PERTHITE, A POSSIBLE INDICATOR OF SUBSOLVUS TEMPERATURE

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Barth's thermometer has been applied to three perthites from hypersolvus alkali syenites of India. Chemical analyses and X-ray data are discussed. Subsolvus temperature as indicated by the perthites may not be applied directly to estimate the feldspar inversion temperature due to migration of Al, but assuming the two processes to be closely related, the inversion temperature in the syenite body may be of the order of 350°-450°C. The chemical composition of alkali feldspars seems to play a dominant role in the inversion problem.

THE CONCEPT OF PERTHITE THERMOMETRY

In existing geological literature, there are numerous reports on non-equilibrium during natural chemical reactions as written in rocks. These findings have certainly added new impetus for better understanding of the physical chemistry that governs the nature of mineral association. The compositions of coexisting feldspars in rocks are normally tied by such a 'law' enunciated by Barth, and a useful application of his principle is embodied in a geothermometer of great petrogenetic importance (Barth 1938, 1956). It appears that the partition relation of sodium is maintained even in a feldspar lattice during subsolidus unmixing of a homogeneous alkali feldspar (Barth 1956, p. 26) and this note records the results of application of Barth's law to the perthites in some hypersolvus alkali syenites of India. The chemistry and crystallisation behaviour of these feldspars have been discussed elsewhere (Bose 1966).

The idea of perthite thermometry is confirmed by the observation that with cooling and progressive unmixing of the alkali feldspar there is a gradual change in the composition of the plagioclase blebs and K-feldspar host in the intergrowth. The change in composition of these two subindividuals in the intergrowth could well be represented by anticlockwise rotation of the tie line in a ternary feldspar diagram. It appears that the slope of the tie line or the partition ratio of albite in coexisting subindividuals in perthite would be a useful indicator of the limiting temperature of diffusion of the alkali atoms in the feldspar lattice which is progressively strained with accompanying Si/Al ordering, ultimately leading to monoclinic-triclinic inversion of the potassic feldspar phase.

COMPOSITIONS OF THE PERTHITES AND APPLICATION OF THE GEOTHERMOMETER

1. Volumetric proportions of the sodic and potassic feldspar components in the perthitic intergrowths were determined fairly accurately by a) point counting of a large number of grains along closely spaced traverse lines orien-

ted across the plane of intergrowth and by b) careful drawing of the grains on graph paper by means of prism camera lucida — the composition being estimated from relative areas occupied by the two feldspar components. The mean composition of the feldspar was determined from values obtained independently from two methods which showed consistency in results. The volumetric composition thus obtained was converted to weight per cent by using density data after Spencer (1930).

2. Chemical composition of the mineral was determined following standard analytical procedure. Normative feldspar composition was calculated from the anlysis.

3. The amount by which the normative albite exceeds the modal plagioclase (in the intergrowth) is in solid solution with the potassic phase and thus the composition of the potassic feldspar component in terms of Ab and Or percentages was determined. Anorthite content of the potash feldspar phase is assumed to be negligible.

4. The rest of albite when combined with normative anorthite gives the composition of the exsolved plagioclase constituent. (The composition could be checked by determinable optical properties when the blebs are appreciably coarse.) In sample 19.13, the composition of the plagioclase blebs in the intergrowth was determined by optical means and the amount of albite in the alkali feldspar phase was calculated from bulk composition of the mineral (Table I).

5. The distribution factor (k) was determined and the corresponding temperature was deduced from the k-T curve established by Barth (1956). Extreme accuracy of the temperature values cannot be claimed but the deduced temperatures appear to be consistent with the thermal history of the mineral. The results are shown in Table I.

DISCUSSION OF RESULTS

The perthites in the Indian nepheline syenite and perthosite indicate different subsolvus temperatures, the limiting temperatures for inter-lattice diffusion of alkali metals. In the lower contact of the nepheline syenite body where cooling was relatively rapid and the perthite shows limited exsolution, the composition of the plagioclase component in the intergrowth is rather calcic (An_{17}). Intra-lattice diffusion of alkali atoms in such cases was arrested at relatively higher temperature. Rather calcic composition of the exolved blebs in the relatively rapidly cooled feldspar again suggests faster movement of calcium into the plagioclase domains during the early history of evolution of a perthite (Barth 1945, p. 58; 1956, p. 26). The K-feldspar phase in such perthite (with limited unmixing) shows no triclinicity when examined on universal stage ($Z \wedge \perp 010 = 0°$). The X-ray powder diagram gives a single, sharp $131/1\bar{3}1$ reflection. The degree of ordering as estimated from c^*/b^* value (Jones 1966) appears to be appreciably low (Table I). The same

Table I.

Rock type and sample No.	Composition of perthites Normative	Volumetric	k	T°C	Remarks
Lower contact of nepheline syenite body, 19.13	$Or_{67\cdot7}Ab_{29\cdot2}An_{3\cdot1}$	$Or_{82}Ab_{18}$	0.207	550	K-feldspar phase monoclinic 2Vx-63° c*/b*=2.018
Coarse nepheline syenite, 19.10	$Or_{37\cdot4}Ab_{60\cdot9}An_{1\cdot7}$	$Or_{47}Ab_{53}$	0.195	490	K-feldspar phase transitional M-T
Perthosite, 17.7	$Or_{42}Ab_{53}An_5$	$Or_{48}Ab_{52}$	0.122	330	K-feldspar phase triclinic

sample, however, when heated for 10 days at 1050°C, indicated enhanced Si/Al disorder (c*/b* = 2.027).

The microperthite developed in an advanced stage of unmixing shows still lower temperature when intra-lattice reorganisation of the feldspar components ceased. The potash feldspar phase in the intergrowth now shows enlargement of optic axial angle and in X-ray powder diagram the 131/1$\bar{3}$1 reflection is slightly diffused but there is no indication of distinct splitting of the line. The potash feldspar has apparently attained a state of microclinic orthoclase (Laves Viswanathan 1967). A single crystal oscillation photograph, however, indicates that the potash feldspar phase is tending to attain triclinicity. Possibly it represents a stage in progressive Al migration when an inversion to triclinic framework is just initiated. The same sample was heated for 8 days at 1050°C, when plagioclase component remixed to form a homogeneous phase. The c*/b* ratio (which is considered to be unaffected by sodium in the structure of the alkali feldspar) indicates a relatively low degree of order and very likely the alkali feldspar phase then attained monoclinic framework.

At the stage of ultimate unmixing of the alkali feldspar, as revealed in the upper part of the nepheline syenite body (Bose 1964), the K-feldspar collapses to a triclinic phase with $\Delta = 0.38$. No attempt is made to estimate the temperature of ultimate unmixing, as the partition of sodium in descrete plagioclase (i.e. outside the alkali feldspar lattice) may be affected by other sodic phases like nepheline. The alkali feldspar in the perthosite also represents a more advanced stage of unmixing corresponding to an increasing time factor for diffusion at still lower temperature (Table I). The K-feldspar in the intergrowth has now attained an appreciably high degree of Si/Al orders as may be inferred from the triclinicity of the phase ($\Delta = 0.74$).

The above observations suggest that the alkali feldspar in hypersolvus rocks attains a higher degree of Si/Al order with falling temperature and increasing time factor for intra-lattice diffusjon of the alkali atoms. The chemistry of the phase, particularly the amount of sodium in the lattice, may affect the stability of the structural framework (MacKenzie 1954). The subsolvus temperatures obtained by application of Barth's law may not be used directly to estimate the monoclinic-triclinic inversion temperature, as Al migration within the lattice may proceed even after the diffusion of alkali metals has ceased. Assuming, howvever, the two processes to be closely related, the present observation would indicate the inversion tempertare to be between ca. 350 and 450°C, very likely closer to the latter value. In a recent contribution Steiger & Hart (1967) suggest the inversion temperature to be 350° — 400°C. It should be emphasised, however, that the chemistry of the alkali feldspar phase may affect the inversion phenomenon even if we completely neglect the influence of pressure in the system.

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