METALLOGRAPHIC COOLING RATE METHODS: APPLICABILITY TO SPECIFIC TEMPERATURE RANGES DURING COOLING.

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Introduction: Cooling rates obtained by a variety of metallographic methods can reveal the thermal history of the asteroids and in some cases the size of the meteorite parent bodies. However, cooling rates obtained by different cooling rate methods are valid only for a specific temperature range [1, 2]. The importance of this phenomenon is discussed.

Metallographic Cooling Rate Methods: In general, the metallographic cooling rate methods are either kamacite-based [3-5] or taenite-based [6-11]. The kamacite-based methods are very sensitive to the temperature-composition value of the / +γ+(Ph.) phase boundary in the Fe-Ni and Fe-Ni-P systems and the results are often inaccurate. On the other hand, taenite-based methods are reliable. In addition, taenite-based methods allow one to obtain cooling rates in specific cooling temperature ranges.

Cooling Temperature Ranges: The determination of the applicable cooling temperature ranges depends on several factors: cooling rate method, cooling rate, and meteorite composition. The meteorite composition controls the effect of the Fe-Ni and Fe-Ni (P saturated) phase diagrams, inter-diffusion coefficients and kamacite nucleation mechanism. For example, the taenite central Ni method [6, 7] or taenite profile matching method [8] gives cooling temperature ranges from ~600 to ~380 C in chemical group IIIA, from ~700 to ~380 C in chemical group IIIB, and from ~580 to ~380 C in chemical group IVA. The cooling temperature range in H chondrites varies from ~700 to ~380 C based on the taenite central Ni method, although grain boundary nucleation and diffusion may be more important [12]. The tetrataenite rim method [10] measures the cooling rate in the temperature range from 380 to 350 C in iron and stony iron meteorites and from 400 to 350 C in stony meteorites. The cloudy zone method [11] measures the cooling rate in the temperature range from 320 C to below 0 C and can be applied in iron, stony iron and stony meteorites. The realization that there is a significant difference in the applicable temperature ranges in chemical group IIIAB raises a concern about the nature of the IIIAB parent body based on past cooling rate calculations [3, 13]. If the measured cooling rates are not all obtained from the same temperature, a uniform cooling rate does not necessarily imply a core for the parent body. On the other hand, non-uniform cooling rate does not necessarily mean that the meteorites are distributed within the parent body. Direct experiments and calculations based on either the tetrataenite rim method or the cloudy zone method can give us new evidence about the structure of the parent body. These two methods give cooling rates at a uniform cooling temperature range for iron, stony iron and stony meteorites and are independent on the composition of the bulk metal.

References: [1] Haack H. et al. 1994. *Meteoritic*s 29:470-71. [2] Yang J. et al. 2004. Abstract #1288. 35th *Lunar & Planetary Science Conference*. [3] Goldstein J.I. et al. 1967. *GCA* 31:1733-70. [4] Willis J. et al. 1978. *EPSL* 40:162-67. [5] Haack H. et al. 1996. *GCA* 60:2609-19. [6] Wood J.A. 1964. *Icarus* 3:429-59. [7] Rasmussen K.L. 1981. *Icarus* 45:564-76. [8] Goldstein J.I. et al. 1965. *GCA* 29:893-920. [9] Short J.M. et al. 1967. *Science* 156:69-61. [10] Yang et al. 2003. unpublished. [11] Yang C-W et al. 1997. *GCA* 61:2943-56. [12] Reisener R.J. et al. 2003. *MAPS* 38:1679-96. [13] Rasmussen K.L. 1989. *Icarus* 80:315-25.