DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

THE 1986 ESTIMATE OF UNDISCOVERED URANIUM ENDOWMENT FOR SURFICIAL URANIUM DEPOSITS IN THE SANDPOINT AND SPOKANE NTMS 1°x2° QUADRANGLES, WASHINGTON AND IDAHO

By

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EXECUTIVE SUMMARY

In accordance with the Memorandum of Understanding (MOU) of September 20, 1984 between the U. S. Geological Survey, U. S. Department of the Interior, and the Energy Information Administration, U. S. Department of Energy (USDOE) the Geological Survey is to provide unconditional uranium endowment estimates for selected areas of the United States on a mutually planned and agreed-upon schedule. This initial report summarizes the estimated undiscovered uranium endowment in newly discovered "young organic-rich uranium deposits" for the Colville-Okanogan favorable area in Washington and Idaho within the Sandpoint and Spokane quadrangles. This new estimate is in addition to the estimates of endowment for other kinds of deposits in these two quadrangles given in the 1980 National uranium assessment report (USDOE, 1980). The estimate was made utilizing a modified NURE (National Uranium Resource Evaluation) method developed in accordance with the MOU (Finch and McCammon, 1987).

"Young organic-rich uranium deposits" occur in the surficial geologic environment in which organic-rich fluvial, alluvial, and lacustrine sediments have been laid down mainly in the past 15,000 years (Holocene). Their young age has not allowed the development of radioactive uranium daughter products in sufficient quantities to give off strong radioactive signatures. Thus, until recently, they have gone undetected by normal surface and aerial radiometric surveys. The uranium deposits in the Lake Gillette area extend from the ground surface to depths as much as 7 meters. The grades of samples range from a cutoff of 0.01 percent U_3O_8 to about 1.0 percent and for known deposits average from 0.03 to more than 0.10 percent U_3O_8. Individual deposits generally range from a few hundreds of pounds of contained U_3O_8 to about a 1,000,000 pounds U_3O_8. Because of the shallow and organic character of these surficial uranium deposits, they constitute a viable low-cost resource, and one of them, the Flodelle Creek deposit, has been mined (Joy Mining Corporation, 1983).

The Lake Gillette proto-control area was established on the basis of sampling the Flodelle Creek deposit and the associated identified uranium occurrences in the Lake Gillette 7.5-minute quadrangle. This proto-control area contains reserves of the Flodelle Creek deposit, and the economic resources are classified as Reasonably Assured Resources (RAR). The odds are 9 to 1 that the true endowment lies between 560 and 8,145 tons of contained U_3O_8. The expected or mean value is about 3,222 tons of U_3O_8. This latter value would include the company confidential reserves of Flodelle Creek. This proto-control area was the basis of calculating the undiscovered endowment for surficial uranium deposits in the Colville-Okanogan favorable area.

Based on probability factors, the result of our assessment of the Colville-Okanogan favorable area using the modification of the standard NURE method, designated as the deposit-size-frequency method, is that the odds are 9 to 1 that the true endowment is between 6,738 and 122,310 tons of contained U_3O_8. The mean (unconditional) undiscovered uranium endowment for the Colville-Okanogan area is 35,299 tons of U_3O_8. The economic portion of this endowment is to be classified as Estimated Additional Resources.

INTRODUCTION

On September 20, 1984, the Memorandum of Understanding (MOU) between the Energy Information Administration (EIA), U. S. Department of Energy (DOE), and the U. S. Geological Survey (USGS), U. S. Department of the Interior (DOI), was signed that "... describes the implementation of a agreement for assistance from the USGS in the assessment of U. S. potential uranium resources in support of EIA's work under Public Law 97-415 (January 4, 1983) to develop and provide information about the viability of the domestic uranium mining and milling industry". This MOU is a continuant to the MOU between DOE and DOI dated November 12, 1983 that called for a plan to conduct research on data collected under the National Uranium Resource Evaluation (NURE) Program and to provide for continuing the assessment of the Nation's uranium resources.

In 1985, a modified NURE method, called the *deposit-size-frequency* (DSF) method was developed (Finch and McCammon, 1987), and the assessment of the undiscovered uranium endowment[1] for the new type of organic-rich surficial uranium deposit in the Sandpoint and Spokane NTMS 1°x2° quadrangles, Washington, Idaho, and Montana, was carried out as our initial assessment project (fig. 1). A large non-contiguous area, named the Colville-Okanogan area after the Colville and Okanogan National Forests, was identified within Washington and Idaho to be favorable for surficial uranium deposits The estimate of the undiscovered uranium endowment in the Colville-Okanogan favorable area was made using the DSF method. This new estimate is in addition to the estimates for endowment for other types of deposits in the two quadrangles given in the 1980 National uranium assessment report (USDOE, 1980). The Colville-Okanogan area also was used to test the DSF method by comparing a preliminary estimate of the endowment to that obtained using the standard NURE method. It was found that the estimate by the DSF method is larger and has a greater range of possible values compared to the standard NURE method (Finch and McCammon, 1987).

The chief purpose of this report is to convey the results of the assessment of the undiscovered uranium endowment. Only brief discussions pertinent to these purposes are given, such as the character and geology of the uranium deposits that might be helpful to mining engineers, metallurgists, and economists, the criteria for the determination of the favorable area, and the method of estimating the endowment. Further information may be gotten from the referenced material and, in particular, the report by Finch and McCammon (1987).

We acknowledge the consultation of Luther Smith, EIA, on many aspects of the assessment.

[1]Uranium endowment: the uranium that is estimated to occur in rock with a grade of at least 0.01 percent U_3O_8. Unconditional endowment is based on the assumption that one or more deposits exists in the favorable area.

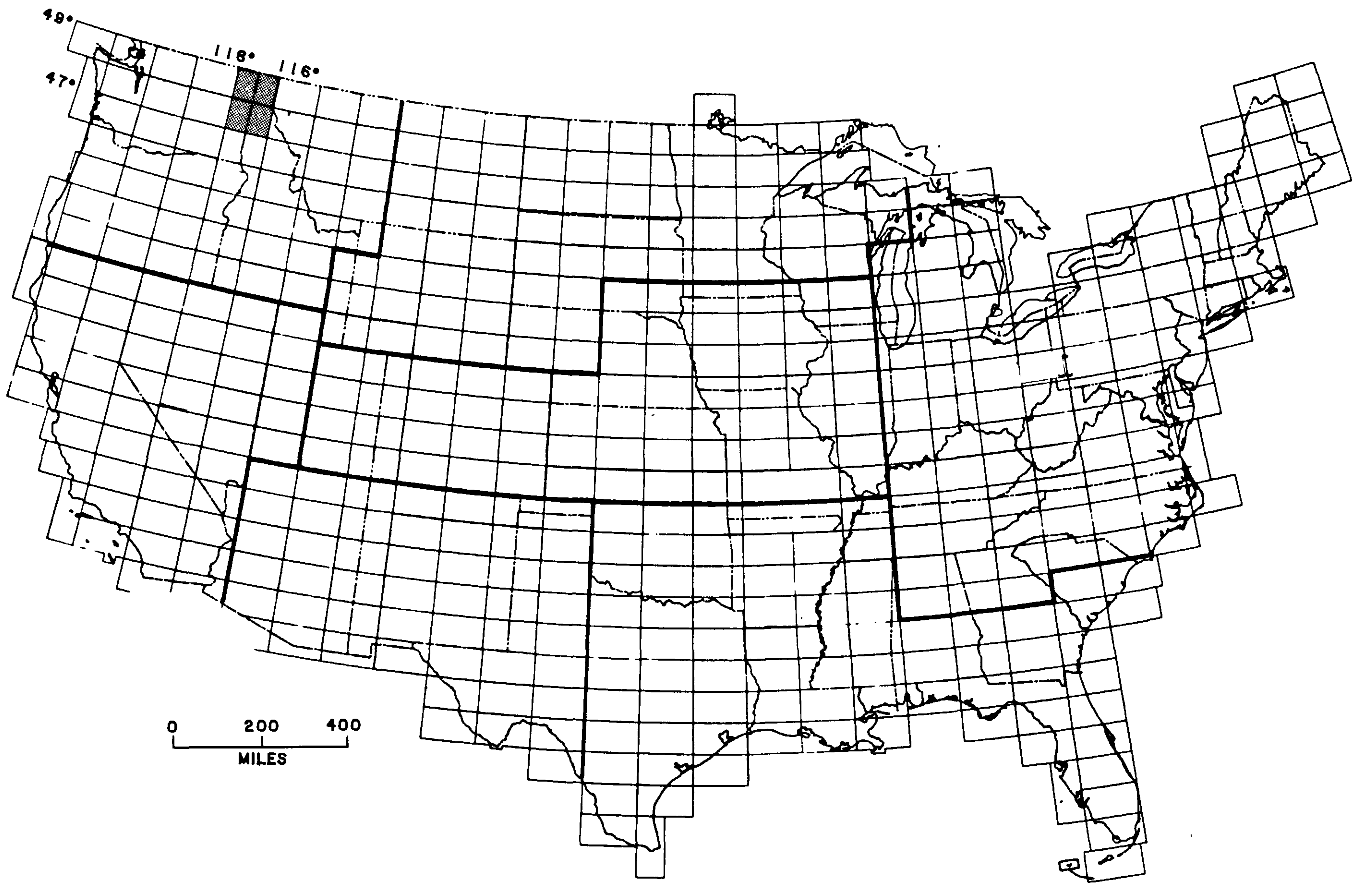

Figure 1.--Location of the Sandpoint (upper) and Spokane (lower) NTMS 1°x2° quadrangles, Washington, Idaho, and Montana.

GEOLOGY AND CHARACTER OF YOUNG ORGANIC-RICH SURFICIAL URANIUM DEPOSITS

Uranium commonly associates with organic matter in sediments and rocks, and research suggests that the uranium is fixed on organic matter by adsorption, ion exchange, and reduction (Otton and Zielinski, 1985,1986). Although several occurrences of uranium in organic sediments of wetland meadows, small stream valleys, and spring seeps were recognized in the U.S. in the late 1950's, largely due to associated radioactivity, it was not until the early 1980's that non- to slightly radioactive occurrences were documented first in Canada and later in the United States (Culbert and others, 1984; Otton, 1984a; Otton and others, 1985; Cameron, 1985). These deposits are low in radioactivity because they are generally less than 15,000 years old, and radioactive equilibrium of uranium and its daughters has not been reached (Zielinski, Bush, and Rosholt, 1986; Levinson and others, 1984).

Formation of these young organic-rich surficial uranium deposits is dependent upon three conditions: 1) a near-surface source of leachable uranium, such as two-mica granite, 2) the presence of surface and ground waters to leach and transport the uranium, and 3) surficial organic-rich sediments to trap the uranium. These conditions most commonly exist in highland to mountainous terranes in the western and eastern states (Cameron, 1985), where uraniferous granitic source rocks are exposed to moderately wet environments and temperate to cool temperatures (Otton and Zielinski, 1985, 1986). The granitic source rocks have an easily mobilized high original uranium content, are highly weathered, and are locally faulted and fractured. Commonly, the granites are markedly eroded due to either tectonic uplift or glaciation.

Meteoric waters associated with known deposits are typical of those that have been in contact with granites in that they have a pH of about 7 and low dissolved solids content, but they have a high uranium content. In mineralized areas, the water table is generally high and streams are permanent streams. In favorable places, much of the uranium is removed from the water by the first organic matter encountered. Thus, many of these surficial uranium deposits occur along small upland stream valleys and are of higher grade than those lower in the stream regimen. In general, larger and wider stream valleys tend to contain lower grade deposits probably because much of the uranium has been removed from the ground water prior to reaching these lower zones.

The character of uranium ores in young organic-rich surficial deposits varies widely. The host material ranges from peat (greater than 75 % organic matter) to organic-rich silt and sand (1-25% organic matter). In general, the uranium concentration increases with increasing organic content. Critical to ore reserve calculations is the density factor. Constant density cannot be assumed for the ore; density measurements (or estimates) must be a part of any sampling for reserve calculations. Dry-weight density of ore in the Lake Gillette area is estimated to range from 0.1 to 1.5 gm/cc (compared to 1.6 to 2.5 for sandstone ores), the most likely value is 1.2. Note the implication that the higher grade ore will be less dense. In some in-place material, the contained uranium in higher grade ore may be less than that of an equivalent volume of lower grade ore because of the overcompensating lower density of the higher grade sediment.

The oxidation state of uranium may vary with depth of the host material. Studies show that uranium is typically adsorbed from oxidized water by organic matter in the upper part of the deposit and remains temporarily in the U^{+6} oxidation state. As this uraniferous organic matter is buried, the hydraulic conductivity decreases, the organic matter decomposes, and reducing conditions are established. Uranium, initially in the U^{+6} state on adsorption sites on organic matter, is subsequently reduced to U^{+4}. Porosity and permeability of the ore varies with changing lithologic and organic character of the host rock along a drainage. Thus, the extraction process (and thus cost) must be able to accommodate variations in oxidation state of the uranium, organic matter content, and porosity in the ore being milled.

Uranium deposits associated with stream-valley sediments are long and sinuous following the valley bottom. The Flodelle Creek deposit is about 4.2 km long and ranges from 25 to 100 m in width. Thickness ranges from 0-6 m. Deposits associated with ponds are small and oval, as much as 200 m in the long dimension.

RECOGNITION CRITERIA FOR YOUNG ORGANIC-RICH SURFICIAL URANIUM DEPOSITS

In order to evaluate the favorability for young organic-rich surficial uranium deposits in the region, new recognition criteria were established for them, and a control area was established to estimate the probability distribution of the number of deposits in various deposit size classes.

The newly established recognition criteria for the new class of deposits, class 260, are intended as an addendum to the report by Mathews and others (1983) and are given in their format in table 1.

Table 1.--Tabulation of recognition criteria for "young organic-rich surficial uranium deposits" in the Lake Gillette proto-control area

Young organic-rich surficial uranium deposit: class 260 (number in sequence with those in Mathews and others, 1979; principal reference: Otton, 1984a)

Tectonic setting: Mobile belt, Precambrian - middle Tertiary.

Regional geology: Faulted, sheared Precambrian to early Tertiary granitic rocks (granodiorite to granite, especially two-mica granite); silicic volcanic terranes in high plateau areas.

Climate: Cool to temperate, moderate rainfall. Usually supports heavy vegetation.

Geomorphology: Glaciated terrane, generally moderate to high relief, 1st-through 3rd-order streams, pothole lakes, fresh-water to alkaline marshes in closed basins.

Regional structure: Faults, fractures, and shears; a regional Tertiary unconformity may be significant.

Host rock:

Age: Late Pleistocene to Holocene.
Geometry: Long winding channel, oval basinal fillings, hill slope.
Lithology: Arkosic sand, sandy silt, silt, clay, and/or peat; 2-100 percent organic matter.
Mineralogy: Organic matter, quartz, feldspar, mica, clay.
Texture: Medium-grained to clay-sized material, poorly to well-sorted.
Depositional environment: Fluvial, lacustrine.

Associated rocks: Granite or silicic volcanic basement in the drainage basin of the host sediment.

Alteration: Decay and humification of organic matter.

U and U-bearing minerals:

Primary: Uranium adsorbed by organic matter; uranium locally reduced during diagenetic processes. No crystalline mineral species recognized to date.
Secondary: Rare. Occur only where an older host is being dissected during the rejuvenation of drainage.

Note: Because of gross secular disequilibrium, these organic-rich uranium deposits are generally very low in radioactivity.

Associated elements: Minor Cu, Mo, Pb, Zn.

Example: Flodelle Creek deposit, Stevens County, Washington.

References: Mathews and others, 1979; Otton, 1984 a, b; Otton and Culbert, 1984; Johnson and others, 1985; Cameron, 1985; Macke and others, 1985; Otton and others, 1985; Otton and Zielinski, 1985, 1986; Zielinski, and others, 1986; Zielinski, and others, 1987.

METHOD OF ESTIMATING THE URANIUM ENDOWMENT

The endowment was estimated using the *deposit-size-frequency* (*DSF*) method described in detail by Finch and McCammon (1987). Briefly, the *DSF* method consists of a modification of the NURE uranium endowment (*U*) estimation equation, $U=A\cdot F\cdot T\cdot G$, in which the factors $F\cdot T$ (F=fraction of area, A, that is favorable for endowment; T=tons of endowed rock per unit area) are replaced by a single factor. This factor shown in the equation below is the summation of the estimates of the number of deposits of different deposit-size classes within the area being assessed, or, equivalently, the spatial density of deposits; hence, the name "deposit-size-frequency". The average grade (*G*) of the endowment is same in both methods. Depending upon the level of knowledge of the control area and level of exploration of the region being assessed, three options, *A, B*, and *C*, are available in the *DSF* method (Finch and McCammon, 1987). Option *C* is the case where the favorable area can be delineated in detail only in some portion so that the number and size of deposits within the control area, A_c, can be estimated. Option *C* is applicable to the Colville-Okanogan assessment and the equation is:

$$U = A \{ \sum_{i=1}^{k} (\frac{n_{ic}}{A_c}) T_i \} G \cdot L$$

where:

U = unconditional uranium endowment in tons of U_3O_8 above a cutoff of 0.01 percent U_3O_8,
A= favorable area in square miles,
k= number of deposit-size classes,
n_{ic}/A_c= spatial density (number of deposits/unit area) of deposits of size T_i (tons of endowed rock) in the i^{th} deposit-size class within a control area A_c,
A_c= control area from which estimates of n_{ic}/A_c are taken,
G- average grade of endowment, in decimal fraction form, and
L= option scaling factor that expresses the relation between the endowment in the favorable area and that in either the control area or some designated subarea for which estimates of the number of deposits in different size classes have been made.

Option C requires that the principal scientist establish the size frequency distribution of deposits in a well-known or control area, A_c , and the relation of the deposit-size-frequency distribution to measurable controlling geologic factors, such as alluvial valleys and lake-fills. Using these relations, the principal scientist first establishes the number and range of the size classes, and then for each size class estimates the lower limit, most likely value, and upper limit for the number of deposits in the control area, A_c. The favorable area, A, is measured, and the grade distribution, G, is estimated. Finally, the scaling factor, L, which relates the endowment on the favorable area to the control area, is estimated in lowest, most likely, and highest values. Using these estimates obtained by elicitation as input into the DSF equation, the probability distribution of undiscovered uranium endowment in a given area is calculated using the TENDOWG program (McCammon and others, 1988), which is modification of the program by Ford and McLaren (1980). The total endowment for a number of subareas, such as in a quadrangle, is calculated using the same TENDOWG program.

DESCRIPTION OF THE LAKE GILLETTE PROTO-CONTROL AREA

The Lake Gillette proto-control (proto is used because of limited production and undeveloped occurrences) area corresponds to the boundaries of the 7.5- minute quadrangle of the same name (fig. 2) and totals 49.68 mi^2. It was chosen because the best known deposit, Flodelle Creek (Joy Mining Company, 1983), occurs in the quadrangle, and this area has been studied in detail (Otton, 1984b). The deposit size distribution is given in table 2. The number of deposits in size classes k=1 and k=2 does not follow the expected distribution of typical epigenetic mineral deposits, for which the largest number are in the smallest size class. This departure is due to the natural occurrence of organic-rich uranium deposits. The uranium deposits are so closely tied to alluvial valley fills and lake-fills that the very nature of the sizes of the host-sediment bodies precludes many small deposits.

Table 2.--Distribution of estimated number of uranium deposits in various size classes in the Lake Gillette proto-control area.

Size class k	Size-class interval Tons ore Lower limit	Midpoint**	Upper limit	Number of deposits Lower* (0.05)	Most likely	Upper* (0.95)
1	$2.5x10^3$	$7.9x10^3$	$2.5x10^4$	2	4	10
2	$2.5x10^4$	$7.9x10^4$	$2.5x10^5$	4	8	18
3	$2.5x10^5$	$7.9x10^5$	$2.5x10^6$	3	6	9
4	$2.5x10^6$	$7.9x10^6$	$2.5x10^7$	0	0	1

* Odds are 9 to 1 that the true values lie within the lower and upper estimates.

** Midpoints of size-class intervals for size-classes 1-4 are calculated as the geometric mean of the upper and lower limit.

The rationales for the parameters in Table 2 are as follows:

1. Number of size-class intervals: a geometric scale was used in defining deposit size. The lower limit of the smallest size class was chosen to include the smallest known deposit, and the largest size class interval was chosen to allow for deposits larger than the largest known deposit.
2. Numbers of deposits in the different size classes: the total favorable area is divided into isolated parts and reconnaissance mapping and sampling permitted the assignment of varying degrees of favorability. Furthermore, lengths and widths of streams varied so that the permissible maximum size of deposit was apparent. Comparison of these observations with the character of the Gillette Creek control area permitted deposits larger than the largest known deposit in the controls area.

DETERMINATION OF THE COLVILLE-OKANOGAN FAVORABLE AREA

The favorable area for the young organic-rich surficial uranium deposits includes terrane underlain by granitic rocks throughout the Sandpoint and the northern part of the Spokane NTMS 2° quadrangles. Study of the data from the NURE folio reports (Castor and others, 1982; Fleshman, 1982), stream sediment and rock geochemical data from U. S. Forest Service studies of the mineral potential of the Colville and Okanogan National Forests (Grant, 1982a, b), limited sampling as part of the USGS Surficial Uranium Deposit Studies (SUDS), and information supplied by companies and individuals from their discoveries let to the conclusion that none of the granite outcrop areas in the quadrangles could be eliminated as potential source rocks for uranium deposits. Reconnaissance of the Colville-Okanogan region revealed clear evidence that uranium is accumulating in organic-rich sediments throughout most areas underlain by granite. All surficial sediments overlying these granites are potential hosts for young organic-rich surficial uranium deposits.

Throughout most of the Colville-Okanogan favorable area, moderate rainfall (average annual 63.5 cm) occurs, and the area is heavily forested. The southern part of the area near Spokane appears to be more arid and thus may be less favorable for uranium deposits. The northern part of the terrane has been glaciated, and major tributaries of the Spokane and Columbia Rivers contain much glacial-fluvial outwash sediment along their valley bottoms. In glaciated terranes, most hill slopes are mantled by glacial till. Glaciated and glacial outwash areas are locally poorly drained, and ponding of surface water along both major and minor drainages is common.

Several drainage settings have yielded young organic-rich surficial uranium deposits in the Colville-Okanogan areas: 1) first- and second-order stream drainages with zones of ponding caused by irregular glacial topography, beaver activity, and damming by tributary fans of coarse sediment; 2) kettle lakes filled with wetlands; 3) lacustrine deltas at inlets of small lakes along larger drainages; and 4) meander cutoffs along larger drainages. Surficial uranium deposits in the area identified as the Lake Gillette proto-control area occur as clusters because of ideal conditions of exposed donor granite and favorable sedimentary settings with organic matter accumulations.

The boundaries of favorable areas shown in figure 2 are drawn on the edges of granite outcrop areas on the the geologic maps (scale 1:250,000) of the two quadrangles (Castor and others, 1983; Fleshman, 1982). The favorable area is 1,970 mi^2.

Estimates of values of other parameters needed to calculate the undiscovered uranium endowment in the Coleville-Okanogan favorable area are given in Table 3.

Table 3. Estimated values for density (*d*), thickness (*t*), grade (*G*), and *L* factors.

Factor	Lower limit*	Most likely value	Upper limit*
d	0.7	1.2	1.5
t	1	3	8
G	.02	.03	.08
L**	.05	.10	1.0

*Odds are 9 to 1 that the values lie between the lower and upper estimates.
**Estimated value of *L*: parts of *A* are less favorable than the proto-control area, and other parts are more favorable. The lower limit, most likely value, and upper limit values of *L* were estimated on the basis of reconnaissance sampling and mapping.

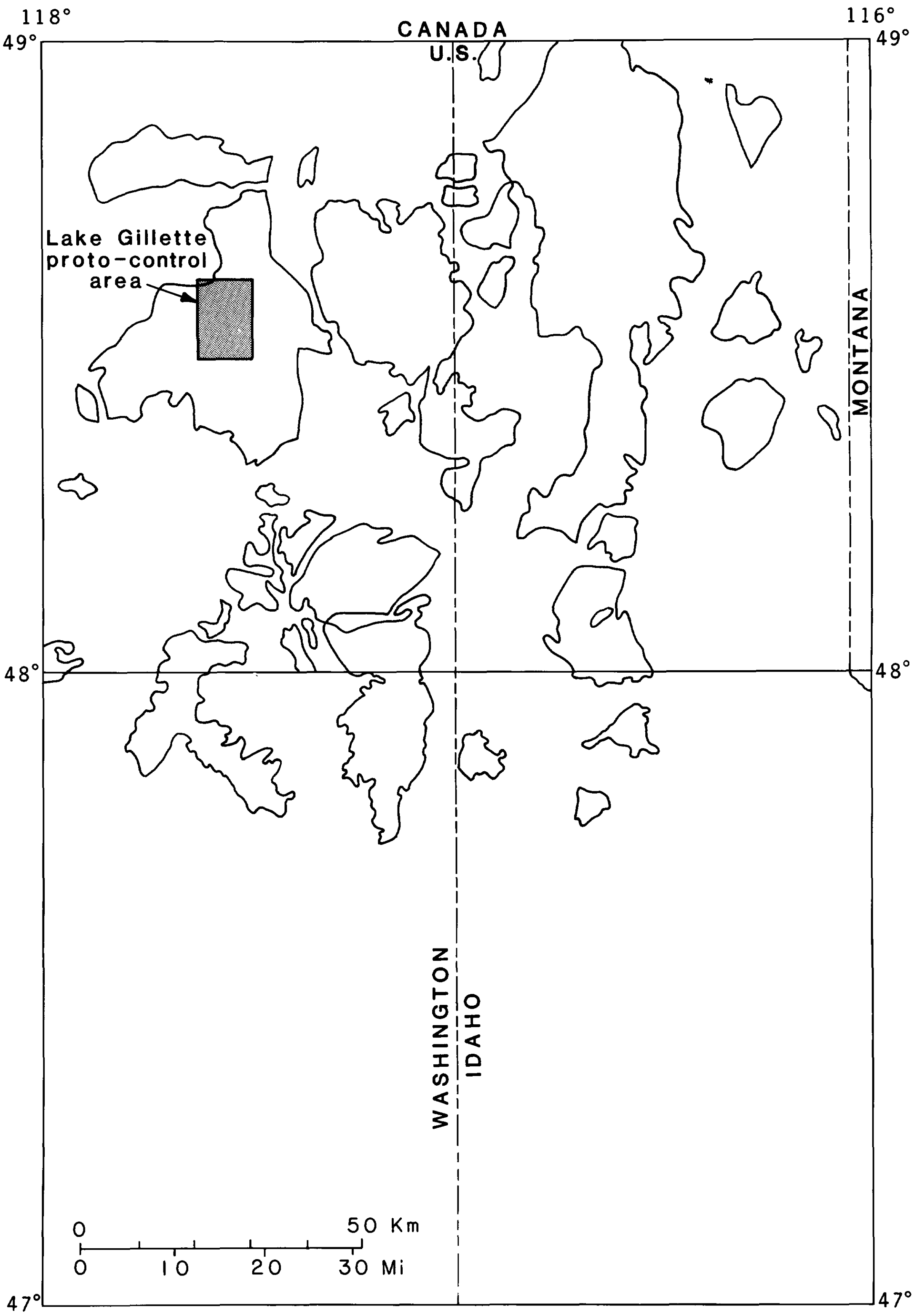

Figure 2. The Colville-Okanogan area favorable for organic-rich surficial uranium deposits and the Lake Gillette proto-control area in the Sandpoint (upper) and Spokane (lower) NTMS 1°x2° quadrangles, Washington, Idaho, and Montana. (Modified by J.K. Otton after Castor and others, 1982, fig. 2 and Fleshman, 1982, pl. 6).

URANIUM ENDOWMENT ESTIMATE FOR THE LAKE GILLETTE PROTO-CONTROL AREA

The probability distribution of uranium endowment in the Lake Gillette proto-control area is given in Table 4. The odds are 9 to 1 that the true endowment is between 560 and 8,145 tons of contained U_3O_8. The mean or expected value is 3,222 tons, which contains the company confidential reserves of Flodelle Creek. The economic portion of this endowment is to be classified as Reasonably Assured Resources.

Table 4.-- The probability distribution of uranium endowment in the Lake Gillette proto-control area

Percentiles for endowment			
Tons U_3O_8	Probability unconditional (in percent)	Tons U_3O_8	Probability unconditional (in percent)
560	0.05	2,838	0.55
795	.10	3,139	.60
1,009	.15	3,475	.65
1,215	.20	3,857	.70
1,421	.25	4,301	.75
1,630	.30	4,843	.80
1,846	.35	5,532	.85
2,072	.40	6,494	.90
2,307	.45	8,145	.95
2,562	.50		

THE UNDISCOVERED URANIUM ENDOWMENT ESTIMATE FOR THE COLVILLE-OKANOGAN FAVORABLE AREA

The probability distribution of the undiscovered (unconditional) uranium endowment for the young organic-rich uranium deposits in the Colville-Okanogan favorable area is given in table 5. The odds are 9 to 1 that the true endowment is between about 6,738 and 122,310 tons of contained U_3O_8 in the area. The mean or expected value for the unconditional uranium endowment is 35,299 tons of contained U_3O_8. This estimate is in addition to the estimates of endowment for other types of deposits given in the 1980 National uranium assessment report (USDOE, 1980). The economic portion is to be classified as Estimated Additional Resources (EAR).

Table 5. The probability distribution of undiscovered uranium endowment in the Colville-Okanogan favorable area.

Percentiles for endowment			
Tons U_3O_8	Probability unconditional (in percent)	Tons U_3O_8	Probability unconditional (in percent)
6738	0.05	23631	0.55
7428	0.10	27582	0.60
8118	0.15	32407	0.65
8808	0.20	38240	0.70
9885	0.25	45517	0.75
11338	0.30	54912	0.80
13000	0.35	67706	0.85
15009	0.40	86882	0.90
17448	0.45	122310	0.95
20285	0.50		

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