METAMORPHIC TEMPERATURE ESTIMATION FOR EQUILIBRATED ORDINARY CHONDRITES BY A PLAGIOCLASE THERMOMETER;

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Summary: Individual plagioclase grains of about 50 μm in size from H6, L6 and LL6 chondrites were x-rayed by a Gandolfi camera after the analysis of chemical compositions by an electron probe micro-analyzer. The x-ray powder pattern recorded on a film was scanned by a micro-densitometer and taken into a personal computer for precise examinations. The distance between 1-31 and 131 reflections in the x-ray powder pattern which is very sensitive to the structural state and correlates to the equilibration temperature of plagioclase was determined precisely by applying a profile-fitting technique. The distance between 1-31 and 131 reflections was corrected for the influence of Or content by using the correction diagram [1]. The maximum temperatures for H6, L6 and LL6 chondrites obtained by using the relation diagram between [2θ(131)-2θ(1-31)] and equilibration temperature [2] are 755, 840 and 830°C, respectively.

Introduction: Plagioclase which has been formed from glass through metamorphic processes in parent bodies is a subdominant constituent mineral of equilibrated ordinary chondrites [3]. The structural states of Na-rich plagioclase, e.g. the degree of Al/Si order in the four symmetrically non-equivalent tetrahedral sites in the framework structure, correlate to its equilibration temperatures [2]. The structural state of plagioclase can be estimated by measuring the reciprocal lattice angle γ* or the distance between the 1-31 and 131 reflections in the x-ray powder pattern of plagioclase [1, 2]. Van Schmus and Ribbe [4] determined the structural states of Na-rich plagioclase from chondritic meteorites by measuring the lattice angle γ and the distance between 1-31 and 131 reflections. They showed that the structural states are in the high to high-intermediate range implying high equilibration temperatures (650-850° C). However, they could not find any significant difference in structural states of plagioclase among different chemical groups of chondrites. After them, the plagioclase thermometer has not been applied to meteorites because of the difficulty in obtaining enough amounts of plagioclase, the chemical composition of which is known, for the x-ray powder diffraction analysis.

Experiments: In this study, the x-ray powder patterns of individual plagioclase grains, about 50μm in size, from H6 (Peekskill, Great Bend), L6 (Holbrook) and LL6 (Dhurmsala) chondrites were obtained by a Gandolfi camera after the analysis of chemical compositions by an electron probe microanalyzer. The distance between 1-31 and 131 reflections in an x-ray powder pattern was determined precisely by applying a profile-fitting technique. An example of the profile-fitting results is shown in Fig. 1. In Fig. 1, dots are the experimental data obtained by a Gandolfi camera, and solid lines are the calculated profile and its $K_{\alpha 1}$ and $K_{\alpha 2}$ components. Differences between observed and

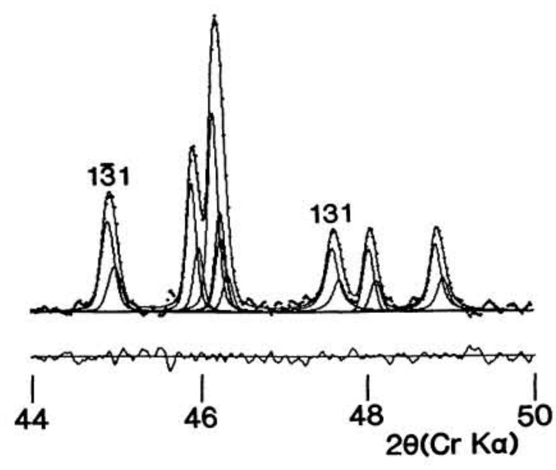

Fig. 1. An example of profile-fitting for the determination of precise peek positions.

TEMPERATURE ESTIMATION BY PLAGIOCLASE: Y. Nakamuta and Y. Motomura

calculated intensities are also shown at the bottom of the figure. Fig. 1 shows that the distance between the 1-31 and 131 reflections can be determined precisely, with an error less than 0.01 degree (2θ), even by using the x-ray diffraction data from a very small particle of plagioclase. The measured distance between 1-31 and 131 reflections was corrected for the influence of Or content by using the correction diagram [1].

Results and Discussion: All the analyzed plagioclases are plotted in Fig. 2. The plagioclases from each chondrite disperse widely along the [2θ(131)-2θ(1-31)] axis on Fig. 2, indicating variable equilibration temperatures. Even the plagioclases taken from the same chondrule also have different [2θ(131)-2θ(1-31)] values. These results reveal that the structural states of plagioclase are not in equilibrium, maybe due to the sluggishness of order-disorder reactions in plagioclase in a dry environment [5]. Therefore, the temperatures estimated from Fig. 2 may correspond to the temperatures at which plagioclase crystallized from pre-existing glass during the progressive alteration processes in a parent body. Then, the maximum temperature indicated by plagioclase from each chondrite corresponds to the maximum temperature reached during metamorphic processes in parent bodies. The maximum temperatures for Peekskill (H6), Great Bend (H6), Holbrook (L6) and Dhurmsala (LL6) are 740, 755, 840 and 830° C, respectively. These temperatures agree well with the equilibration temperatures estimated for orthopyroxenes from H6, L6 and LL6 group chondrites but not for clinopyroxenes [6, 7]. McSween and Patchen [7] pointed out that coexisting ortho- and clinopyroxenes in LL group chondrites are not in equilibrium, and they presumed clinopyroxene temperatures. Present results, on the contrary, support orthopyroxene temperatures.

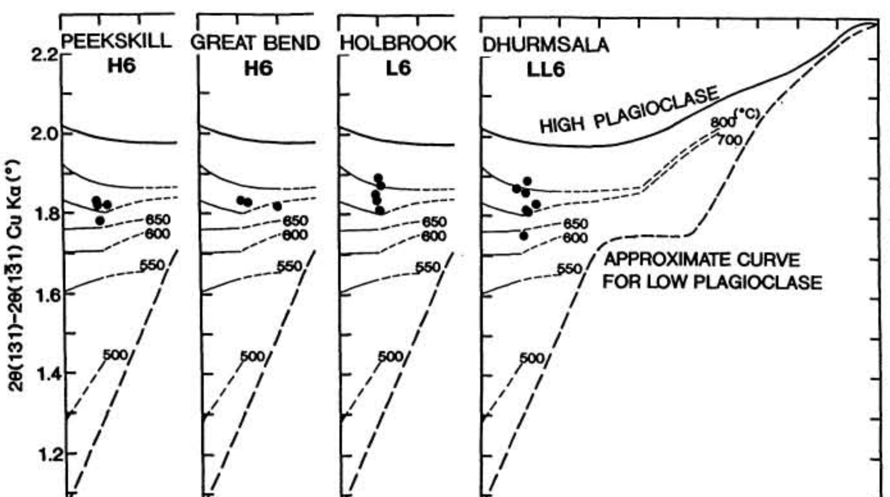

Fig. 2. Plots of chondritic plagioclase on the relation diagram between 131 structural indicator and temperature of synthesis of plagioclase [2].

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