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INTERNATIONAL MINE SERVICES LIMITED

Report On:

THE GRANDE PRAIRIE EXPLORATION PERMITS

ALBERTA

- an exploration venture for sandstone-type uranium mineralization in the Western Alberta Basin

B.A. Edmond, P.Eng.

Toronto, Ontario
March 26, 1970.

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SUMMARY

1. The results of a continent wide, research oriented exploration program for sandstone-type uranium deposits have indicated widespread favourable sedimentary environments in the shallow subsurface strata of the Western Alberta Basin.

2. Since the region is drift covered, conventional prospecting procedures cannot be successfully employed. A method of subsurface investigation for sandstone-type mineralization was developed which integrates stratigraphic analysis, petrographic studies and geochemical data derived from the logging of oil and gas wells.

3. Field and subsurface information revealed the presence of two large fluvial channel complexes with associated anomalous uranium values in the lower part of the Upper Cretaceous Wapiti Group within the northern part of the Western Alberta Basin. The anomalous sandstone intersections occur in an interlensing sandstone-mudstone horizon 250 to 375 ft. above the base of the Wapiti Group and at depths of 500 to 1200 ft. below surface. The size of these fluvial complexes rivals any of the producing units in the southwestern United States. Their geological setting and nature show many important similarities to the Salt Wash member of the Morrison formation which is host to a large number of orebodies on the Colorado Plateau.

4. Those portions of the fluvial channel complexes most likely to contain economically significant mineralization have been covered by six Quartz Mineral Exploration Permits in two adjacent blocks totalling nearly 300,000 acres. The leases are tenable for three years at a moderate rental and commenced on February 19, 1970. (See Appendix A).

5. An exploration program is outlined for the preliminary evaluation of these permits in the current year at an estimated cost of $250,000.

6. The properties are well situated with respect to overall economic factors including road and rail transport.

7. The Province of Alberta levys a 12½% royalty on production of uranium and coproduct base metals in place of a Provincial mining tax (see Appendix B).

8. Participants are invited in a joint venture exploration program to develop these properties.

Plate 1 - Typical exposure of sandstones of the Wapiti Group in the valley of the Wapiti River south of Grande Prairie

Plate 2 - Cross-bedded sandstone of channel origin with irregular lenses of polymictic conglomerate and carbonaceous silt containing plant fragments, section shown is about 20 ft. high, valley of Wapiti River near Iroquois Creek.

1. INTRODUCTION

Sandstone-type uranium deposits in unmetamorphosed post Precambrian sediments contain virtually all of the uranium reserves of the United States which consist of about 190,000 short tons of U_3O_8[1]. Associated potentially valuable metals include vanadium, molybdenum, copper and selenium.

In response to the projected demands for uranium and related coproduct metals, International Mine Services Limited has been conducting a prospecting program for sandstone-type uranium deposits in the western United States and Canada since 1968. Our approach to this phase of resource development has placed a heavy reliance on research into the diverse geological factors responsible for the formation of these deposits and conceptual models have been devised for ore-forming processes in a number of related geological environments. In the course of this work comprehensive evaluations have been made of the published literature and field examinations carried out on typical deposits in the States of Colorado, Utah, Wyoming and Texas. Discussions have been held with geologists of the United States Geological Survey, the Atomic Energy Commission and the staff of various mining companies. One of the primary aims of this effort has been to delineate essentially new exploration targets in economically advantageous regions.

This program has been directed by the writer who has been most ably assisted by Mr. R. Boulay B.Sc. and Miss D.P.L. Jones B.Sc. Professor G. Norris Ph.D. of the University of Toronto has been retained as consultant on stratigraphy, sedimentation and organic geochemistry.

It became evident as the investigation progressed that nearly all of the major uranium-producing areas had been found by exploring the surface expression of mineralized sediments in arid, dissected terrains typified by the Colorado Plateau and the Wyoming Basins. However, large volumes of generally favourable clastic sediments lie concealed in the shallow subsurface within a number of basins which are not amenable to conventional prospecting techniques. One important example is the Western Alberta Basin which contains one of the largest accumulations of such sediments on the North American continent but which remains virtually unexplored for sandstone-type uranium mineralization. The properties described in this report were acquired as the direct result of an experimental method of prospecting which is entirely dependant on subsurface data derived from the logging and sampling of oil and gas wells.

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1. Writer's estimate of reserves recoverable at less than $10/lb. allowing for recent discoveries in Wyoming but discounting byproduct sources such as uraniferous phosphorites.

2. PROPERTY DESCRIPTION

The mining properties known as the "Grande Prairie Exploration Permits" which are the subject of this report consist of a total of six Quartz Mineral Exploration Permits covering two blocks of land in the vicinity of the town of Grande Prairie in northwestern Alberta (see Figure 1). They are:

Permit No.	Area (Acres)	Total Area (Acres)
149	49,920 ±	
150	49,920 ±	
151	49,280 ±	
152	49,280 ±	
153	49,920 ±	
		248,320 ±
and 154	49,920 ±	49,920 ±
		298,240 ±

A more explicit schedule of these permits is given in Appendix A. The permits are held in trust by Mr. John L. Tindale, Chief Geologist, International Mine Services Ltd., for the following companies which share interest as indicated:

Prado Explorations Ltd.	50%
Snowdrift Base Metal Mines Ltd.	25%
Murky Fault Metal Mines Ltd.	25%

There properties are available for development by means of a joint venture exploration program.

A summary of the laws and regulations concerning Quartz Mineral Exploration Permits, Leases and Royalties is presented in Appendix B.

3. COST ESTIMATE

The following is an estimate of the cost of exploration which would be necessary to carry out an adequate preliminary investigation of the permits during the 1970 field season as discussed in section 10.

drilling and downhole mechanical logging 36,000 ft. @ $5/ft.	$180,000.00
fees and salaries	12,000.00
field operating costs including vehicle	10,000.00
assaying	10,000.00
roads and sumps	5,000.00
compensation to owners of surface rights	5,000.00
office and data compilation	5,000.00
contingencies (about 10%)	23,000.00
Total	$250,000.00

4. TOPOGRAPHY, ACCESS AND FACILITIES

The Grande Prairie Exploration Permits are situated near the northern end of the Western Alberta Basin within the Great Plains physiographic province. The land surface is gently undulating prairie which is partially wooded but under cultivation by small farms in a number of localities (11). Bedrock is almost entirely concealed by glacial deposits except in the deeply incised valleys of the Wapiti, Smokey and Simonette Rivers where gorges over 400 ft. deep expose good sections of sediments of the Upper Cretaceous Wapiti Group (see Plate 1).

The only settlement of importance in the area is the town of Grande Prairie situated on the Trans Canada Highway. Since the town owes its existence to extensive petroleum and natural gas exploration in the region in recent years, contractors and suppliers for mineral exploration needs are readily available. Facilities include a modern airport with scheduled flights to Edmonton. Rail transport is provided by the Alberta Northern Railway. Most of the areas encompassed by the permits are accessible by means of secondary roads servicing local farming districts. To the writer's knowledge no mineral exploration (except for coal) has been carried out in the area and no other Quartz Mineral Exploration Permits are in existence.

5. TECTONICS, SEDIMENTATION AND STRATIGRAPHY

Much of the westerly portion of the Province of Alberta is occupied by an extensive foreland basin termed the Western Alberta Basin or Syncline. The boundaries of this Basin are defined in rather arbitrary geographic, tectonic and stratigraphic terms. The Basin is strongly asymmetric. The westerly limb is steep and cut off or overridden by thrust sheets of the disturbed belt. The eastern margin is characterised by low dips and is essentially conformable with the regional slope of the underlying margin of the craton. The basinal axis lies close to and parallel with the edge of the thrust belt. To the south the Basin narrows into a re-entrant between the Sweetgrass arch and the disturbed belt. To the north it is bordered by the Peace River arch in the vicinity of Lesser Slave Lake. The extremely large areal extent of the Basin is demonstrated by the fact that Upper Cretaceous and Paleocene formations near its centre occupy an elongate, somewhat elliptical area following the mountain front from the Montana border to British Columbia - a distance of well over 500 miles (17).

The Paleozoic succession is represented by various stable shelf clastic and carbonate sediments which rest on a peneplained Precambrian basement. During the Mesozoic successive waves of clastic sediments poured into the subsiding basin from the developing Cordillera to the west. Deposition was most pronounced during the culmination of the Laramide orogeny in Upper Cretaceous and Paleocene time. Each depositional episode was contemporaneous with batholith intrusion, uplift and related volcanism along the axis of the orogenic belt (5, fig. 12). Thus the sediments of this thick sequence of clastic wedges were derived from a wide range of sedimentary, igneous, metamorphic and volcanic rocks (40). Wind-transported volcanic ash and derived bentonites made substantial contributions to the sediment supply particularly in the late Cretaceous (6, 19).

Periodic transgression and regression of the Mesozoic epicontinental seas took place across the Basin from the southeast giving rise to facies relationships which are complicated both on regional and local scales. In general thick wedges of coarse grained continental clastic sediments thin and become finer to the east where they interfinger laterally with deltaic and shallow marine facies. By Paleocene time sedimentation was entirely continental and a thick pile of essentially non-volcanogenic clastic debris accumulated in the axial part of the basin overlapping the Upper Cretaceous continental, deltaic and shallow marine sediments (37).

During the remainder of Cenozoic time the soft Cretaceous and Paleocene strata were deeply incised and eroded by eastwardly flowing river systems. Remnants of Eocene to Pliocene alluvial gravels cap ancient land surfaces at a number of localities.

Table 1 shows the relationships of uppermost Cretaceous and Paleocene formations in the central and southern parts of the Alberta basin and in the adjacent Cypress Hills region. In the northern part of the basin, with which this report is specifically concerned, the Wapiti Group comprises a thick accumulation of continental clastic sediments equivalent to all of the post-Alberta Cretaceous section and possibly part of the lower Paleocene (2,4,10,33). The Wapiti Group is coextensive with and similar to the Saunders Group (3) further to the southeast. The thickness of this sedimentary accumulation exceeds 10,000 ft. in the axial portion of the basin and accounts for one half to two thirds of the entire post Precambrian section. The term Brazeau (23, 38,) is essentially synonymous with the Saunders but is used for equivalent strata along the margin of the disturbed belt.

The Wapiti and Saunders Groups conformably overlie the Wapiabi formation consisting of shallow marine shales and sandstone. These intertongue laterally to the south and east with fluvio-deltaic sediments of the Edmonton and Belly River Groups (8,13,31,32). The Bearpaw formation is a prodeltaic deposit separating the Edmonton and Belly River Groups; it wedges out before reaching the type area of Wapiti Group near Grande Prairie. The St. Mary River formation represents a smaller fluvial lobe encroaching into the basin from the southwest and interfingering with the Edmonton Group.

6. ENVIRONMENTS FOR SANDSTONE-TYPE MINERALIZATION IN THE WESTERN ALBERTA BASIN

It is beyond the scope of this report to discuss the complicated subject of the nature and origin of sandstone-type uranium deposits. The reader is referred to an excellent recent summary by Finch (15) as well as a brief outline given in Appendix C. Various aspects of the sedimentology of continental strata which are the host rocks of these deposits are treated by Pettijohn (28), Potter and Pettijohn (30) and others (29,39).

One phase of our program was directed toward an evaluation of the uranium potential of various Upper Cretaceous and Paleocene formations of the Western Alberta Basin which overlie the Alberta Group. A comprehensive literature study revealed that within a broad tectonic-depositional setting, the Basin represents the northerly extension of the Cordilleran foreland province which contains nearly all of the important uranium producing districts of the southwestern United States including deposits in Triassic and Jurassic formations of the Colorado Plateau, those in Eocene strata of the Wyoming basins and those in Jura-Cretaceous and Paleocene rocks of the Black Hills uplift (Diag. 1). Occurrences of subeconomic uraniferous lignites are widely distributed in the Paleocene Ravenscrag formation of southern Saskatchewan suggesting that sandstone-type mineralization may be present in the coarser grained equivalents to the west.

Field reconnaissance surveys were carried out during 1969 on typical exposures of a number of formations of continental and marginal marine origin over a region extending from southern Saskatchewan to northwestern Alberta. Lithologically and sedimentologically favourable fluvial sand units were observed in a number of areas. Certain samples of carbonaceous sandstone, carbonized, pyritic or limonitic plant fragments and bone material collected from them gave anomalous amounts of indicator elements such as vanadium, molybdenum, nickel, selenium and zinc indicating advantageous geochemical conditions. No examples of sandstone-type uranium mineralization were encountered but this was not considered to be significant as the region is extremely large and bedrock exposure is in the order of 0.1% or less.

Studies of outcropping sediments of the Wapiti Group along the valleys of the Wapiti, Smokey and Simonette Rivers in the northerly portion of the Basin revealed the presence of numerous sandbodies of single to multilateral channel origin which rival in size any of those of the major producing areas in Wyoming or the Colorado Plateau. This factor along with the attractive lithological characteristics of the Wapiti sandstones convinced the writer that this unit warranted serious investigation.

Within the Wapiti Group sandbodies tend to occur in clusters of individual channel deposits up to 30 ft. thick and several hundred feet in width. They commonly have erosive, convex-down bases marked by lenticular lag deposits of chert pebbles and clay phenoclasts. Trough cross-bedding and current lamination features are common in the channel fills as are irregular mudstone lenses. The sandstones are typically soft, pale grey or buff, coarse to medium grained, poorly sorted, argillaceous, calcareous and quartzose. Carbonaceous plant material is common and ranges from sections of logs to finely comminuted stem and leaf fragments. Detrital shells and bone fragments are also present, usually near the channel base. Pyrite occurs as small, concretionary-like aggregates of fine disseminated grains. Irregular "kaolinized" streaks transgressive to the bedding were noted in a number of outcrops and suggest post-consolidation fluid migration.

The channel sandstones are interbedded with finer grained, thinly bedded sandstones, siltstones and mudstones of floodplain and lacustrine origin. The latter locally grade into paludal facies with increase in carbonaceous material, sideritic concretions and thin beds of low rank coal. The finer grained sediments are normally slightly to highly bentonitic and indicate that large amounts of vitric, airfall ash were being contributed to the sediment supply.

Several specimens collected from channel deposits gave distinctly anomalous values for several heavy indicator elements. For example a pyritic sandstone nodule yielded 2000 ppm zinc, 200 ppm lead, 100 ppm nickel, 100 ppm cobalt and 8 ppm selenium. A limonitized bone fragment gave 10 ppm. selenium.

Aeroradiometric profiles using a gamma ray spectrometer were flown over exposures along the major river valleys (22). A considerable number of low (2 x b.g. or less) peaks were obtained many of which coincided with good sand facies. This information suggested the presence of higher than normal radioelement content in some of the sandstones which may be largely masked by the effects of weathering.

7. SUBSURFACE PROSPECTING METHODS

It was evident that the lack of bedrock exposures and relatively severe weathering conditions preclude the use of conventional prospecting procedures. Accordingly a method was developed (and is still being perfected) to evaluate large volumes of sedimentary rocks using data provided by oil and gas wells.

Canadian Stratigraphic Service Ltd. of Calgary has been engaged to provide stratigraphic and mechanical well logs as well as data analysis on a consulting basis. A large collection of well cuttings has also been made available for the investigation.

Two complimentary procedures were applied in a region designated the 'northern test area' extending north from Twp. 62 and west of Range 22 W 5 (Fig.1):

1. Stratigraphic and lithofacies analysis based on mechanical and stratigraphic logs.

2. Petrographic and geochemical studies of samples of well cuttings.

While the probability is low that a random well would intersect ore grade mineralization, there is a reasonably good chance of cutting an associated body of altered sandstone of much greater volume and areal extent (Diag.2). Intersections which yield anomalous amounts of uranium or other allied heavy metals and/or evidence of alteration serve to identify specific sand units which may be significantly mineralized. The shape, thickness and attitude of such units can then be determined by means of stratigraphic analysis methods and their significance can be evaluated. It is worth noting that the original discovery in the important Ambrosia Lake district of New Mexico was made by using similar methods (24).

Stratigraphic and Lithofacies analysis

Very little was known initially about sedimentary patterns within the Wapiti fluvial lobe. A regional cross section (A-A of Fig.1) showed very poor correlation from well to well and suggested that the subdivisions proposed by Allan and Carr (4) from surface observations are probably not meaningful.

The base of the Wapiti Group was placed at or near the bottom of the first prominent sand above the Wapiabi formation as recognized from mechanical logs. This basal sand unit is variable in character. In some instances the base is transitional and the pick is somewhat arbitrary. In other examples local discontinuous sandbodies of shallow marine origin lie directly below and can be distinguished only by detailed lithological or mechanical log studies. A series of closed loop traverses from well to well in an area of uncertainty usually resolved any ambiguities. The shallow marine sandstones differ from typical Wapiti lithologies in being better sorted and glauconitic.

The Wapiti-Wapiabi contact is assumed to be conformable and structure contours on it show a rather featureless surface dipping to the south into the basin at about 46 fpm.

The upper limit of the Wapiti is the present land-surface beneath overburden throughout the test area and the unit is progressively truncated downsection to the north. Thickness ranges from zero to 5000 ft.

Because of the lack of well-defined throughgoing markers a main operational unit, designated A, was chosen as a slice 600 feet thick lying above the base of the Group (21). This was subdivided arbitrarily into a lower 100 foot slice, A1, which includes the basal sand unit and A2, the overlying 500 foot slice, which contains the occurrences of anomalous uranium values described below.

A map of total sandstone percentage for unit A was derived from electric log data (Fig.1). It shows the overall pattern of sediment dispersal quite clearly. A well-defined, sand-rich lobe with a scalloped edge convex to the northeast is present. There is an abrupt decrease in sand content along this boundary indicative of a rapid change in depositional conditions.

One of the most important controls of sandstone-type uranium mineralization on both regional and local scales is a rapid lateral transition between channel sandstone facies and thinly interbedded sandstone and mudstone of floodplain deposits. In order to delineate such changes a new image-generating function was defined which is termed the "total percent channel facies". It is based on the fact that channel sand bodies in the Wapiti can be recognized with a reasonable degree of assurance on stratigraphic and mechanical logs. The operational parameters chosen for this facies were:

(1) all sand beds over 10 ft. in thickness (including conglomerate which can only be recognized on stratigraphic logs).

(2) the sand bed must have an associated resistivity peak lying appreciably above a base height defined by the average peak heights of nearby thinly interbedded sand-mud facies and/or

(3) an indication of S.P. expression.

Thin interlenses of conglomerate or finer grained argillaceous material are included with the channel sands. It is evident that two comparable sections may contain equal amounts of total sandstone but differ markedly in percent channel facies. The choice of sandstone beds included in this facies is rather arbitrary and is illustrated by the hatched portions of the columnar sections in Figures 2 and 3.

A map of channel facies (Fig.1) clearly shows a main channel system with three or four radiating "distributary" channels very much like a bird foot delta. The channel deposits consist of superimposed or multistorey sandbodies and account for the generally poor subsurface correlation in the area. Superposition of the total sand and channel facies maps allows various sub-environments to be identified. The overall depositional environment is interpreted as the edge of an extensive alluvial fan, represented by fluvial-floodplain facies of the Wapiti, which terminates at an abrupt decrease in paleoslope gradient and is supplanted by low coast, subaerial sediments of the Belly River Group. The latter include much fine grained, bentonitic material and swamp deposits. Similar transitions occur in the Morrison formation of the Colorado Plateau (Salt Wash and Westwater Canyon members, 7,9,27,34) and in the Gran Chaco of South America (26).

Petrographic and geochemical studies

Mr. R. Boulay is conducting a program of systematic sampling and petrographic examination of well cuttings from the Wapiti Group. Most sampled intervals available start at the casing depth of 600 to 800 ft. but a few begin at surface. The work is being concentrated on relatively permeable, coarse, carbonaceous sandstones and associated mudstones which are believed to be of channel or closely related origin. These are most likely to show evidence of epigenetic alteration which usually accompanies mineralization and to retain abnormal amounts of uranium or geochemically allied elements (16, 18, 36). Sandstone intersections are chosen from stratigraphic or electric logs and the samples examined under the binocular microscope. Sand lithology is noted, especially the mineralogy, grain size, sorting, colour, cement, nature of any carbonaceous material and presence of pyrite or marcasite.

Typical Wapiti fluvial channel deposits consist of coarse to fine, poorly sorted, often calcareous and argillaceous, grey to buff quartz sandstones. These often have a "salt and pepper" appearance due to the presence of dark chert grains. Chert pebbles and granules are usually present especially near the base of a channel. Accessory mica, usually biotite, is often apparent. Feldspar, dark heavy minerals and apatite are generally rare. Carbonaceous plant fragments are common and are infrequently accompanied by pyrite in the form of anhedral grains or minute concretions.

Samples of 20 to 30 gm. from 10 to 40 ft. intervals are selected and the data tabulated. Each sample is cleaned of steel chips with a strong horseshoe magnet; any detrital magnetite removed in this way will not affect the results. All such samples are analysed for trace amounts of uranium by the fluorimetric method and for the indicator elements vanadium, molybdenum, copper, lead, zinc, manganese, nickel, cobalt, and chromium by spectrographic methods; selenium is determined by atomic absorption. Most of the samples taken are from the upper 1500 to 2000 ft. interval in the well although a few have been taken at deeper horizons when well developed sandbodies are present. In addition all available samples are tested for radioactivity using a Scintrex model BGS-1 scintillometer; this should detect uranium in equilibrium in concentrations greater than 0.05%. Very few gamma ray logs are available for the appropriate intervals.

8. RESULTS OF SUBSURFACE INVESTIGATIONS

Initial results of the sampling program proved most encouraging. Analyses of 165 samples from 44 randomly chosen wells gave three intersections in sandstone beds with anomalous uranium contents in the order of 100 ppm. as follows:

	Well	Depth	Lithology
1.	Plymouth Pan Am Bezanson (6-29-71-3W6)	940-960 ft.	very fine, buff, silty slightly carbonaceous sandstone
2.	Stanolind Economy Creek #B-1 (15-5-70-2W6)	1170-1190 ft.	medium to coarse, light grey, bentonitic and carbonaceous sandstone
3.	Merill Calvan Charter Scurry Grande Prairie (4-14-73-7W6)	550-560 ft.	coarse, light grey, calcareous and carbonaceous sandstone

All of the anomalous intersections occur 250 to 375 ft. above the base of the Wapiti in a distinctive, interlensing sandstone-mudstone horizon which varies from 150 to 300 ft. in thickness (Figs. 2 & 3).

Unit A2 was chosen so as to include this horizon in its central part and the lithofacies analysis procedures described above were completed. Intersections in the first two wells were found to be located along the southeast side of a very pronounced, northeasterly striking channel complex within a lithotopic belt lying between the 20 and 25% channel facies contours. Attempts to define and correlate a subunit A3 (Fig.3) containing tha anomalous sand-rich horizons failed; almost certainly the individual sandbodies are lenticular and discontinuous between the relatively widely spaced wells. An additional well, Shell Grande Prairie (2-15-71-6W6) also within the same belt but on the northwest flank of the channel system shows a well defined, sharp peak on the gamma-ray log 958 ft. above the base of the Wapiti. This peak is characteristic of weakly radioactive organic material. The corresponding sediments are grey silt and argillaceous and calcareous sandstone with pyrite. Additional, well developed sand units occur above A2 at this locality and elsewhere but do not show such clear cut patterns of channel facies distribution.

The uranium-bearing intersection in the third well is evidently related to a similar, parallel channel system situated about 25 miles northwesterly from the first. Like the others it is found within the lithotopic belt defined by 20 to 25% channel facies. Unfortunately mechanical control is poor in this region and contours showing facies distribution are rather generalized. Intersections 40 to 50 ft. in length appearing immediately above and below this anomalous occurrence consist of unusual pinkish, crumbly, limonitic sandstone with "kaolin" spots and trace amounts of fine grained pyrite. This material is suspected to be a form of epigenetic alteration which commonly accompanies sandstone-type mineralization.

Spectrographic data showed abnormal amounts of the indicator elements copper, lead, zinc, vanadium, nickel and possibly molybdenum (16,18,36) in a number of other sandstone and mudstone samples. In the Plymouth Pan Am Bezanson well some of the heavy metal values are attributable to extremely fine metallic contamination and electron microprobe studies are being carried out in order to separate these from genuine mineral phases. The work is being carried out by Dr. R.S. Boorman of the Research and Productivity Council, Fredericton, N.B. The uranium content of the samples is, however, not suspect.

9. DISCUSSION AND INTERPRETATION

Combined field and subsurface information has demonstrated a number of important similarities in lithology and sedimentology between fluvial sediments of the Wapiti Group and those of the productive Salt Wash member of the Morrison formation in the Colorado Plateau. The Uravan mineral belt in western Colorado and adjacent Utah includes hundreds of deposits and extends for about 140 miles along the leading edge of the Salt Wash fluvial lobe. The mineral belt is controlled by a zone of sediments with favourable sandstone-mudstone ratios and individual deposits or groups of deposits are localized by channel fills (Diag.3). The dominant Salt Wash lithologies are quartzose sandstones with variable amounts of carbonized plant debris interbedded with bentonitic silt and mudstone; they closely resemble the Wapiti except for being various shades of white to pastel pinkish in colour rather than grey or pale brown.

A somewhat analogous situation to the abrupt Wapiti-Belly River transition obtains near the northern edge of the Westwater Canyon member of the Morrison formation in the Ambrosia Lake district of New Mexico. Three elongate zones of large uranium deposits are present in the Westwater Canyon member in a thick belt of coarse grained sediments which rapidly thins and interfingers with finer grained facies downdip (34, Diag.5). A number of parallel examples in other regions could be cited including deposits in the Chinle formation in Utah (Diag.4) and in the Texas Gulf coastal plain.

Subsurface stratigraphic and geochemical procedures applied to the Wapiti Group have succeeded in outlining two very large fluvial channel complexes with abnormal amounts of uranium in a setting which is conducive to the formation of economically significant deposits.

It is inferred that during the middle or late Cenozoic erosional downcutting exposed the upper parts of the Wapiti succession. Surface waters would then have been able to invade the sedimentary pile along the western edge of the Basin which is topographically high and where coarse, permeable facies are most prevalent. Meteoric water would migrate downdip following the ancient drainage system along aquifers of channel origin. In the process large volumes of sediments enriched in decomposed leucocratic volcanic material would be partially scavenged of their heavy metal content. Reprecipitation of uranium and geochemically related elements would tend to take place under favourable geochemical and hydrological conditions in channel sand deposits adjacent to the Wapiti-Belly River transition. This mechanism of concentration is illustrated in Diagram 2.

10. PROPOSED EXPLORATION PROGRAM

The locations of the Grande Prairie Exploration Permits were chosen so as to cover those portions of the two Wapiti fluvial complexes which are most likely to contain significant mineralization. Empirical data suggests that the borders of these lithosomes with 20 to 25% channel facies are important in this respect.

Further exploration must be based on a drilling program to carry out detailed evaluations of the anomalous sites already known. Offsets would be made from the three wells listed above using small diameter percussion drill holes. No rigid drilling pattern is recommended; successive holes should be located and spaced at the discretion of the field geologist as changing circumstances dictate. Some coring of the sand beds which gave the anomalous uranium values would be necessary particularly in the initial stages of the project. All holes would be logged by the usual self-potential, resistivity and gamma ray methods and the cuttings systematically assayed as required. Dipmeter logging might prove useful in tracing the path of individual channels. All holes should completely penetrate the stack of sandbodies in the middle and upper parts of unit A2.

Minimum staff requirements for field supervision would be met by a geologist and his assistant. The time requirement exclusive of office compilation is estimated at 4 to 5 months.

Respectfully submitted by:

B.A. Edmond, P.Eng.

at Toronto, Ontario

March 26, 1970.

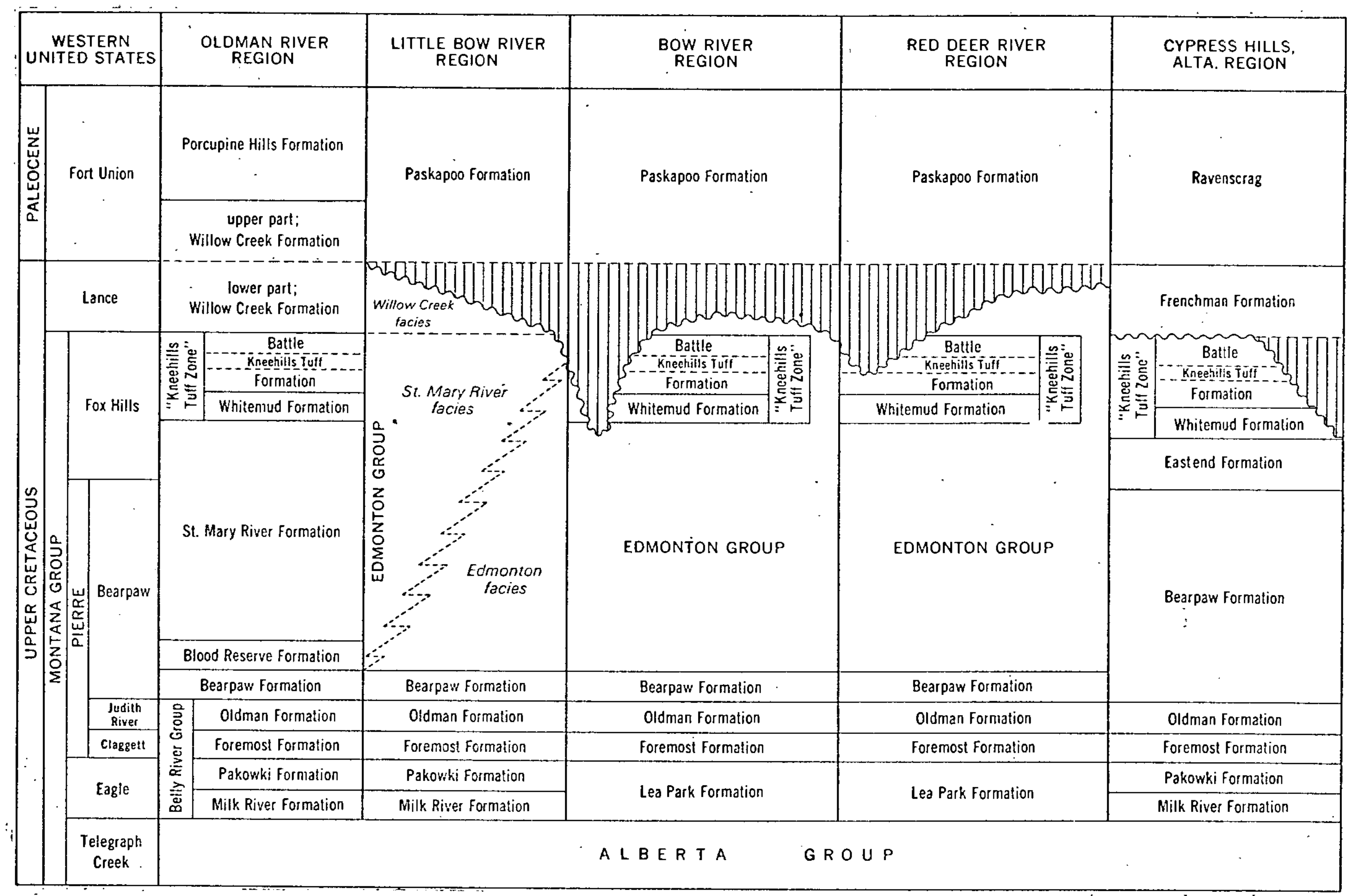
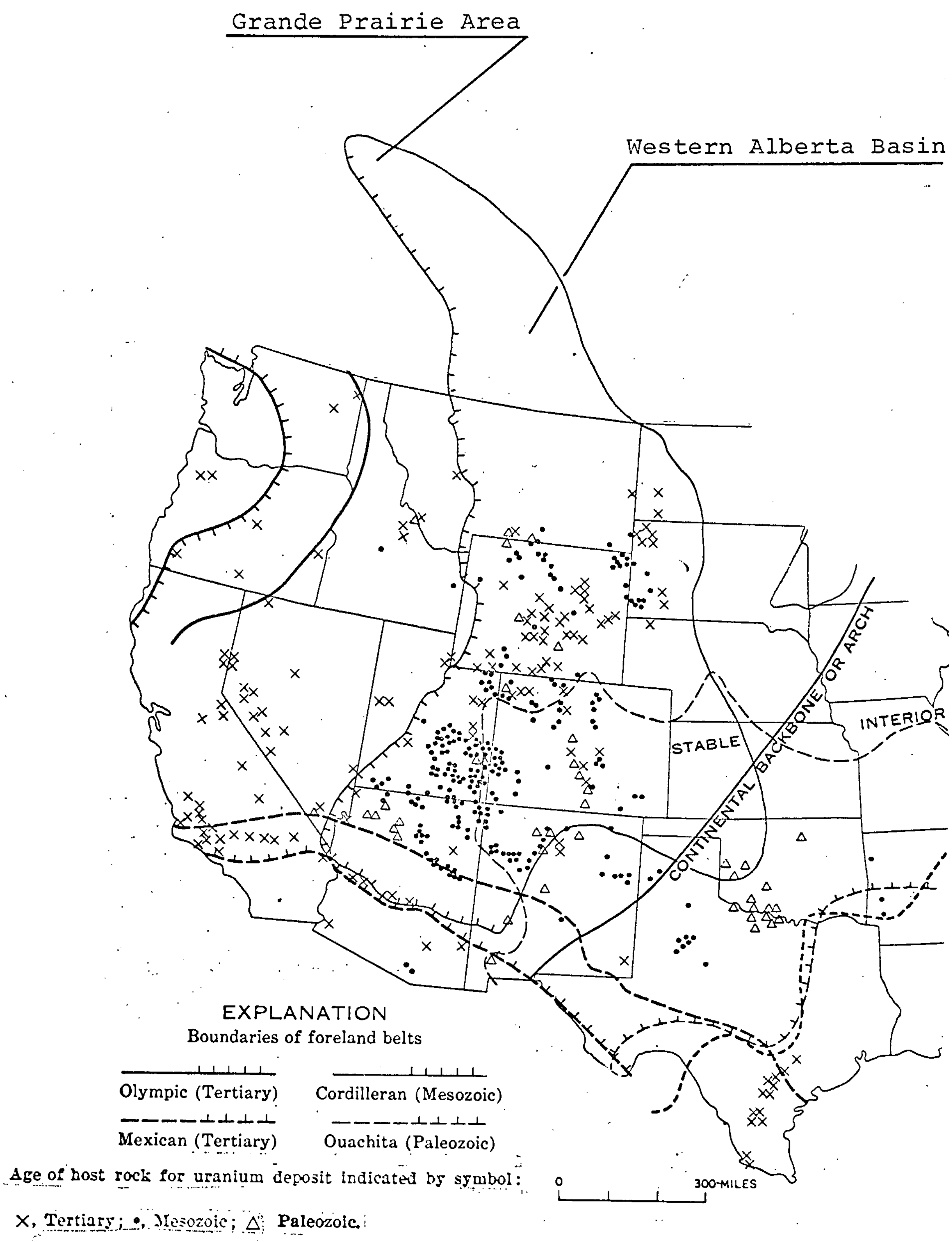
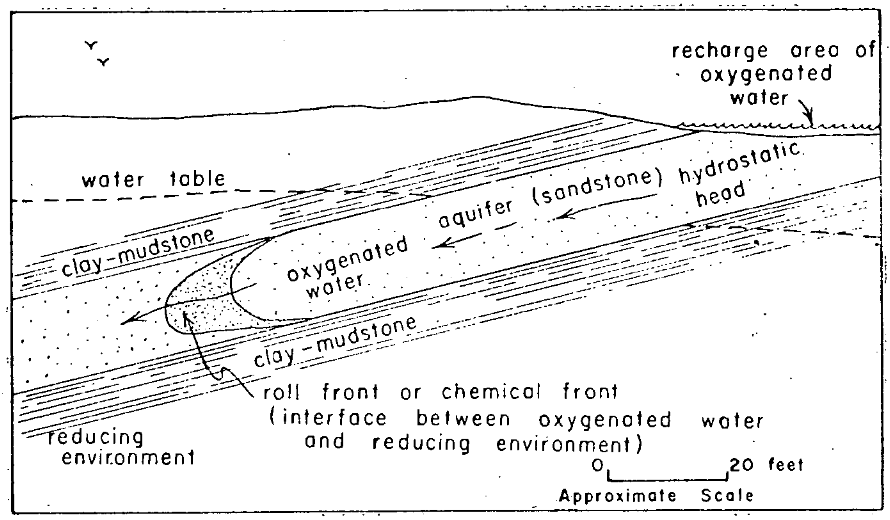


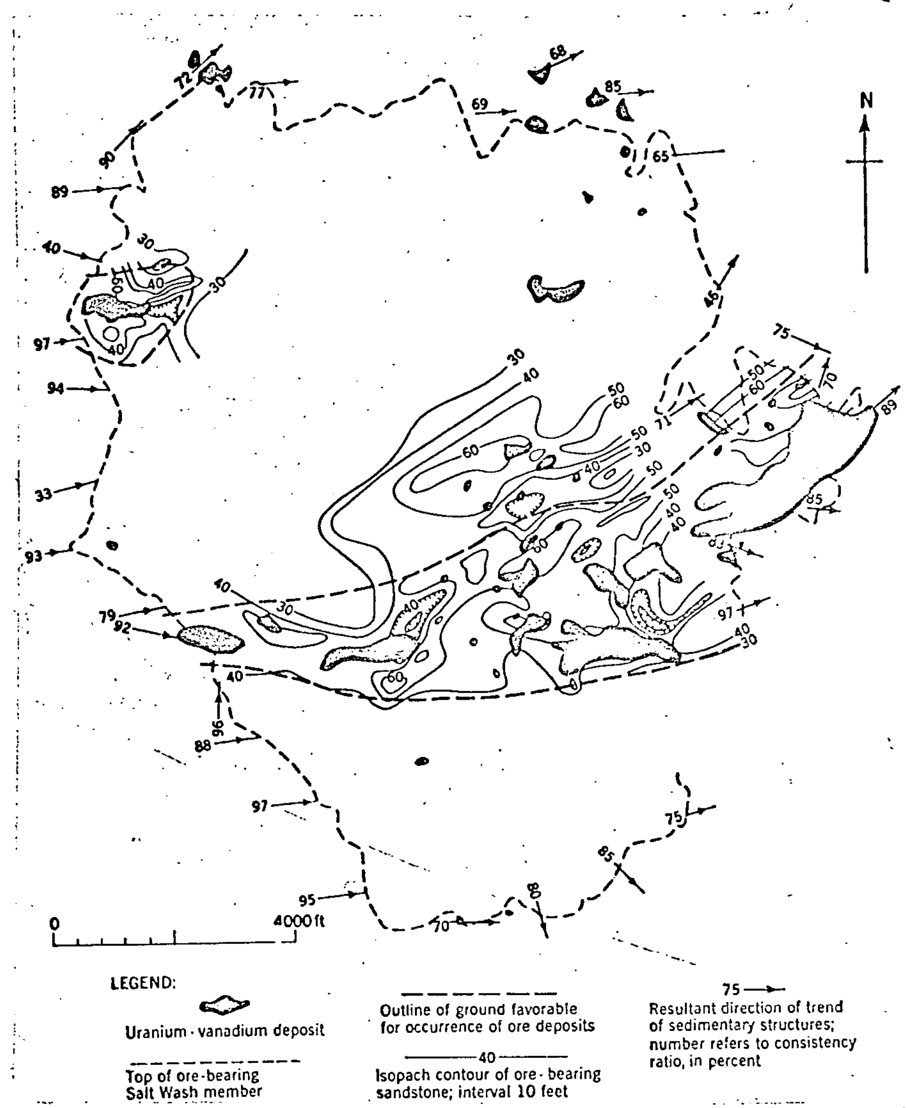
Table 1 -. Correlation chart of the uppermost Cretaceous and Paleocene formations of the southern Alberta plains. (Irish & Harvard, 1968, fig.2)



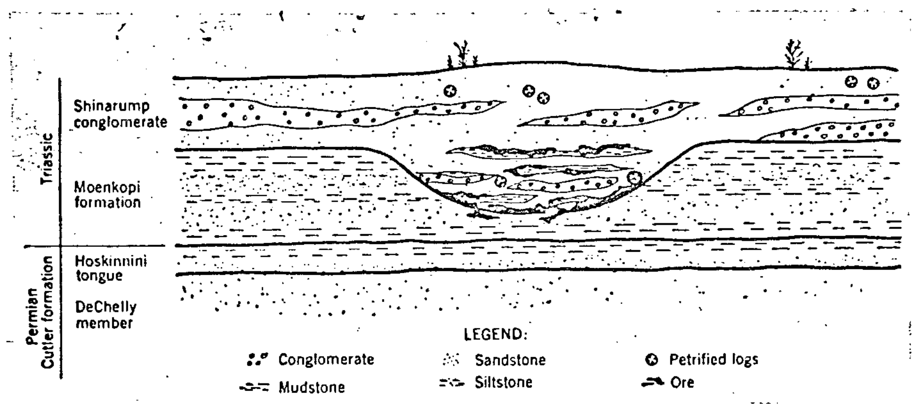
Diag.1 - Uranium deposits in sandstone in the Cordilleran foreland belt of the United States and its relationship to the Western Alberta Basin. (Finch, 1967, fig.3)



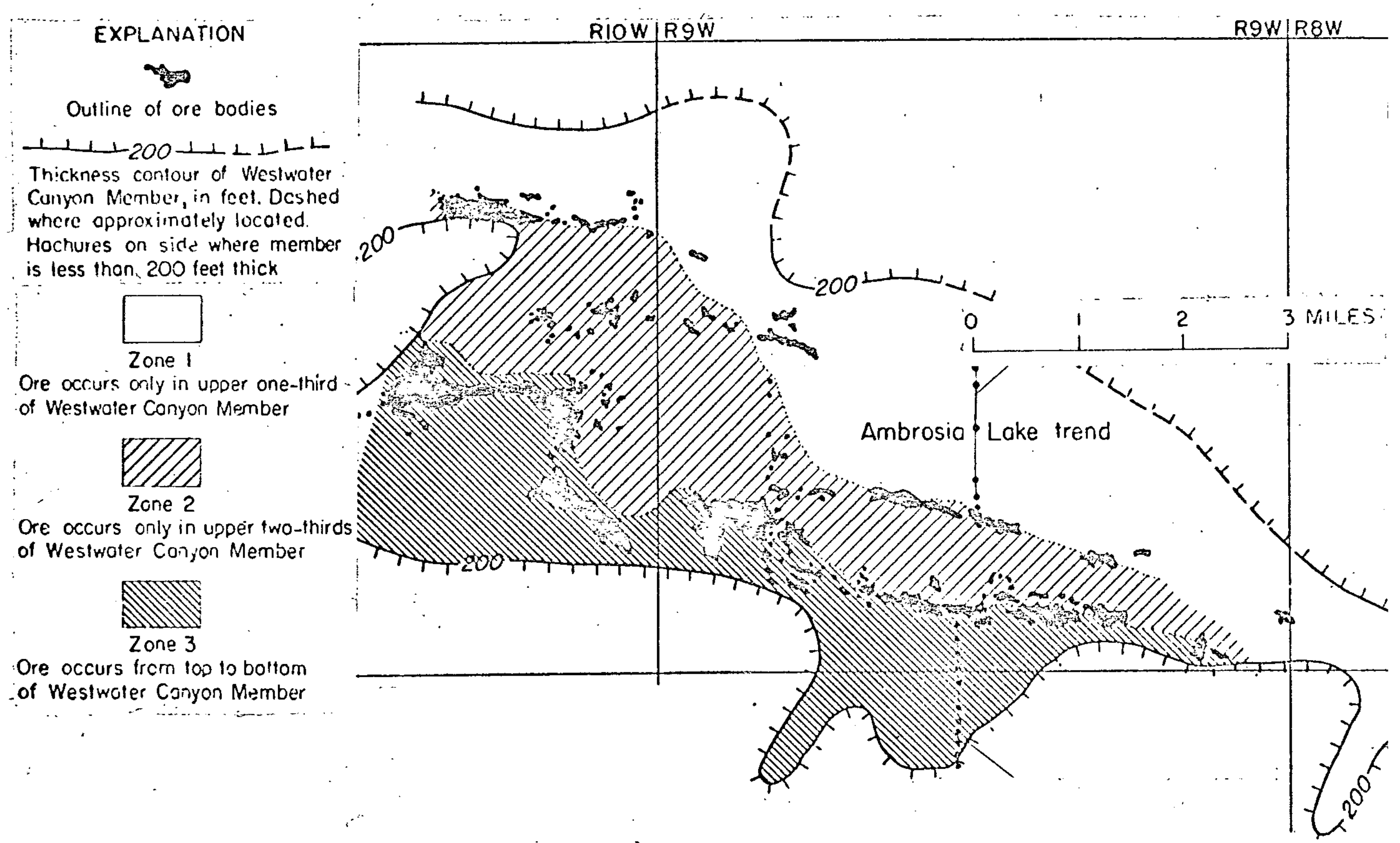
Diag.2 - Schematic cross-section of a sandstone aquifer showing the processes involved in the formation of a roll front orebody
(Adler & Sharp, 1967, fig.2)



Diag.3 - Lenticular, strata-conformal uranium-vanadium deposits in a channel sandbody, Salt Wash member of Morrison formation, Uravan district, Colorado.
(Boardman et al., 1956)



Diag.4 - Uranium deposits in paleochannel at the base of the Shinarump member of the Chinle formation, Monument Valley, Arizona (Mitcham and Evensen, 1955)



Diag. 5 - Elongate clusters of orebodies in braided channel sandstone-mudstone complex of Westwater Canyon member of Morrison formation, Ambrosia Lake district, New Mexico (Santos, 1963, fig.1)

APPENDIX A

Schedule for the "Grande Prairie Exploration Permits", Alberta
(Quartz Mineral Exploration Permits No. 149,150,151,152,153 & 154)

Permit No.	Twp.	R. W6	Sections	No. of Sections	Area (acres)
149	69	2	13-36 incl.	24	
	69	3	25-36 incl.	12	
	70	2	3-10 incl.	8	
			15-22 incl.	8	
			27-34 incl.	8	
	70	3	1-18 incl.	18	
				78	49,920 ±
150	70	3	19-36 incl.	18	
	70	4	25-27 incl.	3	
			34-36 incl.	3	
	71	3	1-36 incl.	36	
	71	4	1-3 incl.	3	
			10-15 incl.	6	
			22-27 incl.	6	
			34-36 incl.	3	
				78	49,920 ±
151	72	3	1-36 incl.	36	
	73	2	19 & 20	2	
			29-32 incl.	4	
	73	3	1-8 incl.	8	
			N½ & SW¼ 9	3/4	
			11-13 incl.	3	
			W½ 10	½	
			N½ & SW¼ 14	3/4	
			15-36 incl.	22	
				77	49,280 ±
152	72	4	1-4 incl.	4	
			9-16 incl.	8	
			21 & 22	2	
			S½ & NE¼ 23	3/4	
			24-28 incl.	5	
			33-36 incl.	4	
	73	4	1-4 incl.	4	
			9-16 incl.	8	
			21-28 incl.	8	
			33-36 incl.	4	
	74	3	1-11 incl.	11	
			E½ 12	½	
			13	1	
			N½ & SW¼ 14	3/4	
			15-18 incl.	4	
	74	4	1-4 incl.	4	
			9-16 incl.	8	
				77	49,280 ±
153	71	5	28-33 incl.	6	
	71	6	25-27 incl.	3	
			34-36 incl.	3	
	72	4	5-8 incl.	4	
			17-20 incl.	4	
			29-32 incl.	4	
	72	5	1-36 incl.	36	
	72	6	1-3 incl.	3	
	73	4	5-8 incl.	4	
			17 & 18	2	
	73	5	1-3 incl.	3	
			10-15 incl.	6	
				78	49,920 ±

Appendix A (Continued)

Permit No.	Twp.	R. W6	Sections	No. of Sections	Area (acres)
154	72	6	30 & 31	2	
	72	7	25-29 incl.	5	
			32-36 incl.	5	
	73	6	6 & 7	2	
			18 & 19	2	
			28-33 incl.	6	
	73	7	1-5 incl	5	
			8-17 incl.	10	
			20-27 incl.	8	
			34-36 incl.	3	
	74	6	4-9 incl.	6	
			16-21 incl.	6	
			28-33 incl.	6	
	74	7	1-3 incl.	3	
			10-15 incl.	6	
			22-24 incl.	3	
				78	49,920 ±

TOTAL AREA = 298,240 ± acres

Notes

1. Permits No. 149 to 153 inclusive form a contiguous block within the boundaries of which are the following parcels of freehold land not included in the permit:

Location		Reference	Title to Mineral Rights
73-3W6	Se ¼ sec. 9	(144M235)	THE GOVERNOR AND COMPANY OF ADVENTURERS OF ENGLAND TRADING INTO HUDSON'S BAY
	E ½ sec. 10	(145M235)	
	SE ¼ sec. 14	(148M235)	
72-4W6	NW ¼ sec. 23	(29D236)	"
74-3W6	W ½ sec. 12	(147L235)	"
	SE ¼ sec. 14	(146L235)	"

(title search by B.A. Edmond, Feb.16, 1970; Provincial Land Titles Office, Land Titles Bld., 102A Ave., & 100 Street Edmonton).

2. The right-of-way of the Alberta Northern Railway crossing the west end of Permit No. 153 and the Grande Prairie townsite are also exempt from the permits (B. Nimchuck, Mining Recorder, per comm. Feb. 16/70)

3. The commencement date of all of the permits is February 19, 1970.

APPENDIX B

Summary of Laws and Regulations pertaining to Quartz Mineral Exploration Permits Leases and Royalties in the Province of Alberta

1. Fee Lands

The government of Alberta controls the mineral rights for over 90% of the province. Mineral rights were granted with some of the earlier homesteads and to the C.P.R. along railroad right-of-way. The Province does not administer the latter however they are still subject to the 12½% royalty described below.

2. Quartz Mineral Exploration Permits

The granting of permits to explore for uranium and base metals falls within the Quartz Mining Regulations (Alta. Reg. 377/67) under The Mines and Minerals Act, 1962. The permits have a maximum tenure of 3 years and may be obtained for tracts of land up to 50,000 acres in area. Rental and deposit for each 10,000 acre parcel or portion thereof is as follows:

year	rental	deposit
1	$125.00	$1000.00
2	1000.00	-
3	1500.00	-

The deposit is refunded when the permit terminates but may be forfeited to the Crown if the permittee does not conduct a program satisfactory to the Director of Minerals. Exploration practise is governed by the Geophysical Regulations (Alta. Reg. 26/59 amended by 425/59, 271/64 and 256/65).

3. Quartz Mineral Leases

A lease with a term of 21 years may be acquired for land already held under an exploration permit. The annual rental is $0.25/acre for the first five years of the lease and $1.00/acre thereafter. Leases are renewable for additional 21 year periods.

Permits or leases do not conflict with coal, oil or gas leases or permits.

4. Royalties

The Government of Alberta levys a free royalty of 12½% on all "quartz mineral" production including uranium and other coproduct metals (Alberta Reg. 318/68). The Minister may allow certain deductions in the royalty computation for costs incurred in processing or transportation of the product.

It is important to recognize that the provision for a royalty exists in lieu of a Provincial mining tax.

Since base metal production in the Province has been negligible to date there is no precedent for either leases or royalties.

APPENDIX C

Some Notes on the nature of Sandstone-type Uranium Mineralization

Sedimentary uranium deposits have been the subject of a vast amount of research in the past two decades and the published literature on them is voluminous. In spite of a variety of differing opinions concerning various aspects of the problem there is a better basic framework of knowledge regarding these deposits than almost any other type of mineralization. This is largely due to the fact that the processes involved are surface or near surface ones which are reasonably well understood compared to those involved in the formation of hydrothermal or magmatic deposits.

The overall tectonic-depositional environment is normally provided by an undeformed, late or post-Paleozoic cratonic basin in which a thick succession of continental and/or marine clastic sediments has accumulated. Breaching of the strata around the basin rim by subsequent erosion allows the influx of oxidizing surface waters which slowly flow downdip along aquifers provided by various kinds of river channel deposits within the basin fill. Uranium and geochemically allied elements such as vanadium, molybdenum, copper, lead, arsenic, selenium, etc. are leached from the invaded sandstones, carried in solution by the meteoric water. They are eventually precipitated as primary ore mineral assemblages at sites of abruptly decreased oxidation potential within or adjacent to the aquifer unit. The presence of low rank, humic organic material incorporated in the sediments provides a fundamental geochemical control in the precipitation process. The primary ore minerals consist of extremely intimate mixtures of oxides, sulphides and organic matter which either replace local concentrations of plant debris or occur as lenticular bodies or strata-transgressive "roll-fronts" marking a redox interface within the host sandstone. Such interfaces are thought to migrate downdip in front of the invasive column of meteoric water and sweep out large volumes of sandstone in the process. They are probably perpetuated and stabilized by bacterial activity. The invaded sediments frequently show some alteration effects involving oxidation, partial decomposition of certain minerals such as feldspars and magnetite, bleaching, formation or removal of interstitial carbonate and changes in minor element content. Alteration effects are sometimes subtle and difficult to recognize.

The elemental composition of the primary ores varies widely and often as many as a dozen extrinsic elements may be present. It is governed by both the supply of heavy metal ions to the mineralizing fluid and the Eh-pH conditions under which precipitation occurs. The decomposition of unstable, vitric volcanic ash in the host sandstone is probably the most important source of metals although leaching of first cycle feldspathic sandstones is the major contributor in some localities.

On a regional scale the nature and history of basin closure is an important hydrological control on the ingress of surface waters to the sediments. Certainly the most important local control of ore deposition is the occurrence of abrupt lateral and downdip interfingering of permeable channel deposits with relatively impermeable floodplain sediments. Such facies changes are characterized by both a rapid decrease in bulk transmissivity and an increase in content of finely divided humic matter. This situation provides both a throttling effect on the inflowing groundwater allowing for adequate reaction time as well as a very reactive geochemical environment.

/Cont'd.

Features such as unconformities, impervious beds and local structural modifications of the basin may also influence the overall hydrological pattern.

Primary ores are highly susceptible to oxidation and usually are rapidly destroyed in the zone of weathering although the relatively soluble secondary minerals may persist under arid climate conditions. Conventional prospecting techniques rely heavily on the detection of radio-element dispersion halos, heavy metal geochemistry and on colour changes in the altered sediments which are enhanced by weathering.

From this brief description it is evident that sandstone-type uranium deposits form as the result of a complicated interplay of sedimentological, geochemical and hydrological factors all of which must be taken into account in the design of an effective exploration program.

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Supplement to Report on:

The Grande Prairie Exploration Permits, Alberta

(dated March 26, 1970)

Extensive resampling of wells within and around the Permit areas and detailed mineralogical studies of the cuttings has been completed. It is evident that the initial difficulties and inconsistencies encountered stem from both contamination and the non-representative character of the samples. Anomalous heavy metal values originate in two ways:

(a) artificial metallic contaminants (lead, zinc, brass, steel filings etc.) from the drilling mud or drill bits, most of which are too fine to be identified under the binocular microscope.

(b) natural sulphide and oxide minerals of various origins.

The very small sample volume (about 20 to 40 gm. for each 10 foot well interval) no doubt has lead to a very high random sampling bias and the results can only be regarded as qualitative at best.

Heavy mineral separates were prepared from duplicates of the samples which gave unusually high heavy metal content (U, V, Pb, Zn, Cu. etc.) and the various components identified by microscopic X-ray and electron microprobe methods (42).

The following ore minerals were identified in small amounts:

sulphides	oxides
pyrite (crystals & spheroids)	hematite
marcasite	magnetite
chalcopyrite	ilmenite
sphalerite	chromite
galena	
lollingite	
Co-Ni-Fe-sulphide	

The distribution of the sulphides is shown in Figures 1 and 2 (revised). No uranium-bearing minerals were identified in the samples which contained in the order of 100 ppm uranium, but, it is quite possible that this element was present as "sooty" pitchblende, a uranyl-organic complex or the hydroxy-silicate, coffinite any of which would probably not appear in the heavy mineral fraction. The average uranium content of sandstones in the Wapiti formation is 0.2 ppm. or less and so the three original high values are definitely anomalous.

The suite of sulphide minerals is interesting and highly significant. All are common phases in sandstone-type uranium deposits (16,18) with the exception of lollingite which evidently represents a varient of arsenic fixation.

Boorman and Sutherland (42) suggest that the relatively high iron content of the sphalerite (11 wt.%) as well as the presence of some exsolved chalcopyrite indicates a high temperature origin and that this mineral is detrital. Unfortunately little is known of phase relationships of sulphides in the temperature range of 100-150° C where sandstone-type mineralization is thought to form. Reaction rates here are often extremely slow and metastable assemblages are common in the laboratory and in nature, especially in systems involving minerals such as pyrite and sphalerite which have a high degree of covalent bonding. Barton and Skinner (41, fig. 7.10) indicate that sphalerite in equilibrium with pyrite may contain as much as 10 mole percent FeS at 200° C and at very low sulpher activities close to the pyrite-pyrrhotite-sphalerite monovarient boundary; there is considerable error in extropolation to lower temperatures. Chalcopyrite is also a possible phase in this region but its presence has little or no effect on the temperature-dependent iron content of sphalerite (45). As yet estimates of temperature based on the sphalerite-pyrite geothermometer cannot be viewed with much confidence.

Brett (43) has also demonstrated that exsolution features involving chalcopyrite are also unreliable temperature indicators. Chalcopyrite exsolution from wurtzite (a metastable zinc sulphide) has been noted in a number of sandstone-type uranium deposits.

Additional data from Barton and Skinner (41, figs. 7.20 and 7.21) suggest that the stability fields of lollingite and galena are more or less coincident with the portion of the pyrite-sphalerite-chalcopyrite field with which we are concerned.

The presence of the arsenic-bearing mineral, lollingite, is important as this element is a widespread indicator in sandstone-type deposits; it's presence was undetected by the routine spectrographic analysis which has a sensitivity of only about 0.1% As. The single rather high vanadium value of 400 ppm remains of uncertain significance. Chromium is evidently present in detrital chromite.

The spectrum of reliable heavy metal indicator elements for sandstone-type mineralization in the Wapiti Group sediments can now be designated with some confidence; it is:uranium, copper lead, zinc, cobalt, nickel and arsenic.

It is possible that some of the sulphides are of detrital origin and derived from the large amount of degraded and reworked acid pyroclastic material within the Wapiti sediments (44). However the widespread areal and stratigraphic range of the various sulphide minerals as well as their restriction to a specific channel border lithotope is strong evidence of an epigenetic origin.

It can be inferred that epigenetic transport and deposition of uranium and geochemically related heavy metals has been a common and pervasive process within the designated channel sandstone bodies. Thus the portions of the transitional bordering facies covered by the six Quartz Mineral Exploration Permits described herein may well be host to significant sandstone-type uranium mineralization.

[redacted]

Respectfully submitted:

Brian A. Edmond, P.Eng.
San Francisco, Calif.
June 10, 1970.

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Second Supplement to Report on:

The Grande Prairie Exploration Permits, Alberta
(dated March 26, 1970.)

Since the writing of the first supplement to this report (dated June 10, 1970) certain technical difficulties have arisen with regard to some of the indicator sulphide minerals (chalcopyrite, galena, lollingite, etc.). The situation is complicated (47) but is briefly this:

The assayer, Technical Service Laboratories of Toronto, in connection with another phase of the project admitted to maintaining unsuitable sample preparation facilities in which contamination by foreign ore minerals was possible. Unfortunately a number of the sulphide minerals identified by the Research and Productivity Council were taken from pulp fractions recovered from Technical Service Laboratories and hence some doubt was cast on the genuineness of some of these critical minerals. Further investigations by Boorman (46) on small amounts of cuttings which duplicated the intersections represented by the pulps (as well as a number of others) revealed lower amounts of the same sulphide minerals. However there was a poor correspondence with the original results. Our experience has demonstrated that such non-reproducibility is almost certainly the result of the high bias factor introduced by the small volume of the original sample. That is, the original sample obtained from a 10 ft. intersection with anomalous amounts of the indicator sulphides would likely contain only a few sulphide grains. The probability is very small of evenly splitting these grains when the original sample was taken and then again on redividing it for assaying and mineralogical studies.

Since the second trial gave the same group of sulphide minerals as the first lot obtained from the pulps, the writer is quite certain that all of the indicator sulphides are genuine but this cannot be proven beyond all reasonable doubt. Consequently in showing the distribution of sulphide minerals on Figures 1 and 2 (revised Sept. 4/70) those obtained from the pulps have been shown with an asterisk to distinguish them from ones taken from cuttings. It should be noted that pyrite and/or marcasite are ubiquitous in the various samples.

In the writer's opinion the original assessment of the properties given in previous documents is still valid with the proviso as stated above.

Respectfully submitted [redacted]

B.A. Edmond, P.Eng.
September 4, 1970
Toronto, Ontario.

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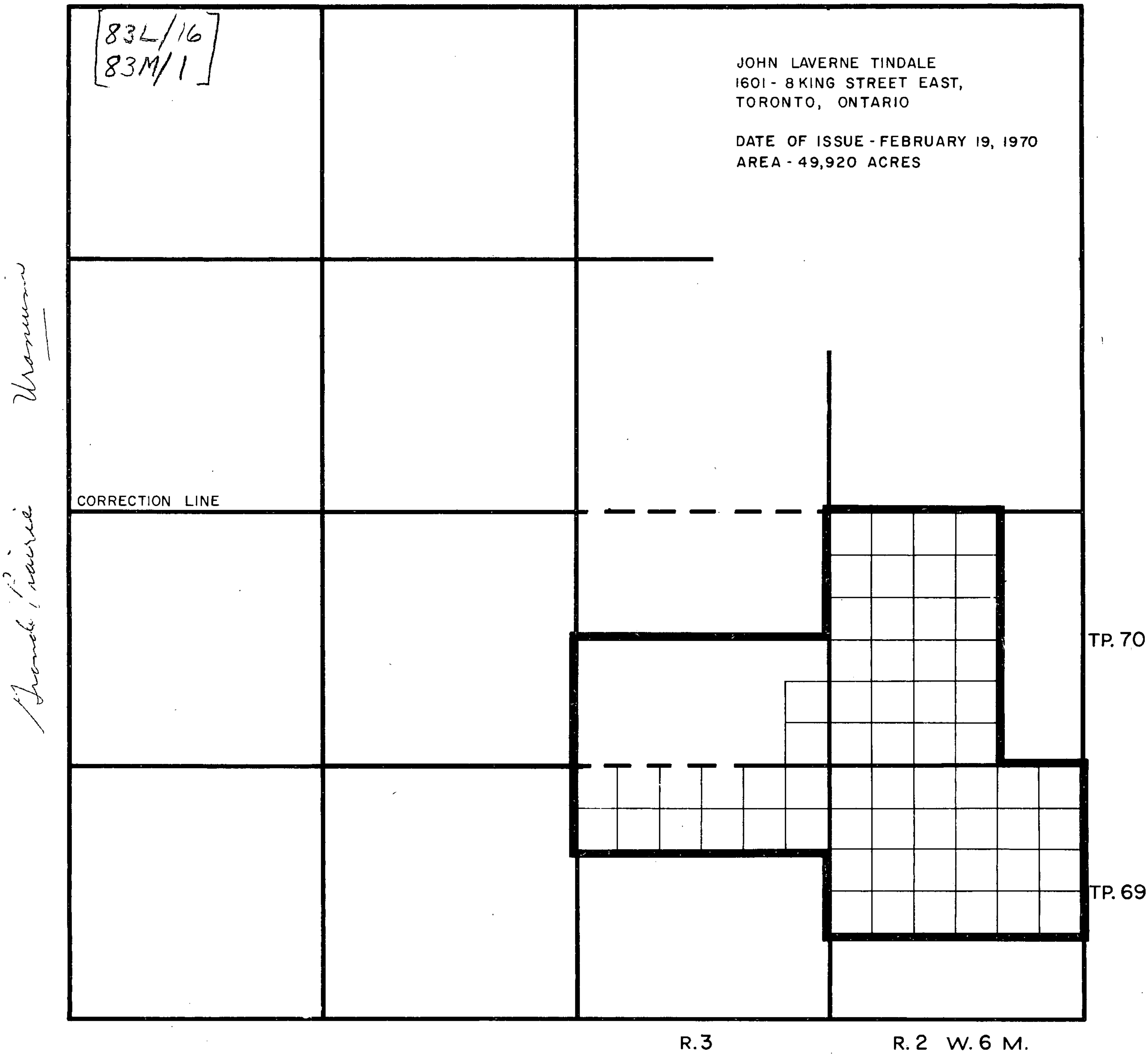
QUARTZ MINERAL EXPLORATION PERMIT No. 149



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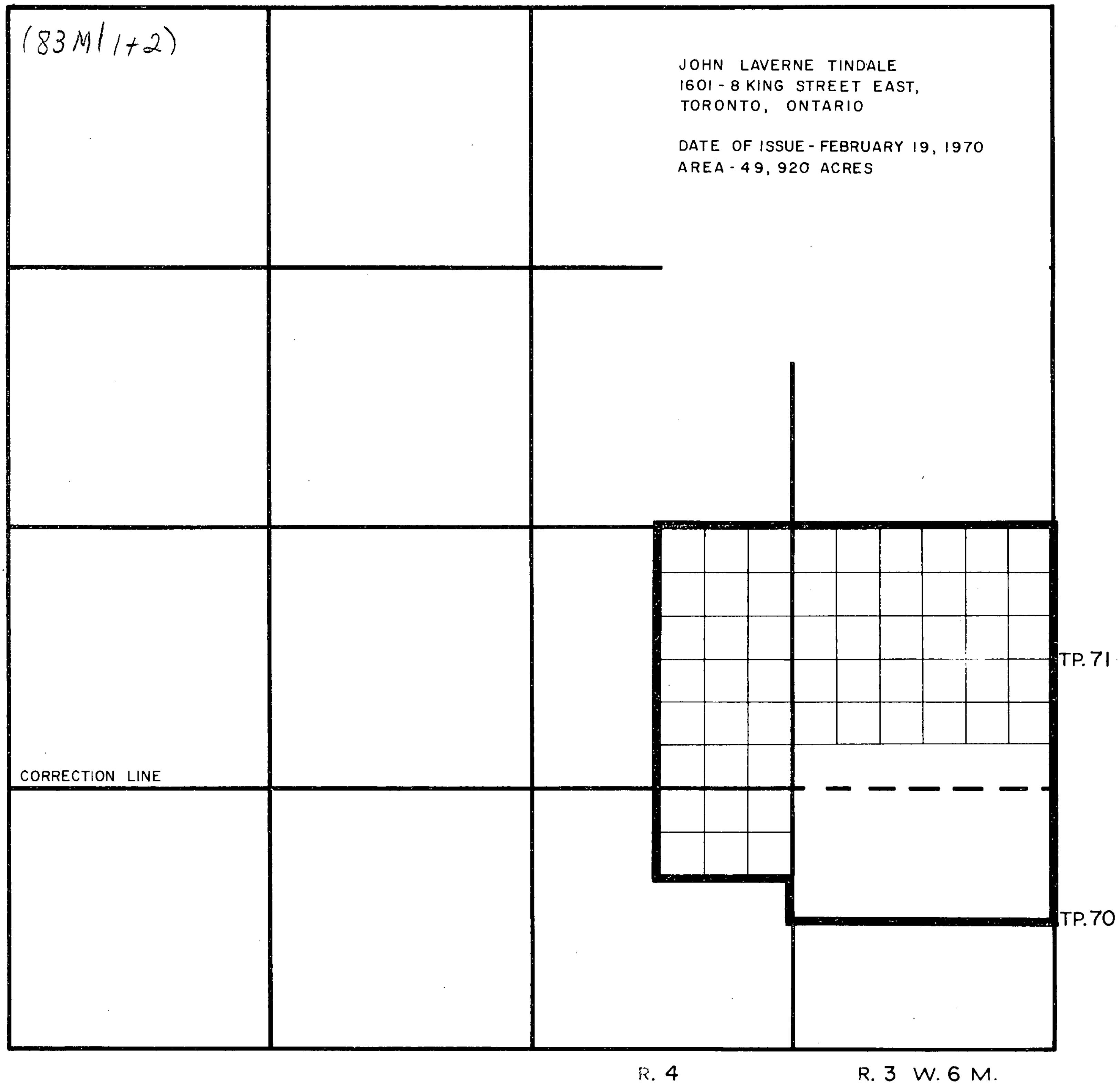

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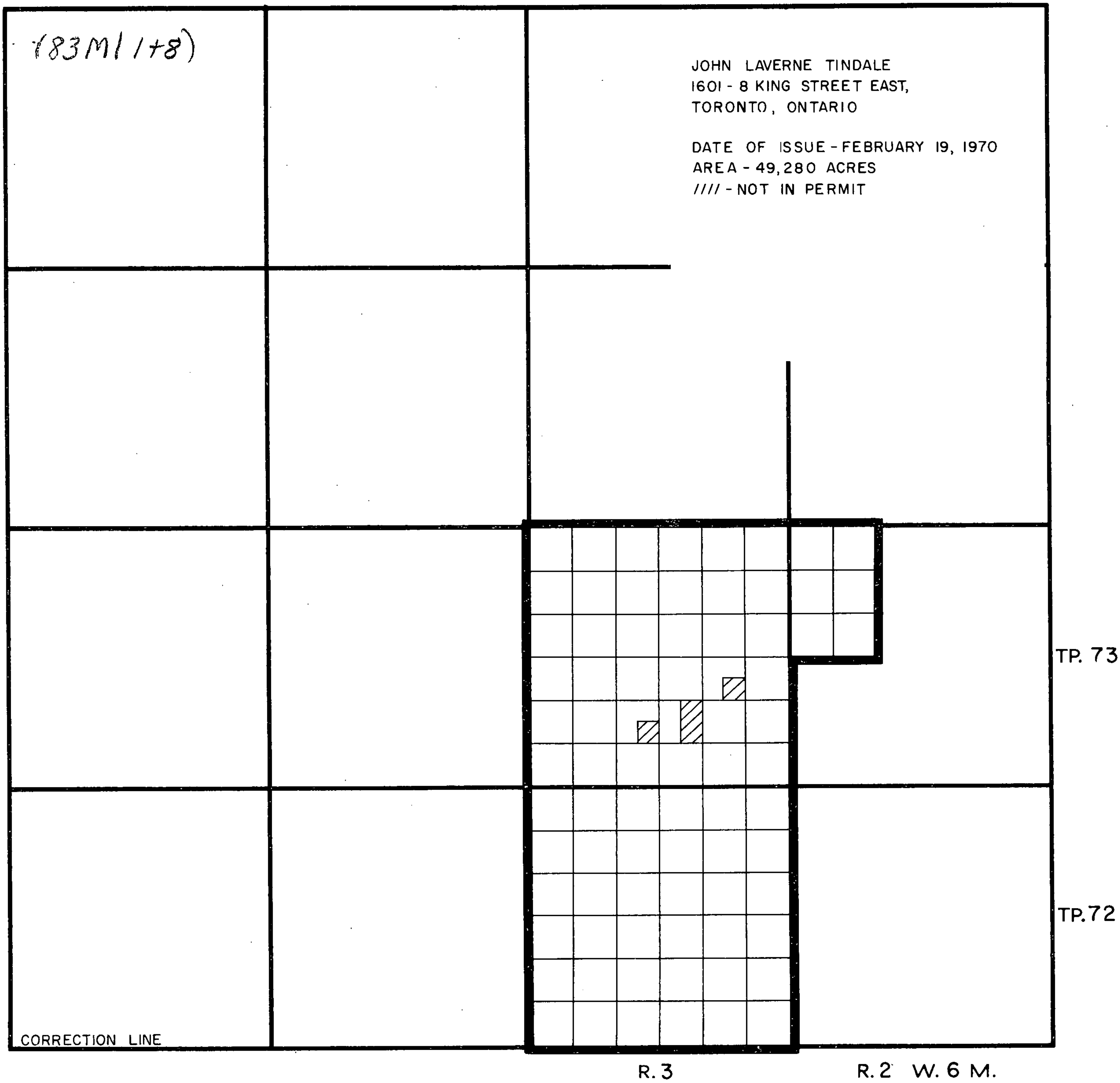

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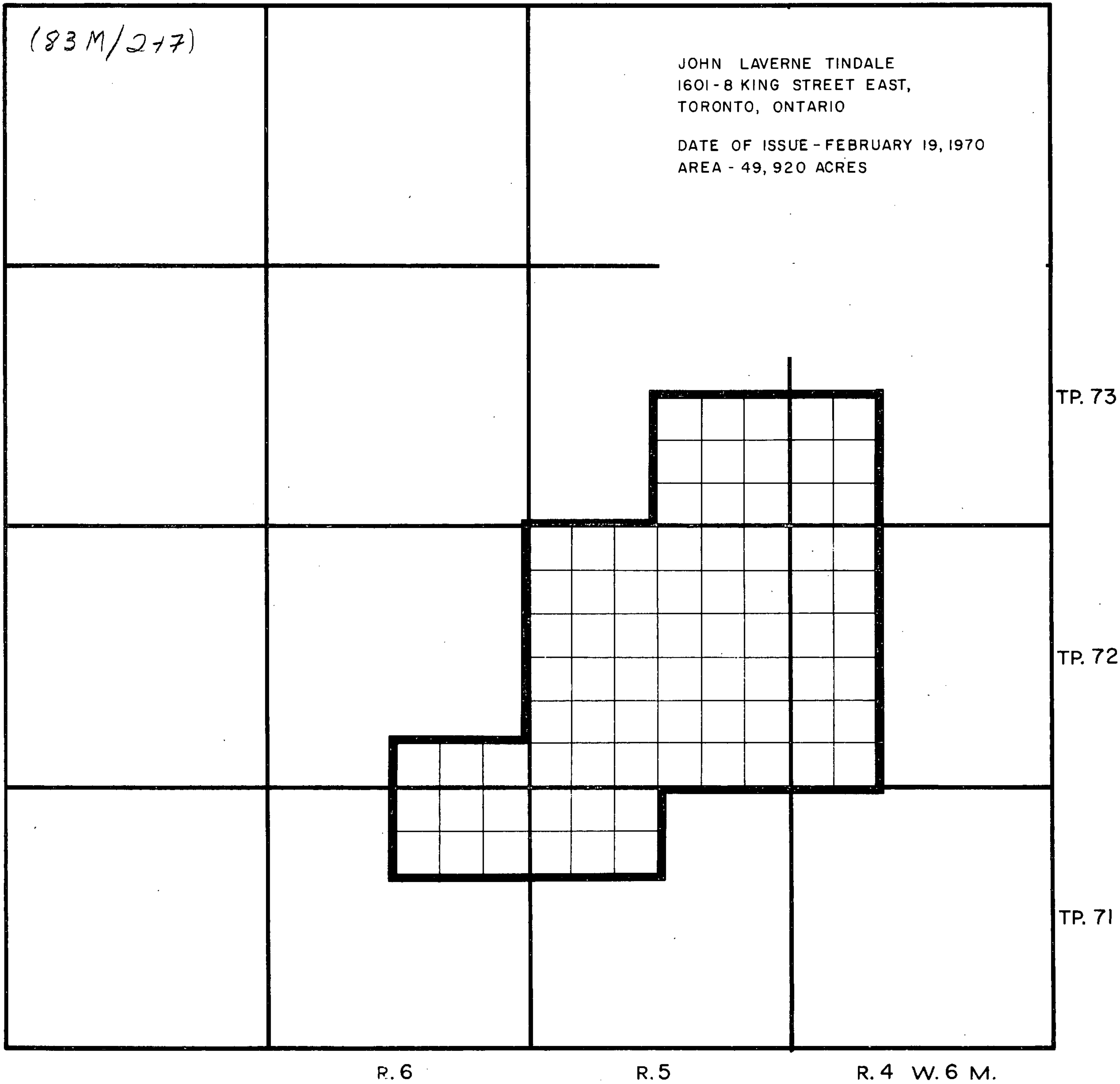

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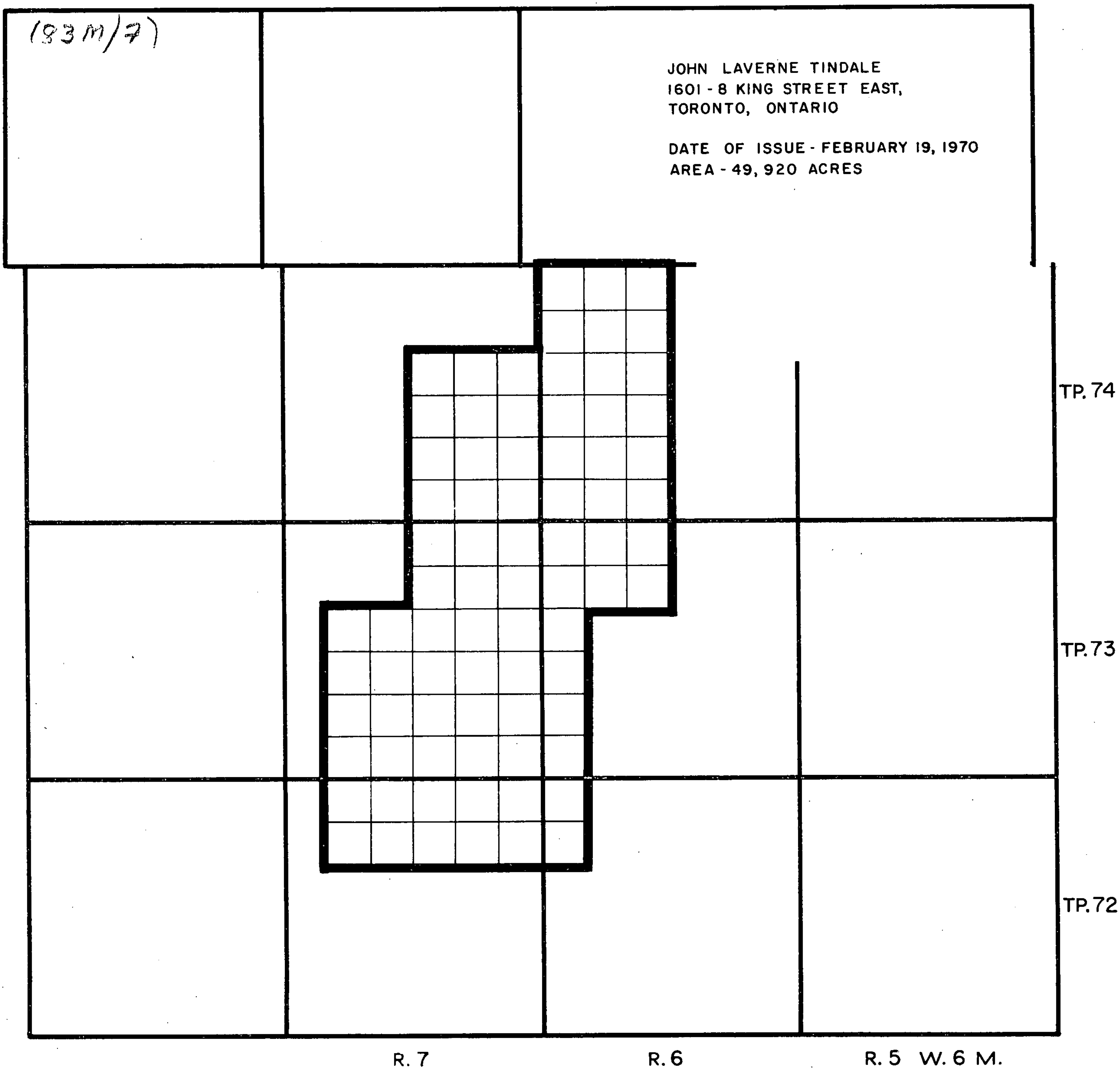
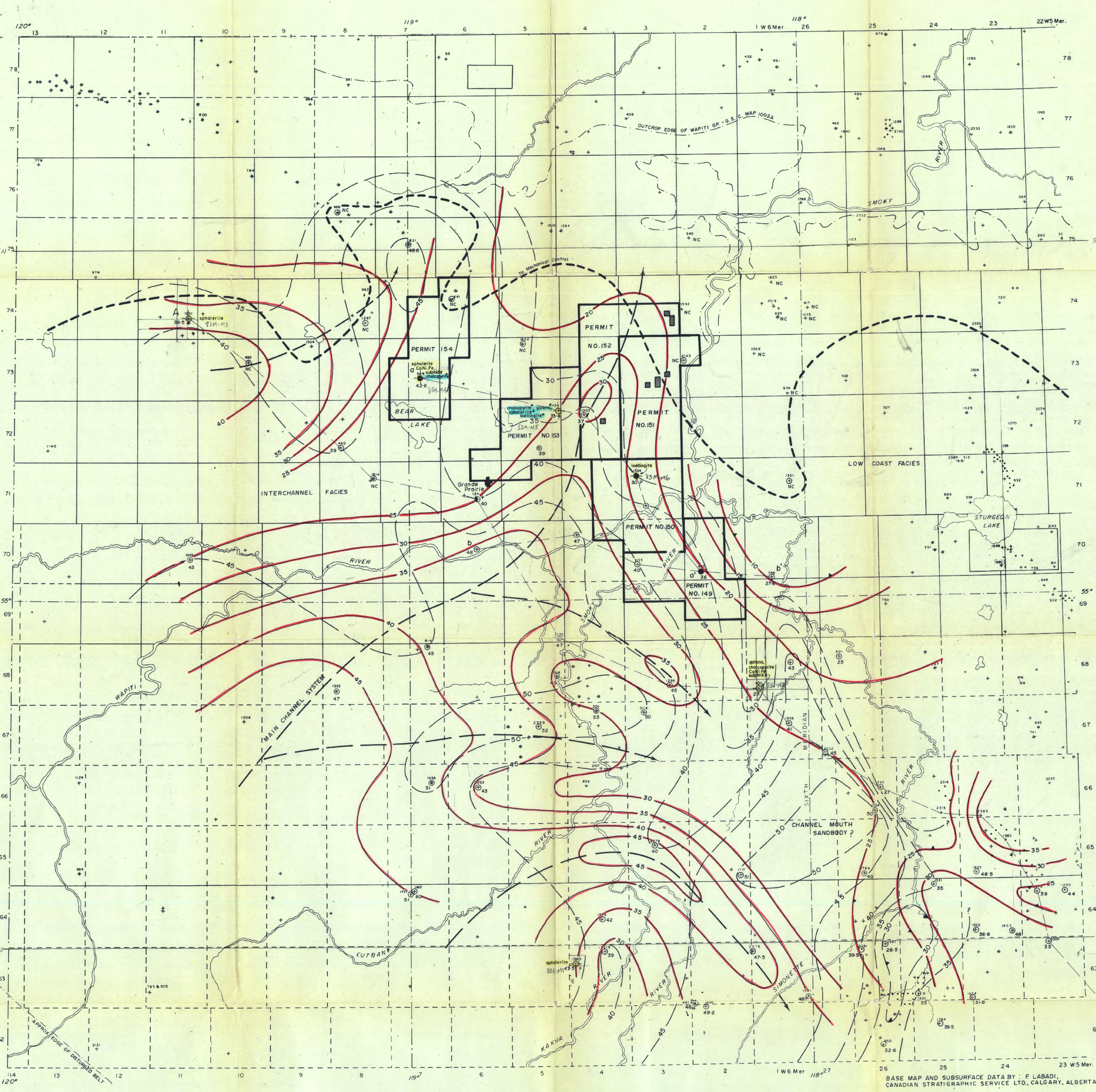
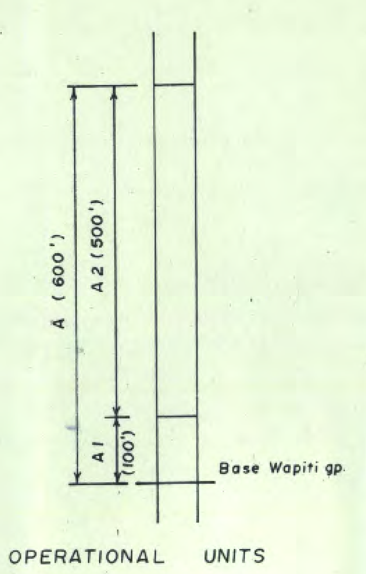




LEGEND

- 20 — Total % sandstone in Unit A (R for A)
- 30 — Total % channel facies in Subunit A2. (S for A2)
- Path of major distributary system
- Boundary of Quartz Mineral Exploration Permit
- Freehold land within Permit
- NC — No mechanical log control
- a — a' Auxiliary section line
- A — A Line of regional cross section
- Well with anomalous metal values and probable alteration in Subunit A2
- Well with possible gamma anomaly 958' above Base Wapiti group
- Well with sulphide mineralization (see fig. 2. for locations)



OPERATIONAL UNITS

LITHOFACIES ANALYSIS

FOR PART OF THE

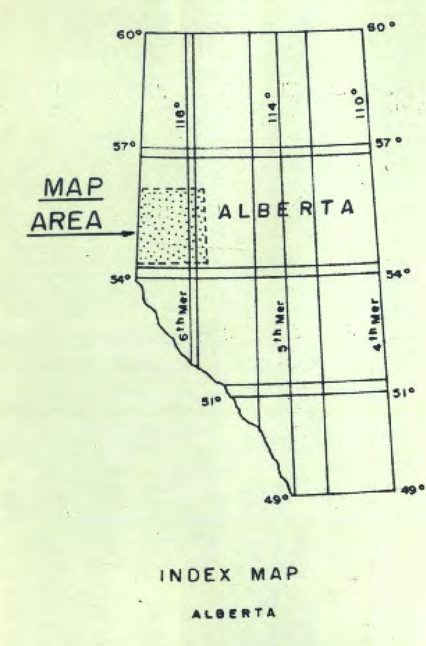
LOWER WAPITI GROUP (U. CRET.)

NORTHERN TEST AREA, WESTERN ALBERTA BASIN

SCALE: 1 INCH = 4 MILES

Revised: Sept. 4, 1970

[redacted]



INDEX MAP
ALBERTA

Fig. 1.

FIGURE 1

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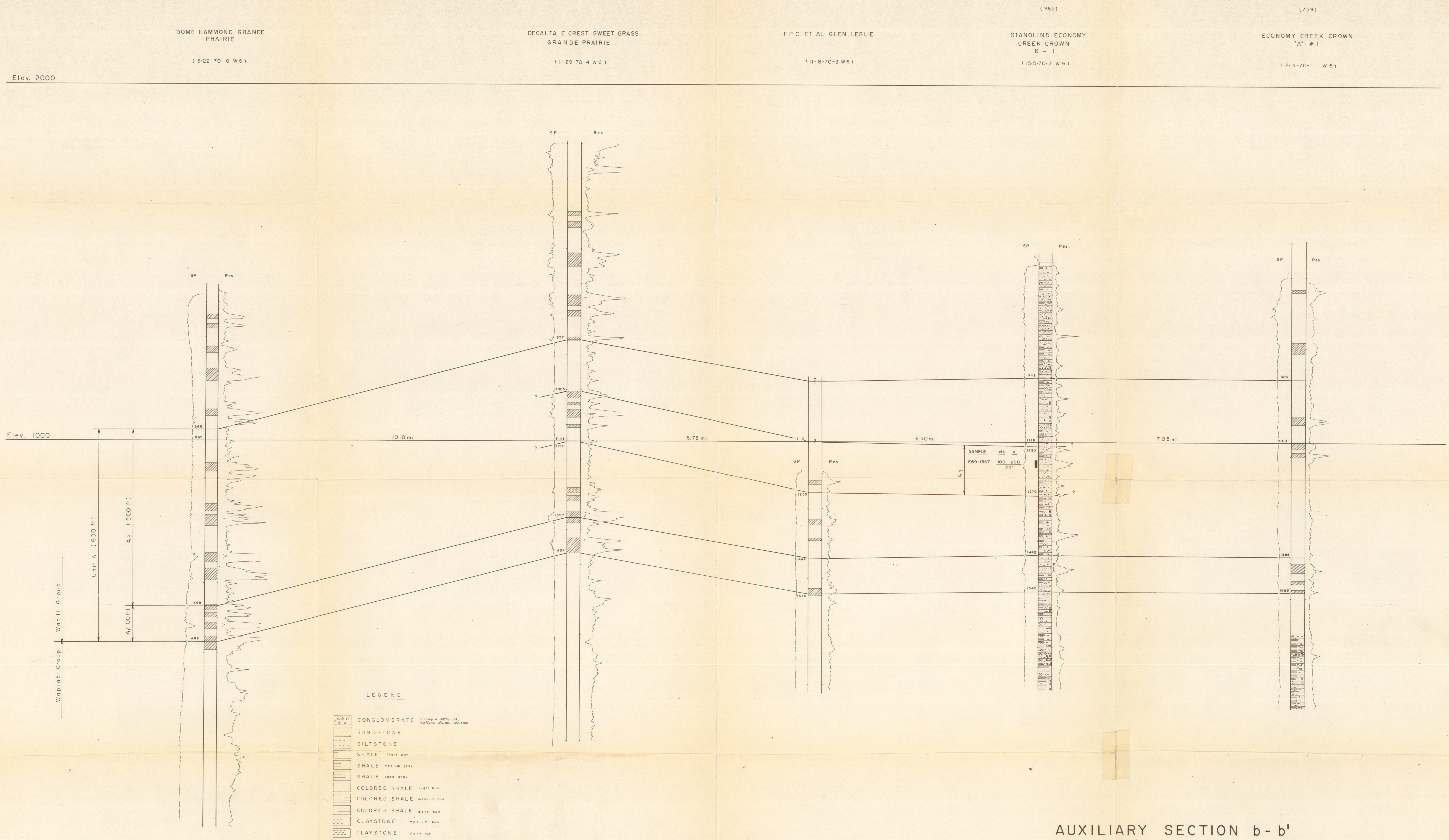

LEGEND

- CONGLOMERATE Example: 40% chl, 40% ls, 10% dol, 10% sand
- SANDSTONE
- SILTSTONE
- SHALE light gray
- SHALE medium gray
- SHALE dark gray
- COLORED SHALE light hue
- COLORED SHALE medium hue
- COLORED SHALE dark hue
- CLAYSTONE medium hue
- CLAYSTONE dark hue
- COLORED CLAYSTONE light hue
- COLORED CLAYSTONE medium hue
- COLORED CLAYSTONE dark hue
- COAL
- SILTY
- ARGILLACEOUS dissominated
- CALCAREOUS
- CHERT PEBBLES
- GLAUCONITIC
- NODULES siderite
- CHANNEL FACIES (shaded)
- 100 Cu. / 20' — SAMPLE LOCATION AND ANOMALOUS METAL CONTENT IN P.P.M (cU.-uranium, V.- vanadium, Cu.- copper, Pb.- lead, Zn.- zinc)
- P — PYRITE AND/OR OTHER SULPHIDES

SEE LOCATION OF AUXILIARY SECTION b-b' ON AUXILIARY SECTION a-a' PART

AUXILIARY SECTION b-b'

LOWER PART OF WAPITI GROUP (U.CRET.)

NORTHERN TEST AREA. WESTERN ALBERTA BASIN

SCALES: 1 IN. TO 100 FT (VERTICAL) ; 1 IN. TO 1 MILE (HORIZONTAL)

B.A. EDMOND P. ENG. FEB. 17, 1970

STRATIGRAPHIC LOGS BY CANADIAN STRATIGRAPHIC SERVICE LTD. CALGARY

MECHANICAL LOGS BY SCHLUMBERGER CANADA LTD.

Fig. 3 [redacted]

Mar 26/70

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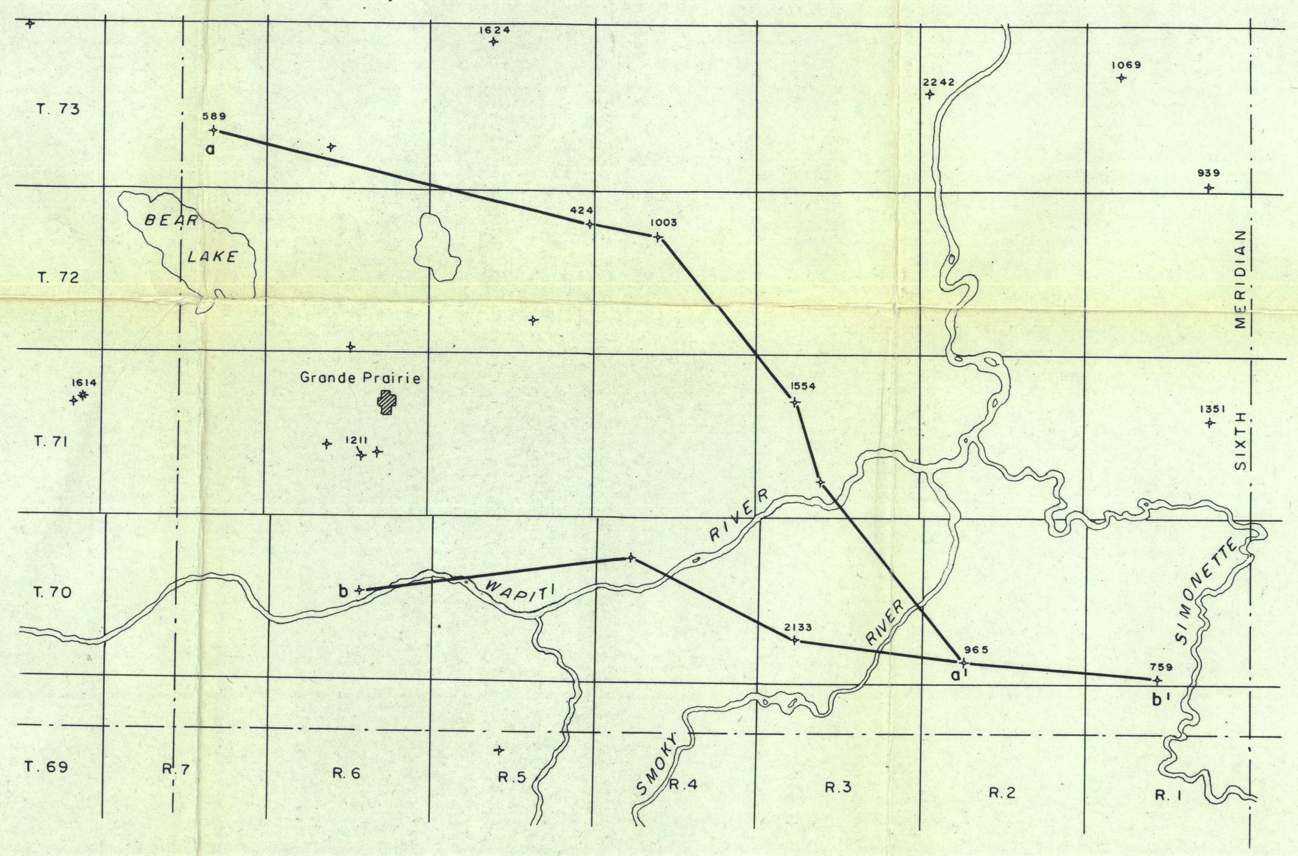

LOCATION OF AUXILIARY SECTIONS

SCALE: 1 in. to 4 miles

LEGEND

- CONGLOMERATE — Example: 40% chl, 40% ls, 10% dol pbl, 10% sand
- SANDSTONE
- SILTSTONE
- SHALE light gray
- SHALE medium gray
- SHALE dark gray
- COLORED SHALE light hue
- COLORED SHALE medium hue
- COLORED SHALE dark hue
- CLAYSTONE medium hue
- CLAYSTONE dark hue
- COLORED CLAYSTONE light hue
- COLORED CLAYSTONE medium hue
- COLORED CLAYSTONE dark hue
- COAL
- SILTY
- ARGILLACEOUS dissominated
- CALCAREOUS
- CHERT PEBBLES
- GLAUCONITIC
- NODULES siderite
- CHANNEL FACIES (shaded)
- 100 Cu. / 10' — SAMPLE LOCATION AND ANOMALOUS METAL CONTENT IN P.P.M. (cU.-uranium, V-vanadium, Pb.-lead, Zn.-zinc, Ni.-nickel)
- PROBABLE EPIGENETIC ALTERATION OF SANDSTONE AND SILTSTONE (limonite - "kaolin" - pyrite)
- p — PYRITE AND/OR MARCASITE, OTHER SULPHIDES AS SHOWN
- h — POSSIBLE HUMATE DERIVATIVES

pyrite, sphalerite etc. - sulphide minerals identified in cuttings (asterisk designates possible contaminant)

AUXILIARY SECTION a - a'

LOWER PART OF WAPITI GROUP (U. CRET.)

NORTHERN TEST AREA. WESTERN ALBERTA BASIN

SCALES: 1 IN. TO 100 FT (VERTICAL); 1 IN. TO 1 MILE (HORIZONTAL)

B.A. EDMOND P.ENG. FEB. 17, 1970

STRATIGRAPHIC LOGS BY CANADIAN STRATIGRAPHIC SERVICE LTD. CALGARY

MECHANICAL LOGS BY SCHLUMBERGER CANADA LTD.

[redacted]

Revised: Sept. 4, 1970 [redacted] see also Supplement dated Sept. 4, 1970)

Fig. 2.

FIGURE 2
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