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GEOLOGIC FIELD WORK and DRILLING PROGRAM

to

EVALUATE SURFICIAL SULPHUR DEPOSITS

FORT VERMILION AREA, ALBERTA

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1968

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INTRODUCTION

Geologic field work and the drilling of a number of shallow auger holes in the Fort Vermilion area of Alberta has been undertaken in an attempt to evaluate reports of a discovery of elemental sulphur at or near the surface. Reports of such a discovery began circulating in western Canada during the late summer of 1967. As outlined in our earlier report (Smith,1968) the location of the discovery was initially unknown. However, as more information became available, the area of interest appeared to center about the Fort Vermilion region of north-central Alberta. At the end of 1967 approximately 60 Sulphur Prospecting Permits had been issued in the Fort Vermilion area. The stampede continued and by May some 192 permits had been issued covering more than 6,500,000 acres.

Little hard factual information on the reported discovery of sulphur has been released to the public. Much of the information has been derived through rumours and innuendo. However, it has been established that Bow Valley Industries Ltd. acquired an option on Sulphur Prospecting Permits 8, 9 and 10 from J. J. O'Connor of Calgary. Permit No. 8 is often referred to as the "discovery permit". Published reports and descriptions of exploratory work on Permits 8, 9 and 10, in some cases based on information released by the operators, have appeared periodically in Oilweek, Nickle's Daily Oil Bulletin and the Northern Miner. A review of this information suggests that native sulphur occurs at or near the surface at several localities on Permit 8 and appears to be associated with flat-lying beds. Several pits and 200 auger holes drilled to a depth of 9 feet have outlined a sulphur deposit over an area measuring 1,400 feet by 1,400 feet and closing off only one side of the deposit. The thickness of the deposit has not yet been established. Assay results have indicated a sulphur content ranging up to 90%. However, high grade areas appear small and may not be economically feasible for exploitation under present production techniques.

Elsewhere in the Fort Vermilion area the presence of sulphur at or near the surface has been known for sometime. The Indians were probably the first to have been aware of the presence of sulphur associated with a great number of gassy, salty, cool water springs that are known at several localities along Lambert and Harper Creeks in Tps. 105 and 106, R.3 W5. Moreover, sulphur occurrences at other localities in the Fort Vermilion area are indicated where Cretaceous strata are interpreted to form bedrock.

Accordingly, geologic field investigations and a drilling program were undertaken in the early summer of 1968 to investigate the reported occurrences of surficial sulphur and to evaluate several Sulphur Prospecting Permits in the area east and generally south-east of Fort Vermilion. The V. Zay Smith Associates Ltd. field party was equipped with light-weight, portable augers for the drilling of shallow bore holes. Transportation was provided by a 3-place helicopter capable of carrying the portable drills.

Three areal geology and structural interpretation maps of the Fort Vermilion area at the scale of 1 inch to 2 miles accompany this report. Two of these illustrations were initially prepared in part to accompany the preliminary investigations undertaken earlier this year (Smith, 1968). However, they have been revised and they show geology from a variety of sources including surface areal geology, subsurface structure on the top of the Paleozoic succession, field observations and the locations of the auger holes drilled during the field investigations.

A number of samples from bore hole cuttings and outcrops was analyzed for sulphur content. Also a water sample from the Lambert Creek springs was analyzed. Five samples were studied for palynological age determination. The results of these analyses are shown in the accompanying Appendix.

Purpose of the Field Work and Drilling

The geologic field investigations and drilling program described in this report were undertaken with two main objectives. The first of these is an investigation of the regional and local geological setting of some known and reported surficial sulphur occurrences in the Fort Vermilion area. These included the reported discovery on Sulphur Prospecting Permit No. 8 and also sulphur occurrences associated with sulphurous water springs on Harper and Lambert Creeks. In conjunction with a preliminary investigation completed earlier this year (Smith, 1968), the drilling program and field investigations were intended to provide leads to the possible location of other deposits and to co-ordinate geologic data from a variety of sources (surface, subsurface, published and unpublished reports and field observations). Moreover, the field investigations were intended to investigate several concepts dealing with the origin of the deposits.

The second main objective of the field effort included the examination and sampling of any rock exposures, surficial deposits, seeps, springs and other surface anomalies on the lands of some participating permit holders. An average of three or four auger holes were drilled on each permit with light-weight portable drilling equipment to an average depth of 4 to 5 feet.

Field Work and Drilling Equipment

Field geology and the drilling of a number of shallow bore holes was undertaken in May and June of 1968 by a V. Zay Smith Associates Ltd. field party consisting of two geologists and supporting personnel. Work was done from Fort Vermilion with transportation being provided by a Bell helicopter chartered from Associated Helicopters, Edmonton. J. F. Conrad served as party chief.

Two types of light-weight, portable, power augers were used to drill bore holes at several localities in the map area. Both drills were transported by helicopter. The heavier and more powerful of the these drills, the Winkie drill (see Color Plate 7), was used to drill three holes to depths of 14 to 27 feet. The lighter weight and more portable drill, the Haynes drill (see Color Plate 8), was used to drill 65 bore holes ranging in depth from 3 to 9 feet. The average depth being between 4 and 5 feet. The locations of bore holes drilled with the Haynes and Winkie drills are indicated on the accompanying areal geology and structural interpretation maps.

Location and Accessibility

The Fort Vermilion area is located in north-central Alberta about 250 miles north of Edmonton. The area is reasonably accessible. An all-weather gravel road extends from the Mackenzie Highway at High Level east to the settlement of Fort Vermilion on the Peace River. An eastern extension of this road is under construction through Wood Buffalo Park to Fort Smith in the Northwest Territories. Scheduled commercial airline service is available for Fort Vermilion from Peace River by way of High Level each day. Access to remote areas in the summertime is best provided by helicopter.

REGIONAL GEOLOGIC SETTING

Physiography

The Fort Vermilion area forms part of the Interior Plains of northern Alberta and has been subjected to multiple continental glaciation. The landscape consists of two main types. These are a low-lying plain or broad valley in which the Peace River flows and a series of plateaus which rise abruptly above the plains. The plateaus are termed the Caribou Mountains in the north, the Birch Mountains to the southeast and the Buffalo Head Hills to the south-west.

Elevations in the gently rolling plain range from about 775 feet along Peace River to more than 2,000 feet along the higher portions of the plateaus. However, much of the land surface stands at elevations ranging from 800 to 1,500 feet and is remarkably flat and featureless. Peace River, the dominant drainage of the area, follows a pre-glacial valley and at places has cut through the veneer of glacial drift. The plain is characterized by numerous swamps, muskegs, bogs and abundant trees. Bedrock exposures are rare due to cover by extensive glacial deposits.

The plateaus rise abruptly above the plain. Crestal elevations on the order of 3,100 feet occur in the Caribou Mountains, 2,500 feet in the Birch Mountains and 2,800 feet in the Buffalo Head Hills. Although the plateaus appear well drained, muskeg is common.

Thus, the landscape of the Fort Vermilion area is made up of a simple plains surmounted by erosional remnants of flat-lying Cretaceous beds. The area had reached the mature stage in the erosional cycle before being subjected to multiple continental glaciation in Pleistocene time. Ice appears to have advanced in a general southwesterly direction. Glacial lakes developed during deglaciation probably as a result of ice damming. The glacial lakes lapped against the lower flanks of the plateaus.

Stratigraphy

Consolidated sediments in the Fort Vermilion area consist of Devonian clastics, carbonates and evaporites. This assemblage is overlain unconformably by Cretaceous shales and sandstones. The Devonian section ranges in thickness from about 3,500 feet in the southwest to some 2,200 feet in the northeast. Much of this thinning is due to truncation on the sub-Cretaceous unconformity. The rate of truncation is about 15 to 20 feet per mile. Cretaceous rocks attain a thickness of about 2,200 feet in the Caribou Mountains and Buffalo Head Hills.

A detailed discussion of stratigraphy is beyond the scope of this report. Several accounts are available in the literature (see Selected Bibliography). The basal unit of the stratigraphic section rests on Precambrian rock and is composed mainly of thick deposits of anhydrite and salt with some important clastics and marine carbonates. The succession is Middle and/or Lower Devonian in age. It has been separated into the following units: the "redbeds" and the Chinchaga, Keg River, Muskeg, Watt Mountain and Slave Point Formations. The overlying unit is a marine fine-clastic succession of Upper Devonian age. It consists of green calcareous shale. It is succeeded by a third subdivision which is also Upper Devonian in age. This unit is dominantly carbonate, made up of the limestones and dolomites of the Mikkwa and overlying Grosmont Formations. The Grosmont Formation is reefoid and probably biostromal in places. The Mikkwa and Grosmont Formations are exposed on the shores of Peace River at Vermilion Rapids and Vermilion Falls. The Mikkwa limestones are also exposed along Harper Creek in Tp. 106, R. 2 W5M. The fourth subdivision of the stratigraphic succession is made of shales and sandstones of Cretaceous age.

Exposures of the Mikkwa and Grosmont Formations were examined on the south shore of the Peace River from Vermilion Rapids downstream to the settlement of Little Red River (field stations 13C to 15C). The lower limestone member of the Mikkwa Formation exposed there consists of some 30 feet of limestones, gray, partly argillaceous, locally dolomitic and aphanitic. The beds contain bulbous stromatoporoids up to 12 inches in diameter and colonial corals including Cladopora (?). The overlying upper limestone member of the Mikkwa Formation is about 55 feet thick and is made up of limestone, brownish-grey with purplish-red mottling, nodular and thin-bedded to locally massive with abundant colonial corals and brachiopods including Alveolites and Atrypa.

Approximately 60 feet of dolomites of the Grosmont Formation are exposed along the Peace River above and below Vermilion Rapids. The beds are characterized by vuggy, petroliferous, finely-crystalline dolomites with poorly preserved stromatoporoids, colonial corals and brachiopods.

The lower limestone member of the Mikkwa Formation and underlying shales were also examined at exposures along Harper Creek in Tp. 106, R.2, W5M (field stations 7C and 8C). Approximately 25 feet of Mikkwa limestones are exposed there. The beds are medium brownish-grey, biogenic, thin-bedded and hackly weathering, 80% of the rock is made up of colonial corals, brachiopods and solitary corals. The underlying shales (map unit Ds) are dark reddish-brown, slightly silty and calcareous, soft and mottled black.

Exposures of Cretaceous rocks were examined at several localities along the northeast flank of the Buffalo Head Hills. The beds form part of the Spirit River (Loon River, Clearwater) Formation and are characterized by a lower shale and an upper sandy unit. The upper sandstone forms the caprock of the Buffalo Head Hills. The sandy beds are about 40 feet thick and are yellowish-brown, medium and fine-grained, cross-bedded, porous, silty and locally contain concretions. About 1,000 feet of the underlying shales are discontinuously exposed down to the channel of Wabasca River. They are made up of black and dark-grey shales which weather to a distinctive pale grey and are soft, flaky and generally non-calcareous. The shales are locally sulphurous (1 to 30%) and contain some thin sandstone beds. Sulphur occurrences in the shales are discussed elsewhere in this report.

Some 60 wells have been drilled for oil and/or gas within the map area. All of them have been dry and abandoned. Thus, the density of drilling is about 1 well for every 4-1/2 townships. Drillstem test reports indicated that Middle Devonian carbonates have yielded significant amounts of salt water which is occasionally gas cut or oil-flecked and rarely sulphurous. Drillstem tests of the Upper Devonian carbonates, the Mikkwa and Grosmont Formations and correlatives, indicate that porosity is abundant. Loss of circulation has been reported. Recovery of significant amount of salt water, which is commonly sulphurous and occasionally gassy has been reported. Moreover, the Geological Survey of Canada reports vuggy porosity in the Grosmont Formation at exposures near Vermilion Chutes and also the presence of the tar-like bitumen in vugs. The Cretaceous section has been drill-stem tested in a few wells and has yielded small amount of gas.

Structure

The Fort Vermilion area lies in the Interior Plains structural province where beds are generally undisturbed. The regional strike of Paleozoic strata is to the north-northwest. They dip to the southwest at 20 to 25 feet per mile. The overlying Cretaceous beds dip very gently to the southwest at rates from 5 to 10 feet per mile. High-angle faults are anticipated in the sedimentary section and are probably related to basement trends. Other structures probably include gentle tectonic features, compaction folds over reefs or irregularities on unconformities and solution collapse phenomena. Some apparently erratic dips have been reported in the vicinity of Vermilion Chutes. Dips as high as 8° and some gentle folds are reported and are indicated on the accompanying areal geology maps. However, field observations suggest that these structures are local features superimposed on the gentle, regional, southwest dip.

Several distinctive alignments were observed on air photographs during the evaluation. They are indicated on the accompanying maps by heavy lines labelled DA. They are marked by straight stream segments and topographic, vegetational and/or tonal alignments. They may indicate faults or fractures. Two dominant trends are apparent: northwest and northeast. Two long persistent alignment trends suggest the possibility of basement faults extending from Tp. 101, R.1 W5 southwest to Tp. 98, R9 W5.

The present structural configuration of the upper surface of Paleozoic rocks is indicated on the area geology maps by means of structural contours. The mapping is based on subsurface data afforded by wells and topographic elevations of known outcrops such as in the Vermilion Chutes area and along Harper Creek.

The structural contours show that the Paleozoic surface dips southwest gently at about 10 feet per mile. Local variations in the rate of dip are indicated by well control. Although these could be attributed to local structures such as folds or faults, they are believed to be due to topographic relief on the sub-Cretaceous unconformity. Evidence exists to suggest a gentle cuesta was developed on the erosional surface extending from the vicinity of Tp. 96, R.6, W5 northwest to the settlement of Fort Vermilion in Tp. 108, R. 12, W5. Another erosional high can be interpreted to have extended from about Tp. 103, R.2 W5. northwest through the Vermilion Chutes area toward Margaret Lake in Tp. 114, R. 8, W5. This erosional feature appears to have been upheld by resistant limestones and dolomites of the Mikkwa and Lower Grosmont Formations which overlie the recessive green calcareous shale unit.

Exposures of Upper Devonian rocks are reported along Mikkwa River in Tp. 104, R. 7, W5 (GSC Map 1161A and Norris, 1963, Figure 3). According to Norris these outcrops were not examined during recent surveys and their identification is based on investigations carried out more than 75 years ago by McConnell (1893). Stream-cut exposures of yellow-brown weathering river gravels were observed along Mikkwa River during the 1968 field investigations. No exposures of bedrock were seen. It is believed that any bedrock exposed in this area is probably Cretaceous in age. However, if Devonian beds are exposed, an anomalous structural condition exists. Regional considerations suggest that Paleozoic beds should be buried at a depth of 250 feet at this locality.

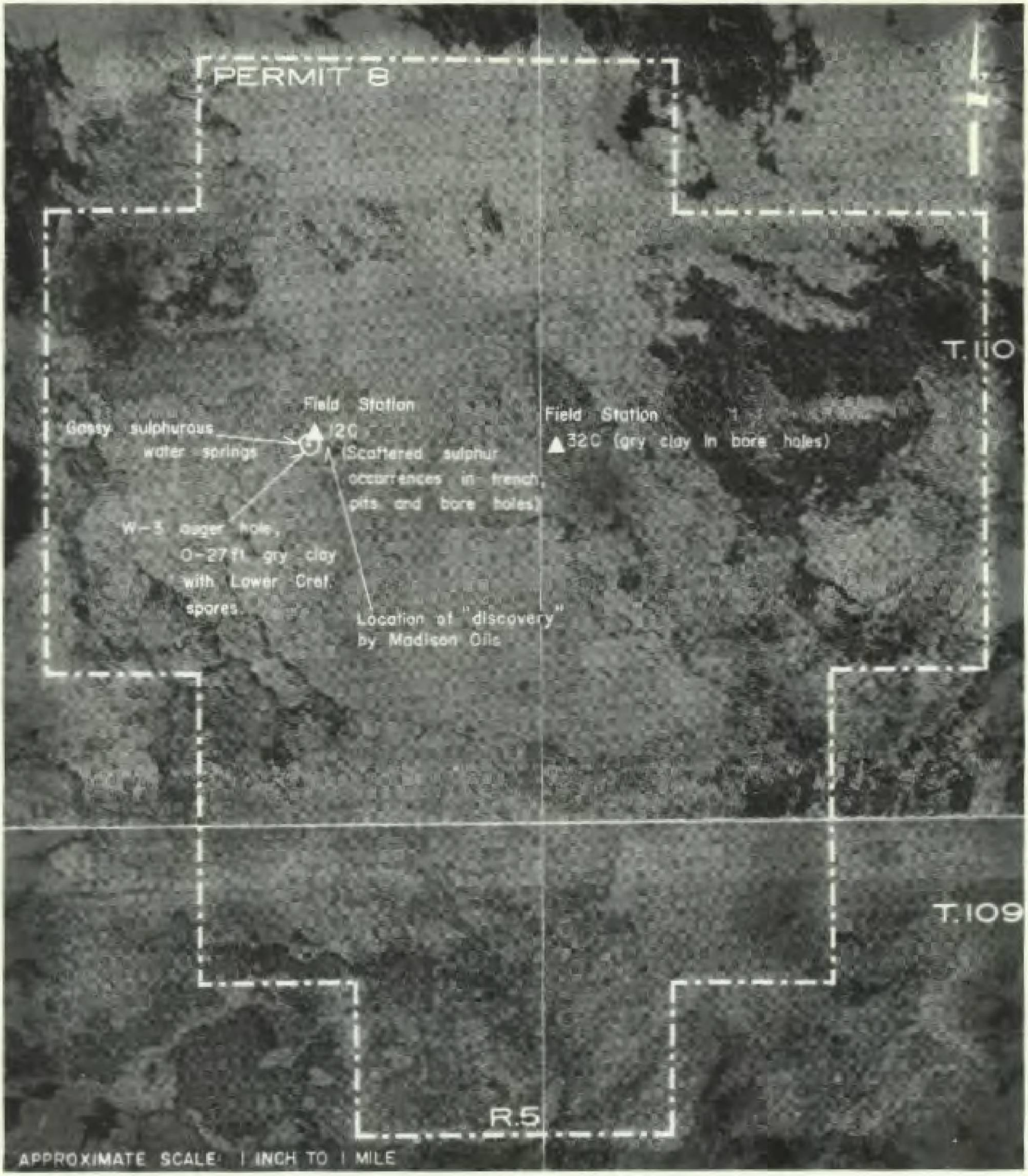
CHARACTERISTICS and ORIGIN of SULPHUR

Sulphur is frequently recognized by and associated with its bright sulphur-yellow color. However, it can be straw and honey-yellow, yellow-brown, yellow-gry and in fact, greenish and reddish. Pure sulphur is relatively light and brittle. It is a nonconductor of electricity and a poor conductor of heat. Sulphur melts at 108°C and burns at 270° C with a bluish flame yielding sulphur dioxide gas. It is insoluable in water and is not acted on by acids, but is soluable in carbon disulphide.

Elemental sulphur originates in various ways. It is frequently associated with volcanic activity and occurs in gases emanating from fumaroles. Sulphur is deposited directly by sublimation or by the incomplete oxidation of hydrogen sulphide gas. Sulphur may also be associated with thermal spring waters and derived either from volcanic sources or by the reduction of sulphates, especially gypsum, which is aided by certain bacterial action. Sulphur may also be formed by decomposition by metallic sulphides. Sulphur is produced by the living action of some bacteria. Some believe sulphur can originate from cold ground waters carrying sulphate and hydrogen sulphide through certain geo-electro-chemical processes.

According to Parks (1959) there are two main types of native sulphur. One type is associated with volcanic activity where elemental sulphur is formed from the mutual action of hydrogen sulphide and sulphur dioxide which occur in volcanic gases. A nonvolcanic origin is indicated for some deposits of native sulphur which appear to have been liberated from gypsum with the reducing action of bituminous matter found associated with gypsum. Calcium sulphide is probably formed from the calcium sulphate. The action of water and carbon dioxide on the sulphide forms elemental sulphur, calcium carbonate and hydrogen sulphide. Parks reports that hydrogen sulphide and its oxidation products are found in the waters of many sulphurous springs.

Sulphurous water springs and associated gas seeps in the Fort Vermilion area would appear to be of the type described above by Parks and thus may have gypsum as a source for the elemental sulphur.



AIR PHOTOMOSAIC

of

Sulphur Prospecting Permit No.8

SULPHUR OCCURRENCES
in the
FORT VERMILION AREA, ALBERTA

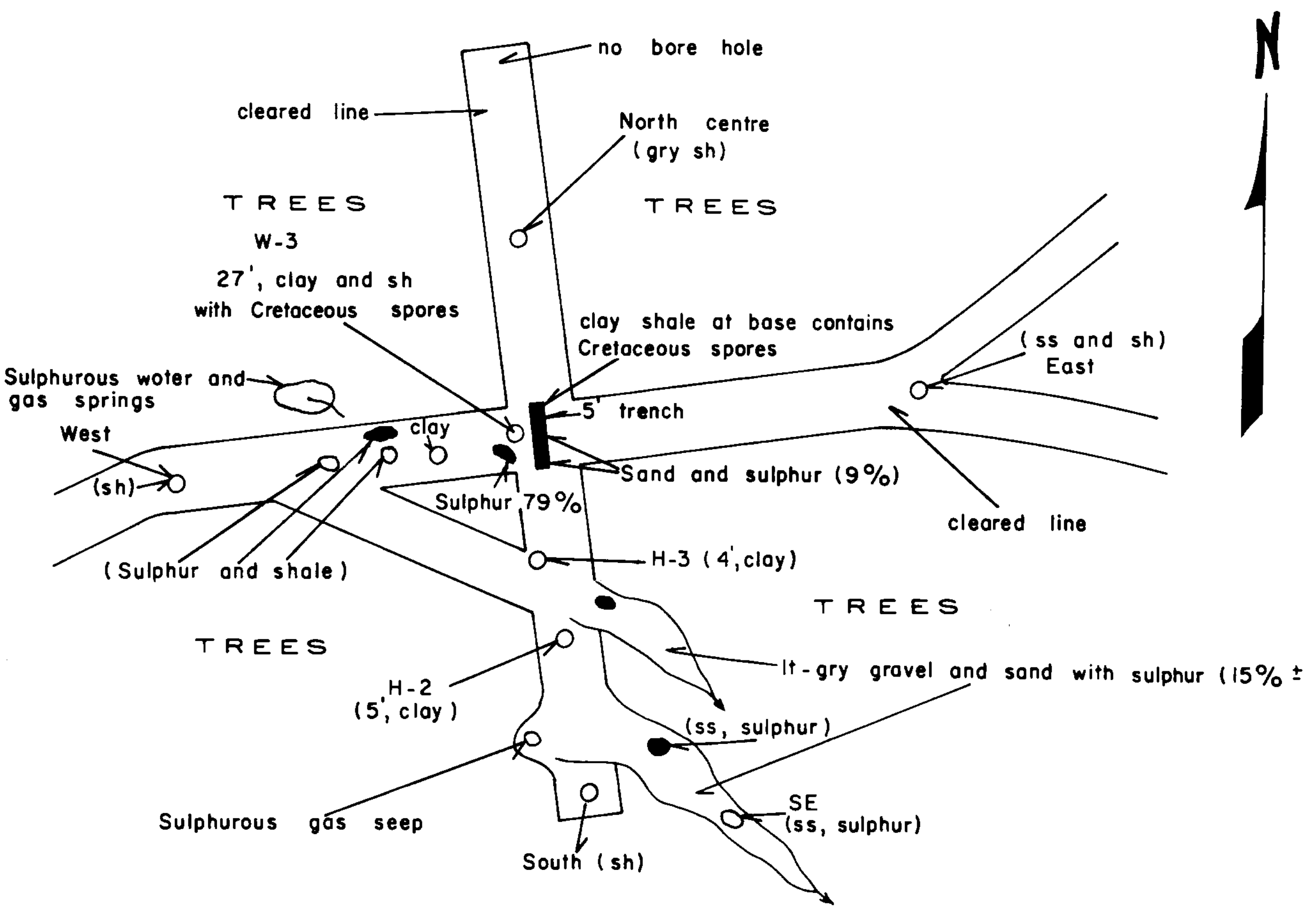
The presence of sulphur at or near the surface in the Fort Vermilion area has been known for many years. The Indians were probably the first to be aware of the presence of sulphur associated with a number of gassy, salty, cool-water springs such as those of the Harper-Lambert Creeks area. Several occurrences of burning sulphurous shales are known in the Buffalo Head Hills south and southeast of Fort Vermilion. These localities have also been known for sometime by the native population due to the smoke and sulphurous vapors which they emit.

The sulphurous springs, burning sulphurous shales and associated sulphur deposits were examined during the course of the field work. It is tentatively concluded that surficial occurrences of sulphur in the Fort Vermilion area are of two types. These are 1. deposits associated with sulphurous springs and 2. concentrations of sulphur in the Cretaceous shales underlying the Buffalo Head Hills and perhaps other plateaus in the Fort Vermilion area. Sulphur concentrations in the Cretaceous shales include the known areas of burning sulphur.

Sulphurous Springs

Sulphurous springs are known at three localities in the Fort Vermilion area. These include springs in the so-called "discovery permit" area in Tp. 110, R.5 W5M and the Harper-Lambert Creeks area Tps. 105 and 106, R.3 W5, and also two occurrences on the north and eastern edges of the Buffalo Head Hills. The sulphur occurs in elemental form and is apparently percipitated from gassy, sulphurous, salty, cold water springs.

FIGURE I



DIAGRAMMATIC SKETCH OF "DISCOVERY SITE"

SEC. 8-T. 110-R.5 - W. 5 M.

PERMIT 8

APPROXIMATE SCALE: I INCH TO 200 FEET

200 0 200 400 FEET

LEGEND

○ Bore hole (by operator, Dec., 1967)

○ H-3 (6', clay) Bore hole Haynes portable power auger to 6 feet, recovered clay (V. Zay Smith)

○ W-3 Bore hole (V. Zay Smith) Winkie portable power auger

Pit
Trench
} by operator, Dec., 1967

V. Zay Smith Associates Ltd. Calgary

Many of the sulphurous springs observed in the field are circular to eliptical in shape and from 100 to 600 feet across along the longest dimension. The associated spring water is clear, cold and salty. Bubbles of foul smelling gas (H_2S?) and possibly methane gas are associated with some of the springs. Native sulphur is deposited around the edges of the springs on boulders, pebbles and alluvial particles. Deposits of bituminous material are reported to be associated with the springs. However, no bituminous material was observed during the course of the field work.

The springs on the edge of the Buffalo Head Hills are small, measuring about 50 feet in length. They are similar in appearance to other springs in the Fort Vermilion area and are located in sec. 32, Tp. 99, R 9 W5, and also in sec. 27, Tp. 103, R 15 W5M (Station 3C).

Discovery Permit

The most publicized occurrence of sulphur in the Fort Vermilion area is located on Sulphur Prospecting Permit No. 8 in sec. 8, Tp. 110, R 5 W5M and is associated with sulphurous springs. This is often referred to as the "discovery permit". The permit is located in a flat-lying mainly tree-covered plain locally marked by muskeg. Plate 15 accompanying this report is an airphoto mosaic of Permit No. 8 and is at the scale of 1 inch to 1 mile. A low-level helicopter reconnaissance of the entire permit indicates a concentration of exploratory work in sec. 8, Tp 110, R 5 W5M. At that locality (Field Station 12C) a trench, several shallow pits and a number of bore holes have been drilled along cleared lines in general north-south and east-west directions. Figure 1 is a diagrammatic sketch of the area which is believed to be the "discovery site" in section 8 and shows the trench centrally located at the intersection of the cleared lines.

Elemental sulphur in fragmental or granulated form was recovered from several of the pits and bore holes and also from the trench. The trench is some 80 feet long, 3 feet wide and up to 5 feet deep locally. Sulphur was observed only in the area west and south of the trench and is apparently absent in other bore holes and pits. Where present the sulphur occurs in thicknesses from 8 inches to 3 feet and is typically overlain by two to twelve inches of soil or clay. In many cases sulphur was observed to be underlain by grey or greyish-brown clay or clay shale. No sulphur was encountered in any of the three auger holes drilled by the V. Zay Smith Associates Ltd. crew. At the W-3 drillsite (Winkie auger hole) 27 feet of clay and clay shale were penetrated and contain Cretaceous spores in the lower beds. The absence of sulphur in this hole illustrates the erratic and discontinuous nature of sulphur occurrences at the discovery site. Some 20 feet east of the W-3 bore hole as much as two or three feet of sulphur occurs locally in the trench. Some 20 feet southwest of the W-3 drillsite, granular or fragmented sulphur was encountered up to a thickness of 3 feet in a shallow pit. Sulphur content of a sample from this pit is 79.44%.

The section excavated at the trench (see Figure 1) can be summarized as follows from the top (sulphur analysis by Core Laboratories-Canada Ltd., see Appendix).

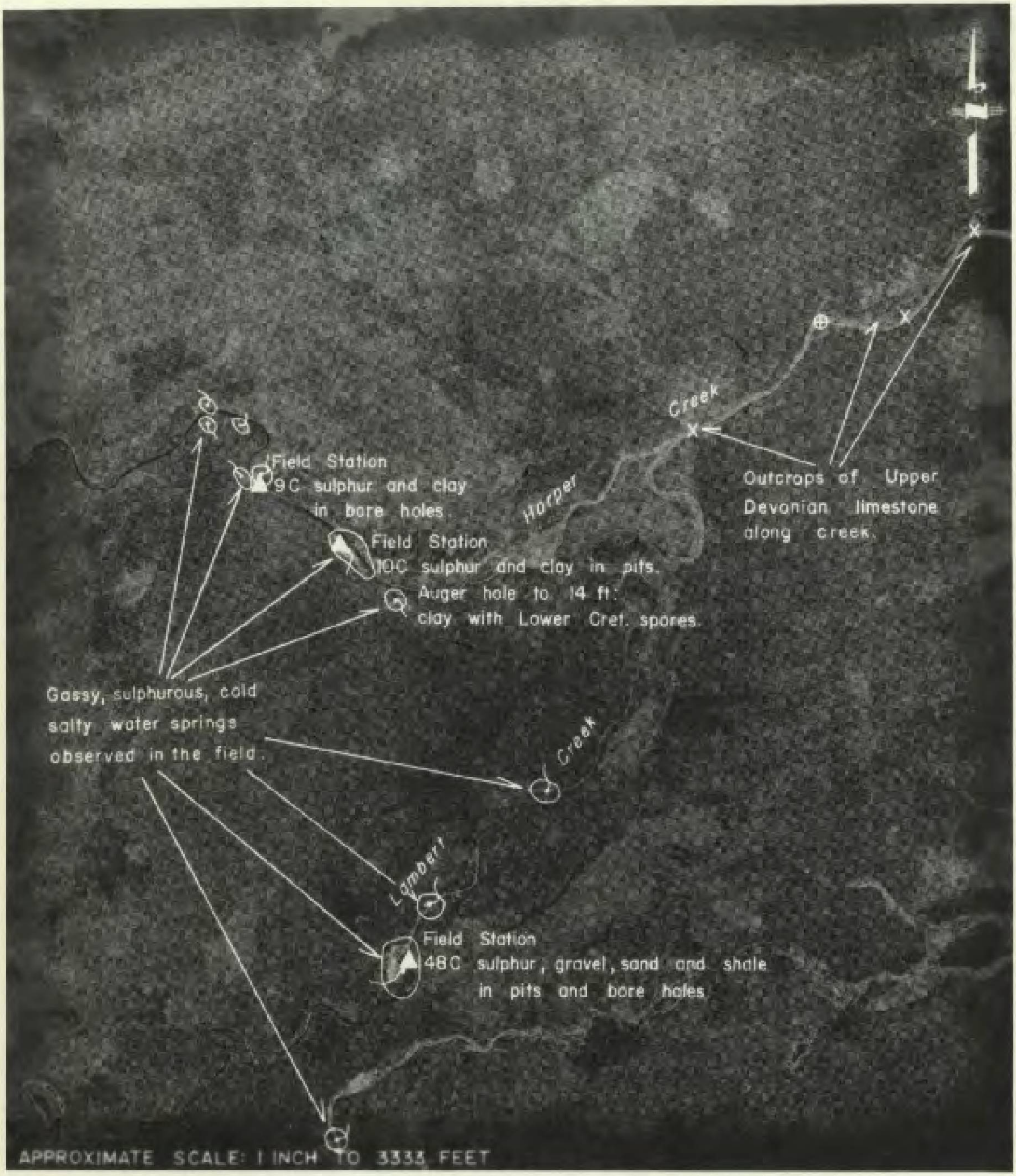
0-2' sand clay, yellow-brown and reddish-brown, unconsolidated, contains vegetation, sulphur content 2.8%.

2-3' sand, silty, clay, mottled red and dark grey, unconsolidated, grades laterally into underlying unit, sulphur content 6.28%.

3-4' sand, vivid yellow-brown, unconsolidated, sulphurous (9.1%), H_2S smell in the pit comes from this unit, grades laterally into overlying unit. Maximum 3 feet thick locally.

4-5' shale or clay shale, dark-grey (not analyzed for sulphur).

Occurrences of sulphur observed at the "discovery site" locally attain thickness up to 3 feet and are typically underlain by grey clay or clay shale. It is believed that the area illustrated on Figure 1 forms part of the area described in the December 18, 1967 issue of Oilweek magazine. In that publication it is reported that the "surface deposit about 40 miles northeast of Fort Vermilion was burning in a large pit-like area". The report stated that more than 150 shallow auger holes were drilled to a maximum depth of 9 feet in an area covering approximately 1/4 section (960 acres). The shallow holes define the limit of the deposit



AIR PHOTOGRAPH

of

Harper—Lambert Creeks Area

Showing field observations and drill hole sites

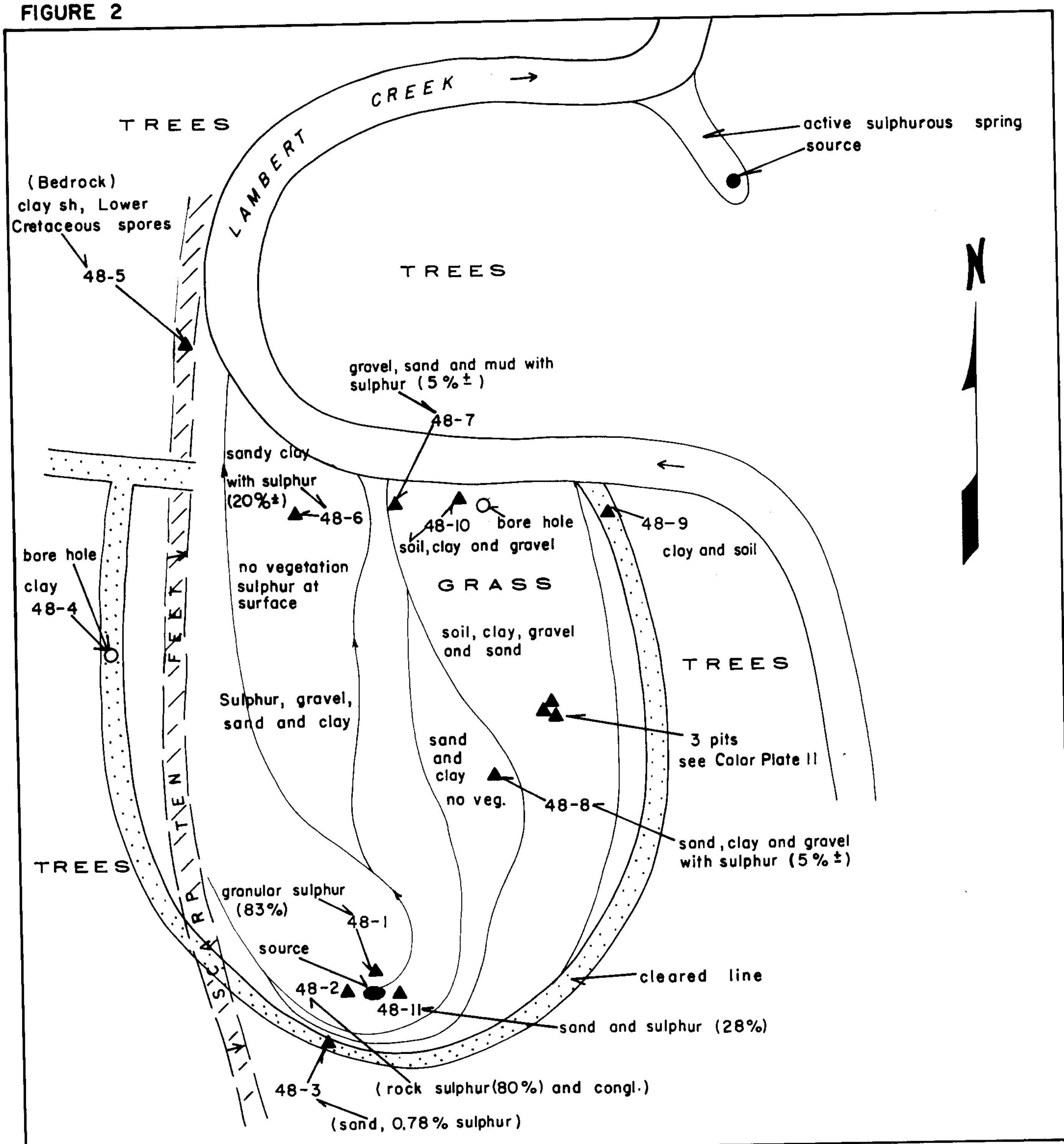
on one side. Assays of samples from the area reportedly show sulphur content ranging from 35% to 89% with no serious impurities. The deposit is covered with overburden clay and gravel ranging from approximately 6 inches to 2 feet in thickness. The bottom of the deposit was reportedly not reached by the holes drilled. Based on field observations and the drilling of 3 auger holes, a small volume of sulphur is indicated in Permit 8 (Figure 1). There many of the bore holes (apparently drilled by the operator last winter) are believed to have bottomed in shale and/or clay shale. Cuttings beside the bore holes drilled by the operator indicate that no sulphur was encountered in many of the holes, especially those east and north of the trench and also the most southerly and most westerly bore holes.

The discovery site of Permit 8 (sec.8, Tp. 110, R 5 W5M) includes at least one sulphurous water and gas spring. As shown on Figure 1 the springs are located some 250 feet west-northwest of the trench. Thus, the nearby occurrences of elemental sulphur may have been brought to the surface and derived from the sulphurous water and gas of the springs.

Harper-Lambert Creeks Area

Surficial deposits of sulphur are known in the Harper and Lambert Creeks area in Tps. 105 and 106, R.3 W5M. The sulphur appears associated with several gassy, sulphurous, salty, cool-water springs. The locations of sulphurous springs observed during the field work are shown on the accompanying areal geology map and also on Plate 16. Two of the springs on Harper Creek were examined in detail during the course of the field work in 1968. These are at Field Stations 9C and 10C (Plate 16) in sections 11 and 2 respectively of Tp 106, R.3. Color Plates 13 and 14 are close-up views of the springs at Field Stations 9C and 10C. The sulphurous spring at station 9C is much the smaller of the two and measures about 200 feet east-west and approximately 100 feet north-south. Sulphurous gas and water are emitted from the source area near the eastern end of the springs. The water flow is estimated to be between 600 and 800 gallons per hour. The water temperature is about 35° F. Sulphur has been deposited at the surface over an area within a radius of approximately 50 feet from the source. Foul-smelling sulphurous gas (H_2S?) is also being emitted at the springs. The sulphur accumulating near the source persists for a depth of only a few inches. Below this is black mud or clay which is completely

FIGURE 2



DIAGRAMMATIC SKETCH OF LAMBERT CREEK SULPHUROUS SPRINGS

SEC.36-T.105-R.3-W.5 M.

APPROXIMATE SCALE: 1 INCH TO 100 ± FEET

100 0 100 200 FEET

LEGEND

○	Bore hole (operator?)
▲	Shallow pit (V. Zay Smith)
48-4	Field station and sample number (V. Zay Smith)
⁝⁝⁝	Cleared line (operator, winter 1967-68)

V. Zay Smith Associates Ltd. Calgary

water saturated and emits a mild sulphurous odor. At a location some 50 feet west-southwest of the source, on the edge of the spring area, a shallow bore hole was drilled with the Haynes portable power auger. An odorless sticky black mud was encountered from the surface to the total depth at 5 feet.

The sulphurous springs at field station 10C on Harper Creek (Color Plate 13) extend for some 600 feet along the south bank of the creek and are from 50 to 100 feet in width. A number of active or dormant source or spring areas were observed at this locality. In the areas immediately adjacent to spring sources, the surface deposits consist of a mixture of sand, gravel and sulphur with a sulphur content estimated at 30%. A bore hole was drilled to a depth of 14 feet with the Winkie portable power auger on a grass covered knoll which rises about 3 feet above the general level of the spring area. The drillsite is bordered on three sides by active or dormant sulphurous springs and sulphur deposits. The following section was encountered: from the surface to a depth of 3 feet, brownish grey soil, from 3 feet to 14 feet, clay, medium-grey to light grey gummy, noncalcareous, nonsulphurous. Resistant rock (bedrock?) was encountered at the total depth of 14 feet. These rocks may mark the top of the resistant beds in the limestone member of the Mikkwa Formation. Limestones of this stratigraphic position are exposed some two miles northeast on Harper Creek. The grey clay at the bottom of the Winkie auger hole contains Lower Cretaceous spores identified by Dr.L.V.Hills (see Appendix).

The thickness of the sulphurous sands which occur near source areas at the sulphurous springs of field station 10C are unknown. The quick-sand-like nature of the sulphurous sand and clay prevented the use of augers. Thus, excavation was restricted to the digging of shallow pits. A pit was dug at one locality to a depth of some 3 feet. The sulphurous sand and clay mixture persists at least to that depth.

Several sulphurous springs were also observed on Lambert Creek, the largest of which is located in the southwest corner of section 36, Tp. 105, R.3 W5M (see Color Plates 9 and 10). Figure 2 is a diagrammatic sketch of the sulphurous springs there where 10 pits were dug within and adjacent to the springs area to an average depth of 2-1/2 feet. The sulphurous springs at this locality is the largest of those observed in the Fort Vermilion area. It measures some 350 feet north-south and ranges in width from 150 to 175 feet east-west. At the source, near the south end of the springs, cold, sulphurous, salty, water and foul-smelling (H_2S?) gas are emitted (see Color Plate 10). The water flow is estimated to be approximately 1,000 gallons per hour and the temperature is approximately 40° F. An analysis of the water from the spring by Core Laboratories-Canada Ltd. (see Appendix) indicates a content of native sulphur of 186 mg per litre (approx. 2 lbs per 1,000± gallons). The most abundant constituents of the water include sodium and potassium, chloride and HCO_3. The water contained no detectable H_2S.

The locations of the pits dug in the area of the springs and the rock type recovered from each pit are indicated on Figure 2. The highest concentrations of sulphur are in granular sulphur at station 48-1 a few feet north of the source area. There, sulphur content is 83%. Some 40 feet southwest nonsulphurous sand was encountered in pit 48-3. It is estimated that the average sulphur content of the surficial deposits in the yellow or sulphurous portion of the springs area would be on the order of 20%.

Analysis of a grab sample of sulphurous deposits from the springs on Lambert Creek in sec. 36, Tp. 105, R.3 W5M can be summarized as follows. It consists of a pale yellow-grey unconsolidated and crumbly assemblage of multisized particles and balls of clay and silty material. The assemblage emits a slight sulphurous odor. When ignited it burns with a rich royal blue flame and gives off a strong acrid sulphurous smell (SO_2). A microscopic examination and assay carried out by Core Laboratories-Canada Ltd. revealed the presence of chert, mica, quartz and feldspar. These rock minerals are distributed throughout the material from grain to pebble size and the particles show the result of water or glacial erosion. A small amount of deposited calcite is also present. Elemental sulphur present was deposited by water action on the surface of the rock particles. A screen test on the sample yielded the following:

	% of Sample		Elemental Sulphur
Pebbles	5.5%	(not assayed for S)	-
Plus 20 mesh	66.5%		31.9%
Plus 40 mesh	18.2%		26.9%
Minus 40 mesh	9.8%		36.1%
	Elemental Sulphur Content of Sample		28.8%

An indication of the age of bedrock in the springs area of station 48C on Lambert Creek is provided by the occurrence of Lower Cretaceous spores in the clay shales at station 48-5 (see Figure 2). These spores were examined by Dr. L.V. Hills of the University of Calgary.

As indicated by the lithologic information shown on Figure 2, the rocks recovered from the pits dug in the Lambert Creek sulphurous springs include a variety of lithologies ranging from nearly pure sulphur near the source to sulphur free clay and soil in the tree covered areas nearby. Markedly different lithologies were observed locally as in the pits dug at a locality some 50 feet northeast of station 48-2 (Figure 2). There, three shallow pits were dug in and adjacent to an occurrence of granular sulphur and are illustrated on Color Plate 11. Blue-black clay was recovered from one pit and a mixture of sulphur and clay from another. Thus, the sulphur occurrences may be nearly pure in sulphur content but are in some cases restrictred to very small areas.

SULPHUROUS SHALES

Surficial occurrences of sulphur are known at several localities along the northern and eastern edges of the Buffalo Head Hills. They occur in the Lower Cretaceous Spirit River (Loon River, Clearwater) Formation and were observed at several localities during the course of the field work. Exposures along the northeast escarpment of the Buffalo Head Hills are indicated on the areal geology and structural interpretation maps accompanying this report (sheets 2 and 3). Concentrations of sulphur were observed on the north flank of the Buffalo Head Hills in Tp. 103, Rges. 13, 14 and 15, W5M and also in Tps. 98 and 99, Rges 9 and 10, W5M along the Wabasca and Muddy Rivers.

Typically the sulphur occurs as a powdery coating on the soft, flaky shales (see Color Plate 4). Locally sulphur occurs as vertical stringers along fractures (Color Plate 5). The Cretaceous shales are dark grey or dark brown and when viewed from a distance, as in Color Plate 3, the sulphurous shales are yellowish-grey.

Locally the sulphurous shales have been burnt or are presently burning as at field station 4C, sec.25, Tp. 103, R.15 W5M and also at station 23C on the Muddy River in sec. 6, Tp.99, R. 10 W5M. At these two areas vividly colored (yellow, red, orange and purple) exposures of burnt or oxidized sulphur (and iron?) were observed. The burning deposits in Tp. 103, R.15 emit sulphurous smoke at several localities and clear sulphurous gas at many others. Nonvolcanic fumaroles have formed locally (Color Plate 6).

At both localities where burnt or burning sulphurous shales were observed large slump blocks have occurred in the soft black fissile shales. The strong, pungent smell of burning sulphur (SO_2) is pronounced.

Field estimates of sulphur concentrations in the sulphurous shales and in the burnt areas are as follows. The highest concentrations of sulphur were noted in unburnt shales adjacent to burnt areas and are believed to be on the order of 30%. Generally in many exposures of sulphurous shale, characterized by the exposures illustrated on Color Plate 4, sulphur concentrations of 5% or less are indicated.

Deposits of sulphur in Cretaceous shales of the Buffalo Head Hills are believed to be secondary. This is suggested by the occurrence of sulphur as a powdery coating on shale flakes. It can be speculated that sulphur migrated vertically upward into the Cretaceous shales along fractures and/or joints, such as those filled with sulphur and illustrated on Color Plate 5.

Sulphur Occurrences in the Bore Holes

Some 68 shallow bore holes were drilled in the Fort Vermilion area in conjunction with the field investigations in 1968. A total of 65 holes were drilled with the Haynes portable power auger (Color Plate 8) which is capable of drilling a hole to a depth of 6 to 9 feet depending upon conditions.

Three holes were drilled with a somewhat larger portable auger, the Winkie drill (Color Plate 7) which is capable of drilling a hole to a depth of more than 25 feet. The locations of some holes drilled with the Winkie and Haynes augers and the gross lithology of cuttings recovered are indicated on the areal geology and structural interpretation maps accompanying this report. Many drillsites were chosen so as to evaluate Sulphur Prospecting Permits held by the participants in this program. Results of the bore holes drilled in the discovery permit area and also those drilled in the sulphurous springs of Harper and Lambert Creeks are discussed elsewhere in this report.

No significant amount of sulphur was encountered in any of the bore holes drilled with the Haynes and Winkie augers at locations indicated on the accompanying maps. A number of samples from selected localities in the map area were analyzed for sulphur content by Core Laboratories-Canada Ltd. The results of this analysis are included in the appendix accompanying this report. A sample of cuttings from a seismic shot-hole at station 18C (Tp. 103, R.5 W5M) in Permit 58 contains 19.55% sulphur and is the only sample analyzed which contains a significant amount of sulphur aside from those gathered at the Harper-Lambert Creek springs and the "discovery site" in Permit 8.

Photogeologic Anomalies

Many of the springs and associated sulphur deposits in the Harper-Lambert Creeks area can be recognized on air photographs (see Plate 16). They are also shown on the accompanying areal geology map in Tps. 105 and 106, R.3, W5M. The areas appear as very light toned patches on air photographs and are characteristically treeless. Some appear associated with small muskegs or bogs. Elsewhere in the Fort Vermilion area, especially in the Harper-Lambert Creeks region, similarly appearing features can be identified on the air photographs. These features were initially mapped as part of a photogeologic evaluation completed earlier this year (Smith, 1968). It is believed that some of these anomalies may be active or inactive springs possibly with associated sulphur deposits. They are indicated on the accompanying areal geology maps with appropriate symbols as defined in the legend. Approximately 80% of the anomalies were investigated during the field work either by foot-traverse or by low-level helicopter reconnaissance but no associated sulphur was observed at the surface. However, several of the anomalies mapped in the Lambert-Harper Creeks area were confirmed as sulphurous springs. Elsewhere in the Fort Vermilion area the anomalies investigated are typical muskeg areas or bogs and do not lend themselves to the drilling of shallow bore holes during the summer months. It is believed that some of the anomalies may have developed over dormant sulphurous springs. If so, exploration of these features could best be accomplished by a winter drilling program when the land surface is frozen.

CONCLUSIONS and RECOMMENDATIONS

With the presently available information concerning the occurrence, distribution and origin of surficial deposits in the Fort Vermilion area, the following conclusions can be offered.

Occurrences of Sulphur

It can be tentatively concluded that the observed surficial occurrences of sulphur in the Fort Vermilion area are in Cretaceous rocks and are of two main types. These are: 1. deposits associated with sulphurous springs and 2. concentrations of sulphur in Cretaceous shales underlying the Buffalo Head Hills and perhaps other plateaus of the map area. Sulphur concentrations in the Cretaceous shales include the known areas of burning sulphur. The sulphurous springs type of occurrence includes the deposits at Permit 8, referred to as the "discovery permit" and also the springs in the Harper-Lambert Creeks area.

Distribution

Concentrations of elemental sulphur are known in three areas in the Fort Vermilion project. These are: 1. the discovery permit in sec. 8, Tp. 110, R. 5 W5M where the deposits are believed to be associated with active and dormant sulphurous springs, and 2. the Harper-Lambert Creeks area where a number of sulphurous, gassy springs and associated deposits of sulphur are known (see Plate 16 and Figure 2) and 3. sulphur concentrations in Cretaceous shales of the Buffalo Head Hills.

The distribution of sulphur deposits associated with sulphurous springs can best be described as erratic. Figure 2 illustrates the percentages of sulphur in several samples from a large seep on Lambert Creek in sec. 36, Tp. 105, R. 3 W5M. Maximum percentages of sulphur are found near the source. Elsewhere in the area of the springs, sulphur concentrations range from 20% to nil. The depth of sulphur deposits at this spring is unknown as the presence of gravels and boulders prevented the use of power augers. From observations made at the Lambert Creek springs and the results of shallow bore holes at other springs on Harper Creek, it is estimated that a thickness of sulphur deposits associated with springs is on the order of 10 to 15 feet and possibly less.

A similarly erratic distribution of sulphur is indicated at the discovery site in Permit 8. Figure 1 shows the locations of sulphur concentrations, sulphurous water and gas springs and sulphurous gas seeps at the discovery site. Where present, concentrations of sulphur apparently do not exceed a thickness of three feet and are typically overlain by soil ranging in thickness from a few inches to twelve inches.

Sulphur concentrations in the Cretaceous shales underlying the Buffalo Head Hills also are erratic. They have been observed along the north and east flanks of the hills and are indicated on the accompanying areal geology maps. The highest concentrations of sulphur in the Cretaceous shales were observed in unburnt shales adjacent to areas where the shales have been burnt or oxidized. Sulphur concentration in these areas is estimated at approximately 30%. Elsewhere sulphurous shales in the Cretaceous section have concentrations of sulphur of 5% or less based on visual esimates. Many of the sulphurous shale occurrences in the Buffalo Head Hills appear to occupy a similar stratigraphic position so that they are often exposed within 50 to 150 feet from the upper plateau surface of the hills.

With one exception, significant concentrations of sulphur have not been observed at localities other than the Cretaceous shales of the Buffalo Head Hills, the Harper-Lambert Creeks sulphurous springs and the discovery site in Permit 8. This one exception is a concentration of 19.55% sulphur in the cuttings from a seismic shothole in Permit 58 at field station 18C (Tp. 103, R.5 W5M). The original depth of the shothole drilled and the depth in the hole from which the cuttings were obtained at station 18C are unknown.

Origin of the Sulphur Deposits

Observations todate indicate that sulphur occurrences in the Harper-Lambert Creeks area and also at the discovery permit are associated with gassy, sulphurous, salty water springs which emanate at the surface. It is believed that this process has been more or less continuous over a long period of time, and has been variable as to geographic location.

Several possible origins for the gassy springs are visualized. The waters and associated gas may originate from porous zones in Upper Devonian carbonates of the Grosmont and Mikkwa Formations where they rise to the Paleozoic surface. Faults and fractures may play a fundamental role and permit the ascent of formation waters, either from Upper Devonian carbonates, Middle Devonian carbonates or evaporites of the Elk Point Group. Waters that had access to the evaporites of the Elk Point Group could contain large amounts of calcium sulphate.

If one visualizes that gassy, sulphurous salty waters have been emanating from Upper Devonian beds, principally the carbonates of the Grosmont and Mikkwa Formations, the process could have been going on periodically for a long period of time. The sulphurous springs could have been active since the removal of much of the Cretaceous cover in Tertiary time. Evidence shows that the Cretaceous cover had been essentially removed prior to glaciation over much of the low lying portion of the map area adjacent to the Peace River. Thus, Upper Devonian strata have been exposed at least since late Tertiary time. One can visualize sulphur deposits forming at the bedrock surface over an extensive area. As one spring became clogged and choked, other gassy springs could have broken through elsewhere. Thus, a thin, patchy but fairly extensive deposit of elemental sulphur may have formed at the pre-Pleistocene bedrock surface.

Pleistocene glaciation could have disturbed and eroded surficial sulphur deposits and disbursed and scattered them elsewhere intermixed with glacial drift. It seems probable that some protected areas were not subjected to glacial scouring and remnants of the original surficial sulphur deposits rest on bedrock in scattered localities along a belt extending from Tp. 103, Rges. 1 to 4, W5M northwesterly to Tp. 110, R. 4 to 7, W5M. During and following deglaciation the process has probably reoccurred more or less continuously but at different geographic locations and at different times. Thus, one could anticipate encountering sulphur deposits associated with springs in a variety of places not only at the surface but at different levels within the glacial drift and on bedrock itself at depths ranging up to 150 feet.

According to Parks (1959), elemental sulphur and hydrogen sulphide are associated with many sulphurous water springs and may have their origin from gypsum. Parks reports that native sulphur appears to have been liberated from gypsum with the reducing action of bituminous matter found associated with gypsum. Calcium is probably formed from the calcium sulphate. The subsequent action of water and carbon dioxide on the sulphide forms elemental sulphur, calcium carbonate and hydrogen sulphide. Parks reports that hydrogen and its oxidation products are found in the waters of many sulphurous springs. Thus, the sulphurous water springs and associated gas seeps in the Fort Vermilion area would appear to be of the type described by Parks as having gypsum as a source for the elemental sulphur, and this origin should also be considered.

Deposits of sulphur in Cretaceous shales of the Buffalo Head Hills are believed to be secondary. This is suggested by the occurrence of sulphur in the shales as a powdery coating on the shale flakes and the absence of sulphur inside individual shale flakes. It is believed that sulphur in liquid form or perhaps associated with sulphurous waters has migrated vertically upward into the Cretaceous shales along fractures and/or joints, such as those filled with sulphur and illustrated on Color Plate 5.

Thus, based on presently available information, surficial sulphur deposits in the Fort Vermilion area are believed to be restricted to relatively small areas and to have erratic or patchy distribution. No extensive concentrations of sulphur were observed during the field work and drilling program having a magnitude necessary to encourage commercial development. However, it should be emphasized that a vast area is involved in the Sulphur Prospecting Permits currently held in the Fort Vermilion area. Concentrations of sulphur may occur below the surface with no apparent surface indication.

Additional exploration should include a winter drilling program, with drillsites located so as to evaluate anomalies and possible springs indicated on the areal geology maps, and also other areas inaccessible during summer months. Moreover, consideration should be given to developing and employing geochemical and geophysical techniques to locate subsurface sulphur deposits.

Respectfully submitted,

V. ZAY SMITH ASSOCIATES LTD.

[redacted]

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[redacted]

J. F. Conrad, Senior Geologist

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CORE LABORATORIES-CANADA LTD.

PETROLEUM RESERVOIR ENGINEERING

EDMONTON CALGARY REGINA

WATER ANALYSIS

File CBH-2-3167 Page 1

Company V. Zay Smith Associates Ltd.

Well Name File No. 99-36F Sample No.

Formation Depth

Location Field Province

Date Sampled Date Analyzed July 3/68 Analyst M.B.

Sampled From Sulphur Spring By

Recovery Elevation

Constituents:

1. Total Solids 22,495 mg/liter 2. pH 7.35 3. Sp.Gr. 1.0160 @60°F.

4. Resistivity 0.285 Ohm-meters @ 75 °F 5. H_2S Absent

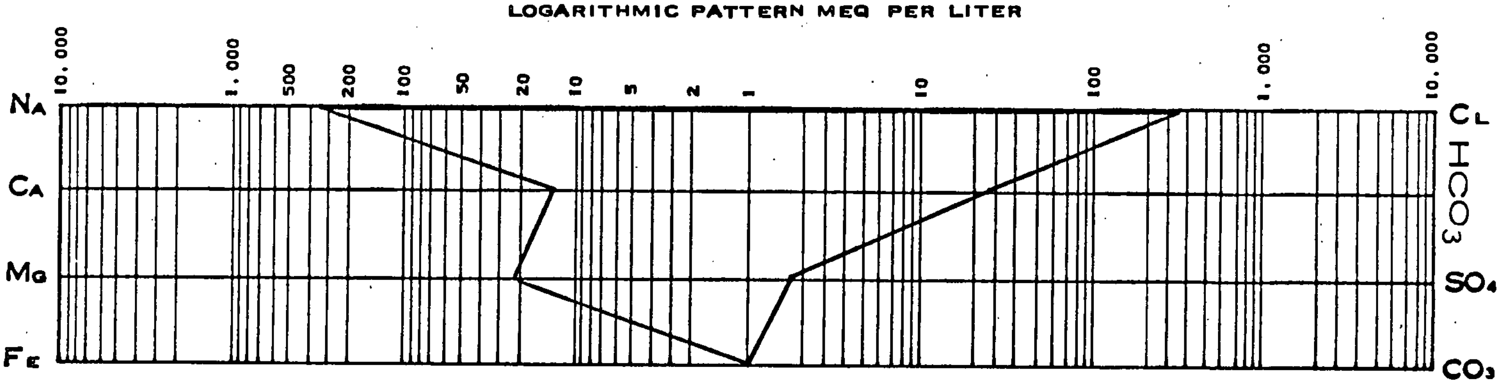
MILLIGRAMS PER LITER

Na & K	Ca	Mg	Fe	Ba		Cl	HCO_3	SO_4	CO_3	OH	
7,917	306	248	Abs.	Abs.		12,672	1,264	88	-	-	

MEQ PER LITER

344.2	15.3	20.4	Abs.	Abs.		357.4	20.7	1.8	-	-	

LOGARITHMIC PATTERN MEQ PER LITER



Remarks: Sulphur was precipitated out in the sample bottle when received.
There was no detectable H_2S in the water when received.
This sample, when saturated with H_2S at 40°F, contained 5061 mg/l H_2S.

Sample as received contained 186 mg/l elemental sulphur.

Appendix II

SULPHUR ANALYSIS

of

OUTCROP and BOREHOLE SAMPLES
FORT VERMILION AREA, ALBERTA

by

CORE LABORATORIES-CANADA LTD.

Calgary, July, 1968

Field Station		Sulphur Prospecting Permit	Sulphur %
5C	Cret.shale	P#101	0.08
12C	0-2') (top)	P#8	2.80
12C	2-3')— Trench	P#8	6.28
12C	3-4')	P#8	9.10
12C	Pit, SW of Trench	P#8	79.44
18C	Winkie borehole 24-27'	P#58	1.52
18C	Seis.shot hole	P#58	19.55
26C	Haynes borehole, 6'	P#96	0.08
28C	Haynes borehole, 6'	P#85	0.61
30C	Haynes borehole, 6'	P#100	0.46
31C	Pit 3'	P#104	1.65
33C	Haynes borehole, 6'	P#59	0.40
38C	Haynes borehole, 6'	P#47	0.14
39C	Haynes borehole, 6'	P#102	0.33
41C	Seis shot hole	P#134	0.32
42C	Haynes borehole (H-37) 6'	P#134	0.20
43C	Haynes borehole 6'	P#113	0.55
44C	Haynes borehole 6'	P#103	0.92
45C	Haynes borehole 6'	P#133	1.95
46C	Haynes borehole 6'	P#105	0.40
C48-3	Lambert Cr.springs	P#20	0.78
C48-1	Lamber Cr.springs (source)	P#20	83.04
49C	Haynes borehole, 6'	P#36	4.94
50C	Haynes borehole, 6'	P#37	0.82
51C	Haynes borehole, 6'	P#38	0.40

PALYNOLOGY OF FIVE SHALE SAMPLES

PREPARED FOR V. ZAY SMITH ASSOCIATES LTD.,

BY

L. V. HILLS, Ph.D.

University of Calgary, July, 1968

Sample C-48-5 P#20 (Lambert Creek Seep) yielded the following palynomorphs:-

1. Oligosphaeridium complex
2. Odontochitina operculata
3. Baltisphaeridium multispinosum
4. ?Palaeohystrichophora brevispinosa
5. Palaeoperidinium granulatum
6. Baltisphaeridium cf. B. neptuni sensu Singh 1964
7. Veryhachium irregulare ?
8. Gleicheniidites senonicus
9. Gleicheniidites ciriniidites
10. Lycopodiumsporites marginatus
11. Hymenozonotriletes lepidophytus (reworked Devonian)

Age: Lower Cretaceous. The first seven palynomorphs are marine planktonic forms which are common in the Clearwater Formation.

Sample 17C Wabasca River, yielded the following palynomorphs:-

1. Gonyaulacysta cf. G. jurassica sensu Singh 1964
2. Odontochitina operculata
3. Canningia calliveri
4. Pseudoceratium pelliferum
5. Baltisphaeridium multispinosum

6. Marine cysts sensu Pocock 1962
7. Stereisporites antiquasporites
8. Gleicheniidites senonicus
9. Gleicheniidites circiniidites
10. Cyathidites minor
11. Cicatricosisporites sp.
12. Alisporites sp.
13. Appendicisporites crimensis
14. Lycopodiumsporites austroclavatidites
15. Dictyosporites sp. cf. D. spesiosus sensu Singh 1964
16. Pityosporites constrictus
17. Vitreisporites pallidus
18. Tsugaepollenites mesozoicus
19. Schizosporis cooksonii
20. Cycadopites sp. Singh (pl. 14, fig. 6)
21. Classopollis classoides

Age: Lower Cretaceous, probably Albian. The first five palynomorphs are dinoflagellates and acritarch, of marine origin. All five are present in the Clearwater Formation (Singh, 1964). The remaining palynomorphs are known to occur in the Clearwater Formation, but are not diagnostic of it. Appendicisporites crimensis has a known geologic range of Hauterivian to Albian. The close correspondence of the palynomorph assemblage from this sample with those previously described from the Clearwater, suggests that the sample was taken from an outcrop of the

Clearwater Formation.

Sample C-12 P#8, TR. 4'-5' yielded the following palynomorphs:-

1. Baltisphaeridium multispinosum
2. Odontochitina operculata
3. Deflandrea sp.
4. Alisporites grandis (common)
5. Pityosporites spp. (common)
6. Vitreisporites pallidus (common)
7. Gleicheniidites senonicus (common)
8. Eucommiidites troedssonii
9. Gleicheniidites circinidites
10. Cedripites cretaceus
11. Cyathidites minor
12. Cycadopites sp.

Age: Lower Cretaceous (probably Middle Albian). The presence of Odontochitina operculata, Baltisphaeridium multispinosum and Deflandrea indicate a marine environment of deposition. O. operculata and B. multispinosum appear in the Wabiskaw Member of the Clearwater Formation, and disappear or are markedly reduced at the top of the formation.

The remaining species are common throughout the Lower Cretaceous.

Sample 12C W3, 18'-21' yielded the following palynomorphs:-

1. Podocarpidites canadensis
2. Cycadopites sp.
3. Pityosporites
4. Lycopodiumsporites marginatus ?
5. Laevigatosporites ovatus
6. Osmundacidites cf. O. primarius
7. Gleicheniidites senonicus
8. Eucommiidites troedssonii
9. Picea modern contaminator ?

Age: Lower Cretaceous. Podocarpidites canadensis has been reported in strata ranging from Barremian? to Middle Albian (Singh, 1964, p. 119). Eucommiidites troedssonii ranges from Jurassic to Lower Cretacous. The remaining palynomorphs are much longer ranging, and therefore, cannot be used for a more precise age determination.

Sample 10C W1, 9'-12' yielded the following palynomorphs:-

1. Oligosphaeridium complex (Hystrichosphaeridium tubiferum)
2. Gonyaulacysta cf. G. jurassica sensu Singh 1964
3. Baltisphaeridium sp.
4. Gleicheniidites senonicus
5. Pityosporites sp.
6. Vitreisporites pallidus

Age: Lower Cretaceous. Singh (1964, p. 138) states that O. complex (Hystrichosphaeridium tubiferum) is common in the Clearwater and Lower Grand Rapids Formations. Pocock (1962, p. 83) lists the geologic range as Barremian to Senonian.

Palynomorph preservation only fair. This sample and 12C W3 18'-21' are more carbonized than the other three samples included in this report.

The presence of Gonyaulacysta, Oligosphaeridium and Baltisphaeridium indicate a marine environment of deposition.

Discussion and Conclusions:-

1. All samples appear to come from approximately the same stratigraphic interval.
2. The common occurrence of marine plankton in Samples C-48-5 P#20; 17C (Wabasca River); C-12 P#8, TR. 4'-5'; 10C W1 9'-12', indicate a marine environment of deposition (probably Clearwater).
3. All samples lack or contain only rare trilete spores such as Appendicisporites, Plicatella, Trilobosporites and Pilosisporites, which are common in Lower Cretaceous strata of Lower Albian or older age.
4. Angiosperms were not encountered, and therefore, it is unlikely that the strata are younger than Albian.
5. The best age assignment on the basis of listed forms is Middle Albian (Clearwater Formation).

6. Samples 12C W3, 18'-21' and 10C W1, 9'-12' appear to be more strongly carbonized than the other three samples. This suggests that after burial they have been subjected to a slightly higher temperature than the remaining samples. This point would require considerably more work to demonstrate conclusively. It also would require equipment not available to the writer.
7. All samples were checked thoroughly for evidence suggesting the possibility of Pleistocene reworking. The lack of modern or Pleistocene contaminators (one exception only), although not conclusive, suggests that the samples are in situ. Further, the lack of mixing of spores of different ages negates deposition as till.

It must be stated, however, that it is not always possible to detect Pleistocene reworking by palynological techniques. For example, Pleistocene varved clays at Fisherman's Lake in the Yukon contain a well preserved reworked Lower Cretaceous microflora. There are no modern or Pleistocene pollen or spores present to indicate the true age of these clays. Therefore, field evidence is required in evaluating whether or not a particular assemblage has been reworked.

In an area where the ice has passed over strata of different ages, reworking can be detected by the resultant mixed assemblage. None of the samples studied for this report yielded a mixed assemblage. This fact suggests that either none of the samples is till, or if they are, they have had a short distance of transport (reflecting nearby bedrock) or else the ice has passed over the unit for some considerable distance.

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[redacted]

P. Geol

Plate 1

Cleared lines, trench and pits at the "discovery permit" (Permit 8, sec. 8, Tp. 110 , R. 5 W5M) view southeast. Note sulphur (yellow and yellow-brown). Sulphur content in pit to right of trench is 79%.

Plate 2

Trench at the "discovery permit". View north showing grey soil and yellow-brown sulphurous sand (9% sulphur).

Plate 3

Burnt and unburnt sulphurous shale, Muddy River, sec. 6, Tp. 99, R.10 W5M.

Plate 4

Sulphurous shale. Buffalo Head Hills Tp. 103, R.16 W5M Field Station 2C.

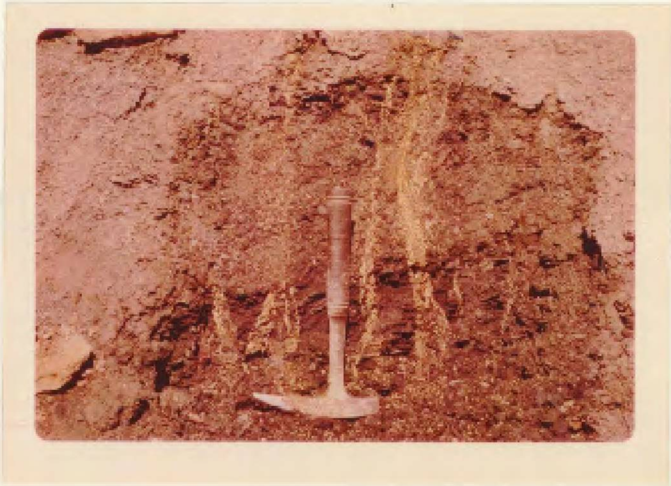


Plate 5

Vertical stringers of sulphur filling fractures in Cretaceous shale, sec. 3, Tp. 99, R.9 W5M.

Plate 6

Fumaroles of nonvolcanic origin in burning sulphurous shale, Station 4C, sec. 25, Tp. 103, R. 15 W5M.

Plate 7

Winkie drill (portable power auger) at Harper Creek sulphurous spring, Field Station 10C.

Plate 8

Haynes drill (portable power auger) making shallow hole at airstrip in sec. 12, Tp. 101, R. 5 W5M.

Plate 9

Sulphurous springs on Lambert Creek, Station 48C in sec. 36, Tp. 105, R. 3 W5M. Note source inside yellow sulphur accumulation in right foreground.

Plate 10

Close-up view of source of springs on Lambert Creek. Flow is about 1,000 gallons per hour of cold (40°F), sulphurous, salty water with much foul-smelling (H_2S?) gas.

Plate 11

Shallow pits at Lambert Cr. sulphurous spring in sec.36, Tp. 105, R.3 W5M showing isolated occurrence of granulated sulphur (to right of note book), blue-black clay (beyond note book) and mixture of sulphur and clay (left of note book).

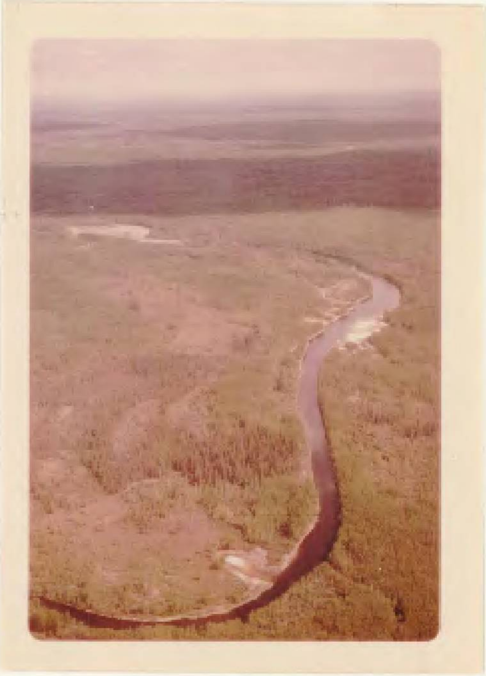


Plate 12

Sulphurous springs (foreground and right middle-ground), Harper Creek. Aerial view SE from centre of Tp. 106, R.3 W5M.

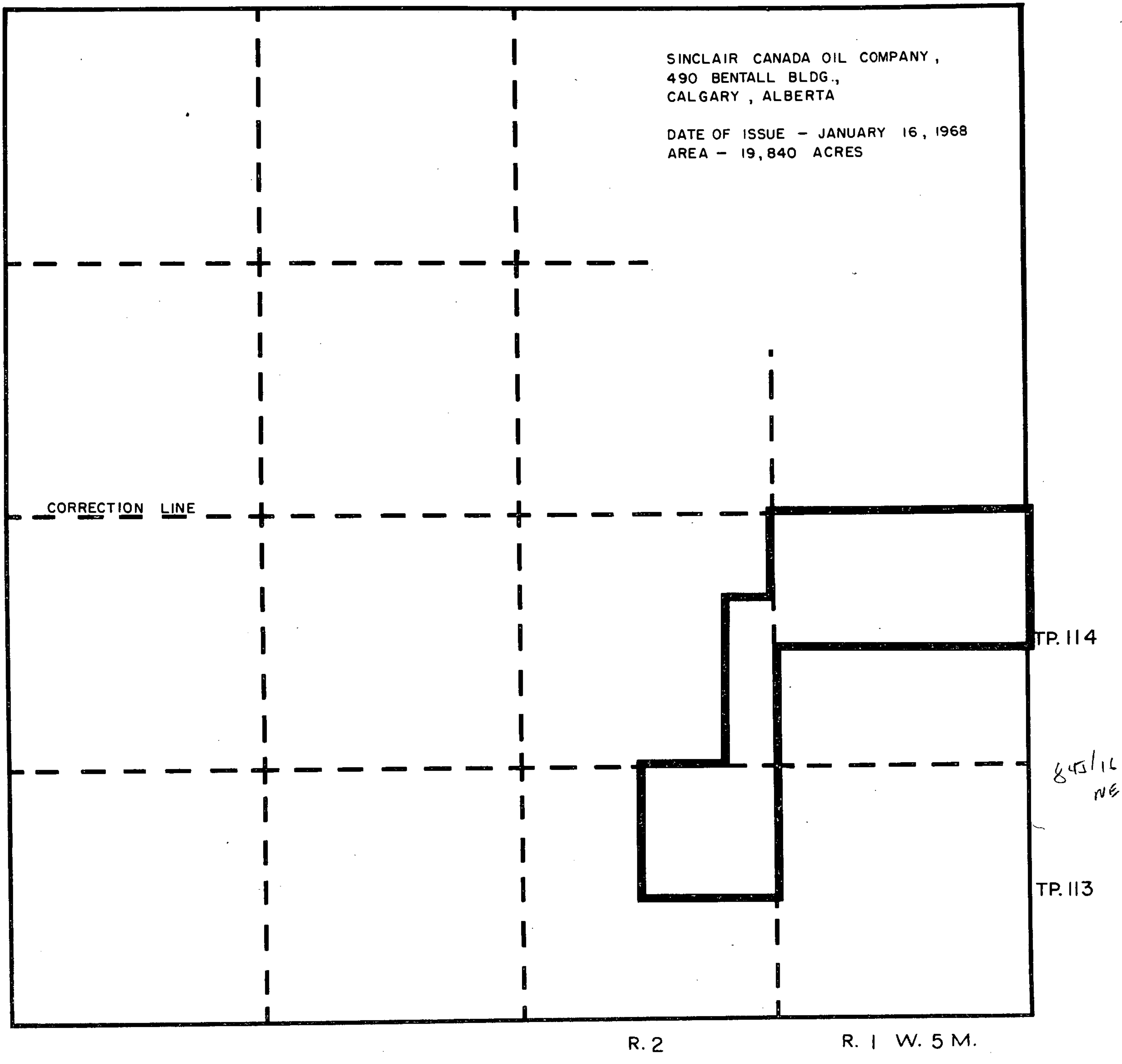
Plate 13

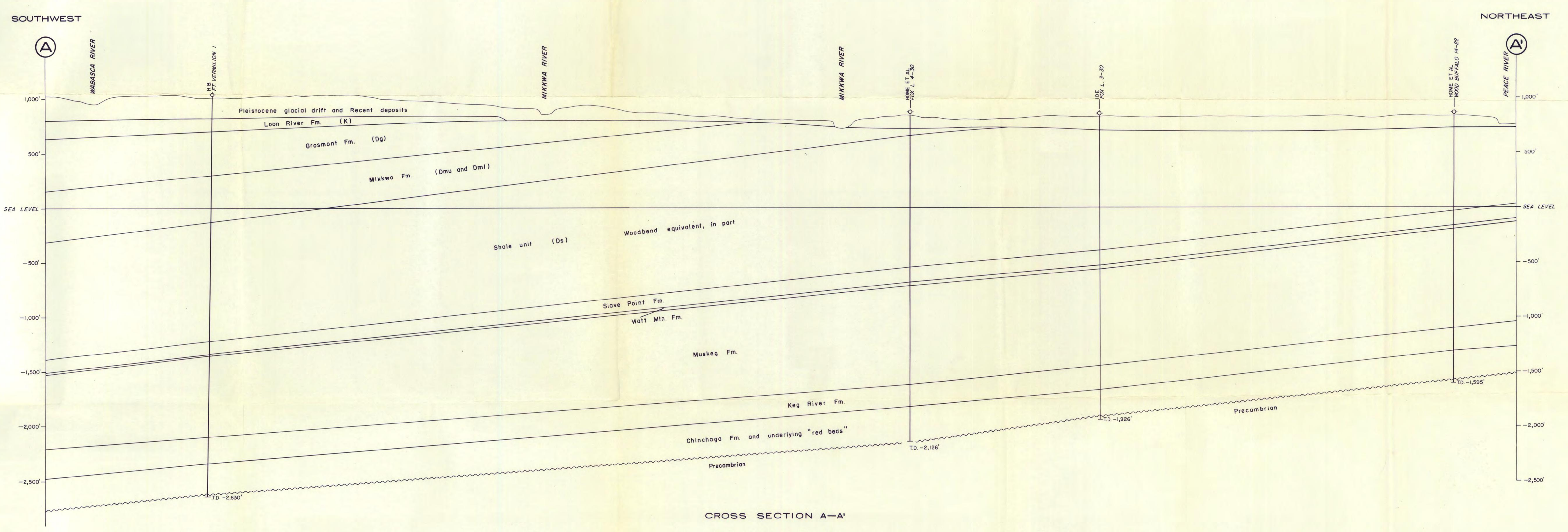
Sulphurous springs (right middle-ground of Plate 12), sec. 2, Tp. 106, R.3 W5M. View southeast, Field Station 10C.

Plate 14

Sulphurous springs (foreground of Plate 12), Tp. 106, R.3 W5M, Field Station 9C.

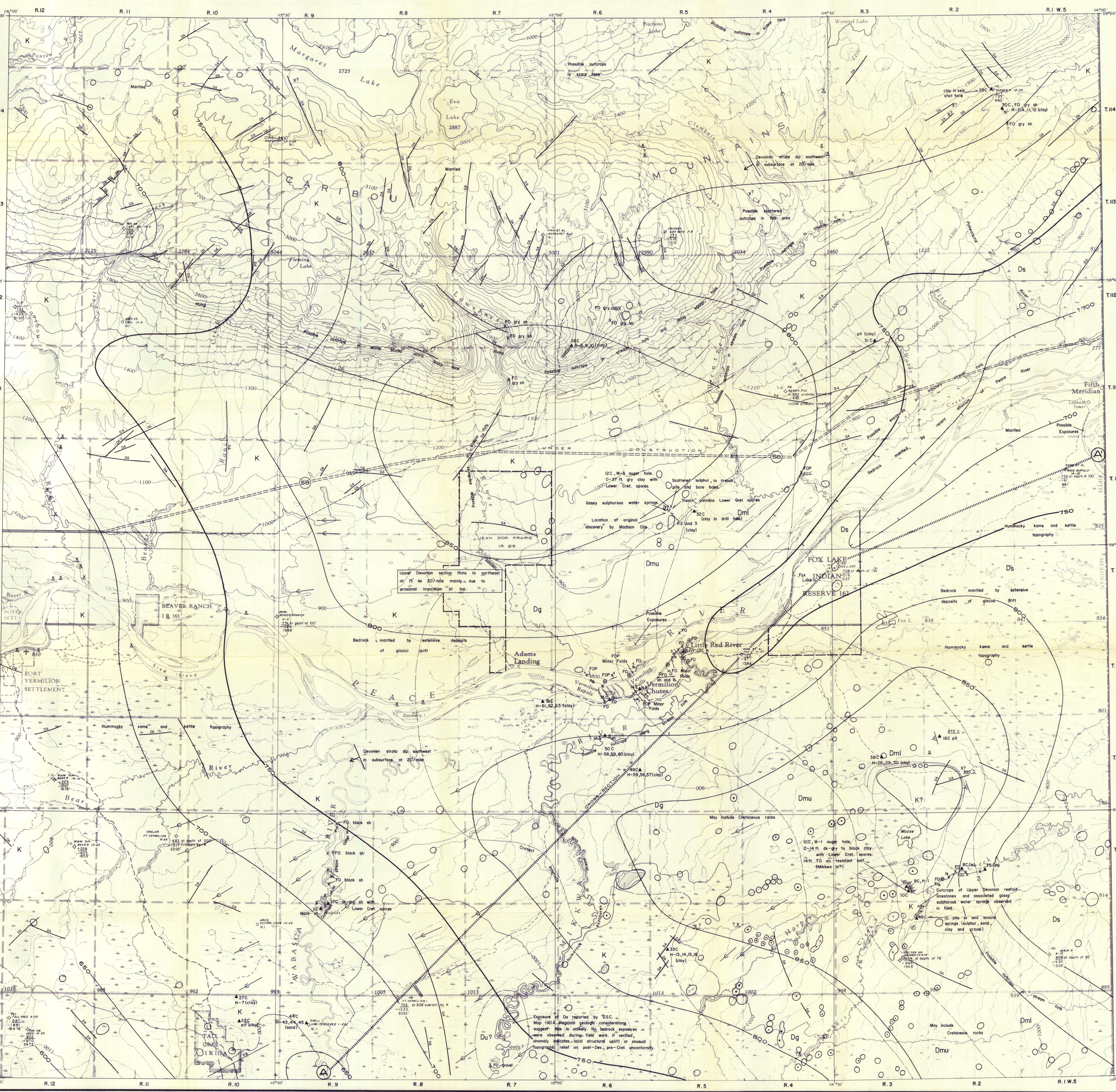
SULPHUR PROSPECTING PERMIT No. 100





CROSS SECTION A–A'

VERTICAL SCALE: I INCH TO 400 FEET
HORIZONTAL SCALE: I INCH TO 2 MILES



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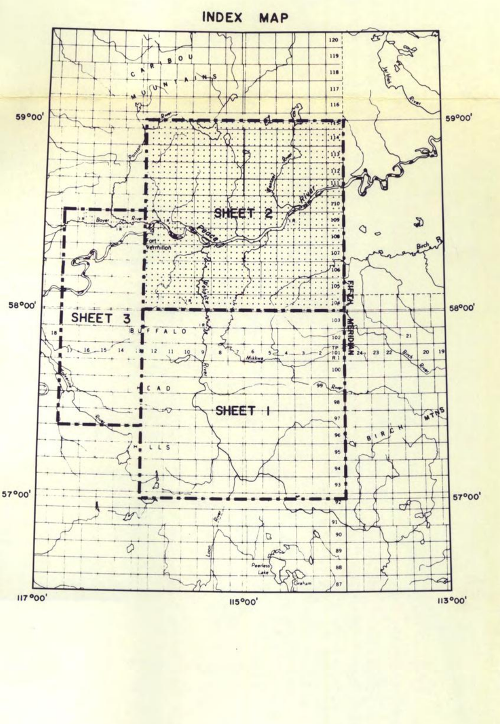


FORMATIONS

CRETACEOUS	K	Loon River and younger; shale and sandstone.
UPPER DEVONIAN	Du	Upper Devonian undivided; (may be Cretaceous)
	Dg	Grosmont: dolomite.
	Dmu	Mikkwa, upper member: limestone and shale.
	Dml	Mikkwa, lower member: limestone.
	Ds	Shale unit: calcareous shale.

GEOLOGICAL SYMBOLS

10	Field observed dip; V. Zay Smith Associates, 1968.
FOP	Field observed published dip.
⊕	Horizontal bedding.
	Gentle dip based on geomorphic evidence.
FO	Field observed.
DA	Distinct alignment.
	Glacial lineation indicating direction of ice-movement.
	Shore line.
	Formational contact.
X	Bedrock outcrop.
X	Exposure of surficial deposits.
▲13C	Field station number, may be outcrop or site of auger hole.
H-15	Auger hole drilled with Haynes portable power drill.
W-1	Auger hole drilled with Winkie portable power drill.
	Active gassy sulphurous salt water spring associated with surficial sulphur deposit.
	Possible active or inactive spring; interpreted from air photographs. No associated sulphur observed during field work.
	Surficial anomaly interpreted from air photographs. No associated sulphur observed during field work.
+808	Structural elevation of Paleozoic bedrock surface.
-684	Structural elevation of top of Elk Point Group (Watt Mountain Formation).
1548'	Thickness of Devonian section preserved above Elk Point Group.
N.I.	No Information.
I.U.	Information Uncertain.
I.D.	Insufficient Depth.
A–A'	Cross Section.
950	Structural contour on Paleozoic surface. Contour interval: 50'.

TOPOGRAPHICAL SYMBOLS

-----	Road or trail
□	Town
o	Village or settlement
	Lake
	River
	Stream
	Muskeg
1900	Elevation contours

AREAL GEOLOGIC MAP

OF THE

FORT VERMILION AREA

ALBERTA

SHOWING CONFIGURATION OF

PALEOZOIC BEDROCK SURFACE

SCALE: I INCH TO 2 MILES

Miles 2 1 0 2 4 6 Miles

Note: Well data as of March 1.

— Prepared by —

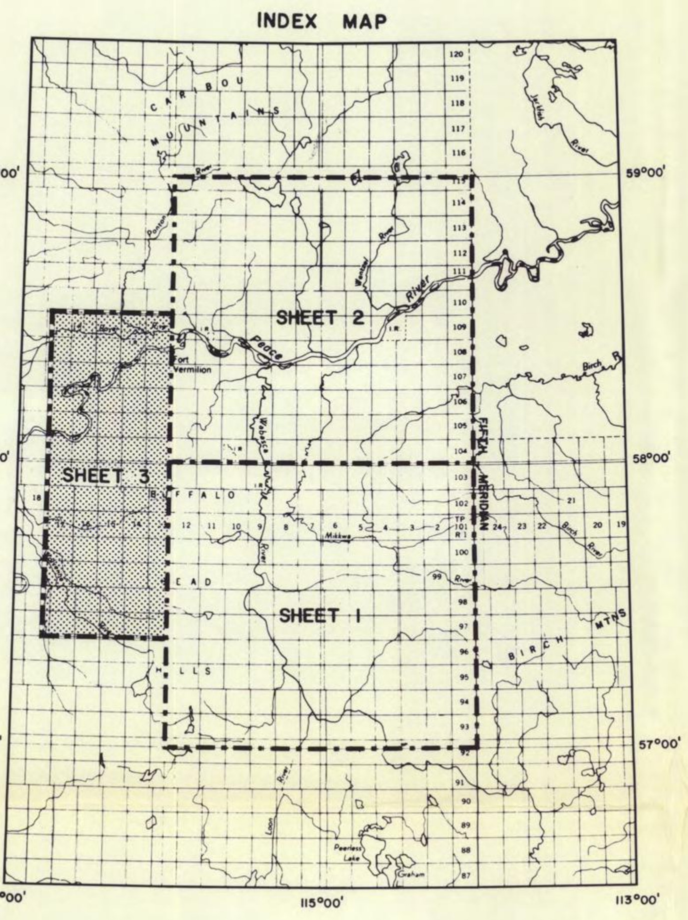
V. ZAY SMITH ASSOCIATES LTD.

1968

SHEET 2

19680090

INDEX MAP



LEGEND

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AREAL GEOLOGIC MAP
OF THE
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ALBERTA

SCALE: 1 INCH TO 2 MILES

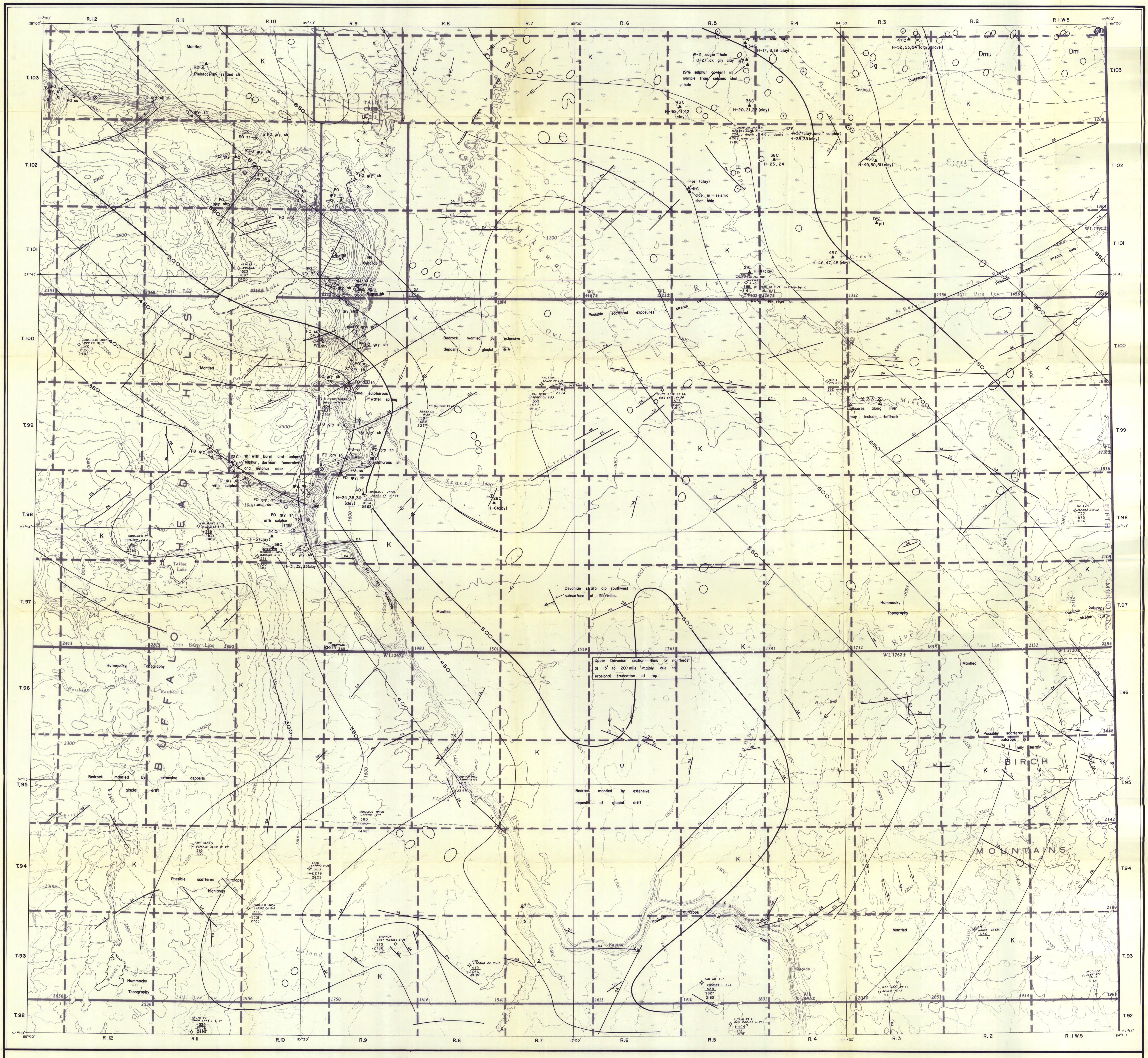
Miles 2 1 0 2 4 6 Miles

Note: Well data as of March 1.

— Prepared by —
V. ZAY SMITH ASSOCIATES LTD.
1968

SHEET 3

19680090



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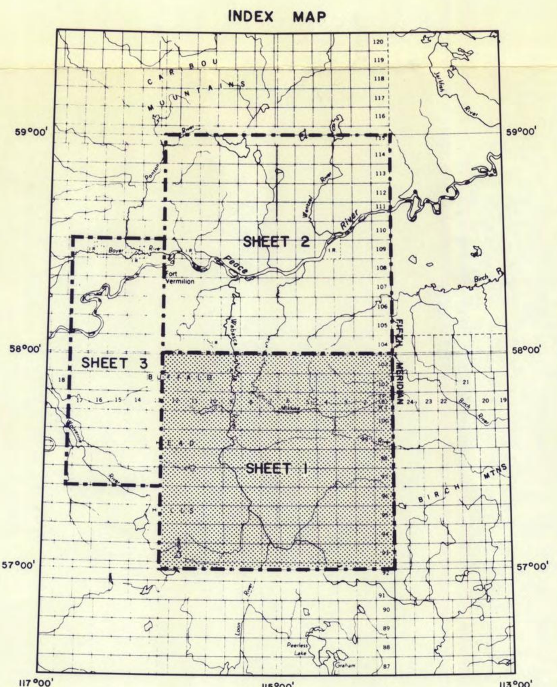

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SHOWING CONFIGURATION OF

PALEOZOIC BEDROCK SURFACE

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Miles 2 1 0 2 4 6 Miles

Note: Well data as of March 1.

— Prepared by —

V. ZAY SMITH ASSOCIATES LTD.

1968

SHEET 1