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Derivation of the Thin Dike Self-Potential (SP) Expression from the Thick Dipping Dike Expression

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Abstract

Hitherto the derivation of the analytical expression of the self-potential (SP) anomaly over a thin dipping dike had been viewed as not related to, but distinctively different from the same over a thick dipping dike. This work derived and deduced the thin dike SP anomaly expression from the thick dike SP anomaly expression. The result shows the inter-relationship between the two, and is consistent with results obtained by previous authors.

Keywords: Self Potential, thin dike, thick dike, anomaly, expression.

1.0 Introduction

Sittig [1}, described the self-potential (SP) method as a natural electrochemical geophysical method in which electrochemical processes cause ore bodies to act as batteries. The ensuing electric current is produced by separate but simultaneous reduction of oxidation of oxidizing agents near the surface and the oxidation of reducing agents at depth [2]. The ore itself does not participate directly in either reaction, but serves as a conductor to transfer the electrons from the reducing agents to the oxidizing agents. It is the differences in oxidation potential of ground water at different depths that makes it possible for such reactions to occur. This results in the surface of the earth over the top of the ore body to have a negative potential with respect to the surrounding area [1]

According to [3], a potential difference exists between electrodes when two dissimilar metal electrodes are immersed in a homogenous solution; this electrolytic contact potential, along with the static self-potential, is among the basic causes of the large potentials associated with certain mineral zones and are known as mineralization potentials. These potentials are especially pronounced in zones containing sulphides, graphites and magnetites; and are the main interest when prospecting with the self-potential method [4, 5]. The potential observed at the field point depends exclusively on the distance from that source and is not modified except if the source itself changes [3].

The quantitative interpretation of SP data is usually accomplished by approximating the causative source to a physical model [6 - 8]. The most commonly used models in SP profile interpretation include polarized rod and sphere, which are three-dimensional; horizontal cylinder and the thin dipping sheet, which are two-dimensional, among others [3]. Many authors had worked on some of these models. In all these works, the use of mathematical bodies in the modelling of the SP data to obtain the geometry of the causative body was shown to be indispensable [9 - 13]. While mathematical models used in the quantitative interpretation of SP data centred mostly around the geometries earlier mentioned the dike as a model had usually been avoided. The dike, thin and thick, is a very important geometry used in mining Geophysics. The thin dike resembles a thin sheet in many respects.

2.0 Methodology

Telford [4] showed that the potential due to thin dipping sheet at a point P on the surface is given by:

$$V = \rho \frac{I}{\pi} \ln \frac{r_1}{r_2} \qquad (1a)$$

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where r_1 is the distance of the upper edge of the sheet from the point of observation;
r_2 is the distance of the lower edge of the sheet from that same point of observation;
ρ is the resistivity of the medium; and
I is the current density.
Makinde [14], showed that the analytical expression for SP anomaly over a thin dipping dike (Fig. 1), which can be used to facilitate the quantitative interpretation of SP data over such a body is,

$$V = \frac{2Pb\sin\delta}{2\pi\varepsilon_0}\ln\frac{r_1}{r_3};$$ which can be re-written as

$$V = \frac{Pt}{2\pi\varepsilon_0}\ln\frac{r_1}{r_3} \qquad (1b)$$

where P is the magnitude of volume polarization and t = 2b sinδ
Makinde [3, 14], showed that the analytical expression for SP anomaly over thick dipping dike (Fig. 2), which can be used to facilitate the quantitative interpretation of SP data over such a body, given that M = (H – h) cot δ and other parameters are as defined in Figures 1 and 2 is,

$$V = \frac{P\sin\delta}{2\pi\varepsilon_o}\left[x\ln\frac{r_1 r_4}{r_2 r_3} + b\ln\frac{r_1 r_2}{r_3 r_4} + M\ln\frac{r_3}{r_4} + H(\phi_4 - \phi_3) + h(\phi_1 - \phi_2)\right] \qquad (2)$$

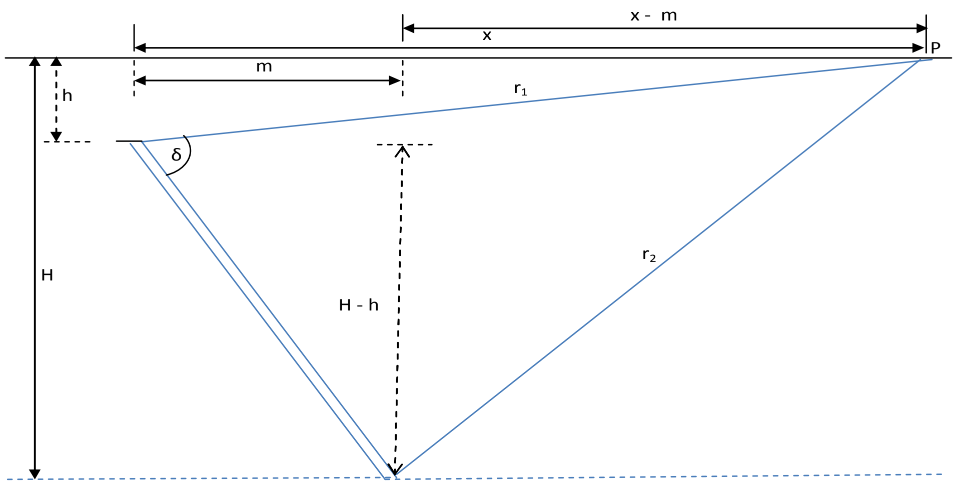

Fig. 1: Parameters of the Thin Dike

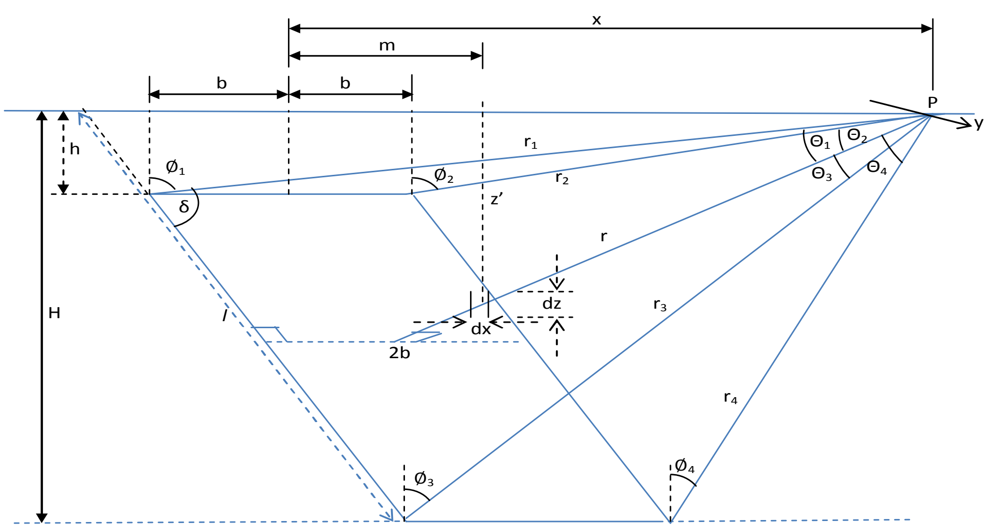

Fig. 2: Parameters of the Thick Dike

Equation (2) is the complete analytical expression for the SP anomaly obtained on a profile across the strike of a buried thick dike polarized along its dip direction.
In this work, an attempt was made to reduce the above analytical expression for the SP anomaly over a thick dike to that obtained over a thin dike using some collapsing equations and approximations.

3.0 Comparison of the Thick Dike SP Anomaly with the Thin Dike SP Anomaly

The thick dike SP anomaly given in eq. (2) readily reduces to the corresponding thin dike anomaly given by eq. (1b) if and when the following observation(s) and reductions are applied.
It was observed that the thickness of the thin dike is negligible when compared with that of the thick dike.
The implication of this important and all-embracing observation on the thin dike is that for the thick dike,

i) $r_1 \rightarrow r_2$; and $r_3 \rightarrow r_4$ ii) $\phi_1 \rightarrow \phi_2$; *and* $\phi_3 \rightarrow \phi_4$

The result is that the thick dike parameters are reduced to that of the thin dike such that:

$$\frac{r_1 r_4}{r_2 r_3} = 1; \quad \frac{r_1 r_2}{r_3 r_4} = \frac{r_1^2}{r_3^2}; \quad \frac{r_3}{r_4} = 1; \qquad \phi_3 - \phi_4 = 0; \quad and \quad \phi_1 - \phi_2 \tag{3}$$

Moreover, from Fig. 2, the effective thickness of the thick dike could be written as $t = 2b \sin\delta$.
However, when the thin (Fig. 1) rather than the thick dike approximated is valid, t – the thickness parameter in the analytical expression, could be used instead of $2b \sin\delta$, the apical width of the dipping dike.
Effecting the approximations of eq. (3) in eq. (2), the equation reduces to the form

$$V = \frac{2Pb\sin\delta}{2\pi\varepsilon_0}\ln\frac{r_1}{r_3}; \qquad \textit{that is}, \qquad V = \frac{Pt}{2\pi\varepsilon_0}\ln\frac{r_1}{r_3} \tag{4}$$

Equation (4) has exactly the same form as eq. (1) when we realize that the symbol r_2 in eq. (1a) is analogous to the symbol r_3 in eq. (4). Apparently therefore, the thick dike SP anomaly of eq. (2) becomes the same as a thin dike anomaly when the conditions set in eq. (3) are satisfied. This usually happens when, as shown in [15] in the case of thick dike magnetic anomalies, the depth of burial *h* exceed the dike's apical width *2b*.

4.0 Conclusion

This work has considered the singleness and uniqueness of the analytical expression of the SP anomaly over a (dipping) dike irrespective of it being thin or thick. The SP anomaly expression over a thick dike was shown to be generally reducible to that of a thin dike when certain parameters are collapsed by convergence and then constrained on equation (2) given. Examination of equations (1), (2), and (4) shows that the SP anomaly is generally made up of two parts – a constant part C which does not vary with x, the horizontal distance on the profile measured from the point on the profile vertically above the centre of dike's top surface, and a variable part G(x) which depends on the value of x. The expression of eq. (4) is found to be consistent with that of eq. (2), and exactly the same as that obtained in eq. (1b) in [14]. It is also consistent with eq. (1a), obtained in [4]. It is therefore evident that the thin dike (SP anomaly analytical expression) is only a special case of the thick dike (SP anomaly expression) and that the thin dike SP anomaly can be interpreted directly using the interpretation worked into the thick dike SP anomaly with the conditions imposed.

5.0 References

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