COMPREHENSIVE DEVELOPMENT AND UTILIZATION OF TAILINGS①

Li, Zhangda *Chinese Academy of Geological Sciences, Beijing 100037, China*
Zhou, Qiulan *Beijing Research Institute of Geology for Mineral Resources*

ABSTRACT

A great number of tailings discharged by nonferrous metals mines are compound mineral resources which consist mainly of aluminiferous silicate and can be used as building materials and raw materials for light and chemical industry, etc. Among others, the taillings with various kinds of micro-component metals and appropriate silicon and aluminum could be used as raw material of microcrystalline glass and new materials. It is an advantageously scientific and technological field to put forward the utitization and development of tailings owing to the following advantages: utilizing mineral resources efficiently for the nonferrous metals industrial enterprises, improving the land management and natural environment, raising the comprehensive economic benefit and so on.

Key words: nonferrous metals tailings comprehensive development and utilization

1 INTRODUCTION

It has been confirmed by many scientists and governments that the discrepancy between supply and demand for mineral resources is going to be increasingly serious, and the development of new materials should become an important research subject and main column for supporting social development in the next century. After ten years of research, the authors have recognized that the tailings of nonferrous metals mines are pragmatic, economical compound mineral resources, and it could be used as building material, raw materials for light and chemical industry and new material as well. However it is necessary for the development and utilization of tailings to combine the researchers, equipments and facilities in the field of geology, mineral processing, metallurgy, material science and engineering concerned with nonferrous metals industry. If so a new scientific and technological branch will be developed at the junction between new mineral resource and new material which could be used for promoting the prosperity of our nonferrous metals industry in the next century.

2 CHARACTERISTICS OF NONFERROUS METALS TAILINGS

A great number of tailings discharged by nonferrous metals mines not only occupied space, contaminated environment and consumed a considerable amount of management funds,but also resulted in serious risk of tailing dams . In fact, most of the tailings are useful

①Manuscript received Oct.24, 1991 and translated by Yaxin

compound mineral resources. According to a statistics, nonferrous metals tailings occupied 60~ 96% of the ores to be processed in concentrator and all are compound mineral resources consisted of aluminiferrous silicate though vary in constituents and features with ore deposits and their surrounding rocks. Its mineral constituents are mainly quartz, feldspar, sericite, carbonate, clay, diabase, hornblende, garnet, felite, chloride and residual metallic minerals. Its chemical composition can be devided into three categories: silicious aluminum ($SiO_2 > 60\%$ and Al_2O_3 8~ 18%); calsium-magnesium (SiO_2 40% and $CaO+MgO_2$ 1~31%); and ferric oxide and various microcomponent of metals (Fe_2O_3 8~ 14%; balance of Cu, Mo Ti, Ni, W, Sn, Pb, Zn, Au, Ag, etc). Each category may contain K, Na, S and other microcomponents Mn and P. It's fine particles (< 0.074 mm) usually exceed 60%. Their constituents and technological features are favourable to be building materials, raw materials for light and chemical industry and new materials as well.

So far, only a few nonferrous metals mines use their tailings to produce brick and glass. According to a statistics in 1985, anual output of tailings of 56 mines exceeded 4.9 million tons, which occupied about 4666 hectores of land, and the total tailings heaped approached 7,820 million tons. Actual tailings are much more than the above figure and will become more from year to year, so it is necessary to be developed and utilized as soon as possible.

3 TAILLINGS ARE ECONOMICAL AND USEFUL COMPOUND MINERAL RESOURCES

Besides residual microcomponent Metals and sulphur, tailings contains mainly quartz, feldspar, hornblende, garnet, mica and their alternational minerals, e.g. sericite (hydromuscovite, illite). Aluminiferrous silicate minerals include kaoline, clay and chloride and magnesium carbonate minerals consisting of calcite and dolomite. Their chemical constituent is mainly Si, Al Ca, Mg, Fe and a small amount of K, Na, Ti and sulphur oxide, which is very close to that of raw materials for building, light and chemical industry, e.g. varnish and filling (see Table 1). For example, raw materials for porcelain-ceramic consists mainly of feldspar, quartz, clay, kaoline, calcium-magnesium carbonate; glaze consists mainly of limestone (calcite), dolomite, zinc oxide, sodium (potash) carbonate, boron acid plus the raw materials for porcelain-ceramic mentioned above. Raw material for glass contains mainly quartz, feldspar, clay, fluorite. Raw material for cement consists mainly of calcite, clay, quartz, iron powder and gypsum. Colorating agent contains ferric oxide, manganes oxide, copper oxide, titanium oxide, cobalt oxide and so on. The chemical component of unburnt ceramic in one famous ceramic factory are: SiO_2 59.57~ 72.4, Al_2O_3 21.5~ 32.53, CaO 0.18~ 1.98, MgO 0.19~ 1.8, K_2O 1.21~ 3.78, Na_2O 0.47~ 2.04 (wt−%). The chemical component of glass are usually: SiO_2 66.00~ 72.19, Al_2O_3 1.81~ 3.60, CaO 2.5 ~ 10.44, MgO 0.60~ 2.30, $K_2O_4+Na_2O$ 13.21 ~ 15.70 (wt−%). Therefore it is evident that tailings could be used to replace many traditional raw material from the view point of chemical components.

Roughly speaking, traditional technological products were made from varieties of purified minerals. Our technological experiment using various tailings demonstrated that

Table 1 Chemical composition of nonferrous metals taillings

Samp	Pattern of taillings	SiO_2	Al_2O_3	CaO	MgO	K_2O	Na_2O	Fe_2O_3	TiO_2	SO_3	P_2O_5	MnO	loss in burn	Note
N1–2	Magnetic nickle ore	36.67	3.89	4.29	27.25	0.31	0.41	14.06	0.26	2.138	0.064	0.157	9.92	Cu 0.237 Ni 0.211
D3	Porphyritic copper ore	61.99	17.89	1.48	1.71	4.88	0.13	4.48	0.74				5.94	Cu 0.10
M3	Porphyritic molybdenum ore	65.29	1.13	3.35	2.34	4.62	0.60	2.86	0.843	1.10	0.278	0.174	2.83	FeO 3.12
M2	Porphyitic copper-molybdenum ore	72.21	11.19	2.33	1.14	4.65	2.14	1.858	0.376	2.07	0.106	0.028	2.34	
M1	Skarn-molybdenum ore	47.51	8.04	19.77	4.71	2.10	0.55	8.57	0.547	1.55	0.098	0.648	6.46	
A1	Skarn gold ore	47.94	5.78	20.22	7.97	1.78	0.90	5.74	0.24			0.17	6.42	Cu 0.10
S1–1	Vein-tungsten-tin ore	61.15	8.50	7.85	2.01	1.98	0.02	4.38	0.336	2.38	0.14	0.262	6.87	
P2	Hydrothermal lead-zinc ore	71.36	7.17	5.94	2.30	3.10	0.10	Fe 2.29		S 0.007	P 0.036		f_{Ca} 7.71	Pb 0.07 Zn 0.075
S1–2	Granite	81.13	8.79	0.12	0.01	3.62	0.21	1.73	0.12	0.16	0.016	0.017	2.02	
Fb–6	Feldspar quartz ore	85.86	6.40	1.38	0.34	2.26	0.996	0.375						FeO 0.427

tailings comminuted to fine particles have usually the same technological characteristics as traditional burdens, and therefore could be used for making the same products as traditional burden provided the amount of tailings is properly adjusted. As a matter of fact tailings are naturally imperfect burden, e.g. the tailings added to burden of porcelain-ceramic, glass and high strength cement could approach to 35～72, 75 and 40%, respectively. Because of tailings having been comminuted to fine particles and mixed homogeneously and often with catalyts / flux activity by its sodium, potasium and microcomponent metals, when they are used instead of traditional burdens or added as additives, the alteration between minerals, the technological properties and the compactness of products are improved and the sintering temperature of porcelain-ceramic and the melting temperature of glass could be decreased by 100 ℃ which result in saving energy due to the existence of sodium, potasium and microcomponent of metals. Tailings from different mines have different features, such as the sintered porcelain-ceramic product using the tailings of porphyritic copper ore displaced a violet sand pattern, using the taillings with high concentration of Fe displayed black ceramic pattern; using the taillings containing high concentration of sulphur displayed blue-yellow ceramic glaze pattern. Because the complexity of chemical component the disadvantages of burden mixed with tailings include that, the requirements for sintering atmosphere and temperature and the technological method are higher than that of traditional burden, e.g. the temperature differentiation required for the sintering of porcelain-ceramic is only 20 ℃ which needs the furnace and technological method to be improved.

A lot of money consumed in mining and invested in corresponding equipment and facilites including crushing, comminution, grinding, extraction and energy consumption as well, can be saved when using tailings as main raw material. According to an estimation, the price of traditional burden consisted of feldspar, quartz, clay, etc, was 10

~ 20 times higher than that of the corresponding tailings, and thus the production cost was also higher by 20%. Considering the other benefits gained in utilization of tailings and the improvement of product quality and the raising of production efficiency, economic profit will be considerable.

The development and utilization of tailings can also transform the mines into a comprehensive enterprise for both supplying nonferrous metals concentrations and building materials, light and chemical industry raw materials, etc, and elongate mine duration, increase employee and product, utilize equipment and facilities effectively, improve economic profit, protect environment against contamination etc.

4 TAILING IS A NEW RESOURCE FOR NEW MATERIALS

New materials with new property and new use are highly thought of all over the world, and utilization of these new matericals will be an important goal and mark of scientific and technological development in the next century. Metalloid minerals with superior property and new materials developed via combining metals with matalloid minerals have also widely developed prosperty and attract the interesting of many scientists. The tailings of nonferrous metals consisting mainly of metalloid minerals and various metals in microcomponent have the characteristics of compound mineral resources and may become the resource of raw material of many new materials.

Our experiment revealed that microcomponent metals existed in aluminiferous silicate minerals have fair effect upon the product property and production technology. e.g the decomposition of calcium carbonate during the calcination of cement using tailings was promoted by microcomponents Mo, Cu, Au, S … and led the raw material to produce liquid phase ahead of normal time, decrease the cohesiveness and surface tension of liquid phase, and improve the feasibility of calcine of the raw material; meanwhile microcomponents existed in tailings can promote the formation of Ca_3AlO_3 and improve the intensity of cement and corrosion resistance, raise the quality and production efficiency of cement, when the other conditions remain unchanged. In the light of experiment, the initial decomposition temperature of cement burden with molybdenum ore as additive was decreased 10 ℃ and the yielding peak of free calcium oxide decreased about 100 ℃ , which demonstrate that with the addition of Mo ore in cement burden improves the calcination ability greatly (see Fig.1). And according to production experiments carried out in cement factories the addition of tailings mentioned above improves the operation and working condition, the feasibility of calcination, and as well the productivity remarkably.e.g. the productivity (t / h) of $d\,2\times 8$ and $d\,1.8\times 8$ m vertical calcinator increased 13% , free calsium oxide (f_{CaO}) decreased 0.60–0.88, the strength of 3 d and 28 d rose 6.25% and 7.2% respectively, coal consumption diminished 50 kcal / kg; it demostrates also the tailings containing microcompound Mo can be used for producing cement instead of iron powder and gypsium and a part of lime and clay.

Various microcrystalline glassed-granites had been made by the authors using tailings of different pattern of ore deposit, its product properties were superior to natural rock material (see Table.2).

Table 2 Comparison of some properties

properties	microcrystalline glassed-granite	synthetic marble	natural marble	natural granite
Moss Hardness	7–9	< 3	3–5	5–7
Comp. str. / MPa	57.2	88.3	88.3–225.6	58.8–294.2
Anti-rupture str. / MPa	47.8–131.3	21.3–31.4	12.7–16.7	14.7
Shock proof str. / J cm^{-2}	24.5–37.3		20.6	19.6
Antidilation str. / $\times 10^{-7} cm^{-1}$	61—77		80—260	50—150
Moisture-absorption ratio / %	< 0.07	0.1	0.3	0.35

Microcrystalline glassed-granite is a newly synthetic building material with superior physical and chemical properties such as hard, compact, durable, homogenious, wear-resistance, corrosion-resistance, natural veins, pure colour, no fissures, could be cut into thin plate and made into various shape via heat treatment. Therefore it is widely used in luxurious building decoration and underground construction and under-water engineering in special, and it is famed as the future building material.

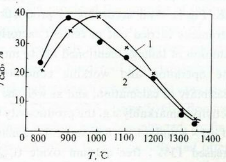

Fig.1 Calcination temperature (*T*) of cement raw material versas free calcium oxide (f_{CaO})

1— no molybdenum ore tailings added;

2— molybdenum ore tailings added

Microcrystalline glass or glassed ceramic is a polycrystalline porcelain-ceramic material developed since 1970's which is produced by combining inorganic material with metallic material, and it has the common advantages of glass and porcelain-ceramic, e.g. high temperature resistance, small dilation coefficient, high oxidation-resistance and corrosion-resisting, high mechanical strength, fair electricity insulating strength and disruptive electricity strength. So it is widely used for luxurious building platform plate, under-water construction material and deep-water container, liner of huge ware in chemistry and food industry, industrial pipe and valve, durable high heat exchanger, special bearings etc; in addition it is possible to produce electronic, micro-electronic and vacuum tube assembly; and microcrystalline glass printed-circuit board, photoelectronic material, heat protecting layer of airplane and spacecraft, etc. In short, the using of tailings develops a perfectly new technical field which traditional materials can not compete.

Up to now, a great amount of scientific research has been done on $CaO-Al_2O_3-SiO_2$, $Li_2O-Al_2O_3-SiO_2$, $MgO-Al_2O_3-SiO_2$, $K_2O-MgO-Al_2O_3-SiO_2$ and another microcrystalline glass. We believe it is fairly favourable for nonferrous metals enterprises to develop such kind of new materials, and it is hopeful to guide the comprehensive development and utilization of tailings.