NOVOSIBIRSK METEORITE: AN FeNi-RICH, HIGHLY SHOCKED H5 ORDINARY CHONDRITE. L. E. McGraw[1], M. M. Jean[1], J. Emery[1], N. M. Podgornykh[2], and L. A. Taylor[1], [1]Planetary Geosciences Institute, Dept. of Earth and Planetary Science, University of Tennessee, Knoxville, TN 37996 (lmcgraw@vols.utk.edu), [2]Institute of Geology and Mineralogy, Siberian Branch of the Russian Academy of Sciences, Novosibirsk, Russia

Introduction: The Novosibirsk meteorite, found on the eastern outskirts of Novosibirsk, Siberia, Russia, in 1978, was initially classified as an *achondrite* by G. M. Ivanova, though her results have not been published [1].

This study classifies the Novosibirsk meteorite as an H5 ordinary chondrite, due to its high metal content and deformed chondrules. However, the current classification scheme for ordinary chondrites fails to accurately characterize this meteorite. The H ordinary chondrites have a total iron content above that of an L or LL ordinary chondrite [2], but the Novosibirsk meteorite has almost three times as much metal necessary to consider it an H chondrite. This meteorite tests the guidelines of current meteorite categories and we feel that new categories should be proposed under the ordinary chondrite classification, in light of our new findings.

Petrography: The Novosibirsk meteorite has many unique features. First, it has a large amount of metallic iron (**Fig. 1A**). The FeNi metal and troilite comprise roughly 30% of the sample, about three times that normally found in high-iron ordinary chondrites, and occurs throughout the meteorite.

Second, it has two distinct regions that are petrographically and lithologically distinct (**Fig. 1B**). One region is light-colored and is dominated by olivine and orthopyroxene, with significant amounts of FeNi metal and troilite. Chondrules are present but deformed, and occur as heavily brecciated barred chondrules with radial pyroxene or granular chondrules composed mostly of small silicate crystals. The other region is darker and does not contain chondrules, though several melt features are present, i.e., FeNi metal plus troilite eutectic textures, melt veins, and metallic droplets. Glass and tiny metal crystals are responsible for the darker color. This region is more altered than the lighter region and is best interpreted as a splash melt, whereas the substantial shocking without melting experienced by the lighter region, in addition to the large amount of metal, makes the lighter region an H5 ordinary chondrite.

Methods: Major- and minor-element compositions were determined with a Cameca SX-100 electron microprobe at the University of Tennessee. Olivine, pyroxene, oxide, sulfide, and metal analyses used a 1-µm beam with a 30-nA probe current and 15-keV accelerating voltage. Feldspar analyses used a 7-µm beam with a 10-nA probe current and 15-keV accelerating voltage, while apatite analyses used a 5-µm beam with a 4-nA probe current and 10-keV accelerating voltage.

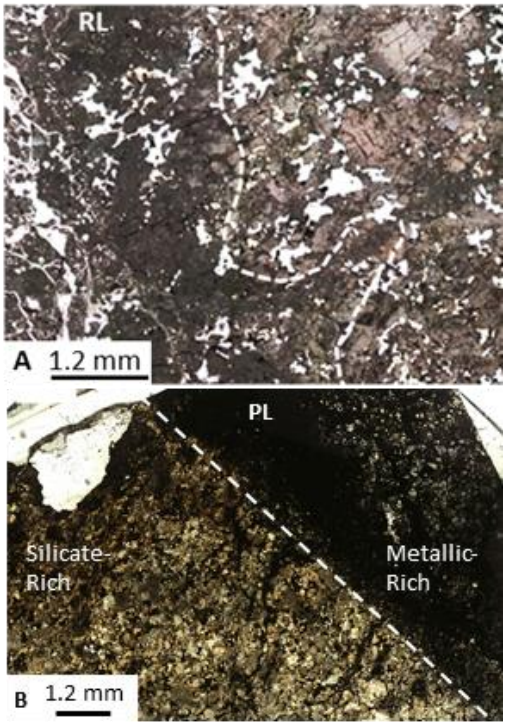

Figure 1: (A) Reflected-light image of Novosibirsk meteorite. White grains are metallic iron and the dashed white line represents the boundary between the metallic- and silicate-rich regions. (B) Plane-polarized light image of another Novosibirsk meteorite thin section distinctly displaying the two regions.

Results: Plagioclase, olivine, and pyroxene occur in all regions of the meteorite. Orthopyroxene is the dominant pyroxene phase and has an average composition of $Wo_1En_{82}Fs_{17}$. Clinopyroxene is primarily found within chondrules ($Wo_{45}En_{48}Fs_7$) (**Fig. 2**), but trace amounts occur along chondrule rims. Olivine ranges from Fo_{78} to Fo_{83} and plagioclase ranges from An_4 to An_{14} (**Fig. 2**). The chondrules and matrix have the same olivine and plagioclase compositions.

Chondrule mineralogy varies significantly between chondrules regardless of type. The granular chondrules are dominated by either orthopyroxene (**Fig. 3A**) or olivine (**Fig. 3B**). Plagioclase occurs as small crystals throughout these chondrules and tiny metal crystals (10

µm) are also present. Olivine is common outside the orthopyroxene chondrules, but is rare within it. A similar relationship for orthopyroxene holds for the olivine-rich chondrules. Clinopyroxene occurs in variable amounts between chondrules. The barred chondrules are either trimineralic (**Fig. 3C**) or bimineralic (**Fig. 3D**). Olivine and plagioclase are always present in equal quantities, with pyroxene being the third component in some chondrules. Clinopyroxene and FeNi crystals are small and are not major contributors to chondrule composition.

There are three oxide phases: chromite, trace amounts of ilmenite, and rutile lamellae within the ilmenite grains. Ilmenite only occurs in the darker region of the meteorite, while chromite occurs throughout the entire sample, often with boundaries shared by FeNi metal and troilite. Troilite is the only sulfide phase present but the FeNi metal crystals are a mixture of kamacite, taenite, and trace amounts of tetrataenite, as nickel content ranges from 6-50%. Chlorapatite and merrillite crystals are also present throughout the sample and can be relatively large, with some approaching 1 mm in length.

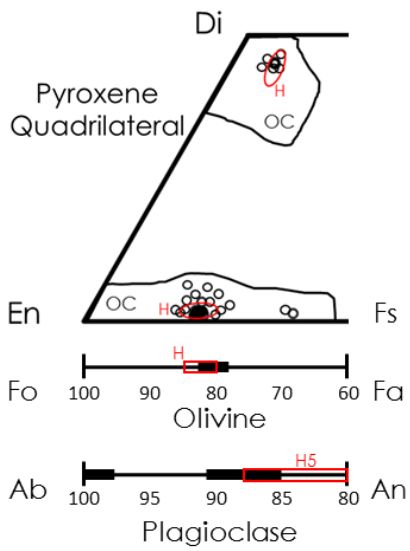

Figure 2: Pyroxene quadrilateral with olivine and plagioclase plots below. Black outlines are equilibrated ordinary chondrite field and red outlines are H chondrites on the pyroxene and olivine plots [2]. Red outline on plagioclase plot is H5 chondrite region [3,4,5].

Discussion: The Novosibirsk meteorite is an H5 ordinary chondrite that is unlike any other meteorite. Its lithologically distinct regions, high FeNi metal-rich content, and numerous shock features suggest it underwent multiple shock events, such as the initial metamorphism from the parent-body impact followed by explosion upon entering the atmosphere. The high level

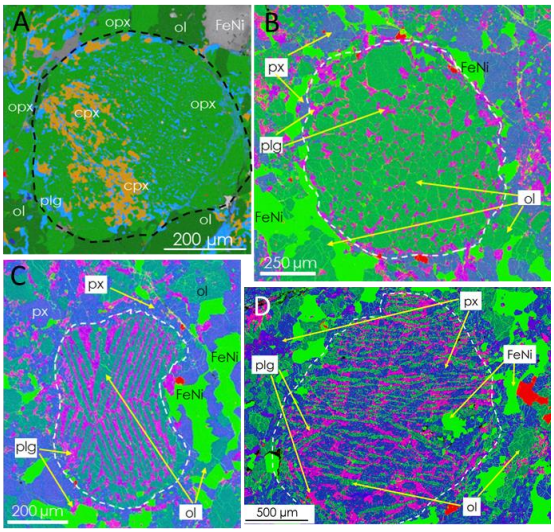

Figure 3: Al Kα, Si Kα, Ca Kα, & Fe Kα maps of various chondrules in the Novosibirsk meteorite. (A & B) Granular chondrule. (C & D) Barred chondrules.

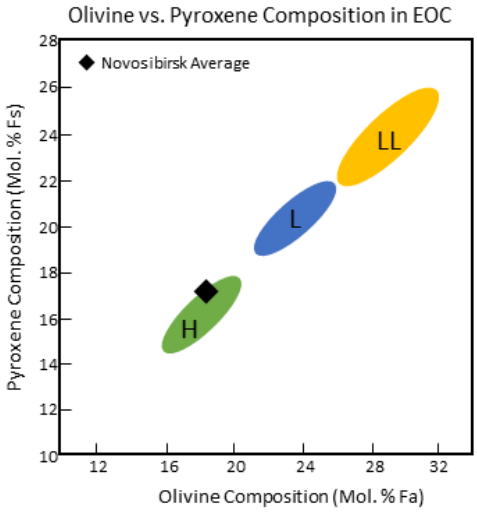

Figure 4: Plot of pyroxene versus olivine Fe content of equilibrated ordinary chondrites (EOC) [6].

of metamorphism and low-Fe silicates suggest that Novosibirsk is an equilibrated ordinary chondrite. A plot of ferrosilite content versus fayalite content for equilibrated ordinary chondrites shows that Novosibirsk lies within the equilibrated ordinary H chondrite region (**Fig. 4**). In summary, this unusual H5 chondrite contains several features that are being investigated at present.

References: [1] Petaev M. N. et al. (1990) *Meteoritika*. [2] Grady M. M. et al. (2014) *Atlas of Meteorites*. [3] Nagao K. et al. (2016) *Geochem. Soc. Japan, Geochem. Jour*. [4] Aoudjehane H. C. et al. (2015) *78th Ann. Met. Soc., Vol. 50*. [5] Sharygin V. V. et al. (2016) *Met. Soc. Bull. 105, in prep*. [6] Brearley A. J., Jones R. H. (1998) *Reviews in Min. and Geochem*.