

Applied Geology in the Discovery of the Spokane Mountain Uranium Deposit, Washington

DAVID A. ROBBINS

Abstract

In 1975, Western Nuclear, Inc. discovered a blind uranium deposit on the north flank of Spokane Mountain approximately 38 miles (61 km) northwest of Spokane, Washington, after extensive geologic, geophysical, and geochemical programs had been conducted over a five-year period to locate the target area. The Spokane Mountain deposit was discovered in a northeast (Midnite) geophysical trend defined by airborne magnetic and reconnaissance induced polarization surveys. Regional and detailed soil and stream sediment geochemical programs helped narrow the target area. The deposit averages 8 ft (2 m) thick with a grade of 0.25 weight percent $eU_3O_8^*$, lies at 150 to 500 ft (46 to 152 m) depths, has a linear trend of N 70°-80° E with a 1,000-ft (305 m) minimum length and 150-ft (46 m) average width. Pitchblende in veinlets or as coatings on fractures is associated with iron sulfides and is located mainly in the unoxidized zone of the graphitic phyllite and chloritic schists of the Precambrian Togo Formation within 100 ft (30 m) of its contact with the intrusive Cretaceous Loon Lake Porphyritic Quartz Monzonite. Preliminary studies indicate the deposit may have been of penesynthetic(?) and hydrothermal origins with remobilization and late-stage supergene enrichment and is related to regional and local structural features. Although the Spokane Mountain deposit has many of the same characteristics of those of the Midnite mine, it differs in the following features: (1) the mineralized body strikes east-northeast; (2) mapable carbonate beds are absent; (3) mineralization penetrates the quartz monzonite; (4) the ore seems to have some stratigraphic control; (5) most of the uranium mineralization is reduced and below the present water table; and (6) ore grades and thicknesses appear to be lower than that of the Midnite but have wider distribution.

Introduction

THE Spokane Mountain uranium deposit is located approximately 38 miles (60 km) northwest of Spokane, Washington, on the Spokane Indian Reservation in Stevens County (Fig. 1). Following the discovery of the Midnite mine (Fig. 1) by the LeBret brothers in 1954 (Sheldon, 1959), exploration by several mining companies of southerly exposed slopes outside the mine area where the quartz monzonite is in contact with the metasedimentary rocks at the surface proved to be unsuccessful. In the early 1970s Western Nuclear began an exploration program in the metasedimentary Precambrian Togo Formation after an appraisal of the economic potential of hard rock uranium deposits such as the Midnite; the Schwartzwalder, in Colorado; and the Alligator Rivers area, Australia.

Discovery of the buried deposit 2 miles (3 km) northeast of the Midnite mine was made on the north slope of Spokane Mountain in 1975 by Western Nuclear after extensive geologic, geophysical, and

geochemical investigations had been conducted to locate the target. The northeast-trending prospect area of slightly less than 0.2 sq mi (0.4 km²) is at about the 3,400-ft (1,030 m) elevation on slopes of 15° to 45° and is covered by dense timber and undergrowth. Soil on the north slope is as much as 70 ft (21 m) thick. The climate is semiarid with 25 to 35 in (64 to 89 cm) of moisture a year (Becraft and Weis, 1963).

Geology of the Deposit

General geology

The Spokane Mountain deposit occurs in the Precambrian Togo Formation of the Okanogan Highland Province (Becraft and Weis, 1963) which probably correlates with the lower Wallace Formation of the Belt Supergroup exposed in the Coeur d'Alene mining district (Nash, 1977). The age of these rocks is approximately 1,300 m.y. (Harrison, 1972). The Togo Formation is tightly folded and is part of the Deer Trail anticlinorium (Becraft and Weis, 1963). These rocks were then sheared, faulted, and intruded by a Cretaceous granitic batholith, and later intruded by a series of early Tertiary dacite dikes (Nash and Lehrman, 1975). During Pleistocene

* eU_3O_8 is equivalent uranium oxide as calculated from the measurement of gamma-ray emitting elements utilizing a calibrated gamma-ray scintillometer. This value can be more or less than the chemical value depending on its equilibrium with its gamma-ray daughter products.

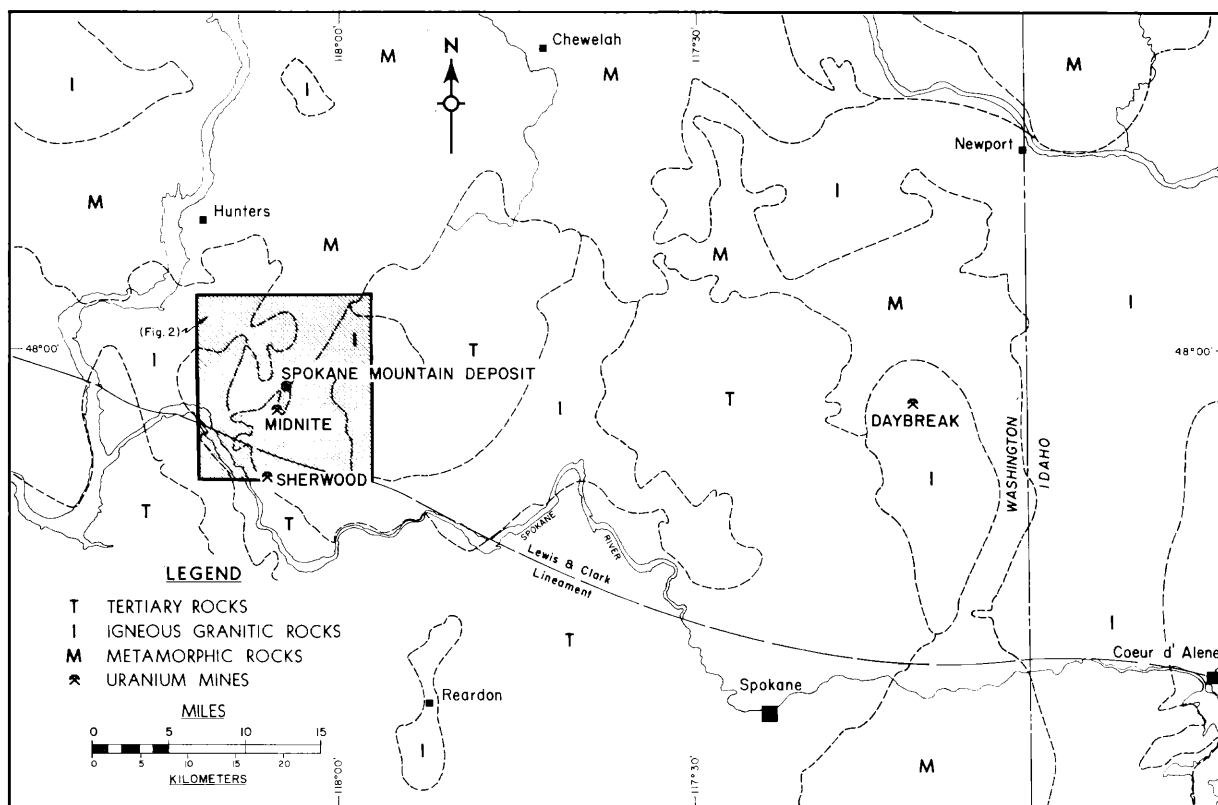


FIG. 1. Generalized geologic map (modified from Hunting, 1961) showing the location of the Spokane Mountain deposit in northeast Washington.

time, areas lower than the deposit were eroded by several glacial advances. Structurally the deposit lies south of a circular feature visible on LANDSAT photographs (J. S. Johnston, oral commun., 1975) and near the intersection of a northeast-trending alignment (Fig. 2) with the northwest extension of the Lewis and Clark disturbed belt. The uranium mineralization occurs in shears and fractures in chloritic schists and graphitic phyllites within a 100-ft (31 m) vertical zone near the contact with the intrusive granitic rocks and is associated with mixed iron sulfides and minor amounts of molybdenite.

Host rocks

The deposit is located in a roof pendant of deeply weathered metapelitic rocks of the Togo Formation with bedding generally striking N 10°-30° E and dipping steeply to the southeast (Fig. 2). The metamorphic rocks are dark gray to gray-green, thin-bedded, graphitic phyllite with disseminated pyrrhotite and lenses of argillite, chloritic schist, quartzite, mica hornfels, and siliceous carbonate. The cross section (Fig. 4) shows the western boundary of the deposit to be in a quartzite. The middle of the deposit is in a dark gray to green-black chloritic-schist

which grades into predominately phyllitic-textured rocks on the east side of the mineral body. Locally, these metasedimentary rocks are strongly foliated, exhibit a mottled to convoluted appearance, and contain medium- to coarse-grained feldspar porphyroblasts visible with a hand lens. Recemented veinlets of quartz and calcite with pyrite are quite common and there are a few northwest-trending Precambrian amphibolite dikes (L. C. Nesbit, oral commun., 1976). Vertically, 150 to 525 ft (46 to 160 m) of Togo Formation overlies the very irregularly shaped surface of the porphyritic quartz monzonite pluton. Thin northerly trending aplitic dikes and granitic sills as well as Tertiary dacite to andesite dikes, intrude the older rock units.

Structure

Structure contours (Fig. 3) drawn on the top of the intrusive show a broad north-trending basement nose in the center of the deposit, with two 50 to 150-ft (15 to 46 m)-wide troughs on each side of the high that averages 90 ft (27 m) deep. Faults and shear zones have been observed in the Togo Formation and are known to extend 100 ft (31 m) into the intrusive. One such fault, which is downthrown to

the east, is shown in Figure 4 and may account for the easterly trough as indicated by the basal contours in Figure 3.

Since the deposit is covered by thick soil and vegetation, the exact structural relations are impossible to ascertain. However, drilling indicates that there are several high-angle fault structures cutting the mineralized body (Figs. 4 and 6). One of these postore faults (June fault) trends N 50° W across the deposit and dips steeply to the northeast (L. C. Nesbit, oral commun., 1976). In addition, the drill core shows extensive shearing in the Togo

Formation with the average fracture plane dipping approximately 50°.

Mineralogy

Both reduced and oxidized uranium minerals have been megascopically observed in the Spokane Mountain mineral body. The reduced mineral is pitchblende and the oxidized uranium minerals are meta-autunite, phosphuranylite, uranophane, and uranopilite(?) (L. C. Nesbit, oral commun., 1976). Most of the pitchblende is associated with a high percentage (3 to 5 percent) of iron sulfides in the form

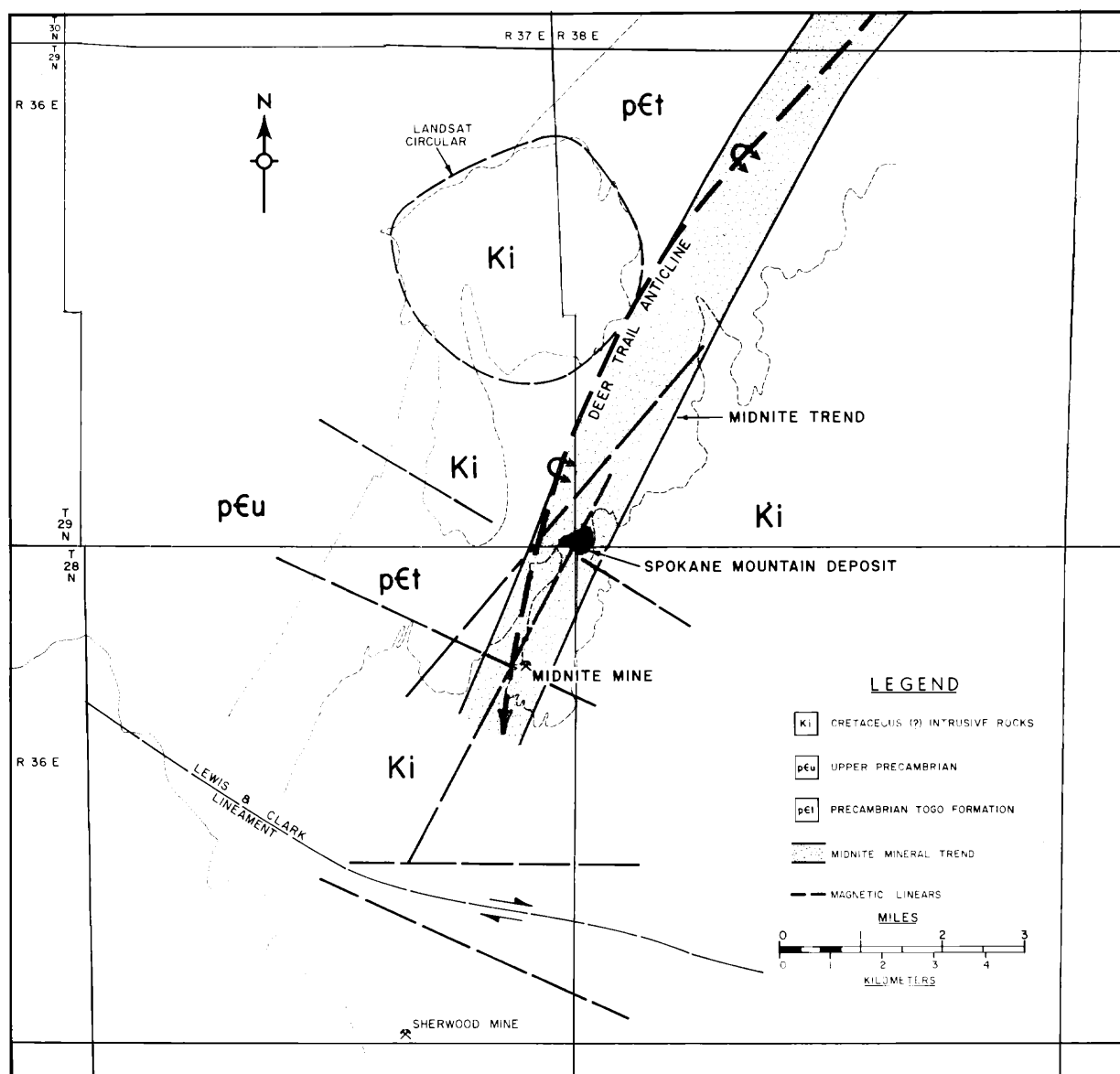


FIG. 2. Geologic map (modified from Becraft and Weis, 1963, and Campbell and Raup, 1964) of the deposit area showing magnetic linears, structures, trends, and uranium mines.

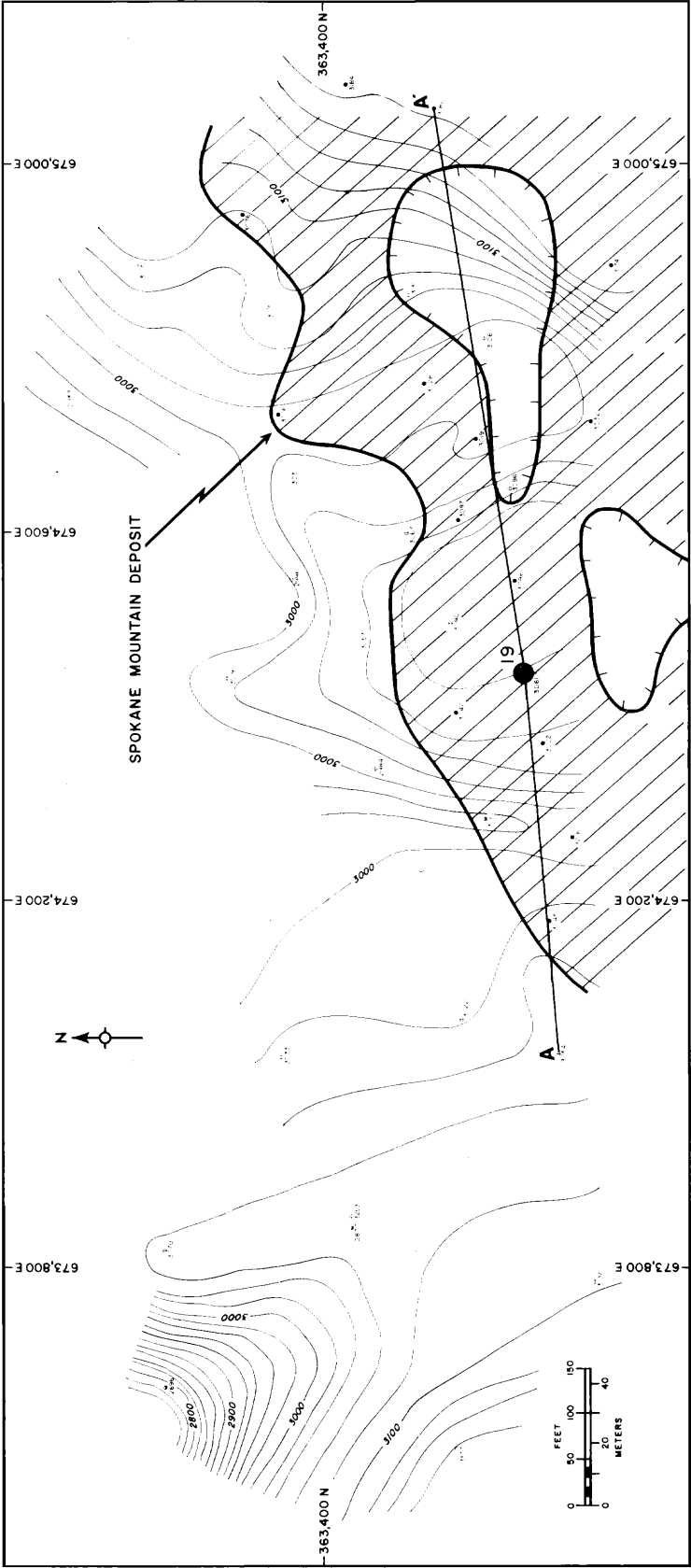


Fig. 3. Map showing the Spokane Mountain deposit and structure contours drawn on top of the quartz monzonite (20-ft contour interval). Line A-A' is the location of the cross section (Fig. 4). Drill hole 19 is the discovery hole.

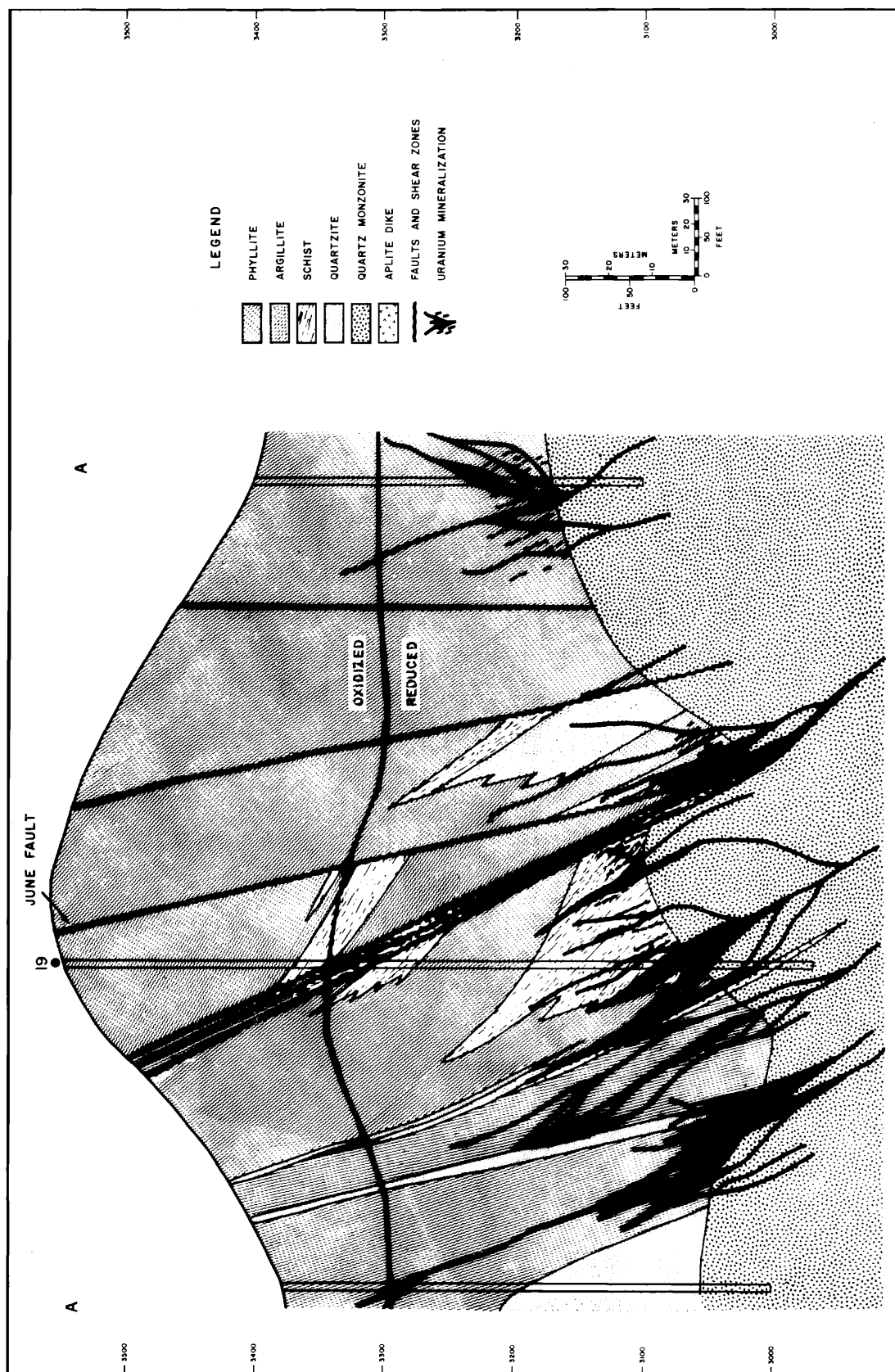


Fig. 4. East-west idealized cross section through the Spokane Mountain deposit. Colluvium about 70 ft thick is not shown. The section includes information projected from drill holes not in the plane of the section.

of pyrrhotite, pyrite, and marcasite as at the Midnite deposit (Nash and Lehrman, 1975). Visible molybdenite and possible jordisite have been identified with the uranium mineralization (L. C. Nesbit, oral commun., 1976). The most common gangue minerals are graphite, chlorite, biotite, calcite, quartz, garnet, tremolite, and muscovite.

Chloritic and sericitic alteration is very common in the metamorphic rocks near the contact with the intrusive. In addition, local kaolinization and silicification have been observed in the mineral body. Weathering of the sulfides in the upper 200 ft (61 m) of the overlying Togo Formation has produced abundant limonitic and hematitic alteration casts of the iron sulfides.

Geometry and tenor of mineralization

The Spokane Mountain deposit appears to have a strong N 70°-80° E linear trend in excess of 1,000 ft (305 m) in length and 150 ft (46 m) in average width (Fig. 3). This trend crosses both the regional bedding strike of N 10°-20° E and the foliation of N 30° E but does not appear to follow the strike of the north-trending troughs in the underlying quartz monzonite as does the mineralization at the Midnite mine (Nash and Lehrman, 1975). However, the uranium mineralization does appear to thicken in the troughs from 3.5 ft (1 m) to 48.5 ft (15 m) and thin over the basement ridges from 6.5 ft (2 m) to 1.5 ft (0.5 m), as it does at the Midnite mine to the southwest (Nash and Lehrman, 1975). Most of the uranium is associated with sulfides in highly foliated, fractured, graphitic phyllite and chloritic schists of the Togo Formation. The higher grade unoxidized uranium mineralization generally occurs near the quartz monzonite contact in pitchblende veinlets up to $\frac{1}{2}$ in (1.3 cm) thick. Lower grade uranium mineralization has been observed as much as 50 ft (15 m) into the quartz monzonite and as far as 100 ft (30 m) above the pluton in metasedimentary rocks. Lower grade oxidized uranium mineralization coats both horizontal and vertical fractures in the oxidized zone, suggestive of Tertiary ground-water remobilization and supergene enrichment of the reduced zone of the mineral deposit. Thicker uranium mineralization is present in faults and shear zones associated with granitic troughs in the basement. Uranium mineralization is absent in the quartzite and argillite at the west end of the mineral body (Fig. 4). The grade of the mineralization ranges from 0.01 to 2.80 wt percent, with an average weighted grade of 0.25 percent eU_3O_8 and an average thickness of 8 ft (2.5 m). The equilibrium of the deposit has not been determined as yet. However, preliminary information reveals that a majority of higher grade mineralization is in the reduced or unoxidized por-

tion of the mineral body and is either in equilibrium or is chemically high.

Hypothesis of Ore Genesis

The author hypothesizes that the Spokane Mountain uranium deposit is the result of five periods of mobilization, transportation, and concentration of uranium minerals in sufficient quantities to form a deposit. Similar hypotheses for emplacement of uranium into the Midnite deposits have been developed independently by Nash (1977).

The first stage could have been a penesynthetic concentration of uranium in the carbonaceous pyritic silts and muds of the Precambrian Togo Formation which was deposited in a low-energy marine environment adjacent to a granitic highland to the southeast in western Montana and known to contain anomalous uranium (Malan, 1972). This could have been similar to the Koolpin Formation of the South Alligator River district in Australia (Dodson et al., 1974).

The second stage may have been the remobilization of sulfides with some uranium during tight folding and metamorphism of the Beltian sediments during the Jurassic period. This mineralization migrated along major planes of weakness, notably in the axes of anticlines and synclines (Needham and Stuart-Smith, 1976). The intense folding also produced shear zones. Pyrite was replaced by pyrrhotite, and there were sufficient sulfides to reduce the uranium to the +4 valence state, allowing it to concentrate in the fractures and shear zones.

The third stage of uranium mineralization could be the result of an enriched uranium plutonic intrusion during the early Tertiary, with a late-stage quartz monzonite from an anatectic melt similar to that described in northeastern Washington and northern Idaho by Miller and Engels (1975). Uranium mineralization was introduced to the system from the melt. Hydrothermal fluids from a convection cell picked up the easily leachable uranium along with other elements previously deposited in the area. These enriched uranium solutions migrated into the northeast and northwest fracture systems where they were precipitated, forming pitchblende and pyrite in veins and veinlets.

The fourth stage of uranium concentration could be the result of mobilization by circulating ground water during Eocene plutonism (Pearson and Obradovich, 1977), with further concentration in structures. This period of concentration is suggested by the presence of aplitic dikes intersected by several of the drill holes on Spokane Mountain (Nesbit, oral commun., 1977).

The last stage of concentration may be the result of deep weathering causing continued remobilization

of the uranium by oxidizing carbonate ground-water conditions which transported it along structural troughs in the basement rocks (Nash, 1975), where it was then reduced by strong sulfide development to form a supergene-enriched deposit.

Exploration Programs

Geologic research

An extensive study was made of the literature dealing with vein-type uranium deposits, even though prior to 1971 there were very few reports on hard rock deposits, and only brief information by word of mouth on the newly discovered deposits in the Northern Territory of Australia and northern Saskatchewan of Canada. Our exploration program was designed to test target areas favorable for four general types of deposits. The four models consisted of: (1) hydrothermal vein-type as developed for the nearby Midnite deposits, and the Marysvale and Schwartzwalder mines (Barrington and Kerr, 1961); (2) same as (1) but adding supergene enrichment (Frank Evoy, oral commun., 1970); (3) syngenetic uranium in metasedimentary rocks, remobilized by hydrothermal and/or supergene processes (H. B. Young, oral commun., 1971); and (4) supergene leaching of uranium from granitic rocks and deposition in reducing environments by ground water (Gruner, 1956).

Geologic programs

In 1968 a photogeologic map on a scale of 1:24,000 was prepared, showing structural and alteration features using 35 mm color stereo pairs of the study area. The dominant apparent structural trend is north to N 45° E with a minor structural trend N 20°-55° W. These features generally cut across the N 10°-30° E strike of the Precambrian metasedimentary rocks (Fig. 2).

Detailed ground geologic mapping was conducted along access roads and southerly slopes. However, it was impossible to produce a detailed geologic map because of the intense structural complexity, monotonous rock units which lack marker beds, intense metamorphism, lack of outcrops, and heavy vegetation. Therefore, emphasis was placed on geophysical and geochemical tools to evaluate the area.

Geophysical programs

Airborne radiometric: Airborne radiometric surveys were attempted in 1968 with a fixed-wing aircraft using 40 cu in (656 cu cm) of scintillation crystals and a 4-channel analyzer and flying at a 200-ft (61 m) mean ground clearance at approximately 100 mph (161 kph) ground speed. However, due to the topographic relief, dense vegetation cover,

and crystal size, these surveys were found to be useless.

Airborne magnetic survey: In 1969, an airborne magnetic survey was flown using a fixed-wing aircraft flying in an east-west direction at a 500-ft (152 m) terrain clearance on $\frac{1}{4}$ -mile (396 m) flight line spacings. The magnetic data (Fig. 5) show that there is a series of magnetic highs (3,600+ gammas) trending northeast and adjacent to both the Midnite and Spokane Mountain uranium bodies. We call this lineation trend the Midnite trend. In addition to this trend, there are several strong N 30° E-trending magnetic linears which intersect minor N 65° W magnetic linears (S. Parker Gay, Jr., written commun., 1969). Both the Spokane Mountain and Midnite uranium deposits are on the flank of magnetic highs near the intersection of these linears (Fig. 5). Some magnetic highs relate directly to the porphyritic quartz monzonite intrusives mapped by Becraft and Weis (1963). One of these intrusives is expressed by the high magnetic lobe trending south in the upper center of Figure 5. The strong N 45° E-trending linear parallels southeast of the Sand Creek drainage indicate a possible normal fault dipping and downthrown to the north in the Togo Formation. The Lewis and Clark lineament may be expressed by the drastic change of direction of magnetic linears and magnetic relief between the Midnite and Sherwood mines.

Ground magnetometer survey: A ground magnetometer survey was made in 1976 covering a 1,300 by 1,900 ft (396 by 579 m) area, using a Geometrics G-816 proton magnetometer on 50, 100, and 200 ft (15, 30, and 60 m) centers (Fig. 6). The stations on 50-ft (15 m) centers were located in the south-central area over the discovery in an experiment to determine the maximum spacing for obtaining a good magnetic signature. A large northeast-trending magnetic high of 62,000+ gammas is present 600 ft (183 m) west of the discovery over weathered quartz monzonite. Two small highs of 43,000 and 51,000 gammas were located approximately 580 ft (177 m) west and southeast, respectively, of the discovery—with the discovery being in a somewhat low magnetic plateau area. There is a major alignment which strikes N55°W. This alignment appears to correspond to a northeast-trending fault (June fault) as suggested by subsequent drilling (L. C. Nesbit, oral commun., 1976; Figs. 4 and 6). Minor magnetic alignments appear to trend in a northeasterly direction paralleling the strike of the bedding planes. To the north of the discovery are two additional highs of 46,200 and 48,700 gammas in an otherwise nearly broad area of undisturbed magnetic signature of 40,000 gammas.

Reconnaissance induced polarization surveys: In

order to better define favorable targets, five time-domain induced polarization profiles were made across the Midnite trend in 1972. The survey lines were approximately 6,000 ft (1.8 km) long and were spaced approximately 0.5 mile (0.8 km) apart (Fig. 5). The surveys were made using a 15 kW Scintrex

transmitter and Newmont-type receiver in an in-line pole-dipole configuration. In order to detect chargeability anomalies at several depths, the lines were measured twice; once using a 500-ft (152 m) dipole spacing and a second time using 1,000-ft (305 m) dipole spacings. The results for line A, located north

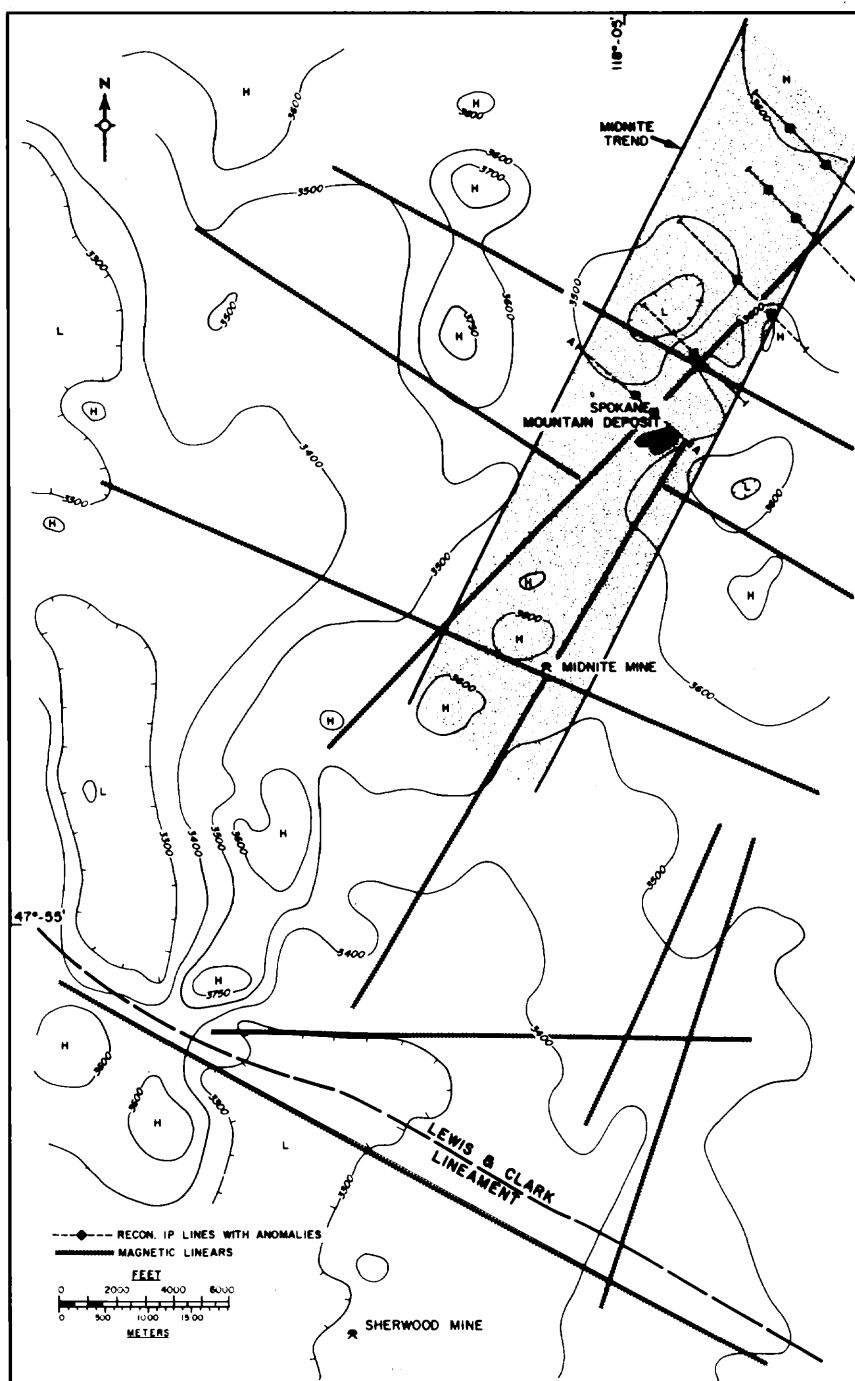


Fig. 5. Map of airborne magnetics showing the Midnite trend and the location of reconnaissance induced polarization lines.

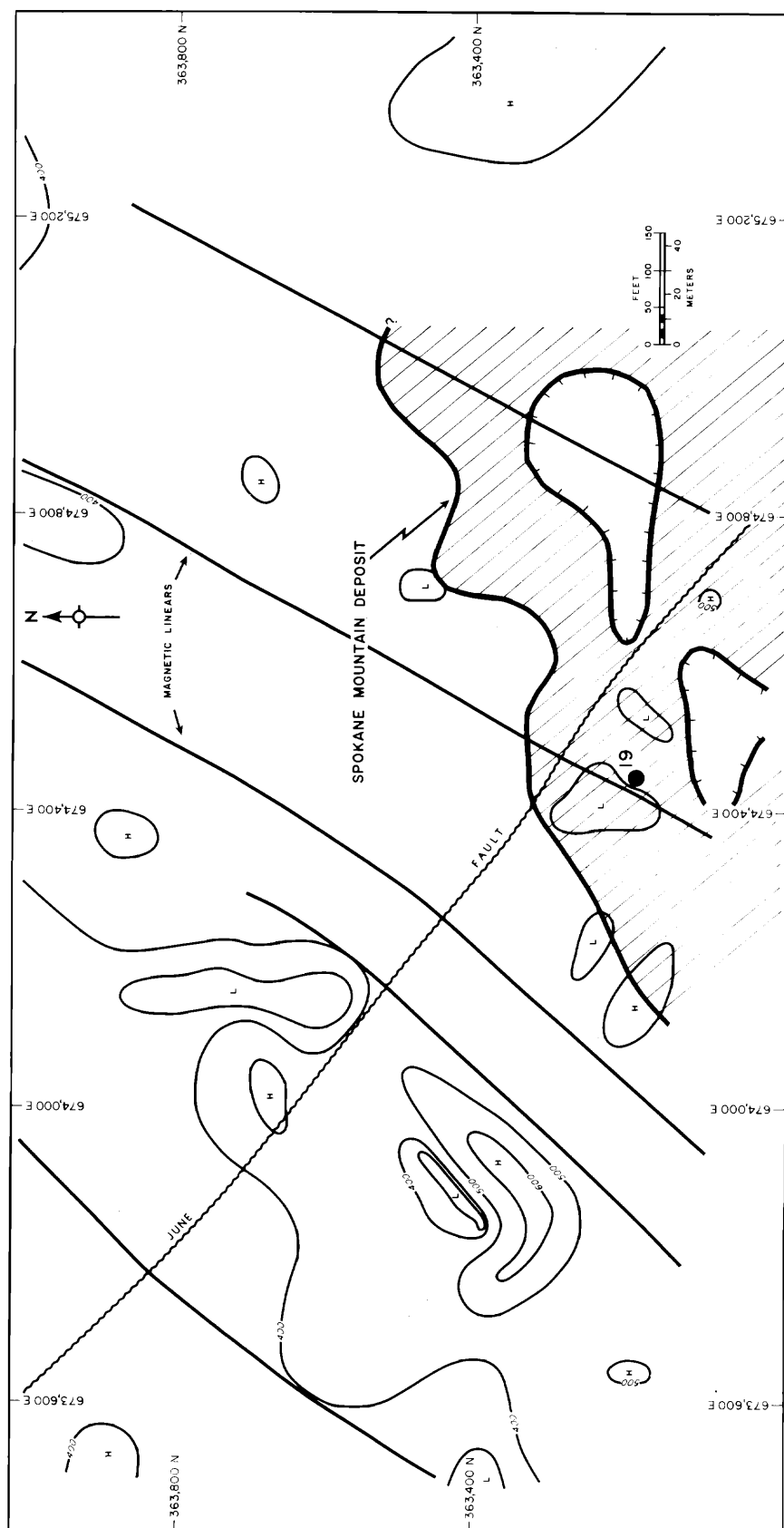


FIG. 6. Map of the Spokane Mountain mineralized area and ground magnetic values (total magnetic value $\times 100$) with magnetic linears and the June fault.

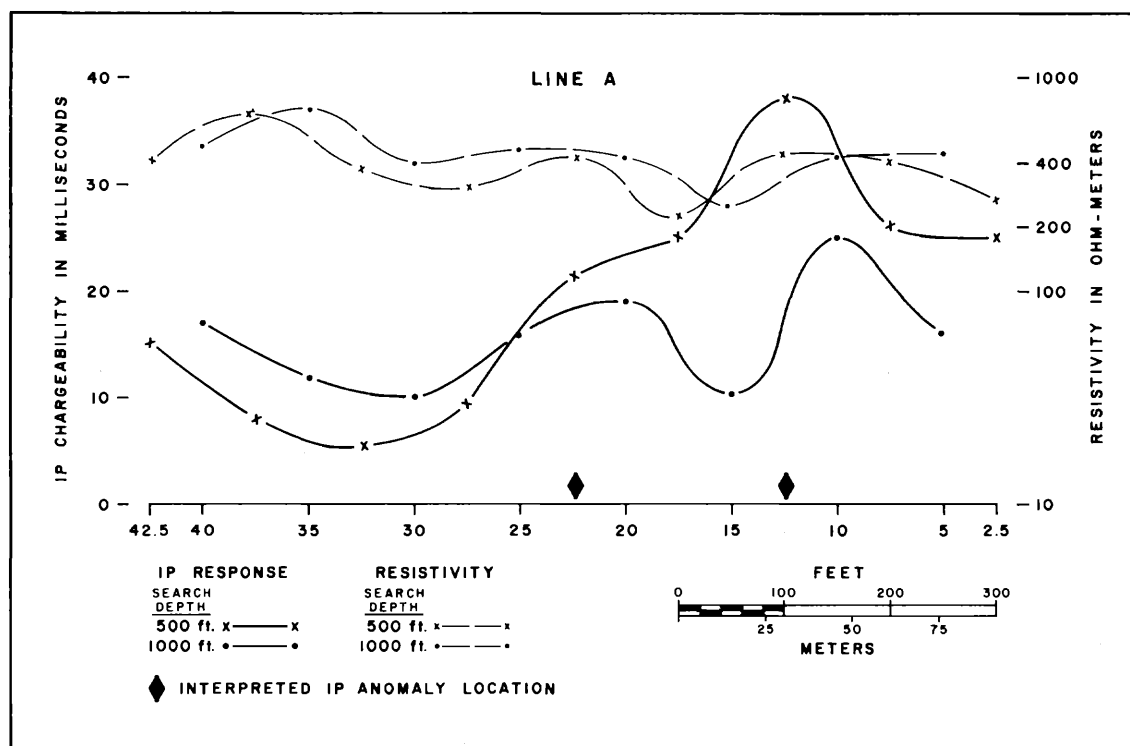


FIG. 7. Profile of pole-dipole induced polarization on line A showing resistivity and chargeability at 500- and 1,000-ft search depths.

of the later discovered uranium body, are shown in Figure 7. The resistivities remained nearly constant (400 ohm m) for both dipole spacings. The chargeability anomalies were found at both the 500-ft (152 m) and the 1,000-ft (305 m) search depths. A dual chargeability anomaly was found at the 1,300-ft (396 m) station, reading 39 milliseconds at the 500-ft (152 m) search depth, and 26 milliseconds at the 1,000-ft (305 m) search depth. At the 2,300-ft (701 m) station, a weak chargeability anomaly was found at the 500-ft (152 m) search depth, with a fairly strong (19 millisecond) anomaly at the 1,000-ft (305 m) search depth. These chargeability highs appear to be on a broad 2,000-ft (610 m)-wide band of anomalous induced polarization readings coinciding almost exactly with the Midnite trend magnetic alignment, as well as with the general axis of the Deer Trail anticline, and may indicate anomalous sulfide concentrations.

Detailed induced polarization: After the discovery hole (19) in the SE $\frac{1}{4}$ of section 36, T29N, R37E, was drilled in 1975, a detailed induced polarization survey was conducted over the area by a Phelps Dodge geophysical crew. The survey was a dipole-dipole frequency domain survey using 300-ft (90 m) spacings and frequencies of 0.1 and 1.0 Hz. One east-west line was run centering over the discovery

hole. A second east-west line was placed 500 ft (152 m) north across the Midnite trend and the broad induced polarization anomalous area found in the 1972 survey (Fig. 8). Results of the survey are shown as standard dipole-dipole pseudosections (Fig. 8), indicating that the discovery hole on the first line was directly in the center of an induced polarization percent-frequency effect anomaly. Modeling of the data indicated the anomalous body is approximately 1,150 ft (351 m) wide and generally corresponds with the higher sulfide development in the Spokane Mountain mineral body. The anomalous chargeability follows the topographic ridge to the northeast and contains higher chargeabilities on the western flanks, with a plunge slightly to the northeast. The resistivity shows contacts on both sides of the anomaly, across the center of the profile (S. I. Gaytan, writ. commun., 1976).

Track-Etch survey: Ninety-eight Track-Etch cups using sensitized film to detect radon gas from the decay of uranium were placed on 50-ft (15 m) centers covering a 200,000-sq-ft (18,600 m²) area across the potential target area (Fig. 9). The cups were implanted 20 to 30 in (51 to 76 cm) deep with the opening down and left in the ground a minimum of 3 weeks to allow integration time for variations in the barometric pressure, temperature, and moisture,

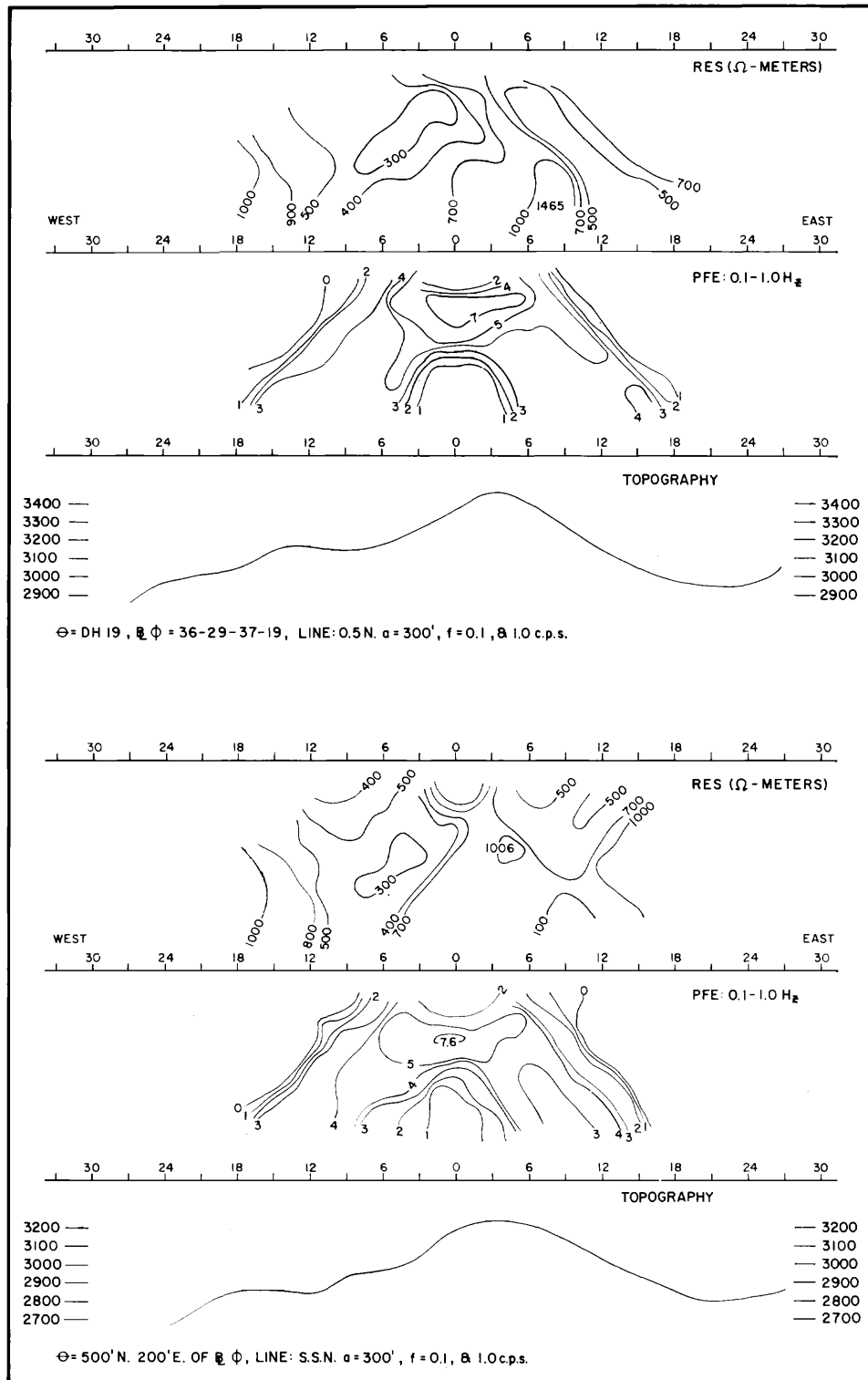


FIG. 8. Detailed dipole-dipole induced polarization pseudosections showing chargeability and resistivity over the Spokane Mountain uranium deposit. The upper section is located east-west across discovery hole 19. The lower section is located in an east-west direction 500 ft north and 200 ft east of the upper section.

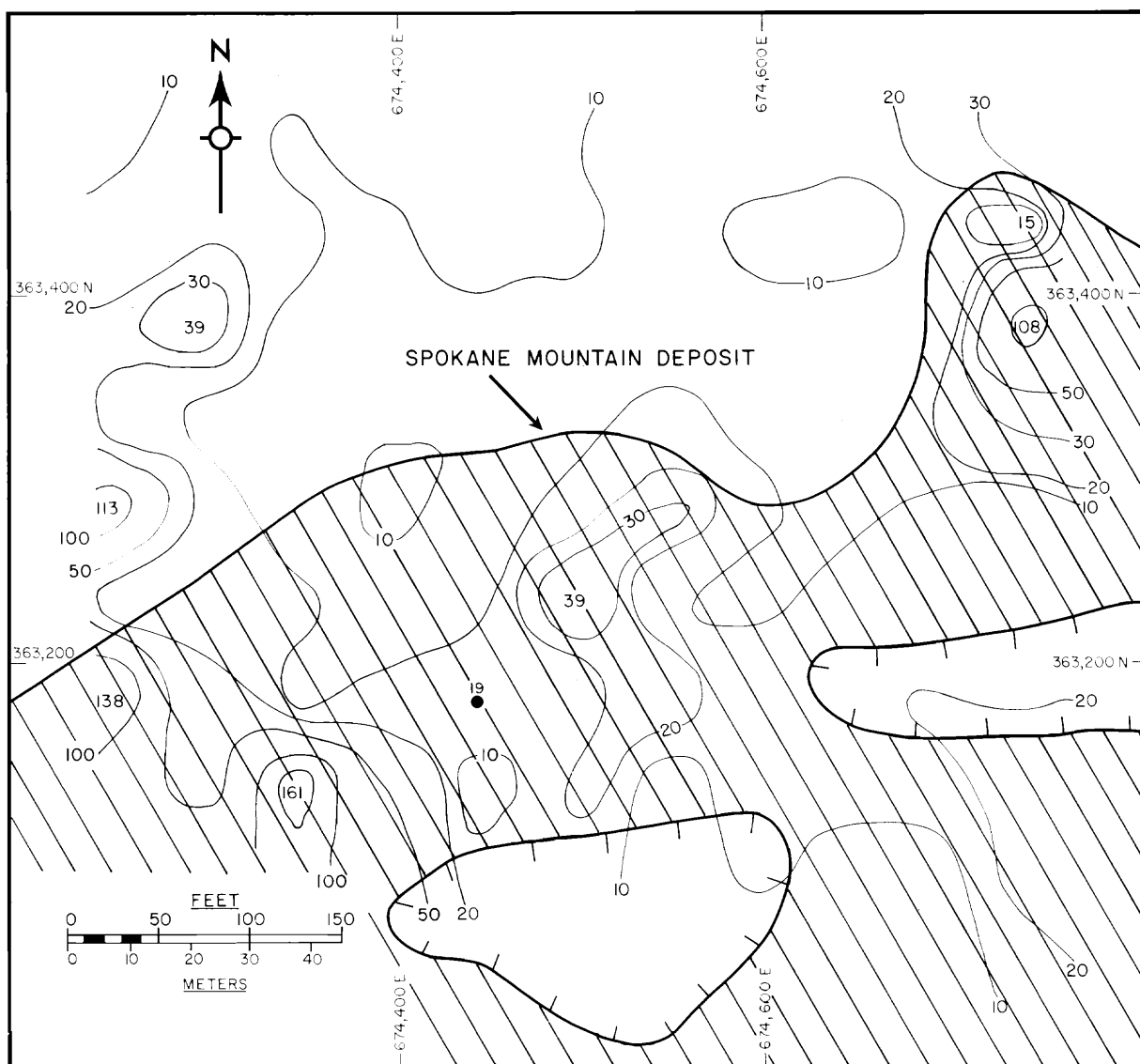


FIG. 9. Map of the Spokane Mountain mineralized area showing Track-Etch survey data with 10 tracks per mm^2 contour interval.

The readings ranged from 2.4 to 161.2 alpha ray tracks per sq mm, with a 11.6 tracks per sq mm mean and 6.7 tracks per sq mm standard deviation. Seventeen points were considered as anomalous with a threshold of 25 tracks per sq mm or mean plus two standard deviations. The anomalies (Fig. 9) generally occur in clusters in an east-west direction along the southwestern part of the area, with one very high anomaly present in the northeast corner. There appears to be a very close relationship of uranium mineralization to the Track-Etch anomalies, even after the spacing between the sample sites had been increased from 50 to 200 ft (15-60 m). Most of the area containing 20 tracks per sq mm or greater, which

has been drilled, contains uranium mineralization. The anomalies northwest of the mineralized area may be the leakage and migration of radon gas along the June fault as drawn by Nesbit.

Geochemical programs

Reconnaissance soil survey: In 1970, wide-spaced reconnaissance soil samples were taken from the B horizon along access roads on 1,000 to 1,500 ft (305 to 457 m) centers on Western Nuclear's property (Fig. 10). A total of 253 samples was taken and sieved through an 80-mesh sieve, then analyzed for uranium, copper, lead, zinc, silver, cobalt, arsenic, tungsten, mercury, and molybdenum. For this sur-

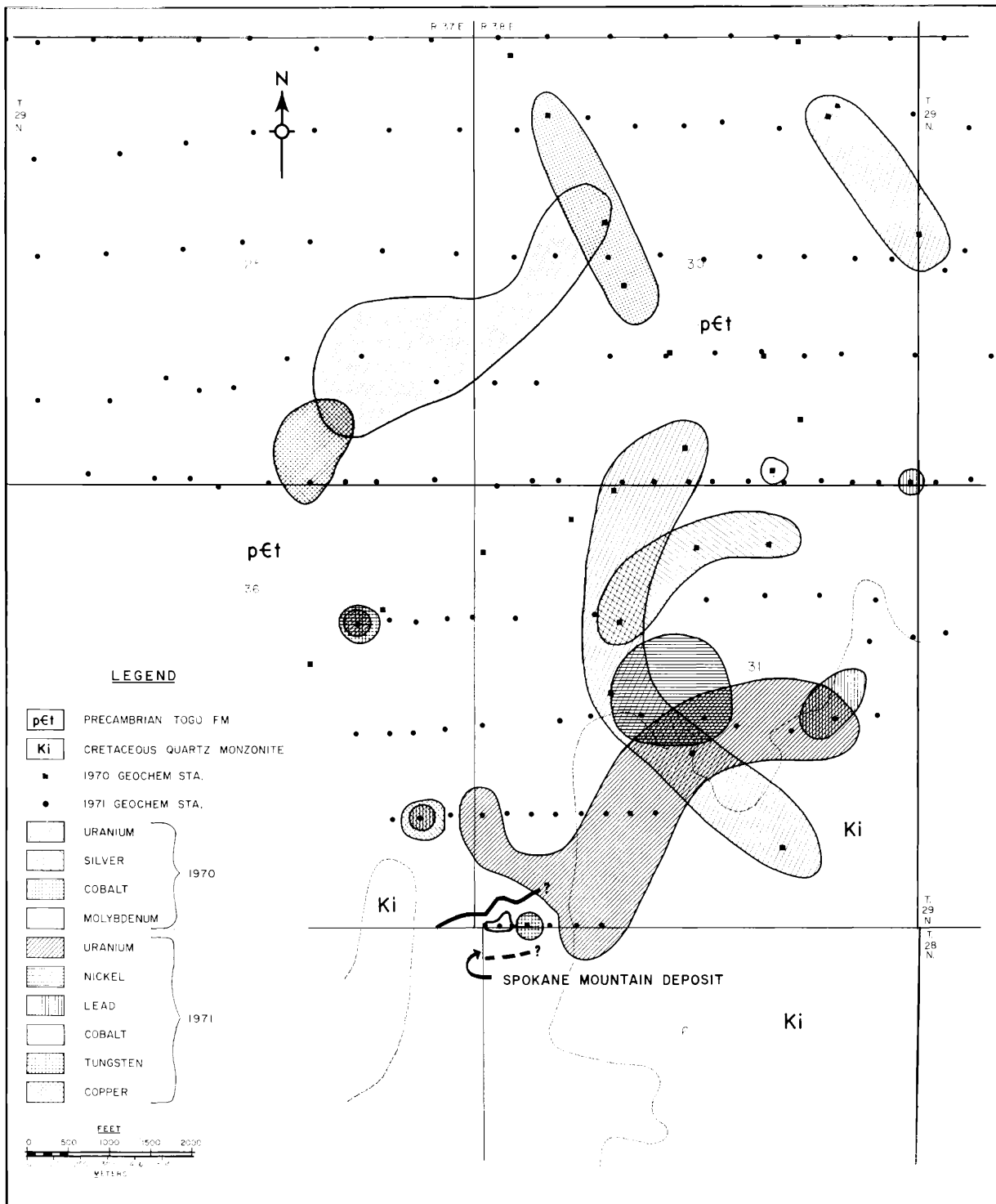


FIG. 10. Map of the Spokane Mountain uranium deposit area showing reconnaissance geochemistry stations and anomalies for the 1970 and 1971 programs.

vey, an anomalous sample was considered to be greater than two times the mean. Uranium values ranged from 0.1 to 7 ppm with a mean of 0.5 ppm and an anomalous threshold of 1 ppm. A large, weak, north-trending uranium anomaly containing seven anomalous points was located in the W $\frac{1}{2}$ of

section 31, T29N, R38E. This anomaly is also in an area which contains anomalous silver values and is generally underlain by the Precambrian Togo Formation.

Humic soil surveys: As a result of the reconnaissance geochemical survey and the defining of the Midnite trend through airborne magnetics, a more detailed humic soil sampling survey (Fig. 10) was made in 1971 on a grid of approximately 200 to 300 ft (60 to 90 m) east and west and 1,150 to 1,400 ft (351 to 427 m) north and south across the trend. This survey contained 200 samples taken from the A0 and A1 horizon which were analyzed for uranium, copper, lead, zinc, nickel, cobalt, tungsten, molybdenum, and loss of ignition. Uranium ranged from 0.01 to 8.13 ppm when adjusted to the ash weight ratio (ash weight/initial weight $\times$ U ppm), with a mean of 0.08 ppm. The ash weight ratio was used to reduce the effect of the varying organic content of the sample. As in the reconnaissance geochemical survey, an anomalous threshold was defined as twice the mean for each rock type. An anomalous uranium area containing ten sample points is present trending northeast from the southwest corner of section 31, T29N, R38E, and a single-point uranium anomaly at four times background was found in section 36, T29N, R37E, in the Sand Creek drainage (Fig. 10). In addition to the uranium anomalies, there were single- and double-point tungsten, nickel, copper, and lead anomalies adjacent to or near the sec. 31 uranium anomaly. The large uranium anomaly is in the contact area of the Precambrian Togo Formation and the Cretaceous porphyritic quartz monzonite. A single-point tungsten anomaly occurred in the Spokane Mountain deposit (Fig. 10).

After the discovery hole (No. 19) on the Spokane Mountain deposit was drilled, a detailed humic sampling program was conducted in 1976 on 50, 100, and 200 ft (15, 30, and 60 m) centers across the area believed to be favorable (Fig. 11). Three or four samples were taken of the A0 horizon at each location, large enough to fill a 100-cu-in bag. Then they were sieved through an 80-mesh brass screen and a two-gram sample was taken, ashed, and assayed for uranium by fluorimetry.

The results of the survey indicate there are four multiple-point uranium anomalies and nine single-point uranium anomalies at plus two standard deviations (Fig. 11). The large anomaly to the west is in quartz monzonite. All of the other three uranium multiple anomalies are located over the mineral deposit. There was fairly good correlation between the Track-Etch and humic sampling programs on the 50-ft (15 m) grid, especially in the southwestern section of the mineral deposit.

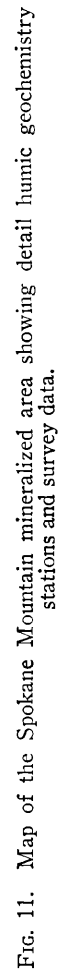
Drilling Programs

Early exploration drilling to 300-ft (90 m) depths in the 1950s and 1960s was generally limited to near-surface contact areas between the Togo Formation and the porphyritic quartz monzonite. In 1971, Western Nuclear started using Ingersol Rand 1000 hydraulic rotary/hammer drills successfully to 400-ft (123 m) depths with a 6-in (15 cm) hammer at an overall drilling cost of \$6 to \$7 per foot. Later the size of the hammer drill rig was increased to an Ingersol Rand 1500, using 250 pounds per sq in (175.8×10^2 kg per sq m) down-hole pressure and injecting foam, but the drill depth only increased to a maximum of 500 ft (152 m) because of excessive water. This was not sufficient to reach the granitic contact in many areas and did not permit drilling of angle holes. Therefore, it was found that NXWL core drilling, with a 1.87 in (4.8 cm) core, gave ten times the information at a slightly greater overall cost (\$12 to \$13 per ft). Had the detailed geophysical and geochemical programs been completed prior to the original drilling, only six holes on 200-ft (60 m) drill centers would have been necessary to make the discovery. Since the discovery (hole no. 19), semidevelopment drilling on 100-ft (30 m) centers has been adequate to follow the mineralized body. Fill-in drilling on 50-ft (15 m) centers may be necessary to provide adequate data for mine planning.

Summary

Through the effective use of multiple geophysical and geochemical exploration programs, none of which could have worked alone, Western Nuclear was able to define the northeast Midnite trend or belt of favorable rocks approximately 1 mile (1.6 km) wide and 9 miles (14.5 km) long. Detailed humic and Track-Etch sampling on 100-ft (30 m) centers delineated buried favorable drill targets. Initial exploration drilling programs were planned utilizing core drilling equipment that was capable of handling the maximum target depth. Careful lithologic logging and sampling of the drill holes with continuous geologic evaluation maximized the drill hole spacing to locate the limits of the deposit rapidly and with a minimum expense. The size and extent of the Spokane Mountain uranium deposit are still not established. However, vertical extent of the uranium mineralization averaging 8 ft (2 m) thick and 0.25 wt percent eU_3O_8 has been outlined in 19 drill holes, covering a $200 \times 1,000$ ft (61×305 m) area at depths of 150 to 500 ft (46 to 152 m).

Although the Spokane Mountain deposit has many of the same characteristics as the Midnite mine 2 miles (3.2 km) to the south, it differs in that:



1. The strike of the deposit is almost at right angles to the strike of the bedding and foliation.

2. Although thin carbonate beds exist, they do not appear to act as a barrier as suggested by Nash and Lehrman (1975) at the Midnite mine.

3. Uranium mineralization extends at least 50 ft (15 m) into the quartz monzonite.

4. Apparent stratigraphic control limits the uranium mineralization to the pelitic section of the Togo Formation.

5. Most of the uranium mineralization is reduced and below the present water table.

6. The mineralization is probably of lower grade and thickness but may be more widely distributed because of larger quantities of acid ground water.

Acknowledgments

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WESTERN NUCLEAR, INC.
NORTH 8623 DIVISION STREET
SPOKANE, WASHINGTON 99208
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