Introduction

Due to substantial costs associated with offshore drilling, attention has turned in recent years to electromagnetic (EM) methods to obtain additional information about reservoir characterisation during exploration for oil and gas. There are two main methods that have the ability to uncover important supplementary geological information:

- MT (Vozoff K., 1991, Chave A.D., 1991, Fox L. et. al., 2006, 2007)
- Sea Bed Logging MCSEM (Farelly B. et. al, 1991)

For deep sea water (up to 3km), EM receivers (Chave A.D., 1991) and transmitters have been developed and their application has shown the geological significance of obtained data. Still, there are some questions about their economic performance and choosing the most cost effective and geologically significant technology. Deep marine instruments were developed at least decade ago and are not ideal for today's surveys. In addition, they have one significant apparatus disadvantage – instruments can only measure four components of the EM field (Ex, Ey, Hx, Hy) instead of the preferable 5-component measurements (Ex, Ey, Hx, Hy, Hz).

These instruments are heavy and large vessels must be used for their field application. Considering the vessel rental costs of upwards of 70,000 USD per day, large quantities of seabed EM receivers have to be deployed every day to make surveys feasible.

For coastal shelf and transition zones, the situation becomes even more complicated, since the operation of large vessels in some areas is limited due to the shallow sea depth. Therefore, specialised seabed EM receivers have to be used for coastal shelf and transition zones to provide reliable geological information at a reasonable cost. Relatively small vessels can be utilized to collect this information.

Marine EM system for coastal shelf exploration

In order to minimize the effects of sea currents, the equipment was designed with minimal use of bulky elements that would create drag and obstruct the flow of water (Figure 1, A, B). The basic element of the system is the frame, which can be composite (carbon fibre or fiberglass) or metal (non-magnetic). A plastic plate is attached at the bottom of the system and houses all the main subsystems, pressure vessels (deep water) and electronics. A geophysical EM receiver (2-4-5 or 8 channels) that can run underwater in an autonomous synchronized mode according to a schedule written on a removable media card (Ingerov O., 2011) is installed in one of the pressure vessels together with the system's controller. The controller monitors the operation of an electroprospecting unit, as well as other parameters of the system, such as depth, azimuth, inclination, temperature, humidity, etc. Systems are equipped with radio and acoustic communication to determining their location, both on the surface and underwater. The second enclosure contains a power source (a set of batteries), where one of them powers the electroprospecting recording unit and the other a control unit.

Four telescoping booms that serve as electric dipoles are securely attached to the system and can be quickly removed or collapsed for transportation or storage. Special low-noise non-polarised silver electrodes are mounted on the end of each boom.

At the top part of the frame there is added buoyancy for levelling of the system and keeping an upright position during descent and accent cycles, and the pop-up buoy that is used for the retrieval of the system upon receiving the command from the surface. The concrete anchor, which is part of the emergency floatation system, is mounted on the bottom of the system's frame. A command to release the anchor is sent via an acoustic link from the surface.

In contrast to the 2-component (2E) coastal shelf system 2AUSS-07A (Figure 1, A)), the 5-component (2E+3H) system 5AUSS-07A (Figure 1, B) has three precisely aligned orthogonal magnetic sensors (in sealed underwater housings) and a levelling system with self-adjusting legs. This sub-system automatically adjusts the horizontal alignment of the 5AUSS-07A system after reaching the seabed.

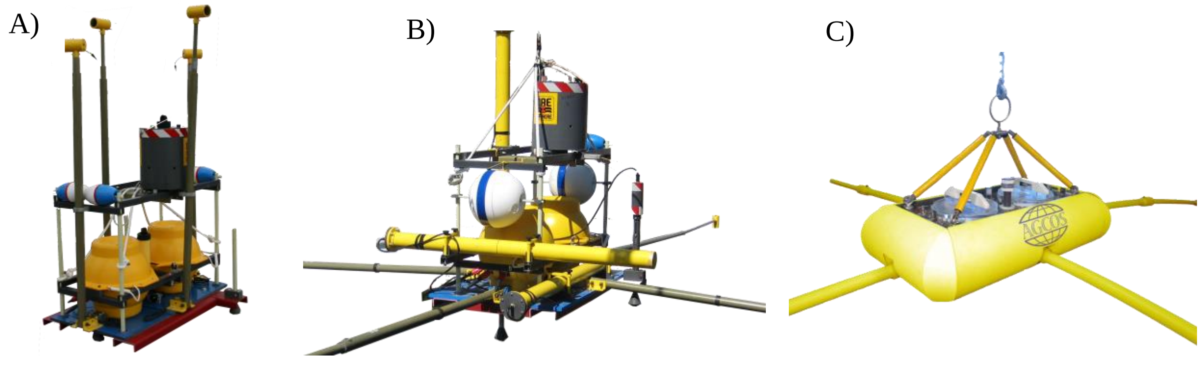

Figure 1 *Marine EM receivers for coastal shelf and transition zone exploration; A) 2-channel 2AUSS-07A; B) 5-channel 5AUSS-07A, C) 2-channel SMMT.*

Deployment/Redeployment of Marine EM Receivers

The crew required to service the marine systems consists of only three experts (two operators and one for data processing and analysis) and the weight of the system is limited (2ch-160kg, 5ch-290kg). As a result, the size of the required vessel can be quite small.

Main requirements for the vessels:

- Local safety regulations;
- Corresponding marine regulations and permits to be as far from the shore as the marine EM surveys require;
- Safe storage for at least 10 systems;
- Open deck space for at least one system operation (transfer from storage to working mode);
- Crane with at least 500kg lifting capacity and an arm with an extension length of at least 5m from the vessel.

Deployment of the system:

- Switch the system to a working position on the deck of a vessel;
- Insert a fresh battery pack and a removable media card with a loaded startup table for the receiver;
- Turn on the EM receiver and the communication module; acquire GPS coordinates and a synchronization lock;
- Seal all pressure vessels;
- Using the vessel's crane, deploy the system in the water.

Recovery of the system:

- Sail to the location where the system was deployed according to GPS coordinates;
- Establish acoustic communication with the system and acquire status parameters;
- Send "Release" command to disengage the pop-up buoy and wait for it to reach the surface;
- Fish out the cable attached to the pop-up buoy and attach it to the winch;
- Pull the system out of the water using the winch;
- Put the system on the deck and retract the telescoping booms;
- Open pressure vessels, extract the data, change the battery pack and the removable media card;
- Move the system to a safe storage space;
- Copy the acquired data to a PC for further processing.

If there is a problem with the pop-up buoy's response, an acoustic command to release the concrete anchor can be sent and system will surface by itself.

Marine EM system for transition zones exploration

There are many bodies of water around the world where the sea depth is less than 10m and, in many cases, less than 5m. For example, one of these vast areas is the northern part of the Caspian Sea, which occupies thousands of square kilometres and is very promising for oil and gas deposits. The AUSS systems described above are not ideally suited for such environments. The SMMT (2-channel shallow marine EM receiver) system (Figure 1, C) was specifically designed for carrying out marine EM surveys in these areas. The system has a very low profile and an aerodynamic shape to minimize the effects of underwater currents and noise induced by the waves. SMMTs are usually deployed close to shore in conjunction with land-based 5-component EM stations (2E+3H). Such an approach reduces the cost of marine surveys by deploying only 2-channel seabed EM receivers.

Figure 2 *Deployment of SMMT system during marine EM survey.*

To make the marine system relatively lightweight and environmentally friendly, a custom deploy/retrieve system was implemented. The SMMT has two quick access pressure vessels for electronics and the power source, which simplify the operation on the vessel's deck and increase productivity.

Figure 3 *2-channel EM receiver for transition zones SMMT. Preparations for the deployment on the deck of the pontoon boat.*

Four quickly detachable telescoping booms act as electric dipoles and are securely mounted to a non-magnetic frame. Small physical dimensions and the low weight of the SMMT allows marine EM surveys to be carried out from small vessels, such as pontoon boats (Figure 3). A simple mechanical crane can be used. The main vessel requirement is that it should be safe according to local marine safety regulations. Deployment/redeployment procedures are very similar to previously described procedures for AUSS systems, except that the pop-up buoy and concrete anchors are no longer used and a custom-designed enclosed subsystem is used to regulate the wet weight of the system.

Conclusions

- Deep water seabed marine EM systems are not economically viable for the exploration of coastal shelf and transition zones;
- Deep water marine EM receivers are not equipped with a vertical magnetic component that can provide important geological information;
- Specialized seabed marine EM systems, 2AUSS-07A and 5AUSS-07A (2 and 5 channel respectively), can be deployed/retrieved from relatively small vessels;
- Specifically designed for the exploration of transition zones, the SMMT system has a very low profile and an aerodynamic shape, resistant to surface waves and underwater currents. It is equipped with marine low-noise non-polarized pots and can be deployed from small vessels or catamarans;
- Marine EM surveys carried out from relatively small vessels with shallow seabed marine EM receivers can be profitable;
- The shallow marine EM systems can also be successfully applied to geological engineering and pipeline and underwater cables route investigations.

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