Archaeologia Polona, vol. 53: 2015, pp. 526-527



# Geophysical investigation of past harbours: challenges and application examples

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KEY-WORDS: marine, magnetics, ERT, seismics, GPR, harbour

The demands on harbours of the past were variegated: A harbour needed to provide shelter against enemies and weather, but also good accessibility for various types of vessels as well as a working logistic network. Therefore, the geological setting at the time the harbour was active is of crucial importance for the understanding of the harbour situation. Sea level changes and sedimentation may let a prosperous harbour of the past become a swampy or even dry area today. Beside the geological setting, the connection to settlements onshore is also of importance for the harbour system. Thus, access routes, storage facilities and even harbour-related settlements have to be investigated. These demands can be summarized in four topics describing the site conditions of a harbour:

- Do we have a sheltering environment for inactive shipping?
- What was the accessibility for certain types of vessels (extent of a water body)?
- Do we have related settlements, transport networks and trade?
- Do we expect fixed harbour structures or a natural hythe?

Within the frame of the priority program "Harbours from the Roman period to the Middle Ages" of the German Research Foundation, different possible harbour sites in Germany, Poland, Iceland, Italy and Turkey have been investigated using geophysics. The tasks of these investigations ranged from prospecting harbour structures and basins, access routes and settlements to the reconstruction of the past landscape by investigating the near-surface stratigraphy. The latter aimed at answering questions about, e.g., past courses of shippable rivers, waterdepths inside harbour basins and past coastlines. Unfortunately, today most of the investigation areas are silted up, characterized by swampy or lagoonal sediments, or covered by water of depths between a few centimeters to a few meters. To deal with these tasks, different geophysical methods have been applied and adapted to the transition zone between land and water. This includes GPR, ERT, magnetic prospection on- and offshore, EMI, and seismic methods on- and offshore.

To resolve the interesting upper few meters of the stratigraphy of a harbour area, GPR and geoelectric methods would be most feasible. Unfortunately, harbour areas are mostly characterized by high electric conductivity, which impairs the applicability of these methods. Therefore, seismic methods were used to a greater extent, including refraction seismics and surface-wave analysis. Furthermore, equipment carriers were constructed specifically for this wetland transition zone. This included lightweight high-resolution marine reflection seismics and a magnetic gradiometer array for very shallow water, a sled-based magnetic array for swampy areas and the construction of underwater geophone-systems (Fig. 1).

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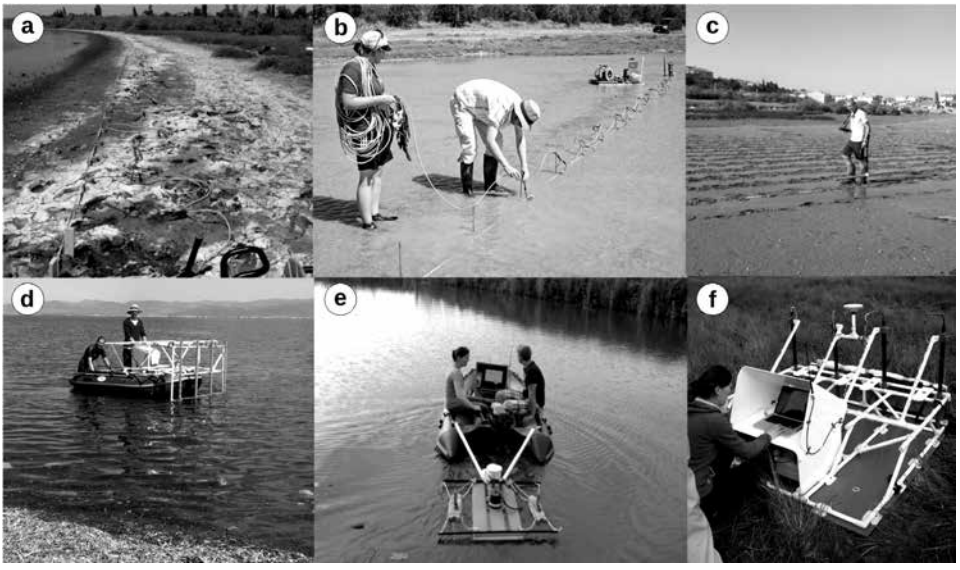


Fig. 1. Setting of measurements: a) and b) wetland seismic measurements and c) wetland EMI measurements in Enez (Turkey); d) lightweight marine magnetic gradiometer array and e) high-resolution reflection seismic system, during measurements in, respectively, Kane (Turkey) and Grimersum (Germany); f) sled-based magnetic gradiometer array for swamps and salt marshes during measurement in Iceland

The presented paper comprises examples illustrating the kinds of geophysical method or system that can be applied to specific tasks. The possible geophysical contribution for solving the above listed questions is illustrated with examples comprising:

- prospection of breakwater structures or natural, sheltered harbour basins,
- reconstruction of old riverbeds and coastlines by marine and land seismics,
- mapping of near-coast settlements by magnetics, and
- prospection of harbour structures, beaches and shoreline stabilization.

## ACKNOWLEDGEMENTS

This work was funded by the German Research Foundation (Deutsche Forschungsgemeinschaft) as project RA 496/26-1 within the frame of the Priority Program 1630 "Harbours from the Roman Period to the Middle Ages" (von Carnap-Bornheim and Kalmring 2011).

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