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Topographic Effects on Telluric Field Measurements

By T. HARINARAYANA and S. V. S. SARMA[1])

Abstract – Using the Schwartz–Christofel transformation and numerical integration, the effect of a sloping topographic irregularity on the telluric field measurements in a sedimentary basin is estimated. Results show that in the vicinity of the topographic feature, the distortion introduced would increase with the angle of inclination of the sloping feature. It is noticed that, for moderate inclinations (20°–50°), the telluric field measured near the topographic feature is within 10% of its undisturbed value for distance greater than $0.1H$–$0.3H$ from the topographic feature, where H is the thickness of the sedimentary column overlying the resistive basement. Suitable charts are prepared to aid as means to arrive at the estimates of errors for various angles of inclinations of such topographic feature and also to help in formulating approximate rules of thumb for selection of station sites in a field survey to minimize such topographic effects.

Key words: Telluric field; Topography.

1. Introduction

Topographic irregularities introduce uncertainties in the measured telluric field data. Since it is difficult to correct the data for such irregularities, the telluric field stations are to be located suitably with respect to such topographic feature in order to minimize such effects. Estimates of effects of different topographic models on telluric field are made using different approaches, analog model studies (WESCOTT and HESSLER, 1962; FARADZHEV *et al.*, 1972), numerical techniques (KU *et al.*, 1973; PARRY and WARD, 1971), conformal mapping techniques (KUNETZ and DE GERY, 1956; THAYER, 1975; ROY *et al.*, 1982). In the present paper attempt has been made to estimate topographic effects, in the vicinity of a sloping topographic feature – a common topographic irregularity encountered very often during telluric field surveys in a sedimentary basin.

In the case of sedimentary basins, it is generally assumed that the telluric currents are constrained to flow mainly in the sedimentary section, bounded by the air–earth boundary on the top and the basement surface below. This is considered to be a reasonable assumption, since, the basement can be treated as infinitely resistive as compared to the overlying sediments, the resistivity of which is generally a few orders of

[1]) National Geophysical Research Institute, Hyderabad – 7, India.

magnitude less than the basement resistivity. Normally the surface of the basin is assumed horizontal, but when the surface becomes non-horizontal, it may be noted that effects due to such distortions in topography would introduce considerable errors in the telluric field measurements. In the present case, as mentioned before, the topographic effects introduced due to one such topographic model namely a sloping surface (Fig. 1) are estimated, using the Schwartz–Christofel transformation.

2. *Theory*

The two-dimensional geometry of the problem is shown in Fig. 1. The Schwartz–Christofel transformation of the geometry of the structure in the Z-plane onto the W-plane (>0) can be expressed in the differential form as

$$\frac{dZ}{dW} = p\omega^{\alpha/\pi}(\omega - 1)^{-1} \tag{1}$$

where α is the angle of the inclined surface, $p = H/\pi$, H = depth to the basement.

We intend to compute the topographic effects on telluric field measurements obtained over the horizontal surface in the vicinity of the topographic feature, i.e. along

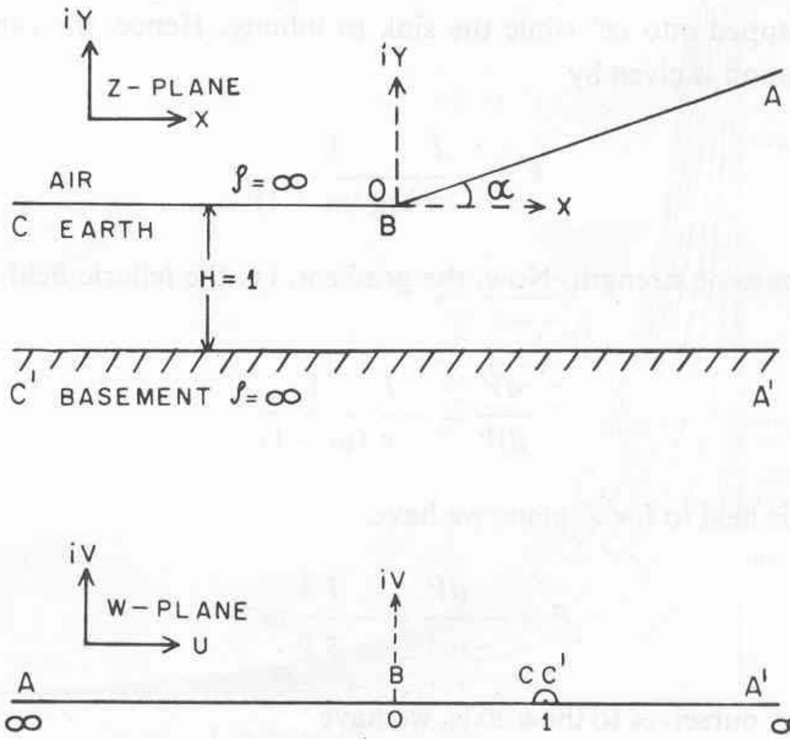

Figure 1

(a) Geometry of the inclined surface model; α-angle of inclination; H-depth to the basement. (b) Schwartz–Christofel transformation of the model shown in (a).

the x-axis of the Z-plane, we limit ourselves to the u-axis in the W-plane and hence in the present case, $V = 0$ and we may write

$$\frac{du}{dx} = \frac{1}{p} u^{-\alpha/\pi}(u-1) \tag{2}$$

Equation (2) is a non-linear differential equation and we integrate this numerically using the Runga–Kutta method of numerical integration. To start with, one needs the initial values, but from Fig. 1 it can be seen that $x = 0$ at $u = 0$, with the result the solution becomes an algebraic singularity. However, this problem has been solved, as illustrated by NAIDU (1965), for obtaining the asymptotic solution of equation (2). We can thus write

$$u = \left[-\frac{1}{p} x \left(1 - \frac{\alpha}{\pi} \right) \right]^{\frac{1}{1-\alpha/\pi}} \tag{3}$$

and hence by assuming x or $u \ll 1$, we can initiate the numerical integration of equation (2).

3. *Calculation of telluric field*

To evaluate the telluric field we assume that the field in the Z-plane is produced from a point source and a point sink placed at $\pm$ infinity respectively. Then, in the W-plane the source is mapped into cc' while the sink to infinity. Hence, the expression for the potential distribution is given by

$$V = -\frac{I}{\pi} \frac{1}{\log(\omega - 1)} \tag{4}$$

where, I is the current strength. Now, the gradient, i.e. the telluric field (E), is obtained as

$$\frac{dV}{dW} = -\frac{I}{\pi} \frac{1}{(\omega - 1)} \tag{5}$$

transforming this field to the Z-plane we have,

$$E = -\frac{dV}{dZ} = -\frac{I}{\pi} \frac{1}{p} \omega^{-\alpha/\pi} \tag{6}$$

Since, we restrict ourselves to the u-axis, we have

$$E = -\frac{I}{H} u^{-\alpha/\pi} \tag{7}$$

4. Discussion

All the computations were carried out on PDP 11/40 computer at NGRI, using double precision arithmetic. Telluric field curves have been obtained for various angles of inclination of the topographic feature, keeping the basement depth (H) to be unity. The computations have shown that the telluric field increases gradually as we approach the inclined surface and also this increase is observed to be more for higher angles of inclination (Fig. 2). Also the effect of topography on telluric field increases as the depth to the basement decreases. These results are summarized in Fig. 3 in the form of a nomogram which helps in estimating the effects due to the topographic feature. The distance of the telluric field stations from the offset, normalized with reference to the basement depth can be read on the x-axis, while the angle of inclination of topographic feature is plotted on y-axis. The set of curves in the figure represent the line of equal value of percentage error in the telluric field anomaly, introduced by the topographic feature. For example, for a flat non-conducting basement overlain by conducting sediments of 1 km thickness, the error introduced due to a 10° inclined surface topographic feature, i.e. ($\alpha = 10°$), at a distance x/H of 0.05 from the offset will be about 10% while for $\alpha = 90°$, the distance (x/H) corresponding to 10% error will be 0.4, conversely to keep the topographic effects within 10% the stations should be located in such a way that they are at a distance of not less than 40 m for $\alpha = 10°$ and 400 m for $\alpha = 90°$ for the above model. Thus knowing α and the approximate depth to

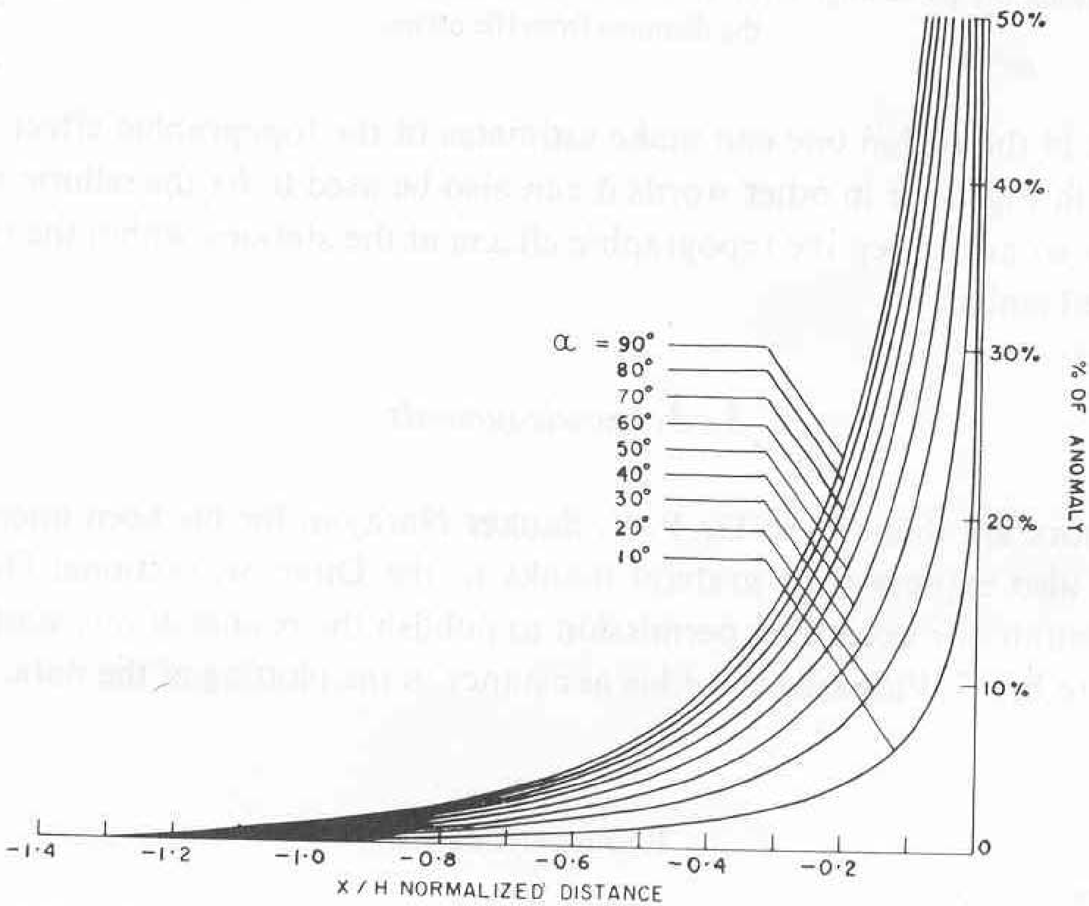

Figure 2

Telluric field anomaly

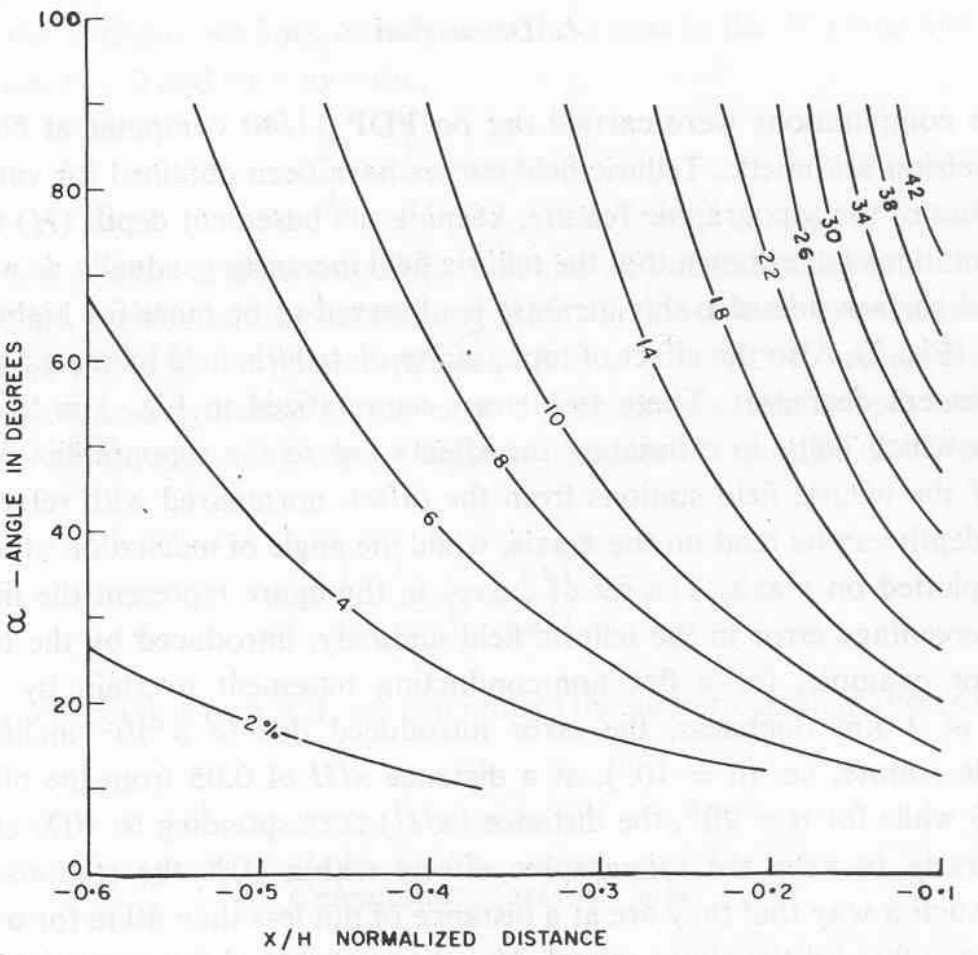

Figure 3

Nomogram showing the percentage error as a function of angle of inclination of topographic feature and the distance from the offset.

the basement in the region one can make estimates of the topographic effect, using the set of curves in Fig. 3, or in other words it can also be used to fix the telluric stations in a field survey so as to keep the topographic effects at the stations within the reasonable and prescribed limits.

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