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REPORT ON FIELD PARTY NO. 46

ROCKY MOUNTAIN FRONT RANGE
(PHOSPHATE PERMITS)

1966

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Mobil Oil Canada, Ltd.
Southeast Exploration Area

October, 1966

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Introduction

Field Party No. 46 (1966) was assigned in May, 1966 to examine, describe, and measure phosphate occurrences in the Permian, Triassic and Jurassic sequences in three Rock Phosphate Prospecting Permits (Nos. 22, 23, and 24). These permits were acquired by (Socony) Mobil Oil Canada, Ltd. on November 30, 1965 and a bond of $7500 was attached to them to be forfeited if the Company did not explore these permits to the satisfaction of the Alberta Government.

The party consisted of P. F. L. de Groot, party chief, and R. H. Herzer, summer student.

Prior to the commencement of the actual field work, the party spent some time on field trips and reconnaissance.

In Permit 22, a total of nine stations were extensively explored; in Permit 23 a total of 21 stations, in Permit 24 a total of 8 stations. Sections were only measured in stations where <u>any</u> amount of phosphate with a grade of 15% or more P_2O_5 was found.

The report of Foothills Field Party #46, 1966, will present the operations, manner of operating, and descriptive results of the field party.

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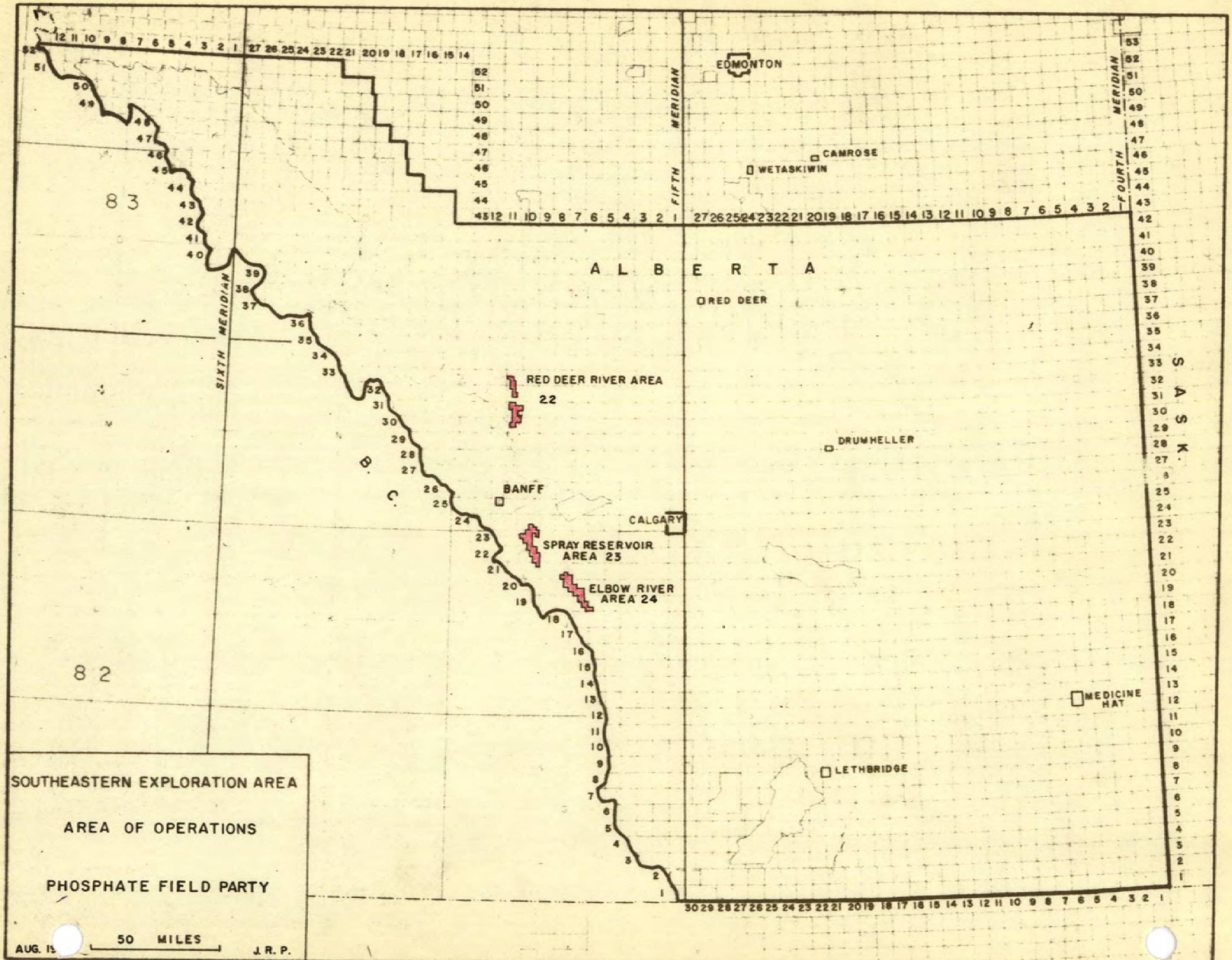
INDEX MAP



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Location and Accessibility of the Permits

All the permits are indicated on the map of the Bow River Forest Reserve.

Permit 22, located in Twps. 30-33 inclusive, Rge. 11 W5M, consists of three areas separated by rivers. The first, to the north of the Red Deer River, stretches from Eagle Creek along Bighorn Creek to the Clearwater Forest boundary. The second lies between the Red Deer and Panther rivers, and the third is situated south of the Panther and east of the Dormer rivers. The only access road is the one to Ya-ha-tinda Ranch, that branches off from the Forestry Trunk Road at the Red Deer River Crossing. This road is good for reaching the general area, but the permit itself is only accessible on horseback. The road along Panther River to Sheep Creek is of no use because the terrain between it and the southern area is too rugged.

Permit 23, located in Twps. 21-24 inclusive, Rge. 10 and 11 W5M, consists of two separate strips, one from Spray Lake to Ribbon Lake, the second from Spray Lake to Mud Lake. A reasonably good road which is used by the Spray Lakes Lumber Company leads to both areas. From this the beds of interest are within walking distance, although the going is often rough and long, especially in the northern strip and near Mt. Engadine. Near Mud Lake several lumber roads shorten the trips somewhat, but to use them to advantage expert advice from the lumber people came in handy.

Permit 24, located in Twps. 19-21 inclusive, Rge. 7 and 8 W5M, consists of a strip from Mt. Evans Thomas near the Little Elbow River to Gibraltar Mtn. along the Sheep River. It is easily accessible by way of the forestry road looping from Bragg Creek to Turner Valley, but within the Forestry Reserve this road is more victimized by the weather than those in the other permits. From it most beds of interest are within easy walking distance.

Operations

Mobil Oil Foothills Field Party #46 (1966) commenced field operations on July 6, 1966 and completed same on August 23, 1966.

In order to familiarize the members of the party with the subject, during the month of June several field trips were made to known outcrops of phosphatic rocks in the Banff and Crowsnest areas, followed by a tour to working phosphate mines and outcrop localities in Montana and Idaho. The breakdown in time for these trips is:

Banff - Spray Lake Area	2 days
Red Deer River Area	1 day
Crowsnest Area	3 days
Montana - Idaho	8 days
	14 days

Weather and terrain conditions mainly determined the sequence in which the permits were worked.

The time breakdown for the actual field operations is as follows:

Movements to and from areas	7 days
Lost because of inclement weather	2 days
Time out for conference and field trip with Mr. A. K. Temple	3 days
Investigations in Permit 22	8 days

Investigations in Permit 23	$22\frac{1}{2}$ days
Investigations in Permit 24	$5\frac{1}{2}$ days
	48 days

Preliminary investigations of the three permits disclosed the fact that while the party could work from a truck-and-kamper unit as a base in Permits 23 and 24, a pack train should be used in the Northern Permit (#22).

From July 6 to August 23, a 3/4 ton truck with kamper unit was hired and from August 1 to August 8 a pack train was used.

A scintillator was used during the whole summer and a field chemical kit was made up for the party.

The cost of the total operations was $7,330. (Can.) or $6,780. (U.S.). The breakdown follows:

Wages	$3,930.
Food and Lodging	720.
Gas	250.
Rent for Kamper Unit	700.
Car Rentals	440.
Operating Supplies	60.
Purchase - Rental Scintillator	240.

Pack Train	$ 630.
Assays, etc.	360.
	$7,330.

These cost figures are estimates as the final data are not yet available, but they will be very close to the final figures.

Manner of Operations

In every permit, the first traverses lay a few miles apart. If any encouraging signs were found, more traverses would be put in. This explains the greater density of stations in Permit 23 as compared to the other permits as, apart from very minor signs of good phosphate rock in the southern parts of both Permit 22 and 24, the Spray Lake area is the only one to have abundant signs of good grade phosphatic rocks. Much of the terrain between stations was cursorily investigated as well. Even if any phosphate beds are present between two barren traverses, their small areal extent would make them uneconomical.

In the Middle and Southern permits, the truck and kamper served as base camp, in the Northern permit a tent camp was erected in any convenient spot.

The field party had a set of aerial photographs of the permit areas, and photogeologic maps based on these at its disposal. Both were very helpful in locating the beds of interest and the routes to be taken to reach them. In the field, some geologic boundaries had to be changed, generally slightly, in a few cases more drastically. These changes have been incorporated in the geological maps included in this report.

Because experiences in other areas have shown that phosphatic rocks generally have a higher radioactivity than comparable non-phosphatic rocks, the party took a scintillator to the field to indicate rocks with higher radiation. This has been effective in eliminating the bulk of the rock sequence. To test the accuracy of the above assumption, the party tested samples from phosphatic-looking rocks without higher radiation level. These never contained phosphate. On the other hand, not all radioactive rocks were phosphatic. Once a rock sequence was known and the general appearance of the phosphate beds had been ascertained, the work proceeded as speedily without as with the scintillator, but in fairly covered sections and unknown sequences the apparatus retained its use to the end.

In the field, all rocks suspected of being phosphatic, and in general all rocks with a higher radioactivity were tested for their P_2O_5 content with the help of a field chemical kit (made up for the Company by Canadian Core Laboratories) and using the Shapiro method. For this method, the reader is referred to "The American Mineralogist", Vol. 37, 1952, pp. 341-2. After a few weeks in the field, the Aquaregia, which is used to detect Wavellite, was left out as this mineral had not been found or was expected and the acid attacked all contents of the kit. Only in one sample was Wavellite suspected after assay. Standard colors (Potassium dichromate solutions) were made up of 5, 10, 15 and 30% P_2O_5

for comparison of the test results. The reagent was never used for more than two weeks, after which time a new portion was made up. The method was quite satisfactory and helped to eliminate the bulk of the rocks sampled. Beds containing more than 10% P_2O_5, or having components containing more than 25% P_2O_5 were investigated more carefully.

Comparison with assays by Canadian Core Laboratories showed that in general the field assays indicated higher percentages than laboratory analyses. There were some exceptions to this rule however. Unless mentioned otherwise the given percentages are those of the Shapiro field method. The one outstanding exception, where the assay indicated a much higher P_2O_5 percentage than the Shapiro test was probably due to the occurrence of Wavellite.

General Geology of the Phosphate Occurrences

In the whole Southern Alberta Front Range Area, the geology is dominated by a series of steep southwest dipping thrust faults (see the accompanying geologic maps of the permits). Within the permits, phosphatic rocks have been found at various levels in the Permian, Triassic and Jurassic System.

The top of the Permian Ishbel Group consists in this area of quartzitic siltstones and dolomites forming the Johnston Canyon formation, overlain by blue, black and grey cherts of the Ranger Canyon formation which sometimes are only represented by a thin cherty or phosphatic conglomerate, and in places do not occur at all. The boundary between the two formations is often hard to place.

The Permian rock sequence is unconformably overlain by Triassic beds of the Sulphur Mountain formation (formerly Sulphur Mtn. member of the Spray River fm.). These consist of a grey and black soft Lower Siltstone and a grey, distinctly brown weathering, often calcareous and sandy, hard Upper Siltstone, often separated by a Middle Dolomite.

Above these beds lies the Jurassic Fernie Group of which only the lower formations interest us. The Triassic beds are followed by a thin sequence of calcareous shales of the Nordegg formation, on which sandier beds of the Rock Creek formation follow containing abundant belemnites and a thin conglomerate.

Phosphate has been found in the permits

- in the upper thirty feet of the Permian, where it occurs in the form of nodules and massive beds, and in conglomerates
- in the Upper Siltstone of the Triassic Sulphur Mountain formation it occurs as disseminated bones, of no economic interest, and as fishscale beds and pellet beds
- in the Belemnite Zone of the Jurassic Rock Creek formation, which contains a few nodules and pebbles of phosphate

In none of the permits does the phosphate occur at all levels

- in Permit 22 only the Permian is phosphatic
- in Permit 23 the phosphate occurs as nodules and beds in the Permian and as fishscale beds and pellet zones in the Triassic
- in Permit 24 there are thin layers with phosphate pebbles and seams of phosphate in the Permian and some phosphate pebbles in the Jurassic Belemnite Zone.

The Permian phosphate beds are the most important ones and form the top of a resistant sequence overlain by a non-resistant one, the Triassic. They are generally stripped away on a dipslope and often are covered with debris from the Spray River Group. Good outcrops therefore are fairly scarce, but occur in sufficient number to allow an adequate investigation of the permits. These beds contain phosphate in nodules which sometimes have coalesced into regular layers. The nodules consist of extremely fine collophane, containing variable amounts of angular quartz grains, generally smaller than $\frac{1}{4}$ mm.

The fishscale beds occur high in resistant Triassic beds that frequently form dangerous cliffs but their thinness makes it hard to spot them. Often they are discovered because of the characteristic blue weathering fragments in the rubble. They contain variable amounts of fishscales. The best beds (near Mt. Bogart) consist exclusively of scales of .1 to .5 mm. thick in a clear mass of apatite and some carbonate.

The pellet beds, higher in the Triassic, are generally covered, but are exposed in creek beds and frequently show up as a slight ledge on a grassy slope. They form nearly the highest fairly resistant Triassic beds in the Spray Lake area. The pellets are seldom more than $\frac{1}{4}$ mm. in diameter and are packed between angular quartz of the same size. Often the quartz grains are coated with collophane.

The Jurassic Belemnite Zone, only found near Gibraltar Mountain, is very soft and generally covered. The fossils from it, showing up in the debris, form an excellent guide to outcrops near creeks.

Investigations in Rock Phosphate Prospecting Permit 22

This area has fewer good exposures than the other two, but enough for an investigation of the permit's potential.

North of the Red Deer River, no high grade phosphate was encountered in the Permian. In Stations 2 and 3 (see geological map of this permit), a phosphate content of 1 to 2% (assay 5, 2%) was found in some samples. The best exposure in this neighborhood, Station 4, just outside our permit, tested less than Stations 2 and 3.

The strip between Red Deer and Panther Rivers did not show a trace of phosphate. The part south of the Panther however, does have some high grade Permian rock. Following is a section taken at Station 7, about 1½ miles from the river:

Overlying black shales of the Triassic Spray River Group

6" dark quartzitic siltstone, less than 5% P_2O_5

6" a.a., no phosphate

1 - 1½' grey quartzitic siltstone, less than 5% P_2O_5, assay 4.4%.

4" dark quartzitic siltstone, 30% P_2O_5

Underlying very fine buff weathering grey quartzite

About a mile and a half to the southwest, due east from Dormer Lake, at Station 8 the section is thicker and has a different sequence:

Overlying black shales of the Spray River Group

1' 5" very fine quartzitic sandstone with calcite in fissures and as fillings of large vugs. In the top half a few phosphatic nodules Nodules 30% P_2O_5, average ± 5%; assay 9.6%.

1' 8" very fine black quartzitic sandstone 5-10% P_2O_5, assay 8.8%.

1' 2" Aa in two beds, less than 5% P_2O_5.

7" fine grained hard black quartzite ±5% P_2O_5, assay 4.4%.

2' very fine buff weathering quartzite, trace P_2O_5.

9" lenticular layer with black quartzite nodules, no phosphate.

Underlying very fine buff weathering grey quartzite

Even if this thickening of the sequence towards the south would result in commercial deposits there, which is extremely unlikely, those would be situated within the boundaries of Banff National Park and thus be unattainable.

Neither the Triassic beds which were investigated less intensively than the Permian in the whole Permit, nor the Jurassic which was investigated cursorily in the north outside, and intensively in the south within the permit boundary showed any phosphate.

Investigations in Rock Phosphate Prospecting Permit 23

This area contains much more phosphate rock than the previous one, but not enough for exploitation.

The permit consists of two strips, one from Spray Lake to Ribbon Lake, the other from Spray Lake to Mt. Chester (see map). These strips belong to two different tectonic units and they will be treated separately.

In the northern part, Station 1 is located west of Spray Lake, where most of the rocks within the permit and especially the contacts are covered. No phosphate was found, but it could easily be missed. Even if it contained any, the isolated location of the beds would preclude economic exploitation.

Stations 2, 3, 4, and 6 are located at the top of the Permian beds. Station 2 had no phosphate shows, either bedrock or rubble, but the terrain was so overgrown that any phosphate rock could easily be hidden.

Station 3, in a creek bed, has essentially the same sequence as Station 6, while Station 4 only shows that the phosphate beds (see below) continue under the scree of the overlying Triassic beds; their dip is 31°, direction 230° SW.

Station 6 where the rocks have the same attitude as Station 4 has the following sequence:

Overlying beds dark brown weathering shales of the Triassic Spray River Group.

$3\frac{1}{2}$ - $4\frac{1}{2}$' medium to fairly coarse grained, buff weathering grey sandstone, with an erosional pitted upper surface.

1' 1"	buff weathering grey sandstone with up to 90% black phosphate nodules weathering with characteristic white line pattern. Nodules 30% P_2O_5, matrix ±5%.
11' 8"	pale buff weathering light grey quartzite, with many white chert nodules and quartz-filled vugs.
4' 8"	buff weathering medium grey quartzitic sandstone with burrows. The top 8" is formed by a dark grey, grey weathering crossbedded quartzite.
10"	black quartzite or chert.
5' 3"	buff weathering dark grey quartzitic sandstone with white chert nodules and dense black quartzite nodules. Trace of phosphate.
12'	dark grey, buff weathering quartzitic sandstone, with a trace of phosphate, with some horizons of dense black quartzite nodules, without phosphate, and higher up black chert nodules, non-phosphatic, and calcite stringers.
2' 5"	buff weathering dark grey very fine quartzitic sandstone with layers of non-phosphatic black nodules.
3'	very fine black spheroidal weathering sandstone with a trace of phosphate.
2' 2"	buff weathering dark grey very fine quartzitic sandstone with in the top a few all-black chert nodules.
3' 1"	very fine black spheroidal weathering sandstone without phosphate.

Underlain by covered slope above slightly dolomitic quartzites.

In the rubble, one piece of rock was found which had a P_2O_5 content of 30% and a radioactivity not matched by any of the local Permian beds. Lower in the Permian there are other slightly phosphatic sandstone beds; the phosphate content herein has been caused by thin layers with many Orbiculoidea shells. These have been found in the rubble of a landslide, but we could not find the exact location of these beds.

The Upper Siltstone of the Triassic Sulphur Mountain formation contains phosphatic beds which consist nearly exclusively of fishscales, with 30% P_2O_5 in the purer parts. This bed does not have a constant thickness; the maximum encountered being 3", while the average may be 1" or less. Intercalated are sandstone lenses and wedges. This bed is located in the highest resistant sequence in the scarp formed by the Upper Siltstone. Under this sequence there is a slightly recessive bed that weathers in round forms.

The Southern strip too has a small part west of Spray Lake, subject to the same remarks as the northern piece. The Permo-Triassic boundary was covered and no phosphate was encountered in situ in either Permian or Triassic. Near the shore, one piece of Permian phosphate was found which could have come from any place, near or far.

Stations 8, 10, 11, 13, 14, 17 and 20 are in the Permian. At Station 8, near Mt. Buller, the Permian was covered. An investigation of the well-exposed Mississippian Rundle Group was negative.

At Station 10, on the flank of Mt. Engadine, no phosphate was found though exposure was good, but at Station 11, west of

Mt. Galatea, phosphate is present as shown by a few high grade phosphate nodules (30% P_2O_5) in the rubble, but the beds have been eroded and no phosphate has been encountered in place.

The first good section is to be seen at Station 13 on Mt. Galatea, which shows the same sequence as Station 14 in the valley at the foot of Mt. Galatea, where it is as follows:

Overlying beds black shales of the Spray River Group

4' 8"	black silty shale, belonging to the Triassic, no phosphate.
2' 1"	black buff weathering sandstone with up to 50% black phosphate nodules (30% P_2O_5) and pyrite nodules.
1' 2"	black quartzitic sandstone with 5% P_2O_5.
10"	black chert with blue bloom, no phosphate.
4' 10"	grey weathering black chert and quartzite with calcite molds, sandstone patches and calcite stringers, no phosphate.
5½"	pyritic phosphorite bed, 30% P_2O_5.
1' 4"	grey quartzite, less than 5% P_2O_5.
1'	quartzitic buff and black mottled weathering grey recessive sandstone, no phosphate.
3"	recessive quartzitic sandstone, less than 5% P_2O_5.
1' 4"	buff weathering grey quartzitic non-phosphatic sandstone with a thin layer on top containing many phosphatic nodules. Nodules 30% P_2O_5.
3' 4"	buff weathering grey quartzite, no phosphate.

9"	dark grey, buff weathering sandstone with 70% nodules. Matrix less than 5% P_2O_5, nodules 30% P_2O_5.
2' 5"	gradational change of quartzite with ±10% chert nodules to chert, sometimes brecciated.
3' 6"	buff weathering dark grey quartzite, sandier on top 0 - 5% P_2O_5.
1' 2"	buff weathering grey quartzitic sandstone, no phosphate.
1'	black chert.

At Station 17 on Mt. Chester, the sequence is roughly the same as at Station 20, in the valley at the foot of that mountain. It is as follows:

Overlying black shales of the Triassic Spray River Group

12'	black massive sandy siltstone, belonging to the Triassic, no phosphate. This layer forms the creek bed.
2' 4"	dark grey quartzitic sandstone with 30-50% hard black phosphatic nodules and occasional bones and patches of calcite. Matrix no phosphate, nodules 30% P_2O_5 (assay 28.7%).
1'	medium grey quartzitic sandstone, containing a few phosphatic bone remains. Trace of phosphate.
8'	medium grey chert with calcite molds, pyrite nodules, calcite vugs, nodules of black quartzite (±1% P_2O_5) and non-phosphatic patches of brown sandstone.
1' 8"	brown weathering medium grey quartzitic sandstone with ±50% black phosphatic nodules and some purple fluorite. Sandstone no phosphate, nodules 30% P_2O_5 (assay 24.1%).
9"	recessive black phosphatic rock with characteristic white weathering pattern (less than 30% P_2O_5, assay 15.4%)

6"	medium grey sandstone with 5-10% black nodules, less than 10% P_2O_5.
6"	buff weathering dark grey fine grained sandstone, no phosphate.
8'	covered.
1' 6"	white weathering medium grey sandstone.
2'	covered.
11"	dark grey quartzite.
1'	covered.
3'	buff weathering light grey quartzitic sandstone, extensively burrowed.

The top beds are badly sheared. Their dip is 49°, direction 220° SW.

Triassic fishscale beds can be found at Stations 19 and 21. At 19, the only evidence is formed by a few small pieces, indicating (a) very thin bed(s). At locality 21, a two-inch bed of dolomitic siltstone contains abundant scattered fish scales and is separated by at least 30' brown weathering sandstone from a higher one-inch bed of concentrated fish scales with 30% P_2O_5.

At Station 21, at least 100' higher than the preceding beds, a rock sequence with phosphatic pellet zones is encountered with a sequence essentially like that found at Station 16 in a creek at the foot of Mt. Chester. There the following beds are exposed:

Overlain by a few tens of feet of covered shales and a non-phosphatic sandstone bed.

The top of the section is the first prominent outcrop in the creek bed, where this is overhung by travertine cemented talus.

9'	medium grey non-phosphatic sandstone.
1' 7"	buff weathering medium grey burrowed sandstone with many calcite patches and ±10% disseminated phosphatic pellets (less than 5% P_2O_5.)
9"	covered.
1-2"	buff weathering medium grey sandstone with 50-70% phosphatic pellets, less than 30% P_2O_5 (assay 20.1%).
8"	buff weathering medium grey sandstone with phosphate pellets concentrated in burrows that make up less than 5% of the rock. These burrows contain about 50% pellets. Total rock 5% P_2O_5.
14"	sandstone Aa without phosphatic pellets.
4"	sandstone Aa with up to 50% disseminated phosphate pellets, and a few larger pieces of phosphate 5-30% P_2O_5, assay 28.7%.
2"	sandstone Aa with up to 75% disseminated phosphate pellets, less than 30% P_2O_5.
5"	sandstone Aa with 5-10% pellets and some small pebbles and some calcite patches, less than 5% P_2O_5.
5"	sandstone Aa with 5-40% phosphatic grains, less than 10% P_2O_5.
5"	sandstone Aa with 25-50% pellets, less than 15% P_2O_5.
3"	Aa with 5-30% pellets, less than 10% P_2O_5.
3"	Aa with ±10% pellets and a large bone, less than 5%, assay 17.3%.
3"	extensively burrowed sandstone Aa with 30-50% pellets and some small pebbles, 30% P_2O_5.

1"	Aa with 70% burrows with pellets, Burrows 30% P_2O_5.
9"	Aa with 5-10% burrows, matrix trace of phosphate, burrows less than 15% P_2O_5.
9"	Aa with only a few burrows.
4' 9"	brown weathering dark grey fine sandstone with a trace of phosphate.

These beds are also encountered in Station 18 as a small outcrop on a grassy slope.

The Jurassic, investigated at Stations 9 and 12 proved to be entirely covered with vegetation.

The phosphate deposits in this permit did not seem economic as compared with the somewhat hazy, but definitely optimistic norms of the party chief. The memorandum on economics which was sent to us by Mr. A. K. Temple of Mobil Chemical International Development on July 19, 1966 used parameters which made the prospect look considerably poorer.

Investigations in Rock Phosphate Prospecting Permit 24

This permit, which would have been attractive because of its location along a forest road that could have been improved for all non-winter transport, turned out to be the poorest of the three. An initial drawback was the fact that the terrain has many faults, some of which have sheared off the top beds of the Permian.

Combined investigations of Permian and Triassic at Stations 1 to 6 had no results whatsoever. Near Gibraltar Mountain, however, a little phosphate was found both in the Permian at Station 7 and in the Jurassic at Station 8, while the Triassic did not show any phosphate.

The Permian phosphate section in the creek valley on the west flank of Gibraltar Mountain (Station 7) is as follows:

Covered beyond this point. No phosphate in the rubble.

1'	medium grey chert with occasional nodules of high grade phosphate.
7'	pure white quartzite grading upwards into a white chert. A few darker quartzite stringers are present.
4'	covered, no higher radiation.
5"	buff weathering pale grey sandstone, with crinoids and burrows.
1'	pale buff weathering white quartzite.
6"	alternating thin conglomerates and sandstones. The pebbles form 5-50% of the rock, consisting of less than one-third of good phosphate (30% P_2O_5) and further quartzite and chert. The radiation higher (.013) than the background reading (.010).

Underlain by pale buff weathering white quartzite.

A hundred yards to the east phosphate occurs as a few layers of 1/16 to 1" thick (30% P_2O_5) in chert.

At Station 8, the section of the Belemnite Zone in the Jurassic Fernie Group, 25' to 30' above a thick resistant thin bedded sequence that forms a 13' bluff in the western fork of the above-mentioned creek is as follows:

Overlain by black shale, very friable and thin bedded.

3' 8"	rubbly sandstones as below, with few fossils and no phosphate.
4'	dark grey to brown, yellowish weathering massive sandstone, grading into the layer above. This bed contains many Belemnites, Ammonites and Pelecypods and 1 or 2% of phosphate pebbles and fossil fillings. (30% P_2O_5).

Underlain by spheroidally weathering brown silty friable sandstone.

Both these occurrences have only academic interest.

Conclusions and Recommendations

In two months, Field Party #46 (1966) has investigated three rock phosphate prospecting permits in Alberta (Nos. 22, 23, and 24) totalling some 60,000 acres.

Permits 22 and 24 contain hardly any phosphate, and hence a discussion of economics in these areas is not necessary.

Conditions for an economic exploitation of phosphate in an area are very variable and depend on many circumstances such as attitude of rocks, amount of overburden, facilities for transport, availability of cheap electricity or cheap sulphurous acid, nearness to plant, etc.

The richest permit is No. 23. There, considering the local circumstances, the minimum conditions for economic exploitation would be 10' - 15' of phosphate rock with 26% or more P_2O_5, easily separable from the matrix, over an interval of 20' - 25' with an overburden of not more than 60'. Larger overburdens would require a smaller ratio of overburden to ore. Nowhere within this permit are these conditions realized or even approached. Strip mining moreover does not seem very feasible because of the thick overburden and the relatively steep dip. For a more elaborate discussion of phosphate economics, the reader is referred to Mr. A. K. Temple's memorandum of July 19, 1966 on this subject.

Because of the lack of economic phosphate deposits in the subject permits, we recommend that they be relinquished before the November 30, 1966 anniversary date.

October, 1966

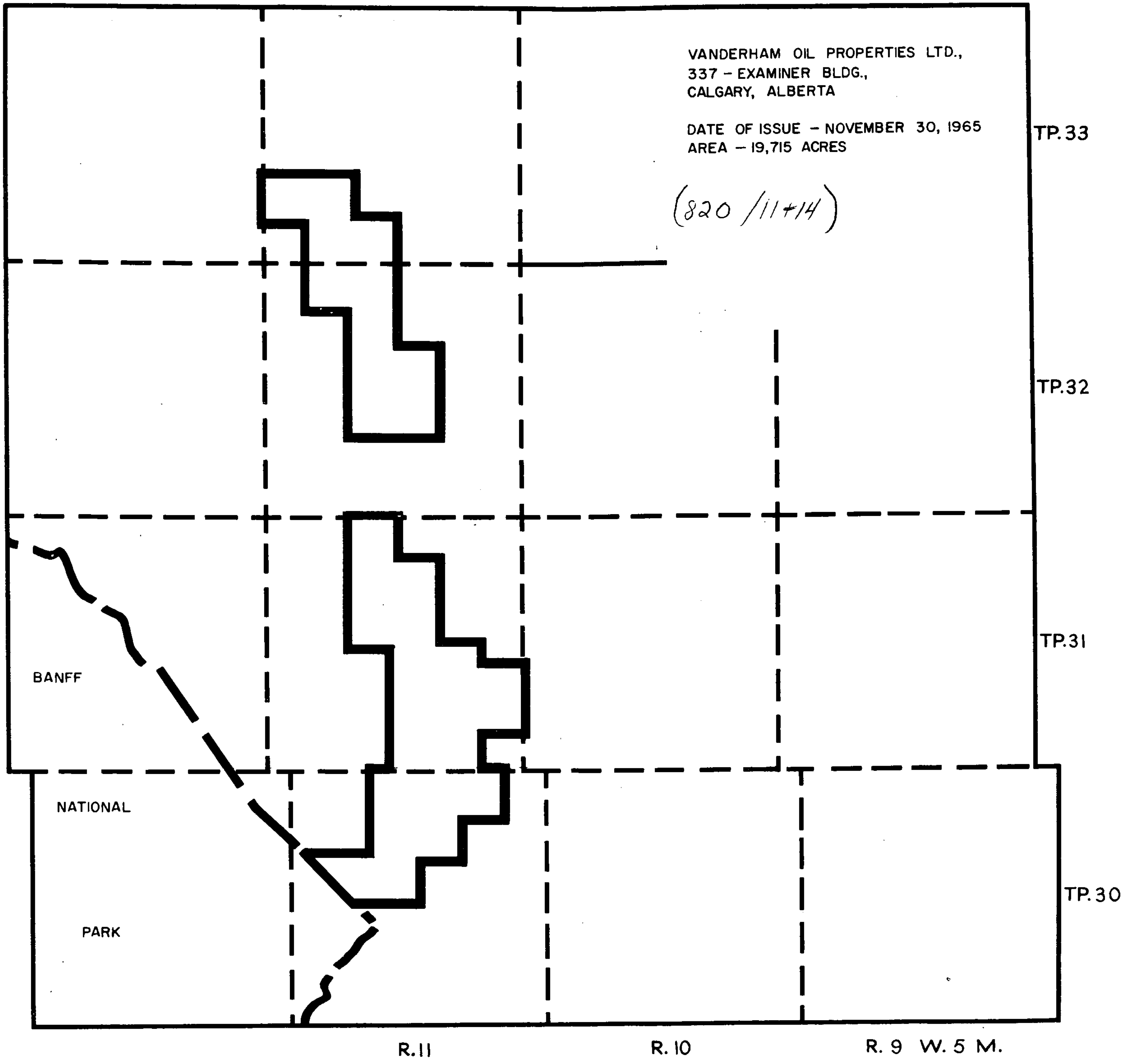
P. F. L. de Groot

ROCK PHOSPHATE PROSPECTING PERMIT NO. 22

VANDERHAM OIL PROPERTIES LTD.,
337 - EXAMINER BLDG.,
CALGARY, ALBERTA

DATE OF ISSUE - NOVEMBER 30, 1965
AREA - 19,715 ACRES

(820 /11+14)



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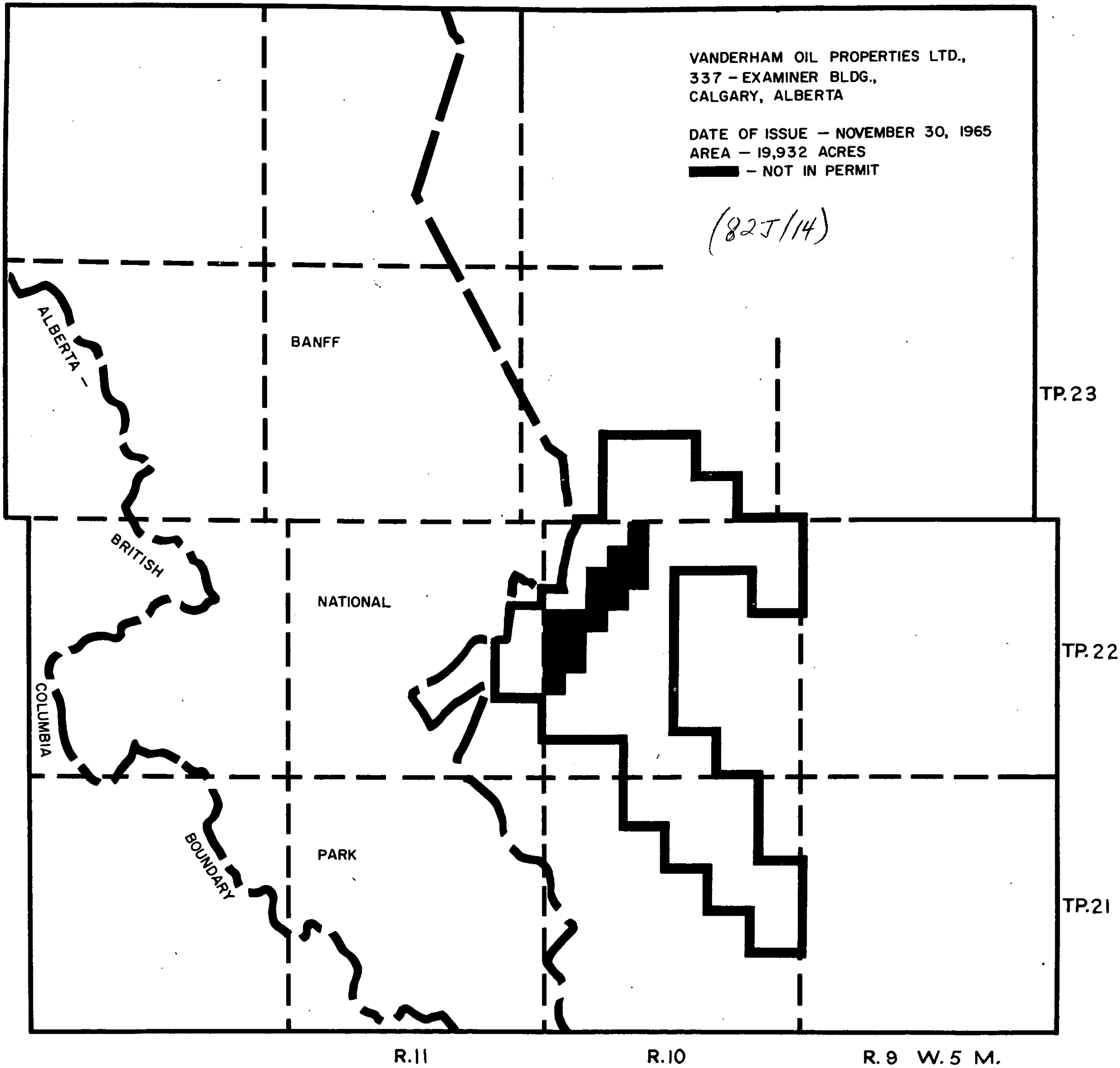
ROCK PHOSPHATE PROSPECTING PERMIT NO. 23



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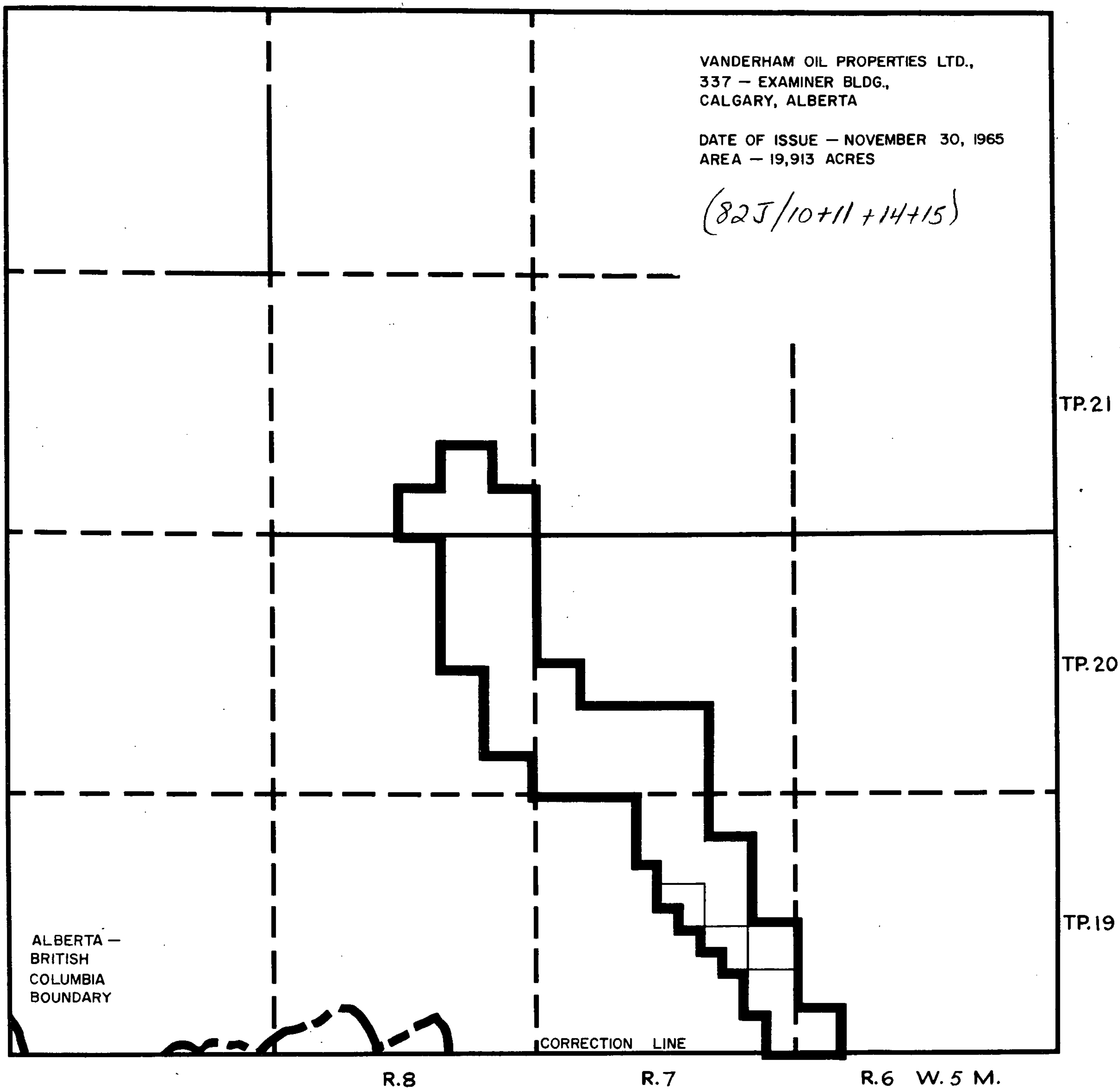
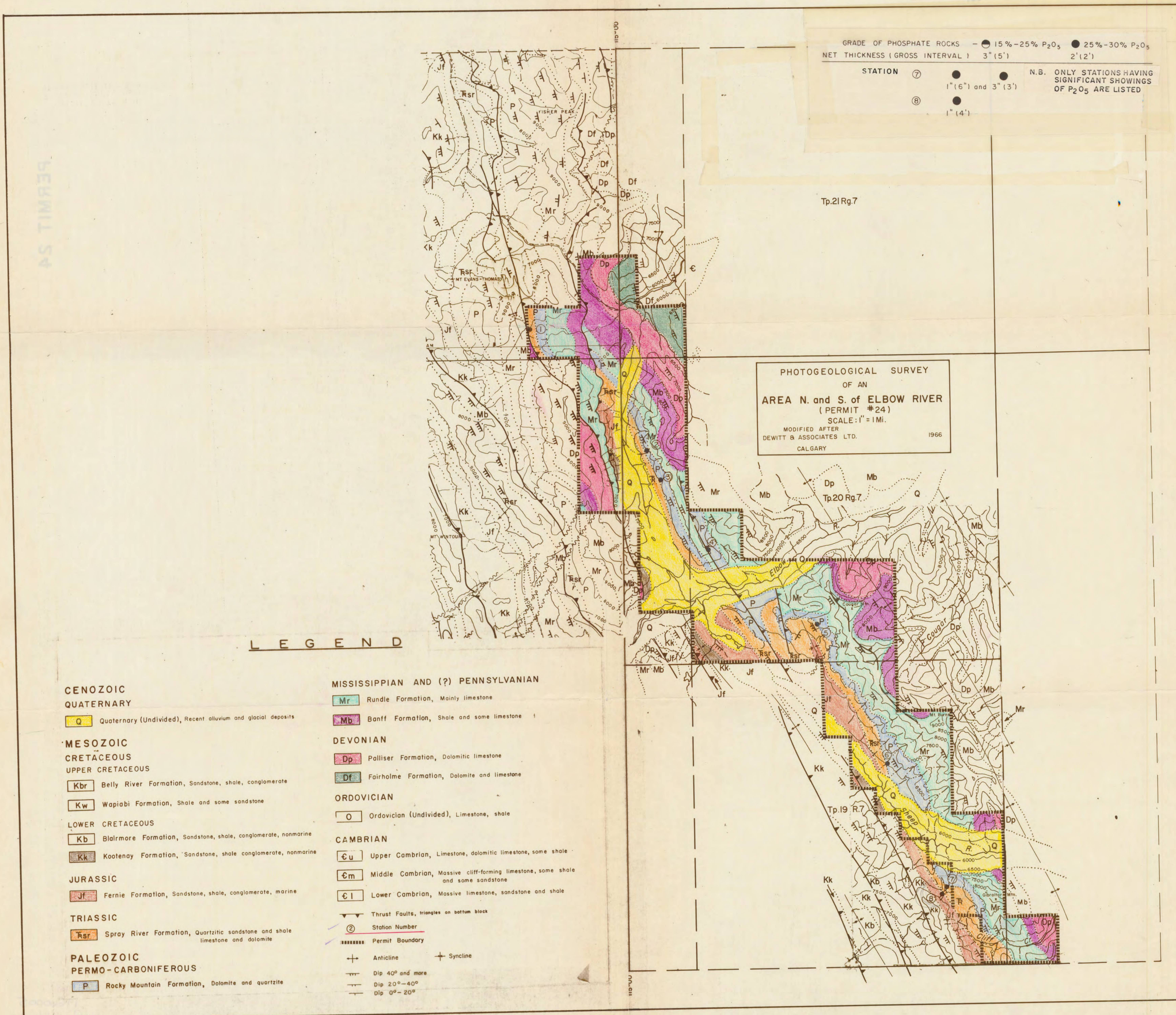
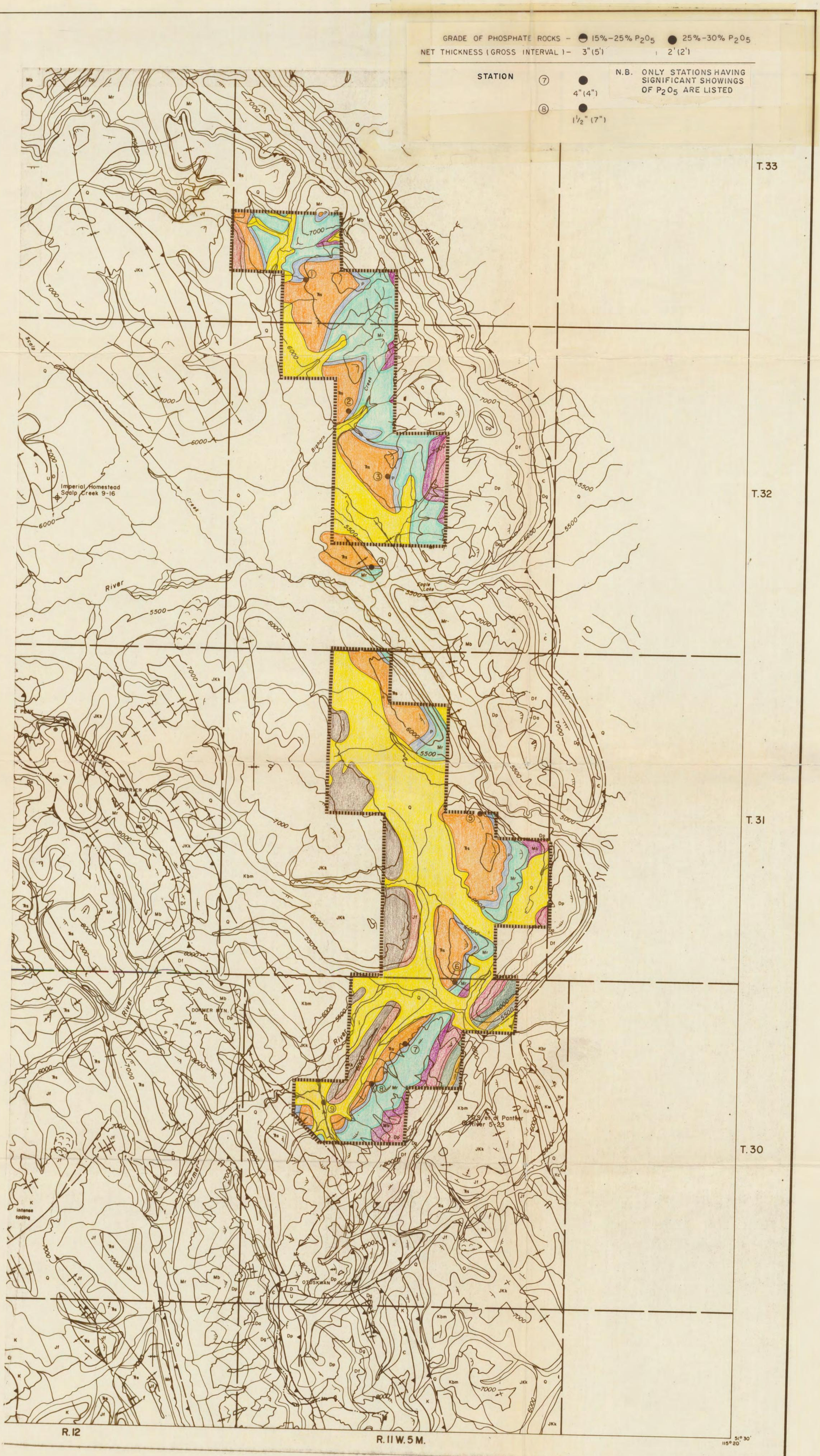
ROCK PHOSPHATE PROSPECTING PERMIT NO. 24




PHOTOGEOLOGICAL SURVEY
OF AN
AREA N. and S. of ELBOW RIVER
(PERMIT #24)
SCALE: 1" = 1 Mi.
MODIFIED AFTER
DEWITT & ASSOCIATES LTD.
CALGARY
1966
GRADE OF PHOSPHATE ROCKS — 15%-25% P2O5 25%-30% P2O5
NET THICKNESS (GROSS INTERVAL) 3"(5') 2'(2')
STATION ⑦ 1"(6") and 3"(3')
⑧ 1"(4')
N.B. ONLY STATIONS HAVING SIGNIFICANT SHOWINGS OF P2O5 ARE LISTED
Tp.21 Rg.7
Tp.20 Rg.7
Tp.19 R.7
FISHER PEAK
MT EVANS-THOMAS
MT WINTOUR
Cougar Mtn.
Mt. Burns
Gibraltar Mtn.
Elbow R.
Cougar Cr.
Sheep R.
Cliff
LEGEND
CENOZOIC
QUATERNARY
Q Quaternary (Undivided), Recent alluvium and glacial deposits
MESOZOIC
CRETACEOUS
UPPER CRETACEOUS
Kbr Belly River Formation, Sandstone, shale, conglomerate
Kw Wapiabi Formation, Shale and some sandstone
LOWER CRETACEOUS
Kb Blairmore Formation, Sandstone, shale, conglomerate, nonmarine
Kk Kootenay Formation, Sandstone, shale conglomerate, nonmarine
JURASSIC
Jf Fernie Formation, Sandstone, shale, conglomerate, marine
TRIASSIC
Ʀsr Spray River Formation, Quartzitic sandstone and shale limestone and dolomite
PALEOZOIC
PERMO-CARBONIFEROUS
P Rocky Mountain Formation, Dolomite and quartzite
MISSISSIPPIAN AND (?) PENNSYLVANIAN
Mr Rundle Formation, Mainly limestone
Mb Banff Formation, Shale and some limestone
DEVONIAN
Dp Palliser Formation, Dolomitic limestone
Df Fairholme Formation, Dolomite and limestone
ORDOVICIAN
O Ordovician (Undivided), Limestone, shale
CAMBRIAN
€u Upper Cambrian, Limestone, dolomitic limestone, some shale
€m Middle Cambrian, Massive cliff-forming limestone, some shale and some sandstone
€l Lower Cambrian, Massive limestone, sandstone and shale
Thrust Faults, triangles on bottom block
② Station Number
Permit Boundary
Anticline
Syncline
Dip 40° and more
Dip 20°-40°
Dip 0°-20°



PHOTOGEOLOGICAL MAP

of the

RED DEER RIVER – DORMER RIVER

ALBERTA (Permit # 22)

0 MILES 1

SCALE

After Hunting Survey Corp. Photogeological map of the Clearwater – Minnewanka area 1961

MAP SYMBOLS

GEOLOGY

- Dip less than 10°
- Dip 10°-30°
- Dip 30°-60°
- Dip more than 60°
- Dip slope less than 10°
- Dip slope 10°-30°
- Dip slope 30°-60°
- Dip slope more than 60°
- Vertical dip
- Horizontal dip
- Overturned dip
- Gentle dip
- Fault — dashed where indefinite
- Thrust fault (Triangles on overthrust block) — dashed where indefinite
- Stratigraphic boundary
- Axis of anticline — dashed where indefinite, arrow denotes plunge
- Axis of overturned anticline — dashed where indefinite, arrow denotes plunge
- Axis of syncline — dashed where indefinite, arrow denotes plunge
- Axis of overturned syncline — dashed where indefinite, arrow denotes plunge

HYDROLOGY & UNRELATED FEATURES

- River and stream
- Lake
- Ice and snow
- Slump
- 5000 Contour
- Park boundary
- Provincial boundary
- ② Station Number
- Permit Boundary

MAPPED ROCK UNITS

QUATERNARY

- Q Quaternary undivided

UPPER CRETACEOUS

- Kbr Belly River formation
- Kw Wapiabi formation
- Kc Cardium formation
- Kbl Blackstone formation
- K Cretaceous undivided

LOWER CRETACEOUS

- Kbm Blairmore formation

JURASSIC

- JKk Kootenay formation
- Jf Fernie formation

TRIASSIC

- Ҏs Spray River formation

PERMO-PENNSYLVANIAN

- P Rocky Mountain formation

MISSISSIPPIAN

- Mr Rundle formation
- Mb Banff formation includes Exshaw formation

DEVONIAN

- Dp Palliser formation
- Da Alexo formation
- Df Fairholme formation
- Dg Ghost River formation

ORDOVICIAN

- Ow Mt. Wilson formation
- Os Sarbach formation
- Om Mons formation
- O Ordovician undivided

UPPER CAMBRIAN

- UC Upper Cambrian including Sullivan and Lyell formations
- UCa Arctomys formation

MIDDLE CAMBRIAN

- MC Middle Cambrian, undivided
- MCp Pika formation
- MCe Eldon formation
- MCs Stephen formation
- MCc Cathedral formation
- MCw Mt. Whyte formation
- C Cambrian undivided

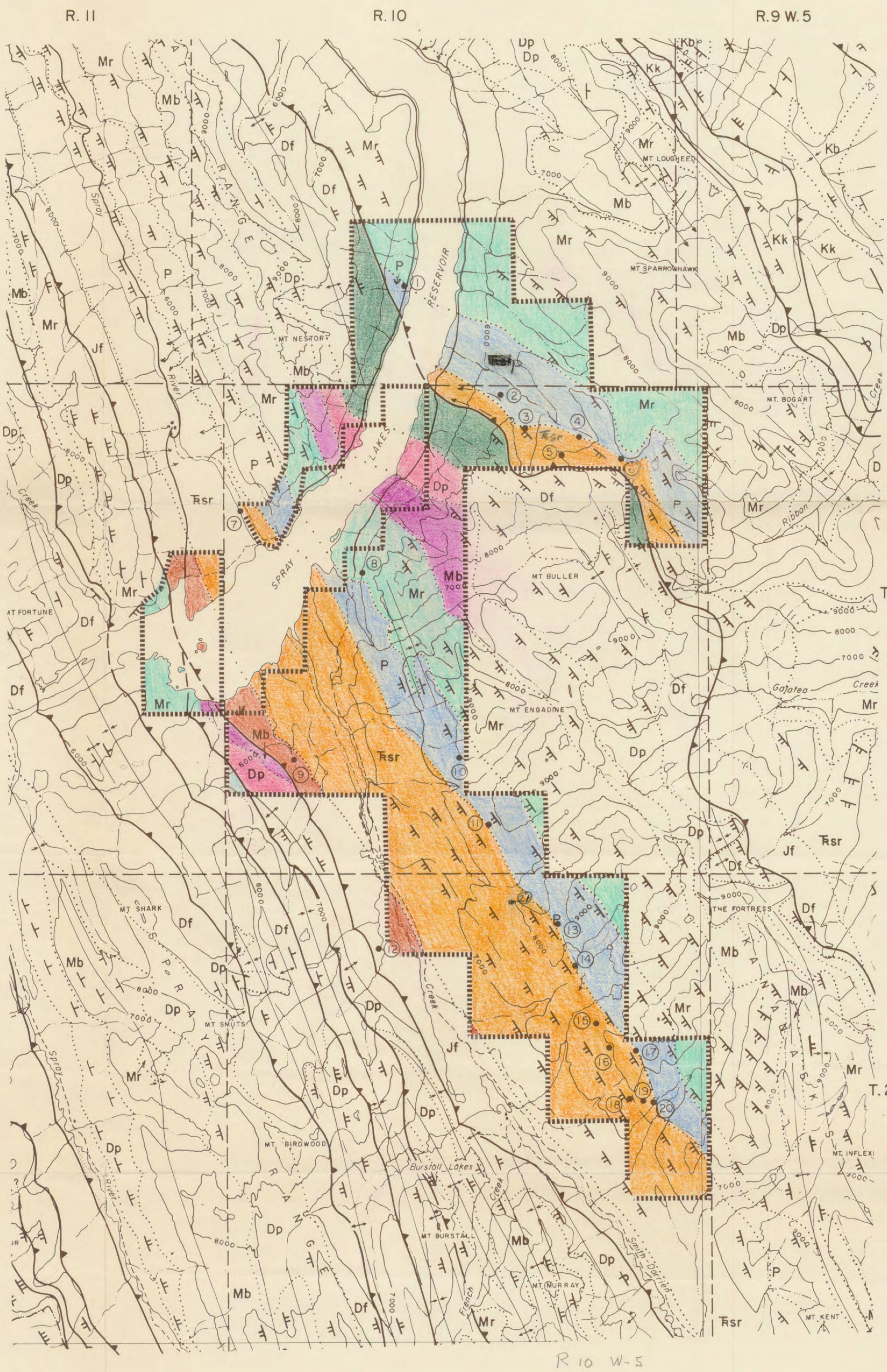
LOWER CAMBRIAN

- LCp St. Piran formation

PRECAMBRIAN

- pCh Hector formation

NOTE: This map is compiled from Alberta Government aerial photography. Scale: 1-40,000.



R 10 W-5

PHOTOGEOLOGICAL MAP

OF THE

SPRAY LAKES AREA

ALBERTA (Permit # 23)

0 MILES 1

SCALE

Modified after Dewitt & Associates

Photogeological Survey of Kananaskis Lake - Mt. Assiniboine 1964

For legend see map of permit 24

PERMIT #23

GRADE OF PHOSPHATE ROCKS – ◒ 15%–25% P_2O_5 ● 25%–30% P_2O_5

NET THICKNESS (GROSS INTERVAL) – 3" (5') 2' (2')

N.B. ONLY STATIONS HAVING SIGNIFICANT SHOWINGS OF P_2O_5 ARE LISTED

STATION		
3	● 1' (1')	
4	● 1' (1'6")	
5	● 1"-3" (1"-3")	
6	● 1'1" (1'1")	
11	● ? (?)	
13	● 1' (15')	◒ 2'
14	● 1'2" (17'4")	◒ 2'3"
16	● 10" (4'7")	◒ 2"
17	◒ 4' (7')	
18	● ?" (?)	◒ ?"
19	● ?" (?)	
20	◒ 4'9" (6'5")	
21	● 1" (1")	