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STUDY ON LOW-GRADE GALENA-BARITE ORE BENEFICIATION IN KHUZDAR, BALOCHISTAN, PAKISTAN

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ABSTRACT

Purpose. Galena and barite are the principal minerals of lead and barium respectively. Both minerals are used extensively in industries because of their distinct properties. In complex poly metallic ores, it is always desirable to produce separate mineral concentrates for subsequent metal extraction. Separation of two or more minerals from complex low-grade multi-metallic ore into commercial grade concentrates requires suitable process.

Methods. This research work is centered on development a suitable process for the beneficiation of a low-grade galena-barite ore originating from Khuzdar region (Balochistan Province, Pakistan).

Findings. The low-grade ore assaying 39.90% Pb and 24.64% $BaSO_4$ was beneficiated on bench-scale by sequential froth flotation process to recover valuable galena and barite concentrates. The important variables of froth flotation process such as feed size, pulp pH, pulp density, impeller speed, type and quantities of flotation reagents, pulp conditioning time and froth collecting time were optimized to achieve maximum recovery and grade of both concentrates. The rougher galena and barite concentrates were re-ground separately and subjected to one cleaning flotation to obtain better grade final concentrates of respective minerals.

Originality. A process flow-sheet was designed in the light of this study.

Practical implications. Froth flotation experiments showed that a galena concentrate containing 77.38% Pb with recovery of 90.64% and a barite concentrate assaying 90.23% $BaSO_4$ with recovery of 80.16% could be recovered from this ore. Both the concentrates fall in the category of metallurgical and chemical grades and are suitable for industrial applications.

Keywords: *galena, barite, beneficiation, froth flotation, grade, recovery*

1. INTRODUCTION

Galena is a primary lead-containing mineral. Other commercially significant lead-containing minerals are cerussite ($PbCO_3$) and anglesite ($PbSO_4$). These are known as secondary minerals because they are derived from galena through natural actions such as weathering. Galena (PbS) often contains silver, zinc, copper, gold, cadmium, bismuth, arsenic and antimony. Utilization of these resources is of significant economic importance (He, Wang, & Yan, 2010; He, Xu, & Fu, 2010). Galena is very widely distributed and occurs in veins, often with sphalerite, pyrite, chalcopyrite, tetrahedrite. It is also found in pegmatites and as replacement bodies in limestone and dolomite rocks with garnets, feldspar, diopside, rhodonite and biotite. The commonly occurring gangue minerals are quartz, dolomite, calcite, barite and fluorite (Wills, 1992). Galena may contain up to 0.5% silver and is also an important source of the silver metal (Ajayi, Ajayi, & Blessing, 2005).

Galena is roasted and smelted to produce lead metal on commercial scale. Lead is a strategic metal used in the production of ammunition. It is also used to manufacture lead acid batteries, hardening element in various non-ferrous alloys, an octane enhancer in petroleum, in making various types of protective devices against radiations and to provide corrosion protection in severe environment. Lead compounds such as litharge, red lead, white lead, lead peroxide, lead nitrate, lead chromate and tetra ethyl lead are used in various industries. Barite is an industrial mineral mainly used as weighting agent in oil or gas well drilling, as additive in the manufacture of paints, rubber, plastics, wallpapers, asbestos, leaded glass and preparation of barium carbonate used in ceramics.

Froth flotation is a mineral separation process which takes place in a mineral-water slurry system. It has been proved to be a very efficient and effective technique for the concentration of galena and other sulphide minerals. The separation is achieved based on differences in physico-chemical surface properties of the individual mineral constituents, particularly, the wettability by water (Yunana, Yaro, & Thomas, 2015). The surfaces of selected minerals of finely ground ores are made hydrophobic (water-repellent) by conditioning them with suitable selective reagents. The specific hydrophobic mineral particles become attached to rising air bubbles that are introduced into the pulp and are carried to a froth layer above the slurry thereby being separated from the hydrophilic (wetted) particles which remain submerged in the pulp (Jain, 1986; Melo & Laskowski, 2006; CPCC, 2016).

An extensive lead-zinc-barite belt lies between Khuzdar and Karachi in the Bela-Muslimbagh Ophiolitic Thrust Belt as shown in Figure 1. A number of galena ore deposits have been reported in Lasbela and Khuzdar districts. The main deposits are located at Shekran, Ranj Laki, Mal Khor (north-west of Khuzdar) Gunga and Surmai (South-east of Bela Town) (Ahmad, 1978; Kassi & Durrani, 2016).

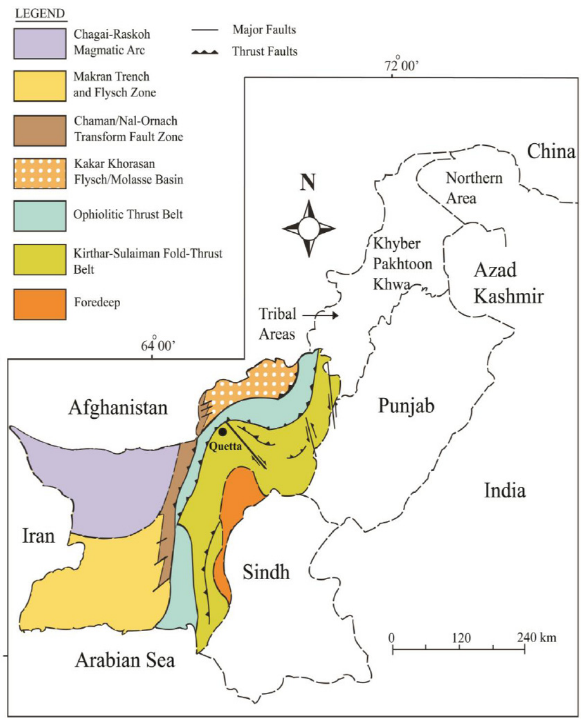

Figure 1. Tectono-metallogenic zones of Balochistan, Pakistan (Kassi & Durrani, 2016)

The aim of this study is to upgrade a low-grade galena-barite ore found in Khuzdar district of Balochistan Province, Pakistan to a metallurgical grade lead concentrate containing more than 70% Pb that is needed as a charge into the lead smelter for lead metal production and barite concentrate containing more than 90% $BaSO_4$ for oil well drilling and ceramics by using froth flotation processing methods.

2. MATERIALS AND METHODS

2.1. Sample preparation

The bulk sample of galena-barite ore weighing approximately 100 kg was collected from the mine of Mal Khor north-west of Khuzdar. This sample was brought to Mineral Processing Laboratory of MPRC, PCSIR Lahore for the R & D work. The sample was consisted of lumps having size in the range of 100 to 150 mm. It was put to primary crushing using jaw crusher to get minus 25 mm product size followed by secondary crushing using roll crusher to attain mines 6 mm product size. A representative sample of ore for chemical evaluation and X-ray diffraction (XRD) analysis was obtained by coning-quartering and riffling of the crushed ore. It was ground in disc pulverizer to obtain minus 200 mesh size. The rest of ore was split into 1 kg samples and put in plastic zipper bags for beneficiation work.

2.2. Chemical analysis

The main elements were determined by applying conventional gravimetric and volumetric as well as instrumental methods. Silica, alumina, lead, barium and sulphur were determined by gravimetric methods (ASTM, 2007a). Iron was determined by redox titration using standard solution of potassium dichromate (ASTM, 2007b). Calcium and magnesium were estimated by EDTA titration (ASTM, 2007c). Sodium and potassium were estimated by flame photometer (PFP7, Jenway Limited, England). The other elements present in minor amount were determined by Atomic Absorption Spectrophotometer (Model: 8000, Hitachi, Japan). The complete chemical analysis of representative ore sample is given in Table 1.

Table 1. Chemical analysis of the composite sample of Khuzdar galena-barite ore

Constituents	Percentage
Lead (Pb)	39.90
Zinc (Zn)	0.02
Silver (Ag)	0.006
Sulphur (S)	7.48
Silica (SiO_2)	9.84
Barium Sulphate ($BaSO_4$)	24.64
Aluminum Oxide (Al_2O_3)	2.19
Iron Oxide (Fe_2O_3)	3.01
Calcium Oxide (CaO)	0.57
Magnesium Oxide (MgO)	0.10
Sodium Oxide (Na_2O)	0.12
Potassium Oxide (K_2O)	0.03
Loss on ignition (LOI) other than sulphur	8.50

2.3. Mineralogy

The mineralogy of head sample was carried out by X-ray diffractometer (Model: D-5000, Siemens, Germany). It is equipped with X-ray tube of Cu anode which produces X-rays. The wavelength of Kα1 radiation: 1.540598 (Å) and Kα2: 1.544426 (Å) was bombarded on finely ground ore sample (minus 200 mesh #) at 25°C at voltage of 45 kV and current of 30 mA to characterize the ore. X-ray diffraction of sample was carried out in continuous mode at a scanning rate of 0.020 step size per second.

The scan angle (2θ) was varied from 5.0 to 70.0° to get the respective peaks of the constituents present in ore. The various types of mineral phases present in the ore were identified by matching the peaks/pattern with standard data. The X-ray diffractrogram (XRD) of the ore is presented as Figure 2.

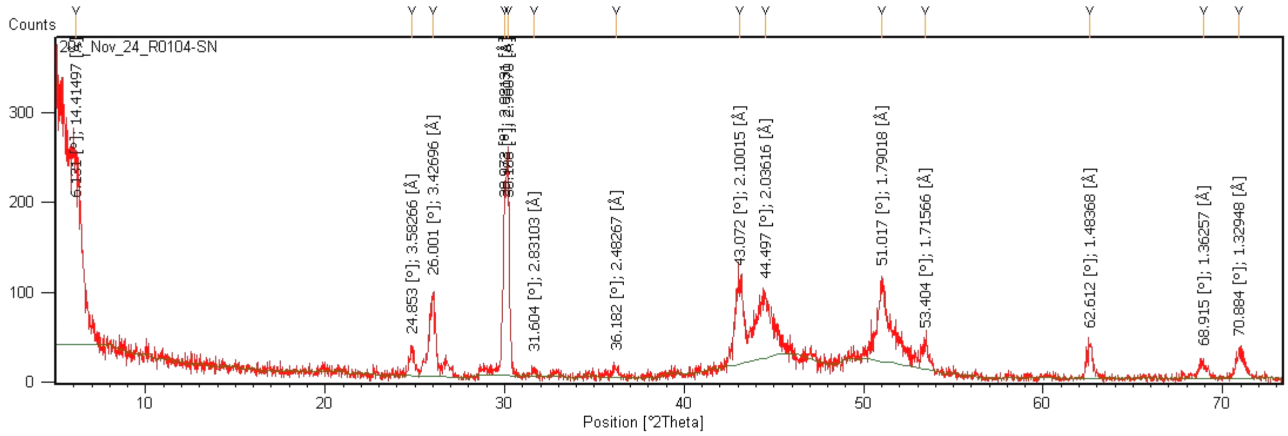

Figure 2. X-ray diffraction spectra (XRD) of galena-barite ore

The d-spacing value, 2-theta, relative intensity and the minerals identified are shown separately in Table 2.

Table 2. Minerals identified in Khuzdar galena-barite ore

Seq.	2-theta (θ)	d-spacing	Relative intensity	Minerals identified
1	24.8528	3.58266	25.32	Stibnite
2	26.0013	3.42696	91.49	Galena/Barite
3	26.6540	3.34240	45.00	Quartz
4	29.9728	2.98131	195.24	Barite/Calcite/ Magnetite
5	30.1864	2.96070	220.32	Galena
6	30.9490	2.88760	37.02	Dolomite
7	31.6044	2.83103	5.78	Barite
8	36.1821	2.48267	8.94	Quartz
9	43.0720	2.10015	89.09	Galena/Barite
10	44.4968	2.03616	67.62	Anhydrite
11	51.0175	1.79018	85.58	Galena/Quartz
12	53.4044	1.71566	25.58	Galena
13	62.6124	1.48368	35.57	Galena
14	68.9153	1.36257	15.56	Galena/Quartz
15	70.8841	1.32948	26.64	Galena

2.4. Flotation tests

The flotation tests were performed in lab-scale flotation machine (Model: D-12, Denver, USA). The flotation feed was prepared by wet grinding of crushed ore in laboratory scale ball mill (Denver, USA) at 1:1 solids to liquid ratio. The grinding time was varied to get the required feed size. The ground ore was transferred to the stainless steel flotation cells of 4 liter capacity and diluted with water to maintain the desired pulp density. Batch type tests were performed utilizing various reagent combinations on samples ground to different mesh sizes. After determining the optimum mesh of grind, the flotation tests were performed to optimize pulp density, pulp pH, stirring speed, quantity of reagents added, flotation time and conditioning time. Based on bench-scale locked cycle tests, the flow-sheet developed to prepare galena and barite concentrate is presented in Figure 3.

The optimum conditions of galena and barite processing are shown in Table 3 and 4 respectively while metallurgical of typical test is shown in Table 5.

Table 3. Flotation parameters and optimum conditions of galena processing

Flotation parameters	Range of variables	Optimum conditions	
		Roughing	Cleaning
Grind size of ore (feed)	60 – 100% – 200 mesh	80% – 200 mesh	80% – 200 mesh
Agitation speed (aeration)	1000 – 1200 rpm	1100 rpm	1000 rpm
Pulp density (% solid)	15 – 35% solids	30% solids	20% solids
pH of pulp (slurry)	8 – 10	~8.5	~8.5
Gangue depressant (sodium silicate)	100 – 500 g/t	300 g/t	100 g/t
Collector (potassium ethyl xanthate)	60 – 100 g/t	80 g/t	60 g/t
Frother (polypropylene glycol)	10 – 30 g/t	20 g/t	10 g/t
Conditioning time	4 – 10 min	6 min	6 min
Flotation time	15 – 30 min	20 min	20 min

3. RESULTS AND DISCUSSION

The chemical analysis (Table 1) shows the presence of 39.90% Pb and 24.64% $BaSO_4$ content in the ore respectively. It is obvious from the results that the % age of lead and barium is sufficient to exploit this multi-metals ore for industrial utilization. The major impurities present include silica, alumina, iron oxide, calcium oxide, sodium oxide and potassium oxide. In order to minimize the impurities level and as a result maximize the % age of lead and barium contents, some beneficiation process is required to be applied before industrial application (Xiang, 2001; Liu, Zhu, Zhang, & Zhang, 2004).

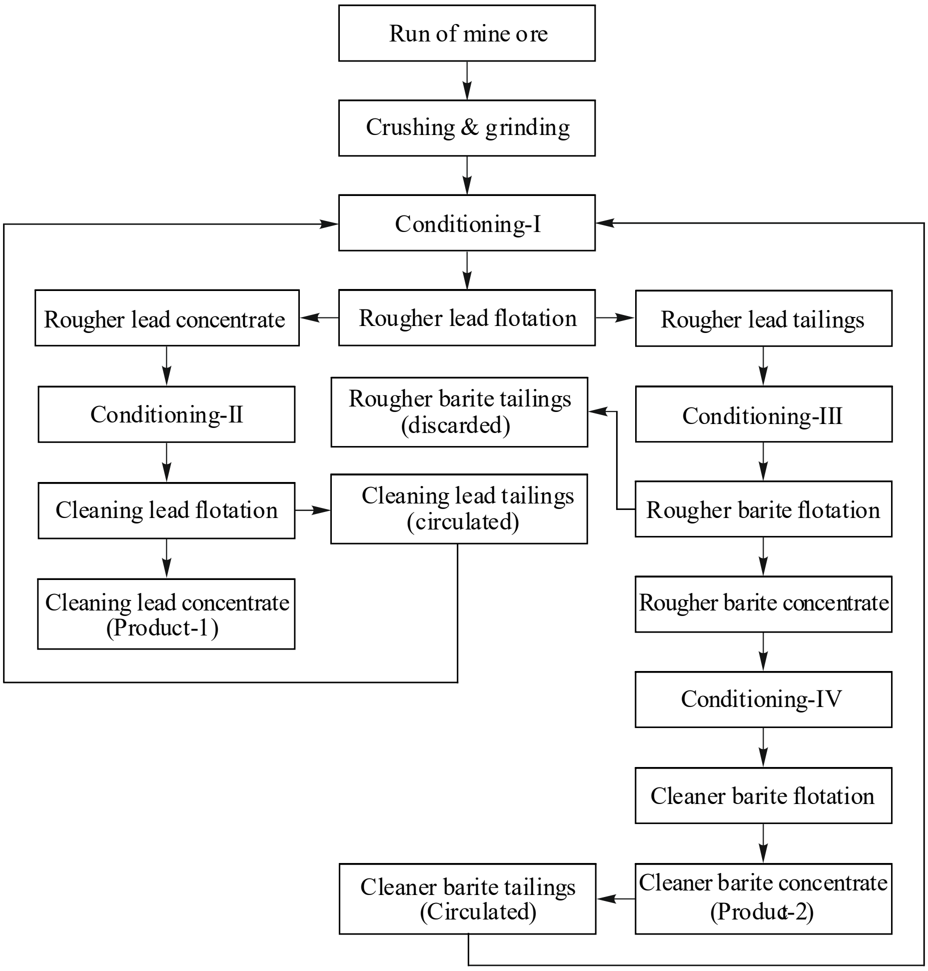

Figure 3. Flow-sheet for the beneficiation of galena-barite ore of Khuzdar district, Balochistan province, Pakistan

Table 4. Flotation parameters and optimum conditions of barite processing

Flotation parameters	Range of variables	Optimum conditions	
		Roughing	Cleaning
Grind size of ore (feed)	60 – 100% – 200 mesh	80% – 200 mesh	80% – 200 mesh
Agitation speed (aeration)	1000 – 1200 rpm	1200 rpm	1200 rpm
Pulp density (% solid)	20 – 35% solids	25% solids	20% solids
pH of pulp (slurry)	8 – 11	~10	~10
Lead depressant (sodium chromate)	30 – 60 g/t	50 g/t	15 g/t
Collector (sodium oleate)	100 – 500 g/t	300 g/t	100 g/t
Frother (kerosene oil)	10 – 40 g/t	30 g/t	10 g/t
Conditioning time	5 – 10 min	7 min	7 min
Flotation time	15 – 20 min	25 min	25 min

The X-ray diffraction analysis (Fig. 1) detects galena and barite minerals as main peaks of X-ray diffractogram match with their standard values. It was identified by JCP.CAT search & match programmes of the X-ray diffractometer that the minor peaks corresponds to quartz, calcite, dolomite, magnetite, anhydrite, stibnite and clay minerals.

Table 5. Metallurgical balance for galena-barite ore flotation

Flotation product	Weight (%)	Grade (%)		Recovery (%)	
		Pb	$BaSO_4$	Pb	$BaSO_4$
Lead cleaner concentrate	46.74	77.38	2.64	90.64	5.01
Lead cleaner tailings	10.68	13.67	13.70	3.66	5.94
Lead rougher concentrate	(57.42)	(65.53)	(4.70)	(94.30)	(10.95)
Barite cleaner concentrate	21.89	3.19	90.23	1.75	80.16
Barite cleaner tailings	2.09	9.54	42.32	0.50	3.59
Barite rougher concentrate	(23.98)	(3.74)	(86.07)	(2.25)	(83.75)
Rougher tailing	18.60	5.94	7.02	3.45	5.30
Head sample	100.00	39.90	24.64	100.00	100.00

Table 2 reveals that valuable minerals are galena and barite and the main gangue mineral is quartz. So froth flotation appears to be a more appropriate method for their up-gradation as these minerals are floatable as well as separate mineral concentrates can be prepared by this technique (Jones & Sajjad, 1994; Atrafi, Hodjatoleslami, Noaparast, Shafaei, & Ghorbani, 2012; Yunana, Yaro, & Thomas, 2015).

The ore is ground to liberate the valuable mineral grains from the associated gangue mineral particles before their separation. Sufficient grinding is necessary for adequate liberation of minerals from fine grained (texture) ore, therefore, gravity concentration methods can not be applied for its economical processing because fine grinding generates slimes which wash away with tailings leading to poor recovery (Wang, Miao, & Xiao, 2004; Bulatovic, 2013). The froth flotation is more suitable technique to upgrade fine grained ore. Froth flotation is a versatile process in which valuable minerals of different nature can be separated from each other as well as from worthless material using specific flotation reagents and controlling various parameters (Allen & Anwar, 1994; Kazmi, Gohar, & Anwar, 2000).

To study the effect of grind size, the ore was ground in rod mill to 70, 80, 90, 100% passing 200 mesh size. It was observed that by decreasing the grind size, the grade and recovery of lead and barium was improved and optimum grade and recovery was obtained at feed size of 80% minus 200 mesh size (Table 3 and 4). This feed size, of course, shows the maximum liberation limit of galena and barite and selected for the further study.

The percentage of solids in the pulp is another very important factor which needs to be optimized. A number of tests were conducted by varying the % age of solids to liquid from 20 – 35%. It was observed that the increase in pulp density decreased the grade slightly but the recovery was increased and maximum recovery was attained at 30% solids. After that the recovery was decreased (Table 3 and 4).

The pH of the pulp is very critical factor during the flotation of sulphide minerals. It plays an important role in lead-barium ore flotation. In present study, sodium carbonate was used to adjust the pH of the pulp. Galena was recovered first with potassium ethyl xanthate and then barite with sodium oleate (Wang, Miao, & Xiao, 2004). It was found that under constant condition of particle size and solid to liquid ratio, the maximum recovery of galena was achieved at a pH of 8.5 and barite at pH of 10.0. It was observed that a little variation in pH significantly changed the grade and recovery. This behavior is attributed to the maximum stability of mineral-collector complex in specific pH medium (Parsonage, 1985; Singh, Banergee, & Srivastava, 2004; Silvestre, Pereira, Galery, & Peres, 2009; Singh, Rao, Sinha, Banerjee, & Bhattacharyya, 2009).

Another important factor affecting the purity and recovery of the galena and barite is the impeller (stirring) speed. It was observed that better results were produced at rougher stage by stirring speed of 1100 rpm while at cleaning stage by stirring speed of 1000 rpm (Table 3 and 4).

Xanthate is used as collector for lead ore because it is quite specific to galena particles and even adsorbs the partially exposed mineral particles (Crozier, 1992). The collector ionizes in solution and produces positively charged ions of alkali metals and negatively charged xanthate ions. The xanthate ion is then adsorbed on the surface of the sulphide minerals due to chemical forces between the polar group of the collector and the mineral surface to form a monomolecular layer of insoluble metal-xanthate complexes which are hydrophobic (Wills, 1992). A number of tests were performed for the flotation of galena and barite. It was observed that 80 g/t of potassium ethyl xanthate produced good result in case of galena and 300 g/t of sodium oleate gave better result in case of barite. It was found that, excessive amount of collector adversely affect the grade and recovery of valuable minerals due to the development of collector multi-layers on the particles that reduces the selectivity.

Various types of frother were tried for the recovery of lead and barium minerals. A number of tests were conducted to optimize the effect of frother. It was observed that Dowfroth-250 (polypropylene glycol) showed comparatively better results for galena and kerosene oil for barite flotation. It was found that about 20 g/t of polypropylene glycol gave better results for galena flotation and 30 g/t of kerosene oil for barite flotation (Table 3 and 4).

The silicate gangue minerals present in lead-barium ore of Khuzdar area were depressed with the addition of sodium silicate (Cebeci, Akdemi, & Sonmez, 2000). It was found that with increase in quantity of depressant, the grade was improved but after 300 g/t of sodium silicate, the grade and recovery decreased due to coating of middling particles. This value was selected for the next series of tests. Similarly, sodium chromate was used to depress galena in barite flotation (Zhang & Shang, 2000). It was found that 50 g/t sodium chromate is sufficient to depress galena during barite flotation.

The conditioning time has a pronounced effect on the grade and recovery of both concentrates. It permits the surfaces of mineral grains to react with the flotation reagents. A conditioning time of 6 – 7 minutes was found to be enough for the contact with the mineral grains for an optimum grade and recovery. Likewise a flotation time of 20 minutes was observed to be enough for completely barren the froth (Table 3 and 4).

Cleaning flotation tests were conducted to further improve the grade of both rougher concentrates. Additional dosage of flotation reagents was added during each cleaning flotation (Keqing, Miller, Tao, & Guanghui, 2005). In order to improve the overall recovery of flotation, the tailings of cleaning stages were circulated according to their grade. Table 4 and 6 present the optimum consumption of flotation reagents for galena and barite flotation at cleaning stages. It can be seen from metallurgical balance sheet of a typical flotation test given in Table 5 that cleaning of rougher concentrate and circulating of cleaning tailings back to subsequent cycle test has ensured a final industrial grade galena and barite concentrate with acceptable recovery. The flow sheet suggested for the beneficiation of Khuzdar galena-barite ore is shown in Figure 3. The beneficiation process developed includes two stage grindings; first coarse and then fine, two flotations, rougher and cleaning to produce commercial grade galena and barite concentrates with optimum recovers.

The metallurgical balance of a typical locked cycle flotation test performed at optimized conditions (Table 5) indicated that lead content of the ore under investigation was raised at rougher flotation stage from 39.90% Pb to 65.53% Pb with 94.304% recovery and barite content from 24.64% $BaSO_4$ to 86.07% $BaSO_4$ with 83.75% recovery.

It is obvious from Table 5 that the rougher lead concentrate was further enriched in the cleaner circuits using additional quantity of reagents into cleaner lead concentrate assaying 77.38% Pb with 90.64% recovery and rougher barite concentrate into cleaner barite concentrate assaying 90.23% $BaSO_4$ with 80.16% recovery. The bench scale flotation tests showed that this low-grade galena-barite ore could be directly beneficiated into separate high-grade galena and barite concentrates without using any kind of pre-concentration method. The successful separation of metallurgical grade galena and barite concentrates by sequential flotation show the suitability of the process selected for beneficiation of this kind of ore. It is evident from the reported results that the flotation process has significantly reduced the gangue materials of the ore. Chemical analysis of lead and barium concentrates (Table 6) shows that both concentrates match the specifications of metallurgical grade. As a result of this beneficiation step the extraction of metals from the respective concentrates become greatly economical.

Table 6. Chemical analysis of lead and barium concentrates

Constituents	Percentage	
	Galena concentrate	Barite concentrate
Lead (Pb)	77.38	3.19
Zinc (Zn)	0.02	traces
Silver (Ag)	0.008	traces
Sulphur (S) other than sulphate	10.36	0.50
Silica (SiO_2)	3.03	1.02
Barium sulphate ($BaSO_4$)	2.64	90.23
Aluminum oxide (Al_2O_3)	0.90	0.50
Iron oxide (Fe_2O_3)	1.20	1.20
Calcium oxide (CaO)	0.44	2.30
Magnesium oxide (MgO)	traces	traces
Sodium oxide (Na_2O)	0.05	0.15
Potassium oxide (K_2O)	0.006	0.02
Loss on ignition (LOI) other than sulphur	—	5.30

4. CONCLUSIONS

It is concluded that ore under investigation comprises of mainly galena and barite as valuable minerals to be concentrated where as the remaining are considered as gangue minerals. The percentage of lead and barium is high enough to exploit the ore for commercial purpose after beneficiation. Depending upon the nature of minerals present in the ore it can be upgraded by two stage (rougher and cleaning) sequential froth flotation to produce separate galena and barite concentrates. The flotation process produced a lead concentrate having 77.38% Pb content with 90.64% recovery and barite concentrate possessing 90.23% $BaSO_4$ content with 80.16% recovery from an ore assaying 39.90% Pb and 24.64% $BaSO_4$. Both concentrates match the specifications of metallurgical as well as chemical grade and therefore can be used for the production chemicals and metals. It is suggested on the basis of bench scale study that pilot plant trials should be conducted on this ore in order to establish the real parameters before the commercial exploitation of this important deposit.

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ЗБАГАЧЕННЯ ПІСНОЇ ГАЛЕНІТ-БАРИТОВОЇ РУДИ В ХУЗДАРІ, ПРОВІНЦІЯ БЕЛУДЖИСТАН, ПАКИСТАН

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Мета. Підвищення якості низькосортної галеніт-баритової руди, знайденої в Хуздарском районі провінції Белуджистан (Пакистан), до концентрату металургійного якості, що містить більше 70% Pb, із використанням методу пінної флотації.

Методика. Масова проба галеніт-баритової руди вагою близько 100 кг була відібрана з шахти Мал-Хор на північному заході від Хуздару та доставлена в лабораторію переробки мінералів MPRC, PCSIR Lahore для проведення досліджень. Зразок підданий первинному подрібненню із використанням щокової дробарки з наступним вторинним подрібненням із використанням валкової дробарки. Зразок до і після флотації піддавався комплексному хімічному і рентгеноструктурному аналізу (XRD). Флотаційні випробування проводилися на лабораторній флотаційній машині D-12. Після визначення оптимального помелу були проведені випробування для оптимізації щільності пульпи, pH пульпи, швидкості перемішування, кількості доданих реагентів, часу флотації й часу кондиціонування.

Результати. Встановлено, що вміст свинцю та барію в поліметалічній руді є достатнім для промислового використання. Отримано оптимальну ступінь подрібнення і відновлення при розмірі подачі 80% мінус 200 меш. Виявлено, що збільшення щільності пульпи дещо знижується при збільшенні В/Т з 20 до 35%, але відновлення збільшується, а максимальне відновлення досягнуто при 30%. При використанні для коригування pH пульпи етілксантата калію, а потім бариту з олеатом натрію, виявлено, що при постійних умовах розміру часток і співвідношення твердої речовини та рідини максимально повторне покриття галену досягається при pH 8.5 і бариту при pH 10.0. Було відзначено, що невелика зміна pH значно змінила ступінь і відновлення. Розкрито вплив швидкості перемішування робочого колеса й відзначено, що оптимальною швидкістю на грубій стадії є швидкість 1100 об/хв, а на стадії очищення – 1000 об/хв. Доведено, що методом пінної флотації з даної руди можна отримати концентрат галеніту із вмістом 77.38% Pb і ступенем відновлення 90.64%, а також концентрат бариту із вмістом 90.23% $BaSO_4$ і ступенем відновлення 80.16%.

Наукова новизна. Встановлено характер впливу специфічних речовин, що поліпшують показники пропроцесу флотації, які сприяють якісному відділенню цінних компонентів руди від порожніх домішок.

Практична значимість. Розроблено принципову схему процесу збагачення галеніт-баритової руди на основі пінної флотації в замкнутому циклі. Отримані концентрати галеніту й бариту відповідають необхідним металургійним і хімічним стандартам та можуть знайти промислове застосування.

Ключові слова: *галеніт, барит, збагачення, пінна флотація, ступінь концентрації, відновлення*

ОБОГАЩЕНИЕ ТОЩЕЙ ГАЛЕНИТ-БАРИТОВОЙ РУДЫ В ХУЗДАРЕ, ПРОВИНЦИЯ БЕЛУДЖИСТАН, ПАКИСТАН

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Цель. Повышение качества низкосортной галенит-баритовой руды, найденной в Хуздарском районе провинции Белуджистан (Пакистан), до концентрата металлургического качества, содержащего более 70% Pb, с использованием метода пенной флотации.

Методика. Массовая проба галенит-баритовой руды весом около 100 кг была отобрана из шахты Мал-Хор к северо-западу от Хуздара и доставлена в лабораторию переработки минералов MPRC, PCSIR Lahore для проведения исследований. Образец подвергнут первичному дроблению с использованием щековой дробилки, с последующим вторичным дроблением с использованием валковой дробилки. Образец до и после флотации подвергался комплексному химическому и рентгеноструктурному анализу (XRD). Флотационные испытания проводились на лабораторной флотационной машине D-12. После определения оптимального помола были проведены испытания для оптимизации плотности пульпы, pH пульпы, скорости перемешивания, количества добавленных реагентов, времени флотации и времени кондиционирования.

Результаты. Установлено, что содержание свинца и бария в полиметаллической руде является достаточным для промышленного использования. Получена оптимальная степень измельчения и восстановления при размере подачи 80% минус 200 меш. Выявлено, что увеличение плотности пульпы несколько снижается при увеличении В/Т с 20 до 35%, но восстановление увеличилось, а максимальное восстановление достигнуто при 30%. При использовании для корректировки pH пульпы этилксантата калия, а затем барита с олеатом натрия, обнаружено, что при постоянных условиях размера частиц и соотношения твердого вещества и жидкости максимальное повторное покрытие галена достигается при pH 8.5 и барита при pH 10.0. Было отмечено, что небольшое изменение pH значительно изменило степень и восстановление. Раскрыто влияние скорости перемешивания рабочего колеса и отмечено, что оптимальной скоростью на грубой стадии является скорость 1100 об/мин, а на стадии очистки – 1000 об/мин. Доказано, что методом пенной флотации из данной руды можно получить концентрат галенита с содержанием 77.38% Pb и степенью восстановления 90.64%, а также концентрат барита с содержанием 90.23% $BaSO_4$ и степенью восстановления 80.16%.

Научная новизна. Установлен характер влияния специфических веществ, улучшающих показатели процесса флотации, что способствовало качественному отделению ценных компонентов руды от пустых примесей.

Практическая значимость. Разработана принципиальная схема процесса обогащения галенит-баритовой руды на основе пенной флотации в замкнутом цикле. Полученные концентраты галенита и барита соответствуют металлургическим и химическим стандартам и могут найти промышленное применение.

Ключевые слова: *галенит, барит, обогащение, пенная флотация, степень концентрации, восстановление*

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