

Controlled Experiment to assess the use of Watercolumn Multibeam Data in the Detection of Gas Seepages in Shallow Waters

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Abstract — In order to simulate the detection of underwater gas seepage by acoustic sensors, a controlled experiment was carried in the Paranoá Lake (Brasília, Brazil) to verify whether multibeam echo-sounders are able to detect and characterize bubbles both at their generation point on the lake-floor and along the water column. The experiment involved the acquisition of acoustic data from a purpose-built submerged target, with and without the presence of gas bubbles. The target was built using a 1x2 meter acrylic plate, mounted on an iron structure, with an air injection system for bubble formation. The air injection system was built using 0.5-inch tubes, which were drilled for air venting, and attached to the bottom of the acrylic plates. Such an arrangement allowed for simulating the presence of gas at the lake-floor. Two vessels were used for the data acquisition, the first equipped with a multibeam sonar system, and the second with an air injection system, including an air compressor powered by a generator. The experiment was carried out at two sites at Paranoá Lake, with different water depths (6 and 13 meters). The study site was chosen due to its proximity to the laboratory facilities and favorable conditions for target implantation. During the experiment, bottom disaggregated sediments and mud buried the controlled target (which is only 4cm thick) in the bottom of the lake, making it difficult to discriminate its position based on bathymetric data. Nevertheless, the results allowed us to observe the bubbles both at their generation point on the lake-floor and along the water column, on a 3D perspective. At the shallower site, the bubbles seemed more densely concentrated near the target, while at the deepest location, they were more spread out around the target area, which can be explained by the increase of ambient pressure with depth which should reduce both bubble size and density.

Keywords — *multibeam; gas seepage; bubbles; controlled experiment; Paranoá lake*

I. INTRODUCTION

Gas seepage detection in aquatic environment can be performed with acoustics sensors, such as side-scan sonars and multibeam echo-sounders, due to the strong impedance contrast of the gas bubbles with the surrounding water. The evidence of gas seepage in sonar records is represented by relatively high

backscattered signal in the water column, produced by the diffusion of sonar signal by the gas bubbles, forming vertical paths as migrating through surrounding water. The individualization of these features is diagnostic of the presence of sub-bottom gas producing geological units.

Both the acquisition geometry and the local conditions are determining parameters in order to control the resolution of the sonar system, and thus, the control of the acquisition conditions is fundamental for testing the detection performance. In the case of hydrocarbons exploration, both in the research and in the exploration phases, the presence of gas can alter significantly the acoustic properties due to the alteration of the elastic parameters of the medium and, as such, may affect the signal.

Among the motivations for studying the efficient ways to remotely detect gas bubble clusters, generated by natural sources or activities in the hydrocarbon industry, are the need to reduce pollution of the aquatic environment [1] and better management of the reservoirs during the production stage. Sonar systems have several applications, such as for bathymetric measurements, seafloor backscattering measurements and water column measurements, and their application to gas seepage detection is straightforward [2]. A good review of water column applications can be obtained from the work of Colbo et. al. [3].

Some studies with controlled sonographic data acquisition tests can be found in the literature. Bergés et al. [1] carried out a controlled test in an 8 x 8-meter tank with 5 meters depth in order to quantify the gas flow using passive measures of the emission of clouds of nitrogen bubbles. A controlled experiment in a 12.5 x 50-meter tank with sea water sheets of 10 to 20 meters with multibeam echo sounder measurements to validate direct and inverse modeling of volumetric bubble flow was also carried [4]. There are also results on the release of CO₂ injected in a controlled way, into shallow marine sediment at Ardmucknish Oban Bay [5] [6]. Cevatoglu et al. [5] studied the flow of CO₂ liberation using 2D seismic reflection surveys before and after the gas release, being possible to observe the

enhancement of the reflectors and the bubbles in the water column.

In this context, a controlled experiment was proposed to test the influence of the presence of gas bubbles on the multibeam sonographic signal. The objective is to identify the gas bubbles in the sonographic signal. The study area chosen for carrying the experiment was Paranoá Lake, in Brasília, Brazil (Figure 1), due to the availability of previous bathymetric data, which facilitated the experiment planning, showed suitable conditions for target implantation. The water depth in the Paranoá reaches a maximum depth of 35 meters.

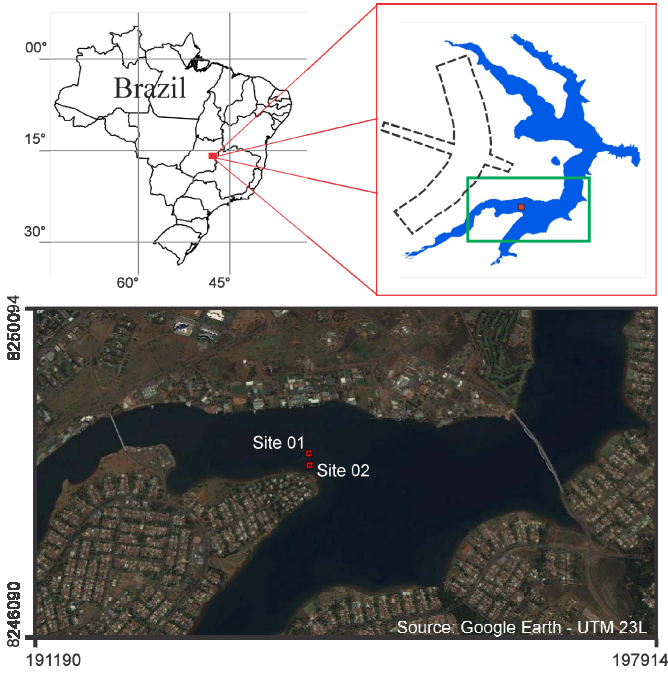


Fig. 1. Study area where data acquisition was performed. Site 01 indicates the deepest area (about 12 meters) and Site 02 the shallowest area (about 7 meters).

II. METHODOLOGY

A. Target construction

The proposed experiment basically consists on the acquisition of data in a submerged controlled target, without and with the presence of gas bubbles. For this purpose, it was necessary to construct a target with a known surface to serve as reference (Figure 2), and to include therein an air injection system for bubble formation, thus allowing to simulate the presence or not of these at the bottom of the body of water.

The dimensions of the target were set to obtain the maximum resolution for the depth at which the experiment should be placed. For example, for a beam with a 15-degree pointing angle, i.e. for targets practically under the vessel, the spatial resolution is around 0.5 meters to a depth of 10 meters. Considering a beam with a large pointing angle, such as 75 degrees, for example, for the same depth the resolution is around 1 meter.

Two 1x2 meter acrylic plates were used, mounted on an iron structure (Figure 2), which can be screwed together to give the largest target (2x2 meters final dimension). The air injection system was built with 0.5-inch tubes attached to the acrylic plates, and drilled for air venting. The air injection tubing became independent for each smaller plate, and it is possible to work together when the larger target is used.

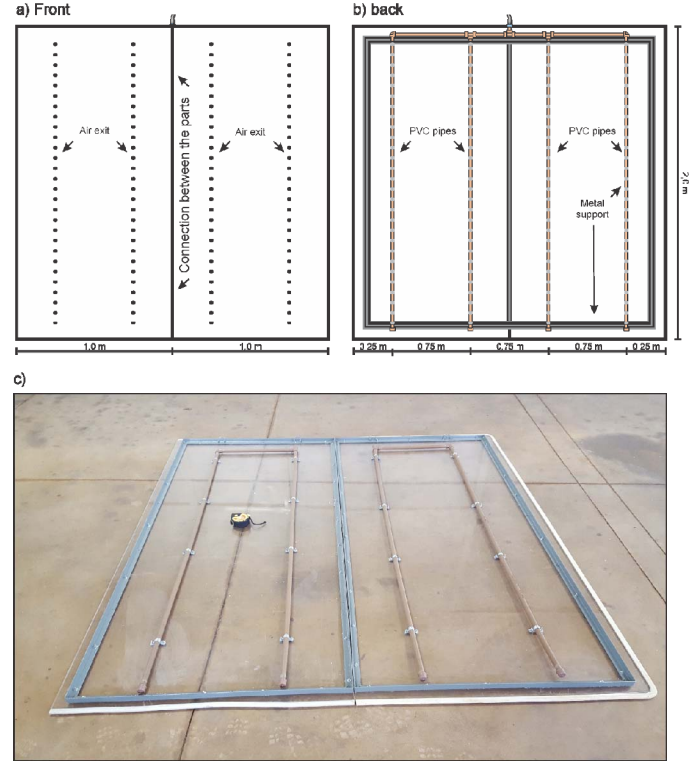


Fig. 2. Controlled target. A) Target Design: Front view with prominence of the holes for the exit of air for the formation of bubbles. B) Target Design: Back view, with emphasis on the air passage pipes. C) Vision of the controlled target built for the project, with emphasis on the air injection system piping and the individualized structures of each plate.

B. Data acquisition

The study area is indicated in Figure 1 where data were collected at two points of Paranoá Lake, with depths around 12 meters (Site 01) and 7 meters (Site 02). The use of two different depths is to verify the behavior of the bubble plume along the water column.

The equipment used to perform the acquisition was the Teledyne Reson Multi-beam Echosounder, model SeaBat T50-P, fixed in a vessel adapted for this type of acquisition, equipped with a Positioning System (GPS) and a rechargeable power system with solar panels. Auxiliary vessel was used for transport and deployment of the targets, as well as operation of the bubble generation system (Figure 3). In Figure 4 it is possible to see a picture of the vessels during the installation of the target in one of the test sites.

The placement of the target at the experiment site was done with the aid of ropes. The auxiliary vessel was used to control

air injection through an air injection system, consisting of an air compressor, with a maximum pressure of 8 bar, powered by a generator. The survey vessel performed repeated passes over the target site, collecting swath data with the bubble generation system on and off.

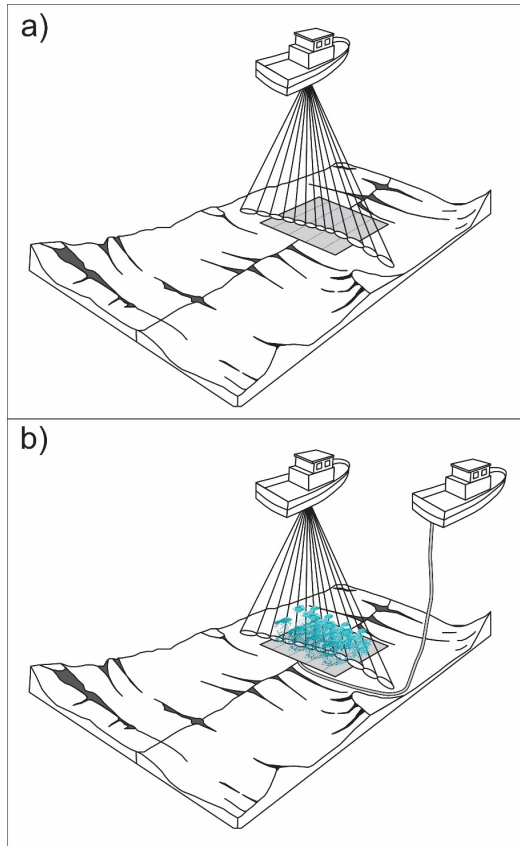


Fig. 3. Data acquisition scheme with multibeam system for the controlled target. a) Acquisition without the presence of bubbles. b) Acquisition with the presence of bubbles injected by an air compressor placed on a support boat anchored near the submerged target.



Fig. 4. Image of the installation of the target at one of the acquisition sites, showing the support vessel (right) and acquisition vessel (left).

III. RESULTS AND DISCUSSION

The results of the survey allow to image the air bubbles released by the injection system and to discriminate them from the controlled target and the bottom of the lake. Figure 5 shows the bathymetry map before and after the air injection for Site 01, with the appearance of anomalies due to bubbles in the latter case. Looking at the water column data (Figures 6 and 7), it is possible to observe that the bubbles appear to be more dispersed and more intense in Site 01 (deeper) than in Site 02 (shallower). We believe that it is occurring due to the size of the bubbles increasing as the pressure decreases while migrating along water column and approaching the surface. Larger bubbles are expected to produce stronger backscattering of the acoustic waves due to the greater surface of diffusion. The dispersion of the bubbles must be related to the minor efficiency of the bubble generation system due to greater column of water and increased ambient pressure.

In the figure without the injection of bubbles (left figure in Figures 5), it was not possible to discriminate the target from the bottom of the lake. This is probably related to two factors: the small thickness of the target (acrylic plate 10 mm); and the amount of mud on the bottom of the lake, that might have covered it when it was installed.

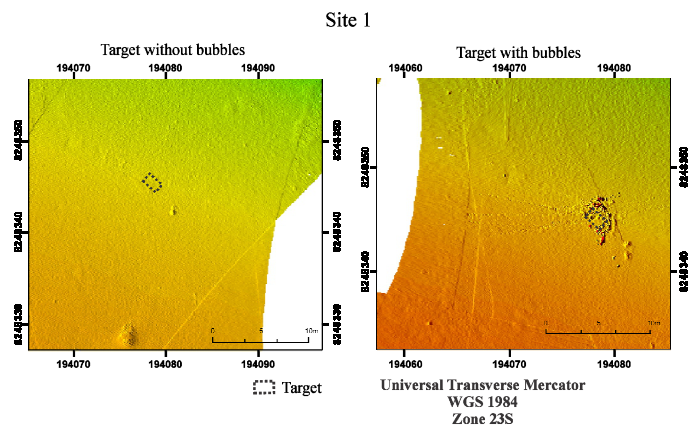


Fig. 5. Results of the imaging of the controlled target at Site 01 (deeper) before (left) and during (right) of the air injection. The dotted rectangle indicates the target's position.

Figures 6 and 7 show vertical profiles along the water column acquired during the air injection for Sites 01 and 02, respectively. In these figures, it is possible to observe the bubbles coming out of the targets towards the surface. The bubbles in the Site 01 (deeper) are a more dispersed than in the Site 02 (shallower), where the bubbles are more concentrated near the target. It is possible to identify a queued pattern along the alignment of the target holes (see Figure 3). In Figure 6 we can observe the rope (string) and the hose used for the air injection.

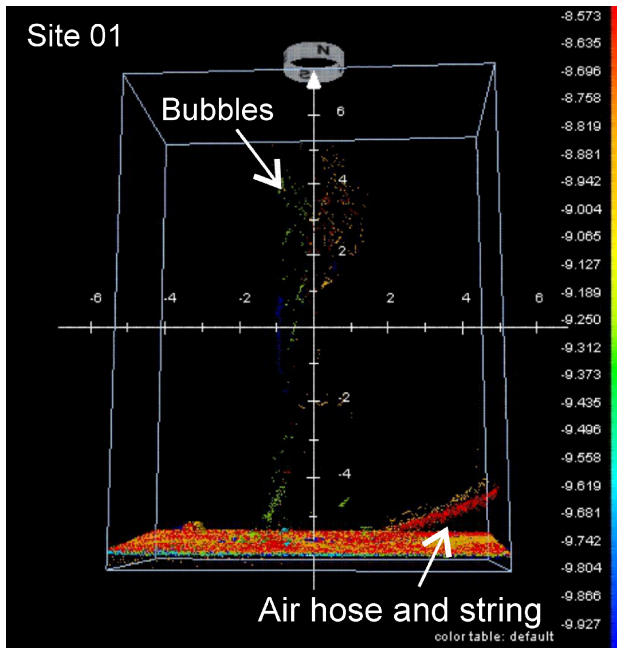


Fig. 6. Vertical profile along the water column for Site 01 (deeper).

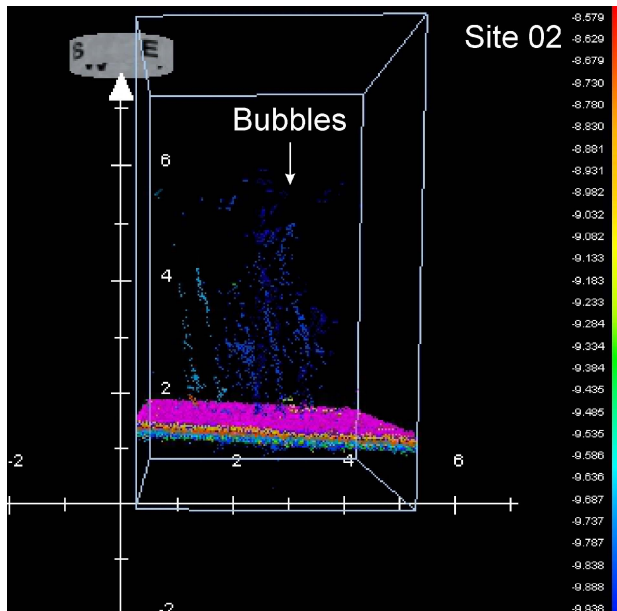


Fig. 7. Vertical profile along the water column for Site 02 (shallower).

IV. CONCLUSIONS AND FINAL REMARKS

The controlled experiment achieved its objectives since it allowed the controlled acquisition of sonographic data to be successfully performed, and it was possible to image the bubbles and to discriminate them from the target and from the

bottom of Lake Paranoá. These results, as well as the methodology, have a great potential for studying the acquisition and processing of sonographic data in presence of gas seepage.

As a next step of the research, we intend to develop processing techniques to allow the estimation of the air volume from the sonographic images, which has a direct application in situations of gas exudation at the bottom of bodies of water.

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