EXPERIMENTAL STUDY OF SEGREGATION IN PLANE FRONT SOLIDIFICATION AND ITS RELEVANCE TO IRON METEORITE SOLIDIFICATION R. Sellamuthu and J. I. Goldstein, Dept. of Metallurgy and Materials Engineering, Lehigh University, Bethlehem, PA 18015

It has been of considerable interest to explain 1) the origin of various meteorite solidification structures and 2) the elemental distribution within a class of meteorites. In the latter, mathematical models of dendritic solidification using partition ratios, measured in laboratory alloys are applied to meteorite compositions. (1,2) Also, direct metallographic and chemical examinations of meteorites have been employed to solve the above problems. (3, 4) Most recently, Esbensen and Buchwald (4) have explained the troilite nodules found in the single grained Cape York meteorite as being entrapped eutectic liquid formed during the last stage of dendritic solidification. Dendritic solification is currently viewed as the mode of solidification of certain classes of meteorites. (5)

In spite of a number of studies, considerable questions exist as to the origin of meteorites with large variations in structure and chemistry. The scope of this study is to understand the solidification structures of meteorites and to explain the variations in elemental distribution within a class of meteorites. The general approach to this study is (i) to grow a single crystal dendrite of considerable size by plane front solidification and to analyze the resulting microstructural features and (ii) to measure the elemental distribution within the dendrite. In plane front solidification, a single grained dendrite is grown by directionally solidifying a column of molten liquid metal with a planar interface between co-existing liquid and solid phases. It is important to note that in dendritic solidification, a single dendrite solidifies with a planar interface. (6) An alloy (Fe-10% Ni-1% C-1.6% S) close to meteorite composition was used for the solidification experiments.

The apparatus consisted of a resistance heated high temperature furnace kept inside a glass chamber and a crystal pulling mechanism. In a typical experimental run, the alumina tube containing the alloy rod is suspended inside the furnace by means of the crystal pulling mechanism. Next, the alloy is melted under argon atmosphere and subsequently withdrawn from the furnace at a growth rate of about 10^{-4} cm/sec to promote unidirectional solidification. The thermal gradient, G, in the furnace was about 170°C/cm. Since the G/R ratio of 1.7×10^6 °C sec/cm^2 employed in this experiment is much higher than the critical ratio of 6×10^5, (5) the planar growth was achieved. The sample thus made was about 5 mm dia. x 15 mm length.

Figure 1 schematically illustrates the microstructural features of the plane front sample. The structure consists of a proeutectic region (austenite, γ and FeS) and an eutectic. The beginning part of the plane front sample represents the dendrite core and the last portion represents the interdendritic region. In eutectic forming systems such as meteorites, the interdendritic region is an eutectic. Though the plane front sample is only about 15 mm long as compared to predicted meteorite dendrite of several meters, (5) it is an excellent macroscopic representation of the general features of a meteorite.

As can be seen fron Figure 1, the sulphides are distributed within proeutectic (γ phase) region, exhibiting an aligned cylindrical morphology. Based on this observation, we propose that the aligned sulphide nodules observed in meteorites, Cape York being an example, were formed along with primary austenite phase, γ, during the last stage of proeutectic solidification ($f_s \geq 0.45$) and thus, embedded in the dendrite core. Another feature that can be noted from Figure 1 is of intertwinned metal/sulphide eutectic region. Some meteorites with high sulphide content, Mundrabilla being an example, could have

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been a broken piece of the eutectic portion of the dendrite.

Concentration profiles were determined along the growth direction using a 50μm x 50μm raster scan in the electron microprobe and are plotted in Figure 2. Ni composition remained constant through most of proeutectic solidification and significantly increased in the eutectic region. Carbon is partitioned to proeutectic region with a considerable concentration gradient. The Ni profile in conjunction with some sulphides in proeutectic region is in accord with the existence of a large number of meteorites close in Ni content containing varying amounts of sulphide. This is a direct experimental confirmation of the view that meteorites within a class can be broken pieces of a dendrite. A focussed electron beam analysis on the γ phase along the growth direction showed that Ni composition varied from 10% in the proeutectic region to about 60% in the eutectic. Based on this observation, we propose that the high Ni anomalous meteorites could be the end members of a class.

We conclude that the elongated troilite nodules observed in meteorites is a feature of dendritic core solidification, and that meteorites with slight variations in Ni content, but exhibiting large variations in troilite content, originate from the same parent melt and belong to the same chemical group.

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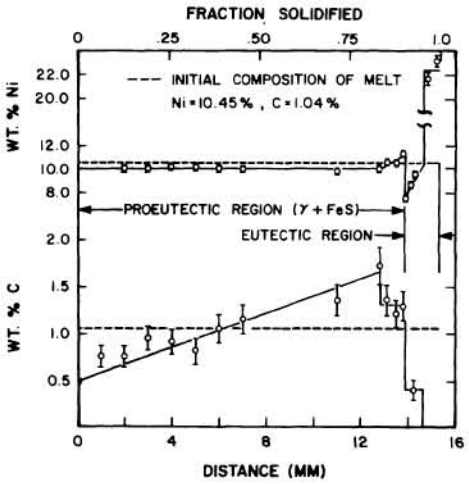

Fig. 2. Concentration profiles

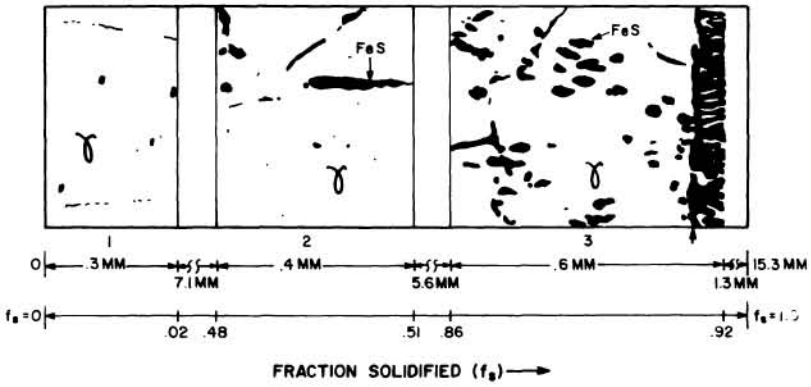

Fig. 1. Schematic illustration of the microstructure of the plane front sample showing sulphide distribution traced from optical micrographs at three locations (1,2,3) in the proeutectic γ phase. The eutectic region is to the right of the arrow.