Successfully Mining Asteroids and Comets

Leslie Gertsch and Richard Gertsch
Mining Engineering Department
Michigan Technological University

Introduction

Most, if not all, asteroids and comets contain substantial natural resources. Such "local" resources are necessary to develop and maintain robust human activity in space. Whether asteroids, comets, or other material sources contain mineable *reserves* instead of just mineral *resources* depends on three factors – economics, technology, and geology – that will determine the success or failure of long-term space activity, just as they determine the success or failure of industries on Earth.

Economic Viability

A mineral resource is not necessarily equivalent to a mineable reserve of ore. A mineral resource is "a concentration of naturally occurring solid, liquid, or gaseous material ... in such form and quantity that economic extraction is currently or potentially feasible" (AGI, 1997). On Earth, pre-existing concentration of the commodity of interest from 100 to 10,000 times greater than the average background level is required for its extraction to be economic. Discovery and initial characterization of mineral resources are traditionally the province of the exploration geosciences, including geology, geophysics, geochemistry, geohydrology, remote sensing, etc.

Ore reserves are a small subset of mineral resources. A reserve is "that part of the resource base that could be economically extracted or produced at the time of determination" (Kirk, 1998). Mineable reserves have met specific minimum physical and chemical criteria related to current production practices, including criteria for grade, quality, orebody size and shape, and orebody accessibility. The reserve designation is the earliest point at which the term "orebody" is used.

Several mineral resource classification systems (MRCS's) have been developed in this century to aid economic investment practice by clarifying the certainty with which a mineral occurrence has been defined. The United Nations recently developed a universal MRCS (UN, 1996) that incorporates the confidence level of economic, technical, and geologic aspects of mineral concentrations in a coded index.

The existence of a viable market is inherent in the economic evaluation of any mineral resource. As in all businesses, a potential orebody must give reasonable expectation that the rightside term of the equation *revenues – costs = profits* will be greater than zero. Costs are estimated on the basis of the technological aspects of mining and processing. Revenues are estimated on the basis of the market as it is expected to exist at the time of sale. Both terms involve extrapolation, which is risky even in well-understood arenas. Mining, even on Earth, is forced to deal with poorly known constraints on this equation. This is why successful mining companies are so conservative. Since we have much less experience with space-based operations, caution is even more necessary there.

It is worth remembering here that the riskier the venture, the higher must be the expected return on investment. Few projects are perceived as riskier than these.

Technological Feasibility

The technologies used to exploit the resources inherent within asteroids and comets will be those that use effectively the characteristics of the space environment[1] to accomplish the unit operations of mining and processing[2]. Through many millennia, humans have developed some very effective ways of extracting natural resources from the Earth's crust. Those methods rely implicitly on the gravity vector remaining constant in both magnitude and direction, and the ubiquity of fluids in the forms of water and/or atmospheric gases. These basic assumptions must be explicitly excised from the exploration – mining – processing sequence before it can be translated to space. However, the goals of the unit operations remain valid.

The most successful mining methods are those that use the least-controllable environmental aspects to greatest advantage. This is the reason, for example, that many ore processing mills were once built on steep hillsides. Gravity moves broken rock from the top of the mill, where it is brought in from the mine, down through the various beneficiation steps to the bottom where the concentrated material is loaded out. Similar utilization of centrifugal force has been proposed for mining and processing in space.

Geologic Certainty

More terrestrial mining projects have failed due to the consequences of incomplete understanding of the orebody structure than any other reason. Minor bodies in space have the advantage of much more surface exposure to remote sensing than is usual on Earth, but they also suffer from the difficulty of establishing "ground truth" – on-site calibration of conclusions reached from orbit. And, even if small, their interior volume still must be characterized. On Earth this means drilling for samples.

Geologic characterization, especially in its later stages, must also deal with the unfamiliar space environment. Deep drilling in a micro-gravity environment will be a non-trivial exercise.

Recommendations

Accurate evaluation of any mining project, whether on Earth or in space, depends on objective examination of the economic, technological, and geologic aspects of the proposal, including the confidence with which the information is known. The success of extra-terrestrial mining requires extra diligence in all three areas. We cannot afford to litter history with the tens or hundreds of failed ventures for every strike that are the legacy of most terrestrial mining districts.

References

American Geological Institute (AGI), 1997. Dictionary of Mining, Mineral, and Related Terms, publ by AGI, Alexandria VA, with Society of Mining Metallurgy and Exploration Inc.

Kirk, William S., 1998. "Iron ore reserves and mineral resource classification systems," Skillings Mining Review, June 6, p 4-11.

United Nations (UN), 1996. UN International Framework – Classification for reserves/ resources, Economic and Social Council, Energy/WP.1/R.57.

---

[1] Low gravity magnitude, variable gravity vector direction, temperature extremes, high radiation, negligible atmosphere, and negligible water.

[2] Mining unit operations: Fragmentation, excavation, material transport, and various support tasks to ensure safety and stability of the worksite. Processing unit operations: Comminution (crushing/grinding), separation (of waste from valuable material), and materials handling.