Kinetic Experiments on Syenite-water Interactions at Temperatures from 20°C To 435°C

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1 Introduction

A series of dissolution experiments on mineral and rocks in aqueous solutions were carried out using flow-through reactors in the temperature range from 20 to 435°C and at pressures of 23-36 MPa (Zhang et al., 2000; Zhang et al., 2005). The steady state dissolution rates of minerals or rocks are measured as functions of temperature, flow rate and pressure. Experiments found that the maximum release rates of Si for silicate minerals are always observed at 300°C (or at 300-400°C for silicate rocks), which indicated that the strong leaching of Si and the break-up of silicate framework structures in minerals and rocks occurred within the critical region: 300 to 400°C, 23 MPa. These results provide useful information for estimating the behavior of crustal fluids and the geophysical nature of the mid-crust (Zhang et al., 2007).

We constructed a new experimental system to measure the dissolution rates at high temperatures as water-rock interactions, and simultaneously measure electronic conductivity of the system. The two ends of the pressure vessel connected to the sensors of the electronic conductivity detector. This detector consists of signal transfer of the detector, electrode of electric conductivity detector, which is from ECD com.

2 Experiments

Experiments on syenite-water interactions were carried out in a horizontally-mounted packed bed reactor. The vessel is 170 mm in length with an inside diameter of 4.5 mm and a volume of 10.81 mL. 7.246g rock sample was put in the vessel. Surface area of the rock sample is 0.6m²/g (BET method). Water was pumped into the vessel with flow rates of 0.5–8 mL/min.

The net dissolution rates (mol/minute/m² or mol/s/m²) normalized to their specific surface area (A) are calculated using the following expression:

\[ r = \frac{C_i - C_0}{t(A/V)\nu_i} \]

where \( C_i \) is the output concentration of species \( i \), \( C_0 \) is the initial concentration of species \( i \), \( A \) is the total reactive surface area of the mineral (m²), \( t \) is the average fluid residence time, and \( V \) is the volume of the pressure vessel (mL), i.e., liquid volume. \( \nu_i \) is the stoichiometric coefficient of the \( i \)th element in the mineral formula (Zhang et al., 2007). Thus, the dissolution rates of syenite in water and the electric conductance can be measured simultaneously at temperature from 20 to 435°C and at pressure from 23-36MPa.

3 Experimental Results

The results indicated that the release rates of Si, Al, K and Na of the syenite increase with increasing temperature, and reached maximum values at 400°C. The release rates of Ca, Mg reached maximum values at 200°C. The release rates of Fe reached maximum values at 374°C (Fig.1).

Another important impact factor of the reaction between syenite and water is pressure. The release rates of Si did not vary with pressure, as pressure was changed from 23 to 36 MPa. The release rates of K and Al in syenite increase with increasing pressure.

The maximum release rates (\( r_m \)) of Ni and Cu are reached at 300°C, 23 MPa, and the \( r_m \) (Zn) is at 374°C 23MPa. But the \( r_m \) (Mn) is reached at low temperature (25°C) and 31MPa. The \( r_m \) (Sr) and \( r_m \) (Ba) are present at low temperature (20-200°C) and 23 MPa. The \( r_m \) (Mo) is at 350°C and 23 MPa. The \( r_m \) of Pb is present at 400°C, 23 MPa. The most metals (Si, Ca and ore-forming elements)
easily release in to aqueous solutions at 23 MPa. If increasing pressure from 23 to 36 MPa, most molar concentration ratio of metal Mi vs Si, Mi/MSi in the effluent solutions decreases with pressure.

The in situ measurements of electric conductances of the water-rock interaction system at temperature range from 20-435°C, 23-36MPa were performed using the flow system. The in situ measurements of electric conductances combined the kinetic experiments found that the maximum electric conductances are present at 374-390°C, 23-36MPa, and simultaneously the maximum release rates of Si, Al, K are reached at the same temperature range.

4 Discussion and Conclusions:

Direct precise geophysical investigations indicated that zones of high conductivity and low seismic velocity are present in the mid-crust at many locations worldwide. In the mid-crust the temperature ranges from 300 to 450°C, and pressure is about 200-300 MPa. From a tectonic perspective, plate motions are ultimately responsible for inducing cracking in rocks, generating porosity, decreasing pressure, and moving fluids across and through continents. Recent reports have described the co-occurrence of fluid flow and horizontal faults in the crust during continent collision (Ito et al., 2007). These processes of decreasing pressure probably lead to the migration of aqueous fluid in the mid-crust to locations where they are close to their critical state at temperatures from 300 to 435°C. Therefore, water rock interactions occurring in the crust will cause strong leaching of Si, breakage of silicate framework structures, and rock collapse. Experiments also demonstrated that the release rates of Si, Ca and most ore-forming elements reached the maximum within the region: 300-400°C. Thus, most of transition elements are released in to the fluids. Experiments indicated that the reacted fluids at T from 300 to 400°C are characterized of high electric conductance.

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References: