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RESEARCH COUNCIL OF ALBERTA

INTERIM REPORT

GEOLOGY OF THE PEACE-ATHABASCA RIVER DELTA REGION, ALBERTA

by

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RESEARCH COUNCIL

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FIGURES

MAPS
(in accompanying atlas)

FOREWORD

This report is an interim report on the geology of the Peace-Athabasca Delta region, Alberta. It was prepared at the request of the Director of the Peace-Athabasca Delta Project, Mr. D. Hornby.

In the near future the Research Council of Alberta will publish a final report concerning the geology and geologic history of the area.

SUMMARY

The Peace-Athabasca Delta is underlain by Canadian Shield granites and gneisses, Athabasca Sandstone, and Devonian limestone and gypsum. The configuration of the bedrock surface underlying the Delta varies with the type of formation present. The bedrock surface of areas underlain by Canadian Shield rocks is knobby with local relief of 200 feet. The bedrock surface of areas underlain by other formations is nearly flat. Large preglacial valleys dissect the bedrock and these valleys have been overdeepended by glacial action. Towards the end of the recession of the continental icesheet large proglacial lakes covered the Delta region and thick deposits of inwash and glaciolacustrine sediments were laid down.

The Peace-Athabasca Delta began to form about 10,000 years ago and it now forms a composite, inland delta of the bird's-foot type. The Peace, Athabasca and Birch deltas occupy an area of 1475 square miles and, at present, extend their total area 1 square mile every 13 years. The Athabasca and Birch rivers are actively extending their delta areas but the Athabasca Delta accounts for the greater proportion by far. The Athabasca Delta has reached a point of development (the present distributaries are overextended) where migration of the active lobe is imminent.

The Peace Delta is now in an old stage of development because the Peace River bypasses the Delta. The delta receives sediment only during high flood stage of the Peace River so that area extension from sediment deposition is small. The Peace Delta is now effectively inactive and will remain so with the upstream regulation of water levels.

A series of barrier islands have formed (as a result of wave action in Lake Athabasca) which extend from Fort Chipewyan to Old Fort Point.

Most of the deposits on the surface of the delta are silts and clays deposited during flood stages. These silts and clays are suitable for road construction. Subsidence due to sediment compaction is evident on the margins of the Peace, Athabasca and Birch Deltas. Wave action has modified portions of the Delta which receive little sedimentation.

Two types of lakes exist in the Peace-Athabasca Delta: lakes connected to open water and lakes not connected. The connected or open lakes raise and lower their water level in response to water level fluctuations in the major lakes. The closed lakes enlarge or decrease in area in response to rainfall or floods.

Erosion features in the Mamawi Lake bed show that the Peace-Athabasca Delta has experienced very low later levels in the past.

No drastic changes will occur in the Peace Delta but the Athabasca Delta is a dynamic feature and large, abrupt changes in its configuration are expected in the very near future.

GEOLOGY OF THE PEACE - ATHABASCA DELTA

INTRODUCTION

Location and Size

The Peace-Athabasca Delta, one of the largest inland fresh water deltas of the world, is located in northeastern Alberta at the southwestern end of Lake Athabasca. It lies between 58°15' and 59°00' north latitude and 110°45' and 112°20' west of Greenwich. The total delta complex covers an area of 1475 square miles (3820 square kilometers) and is comprised of the following deltas: Athabasca Delta - 760 square miles (1968 square kilometers), Peace Delta - 650 square miles (1683 square kilometers) and Birch Delta - 65 square miles (168 square kilometers). Other very small deltas in the delta complex area are associated with the McIvor, Steepbank, Richardson and Maybelle Rivers, and Keane and Buckton Creeks. Though the Peace and Athabasca Deltas have merged they can be separated with reasonable confidence on the basis of the distributary patterns. The Birch Delta is separate from the main delta complex.

Access

Access to the Peace-Athabasca Delta is very difficult and is practically restricted to helicopter transport. Despite the flexibility of the helicopter the lack of suitable landing spots still limits surface mapping and sampling in the delta region.

Climate

The climate of the Peace-Athabasca Delta is warmer than the surrounding regions because of lower elevation and the moderating effects of Lake Athabasca and Lake Claire. The region's frost-free period, summer hours of bright summer sunshine, and mean annual snowfall are comparable to those of Edmonton, but the mean annual temperature is lower than at Edmonton. Lake evaporation is approximately equal to the mean annual precipitation (Longley, 1968). In general, summer temperatures at Fort Chipewyan are comparable to those of Edmonton but for the rest of the year it is relatively colder.

Muskeg Accumulation

In warm climates, the accumulation of organic matter is minimal due to high fungal and bacterial action. In the far north, the accumulation of organic matter is very slow because cold climates inhibit plant growth. There is an intermediate climatic zone in which a maximum accumulation of organic matter occurs (maximum muskeg growth) because plant growth is significant and yet organic disintegration by bacteria and fungii is less than the yearly growth. The Peace-Athabasca Delta is situated in such a zone.

Permafrost

Discontinuous permafrost is present in the surrounding area (Lindsay and Odynsky, 1965), but due to the moderating effect of the large lakes it is not found in the delta.

Permafrost has been encountered at a depth of 89 feet on the extreme western shore of Lake Claire (Drill hole H-2, Appendix 1). During drilling, Dr. G. Nielsen reported that samples contained interstitial and clear ice at the 89 foot depth. No permafrost exists from the present delta surface to 89 feet and hence this ice and associated cold ground is considered to be fossil permaforst remaining from the last glacial age. Permafrost was also noted in drill holes G-2 at 3.5 feet and H-5 from 8 to 54 feet.

Fieldwork and Sources of Information

During the summer of 1970 the senior author mapped the distribution of surficial deposits in the Peace-Athabasca Delta as part of an overall survey of northeastern Alberta conducted by the Research Council of Alberta. The delta was traversed by helicopter and landings were made to sample and identify the surficial material.

In 1961 exploratory mapping of the soils was carried out by a team from the Research Council of Alberta which included the senior author (Lindsay *et al.*, 1962). During the Exploratory Soil Survey landings were made in the delta area to identify and classify the soils. Original field notes and samples were made available to the authors for the present study.

Low-altitude, oblique aerial photographs of the delta taken in 1927 by the Royal Canadian Air Force were obtained for study from the Provincial Museum and Archives, Edmonton, Alberta. These photographs do not cover the entire delta area and only some of the significant portions are represented. Other aerial photographs taken in 1950 at a scale of 1:33,000 and in 1970 at a scale of 1:24,000 were also used in this study.

Samples of the subaqueous portion of the delta were supplied by Dr. A. A. Levinson, Department of Geology, University of Calgary, Alberta.

Lithologs of drill holes bored by Dr. G. Nielsen were supplied by the Water Resources Division of the Department of the Environment, Government of Alberta.

One water-well log was also consulted (on file at the Research Council of Alberta).

Previous Work

No previous systematic or detailed work on the geology of the delta is available. Early travellers through the delta noticed deltaic deposits and high water levels in the deltaic marshes. Alcock (1920) speculated on the origin of the Lake Athabasca basin and contended that the basin was produced by glacial erosion (overdeepening) of weak rocks that floored a pre-existing valley.

Acknowledgments

Acknowledgment is extended to the Research Council of Alberta for providing the information on which this report is based and the base map which accompanies the map atlas.

Dr. J. D. Godfrey (Research Council) provided the information on the Precambrian Shield rocks and read the manuscript critically.

Mr. F. Copeland compiled and drafted the base map and Mr. M. Baaske performed the mechanical analyses of the samples provided by Dr. A. A. Levinson.

Dr. G. L. Nielsen, Water Resources Division, Department of the Environment, provided drill hole lithologs and mechanical analyses of drill hole samples, all of which were invaluable in the interpretation of the geology of the delta.

Thanks are especially due to Dr. G. B. Mellon (Head, Geology Division, Research Council of Alberta) who permitted the early expansion of the study and has given generously of his time and knowledge.

BEDROCK LITHOLOGY

General Setting

The Peace-Athabasca Delta is positioned at the edge of the exposed Canadian Precambrian Shield. Precambrian rocks are found east and north of the delta and Paleozoic gypsum and limestone are found to the west. Mesozoic rocks form the Birch Mountains southwest of the delta (Map 1). The delineation of bedrock types and bedrock topography beneath the delta is difficult. Only a small number of outcrops occur on the periphery of the delta region and the underlying bedrock and its topography have been inferred from these outcrops and the limited available borehole data.

Precambrian Igneous and Metamorphic Rocks

The Precambrian Shield complex of plutonic metamorphic-igneous rocks lies within the Churchill Province and therefore has been severely affected by the Hudsonian orogeny corresponding to an age of about 1800 million years before the present.

The migmatitic gneisses include biotite- and hornblende-bearing phases with small lenses of metasedimentary rock and amphibolite. The metasedimentary rocks are composed of impure quartzites, phyllites and schists, and locally may include minor amphibolite.

These gneisses have been intruded by massive to foliated granites that form bodies of varied sizes ranging from one hundred feet or less up to plutons over 10 miles in length.

The Precambrian terrain has a distinct northeasterly trend expressed by the steeply dipping metamorphic foliation of the rocks, the alignment of lenses and bands in the gneisses, the elongation of the granite plutons and the major faults of the area. Two zones of mylonitization (deep-seated wrench faults) also cross this rock complex parallel to the regional trend; a six-mile wide zone lies adjacent to the shore of Lake Athabasca, and a second two-mile wide zone passes through Flett Lake.

Athabasca Sandstone

Athabasca sandstone is not exposed in the delta area but it crops out along the south shore of Lake Athabasca east of Old Fort Point. The sandstone is composed predominantly of fine- to medium-grained quartz with uncommon thin conglomeratic and shale stringers. Cementation of the formation is variable. In Alberta the sandstone is poorly cemented and friable and no really hard strata have been observed. The poor cementation observed in the outcrops may be the result of weathering and it is possible that the sandstone is much harder a short distance below the surface.

Athabasca sandstone occurs as subcrop on Bustard Island, and crops out on Burntwood Island and on the north shore of Lake Athabasca at Fidler-Point and just east of Fort Chipewyan.

Goose Island in the Athabasca Delta is not a deltaic island but is made of glacially-derived Athabasca sandstone rubble which forms a portion of the end moraine extending along Old Fort Point peninsula.

The thickness of the Athabasca Formation is variable. Though generally thinner at the margins, a boring towards the centre of the basin in Saskatchewan reveals a thickness in the order of 5000 feet. No thickness data are available for the formation in Alberta, but it should exceed 1000 feet in the major outcrop area south of Lake Athabasca.

Paleozoic and Mesozoic Formations

The surface of the Canadian Shield dips gently to the southwest, and no outcrops of Precambrian rocks occur west of a northwest-trending line running through Lake Mamawi and Lake Baril. West of this line Devonian strata overlie the Precambrian granites. A few limestone outcrops of the Slave Point Formation occur near the Birch River Delta. The Keg River and Muskeg Formations crop out on the Slave River but are not found in the Peace-Athabasca Delta area. These two formations are believed to underlie surficial deposits around the mouth of the Athabasca River and west of the Slave River close to the Peace-Athabasca Delta. Thus, they should form the bedrock of the Peace-Athabasca Delta west of Mamawi and Baril Lakes.

A map showing the gross distribution of bedrock formations and their lithology may be found in "Bedrock Geology of Northern Alberta," R. Green *et al.* (1969).

BEDROCK TOPOGRAPHY

Bedrock Topography Underlying Peace-Athabasca Delta

The Canadian Shield rocks which crop out in the Peace River Delta area are continuous in the subsurface with the rocks east of the Riviere des Rochers channel. By constructing projected profiles (of 4 miles projection width) it was determined that the local relief on the Shield is about 200 feet. A line on map 1 marks the theoretical position at which the highest knobs should crop out at the 700 foot elevation. The true westerly outcrop limit of the Precambrian Shield rocks in the delta area is shown to be some 10 miles east of the projected 700 foot line. Consequently, the topographic configuration of the basement beneath the delta west of the true outcrop line is uncertain. The discrepancy may be explained by either a greater downwarping of the Shield surface west of the outcrop line or vertical displacement along a fault. Aeromagnetic maps show evidence of two faults in that area (Map 1). In rocks of high aeromagnetic response (e.g. gneisses) faults are generally evident as valley lows on the maps. In summary, it may only be said that within the Precambrian outcrop area the local relief of the bedrock is about 200 feet. A line passing through Fort Chipewyan projected southwest from the northwest-trending shoreline of Lake Athabasca divides the Shield outcrops from the Athabasca sandstone outcrops within the study area. Aeromagnetic maps show a coincident contrast in response along this same boundary (Map 1). From these observations it is suggested that the bedrock surface under the Athabasca River Delta should be similar in configuration to that in Lake Athabasca.

Northeastwards from the delta the lake is shallow, from 10 to 25 feet deep, and it is assumed that the bedrock is probably not overlain by much recent sediment. Athabasca sandstone could be encountered some 20 to 30 feet below Lake Athabasca water level in that part of the Athabasca Delta.

Local relief on the Athabasca Formation south of Lake Athabasca is very subdued compared to the 200 foot local relief on the Precambrian Shield to the north.

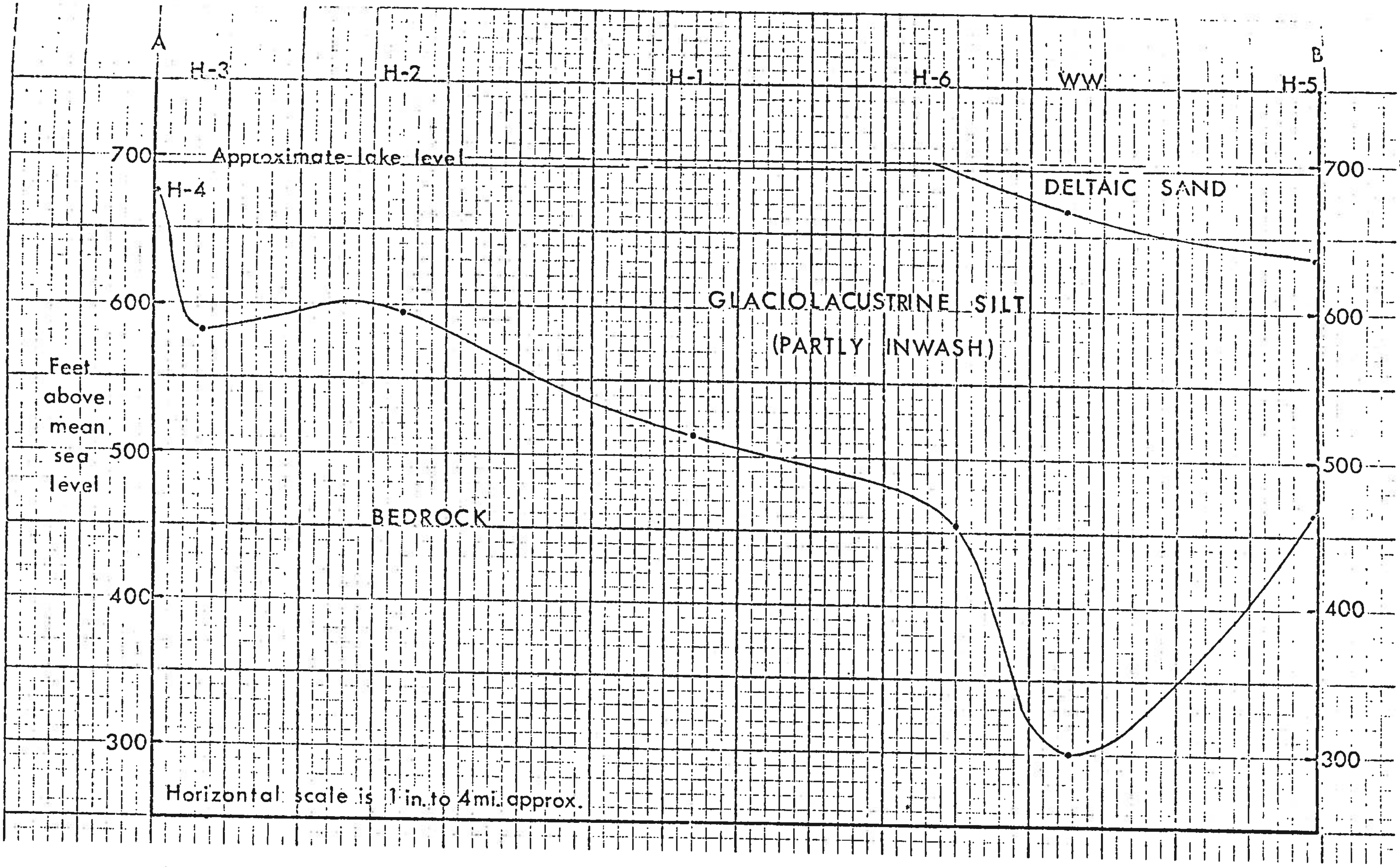
The bedrock surface of the Lake Claire portion of the basin can be interpreted on the basis of drill hole information supplied by Water Resources (Appendix 1). A vertical cross-section of the west shore of Lake Claire is shown in figure 1. The thalweg of the preglacial Peace River is positioned near the northern shore of Lake Claire and at that location bedrock is 400 feet below the surface. To the south near Spruce Point the preglacial bedrock surface is close to the present topographic surface. Hence, it is postulated that bedrock (Slave Point Formation) is relatively close to the surface under Lake Claire south of an east-west line through Spruce Point.

The Formation of Lake Athabasca Basin

Towards the end of the Cretaceous Period the extensive seas withdrew from northeast Alberta and from then on the area was subjected to continuous erosion. All the sediments overlying the Shield rocks in the Fort Chipewyan region were stripped off whereas west of the Slave River erosion removed strata down to Devonian formations. In the Birch Mountains area erosion was less severe and Cretaceous strata are still present.

Towards the end of Tertiary time and at the beginning of the Quaternary Era the gross topographic features of the area were essentially the same as at present. In the very large broad valleys between the erosional remnants (the Birch and Caribou Mountains) large rivers flowed in positions similar to those at present. In the Peace-Athabasca Delta area three rivers converged. One came from the west along the course of the present Peace River, a second came from the south essentially along the course of the present Athabasca River, and the third came from the east through the basin of the present Lake Athabasca. All three rivers united and flowed northwards along the present Slave River route.

The Pleistocene Period began with the buildup of continental glaciers which repeatedly extended over large portions of North America. Pre-Wisconsin glaciers probably flowed in more or less the same direction as the Wisconsin continental glacier. Glacial striae show that the Wisconsin glacier flowed



Note: glacial till and outwash underlying glaciolacutrine silts are too thin to be shown.

Figure 1. Cross-section of bedrock surface from A-B, Map 1.

from the northeast parallel to the long axis of Lake Athabasca. The long axis of Lake Athabasca was also the thalweg of a preglacial river, and thus was a natural topographic low. Pleistocene continental glaciers followed the course of the preglacial river, accelerated the erosion and overdeepened the valley. Overdeepening could have resulted from the removal of soft rocks in the area of the present lake as postulated by Alcock (1920).

Lake Claire is positioned over the axis of the preglacial Peace River valley. Glaciers advancing from the northeast would follow the Peace River valley westward and overdeepening could have taken place in the Lake Claire area in the same manner as the Lake Athabasca basin. Hence, the deep portion of the preglacial Peace River valley (Fig. 1) may be the result of glacial overdeepening rather than being a feature of the original valley.

The deepest portion of the preglacial Peace River valley as shown on figure 1 is only 300 feet above sea level. Along the Slave River are many rapids and bedrock outcrops which preclude the presence of a large preglacial valley that their depth,[1] furthermore, there are no such valleys towards the eastern end of Lake Athabasca. In short is seems very likely that the deep portion of the Peace River valley has been produced primarily by glacial erosion.

The Athabasca River may also be positioned over an overdeepened preglacial valley near the Delta as outcrops are lacking along the Athabasca River close to the delta.

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[1] L. A. Bayrock (1972): Surficial Geology, Peace Point-Fort Fitzgerald, Research Council of Alberta; map, scale 1:250,000 in press.

QUATERNARY HISTORY OF THE DELTA BASIN

Glacial History

The last glacier to cover the area advanced from the east-northeast as indicated by the large number of ice flow features present around the delta (Alcock, 1920), Glacial Map of Canada (Prest *et al.* 1967), and Godfrey (in preparation[2]). It is estimated that at the height of the last of Wisconsin glaciation the area was covered with up to two miles of ice.

The recession of the continental glacier from the area was marked by pauses and short readvances. During maximum glaciation the entire area was covered including the Birch and Caribou Mountains. As glacial recession proceeded the surface of the glacier was lowered and the Birch and Caribou uplands were exposed. Further lowering of the glacier surface exposed the uplands entirely and the margin of the glacier was positioned for a time in the lowlands west and south of the delta.

The glacier receeded further towards the northeast down the regional slope, and since the natural drainage of the area is also to the northeast glacial meltwater formed large lakes in front of the standing ice mass. These ice marginal lakes persisted until the final disappearance of the glacier from the area. Consequently, the deposits left in the lowlands surrounding the delta area are either glaciolacustrine or glacial outwash.

It is not possible to date the time of recession of the glacier from the delta as no samples have been radio-carbon dated. In Saskatchewan the Creek Lake moraine is tentatively dated as being about 10,900 $\pm$ 700 years old. This is based on a radio-carbon date of peat overlying till in front of the Cree Lake moraine (McCallum and Wittenberg, 1962, S - 123).

The Creek Lake moraine in Saskatchewan is one continuous moraine but in Alberta it splits into four separate moraines. These moraines are situated from the northern limit of the Muskeg Hills in the Bitumount map-area (74-L)

[2] Godfrey, J. D: Geology of the Fort Chipewyan District, Northeast Alberta; Research Council of Alberta, Map, in preparation.

northwards to the south shores of Lake Athabasca. The small moraines in the delta area represent separate, short readvances of the glacier during the general recession. Ice-marginal lakes of different elevations are associated with each of these moraines.

Raised glacial lake beaches are well developed west of Lake Claire, west of the Slave River, and on both shores of Lake Athabasca up to 300 feet above the present water level of Lake Athabasca. The beaches on the west shore of Lake Claire show considerable tilting which indicates uneven postglacial isostatic readjustment.

Although individual raised beaches are continuous over long distances, correlation of beaches between different areas is not possible.

Proglacial lakes which occupied the area west and south of the delta received sedimentation directly from both the melting glacier and from the Athabasca and Peace Rivers. Material of nonglacial origin deposited in glacial lakes is called inwash. Both the Peace and Athabasca Rivers deposited thick proglacial deposits of this type in lakes around the delta area. Athabasca River inwash may be seen along the river valley for a distance of about 25 miles south of the Athabasca Delta. Inwash from the Peace River covers a much larger area; its extends from the lowland between the Birch and Caribou Mountains west of Lake Claire to about Vermilion Rapids on the Peace River, a distance of about 90 miles.

Postglacial History

As the proglacial lakes drained, the newly exposed and unvegetated inwash and outwash sediments were subjected to intense aeolian activity. This activity led to the formation of the presently stabilized sand dunes along the Athabasca River and in the lowlands west of Lake Claire. The major dune forming (storm) winds during this time were from the southeast. Dune forming winds at present are from the northwest. The inwash sediments can be readily distinguished from glacial sediments. The former contain coal and bituminous sand derived from the south and the west, whereas, glacial sediments in the Peace-Athabasca Delta area do not contain such organic materials.

Isostatic Readjustment

The recession of the continental glacier led to isostatic readjustment of the land. During the period of maximum development of the Wisconsin glacier, the glacier was about 10,000 feet thick over the delta. (The calculation is based on a formula derived by Nye [1959]). Ice cover of this thickness would depress the continent isostatically by about one third of the thickness of the glacier, then during and after the recession of the glacier the continent would rebound to its former elevation. The glacier was thickest towards the center of the former ice sheet and consequently the continent was depressed more there compared to the peripheral area. Corresponding postglacial isostatic readjustments of the continent are therefore greatest towards the former centers of continental glaciers compared to peripheral areas. The result of the differential movement is tilting of the continental surface during the rebound period.

Based on a series of abandoned beaches west of Lake Claire and on elevations along the 29th baseline (as recorded on the NTS sheet 84 I) it was calculated that the area is tilted up towards the northeast at the rate of two feet per mile. The tilt axis lies at about 40 degrees west of north. The rate of isostatic readjustment was probably highest at the start of deglaciation and it decreased exponentially with time. It can be assumed that the isostatic readjustment is now practically completed.

Surficial deposits of the area surrounding the Peace-Athabasca Delta have been mapped by the Research Council of Alberta on a scale of 1:250,000. Maps showing the distribution of the deposits are now in press and should be available by August 1972.

SEDIMENTATION

Inland Delta

The Lake Claire-Lake Athabasca basin is one continuous depression enlarged by glacial erosion and presently divided into two parts by the Peace-Athabasca Delta. The Peace-Athabasca Delta began to form approximately 10,000 years ago, immediately after glacial recession and draining of the proglacial lakes.

The Peace-Athabasca inland delta will eventually silt up the depression in which it is now growing and the rivers supplying the sediments will then flow through the delta without deposition. Geologically speaking an inland delta is a very short-lived feature of the landscape.

Separate Deltas

Although the Peace and Athabasca Deltas have merged, they can still be differentiated on the basis of their distributary configuration. Active or inactive individual distributaries may be traced back to the major river of their origin. The differentiation of the two major deltas is shown on map 5.

Deposition of Sediment Due to Loss of Current

Deltas are built by the deposition of sediments from streams as they enter bodies of water. A stream loses most of its turbulence on entering a body of water and the sediments are deposited. The river sediment is deposited in reasonably predictable patterns which make it possible to describe the past and future behavior of a delta.

Sedimentation Dynamics

An actively growing delta is a dynamic phenomenon. The position and size of the individual distributaries may change yearly but the greatest changes occur when the area of deposition shifts from one part of the delta to another. For example, since 1927 the distributaries of the Embarras River have been captured by the Fletcher Channel, and during recent geologic time it can be shown that the Peace and Athabasca Deltas have changed their major distributary patterns on a large scale (Map 3).

Rates of Accretion

The Peace Delta has reached the stage of development at which deposition takes place only at flood times (old age). The Athabasca River deposits most of its sediments in the delta and is actively extending that area. The Athabasca Delta is 760 square miles in area and since it originated about 10,000 years ago it is being enlarged on the average at the rate of one square mile every 13 years. The Peace Delta is 650 square miles in area but it is not presently active and the period of inactivity is not known. The Peace Delta is in the old stage of development and the Peace River is bypassing it. Consequently, the growth rates for the Peace Delta have not been calculated. The Birch River Delta is 65 square miles in area and it enlarges its area by about one square mile every 150 years.

Sedimentation Patterns

The Peace-Athabasca Delta is a typical bird's-foot delta. The visible portion of the delta is the result of subaerial deposition in contrast to the portion of the delta which remains below the surface of the water (subaqueous deposition). The growth of the bird's-foot pattern is mainly the result of the buildup of levees along the distributaries to a height above the average water level during flood times. The distributaries commonly bifurcate and reunite to enclose depressions between them. These depressions become deltaic lakes and marshes.

During flood periods, water in the distributaries overflows the banks, sand is deposited on the levees, and silt and clay become trapped in the intervening lakes and marshes. Deltaic lakes in or near an active area of a delta may receive sedimentation during higher than normal water levels (but not necessarily during every flood) through a levee breach called a crevasse. A miniature delta usually forms at the mouth of a crevasse and extends into the lake. The crevasse may also serve as the drainage channel for the lake after a flood stage has receded. Thus, a lake may be flooded and drained via the same crevasse leading into it. T e crevasse is lower than the level of the top of the levee and once formed sedimentation of the deltaic lakes becomes accelerated. Crevasses are commonly resilted thereby resealing the deltaic lake.

Many of the deltaic lakes are directly connected to open major lake water. Such lakes are on the periphery of the delta in depressions between distributaries which have not yet united with other distributaries. In the Peace-Athabasca Delta region partly open deltaic lakes occur on the outer margins of the three deltas and in the zone between the Peace and Athabasca deltas. Mamawi Lake is an open lake between the two deltas.

Active Lobe Migration

A delta is similar in origin to an alluvial fan and in three dimensions they are both half-cone shaped. The gradient of the delta slope is less steep (the apex of the half-cone corresponds to the point where the river enters the delta area). As a delta grows it aggrades the level of the deposits at its terminus which also results in aggradation of the river bed upstream.

In all deltas, the part of the delta which is actively receiving sediment periodically migrates. The distributary channels overextend themselves and the main river abruptly abandons them in order to seek a shorter, steeper gradient to the water body. Over a period of time, the net result is a series of imbricated delta sediments which resemble many layers of overlapping sloping tiles. The sequence of the most recent active lobe migrations (geologically speaking) of the major detlas is shown on map 3. The distributary channels of the Athabasca River are, at present, well overextended to the east of the delta and migration of the active lobe of the Athabasca Delta is imminent. The most likely position for the new active lobe will be in Lake Claire of Mamawi Lake. The gradient from the Athabasca Delta apex to either Lake Claire or Mamawi Lake is much steeper than its present course.

Point Bar Deposits

Bedload is deposited on the inside of meanders. The deposits are called point bar deposits and are somewhat ridged. Most point bar depoists in the Peace-Athabasca Delta are made of sand and are found along both active and inactive distributaries throughout the delta region. Even some of the smallest distributaries in the delta have point bar deposits. A map of the distribution of point bar deposits of the delta has not been made because they could not be accurately delineated on 1:250,000 scale maps. (They could be delineated on 1:50,000 scale maps).

The point bar deposits of the Peace-Athabasca Delta range from course- to fine-grained sand but this deposit with silt and clay is frequently covered (from flood periods). Thus, older point bar deposits have a thicker silt cover than the more recent deposits. The depressions between individual point bars are gradually infilled with silt resulting in a smoother surface.

Rates of Sedimentation

The Peace-Athabasca Delta has been divided into three parts according to the present rates of deposition: active (continual sedimentation), semiactive (sedimentation annually) and inactive (little sedimentation except at extreme flood stage). The active parts of the delta are close to the water level of the lake. This part is devoid of vegetation and shows active depositional features such as extended levees, crevasses, crevasse deltas and enclosed lakes.

The semiactive parts are covered with sparse vegetation and are above lake water most of the time. The growth of vegetation in these areas is inhibited by considerable sedimentation (silt and very fine sand) during flood stages.

The inactive parts of the delta do not receive inorganic sediments at rates which inhibit plant growth and these areas are well above most lake water levels. Large portions of the inactive areas do not receive any sediment at present.

This classification and division is based on a detailed examination of air photographs supplemented by field data wherever possible. Map 5 shows the distribution of the three divisions.

Sedimentation in the Peace Delta

For much of the year the Peace River bypasses the Peace Delta and consequently most of the river's bedload is carried downstream to the Slave River and is not deposited in the Delta. During high flood stages considerable inflow from the Peace River into Lake Athabasca takes place through the Baril River, Chenal des Quatre Fourches, Riviere des Rochers and its fork Revillon Coupe. At the turn of the century the Claire River was also active. Very little bedload of the Peace River entered these channels during flood stages, and hence only silt and clay were deposited in Lake Athabasca. At low water stages (most of the year), the channels serve as outlets for Lake Athabasca water. The rate of sedimentation in the Peace Delta is periodic (high floods) and the areas are classified as semiactive. In the semiactive parts of the Peace Delta only silts and clays are present, in contrast, the semiactive areas of the Athabasca Delta is deposited during floods.

The upstream regulation of water levels of the effectively moderate high floods in the Peace Delta and hence eliminates sediment deposition in the Peace Delta. Some erosion may take place of the deltaic sediments in the semiactive portions. In the vicinity of Fort Chipewyan the absence of high floods on the Peace River may lead to deepening of the channels mentioned above.

Barrier Islands

An elongated bar extends from Fort Chipewyan to Old Fort Point across the mouths of the active distributaries of the Athabasca Delta. This bar is made primarily of sand which is highly compacted in places. In 1969 Professor A. A. Levinson (University of Calgary) sampled the sediments of the subaqueous portion of the Athabasca Delta. He found sampling to be a problem since the sand was so compact that the sampler would not penetrate. The origin of the barrier island or bar is complex. The sand deposited over a wide area in front of the distributaries becomes subjected to intense wave action by the deeper waters of Lake Athabasca. The sand is rewashed, sorted and generally piled up into the bar shape.

Bars such as these are called barrier islands if the surface of the bar is occasionally above water level. The bar in Lake Athabasca is above water level at very low levels of Lake Athabasca and therefore it may be called a barrier island.

Surficial Deposits of the Delta

The surficial deposits in the delta region are sand, silt, and clay, with silt predominant. Appendix 1 gives mechanical analyses of drill-hole samples of the deep holes on the west shore of Lake Claire and some of the hand auger samples of shallow holes in the delta. Locations of the drill holes are shown on map 2.

Samples from hand-auger holes E-1, E-2, E-3, F-1, F-2, and D-3 are of similar composition, made up of silt (60 to 70 percent) and clay (20 to 40 percent) with smaller amounts of sand (less than 10 percent). (These holes were bored across distributary levees (i.e. 90 degrees to the direction of flow) and the numbers following the letter designate the position in the drilling profile. Number 1 is close to the distributary channel and higher numbers extend successively towards the lake adjacent to the levee).

Drilling logs of the auger borings are given in appendix 2. Some of the logs give the composition of the materials as silt, and others show more variation in the deposits. They all show that the predominant material is silt with clay. Sand constitutes only a small portion of the deposits.

A helicopter survey performed by the senior author shows that silt and clay covers most of the inactive part of the delta (inactive part designated on map 5). The active and semiactive parts of the delta and levees along the Athabasca River and other major channels of the delta contain considerable amounts of fine-grained sand. Similar results were obtained by Lindsay *et al.* (1962).

The occurrence of silt and clay at the surface throughout the delta region is due to periodic inundation by sediment-laden flood waters.

There are two causes of floods in the Athabasca Delta. The first is floods resulting from ice jams which occur during break-up in the spring. Very large ice jams form on the Athabasca and Embarras Rivers near Richardson Lake and these rivers overflow their banks and flood the surrounding delta.

The second type of flood occurs in July and results from high precipitation and high runoff. It also causes bank overflow and inundates many of the deltaic lakes.

The ice jam flood in the spring of 1971 was observed by the senior author. During this flood, flood waters from the Athabasca River containing suspended silt and clay inundated most of the delta south of the Athabasca River and large areas along Mamawi Creek and the terrain between the Embarras River and Lake Claire. During the July flood of the same year much of the terrain was inundated. The authors have examined an aerial photograph mosaic taken during that flood and the results of the flooding appear similar to the results of ice-jam flooding.

At both times most of the deltaic lakes of the Athabasca Delta were flooded with water carrying a suspended load. These floods and similar periodic floods during the past (most commonly annually) account for the surficial deposits of silt and clay found throughout the inactive parts of the Peace-Athabasca Delta. In the active and semiactive parts of the Delta very fine- to medium-grained sands are deposited.

Wave Action

Deposits of fine- to medium-grained sand are found along extensive beaches throughout the inactive part of the delta. These beaches have been mapped from aerial photographs and are shown on map 4. They have a northeast-southwest orientation that reflects the direction of the prevailing storm winds (and hence the beach forming winds) from the northwest.

A comparison of 1927, 1950 and 1970 aerial photographs reveal that wave erosion has breached levees in two locations during that period. It may be postulated that wave action is responsible for much of the truncation and destruction of levees in the inactive and subsided areas.

Atterberg Limits of Deltaic Sediments

Liquid and plastic limits were determined on four samples collected in 1969. Three of the samples were from dry delta flats (i.e. former deltaic lake beds) and one is from the levee of the Athabasca River. Sample locations are shown on map 2. The levee sample is made of very fine-grained sand and has a very low liquid limit and plastic index (sample LB-69-93-2). The other three samples (LB-69-93-3, LB-69-95-1, and LB-69-95-2) are of medium plasticity (Fig. 2) and under normal conditions soils having these physical properties are suitable for the construction of highways and other structures designed to support loads.

The Delta's surficial deposits are very similar in composition. From this data it follows that if the three samples are representative of the soils found in the Delta, there should be little problem in constructing all-weather roads through the area. It should be pointed out that this conclusion is based on the analyses of only three samples. However, a more thorough survey should substantiate this conclusion.

Subsidence

Silts and clays are deposited in an oozy state in aqueous environments and thereafter undergo considerable compaction after expulsion of the interstitial water. Silts and clays may compact as much as 90 percent of the depositional volume. Most of the compaction takes place very shortly after deposition, but compaction continues for a much longer time. Many deltas around the world show compaction and the resultant subsidence.

Subsidence in the Peace-Athabasca Delta is characterized by the following: levees below lake water levels, truncated levees close to lake water level and partially destroyed by wave action, and levees in the process of being destroyed or breached by wave action.

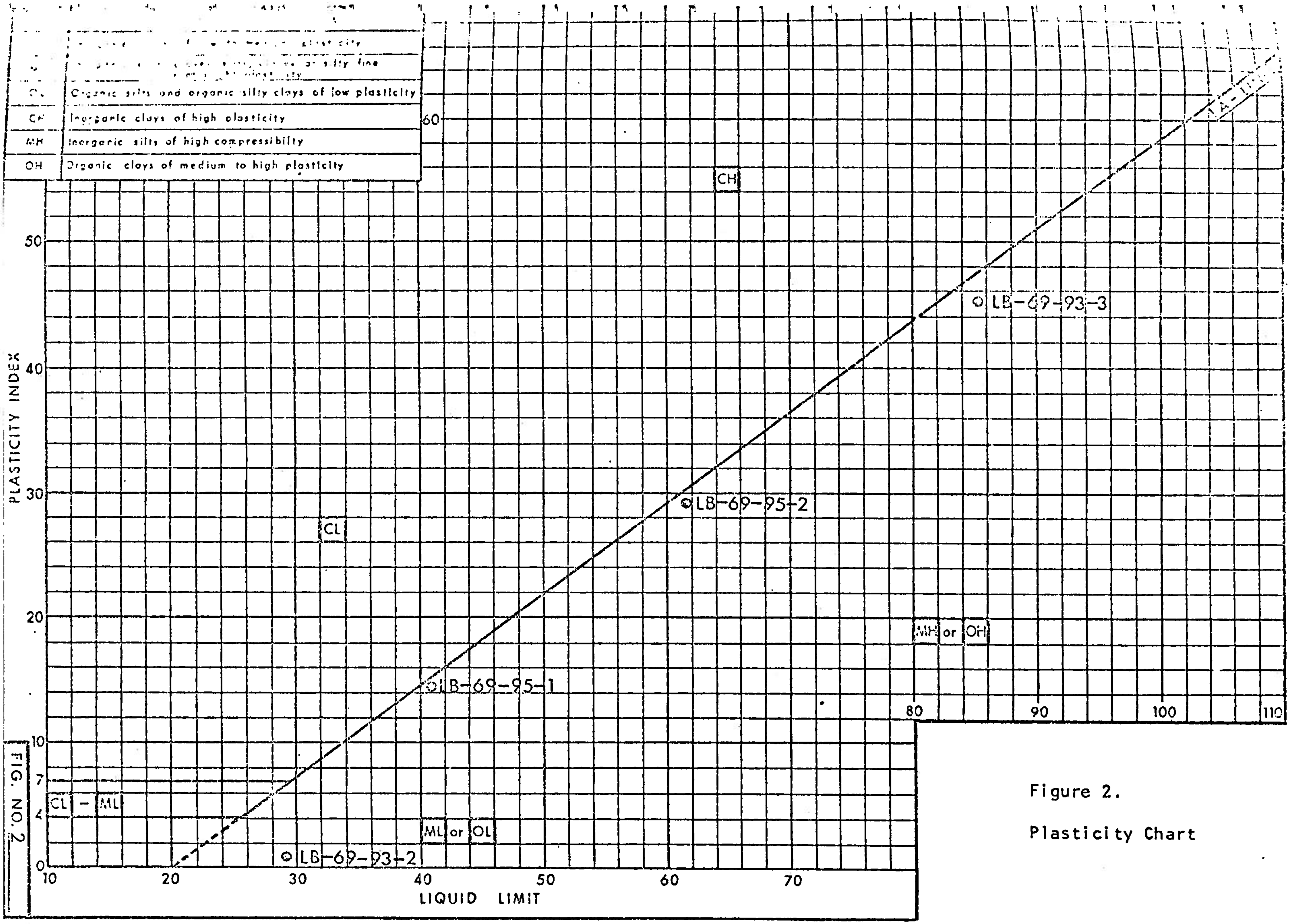

Figure 2.

Plasticity Chart

Map 6 was constructed showing terrain that has undergone subsidence according to the above criteria.

Subsidence areas are more extensive in the Peace Delta than in the Athabasca Delta. This is to be expected because the Peace Delta is made up of a greater proportion of silt and clay than the Athbasca Delta. The Birch Delta also shows significant subsidence. No subsidence was visible in the active or semiactive portions of the Athabasca Delta, but there are some indications of subsidence in the semiactive portion of the Peace Delta.

Deltaic Perched Water Table Lakes

During high floods all deltaic lakes receive silt- and clay-laden waters from the Peace and Athabasca Rivers. These flood waters carry only the suspended load of the rivers to the lakes as the coarse material settles out on the levees.

Flood waters usually remain in these lakes for sufficient time to allow silt and clay to settle out and this clay provides a uniform, impermeable lining to the bed of many of the deltaic lakes. Most of the clay minerals present in the sediments contain a high proportion of montmorillonite derived from bentonitic Cretaceous Formations.

The evaporation from lake surfaces in the Delta area approximately equals the annual precipitation. Hence, lake levels should remain constant where no direct drainage is involved.

Some deltaic lake levels are maintained with flood water and because precipitation is equal to evaporation the levels tend to remain at their high level for a long time. Lakes with drainage channels or open lakes connected directly to the main lakes will adjust their water levels in response to the water level at the outlet or to the main lake level. Closed lakes will not necessarily respond to changes in levels of the major lakes.

Closed lakes in the delta area which have a significant clay lining, (and most of them do) maintain or change their levels regardless of the levels of the major lakes. A heavy rainfall will raise the levels of these lakes very quickly and the high levels will persist for a long time. These lakes are called perched water table lakes.

Subaqueous Sedimentation

The subaqueous portions of the Athabasca and Birch Deltas have been sampled by Dr. A. A. Levinson and aliquots of the samples were supplied to the authors. The results of sieve analyses on the samples (wet sieving through a 250 mesh screen) are shown on tables 1 and 2, appendix 4. Sample locations are shown on map 2. Samples from the subaqueous portion of the Birch Delta are numbered 1 to 19 and the remainder from Lake Athabasca are numbered 23 to 50. Figure 3 shows the sand percentage at the sample locations in Lake Claire, and figure 4 shows sample location in Lake Athabasca.

In Lake Athabasca the distribution of samples that are predominantly sand correspond to the position of the barrier islands described previously. Samples north and northeast of the barrier islands are almost exclusively silt and clay.

Sediments of the subaqueous portion of the Birch Delta are composed predominantly of silt and clay. Two samples (7 and 19) each contain about 40 percent of sand.

Subaqueous Birch Delta sediments are predominantly silt and montmorillonitic clay derived from Cretaceous Formations in the Birch Mountains.

The sand fraction of the Birch Delta sample was examined under the microscope and was found to be composed predominantly of iron oxide oolites derived from the Cretaceous Formations.

Relative Ages of Delta Segments

Deltas change the locations of their active distributaries from time to time and thus different segments of the delta receive renewed sedimentation. The Peace and Athabasca Deltas are subdivided into four age categories and the Birch Delta into two by using the amount of peat formation, the degree of destruction of the delta, subsidence of the delta, and the unaltered, new appearance of distributaries (Map 3).

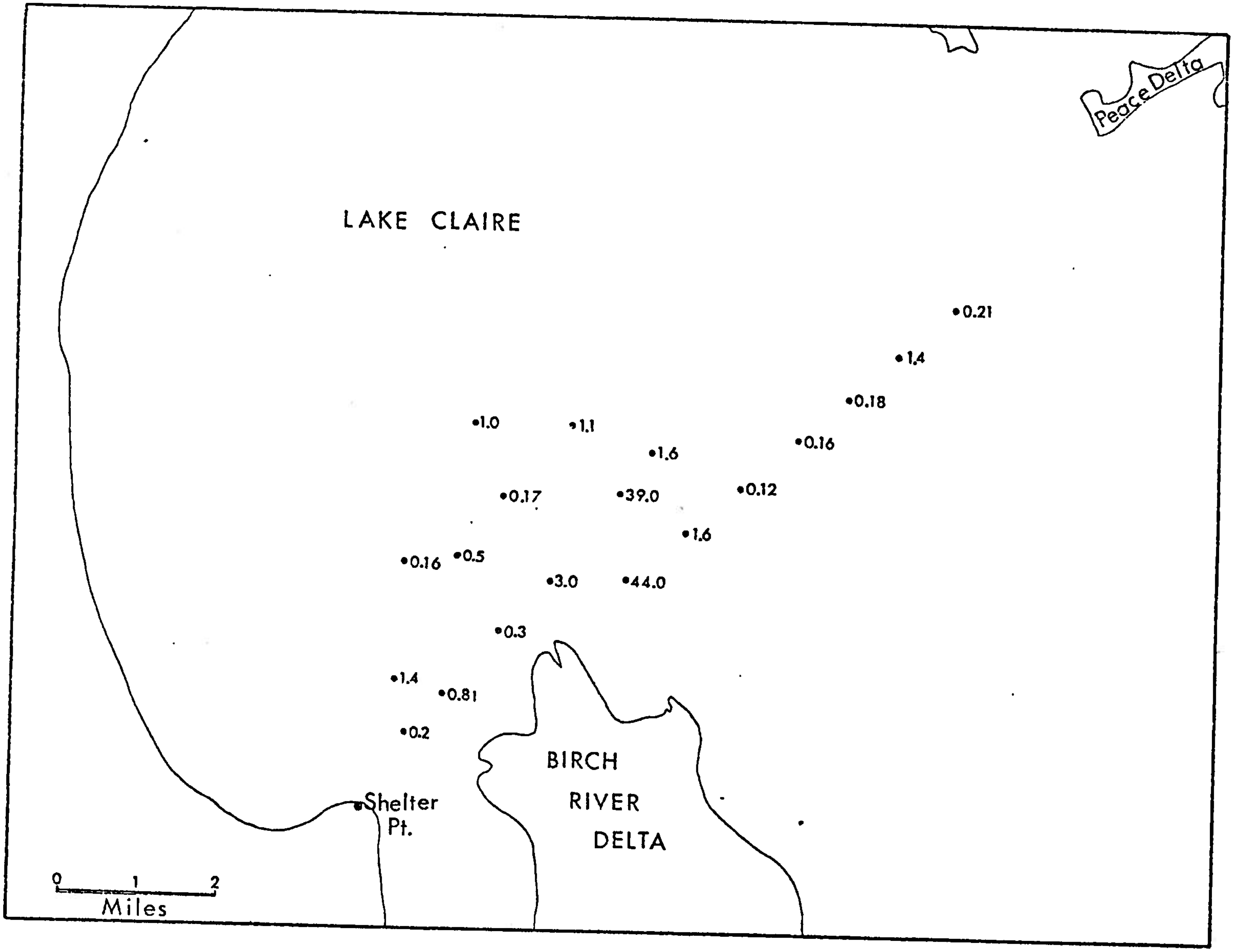

Figure 3. Sand percentage of subaqueous samples in Lake Claire.

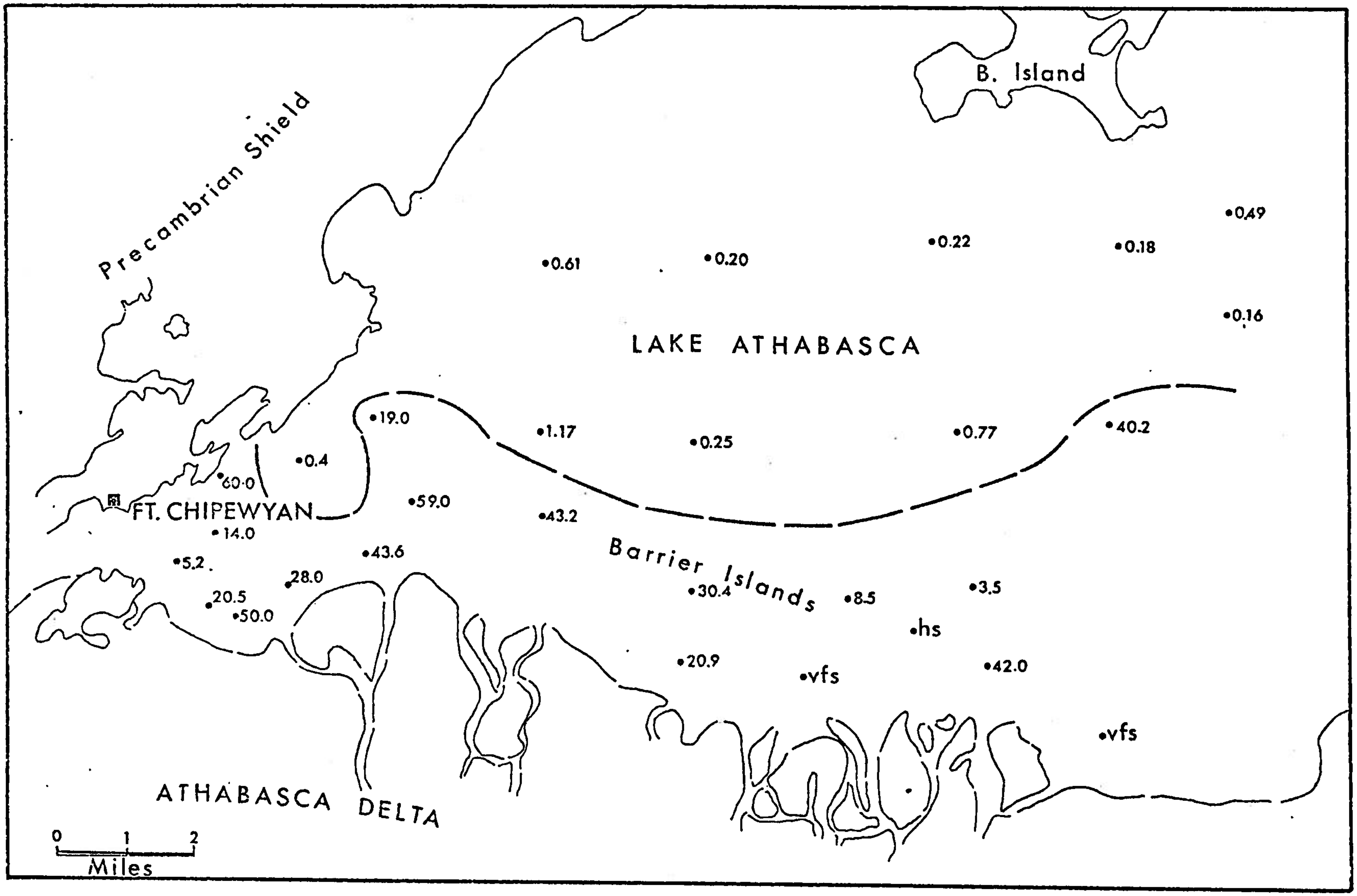

Figure 4. Sand percentage of subaqueous samples in Lake Athabasca.

The relatively older delta segments are not correlated between the individual deltas (i.e. area 3 in the Peace Delta and area 3 in the Athabasca Delta are not necessarily the same are).

The oldest segment of the Athabasca Delta is estimated to be about 3000 years in age (determined on the basis of peat three feet in thickness, which is known to accumulate there at a rate of one foot every 1000 years). No attempt was made to date the surface of the lobes of the Peace and Birch River deltas.

Changes in the Size of Lakes

Aerial photographs taken in 1950 were compared with photographs taken in 1970. It was noted that the dimensions of many deltaic lakes changed, some became larger while others became smaller. A map has been constructed showing the dimensions of lakes in 1970 compared to 1950 (Map 7).

At the time of the 1950 photography (September 10, 1950) the level of Lake Athabasca was 684.2 feet above sea level. During the 1970 photography (October 15, 1970) the Lake Athabasca level was 682.0 feet.

Map 7 shows that open deltaic lakes and most lakes connected by channels or crevasses to flowing or open water decreased in area whereas most of the closed lakes increased in area. The closed lakes are perched water table lakes (as described above) and these lakes are not connected to flowing or open water. It is postulated that the heavy rainfall just prior to the 1970 photography filled these lakes and consequently the occupied larger areas. Lakes which decreased in area are connected to open water of the major lakes and consequently adjusted their level to correspond with the water level of Lake Athabasca.

Low Water Levels of Mamawi Lake

Aerial photographs taken in 1970 show partly buried drainage channels and dendritic erosion patterns in the deepest portions of Mamawi Lake. Mamawi Lake is so shallow that on these photographs its bed may be observed through the lake water. The formation of dendritic drainage patterns on the bed of Mamawi Lake requires that the lake bed be dry at some time in the past. It is not known when such low water levels existed, but a rough estimate would be sometime during the last 200 years. As Mamawi Lake is directly connected to Lake Athabasca, the low water stage must also correspond to a similar low water stage in Lake Athabasca. Such a low water stage (or stages) is lower by about 4 feet than the October 15, 1970 level of 682.0 feet.

Athabasca River Meander Near Embarras Portage

The outside of a large meander on the Athabasca River near Embarras Portage is actively eroding its west bank and in the near future the river will cut through at this point and flow into the adjacent Embarras River. Further details on this situation are included in two reports in appendix 5.

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APPENDIX 1

DRILL HOLE LOGS

The holes were drilled by Dr. Grant Nielsen, Water Resources, Alberta Government, in the spring of 1972. The following are drilling logs based on field description. Genetic interpretation of surficial geological materials is by the authors of this report.

Hole No. H-1

Date: March 12, 1972

Depth (ft)	
	Glaciolacustrine
0-40	silt, light brown, calcareous, soft
40-88	silt, light grey, calcareous, soft
88-145	sandy silt, light grey, calcareous, soft
	Glacial
145-156	till, light grey, gypsum and granite pebbles
	Glacial outwash
156-170	sand, poorly sorted, calcareous
	Bedrock
170-	end of hole - too hard to drill, bedrock?

Hole No. H-2

Date: March 13, 1972

Depth (ft)	
	Glaciolacustrine
0-6	peat, black, soft
6-32	silt, light grey, calcareous, hard
32-40	silt, light grey, very soft
40-48	sand, very fine, slightly silty, calcareous
48-80	silt, light grey, very soft, calcareous
80-88	silt, clayey, light grey, calcareous, very soft
	Glacial outwash
88-89	sand and gravel, pink clay, quartz pebbles, gypsum, glacial permafrost at 89 feet - temperature of samples - 5°C.

Hole No. H-3

Date: March 14, 1972

Depth (ft)	
	Glaciolacustrine
0-16	silt, sandy, grey, calcareous, soft
16-105	silt, light grey, calcareous, soft
	Glacial
105-112	till, reddish, very sandy, gypsum pebbles
	Bedrock
112-	end of hole, bedrock, gypsum, bedded, white to pink

Hole No. H-4

Date: March 14, 1972

Depth (ft)	
	Glacial
0-8	till, gypsum, limestone and granite pebbles and cobbles
	Bedrock
8-11	bedrock, gypsum, white, soft, bedded
11-	end of hole

Hole No. H-5

Date: March 15, 1972

Depth (ft)	
	Alluvial and deltaic - Peace River
0-7	sand, some wood fragments
7-8	silty sand, wood fragments
8-72	sand, angular to subangular, calcareous, occasional organic layers
	Glaciolacustrine
72-240	silt, light grey, calcareous, soft
240-243	sand and fine gravel, granite and quartz pebbles

Hole No. H-6

Date: March 16, 1972

Depth (ft)	
	Organic - Recent
0-4	peat, black, soft
	Glaciolacustrine
4-227	silt, grey, sticky, calcareous
	Bedrock
227-232	bedrock, claystone, brick red, gypsum
232-	end of hole

Hole No. WW

Depth (ft)	
	Deltaic - Peace River
0-25	sand
	Glaciolacustrine
25-391	soft, silt
	Outwash, till?
391-392	gravel with granite boulders
	Bedrock
392-400	bedrock, red shale, soft
400-	end of hole

APPENDIX 2

HAND AUGER DRILL HOLE LOGS

A-1[1]	Location:	NE-21-9-111-W4
	Lithology:	0-10 feet - silts
A-2	Location:	NE-21-9-111-W4
	Lithology:	0-10 feet - silts
A-3	Location:	NE-21-9-111-W4
	Lithology:	0-10 feet - silts
B-1	Location:	Lsd 6-29-9-111-W4
	Lithology:	0-10 feet - silts
B-2	Location:	Lsd 8-29-9-111-W4
	Lithology:	0-10 feet - silts
B-3	Location:	Lsd 8-29-9-111-W4
	Lithology:	0-10 feet - silts
C-1	Location:	Lsd 11-27-9-111-W4
	Lithology:	0-10 feet - silts
C-2	Location:	Lsd 12-27-9-111-W4
	Lithology:	0-10 feet - silts
D-1	Location:	Lsd 9-6-6-109-W4
	Lithology:	0-4 feet - sandy silt, organic material
		4-8 feet - sand, very fine, calcareous
		8-10 feet - sandy silt
D-2	Location:	Lsd 9-6-6-109-W4
	Lithology:	0-2 feet - silt, organic material
		2-6 feet - sandy silt
		6-8 feet - silty sand, very fine
		8-10 feet - sandy silt
D-3	Location:	Lsd 9-6-6-109-W4
	Lithology:	0-2 feet - sandy silt
		2-6 feet - sand
		6-8 feet - silt
		8-10 feet - sandy silt
E-1	Location:	Lsd 8-6-6-109-W4
	Lithology:	0-4 feet - sandy silt
		4-6 feet - silty sand
		6-10 feet - sandy silt
E-2	Location:	Lsd 12-5-6-109-W4
	Lithology:	0-6 feet - sandy silt
		6-8 feet - silty sand
		8-10 feet - sandy silt

[1] Drill hole number

E-3	Location:	Lsd 5-5-6-109-W4
	Lithology:	0-6 feet - sandy silt
		6-8 feet - silty sand
		8-10 feet - sandy silt
F-1	Location:	Lsd 7-36-109-6-W4
	Lithology:	0-8 feet - sandy silt
		8-10 feet - silt
F-2	Location:	Lsd 8-36-109-6-W4
	Lithology:	0-4 feet - silty sand
		4-8 feet - sandy silt
		8-10 feet - sand
G-2	Location:	NE-21-12-114-W4
	Lithology:	0-1 feet - organic silt
		1-4 feet - silt
G-3	Location:	SW-16-12-114-W4
	Lithology:	0-1 feet - clay, organic material
		1-2 feet - silt, organic material
G-4	Location:	NW-5-12-114-W4
	Lithology:	0-0.8 feet - silty clay
		0.8-1.3 feet - sand, very fine
		1.3-2.0 feet - silty sand
		2-4.5 feet - sand, very fine
		4.5-9.0 feet - sand, fine
G-5	Location:	NW-29-12-113-W4
	Lithology:	0-0.3 feet - loam
		0.3-0.5 feet - clay
		0.5-1.0 feet - silt
		1-9.0 feet - sand, very fine
		9-10 feet - silt, sticky

APPENDIX 3

MECHANICAL ANALYSES

Mechanical analyses of drill hole samples collected by Dr. Grant Nielsen, Water Resources, Alberta Government.

Sand-silt-clay percentages of drill hole samples

Drill Hole No.	Depth (ft.)	Sand	Silt	Clay
D-3	10	10	73	17
E-1	2	20	68	12
E-1	4	13	70	17
E-1	6	8	71	21
E-1	8	7	71	22
E-1	10	5	69	26
E-2	2	5	77	18
E-2	4	19	66	15
E-2	6	7	73	20
E-2	8	3	74	23
E-2	10	5	71	24
E-3	2	3	74	23
E-3	4	3	66	31
E-3	6	3	63	34
E-3	8	5	75	20
E-3	10	3	74	23
F-1	2	10	73	17
F-1	4	8	71	21
F-1	6	8	68	24
F-1	8	4	69	27
F-1	10	6	72	22

Drill Hole No.	Depth (ft.)	Sand	Silt	Clay
F-2	2	6	65	29
F-2	4	0	57	43
F-2	6	4	54	42
F-2	8	9	63	28
F-2	10	41	35	24
H-6	24	6	45	49
H-6	40	8	62	30
H-6	64	3	49	48
H-6	80	2	73	25
H-6	104	2	58	40
H-6	120	4	65	31
H-6	136	0	45	55
H-6	168	0	45	55
H-6	184	0	24	76
H-6	192	0	4	96
H-6	216	5	34	61

APPENDIX 4

ANALYSES OF SUBAQUEOUS SAMPLES

Table 1. Analyses of subaqueous samples[1] - Lake Claire

Sample	Sand[2]	Silt & Clay[2]	Sample	Sand	Silt & Clay
1	0.21	99.79	11	0.20	99.80
2	1.40	98.60	12	1.40	98.60
3	0.18	99.82	13	0.16	99.84
4	0.16	99.84	14	0.50	99.50
5	0.12	99.88	15	0.17	99.83
6	1.60	98.40	16	1.00	99.00
7	44.00	56.00	17	1.10	98.90
8	3.00	97.00	18	1.60	98.40
9	0.30	99.70	19	39.00	61.00
10	0.81	99.19			

[1] Samples collected by A. A. Levinson, Department of Geology, University of Calgary

[2] Sand, silt and clay in percentages

Table 2. Analyses of Subaqueous Samples[1] - Lake Athabasca

Sample	Sand[2]	Silt & Clay[2]	Sample	Sand	Silt & Clay
23	42.00	58.00	39	8.50	91.50
24	5.20	94.80	40	30.40	69.60
25	20.50	79.50	41	0.25	99.75
26	50.00	50.00	42	0.20	99.80
27	28.00	72.00	43	0.61	99.39
28	43.60	56.40	44	1.17	98.83
29	20.90	79.10	45	43.20	52.80
32	40.20	59.80	46	59.00	41.00
33	0.16	99.84	47	19.00	81.00
34	0.49	99.51	48	0.40	99.60
35	0.18	99.82	49	60.30	39.70
36	0.22	99.78	50	14.00	86.00
37	0.77	99.23	30	very fine sand[3]	
38	3.50	96.50	31	very fine sand[3]	

[1] Samples collected by A. A. Levinson, Dept. of Geology, University of Calgary.

[2] Sand, silt and clay in percentages

[3] Field description only

APPENDIX 5

Reports by T. Blench and L. A. Bayrock on the condition of the meander on the Athabasca River near Embarass Portage.

14203 - 54 Avenue,
Edmonton, Alberta

May 7th, 1972

Mr. D. M. Hornby, Director,
Peace - Athabasca Delta Project,
512 Baker Centre,
10025 - 106 Street,
Edmonton, Alberta.

Dear Mr. Hornby:

Geologic Conditions of the Athabasca River Bend near Embarras Portage.

1 The following are my additions to and discussions of the report submitted to you by Dr. T. Blench and Associates Ltd. dated April 28th, 1972, in which hydrologic and engineering conditions of the bend of the Athabasca River near Embarras Portage.The bend constitutes a meander of the Athabasca River in the upper portions of the Athabasca Delta. The meander was visited on April 13th, 1972, by helicopter with Messrs. Blench, Yaremko, Card, and Root, while the Athabasca River was still frozen.

2 The previous spring, April 27th and 28th, 1971, the meander was inspected only from the air as it was in a high flood stage caused by ice jams downstream from the location. A description of the conditions in the spring of 1971 is given in the report on geologic situations at the proposed dam site locations in the Athabasca - Peace delta. The report was submitted to R. M. Hardy and Associates Ltd., Edmonton, and a copy of it has been forewarded to you on May 6th, 1972. A Xerox copy of the pertinent pages of the report are enclosed. The possible changes resulting from a breakthrough of the Athabasca River into the Embarras River were discussed in the report and these are essentially the same as held by me at present.

3 On April the 13th of this year the width of the land between the Athabasca and the Embarras rivers was measured - it was found to be 174 feet. The measured traverse is markes with seismic tape on trees. Upon closer examination it was realized that the measured traverse is perhaps ten feet longer than the shortest distance by about ten feet. In other words the shortest distance between the two rivers may be close to 165 feet.

4 On the basis of aerial photographs taken from 1927 to the present it has been estimated that the average yearly erosion rate of the bank between the two rivers is about 35 feet. But it should be noted that the

rate of erosion has been on the increase the last few years, and may be close to 45 feet per year at present.

5 The bank is mainly made of very fine sand and some silt which is very susceptible to erosion. The height of the bank as measured above the ice of the Athabasca River was about 14 feet and on the Embarras side it was the same.

6 I agree with Dr. Blench that the Athabasca River may bypass the meander and cut through the meander loop shortening its course and bypassing the bend.

7. On the other hand if the Athabasca River continues its cutting of the bank towards the Embarras River it may in a relatively short time, within one to three years empty itself into that river.

8. Depending on flood conditions of the Athabasca River the break-through may occur anywhere from one to three years. There were two floods at this location in 1971. The first was the ice jam flood in early May, and the secondthe normal runoff flood in July. At both times the Athabasca river overran its banks and also produced considerable erosion which unfortunately was not measured. The July flood most likely caused the major amount of erosion of the banks as during the first flood the ground was frozen.

9. If the break through to the Embarras should occur first, and it is my opinion that this is most likely to happen, the whole or most of the Athabasca River will be diverted into it in a very short time, maybe within days.

10. The banks of the Embarras River are only about four feet high at points south of the Mamawi Creek, as observed from the air but not measured on the ground. At this location there also occur a number of incipient small channels caused by the overbank flow of the Embarras River towards the Mamawi Creek. Some of these channels originate on the banks of the Embarras River.

11. The Embarras River is at present much smaller than the Athabasca River and also occupies a narrower valley. In case of a break-through the high water levelmay in a short time result in an avulsion towards Lake Mamawi via the Mamawi Creek.

12. Lake Mamawi is very shallow and in a few years it would become completely silted up. The Athabasca River than would most likely flow directly to the Slave River through one of the many existing channels connecting the Peace River with Lake Athabasca.

13. After the break through of the Athabasca into the Embarras, the combined waters in the Embarras may overflow the banks in the Mamawi Creek area and flow directly into Lake Claire. In this case the Lake would be silted up and the Athabasca would again follow one of the existing channels into Peace River.

14. The above observations are in accord with those expressed by Dr. Blanch in his report. The only deviation is my opinion that under natural conditions the break through of the Athabasca River into the Embarrass River is more likely to occur than the natural meander cutoff of the Athabasca River.

15. The lack of precise surveys of the rivers in question and their banks most likely is the cause for small diversion of opinions.

16. In view of the above arguments and the shortness of time, I would favour the following steps to be undertaken as soon as possible:

1) Survey of the rivers and their banks in the area under consideration as outlined by Dr. Blench.

2) Follow up of the conclusions reached from the surveys by scaled model studies.

3) Actions on stabilization of the Athabasca River at the bend should commence within one year or sooner.

17. Geologically speaking, the Athabasca delta is in an extremely unstable state at present, with the Athabasca River being overextended. If left under natural conditions the Athabasca River will change its course to flow into Lake Claire or Mamawi Lake in the very near future. Silting up of the lakes, and the River bypassing the delta without deposition would follow.

L. A. Bayrock

L.A. Bayrock, Ph.D.

Copy #1

T. BLENCH AND ASSOCIATES LTD.
CONSULTING HYDRAULIC ENGINEERS

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CANADA

OUR FILE 72-249

YOUR FILE

April 28, 1972.

Peace-Athabasca Delta Project,
512 Baker Centre,
10025 - 106 St.,
EDMONTON, Alta.

Attention: Mr. D.M. Hornby, Director.

Dear Doug:

Athabasca River Bend near Embarras Portage.

1. I appreciated, greatly, the visit to Fort Chipewyan on 13th, 14th April with Messrs. Bayrock, Root, Yaremko and Card. Our combined knowledge proved most valuable and we soon found agreement in principle on major points; details can be settled when special hydraulic survey information becomes available. The problem of the bend is relatively simple technically, but it is linked with the situation that the Athabasca is headed for an avulsion into Mamawi Lake or Claire Lake near the bend site. Without specific figures I do not think any of us could guarantee that such an avulsion was impossible during the next few years. If it occurred I should expect a major diversion to develop within a couple of days, so the matter is serious. I shall give you opinions and recommendations under the titles THE BEND and THE AVULSION so as to avoid mixing my specific task with the related one which you may not have had cause to expect.

THE BEND.

2. See Fig. 1 (traced from one of your air photos). The ratio of flow path ABC to potential cut-off length AC is about 5.5. So, without any calculation, it is clear that the bend will cut-off with very little incentive if water can spill over paths like AC (which has an incipient channel already), or DE. The more the bend moves outward the more likely the cutoff. Experience shows that cutoffs with this large ratio can develop to almost full river size in a couple of days.

3. Until a cutoff occurs the bend will continue to move outward and one major flood is probably sufficient to cause it to breach into the Embarras River.

4. Because of the proximity of the head of the Embarras to the bend the water level in both rivers at the bend is about the same at all stages, so the breach should not cause the Embarras to start enlarging as a whole.

5. After the breach has occurred the bend should continue to move outward till it hits the left bank of the Embarras. Flow conditions will be locally disturbed (a model could indicate the flow pattern); sooner or later, the Embarras left bank will erode.

6. There are no survey data of the left levee of the Embarras. We know that it has small depressions along its edge between a and b in Fig. 2, and that definite channels start not too far (relative to a river breadth) from the edge and run to the lakes. Also Dr. Bayrock has seen water spilling over the levee during ice-jam flooding and running rapidly as a wide sheet; so an avulsion has been prevented, so far, by the frozen state of the ground plus vegetable cover.

7. If a cut, even very tiny, started through the levee in high flood so as to connect with any of the definite streams into Lakes Mamawi or Claire, and the ground were not frozen, I should expect a full-size river to develop in a couple of days.

8. The consequences of such a happening are so alarming that I recommend an immediate survey of the whole levee from a to b in Fig. 2, combined with hydraulic survey of the adjacent river and relevant extensions by an expert organisation (Alberta Research Council's River Section is the obvious one). The ground survey should include inspection of the river edge for incipient outfall streams, no matter how small, and should proceed towards the lake till obvious flat lake-shore ground is reached. The hydraulic survey should aim to establish maximum possible water-levels during thawed ground conditions and include all definite channels that could be occupied by an avulsion into a lake.

9. There are four obvious actions to take relative to the bend:

(i) Leave it alone but build banks along the left levee of the Embarras (far enough back from the river's edge to avoid the need for stone protection) in places and to elevations shown by the survey of item 8 to be necessary. If this is done the bend will cut off sooner or later -- probably sooner -- and remove danger for several decades.

(ii) Let it cut into the Embarras but give stone protection to the Embarras left bank.

(iii) Protect the Athabasca bend along B in Fig. 1, and give protection to the right bank of the Embarras, which is moving slightly towards the Athabasca.

(iv) Make an assisted cutoff along a path like AC in Fig. 1.

10. Regarding costs of the actions data are poor, but I estimate as follows:

(i) Survey must decide. It may show no action is needed at all.

(ii) Probably requires half the work for the Athabasca portion of (iii).

(iii) For the Athabasca about 2,000 feet of protection which, allowing for apron, would amount to covering some 60 feet of bank slope with a double-layer of 300 lb. stone of thickness about 2.5 feet. Say 10,000 cubic-yards of stone. Add cost of making bank to slope 1 upon 2 and proving a 1 foot thick underlay of pitrun gravel to act as a reverse filter. Add contingencies. For the Embarras protection I guess that length would be about 1,000 feet, so cost would be half.

(iv) Here the navigation authorities would have a say in the alignment and, if they wanted a much longer one, then the cross-section would have to be more for hydraulic reasons. I made a first estimate by specifying that the bed of the cut should be 3 feet lower than lowest annual flood and guessing that the present incipient channel had its bed only three feet below general high bank level. That gave 12 feet of cut (and I had to estimate the low flood level too, for lack of hydraulic survey data). Allowing 20 feet bed-width and 1 upon 2 sides in the probably silty material, the cross-section is 12 x 44 sq.ft. This is a tight figure, so assume 600 sq.ft. and 3,000 feet length, to give 60,000 cubic yards. If we are allowed a minimum cutoff length and ground level is lower than I guessed the amount could probably be halved.

11. The economics of a cutoff deserve consideration. First, a natural cutoff would occur sooner or later, and I think it will be sooner. When it does it has a considerable possibility of being along a path like DE which may be most awkward for navigation; we could make one to navigation requirements, though it would call for some dredging downstream through the shoals caused by the river eroding the cutoff to full size. The shoaling could be trifling if, as is likely, the material at the cutoff site is mainly fine sand and silt which would pass off in suspension.

Again, the cutoff would produce a drop in flood levels at the bend of about 2 feet, and this would not be lost for several decades; the saving in possible diking along the left levee of the Embarras might pay for the job. A simple model costing a few thousand dollars could demonstrate the amount of shoaling downstream of a cutoff of this type, and give some idea of rapidity of development.

12. If a cutoff is contemplated then a hydraulic survey of the whole bend and environments is required to give exact water-levels and their distribution with time during likely floods. In addition a couple of bores would be required along proposed cutoff alignments.

THE AVULSION.

13. Briefly, the hydraulic path from the vicinity of the bend to either Lake Mamawi or Lake Claire is about a sixth of that to Lake Athabasca which is at about the same level as the other two. So the imminence and violence of a cutoff, assuming Embarras spill finds a starting path, is just about the same as expected for the Athabasca bend. Presumably the Quatre Fourches are the relic of an older Athabasca River that went along Mamawi Creek. I can imagine that reversion to the old river might be good in the end, particularly if the unauthorised blocking of the Claire River at Sweetgrass were removed, but I cannot imagine anyone taking the responsibility for letting it happen by accident or giving it a blessing!

14. An interesting speculation is that the avulsion might have occurred in last summer's record high rain flood but for Lake Athabasca being lower than normal because of the dam, and the river itself being somewhat lower again because of the years of DPW dredging preventing the river from aggrading at the bend as much as it would have done naturally; the dredging could also be a cause of Lake Athabasca being a little lower.

15. I see no difficulty in checking the possibilities quantitatively if present information of all kinds (general survey, ecology and geology) are supplemented by a scientific river regime survey of the system -- which has to include the main stems of the rivers -- according to the full routine developed by the River Division of the ARC. Without this supplement the quantitative effects of various actions, their development with time, and their economics cannot be evaluated.

16. I trust this meets your immediate needs, and shall be glad to take any further action you wish.

Yours sincerely,
T. BLENCH AND ASSOCIATES LTD.

T. Blench, P. Eng.

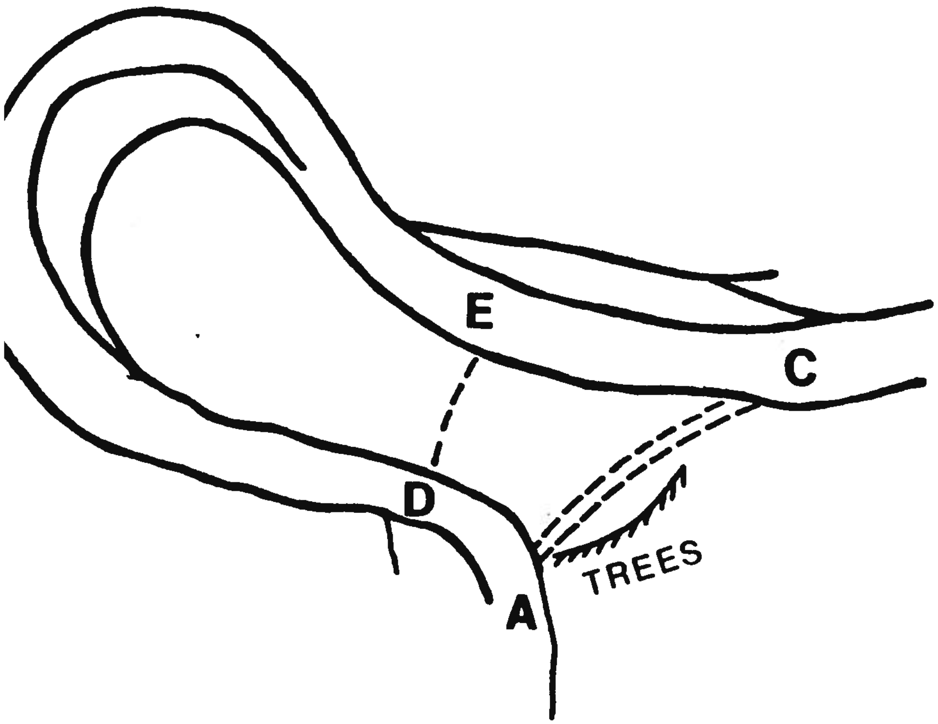


FIG. I
FROM AIR PHOTO 19/10/70
AS 1088. LINE 6.109
1: 24,000

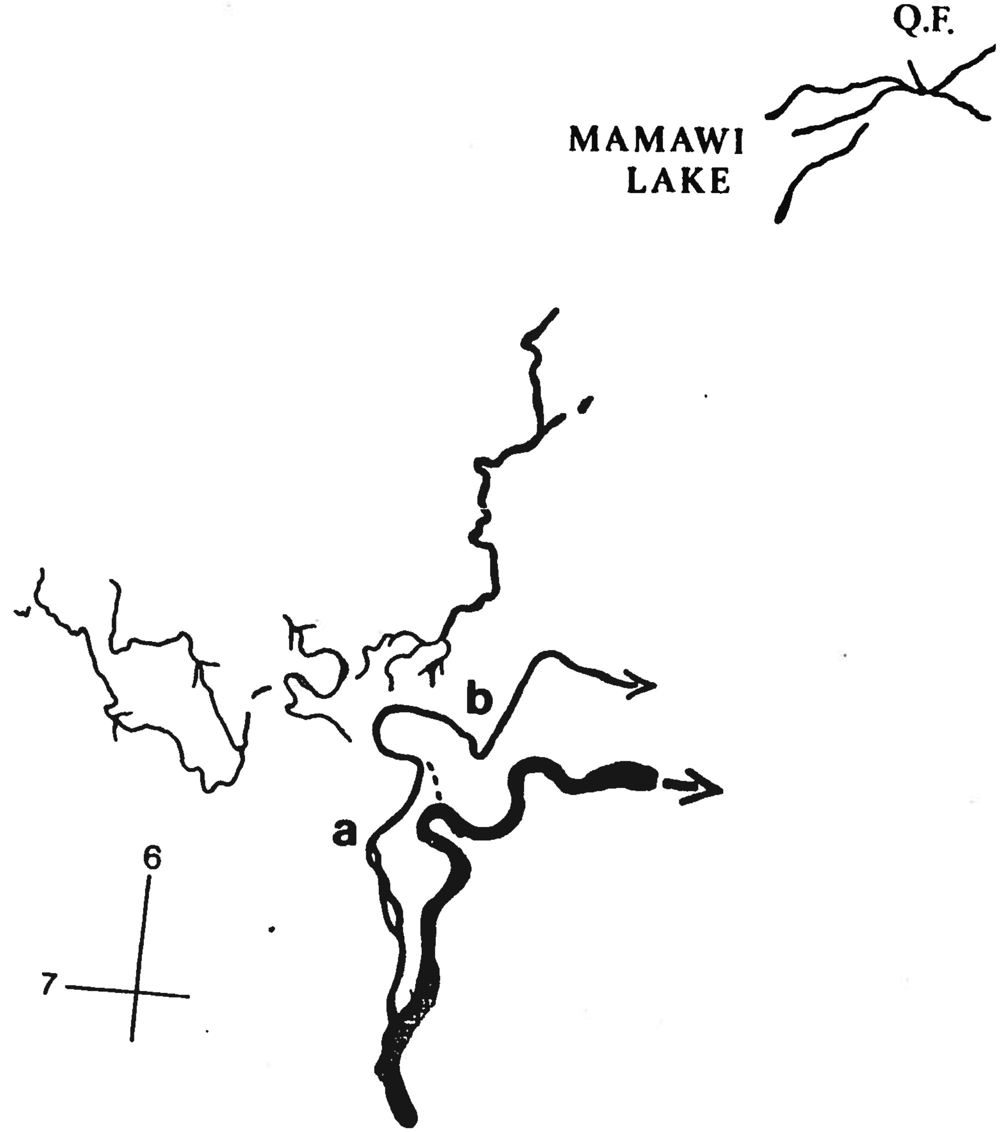
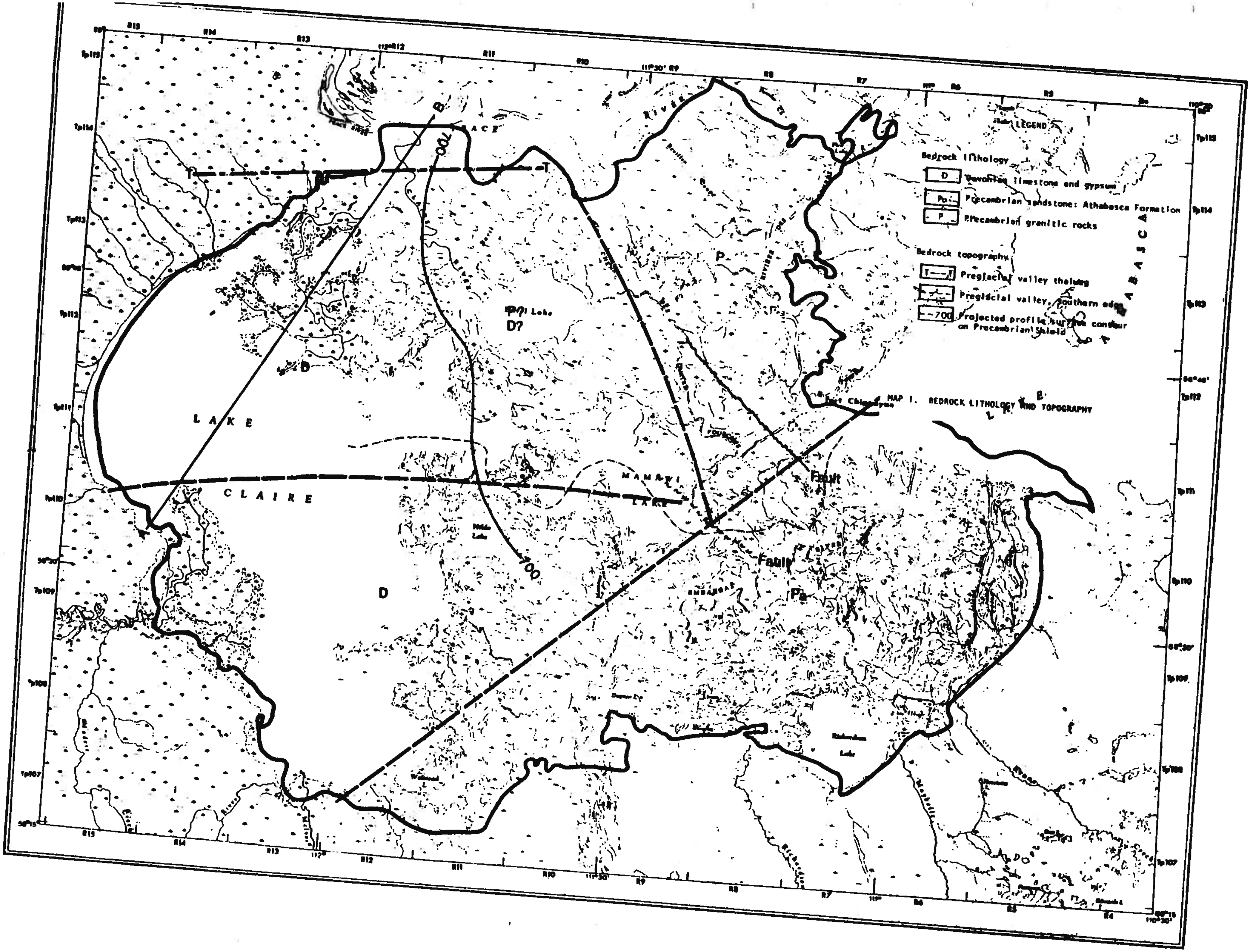
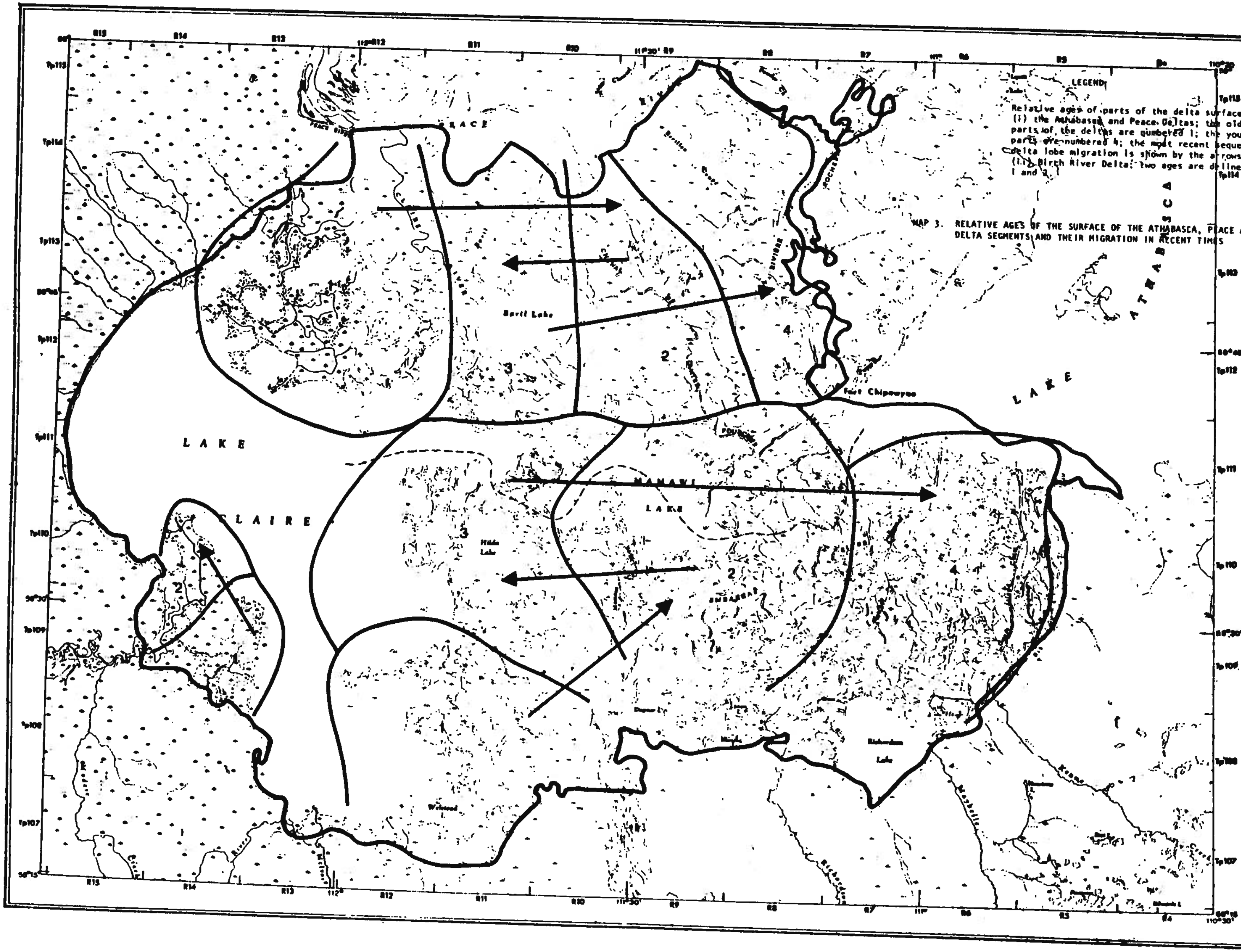


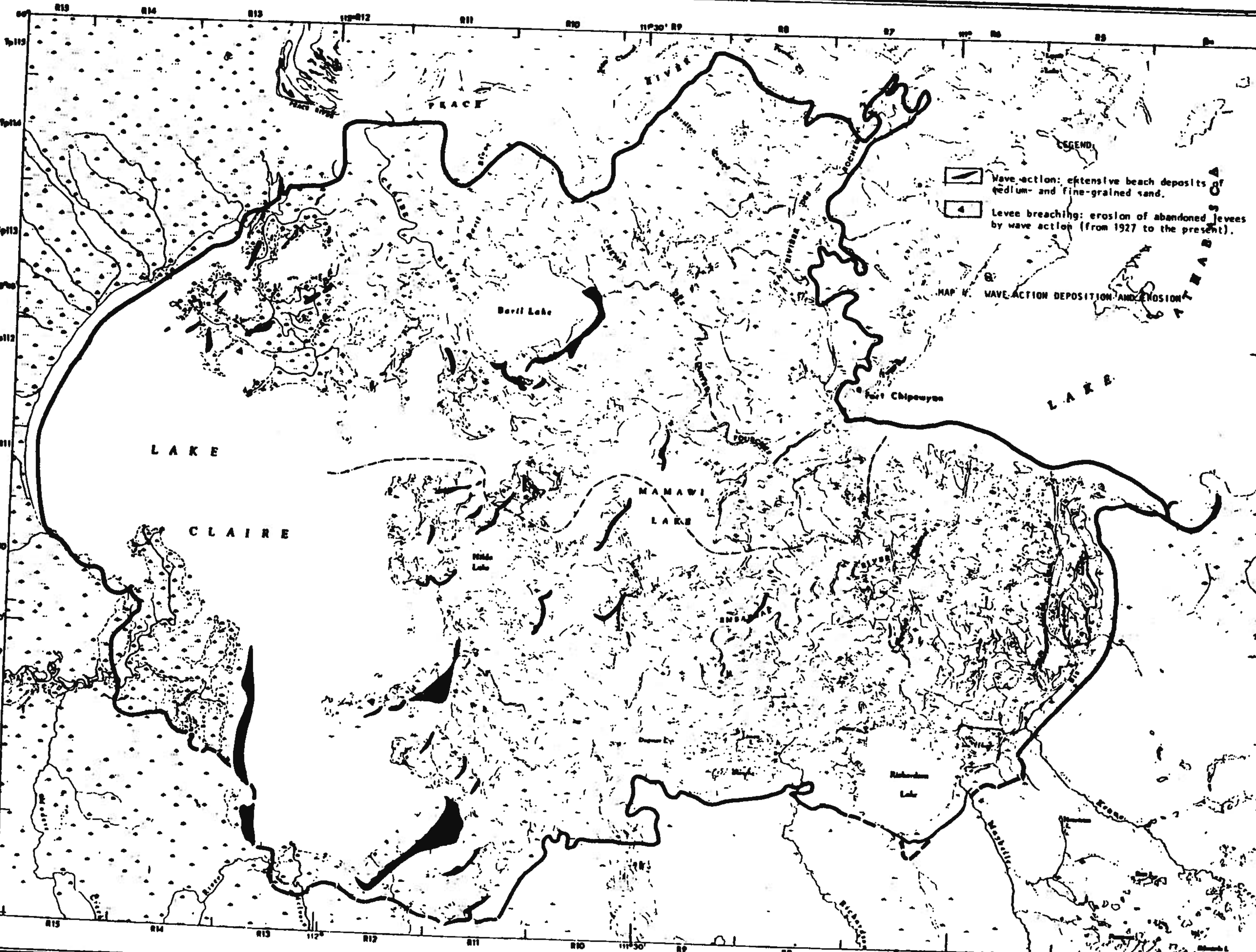
FIG 2
FROM CANADA SHEET,
FORT CHIPEWYAN
1: 250,000

N47

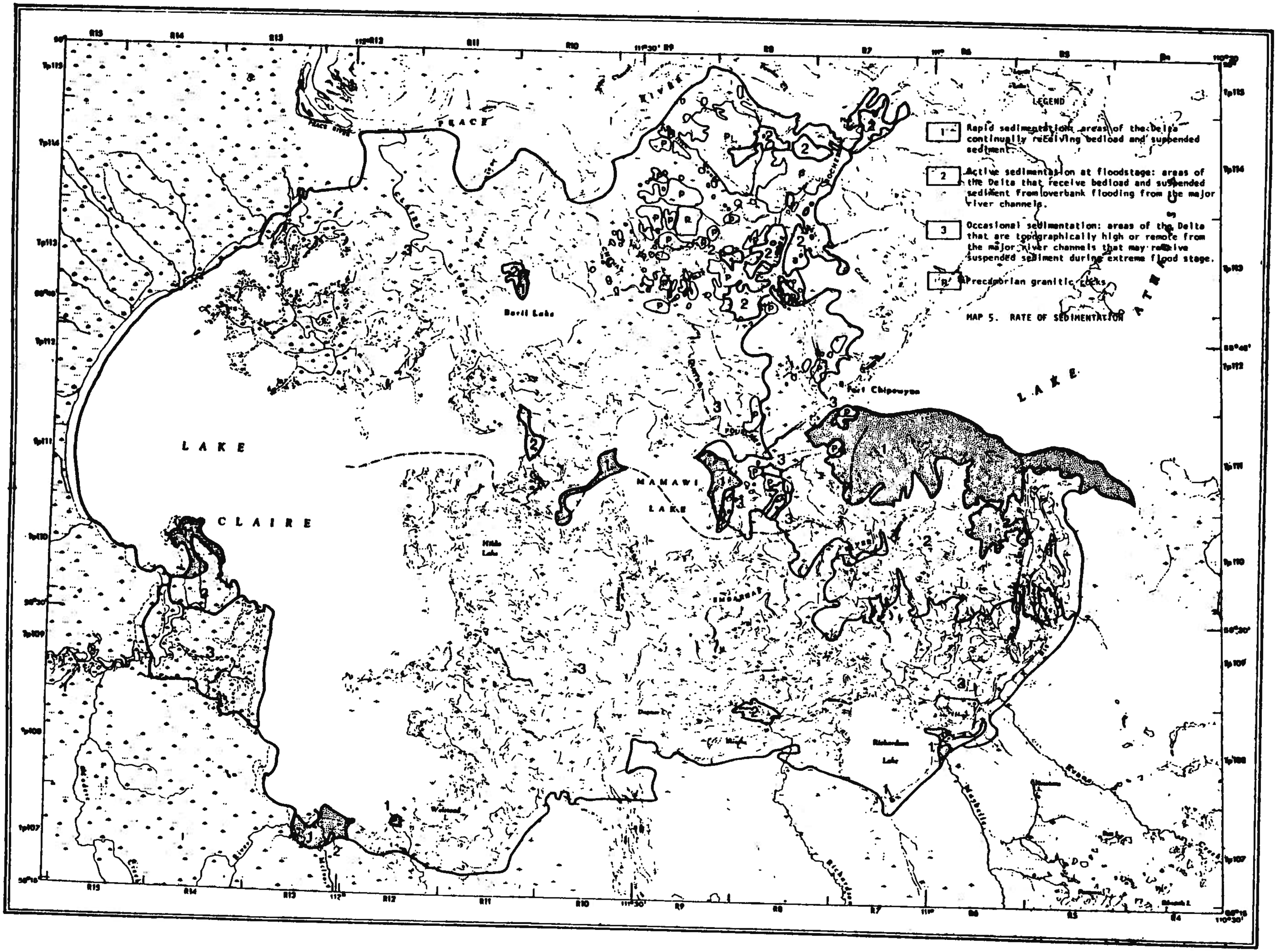


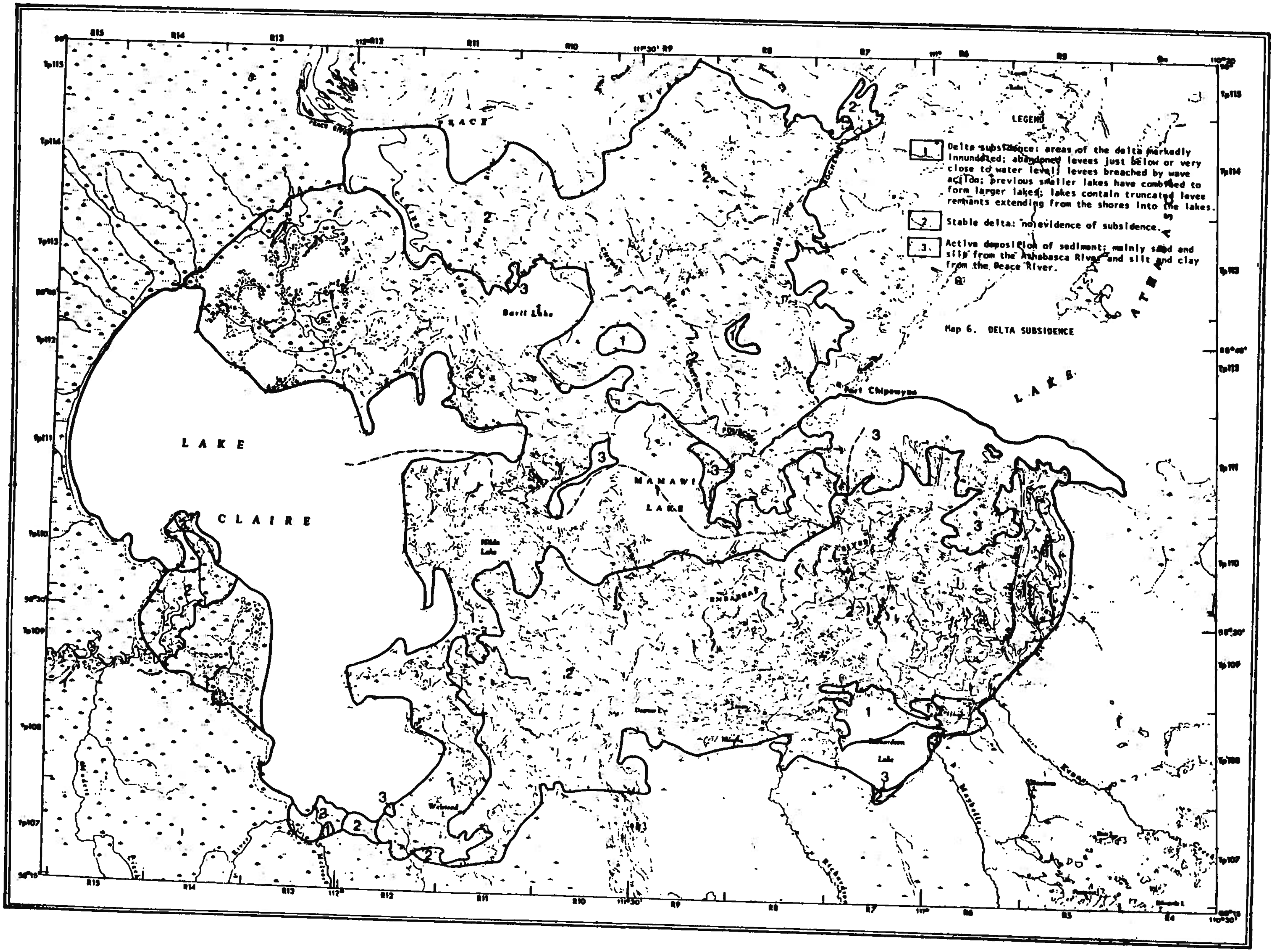
MAP I. BEDROCK LITHOLOGY AND TOPOGRAPHY

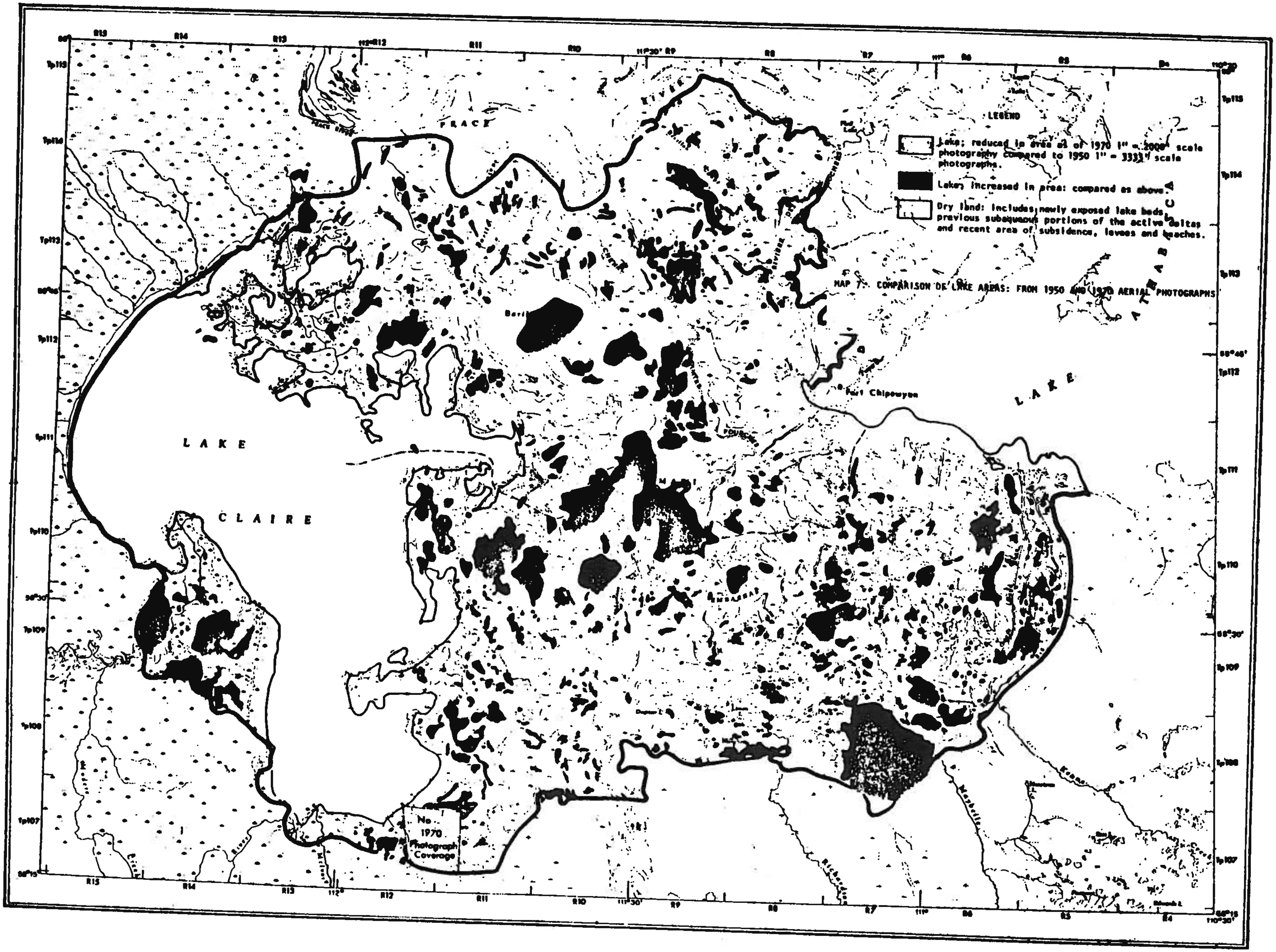

LEGEND
Relative ages of parts of the delta surface:
(i) the Athabasca and Peace Deltas; the oldest parts of the deltas are numbered 1; the youngest parts are numbered 4; the most recent sequence of delta lobe migration is shown by the arrows.
(ii) Birch River Delta; two ages are delineated 1 and 2.
MAP 3. RELATIVE AGES OF THE SURFACE OF THE ATHABASCA, PEACE AND BIRCH RIVER DELTA SEGMENTS AND THEIR MIGRATION IN RECENT TIMES
LAKE ATHABASCA
LAKE CLAIRE
MAMAWI LAKE
PEACE RIVER
Fort Chipewyan
Baril Lake
Hilda Lake
Richardson Lake
Welstead
1
2
3
4
R15
R14
R13
R12
R11
R10
R9
R8
R7
R6
R5
R4
Tp107
Tp108
Tp109
Tp110
Tp111
Tp112
Tp113
Tp114
Tp115



MAP V. WAVE ACTION DEPOSITION AND EROSION


LEGEND
1 Rapid sedimentation: areas of the Delta continually receiving bedload and suspended sediment.
2 Active sedimentation at floodstage: areas of the Delta that receive bedload and suspended sediment from overbank flooding from the major river channels.
3 Occasional sedimentation: areas of the Delta that are topographically high or remote from the major river channels that may receive suspended sediment during extreme flood stage.
R Precambrian granitic rocks.
MAP 5. RATE OF SEDIMENTATION
PEACE RIVER
LAKE ATHABASCA
LAKE CLAIRE
MAMAWI LAKE
Fort Chipewyan
Baril Lake
Richardson Lake


LEGEND
1. Delta subsidence: areas of the delta markedly innundated; abandoned levees just below or very close to water level; levees breached by wave action; previous smaller lakes have combined to form larger lakes; lakes contain truncated levee remnants extending from the shores into the lakes.
2. Stable delta: no evidence of subsidence.
3. Active deposition of sediment; mainly sand and silt from the Athabasca River and silt and clay from the Peace River.
Map 6. DELTA SUBSIDENCE
LAKE CLAIRE
MAMAWI LAKE
LAKE
PEACE
RIVER
Baril Lake
Fort Chipewyan


LEGEND
Lake; reduced in area as of 1970 1" = 2000' scale photography compared to 1950 1" = 3333⅓' scale photographs.
Lakes increased in area: compared as above.
Dry land: includes newly exposed lake beds, previous subaqueous portions of the active deltas and recent area of subsidence, levees and beaches.
MAP 7. COMPARISON OF LAKE AREAS: FROM 1950 AND 1970 AERIAL PHOTOGRAPHS
LAKE CLAIRE
LAKE ATHABASCA
PEACE RIVER
Fort Chipewyan
No 1970 Photograph Coverage
R15
R14
R13
R12
R11
R10
R9
R8
R7
R6
R5
R4
Tp113
Tp112
Tp111
Tp110
Tp109
Tp108
Tp107