CHAPTER V

CLASSIFICATION OF RADIOACTIVE MINERAL DEPOSITS

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5:1 Metallogenetic Scheme:

Based on the geometry and formational environment about 20 basic types of uranium occurrences can be distinguised. Out of them 7 are of economic importance (Dahlkamap, 1982). They are shown in Table 8.

The various types of occurrences can be attributed to the following three metallogenic processes:

1. The primary, magmatogenic uranium occurrences formed by endogenic processes.
2. The secondary uranium occurrences which were formed by subsequent exogenic, i.e. sedimentary or supergene processes from the primary type.
3. The Tertiary generation which was formed by endogenic metamorphic processes from the primary as well as secondary uranium occurrences.

The occurrences of uranium and thorium deposits in India is given in Figure 19 and described in Table 9.

5:2 Thorium Deposits of India:

The host rock thorium deposits in India are mainly beach placers near Chavara and Manavalakurichi situated on the SW coast of India and inland placers situated in Ranchi plateau of Bihar and Purulia in West Bengal.

Table 8, Classification of uranium occurrences and deposits

Mode of origin	Host rock/Type of Deposit		Example	
Sedimentary	OLIGOMICTIC CONGLOMERATES		Elliot-Quirke Lake (Canada)	1
			Witwatersrand (S-Africa	2
	Blackshales		Ranstad (Sweden)	1
	Phosphates		Florida (USA)	2
			Cabinda (Angola	2
Effusive	ACID VOLCANICS		Peña Blanca (Mexico)	1
			McDermitt (USA)	1
Intrusive (Intraintrusive)	Peralkaline Syenites		Ilimaussaq (Greenland)	1 + 2
	Carbonatites		Palabora (S-Africa)	2
	ALASKITES		Rössing (SW-Africa)	1
	Pegmatitic Alkali-Granites		Ross Adams (USA) ☘	1
	Granites		Bingham (USA) (Cu-Porphyry)	2
	Pegmatites		Bancroft (Canada) ☘	1
	HYDROTHERMAL VEINS		Schwartzwalder (USA)	1
Contact-metasomatic	Calc-Silicates		Mary Kathleen (Australia)	1
Metamorphic	Phyllites		Forstau (Austria)	1
	Schists		Portugal	1
	VEIN LIKE TYPES	Subtype A	Beaverlodge (Canada Jabiluka (Australia)	1
		Subtype B	Key Lake (Canada)	1
		Subtype C	Massive Central (France)	1
Supergene	SANDSTONES	Subtype A	Grants Mineral Belt (USA)	1
		Subtype B	Wyoming Basins (USA)	1
		Subtype C	Franceville Basin (Gabon)	1
	CALCRETE		Yeelirrie (Australia)	1
	Lignites		N-S Dakota (USA) ☘	1
	Phosphates		Bakouma (ZAR)	1 + 2
	Karst		Bighorn/Wyo. (USA) ☘	1

CAPITAL LETTERS: economic deposits
CAPITAL LETTERS: probably economic deposits
Small letters: subeconomic deposits
Rössing: 1979 in production
☘: former production
1: main-product
2: by-product

(AFTER. F.J. DAHLKAMP 1982)

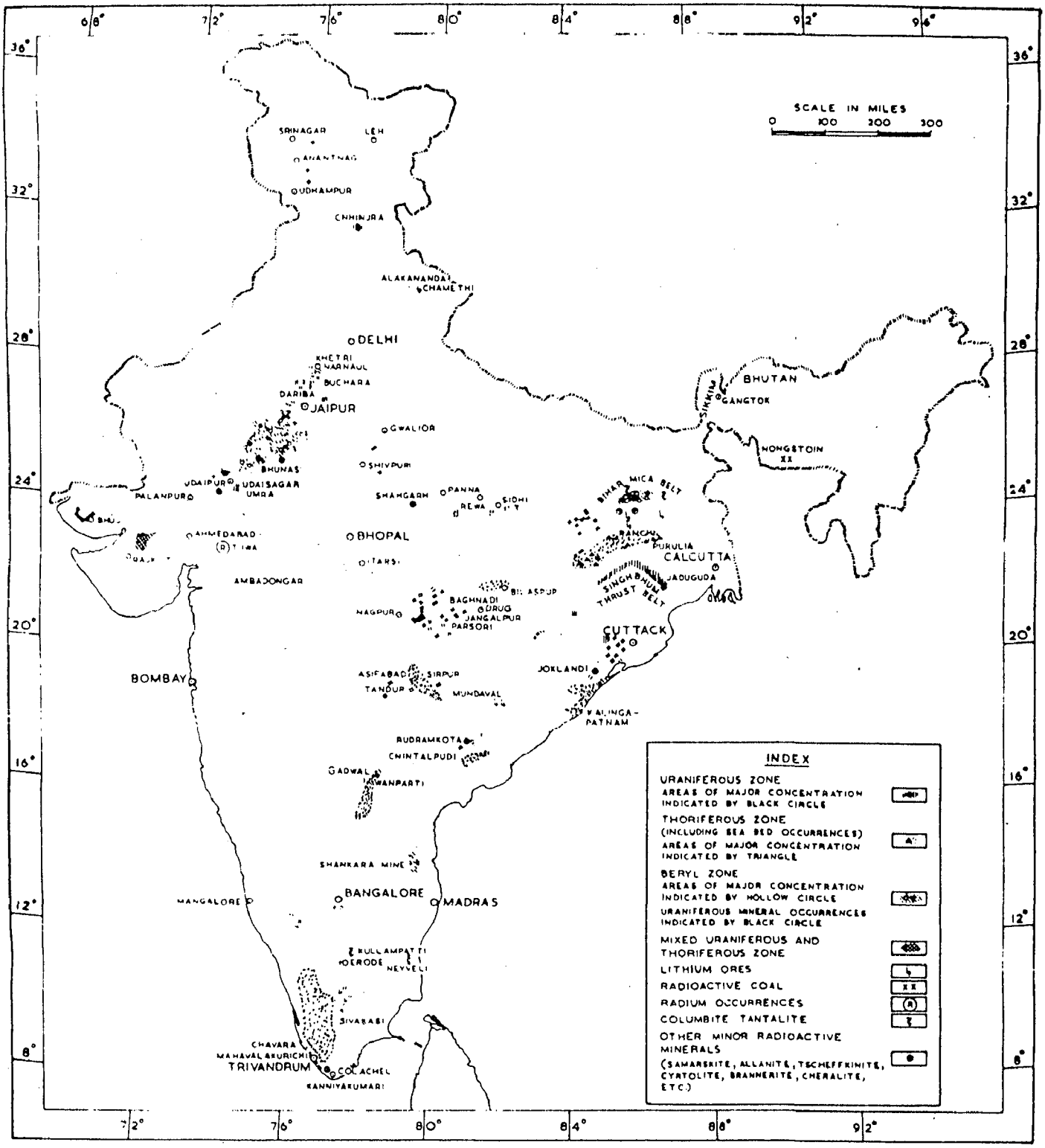

FIG. 19. OCCURRENCES OF ATOMIC MINERALS IN INDIA (AFTER DAR, 1964)

Table 9. Uranium and thorium deposits in India (largely after Bhola, 1968)

S. No.	Host rock	Important deposits in India	Remarks
		Uranium Deposits	
1.	Pegmatites	Pegmatites of Bihar, Rajasthan and Andhra Pradesh. Bhainsi pegmatite, Bhilwara District, Rajasthan, most promising.	Excellent specimens but meagre reserves
2.	Migmatites and aplites	(i) Khandela, Sikar District, Rajasthan—Brannerite in the kaolinised aplite intrusive into the Ajabgarh phyllites and schists (concentrates assay 42.86% U_3O_8), (ii) Kolihan, Rajasthan—Primary davidite and secondary autunite and torbernite (max. grade: 0.33% U_3O_8). (iii) Kullampatti, Salem district, Tamilnadu—Suryamalai granite (0.05% U_3O_8).	Generally low grade; presently uneconomical
3.	Granites	Pink granites of Rajasthan, A.P., Karnataka, Tamilnadu and the Himalayan regions (see Table 4.4 for granites abnormally enriched in U and Th).	-do-
4.	Carbonatites	Amba Dongar, Gujarat—0.005% U_3O_8, 0.06% ThO_2 (Udas, 1971); Pyrochlore (13% U_3O_8 and 0.2% ThO_2) in the Koratti beforsitic carbonatites, Tamilnadu (Borodin *et al.*, 1971).	Carbonatites have excellent potentialities.
5.	Black Shales	Graphitic schists of Kolar (Karnataka), Phyllites of Khandela, Rajasthan, Cumbum shales of A.P. and Kaladgis of Karnataka (0.006—0.023% range); Krols (0.025% U_3O_8), U.P.	Krols may have good potentialities.
6.	Carbonaceous clays and lignites	Carbonaceous clays of Neyveli, Tamilnadu (0.015% e. U_3O_8); Eocene coal of Garo Hills, Assam (0.016—0.08% U_3O_8).	
7.	Phosphatic nodules	Cretaceous formations of Tiruchirapalli District, Tamilnadu—Phosphatic nodules in the Uttattur stage—0.0032% U_3O_8; Phosphorites of Mussorie, U.P. and Jaisalmer, Rajasthan (0.08—0.6% U_3O_8) —extensive reserves.	U content in phosphorites is leachable
8.	Conglomerates	Conglomerates at the base of the Cuddapahs, Aravallis and Alwars.	Radioactivity mostly due to Th.
9.	Sandstones	Upper Jurassic sandstones of Saurashtra and Cutch, Gondwana sandstones of M.P., Godavari valley in Maharashtra and A.P. Arkosic Motur sandstone (Middle Permian) with fossil wood, in Betul area, M.P.	Motur sandstone may have good potentialities.
10.	Hydrothermal deposits	(i) Umra, Udaipur District, Rajasthan—primary uraninite and secondary autunite-torbernite in the Aravalli phyllites and carbonate rocks.	Meagre reserves.

(CONTINUED)

	(ii) Kho Dariba copper Mine, Alwar District Rajasthan; veinlets of pitchblende in Alwars (phyllite, biotite schist and quartzite).	-do-
	(iii) Chinjira, Kulu Dt., H.P.—Sooty pitchblende in the Precambrian Jaunsar (Salkhela) quartzite–0.11% U_3O_8; also in Pat-Pune Sharen Dongri area, Mahasu Dt., H.P. and Chamethi-Pokri-Tunji area, Chamoli Dt., U.P.—Uraninite in the phyllites of Garhwal series (=Jaunsars?)	Excellent prospects; Heap leaching for U has been tried. These areas are relatively inaccessible and have inclement weather.
	(iv) Copper Thrust Belt in the Singhbhum region, Bihar, has three phases of mineralisation—(a) apatite and magnetite, (b) uraninite, (c) chalcopyrites and sulphides. Uranium mineralisation ascribable to the granitic rocks of Singhbhum. Uraninite occurs as disseminations and veinlets in the (i) mylonitised chlorite-sericite schist, (ii) granular rock containing chlorite, quartz, apatite, tourmaline and magnetite (iii) siliceous breccia, (iv) biotite schist, and (v) sheared magnetite-bearing quartzite. Important deposits are: Bhatin (0.07–0.2% U_3O_8), Narwapahar (0.054%), Keruadungri (0.046%). Rajgaon (about 0.05%), Sankadih (0.04–0.1%), Kanyaluka (0.05%). Bagjata (0.05%), (Bhola, 1968).	This is the most important uranium area in India. Jaduguda is the principal uranium mine in India.
	Thorium Deposits in India	
1. Beach placers	Detrital monazite (7.5–10% of ThO_2 and 0.2–0.4% U_3O_8) in the ilmenite-bearing heavy mineral beach sand deposits of Chavara and Manavalakurichi (southwest coast of India). The minerals occur not only on the beach and coastal dunes but also in the bottom sediments of the backwaters ('Kayals'). in the sand bars across the mouths of the rivers. in the river deltas, in the lateritic soils ('Teri') and the inshore sediments, of the southwest coast of India. Less extensive and lesser grade deposits of detrital monazite also occur in the coastal areas of Ganjam (Orissa), Srikakulam, Visakhapatnam, E. Godavari Dts. (A.P.), Ramanathapuram and Tinnavelly Dts. of Tamilnadu, Ratnagiri Dt. of Maharashtra, etc.	The pattern of distribution of heavy mineral beach sand deposits is a consequence of the operation of several factors (Aswathanarayana, 1964). India has 5 m.t. of monazite (Bhola, 1968).
2. Inland placers	Ranchi Plateau (Bihar) and Purulia (W. Bengal).	

Less extensive and lesser grade deposits occur in the coastal areas of Ganjam, Orissa, Srikakulam, Vishakapatnam, East Godavari districts of Andhra Pradesh, Ramanathapuram and Tirunelveli districts of Tamil Nadu and Ratnagiri district of Maharashtra.

5:3 Uranium Deposits of India:

Uranium deposits occur associated with ten host rock types in India. They are:

1. Pegmatites
2. Migmatites and aplites
3. Granites
4. Carbonatites
5. Black shales
6. Carbonaceous clays and lignites
7. Phosphatic nodule
8. Conglomerates
9. Sandstone
10. Hydrothermal deposits.

Out of these Jaduguda uranium mine is located in the copper thrust belt in the Singhbhum region and has three phases of mineralisation.

1. Apatite-magnetite phase
2. Uraninite phase
3. Chalcopyrite and sulphide phase

Uranium mineralisation is ascribed to the granites of Singhbhum. This is the most important uranium area in India containing 0.07 to 0.2% U_3O_8.

The pink granites of Tamil Nadu are abnormally enriched in uranium and thorium. Generally low to medium grade uranium ore deposits occur with migmatites and aplites. Bhola (1968) has classified the Suryamalai granites and gneisses under migmatites and aplites with 0.05% U_3O_8.

5:4 Geochemical-Metallogeny Classification:

Udas (1977) proposed a geochemical-metallogeny model to account for the spatial and temporal distribution of uranium and thorium, lithium, beryllium, niobium and tantalum deposits of the Precambrian in India. It is useful for prospecting strategy for uranium and thorium. It is concluded by Udas that the U-Li, Be-Nb-Ta metallogeny of the Precambrian in India is restricted to middle to late proterozoic (refer Table 10).

It is also regarded that the anatectic granites of Bundelkhand, Dongargarh and Singhbhum in the northern and eastern parts of India offer better prospects for the location of uranium and thorium deposits than the mantle derived from the granites of South India. This is probably a simplistic approach, but it has merits.

Irrespective of whether one accepts the anatectic or mantle-derived origin for the granites in different parts of India, geochemical considerations are consistant with the possibility that some parts of crust in India could be enriched in uranium (Aswathanarayana, 1985).

Table. 10. A geochemical-metallogeny model for rare metals in India (after Udas, 1977)

Date of event	Nature of event	Geological products of the event				
		Southern India	Bihar	Madhya Pradesh	Rajasthan	Nellore (Andhra Pradesh)
Tertiary and Recent	Sedimentation	Monazite placers	Not applicable			
900–1500 m.y. ago	Rare-metallogeny	Inconsequential	U-Th, Li-Be, Nb-Ta in pegmatites	Uranium at Bodal	U-Th, Li-Be, Nb-Ta in pegmatites	Inconsequential
1500–2000 m.y. ago	Rare-metallogeny	Inconsequential	Uranium in Singhbhum	Inconsequential	Uranium in Umra-Udaisagar	U-Th, Li-Be, Nb-Ta in pegmatites
2000–2500 m.y. ago	Regional metamorphism	Metamorphites, migmatites, and anatexites				
2500–3000 m.y. ago	Granitic plutonism	More granitic rocks				
3000–3500 m.y. ago	Komatiitic and basaltic volcanism, and onset of sedimentary cycles	Peridotitic, pyroxenitic, and basaltic komatiites, and basalts, and derivative sedimentary rocks				
3500–4000 m.y. ago	Granitic plutonism	Monazite-bearing granitic rocks	Granitic rocks with uranium, thorium, lithium, beryllium, niobium, and tantalum dispersed in the common rock-forming minerals.			

5:5 Geochemical Province of Precambrian Uranium:

Relatively higher concentration of uranium have been found in numerous belts and they have been deliniated (Fig.20). Out of the 21 belts delineated the Singhbhum uranium province is the most important uranium belt in India (No.1. in Fig.20). In western Karnataka uranium province (No.11 in Fig.20) Walkunji-Yellaki-Arbail and Chikkmagalur belt-uraniferous quartz pebble, conglomerate constitute a prominent strata at the base of metasedimentary metavolcanic sequence overlying the Peninsular gneisses. These are in turn overlain by a succession containing prominent banded iron-formations.

The Pungurthi belt (No.12 in Figure 20) is of high-grade granulite belt, of Coimbatore, Vellore area and are characterised by alkaline complexes, carbonatites and younger anatectic (?) and late-phase pegmatite and quartz reefs (Mahadevan, 1986). Numerous occurrences of uraniferous minerals are known from the pegmatites of this region.

There are number of ages in time band of 1200-1500 m.y. in the granulites mobile belt of South India and Orissa which indicate a long period of continued tectonic, metamorphic and magmatic activity and late thermal events. (Clark and Subba Rao, 1971; Mahadevan, 1986). Table 11 shows the tentative classification of Precambrian uranium mineralisation indicating the infered time bands from the

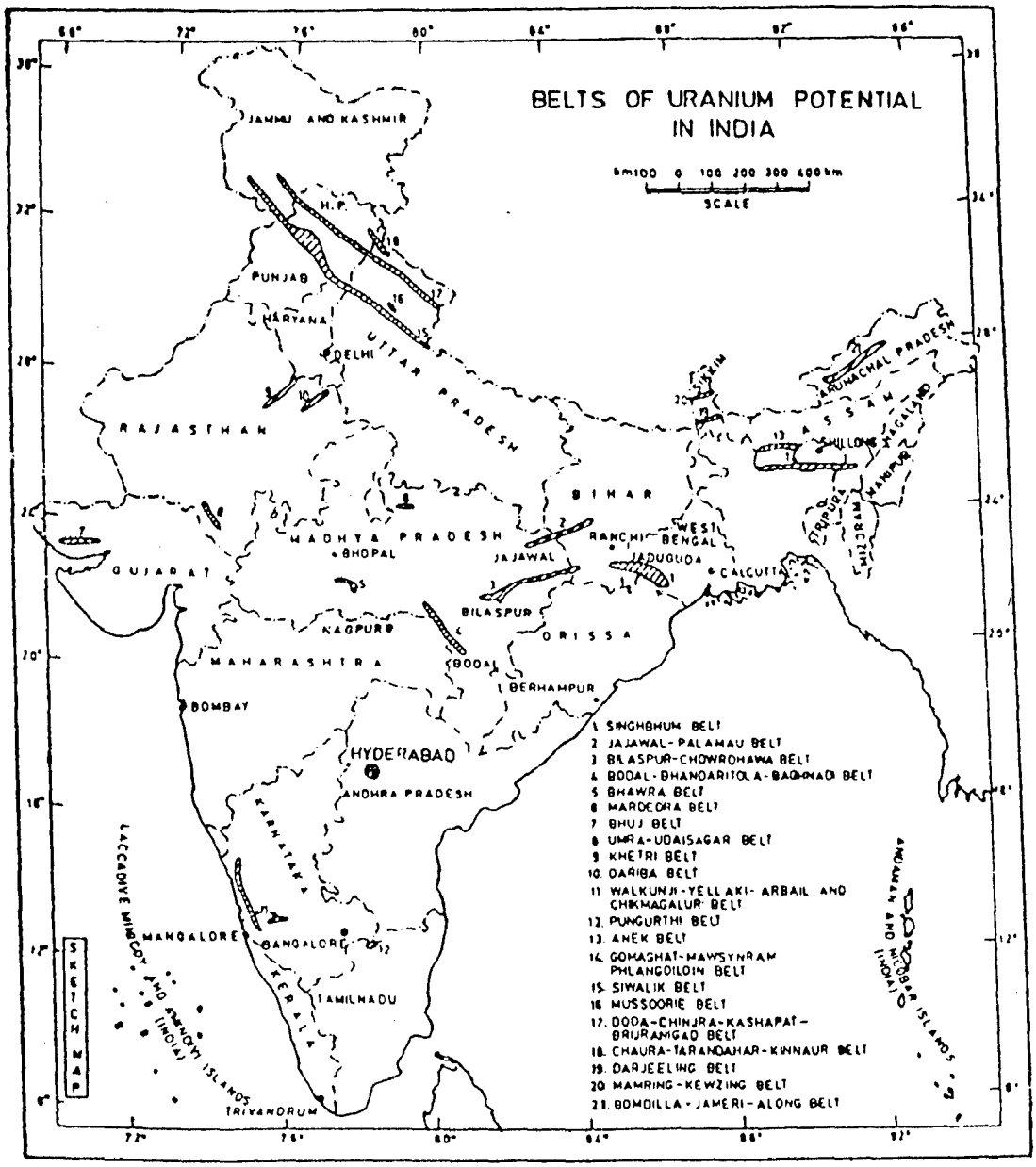

FIG.20. BELTS OF URANIUM POTENTIAL IN INDIA
(AFTER MAHADEVAN 1986.)

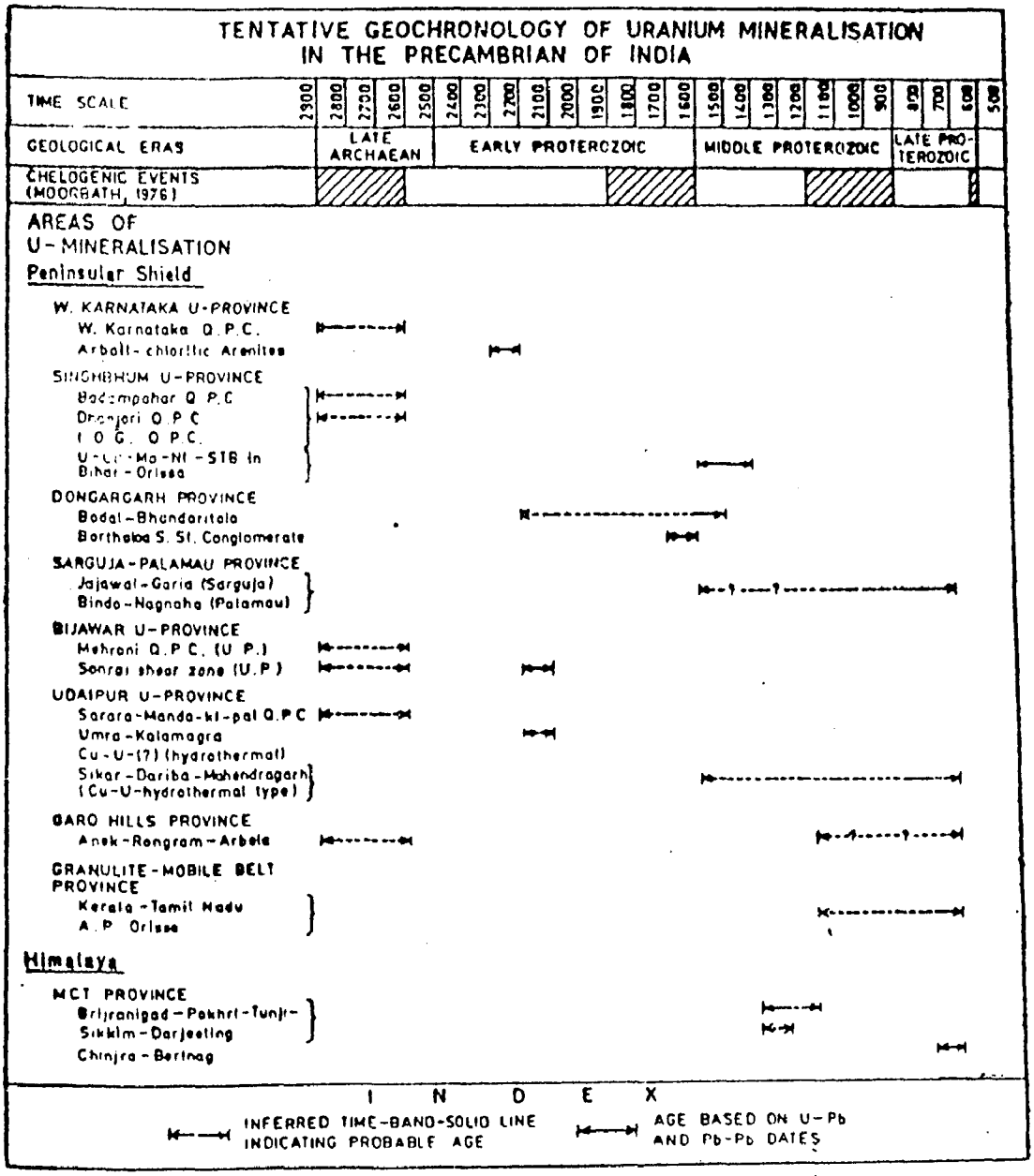

TABLE 11. TENTATIVE GEOCHRONOLOGY OF URANIUM MINERALISATION IN THE PRECAMBRIAN OF INDIA (AFTER MAHADEVAN, 1986.)

existing data. The spatial distribution of uranium mineralisation in Precambrian of India is shown in Table 12.

5:6 Episode of Enrichment of Uranium in India:

The first major episode as envisaged by Moorbath (1976) and Radhakrishna (1983) on enrichment of uranium in the crust is possibly during the early accretion super even around 3000 m.y. which led to the extensive tonalisation of the crust (assuming an original basaltic crust).

Uranium and other LIL elements have been enriched in these but the levels of enrichments are low.

Potassic granites probably emplaced (in the period 3200-2500 m.y.) in the crust either by accretion from the mantle or anatexis or both. This granites represent the second phase and perhaps are the sources of uranium recycled into younger formations.

Dhana Raju et al, (1983) is of the view that characterisation of granitoid into I,S and A types could be helpful in understanding the spatial distribution of uranium mineralisation. Mahadevan (1986) indicate that the search for uranium could be restricted to the younger sedimentary basins which have a provenance in the regions of such younger potassic granitoids.

Many granitoids once believed to be very young intrusives are now regarded as basement granites. Two outstanding examples are the peninsular gneisses of South

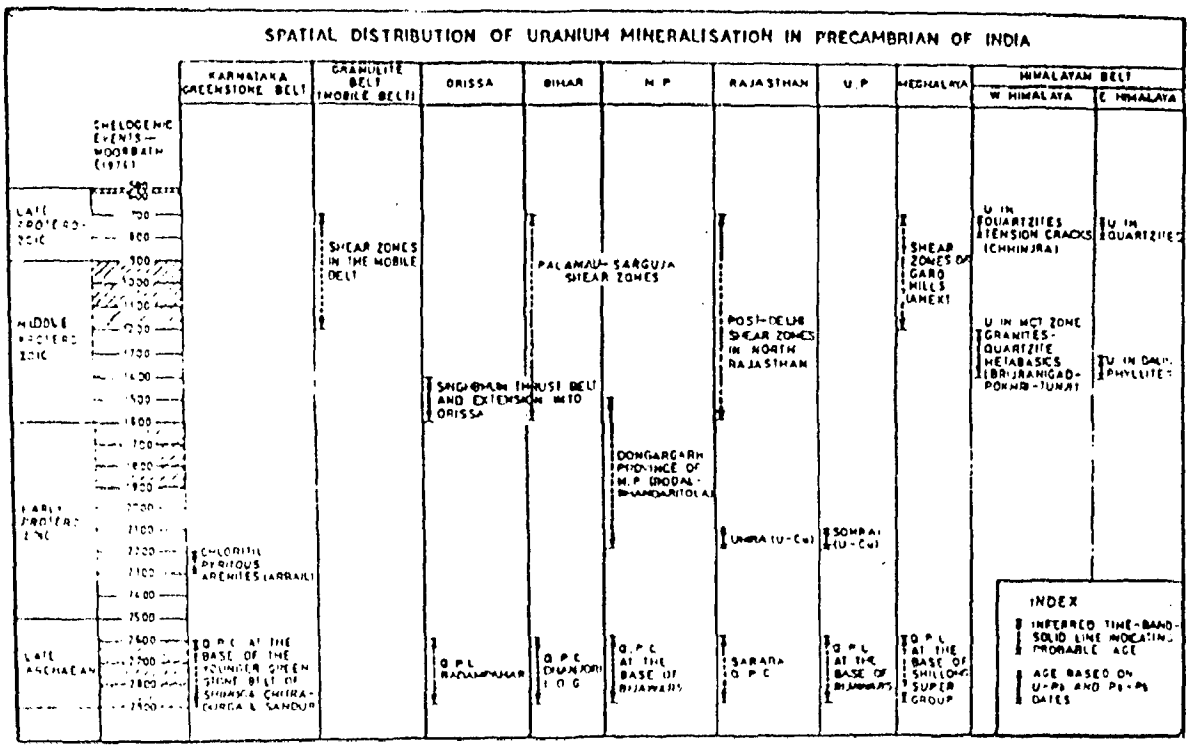

TABLE.12. SPATIAL DISTRIBUTION OF URANIUM MINERALISATION IN PRECAMBRIAN OF INDIA

(AFTER MAHADEVAN, 1986.)

India and the Singhbhum granite of Bihar. The Peninsular gneiss was earlier considered as a late intrusive into the Dharwars and even the charnockites. Now, they are considered as the basement for a major part of Dharwars.

5:7 Diachronous Evolution of Peninsular India:

The diachronous evolution of many parts of Peninsular shield has led to the juxtaposition of high grade mobile belts with cratonised green-schist belts, a feature clearly seen in the southern part of the shield. This distinction is less evident in the east and central part of the shield. The depletion of uranium in the granulite and high-grade metamorphic terrain and the occurrence of most of the uranium deposits in rocks of green-schist and amphibolite facies point to the mobilisation of uranium during metamorphic processes (Heier, 1979).

5:8 Shear Zones:

Shear zones across high grade metamorphic belts are known as intra-mobile belts. Such a belt occurs along Coimbatore-Salem-Vellore lineament (Figure 21). Epigenetic 'vein-type' or disseminated 'hydrothermal' uranium mineralisation is confined to such shear zones.

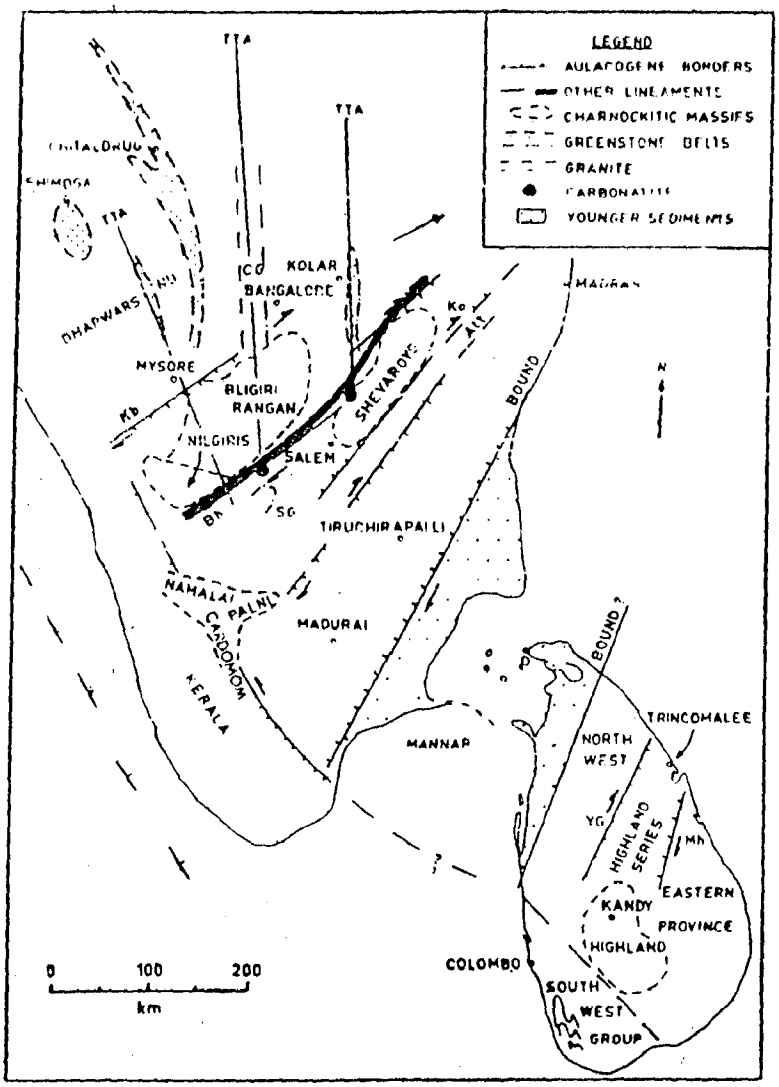

FIG. 21. Aulacogenes of South India - Sri Lanka. The northeast trending Highland Series, Madurai and Salem aulacogenes and the northwest Kerala aulacogene and their boundary lineaments (Mh-Mahaveli River lineament, YG-Yan Ganga lineament, Bound-Boundary lineament, Att-Attur lineament, Ko-Kotapatti fault, Bh-Bhavani lineament, Kb-Kabbani lineament). Dextral transform movement along these bounding lineaments converted the aulacogenes into mobile belts. Charnockite formation was localized along en echelon lineaments and lineament intersections. Major transform movement in the mobile belt caused tensional conditions in the Dharwar craton causing rifting, spreading and emplacement of oceanic crust, the precursors of the greenstones. Tensional thermal axes (TTA) in the mobile belts coincide with greenstone belts (Nuggihalli-NU, Kolar) or granites (Closepet granite-CG) in the craton and granites within the mobile belt (Sankari granite-SG). Intersection of the TTA with the Bhavani lineament (Bh) are loci of carbonatites. Tectonic compilation based on Landsat-1 imagery. Scale 1 : 4,000,000 (after Katz, 1976c).