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Novel solution injection technology for in-situ leaching of weathered crust elution-deposited rare earth ores

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ABSTRACT

Weathered crust elution-deposited rare earth ores are rich in the middle and heavy rare earths. The present study investigated the content of exchangeable aluminum and the exchangeable rare earth in the different layer of orebody and the partitioning of rare earth was determined as well to understand the mode of occurrence of rare earth. Furthermore, the swelling of clay minerals from different layers was investigated. The results shown that, in completely weathered layer and partly weathered layer, the content of exchangeable rare earth was more than 0.06% and the content of exchangeable aluminum was below 0.02%. However, in humic layer, the content of exchangeable rare earth was below 0.015% and the exchangeable aluminum was more than 0.03%. In the weathered crust elution deposited rare earth ore, the exchangeable aluminum is mainly found in the humic layer, whereas the rare earth elements are abundant in the completely weathered layer and partly weathered layer and the rare earth in humic layer belong to light rare earth group. Additionally, the swelling of clay minerals in humic layer was ranged between 2.5% and 2.7%, which were higher than the swelling of clay minerals in completely weathered layer and partly weathered layer. Based on these findings, a novel in-situ leaching technology of weathered crust elution-deposited rare earth ores is proposed. The leaching agents were directly injected into the completely weathered layer without infiltrating through the humic layer. Avoiding the humic layer, only the completely weathered layer and partly weathered layer were leached. According to this method, the exchangeable aluminum in the rare earth leaching solution can be decreased and the purity of rare earth product can be improved. Meanwhile, the ammonium chloride was alternatively applied to leach rare earth and the choices of available leaching reagents were broadened.

1. Introduction

Weathered crust elution-deposited rare earth ore is a special rare earth resource in the world, which is rich in the middle and heavy rare earths (Nesbitt, 1979; Zhang et al., 2013). As a resource of rare earth, the weathered crust elution-deposited rare earth ore has drawn the attention in the globe area. The minerogenic reason of the weathered crust elution-deposited rare earth ore deposit is that rock magma granite and volcanic rock containing rare earth minerals were weathered into clay minerals through biological and chemical processes under hot and damp climatic conditions. Meanwhile, some rare earth (RE) minerals in the original rocks, such as banstnaesite and gadolinite, are easily dissociated as hydrated or hydroxyl hydrated rare earth ions which are adsorbed on the clay minerals during the downward movement of water (Chi and Tian, 2008). The chemical leaching technology is the only method for extraction of rare earth elements (REE) from the weathered crust elution-deposited rare earth ore since other methods cannot rich the rare earth (Moldoveanu and Papangelakis, 2012; Jordens et al., 2013; Moldoveanu and Papangelakis, 2013). The ammonium salts are commonly used as leaching agents to leach rare earth from the clay minerals by means of traditional in-situ leaching technology or dump leaching technology (Chi et al., 2005; Kul et al., 2008). After that, the leached rare earth could be precipitated and collected by using ammonium bicarbonate (Chi and Tian, 2008) or oxalic acid as the precipitant (Tian et al., 2011; Tian et al., 2013a, 2013b). However, there are some problems existed in the dump leaching technology and pool leaching technology. Applying the dump leaching technology or pool leaching technology, the rock was bared and the vegetation of surface was destroyed, which is difficult to recover (Chi et al., 2012). In order to overcome those disadvantages, the dump leaching technology was gradually substituted by the traditional in-situ leaching technology. The orebody of weathered curst elution-deposited rare earth can be divided into four layers as following: humic layer, completely weathered layer, partly weathered layer and bedrock (Yang and Yang, 1999; Yang, 1987). In traditional in-situ leaching technology, the leaching agents was directly injected into the humic layer and completely weathered layer. There are two major problems encountered in traditional in-situ leaching process, such as landslide caused

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Fig. 1. The landside caused by injection improperly.

by injection improperly (Tang and Li, 2002; Tang et al., 2000), which has been shown in Fig. 1.

The other is higher impurities in leaching solution (Xiao et al., 2015a, 2015b), which lower the rare earth products purity and higher the consumption of precipitant (Chi and Xu, 1999; Chi et al., 2003). In order to obtain the rare earth leaching solution with less impurities, the ammonium sulfate was preferred to use as leaching agents in traditional in-situ leaching solution (Moldoveanu and Papangelakis, 2013; Yao et al., 2005). Previous works were focused to investigate the inhibitor to lower the leaching of aluminum and the additive to inhibit the swelling of clay minerals. Ouyang et al. (2003) studied an aluminum inhibitor named HZA that could precipitate the aluminum ions. The results had shown aluminum in leaching solution was decreased 56.85% by adding 0.05% HZA inhibitor. Yang and Zhang (2015) investigated the compound lixiviant included ammonium nitrate, ammonium sulfate and ammonium acetate. The ammonium acetate used as aluminum inhibitor was added into leaching agents in order to decrease the elution of exchangeable aluminum from weathered crust elution-deposited rare earth ores. According to Yang's experiments, it was concluded that the optimum concentration of ammonium acetate was 0.05% and the inhibition rate of aluminum exceeded 80%. Moreover, the clay minerals would swell after adsorption of water, which easily lead to landslides and other geological disasters. Li (2012) investigated the urea used as additive to inhibit the swelling of clay minerals from weathered crust elution-deposited rare earth ores. The swelling of clay mineral could be inhibited by adding urea since the acylamino groups insert into the hexagonal cavities of clay crystal. However, those methods reported in literatures had some limitations, such as high production costs. In this study, the content of exchangeable rare earths and the exchangeable aluminum in humic layer, completely weathered layer and partly weathered layer was analyzed. The partitioning of the rare earth was determined as well to understand the mode of occurrence of rare earth. Additionally, the swelling of clay mineral from different layers in orebody was investigated to understand the swelling of clay mineral. Based on the results above, an improved solution injection technology was proposed to lower the content of impurities in the leaching solution, decrease the possibility of landslide disasters and improve the yield of rare earth products.

2. Materials and methods

2.1. Rare earth ores and chemicals

The rare earth ores sample was collected from Dingnan (DN) in Jiangxi province, China. Chemical composition of the rare earth ore was analyzed by X-ray fluorescence (Axios advanced, Panalytical B.V.) and the results was shown in Table 1. From the Table 1, it reveals that the RE ore contain 0.162% RE and 18.27% Al. The particle size distribution of the experimental samples were shown in Fig. 2.

Table 1
Main chemical composition of the RE ores (mass fraction, %).

Component	REO	Al_2O_3	SiO_2	CaO	MgO	K_2O	Na_2O
Mass fraction/%	0.162	18.27	65.92	0.0031	0.12	6.15	0.23
Component	SO_3	Rb_2O_3	MnO_2	TiO_2	ZrO_2	Fe_2O_3	Lost
Mass fraction/%	0.017	0.034	0.046	0.22	0.027	2.52	6.12

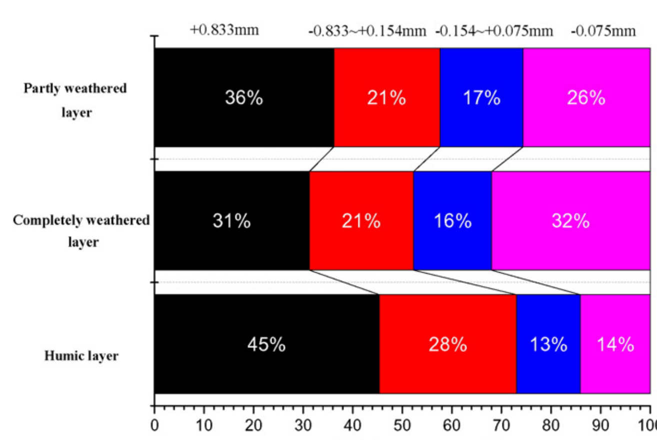

Fig. 2. Particle size distribution of rare earth ores from different layer.