AUVs to pack-hunt for seabed ore bodies

Challenge: How to detect and map deep-sea ore bodies using autonomous underwater vehicles Idea: Use small AUVs working in coordinated packs. And the target? Commercially viable deposits of what geologists call sulphide deposits or, more precisely, 'volcanic-associated massive sulphide' deposits. Incidentally, the 'massive' in VMS does not necessarily mean big, but formless and rich in metals.

Such is the aim of the Melodi (magnetic and electromagnetic ore detection) project set up by a French consortium led by Créocéan with partners ECA Group, RTsys and DCNS. This €4.5m collaborative initiative combines three complementary research programmes: Messidor, Doremi and Docking sponsored by Créocéan, Mappem Geophysics and DCNS, respectively. Messidor brings expertise in the magnetic detection of sulphide deposits; Doremi brings 3D resource characterisation and Docking, know-how in AUV hosting infrastructure.

Enormous potential

"We know the seabed is host to immense ore bodies containing concentrations of valuable and rare metals at least equivalent to those of land-based resources. The techniques currently used for deep-sea exploration are complex, expensive and often cause ecological damage, making them unsatisfactory for industrial scale mineral exploration," say the Melodi partners.

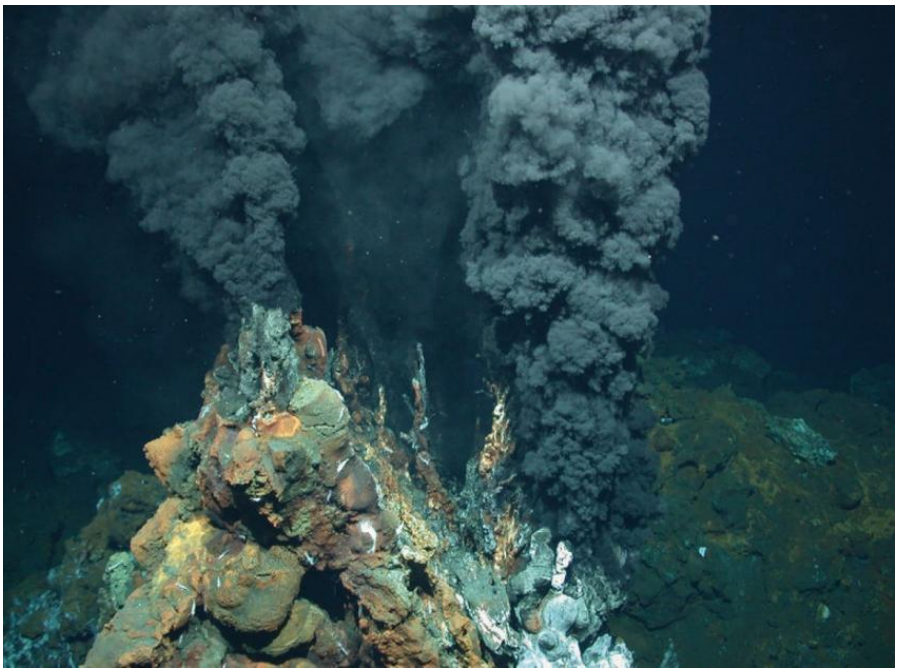
"Given that sulphide deposits are rich in materials used to produce electronic components and develop nanotechnologies, the potential is enormous. With land-based supplies under pressure, seabed deposits are keenly sought, as they are extensive and, as yet, unexploited," says Créocéan project leader Michel Colinet. La Rochelle-based Créocéan, a subsidiary of the Keran group, is a French design bureau specialising in oceanography and the littoral domain. Among other activities, the company records and analyses geophysical and hydrodynamic data, conducts environmental impact studies and prepares initial state inventories as part of an overarching strategy to promote sustainable development.

Zero-impact prospecting

This is precisely what Melodi promises. An innovative survey system that is fast, accurate and economical, with zero environmental impact; a system that radically reduces exploratory drilling and its impact on marine ecosystems.

The project also answers the crying need for a system that can reliably detect sulphide deposits. "The challenge is to identify relatively small geological bodies of a given density and with fairly well defined boundaries scattered across the seafloor at depths from 800 to 4000 metres. The fact that no one has managed to do this to date, explains why we are so keen to develop a method that is 100% reliable," says Michel Colinet. (Note that 'small' here means between 10 and 500 metres across.)

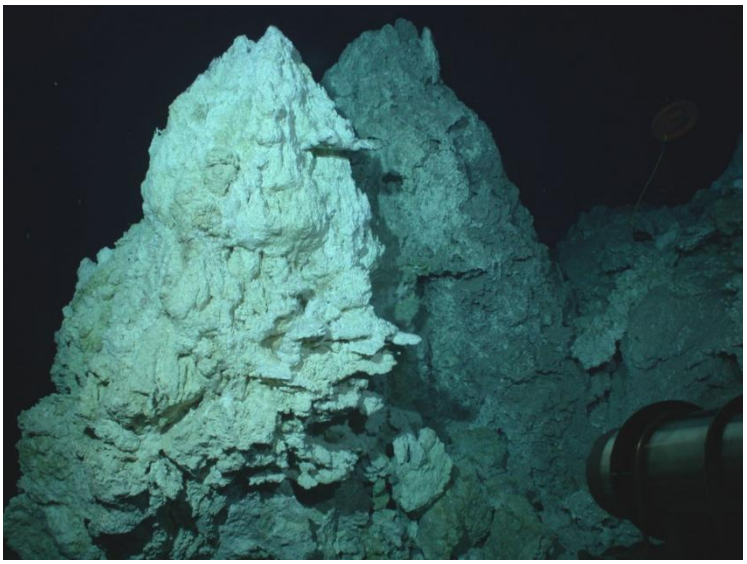
The prime aim of phase 1 of Créocéan's Messidor project was to demonstrate the feasibility of detecting sulphide deposits using magnetometers.



Active smoker (© NOAA)

Rich pickings along mid-oceanic ridges

To gain insight into all this, let us begin by revising some basic concepts of geology and plate tectonics. The earth's mid-oceanic ridges are where tectonic plates are separating as a result of convection currents in the underlying hot magma. The motion of the plates is like a conveyor belt moving slowly from the ridge towards each plate's farther edge. Along the edges of the ridges, heat and plate separation give rise to fissures and fractures while the heat they release give rise to strong convection currents and also allows seawater to penetrate the oceanic crust. The hot seawater modifies the surrounding rocks and minerals by dissolving metal ions, then, on re-emerging, forms so-called 'smokers' or 'hypothermal vents' as it meets cold bottom water, causing the minerals to precipitate, eventually forming VMS deposits. The resulting ore bodies are rich in base metals (copper, zinc and iron), iron sulphides (pyrite, marcasite, pyrrhotite) and 'critical' metals such as manganese, cobalt and nickel. Active sites along mid-oceanic ridges are characterised by 'smokers' that release heat and are home to extraordinary ecosystems. As the conveyor belt carries the plates and their vents away from a ridge, the vents cool down. Prospectors are only interested in inactive sites where there are no fluid flows or exuberant ecosystems, but which are nevertheless still too young geologically speaking (< 2 million years) to have been subducted under thick layers of sedimentary material.



Inactive vent (© NOAA)

Unique magnetic signature

“Academic research, not least that by the *Institut de Physique du Globe de Paris*, has shown,” adds Michel Colinet, “that these sulphide deposits have a specific magnetic signature that we can now measure and interpret which in turn means that they can be detected using the right instruments.” This brings us to the Doremi project by Brittany-based company Mappem Geophysics. Doremi focusses on the electromagnetic characterisation of geological objects and the determination of their metal content.

With clients that include Vale and Eramet, Créocéan established a name for itself in undersea mining before moving on to develop tools to prospect for seafloor sulphide deposits.

(© RTSys)

The prospect of AUVs hunting in packs

Given the vast areas to be covered and the location of potentially viable sites relative to the nearest on-shore infrastructure, not to mention the importance of achieving radically lower prospecting costs, autonomous underwater vehicles and the like were an obvious option,

particularly in view of the rapid improvement in their capabilities in recent years. “After demonstrating the feasibility of using AUVs equipped with magnetometers to locate sulphide deposits, the next step was to develop the concept of AUVs hunting in packs with a pair of specialist partners,” said Colinet.

It is in this context that the ECA Group, the French leader in undersea robotics in hostile environments, joined the Melodi project, along with RTsys, a company specialising in underwater acoustics. RTsys’s Comet project, completed in June 2015, included sea trials that demonstrated the feasibility of squads of AUVs working in unison. “They can be made to work as a pack. One, the ‘leader’, is equipped with a high-performance inertial platform which re-registers its position from time to time either by receiving precision GPS data from a surface vessel over an acoustic link, or by returning to the surface. The other AUVs get their position fixes relative to the leader with the result that each has precision position data using just one inertial platform, thus reducing both weight and costs,” says Vidal Teixeira, CEO of RTsys.

Follow the leader

Melodi will use ‘follower’ AUVs developed by RTsys. Each one, around 2 metres long and weighing 40kg, will carry a magnetometer to detect potentially mineral-rich sites. The leader, or master AUV, leads a pack of ‘followers’. The leader, developed by the ECA Group, will be based on ECA’s A18-D which is 5 metres long, weighs 600kg, offers a mission endurance of 24 hours and can operate down to 3000m. “Equipped with the latest sensors and smart onboard software, the AUVs will survey the deep seafloor beyond 2000m and undertake other programmed collaborative missions, communicate with each other and recharge their batteries without having to surface,” says the ECA Group’s head of R&D.

100sq.km per day

By using a pack of AUVs, with each following a predetermined trajectory while the pack conducts a grid-wise survey, it will be possible to cover vast areas quite quickly. It is estimated that a pack of ten followers could survey 100sq.km in 24 hours while gathering data enabling geologists to identify potentially mineral-rich sites.

Post-survey data analysis will reveal the potential feasibility and profitability of mining a given deposit. Mining companies would then be invited to proceed with exploratory drilling. Recall that the targets are inactive vents, not active smokers. While everyone acknowledges that active smokers are veritable oases of marine life, inactive vents are virtually devoid of life, hence compatible with environment-friendly exploitation.

Aside from the technical challenges, the environments in which prospecting campaigns are undertaken are challenging. “First, given that mid-oceanic ridges are, with few exceptions, thousands of kilometres from the nearest land, the target areas are particularly remote. This means that we need rugged, highly reliable equipment and clearly defined mission objectives,” says Michel Colinet.

The Melodi concept (© ECA Group)

Mother ship and AUVs on 25-day campaigns

A mother ship will carry the AUVs to the target area. This will probably be an offshore supply-type vessel with a large deck and heavy handling gear. The ship will provide a logistic base, support AUV operations and recover the data they record. The consortium believes that it will be technically feasible, depending on mission needs and profile, to undertake campaigns lasting 25 on-site days using two packs of AUVs — one in the field, the other undergoing maintenance — working a 24-hour rotation. This plan would also use a DCNS-designed docking station that would remain under water, but tethered to the mother ship, so as to limit the number of times each AUV needs to be brought to the surface. The docking station will automatically recover data from the AUVs and recharge their batteries.

The **basic mission plan** is as follows:

- launch pack, calibrate sensors then send AUVs to survey starting point

- deploy AUVs as a formation then begin grid-type survey, each AUV following a predetermined trajectory

- during the survey, each AUV stores magnetic data in real time

- use the long-range acoustic communications link between the lead AUV and the mother ship as required according to mission needs and phases

- continuous acoustic communications and relative geolocation between the lead AUV and its followers

- on completion of survey, pack returns to surface, the AUVs are hoisted aboard the mother ship and their data recovered (USB, Wi-fi, network, etc.)

- recharge AUV batteries, carry out preventive maintenance and test in preparation for next mission.

Operational demonstration a year from now

The detailed operational constraints and methodology will be defined as part of phase 2 of the Melodi project which is scheduled to begin in Q3 2016. The aims of this critical phase include risk reduction and the evaluation of how well the envisaged design trade-offs meet the requirements of future deep-sea mining missions. For ECA, the aims will include the validation of each sensor's mechanical, electrical and software interfaces as well as those of the acoustic geolocation system between the lead AUV and the RTsys-designed followers. Phase 2 will also enable ECA to validate the lead AUV's algorithms for mission and pack management.

Phase 2 is scheduled to run until September 2017, by which time a lead AUV and a pack of followers will be ready to test. The test programme will examine sensor operation, AUV launch and recovery, communications between the lead AUV and its followers, formation positioning according to a predetermined 'flight plan', safety protocols in the event of unforeseen events, survey tools and so forth. The sea trials will be conducted off France's SW coast and the deep-water trials in the 2000-m Gouf de Capbreton trench.

Prospecting off Wallis and Futuna by 2020

"Come September 2018, we hope to have demonstrated that the pack concept works before moving on to phase 3." This will take place in 2019/2020 off Wallis and Futuna, a French archipelago in the Pacific Ocean between New Caledonia and Tahiti, where sulphide deposits were discovered in the course of a 2010-2013 campaign by Eramet, Technip and Ifremer. "We will resurvey these areas with the AUVs to check the performance of our systems and methods. We will then survey new areas in search of unchartered deposits. Assuming phase 3 goes well, we will then be in a position to offer our survey services to the relevant French authorities and other countries with maritime domains."

Prospecting for other minerals

Even at this early stage, the Melodi consortium sees additional reasons for optimism beyond the promise of sulphide deposits. "Once we have demonstrated that the concept works, we will investigate ways of tailoring it to prospect for other minerals, including polymetallic nodules and cobalt-rich crusts. To do this, we will first have to characterise their signatures and modify our AUVs to accommodate sensors specific to each resource." Given the challenges and the interest shown by many in this, the only project of its kind in the world, Michel Colinet firmly believes that "with so many looking for the best way to proceed, we fully expect to be inundated with enquiries the moment we succeed in demonstrating our concept's capabilities".

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