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RECONNAISSANCE GEOLOGY OF ISLA MEJIA, GULF OF CALIFORNIA, MEXICO[1/]

PART II - MAGNETIC SURVEY

By

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INTRODUCTION

To aid in the geologic reconnaissance mapping of Isla Mejia, Gulf of California, (see Figure 1 of preceding article), it was decided to carry out a magnetic survey over and around the island. Magnetic surveying is particularly well suited to instances such as this, because of ease of use and mobility and also elevation and terrain corrections such as used in the reduction of gravity data are normally never needed. Although because of the geomorphic severity of Mejia, magnetic traverses were made mostly along the shoreline with only one traverse over the middle of the island, see Figure 1.

I thank Carlos Aiken for critically reading this paper and for offering several constructive criticisms. Gratitude is also extended to my field partner, Paul Handverger, for his great help throughout this research. I offer special thanks to Professor John S. Sumner, for without his congeniality and insight, this study would have been far less rewarding.

THE SURVEY

Vertical intensity magnetic observations were carried out at 118 stations with an approximate station spacing of 100 feet. All measurements were made with a model W505 Jalander vertical field magnetometer, the accuracy of this particular instrument being no better than $\pm$ 40 gammas. The actual traverses taken and the observed magnetic intensity at respective stations are shown in Figure 1. All readings were plotted relative to the observed base station measurement, which is located approximately midway along traverse B - B', see Figure 1.

From a brief inspection of Figure 1, one can immediately notice that along all traverses, except A - A' and B - B', nearly all the magnetic readings are negative in respect to the base station reading. This interesting feature is felt to be caused by the severity of the terrain in the immediate vicinity of each affected traverse. All traverses except B - B' were carried out along the edges of large (300 - 500 feet high) steep cliffs. Traverse B - B' being a minimum of one-eighth mile from such a feature, consequently shows no terrain effect as does profile A - A', which was over the top of the island where the topography is relatively flat.

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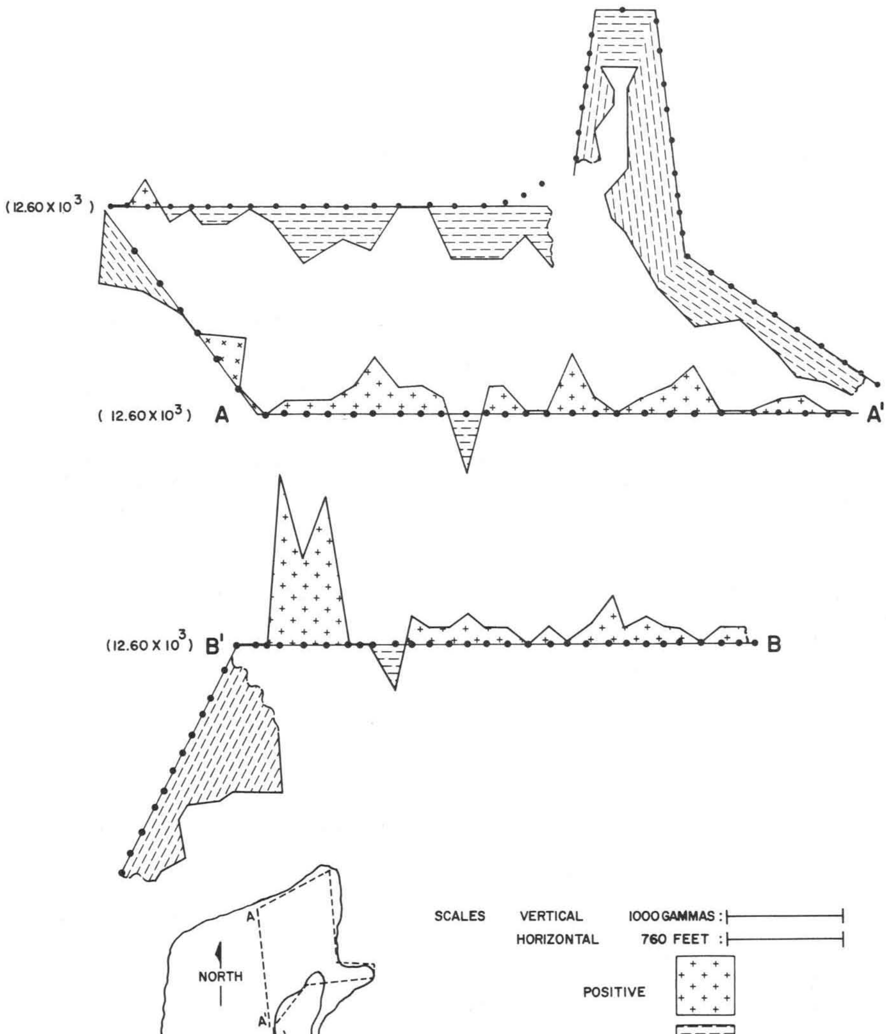

Figure 1.--Locations of Magnetic Traverses and the Actual Observed Data Plotted in a Fence-Like Fashion Relative to a 12.60 x 10^3 Gamma Common Base.

A magnetic terrain effect is defined as the magnetic response produced purely from the surface boundary layer between a homogeneous lithology and the atmosphere, (Marsh, 1971, p. 63). In this case, the terrain effect can be easily envisioned by considering the following formula (Heiland, 1946) for the vertical magnetic intensity across an infinite slope (see Figure 2).

$$\Delta Z = 2K \sin(i)\Big[H_0 \sin(\alpha)\Big(\sin(i) \ln \frac{r_2}{r_1} + \cos(i)(\theta_2 - \theta_1)\Big) - Z_0 \Big(\sin(i)(\theta_2 - \theta_1) - \cos(i) \ln \frac{r_2}{r_1}\Big)\Big]$$

Where: K = Susceptibility (in cgs units).

H_o = Horizontal components of earth's field.

Z_o = Vertical component of earth's field.

i = Dip of slope.

θ_1 = Angle (radians) between a horizontal line through the observation point and a line to the upper limit of the slope face.

θ_2 = Angle (radians) between horizontal line through the observation point and a line to the lower limit of the slope face.

α = Strike of the profile, measured clockwise from north.

r_1 = Distance between the observation point and upper limit of the slope face.

r_2 = Distance between the observation point and the lower limit of the slope face.

By taking a closer look at the formula for a slope, one sees the following:

$$\Delta Z = 2K \sin(i)\Big[H_0 \sin(\alpha)\Big(\sin(i) \ln \frac{r_2}{r_1} + \cos(i)(\theta_2 - \theta_1)\Big) - Z_0 \Big(\sin(i)(\theta_2 - \theta_1) - \cos(i) \ln \frac{r_2}{r_1}\Big)\Big]$$

If we assume a north-south profile, then "α" is zero and consequently, the first term vanishes; i.e.:

$$\Delta Z = 2K \sin(i)\Big[- Z_o \Big(\sin(i)(\theta_2 - \theta_1) - \cos(i) \ln \frac{r_2}{r_1}\Big)\Big]$$

or

$$\Delta Z = -2K \sin(i) Z_o \Big(\sin(i)(\theta_2 - \theta_1) - \cos(i) \ln \frac{r_2}{r_1}\Big)$$

Now, for any given slope, the angle of dip of the slope will be a constant (model assumption); so, sin(i) and cos(i) will also be constant. Therefore, one may denote sin(i) as "A" and cos(i) as "B" and obtain the following:

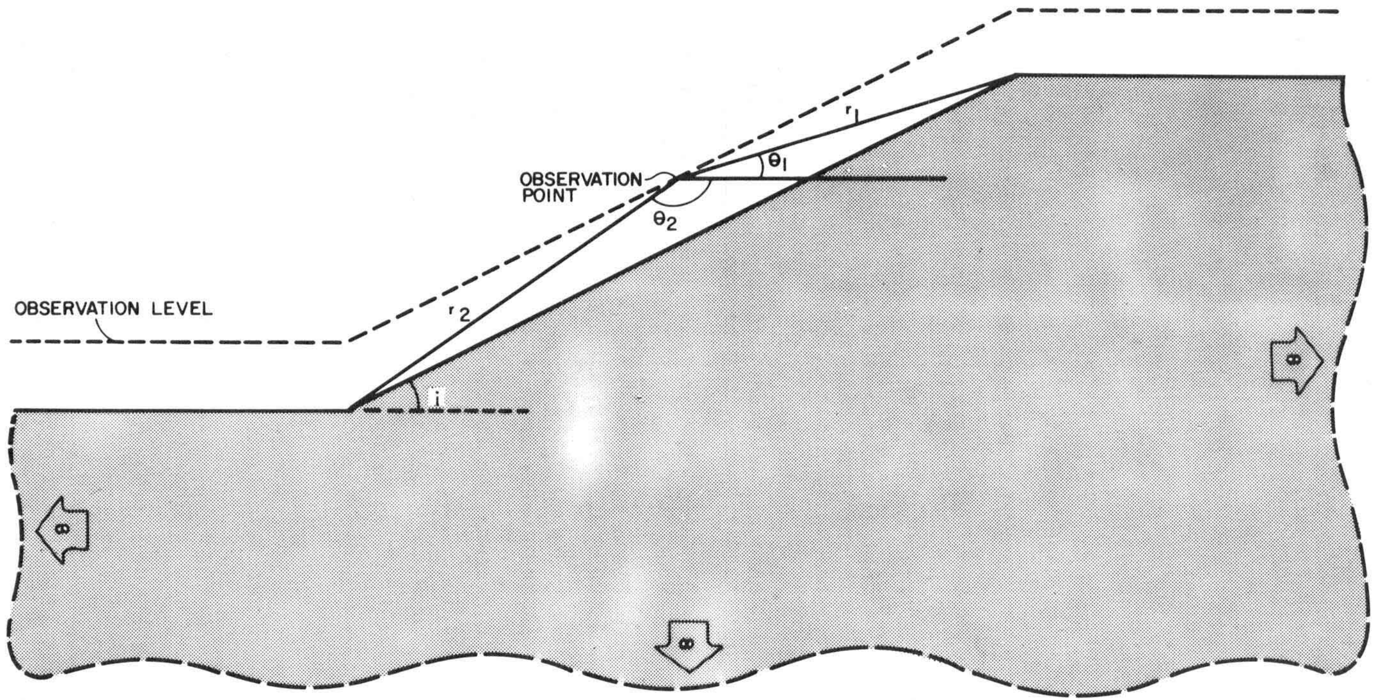

Figure 2.--The Infinite Slope Model; the Strike of the Slope is Perpendicular to the Page and is Assumed to be Infinite (i.e., Strike Length is Greater than 3 Times the Width of the Slope).

$$\Delta Z = -2KAZ_o(A(\theta_2 - \theta_1) - B \ln \frac{r_2}{r_1})$$

or

$$\Delta Z = 2KAZ_o(A(\theta_1 - \theta_2) + B \ln \frac{r_2}{r_1}).$$

One can now see that the vertical magnetic intensity along or about a slope is a geometric factor, (assuming constant lithology and the measured magnetization is purely induced). From the relationship between θ_1 and θ_2, one notes the quantity $(\theta_1 - \theta_2)$ will go to zero at two locations along the slope. At these locations the quantity (r_2/r_1) will take on maximum opposite values at the two locations where $(\theta_1 - \theta_2)$ is zero. That is, if an observation is taken sufficiently close to the lower limit of the slope, $(\theta_1 - \theta_2)$ will be zero and the quantity (r_2/r_1) will be a very small number. For the upper limit of the slope, if an observation is taken near this point, the quantity $(\theta_1 - \theta_2)$ will be zero and the ratio (r_2/r_1) will be a large number. Referring to the equation stated previously,

$$\Delta Z = 2KAZ_o(A(\theta_1 - \theta_2) + B \ln (r_2/r_1))$$

or

$$\Delta Z = 2KAZ_o(A(\theta_1 - \theta_2) + B(\ln r_2 - \ln r_1))$$

and, since $(\theta_1 - \theta_2)$ is zero for these two instances, then one obtains,

$$\Delta Z = 2KAZ_o(B(\ln r_2 - \ln r_1))$$

or

$$\Delta Z = 2KAZ_o B(\ln r_2 - \ln r_1).$$

Since at the lower boundary of the slope the quantity (r_2/r_1) is a very small number $(r_2 \ll r_1)$, then the vertical magnetic intensity will take on a maximum negative value; i.e., r_2 can be set approximately equal to one; then,

$$\ln r_2 \to 0 \text{ as } r_2 \to 1$$

so,

$$\Delta Z = 2KAZ_o B(-\ln r_1)$$

The same logic holds for the upper limit of the slope where $r_1 \ll r_2$ and $\ln r_1$ goes to zero as r_1 goes to one and,

$$\Delta Z = 2KAZ_o B(\ln r_2).$$

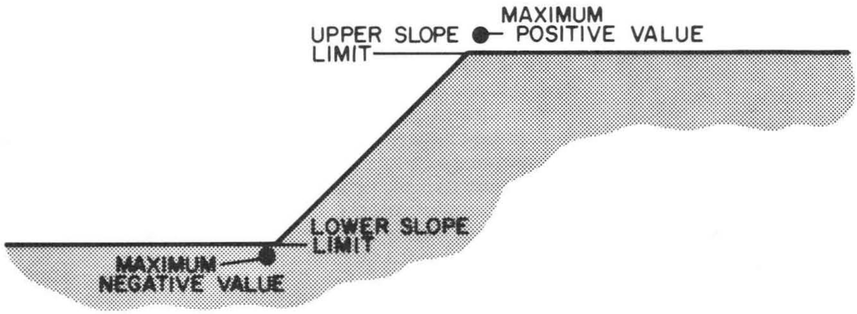

Figure 3.--a) Positions Along the Slope Model Where (O_1-O_2) is Zero.

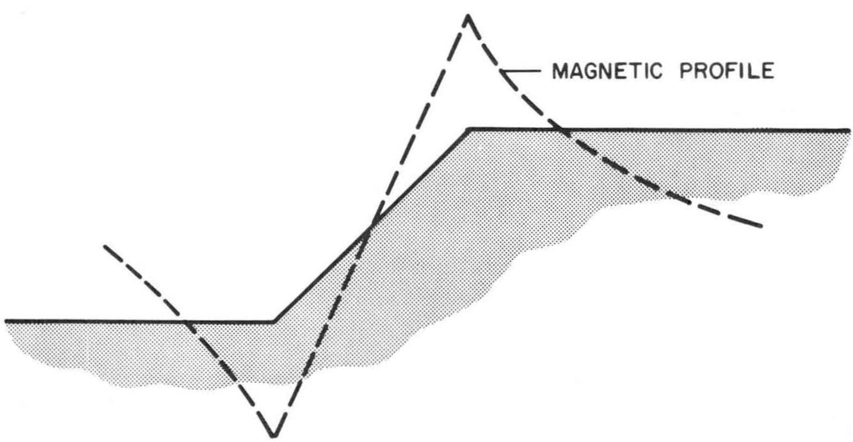

Figure 3.-- b) Inferred Magnetic Profile Across a Magnetically Homogeneous Slope.

In each situation, the magnetic value will be a (±) maximum and each will depend on the distance each observation point will be from the opposite limit of the slope. This relationship is shown in Figure 3a.

From this brief consideration of the slope model, the following magnetic profile (as shown in Figure 3b) may be inferred.

INTERPRETATION OF OBSERVED MAGNETICS

The observed magnetics of Isla Mejia were not corrected for terrain effects simply because of the uncertainty involved in locating the exact location of each station relative to the base of the cliffs. The stations were not selected at a constant distance from the base of each involved cliff because previous to this recognition, a terrain correction has never been a standard consideration in magnetic interpretational theory. As depicted in Figure 3b, the area immediately at the base of the slope model is one of high magnetic gradients, consequently this distance, from the base of the slope to the station, should be maximized whenever possible. In this particular situation, this distance was determined by the close proximity of the ocean which varied from place to place around the island and therefore, could not be maximized. Although these data cannot be quantitatively analyzed, correlations with the geologic framework are possible. The magnetic signature of the shoreline traverses is mostly quite smooth, which reflects the low magnetite content of the underlying quartzites. The large, positive anomaly and associated low of profile B-B' shows the continuation of the intrusive (granodiorite-quartz diorite) pluton southward away from the island. The negative anomaly on profile A-A' probably represents the intrusive contact on the north. Profile A-A' (the southern one-half) also exhibits a more irregular signature, which is interpreted as expression the higher magnetite content of the underlying intrusive. The dikes geologically observed in the vicinity of B are not seen magnetically, which initially seemed peculiar, but upon inspection of thin sections from these dikes it was found that the constituent metallics are nonferromagnetic sulfides which consequently cause no magnetic response.

CONCLUSIONS

Terrain effects, previously rarely recognized in magnetic surveying, have a large effect on ground magnetic measurements. The magnitude of the terrain effect, modeled here through the use of an infinite slope model, depends critically on the distance each station is placed from the bottom of the slope with the terrain effect being inversely proportional to this distance. The magnetic survey itself was found to correlate quite well with the mapped geology of Isla Mejia.

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