Question 1:

Dear Cheap Astronomy – Are rubble pile asteroids easier to mine?

Rubble pile asteroids are a collection of rocks that have accreted together under their mutual gravity, but the object they form isn't massive enough for gravity to compress it into one unified object. Instead, the rocks that gather together remain as individual rocks. So, from a mining perspective there's an advantage in that you can just pick up those individual rocks without needing drilling or explosives. However, from a prospecting perspective this is not an advantage since a rubble pile is just a collection of rocks with lots of empty gaps between them so its very hard to estimate what the rocks are composed of until you get right up close and have a look. Our existing classification of asteroids into clay rock and metal are largely-based on the mass and volume and hence density, as well as their overall appearance – where shiny suggests metal and not shiny suggests not metal, that's about it. So a low-density rubble pile might include rocks rich in platinum palladium ore or just chunks of clay. You don't really know until you get up close.

Rubble-pile asteroids are generally small - less than 1 kilometre in diameter. Any bigger than 10 kilometres in diameter and an asteroid will generally compress into unified object. And rubble piles probably aren't completely random collections of rocks. It's thought most rubble piles are probably accreted debris from an earlier asteroid collision. So, rubble pile fragments may be from a common source and hence be of a common composition as well.

We've sent spacecraft to various near-earth rubble pile asteroids, including Ryugu, on which Hyabusa 2 landed and collected a sample and Bennu from which Osiris Rex collected a sample without actually landing – by use of an extended arm. The Ryugu sample was returned to Earth in December 2020 and the Bennu sample was returned in Sept 2023. Incidentally, having sent its sample back to Earth, the renamed Osiris Apex spacecraft is now on its way to do a fly-by of the asteroid Apophis in 2029.

Apophis is only 300m metres diameter but seems quite dense and has all the features of a stony silicaceous asteroid. So, despite its small size it's more likely a chunk of solid rock than a rubble pile. 1998 KY26, that Hyabusa 2 is going on to visit after its encounter with Ryugu, is really small at just 30m in diameter, but it's spinning so fast it can't possibly be a rubble-pile either or it would have spun itself to bits by now. Itokawa which the original Hyabusa visited, is peanut-shaped about 300 metres long and definitely is a rubble pile – which Hyabusa also sampled a few grains from and returned to Earth in 2010. Itokawa is a rubble pile of silicaceous origin, while Ryugu and Bennu are both carbonaceous. In each case, the classification indicates the nature of the primary object they are post-collision fragments of.

As far as mining potential goes, none of these ones we have observed up close have obvious value. All of them have some water, mostly mixed into mineral compounds, rather than as isolated chunks of ice. That water is potentially extractable, but the value of space-based water lies in supporting more space travel rather than being an end in itself. A metallic rubble pile asteroid might be a better mining prospect though we don't know of any confirmed cases yet.

The option of indiscriminately crashing lots of rubble pile asteroids on the Moon and then sorting through their remains would be great, but attaching a rocket engine to a rubble pile is just going to break up the rubble pile rather than diverting its course. On the bright side a rubble pile asteroid that collides with Earth will readily break up in the atmosphere, hence spreading and dispersing its kinetic energy before impact. So, we could either just leave them be or go visit to pick off any good bits with commercial value. It is very likely that asteroid mining will involve a number of different strategies – so we might be spot-picking bits of rubble piles, but also Moon-crashing any denser objects that need breaking up.

Question 2:

Dear Cheap Astronomy – How do we get mining products back to Earth?

The current narrative on space mining seems to go in two directions. One direction is about in situ resource utilization where there's no doubt it's a lot cheaper to source water from space than to launch it from Earth – and a similar principle applies to most building materials: steel, concrete and glass. Of course, the mathematics of in situ resource utilization makes perfect sense but begs the question of what the economic incentives are to build dwellings in space and source space water to support the people in those dwellings, as well supporting agriculture and making rocket fuel. If we can't identify those incentives, we're just saying that we're going to go into space so we can go into space.

The other direction the narrative goes is that we mine valuable materials in space and bring them back to Earth. If there's a profit in it, then everyone will start looking for efficiencies and economies in the supply chain – which might include building off-planet hostels for the miners and support staff, which means you could then benefit from in situ resource utilization.

So, a key part of this supply chain story is that once you do have a refined chunk of let's-say asteroid-derived platinum ready for sale, how do you get it to market down on the Earth's surface. You could have a vehicle, like the space shuttle, which is launched, ideally with a hold full of space-bound cargo, that you unload in orbit while the refined platinum is loaded aboard for the return trip. However, platinum is heavy stuff so there's limits to how much you can land in this way. The advantage of a space shuttle – or an automated Space-X style vehicle that can do retro-rocket landings is that you get the payload to a purpose-built base where you might have a truck waiting to move it on to the next point in the supply chain. The disadvantage is that these options can't manage a lot of payload mass – or to put it another way, you are expending a lot of fuel to land a lot of mass that isn't actually payload.

So, a better approach might be to do unpowered landings, which allows a lot more of the landed mass to be payload. To protect the integrity of the payload, you'll still want a heat shield which will also usefully slow its descent, though not enough to enable a soft landing. A chunk of platinum could survive a hard landing intact, but it would be hard to convince the surface population that dropping high-speed projectiles from orbit was safe. So, parachutes are probably required, with landing sites in remote areas.

If you are just landing large chunks of platinum, you don't need a pressurized capsule. Indeed, if you're hard landing in the desert rather than on water, you don't even need a capsule – just an aerodynamic framework that holds your payload, heat shield, and parachute together. You'll also need a parachute deployment system and a transponder so you can track your payload – so you need a battery and electrical system too. But that is about it and after you unload the payload, all the remaining bits are either re-useable or recyclable.

That said, there might also be opportunities for in situ resource utilization. So, for example, if we did establish a mining refinery on the Moon, you could launch your refined platinum from crashed asteroids along with a heat shield made of mining waste and regolith, all ready to descend into Earth's atmosphere. Launching in the Moon's lower gravity takes a lot less fuel than launching the same mass from Earth. And of course, there's space junk in Earth orbit, which offers a source of metal and otherwise, it would just be good just to get the junk out of orbit, if it's feasible and cost-effective to integrate that into your space mining supply chain.

A lot of this thinking is pretty-much science fiction or at least very expensive advanced engineering that no-one is likely to invest in without some small-scale proof-of-concept projects that convincingly demonstrate there's really a profit to be made. We do need to get past talking about going into space just so we can go into space. We'll never really do it in a big way unless there is a profit to be made.