Table 4. Results obtained from NPTEST for the three crystals described in Table 3

Crystal	Critical region	Observed value of the test statistic	Decision obtained regarding the space group of the crystal	Actual space group of the crystal
1	[−0.020	0.038	$P\bar{1}$	$P\bar{1}$
2	[−0.021	0.032	$P\bar{1}$	$P\bar{1}$
3	[−0.023	0.047	$P\bar{1}$	$P\bar{1}$

Note: $\alpha = 0.05$. '$[x_0$' stands for the interval $0 \leq x \leq x_0$.

group of the crystal is $P1$) and H_1 (i.e., space group of the crystal is $P\bar{1}$) are shown in Figure 2. The results obtained from the tests are given in Table 4. It is seen that correct results are obtained in all the three cases.

1. Hoel, P. G., Port, S. C. and Stone, C. J., *Introduction to Statistical Theory*, Houghton Mifflin Co., Boston, 1971, pp. 56–60.
2. Rubinstein, R. Y., *Simulation and the Monte Carlo Method*, John Wiley and Sons, New York, 1981.
3. Sobol, I. M., *The Monte Carlo Method*, Mir Publishers, Moscow, 1975, pp. 32–34.
4. Ralson, A. and Rabinowitz, P., *A First Course in Numerical Analysis*, Mc Graw Hill, Intl. Book Co. Tokyo, 1981, p. 346.
5. Eadie, W. T., Drijard, D., James, F. E., Roos, M. and Sadoulet, B., *Statistical Methods in Experimental Physics*, North-Holland Publishing Co., Amsterdam, 1971, p. 73 & p. 83.
6. Wilson, A. J. C., *Acta Crystallogr.*, 1949, **2**, 318–321.
7. Srinivasan, R. and Parthasarathy, S., *Some Statistical Applications in X-ray Crystallography*, Pergamon Press, New York, 1976, pp. 38–42.
8. Brehm, L. and Honore, T., *Acta Crystallogr.*, 1978, **B34**, 2359–2361.
9. Sheldrick, W. S., Brokenstein, A. and Engel, J., *Acta Crystallogr.*, 1978, **B34**, 2055–2058.
10. Herbert, H., *Acta Crystallogr.*, 1978, **B34**, 3128–3131.

ACKNOWLEDGEMENT. Thanks are due to the Council of Scientific and Industrial Research, India for the award of Senior Research Fellowship to K. S.

Received 26 March 1992; revised accepted 22 July 1992

Self-diffusion coefficient of 86-Rb in mica-rich soils

B. B. Mishra*, S. K. Ghosh, P. Sachdev, M. S. Sachdev, D. L. Deb and R. P. Arora

Nuclear Research Laboratory, Indian Agricultural Research Institute, New Delhi 110 012, India

*Present address: Soil Survey and Land Use Planning Scheme, Rajendra Agricultural University, Sabour Campus, Sabour 813 210, India

The self-diffusion coefficient of 86-Rb in four surface soils derived from mica-rich parent materials was determined at field capacity. Its values ranged from 0.54×10^{-10} to 1.674×10^{-10} cm^2 sec^{-1} at zero level K and from 1.788×10^{-10} to 7.02×10^{-10} cm^2 sec^{-1} at 50 ppm level K. These values were found much lower than the values reported elsewhere earlier. Enrichment of these soils with 50 ppm carrier-K resulted in a tremendous increase in the Da–Rb values.

THE movement of K through diffusion is important in soils[1]. Potassium does not have any suitable isotope to use in labelling soil. The ^{42}K and ^{43}K have half-lives only in hours, while enrichment of natural isotope, ^{40}K and the stable isotope ^{41}K is very expensive. The rubidium was tested as a tracer of K in soil studies[2]. The process of Rb uptake from soil by plant roots is similar to that of K uptake[3,4]. The self-diffusion of ^{86}Rb was found linearly correlated positively with soil moisture[5]. In view of this, an experiment was conducted to study the self-diffusion coefficient of ^{86}Rb in soils derived from mica-rich parent materials. Such information particularly for the soils of India is meagre.

Surface soils of four representative pedons of Giridih and Munger districts of Bihar were collected. Half-cell technique as outlined by Sen and Deb[6] was used to study the Rb-diffusion, at two K-levels i.e. 0 and 50 ppm K. The tagging of soils with 86-Rb was performed taking 1 μCi/g of soil. A calculated amount of water corresponding to water content at 0.3 bar (field capacity) was added. Activity of tagged and untagged soil portions was measured using a G. M. counter. All the determinations were made in duplicate. The apparent self-diffusion coefficient of ^{86}Rb was then calculated by using the integrated form of the equation derived by Phillips and Brown[7] and presented in Table 1.

The self-diffusion coefficient ^{86}Rb in all four soils at zero level K ranged from 0.54×10^{-10} to 1.674×10^{-10} cm^2 s^{-1}. The enrichment of these soils with 50 ppm carrier-K before determining the Da Rb, however, resulted in a tremendous increase in the Da Rb values at field capacity. This increase in Da Rb appears to be possibly due to an increase in soil solution concentration of K. The values for Da Rb in these mica-rich soils were observed to be generally lower than the values reported earlier[7,8]. Such low values of Da Rb might have been due to the fact that the soil clays were rich in

Table 1. Apparent diffusion coefficient of ^{86}Rb in mica-rich soils at field capacity associated with soil properties

Surface soil	Da Rb ($cm^2 sec^{-1}$)		Soil properties				
	0 ppm K	50 ppm K	Bulk density (g/cc)	Organic carbon (%)	Exch. K (me/100g soil)	Mica (% clay)	Kaolinite (% clay)
1	0.567×10^{-10}	7.02×10^{-10}	1.73	0.34	0.11	26.36	71.15
2	0.546×10^{-10}	2.856×10^{-10}	1.65	0.46	0.15	70.05	22.79
3	1.674×10^{-10}	1.788×10^{-10}	1.62	1.29	0.34	86.61	7.19
4	0.540×10^{-10}	4.839×10^{-10}	1.52	0.64	0.15	85.97	8.08

non-expandable minerals like mica and kaolinite having practically no interlayer space. Moreover, mica exhibits much higher binding force for K to restrict its movement in soils. Further, the high buffering capacity of these soils varying between 7.50 and 26.67 me/100 g (M L)^{1} as reported by Mishra[9] might also have been associated with low Da-Rb values in these soils. Fairly high values of Da-Rb in the soil of Pedon 3 seem further to be associated with high value of organic carbon (1.29%). The Da-Rb values were, however, found positively and significantly correlated with exchangeable K of these soils ($r = 0.941$).

1. Barber, S. A., *Soil Nutrient Bioavailability—A Mechanistic Approach*, Wiley and Sons, New York, 1984.
2. Fried, M. and Broeshart, H., *The Soil-Plant System in Relation to Inorganic Nutrition*, Academic Press, New York, 1967, pp. 227–228.
3. Fried, M., Hawkes, G. and Mackie, W. F., *Soil Sci. Soc. Am. Proc.*, 1959, **23**, 360–362.
4. Evans, S. D. and Barber, S. A., *Soil Sci. Soc. Am., Proc.*, 1964, **28**, 56–57.
5. Place, G. A. and Barber, S. A., *Soil Sci. Soc. Am. Proc.*, 1964, **28**, 239–243.
6. Sen, A. and Deb, D. L., in *Improving Crop and Animal Productivity* (eds. Sethi, G. R. and Chatrath, M. S.), Oxford and IBH Pub. Co., New Delhi, 1978, pp. 485–497.
7. Phillips, R. E. and Brown, D. A., *Soil Sci. Soc. Am., Proc.*, 1964, **28**, 758–763.
8. Schofield, R. K. and Graham-Bryce, I. J., *Nature*, 1960, **188**, 1048–1049.
9. Mishra, B. B., Ph D Thesis, I. A. R. I., New Delhi, 1990.

ACKNOWLEDGEMENT. B. B. M. is grateful to BARC, Bombay for timely supply of rubidium isotope, and to Dr P. N. Tiwary, I. A. R. I., New Delhi for encouragement.

Received 25 June 1992; accepted 4 September 1992

Trace fossil *Limulicubichnus* from the Lower Miocene rocks of Kutch

S. J. Patel and D. M. Shringarpure
Department of Geology, M. S. University of Baroda, Vadodara 390 002, India

Trace fossils of *Limulicubichnus* indicating their production by the horseshoe crab are reported for the first time from the Lower Miocene rocks of Kutch. Two separate species of the traces are identified and described. The heavily excavated traces are accounted for as either deposit feeding structures or as resting traces made by an animal supported in water. These trace fossils and their associated forms indicate shallow water conditions, predominantly marine, which were subjected to repeated fluctuating water levels and at times exposed to the subareal condition.

THE authors have located trace fossils of *Limulicubichnus* within the Lower Miocene rocks exposed in the Suvernarekha River Section near Ramwada Mandir in Western Kutch (Lat. 23° 26′ 30″ N, Long. 68° 36′ 00″ E). These traces are found on the top of the 20 m thick buff to yellowish coloured argillaceous limestone sequence exposed in the River channel. Most of the argillaceous limestone beds here are hard, compact 3–5 m thick. They often contain a rich assemblage of gastropods, pelecypods, echinoderms and rarely corals. The micro-fossils include species of *Ammonia papillosus*, *Archaiaes angulaties*, *Miogypsina* sp. and *Taberina malabarina* indicating a probable Burdigalion age of the strata.

The trace fossils identified as *Limulicubichnus* are typically heart-shaped, lunate, often teardrop-shaped depressions on the bedding plane. They are characterized by traces exhibiting bilateral symmetry, serrate posterior margin, elongate terminus or appendage markings and rarely with a telson marking or cast indicating its production by a horseshoe crab (limulid Figure 1 *a*).

Incidentally, Molly Miller[1] was the first to attribute resting traces of such limulids to the ichnogenera *Limulicubichnus* (Latin Limulus—horseshoe crab and cubore—to lie down). The other well-established trace fossils include the ichnogenera *Kouphichnium* which is moderately common and stratigraphically and geographically widespread and is interpreted as trackways of Limulids. There appear to be two well-defined trace fossil resting burrows of horseshoe crabs in the limestone bed exposed in the Suvernarekha River