Self-Potential Investigation for Near-Surface Depression Delineation in Seikanian Kirkuk, Iraq

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Abstract
Seikanian is a new suburban in Kirkuk city rich in many environmental problems, it encloses different topographic features such as depressions and open holes which are obstacles for future civilian development. Geophysical surface self-potential method is applied to delineate the location and dimension of the depression. Three survey lines, gradient, total field and gradient-profiling are chosen and taken for recording the SP measurements in addition 18 grid points spread around the open hole. The acquired data is rendered into curves and contour maps. The interpreted gradient, total field and gradient-profiling surveyed SP line curves revealed a clear anomaly which indicate the location of the depression structure, the SP observed, residual and first order horizontal derivative contour maps delineate the boundaries of the depression. The depth of depression is between 1.8-3.3 m.

Keywords: Self-potential; Depression; Gradient; Total field; Interpretation; Kirkuk; Iraq

1. Introduction

Geophysical methods provide information about the physical properties of the earth, its subsurface (Kazemi, 2012). Geophysics is an important science which has potential to discover subsurface of the earth materials, it includes different methods, one of those is self-potential (SP) or spontaneous-potential technique. Different geophysical methods have been used to identify near surface caves such as magnetic, gravity, seismic, electric resistivity, ground penetration radar and self-potential (Jardani et al, 2006). Geophysical surface self-potential method is used in hydrology, Environmental, geotechnical and mineral investigations (Oliveti and Cardarelli, 2017), previously it has been applied in qualitative interpretation only but recently it is essentially carried out for quantitative analysis of the acquired data (Oliveti and Cardarelli, 2017).

The self-potential is measured in millivolts (mV), it is a naturally occurring electrical potential between two electrodes on the surface. They are three mechanism that product self-potential signals, the first is the streaming potential produces by the fluid flows, the second is electrochemical potential produces by different electrolytes concentration and the last is potential which obtain from temperature gradient. The self-potential signals on the surface of the earth are product by the natural electric current and subsurface structure resistivities as Ohm s law, resistive zone would give positive anomaly while the conductive zone gives negative one (Oliveti and Cardarelli, 2017).

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There are abundant explorations concerning conducted in archeology site, Aqar Quf (Iraq) (Ekbal, 1985), the acquired data create a thermal gradient and SP maps which are correlated with the old remains. The deduction was that the low values of SP associated with the old building walls have low thermal amount and more strength than the surround background. A modeling of self-potential technique to detect a cave was discussed by (Yervant and Morgan, 2002), according to the constructed model cave they expect the positive anomalies over cavities unless the cavity is filled with a conductive medium, such as water and concluded that the SP is useful geophysical method to detect caves.

Self-potential signal associated with preferential groundwater flow pathways in sinkhole has been studied in Normandy (Jardani et al, 2006), the SP indicated the position of the sinkholes and crypto-sinkholes in chalk formation, the negative SP signals are associated with downward percolation of the meteoritic water between surface and clay formation. Self-potential tomography applied for the determination of cavities in Normandy North-West of France, a resulted SP map shows a negative anomaly associated with the position of the marl pit (Jardani et al., 2006).

Self-potential and electrical resistivity methods survey carried out on karst prehistoric cave located in southern Italy by (Quarto and Schiavone, 2006) to determine its possible extension. Fixed base survey was used in this work, many anomalies are found which related to the cavities but there is no correlation between SP and electrical resistivity results because of the existence water through the fractures and voids in the caves.

At coal-mine near Shrewburg in United Kingdom, where (Pringle et al., 2008) were carried out near-surface geophysical investigation using different geophysical methods namely, microgravity, electrical resistivity, magnetic and self-potential as well. The SP data revealing a number of marked and characterized anomalies.

A subsidence in Butte Montana USA has been studied (Kristen et al., 2018), it produced from mineshafts which occurred throughout urban development, they applied self-potential method over the circular depressions and found that SP maps support electrical resistivity and electromagnetic results by mapping underground flow along the sediments. The aim of the study is the potentiality of geophysical self-potential method to delineate the depression and its dimensions.

2. Materials and Methods

2.1. Study Area Location and Geological Site Description

The present study area of 424m Elevation is located in Seikanian suburban, Kirkuk city between latitudes (35º 55' 46 - 35º 56' 23' N) and longitudes (44º 35' 39' - 44º 36' 27' E) within the northeastern limb of Kirkuk Anticline (Fig.1). Its subsurface is characterized by inclined beds compose of sandstone, claystone and conglomerate of lower Bakhtiari Formation, the near-surface soil composes of sandy clay with gravel soil. Because of different geomorphology and hydrology situations in the Seikanian area therefore it is rich in many topographies features as small valleys, trenches, open holes and depressions. The recent depression is a small structure, it is open hole filled with air the upper mouth is covering by grass and bush that be dominates in spring time make its features be disappear.
2.2. Field Work

Self-potential survey is achieved by electrical potential difference measurements between two electrodes either by a profile line or it spread over the studied area as a grid point. Environmental problems like cavity, karst, sinkhole and collapse forms different hazards for urban development urge the engineering to held investigations about them.

The self-potential field measurements are applied by three survey procedures, gradient (frog leap), total field (fixed base) and (gradient-profiling spread). In gradient technique the two non-polarized electrodes are moved successively with constant spacing along the surveying line, in total one of the electrodes is fixed in a base as reference electrode while the other is moving in a certain spacing along the surveying line. In this investigation, the gradient-profiling spread is applied, the couple electrodes of constant spacing are moving forward in 1.5m offset in the progressions (Fig.2). The SP device consist of digital voltmeter and two non-polarized electrodes comprises of copper rods immerse in copper sulphate solution to make ionic contact with the ground with aid of porous base solution pots, the SP instrument is available in applied geology department, Kirkuk university.
Field works include the application of three survey techniques which are gradient, total field and gradient-profiling, where the gradient line of 19m length in E-W direction adjacent to the depression mouth, 1 m apart and spacing electrodes 3m was set out showing in Fig.3 in addition gradient-profiling line perpendicular to the first one of 15m length and 3m spacing profiling in 1.5m distance from the depression and the roving electrodes of 1.5 m offset was set out as well. The total field surveyed line was 1m away from the depression and 3m electrodes spacing of 25m length in E-W direction also. In order to gain additional data in the investigation we applied a grid point measurement around the depression (18 points) which might give a good image and results in the interpretation of the recent environmental problem. As the field work achieved in spring time which characterize moderate in temperature, and the measurements were taken in short time So the SP acquired data did not need correction for the any expected drift problem.

![Site plan shows survey lines and SP points](image_url)

**Fig. 3.** Site plan shows the survey gradient, total and gradient-profiling lines of the depression site.

### 3. Results and Discussion

The self-potential acquired data are rendered into profile curves and Surfer software is employed to construct observe contour map by kriging interpolation operation of the SP data, the regional map is yielded using third order polynomial operation, finally the SP residual map is gained by subtracting the regional from observe map by surfer program option. The SP gradient line curve, (Fig.4) shows positive minima is 10.2 mV and has positive maxima 37.5 mV, the curve form characterizes by increasing the SP values from outward into the direction of the depression in left fig between 0-5m distance ending with distinct inclined anomaly.

![Gradient surveyed line SP curve](image_url)

**Fig. 4.** Gradient surveyed line SP curve
The gradient-profiling SP curve line (Fig. 5) has positive minima of 10.5 mV and 26.5 mV positive maxima, there is decreasing in the values terminating with definite anomaly which comfort to the hole structure location.

![Gradient-profiling line](image)

**Fig. 5.** Gradient-profiling surveyed line SP curve

The Total SP curve line (Fig. 6) shows anomaly of 29 mV negative maxima and 13 mV negative minima, it reveals semi-even but ending with clear anomaly before the depression boundaries in a few meters. The negative SP values in this technique may belongs to the nature of survey procedure in which the SP measurements are yielded in cumulative mode.

![Total line](image)

**Fig. 6.** Total surveyed line SP curve

The observe SP contour map (Fig. 7) represent the measured field grid SP points around the depression poses many oval positive and negative anomalies, there are 40 mV and 15 mV positive maxima and negative 25 mV and 15 mV minima. The depression which is located at the (0, 0) coordinate of the map (red circle) is a crossed by the minimum positive and negative 5 mV SP contour lines in which its diameter about 3m.
The regional SP contour map (Fig.8) is comprised of abroad positive and negative contour lines which may represent the self-potential signals of the top soil of area which consider as regional effect, the positive lines range (5-35) mV and (5-25) mV negative.

The residual SP contour map compose of semi-circular anomaly of 25 mV positive maxima and (5, 15) negatives which represent the ultimate top soil, all these anomalies are distinctly bounded the open hole (Fig.9) in which its diameter about 3m (red circle) and passed by the positive and negative (5, -5) mV contour lines.
Many techniques have been used in geophysical interpretation especially in potential signals to determine the geological subsurface structures boundary, one of such applied techniques is the first order horizontal derivative on the residual SP contour map by using surfer software option to identify the depression boundaries (Fig.10), a characterize of positive (10, 18) mV and negative (10, 16) mV SP anomalies surrounding the depression is revealed with more enclosed sight by positive and negative 2 mV contour line, its diameter about 3m.
The First order horizontal derivative SP 3D image (Fig.11) shows the boundaries of the depression clearly (red circle), it is bounded by many positive crests with negative sinks of SP anomalies.

**Fig.11.** First order horizontal derivative SP 3D image (the red circle shows the Boundaries of the depression)

As it has been realized that self-potential acquired data not only contribute in qualitative interpretation but also in quantitative analysis recently for different geological subsurface materials dimension. Many researchers (Adeyemi et al., 2006; Babu and Rao,1988; Hafez, 2005; Maur,2009; Nwsou, 2011) have used conventional methods in depth delineation of the SP anomaly curve, one of that is graphical Half-Max width method which is applied in potential magnetic data interpretation which used by (Adeyemi et al,2006) and (Nwsou, 2011) \( Z=2X1/2 \). The depression depth giving by gradient curve anomaly interpretation of Half- Max width is 3m and total curve is 3.3m, while depth estimation for gradient-profiling curve is 1.8 m which is close to the actual depth of (2 m) (Fig. 12).

**Fig.12.** Half-Max width interpretation of the gradient-profiling surveyed curve anomaly of Seikanian

The three-survey gradient, gradient-profiling and total field methods of surface self-potential investigation for the depression data interpretation yield different curve schemes, but could delineate the location by obvious anomalies with less precisely the total field did. Gradient and total field survey measurements provided excess depth estimation while the gradient-profiling gave the correlated one. Observe, residual and first order horizontal derivative constructed contour maps successively define the
boundaries of the depression indicated by many peripheral positive apex and negative sink SP anomalies it enclosed the minimum positive and negative contour lines value in the that maps.

4. Conclusions

Geophysical self-potential SP method shows powerful potential tool in delineating the near-surface depression by ID and 2D field investigation, it could virtually determine the location and dimensions of the structure. The interpreted gradient, total field and gradient-profiling surveyed SP line curves revealed a clear anomaly which indicate the location of the depression structure, the SP observed, residual and first order horizontal derivative contour maps delineate the boundaries of the depression. The depth of depression is between 1.8 - 3.3 m and diameter about of 3 m.

Recommendations

We appeal the geophysicists to achieve more self-potential research in environmental problems because it being a significant tool in many near-surface geological investigations in the world, recently its quantitative interpretation of the acquired data is lately concern issue.

References


