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Solid Inclusion Piezothermometry I: Comparison Dilatometry

HERBERT G. ADAMS[1,2]
Department of Geology, University of California, Los Angeles, California 90024

LEWIS H. COHEN[2]
Department of Earth Sciences, University of California, Riverside, California 92502

JOHN L. ROSENFELD[2]
Department of Geology, University of California, Los Angeles, California 90024

Abstract

Solid inclusion piezothermometry is a technique for determining the pressure and temperature of inclusion of one mineral in a host mineral. Application of the technique requires knowing the pressure-temperature curves of constant difference in natural strain between two crystallographically oriented mineral rods. For this purpose, two different kinds of comparison dilatometer, designed for use in an internally-heated high pressure gas apparatus, have been developed and are described in detail. Each design offers advantages and disadvantages in fabrication, demand upon size of sample material, and versatility.

The comparison dilatometers have been used at pressures up to 7 kbar simultaneously with temperatures up to that of the low-high quartz transition. Data obtained have been cross-checked successfully between the two kinds of comparison dilatometer and between results from them and previously-determined physical properties of synthetic periclase, synthetic halite, and quartz. As a test of accuracy, results from one design of comparison dilatometer were compared with predictions for periclase *vs* halite for the pressure range up to 7 kbar and temperatures up to ~600°C. The maximum deviation between experimental results and prediction was ~6°C at any pressure. Such accuracy is more than sufficient for developing data for use in solid inclusion piezothermometry and may be of value in determining equations of state.

Introduction

In reconstructing and analyzing the geologic history of an area, a frequent need has been data on the pressure and temperature of an igneous or metamorphic process. Solid inclusion piezothermometry is a procedure for determination of a pressure and temperature of crystallization of a rock by taking advantage of elastic effects in host minerals around mineral inclusions (Rosenfeld and Chase, 1961; Rosenfeld, 1969; Adams, 1971; Cohen, Rosenfeld, and Adams, 1972) or in the inclusions themselves (Harris *et al*, 1970). As currently pursued by us, the method, stripped of details, uses the following strategy:

(1) From a thin section of a given rock, small portions containing appropriately-oriented host inclusion pairs are separated from the slide and subjected to adjustment of pressure (P) and temperature (T) using experimental apparatus; a P and T is found for each pair that just causes the disappearance of the optical effect in the host due to deviatoric stress.

(2) The investigator then refers to sets of *isomekes* (Gr. "equal" + "length"), curves previously determined using separate pieces of host and inclusion minerals. Isomekes are $P - T$ curves along each of which the distance between two reference points

[1] Present address: Department of Geology, California State University, Northridge, California 91324.

[2] The authors consider themselves equal partners in carrying out the work described herein.

embedded in the host mineral remains equal to that between two reference points embedded in the inclusion mineral. In Part II of this series (Adams *et al*, 1975), isomekes are shown to be equivalent to curves of constant difference in natural strain between the two minerals in specific crystallographic directions. For each mineral pair, that particular isomeke is selected which incorporates values of the variables determined in the first operation. Barring complications, that isomeke will pass through the P and T at which the inclusion was incorporated in the host. The intersection of independent isomekes for two or more different pairs should be T_f and P_f, the temperature and pressure of crystallization, respectively.

In this first of two related papers, we detail the design, testing, and limitations of the comparison dilatometers that were built to yield direct determination of isomekes. The second paper of this series gives a theoretical treatment of solid inclusion piezothermometry, the calibration for quartz included in garnets (or the converse), and application of this calibration to conditions of crystallization in selected metamorphic terrains with particular reference to the Al_2SiO_5 triple point.

Comparison Dilatometry

We have developed two basically different types of comparison dilatometer. Both monitor isomekes in an internally heated argon apparatus and are designed in such a way that completion of an electrical circuit indicates presence on the isomeke. Our designs differ from that of Bridgman (1949, p. 194) and many others in that no slidewire or equivalent electrical system is used.

One-Contact Dilatometers

These dilatometers are formed by clamping together pieces of the two minerals to be compared so that the effects of suitable change in P and T will cause a small, preset gap to close. Electrically conductive coatings on the two minerals allow current to flow upon contact and this indicates presence on a particular isomeke. Electrical contact can be broken only by returning to the *same side* of the isomeke as that of the starting condition.

Description of "J" Dilatometer. This dilatometer (Fig. 1), developed by Adams (1971, p. 26–28), was used in the work reported by Adams, Cohen, and Rosenfeld (1970). Even though superseded by the more easily constructed "opposed rods" dilatometer discussed later, it is illustrated here because it is the first dilatometer used to determine isomekes and because five experiments by Adams *et al* (1975) were carried out with it. The "J" dilatometer consists of two elongate pieces machined from oriented samples of the crystals to be compared. The upper crystal, or "rod", is clamped to the lower riser of a crystal shaped into a vertically flattened "J", the "base". The device is converted into an electrical switch by evaporating a thin metal coating onto the top and free end of the rod and onto the base along one side and opposite the free end of the rod. Attachment of electrical leads from a monitor outside the argon apparatus to the coating on top of the rod and on the side of the base completes the circuit.

The rod, which has the cross-sectional shape of an isosceles right triangle, is guided by a complementarily shaped right angle groove in two supports. The rod is clamped to the base by a U-shaped spring of tungsten wire constrained by a centered longitudinal groove in the bottom of the base. So that one of these supports will serve as a fiducial marker for subsquent strains of rod and base, the clamping force of the tungsten spring is positioned near that support. Thus the relatively high frictional force prevents sliding of the rod relative to that support. Motion of the free end of the rod relative to the base thus is only a function of strain of the rod along its length between the free end and the clamped position.

One electrical lead is attached to the tungsten clamp. The clamp, in turn, makes electrical contact with the metal coating atop the rod by means of a conductive paint or by a roller bearing made of stainless steel hypodermic tubing. The other electric lead terminates in a groove on the side of the base

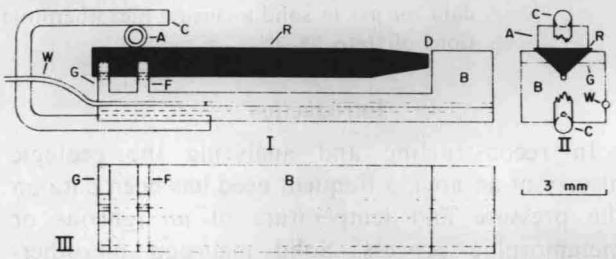

FIG. 1. Scale drawing of "J" dilatometer. I. Side view. Electrical lead to clamp (C) and insulation not shown. II. View from clamp end of dilatometer. III. View from top showing base (B) only. Letters designate the following components: A, roller bearing that is in electrical contact with metallic coating atop rod; B, base, one of minerals being investigated; C, tungsten wire that clamps rod to fiducial ridge in base; D, electrical contact, formed when metal coating at end of rod touches similar coating on upright part of base opposite; F, fiducial ridge; G, guiding support; R, rod, other mineral being investigated; W, other electrical lead, bonded with metallic contact cement to metallic coating on side of base.