METEORITE OR METEOR-WRONG? J. J. Hagerty, J. M. Karner, H. E. Newsom, and R. H. Jones, University of New Mexico, Institute of Meteoritics, Dept. of Earth & Planetary Sciences, Albuquerque, NM 87131 U.S.A. Email: jh2713@unm.edu

Introduction: We have developed a hands-on activity that introduces middle school students to planetary science, the scientific method, and some of the high technology instruments used in scientific research. The main objective of this activity is for students to use simple empirical tests to determine whether a sample is a meteorite or meteor-*wrong*. The students also have an opportunity to run a scanning electron microscope (SEM), which allows them to see how this machine is used in scientific research.

This activity is a result of a collaboration between the Institute of Meteoritics (IOM) and the New Mexico Math, Engineering, Science, Achievement, (NMMESA) initiative supported by the NASA MURED PACE/MSET program. The primary goal of the collaborative effort is to address the misconceptions that most of these students seem to have about pursing a career in Math, Science, Engineering or Technology (MSET) [1,2].

Figure 1: Middle school student using the SEM.

Supplies: At least one meteorite will be needed for this activity, which can be purchased over the internet for around $20 each. It will also be necessary to obtain several (4-8) meteor-*wrongs*, which may consist of any unusual rocks or materials that are easily mistaken for meteorites, such as magnetite, hematite, basalt, obsidian, slag, milling balls, and/or heavily eroded sedimentary rocks. The other materials needed for the activity include magnets, magnifying glasses, and ceramic streak plates, available from scientific supply houses.

Procedure: We begin the activity by introducing the students to the pertinent terminology, including meteoroid, meteor and meteorite. We then ask the students why they think it might be important to study meteorites. An appropriate answer may include the fact that meteorites can give us invaluable information about the parent bodies from which they were derived. It is also important to tell the students that meteorites can be extremely old, some up to 4.5 billion years old, which means that meteorites can provide information about the early solar system. If that doesn't get their attention, we let the students know that some meteorites can be worth up to $1000 a gram. So if they know how to identify a meteorite, they have the potential to make some money!

To further pique the interests of the students we tell them that every year hundreds of suspect meteorites from all over the world are sent to the IOM for identification. In order for the students to be able to identify these meteorites, we introduce them to a few basic characteristics that meteorites may have, such as the presence of metal, fusion crust, regmaglypt textures, and chondrules. We emphasize that almost all meteorites contain some iron-nickel metal and therefore all meteorites will attract a magnet. The fact that meteorites contain some metal means that they will typically be heavier (denser) than an average rock of the same size. Other properties that may be indicative of a meteorite include: (1) Fusion crust - This thin, black-brown surface coating is produced when the frictional heat from atmospheric entry melts the outer surface of the meteor. (2) Regmaglypt texture - This texture, which looks like small dents in the rock, forms during the frictional heating associated with atmospheric entry. As the outer surface of the meteorite begins to melt, small pieces of material will be plucked away. (3) Chondrules – These are small, rounded, BB-sized pieces of silicate material that formed early in the history of the solar system. We conclude this phase by explaining that the streak of a rock/material can help us identify minerals often mistaken for meteorites such as magnetite and hematite.

Once the students have a concept of meteorite properties, we put the students into groups. We randomly give one group a real meteorite and the other groups get meteor-*wrongs*. Each group is then given a "meteorite identification kit" which includes a magnet, a magnifying glass, a streak plate, and a checklist of the above meteorite characteristics. The student groups then examine their samples using the kits and the checklist. The instructors will go to each group and help them with the identification process. As soon as each group comes to a conclusion, a member from each group will describe the characteristics of their sample and decide if they have a meteorite or a meteor-*wrong*. Obviously many students will have difficulty with this task, which is okay because that allows us to admit that we don't always know either. In fact, in many instances we must use advanced instruments such as a scanning electron microscope, to conclusively identify a meteorite.

Introducing students to the SEM: The second part of the activity introduces the students to a couple of high technology instruments that are used in planetary science, namely the light microscope and the SEM. We begin by asking the students what tool they used to look at their samples in greater detail in the first part of the exercise. Their answer should be the "magnifying glass" and from here we explain that if we want to look at samples in even greater detail we first use the light microscope. We explain that a light microscope uses light as its energy source and let the students examine a specimen they can relate to with our Zeiss Photomicroscope. The specimen we use under the light microscope is a piece of a CD. Students are then encouraged to look at the pattern on the CD, which is visible at about 1000X magnification in reflected light.

We tell the students that if we want to examine samples at higher magnifications we can use the SEM. The students are asked what the energy source is for an SEM. The correct answer, of course, is electrons. We explain that an SEM basically uses a beam of electrons to scan the sample to produce a magnified image of the sample. We further explain that the electron beam is generated from an assembly we call an electron gun. Students are asked if they have an electron gun at home. Most reply they don't but in reality almost all probably have at least one inside their televisions. A TV essentially has an electron beam that scans back and forth across the screen to produce an image. To demonstrate this process, we show the students a TV that has been modified not to scan. We then show that we can manipulate the stationary electron beam with a magnet, which is exactly what the SEM does. It is important to tell the students not to put a magnet next to their TV's!

Next, the students are asked what they would like to look at in the SEM if they had a chance to use the machine. After hearing some of their suggestions we show them some of the images that have been taken using our SEM. These images are available on our website at epswww.unm.edu/iom/home.htm. We have several high magnification images including images of a spider, a freshly manufactured razor blade, and small bacteria. The first two images help demonstrate that the SEM can be used by people in many different occupations including geologists, biologists and industrialists. We also use this opportunity to talk about our research. The third image is of micron sized bacteria found deep within Lechuguilla Cave in New Mexico. The bacteria are somewhat remarkable because they thrive in an environment where there is no sunlight for an energy source. The students are then asked what these bacteria eat to survive. The answer is that the bacteria eat the rock they are growing in. An appropriate follow-up question is why would scientists in the Institute of Meteoritics be interested in bacteria that grow in deep caves and eat rock to live. We then answer that in the search for life on other planets, such as Mars, life may exist below the surface and may be somewhat similar to bacterial life found in extreme environments on Earth.

Using the SEM to identify meteorites: After the introduction to the SEM, the students are asked if anyone would like to try and run the SEM. Two volunteers are selected, one to move the sample with a joystick, and one to start and stop the analytical system. We explain to the students that the present sample in the SEM is a suspect meteorite that we could not identify as a meteorite or meteor-*wrong* using the simple tests performed in part one of the activity. Therefore, we have to use the SEM, and in particular the Energy Dispersive Spectrometry system on the SEM, to determine the composition of the metal in the sample, and therefore identify if the sample is extraterrestrial or not. We explain that meteoritic metal is composed of the elements iron and nickel together and that this metal composition is not commonly found on the Earth. Therefore, we need to determine the composition of the metal in our suspect meteorite sample in order to find out if the sample is a meteorite or a meteor-*wrong*.

The students begin the SEM work by selecting metal grains for EDS analysis. It is explained that the brightest grains (in backscattered electrons) will be the most likely grains to contain iron-nickel metal. The SEM operator then centers the electron beam on a metal grain and proceeds to increase the magnification all the way up to 300,000X. At this magnification the other operator can start the EDS system and take a chemical analysis of the metal grain. The students are encouraged to use the computer display to identify the compositional peaks and determine what elements the metal is composed of. Based on this one analysis, the students are asked whether they think the sample is a meteorite or not. Regardless of their answer, we explain that science is not based on just one analysis. With that in mind, two more operators are chosen to analyze another metal grain. After three or four analyses the students will be able to soundly determine if the sample is a meteorite or a meteor-*wrong*.

References: [1] Newsom, H.E., et al. (2000), *LPSC XXX,* #1515. [2] Newsom, H.E., et al. (2000) *Hispanic J. Behav. Sci.*, *22*, 332-345.