since the grade show strong positive relation with Mn/Fe ratio.

The assumption that grade and abundance are independent can cause a considerable overestimation of nodule resources[2]. The correlation coefficients (table 2) calculated on different data sets show that the inverse relation between grade and abundance holds good both regionally and locally (figure 1). Weak coefficients which are statistically significant at the 99.9% confidence level may be due to the mixed population considered in the data set. Considering the disposition and distribution of nodules on seafloor with different chemical compositions, the inverse relation may be proved universal for the world oceans.

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1. Pattan, J. N. and Kodagali, V. N., Paper presented in seminar on Processing of Manganese Nodules, Bhubaneswar, India, February, 1985.
2. Menard, H. W. and Frazer, J. Z., *Science*, 1978, **199**, 969.
3. Mizuno, A. and Moritani, T., *Geol. Surv. Jpn.*, 1977, Cruise rep. no. 8, p. 217.
4. Frazer, J. Z. and Fisk, M. B., *Deep-Sea Res.*, 1981, **A28**, 1533.
5. Frazer, J. Z. and Wilson, L. L., *Mar. Min.*, 1980, **2**, 257.

AZIMUTHAL RATIO TECHNIQUE OF INTERPRETING RADIAL SOUNDINGS

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Vertical electrical resistivity soundings (VES) are generally employed to obtain subsurface information regarding horizontal and vertical discontinuities is an area of interest. To detect the anisotropy of formations, radial soundings are carried out at a given station by obtaining VES data in two or more electrode spread directions (azimuths). The radial sounding data are normally interpreted by plotting the measured apparent resistivity values, using a suitable scale, obtained for the different azimuths on the respective axes and then joining the points obtained for the same current electrode separations, to get the polar diagram. The direction of elongation of the polar diagram indicates the direction of anisotropy, when present. In several polar diagrams it was observed that the direction of elongation changes from one azimuth to another with expanding current electrode separations, rendering the interpretation of such data difficult and ambiguous. In a few cases, the change of direction is so abrupt that the lines in the polar diagram cut across each other, thus making the interpretation almost impossible.

Extensive field investigations were carried out to study these aspects in areas having geological controls. It was observed that the abrupt change in the direction of elongation occurs due to the presence of lateral inhomogeneities or anisotropies other than textural or structural. A new method of presenting and interpreting the geoelectric radial sounding data is suggested in this paper.

The azimuthal ratios are obtained by determining the ratios of apparent resistivity values for corresponding current electrode separations ($\bar{A}\bar{B}/2$) of any two azimuths, (α, β) preferably perpendicular to

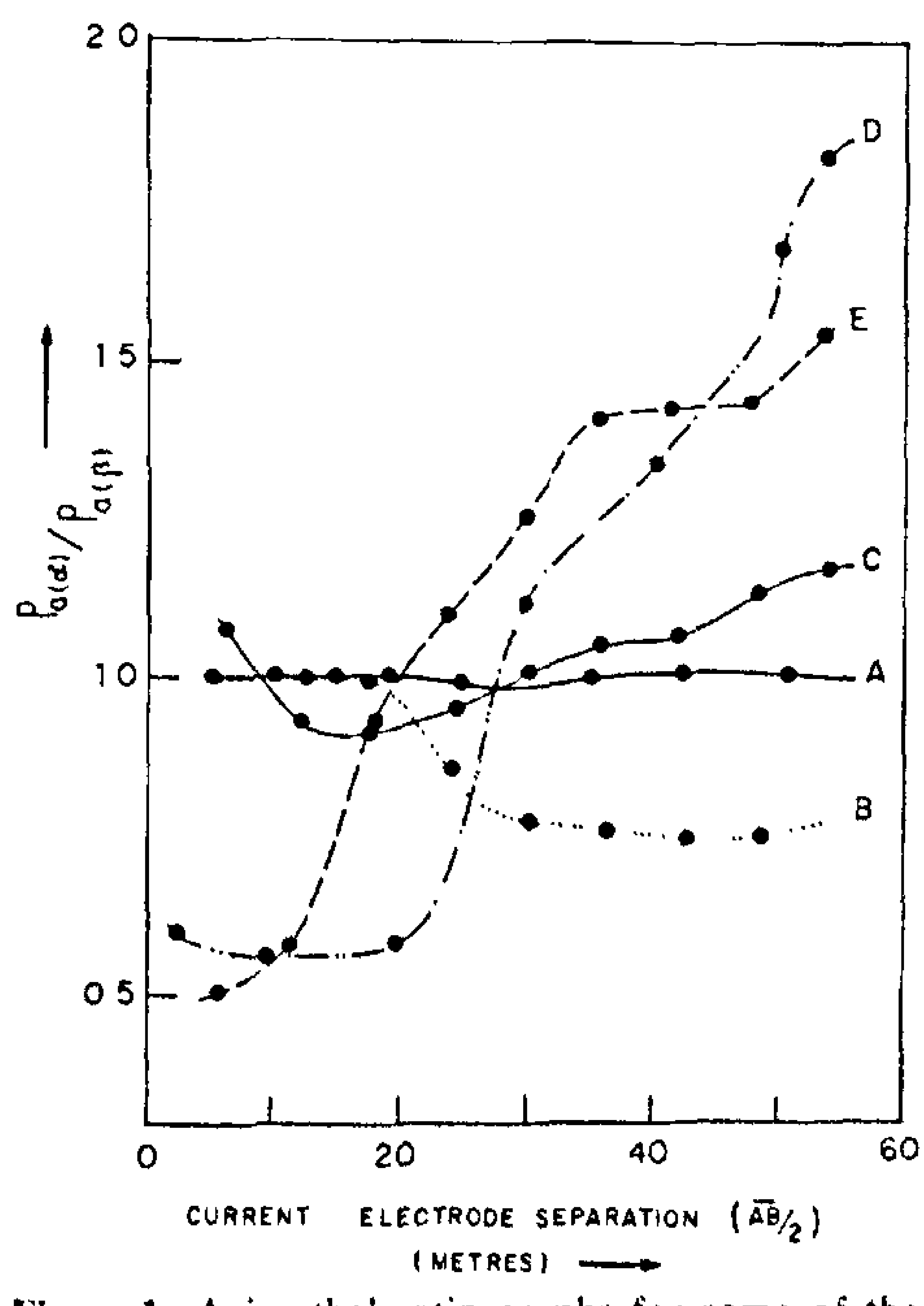

Figure 1. Azimuthal ratio graphs for some of the geological conditions.

each other, in a radial sounding. These ratios can then be analysed and interpreted using the following guidelines: (i) For isotrophic and homogeneous formations, the azimuthal ratio remains unity for all current electrode separations; (ii) When the formations are anisotropic due to textural variations such as foliation, etc. the ratios *either* increase or decrease from unity to some values after which they may level off; (iii) When the ratios vary from less than one to more than one or vice versa, it indicates the presence of lateral inhomogeneities within the electrode spread zone. However, even a distinct horizontal discontinuity at depth may give rise to such an anomaly, but in this case, the transition of the ratios from less than one to more than one or vice versa will be very gradual and over very large electrode separations.

Figure 1 shows the results of some of the field studies carried out to demonstrate the effectiveness of the suggested method. The graphs drawn are for $\rho a_{(\alpha)}/\rho a_{(\beta)}$, which is the azimuthal ratio, versus the current electrode separation. In the figure, curve A can be interpreted as representing a nearly homogeneous and isotropic formation. It is from Kolar, Karnataka, where granitic-gneiss underlies a thin soil cover. Curve B, obtained from Varthur, near Bangalore in Karnataka, again underlain by granitic-gneiss, can be said to be obtained from an anisotropic formation. Curve C is from an area underlain by Charnockite with an exposed dolerite dyke nearby (Chingleput, Tamil Nadu). The gentle slope of the graph reflects low resistivity contrast between the country rock and dyke, since the soil cover here is very thin. Curves D and E, from Anekal, Karnataka, where granitic-gneiss underlain soil cover, with an exposed dyke nearby clearly reflect the sharp resistivity contrast, by their steep slopes. Thus, the presence of lateral inhomogeneities and the relative resistivity contrast are brought out by the azimuthal ratio graphs. The method suggested is fast, simple, more informative and can be employed in the field itself.

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1. Bhimasankaram, V. L. S. and Gaur, V. K., *Lectures on exploration geophysics for geologists and engineers*, AEG, 1977.

EFFECT OF HEAVY METALS ON SUPEROXIDE DISMUTASE ACTIVITY IN *PENNISETUM TYPHOIDEUM* SEEDLINGS

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Superoxide dismutase (SOD) is an indispensable enzyme for oxygen-utilizing organisms where it protects the cells against the deleterious effects of superoxide radicals. The cellular content of SOD in the procaryotes and eucaryotes is governed by the growth conditions[1]. It has been reported that the presence of high nutrient levels of metal ions in the growing medium of plants effected the growth and showed qualitative and quantitative changes in enzymatic activities[2]. The present communication reports the effect of heavy metals on SOD activity in the bajra (*P. typhoideum*) seedlings.

Healthy seeds of bajra were thoroughly washed with deionized water and then soaked in distilled water for 8 h. The imbibed seeds were allowed to germinate in the presence of different metal ions viz. copper, lead, manganese and mercury (added as $CuSO_4$, $CH_3COOHPb$, $MnCl_2$ and $HgCl_2$ respectively) at different concentrations. Control sets of seedlings were grown with distilled water. Seedlings were collected at 48 h and 96 h intervals and homogenized separately in 0.01 M sodium phosphate buffer of pH 7.6. The homogenate was passed through two layers of cheese cloth and the filtrate obtained was centrifuged at 3000 *g* for 10 min. The supernatant obtained was dialysed against the phosphate buffer for 24 h at 4°C and the SOD activity was assayed[3]. Isoenzymes of SOD were analysed by polyacrylamide gel electrophoresis and activity staining as described earlier[4]. The protein[5] and chlorophyll[6] content of the seedlings were estimated.

Results (table 1) indicate that except lead, all other metal ions at 100 μM level (lower concentrations did not have much effect) reduced (13–27%) the levels of SOD in bajra seedling in the order Hg > Mn > Cu. This indicates that mercury inhibited the SOD activity. The inhibition with the other two metal ions was slight at this concentration. There was no induction of new isoenzyme apart from the three isoenzymes of SOD as reported earlier[7]. This is in contrast to the observation made in *Pisum sativum* leaves[2] where a new Mn^{2+} containing SOD was shown to be induced by