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THERMOLUMINESCENCE CHARACTERISTICS AND CHEMICAL COMPOSITIONS OF MESOSTASES IN ORDINARY CHONDRITES

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Abstract: Induced thermoluminescence (TL) images of ordinary chondrites, ALH-77214(L3.4–3.5), Y-74191(L3.6), ALH-77216(L3.8) and ALH-78043(L6), were measured by the TL spatial distribution readout system combined with a microscope and TL characteristics [peak temperature and peak width] of mesostases were analyzed. Their chemical compositions were also analyzed by an electron probe X-ray microanalyzer. We found that; (1) The mesostasis was responsible for much of the TL in the ordinary chondrites, (2) A mesostasis of normative anorthite compositions showed low peak temperature (~90°C) and narrow width (~65°C), while a mesostasis of normative albite compositions showed high peak temperature (~125°C) and wide width (~100°C), (3) A main phosphor in a low petrologic grade chondrite <3.5 was a high anorthite mesostasis and that in high grade chondrites >3.5 was a high albite mesostasis, (4) Some chondrules in the same fragments of the type 3 chondrites showed no or weak TL emission and these mesostases had high normative albite.

These facts suggest that in type 3 ordinary chondrites; (1) The post-accretional metamorphism cannot account for the coexistence of high albite mesostases with TL emission and no emission and a high anorthite mesostasis with TL emission, (2) Low petrologic grade chondrites <3.5 have a large population of rapidly cooled chondrules and high petrologic grade chondrites >3.5 have a large population of slowly cooled chondrules.

1. Introduction

SEARS *et al.* have made great progress in quantitative classification of chondrites, using the induced TL property of meteorites (SEARS *et al.*, 1980, 1990, 1991). The natural TL of meteorites has been used to estimate meteorite orbits (MELCHER, 1981a), terrestrial age (SEARS and DURRANI, 1980; MELCHER, 1981b; NINAGAWA *et al.*, 1983; BHANDARI and SENQUPTA, 1988), heat penetration on atmospheric passage (MELCHER, 1979) and shock heating (HASAN *et al.*, 1987). These TL studies have been performed using ground samples with a photomultiplier. On the other hand, TL spatial distribution readout systems have been developed (WALTON and DEBENHAM, 1980; IMAEDA *et al.*, 1985). Our system was improved to provide a quantitative glow curve of a local area using a two-dimensional photon counting method (YAMAMOTO *et al.*, 1987) and was applied to meteorites (NINAGAWA *et al.*, 1990).

So far the relation between the TL characteristics and bulk composition of separated chondrules has been studied (SEARS *et al.*, 1984) and the main mineral, which is responsible for the TL in meteorites, is known to be a mesostasis [feldspar] (LALOU *et al.*, 1970). But the TL petrography has not been possible until the present.

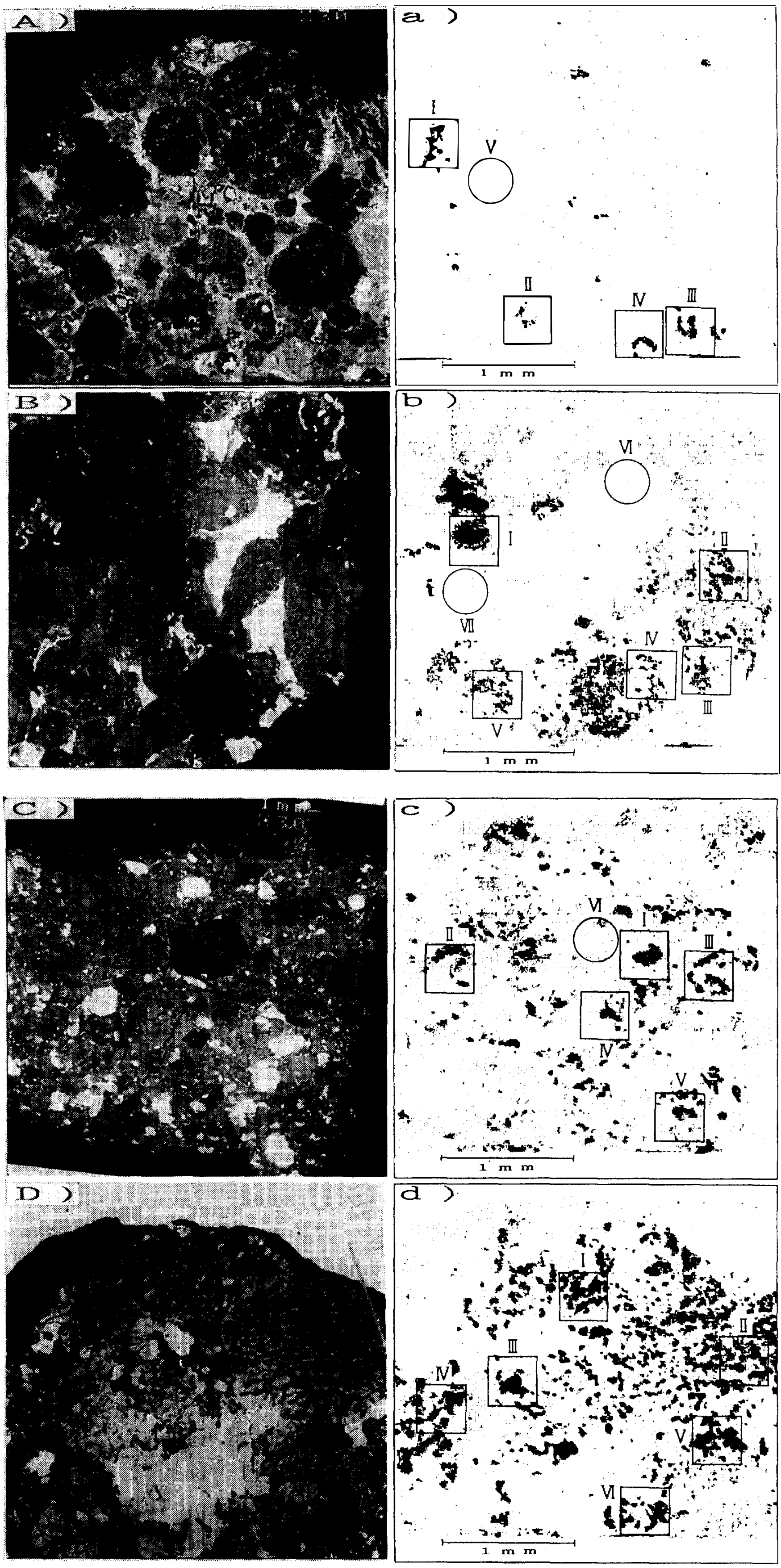
In this report, we firstly measured the TL images of ordinary chondrites in several petrologic grades by the TL spatial distribution readout system and analyzed local glow curves. Next, we analyzed the chemical compositions of mesostases by an electron probe X-ray microanalyzer [EPMA]. The correlation between the locally analyzed TL characteristics and chemical compositions of mesostases was compared directly.

2. Samples and Experiments

Antarctic ordinary chondrites, ALH-77214 (L3.4–3.5), Y-74191 (L3.6), ALH-77216 (L3.8) and ALH-78043 (L6) were examined. The sample preparation and the TL spatial distribution readout system combined with a microscope were described previously (NINAGAWA *et al.*, 1990). ALH-77214 (L3.4–3.5), Y-74191 (L3.6), ALH-77216 (L3.8) and ALH-78043 (L6) were irradiated by γ-rays of doses of 1320, 660, 120 and 120 krad, respectively, because a low petrologic grade meteorite had low TL sensitivity. The TL measurements were done immediately after γ-rays irradiation, at the rate of temperature rise 0.25°C/s with a Corning band pass filter 4–96. An EPMA, JCXA-733 (JEOL LTD.) was used for the chemical composition analysis, operated at 15 kV accelerating voltage and 12 nA beam absorption on PCD.

3. Results and Conclusions

Figure 1 shows backscattered electron images (BEI) and TL images of the meteorites at the temperature interval 100–110°C. The position of high TL intensity in TL image is put by deep black points. The regions of which local glow curves were analyzed were squared in figures. Most TL comes from the mesostasis. A silica phase was found to be also responsible for the TL in ALH-77214 (L3.4–3.5) and had a TL glow peak at ~265°C. The typical glow curves of mesostases are shown in Fig. 2. The glow curve of square region I in ALH-77214 has a peak at 81°C and peak width of 59°C. The glow curve of square region I in ALH-78043 has a peak at 126°C and peak width of 103°C. The TL characteristics [peak temperature and peak width] of the mesostases are described in Table 1a. The mesostasis in ALH-78043 (L6) has become feldspar. The slow rate of temperature rise, 0.25°C/s makes TL peak temperature lower than that of SEARS's measurements (7.5°C/s). Figure 3 shows the correlation between peak temperature and peak width. This figure shows the higher the peak temperature, the wider the peak width. The TL emissions from ALH-77216 (L3.8) and ALH-78043 (L6) concentrate on high peak temperature and wide temperature region. GUIMON *et al.* have classified the TL characteristics into two groups, 'low peak temperature and narrow width' and 'high peak temperature and wide width', and attributed the difference of these TL characteristics to the feld-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spar forms (GUIMON *et al.*, 1985).

The chemical compositions of mesostases at several positions in each square region were analyzed by the EPMA. We obtained the quantity of normative minerals

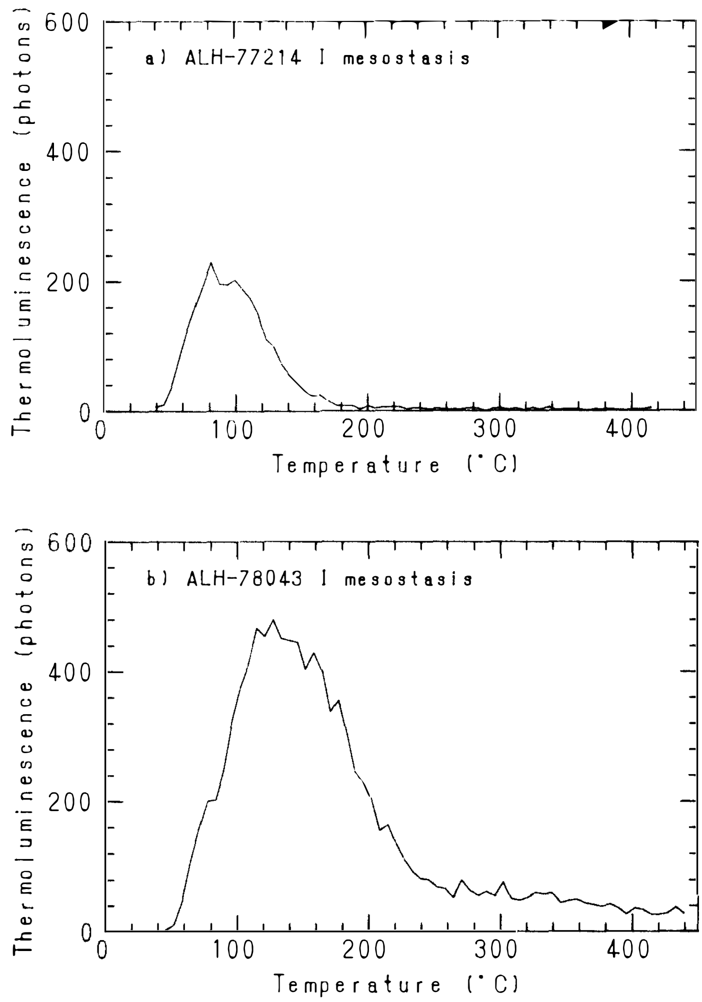

Fig. 2. TL glow curves by the two-dimensional photon counting method.
a) square region 1 [mesostasis] of ALH-77214(L3.4–3.5),
b) square region 1 [mesostasis] of ALH-78043(L6).

Fig. 1 (opposite). BEIs and induced TL images.
Long dimension is 2.9 mm. The position of high TL intensity is put by deep black points. The squares show the regions, where local TL glow curves were analyzed and chemical compositions of mesostases were analyzed by EPMA. The circles show the regions where the mesostases showed no or weak TL and chemical compositions were analyzed by EPMA.
A) a BEI of ALH-77214(L3.4–3.5),
a) TL image of ALH-77214 at the temperature interval 100–110°C,
B) a BEI of Y-77191(L3.6),
b) TL image of Y-77191 at the temperature interval 100–110°C,
C) a BEI of ALH-77216(L3.8),
c) TL image of ALH-77216 at the temperature interval 100–110°C,
D) a BEI of ALH-78043(L6),
d) TL image of ALH-78043 at the temperature interval 100–110°C.

Table 1. TL characteristics and normative ratio of albite/(albite + anorthite).

a) Square regions in Fig. 1

Meteorite region		Induced thermoluminescence		Normative ratio of albite/(albite+anorthite) (mole %)
		peak temperature (°C)	peak width (°C)	
ALH-77214	I	81	59	40.7±2.2
	II	78	57	28.6±1.8
	III	100	82	79.8±2.7
	IV	104	70	28.7±7.7
Y-77191	I	101	71	21.1
	II	133	115	100
	III	133	102	100
	IV	114	93	98.2±1.4
	V	113	80	93.9±8.7
ALH-77216	I	125	100	84.5±1.8
	II	134	98	89.2±1.0
	III	128	107	86.5±2.1
	IV	134	99	93.9±8.2
	V	118	98	84.4±0.3
ALH-78043	I	126	103	81.1±1.1
	II	133	113	82.4±0.5
	III	126	101	80.8±0.6
	IV	126	111	82.2±1.3
	V	119	96	78.1±1.7
	VI	121	93	77.9±2.2

b) Circled regions in Fig. 1

ALH-77214	V	no TL	98.7±1.8
Y-77191	VI	no TL	100
	VII	no TL	100
ALH-77216	VI	weak TL	98.1±1.9

in these mesostases. The average ratio, albite/(albite+anorthite) (mole %), was calculated and was also listed in Table 1a. We obtained that high normative anorthite mesostases >50% in ALH-77214 (L3.4–3.5) and Y-77191 (L3.6) have low peak temperatures and narrow widths, and high normative albite mesostases >50% in all TL measured chondrites had high peak temperatures and wide widths. In our result, the difference of TL characteristics can be attributed to the chemical compositions of mesostases, not to the feldspar forms.

As a bulk TL characteristics the ordinary chondrites under petrologic type 3.5 belong to the group of 'low peak temperature and narrow width' and those above type 3.5 belong to the group of 'high peak temperature and wide width' (GUIMON

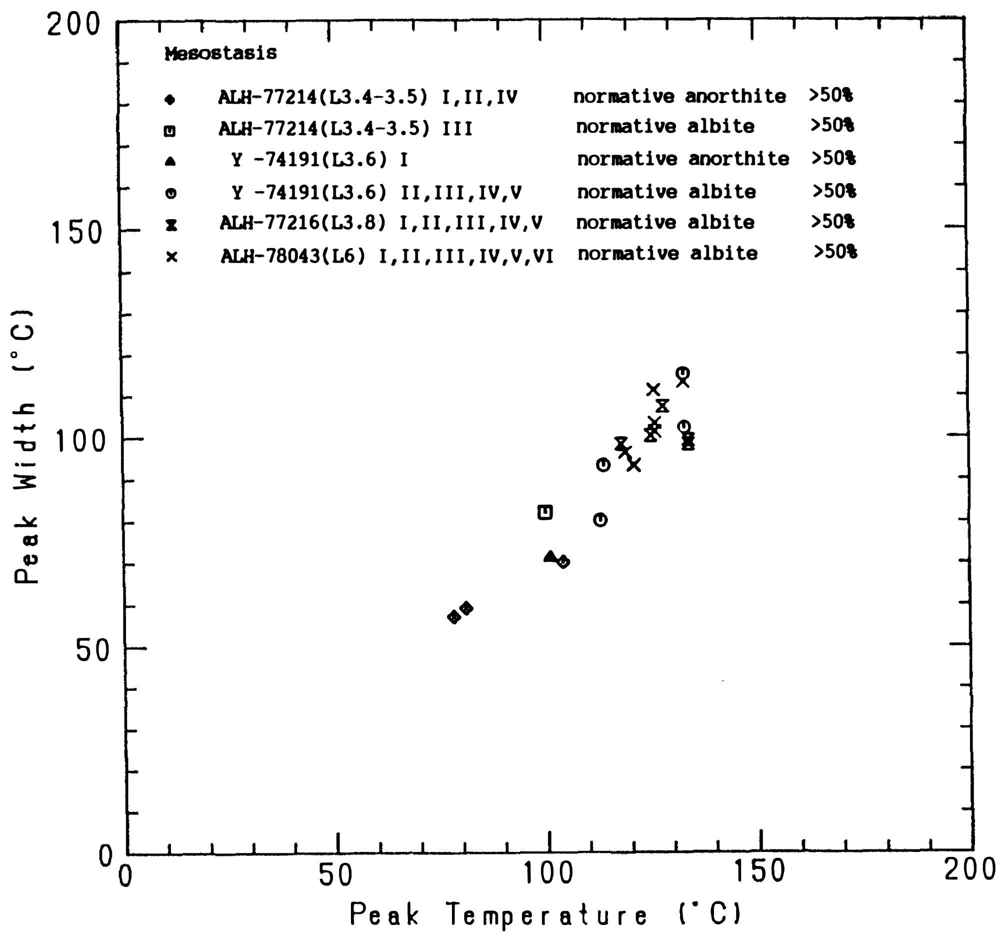

Fig. 3. The correlation between TL peak temperature and peak width.

et al., 1985). We found that the high anorthite mesostasis is mainly responsible for the TL under the petrologic type 3.5, ALH-77214 (L3.4–3.5) and that the high albite mesostasis is mainly responsible for the TL above type 3.5, Y-74191 (L3.6), ALH-77216 (L3.8) and ALH-78043 (L6).

We recognized that there were some chondrules which showed no or weak TL emission in the same fragments of the type 3 ordinary chondrites. These chondrules are shown with circles in Fig. 1, region V in ALH-77214, regions VI and VII in Y-74191, and region VI in ALH-77216. It is considered that glass shows no or weak TL and crystallized mesostasis [feldspar] shows intense TL (SEARS, 1988). The chemical compositions of these mesostases were also analyzed and we obtained the quantity of normative minerals in these mesostases. The average ratio, albite/(albite+anorthite) (mole %), was calculated and was listed in Table 1b. They had a large content of albite.

What dose the coexistence of high albite mesostases with TL emission and no emission and high anorthite mesostasis with TL emission in the same fragments of type 3 ordinary chondrites mean? The melting temperature of albite is lower than that of anorthite. If type 3 ordinary chondrites suffered from a post-accretional metamorphism, the coexistence of crystallized and glassy mesostasis of albite conflicts with the existence of crystallized anorthite mesostasis in the same fragments. Then the coexistence of them means that the type 3 chondrites maintain a state of the formation of each chondrule without suffering from the post-accretional metamorphism. The glassy mesostasis is made by rapid cooling and crystallized mesostasis is by slow cooling in their formation. These results suggest that low petrologic grade chondrites have a large population of rapidly cooled chondrules and high petrologic grade chondrites have a large population of slowly cooled chondrules in type 3 chondrites.

We would like to investigate the relationship between the devitrification process of mesostasis resulting in the formation of feldspar and the effect on thermoluminescence as a next step.

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