



MODULE 5, LESSON 4

METHODS AND TOOLS FOR EXPLORATION FOR POLYMETALLIC SULPHIDES IN THE AREA

LECTURE NOTES

Hello, my name is Alden Denny. I'm the chief geoscientist at ADEPTH minerals, and I'm here to talk to you today about methods and tools for exploration of polymetallic sulphides.

When we discuss polymetallic sulphides, what we're exploring for are extinct sulphide deposits. Most of these are going to occur in mid ocean Ridge environments, especially within the Area, although in other environments within or within exclusive economic zones. These develop because of the process of hydrothermal flow - so water goes down, heats up, alters the host rock, the hot fluid rises up and when it hits the cold sea water again precipitates out to form these types of deposits. The extinct bodies that are the survey target, are really the final phase of sulphide deposit when it's grown to its full size, and when the hydrothermal processes here are complete, so there's no more active hydrothermal flow. These are an analog for the onland volcanogenic massive sulphide deposits, which is a type of deposit that's been mined for thousands of years. So when we're looking for these, what we're looking for are really quite small areas. The sulphide deposits we're looking for are orders of magnitude smaller than an exploration area. To give you an example here, here's the assessment area for the Norwegian Continental shelf and we have to zoom in and in and in again to find the football pitch sized area that represents a hydrothermal body. To put this in an ISA context, this is approximately 1.8 millionth of an exploration area, or the screen you're watching on here, it's one pixel on your screen that we're looking for. So in order to find these, we really need to use a whole suite of technology here. This image here shows the general types of systems that we're looking at to find these hydrothermal deposits. We have ship-based systems, we have systems that operate subsea such as remotely operated vehicles, ROVs and autonomous vehicles, AUVs and we have seafloor systems, such as the tracked vehicle cooling system that you see here.

So the whole suite of technology that can be used to find these seafloor hydrothermal sulphide deposits - are going to be used in these various exploration stages. So the exploration stages begin with the pre-study stage where all of the existing information is compiled. Any reprocessing and that needs to get done has to be done here and the overall regional understanding needs to really come out of this. At the end of this stage here you notice that it says decision for continuation and that's consistent for all of these steps. Each one of these needs to have its own decision gate so that the next operation is done with with full agreement that it should be done. So moving from pre study, we move to regional study; this is mostly a ship-based type survey activity where we're trying to understand the regional geologic and geophysical condition. Given a decision to move forward, we moved to a semi detailed study, this is the first time we're really going to. Move to subsea type assets using autonomous remotely operated vehicles and we're focusing on cost

effective, geophysical exploration to identify these potential deposits. Given another decision to move ahead, we move to the detailed study. This is the full suite of technology that we can use that we'll be discussing today. This is using autonomous vehicles, remotely operated vehicles and moving into the coring phase or removing into the subsurface. This is the last stage of exploration. At the end of this is a go- or no-go decision in order to continue to a pre-extraction operation. So, all of these stages are going to involve various technological solutions, and these generally are grouped into three major categories of technologies:

1. You have a technology for understanding the topography,
2. for understanding the geophysics, and
3. for understanding the oceanographic conditions.

Working at the topographic sensors or geomorphologic sensors you have multibeam sonar size scan sonar and synthetic aperture sonar. The multi beam sonar is going to be a key fundamental tool to understand what the seafloor looks like; from this geologist can interpret basic geologic conditions, whether there's faults, whether there's volcanic eruptions and flows, whether it's sedimented or not and begin to understand what the potential of a given area is to host this type of sulphide body. The side scan and synthetic aperture sonars give an image of the seafloor, which can be much more much higher resolution than the multibeam, but also gives because of the angle at which the sonars operate; they give a side look. They can provide shadows, and those shadows can be used to understand the height of various objects. So very good for imaging, for instance, extinct hydrothermal chimneys.

For looking at the geophysical sensors, you have a suite of active and passive electromagnetic sensors, gravity magnetics and then penetrating acoustic sensors. So, for the electromagnetics an example of a passive source electromagnetics would be a self-potential sensor that uses 2 or more electrodes and simply detects the electrical field of the earth as the vehicle moves through it. Now this can be used to identify sulphide bodies that have this, what's referred to as a Geo-battery effect going on inside them. Your gravity sensor is going to help you understand what the basic composition is in the material below you and the magnetic sensor can be used to understand if there's been a demagnetization, or in some cases actually a magnetization event related to hydrothermal flow. You'll see an anomaly here from the magnetic sensor that's going to be potentially related to this type of sulphide body. And finally, we finish out with a more active energetic type systems, this would be the penetrating acoustic sensors this could be, anything from a sub-bottom profiler either be operated from an AUV or an ROV type platform all the way to multi-channel seismic systems that are run from large dedicated ship platforms, These are going to help you understand the subsurface layering and subsurface properties using acoustics, really understanding the acoustic properties of what's going on underneath the seafloor. I finished up with active source electromagnetics; this can be used to understand the electrical properties sub-seafloor which can be used to delineate some of the sulphide bodies.

And finally the last group of technologies here are oceanographic systems. This would be detecting properties of the water column such as temperature, particulates, geochemical signatures. For sulphide bodies, these are really focused on understanding active systems, so you're looking at the trace of the plume that's coming off of the sulphide system. For inactive fields, this is a less discriminatory, but can be used as a key tool to understand environmental parameters of any deposit area. And finally, I'm just finishing with the tailor-made new technologies category here. This list is not exhaustive. There are promising techniques that exist out there that just haven't been really accepted or established within the field, so, keep an eye out for various new technologies that can really make this type of exploration more efficient.

So, all of these technologies and all of the exploration stages have to deal with the realities of the seafloor and really the challenges that are involved in sulphide exploration. Our first challenge here is topography. The areas that you're operating these types of systems in are steep and they're complex. So any type of vehicle, especially an autonomous vehicle, that's flying round needs to be able to negotiate that type of terrain and do so in a way that allows the sensor that you want to get information from to operate properly. For instance, synthetic aperture sonar requires a very steady flight in order to create the images the seafloor so you have to adapt both your platform and the technique that you're using to be responsive to the topography that you expect in an area.

We also have to be able to deal with burial, whether that's a very thin sediment cover over a deposit, even an altered surface on top of the deposit that's going to mask its underlying chemistry and potential, or volcanism. Subsequent eruptions after the formation of an ending of a hydrothermal body can layer over volcanic material over what could be potentially a large sulphide body, so we need to be able to operate and understand the potential for volcanic repaving.

Finally, the challenge here is really the depth and remoteness of the sites that we're working in. Especially when working in the area you're operating well away from shore and you're operating at fairly high water, deep water depths. So, the systems that you need to bring out need to be robust and you need to be able to operate them and repair them in areas that are very much removed from any sort of support infrastructure. So, all of the technologies that we've discussed here are focused on understanding the deposit occurrence, but when we're exploring, really we're exploring for the potential for minerals that could be extracted in order to get that information, we need to get subsurface; we need to get the core. We need core from a deposit, in order to understand the volume distribution and grade of any sort of mineralization that exists. And you have to move into the subsurface to understand if it is a sustainable and potential commercial extraction operation here.

There are various coring platforms that exist. The coring platforms on this image here move from left to right and in what we're calling platform flexibility. So, they move from dedicated coring platform such as a dedicated riser to riser, less coring ship and increasing flexibility here. So examples of coring systems that exist on the market today via dedicated coring vessel, seafloor coring system, a ROV based coring system, a tracked vehicle coring system and those three can also be operated from one of these more flexible offshore support vessel type platforms or even a scientific research ship. Now on this image I have over in the right autonomous platforms and you see their autonomous underwater vehicles as well, those aren't yet ready to do coring operations,

but that is definitely where the industry is moving here and increasing autonomy. So just to give you an example, this is an image of a tracked vehicle coring system operating on the seafloor in a marine mineral type environment. So these are systems that are deployable now and will be deployed more as we move from deposit discovery through the understanding of various deposits.

Now I've mentioned here that the platform flexibility is important and really what that represents is the ability to go from a purpose set operation such as a coring vessel doing coring to a parallelizable operation where the platform is doing the coring. Operation which from the exploration stages you saw as one of the last stages before you make a decision whether to move forward. But you're also collecting your environmental parameters, you're collecting your geophysical and oceanographic parameters at the same time. So here simultaneous operations is key to the sulphide exploration process so that you can collect this diverse data set combining your environmental parameters with your collection of core with your geophysical, with your geochemical in order to optimize the ship time that using and make sure that you collect all the information you need so that you can make your next decision.

Now these are currently going to be manned platforms and that's what we can point now, but I just want to flag autonomy as the next step here for exploration of sulphide systems. Autonomy is going to increase the efficiency of an operation and one of the keyways it can do that is by increasing the duration that an operation can be out on site, by removing people from the equation and it can reduce risk and improve the quality of life for personnel that are operating in these types of environments. If you're working from a remote control center next to your next to your house, that's a much better situation for the personnel involved than having to be out in these remote areas for months at a time. And finally, this is really one of the key ways to reduce the cost of exploration.

So I hope you enjoyed this deep dive into methods and technologies for polymetallic sulphides. Thank you.