Phase separation process of immiscible binary-Liquid mixture

misuzu sato[1]; Ikuro Sumita[2]

[1] Natural Sci and Tec.,Kanazawa Univ.,; [2] Earth Sci., Kanazawa Univ.

Introduction:Liquid immiscibility exists in nature on various scales,such as in magmatic systems(e.g.,silicate-carbonate), core formation process(iron-silicate)).In these systems,the two liquids mix above the critical temperature.When the temperature drops below the critical temperature,it separates into two liquids (stage1),and then gravitationally separate (stage2)whose process is controlled by parameters such as the volumetric ratio of the two liquids,interfacial tension,density difference and viscosity.There have been number of studies on stage1(plane-layer or under zero gravity),but only a few on stage2.The parameter dependence and the time-scale of the separation,as well as the pattern formation during this process are still poorly understood.Here,we present analogue experiments focusing on this process,using viscous fluids with large viscosity ratio.Such study would form the bases for constraining the separation processes of magma from the textures of volcanic rocks such as carbonatites.

Experimental method:An acrylic tank(5x10x18cm3)is used for the experiments. The working fluids are:colored water(density 1.002g/cc,viscosity 1mPas)and salad oil(density 0.925g/cc,viscosity 55mPas)and change their volumetric ratios. The fluids are mixed in an agitator to form an emulsion.After agitation,photographs are taken at fixed intervals,and the images are analyzed on PC.CCD microscope is used to study fine-scaled structure.The parameter is the volume fraction of the oil(psi0(0)).

Results:(1)Qualitative results:The emulsion separates into 3layers:the oil-rich layer at the top,the water-rich layer at the bottom,and a mixture layer in the middle. When psi0(0)is less than 0.65,oil droplets are packed in the mixture layer,and when psi0(0)is greater than 0.65,both water and oil droples are packed.We define the upper boundary and lower boundary as UB and LB,and calculate the volumetric fraction of oil psi0(t)in the mixture layer from the position of these boundaries from (UB-MB)/(UB-LB).(2)Evolution:The movement of the boundaries depend on the volumetric ratios,but can be divided into 4stages:(stage1)when the two phases form an emulsion,(stage2)where the boundary movement is fast,(stage3)when the boundary movement becomes very slow,(stage4)when the mixture layer collapses

Anaysis:(1)Dependence of the volumetric fraction of oil:(a)When psi0(0)is greater than 0.65,the appearance of the lower boundary is delayed as the fraction of water increases.(b)We modeled the movement of the lower boundary by assuming Darcy's law and permeability formula of Kozeny-Carman and found a good agreement with the experiments.(2)Boundary movements:The fraction of water phiW in the mixture layer decreases with time. Since droplets grow with time,we assumed that the size of the droplets is inversely proportional to the square of phiW.This model explained the movement of the boundary in stage2.

Comparison with the core formation:If iron and silicate was completely molten in the beginning,iron droplets would sink and the silicate melt would rise as permeable flow.This is similar to our experiments for psi0(0)greater than 0.65. On the other hand,if the mixture was partially molten,the iron would percolate along the grain boundary of the rocks,which is similar to our experiments for psi0(0)less than 0.65.Because the Earth is cooling,the core formation would transform from the former to the latter.

Conclusions:

(1)There are 4 stages during separation

(2)Oil droplets form for psi0(0)less than 0.65,and both water and oil droplets form for psi0(0)greater than 0.65.(3)We clarified the psi0(0)dependence of the time-scale for the apperance of the boundaries, terminal psi0(t),and terminal LB.(4)Stage2 can be modeled using time dependent phiW(t)and droplet size.(5)Coalescence of the droplets strongly limit the separation process.