SIDE-SCAN SONAR MAPPING OF ANTHROPOGENICALLY INFLUENCED SEAFLOOR: A CASE-STUDY OF MANGALIA HARBOR, ROMANIA

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Abstract. This paper focuses on identifying and analyzing objects and seafloor features from Mangalia Harbor (Romania). The area was surveyed using a side-scan sonar. After explaining, briefly, the methodology used in scanning and data processing, the results are discussed: a mosaic showing the seafloor of the harbor, which is the basis of further descriptions of some representative areas, and the contact analyses of the debris left from human activity. Furthermore, their position was established taking into consideration the possibility of cleaning the harbor. We concluded that the identified objects, such as wrecks, metal frames do not represent a real danger for navigation. Nevertheless, a mound of rocks situated near the main channel could cause trouble to large ships.

Key words: Black Sea, sea traffic fairways, seafloor features, contact analysis

INTRODUCTION

The history of Mangalia city spans over more than 2500 years. The first to settle in the area were the Greek colonists. The harbor flourishes during the Middle Ages. The first attempts at improving the former harbor were done at the beginning of the 20th century, by building the first part of the northern jetties. After the World War II, the sand barrier enclosing Mangalia Lake was dredged and the military harbor was built. The work at the southern jetties began in the ’70s, together with the one at the shipyard and the oil terminal, while the northern jetties were extended. In the ’80s, Mangalia was the second largest harbor on the Romanian Coast (Lăpuşan & Lăpuşan, 2007).

The Mangalia harbor is located in the southern part of the Romanian Black Sea Coast, near the border with Bulgaria (Fig. 1). It covers an area of 142.19 ha (27.47 on land and 114.72 on water), and has a maximum water depth of 9 meters. The jetties protecting the harbor extend for 2.74 kilometers. The whole complex is composed of berths, a marina, a large shipyard, an oil terminal, a military harbor and a small fishing harbor.

Underwater acoustics is used to deal with human-made matter by mapping and surveying the sea traffic fairways, for assuring their operationality and safety (Wille, 2005). The present study focuses on identification of potential threats for the intense navigation in the harbor, and of the various debris resulted from human activity. Furthermore, the contacts were analyzed and their exact location was pinpointed for the eventuality of a thorough cleaning of the harbor. The paper also discusses some aspects about side-scan imaging and seafloor features, as seen on sonograms. Results from side-scan sonar surveys of harbors were published by Quinn *et al*. (2007), and for searching objects by Naoi *et al*. (2001), but in deep waters. Also, wrecks were surveyed using side-scans by Sakellariou *et al*. (2007), Bates *et al*. (2011) and Brennan *et al*. (2013).

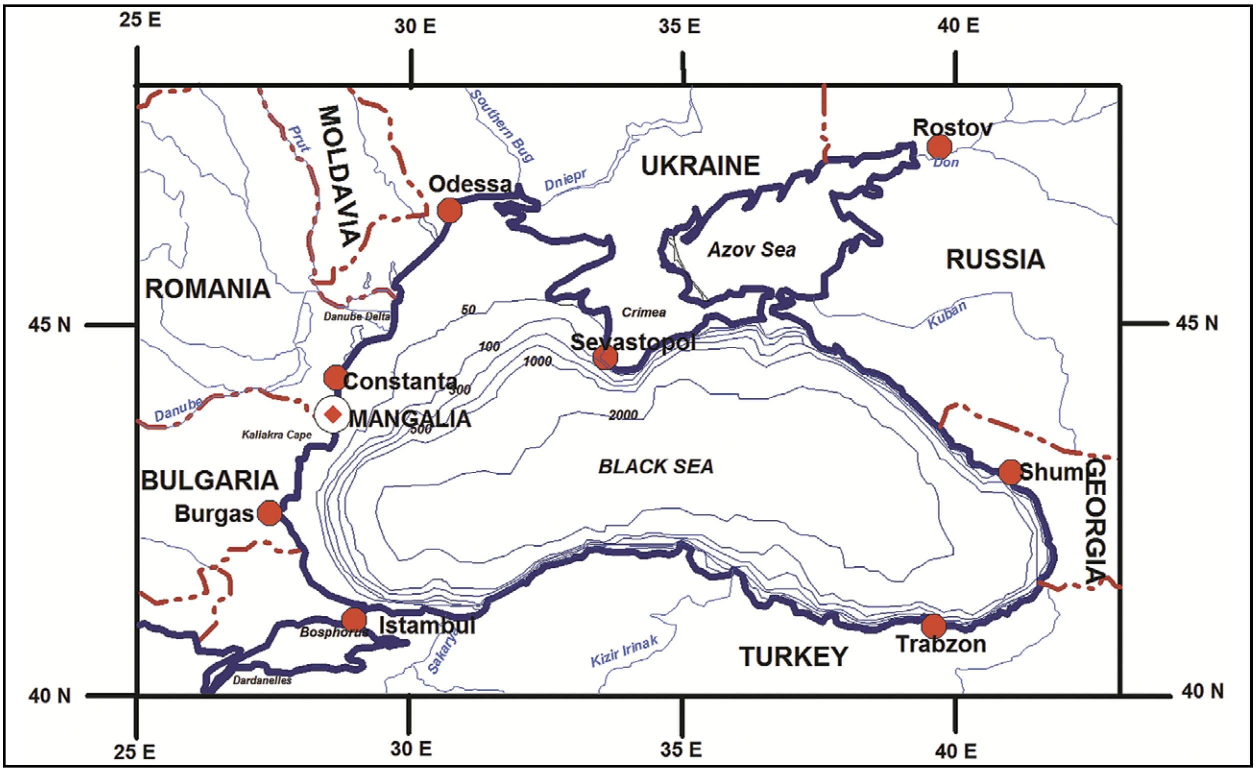

Fig. 1. Location of Mangalia Harbour on the Black Sea coast.

METHODS

The side-scan sonar is a valuable tool in marine research. It is best used for underwater sound imaging of natural and anthropogenic features of the seabed over large areas. The extent of various seafloor lithologies can be mapped since bed rugosity, sediment grain-size and compaction determine back-scatter patterns. Each bottom type has a specific acoustic response, allowing bottom segmentation based on mosaic analysis. Side-scan sonograms are also widely used for visualizing, measuring and analyzing various geological features (*e.g*. bedforms, fracture systems). In the same time, individual targets are pinpointed and can be measured and described.

A side-scan sonar emits sound beams in a fan shape perpendicular to its axis (Blondel, 2009). A blind zone on the nadir caused by the geometry of emitted beams develops below the towed fish (Fig. 2). The acoustic response (backscatter) is recorded and when geo-referenced it forms the image of the seafloor for the given area. The recorded side-scan data were compiled with altitude, attitude and GPS data, and saved as .xtf files. They were processed using DELPH Interpretation software suite. Bottom track, gain and slant corrections (picking up the first return from the sea floor, thus separating the nadir blind area on the sonograms and removing it) were applied and the resulted sonograms were compiled in order to form a mosaic.

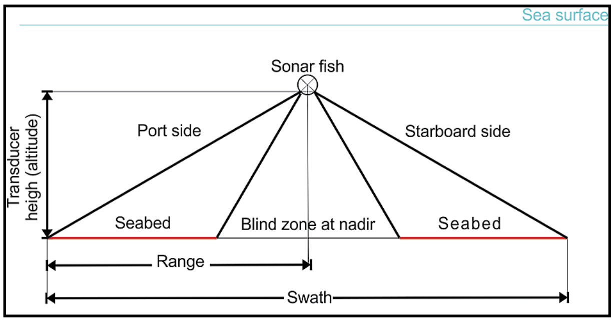

Fig. 2. Transverse view of a side-scan sonar fish system.

For the present study we used an IXSEA Elics 400-1250 side-scan sonar, a system that provides large acoustic images of the seafloor that can be joined together in a mosaic, showing detailed morphology of the seafloor. The system is composed of two main parts: the towed fish and the processing unit. The fish is fitted with sensors for attitude (heave, pitch and roll) and pressure for depth. Altitude above the seafloor is computed using a single beam sonar placed on the head of the fish. On the body of the fish, two large side-scan transducers are mounted. They transmit and receive acoustic signals on two frequencies, 400 kHz or 1250 kHz.

We used the lower frequency (400 kHz), that provides larger swaths; the area near the shipyard was rescanned at 1250 kHz for a better resolution of the artifacts resulted from the activity at the shipyard. We compared the results at the two resolutions, in a similar way as McGowen & Morris (2013). The fish was towed by a 7 meters long vessel at a speed of 4 to 6 knots. The scanned area of the harbor was limited by the depth of the water, as the fish must be a few meters under the surface for avoiding contact with the turbulences from the propeller, and a few meters above the seabed, for ensuring a satisfying coverage.

For the most representative echoes (the resulted image on the sonogram of a given object/feature from the sea bottom), based on the distance and angle from the sonar and the length of the shadow, as well as the dimensions on the georeferenced sonograms, a contact analysis was done, having as purpose the estimation of the length, width and height of the target. To do a contact analysis means to classify the echoes under a certain name or class (IXSEA, 2010). Then, the images of the echoes were interpreted giving the desired results.

RESULTS

As written previously, the first data obtained are the individual raw sonograms, which are processed and sticked together, in order to form the mosaic. The obtained mosaic was divided into two parts (Figs. 3 and 4), in order to increase the visibility of the details if printed on a small sheet of paper.

Some areas of the mosaic were detailed in snapshots, for showing features of the seabed, like sand ripples or traces of dragged heavy objects, such as anchors or oil hoses (Fig. 5).

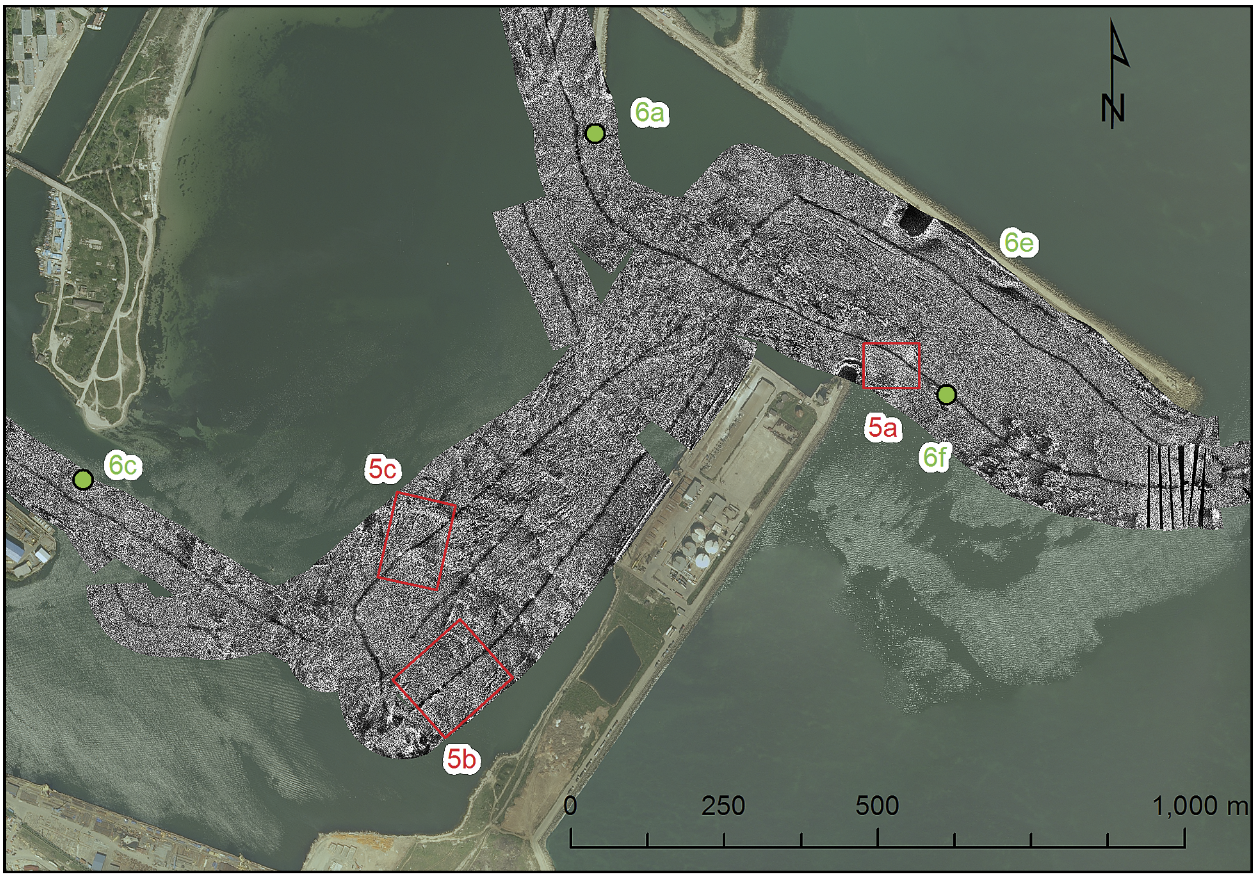

Fig. 3. Mosaicked sonograms comprising the central Mangalia harbour area and the entrance from the Black Sea. The position of mosaic cropped details and analysed objects presented in the following figures (Fig. 5, 6 and 8) is pinpointed by numbers, borders and arrows.

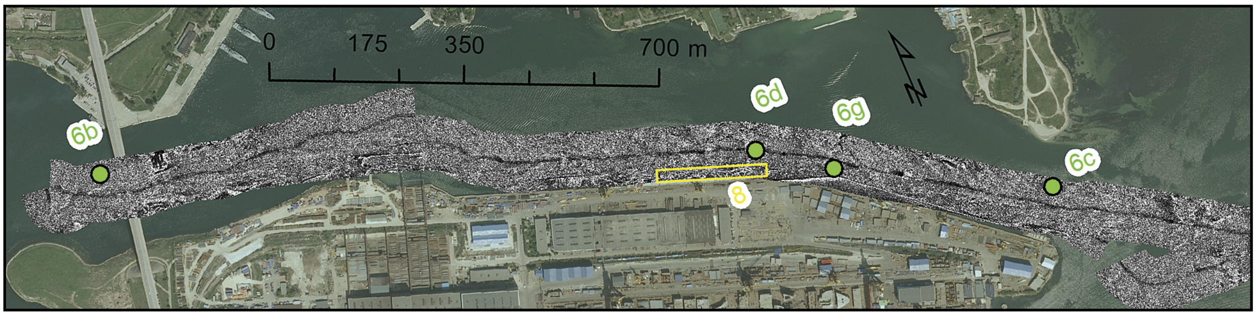

Fig. 4. Mosaicked sonograms of the area in front of the Mangalia Shipyard and further of Mangalia Lake. The position of objects from other figures is shown by numbers and arrows.

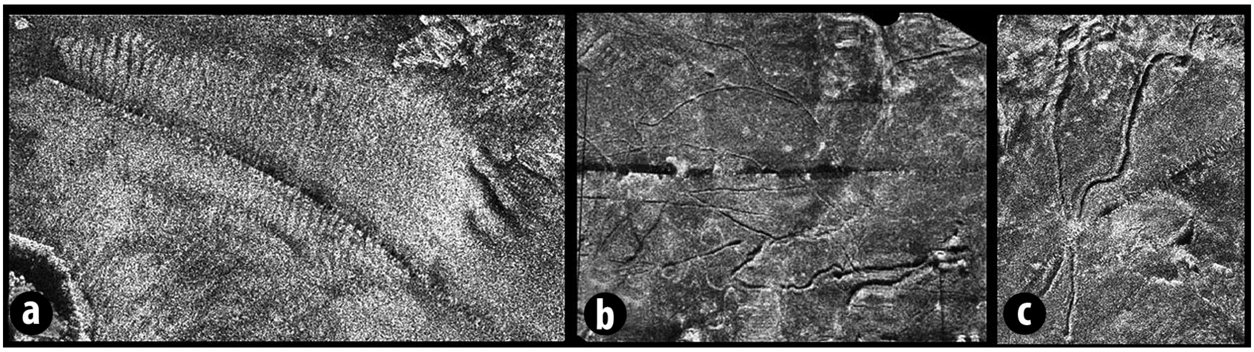

Fig. 5. Details from the mosaic: **a** - wave ripples near the entrance; **b**, **c** - traces of dragged heavy objects.

Further on, a contact analysis was carried out on the individual sonograms without slant correction. The most interesting of them are detailed in Fig. 6. There are many debris and some wrecks near the docks of the shipyard. Near the entrance of the harbor, a large mound of rocks can be found. As it measures up to 2 meters in height, in an area where the water is 8 meters deep, large ships with the draught greater than 6 meters should avoid drifting from the main channel to its side, for avoiding the threat of shipwrecking (Fig. 6f).

The most striking contrast is visible in the case of the ships. In Fig. 7, it shows, comparatively, the effect of the frequency change on the cargo boat Marcarolina, at the dock in the Mangalia shipyard. Remarkably, at 400kHz, there is a response from both the outer shell and the beam supporting it, while at 1250 kHz, only a faded contour is observable. This happens because lower frequencies have better penetration. Higher frequencies are used for a better resolution, but having the disadvantage that coverage is poor, while the lower

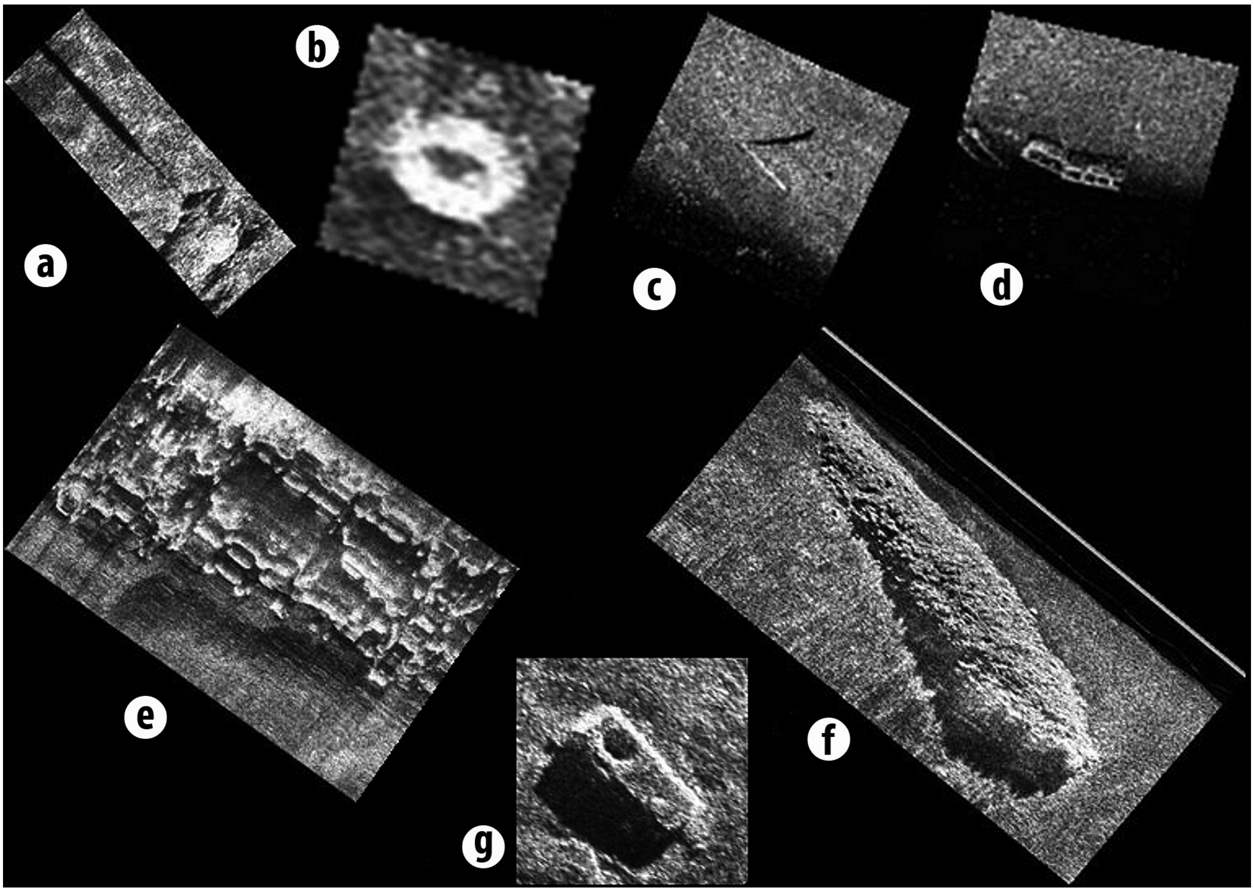

Fig. 6. Echoes from the seafloor; **a** - the anchor of a traffic buoy (diameter 3.5 ± 0.25 m); **b** - sunken rubber tire (diameter 0.7 ± 0.1 m); **c** - rope tied to the bottom (length 1.75 ± 0.07 m); **d** - frame (length 3.84, width 0.40, height 0.40± 0.17 m); **e** - base of the jetties; **f** - mound of rocks (length 49.76m, width 8.31 m, height 1.99 ± 0.72 m); **g** - box-like object (length 7.88 m, width 2.81, height 1.66 ± 0.41 m).

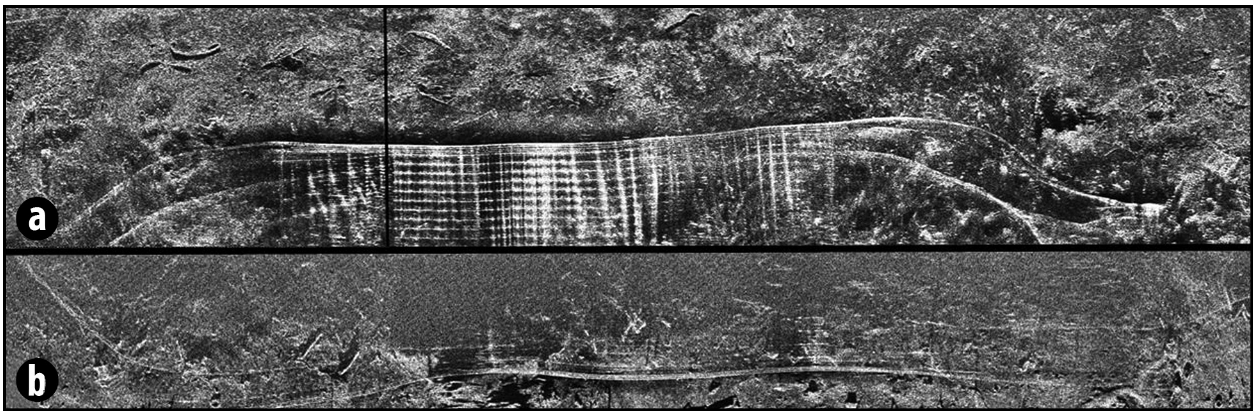

Fig. 7. The cargo boat "Marcarolina" seen at different resolutions; **a** - 400 kHz, **b** - 1250 kHz.

ones provide less resolution, but can cover a larger area. A good example is shown in the two images at different resolutions of a metal frame (Fig. 8).

DISCUSSION AND CONCLUSION

The side-scan sonar is a valuable tool in investigating harbor areas and traffic fairways, for its capacity of imaging the seafloor objects and features, as well as offering information regarding their position and dimensions. Debris and other traces of human activity were inventoried and monitored much easier using underwater acoustics than with conventional techniques.

The scanned area of the Mangalia Harbor shows intense human activity signs, such as various debris, traces of dragged anchors and dredging areas, all of them being clearly visible on the sonograms. Most objects pose no threat to the intense navigation in the harbor, as no high object was identified in the area where large ships manoeuvre. There is still the danger of shipwrecking in case of large ships moving outside of the main channel, as a mound of rocks lies on the floor near the harbor entrance.

We have also compared images of the same objects scanned at different frequencies, in an attempt to underline the advantages for both high and low ones. Considering the relation between resolution and range, high frequencies are more suitable for shallow waters, where they can provide better details. However, in deeper waters, as the frequencies have a very limited range, they tend to have less coverage, as the nadir blind area gets wider, thus requiring a lowering of the tow fish. Therefore, we recommend the use of the highest frequency available for practical applications in harbor areas.

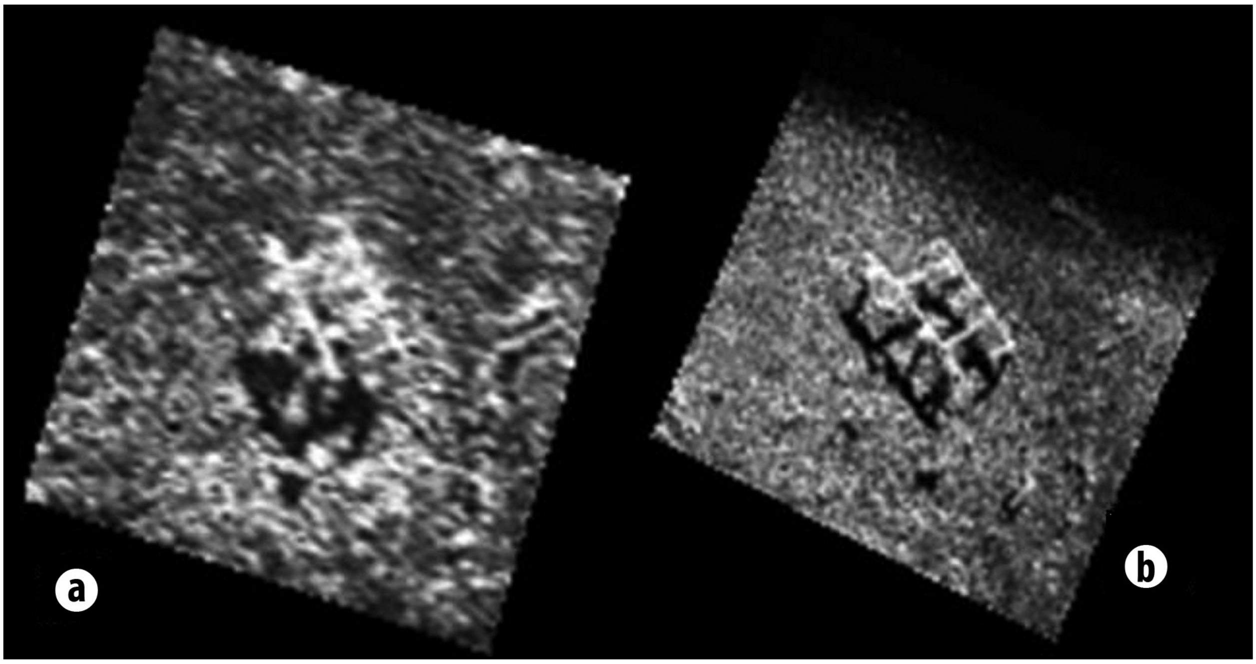

Fig. 8 The same metal frame seen on 400 kHz (**a**) and 1250 kHz (**b**); the difference in resolution is obvious.

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