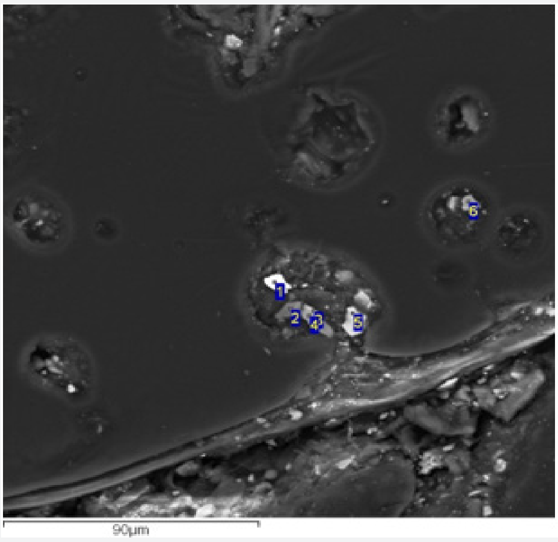

Figure 7: Bacterial mat of Kuliniye swamps sandy-silt mud volcanic deposits, interpenetrated with gas-oil fluid mineralized microchannels 1 -intermetallics Fe-Cr-Ni, 2- Fe-Mg carbonate with a sericite mixture 3 - Fe-Mg carbonate with a quartz mixture, 4 - Fe-Mg carbonate, 5 -calcite, 6 - corundum.

Mud volcanic feature of the Transbaikalia aquatic ecosystems is their participation in gas-oil fluids formation, creating an ecologically extreme environments for the existence of bacterial biocenoses (communities) and often leading to death, in particular, microorganisms combustion, their biomass transformation into crystalline carbon. In areas of bacterial mats crossing by microchannels, through which the gas-oil fluids enter due to thermal transformation of living matter, releasing from it and also additional supply by the fluids of many micro-components, the specific micro - and nanomineral, fluid-combustion metamorphic association, represented with native elements (Fe, Au, Ag, Cu, Zn, S, graphite), intermetallics (Ni-Cu, Fe-Cr-Ni, Fe-La-Ce-Si, Ce-La-Nd-Pr), cogenite and other minerals are formed (Table 4, Figure 6-8).

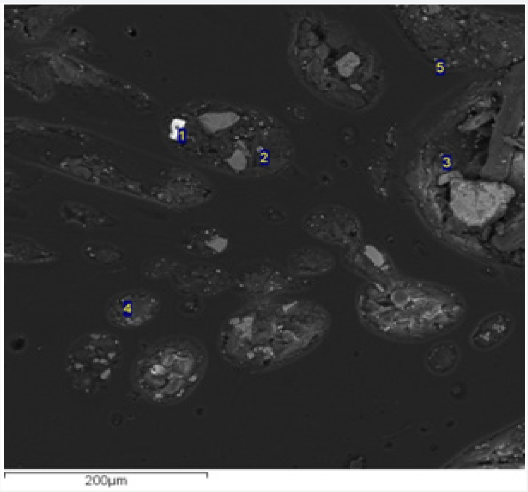

Figure 8: Bacterial mat of Kuliniye swamps sandy-silt mud volcanic deposits interpenetrated with gas-oil fluid microchannels 1 - barite, 2 - brimstone with insanit (Pd=0.81%), 3 -Au nanoparticles in the oil fluid carbonaceous matter, 4- Galena , 5 - native iron.

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