DEPARTMENT OF ENERGY, MINES AND RESOURCES

Geological Survey of Canada

# REPORT ON RUMPEL LAKE

# STRATIGRAPHIC TEST, SASKATCHEWAN

per

W.F. Fahrig

OPEN FILE 668

January 1980
OTTAWA, Canada

GULF MINERALS COMPANY

ATHABASCA FORMATION
RUMPEL LAKE STRATIGRAPHIC TEST
LITHOLOGIC DESCRIPTION

by M. M. Lerand January 22, 1970

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Calgary, Alberta, Canada

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## TABLE OF CONTENTS



## ILLUSTRATIONS

## ABSTRACT

The Athabasca Formation of middle Proterozoic age is an unmetamorphosed, cross-bedded, pure quartz sandstone occupying an oval, 38,000 square mile basin, more than 5,000 feet deep, in northern Saskatchewan.

In 1968 Gulf Minerals continuously cored 4,776 feet of the Athabasca Formation and 340 feet of underlying basement near the basin centre, at Rumpel Lake, where the formation consists of two members. The Upper Member, 1,408 feet thick, is a well stratified, predominantly medium-grained, largely clay-cemented, purple, maroon and white, pure quartz sandstone containing less than 5% shale-siltstone. Cross-bedding and a strong textural lamination are characteristic. All clays are composed of illite and chlorite. Glauconite, altered to illite, and detrital green mica, as well as tourmaline, are the main accessories. The member was probably deposited in beach, barrier, lagoon and near-shore marine environments. The Lower Member, 3,368 feet thick, is a massive, pink and purple banded, cross-bedded, pure quartz sandstone with 24-foot thick basal conglomeratic zone. It possesses a strong textural lamination, is poorly sorted, has poor porosity and is very hard. The average grain size increases from medium-coarse at the top to very coarse at the base. Granules and small pebbles increase in quantity with depth. The sand is cemented with quartz, and clay composed of illite and kaolinite. Intraformational clay pebbles are common, and heavy minerals include tourmaline with zircon and magnetite at the base. The member was deposited in a fluviatile environment. The upper contact may represent a brief hiatus, and the lower contact is a major unconformity.

Underlying the Athabasca at Rumpel Lake is a six-foot thick, red-maroon, clay regolith that represents the intense, *in situ*, chemical weathered zone at the top of the granitic basement complex.

Locally the Athabasca is overlain, probably conformably, by the Carswell dolomite, and below, but nowhere in mutual contact is the thick, arkosic Martin redbed succession.

# ATHABASCA FORMATION

# RUMPEL LAKE STRATIGRAPHIC TEST

# LITHOLOGIC DESCRIPTION

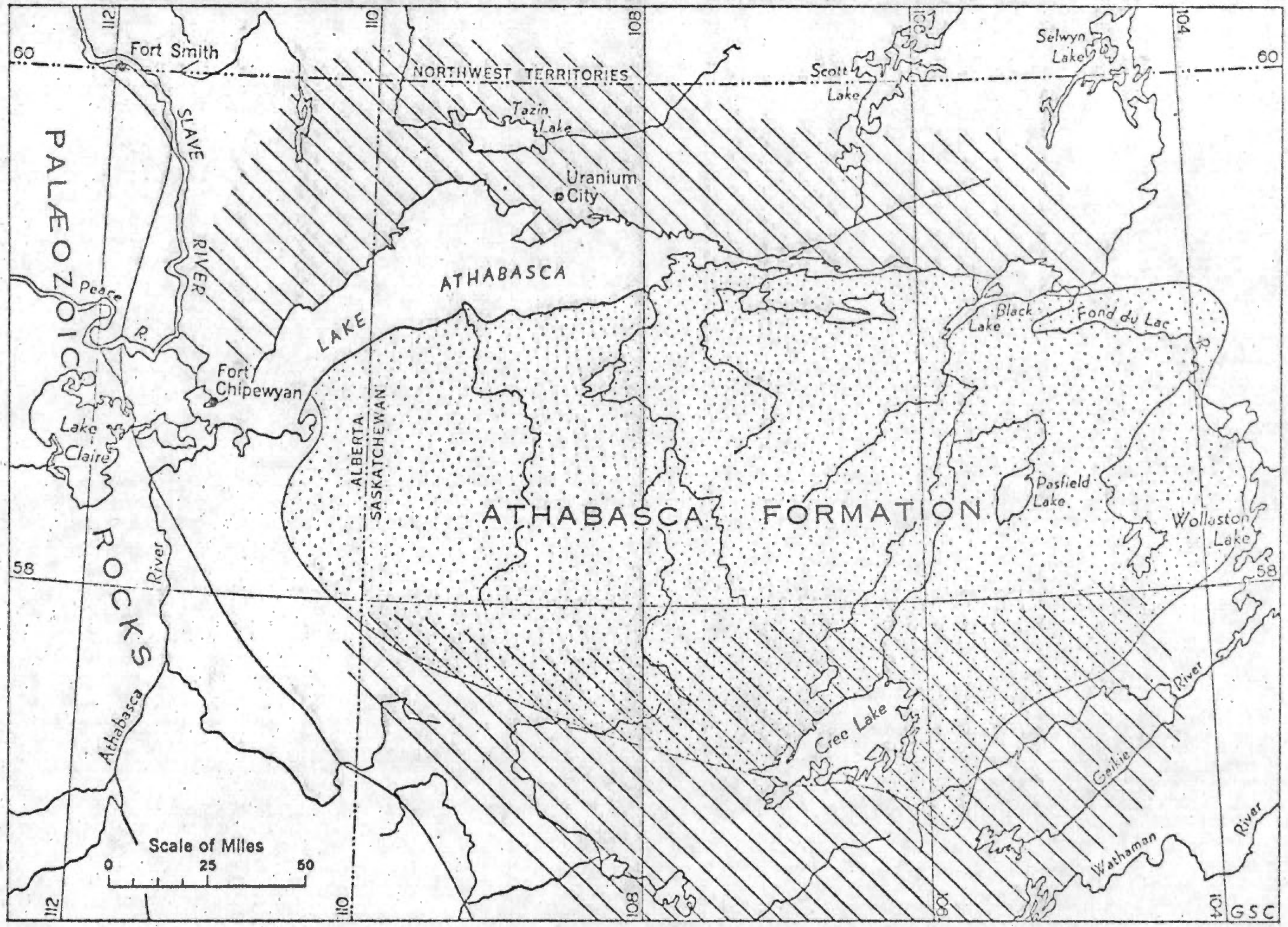
## INTRODUCTION

The Athabasca Formation, composed almost entirely of quartz sandstone roughly 5,000 feet in thickness, occupies an oval-shaped basin covering about 38,000 square miles in northwestern Saskatchewan (Figs. 1, 2). The unmetamorphosed and almost undeformed character of the formation render it indistinguishable from Phanerozoic strata, however, the mid-Proterozoic age of the Athabasca is confirmed from K-Ar isotope determinations and its place in the geologic history of the Canadian Shield is well established.

Since uranium was discovered in the Beaverlodge area in 1935 and minor secondary mineralization in the Athabasca Formation in 1951, the Athabasca sandstones have been regarded as an unlikely but possible source of uranium. Analogy between the Athabasca Formation and the Blind River and Colorado Plateau deposits have been obvious, but it was not until 1968 that the analogy was tested by Gulf Minerals.

### Purpose of the Report

One of the diamond core holes drilled into the Athabasca Formation by Gulf Minerals in 1968 was a unique stratigraphic test near the middle of the basin, that continuously cored 4,776 feet of Athabasca




(Zones of post-Athabasca positive movement (shown by ruling) relative to an intervening zone.)

DISTRIBUTION OF THE ATHABASCA FM. from Fahrig 1961

FIGURE 2

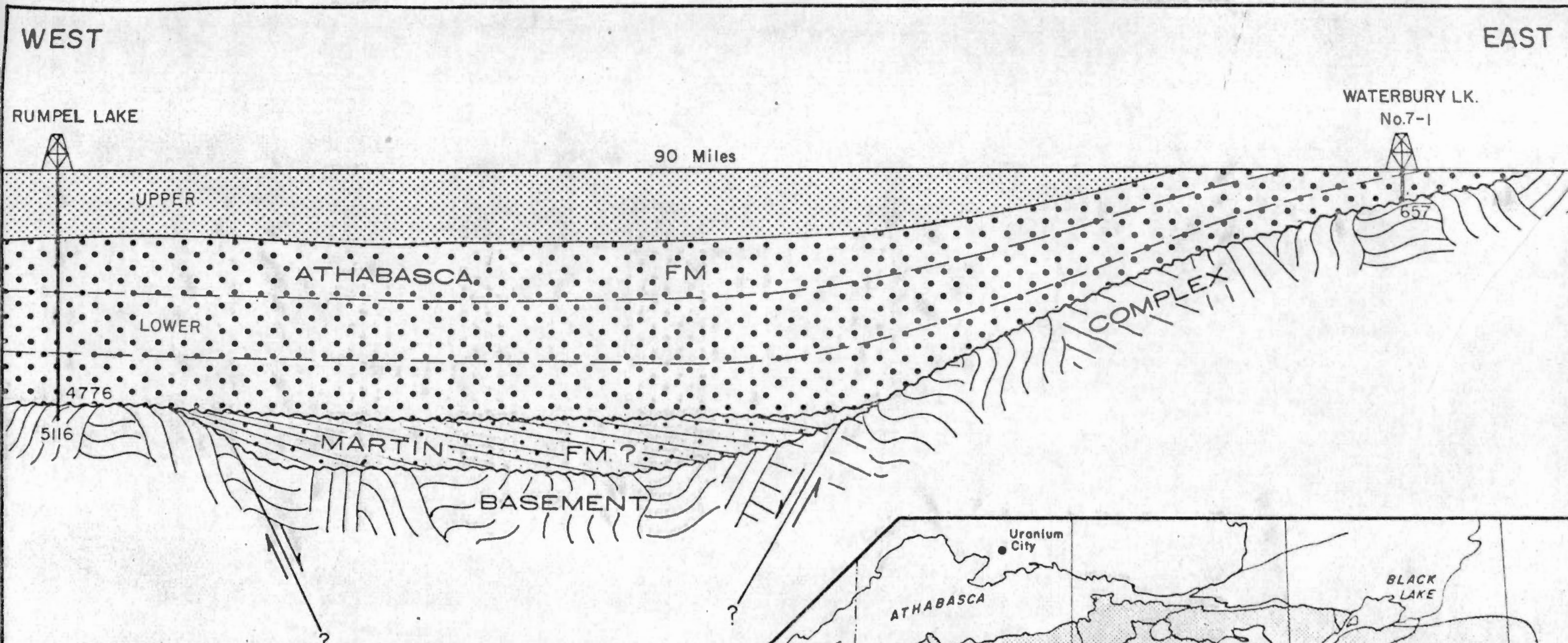
sandstone and 340 feet of basement rock. This cored hole is located at Rumpel Lake, which is about fifty miles north of Cree Lake and thirty-nine miles west of the south end of Pasfield Lake (Figs. 2, 3). The petrographic study of this core forms the basis for this report.

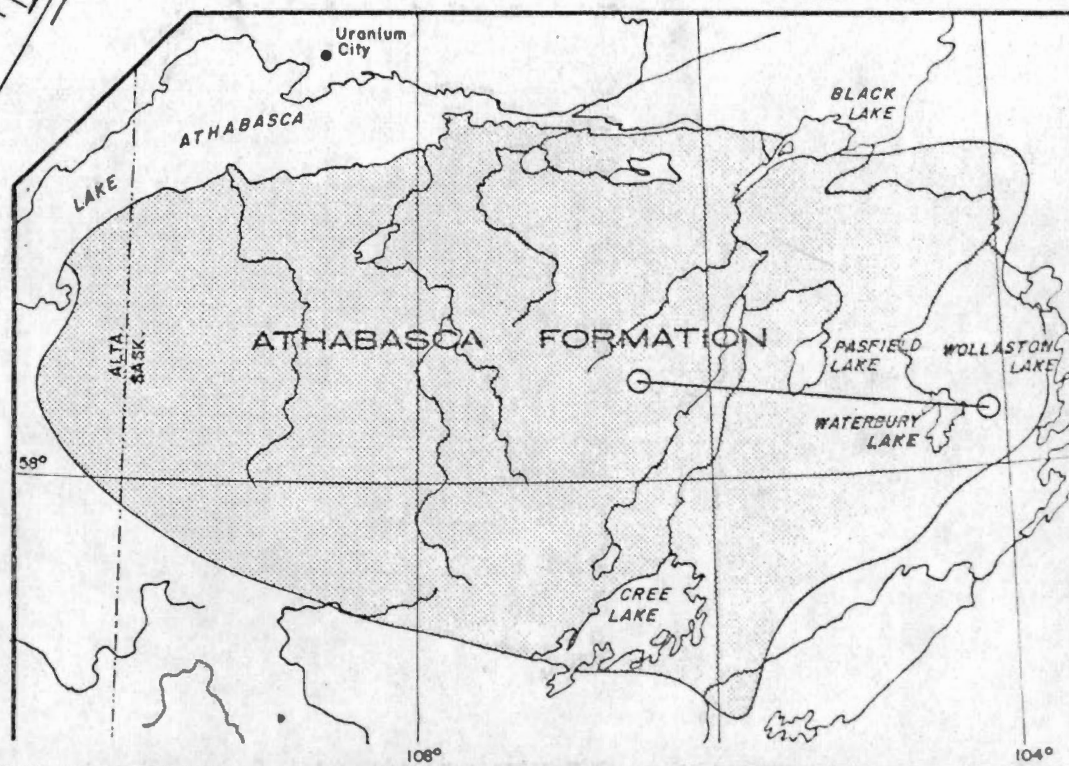
## Method of Study

The study was begun with the initial description of the Rumpel Lake core, during mid-September, at the Saskatchewan Department of Mineral Resources Precambrian Geology Laboratory in La Ronge. Spot samples were taken and examined in greater detail later. The core description (Appendix I) is based solely upon visual and binocular examination. It is stressed that this study is of a semi-detailed nature only, and much greater detail, both qualitative and quantitative, could be achieved if a lengthy mineralogical and thin section analysis was performed.

In order to determine the clay mineralogy of sandstone pore fillings and intercalated shales, eighty-one samples were analyzed with the X-Ray Diffractometer, the results of which appear in Appendix II and Table IV.

Mineral identifications of three samples were made by Dr. G. B. Mellon, Research Council of Alberta.




SCHEMATIC CROSS-SECTION
OF
ATHABASCA FM.

RUMPEL LAKE – WATERBURY LAKE

HORIZONTAL 1" = 10 miles VERTICAL 1" = 3000 feet

——— INFERRED TIME LINES

FIGURE 3

## STRATIGRAPHY

The stratigraphic relationships of unmetamorphosed sedimentary rocks above the metamorphic and igneous basement complex in the Lake Athabasca area are difficult to determine and for many years a number of divergent views have been held. Three stratal units are involved: the thick, deformed, arkosic, redbed succession with intercalated basalt flows north of Lake Athabasca at Tazin and Beaverlodge Lakes; the widespread, essentially flat-lying, blanket-like quartz sandstone succession south and southeast of Lake Athabasca; and, the small circular body of dolomite at Carswell Lake south of Lake Athabasca.

In his study of the sandstone succession south of Lake Athabasca Fahrig (1961) proposed a partly new terminology (Table I), which appears to be the most reasonable interpretation yet propounded. He suggested the following usage of formation names: Martin Formation for the redbed succession north of Lake Athabasca; Athabasca Formation for the flat-lying quartz sandstone succession south of the lake; and, Carswell Formation for dolomite locally lying above the Athabasca Formation. He suggested that the Martin is the oldest and the Carswell the youngest of the triad. This terminology and relative age relationship is followed in the present report. For a lithologic description of the Martin Formation the reader is referred to Christie (1953, p. 48), and for the Carswell Formation to Blake (1956, p. 5), Fahrig (1961, p. 18), and Currie (1969).

TABLE I

# TABLE OF FORMATIONS *

| EON | ERA | SUB-ERA | FORMATION | LITHOLOGY |
|---|---|---|---|---|
| PHANEROZOIC | QUATERNARY | | | PLEISTOCENE AND RECENT SAND, GRAVEL, DRIFT. |
| PROTEROZOIC | HADRYNIAN | | | |
| | HELIKIAN | NEOHELIKIAN | | |
| | | PALAEOHELIKIAN | CARSWELL FM. | DOLOMITE; ? CHERTY, STROM; MARINE |
| | | | ATHABASCA FM. UP. | PURPLE-RED-WHITE QTZ. SS.; MARINE |
| | | | ATHABASCA FM. LOW. | PINK-PURPLE QUARTZ SS.; FLUVIAL |
| | | | MARTIN FM. | ARKOSE, REDBEDS; BASALT; NONMARINE |
| | APHEBIAN | | TAZIN GROUP | METAMORPHIC AND IGNEOUS ROCKS OF HUDSONIAN OROGEN COMPRISE BASEMENT COMPLEX |
| ARCHAEAN | | | | |

* AFTER FAHRIG 1961

## PETROGRAPHY

The Athabasca Formation was studied by Fahrig (1961) whose excellent report provides the essential foundation upon which all other detailed studies can be based. In order to put the Rumpel Lake core in its proper context with regard to the Athabasca Formation as a whole, a summary of the lithology as found in Fahrig (1961) is given below.

### Description of the Athabasca Formation

The formation consists of sandstone with some interbeds of conglomerate, and very minor shale and siltstone beds generally less than one foot thick. Grit and conglomerate beds total about two per cent of the formation; shale and siltstone amount to less than one per cent of the total section.

About half the particles in the sandstones are coarse and very coarse sand. Interbedding of finer and coarser grained sand occurs throughout. Granules and pebbles are rare in the upper part but occur in considerable amounts in the lower part. Cobbles and boulders are lacking except locally in the basal few feet. Shale chip fragments are common throughout the basin and are mainly cream coloured but some are maroon. Locally they form an almost continuous pavement.

The most common colours are light buff, grey, white, cream and various combinations and mixtures of these. Light to dark purplish and pink, red and maroon are also common. Most reddish colours result from hematite staining and much cuts across primary stratification. Much of the hematite stain has been removed as a result of selective reduction.

Potash feldspar is present in negligible amounts and the sandstones are composed almost entirely of quartz with a little chert. The quartz is strongly undulose and strained quartz of metamorphic origin is more abundant than unstrained igneous quartz. Heavy minerals occur in very small amounts, and tourmaline and zircon are the only non-opaques occurring in significant amounts. Both are well rounded and the tourmaline grains typically exhibit clear authigenic overgrowths.

The pebbles, most of which are less than 2 cm. long, the largest being 6-7 cm., are composed mostly of quartz and chert, but some feldspar, granite, gneiss, quartzite and greenstone were identified in the basal part where cobbles and boulders occur.

Cross-bedding is the most prominent sedimentary structure and ripple marks are common. Many pebbles have a preferred orientation parallel with the direction of sediment transport shown by cross-bedding azimuths.

The Athabasca sediments possess many features typical of fluviatile deposits such as: consistent and widespread cross-bedding; overturned cross-bedding; rain-prints; dessication cracks; shale chip fragments; poor sorting and strong textural lamination. The sediment, which was derived from the east and southeast with a minor contribution from the northeast, was probably deposited on a coastal plain onto which rivers converged towards the sea.

In the Black Lake area the Athabasca sandstones are involved in folding and faulting. Post-depositional basement adjustments titled the strata and created dips as high as 25 degrees in local parts of the basin. Diabase dykes cut the sandstone at a number of localities.

The Athabasca rests with major unconformity on older rocks. At some points, probably depending on the composition of the Archean rocks, a regolith is developed. Locally the Athabasca rests on intensely weathered gneiss, and at other localities it rests on Tazin quartzite, where a basal breccia of angular quartzite boulders occurs while at other places only fine conglomerate and sandstone are found.

Fahrig (1961) concluded that because of the high degree of mineralogical maturity of the light and heavy mineral fractions, high degree of roundness, and presence of chert, that the Athabasca was a multicycle sediment derived from a largely sedimentary terrain.

## Description of the Rumpel Lake Core

The Athabasca Formation at Rumpel Lake consists of two sandstone members of contrasting thickness, stratification, colour, and clay mineralogy. The Upper Member, 1,408 feet thick, consists of a series of maroon, purple and white sandstone beds of varying grain size, sorting and texture from one foot to more than 200 feet thick. Interbedded siltstone and shale account for less than five per cent of the total section and conglomerate is absent. The Lower Member consists essentially of a single, uniform, cross-bedded sandstone unit 3,368 feet thick in which siltstone and shale occur in negligible amounts and a thin pebble conglomerate occurs at the base. A detailed description of the core is included in Appendix I and this data is graphically illustrated in Table II (lithologic log in back pocket), and summarized in Table III. The following description is a general summary.

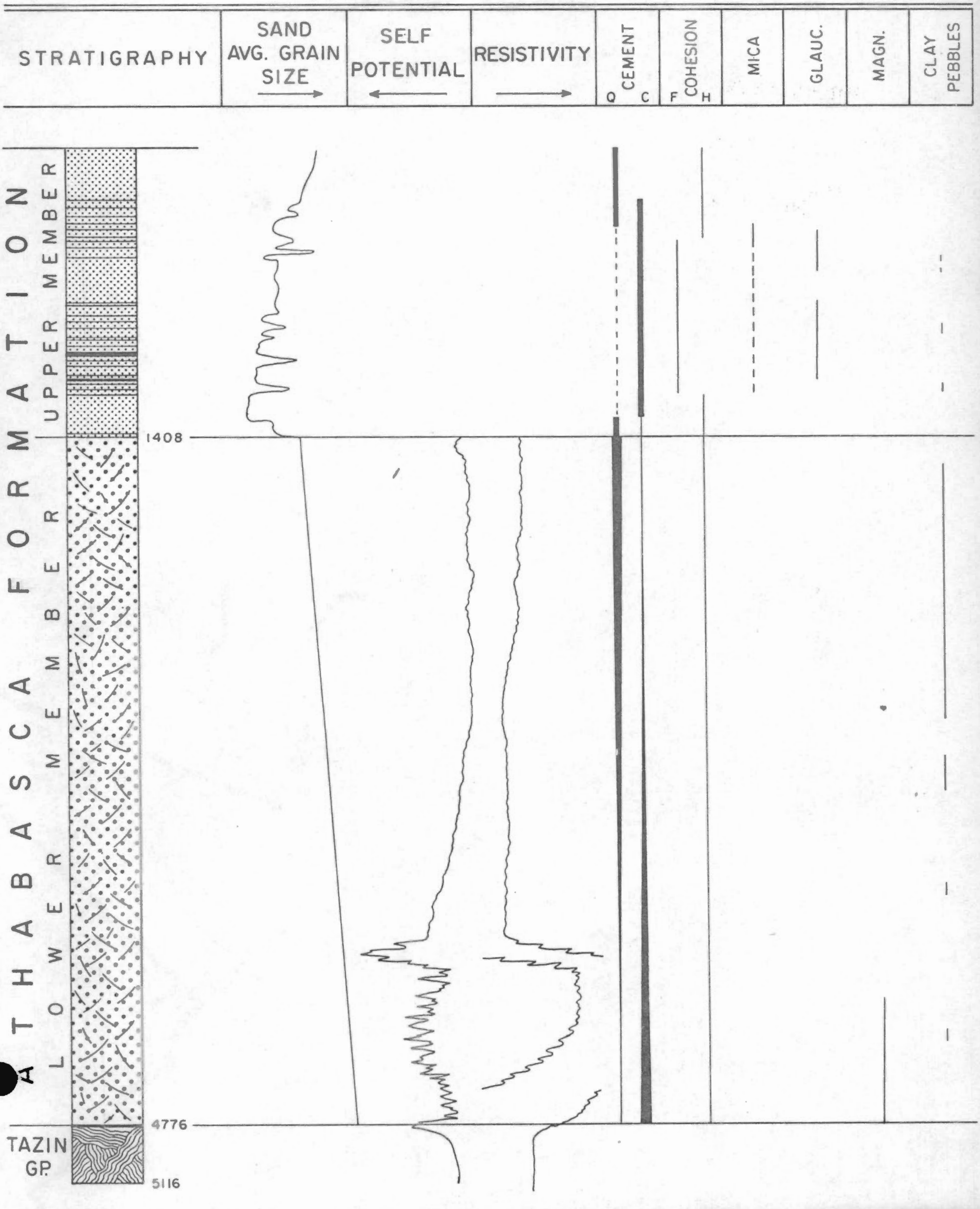
### Upper Member

Thickness: 1,408 feet

TABLE III

SUMMARY OF PETROLOGY

RUMPEL LAKE CORE



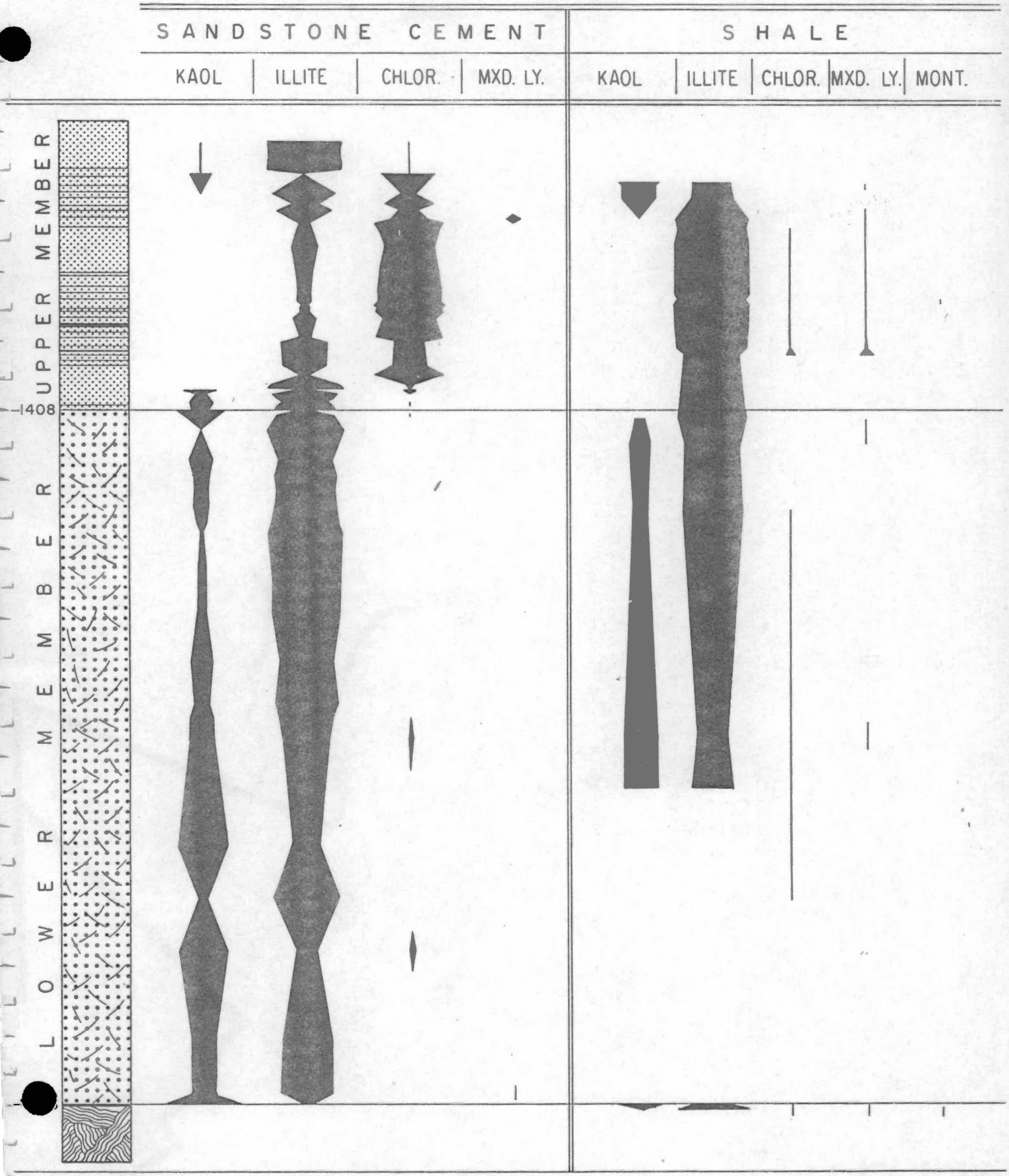
Gross Lithology: The member consists almost entirely of sandstone of varying grain size, texture, cement and colour. Conglomerate and carbonates are both absent, but there are a number of shale and siltstone beds that range in thickness from a fraction of an inch up to beds several feet thick, the largest being a silty and sandy shale unit 14 feet thick. The total combined thickness of individual laminae and beds of shale is roughly forty-two feet and that of siltstone is twenty feet.

Composition: Although no detailed mineralogical analysis was made of the sandstone it appears from the work of Fahrig (1961), and the study of three representative thin sections in connection with the clay analysis by G. B. Mellon (personal communication), that the sand fraction is composed almost entirely of quartz with minor amounts of chert and virtually no feldspar. The shales are composed almost entirely of illite, with very minor amounts of chlorite and mixed-layer clays (Appendix II; Table IV). Within the upper 400 feet, however, the shales are composed of roughly equal amounts of illite and kaolinite.

Colour: The sandstones are purple, maroon and white, and shades of purple and maroon range between pale and dark. Purple colours probably result from very finely crystalline specular hematite whereas the maroon colours result from a stain of hematite on the grains or in the clay cement. The colours typically alternate in bands that range from a fraction of an inch up to several inches and which are characterizied by extremely sharp contacts. All combinations of purple, maroon and white bands occur. Most bands are regular and uniform, but many, especially those coloured purple, are irregular bands, lenses, mottles and patches with boundaries that cut across the primary stratification. The unit is coloured by alternating zones up to several tens of feet thick, each

TABLE IV

# CLAY MINERALOGY OF THE ATHABASCA FORMATION



zone characterized by a particular colour combination. Some sandstones are white and lack iron pigments altogether, but these account for only 16 per cent below the uppermost 150 foot white zone. This relatively thick zone may reflect bleaching and removal of all iron oxides by surface waters.

Fine pale green to pale maroon speckles, due to bleaching of maroon hematite stain from around green mica grains, is a distinctive feature that occurs in two zones, 390-523 feet and 847-1149 feet below the top.

The shales and siltstones are predominantly maroon but some are coloured by alternating maroon and green laminae and a few are entirely green.

<u>Cement</u>: The principle bonding agent of the sandstone is a snow-white, fine to coarsely crystalline, largely secondary clay cement. The only other bonding material noted was quartz, in the form of secondary overgrowths, and except in the uppermost 247 feet and lowermost 85 feet, is much subordinate to clay. In the middle part of the member laminae and thin zones cemented mainly by quartz are fairly common.

Thirty-six sandstone samples were analyzed with the X-Ray Diffractometer to determine the clay mineralogy of the pore fillings, the results of which are shown graphically in Table IV and tabulated in Appendix II. These data show that the clay material consists of chlorite and illite, in all but the upermost and lowermost parts where illite and kaolinite comprise virtually all of the material.

Dr. G. B. Mellon, Research Council of Alberta, prepared thin sections of three sandstones (422', 525', 900') and also made an x-ray analysis of the clay constituents. His brief study (personal communication) confirmed that illite and chlorite were the two minerals comprising the pore fillings in the middle part of the member. In addition, he suggested that the clay is distributed in the sandstone in two ways:

1) As large patches and lenses a few millimeters thick of detrital matrix composed of illite, presumably of clastic origin;

2) As authigenic pore fillings composed of illite and chlorite.

The detrital matrix consists of unoriented to partly micromicaceous illite. The authigenic pore fillings include needle-like platelets of an illite-chlorite mixture, fibrous nearly colourless chlorite, and fibrous inward-growing illite.

Hardness: About half the sandstones are sub-friable to friable, and half are moderately hard. In general, cementation by soft clay produces a weak bond and sand grains pluck out readily, thereby producing a friable sandstone. In contrast, even a small amount of quartz cement at grain contacts effects a bond of considerable strength and a firm, compact sandstone. Even though some sandstones appear to be completely cemented by clay, traces of secondary quartz are present and the rock is not friable.

The uppermost 400 feet and lowermost 200 feet are moderately hard and non-friable. The remainder is predominantly sub-friable except for some relatively thin beds. In those parts where clay- and quartz-cemented laminae occur, some of the quartzitic zones are very hard.

Porosity: The porosity is highly variable throughout the section, and all degrees from mere traces to very high porosity exist. In general, the white clay cement is so abundant as to essentially destroy most porosity, however, the member is characterized by alternating tight and porous laminae which imparts to the member as a whole a fairly high porosity. In spite of the ubiquitous clay cement many of the sandstones are completely cemented by clay and commonly the friable sands are very porous, both in thin laminae and thicker zones inches of feet thick.

Grain Size: All sand grades are present in the member and a high degree of variability in adjacent zones is characteristic. The most common size grades are fine, medium to coarse sand, and probably the single most abundant grade is medium sand. Granules are uncommon but do occur in some of the coarsest laminae.

A very strong textural lamination is typical of the member, especially in the thicker units. These consist of alternating laminae of contrasting grain size and sorting such that it becomes difficult to describe the unit except in general terms. All combinations of grain size and sorting may be observed in the individual laminae. In addition to the laminae, zones of uniform grain size and texture measured in inches and feet also alternate throughout. The coarsest grained part of the member comprises the uppermost approximately 150 feet, which is coarse- and very coarse-grained with scattered medium sand and some granules.

Sorting: Sorting, like the grain size, is highly variable due to the strong textural lamination. Individual laminae are commonly well sorted, but all degrees of sorting through to distinctly bimodal are also common. Some units are well sorted and lack textural lamination, but many are rather poorly sorted when all size grades present are considered. Perhaps the overall sorting of the member could be classed as moderate.

Roundness: Most of the grains appear to be rounded to well rounded though a detailed analysis was not made. Secondary quartz overgrowths destroy the roundness of grains in the quartzitic parts. Frosting of the grains was not observed, in fact, a good polish seems characteristic.

Accessory Grains: The two most distinctive accessories are detrital green mica (or biotite) and pale green clay grains. Detrital green mica occurs in certain units throughout the middle part of the member, but is most abundant in a one-hundred-foot zone between 390 and 496 feet. The grains are found in all lithologies, and in shales they possess a strong preferred orientation parallel to the stratification. The grains are only a few flakes thick and are highly rounded in plan view. Almost invariably the grains are surrounded by a white or pale, bleached halo within which the hematite staining the enclosing rock maroon, has been apparently bleached by reduction. It seems that through chemical alteration the mica grains lose their iron content, for they appear to become colourless and transparent in the white sandstones.

Detrital clay grains occur in the middle part of the member and are represented by two floods centered around the 500 and 950 foot levels respectively. These grains, of sand size, are pale apple green, highly rounded, smooth-surfaced and very soft. They show little evidence of crushing except for small pits made by the enclosing quartz grains. Commonly they exhibit a "cleavage" or "parting" that resembles books of mica. The grains appear to be pure clay and are totally devoid of silt. The origin of these grains may be complex, for they could be either detrital shale fragments, altered glauconite, or in situ secondary alteration products of some detrital grain.

A thin section and x-ray analysis of these detrital clay grains was made by Dr. G. B. Mellon, Research Council of Alberta, who identified the material comprising the grains as illite and identical in appearance to the patches of micromicaceous illite comprising the enclosing matrix (personal communication). Apparently all gradations exist between relatively fresh biotite (the green mica mentioned above), through subequant, bleached, pale green-brown grains, to pale brown ovoid grains composed of partly oriented micromicaceous illite aggregates which tend to be concentrated along certain laminae like the mica. These clay grains are identical in all respects to glauconite except for their light green colour. Similar series of grains showing all gradations between biotite and rounded glauconite composed of illite have been observed by Dr. Mellon in Lower Cretaceous rocks of northeastern Alberta.

Dr. Mellon believes that in some manner unaltered biotite was first, in the glauconitization process, expanded, then abraded and rounded, converted to glauconite, and finally altered to illite.

Tourmaline and zircon are the only non-opaque heavy minerals present in significant amounts (Fahrig 1961); Gravenor (1959) reported that tourmaline is the major non-opaque mineral, along with minor amounts of zircon and monazite, with traces of rutile, garnet and biotite. Very fine and fine, well rounded, green and brown varieties of tourmaline were the only grains observed by the writer.

The only pyrite observed occurs as tiny crystals that form irregular-shaped patches on some fracture surfaces between 269 - 285 feet below the top.

Structures: Probably every sandstone bed is cross-stratified. In some beds cross-stratification is indicated by inclined laminae and angular truncations, but in many parts it is not obvious, probably through lack of contrast in the textural elements.

Intraformational pebbles composed of white, soft, chalky clay occur in only three thin zones. The pebbles are sub-rounded and up to about two inches in length.

Radioactivity: No radioactivity above normal background was noted in this member.

Contact: The lower content is drawn at the base of a purple, clay-cemented, fine-grained sandstone which seems to mark the base of a rather heterogeneous well stratified sandstone succession that differs significantly from a more uniform division below. No obvious unconformity was observed, and indeed, at the time of logging the core, it appeared to be conformable and somewhat arbitrary. It is possible, however, that a period of non-deposition, and perhaps even erosion, could have intervened between deposition of the two members because:

1) The clay mineralogy is significantly different between the two members;
2) The Upper Member is probably mostly marine and the Lower Member is probably all nonmarine;
3) The upper 400 feet of the Lower Member is white, similar to the uppermost part of the Upper Member, suggesting a Precambrian interval of subaerial weathering removed the iron from the otherwise pink and purple sandstone.

Beyond these observations, no direct evidence of a discontinuity between the two members is at present available.

Lower Member

Thickness: 3,368 feet

Gross Lithology: This member consists almost entirely of cross-stratified sandstone, and indeed is almost a single massive unit. At the base is 24 feet of conglomerate and conglomeratic sandstone with intercalated sandstone. The total combined thickness of thin shale and argillaceous siltstone laminae, which are mostly less than one inch thick, is about one and one-half feet.

Composition: The sand and pebbles appear to consist almost entirely of quartz and probably minor amounts of chert are present (see Fahrig, 1961). Although a detailed mineralogical study was not made, quartz was the only component observed in the basal conglomerate.

The shale and argillaceous siltstone partings are composed mainly of illite with subordinate amounts of kaolinite, and very minor amounts of chlorite and mixed-layer clays (Appendix II; Table IV).

Colour: Almost the entire member consists of a remarkable series of alternating purple and pink bands each ranging from less than one inch to more than 12 inches in width. Contacts of the bands are typically sharp, and they exhibit both parallel and cross-cutting relationships to the primary stratification.

The upper 400 feet is light grey-white with two thin zones of pale purple banding. The uppermost 32 feet is also strongly banded, with pale purple, maroon and white. The fact that this zone is white similar to the uppermost part of the Upper Member, may indicate that a period of surface bleaching and weathering in the Precambrian, preceded deposition of the Upper Member.

Several zones of pale purple and light grey occur in the otherwise continuously purple-pink banded part of the member. The conglomeratic zone at the base consists of alternating zones of pale pinkish-maroon and light grey with a faint maroon cast.

Cement: Both white clay and quartz comprise the bonding material and in a general way show an inverse relationship. Quartz cement predominates in the upper part, white clay predominates in the lower part, and in the central part they occur in roughly equal quantities. Clay cement predominates in the basal conglomeratic zone.

Twenty-five sandstone samples were analyzed with the X-Ray Diffractometer to determine the mineralogy of the clay cements (Appendix II; Table IV). The results show that illite and kaolinite, and rarely a little chlorite, are the two constituents of the clay fraction.

Hardness: All of the sandstones are hard to very hard, and are notably more compact than those of the Upper Member, however, none can be called true quartzite as metamorphism has not affected the sediments. Even zones cemented mainly with clay are hard and non-friable because small amounts of quartz bonds the grains at their points of mutual contact.

Porosity: The sandstones are for the most part well cemented and porosity is low or very poor in all but the upper few hundred feet where a number of laminae and thin zones are very porous. Zones in the lower conglomeratic zone are relatively porous also.

Grain Size: The sediment ranges from very fine sand through fine pebbles, but the larger sand grades are probably the most abundant. From top to base there is an almost imperceptible increase in the average maximum grain size, from medium-coarse in the upper part to very coarse in the lower part. In detail the unit is characterized by a very strong textural lamination in which there are marked contrasts in grain size, and degree of sorting in adjacent laminae and layers. Throughout, very coarse laminae alternate with very fine laminae, and with increasing depth the frequency of occurrence and thickness of the coarser laminae increases.

In the upper part granules are localized along thin laminae containing very coarse sand, and by 3,000 feet fine pebbles are associated. By 3,700 feet the coarsest laminae have increased in number and in thickness to several inches. Below 3,900 feet granule zones up to four inches thick occur, and below the coarsest sandstone zones are up to one foot thick. In this lower part the member is a coarse- and very coarse-grained granuliferous sandstone with fine pebbles scattered in many zones. Between 4,400 and 4,650 feet the sand becomes distinctly finer grained, averaging medium sand with a notable absence of very coarse sand and granules.

The pebble size in the basal conglomerate increases from ¼ inch or less at the top to 3/4 inch or less in the lower part. In the basal one or two feet pebbles attain a length of two inches, the largest observed in the core, but much smaller than the quartzite boulders observed by other writers in outcrop.

Sorting: The member as a whole must be classed as poorly sorted, to very poorly sorted in the lower part. Individual laminae range from well sorted to very poorly sorted, and many are distinctly bimodal.

Roundness: Probably all of the grains were originally rounded and well rounded, but the abundance of secondary quartz overgrowths has destroyed much of this original roundness. It is possible, however, that the roundness of quartz grains in the Lower Member was originally less than that of grains in the Upper Member as the sediments of each division were deposited in different environments.

Accessory Grains: Very small, well rounded grains of tourmaline appear from the binocular examination to be the main heavy mineral present, but zircon may be distributed throughout also (see Fahrig, 1961; Gravenor 1959). Within the lower 400 feet are numerous, very delicate, wispy laminae composed of highly rounded, detrital, very fine, black, metallic heavy mineral grains that are non-magnetic but may be weathered magnetite as most appear oxidized. Associated with these grains are abundant, well rounded, very fine, equant to elongate zircon grains. Within the lower 175 feet these heavy mineral laminae are fairly abundant.

Specular hematite crystals, very fine and fine, although not detrital, occur throughout all but the upper few hundred feet of white sandstone, and impart the purple colour to the sandstones. In view of the thickness of the Lower Member, the quantity of hematite is considerable.

In the upper 36 feet of the member, and from 1867 to 2175 feet in the core, many translucent, honey-coloured dolomite crystals occur on parts of vertical fracture surfaces. Pyrite is almost non-existent except for small irregular patches of very fine crystals on fracture surfaces at 1696 and 1707 feet below the top of the core.

Structures: Inclined and truncated laminae throughout indicate that the entire unit is cross-stratified, and although the size of the sets and inclination of the laminae was not recorded there is probably a considerable range.

Intraformational, detrital, clay pebbles are characteristic components which occur throughout most of the member, but decrease in number with depth and in the lower half are rather rare. No intraformational fragments were noted below 4,367 feet. The fragments are of two types:

1) One type is soft, pale pinkish-cream-white, angular or subangular, disk-shaped to equant block-like fragments;

2) The other consists of light green, somewhat harder, typically thin, curled and bent plates

commonly 1/8 inch thick and up to one inch long.

The fragments range from pure clay to highly silty clay and many of the white fragments are stained maroon from hematite. In the upper part they commonly occur in widely separated zones up to three inches thick, however, nowhere are they abundant, and they generally occur as sparsely scattered individual grains. The largest fragments noted were about two inches long.

Radioactivity: The only radioactive zones in the entire member occur in the lowermost few feet of the basal conglomerate. There, in several zones up to about six inches thick, counts per second reach only 1½ - 2 times normal background.

Contacts: As discussed above the upper contact may represent an hiatus but conclusive evidence is not available. The lower contact represents a profound unconformity, but for all its magnitude it is merely a flat, smooth, very sharp surface above which lies a fine quartz pebble conglomerate, and below which is a thin, maroon, clayey regolithic zone that grades down uniformly into unaltered metamorphic rocks of granitic composition.

## Regolith

Directly underlying the basal conglomerate are the metamorphic and igneous rocks of the basement complex of which 340 feet were cored. The uppermost part has undergone intense weathering and with depth the alteration gradually disappears within several tens of feet. Because of the very transitional nature of the weathering effects it is difficult to define the lower boundary of the regolith proper, but a zone about six feet thick at the top of the basement may be regarded as such.

Twenty-five to forty feet below the Athabasca the mica of the fine- to medium-grained granitic rock is dark green, and what must have been feldspar originally is dull, pale maroon, soft, structureless material. From about 9 to 25 feet the mica becomes brown to rusty brown, and the feldspar is altered to soft, chalky, white clay. This zone grades up into the regolith proper through several feet of rusty-maroon mica, and pale, dull maroon, structureless, soft, altered feldspar.

The upper six feet is rusty-red-maroon, and although the mineralogy is almost totally different from that of the original granitic rock, all of the original texture, including irregular-shaped quartz, is present. The original mica is represented by rusty, hematite-like, soft, clayey material and the feldspar by maroon, soft, structureless material which in the upper part possesses a waxy, talc-like texture and lustre. Core recovery was poor from the uppermost few inches and the regolith is represented here by fragments of pale greenish, "greasy", talc-like, structureless material. Within the upper eight feet of the weathered zone, kaolinite decreases and illite increases in amount. (Table IV; Appendix II).

In the regolith there is no evidence of reworking of detritus or soil by wind, water or ice, and there seems only to have been an *in situ* chemical alteration of feldspar and mica. No pisolitic structures are present, and no secondary concentration of metallic or other minerals was noted.

No increase in radioactivity within the basement rocks was found, and only a very slight increase above background was observed in the upper four feet of the regolithic zone.

## DEPOSITIONAL ENVIRONMENT

The depositional environment of the Athabasca Formation has been interpreted as both continental and marine by various writers, (see Fahrig 1961, p. 35), but Fahrig and most other geologists have lately favoured a predominantly fluviatile origin.

The Rumpel Lake core provides a unique cross-sectional view of the Athabasca, and indicates that the formation probably contains both fluviatile and marine parts. It is here suggested that the Lower Member is entirely fluviatile and the Upper Member is composed of sediments probably deposited in near-shore marine and coastal environments.

The Lower Member possesses a number of sedimentary features characteristic of fluviatile deposits, such as cross-stratification, intraformational clay pebbles, strong textural lamination, overall poor sorting and presence of kaolinite in the intercalated shaly laminae and clay mineral cements of the sandstones. It seems probable that the sediments of this thick, homogeneous unit were deposited under relatively stable, tectonic conditions, on a broad plain of little relief, by a number of braided river systems. The virtual absence of significant shale beds indicates that lakes and flood plains of meandering rivers were not formed.

The Upper Member differs from the Lower Member in a number of significant respects. First, this division consists of a large number of individual lithologic units of contrasting grain size, sorting, colour, degree of cementation and composition, implying migration and alternation of a number of different environments. Second, it contains a considerable thickness of sandstones with altered glauconite grains that suggest marine environments may be represented. Third, intraformational clay pebbles typical of fluvial deposits are rare. Fourth, highly rounded, abraded, detrital biotite grains are common and locally abundant in the middle part. Fifth, the shales and clay mineral cements are composed of chlorite and illite, and kaolinite is absent except in the uppermost and lowermost parts. On the basis of these data, it is suggested that the Upper Member may have been deposited in a variety of Transitional Realm "marine" sub-environments, such as beach, dune, lagoon, barrier, and near-shore. The basal hundred feet of sandstone containing the kaolinite clays with illite may either represent fluviatile deposition or reworking of clays from the Lower Member, probably the latter. On the basis of the illite-kaolinite clay suite, and the near absence of chlorite in the upper few hundred feet of the Upper member, it could be suggested that nonmarine conditions had returned to the area, however, this may represent only the continental conditions that have characterized the region since mid-Proterozoic time.

The Carswell Formation (Blake 1956; Fahrig 1961), a cherty and stromatolitic dolomite of local occurrence conformably overlies the Athabasca sandstones (Currie 1969). As both the Carswell and the Upper Member of the Athabasca are interpreted as marine deposits, these two closely related units indicate that the sedimentation cycle of the Athabasca was terminated because the source of the sand disappeared and the area inundated by marine water.

## CONCLUSIONS

1. The thick, cross-bedded, Lower Member of the Athabasca Formation is composed of nonmarine, fluviatile sandstones, and the thinner, well bedded Upper Member consists of coastal-near shore marine sandstones that are probably conformably overlain by the Carswell dolomite.
2. A period of non-deposition, with or without erosion, may have intervened between deposition of the two members.
3. Distinctive, well rounded, detrital, pale, apple green clay grains that are common in the Upper Member are composed of illite, and probably represent diagenetically altered glauconite, which in turn is believed to have originated by alteration of detrital biotite grains.
4. The clays in the shale partings and sandstone cements of the Lower Member are composed of illite and kaolinite, and those of the Upper Member are composed of illite and chlorite, the contrast in mineralogy probably reflecting the difference in depositional environment.
5. The only radioactivity in the Rumpel Lake core exists in a few zones, each several inches thick, in the lowermost few feet of the basal conglomerate in the Athabasca Formation, and in a few thin zones of the underlying regolith where counts per second rise only 1½ - 2 times normal background.
6. The 6-foot thick, red-maroon clay regolith that directly underlies the Athabasca Formation probably represents the *in situ*, chemical weathered zone of granitic metamorphic and igneous basement rocks, and exhibits a downward decrease in kaolinite content, and complementary increase in illite.

## REFERENCES


ALCOCK, F. J. (1920) "The Athabasca Series", Am. Jour. Sci., 4th ser., vol. 50, no. 295, p. 25-32

(1936) "Geology of Lake Athabasca Region, Saskatchewan", Geol. Surv. Can., Mem. 196

BAER, A. J. (1969) "The Precambrian Geology of Fond-du-Lac Map-Area (74-0), Saskatchewan", Geol. Surv. Can., Paper 68-61

BECK, L. S. (1969) "Gnesis of Uranium in the Athabasca Region and Its Significance in Exploration", C.I.M.M. Annual Meeting, Montreal, April 1969

BLAKE, D. A. W. (1956) "Geological Notes on the Region South of Lake Athabasca and Black Lake, Saskatchewan and Alberta", Geol. Surv. Can., Paper 55-33

BROWN, I. C. and WRIGHT, G. M. (1957) "Proterozoic Rocks of the Northwest Territories and Saskatchewan", in The Proterozoic in Canada, Royal Society of Canada, Sp. Pub. No. 2, p. 79-92

BURWASH, R. A., BAADSGAARD, H., and PETERMAN, Z. E. (1962) "Precambrian K-Ar Dates from the Western Canada Sedimentary Basin", Jour. Geophys. Research, vol. 67, no. 4, p. 1617-25

BURWASH, R. A., BAADSGAARD, H., PETERMAN, Z. E., and HUNT, G. H. (1964) "Precambrian," Chapter 2 in Geologic History of Western Canada, Alta. Soc. Petrol. Geol., p. 14-19

CHRISTIE, A. M. (1953) "Goldfields-Martin Lake Map-Area, Saskatchewan", Geol. Surv. Can., Mem. 269

CURRIE, K. L. (1969) "Geological Notes on the Carswell Circular Structure, Saskatchewan (74K)", Geol. Surv. Can., Paper 67-32

DONALDSON, J. A. (1965) "The Dubawnt Group, Districts of Keewatin and Mackenzie", Geol. Surv. Can., Paper 64-20

(1967) "Two Proterozoic Clastic Sequences: A Sedimentological Comparison ", Geol. Assoc. Can., Proc., vol. 18, p. 33-54

DOUGLAS, R. J. W., and DUFFELL, S. (1962) "Some Aspects of Phanerozoic Epeirogenic and Orogenic Events that Involve Precambrian Rocks", in The Tectonics of the Canadian Shield, Royal Soc. Can., Sp. Pub. No. 4, p. 149-61

FAHRIG, W. F. (1961) "The Geology ofnthe Athabasca Formation", Geol. Surv. Can., Bull. 68

FENIAK, M. (1948) "MacAlpine Channel", Geol. Surv. Can., Map 1011A

FRASER, J. A. (1964) "Geological Notes on Northeastern District of Mackenzie, Northwest Territories", Geol. Surv. Can., Paper 63-40

GOLDRICH, S. S., NIER, A. O., BAADSGAARD, H., HOFFMAN, J. H., and KRUEGER, H. W., (1961) "The Precambrian Geology and Geochronology of Minnesota", Univ. of Minn., Minn. Geol. Surv., Bull. 41

GOODWIN, A. M. (1968) "Evolution of the Canadian Shield", Geological Assoc. Canada, Proc., vol. 19, p. 1-14

GRAVENOR, C. P. (1959) "Heavy Minerals of the Athabasca Sandstone", Jour. Alta. Soc. Petrol. Geol., vol. 7, no. 1, p. 1-6

HALE, W. E. (1954a) "Black Bay Map-Area, Saskatchewan", Geol. Surv. Can., Paper 53-15

(1954b) "Gulo Lake, Saskatchewan", Geol. Surv. Can., Paper 54-6

HARRISON, J. M. (1963) "The Canadian Shield Mainland", Chapter II, in Geology and Economic Minerals of Canada, Geol. Surv. Can., Economic Geology Series No. 1, Ed. by C. H. Stockwell, p. 19-122

HOBSON, G. D., and MACAULAY, H. A. (1969) "A Seismic Reconnaissance Survey of the Athabasca Formation, Alberta and Saskatchewan", Geol. Surv. Can., Paper 69-18

HOFFMAN, P. F. (1968) "Stratigraphy of the Lower Proterozoic (Aphebian), Great Slave Supergroup, East Arm of Great Slave Lake, District of Mackenzie", Geol. Surv. Can., Paper 68-42

KERMEEN, J. S. (1956) "A Study of Some Uranium Mineralization in Athabasca Sandstone Near Stony Rapids, Northern Saskatchewan, Canada", unpub. M.Sc. Thesis, University of Sask.

KING, P. B. (1959) "The Evolution of North American", Princeton University Press

KOEPPEL, J. (1968) "Age and History of the Uranium Mineralization of the Beaverlodge Area, Saskatchewan", Geol. Surv. Can., Paper 67-31

LEECH, G. B., LOWDON, J. A., STOCKWELL, C.H., and WANLESS, R. K. (1963) "Age Determinations and Geological Studies, Including Isotopic Ages, Report 4", Geol. Surv. Can., Paper 63-17

LOWDON, J. A. (1960) "Age Determinations by The Geological Survey of Canada", Report 1, Isotopic Ages, Geol. Surv. Can., Paper 60-17

(1961) "Age Determinations by The Geological Survey of Canada", Report 2, Isotopic Ages, Geol. Surv. Can., Paper 61-17

LOWDON, J. A., STOCKWELL, C. H., TIPPER, H. W., and WANLESS, R. K. (1963) "Age Determinations and Geological Studies, Including Isotopic Ages, Report 3", Geol. Surv. Can., Paper 62-17

MCGLYNN, J. C. (1966) Thekulthili Lake Area", in Report of Activities, 1965, Geol. Surv. Can., Paper 66-1

PETTIJOHN, F. J. (1957) "Sedimentary Rocks", Harper & Brothers, New York, Second Edition

REESOR, J. E. (1957) "The Proterozoic of the Cordillera in Southeastern British Columbia and Southwestern Alberta", in The Proterozoic in Canada, Royal Society of Canada, Sp. Pub. No. 2, p. 150-177

SPROULE, J. C. (1938) "Cree Lake, Saskatchewan", Geol. Surv. Can., Paper 38-9

STOCKWELL, C. H. (1964) "Age Determinations and Geological Studies", Part II, Geol. Surv. Can., Paper 64-17

TREMBLAY, L. P. (1955) "Uranium City, Saskatchewan", Geol. Surv. Can., Paper 54-15

(1968) "Preliminary Account of the Goulburn Group, Northwest Territories, Canada", Geol. Surv. Can., Paper 67-8

WALLIS, R. H. (1969) in Summary Report of Geological Surveys Conducted in the Precambrian Area of Saskatchewan, by L. S. Beck, p. 14-17

WANLESS, R. K., STEVENS, R. D., LACHANCE, G. R., and EDMONDS, C. M. (1967) "Age Determinations and Geological Studies, K-Ar Isotopic Ages, Report 7", Geol. Surv. Can., Paper 66-17

(1968) "Age Determinations and Geological Studies, K-Ar Isotopic Ages, Report 8", Geol. Surv. Can., Paper 67-2, Part A.

WANLESS, R. K., STEVENS, R. D., LACHANCE, G. R., and RIMSAITE, J. Y. H. (1966) "Age Determinations and Geological Studies K-Ar Isotopic Ages, Report 6", Geol. Surv. Can., Paper 65-17

APPENDIX I

DESCRIPTION OF THE RUMPEL LAKE CORE

CORE DESCRIPTION OF ATHABASCA FORMATION, RUMPEL LAKE, SASKATCHEWAN

| Unit | Lithology | Thickness | Depth |
|---|---|---|---|
| 1 | Sandstone, predom. white, pale pink in uppermost part; some zones maroon; at 150' is 2½' maroon with 1/8-1/16" dark maroon spots which are very porous, grains coated with hematite; from 160-180' consid. dark maroon speckelling and zones of pale maroon; 210-18' maroon mottling; 218½-22' maroon with few white bands to 1", color grading down; 237½-242' maroon; 245-47' maroon;<br>quartz cemented with traces white clay; some zones up to several feet clay cemented;<br>porosity generally fair, very good in some zones; good in upper few feet;<br>middle and upper part coarse- and very coarse-grained with scattered medium sand and some granules; lower part predom. medium-grained;<br>sorting fair to poor in upper part; good to fair in lower; textural lamination throughout in which grain size and sorting vary considerably;<br>good rounding of grains destroyed by quartz overgrowths;<br>cross-bedded . . . . . . . . . . . . . | 247 | 247 |
| 2 | Sandstone, numerous maroon-purple bands 1/8" to several inches alternating with thin white bands;<br>cemented with white clay; trace of quartz cement sand ranges from very fine to medium; some very thin lam. with coarse sand and rare micaceous clay film; average grain size fine;<br>strong textural lamination representing all combinations of grain size and sorting from good to poor;<br>roundness ranges from sub-angular to rounded with increasing size;<br>porosity mostly poor but fair to good in some laminae and thin zones;<br>cross-bedded;<br>grades down evenly and maroon fades to white . . . . . . . . . . . . . . . | 22 | 269 |

| Unit | Lithology | Thickness | Depth |
|---|---|---|---|
| 3 | Sandstone, white; predom. quartz cemented but small amount of white clay; sand ranges from fine to coarse; medium sand predomin.; sorting ranges from good to fair; textural lamination; porosity good but poor in parts; grains rounded; partly destroyed by quartz cement; traces of pyrite on vertical fracture surfaces . . . . . . . . . . . . . . | 16 | 285 |
| 4 | Sandstone, purple and maroon bands fraction of inch to several inches wide alternate with white; purple bands commonly cross-cut primary lamination, occurring as irregular bands, blotches; some blotchy white patches in maroon; color bleached white along fractures; below 302' purple lenticular patches up to several inches wide do not follow definite layers; color fades to white at base; cemented with quartz and white clay; proportions vary but clay abundant; porosity poor though fair in some zones; sand ranges from very fine to coarse; fine sand predom.; some medium sand scattered, rare coarse grains; some purple zones predom., very fine; lower part contains more medium sand and less very fine; sorting is good throughout most of unit roundness increases with increasing size; thin layers claystone occur at: 300' is 3" pale greenish-grey, silty, with muscovite, occurs as laminae up to ½"; 302' is 2" pale tan, silty claystone; 316' is 3" pale greenish-tan, silty, micaceous clay upper contact very sharp and irregular, erosional; cross-bedded throughout . . . . . . . . | 71 | 356 |
| 5 | Sandstone, white; color grades up and down; slightly cemented with small amount of quartz and white clay in upper part; lower part small amount of quartz; porosity good to excellent; sand ranges from fine to very coarse; medium and coarse sand predominate; granules rare in coarsest zones; | | |

| Unit | Lithology | Thickness | Depth |
|---|---|---|---|
| 5 (Continued) | | | |
| | sorting fair to good; strong textural lamination; cross-bedded . . . . . . . . . . . . . | 14 | 370 |
| 6 | Sandstone, white with purple bands ½" to several inches in upper part; in middle are pale purple bands; lower part white; mainly white clay cement but some parts mostly quartz; porosity poor but near base in quartzitic zone fair; sand ranges from very fine to medium; very fine and fine predom.; in lower few feet slightly coarser with some medium and coarse sand in laminae; sand subangular to subrounded; at 378' is 6" pale tan, silty claystone with sharp contacts; at 382' is 6" pale tan-grey silty claystone; lithology changes abruptly at base .. | 20 | 390 |
| 7 | Siltstone-claystone, maroon with pale green speckels and blotches; upper 15" non-silty claystone, maroon with tiny green speckels and blotches 1 mm. to 1"; very highly micaceous with green and white mica; having strong parallel orient; mica is of silt to medium sand grade; middle 30" siltstone, maroon, strongly speckeled pale green; very highly micaceous, white and green, with parallel orient; white clay cement; argillaceous; some ½-1" lenses of pale green siltstone; lower 6" claystone similar to upper part; lower contact extremely sharp . . . . . . | 6 | 396 |
| 8-9 | Sandstone, upper 7-8' purple and maroon with bleached speckels 1 mm.-¼" common and some 6-8" zones pale greenish-grey; remainder maroon with abundant pale speckels; cemented with white clay except for some thin layers and laminae of quartz; porosity generally poor but very good in some friable zones; below 420' very porous; | | |

| Unit | Lithology | Thickness | Depth |
|---|---|---|---|
| 8-9 Continued | | | |
| | sand varies in adjacent laminae and zones but fine and medium sand predominate; parts are distinctly bimodal with fine sand and scattered medium to very coarse sand; some zones are predom. medium to very coarse; below 420' medium and coarse grained; larger grains rounded to well rounded; below 404' sand is friable (highest occurrence) and rep. boundary between units 8 and 9; abundant very well rounded mica flackes (green) and soft, apple green clay grains which are very numerous in thin laminae as well as scattered in wider zones; cross-bedded . . . . . . . . . . . . . . | 40 | 436 |
| 10 | Siltstone-sandstone, maroon with fine pale green speckels; argillaceous siltstone to very fine, silty sandstone; non-porous; sorting good; abundant highly rounded green mica grains with bleached halos; some apple green clay grains; lower contact sharp . . . . . . . . . . | 4 | 440 |
| 11 | Sandstone, white; cemented with white clay; no porosity; medium-grained; well sorted; apple green, well rounded, soft clay grains common . . | 1 | 441 |
| 12 | Sandstone, maroon with pale maroon to pale green speckels; color changes abruptly at base; cemented with white clay stained by hematite; unit not homogeneous; mostly very fine to fine grained, well sorted, tight; at 465' is 3' purple, clay cemented, fine to coarse sand with some very coarse sand and very abundant highly rounded soft, apple green clay grains; underlain by 20" pale greenish-grey siltstone; at 472' is 6" pale greenish-grey, silty, very fine sand with abundant clay cement and numerous mica and apple green clay grains; from 480-82½' is pale greenish-grey, very fine sand; contains a few beds up | | |

| Unit | Lithology | Thickness | Depth |
|---|---|---|---|
| 12 (Continued) | to a few inches thick of maroon, speckeled claystone grading vertically to siltstone and sandstone; well rounded green mica and soft, apple green clay grains common to very abundant in some zones . . . . . . | 55 | 496 |
| 13 | Sandstone, maroon to white; cemented with white clay; friable; non-porous; predom. medium-grained, but sand ranges from fine to very coarse, few granules; sorting is variable, good to poor; parts are well sorted fine-grained (commonly maroon), parts fine and medium, parts poorly sorted medium to very coarse; grains rounded to highly rounded; soft apple green clay grains fairly abundant; negligible green mica grains; lower contact sharp . . . . . . . . . | 19 | 515 |
| 14 | Claystone, sandstone; maroon claystone with tiny bleached speckels occur at top; middle, bottom: 11", 36", 7" respectively; pale greenish-white fine-grained, well sorted, clay cemented sandstone is interbedded 14" and 27" respectively; lower contact rapidly gradational ..... | 8 | 523 |
| 15 | Sandstone, white with maroon and purple banding; zones of white and pale maroon each several feet thick alternate in upper part; purple bands begin at 611' and continue to base with some breaks; from about 625' almost continuous purple bands fraction of inch to 3" thick; purple bands follow laminae and also are irregular and cross-cutting, being very irregular in part; cemented with white clay very abundant; in some zones up to several feet thick clay cement is absent or incipient and slightly quartzitic; friable to compact; porosity mostly poor; some zones very good; some quartzitic zones tight, others have fair porosity; sand ranges from very fine to coarse, with some very coarse and rare granules in some laminae; fine and medium sand predominate; unit not homogeneous; consists of alternating zones from | | |

| Unit | Lithology | Thickness | Depth |
|---|---|---|---|
| 15 (Continued) | laminae up to several feet of contrasting grain size and sorting, such as: very fine-fine; fine; fine-medium; medium; medium-coarse; fine-medium-coarse; very fine-medium; contains occasional argillaceous and silty, maroon or green zones a few inches thick:<br>528-32' maroon, argillaceous, silty, very fine sand, with abundant green mica<br>576-80' maroon argillaceous and silty zone<br>584' is 3-4" greenish silty claystone<br>585' is 6" maroon silty claystone<br>587' is 8" maroon silty claystone<br>sorting is generally good but in alternate zones ranges from very good to fair; above 600' soft, highly rounded apple green clay grains are very abundant in some zones, typically conc. in thin laminae and also scattered; become less numerous downwards and only rare grains below;<br>green mica up to very coarse grade very abundant in the argillaceous and silty maroon zones; very rare elsewhere;<br>at 562' is a white intraformational clay fragment 2" long;<br>596-97' are small rounded intraformational white, chalky clay pebbles, one possibly several inches long; much is cross-bedded . . . . . . . . . . . . . . . . . . | 239 | 762 |
| 16 | Sandstone, white or white and purple banded; cemented with white clay; non-porous; predominantly fine-grained; fairly well sorted; contains some maroon siltstone units and several inches to 1' thick with green mica; apple green clay grains occur sparingly;<br>recovery poor; thickness and lithology poorly known . . . . . . . . . . . . . . . . | 16 | 778 |
| 17 | Sandstone, white, partially cemented with white clay; good porosity; fine-grained with small proportion medium sand; well sorted; grains subrounded . . . . . . . . | 9 | 787 |

| Unit | Lithology | Thickness | Depth |
|---|---|---|---|
| 18 | Siltstone, maroon; clay cemented; coarse silt; well sorted; tight; hard; micaceous, green and white mica; upper contact sharp; grades down evenly . . . . . | 5 | 792 |
| 19 | Sandstone, white with purple to pale purple bands 1 mm. to several inches thick; cemented with white clay; some laminae with quartz cement; porosity ranges from very poor to excellent in adjacent laminae and layers; some zones a few feet thick cemented with quartz and tight and hard; sand ranges from very fine to very coarse; medium sand predominates, considerable variation, strong textural lamination including; fine-medium, fine, medium, medium-coarse, medium and coarse with some very coarse, very fine to coarse, sorting in adjacent laminae ranges from good to poor; about 842' are abundant, apple green, soft clay grains and rare green mica; 20" above base is 3" pale green claystone with some small green mica flakes; 10" above base is 1" maroon clay; cross-bedded; lower contact sharp . . . . . . . . . . . . | 55 | 847 |
| 20 | Siltstone, maroon; clay cemented; coarse-grained; well sorted; tight; hard; green mica with bleached halos; lower contact sharp . . . . . . . . . . . . . | 4 | 851 |
| 21 | Sandstone, white; cemented with white clay; non-porous; upper part very fine-grained becoming coarser in lower part where it is very fine-fine-medium; fairly numerous soft, apple green, well rounded clay grains in lower part; lower contact sharp . . . . . . . . . . . . . | 9 | 860 |
| 22 | Siltstone, pale green; cemented with white clay; possibly argillaceous; well sorted; abundant small green mica grains; lower contact very sharp . . . . . . . . . . . . . | 1½ | 861½ |
| 23 | Sandstone, white; partially cemented with white clay; friable; good to excellent porosity; predominantly medium-grained, but sand ranges from fine to coarse; parts are | | |

| Unit | Lithology | Thickness | Depth |
|---|---|---|---|
| 23 (Continued) | fine-medium, medium-coarse; mostly well sorted; well rounded, soft, apple green grains locally abundant and occur commonly as laminae . . . . . . . . . . . . . . . . . . | 22½ | 884 |
| 24 | Claystone, pale green; soft . . . . . . . | ½ | 884½ |
| 25 | Sandstone, pale maroon, speckeled and mottled; below 902 color highly speckeled but also distinctly laminated; cemented with white clay; subfriable; porosity poor; sand ranges from very fine to medium; fine sand predominates; textural lamination in which grain size and sorting vary considerably; a few zones are silty, very fine sand; sand grains rounded; soft apple green clay grains very abundant; green mica few to rare; occasional intraformational white clay pebble to common in some zones above 900'; at 922' occur two subrounded 2" clay pebbles; cross-bedded . . . . . . . . . . . . . . . . | 43½ | 928 |
| 26 | Claystone, maroon; green mica grains; contacts sharp . . . . . . . . . . . . . . | 1 | 929 |
| 27 | Sandstone, white; cemented with white clay; friable; porosity poor; predominantly medium and coarse sand; some fine sand; sorting fairly good; grains subrounded to rounded; soft, apple green clay grains common; gradational downwards . . . . . . . . . | 6 | 935 |
| 28 | Sandstone, maroon with some bleaching and mottling; uniform to base where sharp colour change occurs; cemented with white clay stained by hematite; friable; sand ranges from fine to coarse; medium and coarse sand predominate; sorting fair; sand rounded to well rounded; soft, apple green clay grains abundant | 8 | 943 |
| 29 | Sandstone, white with regular to irregular purple-maroon bands; below 968' are pale pink bands; cemented with white clay; friable; porosity varies in adjacent laminae and zones from very poor to very good; purple | | |

| Unit | Lithology | Thickness | Depth |
|---|---|---|---|
| 29 (Continued) | bands commonly more porous than white; much has fair porosity; sand ranges from fine to coarse; medium and coarse predominate; below 976' becomes gradually finer grained; sorting is fair to good; some zones are fine, fine to medium, or medium and coarse; grains rounded to well rounded; soft apple green clay grains very abundant in some zones, absent in others; at 968' is 6" of maroon clay with green mica flakes and very sharp contacts; lower contact gradational and arbitrary . . | 35 | 978 |
| 30 | Sandstone, pale maroon, becoming darker in lower half with trainsition zone downwards; cemented with white clay; non-porous; fine-grained, slightly argillaceous; well sorted; lower half very fine-fine, maroon, speckeled, abundant green mica; soft, apple green clay grains abundant . . . | 5 | 983 |
| 31 | Sandstone, maroon to pale maroon down to about 991'; to base predominantly greenish and maroon banded with abundant speckels; cemented with white clay; non-porous; hard, compact; very fine-grained, silty; grades down gradually by becoming siltstone; laminated texturally; contains a few thin zones up to a few inches thick of claystone; soft, apple green grains and green mica common . . . . . . . . . . . . . . . . . . . . . | 12 | 995 |
| 32 | Claystone, laminated pale green and maroon; above 1000' very distinct green speckelling; below maroon with pale maroon mottling; very highly silty and sandy in some zones; contains some green mica; 1009-12' pale greenish-grey-white, very fine-grained sandstone cemented with white clay; contains a 6" pale green claystone with green mica and sharp contacts . . . . . . . . . . . | 20 | 1015 |
| 33 | Sandstone, upper 5' white; below 1023' becomes purple banded many of which are quite irregular and blotchy, with mottling; purple bands define definite inclined lamination; some zones uniquely banded on a very small scale (white-purple-maroon within 1"); in lower half zones are white and others are white with purple bands; | | |

| Unit | Lithology | Thickness | Depth |
|---|---|---|---|
| 33 (Continued) | upper 5' white, quartz and clay cemented, hard, tight, to fairly porous, with some green, soft clay grains; below 1021' cemented with white clay; 1095-1102' more quartzitic, hard, brittle with little clay cement; sand ranges from fine to very coarse; consists of zones and extremely numerous thin laminae composed of all combinations of grain size and sorting from fair to very good; very strongly laminated throughout; sand is mostly friable and the porosity is fair to very good in alternating laminae; occasional laminae are quartzitic and tight; grains rounded to well rounded; some soft, highly rounded apple green clay grains commonly occur in some zones, absent in others; rare below 1077'; at 1021' is 1" dark green clay with sharp contacts; at 1073' is 1' of claystone, maroon and green, finely mottled, with abundant green mica and sharp contacts; at 1103' is 6" of pale maroon claystone with very sharp contacts; at 1105½' is 2" dark maroon claystone, pure, with green mica and sharp contacts; lower contact very sharp and flat . . . . | 101 | 1116 |
| 34 | Claystone-siltstone, maroon with green laminae; lenses and laminae of silt; very abundant green mica in very thin laminae; very sharp contacts . . . . . . | 1 | 1117 |
| 35 | Sandstone, white with pale maroon bands; cemented with quartz and white clay; non-friable; porosity fair to poor; sand fine to coarse; predominantly medium and coarse; parts have high proportion of fine sand; sorting ranges from poor to good in different zones and laminae; sand well rounded; in lower half are some soft, apple green clay grains and green mica in laminae . . | 17 | 1134 |
| 36 | Claystone-siltstone; upper 3' maroon claystone, silty in laminae; micaceous; speckeled green; ½" green clay | | |

| Unit | Lithology | Thickness | Depth |
|---|---|---|---|
| 36 (Continued) | at base; lower contact very sharp; below is 3" sandstone, medium-grained at base grading up to fine; quartz and clay cemented; hard; lower contact very sharp; down to about 1142'+ is maroon claystone with green speckeling; contains some thin beds of grey-white sand ¼-2" thick; clay adjacent to sand layers bleached to pale green 1/16-¼" wide; sands are fine-medium, cemented with clay and quartz, tight, and both contacts of sand layers extremely sharp; lower contact sharp . . . . . . . . . . . . . | 8 | 1142 |
| 37 | Sandstone, light grey-very pale maroon-pinkish; cemented with white clay; non-porous; hard; medium-grained with some fine sand; contacts sharp . . . . . . . . . . . . . . . . . . . . . . . | 2 | 1144 |
| 38 | Claystone with sandstone; maroon with pale green speckels; contains an 8" and 11" medium-grained sandstone similar to #37; some green mica present; all contacts very sharp . . . . . . . . . . . . . . . . . . | 5 | 1149 |
| 39 | Sandstone, upper half down to 1173' is as follows: white and purple banded; cemented with white clay; friable; low porosity; sand ranges from fine to very coarse; very strongly laminated; grain size and sorting vary widely in adjacent laminae; sorting ranges from poor to good; thin laminae with coarse and very coarse sand typical; some specular hematitie in the purple bands; rare green mica and apple green clay grains; cross-bedded;<br><br>lower half below 1173' is as follows: white; cemented with white clay; friable; low porosity; sand ranges from fine to very coarse with some granules; strong textural lamination; all degrees of sorting and grain size found in adjacent laminae; some laminae are fine-grained and well sorted; others contain very coarse sand with granules; sorting of the unit as a whole is poor; a very distinctive coarse, poorly sorted unit; sand rounded to well rounded; | | |

| Unit | Lithology | Thickness | Depth |
|---|---|---|---|
| 39 (Continued) | | | |
| | very little green mica present; rare intraformational clay chips up to 1"; strongly cross-bedded; lower contact very sharp | | |
| | this is the lowest occurrence of friable sandstone in the formation . . . . . . . | 51 | 1200 |
| 40 | Sandstone, upper part to 1323' is as follows: pale maroon with considerable banding of light grey and pale maroon; also very fine speckels abundant; banding and blotches are pink, pale maroon; darker maroon and light grey; some zones are white; cemented tightly with white clay; hard; non-porous; this unit seems much harder than overlying clay cemented sands and may be slightly siliceous; unit distinctly finer grained and better sorted than #39; sand ranges from very fine to medium; very fine and fine predominates; considerable variation of grain size and sorting in zones and laminae which occur in some parts; laminae containing medium sand occur throughout and also there are zones inches thick with medium sand; a few laminae contain coarse, well rounded sand but this is rare; sorting ranges from predominantly good to fair in adjacent laminae and some laminae are poorly sorted; contains a few extremely thin pale greenish clay partings; green mica exceedingly rare; cross-bedded; | | |
| | lower part below 1323' is as follows: light greyish, pale purplish grey; cemented predominantly with quartz and a small amount of interstitial white clay; very hard; tight, non-porous; sand is fine to coarse; rare very coarse grains in some laminae; good textural lamination with considerable range of grain size and sorting in adjacent laminae and layers; sorting moderate to good; quartz cement destroys good roundness of most grains; | | |

| Unit | Lithology | Thickness | Depth |
|---|---|---|---|
| 40 (Continued) | a little specular hematite occurs throughout; green mica grains very rare; occasional 1-2" maroon or green argillaceous zones; at 1369' is 2" of green clayey siltstone with very sharp contacts; at 1385' is 1½" bed; cross-bedded; lower contact very sharp . . . . . . . . . | 203 | 1403 |
| 41 | Sandstone, purple; cemented with white clay; very hard; tight, non-porous; predominantly ver fine and fine sand with scattered medium and coarse sand; upper foot very fine to coarse, poorly sorted and spotted; sorting fair; larger grains well rounded; contains a little specular hematite . . . | 5 | 1408 |
| 42 | Sandstone, purple and pink banded with some white; cemented with quartz and white clay; no visible porosity except in upper few hundred feet; hard; grains range from very fine to very coarse sand, granules and small pebbles; definite increase in grain size with depth; very strong textural lamination and layering throughout; sorting as a whole is poor but individual laminae may be well sorted; grains are rounded to well rounded; characterized by small intraformational clay pebbles; contains a number of green to maroon silt and clay layers 1/8" to 4" thick; probably cross-bedded throughout;<br><br>in detail the unit is as follows:<br><br>Color:<br>1408-40 strongly banded with pale purple and pale maroon; over many feet in some parts no banding<br>1440-1711 light grey-white<br>1711-22 wide pale purple bands<br>1722-1809 light grey-white<br>1809-34 pale purple banding<br>1834-50 pale purple and pale maroon bands alternate with light grey<br>1850-1988 by 1850 very colorful pink and purple banding, pale to dark, some | | |

| Unit | Lithology | Thickness | Depth |
|---|---|---|---|

following textural lamination, many cross-cutting
1988 abrupt termination of maroon and below pale purple bands alternate with light grey; within next hundred feet light grey bands become pinkish and gradually darken so by 2100 purple and dark pink bands occur as before; banding extremely uniform; extends to 2255
2255-68 purple and light grey bands
2268-2900 purple and pink bands; contacts of color bands very sharp; pink fades to light grey to very faint pinkish
2900-3078' pink fades to light grey gradually and by 3019 is more grey than purple with some thin pink laminae
3078-4450 pink and purple bands, very well developed; by 3716 some light grey bands appear; 3735-60 abundant delicate purple and maroon laminations above and below wide bands
4450-70 purple and light grey bands
4470-4538 pale pink, purple and some light grey bands
4538 light grey bands change to distinctive pink that alternates with purple; some white zones occur below 4600

Cement:

quartz and white clay in general vary inversely in amount,
quartz dominating in the lower part,
clay in the lower part;

1408-2900 quartz cement predominates and bonds most of the sand; some laminae are cemented with white clay, and there are others cemented entirely with quartz; between these two end members are laminae containing all intermediate combinations; at least a little clay is present in most laminae; most of the rock is hard and brittle and much is extremely hard and quartzitic; many laminae have good to excellent porosity, while adjacent laminae are tight; below about 2900' thin laminae with some clay become fairly common though the sand is bonded by quartz and clay is interstitial;
by 3000 clay becomes abundant but still interstitial;

| Unit | Lithology | Thickness | Depth |
| --- | --- | --- | --- |

Cement (Continued)
below 4000 a considerable amount of white clay occurs in the sand and quartz is subordinate
with greater depth white clay increases in quantity and quartz becomes quite minor

Grain Size:
very strong textural lamination and layering throughout;
gradual increase in average maximum grain size with depth;
sand ranges from very fine through very coarse

1408-1555 very fine to coarse sand; sorting and grain size vary in adjacent laminae and layers; parts are very fine-fine grained;
below some granules occur in laminae containing abundant very coarse sand;
sand is fine to very coarse, strongly laminated;
by 2731 and possibly above granules are localized along laminae one grain thick and are quite numerous; laminae of very coarse sand and granules are quite numerous below;
by 2925 a few ¼" pebbles are associated with the granules and very coarse sand;
by 2961 very coarse sand becoming commonly disseminated with finer sand along laminae;
at 2998 are laminae with ¼" rounded quartz pebbles;
sand is fine to very coarse and rather poorly sorted as a whole but individual laminae may be well sorted though some are poorly sorted, and commonly biomodel;
sedimentation units range from laminae up to many inches thick and may be predominantly fine, medium, or coarse and poorly sorted; a large part is predominantly medium-grained and moderately sorted;
at 3379 are scattered ¼" subrounded quartz pebbles in a 2" zone; below very coarse sand, granules and small pebbles in laminae become thicker and

| Unit | Lithology | Thickness | Depth |
|---|---|---|---|

Grain Size (Continued)

by 3400 reach 1" in thickness; at 3465 is 6" of very coarse sand with granules, hematite staining, high porosity and very sharp contacts; from 3500 very coarse sand laminae and layers become more numerous and thicker, some zones of very coarse grained laminae up to 6"; below 3600 is a high proportion of coarse and very coarse sand; commonly the coarsest zones containing granules and fine pebbles are purple; below 3700 laminae with medium to very coarse sand and granules and zones of coarser grained laminae are up to several inches thick; there are a few ¼" pebbles scattered throughout; very coarse sand and granules are abundant; 3774 predominantly coarse grained with medium and very coarse sand; strong textural lamination and layering; around 3900 and below predominantly coarse and very coarse grained with granule zones up to 4" thick; at 3965 a 7/16" quartz pebble noted coarser zones up to 1' thick alternate with finer zones of similar to greater thickness; unit is becoming predominantly very coarse-grained, granuliferous sandstone; at 3985 is a 2" thick granule conglomerate, well sorted, porous; below 4000 rock is generally coarse-very coarse sand with granuliferous zones; but also medium grained zones with coarse to very coarse sand laminae occur; 1/4-3/8" pebbles are present in many zones; pebbles rarely ½"; coarse and very coarse sand predominates and contains granules; finer grained zones of medium-coarse sand are up to 6" thick; coarser zones up to 12"; at 4165 is approximate beginning of trend to finer size with loss of very coarse sand and granules layers; by 4185 all very coarse grained layers disappear and average grain size is medium sand with fine and coarse sand layers; very coarse sand and grandles absent; much is predominantly fine and medium grained with some coarse

| Unit | Lithology | Thickness | Depth |
|---|---|---|---|

Grain Size (Continued)

laminae and scattered coarse grains; very strongly laminated; around 4390 some thin laminae of very coarse sand begin to appear and increase in number and thickness downward; by 4470 fine to very coarse sand occurs; strongly laminated and layered; zones with very coarse sand range up to about 12"; unit very poorly sorted here; below 4538 predominantly coarse and very coarse grained but with much interstitial medium and fine sand; by 4600 and probably well above it some thin laminae with granules occur; sand is coarse and very coarse with zones and laminae of medium sand; finest grained laminae are of fine sand; coarsest are of very coarse sand with a few granules; at base very coarse-grained with granules ;

Sorting:

the unit as a whole is poorly sorted to very poor; in detail, however, many laminae are fairly well sorted though many are poorly sorted;

Roundness:

sand grains cemented by white clay are rounded to well rounded; those cemented by quartz have had the original good roundness destroyed by secondary overgrowths;

Accessories:

beginning at 1558' intraformational detrital clay fragments appear and continue to near the base; two types of fragments are present; one is soft, pale pinkish-cream-white, typically angular; the other is light green, somewhat harder, typically thin, curled and bent plates commonly 1/8" thick and up to 1" long; many fragments are disk-shaped; others are equant blocks; at the

Accessories (continued)

top they occur in widely separated zones up to 1-3" thick; they range from pure clay to highly silty; nowhere are they abundant, very sparsely scattered throughout;

around 1700' about 6 fragments noted in 20';

at 1923' fragments at least 2" long occur;

at 2000 white fragment with maroon blotches; pale purple fragments with white blotches also noted;

by 2400 fragments rather rare;

below 2600 many fragments maroon;

below 4367 no fragments observed;

in upper 36' crystals of honey-coloured dolomite abundant on fracture surfaces

at 1696 and 1707 small irregular patches of very fine pyrite crystals occur on fracture surfaces

small crystals (very fine-fine sand size) of specular hematite occur throughout all but the upper white part of the unit, and give the colour to the purple bands

from 4411' down are numerous very delicate black laminae composed of highly rounded, very fine, black, detrital metallic grains which follow primary lamination and seem to be confined to the purple bands; occurring in the laminae are numerous well rounded, very fine zircon grains, below 4600 these laminae are fairly abundant;

between 2081' and 4113' are twenty-three argillaceous layers ranging from pure clay to siltstone, and in thickness from 1/8" to 4" but most are less than 1"; they range in colour from maroon to pale green and typically they have very sharp contacts; combined thickness is only about 28"

Structure:

inclined laminations throughout sug-

| Unit | Lithology | Thickness | Depth |
| --- | --- | --- | --- |
| | Structure (Continued)<br>gest that probably the entire unit is cross-bedded though on different scales and in different degrees in particular zones<br><br>lower contact highly gradational and arbitrary . . . . . . . . . . . . . . | 3344 | 4752 |
| 43 | Conglomerate and conglomeratic sandstone<br>upper 8' conglomerate light grey to pink; cemented with white clay; very little porosity; hard; well rounded quartz pebbles 1/8-¼"; matrix consists of fine to coarse sand and granules; abundant flecks of specular hematite; near middle is zone with scattered mustard-colored limonite grains; at top laminae with abundant detrital black metallic fine to medium grains;<br>lower 2 feet is conglomeratic, granuliferous sandstone cemented with white clay and containing abundant detrital black metallic grains<br>4760-76 is as follows:<br>15" fine to very coarse, very poorly sorted, sandstone, conglomeratic, cemented with white clay<br>9" conglomerate, pink fine pebbles ¼", matrix of fine to coarse sand cemented with white clay; scattered mustard-colored altered limonite grains;<br>14" sandstone, pale pinkish, medium to very coarse sand, highly granuliferous, cemented with white clay, tight, abundant very fine weathered black detrital metallic grains<br>2" conglomerate, fine pebble as above<br>19" sandstone, medium to very coarse sand; cemented with white clay, abundant flecks of specular hematite<br>15" sandstone, pale pinkish, cemented with white clay, sand mostly coarse and very coarse, some medium and little fine; many granules and fine pebbles; very poorly sorted; hematite staining and flecks of specular hematite; some partings and laminae of mustard-colored limonite | | |

| Unit | Lithology | Thickness | Depth |
|---|---|---|---|
| 43 (Continued) | 3" conglomerate, greyish, fine pebbles ¼-3/8", rarely ½", medium to very coarse sand and granules; cemented with white clay; very abundant black detrital metallic grains; a grain of maroon, flaky clay material from underlying regolith zone | | |
| | 4" sandstone coarse to very coarse, similar to above | | |
| | 18" conglomerate to sandstone, fine pebble 3/8-½" to conglomeratic sandstone; medium grey; cemented with clay; sand medium to very coarse; abundant specular hematite; abundant black, metallic detrital grains in zones | | |
| | 15" conglomerate, pinkish-maroon; highly stained with hematite; pebbles average 3/8-½" and become finer in lower few inches; sand fine to very coarse, with granules; cemented with white clay; abundant powdery mustard-colored limonite and altered grains; rare rounded mica book | | |
| | 8" sandstone, grey, quartz cemented; predominantly medium and coarse grained but with finer and coarser grained laminae; some clay cement; very abundant black detrital metallic grains | | |
| | 7'3" conglomerate, pale maroon; cemented with white clay; pebble size average maximum is ½-3/4"; in lower 1-2' rounded to well rounded quartz pebbles reach 2"; matrix consists of fine to very coarse sand with granules; very abundant hematite staining of clay cement; flecks of powdery, mustard-colored limonite common throughout; contains a little pyrite; scattered thoughout and fairly abundant in lower 3' are detrital, well rounded, black metallic grains of the finer sand grades; in sample 3½' above base are some whitish-grey, opaque mica grains; lower contact extremely sharp and flat . . . . . . . . . . . . . . . . . . | 24 | 4776 |

Total Thickness Athabasca Formation ....... 4776

| Unit | Lithology | Thickness | Depth |
| --- | --- | --- | --- |
| | Basement Complex | | |
| 44 | Regolith, rusty red-maroon, clay-like material, relatively hard rock but easily scratched with knife; scattered small irregular light grey masses of quartz; waxy textured, talc-like material in upper few inches; no pisolitic structures; relict crystalline granitic texture throughout; no evidence of reworking by water; weak radioactivity in a few thin zones; grades down rapidly . . . . . . . . . . | 6 | 4782 |
| 45 | Transition Zone; underlying granitic rocks change gradually from greyish with brown to green mica below to distinctly maroon with light grey quartz patches above . . . . . . . . . | 3 | 4785 |
| 46 | Basement Rocks, granitic metamorphic and possibly igneous; from about 9-25 feet below top the granitic rock contains mica which is brown to rusty brown and feldspar that is soft, chalky, white, altered; from 25 to 40 feet below topmica is dark green and feldspar drull, pale maroon, relatively soft, and structureless; core ends in granitic rocks at 5116 feet | | |

# APPENDIX II

## RESULTS OF X-RAY DIFFRACTOMETER CLAY ANALYSES

## X-RAY DIFFRACTOMETER CLAY ANALYSES
## ATHABASCA FORMATION

### SANDSTONE CEMENT

| Member | Unit No. | Depth | % Clay Kaol. | Ill. | Chl. | Mxd. Lay. |
|---|---|---|---|---|---|---|
| | 1 | 102 | 3 | 96 | 1 | |
| | 1 | 135 | 5 | 93 | 2 | |
| | 1 | 180 | 6 | 93 | 2 | |
| | 1 | 211 | 5 | 95 | 1 | |
| | 1 | 235 | 4 | 96 | 1 | |
| | 2 | 258 | 28 | 3 | 69 | |
| | 4 | 353 | 2 | 79 | 19 | |
| | 8 | 403 | | 36 | 64 | |
| | 9 | 435 | | 73 | 27 | |
| | 12 | 475 | | 33 | 48 | 19 |
| | 13 | 497 | | 12 | 88 | |
| | 15 | 538 | | 24 | 76 | |
| | 15 | 610 | | 35 | 65 | |
| | 15 | 717 | | 24 | 76 | |
| | 17 | 781 | | 18 | 82 | |
| | 19 | 825 | | 19 | 81 | |
| | 23 | 876 | | 10 | 90 | |
| | 25 | 899 | | 15 | 85 | |
| | 25 | 907 | | 13 | 87 | |
| | 25 | 925 | | 29 | 71 | |
| | 29 | 959 | | 16 | 84 | |
| | 33 | 1030 | | 97 | 2 | 1 |
| UPPER | 33 | 1048 | | 60 | 40 | |
| | 33 | 1073 | | 56 | 44 | |
| | 39 | 1188 | | 12 | 88 | |
| | 40 | 1237 | | 14 | 86 | |
| | 40 | 1276 | | 86 | 14 | |
| | 40 | 1295 | | 100 | | |
| | 40 | 1309 | 43 | 39 | 17 | |
| | 40 | 1324 | 14 | 84 | 2 | |
| | 40 | 1329 | 12 | 87 | 1 | |
| | 40 | 1346 | 23 | 76 | 1 | |
| | 40 | 1364 | 29 | 71 | | |
| | 40 | 1382 | 26 | 73 | 1 | |
| | 40 | 1397 | 23 | 76 | 1 | |
| | 41 | 1408 | 70 | 30 | | |

X-RAY DIFFRACTOMETER CLAY ANALYSES
ATHABASCA FORMATION
SANDSTONE CEMENT

| Member | Unit No. | Depth | % Clay Kaol. | Ill. | Chl. | Mxd. Lay. |
|---|---|---|---|---|---|---|
| | 42 | 1429 | 24 | 75 | 1 | |
| | 42 | 1560 | 1 | 99 | | |
| | 42 | 1644 | 29 | 71 | | |
| | 42 | 1726 | 21 | 79 | | |
| | 42 | 1796 | 18 | 77 | | 4 |
| | 42 | 1867 | 20 | 80 | | |
| | 42 | 1962 | 12 | 88 | | |
| | 42 | 2001 | 5 | 95 | | |
| | 42 | 2170 | 10 | 90 | | |
| | 42 | 2239 | 12 | 88 | | |
| | 42 | 2393 | 13 | 87 | | |
| LOWER | 42 | 2633 | 31 | 69 | | |
| | 42 | 2841 | 21 | 79 | | |
| | 42 | 2913 | 31 | 69 | | |
| | 42 | 3019 | 32 | 61 | 6 | |
| | 42 | 3529 | 64 | 36 | | |
| | 42 | 3784 | 12 | 86 | 1 | |
| | 42 | 4054 | 63 | 28 | 9 | |
| | 42 | 4477 | 33 | 67 | | |
| | 42 | 4650 | 32 | 68 | | |
| | 42 | 4727 | 30 | 68 | | |
| | 42 | 4739 | 34 | 64 | | |
| | 43 | 4753 | 52 | 48 | | |
| | 43 | 4758 | 76 | 24 | | |
| | 43 | 4760 | 83 | 18 | | |

## X-RAY DIFFRACTOMETER CLAY ANALYSES
## ATHABASCA FORMATION

SHALE

| Member | Unit No. | Depth | Kaol. | Ill. | Chl. | Mxd. | Mont. |
|---|---|---|---|---|---|---|---|
| | | | % Clay | | | | |
| | 4 | 300 | 51 | 49 | | | |
| | 4 | 302 | 67 | 33 | | | |
| | 4 | 316 | 44 | 49 | | 7 | |
| | 6 | 378 | 45 | 55 | | | |
| | 12 | 478 | 3 | 94 | | 4 | |
| | 14 | 526 | | 88 | 4 | 8 | |
| UPPER | 15 | 586 | | 93 | 4 | 2 | |
| | 19 | 845 | | 93 | 4 | 4 | |
| | 22 | 861.5 | | 87 | 3 | 4 | 6 |
| | 24 | 884 | | 97 | 2 | 1 | |
| | 32 | 1000 | | 93 | 2 | 4 | |
| | 33 | 1100 | | 91 | 3 | 6 | |
| | 36 | 1136 | | 71 | 10 | 19 | |
| | 42 | 1442 | 11 | 87 | | 3 | |
| | 42 | 1570 | 28 | 69 | | 2 | |
| LOWER | 42 | 2986 | 45 | 38 | 4 | 5 | |
| | 42 | 3251 | 43 | 52 | 1 | | |
| | 44 | 4777.5 | 52 | 42 | 2 | 4 | |
| REGOLITH | 44 | 4780 | 23 | 67 | 1 | 4 | 4 |
| | 44 | 4784 | 7 | 90 | 1 | 1 | 2 |