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A Fission Track Technique Used for Hydrogeochemical Prospecting in Northern India

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Abstract—A fission track technique is employed to determine the uranium content of water samples collected from different locations of the middle and outer Himalayas. The regional threshold for the uranium content is determined for water samples of different areas. The identification of anomalies in an area of uranium mineralization confirmed that the hydrogeochemical technique could successfully be used for uranium exploration.

1. INTRODUCTION

Hydrogeochemical prospecting was successfully used in search for uranium as early as the 1950's by Ostle.[1] More recently, with the development of rapid and accurate methods of detection of uranium and its decay products in natural waters at very low concentrations, the hydrogeochemical method has become a powerful tool in the research for uranium ore bodies.[2] By far, the largest number of uranium analyses in water have been carried out by the fluorometric technique.[3] Ion exchange is also employed by some authors.[4,5] The present work reports investigations on hydrogeochemical prospecting for uranium in Punjab, Himachal Pradesh and Uttar Pradesh regions of the outer middle Himalayas, using the fission track[6] method of analysis.

2. SAMPLE COLLECTION AND GEOLOGY OF THE AREA

The samples were collected from different locations of the middle and outer Himalayas in May and October of 1983 and 1984 and the main sample locations around which the samples were collected are shown in Fig. 1. In the Kulu area, water samples were collected from the river Beas, flowing between Rohtangpass and Mandi, a major stream of the river, Parbati Ganga, between Manikaran and Bunter and mountain springs, falling at various places in it. The samples in Dehradun and Siwalik areas were collected along road traverses.

Phosphorite and chert are the prominent rock formations in Dehradun. In the Kulu area, the rocks are quartzite, schist and gneiss. Rocks in the Siwalik area comprise mainly of the massive, soft and grey micaceous sandstones and clays.

3. EXPERIMENTAL TECHNIQUE

The fission track method is used for uranium estimation in natural water samples. The experimental procedure is given elsewhere.[6,7] A known volume of each water sample is taken on lexan plastic discs and allowed to evaporate. The non-volatile constituents including the uranium in the water are left over the disc in the form of a thin film. Subsequent exposure to ϕ thermal neutrons per cm^2 in a nuclear reactor induces fission of a fraction $\sigma\phi$ of uranium atoms, where σ ($=4.2\times10^{-24}$ cm^2) is the cross-section for fission. After irradiation, the lexan detectors are etched using 6.25 N NaOH for 25 min at 65°C, which develops the tracks for visualization under a microscope.

The resultant character of the distribution of the deposited residue of water droplets is displayed in a track array [Fig. 2(a)], a rim of thicker deposition at the edge of the droplet and a center region of uniform deposition. Particulate concentrations of uranium are indicated by clusters of tracks [Fig.

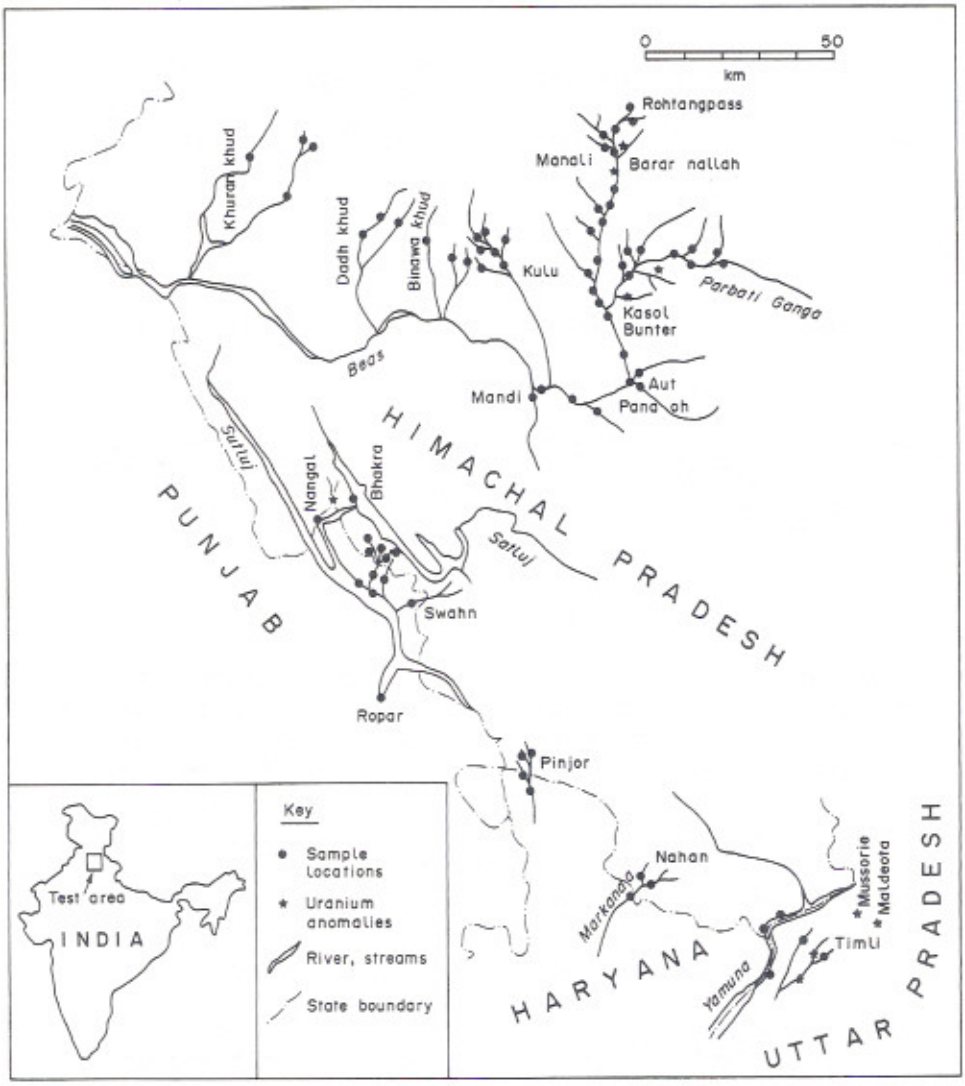

Fig. 1. Map showing major locations of water sampling (adopted from a survey of India).

2(b)] which show the track pattern in the center of a water drop residue that contained suspended solids.

Using a detector with an etching efficiency (E), the concentration of uranium (C_U) is given by the formula

$$C_U = TM/VN_A\sigma\phi G, \tag{1}$$

where

T = total number of tracks,
V = volume of a drop (0.04 ml),
N_A = Avogadro's number (6.02×10^{23}),
M = atomic weight of ^{238}U,
G = geometry factor

and

ϕ = total thermal neutron dose (nvt).

When C_U is in parts per billion (ppb) and the volume, V, of the drop is in ml, then equation (1)

Fig. 2. Etched track detector with the record of uranium from a portion of evaporated droplet (a) suspended particles leading to fission stars in the interior of the track pattern from a water droplet (b).

reduces to

$$C_U = 94.4T/\phi V. \tag{2}$$

The uranium concentration is determined by counting the entire T tracks associated with a drop, but high track densities sometimes make it inconvenient to do so. In most cases, the drop pattern is circular and can be described in terms of a constant number of tracks per unit length (T_L) along the rim of the distribution and a constant number of tracks per unit area (T_A) in the interior. If the radius of the circular track distribution from the droplet is R, and the radial non-uniformity near the rim has a width r, for $r \ll R$, then

$$T = 2\pi R T_L + \pi(R - r)^2 T_A. \tag{3}$$

The detection limits for uranium determination by fission track method are reported to be 0.01 ppb[8] and 80 ppb[9]. This large range results from the use of different irradiation times and different neutron fluxes. The precision is reported to be $\pm$10–15% by Ward and Price[10] and $\pm$5% by Mahajan *et al.*[11]

Table 1. Water samples showing only anomalous uranium concentrations

Sample No.	Sample location	Area	Uranium content (ppb)	Contrast	Remarks
1	Shat	Kulu (5.6 ppb*)	8.0 ± 0.1	1.4	Related to Shat-Chinnjra and Kasol mineralization.[1]
2	Kasol		37.0 ± 0.4	6.6	—do—
3	Rangri		8.8 ± 0.0	1.6	—do—
4	Nangal	Siwalik (5.9 ppb*)	21.0 ± 0.2	3.6	—do—
5	Renuka		12.0 ± 0.2	2.0	—
6	Timli		72.0 ± 0.5	12.2	—
7	Anandgarh (I)		7.4 ± 0.1	1.3	Anomalies due to contamination.
8	Anandgarh (II)		9.7 ± 0.1	1.6	
9	Maldeota	Dehradun (8.7 ppb*)	63.0 ± 0.4	7.2	Related to the mineralization of Mussorrie syncline.[2]
10	Paritibba		27.0 ± 0.4	3.1	

* Regional threshold.
1. Narayan Dass *et al.* (1979).
2. Saraswat *et al.* (1970).

3.1. *Merits of the fission track method*

(i) This method provides a detection limit of 0.01 ppb (with the possibility of lowering this) in water samples with a better sensitivity than other recent methods such as fluorochlorimetry and laser fluorometry.[12]
(ii) The sample size, typically 0.1–1 ml, is a distinct advantage of this method.[10]
(iii) By this technique the dissolved uranium can be separately determined from that which is suspended in particulate matter.[7]

4. RESULTS AND DISCUSSION

The background concentration of uranium in water samples of different areas was determined by taking the mean uranium content values for water samples from non-mineralized locations in the area. From the background value ($\bar{x}$) and standard deviation (σ), we have assessed the regional threshold level of uranium for different areas. Taking the threshold at ($\bar{x} + 2\sigma$), uranium anomalies were identified in water samples collected from Shat, Kasol and Rangri in the Kulu area, Nangal, Renuka, Timli and Anandgarh of Siwalik Himalayas of Himachal Pradesh, Maldeota and Paritibba in the Dehradun-Mussoorie area of Uttar Pradesh (Table 1). The presence of uranium mineralization in the Kulu and Dehradun-Mussoorie areas[13–16] confirms the hydrogeochemical anomalies of Paritibba, Maldeota, Timli, Shat and Kasol identified in these areas. These results indicate the potential of the hydrogeochemical technique for uranium prospecting in the area.

The present study also highlights the anomalous uranium content of 21.0, 12.0 and 8.8 ppb in water samples of Nangal and Renuka of Siwalik area and Rangri of Kulu area, respectively, indicating the need for further investigations for uranium mineralizations in these areas.

The uranium contents of 7.4 ± 0.1 and 9.7 ± 0.1 ppb recorded in water samples of Anandgarh also seem to be anomalous. By counting randomly arranged fission tracks and clustered fission tracks, the dissolved and suspended uranium was found to be 4.9, 4.2 ppb and 2.5, 5.5 ppb, respectively, in these samples. Since the uranium in suspension is due to contamination, and dissolved uranium of 4.9 and 4.2 ppb were less than 5.9 ppb, the threshold value, these values cannot be considered as anomalous.

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REFERENCES

1. Ostle D. *Min. Mag.* **91**, 201 (1954).
2. Dyck W. In *Geol. Surv. Can. Econ. Geol. Rep.* (Ed. Hood P. H.) **31**, 489–510 (1979).
3. Samasoni Z. *Micro. Acta* **1**, 88 (1967).
4. Danielson A., Roenholm O., Kjellstroem L. E. and Ingman F. *Talanta* **20**, 185 (1973).

5. Parslow G. R. and Duiri I. *J. Geochem. Explor.* **8,** 541 (1977).
6. McCorkell R. H. *CIM Bull.* **76,** 89 (1983).
7. Fleischer R. L. and Delany A. C. *Anal. Chem.* **48,** 642 (1976).
8. Ward F. N. and Bondar W. F. In *Geol. Surv. Can. Econ. Geol. Rep.* (Ed. Hood P. H.) **31,** 365–383 (1979).
9. Reimer G. M. *J. Geochem. Explor.* **4,** 425 (1975).
10. Ward F. N. and Price V. *J. Geochem. Explor.* **13,** 97 (1980).
11. Mahajan G. R., Chaudhurry N. K., Sampath-Kumar R. and Iyer R. H. *Nucl. Instrum. Methods* **153,** 253 (1978).
12. Guo S. L., Xin-Lu Deng, Sheng-Fen, Sun Mv Meng, Peng-Fa Zhang and Xiv-Hong Hao. *Nucl. Tracks Radiat. Meas.* **12,** 801 (1986).
13. Saraswat A. C., Sankaran A. V., Varadaraju H. N., Taneja P. C. and Bargaje V. V. *Unesco-Ecafe session on Geochemical prospecting*, Colombo, Ceylon (1970).
14. Narayandas G. R., Parthasarthy T. N. and Taneja P. C. *J. Geol. Soc. India* **20,** 95 (1979).
15. Singh N. P., Singh M., Singh S. and Virk H. S. *J. Geochem. Explor.* **26,** 259 (1986).
16. Udas G. R. and Mahadevan T. M. *Proc. Symp. formation uranium ore deposits*, IAEA, Vienna, pp. 425–436 (1974).