METALLOGRAPHIC TINT ETCHING REVEALS NICKEL ZONATION PATTERNS IN METEORITIC METAL: APPLICATION TO THE ISHEYEVO (CH/CBb) CARBONACEOUS CHONDRITE Laurence A.J. Garvie[1,2], [1]Center for Meteorite Studies, [2]School of Earth and Space Exploration, Arizona State University, 781 East Terrace Rd., Tempe, AZ 85287-6004 (lgarvie@asu.edu).

Introduction: Elemental examination of metal particles is normally the domain of SEM/EPMA, e.g., [1]), and broader information through elemental mapping. However, this type of microprobe-based elemental mapping is time consuming. Detailed metallographic information can also be revealed after etching, primarily with nital, which has been the cornerstone of meteoritic iron structural analysis [2], and coupled with elemental concentrations determined through electron microprobe and INAA forms the basis of iron meteorite classification [3]. Nital differentially etches the meteoritic metal phases producing surface topography that provides structural information. The structural information gained through optical and SEM examination of etched surfaces is revealed through the light-shade contrast between the different phases, producing "black-and-white" images. It is also possible to tint etch metals, with the tint color providing structural and compositional information [4]. Tint etching is used extensively in the metallurgical fields, but only rarely on iron meteorites, e.g., [5, 6]. Here is described the information revealed through the application of the sodium bisulfite ($NaHSO_3$) tint etch on the Isheyevo CH/CBb chondrite.

The sodium bisulfite ($NaHSO_3$) tint reveals chemical zoning and deformation microstructures in Fe-Ni alloys and ferritic steels [4, 7, 8]. In particular, the etch produces colors related to Ni content, and also reveals relative crystallographic orientations and deformation microstructures [7, 9].

Samples and preparation: Pieces of Isheyevo were mounted in resin, ground flat, polished with 1 μm diamond polish and then 0.3-μm alumina. Samples were then washed and immersed into freshly prepared tint etch solution, removed and washed in water then methanol. The tint etch was prepared by adding 20 g sodium bisulfite to 100 ml water and sample immersed for ~10 s. Care was taken to not touch the tint-etched surface, as the tint layer is easily scratched. Samples were photographed with reflected light using a petrographic microscope (Leica DM 2500P). Samples were then repolished and elemental data acquired from individual grains of interest at The Michael J. Drake Electron Microprobe Laboratory (University of Arizona) using the Cameca SX100 Ultra electron probe. Element line scans were acquired across selected grains so as to correlate tint colors with elemental data.

Results and discussion: Tint-etched sections show a range of colors on the metal grains, varying from blue through tan (Fig. A). EMPA analyses of grains with different colors show a color constancy with respect to Ni content. Many of the grains show a uniform blue color; EMPA line scans of these grains show uniformity in their Fe/Ni ratio, with Ni below ~7 at% (Fig. A, inset). Direct correlation between tint color and Ni content was revealed by the chemically zoned grains that are abundant in Isheyevo (e.g., [10-12]); these grains have blue rims and tan cores (Fig. B). EMPA line scans across these grains shows continuous composition gradients at the micron level, which is further corroborated by the smooth tint color gradations (Fig. B). No Ni-poor or -rich precipitates are visible by EMPA, BSE imaging, or through tint etching in these zoned particles. Under the tinting conditions described above, the colors correlate with Ni content: pale blue (~4 to 5 at% Ni), dark blue to purple (~6 at% Ni), brownish tan (~7 at% Ni), light tan (~8 at% Ni). Above ~10 at% Ni, the metal is only lightly stained and above 20 at% Ni, the grain is unstained and shiny. Two such Ni-rich grains are visible in Fig A (grains 1 and 2). Inclusions in metal grains, such as phosphides and sulfides, remain unstained, e.g., grain 3 in Fig. A. Particles with complex microstructures composed of differing compositions are revealed through tint etching. For example, a grain decomposed into Ni-rich and Ni-poor subgrains shows light or unstained Ni-rich lamellae in a stained Ni-poorer groundmass.

The tint-etching method provides a rapid and reliable way to reveal metal grain compositions and structures. For example, a typical area of stained Isheyevo imaged by optical microscopy allows different metal grain types to be quantified. One such representative area shows 33% zoned-metal grains, 44% unzoned kamacite, 3% cellular kamacite, 4% unzoned decomposed, 8% kamacite with inclusions, 4% high Ni grains, 3% zoned grains with decomposed cores, and 1% high Ni grains with inclusions. Since a whole section can be stained and easily imaged by optical microscopy, rare grain types can also be readily observed. For example, one 1" round section contained two reversely zoned grains (Fig. C), containing high Ni rims and low Ni cores.

Acknowledgement: Support for this research was provided by the NASA Emerging Worlds (EW) program through grants NNX15AH62G and NNH16ZDA001N.

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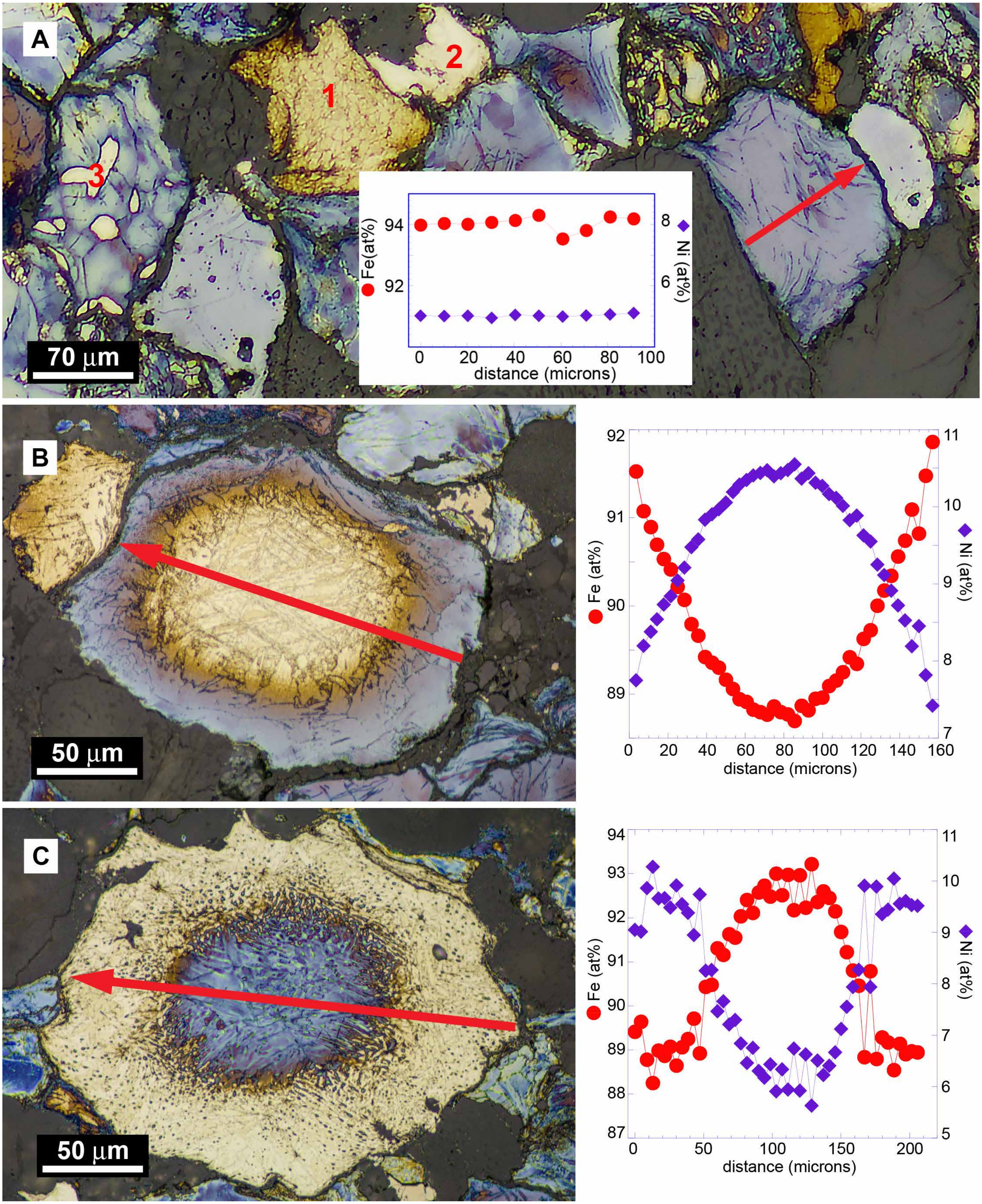

Reflected-light images (A through C) of tint-etched Isheyevo and EMPA element (Fe and Ni) line scans of selected grains (red arrows). A) Collection of grains stained a range of colors. Light-blue stain corresponds to metal grains with low Ni, typically <7 at% Ni. The uniformity of color across a grain reflects the constant Fe/Ni content. Grain 1 - 7 to 8 at% Ni. Grain 2 - ~15 at% Ni. Grain 3 - kamacite with troilite inclusions (bright). B) Compositionally zoned grain with kamacite rim and high Ni core of martensite α2.C) An unusual reverse zoned grain with high Ni rim (tan) and low Ni core (blue).