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HEAT AND HELIUM RELEASE FROM THERMAL SPRING AND INFLUENCE OF VOLCANIC ERUPTION

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The escape gas from the vents of the thermal springs at Bakreswar contain helium to the extent of 1.88% average. The heat flow and helium abundance are variable quantities that are controlled by earth parameters. A study has been made on the variations of these two quantities over a long period. Sharp changes in helium concentration is noticed to be related to seismotectonic disturbances.

Key Words: Thermal Spring; Heat; Helium; Volcanic Eruption

Introduction

A distinctive feature of the earth is its ability to retain a significant amount of the heat that had been associated with it at the time of its formation. During the course of subsequent geologic history the related thermal energy has played an important role in the evolution of the Earth and the formation of its atmosphere. The present day terrestrial thermal field may be ascribed to contributions from three separate components. The perimordial heat retained since the time of its formation, radiogenic component and the secondary heat subsequently generated through exothermal processes such as polymorphic changes, gravitational differentiation, chemical reactions and nuclear disintegrations. We may therefore designate terrestrial heat as

$$\text{Heat}_{(\text{terr})} = \text{Heat}_{(\text{prim})} + \text{Heat}_{(\text{rad})} + \text{Heat}_{(\text{sec})}$$

Although the average heat lost from the land surface is about 5.02×10^{-6} J/cm^2/sec and happens to be paradoxically almost similar to the average heat escape through the ocean floor, wide anomalies in the heat flow pattern do exist[1]. Craig *et al.*[2] had discovered spectacular Helium and heat flow anomalies in mid-oceanic ridges where new continental masses are being created. Similar variations were discovered in many other areas by subsequent investigators[3,4,5]. These anomalies have been related to the heat loss from mantle plumes wherein enrichment of ^{3}He in the associated Helium in the thermal waters indicate its origin from significant depths.

During the course of our investigations relating to the determination of the Helium content in the gases evolved from some of the thermal springs in eastern India, we had observed that many of them showed variations in the temperature of the thermal waters within certain limits over a period of time. Fluc-

tuations were also observed in the Helium content of the emanations from these springs. Since the temperature of the waters of some of these are fairly high, as much as 92°C in some cases, it was thought worth-while to investigate into the nature of the variation of the temperature along with variations in the Helium content if any. For the purpose of the study we have confined our attention to one of the springs ('Agnikunda') at Bakreswar (23.9°N, 87.4°E) about 240 km north-east of Calcutta where a Laboratory has been set up to collect and recover the Helium from the emanating gases. The spring gas has a typical volume composition:

N_2	O_2	A	He	CH_4	H_2
92.0%	0.8%	2.62%	1.88%	2.7%	—

Since variations in the helium percentage influences the total output available for extraction it is of some importance to observe diurnal helium variations in the emanating gas.

Experimental Methods

The temperature of the thermal waters was measured with a specially constructed digital thermometer. The sensor of the thermometer was a 2N 222A transistor used as a diode and appropriately encased in a low thermal capacity SS tube. The diode is introduced into one arm of a bridge circuit. Changes in the resistance of the diode brought about by changes in the temperature unbalances the bridge. The out put from the bridge is amplified with the help of an operational amplifier and is registered in a $3\frac{1}{2}$digit DPM. The readings are calibrated against the boiling and freezing points of water. Intermediate values are compared with a set of fractional range mercury in glass standard thermometers. Sample gases for Helium analysis were collected at about the same time as the temperature were recorded mostly around 08.30 hrs. Gases were collected in 500 ml narrow mouthed borosilicate glass containers by the usual method of downward displacement of water. In order to prevent atmospheric air contamination, a small amount of water was left inside the container, the mouth being closed with a tight fitting rubber stopper and sealed by covering the stoppered end with a thin layer of bees wax. The containers were kept inverted so that the gas was always confined over a seal of water. The helium concentration in the thermal spring gases is determined as follows: The collected gas was analysed by a dual column gas chromatograph with a thermal conductivity detector (TCD). Hydrogen is used as the carrier gas while molecular sieve 5A maintained at 50°C is the stationary phase. In order to ensure a high sensitivity the filament current is suitably raised to 220 mA or more. 100 μl of the sample gas is injected at a time. The helium peak is compared to the peak obtained by injecting 2 μl of chromatographically pure helium. The chromatograph data are compared to the helium values obtained by a second method similar to that described by Frost[6]. About 360 ml of the sample gas is allowed to slowly enter a previously evacuated trap containing activated charcoal maintained at liquid nitrogen temperature. Except helium, all the other gases are quantitatively adsorbed. The residual helium pressure is read off accurately by

a modified form of a McLeod gauge. The helium content in the original sample gas is determined from the pressure readings and the constants of the instruments.

Results and Discussion

Temperature measurements and determination of the associated Helium content were carried out in three equal spells over a cumulative period of about two years with interruptions during the monsoon. In order to facilitate reconstruction of the field Laboratory at the spring site, measurements could not be carried out beyond mid March 1988. The work was restarted from January 1991 and is being continued. The values obtained are plotted in Figs. 1-3. The rate of water discharged from the springs is approx. 3412.5 l/min. The calculated quantity of heat released per minute from Bakreswar is 85.1×10^7 J. This is equivalent to an energy of 26.3 kw hrs. A temperature change of 0.1°C would correspond to a change in the heat flux of 1.41×10^6 J per minute. The Helium flow appears to be in advance by approximately 60 days with respect to the heat flow, but this needs confirmation by a series of experimental measurements. It is observed that at the point of emergence helium is liberated at a higher temperature, approximately 2°C, in comparison with the ascending thermal fluid. This most likely is due to the high heat capacity of helium. Furthermore its interaction time with the surrounding media being relatively less by virtue of its greater mobility heat lost due to diffusion and convection during the passage is small. From the report of Oldham[7] who was one of the first to have recorded the temperature of the thermal springs in India, it is seen that the water temperature has remained practically unchanged upto the present time. The uneven pulsations of heat and helium outflow owe their origin to multifarious hypogene forces thereby ensuring the unceasing compression and rarefaction of semifluid state of matter at a considerable depth. Changes in pressure upset the balance between the hot fluid and its interstial solution. A

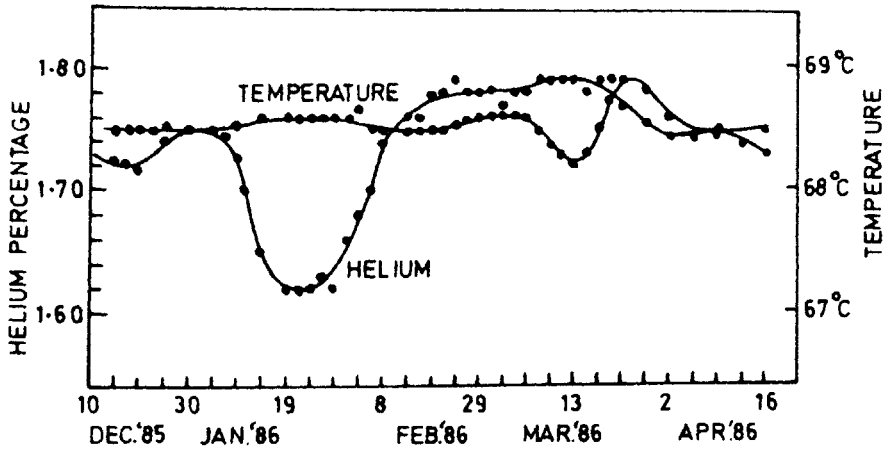

Fig 1 Helium and heat variations at Bakreswar Thermal Springs between December 1985 to April 1986.

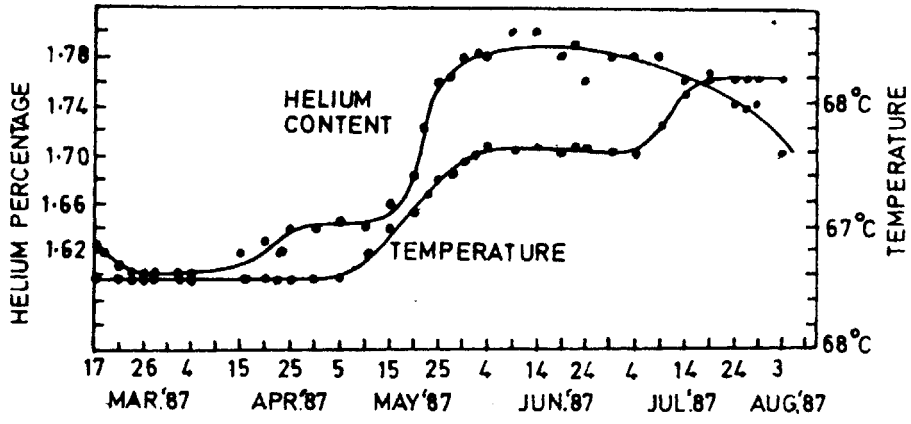

Fig 2 Helium and heat variation between March 1987 to August 1987.

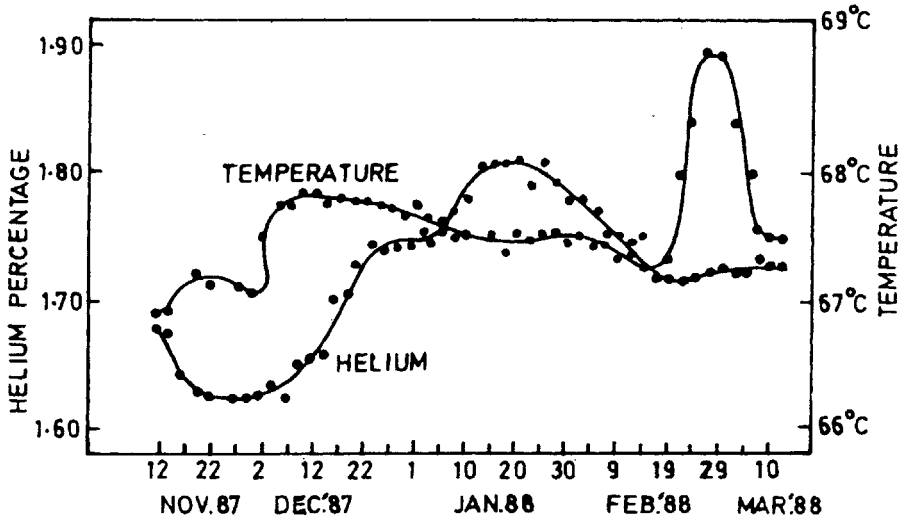

Fig 3 Helium and heat variations between November 1987 to March 1988.

rarefaction would result in a decrease in pressure accompanied by a simultaneous release of heat and helium. A sudden decrease in pressure such as that preceeding an earthquake would result in a corresponding sharp increase in the heat and helium flow as observed by Sultankhodjev[8]. An increase in the temperature of the water would in turn increase its solubility and consequently raise the level of its dissolved mineral components. Such change in the concentration of the dissolved salts prior to an earthquake has been noticed by Sadovsky *et al.*[9]. The added concentration of U and Th minerals would enhance the Radon content in the waters before an earthquake. The variation of helium content in the escaping gas for the months June, July and August 1991 are shown plotted in Fig. 4. It appears to be a fluctuating quantity sporadically varying about a long time average value of 1.88%. The limits of fluctuation is generally between $\pm 0.4\%$ about mean. These variations most likely are on ac-

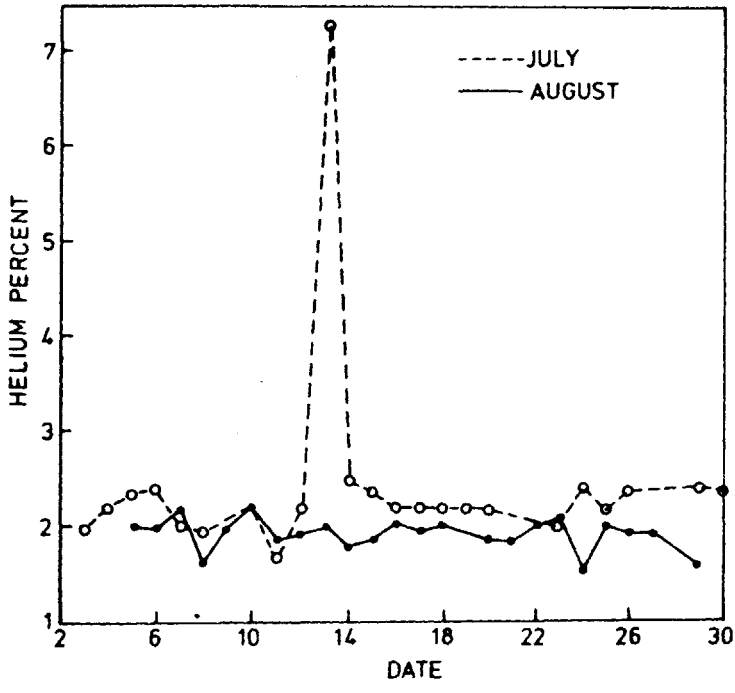

Fig 4 Helium variations during July and August 1991.

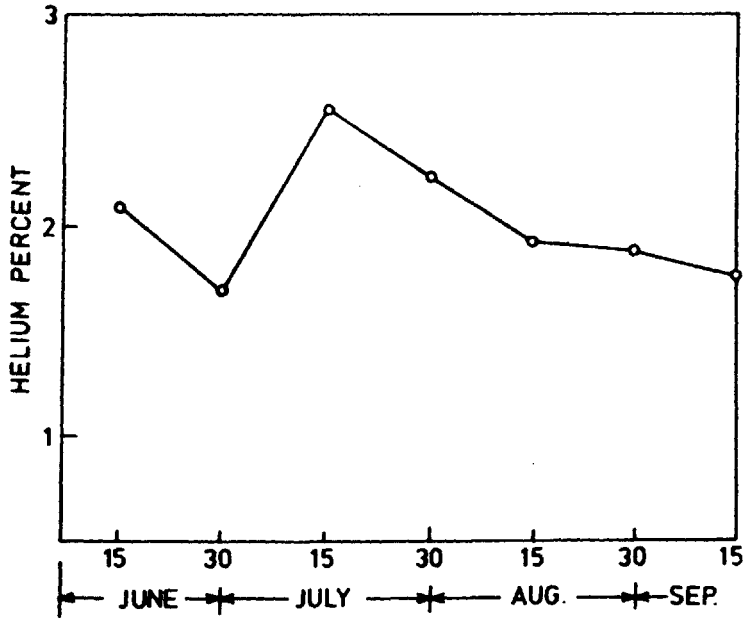

Fig 5 Helium variations average for 15 days plotted for the month June to September 1991.

count of local seismic activity[10,11,12]. The helium concentration however recorded an unusually sharp increase to 7.3% on July 13. The sudden spurt in the helium value appears a precursor to the subsequent volcanic eruption reported on July 16 at the Barren Islands (12.5°N, 94°E) in the Andamans. The helium content of the gas dropped soon thereafter but stayed at a relatively high level of 2.16% till the 20th July. The changes in concentration due to volcanism must certainly be intermingled with local seismic variations also. The seismic contribution may therefore be treated as an interference superimposed upon changes in the helium concentration due to volcanic activity. In order to minimise this contribution, we have taken the time averaged helium values spread over 15 days, plotted for the 3 months June 15 to September 15 (Fig. 5). It is seen that the average helium output which had at first a decreasing tendency increased substantially in the 15 day interval preceeding the eruption. Subsequently it declined gradually till September. This is probably indicative of the progressing decay of the volcanic activity since it first erupted. It may be observed that the heat outflow, as indicated by the temperature, along with associated Helium emanation undergo uneven oscillations about a slowly varying mean value. Furthermore, the helium and heat release are not synchronous. The remarkable simultaneity of the two events, we believe, appears to be a signature in the Indian mainland to a volcanic eruption that took place in a small Ocean Island some 1500 km away.

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