GEOARCHAEOLOGICAL INVESTIGATIONS AROUND THE PORPANAI FORT USING GROUND MAGNETIC SURVEY

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Abstract

Porpanai Fort in Tamil Nadu is a significant archaeological site, offering insights into Chola prehistory. This study aims to identify buried features and demolished structures at Porpanai Fort in Pudukottai District using a ground magnetic survey. The survey was conducted over 0.85 square kilometers, with profile intervals of 50 meters and sample intervals of 20 meters, collecting a total of 507 samples. These samples were processed and interpreted both qualitatively and quantitatively. The total magnetic intensity in the area ranged from 41073.504 nT to 41309.283 nT, with an average value of 41191.393 nT. The Analytical Signal map revealed a circular magnetic anomaly in the western and southern parts of the study area. Regional and Residual anomaly maps highlighted significant causative bodies in the eastern and southern sections. A band pass filter further confirmed a circular anomaly in the eastern area. East-west profiles of residual, regional, and analytical signal maps showed a sudden decrease in magnetic values around 800 meters, indicating the depth of causative bodies. Depths were estimated using the radially averaged power spectrum, revealing shallow sources around 10 meters and deeper sources around 30 meters. The Euler method, applied with various structural indexes (0, 1, 2, and 3), estimated depths of buried features ranging from less than 10 meters to more than 30 meters. The study identified four zones for detailed investigation: Zone 1 in the northeast, Zone 2 in the north, Zone 3 in the south, and Zone 4 in the northwest. This research demonstrates that magnetic methods are highly effective for geoarchaeological investigations, helping to uncover subsurface features at archaeological sites like Porpanai Fort.

Keywords: *geoarchaeological excavations, ground magnetic survey, causative bodies, geophysical methods*

1. INTRODUCTION

Geoarchaeology applies geoscience techniques to address archaeological research problems. This interdisciplinary field merges geology and archaeology, tracing its origins to the early 19th century when both disciplines significantly advanced in parallel. Traditionally, geoarchaeology encompasses geomorphology, sedimentology, pedology, and stratigraphy, reflecting Renfrew's 1976 assertion that archaeological problems often begin as geoarchaeological ones, especially in prehistoric contexts where excavation yields most data (Renfrew, 1976). This perspective also aligns with the 1980s focus on site formation processes, which these geoscientific techniques have greatly elucidated.

Magnetic surveys are a key method in archaeological prospecting, detecting features like buried walls, pottery, bricks, fire pits, pathways, and tombs due to their magnetic properties compared to surrounding materials (Gaffney & Gater, 2000). While total

magnetic field (TMF) measurements are common, magnetic gradients often provide more effective results in archaeological contexts (Li & Oldenburg, 2003). Geophysical surveys in small areas can critically fill knowledge gaps, revealing the location, depth, and dimensions of buried archaeological remains efficiently and non-invasively.

Porpanai Fort, a notable archaeological site in Tamil Nadu, India, was historically an industrial hub for weapon manufacturing. Limited excavations have already uncovered evidence of ancient human activities, highlighting its potential for further study. This research focuses on employing ground magnetic surveys to uncover subsurface features and the structure of the demolished fort across the entire site.

In this study, a proton precession magnetometer was used to perform a total magnetic field survey at Porpanai Fort in Pudukottai District, Tamil Nadu. This method aimed to identify archaeological ruins at various depths and characterize in situ stratigraphy, facilitating a detailed reconstruction of the settlement. The methodology was chosen based on the site's architectural remains, predominantly high magnetic intensity laterite brick stones. Precise geophysical measurements were recorded using a Garmin GPS device, ensuring accurate data georeferencing and aiding the interpretation of the magnetic survey results. This approach guides future excavations to areas highlighted by the magnetic data, enhancing the understanding of the site's archaeological context.

2. STUDY AREA

In Tamil Nadu, Porpanai fort is an ancient archaeological site located in Pudukottai District. The Geolocation of the study area is 10° 22' 24.202''N latitude and 78° 52' 19.248''E longitude and 10° 23' 2.591''N latitude and 78°52' 44.323'' E longitude. The Porpanai fort was assumed to be an industrialized area by making war weapons in ancient days based on the carving structured recorded in the study area over the Laterite. The fort has been constructed by a Chola king in 1st century A.D. The fort regions has split into, Upper part of the fort and lower part of the fort. The areal extent of our study area is 2.85 sq.km. There are two guardian deities on either side of the fort.

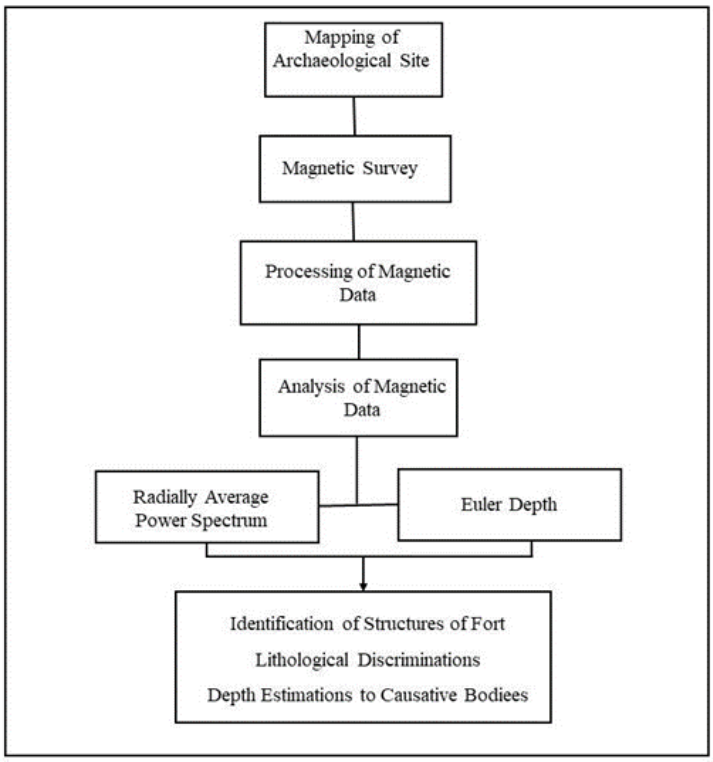
3. MATERIALS AND METHODS

The magnetic readings are obtained from a magnetic survey which reflect the Total Magnetic Intensity(TMI) including the earth’s main field, diurnal variation, and the subsurface structures and lithologies. The instrument used to collect the magnetic field data is proton precision magnetometer-600. Based on the principle of Earth’ s Field Nuclear Magnetic Resonance (EFNMR), it measures very small variations of magnetic field in the Earth, allowing ferrous objects on land and at sea to be

detected. The principle of the instrument is that a direct current flowing in a solenoid creates a strong magnetic field around a hydrogen-rich fluid (kerosene and water are popular fluid), causing some of the protons to align themselves with that field. The current is then interrupted, and as protons realign themselves with the ambient magnetic field, they process at a frequency that is directly proportional to the magnetic field. This produces a weak rotating magnetic field that is picked up by an inductor which is further amplified electronically, and fed to a digital frequency counter whose output is typically scaled and displayed directly as field strength or output as digital data.

The structures of the buried features and its depth is estimated in this study with the aid of proton precision magnetometer in and around the Porpanai Fort, Pudukottai district. The samples were collected by preparing a spatial location map. The surveying were carried out in N-S direction over an area of 2.85 sq.km and found some deviations in TMI values from the demolished wall region to the remaining adjacent areas in and around the fort. Totally, 507 magnetic datum were collected along 13 profile lines with a sampling interval of 20m and profile interval of 50m. The preprocessing of magnetic data were required few corrections. The most common process is to remove diurnal variations using the data collected in a base station. The base station data are plotted versus time. The first reading at the base station is regarded as the base value and any variations from this value at the base station for later times is subtracted or added to the field data.In the study area, diurnal changes were done by taking the readings once one hour at the base station and the correction was applied to the field magnetic values by subtracting the base station one.

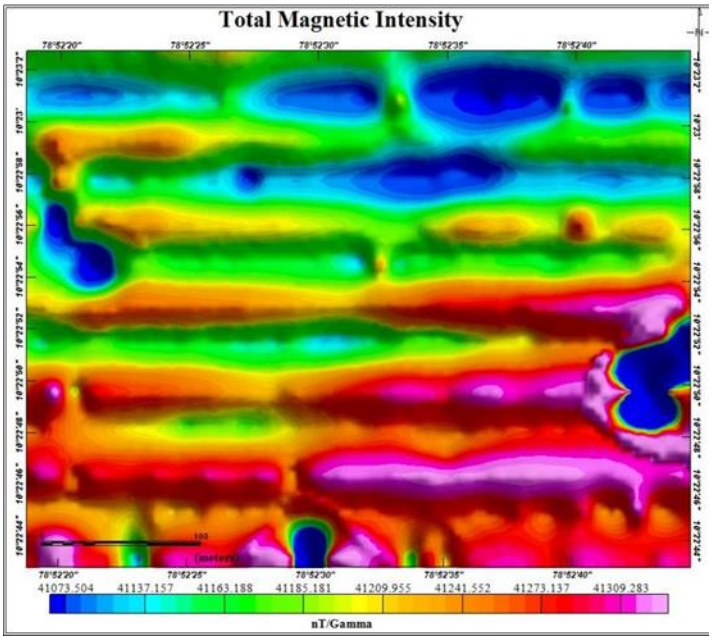
After removing the diurnal variation from the field data, the magnetic data was contoured and then they were processed into total magnetic intensity map, regional, residual, analytical signal and bandpass filter map. All these maps were produced on WGS84 ellipsoidal datum with geographic Lat/Lon projection. Interpretations were made from these maps to identify the subsurface structural elements traversing in the study area. Finally, proposing zones for future detailed excavations either by close spacing of magnetic survey or GPR method.



3. RESULTS

3.1. TOTAL MAGNETIC INTENSITY

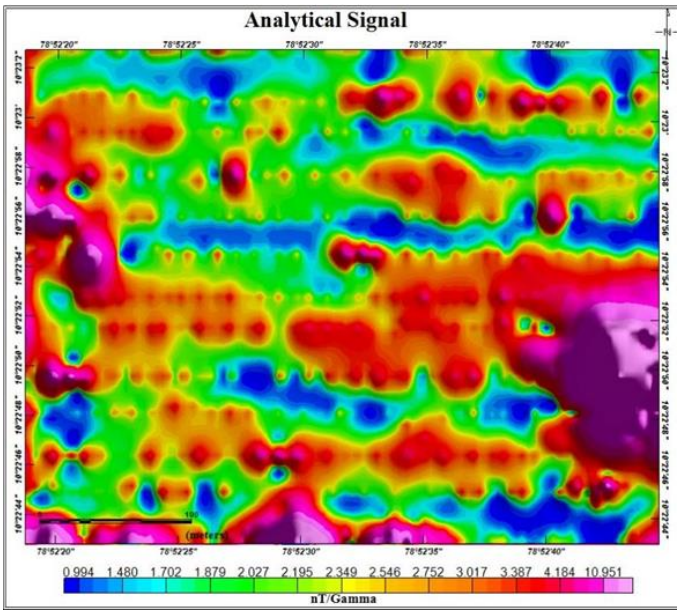
The total magnetic intensity exhibits some different types of positive and negative anomalies. The map reveals three prominent negative features in elliptical and broad shapes distributed in the north-east, southern part of the Porpanai Fort shows the magnetic value of 41073.504nT. These anomalies are trending NE-SW. These trends with large magnitudes suggest the presence of highly magnetized cylindrical intrusive bodies within the basement. The correlation of TMI anomalies map and subsurface structures contact is weak. It is noted that the positive anomalies are showing the lot of line error from which interpretation of the wall structures and buried features have been very difficult. Hence, Analytical signal map has been taken up to interpret the geoarchaeological features present in the surveyed area.



1. ANALYTICAL SIGNAL

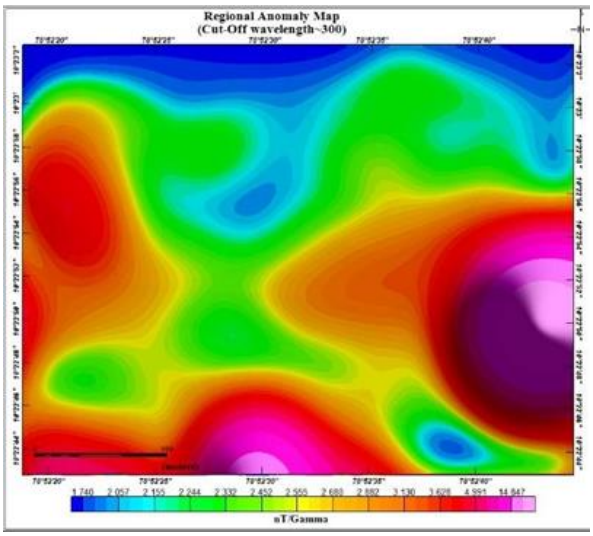
The analytical signal amplitude was calculated from the total magnetic intensity of the study area. It reduces magnetic data to anomalies whose maxima mark the edges of magnetized bodies and whose shape can be used to determine the depth of these edges. It transforms the bipolar anomaly signal positive symmetric anomaly. An important characteristic of the analytical signal is that it is independent of the direction of magnetization of the source (Kenny M. Graham, 2014). Since amplitude of the anomalies combines all vector components of the field into a simple constant, Interpreter can consider that the analytic signal is as a map of magnetization in the ground. Keeping this in the knowledge, one can map strong anomalies to exist over where the magnetization vector intersects magnetic contrasts, even if we were not aware of the source of the contrasts from the signal amplitude alone. The AS map makes it possible to limit the contacts of the subsurface structures of strong magnetization on this map. The analytic signal amplitude over the study area ranges from 0.994 nT/m to 10.951 nT/m. The partial part of the wall structures are highlighted with moderate anomalies. The pseudo-circular shape anomalies have maximum amplitudes. The map illustrates a large positive magnetic zone located to north-eastern part. Another positive magnetic anomaly is located at the western part of the map of the Porpanai Fort. The low anomalies may be due to the presence of sediments and sedimentary rocks. Apart from these anomalies, many isolated magnetic high anomalies have been

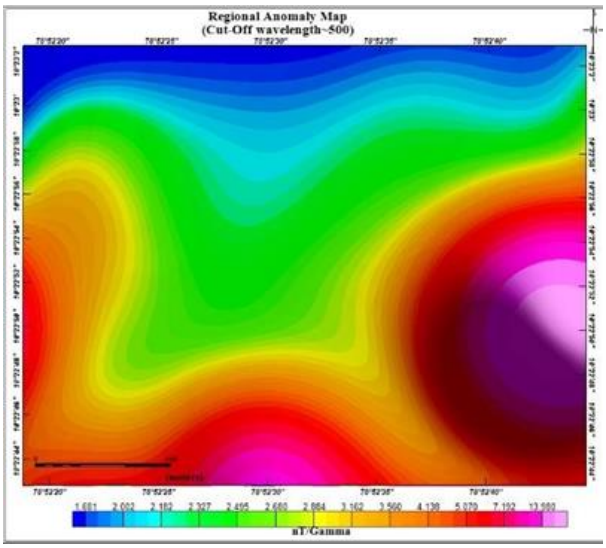
noticed which are also very important pertained to archaeological investigations. Analytical signal map were further used for the preparation of Regional anomaly, Residual anomaly and Bandpass filter map.

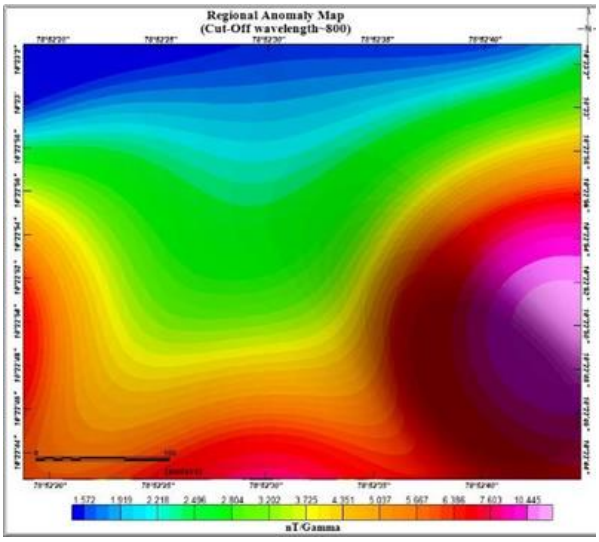


2. REGIONAL & RESIDUAL ANOMALY

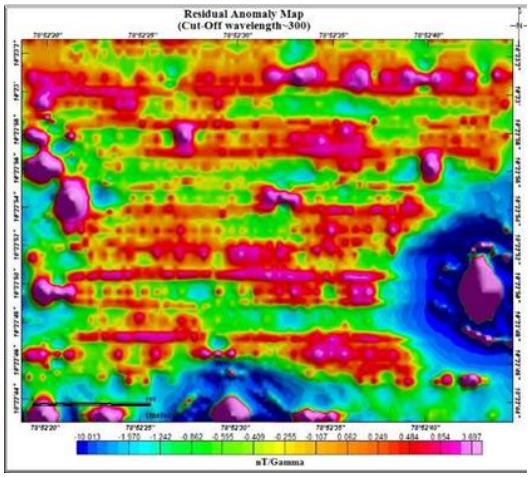
Regional anomaly map were generated using low pass filter under Geosoft Oasis Montaj. It is used to delineate information about the deep causative bodies located in the subsurface of study area. It indicates that the depth perception for those rocks are deep when compared to the other magnetic intensity noticed in the study area indicating that they are very significant in understanding the depth of the buried structures. Residual anomaly map pretains the individual causative bodies were separated and shallow features are clearly highlighted in the residual anomaly map. Sources of anomalies that are shallow have a higher frequency as the signals can reach the detector In the regional anomaly map the circular magnetic bodies are present in the north eastern and south western region of the map , which indicates the depth of the subsurface archaeological structures.

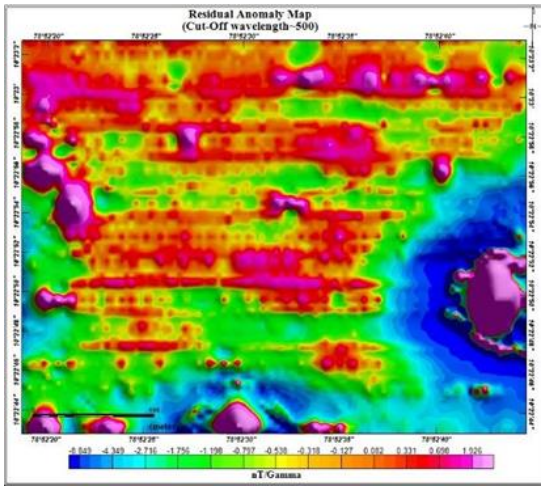






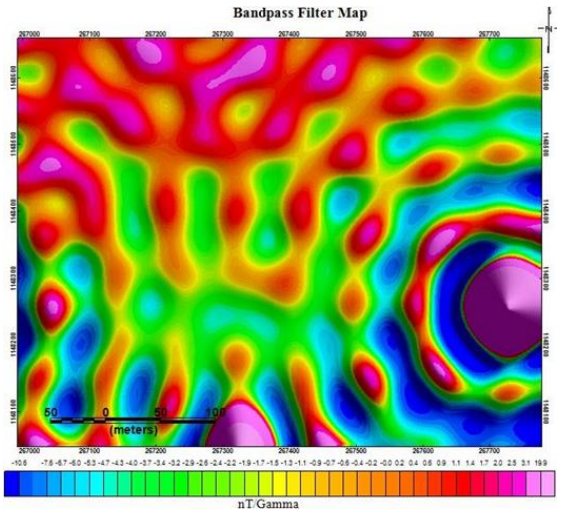
The residual anomaly map shows the magnetic value distribution along the near surface region. In the study area, there is a trend of magnetic high regions observed in the north eastern and south western region which coincides with the magnetic high recorded in the AS map. Numerous residual causative bodies in the near surface has been noticed in the surveyed area.





3. BANDPASS FILTER

The bandpass filter map was produced by applying FFT in Oasis Montaj. The bandpass is by removing the band of signals a wave number between 800 and 300m.This band represents the deep seated bodies in the area. Therefore, the signals at the right on the filter are the deeper causative bodies. The structures highlighted in this band pass filter map.



4. RADIALLY AVERAGED POWER SPECTRUM

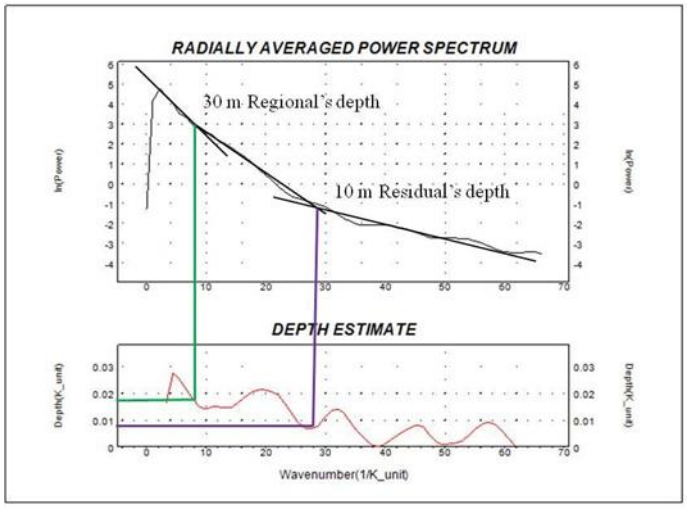
Radially averaged power spectrum is used to detect the depths of the shallow and deep sources, basement complex, and subsurface geological structures. Many authors have explained the spectral analysis technique (Spector and Grant, 1970; Gracia and Ness, 1994; Tatina and Angelo, 1998;). Fast Fourier Transform (FFT) has been applied to Analytical signal data to calculate the energy spectrum under geosoft environment. The resulted diagrams of the radially averaged power spectrum indicated the average depth levels to the deep and shallow segments. Depth of the causative body has been determined by calculating slope and then the slope has been used to estimate the depth using the formula [h=s/4 π]. Power spectrum shows residual anomalies occur at 10m depth and regional's anomalies around 30m depth. The profile shows only three slopes from which the above depth has been estimate

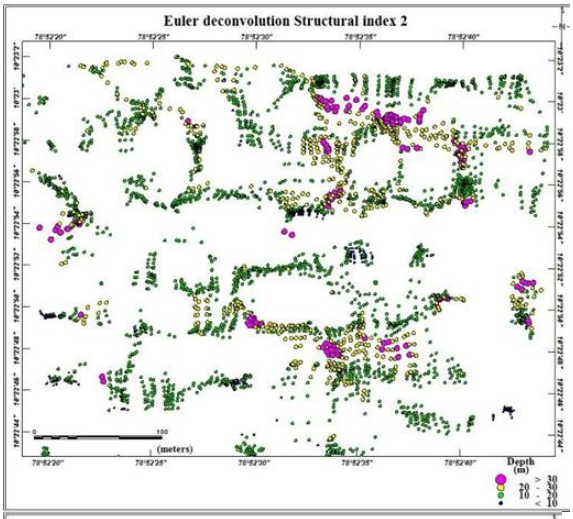
5. EULER'S DECONVOLUTION METHOD

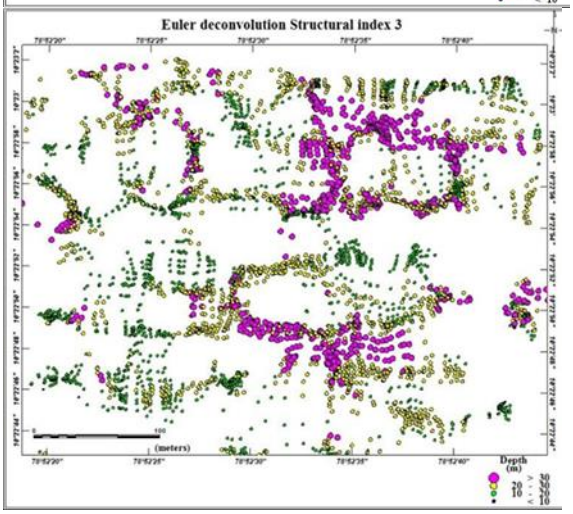
This method is used in the geosoft program, which is based on Euler's homogeneity equation.

Euler's homogeneity equation relates the magnetic field and its gradient components to the location of the source. According to (Reid et al.1990) and (Thompson 1982), the degree of homogeneity N has been interpreted as a structural index (SI). It is a measure of the rate of change of a magnetic field with distance. Proposed models like contacts are demarcated by the structural index N=0, the magnetic field of a narrow 2-D dyke has a structural index N=1, while a vertical pipe or horizontal cylinder has N=2 and the magnetic sphere has N=3. In the present study, the structural indexes that applied to Analytical signal map are 0,1,2,and 3 to select the best solution. Analytical signal map using SI=0,1,2, and 3 were prepared. Structural index 2 and 3 gives better solutions than structural index 0 and 1 because the depth clusters are concentrated in a spherical shaped at some places in the study area. The structural index 2 was taken for the interpretation also integrated with google satellite imagery and Magnetic maps.

4. DISCUSSION



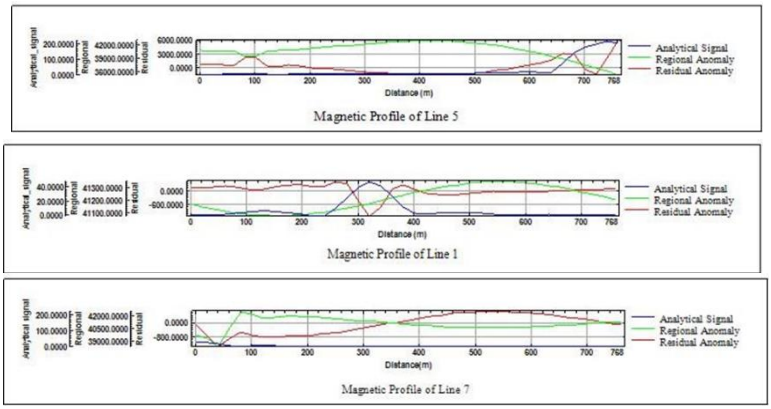




4.1. INTERPRETATION OF MAGNETIC PROFILES

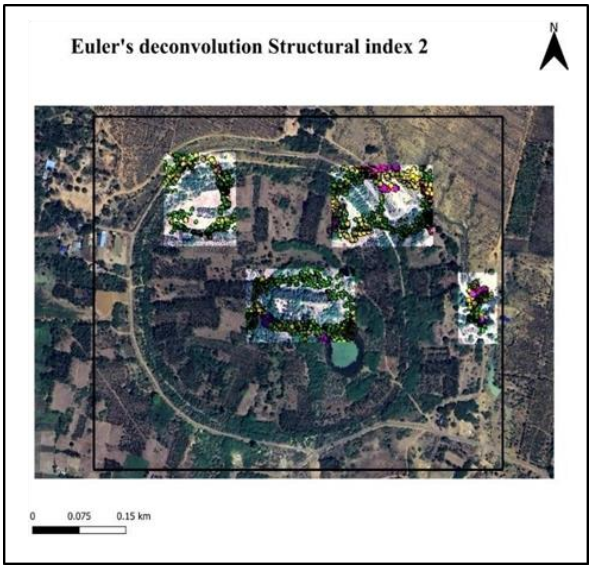
The profile interpretation of the various cut-off wavelengths of Regional, Residual and Analytical signal indicate anomalies which are an indication of susceptibility contrast of the buried structures. These profiles shows that the causative bodies are not evenly distributed across the study area. Profile number 1, 5 and 7 has been consider as very important due the presence of anomaly. The major differences were noticed in the profile direction. Profile 1 shows anomalous structure around the distance of 320m followed by 670m in profile 5 and finally around 90m in the profile number 7. All the profiles show some variations in that particular distance which is very significant either geological or archaeological purpose.

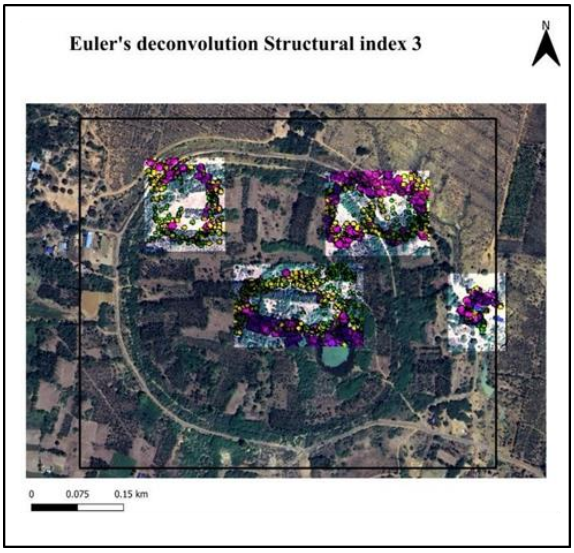
The profile also helps us to enhance our study.



4.2. INTERPRETATION OF EULER'S DEPTH WITH GOOGLE SATELLITE IMAGERY

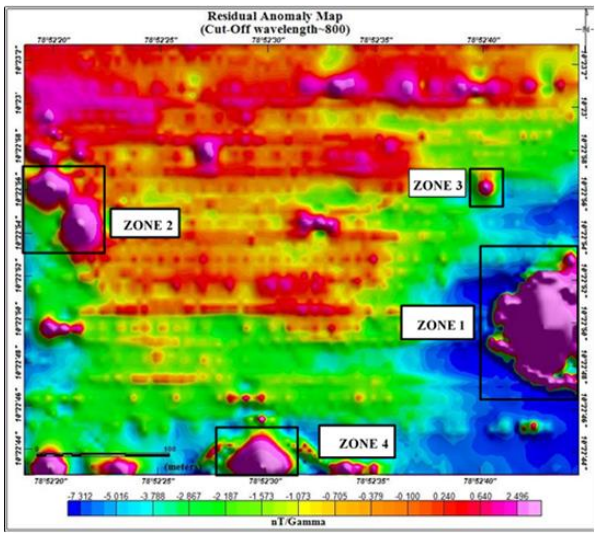
The Euler's deconvolution structural indices were integrated with Google satellite imagery By comparing, Euler's depth and google satellite imagery the spherical structures observed in the Euler's deconvolution structural indices of 2 and 3 have matched with the structure seen in the middle portion of the fort but not exactly fits to it because of the disturbance of geographical co-ordinates ,it is slightly elongated. The anomalies with the depth range of 20-30m were noticed in that particular zone because we found some destructional laterite bricks during our magnetic survey. These interpretations suggests us the any building may be built upon that zone now it may demolished.





4.3. PROPOSING A ZONES FOR DETAILED EXCAVATION

The perspective zones were proposed, based on the indication of subsurface structures from the regional, residual and bandpass filter maps. A prominent structures were noticed in 4 different location which lie in the eastern and southern part of the fort. The zones were suggested to the Geophysicist and archaeologist for future detailed excavations either by close spacing of magnetic survey or GPR method.



Zone	Location	Areal Extent	Approximate Depth
1	Zone 1	200x125m	30m
2	Zone 2	20x35m	10-20m
3	Zone 3	70x70m	20-30m
4	Zone 4	40x110m	20-30m

5. CONCLUSION

The multidisciplinary study has been carried out on the Porpanai Fort, Pudukkottai with the contribution of Satellite imagery and geophysical data. Magnetic maps such as analytical signal, regional and residual maps significantly indicated about the presence of shallow and deep causative bodies and the analysis of depth provides new interesting information about this important buried structures. The first advantage of magnetic data is the possibility of reconstructing the real geometry of the buried structures and their spatial distribution. It is clear that the possible evidence of the presence of the traces of the human prehistory. In addition to that, historical information about these structures were also gathered from the local peoples in that area. The satellite imagery provides the partial wall structure of the demolished fort. The lithological information were studied over the study area. The results of the multidisciplinary study carried out at the Porpanai Fort, here presented, allows us to obtain information of this ancient fort, also suggesting some preliminary considerations on the human civilization, and proposing a new perspectives and zones where the structures are noticed to the archaeologists for future excavations on this archaeological site.

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