THERMAL HISTORY OF UREILITE AS INFERRED FROM MINERALOGY OF PECORA 
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It is generally understood that most ureilites experienced a high 
temperature episode, a shock event and rapid cooling (1)(2). However, 
quantitative estimate of some of the parameters of these processes has been 
difficult, partly because large unshocked specimens were not available for 
detailed mineralogical studies. Pecora Escarpment 82506 (PCA82506) is a new 
Antarctic ureilite weighing 5.3 kg. Mason (Antarctic Meteorite Newsletter, 
1983) reported that the meteorite appears to be relatively unshocked 
compared to most ureilites. We investigated olivine and pigeonite from 
PCA82506, by combined single crystal X-ray diffraction, microprobe, and 
transmission electron microscope (ATEM) techniques, to gain better under-
standing of the thermal history of ureilite. A computer program written by 
Miyamoto (3) to reproduce a diffusion profile of a chemically zoned pyroxene 
has been applied to estimate the cooling rate of olivine.

A polished thin section (PTS), PCA82506,24 has been investigated by an 
electron microprobe. Quantitative analyses were made of olivine crystals, 
for every 4 microns from core to rim along the c axis, to obtain a diffusion 
profile towards the carbonaceous (C) matrix. Two crystals with a face 
coated with carbon nearly perpendicular to the plane of the PTS have been 
selected for the measurements. Several crystals separated from a small 
chip, PCA82506,13 were examined by an X-ray precession camera and 4-circle 
diffractometer to identify the orientation and the degree of shock deforma-
tion. After X ray study, the crystal for ATEM work was mounted in thick 
resin with the b axis perpendicular to the plane of a glass slide.

The pigeonite and olivine grains are present in subequal amount (Oliv. 
52 : Pyx 48). The crystals gave very sharp diffraction spots in comparison 
with known ureilite minerals, except for ALH78019, for which no pigeonite 
crystal was available. Some large crystals of pigeonite show slight split-
ting of diffraction peaks. The pigeonite crystal show no evidence of 
exsolution. Faint diffuse streaks along a* indicate the presence of 
stacking faults. The observed cell dimensions are: a 9.660(2) A, b 8.870 
(2), c 5.212(1), B 108.53(1) with possible space group, P21/c. The chemical 
composition of pigeonite is uniform Ca6Mg77Fe17 (Fig. 1) and does not show 
variation at the grain boundary. The olivine crystals Fa20 show Mg enrich-
ment zoning at the rim with C-matrix. A thin layer of enstatite about 10 
microns thick was produced at the extreme rim, and fine iron particles at 
the most Mg-rich rim of the olivine crystal. The chemical zoning was 
observed within about 30 microns from the rim.

The reverse zoning at grain boundary of ureilite olivines is generally 
thought to be formed by reduction by C-matrix. We assumed that iron atomic 
diffusion in olivine controls the formation of the zoning profile. We have 
numerically solved the diffusion equation taking both temperature and 
concentration dependence of diffusion coefficient of Buehning and Buseck (4) 
into consideration. Boundary condition is that Fa content at edge of grain 
is zero. Initial profile is assumed to be a step function. We approximated 
an olivine grain as spherical shape. We have calculated the linear cooling 
rate from the initial temperature (1300, 1250, 1200, 1150°C) to 800°C to fit 
the calculated profile to the observed profile. The initial temperature
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(1150 to 1250°C) was estimated from the chemical compositions of three coexisting pyroxenes in Y74130 (5) and the pyroxene geothermometer of Lindsley and Anderson (6). The calculated profiles of four typical cooling rates are compared with the observed profile in Fig. 2. 10°C/hr gives the best fit for the outer profile.

The estimated cooling rate, 10°C/hr is in good agreement with the rates estimated for Y74130 and Y790981 pyroxenes (3 to 20°C/hr) from the wave length of the spinodal decomposition of Ca-rich pyroxenes by Mori and Takeda (7). The cooling rates suggest very rapid cooling from high temperature. We attribute this event to destruction of a ureilite parent body or to an impact-induced excavation of the ureilite parental mass from their deep seated residence. The parental mass may be small, if the sample was resided in the center.

In summary, crystallography and mineralogy of the pigeonite and olivine crystals in PCA82506 indicate that this meteorite is relatively less shocked than others, and cooled rapidly from high temperature at cooling rate of 10°C/hr. The results are in agreement with our proposed working hypothesis on the origin of ureilites (8).

We thank U.S. Antarctic Meteorite Working Group and NIPR for meteorite samples and the Ministry of Education for a Fund for Scientific Research and Dr. N. Haga and Mr. O. Tachikawa for technical assistance.


Fig. 1. A part of pyroxene quadri-lateral of ureilites.

Fig. 2. Examples of calculated diffusion profiles (lines) for cooling rates, from 5-30°C/hr +: observed profile.