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Geophysical seismic investigation using high resolution sub-bottom Profiler in the Eastern Harbour, of Alexandria Egypt

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Abstract

Seismic methods are widely applied to exploration problems involving the detection and mapping of subsurface boundaries of normal simple geometry. The methods are particularly well-suited to the mapping of layered sedimentary sequences and are therefore widely used in marine exploration for oil and gas at sea, detection of fluid mud layers and dredging levels below siltation, detection of the buried objects and the marine archaeological investigations like wrecks, historical buildings and settlements. The present work is mainly devoted for the collection and analysis of the seismic oceanographic and geophysical data in Alexandria Eastern Harbour, Egypt. It is based on quantitative and qualitative interpretations using an up-to-date version of a shallow parametric non linear sub-bottom profiler.

Keywords: Eastern Harbour, Sub-bottom Profiler, modelling, mapping, Mass excess & deficiency

1. Introduction

The value of sub-bottom profiling techniques has become increasingly apparent to geologists as instruments capable of recording echoes from layers, not just a few meters beneath the sea bed, but from depths of tens, then hundreds and eventually a few thousand meters. Increased penetration is being achieved by the development of high energy acoustic sources.

Sub-bottom profiling systems can be useful for characterizing benthic habitats, since they provide information about very shallow sub-surface sediment structure with high resolution. It is one of the up to date acoustic techniques that provides this type of information, and only physical sampling via cores or in-situ photography via sediment profile imaging will allow confirmation for characterization of this subsurface structures. However, the penetration depth depends on the hardness of the overlying layers and the presence of gas deposits (Jones, 1999).

2. Sub-bottom Profilers

The Sub-bottom profiling systems use a technique that is similar to the simple echo sounder. A sound source generates a signal vertically downwards into the water and a receiver monitors the return signal that has been reflected off the sea floor. Some of the acoustic signal will penetrate the sea bed and be reflected when it encounters a boundary between two layers of different acoustic properties i.e. Acoustic impedance = (ρ x v), where: ρ = formation density kg.m^{-3}, v = formation seismic velocity m/s.

The deployed system uses reflected energy to provide information on shallow sediment layers beneath the sediment water interface.

This energy is reflected when it encounters boundaries between deeper sediment layers having different acoustic impedance, Figure 1, (Awad & Hammouda, 2003).

It depends on the reflection coefficient of the reflective surface, which is defined as;

$$K = (\rho_1 v_1 - \rho_0 v_0)/(\rho_1 v_1 + \rho_0 v_0)$$

Where '$_0$' and '$_1$' are related to the upper and lower layers respectively. The energy reflected by these layers is in continuous coverage profiling of the sub-bottom sediment.

Several sonar parameters (output power, signal frequency, and pulse length) affect the instrument performance as follows:

- An increase in output power gives a better penetration into the sub-bottom layers and provides a deeper penetration into the sub-bottom layers. Sometimes, however, if the bottom is very hard and/or not very deep, the increase in power will cause more signals to be reflected back off the sea floor. The signal might then be reflected off the sea surface, leading to multiple reflections and "noise" in the data.

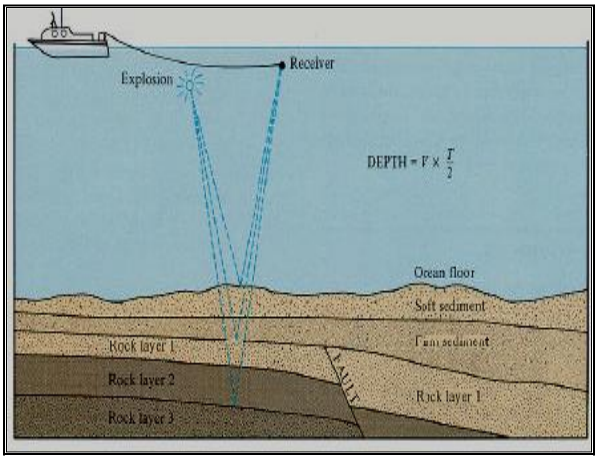

Figure 1. Energy reflected from boundaries.

- Higher frequency systems (2 to 20 kHz) will produce high resolution data of the upper sea floor sediment layers. These higher frequency signals have shorter wave lengths, and they are able to distinguish between so closed layers. While lower frequency systems will give greater penetration but at a lower resolution.
- Long wave length pulse contains more energy and yields deeper sea bed penetration. However, a long pulse may decrease the ability to distinguish between adjacent reflectors, thus decreasing the system resolution. (www.innomar.com)

3. Parametric Sub- bottom Profiler

The principle of the parametric acoustical effect is briefly due to transmission of two high frequencies with very high sound pressure which results in a nonlinearity of the sound propagation. At high pressures, the density of water and therefore the sound velocity are changing non-linearly.

This results in a signal distortion and spreading of the spectrum. The two primary high frequency sound waves interact in the water column which comes up with two new transmitting products i.e. the sum and differential frequencies. The resulting differential frequency is involved with the same small directivity as for the transmitted high frequency. The primary high frequency can be used to determine the exact water depth; the secondary low frequency is able to penetrate the bottom and can give information about the sediment layers and embedded objects and structures with very high resolution.

Therefore:

- Two signals of different frequencies will be transmitted with high sound energy.
- Pressures in the same direction, the transmitted sound waves become inharmonious; both signals ($Freq_1$ and $Freq_2$) interact in the water.
- Signals with frequencies $Freq_1$ and $Freq_2$, ($Freq_1$-$Freq_2$) and ($Freq_1$ + $Freq_2$) arise.
- The primary frequencies $Freq_1$ and $Freq_2$ are used for an exact determination of the depth, Figure 2.
- The difference frequency (secondary frequency) is a low frequency and is able to penetrate the sea bottom.

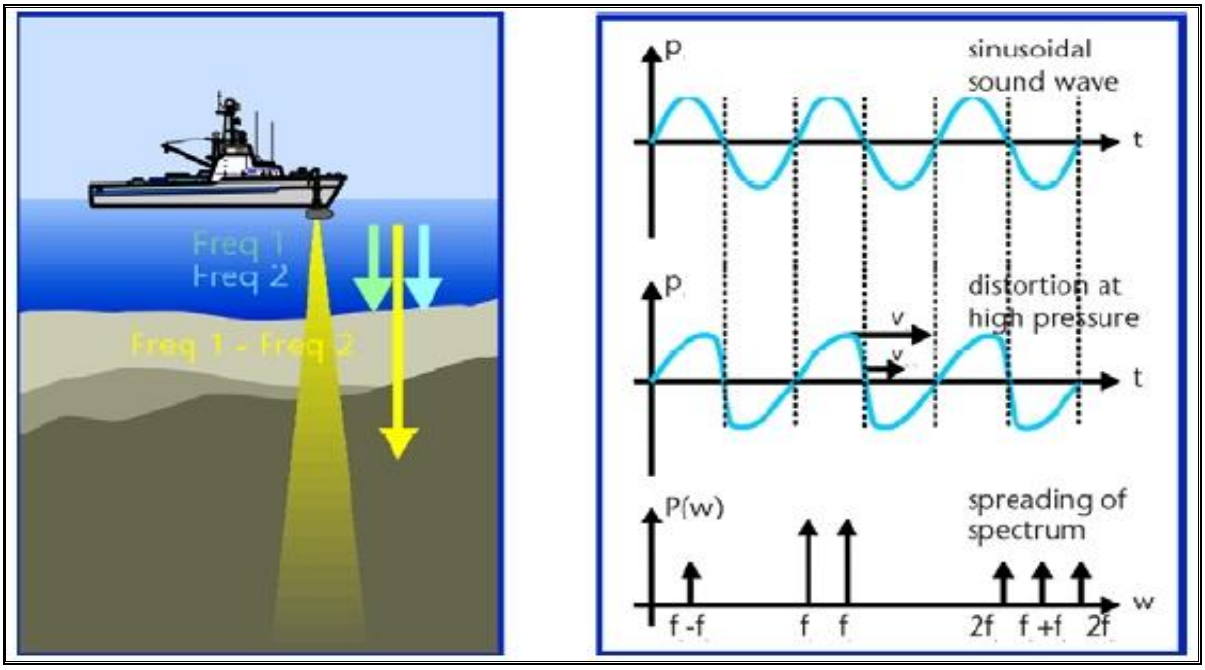

Figure 2. Parametric Sub-bottom profiler.

4. The survey area and operation

The survey area is the Alexandria Eastern Harbour, of Egypt, Lon. (29°52´8″ - 29°54´4″ E), lat.(31°12´- 31°12.9´N), Figure 3. The area is a marine archaeological site, as the harbor was established in 322 BC by Alexander the great. It has encountered many historical earthquakes since that time. Some archeological remains are standing on the sea-bottom, while others are buried under sediment, that's the importance of this study area. The survey was carried during November (27th-29th), 2006.

Sub-bottom profiler data were collected by the Inommar SES2000 System in cooperation with PDS2000 Navigation Software, RTK GPS dual frequency receiver, MAHRS motion sensor for heave compensating.

The primary and secondary frequencies were 100 KHz & 95 KHz, and the low freq. is 5 KHz to achieve penetration. While the power was12 KW.

SESWIN software was used during the acquisition that dealing for (HF, LF) at the same time as in Figure 4, the HF is to detect the seafloor and the LF is to define the sub-bottom layers.

Twenty seven profiles were conducted, heading N to S & S to N alternatively. Figure 5 is a sample of the profiles, where it shows the bottom layer, sub-seated layers as well as an embedded wreck.

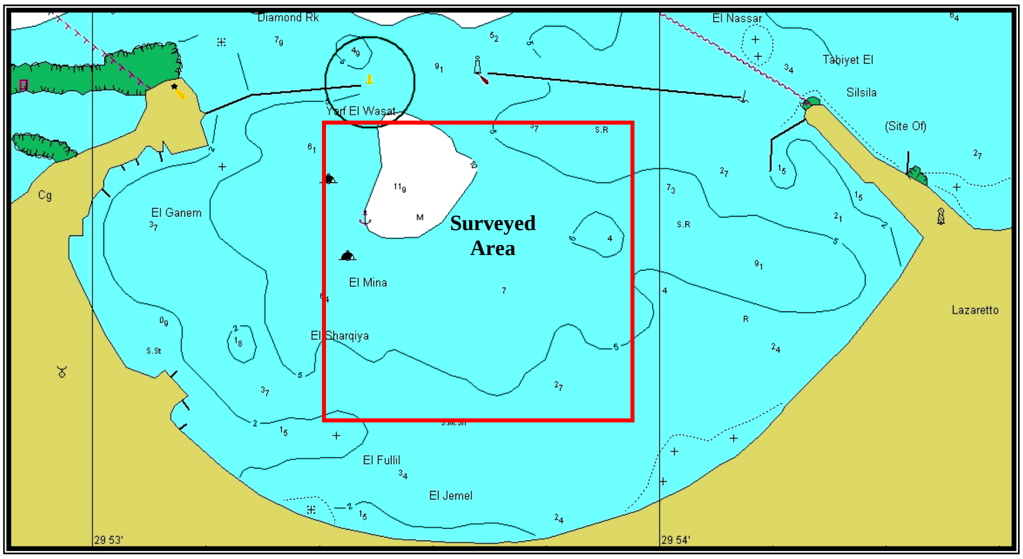

Figure 3. The surveyed area.

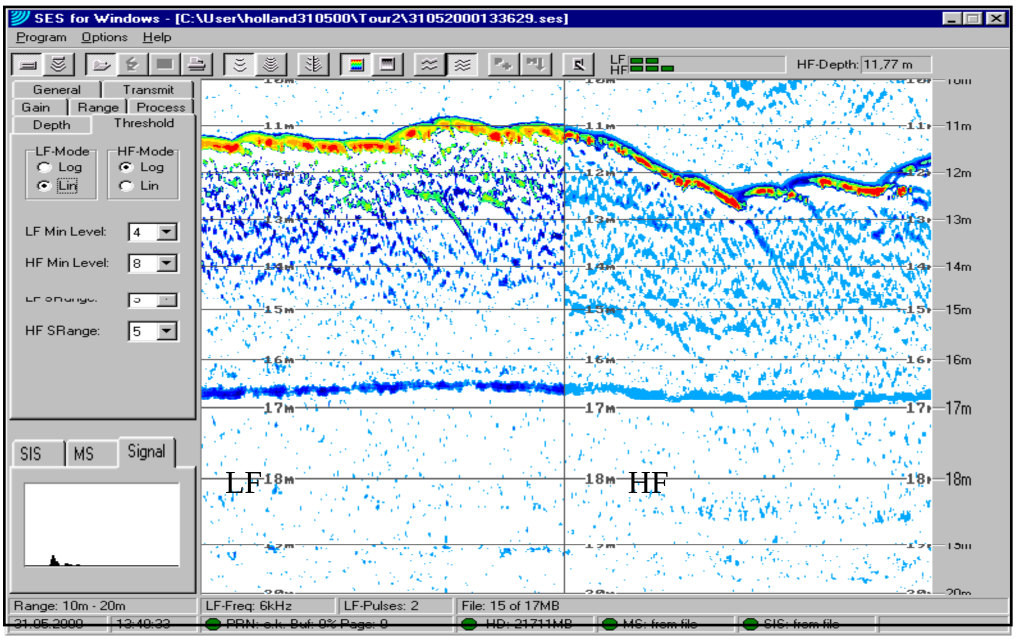

Figure 4. The acquisition software.

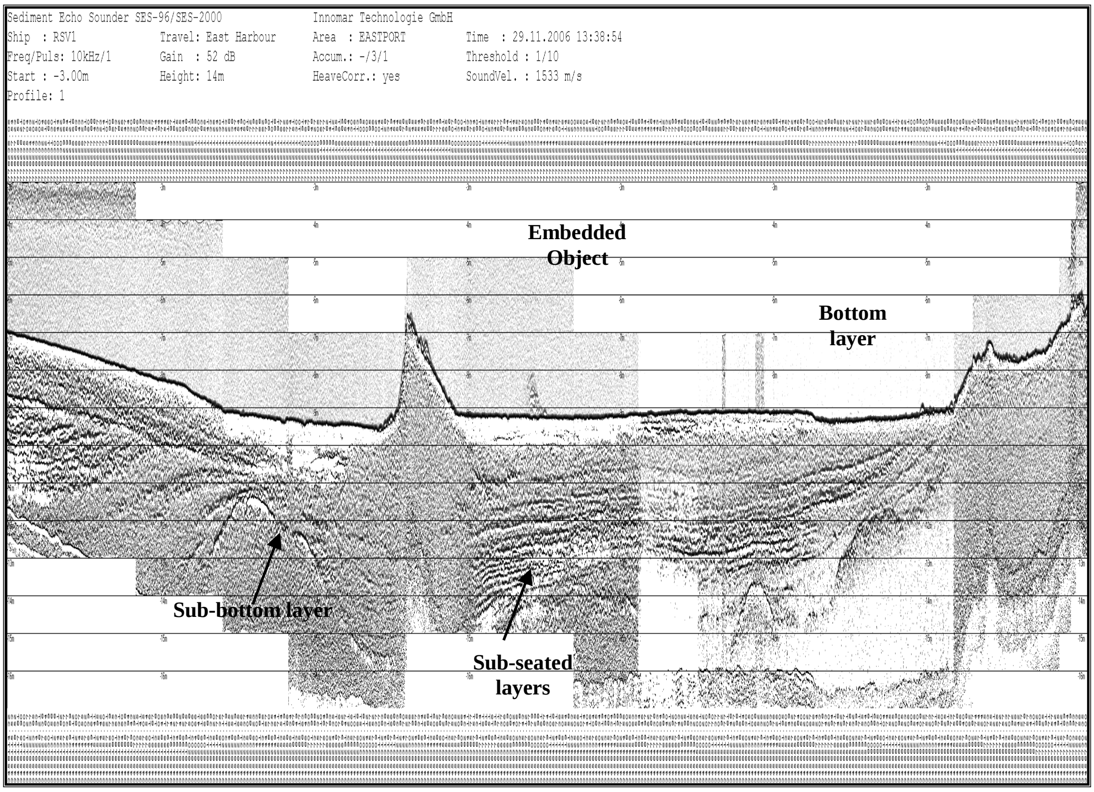

Figure 5. Profile sample

5. Data processing and analysis

The ISE software was used firstly for different processing tasks, like digitizing layers, correcting echo plots with tide data, GPS data and extracting the information to compatible formats.

The raw data was loaded, corrected for tide and heave compensated, the reversed legs were mirrored in order to keep all the profiles with the same headings (South to North). The bottom and sub-bottom interfaces were exported in ASCII format, keeping all the profiles to be with same scale. Most continuous sub-bottom layer was found in the range from 7.5 to 5 m beneath the seafloor. ISE software was the exporting of the sub-bottom layer in xyz format.

The xyz data of the bottom and the sub-bottom surfaces were girded separately using the surfer8 software as in Figure 6.

Fifteen polynomial fitting trials have been made using the regression girding method to obtain the fit model that corresponds to the regional z data for both interfaces to obtain the polynomial equation that mostly represents the data; so, starting with the second polynomial order (xy) and lasting with the sixth order. All the girded z output values were compared to the regional z data using the correlation coefficient to distinguish the fit model. Accordingly, it was found that the third polynomial order (x^3y^3) has the highest correlation value with the original z data (0.85).

The optimum fitting polynomial equation for the bottom layer is:

$$\mathbf{Z\,(x,y)} = A_{00} + A_{01} * y + A_{02} * y^2 + A_{03} * y^3 + A_{10} * x + A_{11}\,xy + A_{12} * xy^2 + A_{13} * xy^3 + A_{20} * x^2 + A_{21} * x^2y + A_{22} * x^2y^2 + A_{23} * x^2y^3 + A_{30} * x^3 + A_{31} * x^3y + A_{32} * x^3y^2 + A_{33} * x^3y^3$$

Where x and y are the coordinates of the depth point z, while the A_{00}… A_{33} are the regression coefficients.

Then, the two grid files, the original of the raw data, and the output polynomial fitting for both layers; by subtracting the two surfaces by means of the surfer8 software, the residual surface would be the output, which simply represents the difference between both grids.

Figure 7 shows the contour diagram for the raw data, the polynomial fitting and the residuals between both of them for the bottom layer.

Accordingly the residual surface is edited by means of the AutoCAD software to calculate the volume of each closure surrounded by the same contour, using the Quick surf module in calculating the volume. Each separate closure is multiplied by 1.8 Tm^{-3} as an assumed density of the marine sediment in the study area, (Faragallah, 1995) to obtain the mass distribution of the marine sediment (Figure 8).

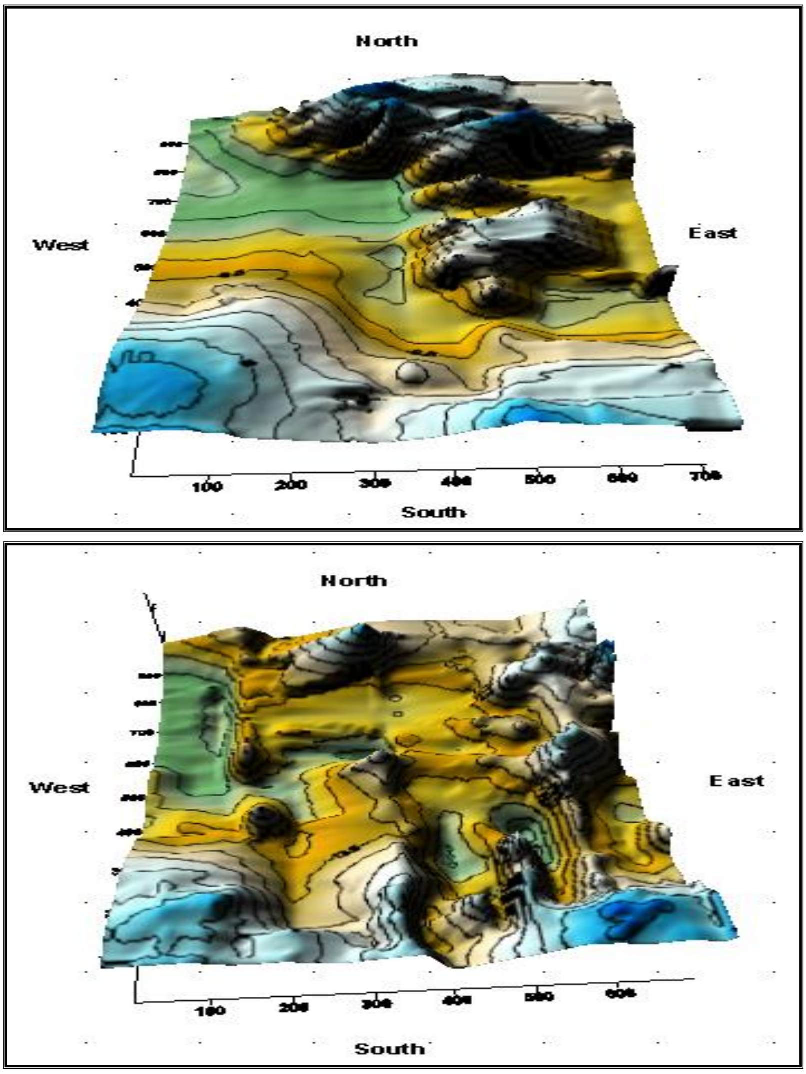

Figure 6. Bottom & Sub-bottom layers.

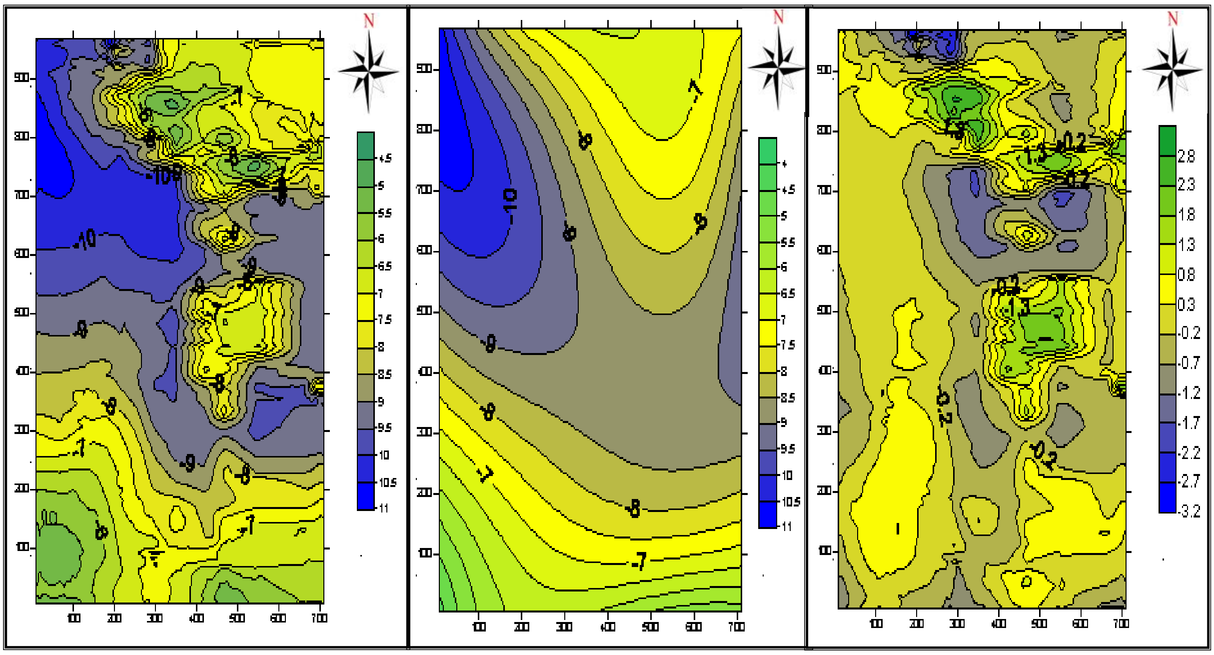

Figure 7. 3 phases for the bottom layer.

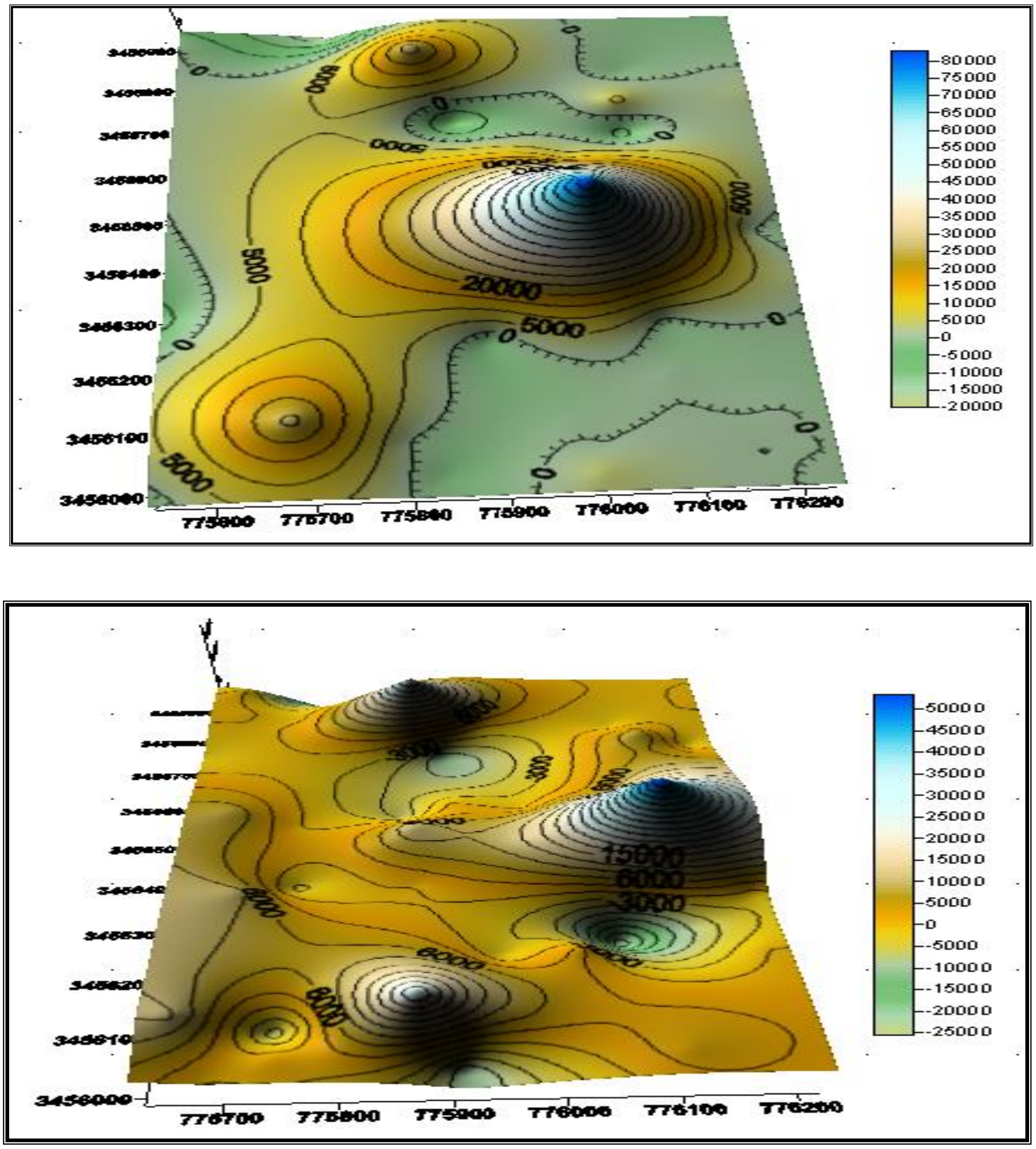

Figure 8. Mass distribution for layers

6. Conclusions

Information technology of the present work is supposed to be of continuous enhancement to encourage and support investigation of new areas using the same techniques. The qualitative & quantitative investigation mainly showed the configuration of the bottom as well as the subsequent bed layer which lead to detect the mass deficiency (erosion) and the mass excess (accretion) of marine sediment in the study area.

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