Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu.dp.ua

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph. Geology, 32(1), 059-066.
doi:10.15421/112307

Study of spontaneous combustion of the main industrial types of sulphide ores of sulphide-polymetallic deposits of Azerbaijan

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Received 28.11.2021;
Received in revised form 10.03.2022;
Accepted 28.11.2022

Abstract. The article is devoted to the study of the causes and conditions of spontaneous combustion of sulphide ores, which may result in endogenous fires that complicate mining operations in mines, causing enormous material damage to the national economy, and often also leading to human casualties. There are several sulphide-polymetallic deposits in Azerbaijan, the reserves of which were approved back in the days of the USSR. Of these, the Filizchay deposit is the most unique in terms of its reserves and ore composition. The development of other deposits adjacent to the Filizchay deposit, separately, is inexpedient because of their small reserves. However, the development of sulphide-polymetallic deposits in Azerbaijan is complicated by the revealed tendency of industrial types of ores to oxidation and spontaneous combustion. In this regard, there was a need for a special study of the chemical activity of sulphide ores and the phenomena accompanying oxidative processes, taking into account the natural features of the deposits in order to obtain the initial parameters necessary for scientifically based technological solutions for their development. Sulphide ores of sulphide -polymetallic deposits of Azerbaijan significantly differ in material composition, conditions of occurrence and mining technical features of their development from the listed deposits, the issues of spontaneous combustion of which have been studied for a long time. Until now, there are no general criteria for assessing the fire hazard of sulphide ores, suitable for any deposit, since the conditions for the occurrence of underground fires at different deposits are different. It is this circumstance that makes it necessary to conduct special studies for each deposit separately. Therefore, the need for a special study of this problem on the example of the conditions of sulphide-polymetallic deposits in Azerbaijan, which are prone to oxidation and spontaneous combustion, is of great importance. Identification of causes and factors affecting spontaneous combustion of sulphide ores, classification of sulphide-polymetallic deposits of Azerbaijan according to the degree of their tendency to spontaneous combustion by analyzing the collected materials, as well as by the results of studies to determine the oxidative activity of sulphide ores. The article presents the results of experimental studies to determine the oxidative activity and spontaneous combustion of sulphide ores of the Katsdag, Filizchay and Katekh deposits, carried out in laboratory conditions by the method of Institute of Mining named after. A.A. Skochinsky, the basis of which is the determination of the oxygen absorption rate constant. It is known that the susceptibility of ore to spontaneous combustion is determined by its oxidizability at low temperatures and depends on a large number of factors. In this regard, the dependence of the total amount of oxygen absorbed by sulphide ores on time has been studied, it has been established that the rate of oxygen absorption by sulphide ores is long-live and slowly fading, but incessant. On the basis of extensive experimental material, a classification of sulphide ores of Azerbaijan according to the degree of tendency to spontaneous combustion according to low-temperature oxidation is proposed, since it is this that forms the basis of the spontaneous combustion process. The classification is also based on differences in textural and structural features and mineralogical composition of ores. Of great interest is also the influence of the size of the free reacting surface of the ore on the oxidation process. Analysis of ore samples shows that for their spontaneous combustion, the most dangerous are its coarse fractions than the dust. The results of the conducted studies allow a scientifically sound approach to planning the sequence of development and designing mines.

Key words: sulphide ore, sulphide-polymetallic deposit, oxygen absorption, oxygen absorption rate constant, oxidation, spontaneous combustion, tendency of ore to self-ignite.

Дослідження самозаймання основних промислових типів сульфідних руд колчеданно-поліметалічних родовищ Азербайджану

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Анотація. Стаття присвячена дослідженню причин та умов самозаймання сульфідних руд, в результаті якого можуть виникати ендогенні пожежі, що ускладнюють на рудниках ведення гірничих робіт, що завдають величезних матеріальних збитків

народному господарству, а нерідко також призводять до людських жертв. В Азербайджані є кілька колчеданно-поліметалічних родовищ, запаси яких затверджені ще за часів СРСР. З них Філізчайське родовище є найбільш унікальним за своїми запасами та складом руди. Розробка інших, що примикають до Філізчайського, родовищ окремо недоцільна через невеликі запаси їх. Однак освоєння колчеданно-поліметалічних родовищ Азербайджану ускладнюється схильністю промислових типів руд до окислення і самозаймання, що виявилася. У зв'язку з цим виникла необхідність спеціального вивчення хімічної активності сульфідних руд та явищ, супутніх окисних процесів, з урахуванням природних особливостей родовищ для отримання вихідних параметрів, необхідних для науково-обґрунтованих технологічних рішень щодо їх розробки. Сульфідні руди колчеданно-поліметалічних родовищ Азербайджану значно відрізняються за речовинним складом, умовами залягання та гірничотехнічними особливостями їх розробки від перерахованих родовищ, питання самозаймання яких досліджувалися протягом тривалого часу. До цих пір не існує загальних критеріїв оцінки пожежонебезпеки сульфідних руд, придатних для будь-якого родовища, оскільки ситуація виникнення підземних пожеж на різних родовищах різна. Саме ця обставина змушує проводити спеціальні дослідження для кожного родовища окремо. Тому необхідність спеціального вивчення цієї проблеми на прикладі умов колчеданно-поліметалічних родовищ Азербайджану, які мають схильність до окислення і самозаймання, набуває дуже важливого значення. Виявлення причин і факторів, що впливають на самозаймання сульфідних руд, класифікація колчеданно-поліметалічних родовищ Азербайджану за ступенем їхньої схильності до самозаймання шляхом аналізу зібраних матеріалів, а також за результатами досліджень щодо визначення окисної активності сульфідних руд. У статті наводяться результати експериментальних досліджень щодо визначення окисної активності та самозаймання сульфідних руд Кацдаг, Філізчай та Катехського родовищ, проведені в лабораторних умовах методом Гірничого Інституту ім. А.А. Скочинського, основою якого є визначення константи швидкості поглинання кисню. Відомо, що схильність руди до самозаймання визначається її окислюваністю за низьких температур і залежить від великої кількості факторів. У цьому дослідженні вивчен загальної кількості поглиненого кисню сульфідними рудами від часу, встановлено, що швидкість поглинання кисню сульфідними рудами носить тривалий і повільно загасаючий, але безперервний характер. На великому експериментальному матеріалі запропоновано класифікацію сульфідних руд Азербайджану за ступенем схильності до самозаймання за даними низькотемпературного окислення, оскільки саме воно становить основу процесу самозаймання. В основу класифікації покладено також відмінності в текстурно-структурних особливостях та мінералогічному складі руд. Великий інтерес представляє також вплив величини вільної поверхні руди, що реагує, на процес окислення. Аналіз проб руд показує, що для їх самозаймання найбільш небезпечними є більші фракції, ніж пил. Результати проведених досліджень дозволяють науково обґрунтовано підійти до планування черговості освоєння та проектування копалень.

Ключові слова: сульфідна руда, колчеданно-поліметалеве родовище, поглинання кисню, константа швидкості поглинання кисню, окислення, самозаймання, схильність руди до самозаймання.

İntroduction

Sulphide ores are characterized by increased activity to atmospheric oxygen. During their development, along with the release of natural and tecnological gases due to low-temperature oxidation, significant oxygen losses, self-heating and the appearance of sulphur dioxide occur, as well as under favorable conditions a large amount of dead air is formed.

The presence of dead air poses a real danger to miners, since deoxygenated air accumulates in isolated workings or voids formed as a result of excavation of a mineral. When these accumulations and voids are opened by mine workings, dead air is released into the workings. This is confirmed by the practice of developing sulphide deposits in the Urals, Norilsk and Azerbaijan, during the development of which there have been cases of a significant decrease in the oxygen content in the atmosphere of mine workings.

As a result of the oxidation and spontaneous combustion of sulphide ores, endogenous fires arose, complicating mining operations in the mines and causing enormous material damage to the national economy. In practice, ores of those deposits were usually considered prone to spontaneous combustion, on which endogenous fires occurred during their exploitation. As a result, these mines were unprepared for fire suppression. This situation led, firstly, to temporary conservation or even to the irretrievable loss of part of the ore reserves prepared for excavation in the zones of their spontaneous combustion and, secondly, to large expenditures of material and labor resources for the prevention and control of self-heating and spontaneous combustion of sulphide ores. A typical example is the practice of developing copper pyrite deposits in the Urals, the Tekeli polymetallic deposit (Kazakhstan), Ain-Ben Meruan (Algeria), United Verde (Arizona, USA), Homestake (Black Hills, South. Jakota, USA), Chiragidzor, Gadabay (Azerbaijan), Sullivan (Canada), etc. (Veselovsky et al., 1974; Zaitseva et al., 1975; Ismayilov, 1975; Pikhlak, 1974; Rapp, 1975; Ermolayev and Teterev, 2015).

From a social standpoint, spontaneous combustion of sulphide ores is dangerous to the health and life of workers in underground workings. Firstly, due to the reduction to dangerous concentrations in the mine atmosphere of oxygen absorbed by sulphide ores during intensive oxidative processes; secondly, an increase in the content of unsuitable (CO_2) or toxic (SO_2, CO, etc.) products of oxidation and subsequent combustion in the air (Zholmagambetov et al., 2017; Chao Wu. et al., 2005; Liu Hui et al. ., 2011; Hui Liua,

et al., 2010). So, for example, at the Sunshine silver mine (USA), a fire caused by spontaneous combustion of pyrite rocks with crushed wood killed 92 people out of 173 who were in the mine.

Therefore, a mandatory item was included to the SCR instructions for calculating reserves, requiring the study of the spontaneous combustion of sulphide ores during detailed exploration and calculation of the reserves of the deposit (Fig. 1).

Sulphide-polymetallic deposits of Azerbaijan are composed clayey-shale sandstone of Jurassic age. Mineralization is represented by one (Filizchay) or several (Katekh, Katsdag) lenticular deposits, which include sulphide minerals, quartz and carbonates. The sulphur content in ores reaches 45-50%. According to the mineralogical composition, the main part of the ores is consist by pyrrhotite, pyrite, sphalerite, galena, chalcopyrite and the subordinate arsenopyrite and magnetite. Detailed exploration has been completed at the deposits, reserves have been approved, and it is planned to start developing the Filizchay deposit in the near future.

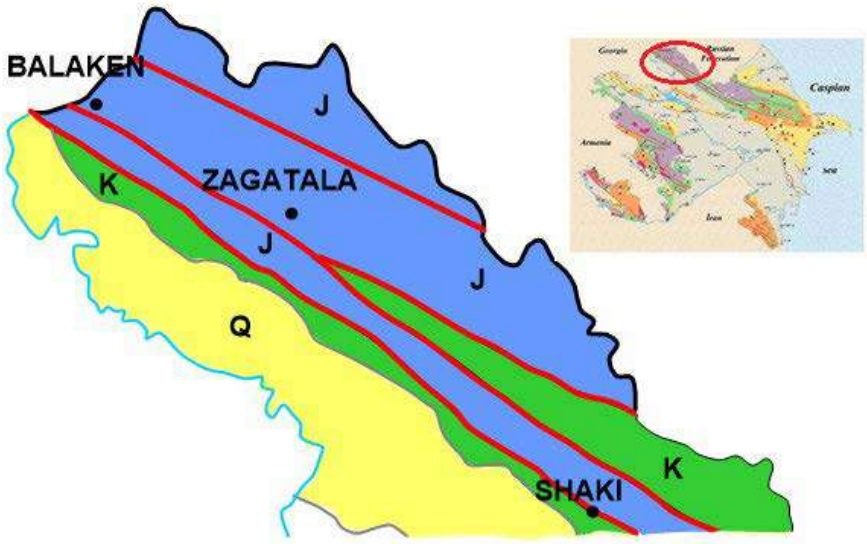


Fig. 1. Overview map of Azerbaijan

The Filizchay deposit is considered one of the biggest in the world and is the most unique by of its reserves and ore composition. The development of other deposits adjacent to the Filizchay, separately, is impractical due to small reserves.

The development of sulphide-polymetallic deposits in Azerbaijan is complicated by the revealed tendency of industrial types of ores to oxidation and spontaneous combustion (Ismayilov, 1975). Cases of self-heating and a significant decrease in the oxygen content in the atmosphere of workings were observed in the exploration workings of deposits of sulfide ores in Azerbaijan. Using the rich experience of similar mines to prevent the oxidation and spontaneous combustion of ores is not possible without knowledge of the properties of ores that characterize their oxidative activity and are determined experimentally.

In this regard, there was a need for a special study of the chemical activity of sulphide ores and the phenomena accompanying oxidative processes, taking into account the natural features of the deposits in order to obtain the initial parameters necessary for scientifically based technological solutions for their development.

It is known that the tendency of ore to spontaneous combustion is determined by its oxidizability at low temperatures. This is a special case of oxidizability, and the spontaneous combustion of ore is due not only to oxidation, but also to heat exchange with the environment. (Veselovsky et al., 1974; Zholmagambetov et al., 2017).

The tendency of ore to spontaneous combustion depends on a large number of factors. Therefore, it is extremely difficult to establish any single-phase criterion determined by the method of laboratory tests of ore samples. There are many laboratory methods for testing the chemical activity of solid fossil fuels (Veselovsky et al., 1974; Zaitseva et al., 1975; Ismayilov, 1975).

The disadvantages of all these methods lie in the fact that the oxidation of coal or ore with gaseous oxygen was replaced by oxidation at increased temperatures, except for the compensation method and the IM method. Named after A.A. Skochinsky, since it is

easily reproduced in laboratory conditions. Most research methods are based on continuous heating of a sample (Liu Hui, et al., 2011; Fu-qiang Y. et al., 2014; Manakov et al., 1964; Murphy et al., 2009; Hui L. et al., 2010; Stepanov et al., 1974; Chao Wu., et al., 2005; Somot et al., 2010; Iliyas et al., 2011; Wang H., et al., 2013). Naturally, in this case, not the processes that take place in reality at the mine are reproduced (Skochinsky, 2011).

It should be noted that only the method for determining chemical activity and the compensation method for determining heat release, where the experimental conditions are close to natural, correspond to modern concepts of physical chemistry (Veselovsky et al., 1972; Zaitseva et al., 1975; Pikhlak, 1974; Zhislina, 1964; Zhang, et. al., 2014; Zhi, et al., 2015).

The tendency of sulphide ores of sulphide-polymetallic deposits of Azerbaijan in terms of their tendency to oxidation and spontaneous combustion was studied in laboratory conditions by the method of IM named after. A.A. Skochinsky (Veselovsky et al., 1974; Ismayilov, 1975;). An indicator of chemical activity is the oxygen absorption rate constant – U (ml/g· hour), the value of which for the main industrial types of ores of the studied deposits ranges from 0.072 to 0.005 ml/g·hour (Table 1) (Ismayilov, 1975).

Table 1. Classification of sulphide ores according to the degree of tendency to spontaneous combustion

Deposits	Types of ore	The oxygen absorption rate constant U, ml/g· hour	The tendency to spontaneous combustion
Katsdag	Massive pyrrhotite	0.072	Most tendency
	Stringer-disseminated quartz – chalcopyritic	0.016	Tendency
Filizchay	Banded pyrite – polymetallic	0.030	Most tendency
	Massive pyrite	0.015	Tendency
	Spotted-disseminated pyrite	0.006	Low tendency
Katekh	Massive galena-sphalerite-pyrite	0.011	Tendency
	Clastic shape-massive, galena-sphalerite-pyrite	0.008	Low tendency
	Stockwork-stringer-pyrite-sphalerit -galena	0.005	Low tendency

We have proposed to classify sulphide ores of sulphide-polymetallic deposits according to the power of tendency to spontaneous combustion according to low-temperature oxidation, since it is this that consists the basis of the spontaneous combustion process.

Since spontaneous combustion is a physicochemical process, a reliable classification of sulphide ores according to the power of tendency to spontaneous combustion can only be obtained taking into account the chemical activity of sulphide ores with respect to atmospheric oxygen during low-temperature oxidation (Table 1). The classification is based on differences in textural and structural features, mineralogical composition and rate of oxygen absorption constant by sulphide ores (U, ml/g h). According to these signs, various mineralogical groups of ores with similar spontaneous combustion indices are combined.

Ores whose activity is equal to or less than the activity of barren gabbro-diabases are accepted as non-hazardous in terms of spontaneous combustion, since cases of their spontaneous combustion are unknown in practice. (Veselovsky et al., 1974; Pikhlak, 1974; Gorinov, and Maslov, 2017).

According to the proposed classification, massive pyrrhotite ores of the Katsdag and pyrite-polymetallic ores of the Filizchay deposits are highly prone to spontaneous combustion. Stringer-disseminated quartz-chalcopyrite, massive pyrite-pyrrhotite and massive galena-sphalerite-pyrite ores are hazardous, and other types of sulphide ores of the studied deposits are less hazardous.

As studies have shown that the massive pyrrhotite ore of the Katsdag deposit has the highest activity, which in terms of U value is close to the most active ores of the Norilsk copper-nickel deposits.

The results of laboratory studies have shown that the total amount of oxygen absorbed by ore, rock and wood is determined by the dependence (Fig. 2).

$$Q_{abs.O_2} = A\tau^a; \; ml/g \qquad (1)$$

where $Q_{abs.O_2}$ – total amount of absorbed oxygen of 1 g of ore, rock or wood, *ml; A* – coefficient, numerically equal to the amount of oxygen absorbed by ore, rock and wood at τ *= 1 hour, ml/g· hour*, that in this case $Q_{abs.O_2}$ *= A,* τ – time of contact of ore, rock and wood with atmospheric oxygen, *hour, a* – coefficient, characterized intensity of slowdown of oxygen absorption rate of air by time.

The coefficients A and a for various types of ores are determined by processing the results of experiments using the least squares method (with a correla-

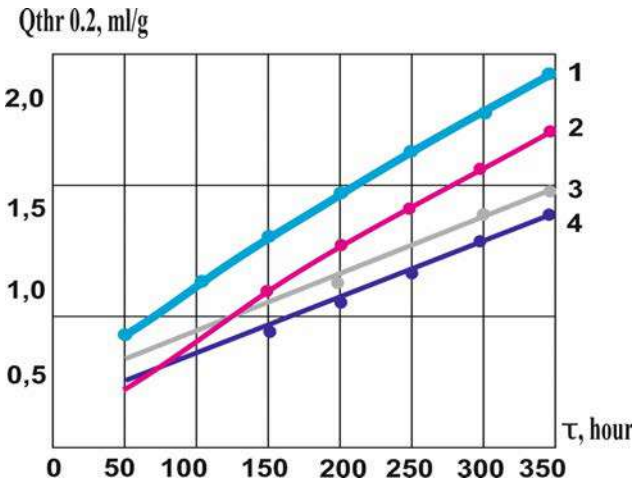
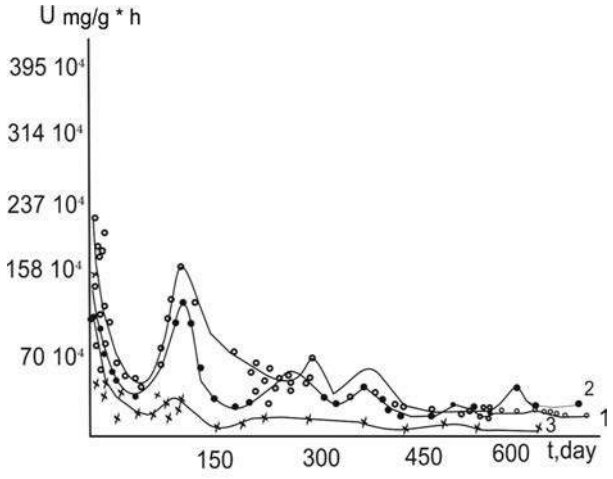


Fig. 2. Dependence of the total amount of oxygen absorbed by sulfide ores on time: 1 – massive pyrrotite ore of the Katsdag deposit; 2 – strip-coloured pyrite ore of the Filizchay deposit; 3 – vein-impregnated ore of the Katsdag deposit; 4 – massive galena-sphalerite-pyrite ore of the Katekh deposit



○ 1 – Ore of the Katsdag deposit
● 2 – Ore of the Filizchay deposit
x 3 – Ore of the Katekh deposit

Fig. 3. Dependence of the rate constant of de-oxygenation by sulfide ores based on time

tion coefficient of 0.78-0.92 A=0.0029-0.0185 ml/g hour, a = 0.7-0.9, depending on the type of ore). In most cases, the values of the coefficient characterizing the intensity of the slowdown of oxygen absorption over time at the same temperature differ slightly.

During the oxidation of freshly fragmented ore, the initial absorption of oxygen proceeds rapidly (Fig. 2, Table 2), in this case an oxide layer is formed, which prevents further oxidation. Further, the process slows down, representing not a monotonically decreasing, but a pulsating function in time, which is explained by a change in the distribution of electrochemical potentials and the concentration of hydrogen ions (pH) on the ore surface.

Studies carried out over several years have shown that the oxygen absorption rate by sulphide ores is long-live and slowly fading, but unceasing in nature (Fig. 3, Table 2). Slowdown of the oxygen absorption rate not occur along a monotonically decreasing curve, but along a sinusoidal one, which is explained by the periodic destruction of a part of the oxidized layer. As studies have shown that the period between the destruction of the oxidized layer depends on the type of ore.

Table 2. Change of the oxygen absorption rate by sulphide ores depending on the time of contact with air

Ore types	Oxygen absorption rate constant for the period from the beginning of the experiment, ml/g hour							
	0-24 hour	50-250 hour	50-500 hour	50-1000 hour	50-2000 hour	50-5000 hour	50-10000 hour	50-15000 hour
Massive galena-sphalerite-pyrite ore	0.0210	0.0088	0.0065	0.0057	0.0040	0.0030	0.0021	0.0013
Banded pyrite –polymetallic ore	0.0292	0.0156	0.0124	0.0093	0.0083	0.0100	0.0054	0.0043
Massive pyrrhotite ore	0.0393	0.0224	0.0295	0.0229	0.0065	0.0140	0.0067	0.0032

Since the slowdown in oxygen absorption is caused by the growth of a layer of oxidation products on the surface of the grains, it should be expected that this layer can be dissolved with sulphuric acid and the oxygen absorption rate will increase. For this purpose, an experiment was carried out with a sample of sulphide ore and the following results were obtained (Table 3).

Table 3. Effect of H_2SO_4 on the oxygen absorption rate by sulphide or

Oxygen absorption rate constant U, мл/г час	Ore			
	By ordinary method	Humidified with distilled water	Wetted with 10% solution of H_2SO_4	Wetted with 20% solution of H_2SO_4
K_{24}	0.0082	-	0.0757	0.1693
U_{250}	0.0059	-	0.0087	0.0376
K_{24}	0.0074	0.0117	0.1857	-
U_{250}	0.0046	0.0029	0.1160	-

Thus, sulphuric acid accelerated the oxygen absorption process. However, a similar experiment with samples of Dehtar pyrite showed opposite results. Based on this, the authors of this work (Veselovsky et al., 1974) decided that the sulphuric acid formed during pyrite should participate in slowing down the absorption of oxygen, which, in our opinion, is erroneous.

There is an influence of the value of the free reacting surface of the ore on the oxidation process. It has a great interest. Studies carried out with samples of ores of various sizes showed that at the beginning the rate of oxygen absorption for fine fractions is greater than for coarse fractions. However, for fine fractions, it decreases faster with time and after approximately 700 hours from the start of the experiment, the curves of the oxygen absorption rate along time intersect for different fractions, after which the fine ore fraction becomes less active than the coarse one (Fig. 3).

It follows from this that more smaller fractions – 0.25 + 0.0 mm, – 0.5 + 0.25 mm are deactivated faster than coarse ones. This allows us to make a very important conclusion that coarse fractions are the most dangerous for spontaneous combustion than the dust.

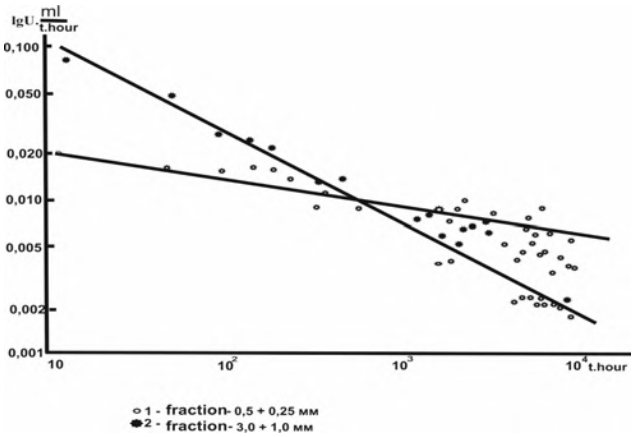


Fig. 3. Dependence of the rate constant of de-oxygenation by ores of various fractions based on time

It should be noted that the ignition temperature, besides to the nature of the oxidizing substance, depends on the heating conditions. Therefore, different methods of its determination give different results. The ignition temperature depends primarily on the rate of oxidation and the dissipation of the heat generated during the oxidation of the ore. However, these rates are so difficult to reproduce that the results obtained even by the same method, but on different instruments, are difficult to compare with each other. For different methods, at best, the same patterns are obtained for a series of samples.

We tried to classify sulphide ores according to the degree of their tendency to spontaneous combustion according to the rate of their heating. However, no positive results were obtained. Since spontaneous combustion is a complex physical and chemical process, a reliable classification of industrial types of ores according to their tendency to spontaneous combustion can be obtained only by the totality of the main indicators that determine the low-temperature oxidation of sulphide ores.

Methods of artificial oxidation at elevated temperatures, which make it possible to determine the relative increased temperature of sulphide ores and minerals, are used by many researchers. The ignition temperature is proposed by a number of authors as the basis for the classification of sulphide ores according to the power of tendency to spontaneous combustion. However, our studies show that the ignition temperature of sulphide ores of sulphide-polymetallic deposits in Azerbaijan is almost independent of the mineralogical composition of sulphide ores and fluctuates in a very narrow (390 – 400^{0}C) range. This does not make it possible to use the ignition temperature as a criterion for determining the tendency of sulphide ores of sulphide-polymetallic deposits of Azerbaijan to spontaneous combustion. Therefore, it is impossible to judge the tendency of sulphide ore to spontaneous combustion from the ignition temperature only.

If for the ores of the Ural copper-sulphide deposits the main criteria for the tendency to spontaneous combustion are the ignition temperature of ores and the oxidation rate according to the release of sulphur dioxide, which, according to Ural Research and Design Institute of Copper Industry, is confirmed with sufficient reliability by the actual fire hazard of these deposits, then to assess the spontaneous combustion of the ores of the studied deposits that differ from the Ural copper sulphide deposits in their structure and material composition, these criteria were not typical (Ismayilov, 1975; Manakov et al., 1964; Valiev et al., 2008). It turned out that despite the difference in mineralogical and chemical composition, textural and structural features and chemical activity, all types of sulphide ores of the studied deposits ignite at almost the same temperature (390 – 400ºC). For example, the massive pyrrhotite ore of the Katsdag deposit, which has a chemical activity at 25ºC Us = 12.5 ml/m^{2}h, ignites at a temperature of 390ºC, and the stockwork- stringer ore of the Katekh deposit, having an order of magnitude lower activity Us = 1.2 ml/m^{2}h , ignites at a temperature of 395ºC. This circumstance did not allow using the ignition temperature to classify sulphide ores from Azerbaijan

deposits according to the power of their tendency to spontaneous combustion.

At the same time, at low temperatures (up to 100°C), all types of sulphide ores of the studied deposits have different chemical activity. Therefore, we proposed to classify sulphide ores of sulphide-polymetallic deposits according to the power of tendency to spontaneous combustion according to low-temperature oxidation, since it is this that forms the basis of the spontaneous combustion process. Since spontaneous combustion is a complex physical and chemical process, a reliable classification of industrial types of ores according to their tendency to spontaneous combustion can be obtained only by the totality of the main indicators that determine the low-temperature oxidation of sulphide ores.

A detailed classification of ore reserves according to the power of their fire hazard allows a scientifically sound approach to planning the sequence of their development and to the design of mines (Rylnikova and Mitishova, 2019; Rylnikova, et al., 2020). Of great importance is the identification within the deposits of areas and ore deposits that are not dangerous for spontaneous combustion.

Conclusions

1. The carried out studies on oxidative activity have shown that sulphide ores of sulphide-polymetallic deposits of Azerbaijan are characterized by high oxidative activity. The most active in relation to atmospheric oxygen are the ores of the Katsdag deposit (U=0.072-0.0159 ml/g·h), the least active ores of the Katekh deposit (U=0.0041-0.0102 ml/g·h), ores of the Filizchay deposit occupy an intermediate position (U=0.0052-0.0304 ml/g·hour).

2. The effect of temperature on the chemical activity of sulphide ores of the sulphide-polymetallic deposits of Azerbaijan has been established. With an increase in temperature for every 10ºC in the temperature range of 2.5-80ºC, the temperature coefficient Kt <2.0. This confirms that the rate of oxidation of the sulphide ore is controlled by the diffusion of oxygen and not by the rate of the chemical reaction.

3. Under certain conditions, carbon dioxide appears in the workings of sulphide-polymetallic deposits in Azerbaijan. The influence of humidity and temperature on the appearance of carbon dioxide, which are similar to the change in the chemical activity of U from W and t, has been established. With an increase in temperature, the increase in CO^2 is greater than U. This is a very important factor that can be used to judge the early stages of ore self-heating.

4. The ignition temperatures of industrial types of sulphide ores of sulphide-polymetallic deposits of Azerbaijan have been established. It turned out that, regardless of textural and structural features and mineralogical composition, all types of sulphide ores of sulphide-polymetallic deposits of Azerbaijan ignite in the temperature range of 390 – 400ºC. This did not allow us to classify the sulphide ores of the studied deposits according to their tendency to spontaneous combustion according to their ignition temperature.

The classification of ore reserves according to the power of tendency to spontaneous combustion will allow a scientifically sound approach to planning the sequence of their development and designing mines.

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