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A REVIEW OF OIL SHALE INVESTIGATIONS IN AUSTRALIA WITH COMPARISONS TO CANADIAN SYNFUEL DEVELOPMENT

G. Macauley

Geological Survey of Canada (Calgary)
3303 - 33 Street NW
Calgary, Alberta T2L 2A7

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A REVIEW OF OIL SHALE INVESTIGATIONS IN AUSTRALIA WITH COMPARISONS TO CANADIAN SYNFUEL DEVELOPMENT

The world conventional oil market is dominated by three groups. Of these, the most important to Australia and to Canada is the Industrial Free World, of which they are a part, and which comprises the world's principal oil consumers and the world's largest oil importers. A second group, the OPEC nations of the Middle East, are essentially non-industrialized oil producing nations consuming little oil themselves. The third group, Russia and its satellites, produce and consume in balance, being self-sufficient in conventional oil reserves.

Table I outlines the approximate 1984 consumption, production and reserves of conventional oil (and natural gas liquids in the US) for the key areas of the Industrial Free World.

	10^6bbls/day		10^9bbls/year		Reserves		Self Sufficiency
	Con-sumption	Pro-duction	Con-sumption	Pro-duction	10^9bbls	Years	
Canada	1.7	1.4	0.62	0.51	7	11.3	82%
Aust.-N.Z.	0.7	0.5	0.26	0.19	2	7.7	70%
United states	15.6	10.0	5.69	3.65	35	6.2	64%
W. Europe	12.7	3.6	4.64	1.31	23	5.0	28%
Japan	4.6		1.68			0.0	0%
	35.3	15.5	12.89	5.66	67	5.2	43%

Table I: Industrial Free World Oil Consumption, Production and Reserves (from McFarlane, 1984).

The major countries of the Industrial Free world produce approximately 43 per cent of their own oil needs, importing close to 20 million barrels per day, mostly from OPEC countries which produce around 17.5 million barrels/day.

From a trade surplus in 1981, the United States in 1984 will have a balance of payments deficit close to $80 billion, of which over $60 billion can be attributed directly to petroleum imports. The outlays to import oil for Western Europe and Japan are equally as severe.

Synfuels are of great interest within the Industrialized Free World at the present time, not to acquire petroleum products at a lesser cost, but as a means to reduce the extreme balance of payments debts of these nations and at the same time to improve their energy self-sufficiency. Increased internal employment and reduced social benefit costs are also signficant factors.

Oil sands and oil shales are the two major potential sources of synfuels. Liquifaction and gasification of coal resources are also possible but yields from this source are insufficient to reduce significantly the present shortfall of petroleum products. Canada is fortunate in having both of the principal synfuel source sediments. All the other areas, excepting Japan, contain oil shales: Japan is financially active in synfuel development in these other areas.

Canada has maintained a high degree of self-sufficiency by early development of oil sand synfuel. Any comparative analysis of Canadian oil shale developments with those of other countries must recognize that efforts toward oil sands exploitation must be part of the total analysis.

Canadian shortfall of production to consumption is approximately 4.6 bbls/person/year; that of Australia-New Zealand nearly 7.0 bbls/person/year, whereas the United States shortfall is close to 7.3 bbls/person/year. Although the total figures are mostly different, the net trade effect per capita is almost identical for the United States and for Australia-New Zealand.

Remaining conventional oil reserves in Canada have declined steadily over the past several years. The potential for further oil reserves in the western Canada sedimentary basin are limited: probably 2 billion barrels, or less, is the maximum addition that can be achieved by the drilling of a multitude of exploratory wells and developed at a high cost per barrel: offshore and frontier exploration have not achieved the exploratory success anticipated with the initiation of the National Energy Program. The one significant discovery, Hibernia in the east cost offshore, is still debatably economical.

In Australia, the major offshore Gippsland area is expected to enter the decline phase within the next couple of years. Australian petroleum explorationists are not optimistic that new major discoveries are to be anticipated: most of the recent activity has encountered accumulations of limited size.

Thus both Australia and Canada must turn now to the evaluation and development of their synfuel resources. Oil sands are herein Canada's problem, but oil shale knowledge can be mutually beneficial. Australia has several major oil shale resources which are geochemically analogous to Canadian deposits. Although the geological conditions are not identical, a continuing knowledge of Australian oil shale developments can be of great benefit to Canada.

AUSTRALIAN OIL SHALE DEPOSITS

Like Canada, Australia contains a variety of oil shale deposits which range in age from Cambrian to Tertiary, and which represent a variety of kerogen types. Hutton's (1981a) classification of these oil shales is the basis for the classification of Canadian deposits as outlined by Macauley (in press).

All Australian deposits are located in the eastern part of the continent (Fig. 1): of these, the Tertiary Type I lamosites and the Cretaceous Type II mixed oil shales contain the greatest potential reserves (Table II), and have been the object of the greatest exploratory efforts and development research.

TERTIARY DEPOSITS

Tertiary oil shales were deposited in a fresh to brackish water lacustrine environment (Knutson et al., 1984), with deposition occurring in grabens formed during epeirogenic uplift and block faulting (Noon, 1984). Within the north-northwesterly trending grabens, the sediments are essentially flat-lying to gently dipping undisturbed, and oil shales occur as distinct sub-units within the gross interval.

The graben sequences comprise terrigenous clastics, including shales, claystones, siltstones and sandstones. Montmorillonite and kaolinite are variably reported as the dominant clay mineral: illite and mixed layer clays are less common. Quartz is common throughout, both as quartz grains and as opaline silica, whereas feldspar is only present in trace amounts. Carbonates are secondary components, with calcite and occasional dolomite relating to faunal (essentially ostracod) content. Minor pyrite is also associated with the faunal remains. The oil shales occur variably as claystones,

Deposit	Yield l/t	Area km^2	Thick-ness m	Reserves 10^6bbls	Moisture %	Oil sp gr	Delineation	
							Holes	m
Tertiary Type I continental lacustrine lamosites								
Byfield				small				
*Condor	61	60		8,450	7.6	0.89	156	36,000
Duaringa	63		15 25	3,720	31	0.89	68	8,612
Lowmead	65			738	23		22	4,416
Mt. Coolon	120	10	8	600			200	14,000
Nagoorin	67	24		2,650	26		49	10,354
Nagoorin S	57			467	27		16	4,126
*Rundle	84	35		2,650	20		170	33,000
(Kerosene)	95		42	158	21			
(Brick Kiln)	86		85	1,334	20			
*Stuart	76	60		2,510	19	0.89	72	14,195
Yaamba	68	32		3,700	28		42	15,500
Cretaceous Type II marine mixed deposits								
Julia Creek	38	1600	5-7.5	1,700	<10	0.98	1,000	
Jurassic Type I-III continental bog cannel coals **Permian Type I continental bog torbanites**								
Alpha	400		1.0-1.5	20				
Baerami-W	250-500		0.3-1.0	25?				
Carnarvon Ck	250-500		0.3-1.0					
Glen Davis	250-500		0.3-1.0				6	
Newnes	250-500		0.3-1.0	2				
Joadja	250-500		0.3-1.0	2				
Permian Type I marine tasmanites								
Mersey R	113-150		1-2					
Cambrian								
Camooweal	30						2	

Table II: Pertinent data for the evaluation of Australian oil shale deposits, compiled from various sources.
* most studied deposits

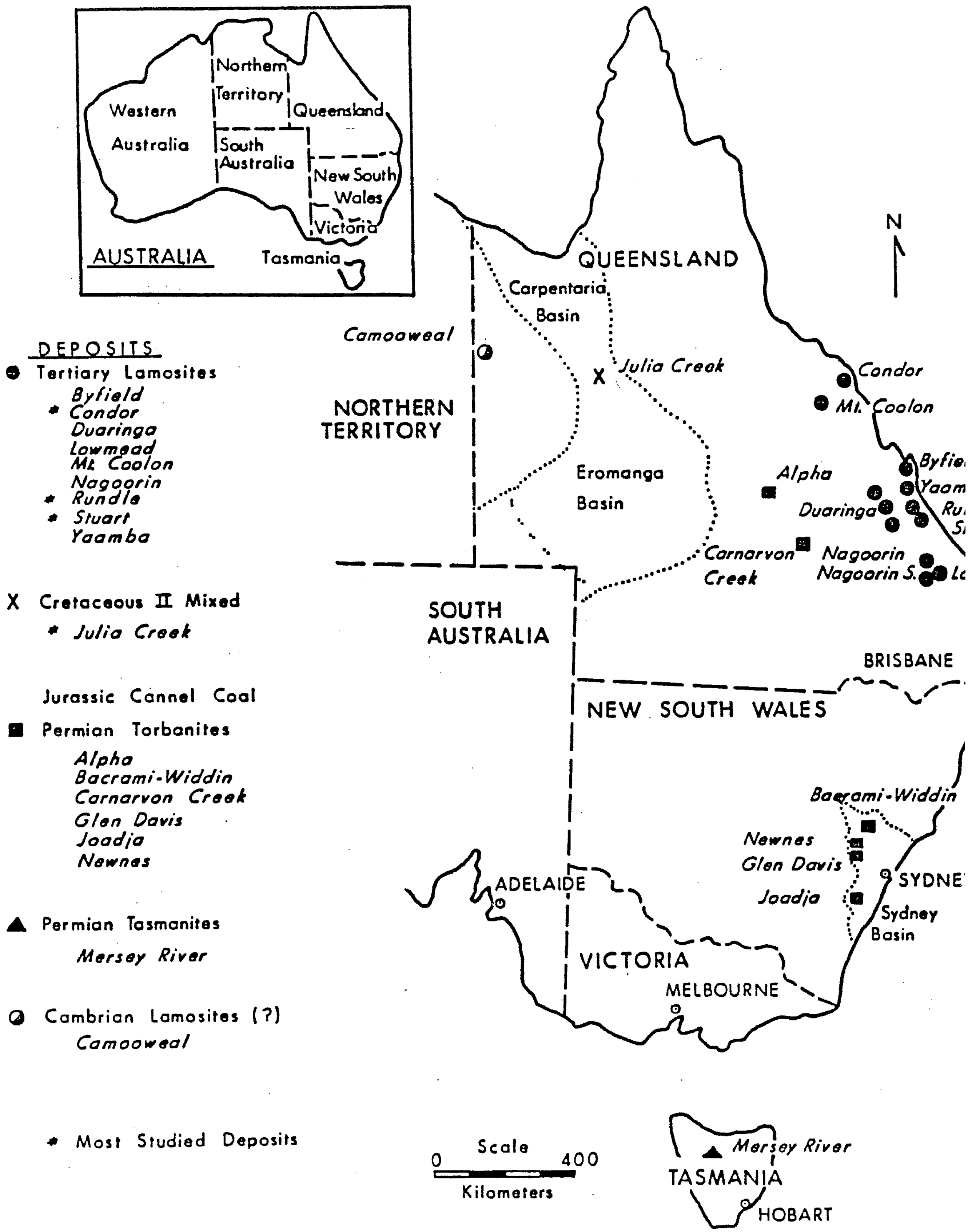

Figure 1: Principal Australian oil shale deposits.

shales and siltstones, may be laminated to massive, and vary through shades of brown to black and olive tinged.

Organic detritus within the Tertiary lamosites is predominantly lamalginite (alginite B) with minor telalginite (alginite A), and a humic content, variable in amount, represented by vitrinite. Locally, beds of brown coal contain mostly vitrinite with secondary resinite, sporinite and cutinite (Hutton, 1983; Henstridge and Hutton, 1984).

Rundle Formation oil shales are closest in character to the Mississippian Albert oil shales of New Brunswick, but significant differences can be recognized. Both are lamosites, composed primarily of lamalginite with minor telalginite; however the lamalginite of the Rundle contained slightly better structural definition than does that of the Albert Formation. There is also considerably more humic content in the Australian shales. Both yield oil products in the 0.88 to 0.89 specific gravity range, have yields in the range 75 to 95 litres/tonne, and are low in sulphur.

Mineralogical differences are the most significant between these deposits, notably the much lower carbonate content of the Australian sediments opposed to the major dolomite constituent of the marlstones and dolostones in New Brunswick. Water content in Rundle beds generally averages 20 per cent, but may be as high as 31 per cent, reflecting the clay nature of the matrix in contrast to the low water content of the dolomite marlstones and the almost water-free nature of the dolostones in the Canadian deposit. Only the clay marlstones of the Albert oil shales have high water content. The Australian Condor deposit is unique among the Tertiary Rundle oil shales at 7.6 per cent moisture (Table II): no explanation was encountered in the literature for this phenomenon.

Another noteable difference is the extreme structural deformation in the faulted and folded Albert beds in contrast to the Rundle oil shales whichare flat-lying to gently dipping.

CRETACEOUS DEPOSITS

Australia's areally largest oil shale deposit is in the Cretaceous Toolebuc Formation of the Eromanga and Carpentaria Basins of western Queensland (Fig. 1). Toolebuc oil shales are Type II marine mixed deposits, having both a marine sapropelic and terrestrial humic kerogen component

(Sherwood and Cook, 1983) from organic petrological studies, and confirmed by geochemical Rock-Eval investigations (Boreham and Powell, 1984). The oil shales are essentially flat-lying, everywhere structurally undisturbed.

Toolebuc oil shale is well laminated, with carbonate interbeds which have the organic matter admixed in a clay-lime micrite groundmass (Hutton et al., 1980a). Saxby (1983) reported the clay to be secondary to the calcite in content, thus defining the low water content (Table II); however, Saxby's samples may have been taken toward the south where the oil shale facies grades to limestone. Dale et al. (1984) indicated quartz to be the second most prevalent mineral after calcite, with a small clay content (mixed layer clays and kaolinite), and minor feldspars and pyrite. The low clay content (<10%) appears to correlate with the low moisture in these oil shales.

Sherwood and Cook (1983) described the kerogen of the Toolebuc oil shales as largely bituminite, a non-fluorescing lamellar component, derived from benthonic or planktonic algae; lesser lamalginite and liptodetrinite, the fluorescing remains of acritarchs, dinoflagellates and algae; and minor telalginite. Hutton (1980a, 1981b) considered the bituminite to be humic detritus because of the non-fluorescing character: the presence of Type III kerogen has since been confirmed by Boreham and Powell (1984) geochemically.

Hutton (1980a, 1981b) recognized the distinct similarity of the Australian Toolebuc oil shale and those of the Cretaceous Boyne and Favel formations of the Manitoba Escarpment in Canada. Both are marine Type II mixed oil shales. Both are mineralogically similar, being best developed where calcite is the grain support mineral; however, the roles of clay and quartz are reversed as low clay account for low Toolebuc water content in contrast to much greater clay and water content for the Canadian shales. The Boyne and Favel beds also contain an abundance of hydrated secondary minerals (zeolites, sulphates, carbonates, etc.), which contain considerable water, and which are not reported from the Australian Toolebuc beds.

Yields on pyrolysis are similar, averaging 40 l/t in the better areas. The pyrolyzed oils are of similar quality, approximately 0.96 to 0.98 specific gravity, and basically are aromatic crude oils. Some of the Julia Creek oil has recorded a specific gravity of 1.037 (Muradian and Stephenson, 1984), somewhat higher than the highest (and thus poorest quality) known specific gravity (0.975, Macauley et al., in press) of the Boyne-Favel oil shales.

JURASSIC CANNEL COALS

Small deposits of cannel coal occur west of Brisbane and southward from the Nagoorin-Lowmead and Carnarvon Creek oil shale areas: none of the Jurassic deposits is considered to be sufficiently large for economic interest even though yields up to 85 l/t have been reported (Noon, 1984). According to Hutton (1981a) these cannel coals, which are also present in Permian and Tertiary strata, contain abundant sporinite, cutinite and resinite, from which the oil is derived. These are all the softer parts of the humic higher plant forms from which the vitrinite is also derived within the cannel coal.

PERMIAN TORBANITES AND TASMANITES

Torbanites occur within the Permian, generally within coal sequences and in direct association with canneloid coals (Knutson et al., 1984). The kerogen comprises up to 90 per cent (of the rock volume) alginite "A" (telalginite), the *Botryoccous* type algae, with secondary amounts of inertinite, vitrinite, sporinite and mineral matter (Hutton, 1981a). These torbanites are comparable to those of the Pictou Group in the Stellarton area of Nova Scotia, but have better average yields than the Canadian deposits because of relatively greater telalginite and lesser vitrinite contents. The Australian torbanites also contain relatively less inorganic mineral matter.

Tasmanites contain the unicellular alga *Tasmanites*, a marine form similar to the fresh-water telalginite of the torbanites. Tasminite oil shales are similarly thin, of limited areal distribution and of low potential shale oil reserves in comparison to the vast Tertiary and Cretaceous deposits. Kerogen in the tasmanites constitutes about 50 per cent of the bulk rock (Hutton, 1981a); consequently, the average yield range is considerably less than that of the torbanites (Table II).

Torbanite deposits of the Sydney Basin (Fig. 1) were first mined in 1865 with a rapid expansion of the industry from 1870-1900 and then a cessation of mining in 1924. Continuous retorting resumed in 1938 and continued through the war years until 1952 (Knutson et al., 1984): at that time, the Sydney Basin area had been essentially mined out. From 1910 through 1934, 10,400 barrels of shale oil were recovered from the tasmanite deposits of Tasmania (Fig. 1).

Of the presently remaining deposits, only that at Alpha in Queensland seems to be of any economic interest but the reserves, estimated at 20 million barrels shale oil, are too low to warrant any serious present investigations.

CAMBRIAN DEPOSITS

Camooweal is a small area of low yield Cambrian oil shale in Queensland (Fig. 1) composed of apparent lamalginite in association with vitrinite-like bituminite which is a possible contributor to the oil yield (Hutton, 1980b). Because of relatively low yield potential and the unit thicknesses (Gibson and Boreham, 1984), these beds are not undergoing any intensive exploratory efforts.

The Camooweal oil shales are limestones, apparently of marine origin. From brief descriptions and limited mineralogical data, they appear to be similar in character and possible origin to the Ordovician Collingwood oil shales of southwestern Ontario, although the groundmass "bituminite" of the Collingwood beds may be more fluorescent than that of the Australian Cambrian oil shales.

PROJECT FUNDING

Oil shale deposits of the Sydney Basin and Tasmania were mined some years ago but the financing and operation of these small ventures are of little consequence to today's problems. The exploration and development of the Queensland oil shales are today's concerns. Most of the financial data for the Rundle Group Tertiary deposits were obtained from the annual reports of Southern Pacific Petroleum N.L. (SPP) and Central Pacific Minerals N.L. (CPM), although data for some of the smaller Tertiary deposits and those of the Cambrian and Permian were obtained from Noon (1984). Data for the Cretaceous Toolebuc oil shales were largely excerpted from a private report published by CSR Limited (1982). The most advanced studies involve three deposits, the Tertiary Rundle and Condor deposits and the Cretaceous Julia Creek oil shales.

PROJECT PARTICIPANTS

Southern Pacific Petroleums N.L. and Central Pacific Minerals N.L. are two Australian companies, basically Australian owned, which joined together in 1973 to undertake oil shale exploration and development. These two companies are closely interlocked, with virtually identical directorships, major common shareholders and shareholdings one to the other. These two companies are involved in all the key Tertiary deposits, Condor, Rundle, Stuart, Yaamba, Nagoorin, Lowmead and Duaringa. In conjunction with partners, these companies have been involved in over $100 million of expenditures on oil shale projects.

CSR Limited (Colonial Sugar Refineries Ltd.) is an Australian share-controlled company with interests in cane sugar, coal, oil, gas, bauxite, alumina, iron ore, chemicals and building and construction materials and which has considerable international interests. CSR controls the Julia Creek oil shale area of the Toolebuc Formation.

Many smaller Australian mineral, mining, coal and energy companies are also represented, mostly in the areas of smaller deposits and fringe to the larger ones.

Exxon is the major western oil company representative, having financed the Rundle Commercializations Study at a cost of A$32 million to earn 50 per cent interest in that deposit. Esso Exploration and Production Aust. Inc. (Exxon) also holds prospecting permits in the Julia Creek area. The only other readily obvious worldwide petroleum participants are Australian Acquitaine Petroleum Pty Ltd. and Shell Development (Australia) Pty Ltd., both of which hold limited acreage in the Eromanga Basin near Julia Creek.

Japanese interests are the other major source of external funding in addition to Exxon. In 1981, the Japanese National Oil Company (JNOC) entered an agreement for a Joint Feasability Study of the Condor deposit by which JNOC would spend US$24 million to earn a major interest. A new corporation, the Japanese Australia Oil Shale Corporation (JAOSCO) was set up with JNOC as the principal shareholder and joint Australian-Japanese personnel to conduct the study. A list of shareholders of JAOSCO (Table III) provides an insight into the broad spectrum of Japanese interests which support oil shales research. The Japanese Oil Shale Engineering Corporation will make further expenditures to test Condor shales in an oil shale processing pilot plant which has been constructed in Japan. Considering that Japan must import all of that nation's 4.6 million barrel per day oil consumption, and recognizing the exports required to balance these oil imports, one can readily understand the participation of so much Japanese industry in the quest to assure oil supplies and to gain back at least some of the profit of the import costs.

JAPAN AUSTRALIA OIL SHALE CORPORATION

Japanese National Oil Corporation

Oil Refining
- Asia Oil Co. Ltd.
- Idemitsu Kosan Co. Lta.
- Kashimi Oil Col. Ltd.
- Kyodo Oil Co. Ltd.
- Maruzen Oil Co. Ltd.
- Mitsubishi Oil Co. Ltd.
- Nippon Mining Co. Ltd.
- Showa Oil Co. Ltd.
- Taiyo Oil Co. Ltd.

Trading
- C Itoh & Co. Ltd.
- Marubeni Corporation
- Mitsui & Co. Ltd.
- Nichimen Co. Ltd.
- Nissho Iwai Corporation
- Sumitoma Corporation

- The Industrial Bank of Japan
- The Long-Term Credit Bank of Japan Ltd.
- The Nippon Credit Bank Ltd.

City Banks
- The Bank of Tokyo Ltd.
- The Dia-Ichi Kangyo Bank Ltd.
- The Fuji Bank Ltd.
- The Mitsubishi Bank Ltd.
- The Sanwa Bank Ltd.
- The Sumitoma Bank Ltd.
- The Tokai Bank Ltd.

Steel
- Kobe Steel Ltd.
- Nippon Kokan KK
- Nippon steel Corporation

Heavy Machinery
- Hitachi Shipbuilding and Engineering Co. Ltd.
- Mitsubishi Heavy Industries Ltd.
- Mitsui Engineering and Shipbuilding Co. Ltd.

Cement
- Mitsubishi Mining and Cement Co. Ltd.
- Onoda Cement Co. Ltd.

Engineering
- Chiyoda Chemical Enginerring & Construction Ltd.
- JGC Corporation

Construction
- Aoki Construction col. Ltd.
- Kajimi Corporation
- Shimizu Corporation

Table III: Shareholders of Japan Australia Oil Shale Corporation (JAOSCO)

EXPLORATORY-DEVELOPMENT DRILLING

The Queensland Department of Mines drilled 33 holes for oil shale exploration in the period 1915-1982, with 18 of these drilled in 1941-1943 because of the petroleum shortage during the war years. Over 1800 core and drill holes, representing a minimum 140,200 m of penetration, are jointly listed in Table II: these data are very much incomplete, but indicate the major ore delineation effort by the corporate sector of the economy. Actual drilling costs are lost within the total expenditure values reported for individual deposits.

In contrast, only 185 coreholes (Nfld, 2; N.S., 5; N.B., 94; Ont., 40; Man. Escarpment 41; QCI., 3) have explored for Canadian oil shales. Of these 125 were financed by government sources and 58 by industry. This ratio is not directly comparable to Australian activity as no Canadian delineation coring has yet been done. Eighty of the N.B. cores and 36 from the Manitoba Escarpment have been lost or destroyed.

On the basis of oil shale comparison alone, Canada severly lags Australia, but, on a synfuel basis including the Alberta oil sands, the Canadian drilling record will certainly surpass considerably that of Australian efforts toward petroleum self-sufficiency.

RUNDLE PROJECT

The Rundle Commercialisation study was carried out by Esso Exploration and Production Australia Ltd. at a cost of A$32 million over a three year period and has just been completed. The programme involved investigations on mine planning, shale retorting, product upgrading, infrastructure and environment as well as pilot plant testing in the US, Sweden and Germany. Much of the effort was directed at techniques to minimize costs. First stage production of 5.2 million barrels of upgraded shale oil is estimated to require US$645 million: the total project, to produce 26 million barrels per year (71,000 BOPD), would have an investment cost of US$2.65 billion. Delineation drilling to establish reserves was completed by SPP-CPM prior to Esso's participation in the Commercialization study.

CONDOR PROJECT

As a result of the US$24 million JAOSCO study, the best economics are calculated at 26.7 million barrels per annum of upgraded shale oil at a capital cost of US$2.3 billion, an almost identical figure to the independent estimates for the Rundle deposit. The project estimates 12 years to design and complete construction, with the first product in year 6, and build-up to full production over three 2 year staged increases.

Three hundred twenty individual contracts were included within the Condor feasability study.

JULIA CREEK PROJECT

CSR Ltd. has spent approximately $15 million to determine the ore reserves of the deposit, to construct a pilot plant for oil shale retorting and to investigate economic and market conditions. A preliminary feasability study for the construction of a 100,000 to 115,000 barrel per day upgraded shale oil operation was prepared at a cost of $1.1 million over a 19 month period. The capital cost is estimated at $5.8 billion and includes three open cut mines, several retorts, a hydrotreater, a 100 km pipeline to Brisbane, a townsite for 16,000 people, water supply and other infrastructure.

GOVERNMENT FUNDING

Alfredson (1984) has outlined the scope for future Australian oil shale research and development and the probable funding sources, as follows:

a) Characterisation of their behaviour in a variety of established retorting processes, principally by testing in overseas pilot plants (industry cost).

b) Research, development and demonstration of new processes and technologies tailored to specific deposits (industry and government funding, in initial stages, industry in final phase).

c) Solution of problems in the initial (mining, beneficiation and drying) and final (upgrading, waste disposal and rehabilitation) processing stages for specific deposits (government and industry).

d) Novel processes which may lead to significant improvements in economics (government and industry).

e) Assessment and feasibility studies (industry).

The Australian Commonwealth Government is currently contributing approximately $4 million to research at the Universities and to the Commonwealth Scientific and Industrial Research Organization (CSIRO), a research organization similar to the Research and Productivity Council of New Brunswick. Industry is currently contributing about $1.5 million to University Research.

A specific example of a federal contribution is a grant of approximately $300,000 to the University of Wollongong where facilities have been established for all aspects of organic petrology: Wollongong is now the key center for this specific research for all Australian requirements of this nature.

The Commonwealth Government is also involved through the Bureau of Mineral Resources, Canberra, where the Geology-Geophysics section now have a geochemical laboratory similar to that at ISPG, Calgary.

Direct grants are made to CSIRO and the Universities through the National Energy Research Development and Program (NERDP).

The Queensland State Government does not appear to be directly involved in financial grants and/or research facilities, but does act as the sorting ground for industry reports and the Queensland Geological Survey is actively involved in geology from the area, particularly in reports such as Noon (1984).

RESEARCH FACILITIES

Table IV, excerpted directly from Alfredson (1984), summarizes the areas of oil shale research and institutions and organizations involved in each general area. More specific comments will be made in the review of individual research categories and projects.

The Commonweatlth Scientific and Industrial Research Organisation (CSIRO) is funded by a combination of government grants and industry contracts. In this aspect, CSIRO must be financially self-sustaining as there is no continuing government base level support. Although CSIRO and RPC, New Brunswick, are similar in character, CSIRO is much larger, has many more divisions, is nationwide, and encompasses other research domains (i.e., agriculture).

Topic	Organisations Involved		
	Tertiary Institutions	CSIRO Divisions	Industry and Others
Characterisation - geology, petrography, chemistry, physics	ANU, JCU, Melb, New, NSW, QIT, Qld, Woll	EC, FF, M, ME	BMR, CSR, MRL, QLD, SPP/CPM
Beneficiation, online analysis	QLD	MP	ACIRL, Esso, SPP/CPM
Chemistry of retorting (pyrolysis mechanisms, kinetics and thermo-chemistry), combustion and gasification of spent shale	QLD, Tas, WAIT, Woll	EC, FF, MC, ME	AMDEL, CSR, Esso, MRL, SPP/CPM
Retorting processes, technology, flowsheets, economics	Mon, Qld	EC, ME	CSR, SPP/CPM
Upgrading of shale oils - characterisation, hydrotreatment, testing	NSW, Mac, Woll	EC, MS, ET	BHP, CSR, Esso
Environemtal studies - leachates, retort waters, waste treatment, revegetation	Qld, Woll	EC, FF, GWR	CSR, Esso

Tertiary Institutions*: ANU-Australian National University, JCU-James Cook, Mac-Macquarie, Melb-Melbourne, Mon-Monash, New-Newcastle, NSW-New South Wales, Qld-Queensland, QIT-Queensland Institute of Technology, WAIT-West Australian Institute of Technology, Woll-Wollongong (*Universities unless otherwise stated).

CSIRO Divisions: EC-Energy Chemistry, ET-Energy Technology, FF-Fossil Fuels, GWR-Groundwater Research, M-Mineralogy, MC-Mineral Chemistry, ME-Mineral Engineering, MP-Mineral Physics, MS-Material Science.

Industry and Others: ACIRL-Australian Coal Industry Research Laboratories Ltd; Amdel-Australian Mineral Development Labratories Ltd., BHP-Broken Hill Proprietary Co. Ltd. BMR-Bureau of Mineral Resources, Geology & Geophysics, CSR-CSR Ltd., Esso-Esso Australia Ltd., MRL-Materials Research Laboratories, Department of Defence, QMD-Queensland Mines Dept., SPP/CPM-Southern Pacific Petroleum NL/Central Pacific Minerals NL.

Table IV: Summary of oil shale research in Australia (excerpted from Alfredson, 1984).

Although only indirectly involved in oil shale projects, the Australian Coal Industry Research Laboratories Ltd. (ACIRL) is in part similar to CSIRO in doing contract research but has a continuous, somewhat fluctuating base fund from a royalty of 1¢/ton on coal production.

Although CSIRO overshadows RPC, a comparison to Canadian research must also include the major efforts of the Alberta Oil Sands Technology and Research Authority (AOSTRA) which is similarly funded to the above research groups, and which provides the major research impetus for Canadian synfuel investigations.

Numerous Universities are listed in Table IV as efforts are being made to include most of the educational institutions of that country. Within each topic group, the more specific topics are generally related to only one of the research organizations. Within the characterisation section, organic petrology is concentrated at the University of Wollongong, and organic geochemistry (Rock-Eval pyrolysis and related investigations) is carried out at the Bureau of Mineral Resources. Retorting and beneficiation research is most significant in the Engineering department at the University of Queensland.

Like Canada, Australia has a small population and limited funds for research facilities; consequently, efforts are being made to avoid duplication of facilities. A major concern, expressed by oil shale workers from all facets of oil shale research, was the lack of a specific co-ordinating person or persons to ensure the continuous exchange necessary to prevent such duplication. This should be the duty of the Bureau of Mineral Resources, Canberra, the comparable body to the Geological Survey of Canada. Canada has been fortunate that ISPG has been able to assist Canadian research cooperation on oil shales, but a closer coordination with oil sands efforts will be necessary in the future. Minimum water supplies for the present oil sands type of oil separation process and the difficulty in disposing of the contaminated residue water make a retorting process, similar to those for oil shales, essential for further oil sands development.

Research facilities contained within industry laboratories are not often described, but two research approaches have been reported. CSR Ltd. has a pilot retort and Esso Australia Ltd. is conducting bench scale testing of a fluidized bed retort system.

During the past five years of involvement with the Canadian oil shale scene, one concern has nagged at this writer throughout. Many of the Universities appear to be building facilities based on major research contracts. Within these contracts, much of the technical work is being done by research graduate students who appear to be earning a degree for technical efforts rather than for an expanded knowledge base. The primary purpose of a University is the gathering and distribution (teaching) of knowledge. Research is part of this process, but the development of new knowledge must remain secondary to teaching and learning. There is an impression that the present style of research contracts obtained by Universities, both in Australia and Canada, is leading to the use of students as technical assistants whereby the broadening aspect of education, especially at post-graduate levels, is lost for these students. Major research projects may be much better retained within organizations such as RPC and CSIRO.

RESEARCH PROJECTS

Although considerable research has been done on Australian oil shales, only few data and results are currently available in the "scientifically acceptable" journals and periodicals. Most are published as un-refereed unedited brief (6 pages or less) concise resumes of the activities in the Proceedings publications of the Australia Workshops on Oil Shale*. These papers do not provide details from which the reader can re-interpret the results and conclusions, but do provide the source whereby research concepts can be aquired. Further direct contact with the authors, research laboratories and organisations involved can allow investigators to determine the implications of the reported results, both positive and negative, long before publication appears in a scientifically precise form. Similarly, in North America, Proceedings of the Eastern Oil Shales Symposia are published by the Institute for Mining and Minerals Research, University of Kentucky, and papers from an annual oil shale meeting, mostly concerning western US oil shales, are published by the Colorado School of Mines. All of these publications are essential to the libraries of any organization involved in oil shale research.

*Available through: The Secretary, Australian Workshops on Oil Shale, CSIRO Division of Energy Chemistry, Private Mail Bag 7, Sutherland, NSW 2232, Australia.

GEOLOGY

Stratigraphy and structure are relatively straightforward for all Australian oil shale deposits. Stratigraphic problems primarily concern the correlation, areal distribution and thickness variations of oil shale beds and related lithologic variations within shallow dipping structural monoclines. These geological factors have all been mapped from the major coring and drilling programs for almost all deposits.

There are presently insufficient cores of most Canadian deposits to define zonation with the oil shale intervals, although such efforts by the Ontario Geological Survey are well advanced for the Collingwood and Kettle Point deposits of southwestern Ontario. Because of the complex stratigraphic-structural characteristics of the New Brunswick Albert Mines desposit, the lack of sufficient core data is there a serious inhibiting factor for economic evaluation.

Excellent core storage facilities appear to be available at or near almost all deposits: several articles include pictures of excellent modern storage racks and core boxes wherein core slabs are retained for permanent reference, and the remainder of the core is available for analyticial studies. Facilities are listed at Prosperpine near the Condor deposit and at Gladstone near the Stuart and Rundle oil shale areas. The financing of the storage facilities, whether government or industry, was not determined.

Cores of Alberta's oil sands deposits are retained and stored by the operating companies: selected cores are available at the Energy Resources Conservation Board in Calgary. British Columbia has the cores of the Kunga oil shales, even though uneconomic as oil shales beds, stored in adequate facilities at Fort St. John. Although most of the Canadian oil shale core is now stored indoors, little is contained within good facilities with proper boxing and recording, and appropriate examination areas.

Although not an apparent problem for Canadian oil shales, surface weathering of deposits below the overburden is an Australian concern because of variations of yield related to this phenomenon. The weathering effects are easily identified from the large amont of available core.

CHARACTERIZATION

As in Canada, oil shale characterization is being accomplished by a variety of techniques.

Organic petrology is available for all the Australian oil shales and includes both transmitted and reflected white light microscopy as well as fluorescence mode microscopy. Most of these studies were conducted at the University of Wollongong.

Rock-Eval pyrolysis data and interpretations, produced at the Bureau of Mineral Resources, Canberra, are now available for several key deposits. In Australia, Rock-Eval is following up the organic petrology, a reverse order to Canadian investigations. In both countries, all deposits will ultimately be covered by both techniques as together they provide an excellent understanding of the kerogen content and thermal maturation levels.

Although Rock-Eval pyrolysis can be equated directly to Fischer Assay results, the economic potential is being defined in Australia primarily by the Fischer Assay methods. The measurement of water content is an essential value derived from the Fischer Assay. The amount of water must be characterized for two reasons; the water consumes considerable heat within a retorting process, and hydrogenation during retorting requires a molecular ratio of 2:1 water to CH_4 to generate CO_2 plus free hydrogen. Hydrogenation during retorting will be controlled by the water in the system and the CH_4 available from primary retorting process.

Some Fischer Assay results are considered to be in doubt as water will separate from the oil yield for several weeks after the analysis. Somewhat lower average oil yields result if the oil is centrifuged to remove water prior to measurement.

Direct analyses of hydrogen, carbon, sulphur and nitrogen are standard procedures. Care is being taken to determine the hydrogen available from the kerogen as opposed to inorganic hydrogen, especially that from the water phase. Similarly, careful determinations are being made for all deposits to define organic versus inorganic sulphur and nitrogen. Interpretations of kerogen classification have been attempted from nitrogen content variations.

Several other techniques have variably been utilized to classify kerogen type and determine maturation levels. Solid state nuclear magnetic resonance (NMR) has been used to define the aromaticity of the kerogen, especially near igneous intrusive bodies. Electron spin resonance (ESR) studies have also been equated to type and maturation, and correlated to Fischer Assay results. Although correlative to the Fischer Assays, the correlation relationships differ with individual deposits. XRD and scanning electron microsocpy have been used to investigate the kerogen components as has infra-red spectrophotometry. These sophisticated techniques have invariably confirmed the interpretations of the combined organic petrology, Rock-Eval pyrolysis and Fischer Assays.

Trace elements have been determined by spark source mass spectrometry, neutron activation analysis and nuclear magnetic resonance determinations. Some 70 elements, of which 64 are trace, were evaluated, and are still under study with three primary objectives: to determine any potentially commercial by-products; to determine whether these elements are contained within the organic or inorganic phase; and to determine their direction during retorting, whether to the oil, the retort waste water, or to remain in the char. These aspects are important to the oil product and also extremely significant as harmful elements (i.e. arsenic), can ultimately be released to the environment in water or in waste residue .

Like most oil shales, nickle and vanadium are common with vanadium present as both organic vanadium prophyrin compounds and as inorganic calcium vanadates. Vanadium is generally present in sufficient quantities that by-product extraction would saturate and flood the world market well beyond present requirements. Trace element analysis has only been scratched for Canadian deposits; much additional study will be required for environmental concerns.

MINING

Slot cuts, long linear shallow cuts to acquire sufficient tonnage of ore for retorting research, have already been described for the Condor and Rundle deposits. These cuts have additionally provided the necessary geotechnical (rock mechanics) studies to determine the potential for selective seam mining and for the mining methods. These include equipment types, blasting requirements and conveyor systems.

Blasting experiments at Condor included holes both parallel and perpendicular to bedding to determine the character of the blast hole and the influence of bedding and joint planes on the size and shape of the blast fragments.

Because of the extreme lithologic variations within the New Brunswick Albert oil shales, a north-south slot cut across this deposit will certainly be an initial requirement to determine the preferred mining techniques and to assess the rock characteristics for wall stabilities, blasting requirements etc. This Canadian deposit is also at the stage where large volumes of ore will soon be required for larger scale retort testing beyond the present bench systems.

The large amounts of coring and drilling for resource assessment has also provided excellent control for overburden to ore ratio calculations: these data are systematically reported for all Australian deposits.

One *in situ* experiment was carried out on the Toolebuc oil shale at Julia Creek. Rock mechanics data, including Young's Modulus, Poisson's ratio and compressive strengths for the oil shale, and for overlying and underlying strata, were computer modelled to determine the sizes and locations of charges. The oil shale was fractured satisfactorily but an overlying coquina bed did not compress as desired and the underlying shale was undesirably fractured. Combustion was hard to maintain in coal used for retort ignition. Although a burn most certainly occurred in the *in situ* retort, no oil was recovered, presumably because of condensation into the underlying shale beds.

BENEFICIATION

Oil shale economics dictate that a maximum amount of oil must be recovered from a minimum amount of ore; consequently, beneficiation, the concentration of kerogen by the removal of waste host rock prior to retorting, is now a prime concern of Australian oil shale projects. Beneficiation of Stuart oil shales has been attempted by flotation, crushing/screening, grinding/screening and gravity separations. Flotation is considered unsatisfactory because of excessive grinding required and the cost of de-watering of a fine concentrate. Although a flowsheet indicated that 75 per cent of the oil could conceivably be recovered from 50 per cent of the original rock at Stuart, from processes including crushing, wet tumbling, size sorting and gravity separation, the defined benefication procedure is not thought to be directly applicable to other oil shale deposits.

The three oil shale lithotypes at Albert Mines, Canada, are known to grind differently and to have different specific gravity ranges. The benefication of these beds, especially by the removal of the lowest grade clay marlstone from the system prior to retorting, will be essential to an economic operation, and separation techniques should be a subject for study in the near future.

RETORTING-UPGRADING

Some of the Australian oil shale workers feel that too much effort is being placed on retorting and upgrading, especially retorting, in comparison to the expenditures toward environment, infrastructure and other related topics. Because the economics of oil shale development will become profitable only by successfully improved retorting-upgrading processes, all other investigations are, in essence, inconsequential until that success has been achieved.

Ore from both the Rundle and Condor deposits has been pilot retorted in the German Lurgi retort and in the United States Tosco and Dravo retorts. Condor ore has also been retorted at the Paraho site in the US. Mention is made of tests in Sweden but the specific retort type has not been reported. Both Paraho and Dravo generate heat by burning char below the oil generation zone: the Paraho retort is vertical whereas Dravo utilizes a circular grate. A benefit of the Dravo process is the ability to utilize fines by an agglomeration process. Most retorts are unable to process the fines fraction of the ore. Tosco introduces heat through ceramic balls whereas Lurgi introduces heat from an external source but by utilizing the heat from spent shale. The CSR continuous retort, which has operated at Sydney since 1970 using Toolebuc ore at 0.5US tonne/day, also derives heat and power from spent shale. Several retort processes provide heat by the introduction of hot gases: none of these has been investigated for the Australian deposits. By general concensus, the Lurgi retort appears to be most favoured at the present time.

Exxon is conducting bench scale fluidized bed retorting studies on the Rundle oil shales, and CSIRO is now also involved in fluidized bed research.

Sulphur content of the Toolebuc shales averages over 3 per cent and up to 10 per cent in the better oil yield intervals. When spent shale is used as the heating agent at the CSR retort, the lime content reacts to produce $CaSO_4$, thus signficantly reducing SO_x emissions.

Bench scale retorting has been attempted with varying atmospheres, including nitrogen, hydrogen, steam and with toluene dense gas solvent in the presence of hydrogen. In general, nitrogen had little beneficial effect, but the value of hydrogen has been definitely established. The effect in hydrogen is greatest where the aromaticity of the original shale oil is highest. The quality of the oil is not particularly upgraded but the quantity is greatly increased as the additional hydrogen retains aromatics which are normally reduced to gas and coke. The presence of steam in fluidized bed tests of the Condor shales appears to have promoted much better initial evaporation of the oil, to have reduced the coking effect and also to have promoted better and quicker condensation of the oil in the recovery sector of the retort.

Similar studies are basic research efforts at the Research and Productivity Council in New Brunswick for Canadian oil shales. Very little shale oil is of sufficiently good quality to be an immediate refinery feedstock. The upgrading, i.e. the addition of hydrogen, can be done in three areas; during the retorting process, at an upgrading plant associated with the mine, and at modified refineries designed to utilize the lower quality crude. The Australian industry estimates the cost of upgrading after retorting at 40 per cent of the product value. Similar major expense would also be anticipated for the modification and/or replacement of refineries, especially in Canada where our refineries are all designed to operate on high quality crude. An analysis of the Australian retorting research indicates that the supply of hydrogen to the retort by a combination of steam and recycled gas may be a most effective technique, although this may not solve the problems if only quantity is increased and quality is not substantially improved. Sun Oil Company attempted steam-gas upgrading of the very heavy shale oil from the Cretaceous Boyne and Favel formations of the Manitoba Escarpment.

The retort char is receiving considerable attention from Australian researchers because of the large amount of energy left in this residue. The use of spent shale as a heating agent in the retort has been discussed. The char can also be burned in an oxygen atmosphere for the direct production of heat, or can be gasified with steam or CO_2 to produce low to medium Btu gas for plant or other use. These prospects are all under review in Australia.

Because of the poorer quality of Toolebuc shale oil compared to the Rundle oils, most of the upgrading research concerns Toolebuc oil. Jet and diesel fuels have both been produced successfully from Julia Creek shale oil at the CSIRO laboratories and research continues into the upgrading of the shale oil naphtha to gasoline. Thiophenes in the shale oil are a major problem. Three commercial catalysts, involving Ni-Mo, Co-Mo and Ni-W, have been evaluated for their effectiveness in upgrading Rundle shale oil. Research on this phase of the New Brunswick deposit should be an early further step in Canadian oil shale evaluation. Although retorting and upgrading research may soon be warranted on the Ontario Kettle Point oil shales, the research into eastern United States oil shales,of equivalent age and character, will be there of greater assistance than will the Australian efforts.

OIL CHARACTERIZATION

Most of the characterization of oils from pyrolysis of both whole rock and kerogen concentrates involves analysis by gas chromatography, similar to Canadian procedures. The results vary between yields from whole rock and those from kerogen concentrates. On an economic basis, only the whole rock results are significant as the extraction and retorting of pure kerogen is not considered as a potential industrial process. Analysis of the oil product from isolated kerogen is strictly a scientific investigation. Other factors, such as inorganic mineralogy, kerogen distribution (laminated, isolates, matrix material) and retorting processes often negate direct correlation of shale oil and kerogen characteristics.

Comparisons of retorted and upgraded oils usually involve nuclear magnetic resonance (NMR) and electron spin resonance (ESR) as the molecular structures of the oil products must be identified for refining purposes. Gas chromatography-mass spectrometry is also being utilized for specific component identifications. Such studies are not particularly advanced in Canada at this time.

ENVIRONMENT

Rundle oil shale deposits occur sufficiently close to the Australian coastline that the climate is generally hot, humid semi-tropical: in contrast, the Toolebuc deposits occur inland in a hot but dry climate. Environmental problems will be minimal for Toolebuc shales in comparison to those for the Rundle; consequently, virtually all Australian environmental research is being concentrated on the Rundle deposits. Canadian investigations have not yet advanced to the stage requiring environmental evaluations as the organic-inorganic nature of residue materials and retort waters have not been defined. Because of the great difference of the Alberta oil sands environment to those of Canadian oil shales, the applicability of the oil sands environmental research may be of limited applicability to oil shale development.

Australian research is concentrating in three key areas: retort water, leachates from the residues, and the revegetation over waste materials.

Trace elements have been characterized for both retort waters and leachates, and are particularly concentrated on such poisonous elements as arsenic. Retort waters have been studied for cyanides and thiosulphates. Some of organics in the retort water were found to be carcinogens. The use of spent shale to absorb the retort water is under investigation. Even though the intent is to isolate residue deposits within the total environment, studies have been made to determine the distance that leachates will travel within streams and the ultimate disposition of any such leachates.

In this aspect, the retorting technique becomes extremely significant. Where retorted shale can be again utilized within the process for heating, both in heat transfer and in direct burning, the carbon available for organically undesirable residue can be severely reduced. Preferably all organic carbon should be removed during the process, all residue coke should be burned, and the mine fill should be essentially free of potential organic leachates. This would not be such a significant factor for the dry climate of the Julia Creek area.

Waste deposits comprise spent shale, consolidated (rock) and unconsolidated overburden materials, lower grade oil shale rejected from the process, and topsoil. Admixtures of these components have been subjected to seeding, with and without fertilizer addition, by a seed mixture of a variety of indigneous plants types. These various waste admixtures have also been studied in their growth support for woody types (primarily eucalyptus) and have been analyzed for the depth of root penetration.

ECONOMICS

The intial economic evaluations for Australian oil shales indicated a required price of US$40/barrel, approximately $10/bbbl above world oil price at that time. World oil price has since dropped $2/bbl, widening the gap, but the results of Australian research indicate that a reduction of shale oil value by at least $6/bbl can be achieved, primarily by improved retorting methods to provide greater yields and better by-product quality. A gap of $6/bbl is still in their calculations.

Because conventional oil production has in the past been a high profit industry, government royalty has become an integral part of the system, based on the concept that the petroleum resources belong to the people. This royalty aspect is built in to the cost estimates for oil shales. Although the specific amount is difficult to determine from the summarized data available, the Australian calculations apear to allow up to 25 per cent of the sale value for royalty and tax, that is $9 to $10/bbl. Without an allowance for royalty, the Australian deposits are currently economic.

Any undeveloped resource has potential value, but while still in the ground, is valueless. A monetary profit to the nation and the developer can be ascertained directly by the difference in cost of production and the sale value. But socio-economic benefits to the nation can go beyond the direct profit in an unmeasureable way.

For any country to remain economically sound, the trade of goods must remain in balance. The import of oil from the OPEC nations is creating major trade deficits because those nations do not buy goods in exchange. The money returns as a purchase of the assets of the importing nations. Such imports can only be continued by the continuing sale of the nation to foreign control through the above loss of corporate control and increasing national deficits.

Internal development of more expensive resources, such as oil shales and oil sands, can have major effects on a country's control of its own industry and its ability to maintain an even trade balance. This has a direct financial benefit to any nation. Further socio-economic benefits are readily visible by increased employment and increased personal taxation income to the governments.

Large amounts of money have been spent on oil sands research in Canada, probably much more comparatively than on Australian oil shales. Canadian funding is from government sources. Much of the Australian funding has been from industry, with a considerable part from foreign sources, especially Japanese.

When the Canadian oil industry first started after Leduc, tax laws prevented write-off of petroleum industry expenses against income from any other business sources. More recently, the Canadian Government has allowed companies to write off oil industry investment against other income at 20 per cent per year. This resulted in a plethora of individuals providing funds for a multitude of exploratory programs, many of them scientifically unsound, but did not create an influx of capital from Canadian corporate entities.

Considerable insight can be gained from a review of Table II, the list of companies involved in JOASCO. At the Yaamba deposit, the Australian Peabody Pty. is backed by six American corporations; Boeing Company, Bechtel Corporation, Fluor Corporation, Newmont Mining Corporation, Equitable Life Assurance Society and the Williams Companies. If Canada provides incentives for the development of its own oil shales only a small part of profits leaves the country and facilities and employment will remain in Canada. One must contrast this to present oil imports from OPEC where all such fuel costs leave the country and no facilities or employment result. One possibility is for governments to participate on a shared profits basis, so that the guaranteed prices now sought for oil shales-oil sands development perhaps would not be necessary. A price structure which would assure a minimum return of capital expenditure would be required, but would allow considerable price flexibility relative to world oil prices.

Australians estimate that, starting now, an oil shale industry could produce 500,000 bbls/day by the year 2002, a seventeen year devlopment period. The CSR report on Julia Creek does not anticipate starting full scale constructuion until 1995 as ten years lead time are still required to reach that point in oil shale development. This potential oil shale production is not considered sufficient to cover both the present Australian shortfall and the anticipated decline of domestic conventional oil by that time.

SUMMARY

A continuing knowledge of Australian oil shale developments will be most beneficial to Canada for development of the New Brunswick Albert Mines deposit, somewhat comparable to the Australian Rundle oil shales, and for the Cretaceous oil shales of the Manitoba Escarpment, geologically similar to the Australian Cretaceous Toolebuc deposits. Because there are no Australian deposits directly comparable to the southern Ontario Kettle Point and Collingwood oil shales, Australian research may be only indirectly pertinent; however, research into Devonian oil shales of the eastern United States will benefit the stratigraphically equivalent Kettle Point beds. Australian torbanites of the Sydney Basin, comparable to those of the Nova Scotia Pictou area, have been previously mined and present reserves are insufficient to warrant much interest.

A reversal of water content across the Australian-Canadian comparable oil shales (Rundle, high - Albert, low; and Toolebuc, low - White Specks, high) will restrict the direct application of retorting results across the otherwise similar deposits.

The Canadian deposit at Albert Mines, New Brunswick, is now at the point where a slot cut should be mined and larger scale retorting attempted. Much greater detail of lithotype and ore distribution could thus be obtained. The proposed pilot plant, co-retorting with high sulphur coal should encompass the above concerns.

All Canadian oil shale deposits are lacking in geological definition because of minimal coring efforts to date. This is best done by work commitments to the exploring companies, except in Ontario where the acreage is all freehold.

On the basis of a synfuels development, Canadian efforts probably exceed those of Australian by a significant margin because of the construction of two oil sands plants which reduce considerably Canadian dependence on offshore crude. Canadian oil shale investigations match those of Australia in characterization of the oil shales and of pyrolyzed oil but severly lag those of Australia in retorting and upgrading.

Several thoughts are key to the formation of government policies regarding synfuels:

1. Almost all oil producing areas of the western free world are at, or are near to, the period of conventional oil decline, especially of the early discovered inexpensive oil fields. The development of a synfuel industry in Canada will require at least five years for further oil sands plants, and as much as 18 years to develop significant oil shale production. Whether or not synfuels can be developed at a rate to offset decline of conventional oil and reduce imports is doubtful.
2. Strong social benefits from synfuel development would include increased employment, increased petroleum self-sufficiency and control of ones own corporate structure.
3. The United States and Australia do not as yet have any synfuel production, and Canada has essentially halted oil sands development.
4. Without any supporting economic statement, this writer intuitively feels that the development of a 5,000 to 10,000 barrel/day shale oil operation at Albert Mines, co-combusted with coal, would be profitable to Canada and to the Maritimes area. Minor oil import reduction could be achieved, employment would be stimulated, and the entire synfuels industry would be advanced significantly. At present prices, the import reduction (10,000 bbbls/day) would improve Canada's trade balance by Can$128 million per year.

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