HOT WATER SEEPAGE INTO SHALLOW COAL MINES OF MANUGURU COALBELT, GODAVARI VALLEY COALFIELD ANDHRA PRADESH, INDIA.

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ABSTRACT

Occurrence of hot water in shallow coal mines of Permian age in Manuguru coalbelt, without apparent igneous activity is being reported for the first time in this country. A number of hot and cold springs are located in and around this coalbelt in fault zones. This anomalous thermal gradient is possibly due to the spatial redistribution of heat by convection in ground water, flowing through high permeability conduits in the basement rocks extending into the overlying lower Gondwana sediments of this coalbelt. It is estimated that the thermal reservoir temperature is around 150°C. It is likely that the thermal water emerge onto the surface after the circulation of the meteoric water mainly through Archaean gneisses which are the basement rocks, upto depths of about 5 kms. The waters both in the shallow and deep aquifer systems have a high fluoride and silica contents.

INTRODUCTION

Hot water seepage (41°C) were encountered in two coal mines in the Manuguru coalbelt of Godavari Valley Coalfield, Andhra Pradesh, India, at very shallow depths of 70 to 140m. This is the first recorded occurrence of hot water in a coal mine in this country which is apparently not connected with any igneous activity. The hot water seepage into the coal mines, though not much in quantity, locally raises the humidity to uncomfortable levels and poses a hazard to the smooth working at the faces. The status of this hot water problem is briefly presented in this paper.

The Godavari Valley Coalfield defines a major north-northwest-south-southeast trending basin belt on the pre-Cambrian platform. It forms a major part of low land mostly between the two sub-parallelly trending high ranges of Proterozoic sediments, with an undulating topography of Gondwana sequence, probably representing the remnants of an earlier peneplained surface. The area is drained by Godavari river and its tributaries and enjoys a typical tropical climate with an average annual rainfall of 1090 mm.

Location

Manuguru coalbelt is located on the north-eastern margin of the Godavari Valley Coalfield in its southeastern part (Fig.1). The location of the other known hot and cold springs in and around Manuguru coalbelt are located in the faulted contact zones of the Proterozoic (Pakhal) metasediments with that of the Permian sediments of Lower Gondwana sub-group. A spring with a discharge temperature upto 30°C has been considered as a cold spring. The known limits of this hydrothermal reservoir are Pagideru (N.Lat.17°58': E.Long.80°44'; 65C) in the northwest, Parnasala (N.Lat.17°56': E.Long.80°54'; 65C) in the northeast, Bugga (N.Lat.17°55': E.Long.80°43'; 65C) in the southwest and Agnigundala (N.Lat.17°38': E.Long.80°56'; 65C) in the southeast covering an area of about 150 sq.km. and located in the basement rocks at a depth of about 5 kms.

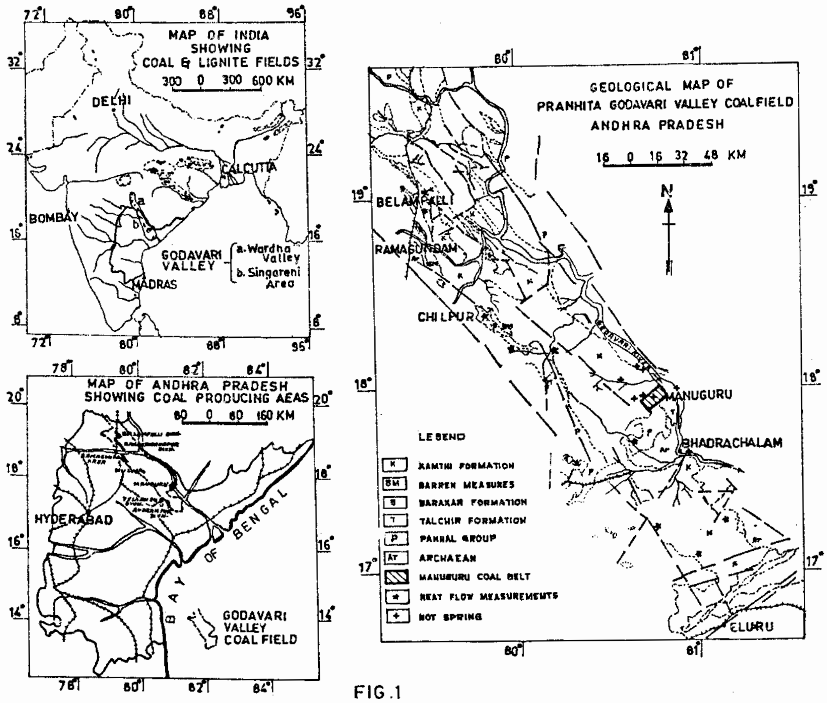


FIG.1

GEOLOGY

On regional geological and structural considerations the Godavari Valley Coalfield, is a broad graben containing a thick pile of fluviatile/continental sediments of Gondwana Super Group comprising arenaceous and argillaceous facies with widespread vertical as well as lateral variations (Ramanamurty, B.V., 1981).

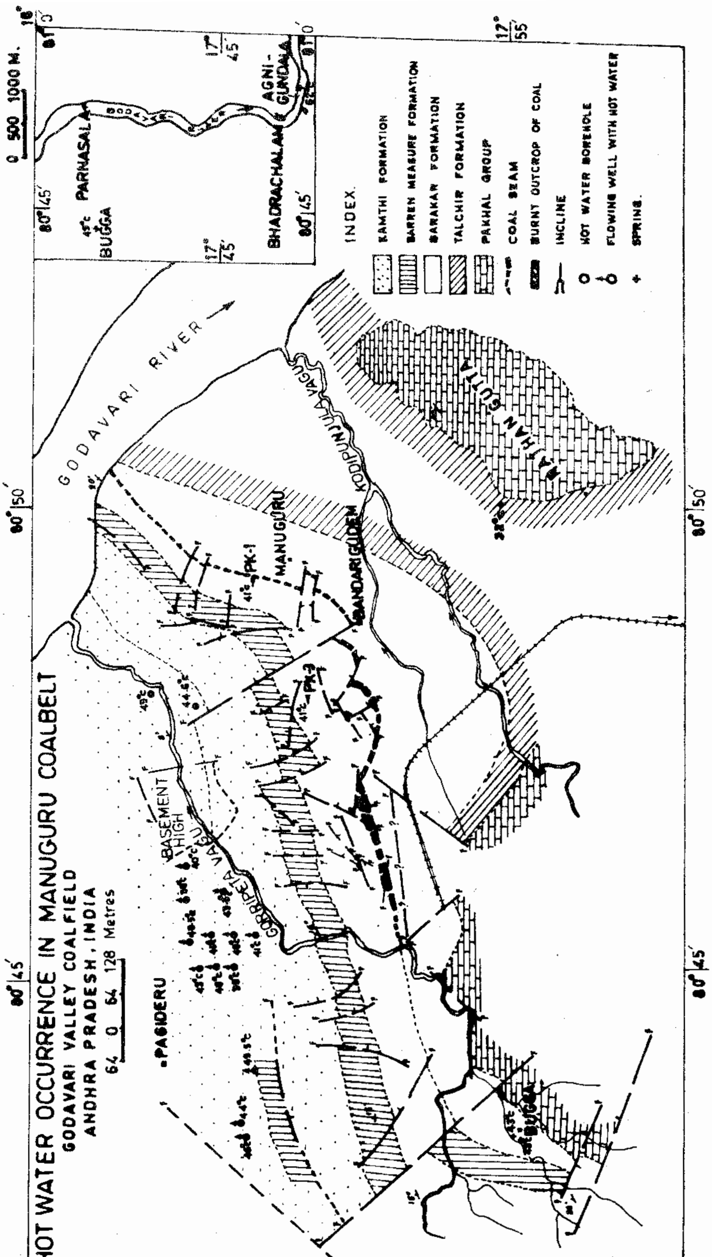
The Manuguru area comprises lower Gondwana sedimentary sequence unconformably overlying the Proterozoic Pakhal metasediments which form the basement rocks in this area. The lower Gondwana sub-group consists of the Talchir Formation (250 ± 50 m.), the Barakar Formation (275 ± 25 m.), the Barren Measures Formation (100 ± 20 m.) and the Kamthi Formation (+275 m.)

Coal exploratory borehole data has revealed the presence of nine major sandstone horizons in the thick sequence of lower Gondwana group of sediments of this coalbelt. They split up, coalesce and pinch out locally over a strike length of about 13 kms. These sandstones are separated from each other by aquicludes like clays, shales and coal seams. Two recognisable coal horizons, named as 'Thick Seam' and 'I Seam' in the ascending order, occur in the Barakar Formation of this coalbelt. The in between parting zone comprising 6 major sandstone horizons separated from each other by clays and shales varied in thickness from 120 to 190 m. A schematic borehole fence diagram of this parting zone in a centrally located representative area, is depicted in figure-3. These formations generally trend in a northeast-southwest direction, in the northeastern part of the basin and in a east-west direction in the western end, with a general north-west to northerly dip of 10° to 20°. Based on the interpretation of sub-surface data as many as 61 faults of normal gravity type were delineated with throw ranging from 5 m. to as much as 120 m. (Fig.2).

DATA ON HYDROTHERMAL RESERVOIR

The Godavari Gondwana basin has evolved in a multi-stage tectonic (rift) activity with reported high heat flow anomalies at places (Fig.1) and ideal to support large geothermal anomaly. Recent (13th April, 1969) earthquake that occurred near Bhadrachalam (N.Lat.17°40': E.Long.80°53'; 65C) shows the neotectionic activity and continued intracrustal disturbance in this region. Manuguru coalbelt is located at the junction of two major lineaments - one trending northwest-southeast and the other in northsouth direction.

Limited studies carried out in parts of Godavari Valley Coalfield have indicated high heat flow values ranging from 1.06 to 2.49 (Rao, R.U.M. et al, 1970) (Fig.1). A number of hot springs (32° to 62°C) are located in and around Manuguru coalbelt area both within the coal bearing Gondwana sequence (Bugga) as well as in the underlying basement rocks (Agnigundala and Parnasala) (Fig.2). Hot water (38° to 49.5°C)


HOT WATER OCCURRENCE IN MANUGURU COALBELT
GODAVARI VALLEY COALFIELD
ANDHRA PRADESH, INDIA
64 0 64 128 Metres
0 500 1000 M.
GODAVARI RIVER
PASIDERU
MANUGURU
PK-1
PK-2
BASEMENT HIGH
GORRIPETA VAGU
KODIPUNJULA VAGU
BANDARIGUDEM
BUGGA
PARNASALA
BHADRACHALAM
AGNI-GUNDALA
RATHAN GUTTA
INDEX
KAMTHI FORMATION
BARREN MEASURE FORMATION
BARAKAR FORMATION
TALCHIR FORMATION
PAKHAL GROUP
COAL SEAM
BURNT OUTCROP OF COAL
INCLINE
HOT WATER BOREHOLE
FLOWING WELL WITH HOT WATER
SPRING

F I G . 2

was also encountered in some of the exploratory boreholes drilled for coal and as well in two of the coal mines at shallow depths, through the thick (120 to 190 m.) parting zone between 'I Seam' and 'Thick Seam'. This parting zone comprises of sandstones and clays. The studies have revealed that the hot water is confined to two aquifers - a pebble bed about 30 to 50 m. below I Seam and silicified sandstone horizon about 40 m. above Thick Seam (Horizon Nos.3 and 6 - Fig.3).

SCHEMATIC BOREHOLE FENCE DIAGRAM
SHAFT BLOCK-I, MANUGURU COALBELT
GODAVARI VALLEY COALFIELD., ANDHRA PRADESH, INDIA

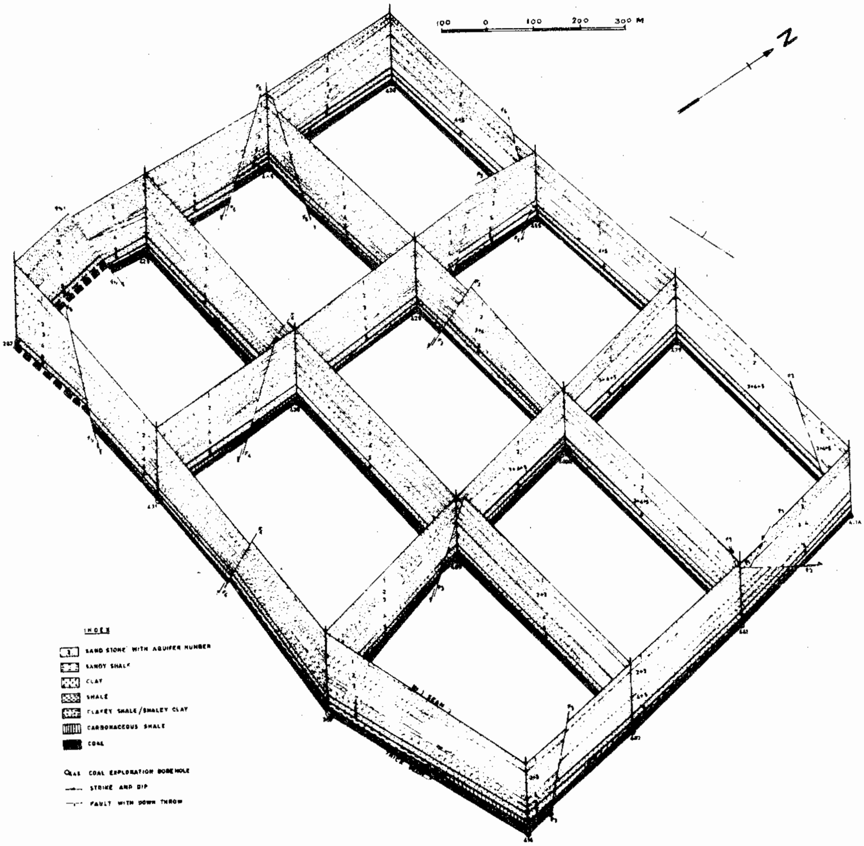


FIG. 3

As an exception to this general occurrence of hot water between I Seam and Thick Seam, hot water in PK-3 Incline was encountered immediately below Thick Seam at a depth of about 85 m. from surface. Joint planes trending approximately in north-south direction are noticed in the floor of coal seam extending into the floor sandstone of the seam. Resistivity profiling has brought out two 'low' zones of resistivity, approximately aligned in north-south direction. One of these zones passes close to the surface projection of the fractures encountered in PK-3 mine. Thermal profiling reveals that these low resistivity zones are associated with small temperature high anomalies of the order of 2°C (Reddar, R.B. et al, 1983). Thus the thermal manifestation in PK-3 mine is seen in the form of hot water with temperature of about 42°C., flowing through open joints in the coal seam and the sandstone horizon forming the floor of coal seam. The hot water discharge is estimated to be about 300 lit./min. This flow of hot water has caused acute deterioration in working conditions of the mine, due to abnormal increase in the humidity and seriously hampering the progress of work in the mine, specially at the working face.

It is likely that hot water coming upwards along the basement faults is recharging these two high permeable sandstone horizons (No.3 and 6). Coal exploration in north-central part of Manuguru coalbelt has revealed a natural hidden basement high of schists and phyllites (of Proterozoic Pakhal group) over an area of 2.6 sq.kms. Due to this basement high acting as a local barrier, the normal flow path of ground water in the deeper aquifer system is diverted towards west instead of its usual northerly direction. To the west of the basement high, an artesian belt of hot water was encountered with the piezometric head ranging from 2.68 to 8.25 m. above ground level and free flow discharge of 60 to 1230 lit./min. The temperature of hot water in this artesian belt ranges from 38° to 49.5°C (Table-1). But in the future workings of Thick Seam in this area, which are deeper, the temperature of hot water seepage shall be more than what is observed in the exploratory boreholes, because the hot water mixes with lesser quantum of cold water in the upper aquifers (above Thick Seam). Agnigundala thermal water is of Na-Cl type, while in the rest of the area the water is $Na\text{-}Ca\text{-}HCo_3\text{-}So_4$ type. The difference in the chemical composition of water may be due to the interaction of hot water from the basement rocks with that of Gondwana formations, during the course of which it is more mineralised. Using silica as geochemical thermometer the temperature of the deep seated reservoir is estimated to be about 150°C using the formula

$$T_{SiO_2} \ ^\circ C = \{1533.5/(5.768 - \log SiO_2)\} - 273.15$$

In general, the waters have a high silica content (34 to 143 ppm) and high fluoride content 2.5 to 6.2 ppm) making the waters unsuitable for drinking purpose (Table-2).

TABLE-1

ATTITUDE OF PIEZOMETRIC SURFACE IN NORTH-CENTRAL PART OF MANUGURU COALBELT, GODAVARI VALLEY COALFIELD, ANDHRA PRADESH, INDIA.

Sl. No.	Bore-hole No.	Depth of borehole (m.)	Depth to		Hot water encountered at (m)	Piezometric head (m. above ground level)	Free Flow discharge (lit./min.)	Temperature °C
			I Seam	Thick Seam				
1	359	248.9	-	-	51.0	5.00	80	46.0
2	360	193.7	-	-	95.0	5.26	180	44.0
3	363	266.6	-	-	65.0	8.25	525	49.5
4	421A	507.1	277.7	467.5	414.9	4.10	65	40.0
5	425	476.4	226.5	447.6	405.0	2.85	110	39.0
6	426	455.2	262.2	448.6	200.0	3.68	70	40.0
7	429	487.5	277.2	458.6	391.3	3.20	60	38.0
8	430	525.0	320.9	509.8	368.3	2.68	120	43.0
9	431	365.0	152.9	351.8	312.5	5.90	250	41.0
10	438	410.5	196.5	395.0	268.9	5.64	650	48.0
11	446	474.4	264.5	461.8	431.2	6.20	780	49.0
12	455	490.9	242.0	468.0	266.9	6.85	1230	48.5

TABLE - 2.

HYDROCHEMICAL DATA OF SPRINGS, COAL MINES AND BOREHOLES IN AND AROUND MANUGURU COALBELT, GODAVARI VALLEY COALFIELD, ANDHRA PRADESH, INDIA

Sl. No.	Location	Temp. °C.	pH	E.C.	Na	K	Ca	Mg	Cl	SO_4	CO_3	HCO_3	F	SiO_2
1	Agnigundala hot spring	62.0	7.50	1750	321	23.6	32.5	0.9	430.0	146.5	Nil	38.0	3.5	143
2	Bugga hot spring-1	43.0	8.05	758	92	6.4	28.5	14.5	28.4	14.6	Nil	170.8	4.5	56
3.	Bugga hot spring-2	43.0	8.10	578	100	7.1	28.0	5.5	24.8	13.2	Nil	170.8	4.6	60
4.	Rathangutta spring	32.0	6.91	224	32	Nil	Nil	Nil	46.1	12.0	Nil	8.2	1.0	40
5.	PK-1 mine water	41.0	7.95	968	215	0.9	44.0	2.2	63.9	14.2	Nil	193.5	4.2	34
6.	PK-3 mine water	41.5	7.81	1180	219	0.9	54.0	14.7	74.5	30.2	Nil	219.6	4.4	40
7.	Borehole No.359	44.0	6.40	576	127	0.8	22.0	13.8	14.2	9.8	Nil	79.3	4.2	62
8.	Borehole No.360	46.0	6.62	694	122	2.0	30.0	3.1	14.2	6.2	Nil	159.9	4.3	68
9.	Borehole No.363	49.5	8.08	775	154	1.2	28.0	8.7	17.8	6.0	6.0	115.9	4.1	96
10.	Borehole No.426	40.0	7.79	705	121	0.9	28.0	3.6	24.8	4.6	Nil	170.8	5.8	54
11.	Borehole No.431	41.0	7.76	602	82	9.0	90.1	6.0	63.9	7.0	Nil	217.5	2.5	121
12.	Borehole No.438	48.0	7.65	588	66	13.2	80.1	13.6	53.2	8.2	Nil	198.0	4.0	43
13.	Borehole No.441	32.0	7.85	493	88	6.2	60.1	6.0	81.6	10.0	Nil	109.0	2.5	45
14.	Borehole No.455	48.5	7.03	1140	252	1.6	42.0	3.6	28.4	16.2	Nil	195.2	6.2	126

Geothermal anomaly in Manuguru coalbelt without apparent igneous activity is a unique phenomenon. This anomalous thermal gradient is possibly due to the spatial redistribution of heat by convection in the ground water flowing through high permeability conduits (Freeze and Cherry, 1979) (Fig.4). Possibly, the cold water flowing down through the major dip fault in the Godavari river bed is picking up the temperature due to normal thermal gradience and discharging vertically up through the deep seated basement faults and interconnected high permeable fracture zones. It is probable that the deep thermal water of about 150°C mixes with cold waters during its ascent and thereby its temperature was reduced. If we assume that the temperature of normal cold water as 30°C which mixes with the ascending hot waters, we obtain 75% as the component of cold water. It is likely that the thermal waters emerge onto the surface after the circulation of meteoric water mainly through Archaean gneisses upto depths of about 5 kms.

The discharge from the springs in this area is very low (3 lit./min. approx.), presumably due to the low confining pressure. To reduce, if not totally prevent, the hot water seepage into the mine workings, it is imperative that the piezometric head of the aquifer(s) circulating it, has to be depressed below the working seam level. But in practice, the dimension of the geothermal reservoir (about 150 sq.kms.), high potentiality of the aquifer system (about 50 to 100 m^3/hr.) and depth of the workings involved (130 to 510 m.) prohibit tackling this geothermal problem on a regional scale.

Utilisation of geothermal waters

During the process of winning the precious coal reserves in Manuguru coalbelt, it is expected that huge quantities of hot water are to be pumped out, so as to reduce the seepage into the existing as well as further dip side workings. In view of the considerably large extent and potentiality of the geothermal reservoir, it may be possible to utilise the hot waters as pre-heated water for the boilers of thermal power plants in this area, as a source of non-conventional energy. Also, these waters can be utilised for extensive irrigation in this area.

Future work programme

Before planning the dewatering operations of hot water on a large scale, it is a pre-requisite to delineate the hot water aquifer system, the conduits prevailing in these aquifers through which the hot water is being circulated and to estimate the potentiality of the geothermal reservoir. So, it is recommended to carry out geophysical resistivity surveys, thermal mapping, exploratory drilling and their thermal logging and conducting aquifer performance tests with a view to understand the geometry of the hot water aquifer system, its structural configuration and to evaluate

FIG-4

MECHANISM OF HOT WATER CIRCULATION MANUGURU COALBELT

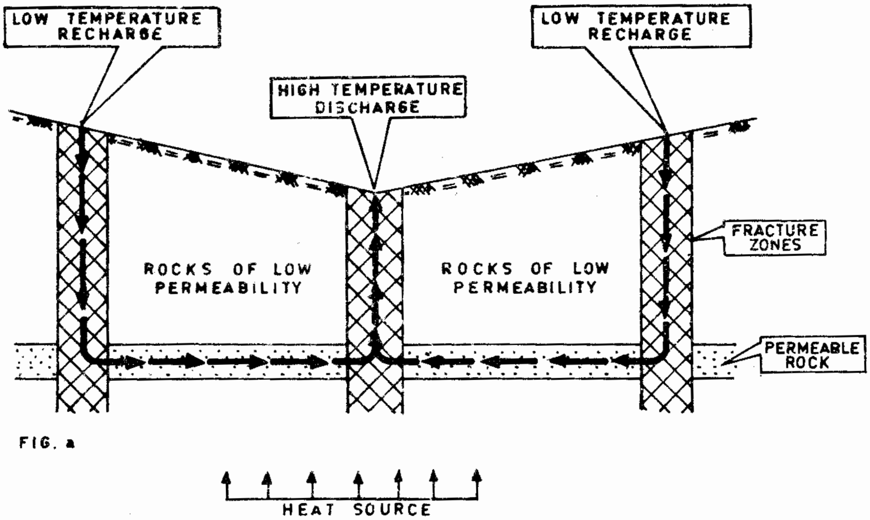


FIG. a

UPWARD MIGRATION OF HOT WATER INTO SHALLOW GEOTHERMAL RESERVOIRS DUE TO

a. FORCED CONVECTION THROUGH HIGH PERMEABILITY CONDUITS(AFTER WHITE,1973)
b. FREE CONVECTION IN A CONFINED AQUIFER(AFTER DONALDSON,1962)

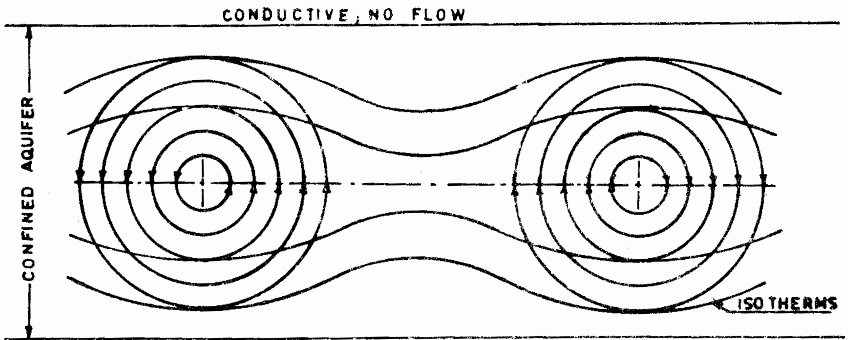


FIG. b

the potentiality of the hydrothermal reservoir in total. The data generated by these studies is expected to help in planning the dewatering system and effective coal mining.

CONCLUSION

Preliminary hydrogeological and geophysical surveys have given an insight into the nature and severity of the geothermal problem encountered in the shallow coal mining in Manuguru coalbelt. In the future dip side workings the severity of the problem is likely to be more. Carrying out detailed geophysical surveys and hydrogeological testing in specially designed structures is expected to help in a better understanding of the geometry and structural configuration of the hot water aquifer system and in planning the dewatering operations. Hot water pumped out in this process may be utilised for thermal power generation and irrigation.

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