

The Aquares Resistivity System, as an Exploration Tool for Rock Dredging Applications

Peteralv Brabers
Demco NV
Belgium

Jason Errey
Demco NV
Australia

Abstract - Aquares resistivity surveys are proving invaluable to dredging companies and particularly those involved with high risk dredging projects that require the removal of rock in ports, access channels and pipe line trenches throughout the world. The unique ability of the Aquares Resistivity System (ARS) to distinguish different types of rock and clearly define thickness and depth of each of the present geological units is very useful in these applications. This paper provides an insight to the theory of the ARS, a brief comparison between acoustic and geo-electric methods as well a number of case studies of dredging projects involving the use of explosives to remove very hard rock.

Keywords – component; Aquares Resistivity System, sub bottom profiling, rock dredging

I. INTRODUCTION

The ARS is a geo-electric, hi-resolution sub-bottom profiling system modified from the principles of land based systems (Fig 1), that is capable of providing a detailed qualitative and quantitative view of the first 10 to 12 meters below the seabed. Unlike acoustic methods, the ARS provides depth, thickness and density data for virtually all rock and

sediment types commonly encountered, regardless of their state or the order of the strata. Although shallow water reflection systems often may provide useful results regarding depths and thicknesses of sedimentary structures, most of the acoustic energy tends to be reflected at the sediment rock interface. As such, virtually no information is attained from the rock structure(s). Additionally, in cases where a sediment layer is gaseous in nature, for example through biological decay, the acoustic energy is unlikely to penetrate this layer (Fig 2). Refraction systems may provide limited qualitative information about the sub-bottom, however, even in ideal conditions, tend to be less effective and often even fail to provide accurate thicknesses and depths of the geological units (Fig 3).

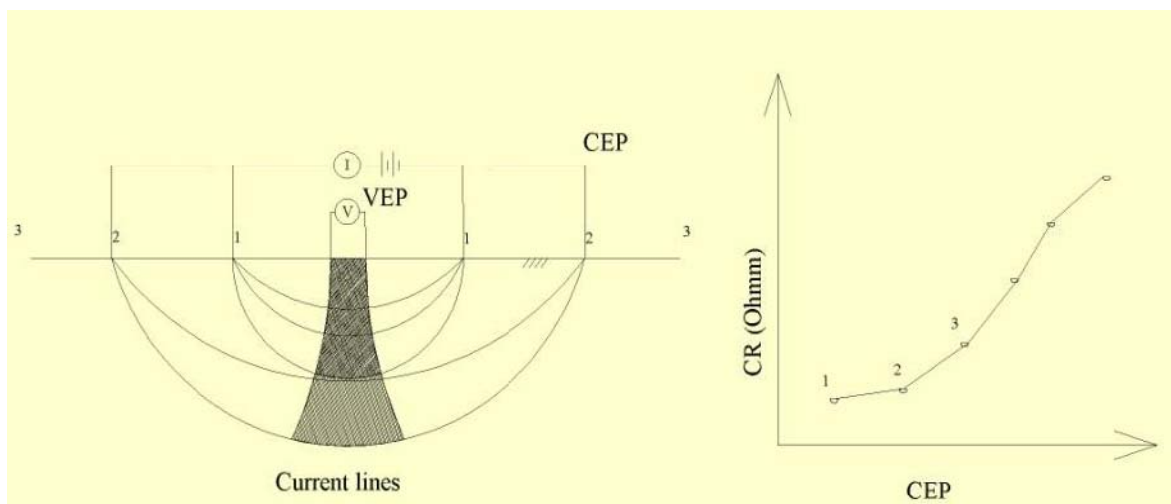


Figure 1. Land based geo-electric systems require that a Current Electrode Pairs (CEPs) are placed about a Voltage Electrode Pair (VEP). The CEPs are used to inject current into the sub-surface and the VEP is used to calculate the apparent resistivity of the sub-surface between the VEP. Penetration of the system is determined by the distance between each CEP, the greater the distance between the CEP, the greater the penetration.

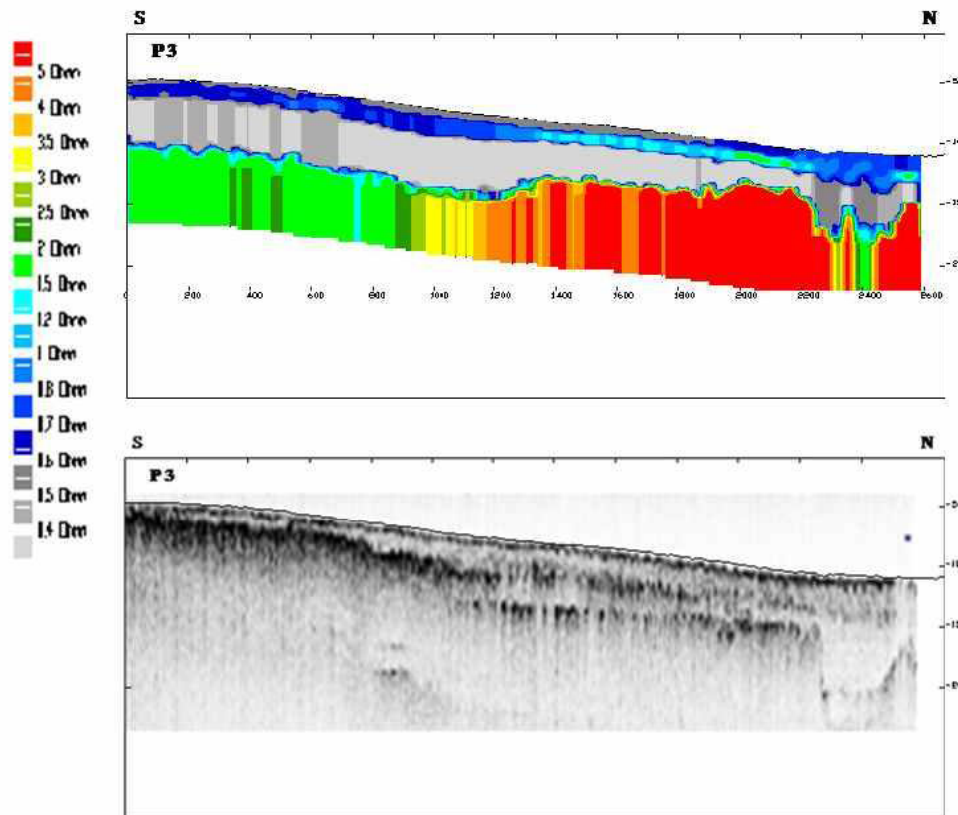


Figure 2. This is a comparison of an ARS line (top) run in conjunction with a boomer line (bottom). Sediments to the left are likely gaseous and impenetrable by the boomer. In addition the ARS shows a transition in the quality of the bedrock

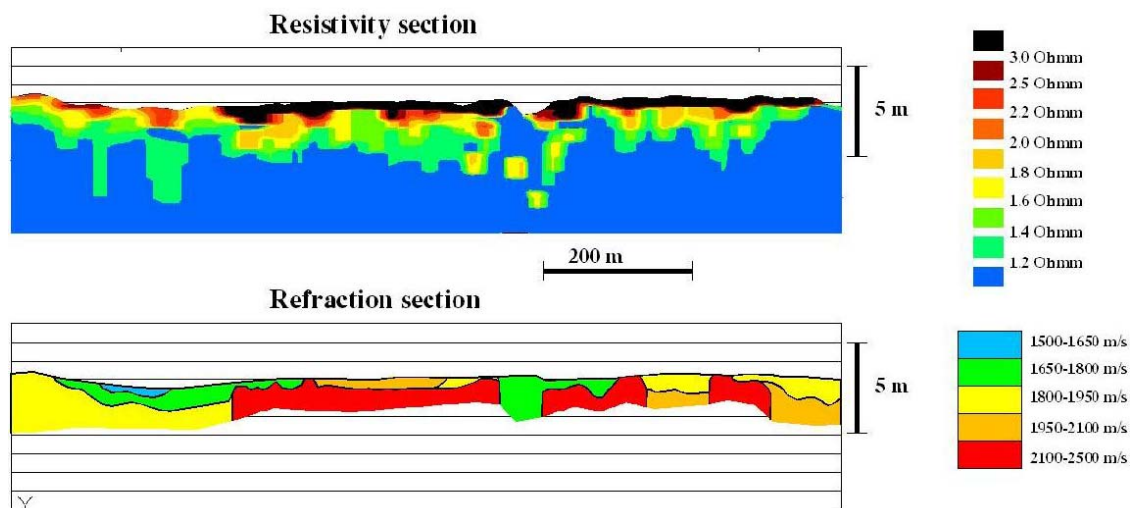


Figure 3. This is a comparison of an ARS survey line run along the same line as a refraction line. The refraction results show a low velocity layer on top of a high velocity base structure, while the resistivity results suggest the opposite: a high resistivity structure on top of low resistivity sediments at depth. The resistivity results were confirmed by drilling and sampling results.

II. MARINE DEPLOYMENTS

The ARS is a bottom towed system (Fig 4) that can rapidly acquire data in areas and conditions that are beyond the capabilities of acoustic systems for example, in water depths of as little as 20cm, in surf zones, through calcarenites, gaseous layers and into bedrock. Typically a shot is recorded every 2.5 seconds and at a survey speed of 2 m/s, a sounding is therefore recorded approximately every 5m with information being gathered along the entire length of the cable. Processing is again based on principles for land-based resistivity, but has been extended to be suitable for marine applications. Once the resistivity results have been cleaned and compensated for depth and ambient seawater salinity, they are interpolated to a regular grid. Results are visualised in colour as maps and as horizontal cross-sections or vertical slices showing different geological structures as a function of geographic position and depth (Fig 5). The ARS may also be used in conjunction with acoustic sensors such as Sparker or Boomer, Side Scan Sonar and single or multi-beam systems (Fig 6).

Case studies including detailed analyses of the results for dredging activities that require blasting are provided for New York, Spain and Cameroon.

III. CASE STUDY – NEW YORK

Based on previous dredging experience rock was known to exist in the dredge area and as a consequence, extensive geophysical studies were carried out to reduce dredge risks. Five different seismic reflection methods were undertaken in the survey area as well as an ARS survey, with the objective of determining if the proposed works would require the use of explosives. A typical vertical resistivity section from this survey is shown in Fig 7. High resistivity values are presented in red, brown and black colours while low resistivities are presented in grey and blue colours. Based on borehole information available, high resistivity values are correlated with solid rock, low resistivity values with sandy sediments and very low resistivity values ($<0.4 \Omega \text{ m}$) with silt.

A remarkable feature in this profile is the high near-surface resistivity structure (brown-black) overlying a highly irregular lower resistivity zone (green-yellow-blue) above the compact rock (orange-red). At the time of the survey no explanation existed for this feature. Seismic reflection methods were not able to find the above described structures.

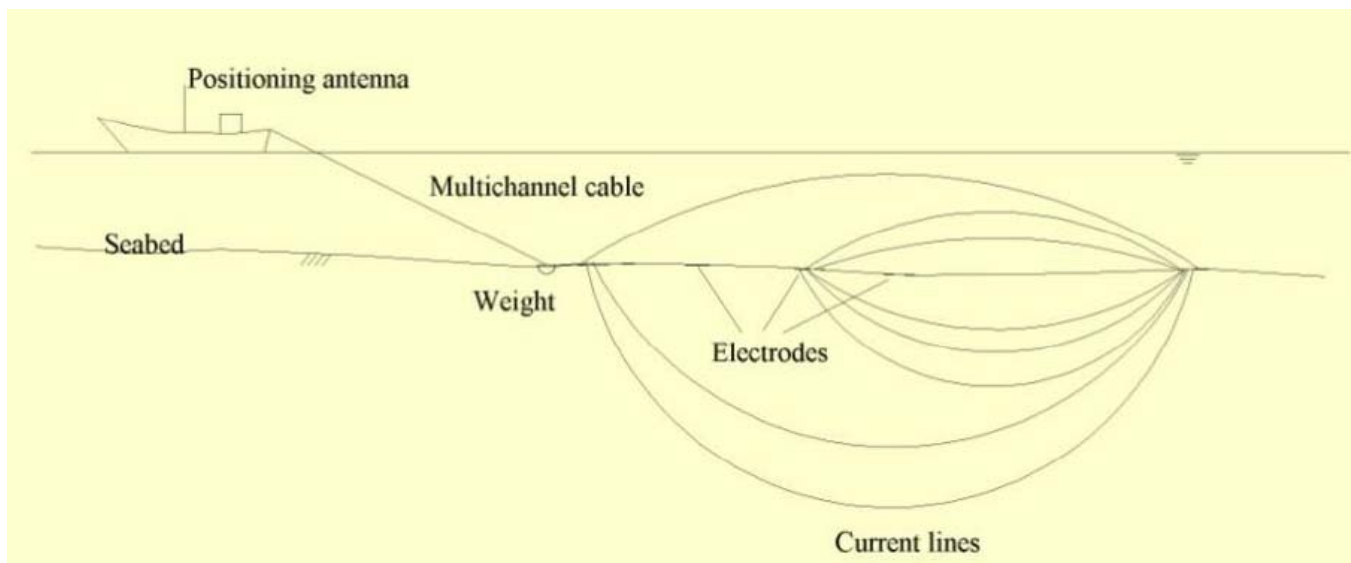


Figure 4. The ARS is modified form land based principles to operate effectively in the marine environment. CEP and VEPs are placed in a multi-channel cable and towed along the seabed. Acquisition is usually in the order of 4 to 5 knots, and the system operated between 0.1m and 180m.

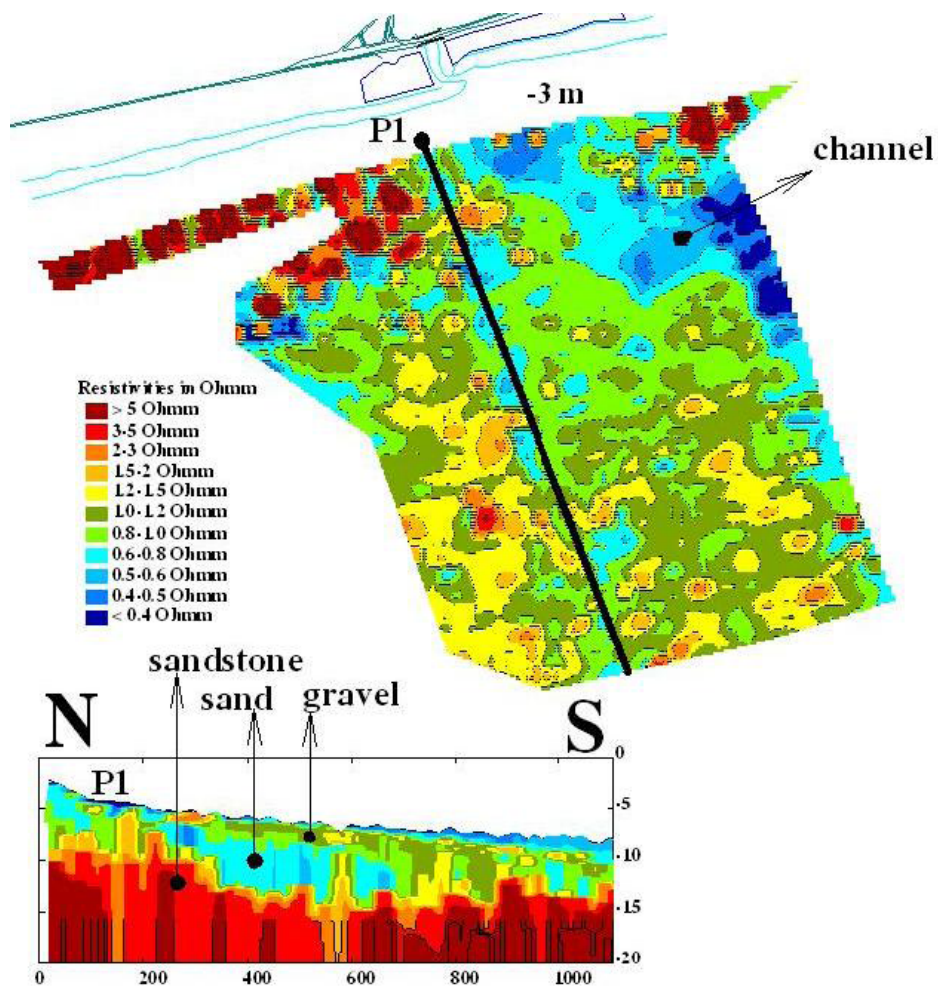


Figure 5. Horizontal slices and vertical sections from a Pipelay survey. The high density of resistivity information obtained allows very powerful statistical noise reduction algorithms to be run. At this stage, if boreholes or additional geophysical data are available they are used to calibrate results. If survey lines are run with sufficient density, the vertical sections are stitched together to form a 3D model, allowing vertical sections or horizontal slices to be made along any line desired.



Figure 6. Deployment of the ARS (orange cable) in conjunction with a Boomer system (blue cables either side of the vessel wake).

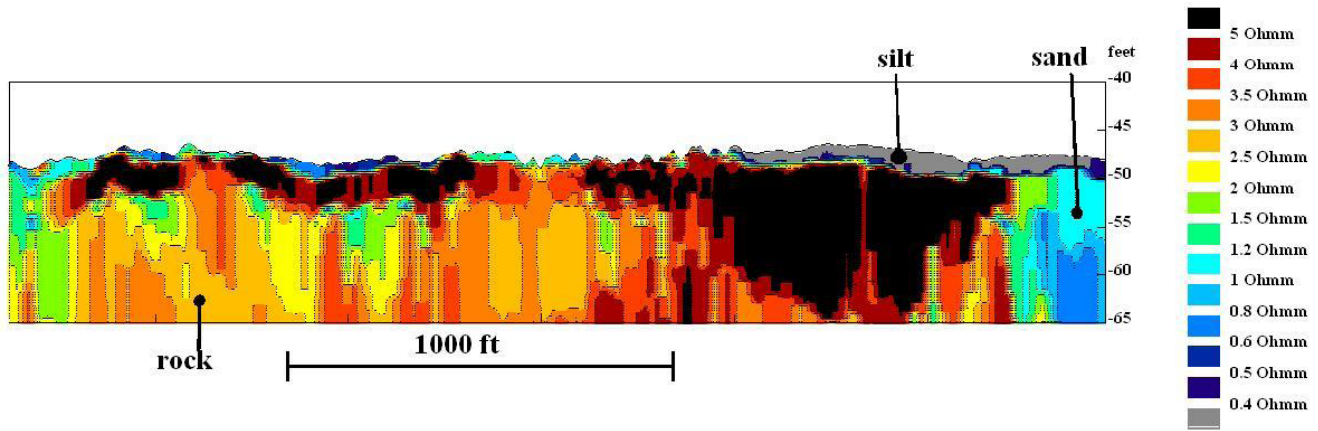


Figure 7. A typical cross-section from NY harbour. The anomalous dark features overlying softer sediments are clearly visible to the left of the section.

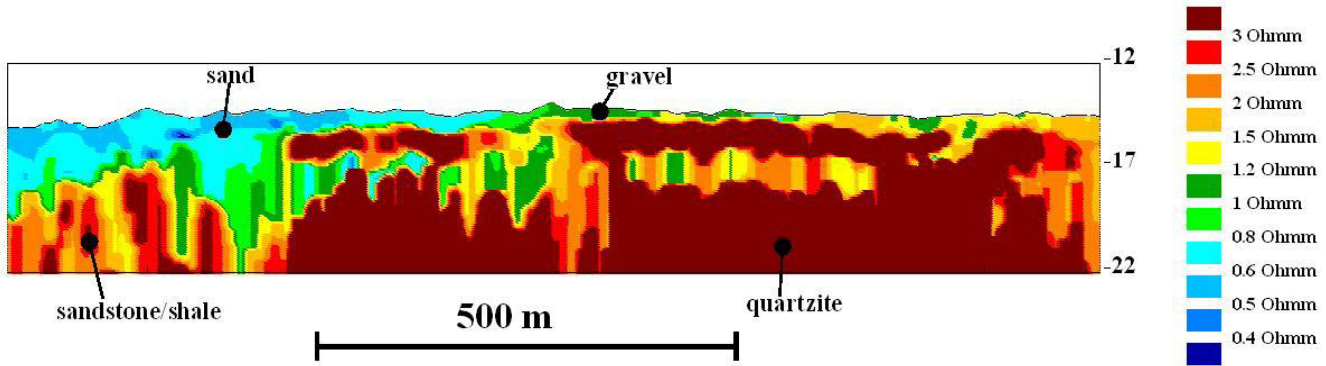


Figure 8. A typical section from Spain showing a similar hard structure overlying softer sediments.

IV. CASE STUDY – SPAIN

A dredging company responding to a dredge tender in a port in northern Spain elected to carry out a resistivity survey in order to assess the dredge risks and define the most suitable dredge technique to carry out planned works. A typical resistivity section is shown in Fig 8. The colour scale goes from blue for low resistivity values to green, yellow and orange for intermediate resistivity values to red and brown for high resistivity values. From boreholes, the location of quartzite and shaly sandstone formations in the bedrock is known. The shaly sandstone showing slightly lower resistivity values as compared to quartzite rock. Gravel (green-yellow: $0.8\text{--}2\ \Omega\ \text{m}$) is found covering the bedrock and in offshore directions (left on the profile) sand with lower resistivity values (blue: $<0.8\ \Omega\ \text{m}$). The same high resistivity near-surface structures overlying a low resistivity zone above the bedrock is seen as in the New York case.

Although, both in New York as in Spain the respective survey areas were known to have been dredged previously using explosives and a backhoe to remove the blasted rock, no explanation could be provided to explain the resistivity structures described above. It was only after a resistivity survey carried out in a port in Cameroon that a logical explanation was determined.

V. CASE STUDY – CAMEROON

In a coastal area in Cameroon, plans were made to build a new port. In order to economise dredging costs, the port, including the quay walls were designed based on a 3D resistivity model of the area acquired using the ARS. The upper profile (Fig 9.), shows a particular section along the position of one of the quay walls before commencement of the dredging operations. It shows very high resistivity values representing compact basalt, intermediate resistivity values representing sand and gravel and low resistivity values representing mud.

Based on the first resistivity survey the port was designed, relevant parts of the port had to be dredged using explosives with subsequent removal using a backhoe. The same vertical section after dredging is shown in the lower profile of Fig 9. The high resistivity values of the bedrock, as shown in the resistivity section before dredging, have been replaced by significantly lower resistivity values of the fractured bedrock caused by the use of explosives. The overlaying muds have been almost entirely removed. Part of the original intermediate resistivity values representing sand and gravel before dredging have been replaced by the same remarkable high resistivity structure as seen in New York and in Spain.

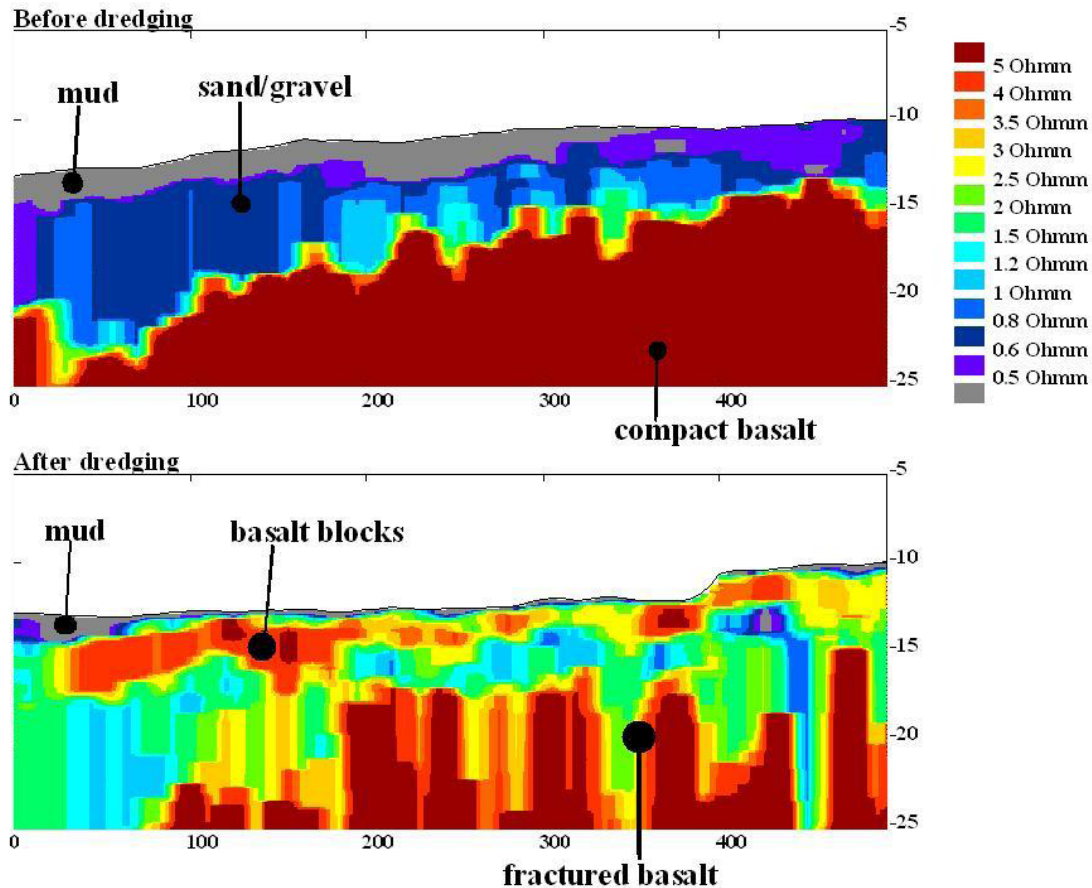


Figure 9. Pre and post blast dredging during port construction in Cameroon.

The following explanation was given. Using explosives for deepening a port the boreholes drilled to emplace the explosives are always drilled deeper than the requested dredge level in order to avoid hard pinnacles to remain behind. The fractures caused by blasting penetrate even deeper than the borehole depth explaining the lower resistivity values of the bedrock after blasting. When removing the blasted rock with a backhoe dredging companies tend to dump the larger blasted blocks of rock in deeper areas, dredged in softer areas. This explains the remarkable very high resistivity near-surface structure.

With the realisation that these near-surface high resistivity structures are linked to the presence of loose blocks of blasted rock previously moved using a backhoe, it becomes obvious that in both the New York and the Spanish cases, the latter structure could well be removed without the use of explosives.

VI. CONCLUSIONS

The Aquares Resistivity System is a unique sub-bottom profiling system that can be operated in water depth of up to 180m. The system is tailored to each job and will usually work in weather and site conditions which preclude the use of

acoustic methods. Detailed information is acquired regarding qualitative and quantitative nature of the sub-seabed strata providing the end user unparalleled data quality. These results are then used to estimate dredge costs Figure 1. Deployment of the ARS (orange cable) in conjunction with a Boomer system (blue cables either side of the vessel wake).

VII. AUTHORS

Peteralv Brabers is the founder and Managing Director of Demco NV, a geophysical survey company involved with the development and application of the Aquares resistivity survey method.

Jason Errey has been conducting Hydrographic and Oceanographic surveys primarily in the Middle East for over 12 years. He has undertaken extensive near-shore surveys utilising reflection systems prior to joining Demco NV.