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Basalt-Water Interaction Experiments at Temperatures up to 550℃: Implication for Metal Origin of Deposits Hosted in Basalt

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1 Introduction

Water- basalt interactions take an important role in ore depositions occurred in basaltic rocks，which are present in arc volcanism, Mid-Oceanic Ridge MOR, continental volcanic activities and metamorphic processes in green sheet. This study focuses on revealing the dissolution rates of basaltic rocks in water, and kinetic behaviors for different metals in the rock as carried out water rock interaction experiment at high temperatures from 20 to 550 ℃, 23-34MPa.

Experiments of basaltic rock–water interactions are carried out using flow through reactor at temperatures from 20 to 550°C and 23-34MPa. Experiments found that the release rates for different metals from the rock vary with temperatures. The release rates of Si, rSi increase with temperature from 20°C to 300°C (or 300-400°C，at 23-34 MPa)，then decrease with increasing temperatures from 400 to 550°C. The maximum rates rSi always are observed at 300°C (300-400°C). Release rates for Na, Mg, Ca and Fe reach maximum values at temperatures from 20-200° C, and decrease with continued increasing temperatures to 550°C. The maximum rAl and rK are at about 350° C. Fe is mostly not released to water at temperatures of 400 to 550°C, and Fe oxide or hydroxide is formed at rock surface. Experiments demonstrated that iron of ores hosted in basaltic rocks is originated from basaltic rocks.

2 Experimental Approach

The basaltic rock used in these experiments is collected from natural rock alkali-basaltic rock, from drill core in Luzong basin, Middle-Lower Yangtze valley, China. The methods about preparing rock samples for experiments were described before see ref. (Zhang et al., 2002). We utilized two types of reactor systems to determine dissolution rates of the rocks: packed bed reactor (PBR) and approximate mixed flow reactor. The equipments used in those experiments include a pressure vessel, a liquid pump, a backpressure regulator, furnace, temperature controller, pressure and temperature sensors, and an electric conductivity detector (see Mogollon et al. 1996; Zhang et al., 2002, 2011). The calculation methods for dissolution rate of minerals is used to calculate the dissolution rate of rock, see ref (Zhang et al., 2011; 2013).

3 Experimental Results

The experiments for water rock interactions are performed using flow through reactors at temperatures from 20 to 550 ℃, and 23-34MPa. The steady state concentrations and dissolution rates were measured as functions of temperatures and flow rates at a constant pressure. Results indicate that the relative release rates for different metals from the rock are dependent upon the temperature.

The dissolution rate of the rock, i.e., the release rate of Si increased as the temperature increased from 20 ℃ to 300 ℃(or 300 – 400 ℃), and then decreased with continued increasing temperature from 300 ℃ (300-400 ℃) to 550 ℃. The maximum release rates r_{Si} are reached at near 400℃ (300-400 ℃ for 23-34MPa). The maximum r_{Al} are at about 350℃, maximum r_K at 300-400℃, maximum r_{Na} at 20℃. Maximum r_{Ca}, r_{Mg} and r_{Fe} are at temperatures from 20 to 300℃: the maximum r_{Mg} at temperatures from 20-100℃, maximum r_{Ca} at temperatures from 100-200℃, maximum r_{Fe} at 200℃ and the lowest r_{Fe} at 400-550℃. Maximum r_{Mn} is at 20℃, the lowest values at 300℃.

It can be seen that DM_i/DSi values vary with temperature (DM_i is the difference between input concentration and output concentration for metal i in the

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solution; DSi is corresponding to Si in the solution). The increase of DM_i/DSi with temperature indicates that the metal M_i is released fasters than Si as temperature increasing. DNa/DSi decreases with increasing temperatures from 20 to 550℃; DCa_i/DSi and DMg/DSi decrease with temperatures from 20 to 400℃, and a little increase at 500℃. DAl_i/DSi and DK/DSi increase slowly with temperatures until 350-400℃, then decrease from 400 to 550℃; DFe_i/DSi decreases sharply with increasing temperatures from 300 to 550℃.

Experiments show that Ca, Mg, and Fe, dissolved more quickly than Si at temperatures from 25–300℃, but more slowly at temperatures from 300 to 550℃. Si will be fixed at rock surface at temperatures from 100-300℃, and strongly released from 300 to 400 ℃. K and Al are easily released at about 350℃. But Mg, Ca and Fe will be fixed at the surface at temperatures from 300 to 550℃. Fe is not easily released from rock at temperatures from 400 to 550 ℃, and release rates of Fe are almost zero. SEM and HRTEM analysis also found Fe oxide and hydroxide compounds are formed at mineral and rock surface after water rock interaction at high temperature above 400 ℃.

4 Discussion and Conclusion

Strong fluctuation of metal release rates (e.g., r_{Si}) always occurred at 300 to 400℃, which is attributed by significant changes of water property within the critical region. The water density and dielectric constant decrease rapidly from a sub-critical state to a supercritical state, resulting in weakening and breaking hydrogen bond of water molecules. As non-hydrogen bond of water molecules is dominated, water tends to reduce the ionization of metal-oxygen bonds (Na-O, Mg-O, Ca-O, Fe-O) and gradually become capable of dissolving polar-bonded substances (e.g., Si-O bond). At T≥300℃, water dissolves Si faster than other metals and release of Fe(or Mg, Ca) is prohibited at temperatures of 400-550℃(Zhang et al., 2013). As predicted by Seyfried and Bischoff (1981): seafloor heavy-metal deposits can result from seawater-basalt interaction at relatively high temperatures (~400 ℃), present experiment results demonstrated that iron for Fe bearing ores hosted in basaltic rocks is originated from basaltic rocks due to water rock interactions at temperatures from 400 to 550℃

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