ON THE OCCURRENCE OF RADIOACTIVE XENOTIME AND MONAZITE AROUND KUNKURI, JASHPUR SUB-DIVISION, RAIGARH DISTRICT MADHYA PRADESH

by K. P. GHOSH, *Directorate of Geology and Mining, Raipur, Madhya Pradesh*

(Communicated by Prof. A. K. Saha, FNA)

(*Received 23 January 1976*)

Radioactive xenotime and monazite have been recorded for a considerable stretch in the placer sands and nala soils along Kandera nala (Lat. 22° 45′ 50″–22° 46′ 38″ and Long. 84° 58′–84° 1′) and Baljora nala (Lat. 22° 46′ 50″–22° 46′ 38″ and Long. 84° 1′ 20″–83° 56′ 38″ in Raigarh district, Madhya Pradesh.

The observed radioactivity of the samples of sand and soil has been correlated with the mineral constituents of the placer sands and soils. It has been confirmed that the major activity is contributed by monazite and xenotime and the ratio (ϵ) of monazite/xenotime remains nearly constant as 2 in all the samples studied. Statistical analyses of the mineral constituents and the radioactivity bring out three ratios, Ω (opaque/zircon+epidote—zoisite+chlorite), γ (xenotime+opaque/monazite+epidote—zoisite+chlorite) & ϕ (Ω/γ), vary linearly with eU_3O_8,U_3O_8 and eU_3O_8/U_3O_8 values respectively with the correlation coefficients of 0.94, 0.90 and 0.95 respectively. Composition of the xenotime has been proposed as $^*X_{82-80}$ $^*Ch_{18-20}$. The xenotime and monazite in the original host rock probably formed at the alkaline-acidic interface of the granitic melt.

INTRODUCTION

Radioactive xenotime and monazite have been located in the placer sand and soil of Baljora and Kandera nalas, near the village Raikera, Jashpur Sub-Division, Raigarh district, Madhya Pradesh. The active zone in the order of 3 to 25 BGC stretches for 1½ km along the Kandera nala (Lat. 22° 45′ 50″ – 22° 46′ 38″ and Long. 84° 58′—84°1′, Fig. 1), while in the Baljora nala, the active zone of the same order covers a distance of 10¼ km falling within the Lat. 22° 46′ 30″–22° 50′ 30″ and Long. 84° 1′ 20″–83° 56′ 38″ (Fig. 1).

GEOLOGY OF THE AREA

The area is the western extension of the southern belt of Chota-Nagpur granite-gneiss (Krishnan 1968). In places it weathers into tors to form the typical dome-gneiss. The dome-gneiss and for the matter, the whole of the granite-gneiss are distinctly intrusive to the Iron-ore-series. While the country rock is mainly represented by the granite-gneiss, the mica-schists of Iron-ore-series are widely scattered. The mafic intrusives and pegmatites of smaller dimensions are very common.

---

*X = xenotime.
*Ch = chernovite.

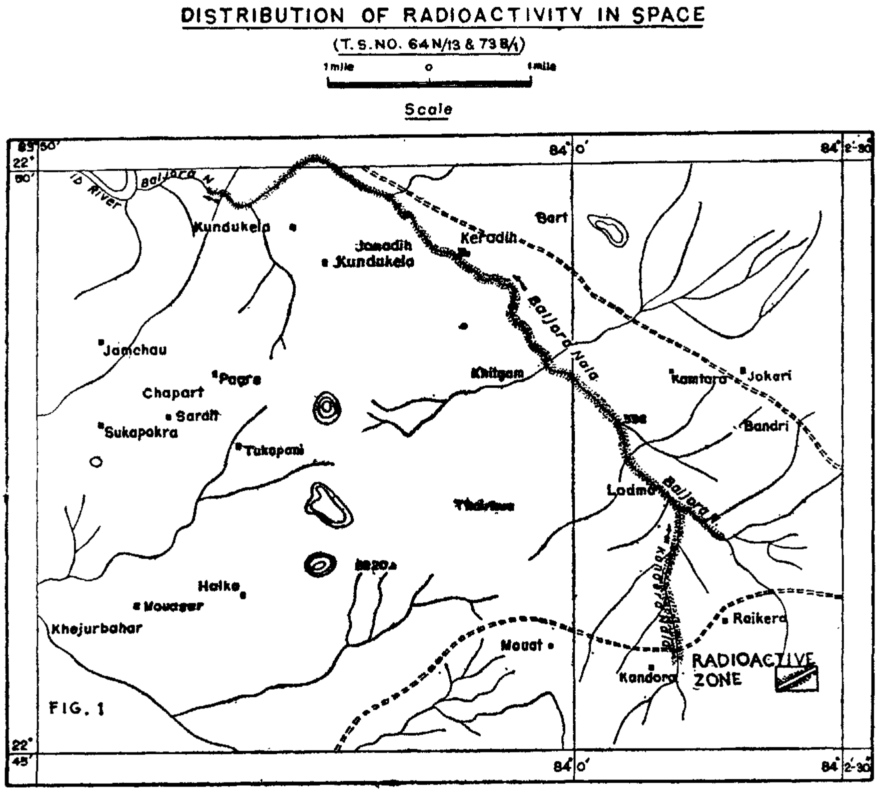


FIG. 1.

The Baljora and Kandera nalas originate from a small hillock near Raikera village in the south and flows northwards to converge with the Ib river near the village Bilaspur. Kandera nala after flowing through a distance of $1\frac{1}{2}$ km meets with the Baljora nala. (Fig. 1).

Both the nalas all along their banks record the minimum activity in the order of 3 BGC. The high activity in the order of 6 to 20 BGC in average has been recorded in Kandera nala along the bank soil and within the soil islands exposed in the nala bed. The width of the active zone varies from 2 to 10 metres, depending on the width of the exposed soil.

In the Baljora nala, the active zone, in the order of 3–20 BGC, has been stretched for a distance of $10\frac{1}{2}$ km. The activity is being confined to the bank soil and soil-islands. The width of the active zone varies from 3 to 10 metres.

The intensity of activity and the stretches of active zone are the function of three major variables—the length of the soil exposed along the banks, the width of the banks and the islands within the nala and the presence of the admixtured soil and sand along the nala bed. The soil-islands in the nala are not continuous all along but they are separated by an average distance of 30 to 50 metres. The individual unit varies in dimension from 15–200 metres in length and 4–20 metres in width. The disposition of parallel orientation of soil islands in the nala is very conspicuous.

Collection and Preparation of Sample

Bulk garb-sampling were made from the places where the activity stretches for a sufficient length along the nala. Samples of materials with various activity were collected.

In the laboratory, five samples of different BGC of different spots were mixed together to prepare one representative bulk crop and likewise four bulk-crops of average X15 BGC, X10.2 BGC and X9 BGC were prepared. The two bulk samples (KPG/KN/PI(2) and KPG/KN/P1(4) were treated in the laboratory as such.

All the bulk samples were concentrated by gravity separation (hand panning) (Table I) and the produced concentrates were further treated by bromoform heavy-liquid separation.

Table I

Results of the gravity separation

Sample No.	Wt. of feed gms.	Wt. of slime gms.	Wt. % slime	Wt. of tails gms.	Wt. % tails	Wt. of conc. gms.	Wt. % conc.	% loss	BGC
KPG/KN/P1/2	10000	1165	11.65	7925	79.25	815	8.15	0.95	X20
*KPG/B/1/P1(21)/6	10000	1180	11.80	7500	75.00	1220	12.20	1.00	X15
*KPG/B1/(17)/8-74	4000	607	15.17	3090	77.25	260	6.00	1.70	X10.2
*KPG/B1/(24)/1	5000	887	16.74	3825	76.50	277	5.54	1.20	X9.6
*KPG/B1/(16)/8-74	5000	478	9.56	4095	81.18	418	8.36	0.90	X8.12

*Each sample prepared by mixing five samples of variable activity.

Two of the concentrates (KPG/KN/P1(2) and KPG/B/1/(24)/(1) have been treated by Isodynamic separator (15° side slope, 20° forward slope and the grain size —72BSS) to separate the different fractions at different amperages. This has been observed that under this working set-up, xenotime separated maximum at 0.5 and 0.6 amps. while the monazite concentrates were maximum at 0.8 and 0.9 amps.

Mineragraphic Studies

The concentrates of six bulk samples were studied under microscope after mounting the grains with canada balsam.

The concentrate crop is mainly composed of xenotime, monazite, opaques (hematite, magnetite and ilmenite), zircon, epidote, zoisite, chlorite, quartz and feldspar as major constituents while sphene, rutile, biotite and granet form the accessory. [Pl. 1(d)].

Monazite and xenotime occur as small subhedral to elongated grains. The zoning in monazite and xenotime is very common [Pl. 1(a) & 1(c)]. Consideration of the refractive indices of xenotime grains and its extrapolation in the curve of Graeser *et al.* (1973) favour its composition to fall within the range $X_{82}Ch_{18}$—$X_{80}Ch_{20}$.

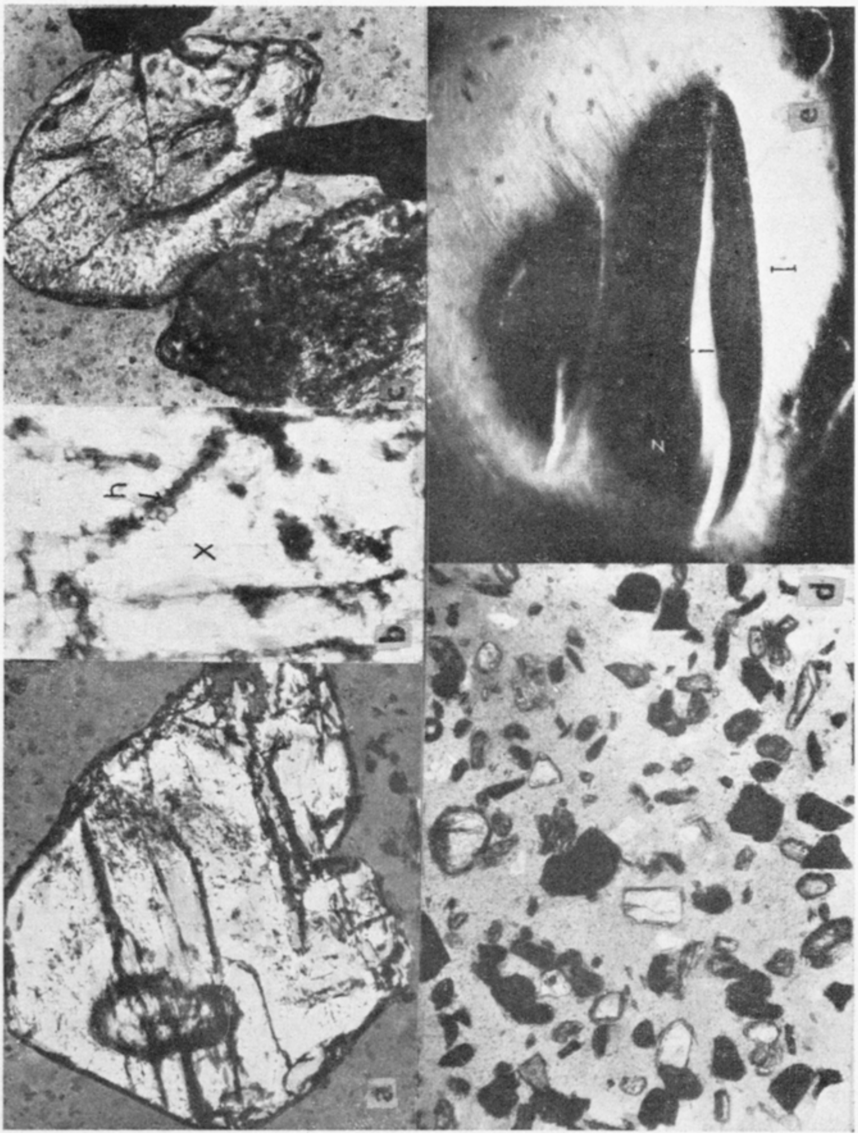


PLATE 1 a–e. (a) Zoned xenotime × 200 (plane polarised); (b) Thin veins of hematite are filling the fracture plane of xenotime × 200 (cross nicols, *X* = xenotime, *h* = hematite); (c) Zoned monazite × 200 (cross nicols); (d) Bulk crop of the radioactive placer sands × 35 (cross nicols); (e) Inclusion of zircon in ilmenite, note the fracture in the included zircon has been filled up by ilmenite × 600 (oil, plane polarised, I = ilmenite (1st), i = ilmenite (2nd) and Z = zircon).

TABLE II

Results of the Radiometric Assay

Sample No.	Feed		Slime		Tails		Concentrate		ThO_2
	$\%eU_3O_8$	$\%U_3O_8$	$\%eU_3O_8$	U_3O_8	eU_3O_8	U_3O_8	eU_3O_8	U_3O_8	
KPG/B1/P1/(21)/6	0.13	<0.02	<0.01	<0.02	<0.01	<0.02	<1.40	0.15	2.90
KPG/KN/P1(2)	0.23	<0.02	<0.01	<0.02	<0.01	<0.02	1.80	0.08	3.80
KPG/B1/(16)/8-74	0.096	<0.02	<0.01	<0.02	<0.01	<0.02	0.98	0.1	
KPG/B1/(17)/8-74	0.099	<0.02	<0.01	<0.02	<0.01	<0.02	1.34	0.06	
KPG/B1/(24)/1	0.052	<0.02	<0.01	<0.02	<0.01	<0.02	0.82	0.12	1.66
KPG/KN/P1(4)							1.90	0.17	

TABLE III

Results of the model analyses

Sample No.	Xenotime %(average of two)	Monazite %(average of two)	ϵ = Monazite/ Xenotime
KPG/KN/P1(4)	11.15	24.60	2.2
KPG/B1/P1/(21)/6	14.00	26.40	1.80
KPG/B1/(16)/8-74	13.50	25.20	1.86
KPG/B1/(24)/1	13.20	25.85	1.88
KPG/KN/P1(2)	15.40	34.30	2.20
KPG/B1/(17)/8-74	12.60	28.80	2.28
Average	13.3	26.76	2.00

From the modal analyses of the samples, it is evident that the xenotime percent varies in the concentrates from 11.15 per cent to 15.40 per cent (average 13.3 per cent) while the monazite maintains a variation from 20.00 per cent to 34.85 per cent (average 26.76 per cent). The (ε), ratio between monazite and xenotime, varies from 1.80 to 2.28, maintaining the average of 2. (Table III).

CORRELATION OF RADIOACTIVITY WITH THE MINERAL CONSTITUENTS OF THE CONCENTRATES

The minerals that may be responsible for radioactivity in the placers are xenotime, monazite, opaques (magnetite, hematite, ilmenite, titano-ilmenite), zircon, epidote, zoisite and chlorite (Pl. 1(b) & 1(e)]. Radioluxographic analyses and radiometric assay, however, confirm that the major activity is contributed by monazite and xenotime. Yet, the consideration of the role of other minerals is very significant to find out a meaningful reasoning for the overall change of radioactivity from sample to sample.

Three factors have statistically been found out which control the eU_3O_8, U_3O_8 and eU_3O_8/U_3O_8 values of the area (Tables IV & V).

TABLE IV

Results showing the relations between (Ω), (γ), (φ) and eU_3O_8, U_3O_8 and (ω)

Sample No.	(Ω)	eU_3O_8	(γ)	U_3O_8	(φ)	(ω)
KPG/KN/P1/(4)	3.80	1.90	1.60	0.17	2.37	11.17
KPG/KN/P1/(2)	2.90	1.80	0.82	0.08	3.65	22.50
KPG/B1/P1/(21)/6	2.80	1.40	1.19	0.14	2.35	10.00
KPG/(B1/(II)/8-74	2.07	1.34	0.819	0.06	3.30	22.30
KPG/B1/(16)/8-74	2.50	0.98	0.96	0.10	1.56	9.80
KPG/B1/(24)/1	1.40	0.82	0.88	0.12	1.57	6.83

$$(\Omega) = \frac{\text{Opaque}}{\text{zircon} + \text{epidote} - \text{zoisite} + \text{chlorite}}$$

$$(\gamma) = \frac{\text{xanotime} + \text{Opaque}}{\text{monazite} + \text{epidote} - \text{zoisite} + \text{chlorite}}$$

$$(\phi) = \frac{\Omega}{\gamma} \qquad (\omega) = \frac{eU_3O_8}{U_3O_8}$$

TABLE V

Results showing the regression equations, correlation coefficients and average X & Y of the different variables

Variables	Regression equation	Correlation coefficient	Average of X and Y
$X = U_3O_8$	$Y = 6.87X+0.29$	0.90	$X = 0.11$
$Y =$ (γ)			$Y = 1.045$
$X = eU_3O_8$			$X = 1.37$
$Y =$ (Ω)	$Y = 2.02X-0.26$	0.94	$Y = 2.50$
$X =$ (ω)			$X = 13.76$
$Y =$ (φ)	$Y = .12X+0.75$	0.95	$Y = 2.4$

$$(\Omega) = \frac{\text{opaque}}{\text{zircon} + \text{epidote} - \text{zoisite} + \text{chlorite}},$$
directly proportional to eU_3O_8, correlation coefficient = 0.94

$$(\gamma) = \frac{\text{xenotime} + \text{opaque}}{\text{monazite} + \text{epidote} - \text{zoisite} + \text{chlorite}},$$
directly proportional to U_3O_8, correlation coefficient = 0.90

$(\phi) = \frac{(\Omega)}{(\Upsilon)}$, directly proportional to $\frac{eU_3O_8}{U_3O_8}$ (ω)

correlation coefficient = 0.95

The regression equations connecting the above noted variables are:—

$(\Omega) = 2.02\, eU_3O_8 - 0.26$ ....(1)

$(\tau) = 6.67\ U_3O_8 + 0.29$ ....(2)

and $(\phi) = 0.12\ eU_3O_8/U_3O_8 + 0.75$ ....(3)

From these above relations, it is evident that an extremely good linear relationship is maintained among the functional variables (Figs. 2, 3 & 4). The positive regression coefficient (slope of the line) indicates an increase of *'x'* with increase of *'y'* and vice-versa (Figs. 2, 3 & 4).

Petrological observation confirms the presence of zoned xenotime and monazite [Pl. 1(a) & 1 (c)] in the concentrates. The zonation itself indicates a break in the crystallization process, even if, the crystallization takes place in a single continuum.

The electro-negativities of Yttrium (Ey = 1.20) and cerium (Ece = 1.05) favour them to be concentrated in the residual melt (Ringwood 1955). The same is very much applicable in the case of uranium and thorium (Ringwood 1955). Leonova *et al.* (1967) have shown the higher concentration of uranium and thorium in xenotime of inner zone than the outer zone during their studies of Chupa pegmatites.

Proposed Genesis

Granites and pegmatites have universally been accepted as the source rock for xenotime and monazite (Vinogradov 1959; Leonova *et al.* 1967; and Favertto 1968).

During the process of fractional crystallization of granitic melt, the rare earth elements and Yttrium follow some regularities. It is widely accepted that the lighter

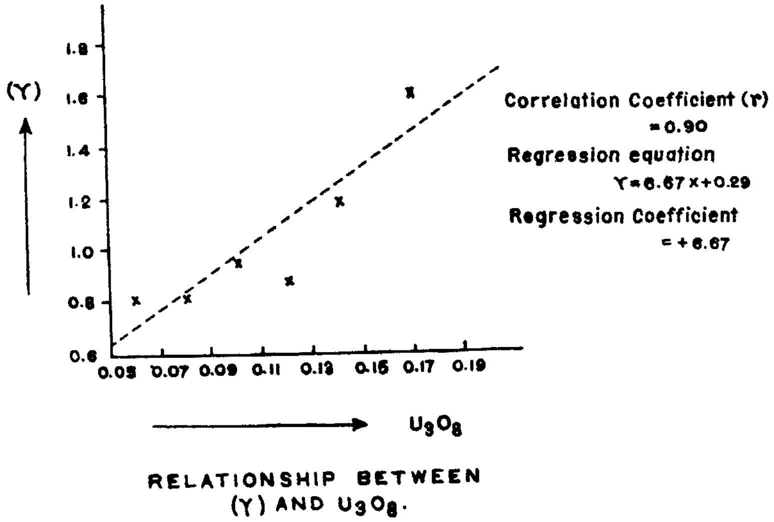
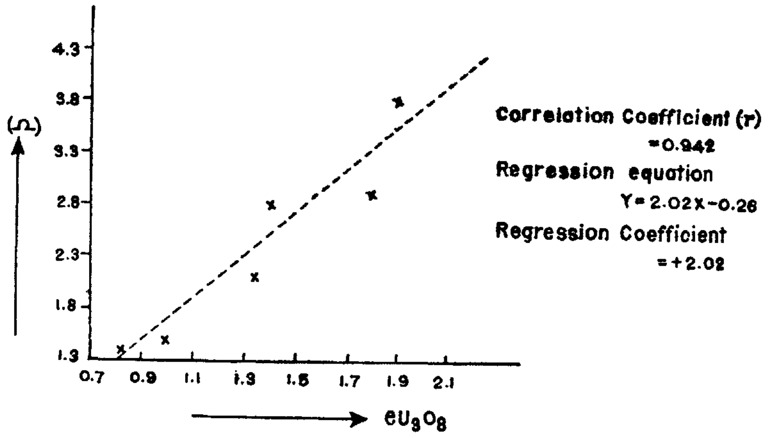
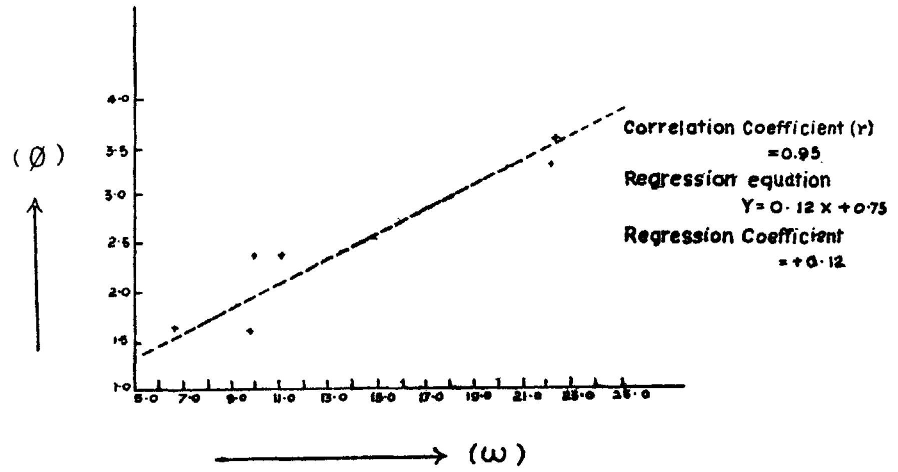


FIG. 2.



RELATIONSHIP BETWEEN
(Ω) and eU_3O_8.

FIG. 3.



RELATIONSHIP BETWEEN
(φ) and (ω)

FIG. 4.

lanthanides (basic) would prefer to crystallize in the acid-basic or less-acid melt while crystallization of the heavy lanthanides and the Yttrium would be favoured in the acidic pegmatitic phase of the fractionated granitic melt. Murata *et al.* (1959) describing the behaviour of Brazilian pegmatites, pointed out that less-basic the lanthanides, the more stable would be the soluble coordination complex it forms and lower will be the concentration of simple cations in equilibrium with the coordination complex. When an increment of phosphate is added to such a solution, the basic rare earths (lighter) that form least stable coordination complex will crystallize early. This has further been substantiated by the work of Lyakhovich and Barinski (1961) and Lyakhovich (1962, 1967) when they have shown notable change in the concentration of Yttrium and La-Lu in the accessory minerals in the sequence from granite to hydrothermal veins. Fleicher (1965) has also shown that monazites from granite-pegmatite are more enriched in heavier lanthanides than those from granite. Wager and Mitchell (1951) have also shown that the Yttrium concentration changes from nil in the chilled marginal gabbro to 270 ppm in the fifth stage of fractionation of basic magma culminating to an acid-alkaline salic melt.

The area of our investigation is mainly represented by the Chota-Nagpur Granite-gneisses with some small veins of pegmatites and mafic intrusives. The granite-gneiss varies texturally from fine to medium to coarse grained.

Petrologically, the granites are essentially composed of micro-perthite, alkaline feldspars (oligoclase and labradorite), biotite and quartz. The graphic intergrowth between quartz-feldspar favour their eutectic crystallization rather than mutual replacement. The intense sericitization of feldspars along their cleavages and along their peripherial boundary and neomorphic growth of biotites favour the existence of partly alkaline melt during the crystallization process.

The Baljora and Kandera nalas are flowing across the granitic terrain and it is believed that the xenotime and monazite carried away by the nalas, are originally derived from the granitic rocks. From the composition of the granitic rocks and from the observations of the other workers around the world, it can be assumed that the granites are the host rocks for the xenotime and monazite and probably the heavier lanthanides and Yttrium have been concentrated during the transition between alkaline and acid melt while the monazite crystallized in a purely alkaline melt during the fractional crystallization.

Conclusion

Vinogradov (1959) and Krauskopf (1967) reported that cerium occurs in nature in greater abundance than Yttrium in lithophile group. The ratio between Ce/Y in rocks has been calculated as 2.6 by Vinogradov (1959), after the compilation of number of available data. Our present studies confirm the contention of earlier workers. The ratio for monazite/xenotime maintains a nearly constant value of 2 in the samples of soil and sand.

While the radioactivity is mainly contributed by monazite and xenotime, yet, the variation in the activity cannot be correlated with the variation of monazite and xenotime per cent. The role played by the opaques, ilmenite, zircon, epidote, zoisite and chlorite to control the radioactivity should not be overlooked.

Acknowledgements

The problem was initiated during the field work at Kunkuri, Raigarh district, while prospecting for radioactive minerals for the Atomic Minerals Division in 1973-74. Thanks are to Mr. N. H. Kulkarni and Mr. J. S. Chimote, Physics Laboratory, A.M.D., Nagpur, for their keen interest in the problem and for taking the trouble of analysing the samples for radiometric assay.

Sincere thanks are also to Mr. D. B. Asthana, Director, Geology and Mining, M.P. Govt., for giving me the petrological laboratory facilities and for his valuable suggestions and to Prof. A. K. Saha, F.N.A., for critically going through the manuscript.

REFERENCES

Favertto, Luciano (1968). Xenotime from the le cave pegmatites, bressanone granite massif, Autes Adige. *Mem. Tridentino Sci., Nature, Studi Trentini Sci., Nature*, Ser. A, **45**, pp. 38–45.

Fleischer, M. (1965). Some aspects of geochemistry of Yttrium and lanthanides. *Geochim cosmochim Acta*, **29**, pp. 755–772.

Graeser, S., Schiwander, H., and Stalder, H. A. (1973). A solid solution series between xenotime ($ytPO_4$) and Cheronovite ($ytAsO_4$). *Miner. Mag.*, **39**, 302, p. 142.

Krauskopf, K.B.(1967). *Introduction to Geochemistry* (International Student Edition).

Krishnan, M.S.(1968). *Geology of India and Burma.* Higginbethams, Madras.

Leonova, V. A., Firyubina, V. V., and Zvarykina, A. V. (1967). Accessory xenotime from Cleupa pegmatite veins and rare element distribution features in them. *Zap. Veses Min. Obshch,* **96**, pp. 117–132.

Lyakhovich, V. V. (1967). Rare earth elements in the accessory minerals of granitoids. *Geochem. USSR, Eng. tr.* pp. 39–55.

Lyakhovich, V. V. (1967). Distribution of rare earths among the accessory minerals of granites. *Geochem. Internal.*, **4**, pp. 691–696.

Lyakhovich, V. V., and Barinskii, R. L. (1969). Characteristics of the rare earth assemblages in the accessory mineral of granitoids. *Geochem. USSR*, English tr., pp. 495–509.

Murata, K. J., Dutra, C. V., and Decosta M. Teixeira (1959). Composition of monazite from pegmatites in Eastern mines, Gerais, Brazil. *Geochem. et Cosmochim. Acta*, **16**, pp. 1–14.

Ringwood, A. E. (1955). The principle governing trace element distribution during magmatic crystallization—Part I: The influence of electronegativity. *Geochim et. cosmochim Acta,* **7**, pp. 189–202.

Vinogradov, A. P. (2959). *The Geochemistry of Rare and Dispersed Chemical Elements in Soil* (2nd edition). Chapman & Hall Ltd., London, pp. 91–94.

Weger, L.R., and Mitchell, R.L.(1951). The distribution of trace elements during strong fractionation of basic magma. *Geochim. et Cosmochim Acta.*, **1**, pp. 129–208.