ISSN (Print): 2476-8316
ISSN (Online): 2635-3490
Dutse Journal of Pure and Applied Sciences (DUJOPAS), *Vol. 4 No. 2 December 2018*

Ground magnetic signature over ancient buried Kiln at Sik, Kedah Malaysia

Yakubu Mingyi Samuel[1,3], Rosli Saad[1]*, Nordiana Mohd Muztaza[1], Mokhtar Saidin[2], Muhammad Sabiu Bala[1,4]
[1]Geophysics Programme Universiti Sains Malaysia, 11800, Penang Malaysia
[2]Centre for Global Archeological Research Malaysia, 11800 Universiti Sains Malaysia Penang.
[3]Department of Sci. Lab. Tech, Federal Polytechnic Damaturu, Yobe State Nigeria.
[4]Usmanu Danfodio University Sokoto, Nigeria.
Email: rosli@usm.my

Abstract

Ground magnetic data were acquired on a grid pattern over an ancient buried kiln at Sik, Kedah Malaysia. The objective of the survey was to study and interpret the response of the targets towards ground magnetic sensor. The data were acquired using Geometrics G856 proton magnetometer for rover stations, while GEM system 19T proton magnetometer was used for base station. Conventional diurnal correction was carried out on the data to correct the variation of the Earth's magnetic field and this was followed by regional-residual separation to isolate anomaly of interest. Thereafter, the residual data were gridded and contoured to produce residual magnetic intensity contour map. Qualitatively, the map revealed variation in magnetic field intensity and was identified into low (-90 to -10 nT), medium (10 to 30 nT) and high (10 to 80 nT) zones. A dipolar magnetic anomaly with intensity ranging between -96 to 80 nT was observed at the mid southwestern flank of the survey area. A perpendicular profile AA' was drawn N-S crossing the suspected anomaly and plotted to produce profile curve. The curve was then compared with templates of common magnetic anomaly curves of some archaeological features and it was found to correlate with the anomaly curve that describes a baked (clay) kiln. The study further buttresses the reliance of the magnetic method as a suitable tool in archaeological studies.

Keywords: Ground magnetic, buried kiln, baked clay, archaeological studies

1. Introduction

Geophysical imaging techniques are becoming popular in archaeological projects used to delineate, describe, or image cultural remains (Weymouth, 1996; Roger *et al*., 2012; Gaber,*et* al., 1999; Carr, 1982; Young and Droege,1986; Tite, 1972; Chuker, 2001). The techniques are non-invasive, cost-effective and provide rapid coverage to explore large areas in lesser time. In addition, advent of computers in the last two decades has revolutionized the use of geophysics as a remote sensing technique in subsurface investigation. This has provided a means by which a large volume of data can be processed fast and efficiently with high resolution result which enables archaeologists to optimize their resources and increase the effectiveness of excavation.

**Author for Correspondence*

Recently, geophysical methods have been employed in several works related to archaeology around Sik, Kedah, Malaysia. Nordiana *et al.* (2014) conducted a 2-D resistivity and ground magnetic survey with the objective of identifying the extent of a furnace. The results indicate an anomaly of interest with low resistivity and high magnetic contrast and was interpreted as baked clay. Norhidayati *et al.* (2012) applied ground penetrating radar (GPR) to detect buried archaeological structure at Kampung Sungai Perahu, Jeniang Kedah. The GPR successfully detected an ancient Kiln. These previous studies have shown the suitability of geophysical methods as a reliable tool in archaeological investigations.

This paper presents ground magnetic signature over a buried archaeological remains (kiln) at Sik, Kedah. The method was informed by the fact that it is one among other geophysical methods that is efficient and commonly used in archaeological studies since most archaeological targets have distinct magnetic properties which distinguish them by the anomaly pattern they created (Smekalova and Smekalov, 2008; Calabres *et al.*, 2003).It was first used in the 1950s (Belshe, 1957; Aitken, 1974) and proven in detecting topsoil or subsurface property that has been disturbed by human activities (Breiner, 1999; Clark, 2013). It is also attractive for its cost-effectiveness, with less crew members needed.

2. Theory

Magnetic susceptibility, k, which is the tendency of a substance magnetized by the Earth's magnetic field forms the basis of magnetic prospecting (Dalan, 2006). Magnetic method measures the distribution of magnetic susceptibility of the subsurface materials which manifest as magnetic anomaly. Generally, the targets of magnetic survey are the magnetic anomaly which may be positive or negative depending on whether the contrast is higher or lower than the surrounding medium.

Theoretically, magnetic method can be explained using the concept of magnetic dipole which can easily be understood from a simple bar magnet. A bar magnet has two equal and opposite poles (dipolar) existing in pairs with a positive (north-seeking) pole and a negative (south-seeking) pole. The poles produce magnetic field, **H**. In the presence of an external magnetic field such as the Earth, a magnetizable body will be magnetized and produce a secondary magnetic field based on the magnetic polarization of the material. The relation shown in Equation 1.

$$\mathbf{M} = k\,\mathbf{H} \qquad (1)$$

where, k is magnetic susceptibility. The total field, **B**,with the unit of Tesla, is the sum of external field and magnetization expressed in Equation 2.

$$\mathbf{B} = \mu\,(1 + k)\,\mathbf{H} \qquad (2)$$

where,μ is magnetic permeability of free space. The amplitude of **B** is what the instrument measures and it is called the total field.

Rocks and soils have variable magnetic susceptibilities. The susceptibility of rock is highly dependent on magnetic mineral content. Sedimentary rock has the least magnetic susceptibility; followed by metamorphic rock, while igneous rock has the highest susceptibility (Dobrin, 1976). On the other hand, soil has a variable magnetic susceptibility depending on the magnetite content of the parent rock, even though pedogenesis enhancement also leads to increase in magnetic content of soil (Meg, 2013). Figure 1 shows magnetic susceptibility range of some common rocks (Dobrin and Savit, 1988).

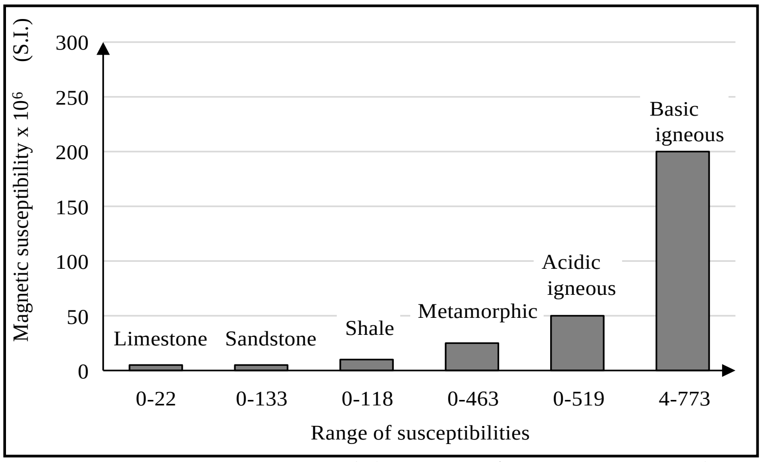

Figure 1. Magnetic susceptibility range of some common rocks (Dobrin and Savit, 1988).

3. Location and geology of the study area

The study area is located at Kampong Padang CicakSik, Kedah (Malaysia). It is situated close to a river and residential area which is bounded by latitudes 5.933° N to 5.9336° N and longitudes 100.6785° E to 100.6787° E. Figure 2 shows the map of the study area with two kilns of 1.4 m diameter discovered onsite. Geomorphologically, the area is relatively flat having some planted rubber trees and bushes. Sik is part of Sungai Petani formation which consist of shale, siltstone, sandstone, orthoquartzite and homologous with Mahangformation (Jane, 1990). The soil is characterized with fine sandy clay. Figure 3 shows the geological map of Sik, Kedah(Malaysia).

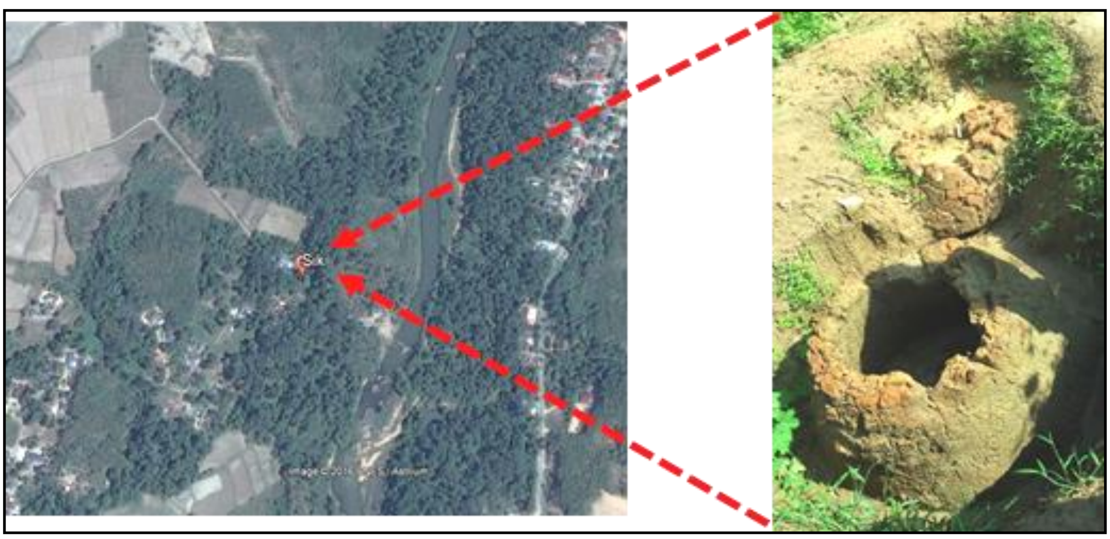

Figure 2. Location of the study area showing two discovered Kiln (Google Earth, 2016).

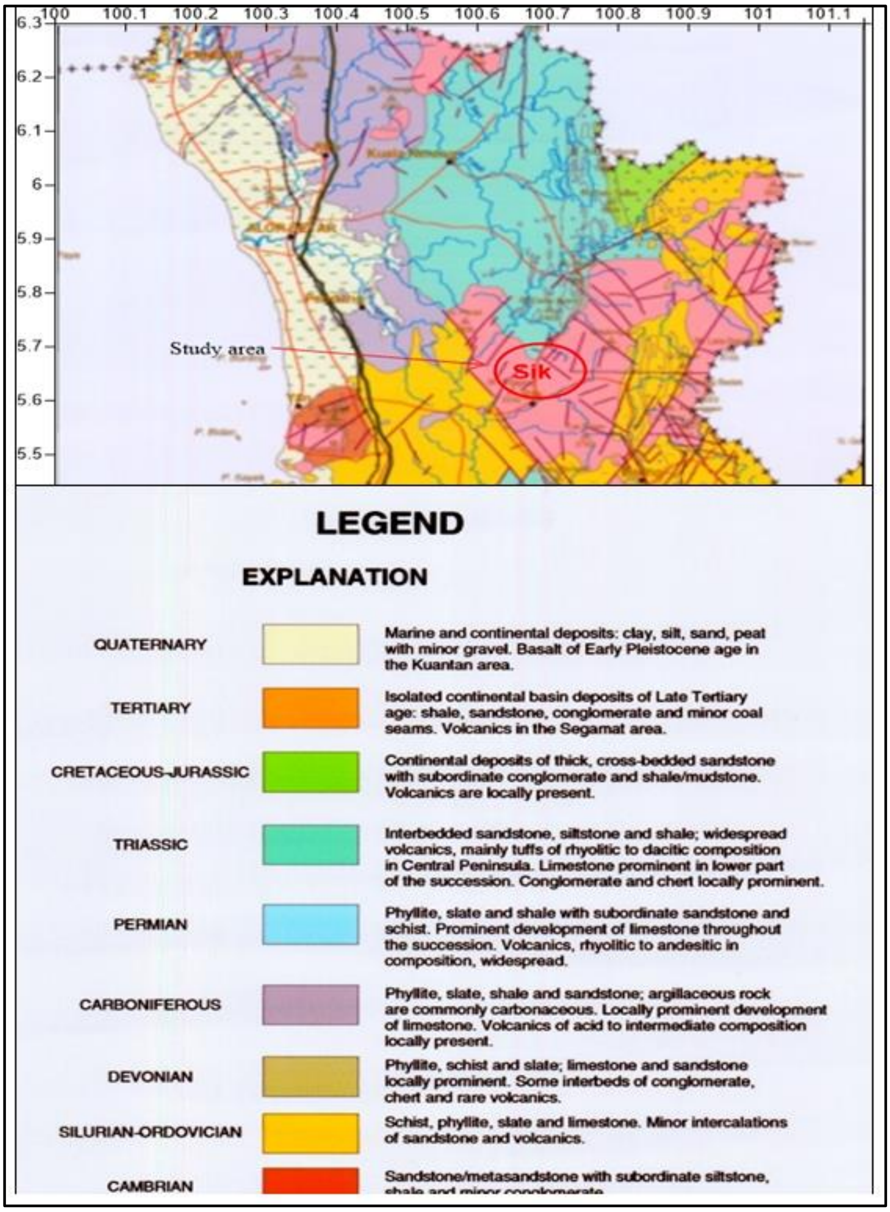

Figure 3: Geological map of Sik, Kedah
(Geological map of Peninsular Malaysia, 1985).

4. Methodology

A ground magnetic survey was conducted using Geometrics G-856 proton precision magnetometer for rover stations with hand-held Garmin Global Positioning System (GPS) for real time measurement, while GEM system 19T magnetometer placed at a carefully selected location free from magnetic noise was used for base station, and readings were continuously recorded at sixty (60) seconds interval (Fig.4). Grid data were acquired on close line spacing at a grid interval of 0.5 m to achieve good accuracy in determining the target. At end of the survey, data from both consoles were downloaded, synchronized, and diurnal correction was applied to account for the variation of the Earth's magnetic field, while regional-residual separation was performed to isolate anomaly of interest (Breiner, 1999) using Microsoft Excel application software. Thereafter, the data were gridded and contoured using surfer 8 golden software to produce residual magnetic contour and 3-D surface maps.

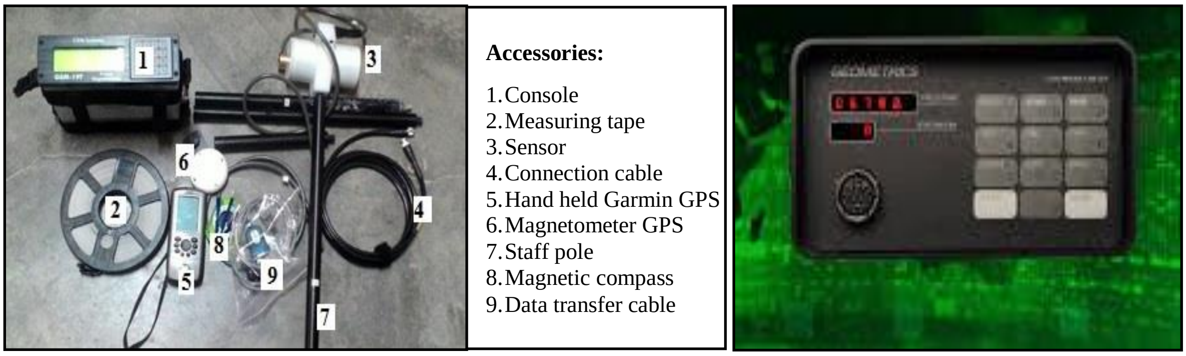

Figure 4: Magnetometer; (a) GEM system 19T and (b) G-856 console box

5. Results and discussion

Figure 5 shows magnetic residual contour map of the study area. The area is covered with varying residual magnetic field intensity with amplitude as low as -120 nT and as high as 80 nT. Generally, the area is categorized into three magnetic anomalous zones; low zone, (-90 to -10 nT), medium zone (10 to 30 nT) and high zone (40 to 80 nT). The high amplitude (80 nT) appearing concurrently with low amplitude (-120 nT) as dipolar anomaly located at the southwestern part of the map are interpreted as suspected anomaly of interest (kiln). Abrahamsen *et al.* (1998) and Smekalova and Smekalov (2008) reported kiln is associated with high amplitude anomaly because its magnetic property had been modified by fire. The medium zone indicates the background reading and covered most part of the area. Few pockets of negative anomalies (-30 to -10 nT) observed at the centre area but more predominantly at the western flank. These could be response from materials of low susceptibility such as sediments (Keary and Brooks, 2002).

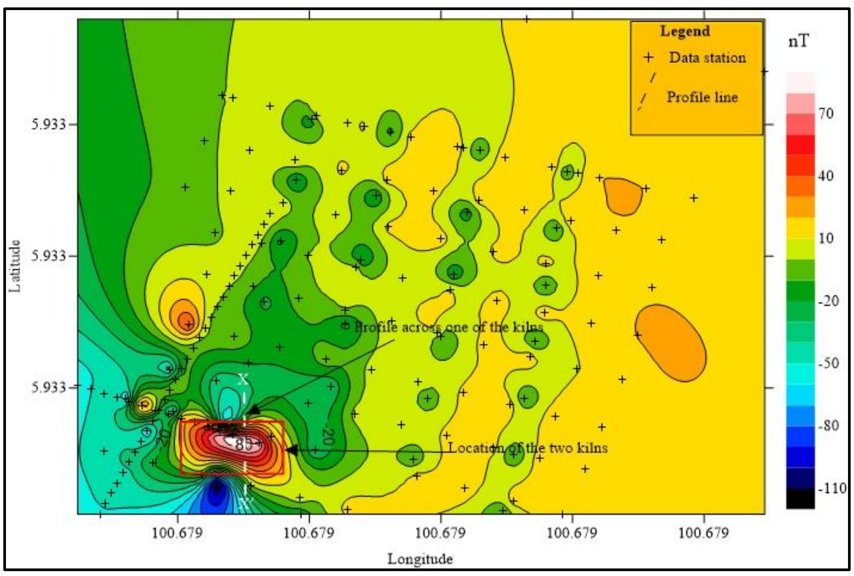

Figure 5: Residual magnetic intensity map of the study area.

Figure 6 shows 3-D surface map indicating high amplitude anomalies generated by two adjacent kilns with amplitudes at 40 and 80 nT respectively, while low intensities in the area appeared as depression.

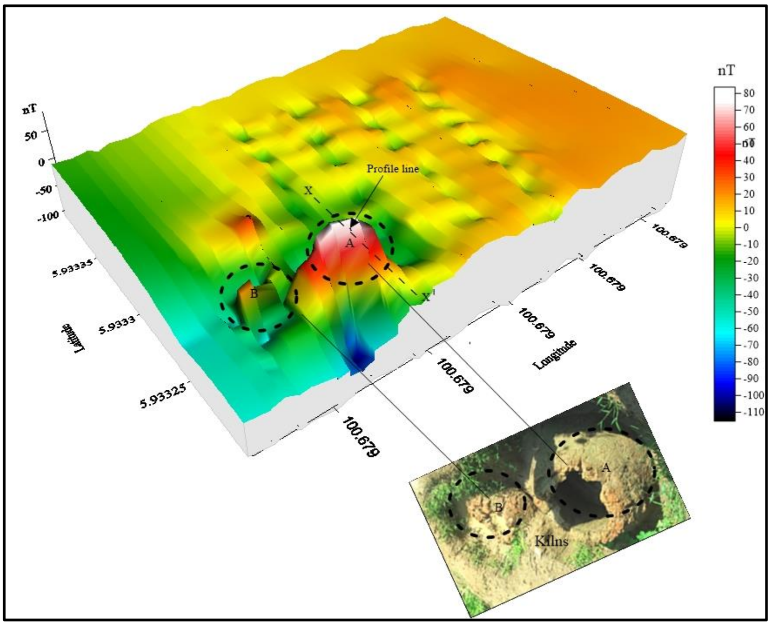

Figure 6: 3-D surface map of residual magnetic anomaly of the suspected target.

A profile line XX' drawn perpendicularly crossing one of the suspected target generated a curve with peak at 80 nT(Fig.7). The curve has similar pattern with anomaly curve from a template of common archaeological feature and is interpreted as kiln-baked clay (Breiner, 1999). Similar studies conducted by Noel (2001) at a Medieval pottery Kiln, revealed kiln is associated with high magnetic field intensity. Nordiana *et al*. (2014)conducted 2-D resistivity imagingat the same site where low resistivity anomaly was observed over the suspected target; these previous results confirm the observed magnetic signature is due to the kiln at the site.

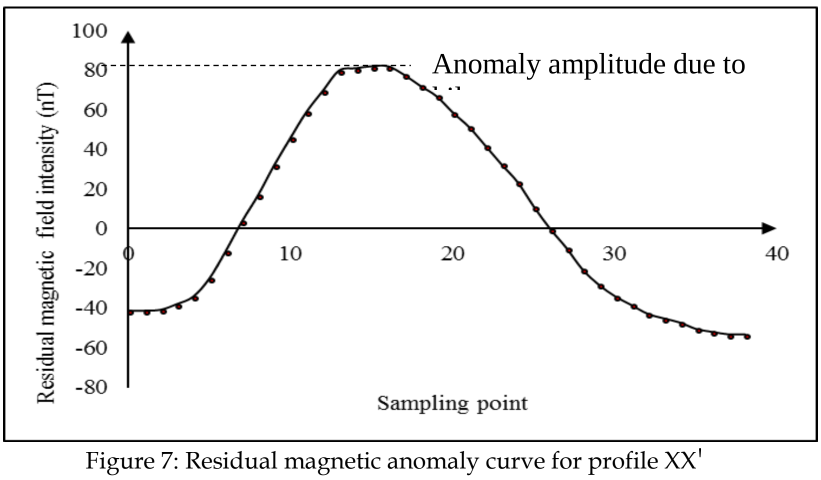

Figure 7: Residual magnetic anomaly curve for profile XX'

7. Conclusion

Ground magnetic survey conducted across baked kilnsat Sik Kedah categorized the area in to three magnetic anomalous zones; low zone (-90 to -10 nT), medium zone (10 to 30 nT) and high zone (40 to 80 nT). The study could identify the kiln based on its high amplitude magnetic contrast as well as similarity in profile curve which matched the template of curves from common archaeological remains. The study agrees with result from other geophysical survey conducted at the site. This buttresses the importance and reliance of magnetic method as a tool for archaeological investigation.

Acknowledgements

The authors thank the technical staff of the geophysics laboratory and geophysics postgraduate students, School of Physics, Universiti Sains Malaysia for their assistance during the data acquisition and Centre for Global Archaeological Research (CGAR) Universiti Sains Malaysia for sponsoring the project.

References

Abrahamsen, N., Jacobsen, U., Mejdahl, V., &Mejdahl, U. (1998). Magnetic investigations and datings of a brick kiln at Veldbaek near Esbjerg (Denmark). *Physics and Chemistry of the Earth*, *23*(9), 1015-1019.

Aitken, M.J. (1974). *Physics and archaeology,* 2nd edition. Oxford: Clarendon Press, 286 pp. Aitken, M.J., Webster, G., and Rees, A. (1958). Magnetic prospecting: *Antiquity* 32, 270-271

Belshe, J.C. (1957). Recent magnetic investigations at Cambridge University. Advances *in Physics* 6,192193.

Breiner, S. (1999). Application Manual for portable Magnetometer, San Jose, USA: Geometrics

Calabrés, C., Pinto, V., Tapias, J. C., & Casas, A. (2003). Magnetic mapping and soil magnetic properties applied to the heritage preservation of Roman kilns. *Bollettino di GeofisicaTeorica ed Applicata*, *44*(3-4), 181-191.

Carr, C., 1982, Handbook on soil resistivity surveying. Centrefor American Archaeology Press, Evanston

Chouker, F. (2001). Archaeological site investigation by geoelectric measurements in Tel-Halawi (Northern Syria) Archaeological Prospection, Vol 8, issue 4, p 257 – 263

Clark, A.J (2013), Magnetic Susceptibility in Archaeological Prospecting, AN0009 13/05

Dalan, R. (2006), A geophysical approach to buried site detection using down-hole susceptibility and soil magnetics techniques, archaeological prospection 13:182-206

Dobrin, M.B. (1976). *Introduction to geophysical prospecting* McGraw-Hill, New York. Dobrin, M.B. and C.H. Savit, (1988). Introduction to Geophysical Prospecting. 4th Edition McGraw Hill Book Co., New York.

Gaber, S., El- Fiky, A.A., AbouShagar,S. and Mohamaden, M.(1999). Electrical Resistivity Exploration of the Royal Ptolemic Necropolis in the Royal Quarter of Ancient Alexandra, Egypt, Archaeological Prospection,6: 1-10

Geological Map of Peninsular Malaysia (1985). Minerals and Geosciences Department Malaysia, 8th Edition.

Google Earth (2016)

Jane, A. (1990). Trade and site Distribution in early historic –period Kedah geoarchaeological historic and locational evidences.

Noel, M. (2001). Archaeomagnetic Study of a Medieval Pottery Kiln at St. Michael's Terrace, Spring Hill Lincoln. *Centre for Archaeology* Report 41.

Keary, P and Brooks, M (2002) An Introduction to Geophysical Exploration Pergamon Press London.

Meg Watters Co-PI, Remote sensing and visualization Coordinator Time Team America, Series 2 Oregon Public Broadcasting April, 2013.

Nordiana, M.M., Rosli, S., and Mokhtar, S. (2014). 2-D Resistivity Imaging of Buried Furnace at Sik, Kedah (Malaysia)," Electronic Journal of Geotechnical Engineering (EJGE), Vol. 19, Bund. Z6 17635-17642.

Norhidayahti, M.M., Mokhtar,S., Azwin, I.N., and Rosli, S. (2012). 3-D GPR mapping for excavation plan in Jeniang Kedah Malaysia "International Journal of Environmental science and Development Vol.3, No. 6.

Roger Sala, Ekhine Garcia and Robert Tamba. (2012). Archaeological Geophysics - From Basics to New Perspectives, Archaeology, New Approaches in Theory and Techniques, Dr. ImmaOllich-Castanyer (Ed.), ISBN: 978-953-51-0590-InTech, Availablefrom:

http://www.intechopen.com/books/archaeology-newapproaches-in-theory-and-techniques/archaeological-geophysics-from-basics-to-new-perspectives

Smekalova, T.N, Voss, O. and Smekalov, S.L (2008), Magnetic Surveying in Archaeology; 2nd revised edition,

Tite, M.S., (1972). Methods of physical examination in archaeology; Sminar Press.

Weymouth, J. (1996). Magnetic survey of archaeological Sites in the knife River Indian Village National Historic Site: Small and Non- Village sites. Manuscript, Midwest Archaeological Center, Lincoln.

Young, C. T and Droege D. R., (1986) Archaeological applications of resistivity and magnetic methods at Fort Wilkins state Park,Michigan.Geophysics Vol 51 No. 3 575-58.