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THERMAL EXPANSION OF MUSCOVITE MICA

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Summary

The thermal expansion of a sample of Indian muscovite mica parallel to the cleavage plane has been investigated up to 400° C. employing the interferometric technique. The coefficients of expansion along the *a* and *b* axes and their temperature variations have been measured. At about 50° C. they have the values of $8 \cdot 1 \times 10^{-6}$ and $7 \cdot 5 \times 10^{-6}$ respectively. They are found to vary anomalously in the temperature range from 150° C. to 250° C.

1. Introduction

Although the thermal expansion of micas was investigated by a few workers, the first systematic study was made by Hidnert and Dickson (1945). Using the comparator method, they measured the coefficient of linear expansion and its temperature variation for fifty samples of various types of micas over a wide range of temperature and reported tremendous variation in their expansion properties. The micas belonging to the phlogopite and the biotite groups showed anomalous behaviour in the temperature range from 150° to 250° C., while those of the muscovite variety exhibited regular expansion up to 700° C., except one sample of Canadian muscovite which showed a sharp break in the dilatation curve near about 100° C. The measurements carried out by Hidnert and Dickson were, however, confined to the direction perpendicular to the cleavage plane. Under the circumstances, the observed thermal expansion represented the sum of the real thermal expansion of the laminas of one or more discs of mica in a direction perpendicular to the cleavage plane and the possible displacement or separation between the laminas during heating. In view of this complication, Hidnert and Dickson remarked that certain specimens of mica did not give reproducible results. The difficulty mentioned above is not likely to arise in the case of measurements of thermal expansion in the cleavage plane. Among the earlier investigators, Ebert (1927, 1928, 1935) was the only one who reported measurements of the thermal expansion of mica parallel to its cleavage plane. He determined the expansion of muscovite mica in the cleavage plane using the comparator method and found a noticeable decrease in the expansion in the range from 100° C. to 200° C., but the direction of measurement in the cleavage plane had not been indicated in his published papers.

In all the earlier investigations on the thermal expansion of micas only the usual dilatometer technique was employed. It was therefore felt desirable to measure the thermal expansion of muscovite mica in the cleavage plane using the Fizeau interferometric technique which is known to be an absolute and most accurate method for such measurements.

2. EXPERIMENTAL DETAILS

Micas belong to the monoclinic system with β almost equal to 90° for the muscovite variety. The cleavage plane is the c or the (001) plane and thus contains the a and b axes. Since b is the symmetry axis, measurements along the b direction and in a direction perpendicular to it (*i.e.*, along a) are sufficient to completely fix the dilatation characteristics in that plane. The a-axis is easily identified as the direction perpendicular to the line joining the two melatropes, which are formed when the mica is viewed between crossed polaroids. The line joining the melatropes fixes the b-axis. Six-rayed percussion figures obtained by gently tapping the mica sheet with a sharp instrument also help in fixing the crystallographic axes. After thus fixing the axes of the mica specimen, it was cleaved to a thickness of about two or three hundredths of a millimetre. This thickness was used in order to prevent further cleaving at higher temperatures. From such a thin sheet, three rectangular strips of size $2 \cdot 5 \times 12 \cdot 5$ mm. were cut. The cutting was carried out with great care so that the edges of these strips were straight and unsmudged. It was also important that all the three strips should have exactly the same width and they had the same orientation. The strips were then gently folded in the middle such that they formed a " V " when viewed from above. These three-folded strips were then used as the spacers between the interferometer plates.

The technique of measurements was the well-known Fizeau interferometer method as modified by Merritt (1933) and Saunders (1939). The experimental arrangement used was similar to the one set up by Press (1950) for thermal expansion measurements. The interferometer plates were made of fused quartz. With the three " V "-shaped mica strips as spacers for the interferometer, a preliminary heat treatment was given to it up to about 500° C. so as to get reproducible results. It was found that on heating, the fringes were seen to more across the field of view regularly without any distortion, rotation or change in fringe width. The measurements of thermal expansion were carried out in the usual way. From the observed fringe shifts, the coefficients of expansion along the *a* and *b* axes and their variation with temperatures were evaluated from room temperature up to about 370° C.

3. Results and Discussion

Table I contains the values of the coefficients of linear expansion along the *a* and *b* axes respectively in the plane of cleavage of muscovite mica.

TABLE I

Coefficient of Linear Expansion of Muscovite Mica in the Cleavage Plane

The authors				Ebert	
along *a*-axis		along *b*-axis		along arbitrary direction	
Mean temp. ° C.	$\alpha_1 \times 10^6$	Mean temp. ° C.	$\alpha_2 \times 10^6$	Temp. range	$\alpha \times 10^6$
50·9	8·1	51·2	7·5	0–100	8·5
92·4	9·7	69·8	8·5		
137·2	10·0	109·8	9·9	100–200	8
184·9	9·9	144	10·5		
235·9	10·1	210	10·2		
292·5	10·6	234	10·2	200–300	10
367·5	10·7	268	10·7		
		298·8	11·2		
		359·2	11·7	300–400	12

The values have been plotted in Fig. 1. In Table I are also given the values of the coefficient of linear expansion of muscovite mica in the cleavage plane

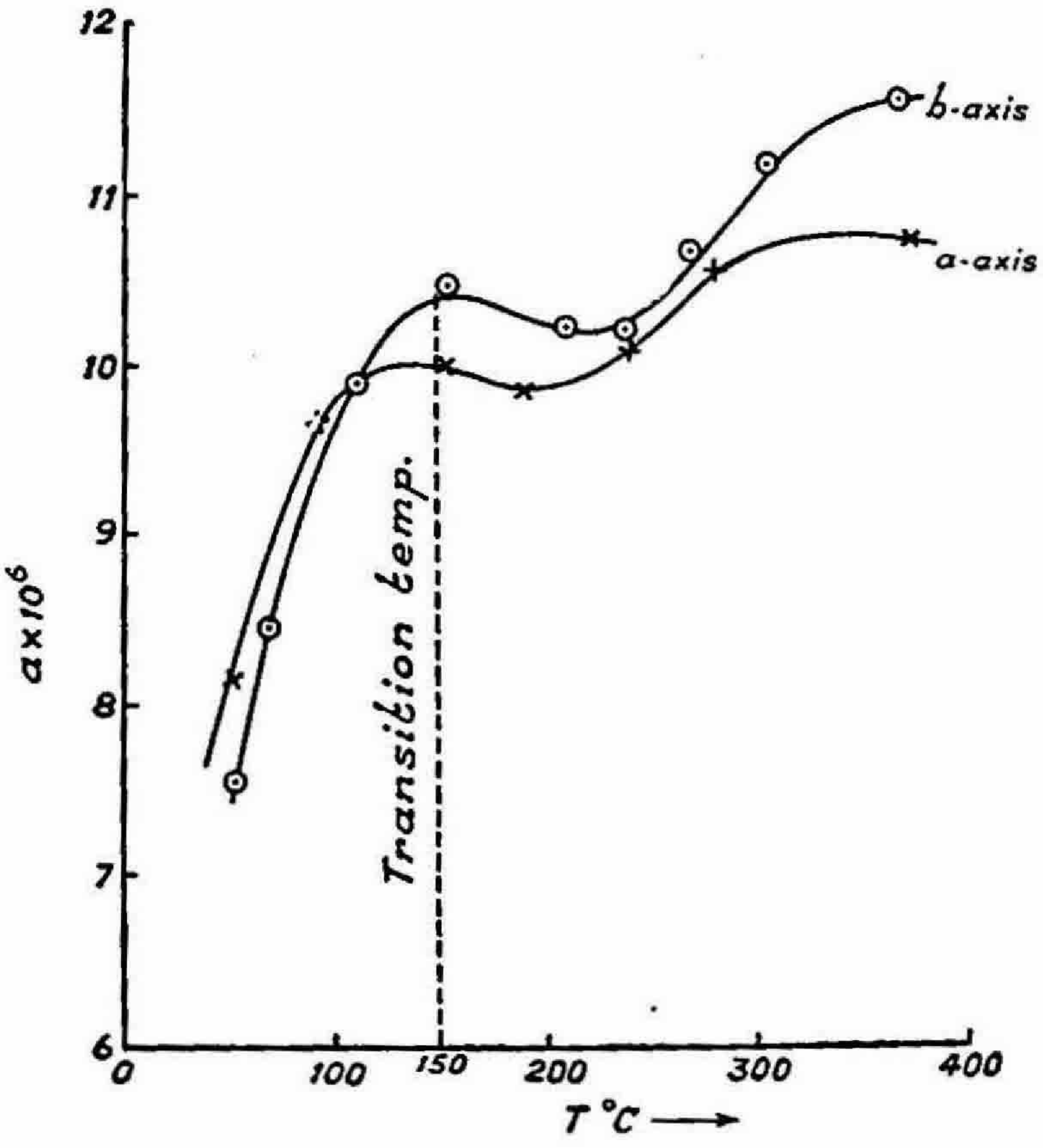

FIG. 1. Thermal Expansion of Muscovite Mica.

calculated from the observations of Ebert (1935). Ebert claimed an accuracy of about 2% for his values. He had not specified the direction of measurement in the cleavage plane. He measured the proportional variations in the length of the specimen for 100 degrees rise in temperature at a time. The temperature ranges as well as the average values of the coefficient are indicated in the table. The authors' values agree reasonably well with those of Ebert.

Up to about 130° C., the expansion along the *a*-axis has a value greater than that along the *b*-axis, while above this temperature there is a reversal, the coefficient along the *b*-axis being greater than that along the *a*-axis. By comparing the measurements carried out by Hidnert and Dickson (1945) on muscovite mica with those of the present authors, one finds that in the range 0–300° C., the average expansion in a direction perpendicular to the cleavage plane, *i.e.*, along *c*-axis, is roughly twice that parallel to the cleavage plane, *i.e.*, along either *a* or *b* axis.

Unlike the expansion perpendicular to the cleavage plane, the expansion in the cleavage plane of muscovite mica exhibits an anomaly in the temperature range from 150° to 250° C. with the transition appearing at 150° C. (see Fig. 1). The coefficients of expansion along *a* and *b* axes increase uniformly up to about 150° C. and then decrease up to about 250° C. Above this temperature the expansion increases again. Above 380° C., the coefficients of expansion tend to attain constant values, the expansion along the *b*-axis being greater than that along the *a*-axis. Ebert's (1935) measurements parallel to the cleavage plane also confirm the existence of such an anomaly (see Table 1). The experiments of Hidnert and Dickson (1945), on the other hand, indicate no such anomaly in the expansion perpendicular to the cleavage plane of muscovite mica except for one specimen from Canada.

It is well known that some specimens of mica contain varying proportions of H_2O. When such specimens are heated up to very high temperatures the water molecules may tend to escape. In order to find out whether such escape of water molecules did take place in the specimen of mica used for the present investigation and was responsible for the observed anomalous expansion, the following experiment was carried out. Three samples of the same mica were taken and accurately weighed. They were then heated to 250° and maintained at that temperature for about twenty hours, cooled and separately weighed again. No appreciable loss of weight could be detected in the three specimens, showing thereby that no loss of water had taken place on heating up to 250° C. It is therefore obvious that the abnormal thermal behaviour of muscovite mica in the region of 150° C. is not due to any loss of water from the specimen on heating, but due to some change in structure. X-ray diffraction studies carried out by H. C. Vacher (Hidnert and Dickson, 1945) on muscovite micas showed the doubling of some of the Laue spots when the temperature was raised to 145° C. This observation of Vacher has also been confirmed by us. The change in the diffraction pattern is indicative of a change in the structure of mica. The doubling of the diffraction spots occur at the same temperature at which the thermal expansion along the cleavage plane shows an anomaly. These results indicate that the crystalline arrangement in muscovite mica undergoes a transition at about 150° C. such that the expansion perpendicular to the cleavage plane is unaffected, while that in the plane of cleavage is altered.

Although the anomalous behaviour of the thermal expansion of phlogopite micas perpendicular to the cleavage plane is exhibited in the same region of temperature as that of muscovite micas parallel to the cleavage plane, there is considerable difference in the thermal behaviour of the two types of micas. In the case of the former type, there is a steep rise in the coefficient of expansion in the region 150° to 200° C. above which the expansion varies only slowly with temperature the value of the coefficient above 250° C. being many times the value at room temperature. In the latter type, the temperature expansion curve exhibits a dip in the region 150° to 250°, the value of the coefficient above 250° C. being only one and a half times that at room temperature.

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