Resistivity methods

1. Electric resistivity imaging

Principle: In electric resistivity imaging (ERI) electric currents are injected into the ground and the resulting potential differences are measured at the surface, yielding information about the distribution of electrical resistivity below the surface. Finally this gives an indication of the lithological and structural variation of the subsoil (since resistivity depends on sediment porosity and pore water). On land the ERI technique has been around for quite some time, but at sea it is still not often used. The resolution of the resistivity image will decrease with the target depth, whereas the penetration depth depends on the length of the electrode array (long array = deeper penetration).

Basic features: For marine applications the electrodes are contained within a long cable that is towed behind the survey vessel. Different source-receiver electrode configurations can be applied depending on the subsoil, depth of investigation, data coverage, etc. The data are recorded with a small acquisition unit on board the vessel. Both floating cables and cables towed over the bottom can be used. The advantage of the latter is that it increases the penetration depth and reduces the influence of the (highly conductive) water layer. Through a dense network of 2D lines finally a 3D resistivity volume can be obtained.

Most of the marine electrical resistivity work carried out so far concerns either groundwater studies (e.g. freshwater/saltwater intrusion) or rock/sediment identification (e.g. for dredging operations or harbor works). A recent case study in Italy applied the method on shipwreck detection, but the results are not very convincing. It remains uncertain whether wood, peat or stone artefacts can be detected. For the moment the applicability of the ERI method for underwater archaeological studies therefore seems to be limited to (lithological/structural) information on palaeolandscapes, complementary to acoustic data.

Commercial examples: AGI Supersting, DEMCO Aquares, IRIS SYSCAL Pro, ZONGE.

Advantages:

- Lithological/structural information
- Relatively simple and fast method
- Operated from small vessels
- Image quality is not affected by gassy sediments

Disadvantages:

- Low resolution
- Limited penetration depth (< 15-20 m)
- Small structures are filtered out during the inversion process
- Wood, peat, stone possibly not detected

Literature:

Passaro, S. 2010. Marine electrical resistivity tomography for shipwreck detection in very shallow water: a case study from Agropoli (Salerno, southern Italy). Journal of Archaeological Science 37, 1989-1998.

Fig. 1 Deployment of bottom electric cable for marine resistivity survey (© RCMG Universiteit Gent)

Fig. 2 Floating electrode cable during marine resistivity survey (© AGI)

Fig. 3 Marine resistivity acquisition unit (© AGI Super Sting)

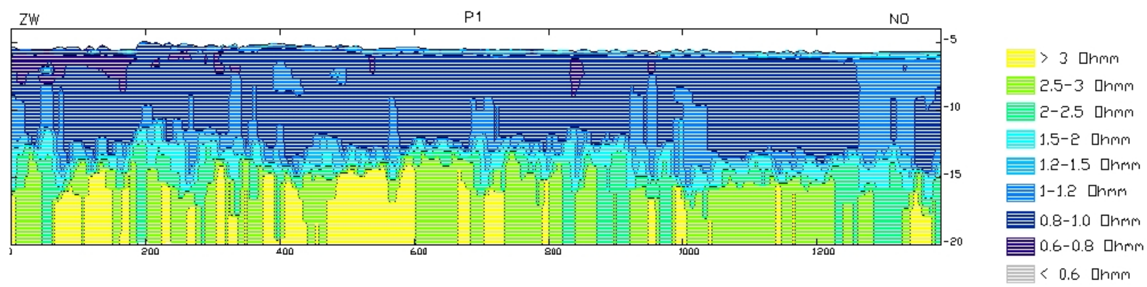

Fig. 4 2D resistivity section off the Belgian coast showing a succession of sandy and silty sediments (© RCMG Universiteit Gent).

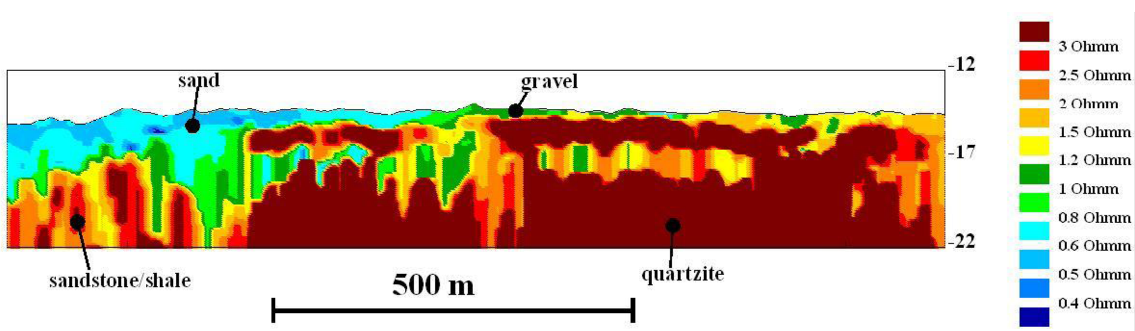

Fig. 5 2D resistivity section recorded offshore Spain showing a harder structure overlying softer sediments (© DEMCO).

2. Electromagnetic imaging

Principle: In electromagnetic (EM) surveys an electromagnetic field is generated by a coil, which induces a secondary magnetic field. The amplitude and phase variations of this secondary field allow to calculate the conductivity of the subsoil (inversely proportional to resistivity). EM imaging has been used for many years on land, including archaeological studies (palaeogullies, buried structures, etc). Similar to electrical resistivity surveys, also here the resolution will decrease with the target depth and the source-receiver configuration will determine the penetration depth.

Basic features: Marine EM surveys mostly involve the use of a large source coil and several receiver coils that are towed near to the bottom. In some cases a surface-towed source is used together with fixed receivers on the sea floor (so-called marine source electromagnetic or mCSEM method), which is nowadays more and more used for the characterization of oil and gas fields. Both time-domain (TEM) and frequency-domain electromagnetic (FEM) measurements are possible. It is generally believed that a higher resolution is obtained with the time-domain method (although recent studies seem to refute this), but due to the limited penetration the array needs to be towed close to the sea bottom.

Most of the current marine EM technology was developed by major research institutes (Scripps, WHOI, SOC) and/or the oil industry, often in close collaboration. Examples: AOA GeoMarine Operations, NGI/Statoil SeaBedLogging, Phoenix, Seismic Sciences.

Platforms: Marine EM techniques often involve the use of heavy and bulky equipment which implies the use of relatively large boats. The resolution of the obtained data is generally much lower compared to acoustic techniques, and their application for small-scale, detailed archaeological studies at sea therefore remains questionable. Recently, however, a marine EM induction profiler was developed in Germany for the study of near-surface sediments, which allows to resolve variations in porosity and clay/sand content in shallow sediments. This could open new perspectives for archaeological studies.

Advantages:
- Lithological/structural information
- Image quality is not affected by gassy sediments

Disadvantages:
- Low resolution
- Heavy equipment requires larger boats
- Not in shallow water (min.10 m)

Literature:
Muller, H., Dobeneck, T., Hilgenfeldt, C., Frederichs, T. et al. 2009: GEM-Shark – electromagnetic subsurface profiler for coastal shelf research. Marum.

Fig. 1. FEM profiler array for marine surveys. Left: receivers, right: source (© Woods Hole Oceanographic Institute)

Fig. 2 Bottom-towed EM profiler array "GEM-Shark" for marine surveys (© University of Bremen)

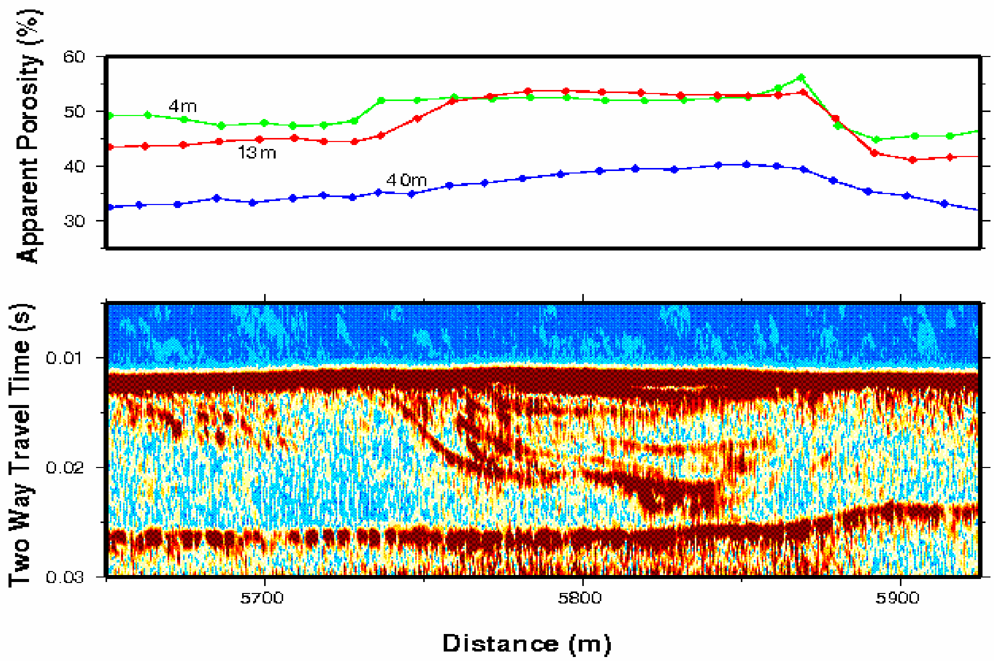

Fig. 3 Porosity profile (top) and concurrent acoustic) recorded offshore North Carolina (© WHOI)

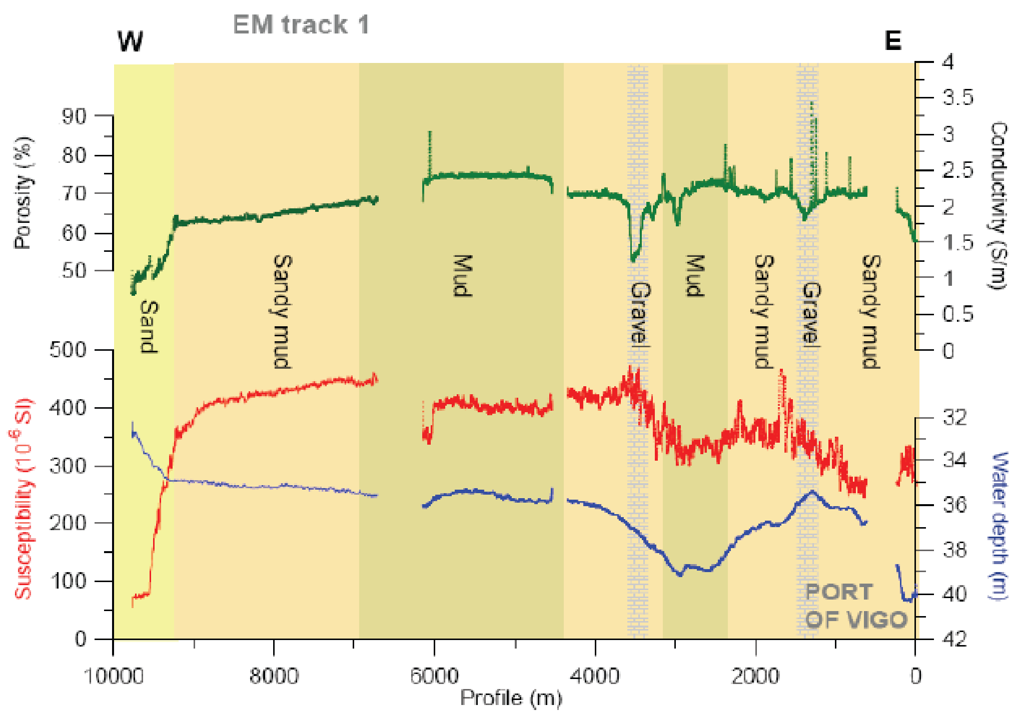

Fig. 4 Conductivity and susceptibility data of transects recorded in the Vigo estuary, Spain. (© University of Bremen)