COAL AND URANIUM INVESTIGATION OF THE YUKON FLATS CENOZOIC BASIN

By

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OPEN FILE REPORT 140-81

UNITED STATES DEPARTMENT OF THE INTERIOR

James G. Watt, Secretary

BUREAU OF MINES

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ILLUSTRATIONS

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ABSTRACT

The coal and uranium resource potential of the western Yukon Flats was investigated by the Bureau of Mines during the field seasons of 1978 and 1979. Previously, the mineral endowment of the area was largely unknown and there only existed partial 1:250,000 scale geologic reconnaissance mapping. The Yukon Flats is an extensively vegetated sedimentary basin of interior Alaska in which terrigenous sediments have been accumulating since Eocene (?) time. Preliminary evidence presented in this report suggests that sedimentation apparently has been taking place under climatic conditions typical of the mid-Tertiary at higher latitudes elsewhere. Conditions then were warm to para-tropical and may have varied to rather hot and arid. Evidence includes relatively thick coal formations, the extensive occurrence of non-marine evaporite minerals, undated but typical of continental arid saline lakes, stratiform tungsten enrichment, and fossil data which was previously reported. A sample of volcanic ash gave a Late Eocene K-Ar date of 38.6 $\pm$ 1.6 m.y.

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Coal occurrences of the upper Dall River were sampled by shallow auger holes where a coal seam of 5.49 meters or more in thickness was found. Lignite A to subbituminous B coal was sampled on the Ray River, the Tozitna River, and the Hodzana River, in addition to other Yukon valley locations. Coal occurring on gravel bars at a second location on the Hodzana River was found to exhibit coking characteristics.

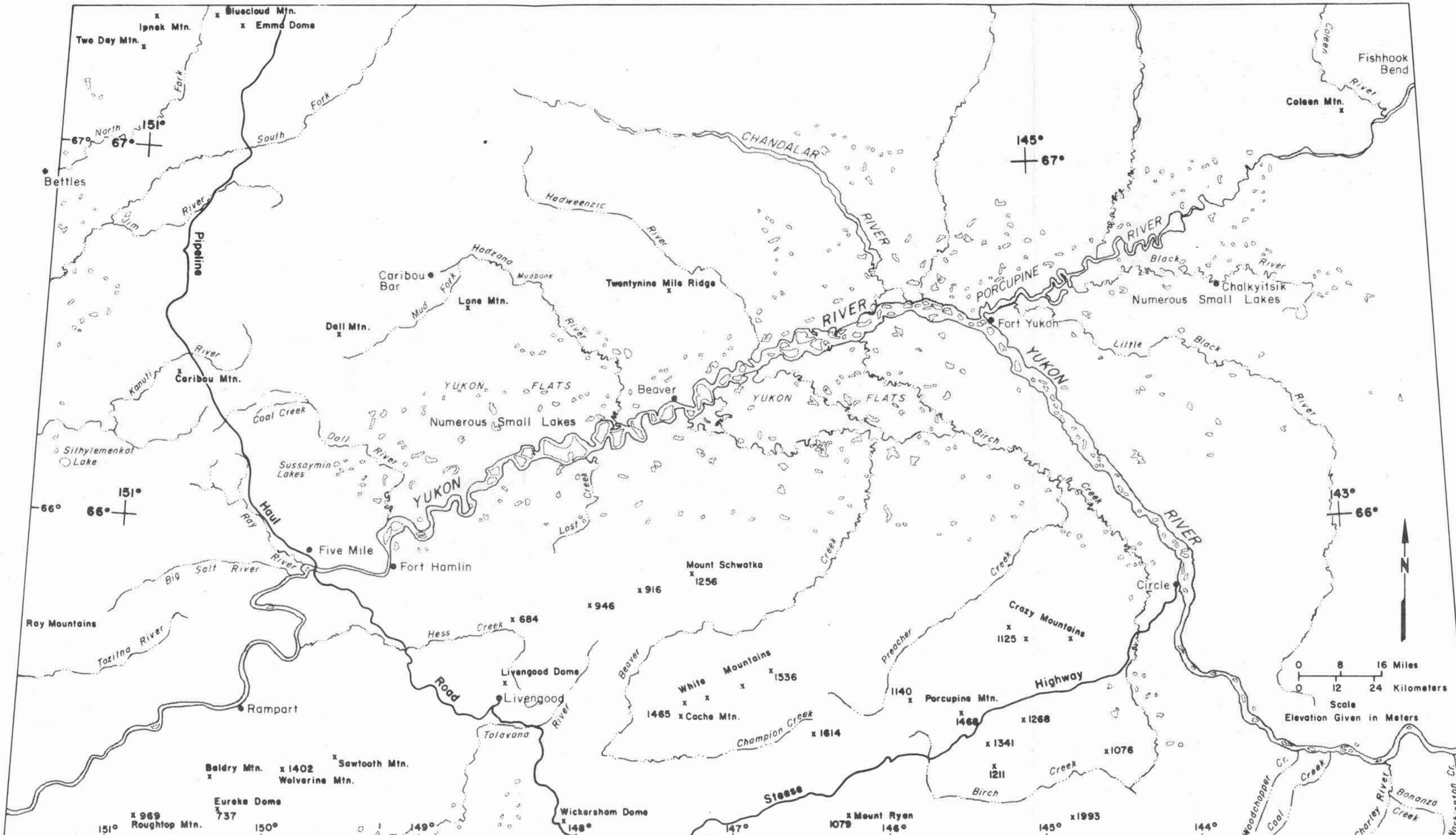
Felsic volcanism in the northwest Yukon Flats has resulted in a favorable setting for the occurrence of uranium deposits. Water-lain tuffs, volcaniclastic sediments, pyroclastics and welded tuffs were mapped and described. Interbedded sandstones and conglomerates with abundant carbonaceous plant material and favorable porosity are available as host rocks. Chemically complex ground waters during the mid-Tertiary are suggested by the presence of phosphorous minerals and anomalous tungsten. On Coal Creek, uranium rich in outcrops of interbedded tuffaceous water-lain sediments and mudstones was on the order of 20 to 50 ppm uranium.

No subsurface exploration was conducted and while no uranium deposits were found, it was felt that the necessary conditions for their formation may have existed in the western Yukon Flats.

A variety of other mineral occurrences were found, e.g. soda ash (trona), bromine minerals, bentonite, placer gold, cesium, and zeolites. Locations are given, but no specific study of these commodities was made.

INTRODUCTION

In 1978 the U. S. Bureau of Mines initiated a mineral resource review of a region that constitutes the drainage systems of the Hodzana and Dall Rivers, and portions of the adjoining Yukon Flats (fig. 1). Field work was undertaken in 1978 and 1979 by means of foot and boat traverses with



Base taken from USGS Fairbanks and Dawson 1:1,000,000 Quads (Lambert Conformal Conic Projection)

FIGURE 1 : LOCATION MAP

limited helicopter and fixed wing support. The report also draws on ten years of intermittent experience in the Yukon Flats region by the author. After review of the field data it was felt that a report of investigations specifically addressing the potential of coal and uranium was warranted.

Earliest exploration of the Yukon Flats region probably began with Dall (1870)(20). [2/] Others, Schwatka (1885)(39), Spurr (1898)(42), Raymond (1900)(36), and Stone (1906)(43) made mention of the area during their travels in the Interior. Reconnaissance of the sedimentary rocks of the western Yukon Flats was first reported in detail by Mendenhall in 1902 when he visited the Dall River valley and noted the coal occurrence there (27). Collier in 1903, reported on coals in the Rampart district (19). While many workers have made passing geological references to the area since then, including Brooks (7) and Mertie (30), it wasn't until Williams in 1962 (49), that the geology of the Yukon Flats was specifically addressed. His work has remained to date the most complete reference to that area. Geologic reconnaissance quadrangle maps, 1:250,000 scale, were prepared by Brosge, 1973 (13), of the Beaver Quadrangle, in 1964 of the Chandalar Quadrangle (11), and in 1969 of the Coleen Quadrangle (12); Chapman et al, 1971 (15), of the Livengood Quadrangle; the Black River Quadrangle was mapped by Brabb, 1970 (6); and the Christain Quadrangle by Brosge, 1962 (10).

Several reconnaissance scale geophysical studies have been made which include the Yukon Flats. Zietz and others in 1960 (51) and Brosge and others, 1970 (8), reported possible interpretations of

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2/ Numbers in parenthesis refer to references cited at the back of this paper.

aeromagnetics. Barnes, 1971, conducted a broad scale gravity survey (2).

In 1977, results of an airborne radioactivity survey were released by the Energy Research and Development Administration under the NURE (National Uranium Resource Evaluation) program (46). This nineteen quadrangle survey included most of the study area.

There has been little past interest on the part of the mineral industry in the Yukon Flats and at present the entire area east of the pipeline corridor is withdrawn from mineral entry or lease under the statutes of the Alaska Native Indian Lands Claim Act (ANILCA) of 1980, and currently included within the Yukon Flats National Monument.

The results and conclusions presented in this report are preliminary and should not be considered in any way to be conclusive with respect to the ultimate mineral potential. Due to the extreme lack of outcrop available for examination, this report is only intended as a guide to the depositional environments potentially favorable for mineral deposits of the types discussed.

ACKNOWLEDGEMENTS

Investigations of the western Yukon Flats was funded in part by the U. S. Bureau of Land Management as part of their inventory of mineral resources near and within the Trans Alaska Pipeline Corridor.

The author would like to particularly acknowledge the assistance of T. C. Mowatt and W. S. Roberts, who provided x-ray diffraction and mineralogical analyses, as well as a technical review of the paper. Technical review was also provided by K. Clautice of the Bureau of Mines. The project was assisted by Carl Backlund who served as a geological field assistant.

Samples were analyzed under a grant from the Department of Energy to the Los Alamos Scientific Laboratory. Analyses were made of 44 elements including uranium and thorium by a combination of x-ray fluoresence and neutron activation methods. Their results and procedures will be concurrently open-filed by that department. Sample analyses, in a few cases, as noted, were also done by TSL Laboratories of Spokane, Washington. Coal analyses were performed by the Mineral Industry Research Laboratory, University of Alaska under the direction of Dr. P. D. Rao. The age date determination was made by Krueger Enterprises, Inc., Geochron Laboratories of Cambridge, Massachusetts.

Base maps used in this report are adapted from standard U.S.G.S. quadrangle maps of the area.

PHYSIOGRAPHY

The study area in figure 1 comprises the western Yukon Flats, which is part of a large lowland alluvial plain and marginal upland. The region has been termed the Yukon Flats section of the intermontane plateau system of Alaska (48). The flat, marshy, lake dotted central flood plain dips slightly to the west, varying in altitude from 183 meters above sea level in the east, to 91.5 meters in the west.

The flats are entirely drained by the Yukon River which exits through a canyon at the western-most edge of the basin. The Yukon River and its tributaries are constantly changing and eroding new water courses. The results are abandoned and filled meanders and ox-bow lakes covering hundreds of square miles of the terrain.

Figure 2. Central Lowlands of the Yukon Flats:
Yukon River flowing S. E. across the central lowland of the Yukon Flats toward Ft. Yukon. The Hodzana River enters the Yukon from the left.

All of the major tributaries are gravel-bottomed and flow with a moderate current. While all tributaries to the Yukon Flats are clear water streams, the Yukon itself, is extremely turbid with glacial flour derived from its headwaters in the coastal mountains and the Alaska Range.

Surrounding the central lowlands are gently rolling marginal slopes which gradually grade into the adjacent hills of the highlands. Generally an escarpment was observed where the flood plain joins the marginal slopes. Streams entering the basin have cut V-shaped canyons into this escarpment. The entire region is covered with continuous, unbroken vegetation of muskeg and tundra with thick growths of alder, willow, aspen and spruce forest and accompaning dense underbrush. Tree growth is extremely cyclic and climaxes with spruce growth that supports the frequent summer forest fires, burning as much as hundreds of thousands of acres at a time.

The Yukon Flats and surrounding areas are classified as being underlain by discontinuous permafrost (48). However, permafrost will nearly always be found in all terrain except under active principle water channels and some larger lakes. Pingos and thaw lakes are occasionally observed on the marginal upland slopes and in highland valleys where thick deposits of ice-rich, fine-grain silt have accumulated. A well at Ft. Yukon encountered ice lenses to a depth of 119 meters (49).

The intermontane region, and particularly the Yukon Flats, is noted for being one of the coldest (mean minimum January temperature of -33°C. [-28°F.] at Ft. Yukon), warmest (mean maximum July temperature of 24.5°C. [76°F.]) and one of the driest areas of Alaska, only receiving approximately 20.3 cm. of annual precipitation (48). Mean total snowfall is 114.3 cm., as recorded at Ft. Yukon (49).

Ground access to the region is generally limited to barges and other water craft which can operate on the Yukon and its larger tributaries (mid-May through October). The Steese Highway, open only in the summer, terminates at Circle on the Yukon and the pipeline haul road crosses the Yukon River 32.18 km. (20 mi.) downstream of the westernmost end of the flats. Improved air strips exist at all of the villages. Ft. Yukon, the largest settlement in the region, has a 1524 m. IFR gravel runway capable of handling all bush and cargo planes operating in the Interior of Alaska. Total population of the region is approximately 1500, with about 800 of those residing in Ft. Yukon.

GEOLOGY

Regional Setting

The Yukon Flats lies over a structural basin [Yukon Flats Basin (34)] representing the presumed intercept of the Tintina and Porcupine-Kaltag

Fault systems. The western Yukon Flats region is bordered to the west and north by the tectonically disturbed, crystalline, Hodzana Highlands. Basement rocks of lower Paleozoic quartz-mica and quartz-feldspathic schist, marble, quartzite and phyllites are regionally metamorphosed to greenschist facies (13). Small bodies and sills of greenstone of unknown age are also found. A northeast trending series of quartz-monzonite to granite plutons have intruded the lower Paleozoic basement and form the core of the Ruby Geanticline (34)(fig. 3). Contact metamorphic aureoles and hornfels development are a notable feature of the highlands with frequent biotite, andalusite, staurolite, pyroxene and actinolite development being observed. Bordering and apparently underlying much of the southern and northern portions of the western flats are Permian to Triassic mafic intrusive and volcanic rocks with undifferentiated sedimentary strata. Collectively the lithology is known as the Rampart Group (9). Sheeted dikes, as well as intrusive masses of diorite and gabbro are found intruding andesite flows and the chert and clastic units.

Tertiary bedrock is exposed at only three localities in the extensive western Yukon Flats study area (Coal Creek and two locations on the Hodzana River)(fig. 3). Float rock and creek rubble of coal were found at several additional locations (Ray, Dall and Hodzana Rivers) and sandstone, tentatively of Tertiary age, at Lost Creek. In addition, although not in the study area, Tertiary outcrops on the Porcupine River, Tozitna River and the Yukon River in the Rampart area were also examined and will be referred to in this report. Felsic volcanics of probable Tertiary age are found near Lone Mountain (16) and were identified in this study on the Hodzana River.

Although bedrock exposure is frustratingly scant, much of the gently sloping marginal uplands to the western flats are believed to be underlain by

LEGEND - FIGURE 3

Felsic volcanics

Strucural basins with Cenozoic sediments

Quartz monzonite — granite terrane, after Biekman, 1978 (5)

Pre – Cenozoic bedrock

Yukon Flats

Marginal uplands

Inferred contact

The locations of the Kaltag (—) Porcupine and Tintina Faults are approximate projection only, based largely on evidence from satellite imagery of major fault trenches. Currently there is considerable dispute regarding the actual fault traces and their interpreted displacements.

Coal occurrence

Evaporite minerals occurring on dry lake beds

1/ Adapted from Payne, 1955 (34)

2/ Adapted from Williams, 1962, modified in accordance with additional field operations (39)

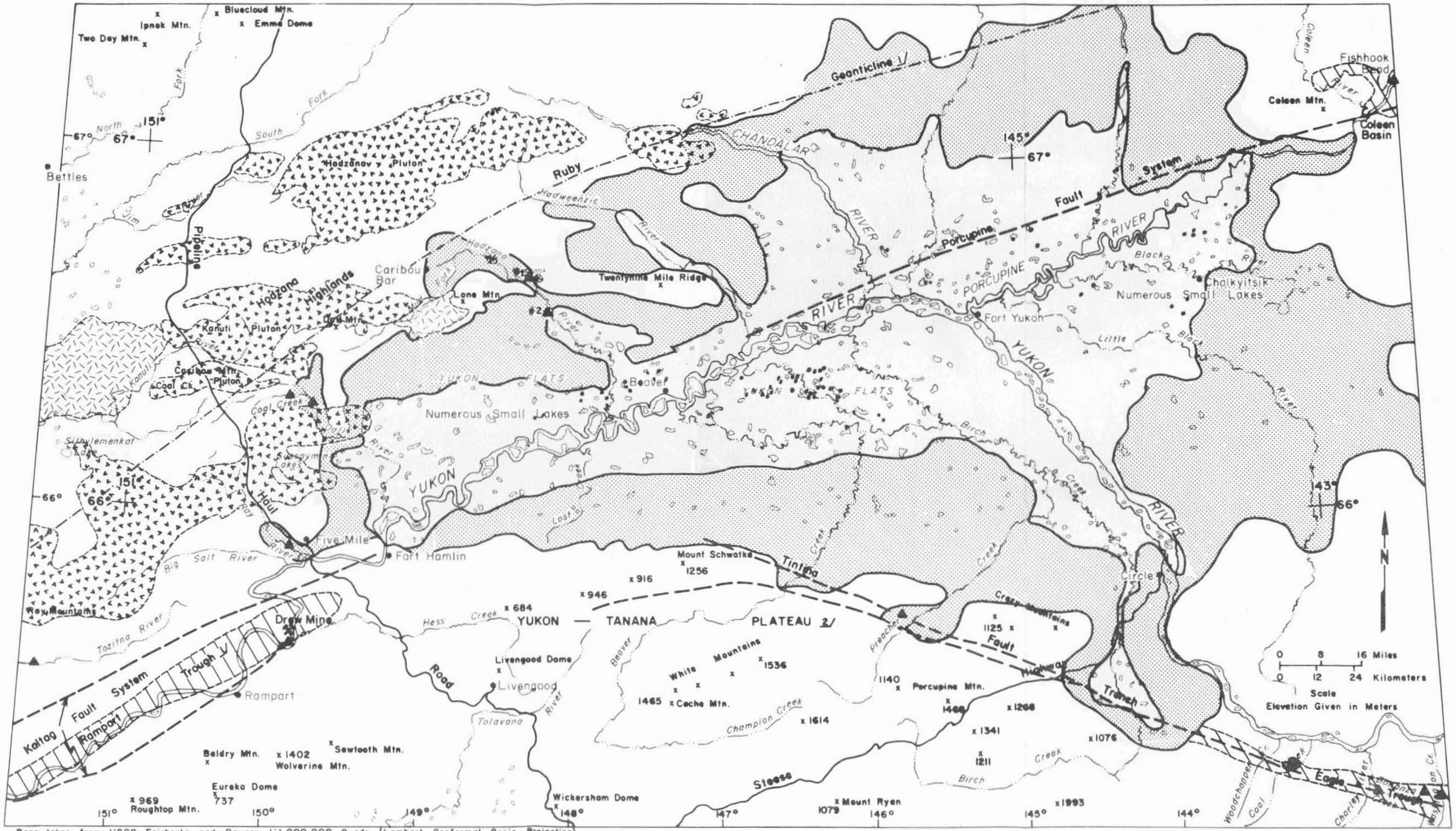


FIGURE 3 : REGIONAL GEOLOGY

stratified Tertiary rocks (49). In the study area, this would include the region between the Dall and Hodzana Rivers, approximatley 80 km (50 mi.) distance, as well as the southern margin eastward to Lost Creek. Very limited helicopter reconnaissance of these areas failed to find any additional Tertiary outcrops. Extension of the same Tertiary strata under the Yukon Flats proper is quite probable, but in view of the total lack of drill data is purely speculative at this time.

Extensive late Tertiary or early Quaternary deposits of high level gravels overlie and surround the flats. Some are composed of metamorphic and igneous clasts, obviously of local derivation, while others are composed of chert quartz-pebble aggregate similar to present day gravels of the Yukon River.

Stratigraphy and Age Relationships

Pre-Cenozoic

The Cenozoic succession is disconformably underlain by early Mesozoic mafic volcanics and early to mid-Paleozoic meta-sedimentary rocks, which have been intruded by rocks of quartz-monzonite to granite composition (16, 19). There is a notable absence of Cretaceous sediments, which can be explained by any one of several scenarios of erosion and orogeny at that time. While no age dates have been made on the felsic intrusions in the immediate vicinity (including Coal Creek and Ft. Hamlin Hills plutons) they are believed to be Cretaceous based on spatial association and compositional similarities to other intrusions of the Ruby Geanticline. A potassium-argon date on biotite of 101 ± 5 m.y. was calculated for the Hodzana pluton, approximately 80 km. (50 mi.) north of Coal Creek (16). Another potassium-argon date on biotite gave 90 ± 6 m.y. for the Kanuti pluton (18), located approximatley 35 km. (22 mi.) north of Coal Creek. A third date of 106 ± 3 m.y., also on biotite, was calculated for the Sithylemenkat pluton, 64 km. (40 mi.) west (16).

Further stratigraphic differentiation of the pre-Cenozoic basement rocks will not be attempted, given the scope of this report. The reader is referred to Brosge, et. al. 1969 and 1973, (9, 12), Williams, 1962, (49), and Chapman et. al., 1971 (15), for additional descriptive information.

Early - mid Tertiary

The Tertiary sediments of the Yukon Flats region were deposited in what is believed to be an Eocene (see Table 1) structural depression (34).

TABLE 1: Subdivisions of the Cenozoic
"Millions of Years Ago"

Quaternary	Holocene	.012 m.y. to present
	Pleistocene	1.5
Tertiary	Pliocene	5
	Miocene	23
	Oligocene	33
	Eocene	53
	Paleocene	65

Adapted from Wolfe, 1978 (50)

The Tertiary sequence of the western Yukon Flats, where it could be examined for this report, consists of non-marine, coal-bearing mud and claystones, quartz sandstones and poorly sorted conglomerates with a soft, sandy matrix, rarely with a carbonate component. Carbonized wood and plant fragments were commonly observed in sandstone and conglomerate.

Rhythmically bedded conglomerates and sandstone appear to be basal in the section observed on Coal Creek. The conglomerates are composed largely of sub-rounded to sub-angular schist, quartzite, greenstone, micaceous sand, and vein-quartz clasts apparently derived during a period of up-lift of the surrounding Paleozoic/Precambrian (?) highland, or conversely, by subsidence of the Yukon Flats basin. Further removed from the highlands, Tertiary gravels/conglomerate such as those exposed on the Hodzana River (fig. 4) show a higher degree of roundness and reworking, typical of gravels in meander channels along the present Yukon River.

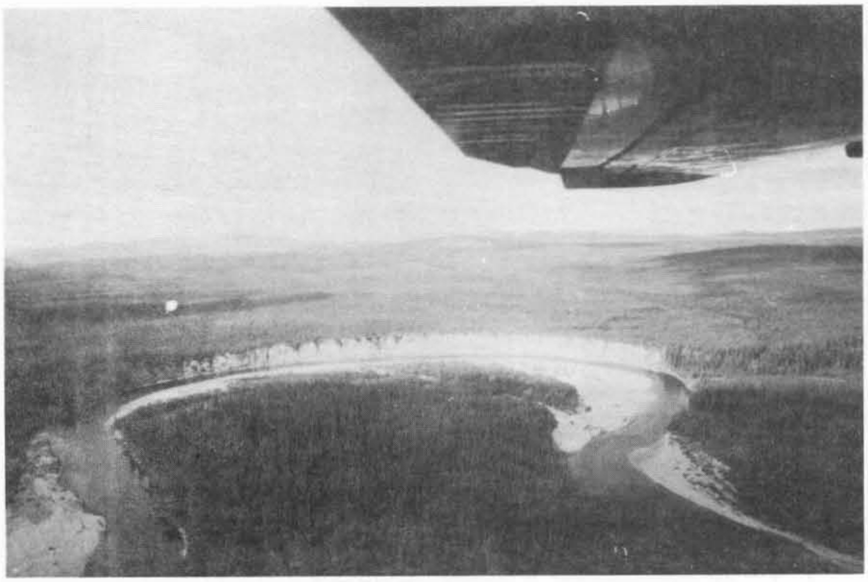


Figure 4. Mudbank: Tertiary bedrock at "Mudband" on the Hodzana River

Higher in the section coal beds were observed to occur with carbonaceous shale and thin clay seams. Associated with the coal are alternating lacustrine (?) mudstones, claystones and silty sandstones with uniform finely disseminated carbonaceous material, and interbedded water-lain tuff and tuffaceous mudstone and pyroclastics (e.g. Coal Creek and the Hodzana River localities). They weather to yellow and buff colors and are frequently stained with iron and manganese.

Pollen found in tuffs and siltstones of the Tertiary sequence exposed on Coal Creek indicated a probable Miocene age (13). Brosge and others (13) report this fossil locality to contain "indeterminate" plant fragments and a diverse and well preserved pollen assemblage containing some conifer (*Picea*, *Pinus*, *Tsuga*), but dominated by broad-leaved genera (*Carya*, *Juglans*, *Pterocarya*, *Fagus*, *Ulmus-Aelkova*, *Liquidamlar*, and others).

During this investigation, however, a sample of water-lain tephra which appeared to overlay a coal section was collected from the Coal Creek locality and dated by the potassium-argon method on fresh glass shards and feldspar phenocrysts. The analyses gave a Late Eocene date of 38.6 $\pm$ 1.6 m.y. as presented below:

TABLE 2: Analytical data for K-Ar age determination

Sample No. HA-15577 - fresh glass shards and feldspar phenocrysts (?)

% K	2.963 3.029 2.996 ave.
Ar^{40} rad (ppm)	.008244 .008419 .008332 ave.

$$\frac{Ar^{40}\ rad}{K^{40}} = .002279$$

$$\frac{Ar^{40}\ rad}{Ar^{40}\ total} = .595$$

Age (m.y.) = 38.6 $\pm$ 1.6 m.y.

Constants used:

$\lambda\beta = 4.72 \times 10^{-10}$/year

$\lambda\varepsilon = 0.585 \times 10^{-10}$/year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

* Analyses by Krueger Enterprises Inc., Geochron Laboratories, Cambridge, Massachusetts.

Felsic volcanism in the northwest portion of the study region has been an obvious contributor to Tertiary sedimentation in the basin, although the total volume is presently unknown. Sources of the volcaniclastic material are conjectural at this point, but presumably at least one source existed near the Hodzana #1 locality in figure 1 (Mudbank) since angular rubble of pyroclastics, welded tuffs and volcanic glass were found there during this investigation. Several miles to the north a paleo-channel system exposed at Mudbank contained coarse gravels and cobbles of similar material, in addition to massive hematite fragments and chips of very vitreous coal.

Immediately west of Lone Mountain, an approximately 103.6 sq. km. (40 sq. mi.) area of Tertiary (?) rhyolites, welded tuffs, rhyolite porphyry and silicified laminated rhyolite flows are mapped (13). The rhyolite is undated but has been suggested to be of Tertiary or Cretaceous age (13). Varieties of the tuffs were similar in hand sample to material found near the Mudbank (Hodzana River) locality, which are Tertiary in age. To the west of the flats, a rhyolite flow on the Kanuti River [48.3 km. (30 mi.) west of Coal Creek] gave a Paleocene hornblende K-Ar date of 58 $\pm$ 1.7 m.y. (33). Investigations along the Mud Fork of the Hodzana River during this study located outcropping and protruding pipe-like (?) structures of obsidian and hematite-rich volcanic breccia with rhyolite clasts and areas of trachyte rubble [12.9 km. (8 mi.) due south of Caribou Bar]. Relationship of the volcanics of Lone Mountain to the quartz monzonite and granite of the eastern Kanuti pluton was unclear due to poor outcrop exposure.

Similar rhyolite was found occurring as abundant detritus in the gravels for several kilometers along the Hodzana River to the northeast of Lone Mountain. Thus, additional unmapped rhyolite is apparently present, although covered by vegetation.

Evidently there was at least a temporary emergence of a shallow lake(s) in the Late Eocene as suggested by the water-lain sediments at Coal Creek and Mudbank. Presumably the Yukon Flats basin is filled with non-marine material, however, the possibility has been raised that a Cenozoic (Miocene?) transgression of the Bering Sea took place and seawater encroached well into Interior Alaska (31). There is presently no direct evidence to support this theory, although Brosge (12) has reported clams (Miocene?) in Tertiary sediments in the Coleen Basin to the northeast, see figure 3.

No estimate of early to mid-Tertiary stratigraphic thickness is possible other than a minimum of the 75 m. exposed in outcrop along the Hodzana River. Miller and others, 1959 (31), were uncertain what relation may exist between the stratigraphic thickness of the Cenozoic rocks on the marginal uplands with those in the basin center. However they postulated a thickening toward the center due to stages of regional downwarping as one possibility. Two structural troughs (Rampart and Eagle) extend from either end of the Yukon Flats in which Tertiary rocks are found and measured. A poorly known third extends to the northeast (Coleen Basin) along the Porcupine River valley. The Rampart Tertiary section (e.g. Drew Mine) to the southwest (fig. 3) is believed to be 1524 m. thick (15). Reportedly the Tertiary rocks comprise a relatively complete section from Eocene through Pliocene (22). Southeast of the Flats along the Eagle Trough (34) it has been estimated that between 900 and 3050 m. of Tertiary sediments were deposited (28, 29). Based on these observations, a similarly thick or perhaps thicker section can be inferred for the Yukon Flats.

Several geophysical surveys have been attempted to ascertain the sedimentary thickness of the basin but conclusions are conflicting. Brosge and others (1970), felt the basin was quite shallow due to aeromagnetic anomalies suggesting a pre-Cenozoic volcanic basement at a shallow depth (8). Barnes (1971), suggested the basin to be comparable in thickness to other Cenozoic basins in Alaska based on low Bouguer gravity anomalies. Interbedded basalt flows in or above the Cenozoic section of the flats may be present and account for the magnetic interpretation. Remnant basalt flows were found (this study) on Coal Creek and late Tertiary or Quaternary basalts are mapped in the eastern Yukon Flats region (6, 12).

The unlikely (?) possibility of erosional removal of the Tertiary sediments below a late Tertiary unconformity (Miocene?) must be considered, although there is no direct evidence for it. Miller and others, 1959 (31), estimated an erosional event in central Alaska which reduced much of the region to a lowland by the end of the Miocene. As a result, much or part of the sedimenatry rocks within the basin proper could have been removed. The Tertiary sections such as those exposed on Coal Creek would thus only be erosional remnants in isolated valleys. This possibility, however, would appear remote.

Late Tertiary - early Quaternary

Amygdaloidal basalts, occasionally with olivine, occur locally on the marginal uplands and appear to cap the Tertiary sections, such as on the Ray River north of Five-Mile Camp and immediately north of Coal Creek. Limited rubble exposures occur along the trace of the North Slope winter trail. The basalts in turn are overlain by the high level gravels.

Sedimentary deposition in the central lowland apparently continued into or resumed in late Tertiary or early Quaternary as indicated by drill cuttings at Ft. Yukon. A well drilled to 134.1 m. encountered 89 + m. of lacustrine silt and silty sand deposits (49). A sample taken from the 95.5 m. level in the well was interpreted to be of late Tertiary or early Quaternary age (49). No fossils were found but pollen of hickory (Pterocarya and Platycarya) occurred in colloidal organic material that Williams suggested was deposited in a deep lake. Interpreted tree genera include pine, spruce, alder, birch, hemlock and fir (49).

On the periphery of the present Yukon Flats are found abundant terraces (Brosge, 1973), composed of poorly cemented to unconsolidated gravels. The assignment of a late Tertiary to early Quaternary age to these high level gravels by Williams, 1962 (49), is based on the weak degree of lithification and a stratigraphic position below an early Pleistocene fan of the Chandalar River.

Excellent, though unstable, exposures were found (this study) along the lower canyon of the Dall River near Sussaymin Lakes, apparently due to a recent down-cutting of the Dall River as it approaches the basin. Relatively youthful canyons were also observed through which flow most tributaries to the flats (e.g. Yukon, Porcupine, Beaver, Birch, Hodzana, Chandalar, Black, etc.)

The escarpments of 30-100 m. that generally mark the foot of the marginal uplands (fig. 3), and which are cut by the river canyons, are probably caused by recent downfaulting or downwarping. The poorly consolidated gravels apparently represent a general period of uplift and erosion of the margins of a subsiding basin. Deposition explained by a setting in which deep-lake sediments near Ft. Yukon were also being deposited has been advanced by Williams (1962). This was followed by eventual filling of the basin, occurring perhaps in the Pleistocene. The proximity of major fault systems (fig. 3) would explain the tectonics of a downwarping basement. The implication of Pleistocene downwarping would be to place the Tertiary strata of the central lowlands at considerable depth, thus adversely affecting the economic potential for coal and uranium in the central basin.

Quaternary

Overlying much of the bedrock of the Yukon Flats are a complex section of glaciofluvial sediments having a northward source, loess and alluvial and fresh water lake sediments as further described by Williams, 1962. The well at Ft. Yukon encountered gray, sandy gravel, interpreted as Pleistocene alluvium of an alluvial fan between 14.6 m. and 45.1 m. in depth. The gravel was overlain by 14.6 m. of recent silty dune sands (49).

Notably extensive fan deposits occur along the northern margin of the Yukon Flats (e.g. Chandalar River). Some eolian sand deposits which have resulted in dune formation are also recognizable.

An extensive mantle of eolian micaeous loess covers much of the underlying geology of the flats, particularly in the marginal uplands. Such deposition is continuing at present. Numerous localities were examined where thickness of 5+ m. occurs. The silt is generally very fine grained, quite homogeneous and extremely susceptible to frost wedging, with interstitial ice contents as high as 50%. Stratification is commonly lacking.

Paleo-Climate and Depositional Environment

The climatic discussion presented here is compiled in this separate section because of the tentative nature of the evidence and assumptions. It is discussed in order to provide some framework in which to consider the following data regarding coal and uranium resource potential.

The climate of the Alaskan early to mid-Tertairy period was obviously favorable for relatively thick coal-forming peat bogs and in some aspects (i.e. weathering and leaching) for mobilizing and precipitating uranium. This subject will be further discussed later in this paper. Climatic conditions at the time and location of the Yukon Flats Cenozoic deposition, presuming correlation to the Late Eocene age date, can only be generalized until more precise age correlations can be made with the stratigraphy. However, it is generally held that through the Eocene period, Alaska experienced a variable warm-temperate to sub-tropical environment (50). Precipitation, at least during the origin of the coal beds, is thereby indicated to be moderately plentiful, suggesting swampy, bog-like conditions with lush vegetation.

The Cenozoic era (65 m.y. through present) in Alaska was one of extensive erosion. Much of Alaska was dry land in which various tectonic depressions formed, with subsequent filling by continental sediments. Most of these sediments were the erosional result of the Laramide orogeny of the early Tertiary (31). Miller and others (1959) felt that this condition existed through to Miocene or later time, and as a result the surface of central Alaska was reduced to a lowland (31).

Wolfe, 1978 (50), described a "Terminal Eocene Event" as a point in the geologic history of northern latitudes where the climate began to cool and annual temperature fluctuations became less equable. This deterioration continued through the late Tertiary until the advent of initial glaciation in Late Miocene. In southern Alaska, Wolfe suggests a decline in the mean annual temperature beginning about 35 m.y. This is based largely on paleobotanical data from the Gulf of Alaska coast. No such data is available in the Interior, where presumably a more continental climate would have existed. In southern Alaska, Wolfe estimates the mean annual Late Eocene temperature ranged as high as 22°C. (70°F.).

There is also evidence in the Yukon Flats that an Eocene or later period or rather warm and arid conditions occurred, which would be expected in an intermontane region. There have been reports of muskeg lakes north of Ft. Yukon which do not freeze in the winter due to the high content of dissolved potassium salts (41). While investigating this further, an extensive east-west trend of shallow alkaline lakes was found that are seasonally re-precipitating non-marine evaporite minerals, e.g. trona and thermonatrite (soda ash), with associated quartz, plagiclase, and calcite, as well as minor amounts of K-feldspar, illite, amphibole, chorite, dolomite and siderite (see fig. 3). 3/ This trend was found occurring from near Chalkyitsik in the east to the Hodzana River in the west (approximately 193 km. [120 mi.]). In late summer when many of these lakes are dry, areas as large as several square kilometers (visible on satellite imagery) are mantled with brilliant white coatings composed of these minerals. False-color photo imagery indicates the mineral-rich alkaline waters are being introduced into present-day lakes from underground sources. Thus the evaporites are apparently being transported by ground water of the Cenozoic basin. It should be noted that there is no surface water drainage into these sites from present upland sources to account for a present day leaching, transport and precipitation system.

3/ X-ray diffraction analyses determined by B. H. N. Veach (47).

Commonly, elsewhere in the world, evaporite and soda ash deposits presently forming occur in hot, dry climates (e.g. Salt Lake, Utah, and Mojave Desert, California). They require a closed continental basin, limited upland drainage and rapid evaporation leading to a concentrated brine that precipitates the salts as successive crystallizations (40). The rate of evaporation must exceed the rate of precipitation. Commonly, the bedded crystalline deposits are associated with continental Tertiary formations and frequently the soda ash minerals (sodium carbonates) are derived from drainage of a volcanic terrane (40). No subsurface investigations have been done in the Yukon Flats to ascertain the presence of bedded deposits.

Samples from the water-lain tuffs and mudstones on Coal Creek are anomalous in tungsten (up to 105 ppm) and phosphorous (see discussion under "Uranium Resources"). Enrichment of tungsten is present only in the mudstone strata, not the tuffs. The mud fractions from which these rocks formed were apparently derived from the Hodzana Highlands where the author has observed a number of minor scheelite occurrences in calc-silicate rocks.

Arid playa-lake brines and muds in southeastern Calfornia are known to contain unusual amounts of tungsten (e.g. Searles Lake)(14). The element occurs as a complex ion in amounts of about 70 ppm and is believed to have come from sediments originally derived from the Bishop tungsten district. A depositional similarity is suggested for further study; no other evidence is currently available and there is presently no evidence of correlation of the Coal Creek tungsten occurrences to the evaporite deposits in the central lowland.

Mudstones of the Hodzana River locality #2 were found to contain local disseminations of nodular vivianite [$Fe_3(PO_4)_2 \cdot 8H_2O$] up to 0.6 cm. in diameter, and veins of hydroxylapatite [$Ca_5(PO_4)_3(OH)$] were found in the Late Eocene outcrops on Coal Creek. 4/ Coal-bearing mudstones with volcanic ash exposed in outcrop on the upper Porcupine River (Coleen Basin) also contained vivianite nodules to 7.6 cm. in diameter, and locally the mineral was found replacing partially coalified wood. These occurrences would suggest reducing conditions, with a warmer climate. Subsequent ground water conditions and diagenetic processes would be chemically different from that now present.

Poorly consolidated gravels of probable late Tertiary or Quaternary age (13) outcropping along the lower Coleen River were found to contain massive conifer logs partially to totally replaced by hematite, indicating a swampy environment for that period in the Coleen Basin.

During Quaternary time (post 1.5 m.y.) the climate of Alaska grew increasingly colder, precipitation increased and glaciation began (50). Large braided streams from the north introduced glaciofluvial material (49). Wind-blown loess from exposed river bars was transported and deposited throughout the flats by winds originating as thermal convections from ice fields. Williams speculated tenuously on the existence of a large Pleistocene lake, perhaps due to glacial damming of the Yukon downstream of the flats, and thus accounting for deposition of lacustrine sediments (49). However, no field evidence of glaciation of this magnitude has been reported. A further downwarping of the basin could also account for such lake formation.

4/ Determination from X-ray diffraction analyses, written communication by B. H. N. Veach and W. S. Roberts (47, 38).

COAL RESOURCES

General Discussion

There has been no production of coal nor systematic exploration of coal deposits in the western Yukon Flats region. Coal occurrences have been known on the Dall River in the vicinity of Coal Creek since 1902, when Mendenhall first visited the area and recorded the occurrence there (3, 27). Over the years there have been reports from the residents of the village of Beaver that coal also occurs on gravel bars in the Hodzana River. A sample collected by villagers and given to the U.S.G.S. was analyzed by the Alaska Railroad in 1942. The analysis showed a "as received" BTU content of 9,400. It was ranked as subbituminous C and gave poor coking characteristics. The exact location of the occurrence of coal on the Hodzana River is not presently known but is believed to be downstream of the occurrences collected and sampled by Bureau of Mines during this investigation. Therefore, an additional occurrence may exist beyond those shown on figure 3.

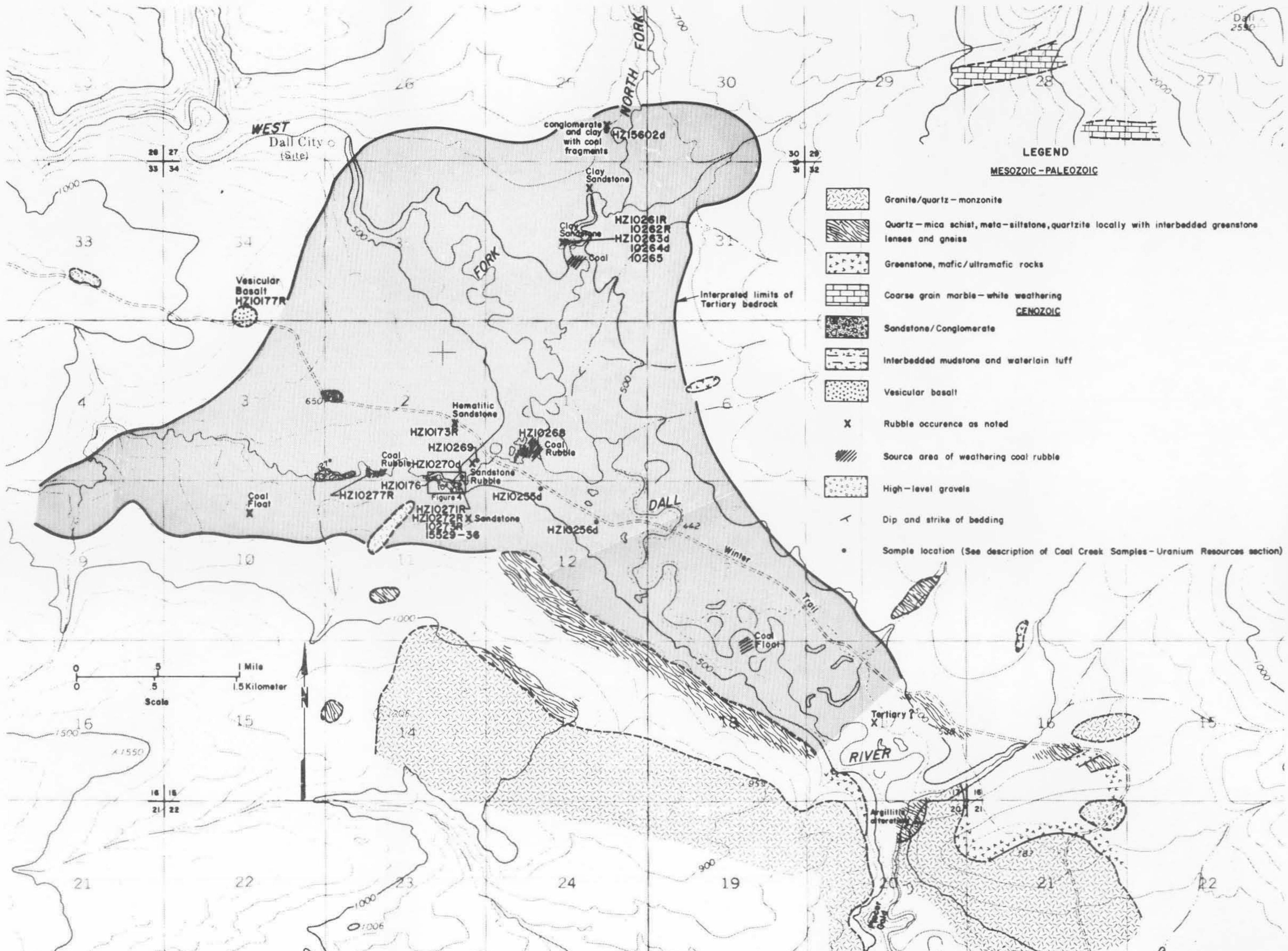
To the southwest of the Yukon Flats in the Rampart district, coal occurrences are known in the Tertiary rocks (3). In the days of the river boats on the Yukon River when steam engines provided power, coal was mined at the Drew Mine opposite the mouth of Hess Creek (fig. 3). To the southeast of the flats, coal also occurs in the Eagle trough (e.g. Coal and Washington Creeks). Minor amounts have been mined for local use.

It must be noted that the heavily vegetated Yukon Flats is particularly prone to sweeping forest fires, the result of which has been loss of coal outcrops which would otherwise exist. Moreover it is quite possible that extensive underground coal fires have occurred. This must be borne in mind when considering the potential of coal deposits based on surface expression only.

During investigations by the Bureau of Mines, two coal occurrences on the Hodzana River were examined, as well as the coal occurrences on the upper Dall River at Coal Creek. In addition, previously unreported coal was sampled on the Ray River adjacent to the Trans Alaska Pipeline, and in the valley of the Tozitna River to the west. Samples collected from these occurrences are listed in Table 3, as well as sample data collected by the Bureau of Mines in previous investigations from the Drew Mine, Porcupine River, Coal Creek (Circle area) and Woodchopper. Classification of rank was done in accordance with ASTM (1) standards on a moist, mineral-matter free basis as follows: BTU (classification = BTU/[100-(1.1 A + 0.1 S)] x 100, where A is ash and S is sulfur. Samples for which no sulfur data was determined, an estimated average value of 0.2% was arbitrarily used. No heavy media cleaning or other special treatment to enhance rank was made during sample preparation.

Coal Creek - Dall River

Coal Creek, a tributary to the upper Dall River, was examined as a follow-up to reports of a coal occurrence there. In addition to the previously reported coal outcrop on Coal Creek itself, several additional sites of rubble were found which indicate near surface occurrences of coal seams (see fig. 5). From the surface expression available, it appears that 15.4 to 20.7 sq. km. (6 to 8 sq. mi.) of the upper Dall River, Coal Creek region, are underlain by Tertiary sediments that are coal-bearing. Within the section, two different seams appear to be present due to the fact that the downstream occurrence of coal on the Dall River has a high content of amber, compared to the coal of Coal Creek where visible amber is rare. There was no associated radioactivity with any of the coal occurrences.



Base topography adapted from Beaver B-6 Quadrangle

FIGURE 5 — UPPER DALL RIVER REGION

Geological data collected during fieldwork 1978-79

Work by the Bureau of Mines consisted of mapping the available showings (fig. 6), collecting representative coal samples, and auger holes drilled to shallow depths. Results of the analyses are shown in Table 3. According to ASTM standards (1), all of the coal from this region is generally of a high grade lignite to subbituminous C grade. This range is typical of Tertiary coal in the interior of Alaska (4). All of the upper Dall River Tertiary strata were found to be generally flat to very gently dipping (up to 10°) to the south-southeast. The coal, where present, would be amenable to standard excavation practices. The extent to which previous episodes of erosion may have removed portions of the Tertiary section in this region is unknown. A grid of auger drill holes will be required to answer this question.

Hodzana River Locality No. 1 (The Mudbank)

Coal seams are exposed in a large cutbank of the Hodzana River (fig. 2) approximately 56.3 km. (35 mi.) northwest of the village of Beaver. Coal occurs as thin seams, not exceeding 30 cm. in thickness and as fragmental debris in strata of mudstone, sandstone and volcanic ash. Seams appear to be discontinuous and folded, but this may be due to weathering and gravity slumping. Much of the coal observed had a very high content of ash. Thinly bedded layers of partially coalified wood also occurred in this sequence. A sample collected from this location, (No. HZ-15542), was from a 30 cm. strata of obviously higher grade coal.

Coal is exposed in only this single outcrop; however, the westerly dipping Tertiary coal-bearing sediments appear to underlie between 10.4 to as much as 130 sq. km. (4-50 sq. mi.) of the Hodzana River valley upstream of The Narrows (fig. 1). Coal horizons lie both above and below strata

TABLE 3. Coal Analyses

USBM Sample No. & Location		Coal (As Rec'd)	Coal Air Dried	Coal Equiv. Bed Moist.	Coal Moisture Free	Coal Moist. & Ash Free	Reflectance	Estimated Rank	Sample Description & Comments
				Basis					
HZ 10174							0.45		Cuttings from 14.5 ft. auger hole,
Coal Creek (Dall River)									coal is continous from 1.5 ft. to
									T.D. of hole, thin clay seam at
Proximate Analysis									10 ft. included in the sample.
	Moisture	NA	17.70	31.69				Subbituminous	
	Volatile Matter	NA	20.23	16.79	24.58	28.25		C	Coal is overlain by thin (6 in.)
	Fixed Carbon	NA	51.37	42.64	62.42	71.75			layer of unconsolidated gravel and
	Ash	NA	10.70	8.88	13.00				soils indicating erosional surface
	BTU	NA	9,918	8,232	12,100	13,852			at top of coal strata.
Ultimate Analysis									
	Hydrogen	NA	5.32	6.32	4.06	4.67			
	Carbon	NA	48.25	40.05	58.62	67.38			
	Nitrogen	NA	0.77	0.64	0.94	1.08			
	Oxygen	NA	34.76	43.95	23.14	26.59			
	Sulphur	NA	0.20	0.16	0.24	0.28			
	Ash	NA	10.70	8.88	13.00				
HZ 10266							0.33		Cuttings from 18 ft. auger hole,
Coal Creek (Dall River)									entire hole was in coal.
Proximate Analysis									
	Moisture	NA	18.73	28.97				on border	
	Volatile Matter	NA	16.87	14.75	20.76	23.17		Lignite A to	
	Fixed Carbon	NA	55.94	48.89	68.83	76.83		Subbituminous	
	Ash	NA	8.46	7.39	10.41			C	
	BTU	NA	8,688	7,593	10,686	11,932			
Ultimate Analysis									
	Hydrogen	NA	5.91	6.58	4.69	5.23			
	Carbon	NA	51.30	44.84	63.12	70.46			
	Nitrogen	NA	0.79	0.68	0.97	1.08			
	Oxygen	NA	33.36	40.35	20.59	22.98			
	Sulphur	NA	0.18	0.16	0.22	0.25			
	Ash	NA	8.46	7.39	10.41				
HZ 10392							0.37		Bulk sample dug from upper 2 ft. of
Coal Creek (Dall River)									coal strata in 3 foot deep test pit.
Proximate Analysis									
	Moisture	NA	11.64	28.76				Lignite A	
	Volatile Matter	NA	28.86	23.27	32.66	40.26			
	Fixed Carbon	NA	42.83	34.53	48.47	59.74			
	Ash	NA	16.67	13.44	18.87				
	BTU	NA	8,021	6,467	9,064	11,189			
Ultimate Analysis									
	Hydrogen	NA	4.64	5.91	3.78	4.66			
	Carbon	NA	46.59	37.56	52.72	64.98			
	Nitrogen	NA	0.76	0.61	0.86	1.06			
	Oxygen	NA	31.13	42.31	23.53	29.00			
	Sulphur	NA	0.21	0.17	0.24	0.30			
	Ash	NA	16.67	13.44	18.87				

TABLE 3. Coal Analyses (continued)

USBM Sample No. & Location		Coal (As Rec'd)	Coal Air Dried	Coal Equiv. Bed Moist.	Coal Moisture Free	Coal Moist. & Ash Free	Reflectance	Estimated Rank	Sample Description & Comments
		Basis							
HZ 15639 Hodzana River							0.15		Coal occurs only as rubble in the river bed. Sample was very vitreous with concoidal fracture taken from small boulder of fresher looking material.
Proximate Analysis									
	Moisture	NA	6.63	23.80				Subbituminous C	
	Volatile Matter	NA	35.01	28.58	37.50	38.49			
	Fixed Carbon	NA	55.95	45.65	59.92	61.51			
	Ash	NA	2.41	1.97	2.58				
	BTU	NA	10,650	8,691	11,395	11,708			
Ultimate Analysis									
	Hydrogen	NA	5.84	6.82	5.46	5.60			
	Carbon	NA	55.09	44.96	59.00	60.56			
	Nitrogen	NA	0.23	0.19	0.25	0.26			
	Oxygen	NA	35.36	45.19	31.56	32.40			
	Sulphur	NA	1.07	0.87	1.15	1.18			
	Ash	NA	2.41	1.97	2.58				
HZ 15542 Hodzana River							0.41		Channel sample of one foot thick seam of coal exposed in outcrop at Mudbank. Coal seam is highly folded (perhaps gravity slumping) and bedded in mudstone with variable ash content. Interlayered 3 inch clay seam was excluded from sample.
Proximate Analysis									
	Moisture	NA	19.54	27.20					
	Volatile Matter	Na	21.79	19.71	27.08	31.29		on border Lignite A to Subbituminous C	
	Fixed Carbon	NA	47.84	43.29	59.46	68.71			
	Ash	NA	10.83	9.80	13.46				
	BTU	NA	8,251	7,466	10,232	11,850			
Ultimate Analysis									
	Hydrogen	NA	5.82	6.33	4.52	5.22			
	Carbon	NA	46.18	41.78	57.39	66.32			
	Nitrogen	NA	0.69	0.63	0.86	0.99			
	Oxygen	NA	36.14	41.15	23.35	26.98			
	Sulphur	NA	0.34	0.31	0.42	0.49			
	Ash	NA	10.83	9.80	13.46				
PB 10384 Ray River							0.32		Coal occurs only as rubble in river bed. Sample was the least weathered coal boulder that could be found. The origin point of this rubble is north of that of PB 10386.
Proximate Analysis									
	Moisture	NA	11.60	33.50				Lignite A	
	Volatile Matter	NA	21.94	16.50	24.81	31.17			
	Fixed Carbon	NA	48.44	36.44	54.80	68.83			
	Ash	NA	18.02	13.56	20.39				
	BTU	NA	8,321	6,259	9,403	11,823			
Ultimate Analysis									
	Hydrogen	NA	5.05	6.57	4.24	5.33			
	Carbon	NA	47.43	35.68	53.66	67.40			
	Nitrogen	NA	0.64	0.48	0.72	0.90			
	Oxygen	NA	27.88	42.97	19.88	24.98			
	Sulphur	NA	0.98	0.74	1.11	1.39			
	Ash	NA	18.02	13.56	20.39				

TABLE 3. Coal Analyses (continued)

USBM Sample No. & Location		Coal (As Rec'd)	Coal Air Dried	Coal Equiv. Bed Moist.	Coal Moisture Free	Coal Moist. & Ash Free	Reflectance	Estimated Rank	Sample Description & Comments
				Basis					
PB 10386							0.34		Coal occurs only as rubble in river bed. The origin of the rubble is south of the coal of PB 10384.
Ray River									
Proximate Analysis									
	Moisture	NA	10.80	24.12				Subbituminous C	
	Volatile Matter	NA	39.13	33.29	43.87	49.01			
	Fixed Carbon	NA	40.71	34.63	45.64	50.99			
	Ash	NA	9.36	7.96	10.49				
	BTU	NA	9,260	7,877	10,371	11,598			
Ultimate Analysis									
	Hydrogen	NA	5.08	15.99	4.34	4.85			
	Carbon	NA	54.81	46.63	61.45	68.65			
	Nitrogen	NA	0.46	0.39	0.51	0.57			
	Oxygen	NA	28.92	37.86	21.67	24.21			
	Sulphur	NA	1.37	1.17	1.54	1.72			
	Ash	NA	9.36	7.96	10.49				
RM 8666							0.25		Coal occurs only as rubble in river bed, often is rich with amber. Coal ranges from black to dark brown and breaks on laminations. Sample taken from less weathered boulders.
Tozitna River (Ray Mts.)									
Proximate Analysis									
	Moisture	NA	15.23	31.88				Lignite A	
	Volatile Matter	NA	23.34	18.75	27.53	32.30			
	Fixed Carbon	NA	48.90	39.30	57.69	67.70			
	Ash	NA	12.53	10.07	14.78				
	BTU	NA	8,463	6,801	9,986	11,715			
Ultimate Analysis									
	Hydrogen	NA	5.73	6.80	4.75	5.57			
	Carbon	NA	49.22	39.55	58.05	68.12			
	Nitrogen	NA	0.79	0.64	0.94	1.10			
	Oxygen	NA	30.91	42.28	20.51	24.07			
	Sulphur	NA	0.82	0.66	0.97	1.14			
	Ash	NA	12.53	10.07	14.78				
HZ 11786R									Channel sample of 5 foot. Thick coal section exposed in creek bank. Includes a 1 ince and a 2 inch clay seam.
Coal Creek (Dall River)									
Proximate Analysis									
	Moisture	11.21	NA	NA				Subbituminous B	
	Volatile Matter	43.10	NA	NA	48.55	51.22			
	Fixed Carbon	41.06	NA	NA	46.24	48.78			
	Ash	4.63	NA	NA	5.22				
	BTU	9,821	NA	NA	11,061	11,671			

TABLE 3. Coal Analyses (continued)

USBM Sample No. & Location		Coal (As Rec'd)	Coal Air Dried	Coal Equiv. Bed Moist.	Coal Moisture Free	Coal Moist. & Ash Free	Reflectance	Estimated Rank	Sample Description & Comments
		Basis							
HZ 11812R Coal Creek (Dall River)									Coal occurs only as rubble in river bed. The coal from this location contains abundant amber unlike other coal in the Dall River area.
Proximate Analysis									
	Moisture	10.07	NA	NA				Subbituminous B	
	Volatile Matter	42.88	NA	NA	47.68	50.47			
	Fixed Carbon	42.09	NA	NA	46.80	49.53			
	Ash	4.96	NA	NA	5.52				
	BTU	9,689	NA	NA	10,774	11,404			
PR 11407R Porcupine River (Coleen Basin)									Channel sample of a 3 foot section of "dirty" coal exposed in river bank on Fishhook Bend.
Proximate Analysis									
	Moisture	34.02	NA	NA				Lignite A	
	Volatile Matter	28.09	NA	NA	42.57	59.12			
	Fixed Carbon	19.42	NA	NA	29.44	40.88			
	Ash	18.47	NA	NA	27.99				
	BTU	5,155	NA	NA	7,812	10,849			
1 Rampart District (Drew Mine)							NA		Sample collected from coal exposure in undercut bank near water's edge about 200 yds upstream of the mine site.
1/									
	Moisture	19.00						Subbituminous B to C	
	Volatile Matter	28.50			35.30	42.10			
	Fixed Carbon	39.30			48.40	57.90			
	Ash	13.20			16.30				
	BTU	8,250			10,190	12,180			
2 Rampart District (Drew Mine)									Sample from coal exposure downstream of the mine site.
	Moisture	17.20						Subbituminous B	
	Volatile Matter	31.90			38.50	45.80			
	Fixed Carbon	37.80			45.60	54.20			
	Ash	13.10			15.90				
	BTU	8,620			10,400	12,360			
4 Rampart District (Drew Mine)									Same as #2, note high ash.
	Moisture	14.90						Subbituminous B	
	Volatile Matter	27.30			32.10	45.90			
	Fixed Carbon	32.30			37.90	54.10			
	Ash	25.50			30.00				
	BTU	7,290			8,560	12,230			

TABLE 3. Coal Analyses (continued)

USBM Sample No. & Location		Coal (As Rec'd)	Coal Air Dried	Coal Equiv. Bed Moist.	Coal Moisture Free	Coal Moist. & Ash Free	Reflectance	Estimated Rank	Sample Description & Comments
		Basis							
5 Rampart District (Drew Mine)									Same as #2, note high ash.
	Moisture	16.20						Subbituminous C	
	Volatile Matter	23.10			27.60	48.80			
	Fixed Carbon	24.30			29.00	51.20			
	Ash	36.40			43.40				
	BTU	5,560			6,630	11,730			
1-CC-62 Coal Creek (Circle District) 1/									Highly fragmented, crushed clean coal 1.5 feet thick.
	Moisture	33.70						Lignite B to A	
	Volatile Mater	29.30			44.10	53.80			
	Fixed Carbon	25.10			37.90	46.20			
	Ash	11.90			18.00				
	BTU	5,500			8,290	10,110			
2-CC-62 Coal Creek (Circle District)									Coal seam 2.5 feet thick with a 3/4" clay seam included in sample.
	Moisture	30.90						Lignite A	
	Volatile Matter	30.70			44.40	51.40			
	Fixed Carbon	29.00			42.00	48.60			
	Ash	9.40			13.60				
	BTU	6,160			8,920	10,320			
3-CC-62 Coal Creek (Circle District)									Coal seam 2.8 feet thick with 4 clay seams, totalling 10 inches included in sample.
	Moisture	32.40						Lignite B	
	Volatile Matter	25.60			37.90	54.60			
	Fixed Carbon	21.30			31.50	45.40			
	Ash	20.70			30.60				
	BTU	4,670			6,910	9,960			
1-Wash-62 Washington Creek (Eagle District) 1/									Fresher, less weathered coal found on gravel bars.
	Moisture	20.50						Subbituminous C to B	
	Volatile Matter	37.60			47.20	50.30			
	Fixed Carbon	37.10			46.70	49.70			
	Ash	4.80			6.10				
	BTU	9,080			11,420	12,160			
2-Wash-62 Washington Creek (Eagle District)									Mixed coal and carbonaceous shale strata 1.75 feet thick exposed in creek bank. Strata is probably thicker than that exposed for sampling. Creek float indicated other seams of higher quality in the area.
	Moisture	19.30						Subbituminous C to B	
	Volatile Matter	25.60			31.70	49.20			
	Fixed Carbon	26.30			32.70	50.80			
	Ash	28.80			35.60				
	BTU	6,440			7,980	12,390			

1/ Unpublished U. S. Bureau of Mines data from investigation of the Rampart Dam project.

of volcaniclastic debris. Near the base of the section that could be examined at Mudbank, a paleo-channel consisting of aggregate composed of volcanic ash, welded tuff and volcanic glass also contained fragments of a higher grade, highly vitreous coal. This suggests additional older underlying coal seams possibly of a higher grade than the section in exposed outcrop. The Tertiary section dips gently, at 5 to 10°, to the west-northwest.

Hodzana River Locality No. 2

Fragments and blocks of coal were found in the river gravels along a stretch of the Hodzana River approximately 8 km. (5 mi.) southeast of "The Narrows". No outcrops of Tertiary rocks were seen in the vicinity. Sample No. HZ-15539 (Table 3) was collected from the least weathered fragments of coal that could be found along the beaches. Coal from this locality was generally quite vitreous and broke with a conchoidal fracture. Coking tests, run as a matter of procedure on all of the coal samples collected during this investigation, indicated that this sample would produce a poor to moderately hard button. As indicated in Table 3, reflectance and BTU content indicated that this sample graded, at best, as a subbituminous coal. Ranking test of surficial coal could have been distorted by weathering or surface oxidation. No estimate is possible of the lateral extent of coal horizons in this area since no structural dip could be measured. The valley bottom is over 1.5 km. (1 mi.) across and extends and widens downstream into the flats. Flat lying Tertiary mudstone does outcrop in the riverbank approximately 3.2 Km. (2 mi.) to the southeast, but no coal horizons were observed. These mudstones lie unconformably on pre-Cenozoic basement rock.

Residents of the village of Beaver in the past have reported coal occurring on gravel bars of the Hodzana. It is possible that the occurrence discussed in this section (Locality #2) is the one referred to, however, the distance to the village is considerable, approximately 161 km. (100 mi.) by river. Aerial photos indicate that an area approximately 32 to 40 km. (20-25 mi.) west-northwest of Beaver also may have bluffs composed of Tertiary sedimentary rock along the southern side of the Hodzana valley (west of an area known as "The Spitover" on the U.S.G.S. Beaver Quadrangle). Coal exposures at this locality are possible but time was not available for on the ground examination.

Ray River

Coal was found as fragments and blocks rising through river gravels at three locations on the Ray River approximately 0.8 km. (1/2 mi.) west of the Trans Alaska Pipeline. No outcrops of Tertiary rocks were found in the area, although a considerable accumulation of mudstones and sandstones typical of that sequence were observed in creek aggregate. Eakin, 1916 (21), makes brief mention of an unverified report of Tertiary strata somewhere in the Ray River basin. Based on the location of this float material it was estimated that Tertiary sediments may underlie approximately 10.6 to 15.5 sq. km. (4-6 sq. mi.) of the small basin extending upstream from this locality. The basin and its margins are in turn overlain by vesicular basalt of a younger age (Quaternary?). Of particular note are the sulfur values of these samples (0.74% and 1.17% @ bed equiv. moist), unusually high for typical Alaskan coal.

Tozitna River Valley

Massive blocks of coal were seen for approximately 9.7 km. (6 mi.) along the Tozitna River between the mouth of Fleshlanana and McQuesten Creeks. The coal occurrence is 64.4 km. (40 mi.) west of Rampart (fig. 3). Creek names are from the U.S.G.S. Tanana Quadrangle. Coal grade ranges from a brown lignite to a black, possibly subbituminous C rank. Disseminated specks of amber are common. Tertiary rocks appeared to be underlying many square kilometers of the wide, flat bottomed valley of the Tozitna River. Chapman and others, 1975, have mapped Tertiary sedimentary bedrock along the south margin of the valley of this area (15). Outcrops are yellow, gray to brown in color, composed of intermittent sandstone and pebble-boulder conglomerates, shale, siltstone and lignite. Based on available outcrop and occurrence of coal in the gravel beds it is estimated that 105 to 130 sq. km. (40-50 sq. mi.) of the Tozitna valley downstream of Gisna Creek is underlain by the Tertiary section. Sample RM-8666 was ranked as lignite A. The sulfur value was slightly high (0.66% @ bed equiv. moist) for Alaskan coal.

Rampart Area - Drew Mine

There are numerous minor occurrences of coal along the Yukon River in an area known as the "Rampart district". Since the area is not within the project area it will only be dealt with briefly and to the extent of previously unavailable Bureau of Mines information and present observations. Studies were conducted by the Bureau in conjunction with investigations of the proposed Rampart Dam project in 1962.

The site of the former Drew Mine is on the west bank of the Yukon River just above high waterline, opposite the mouth of Hess Creek about 40 km. (25 mi.) upstream from the village of Rampart. Between discovery in

1897 and abandonment about 1900, 1,089 metric tons (1,200 tons) of coal are reported to have been mined. Workings are now inaccessible, and virtually no surface evidence of the former development remains.

The former workings and the local geology are described by Collier (19). The workings consisted of a 23 m. shaft with a short crosscut at the bottom leading to a drift which followed the coalbeds for several hundred feet. Much of the coal above the drift was mined out before abandonment. The coal was mined from two seams aggregating 97 cm. of coal within about 5.8 m. of coaly material.

The rocks which include the coal seams are shales, sandstones, and conglomerates believed by Collier to be of the Kenai Series and of Tertiary age. They appear to underlie several square kilometers in a large bend of the river, and lie on the trend of the Rampart Trough. The only rocks seen - shale, sandstone, conlomerate, and coal - were in limited exposures on the steep banks which rise abruptly nearly 60 m. above the river at the mine site. Within the section, a 2.3 m. strata of montmorillonite bentonite, reportedly of non-commerical grade, was observed by Triplehorn (44).

About 5.1 m. of coal and coaly material was sampled (Table 3) and logged (Table 4), and is exposed at the river's edge just downstream from the Drew Mine. The strike of these beds is N 70° E and dip is 80° S, probably with the top of the section downstream. The strike of the beds is about normal to the course of the river. A small exposure of shale overlies the coal, and conglomerate, composing the next exposure, is exposed 61 m. downstream. The material lying immediately beneath the coaly beds is covered by slide debris at the mine site and by river silts beyond. Sandstone, shale, and conglomerate are exposed in the river bank some distance upstream.

TABLE 4. - Log of exposed material-Drew Mine

Material	Thickness Meters	Composite Sample No. (see Table 3)
Shale (roof?)............................	-	-
Brownish-black coal, minor fossil, resin, subconchoidal fracture, no apparent woody texture........................	.9906	2
Organic brown-black shale................	.9144	3
Coal (similar to sample 2-Table 3).......	.5080	4
Soft shale or clay.......................	.0254	3
Slightly shaley coal.....................	.3556	4
Clay.....................................	.2794	3
Bright hard coal.........................	.1524	4
Coaly clay--mostly clay..................	.7620	3
Coal somewhat crushed, minor shale.......	1.3470	5
Mine slough..............................	-	-

It is uncertain whether the coal sampled was the same as that reported to have been mined. The coals sampled were classified tentatively by rank according to standards of the ASTM as subbituminous B and C. The only coal seen was that sampled at the water's edge. There is little to indicate whether thickness of beds persists and whether structure continues without interruption.

Coal occurrences in the Rampart district are generally more highly folded and tectonically disturbed than other known coals of the Interior. While this has resulted in somewhat higher rank coals, the seams are faulted, appear to be discontinuous and frequently are steeply dipping.

Coal Creek (Circle District)

An occurrence of coal 9.7 km. (6 mi.) from the Yukon River on Coal Creek (fig. 3), a tributary to the Yukon River, upstream from Circle, was noted but not visited by Collier. Another more recently discovered exposure of coal 7.2 km. (4.5 mi.) from the Yukon near the left limit of Coal Creek was reportedly found by projection of the location of coal float in dredge tailings; it was uncovered in 1961. Subsequent continued stripping of the thin overburden to allow thawing had reburied part of the section of coal previously uncovered so that only 1.98 m. were exposed and available for sampling at the time of the Bureau of Mines visit in July, 1962. The total thickness was said to be 10.6 m. or more. The coal seam was crushed and fragmentary, and had an apparent east strike and dip of 55° south. Chert pebble conglomerate lies above dark shale at the top of the coal section while a fine-grained, reddish shaley sandstone lies below.

A section near the structural top (may be overturned?) of the coal strata was logged and is shown in Table 5. Table 3, presents approximate analyses of three samples from this deposit.

TABLE 5. - Log of material-Coal Creek (near Woodchopper)

Material	Thickness Meters	Sample No. (see Table 3)
Shale (roof?).......................	-	-
Highly fragmented, crushed clean coal	.4572	1
Inaccessible section (probably coal).	.3048	-
Coal less fragmented than that of sample 2; includes 1.9 cm. clay seam	.7620	2
Coal; incudes 25 cm. of clay in four seams.........................	.8636	3
Covered by overburden................	?	-

Washington Creek (Eagle District)

Before 1900, several companies attempted to mine coal on Washington Creek (fig. 3), which enters the Yukon River from the south, 48.3 km. (30 mi.) upstream from Coal Creek. Some coal was hauled by dogsled to the Yukon, a distance of more than 16 km. (10 mi.) for use on river steamers. Attempts to adapt a steam tractor to winter haulage on a road constructed for that purpose were unsuccessful; production was negligible.

Samples were taken of coal float found on gravelbars (sample 1), and from an outcrop newly exposed in a sloughing undercut streambank about 16 km. (10 mi.) from the Yukon (sample 2). This outcrop was the only one found containing coal in-place, although considerable coal float was found on some of the gravel bars both above and below the sampled outcrop. About 50.8 cm. of mixed coal and coaly shale were exposed in the creek bank; all of the material was included in sample 2. The full width of the seams of better quality coal than that exposed in the creek bank outcrop.

The coal float that constitutes sample 1 may not be representative of the source coal because of selective washing action by the stream. Proximate analyses of samples 1 and 2 are shown in Table 3.

Collier considered the Washington Creek coal to be of probable Tertiary age (19).

Big Salt River

Collier, in 1903, mentions reports by prospectors of coal on "Salt Creek" (19). It appears that this is the drainage currently known as the Big Salt River, a tributary to the Yukon. No investigation was made during the present study, but since coal was found in the adjoining Ray River valley it is quite possible it also occurs on the Big Salt.

Lost Creek

Over the years there have been unconfirmed reports from local inhabitants of thick coal seams exposed in cutbanks along Lost Creek. A helicopter reconnaissance was flown during this investigation which failed to locate any coal outcrops. Nor were coal fragments seen when examining gravel bars. Presumably coal could have been exposed in past years and subsequently burned during forest fires in the area, however, no typical burnt shale was observed either.

A few fragments of soft sandstone were found on gravel bars, however, which are typical of Tertiary sandstone elsewhere. No outcrops were observed.

Hadweenzic River

The upper river flows through a large basin which has a geomorphologic setting similar to the Hodzana and Dall Rivers. Very limited aerial reconnaissance found only continuous Quaternary cover and no bedrock outcrop. Nevertheless, the valley is considered favorable for coal deposits through geologic inference.

URANIUM RESOURCES

General Discussion

There are no reported occurrences of uranium in the western Yukon Flats region, and past exploration has been minimal if not non-existent. Eakins, in 1976, reviewed geology and possible uranium provinces of Alaska including the Yukon Flats basin. No field work was undertaken but further investigation of the Tertiary section between the Dall and Hodzana Rivers was recommended (22). This recommendation was based on the geology described by Williams (1962)(49).

The NURE report on the government-sponsored aerial radiometric survey (1977), indicated a scattering of anomalies, but with no discernible geological pattern. Results were inconclusive. Several of the "preferred" anomalies (high U/Th ratios) south of Lone Mountain were examined by this investigator (No's. 38, 51, 56) and found to be apparently due to differences in the degree of drainage of loess deposits. Dryer loess reflected a higher radiometric background than high moisture/ice content material which generally was overlain by thicker muskeg vegetation. The water-saturated Quaternary cover of loess and alluvium will most effectively shield any uranium concentrations from airborn gamma-ray spectrometry. Throughout the flats a minimum of 50 to 100 meters of frozen loess, sand, and terrace/fan gravels overlie Tertiary bedrock. With thick peat and vegetation cover above that, it is doubtful if aerial or surface radiometrics can be of any effectiveness.

The NURE report and Eakins both concluded that:

> "the Yukon Flats basin contains non-marine sediments of probable Tertiary age, including lignitic or coaly materials, and with tuffs and acidic volcanics in the sediments or in their drainage. These favorable characteristics for potential stratiform uranium deposits are offset by unfavorable aspects including the large amount of water flowing in the Yukon River, the small amount of uranium that has been found, and the frozen ground that prevents water from percolating down from the surface. On this basis, the stratiform uranium potential is generally unknown, but probably not high." (22, 45).

This conclusion, while probably valid for the current physiographic conditions, should be reassessed in the light of the probable paleo-climatic settings as previously discussed in the present report. Arid, para-tropical to warm temperate conditions appear to have persisted throughout the mid-Tertiary. The area apparently continued to be warmer than present and permafrost free, through the late Tertiary, based on the pollen data reported by Williams in 1962, from Ft. Yukon. Only during the last 1.5 m.y. (Quaternary) have conditions tended toward those of the present time.

This investigation considered sedimentary stratiform uranium possibilities of various types, included among which are those associated with erosional margins of granitic plutons. Reconnaissance of the granitic rocks of the Hodzana highlands gave little indication toward their favorability as uranium source rocks. Visible alteration was rare, radiometric background was low compared with other plutonic rocks in Alaska, and rock and stream-sediment sampling indicated no anomalous pattern of uranium or typical path-finder elements (45). 4/ The only exception was one isolated anomaly of 185 ppm uranium found in sediments of a small stream entering the Dall River 6.4 km. (4 mi.) downstream of the confluence of Coal Creek. The creek drained granitic bedrock with quartz-vein material in rubble. No follow-up investigation was made. Since no other anomalies were found associated with the plutons it was felt that the granites were not a particularly likely source of uranium.

Just outside of the western Yukon Flats area the granites at the head of the Ray River had a higher radiometric backgound, approximately twice that of the Hodzana highlands. Chloritic alteration was common, and locally clay and white mica development was observed. An occurrence of radioactive yttrofluorite in greisenization was found (35) 6.4 km. northwest of the Ray River hot springs. Stream sediments in creeks draining this area contained 14 to 79 ppm U. 4/ Further evaluation of the Tertiary section in the Ray River valley for secondary uranium is indicated.

In the past several years there has been considerable new insight and resulting exploration interest regarding uranium deposits of volcanic environments, i.e. the McDermitt Caldera, Nevada; the Challis Volcanics, Idaho, and areas of west Texas (Trans Pecos). While the average uranium content of the earth's crust is 2 ppm, the typical content of felsic volcanics is 5 ppm (37). Deposits occur in a variety of geological

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4/ Data also from forthcoming Dept. of Energy report of analytical results of Bureau of Mines 1979 samples. Grand Junction, Colorado.

settings. During the recent Symposium on Uranium in Volcanic and Volcaniclastic Rocks, held in El Paso (23), many of the newer concepts in origin and ore controls were presented. It is not the intent of this paper to make specific comparisons to these well studied deposits. The knowledge of the Yukon Flats is far too meager for that. It will be attempted, however, to review the known favorable aspects of this region with volcanic uranium deposits as described by Robbins in 1979 (37). The Cenozoic volcanic history of the Yukon Flats does indicate: available source rock; a mode of release through devitrification and intense weathering, i.e. clay, zeolites, etc.; transport of complexed uranium ions; development of lithologic and/or structural traps. Precipitation into suitable host rocks, though not presently documented, is considered favorable.

Uranium deposits forming from volcanic material require the initial release of uranium from volcanic glass fragments through alteration. This can be due to cold ground water circulation. Henry and Walton, 1978, (24), in an exhaustive review of the volcanic terrane of the Trans-Pecos area of Texas and northwest Mexico, described the uranium release and concentration processes which should be applicable elsewhere, including the Yukon Flats. Their work is recommended as background on volcanic uranium deposits such as may be found in the flats.

Coal Creek-Dall River

Thinly bedded water-lain tuffs and mudstones are exposed in a series of low cutbanks along Coal Creek. A stratigraphic section of this outcrop of Tertiary sediments is shown on figure 6. Specific beds contain variable proportions of very fine grained tephra, silt and organic carbonized matter.

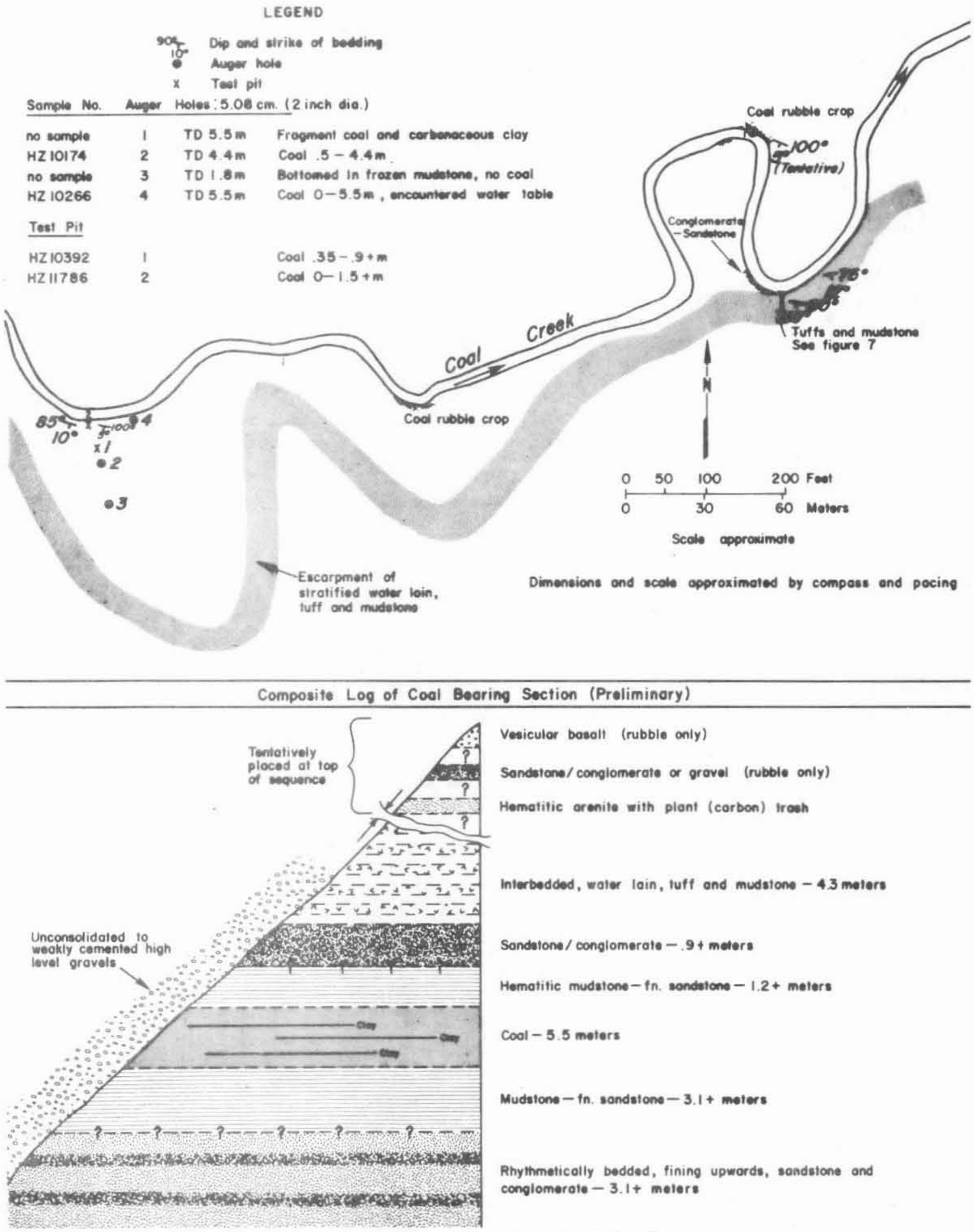

Figure 6 — Coal Creek

Locally, ash appeared to be partially altered to clay. Ash from one of the horizons was dated as Late Eocene during this study.

Increased radioactivity was consistently found over the highly weathered outcrops. Channel sampling of specific beds (fig. 7), was done to determine trace element content as shown on Table 6. Uranium content was anomalous, ranging from 20 to 50 ppm in the mudstone strata. Notable were trace amounts of tungsten (up to 105 ppm), its presence was unexpected but possibly explainable as described in the "Paleo-Climate and Depositional Environment" section. Also anomalous were As, Ce, Cs, Cu, P, and Th, which are sometimes typical of uranium environments (25). Vanadium and nickel were tested for separately but no enrichment was detected. No tests were made for fluorine or molybdenum. All of the anomalous values were found in the mudstone strata, while the tuffaceous beds contained consistently lower concentrations of these elements (see Table 6). Field examination and higher radiometric readings suggested that the uranium was concentrated with manganese as fracture coatings and in carbonaceous matter, presumably derived from the alteration of the tuffs.

Whole rock oxide content (Table 7) was determined for a representative sample from a 7.6 cm. tuffaceous strata (HZ-15534)(partially consolidated volcanic tephra), and from a 30.5 cm. bed (HZ-10272) of thinly bedded tuffaceous mudstone.

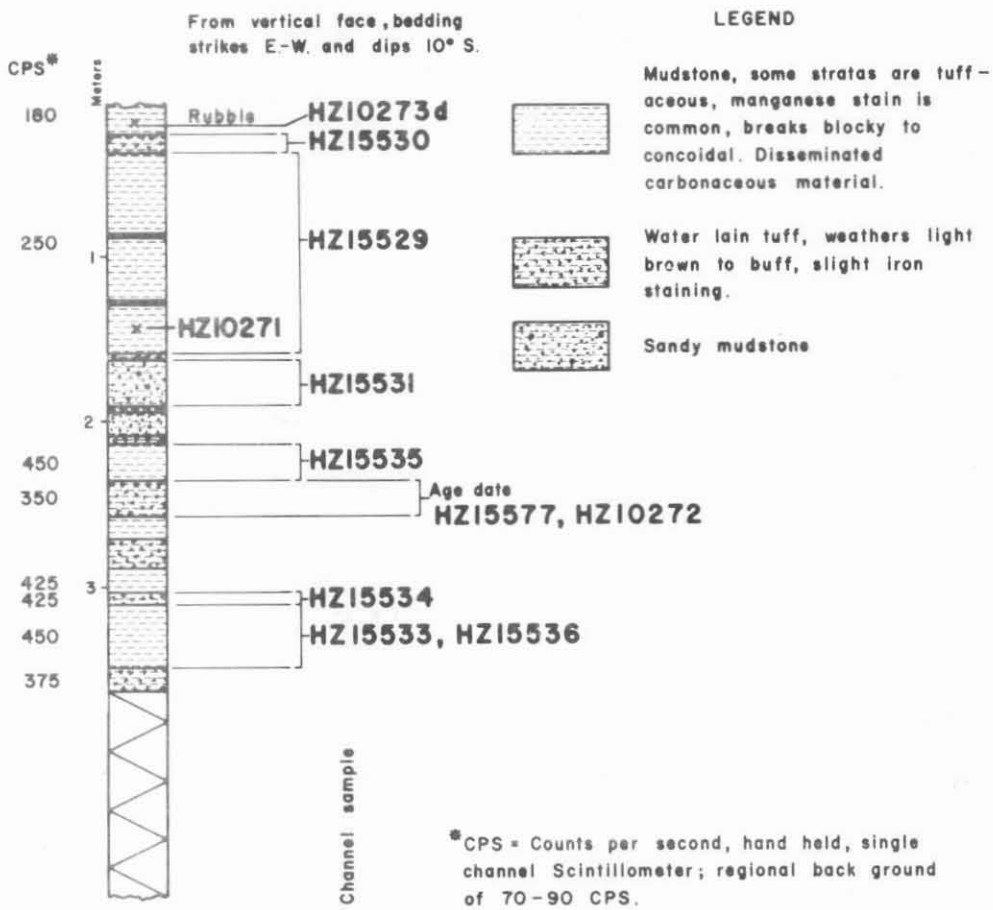

Figure 7.- Profile of water lain tuffs — Coal Creek

TABLE 6. Trace Element Analyses - Coal Creek

	U	Th	Cu	W	As	Ce	Cs	Dy	Eu	La	Sm	Zn	Other	
1/Avg. for earth's crust	2.7	10	55	1.5	1.8	60	3	3	1.2	30	6	70		
Ash Beds	U	Th	Cu	W	As	Ce	Cs	Dy	Eu	La	Sm	Zn	Other	
HZ10272R 2/	8.8													Six inch bedded tuff strata with slight iron staining.
10273d(soil)	5.12	9.4	13	-15	372	60	8.3	5	0.8	32	3.8	98		Soil development at base of cut-bank near HZ10272.
10277R 2/	42.0													Thinly bedded water lain tuff and mudstone ash layers are green to white in color, contain carbonized plant material and disseminated hematite.
15530R	4.75	6.5	26	94	43	23	9.3	3	2.2	12	3.0			Channel Sample, see fig. 5.
15534R	4.13	5.2	19	-15	11	33	5.0	6	1.2	18	-5.9	-157		Channel Sample, see fig. 5.
Mudstones														
HZ10271R 2/	50.0													Grab sample from ten inch tuffaceous mudstone. Slight silicification, manganese stain and minor carbonized plant material.
15529R	24.57	39.0	84	105	58	173	19.1	12	2.0	73	15.7	284	Ag=6ppm	Channel Sample, see fig. 5.
15531R	29.82	47.9	75	73	71	221	24.2	11	2.0	85	18.7	-80		Channel Sample, see fig. 5.
15533R	28.25	35.0	51	68	97	165	14.1	11	2.0	78	14.0	223		Channel Sample, see fig. 5.
15535R	28.36	37.2	89	50	54	191	22.5	13	2.3	77	17.5	-265	Pb-93	Channel Sample, see fig. 5.
15536R	5.89	23.0	26	-15	30	68	25.1	6	0.5	31	5.0	-31	Rb-334	Channel Sample, see fig. 5.
Clay														
HZ10263d	3.27	15.3	70	-15	49	72	10.3	7	1.7	40	7.1	-65		Green clay and shale fragments in gully.
10264d	4.81	19.8	54	-15	32	125	11.7	14	2.8	87	17.5	170	Co-51	Hematitic clay in same location as above.
15602d 2/	4.8													Hematitic micaceous clay in slump are overlying conglomerate.
Stream Sediments														
HZ10176	6.95	30.2				149	5.9	11	1.6	70	11.4	135		
10265	7.50	16.9				155	8.0	11	2.3	71	14.5	-52		
10268	5.15	16.4	22	-15	22	112	4.0	7	1.2	48	7.4	121		
10269	6.44	22.6	30	-15	34	119	6.7	9	1.5	55	9.2	167		
Other														
HZ10255d	5.11	16.0	42	-15	12	108	12.0	9	2.0	57	10.0	-58		Soil from frost boil.
10256d	7.22	15.4	52	-15	24	93	10.7	6	1.4	42	7.1	-146		Soil from frost boil.
10270d 2/	-10			-5	48									Soil down hill of HZ10271
10261R 2/	-10			5	-10									Micaceous sandstone
10262R 2/	-10			-5	-10									Hematitic, micaceous sandstone

1/ Adapted from Levinson, 1974 (25).
2/ Analyses by TSL Laboratories, Spokane, Wa.
All other analyses by Los Alamos Scientific Laboratories, N. M.
U by Delayed Neutron Counting.
As, Cu, W by X-ray Fluorescencel
All others - Neutron Activation.
(-) Indicates value below individual sample matrix detection level.

TABLE 7. Major oxide analyses of tuffaceous sediments - Coal Creek

	percent composition	
	HZ 15534	HZ 10272
SiO_2	55.80	63.30
Al_2O_3	13.70	13.20
Fe_2O_3	4.30	2.70
FeO	9.00	2.00
MgO	0.46	0.30
CaO	1.50	3.10
Na_2O	0.60	0.77
K_2O	1.80	3.40
P_2O_5	0.05	1.60
MnO	0.23	0.14
LOI*	11.20	9.20
TOTAL	98.64	99.71

*LOI - loss on ignition
Analyses by TSL Laboratories, Ontario

The relatively high LOI probably is partially accounted for by the finely disseminated carbonaceous material. The 1.6% content of P_2O_5 in HZ-10272 was felt to be significant because of the vivianite nodules [$Fe_3(PO_4)_2 \cdot 8H_2O$] found in Cenozoic mudstones on the Hodzana and Porcupine Rivers, and the frequent association of uranium with phosphorous as a complexing agent. The occurrence of hydroxylapatite [$Ca_5(PO_4)_3(OH)$] veins in outcrop on Coal Creek suggests the presence of phosphorous during diagenesis. The origin of phosphorous in these fresh water sediments is not clear, but such enrichment has been documented elsewhere, including Tertiary lake beds in Wyoming and Nevada known to be enriched in phosphate and uranium (26). Whether or not the phosphorous content is responsible for uranium enrichment has not been determined to date, but minor amounts of phosphorous, if present during diagenesis and uranium release, would certainly enhance transport of soluable complexes and deposition potential. Select samples of hydroxylapatite vein material did not appear to have increased radioactivity.

Permeability of the water-lain tuffs and mudstone would be considered poor, particularly where clay alteration is further advanced. However, the thinly bedded nature of the units, the presence of coalified plant material, and the close stratigraphic position to the moderately indurated sandstones and conglomerates indicates target areas for mineralization across bedding and/or lateral facies changes.

At sample location HZ-10173, highly oxidized, hematitic, quartz arenite rubble was found where the ground surface was cut by a winter trail. There was a slight but noticeable increase in the radiometric background. The rock was composed of about 3-5% plant trash and was quite porous. Stratigraphic correlation to the tuffaceous beds was uncertain. These sandstones were apparently overlain by a succession of poorly consolidated quartz-schist conglomerate, followed in turn by vesicular basalt. It is likely that there were other interbedded, but unexposed strata of unknown lithology. The affinity of uranium for carbon-rich sandstone (at oxidizing/reducing interfaces) is well documented and should be pursued in this area. The basalt capping, if extensive in the area, offers an additional favorable zone for uranium deposition, where it presents an overlying migration barrier.

Hodzana River

Investigation of this locality was undertaken because of the report of Tertiary sedimentary bedrock exposed at "The Mudbank" (13). The stratigraphic section, as mapped during this investigation, figure 8, includes a variety of mudstone, tuffaceous sediments, ignimbrites, pyroclastics, lignite, clay, chips of vitreous coal and other terrestrial clastics.

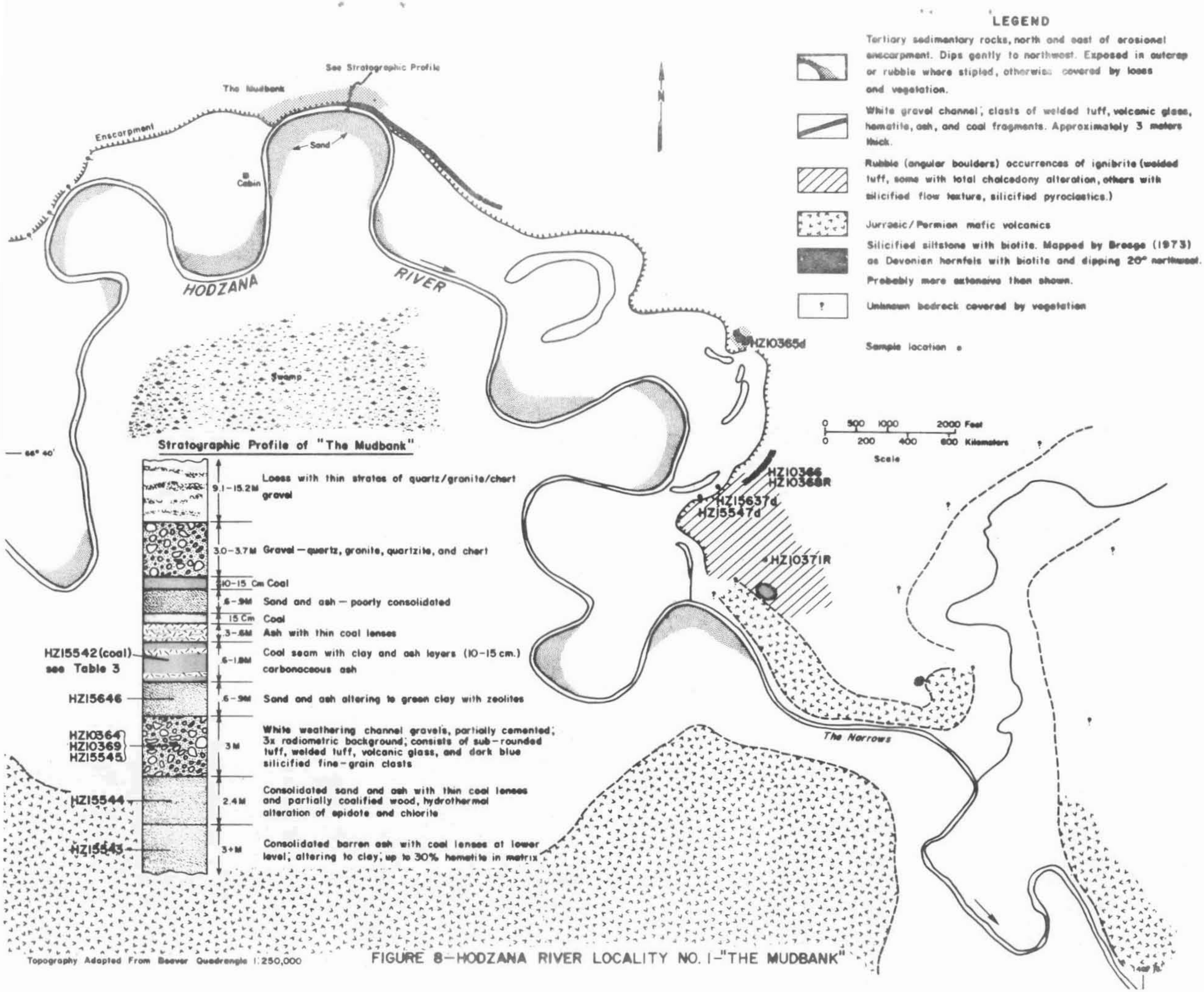

FIGURE 8—HODZANA RIVER LOCALITY NO. 1—"THE MUDBANK"

Of particular interest was the identification of a paleo-channel (possibly a fan deposit) composed of coarse, rounded pyroclastic and welded tuff material, coal chips and other fine grained rock. Massive hematite is also present with the volcaniclastics, and is possibly related to the volcanism. A depositional energy increase and aggregate coarsening was noted as the channel was traced to a volcanic rubble flow area to the southeast. The gravels can be readily traced by their radiometric background of 2-3 times that normal for the Tertiary sediments. They are very poorly indurated and weather as white gravels. Porosity would be considered high.

Volcaniclastic material is of rhyolitic composition with SiO_2 ranging from 72.5 to 83.9%, Table 8. Furthermore, devitrification and secondary (?) silica were noted features. While no unusual uranium values were detected (Table 9), extensive alteration to clay (often green with chlorite) was present, which indicates that any uranium originally present has since been released. Also characteristic of the volcanic glass was a black cast, possibly due to radioactivity damage.

X-ray diffraction mineralogy [5/] of a fine grained, green clay horizon indicates its crystalline phases can be attributed to a volcanic ash origin. Mineralogy included:

- quartz
- cristobalite
- plagioclase feldspar
- potassium feldspar (predominently sanidine)
- zeolite (clinoptilolite/heulandite)
- smectite
- kaolinite
- vermiculite
- chlorite
- biotite (by optical microscopy)

5/ Determinations by T. C. Mowatt, U. S. Bureau of Mines, Juneau (32).

TABLE 8. Major Oxide Analyses of Felsic Volcanics - Mudbank

	SiO_2	AL_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	LOI*	P_2O_5	MnO
HZ 10368	83.9	8.5	-.01	.43	.018	.10	.66	4.9	1.0	.02	.002
tuffaceous breccia in a welded tuff matrix - slight chloritic(?) alteration of matrix, minor biotite and occasional smoky quartz											
HZ 10370B	74.0	13.8	.50	.43	.180	.50	2.80	4.7	1.2	.02	.015
welded, vuggy tuff with quartz laminations and minor biotite											
HZ 10371B	80.3	10.1	-.01	.43	.033	.25	1.40	5.7	1.1	.02	.005
volcaniclastic rock totally altered to cherty matrix with chalcedony fillings and tridymite and clay, very vuggy, relict breccia texture											
HZ 10364	72.5	13.0	.72	.34	.210	.90	2.50	5.4	3.6	.02	.054
volcanic glass, amorphous crystal structure, index of refraction - 1.502											

Analyses by TSL Laboratories, Ontario, Canada
(-) less than
*LOI - Loss on ignition

TABLE 9. Trace Element Analyses - Mudbank

	U	Th	Cu	W	As	Ce	Cs	Dy	Eu	La	Sm	Zn	Other	
1/Avg. for earth's crust	2.7	10	55	1.5	1.8	60	3	3	1.2	30	6	70		
Ash Beds	U	Th	Cu	W	As	Ce	Cs	Dy	Eu	La	Sm	Zn	Other	
HZ15543R	2.79	6.6	55	-15	17	43	3.6	4	0.8	25	3.1	194		Grab sample of typical ash bed-suspended subangular glass shards, no orientation, 30% hematite in matrix and 2% opaques. Fractures blocky.
15544R	3.61	9.5	52	-15	20	58	8.7	5	1.0	22	3.4	-67		Grab sample of ash bed with carbonaceous seams. Very angular quartz fragments suspended in matrix of glass, chlorite, muscovite, clay, iron oxide, and zeolites(?). Altered with epidote and chlorite.
Pyroclastic														
HZ10365d(soil)	6.27	22.8	30	-15	55	132	19.5	9	1.8	60	8.6	61		Soil sample from near or below 'white gravel' unit.
10368R	5.10	19.5	18	-15	47	74	23.9	5	0.7	42	5.0	-39	Rb-313	Tuffaceous breccia - see Table 7.
10369R	5.16	17.6	41	-15	24	71	4.4	4	1.0	37	5.6	139		Bulk sample of weakly cemented 'white gravel' unit.
10371R														Altered volcaniclastic, see Table 5.
15547d	4.85	16.8	13	-15	29	88	48.3	5	1.1	42	5.1	-92		Sandy soil sample with chips of angular rhyolite and banded chalcedony.
15637d	8.5													Sandy soil sample with chips of angular rhyolite and banded chalcedony.
Volcanic Glass														
HZ10364R 2/	-10			5	-10									Volcanic glass, see Table 7.
15545R 2/	-10			-5	-10									Replacement hematite, less than 1% quartz.
Clay														
HZ15646d	3.8													Tuff extensively altered to green(chloritic) clay.
Stream Sediments														
HZ10366R	6.07	18.5	28	-15	38	97	23.1	7	1.4	55	6.6	87		Sediment in gully cutting the 'white gravel' unit.

1/ Adapted from Levinson, 1974 (25).
2/ Analyses by TSL Laboratory, Spokane, Wa.
(-) Indicates value below individual sample matrix detection level.

Analyses by Los Alamos Scientific Laboratories, N. M.
U by Delayed Neutron Counting.
As, Cu, W by X-ray Fluoresence.
All others - Neutron Activation.

Tuffaceous mudstones are interbedded within the section. Glass shards are noticeably coarser in thin section than those observed on Coal Creek. In comparison, tephra beds are not stratified; but rather mixed with quite variable amounts of lacustrine (?) muds and carbonized plant fragments. The matrix included approximately 3-5% thin coaly seams and 5-10% white mica. Alignment of individual glass grains in this section is poor, and they appear suspended in an iron-rich micaceous matrix. Possible zeolites were seen in thin seciton.

No vivianite nodules were observed at this locality but they are found in mudstones of Hodzana locality #2, outcropping 11.26 km. (7 mi.) to the southeast (figs. 3 and 9, and Table 10). Chilingar, 1955 (17), has cited the occurrence of vivianite as indicative of at least a weakly reducing depositional environment. No volcanic constituent was identified in the sedimentary rocks at locality #2, which lies unconformably on pre-Cenozoic basement rocks.

Field data collected at the Mudbank locality suggests several exploration targets favorable for the occurrence of uranium:

1) Mineralization occurring in the down dip (down paleo-channel) extent of the volcanic glass and tuff gravels, where mixing occurs with carbon-rich fine grained rocks with clay composition. This model is discussed by Henry and Walton (24).

2) Permeable gravels with carbon material, overlain by tuffaceous mudstones rendered impermeable by clay alterations, could provide a suitable trap.

3) The pyroclastic rubble observed east of Mudbank (fig. 8) indicates a nearby volcanic source. Uranium mineralization can be associated directly with altered pyroclastics, e.g. ring fractures, caldera margins, structural

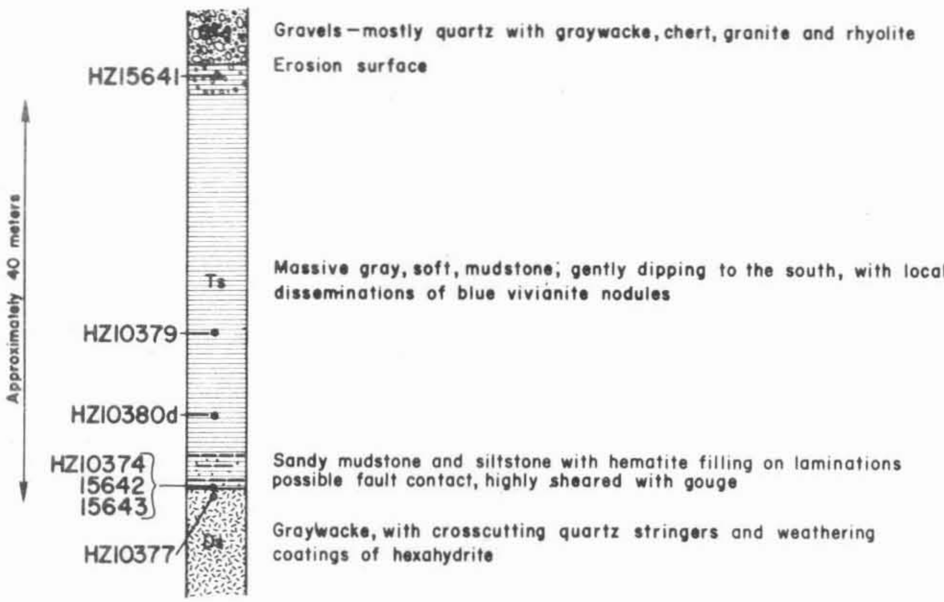

Figure 9 : Composite Section and Sample Locations of Hodzana Locality 2

TABLE 10. Trace Element Analyses - Hodzana River Locality #2

	U	Th	Cu	W	As	Ce	Cs	Dy	Eu	La	Sm	Zn	Other	
1/Avg. for earth's crust	2.7	10	55	1.5	1.8	60	3	3	1.2	30	6	70		
Mudstones	U	Th	Cu	W	As	Ce	Cs	Dy	Eu	La	Sm	Zn	Other	
HZ10379	4.41	12.3	76	-15	23	71	7.2	6	1.4	39	5.7	180		Three foot channel sample.
10380	2.63	9.0	41	-15	11	72	6.5	5	1.5	30	4.7	-65		Grab sample of mudstone with disseminated hematite, distinct grain orientation in layering.
15641	3.8													Chip sample of mudstone with disseminated vivianite.
15642	2.1													Bleached, partially silicified fine grain material at contact.
Pre-Cenozoic Graywacke Contact														
HZ10374	3.78	11.6	48	-15	19	64	7.7	5	1.4	42	6.3	-23		Eighteen inch channel sample across contact which is highly sheared with clay, vivianite, minor pyrite nodules and secondary hexahydrite.
10377	2.02	6.5	31	-15	20	53	2.3	3	0.7	22	3.6	96		Typical grab sample of graywacke, partially silicified contains a few pyrite nodules and unidentified minor blue stain.
15643	2.2													Black gouge and clay at contact.

1/ Adapted from Levinson, 1974 (25).
Analyses by Los Almos Scientific Laboratories, N. M.
U by Delayed Neutron Counting.
As, Cu, W by X-ray Fluoresence.
All others - Neutron Activation.
(-) Indicates value below individual sample matrix detection level.

intersections, etc. These are commonly associated with features such as chalcedony boxwork, which is present here. The Lone Mountain felsic volcanics should also be examined for these types of deposits. For example, an outcrop (36.04 km. west of Mudbank) of altered glassy hematitic volcanics on the Mud Fork of the Hodzana contained stockworks of chalcedony veins and with apatite (?). Analyses (45) indicated trace values of uranium (11.06 ppm) and cesium (231 ppm).

Location(s) of a volcanic vent or caldera(s) responsible for the rubble observed are unknown. To the south, a large circular feature approximately 9.7 km. (6 mi.) in diameter was seen on satellite imagery (image No. 1285-21014). A prominent lineation intercept is also visible to the north in the Hadweenzic valley. No further investigation was made and any further study should include a review of the soon-to-be-released U-2 false color photos sponsored by the U. S. Dept. of Interior, Bureau of Land Management, Anchorage.

DISCUSSION AND CONCLUSION

The Tertiary sediments of the western Yukon Flats were apparently deposited during a Late Eocene period of upper latitude warm temperate to para-tropical climate. Meanwhile, active felsic volcanism occurred and volcaniclastic sediments can be expected to be relatively widespread. Burial and subsequent diagenesis of terrigenous and volcanic sediments took place within geologic and apparent climatic environments favorable for the development of both thick coal seams and uranium deposits.

Although the tectonics are poorly understood at this time, the current evidence generally indicates at least an intermittently downwarping Yukon

Flats basin throughout the Cenozoic. Therefore, the early (?) to mid-Tertiary section is likely to be intact although it may lie at a considerable depth in the central lowlands. A thick section of unconsolidated late Tertiary to early Quaternary sediments overlies the earlier Tertiary rocks in the basin. There is presently no existing subsurface data on the Yukon Flats other than a 121.9 m. well at Ft. Yukon.

Minerals other than coal and uranium may occur in significant quanities in or near the Yukon Flats basin. Included among which are evaporite minerals of soda ash and potash, (other common non-marine evaporites might be expected) etc., low grade tungsten, placer gold, bentonite, zeolites, and construction aggregate. Oil and gas potential is unknown. Other metallic minerals can be associated with felsic volcanism but no direct evidence for any was found. It is not, however, the intent of this paper to discuss the potentials of these minerals in detail.

Coal Resources:

Coal occurrences, tentatively of Eocene age, found on the Hodzana and Dall Rivers of the western flats were examined and sampled. Additionally, in order to obtain a better overall data base on coal in the intermontane plateau system, investigation was made of coal on the Ray, Tozitna and Porcupine Rivers; of the Drew Mine in the Rampart area; and in the Coal Creek-Woodchopper region in the Circle district. Quality of the coal seams, in terms of ash and moisture, can be expected to vary significantly between seams, although rank generally falls between lignite A to subbituminous C. A few localities of subbituminous B were found. Coal occurring as float on gravel bars of the Hodzana River exhibited low to moderate coking characteistics and gave a subbituminous B rank. Further investigation is suggested there.

Some increase in rank was noted in coals found in close proximity to the Tintina and Kaltag Faults, apparently due to slight dynamic metamorphism. Unfortunately these particular coals are also highly faulted, folded, and steeply dipping. Otherwise, coal occurrences that could be measured were generally flat-lying to gently dipping.

A geomorphological setting strikingly similar to Coal Creek and the Hodzana River was found to the east on the Hadweenzic River. The valley upstream of the low canyon near Twentyfour Mile Creek (see USGS Beaver Quadrangle) should be considered favorable for coal deposits. The area, where examined by air, was found completely covered with Quaternary deposits and no bedrock is mapped. However, further detailed reconnaissance is indicated.

From the available data it would be estimated that the hypothetical to inferred coal resources in the marginal uplands are significant, perhaps high. No estimate can be refined until at least limited stratigraphic correlations can be made from future drill holes. Coal, if present in the central basin is likely to be too deep for economic consideration.

Assuming a Late Eocene age for the coal-bearing strata based on the age date from Coal Creek, the coal would then predate the Miocene coal-forming period which resulted in the deposition of the Nenana Coal Field on the north side of the Alaska Range (50). The older age implies a possible increase in rank over typical Alaskan Miocene coals.

Uranium Resources:

There was little encouraging evidence that uranium deposits may be associated with the granitic plutons in the immediate area. However, as in any surficial survey of this type, the possibility can not yet be dismissed. Preliminary field reconnaissance indicated, however, that further investigation should be made of the Tertiary section and granitic rocks of the upper Ray River to the west of the flats.

Interpretation of the field observations clearly does suggest a general favorability for uranium derived from felsic volcanism. There are four basic criteria for the type of uranium deposits that develop in volcanic terranes. First, a source must be present, such as alkaline to silicic volcanic rocks. These contain uranium on the order of the worldwide average of 5 ppm, as compared to the 2 ppm average for the earth's crust. In the case of the Yukon Flats, rhyolite and volcaniclastic material of unknown volume are available as source rocks and anomalous uranium is present. In addition, the sample results have indicated favorable uranium to thorium ratios. Second, transport by complexing agents in chemically favorable groundwaters is necessary. This seems to have taken place at least locally in the flats throughout much of the mid- and perhaps late Tertiary as indicated by the vivianite and hydroxylapatite occurrences, the zeolites and perhaps the tungsten enrichments. Third, a trap to accumulate uranium must be encountered by uraniferous waters. Evidence of permissible traps at Coal Creek include reduction/oxidation interfaces, porous, carbon-rich facies with overlying impermeable stratigraphy, basalt flows and clay zones. Folding and faulting may also be present to aid in development of structural traps. Fourth, a reductant is necessary to precipitate the uranium ions. Field examination showed the frequent presence of carbonized plant material and the occurrence of phosphate minerals which enhances the ability to complex uranium ions and in some cases precipitate uranium minerals. The presence of hematitic sandstone on Coal Creek may indicate reduced pyrititic zones at depth, although in this highly weathered environment none were seen.

Uranium in a typical volcanic terrane can be categorized in four basic models of deposition: 1) Breccia pipes and diatremes; 2) structural and contact intersections; 3) volcaniclastic sediments including tuffaceous sedimentary rocks; 4) calderas and resurgent domes. To this list should be added the well-known sandstone-type deposits which frequently are distally associated with volcanism. These are the exploration models apparently most applicable to the western Yukon Flats based on the present information.

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