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A RECONNAISSANCE TELLURIC SURVEY IN NORTHERN PARTS OF KONKAN GEOTHERMAL PROVINCE, INDIA*

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Abstract

The Konkan hot spring zone stretching over a few hundred kilometres mostly in the Deccan Basalts along the west coast is one of the important geothermal provinces in India. In the present programme of geophysical investigations, a reconnaissance telluric survey has been carried out covering an area of more than 200 square kilometres surrounding the Akloli-Ganeshpuri-Sativili-Koknere hot spring belt. Using an orthogonal pair of dipoles, a total of 30 telluric stations distributed mainly along three traverses were occupied by recording telluric signals in the frequency range 0.02-.05 Hz. The results of this study indicate a systematic distribution of telluric field strength in the area and a conspicuous, well-defined telluric field anomaly has been identified. This anomaly, located in the north-western part of the area, surrounds the Sativili-Koknere hot spring and points to the existence of a subsurface conducting zone in the area. The significance of this telluric anomaly is discussed in relation to geothermal aspects of the area.

Introduction

The west coast geothermal province is considered to be one of the important geothermal prospects in India (KRISHNASWAMY, 1976, GUPTA *et al* 1976). The surface expression of geothermal activity in this province is characterised by the occurrence of several groups of hot springs dotting the west coast over a few hundred kilometres. This province forms a part of a large region in the Indian Peninsula occupied by a vast cover of basalts (Deccan traps) of Upper Cretaceous-Paleocene age. The Deccan traps by themselves occupy a siginificant place in Indian geology and have been of special interest to earth scientist because of several complex geological and structural problems associated with them. Regional geophysical studies in the Deccan trap area on the west coast have brought out several possible basement features which would reflect the tectonic framework of the region in general KAILASAM *et al*. 1972, 1976; KRISHNA BRAHMAM 1975; KAILA *et al*, 1981). However, for obtaining an understanding of the geothermal significance of the area in particular, geophysical surveys with sufficient detail and coverage are to be carried out so as to delineate the areas of interest.

Since many of the geothermal reservoirs are known to be associated with high conducting zones (KELLER, 1970, COMBS and MUFFLER, 1972), electrical prospecting methods play an important role in the exploration of geothermal resources. Amongst this group of geophysical methods, besides the conventional D. C. resistivity method, the telluric method has been recognised as a rapid, powerful and less expensive

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reconnaissance technique and during the past one decade several of the recent geothermal investigations around the world have included the telluric method as a regular geophysical tool in the field programmes (COMBS and WILT, 1975; BEYER *et al.* 1975; LONG and KAUFMANN 1980). Under the present programme of geophysical investigations in the west coast geothermal province, a reconnaissance telluric field survey was conducted during April–May, 1980 in the area covering the northern group of springs i.e., Vajreshwari-Koknere group. The details and results of these investigations are presented and discussed in this paper.

Location

The area for the present investigation is located in the Thana district of Maharashtra and lies between 19°25′ to 19°45′N latitude, and 72°50′ to 73°15′E longitude (Fig. 1). Thermal springs occur in eight different localities, mainly concentrated in two separate groups viz., Akloli-Nimboli-Ganeshpuri (Vajreshwari group) on the southern half of the area and Sativili-Haloli-Paduspada-Koknere group in the northern part of the area. The discharge temperature of the springs range from 38°C to 57°C and their waters are mainly of Na–Ca–Cl type, except that of Koknere. By virtue of the occurrence of hot

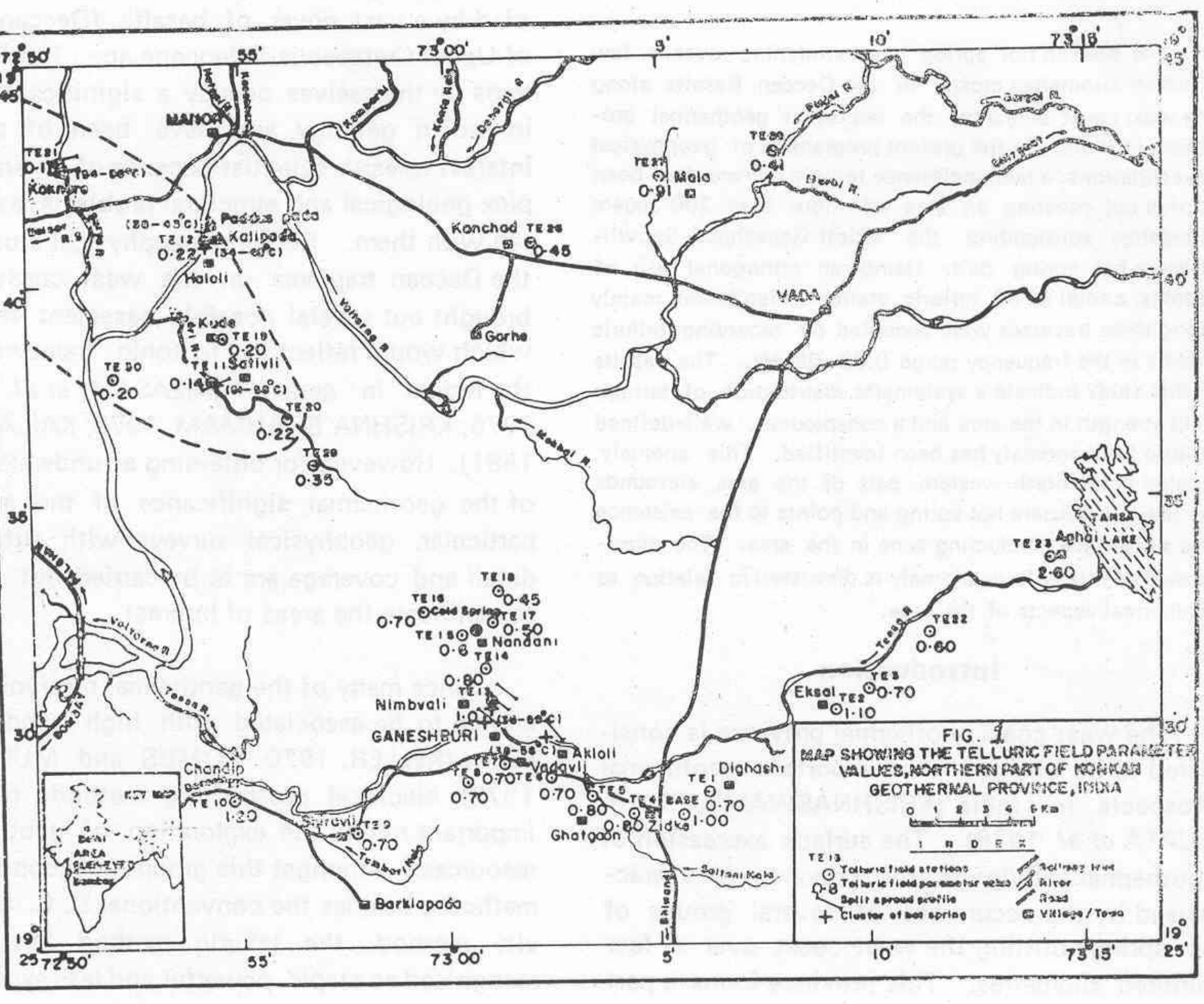

Fig. 1

springs and the associated belief with regard to their therapeutic value, the Vajreshwari area has gained importance from the view-point of pilgrimage and a holiday resort. The east-west flowing Thansa river meanders through the Vajreshwari area and some of the hot springs occur in the river bed itself while some others are on the the banks of the river. Other important rivers that traverse the area are Surya and Vaitarna, with which the northern ones (viz., Koknere-Sativili group) are associated.

Geology

The entire area under investigation is covered by the Deccan traps, these being mainly the tholeitic basaltic flows of Eocene to Paleocene age. The Deccan traps in this region comprise of several individual flows with varying thickness. According to RAJA RAO (1976) the lava flows in this area are classified mainly as 'Pahoehoe' type in which compound pahoehoe flows are more common. The dips are gentle and westerly with dip tangles ranging from 10° to 20°; and thickness of individual flows varying from a few metres to as much as 150 metres. In the case of pahoehoe type, each flow consists of several layers. Each of the layer consists of three sections with a high vesicular top portion with vesicules filled with secondary minerals, a middle section with compact dense basalt and the bottom section with amygdaloids. The traps are traversed by several dykes with widths ranging from a few feet to a few tens of feet and having a general trend varying between NNE-SSW to NNW-SSE. A few shear zones located trend 10° to 30° west of north and some of them when joined together are reported to form a single arcuate feature with its convex side towards east (RAMASWAMY *et al.*, 1979).

There occur several minor faults displacing the individual flows. Many of the hot springs occur along the margin of the dykes, along fracture/shear zones and along major joints.

The west coast region is believed to have under-gone late Tertiary uplift. Geological as well as geophysical studies indicate an anomalous upper mantle configuration and the possible existence of a deep-seated fault along the west coast following the trace of the well-known Panvel flexture in this region. Regional geophysical studies particularly gravity, deep seismics as well as photo-geological studies have indicated the possible existence of several major faults, lineaments and rift zones in the region. The region is also not free from seismic activity.

Telluric method

The telluric method utilizes low frequency (0.1 to .01 Hz) natural source signals and therefore offers a large depth of investigation without much difficulty which is an advantage over other conventional electrical/electro magnetic methods for geothermal exploration. The source signals measured in the method namely the 'telluric currents' are large regional systems of natural currents that flow in the crustal layers of earth and are generated by transient variations of the geomagnetic field through induction in the conducting earth. The strength and direction of these regional currents are influenced by subsurface conductivity distribution and hence by subsurface lithology and structure. In view of this, measurement of relative strength of telluric field at various stations in a region with respect to a fixed 'base station' yields information concerning relative differences in the subsurface conductivity distribution in the area and the telluric field anomalies thus obtained can be directly related to subsurface conductivity anomalies.

In telluric field surveys the field data acquisition involves obtaining the simultaneous recording of telluric signals at different field stations and a base station. This is carried out by employing at least two sets of telluric signal-sensing equipment with one set used for occupying field stations one after the other for limited intervals of time, and the other set kept fixed at the base station for operation during the intervals of recording corresponding to that at the different field stations. The data analyses include the synchronization and comparison of corresponding field and base tellurograms and computation of telluric field parameters which represent average telluric field strength for each the field stations (BERDICHIVISKI, 1960: YUNGUL, 1977; SANKER NARAYAN *et al.* 1980).

Data acquisition

Field investigations for the present study were carried out during April-May, 1980. Though the area under investigation, lying between Akloli and Koknere hot springs, is characterized by several stretches of flat topography, the occurrence of a series of hill ranges and thick vegetation in the area have made the task of location of telluric stations a difficult one. Other factors contributing to the limitations in the choice of field stations are intense electrical noise present in the area and also the limited network of linkage roads. During the field operations a total number of 30 stations could be occupied for the present investigation which is mainly of an exploratory and reconnaissance nature. The two base stations (Chandip and Ambadi, Fig. 1) chosen for the survey are located well away from the known hot springs in the area. Ambadi base station is about 10 km east of Vajreshwari group of springs, while Chandip is about 13 km west of these springs. Field stations were chosen approximately along EW and NS tracks such that they are located in the proximity of known springs as well as away from them.

The field data acquisition was carried out using two telluric unit assemblies designed and developed at the National Geophysical Research Institute, Hyderabad. Each field assembly comprises basically of a D. C. amplifier-filter unit and a recording unit. The amplifier unit is a chopper-stabilized, low frequency, low noise unit with provisions such as appropriate filter setting for rejection of industrial noise, compensation of background self potentials, different low-pass and high-pass settings for covering the frequency range from D.C. to 1 Hz etc. The recording unit is a portable, battery-operated, potentiometric, strip-chart recorder, with provision for operating at different sensitivities ranging in steps from 1 mv. to 100 V. and at different chart speeds ranging from 320 mm/min to 5 mm/hr.

During the field surveying, telluric field signals were picked up along two mutually perpendicular dipoles each comprising a pair of porous pot electrodes (copper rods in copper sulphate solution) planted in the ground. The signals across the electrodes are fed to the amplifier unit where they are amplified and then passed through a filter assembly which facilitates the selection of desired frequency band of signals to be recorded. It has been found that even in the presence of some noise that might arise from the electrodes, the amplifier-recorder assembly with its low noise Figs. 1-2 μv. records the telluric signals faithfully with a very high signal-to-noise ratio.

The dipole length in the present survey was set at nearly 200 metres. The two dipole lines at field as well as at base stations were oriented along NS-EW directions so that the north-south and east-west components of the telluric field are obtained at each of the stations. Signals at all the stations were recorded mainly in the Pc3 range employing the appropriate filter setting with a nearly flat frequency response in the 0.02–0.05 Hz range. Chart speed for the recording of signals was set at 20 mm/min so that the signals in the period range 20 to 50 sec can be recorded with sufficient time resolution and time marks were given for every ten minutes. The recording time for each of the field stations was about 45 minutes. Fig. 2 shows a few sets of examples of tellurograms obtained at some of the field stations and the base station.

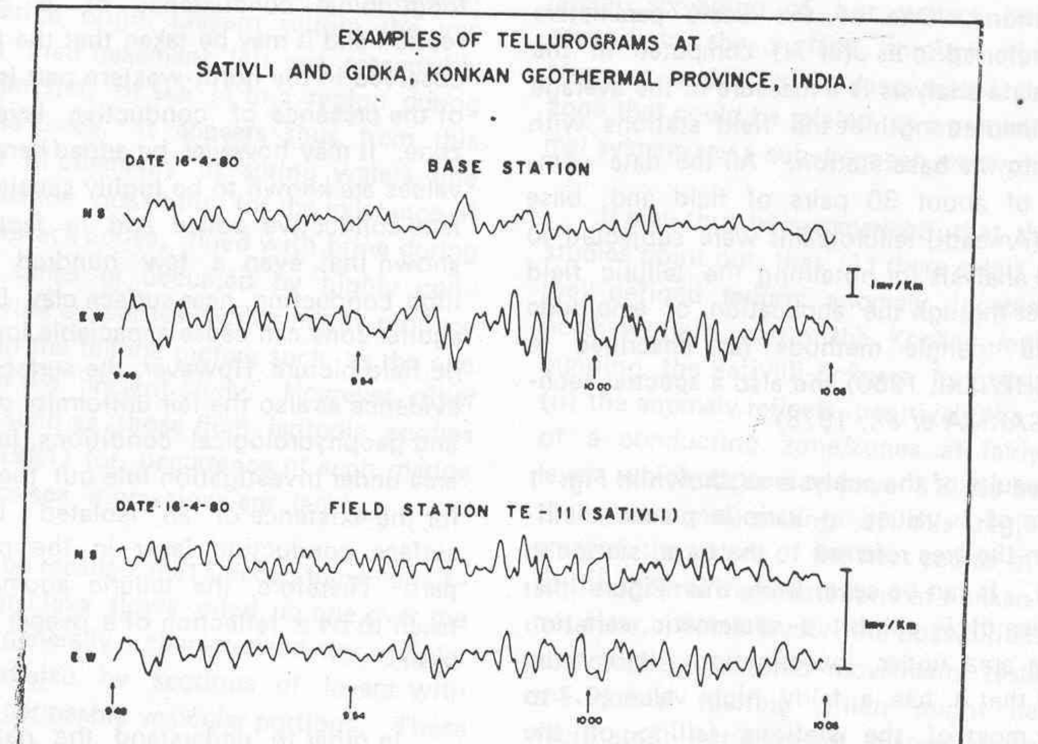

Fig. 2

Data analysis and results

It may be recalled that analysis of telluric field data entails a comparison of telluric field signals recorded simultaneously at field and base stations. One of the basic parameters usually referred to as J(or μ) computed in the telluric data analysis is a measure of the average telluric field strength at the field stations with respect to the base station. All the data comprising of about 30 pairs of field and base station (Ambadi) tellurograms were subjected to detailed analysis for obtaining the telluric field parameter through the application of amplitude ratio and triangle methods (as described in BERDICHIVISKI, 1960) and also a spectral technique (SARMA *et al.*, 1978).

The results of the analysis as shown in Fig. 1 are plots of μ values at various places distributed in the area referred to the base station at Ambadi. It can be seen from this Figure that the values of μ exhibit a systematic variation over the area under investigation. It can be noticed that it has a fairly high value (0.7 to 1.0) for most of the stations falling on the Ekșal Ganeshpur-Chandip road. The stations numbered 13 to 15 (Fig. 1) which are close to the Vajreshwari hot springs maintain also similar high μ values. However, as we go towards north of station TE 14 the value tends to show a gradual decrease and further north this decrease is quite perceptible. In fact, the stations in the northwestern region present distinctly smaller values ranging from 0.4 to 0.1. The low μ values are observed not only at the stations close to Sativili, Haloli, Koknere hot springs but also at stations located well away from these spring. It can thus be concluded that the low values are not isolated ones, but constitute a continuous single, large anomalous zone approximately shown by the dotted line in Fig. 1.

Discussion

The presence of well defined telluric anomaly in the northwestern part of the study area (Fig. 1) is of considerable significance in understanding the subsurface conductivity distribution in the region. It may be recalled that telluric field parameter μ is inversely related to the total longitudinal conductance of a geoelectrical section and it may be taken that the telluric low observed in the north-western part is a reflection of the presence of conductive layer/s in this zone. It may however, be added here that the μ values are known to be highly sensitive to surface conductive zones and in fact it can be shown that, even a few hundred feet thick, high conducting, near-surface clay layer, or an aquifer zone can cause appeciable lows in telluric field picture. However, the surface geological evidence as also the fair uniformity of geological and geophydrological conditions in the entire area under investigation rule out the possibility for the existence of an isolated, large, near-surface, conducting layer in the northwestern part. Therefore, the telluric anomaly can be taken to be a reflection of a deeper conducting layer.

In order to understand the nature of this deeper conductivity source in relation to the geothermal setting of the area, some of the aspects that should be taken into account are : (i) the chemistry of spring waters, and (ii) the aquifer conditions of Deccan traps as well as those formations lying between the traps and the basement, if any.

The majority of Konkan spring waters belong to Na—Ca—Cl type and the TDS (Total Dissolved Salts) range from about 800 to 2500 ppm generally. However, some of the spring waters particularly of Koknere shows a relatively high TDS (i.e. over 8000 ppm). In addition some of the other features noticed for Koknere spring water are : (a) presence of I, Br, and Sr in considerable quantities (b) observational evidence for presence of high $CaCl_2$ content and (c) a high Cl Br ratio amounting to about 282 a value very close to that for sea water (GUPTA and SAXENA 1979; DOWGIALLO, 1975). All the observations are taken to indicate (a) the possibility for considerable admixing of thermal waters with sea water which has undergone evaporation or (b) the possible leaching of salts of marine origin present within the trap series or at their basement left out presumably due to ingression of sea in this region during post-Eocene times. It appears thus from this view-point of chemistry of spring waters, one can consider the possibility for the existence of such subsurface zones, filled with brine during geological times or occupied by highly conducting marine evaporites which might produce anomalies In the telluric picture such as the one observed in the present study. However, other evidences such as those from isotopic studies (KUMAR, 1981) for occurrence of such marine evaporites or sea ingressions are lacking.

It may be recalled that Deccan traps consisting of several lava flows piled up one over the other are generally characterized by joints, fractures and also by sections of layers with porous and permeable vesicular portions. These features, when they occur extensively in the trap layers, can provide fairly good aquifer conditions and these can occur at any depth so that the ascending thermal waters in such geological environments would tend to spread laterally, also. When this lateral spreading of waters Is extensive, one can visualize the existence of hot water acquifer at the depth corresponding to the level of spreading. Such a zone filled with hot water constitutes a high conductive layer and hence should find an expreseion in the telluric field or resistivity picture. It may be noted here that the results of D. C. resistivity sounding survey carried out in the Ganeshpuri-Akloli area (SINGH and GUPTA, 1979) has not indicated the presence of any conducting layer within the first few hundred metres. This, however, is understandable because the possible location of the conducting zone inferred from the telluric picture lies well away from the Ganeshpuri-Akloli hot springs. Thus, the telluric anomaly observed here can be attributed partly to hot water aquifer that might exist at deeper levels (>I km), formed presumably due to extensive lateral spreading of hot waters before they ascend to the surface through the primary fractures and/or to a deep-seated conducting zone that could be related to a primary geothermal system-say a sub-trappean reservoir.

It may thus be summarised that the present studies point out that (1) there exlsts a distinct well-defined telluric anomaly located in the north-western part of the Konkan region surrounding the Sativilli-Koknere hot spring belt,; (ii) the anomaly reflects positively the presence of a conducting zone/zones at fairly deeper levels which appears to have a close bearing on the geothermal setting of this region. At present, the nature of the heat source in relation to the thermal manifestations of Konkan coast is not clear. Some favour the possibilities of the post-trappean tectonic movements resulting in the normal faulting which might have also facilitated intrusion of magmatic bodies at shallow depths. Others argue in favour of the possible existence of a deep circulation system of meteoric water and its heating to temperature around 100-140°C (estimated reservcir tamparature from geochemical thermometers, GUPTA and SAXENA, 1979) on account of regional/local geothermal regime. However, detailed work including deep resistivity soundings, magneto-tellurics, tellurics, stable and radioactive isotopic studies would throw more light on the nature of geometry of the conductive zones reflected in the present study and the nature of the heat source.

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