Edmonton Geological Society

Geology of the Fort McMurray Area, Northeast Alberta

Trip Leaders:
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September 24-26, 2004

Type section of the McMurray Formation, Athabasca River

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Disclaimer:

Acknowledgements:

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2004 Field Trip Leaders

Roger Paulen (editor)
Randy Rice
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ITINERARY

Friday, Sept. 24

16:30	*Drive to Fort McMurray, Dinner stop in Grassland*	

Saturday, Sept. 25

09:30	*Board bus*	
10:00 – 11:30	STOP 1	*Fort McMurray Discovery Centre*
11:30 – 15:00	STOP 2	*Syncrude Mine Tour*
15:30 – 16:00	STOP 3	*MacDonald Island Outcrops*
16:00 – 17:00	STOP 4	*Hangingstone River Section*

Sunday, Sept. 26

07:45	*Board bus and drive north to Daphne Island*	
08:45 – 10:00	STOP 5	*Daphne Island East Sections*
10:15 – 10:45	STOP 6	*Susan Lake Gravel Pit*
11:00 – 12:30	STOP 7	*Amphitheater Section*
12:30 – 12:45	STOP 8	*Beaver Creek Sandstone* (Time Permitting)
13:00 – 13:30	STOP 9	*Syncrude Overview Stop*
13:30 – 14:15	STOP 10	*Water Treatment Plant section*
14:15 – 20:00	*Return to Edmonton*	

Geological Stops

1 - Fort McMurray Discovery Centre

2 - Syncrude Mine Tour

3 - MacDonald Island Outcrops

4 - Hangingstone River Section

5 - Daphne Island Sections

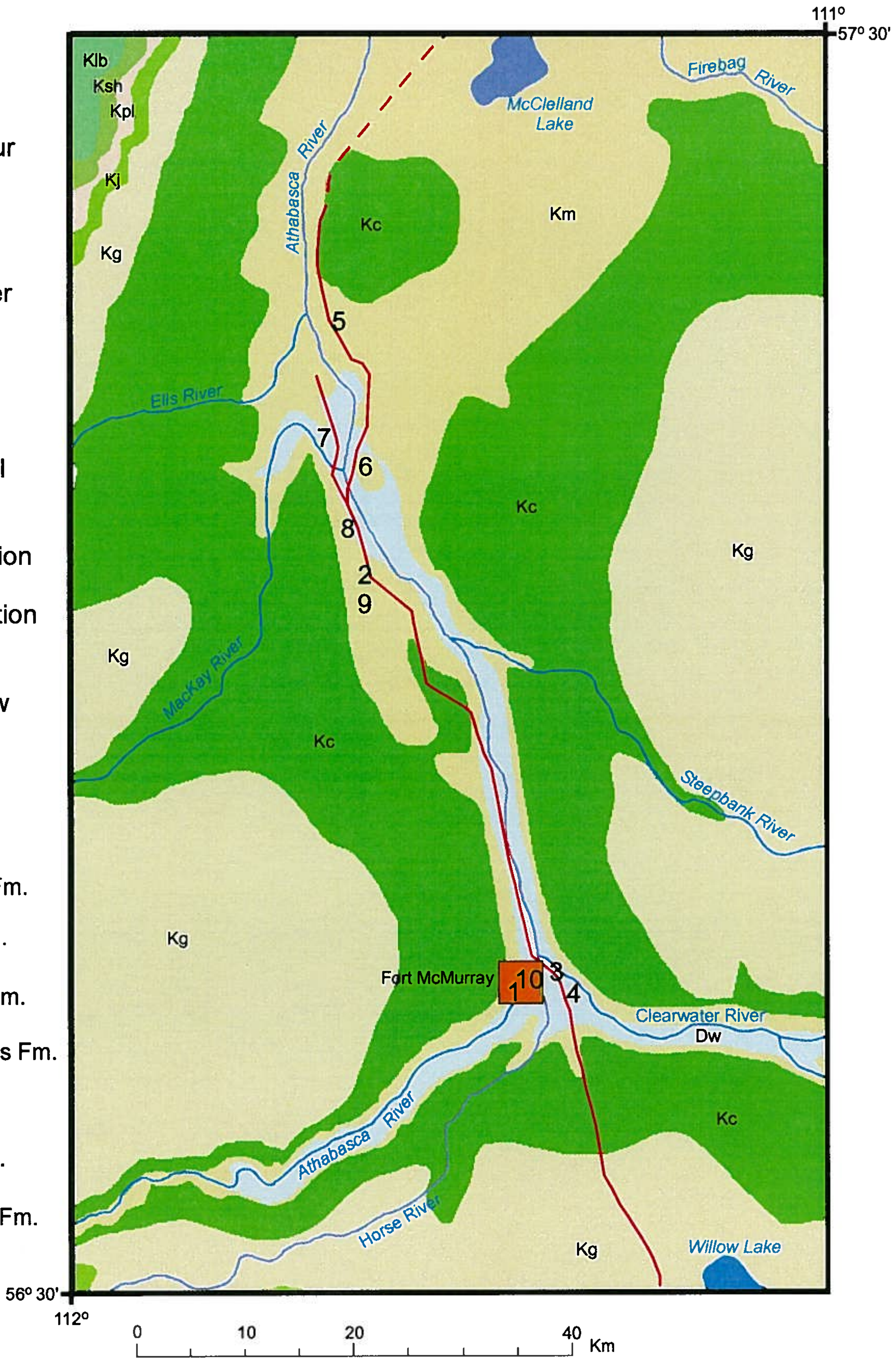
6 - Susan Lake Gravel Pit

7 - Amphitheater Section

8 - Beaver Creek Section (Time Permitting)

9 - Syncrude Overview Stop

10 - Water Treatment Plant Section

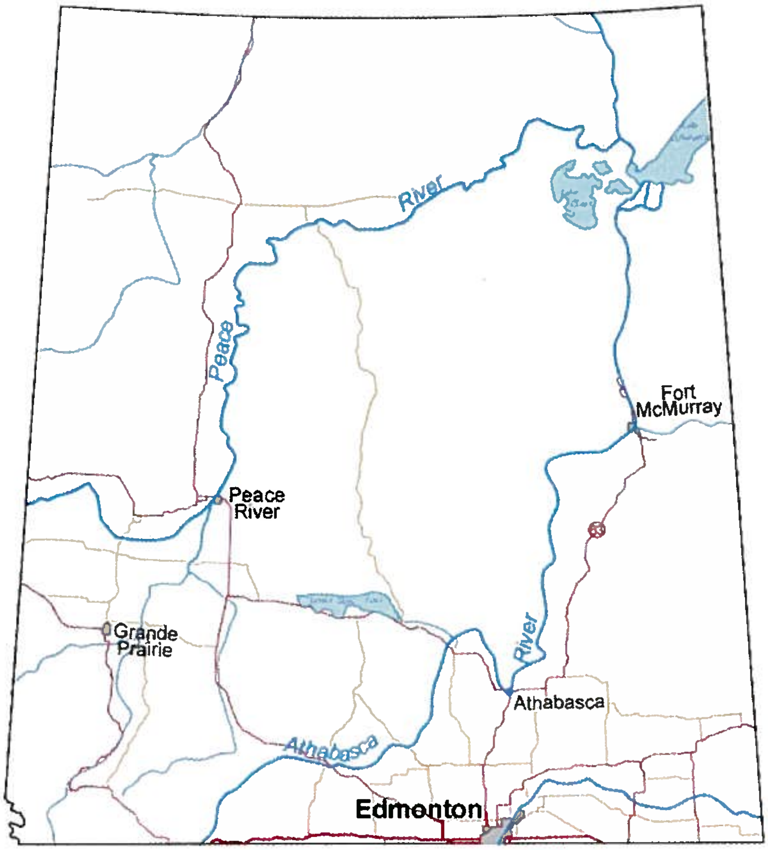


Dw	Waterways Fm.
Km	McMurray Fm.
Kc	Clearwater Fm.
Kg	Grand Rapids Fm.
Kj	Joli Fou Fm.
Kpl	Pelican Fm.
Ksh	Shaftesbury Fm.
Klb	Labiche Fm.
———	Highway
— — —	Winter Road

Introduction

By popular demand, the Edmonton Geological Society (EGS) annual field trip returns to Fort McMurray for the third time. The EGS first visited the region in 1969 (Ziegler 1969) and more recently in 1996 (Wightman et al. 1996). The oil sands have always been of interest to geologists since the dawn of geological mapping in Canada. Bell and Cochrane (1883) produced the first bedrock map of the region and since that time, geologists have been drawn to the largest oil sands deposit in the world.

The highlight of all field trips to the region, including this one, is a visit to oil sands mine. The oil sands industry is the main driver of Alberta's economy – and the whole country. About $22 billion in capital has been already spent in the region on new and sustaining projects during 1996-2002. A further $50 billion investment is planned in the near future (Oommachan 2004). Again, the EGS decided to make the mine tour the focal point of our annual field trip. Several stops of geological interest are also included with small hikes to river sections and some roadside outcrops. Field trip participants are to remember that several of the planned stops occur along busy roadways, so exercise extreme caution when exiting the bus and walking along the shoulders of the highways.



Historical Overview of the Fort McMurray Area

Editor: The following overview is reprinted with permission from Fran Hein, Alberta Geology Survey (Hein 2000; p. 1-2).

Originally the Athabasca area was inhabited by a number of First Nations and Metis people, including the Cree, Chipewyan, Prairie Dene, and Anzac Metis. Descendants of Chipewyan people, who call themselves Dene, inhabit the Cold Lake area. The Dene and Chipewyan people refer to themselves as cousins. According to early government records, the first European to see oil sands was Henry Kelsey, Manager of York Factory on Hudson's Bay, who received in 1719 a sample of oil saturated, bituminous sand, that was delivered to York Fort by a Cree guide, named Wa-Pa-Su. In 1776 Peter Pond, a fur trader and one of the founding members of the Northwest Trading Company (later amalgamated with the Hudson's Bay Company), became the first European to enter the Athabasca region upon crossing the confluence of the Clearwater and Athabasca rivers.

Although the indigenous peoples knew of the bitumen from the oil sands occurring along the Athabasca River, Peter Pond was credited, along with two cases of suspected murder in duels, for first writing about the occurrence of the oil sands in 1778. In 1792 Alexander "Mac" Mackenzie traversed the Methys Portage, crossing the confluence of the Clearwater and Athabasca rivers, and described the oil sands along the outcrops of the Clearwater-Athabasca river system. This was followed by other explorations in 1799 by David Thompson and in 1819 by Sir John Franklin who traveled and surveyed the Athabasca River between Lake Athabasca and the confluence of the Athabasca and Clearwater rivers. Sir John Richardson did the first geological assessment of the oil sands in 1848 along his journey to the Arctic to search for the missing Franklin expedition. Sir John Richardson correlated the oil sands with the Devonian shales of the Marcellus Formation of New York and also did acid tests on the oil and microscopic examination of the sand, identifying the principal component as quartz. In 1875 "oil springs" (seeps) were found on the Peace River by John Macoun of the Geological Survey of Canada.

In 1870 a fur trading post, located at the confluence of the Clearwater and Athabasca rivers, was founded by John Moberly and named Fort McMurray after William McMurray who was chief factor of the Athabasca region for the Hudson's Bay Company. The Hudson's Bay Company closed Fort McMurray in 1898 due to a dwindling fur trade, but reopened the fort again in 1912 as a large-freight storage warehouse. Until 1921 there was only river access to Fort McMurray, and the fort served as the gateway to the Arctic. Goods were shipped from Fort McMurray on the Athabasca River to Lake Athabasca, then on the Mackenzie River to the Arctic. River transportation continued as the only access to the North until 1965 when the Mackenzie Highway and the Great Slave Railway were opened. Until this time the shipyards at Fort McMurray were used for building scows, barges and paddle wheelers. As the age of river transportation was closing and railways were being built, the industry of Fort McMurray started shifting to more local resources, including fishing, logging, lumbering, salt, and the newly emerging development of the vast oil sands resources.

In 1906 Count Alfred von Hammerstein, originally from the Prussian army, drilled for oil in the Devonian limestone along the banks of the Athabasca River. He was hoping to discover "free" oil that he thought was a reservoir of pure petroleum underneath the oil sands outcrops. He failed to discover oil, but did find salt at the confluence of the Horse and Athabasca rivers. In 1925 a salt mine was opened on the Horse River by the Alberta Salt Company, which closed in 1927 due to problems with transportation and shipping of salt. In 1936 Industrial Minerals Ltd. opened another salt plant at the town site of Waterways that had rail service to Lac La Biche. At Waterways the salt plant used a hot water pumping process to extract the salt. Hot water was pumped down a shaft to dissolve the salt and the resulting salt-water brine was pumped up within a nearby parallel shaft. The salt brine was then evaporated, the salt retrieved and shipped as table salt until the 1940s. The Waterways salt plant closed in 1950 with the opening of a new salt plant in Elk Point, Alberta.

Fort McMurray served as a military site during World War II and the Cold War. The Canol Project by the United States military was designed to secure safe delivery and supply of oil for North America across the Arctic. The pipeline was started and built at Norman Wells. All troops, supplies and materials for the Norman Wells pipeline were first shipped to Waterways by rail, then from Fort McMurray by barge and boat to Norman Wells. In 1944 oil was shipped along the pipeline from Norman Wells at a cost of $106 U.S. per barrel. During the Cold War a RCAF radar station was established on Stony Mountain south of Fort McMurray as part of the mid-Canada DEW (Distant Early Warning) Line. The Stony Mountain site was dismantled in 1964. In 1989 the railway to Waterways was closed by Canadian National Railway, ending rail service to the area.

Historical Overview of the Oil Sands Industry in Northeast Alberta

Editor: The following overview is reprinted with permission from Fran Hein, Alberta Geology Survey (Hein 2000; p. 2-6).

An historical overview of the discovery and development of the Athabasca Oil Sands is given in Carrigy and Kramers (1973), with updates presented in Strom (1986), Houlihan and Evans (1988), Wightman et al. (1992), Mink and Houlihan (1995), Polikar et al. (1998), and Sadler and Houlihan (1998). The first published geological descriptions of the Athabasca oil sands were given by Bell (1884) and McConnell (1893). The McMurray Formation was named by McLearn (1917), with assessments done by the Canadian Government surveys from 1926 to 1949 (Ells, 1926; Government of Canada, 1949; Hume, 1947, 1949). A brief summary of this historical work, and how it relates to commercial development of the oil sands, is given as follows. A succinct timeline is also presented in Appendix 1.

For over 200 years, since the first documentation of the oil sands by Peter Pond in 1778, a number of adventurous entrepreneurs, government and industry scientists have greatly invested time, money and effort in the area to build the oil sands industry of today. In 1870 Canada purchased 'Rupert's Land' from the Hudson's Bay Company. Rupert's Land was a vast tract of land that extended from Ontario to the Rockies and north to the Arctic. At that time Dr. Robert Bell served as director of the Geological and Natural History Survey of Canada and in 1882 Bell identified the oil sands as Lower Cretaceous in age, and proposed that the bitumen was sourced in the Devonian strata. During 1882 to 1884 Bell analyzed samples of the Athabasca oil sands; and, at that time, the Survey initiated experiments using hot water to separate the bitumen from the sand. Following this work, Bell proposed that it would be feasible to extract the bitumen from the oil sands by using a hot water extraction process, and that a pipeline could be constructed from Lake Athabasca to the Hudson's Bay to transport the extracted oil to foreign markets. This was followed in 1888 by Bell's report to a Senate Committee, that stated as follows: "The evidence ... points to the existence in the Athabaska and Mackenzie valleys of the most extensive petroleum field in America, if not in the world... it is probable this great petroleum field will assume an enormous value in the near future and will rank among [Canada's] chief assets."

In 1888, R. G. McConnell of the Geological and Natural Survey of Canada gave a geological description of the oil sands and correlated the oil sands with the Cretaceous Dakota sandstone in the Western Interior Basin of the United States. McConnell estimated that the reserves of bitumen in the oil sands were not less than 4.2 million 'long tons,' further suggesting that lighter oil would be found downdip in correlative strata at Pelican Rapids. McConnell agreed with Bell that "The source of these hydrocarbons is probably existing in the porous beds of this Devonian... [and that] The question of their (tar sands) petroliferous character can only be settled in a decided manner by boring." McConnell obtained a $7,000 grant from Parliament to hire a contractor, a drilling rig, and moved the equipment up to the Athabasca River. The well was spudded on August 15, 1894, and after much difficulty in drilling they reached a depth of 1,600 feet at which time "a roar of gas at a pressure of 500 psi could be heard three miles away." In 1897 McConnell drilled another well downstream from the town site of Redwater along the banks of the North Saskatchewan River. From 1906 to 1910 two vibrant entrepreneurs, the Count Alfred von Hammerstein and "Peace River Jim" Campbell drilled wells in the Athabasca area, hoping to tap into an underground liquid pool of oil that they thought underlie the oil sands.

Although much reconnaissance work on the oil sands was done by other people, the recognized 'Father of the Oil Sands' was an engineer and Assistant to the Director, Dominion Department of Mines, Mines Branch in Ottawa. Ells was a genius, rogue, entrepreneur and eccentric who studied oil and oil shale occurrences in eastern Canada and the West Indies. Ells was completely obsessed with the Athabasca oil sands and their origins; and, he is quoted as saying "I was so enthralled with the possibilities of the oil sands that I preferred resigning my position rather than being deprived of making an investigation" (McRory, 1982). In 1913 Ells joined the Mines Branch and launched a field party that year to begin a detailed survey of the oil sands in the Athabasca River valley.

During his first survey of the area, Ells collected 200 samples, totaling nine tons, which were towed by hand on a scow upstream along the Athabasca River to Fort McMurray (Figure 1). In 1915 Ells continued his reconnaissance work and backpacked out another seventy pounds of oil sands from Fort McMurray to Edmonton in three weeks. Ells lay bituminous pavement in the City of Edmonton and in Jasper National Park as a practical demonstration of the potential use of the tar sands from the Fort McMurray area. During World War I Sidney Ells was a lieutenant in the Royal Canadian Field Artillery. During the war Ells continued to do his own experiments on hot-water separation processes of the bitumen from the oil sands at the Mellon Institute of Industrial Research in Philadelphia (McRory, 1982). In 1926 Ells, along with support from Max

Ball, successfully drilled and cored the oil sands in the Mildred Lake – Ruth Lake area, immediately west of both the present Suncor and Syncrude plants, and also drilled and cored wells east of the Steepbank area, and in the Horse River area. Today some of these original cores are stored at the Geological Survey of Canada in Ottawa.

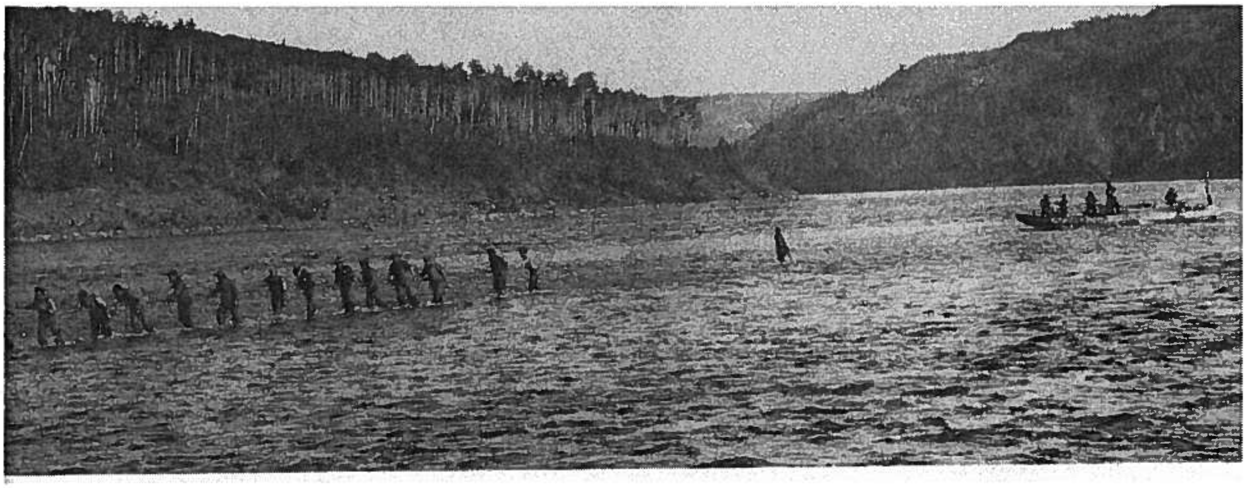


Figure 1. A Geological Survey of Canada field party hauling a scow up the Athabasca River, Alberta in 1914 (Geological Survey of Canada Archives).

In 1920 D. Diver was the first to try and produce oil from the bitumen by an *in-situ* method. Diver's method consisted of distilling the oil from the oil sands by lowering a heating unit to the bottom of a well near Fort McMurray. In 1920 work on the oil sands also continued at the Alberta Research Council, with the pioneering work of Dr. Karl Clark, a chemical engineer, who in 1925, working with Sidney Blair at the University of Alberta, built a hot-water separation plant at the Dunvegan railyards in Edmonton. This hot-water separation process became the basis for today's thermal-extraction processes. In 1929 the International Bitumen Company, under the leadership of Robert C. Fitzsimmons, opened the first commercial oil sands hot-water separation plant on the Bitumount lease, with 4,500 drums of asphalt and 2,000 barrels of fuel oil produced.

In 1936 Max Ball obtained a 6-section lease on the Horse River on which he built an extraction plant. This was followed in 1940 by the Abasand (short for Athabasca Sands) separation plant, built along the Horse River near the present subdivision of Abasand Heights in the town site of Fort McMurray. The Abasand plant, founded by Max Ball along with Sidney Ells, invested a million dollars in research and development. In 1941 the Abasand plant processed 19,000 tons of sand, yielding 17,000 tons of bitumen. This bitumen was then reprocessed into fuel oil, diesel fuel, gasoline and coke. By the time the Canol Project was being built in Norman Wells, the Bitumount plant was shut down, and the Federal Government took over the Abasand plant, which burned down in 1941, rebuilt in 1942 and 1943, destroyed again by fire in 1945. In 1942 the Canadian Government began a reconnaissance drilling and coring program to outline the reserves of the oil sands for wartime contingency plans. By 1947 the Canada Mines Branch completed its drilling and estimated reserves of the oil sands to be 1.75 billion tons of commercial grade oil sands. The richest deposit was located at Tar Island, along the Athabasca River, at the location of the present Suncor tailings pond. In 1948, the Alberta government reopened the Bitumount plant and made a commercial test of Clark's hot-water separation process, with production of 500 tons per day.

In 1942 L.R. Champion took control of International Bitumen Company, renaming the company Oil Sands Ltd., which was taken over by Great Canadian Oil Sands Ltd. in 1954. In 1962 Great Canadian Oil Sands Ltd. received permission from the Alberta Oil and Gas Conservation Board to produce 31,500 barrels per day from the oil sands at the Tar Island plant. In 1967 Great Canadian Oil Sands Ltd., whose controlling interest was held by Sun Oil Company of Pennsylvania, opened the first commercial oil sands plant and showed that the oil sands could be economically developed and that bitumen products could be successfully upgraded to crude oil. The Great Canadian Oil Sands served as the legacy to the Suncor of today (Figure 2). In the 1950s Royalite, an independent subsidiary of Imperial Oil, also pioneered serious exploration, development and production of the McMurray oil sands. In 1962 Royalite Oil Company formed a consortium with Atlantic Richfield, Cities Service Athabasca Inc., and Imperial Oil Ltd. Royalite was later sold and resold again, the vestiges left in what is now Syncrude, incorporated in 1964. Shell Oil Company of Canada began experiments on *in situ* steam drive in 1957 on its lease 26, and by 1962 Shell applied to the Alberta Oil and Gas Conservation Board to produce 130,000 barrels per day of bitumen by *in situ* steam process. In 1978 Shell Canada Ltd. also applied to the Alberta Energy Resources Conservation Board for a 100,000 barrels per day mining operation.

Figure 2. Great Canadian Oil Sands (now Suncor) mine in the late 1970s (Photograph courtesy of Grant Mossop, GSC).

In 1974 the Alberta Oil Sands Technology and Research Authority (AOSTRA) was formed to provide funding and synergies needed for research dedicated for bitumen extraction and upgrading. Ten years later, in 1984, AOSTRA constructed the Underground Test Facility (UTF) at the present Dover River Project operated by Northstar Energy Ltd. The UTF was used to test horizontal wells and Steam Assisted Gravity Drainage (SAGD) technologies for recovery of the bitumen from the oil sands, which by 1990 more than 60% of the bitumen was recovered (Wightman et al. 1992). Although the bitumen deposit at UTF is good and high recovery was achieved, this should not be considered as average conditions for the whole Athabasca deposit.
In 1991 Phase B of the UTF began its pre-commercial testing, which now, 9 years later, is now in wind-down stages.

Since the historical and pioneering work, at present both Suncor and Syncrude, have successfully produced synthetic crude oil from bitumen in the oil sands at competitive costs. In 1997 established reserves of crude bitumen were 1021 million cubic metres. Until recently large scale surface strip mines were the only economically viable process for extracting the bitumen. Unfortunately, only about 7% of the vast oil sands deposit is accessible using surface mining techniques, confining exploitation of the resource to the Athabasca River valley where the overburden is thin. Recent technological advances, including *in situ* bitumen and heavy-oil extraction methods along with improved horizontal drilling, may open up the remainder of the Athabasca deposit for potential development and exploitation. In 1998, total remaining established reserves of crude bitumen under active development were 340 million cubic metres for surface mineable and 240 million cubic metres for *in situ* schemes (AEUB, 1999).

Along with extensive research and development on the Suncor and Syncrude leases, there was a parallel stream of scientific and technological pioneering work concerning the other, more deeply seated bitumen deposits in the Athabasca, Cold Lake and Peace River areas. For example, at Cold Lake the oil-bearing Clearwater Formation is overlain by more than 400 metres of overburden, making it unsuitable for mining techniques. In 1985 Imperial Oil conducted the first Steam-Assisted Gravity Drainage (SAGD) experiment at its Cold Lake Production Project that clearly demonstrated the potential of *in situ* thermal process to recover bitumen from oil sands. Since that time, as a result of the concentrated effort by AOSTRA at the UTF facility, a number of SAGD projects have been developed in the Athabasca, Cold Lake and Peace River oil sand deposits. Some of these other projects included: for the Athabasca deposit -- Syncrude OSLO (Other Six Leases Operation); Mildred, Kearl, and Gregoire lakes; Hangingstone and Tar rivers; for the Cold Lake deposit – Cold, Burnt, Marie, Marguerite and Wolf lakes, Primrose and Lindbergh; and, for the Peace River deposit – the Cadotte Lake project (Figure 3). The bitumen deposits at Cold Lake were discovered in the 1920s. In 1962 Imperial Oil drilled 10 evaluation wells, and in 1963 a pilot plant was built. In 1985 commercial production began at the Maskwa processing plant; and today, the Cold Lake Production Project is the world's largest *in situ* oil sands steam-generation and bitumen-production operation. Second place, after the Syncrude project, the Cold Lake Project produces about 100,000 barrels of bitumen per day, with production averaging about 35 million barrels per year. Over 30 years of research and technological developments by Imperial, along with 10 years of commercial production, have resulted in various technological schemes including: the development of cyclic steam stimulation

HISTORICAL THERMAL PROJECTS

ATHABASCA

1. Syncrude Mildred Lake
2. Suncor Mildred Lake
3. AOSTRA McKay
4. Canterra Kearl Lake
5. B.P. Tar River
6. Amoco Gregoire Lake
7. Unocal McLean (2)
8. Gulf Pelican (2)
9. Amoco Britnell
10. Petro Can Hangingstone
11. AEC Ipiatik Lake

PEACE RIVER

12. Shell Cadotte Lake

COLD LAKE

• Oil Sands Projects

HEAVY OIL

★ Heavy Oil Projects

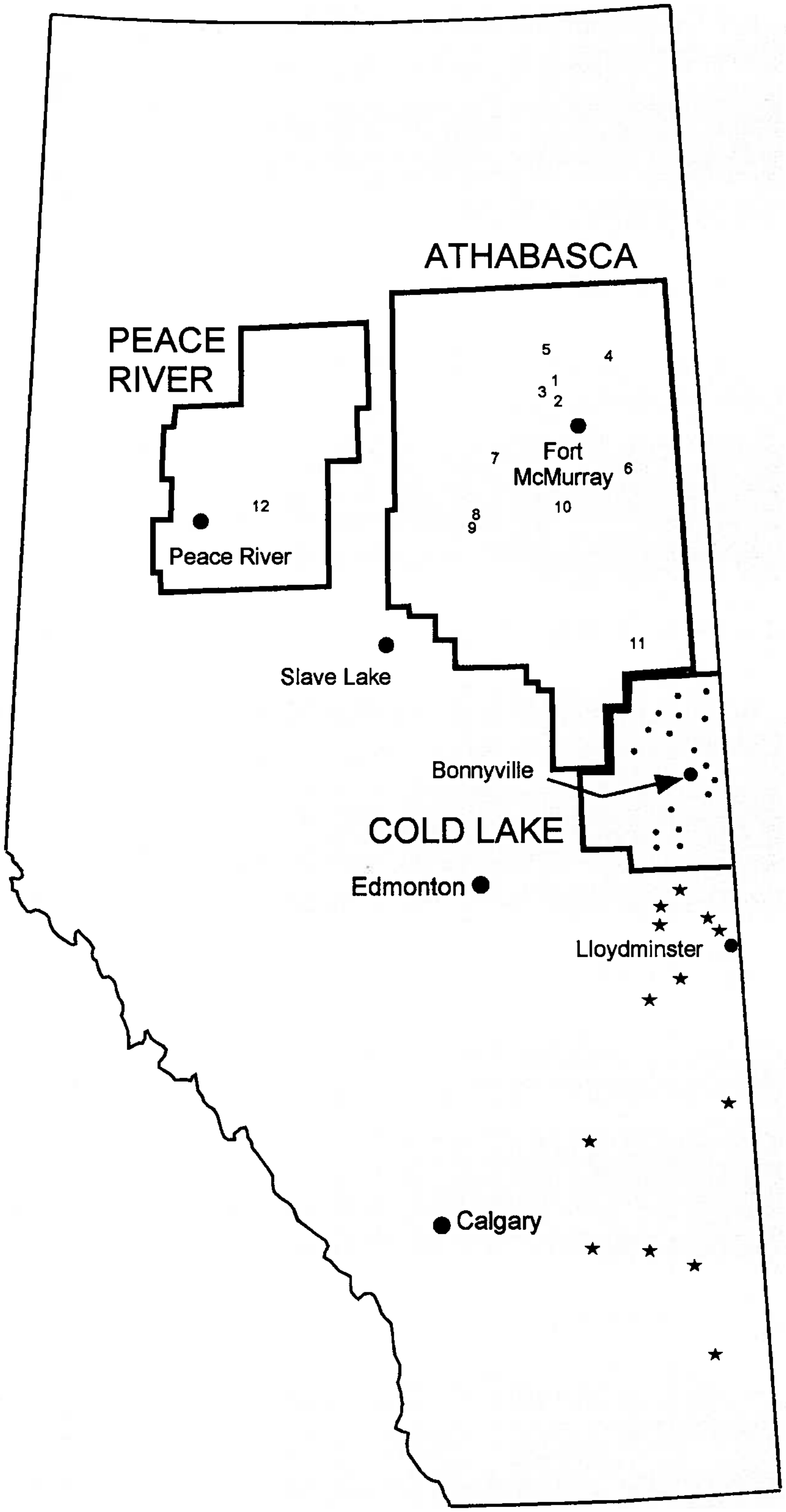


Figure 3. Location map showing Alberta oil sands and heavy oil areas with historical thermal projects to December 1988 (from Houlihan and Evans 1988).

(CSS) assisted by formation fracturing; improved water processing techniques; upgrading of well casing designs for cyclic thermal stress; optimization of pad designs and satellite facilities, among other innovations. More than 2,200 producing wells have been directionally drilled from satellite pads at the Cold Lake Production Project. At present, the cyclic steam-stimulation process used at Cold Lake consists of injection of steam under conditions of high temperature and pressure through well bores into the oil sands at depth. Once bitumen melts, and the viscosity is reduced, surface pumps lift the hot water-and-bitumen mixture through the same wellbore to the surface, where separation and processing occurs. Bitumen is blended with lighter hydrocarbons and shipped by pipeline principally to markets in the U.S. Midwest and secondarily to Canadian refineries.

The Future of Oil Sands in Alberta

Editor: The following is reprinted with permission from Fran Hein, Alberta Geology Survey (Hein 2000; p. 8).

In the past major companies involved with the oil sands development and production were, for the most part, the large integrated companies or consortia, such as Imperial Oil Ltd., Suncor Energy Ltd. and Syncrude. More recently, in today's market of improved technological methods for recovery and upgrading and improved environmental safeguards (Gray, 1999; Luhning and Luhning, 1999), a number of small and medium-size companies have invested in the oil sands (Ross, 1998). At present, according the Oil Sands Developers of Alberta, $24 billion Canadian in projects have been announced for the next decade in the Athabasca, Cold Lake and Peace River oil sands deposits. Part of this shift to development of heavy oil and oil sands, in addition to the technological advances, has been the renovation of North American refineries to increasingly process the heavier crude (Ross, 1998; Auchinleck, 1999; Fisher, 1999). During the previous twenty years, production of crude oil from the oil sands of Alberta has increased ten-fold (Polikar et al., 1998). Future production of synthetic crude oil from mining and in situ projects is anticipated to increase even more significantly, as refined products from the oil sands replace the depleting conventional oil and gas reserves of the Province (Polikar et al., 1998). Along with the technological development for in situ recovery have been improved developments in the mining, upgrading and extraction processes, along with more efficient handling and processing procedures (Sadler and Houlihan, 1998). In September 1999 a dedicated issue of the Journal of Canadian Petroleum Technology, "The Canadian Advantage: Oil Sands," highlighted some of these improved methods of in situ and mining operations (Newell, 1999). Overviews included a discussion of Suncor's Project Millennium (George, 1999); updates on the UTF project (Ito and Suzuki, 1999; Komery et al., 1999 and O'Rourke et al., 1999); secondary bitumen recovery from tailings (Cheng et al., 1999); and permeability damage effects associated with thermal recovery at Cold Lake (Zhou et al., 1999).

Coupled with these factors are environmental concerns, mainly focused on land disturbance, management and reclamation, water and air quality. Land disturbance largely relates to open pit development and overburden and tailings disposal. Water quality is an issue related to tailings disposal from pit mining and for thermal in situ projects obtaining sources of non-potable water, groundwater impacts, and water recycling technology. Finally, air quality relates mainly to emissions of carbon dioxide and other greenhouse gases (Polikar et al., 1998; Sadler and Houlihan, 1998).

At present, the responsibility for environmental issues is shared by Alberta Environmental Protection along with the Alberta Energy and Utilities Board (EUB), through their regulatory review, application and approval process. At present, each new project has to conduct an Environmental Impact Assessment (EIA). In addition, government and industry stakeholders are building environmental databases to be able to assess background environmental levels and thresholds for various environmental impacts associated with both open-pit mining and in situ production plants (Sadler and Houlihan, 1998). Forecasts show substantial increases in production of synthetic crude oil and other byproducts from the oil sands in the next ten years. This increased production and activity will have to be balanced with environmental and socio-economic concerns to bring about a prudent planning and mitigation of major issues involved with the development of this vast resource (Sadler and Houlihan, 1998).

2003 Oil Sands Statistics (Alberta Energy)

initial volume in place:	1.6 trillion barrels
remaining ultimate potential:	311 billion barrels
production (marketable):	882.5 thousand barrels per day
royalties:	$182 million (fiscal 2002-2003)
employment (total)	95.4 thousand (direct upstream)
cumulative investment:	$24 billion (1996-2002)
investment	$6.7 billion

Oil Sands General Information

Oil sands are deposits of bitumen, a heavy black viscous oil that must be rigorously treated to convert it into an upgraded crude oil before it can be used by refineries to produce gasoline and diesel fuels. Until recently, Alberta's bitumen deposits were known as tar sands but are now referred to as oil sands. Bitumen is best described as a thick, sticky form of crude oil, so heavy and viscous that it will not flow unless heated or diluted with lighter hydrocarbons. At room temperature, it is much like cold molasses. Oil sands are substantially heavier than other crude oils. Technically speaking, bitumen is a tar-like mixture of petroleum hydrocarbons with a density greater than 960 kilograms per cubic metre; light crude oil, by comparison, has a density as low as 793 kilograms per cubic metre. Compared to conventional crude oil, bitumen requires some additional upgrading before it can be refined. It also requires dilution with lighter hydrocarbons to make it transportable by pipelines.

Bitumen makes up about 10-12 per cent of the actual oil sands found in Alberta. The remainder is 80-85 per cent mineral matter – including sand and clays – and 4-6 per cent water. While conventional crude oil flows naturally or is pumped from the ground, oil sands must be mined or recovered *in situ*. Oil sands recovery processes include extraction and separation systems to remove the bitumen from sand and water. Alberta's oil sands comprise one of the world's two largest sources of bitumen; the other is in Venezuela. These deposits, which account for the majority of the province's crude oil reserves, are located in three regions:

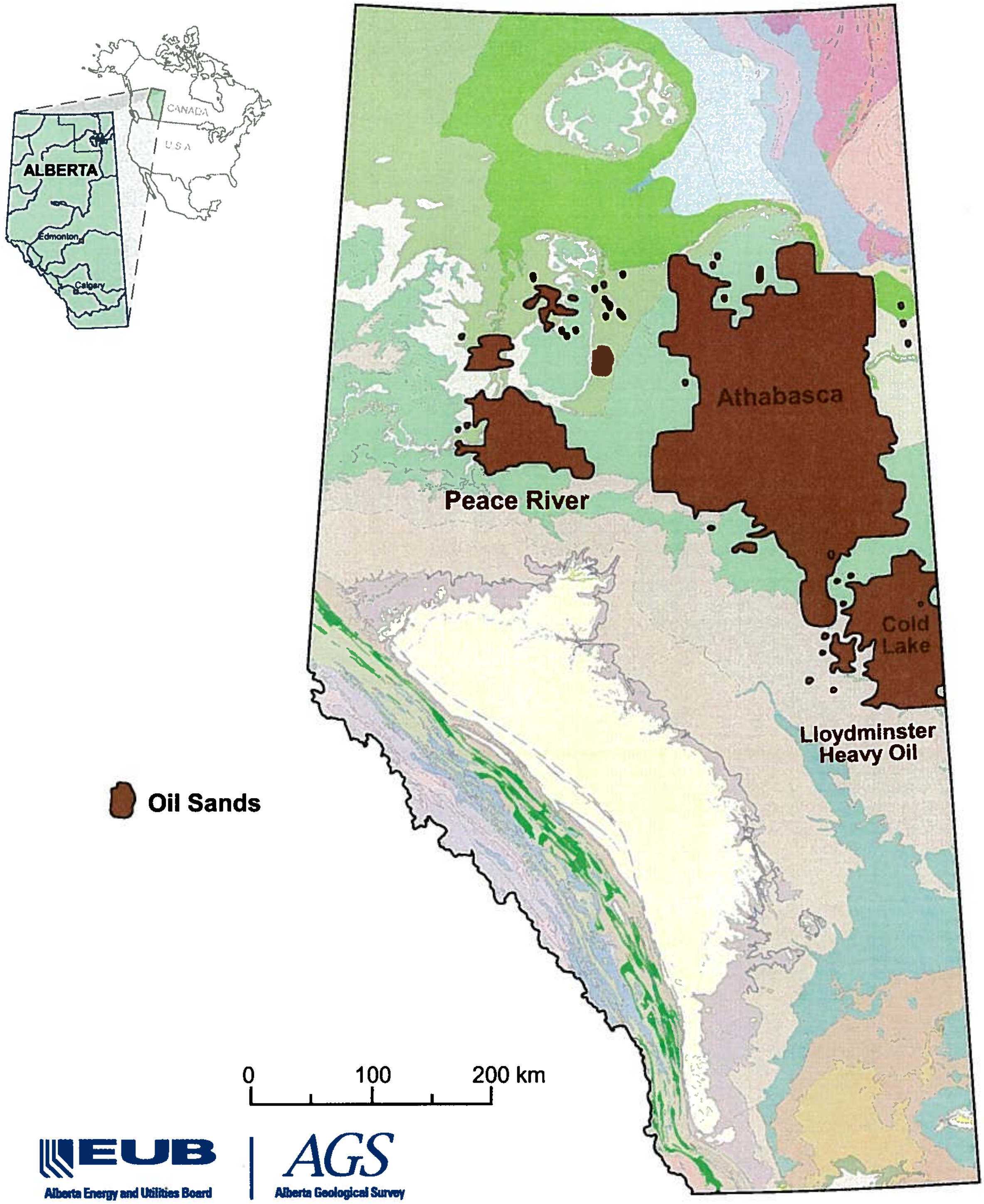


Figure 4. Oil sands deposits in Alberta.

Athabasca (Fort McMurray region), Cold Lake (north of Lloydminster), and Peace River. Oil sands cover a total of nearly 141,000 square kilometers (Figure 4).

Oil sands currently represent 54 per cent of Alberta's total oil production, and about one-third of all the oil produced in Canada. By 2005, oil sands production is expected to represent 50 per cent of Canada's total crude oil output, and 10 per cent of North American production. Mineable bitumen deposits are located near the surface and can be recovered by open-pit mining techniques. For example, the Syncrude and Suncor oil sands operations near Fort McMurray, Alberta, use the world's largest trucks and shovels to recover bitumen. About two tonnes of oil sands must be dug up, moved and processed to produce one barrel of oil. Roughly 75 per cent of the bitumen can be recovered from sand; processed sand has to be returned to the pit and the site reclaimed.

In situ recovery is used for bitumen deposits buried too deeply – more than 75 metres – for mining to be practical. Most *in situ* bitumen and heavy oil production comes from deposits buried more than 400 metres below the surface of the earth. Cyclic steam stimulation (CSS) and steam-assisted gravity drainage (SAGD) are *in situ* recovery methods (Figure 5), which include thermal injection through vertical or horizontal wells (Figure 6), solvent injection and CO2 methods. Canada's largest *in situ* bitumen recovery project is at Cold Lake, where deposits are heated by steam injection to bring bitumen to the surface, then diluted with condensate for shipping by pipelines. Other technologies are emerging such as pulse technology and vapour recovery extraction (VAPEX), which involves the use of solvents as a supplement or alternative to steam.

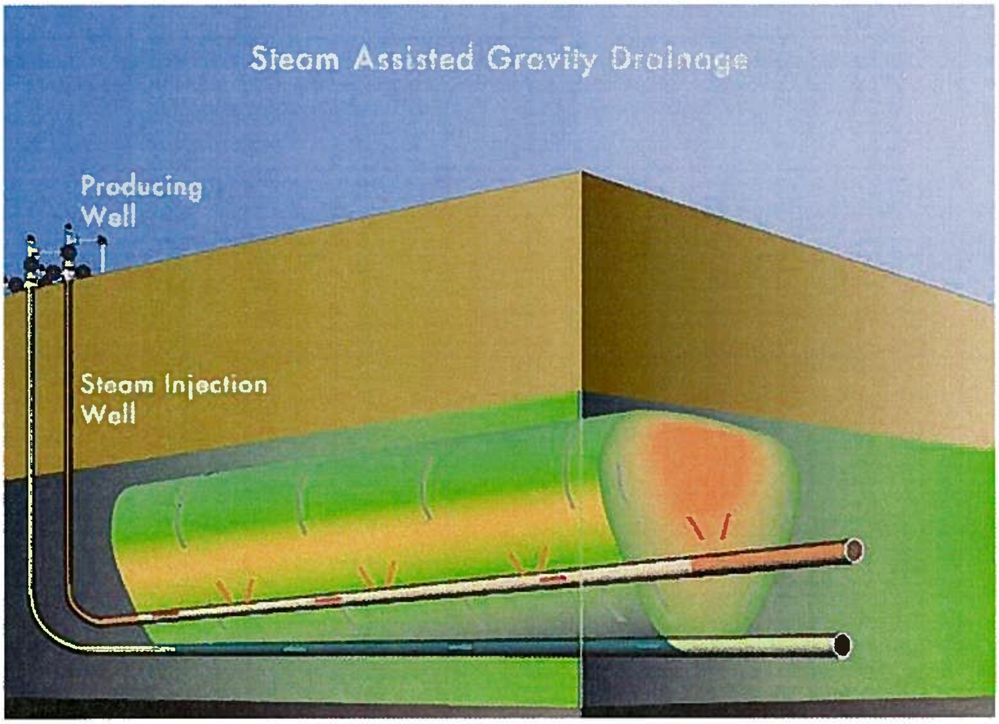


Figure 5. Steam assisted gravity drainage (SAGD) system.

Figure 6. A SAGD production well.

Another approach to in situ recovery of bitumen is known as primary or cold production, which can be employed in reservoirs where the oil sands will flow to the well bore without the introduction of heat. Alberta oil sands production figures for 2002 indicate that mining operations accounted for approximately two-thirds (540,000 bpd) of the total, with in situ operations accounting for one-third (284,000 bpd). Of the in situ production, approximately two-thirds (188,000 bpd) was recovered through thermal methods and one-third (96,000 bpd) through primary ("cold") production.

The bitumen obtained through either mining or in situ production methods can be used directly for asphalt, diluted and transported by pipeline to refineries for processing, or upgraded into synthetic crude oil (SCO). SCO itself is an input for refineries, where it can be further processed into gasoline, aviation fuel, or other products. Syncrude and Suncor have upgraders on site north of Fort McMurray and the Albian Sands mine is integrated with the Shell upgrader in Scotford to the northeast of Edmonton in Strathcona County. Stand-alone upgraders are located in Lloydminster and Regina.

Oil Sands Industry Activities – Fort McMurray Region

- Suncor produced an average of 217,000 bpd from its oil sands operations in 2003, up from 206,000 in 2002. In January 2004 production was down to 209,000 bpd due to equipment maintenance and cold weather, but the company is expecting to produce an average of 225,000-230,000 bpd in 2004. The company continues to pursue its Voyageur growth strategy in order to raise oil sands production to 500,000-550,000 bpd by 2010-2012. Phase 1 of Suncor's Firebag In Situ Oil Sands Project began production in January 2004 and is expected to produce 28,000 bpd by 2005. Construction of the 35,000 bpd Firebag Phase 2 is in progress. Suncor has also:

– Obtained regulatory approval for the expansion of the Millennium Coker Unit, expected to raise the company's oil sands production capacity to a minimum of 330,000 bpd by late 2007. Commercial decision for this project is expected in late 2004;
– Applied for regulatory approval to construct and operate a proposed South Tailings Pond, an external tailings pond; and
– Entered into a long-term agreement with Petro-Canada whereby Suncor will process a minimum of 27,000 bpd of bitumen from Petro-Canada's MacKay River operation and sell Petro-Canada an additional 26,000 bpd of sour crude production. The provisions of the agreement are expected to take effect in 2008.

- Syncrude produced an average of approximately 212,000 bpd during 2003, down from approximately 230,000 bpd in 2002. The decline was due to an unscheduled coker turnaround and extended maintenance work. Following completion of the coker turnaround, production rose to an average of 264,000 bpd in December 2003. The company continues to pursue its Syncrude 21 growth strategy, including:

– Commissioning of Aurora Train 2 in the fourth quarter of 2003; and
– Construction of Upgrader Expansion 1 (UE1), now 35% complete.

In 2003 the company filed an application for a $400 million project designed to reduce sulphur dioxide emissions from the Mildred Lake upgrader by as much as 50%. Construction of this project is expected to begin after the upgrader expansion is complete.

- Athabasca Oil Sands Project (a joint venture between Shell, Chevron Canada Resources, and Western Oil Sands), which includes the Albian Sands Muskeg River Mine, the Shell Scotford Upgrader, and the Corridor Pipeline, achieved fully integrated commercial operations in June 2003. Production during the fourth quarter of 2003 averaged 130,000 bpd, up from 115,000 bpd in the third quarter. Design capacity for the project is 155,000 bpd. The companies continue to seek recovery of costs related the fire at the Muskeg River Mine in January 2003.

- Petro-Canada produced an average of 16,000 bpd at its MacKay River In Situ Project during the fourth quarter of 2003, up from 4,500 bpd in the same period in 2002. The MacKay River project has a design capacity of 30,000 bpd. Production in 2004 is expected to average 25,000 bpd.

- EnCana Energy is producing about 5,300 bpd from the first phase of the Christina Lake Thermal Project, up from 3,500 bpd in September of 2003. The design capacity of the project is 10,000 bpd. The company is currently testing a Solvent Aided Process (SAP) at Christina Lake. SAP is an enhancement of the SAGD process in which a small amount of solvent is added to the injected steam to decrease in situ oil viscosity.

- ConocoPhillips has given company approval to proceed with its Surmont Project, a multi-phased in situ project designed to produce 100,000 bpd (regulatory approval obtained in May 2003). Construction of the first phase of the project is expected to begin in 2004, with initial production anticipated in 2006. The Surmont project is expected to require capital expenditures of $1 billion.

- Japan Canada Oil Sands (JACOS) continues to operate its SAGD Pilot Plant at the Hangingstone lease. This plant was constructed in three phases, the last one of which was completed in 2002. The company is progressing towards the submission of an application for a 30,000 bpd commercial SAGD project on the Hangingstone lease.

- Opti Canada and 50/50 joint-venture partner Nexen have given company approval to proceed with their $3 billion Long Lake Project (regulatory approval obtained in August of 2003). The first phase of this SAGD project consists of 70,000 bpd and an upgrading facility. Construction is expected to begin in the latter half of 2004, with bitumen production in 2006 and synthetic crude production in 2007. Pilot testing of the SAGD technology is in progress.

- TrueNorth Energy continues to defer construction of its Fort Hills Project. TrueNorth partner UTS Energy is exploring options that would allow the project to proceed, including a downsized initial phase of 50,000 bpd supported by an on-site upgrading component. The government approvals now in place for Fort Hills bitumen production of up to 235,000 bpd would need to be amended to reflect this re-scoping.

- Shell Canada has obtained regulatory approval to build and operate phase 1 of the Jackpine Mine, a 200,000 bpd mining and extraction facility straight east of the Muskeg River Mine. Phase 2 of the Jackpine Mine, which would require additional regulatory approval, may eventually increase production capacity of the operation to a total of 300,000 bpd.

- Canadian Natural Resources (CNRL) has obtained regulatory approval for its Horizon Project, an $8 billion facility that includes a 270,000 bpd mine and an integrated upgrader. Construction is expected to begin in 2005, with initial production in 2008 and full production in 2011. The company has completed construction of a 30 km access road that bypasses the community of Fort McKay.

- Devon Energy Corporation has applied for regulatory approval for its Jackfish SAGD Project. The project, located near Conklin, has a design capacity of 35,000 bpd and a cost estimated at $400 million. First production is expected in 2006/2007 and full production in 2008. The company continues to operate the Dover Vapex Pilot Project at its test site (formerly that of the Alberta Oil Sands Research and Technology Authority (AOSTRA)). The Vapex technology, which uses vaporized solvents instead of steam to extract in situ oil, uses far less natural gas than conventional SAGD operations and therefore promises significant reductions carbon dioxide emissions. The Alberta government and various oil and gas producers are also participating in the Dover project.

- Synenco Energy's formal disclosure document for its Northern Lights Project remains on file. The project is an integrated mine, extraction and upgrading facility with a design capacity of 100,000 bpd and an estimated construction cost of $4 to $5 billion. Assuming regulatory approval in 2005, start-up of the project is planned for 2007, with peak production expected in 2010.

- Fort McKay First Nation has discussed publicly its plans for a 35,000 bpd oil sands mining project near the settlement of Fort McKay. Current plans do not include an upgrader. Timing of the project is uncertain.

- Imperial Oil has announced its intention to proceed with its Kearl Oil Sands Project (belonging formerly to Mobil Oil Canada). Current planning for the project, which includes both mine and upgrading components, envisions an initial 100,000 bpd development with later expansion to production of 200,000 bpd. Application for regulatory approval is anticipated in 2005, with first production scheduled for 2010.

- Husky Energy has made a public disclosure of its Sunrise Thermal Project (formerly known as Husky's Kearl in situ Project), which is designed to produce 50,000 bpd initially, increasing eventually to 200,000 bpd during a 40-year period commencing in 2008. Application for regulatory approval is anticipated in 2004 and construction of phase 1 in 2006-2008.

- Deer Creek Energy is constructing Phase 1 of its Joslyn Oil Sands Project, a SAGD facility designed to produce some 600 bpd. Start-up of the operation is expected in the second quarter of 2004 and full production in 2005. The company is expecting regulatory approval of Phase 2, designed to produce 10,000 bpd, in the first quarter of 2004. Facility construction and drilling completions integral to Phase 2 are expected to begin in the third quarter of 2004, steam injection in mid 2006, and full production in 2007. Phase two capital costs are estimated to be $270 million. During 2004, Deer Creek plans to evaluate Phase 3 of the project, an expansion of 30,000 bpd.

- Petrobank has received regulatory approval for its Whitesands Pilot Project, the first field-scale application of the patented Toe-to-Heel Air Injection (THAI) in situ heavy oil recovery technology. The design of the project is being finalized and construction is scheduled to begin in mid-2004. First results from the pilot are expected early in 2005.

Regional Stratigraphy

The stratigraphic section preserved in outcrop in the Fort McMurray area includes the uppermost portions of the Devonian Christina and Moberly Members of the Waterways Formation (Beaverhill Lake Group) and the overlying Lower Cretaceous McMurray Formation and Wabiskaw Member of the Clearwater Formation (Mannville Group) (Figure 7). Selected outcrop sections selected for this fieldtrip along the Athabasca River valley and its associated tributaries, mainly to the west and north of Fort McMurray. The unconformable contact between the Devonian and Cretaceous successions locally has significant relief (from 5 m to >130 m) a result of profound differential weathering of the variably argillaceous carbonate units, combined with tectonic collapse caused by dissolution of underlying Devonian Elk Point Group evaporates (Hein et al. 2001). In the Fort McMurray area, positive structural elements along the sub-Cretaceous unconformity surface include the Grosmont High and the Beaverhill Lake High. Negative structural elements are the Bitumount Basin and the associated regional linear depression, called the Prairie Salt Scarp, that trends roughly parallel to the strike of the subcropping Devonian units and slightly oblique to the present-day valley of the Athabasca River (Figure 8). Collapse of the carbonate units, after regional dissolution of the underlying salts, resulted in small-scale folding and faulting in areas proximal to the dissolution front. Karstification along the sub-Cretaceous unconformity created numerous sinkholes and other paleokarst features. The highly variable structural and erosional relief on the sub-Cretaceous unconformity greatly influenced sediment dispersal patterns and facies architecture of the overlying McMurray Formation and the Wabiskaw Member of the Clearwater Formation (Figures 9 and 10).

A high degree of reservoir heterogeneity characterizes the McMurray Formation. This heterogeneity presents an enormous challenge for economic development of the oil sands. For example, Suncor was unpleasantly surprised when they found some mud-filled channels in their Steepbank Mine, which were never seen in fairly dense pre-mine drilling. The heterogeneity is caused by a wide variety of depositional environments that occur within the McMurray Formation. The environments range from fluvial-dominated to fluvial-estuarine channel and point bars, tidal flat/channel, brackish bay, open estuarine, and various overbank settings, including peat swamps. The depositional setting and types of deposits are controlled by pre-Cretaceous topography and syn-depositional solution-collapse of underlying evaporates.

The Upper McMurray contains channel complexes, where a channel complex is a lithofacies package defined by major bounding surfaces, with genetically-related facies and consistent paleoflow patterns. These channel complexes can be mapped using outcrop and subsurface data, greatly aided by seismic information (Langenberg et al. 2002). The definition of these channel complexes will aid economic oil sands exploration and exploitation.

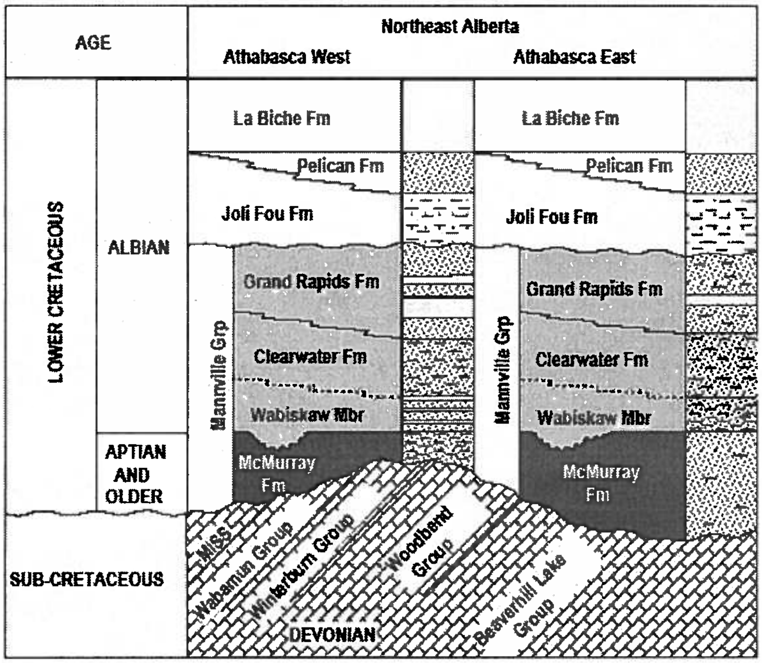


Figure 7. Schematic cross section, Fort McMurray area (modified from Wightman, et. al.1997; from Hein et al. 2001).

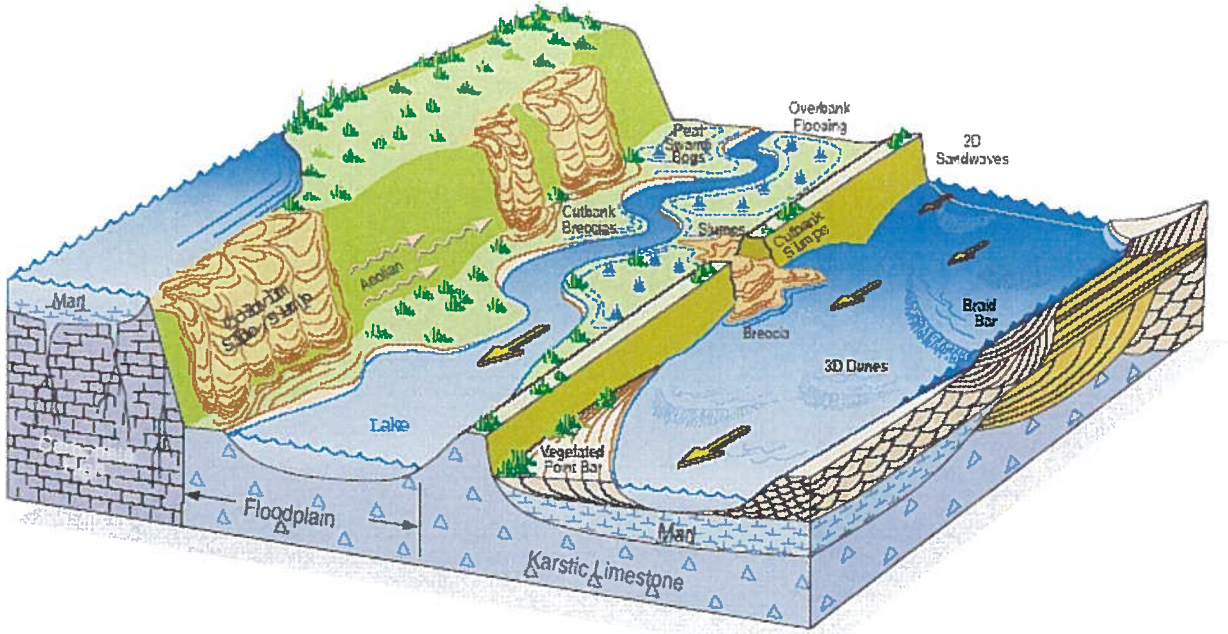


Figure 8. Schematic facies model for the Lower McMurray Formation, Athabasca deposit, northeast Alberta (modified from Hein et al. 2000).

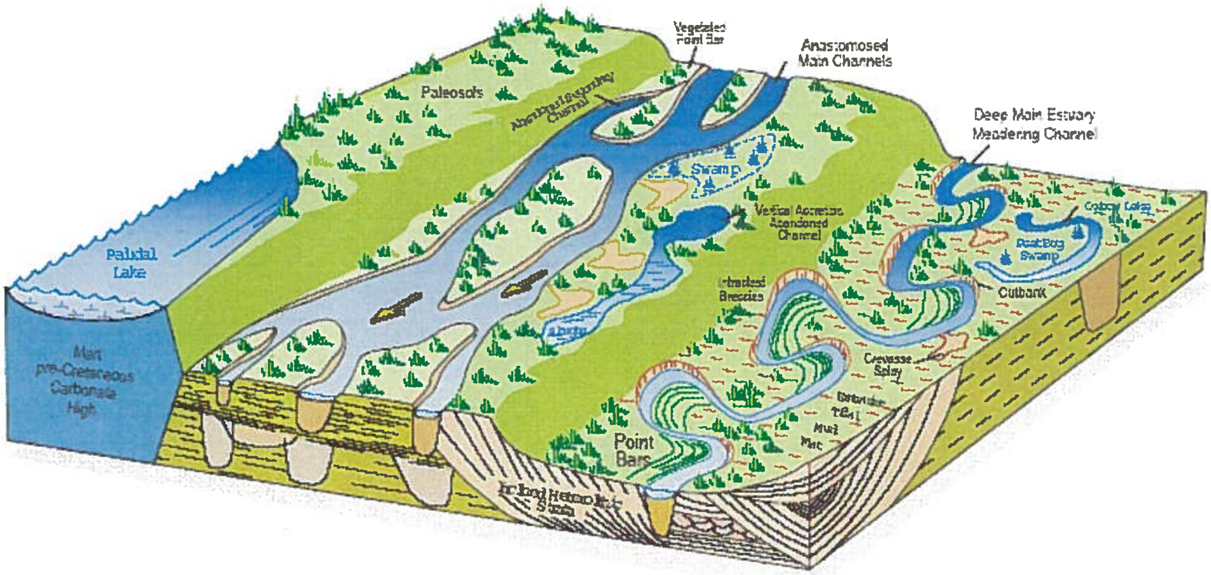


Figure 9. Schematic facies model for the lower part of the Upper McMurray Formation, Athabasca deposit, northeast Alberta (modified from Hein et al. 2000).

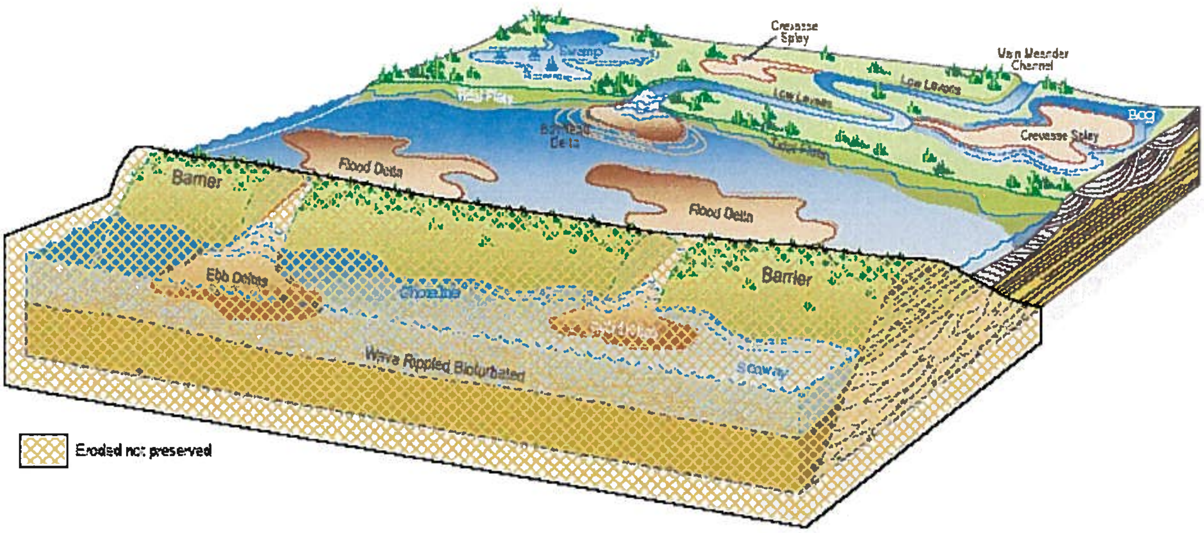


Figure 10. Schematic facies model for the upper part of the Upper McMurray Formation, Athabasca deposit, northeast Alberta (modified from Hein et al. 2000).

Stop 1: Fort McMurray Discovery Centre

The Oil Sands Discovery Centre is located in Fort McMurray, Alberta, Canada and presents the history, science and technology of Alberta's Oil Sands. At the Centre you'll be surrounded by BIG things - a dragline bucket, a 150 tonne heavy hauler with tires three metres high and "Cyrus," an 850 tonne bucketwheel excavator. The Centre opened in 1985 as the Fort McMurray Oil Sands Interpretive Centre. The Centre is an educational facility committed to increasing public awareness, appreciation and knowledge about the oil sands industry.

In September 2002, a newly redeveloped exhibition gallery was opened. It was created through donations by private companies, individuals and the Alberta Government and by the hard work, dedication and vision of advisory and fund raising committees and the former Friends of the Oil Sands Discovery Centre. The Centre is a provincial facility, operated and maintained by the Alberta government, Department of Community Development, Historical Resources Division, Historic Sites and Cultural Facilities Branch.

Stop 2: Syncrude Mine Tour

Syncrude is one of the largest open pit mines in the world. The company commenced large scale operations in June 1977 (Figure 11) and in 2003, it produced 77.3 million barrels of Syncrude Sweet Blend. The current daily output represents 13 percent of Canada's total oil requirements. Syncrude is currently in the midst of a multi-staged expansion called Syncrude 21. By 2005, total daily production from the Syncrude Project is expected to reach around 350,000 barrels of Syncrude Sweet Blend. Syncrude is one of the largest private sector employers in Alberta, employing approximately 4,000 people directly and an average of 1,000-1,500 maintenance contractor employees.

Figure 11. Pit wall at the base mine in 1978 (Photograph courtesy of Grant Mossop, GSC).

Mine Facts:

- Dimensions of the Base mine — 5.0 km by 7.0 km by 60 m deep.
- Dimensions of the North mine — 2.5 km by 4.0 km by 80 m deep.
- Dimensions of the Aurora mine (after development in 2010) — 5 km by 2.5 km by 70 m deep.
- Oil sand mined in a typical year — 74 million BCMs (banked cubic metres) or 155 million tonnes per year. In 2001, 164.7 million tonnes were mined.
- Overburden and rejects handled in 2001 — 83.6 million BCMs or 175.4 million tonnes.

Three of the four walking draglines and bucketwheel reclaimers have been retired and have been replaced with electric and hydraulic shovels and a fleet of 46 mechanical and electric drive trucks. The hydraulic shovels used at Aurora are the biggest in the world - digging 56 cubic-yards of material with each scoop (Figure 12). The haul trucks at Aurora and the North Mine are the 400-ton Caterpillar 797's, the largest in the world (Figure 13). These trucks have 3,550 horsepower and can carry over 400 tons! The last dragline and bucketwheel reclaimer are slated to retire in 2006. The oil sand itself poses difficulties beyond conventional hardrock mining. Oil sand is more abrasive and dense, and it becomes wet and sticky in the summer. Unlike hardrock mining, where blasting rolls material toward the excavator, oil sand remains in place without the benefit of free fall.

Before the oil sand can be mined roughly 1 to 3 m of organic deposits are removed and stockpiled for reclamation purposes. Over 25 metres of 'overburden' is removed, this includes the glacial deposits and any bedrock that lacks oil sands. The oil sands deposit itself is approximately 50 m thick.

Once the oil sand at Aurora is mined, the trucks deposit it into a double-roll crusher to break up the big lumps of oil sand and rock. The crusher operates at a peak rate of 11,000 tonnes per hour. Then a conveyor system transfers the crushed oil sand into a cyclofeeder. The cyclofeeder combines the oil sand from the crusher with hot water, in a low energy extraction process. At Aurora, the temperature in this process is approximately 35°C (at the North mine, the temperature is 50°C), which is substantially lower than the 80°C extraction temperature in the original process.

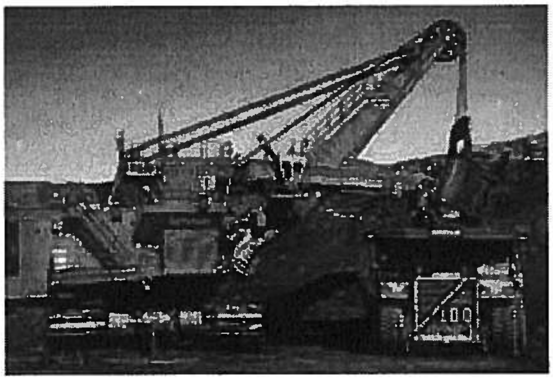


Figure 12. Electric Cable Shovel

Figure 13. 360-ton mechanical drive truck

Hydrotransport technology has truly changed the face of mining at Syncrude. It all started back in 1989 when the first hydrotransport pilot work began. By 1993, the Syncrude-developed hydrotransport technology was being used as a production unit at the site called the Extraction Auxiliary Production System (EAPS). In 1997, the first North mine hydrotransport train came into full production and in 1999 the second North mine train came on-line.

Now, truck and shovel operations mine the oil sand and deliver it to crushers that size the feed. The oil sand is then conveyed to a mixing operation that combines the oil sand with hot water to create a slurry that is pumped via pipeline to the extraction plant. As a result, hydrotransport improves energy efficiency and environmental performance. In 2000, the first hydrotransport-low energy extraction production train started up at the Aurora project. There, mining and extraction of oil sand occurs at facilities 35 kilometres north of the existing Mildred Lake facilities.

Extraction:

Bitumen is extracted from the oil sand in extraction plants located at both the Mildred Lake and Aurora sites. At the Mildred Lake site, 50 percent of the oil sand processed comes from the dump pocket by conveyor and enters the tumblers (large horizontal, rotating drums – Figure 14). The oil sand is slurried by steam, hot water and caustic soda to condition it for bitumen separation. The rotary action also aerates the slurry. The slurry from the tumblers is discharged onto vibrating screens where large materials such as rocks and lumps of clay are rejected. The slurry is then diluted in pump boxes and pumped to the "Superpot" distributor where it is blended with the slurry from the North mine hydrotransport system. (Currently, some 50 percent of oil sand processed at Mildred Lake arrives at the extraction plant as a hydrotransport slurry. This will increase to 100 percent by 2006.)

The blended slurry is fed to the four Primary Separation Vessels (PSVs) and the two Auxiliary Settling Areas (ASAs), which are smaller versions of the PSVs. In the PSVs and ASAs, bitumen floats to the surface as primary froth (Figure 15). The sand settles out and the middlings and underflow streams are pumped to the Tailings Oil Recovery (TOR) vessels. These deep cone vessels recover most of the remaining bitumen using Syncrude-developed technology. Froth from the TOR vessels is recycled to the PSVs to improve its quality.

Bitumen recovery is further improved by the secondary flotation plant which processes middlings from the TOR vessels. Froth from the secondary flotation plant is combined with the primary froth stream from the PSVs, deaerated and heated, and fed to the froth treatment plant. Froth treatment minimizes the water and solids going to the upgrader. Froth is diluted with naphtha and this diluted bitumen is either put through inclined plate settlers or through two stages of centrifuges. The combined product from the inclined plate settlers and centrifuges is then put through another set of centrifuges to remove the water and solids as tailings before going to the upgrader. A Naphtha Recovery Unit (NRU), developed by Syncrude, recovers naphtha from all froth treatment tailings.

This system processes approximately 500,000 tonnes of oil sand per day to produce 92,000 m3, or 580,000 barrels per day of diluted bitumen. This produces 95 million barrels of bitumen per year. Currently, extraction techniques recover over 91 percent of the bitumen contained in the oil sand feed.

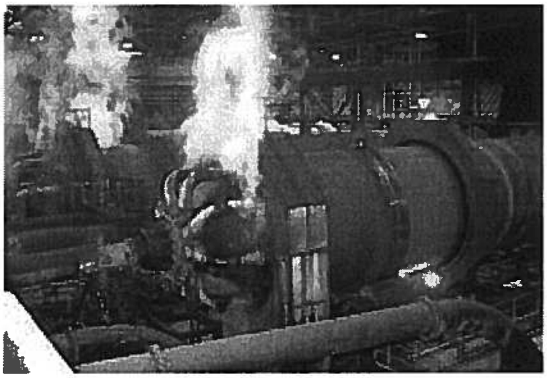


Figure 14. Tumblers prepare the oil sand for separation.

Figure 15. Bitumen froth floats to the top of a primary separation vessel.

Tailings:

The tailings stream is a combination of coarse sand and a liquid component, which consists of water, fine silt and clay particles and some residual hydrocarbons. The tailings are stored in three main areas on the base leases: the Mildred Lake Settling Basin (MLSB), the southwest sand storage area, and the Base mine pit where mining has been completed. The MLSB was the original storage site for all tailings materials in the initial years of operation. While it continues to provide some storage for tailings streams, its primary function is to serve as a settling basin, allowing solids to settle to the bottom and providing clarified water for use in the Syncrude processes. In 1991, as the MLSB reached its final design height, the southwest sand storage area was brought on stream to serve as the main site for sand storage. At this site, the solids (sand, silt and clay) settle out and the remaining water and fines are transported by gravity to the Base mine lake for further clarification.

Major mining activity in the Base mine area east of Highway 63 was completed in late 1999. Shortly after mining was completed, the mined-out pit began serving as a storage site for tailings. Currently the area is being used for sand storage with minimal water. This area will also serve as the primary site for land reclamation using Composite Tailings (CT). The area located west of Highway 63 serves as a clarification pond for water from the southwest sand storage and the East mine. As with MLSB, the fines and solids settle out and the clarified water is returned to the plant for reuse. Eventually, this pond will be capped with water to create a biologically self-sustaining lake.

Upgrading:

During the upgrading process, bitumen is converted from a viscous, tar-like substance to Syncrude Sweet Blend, a high quality, light sweet crude oil with no residual bottoms and the lowest sulphur content of any crude in North America.

<u>Diluent recovery</u>

The upgrading process begins with diluted bitumen being processed through two Diluent Recovery Units (DRU). The DRUs are distillation units that operate at atmospheric pressure and serve three purposes: distilling off diluent naphtha and returning it to the extraction process;

distilling off light gas oil and sending it directly to a light gas oil hydrotreater; and producing hot Atmospheric Topped Bitumen (ATB) as feed stock for the fluid cokers, LC-Finer hydroprocessor and Vacuum Distillation Unit (VDU).

<u>Vacuum distillation</u>

The VDU processes approximately 55 percent of ATB from the DRU. The VDU is a distillation unit operating under vacuum conditions. It distills off light and heavy gas oils which are then sent directly to hydrotreaters. The remaining bitumen, or Vac Topped Bitumen (VTB), is blended with the other 45 percent of ATB and then sent to the LC-Finer and fluid cokers for further processing. The VDU took 17 months to construct and is the largest of its kind. Currently capable of processing 175,000 barrels of bitumen per day, the VDU can be expanded in the future to a capacity of 300,000 barrels per day.

<u>Processing bitumen with the LC-Finer</u>

The LC-Finer hydroprocessor breaks down bitumen feed through a reaction with hydrogen over an ebulated catalyst bed and produces a light gas oil (LGO). Unconverted feed or residuum from the LC-Finer is sent to the fluid cokers for further cracking. The LC-Finer hydroprocessor is the third unit of its kind built in the world. It was designed to process 40,000 barrels of bitumen per day, but can now process up to 55,000 barrels of bitumen per day.

<u>Processing bitumen with the Fluid Cokers</u>

Hot ATB, VTB and residuum are fed to Syncrude's two fluid cokers to be cracked or broken down into lighter products. High temperatures in the coker reactors cause the long chain molecules to thermally crack in a fluidized bed of coke. The high temperature comes from coke that has been heated in the coker burner. The lighter liquid products, primarily naphtha and gas oils, are sent to hydrotreaters for sulphur and nitrogen removal. The coking reaction also produces sour fuel gas which is sent to amine treaters for hydrogen sulfide removal. The resulting sweet fuel gas (much like natural gas) is used as an energy source throughout the upgrading and utilities operations. The coking reaction also produces coke, some of which is burned to produce heat for the high temperatures in the reactor. Excess coke is mixed with water and transported to coke cells in the mine area to be stored for potential future use. The two fluid cokers are the largest ever built and were designed to process 72,900 barrels of bitumen a day. As a result of continuous improvement efforts, both cokers routinely process over 110,000 barrels of bitumen per day. When a coker and associated units are taken down for maintenance, approximately 1,500 extra contractors are brought to site.

<u>Sulphur and nitrogen removal</u>

Liquid products (heavy gas oil, light gas oil and naphtha) from the DRU, VDU, cokers and LC-Finer are high in sulphur and nitrogen, which are removed by hydrotreaters. This is accomplished by reacting the oil with hydrogen over a packed catalyst bed at high temperatures and pressures in the hydrotreater reactors. The reaction produces hydrogen sulfide and ammonia as byproducts. The hydrogen sulfide is converted to elemental sulphur and stored at the plant site in sulphur blocks. The ammonia is burned in the CO boilers in the utilities plant.

Utilities:

Syncrude's utilities department supplies steam, electricity, air, water, and nitrogen for all Syncrude operations. At the Mildred Lake plant, electricity is produce by four steam turbines and two gas turbine generators that produce 268 megawatts – enough to power a city of 300,000 people.

Stop 3: MacDonald Island

Middle Devonian Waterways Formation (Moberly Member) limestone, Athabasca River. The MacDonald Island location is on the south bank of the Athabasca River approximately 0.5 km east of the bridge over the river and within the town of Fort McMurray. From this location the type section of the McMurray Formation can be seen in the distance further down river on the eastern bank. Flat lying limestones of the Moberly Member of the Middle Devonian Waterways Formation are well exposed here and display several different depositional facies, as shown in the above photo. The lower, more resistant facies is fossiliferous, commonly displaying stromatoporoids and other fossils representing a shallow marine continental shelf setting (Buschkuehle 2002). The upper, rubbly-weathering, less resistant facies is finer-grained and appears to be highly bioturbated. This depositional setting is still that of a shallow shelf but may represent a lower energy setting on the shelf where burrowing organisms could thrive.

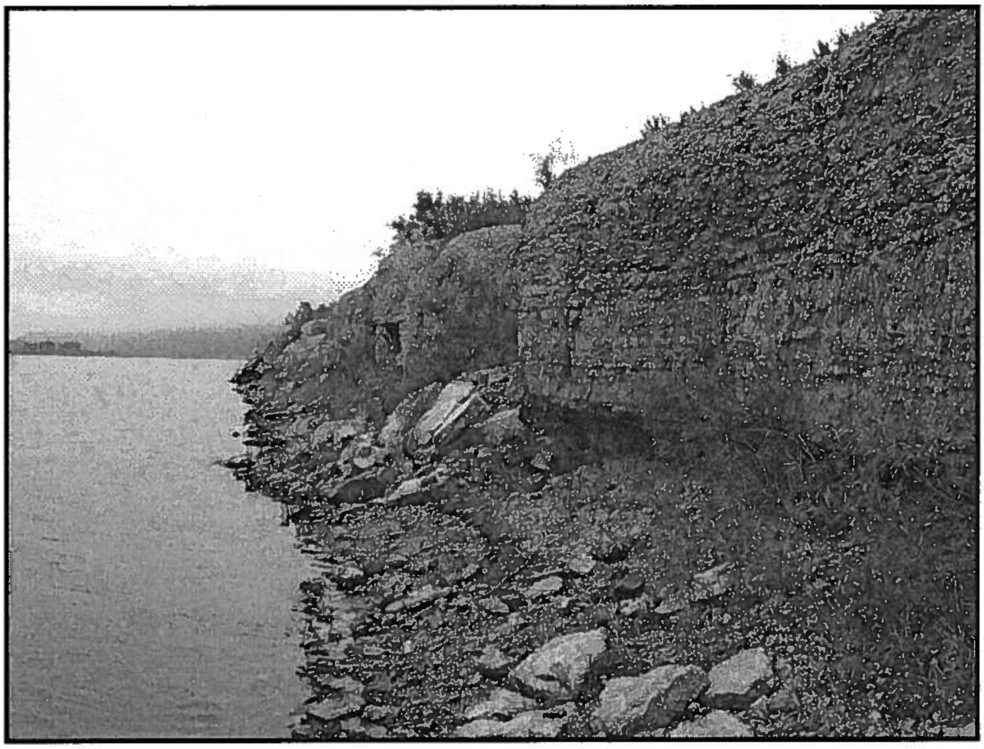


Fig. 16. Moberly Member limestone, Waterways Formation, at MacDonald Island in the town of Fort McMurray. Athabasca River and part of the type section of the McMurray Formation on the left and in the distance, respectively.

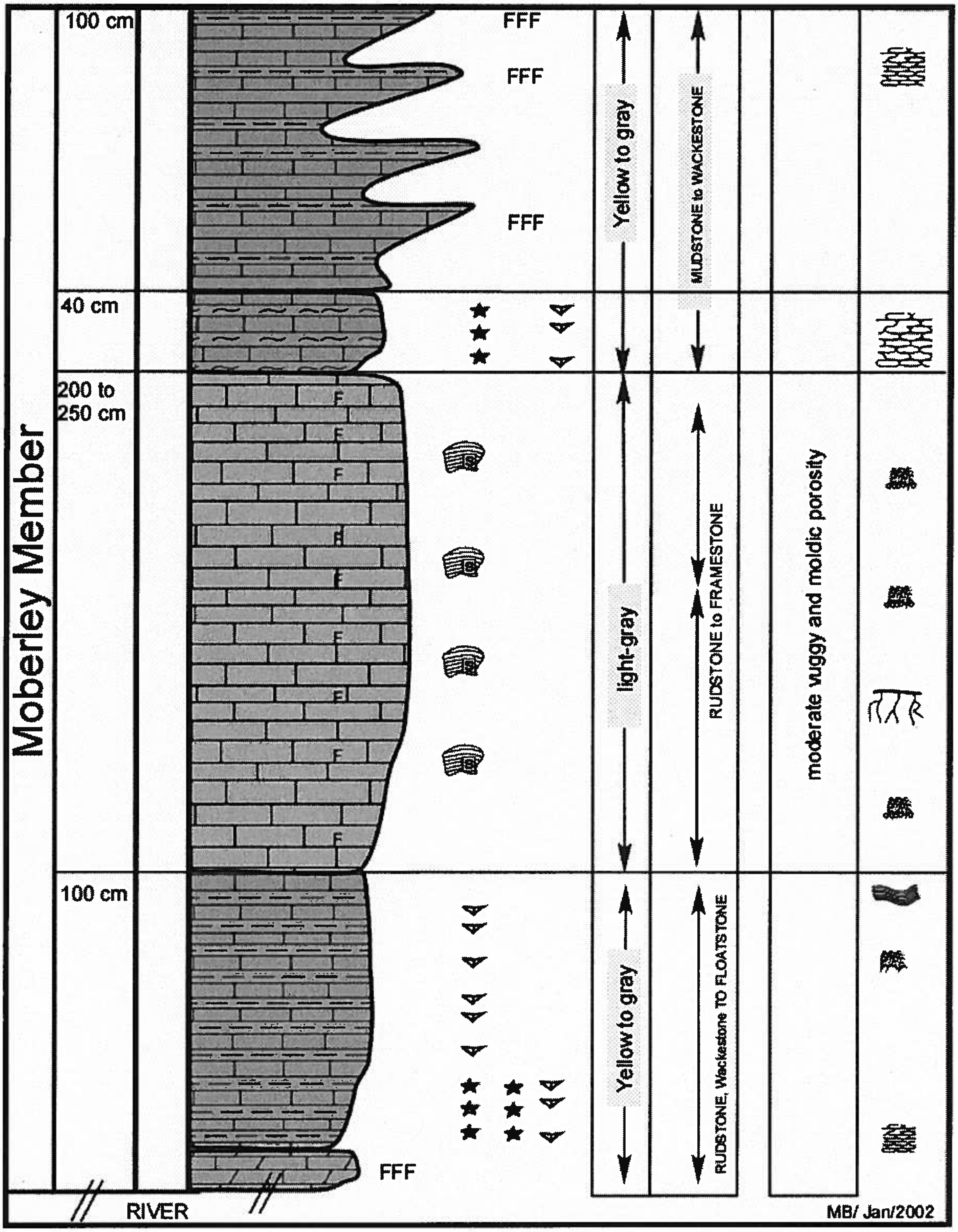


Figure 17. Lithostratigraphy of the Middle Devonian Moberly Member, Waterways Formation, Athabasca River (from Buschkuehle; Rice et al. 2003).

Stop 4: Hangingstone River

The Hangingstone River section lies along the Hangingstone River within the town of Fort McMurray. The lower portion of the section is covered but the upper third of the exposure displays estuarine channel point bar deposits with inclined heterolithic stratification (IHS) containing abundant bioturbation.

Fig 18. Estuarine channel deposits, McMurray Formation.

Keynote things to see:

- Thick mudstones at the base of the sections;
- Estuarine channel and point bar deposits;
- Coquinas and ironstone concretions and cemented ledges, from which dinosaur and mosasaur remains have been found in float;
- Contact between the McMurray Formation and the glauconitic Wabiskaw C sand.

Description (from Hein et al. 2001): In this thick outcrop section, about 50 m high, is exposed the estuarine sediment. The succession at this outcrop starts with a fine-grained mudstone, mainly slumped at the base of the outcrop (Figure 19). This mudstone is overlain by sediment with abundant cross-bedding, including trough, high angle planar tabular, planar tangential, and low-angle, sandy or muddy inclined units. Mudstone interbeds and lenses are common, with an increase in frequency and thickness going upsection. Concomitant with this increase in mudstones, is also an increase in bioturbation intensity, with the most common types being Cylindrichnus and horizontal Planolites, with rare vertical Skolithos. Thin, indurated coquina beds are located in the middle and upper parts of the section. At the top of the outcrop is exposed approximately 4.5 metres of glauconitic, bioturbated, well sorted sand. This is the Wabiskaw C unit (Wabiskaw Member, Clearwater Formation) that unconformably overlies the McMurray Formation in this area. The Wabiskaw C is, in turn, unconformably overlain by Quaternary-age sediment.

Interpretation: The recessive basal mudstone is interpreted as an abandoned channel, vertical accretion deposit. Thick estuarine channel and point bar sands overlie this. Coquinas are interpreted as stormsurge channel deposits. Although there is limited biostratigraphic dating from this outcrop, what is available indicates brackish water (not fluvial) settings. This, in addition to the abundance of burrowing and burrowed mudstone intraclasts, common occurrence of muddy inclined heterolithic stratification, presence of wave-formed features and coquinas indicate that this section comprises Upper McMurray successions.

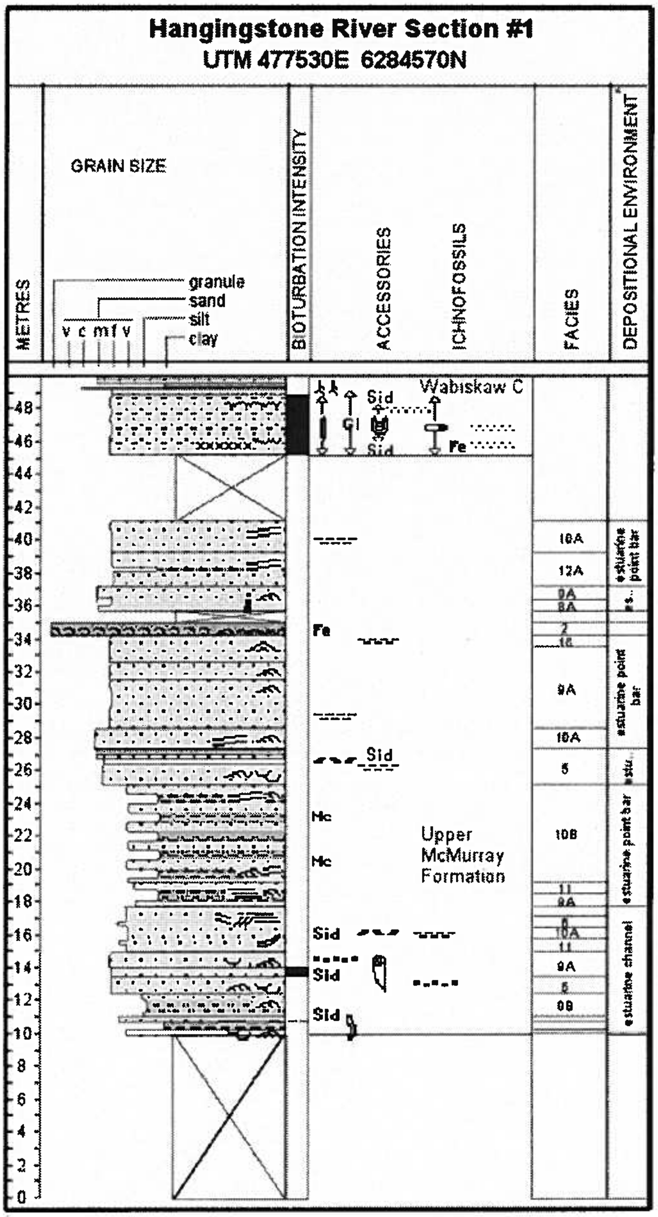


Figure 19. Schematic representation of the measured Hangingstone River Section #1 (from Hein et al. 2001).

Stop 5: Daphne Island East Sections

The Daphne Island East exposure is on the east bank of the Athabasca River opposite of Daphne Island. The location lies north of the hamlet of Fort MacKay and is accessed by crossing the Athabasca River at the "bridge to nowhere", following the road to the Firebag River for several 10's km, and then a wood road to the river bank. At this location both estuarine point bar deposits and fluvial deposits can be seen. At the north end of the outcrop estuarine and fluvial deposits are interstratified suggesting fluctuations between progradational and transgressive regimes controlled by relative sea level variations. Estuarine sediments are finer-grained and bioturbated relative to the coarser-grained fluvial channel deposits. At the south end of the outcrop, river level permitting, we will see the southern margin of the channel exposed (see photo above) and clearly eroding into underlying estuarine deposits.

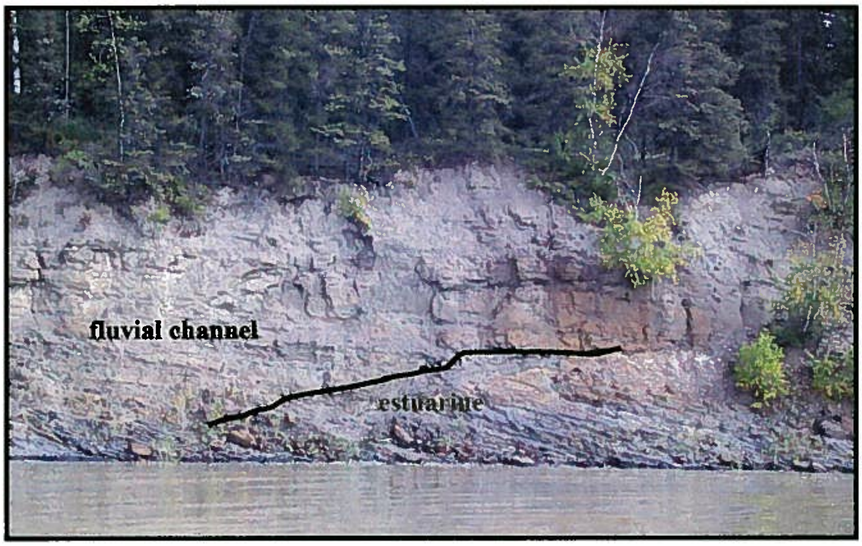


Fig 20. Fluvial channel eroded into underlying estuarine sediments, McMurray Formation, Athabasca River.

Keynote things to see:

- Stacked and laterally interfingering fluvial, marl and estuarine channel deposits;
- Thick, marl at the downstream and upstream parts of the outcrop
- Large fluvial channel incision in the middle part of the outcrop and at the downstream end

Description (from Hein et al. 2001): In the Daphne Island East (Section #2 in Hein et al. 2001) a thin remnant of low-angle, sandy inclined heterolithic stratified sand (<0.5 m thick) is scoured out by trough cross-bedded, pebbly to coarse-grained sand. The pebbly sand fines upward into rippled medium-grained sand, that is scoured out by another fining-upward, rippled and trough cross-bedded sand (0.5 to 1 m thick). The next 4 to 5 m is an alternating sequence of thick-bedded, planar tabular and planar tangential cross-bedded sand, with unidirectional paleocurrents to the north (paleoseaward). A thin gravel cuts this unit out, and is capped by a 2 to 3 m thick trough cross-bedded, coarse-to very coarse-grained sand.

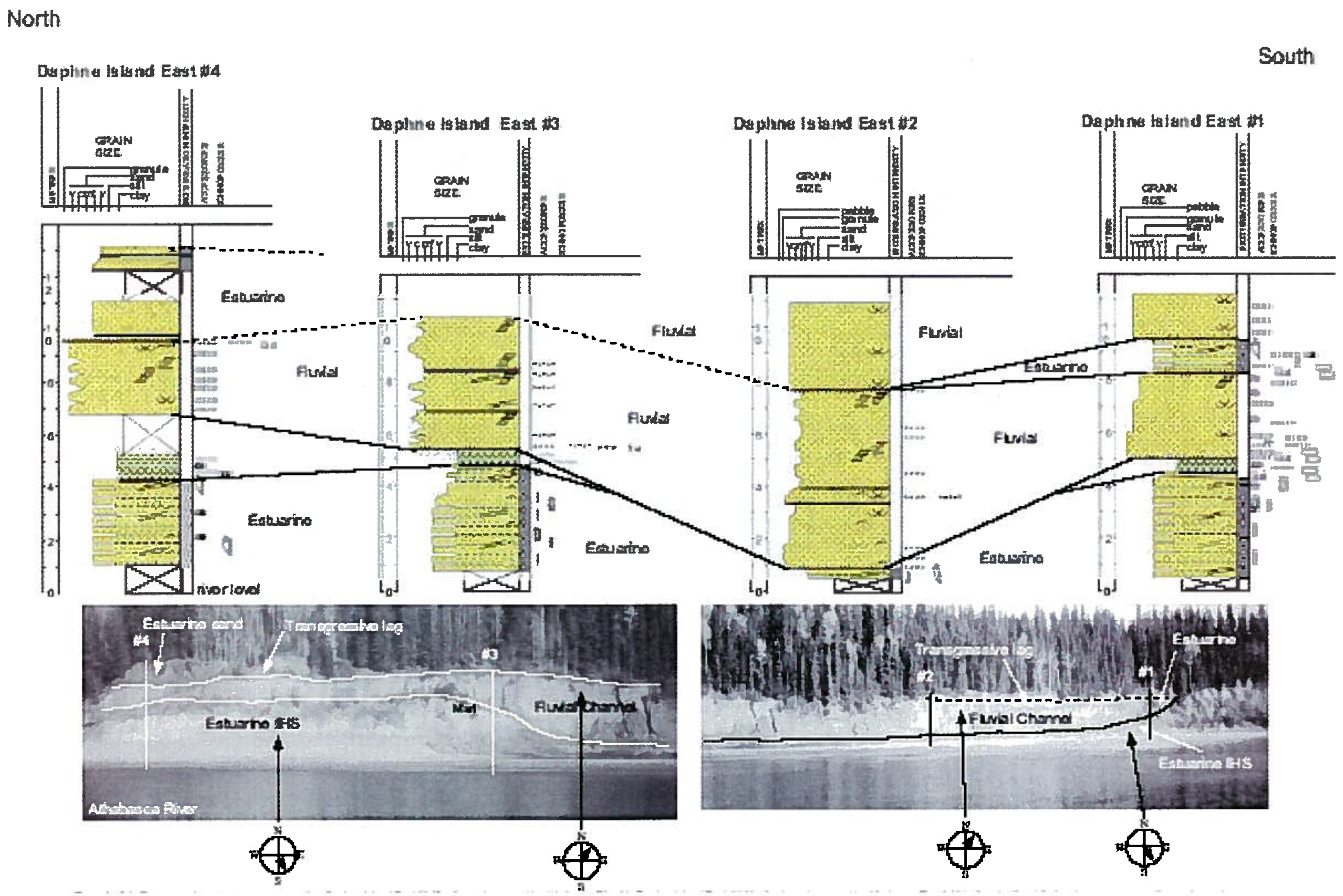


Figure 21. Photo mosaic and outcrop cross section, Daphne Island East (north, downstream on the Athabasca River). Note the significant facies changes, cross-cutting and complex interfingering of estuarine and fluvial successions. Arrows indicate paleoflow trends

Interpretation: The sequence at Daphne Island East is a thin remnant of estuarine point bar sands at the base, scoured out by the base of a fluvial channel. The fluvial succession consists of a series of cross cutting individual fluvial channel sands that show complex vertical and lateral facies changes.

Stop 6: Susan Lake Gravel Pit

The Susan Lake gravel pit is an example of catastrophic flood deposits during a rapid outflow of waters from glacial Lake Agassiz through the Clearwater-Athabasca spillway. During regional deglaciation, as the ice margin retreated to the Cree Lake moraine in northern Saskatchewan, the eastern outlets of glacial Lake Agassiz in the Lake Superior basin were dammed by a readvance of Laurentide ice (Teller and Thorleifson 1983). Across the Prairie Provinces, the level of Lake Agassiz rose to its maximum extent of 490 m, the approximate elevation at the head of the spillway crossing the MacKenzie-Churchill drainage divide (Fisher and Smith 1994).

The Beaver River moraine was breached and allowed a catastrophic flood out of the northwestern outlet of glacial Lake Agassiz. The water level in the lake dropped 52 m (Fisher and Smith 1994) until resilient bedrock prevented further incision. Smith and Fisher (1993) have dated wood from various gravel pits, including this one, at placed this event at 9.9 ka BP. The outlet continued to drain Lake Agassiz until 9.5 ka BP, at which time the eastern outlets re-opened (Teller and Thorleifson 1983).

The floodwaters flowed west down the Clearwater valley and into the Athabasca valley. Evidence for a significant flood has been described by Fisher (1993), Fisher et al. (1995) and Smith and Fisher (1993). Features include extensive fluvial bouldery deposits emplaced on terraces and channels eroded into the south edge of Fort Hills. During the initial stages of the spillway, all materials were entrained from the glacigenic materials, regardless of their size. When the spillway began to incise a deep, narrow channel, subcrop was eroded. Distal deposits are enriched in material derived from the local bedrock, including tar sand rafts.

Keynote things to see:

- Lower, well-sorted fluvial sands, blue-grey colour indicates a reducing environment and recent preliminary work by Teller and Paulen (In Prep) suggest that this unit could be middle Wisconsin in age (or older).
- Open framework in individual beds, even in coarse units.
- Erosional remnants of bedrock, occurring as isolated knobs within the pit.

Stop 7: Amphitheater Section

The amphitheatre section lies on the north bank of the MacKay River just outside of the hamlet of Fort MacKay. A thick section of the McMurray Formation is examined here that displays two, estuarine associated, depositional environments. The upper third of the outcrop contains well bioturbated vertical accretion deposits interpreted as tidal flat sediments. Underlying these sediments, the remainder of the exposure consists of lateral accretion deposits representing stacked estuarine channel point bar sediments displaying inclined heterolithic stratification (IHS) with abundant bioturbation. At the east end of the outcrop coarser-grained, highly cross-stratified deposits occur which could represent a smaller, high-energy tidal channel feeding into the estuarine point bar setting. The photo of the amphitheatre section shown above is looking east along the MacKay River which lies just outside the right of the photo.

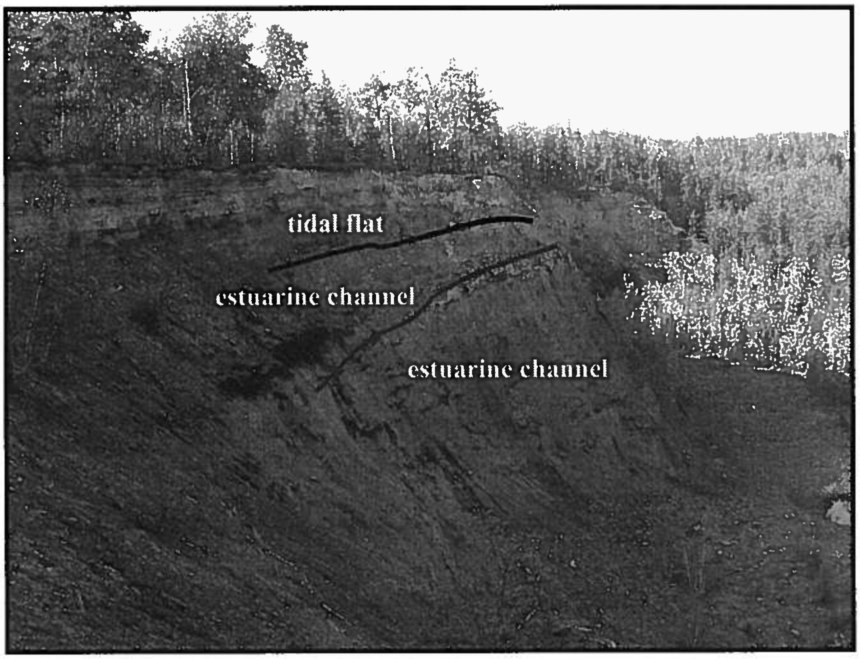


Fig 22. Tidal flat sediments at the top of the section overlying stacked estuarine channel deposits; McMurray Formation, MacKay River.

<u>Keynote things to see:</u>

- Excellent burrow structures in the float;
- Thick, muddy, vertical accretion abandoned channel fill deposits;
- Tidal channel sediments;
- Glacial-scour and thrust contacts between the Quaternary and McMurray units.

<u>Description (from Hein et al. 2001):</u> At the very base of the Amphitheatre section along the MacKay River is a thick succession of poorly exposed organic shaly siltstone and coaly siltstone/shale that occurs within a paleokarst low along the sub-Cretaceous unconformity. The overlying contact with the more typical coarse-grained channel facies of the Lower McMurray Formation is covered. At the northernmost limit of the main Amphitheatre outcrop is a thin, coarse-grained pebbly sandstone that shows trough cross-bedding, and represents the Lower McMurray succession. This exposure is often covered, depending upon the degree of recent slumping. Most of this outcrop exposes dominantly fine-grained sand, with high-angle planar tabular, trough and ripple cross-bedding structures and bioturbation features. Cylindrichnus burrows, both in place and as resedimented mudstone intraclasts, are common. Rare resedimented coaly detritus, as coalified or mummified stems and logs, occur about half way upsection, but mainly within the inaccessible cliff faces. Capping the burrowed sands is a succession of interbedded sand and mudstone, with intense bioturbation consisting of

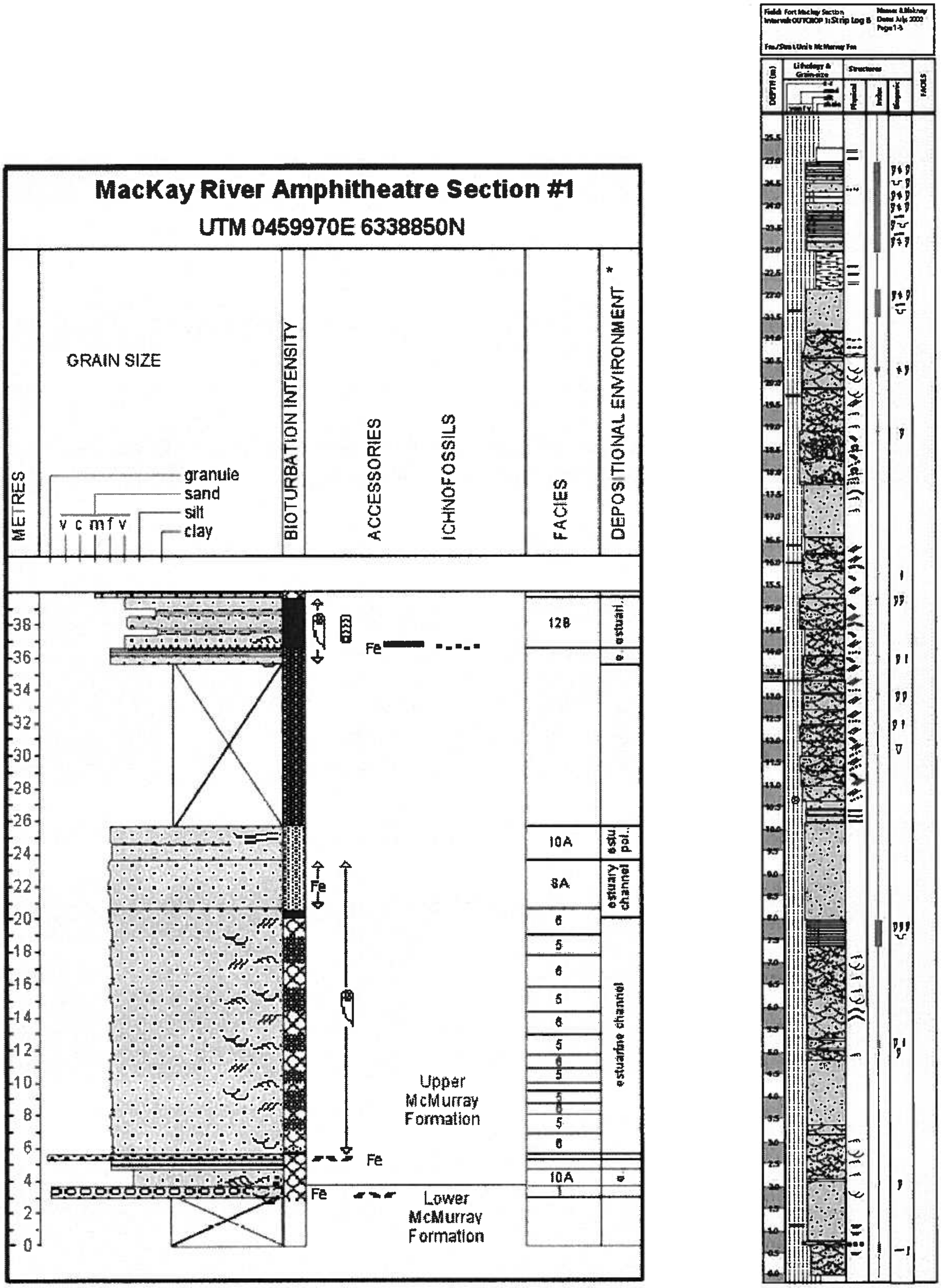


Figure 23. Schematic representations of the measured MacKay River Amphitheatre Section (left figure: Hein et al. 2001).

predominantly Cylindrichnus and Teichichnus trace fossils. The contact with the underlying sediments is sharp often containing isolated siderite concretions or nodules and coalified logs or coaly laminae. Where accessible, gray, fine-grained bioturbated sands that show parallel lamination, with ripple structures overlie the interbedded and bioturbated fine-grained interval, and minor ironstone (siderite) cementation associated with coaly detritus. The unit becomes muddier upsection, with sands showing current-rippled, wave ripple, combined-flow and herringbone structures. The bedding style of this uppermost unit is very even, has a high degree of bioturbation and high amount of fine-grained sediment. Low cliffs strike along the valley wall at the southern end of the Amphitheatre outcrop exposure. This section starts fairly high uphill (about 2/3 the way upslope) from river level. Here is exposed part of the upper portion of the section that is generally inaccessible within the main Amphitheatre outcrop. A thick succession of sands dominates the section, comprised of stacked, pin-striped high angle planar tabular cross-bedded facies, some of which have been deformed into oversteepened cross-bedding (Figure 6.1.4b), large-scale convolutions. Flows are predominantly to the north. The trace fossils include Skolithos, Cylindrichnus, escape burrows, and reworked Cylindrichnus burrows as intraclasts derived from underlying estuarine point bar deposits. At the top of the section, the burrowed sands are disconformably overlain by a thin (4 m thick) gray, muddy, fine-grained sand, that is thin-bedded with an even-bedding style, and is intensely burrowed with traces similar to those in the upper portion of the main Amphitheatre section (mainly Cylindrichnus and Teichichnus). Wightman et al. (1992) reported that sea anemone trace fossils and escape burrows were found at this outcrop.

Interpretation: The pebbly sand at the base of the main Amphitheatre section is a remnant of the Lower McMurray fluvial channel sand. Most of the Amphitheatre outcrop exposure is interpreted as part of the Upper McMurray estuarine channel system, with less common lateral accretion estuarine point bar deposits at the base and top of the channel sands. The fine-grained muddy interval with a high degree of bioturbation and continuous, even bedding style is indicative of a vertical accretion abandoned channel fill deposit. The pin-striped sands located along-strike from the main Amphitheatre outcrop is part of a tidal channel complex. These, in turn, are overlain by bioturbated muddy fine-grained sand. This upper muddy sand is interpreted to be flooded estuarine, vertical accretion, abandoned channel or estuarine open-bay deposits.

Stop 8: Beaver Creek Sandstone Quarry (Time permitting)

Keynote things to see:

- Silica-cemented sandstones within the McMurray Formation;
- Plant fossils and root traces

Description (from Hein et al. 2001): These are outcrops of the 'Beaver River Sandstone' a silica-cemented unit within the McMurray Formation. Lithologically the silica-cemented sandstone at this site is identical with the underlying bituminous quartz sand of the McMurray Formation, both consisting of angular and rounded quartz and quartzite grains, with fine-grained quartz matrix. Additionally, there is a gradational change over a thickness of <0.5 m, from typical bituminous-saturated sand of the McMurray succession and the non-bituminous, silica-cemented sand of what has been called the Beaver River sandstone.

On bedding plane surfaces and in cross section are root trace imprints, some of which are up to 1 cm in diameter. Abundant comminuted organic detritus occurs throughout the sandstone, and isolated loose organic rubble, including fossil stems and branches and coaly debris, are found as float in the area. Limited palynological dating done on a coaly fragment from the sandstone yielded a modest terrestrial assemblage of palynomorphs that appear to be Aptian-Cenomanian in age. Historically First Nation's people quarried the silica-cemented sandstone at this site (Fenton and Ives, 1982, 1990; Ives and Fenton, 1983). Diagenesis of the Beaver River Sandstone has been examined by Brian Tsang as part of his M.Sc. thesis work at the Department of Geology and Geophysics, The University of Calgary (Tsang, 1998).

Interpretation: The silica cement makes the sandstone distinct lithologically from the other more typically uncemented McMurray Formation sands. The interpretation is that the silica-cemented Beaver River Sandstone was within a paleolow karst feature at the time of cementation, probably associated with silica- saturated connate waters. A number of similar silica-cemented units within the Lower McMurray Formation have also been encountered in subsurface cores from the surrounding area. Quite commonly siderization and siderite cement is associated with the areas that have silica cement. The stratigraphic position, preliminary palynological age date, and lithologic characteristics indicate that the Beaver River Sandstone at the site is part of the Lower McMurray Formation, and not a distinct 'pre-McMurray' succession.

Stop 9: Syncrude Overview Stop (Giants of Mining Exhibit)

The Wabisca Member of the Clearwater Formation represents a general flooding of the ancient Boreal Sea over the primarily marginal-marine McMurray Formation. Thus, inner shelf and lower-shoreface sediments lay directly on top of the estuarine sediment pile throughout much of the Fort McMurray area. For the most part, Wabisca rocks are too fine grained to have been saturated by bitumen, and abundant shale layers inhibited the upward migration of hydrocarbons. For that reason, the marine deposits are overburden in the area of the mine-site and are removed without being processed.

The cohesive blocks at the Giants of Mining Exhibit and the Information Center represent a specific bed within the Wabisca Mbr. They are stored apart from the other tailings because they are well cemented and cannot be handled in the same manner as unlithified material. Within these blocks are an array of trace fossils that represent the vestiges of a robust marine community. Some of the trace fossils are always associated with marine environments. These include Zoophycos, Chondrites, Asterosoma, Rosselia and Rhizocorallium. Other trace fossils found are Thalassinoides, Planolites, Paleophycos, Skolithos, and Diplocraterion. All of these are atypically large and provide convincing evidence for marine deposition. It is especially interesting to note the large Thalassinoides, which were likely made by a large crustacean such as a lobster. Notably, plesiosaurs have been found within the mine site. These, taken with the ichnological evidence, suggest that the sea was vibrant and thrived with life. Probably sedimentation rates were generally low, and food was abundant.

There is evidence of minor storm reworking. This is in the form of short-wavelength hummocky cross stratification and large wave-induced ripple. The storm beds are spaced 10-30cm apart and show that low- to moderate-energy storms disrupted the environment from the north. However, storm reworking is not the dominant aspect of these sediment facies so it is inferred that the marine system was somewhat sheltered from processes to the north.

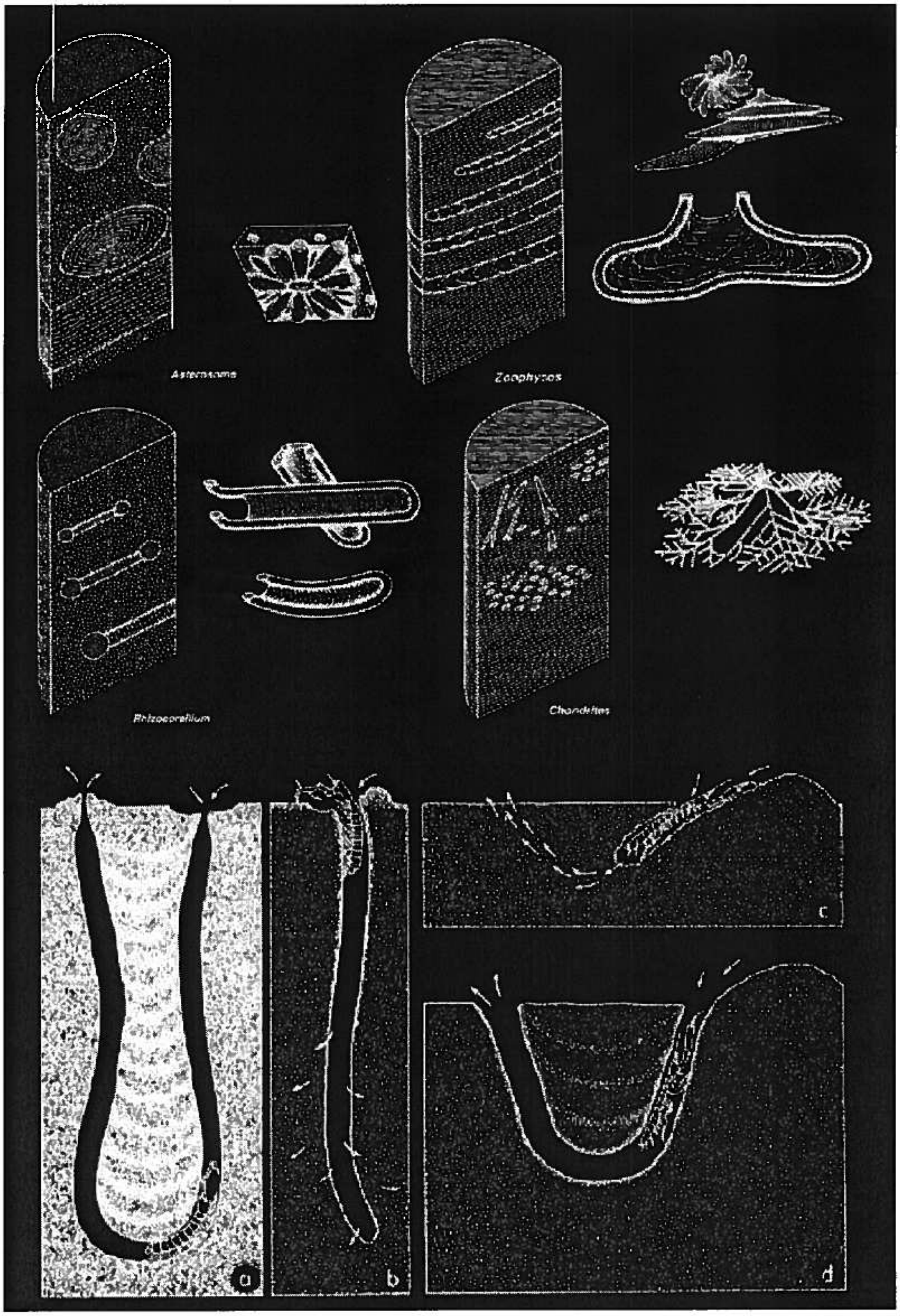


Figure 24. Typical trace fossils of the Wabisca, including Asterosoma, Zoophycos. Rhizocorallium, Chondrites, and Diplocraterion. In the Wabisca, these ichnofossils commonly co-occur and form a complex fabric. *(Schematics courtesy of Dr. George Pemberton, University of Alberta).*

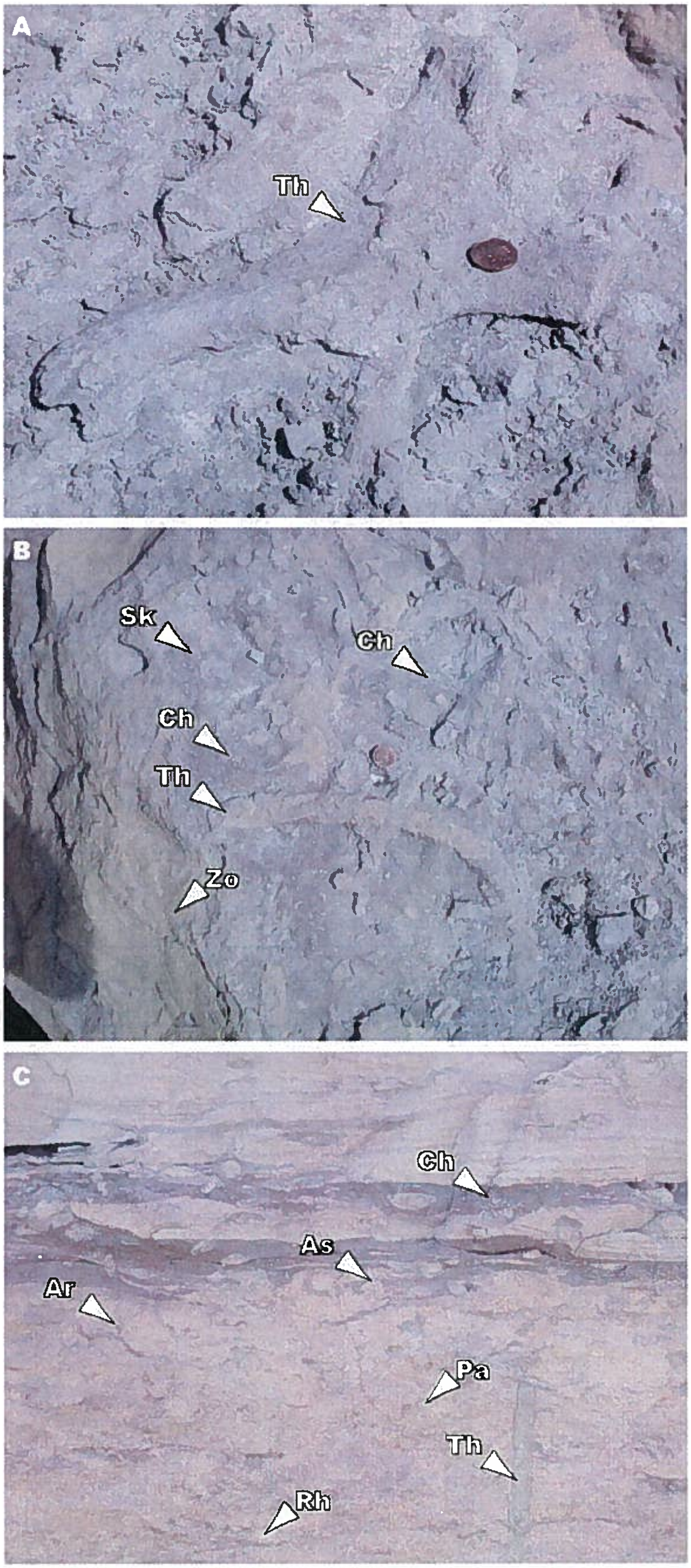


Figure 25.

A) A large, branching Thalassinoides (Th) on a bedding plane.

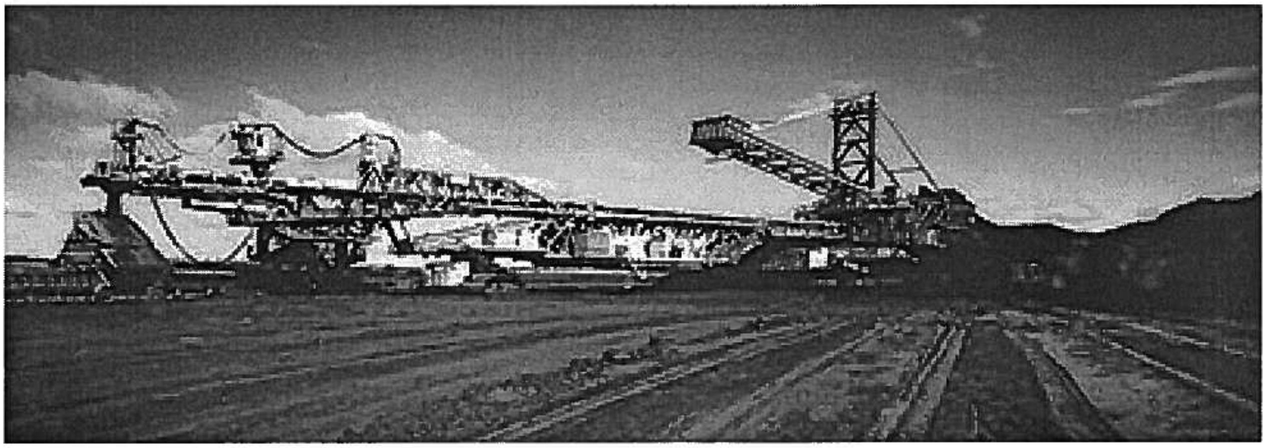
B) Skolithos (Sk), Chondrites (Ch), Thalassinoides (Th), Arenicolites (Ar), and Rhizocorallium (Rh) as seen on a bedding plane.

C) Chondrites (Ch), Thalassinoides (Th), Arenicolites (Ar), Rhizocorallium (Rh), Arenicolites (Ar), and Palaeophycos (Pa) shown in side view. Note the small-scale HCS defining lamination near the top of the photo. This is the preserved record of storm events.

Also at this site, the walking dragline "Discovery" was retired and moved here in 1999. Bucketwheel loaders, which worked synchronously with the draglines (Figures 26 and 27).

Dragline Facts

- four walking draglines (three retired)
- bucket size: 61 and 68 m^3 or 80 and 89 cubic yards
- boom length: 110 m or 360 ft.
- operating radius: 104 m or 340 ft.
- horsepower installed: 28,000 hp each
- operating weight: 6,200 tonnes each



Bucketwheel Reclaimer Facts

- four bucketwheel reclaimers (three retired)
- three bucketwheels have 14 buckets at 2.4 m^3 or 3.1 cubic yards each; the other bucketwheel is equipped with 24 buckets measuring 1.38 m^3 or 1.8 cubic yards each
- total length of machine — 140 m or 560 ft.
- wheel diameter — 13.4 m or 44 ft.
- horsepower installed — 12,000 hp each
- operating weight — 2,400 tonnes each

Stop 10: Water Treatment Plant

The location near the water treatment plant is on the north bank of the Athabasca River approximately 1 km west of the bridge over the river. At this location, the disconformable contact between the limestone of the Middle Devonian Moberly Member of the Waterways Formation and the overlying Cretaceous (Aptian) McMurray Formation oil sand can be viewed. The disconformity surface represents approximately 230 million years of earth history. Another, excellent perspective of this disconformity is seen on the south bank of the river where its irregular rolling nature can be seen.

The north bank exposure also shows the contact between the McMurray Formation oil sand and overlying Quaternary-age glacial sediment and represents approximately 111 million years of earth history. It is interesting to speculate as to why the oil sand is only a few metres thick at this location. Is it simply depositionally thin, or is its thinness due to erosion, and if so, did the erosion occur prior to deposition of the glacial sediment or synchronous with it?

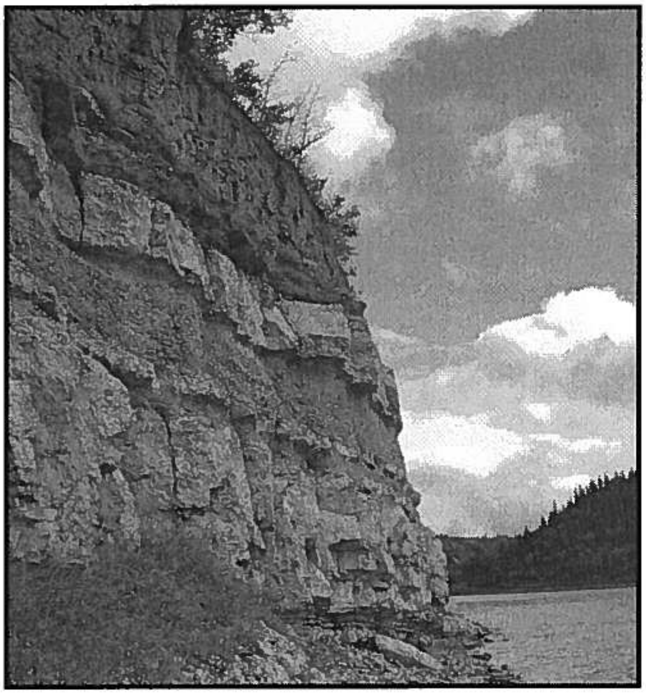


Fig. 28. Disconformable contact between Middle Devonian, Moberly Member limestone of the Waterways Formation and Cretaceous (Aptian) McMurray Formation oil sand. The McMurray Formation here is thin and overlain by Quaternary glacial deposits.

References

AEUB (Alberta Energy and Utilities Board) 1999. Alberta's Energy Resources 1998 in Review. Statistical Series 99-40.

Auchinleck, R. 1999. Opening Keynote Presentation, Beyond 2000 The Future Looks Heavy. Canadian Heavy Oil Association Conference Proceedings (Calgary).

Bell, R., 1884. Report on Part of the Basin of the Athabasca River, Northwest Territory. Geological Survey of Canada, Report of Progress 1882-83-84 (cc): 5-35.

Bell, R. and Cochrane, A.S. 1883. Map of part of the Athabasca River. Geological Survey of Canada, Map 173, scale 1:506,880.

Buschkuehle, B.E. 2003. Sedimentology and Stratigraphy of Middle and Upper Devonian Carbonates in Northern Alberta: A Contribution to the Carbonate-Hosted Pb-Zn (MVT) Targeted Geoscience initiative. Alberta Energy and Utilities Board, EUB/AGS GeoNote 2002-14.

Carrigy, M.A. and Kramers, J.W. 1973. Guide to the Athabasca Oil Sands Area. Research Council of Alberta, Information Series 65 (available from the Alberta Geological Survey).

Cheng, Y.H., Mikhail, M.W., Salama, A.I.A., and Burns, B. 1999. Bitumen Recovery From Oil-Sand Extraction Tailings: I. Bench-Scale Tests. Journal of Canadian Petroleum Technology 38 (9):20-26.

Ells, S.C., 1926. Bituminous Sands of Northern Alberta: Occurrence and Economic Possibilities, Report on investigations to the end of 1924. Canada Mines Branch Report 632.

Fenton, M. and Ives, J.W.. 1982. Preliminary Observations on the Geological Origins of Beaver River Sandstone. *In* Brink, J., D. (ed.), Archaeology in Alberta 1981, Archaeological Survey of Alberta, Occasional Paper 19: 166-189.

Fenton, M.M. and Ives, J.W. 1990. Geoarchaeological Studies of the Beaver River Sandstone, Northeastern Alberta. *In* Lasca, N.P. and Donalue, J. (eds.), Archaeological Geology of North America, Geological Society of America, Centennial Special Volume 4(6): 123-135.

Fisher, L.J. 1999. Supply Costs for Heavy Oil. Beyond 2000 The Future Looks Heavy, Canadian Heavy Oil Association Conference Proceedings (Calgary).

Fisher, T.G. 1993. Glacial Lake McMurray, northeastern Alberta. Program with Abstracts, Geological Association of Canada – Mineralogical Association of Canada – Canadian Geophysical Union, Joint Annual Meeting 18, p. 30.

Fisher, T.G. and Smith, D.G. 1994. Glacial Lake Agassiz: its northwest maximum extent and outlet in Saskatchewan (Emerson Phase). Quaternary Science Reviews, 13: 845-858.

Fisher, T.G., Jol, H.M., and Smith, D.G. 1995. Ground-penetrating radar used to assess aggregate in catastrophic flood deposits, northeast Alberta, Canada. Canadian Geotechnical Journal 32: 871-879.

George, R. 1999. Suncor Energy's Project Millennium – Overcoming the Challenges of Oil Sands Development. Journal of Canadian Petroleum Technology 38 (9):8-10.

Government of Canada 1949. Drilling and Sampling of Bituminous Sand of Northern Alberta: Results of Investigations 1942-1947. Canada Mines Branch Report 826 (3 volumes).

Gray, M. R. 1999. Field Upgrading Technologies. Beyond 2000 The Future Looks Heavy, Canadian Heavy Oil Association Conference Proceedings (Calgary).

Hein, F.J. 2000. Historical overview of the Fort McMurray area and oil sands industry in northeastern Alberta. Alberta Energy and Utilities Board, EUB/AGS Earth Science Report 2000-05, 32 p.

Hein, F.J., Cotterill, D.K., and Berhane, H. 2000. An Atlas of Dominant Lithofacies of the McMurray Formation, Athabasca Oil Sands Deposit, Northeastern Alberta: Surface and Subsurface. Alberta Energy and Utilities Board, EUB/AGS, Earth Sciences Report 2000-07, 216p.

Hein, F.J., Langenberg, W., Kidston, C., Berhane, H., Bereznuik, T. 2001. A Comprehensive Field Guide for Facies Characterization of the Athabasca Oil Sands, Northeast Alberta. Alberta Energy and Utilities Board, EUB/AGS Special Report 13, 415 p.

Houlihan, R.N. and Evans, R.G. 1988. Development of Alberta's Oil Sands. Fourth UNITAR/INDP International Conference on Heavy Crudes and Tar Sands Proceedings (Edmonton): 76-1 to 76-17.

Hume, G.S. 1947. Results and Significance of Drilling Operations in the Athabasca Bituminous Sands. Transactions of the Canadian Institute of Mining and Metallurgy 50: 298-333.

Hume, G.S. 1949. Geology of the Bituminous Sands Area, Drilling and Sampling of Bituminous Sands of Northern Alberta, Results of Investigation 1942-1947. Canada Mines Branch Report 826(1).

Ito, Y. and Suzuki, S. 1999. Numerical simulation of the SAGD process in the Hangingstone Oil Sands Reservoir. Journal of Canadian Petroleum Technology 38(9):27-35.

Ives, J.W. and Fenton, M. 1983. Continued Research on Geological Sources of Beaver River Sandstone. *In* Burley, D. (ed.), Archaeology in Alberta 1982: Archaeological Survey of Alberta, Occasional Paper 21: 78-133.

Langenberg, C.W., Hein, F.J., Lawton, D. and Cunningham, J. 2002. Seismic modeling of fluvial-estuarine deposits in the Athabasca oil sands using ray-tracing techniques, Steepbank River area, northeastern Alberta. Bulletin of Canadian Petroleum Geology, 36: 178-204.

Luhning, R.W. and Luhning C.P., 1999. The Vapex Process: Non-Thermal Recovery of Bitumen and Heavy Oil for Improved Economics and Climate Change Advantage. Beyond 2000 The Future Looks Heavy, Canadian Heavy Oil Association Conference Proceedings (Calgary).

Komery, D.P., Luhning, R.W., and O'Rourke, J.C. 1999. Towards Commercialization of the UTF Project Using Surface Drilled Horizontal SAGD Wells. Journal of Canadian Petroleum Technology 38(9):36-43.

McConnell, R.G. 1893. Report on a Portion of the District of Athabasca, Comprising the Country Between Peace River and Athabasca River North of Lesser Slave Lake. Geological Survey of Canada Annual Report 1890-1915 (d): 5-7.

McLearn, F.H. 1917. Athabasca River Section, Alberta. Geological Survey of Canada, Summary Report 1916: 145-151.

McRory, R.E. 1982. Oil Sands and Heavy Oils of Alberta. Energy Heritage (Edmonton: Alberta Energy and Natural Resources).

Mink, F.J. and Houlihan, R.N. 1995. Tar Sands. *In* Ullmann's Encyclopedia of Industrial Chemistry A26:129-162, 5th edition (New York: VCH Publishers).

Newell, E. 1999. Canada's Oil Sands Come of Age. Journal of Canadian Petroleum Technology 38(9):5-7.

Oommachan, J. 2004. Big investments fuel McMurray – and the country. The PEGG, vol. 32, no. 8, p. 3.

O'Rourke, J.C., Begley, A.G., Boyle, H.A., Yee, C.T., Chambers, J.I., and Luhning, R.W. 1999. UTF Project Status Update, May 1997. *Journal of Canadian Petroleum Technology* 38 (9): 44-54.

Polikar, M., Cyr, T., and Sadler, K. 1998. Alberta Oil Sands: The Advance of Technology, 1978-1998 and Beyond. 7th UNITAR/INDP International Conference on Heavy Crudes and Tar Sands Proceedings (Beijing, China) 10: 91-101.

Rice, R.J., Buschkuehle, B.E., Pana, D.I., Eccles, D.R. and Adams, J.J. 2003. Multidisciplinary Evaluation of the Carbonate-Hosted Mississippi Valley-Type Pb-Zn Potential of Northern Alberta. Program with Abstracts, The 12th Annual Calgary Mining Forum & Alberta Geological Survey Minerals Section Open House, "Meeting Future Challenges in the Mineral Industry" 2003, Calgary.

Ross, E. 1998. The Big Picture: Riding the Heavy Oil and Oil Sands Roller Coaster. New Technology Magazine (Nickle's Energy, Information and Technology): 6-7, 10-13.

Sadler, K. and Houlihan, R. 1998. Oil Sands Development in Alberta – An EUB Perspective. 7th UNITAR/INDP International Conference on Heavy Crudes and Tar Sands Proceedings (Beijing, China) 012: 111-125.

Smith, D.G. and Fisher, T.G. 1993. Glacial Lake Agassiz: The northwestern outlet and paleoflood. Geology 21: 9-12.

Strom, N.A. 1986. Energy Technology Development in Times of Fluctuating Market Signals. Presentation to the Canadian Heavy Oil Association, April 30, 1986.

Teller, J.T. and Thorleifson, L.H. 1983. The Lake Agassiz-Lake Superior connection. *In* J.T. Teller and L. Clayton (eds.), Glacial Lake Agassiz. Geological Association of Canada Special Paper 26: 261-290.

Tsang, B.W.B. 1998. The Origin of the Enigmatic Beaver River Sandstone. University of Calgary, unpublished M.Sc. thesis.

Wightman, D.M., Pemberton, S.G. and Strobl, R. 1992. The McMurray Formation Reservoir Heterogeneities Exposed in Outcrop. American Association of Petroleum Geologists Annual Convention (Calgary) Field Trip Guidebook 19.

Wightman, D.M., Pemberton, S.G. and Strobl, R.S. 1996. Fort McMurray / Oil Sands area. Edmonton Geological Society Annual Field Trip, 62 p.

Wightman, D.M., Strobl, R.S., Cotterill, D.K., Berhane, H., Attalla, M.N. 1997. Stratigraphy, Depositional Modelling and Resource Characterization of the McMurray/Wabiskaw Deposit, West Portion of the Athabasca Oil Sands Area, Northeastern Alberta. *In* Pemberton, S.G. and James, D.P. (eds.), Petroleum Geology of the Cretaceous Mannville Group, Western Canada, Canadian Society of Petroleum Geologists, Memoir 18: 345-374.

Zhou, Z., Dudley, J.S., Wichar, B., and Gunter, W.D., 1999. The Potential of Permeability Damage During Thermal Recovery of Cold Lake Bitumen. Journal of Canadian Petroleum Technology 38(9):55-60.

Ziegler, P.A. 1969. Field conference 1969, Edmonton Geological Society, 90 p.

APPENDIX 1

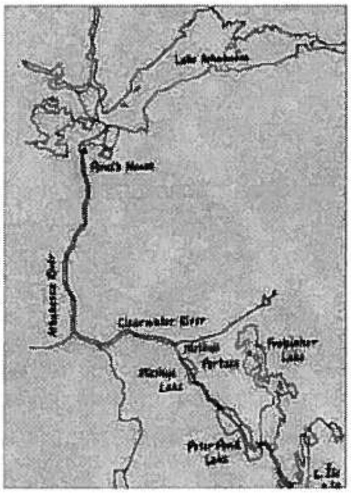
Historical Timeline

Fort McMurray and the Athabasca Oil Sands

1715 – 2002

1715 Waupisoo, known as Captain Swan, brought samples of salt and brimstone to York factory and described the Great River (Athabasca).

1719 Waupisoo brought samples of pitch (oil sand) to York factory.



1778 Peter Pond, crossed the Methye Portage. Pond descended the westerly flowing Clearwater River, and built a post on the Athabasca River near Lake Athabasca. This opened up the valuable MacKenzie Basin fur region. He becomes the first European to see the oil sands outcrops. The portage was used for over 100 years. Peter Pond's post closed in 1788 in favor of Fort Chipewyan (*map courtesy of the Fort McMurray Historical Society*).

1780 Fur traders established posts on the Athabasca, Slave and Peace Rivers. Independent traders, called Pedlars or Canadians, were the first to move into the region, followed by the Hudson's Bay Company (*Photo courtesy of the Fort McMurray Historical Society*).

1792 Alexander MacKenzie enters the Clearwater-Athabasca River system via Methy Portage and describes the 'tar sands'.

1799 David Thompson makes a track survey of the Athabasca River from the Clearwater Forks to Lake Athabasca.

1819 Sir John Franklin examines the Athabasca River between Lake Athabasca and the mouth of the Clearwater River.

1848 Sir John Richardson makes geological notes on a journey to the Arctic in search of Franklin. He correlates the tar sands with the Marcellus shales of the New York State Devonian sequence.

1870 A Hudson's Bay Company post was established at the confluence of the Athabasca and Clearwater Rivers by Henry "John" Moberly. He named the post Fort McMurray, after Chief Factor William McMurray (Pictured at left). (*Photo courtesy of the Fort McMurray Historical Society*).

1875 A sudden April thaw broke the Athabasca River jamming it at the mouth of the Clearwater River causing Fort McMurray's worst flood.

1875 A Geological Survey of Canada expedition examined the rivers draining into Lake Athabasca. John Macoun, a botanist, recorded his observation of water naturally washing oil out of the oil sands that is the essence of today's technology for extracting bitumen from oil sands. His main impression was that the "tar" wasn't mixed with mineral matter rather that the tar flowed through it.

1882 Dr. Robert Bell of the Geological Survey of Canada examines the tar sands area in detail. He recognizes the lower Cretaceous age of the strata and proposes a Devonian origin for the bitumen, and reports that hot water extraction of the bitumen might be feasible. He also proposes building a pipeline from the east end of Lake Athabasca to Hudson's Bay to transport the oil to foreign markets.

1883: The separation of bitumen from oil sand with the use of water was first attempted by G.C. Hoffman of the Geological Survey of Canada. He reported that the bitumen separated readily from the sand.

1884 William Ogilvie D.L.S. makes a new track survey of the Athabasca River.

1888 R.G. McConnell of the Geological Survey of Canada gives the first modern geological description of the tar sands, and correlates them with the Dakota sandstones of the U.S. western interior. Estimates that the area is underlain by tar sands was thought to be in excess of 1,000 square miles and the reserves of bitumen at not less than 4.2 million long tons. He also suggests that lighter oil might be found in the same strata down dip at Pelican Rapids.

1898 The Hudson's Bay Company closed the Fort McMurray post because of poor fur returns. Fort McMurray continued as a transportation terminus only. Many of the prospectors using the inland route to the Klondike passed through Fort McMurray.

1901 Total population of Fort McMurray: 28

1906 Count Alfred von Hammerstein (below) follows Robert Bell's suggestion and drills for oil in the Devonian limestones along the banks of the Athabasca River in the Fort McMurray area. He did not find oil, but found salt deposits at the mouth of the Horse River. *(Photograph courtesy of the Provincial Archives of Alberta, B6492)*

1910 The Athabasca Oil and Asphalt Company was formed by Alfred von Hammerstein. There was a flurry of speculative activity in the Athabasca region and in the village of Fort McMurray.

1911 Total population of Fort McMurray: 312

G.H. Blanchette completes a survey of the 23rd base line.

1912 An oil sands boom begins in Fort McMurray with lots selling for $200 or more (*Editor: demand for land is just as strong today!)*

1913 The RNWMP (Royal North West Mounted Police) opened a detachment in Fort McMurray with one Corporal *(Photograph courtesy of the Fort McMurray Historical Society).*

Between 1913 and 1914 the Northern Alberta Exploration Company drilled six shallow wells at the confluence of the Horse and Athabasca Rivers. Although they drilled through tar sand layers, they found that the salt beneath these layers would be the most likely commercial product at that site.

A survey of the Athabasca country was conducted by Sydney C. Ells of the Mines Branch. He saw the potential for using asphalt reserves as a road-surfacing material. Sydney Ells visited ten plant sites in the United States in 1913, and discovered that a plant in California separated bitumen from the sand with hot water.

1915 Based on his findings during his survey, Ells convinced the Mines Branch to grant him funds to conduct a paving experiment using oil sands supplied from the Horse River Reserve. The experiment was a joint federal-provincial-municipal venture in the city of Edmonton and the results of the experiment were satisfactory. In January Ells was invited by the Mellon Institute of Industrial Research, Pittsburg, to study the problem of separating the oil from the sand. Eventually three types of flotation cells were constructed and extraction was attempted by use of heated water both with and without the addition of reagents.

J.D. Tait of Vancouver drilled a well in the Athabasca area that reached a depth of 1,000 feet.

1917 Based on his work at the Mellon Institute, Sidney Ells produced the two volume "Notes on Certain Aspects of the Proposed Commercial Development of the Bituminous Sands in the Province of Alberta, Canada."

Dr. F.H. McLearn of the Geological Survey of Canada gives the name McMurray Formation to the strata containing the tar sands.

1920 Dr. Karl A. Clark joins the Alberta and Scientific and Industrial Research Council in Edmonton and is given approval to conduct research concerning the extraction of bitumen from oil sands and to assess the value of bitumen as a road-covering material.

D. Diver makes the first attempt at production of oil by an *in situ* method. He tries to distill oil from the bituminous sands by lowering a heating unit to the bottom of a well drilled in Sec. 9, Twp. 89, R. 9, W. 4th Mer. near Fort McMurray.

1921 The Scientific and Industrial Research Council of Alberta was formed on January 6. It identified various areas for research, including coal resources, mineral deposits, and the tar sands. The Research Council of Alberta was the first such government research council of Canada.

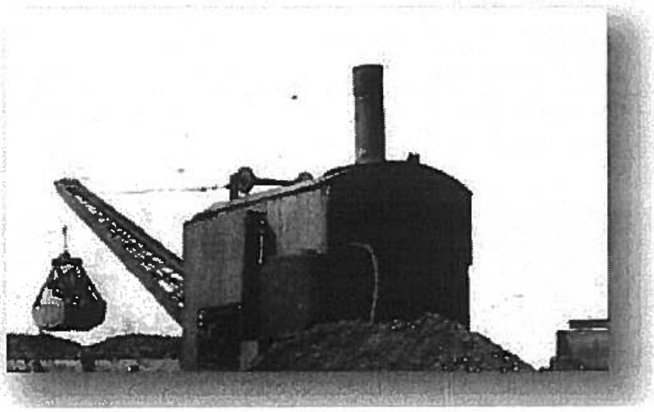
Thomas Draper secured a lease in Waterways. In 1922 he opened up a quarry and began to do business as The McMurray Asphaltum & Oil Company (photo at right). It was destroyed by fire in 1924 *(Photograph courtesy of the Fort McMurray Historical Society).*

Total population of Fort McMurray 483

1922 A group of New York city policemen form the Alcan Oil Company to drill for oil near the tar springs found along the Athabasca River in the Bitumount area approximately 90 km north of Fort McMurray (townships 96 and 97). This lease was taken over by Robert Fitzsimmons.

1923 Dr. Karl A. Clark built a small separation plant in the basement of the U of A power plant in 1923. A supply of tar sand was provided by Thomas Draper of the McMurray Asphaltum & Oil Company. 85 tons of sand was processed but work was hampered by problems with continuous operation and high heat costs.

1924 A separation plant was built in the Dunvegan railways yards in northeast Edmonton, based on Clark's design *(Photograph courtesy of the Provincial Archives of Alberta, A3529).*



1925 Thomas Draper began experimenting with oil sands as a paving material, either untreated or mixed with asphalt. He was one of the most persistent experimenters in the use of oil sands as paving materials. He had several road paving contracts, among them sections of pavement in Medicine Hat and Vegreville, a portion of Wellington Street in Ottawa, and part of Parliament Hill.

R. Fitzsimmons constructs model hot-water separation plant at the Bitumount site.

The Alberta and Great Waterways Railroad reached present day Waterways. The Hudson's Bay Company had threatened to use the Peace River route if the line was not extended. This ended the water route from Athabasca Landing to Fort McMurray. All shipping to the north went through Waterways until road and rail reached Hay River in the 1960's.

The Alberta Salt Company began producing high grade salt and became the first commercial salt plant in Alberta. Transportation problems forced it to close in 1927. The plant was located on Horse Creek near the Athabasca River.

1926 S.C. Ells successfully drills and cores tar sands.

1927 The Alcan Oil Company became the International Bitumen Company, under the control of Robert Fitzsimmons. Alcan did some drilling in the 1920's and was as unsuccessful as other firms. Fitzsimmons concluded that mining and surface extraction would be the best commercial process.

Clark experimented using bitumen for road surfacing on a 600 foot stretch of the St. Albert Trail (see photograph below). Ultimately, Clark's goal was that bitumen should be used as a base for motor fuels and lubricants *(Photograph courtesy of the Provincial Archives of Alberta, A3399).*

S.C. Ells lays tar sands pavement in Jasper National Park, from the CNR railway to Jasper Park Lodge.

1928 Dr. K.A. Clark and Sidney Blair were granted a Canadian patent for the hot water process.

Dr. Karl A. Clark in his laboratory. 1929 *(Photograph courtesy of the Glenbow Archives, Calgary, Canada, ND3-4596a)*

1929 The Research Council of Alberta hot water extraction plant (Dunvegan separation plant) was redesigned, dismantled and moved from north Edmonton to a site on the Clearwater River near Waterways. The quality of the bitumen product ensured that this plant became a model for future projects. The plant processes tar sands mined by the Mines Branch of Canada.

J.O. Absher attempts *in situ* distillation near Fort McMurray. He tries to ignite the tar sands at the bottom of a well to induce production.

S.C. Ells conducts blasting experiments to soften the tar sands for easier digging.

1930 R.C. Fitzsimmons produces 8,400 gallons of bitumen at the Bitumount plant of the International Bitumen Company and makes the first sale of commercially produced bitumen in Edmonton.

Max Ball, with his group (Basil Jones, James McClave) applied for oil sands leases. The proposal was accepted and Bituminous Sands Permit No. 1 on properties at the Horse River and farther south on the Athabasca were granted to Canadian Northern Oil Company, later called Abasand Oils Ltd.

B. F. Haanel of the Mines Branch in Ottawa begins hydrogenation experiments on Athabasca bitumen.

1936 Bitumount plant improved, expanded, and a new refinery constructed. By late summer the Abasand Oils plant was complete and was ready to operate at a rate of 250 tons per day. The Abasand process combined a solvent extraction with hot water extraction in two stage operation. Based on the previous work at the Abasand Oil plant, it was redesigned for a capacity of 400 tons per day. Work progressed over 3 years, there were delays due to technical problems; no product was actually produced until 1940.

Dr. K.A. Clark awarded a U.S. patent for the hot water process and apparatus.

International Bitumen Company enlarges its plant at Bitumount to 350 barrels per day and adds a distillation unit.

The Dominion Tar and Chemical Company, later called Industrial Minerals Ltd., built the second salt plant of the area in Waterways. It operated until 1950.

1938 International Bitumen Company produces 4,500 drums of asphalt and 2,000 barrels of fuel oil at Bitumount.

1941 Abasand Oils began operating on a regular basis (plant pictured below), production was quite extensive. Production at Abasand Oils ceased when the separation plant burned down on November 21 *(Photograph courtesy of the Provincial Archives of Alberta, A9103).*

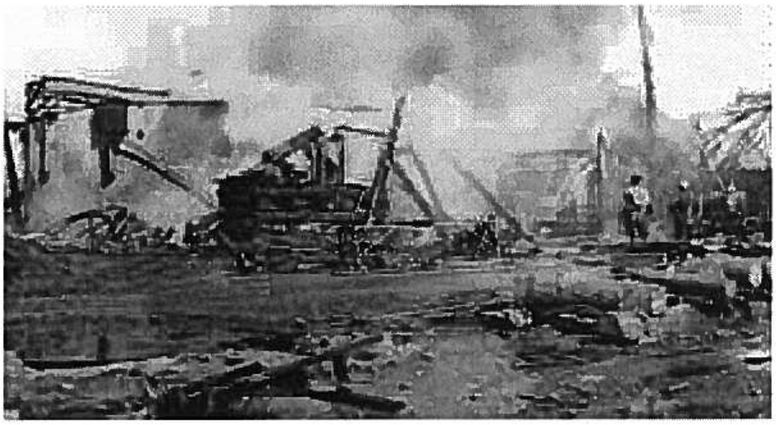
1942 L.R. Champion acquires control of International Bitumen Company and renames it Oil Sands Limited. Rebuilding of the Abasand plant begins.

The Government of Canada begins an exploratory drilling and coring program to outline the tar sands reserves for war-time emergency use.

1943 Mines Branch takes over Abasand property and begins to redesign and reconstruct the plant.

1944 There were too many delays in the refurbishing at Abasand Oils. The separation plant was completed in the summer of 1944 and was operating by autumn. Construction on the refinery was completed by December 9 and began operating on December 16.

1945 On June 16 a welder's torch accidentally ignited some oil at the feeder of the original separation plant at Abasand Oils Ltd. The resulting fire consumed the separation plants, the warehouse, the machine shop, the fire hall, and other equipment. Basically the whole plant was destroyed (below) *(Photograph courtesy of the Fort McMurray Historical Society).*



1947 Dr. P.E. Gishler begins investigation of a fluidized solids process for bitumen recovery at the National Research Council of Canada.

Canada Mines Branch drilling is completed after proving up reserves of 1.75 billion tons of commercial grade tar sand and discovering a rich deposit near Tar Island.

The settlements of Waterways and Fort McMurray amalgamated as the village of McMurray. Alfred Penhorwood became the first mayor.

1948 Bitumount plant commences operation in summer of 1948. Due to accidents, fires and low river levels it was never successful. It closed Sept. 30, 1949.

Government of Alberta builds a 500 ton per day plant at Bitumount to demonstrate the commercial feasibility of the Clark hot water process.

McMurray incorporated as a town, population: 621

1949 The Province of Alberta takes over the Bitumount site as Oil Sands Project.

1950 S.M. Blair publishes a report indicating that a large-scale economic development of the tar sands is now feasible. He estimates the cost of producing one barrel of synthetic oil and delivering to Edmonton by pipeline at $2.36.

1951 The first Athabasca Oil Sands conference is held in Edmonton. Alberta Government publishes it bituminous sands leasing policy and issues the first permits to oil companies.

1953 Oil Sands Ltd. reconstituted itself by late 1953. The Great Canadian Oil Sands consortium was formed in 1953 from Abasand Oils, Canadian Oils Ltd., Champion's Oil Sands Ltd., plus the prevailing force of the dynamic American oil firm, Sun Oil Co. of Philadelphia.

The provincial government tried to sell the Bitumount plant. In 1954 a Calgary company, Can-Amera Oil Sands, took over the plant and used it for testing.

1956 Total population McMurray: 1,110

1957 Shell Oil Company of Canada begins *in situ* steam drive experiments on lease 26.

The first car trip was made from McMurray to Edmonton. Their route followed 447.5 kilometers (273 miles) of winter trail to Slave Lake and 310 kilometers (189 miles) on Highway 2 through Athabasca to Edmonton. It took eighteen hours!

CanAmera sells the Bitumount plant to Royalite Oil Company.

1958 Royalite closes down operations at Bitumount.

1959 Cities Service Athabasca Inc. builds a pilot plant near Mildred Lake to test various separation methods.

Pan American Petroleum Company begins *in situ* combustion experiments near Gregoire Lake.

Atlantic Richfield and partners propose an experiment to release oil by exploding a nuclear device beneath the oil sands.

1960 Great Canadian Oil Sands Ltd. applies for permission from the Alberta Oil and Gas Conservation Board to produce 31,500 barrels per day from the oil sands.

1961 The population of McMurray was 1,186.

1962 The town's name was changed from McMurray to Fort McMurray.

After years of financial jockeying and negotiations with provincial and federal government and with the support of John Howard Pew, President of Sun Oil, the Great Canadian Oil Sands group contracted in December 1962 with the Bechtel Co. of San Francisco first to study and then to construct a large-scale commercial plant in the Mildred-Ruth Lakes deposit, north of Fort McMurray. In 1962 a pilot plant was constructed. The main plant of Great Canadian Oil Sands was built between 1964 and 1967. It was authorized to produce an initial capacity of 31,000 barrels per day.

Great Canadian Oil Sands Ltd. receives permission to build a 31,500 barrel per day plant at Tar Island.

The Shell Oil Company of Canada applies to the Alberta Oil and Gas Conservation Board for permission to produce 130,000 barrels per day of bitumen by an *in situ* steam drive process.

1963 Sun Oil Company of Philadelphia decides to back a separation plant for Great Canadian Oil Sands Company.

Second Athabasca Oil Sands Conference is held in Edmonton.

The Alberta Oil and Gas Conservation Board publish the first comprehensive estimate of bitumen reserves in the Athabasca deposit at 626 billion barrels in place.

1964 The Alberta Oil and Gas Conservation Board increases Great Canadian Oil Sands Ltd. production allowable to 45,000 barrels per day.

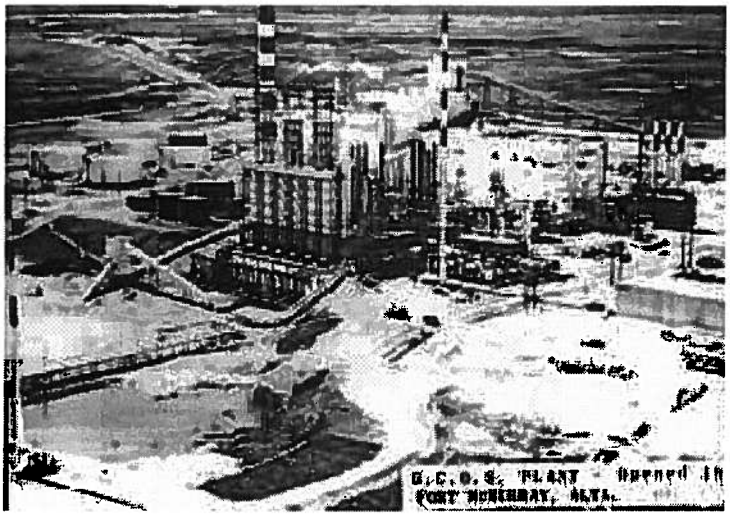
The Syncrude consortium (Atlantic Richfield, Cities Service, Imperial Oil, and Gulf Oil) is incorporated as Syncrude Canada Ltd. to operate oil sands projects for member companies.

1964 Fort McMurray was granted "New Town" status. This entitled Fort McMurray to financial assistance for capital projects, but also meant that the town lost its autonomy to the province.

1965 The Grant McEwan bridge opened providing access across the Athabasca River for the Great Canadian Oil Sands project *(Photograph courtesy of the Fort McMurray Historical Society).*

1967 Highway 63 (an all-weather, gravel road to the south) was completed *(Photograph courtesy of the Fort McMurray Historical Society).*

Great Canadian Oil Sands plant officially opened on September 30 by Ernest Manning, Premier of Alberta *(Photograph courtesy of the Fort McMurray Historical Society).*



1968 Muskeg Oil Company (Amoco) applies to the Alberta Oil and Gas Conservation Board for permission to produce 8,000 barrels per day of bitumen by a modified *in situ* combustion process.

1969 Syncrude application is amended to 80,000 barrels per day

Royalite merges with Gulf Oil Company Limited, the present owner of the Bitumount site.

1970 Fort McMurray received television viewing. The "Frontier Package" provided 4 hours of pre-packaged programming per day.

1971 Fort McMurray population: 6,743.

1972 Great Canadian Oil Sands Ltd. applies for permission to increase production to the 50-60,000 barrels per day range.

Alberta Energy Resources Conservation Board gives conditional approval for Syncrude to build a 125,000 barrels per day plant at Mildred Lake.

1973 Shell Canada Limited applies to the Alberta Energy Resources Conservation Board for approval of a mining operation to produce 100,000 barrels per day from the Athabasca oil sands.

Texaco's Fort McMurray Pilot initiates steam-based recovery processes.

1974 Alberta Oil Sands Technology and Research Authority (AOSTRA) established. Recognition of the need for focused research on *in situ* bitumen recovery.

Syncrude became a joint public-private venture, sponsored by Esso Resources, Gulf Canada, Canada Cities Service, Hudson's Bay Oil and Gas, and the Alberta and Canadian governments. Construction of the Syncrude plant at a site near the Great Canadian Oil Sands Ltd. (now Suncor) plant north of Fort McMurray took 4 years to complete. Canadian Bechtel Co., handled most of the construction. The plant was initially licensed to produce 125,000 barrels of oil per day.

1977 Amoco and Gulf/Numac pilots utilize hydraulic fractures to establish interwell communication.

1978 September 15, 1978 official opening of the Syncrude Canada Ltd. plant at Mildred Lake north of Fort McMurray *(Photograph courtesy of the Fort McMurray Historical Society).*

1979 In August after some business reorganization, the Great Canadian Oil Sands plant north of Fort McMurray was renamed Suncor Inc., Oil Sands Group.

Petro-Canada with partners Cities Service, Esso and Japan Canada (PCEJ) test electrical preheating to establish horizontal communication.

1980 Fort McMurray was incorporated as a city, population: 30,772.

1981 Canterra (Husky) pilot tests a process utilizing a central injector with surrounding steam stimulated production wells.

1983 AOSTRA developed its own detailed designs for an Underground Test Facility (UTF) project. The development of in-situ techniques and strategies for accessing the bulk of the oil sands reserves (too deep for surface mining) became a cornerstone of AOSTRA's mandate. The Steam-Assisted Gravity Drainage (SAGD) process field-tested at the UTF has demonstrated the effectiveness of gravity forces in contacting and draining an oil sands reservoir. Recovery of more than 60% achieved by 1990.

1985 Fort McMurray population: 36,810

1991 AOSTRA initiates pre-commercial testing at UTF Phase B.

1992 Chevron commences piloting of their patented HAS Drive technology (vertical injection wells and a horizontal recovery).

1993 In March Syncrude began a five-year pilot project to develop a wood bison habitat on reclaimed land. The original herd of 29 bison has increased to over 200 animals to date.

1993 As of October, Suncor has used truck and shovel equipment for overburden removal and oil sand mining. Four bucketwheel excavators, worth $50 million each, were retired and replaced by the new trucks and shovels.

1995 In June both Suncor and Syncrude announced plans for expansion. Syncrude's new "Aurora" mine site is located about 35km northeast of the Mildred Lake site. It began operation in 2001 and uses trucks, shovels, and a pipeline system (hyrdrotransport) to move the oil sand. Suncor's "Steepbank Mine" will be located on the east side of the Athabasca River.

Syncrude opens the Wood Bison Trail and the Matcheetawin Discovery Trail - four kilometres of trails on reclaimed land.

City of Fort McMurray and Improvement District No. 18 amalgamated to form the Regional Municipality of Wood Buffalo April 1, 1995. This is the largest land area municipality in the North America. Population of the Regional Municipality of Wood Buffalo: 37,139.

1996 Solv-Ex Corporation from Albuquerque, New Mexico plans to build a $100-million US plant on its Bitumount lease, located 85 kilometres north of the city. Solv-Ex wants to prove it can process industrial grade alumina and other metals from oil sands tailings sludge.

June, 1996 Prime Minister Chretian visits the City and announces $25 billion worth of tax breaks for the oil sands industry. Building starts are up and housing prices have increased 20.4% over December 1995.

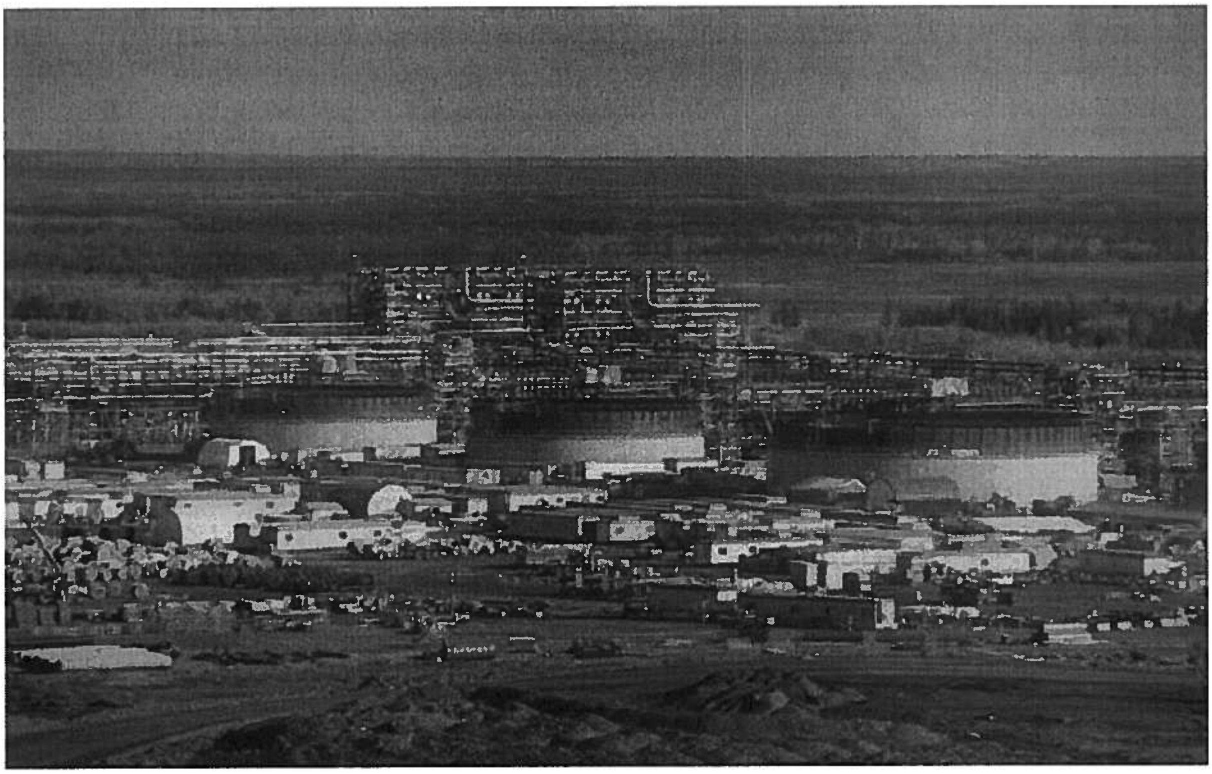
1997 On March 10 Suncor Inc. Oil Sands Group became Suncor Energy. The new name and logo is meant to symbolize the dawn of a new era in the oil company's history.

A new development linked by a bridge (commissioned in 1997) over the Athabasca River is situated on the east side of the river. This development, which includes Steepbank Mine, Steepbank ore preparation plant and a service complex, and commenced operation in late 1998. Steepbank Mine, together with Fixed Plant Expansion Project (to be commissioned in mid-1998) will boost Suncor Oil Sands production capacity to 105 000 bbl/cd from the current 85 000 bbl/cd by year-end.

On March 14 Shell Canada announced plans to develop a new $1-billion oil sands operation on Lease 13, located about 70 km north of Fort McMurray. On April 25 Mobil Oil Canada announced plans to develop a $1-billion oil sands project on Lease 36 located north of Fort McMurray *(Photograph courtesy of the Fort McMurray Historical Society).*

2000 Exploration begins on Synenco's Northern Lights Project, northeast of Fort McMurray near the Firebag River. Plans include a design capacity that will manufacture over 100,000 barrels per day of synthetic crude oil. Initial production from the Northern Lights Project could commence by 2009.

2002 The Muskeg River Mine produced first ore in August of 2002 with first bitumen production commencing on December 29, 2002. Full production of 155,000 barrels per day of bitumen is expected later in 2004. The mine (below) is operated by Shell Canada Ltd. in a joint venture with Albian Sands Energy Inc *(Photograph courtesy of Shell Canada Ltd.).* Froth treatment at the Muskeg River Mine removes fine clay and sand particles. The result is a very clean bitumen product which is transported to the Scotford Upgrader, near Fort Saskatchewan.



APPENDIX 2

Oil Sands Industry Update – Alberta Department of Energy

Alberta Economic Development

March 2004

WHAT IS NEW?

Company approvals have been given to proceed with the following oil sands projects:

- Opti Canada/Nexen's Long Lake Project, a SAGD in situ facility with an integrated upgrader. The first phase is designed to produce 70,000 bpd regulatory approval obtained in August 2003).

- ConocoPhillips' Surmont Project, a SAGD in situ facility with a design production capacity of 100,000 bpd (regulatory approval obtained in May 2003).

- Petro-Canada's Strathcona Refinery Conversion Project, designed to increase the refinery's bitumen upgrading capacity by 53,000 bpd.

Regulatory approvals have been obtained for three major developments and a new pilot project, as follows:

- CNRL's Horizon Project, a mine/upgrader facility with a design capacity of 270,000 bpd.

- Shell Canada's Jackpine Mine, Phase 1, a mine and extraction plant with a design production capacity of 200,000 bpd.

- Suncor's Millennium Coker Unit Expansion, designed to increase the company's Fort McMurray oil sands production to 330,000 bpd by the end of 2007.

- Petrobank's Whitesands Pilot Project, the first field-scale application of the patented Toe-to-Heel Air Injection (THAI) in situ heavy oil recovery technology.

Applications for regulatory approvals have been filed for:

- Suncor's South Tailings Pond, an external tailings pond located southeast of the Millennium Mine.

- Devon Energy's Jackfish Project, a SAGD in situ facility with a design capacity of 35,000 bpd.

Formal public disclosures have been made for the following projects:

- Husky's Sunrise Thermal Project, a SAGD in situ project with initial production of 50,000 bpd and a final design production capacity of 200,000 bpd

- BA Energy's Alberta Heartland Upgrader, with an initial bitumen processing capacity of 50,000 bpd and an ultimate design capacity of 150,000 bpd.

- Imperial Oil has publicly announced its plan to develop the Kearl Oil Sands Project, an integrated open-pit mining/upgrader operation with an initial production capacity of 100,000 bpd and an ultimate design capacity of 200,000 bpd.

The following projects have recently been completed:

- Train 2 at Syncrude's Aurora Mine, which was commissioned in the fourth quarter of 2003 and is now in production

- Phase 1 of Suncor's Firebag Project, which began production in January 2004.

New project construction continues on:

- Suncor's Firebag Project, Phase 2.

- Syncrude's Upgrader Expansion Project 1 (UE1), which is now more than 35% complete.

- Deer Creek Energy's Joslyn Project, Phase 1.

- CNRL's Primrose/Wolf Lake Expansion.

- Husky's Lloydminster Upgrader.

Other recent happenings that have a bearing on oil sands activity include the following:

- Syncrude has announced that the completion date for Stage 3 of the Syncrude 21 expansion plan has recently been extended from mid-2005 to mid-2006. In keeping with this change in construction schedule, the cost estimate for the Stage 3 has been increased from $5.7 billion to $7.8 billion.

- The Province of Alberta has expressed an interest in working with industry to explore the feasibility of constructing a rail link connecting the Fort McMurray oil sands and Edmonton to potentially reduce traffic on northern highways (especially Highway 63) and move heavy equipment and construction modules more quickly and economically than by truck. The first step for the proponents of the project will be to arrange for a feasibility study.

Summary

Oil sands production continues to increase, although unexpected maintenance needs and other factors have kept production below actual capacity, as reflected in the following figures from selected oil sands facilities:

- Suncor averaged daily oil sands production of approximately 217,000 bpd in 2003, up from approximately 206,000 in 2002. In January 2004 production was down to approximately 209,000 bpd due to equipment maintenance and cold weather, but the company is expecting to produce an average of 225,000-230,000 bpd in 2004.

- Syncrude produced an average of approximately 212,000 bpd during 2003, down from approximately 230,000 bpd in 2002. The decline was due to an unscheduled coker turnaround and extended maintenance work. Following completion of the coker turnaround, production rose to an average of 264,000 bpd in December 2003.

- The Athabasca Oil Sands Project (the Muskeg River Mine, Corridor Pipeline, and Scotford Upgrader) averaged production of 130,000 bpd during the fourth quarter of 2003, up from 115,000 bpd in the third quarter. Design production capacity for the project is 155,000 bpd.

- Petro-Canada produced an average of 16,000 bpd at its MacKay River In situ Project during the fourth quarter of 2003, up from 4,500 bpd in the same period in 2002. Design capacity of the project is 30,000 bpd.

- EnCana Energy is producing about 5,300 bpd from the first phase of the Christina Lake Thermal Project, up from 3,500 bpd in September of 2003. Design capacity is 10,000 bpd. The company is also producing 30,000 bpd from its in situ Foster Creek Thermal Project.

- Imperial Oil produced an average of 130,000 bpd from its Cold Lake Production Project in 2003, up from 112,000 bpd in 2002.

- CNRL is producing 35,000 bpd from its Primrose/Wolf Lake operation.

- Suncor has completed construction of Phase 1 of its Firebag Project and has begun construction of Phase 2. The Firebag project is an integral part of the company's Voyageur growth strategy, which is designed to increase production capacity to over 500,000-550,000 bpd by 2010-2012.

- Deer Creek Energy is working on its Joslyn Project (Phase 1), a SAGD facility designed to produce some 600 bpd.

- Husky is proceeding with the engineering of debottleneck and on-stream reliability projects designed to enhance the performance of its Lloydminster Upgrader.

Company approvals have been given to proceed with the following oil sands projects:

- Opti Canada/Nexen's Long Lake Project, a SAGD in situ facility with a first phase designed to produce 70,000 bpd (regulatory approval obtained in August 2003).

- ConocoPhillips' Surmont Project, a SAGD in situ facility with a design production capacity of 100,000 bpd (regulatory approval obtained in May 2003)

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- Imperial Oil has publicly announced its plan to develop the Kearl Oil Sands Project, an integrated open-pit mining/upgrader operation with an initial production capacity of 100,000 bpd and an ultimate design capacity of 200,000 bpd.

Two initiatives are exploring the use of solvents as a means of extracting in situ oil:

- Devon Canada is operating the Dover Vapex Project to test the effectiveness of vaporized solvents instead of steam.

- EnCana is testing a Solvent Aided Process (SAP) that uses solvent as a supplement to steam.

The total oil sands industry investment in new and sustaining capital may reach $93.5 billion in the 1996 to 2012 period. $22.5 billion has already been spent on new and sustaining capital in the 1996-2002 period. Production levels may reach 1.8 million bpd of synthetic crude oil (SCO) by 2012, plus an additional 1.2 million bpd of bitumen. Not all projects may proceed in the timeframe or scope that companies currently indicate. The Regional Issues Working Group has devised a way of discounting project capital and production on the basis of where the project is in the regulatory and commercial approval process. Using this discounting schedule, the total construction and sustaining capital expenditure in the 1996 to 2012 period is estimated at $65.1 billion. Production is expected to reach 1.2 million bpd of Synthetic Crude Oil and an additional 900,000 bpd of bitumen.

Most of the oil sands industry activity remains focused on the Fort McMurray region, which is growing rapidly in response to the intensifying economic activity. The 2002 municipal census places the population of Fort McMurray at 47,240, up from 34,000 in early 1996. The population of Fort McMurray is forecast to reach 50,000 in 2005 and may exceed 70,000 before the end of this decade.