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High heat generating granites of Hyderabad, India

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ABSTRACT

Granites and rocks of granitic composition out cop over the entire Indian subcontinent. These rocks are found from the southern part of India (Kanyakumari) to the Himalayas on the north and represent a large age spectrum extending from one million (Nanga Parbat) to 2700 Ma (Darwad Craton) of south India. The outcrop area of these rocks is about 150000 sq km. The most striking feature of these granites is their ability to generate high heat due to high radioactive element content. For example, the uranium and thorium content of the Bundelkhand granites (age 2550 Ma) of Madhya Pradesh, India is 14 and 101 ppm respectively and the heat generated by these granites is 8 $\mu W/m^3$. However, radioactive element data on all the granites occurring over the Indian sub-continent is not available. This is a pre-requisite to evaluate their suitability for EGS projects. With this objective, in 2017 we have initiated a state wide (Telangana State) programme to create a data base on uranium, thorium and potassium on granites and associated rocks. Initially we have selected northwestern part of Telangana State (Sangareddy district, where IITH is located) for this work. Granites are wide exposed in and around the IIT Campus (Indian Institute of Technology Hyderabad) in Sangareddy district. The uranium, thorium and potassium contents in these granites vary from 12-86, 20-107 ppm and 2-5% respectively. The radioactive heat generation and the surface heat flow over the area and the power generation capacity of these granites are discussed in the paper. This work is being continued in the current year.

1. INTRODUCTION

Demand for electricity will never decrease and the demand will increase exponentially with increase in population. This is especially true with non-OECD countries like India where the population growth is pitched at 1.13%. In the next decade coal will dominate the energy source and will be the major contributor of CO_2 to global atmosphere. India is a major contributor of CO_2 making the global emissions amounting to 33 Gt (Boden et al., 2011). With increase in energy demand, the CO_2 emissions in 2018 globally showed an increase of 1.7 % amounting to about 33 Gt CO_2 (Boden et al., 2011). Indian thermal power holds over 87% share in the country's electricity supply. Although renewable energy generation growing steadily, registering an increasing of 9% from the previous year, this is not making an impact in CO_2 emissions reduction. The main renewable energy source is solar pv. However, there are several issues with solar pv as discussed in detail by Chandrasekharam and Ranjith (2019). Geothermal energy is still in its infant stage in India and has a large scope in reducing CO_2 emissions and providing the country with a sound clean energy source. Besides hydrothermal resources, India has a large EGS (Enhance Geothermal System) resource represented by granites that have anomalous high concentration of radioactive elements. In this paper we report new data on uranium, thorium and potassium in granites occurring in and around IIT Hyderabad campus, Kandi, Hyderabad (Figure 1) and assess the heat generating capacity of these rocks and estimate the heat flow over the surface.

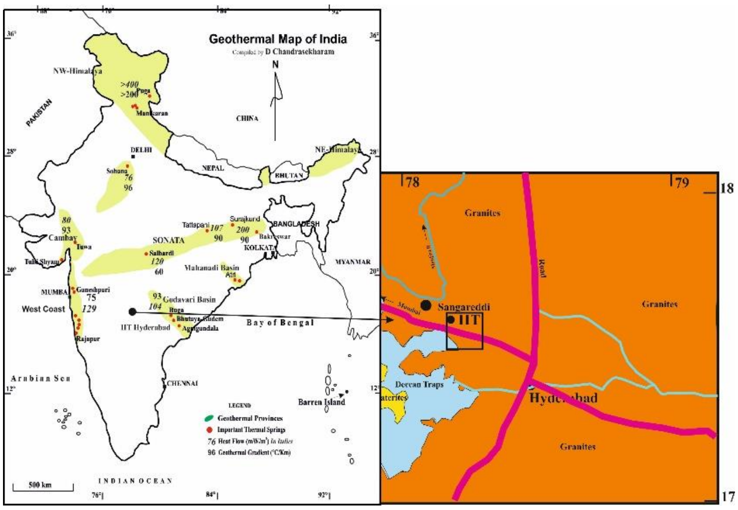

Figure 1: Hydrothermal provinces of India. Sample location of granites currently studied is shown.

2. GRANITES AND GRANITES

India is one of the few countries that contain geological Formations extending from Archean to Recent. Large area is covered by plutonic rocks represented by granites and related rocks. These granites occur as intrusives into Early to Late stratigraphic units. The country has excellent exposures of rocks belonging to the entire geological age spectrum and a major volume is represented by volcanic and plutonic rocks. The volcanic flows and the sedimentary Formations provide excellent heat insulation to these plutonic intrusives. The evolution of granite plutonism in the stratigraphic evolution in India is shown in Table 1. Granites, representing the continental crust, occur as intrusives in early and late stratigraphic units, as shown in Table 1. As shown in Table 1, granites of age varying from the Precambrian to Recent (1 Ma) occur in the Indian stratigraphy. The outcropping area of the granite over the continent is about 150,000 sq. km (Chandrasekharam and Chandrasekhar, 2008, Chandrasekhar and Chandrasekharam, 2008). These granites are covered by sedimentary sequences of varying ages or by the Deccan flood basalts. While Precambrian granites are widely exposed in the central and southern parts of India, post Cretaceous granites are widely exposed in the northern part of India and the Himalayas.

Table 1. Granite plutonic activities (vertical Bars) in the Indian stratigraphic sequence. For the sake of simplicity, the Formations representing each Era are deleted (modified from Chandrasekharam and Chandrasekhar, 2008).

ERA	Ma	System	Granite plutonism
CENOZOIC (CZ)	<65		
		Quaternary	
		Neogene	█
		Paleogene	█
MESOZOIC (MZ)	250-65		█
		Cretaceous	█
		Jurassic	
		Triassic	
PALEOZOIC (PZ)	540-250		
		Permian	
		Carboniferous	
		Devonian	█
		Silurian	
		Ordovician	
		Cambrian	
PRECAMBRIAN (PE)	>540		
		Proterozoic	
		Archean	█

Figure 2: Granite exposures in the study area.

The area currently studied falls within the Precambrian territory of southern part of India (Figure 1). Due to weathering, these granites exhibit different shapes and sizes (Figure 2).

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3. SAMPLE COLLECTION

Ten fresh granites samples were collected from the study area. The samples were broken to small pieces, cleaned and preserved in polythene bags. Uranium, thorium and potassium concentration in the samples were analyzed from Atomic Minerals Directorate for exploration and research laboratory located in Hyderabad. Sample location and analytical data are presented in Table 2.

Table 2. Location of the granite samples and concentration of uranium, thorium and potassium in the granites.

Sample name	Lat	Long	eU_3O_8 (ppm)	ThO_2 (ppm)	Ra(eUO_8) (ppm)	U (ppm)	Th (ppm)	K (wt%)	RHP $\mu W/m^3$	HF mW/m^2
Peddapur A4	17.6	78.0	36	42	9	34.1	36.9	4.7	11.8	157.7
Lingampally D2	17.5	78.3	91	122	24	86.8	107.2	5.1	30.2	342.1
Kondapur A5	17.6	78.0	25	19	4	22.8	16.7	5.5	7.5	115.3
Rudraram E5	17.6	78.2	19	32	3	17.3	28.1	1.6	6.5	105.5
Kandi C5	17.6	78.1	13	12	3	12.2	10.5	2.4	4.1	81.0
Pottirreddipalli B5	17.6	78.1	47	57	12	44.7	50.1	5	15.4	194.2
Yeddumanaram	17.5	78.5	49	60	14	47.2	52.7	4.9	16.2	202.3
Isnapur x road F5	17.6	78.2	50	60	14	48.0	52.7	4.9	16.5	204.5
Kasaram	17.5	78.2	27	24	4	24.5	21.1	5.1	8.2	122.4
Lakdaram E4	17.6	78.2	58	64	18	56.4	56.2	5.3	18.9	228.9

In order to compare the present data with the granites from other parts of the south Indian province, published data on uranium, thorium and potassium concentration on some of these granites are shown in Table 3.

Table 3. Concentration of heat producing radioactive elements and the heat production in certain granite of south India (adapted from Gupta and Venkateswr Rao, 1970)

Sample No.	Rock type	Area/system	Heat generation ($\mu w/m^3$
1	Granite	SE Mysore	6.35
		Hyderabad	5.57
		Hosdurga	3.80
		Closepet	2.38
		Chitradurga	1.08
2	Gneiss	SE Mysore	3.07
		Karadikuttam	2.93
		Dharwar	0.59
3	Granite-gneiss	Kolar schist belt	1.51
		Holesnarsipur	1.38
4	Gneiss	Kolar schist belt(Karnataka)	2.80
5	Anorthosites	Kondapalli	0.21
		Holenarsipur(Karnataka)	0.10
6	Amphibolite	Kolar schist belt(Karnataka)	0.26
		Holenarsipur	0.23
		Sargur schist belt	0.16
7	Pegmatite	SE Mysore	3.67
8	Hornblende	Kolar schist belt	0.26
9	Hornblende	Kolar	0.98

From the current work and previous literature (Tables 2, 3) it is very evident that compared to other Precambrian rocks of Southern India, granites occurring in Telangana State are enriched in uranium, thorium and potassium (Table 2),

4. STRESS FIELD OVER THE INDIAN PLATE

The Indian plate is under the stress regime characterized by NNE-ENE oriented S_{Hmax} (Gowd and Srirama Rao, 1992). The stress regime pattern over the Indian plate deduced from various sources is shown in Figure 3. These stresses are induced on the granites due to the northward compression of the Indian plate together with the net resistive forces arising from the Himalayan collision zone. The tectonic forces acting on these granites are of the order of 7 x 10^{12}N/m. The S_{Hmax} in these provinces increases at the rate of 55 MPa/km while the global average is about 29 MPa/km (Gowd et al., 1996, Chandrasekharam et al., 2006). Such high horizontal stress regime on these high heat generating granites, with estimated resource base discussed above, appears to be excellent sites for initiating enhanced geothermal resource projects in the country.

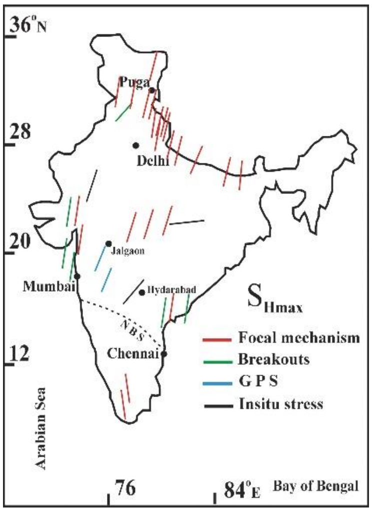

Figure 3: Stress pattern over the Indian continent. Compiled from various sources.

5. DISCUSSION

The southern India represents a stable continental shield region with very few seismic events. This region has not recorded any anomalous geothermal gradient as has been observed in the geothermal provinces of SONATA, West Coast, Gujarat and Bihar and Jharkhand (CRUMANSONATA, 1995, Senthil Kumar et al., 2007, Singh et al., 2014, 2015a, b, c, Roy and Rao, 2000, Chandrasekharam and Chandrasekhar, 2010). The geothermal gradient measured from a bore hole at Killari, Maharashtra, about 250 km from the study area is about 17 to 20 °C/km (Roy and Rao,1999). The crustal heat production model of Roy and Rao (1999) mantle contribution to the crustal heat flow is 12 mW/m^2. The measured heat flow values at Manuguru and Aswaraopet in the Godavari (~300 km east of the study area) 52 to 104 mW/m^2 (Roy and Rao, 1999). Thus, the crustal contribution to the surface heat flow in and around Manugru is about 92 mW/m^2. This additional heat flow is contributed by the granites with high concentration of uranium, thorium and potassium. The heat generation values report for the granites from the study area (Table 2) is similar to that report by earlier workers for the southern Indian craton (Roy and Rao, 2000, Singh et al., 2015c). The hydrothermal system along the Godvari valley is driven by these high heat generating granites. The measured thermal water temperature from a 1 km bore-well in Manuguru is 82 °C (Figure 4, Chandrasekharam and Chandrasekhar, 2020: this volume). This bore well penetrates the thick Gondwana sedimentary formation and taps the geothermal reservoir in the granites lying below the sedimentary sequence.

Figure 4: Steam field near the bore well, Manuguru, Godavari Valley (Phto: D Chandrasekharam).

Assuming a natural geothermal gradient of 25 °C/km in this region, the temperature of the reservoir would be around 120 °C at 2 km depth. Based on these assumptions a schematic model for the temperature regime below the study area is proposed in Figure 5.

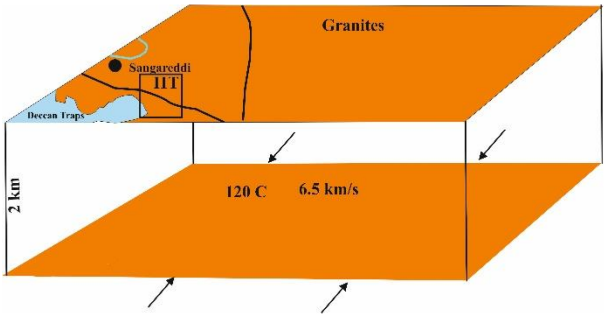

Figure 5: Schematic model for subsurface temperature regime below the study area. Arrows indicate regional stress acting on the granite body

These granites, like the Bakreswar granites (Chaudhuri et al., 2015, Singh et al., 2015a, b) may be releasing large amount of He into the circulating fluids. There is no data on the He content in the thermal waters of Godavari Valley thermal springs. The heat generation values for the Kandi granites is higher compared to the Gugi Granites in Dharwad (Singh et al., 2014)

6. CONCLUSIONS

New data on uranium, thorium and potassium in granites from IITH campus are reported. These granites are rich in these elements and heat generation varies from 4 to 30 mW/m^3. These granites are the main heat source for many existing thermal springs along the Godavari Valley. The recorded surface heat flow values indicate that these rocks, together with the regional stress distribution pattern, are potential candidates to support enhanced geothermal systems projects. The exploration work on granites from other sites in the state is being continued.

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