

# Investigation of the effects of upward and downward continuation operations on regional trends in parts of Southern Niger Delta of Nigeria using gravity data

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**ABSTRACT:** Analytical operations of upward and downward continuations were applied to structural trends obtained from airborne gravity data in parts of Southern Niger Delta of Nigeria with varying depths of 500 to 1,000 m to observe the effects of the continuations on the structural trends. The data were first gridded and the regional effects separated from the residuals using a second-order polynomial operation. The continuation operations show that at a depth of 500 m, both upward and downward continuations did not affect the observed trends much as the difference between the original trends and the ones with continuation operations were almost the same. However, with continuation depths of 1,000 to 5,000 m, the upward continuations enhanced the sharpness of the structural trends with increasing depths while the downward continuations suppressed and distorted the structural trends with increasing depths. The results confirm the instability in downward continuation operations with increasing depths for long-wavelength regional trends since the operations increase the noise levels exponentially and hence distort the sharpness of the trends. The enhancement of the regional trends by the upward continuation shows it as a stable operation for long-wavelength regional trends for proper visualization.

**Keywords:** Airborne gravity data, downward continuation, upward continuation, structural trends.

## INTRODUCTION

The gravity method has been identified as a suitable geophysical method for the study of regional structures (Reynolds, 1997). The major reasons for these are the ease by which data can be acquired in remote and inaccessible regions by use of airborne gravimeter; and the ability of the method to identify trends in a region resulting from density contrast in subsurface rocks. For homogeneous formations, the density remains the same until a formation of different density contrast is encountered, giving rise to a change in density value that can be recorded from an airborne survey. This record is a combination of anomalous effects of regional and residual bodies and requires analytical operations to separate them. To properly visualize either the regional or residual trends, upward and downward continuation operations are applied to enhance or suppress either of them.

Ravat (2007) explains that an upward continuation operation projects a field data from one surface to a surface level above the original datum. This attenuates short wave-length anomalies associated with high wave number shallow gravity sources and allows for easy interpretation of regional anomalies from the deeper sources. A downward continuation operation on the other hand projects the field data from a surface to a surface below the original datum so that long-wave length anomalies associated with low wavenumber deep gravity sources are attenuated allowing for proper visualization of the residual anomalies.

Continuation operations have limits on depths of continuation for enhancement. This work demonstrates this with regional structural trends in parts of Niger delta obtained from airborne gravity data and subjected to

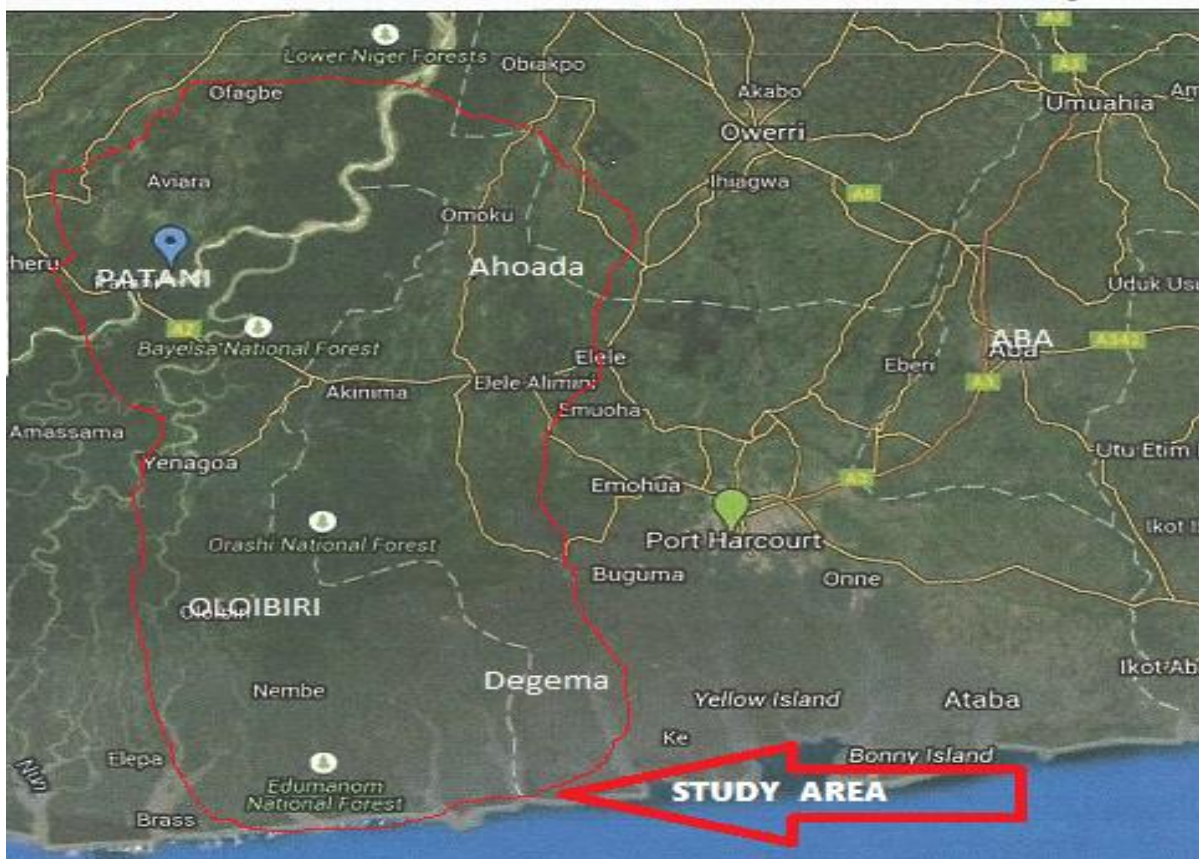


Figure 1. The study area (Google Maps, 2018).

different upward and downward continuation depths.

## MATERIAL AND METHOD

### The study area and its geology

Opafunso (2007) identifies the coordinates of the Niger delta as longitudes  $5^{\circ}.00$  to  $8^{\circ}.00$  E and latitudes  $4^{\circ}.00$  to  $8^{\circ}.00$  N. The area of study is south of the Niger Delta and lies within longitudes  $6^{\circ}.00$  to  $7^{\circ}.00$  E and latitude  $4^{\circ}.30$  to  $5^{\circ}.30$  N. Digitized data from four zones identified as sheet 319, sheet 320, sheet 327 and sheet 328 were obtained from the Nigerian Geological Survey Agency (NGSA), Abuja for this study. The sheets cover major cities in the Niger Delta that include the following towns; Oloibiri, Patani, Ahoada, Abua, Elele, Isiokpo, Degema Omoku, Mbiama, Aviara and Uwhheru (the region indicated a red contour in Figure 1).

According to Eke et al. (2016), the setting and geology of the Niger Delta have been discussed by several authors. Rayment (1965), Short and Stauble (1967) and Doust and Omatsola (1990) show that marine sedimentation in the region started to evolve in the early tertiary times and lasted over several years prograding a distance of more

than 250 km from the Benin and Calabar flanks to the present delta front. Similarly, Merki (1972) opined that this progradation had been controlled by syndimentary faults, folding and interplays between subsidence and sediment supply mainly from the Niger, Benue and Cross Rivers. The above authors explain that the progradation continued into the Gulf of Guinea in response to the evolution of the drainage areas and continued basement subsidence. According to Short and Stauble (1967), the morphology of the Niger Delta in response to these depositions continued to change from an early stage (Palaeocene to early Eocene) to a later stage of delta development in the Miocene time.

Three major lithostratigraphic units have been identified in the Niger Delta (Eke and Okeke, 2016). The topmost of these formations, with an average thickness of 2,100 m, is the Benin formation composed mainly of non-marine sands (70-80%), gravels and back swamp deposits with few shale streaks (Reijers, 2011). The Benin formation is underlain by the Agbada formation which is the major petroleum-bearing unit of the Niger Delta (Tuttle et al., 1999). It consists of paralic siliciclastics over 3,700 m thick. The base of the formation is the Akata formation composed of thick shale sequences which are the potential source rocks and turbidite sands, which are the

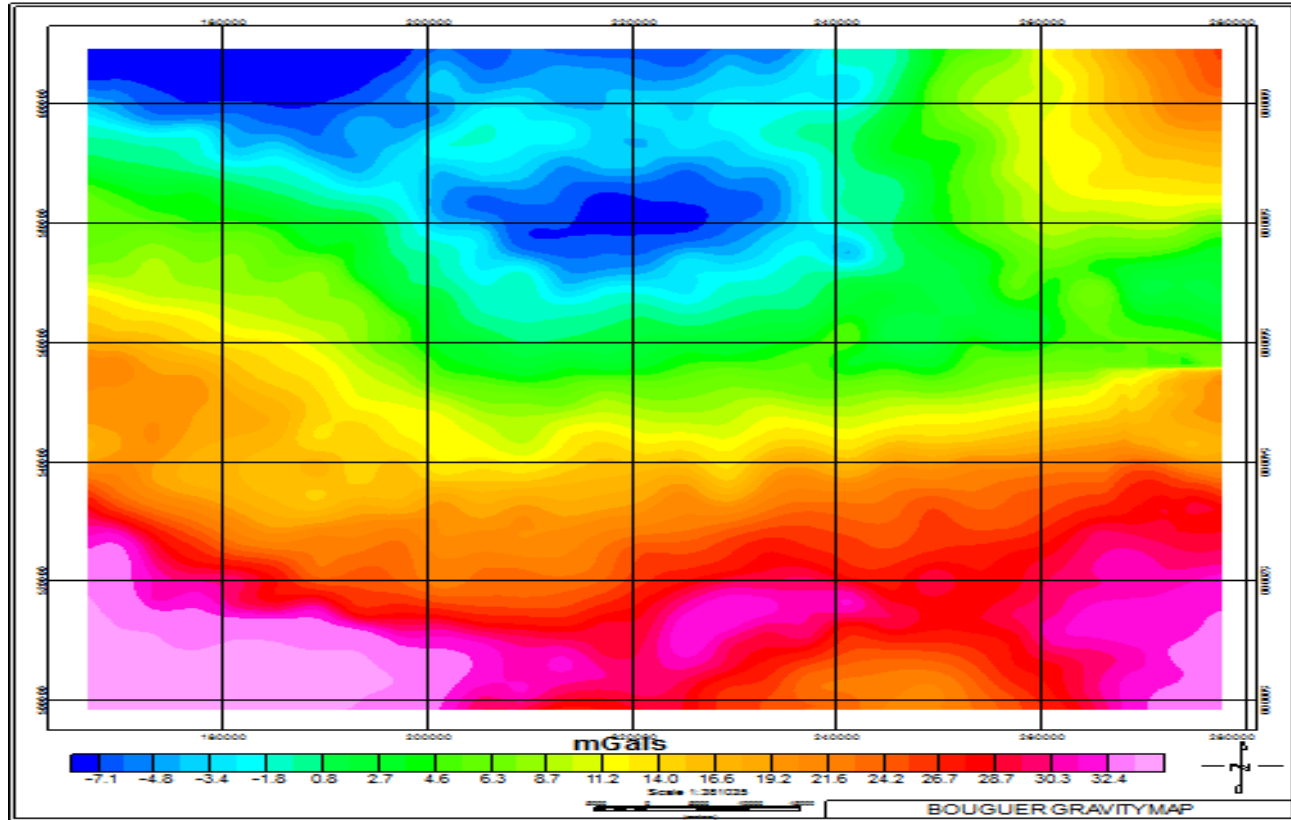


Figure 2. Base map of study area showing structural trends in the area.

potential reservoirs, with minor amounts of clay and silts formed within the periods of the Paleocene to the recent (Reijers, 2011).

**Methods**

The aero gravity data collected by Fugro Airborne Survey Limited between 2003 and 2010 for the Nigerian Geological Survey Agency (Abuja) were used in this work. Digitized data from four sheets (319, 320, 327 and 328) data were first gridded using Briggs (1999) method. A base map was produced from it and the regional structural trends of the region obtained using a second-order polynomial (Mishra, 2018; Hinze, 1990). The trends were then subjected to the upward and downward continuation, all with the aid of Oasis Montaj software.

Continuation as a mathematical operation, projects an observed field to another level and in the frequency, *f*, the domain operation according to Mishra (2018) is

$$\sum_{f=-n/2}^{+n/2} \exp 2\pi i f (z_o - z_1) / \lambda \tag{1}$$

*z* is positive in the downward continuation. For an upward continuation operation,  $\Delta z = z_o - z_1$  and the upward continuation equation is

$$\sum_{f=-n/2}^{+n/2} \exp 2\pi i f / \lambda (-\Delta z) \tag{2}$$

For downward continuation the equation is

$$\sum_{f=-n/2}^{+n/2} \exp 2\pi i f / \lambda (\Delta z) \tag{3}$$

Practically, the upward and downward continuation operations is filtering that are achieved with these equations respectively,

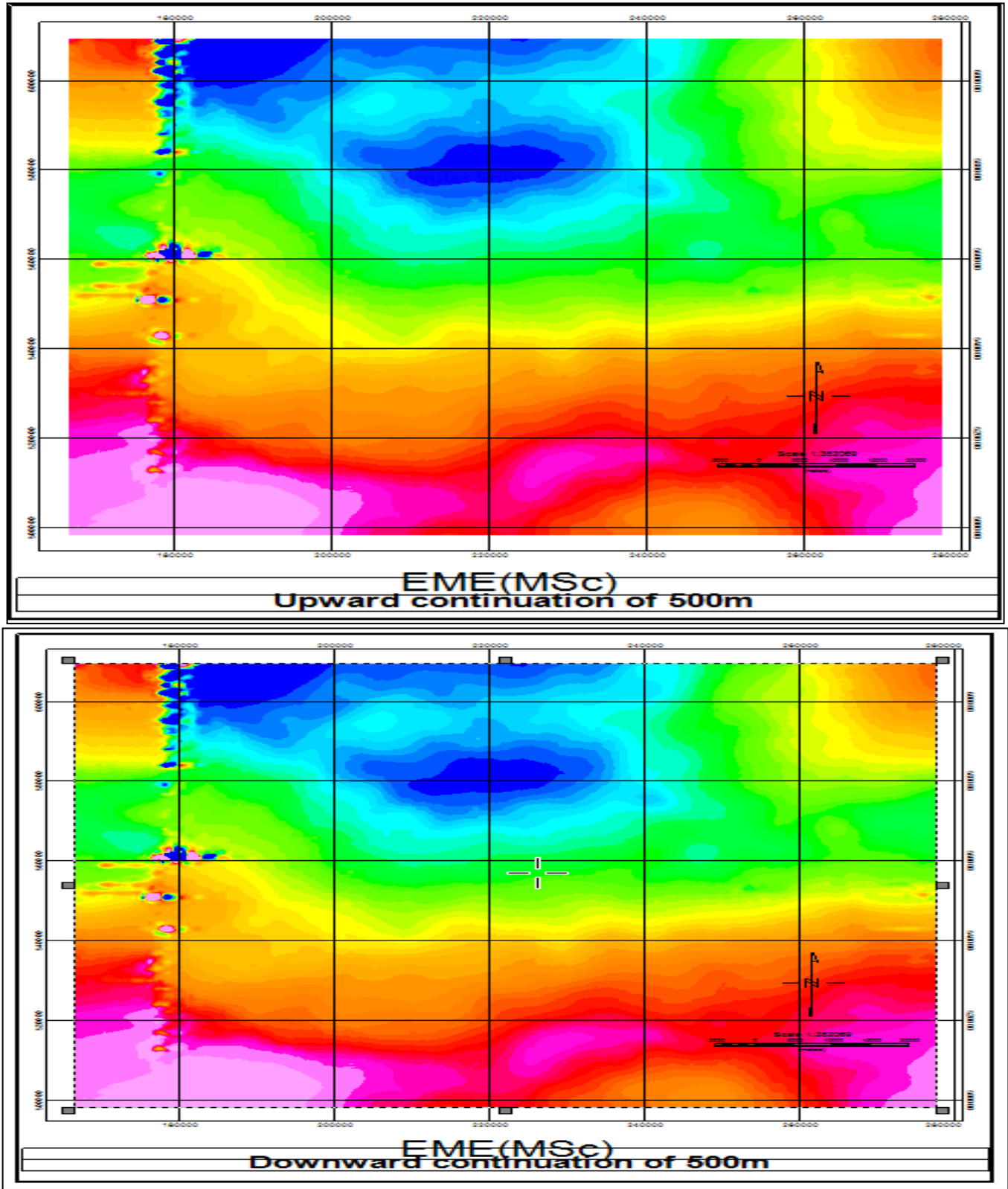
$$F(\omega) = e^{-\omega z_1} \tag{4}$$

and

$$F(\omega) = e^{\omega z_1} \tag{5}$$

**APPLICATION AND RESULTS**

Figure 2 is the contour base map of the study area showing the regional structural trends obtained from a second-order polynomial equation lying in an east-west and northeast-southwest directions.



**Figure 3.** Upward and downward continuation of 500 m.

Upward and downward continuation operations using depths of 500 m to 5,000 m were applied to these trends

to ascertain the effects of the continuation operations. Figures 3 to 7 highlight the effects of these operations.

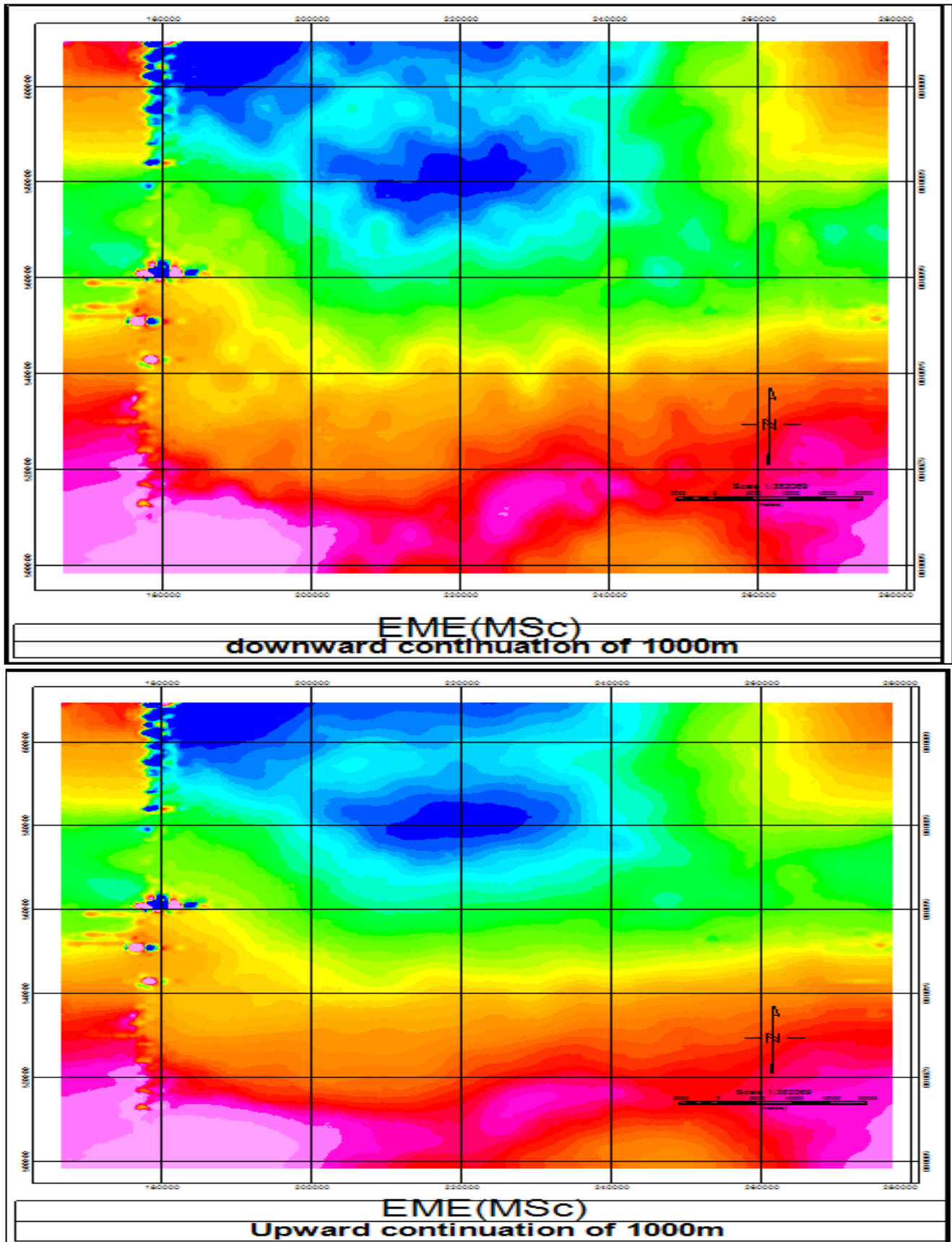


Figure 4. Downward and Upward Continuation to depth of 1,000 m.

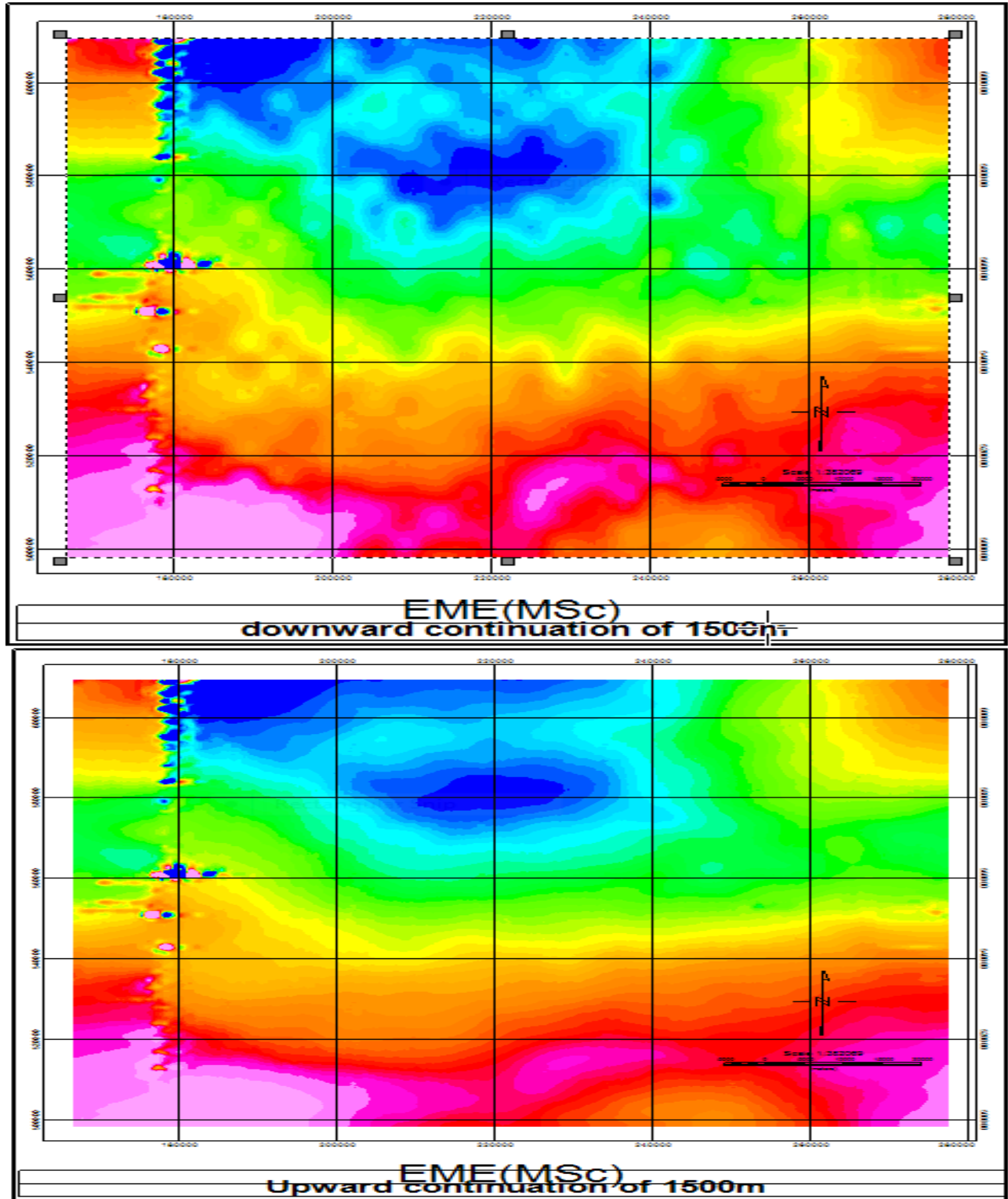
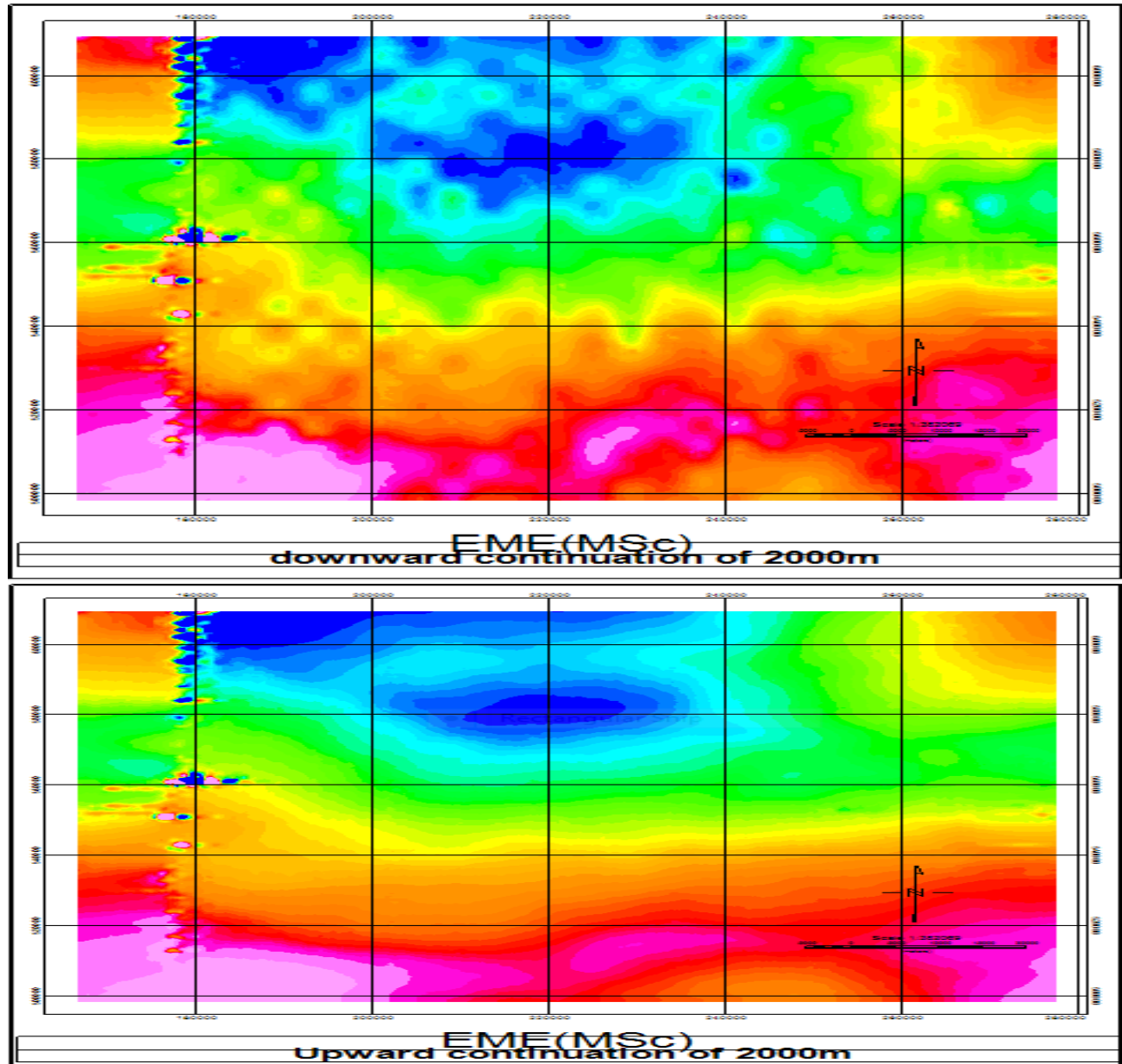


Figure 5. Downward and Upward Continuation to depth of 1,500 m.

Figure 3 compares the continuation operations for a depth of 500 m. The results show that the observed structural trends are not affected by both operations

because they maintain their shape.

However, as we increase the depth of continuation to 1,000 m, the changes in sharpness starts to manifest. The



**Figure 6.** Downward and Upward Continuation to depths of 2,000 m.

upward continuation enhances the structural trends as shown by the sharpness, while the downward operation distorts the sharpness of the structures (Figure 4).

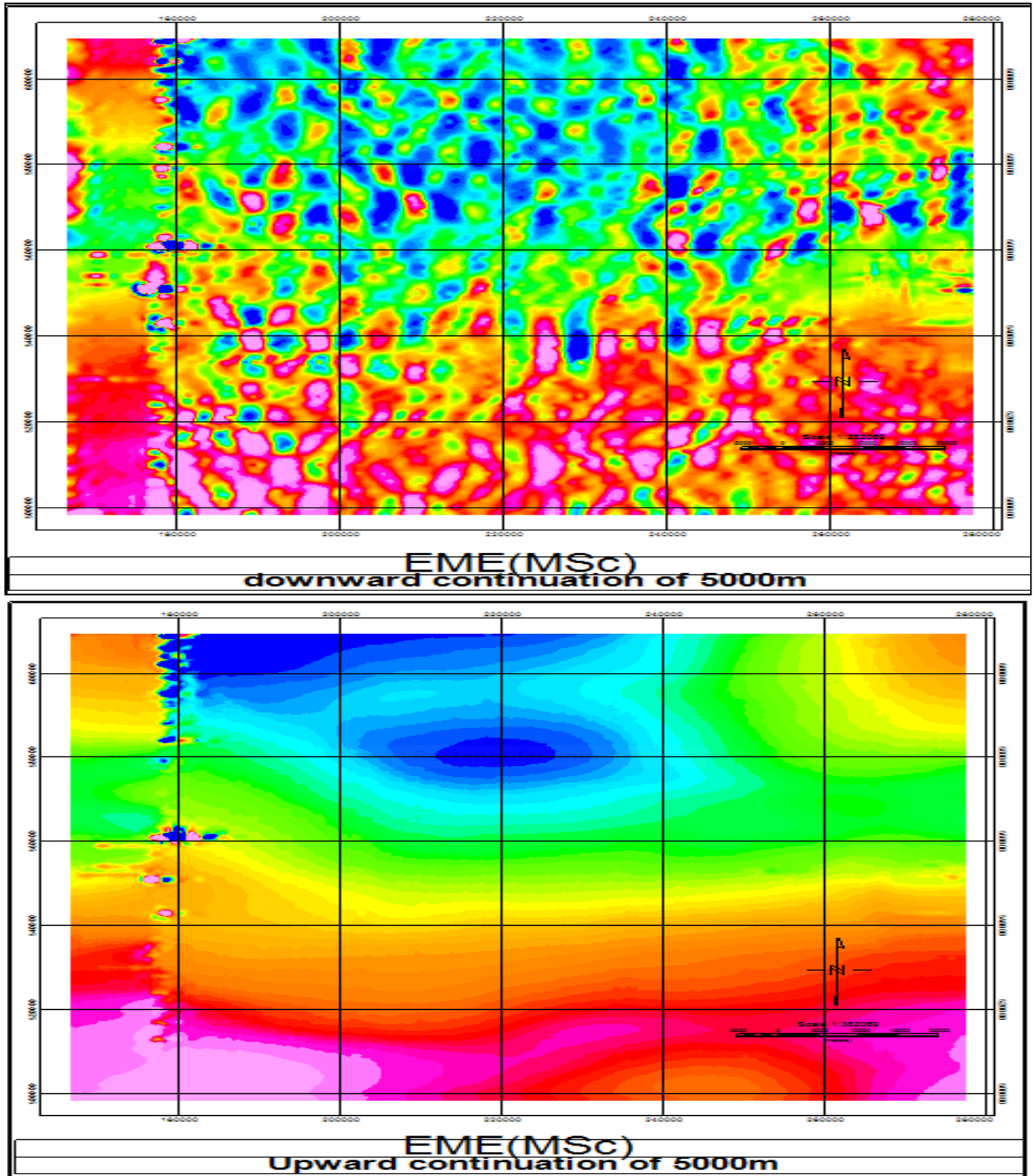
The deterioration in the structural trends as the depth of downward continuation increase can be seen from Figures 5 to 7, while the reverse is the case for the upward continuation of the same depths.

## DISCUSSION

These results confirm that the harmonic downward continuation of a regional structural trend is a classical

unstable operation because it is essentially a high-pass filtering operation which amplifies the short wave-length noise in air borne gravity data (Tziavos et al., 2005). From the depth of 1,000 m and above, the noise distorts the data such that at the depth of 5,000 m, the structural trends are completely obliterated.

On the other hand, the upward continuations show significant changes and an increase in sharpness of the structural trends in comparison to that of the unenhanced structures. This confirms that upward continuation operations enhance regional structural trends because it is a numerically stable operation that illustrates the change in anomaly character with increasing source distance and



**Figure 7.** Downward and upward continuation to depth of 5,000 m.

hence is a low-wave number pass filter (Jacobson, 1987). Typically, upward continuation by an amount equal to the line spacing does not affect resolution much as seen in a depth of 500 m as the line spacing for the survey is within

this range (Figure 3). At greater depths, the sharpness is improved and this is more evident at a depth of 5,000 m (Figure 7) which depicts an excellent integrated view of the undistorted structural trends in the study area.

The conclusion from the above results is that regional structural trends in a region can best be visualized from an upward continuation operation and should not be used to enhance residual trends, as it distorts the sharpness of the residual trends with depth.

## CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

## ACKNOWLEDGMENT

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