

Ore-forming Processes of Iron Ores of the Lisakovsk Deposit

¹*KASKATAYEVA Kuralai, doctoral student, aigakk@mail.ru,

¹KRYAZHEVA Tatyana, Cand. Geol. and Min. Sci., Associate Professor, kryazheva_t@mail.ru,

¹SADCHIKOV Alexander, Cand. Tech. Sci., Senior Lecturer, a.sadchikov@kstu.kz,

²MUKHAMETHAN Marzhan, doctoral student, marzhan_mukhametkhan@mail.ru,

²MUKHAMETHAN Yerlan, doctoral student, Erema_goi@bk.ru,

¹Karaganda Technical University, Kazakhstan, 100027, Karaganda, N. Nazarbayev ave., 56,

²Karaganda Industrial University, Kazakhstan, 101400, Temirtau, Republic ave., 30,

*corresponding author.

Abstract. The purpose of the article is to study ore-forming processes in the geochemical zone, oolitic iron ore from the Lisakovsk deposit, to clarify the reasons for the formation of chlorites and oolites. The article describes the stages of ore formation. The process of oolite formation is shown. At the stage of late diagenesis, hydrogoethite oolites experience the phenomena of dehydration, syneresis, and recrystallization. This leads to the obscuring of the concentric structure in the ooliths. The formation of oolites in them by hydrogoethite and chlorite concentrates is also considered.

Keywords: oolites, iron ores, Lisakovsk deposit, ore deposits, stages of sedimentation, early and late diagenesis, hydrogoethite and leptochochlorite concentrates.

Introduction

The Lisakovsk iron ore deposit is located in the northwestern part of the Republic of Kazakhstan, in the territory of the Kostanai region. This deposit is located within the northern part of the vast Turgai trough. The deposit is located 20 km south of the Tobol railway station. The ore reserves approved by the State Reserves Committee are estimated so: in categories A+B+C1 with the average iron content of 35.4% they amount to 1,728.2 million tons and in category C2 with the average iron content of 25.56% they amount to 1,158.36 million tons. Ores with the average iron content of 25.56% amount to 3,031.6 million tons. The ores contain 0.071% sulfur and 0.64% phosphorus.

The Lisakovsk ore that lies at a shallow depth, is mined with the minimum amount of blasting operations [1].

Iron is the most abundant metal element in the earth's crust after aluminum. Its average content in the earth's crust (clarke) is 4.65 wt. %. Increased concentrations (up to two clarkes) are observed in ultrabasic, basic and intermediate intrusive, as well as in some metamorphic rocks. The concentration factor of iron representing the ratio of the average metal content in industrial ores to its clarke is low (about 10). Iron has two stable valences: Fe²⁺ compounds are mainly associated with endogenous processes, and Fe³⁺ with exogenous ones.

Endogenous magmatic concentrations of iron

are noted in basic and medium rocks, as well as in postmagmatic products genetically related to them. Exogenous iron concentrations are characteristic of sedimentary rocks and the weathering crust of ultrabasic rocks. Iron migrates under endogenous conditions probably in the form of chlorides, and in exogenous conditions in the form of bicarbonates, sulfates, and humic compounds. Ferric hydroxide is the end product of natural iron compounds entering the oxidation zone [2].

Methods of study

The research methodology is based on considering the processes of sedimentary rocks formation including oolitic iron ore.

Studies have shown that the processes of sedimentary rocks formation including oolitic iron ore, proceed at stages. In the process of ore formation, each stage plays a different role.

The processes occurring at the stage of sedimentation and early diagenesis play the main role in the formation of oolites, while at the stage of late diagenesis the processes of dehydration, drying out, syneresis and recrystallization of the mineral matter are mainly manifested.

At the stage of sedimentation under river conditions, in an oxidizing geochemical setting, there deposited the following:

a) terrigenous materials (pebbles, gravel, sand grains, silt particles, pelites);

b) chemical precipitation falling out of true solutions (calcium carbonates, etc.);

c) physical-and-chemical deposits falling out of colloidal solutions (coagulates and coagels $\text{Fe}(\text{OH})_3$, $\text{Al}(\text{OH})_3$, MnO_2 , SiO_2 , etc., which under different environmental conditions form oolites, peas, clots, aggregates and flocculent masses).

The formation of oolites in general can occur both in the moving aquatic environment, for example, in river channels or in the coastal part of lakes or lagoons, where the movement of water is caused by surf and waves, and in the calm environment, in the ground solution, in the sandy-silty mass of bottom sediments.

Earlier it was noted that for oolitic ore deposits a characteristic feature of river sediments is their multiple erosion and redeposition. In this regard, under river conditions, oolites accumulate and form ore deposits not at the place of their formation but where they are carried away by river water flows [3].

The starting materials for the formation of hydrogoethite oolites were as follows:

a) colloidal particles of iron oxide hydrate, partially aluminum, manganese, colloidal particles of silica, etc.;

b) electrolytes that underwent dissociation in solutions, with the formation of various ions (Ca^{++} , Mg^{++} , K^+ , Na^+ , Cl^- , etc.);

c) mechanical particles: grains of quartz, sometimes feldspar, hydrogoethite, fragments of broken ferruginous oolites and peas, secondary aggregates and clots of coagulates of iron oxide hydrate and other substances.

Ore banks in the studied deposit are mainly represented by river pebble-gravel deposits, sands, oolitic iron ore, silt and sandy clays. All these deposits have not experienced any significant submersion in their history. The lower horizons of ore deposits hardly subsided deeper than 80-100 m. Under these conditions ore deposits should have experienced very weak manifestations of regressive epigenesis.

The wandering and displacement of river channels in one direction or another from the place of deposition of one or another deposit, the separation and isolation of sediments from the aquatic environment that gave rise to them led to the complication of diagenesis processes, to their acceleration and termination. Being near the daylight surface, a significant part of the ore deposits underwent the processes of weathering and hydrogenation accompanied by infiltration and cementation of ore deposits with iron hydroxides, calcium carbonates, etc.

Under the impact of these processes, quartz grains underwent corrosion and replacement with iron hydroxides; quartz and oolitic sands were compacted in some places, cemented by hydrogoethite and calcite. Upon reaching the surface, oolite ores were destroyed, eroded and redeposited [4].

Under river conditions, where there is a constant movement of water flows containing an excess of free oxygen, the oxidizing environment prevails.

The recovery situation can arise here only in some of the deepest places of the river system, not in the aquatic environment itself but mainly in sediments under the surface of the river bottom, where sandy-clay sediments are enriched with decomposing organic matter and where an excess of CO_2 and the lack of free oxygen are formed. Here, in the places of contact between the oxidizing and reducing environment, the environment arises in which the redox systems in solutions tend to assume equilibrium states. It is important to emphasize the fact that under these conditions, ferrous and oxide forms of iron (Fe^{+++} and Fe^{++}) can be simultaneously present in solutions. This shows why chlorites containing ferrous and ferric iron can form in the redox environment at pH values of 7.2-7.4. The above is very important for explaining the reasons for the formation of chlorites and the formation of oolites consisting of alternating concentrates of hydrogoethite and chlorite, or the formation of chlorite rims on hydrogoethite oolites. The processes of formation and formation of such oolites until recently remained unclear and difficult to explain [5].

At the Lisakovsk iron ore deposit we studied, intermediate alternating redox and reduction conditions could arise only in certain places of the river reservoir, under the surface of the river bottom, in the sandy-clay mass of sediment enriched with decomposing organic matter, for example, plant residues. These sediments had to be preserved by covering them with a layer of clayey sediments, which impede the penetration of free oxygen to them. In these conserved layers consisting mainly of quartz sands and hydrogoethite oolites, formed as early as the stage of sedimentation in the oxidizing setting or at the earliest period of diagenesis, ore-forming processes continued but already in the redox setting, and were accompanied by the development of chlorite rims or external concentrates, on hydrogoethite oolites and on separate fragments of fractured oolites. The formation of oolites with alternating hydrogoethite and leptochlorite concentrates was not widespread there. This circumstance can be explained by the fact that iron oxide that was a part of the colloidal particles and suspensions of iron oxide hydrates in the sludge solution, was partially reduced to Fe^{++} , and the $\text{Fe}^{+++} \rightleftharpoons \text{Fe}^{++}$ redox systems appeared in the solutions. The physical-and-chemical processes that took place there were accompanied only by the formation of chlorite sols, consisting of Fe^{+++} and Fe^{++} . Colloidal particles of the latter, having a negative charge sign, were adsorbed and layered on the positive surface of hydrogoethite oolites forming chlorite rims on them. *This was the end of the process of oolite formation* [6].

The stage of late diagenesis in the redox zone was accompanied by the development of dehydration, syneresis, and recrystallization of mineral substances. These phenomena led to the formation of veins, nests and accumulations of chlorites in the composition of the cementing mass, sometimes with an admixture

of siderite. At this stage, crystallization of the leptochlorite mass that cements the oolites occurs, with the formation of spherulite structures in it.

In the river channels at the Lisakovsk field, the reducing aquatic environment was most likely absent. Its appearance could take place only at the depth, in layers enriched with decomposing organic matter. Moreover, these layers had to be isolated from the aquatic environment and generally from the oxidation zone by a cover of clay deposits and thus conserved. Being at the depth, the indicated ore-bearing sediments were already experiencing the phenomena of late diagenesis. The latter were accompanied by dehydration, syneresis, and recrystallization of mineral substances. Oolites of any mineral composition did not form there. At that stage, the processes of migration of gaseous substances released from decomposing plant residues and the release of liquids (hydrosols) from gels with syneresis phenomena could still take place [2].

With the development of the aging processes of gels and their drying at the stage of late diagenesis, recrystallization of chlorites and the development of spherulite structures occur. However, the most characteristic feature of this stage is siderite recrystallization with the formation of spherulite structures. At this stage, many ooliths are covered from the surface with outer rims of siderite.

Conclusions

It follows from the above-said that the oolitic iron ore of the Lisakovsk deposit belongs to the sediments of the river valleys of the Middle Oligocene, and the formation of hydrogoethite oolites that are a part of iron ores, occurs in the oxidizing environment, and hydrogoethite-leptochlorite oolites with alternating hydrogoethite and leptochlorite in the redox environment.

The formation of hydrogoethite oolites takes place partly in the suspended state or on the surface of the bottom of a reservoir at the stage of sedimentation of sediments and partly at the stage of early diagenesis in the sandy-silty mass at the bottom of the river channel. The very formation of hydrogoethite oolites occurs physically and chemically, through successive and alternating layering on grains of quartz, feldspar, on the fragments of fractured oolites, etc., positively charged colloidal particles of iron oxide hydrates, partially aluminum, Ca^{++} , Mg^{++} , Na^+ , K^+ cations, etc.,

and negatively charged colloidal particles of SiO_2 , MnO_2 , clays, phosphorus compounds, vanadium, etc. At the stage of late diagenesis, hydrogoethite oolites experienced the phenomena of dehydration, syneresis, and recrystallization, *which led to the shading of the concentric structure in oolites* [3].

The formation of oolites with alternating hydrogoethite and chlorite concentrates in them also occurs physically and chemically but already from mixed colloidal and true solutions of redox systems, and the solutions contained ferrous and oxide forms of iron-hydrosols consisting of colloidal particles of iron oxide hydrates, chlorites and other compounds.

The formation of oolites with alternating hydrogoethite and chlorite concentrates in them occurs at the stage of early diagenesis with participation of coagulation and adsorption processes, through successive concentrically zonal layering on grains of quartz, feldspar, oolite fragments, on clots of coagulates of iron oxide hydrate or chlorites and other positively charged colloidal particles of iron oxide hydrates and other substances and negatively charged particles of chlorites, silica, manganese, titanium, phosphorus, etc.

Hydrogoethite oolites formed at the stage of sedimentation or early diagenesis (in the oxidation zone), often continue their development being buried in the muddy mass of sediment, where, under conditions of the intermediate redox setting, while being still at the stage of early diagenesis, they are covered with chlorite rims. Such oolites are by their nature sedimentation-diagenetic formations.

At the stage of late diagenesis, there are phenomena of syneresis and drying of coagulates, their dehydration, recrystallization of mineral substances with the formation of veins and nests of chlorites and siderites. Usually at this stage, there is noted the replacement of chlorites by siderite and the growth of siderite rims around the oolites, which often consist of the smallest spherulite formations.

At the stages of weathering accompanied by the phenomena of hydrogenesis, oxidation and decomposition of chlorites and siderites with the formation of iron hydroxides took place in the oxidizing zone. In the reduction and in the intermediate redox zones under the level of stagnant groundwater, the processes of cementation of ore deposits with chlorites and siderite took place [7].

СПИСОК ЛИТЕРАТУРЫ

1. Месторождения железа Казахстана: справочник. Алматы, 2013. – С. 110-116.
2. Kokal H.R., Singh M.P., Naydyonov V.A. Removal of phosphorus from Lisakovsky iron ore by a roast-leach process // В сборнике: Proceedings of the TMS Fall Extraction and Processing Conference editors: Young C., Alfantazi A., Anderson C., James A. – 2006. – S. 1517-1530.
3. Каскатаева К.Б., Кряжева Т.В., Дьяконов В.В. Условия образования рудных залежей Лисаковского месторождения // Труды Международной научно-практической конференции «Интеграция науки, образования и производства – основа реализации Плана нации». Караганда: КарГТУ, 2020. – № II. С. 63-65.
4. Кряжева Т.В., Каскатаева К.Б., Асқарова Н.С. Минеральный состав руд Лисаковского месторождения // Труды Междуна-

родной научно-практической конференции «Интеграция науки, образования и производства – основа реализации Плана нации». Караганда: КарГТУ, 2019. – № III. С. 287-289.

5. Сорокина А.М., Рева И.В., Рудмин М.А. Минеральная форма редкоземельных элементов в морских оолитовых железняках // Минерально-сырьевая база алмазов, благородных и цветных металлов – от прогноза к добыче: Сборник тезисов докладов I молодежной научно-образовательной конференции ЦНИГРИ. – М.: Центральный научно-исследовательский геологоразведочный институт цветных и благородных металлов, 2020. – С. 179-182.
6. Кряжева Т.В., Досетова Г.Ж., Шынбергенова К.Т., Максютин Л.А. Исследования лисаковских железных руд // В сборнике: Повышение качества образования, современные инновации в науке и производстве: Сборник трудов Международной научно-практической конференции. – Экибастуз: КузГТУ, 2018. – С. 389-397.
7. Рева И.В., Сорокина А.М. Геохимические особенности оолитовых железняков Лисаковского месторождения (Торгайский прогиб, Казахстан) // Проблемы геологии и освоения недр: Труды XXIII Международного симпозиума имени академика М.А. Усова студентов и молодых ученых, посвященного 120-летию со дня рождения академика К.И. Сатпаева, 120-летию со дня рождения профессора К.В. Радугина. Томск: Изд-во ТПУ, 2019. – Т. 1. – С. 169-171.

Лисаковск кен орнының темір кендерінің кен түзу процестері

¹*КАСКАТАЕВА Куралай Балапашовна, докторант, aigakk@mail.ru,

¹КРЯЖЕВА Татьяна Владимировна, г.-м.ф.к., доцент, kryazheva_t@mail.ru,

¹САДЧИКОВ Александр Викторович, т.ф.к., аға оқытушы, a.sadchikov@kstu.kz,

²МУХАМЕТХАН Маржан, докторант, marzhan_mukhametkhan@mail.ru,

²МУХАМЕТХАН Ерлан, докторант, Erema_goi@bk.ru,

¹Қарағанды техникалық университеті, Қазақстан, 100027, Қарағанды, Н. Назарбаев даңғылы, 56,

²Қарағанды индустриалды университеті, Қазақстан, 101400, Теміртау, Республика даңғылы, 30,

*автор-корреспондент.

Аңдатпа. Мақаланың мақсаты – геохимиялық аймақтағы кен түзуші процестерді, Лисаковск кен орнының оолитті темір кендерін зерттеу, хлориттердің пайда болу және оолиттердің қалыптасу себептерін анықтау. Мақалада рудалардың пайда болу кезеңдері сипатталған. Оолитті қалыптастыру процесі көрсетілген. Кеш диагенез кезеңінде гидрогетитті оолиттер дегидратация, синерез, қайта кристалдану құбылыстарына ұшырайды. Бұл оолиттердегі концентрлік құрылымның күңгірттенуіне әкелді. Сондай-ақ, оларда оолиттердің гидрогетитті және хлоритті концентраттармен қалыптасуы қарастырылды.

Кілт сөздер: оолиттер, темір кендері, Лисаковск кен орны, кен шоғырлары, шөгү сатылары, ерте және кеш диагенез, гидрогетитті және лептохлоритті концентраттар.

Рудообразующие процессы железных руд Лисаковского месторождения

¹*КАСКАТАЕВА Куралай Балапашовна, докторант, aigakk@mail.ru,

¹КРЯЖЕВА Татьяна Владимировна, к.г.-м.н., доцент, kryazheva_t@mail.ru,

¹САДЧИКОВ Александр Викторович, к.т.н., старший преподаватель, a.sadchikov@kstu.kz,

²МУХАМЕТХАН Маржан, докторант, marzhan_mukhametkhan@mail.ru,

²МУХАМЕТХАН Ерлан, докторант, Erema_goi@bk.ru,

¹Карагандинский технический университет, Казахстан, 100027, Караганда, пр. Н. Назарбаева, 56,

²Карагандинский индустриальный университет, Казахстан, 101400, Темиртау, пр. Республики, 30,

*автор-корреспондент.

Аннотация. Цель статьи – изучение рудообразующих процессов в геохимической зоне, оолитовых железняков Лисаковского месторождения, выяснение причин образования хлоритов и формирования оолитов. В статье описаны стадии образования руд. Показан процесс оолитообразования. В стадию позднего диагенеза гидрогетитовые оолиты испытывают явления дегидратации, синерезиса, перекристаллизации. Это привело к затухиванию концентрического строения в оолитах. Также рассмотрено формирование оолитов в них гидрогетитовыми и хлоритовыми концентратами.

Ключевые слова: оолиты, железные руды, Лисаковское месторождение, рудные залежи, стадии седиментации, раннего и позднего диагенеза, гидрогетитовые и лептохлоритовые концентраты.

REFERENCES

1. Mestorozhdeniya zheleza Kazahstana: spravochnik. Almaty, 2013. – S. 110-116.
2. Kokal H.R., Singh M.P., Naydyonov V.A. Removal of phosphorus from Lisakovsky iron ore by a roast-leach process // V sbornike: Proceedings of the TMS Fall Extraction and Processing Conference editors: Young C., Alfantazi A., Anderson C., James A. – 2006. – S. 1517-1530.
3. Kaskataeva K.B., Kryazheva T.V., D'yakonov V.V. Usloviya obrazovaniya rudnyh zalezhej Lisakovskogo mestorozhdeniya // Trudy Mezhdunarodnoj nauchno-prakticheskoy konferencii «Integraciya nauki, obrazovaniya i proizvodstva – osnova realizacii Plana narii». Karaganda: KarGTU, 2020. – № II. S. 63-65.
4. Kryazheva T.V., Kaskataeva K.B., Askarova N.S. Mineral'nyj sostav rud Lisakovskogo mestorozhdeniya // Trudy Mezhdunarodnoj nauchno-prakticheskoy konferencii «Integraciya nauki, obrazovaniya i proizvodstva – osnova realizacii Plana narii». Karaganda: KarGTU, 2019. – № III. S. 287-289.
5. Sorokina A.M., Reva I.V., Rudmin M.A. Mineral'naya forma redkozemel'nyh elementov v morskih ooidovyh zheleznyakah // Mineral'no-syr'evaya baza almazov, blagorodnyh i cvetnyh metallov – ot prognoza k dobyche: Sbornik tezisev dokladov I molodezhnoj nauchno-obrazovatel'noj konferencii CNIGRI. – M.: Central'nyj nauchno-issledovatel'skij geologorazvedochnyj institut cvetnyh i blagorodnyh metallov, 2020. – С. 179-182.
6. Kryazheva T.V., Dosetova G.Zh., Shynbergenova K.T., Maksyutin L.A. Issledovaniya lisakovskih zheleznyh rud // V sbornike: Povyshenie kachestva obrazovaniya, sovremennye innovacii v nauke i proizvodstve: Sbornik trudov Mezhdunarodnoj nauchno-prakticheskoy konferencii. – Ekibastuz: KuzGTU, 2018. – S. 389-397.
7. Reva I.V., Sorokina A.M. Geohimicheskie osobennosti oolitovyh zheleznyakov Lisakovskogo mestorozhdeniya (Torgajskij progib, Kazahstan) // Problemy geologii i osvoeniya nedr: Trudy XXIII Mezhdunarodnogo simpoziuma imeni akademika M.A. Usova studentov i molodyh uchenyh, posvyashchennogo 120-letiyu so dnya rozhdeniya akademika K.I. Satpaeva, 120-letiyu so dnya rozhdeniya professora K.V. Radugina. Tomsk: Izd-vo TPU, 2019. – T. 1. – S. 169-171.