MODULE 2, LESSON 5
FROM EXPLORATION TO EXPLOITATION: THE MINERAL RESOURCES ASSESSMENT

LECTURE NOTES

Welcome to this lesson on from exploration and exploitation and mineral resource assessment. I'm John Parianos. We've got a lot to cover and not that much time, so I'm not going to be talking to all of the slides in detail. You can just revert back to them as you need to. This particular lesson is a little bit like a bridge between what you would recovered in lesson 1 to do with mineral resource estimation and our lesson that as an exists yet, and that's because no one's ever estimated a mineral or reserve. We'll be looking at things like the modifying factors and some of the other aspects that are listed over here on the left-hand side of the slide. Whilst the resource types are quite varied, for example nodules and sulphides could be considered like chalk and cheese, you will notice we don't talk anything about ferromanganese crusts. That's because no one's actually published an estimate yet for them, and this particular lesson is based on published estimates. Estimates that are published are normally done to a code. Some of those are mentioned here, and there's additional guidance that's been given out by the LTC.

So just a brief recap on what you would have covered in lesson 1. We're talking about how we increase confidence in mineral resources and what are some of the modifying factors to get across from the resources to the reserves. We'll also be touching on reasonable prospects of eventual economic extraction. So it's good to know why you're doing something and this particular slide addresses how the mineral resource fits in with other elements required to deliver a project. We've got, of course, our work plan and an exploration phase and then a development phase. Then there's understanding of inventory, what we're talking about here, resources through to reserves and then there's some permitting in the environment and general development. There's a big difference today between where polymetallic modules versus polymetallic sulphide sit. Whilst there are some module projects that are partway through pre-feasibility study and on the cusp of maybe declaring mineral reserves polymetallic sulphides, at least within the area, a much earlier stage without even a single inferred resource estimate having been pub;oshed. There are polymetallic sulphide resource system that's out there, but they're from within territorial waters, countries like Papua New Guinea and Japan.

The next couple of slides look at a rather involved interrelationship between confidence, continuity and production, even production rates. Resources and reserves are estimated to a level of confidence. There are various things you can do to define and support the confidence in the estimate. Probably the most important thing though, is continuity, either with the grade or in the case of nodules, abundance. There's some guidance here from the dual code as to what's expected when the competent person does the estimate and the most significant single diagram is this semi variogram. You've got an experimental semivariogram in a dashed line and you've got a model semivariogram in a solid line, I'm not going to explain exactly how semi variograms work, because hopefully that was all covered in lesson one. But when you're within the range where you can start to predict the continuity of the grade, in this case abundance, then you can start to go to higher levels of estimate, especially a measured level estimate where you need to confirm that you've got the continuity. This particular semi program is supported by this diagram here, where we've got 30 metres based estimates of abundance and roughly the same. You can see how that would support a 5 kilometre range. And how would that then relate to production? Well, you don't need to do a single estimate of the continuity of the abundant side; you can actually do a series of estimates and that's called conditional simulation, and then you can just take the average of those and that should give you a more precise and accurate estimate, especially locally, of the thing you're trying to. Model.

The key point is that you don't really need to estimate that beyond a certain precision and what the estimator often takes is 1/4 or three months of production and then they look at how much change you get from the average of all the different estimates that are in the conditional simulation. And this is what is being shown here, this is an example from the Nordic area and the CCZ, where they've got higher confidence in the darker colours. They believe that can be classified as measured and then when they've got more moderate confidence, it's indicated this picture on the right hand side simply shows what happens if you increase your period to yearly you and the whole lot is now much more confident, which tells you the mean abundance is globally much more accurate than say locally. The next few slides look at what's probably the most important modifying factor for seabed minerals, which is topography with regards to deposit disposition. That this first slide is simply looking at a hypothetical purely hypothetical case, it could be any kind of or body. And you've got a couple of lenses shown here in blue. The one on the leftleft-hand here is smaller than say the orange box and the orange box represent the minimum area you'd require to pay the cost of deploying the mining or mineral harvesting equipment to site to start work. So as this blue area is smaller than the orange area, it would just wouldn't be worth setting up on. And so this particular part of the mineral resource would need to be excluded should you go and estimate a or reserve. And of course you can't work this out until you know how big and expensive the mining system is that you're going to be putting on site. This second example here, obviously the blue area is bigger than the orange area, so it's worth moving the equipment to site to start work, but once you get outside the orange area, none of the blue is big enough for a second orange block but that's OK, you're already on site, you paid those employment costs off, and the yellow boxes then represent the minimum byte or we call it selective mining unit that the mining equipment requires to do the work. So In the case where the yellow boxes inside the blue, that's pretty straightforward, but where you get the overlap, this shows, for example, where you'd get dilution if you wanted to take that entire area, you would have to reduce the quality of the product by taking in things that don't relate, or you'd have to reduce in effect, your production rate for nodules in this case here, there's a little bit of blue left out and in that case you'd have to leave that behind; it's not worth going after and so this is would be a reduction in the tonnage of the material in the resource when you go to reserve.

Now we're looking at an example with regards to polymetallic modules. This is a particular mining concept put out by the metals company, where they have a mineral harvesting vessel and a fleet of collectors followed by transport vessel. The way it works is the ships and the collectors followed Path 1, then curve down to PATH 2, then curve back up to PATH 3 and so form basically a loop that moves its way down the screen in this particular direction. So the idea is that enough nodules are being produced to feed and pay for the surface spread of the vessels and the collectors and they would have designed this particular system to enable enough not just be collected efficiently enough to cover those costs. So what we can do then is we can take that concept and we can put it onto some real seabed bathymetry or topography and we've got 2 examples here on the right hand side, we've put the panel over area fairly flat seafloor, wherever it's grey is where there are vessel slopes greater than six degrees, we've assumed that the system will only work on flatter areas and that and it's obvious that there's lots and lots of room for blue panels to be fitted anywhere or to make them wider or longer and things like that. However, if you take a different area of sea floor, this is another part of the CCZ on the left hand side you can see that there's no way that panel will fit amongst those at Thistle Hills in in many cases. So in that situation the engineers would have to try and work out a way to still get the volume of nodules they need to make a profitable operation but fit it in and around all these of whistle hills and it's very, very likely that in some cases between some of the narrower abyssal hills you you'd never actually get it to work.

Now here's an example for a polymetallic sulfide deposit. This one happens to be from within the EEZ of Papua New Guinea and sulphides are often on the sides of slopes of underwater volcanoes. So the engineers have designed a series of panels that you can see marked up here and they're using, they plan to use this large white machine here to cut its way through the rock, collecting the sulfide. Each of these panels is a different cut in effect, and you can see areas where they'll either take dilution or they'd have to leave some of the sulphide behind. Because the area is quite rugged, they had a second machine to pick up the area here in purple, but the bulk of production was going to come from the area marked in green. Another important modifying factor is recovery. There's no system I think ever been built that's gonna pick up every single nodule. The question is, how much would get left behind and where would it get left behind. And there's is likely to get left behind either on the edges of the tracks or even within the tracks if the nodules are the wrong size fraction, or if the machine has some irregularities in its passage. So here are some examples shown of where you could lose nodules on the left hand side as well as some photos from a trial done in the 1970s in the CCZ where you can see some modules are left behind as well.

The engineers can use that to their advantage or they can estimate how that would work depending on how they plan the tracks of the collector, this particular concept from 2012 left green zones between the paths of the collectors, the collectors we're going to go around in these race tracks and the engineers at the time felt that that was appropriately efficient, and I guess it had some side effect, which was it was going to leave some nodules behind, which fauna could take advantage of. Ultimately, the engineers who are designing the operation, who are going to use these figures to convert from resource to reserve, need to come up with factors. And here are two examples. The top one here is for polymetallic modules and you can see the overall recovery factors 73% with collector efficiency, the bulk of that getting 80% of what was there originally. Just a little bit extra is lost in the transshipment. Then for polymetallic sulfides, it tends to be a little bit more complicated because the geometry of each sulfide lens might be different. This particular example, again from Papua New Guinea, shows how for each zone, they get different levels of dilution and different decreases in grade affected by that dilution. Another factor to seriously take into account when making the transition from resources to reserves is marine environment. Now we're not talking about license to operate, I'll talk a little bit about that later, but it's beyond really the scope of this lesson, we're talking about using marine environmental measures that reduce the tonnage when you go from resource. The reserve, an obvious one, is in the derivation of preservation reference zones. We've got 2 examples here. These are preservation reference zones proposed by the German contractor and the CCZ. So wherever you've got the shaded part of the nodule resource, you would have to cut that out of the resource if you ever went to a reserve estimate, because there's no expectation that that would ever be mined. This is a sea floor massive sulphide example, again one in Papua New Guinea. Beginning and whilst the entire deposit at Solwara 1 was planned to be mined, there was another SMS nearby called South Sue and that was going to be preserved and left for reference reasons and to also maybe help repopulate the farmer in Solwara 1 as a nursery. As already alluded to an earlier slide, the details on how module harvesting would be carried out might have bearing as a modifying factor. We've already talked about this particular diagram, but it's worth noting that the TMC system proposed back in 2021 left a meter between each of the collective paths.

So if you want to call it a little bit of under lap and so that 1M, that would be left behind needs to be subtracted from the resource. When you're estimating a resources. And then of course, finally using environment as a modeling. In fact it also has some application at the regional level. The ISA has done estimates of the total resource base of the CCZ, but with the definition of APEI's within the regional Environmental management plan any future estimates of minable resource or reserve from the region as a whole would need to take into account the expectation that there would never be any mining within an APEI. The next thing to consider when going from resources to reserves is the role of modelling, especially financial modelling and mine planning. One way to look at it is you have these three different types of modelling mentioned here that all need to interrelate when you're making the conversion, we're going to go into a little bit more detail as to how mine plan Modelling and financial modelling work together and the reasons you do that are spelt out here and ultimately it's all about getting at the best or optimum return from the project.

The first thing to bear in mind when you get into this this side of the business is even though we're only really talking about the planning on the seabed, going from a resource to reserve, you need to consider the entire value chain, because if you don't have a sustainable value chain, you don't have a sustainable business. Everywhere you see a little red flag is a cost. Everywhere you see, a little green flag is a profit and of course there's a royalty that needs to be paid to the owner of the resource. In the area, of course, that's the common heritage. Again, coming to the question of why, well, there's lots of reasons to try and optimise an operation. They're discussed in a little bit more detail here on the left hand side, but ultimately it's about faster payback and getting more value earlier on in the project and ultimately more value longer term and that's really of course because discounting is often used in financial modelling because discounting is a way for investors to decide where they would rather put their money either into a particular project or put it in the bank or something like that. So this particular example shown here on the right hand side of the screen is completely hypothetical. All we did to change the Gray bars into the orange bars was to increase the grades and bring some of the tonnage production forward. So in this particular operation. We assumed that you could ramp up your production rate through slightly higher capital investment up front and you could focus on the parts of the ore body have slightly higher grade and then that would give you a better return and what you're seeing here, of course, is the value that you would get back saving hundreds of millions of dollars or something, whereas on this axis what you're looking at is the period, which is traditionally done in years.

And how might that look in real life? Well, here's an example again from Nori from the 2021 report and what they've done is they've scheduled all of Nori, starting with the green in the first period through to the Brown in the last period, and each period being, I think five years and of course there's some really clear trends that you can see coming out in that scheduling and those trends become obvious when you look at abundance and some of the grades. So I would say the, schedule mine plan is focusing on higher abundance areas first, probably because they think they'll get high production rights, all for lower capital cost on the onset. When looking at development of projects, especially in projects that are novel, especially in terms of technology, but also in terms of approach, Metals basket and things like that, which is marine minerals are often like that it's really interesting to talk about the role of the mining test. The mining test does a lot of different things they're all they’re listed here, of course, but the main one is it allows you to validate your modifying factor. So today we've recently seen a mining test in the CCZ we haven't seen the results of that yet, but we're looking forward to see those results come out through the course of this year. And there's a good chance that this entire lesson will be a little bit obsolete in about 12 months time once the results of this mining test from the CCZ. Yeah. Up until now, though, we've been very much dependent on results from the 1970s, as you can see from some of the comments here on the bottom right hand side.

So we've made it now to the final part of the of the lesson and this is a little bit more of a philosophical part of the lesson where we talk about reasonable prospects of eventual economic extraction. To go back to fundamentals, you're not supposed to work out a mineral resource unless you think there are reasonable prospects of venture economic extraction. Otherwise, you could estimate the metal content of anything anywhere, because there's always a few atoms of something somewhere. So for seabed minerals, if you're seeing mineral resource estimates coming out, it means that the competent persons have assessed RP triple E, as it's called, and the requirements are P triple E vary between the different codes, but for example, that your code requires that it's more likely than not that, RP Triple E exists for every single category that might be relevant. Then the question is, could RP triple ever change? And in effect, it kind of has in the past, the best example is with regards to seabed minerals, polymetallic nodules. Were prices that were high in the 1980s dropped going into the 1990s, there were other confounding factors as well. But it kind of explains why. One reason why there's a lot of interest in seabed minerals in the 1970s and early 80s, but then it died off through the 90s and even in the beginning of the 90s. With the rise of the Chinese economy, there has been a structural shift in metal prices, so we've just taken some of the most recent prices here and put them on the same scale and that, not coincidentally has led to an increased interest in seabed minerals.

I guess the question then is, could that change again or could there be other factors that could affect RP triple E? The most obvious one is, of course, ESG, especially the environmental side of the seabed minerals, where seabed minerals is quite controversial and there are some opponents who speak very frankly about the environmental risks. Obviously their mining. So I'm not going to of course get into all of that, but this particular diagram on the right hand side is a survey of mining company CEO's. It's a a survey just of their feelings, the sentiment and you can see both in 2021 and in 2022, ESG was rated as their biggest single concern. So, it would be interesting to see how things continue in the seabed mineral space with regards to RP Triple E. Thank you very much for your attention during this lesson. If you've got any questions that aren't really properly addressed within the slides or these references, don't hesitate to reach out. Goodbye.