Large-scale helium escape from earth surface around Bakreswar–Tantloi geothermal area in Birbhum district, West Bengal, and Dumka district, Jharkhand, India

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Helium has been detected above the atmospheric background to levels of 2% in air at the surface within 1 m above the ground, in the Bakreswar–Tantloi geothermal area. The gas is released in periodic bursts. Soil air within shallow auger holes (75 cm deep) shows anomalous high helium concentrations at some locations. This communication describes details of the observed unusually large-scale helium escape through the earth's surface in the geothermal area and the experimental methods adopted for its quantitative confirmation.

THERE is a constant upward migration of gases from the earth's crust to the overlying atmosphere. The process known as 'earth degassing', is nonuniform[1,2] across space and time. Enhanced concentrations of a variety of gases are seen[3,4] along active faults, oceanic ridges, geothermal fields or even deep wells. The best-known example is the degassing of helium. The degassing rate of helium at the surface is thought to be constant, except in areas of high crustal activity. Recently, we conducted a helium survey in surface air at five spots spread over about 900 km^2 in the geothermal area lying in Birbhum district, West Bengal and Dumka district, Jharkhand. It was observed that helium levels went up to as high as 2% from its normal atmospheric value of about 5 ppm, at some places in this area. The duration of the survey was sixteen months beginning from May 1999. The aim was to study the pattern of subsurface helium release in the region and to link observed variations to possible crustal mechanisms involved *vis-à-vis* to find a large-scale natural resource for helium extraction[5].

In geothermal fields, two distinct types of subsurface gases are known to exist[6,7]: type-I gas, that is rarely associated with water, but is charged mostly within fracture zones and fault airs and type-II gas, which occurs mostly as bubbles along with flowing waters in hot springs. We have been monitoring the helium content[8] of the hot spring discharges at Bakreswar (23°52′, 87°23′) for over two decades. Episodic changes[8,9] have been noticed in helium levels due to earthquakes.

The Bakreswar–Tantloi geothermal field exposes Archaean gneisses and shists belonging to the Chotanagpur Gneissic Complex[10]. This geothermal area lies in the West Bengal Basin (WBB). WBB developed in the margin of eastern Indian Shield in response to Gondwana rifting. The basin underlies a deep Gondwana trough covered by Rajmahal basalts of Jurassic age and younger sediments. The springs occur along the fractures associated with faulted contacts of the Gondwana sediment in the coal belt of Birbhum, which is aligned north-south, and the Raniganj–Jharia coal fields aligned east-west. The rocks in the region are highly sheared, brecciated and mylonitized resulting in a highly porous and permeable subsurface of the earth[11]. There are five groups of hot springs in the area measuring 20 km × 45 km, as shown in Figure 1. A large number of samples of discharged gases from these springs were analysed[12] by gas chromatography and quadrupole mass analyser. The percentage compositions of these gases are presented in Table 1. Helium content from most of these springs exceeds 1% (vol.).

For the estimation of helium in soil gas, mild-steel cylindrical canopies (20 cm diameter and 30 cm height) were implanted at a depth of about 75 cm and kept in position for 24 h before sampling. Twenty samples of soil gas were collected from such auger holes along the 1.2 km long trending fault zone covering an area of 2 km × 1.5 km near the Bakreswar hot springs. Helium abundances have been found to be in the range of 80 to 110 ppm at some of the dug holes; this is about 15 to 20 times its normal atmospheric content. It was, therefore, thought worthwhile to survey the helium concentration in surface air over a larger area in this geothermal field.

The monitoring of helium levels was carried out by a portable helium leak detector (Varian Helitest) during the field survey. This instrument senses only helium and is capable of responding to concentration from 2 ppm to 90%. For the purpose of sniffing helium in the air, the Helitest probe was positioned at a height of about 1 m above the ground. Air is taken into the instrument by a built-in pump through an entry port (1 mm diameter). Helium content in air is directly obtained from the Helitest reading and the indicated values were recorded manually at intervals of one minute. Helium profiles thus obtained against time at Bhabanipur (indicated by X in Figure 1), near Bakreswar are shown in Figure 2. The profiles clearly indicate that helium is released in periodic bursts. Once emission begins, there is a gradual helium build-up in the air till it reaches a maximum, typically between 2000 and 20,000 ppm, at which level it remains steady for a duration ranging from about 5 to 20 min before falling rapidly to normal background. The duration of emanation from start to finish, generally

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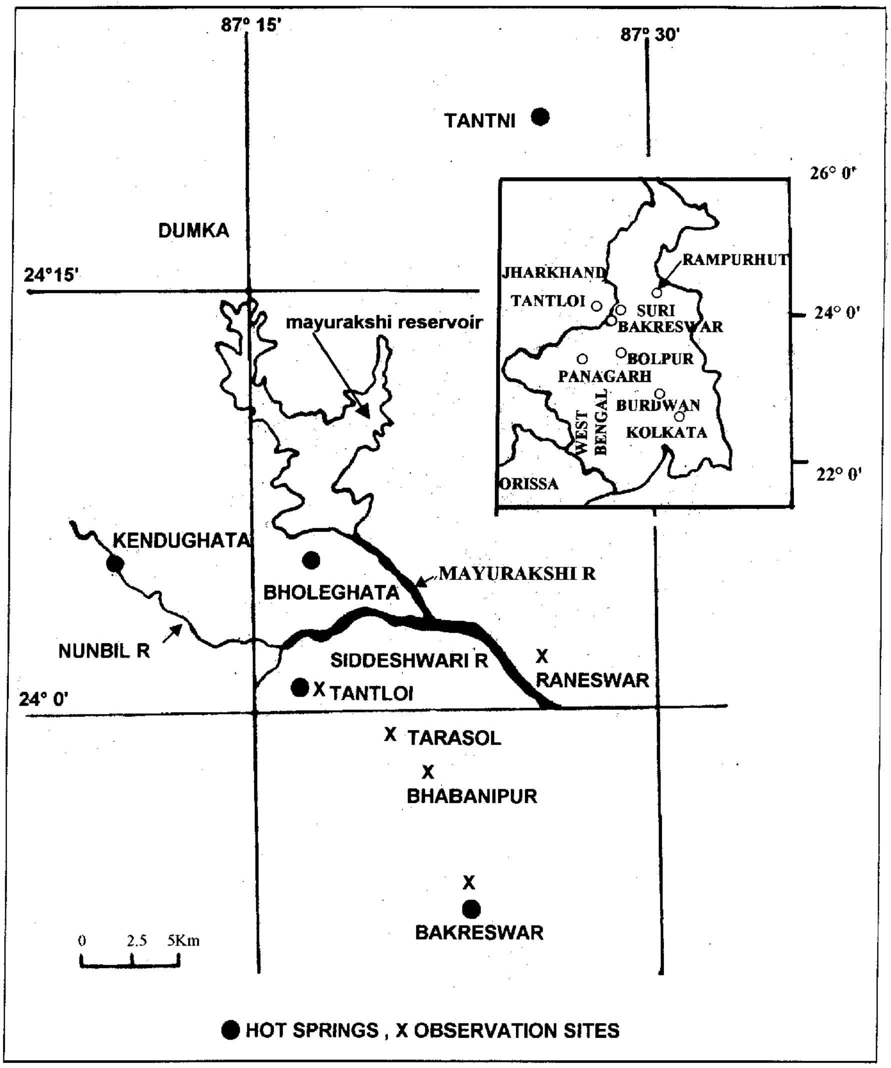

Figure 1. Location map showing hot springs and observation sites of helium escape from the earth surface. (Inset) Location of Bakreswar–Tantloi geothermal area with reference to Kolkata.

Table 1. Percentage composition* of type-II spring bubble gases from hot springs in the Bakreswar–Tantloi geothermal area[12]

Spring (Temperature) °C	Number of analysis	He	N_2	Ar	CO_2	CH_4	O_2	H_2
Bakreswar (69)	455	1.8	90.0	2.6	2.0	2.7	0.8	50 ppm
Tantloi (66)	86	1.5	92.5	1.4	0.2	2.8	0.9	0.7
Kendughata (65)	53	1.1	92.7	1.3	0.6	2.1	1.7	0.5
Bholeghata (42)	50	0.8	68.1	0.8	17.9	–	12.4	–
Tantni (62)	67	1.0	94.8	2.6	0.3	0.6	0.3	0.4

*Listed values are averages with ± 10% variation.

lasts from 15 to 40 min. This characteristic feature has been observed throughout the year, irrespective of seasons. Meteorological factors such as wind speed, temperature and barometric pressure have little influence on the nature and rate of helium emission. Similar observations have been recorded at other places, namely Bakreswar, Tarasol, Tantloi, Raneswar (indicated by X in Figure 1) in this area.

Since the Helitest probe has an aperture of only 1 mm diameter for air entrance, the possibility that the instrument may be indicating highly localized helium concentration is not ruled out. The Helitest is very useful in the

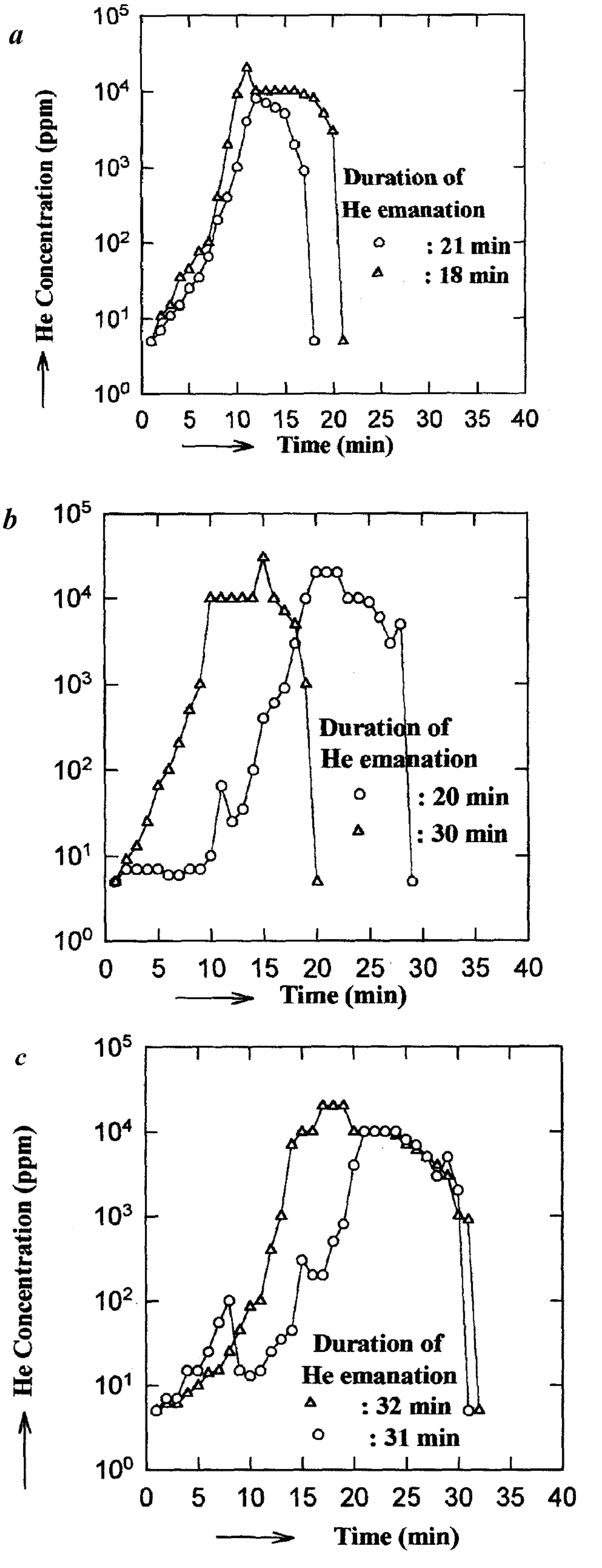

Figure 2. Variation of helium concentration in air at a height of 1 m from the earth surface at Bhabanipur. ***a***, O, Starting time 1200 h, 8.7.99; Δ, Starting time 1150 h, 9.7.99; ***b***, O, Starting time 1304 h, 25.8.99; Δ, Starting time 1100 h, 22.9.99; ***c***, O, Starting time 1031 h, 6.10.99; Δ, Starting time 1200 h, 9.12.99.

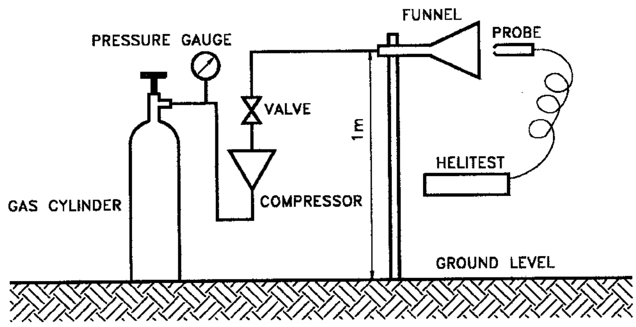

Figure 3. Schematic drawing showing the arrangement for air sample collection at observation sites.

field survey for the initial detection of helium. The indicated value, however, may not necessarily be the true representative concentration of helium for that particular area where degassing is taking place. Hence, we collected bulk quantities of air in cylinders through an arrangement shown in Figure 3, at the time of degassing. Air was drawn through a wide mouth (40 cm diameter) galvanized iron funnel placed in line with the Helitest probe at a height of 1 m above the ground. It was then passed to the intake of a semi-sealed compressor which delivered it to pre-evacuated cylinders of 65 l volume. The cylinders were filled to a pressure of 20 kg/cm^2. About 133 such air samples were collected at the five locations mentioned above (Figure 1) in this geothermal area. These samples were analysed by a gas chromatograph (M/s AIMIL 5700) in the field laboratory at Bakreswar and a 300AMU Quadrupole Mass Analyser (QMA, M/s ASI) at the Variable Energy Cyclotron Centre, Kolkata, for the determination of its total composition. Gas chromatography was carried out using molecular sieve 5A column, hydrogen as carrier gas and a thermal conductivity detector, for the quantitative estimation of He, N_2 and CH_4. Complete analysis of the samples was carried out with QMA. Thus He, N_2 and CH_4 values, obtained by gas chromatography, were also confirmed by QMA. The average composition of the constituents of air samples taken at five locations during helium emission is presented in Table 2. These results give the actual representative value of helium at the time of degassing at that place. Such large helium concentration in air through earth degassing has not been reported elsewhere. As a comparison, we have measured the helium concentration in air at six other places (Kolkata, Burdwan, Panagarh, Bolpur, Suri, Rampurhat; inset, Figure 1), away from the geothermal area. These observed values are presented in Table 3. It is evident that a large-scale leakage of terrestrial gases exists in this geothermal area.

There are some significant mass anomalies in the Bakreswar–Tantloi region of the Indian palaeocontinental margin[13,14]. These are: (a) the Indian Shield crust

Table 2. Average composition of type-I fault air during maximum helium emission at five locations in the Bakreswar–Tantloi geothermal area

Location	Bhabanipur	Bakreswar	Tarasol	Tantloi	Raneswar
Measurement period	May 1999 to November 2000	June 1999 to September 2000	September 1999 to April 2000	June 1999 to June 2000	August 1999 to January 2000
Number of analysis	38	47	19	23	6
He (ppm)	780 ± 132	562 ± 128	367 ± 110	342 ± 39	634 ± 65
H_2 (ppm)	822 ± 54	694 ± 61	482 ± 18	1044 ± 280	521 ± 15
Ar (%)	1.0 ± 0.2	1.2 ± 0.3	1.0 ± 0.1	1.23 ± 0.3	1.0 ± 0.1
N_2 (%)	77.87 ± 1.64	79.36 ± 0.90	79.72 ± 0.90	79.41 ± 1.21	78.60 ± 1.22
O_2 (%)	16.91 ± 2.15	17.01 ± 1.66	18.20 ± 1.11	16.84 ± 0.94	18.13 ± 0.87
CO_2 (%)	1.93 ± 0.30	0.77 ± 0.25	0.35 ± 0.12	1.28 ± 0.46	0.94 ± 0.36
CH_4 (%)	1.75 ± 0.37	1.52 ± 0.41	0.39 ± 0.26	1.66 ± 0.29	2.22 ± 1.54

Table 3. Average helium concentration of air at some other places away from the geothermal area

	Kolkata	Burdwan	Panagarh	Bolpur	Suri	Rampurhat
Distance from Kolkata (km)	0	106	140	178	212	272
Number of analysis	23	5	7	7	17	7
He content (ppm)	4.1 ± 1.4	19.7 ± 2.1	31.9 ± 5.3	12.9 ± 1.3	13.6 ± 2.6	6.9 ± 1.2

undergoes almost 33% thinning (from 36 to 24 km) in WBB; (b) anomalous layers appear in some lower parts of the crust; (c) the upper part of the crust (8–12 km depth) is highly stretched and less dense by 0.14 g/cm^3. These conditions would favour the passage of helium through the faults and fissures in the geothermal area. The temperature of the thermal springs has remained constant over the last 50 years[15]. This would suggest that the factors leading to high heat flow may also be responsible for the escape of helium.

Hydrocarbon gases in India are known to be lean in helium[16]. Many thermal spring gases are rich in helium, but because of low flow-rates the yield is not sufficient enough for commercial extraction. The observed large-scale helium emission reported here is unique and important. It signifies a potential source for obtaining the gas in a large-scale. Work in this direction has already begun.

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