MINERAL RESOURCES OF ALBERTA

compiled by staff
Geology Division, Alberta Research Council
and Energy Resources Conservation Board

April 1974

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Alberta
RESEARCH COUNCIL

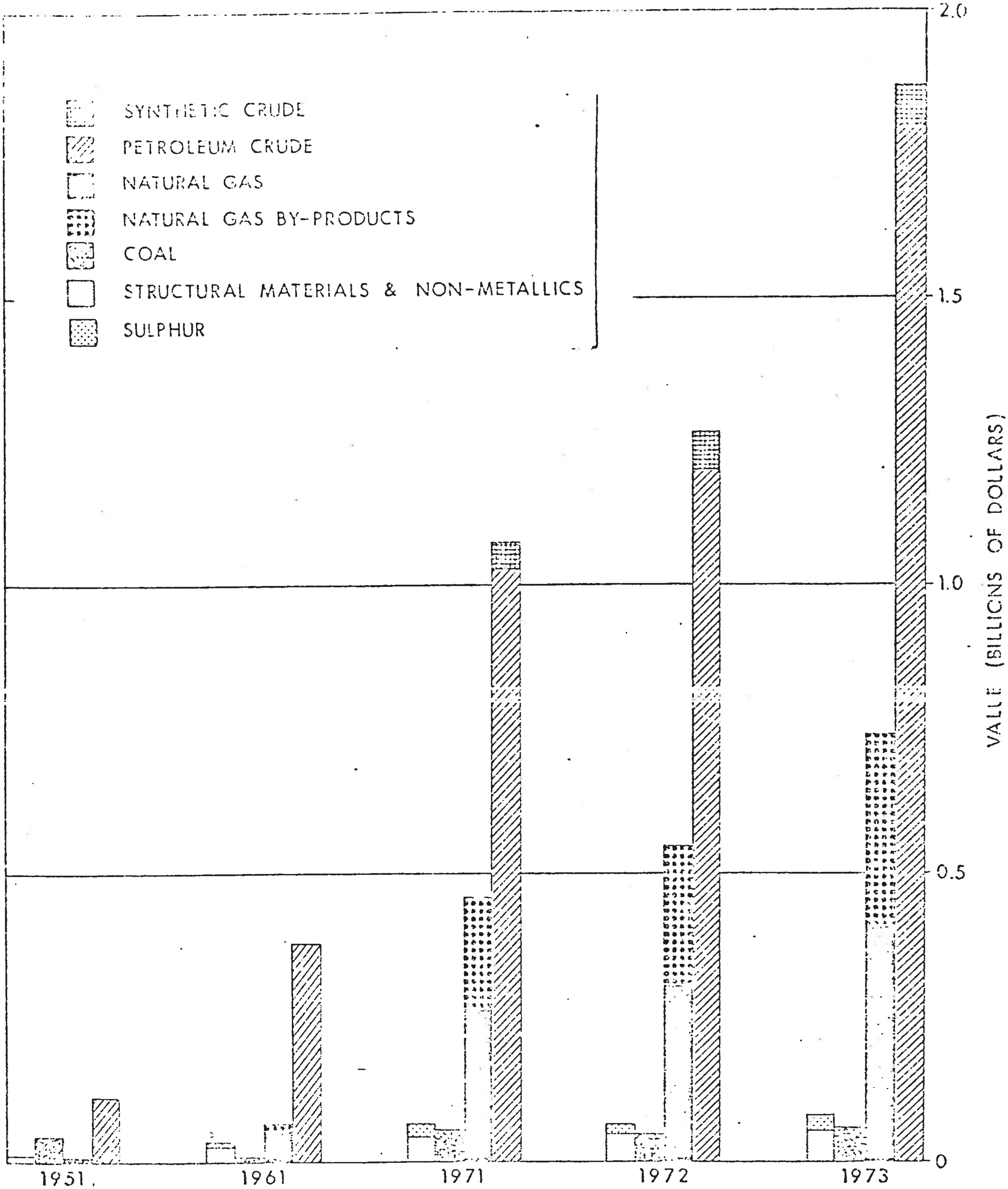
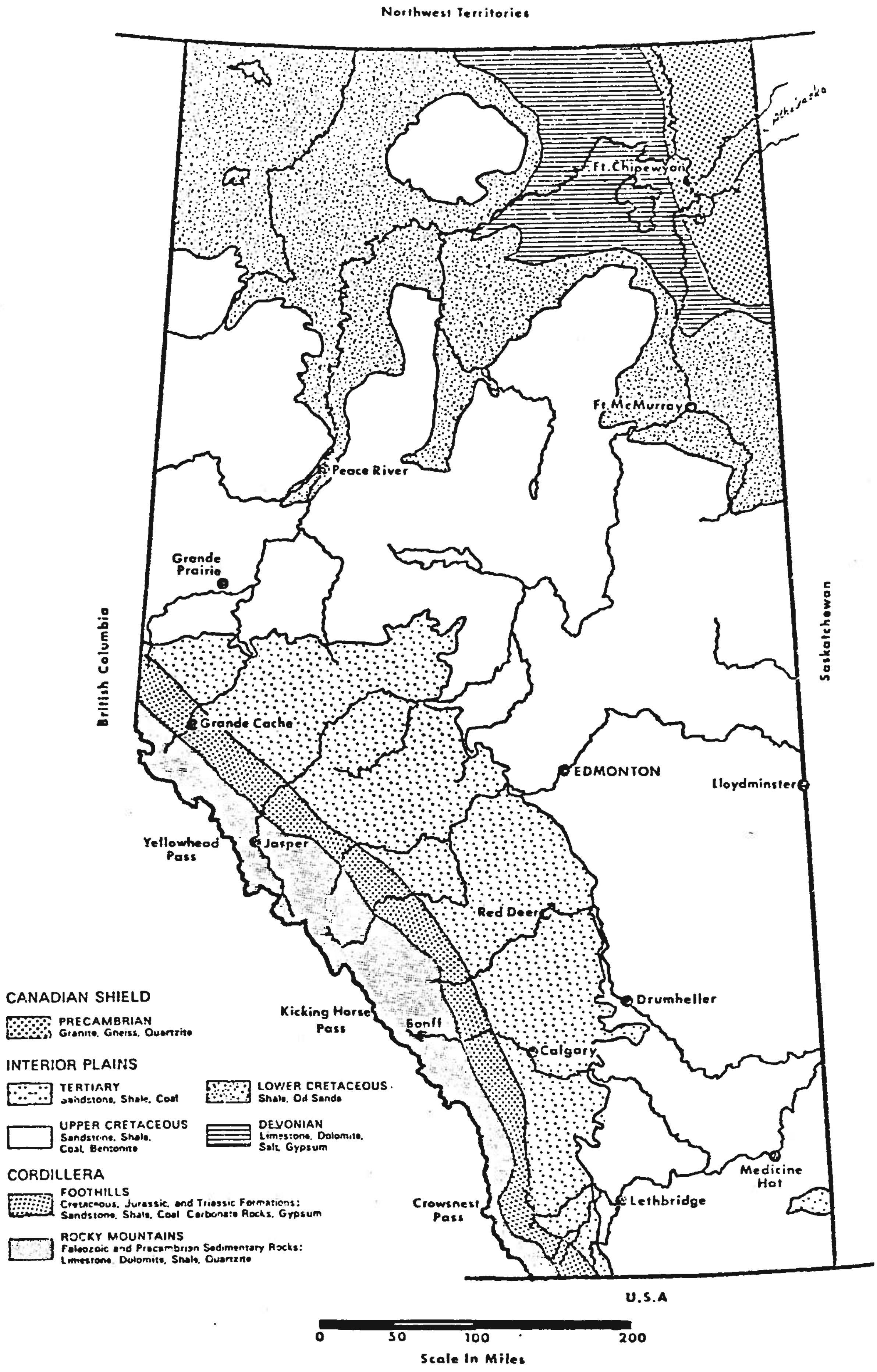


FIGURE- / VALUE OF MINERAL PRODUCTION IN ALBERTA



ALBERTA BEDROCK GEOLOGY

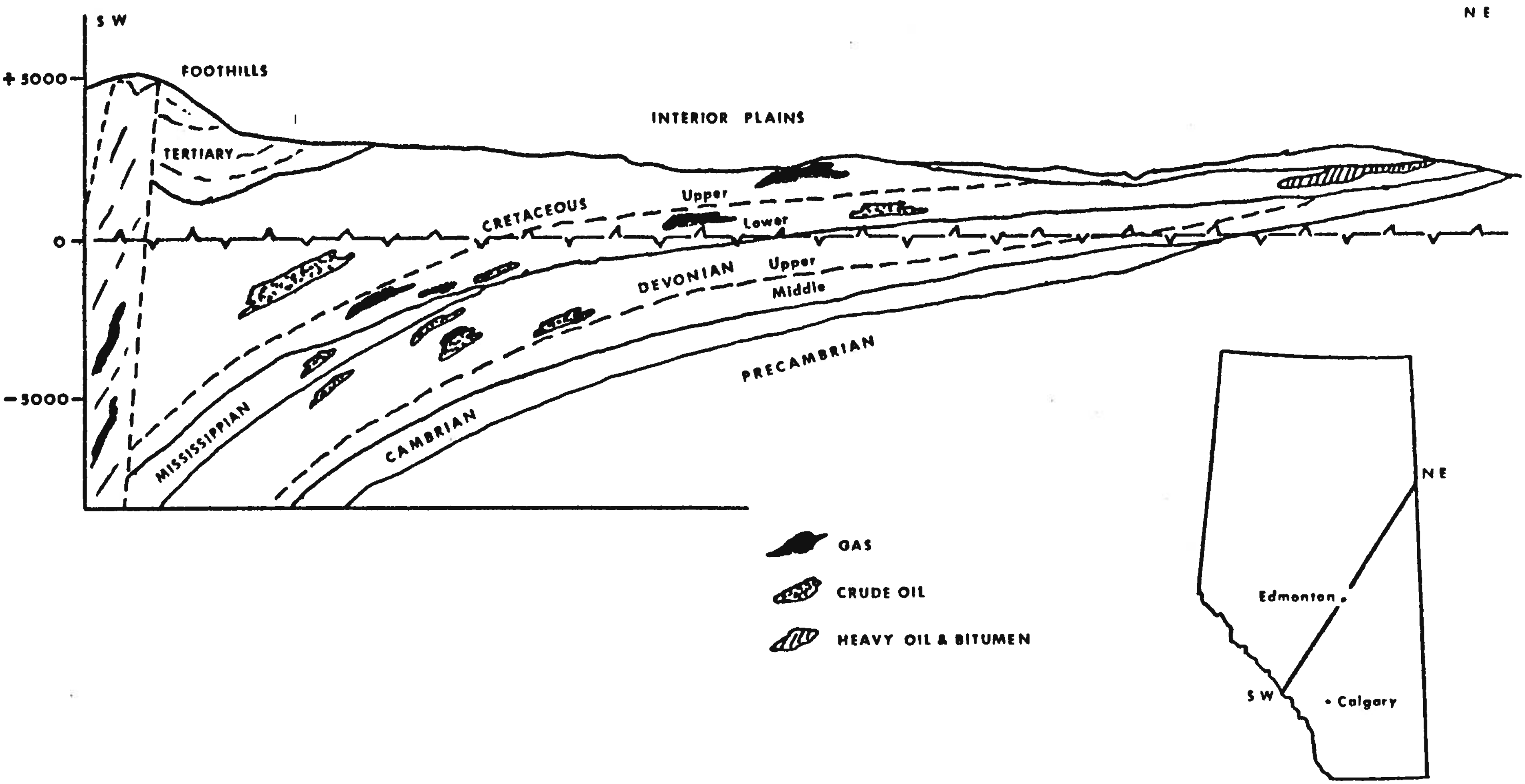
Figure 2

rocks underlie the lowlands about the margin of the Canadian Shield, dipping gently southwest under the cover of younger Cretaceous strata. The Devonian rocks contain large deposits of limestone, gypsum, and salt at or near the surface, and the salt deposits continue at greater depths beneath much of east-central Alberta. Also, the more deeply buried Devonian strata of northwestern and central Alberta contain much of the province's oil and gas reserves, found largely in rocks formed from ancient reefs.

Cretaceous and Tertiary strata comprise the bedrock over the major part of the Alberta Plains, forming a series of alternating sandstone and shale formations which dip gently to the south and west, with the result that successively younger strata form the bedrock towards the margin of the Rocky Mountain Foothills (Fig. 3). Cretaceous strata of the Plains contain much of Alberta's mineral wealth: the Athabasca and Cold Lake oil sands, the sub-bituminous (thermal) coal deposits of central and southern Alberta, and a significant portion of the province's conventional oil and gas reserves. They also contain important deposits of industrial and metallic minerals, including bentonite, ceramic clays, silica sand, and iron.

The Rocky Mountains and Foothills are formed of folded and faulted sedimentary strata in a belt 25 to 75 miles wide extending along the southwestern margin of the province. The strata range in age from Precambrian to Tertiary: in general, the Foothills are composed of sandstone and shale formations of Jurassic and Cretaceous ages, and the Rocky Mountains are composed of carbonate and quartzite formations ranging in age from Precambrian to Triassic. The Foothills contain important reserves of sour gas and high grade bituminous coal, much of which is of coking quality. Vast reserves of limestone and dolomite are found within the front ranges of the Rocky Mountains. Scattered deposits or showings of other industrial and metallic minerals also have been reported from this region.

Except for some of the higher ridges in the Rocky Mountains and the Cypress Hills in the southeast, the province was covered by thick ice sheets during the Pleistocene epoch. Consequently, much of the land surface is covered by unconsolidated glacial sediments ranging from a few inches to several hundred feet in thickness. The deposits vary widely in composition, consisting of sand, gravel, clay and unsorted mixtures of all three materials (till). Although glacial deposits obscure or otherwise hinder development of underlying bedrock mineral deposits in some areas, they provide much of the sand and gravel used in the construction industry, and also some of the clay and silica sand used in manufacturing products like brick and fibreglass.



ALBERTA SCHEMATIC CROSS SECTION

Figure 3

Oil and Gas*

Alberta's vast resources of gas, oil and crude bitumen are located in that part of the Western Canadian Sedimentary Basin lying between the mountain ranges along the western border of the province and the Precambrian Shield in the northeastern part. This region is about 750 miles in length and averages 250 miles in width. On the basis of subsurface geology, the region is divided into a Foothills and a Plains area, and the topography and geological conditions include areas of high relief in the Foothills, muskeg terrain in the northern Plains and generally an area of low relief in the southern Plains.

The ultimate potential for hydrocarbon reserves of any area is generally dependent on the nature of the stratigraphy and the subsurface geological framework of that area. In Alberta, the stratigraphic section is thickest in the Foothills area and progressively thins west to east as shown on Figure 3. A number of subcropping edges of the older formations resulted from the processes of erosion and in some instances these edges have been favorable spots to explore for hydrocarbon accumulations. Strata in the Foothills area have undergone rather severe tectonism and therefore are characterized by thrust and normal type faulting, steeply inclined beds and long anticlinal features generally paralleling the strike of the beds. The faulted and fractured sheets of Mississippian and Devonian limestones in the Foothills have been the key targets of explorers, and success in the Foothills usually culminates in the discovery of sour gas pools.

Except for the area covered by the Peace River and Sweet Grass Arches, where normal type of faulting is known to exist, the Plains area is characterized by beds having a relatively uniform southwesterly regional dip of 30 to 50 feet per mile. The majority of oil and gas pools in the Plains are found in stratigraphic traps, the most common of these being biohermal and biostromal reefs, blanket-type subcropping sheets of Paleozoic limestone, blanket-type sandstone deposits, sand bars, and very prolific but difficult to find channel-fill sand deposits. The vast oil sands deposits are in the Cretaceous sands of the Mannville Group. Oil sands of the Athabasca deposit outcrop at Fort McMurray and along the banks of the Athabasca River. It is in the general vicinity of the Athabasca River valley where the overburden is less than 250 feet in thickness that commercial mining and extraction operations are established and are also in the development stage.

The first drilling for petroleum in Alberta dates back to the 1890's, when wildcatters discovered natural gas by drilling shallow wells in the general Medicine Hat area. In 1902, drilling activity was spurred on by the presence of an oil seep in the mountainous area of southwestern Alberta, now known as Waterton National Park. The results of this drilling were unsuccessful, but in the ensuing years the persistent search along the Foothills paid off when the first major oil and gas pool was discovered at Turner Valley in 1936. This was followed by a relatively unsuccessful exploration period, and not

* by Energy Resources Conservation Board

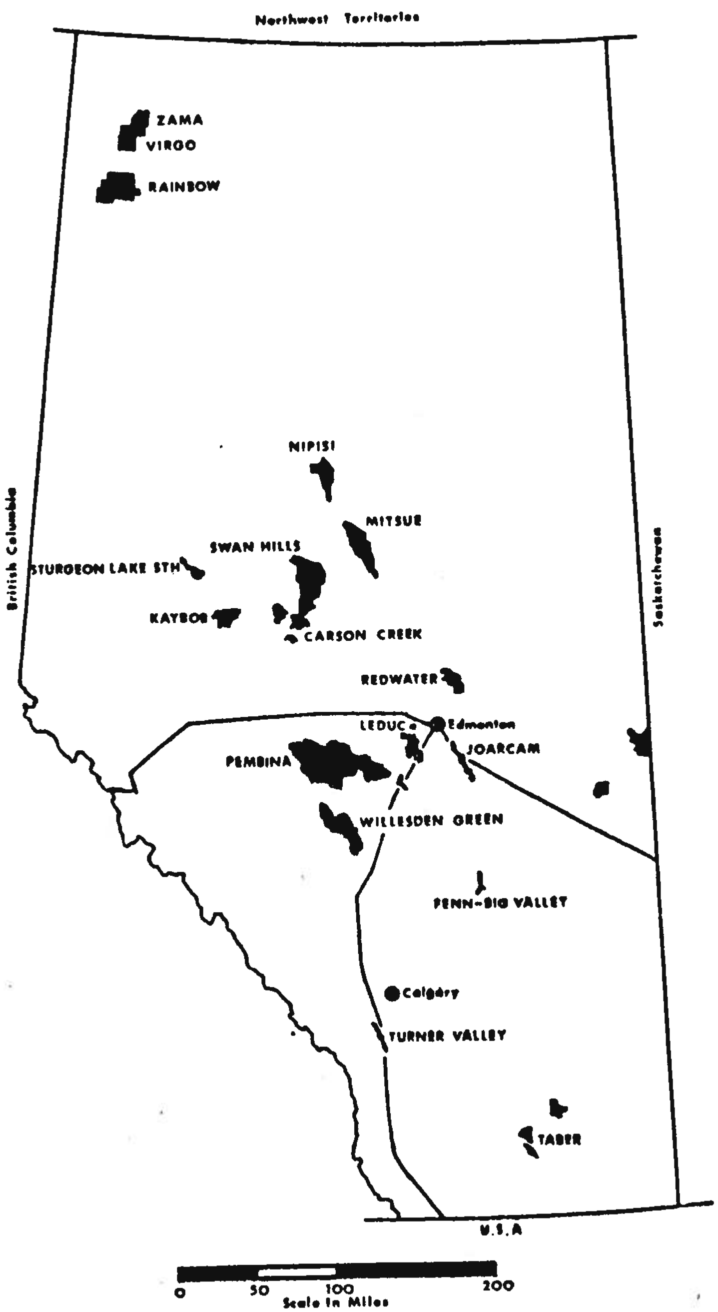
until 1947, when the second major oil pool was discovered in a Devonian reef at Leduc, did the petroleum industry flourish in Alberta. Development and exploratory drilling increased considerably following the discovery at Leduc, resulting in the discovery of hundreds of oil and gas pools, the construction of numerous on-site gas plants and refineries, and installation of a network of pipeline systems. The locations of the major oil and gas fields are shown on Figure 4 - Major Oil Fields in Alberta; and Figure 5 - Major Gas Fields and Processing Plants in Alberta, respectively. The relentless efforts and risks that have been expended since it all started in the 1890's have resulted in a diversified multi-billion dollar industry for the Province, with production of conventional crude oil currently at its peak. The daily average production of conventional crude oil, synthetic crude oil, pentanes plus and deliveries of marketable natural gas, propanes and butanes less volumes returned to reservoirs, and sulphur are shown on charts 2, 6, 8, 9 and 10 which have been reproduced from the report "Conservation in Alberta 1973" (published by the Energy Resources Conservation Board in Calgary). The estimated ultimate initial recoverable reserves of conventional crude oil in Alberta are in the order of 20 billion barrels, of which 11 billion, or about one-half, have been discovered so far. Similarly, the ultimate initial recoverable reserves of natural gas are in the order of 110 trillion cubic feet, of which 66 trillion have been discovered so far. The task of finding new reserves will be challenging, but not beyond the scope of an industry that is progressively developing more sophisticated equipment and technology.

Oil Sands

Major deposits of heavy oil impregnated sands, with reserves in excess of 895 billion barrels, are found underlying 15,000 square miles of northeastern Alberta (Fig. 6). These deposits outcrop along the Athabasca River at Fort McMurray; in other areas such as at Peace River, Wabasca and Cold Lake they occur at depths up to 2,000 feet. The oil in these sands cannot be produced in the same manner as that of conventional oil fields, because the oil will not flow unless heat is applied to it. Oil's inclination to flow is indicated by its viscosity; conventional crude oil generally has a viscosity at 100°F of less than 10 centipoise, whereas the viscosity of the bitumen in the Athabasca area is 20,000 to 500,000 centipoise. Oil is obtained from the bitumen by a refining process and is referred to as synthetic crude oil.

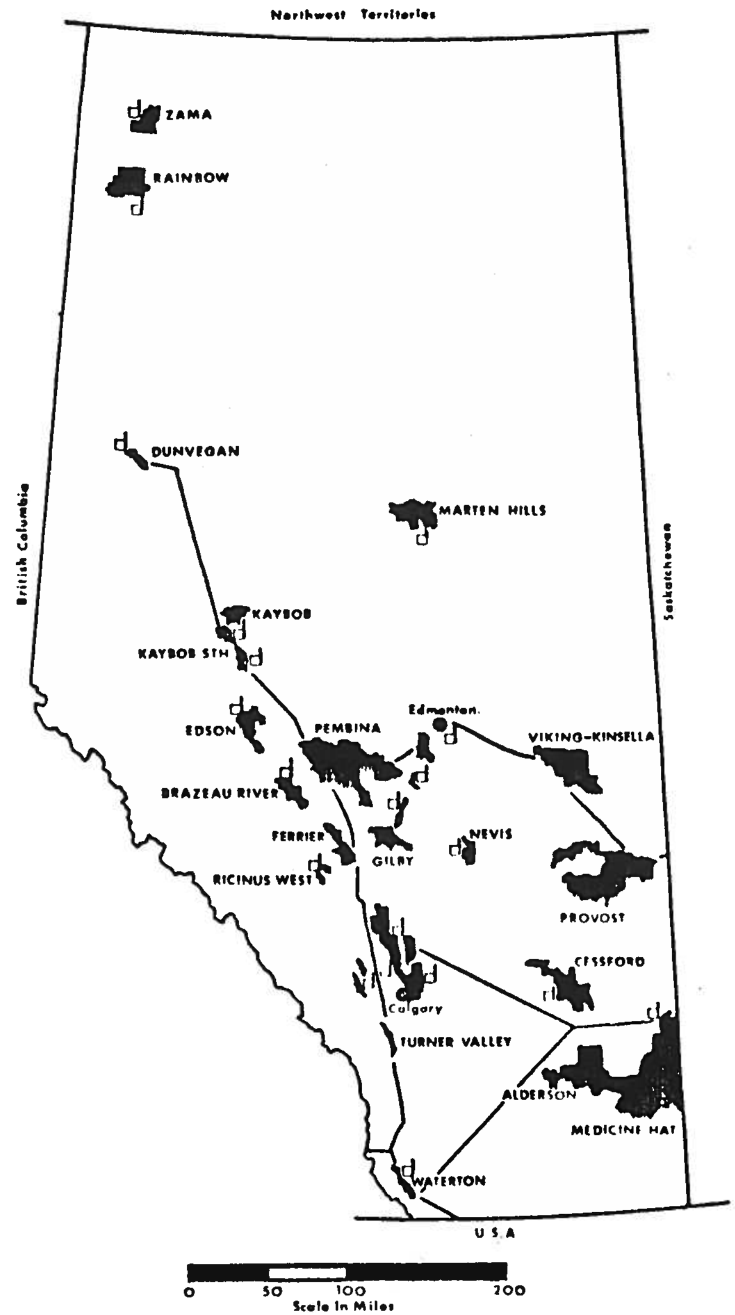
The synthetic crude from Athabasca yields generous amounts of aromatics used in the production of phenol, styrene, polyesters, surfactants and dyestuffs and commands a premium of some ten percent in the market place when compared with typical conventional crude oil.

In 1778, Peter Pond, a fur trader with the North-West Company, was the first European to see the oil sands outcrops in the Fort McMurray region.



ALBERTA-MAJOR OIL FIELDS

Figure 4

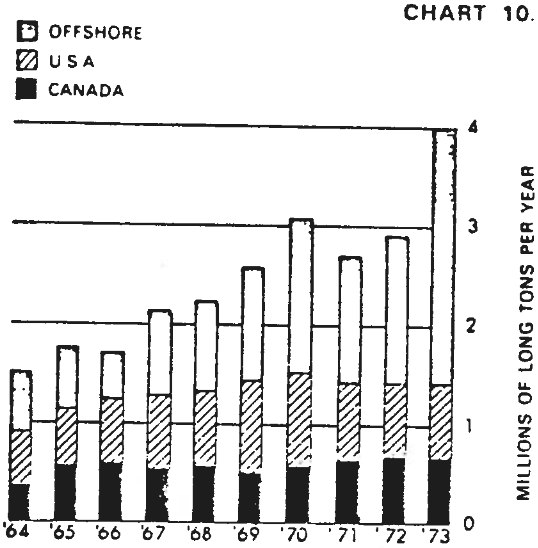


ALBERTA-MAJOR GAS FIELDS & PROCESSING PLANTS

Figure 5

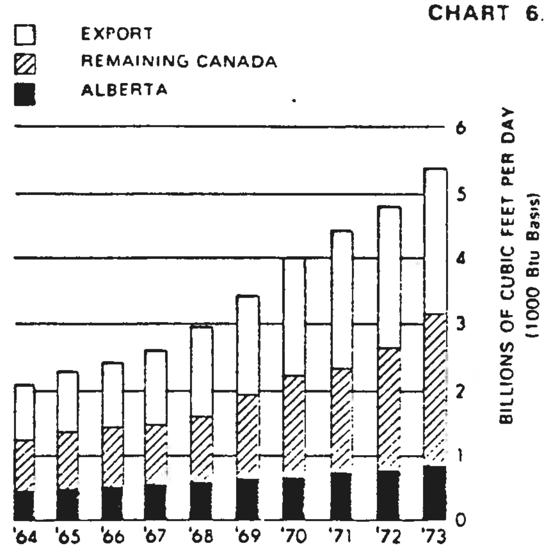
SULPHUR DELIVERIES

CHART 10.



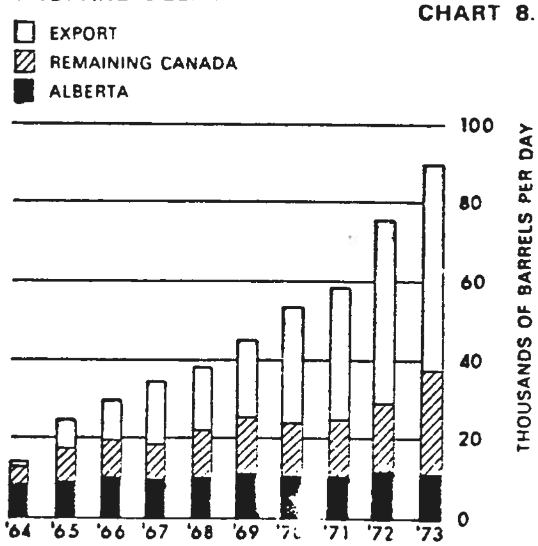
NATURAL GAS DELIVERIES

CHART 6.



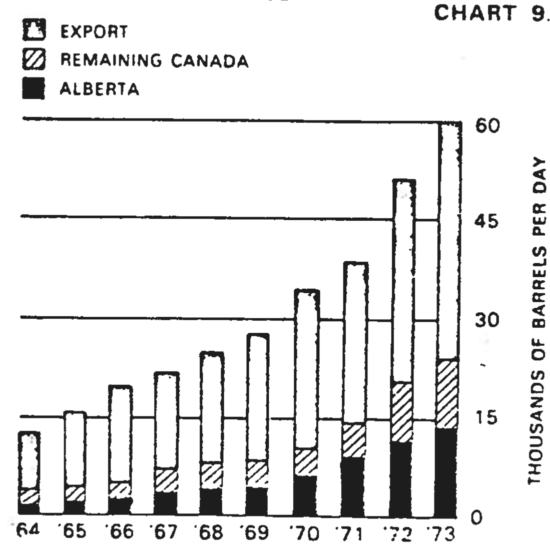
PROPANE DELIVERIES

CHART 8.



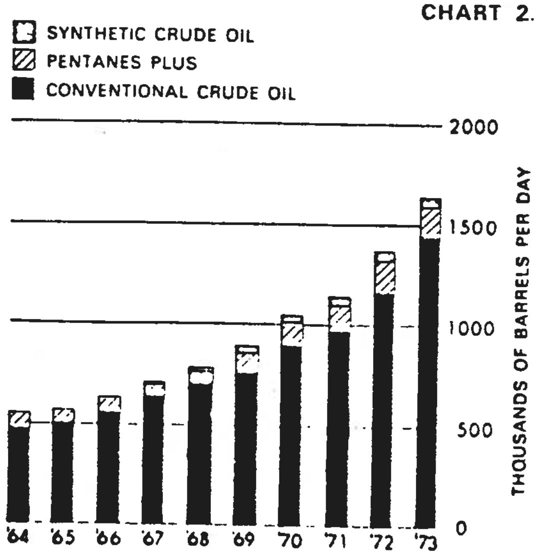
BUTANES DELIVERIES

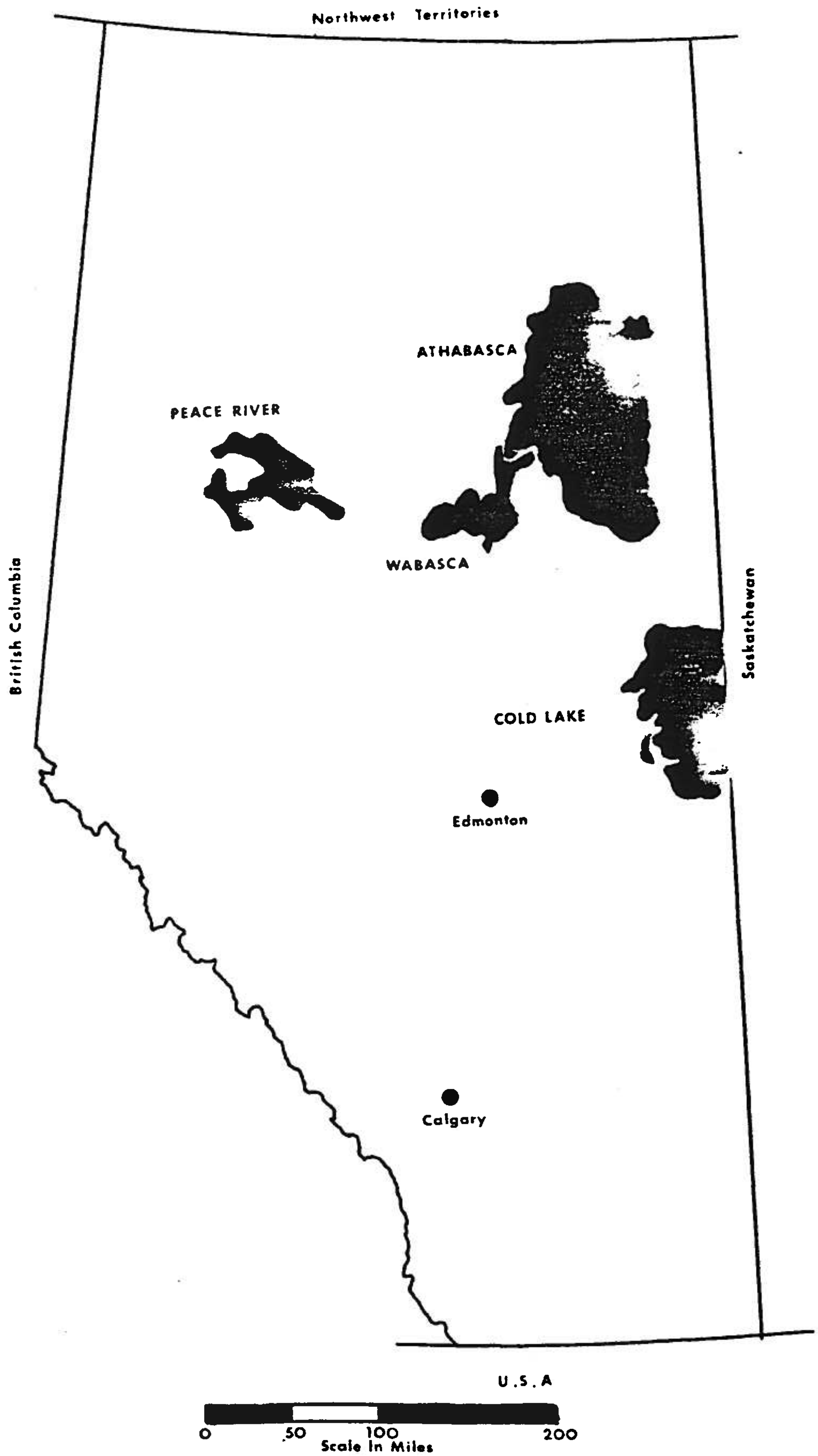
CHART 9.



DAILY PRODUCTION OF OIL BY TYPE

CHART 2.





ALBERTA-OIL SANDS DEPOSITS

Figure 6

The first proposal for exploitation of the oil sands was by Dr. Robert Bell of the Geological and Natural History Survey of Canada in 1882. Dr. Bell proposed building a pipeline from the east end of Lake Athabasca to Hudson Bay, to transport the oil to foreign markets. Starting in the early 1900's several unsuccessful attempts were made to get commercial production from the Athabasca oil sands. In 1948, the government of Alberta built a 500 ton per day plant at Bitumount, to demonstrate the commercial feasibility of the "hot-water" process, developed by Dr. K. A. Clark of the Research Council of Alberta in the 1920's. In 1962, Great Canadian Oil Sands Limited received permission from the Alberta Government to build a 31,500 barrel per day plant at Tar Island.

The Great Canadian Oil Sands recovery plant, situated 20 miles north of Fort McMurray, began production in 1967. The deposit being developed is sufficiently close to the surface to permit strip mining on an economical basis. Recovery is achieved by the "hot water" process, whereby the sand is exposed to steam which causes an oily slush to be dropped into a hot water bath; the sand sinks to the bottom and oil is skimmed off the top. The product of the separation process, referred to as raw bitumen, is upgraded in a refining process to synthetic crude oil. This initial plant is designed to produce some 65,000 barrels per day of synthetic crude. Numerous early difficulties encountered in the operation of the plant have now been largely overcome. The growth in the production of synthetic crude from the plant can be seen from the following figures:

Year	Average Production Barrels/Day
1967	3,100
1970	33,101
1973	54,300

A second plant to be built by Syncrude Canada Limited to produce 125,000 barrels per day has been approved by the Alberta Government and is scheduled to begin production in 1978. Two other plants have been proposed, one by Shell Canada Limited and one by a consortium headed by Petrofina Canada Limited. Other companies holding leases in the oil sands areas are or will be conducting experimental work towards the development of in-situ recovery methods, applicable to that portion of the oil sands that is too deeply buried for surface mining. Amoco Canada Petroleum Co. Ltd. and Texaco Exploration Canada are operating experimental projects just south of the town of Fort McMurray. Imperial Oil Limited is starting an experimental scheme to recover 4,000 barrels per day from the oil sands in the Cold Lake area. Shell Canada Limited will soon initiate an experimental project near Peace River.

An indication of the potential effects of the oil sands development is provided by the growth of Fort McMurray. To 1972 its population had increased to some 7,000 from 1,800 in 1965.

Coal

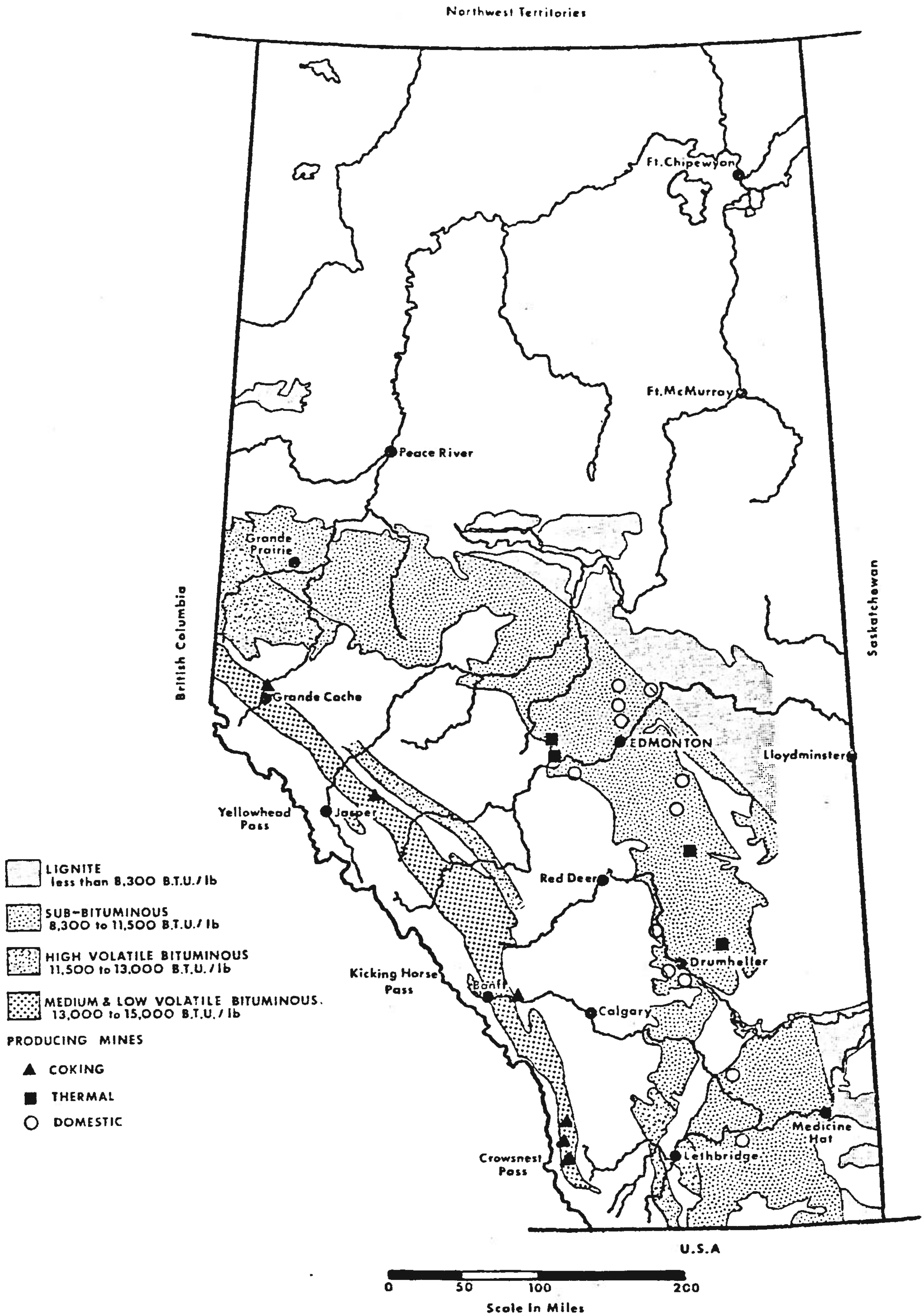
Extensive coal deposits occur in both the Plains and Rocky Mountain Foothills regions of Alberta. The oldest and highest-ranking coals are found in the Foothills and are assigned to two major stratigraphic intervals. The Lower Cretaceous Kootenay Formation includes commercial beds of low volatile bituminous coal between the Crowsnest Pass and Clearwater River areas. Strata belonging to the overlying Lower Cretaceous Luscar Formation contains prominent coal seams of similar rank between the Clearwater River and the Kakwa Falls area adjacent to the British Columbia boundary.

The Plains region is underlain by two significant coal sequences both of which are younger and include coal of lower rank than those of the Foothills. In the western Plains and outer Foothills, high volatile bituminous coal occurs in the Upper Cretaceous Belly River Formation and approximately equivalent strata (Oldman, Brazeau and Wapiti Formations). Farther to the east, in the central Plains, stratigraphically higher successions belonging to the Upper Cretaceous Horseshoe Canyon Formation and the Tertiary Paskapoo Formation yield subbituminous coal.

The pattern of distribution of coal according to rank appears to be a function of age (rank decreasing from oldest to youngest) and distance from areas influenced by Laramide disturbances (rank decreasing towards the east). As a result, a series of zones roughly paralleling the Rocky Mountain front may be delineated for different ranks of coal (Fig. 7).

The Geological Survey of Canada (Latour and Christmas, 1970) has calculated the measurable reserves of Alberta coal to be 47.2 billion tons. Medium and low volatile bituminous coals constitute 28 billion tons; high volatile bituminous coals, 9.3 billion tons; and subbituminous 9.9 billion tons. The Alberta Energy Resources Conservation Board estimates coal reserves economically recoverable by present day technology to be approximately 11 billion tons.

During the early 1950's, production of Alberta coal experienced a drastic decli e because of its replacement by oil and gas for such purposes as railway locomotion and home heating. The total annual production fell from 8 1/2 million tons in 1949 to a low of 2 million tons in 1961. Thermal plants established at Wabamun and Forestburg assisted in increasing the total coal production to 4.4 million tons by 1969. At present, the thermal plants are being fed by subbituminous coal from four strip mines: two on either side of the Battle River in the Forestburg area, and the Whitewood and Highvale mines on the north and south sides of Lake Wabamun in the Wabamun area. The 1973 production of subbituminous coal was an estimated 4.5 million tons. Coal remains most favored in terms of comparative costs and other benefits for electric power generation, and as a result it is forecast that by 1980 Alberta will be using 10 million tons of coal annually for this purpose.



ALBERTA COAL BEARING FORMATIONS

Figure 7

In the last few years, very extensive markets have opened up in Japan for bituminous coking coal, and of the total provincial coal production of 9.0 million tons in 1973, approximately 4 billion tons were exported for coking purposes. At the present time four major companies are producing coking coal: Coleman Collieries Ltd. in the Crowsnest Pass area; Canmore Mines Ltd., Canmore; Cardinal River Coals Ltd., Luscar; and McIntyre Porcupine Mines Ltd., Grande Cache.

Sales of coal from Alberta mines in 1973 were valued at approximately 59 million dollars, reflecting the recent surge of development in the coal industry of the province. The continuing interest by companies in Alberta's resources for coking coal, thermal plant feed, and possibly, coal gasification will doubtless result in considerable future exploration and investment.

Industrial Minerals

A diverse array of industrial minerals is found in Alberta, forming a broad raw material base for industry. The minerals are listed in the following table by groups according to principal industrial uses, these groupings indicating to some extent the current state of development of mineral-based industry in Alberta. Because the industrial minerals generally are low valued materials, they make up only a small percentage of the total value of mineral production (about $78 millions in 1973, less than 3 percent of the total), but their importance in the complete economic structure of the province is disproportionately much larger.

Known deposits of the more important industrial minerals in Alberta, that is, those with potential for major industry development, are described briefly below. Some of the minerals listed in the table are of relatively minor importance and are not further mentioned.

Accessory "Heavy" Minerals (Titanium-Zirconium)

The McMurray oil sands composed mainly of quartz with minor feldspars and muscovite also contain trace amounts of accessory, or "heavy" minerals (sg 2.95), which constitute approximately 0.3 percent by weight of the solid mineral matter of the sands. These "heavy" minerals include titanium-bearing minerals [rutile (TiO_2), anatase (TiO_2), "leucoxene"] and zircon ($ZrSiO_4$), along with a number of others of less significance such as tourmaline and garnet. "Heavy" minerals become concentrated in the froth as an incidental effect of the flotation process in bitumen extraction, forming up to 30 percent by weight of the froth solids. The "heavies" fraction is rich in titanium (up to 25 percent) and zirconium (10 to 20 percent), and represents a potential source of these two transition elements and their oxides, recoverable as a byproduct of oil sands development.

INDUSTRIAL MINERALS OF ALBERTA

CHEMICAL & METALLURGICAL INDUSTRIES	CONSTRUCTION MATERIALS INDUSTRIES	OTHER INDUSTRIES
Pulp processing minerals - salt - saltcake - sulfur - limestone	Cement raw materials - limestone - shale - gypsum	Agricultural and related materials - marl and coquina - peat moss
Fertilizer raw materials - sulfur - phosphate rock - potash	Ceramic raw materials - clay - silica sand - fly ash	Miscellaneous - abrasives - helium
Lime: limestone & dolomite - limestone - dolomite	Building products minerals - gypsum - dimension stone - industrial sand	
Refractories - kaolinite-base clay (fireclay) - dolomite - silica	Aggregates - sand and gravel - lightweight aggregate	
Miscellaneous - formation waters - bentonite - fly ash (Ni-V) - accessory "heavy" minerals (Ti-Zr)		

Despite the almost negligible percentage of accessory minerals in the raw sand, the amount becomes signficant in consideration of the enormous tonnages of sand handled in the extraction process. Thus, for a 100,000 barrels per day operation involving 140,000 tons of raw oil sand, approximately 350 tons of accessory minerals are being put through the process each day. A substantial (but as yet undetermined) portion of these will collect in the bitumen froth, and therefore may be available for subsequent benefi-ciation and treatment.

Bentonite

Bentonite deposits are found in a number of localities in Alberta associated with sandstone and shale formations of Late Cretaceous age, in the Plains region of southeastern and central Alberta and in the Peace River district of northern Alberta. The quality and extent of the deposits vary widely from one locality to another; in some cases, samples from adjacent sections of the same deposit or bed exhibit noticeable differences in bentonite characteristics.

Two Alberta bentonite deposits have been mined in recent years; near Rosalind along the Battle River about 70 miles southeast of Edmonton, and at Onoway about 30 miles northwest of Edmonton. Total production at Rosalind is approximately 12,000 tons a year, and most is sold as foundry clay. The Onoway deposit has not been mined since 1968; however, about 2,000 tons a year currently are processed from stockpiles, mainly for use in drilling muds.

Clay and Shale

Clays and shales are widespread in Alberta, found in varying proportions in practically all the Cretaceous and Tertiary formations that outcrop on the Plains. Clay is present extensively in the surficial deposits as well, and shale is the dominant rock type of the Mesozoic strata in the Rocky Mountains and Foothills. The clays are mostly of the low grade, low alumina variety, suitable only for low value ceramic ware or for cement-making, although intermediate grades such as stoneware clay and fireclay are known in a few deposits.

The better grades of clay are found mostly in southeastern Alberta, in the Cypress Hills area, where clays of the Upper Cretaceous Whitemud Formation are quarried. The Whitemud Formation, a thin but complex sedimentary unit, is undoubtedly the most important source of clays in Western Canada: its eastward development in Saskatchewan has provided fireclay and ball clay in addition to stoneware clay, which is the dominant clay type of the formation in Alberta. Other stoneware clays are reported in a few widely scattered deposits, the most promising exposed along the Athabasca River in northeastern Alberta, directly under the Athabasca oil sands.

Good quality fireclay has been found in the coal measures being mined at Wabamun Lake, 40 miles west of Edmonton, forming extensive partings up to 2 feet thick between minable coal seams. The clay appears favorably disposed for large-tonnage recovery as a coproduct of the coal stripping operation; it is white-burning, consists mainly of kaolinite, and shows promise for ceramic use. At present, this clay is being wasted as backfill at a rate of 200,000 tons yearly.

The clay products industry in Alberta is centered largely in the southeastern part of the province, with plants also in Calgary and Edmonton. Production in 1973 was valued at $4.6 millions.

Fly Ash (Vanadium-Nickel)

In oil sands processing, one of the basic steps involves thermal coking of the separated bitumen to produce an upgraded distillate crude, leaving a residual product of bitumen coke. Virtually all of the mineral solids and most of the trace metals present in the bitumen accumulate in the residual coke, constituting 3 percent of the coke by weight. These solids accumulate as fly ash and bottom ash where the coke is burned for boiler fuel at the existing GCOS plant, and represent a potential mineral resource principally for the vanadium and nickel concentrations (3.5 and 1.2 percent respectively).

The amount of coke ash produced daily at the GCOS power plant for its 45,000 barrels/day operation is only 65 tons, but at the projected peak development for the region of 1 million barrels per day, coke ash production could amount to 1,400 tons daily, representing 48 tons and 16 tons of metallic vanadium and nickel respectively. According to a press release by the Federal Department of Energy, Mines and Resources, recovery of the two metals by a pyrometallurgical process developed at EM&R would become economically feasible when production facilities reach 200,000 barrels per day.

The amount of byproduct coke (and hence, coke ash) to be expected at peak oil sands development is uncertain, for it depends upon the upgrading methods chosen. Methods that utilize hydrogenation processes, converting more of the carbon to salable petroleum products and leaving less residue, probably will come into increasing use with future development.

Fly ash is also produced from coal combustion in Alberta, in power stations at Wabamun, Forestburg, and Drumheller. At present, only the Wabamun fly ash is commercially utilized, for making tile in a brick and tile plant at Wabamun and also for use as pozzolan. A variety of minor uses for fly ash hold promise for future application in Alberta.

Formation Waters

Formation brines with more than 60,000 mg/l calcium and more than 9,000 mg/l magnesium underlie relatively large areas of southern and central Alberta, in the Upper Devonian Beaverhill Lake Formation and in the Middle Devonian Elk Point Group. These brines are similar in composition to brines presently being commercially exploited for calcium chloride in the U.S.A.; they may also be a potential source of magnesium metal, inasmuch as the concentrations are several times the magnesium content of sea water -- the main commercial source of magnesium.

Bromine and iodine also are found in the formation waters in Alberta, and may be present in commercial concentrations in other than those stratigraphic units containing the calcium and magnesium brine fields.

Gypsum

Several known deposits of gypsum in Alberta are undeveloped at the present time, due partly to low grade but primarily to remote location or difficult accessibility. Three of the deposits considered to have potential for future development are the so-called Kananaskis, Fort McMurray, and Fetherstonhaugh deposits.

The Kananaskis deposit lies in the vicinity of Kananaskis Lakes, in the Rocky Mountain front ranges 80 miles southwest of Calgary. The deposit outcrops on a mountainside near the 7,000-foot level, where an 80-foot thickness of gypsiferous strata is exposed. Grab samples assayed 90 to 92 percent purity, but the average grade and extent of the deposit are undetermined. The gypsum beds dip steeply into the mountain and would require underground mining methods for recovery; however, any mining activity -- if allowed -- would be subject to severe regulatory constraints, for the Kananaskis Lakes region is one of great scenic attraction and recreational importance.

In the Fort McMurray region, a gypsum deposit 30 to 50 feet thick underlies the Clearwater River valley at depths ranging from near-surface to 300 feet over a distance of 18 miles. The average grade of gypsum in the deposit is 84 percent. A similar deposit but of higher grade is postulated to exist beneath the Athabasca River valley 60 miles north of Fort McMurray.

The Fetherstonhaugh deposit straddles the Alberta-British Columbia border in the Smoky River headwaters, approximately 270 miles due west of Edmonton, forming a small hill on the Continental Divide between elevations of 6,500 and 7,000 feet. Its remote location is offset somewhat by proximity to the Alberta Resources Railway, passing 40 miles to the east. The deposit appears to contain several million tons of ore, but estimates of reserves are hampered by structural complexities. The grade also is uncertain, due to a discrepancy in assays reported for outcrop channel samples (95 percent) and test hole samples (75 to 80 percent).

All of Alberta's gypsum requirements, now totalling about 200,000 tons per year, are shipped in from outside the province at heavy freight cost.

Limestone

Limestone exists in vast quantities in Alberta, in formations of Cambrian, Devonian, and Mississippian ages exposed almost continuously along the Rocky Mountains in western Alberta, and in Upper Devonian strata exposed along the Athabasca and Clearwater Rivers in northeastern Alberta. Limestone also exists in the subsurface throughout the province, but its shallowest depth near any major industrial area is below 3,000 feet -- too deep for consideration as a raw material source.

The best industrial potential for limestone exists for the deposits along the front ranges of the Rocky Mountains adjacent to railway lines that extend into and across the mountain ranges. Quarries are operated in several of the deposits, and at two of the quarries limestone is produced for cement making. At Cadomin, 180 miles west of Edmonton, limestone is quarried to be hauled by unit train to a cement plant in Edmonton. The limestone deposit is in the Palliser Formation of Late Devonian age and has a stratal thickness of 500 feet, with proven reserves calculated in excess of 22 million tons. About 600,000 tons are quarried annually. At Exshaw in the Bow Valley, 160 miles southeast of Cadomin, a cement plant uses limestone of the same formation, quarried on the plantsite, in roughly the same quantities as at Cadomin.

Other quarries in the mountains produce limestone mainly for lime manufacture. In the Crowsnest Pass, limestone from the Mississippian Rundle Group is produced near the site of a lime plant west of Crowsnest Lake. In the Bow Valley, limestone also from the Rundle Group is produced for use in a lime plant near Kananaskis, from quarries 9 miles west of the plant site. Formerly, limestone from the Cambrian Eldon Formation was quarried on the plant site. Production from these two quarrying areas runs in the order of 250,000 to 300,000 tons annually.

Marl and dolomite are two other materials found abundantly in Alberta that can substitute for limestone in certain industrial applications. Marl deposits of Recent lacustrine origin are widespread, although many are thin, lumpy, and of limited extent. One deposit near Clyde, 40 miles north of Edmonton, is worked for use in a small-scale cement plant.

Dolomite is extensive in the mountains of Alberta, its distribution closely paralleling that of limestone. Some dolomite is quarried in the Crowsnest Pass area, from Upper Devonian Fairholme Group strata and also from Mississippian Rundle Group strata, to be crushed for use as flux stone in British Columbia smelters. Dolomite is found also in northeastern Alberta in the Middle Devonian Methy Formation, a reef rock unit that crops out on the Clearwater River and lies near the surface along the lower stretch of the Athabasca River.

Salt

Salt (halite) deposits of vast extent are present in the subsurface of the Alberta Plains, underlying almost the entire area east of the diagonal joining the southeast and northwest corners of the province. The salt beds, belonging to a group of strata of Middle Devonian age called the Elk Point Group, dip southwesterly from a depth of 700 feet at Fort McMurray to about 6,000 feet at Edmonton and reach an aggregate thickness of nearly 1,400 feet at one point in east-central Alberta about 110 miles east-northeast of Edmonton. From here, the beds become thinner in all directions, but the salt (which is generally of excellent quality) retains brinable thicknesses sufficient to support a major brining operation practically anywhere within the salt-bearing area.

The salt beds in Alberta form part of a much larger evaporite unit that extends in a continuous, broad belt southeastward across Saskatchewan. However, the equivalent salt beds in Saskatchewan are extensively potash-bearing, giving rise to the enormous commercial deposits of potash in that province. Only in one small area of eastern Alberta is potash mineralization inferred to extend across the border, but here the potash deposit is sub-economic in terms of grade, thickness, and depth.

Salt is produced at two localities in Alberta. At Fort Saskatchewan, a few miles northeast of Edmonton, salt is brined from beds as deep as 6,100 feet for the manufacture of chloralkali chemicals. At Lindbergh, about 120 miles east of Edmonton, salt for domestic and industrial use is brined from beds 3,600 feet below the surface. Total production in 1973 was 310,000 tons valued at nearly $3 millions. Of this, about 200,000 tons was for chemical use.

Salt beds are used also in an indirect way at three localities in the province for underground storage of petroleum products (in artificially created caverns).

Sand and Gravel

Commercial deposits of sand and gravel are plentiful in Alberta, although not uniformly distributed. The most widespread are the glacial outwash gravels, supplying most of the needs of central and southern Alberta. In northern Alberta, gravel deposits are more scattered, and long haulages frequently are involved in meeting local gravel needs. Edmonton is supplied largely from preglacial channel deposits, some of which are up to 40 miles outside the city.

In 1973, the production of sand and gravel in Alberta was 20.6 million tons valued at $18.2 millions.

Silica Sand

A few deposits of good quality silica sand are known in Alberta, but are poorly situated with respect to transportation and markets, and are undeveloped. The best known deposit, in a Cretaceous marine sandstone exposed along the Peace River in northwestern Alberta, has a 40- to 60-foot thickness of friable, clean quartz sand, which can be upgraded readily to glass sand specifications. Other potential sources are in the Fort McMurray region, the most obvious being the tailings sand from oil sands processing, known from earliest research efforts in extracting the oil to be very high in silica. Another source is an alluvial sand deposit of excellent quality found in a buried (possibly preglacial) river channel of the Clearwater River valley at Fort McMurray. Lesser possibilities include some quartzite formations exposed in the Rocky Mountains, and alluvial quartzite pebbles found in the major river valleys of Alberta: these materials would have to be crushed to the specified grain sizes for silica sand.

For uses of silica sand in which the specifications are not so exacting, the dune sand deposits common in many parts of Alberta have some potential. Although of relatively low grade, these sands respond well to beneficiation treatment and probably could be upgraded sufficiently for some industrial uses, for example, colored container glass. Sand from dune deposits near Edmonton has been used with beneficiation for some time in the production of fibreglass.

Most of Alberta's requirements for high quality silica sand continue to be imported, between 60,000 and 80,000 tons annually. Figures for production of silica (dune) sand in the province are unavailable.

Sodium Sulfate

Sodium sulfate deposits are found at many localities in eastern Alberta and Saskatchewan and are the source of most Canadian saltcake production. Only one deposit is worked in Alberta, at Metisko Lake 140 miles southeast of Edmonton, which contains an estimated 1.8 million tons of sodium sulfate. Production in 1973 was about 76,000 tons valued at $1 million. Several other known deposits in Alberta appear too small for economic development.

Sulfur

Alberta is a major world producer and exporter of sulfur, and has the world's largest production from hydrocarbon sources. Practically all the province's sulfur comes as a byproduct or coproduct of sour natural gas production, with a small percentage also recovered from synthetic crude oil extracted from the Athabasca oil sands. Sulfur recovery plants operate at a number of localities in southwest and west-central Alberta where sour gas is found. Hydrogen sulfide concentrations in these gas fields range as high as 53 percent, although in most they are between 3 and 20 percent. As a rule, the H_2S percentages increase to the southwest, that is, with increasing depths and temperatures of formation reservoirs. Recoverable reserves of sulfur from Alberta's sour gas fields are estimated to be more than 200 million long tons.

In 1973, sulfur production in Alberta was about 7 million tons, with sales of 4.5 million tons valued at $22 millions. Unsold production is stockpiled. About one-fifth of the sulfur sold is consumed by Canadian industries, with most of the remainder going to export markets throughout the world. Sulfur is one of the few nonmetallic minerals valued highly enough for long distance marketing and export trade.

Metallic Minerals

In Alberta, metallic minerals constitute a relatively minor group; few deposits are known to exist and no commercial production presently is taking place. Nevertheless, some potential exists for production in the future, and this potential is best summarized with reference to the geological framework of the province.

The Canadian Shield in northeastern Alberta, underlain by Precambrian crystalline rocks, provides a favorable geologic setting for metallic minerals exploration. Although no commercial deposits have been found to date, the terrain is similar to the uranium-producing region in nearby Saskatchewan and offers considerable scope for mineral prospecting. Uranium and molybdenite showings have been found in the area north of Lake Athabasca.

In the Interior Plains, the area bordering the Shield in northeastern Alberta is underlain by Devonian carbonate and evaporite rocks in which copper mineralization of undetermined significance has been found, and in which lead and zinc mineralization (of the Pine Point type) could be expected. However, much of this area lies within Wood Buffalo National Park and is therefore interdicted from mineral exploration.

The Cretaceous and Tertiary strata which underlie most of the Plains region contain a large deposit of sediment[illegible] iron (in the Clear Hills area of northwestern Alberta), but otherwise have little potential for metallic minerals production.

In the Rocky Mountains and Foothills, few indications of metallic minerals have been found apart from scattered copper and lead-zinc showings in southwestern Alberta. The areas most suitable for metallic minerals deposits are contained within federal or provincial parks; thus, only limited scope exists for metallic minerals exploration in this region, outside the parks boundaries.

Known deposits or potentially economic showings of metallic minerals in Alberta are described below.

Copper

Showings of copper minerals have been recorded from two main areas, the most extensive of which is in the Clark Range of the Rocky Mountains, in the southwestern corner of the province. In this region, scattered showings of copper sulfide minerals are found in Precambrian quartzites and dolomites over an area of approximately 250 square miles. The grades and thicknesses of copper-bearing zones found to date appear to be noncommercial; however, some showings are still being explored.

A second copper showing of interest is in northeastern Alberta, on a small island in the Slave River near the margin of the Canadian Shield. The copper is present as veins of copper sulfides and carbonates in Devonian dolomite rocks which overlie the granitic basement rocks of the Shield. The grade and extent of the mineralized zone are unknown, but a soil sample from the adjacent mainland has an anomalously high copper content, indicating that this area deserves further attention.

Iron

Two types of sedimentary iron deposits are found in Alberta. The largest and most important are situated in the Peace River district, 300 miles northwest of Edmonton. There, the main deposits are exposed about the flanks of the Clear Hills, a dissected upland region underlain by flatlying sandstone and shale formations of Late Cretaceous age. The iron beds consist of widespread bodies of oolitic sandstone up to 30 feet thick, with an average iron (Fe) content of 35 percent present in the form of hydrous iron oxide and silicate, and siderite ($FeCO_3$).

Estimates of reserves based on drilling data indicate that approximately 250,000,000 tons of strippable ore are present in the Clear Hills, with much larger tonnages buried at depths presently considered too great for strip-mining. Although the low grade and complex mineralogy of the ore, together with the remoteness of the deposits from potential markets, has prevented development to date, the Clear Hills beds contain the only deposit of iron ore in Western Canada with what is considered reasonable economic potential, apart from scattered deposits along the west coast in British Columbia.

In the Crowsnest Pass region of southwestern Alberta, scattered deposits of sedimentary magnetite (Fe_3O_4) are found, forming thin lenses in complexly folded and faulted Cretaceous sandstones exposed along the eastern margin of the Foothills. The magnetite-bearing beds tend to be thin and discontinuous as well as structurally complex, thus limiting the combined strippable reserves to less than 8 million tons. The deposits average less than 30 percent iron content, with relatively high amounts of titanium (4 to 5 percent TiO_2) present as ilmenite and titaniferous magnetite -- minerals which cannot be economically separated from the magnetite. Consequently, the deposits have limited potential as a source of iron ore.

Lead-Zinc

Scattered showings of lead-zinc minerals are present in the Rocky Mountains of southwestern Alberta, but none has yet proven to be of commercial grade. The best known and most promising are about 30 miles north of the Crowsnest Pass, in the High Rock Range near the interprovincial boundary. There, disseminated lead and zinc sulphide minerals (galena, sphalerite) are found in faulted limestone beds of Devonian age. The extent and average grade of the deposits is uncertain, but the lead content is locally quite high (40 percent or more). No reserve estimates are available, although some drilling and tunnelling has been done in the area.

Few reliable data are available on the other lead-zinc showings in south-western Alberta (north of Waterton Lakes National Park and near Canmore).

Sources of Additional Information

Maps and reports describing in detail the geology and mineral resources of Alberta are published by both provincial and federal government agencies. Catalogues of these publications may be obtained from:

Publications Section
Alberta Research
Edmonton, Alberta
T6G 2C2

Energy Resources Conservation Board
Calgary, Alberta
T2P 0T4

and

Institute of Sedimentary and Petroleum Geology
Geological Survey of Canada
Calgary, Alberta
T2L 2A7

In addition, Alberta Research maintains an extensive file of unpublished reports and memoranda dealing with the industrial and metallic minerals of the province. More detailed information on these minerals c[illegible] provided upon request by the Geology Division, Alberta Research.

General References

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