BIOGENIC NATURE OF CORROSIVITY OF SULPHIDE DESPOSITS MINE WATER AND SOME OF ITS GEOCHEMICAL AND MINING-TECHNICAL IMPACTS

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ABSTRACT

Any ore deposit under production represents an open thermodynamic system. The composition and properties of the solid, liquid and gaseous phases of this system are gradually changed answering the changes in physical-chemical conditions in the process of hypergenesis.

In the development of sulphide deposits with underground mine workings a sharp activization of these processes under the impact of aerobic autotrophic and heterotrophic microorganisms activity takes place. This is followed by mine water enrichment with biogenic components (sulphuric acid, ferric sulphate, organic complexes, carbon dioxide) and formation of mine water corrosivity.

The impact of this water on ore and rock-forming minerals causes irreversible changes in their crystalline-chemical structure, decrease in strength and elastic properties, removal of metals outside the boundaries of ore bodies. This results in lessening ore and enclosing rock stability, ore impoverishment, destruction of concrete mine lining, corrosion of metal constructions and mining electrical equipment, hazardous possibility of surface water contamination by mine water.

ORE DEPOSIT - OPEN THERMODYNAMIC SYSTEM

The state, composition and properties of ore, ore-enclosing rocks and ground water interacting with them directly in the massif are continuously transformed in accordance with changing-in-time physical-chemical conditions in this open thermodynamic system.

The example of such transformations is the change of geoenvironment during a continuous formation of the natural oxidation zones of sulphide ore deposits, as well as rapid transformations when opening an ore body by mine workings at the stages of prospecting and production.

In the latter case these transformations are mainly accounted for by acceleration of the water exchange process which leads to intensification of ore aeration at the expense of dissolved oxygen, increase in nearsurface biogenic organic matter entering the ore bodies, development of biochemical ore oxidation processes and sharp activization of biogenic oxidative destruction of ore and rock-forming minerals in the zone of ore oxidation and dispersion haloes of soluble products of aerobic microorganisms activity.

MICROFLORA - MAIN SOURCE OF COMPONENTS OF MINE WATER CORROSIVITY

Aerobic bacteria - autotrophs

Ore destruction by mine water was attributed for a long time mainly to Thiobacillus ferrooxidans and Th. thiooxidans due to a well-known manifold intensification in their presence of the processes of sulphide oxidation and leaching of iron, copper, zinc and other metals out of them. This effect is accounted for by the direct action of the above mentioned bacteria, as well as sulphuric acid and ferric sulphate produced by them [I].

Aerobic heterotrophic microorganisms

The results of the studies carried out in a number of ore provinces of the USSR showed that heterotrophic microflora has a not less influence on the formation of mine water corrosivity. Quantitatively, it amounts to 50% of the biomass of acid mine water and to about 100% of bacterial population of low-alkaline and close-to-neutral mine water.

The main source of energy for the growth of heterotrophs are the processes of oxidative destruction of the organic matter of ore and enclosing rocks which passes into a soluble state.

The total amount of organic carbon in ground water of the studied copper pyrite deposits varies in the range of 16.3-99.5 mg/l. This water is characterized by a high content of carbon of non-volatile compounds (7.1-79.6 mg/l or 31-90% of the total organic carbon) including carbon of humus and bituminous compounds, high-molecular acids, phenols and hydrocarbons. The content of carbon of low-molecular saturated carboxylic acids - formic, acetic, butyric, caproic and valeric acids - is rather low (3.9-24.8 mg/l or 6-50%). The content of organic carbon of volatile neutral and main compounds - benzenes, spirits, aldehydes, etc. - is even lower (1.2-5.6 mg/l or 2.4-25.4%).

The above mentioned compounds possessing a complex-forming capacity intensify mine water corrosivity and its dissolving power. Their presence in water results in activization of ore- and rock-forming minerals destruction and removal of leached components outside the boundaries of ore deposits due to a wide development of the processes of metallo-organic compounds synthesis.

Metallic content in such a form may amount to more than 35% of the total cation composition of mine water.

Analogous results are obtained when studying complex deposit, ore and enclosing rocks of which are enriched with pyrite. However, the most important factor in this case is activization of the process of removal out of rocks of Ca and Mg which belong to main lithophilous elements. Mine water containing these cations have a wide-spread occurrence. The share of calcium organic complexes in 20 samples varies in the range of 0.0-66.7% of their total content in complex deposits water, the mean value is 19.8%; for magnesium in 18 samples - 0.0-99.1% (75.7%).

On the other hand, organic matter of ore and ore-enclosing rocks is often an active reducer of metals and its decomposition by heterotrophs leads to intensification of oxidation processes in ore.

The activity of mine water mocroflora results also in mine water enrichment with carbon dioxide, the concentration of which exceeds in tens of times the CO_2 - concentration in water which is in equilibrium with CO_2 - concentration in air.

Thus, considering the simultaneous development of purely chemical and bio-geo-chemical oxidation processes in ore one can see that passing of solid phase components into the solution is to a greater extent accounted for by the influence of biogenic factor, i.e. not so much the influence of dissolved oxygen on the minerals, as the production of H^+- and sulphate ions by aerobic microflora, as well as organic complexes, oxidative cations and carbon dioxide, responsible for superimposed hydrolitic, sulphur acid, oxidation and carbon dioxide decomposition of ore and enclosing rocks under redox and main-acidic conditions of the geoenvironment.

AFTEREFFECTS OF BIOGENIC INTERNSIFICATION OF MINE WATER CORROSIVITY

The study of regularities of the processes occurring within the boundaries of ore deposits under the action of corrosive mine water formed under the impact of biogenic factor has a scientific and applied value for the solution of the problem of environmental and ground surface protection and, in particular, for the development of methods for the prevention of ore impoverishment, deterioration of physical-chemical properties of rocks and lessening of mine lining stability, intensive corrosion of mining equipment and ground surface contamination by mine water.

Ore impoverishment

Development of biogenic sulphuric acid ore leaching during acid sulphate solutions formation within oxidation zones of sulphide deposits is followed by mine water enrichment with metals and removal of them in dissolved state outside the boundaries of ore bodies.

In the absence of special protective measures the above mentioned biogenic processes result in ore-forming material removal which may progress and reach 10-15% of the total weight of rocks removed to the ground surface.

Change in mining-technical conditions

The above processes are followed by a marked decrease in strength and elastic properties of rocks. These changes are associated with disturbance of structural bonds between rock-forming minerals, irreversible transformation of crystalline-chemical structure of the minerals, as well as natural and technogenic defects of rocks (tectonic and technogenic fissures, cavities of leaching, etc.).

A laboratory simulation of the process of interaction between rocks and solutions similar to complex deposits water was performed for a quantitative estimation of the mine water impact on rock properties.

Laboratory simulation data

The results of simulation of the interaction process of sulphate (pH-3.05), sulphate-hydrocarbonate (pH-7.35) and hydrocarbonate (pH-8.1) solutions with sedimentary (aleurolite) and igneous (porphyrite, quartz porphyry, tuff, tufflava) rocks showed that even a comparatively short-term contact of solid phase with liquid phase (35 days) is followed by significant changes in elastic properties of rocks [2].

The determination of the ultimate compression strength and elastic waves rate after each three days of interaction between the solution and rock showed irregularity of the above properties change. An active interaction between the solution and rock is observed during the first 20 days and then it is slowed. In the first period, the rock strength decreases by 30-55% comparative to the strength of rock in air-dry state, and the rate of elastic waves decreases by 8-12%.

Most intensive decrease in strength and elastic properties of rocks is observed under the action of acid sulphate solutions; alkaline and low-alkaline solutions produce a less effect on rocks.

No doubt that biogenic factor, which is of a special importance in the formation of chemical composition of acid sulphate water of ore deposits, has a great influence on transformation of the composition and properties of ore and ore-enclosing rocks during each deposit production.

Field observation data

The results of the studies showed that most intensive water activity occurs at pyritiferous ore deposits. High acidity of mine water is observed in close vicinity to ore bodies where the water exchange between the horizons under production is most active. Particularly here, oxidation of sulphide minerals, oxigenated during production, takes place. High acidity of mine water promotes lessening of enclosing rock stability and produces a corrosive effect on concrete lining of mine workings, metallic mine constructions and mining electrical equipment.

Chemical weathering of rocks, as well as concrete destruction under the action of chemically active mine water is observed at ore deposits under production in the zones of groundwater drainage. The weathered rocks obtain brown colour as a result of iron hydroxides formation. Over 1-3 years of exploitation the thickness of weathered rocks amounts to 1-5 cm. In places of highly corrosive water discharge a complete loss of load-carrying capacity of sprayed concrete base takes place, the latter converts into loose mass over the period of 3 years.

Surface water contamination

Underestimation of biogenic factor during long-term mine life leads to adverse impact of mine water on surface water, if protection of the latter is insufficient.

The efforts toward neutralization by lime and treatment of mine water are followed by slag accumulation in settling ponds and sometimes are insufficient to provide for absolute surface water protection. The studies revealed a hazardous possibility of surface water pollution by biogenic metallo-organic compounds of iron, aluminium, zinc in amounts exceeding MPC in many times.

CONCLUSIONS

The development of measures of the geoenvironment and ecological balance protection in mining regions should be carried out with allowance for biogenic nature of mine water corrosivity. In addition to a further modification of waste treatment techniques, the methods for the prevention of microbiological ore oxidation within the boundaries of ore deposits should be developed.

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