MINERAL RESOURCE ESTIMATION FOR ASTEROID MINING PROJECTS.
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Introduction: This paper reviews and seeks to apply concepts from terrestrial mineral exploration to the task of target identification and quantification of resource potential of Near Earth Asteroids.

Definitions: ‘Mineralization’ is a mass containing mineral values that may hypothetically be worked to recover these values. This material is only definable as ‘Ore’ if it can be mined and processed to make a profit. An ‘Orebody’ is defined as a specific volume of mineralization of a grade that is significantly higher than the economic cut-off grade value and that can be confidently asserted to be extracted and processed at a cost low enough to allow an economic operation.

The ‘Orebody concept’ is a model describing the geometry, geological & grade continuity, and mineralogy of the ‘orebody’, in terms (generally) of a hypothesis developed to explain its origin.

A ‘Mineral Resource’ is an occurrence of a mineral that has been shown to exist in such form, grade, continuity, quality and quantity as to be economically viable for eventual extraction. Such Resources are categorized into Inferred, Indicated or Measured, depending on the level of geological confidence (generally obtained via direct sampling) in the quantification of total tonnage and grade.

Once the economically mineable part of a Measured and/or Indicated Mineral Resource has been established, the ‘orebody’ is then upgraded to an ‘Ore Reserve’ in which total tonnage and grade are above the economic cut-off and a specified mining operation working on a specified mining plan, with a specified metallurgical flowsheet will be supported.

Orebody Model: Note the key role of the Orebody model as the basis for the estimation of ore reserves. If the concept or model is wrong, then the reserve calculation, mining recovery or both can be wildly inaccurate.

In the asteroid mining context, an important consideration is: “You cannot quote a Mineral Resource or an Ore Reserve, because you cannot sample it by drilling.” How asteroidal resources can come to be quantified in a reasonably robust way is therefore an important issue.

During the 20th Century, concepts of orebody genesis have developed to give a theoretical background to mineral search campaigns, thereby providing prospective targets for in-field sampling. By the 1970s, there was greatly increased emphasis on formal quantification of mineral resources, for the purpose of prospectus issue and project valuation, and on ore reserve and grade calculation for accurate mine and process plant planning. In Australia the JORC Code, and in Canada the National Instrument 43-101 specify the legal constraints on making public resource and reserve statements in pursuit of fundraising efforts.[1,2]

Classically in the hard rock (base metals; gold) mining area, ‘tonnes and grade’ have been assessed deterministically, by orebody drilling and sampling at close-spaced intervals, and then interpolating to estimate grade in the body of rock between samples.

Coal and iron ore deposits differ from the classical base metal orebody inasmuch as they tend to be extensive, tabular, and continuous, with gradational rather than structural cutoffs. This reduces the need for close-spaced drillout for proof of continuity, and facilitates adoption of stochastic or probabilistic resource assessment. For extensive orebodies, the constraining parameters defining ’ore’ are: lower cutoff grade, minimum thickness, and maximum level of penalty elements.

In recent times, the literature has moved towards stochastic (probabilistic) methods to alleviate the previous reliance on deterministic ‘drill
pattern’ data, and additionally, to quantify the risk profile for the assessments made.[3,4]

**Asteroid Mining:** The philosophical problem with discussions of future asteroid mining is that according to the ‘deterministic’ approach to resource estimation, because we cannot undertake wildcat or greenfield scout drilling, it would appear to be impossible to issue an Inferred, Probable or Measured Resource.

However, the new probabilistic approaches now being developed may enable some rigor to be applied to ‘risk-based’ statements of resources, even in the absence of site data, using probability distribution approaches to statements of grade, etc.

‘Resource range analysis’, which develops and then multiplies together probability distributions for each of the various ore-defining and ore recovery parameters; and ‘scenario probabilistic’ derived risk distributions, are increasingly being applied in terrestrial resource estimation, and are improvements over the classical deterministic approach, because they give quantitative risk for the resource estimates. It turns out that these approaches also assist us to arrive at reasonable assessments of the risk function applying to resources recovery, for different asteroidal types.

Thus, for example, asteroidal targets within a restricted albedo range will split probabilistically into several mutually exclusive asteroidal types. For each of these types there can be constructed a probability distribution which describes the percent likelihood of presence of at least some particular percent-by-mass of (a) water, in water of hydration and chemically bound in minerals; and (b) magnetics such as magnetite. For each of several different mutually exclusive ‘orebody models’ we can propose a probability distribution for percent likelihood of some minimal percent recovery in a surface or subsurface mining process.[5]

**Conclusion:** By adding the mutually exclusive scenario probabilities and by multiplying the mineral presence and mineral recovery probability functions, one can construct supportable estimates of mass recovery and hence mining process valuation. These and other recent resource estimation tools provide basis for valuation of asteroid mining missions, and for choosing between competing missions, and will become important as would-be asteroid mining companies begin planning commercial missions.

**References:**


