Report on :

Visit to
Geochemical Monitoring Laboratory, at Bakreswar-Tantloi Geothermal Area, West Bengal & Jharkhand

Date of Visit: August 23-24, 2015

Helium and Geothermal Project
NIT Durgapur
Mahatma Gandhi Avenue
Durgapur 713 209

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Visit to
Geochemical Monitoring Laboratory, at Bakreswar-Tantloi Geothermal Area, West Bengal & Jharkhand

1. Aim:

1. To collect Water & Gas samples from Hot Springs at Bakreswar Geothermal Area, West Bengal.
2. To collect Water & Gas samples from Hot Springs at Tantloi Geothermal Area, Jharkhand
3. Field reconnaissance to study the local geology of the area.
4. To estimate the Helium potential of the area.
5. To estimate the Geothermal potential of the area.

2. Duration of visit: August 23-24, 2015

3. Team Members:

1. Dr. Hirok Chaudhuri, Asst. Prof. Dept. of Physics, NIT Durgapur
2. Dr. R. K. Agarwal, Director, GSI, Lucknow
3. Mr.P. C. Das, Director, GSI, Kolkata
4. Mr. NathuSingh,Geologist, GSI, Lucknow
5. Mr. ChiranjitMaji (JRF, Helium & Geothermal Project, NIT Durgapur)
6. Miss. Tapapriya Gupta (JRF, Helium & Geothermal Project,NIT Durgapur)
7. Mr. Ritesh Kant Gupta (M. Tech Student,Dept. of Physics &Helium & Geothermal Project, NIT Durgapur)
8. Mr. Ritwik Das (M. Tech Student,Dept. of Physics &Helium & Geothermal Project, NIT Durgapur)
9. Mr. Prithwijit Roy, Technical Assistant, Geochemical Monitoring Laboratory, Tantloi, Jharkhand

4. Introduction:

A field trip was carried out at Bakreswar-Tantloi Geothermal Area with a research team from GSI, Northern Region, Lucknow along with research students from NIT Durgapur and Dr.Hirok Chaudhuri, Asst. Professor Department of Physics, NIT Durgapur during August 23-24, 2015 This was organized by the Helium and Geothermal Project, NIT

Durgapur. This documentation is a report of the research work carried out during the course of the field visit.The visit was scheduled in three phases-

- To collect Water & Gas samples from Hot Springs at Bakreswar Geothermal Area, West Bengal.
- To collect Water & Gas samples from Hot Springs at Tantloi Geothermal Area, Jharkhand
- Field reconnaissance to study the local geology of the area.

5. Location and accessibility of the study area

These thermal springs occur at Bakreswar (23°52'48"N; 87°22'40"E, Birbhum district, West Bengal) - toposheet No.73 M/5. The site is located approximately 220 km from Kolkata. Tantloi (24°28'N; 87°17'15"E, Dumka district) is in Jharkhand - toposheet No.72 P/8 which is about 20km NW of Bakreswar.Both the places are well connected by road and can be approached from Suri and Dumka town by metalled road up to Sishalfarm village, and by fair weather road through tribal hamlets (Fig. 1)

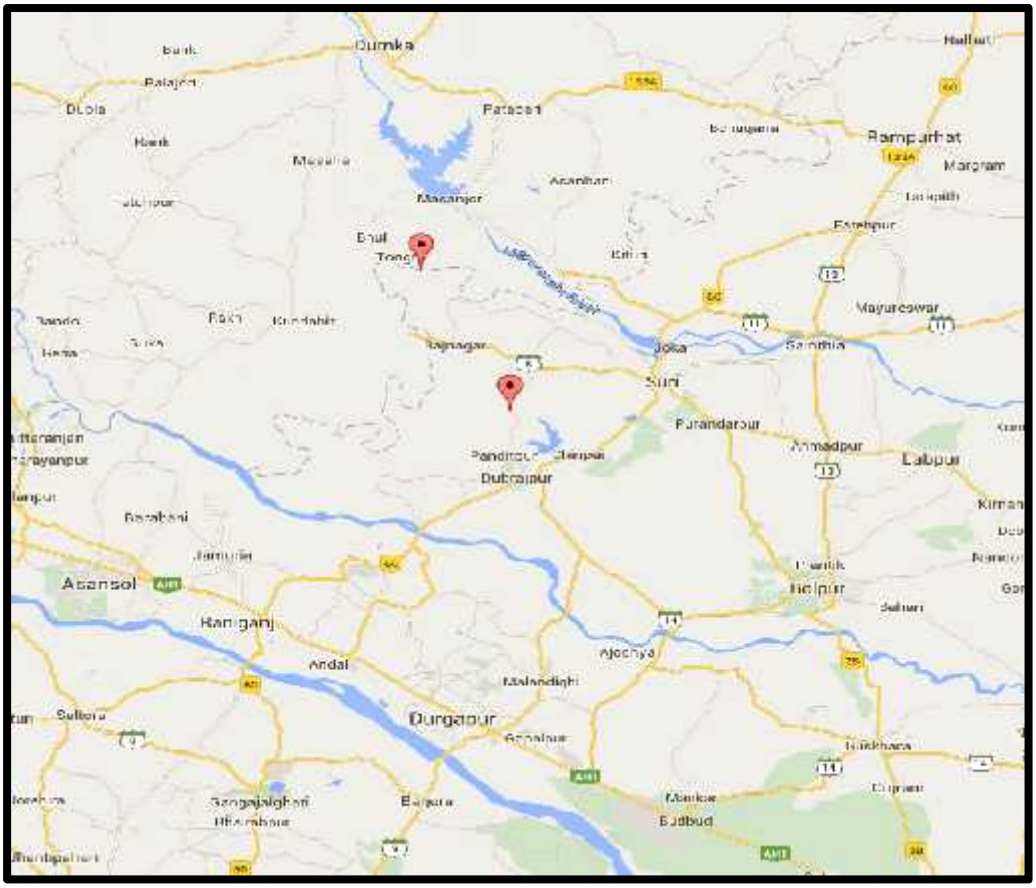

Fig 1. Location of the sites for water sample collection and gas sample collection

6. Geological Settings of the study area

The geothermal area is located at the Eastern end of the SONATA rift which is extended from Gujarat in the West to West Bengal in the East (Fig.2) This lineament is cut by a N-S trending fault in West Bengal & Jharkhand (Fig.2) which is well within the Singbhum Shear Zone. The Bakreshwar thermal springs flow along the N-S trending fault that cuts the main mega SONATA lineament and the Tantloi thermal spring flow along E-W trending fault cutting the same SONATA lineament. shows the geological outcrop of the eastern part of the SONATA fault system which mainly comprises of Chotanagpur Granite Gneiss with minor occurrence of pegmatite, amphibolites, calc-silicates, dolerites etc. belonging to the Precambrian age.(Fig. 2)

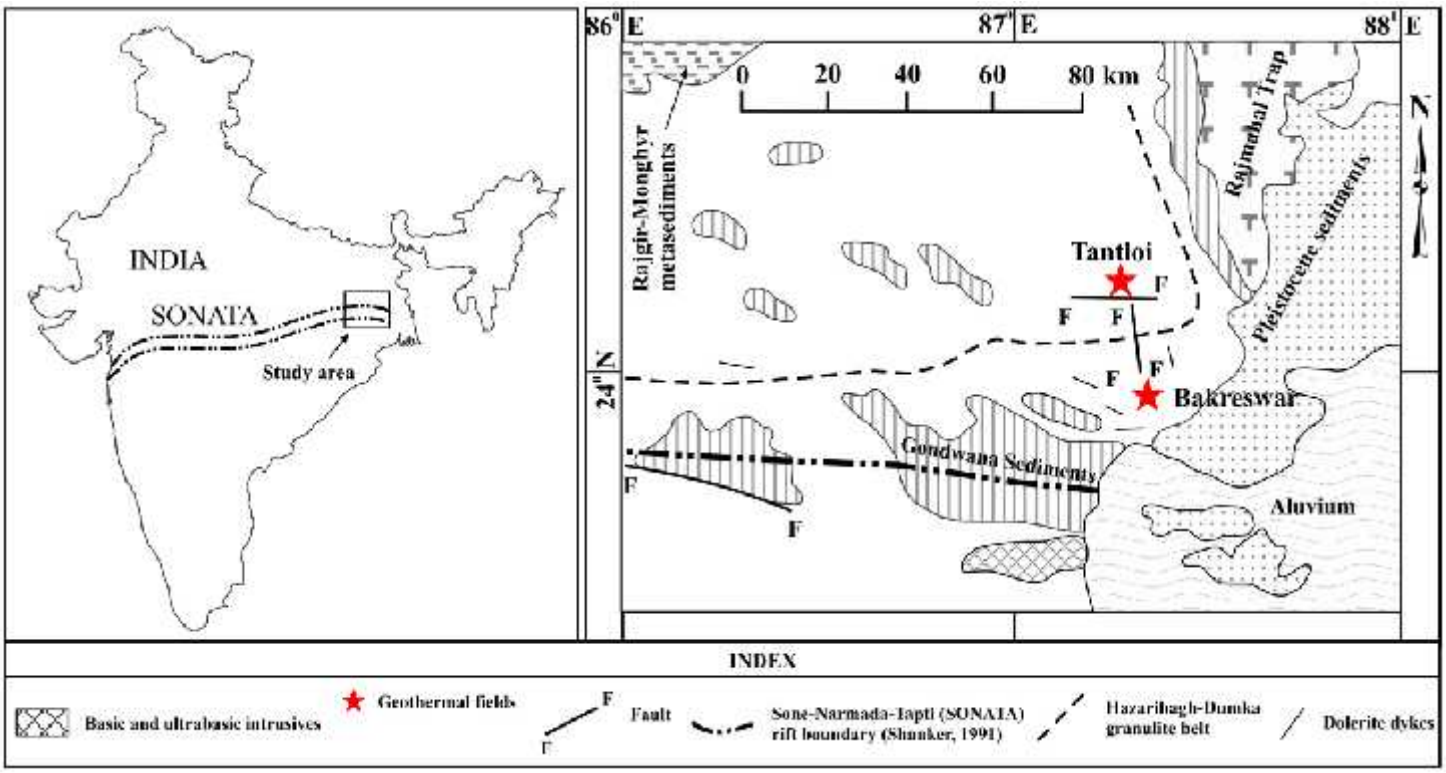

Fig. 2. Map showing study area & Regional geological settings of the study area, (modified after Nagar et al.,1996, Singh et al., 2014).

General Geological Succession :(Ref: Nagar et al, 1996)

Table 1a:

Archaean Chotanagpur Granite Gneissic Complex	Extrusive Basalts Intrusive Gabbros, granites Pegmatites, aplites, vein quartz
	Siliceous and feruginous breccia, Brecciated granite, granite gneiss, hornblende gneiss, hornblende-granite gneiss with granitoids and amphibolites.

Relative characteristics of Bakreswar Hot Spring (West Bengal) and Tantloi Hot Springs (Jharkhand)

Table 1b:

Spring Characteristics	Geological Age	Jurassic ~ 200 Ma
	Formation	Rajmahal Traps- Faulted anticline
	Total Depth	Not Determined
	Reservoir Pressure	Not Determined
Oil Characteristics	NA	

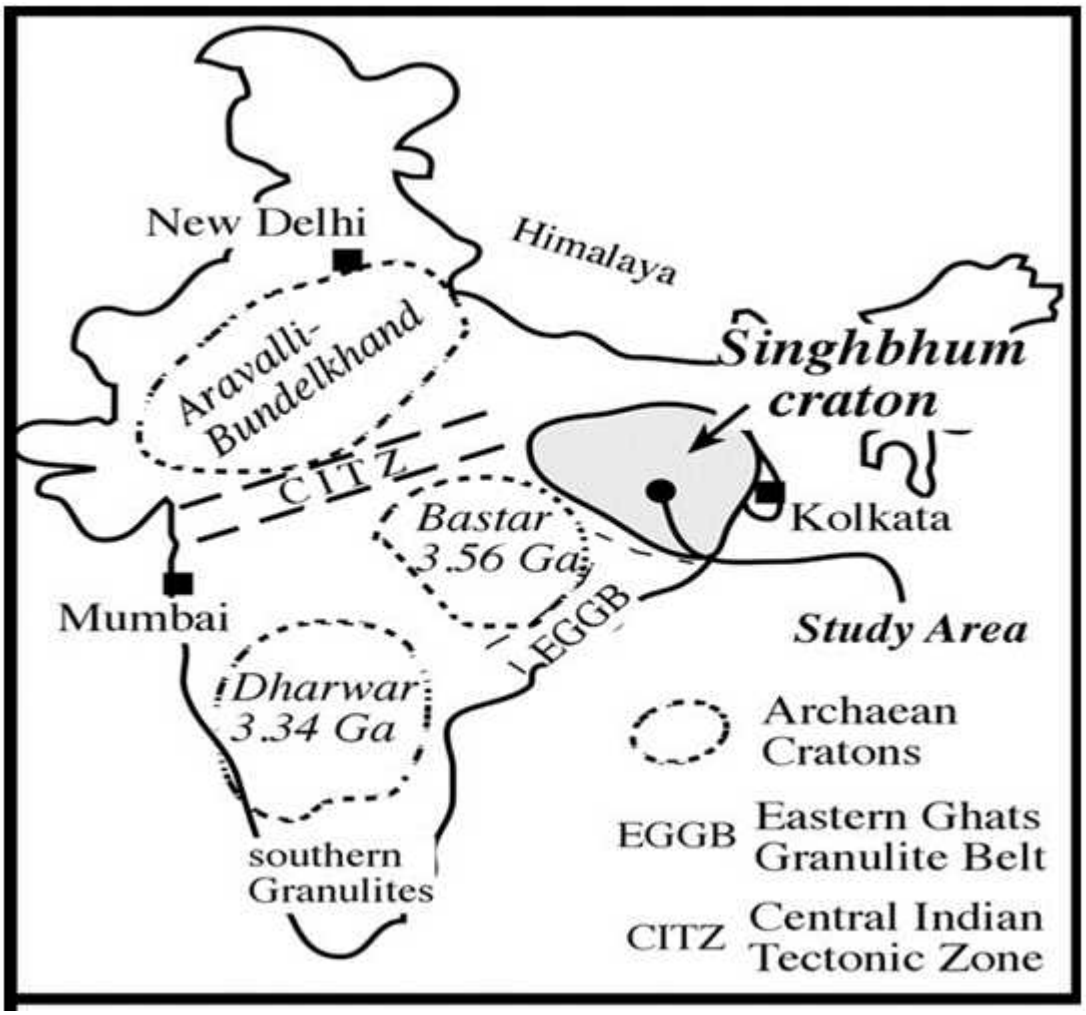

Fig 3. Map showing the study area that falls within the Singhbhum Craton.

The Singhbhum Craton (also called the Singhbhum-Orissa craton; Fig. 3) lies in the eastern part of India and borders the Mahanadi graben to the west, the Central Indian Tectonic Zone (CITZ), and the Indo-Gangetic plain. It is bordered to the north by the Chhotanagpur granite-gneiss terrain (CGGC). The CGGC is thought to be an extension of the Central Indian Tectonic Zone (CITZ). The craton is subdivided into several different assemblages including the Older Metamorphic Group (OMG), the Older Metamorphic Tonalite Gneisses (OMTG) the Singhbhum granite and the Iron Ore Group (IOG).

7. Field Work

A total reconnaissance of the area was done to find the lithology and rock structures present in the area. Thermal Water samples and gas samples from the hot spring were collected from the respective places for experimental analysis.

Fig. 4. A photograph of field research activity at Bakreswar hot spring site by research team from GSI and NIT Durgapur

7.1 Equipment and accessories used for the field work:

1. GPS Garmin eTrex 10
2. pH meter – Eco Testr pH2
3. Digital thermometer HTC DT-1, alcohol thermometer

4. Gas collection glass funnel and plastic funnel 5.0 dia
5. Glass connector
6. Tygon tube ¼ inch dia
7. Tedlar bag 1 liter
8. Water sampling bottles 500 ml and 50 ml
9. Bucket 1 l along with rope
10. Syringe 50 ml
11. Dropper 10 ml
12. 50% diluted HCl

Fig. 5. Research team at the field site of Tantloi, Jharkhand

7.2 Water sample collection methodology:

Water sample were collected in 500 ml reagent bottles. The bottles were rinsed with the sample water 2-3 times before collecting the sample to avoid the contamination. Two

sets of water sample were collected for each source. One set of sample was acidified with dilute HCL (50%) on the site itself and the other set stored at a lower temperature at laboratory at NIT Durgapur for future analysis.In total five (05) samples were collected (Table 2) fromBakreswar- Tantloi Geothermal Area.Fig.6 & Fig. 7 shows the photograph of water sample collection methodology.

Fig. 6. Collection of thermal water from hot spring, Bakreswar, West Bengal

Fig. 7. Acidification of water sample at the field site, Bakreswar, West Bengal

7.3 Gas sample collection methodology:

An experimental set up was prepared on the field itself to collect the gas samples from hot spring vents. The gasses releasing out of the spring vents were trapped in the glass funnel and immediately transferred through tygon tube to the 1lit.tedler bag (gas sampling bag) as shown in Fig. 8. However prior to fill the bag with the sample gas the

bag was purged and flushed with sample gas 2-3 times to avoid contamination. Finally he gas was collected using the same procedure.

Fig. 8. Collection of gas sample in the Tedler Bag at the Hot Spring field site , Tantloi, Jharkhand

7.4 Temperature and pH measurement

The pH and temperature of the hot spring water were measured on the field itself using digital thermometer**(HTC DT-1, graduated -50^0- +300^{0}C,)** and pH meter(**eco Tester pH2, graduated 0 to 14.0 pH**).

Table 2. Gas & Water Samples collected at Bakreswar-Tantloi Geothermal Region, West Bengal& Jharkhand

Sl No.	Location (Latitude, Longitude, Elevation)	Landmark	pH	Temp. (^{0}C)	Gas Sample with sample no.	Date & Time of gas sample collection (hrs.)	Water Sample with sample no.	Date & Time of water sample collection (hrs.)
1.	23° 52' 52.3" N 87° 22' 32.9" E (88m)	**AgnikundaHotspring**	10.7	67^0	Collected GS 1	23.08.2015 17.40	Collected, WS1	23.08.2015 17.45
2.	23° 52' 51.9" N 87° 22' 34.4" E (93m)	**Souvagyakunda Hotspring**	10.4	55.4^0	Not Collected	23.08.2015	Collected, WS2	23.08.2015 18.00
3.	23° 52' 52.8" N 87° 22' 34.8" E (93m)	**SwetgangaHotspring**	10.5	48.6^0	Not Collected	23.08.2015	Collected, WS3	23.08.2015 18.10
4.	24° 02' 25.8" N 87° 17' 3.8" E (95m)	**Tantloi 1 Hotspring**	10.7	66^0	Not Collected	24.08.2015	Collected, WS4	24.08.2015 11.15
5.	24° 02' 24.9" N 87° 17' 3.8" E (97m)	**Tantloi 2 Hotspring**	10.7	69.4^0	Collected GS 2	24.08.2015 10.35	Collected, WS5	24.08.2015 11.30

7.5 Analysis of gas and water sample at laboratory work at NIT Durgapur and at GSI Lucknow

Water samples were analysed for major ion concentrations. Essential chemical parameters of these samples were analyzed using different techniques as follows:

Atomic Absorption Spectrophotometer:

Concentration of the cations viz. Ca, Na, K & As were measured by Atomic Absorption Spectrophotometer (**Perkin Elmer Pinaacle900T**) installed at Department of Earth and Environmental Studies at NIT Durgapur (Fig 9).

Titration method:

For analysis of Cl, the samples were titrated with $AgNO_3$ in the presence of K_2CrO_4(Fig 10).

The research team wishes to express sincere gratitude to Prof.AniruddhaGangopadhyay, Senior Professor, Dr.KalyanAdhikari, Associate Professor and Dr.Sandip Mandal, Assistant Professor at Dept. of Earth & Environmental Studies, NIT Durgapur for their helpful instructions, suggestion and generous support and cooperation in case of measuring the samples.

Fluoride Ion Selective Electrode:

Determination of F were done with the help of Orion Fluoride Ion Selective Electrode, using respective electrode(Fig. 11). The research team wishes to express sincere gratitude to Dr.Gopinath Halder, Associate Professor at Dept. of Chemical Engineering, NIT Durgapur for his helpful instructions, suggestion and generous support and cooperation in case of measuring the samples.

Fig. 9. Atomic Absorption Spectrometer at NIT Durgapur (Dept. of Earth & Environmental Studies)

Fig. 10. Experimental work at NIT Durgapur Laboratory
(Dept. of Earth & Environmental Studies and Department of Physics)

Fig. 11. Experimental work at NIT Durgapur Laboratory
(Dept. of Chemical Engineering)

Table 3: Chemical composition of water sample collected at Agni kunda hot spring, Bakreswar Geothermal Region,West Bengal

Sl. No.	pH	Spec.Cond. (EC) at 25°C (µS/cm)	CO_3^{--} (ppm)	HCO_3^{--} (ppm)	OH^- (ppm)	Cl^- (ppm)	NO_3^- (ppm)	SO_4^{--} (ppm)	B (ppm)	F^- (ppm)	Total Hardness as $CaCO_3$ (ppm)	Ca^{2+} (ppm)	Mg^{2+} (ppm)	Na^+ (ppm)	K^+ (ppm)	Li^+ (ppm)	TDS at 180°C (mg/l)	SiO_2 (ppm)
GSI Lucknow	9.5	552.0	26.0	70.0	Nil	92.0	<1	26.0	2.0	15.0	5.0	2.0	Nil	112.0	1.0	<0.2	315.0	87.0
Helium Group NITD	10.7	NM	NM	NM	NM	82.36	NM	26.0	NM	10	NM	0.48	NM	124.8	2.29	NM	NM	NM

NM - Not Measured **NA**- Not Available

Table 4: Chemical composition of water sample collected at Bakreswar hot spring (SouvagyaKunda and Swet Ganga), Geothermal Region,West Bengal

Sl. No.	pH	Spec.Cond. (EC) at 25°C (µS/cm)	CO_3^{--} (ppm)	HCO_3^{--} (ppm)	OH^- (ppm)	Cl^- (ppm)	NO_3^- (ppm)	SO_4^{--} (ppm)	B (ppm)	F^- (ppm)	Total Hardness as $CaCO_3$ (ppm)	Ca^{2+} (ppm)	Mg^{2+} (ppm)	Na^+ (ppm)	K^+ (ppm)	Li^+ (ppm)	TDS at 180°C (mg/l)	SiO_2 (ppm)
SouvagyaKunda	10.4	NM	NM	NM	NM	68.88	NM	NM	NM	10.0	NM	0.51	NM	123.2	1.64	NM	NM	NM
Swet Ganga	10.5	NM	NM	NM	NM	63.34	NM	NM	NM	10.0	NM	0.73	NM	120.6	1.70	NM	NM	NM

NM - Not Measured **NA**- Not Available

Table 5: Chemical composition of water sample collected at Tantloi hot spring 1, Geothermal Region,Jharkhand

Sl. No.	pH	Spec.Cond. (EC) at 25°C (µS/cm)	CO_3^{--} (ppm)	HCO_3^{-} (ppm)	OH^{-} (ppm)	Cl^{-} (ppm)	NO_3^{-} (ppm)	SO_4^{--} (ppm)	B (ppm)	F^{-} (ppm)	Total Hardness as $CaCO_3$ (ppm)	Ca^{2+} (ppm)	Mg^{2+} (ppm)	Na^{+} (ppm)	K^{+} (ppm)	Li^{+} (ppm)	TDS at 180°C (mg/l)	SiO_2 (ppm)
GSI Lucknow	9.57	451.0	36.0	46.0	Nil	55.0	<1	38.0	2.0	12.5	5.0	2.0	Nil	92.0	1.0	<0.2	255.0	81.0
Helium Group NITD	10.7	NM	NM	NM	NM	37.44	NM	36.0	NM	10.0	NM	0.26	NM	105.6	1.45	NM	NM	NM

NM - Not Measured **NA**- Not Available

Table 6: Chemical composition of water sample collected at Tantloi hot spring 2, Geothermal Region,Jharkhand

Sl. No.	pH	Spec.Cond. (EC) at 25°C (µS/cm)	CO_3^{--} (ppm)	HCO_3^{--} (ppm)	OH^- (ppm)	Cl^- (ppm)	NO_3^- (ppm)	SO_4^{--} (ppm)	B (ppm)	F^- (ppm)	Total Hardness as $CaCO_3$ (ppm)	Ca^{2+} (ppm)	Mg^{2+} (ppm)	Na^+ (ppm)	K^+ (ppm)	Li^+ (ppm)	TDS at 180°C (mg/l)	SiO_2 (ppm)
GSI Lucknow	9.6	454.0	43.0	31.0	Nil	56.0	<1	NA	NA	12.5	5.0	2.0	Nil	91.0	1.0	<0.2	260.0	81.0
Helium Group NITD	10.7	NM	NM	NM	NM	60.89	NM	NM	NM	10.0	NM	0.28	NM	106.2	1.34	NM	NM	NM

NM - Not Measured **NA**- Not Available

Table 7: Comparisons of Chemical composition of water sample collected at Agni kunda hot spring, Bakreswar Geothermal Region,West Bengal

Sl. No.	pH	Spec.Cond. (EC) at 25°C (µS/cm)	CO_3^{--} (ppm)	HCO_3^{--} (ppm)	OH^- (ppm)	Cl^- (ppm)	NO_3^- (ppm)	SO_4^{--} (ppm)	B (ppm)	F^- (ppm)	Total Hardness as $CaCO_3$ (ppm)	Ca^{2+} (ppm)	Mg^{2+} (ppm)	Na^+ (ppm)	K^+ (ppm)	Li^+ (ppm)	TDS at 180°C (mg/l)	SiO_2 (ppm)
GSI Lucknow	9.5	552.0	26.0	70.0	Nil	92.0	<1	26.0	2.0	15.0	5.0	2.0	Nil	112.0	1.0	<0.2	315.0	87.0
Helium GroupNITD	10.7	NM	NM	NM	NM	82.36	NM	26.0	NM	10.0	NM	0.48	NM	124.8	2.29	NM	NM	NM
GSIGeothermal Atlas	9.3	595.0	44.0	39.0	-----	88.0	0.22	28.0	<.25	10.0	<4.0	<1.0	<1.0	125.0	2.50	nil	400.0	78.0
Ghatak et. al 2012	8.2	693.3	24.0	146.9	-----	99.0	NA	28.9	NA	11.5	NA	15.5	0.7	160.7	4.4	NA	348.0	NA
Majumdar et. al 2009	9.3	612.0	24.0	60.0	-----	92.0	0.08	30.0	NA	10.0	NA	2.40	0.6	118.0	3.7	NA	413.0	72.0
Mukhopadhyay. et al. 2012	9.3	NA	44.0	39.0	-----	88.0	0.22	28.0	NA	10.0	4.0	1.0	1.0	125.0	2.5	NA	400.0	78.0

NM - Not Measured **NA**- Not Available

Table 8.Composition of the gas released from some of the hot springs in the Bakreswar-Tantloi geothermal region

Sl. No.	Location	State	Sample type	He (vol.%)	N_2 (vol.%)	O_2 (vol.%)	Ar (vol.%)	CO_2 (vol.%)	CH_4 (vol.%)
01.	Agnikunda (Bakreswar)	West Bengal	Hot Spring Gas	**1.88**	91.45	0.85	1.80	1.20	2.82
02.	Tantloi (Dumka)	Jharkhand	Hot Spring Gas	**1.25**	91.38	2.65	1.92	Trace	2.80

8. Results & discussion:

Geothermometry:Geothermometers helps to estimate the temperature of under earth fluid reservoir. These are valuable tools in the evaluation of unknown geothermal fields.

Silica geothermometer equation **:(Ref. Truesdell, 1976; Fournier, 1981)**

t^0 C = [1309/(5.19- log SiO_2)] - 273
= [1309/(5.19- log 87)] - 273

= **129.77**{**using the value provided by GSI Lucknow**}

t^0 C = [1309/(5.19- log SiO_2)] - 273
= [1309/(5.19- log 78)] - 273

= **123.67**{**using the value provided by GSI book**}

t^0 C = [1309/(5.19- log SiO_2)] - 273
= [1309/(5.19- log 72)] - 273

= **120.09**{**using the value provided by Majumdar et. al** }

Na- K- Ca geothermometer equation**:(Ref. Truesdell, 1973)**

t^0 C = 1647/{log (Na/K) +b [log ($Ca^{1/2}$ / Na) +2.06] + 2.47} - 273
wheret> 70^0 C
Na, Ca, K = Concentrations of Sodium, Potassium and Calcium in ppm
b= 4/3, if t < 100^0 C
b= 1/3, if t > 100^0 C

t^0 C = 1647/{log (Na/K) +b [log ($Ca^{1/2}$ / Na) +2.06] + 2.47} - 273
= 1647/{log (112/1) +b [log ($2^{1/2}$ / 112) +2.06] + 2.47}– 273

= **74.84**{**using the value provided by GSI Lucknow**}

t^0 C = 1647/{log (Na/K) +b [log ($Ca^{1/2}$ / Na) +2.06] + 2.47} - 273

= 1647/{log (125/2.5) +b [log ($0.8^{1/2}$ / 125) +2.06] + 2.47}– 273

= **124.73**{**using the value provided by GSI book**}

t^0 C = 1647/{log (Na/K) +b [log ($Ca^{1/2}$ / Na) +2.06] + 2.47} - 273

= 1647/{log (160.7/4.36) +b [log ($15.5^{1/2}$ / 160.7) +2.06] + 2.47}– 273

= **82.31**{**using the value provided by Ghatak. et al**}

t^0 C = 1647/{log (Na/K) +b [log ($Ca^{1/2}$ / Na) +2.06] + 2.47} - 273

= 1647/{log (118/3.7) +b [log ($2.4^{1/2}$ / 118) +2.06] + 2.47}– 273

= **118.1**{**using the value provided by Majumdar. et al**}

t^0 C = 1647/{log (Na/K) +b [log ($Ca^{1/2}$ / Na) +2.06] + 2.47} - 273

= 1647/{log (124.8/2.3) +b [log ($0.5^{1/2}$ / 124.8) +2.06] + 2.47}– 273

= **124.61**{**using the value provided by Helium Group NITD**}

Table. 9 Molecular ratios of some of the constituents of thermal water:

(on-going process)

Hotspring	**Na/K**	**Cl/SO_4**	
Bakreswar 1	112	3.54	Values provided by GSI Lucknow
Tantloi 1	92	1.46	
Tantloi 2	91	NA	
Bakreswar Agni Kunda	54.49	18.30	NITD
BakreswarSoubhagayaKunda	75.12	22.96	
BakreswarSwet Ganga	70.94	16.97	
Tantloi 1	72.83	5.99	
Tantloi 2	79.25	10.14	

Molecular ratios of Na/ K for the hotspring water of Bakreswar range from 91- 112 as provided by GSI, Lucknow while the values range from 54- 75 as estimated by NITD research group indicating.....(low/ moderate/ high) temperature. High Cl/ SO_4 value indicate deeper source.

Report on :

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Birbhum, West Bengal

Date of Visit: October 7, 2015

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Report on :

Visit to Mallarpur Geothermal Area, Birbhum, West Bengal

1. Aim:

1. To collect water samples and gas samples from the boreholes (made by GSI) at this geothermal region.
2. To find the geochemical and geophysical properties of the area.
3. To estimate the Helium potential of the area.
4. To estimate the Geothermal potential of the area.

2. Date of Visit: October 7, 2015

3. Team Members:

1. Ms. Tapapriya Gupta, JRF, Helium and Geothermal Project, NIT Durgapur
2. Mr. Chiranjit Maji, JRF, Helium and Geothermal Project, NIT Durgapur
3. Mr. Ritwik Das, M. Tech student, Advanced Materials Science & Technology, Department of Physics, NIT Durgapur
4. Mr. Ritesh Kant Gupta, M. Tech. student, Advanced Materials Science & Technology, Department of Physics, NIT Durgapur
5. Mr. Soumya Mukherjee, M. Sc. Student, Department of Physics, NIT Durgapur
6. Mr. Somen Adhikary,
7. Mr. Prithwijit Roy, Technical Assistant, Helium & Geothermal Project, NIT Durgapur

All the above mentioned students (sl. no. 1-5) are working in the Helium & Geothermal project under the supervision of Dr. Hirok Chaudhuri, Asst. Prof. Dept. of Physics.

4. Introduction:

Through literature survey related to Mallarpur Geothermal Area, we came to know that this area has already been investigated by the GSI by making various boreholes (range for depth…....) to study the geothermal potential of the area. Accordingly we planned a field trip to Mallarpur Geothermal Area to collect water samples from thermal springs & nearby tube wells and borewells and gas samples from the thermal springs and borewells.

Reference: Sarolkar P.B. (2010): Exploration Strategy for Hot Springs Associated with Gondwana Coalfields in India, Proceedings World Geothermal Congress 2010 at Bali, Indonesia, 25-29 April 2010

5. Location and accessibility of the study area:

Mallarpur ($24^0$05’48”N, $87^0$44’23”E) and Bilaspur ($24^0$04’19”N, $87^0$44’44”E) are situated in the Birbhum district, West Bengal. The places are approximately 210 km from Kolkata by road. The places are also well connected by train from the Mallarpur station which lies on the Howrah-New jalpaiguri Railway Route. The places are around 100 km from Durgapur and can also be reached by train via Andal Junction Railway Station or Burdwan Junction Railway Station.

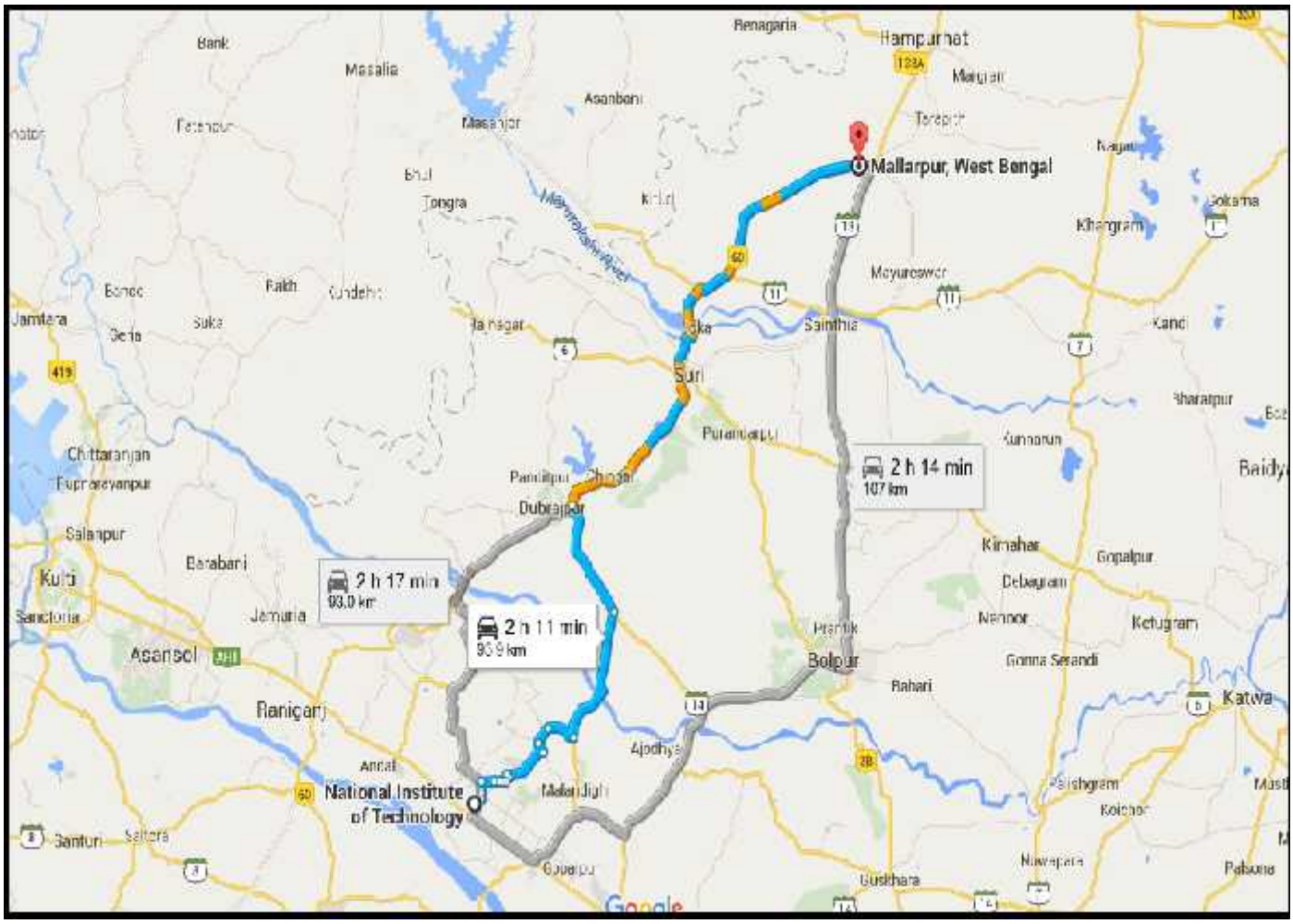

Fig. 1.: Location of the study area - Mallarpur in Birbhum district, WB

(Source:https://www.google.co.in/maps/dir/National+Institute+of+Technology,+Mahatma+Gandhi+Road,+AZone,+Durgapur,+West+Bengal+713209/Mallarpur,+West+Bengal+731216/@23.843054,87.47649,10z/data=!4m14!4m13!1m5!1m1!1s0x39f772081cede5e9:0x33fb9ccb243dfa5!2m2!1d87.290428!2d23.550853!1m5!1m1!1s0x39f9f79d0fe0b5a1:0x3a7802ddd72ad740!2m2!1d87.7098723!2d24.0763414!3e0)

6. Geological Setting of the study area:

This Geothermal area lies within the Gondwana coalfields in Birbhum district. Both the hot springs lie in the eastern part of the Birbhum district in the Mahallah block. This area comprises Barakar Formations (lower-middle Permian age) which were deposited in the basin with basement rocks separated by the faulted margins. The lithology includes coarse to fine sandstone, shale beds and coal seams. Since sedimentary rocks are mostly permeable which allows deep percolation and lateral movement of ground water, the penetrating water collects heat during subsurface movement and follows the conduit provided by fault zone for upward movement towards the surface giving rise to hotsprings along the Gondwana margins.

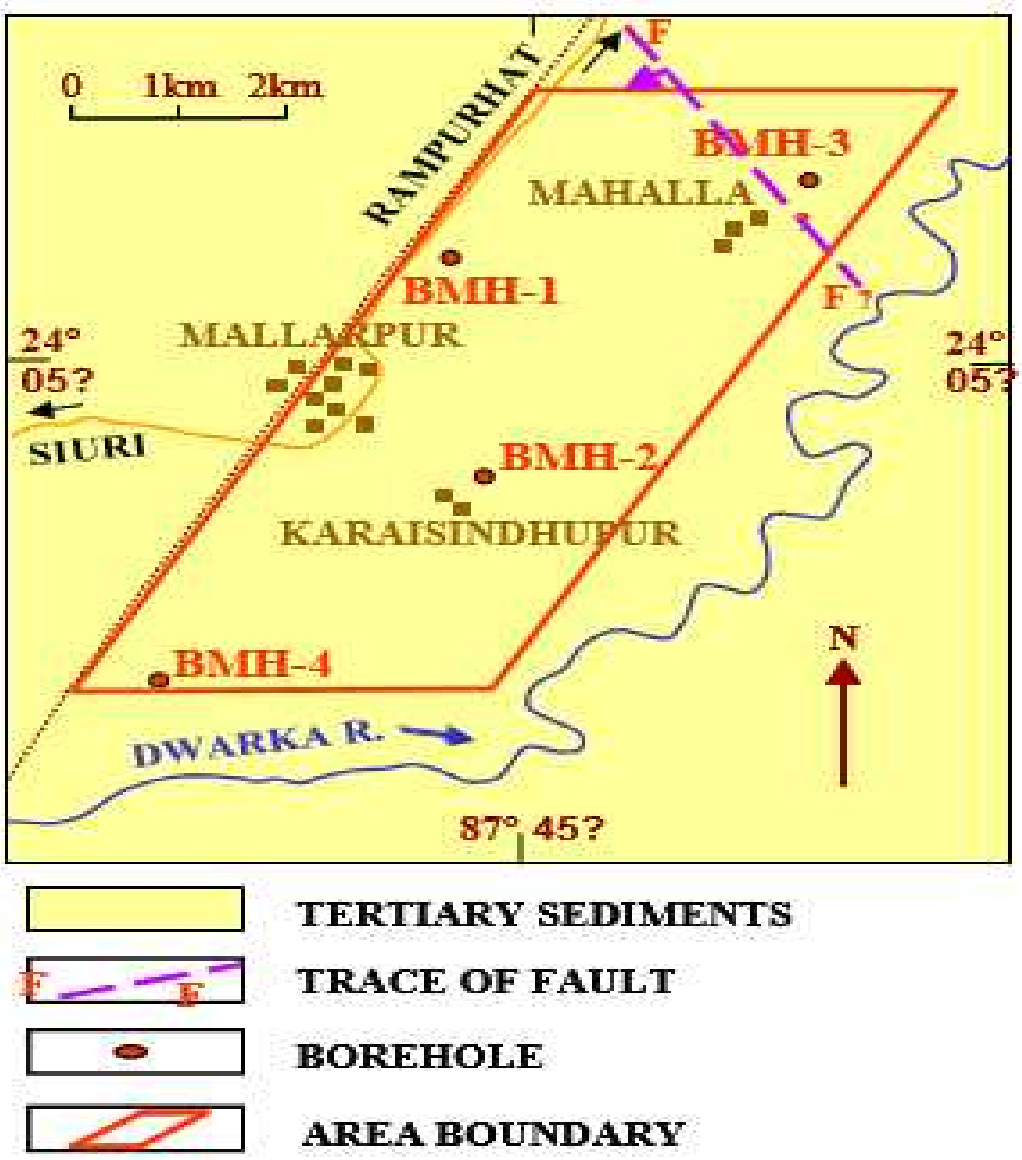

Fig 2: Geological Map of study area (Mallarpur), Birbhum

(Source: Sarolkar P.B. (2010): Exploration Strategy for Hot Springs Associated with Gondwana Coalfields in India, Proceedings World Geothermal Congress 2010 at Bali, Indonesia, 25-29 April 2010)

7. Field Observations:

7.1 Equipment and accessories used for the field work:

1. GPS Garmin eTrex 10
2. pH meter – EcoTestr pH2 (graduated 0.0 to 14.0 pH)
3. Digital thermometer HTC DT-1 graduated -50^0C to $+300^0$C, alcohol thermometer
4. Gas collection glass funnel and plastic funnel 5.0 dia
5. Glass connector
6. Tygon tube ¼ inch dia
7. Tedlar bag 1 liter
8. Water sampling bottles 500 ml and 50 ml
9. Bucket 1 l along with rope
10. Syringe 50 ml
11. Dropper 10 ml
12. 50% diluted HCl

7.2. Water sampling methodology:

The bottles were rinsed with the sample water two to three times before collecting the sample to avoid the contamination. Two sets of water samples were collected for each source. One set of sample was acidified with 50% dilute HCl on the site itself and pH was brought <2.0. The other set was stored in lower temperature at laboratory at NIT Durgapur for future analysis. Water samples were collected from five locations (two sample from thermal springs and three sample from nearby tubewells – approximately within a distance of 100m from the hot springs.

7.3. Gas sampling methodology:

An experimental set up was prepared on the field site itself to collect the gas samples from hot springs vents. The gases releasing out of the spring vents were trapped in the glass funnel and immediately transferred to a tygon tube to the 1 litre tedlar bag (gas sampling bag). However, prior to fill the bag with the sample gas the bag was purged and flushed with sample gas 2-3 times to avoid contamination. Finally, the gas was collected using the same procedure. Due to technical difficulties gas samples were collected from the Bilaspur thermal spring only, and not from the other springs. Gas was emanating from

the opening of the borehole and manifestation was seen through bubbles of gas emission at the opening of the borehole.

7.4. Temperature and pH monitoring:

The pH and the temperature of the hor spring waters were measured on the field itself using digital thermometer HTC DT-1, graduated -50^{0}C to +300^{0}C and pH meter (Eco Testr pH2) graduated 0.0 to 14.0 pH. The pH and temperature of the water samples were measured at the field site as given in the table below:

Table 1: Details of Water and Gas Sample collected at Mallarpur, Birbhum, WB

Sl No.	**Location (Latitude, Longitude, Elevation)**	**Landmark**	**pH**	**Temp. (^{0}C)**	**Gas Sample with sample no.**	**Date & Time of gas sample collection (hrs.)**	**Water Sample with sample no.**	**Date & Time of water sample collection (hrs.)**
1.	24^{0}05’48”N 87^{0}44’23”E Elevation: 40 m	On Katccha Road between Highway towards Rampurhat and School	8.0	47.1	Not Collected	.....	Collected WS1	07.10.2015, 09:15
2.	24^{0}05’48”N 87^{0}44’23”E Elevation: 40 m	On Katccha Road between Highway towards Rampurhat and School	6.5	30.4	Not Collected	.....	Collected WS2	07.10.2015, 09:35
3.	24^{0}04’19”N 87^{0}44’44”E Elevation: 40m	On metalled road between Morishor Block I (Mollarpur) and Bilaspur	7.7	58.3	Collected GS3	07.10.2015, 12:45	Collected WS3	07.10.2015, 10:35
4.	24^{0}04’20”N 87^{0}44’38”E Elevation: 44m	Madrasa opposite Bilaspur hot spring	6.7	27.4	Not Collected	.....	Collected WS4	07.10.2015, 11:05
5.	24^{0}05’41”N 87^{0}44’28”E Elevation: 41m	Near School	6.1	27.6	Not Collected	.....	Collected WS5	07.10.2015, 13:05

It is notable that Sadhan Babu (Mobile: +91-9474165847/+913461-263340) of Mallarpur helped us with the local transport and accessibility to all the field sites. We are very much indebted to him. He is running an NGO which provides education to the tribal boys and girls in the locality.

7.5. Gas and Water Analysis : on-going process

8. Photographs of Field Work:

Fig. 3. Measurement of temperature of hot water at the borehole opening Mallarpur thermal spring site.

Fig 4. Measurement of GPS reading

Fig. 5. The team is looking for any bubbling that may take place around the concrete surface of the thermal spring at Mallarpur

Fig. 6. Collection of Water sample at Bilaspur thermal Spring.
(Water temperature was 58.3^0C)

Fig. 7. Gas Sampling at Bilaspur thermal spring.

Report on :

Visit to
Geochemical Monitoring Laboratory, Tatta Pani, J & K;
NIT Srinagar, J&K
and
Kashmir University, Srinagar, J & K.

Date of Visit: July 01, 2015 to July 11, 2015

Helium and Geothermal Project
NIT Durgapur
Mahatma Gandhi Avenue
Durgapur 713 209

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Report on:
Visit to Geochemical Monitoring Laboratory, Tatta Pani, J & K; NIT Srinagar, J&K and Kashmir University, Srinagar, J & K.

1. Aim:

1. To collect water & gas samples from the Hot springs and Cold springs at TattaPanigeothermal region to explore geothermal potential of the site.
2. To collect the geochemical & geophysical data from Geochemical Monitoring Laboratory, TattaPani, J&K related with earthquake precursory study.
3. Installation of new equipment Gamma Tracer at Geochemical Monitoring Laboratory, TattaPani, J&k
4. Routine maintenance of the installed equipment and computers.
5. Meeting with Director, NIT Srinagar along with faculties from different departments to finalize the initiation process on possible research collaboration between NIT Durgapur and NIT Srinagar.

2. Duration for visit: July 01, 2015 to July 11, 2015

3. Team Members:

1. Dr.Hirok Chaudhuri, Project Manager: Helium & Geothermal Project & Assistant Professor, Department of Physics, NIT Durgapur
2. Mr. ChiranjitMaji, JRF, Helium & Geothermal Project, NIT Durgapur,
3. Miss Tapapriya Gupta, JRF, Helium & Geothermal Project, NIT Durgapur,
4. Mr. Ritesh Kant Gupta, M.Tech. Student, Physics Department, working at Helium & Geothermal Project, NIT Durgapur.
5. Mr. SumitKhajuria, Technical Assistant, Geochemical Monitoring Laboratory, TattaPani, J&K

All the above mentioned students (Sl. no 2-4) are working in Helium and Geothermal Project under the active supervision of Dr.Hirok Chaudhuri, Project Manager, Helium & Geothermal Project & Assistant Professor, Department of Physics, NIT Durgapur

4. Introduction:

The project manager, Helium & Geothermal Project, Dr.Hirok Chaudhuri with two Ph.D students and one M.Tech student visited the TattaPani geothermal area in northern region of India (in the vicinity of MBT of Lesser Himalaya), NIT Srinagar & Kashmir University, J&K during July 01 to July 11, 2015. The objective of the said visit was to explore geothermal potential of the site and routine maintenance of the installed equipment and computers at Geochemical Monitoring Laboratory, TattaPani, Rajouri, J&K. The different gases coming fromTattaPani -Meharot (33° 14' 16.8" N, 74° 24' 43.2" E) hot spring is continuously being monitored by different equipment installed at the said laboratory for precursor study of Earthquake Precursor . The geochemical & geophysical data from Geochemical Monitoring Laboratory, TattaPani, J&K related with earthquake precursory study was collected in the same visit.

The said visit was scheduled in two phase-

I. Visit to Geochemical Monitoring Laboratory, TattaPani, Rajouri, J&K.
II. Visit to NIT Srinagar against a formal invitation from Prof.Rajat Gupta, Director NIT Srinagar.

5. Location & Accessibility of the study area:

TattaPani (33° 14' 16.8" N, 74° 24' 43.2" E, height- 736m from mean see level) is a small village in Rajouri District of Jammu, J&K. This is completely hilly area situated in the vicinity of MBT of Lesser Himalaya.

One can reach TattaPani from Jammu city by road (NH-144A) covering 150km via Sundarbani and Kalakote. It is near to Rajouri town, just 35 km. It is situated in the north west of Jammu.

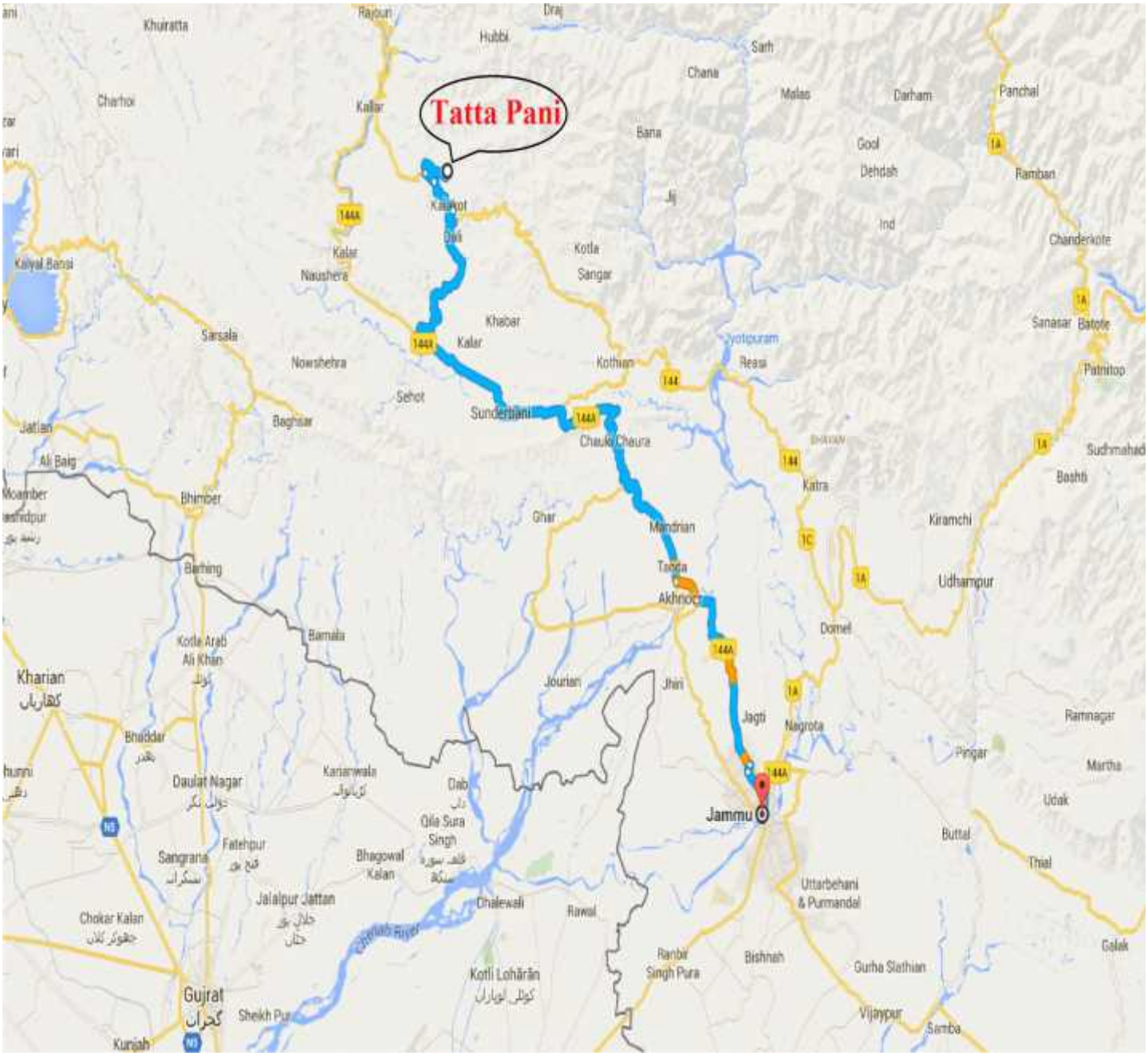


Fig. 1. Location of TattaPani (Measurement site), J&K

6. Geological settings of the study area:

Theareaisunderlain by rockformations ranging inagefromPre-Cambrianto Quaternary period.Thegeneralizedgeologicalsuccessionisgiven below:

Group	Lithology	Age
Quaternary	Heterogeneous Clasticsediments comprisingofSand, Silt, Clay	Sub-recent toRecent
Siwalik	Sandstone,Clays, shale,boulder/pebble etc.	Lower Miocene toPleistocene
Murrees	RedcolouredSandstone&Clay	LowerMiocene
UNCONFORMITY		
Older crystallineand Metamorphic rocks (Subathu, Salkhala, SirbanFormations)	limestone, shale, Sandstone, Phyllites, Gneisses	Precambrian toEocene

OlderCrystalline andMetamorphic rocks comprises ofSalkhala,TanawalandRambanFormationsof PrecambriantoEocene age. TheLowerSiwalik subgroupconstituteslightgrey,mediumtocoarse sandstone,fewclaystones.Thesandstonesarewellcompact.TheSiwalikconsistspredominantly of light grey, medium to coarsesandstoneandclays. Murree Groupof rocksbelongs to late Eocene- Early MioceneageandisdisconformablyunderlainedbytherocksofSubathuFormation. The MurreeGroupconsistsofpinkSandstone&Clay.Itis separated fromSiwalikinsouthby Mandli-Kishanpurthrustandinnorthby MurreeThrust fromOlderCrystallineand Metamorphic rocks.

The Himalayan orogenic belt in Jammu & Kashmir state preserves an almost complete stratigraphic record from Precambrian to Recent age which is separated into five major geotectonic zones , each separated by a prominent thrust system.

Tattapani area is underlain by a network of faults and joints of the Proterozoic Sirban limestone along a major NW-SE trending thrust zone MBT that juxtaposes the Sirban limestone formation in the hanging wall against the Eocene Subathu and Miocene Muree formation in the footwall. The Sirban limestone at this location contains two sets of joint, one parallel to the NW-SE strike and other perpendicular to it dipping towards northwest and northeast direction respectively.

Refference: Craig, J., Absar, A., Bhat, G., Cadel, G., Hafiz, M., Hakhoo, N., Kashkari, R., Moore, J., Ricchiuto, T.E., Thurow, J., Thusu, B., 2013, "Hot springs and the geothermal energy potential of Jammu & Kashmir State, N.W. Himalaya, India," Earth-Science Reviews, 126, pp. 156-177

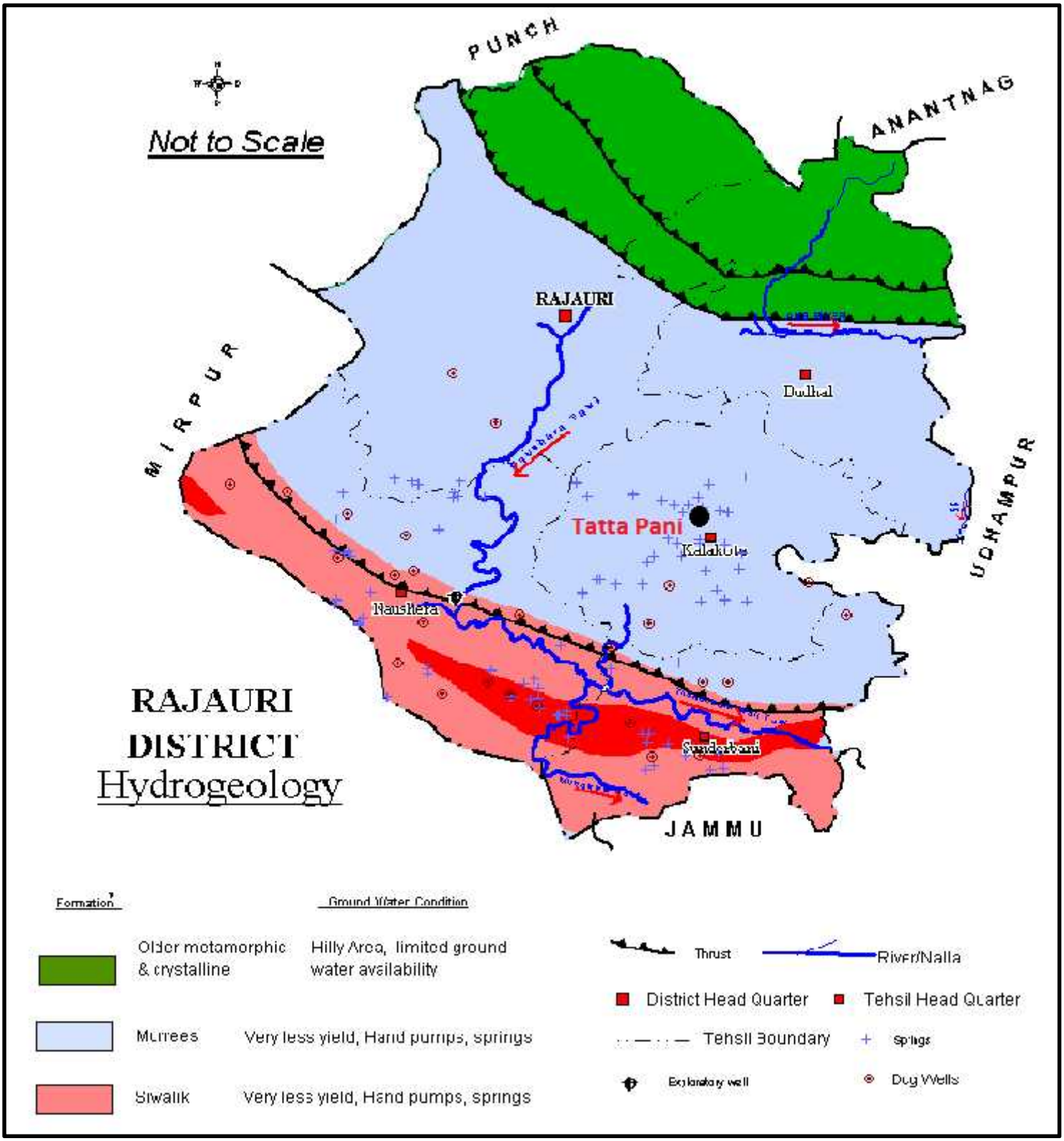


Fig. 2: Diagram showingTattaPani Geothermal area with Hot Springs

(Source :Govt. of India, Ministry of water Resources Central ground water Board, ground water Information Booklet, RajauriDist, J&K N-W Himalayan Region Jammu, November 2009)

7. Field observation:

7.1 Equipment and accessories used

Equipment and accessories which were used at the field site in the time of sampling are as follows

1. GPS - GermineTrex 10
2. pH Meter - Eco Testr pH2
3. Digital thermometer HTC DT -1,
4. Alcohol thermometer
5. Gas collecting glass funnels and plastic funnels 5.0 inch dia, along with glass connectors
6. Tygon tube ¼ inch diameter
7. Tedler bag 1 lit
8. Water sampling bottle 500 ml and 50 ml
9. Bucket 1 lit along with rope
10. Syringe 50 ml,
11. Dropper 10 ml
12. 50 % diluted HCL,

7.2 Water sampling methodology:

The attention was given on exploration of geothermal energy and possibility of helium exploration at TattaPaniregion. 05 (five) hot springs and 01 (one) cold spring are scattered around this region from where the water sample were collected. Another one water sample (WS-7) was collected from Mughal Garden, Cheshmashahi (Lush Green Forest, Fresh spring water Scenic Meadows), Srinagar, Kashmir, J&K.

Water sample was collected in 500 reagent botte. The bottles were rinsed with the sample water 2 to 3 times before collecting the sample to avoid the contamination. Two sets of water samples were collected for each source. One set of sample was acidified with dilute acid (50%) on the site itself. And the other set stored in lower temperature at Laboratory at NIT Durgapur for future analysis.

7.3 Gas sampling methodology:

The gas samples were collected from three hot springs only. The gas sample from others hot springs could not collected because those were technically uncomfortable.

An experimental set was prepared on the field site itself to collect the gas samples from the hot spring vent. The gases releasing out of the spring vent where trapped in the glass funnel and immediately transferred to a tygon tube to the 1 litre Teddler bag (gas sampling bag). However prior to fill the bag with the sample gas the bag was purged and flushed with sample gas 2 to 3 times to avoid contamination. Finally the gas was collected in the same procedure

7.4 Temperature and pH monitoring:

The pH & temp of the hot spring water on the field itself using respectively digital thermometer (HTC DT-01), graduated -50^0 C to 300^0 C and pH meter (Eco tester Ph 2) graduated 0.0 to 14.0 pH were measured. Other different physical parameters such as bubbling rate of gas emanation from hot spring vent, Lat/Long position (using GPS, make GermineTrex 10) of the field site were measured during the time of sampling.

Table 1. Details of the Gas & Water Sampling collected at TattaPani Geothermal Region, J & K

Sl No	Location (Latitude, Longitude, Elevation)	Landmark	pH	Temp. (^{0}C)	Gas Sample with sample no.	Date & Time of gas sample collection (hrs.)	Water Sample with sample no.	Date & Time of water sample collection (hrs.)
1.	33° 14' 12.444" N 74° 24' 38.88" E (Elevation 725m)	River side Hot Spring- I (Near Nahra Cold Spring)	6.9	31.9 (Flow water Temp.=30.2 ^{0}C)	Collected, GS-1	05.07.2015, 12:30	Collected, WS-1	05.07.2015, 13:25
2.	33° 14' 17.88" N 74° 24' 39.132" E (Elevation 725m)	River side Hot Spring- II (Near Nahra Cold Spring)	7.1	32.9 (Flow water Temp.=30.2 ^{0}C)	Collected, GS-2	05.07.2015, 13:00	Collected, WS-2	05.07.2015, 13:30
3.	33° 14' 24" N 74° 24' 36" E (Elevation 734m)	Tantunia Hot Spring	6.8	50.2	Collected, GS-3	05.07.2015, 19:16	Collected, WS-3	05.07.2015, 19:00
4.	33° 14' 35.844" N 74° 24' 55.008" E (Elevation 761m)	TattaPani Hot spring	6.7	45.8	Not Collected	.....	Collected, WS-4	05.07.2015, 20:00
5.	33° 14' 16.8" N 74° 24' 43.2" E (Elevation 752m)	Meherot, TattaPani Hot Spring	6.9	35.2	Not Collected	.....	Collected, WS-5	05.07.2015, 16:00
6.	33° 14' 9.492" N 74° 24' 38.88" E (Elevation 739m)	Nahra Cold Spring	7.6	21.4	Not Collected	.....	Collected, WS-6	05.07.2015, 13:45

7.5. Analysis of gas and water samples:

The gas samples were measured at Geochemical Monitoring Laboratory, TattaPani, J&K using micro GC (Varian, Model No: CP 4900) already installed there.

The water samples were analysed at NIT Dugapur and measured by Atomic Adsorption Spectrophotometer (Perkilelmer, Model no: Pinaacle 900T) and Titration method at Department of Earth & Environmental Studies.

Water samples were analysed at NIT Durgapur for major ion concentrations. Essential chemical parameters of these samples were analysed using different techniques as follows:

Concentration of the cations viz. Ca, Na, K & As were measured by Atomic Absorption Spectrophotometer (**Perkin Elmer 900T**). For Cl analysis, the samples were titrated with $AgNO_3$ in the presence of K_2CrO_4.Determination of F were done with the help of **Orion Fluoride Ion Selective Electrode**, using respective electrode

The research team wishes to express sincere gratitude to Prof.AniruddhaGangopadhyay, Senior Professor, Dept. of Earth & Environmental Studies, NIT Durgapur; Prof.KalyanAdhikari, Associate Professor, Dept. of Earth & Environmental Studies, NIT Durgapur and Dr.Sandip Mandal, Assistant Professor, Dept. of Earth & Environmental Studies, NIT Durgapur and Dr.GopinathHalder, Associate Professor, Chemical Engineering, NIT Durgapur for their helpful instructions, suggestion and generous support and cooperation in case of measuring the samples.

Mr. SumitKhahuria, Technical Assistant, Geochemical Monitoring Laboratory, TattaPani, J&K actively took participation in this research activity.

The result of the measured parameters are given in the table below.

Table 2. Concentration of gases in different hot spring atTattaPani geothermal area

Serial No.	Sample no.	Concentration (Vol. %)		
		Helium	Nitrogen	Methane

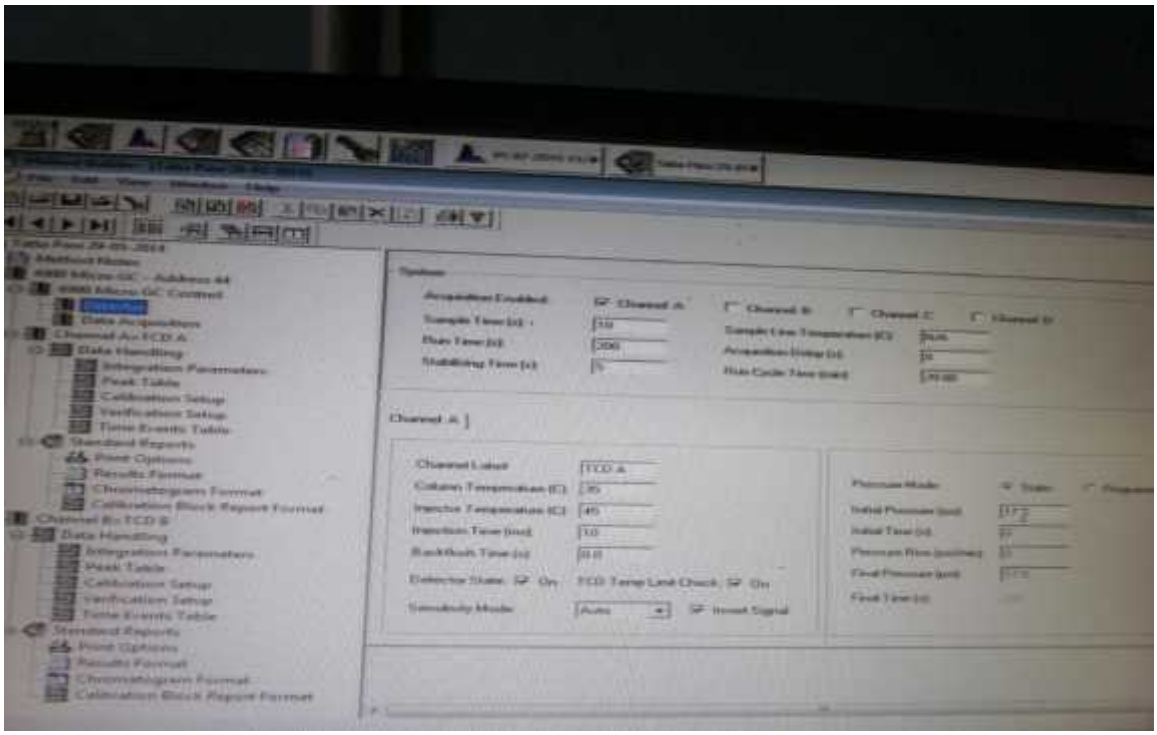
1.	GS-1	0.788	94.234	4.978
2.	GS-2	0.881	93.780	5.339
3.	GS-3	1.658	97.411	0.931

Table 3: Chemical composition of water sample collected atTattaPani Geothermal Region, J&K

Sample No.	Na^+ (ppm)	K^+ (ppm)	As^{+++} (ppm)	Cl^- (ppm)	Ca^+ (ppm)	F^- (ppm)	TDS (ppm)	EC (µS/cm)
WS1	54.26	19.25	BDL	93.1728	70.25	2.0	630	887.324
WS2	56.16	20.71	BDL	66.552	66.12	0.9	650	915.493
WS3	83.02	39.03	BDL	Not Measured	38.42	2.0	500	704.225
WS4	55.03	18.73	BDL	42.59328	25.28	2.0	550	774.648
WS5	70.04	30.14	BDL	119.7936	68.03	2.0	680	957.746
WS6	7.08	1.01	BDL	13.3104	30.37	2.0	360	507.042
WS7	5.03	BDL	BDL	Not Measured	13.51	2.0	470	661.971

8. Photographs:

Picture-1: Micro GC and Alpha Guard installed at
Geological Monitoring Laboratory, TattaPani, J&K



Picture-2: Display of Gas sample measurement (Software:Star Workstation) at Geological Monitoring Laboratory, TattaPani, J&K

Picture-3: Geological Monitoring Laboratory, TattaPani, Rajouri, J&K

Picture-4:
A) Geological Monitoring Laboratory, adjacent to Meharot-TattaPani Hot Spring, Rajouri, J&K;

B) Hot Spring gas emanation (Bubbling) at River side Hot Spring- I (Near Nahra Cold Spring), Tatta Pani, Rajouri, J&K;

C) Rate of bubbling measurement at River side Hot Spring- I (Near Nahra Cold Spring), TattaPani, Rajouri, J&K;

D) Different Rock samples at River sides, TattaPani, Rajouri, J&K.

Picture-5:
E) Setting up equipment to collect gas sample from River side Hot Spring- I (Near Nahra Cold Spring), TattaPani, Rajouri, J&K;
F) Gas measuring set up at River side Hot Spring- I (Near Nahra Cold Spring), TattaPani, Rajouri, J&K;
G) Water sample collection from Nahra Cold Spring, TattaPani, Rajouri, J&K;
H) Measuring temperature at Tantunia Hot Spring water, TattaPani, Rajouri, J&K;

9. Visit to NIT Srinagar and Kashmir University, Srinagar:

To finalize the initiation process on possible research collaboration between NIT Durgapur and NIT Srinagar, the team visited NIT Srinagar on July 07, 2015 against a formal invitation from Prof.Rajat Gupta, Director NIT Srinagar.
A discussing meeting was held at the committee room of Director's Office at NIT Srinagar followed by a discussion meeting at the Director's Chamber (Office of Prof.Rajat Gupta). Details discussion were made on administrative, academic and research and financial aspect.
The discussion was made in the following areas:

(i) To explore the possibility of collaborative research work between NIT Durgapur and NIT Srinagar on "The Study of Earthquake Precursory Signals in Geochemical and Geophysical Methods" at Geochemical Monitoring Laboratory at TattaPani hot spring site, Rajouri, J&K (A field laboratory of NIT Durgapur).

(ii) To explore the possibility of harnessing "Geothermal Power and Helium Gas" from Tattapani hot spring, Rajouri, J&K through a joint venture of NIT Durgapur and NIT Srinagar.

Picture-6: Formal meeting at the committee room of Director's Office at NIT Srinagar, Srinagar, J&K.

Picture-7: Prof.Rajat Gupta, Director, NIT Srinagar and other faculty members from different departments of NIT Srinagar are present in the aforesaid meeting

Picture-8: I) Research Team members from NIT Durgapur are present at the meeting; J) Dr.Hirok Chaudhuri is delivering a Power Point Presentation at the committee room of Director's Office at NIT Srinagar, J&K.

Picture-9: Research Team Members from NIT Durgapur with Dr. Waseem Bari and Dr.Naseer Iqbal, Physics Department, Kashmir University,Srinagar,J&K.