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Estimation of time interval of emplacement between basaltic and rhyolitic magmas forming a composite dike

Yutaka WADA[1], Chizu Itota[2]

[1] Dept. Earth Sci., Nara Univ. Education, [2] Management Info., Osaka College

1. Introduction

The composite dikes have been a considerable candidate as a place for magma to be mixed for many years (e.g., Carrigan, 1994; Koyaguchi and Takada, 1994; Wiebe and Ulrich, 1997). This comes from an assumption that two or more magmas to form a composite dike are in liquid and coexist simultaneously. From this assumption contemporaneous intruding of two magmas into a fracture is convenient. However it is still unknown whether two magmas intruded in the same time through a dike conduit. In this study, we estimated the time interval of emplacement between initial basaltic and following rhyolitic magmas forming a composite dike, based on the one dimensional heat conduction model including latent heat of solidification, constrained by the field observations.

2. Constraints by Field Observations of the Basalt-Rhyolite Composite Dike

The studied composite dike is exposed in a riverside of Yoshino river, Nara prefecture, and trending E-W (Wada and Nakamura, 2000: VSJ Fall Meeting). The exposure ca. 200m long of the dike is composed of a 2m wide- and 20m long-simple dike and a remaining 10m wide-composite dike, from west to east. The simple dike is basaltic while the composite one is composed of marginal basalts (1m wide each) and central rhyolite (8m wide).

There is no evidence that the marginal basalt chilled the central rhyolite. While the boundary between the basalt and the rhyolite is mostly clear, cooling joints observed in the center is discontinuous in the margin. On the surface of a rhyolite boulder showing a boundary plane of basalt/rhyolite, wrinkle patterns are observed. Furthermore, in the basalt there are rhyolitic dikelets derived from the central rhyolite. Therefore, the physical conditions of magmas are:

(a) The marginal basalt was cooled down to some extent until the emplacement of the central rhyolite; and

(b) Although temperature difference between magmas was small, the basalt was solidified to occur brittle failures.

In addition, it is regarded that basaltic and rhyolitic magmas existed contemporaneously in fluid or semi-fluid condition since the central rhyolite includes many irregular basaltic enclaves.

3. Cooling Model of Basaltic Simple Dike

From the field observation mentioned before, there are two constraints in the studied composite dike formation. The first is that the basaltic magma should be cooled and solidified before intruding the rhyolitic magma. The second is that temperature difference between two magmas within the dike should be small. Then, we estimate the time interval of cooling of the basaltic magma down to the temperature of the rhyolitic magma, by using the one dimensional heat conduction model including latent heat of solidification. The following initial conditions and parameters were used to calculate. The resulting time interval required to cool a 2m-wide basaltic dike from 1200 degree to 1000 degree C was 18.1 days.

Dike (basalt): initial temperature: 1200 degree C; solidification temperature: 1000 degree C; latent heat: 396kJ/kg; density: 2630kg/m3; specific heat: 1500J/kgK; and thermal conductivity: 1.5J/msK

Host rock (psammitic schist): initial temperature: 50 degree C; density: 2600kg/m3; specific heat: 800J/kgK; and thermal conductivity: 2.0J/msK

4. Implications to Composite Dike Formation

There are two models for the composite dike formation: one is formed by two kinds of magma derived from a chemically zoned chamber (Carrigan, 1994; Koyaguchi and Takada, 1994), and the other is formed by the penetration of magma derived from one magma chamber through the other magma chamber, thus two chambers is necessary (Wiebe and Ulrich, 1997). Anyway these models need an assumption that two types of magma flow through a dike conduit simultaneously. However, in the case of the studied composite dike, 20 days interval of emplacement between first and second magmas are necessary based on field observations and the cooling model presented.