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A Multi - Parameter Geophysical Experiment at Kalava area (Cuddapah basin), Kurnool District, Andhra Pradesh — India.

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ABSTRACT

The Kalava area in Cuddapah basin, located approximately 50 kilometres south of Kurnool, had been studied earlier by the Geological Survey of India initially using self-potential, vertical intensity magnetic and electrical resistivity survey and subsequently by using dual frequency EM and frequency domain I P. surveys. The G.S.I. had delineated in and around the conductive belt region carbonaceous shales with minor sulphide mineralization.

Inview of the scope offered by the area for testing the applicability of other geophysical methods also, an integrated geophysical survey experiment has been conducted across this known anomalous belt during December, 1981. Magnetic (Total Intensity) Radiometric, Telluric and multi-frequency EM surveys were carried out besides SP and time-domain IP surveys.

The experiment has revealed that the geology has responded not only to EM, SP and IP, but also to the other methods such as

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magnetics, radiometrics and tellurics, though, in a different, but useful way. The total intensity magnetic surveys has helped in delineating two important anomalies at the ends of the profiles revealing certain structures controlling the mineralized conducting zone. The telluric survey has served as an excellent reconnaissance tool in the delineation of the electrically conducting zones. The radiometric anomaly peaks on all the profiles align themselves along the major axis of the conducting zone delineated by electrical and EM methods indicating, possibly that the common source for these anomalies are perhaps the organic shales. The significance of these observations in relation to the possible controls of mineralization is discussed.

INTRODUCTION

The Gani-Kalava area situated in the northern part of Cuddapah basin has been identified as one of the important zones for possible base metal (copper) mineralization, thanks to the systematic efforts of the Geological Surveys of India, which conducted several geophysical surveys including electromagnetic, IP and SP surveys in this area and brought to light several significant anomalies. Subsequent test drilling by the G.S.I. has provided some direct insight into the main causative source for these anomalies which is reported to be carbonaceous shales. However, it is also noticed that some of the zones are associated with some copper mineralization though not sufficient enough in tenor to be classed as an economic ore deposit. It is also noticed that the amplitude and nature of some of the IP anomalies are not entirely explainable on the basis of corbonaceous shales alone as pointed out by G.S.I. (Reference No. 8 GSI Report). Be this as it may, it is obvious that the area offers considerable scope for a more comprehensive application of geophysical technology employing an integrated approach to delineate and decompose the complex nature of geophisical anomalies in this important mineralized zone. In view of this, a preliminary geophysical experiment involving a wide spectrum of geophysical methods viz., multi-frequency electromagnetic, Time-domain induced-polarization, self-potential, tellurics, magnetic and gamma-ray spectrometry techniques, has been conducted along a few select profiles in the Kalava area. Figure 1 shows the layout of the geophysical traverses in the Kalava area together with some of the geological details of the area The main rock units present in the area are the Tadipatri shales (Lower Cuddapahs, Panyam quartzites (Kurnools), dolerite sills and dykes appearing as intrusives. The well-known Kalava 'wall' comprising Panyam quartzite forms the northern boundary of the area surveyed. The copper mineralization (mainly chalcopyrite) along with traces of covellite, chalcocite, pyrite and magnetite, is reported to be associated mainly with quartz veins, mostly confined to the vicinity of shale/trap contacts.

Geophysical Surveys

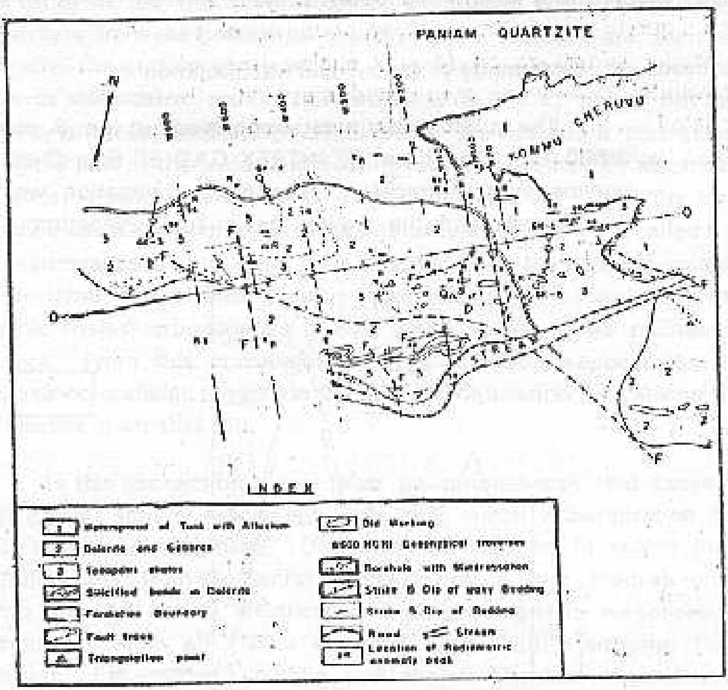
1. Magnetics : Survey and Interpretation

The magnetic survey consisted of measurement of total intensity using NGRI proton precession magnetometer along 6 traverses across the known conductive zone delineated by the GSI. The traverse lengths varied from 100 to 300 metres on either side of the central line (0 to 0 in Fig. 1). The sampling was done at 10m station interval. The stacked profiles (Total Intensity) are shown at Figure 2. The contour map presented in Figure 3 also brings out these features very clearly. For instance a close study of these series of stacked profiles W300, W400, W500 and W600 (Fig. 2) reveals that the northern end in every case ends up in sharp to pronounced 'low' of amplitude about 500 to 600 gammas, followed by a featureless broad hump to the south, again to be followed by another weaker 'low' of amplitude about 150 gammas at the south-end. The northern 'low' is maintained on the rest of the profiles as well, namely W70, 100, 130, 160, 200 and 300 and, in fact, on these profiles the northern 'low' is relatively narrow and deep. It looks certain that all these latter profiles would also have picked up the southern 'low' as well if continued. A Contour presentation of the same results can be seen at Figure 3 which also brings out these features.

All the profiles are along roughly 20° west of north. On these profiles, at the location of the present study (Kalava) having a mean magnetic inclination of 16° to 18° N if we assume the mag-

GEOLOGICAL MAP OF KALAVA AREA WITH LOCATIONS OF GEOPHYSICAL TRAVERSES

SCALE



netic picture as arising from simple induction of a thin/thick dyke in the present field of earth, the northern sharp 'low' would call for a dip (around 90°) and the southern, weaker and broader 'low' would demand a fairly low dip (less than 45°) to the south. It is also seen that the northern and southern lows on practically all the profiles show a further splitting

The complete magnetic picture, as can be judged from the stacked profiles and contour map, seems to arise from two nearly E-W tranding dyke-like or tabular bodies, the northern one having a dip greater than 75° and the southern one having low dip less than

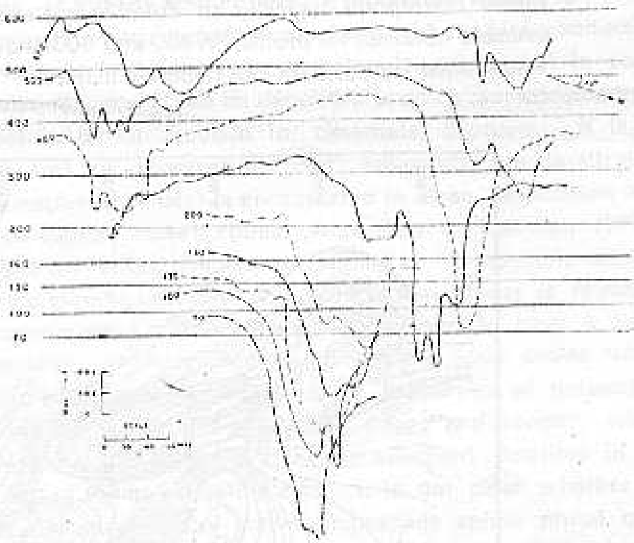


Fig. 2. Stacked Profiles of (Total Intensity) magnetic (Kalava area.)

45°. Also, possibly both these tabular bodies seem to be the composite of finer tabular elements which conform to the strike and dip of the major body.

The northern lows on practically all the profiles align closely with the northern boundary of a known conducting zone and seems to reflect a structural feature which might be associated with mineralized zone. The southern, weaker 'low' appearing on profiles 400, 500 and 600 (Fig. 1) seems to fall quite far away (south) from the known conducting zone, were dolerites and gabbros.

These magnetic anomalies have been further analysed quantitatively to get the paramaters of the causative source. Assuming a thin/thick sheet model for the source body and employing Parker Gay (1963) and Atchuta Rao and Ram Babu (1981) methods quantitative estimates were made and presented in Table 1.

It may be seen from the table that the dips of the source body varies around 90° while its depth is only few tens of metres varying from 40 to 80 metres. It may be seen rom most of the susceptibility values correspond typically to doleritic material. However, the estimate obtained for profiles W300 and 400 showed relatively higher value rather representative of gabbroic material.

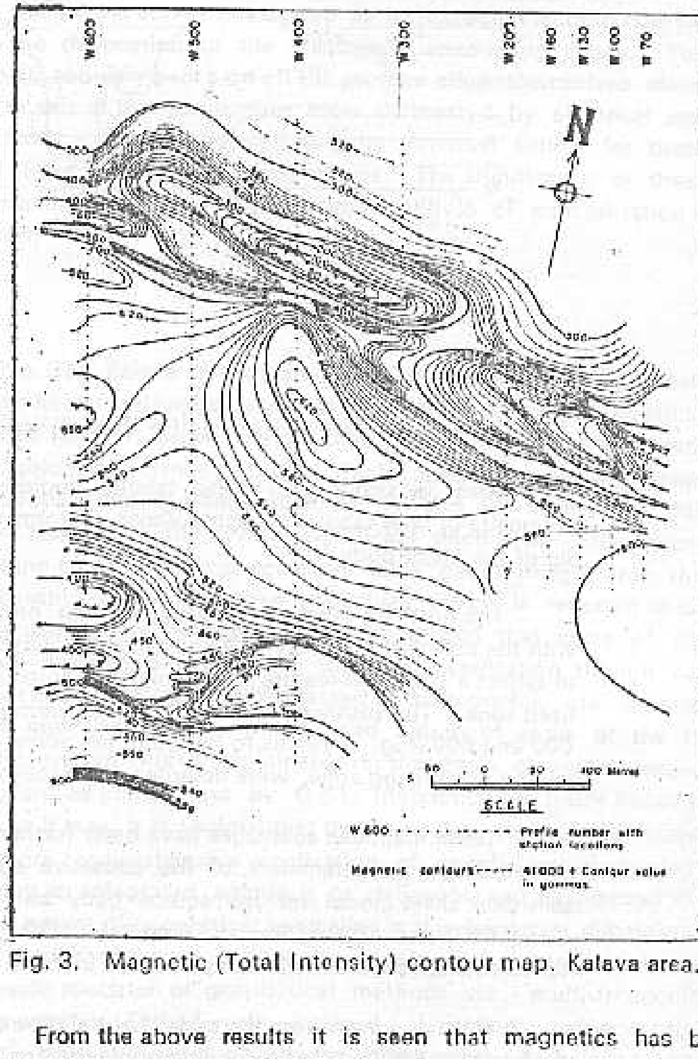


Fig. 3. Magnetic (Total Intensity) contour map. Kalava area.

From the above results it is seen that magnetics has been able to make a vital contribution in gleaning and delineating the structural controls responsible for the localization of this mineralized belt. Magnetics together with any one electrical method (as will be shown subsequently in this paper) could have provided sufficient conformation that the environ shows promise and could merit a detailed search.

2. Radiometry I Survey and interpretation :

The radiometric survey was carried out on 6 profiles W100 - W600 (Fig. 1) using a "SCINTREX GAD-6" Four-Channel stabilized gamma-ray spectrometer. The gamma radiation was counted for 30 seconds and the count rates in Total, Potassium(K), Uraniam(U)

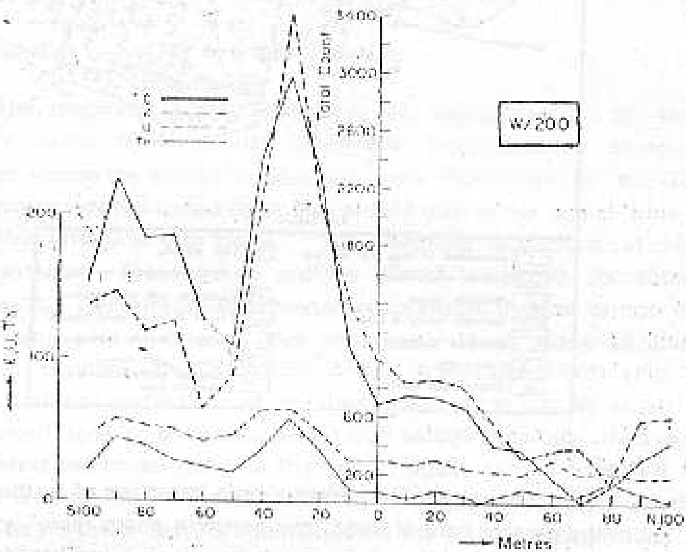


Fig. 4. — Ray Intensity profiles over W/200, Kalava area.

Thorium (Th) channels were recorded at stations with 10 metres intervals, all the six traverses being covered with this station interval. One of the typical radiometric profiles is presented in Figure 4.

It is known that, as compared to granites and other acidic rocks, the sedimentaries and basic rocks like dolerites and basalts have low levels of radioactivity. The present area it may be recalled, has several sills, dolerite dykes and other intrusives, with shales mainly playing the host medium for these intrusives. From this, it may at first appear that the area does not have any rock formation with appreciable radioactivity except shales if they are organic. But, as can be seen from the profiles presented here, a few locations on the profiles show significant radioactivity level, particularly from the potassium source. Such features are seen on almost all the profiles obtained. A close examination of the locations of these radioactive 'peaks' (marked as 'R' in Fig. 1) points out that majority of these, appearing on different profiles align themselves along the axis of the major conducting zone delineated by electrical and electromagnetic methods. This again indicates the possibility for a common causative soarce for these anomalies. It may be recalled that the carbonaceous shales had been reported to be the possible sources of electrical and electromagnetic anomalies. It is also known that organic shales/carbonaceous shales could act as good radioactive sources. From this consideration, at a first look, it appears that the carbonaceous shales present in the area might possibly be causing the radioactive anomalies too.

In this connection it may also be pointed out that cases of high gamma activity associated with base metal mineralization had been reported occasionally. One such observation in recent times in India comes from the Sonrai Cu-Pb-Zn belt in Uttar Pradesh where along with the strong electrical and electromagnetic responses on ground and from air (latter recorded with NGRI's airborne Pulse Transient EM system) drilling had shown Uranium mineralization in hard bitumen occuring in fractures along preferred beds (Ravi Prakash et al., 1976).

However, in the present case the question remains as to how the shales from subsurface levels could reveal their signature on the surface radioactivity measurements. Alternatively one could also think of other sources such as pegmatites and other late phase emanations of acidic intrusives to account for the anomalies in the area. Also, it is possible that some of the silicified bands in dolerites can cause some local 'highs' in the radioactivity picture One such surface evidence for the association of radioactive anomalies with the bands was noticed on the southern side (150, to 200 m) from base line) on the W 400 profile.

While, as already pointed out, a straightforward explanation of the strong radiometric response coinciding with the high conducting zone has not been forthcoming, nevertheless it appears that in cases like the above radiometry can be depended upon as an added confirmatory tool in the exploration for basemetal deposits. It is an established fact of observation that radiometric mineralization (Primarily Uranium minerals) is encountered in close association with sulphides of copper, nickel, cobalt. According to Bateman (1958) in such cases the radioactive mineralization has "a magnetic source, presumably a granitic intrusive with which the copper is related". In the present context high gamma activity appears to have a two-fold association, namely one with carbonaceous shales which possibly can account for the lining up of the series of radiometric 'highs' along the axes of the conductive zone, and second, where the radiometric highs occur close to silicified dolerites in the southern part of the investigation area. It is not clear whether this is possibly indicative of any active pegmatitite aplitic phase of an acidic intrusion in the area since significantly the potassium channel shows high peaking of gamma activity though uranium and thorium also do show but on a much more subdued scale.

3. Tellurics : Survey and Interpretation

Though the telluric method had been introduced long time back (1920's) its application in India has been limited to last few years only (Sanker Narayan et al., 1979). In a given area the telluric method can be used as a quick reconnaissance tool for locating qualitatively, lateral variation of electrical resistivity of subsurface material. For detecting lateral inhomogenetics such as those encountered in mineral exploration, a commonly adopted telluric field method is the split-spread technique (Yungul, 1977) and this has been employed for the present investigations.

Field Data Acquisition

The telluric field data acquisition in the Kalava area was accomplished by conducting a split.spread survey along 12 select profiles (same as those shown in Fig 1 for magnetics). For this purpose, the telluric field units designed and fabricated at NGRI were used and the 12 profiles covered under the present programme have lengths varying from 1 to 1.5 km and are spaced at 100 m. interval. A dipole length of 100 m. was used for the split-spread set up and telluric signals were recorded in 0.02 - 0.05 Hz. range. All the data were processed to yield the telluric field ratio "E_R"

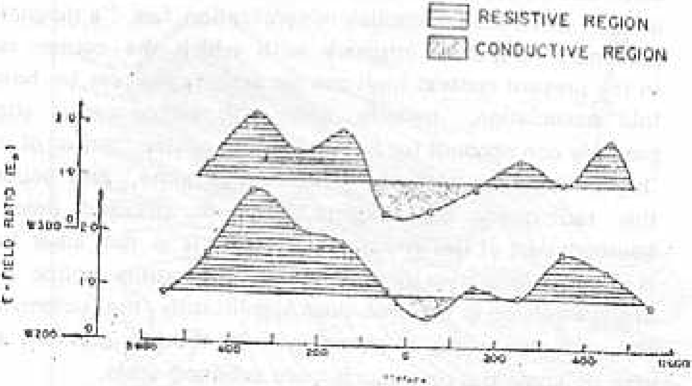


Figure 5. Telluric field ratio (E_R) profiles, Kalava area.

using the conventional method of calculating amplitude ratios of synchronised signals (Yungul). 1977). The E_R ratios are computed with reference to the base dipole located at O to S 100 on W200 profile (Fig. 5) supposed to be in the known electrically conducting zone and Figure 5 shows a pair of these telluric field ratio (E_R) profiles (along W 200 and W 300).

Interpretation

It can be seen that the "E_R" ratio variation on both the profiles shows a well-defined pattern with a 'low' in the middle accompanied by two 'highs' on either side of this low. Though from geological considerations, the area is known to be occupied predominantly by shale it may be added that some intrusive bodies like sills, dykes are also reported particularly on the southern side. In view of this, the relatively resistive zone indicated as a 'high' on the southern side of the E_R profiles can be attributed to this intrusive-dominated shale country. While part of the 'high' seen on the northern side could be due to the well-known Kalava wall consisting of relatively high resistive quartzites. The 'low' region lying between the two 'highs' represents a highly conductive zone and spans about 200 m in width on both the profiles and roughly coincides with the known anomalous conducting zone delineated from earlier EM and IP surveys by G.S.I. Rest of the E_R profiles also reflect these features well and bring out the conducting zone in the area clearly.

It can thus be seen that the telluric method has reproduced very well in locating the resistivity contrasts and, considering the rapidity of operation and low field costs this method certainly appears to stand out as an effective and less expensive geophysical method for delineating conducting regions which can be taken up for further detailing with other geophysical tools such as EM, IP and SP. The method has the additional advantages that (a) it uses only natural source signals and (b) provides large depth of subsurface sampling capability.

4. Self-Potential Survey

S.P. survey was carried out on five traverses out of the set shown on Figure 1 with a station interval of 10 m. and traverse interval of 30 m. The base was chosen at station N 90 on the traverse W 200. S. P. measurements on the traverse W 130 has brought out an interesting feature, namely a well-defined "negative" of the order of -100 mv. around station S 30. Data on adjecent traverses also show the same features, but with a slightly reduced magnitude of the anomaly. The nearly E - W trending negative S.P. anomaly is clearly brought out on the contour map presented in Figu e 6.

The interpretation of S.P. data, unlike other geophysical data, has been largely qualitative. It is not generally not possible to determine the shape and the size of the causative body, though the depth to the top surface of the underground target can be estimated by analytically continuing the S.P. data downward. On the basis of the S.P. contour map (Fig. 6) we assume a two - dimensional structure (strike of the body can be assumed almost along east-west, extending to a great length) and therefore one can adopt a one-dimensional scheme for the continuation downward (Roy, 1966).

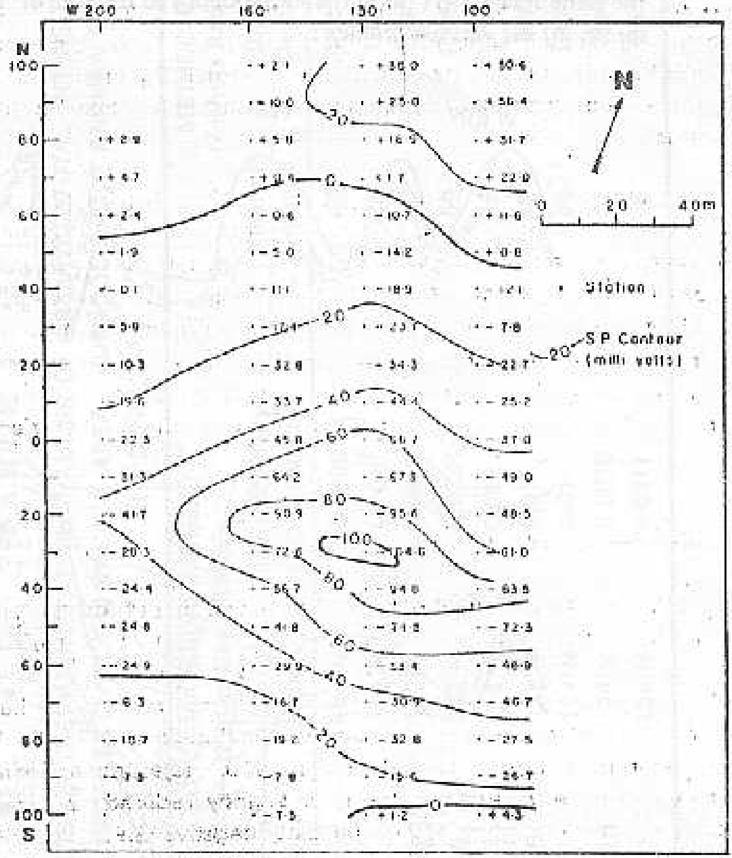


Figure 6. Self-potential anomaly map, Kalava area.

Figure 7 shows the downward continued S.P. values at four different depths, Z = 5, 10, 15 and 20 m for the anomaly on profile W 130. The ground surface corresponds to Z = 0 and the uppermost portion of this figure shows the S P. profile a smoothed curve drawn through the observed points. When continued downward

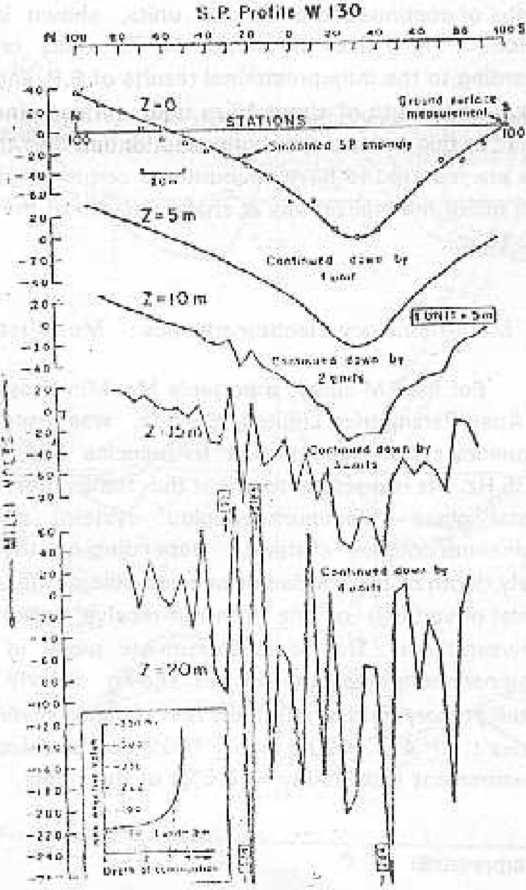


Figure 7. Downward continued self-potential anomaly profiles Kalava area

to a depth of 5m, the S.P. values are only slightly enhanced but the general broad nature of the anomaly remains unchanged. The profile at depths of 10 m and 15 m start showing oscillation? in S.P. values but preserve the central 'low', while the oscillations of S.P. values at a depth of 20 m become violent. A visual examination of the curves presented in Figure 7 clearly indicates that the depth to the top of the causative body is somewhere between 3 and 4 units (15-20 m). The semilog plot between maximum negative value and depths of continuation at various units, shown in the inset at the bottom of Fig. 7 fixes the depth at 3.2 units or 16 m. Therefore, according to the intrerpretational results of S.P. anomaly the conductor occurs at a depth of about 16 m from surface and it may be mentioned in this context the boreholes drilled by the G S I in Kalava area are reported to have encountered carbonaceous rocks associated with minor mineralizations at shallow depth of the order of 10-15 m (10-15 m).

5. Multi-frequency Electromagnetics : Multi-frequency EM survey

For the EM surey, a portable MaxMin II system, manufactured by Apex Parametrics Limited, Canada, was used. This is a multi-frequency system operating at frequencies 222, 444, 888, 1777 and 3535 Hz. It is possible to orient the transmitter coil either in horizontal plane ('maximum coupled' system) or in a vertical plane ('minimum coupled' system). Depending on the expected dip and likely depth of the conductor one can select the configuration (horizontal or vertical) of the transmit-receive coils and the separation between them. The measurements are made in terms of real and imaginary components which are shown directly as the percentage of the primary field strength on two separate meters. Three different scales : $\pm$ 4% $\pm$ 20% and $\pm$100% can be selected for an accurate measurement (readability = 0.5%) of the signal.

Interpretation

Since the objective of the present survey was to delineate steeply dipping shallow conductors present if any, the horizontal loop configuration was used which provides the best coupling for vertical conductor. The coil separation used was 50 m and readings were taken at a station interval of 10 m to get a smooth profile. Measurements were taken along the profiles W100, W160. The starting station in all cases was N100 (Figs. 8a & b) where the transmitter coil was placed. The receiver was placed at N50 and the anomaly was plotted midway point N75. Subsequently, both the transmitter and the receiver were moved to the next station. Results of these measurements (presented in Fig. 8a & b) showed that the profiles

W160 and W130 run accross conducting bodies. Detailed analysis of these anomalies was done for all frequencies using an infinite sheet model in free space. The individual results obtained for various frequencies were in very good agreement with each other. Presented in Table 2 below are the average values of the dip δ (in degrees) the conductance $\sqrt{t}$ (in Sm) and the depth to the top of the conductor (in m) for various profiles :

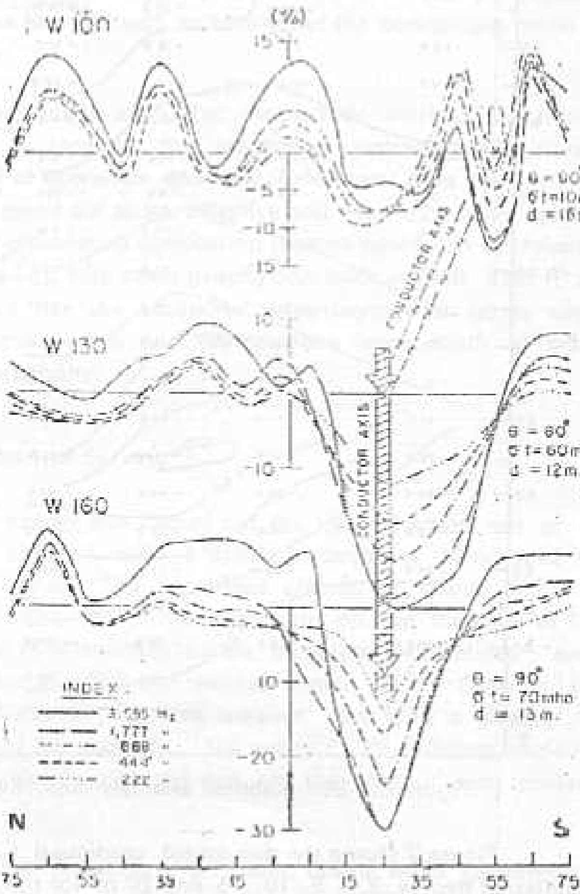


Fig. 8a. Electro Magnetic response (In-phase component) over profiles W/100, W/130 and W/160. Kalava area.

TABLE I

RESULTS OF THE QUANTITATIVE ANALYSIS OF OBSERVED TOTAL INTENSITY ANOMALY PROFILES OVER THE KALAVA AREA, KURNOOL DIST., ANDHRA PRADESH (INDIA)

Profile No.	CURVE-MATCHING METHOD (Parker-Gay, 1963) Depth in Metres	Dip in Degress	Susceptibility in cgs units	METHOD OF NOMOGRAMS (Atchuta Rao & Ram Babu, 1981) Depth in Metres	Dip in Degrees	Susceptibility in cgs units
W/70	42	144°N	0.0038	40	132°N	.002
W/100	48	124°N	0.0011	48	102°N	.0019
W/130	40	102°N	0.0011	40	100°N	.0019
W/160	62.5	142°N	0.0034	59.9	120°N	.0029
W/200	62.5	124°N	0.002	74	111°N	.002
W/300	62.5	122°N	0.01	58	90°N	.009
W/400	48	114°N	0.01	58	106°N	.009
W/500	78.13	74°N	0.0030	61	90°N	.003
W/600	82	124°N	0.0011	76	90°N	.009

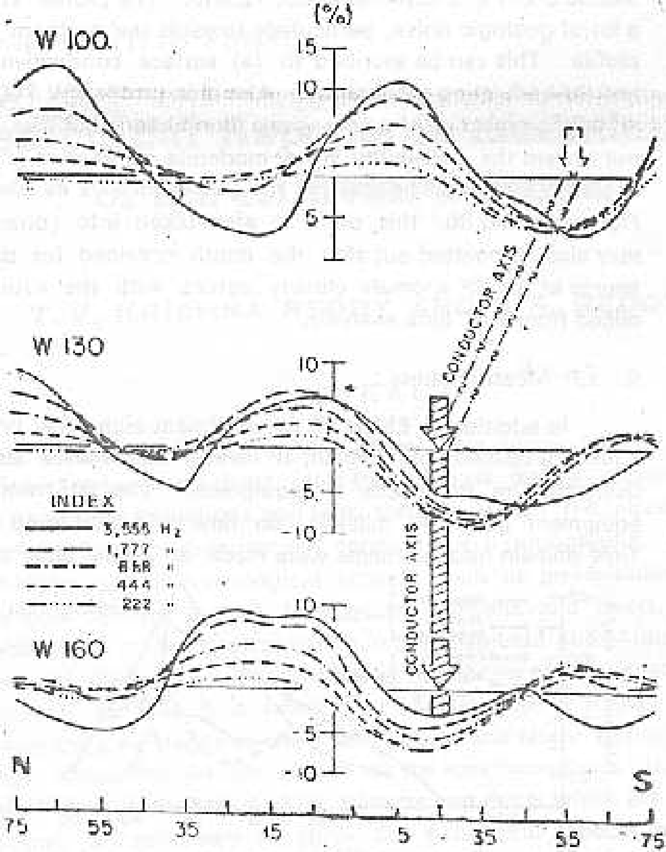


Fig. 8b. IP anomaly curves over W/130, Kalava area.

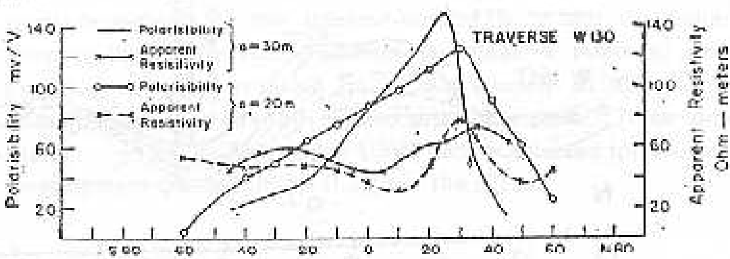
TABLE 2

Profile No.	Dip (δ)	Conductance (σt)	Depth
W 160	90°	70 S	13 m
W 130	80°	60 S	12 m
W 100	90°	10 S	16 m

The quantitative analysis thus shows that the profiles W 160 and W 130 indicate the presence of very good conductors (σt = 65 at station S 25) at a depth of about 12.5 m. The profile W 100 shows a lot of geologic noise, particularly towards the northern end of the profile. This can be ascribed to (a) surface conductivity variations and (b) undulating topography. Also this profile (W 100) does not reveal the presence of a very good conductor, but the result point out toward the possibility of a moderate conductor ($\sigma t = 10$ Sm) at station S 55. While drawing the conductor axis as shown in the Figures 8a and 8b, this point is also taken into consideration. It may also be pointed out that the depth obtained for the causative source of the SP anomaly closely agrees with the estimates determined from E.M. data analysis.

6. I.P. Measurements :

In addition to EM & SP measurement along the W 130 profile a few multipaced time domain, IP measurements were also obtained, using the Ore' Prospector' IP equipment. The transmitter with the equipment has 400 millisec. on time and 800 milli sec. offtime. Time domain measurements were made at 20 m. after switching-off



the current. These measurements were carried out with Wenner spacing of 20 and 30 metres. IP anomaly (Fig. 9) corroborates well with EM, SP and Total magnetic anomaly as also with the frequency domain IP anomaly of the GSI. The cause of the anomaly seems to be at shallow depth as it is picked up at smaller Wenner spacing.

7. SUMMARY AND CONCLUSIONS

It can be seen from the foregoing that the multiparameter geophysical field experiment employing a number of geophysical tools as clearly shown that the geology responded not only to EM, IP and SP but also to the other geophysical methods, such as magnetics, tellurics and radiometry and that the responses on the various parameters, all corroborate each other when examined in their entirely. While the magnetics can act as a very quick and effective tool for delineating the important structural controls associated with the mineralized belt, the tellurics serves as an excellent reconnaissance tool to delineate the electrically canducting zones which are the probable locales of mineralisation. IP and EM methods help in obtaining details on the parameters of the targets. Radiometry obviously can play an important role in the identification of anomaly producing lithology which are presumably related paragenetically with probable copper mineralisation in this belt, and also for locating any late stage products of acidic intrusives such as pegmatites/aplites etc .

In summing up, it would appear that with a whole variety of geophysical tools on duty in search of a prospect say of base metal, certain methods offer better lateral discrimination as to detectability, whereas certain others give better depth determination and also possibly information on attitude (i.e., dip), while yet certain others possibly give clues about structural and metallogenetic environment of control etc.

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