

# Application of Acoustic, Magnetic and Electromagnetic Systems in Marine Archaeology

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The importance of integrated geoscientific studies is reiterated for underwater archaeological exploration. Geophysical systems applied for the detection of artefacts, ancient places and underwater sites/objects are explained and detailed with applications of case histories. Sampling alongwith various geological analysis and datings are suggested for their precise identification interpretation.

## INTRODUCTION

In India, a good amount of integrated geoscientific studies for underwater archaeological exploration is already contemplated for transforming the latter from its nascent stage to adolescence.

At the conference of "Marine Archaeology of Indian Ocean Countries" organised by National Institute of Oceanography (Rao, 1988), it is brought to limelight that latest geoscientific techniques have been adopted and sophisticated equipments are deployed for target search, documentation and retrieval of wrecks. To strengthen the marine archaeological activities in the country, the Tamil University and Andhra University are taking steps to undertake geoscientific surveys of their respective coasts (Gangadharam, 1989; Rajamanickam, 1989) for exploration of marine archaeological remains.

## MARINE GEOSCIENTIFIC METHODS

Underwater Archaeology is the study of ancient shipwrecks, ports, harbours, submerged towns and other underwater sites or objects associated with history, folklore and local traditions. Marine geoscientific studies have come in handy for the identification of underwater strata/artefacts. Systems that can be applied for their detection are divided into three categories viz. 1) Acoustic, 2) Magnetic 3) Electromagnetic, followed by sampling by deploying snapper/grab, corer & vibracore etc.

### 1. Acoustic System

Instruments such as echosounder, side scan sonar, mud penetrator and subbottom profiler are used invariably to have the seabed topography, horizontal plan view of the seabed and thickness of the various subsurface layers in which any archaeological artefacts are sandwiched. The principle and usefulness of these instruments with reference to the underwater archaeology are reiterated.

#### a. Echo Sounder

This is useful for obtaining the profile of the seabed and its depth. Apart from this, the nature of the bottom and in some favourable geological regions, even subbottom can also be recorded. At times, it becomes difficult to identify a wreck resting on a rocky terrain. When the echosounder passes over the object, the latter is recorded in the echogram as a sharp rise/pinnacle. It is possible that even the hardformations with sharp pinnacles may be interpreted as ship wreck. If any structure/ship wreck is recorded in the echogram, it is advantageous if a systematic grid survey across the exposed one is carried out to confirm its continuation and to delineate its boundary. A suitable combination of the power and frequency of the signals optimally improves the resolution of the recorded object and the information about the seabed which probably gives bright scope to the correct interpretation of the desired object on the seabed. This system is useful to pinpoint a site rather than searching large areas at a time provided an accurate position fixing system is used.

#### b. Mud Penetrator

If an object/site of archaeological importance is buried in the soft sediments like clays and silty clays, and the echosounder is not able to record, the same may be recorded with the help of mud penetrator. Having the power for penetration and resolution for demarcation in the sediments, mud penetrator improves the signal to noise ratio for recording the details of the buried parts of the objects through the selection of proper frequency and power (Pls. 47 & 48) Reverberations can be removed by time varying gain facility. At shallow depth, power between 15 and 2.5 kw with a frequency of 350-500 kHz can give good results. Palaeo-channels which are existing beneath the clayey seabed in some offshore areas and assumed to be the continuations of the present rivers/rivulets flowing in the adjacent coast can even be delineated effectively with this system (Subba Raju et al., 1991).

### c. Sub-Bottom Profiler

Objects/sites buried in compact sediments like sands can be identified with a high power profiler by using boomer or sparker as an energy transmitting source. The signals from these sources induce deeper penetration in the sediments and may help in identification of the buried objects. Lower frequencies are used for obtaining the better penetration in the sediments of the sub-bottom formations and those buried inside the unconsolidated sediments thus providing useful information for locating the underwater buried sites of even archaeological interest, such as palaeo-channels even in the sandy formations (Stright, 1986; Rajamanickam and Subba Raju, 1988). Often scarps (Pl. 49) in the subbottom rock terraces can be recorded (Subba Raju, 1991) with this system.

The above instruments give only on-line recording of the bottom and sub-bottom formations and the features are recorded only when the concerned instrument passes directly over the same. These instruments can also distinguish the geological interfaces between the sediments and the rocks which enable the marine geoscientist/archaeologist to chalk out a plan about the silt and sand movement against the rock formations and the chances of ship wreckages and their burial in these environments.

### d. Side Scan Sonar

This is quite useful in obtaining a horizontal and broad plan view of the sea floor. This can also locate split up underwater archaeological sites. When wrecks or features protrude above the seabed, this system offers as an effective tool. In this system, the towed transducers, located in a 'fish' enclosure, on either side, transmit and receive the sonar signals from the seabed. As the transducer moves forward through the water, successive strips produce a map of the seabed on either side of the recorded track of the sonar. The back scattering property of the sea floor returns the signals which are recorded in the form of tonal differences. Because of the angle of the sonar that strikes the objects on the seabed, there will be a delay beyond the object before the sound strikes the seabed. This causes a white shadow behind the strong signal, allowing the height of the object above the seabed to be calculated. Nearer the transducer to the seabed, better is the imagery. This is extremely sensitive and pictures of even deeper water shipwrecks will be obtained with sufficient details depending upon the sweep range. The extent of pipeline exposures, scouring areas, ripples and ridges formed due to the currents and wave action can also be identified in the sonograms (Subba Raju and Vora, 1987).

## 2. Magnetic System

The magnetometers used in this respect are Proton Preces-

sion Magnetometers which measure both absolute and differential magnetic fields working on the physical principle of proton precession in aromatic liquids such as kerosene, hexane or aviation fuel etc. which is filled in the sensor and towed behind the vessel. As it is known, the frequency of the precession of the protons in the liquid depends on the intensity of the local magnetic field. When the protons are subjected to a magnetic field induced by a momentary electric current transmitted through a coil, they are polarised and realigned uniformly in a new direction. When the current is stopped abruptly, the protons orient themselves randomly as before. In this process, they precess generating within the coil, a current of the same frequency as their frequency of precession, which is amplified, counted and recorded. The frequency of precession, of course, depends on the intensity of the local magnetic field.

As the sensor passes over the ferromagnetic object, an anomaly in the earth's magnetic field is recorded. Generally, iron ship wrecks or rocks containing ferruginous formations create magnetic anomalies (Anonymous, 1981; Breiner, 1975). Neither a huge bronze statue nor a wooden wreck can disturb the magnetic field since they are non-magnetic. Iron fittings in the wooden wreck can create the anomalies. It is generally expected that the magnetometer can detect an anomaly of 5 nT safely depending upon the distance between the sensor and the object. According to the theoretical formulae (Hall, 1966), an object having a weight of 10 tonnes, can be detectable from a distance of 45 m. The same way, 10,000 tonne ship can be detected from a distance of 450 m. 10 kg cannon ball and 2 ton cannon can be detected from the distances of 3 and 27 m respectively.

It is theoretically calculated that the signal increases nearly eight times if the distance between the sensor and the object is reduced to half the original. This gives a meaningful idea for surveying the target if the theoretical distances are known (Fig. 1). If a point source is assumed for the cause of the magnetic anomalies, it is possible theoretically to assess the size and mass of the object producing the same (Subba Raju, 1987). Both operation-wise and manufacture-wise, instruments measuring absolute field are more widely used because of their versatility and wider range of applications.

## 3. Electromagnetic System

Another common and effective instrument is underwater metal detector (Foster, 1970; Green and Martin, 1970). The metal detector uses the pulse induction techniques and is very simple for use by divers holding it with the hand like a torch but within a range of not more than 3 to 4 m from the target (Personal communication, LSE brochure) to get detectable signals. As soon as the diver dips it in the water, it switches on automatically and triggers the pulse, generating a signal and receiving the return signal from the objects. Of course, the size, shape and composition of an object in

addition to its orientation to the search loop, affects the detection range. However, this is used to pinpoint the objects on the seabed or buried within permissible depth range. These instruments detect both ferrous and non-ferrous objects e.g., 1 m length steel pipe and 1 kg gold bar can be detected from the distances of about 3 m and 0.8 m respectively. By and large, this system appears to be useful for salvage operations, offshore debris search, lost well heads, pipeline burial surveys etc.

So far, whether all these three systems are used simultaneously for underwater archaeological exploration in India is not well known. But the application of acoustic and magnetic systems in both the coasts are evident through the surveys conducted off Tamilnadu in the east coast (NIO Tech. Rep., 1984) and off Maharashtra in the west coast (Siddiquie et al., 1982, Subba Raju et al., 1991) by National Institute of Oceanography. East coast surveys were conducted in a bid to explore the possibilities of discovering the ancient submerged port city which is evident through the great epics of Tamil literature like *Silappadikaram* and *Manimekalai* and continuously heard through the folklore and traditional songs of the region (Subba Raju, 1987; Vora, 1987) while the west coast surveys were conducted in connection with exploration of placer deposits (Rajamanickam, 1983) and for installation of underwater structures (NIO Tech. Rep. 1989). In the latter surveys, the buried palaeochannels have been observed beneath the clayey seabed which are important due to the fact that the river/channel banks were the ancient habitat sites.

## APPLICATIONS

### a. Submerged structures off the east coast

Poompuhar was a flourishing port in the first century B.C. on the east coast of India, at the confluence of river Cauvery with Bay of Bengal. It had lost its glory and eminence as it is reported to be swallowed by the transgression of the sea. Local fishermen have reported household articles that have been netted by them and also apparent temple-like structures, where shoals of fish occurred abundantly.

Alongwith the smooth topographic nature of the seabed, echograms have recorded strange conspicuous features as peaks/pinnacles in water depths of about 18-19 m. The features have at times broad and slender bases on the seabed having considerable heights in water layer. Some of these features have even twin peaks with blunt and sharp nature and single peaks with one side sloping and other side straight (Vora, 1987).

Sonograms have also revealed interesting linear, rectangular, circular, oval and irregular shaped features having the diameter of 20 m and even more. These features, associated with shadow zones in the sonograms, represent considerable heights of the objects and appear as three dimensional. Magnetic records have shown a number of anomalies and as

such it is difficult to interpret these anomaly sources as natural geological ones. However, the sources causing the anomalies are likely to be man made and due to i) the single body with a single peak. ii) the shallow and wide bodies appearing with two or more peaks, and iii) the bodies spread irregularly or haphazardly on the sea floor (Subba Raju, 1987). It is inferred that both acoustic and magnetic surveys tend to represent the submerged structures and/or shipwrecks.

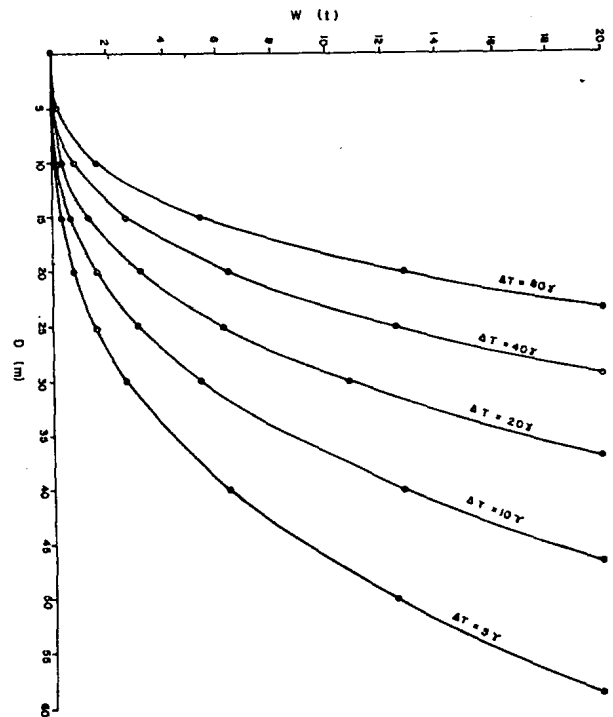


Fig. 1 Theoretical curve illustrating the relationship between the weight of the source ( $W$ ) and the distance between the sensor and the source ( $D$ ) for creation of different magnetic anomaly values ( $\Delta T$ ).

### b. Palaeo-channels off the west coast

The period of the last 11,000 yrs B.P. is quite interesting in view of cultural heritage and early human civilisation. However, it is reported that the ancient civilisations were active in the last 6,000 yrs B.P. The estimates of the sealevel about 12,000 yrs B.P. on the west coast gives rise to the water depths of 138 m which compares well with the global findings (Merh, 1987). Kale and Rajaguru (1985) have also postulated a rise in the sea level from 12,000 yrs B.P., the rate being very rapid and about 18 mm/yr during the late Pleistocene and early Holocene. According to them, the sea level along the west coast reached very close to the current

level during 5,000 to 6,000 yrs B.P. Since then it seems to have oscillated to the position both above and below the present level.

It is evident that earlier civilisation had its habitat sites along the river banks or channel courses. Consequently, the attention of marine archaeologists is drawn to these palaeo-rivers/courses, that are better preserved in the seabed as the earlier extensions of the existing rivers on the adjacent land. Buried below 12 m subsurface, fluvial creeks were observed off Vengurla in 30–38 m water depths (Subba Raju et al., 1991). The creeks were also observed below the seabed in the sandy and clayey formations off Jaigarh and Batye in shallow waters (Rajamanickam and Subba Raju, 1988) and in the areas of previous sea level stands around Bombay High (NIO, 1977).

### SAMPLING

After analysing the recorded data, sampling should be conducted to find out the nature and geology of the surface and subsurface layers and to bring out a composite evidence leading to accurate identification and interpretation which is the ultimate concern of the marine archaeological studies.

Sampling can be done with the help of snapper/grab, corer and vibracore depending upon the desired depth at which the sample is to be collected to verify or confirm the ancient habitat sites.

#### i) Snapper/Grab

For collection of surficial samples, a snapper/grab can be operated from the forward/aft derrick according to the convenience.

#### ii) Corer

A piston gravity corer can be used for collection of subsurface sample. The corer 3.3 m long with an inner diameter of 50 mm with acrylic tubes of inner diameter 44 mm with the weight of 132 kg will be useful with a free fall of 3 m (NIO, 1977). The sampling sites may be decided after an examination of the echograms, sonograms and shallow seismic records.

#### iii) Vibracore

This consists of an impacting bin vibrator working by deploying the pneumatic pressure and mounted on top of a core pipe made of 4-in standard pipe which contains a 3.5-in interior-diameter tubular plastic liner for carrying the core. A check valve at the top of the core barrel and a springleaf core retainer at the bottom are fixed to retain the core sample in the plastic liner during withdrawal and raising of the

vibracore. Usually, a mast consisting of a steel H-beam supported in vertical position by a base consisting of four legs attached to the mast, was fixed on the sea floor. The vibrator and the core pipe were spring mounted to a slide attached to the mast and thus were set free to move vertically, guided by the mast, with weight of the slide exerting a constant pressure on the core pipe. The core barrel was designed to be driven into the sediment and pulled back along with the core into the frame before lifting from the seafloor. Power was supplied to the pneumatic vibrator by an air compressor on the support vessel through a flexible wire-reinforced hose. A strip-chart record provides the depth of penetration achieved by the vibracore (Pearson et al., 1986). When the vibracore was sent to the seafloor, the weight of the vibrator and core tube alone normally drives the core through considerable depth in the sediments. The pneumatic vibrator is activated till the desired depth is achieved.

Any identified features or geological strata depends much on the results of the number of analyses through which these collected samples were scrutinized. These analytical techniques such as grain-size analysis, point count analysis, geochemical analysis (Pearson et al., 1986), foraminiferal analysis (Nigam, 1988) and radiocarbon dating (Agarwal and Kusumgar, 1974) allow a specific assessment of the sample but together bring an integrated evidence leading to precise and accurate identification and interpretation. This ultimately paves the way to confirm or reject whether the sample has an archaeological site/deposit or not.

Along with the above systems, optical systems can be used for confirmation of the location of the archaeological objects/sites in various places (Bass and Katzev, 1968; Rao, 1988).

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