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PHOTOMOSAIC AND FIELD RECONNAISSANCE STUDY

SELECTED SULPHUR PROSPECTING PERMITS

FORT VERMILION AREA, ALBERTA

Prepared For

Inland Chemicals Canada Ltd.

December, 1967

J. C. SPROULE AND ASSOCIATES LTD.
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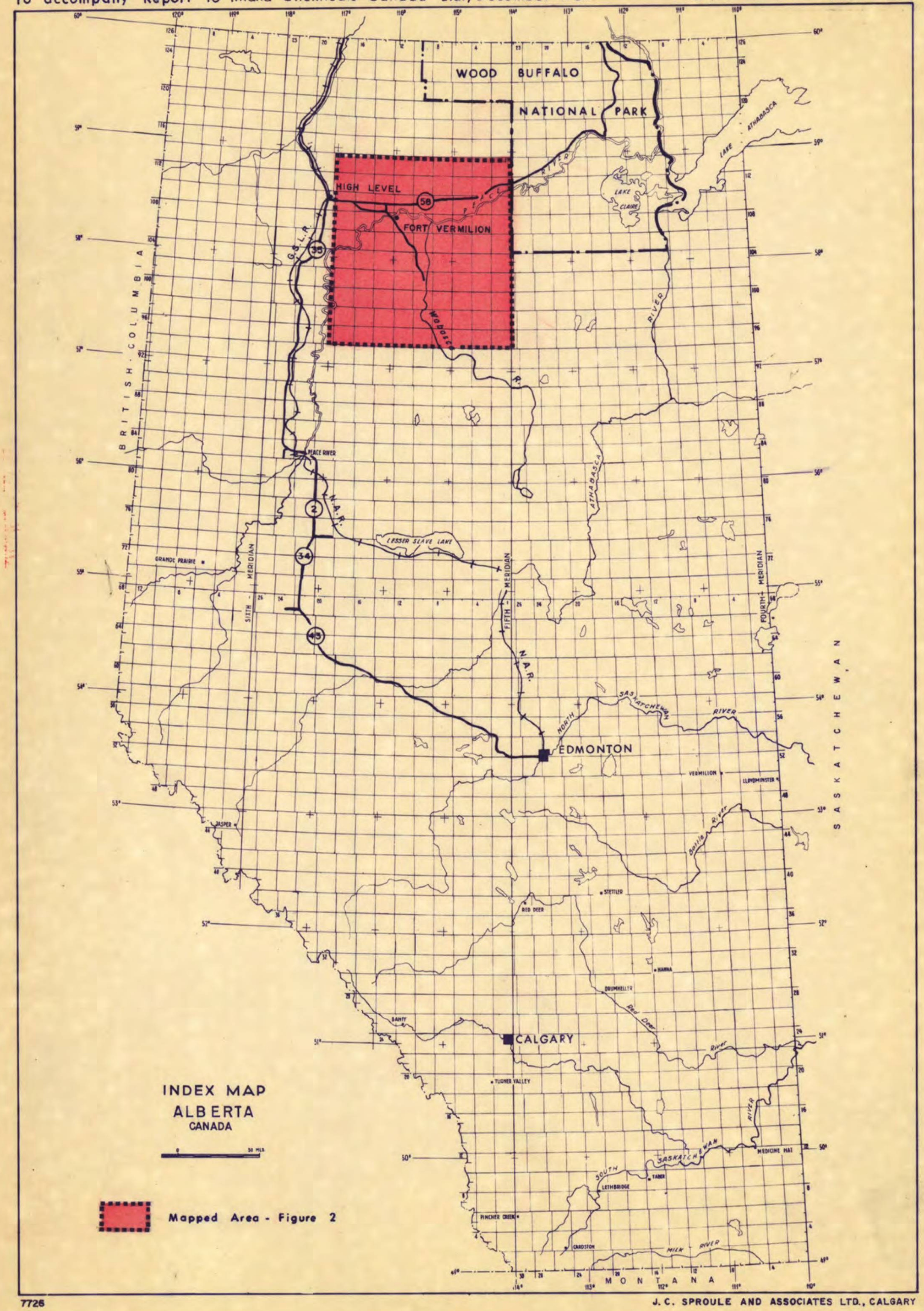

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J. C. SPROULE AND ASSOCIATES LTD., CALGARY

PHOTOMOSAIC AND FIELD RECONNAISSANCE STUDY

SELECTED SULPHUR PROSPECTING PERMITS

FORT VERMILION AREA, ALBERTA

INTRODUCTION

A reconnaissance study of the Fort Vermilion area was undertaken at the request of Mr. R. Campbell, President of Inland Chemicals Ltd., and Mr. H. Rekuynk, representing Inland Chemicals, for the purpose of selecting and evaluating Sulphur Prospecting Permits. Four such Permits were taken out by Inland Chemicals during the course of the study.

This report is submitted to explain the methods and results of the reconnaissance study. It is not intended to be a comprehensive geological report. The enclosed map of the Fort Vermilion area, Figure 2, shows the locations of prospects and Permits, in relation to some subsurface and surface geological features, superimposed upon a base showing certain geographical features. Township and range, latitude and longitude, a few principal roads, settlements and Indian Reserves are shown.

The area selected for study, hereinafter called the "Fort Vermilion area" because the village of Fort Vermilion is the largest and best known settlement within the area, includes Townships 98 through 112 and Ranges 4 through 15, W. 5 M., in north-central Alberta. The northern and southern boundaries are approximately 58°45' and 57°30' N., while the eastern and western boundaries are approximately 114°30' and 116°30' W. Fort Vermilion is on the south bank of the Peace River, 42 miles east-southeast of the booming exploration centre of High Level, which is located on the Mackenzie Highway and the Great Slave Lake Railroad which follows the route of the highway. Fort Vermilion is 155 miles north-northeast of Peace River and 335 miles north-northwest of Edmonton.

Highway No. 58, like the Mackenzie Highway, is an all-weather unpaved road. It extends eastward from High Level across the northern portion of the Fort Vermilion area and on to Wood Buffalo National Park, and will eventually reach Fort Smith. A similar all-weather road extends southeastward from Highway No. 58 to the ferry crossing on the north bank of the Peace River, just northwest of Fort Vermilion. Vehicles can reach Fort Vermilion by ferry during the summer and by driving across the ice on the Peace River during the winter; but during freeze-up in November, and break-up in April and the first half of May, Fort Vermilion is accessible by air only. A new road is being built in a south-southeasterly direction from Fort Vermilion to the Tall Cree Indian Reserve No. 173 on the west bank of the Wabasca River (formerly spelled Wabiskaw). This road is projected to go to Lesser Slave Lake and would perhaps serve as a short-cut to Edmonton. There are numerous other roads, especially in the flat farming country of the Peace River valley. Some of the roads in the back-country are winter roads only. There are no railroads in the Fort Vermilion area.

Keir Air Transport has daily scheduled DC-3 flights from Peace River to High Level and smaller scheduled aircraft serve Fort Vermilion from High Level three times weekly. The Peace River-High Level flights connect with regular Pacific Western Airlines flights between Edmonton and Peace River. Keir also offers charter service. In November 1967 there were four helicopter operators based in High Level.

The photomosaic and field studies were conducted by C.W. Drew, Jr., P. Geol.

GEOGRAPHICAL SETTING

The Fort Vermilion area lies entirely within the Interior Plains of western Canada. These lowland plains have a regional slope to the east-northeast and are broken sporadically by low ranges of hills and mountains, so-called, although they are really slightly dissected plateaus. Northern Alberta falls within the transitional zone between the parklands of central Alberta and the taiga, or northern coniferous forest, of the Mackenzie area. Consequently, it is covered by mixed broadleaf and coniferous forest interspersed with numerous muskegs, swamps and small lakes, as well as meandering rivers, generally with low gradients. This is the so-called "bush."

The Fort Vermilion area is bisected from west to east by the broad flat valley of the Peace River, which occupies about half of the total study area. The average elevation of this valley is about 900 feet, which is the elevation of Fort Vermilion. Along the Peace River, near the eastern boundary of the study area, the elevation is slightly less than 800 feet. The southeastern portion of the area is occupied by a low interior plain that is contiguous to, and slopes gently northward into, the Peace River valley. The Buffalo Head Hills occupy the southwestern portion of the Fort Vermilion area. They rise rather abruptly in forested slopes from the lowlands on their northern and eastern sides and have a broad hilly summit area between 2,500 feet and 3,000 feet above sea-level. The Caribou Mountains rise from the northern side of the Peace River valley and occupy the extreme northern portion of the Fort Vermilion area. They are similar to the Buffalo Head Hills but the rolling uplands reach an elevation of 3,200 feet.

Except for the extreme east-central portion, the Fort Vermilion area is drained by the Peace River and its tributaries. The largest tributary is the Wabasca River, which flows northward through the south-central and central parts of the study area to join the Peace River east of Fort Vermilion. South of Township 103, the Wabasca is entrenched along the eastern edge of the Buffalo Head Hills; its canyon forming the boundary between these hills and the lowlands to the east. One of the principal tributaries of the Wabasca is the Muddy River, which flows southeastward out of the Buffalo Head Hills to join the Wabasca River near the southern boundary of the Fort Vermilion area. The Bear River, which drains the northwestern portion of the Buffalo Head Hills and then flows northeastward into the Wabasca River near its mouth, is the other major tributary of the Wabasca. Wadlin Lake, the only lake of consequence in the study area, lies in the northeastern part of the Buffalo Head Hills to the north of the Muddy River, and to the west of the Wabasca River into which it drains. The only important river in the Fort Vermilion area east of the Wabasca is the Mikkwa River at the settlement of Little Red River. The Mikkwa River was formerly called the Red River, while the lower portion of the Wabasca River was formerly called the Loon River.

Several small rivers flow southward from the Caribou Mountains into the Peace River, draining the northern portion of the Fort Vermilion area. They are, from west to east, the Ponton, Caribou, Lawrence and Wentzel rivers. The Ponton River actually joins the east-flowing Boyer River before reaching the Peace River and thus is a tributary of the Boyer, which drains the higher plains to the west of the Fort Vermilion area.

The lowlands are forested mainly with aspen, with some white spruce and less common jack pine and paper birch. In the highlands, the white spruce is the dominant tree with some aspen and, again, rarer jack pine and paper birch. Black spruce and tamerack grow in the muskegs or swamps at all elevations. The Peace River valley has areas of natural prairie which are commonly farmed.

Climate

The Fort Vermilion area has the severe climate with long, very cold winters typical of continental interiors at this latitude. Fort Vermilion has over five decades of climatological record, which shows that it has summers similar to those of Vancouver and Calgary, but much colder winters. The mean temperature for July, the warmest month, is 62°F and for January, the coldest month, is -9°F. The mean annual temperature is 29°F. If some of the older records can be believed, Fort Vermilion has recorded phenomenal extremes of temperature. July temperatures have ranged from 101°F to 20°F and in January extremes from 52°F to -78°F have been recorded. This last temperature is the lowest on record in North America, outside of the Yukon. The average annual precipitation at Fort Vermilion is 14 inches, including 51 inches of snowfall (arbitrarily converted to rainfall at a 10:1 ratio.) July is the wettest month and April the driest. The ground should normally be snow-covered during November through April.

With increasing altitude away from the Peace River, summers become slightly cooler and the winters are slightly milder with lesser extremes of temperature. Precipitation and snowfall increasewith altitude, but even the highest areas should normally become almost entirely free of snow in May.

GEOLOGICAL SETTING

The Fort Vermilion area lies on the eastern flank of the Alberta Syncline and consequently the strata dip gently west-southwestward. Devonian rocks underlie the entire area, but in most parts of the study area are overlain by various thicknesses of Cretaceous strata and/or glacial deposits including glaciolacustrine deposits. The bedrock at the surface becomes progressively younger towards the west-southwest and also with increasing elevation of the ground. Upper Devonian strata outcrop along the Peace River from Vermilion Rapids eastward and downstream at elevations below 800 feet. The oldest formation exposed in the Fort Vermilion area is the Upper Devonian Mikkwa Formation, which consists of stromatoporoidal dolomitic limestone and argillaceous limestone. It is overlain by the dolomite and dolomitic limestone of the Grosmont Formation. The eroded edges of these strata form the Vermilion Rapids and Vermilion Falls at Vermilion Chutes on the Peace River, just upstream from the mouth of the Mikkwa River.

The largest portion of the Fort Vermilion area is underlain, beneath a thin glacial cover, by Lower Cretaceous strata, which are predominantly shales. The oldest Cretaceous rocks are the dark grey shales of the Spirit River Formation (formerly called the Loon River,) which outcrop along the Peace and lower Wabasca rivers. These are overlain by the sands, sandstones, shales and sporadic coal of the Peace River Formation, and then by the dark grey to black shales with ironstone bands and concretions of the Shaftesbury Formation. These three formations belong to the Fort St. John Group. The higher parts of the Buffalo Head Hills, and probably of the Caribou Mountains, contain Upper Cretaceous strata, which include the sandstones, shales and sandy shales of the Dunvegan Formation overlain by the shales and carbonaceous shales of the Kaskapau Formation. The latter is believed to be the youngest bedrock in the Fort Vermilion area. Most of the bedrock of the Fort Vermilion area is covered by variable thicknesses of glacial, glaciolacustrine and glaciofluvial deposits that consist mainly of clay, sand and gravel with some large boulders. Bedrock outcrops are generally confined to stream-cuts and other steep slopes, especially along stream canyons where they have been exposed by landslides.

Of more interest to the present study are the subsurface Devonian strata. The outcropping Devonian rocks described above form a part of the Upper Devonian Woodbend Group. They are underlain by the "Shale Unit," and by the limestone and argillaceous limestones of the Beaverhill Lake Equivalent. Underlying the Woodbend Group is the Upper Devonian Slave Point Formation, which consists of argillaceous limestone except for its Fort Vermilion Member, which contains brown and white anhydrite along with some limestone and dolomite. The Slave Point Formation is underlain by the Elk Point Group, of Middle Devonian age, which includes the following formations, in descending order: the Watt Mountain Formation, consisting of clastics, anhydrite and dolomite; the Muskeg Formation, consisting of dolomite, anhydrite and salt; the Keg River Formation, consisting of dolomite and limestone; and, finally, the Chinchaga Formation, consisting of anhydrite, minor amounts of salt and dolomite. Red beds of questionable age separate the Elk Point strata from the crystalline Precambrian rocks beneath. The various Devonian anhydrites are regarded as the probable source of sulphur found in the Fort Vermilion area and other portions of north-central Alberta. The sulphur was probably carried upwards either as $CaSo_4$ in solution or as H_2S. The complex chemistry of sulphate reduction and oxidation is beyond the scope of this study.

The major unconformity separating the Cretaceous from the Devonian rocks truncates progressively younger Paleozoic strata towards the west-southwest, just as the present surface exposes progressively younger Cretaceous strata in that direction. In all but the southwestern portion of the Fort Vermilion area, strata of the Upper Devonian Woodbend Group are the youngest occurring beneath this unconformity and thus form the subcrop. In the southwestern portion, the subcrop consists of generally argillaceous carbonates of the Winterburn Group and possibly the limestones and dolomites of the Wabamun Group, which sometimes has a basal anhydrite. If this Wabamun basal anhydrite does occur beneath the extreme southwestern portion of the Fort Vermilion area, it would be another possible source of sulphur although it would be covered by about 1,500 feet to 2,000 feet of Cretaceous strata. To the west-southwest of the Fort Vermilion area, the Mississippian Banff Formation forms the subcrop beneath the unconformity.

McConnell, in 1893 (see Bibliography,) published a report of outcropping Devonian limestone 34 to 36 miles up the Mikkwa River (or the Red River as he called it) from the Peace River. This locality has not since been investigated by the Geological Survey of Canada and could not be located during our recent rapid field study. The isolated outcrop of Devonian is indicated on the Survey's latest geological map of the area, the Hay River Sheet, published in 1965. This isolated outcrop is undoubtedly of Late Devonian age.

Since the interpreted potential sulphur source beds beneath the Fort Vermilion area are overlain by hundreds, or even a few thousands, of feet of Upper Devonian and Cretaceous strata, any large surface or near-surface sulphur deposits would have to have access by fault or fracture openings to the Middle Devonian source beds beneath, unless melt waters from the retreating glaciers were able to carry enough sulphur from Middle Devonian outcrops to the northeast to form sizable deposits in the glaciofluvial or glaciolacustrine beds. Deposits of the latter type would be extremely difficult to find by means of a photomosaic study or field reconnaissance and, consequently, our study was directed primarily toward the location of fault or fracture zones intersecting probable bedrock outcrop areas.

METHODS OF STUDY

Photomosaic Study

Since this project was undertaken on extremely short notice, only a few days before leaving for the field, there was not time to obtain air photographs covering the area. Fortunately, J.C. Sproule and Associates Ltd. had some rough "lay-down" photomosaics completely covering the area of interest at a scale of about 1:40,000 or 1 1/2 inches to the mile. A preliminary geomorphological study was made using these mosaics to locate the major probable fault and fracture zones. These fault or fracture zones were then plotted upon a combined base and subsurface contour map at a scale of 1:250,000 or approximately four miles to the inch. A map was prepared (Figure 2) showing the ground elevation and the top of the Devonian at those wells for which this information is available. In a number of cases, logs for pertinent wells have not yet been released. In other cases, the top of the Devonian is behind surface casing which makes determination of this top very difficult. Where we did not have adequate well logs, the first Devonian top was plotted on the map. This first reported Devonian pick does not necessarily represent the top of the Devonian but only the minimum elevation of the top of this system. In the northwestern part of the map, much of the control was so doubtfull that contouring is not justified. The data on the map do, however, provide an indication of the maximum depth of the Devonian. In areas where control was too doubtful for structure contouring to appear on the final map, tentative contours were drawn on the field copy and depths to Devonian were estimated from them. Between wells, the ground elevation was obtained from the topographic maps covering the area at a scale of 1:250,000.

A study of the photomosaics showed where bedrock outcrops were most likely to occur. It was noted that two of the fault or fracture zones found on the photomosaics crossed the Madison et al Sulphur Prospecting Permit No. 8 with its known deposits of sulphur. Twenty six sulphur prospecting areas, not then known to be already under permit, were selected, where fault or fracture zones, which might provide a route for the ascent of sulphur to the surface, intersected areas of probable outcrop where the post-Devonian cover was not exceedingly thick. These areas were circled on the base and subsurface map (Figure 2). Those prospects that appeared to be the most promising on the basis of the office study, were surrounded by a double rather than a single line.

Alberta Government photomosaics were obtained just in time to be taken to the field as an aid to field studies. The office study was essentially made to give the necessary guidance for a productive field study under early winter field conditions with light snow cover.

Field Study

Nine days during November were spent on the field portion of this study. With one day necessary for air travel in each direction between Calgary and High Level, there were seven days for actual field work. A Bell 47 G3-B1 helicopter, piloted by Mr. R. Phillips, was chartered from Alpine Helicopters Ltd., at High Level, and the seven days of helicopter field work were carried out from High Level. On the first day only, a Bell J2 helicopter was used (piloted by Mr. R. Phillips). In spite of a variety of early winter weather conditions, helicopter field work was undertaken during each of the seven days and efforts were made to take full advantage of the nine hours of daylight per day, with most of the "commuting" between High Level and the prospect areas being done by twilight or near-twilight. Practically all of the ground, except on vertical or near-vertical cuts and cliff faces, was obscured by a thin but uniform snow cover. Consequently, our reconnaissance was made mainly along streams. The prospects were checked from the air and when a feature of apparent interest was seen, a landing was made to permit ground studies. The most interesting localities visited were ones where there was some evidence of thermal activity which might indicate faults. Such evidence in winter is usually indicated by snow-free ground where one would normally expect snow cover. Areas of yellow colouration were also sought, where it appeared that such colouration might be something other than limonite or related staining of the shale. If the ground investigation showed abnormally high temperatures or yellow mineralization that might include sulphur, samples were taken. These samples were obtained by the use of either a geological pick, shovel, or post-hole auger, and were taken at depths of up to five feet. Subsequently, selected samples have been sent to Core Laboratories Ltd. for sulphur and ash analyses.[1]

It was hoped to visit Madison et al Sulphur Prospecting Permit No. 8 and land at the known sulphur show in the N. 1/2 Section 9, Township 110, Range 5, W. 5 M., on the first day of the field check and to study that deposit as background information to guide the rest of the work. Because of the fresh snow cover on the featureless terrain, it was not possible to locate the area of pits and boreholes until late in the study.

(1) Results shown in Appendix I.

RESULTS OF FIELD STUDIES

The areas which were delineated for field checking are labelled 'A' to 'Z' (including 'TT') on the accompanying map (Figure 2). Due to limitations of time and/or weather, Areas 'X', 'Y' and 'TT' were not visited. Areas 'D', 'E', 'F', 'G', 'J', 'K', 'N', 'O', 'R', 'U', 'V', 'W' and 'Z' were studied from the air while travelling at low speed and low altitude but no landings were made, mainly because no worthwhile outcrops were seen due to snow, vegetation or glacial drift cover. In a few instances, heavy forest and rough topography prevented landing the helicopter near the prospect. Nothing of great interest was seen from the air in these latter cases however.

In Area 'B', a landing was made at locality B-1 on the lower Wentzel River in Township 110, Range 4, W.5 M. Only soil-covered sand and gravel were seen in the stream banks and from the air all other stream banks appeared to be the same throughout Area 'B'.

A landing was made one-quarter mile from an interesting looking landslide outcrop at locality C-1 in Area 'C', about half way up the Wentzel River in Township 112, Range 4, W.5 M., in Inland Chemicals' Sulphur Prospecting Permit No. 25. Some warm, snow-free, muddy ground was found. Otherwise the ground was frozen and snow covered. The warm ground was on a slump area at the bottom of a cut-bank exposing dark shale with ironstone concretions and abundant yellow and rust-coloured staining, probably due to limonite. The area of warm ground extended 55 feet in a north-south direction, paralleling the Wentzel River at that point, and 15 to 20 feet in an east-west direction. The south end of this warm area appeared to be the warmest, and, at a depth of one foot, the ground had a temperature of 64°F. while the air temperature was about 24°F. This warm, wet ground suggests the possibility of hydrothermal activity connected with a fault zone. Sample D-C-1a(1) is of the shale from the outcrop above. Sample D-C-1b was obtained by shovel from a depth of two feet near the south end of the warm area at the point where the temperature was taken. Sample D-C-1c was taken from a depth of four feet, at the same locality as 1b, but only a very small sample could be obtained by the drill-type auger, which proved unsuitable for this type of sampling. The light was too poor for taking photographs at this point.

Two days later, this locality (C-1) was visited again with a post-hole auger. Sample D-C-1d was taken from the same depth and location as 1c, and a large sample was obtained using this type of auger. Sample D-C-1e was taken by auger at a four-foot depth at the north end of the warm area, about 55 feet north of the other sample location. The subsequent analyses of samples D-C-1d and D-C-1e (see Appendix) showed less than three percent sulphur, which is a normal amount to be expected in shale. These analyzed samples were of shaly slump material.

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(1) 'D' stands for the sampler (Drew) and 'C-1' is the locality from which the sample was obtained, with the capital letter corresponding with the Areas designated in the previous paragraph.

Ground study at locality H-1, just northeast of Area 'H' on Carl Creek in Township 113, Range 11, W.5 M., disclosed only a landslide of soil, glacial drift and shale, mostly covered by snow.

There are numerous outcrops of yellow stained shale in and near Areas 'I' and 'J'. A landing was made at one of the most striking of these, locality I-1, just northeast of Area 'I' on the Caribou River in Township 112, Range 12, W.5 M. A cut-bank, about 75 feet high and 140 feet long at its base, exposed very dark grey shale heavily stained by yellow minerals and overlain by glacial drift and soil. Sample D-I-1 was obtained from various points along the lower part of this cut together with a portion of the most marked yellow mineralization from the middle of the cut obtained by chopping steps in the near vertical face of the cut up to that point. There was a little water seepage, but no warm ground (Plate I).

The subsequent analysis of Sample D-I-1 showed over five percent sulphur for a representative cut of the shale and yellow minerals combined. Another cut, high-graded by selecting as much yellow material with as little dark grey shale as feasible, was then sent for analysis to see if the yellow minerals did indeed contain an appreciable amount of sulphur even though field tests showing yellowish streak, opaqueness, lack of sulphur odour and inability to burn, were all negative; just as they were for the yellow minerals found at other localities (except 'A') during this field study. The second analysis (of the high-graded sample) showed virtually the same percentages of sulphur and ash as did the previous sample, which contained much more shale, showing that the yellow material is not significantly richer in sulphur than the shale.

It was noted at locality I-1 and elsewhere, even from the air, that the yellow staining and mineralization in the dark grey Cretaceous shales are generally most pronounced up near the drift contact or soil zone rather than at lower horizons in the shales. This suggests that water percolating down from the surface may have been a factor in the deposition of the yellow minerals, which generally coat joint, fracture or bedding surfaces. It is believed that in most or all of the places where they were seen in outcrop, these yellow minerals contain a great deal of limonite.

Ground study at locality L-1 on the Wabasca River in Township 105, Range 9, W.5 M., at the south end of Area 'L', disclosed only grey Cretaceous shale and glacial drift, mostly in the form of slump. Snow cover was extensive.

A prominent stream cut along the lower Wabasca River was at locality M-1 in the central part of Area 'M' in Township 102, Range 9, W.5 M., in Inland Chemicals' Sulphur Prospecting Permit No. 27. All the stream cuts in this area were sufficiently inclined from the vertical that they were extensively snow covered. Locality M-1 consisted mainly of grey shale and glacial drift, mostly in the form of slump. Sample D-M-1a consists of grey crumbly shale with iridescent purple calcite fragments, which are probably shell fragments. Sample D-M-1b was taken 100 yards to the northeast and consists of dark grey well-bedded shale with limestone concretions and some iron-staining. Neither sample showed any indication of containing sulphur and analysis of D-M-1b showed less than one percent sulphur.

Farther to the south, upstream along the Wabasca River, Areas 'P' and 'Q' are much alike and closely resemble the area of the Madison et al Sulphur Prospecting Permit No. 9, which lies just to the north of 'P' and in which a showing of sulphur has been reported. At locality Q-1, in the northern part of Area 'Q' in Township 99, Range 9, W. 5 M., in Inland Chemical's Sulphur Prospecting Permit No. 26, landsliding on the 200-foot high river bank has exposed a lot of dark grey shale with iron concretions and the common orange and yellow limonite-looking staining. A pool on a gravel bar beside the Wabasca River at the foot of the cliff was thinly covered by rusty-orange coloured ice. Several springs produced holes in the ice above them. By placing logs upon the thin, soft ice it was possible to get out to the springs, measure the temperature of the water as 37°F, and get a sample of the rusty-orange coloured water (sample D-Q-1). The 37°F temperature was about the same as the ambient air temperature. Analysis of this water yielded less than one-half of one percent sulphur.

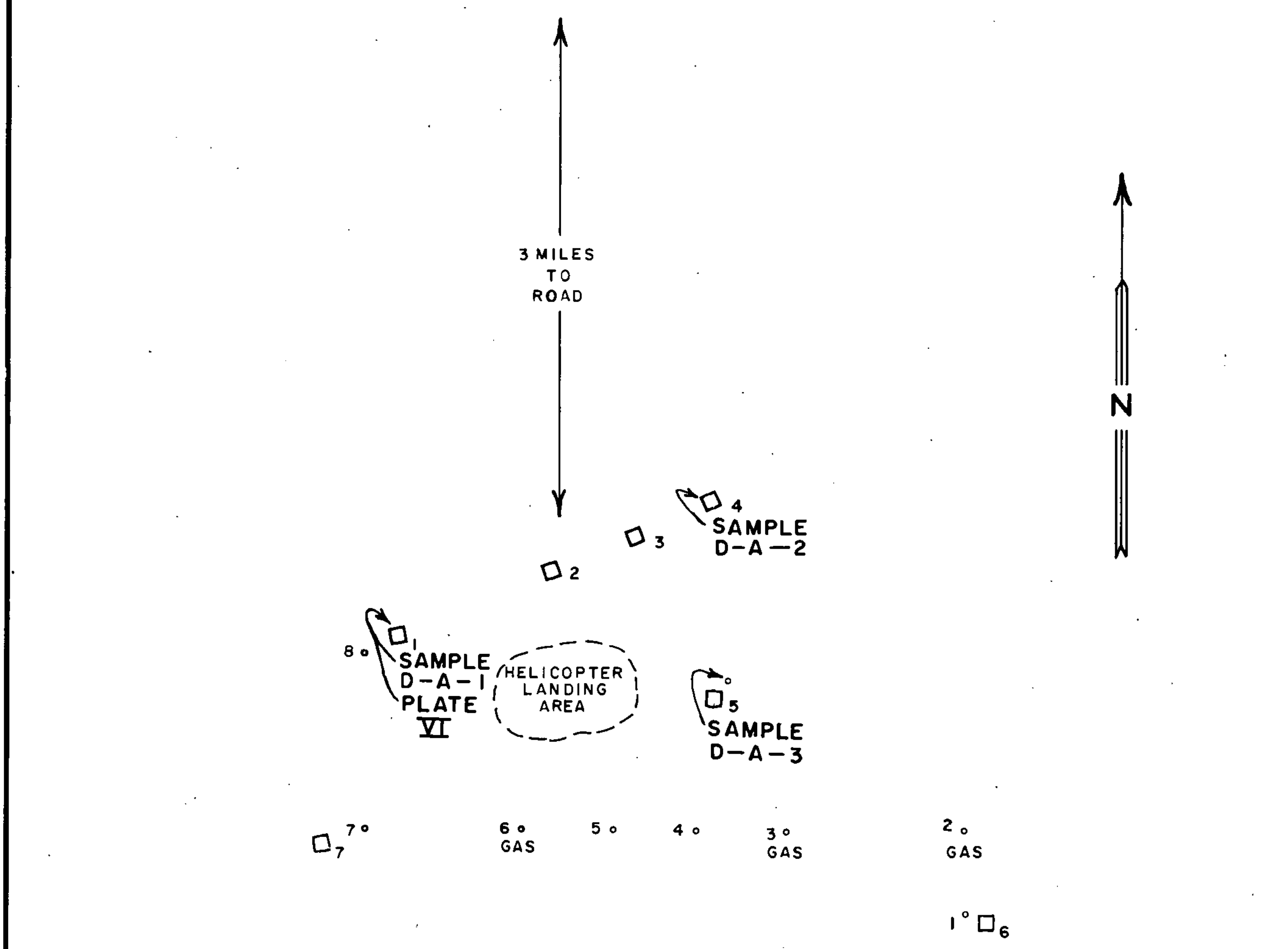
Locality P-1, in the central portion of Area 'P', in Township 100, Range 9, W. 5 M., was very similar, in both shale exposures and the presence of a rusty-orange coloured pool with springs, to locality Q-1, but the springs appeared to have less volume at P-1.

Locality S-1, in the northwestern corner of Township 98, Range 10, W. 5 M., in Area 'S' proved to be of interest. A slump area on the north bank of the Muddy River had a portion anomalously free of snow. Ground observations showed that a muddy area had steam vents with temperatures well in excess of 120°F at a depth of one foot. The slump material consisted mainly of grey shale with incrustations of yellow, orange and white minerals with the yellow being most abundant, often gelatin-like, and in reniform and other globular shapes. There was a strange odour reminiscent of 'sweet pickles'. The warm, steaming area extended about 130 feet in a northwest-southeast direction and approximately 100 feet in the northeast-southwest direction. Three samples were taken: sample D-S-1a was taken from the surface around a steam-vent near the centre of the steaming area, sample D-S-1b was taken at the same location from a depth of five-feet with the auger, and sample D-S-1c was taken from the north corner of the steaming area at a depth of about four feet with the auger. Analyses of samples D-S-1a and D-S-1b showed that they contained only about four percent sulphur. Four photographs of this locality are included in this report as Plates II through V. Unfortunately, it was subsequently learned that this area was already under Sulphur Prospecting Permit to another party.

Ground observations at locality T-1, in the western portion of Area 'T' in Township 104, Range 7, W. 5 M., in Inland Chemicals' Sulphur Prospecting Permit No. 19, disclosed glacial drift containing grey limestone pebbles and boulders. No bedrock was seen anywhere within Area 'T', but there were very few exposures due to snow cover and low river banks. The rapids in the Mikkwa River, in and near Area 'T', were formed by large boulders rather than by limestone ledges. The existence of the outcrop of Devonian limestone, described by McConnell in 1893 and referred to earlier in this section, could be neither proved nor disproved as the result of this field study, but an examination under summer conditions should solve the problem.

On the final day of the helicopter survey, the Madison et al prospect in their Sulphur Prospecting Permit No. 8, Area 'A' on our map, was examined. The whole flat, wooded and marshy locality, then frozen, smelled of hydrogen-sulphide gas. The numerous pits and boreholes were examined, although they were largely filled with snow and debris, such as leaves. Aside from the man-made holes, nothing could be seen but flat snow-covered ground, not even any steam or areas of warm ground. Judging from exposures in the pits, the sulphur appears to be concentrated in lenses in the brown soil zone above a hard-pan of light grey clay. These lenses extended from about one foot beneath the surface to the top of the hard-pan at a depth of about three feet, and nearly pure sulphur appears to coat small clumps of dark brown soil and to be disseminated through the soil. Sulphur is also disseminated through the clay of the hard-pan, and some could be seen coating glacial boulders on the ground surface. It is not known whether these boulders came from the pits. Plate VI illustrates the nature of the sulphur occurrence in the soil zone.

Sample D-A-1 was taken from the side of pit No. 1 (see Figure 3) at a depth of two to three feet with a shovel and subsequently yielded 39 percent sulphur upon analysis. Sample D-A-2 was taken from the clay hard-pan in the bottom of pit No. 4 at a depth of three and one-half feet. It took quite a number of minutes to obtain a very small sample with the auger due to the hardness of this hard-pan. This sample was found to contain about 23 percent sulphur. Sample D-A-3 was taken from the sidewall of a large machine auger hole or bore near pit No. 5 and this wet sample of muddy clay with a strong odour of hydrogen-sulphide gas was obtained from a depth of four feet with the post-hole auger, but yielded less than three percent sulphur upon analysis.



SCALE: 1/2" = 100 FEET

AREA: N 1/2 of Sec. 9-Twp 110-Rge 5 - W.5

FORT VERMILION AREA
NORTH CENTRAL ALBERTA

Detail of Sulphur Show
in
Madison et al Sulphur Prospecting
Permit No. 8 (Area A)

□ PIT UP TO 4 FEET DEEP

° DRILL HOLE

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SUMMARY AND CONCLUSIONS

In this project, the instructions were to evaluate the four Sulphur Prospecting Permits of Inland Chemicals Canada Ltd. on a rapid reconnaissance basis and try to locate additional sulphur prospects in the Fort Vermilion area (as designated in the Introduction of this report) which is almost entirely underlain by Cretaceous strata. No sulphur deposits of apparent commercial value were found. Inland Chemicals' Permits cover, or partially cover, our recommended field check areas 'C', 'M', 'N', 'O', 'Q' and 'T'. Due to the intensively competitive situation existing during November 1967, the field work had to be carried out when probably more than 90 percent of the outcrops were covered by snow.

The reconnaissance was based primarily upon the theory that sulphur deposits in the Cretaceous or uppermost Devonian rocks should be located along fault or fracture zones that would provide an avenue for the ascent of the sulphur from the Middle Devonian sources beneath. During the field investigation, no evidence of any major faulting or fracturing could be seen at the sulphur deposit in Madison et al Permit No. 8, however, this neither proves nor disproves the theory.

The warm areas found in slump at localities C-1 and S-1 could represent oxidation of iron sulphide in the shale causing spontaneous combustion and heating of the surrounding materials and water, such as the situation described by Rutherford (1930) and othersalong the Smoky River (see Bibliography); in such case they would not necessarily indicate the deep-seated fault or fracture zones that were sought.

If sulphur deposits are associated with deep-seated fracturing or faulting in Cretaceous or uppermost Devonian rocks, the methods employed in this present project should help to find such deposits. Stereoscopic examination of air photographs, although more time consuming and rather more expensive, would yield better results than a photomosaic study.

In the rather unlikely event that the sulphur compounds in solution, or sulphur in colloidal form, were carried from the northeast by glacial melt-waters and laid down in glacial outwash, or lacustrine deposits, as could possibly be the case in the Madison et al Permit No. 8, it would be very difficult to find by surface field studies, unless it emitted steam or was subject to spontaneous combustion. A good approach, if such were the case, would be to undertake a detailed regional photogeomorphological study to locate likely glacial outwash and lacustrine deposits followed by aerial reconnaissance of these deposits to look for steam or smoke and then by ground studies. Finally, the more expensive geochemical method, or use of infrared aerial photography, might have to be used to determine the locality to be auger-drilled or core-drilled. This "glacial outwash and lacustrine" theory of origin of sulphur deposits is considered less likely than the "fault and fracture" theory discussed previously or of the "unconformity" theory suggested below.

Field examination of the sulphur deposit in the Madison et al Permit No. 8 and subsequent studies and discussion have engendered the idea that the most prospective deposits may be associated with the unconformity between the Devonian and Cretaceous strata. Sulphur-containing fluids or vapours rising through fractures in the Devonian carbonates, could be trapped along this unconformity by the overlying Cretaceous shales, or glacial or lacustrine clays. That might be the type of sulphur deposit that appears to be present near the unconformity close to the top of the Devonian in the subsurface in the Ankerton (Devil's Elbow) area, about 70 miles southeast of Edmonton, where sulphur was found to be about 100 feet below the unconformable Devonian-Cretaceous contact in two wells. Surface, or near-surface, sulphur deposits of this type should be found only in the vicinity of the surface trace of the Devonian-Cretaceous unconformity. It should be noted that the Madison et al deposit at 'A' is located very close to the surface trace of this unconformity and the best sulphur deposits appear to be near the surface in the soil zone, or in the post-glacial lacustrine deposits rather than in Cretaceous shales.

It is now believed that this theory of the concentration of sulphur at or near the Devonian-Cretaceous unconformity gives the most plausible explanation for the largest reported sulphur deposits that occur in the Fort Vermilion area. If this hypothesis is correct, the present exploration has been centred slightly too far west, where the unconformity is rather deeply buried. To check out this theory of accumulation it is now suggested that a photogeological study should be undertaken along the inferred surface trace of the Devonian-Cretaceous unconformity and for several miles on either side of it, west of Wood Buffalo National Park, the western boundary of which is the Fifth Meridian (or 114° W. longitude,) between Township 104 (about 58° N. latitude) and Township 121 (about 59°30' N. latitude.) A study of the airphotos along the Mikkwa River to see if McConnell's outcrop of Devonian can be found is also suggested. Any prospective locality thus found by the stereoscopic study of the air photographs should be field checked first, by aerial reconnaissance to search for any steam or smoke indicating hot "sulphur springs" or spontaneous combustion of sulphur or associated compounds and then by ground studies. Depending on the results obtained by the air and ground studies, it might be further desirable to use geochemical methods or infrared photography to determine the localities to be explored in detail by augering or core drilling. Infrared photography would be one of the best ways to find warm areas possibly indicating spontaneous combustion of sulphur or areas with hot "sulphur springs", but would be expensive since it is not available and would have to be specially flown. It should be emphasized that the sulphur prospects of the region are not confined to areas of active "heat phenomena" so that areas lacking such phenomena still require ground checking.

If the program described above should uncover significant quantities of sulphur, it might then be worthwhile to initiate a deeper drilling program in selected areas of Cretaceous outcrop, including some of the Company's present Permits, so as to search for large deposits of the Ankerton (Devil's Elbow) type near the Devonian-Cretaceous unconformity where it is at moderate depth. Such a drilling program should be immediately preceded by a detailed study of the then available information from the wells in the adjacent area, which should further define the position of the unconformity and might permit drilling to be concentrated in areas where the Devonian sub-crop is formed of porous carbonates or other rocks which might have provided a suitable environment for large-scale sulphur deposition.

The land situation for Sulphur Prospecting Permits is becoming very tight in this portion of Alberta, so it is recommended that any available land near the surface trace of the Devonian-Cretaceous unconformity be taken under Permit at once. These holdings, and others, could then be explored as described above and consideration could be given to securing other areas of high sulphur potential, where it is feasible to enter into reasonable farmout agreements.

In conclusion, the field study of the Fort Vermilion area conducted in November 1967 did not yield any direct evidence of previously unreported sulphur deposits, but the knowledge gained from this study could be used advantageously in further prospecting for sulphur in this region of intense interest and activity. It is now believed that commerical deposits of sulphur in north-central Alberta are most likely to be found along, or near, the Devonian-Cretaceous unconformity and that future exploration should be concentrated in the vicinity of this unconformity. Due to the relatively low cost of evaluation in areas where the trace of this unconformity intersects the surface, it appears to be worthwhile to concentrate attention on such areas first. Later, however, more costly efforts to evaluate areas where the unconformity is buried by appreciable thicknesses of younger deposits may be justified. Due to the economics of Frasch production with simultaneous purification of sulphur, a sizable buried deposit with suitable conditions of permeability might eventually turn out to be of more long-term value than the more easily evaluated surface deposits which may present benefication problems. It is still considered possible that some commercial deposits of sulphur may be concentrated along fault or fracture zones higher up-section in the Cretaceous strata so that at least one Sulphur Prospecting Permit should be retained in the Wabasca River area. The theory that commercial amounts of sulphur may have been deposited by glacial melt-waters is considered the least plausible of the three proposed above, and should not influence further exploration unless new factors come to light.

Finally, it should be pointed out that the present report is essentially based on the local field observations and related ideas of Mr. C.W. Drew, Jr., who has not had access to certain information regarding north-central Alberta sulphur exploration which has been accumulated in our files on behalf of other clients. Likewise, the specific field and other information accumulated by Mr. Drew on behalf of Inland Chemicals Canada Ltd. has not been made available to other clients. Mr. Drew has had the opportunity to discuss the general principals of sulphur occurrence and exploration with other senior geologists of the firm, who have also given their editorial advice, but such advice has been necessarily limited in scope so as not to use restricted information.

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[redacted]

C.W. Drew, Jr., P. Geol.

[redacted]

Gordon H. Jones, P. Geol.

1009 Fourth Avenue S.W.,
Calgary, Alberta.
January 11, 1967.
GHJ/CWD/ldl

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MAPS

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PLATE I Locality I-1

View north-northeast across Caribou River to stream-cut exposing very dark grey Cretaceous shale with abundant staining and some encrustations of yellow minerals overlain by lighter coloured glacial drift and soil.

PLATE II Locality S-1

View from helicopter looking north over locality S-1 which is the white oval-shaped slump area on the north bank of the Muddy River near the centre of the photo. The snow-free area does not show up well in this picture.

PLATE III Locality S-1

View north across the Muddy River to locality S-1 which is the snow-free area extending from behind the rotor blade almost to the tail rotor of the Bell G3-Bl Helicopter. Pilot R. Phillips shown by his machine was usually able to land this close to the area of interest.

PLATE IV Locality S-1

View east-southeast over the central portion of the steaming ground. Careful examination will show some steam rising around the post-hole auger just above the left of the centre of the photo. With mild and dry air at about 30°F the steam does not show up well.

PLATE V Locality S-1

View north-northwest showing W. Drew at work with the post-hole auger which is in the same location as in Plate IV. The predominantly yellow mineralization shows as light grey upon darker clay and shale across lower and right portions of the picture. The white patches are snow.

PLATE VI Locality A

View into the east side of Pit No. 1 in Madison et al Permit No. 8 showing light coloured sulphur lens with dark brown soil above and to its left. A small portion of the light grey clay hard-pan can be seen at bottom centre just above the lip of snow on the near edge of the pit. The clay appears slightly darker than the overlying sulphur. Sample D-A-1 was taken from the sulphur lens.

RESULTS OF LABORATORY ANALYSES OF SELECTED SAMPLES

Analyzed by Core Laboratories-Canada Ltd., Calgary, Alberta

Sample Number	Sulphur Content %	Ash Content %	Moisture Content %
Solid Samples			
D-A-1	38.93	61.79	0.97
D-A-2	22.63	43.22	1.50
D-A-3	2.58	3.44	0.72
D-C-1d	2.46	8.03	2.88
D-C-1e	2.90	11.76	1.27
D-I-1	5.69	21.43	1.15
D-I-1 (high-grade)	5.84	22.10	3.19
D-M-1b	0.98	6.25	1.36
D-S-1a	3.48	14.18	1.22
D-S-1b	4.38	75.25	4.13
Liquid Sample			
D-Q-1	0.048 (47.71 ppm)	---	---

Abbreviated Summary of the Report Entitled

"PHOTOMOSAIC AND FIELD RECONNAISSANCE STUDY"

"SELECTED SULPHUR PROSPECTING PERMITS"

"FORT VERMILION AREA, ALBERTA"

(Dated January 11, 1968)

Summary of the Sulphur Prospects

1. Inland Chemicals Canada Ltd. benefically owns Sulphur Prospecting Permit Nos. 19, 25, 26 and 27 covering a total of 98,499 acres, located within the region of north-central Alberta, which is currently under most active exploration and within which several shows of considerable interest have been reported. Serious interest of the sulphur, mining, petroleum and natural gas industries in the region, in which the subject Permits are located, is clearly demonstrated by the fact that more than 75 Sulphur Prospecting Permits covering well over 3,100,000 acres had been issued by January 5, 1968. The majority of such Permits granted and applied for have been on behalf of very large national and international corporations including some of the principal sulphur producers and users. No definite commercial bodies of sulphur have yet been proven, but one of the reported deposits is of considerable size and several show high sulphur values.

2. Inland Chemicals' Permits are located in a general zone of similar geological characteristics stretching across the main region of present sulphur prospecting activity in which several sulphur shows have been reported. These Permits are located near the unconformity separating the Cretaceous and Devonian strata and the Devonian rocks are located near the surface or are buried at depths of less than 1,000 feet on all four Inland Chemicals' Permits. The principal previously discovered sulphur shows appear to be associated with the Devonian-Cretaceous unconformity. Certain features of each of the four Sulphur Prospecting Permit areas are summarized as follows:

a) Sulphur Prospecting Permit No. 19 is located on the Mikkwa River where Devonian rocks are reported to outcrop on the crest of an anticline surrounded by Cretaceous and Quaternary deposits.

b) Sulphur Prospecting Permit No. 25 is located immediately northwest of the surface trace of the unconformity. There is evidence of combustion and related phenomena on this Permit, but the relationships of such phenomena to sulphur deposits are not yet known. Sulphur Prospecting Permit No. 25 is located some one to two Townships north of the Madison et al Sulphur Prospecting Permit No. 8, which contains the substantial sulphur show on the basis of which sulphur prospecting activity in north-central Alberta was initiated.

c) Sulphur Prospecting Permit Nos. 26 and 27 are located along the Wabasca River on either side of an area in which some sulphur shows are reported. Both of the above Permits have geological conditions very similar to those in the intermediate area.

3. At the present early stage of exploration, hampered by the presence of snow cover and preceding a drilling program, these regional factors are considered to be of much more significance than the relatively sparse local information on the Permits themselves.

4. On the basis of our present knowledge, we would not expect major concentrations of sulphur on Sulphur Prospecting Permit Nos. 26 and 27 and on most parts of Sulphur Prospecting Permit No. 25 to be at the surface, but rather in the subsurface near the Cretaceous-Devonian unconformity at depths of 100 to 1,000 feet, but generally less than 700 feet. Under suitable conditions of burial, such deposits should be amenable to development by the Frasch process should commercial quantities of sulphur be found. There are greater prospects of encountering appreciable surface or near-surface sulphur deposits on Sulphur Prospecting Permit No. 19 and in the southeasterly portions of Sulphur Prospecting Permit No. 25.

5. A new all-weather road leads into the northern end of Sulphur Prospecting Permit No. 27, and Sulphur Prospecting Permit Nos. 19, 25 and 26 are all within 20 miles of all-weather roads. All Permits are within limited distance of a major highway, a railroad, and a scheduled airline airport. If commerical deposits of sulphur are located, transportation should therefore not constitute a major problem.

6. The area is surrounded by some of the most prolific fuel sources in Canada, including Rainbow, North Zama and Red Earth oil fields, as well as sources of natural gas and the Athabasca Oil Sands development, so that low cost fuel should be readily available.

7. The future price and market position for any sulphur produced appears to be excellent in view of the continuing world shortage of this mineral and the increasing demand for its use.

8. Evaluation of the subject Sulphur Prospecting Permits should be carried out in several stages with the continuation and the intensity of any given stage to be commensurate with the results obtained during the previous stages. We would recommend the following steps:

a) A stereoscopic study of the aerial photographs to provide background knowledge of the structure and surface features on which to base planning of a pattern of test-hole drilling.
Estimated cost -- $2,750

b) A brief field examination under snow-free conditions to provide further background for planning a test-hole program.
Estimated cost -- $3,000 to $4,000

c) Geochemical studies on the surface to detect indications of buried sulphur.
Estimated cost -- $1,000 to $3,000

d) A test-hole program, principally on Sulphur Prospecting Permit No. 19 and portions of Sulphur Prospecting Permit No. 25, with a portable power-auger or ultra-light drill. Extent of program to depend upon initial results.
Estimated cost -- $10,000 to $20,000

e) A core-hole program for objectives beyond the reach of the above-mentioned drilling, only if previous results on subject Permits and the region as a whole justify this more costly step.
Estimated cost -- $40,000 upward.

Finally, it should again be emphasized that plans and budgets for each new step of the evaluation program should be adapted in the light of the results of the preceding stages. The more expensive later stages need only be undertaken if earlier results offer tangible encouragement.

This abbreviated summary has been prepared for the exclusive use of Inland Chemicals Canada Ltd., the holder of the subject Sulphur Prospecting Permits, and it is not to be reproduced in whole or in part in any form without the written permission of J.C. Sproule and Associates Ltd.

[redacted]

Gordon H. Jones, P. Geol.

1009 Fourth Avenue S.W.,
Calgary, Alberta.
January 15, 1968.
GHJ/ldl

CERTIFICATE

I, Gordon Harris Jones, consulting geologist, of [redacted], Calgary, Alberta, do declare:

1. That I graduated as a geologist from the University of Birmingham, England, with the degree of Bachelor of Science (Honours) in the year 1948; I obtained the degree of Doctor of Philosophy in Geology from the same university in the year 1955, and that I have practised my profession as a Geologist over the past twenty years.

2. That I am a Fellow of the Geological Society of London, a Member of the Alberta Society of Petroleum Geologists, the Arctic Institute of North America, the American Polar Society, and the American Geographical Society, and that I am a registered Professional Geologist of the Association of Professional Engineers of Alberta.

3. That I have no interest, direct or indirect, nor do I expect to receive any interest, direct or indirect, in the properties described in the attached report entitled "Photomosaic and Field Reconnaissance Study, Selected Sulphur Prospecting Permits, Fort Vermilion Area, Alberta," dated January 11, 1968 which report is further summarized in an addendum "Abbreviated Summary" dated January 15, 1968, nor have I any interest, present or expected, in the securities of the Company for whom this report is prepared.

4. The above report is based on my geological knowledge of the areas described above, and that of my Associates in the firm of J.C. Sproule and Associates Ltd., Calgary, Alberta, and upon a consideration of available data on wells drilled in adjacent areas as well as field and other pertinent data. I have not personally been on the properties described. The report sets forth sources of reference and the results of the field examination made by Mr. C.W. Drew, Jr.

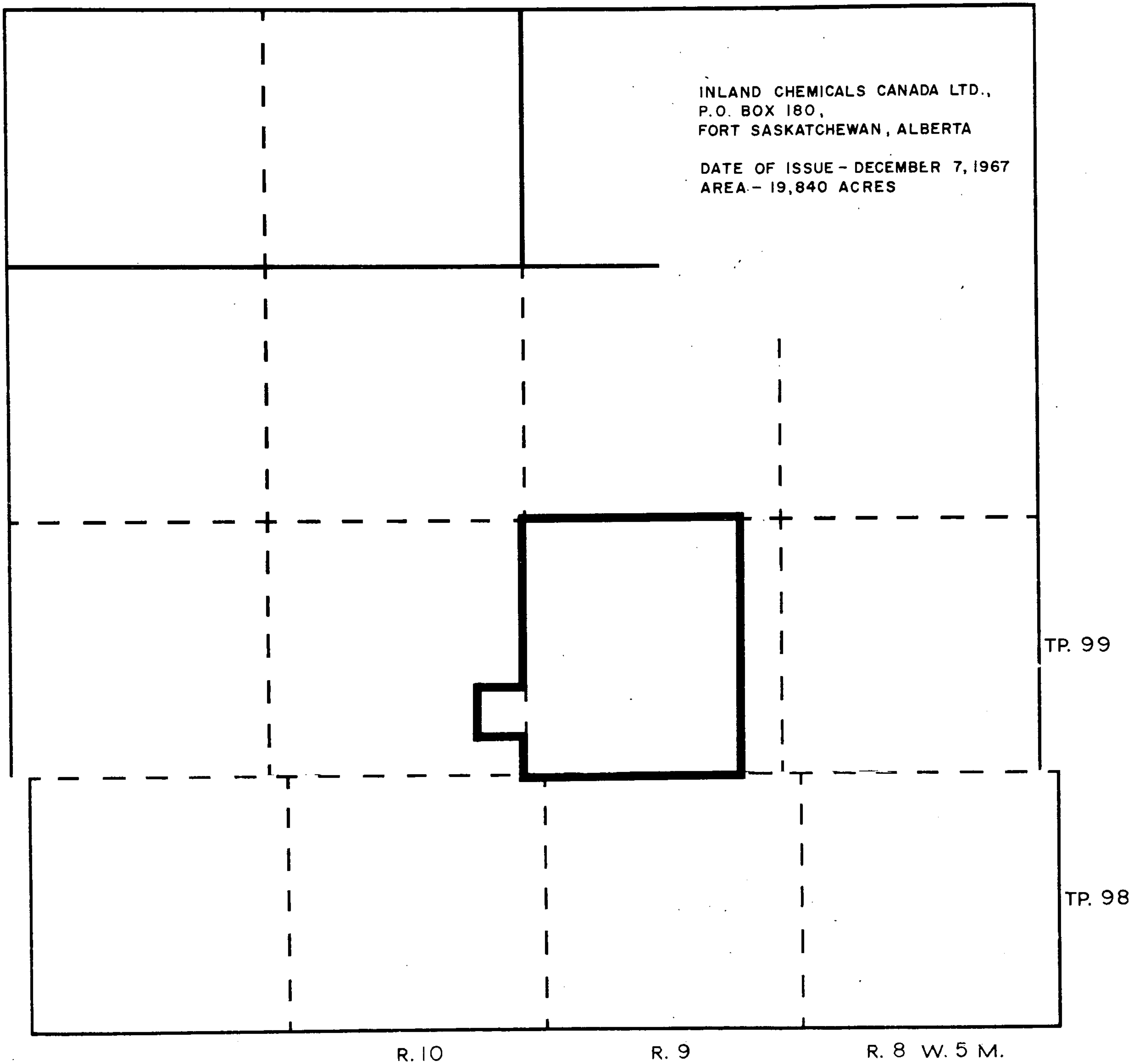
[redacted]

Gordon H. Jones, P. Geol.

[redacted],
Calgary, Alberta.
January 15, 1968.

19670009

SULPHUR PROSPECTING PERMIT NO. 26



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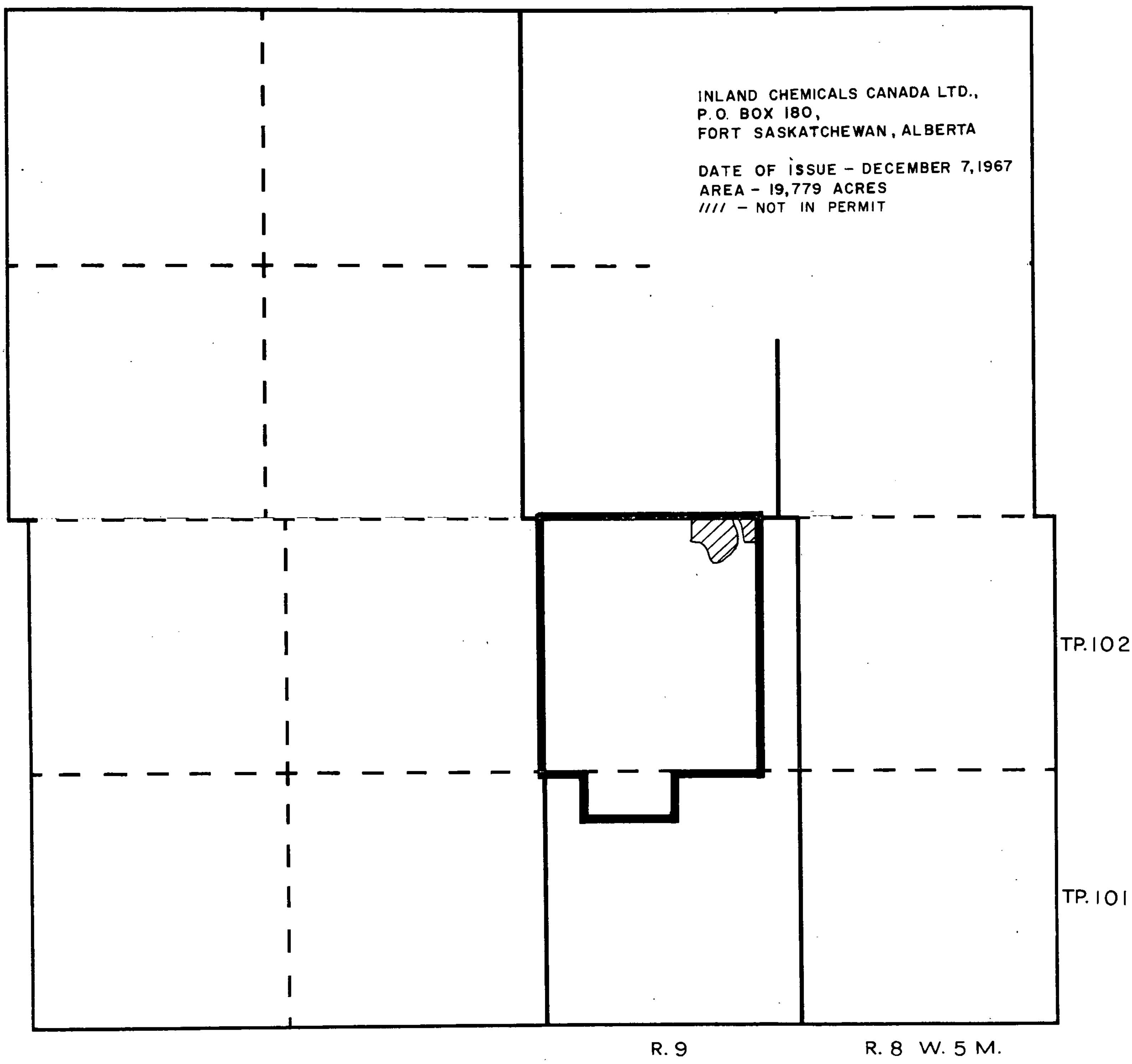
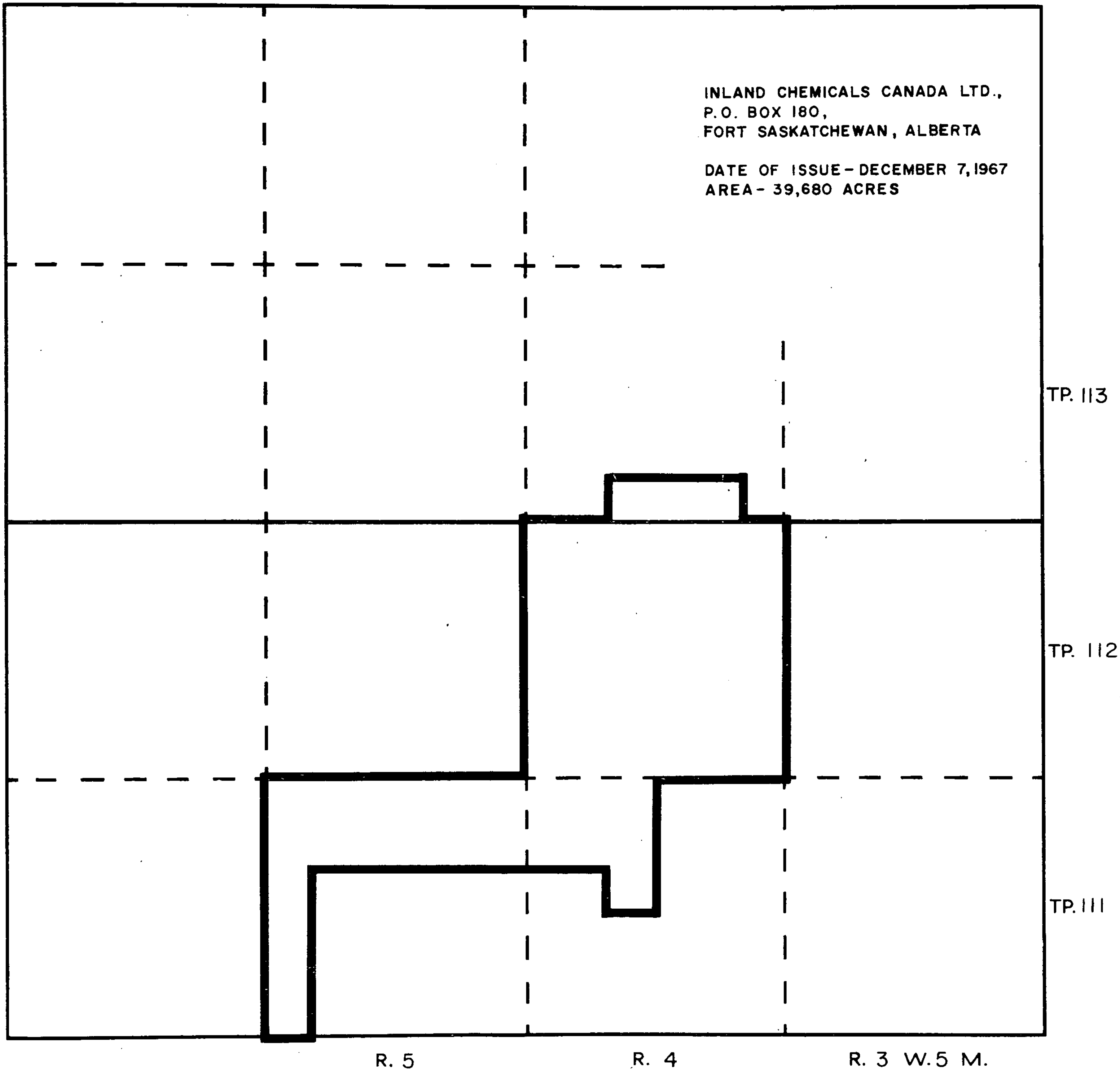
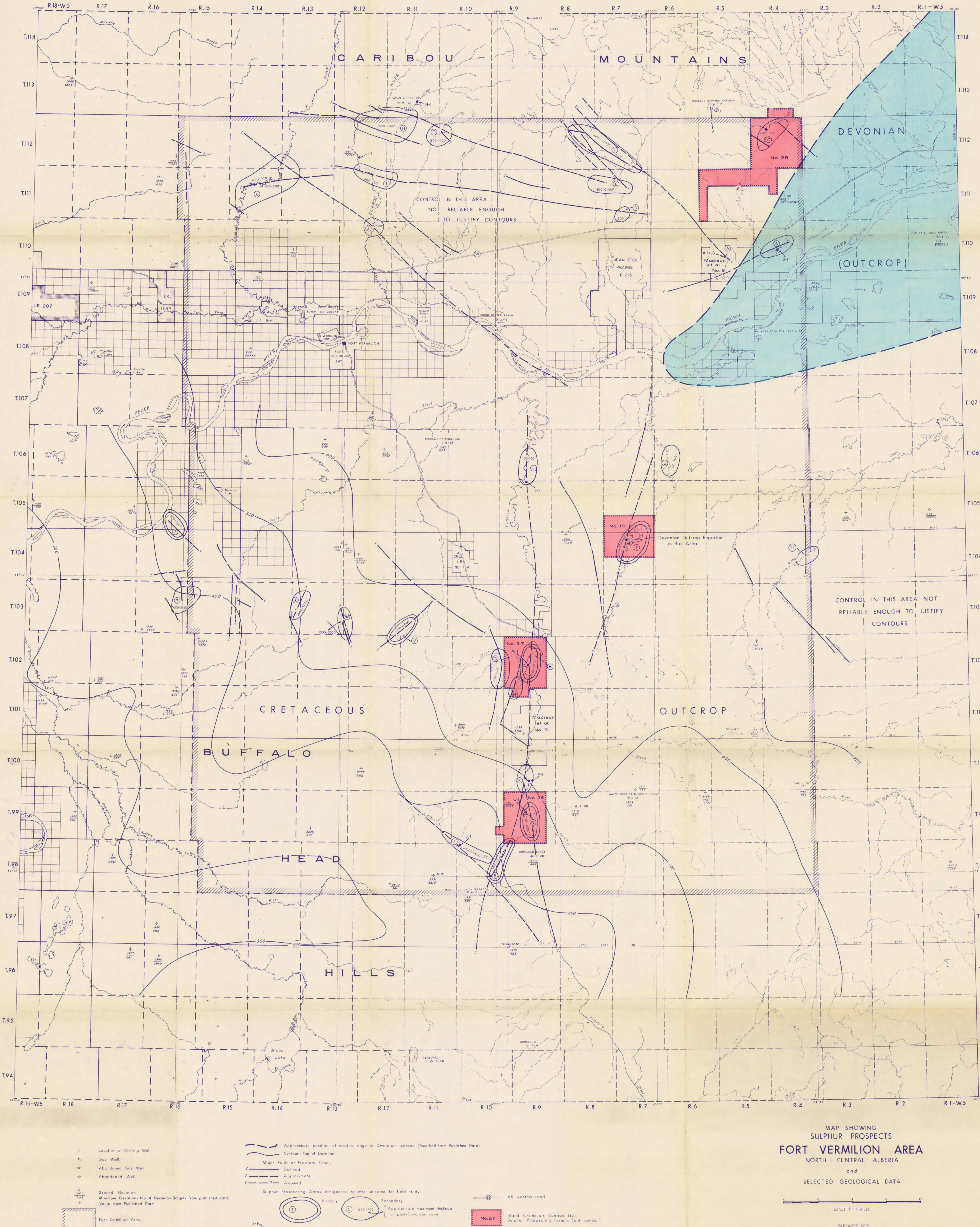
SULPHUR PROSPECTING PERMIT NO. 27



SULPHUR PROSPECTING PERMIT NO. 25





MAP SHOWING
SULPHUR PROSPECTS

FORT VERMILION AREA

NORTH – CENTRAL ALBERTA

and

SELECTED GEOLOGICAL DATA

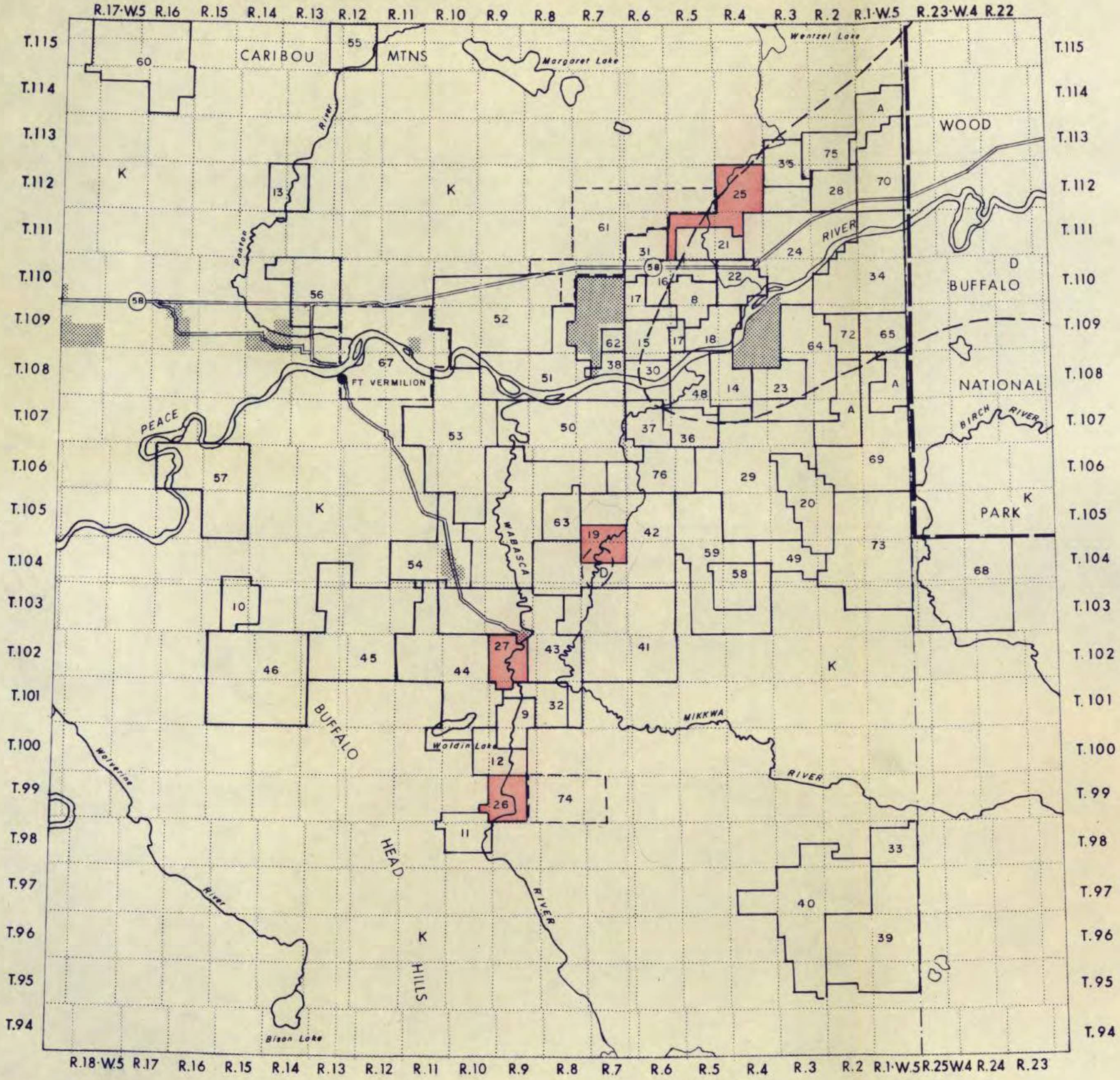
SCALE: 1" = 4 MILES

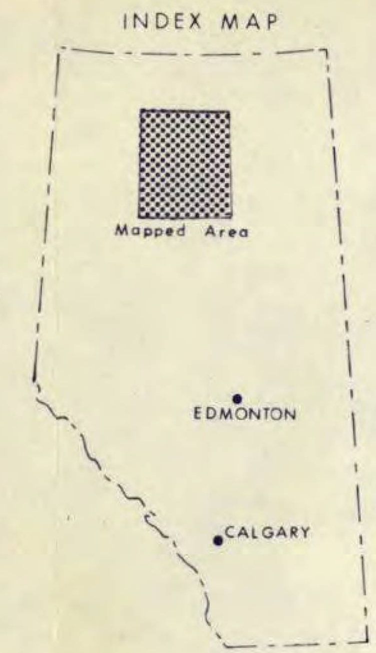
PREPARED FOR
INLAND CHEMICALS CANADA LTD.
DECEMBER 1967

Wells Revised to Dec. 18, 1967

J. C. SPROULE AND ASSOCIATES LTD., CALGARY

A670009





K Cretaceous Formations

D Devonian Formations

Approximate Position of Eroded Edge of Devonian Outcrop

8 Sulphur Prospecting Permit (Approx as of Jan. 5, 1968)

74 Assumed Boundary of Sulphur Prospecting Permit

A Permit Applied For

27 Inland Chemicals Canada Ltd. Sulphur Prospecting Permit

Indian Reserve

SULPHUR PROSPECTING PERMITS
IN
NORTH-CENTRAL ALBERTA

PREPARED FOR

INLAND CHEMICALS CANADA LTD.

JANUARY 1968

16 0 16 32

SCALE: 1" = 16 MILES