**THE CASE FOR NEAR-EARTH ASTEROID SAMPLE RETURN.** D. W. G. Sears[1], C. M. Pieters[2], D. E. Brownlee[3], M. M. Lindstrom[4] and D. Britt[5], [1]Center for Space and Planetary Science, Univ. of Arkansas, Fayetteville, AR 72701 (dsears@uark.edu), [2]Dept of Earth & Planetary Science, Brown University, Providence, RI 02912, [3]Dept of Astronomy, Univ. of Washington, Seattle, WA 98195, [4]SN2, NASA Johnson Space Center, Houston, TX 77058. [5]Department of Geological Sciences, Univ. of Tennessee, Knoxville, TN 37996.

**Introduction:** Asteroids and the comets are an integral and uniquely important part of our solar system. Not only do they provide insights into the nature of primordial solar system material - the material from which the Sun and planets were formed - but their impact onto planetary surfaces is one of the most important geological and biological forces for change. They are also a potential natural resource and target for human exploration and development of space. Thus there are both scientific and sociocultural reasons for asteroid sample return.

**Scientific case:** *Understanding the nature and history of our Solar System.* Current scientific opinion is that with the exception of the rare lunar and martian meteorites, meteorites are ancient fragments of asteroids. The chondrites experienced little or no alteration since formation, while differentiated meteorites – which range from basalts to iron-nickel alloys – testify to igneous processes at the earliest stages of solar system evolution [1]. However, understanding the detailed properties of meteorites requires that the nature and number of their source objects are identified and properties inherited from the solar nebula are distinguished from those of the parent body.

Unfortunately, meteorites are cosmic jetsam, and, with a few notable exceptions, it has proved difficult to identify the asteroids or even the type of asteroid from which they came. In the last instance meteorites are presumably coming from near-Earth asteroids (NEA). The Main Belt asteroids and the NEA show similar class distributions [2-4], suggesting that the NEA fairly represents the main belt, even though perhaps half of the NEA may be cometary in origin [5]. But there are major differences between asteroids and meteorites. One difference is the remarkably low density of the asteroids which resemble only the CI and CM chondrites that are ~20% water. Even the apparently anhydrous S asteroids have low densities [6]. Are all asteroids water-rich, even though their spectra suggests anhydrous materials? Do they have an unusual internal structure, more porous than the most porous sandstones?

It is possible to find meteorites with similar spectral properties for most of the major asteroid classes, although in many cases, like the large S class, there are many potential fits by widely varying meteorite types. The largest meteorite class, the ordinary chondrites, are ~95% by number of falls but are matched closely only by the Q asteroids (<1% by number). Space weathering can change the spectra of an asteroid [7], but even then acceptable matches are found for only the S(IV) asteroids (~11% by number). Eros is an S asteroid and a possible match for L chondrites.

We are not receiving a representative flux of main belt asteroids. To reach Earth, an asteroid fragment must be in an orbit suitable for ejection from the belt [8]. To reach our collections, the meteorite must be able to endure atmospheric passage [9] and the fragments must be recognized in the field [10]. The large number of meteorites sharing common fragmentation ages suggests that large numbers of some classes came from a single parent object [11,12]. Thus relatively few (and perhaps atypical) parent objects are supplying most of the terrestrial meteorite flux.

Linking spectra with rock types will be a major contribution of NEA sample return. In an excellent example of the synergy between subject areas made possible by space missions, such data will improve our understanding of both the astronomical data for asteroids and the laboratory data for meteorites. Returned samples from NEA could also help us address the long standing question of the connection between comets and asteroids.

*Relationship between stars and planets.* Isotopic analysis on Earth has shown that meteorites contain evidence for short-live isotopes (e.g. $^{244}$Pu, $^{129}$I, $^{26}$Al and $^{60}$Fe) being present in precursor dust when the meteorites formed [13]. Some meteorites contain silicon carbide, graphite, diamond, alumina and titania grains that are presolar [14] and there are interstellar molecules in meteorites [15]. There is some uncertainty as to how widespread these isotopes were and whether they were distributed uniformly through out the solar system but they do provide unique insights into the type and distribution of stars that contributed material to the solar system and the timescales or early solar system processes.

The classes of meteorites that contain interstellar materials are relatively rare on Earth, presumably because of one or more of the selection effects above, but asteroids with similar spectral signatures appear to be fairly common [3]. One might expect therefore that the asteroids sampled by spacecraft will contain new kinds of presolar materials that carry information about stellar precursors and processes by which interstellar material becomes solar system material.

*The origin and evolution of life on Earth and other planets.* There are two possible origins for life on Earth (or on any planet). Life either evolved from relatively simple organic molecules by processes occurring on Earth, or living organisms were brought to Earth on a comet or asteroid, the “Panspermia Principle”. The volatile-rich CI and CM chondrites contain large amounts of a wide variety of organic and potentially biogenic compounds. Even if such meteorites did not bring life to Earth, such materials offer unique opportunities to identify life’s chemical precursors.

Asteroids with spectra resembling those of the CI and CM chondrites are the second most abundant asteroid type. Thus C asteroids would be prime targets for sample return. On the other hand, because of their friability, such meteorites undergo considerable destruction in the atmosphere and C chondrites are rare.

An additional, persistent problem for meteorite research is that the samples are invariably contaminated. Even freshly collected falls have been found to contain terrestrial contaminants. The samples returned by missions would be some of the least contaminated primitive material brought to Earth.

*Solar variability.* Airless bodies in space, without magnetic fields, capture solar wind and solar energetic particles non-selectively, so studies of their surface materials will contain a record of solar activity at their locations. Thus asteroid samples record a history of solar activity and, unlike meteorites, their most recent orbits are known.

**Sociocultural case:** *Understand the external forces, including comet and asteroid impacts, that affect life and the habitability of Earth.* An impact caused major extinctions at the end of the Cretaceous period and since such impacts should occur every ~100 million years mass extinctions are common in the fossil record. Many methods have been proposed for deflecting a potential impactor, but these depend on the composition and properties of the asteroid, which at the moment are essentially unknown. Buried nuclear devices or impact might be best suited to coherent masses, but standoff nuclear or shallow nuclear explosions might be best suited to incoherent masses, for example. The behavior of a water-rich asteroid under a laser will be very different to that of an anhydrous object. The data obtained by sample return missions and the returned samples will enable these issues to be addressed.

It is also important to know the structure of the asteroid in order to predict its behavior in the atmosphere should deflection be impossible [16]. A poorly-coherent mass (e.g. the Tunguska impactor) would fragment high in the atmosphere and a large number of small fragments or an attenuated shock wave would reach the surface [17]. On the other hand, a coherent mass (e.g. the Meteor Crater impactor) might reach the surface intact and create a large crater [18].

*Locales for future human eploration and habitation of space.* NEA are the natural next step in space for exploration and even colonization because they are easy to get to and they are numerous and diverse in character. Many NEA are easier to get to than the Moon and some require flight times less than some past human LEO missions. Sample return missions to NEA would be analogous to Surveyor’s role as a robotic pathfinder for the Apollo missions.

*Resources for space stations and colonies.* The NEA also provide natural resources, most notably water, that could be used to support human exploration in space. Transporting water from a NEA to a space station or a lunar colony would be less demanding in energy than transporting it from Earth. NEAs as a natural resource for many materials has been the subject of several books [e.g. 19].

**A logical next step:** *In situ* measurements are necessary for global geophyical and geochemical studies, but sample return has the advantage of an unlimited range of techniques, the vastly superior precision for the techniques, and the sample archive pending better techniques. A geologist exploring a new region on Earth maps, choses sample areas, collects samples, takes them to the laboratory for sophisticated analysis. The asteroid equivalent is to obtain reflectivity spectra, select interesting asteroids, return samples, return them to the laboratory for sophisticated analysis. It is a time-tested strategy.

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