Mining asteroids – a front?

Asteroids and comets are part of the debris from which the solar system planets have been formed. Judging by appearance and by the tiny pieces of debris that fall to Earth as meteorites, asteroids are mainly either stony, iron-nickel or carbonaceous. There are a million of them over 100 m across but we have only known this for less than two centuries. As a result asteroids aren't part of the traditional culture of any society, unlike the Moon and major planets. No-one has any moral or legal right to own an asteroid. In a way they are like jetsam thrown up on the tidal shore – finders keepers, if you want to. Of course no-one has any legal claim to the Moon either but mankind as a whole has a moral claim on it and an interest in what happens there. Not so with any asteroid. In short, there's unlikely to be a hue and cry stopping anyone from attempting to mine an asteroid. Is it 'game on' then, for those who can afford it?

If the game is on then it seems to me as I write this in 2014 that the billions spent in its pursuit will not produce any winnings. I have to wonder if the intention to 'mine asteroids' isn't a cover for developing space technology that ultimately will have other pay-backs, if it ever has any payback at all.

First, no early prospector will be in a position to pick and choose any asteroid they like. Most asteroids are further from the Earth than Mars, lying in a belt between Mars and Jupiter. Practically speaking they are inaccessibly far away. The Earth's Trojan asteroids are in the same orbit as the Earth but four months ahead or behind us and hence always some 250 million kilometres away. That leaves the tiny fraction whose orbits by chance take them close to the Earth's orbit, though only a small fraction of these will actually come close to the Earth itself, for the Earth's orbit is nearly 1000 million km long. Not much of a choice. Certainly not the pick of millions. What difference does distance make? It affects the time taken to get there and back, the energy needed and the ease and reliability of communications between base, assumed to be on Earth, and any autonomous mining operation. Distance underpins the economics of the venture. In addition, asteroids beyond Mars have surface temperatures over 100 degrees Celsius below zero and receive reduced sunlight that will be needed as a power source for operations.

Secondly, as far as I know, no asteroidal compositional surveys have revealed substantial amounts of anything worth mining. Iron and nickel are not running out on Earth. You'll hear the argument that asteroids are made of the same stuff as the Earth and hence there must be similar valuable deposits on asteroids. This is not necessarily true since deposits may have aggregated in the early history of the Earth in a way they would not have done on an asteroid. Also the Earth has over 500 million square km of surface and mines are found only in select places (though to be fair, not much of the ocean has been mineralogically explored). An asteroid 10 km in diameter has a surface area of just over 300 square km, quite small enough for nothing of interest to be present. If the stuff is running out on Earth, what are the chances of finding it on any of the small fraction of asteroids that are accessible? Pretty slim. A mining operation of any credibility anywhere needs an available resource survey. There is no point in mining pie in the sky.

Thirdly, the energy and expense of getting to any asteroid and staying with it in orbit is phenomenal. Robotic sample and return missions to date have brought back a few hundred grams of lunar material, thanks to the Russians, and swept up microscopic dust grains from comet tails and possibly circulating interstellar dust in the solar system for our analysis on Earth. That's it. The cost and effort of these miniscule 'mining' efforts has been huge. Serious mining requires a much bigger operation, all robotically controlled. Moreover, one can't send back raw ore, since transport costs are astronomical, so refining must be part of the on-asteroid, or near-asteroid process. On Earth, anyone can pan for gold with equipment bought for small change at an ironmonger's shop but establishing a robotic mining facility on an asteroid is not only out of this world physically but so far beyond our capabilities that it seems to me to be more fantasy than reality for decades to come.

I've taken it that robotic mining is the only option worth exploring since human missions have so many more hazards, require so much more equipment in the form of life-support and safety that, in spite of some advantages on-site, they aren't worth it. It's true that humans have returned hundreds of kilograms of material from the Moon but that experience isn't a model for future asteroid exploitation.

Fourthly, getting any product back to Earth is also hugely expensive and tricky. It will arrive at our outer atmosphere travelling at about 10 km per second, just like any meteorite. The expense is in avoiding the meteorite's fate of being converted into a fireball. Re-entry has to be just so, landing in a safe, controlled trajectory at the right place. It can be done but mankind does not need a train of returning objects from space plummeting to Earth. The enthusiast could argue that asteroid mining has already happened, since some nickel mines in Canada and Australia at least are believed to be the residue of meteorites that have fallen to Earth uncontrollably. That's one potential model for future 'asteroid mining', deflecting a very small asteroid of say a few tens of metres diameter to make a crater in an isolated region of Earth and mining the residue by conventional means. It is of course a crazy idea more suitable as a plot for a James Bond villain than a respectable development. Controlled landing is such a tough ask, though, that the most sensible argument is that asteroid mined products are best used off-world and never landed. This can only happen if there is an off-world economy capable of using them, which will be decades in the future.

Fifthly, the gravity of a small asteroid is pitifully small and not necessarily at right angles to the surface, since small asteroids that have been imaged are seen to be more the shape of an irregular deformed potato than spherical. The properly big asteroids are out-of-range. An irregular shape makes it complicated to work out gravity at any point on the surface. One can get an idea by taking the simple case of a spherical lump of mainly iron-nickel of diameter 10 km and density similar to the Earth's. In impact damage terms, even this is a big one that would create devastation if it collided with the Earth, leaving an impact crater many hundreds of km across. It will have a mass of 2.9×10^{12} tonnes but a surface gravity of 7.7×10^{-3} m s^{-2} (less than one thousandth that on Earth) and an escape velocity of 8.8 m s^{-1}. Anything given an upward speed greater than 8.8 m s^{-1} and not restrained will fly off into the black yonder, never to be seen again. A smaller speed and the item will fall to the surface, probably a long way away since local gravity is so small, and who knows where since asteroids not only orbit but

spin as well. Basically everything has very little weight, which is fine for moving things around but hopeless for control. Of course asteroids have no atmosphere either.

The arguments above against asteroid mining are physical rather than political or social. It's not hard to find science fiction stories in which aliens hold the world to ransom by aiming an asteroid towards us. For this threat to be real enough, aliens are not needed. Mining asteroids implies the ability to break them into pieces and steer fragments, refined or otherwise, towards the Earth. That's all the technology you need to hold the world to ransom, deliberately or by accident. History has shown that mad people can indeed get into power by quite legitimate means. A strong socio-political argument is that world society is not mature enough for anyone to develop the underlying technology needed, for it could fall into the wrong hands. A counter-argument appears to be that one-day a sizeable asteroid will head towards the Earth without the intervention of aliens or mankind, bringing substantial devastation to civilisation world-wide. Should we not be prepared to deflect it? It's all a matter of timescale and probabilities. The probability of a natural, catastrophic asteroid impact is exceedingly low, meaning that several hundred thousand years is likely to pass before it happens. I believe that the last big asteroid impact with Earth was about 2 million years ago in the sea near Antarctica. There have been numerous smaller impacts since, some of whose craters can still be seen but they haven't be civilisation threatening. The probability of asteroid moving technology falling into rogue hands if developed in the next few centuries is much larger and the result could be equally devastating. My conclusion, and it's not just mine for others have said the same thing, is that we should leave asteroids alone just now. There is likely plenty of time for humanity to develop the necessary protective technology when we are responsible enough to ensure it is not misused.

You'll gather by now that I have no intention of investing in any asteroid mining venture. It's noticeable that no governments do either – just a few individuals with very deep pockets who like the grand challenge of 'boldly going' and have maybe watched too many Hollywood movies. I suspect that asteroids will mine their pockets long before the investors have mined any asteroids. The Moon, though, is a very different prospect. It's closer, it's bigger than all the asteroids put together (with a surface area bigger than Europe and North America combined), it's surveyable and liveable on, all albeit with some difficulty and some hazards. It's not easy to get a feel for the distances and sizes involved but imagine they are reduced in scale by one million. The Moon would be a ball about 3.5 m in diameter that stays at a distance of some 370 m from you. An asteroid 1 km across that came within 10 million km of the Earth, sufficiently close to give media headlines across the world, would be a speck 1 mm across at a distance of 10 km, after which it would recede in its orbit to hundreds of km away in our scaled down picture. This doesn't exactly put mining asteroids in the frame.

I certainly wouldn't say that mining asteroids can't be done but I don't see it as a commercial venture that makes economic sense. Worse, in the long term it's not a sustainable venture for mankind. If minerals are really running out on Earth then the sensible option is to invest in recycling what we have. That is close to being sustainable. Mining off-world, even if it makes sense in a future economic scenario, will gain mankind a millennium or so before the available asteroids are cleaned out, and then the larder will be empty. Mankind has to learn to recycle.

The Moon, though, belongs to mankind as a whole, morally at least, and not to any mining corporation. You had better not say just now that you are developing technology to mine the Moon for profit. In future, it still makes sense to use any mined products only off-world but by the time mining is established on the Moon after the lawyers and environmentalists have battled it out, there will be an off-world economy. Besides, if you really want to go mining where no-one has gone before, what about under the seas? It's a lot nearer.

In the very long term, though, the law of ever increasing entropy will ensure that rare elements will inevitably become diluted beyond the recoverable. There seems to me to be only two solutions to this: either develop technology that doesn't use them or make them by nuclear transmutation. Neither option is on the horizon at present.

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