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CHEMICAL AGES AND MOBILITY OF U AND Th IN ANATECTITES OF THE CREE LAKE ZONE, SASKATCHEWAN

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Abstract

Microprobe analyses have been carried out, and chemical ages determined, on the radioactive phases in anatectites from five localities in the Cree Lake zone (Saskatchewan). In addition, bulk analyses for U, Th and Pb were completed on over 150 samples of the anatectites and their host rocks. Exclusive of zircon and monazite, the U- and Th-bearing phases range from old "uraninite" through various unnamed U–Th silicates to young "uranophane", "coffinite" and "kasolite". Only one rare phase, a U–Fe silicate, was encountered; the only known analog occurs in Styria (Austria). Chemical ages range from 1.9 to <0.1 Ga and bulk values from 23 to 413 ppm U, 10 to 285 ppm Th and 26 to 144 ppm Pb. Both the petrographic data and the inferred ages indicate that extensive mobilization of the radioactive phases has occurred, either continuously or episodically. The mobility, however, was restricted to the interior of the anatectite bodies, which behaved essentially as closed systems. The oldest chemical ages are in close agreement with geological estimates of the timing of anatectite formation.

Keywords: anatectites, U, Th, Pb, mobility, microprobe data, chemical ages, Cree Lake zone, Saskatchewan.

Sommaire

On a analysé à la microsonde électronique les phases radioactives des anatexites de la zone du lac Cri (Saskatchewan), échantillonnées à cinq endroits, et on a déterminé leur âge chimique. De plus, on a analysé 150 échantillons des anatexites et de leurs roches-mères pour y doser uranium, thorium et plomb. Sans compter le zircon et la monazite, les phases uranifères et thorifères passent de l'uraninite ancienne, par divers silicates sans nom de U et Th pour arriver, tardivement, à uranophane, coffinite et kasolite. On n'a décelé qu'une seule espèce rare, silicate d'uranium et de fer, dont le seul analogue est connu en Styrie (Autriche). Les âges chimiques vont de 1.9 à moins de 0.1 Ga, et les roches globales contiennent de 23 à 413 ppm U, 10 à 285 ppm Th et 26 à 144 ppm Pb. Les observations pétrographiques et les âges calculés font penser que les phases radioactives ont été soumises à une vaste mobilisation, continue ou épisodique. Toutefois, les anatexites se sont comportées en systèmes pratiquement fermés pendant cette remobilisation. Les âges chimiques les plus anciens concordent bien avec l'âge estimé de la formation des anatexites, d'après les critères géologiques.

Mots-clés: anatexites, U, Th, Pb, mobilisation, microsonde, âges chimiques, lac Cri (Saskatchewan).

Introduction

Radioactive anatectites abound in the Cree Lake Zone of Saskatchewan; however, no description of the radioactive phases has been published. This paper presents data on the various phases present in samples taken from five different localities (Fig. 1) and on the extent of remobilization of U and Th since the formation of the anatectites.

Methods of study

Thomas (1983) tentatively identified uraninite crystals in thin section. Although these crystals are euhedral, subsequent XRD analyses proved that all are metamict. Consequently, for the present work the phases were studied using an automated ARL–SEMQ electron microprobe. The operating conditions were as follows: 15 kV and 15 nA, with a 102-μm beam and on-line drift correction and data-reduction programs following the Bence & Albee (1968) method. Chemically analyzed standard minerals were used; in particular, for the main elements of interest, we used uraninite (U), thorite (Th) and vanadinite (Pb). For chemically homogeneous phases, multiple analyses were carried out across grains; in these cases the major components U, Th and Pb have standard errors (based on comparative chemical analyses of the same material) of 0.5, 1.5 and 0.7%, respectively. In the case of complex het-

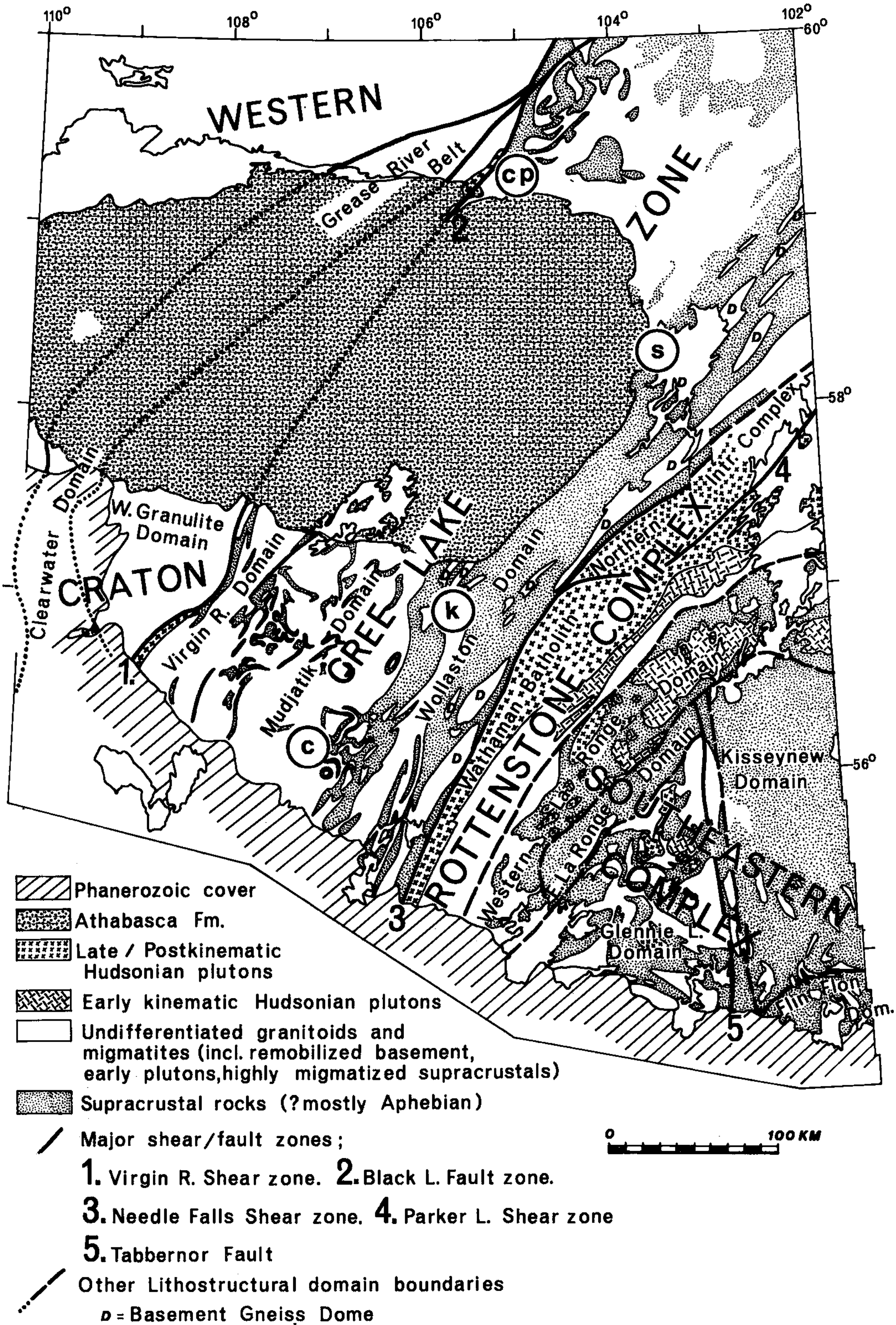

FIG. 1. Lithostructural domains in Churchill Province in Saskatchewan (after Lewry & Sibbald 1978). Localities of samples used in the present study are marked: cp Charlebois Lake and Pluto Bay, s Spurjack Island, k Karin Lake, c Cup Lake.

erogeneous phases, fewer analyses were performed, and error estimates (also based on comparative chemical analyses of the same material) rise to as high as 10% for major components. Where chemical data and derived structural formulae suggest a particular mineral, the name is given in quotes (*i.e.*, "uraninite"); nonstoichiometric phases are given a general name based on their major components (*i.e.*, U-silicate).

Analyses of bulk samples of the anatectites and host rocks were carried out using neutron-activation analysis for U and Th and atomic-absorption spectrophotometry for Pb. The standard errors are estimated to be 2% for U and Th, 5% for Pb.

Chemical ages were determined from the standard decay-equations for U and Th using an iteration technique (computer program available from G. Kurat) to apportion the Pb between the U and Th equations. The formulae have the following form:

$$3.323*4.5*10^9(\log[1 + \tfrac{x}{U}]) = t = 3.323*14*10^9(\log[1 + \tfrac{Pb-x}{Th}])$$

where U, Th, Pb, x are expressed in either molecular or atomic proportions and iteration is carried out with increasing values of x until both equations yield the same age t. The rationale and validity of these calculations are discussed later in the text.

Geological, Petrographic and Compositional Data

The Cree Lake Zone in Saskatchewan is a NE–SW-trending belt of high-grade granitic and supracrustal rocks. To the west it is separated from the Western Craton by the Black Lake – Virgin River shear zone and to the east from the Rottenstone and Southeastern complexes by the Needle Falls shear zone (Fig. 1). Briefly, the interpretation of the geology of northern Saskatchewan by Lewry (1981) and Lewry & Sibbald (1978, 1980) is as follows: the Western Craton consists of deep crustal rocks of probable Archean age that enclose scattered remnants of Aphebian supracrustal rocks. The Cree Lake Zone is composed of both Archean (?) granitic rocks (to the west) and Aphebian shelf to miogeoclinal cover rocks (to the east). This assemblage was extensively reworked and interfolded during the Hudsonian orogeny and was subjected to anatexis at a granulite-facies metamorphic grade. The Rottenstone Complex is a major zone of Hudsonian batholithic intrusive bodies, and the Southeastern Complex comprises eugeoclinal and volcanic rocks of Aphebian age; the volcanic component is genetically associated with the Hudsonian event, probably as island-arc complexes (Coombe 1979, Watters 1981).

Evidence of anatexis is common in the Cree Lake zone. Anomalous radioactivity is ubiquitous; of the more than 100 documented radioactive occurrences in the Cree Lake zone, the vast majority are hosted by anatectites. Earlier investigators (Thomas 1983, Parslow & Thomas 1982) described the geological and petrographic characteristics of some of the larger areas of "pegmatites". Since the textures are commonly granitic and only locally pegmatitic, the term *anatectite* is now used to describe these rocks. However, this term must be interpreted broadly to include such rocks as silexites and mafic pegmatites (associated with calc-silicate rocks) that, on field evidence, are spatially related to the much more dominant felsic partial-melt material. The silexites suggest some process of volatile transfer of silica, but the exact mode of formation of the much rarer mafic pegmatites is enigmatic; these rocks are called anatectites because of their intimate association with demonstrably anatectic material.

In situ melting is inferred from the following field relationships: the "pegmatites" are generally stratabound, contact-metamorphic phenomena are absent, many bodies have mafic selvedges, their form is nondilational, and their textures are igneous (Thomas 1983). In additon, the mineralogy of the felsic bodies is compatible with partial melting of the country rocks observed (Parslow & Thomas 1982). That other processes than pure anatexis were involved is observed from the somewhat limited evidence indicating metamorphic differentiation, metasomatism, and melt migration. *In solidus* metamorphic differentiation is inferred from the preservation of S_0/S_1 fabrics in narrow veins or laminae of quartz and feldspar; evidence of metasomatism is seen in the coexistence of fresh, undeformed K-feldspar with altered and deformed feldspar; melt migration and injection of material are suggested by dilation of pre-existing foliations and occasional chilled margins. Geological and radiometric (Bell 1981) evidence dates this complex anatectic event as Hudsonian, with a minimum age of 1.75 Ga.

Karin Lake area

The region has been prospected for radioactive minerals since 1969. The local structure is that of a NE–SW-trending dome of Archean granite gneiss conformably enveloped by Aphebian metasedimentary rocks. The zones of anomalous radioactivity are concentrated in the basal assemblage of Aphebian graphitic pelites. Sample 72a is a tonalite (Qtz 29%, Kfs 5%, Pl 46% and Bt 20%) with extensively altered plagioclase and biotite books up to 2 cm in size. In thin section, molybdenite and possible uraninite occur in association with biotite. Electron-microprobe studies indicate the presence of numerous essentially unaltered grains of "uraninite", some secondary U–Th silicates and occasional "coffinite".

TABLE 1. CHEMICAL COMPOSITION OF SAMPLE FROM KARIN LAKE*

Sample #					72a				
Phase	A	B**	C	C	C	C	D	D	D
# anal.	10	3	1	1	1	1	1	1	1
T/S #	5	6	4/12	4/14	4/16	4/13	4/3	4/22	4/23
SiO_2	0.09	1.71	7.2	6.8	6.8	6.6	13.1	11.4	14.6
TiO_2	0.03	-	0.10	0.10	0.14	0.07	0.10	0.08	0.12
UO_2	66.7	0.45	50.8	55.2	57.5	54.0	55.2	59.8	54.7
ThO_2	7.3	14.3	16.6	15.4	13.4	16.0	3.3	6.0	3.2
V_2O_3	-	-	0.09	-	-	-	0.10	0.05	-
FeO	0.05	0.02	0.42	0.40	0.57	0.29	0.64	0.54	0.59
MgO	-	0.02	0.02	0.03	0.06	0.03	0.08	0.05	0.14
CaO	0.22	1.12	0.57	0.65	0.62	0.80	1.32	1.37	1.31
BaO	-	-	-	-	-	-	-	-	-
PbO	19.7	1.32	11.7	8.90	7.20	6.10	3.40	2.25	0.60
Na_2O	0.11	0.10	0.02	0.03	-	-	-	-	-
Total	94.20	19.04	87.52	87.51	86.29	83.89	77.24	81.54	75.26
Chemical Age (Ma)	1930	1888	1466	1071	857	764	458	280	84

*Analyses are averaged according to stepwise microprobe analyses on a single grain listed as # anal. Phases present are A) uraninite, B) monazite, C) U-Th silicate, D) coffinite, E) Th-U silicate, F) U-Fe silicate, G) uranophane, H) U-Ca silicate, I) kasolite, J) U silicate, K) zircon, L) Th-Fe silicate, M) U-Th oxide. This information applies to Table 1 through 4.

** Ce 27.3% P 26.4%

Typical compositions are shown in Table 1. Figure 2 illustrates the homogeneous nature of a "uraninite" grain; the sample contains the best-preserved "uraninite" that we encountered.

Cup Lake area

Explored for radioactive mineralization between 1953 and 1969, this area is very similar to the previous one in that the supposed Archean–Aphebian contact is exposed. However, both felsic and mafic "pegmatites" are present. Sample 374b is from a silexite (Qtz 98%, Kfs 1%, Bt 1%) occurring in the graphitic pelites directly above the Archean basement. A thin-section study did not reveal any obvious primary uraninite. A microprobe investigation indicates that the

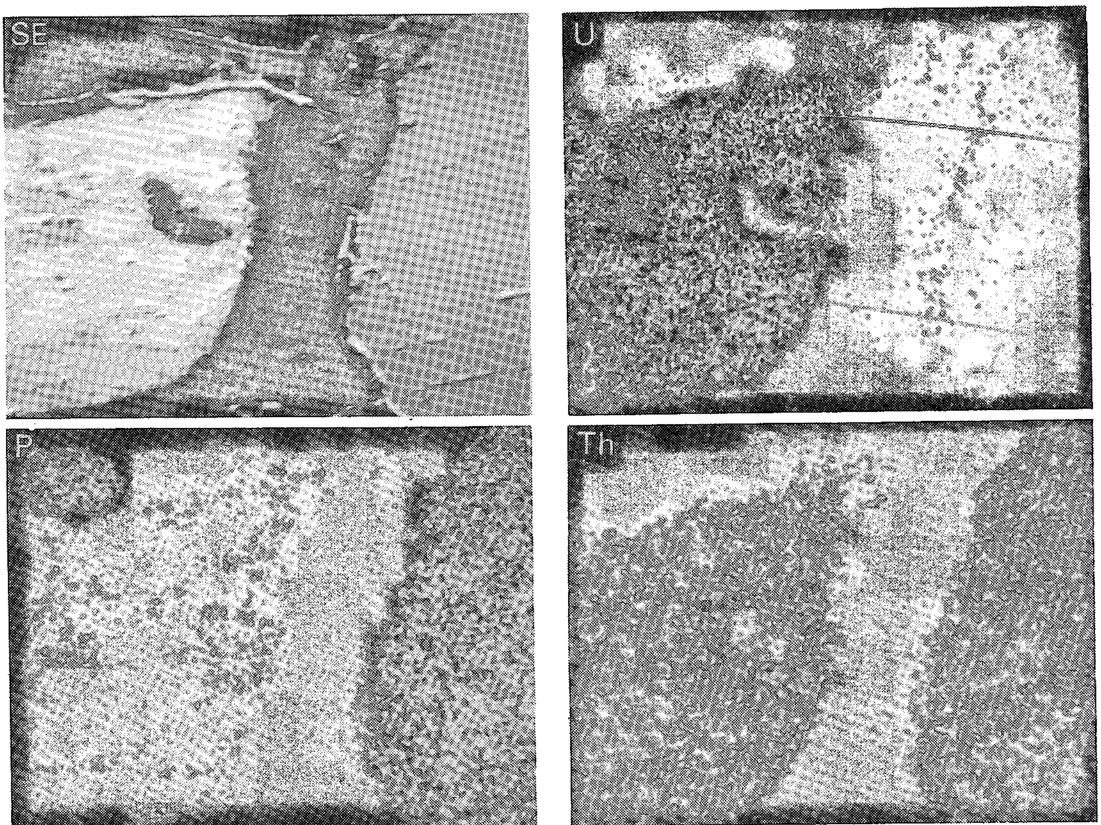

FIG. 2. Secondary-electron (SE), uranium (U), phosphorus (P) and thorium (Th) images of an unaltered "uraninite" (lower grain) and a monazite crystal (upper grain) in Karin Lake sample 72a. Width of field of view: 225 μm.

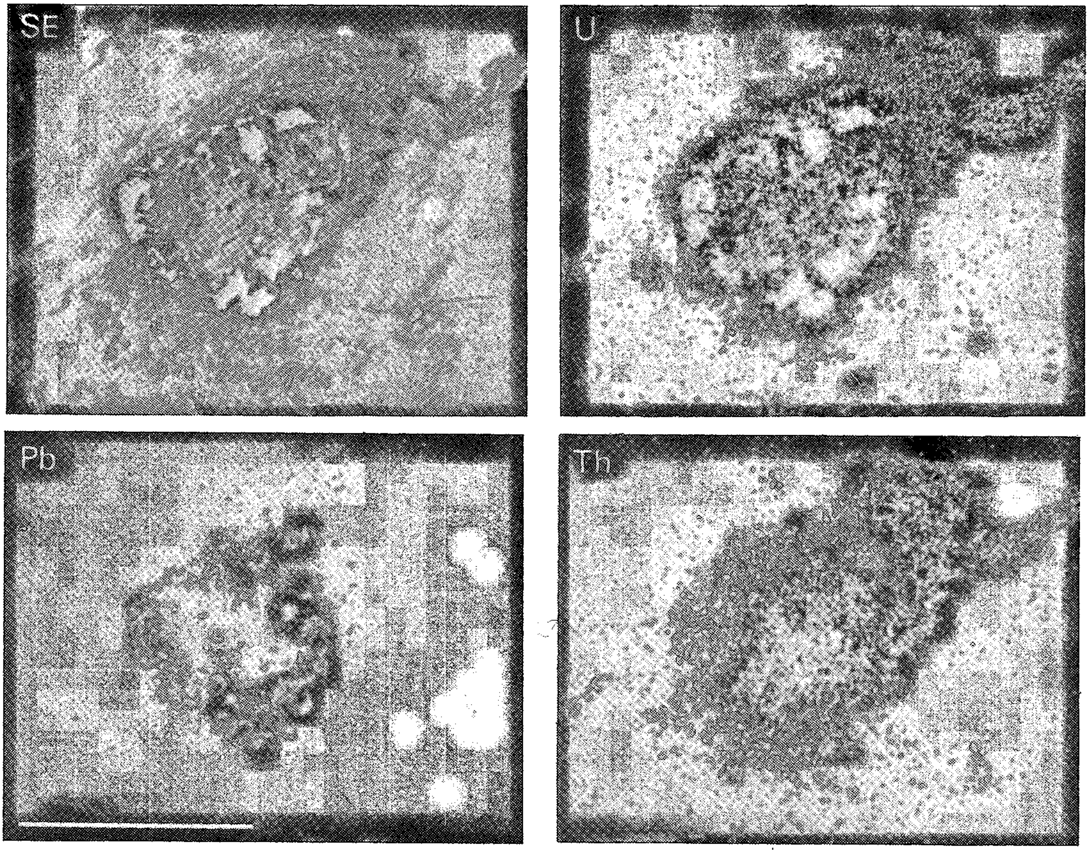

FIG. 3. Secondary-electron (SE), uranium (U), lead (Pb) and thorium (Th) images of a relict "uraninite" in a biotite in sample 374b from Cup Lake. The "uraninite" is the light-colored material on the SE image surrounded by darker Th–U silicates. Scale bar 100 μm.

common radioactive phases are U–Th silicates complexly intergrown with the biotite. Only one area (Fig. 3) within a biotite grain shows traces of a relict "uraninite" preserved in a mass of diffuse Th–U silicate material. The composition of typical phases is shown in Table 2. Of interest is the Fe–U silicate

TABLE 2. CHEMICAL COMPOSITION OF SAMPLE FROM CUP LAKE (374b) AND LENZ IM KALTENEGG (AUSTRIA) WITH CATION PROPORTIONS FOR PHASE F

Sample #	374b				Lenz im Kaltenegg		Cations per 24 O 374b	Lenz im Kaltenegg	
Phase	A	E	F	G	F	F	F	F	F
# anal.	1	6	4	3	7	4	-	-	-
T/S #	A/6	A	B	B	17/C	17/C	-	-	-
SiO_2	0.07	23.2	9.9	12.8	12.4	12.8	3.00	4.08	3.93
TiO_2	0.14	0.60	0.08	0.14	-	-	0.018	-	-
UO_2	61.0	15.4	13.8	64.8	21.8	24.5	0.931	1.595	1.676
ThO_2	8.0	28.3	-	-	0.83	0.06	-	0.062	0.004
V_2O_3	0.04	0.08	0.04	0.04	-	-	0.010	-	-
FeO	0.69	2.99	60.7	1.37	44.9	49.0	15.383	12.344	12.595
MgO	0.06	0.85	0.13	0.35	0.04	0.02	0.059	0.020	0.009
CaO	0.05	0.87	0.27	5.2	0.07	0.05	0.088	0.025	0.016
BaO	-	0.02	-	0.05	-	-	-	-	-
PbO	17.6	1.30	6.7	0.07	1.46	1.73	0.547	0.129	0.143
Na_2O	0.05	0.12	0.04	0.09	0.05	0.03	0.024	0.032	0.018
Total	87.70	73.73	91.66	84.91	81.55	88.19	20.060	18.283	18.395
Chemical Age (Ma)	1880	403	3001	8	500	532			
Radiometric Age (Ma)		1750			240				

Phases as listed in the legend in Table 1.

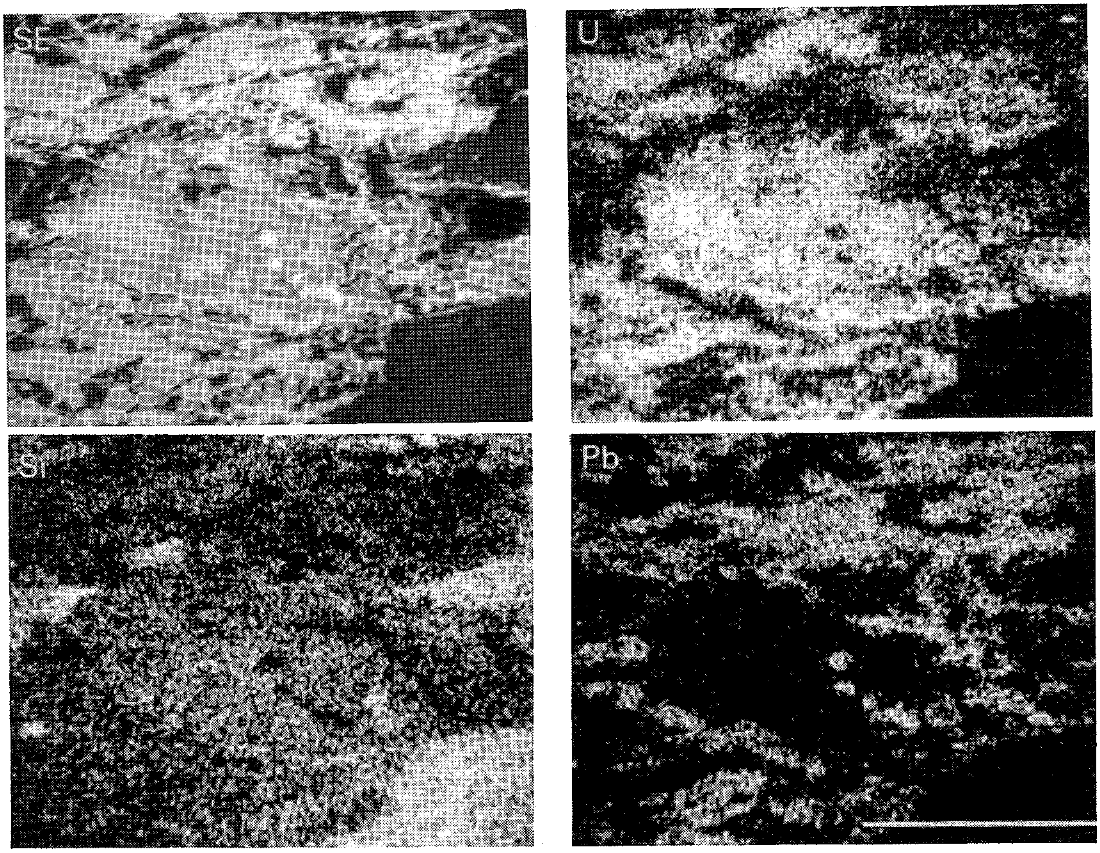

FIG. 4. Secondary-electron (SE), uranium (U), silicon (Si) and lead (Pb) images of extensively remobilized radioactive phases in a calc-silicate anatectite (sample 1010c) from the Spurjack Island area. Scale bar 100 μm.

phase found in conjunction with pyrite; the only similar material known comes from Lenz im Kaltenegg, Austria. Both samples of the Fe–U silicate have chemical ages markedly higher (by up to a factor of two) than the assumed (or known) age of the host rocks. No other samples from the present survey show such high ages. Both Koeppel (1968) and Rimsaite (1978) also observed that the oldest radiometric ages in the Beaverlodge and Rabbit Lake areas tend to be found in U minerals (pitchblende) closely associated with iron-rich phases (such as pyrite and hematite). Although the evidence is fragmentary, the data suggest that Fe stabilizes, or prevents, later remobilization of the radioactive phases.

Spurjack Island area

Situated in the northern part of Wollaston Lake, the island was prospected for U between 1968 and 1973. The antiformal structure exposes only supracrustal rocks, pelites and calc-silicates of Aphebian age. Anatexis of the calc-silicate material has produced a number of mafic pegmatitic bodies. Sample 1010C is a hornblende–diopside–scapolite rock containing molybdenite; it has a yellow U stain on weathered joint-surfaces. Microprobe studies show that extensive remobilization of U has taken place pervasively along grain boundaries and cleavages of diopside and hornblende (Fig. 4). The phases are extremely variable and generally nonstoichiometric (in terms of known U and Th minerals), although some approximate the composition of "uranophane" and "kasolite". Typical compositions are shown in Table 3.

Pluto Bay area

This area, on the north shore of Black Lake, was prospected for U between 1949 and 1967. The basin-like structure has a similar stratigraphy to that observed at Charlebois Lake (following section): calc-silicate and pelite assemblages overlie granitic gneisses of the presumed basement-complex. Radioactivity is restricted to anatectites within the basement gneisses, and only molybdenite is found in similar rocks in the overlying supracrustal rocks. Sample

796a has the composition of a monzogranite (Qtz 53%, Kfs 24%, Pl 22% and Bt 1%). In thin section, crystals (< 0.25 mm) apparently of uraninite are observed mainly in the biotite and occasionally within feldspar and along grain boundaries. Zircon and monazite are common. Microprobe studies illustrate the presence of "uraninite" (similar to the Karin Lake material) with variable Th and Pb content. Alteration in the form of U silicates is minor and restricted to fractures in "uraninite" and small grains of zircon. Two types of zircon are present: small Th- and U-rich grains and large, Th-free and U-poor grains. Typical compositions are shown in Table 3.

TABLE 3. CHEMICAL COMPOSITION OF SAMPLES FROM PLUTO BAY (796a) AND SPURJACK ISLAND (1010c)

Sample #	796a						1010c		
Phase	A			J	K		G	H	I
# anal.	4	9	7	1	3	2	4	4	9
T/S #	B/3	B/2	B/3	B/4	B/1	B/3	1	5	2
SiO_2	0.45	0.37	0.28	21.0	33.2	33.2	13.1	18.5	11.1
TiO_2	0.05	0.03	0.03	0.33	-	-	0.03	0.02	0.05
UO_2	67.5	66.6	62.3	66.6	0.12	2.13	72.3	46.3	46.2
ThO_2	11.0	9.1	8.2	0.06	-	12.3	-	0.02	-
V_2O_3	0.04	-	-	-	-	-	0.03	0.05	0.05
FeO	0.43	0.24	0.07	0.03	1.38	4.7	0.10	3.2	0.41
MgO	0.05	0.02	0.02	0.18	-	0.13	0.05	0.27	0.03
CaO	2.04	1.72	0.33	1.89	2.18	1.84	6.0	4.1	0.24
BaO	0.03	0.03	0.02	0.04	0.05	-	0.06	0.02	0.03
PbO	8.9	11.9	18.0	0.58	0.12	0.67	-	0.11	37.5
Na_2O	0.37	0.36	0.23	0.16	0.07	-	0.20	0.44	0.20
Total	98.86	90.37	89.48	90.71	37.12	54.97	91.87	73.03	95.81
Chemical Age (Ma)	917	1224	1883	68	-	818	-	19	-

Phases as listed in the legend in Table 1.

TABLE 4. CHEMICAL COMPOSITION OF SAMPLES FROM CHARLEBOIS LAKE

Sample #	682C			730b		
Phase	A		C	M	E	G
# anal.	11	1	1	8	4	6
T/S #	A+B	A/3	A/1	1-3	1-3	1-3
SiO_2	18.1	17.4	18.6	1.14	13.7	13.9
TiO_2	0.04	0.04	0.08	0.55	0.46	0.11
UO_2	7.9	16.7	55.1	34.6	7.4	65.1
ThO_2	55.6	50.8	14.2	11.1	53.6	-
V_2O_3	0.04	0.05	0.03	0.03	0.08	0.02
FeO	8.7	8.9	2.31	1.92	2.04	1.08
MgO	0.12	0.10	0.09	0.38	0.23	0.26
CaO	0.85	1.27	0.79	2.41	2.95	5.5
BaO	0.13	0.15	0.11	-	-	-
PbO	0.49	0.35	0.14	5.0	0.62	-
Na_2O	-	-	-	0.30	0.22	0.23
Total	91.97	95.76	91.45	57.43	81.30	86.20
Chemical Age (Ma)	145	82	18	957	192	0

Phases as listed in the legend in Table 1.

Charlebois Lake area

Two samples were studied (682c and 730b), from the Cathy and Bell showings; these showings were discovered in 1949 and have been prospected through 1976. Approximately 17 major "pegmatite" prospects occur in the area around Charlebois Lake; most lie within migmatized and remobilized pelitic assemblages overlying granitic gneisses. Structural evidence suggests that the former are Aphebian and the latter Archean, separated by an unconformity. There are at least four distinct "anatexis-related" phases, varying from granodiorite–tonalite through granite to silexite in composition, and from concordant through subconcordant to cross-cutting in form. Although irregularly distributed, the radioactivity is apparently concentrated in either granodiorite-tonalite or later silexite phases.

Sample 682c is a silexite (Qtz 82%, Kfs 2%, Bt 16%) containing large books of biotite (> 1 cm) and quartz grains (~ 0.5 cm) with sutured grain-boundaries. Some molybdenite is present. The radioactivity is associated with small euhedral crystals (0.1 – 0.2 mm) within the biotite. Microprobe analyses reveal that these euhedra are (unnamed) Th–Fe and U–Th silicates. The presence of discrete crystals of galena and of zonation in U from < 10% to > 30% from the centre to the rim of grains suggests extensive mobility of U and Pb. Typical compositions are given in Table 4.

Sample 730b is a monzogranite (Qtz 37%, Kfs 29%, Pl 22% and Bt 12%) containing large books of biotite (~ 1.5 cm) and displaying yellow staining on outcrop surfaces. In thin section the radioactivity can be traced to grains within biotite that were tentatively identified as uraninite. Microprobe data indicate that these grains consist of various complex fine-grained intergrowths of U–Th oxides and silicates. In addition, "uranophane" occurs both associated with the oxides and extending significant distances along cleavages and cracks in the biotite. Typical compositions are given in Table 4.

The Charlebois Lake samples suggest that any primary mineralization has been replaced by U–Th-rich phases and affected by a general remobilization of parent and daughter elements.

Discussion of Results

In all the samples and areas studied, the main zones of radioactivity occur proximally with respect to the Aphebian–Archean unconformity. The microprobe data clearly show that the primary U–Th mineralization, a result of the anatectic processes, has been extensively modified, as exemplified by the common occurrence of various radioactive silicates like "uranophane' and "coffinite" along cleavages and fractures. The presence of nonstoichiometric, metamict minerals and of segregations of galena further validates the view that, with the exception of some grains of "uraninite", none of the phases can be considered to have behaved as a closed system.

The extreme range of the chemical ages (0–1.9 Ga), illustrated in histogram form in Figure 5, is also indicative of element mobility, in particular Pb loss or U–Pb redistribution. Normally, chemical ages are too high, owing to the fact that a) all the Pb is considered to be radiogenic, b) ^{235}U (as a source of Pb) is ignored because its effect, even in the late Archean

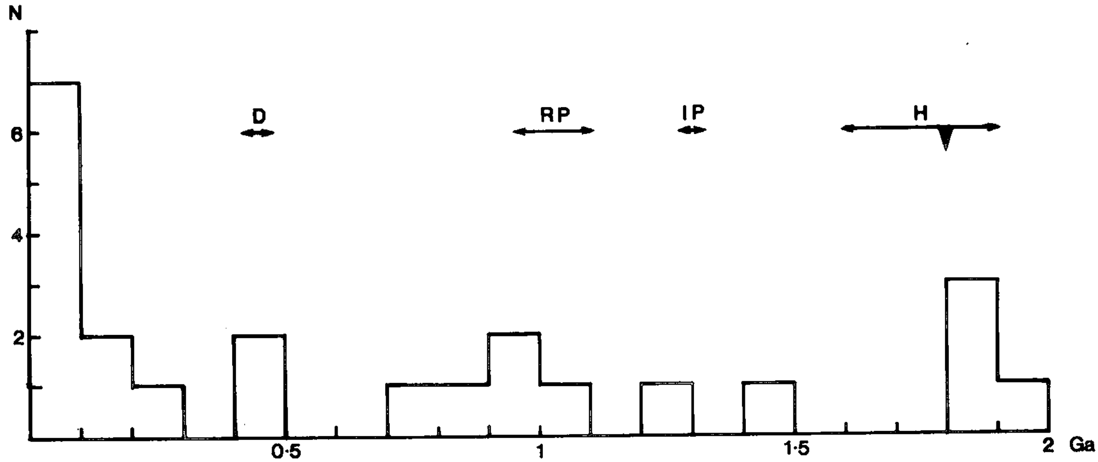

FIG. 5. Histogram of chemical ages in U–Th phases in Cree Lake Zone anatectites. H range of Hudsonian orogeny (peak metamorphism marked), IP initial age of pitchblende mineralization at Rabbit Lake and Midwest Lake, RP major remobilization of IP and D discordia of Cumming & Rimsaite (1979).

times, would be small (in view of its short half-life relative to ^{238}U), and c) Th, with its long half-life, is usually ignored (as a contributor of Pb). The Th effect can be corrected as mentioned earlier, but the presence of detritally derived lead, primeval lead and ^{235}U-generated lead all contribute to a chemical age, giving slight overestimates of the "true" age. Needless to say, chemical ages are only valid indicators of the "true" age in igneous or partial-melt situations, where "detrital" lead is at a minimum and radioactive phases crystallize as primary minerals. Typical chemical ages of some Phanerozoic rocks are shown in Table 5. In the case of the shale, the inordinately old age is clearly due to assumption a) above being incorrect; in most clastic environments, "detrital" lead will be present in significant amounts. The uncorrected chemical ages for the nordmarkite and granite, supposedly favorable host-environments for calculations of a chemical age, are higher than expected because of the significant contribution of Th. The Th-corrected values are much closer to the "true" (radiometric) age and illustrate that chemical ages in favorable environments overestimate slightly the radiometric age. Similar results are obtained using the bulk U, Th and Pb data of Koeppel (1968) on pitchblende of the Beaverlodge area. Thus, the observed spread of chemical ages in the present data corroborates the microprobe petrographic evidence of extensive mobilization of parent and daughter elements to produce very young phases. Apparently fresh "uraninite" shows evidence of U mobilization and loss on a microscopic scale; for example, two euhedral grains of "uraninite" (sample 796a, T/S #3) no more than 50 μm apart give respective ages of 1883 and 917 Ma.

TABLE 5. COMPARISON OF RADIOMETRIC AND CHEMICAL AGES OF PHANEROZOIC AND CREE LAKE ZONE ANATECTITES USING WHOLE-ROCK TRACE-ELEMENT DATA

	UO_2 (ppm)	PbO (ppm)	ThO_2 (ppm)	Radio-metric	Age (Ma) Chemical	Th corrected
Some Phanerozoic chemical ages (based on bulk chemistry)						
Shale	77.5	34.3	?	350	2785	-
Nordmarkite	414	23.1	446	259	424	316
Granite (Zr)	2339	405	9240	523	1235	573
Cree Lake Zone chemical ages (based on bulk chemistry):						
Pelite	25.8	28	21.3		5445	4774
Anatectites:						
Group A	254	86	135	↑	2229	1966
Group B	76	(28)	74	≈ 1750	2393	1926
Group C	469	155	(324)	minimum	2184	1858
Mafic	202	58	11.4	↓	1936	1908

( ) enclose ppm average values based on limited information

The histogram (Fig. 5) exhibits weak clusters at 1.8 - 1.9, 0.8 - 1.2 and < 0.5 Ga. The oldest group is interpreted as the initial phase of mineralization, coeval with the formation of the anatectites, during the Hudsonian event. The middle group of 800 – 1200 Ma is significant in that it covers the period of time attributed to the formation and remobilization of the unconformity-related U deposits of Saskatchewan (Cumming & Rimsaite 1979, Baadsgaard *et al.* 1984). The youngest group of ages correlates with the data of Koeppel (1968) and Cumming & Rimsaite (1979) who concluded, from studies on Beaverlodge and Rabbit Lake, that a discordia intercept at 450 Ma represents the initiation of a period of remobilization that has continued to the present day. Thus the chemical ages determined from the microprobe data are not at variance with known radiometric and estimated geological ages of events in the region.

It was noted earlier that the petrographic evidence seems to suggest remobilization of parent and daughter elements on a microscopic scale only. To test whether or not any major bulk-loss or gain of U, Th and Pb occurred in the anatectites, the available bulk chemical compositions of pelite and the four groups of anatectite, as classified by Parslow & Thomas (1982) and Thomas (1983), were averaged. These averages and derived chemical ages are shown in Table 5. Predictably, the pelite gives a gross overestimate of age because of the presence of "detrital" Pb. However, the other dates are remarkably consistent at about 1.9 Ga which, if chemical ages are generally slight overestimates, fit very well the geological and radiometric dates of about 1.75 Ga (*i.e.*, Hudsonian). Hence, the bulk data tend to confirm that remobilization was extensive but local, and that the anatectites as complete entities, as mapped in the field, have remained an essentially closed system since their formation.

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References

Baadsgaard, H., Cumming, G.L. & Worden, J.M. (1984): U–Pb geochronology of minerals from the Midwest uranium deposit, northern Saskatchewan. *Can. J. Earth Sci.* **21**, 642-648.

Bell, K. (1981): A review of the geochronology of the Precambrian of Saskatchewan – some clues to uranium mineralization. *Mineral. Mag.* **44**, 371-378.

Bence, A.E. & Albee, A.L. (1968): Empirical correction factors for the electron microanalysis of silicates and oxides. *J. Geol.* **76**, 382-403.

Coombe, W. (1979): Mineral deposits and regional metallogeny, southeastern Shield. *In* Summary of Investigations 1979 (J.E. Christopher & R. Macdonald, eds.). Sask. Geol. Surv., Regina, Sask.

Cumming, G.L. & Rimsaite, J. (1979): Isotopic studies of lead depleted pitchblende, secondary radioactive minerals, and sulphides from the Rabbit Lake uranium deposit, Saskatchewan. *Can. J. Earth Sci.* **16**, 1702-1715.

Koeppel, V. (1968): Age and history of the uranium mineralization of the Beaverlodge area, Saskatchewan. *Geol. Surv. Can., Pap.* **67–31.**

Lewry, J.F. (1981): Lower Proterozoic arc-microcontinent collisional tectonics in the western Churchill Province. *Nature* **294**(5836), 69-72.

_____ & Sibbald, T.I.I. (1978): A review of pre-Athabasca basement geology in Northern Saskatchewan. *In* Uranium Exploration Techniques (G.R. Parslow, ed.). *Sask. Geol. Soc., Spec. Publ.* **4**, 19-58.

_____ & _____ (1980): Thermotectonic evolution of the Churchill Province in northern Saskatchewan. *Tectonophys.* **68**, 45-82.

Parslow, G.R. & Thomas, D.J. (1982): Uranium occurrences in the Cree Lake Zone, Saskatchewan, Canada. *Mineral. Mag.* **46**, 163-171.

Rimsaite, J. (1978): Application of mineralogy to the study of multi-stage uranium mineralization in remobilized uranium deposits, Saskatchewan. *In* Uranium Deposits: their Mineralogy and Origin (M.M. Kimberley, ed.). *Mineral. Assoc. Can., Short-Course Handbook* **3**, 403-430.

Thomas, D.J. (1983): *Distribution, Geological Controls and Genesis of Uraniferous Pegmatites in the Cree Lake Zone of Northern Saskatchewan.* M.Sc. thesis, Univ. Regina, Regina, Sask.

Watters, B.R. (1981): Geochemistry of metavolcanic rocks in the La Ronge domain. *In* Summary of Investigations 1981, (J. E. Christopher & R. Macdonald, eds.)., Sask. Geol. Surv., Regina, Sask.

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