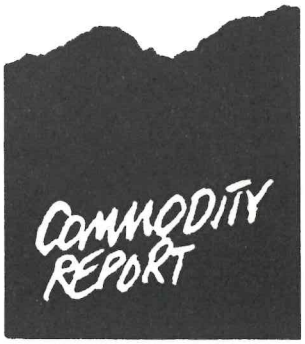

The world uranium industry

By A D Owen

In the 1970s there was a worldwide boom in uranium exploration and recovery. Since then the accident at the Three Mile Island reactor in the US, the global recession and the subsequent reduction of the demand for electricity has led to a de facto moratorium on the construction of new nuclear plants. The result has been a severely depressed uranium market and large stockpiles, especially in the US, which has the largest nuclear-electric generating capacity among the OECD countries.
From this perspective A D Owen analyses the world uranium market today, and particularly the configuaration of ownership and control in the industry.

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INTRODUCTION

Currently just eight countries account for the bulk (about 98 per cent) of the Western World's production of uranium, with little possibility of this group being expanded over the next decade. Current and projected levels of production for these countries are given in Tables 1 and 2. Table 1 presents projections of production capabilities made by the Organization for Economic Co-operation and Development (OECD) in 1981, whilst Table 2 presents more recent estimates of future levels of production published by the Nuclear Exchange Corporation (NUEXCO)[1] in April 1982. Even allowing for the different dates on which the data were gathered, the difference between these two sets of estimates is remarkable.

The OECD projections given in Table 1 "show the maximum rate of production (chiefly from existing reserves) that could be achieved from the existing and planned production centres supported by the principal resource categories given an adequate market, a favourable economic climate and realistic assumptions for lead times and ore processing plant capacity". They predict a reasonably high rate of growth of world uranium production up to 1985, with a noticeable slow down occurring thereafter. Australia, Canada, Niger and the United States are all envisaged to experience significant levels of growth during the 1980s, with U S production[2] rising to 28 kt U_3O_8 by 1990. The critical phrase in the above quotation, however, is "given an adequate market, (and) a favourable economic climate", two conditions which have been noticeably absent during the early 1980s.

The NUEXCO projections given in Table 2 are, on average, only about 60 per cent of the corresponding OECD estimates of world production during the 1980s. The really marked difference between these two sets of data, however, occurs with projections for US production. NUEXCO envisage that U S production will fall throughout the 1980s to reach just 7.45 Kt U_3O_8 by 1990 (i e only 27 per cent of the OECD estimate). Whilst NUEXCO estimates for the other seven countries are also lower than the

Table 1

World uranium production forecast: OECD (in kt U_3O_8)

	1983	1984	1985	1986	1987	1988	1989	1990
Australia	5.85	5.85	4.94	7.80	7.80	6.76	6.11	6.11
Canada	14.04	19.24	19.11	18.20	16.77	15.99	14.95	13.65
France	5.07	5.07	5.07	5.26	5.26	5.26	5.26	5.26
Gabon	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95
Namibia	5.10	5.10	5.10	5.40	5.40	5.40	5.40	5.40
Niger	7.54	10.40	13.65	15.60	15.60	15.60	15.60	15.60
South Africa	10.14	10.66	10.40	10.27	10.14	10.14	10.01	9.88
USA	25.35	26.65	29.90	32.11	30.55	29.90	28.99	28.34
Other	3.14	3.08	4.22	4.60	4.91	4.84	4.95	5.10
Total	**78.18**	**88.00**	**94.34**	**101.19**	**98.38**	**95.84**	**93.22**	**91.29**

Source:
Uranium: Resources, Production and Demand, Organization for Economic Co-operation and Development, Paris, February 1982.

corresponding OECD figures, the difference is far less dramatic than for the US. Only Canada is envisaged to experience a significant growth in production during the 1980s, and by 1990 is expected to account for about 30 per cent of world production. A surge in Australian production is estimated to occur around the turn of the decade and to gather momentum in the early 1990s. For all other countries production is envisaged to remain fairly static.

In 1982, the United States accounted for 25 per cent of the non-communist world's uranium production. The other major producers were Canada (18 per cent), South Africa (15 per cent), Australia, Namibia and Niger (about 10 per cent each) and France (6 per cent). Since the inception of a commercial market for uranium in 1968, the USA has not only been the principal uranium producer in the world, it has also accounted for over half of the total annual consumption and has thus been the dominant influence in the industry. Up until 1977, however, a total embargo on the use of foreign uranium for domestic power generation was maintained by the US Government, thus effectively prohibiting non-US uranium producers from competing in the world's largest market whilst simultaneously shielding many high-cost domestic producers from the rapid demise which free trade would have ensured. The gradual lifting of this embargo is scheduled for completion in 1984. The removal of this embargo and the current depressed state of the uranium market have combined to force many high-cost US uranium producers out of business and US production is falling rapidly from its record level achieved in 1980.

Resources

Uranium resources are classified by the OECD on the basis of geologic knowledge and the estimated cost of their exploitation. Geologic knowledge is reflected in the levels of confidence in the occurrence and quantities of resources for which purpose three resource categories are defined: *Reasonably Assured Resources (RAR), Estimated Additional Resources (EAR),* and *Speculative Resources.* These are further separated into three levels of exploitability based on the cost of their recovery:[3] less than 30 USD/lb U_3O_8, 30 to 50 USD/lb U_3O_8, and 50 to 100 USD/lb U_3O_8.

Reasonably Assured Resources refers to known uranium deposits which can be recovered within the given production cost range. For the lower cost category these are known as "reserves". Estimated Additional Resources refers to uranium which is thought to occur in addition to Reasonably Assured Resources and which could be mined within the given cost range. Speculative resources are those estimated to occur in undiscovered or partly defined deposits.

Estimated world uranium resources at January 1, 1981, are summarized in Table 3 for the less than 30 USD/lb U_3O_8 and 30–50 USD/lb U_3O_8 cost categories. About 88 per cent of "reserves" (i e < 30 USD/lb U_3O_8 RAR) are located in Australia, Brazil, Canada, Namibia, Niger, South Africa and the USA. *This figure, however, probably reflects the size and extent of the exploration efforts which have occurred in these countries, rather than an asymmetric geological distribution* of the world's uranium resources. Resource estimates for the higher cost category must be considered very tentative. Even where known resources exist, little effort may be made to evaluate the extent of such resources because of their high cost.

Uranium has only one major use, which is as an input in the fuel cycle for nuclear power reactors.[4] Other applications of uranium are so minor (and likely to remain so) that they can be ignored. Current reactor consumption[5] of uranium, however, is only about 60 per cent of total production, with the surplus going into a largely unintended accumulation of inventories. At the end of 1982, total uranium inventories in non-communist countries were equivalent to 5 years of for-

Table 2

World uranium production forecast: NUEXCO (in kt U_3O_8)

	1984	1985	1986	1987	1988	1989	1990	1991	1992
Australia	5.15	4.10	3.50	4.20	5.60	7.00	7.00	8.50	8.80
Canada	11.70	11.60	14.10	14.85	15.35	15.35	15.35	17.35	15.80
Central Africa[1]	6.70	6.70	6.70	6.70	6.70	6.70	6.70	6.70	4.85
France	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	4.00
Namibia	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	3.25
South Africa	9.20	9.15	9.05	8.90	8.90	8.90	8.90	8.90	8.50
USA	9.50	8.80	8.90	8.90	8.85	8.15	7.45	6.65	11.15
Other	2.00	2.00	2.00	2.00	2.00	1.80	1.80	1.75	1.90
Total	**53.05**	**51.15**	**53.05**	**54.35**	**56.20**	**56.70**	**56.00**	**58.65**	**58.25**

Note:

[1] Gabon and Niger combined.

Source:
NUEXCO, Monthly Report on the Uranium Market, October 1983.

ward consumption, which is excessive by any yardstick.

The uranium market is at present depressed. In July 1983, NUEXCO's Exchange Value[6] stood at 23.50 USD which is a substantial improvement on the all-time low (in real terms) reached in August 1982, but considerably below the heights it reached during the boom of the late-1970s. Whilst a fairly rapid expansion of uranium requirements is envisaged to occur during the 1980s, excessive inventory levels are certain to maintain a dampening influence on the price of uranium for a number of years to come. Thus NUEXCO do not anticipate any substantial increase in world production of uranium during the 1980s.

PRODUCTION

The current status and prospects for the major uranium producing nations of the Western world are now considered on a country-by-country basis (in alphabetical order).

Australia

Before the Second World War, uranium was a mineral of only minor commercial interest in Australia. Uranium ore had been mined intermittently for the recovery of radium, but little of its uranium content was recovered. The rapid wartime development of nuclear technology for military purposes, however, created a commercial market for uranium, and in 1944 exploration for uranium deposits began in Australia at the request of the UK Government.

The advent of the "Cold War" further stimulated the demand for uranium, and hence intensified the worldwide search for uranium deposits, as the world's superpowers embarked on plans for rapid expansion of their nuclear arsenals. In Australia, private exploration was encouraged by tax free rewards from the Federal Government for the discovery of uranium deposits. All marketing was controlled by the Federal Government who offered guaranteed prices for uranium ores of various types and grades as well as tax concessions for companies mining and treating uranium ore. The majority of the uranium mined in Australia during the period 1954–64 came from the Rum Jungle (Northern Territory) and Mary Kathleen (Queensland) deposits and was produced to meet export contracts with the Combined Development Agency.[7]

Whilst the market for uranium began to decline in the late 1950s, the Australian deposits which were being mined (with the exception of Mary Kathleen) were also near depletion. By 1964 all uranium mining in Australia had ceased, although production of uranium from stockpiled ore continued until 1971. No uranium ore was mined on a commercial scale in Australia from 1964 to 1975.

The second half of the 1960s saw a substantial rise in orders for nuclear plants in the USA and Western Europe, when it became apparent that nuclear energy was an economically viable method of generating electricity. This trend continued until 1974. With a large growth in capacity coming on-stream during the 1970s and early 1980s the recovery of the uranium mining industry was assured. Exploration

Table 3

Estimated world[1] resources of uranium (in kt U_3O_8)

	Cost range (< 30 USD/lb U_3O_8)		Cost range (30–50 USD/lb U_3O_8)	
Country	**Rar**	**Ear**	**Rar**	**Ear**
Algeria	34	0	0	0
Argentina	33	7	5	13
Australia	384	30	345	27
Brazil	156	0	106	0
Canada[2]	300	37	468	525
France	77	20	37	24
Gabon	25	3	0	13
India	42	0	1	32
Namibia	155	21	39	30
Niger	209	0	69	0
South Africa	323	142	110	119
Sweden	0	50	0	57
USA	473	317	890	543
Other	71	86	27	74
Total	**2 282**	**713**	**2 097**	**1 457**

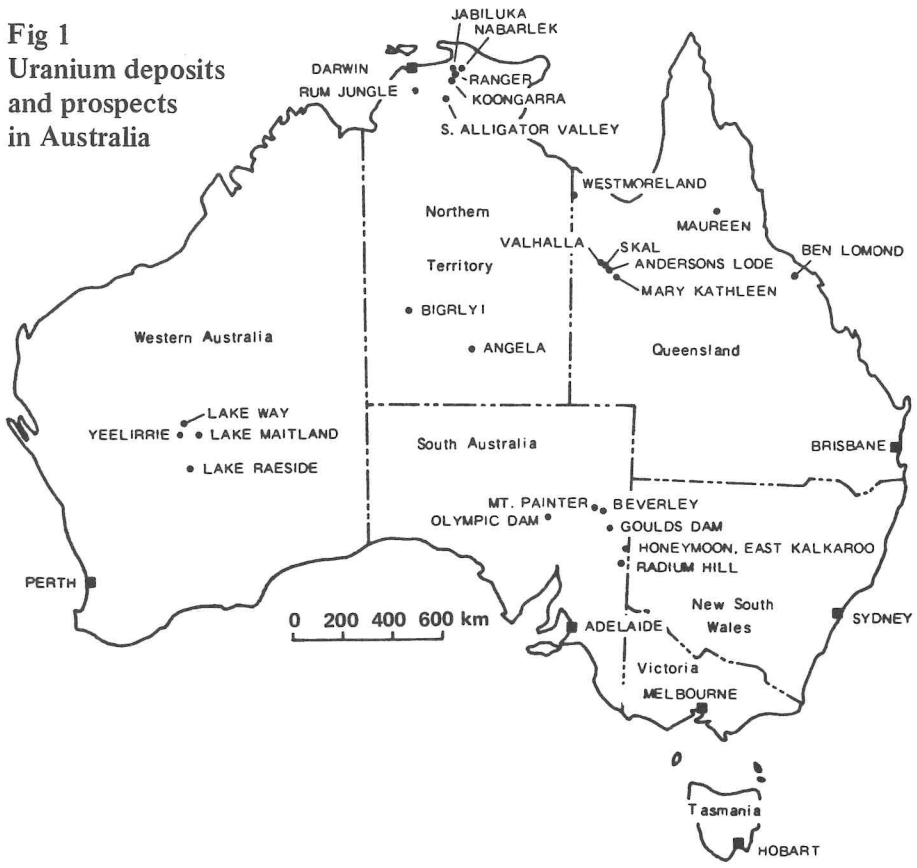
Notes:

[1] "World" resources excludes those in China, Eastern Europe and the USSR.

[2] Cost ranges for Canadian resources are < 135 CAD/kg U (52 CAD/lb U_3O_8) and 135–200 CAD/kg U (52–77 CAD/lb U_3O_8).

Source:
As for Table 1.

Fig 1
Uranium deposits and prospects in Australia



Prospecting for uranium close to the Ranger deposit in the Northern Territory, Australia. (Below, left).

in Australia by private companies started in earnest and important new deposits in the Northern Territory (NT), Koongarra, Nabarlek and Ranger, were announced in 1970. By the middle of 1971, more than 80 companies were engaged in uranium exploration programmes and during the following year major discoveries were announced at Yeelirree (Western Australia) and Jabiluka (NT). By now it was apparent that Australia had the reserves to become a major exporter of uranium in the 1980s. In mid-1973 total uranium reserves (recoverable at a cost of less than 10 USD/lb U_3O_8) were estimated to be 140 kt U_3O_8, about 25 per cent of the world's known reserves.

Between 1970 and 1972 Australian companies obtained contracts for the export of approximately 11.5 kt U_3O_8 for delivery during the period 1976–86. In early 1973, however, the Federal (Labor) Government indicated that approval for all new export contracts would be withheld pending the development of policies for environmental protection, Aboriginal land rights and appropriate safeguards.[8] Thus, as worldwide exploration and production activity surged in response to a post-1973 explosion in uranium prices, the industry in Australia stagnated. The election of a Liberal Government in 1976 and the publication of the Ranger Uranium Environmental Inquiry produced an atmosphere more conducive to the expansion of the uranium mining industry. Mary Kathleen, which had been placed on a "care and maintenance" basis following its closure in 1963, was reopened in 1974 and exports of yellowcake commenced in late 1976. Progress on the "new" Northern Territory deposits, however, was further delayed by protracted negotiations with the Northern Land Council (NCL), representing Aboriginal (i e native) interests in the Northern Territory, and stringent environmental requirements. By the time the Nabarlek and Ranger deposits commenced production (in 1980 and 1981 respectively), the boom in uranium prices had been and gone.

The mining of uranium in Australia has produced a vast amount of controversy, and total opposition to mining has been supported by the Australian Council of Trade Unions (ACTU) until what they consider to be adequate safeguards on a wide range of issues are developed. Union opposition has been of little consequence to date, however, and the mining compa-

nies have experienced little difficulty in attracting labour to the well paid jobs on the mine sites (this is probably because unemployment in the Northern Territory is considerably above the national average). In fact, a number of unions are actively recruiting members among the workers of the uranium mines. Although the ACTU is opposed to uranium mining, its decision is not binding on individual unions. Early shipments of uranium from the Ranger deposit were delayed by union bans on the transport and handling of uranium, but these bans have now been lifted.

The Alligator Rivers region in the Northern Territory is estimated to contain about 83 per cent of Australia's known reserves[9], i e approximately 320 kt U_3O_8. Battey[10] conjectures that "the potential of this province is of the order of five to ten times the known reserves". The uncertainty surrounding the industry during the mid-1970s, however, discouraged more detailed quantification of reserves at existing deposits. Whilst the Liberal Federal Government attempted to encourage the mining and export of uranium in the Northern Territory, environmental protection measures and agreement with the NLC concerning the preservation of Aboriginal sacred sites have proved very time consuming. Uranium mining projects in Queensland, South Australia and Western Australia are not subject to the same degree of legislation, and consequently delays in these states should be less than those for Northern Territory projects. Uranium exploration and mining in New South Wales is prohibited by the current state government.

Whilst there is no restriction on the amount of foreign ownership of uranium exploration projects, a minimum of 75 per cent Australian equity *and* 75 per cent Australian control is required of all projects entering the development stage. Prior to 1976, 100 per cent Australian ownership was required. The locations of the major uranium projects in Australia are shown in Figure 1 and their current ownership and estimated reserves are summarised in Table 4.

At present, Australia has no commercially operating nuclear power reactors and this position is unlikely to change in the foreseeable future. Domestic consumption of uranium, therefore, is negligible and likely to remain so. Only two deposits are currently operational, Nabarlek and Ranger. The former has export contracts with two Japanese utilities (both of whom provided finance to fund the project), the Commissariat a l'Energie Atomique (France), and a Finnish utility amounting to about 65 per cent of current mill capacity (all ore has been mined and stockpiled). Ranger, however, has over 95 per cent of its initial planned production to 1996 under contract with US, Japanese, Korean and Western European buyers (many of whom are equity holders). The prospects for the development of further deposits are at present rather bleak. Japan, South-East Asia and Western Europe represent potential markets but elements within the current Australian Labor government elected in 1983 are fairly hostile to the prospects of an expanded domestic uranium industry. If justified by demand, production from the

Table 4

Ownership and reserves of major Australian uranium deposits

Deposit	Ownership (in per cent)		Estimated reserves (planned production) (kt U_3O_8)	
Ben Lomond (Q)	Minatome (F)[2]	100	7	(0.4)
Beverly (SA)	Western Nuclear (US)[3]	50		
	Oilmin (Aus)	16.66	17	(–)
	Petromin (Aus)	16.66		
	Transoil (Aus)	16.66		
Honeymoon (SA)	Mines Administration (Aus)[4]	25.5	4	(0.5)
	Teton Australia (Aus)[5]	25.5		
	Carpentaria Exploration (Aus)[6]	49.0		
Jabiluka (NT)	Pancontinental Mining (Aus)	65.0	230	(5.0)
	Getty Development (US)[7]	35.0		
Koongarra (NT)	Denison Australia (Can)[8]	100.0	15	(2.2)
Lake Way (WA)	Delhi Petroleum (Aus)[9]	53.5	7	(0.55)
	Vam (Aus)	46.5		
Mary Kathleen[1] (Q)	CRA Ltd (Aus)[10]	51.0	0	(0.95)*
	Australian Federal Government	41.64		
	Australian public	7.36		
Maureen (Q)	Central Coast Exploration (Aus)	51	4	(–)
	Getty Mining (US)[11]	49		
Nabarlek (NT)	Queensland Mines (Aus)[12]	100	13	(1.4)
Olympic Dam (SA)	Western Mining (Aus)	51	1.300	(3.3)
	BPAustralia (UK)	49		
Ranger (NT)	Energy Resources Australia (Aus)[13]	100	140	(3.45)*
Yeelirrie (WA)	Western Mining (Aus)	90	50	(2.75)
	Urangesellschaft Australia (FRG)	10		

Ranger deposit could be doubled relatively quickly.

A vast new copper/uranium/gold deposit is currently being evaluated at Olympic Dam on Roxby Downs in South Australia. While development of the project is still at the pilot stage, uranium resources are currently (1983) estimated to be in the vicinity of 1.3 million tons U_3O_8. In addition, there is an estimated eight million tons of copper metal and commercial quantities of gold. The viability of the project will depend on the demand for copper, uranium being the secondary co-product. While the deposit is of relatively low ore grade (averaging 0.065 % U_3O_8), if uranium is mined as a co-product its extraction may prove relatively economical. Cost studies are currently being undertaken by the joint owners of the project with a preliminary estimate of production around 165,000 tons of copper and 3,300 tons U_3O_8 per year commencing around 1990.

If the uranium resources at Olympic Dam prove to be economically viable (i e if they can be classified as uranium "reserves"), then current WOCA uranium reserves will be boosted by 50 per cent. As a further illustration of the size os the resource, consider annual WOCA uranium consumption requirements during the 1990s. For reactors currently operational, under construction, or on firm order these requirements are estimated to average approximately 65,000 tons U_3O_8 over the decade, at which rate of consumption Olympic Dam could provide the equivalent of almost 24 years supply. In terms of 1982 WOCA uranium consumption, this resource could provide at least 30 years of requirements at that level.

OECD estimates made in 1979 envisaged a prosperous future for Australian uranium producers. Production was forecast to reach 15.5 kt U_3O_8 by 1985, and 26 kt U_3O_8 (or 17 per cent of WOCA production) by 1990. Assuming a price of 30 USD/lb U_3O_8 (which is slightly less than the average contract price received for Australian uranium in 1982), this would have represented annual export receipts (at 1982 prices) of 960 M USD in 1985 and 1 600 M USD in 1990. This would probably have ranked uranium in Australia's top three in terms of annual mineral export revenue earnings during the 1980s.

Just two years later this apparent bonanza had vanished! The corresponding OECD forecasts made in 1981 estimated that Australian uranium production would rise to just 5.8 kt U_3O_8 in the early 1980s, peak at 7.8 kt U_3O_8 in the mid-1980s, and then fall to 6.1 kt U_3O_8 by the end of the decade. Whilst this dramatic revision of OECD production estimates was not peculiar to Australia, the decline was envisaged to be greater there as the industry is still in its infancy.

Production of uranium in Australia in 1982 totalled 5.79 kt U_3O_8 (1981 = 3.7 kt U_3O_8) with exports amounting to 6.86 kt U_3O_8 (1981 = 1.79 kt U_3O_8) for a total export revenue of about 490 M AUD (1981 = 120 M AUD). This represented an average 1982 export price of 35.68 AUD/lb U_3O_8 (or 36.30 USD/lb U_3O_8).

Abbreviations:
NT = Northern Territory, Q = Queensland, SA = South Australia, WA = West Australia, Aus = Australia, US = United States, Can = Canada, UK = United Kingdom, FRG = Federal Republic of Germany, F = France.

Notes:

* Actual production in 1982.

[1] Mary Kathleen was shut down permanently in September 1982.

[2] A wholly-owned subsidiary of Compagnie Francaise des Petroles.

[3] A wholly-owned subsidiary of Phelps Dodge (US).

[4] A wholly-owned subsidiary of CSR.

[5] Ownership is UNC (United Nuclear Corporation) Resources (US) 50 %.
North Kalgurli Mines (Aus) 50 %.

[6] A wholly-owned subsidiary of MIM Holdings.

[7] A wholly-owned subsidiary of Getty Oil.

[8] A wholly-owned subsidiary of Denison Mines.

[9] A wholly-owned subsidiary of Commonwealth Sugar Refineries (CSR).

[10] Rio Tinto-Zinc (UK) owns 57.2 per cent of CRA, the Australian public hold the remaining shares.

[11] A wholly-owned subsidiary of Getty Oil.

[12] A wholly-owned subsidiary of Pioneer Concrete Services.

[13] Ownership (in per cent) is

Electrolytic-Zinc Company of Australian (Aus)	30.85
Peko-Wallsend Operations (Aus)	30.85
Australian Public	13.30
Japan Australia Uranium Resources Development (Japan)	10.00
Rheinbraun Australia (FRG)	6.25
UG Australia Developments (FRG)	4.00
Interuranium Australia (FRG)	3.75
Oskarshamnsverkets Kraftsgrupp Aktiebolag (Sweden)	1.00

Canada

Exploration for uranium by the Eldorado Gold Mining Company began in Canada in 1942 to supply uranium for the US nuclear weapons programme. In 1944 this company was acquired by the Canadian Government and a Crown company Eldorado Mining and Refining (subsequently known as Eldorado Nuclear and currently Eldorado Resources) was formed. A ban on private prospecting for radioactive materials was lifted in 1947 and various incentives were offered by the Federal Government in an effort to encourage exploration. By 1959, 23 mines with 19 treatment plants were in operation in five producing districts, with the majority of the uranium being produced in the Beaverlodge area of northern Saskatchewan, the Elliot Lake district in northern Ontario, and the Bancroft area of south-east Ontario.

The abrupt decline in uranium demand from the USA in the late-1950s saw uranium exploration virtually cease in Canada, whilst production fell sharply from a record 15.89 kt U_3O_8 in 1959 to 3.7 kt U_3O_8 in 1968. By 1968 only four uranium companies were still in business, largely due to stretch-out programmes and a Government stockpiling programme which, between 1963 and 1970, purchased about 9.1 kt U_3O_8 at a total cost of 101.4 M CAD. The 1966 US embargo on the enrichment of foreign uranium for use by domestic electricity generating utilities was particularly severe on the Canadian uranium industry which was heavily dependent upon the US market.

When the market recovered in the mid-1970s, established Canadian producers were better placed to take advantage of the rapid surge in prices than their Australian counterparts. Between 1973 and 1980 Canadian production was almost doubled (from 4.76 kt U_3O_8 to 9.29 kt U_3O_8), whereas Australian production was "frozen" pending the outcome of the Ranger Uranium Inquiry and negotiations with the Northern Land Council. The native "land-rights", proliferation, and environmental issues which delayed the development of the fledgling Australian uranium industry during the mid-1970s only affected new Canadian developments and, even then, they were resolved more expeditiously than in Australia.

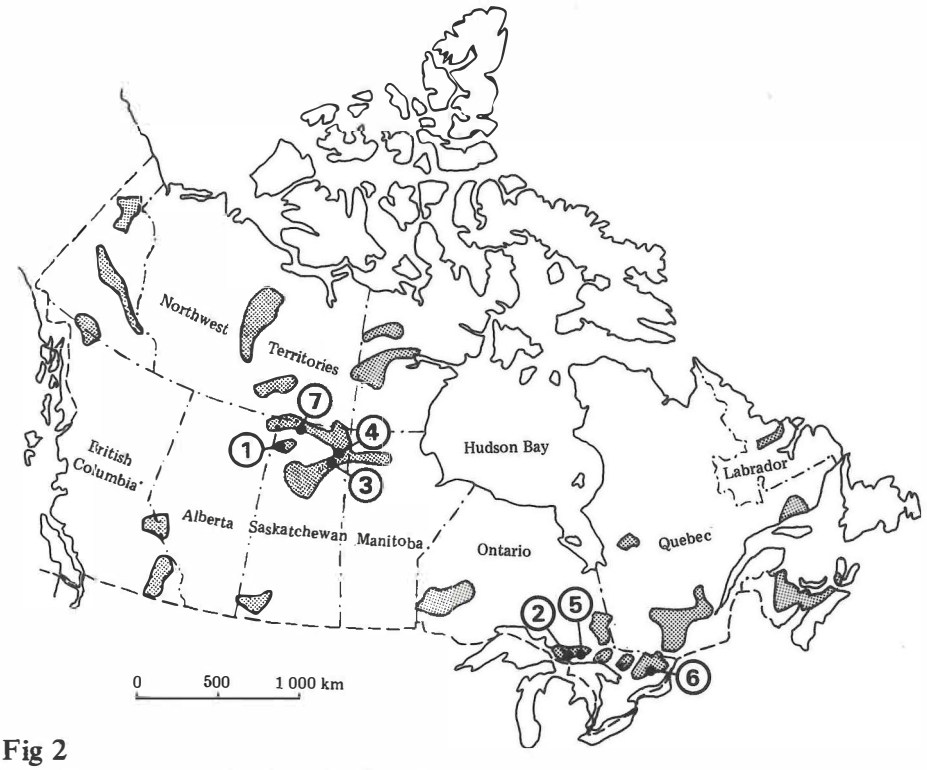


Fig 2
Uranium areas and mines in Canada

Mines operating 1984

Cluff Lake (1)
Elliot Lake (2)
Key Lake (3)
Rabbit Lake (4)

Operations suspended 1982/3

Agnew Lake (5)
Bancroft (6)
Beaverlodge (7)

In 1977 the Canadian Government placed a temporary embargo on deliveries of uranium to the European Economic Community and Japan whilst it considered a formal policy relating to the long-term security of uranium for domestic use, in addition to pricing, reprocessing and proliferation issues. It resolved that:

- there must be a 30 year reserve requirement for existing, committed or planned reactors in Canada before export permits are permitted;
- exports must be made at the world price or a floor price plus escalation, whichever is higher, and if possible must be upgraded to UF_6 prior to leaving Canada;
- appropriate safeguards regarding the use of Canadian uranium were to be agreed to by prospective customers.

Currently 60 per cent of production comes from the Elliot Lake deposits in Ontario, with the remaining 40 per cent from northern Saskatchewan. Whilst the development of new deposits in northern Saskatchewan during the 1980s will probably raise its share of total production above 40 per cent, the huge reserves at El-

Table 5
Ownership of operational Canadian uranium projects

Location	Ownership (per cent)		Annual production rate (tons U_3O_8) – 1982
Agnew Lake[1] (O)	Kerr-Addison (C)	90	
	Uranerz (FRG)	10	90
Bancroft[2] (O)	Madawaski Mines (C)	100	200
Beaverlodge[3] (S)	Eldorado Nuclear (C)	100	360
Cluff Lake (S)	Amok[4] (F)	80	2 000
	SMDC[5] (C)	20	
Elliot Lake (O)	Denison Mines (C)	100	3 000
Elliot Lake (O)	Rio Algom[6] (C)	100	3 400
Key Lake (S)	SMDC (C)	50	4 000–6 000[9]
	Uranerz (FRG)	33 1/3	
	Eldor Resources (C)[7]	16 2/3	
Rabbit Lake (S)	Eldor Mines[8] (C)	100	1 450

Abbreviations:
O = Ontario, S = Saskatchewan, C = Canada, FRG = Federal Republic of Germany, F = France.

Notes:

[1] Mining was suspended in 1979, but a surface salvage leaching operation continued into 1982. All operations ceased in early 1983.

[2] The mine was placed on stand-by in mid-1982 following the termination of a long-term contract with the Italian state owned company, Agip, and was shut down early in 1983.

[3] After 30 years of production, the mine was closed during 1982.

[4] Ownership is Compagnie Francaise de Mokta 37 %
Commissariat a l'Energie Atomic 30 %
Pechiney-Ugine-Kuhlmann 25 %
Cogema 8 %

[5] Saskatchewan Mining Development Corporation.

[6] Rio Tinto.Zinc (UK) owns 52.75 per cent of Rio Algom.

[7] A wholly-owned subsidiary of Eldorado Resources Limited.

[8] A wholly-owned subsidiary of Eldorado Resources Limited.

[9] Planned rate. Production will commence in late 1983/early 1984.

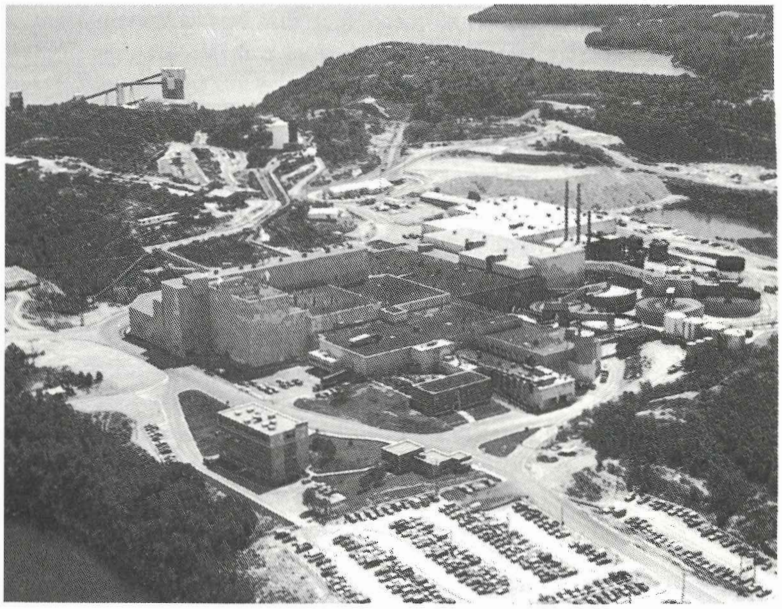
liot Lake mean that this area will maintain its importance as a major uranium producer for at least the next 30 years. Significant deposits are also known to exist in British Columbia, but exploration activity was curtailed in 1980 by a seven year moratorium on uranium exploration and mining imposed by the provincial government.

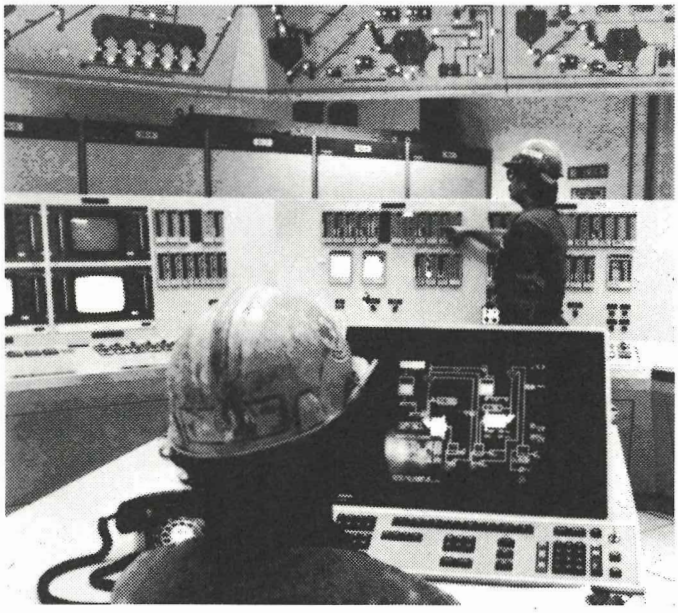
The development of the large, high grade, deposits discovered in the mid-1970s at Cluff Lake and Key Lake in the Athabasca Basin region of northern Saskatchewan were the subject of major provincial government inquiries before development approval was forthcoming. The development of both projects was subject to a long list of conditions regarding environmental protection, employment opportunities for local native labour, the investigation of native land claims, and the provision of financial aid to northern Saskatchewan to enable the local inhabitants to share the benefits of the proposed mines.

Many Canadian politicians believe that the Canadian economy is excessively dependent on exports of its natural resources and that foreign (mainly US) ownership of these resources is too great. In the case of uranium, there are no restrictions on foreign investment in Canada's uranium industry at the exploration stage but new production operations are required by Federal Government policy to have no more than one-third foreign ownership. In exceptional circumstances this could be raised to 50 per cent. The current ownership and levels of production in 1982 of Canada's major uranium projects are summarised in Table 5. Almost 50 per cent of Canada's reserves are contained in the Elliot Lake and Agnew Lake areas of Ontario.

Ore grades in these areas, however, are low, generally averaging about 0.10 per cent U_3O_8. Most of the remaining reserves are in northern Saskatchewan where ore-grades are, on average, considerably higher. The Key Lake deposit, which officially commenced production in late Septem-

Computer room at Rio Algom Ltd's Stanleigh uranium mill complex at Elliot Lake, Ontario. (Right). Aerial view of Denison Mines Ltd's uranium operations at Elliot Lake. (Left).





ber 1983, is envisaged to have an annual production rate of 4,000 tons U_3O_8 when it attains full capacity. This would make it second only to the Rossing mine in Namibia in terms of annual mine production of U_3O_8, pushing Australia's Ranger mine into third place. Ore mined from the Key Lake deposit will initially average 2.50 per cent U_3O_8, while the average ore grade at the "D" deposit at neighbouring Cluff Lake was 7.00 per cent U_3O_8. Ore grades at this latter deposit (all ore from which has now been completely mined and stockpiled) sometimes reached 45 per cent U_3O_8 and special protective shielding was required for the mine operations.

Whilst the Elliot Lake deposits are of relatively low grade and high cost, Denison Mines and Rio Algom have received substantial orders from the Ontario Hydro Electric Company which have ensured their existence for the next 30 years. Denison Mines has considerably expanded its mill capacity despite objections from Ontario Hydro that such action was not warranted by current market conditions. Denison's expansion combined with the current and potential production capabilities of the Cluff and Key Lakes deposits could push annual production to 19 kt U_3O_8 by the mid-1980s, although in view of current market conditions this is unlikely to be achieved. In theory annual production could reach 22 kt U_3O_8 by 1990.

At year-end 1982, Canada had 4.7 GWe of installed nuclear operational, all in Ontario. Early in 1983 two new nuclear power plants became operational, one in New Brunswick, the other in Quebec, bringing total capacity to almost 6 GWe. By 1991 the 8.1 GWe of nuclear capacity now under construction in Ontario will raise this total to about 14 GWe. These figures represent a growth in annual uranium consumption from 1.35 kt U_3O_8 in 1983 (or about 13 per cent of Canadian production in that year) to approximately 2 kt U_3O_8 by 1992.

The bulk of Canada's current and long-term (up to 30 years for some contracts) domestic uranium requirements are under contract with the Elliot Lake producers, Denison Mines and Rio Algom. The former also has a large contract (20 kt U_3O_8 over 10 years beginning in 1984) with Tokyo Electric Power and no further commitments are envisaged. The remainder of Rio Algom's production over the near future is also largely under contract, mainly with West German, Japanese, Korean and US utilities. The major French equity interests in the Cluff Lake project has ensured a substantial market for its output, with additional sales to West Germany. Although the Key Lake project was developed at the time of a depressed market, it has nevertheless managed to achieve sufficient contracts to 1990 to achieve a "base loading".

Canada's past and committed (future) exports of uranium are the largest of any nation. Since commercial contracting began in 1966, Canadian producers (by year-end 1982) had entered into arrangements to export about 130 kt U_3O_8 of which about 50 kt U_3O_8 had already been exported. Thus forward export commitments amount to about 80 kt U_3O_8, whilst about 100 kt U_3O_8 has been committed for domestic use. Production in 1982 was about 10.5 kt U_3O_8, a small increase over the 1981 figure of 10 kt U_3O_8.

The 1982 average weighted price for all export contracts made by Canadian producers for deliveries in 1982 was approximately 35.50 USD/lb U_3O_8. "Spot" sales accounted for only about 1 per cent of total exports.

The large, high-grade deposit at Cluff Lake, Saskatchewan is jointly owned by French and Canadian interests.

France

Uranium prospecting in France began in 1946. Since then, only the USA has spent more on domestic and foreign uranium exploration, as the French have sought to achieve an independent nuclear arsenal and fuel for one of the world's major nuclear power expansion programmes. Currently production is mainly from the Massif Central and Massif Armoricain areas.

The dominant company in all aspects of the nuclear fuel cycle in France is COGEMA, a 100 per cent subsidiary of the French Government's Commissariat a l'Energie Atomique (CEA). Four industrial groups are also involved in exploration and mining: Imetal, Compagnie Francaise des Petroles (CFP), Societe Nationale Elf-Aquitaine (SNEA) and Rhone-Poulenc. The extent of their ownership in 1982 of France's major uranium (exploration, mining and concentration) companies is shown in Table 6.

In general, individual uranium deposits in France are small and of relatively low grade. The prospects for expansion of both resources and production are limited and consequently by 1990 domestic production will only represent about one-third of France's domestic uranium requirements. The comparable figure for 1982 was about 80 per cent. With the prospect of a heavy reliance on imported uranium to meet its expansionary nuclear programme, French companies have been extremely active in overseas ventures, especially in France's former territories of Gabon and Niger. In addition, four French companies (through Amok Ltd) have the major shareholding in Canada's rich Cluff Lake deposit, whilst several French companies have shown interest in possible participation in the development of new Australian deposits. France does not export uranium. Uranium production in France totalled 3.17 kt U_3O_8 in 1982, this total being augmented by an additional 3.22 kt U_3O_8 from Gabon and Niger.

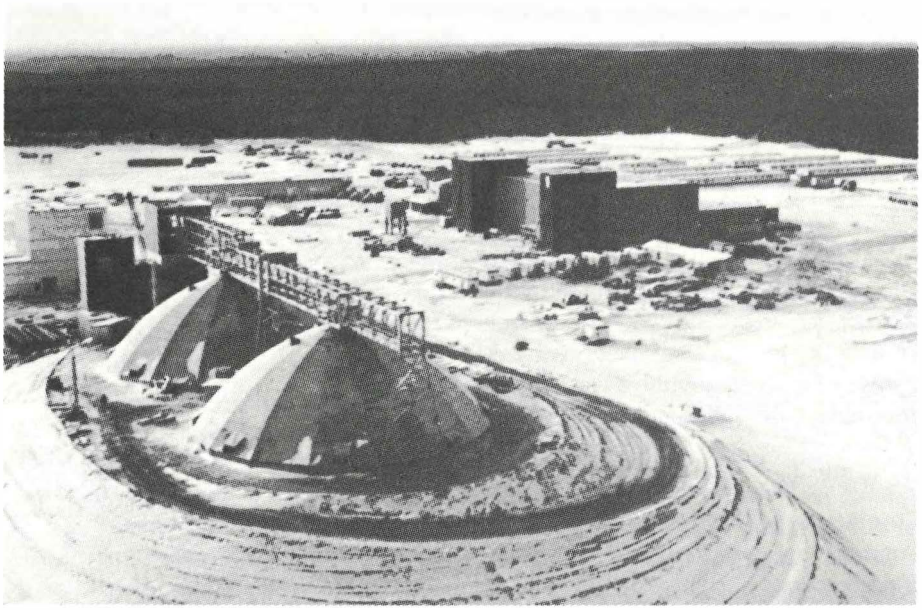


Table 6
Ownership of uranium mining industry in France

	Organizations and groups					
Companies[1]	CEA	Imetal	CFP	SNEA	Rhone-Poulenc	Others
CFM		100				–
CIM					100	–
CMDT			100			–
COGEMA	100					–
MINATOME			100			
SCUMRA			94			6
SIMURA		51				49
SMUC	33 1/3	33 1/3				33 1/3
SNEA-P				100		–
SIMO	81					19

Note:

[1] Compagnie Francaise de MOKTA (CFM),
Compagnie Industrielle et Minere (CIM),
Compagnie Miniere DONGTRIEU (CMOT),
Compagnie Generale des Matieres Nucleaires (COGEMA),
Société Centrale de l'Uranium et des Minerals et Metaux Radioactifs (SCUMRA),
Société des Mines d'Uranium du Centre (SMUC),
Société Industrielle des Minerals de l'Ouest (SIMO).

Source:
Uranium: Resources, Production and Demand, OECD/IAEA, Paris, February 1982.

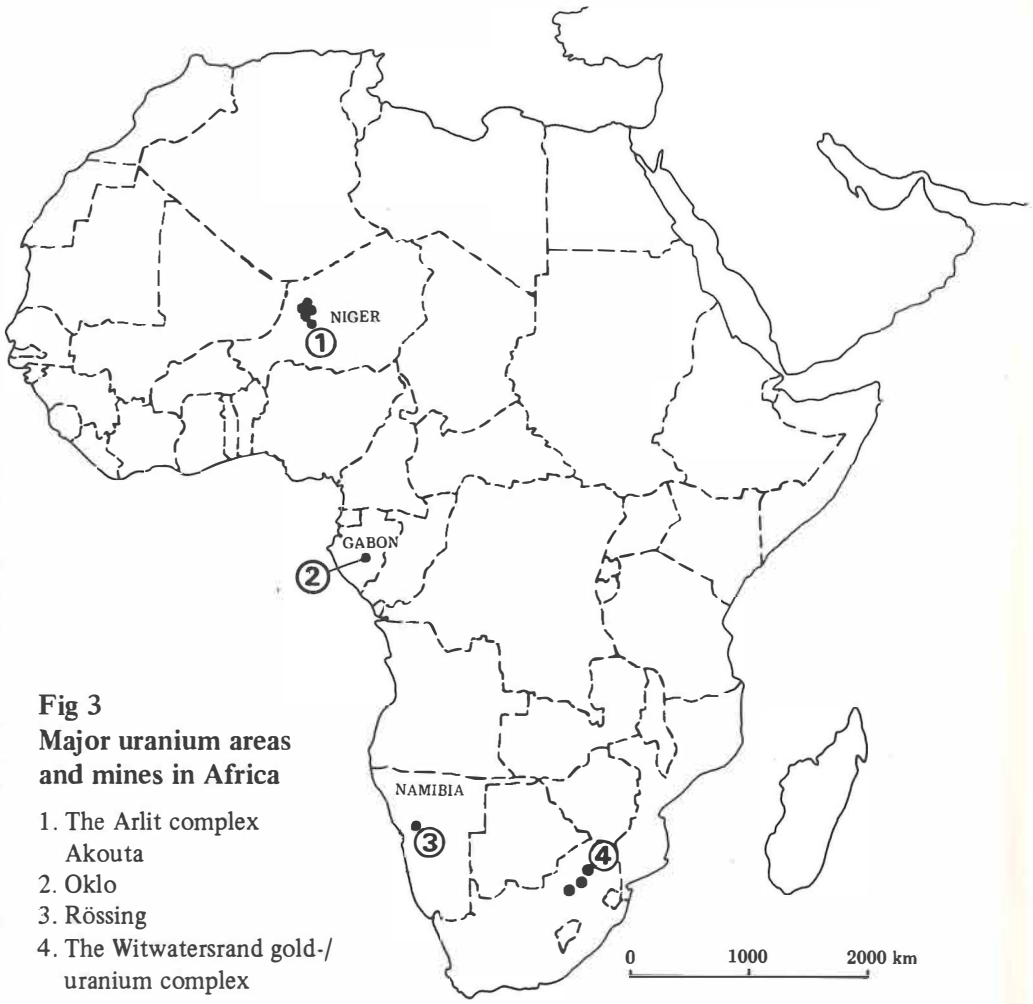


Fig 3
Major uranium areas and mines in Africa

1. The Arlit complex
   Akouta
2. Oklo
3. Rössing
4. The Witwatersrand gold-/ uranium complex

Gabon

Uranium exploration began in 1948 and the Mounana deposit (see Figure 3) was discovered in December 1956. The Compagnie des Mines d'Uranium de Franceville (COMUF) was established in 1958 to mine the Mounana deposit and currently it is the only uranium producer in Gabon. Production in 1982 was almost 1.2 kt U_3O_8. COMUF is jointly owned by the government of Gabon and a consortium of French companies. Shares (in per cent) are as follows:

Government of Gabon	24.75
Cogema	18.81
Minatome	13.00
CFM	39.98
COMUF employees	0.99
Unknown	2.47

(Details of ownership of the above French companies were given in Table 6. The government of Gabon has recently announced its intention to increase its holding in COMUF to over 25 per cent).

In addition to the French (through Cogema), the Japanese Power Nuclear Fuel Corporation and the Korean Electric Company are actively involved in exploration programmes in association with the government of Gabon.

The current status of Gabon's uranium deposits is as follows:

Deposit	Ore content (%)	Reserves kt/U_3O_8
Mounana	0.48	7,4
Mikovloungou	0.352	13,0
Boyindzi	0.407	4,0
Oklo	0.420	17,0
Okelobondo	0.436	5,0

The Mounana deposit was discovered in 1956 and is now mined out. The four others were discovered in respectively 1965, 1967, 1968 and 1974. Mining is now commencing at Boyindzi and is in progress att Oklo.

A yellowcake plant started operations in 1978, prior to which all ore was shipped to France. France remains the dominant buyer with small amounts being shipped to Italy and Japan. As with Niger, infrastructural problems cause the ore to be of relatively high cost.

Namibia

Namibia is rich in mineral resources and mining accounts for approximately 50 per cent of Gross Domestic Product and 70 per cent of export earnings. Diamonds are its major extractive industry, with uranium ranked second. Cadmium, copper, lead, manganese, silver, tin, tungsten and zinc are also important minerals in the Namibian economy.

Currently there is only mine, Rössing, producing uranium in Namibia. The Rössing deposit was discovered in 1928 but its low ore grade made it an uneconomic mining proposition. Extensive prospecting activities commencing in 1966, when the British company Rio Tinto-Zinc (RTZ) acquired the exploration rights, culminated in the establishment of the world's largest open-cut uranium mine in 1975. Whilst the ore grade is low (averaging around 0.04–0.05 per cent U_3O_8) the massive scale of the project (a total of 300 Mt of ore) allows this open cut mining venture to reap considerable economies of scale. Early problems with the abrasive nature of the ore and a fire in the process plant restricted production prior to 1979, but Rössing is due to reach design capacity of 5 kt U_3O_8 in 1983. Production in 1982 was 4.9 kt U_3O_8. Rössing's reserves are estimated to be about 135 kt U_3O_8. Current ownership of the mine is given in Table 7.

South African controlled uranium mining ventures are generally veiled in secrecy. The "others" in Table 7 probably include a South African interest and was rumoured at one time to have included an Iranian interest. Contract agreements are also secret, although its major customer in the past has been the UK through RTZ. Shipments have also been made to France, Japan (the latter through an agreement with RTZ) and Taiwan.

A second Namibian uranium deposit, at Langer Heinrich, is operating a pilot

plant. This deposit, which is close to the Rössing mine, is controlled by South African interests but specific details have not been disclosed.

Apart from machinery problems, the operation at Rossing has been hampered by labour unrest, generally with regard to different wage scales for different races. Whilst Rossing is supposed to come under South African apartheid policy, the Rossing management have in general ignored it and have operated a non-racial mine. A far greater problem, however, is the current political unrest and pressure on major uranium consuming nations not to purchase uranium from (or invest in) a country which is being controlled against its will by South Africa.

Unless a realistic settlement to the question of nationhood for Namibia can be reached in the near future, exploration and investment in the uranium industry is likely to be serverely discouraged.

Niger

Up to 1974, Niger's main export income was derived from sales of ground nuts, but a severe drought in the mid-1970s destroyed this source of income entirely. Until the mid-1970s Niger had a chronic balance of trade deficit, but the expansion of its uranium trade at mid-1970s prices has turned this into a small surplus. In 1980, uranium exports accounted for 76 per cent (by value) of total exports. In turn imports are greatly influenced by the requirements for capital equipment, sulphur and fuel for the uranium industry.

In the mid-1950s the French Atomic Energy Commission made surveys of the Air region in the north-central part of Niger, although it was not until 1965 that the first economically viable deposits were found in the Arlit region. Production did not begin until 1971. Exploration and development work have accelerated ever since, until today the area to the west of the Air mountains – stretching for nearly 200 km – comprises one of the world's most prolific uranium provinces. The high cost of exploration, however, has prevented detailed enumeration of Niger's uranium resources, with Koutoubi and Koch[11] giving a range of from 130 kt to nearly 650 kt U_3O_8.

Niger has two uranium facilities. Arlit and Akouta, which produced a combined annual total of about 4.6 kt U_3O_8 in 1982. All exploration, production and marketing of mineral resources within Niger is the responsibility of ONAREM (Office National des Ressources Miniere), a government institution organized like a private, commercial company. ONAREM can participate in all companies or groups engaged in exploration or mining activities in Niger and currently controls about one-third of the country's uranium production. France, through Cogema and

Table 7
Ownership of the Rössing deposit in Namibia

Company	Share (per cent)
Rio Tinto-Zinc (UK)	46.50
Rio Algom (C)[1]	10.00
GENCOR (SA)	2.30
Industrial Development Corp[2] (SA)	13.47
Minatome (F)[3]	10.00
Others (unknown)	17.73

UK = United Kingdom, C = Canada, SA = South Africa, F = France.

Notes:

[1] Rio Tinto-Zinc owns 52.75 per cent of Rio Algom.

[2] A state-owned corporation.

[3] A wholly-owned subsidiary of Compagnie Francaise des Petroles (F).

Table 8
Niger's uranium deposits[1]

Company (deposit)	Ownership (per cent)	
Somair[2] (Arlit)	ONAREM (N)	33
	Cogema (F)[5]	26.96
	Minatome (F)[6]	26.96
	Urangesellschaft (FRG)	6.54
	Agip (I)[7]	6.54
Cominak[3] (Akouta)	Cogema (F)	34
	ONAREM (N)	31
	OURD (J)[8]	25
	Enusa (S)[9]	10
SMIT[4] (Arni)	ONAREM (N)	33 1/3
	Cogema (F)	33 1/3
	KFTC (K)	33 1/3

Abbreviations:
N = Niger, F = France, FRG = Federal Republic of Germany, I = Italy, J = Japan, S = Spain, K = Kuwait.

Notes:

[1] Plans for the early development of a fourth mine, Imouraren, have been shelved pending an improvement in the uranium market. Feasibility studies are continuing at a number of other promising uranium finds.

[2] Société des Mines de l'Air.

[3] Compagnie Miniere d'Akouta.

[4] Société Miniere de Tassa N'Taghalgué.

[5] A wholly-owned subsidiary of France's Commissariat a l'Energie Atomique (CEA).

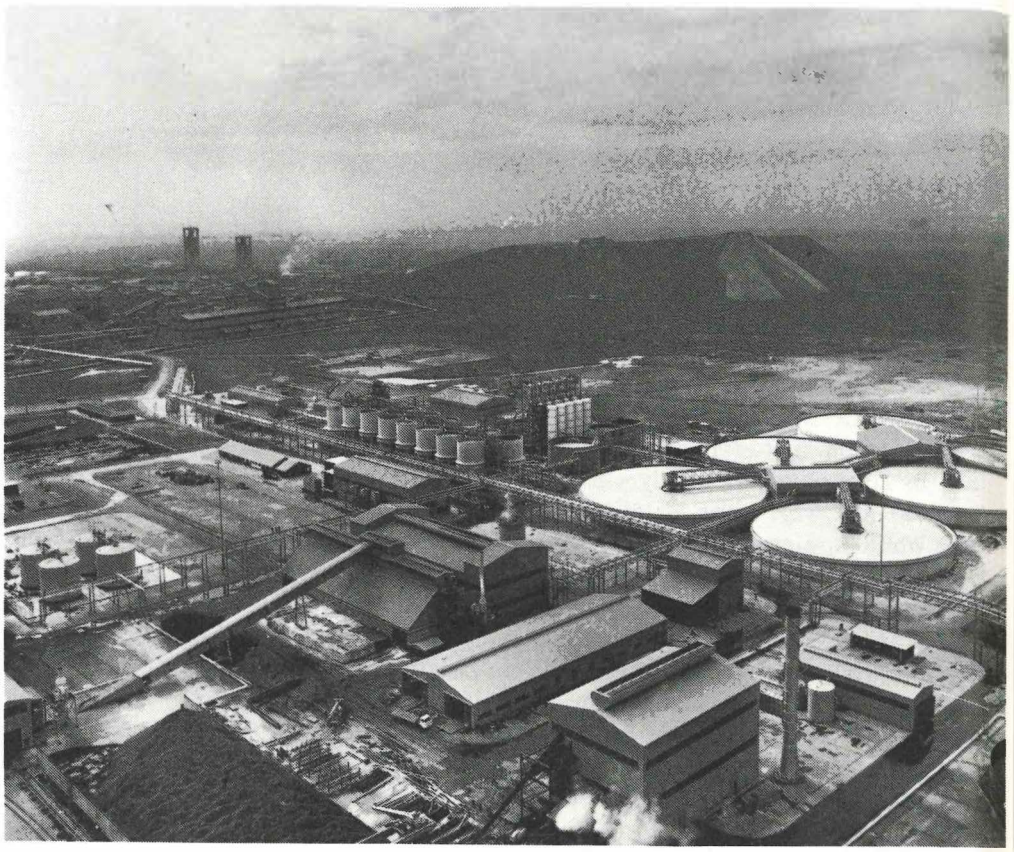
[6] A wholly-owned subsidiary of Compagnie Francaise des Petroles.

[7] An agency of the Italian government.

[8] Overseas Uranium Resources Development Company.

[9] Empresa Nacional del Uranio.

[10] Kuwait Foreign Trade and Contracting Company.



The Vaal Reefs South uranium plant, controlled by the Anglo American Corporation.

other French shareholders, has about 45 per cent of the equity in the two projects that are currently operational. Details of these two projects and the Ami deposit, which is expected to proceed , are given in Table 8.

With the exception of Onarem, Niger's uranium production has in the past been committed to the equity partners on a pro-rata basis. Onarem is not required to take all of its share and it appears that French interests have in the past absorbed any residual. More recently, however, Onarem has become more independent and has made small sales to a number of different buyers. A substantial sale to Libya, totalling approximately 1.5 kt U_3O_8, in early 1981 caused great concern to some Western governments as the latter has no legitimate use for unenriched uranium. It is rumoured that sales have also been made to Iraq and Pakistan, both of whom are rumoured to be actively involved in constructing nuclear weapons. Niger has no safeguards policy and such sales would attract a premium in excess of current market prices. In addition, Niger cannot afford to offend its powerful northerly neighbour, Libya.

Niger is a high cost (i e over 30 USD/lb U_3O_8) producer of uranium. The mines are situated in a desolate and remote area and, whilst the infrastructure has been substantially up-graded by the building of an all weather, sealed "Uranium Road" linking the inhabited south of the country to the mining areas 650 km to the north, the costs associated with transporting uranium to its overseas markets and importing fuel and mining equipment are substantial.

Prospects for Niger's uranium industry appear reasonably good provided the French maintain their "high cost" (relative to say Australian or Canadian yellowcake) purchases. Uranium sales (and the foreign currency they provide) are vital to the economic and political stability of Niger and the French can undoubtedly justify the high cost of their uranium in terms of foreign aid.

South Africa

Active exploration for uranium in South Africa began in the late 1940s and culminated in the large scale production of uranium oxide as a by-product of the gold mining industry. By 1960 production had reached 6.4 kt U_3O_8 (approximately 16 per cent of world production) with the UK and US weaponry programmes being the major customers. Thereafter production dropped rapidly and it was not until the late 1970s that it passed its 1960 level.

Gold is South Africa's primary export commodity, accounting for almost half of all exports in recent years. Other minerals of importance are coal, diamonds, iron ore, copper and manganese. Uranium is of relatively minor importance, accounting for only about 2 per cent of total exports.

Virtually all of South Africa's uranium is produced as a by-product of gold mining in the Witwatersrand basin (see Figure 3). As a consequence, its recovery costs are very low. South Africa's gold producers, however, attempt to maximise the life of their mines by mining the "marginal" grades of ore. Thus if gold prices rise, lower grade ore which has now become profitable will be mined. Whilst ore production may rise, therefore, the level of gold production may actually decline. Since uranium and gold appear in the ore in a fairly constant ratio, it follows that as the price of gold rises, uranium production may also fall.

Slimes (tailings) dams resulting from the operations of gold and gold/uranium contain low concentrations of gold, uranium and pyrite. The high price of these three minerals in the late-1970s encouraged their extraction from the slimes dams. Currently three such projects are operational.

Uranium is also produced as a (minor) by-product from the Palabora open-cut copper mine.

Two mines, Beisa and Afrikander Lease, came on-stream in 1982 as the first, primarily uranium, mines (with gold as a by-product) in South Africa. The development of other such mines awaits recovery of the uranium market.

The major mines and mining houses engaged in uranium recovery are shown in Table 9 together with their levels of uranium production in 1982. Overall, the average recovery grade is very low, approximately 0.01 per cent U_3O_8, reflecting the by-product nature of South African uranium mining. With the exception of Palabora's uranium production, all South African uranium is marketed by

Table 9
South African uranium production (1982)

Mining group[1]	Major mines	production tons U_3O_8
(a) Uranium deposits		
Anglo American Corporation	Afrikander Lease[2]	–
GENCOR	Beisa	280
Total		**280**
(b) Goldmining by-product		
Anglo American Corporation	Vaal Reefs	1 898
	Western Deep Levels	202
Anglovaal	Hartebeestfontein	470
Barlow Rand	Blyvooruitzicht	278
	Harmony	652
Gold Fields of SA	Driefontein Cons	250
GENCOR	Buffelsfontein	640
	West Rand Cons[3]	–
	St Helena	280
Johannesburg Consolidated Investment	Randfontein	510
	Western Areas	190
Total		**5 090**
(c) Tailings mining co- and by-product		
Anglo American Corporation	East Rand Gold & Uranium	378
	Joint Metallurgical Scheme	952
GENCOR	Chemwes	670
Total		**2 000**
(d) Copper mining by-product		
Palabora[4]	Palabora	–
Total		–
Overall total		**7560**

Notes

[1] Companies administering the projects. The ownership of individual mines is generally spread across a large number of companies. Cross-ownings are commonplace.

[2] Mining is suspended pending recovery of the uranium market.

[3] Uranium production ceased at the end of 1981 because of a depressed market.

[4] Rio Tinto-Zinc (UK) owns 38.9 per cent of Palabora, with the Newmont Mining Corporation (USA) being the other major shareholder (28.6 per cent).

NUFCOR, a private company managed by the country's major uranium producers. South Africa's Atomic Energy Act forbids the release of details concerning uranium contracts. In the past, however, Japan, West Germany, the USA, France, Taiwan, Belgium and Spain have all been major customers. South African producers rely on spot market sales for a substantial amount of their production. Recently, in an unusual break with the normal practice of secrecy, Japanese customers were identified as contracting for about 80 per cent of the planned production from the Beira mine, commencing in 1983. This action may have been intended to assure potential customers of reliable supplies in the face of mounting world pressure on the South African government over its apartheid policies and its apparent desire to retain control over Namibia.

South Africa maintains a policy of racial segregation and separate "development". The majority of black "South Africans" are forced to live in their tribal homelands and are regarded as migrant workers in the mines. Most skilled and semi-skilled jobs are not open to non-whites. As a consequence, in times of high demand for minerals a chronic shortage of skilled (white) labour arises. In recent years black workers have been permitted to form labour unions and their wages have been rising fairly rapidly as a result of both unionization and external pressure on South African companies which are owned by overseas interests. Nevertheless, the gulf in earnings between blacks and whites remains considerable.

South Africa has been one of the world's major uranium suppliers for over 30 years. Now that uranium is in relatively abundant supply, however, South Africa's continuing policy of apartheid and intransigence over Namibian independence may drive potential cursomers for uranium towards politically "safer" (i e less controversial) producers.

United States of America

Radioactive metals were discovered in the western United States in the late 1880s and, subsequently, the discovery of radium (in 1898) and its development for medical purposes and luminous paints generated a small mining boom in Colorado between 1912 and 1918. Thereafter the market was dominated by low-cost production from the Belgian Congo (now Zaire). Prior to the Second World War uranium ore was also produced as a co-product of vanadium mining in the Colorado Plateau region but less than 100 tons of yellowcake (primarily for use as paint or glass colorant) was recovered.

The Manhattan project created the first real demand for uranium, most of which was met by supplies from the Belgian Congo and Canada. Following the establishment of the US Atomic Energy Commission (AEC) in 1946, however, a nationwide search for uranium resources was launched, encouraged by generous discovery and development bonuses together with guaranteed prices for uranium ore. Exploration activities were centred primarily in the Colorado Plateau states: Arizona, Colorado, New Mexico, Wyoming and Utah. The AEC also encouraged exploration for uranium and the development of existing uranium deposits in many overseas countries.

The AEC's domestic programme was extremely successful. Uranium production rose from less than 0.1 kt U_3O_8 in 1948 to over 8 kt U_3O_8 in 1956. Although the AEC was the sole purchasing body for uranium ore, it encouraged private companies to enter the uranium milling industry with extremely generous investment allowances. By the end of 1956 there were 12 privately owned uranium mills in operation and this number had risen to 26 (processing 30 kt of ore a day) by 1962. No new mills were constructed over the ensuing 15 years, however, as the uranium industry entered the void between the decline in demand from the US nuclear weapons programme and the growth of the nuclear power industry.

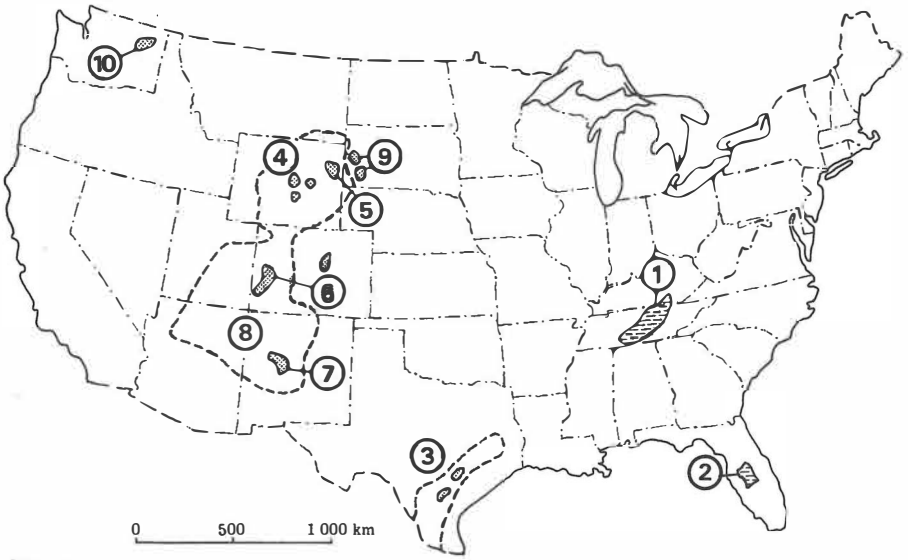


Fig 4

Uranium areas in the United States

1. Chattanooga shale
2. Florida phosphates
3. Texas Coastal Plain
4. Wyoming Basins
5. Powder River Basin
6. Uravan Mineral Belt
7. Grants Mineral Belt
8. Colorado Plateau
9. Black Hills
10. Spokane (Washington)

During the 1950s and early 1960s, Colorado and Utah were the leading states with regard to uranium production but their fortunes deteriorated in the mid-1960s and never recovered. Their places were taken by New Mexico and Wyoming who have dominated production for the past 20 years. In 1981 New Mexico and Wyoming accounted for 55 per cent of US uranium production. When combined with Texas, these three states accounted for over 70 per cent of the total. The remainder is produced in Arizona, Colorado, Florida, Louisiana, South Dakota, Utah, and Washington. The bulk of low cost (< 50 USD/lb U_3O_8) reserves are also located in New Mexico and Wyoming, with shares of 43 per cent and 33 per cent respectively at the beginning of 1983. Areas of uranium ore production in the USA are shown in Figure 4. Production of uranium in Florida and Louisiana is as a by-product from phosphoric acid mills.

The degree of involvement of major oil companies at the mining and milling stages of production is very noticeable, being involved as owners or partners in about 50 per cent of both activities. Gulf Oil, Continental Oil, Getty Oil, Exxon, Chevron, Conoco and Phillips Petroleum, all have substantial industry interests. The largest company in the uranium industry, however, is the energy company Kerr-McGee which is engaged in the exploration, production and marketing of oil, gas and coal in addition to its widespread holdings in the uranium industry. In addition to owning 10 uranium mines (not all operational), Kerr-McGee also controls a UF_6 conversion facility. In 1982 its output of 2 105 tons U_3O_8 represented about 16 per cent of US production in that year. United Nuclear and Utah International (through Pathfinder Mines) also have substantial interests in the US uranium industry. Production figures for individual deposits are confidential, but an indication of the scale of involvement of companies in uranium mining can be obtained by noting their nominal daily milling capacity (Table 10). These figures are far from perfect as indicators of actual company production of yellowcake, as they neglect the grade of ore processed and hence actual output of U_3O_8 is unknown. In addition, no allowance is made for milling which is done on a toll basis for (gen-

Table 10

US Uranium processing plants (operating as of January 1, 1982)

Conventional mills Company	Location	Nominal capacity (kt ore/day)
Kerr-McGee Nuclear[1]	Grants, New Mexico	7.00
Anaconda Minerals[2]	Grants, New Mexico	6.00
Pathfinder Mines[3]	Gas Hills, Wyoming (2.5) Shirley Basin, Wyoming (1.8)	4.30
Conoco-Pioneer Nuclear[4]	Falls City, Texas	3.40
Homestake Mining	Grants, New Mexico	3.40
Exxon Minerals[5]	Powder River Basin, Wyoming	3.20
Minerals Exploration[6]	Red Desert, Wyoming	3.00
United Nuclear[7]	Church Rock, New Mexico	3.00
Union Carbide	Natrona Country, Wyoming (1.4) Uravan, Colorado (1.3)	
Chevron Resources[8]	Hobson, Texas	2.50
Bear Creek Uranium[9]	Powder River Basin, Wyoming	2.00
Energy Fuels Nuclear	Blanding, Utah	2.00
Western Nuclear[10]	Wellpoint, Washington	2.00
Petrotomics	Shirley Basin, Wyoming	1.50
Atlas Minerals[11]	Moab, Utah	1.40
Cotter[12]	Canon City, Colorado	1.20
Rio Algom[13]	La Sal, Utah	0.75
Dawn Mining[14]	Ford, Washington	0.45
Total nominal capacity (tons ore/day)		**49.80**

Conventional Mills: total nominal capacity	19.0–21.0 kt U_3O_8/year
Solution Mining operations (largely in Texas and Wyoming)	1.7– 2.1 kt U_3O_8/year
Phosphoric Acid by-product (Florida and Lousiana)	0.8– 1.2 kt U_3O_8/year
Heap Leachings, Dumps, Tailings (Arizona, Colorado, Texas, Utah)	0.2– 4.0 kt U_3O_8/year
Total US nominal capacity	**21.7–24.7 kt U_3O_8/year**

Source:
"Statistical Data of the Uranium Industry", US Department of Energy, Grand Junction, 1982.

Notes:

1 A division of Kerr-McGee Corporation.
2 A wholly-owned subsidiary of Atlantic Richfield Company (Arco).
3 A wholly-owned subsidiary of Utah International (itself a wholly-owned subsidiary of General Electric).
4 Jointly operated by Conoco (a wholly-owned subsidiary of Du Pont) and Pioneer Nuclear.
5 A division of Exxon Corporation.
6 A wholly-owned subsidiary of Union Oil Corporation of California.
7 A wholly-owned subsidiary of Homestake Mining.
8 A wholly-owned subsidiary of Standard Oil Corporation of California.
9 Jointly owned by the Rocky Mountain Energy Company and Southern California Edison.
10 A wholly-owned subsidiary of Phelps Dodge.
11 A division of the Atlas Corporation.
12 A wholly-owned subsidiary of Commonwealth Edison.
13 Rio Tinto-Zinc (UK) owns 52.75 per cent of Rio Algom.
14 Newmont Mining owns 51 per cent of Dawn Mining.

erally small) mines without their own milling facility.

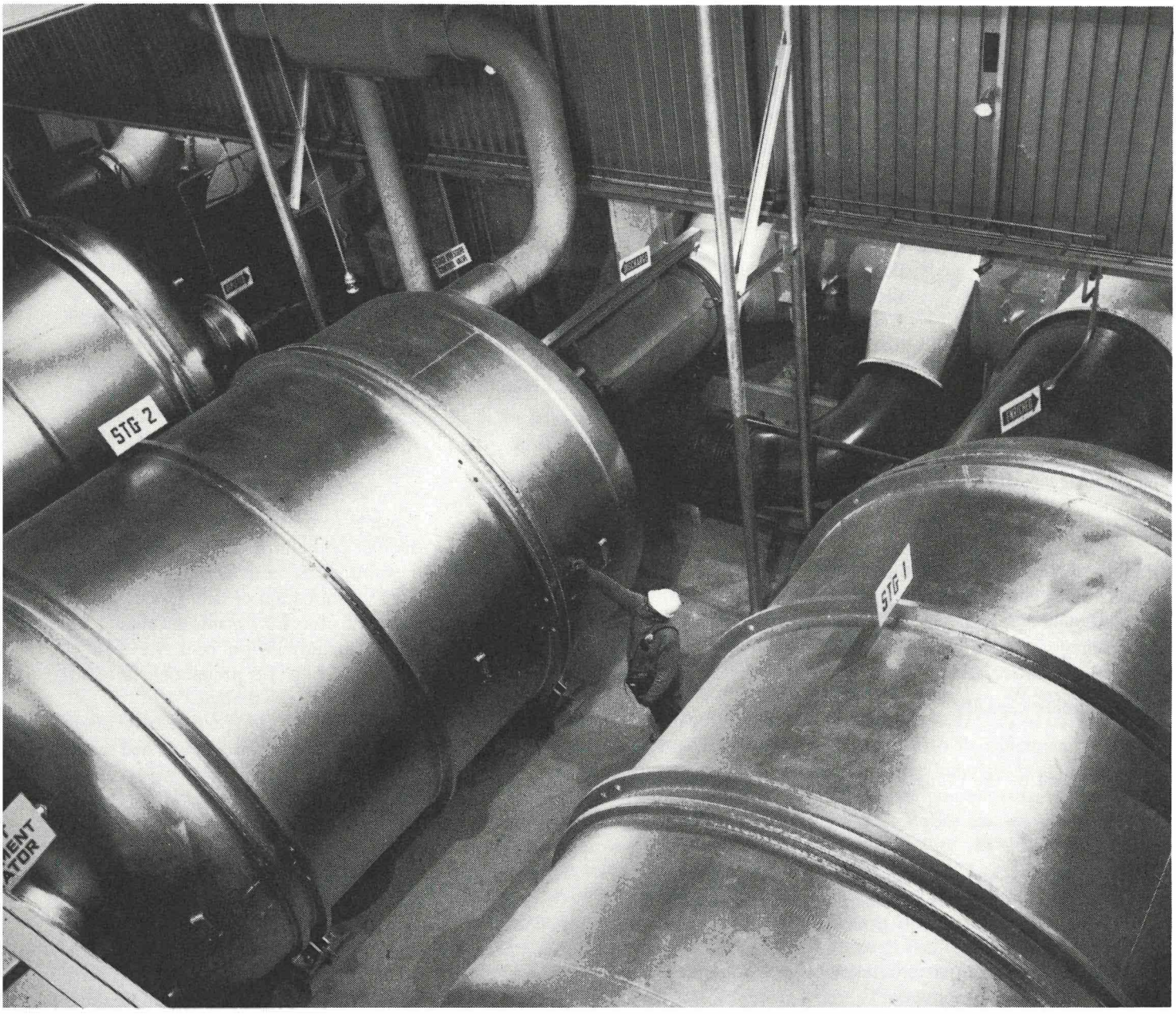
As at January 1, 1982, 20 uranium mills were operating in the USA, of which 14 were working at a weighted average of about 60 per cent of nominal capacity during 1981. The remaining 6 were working at full capacity. The current depressed state of the uranium market, however, forced 3 mills to be shut down during 1981 (although one new mill commenced production) and this trend is envisaged to continue over the next few years as high-cost mines are forced out of business by imports from low-cost mines in Australia, Canada and (to a limited extent) South Africa.

In addition to the conventional mines recovering yellowcake from ore, in 1981 there were 11 solution mining operations, 7 plants recovering uranium as a by-product of phosphoric acid production, and 4 plants using heap leaching to extract U_3O_8 from dumps or tailings. Combined, these 22 processing plants accounted for approximately 19 per cent (i e 3.58 kt U_3O_8) of total US production of uranium concentrate in that year.

By year-end 1981, cumulative (from 1947) US uranium production had reached 365.96 kt U_3O_8, which was produced from over 200 Mt of ore yielding an average grade of about 0.18 per cent U_3O_8. As might be expected, the average grade of processed ore has fallen considerably over this period, from a high of 0.32 per cent U_3O_8 in 1952 to 0.20 per cent U_3O_8 in 1975 and 0.11 per cent U_3O_8 in 1979. Since 1979, however, cost pressures have forced many marginal (generally low ore grade) producers out of business and consequently there was a small increase in ore grade to 0.12 per cent U_3O_8 in 1982. This trend can be expected to continue as US producers attempt to compete with imports from the low cost, high grade, deposits in the Northern Territory (Australia) and Saskatchewan (Canada).

In 1980, US uranium production reached an all-time peak of 21.84 kt U_3O_8 in (a lagged) response to the boom

The Oak Ridge gaseous diffusion plant, operated by the Union Carbide Corporation for the US Atomic Energy Corporation.



conditions of the late-1970s. The corresponding figures for 1981 and 1982, however, were 19.24 kt U_3O_8 and 13.43 kt U_3O_8 respectively, reflecting the rapid demise of many high cost producers as the NUEXCO Exchange Value fell to its lowest ever level (in real terms) in late 1982. Given the lagged response to price changes that is inherent in the uranium mining industry, US production is likely to continue its rapid fall during the mid-1980s.

As an indication of the effects of the plunge in uranium prices on the mining sector since the late 1970s, Table 9 shows the dramatic fall that has occurred in US domestic production potential for the years to 1992 as estimated (from survey data) by the US DOE. In 1980 the survey indicated that production could reach 25.4 kt U_3O_8 by 1983, whereas a figure nearer 10 kt U_3O_8 now appears likely. The corresponding DOE figure for 1985 was 23.2 kt U_3O_8, which, by its 1982 survey, had been revised to 14.3 kt U_3O_8. This amounts to a reduction of almost 40 per cent in just 2 years. These figures simply confirm the NUEXCO estimates in Table 2 as both envisage a rapid demise

for many US uranium mining and milling operations.

Whilst US uranium production is envisaged to decrease substantially during the 1980s, US domestic consumption requirements are expected to increase considerably from about 10.5 kt U_3O_8 in 1982 to about 19.0 kt U_3O_8 by 1990. Thus during the 1980s the US will come to be more reliant on imported uranium to supplement its domestic supplies than at any time since the 1950s.

US exports of (domestic source) uranium have never been large, amounting to a cumulative total of only 21.6 kt U_3O_8 since 1966. Imports have also been of minor importance, amounting to a cumulative total of 14.5 kt U_3O_8 since the import embargo was partially relaxed in 1977. Over the next decade, US exports will diminish to a negligible quantity whilst imports should rise at a relative steady rate.

US production during the 1980s will be supplemented by a large inventory of uranium held as both U_3O_8 and enriched UF_6. Currently, total US uranium inventory amounts to approximately 9 years forward consumption[12], which is excessive by any yardstick. Whilst a certain amount of enriched UF_6 inventory is required by the DOE as a working-inventory to assure enrichment service customers that their deliveries can be met on contracted schedule, the high inventory of U_3O_8 has been reflected by depressed prices and consequently reduced levels of production.

Table 9

Total US domestic production potential (kt U_3O_8)

	Date of survey		
Year	**1980**	**1981**	**1982**
1983	25,4	21,6	18,0
1984	24,3	20,1	14,9
1985	23,2	19,2	14,3
1986		17,6	14,3
1987		15,7	13,7
1988		15,2	13,4
1989		13,4	13,4
1990		12,4	12,6
1991			11,9
1992			

Source:
"Survey of United States Uranium Marketing Activity", US Department of Energy, 1980–1983.

CONCLUSION

Over-optimistic projections of electricity requirements made during the 1970s, combined with delays in licensing and constructing nuclear power installations and the current industrial recession, have produced a situation where uranium production currently exceeds consumption by about 60 per cent, with the excess contributing to a largely unintended increase in utility inventories. Since these conditions have prevailed for a number of years, the uranium market is currently characterised by an excessive level of inventories, surplus production capacity and, consequently, depressed prices.

Market forces, however, are now forcing an adjustment in production levels and a geographical redistribution of producing areas, with the USA in particular contracting rapidly to the benefit of Canada and, to a lesser extent, Australia. When demand and supply eventually balance towards the middle of this decade, new production facilities may be required. At present, however, only the more cost efficient centres are likely to survive the current period of adjustment.

Notes:

For simplicity the symbols *t* and *kt* are used for denoting short and thousand short tons respectively throughout the paper.

[1] NUEXCO is the world's principal private uranium brokerage company.

[2] All quantity data is reported in terms of short tons (i e 2000 lb) of uranium oxide, or yellowcake (i e tons U_3O_8).

[3] The price of uranium and cost categories for uranium reserves are conventionally expressed in US dollars per pound of uranium oxide (USD/lb U_3O_8), or per kilogram of uranium oxide (USD/kg U_3O_8), or per kilogram of uranium metal (USD/kg U), where (USD/lb U_3O_8) = 2.2046 USD/kg U_3O_8 = 2.6128 USD/kg U.

[4] A D Owen, "The Economics of Uranium Demand", *Resources Policy,* June 1983, pp 110–121, provides a more detailed account of factors influencing the demand for uranium.

[5] Consumption is defined as the amount of uranium entering the conversion-enrichment-fuel fabrication pipeline. It differs from reactor consumption, therefore, by changes in inventories at each of these three "stages" in the fuel cycle.

[6] The Exchange Value is widely quoted within the industry as a spot or short-term price for uranium. NUEXCO issues a monthly Exchange Value which represents their judgement of the price at which transactions for significant quantities of uranium could be concluded on the last day of the month.

[7] The Combined Development Agency was formed in 1944 by the Governments of the USA and the UK to purchase foreign uranium to meet their weaponry requirements. It was dismantled in 1960.

[8] Australian Government Publishing Service, *Ranger Uranium Environmental Inquiry* (2 reports), Canberra, 1976.

[9] Excludes speculative estimates regarding the size of the uranium reserve at Olympic Dam on Roxby Downs.

[10] C G Battey, "Australian Uranium Resources", *Atomic Energy in Australia,* Vol 21, No 4, October 1978, pp 2–9.

[11] S Koutoubi and L W Koch, "Uranium in Niger", in *Uranium and Nuclear Energy,* Mining Journal Books Limited, London, 1980.

[12] J Oliver, B Liggett, and B Poole, "US Uranium Marketing Developments: Highlights from US Uranium Marketing Activity Surveys", US Department of Energy, October 1983. ■