345 Darbyhurst Rd.
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Mr. Oscar E. Monnig
29 Chelsea Drive
Fort Worth, Texas. 76134

Dear Mr. Monnig:

Thank you for your letter discussung the Tishomingo meteorite. I will be happy to send to Mr. Orr a copy of the publication concerning our metallographic observations of the meteorite.

You raised several questions in your letter which I will attempt to answer. I doubt, too, that impact with earth provided the mechanical shock that was evident in the microstructure of the meteorite. A celestial collision would receive my vote. Since I am not knowledgeable about solar temperatures, other than the fact that presumeably somewhere temperatures approach absolute zero, -270 deg. C, I don't know how far away from the sun this meteorite traveled. Actually, we have no proof that it didn't originate in another galaxy far removed from our own, do we? If the meteorite approached near to the sun at some time, the temperature may well have provided the thermal energy to cause "reverse transformation" or cause alpha iron (kamacite) to form from the unstable martensite structure.

This brings me to the question you asked about the term, "martensite". As far as terms go, it is in the same category of terms as kamacite (alpha iron or ferrite) and taenite (gamma iron or austenite), but not the same category as the term, "plessite", a mixture of kamacite and taenite. Kamacite, taemite and martensite are "phases", whereas plessite is a mixture of two phases and really has little meaning except to describe the manner or pattern in which the two phases occur. Plessite is in the same category of terminology as "Widmanstatten"; it describes a structural pattern that consists of more than one phase.

The difference between kamacite and taenite is their atomic lattice structures. The unit cell of kamacite is body-centered-cubic and, of taenite, is face-centered-cubic. Pure iron can exist as either phase, however, pure iron exists as the taenite phase only above 1670 deg. F; the kamacite phase exists below 1670 deg. F. Since pure iron behaves this way, it is called allotropic; allotropic elements by definition can exist in two or more distinct forms which are identical chemically, but have different physical properties(e.g., density, crystalline form, solubility, etc.)

On the other hand, in iron alloys martensite has a body-centered-tetragonal unit cell and is a metastable phase, not an equilibrium phase, as is kamacite and taenite. Years ago, martensite was thought of only as a transition structure which occurred when taenite started to change to kamacite upon cooling.

Later, metallurgists recognized that the martensite reaction is a basic type of phase transformation brought about by the coordinated shear of many atoms without diffusion. The product of the transformation is called martensite. In iron alloys it is also called "alpha prime". Because of the mechanism by which martensite forms, martensite reactions are commonly referred to as diffusionless phase transformations; no change takes place in the chemical composition. By this definition martensite reactions occur in a number of alloy systems that undergo phase transformations, such as titanium-molybdenum, indium-thallium, gold-cadmium, iron-carbon, and iron-nickel alloy systems, and the product of the reactions is always called martensite, regardless of the alloy system.

The Tishomingo is nominally an Fe-32.5% Ni alloy in which the taenite phase is present in the amount of 21% by volume. As pointed out in the paper, the remainder of the mass (79% by volume) is not "martensite", technically, since we observed that the structure referred to as martensite really consists of <u>two</u> phases, and martensite is a <u>single</u> phase. The 79% portion of the total meteorite structure was definitely all martensite at some time, but it has been altered in some way, such as by decomposing, aging, or by transforming back to taenite. Since we never had the opportunity to identify what the two phases are, we can't say exactly how it was altered. The two phases must of necessity be any two of the three phases which can exist in the Fe-Ni binary alloy system, namely, kamacite, taenite, or martensite. One of the phases, I feel certain, is still martensite, just as it was when it first formed from taenite. When martensite changes by aging, for instance, it doesn't all change at once. It is time and temperature dependent. I have a hunch the other phase is kamacite.

The structural composition of the Tishomingo was 21% taenite and 79% martensite (excluding minor constituents such as inclusions) <u>before</u> the structural alteration took place in the regions of martensite. <u>Now</u>, the structural composition of the Tishomingo is that same <u>21%</u> taenite and 79% altered, decomposed, aged, or "something", martensite which consists of two phases. At the present time I believe these two phases to be martensite and kamacite. This is the only way I know to accurately describe the <u>Structural</u> composition of the Tishomingo meteorite at this time. This is one reason why more studies of the structure need to be made. Thus, you cannot call the Tishomongo a mass of taenite, nor, in my opinion, can you call it a mass of plessite. The Tishomongo structure doesn't fit the definition of any of the established terms used for describing other meteorites.

I'm sorry this discussion got so lengthy and my intention was not to "snow you under" by any means, but I hope that you now understand a little better what we (metallurgists) mean when we talk about martensite, austenite (taenite), and ferrite (kamacite) in iron and/or iron-base alloys. You see, basically, the difficulty is confusion with terminology and the definitions of the terms. For instance, I'm not sure what you mean relative to meteorites by the term, "composition". To me, this has to be further qualified, such as, "Chemical composition", "structural composition", or "physical composition", etc. None of these types of composition have been determined completely for the

Tishomingo, but I have described in this letter how we interpret the "structural composition" we observed under the microscope.

It was a pleasure to hear from you and I will be happy to discuss other questions you might have about the Tishomingo; it is extremely interesting. If you ever get to Columbus, Ohio, come visit me at Battelle Memorial Institute.

Very truly yours,

Richard Buchheit

R. D. Buchheit