Reprinted from the 4th workshop on "Status, Problems and Programmes in Cuddapah Basin", Institute of Indian Peninsular Geology, 1981.

RESULTS OF A TELLURIC FIELD SURVEY IN THE SOUTHWESTERN REGION OF CUDDAPAH BASIN

S. V. S. SARMA,
T. HARINARAYANA,
C. VENUGOPALA KRISHNA
P. V. SANKER NARAYAN
National Geophysical Research Institute,
Hyderabad-500 007.

Introduction

The Cuddapah basin, because of its complex geology and structure and vast wealth of mineralization, has been one of the prime centres of focus for the earth scientists. Besides an extensive coverage of the basin with a wide range of geological studies during the past several decades (for eg. see. King 1872, Raja Raman & Sood 1966, Krishna Swamy 1978, Balakrishna et al 1979), application of geophysical methods for the study of the basin has also increased considerably, particularly during the last two decades (Balakrishna and Sekhar Reddy 1961, Balakrishna et al, 1964, Mathew et al, 1967, Balakrishna et al, 1967, Qureshy et al, 1968, Balakrishna et al, 1970, Balakrishna and Paul 1970, Bhaskar Rao et al, 1970, Atchuta Rao et al, 1970, Bhimasankaram et al, 1978).

In addition to the conventional gravity and magnetic methods, other methods such as deep seismic sounding method (Kaila et al, 1979) and the telluric methods (Sanker Narayan et al, 1979) have also been employed in the recent past. It has been shown in the latter study that the telluric response of different lithological units of Cuddapah sediments is very distinct, thus providing a basis for an effective application of electrical methods in general and the telluric and magnetotelluric methods in particular for the study of this basin. Under a multi-disciplinary collaborative project on Cuddapah basin between IIPG and NGRI, the NGRI has initiated telluric surveys, to start with, in the southwestern region of Cuddapah basin (Fig. 1). Preliminary results of telluric surveys along the two profiles viz. Tadapatri-Anantapur and Bhogasamudram-Gooty have been reported in Sankar Narayan et al, 1979. In the present paper, the results of the telluric split spread profile across the western margin of Cuddapah basin, as also a discussion on the results of the earlier two telluric traverses are presented.

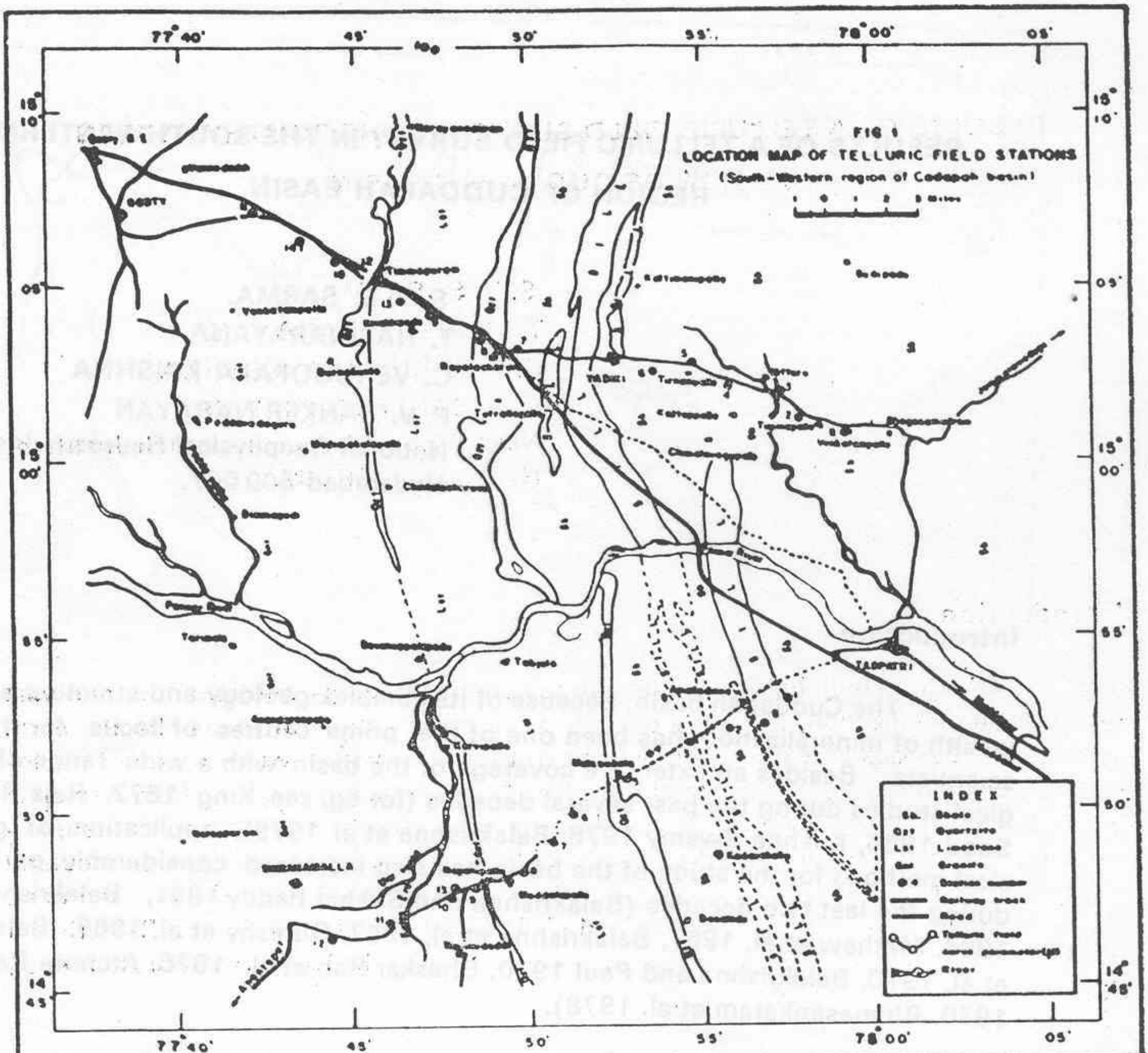


FIG 1
LOCATION MAP OF TELLURIC FIELD STATIONS
(South-Western region of Cuddapah basin)

Telluric Method :

The telluric method, belonging to the electrical / electromagnetic group of geophysical methods, utilizes a natural source field, for its measurements Though known for a long time in other parts of the world, its utilization in India, has been initiated only recently. The temporal variations of Geomagnetic field, in the low frequency range (1 to 10^{-3}Hz) induce corresponding natural currents of global nature in the crustal layers of the earth and these are referred to as 'telluric currents'. The strength and direction of these currents are considerably influenced by the sub-surface electrical conductivity characteristics and hence by the sub-surface geology. In view of this, measurement of relative strength of telluric fields at various places in an area would yield information with regard to sub-surface geology and this forms the general basis for the application of telluric current method.

The data acquisition in the telluric method involves, recording of telluric signals at field stations and a fixed Base Station simultaneously. In the actual field practice, keeping in recording of telluric signals at the Base Station continuous, one occupies the field stations successively for limited intervals of time. Thus in the telluric method of prospecting, one needs atleast two similar units of equipment, one meant for the Base Station and the other for occupation of field stations. Normally recording at each field station is done for about 30 to 45 minutes and the frequency range of signals recorded is generally between 0. 1 and 0.01 Hz. The analysis of telluric data entails the comparison of telluric signals recorded simultaneously at a field station and the Base Station, and the computation of relavant telluric parameters (J or μ) representing the average telluric field strength for each of different field stations, relative to that at the Base Station. The variation in the telluric field parameter along the profile depends mainly on the total longitudinal conductance of the sub-surface section and hence is a measure of the variations in the geoelectric section which in turn can be related to subsurface geology and structure along the profile. The method finds its extensive application in the study of basement configuration of sedimentary basins and very often it can yield quite useful depth estimates if the telluric data are supplemented partly by other data such as D.C. resistivity and magnetotellurics.

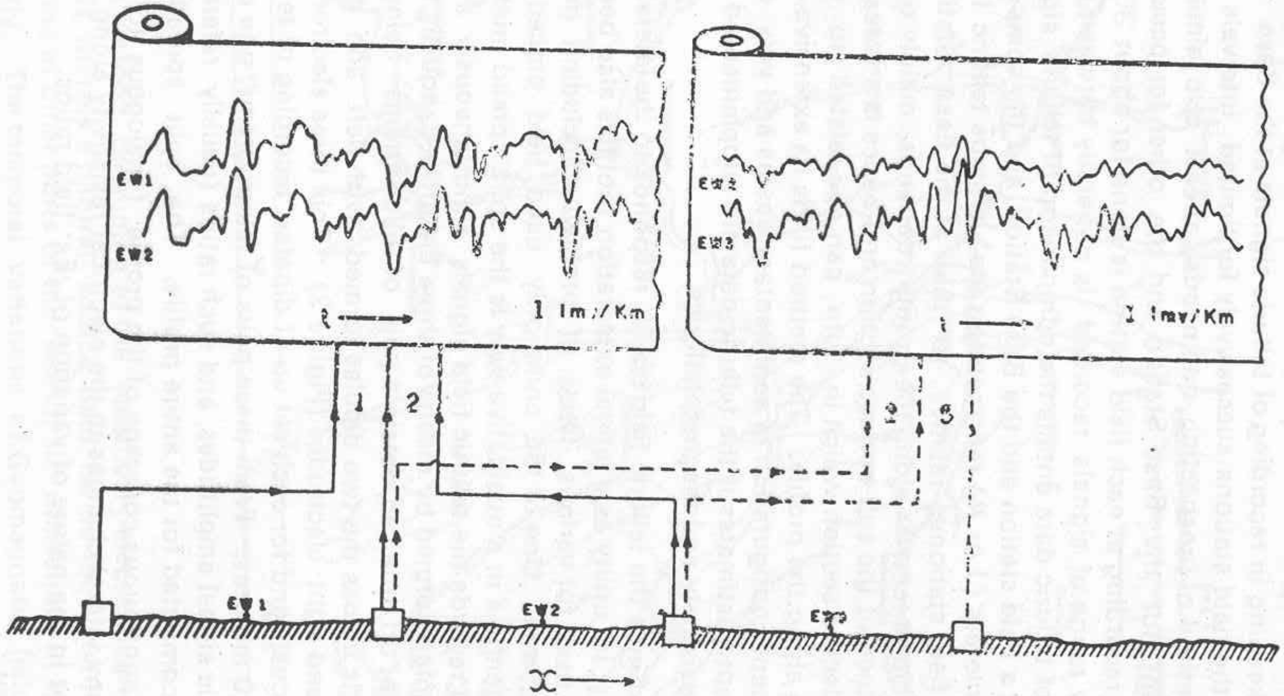
Since the telluric field readily responds to the lateral changes of the electrical resistivity, its utility as a lateral exploration tool has also been widely recognized and is being used for various types of problems including geothermal, and structural investigations. One of the commonly used field procedures for detecting lateral inhomogenities in a qualitative way is the split spread method (Yungul 1977). In this, one records the telluric field signals simultaneously across two adjacent collinear dipoles, formed by means of three electrodes equally spaced along a line. For such a set up, one can obtain a pair of tellurograms being the records of telluric potentials across the two dipoles formed with 'left and centre' electrodes and the 'centre and right' electrodes (Figure 2). This three electrode array is 'leap frogged' continuously and for each set up of dipoles, recording of telluric signals is done for about 20 minutes. From these pairs of tellurograms, one can determine the ratios' of telluric signal amplitudes, and such ratios (usually referred to as E_R field ratios) can be computed for the entire profile. The split spread profile, as can be seen, gives a continuous coverage of the profile (analogous to resistivity profiling) and hence any lateral changes in the electrical resistivity along the profile will be readily apparent in the nature of variation of 'E_R' field ratios.

Geology :

The Southwestern region of Cuddapah basin is occupied by lower Cuddapah formations belonging to Papaghni and Cheyair series. Starting from Gulcheru

FIG. 2 THE METHOD OF SPLIT SPREAD

FIELD SET UP WITH EXAMPLES OF TELLUROGRAMS



quartzites on the extreme west at the margin of the basin, as we go towards east, we find Vempalle dolomitic limestones, followed by Pulivendla quartzites and Tadapatri shales. The formations, have a general NE-SW strike direction, dip towards east with dip angles ranging from 10 to 15°. Besides these, there are surface evidences for the occurrence of basic intrusives in the form of basic sills. It is interesting to note that the igneous activity in the Cuddapah basin is confined mainly to a narrow zone stretching along the western margin of the basin. Though the surface geology indicates a fairly simpler sub-surface picture,the geophysical surveys however, particularly the gravity and magnetics have brought out conspicuous anomalies, indicating a more complicated sub-surface structure in this region. In fact, the gravity and magnetic "highs" in this region have been considered to be arising from the same causative source and this body is provisionally interpreted to be the feeder/parent body responsible for the basic sills and dykes in this region (Balakrishna and Paul, 1979).

Field Investigations :

During July-August, 1979, a telluric field survey was conducted along two profiles–one along Tadapatri-Anantapur road and the other along Bhogasamudram-Gooty road. All the telluric field data have been reduced to a common base station, located at Bhogasamudram. In all, 30 stations were occupied along these two profiles and the stations were located such that they are evenly distributed covering all the geological formations which the traverse cuts across. At all these stations, telluric signals were recorded in the .02—.05 Hz frequency range and the recording time for each station was about 45 minutes. Telluric field parameter (μ) which represents the relative magnitudes of average telluric field strengths at various stations with reference to the Base Station was computed using the spectral method (Sarma et al, 1978), as also the conventional methods namely the amplitude ratio method and the triangle method (for eg. see Berdichevisky, 1966, Yungul 1977) Fig. 3a, b show the telluric field profiles obtained along these two traverses, together with a sub-surface section inferred from surface geology.

In addition to the above traverses, two split spread profiles were also run traversing across the western margin of Cuddapah basin, one near Nayanapalli on the Tadapatri-Anantapur road and the other near Timmapuram on Bhogasamudram-Gooty road. Using the data from these split spread traverses, the telluric field ratios (E_R) have been computed. In its raw form, E_R is given by the ratio of amplitudes of the same telluric signal appearing on adjacent dipoles for each set up and in practice however, the E_R value assigned for each set up represents the average of several values of amplitude ratios computed for several corresponding signals appearing on the same pair of tellurograms. E_R values are computed along the traverse and the profiles thus obtained are shown in Fig. 4. The values plotted in these figures represent the E^R values, normalized with respect to the first dipole on the eastern end of the profile.

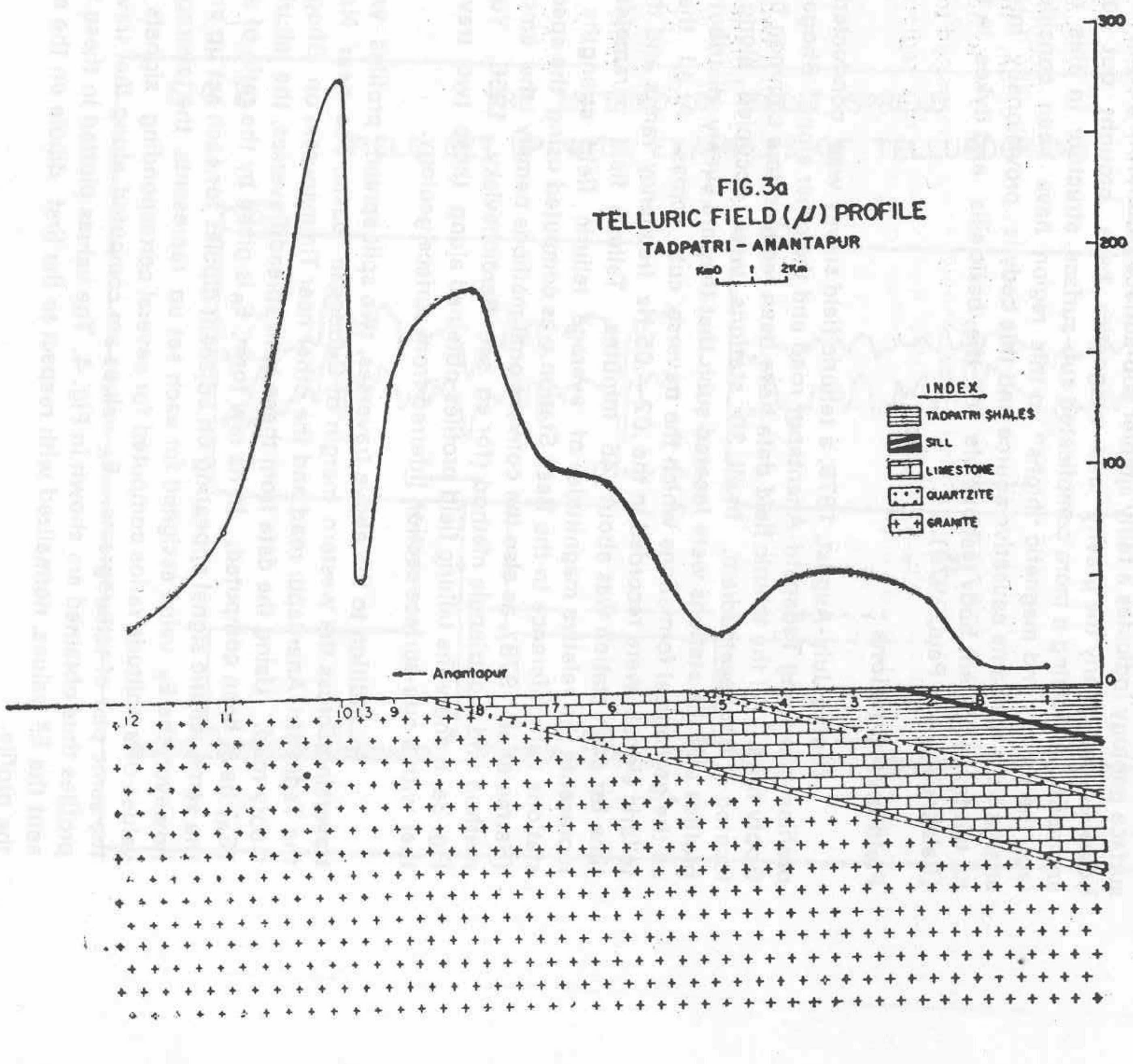


FIG.3a
TELLURIC FIELD (μ) PROFILE
TADPATRI - ANANTAPUR

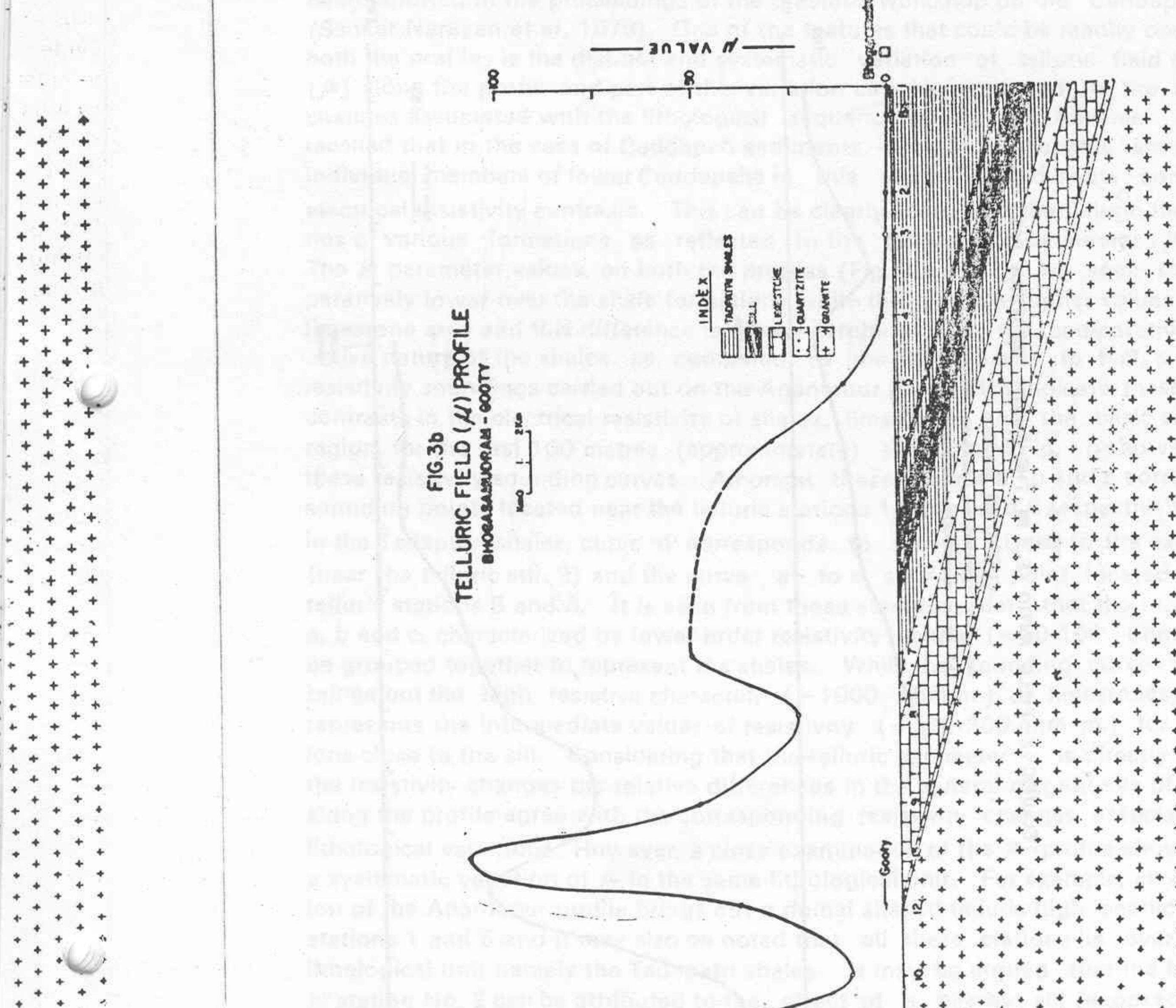
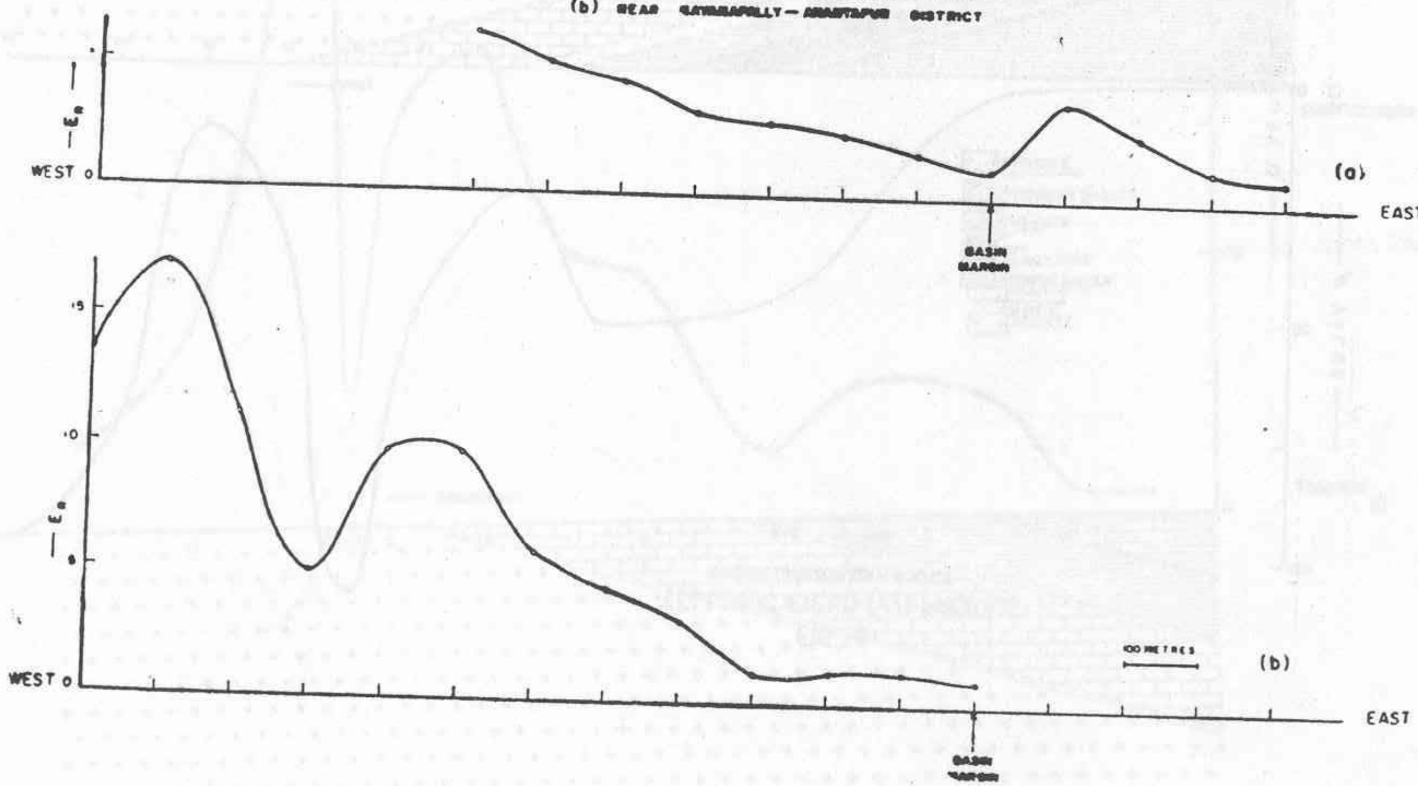


FIG.3b TELLURIC FIELD (μ) PROFILE BHOGASAMUDRAM GOOTY

FIG 4

TELLURIC E-FIELD RATIO (E_R) IN THE SOUTH WESTERN PART OF CUDDAPAH BASIN

(a) NEAR [illegible] DISTRICT
(b) NEAR [illegible] DISTRICT



Discussion of Results :

A preliminary assessment of the telluric field data obtained in this region has been reported in the proceedings of the previous workshop on the Cuddapah basin (Sanker Narayan et al, 1979). One of the features that could be readily observed on both the profiles is the distinct and systematic variation of telluric field parameter (μ) along the profile and part of this variation can be attributed to the resistivity changes associated with the lithological sequence along the traverse. It may be recalled that in the case of Cuddapah sediments, it can be reasonably assumed that individual members of lower Cuddapahs in this region should show considerable electrical resistivity contrasts. This can be clearly seen, from the telluric field respones of various formations as reflected in the telluric field parameter (μ) profile. The μ parameter values, on both the profiles (Fig 3 a and b) are seen to be comparatively lower over the shale formations while they assume higher values over the limestone area and this difference is readily attributable to the comparatively conductive nature of the shales as compared to the limestones. In fact, a few D. C. resistivity soundings carried out on the Anantapur profile also indicate these relative-contrasts in the electrical resistivity of shales, limestones and the basic sills in this region, for the first 100 metres (approximately) section and Fig. 5 shows a few of these resistivity sounding curves. Amongst these, curves a, b and c correspond to sounding points located near the telluric stations 1, base and 5 respectively all lying in the Tadapatri shales, curve 'd' corresponds to a point close to the exposed sill (near the telluric stn. 2) and the curve 'e' to a sounding point located between telluric stations 5 and 6. It is seen from these sounding data, that the three curves a, b and c, characterized by lower order resistivity values ($\approx$50-100 ohm-m.) can be grouped togather to represent the shales. While the sounding curve 'e' clearly brings out the high resistive character, ($\sim$1000 ohm-m.) of limestones, curve 'd' represents the intermediate values of resistivity ($\approx$200-300 ohm-m.) for the locations close to the sill. Considering that the telluric parameter μ is directly related to the resistivity changes the relative differences in the general magnitudes of μ values along the profile agree with the corresponding resistivity changes associated with lithological variations. However, a close examination of the μ profile shows further, a systematic variation of μ in the same lithological unit. For example, an examination of the Anantapur profile brings out a domal shaped telluric high located between stations 1 and 5 and it may also be noted that all these stations lie over the same lithological unit namely the Tadapatri shales. It may be argued that the high value at station No. 2 can be attributed to the effect of a nearby sill (exposed between Station 2 and 3) which can provide a shallow electrical basement. However, stations 3 and 4, located (west of the sill) well away from the sill outcrop also show equally high values. Thus, it appears that this hump in telluric profile between stations 1 and 5, may perhaps be assumed as a continuous one, forming a single anomalous feature. In such a case, this domal shaped telluric anomaly can be attributed to a single resistive mass lying at some depth in this region and such a mass might represent a part of a large parent/feeder dyke responsible for the emplacement of sills in this region. Alternatively however, this type of telluric high can also be produced due to the combined effect of shallow electical basements at individual stations in this zone which could be provided by, for example by a number of sills, along the profile between stations 1 and 5. Though such a possibility cannot be ruled out, surface evidence shows that there is only one sill, exposed on the profile and is located between stations 2 and 3 Thus the other assumed sills, if present, might lie at some depth and hence lie unexposed in the region.

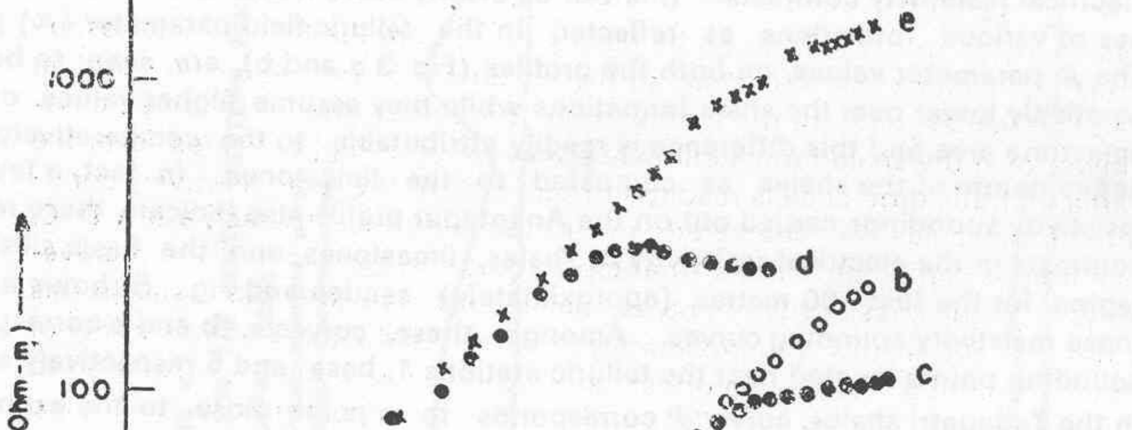


FIG. 5. RESISTIVITY SOUNDING CURVES TADAPATRI–ANANTAPUR PROFILE.

Further west on the profile, from spation 6, the telluric field continously increases upto the boundary of the basin. This part of the profile is occupied mainly by Vempalle limestones, (bounded by a narrow band of Pulivendala quartzites on the east and Gulcheru quartzites on the west) all along the 10 km. streth. The change in the μ value, in the case of a uniform geology, or in otherwords where there are no changes in the lithology would reflect the relative changes in the thickness of the sedimentary section overlying the resistive basement. Viewed from this angle, the gradual rise in the μ value from east to west on both the profiles, is naturally a reflection of the decreasing thickness of Vempalli limestones, as we go towards the western margin and thus shows a qualitative agreement with the normal section drawn from surface geology, for the region covered by limestones.

After this rise in the telluric field which continues upto the boundary of the basin, the μ parameter shows a sudden decrease in the adjoining country for both the Anantapur and Gooty profiles, followed by an increase again. In the case of Anantapur profile, however the μ value tends to show a second depression well away from the known margin of the basin. Such depressions in the telluric field would generally indicate the presence of low resistive material. The nature and location of such anomalous features in the telluric field can be seen more clearly on the split spread traverses which would provide a continuous coverage of the profile. The E_R ratio obtained on split spread profiles across the margin of the basin have also indicated tee presence of a telluric 'low' (particularly in the Anantapur profile) in the granitic region adjacent to the western margin and such features can be considered to be due to linear fracture, fissure or sheared zones in the granitic country adjoining the western margin of Cuddapah basin. Groundwater leaking deep into such zones would bring down their electrical resistivity to a considerable extent, so that they find distinct expression in the form of 'lows' in the telluric picture. Though the western margin of the basin, from surface geological evidence is generally considered to be fairly stable and free from any faulting, the presence of fracture zones running parallel to the western boundary cannot be ruled out. It may however, be added that detailed telluric studies aided by additional and independent information from D. C. resistivity, gravity and magnetic investigations would be highly effective in arriving at an acceptable model for sub-surface section in the Cuddapah basin.

Acknowledgements :

The authors aıe grateful to the Director, National Geophysical Research Institute, Hyderabad, for according permission to publish this paper. They are also thankful to Sri T. Venkateswara Rao and Sri M. R. K. Prabhakar Rao for their assistance in carrying out resistivity survey.

References :

Atchuta Rao, D. Sanker Narayan, P. V. and Hari Narain - A study of aeromagnetic profiles across the Cuddapah basin, India. Bull. NGRI 1970, 8, (1 and 2) 11-26.

Balakrishna, S. and Sekhar Reddy, R. - Application of variation of magnetic intensities for thickness estimating of limestones beds. Bull. Nat. Inst. Sci. India 1961, 22, 56-63.

Balakrishna, S., Vijaya Raghava, M. S. and Mironov, V. S. - A magnetic survey near Kurnool. Jour. Ind. Geosci. Assn., 1964, 4, 139-147.

Balakrishna, S., Christopher, G. and Ramana Rao, A. V. - Regional magnetic and gravity studies over Cuddapah basin. Proc. U. M. P. Hyderabad, 1967, 303-319.

Balakrishna, S., Paul, P. A. and Ramana Rao, A. V. - The influence of basic bodies on magnetic anomalies in SW region of Cuddapah basin, Bull. NGRI, 1970, (1 and 2) 55-56.

Balakrishna, S. and Paul, P. A. - Geological and Geophysical studies in parts of Cuddapah basin. Bull. NGRI. 1970, a, 8, 143-158.

Balakrishna, S., Paul, P. A. - Magnetic studies on the Igneous rocks in the south-western region of Cuddapah basin and in the adjoining granitic country - Paper presented in the second workshop on Status, Problems and programmes in Cuddapah basin, IIPG, Hyderabad, Jan. 1979.

Balakrishna, S., Venkatanarayana, B. and Rao, M. N. - A short review of the geological studies in the Cuddapah basin, Second workshop on Status, Problems and programmes in Cuddapah basin, IIPG, Hyderabad, Jan., 1979, 1-15.

Berdichivisky, M. N. - Electrical prospecting with the telluric current method : Quarterly of the Colorado School of Mines, 1965, v. 60, No. 1.

Bhaskara Rao, V - Regional Geophysical studies in the Cuddapah basin, Proc. of second symp. on Upper Mantle project. 1970, NGRI, Hyderabad, 409-422.

Bhimasankaram, V. L. S. and Murali, S. - Report on Deep electrical sounding (DES) carried out in peninsular India by the Centre of Exploration Geophysics, Proc. on workshop on Status, Problems and Programmes in Cuddapah basin, IIPG, Hyderabad, March, 1978, 19-24.

Kaila, K. L., Reddy, P. R., Krishna, V. G., Hari Narain, Sibbotin, I, Checkunov, A. V., Kharechko, G. E and Tiplosky, A. - Crustal structure along Kavali-udipi profile on the Indian Peninsular shield from Deep Seismic Sounding. Jour. Geo. Soc. of India, 1979, v. 20, 807-333.

King, W. - The Cuddapah and Kurnool formations in the Madras Presidency. Mem. GSI, 1872, v. 8.

Krishnaswamy, V. S. - Some concepts, problems and interpretation of peninsular geology, with emphasis on the Cuddapah basin of Andhra Pradesh, Inaugural address, Proceedings of workshop on Status, Problems and programmes in Cuddapah basin, IIPG, Hyderabad, 1978.

Mathew, P. N., Reddy, A. G. B. and Kailasam, L. N. - Geophysical studies in the Cuddapah basin. Symp. on UMP, CRD and NGRI, 1967, Pub. No. 8, 286-309.

Quresehy, M. N and Krishnabrahmam, N - Role of granitic intrusion in reducing the density of the crust and other related problems as illustrated from a gravity study of the Cuddapah basin, India. Proc. Roy. Soc. A. 1968, 304, 449-464.

Rajaraman, S. and Sood, N. K. - Cuddapah basin - a peep into the precambrain. Proc. of the Cuddapah basin, Symp. by post organised by Doris, S. R., GSI, Hyderabad, 1966.

Sanker Narayan, P. V., Paul, P. A., Sarma, S. V. S., Harinarayana, T. and Virupakshi, G. - Telluric field investigations in the southwestern region of Cuddapah basin- Proliminary results: Paper presented in the Second workshop on Status, preblems and programmes in Cuddapah basin. IIPG, Hyderabad, Jan. 1979.

Sarma, S V. S., Rakesh Kumar, Sanker Narayan, P. V. - On the use of spectral methods in the telluric data analysis. Paper presented at AEG, symposium held at Waltair, Feb., 1978.

Yungul, S. H. - The telluric methods in the study of sedimentary structures - A survey. Geoexploration, 15, 1977, 207-238.