UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Silver Plume Granite--Possible Source of Uranium in Sandstone Uranium Deposits, Tallahassee Creek and High Park Areas, Fremont and Teller Counties, Colorado

By

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This report has not been reviewed for conformity with U.S. Geological Survey editorial standards.

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ABSTRACT

Anomalously high concentrations of thorium and of the light rare earth elements lanthanum and cerium suggest that the actinides and light lanthanides were enriched to an abnormal degree by the magmatic processes that formed the Proterozoic Y Silver Plume Granite in areas adjoining Tallahassee Creek and High Park. However, no such enrichment is found in the Proterozoic X Boulder Creek Granodiorite. Although uranium presently does not appear to be significantly enriched in sampled outcrops of Silver Plume Granite, a large part of the original uranium content of Silver Plume may have been removed by oxidizing ground waters, leaving behind mainly the uranium bound in resistate minerals such as zircon and monazite.

Lead isotopic compositions of acid leachate from barren shale and sandstone associated with the Hansen uranium deposit (Tallahassee Creek area) indicate that (1) the predominant source of acid-soluble lead is 1410 m.y. old (Silver Plume age); (2) the source of the lead is characterized by Th/U around 1 (this ratio in the source may apply to soluble minerals only and may exclude thorium and uranium in resistate minerals), and the mean uranium content of this source may be as high as 30 ppm; and (3) at the time of sediment deposition, a paleohydrologic system existed that was capable of transporting Silver Plume lead and, therefore, Silver Plume uranium to the Hansen deposit.

Although a significant contribution of uranium from Tertiary volcanic rocks cannot be ruled out and is even probable (Dickinson and Hills, 1982), it appears probable that some of the uranium in deposits of the Tallahassee Creek area was derived from Silver Plume Granite.

INTRODUCTION

The Tallahassee Creek uranium area (Figure 1) has been a minor producer of uranium since the late 1950's, but only during the middle and late 1970's were large deposits discovered. Presently, two large sandstone-type ore bodies are known along Middle Tallahassee Creek (the Hansen ore body, containing about 12,000,000 Kg U_3O_8, and the Picnic Tree ore body, containing about 1,000,000 Kg). A smaller one (containing about 400,000 Kg) has been located in High Park (Figure 2). (See Dickinson, 1981 for reserve data.)

The Hansen ore body is in the upper Eocene Echo Park Alluvium, and the Picnic Tree and High Park ore bodies are in lower Oligocene Tallahassee Creek Conglomerate. These deposits and numerous other subeconomic mineralized zones occur in upper Eocene and Oligocene strata deposited in fault-controlled paleovalleys that crossed the uplifted crystalline blocks of the Front Range (Epis and others, 1976). The flow directions in these paleovalleys were more or less from northwest to southeast. Dickinson (1981) describes the geologic controls on uranium mineralization in the Tallahassee Creek area, and Scott and others (1978) mapped the geology of the Tallahassee Creek and surrounding areas.

The purpose of the present report is to assess the favorability of Precambrian granitic rocks as uranium source rocks in areas adjoining Tallahassee Creek, and to a lesser extent, around High Park. For this purpose, sampling was begun during our evaluation of the uranium potential of rocks in the Pueblo $1^{\circ}X2^{\circ}$ quadrangle (Dickinson and Hills, 1981) for the U.S. Department of Energy's National Uranium Resource Evaluation (NURE) program, but sampling was continued after the NURE evaluation was completed. The Proterozoic Y Pikes Peak Granite has not been included in this study because the paleodrainage system appears to preclude any significant contribution from

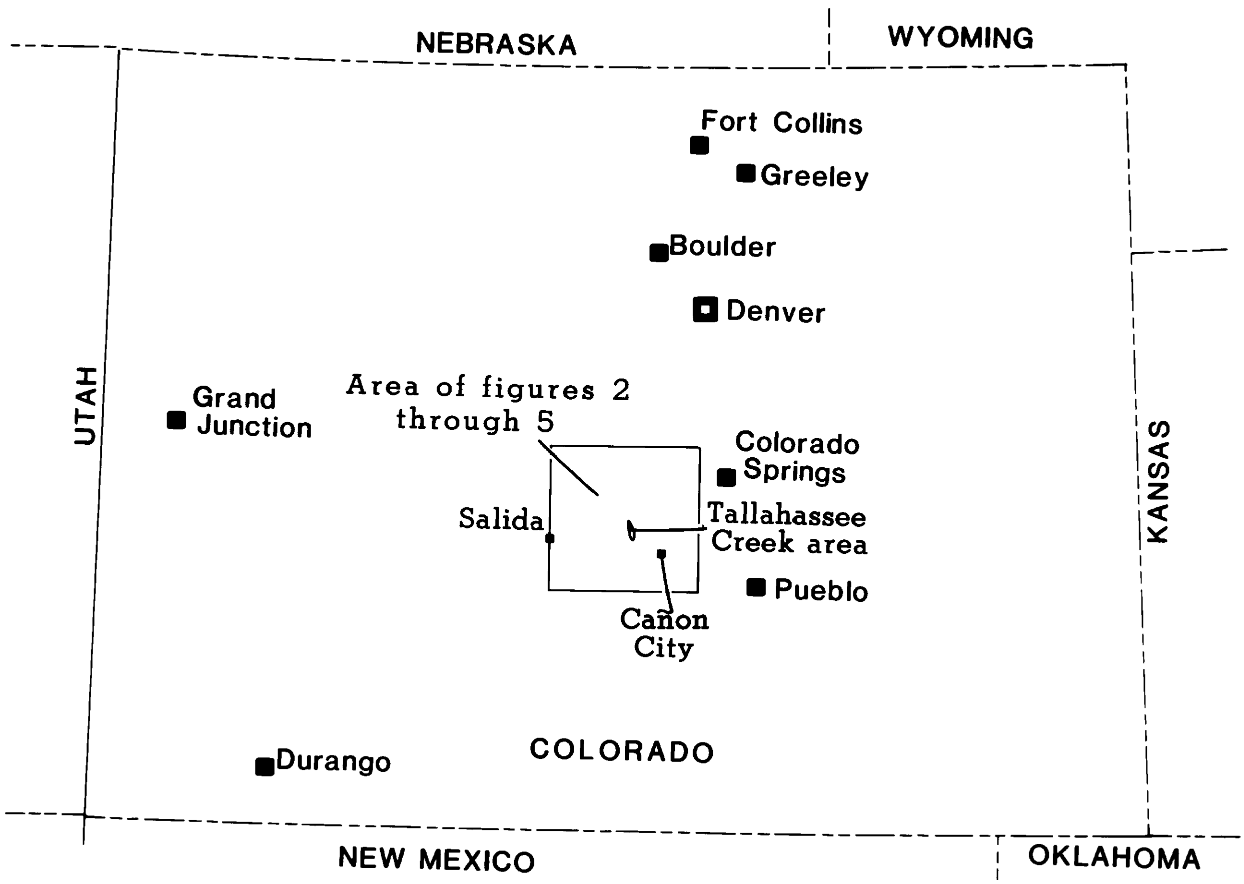


Figure 1.--Location of the Tallahassee Creek study area.

that source to the Tallahassee Creek area. However, Pikes Peak Granite probably did contribute to the drainage system of the High Park area and could have supplied uranium to deposits in that area.

In addition to the Precambrian granites that form much of the basement on which Eocene and Oligocene sedimentary rocks are deposited, and into which Oligocene streams eroded, Oligocene volcanic rocks, which may be a source for uranium (Dickinson and Hills, 1982), were spread in profusion throughout the area.

GRANITIC ROCKS

General

Presently no lead isotope data are available for samples of granite, which data would enable us to calculate the original uranium content of the granitic rocks in and around the Tallahassee Creek area. However, by comparing some trace element concentrations in the local granites with those in better studied granites elsewhere and by inferences from the isotopic composition of common lead in the uranium deposits, it is possible to draw some interesting, if somewhat speculative, conclusions that nevertheless may be helpful in planning future research and uranium exploration.

Rosholt and Bartel (1969) and more recently Stuckless and Nkomo (1978) have demonstrated, using lead isotopes, that granites in the Granite Mountains, central Wyoming, have lost surprisingly large quantities of uranium as a result of leaching by ground water during the Tertiary, and that this leached uranium is sufficient to account many times over for known ore deposits in surrounding areas. These granites are not exceptionally uraniferous where they are exposed in outcrops today (they contain 3 to 5 ppm U according to Stuckless, 1979), however the isotopic compositions of their leads suggest that they were highly enriched in uranium before they were uplifted and exposed to circulating, oxygenated ground water early during the Tertiary.

All granitic rocks do not contain such large quantities of leachable uranium as do the granites of the Granite Mountains, and in fact such granites with high content of leachable uranium, referred to as fertile granites, appear to be uncommon. In the more common granitic rocks, uranium occurs in such low concentrations that it behaves as a trace element throughout the magmatic process, and is incorporated into minerals composed chiefly of other elements (mostly resistate minerals) from which it is not readily removed by leaching. Apparently, in magmas that produce the fertile granitic rocks, uranium occured in such high concentrations that during the final stages of crystallization it formed phases in which uranium is a principal component (including uraninite and possibly grain-boundary phases), and from which it is readily leachable.

The magmatic processes that produced high concentrations of uranium in fertile granites also produced other trace element anomalies, and these anomalies, although incompletely studied, possibly can be used to distinguish leached fertile granites from barren granites. In addition to high concentrations of uranium, fertile granites are characterized by high concentrations of thorium, by high concentrations of light rare earth elements (REE), and by being relatively depleted in europium and heavy REE. Thorium and REE are of low solubility in low temperature solutions and remain almost undisturbed by the ground waters that leach uranium. At the present time, we do not know whether all fertile granites have these trace element chacracteristics or whether all granites with these characteristics are fertile, and therefore our conclusions regarding potential granitic source rocks in the Tallahassee Creek district are somewhat speculative.

Granodiorite of Boulder Creek age

Granodiorite of Boulder Creek age (1700 m.y. old) is pinkish-gray, massive to foliated, medium to coarse grained, and it contains hornblende and biotite (Scott and others, 1978). The unit crops out in several areas within and around the Tallahassee Creek uranium district, and much of the late Eocene erosion surface was carved on this rock. The unit also contributed much detritus to the Echo Park Alluvium and a lesser amount to the Tallahassee Creek Conglomerate.

Concentrations of uranium, thorium, lanthanum, and cerium in 69 samples of granodiorite of Boulder Creek age from areas adjoining Tallahassee Creek are listed in Table 1, and sampling locations are shown on figure 2. Their average thorium content of 17 ppm is almost identical with the average for granitic rocks (18 ppm for silicic igneous rocks, Rogers and Adams, 1969; 17 ppm for low-calicium granitic rocks, Turekian and Wedepolhl, 1961) and their average uranium content of 2.9 ppm is somewhat lower (4 ppm and 3 ppm respectively for the sources cited above). Our samples of Boulder Creek age rocks, mostly mapped as granodiorites by Scott and others (1978), may be less silicic and more calcic than the silicic igneous rocks and low-calcium granitic rocks with which we compare them here. Nevertheless, on average, they appear to be quite unremarkable in their uranium and thorium contents, and indeed few individual samples appear to be significantly anomalous. Lanthanum and cerium contents, many of which are below detection limits, are likewise quite ordinary for granodioritic rocks, and along with thorium, do not suggest

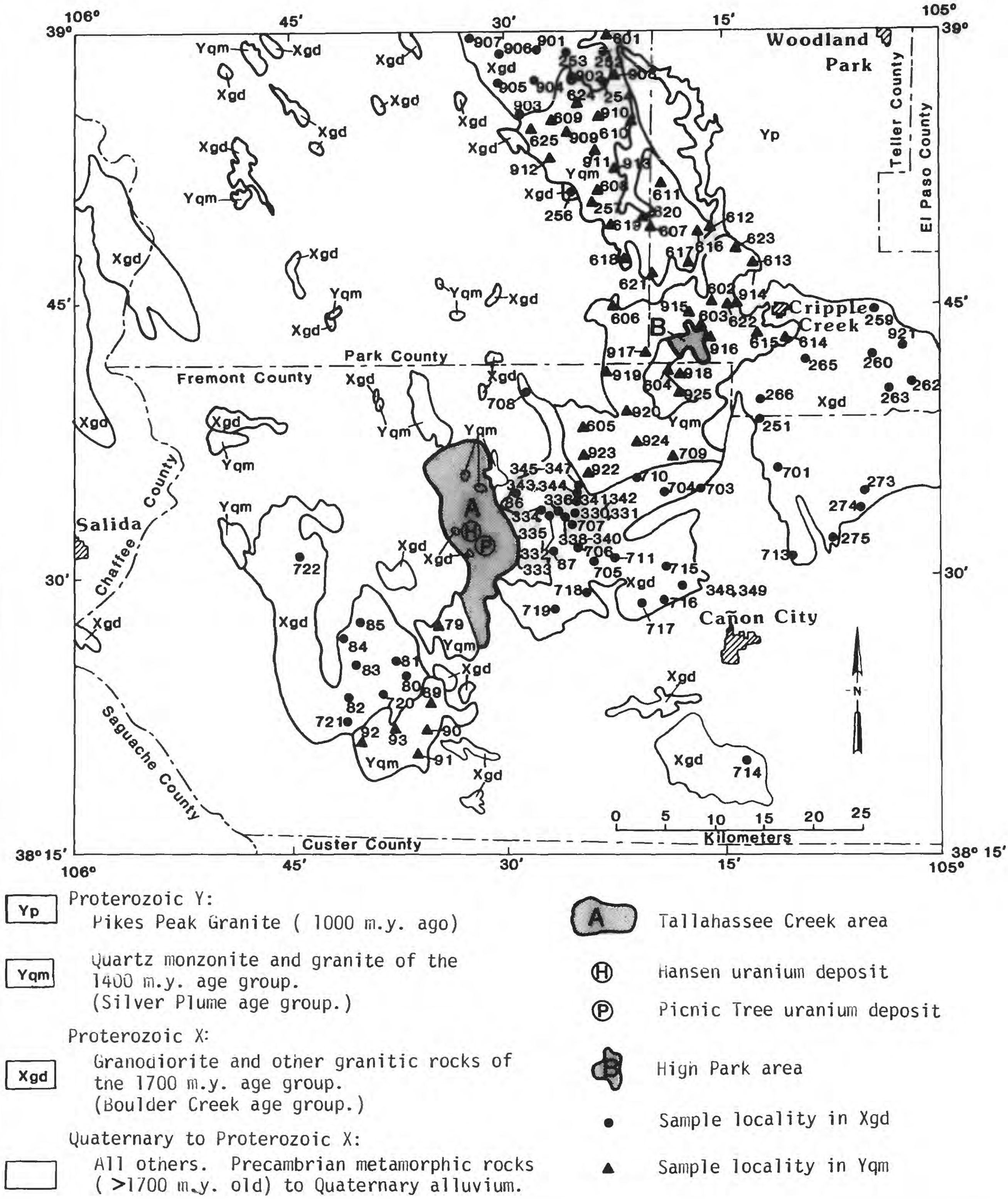


Figure 2.--Sample locations and distribution of Precambrian granitic rocks adjoining the Tallahassee Creek and High Park areas. (Geology from Scott and others, 1978.)

Table 1.--Uranium, thorium, lanthanum, cerium, and chondrite-normalized lanthanum and cerium in granodiorite of the Boulder Creek age group from the vicinity of Tallahassee Creek.
[Delayed neutron analyses of U and Th by H. T. Millard, Jr., R. Bies, B. Keaton, M. Coughlin, and S. Lasater. La and Ce analyses by emission spectrometer with digital direct reader by P. J. Lamothe, R. Mays, R. Lerner, and T. Fries.]

Sample Number	U ppm	Th ppm	La ppm	Ce ppm	Th/U	La/La_c 1/	Ce/Ce_c 1/
MDE 080	5.0	28	54	110	5.6	171	135
MDE 081	7.2	51	74	116	7.1	235	143
MDE 082	4.4	31	110	210	7.0	349	258
MDE 083	1.9	15	48	180	7.9	152	221
MDE 084	3.9	16	36	110	4.1	114	135
MDE 085	2.3	13	<20	<100	5.6	<63	<123
MDE 086	1.3	10	40	120	7.7	127	148
MDE 087	1.4	18	76	150	12.9	241	184
MDE 251	3.1	14	97	200	4.5	308	246
MDE 252	2.9	14	30	<100	4.8	95	<123
MDE 253	2.0	10	21	<100	5.0	67	<123
MDE 254	2.1	17	63	170	8.1	200	209
MDE 256	1.2	19	43	<100	15.8	136	<123
MDE 259	3.7	11	69	110	3.0	219	135
MDE 260	4.6	17	<20	<100	3.7	<63	<123
MDE 262	3.1	11	77	150	3.5	244	185
MDE 263	7.0	18	49	130	2.6	156	160
MDE 265	2.4	14	60	110	5.8	190	135
MDE 266	2.8	19	78	170	5.8	248	209
MDE 273	5.2	16	42	<100	3.1	133	<123
MDE 274	5.9	<3	<20	<100	<.5	<63	<123
MDE 275	3.2	9	<20	<100	2.8	<63	<123
MDE 330	5.0	16	49	<100	3.2	156	<123
MDE 331	2.4	13	22	<100	5.4	70	<123
MDE 332	2.5	14	45	<100	5.6	143	<123
MDE 333	2.6	16	57	110	6.2	181	135
MDE 334	1.0	17	40	<100	17.0	127	<123
MDE 335	.8	19	42	<100	23.8	122	<123
MDE 336	.9	13	54	140	14.4	171	172
MDE 338	2.8	17	<20	<100	6.1	<63	<123
MDE 339	2.4	11	<20	<100	4.6	<63	<123
MDE 340	2.4	8	<20	<100	3.3	<63	<123
MDE 341	3.9	14	<20	<100	3.6	<63	<123
MDE 342	3.1	9	<20	<100	2.9	<63	<123
MDE 343	3.3	48	<20	<100	14.6	<63	<123
MDE 344	3.7	10	<20	<100	2.7	<63	<123
MDE 345	4.7	30	79	150	6.4	251	184
MDE 346	2.8	28	90	170	10.0	286	209
MDE 347	1.8	9	<20	<100	5.0	<63	<123
MDE 348	1.8	20	30	<100	11.1	95	<123
MDE 349	1.8	20	<20	<100	11.1	<63	<123
MDE 701	4.5	14	86	180	3.1	273	221
MDE 702	6.2	28	180	340	4.5	571	418
MDE 703	3.5	11	27	<100	3.1	86	<123
MDE 704	2.4	17	45	<100	7.1	143	<123
MDE 705	2.4	7	41	<100	2.9	130	<123
MDE 706	1.4	19	44	<100	13.6	140	<123
MDE 707	4.9	<3	<20	<100	>.6	<63	<123
MDE 708	3.1	28	65	110	9.0	206	135
MDE 710	1.0	<2	<20	<100	<2.	<63	<123
MDE 711	2.2	5	50	<100	2.3	159	<123
MDE 713	2.8	17	48	<100	6.1	152	<123
MDE 714	1.8	26	77	110	14.4	244	135
MDE 715	1.7	4	48	<100	3.4	152	<123
MDE 716	1.3	15	42	<100	11.5	133	<123
MDE 717	1.0	21	49	<100	21.0	156	<123
MDE 718	1.6	22	76	110	13.8	241	135
MDE 719	1.7	24	88	160	14.1	279	197
MDE 720	1.9	9	--*	--*	4.7	--*	--*
MDE 721	1.8	16	66	110	8.9	209	135
MDE 722	4.1	18	67	110	4.4	213	135
MDE 901	1.4	17	58	<100	12.1	184	<123
MDE 902	1.0	13	33	<100	13.0	105	<123
MDE 903	1.3	4	<20	<100	3.1	<63	<123
MDE 904	6.8	28	21	<100	4.1	67	<123
MDE 905	1.7	14	29	<100	8.2	92	<123
MDE 906	1.0	15	42	<100	15.0	133	<123
MDE 907	0.8	8	22	<100	10.5	70	<123
MDE 921	5.9	37	<20	<100	6.3	<63	<123
Mean	2.9	17	<47	<118	7.3	<150	<145

*La and Ce not reported because of irreproducible analytical results.

1/ La/La_c and Ce/Ce_c are chondrite-normalized values.

exceptional enrichment of incompatible trace elements. Therefore, granodioritic rocks of the Boulder Creek age group are not likely to be the source of significant amounts of the uranium found in the Tallahassee Creek area.

Quartz Monzonite of Silver Plume age

Quartz monzonite (granite in the classification of Streckeisen, 1976) of Silver Plume age (~1400 m.y. age group of Tweto, 1977) commonly is a tan to gray, alkali-rich, biotite-muscovite (two-mica) rock with phenocrysts of microcline. It crops out in a large batholith northeast of the Tallahassee Creek area and in numerous smaller plutons and small exposed parts of larger buried plutons throughout the area.

Like the Boulder Creek age group, the Silver Plume age group contributed detritus to the Echo Park Alluvium and to the Tallahassee Creek Conglomerate, and much of the late Eocene erosion surface was carved in it. Therefore, it is a plausible source of uranium for the deposits of the Tallahassee Creek district.

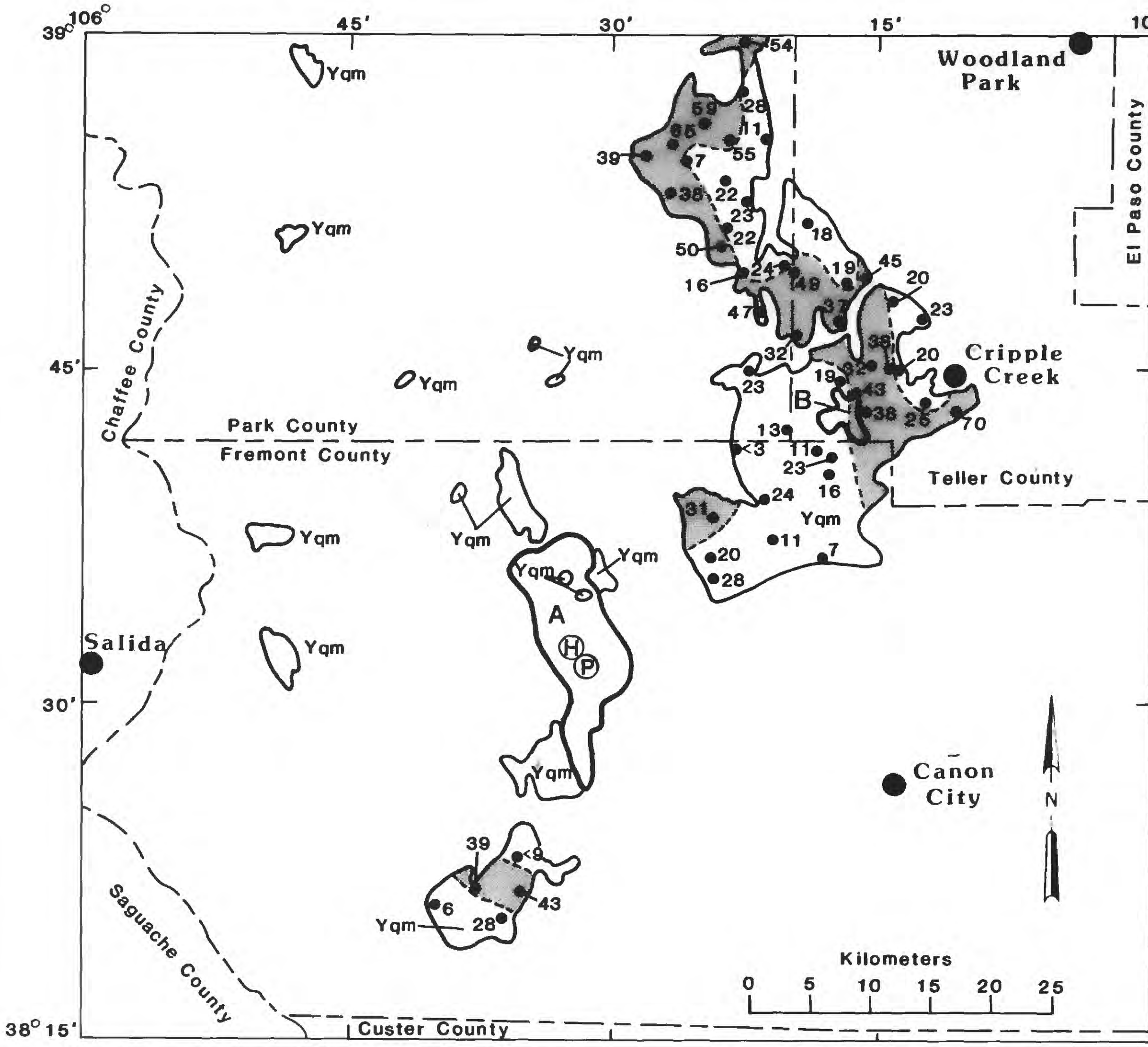
Concentrations of uranium, thorium, lanthanum, and cerium from 50 samples are listed in Table 2 and sampling locations are shown on figure 2. Thorium concentrations average 30 ppm and uranium concentrations average 5.2 ppm--values which are respectively 75 and 80 percent higher than for the Boulder Creek age group. Likewise, lanthanum and cerium concentrations are higher and comparable with concentrations in rapakivi granites (for examples see Vorma, 1976).

Figure 3 shows the distribution of thorium concentrations within Silver Plume age rocks. Large areas are characterized by concentrations greater than 30 ppm, and smaller, but still appreciable areas by concentrations greater

Table 2.--Uranium, thorium, lanthanum, cerium, and chondrite-normalized lanthanum and cerium in granitic rocks of the Silver Plume age group from the vicinity of Tallahassee Creek and High Park. [Delayed neutron analyses of U and Th by H. T. Millard, Jr., R. Bies, B. Keaton, M. Coughlin, S. Lasater, B. Vaughn, M. Schneider, and W. Stang. La, Ce, and Pb analyses by emission spectrometer with digital direct reader by P. J. Lamothe, R. Mays, R. Lerner, and T. Fries.]

Sample Number	U ppm	Th ppm	La ppm	Ce ppm	Pb ppm	Th/U	La/La_c 1/	Ce/Ce_c 1/
MDE 079	7.2	44	52	150	28	6.1	165	184
MDE 089	29.0	<9	<20	<100	31	<.3	<63	<123
MDE 090	5.5	43	140	280	26	7.8	444	344
MDE 091	6.0	28	55	140	20	4.7	175	172
MDE 092	2.9	6	<20	<100	20	2.1	<63	<123
MDE 093	3.9	39	75	160	15	10.0	238	197
MDE 257	4.0	50	68	180	34	12.5	215	221
MDE 601	2.8	54	110	230	26	19.3	349	283
MDE 602	2.9	32	96	200	12	11.0	304	246
MDE 603	6.8	43	79	160	41	6.3	251	197
MDE 604	5.1	11	<20	<100	<10	2.2	<63	<123
MDE 605	5.3	31	98	190	18	5.8	311	234
MDE 606	4.1	23	42	120	12	5.6	133	148
MDE 607	7.4	49	110	190	20	6.6	349	234
MDE 608	4.3	22	33	110	28	5.1	105	135
MDE 609	6.7	65	120	210	53	9.7	381	258
MDE 610	4.2	11	53	130	<10	2.6	168	160
MDE 611	4.1	18	130	230	<10	4.4	413	283
MDE 612	6.9	45	120	210	17	6.5	143	258
MDE 613	6.1	39	51	100	52	6.4	162	123
MDE 614	7.7	70	100	190	35	9.1	317	234
MDE 615	2.0	25	140	290	30	12.5	444	357
MDE 616	3.9	19	170	290	20	4.9	540	357
MDE 617	4.6	37	79	130	18	8.0	251	160
MDE 618	5.6	47	74	170	31	8.4	235	209
MDE 619	2.3	16	84	180	19	7.0	267	221
MDE 620	5.7	42	110	180	23	7.4	349	221
MDE 621	5.3	32	29	<100	25	6.0	92	<123
MDE 622	4.9	38	60	110	26	7.8	190	136
MDE 623	3.5	17	77	170	24	4.9	244	209
MDE 624	2.2	59	140	240	26	26.8	444	295
MDE 625	5.3	39	21	<100	35	7.4	67	<123
MDE 709	3.9	7	53	<100	14	1.8	168	<123
MDE 908	2.8	28	210	320	32	10.0	667	394
MDE 909	6.1	7	<20	<100	28	1.2	<63	<123
MDE 910	8.7	55	94	205	33	6.3	298	252
MDE 911	6.6	22	28	<100	27	3.3	89	<123
MDE 912	2.6	38	57	190	30	14.6	181	234
MDE 913	4.3	23	46	150	28	5.4	146	184
MDE 914	2.8	20	41	100	26	7.1	130	123
MDE 915	5.4	19	170	340	16	3.5	540	418
MDE 916	5.9	38	67	140	26	6.4	212	172
MDE 917	2.2	13	<20	<100	33	5.9	<63	<123
MDE 918	5.9	33	64	100	38	5.6	203	123
MDE 919	4.1	<3	<20	<100	22	<.7	<63	<123
MDE 920	5.0	24	33	<100	21	4.8	105	<123
MDE 922	3.0	28	<20	<100	22	9.3	<63	<123
MDE 923	4.6	20	<20	<100	22	4.4	<63	<123
MDE 924	3.0	11	<20	<100	22	3.7	<63	<123
MDE 925	4.4	16	<20	<100	25	3.6	<63	<123
Mean	5.2	30	<72	<160	25	6.9	222	196

1/ La/La_c and Ce/Ce_c are chondrite-normalized values.



Yqm Proterozoic Y quartz monzonite and granite of the 1400 m.y. age group (Silver Plume age group)

38 Quartz monzonite and granite characterized by >30 ppm thorium and generally high concentrations of cerium and lanthanum

49 Sample locality with concentration of thorium in ppm

(A) Tallahassee Creek area

(H) Hansen uranium deposit

(P) Picnic Tree uranium deposit

(B) High Park area

Figure 3.--Thorium concentrations in granitic rocks of Silver Plume age. (Geology from Scott and other, 1978.)

than 45 ppm. Areas characterized by high thorium concentrations are also characterized by high lanthanum and cerium, but those elements are not shown on figure 3.

Unpublished REE data (John M. Fountain, 1980, written communication) from the Silver Plume batholith west of Georgetown, Colorado, indicate that granite of the Silver Plume batholith is highly enriched in light REE, has large negative europium anomalies, is relatively depleted in heavy REE, and has a REE differentiation pattern similar to the patterns found in rapakivi granites. Lanthanum, cerium, and thorium concentrations in rocks of the Silver Plume age group near the Tallahassee Creek district suggest similar affinities for those rocks.

Sampled outcrops of quartz monzonite of Silver Plume age adjoining the Tallahassee Creek district, although decidedly high in concentrations of incompatible trace elements show less extreme concentrations of these elements than does the Silver Plume batholith. Concentrations of thorium, lanthanum, and cerium in the Silver Plume batholith average (respectively) 73 ppm, 124 ppm, and 231 ppm (based on 46 samples, Hills and others, 1981), values that strongly suggest extreme concentration of the incompatible trace elements, a group which should include uranium.

Quartz monzonite of Silver Plume age adjoining the Tallahassee Creek district is less highly enriched in thorium than fertile granite of the Granite Mountains. Approximately one-third of the Granite Mountains samples contain more than 50 ppm thorium, and Stuckless (1979) states that samples that contain greater than 50 ppm thorium outnumber samples with between 10 and 20 ppm by more than 2 to 1.

Thus, in their content of thorium, rocks of Silver Plume age near the

Tallahassee Creek district appear to be intermediate between normal granitic rocks and the better studied fertile granites of the Granite Mountains. The Silver Plume rocks are also intermediate in light REE between normal granitic rocks and those with extreme enrichment such as the Silver Plume batholith. However, individual samples representative of appreciable area suggest the presence of fertile granite of Silver Plume age adjoining the Tallahassee Creek district.

INFERENCES FROM LEAD ISOTOPES

Table 3 lists uranium and lead concentrations and lead isotope compositions of the HNO_3-soluble fractions of several samples of ore and barren rock from in and near the Hansen ore body and of one sample of ore from the Picnic Tree ore body (K. R. Ludwig, 1981, written communication). Because these samples apparently have widely varying initial lead compositions, it was not possible to calculate a reliable age of ore formation.

The initial or common lead compositions of the barren samples, however, provide some interesting clues regarding the possible source of uranium in the ores. Samples A4 through A6 yield $^{207}Pb/^{206}Pb$ ages of 1200, 1410, and 1410 m.y. respectively. The ages from samples A5 and A6 are essentially pure Silver Plume (1400-1420 m.y.), with no detectable contributions from Boulder Creek age rocks or from Tertiary volcanic rocks. However, if leads from sources other than granite of Silver Plume age were not radiogenic, small percentages would be difficult to detect. The $^{207}Pb/^{206}Pb$ age of sample A4, a granite boulder from within mineralized ground, indicates that it is contaminated with young radiogenic lead from surrounding uranium ore, and the origin and significance of this boulder are uncertain.

Table 3.--Uranium and lead content and lead isotopic composition of the hot-HNO_3 soluble fraction of ores and barren samples from deposits in the Tallahassee Creek area. (K. R. Ludwig, 1981, written communication).

Sample Number	U (%)	Pb(ppm)	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$	$^{207}Pb^{206}Pb$ Age, m.y.	Description
HANSEN DEPOSIT							
A1	0.433	71.6	234.2 ± 0.8	30.76 ± 0.09	52.26	---	Ore
A2	0.269	28.0	324.7 ± 1.5	34.68 ± 0.11	52.62	---	Ore
A3	0.551	103	268.3 ± 0.6	32.77 ± 0.07	54.41	---	Ore
A4	0.00199	3.03	128.5 ± 2.0	24.36 ± 0.17	56.45	1200	Granite cobble from mineralized strata
A5	0.00326	3.69	53.83 ± 0.26	18.76 ± 0.05	47.63	1410	Barren clay
A6	0.00298	4.38	40.87 ± 0.10	17.61 ± 0.03	43.72	1410	Barren sandstone
PICNIC TREE DEPOSIT							
B1	0.413	19.8	44.84 ± 0.09	17.17 ± 0.03	38.04	---	Ore

An approximate mean Th/U ratio of the rocks that were the source of lead in the two barren samples A5 and A6 can be estimated with the following equation:

$$\frac{U}{Th} = \frac{^{206}Pb_r}{^{208}Pb_r} \times \frac{(e^{\lambda' t}-1)}{(e^{\lambda t}-1)} \times \frac{A_U}{A_{Th}}$$

where $^{206}Pb_r/^{208}Pb_r$ is radiogenic lead, t is 1410 m.y., λ is the decay constant for ^{238}U, λ' is the decay constant for ^{232}Th, and A_U and A_{Th} are the atomic weights of uranium and thorium. This equation yields mean Th/U ratios of 1.05 and 1.07 for the rocks that supplied hot-HNO_3-soluble lead respectively to the barren clay (A5) and to the barren sandstone (A6).

Although these calculated values agree very closely, it is important to realize that this is a model calculation. Implicit in the model is the assumption that uranogenic lead (^{206}Pb) and thorogenic lead (^{208}Pb) were removed from the source rocks, delivered to the depositional site, and dissolved by hot HNO_3 in the same proportions as they occurred in the source rock. However, for the most part, the analyzed lead probably was derived from the more soluble minerals in the source rocks of Silver Plume age, with perhaps little lead being derived from resistate minerals, such as zircon and monazite. Therefore, the calculated Th/U ratio is only an approximation of the source-rock ratio. Nevertheless, it is in good agreement with original Th/U ratios of fertile granites from the Granite Mountains (Stuckless, 1979) and with data (Hills, unpublished data, 1981) from drill core in granite of Silver Plume age from the Log Cabin batholith, in the Front Range near Red Feather Lakes, Colorado, and it strongly suggests the presence of fertile Silver Plume-age granites in the drainage basin that supplied detritus to the

Tallahassee Creek uranium deposits.

Ratios of $^{208}Pb/^{204}Pb$ in samples A1, A2, and A3 are significantly higher than $^{208}Pb/^{204}Pb$ in the two barren samples, and along with the cobble (A4), which has the highest $^{208}Pb/^{204}Pb$ of any of the samples, suggest a local source of Precambrian granitic rock that is exceptionally rich in thorium. Evidently at the time of ore formation ratios of $^{206}Pb/^{204}Pb$ and $^{207}Pb/^{204}Pb$ in the ore samples also were comparable to those presently found in the cobble, suggesting that the local Precambrian source rocks were exceptionally rich in uranium as well as in thorium. Unfortunately, because we know neither the time of uranium mineralization nor whether the ores have been closed systems since they formed, we cannot calculate the ratio of Th/U in source rocks using data from these samples.

In marked contrast to samples from the Hansen deposit, $^{208}Pb/^{204}Pb$ from sample B1 from the Picnic Tree ore body is less radiogenic than lead from the barren samples. This sample may contain a significant proportion of lead from Tertiary volcanic rocks.

Despite uncertainties in the quantitative estimates of uranium in the source rocks, several conclusions can be drawn:

(1) Tertiary strata that contain the Hansen uranium deposit are characterized by uranogenic lead from a Silver Plume age source. No uranogenic lead from Boulder Creek or other older rocks has been detected.

(2) A paleohydrologic system existed that derived lead from a Silver Plume-age source and deposited it at the site of the Hansen ore body. Although lead may have been transported in detrital phases and uranium in solution, nevertheless an appro-

priate drainage system did exist that could have brought uranium from a Silver Plume-age source to the Hansen site.

(3) Silver Plume age rocks in the drainage area have the high thorium concentrations and low Th/U ratios, characteristic of fertile granites.

(4) Although no evidence for lead from a Tertiary source has been recognized at the Hansen deposit, a Tertiary source for at least part of the uranium there is nevertheless possible. Tertiary common lead could be present and still not be discernible from 1400 m.y. old common lead in the uranogenic leads of samples A1 through A6. In contrast, Tertiary common lead may constitute the major proportion of lead in sample B1 from the Picnic Tree deposit.

PALEODRAINAGE

Epis and others (1976) present a remarkably complete history of the evolution of the late Eocene through Oligocene paleodrainage systems in the area surrounding Tallahassee Creek. Figures 4 and 5 show their inferred late Eocene and early Oligocene paleovalleys (paleovalleys extant during Echo Park and Tallahassee Creek time) superimposed on the simplified geologic map of figure 3. The two major paleovalleys on the southern part of the map (one apparently draining through the Tallahassee Creek area, and the other draining through the High Park area) persisted in much the same positions from the late Eocene through the middle Oligocene. During the late Oligocene both paleovalleys may have been blocked by volcanic deposits (Epis and other, 1976, figures 7 and 8).

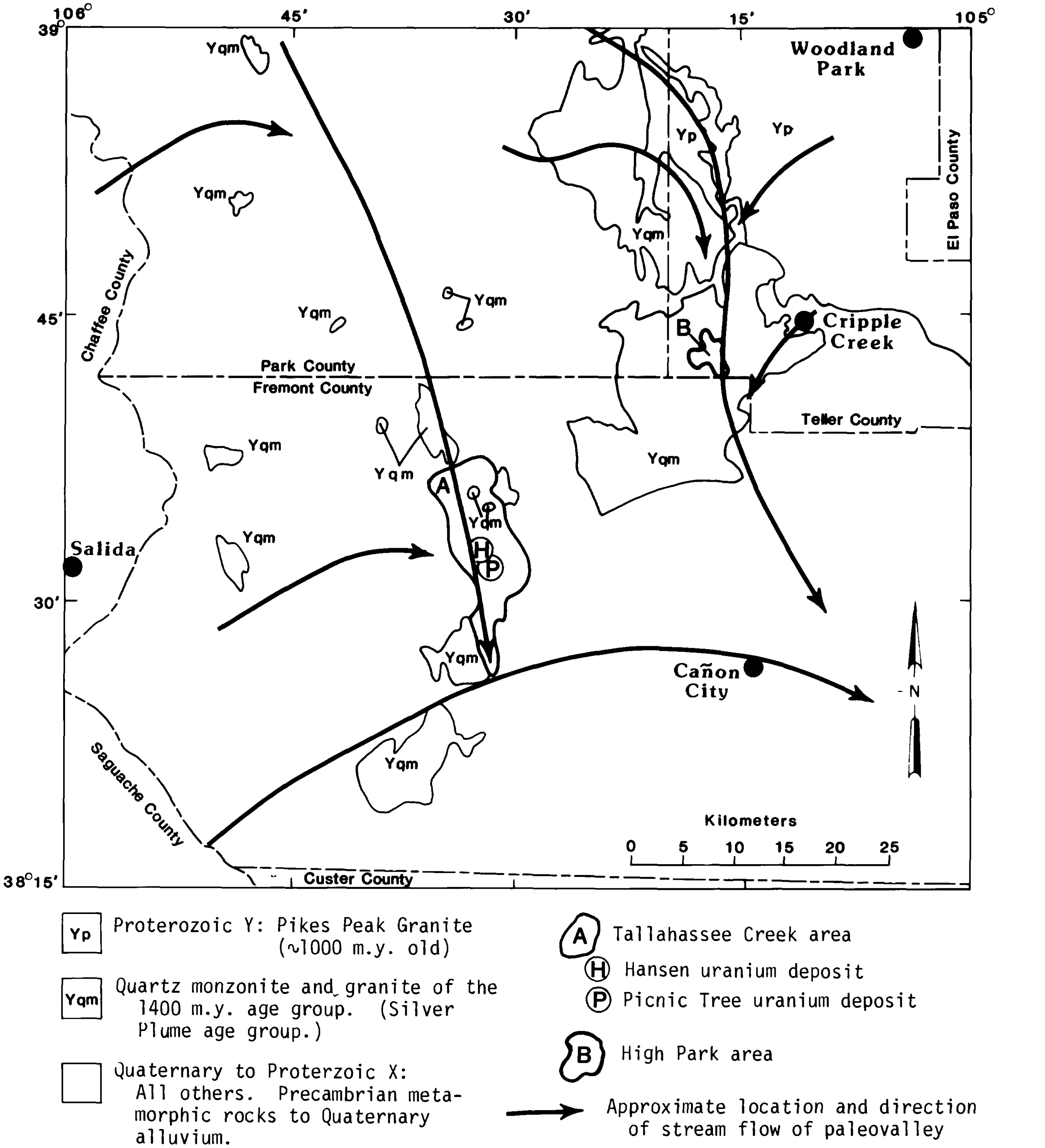


Figure 4.--Late Eocene paleovalleys (after Epis and others, 1976) and granitic rocks of Silver Plume age (after Scott and others, 1978) in the vicinity of the Tallahassee Creek area.

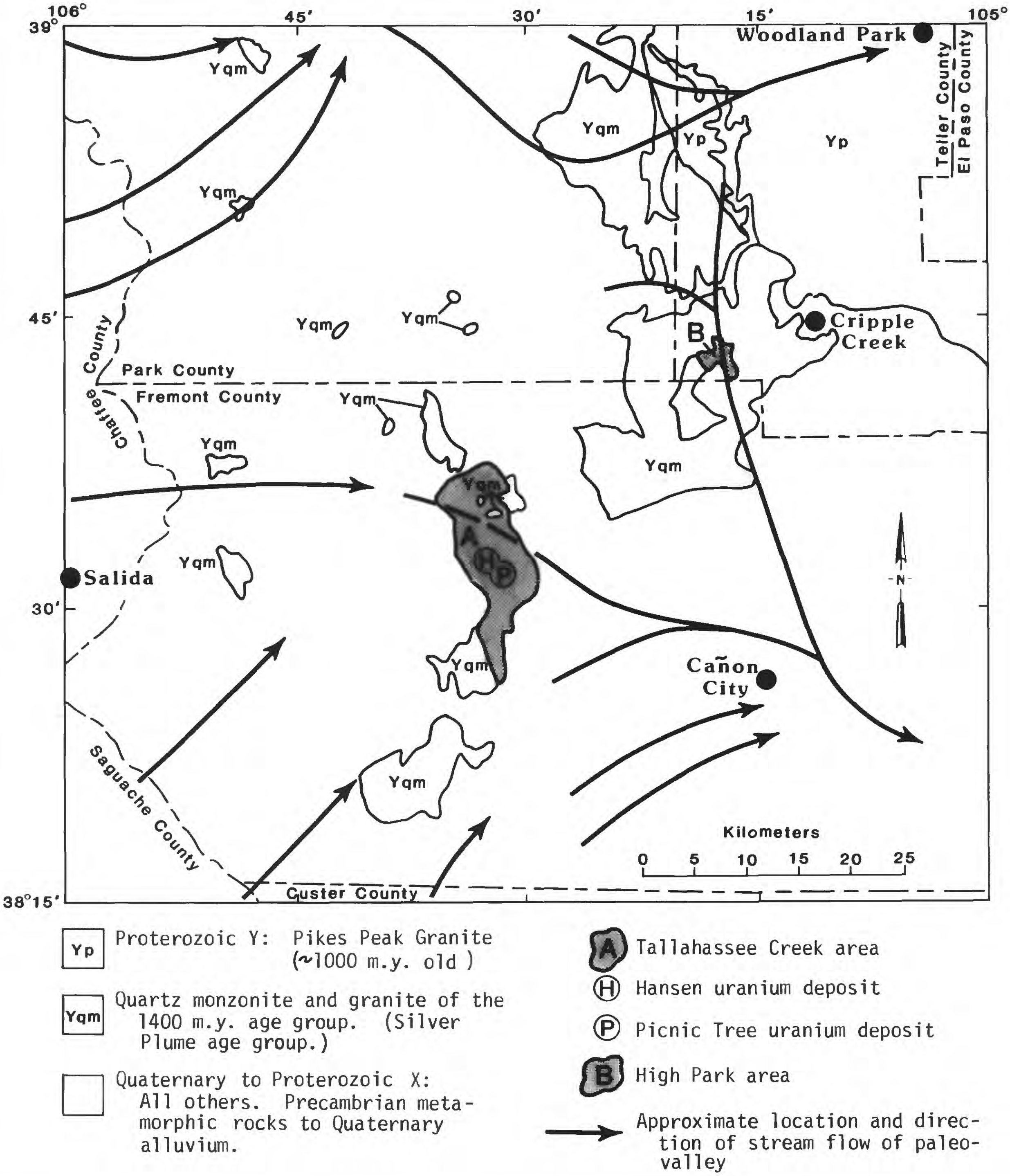


Figure 5.--Early Oligocene paleovalleys (after Epis and others, 1976) and granitic rocks of Silver Plume age (after Scott and others, 1978) in the vicinity of the Tallahassee Creek area.

It appears from the work of Epis and others (1976) that the paleovalley through High Park blocked drainage from the Pikes Peak Granite to the Tallahassee Creek area, and that paleovalley and the one through Woodland Park also may have blocked drainage from much of the most thorium-rich granite of Silver Plume age in the area sampled. Therefore, the most probable location of Silver Plume age source rocks for the Tallahassee Creek deposits is northwestern Fremont and southwestern Park Counties, where presently Silver Plume is exposed in only small areas (figure 2). The Oligocene Thirtynine Mile Andesite and other deposits younger than Tallahassee Creek Conglomerate now blanket most of this area, but during Tallahassee Creek time and earlier, it appears from the geologic map (Scott and others 1978) that more Silver Plume age granitic rocks were exposed there.

CONCLUSIONS

Granitic rocks from outcrops of the Silver Plume age group in the vicinity of Tallahassee Creek contain anomalously high concentrations of such trace elements as thorium and the light REE. High concentrations of these trace elements suggests that magmatic processes that produced Silver Plume plutons favored to an unusual degree enrichment of late differentiates with a group of incompatible elements that probably includes uranium. Therefore, at least some of the Silver Plume Granite in the area probably is a fertile source rock for uranium. By contrast, granitic or granodioritic rocks of the Boulder Creek age group appear to be unexceptional in their content of thorium and light REE, and Boulder Creek rocks probably do not contain much uranium that is available to leaching ground water solutions.

Lead isotope ratios of barren shale and sandstone and of ore from the Hansen uranium deposit appear to confirm our inference for the availability of leachable uranium in the Silver Plume. Acid soluble lead from the shale and sandstone indicate a 1410 m.y. (Silver Plume) source characterized by high thorium concentrations and by a low ratio of Th/U. A paleohydrologic system capable of transporting and depositing uranogenic Silver Plume lead to the Hansen deposit also could have carried uranium from the uraniferous Silver Plume source area.

Although we cannot prove that the source of uranium in the Tallahassee Creek area was Silver Plume Granite, and Tertiary volcanic rocks also probably supplied significant amounts of uranium (Dickinson and Hills, 1982), the inferred fertility of the Silver Plume Granite, its abundance in areas adjoining Tallahassee Creek, and the demonstrated former existence of an appropriate paleohydrologic system for transporting lead from the Silver Plume and depositing it in the Tallahassee Creek area make highly probable that the Silver Plume Granite supplied part of the uranium now found in the Tallahassee Creek deposits.

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