THE WORLD'S POTASH INDUSTRY AS IT RELATES TO SOUTH AFRICA

J C BOTHA & B G RUSSELL, Minerals Bureau, Department of Mines, Republic of South Africa

Abstract

The price of potash, which increased dramatically following the overbuying which occurred in 1974, returned to the previous lower levels in 1976 mainly because of consumer resistance to high fertilizer prices. The real price is not expected to increase in the short to medium term. Very little growth in potash production occurred during 1975 and 1976 and this growth was in the U S S R, the World's largest potash producer, where significant investment in potash-production capacity is still taking place, and exports to western countries are expected greatly to increase in future. South Africa depends entirely on imports for its supply of potash. Of the known occurrences of potassium minerals, Phalaborwa phlogopite is considered to be the most promising for local potash production. The South African consumption of potash as fertilizer was 133 000 t of K_2O in 1976, and this figure is expected to increase to 200 000 t by 1985.

Introduction

The term potash is commonly used for compounds of the element potassium and is frequently used to express the potassium oxide (K_2O) equivalent content of substances, even though no actual oxide is present. There are many potassium-bearing minerals, but only those that are soluble in water are at present exploited commercially.

A German discovery proving that potassium is essential to plant growth was made in 1840. Discoveries of large deposits of soluble potassium minerals were made in Germany in 1857, and in the U S A in 1914. Several important subsequent discoveries were made and at present the main World producers of potash are the U S S R, Canada, the Democratic Republic of Germany, the Federal Republic of Germany, and the U S A.

In this paper, t is used to signify 1 000 kg, R signifies the South African unit of currency, the Rand, and $C signifies the Canadian dollar.

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South Africa, although fortunate in having extensive exploitable deposits of most minerals, is entirely dependent on imports for her supplies of potash, and although various potential sources of the commodity have been investigated, none has proved economically exploitable to date.

Mining and Beneficiation

Almost all commercial potash is recovered from underground deposits of soluble minerals or from potash-bearing brines.

Three methods are normally used for the mining of potash: the conventional room-and-pillar method, a system similar to sublevel-stoping with waste fill, and the longwall mining technique. Mining depths can be over 1 000 metres, e g, in the Federal Republic of Germany. Potash is also, on rare occasions, extracted by solution mining but this method is only applicable to readily soluble potassium chloride minerals and is only considered profitable for thick, high-grade, sylvinite ores. The grade of deposits mined generally varies between about 10 and 35 per cent K_2O equivalent. Table 1 presents the composition of potash ores mined in the World.

(Sources: Notholt, 1976; Adams 1975; Keyes, 1975).

When it has once been extracted from the host rock in which it occurs, potash is usually concentrated by means of flotation, or recrystallization from a hot brine; the latter being the oldest method. The majority of sylvinite ores mined in the U S A and Canada are upgraded by means of flotation, and in Europe and the U S S R both flotation and recrystallization are generally used. The two techniques are often combined when a highergrade product is required.

Potash for use as fertilizer is produced in the form of muriate of potash (KC1), the double sulphate of potassium and magnesium ($K_2SO_4.2MgSO_4$) known as langbeinite, potassium nitrate (KNO_3), and potassium sulphate (K_2SO_4). The first three occur naturally as minerals, although potassium nitrate is also manufactured, for example, by reacting potassium chloride with nitric acid. Potassium sulphate is produced by evaporation of lake brines high in sulphate, by reacting langbeinite with potassium chloride to displace the magnesium, or by converting potassium chloride to sulphate by using sulphuric acid.

There are more than 70 different potassium-bearing minerals, but only a few are of any real economic significance (Table 2).

TABLE 1 Potash Ores (Adams, 1975)

Ore	Composition	Equivalent K_2O content, %	Countries where found
Sylvinite	$KCl+NaCl$	10–35	Canada, U S A, U S S R, Congo
Hartsalz	$KCl+NaCl+CaSO_4+MgSO_4.H_2O$	10–20	Germany
Carnallitite	$KCl.MgCl_2.6H_2O+NaCl$	10–16	Germany, Congo
Langbeinite	$K_2SO_4.2MgSO_4+NaCl$	7–12	U S A, U S S R
Mischalz	Hartsalz+$KCl.MgCl_2.6H_2O$	8–20	Germany
Kainite	$4KCl.MgSO_4.11H_2O+NaCl$	13–18	Italy
Nitre (caliche)	$KNO_3+NaNO_3+Na_2SO_4+NaCl$	0,6–1,9	Chile

TABLE 2 Potassium-bearing minerals of economic significance (Botha, 1976)

Mineral	Composition	Equivalent K_2O content %
Silvite	KCl	63,17
Carnallite	$KCl.MgCl_2.6H_2O$	16,95
Kainite	$4KCl.4MgSO_4.11H_2O$	19,26
Langbeinite	$K_2SO_4.2MgSO_4$	22,6
Nitre	KNO_3	46,5

World situation

Table 3 lists World statistics for three periods of one year each, for the production, consumption, and export of potash for important producing and consuming countries. Estimated reserves, as published by the U S Bureau of Mines (Keyes, 1975), and believed to be economically exploitable at prices ruling in 1974, are given in the last column. Figure 1 (Botha, 1976; *Phosphorus and Potassium*, Mar/Apr 1976), shows the World Production from 1965 to 1975. The Federal Republic of Germany, the Democratic Republic of Germany, the U S S R, and Canada have reserves estimated to exceed 700 million t and an excess of production over consumption of more than 1,5 million t of K_2O equivalent per annum. Only Eastern Europe (including the Democratic Republic of Germany), and North America, have a sufficient excess of production over consumption (as reflected by the net export figures) to exert pressure on the World potash markets. Events in the U S S R, and in Canada (the World's two largest producers, which together account for more than half of the World's potash production, and have the lowest production costs in the World) particularly will influence the future World potash situation.

World production of potash increased by 5,8 per cent per annum from 1965 to 1975. The over-buying which occurred during 1974 led to an increase in World potash production of 14,3 per cent over that for 1973. This was not matched by a corresponding increase in consumption which continued to be depressed through 1975 and 1976 under the impact of large price increases for fertilizer and of the World economic recession. Very little growth in potash production occurred during 1975 and 1976 and the growth that did occur was essentially in the U S S R and East Germany, places that were not affected to any extent by increased prices in the Western World. Indeed, the U S S R is the only area where significant investment in potash production capacity is still taking place.

Essential features of the potash industry in the major producing countries and countries which supply South Africa are discussed in the following sections.

Canada

Production of potash in Canada commenced in the early 1960s in the Province of Saskatchewan and, as it has the World's largest reserves of potash (estimated at 4,5 x 10^9 t of K_2O equivalent), production expanded rapidly to reach almost 20 per cent of the World's production by the late 1960s, and 20 per cent by 1976.

The sylvanite deposits occur at depths of about 1 000 metres (*Ind. Miner.*, Feb. 1971). Large water-bearing zones are encountered above the potash and these have to be frozen during shaftsinking operations, a process which gives rise to high costs of mine development. The shafts are lined with cast-iron tubbing in the water-bearing zones.

The high grade of the ore (average 25 to 32 per cent K_2O) (Keyes, 1975), and the flat, regular beds ensure low production costs in spite of a relatively low ore recovery of approximately 50 per cent (Adams, 1975). This low recovery

TABLE 3 *World supply, demand and reserves of potash fertilizer* — 1 000 t K_2O equivalent
(Keyes, 1975; *British Sulphur Corporation*, 1973, 1974, 1975, 1976)

Area/Country	Production				Consumption				Net exports		Reserves + (Keyes, 1975)
	1970/71 Mass	1974/75 Mass	1975/76 Mass	% of Total	1970/71 Mass	1974/75 Mass	1975/76 Mass	% of Total	1970/71 Mass	1974/75 Mass	
Western Europe	4 791	5 289	4 351	18,3	4 749	4,667	4,532	21,0	– 8*	– 27*	1 800 000
France	1 820	2 082	1 720	7,2	1 342	1 413	1 328	6,1	522*	629*	90 000
West Germany	2 293	2 659	1 950	8,2	1 185	1 171	1 099	5,1	1 132	1 254	1 600 000
Eastern Europe	6 506	9 450	10 963	46,0	5 250	7 211	8 719	40,3	904	1 632	3 200 000
East Germany	2 419	2 864	3 019	12,7	614	716	707	3,2	1 739	2 089	2 500 000
U S S R	4 087	6 586	7 944	33,3	2 574	3 710	4 997	23,1	1 309	2 330	700 000
North America	5 591	7 994	7 062	29,6	4 023	4 281	4 975	23,0	1 208	2 128	4 680 000
Canada	3 178	5 623	4 842	20,3	184	230	250	1,2	n.a.	n.a.	4 500 000
U S A	2 413	2 371	2 220	9,3	3 839	4 051	4 725	21,9	n.a.	n.a.	180 000
Central America	Nil	Nil	Nil	0	257	258	299	1,4	– 246	– 333	0
South America	21	13	10	0,0	441	710	621	2,9	– 478	– 759	9 000
Africa	166	285	278	1,2	245	343	316	1,5	– 244	– 432*	18 000
Congo-Brazzaville	166	285	278	1,2	6	4	4	0,0	n.a.*	n.a.*	18 000
South Africa	Nil	Nil	Nil	0	90	137	128	0,6	– 108	– 195	0
Asia	813	1 007	1 166	4,9	1 434	2 206	1 929	8,9	– 708	– 1 769	225 000
China (Peoples Republic)	210	400	450	1,9	210	562	560	2,6	– 9	– 149	5 000
Israel	603	607	716	3,0	11	15	15	0,0	507	531	220 000 #
Oceania	Nil	Nil	Nil	0	199	285	225	1,0	– 204	– 284	9 000
World Total	17 888	24 038	23 830	100,0	16 598	19 961	21 616	100,0	222	141	10 000 000

* Exports from Congo included in French export statistics.

\+ At average 1974 domestic mine price.

\# Including Jordan.

n.a. not available.

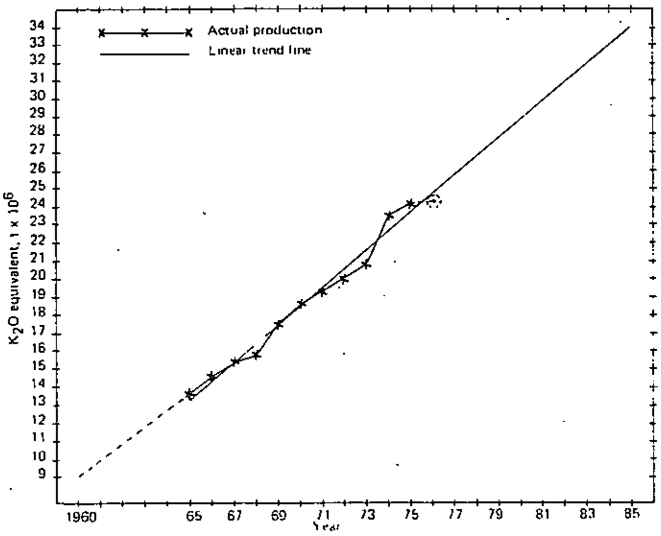

FIG 1 World production of potash production

is caused by the necessity of leaving extensive supporting pillars so as to avoid the risk of fracturing the overlying salt bed, and thus causing flooding of the mines. The low production costs enabled the Saskatchewan producers to undercut World potash prices during the oversupply situation that developed during the later 1960s and eventually led to the intervention of the Saskatchewan Provincial Government which established a floor price for Canadian potash and a prorationing system. This was followed by further government intervention which resulted in all potash producers being required to pay a reserves tax, a prorationing fee, and a royalty on the ore extracted, these levies being in addition to federal and provincial income tax. This action rendered mining by private companies financially unattractive and culminated in the planned nationalization of the potash industry by the Provincial Government, and to the postponement of the installation of new production capacity, with the object of forcing prices upwards through the creation of a commodity shortage. In spite of the Saskatchewan government's intervention, Canada has remained, and is expected to continue to remain, one of the two leading potash producers. This contention is supported by the fact that two Saskatchewan potash companies have commenced exploration of potash resources in New Brunswick, and that one of these companies has announced preliminary plans for the establishment of a potash mine (*Mining Annual Review*, 1976; *Eur. Chem. News*, 8 Oct 1976).

Because Canada consumes less than 5 per cent of its potash production it is greatly dependent on exports to foreign consumers, especially the U S A. About 70 per cent of Canada's potash sales are to her southern neighbour, and some 70 per cent (*Phosphorus and Potassium*, Mar/Apr 1976) of the balance is shipped to consumers in Asia. A recently announced agreement whereby 600 000 t (*Phosphorus and Potassium*, Sept/Oct 1976) of potash will be supplied to the U S A each year by the U S S R, in exchange for phosphoric acid, is seen as a significant setback for the Canadian industry, and is described in the next section.

U S S R

The first potash mine in the U S S R was opened in 1931. The industry is based largely on deposits that lie to the west of the Urals, and in central Byelorussia, where the principal mineralization is sylvinite with an average K_2O content of about 17 per cent. Room-and-pillar mining methods are generally used, but the longwall mining system, with roof caving, has recently been adopted on a large scale at certain mines with an increase of total ore recovery from 45 to 75 per cent and an improvement of the grade of the ore extracted (Wld. Min., 8 Jul 1976).

The U S S R is the World's largest potash producer and the implementation of large-scale automation and mechanization in both new and existing mines has contributed to the 145 per cent increase in production from 1969 to 1975.

As a result the U S S R's share of World production rose from 19 to 35 per cent during this period. An increase in production capacity of 5,8 x 10^6 t of K_2O is planned during 1977 and 1978, and total production is planned to reach 12 x 10^6 t by 1980 (*Phosphorus and Potassium*, Sept/Oct 1976).

The U S S R exports potash mainly to countries in Europe and during 1975, 67 per cent was exported to Eastern European countries, and 20 per cent to Western Europe (*Phosphorus and Potassium*, Sept/Oct 1976).

A factor which may affect the balance of World trade in potash significantly, particularly Canadian exports to the U S A, is the contract recently signed between the Occidental Petroleum Corporation of the U S A, and the government of the U S S R whereby the U S A will receive Russian potash in exchange for superphosphoric acid. The supplies of potash are expected to start in 1978 and to reach 600 000 t of K_2O per annum by 1980 (*Phosphorus and Potassium*, Sept/Oct 1976).

This will be in addition to the 730 000 t of K_2O equivalent (*Phosphorus and Potassium*, Sept/Oct 1976) already shipped to the Free World by the U S S R in 1975. However it has been suggested that much of this potash may not reach the U S A but may be rerouted to consumers in other countries, probably to existing customers of producers in the Western World. Whichever may be the case, the U S S R material will compete effectively with all western producers of potash.

Although the 10 per cent annual increase in consumption of potash in the U S S R from 1971 to 1975 has been greater than the World average of about 6 per cent per annum, production has increased at about 13 per cent per annum, and with planned further increases in production capacity over the next two years, a concerted export drive to countries traditionally supplied by Canada and Western Europe is to be expected and the Occidental Petroleum Corporation contract may only be the beginning. (Other sources: Adams, 1975; *Ind. Miner.* Feb 1971a; Keyes, 1975).

U S A

Potash production in the U S A is principally from the Carlsbad District in New Mexico, although a small but increasing amount is produced from natural brines. Reserves are relatively small and the higher-grade material is exhausted. Canada supplies some 95 per cent (Keyes 1976a) of the U S A's imports of potash which, during 1975, amounted to 56 per cent of their total potash consumption of about 4,5 million t (Keyes, 1976b). (Other sources: Adams, 1975; Keyes, 1975; *Ind. Miner.* Mar 1974).

East Germany

East Germany, the World's third-largest producer, exploits the sylvinite reserves of the Zechstein basin in Northwestern Europe and, together with the U S S R, accounts for all of Eastern Europe's production, or about 46 per cent of World production. Although about 65 per cent of exports are to Eastern European countries, some 20 per cent of the total is exported to Western Europe (*Phosphorus and Potassium*, May/Jun 1975). (Other sources: Adams, 1975; Keyes, 1975).

West Germany

The potash industry has exploited the potash beds of the Zechstein basin for more than a century. The deposits lie between 300 and 1 200 metres below the surface and mining is generally by stoping and back-filling. Ores containing sylvite, carnallite, and sulphate minerals are mined at grades between 9 and 17 per cent K_2O.

Although West Germany produces about half of the Western European potash its production has remained virtually constant since 1969 whereas its share of World production has decreased from 15 per cent in 1969 to 9 per cent (*Phosphorus and Potassium*, Apr/May 1976) during 1975. Its major export markets are Western Europe and Asia (65 and 13 per cent respectively during 1975) and its exports to the Eastern European market have decreased from 9 per cent in 1973 to 4 per cent in 1975 due to the lessening of the dependence of Eastern Europe on the West because of the preference being given to supplies from the U S S R and East Germany, (*Phosphorus and Potassium*, May/Jun 1976). (Other sources: Adams, 1975; Keyes 1975, *Ind. Miner.*, Mar 1971a).

France

The French potash industry is based on the reserves of the Oligocene evaporites at Alsace. Mining is by the state-owned Mines de Potasse d' Alsace. The two ore zones mined contain 15 to 20, and 20 to 25 per cent K_2O respectively. The longwall mining system is generally used.

The potash industry's location alongside the Rhine has led to considerable dumping of salt waste into the river. During 1964 legislation was passed limiting the discharge of salt to 7 million t per annum which limits potash production to 1,8 million t of K_2O per annum. (Sources: Adams, 1975; Keyes, 1975; *Ind. Miner.*, May 1974; *Phosphorus and Potassium*, Sept/Oct 1976).

Israel

Potash is recovered from the Dead Sea which is situated between Israel and Jordan, by the company Dead Sea Works Ltd. Carnallite is harvested from more than 10 000 hectares of solar evaporation ponds, and is converted to sylvite. The production capacity has recently been increased to 720 000 t of K_2O per annum. During 1975/76 about 84 per cent of the potash sales were directed to export markets, some 60 per cent being destined for Europe, and about 3,6 per cent, or 23 000 t, for South Africa. The exports to South Africa are expected almost to double during 1977. (Sources: Adams, 1975; Keyes, 1975; *Ind. Miner.*, May 1974; *Phosphorus and Potassium*, Jul/Aug 1976).

Congo-Brazzaville

The potash deposits consists of carnallite and sylvinite and are the largest deposits of such high-grade carnallite in the World. Exploratory drilling in 1960 revealed a carnallite bed containing 16 per cent K_2O equivalent, with less than 0,1 per cent insolubles over a thickness of 8 m.

Pods and lenses of silvinite with a K_2O content of 38 per cent had formed in the carnallite bed. One lens having a K_2O content of more than 35 per cent, covering an area of 9 km^2, and having an average thickness of 2,7 metres and an average depth of 370 metres, is currently exploited.

The potash mine is operated by Compagnie des Potasses du Congo which is said to have a major French shareholding and the potash is marketed by the sales arm of the French, state-owned potash group. It is probable that the Congolese Government will soon become the sole owners.

Production of potash from the sylvinite commenced in 1970. Mining is from long-rooms with intervening pillars which are left unrecovered. Sylvite is recovered from the ore by a two-stage flotation.

The production capacity is reported to be 500 000 t of K_2O per annum but due to adverse geological characteristics of the sylvinite lens the output has never exceeded 300 000 t of K_2O per annum and the operation is at present unprofitable.

Further investigations of the carnallite seam have shown it to be thick and regular, and unaffected by folding which occurred in the sylvinite body. Future exploitation of the carnallite bed, possibly at a rate of 600 000 t of K_2O per annum, seems inevitable for profitable production of potash and eventual recoupment of the losses already incurred. (Sources: Adams, 1975; Keyes, 1975; *Ind. Miner.*, Mar 1971a; *Ind. Miner.*, May 1974; *Phosphorus and Potassium*, Nov/Dec 1976).

Botswana

Potassium chloride occurs together with sodium carbonate, sodium chloride, and sodium sulphate in the brines of the Sua pan which is part of the Makgadikgadi pans. The amount of potassium chloride contained in the brines is estimated at 4 x 10^9 t and constitutes the only substantial deposit of soluble potassium compounds in Southern Africa.

Past investigations at the Botswana Rand Selection Trust's pilot plant in the area, have shown the recovery of potash and sodium compounds from the Sua pan to be feasible technically but the Trust has subsequently allowed its prospecting rights to lapse (*Ind. Miner.*, Dec 1974).

World Prices

From 1949 to 1969 the price of potash fell steadily in real terms in the U S A (Lewis, 1970; *Fertilizer Int.*, 1975, 1976, 1977). The World oversupply situation towards the end of the 1960s, brought about by the Canadian potash industry's spectacular decade of export-orientated production growth, caused prices to plummet to an all-time low in actual terms of $C20 per t of K_2O during the peak of the buying season in 1969. The Saskatchewan Provincial Government stepped in during 1970 with a prorationing program whereby minimum prices and minimum production quotas were set for each mine. As a result the price of potash ex-mine rose from an average of $C21,90 per t of K_2O in 1969, to $C40,48 per t in 1971, whereupon prices again increased slightly during 1972 and 1973. During 1974 the demand for potash, caused by consumer overbuying, increased dramatically and was reflected in an equally dramatic price increase. (Figures 2 and 3). When oversupply once again became evident early in 1975 the prices were slow to reflect the change in the supply-demand pattern which followed, and it was only in 1976 that the price returned to the lower levels of 1974. This is suspected to have been due to cartel-type agreements between Western producers.

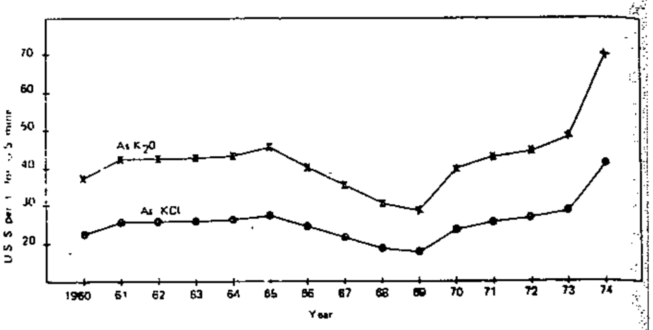

FIG 2 U S Domestic prices of potassium chloride

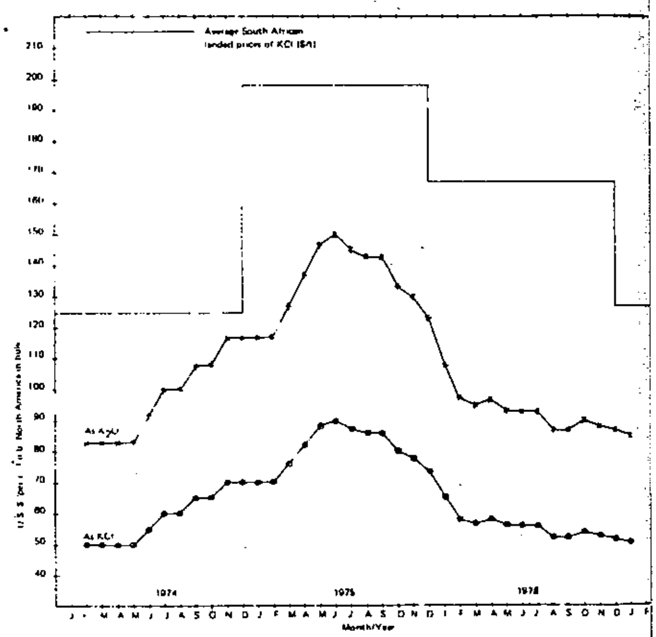

FIG 3 North American export prices of potassium chloride

The price of potash in real terms is not expected to increase in the short to medium term at least, because of several factors that have recently become inherent in the industry:

1 A decrease in consumption growth rate caused by several factors, as follows

(a) Western Europe approaching a consumption plateau.

(b) Low prices for agricultural products, which are expected to encourage farmers to continue to resist high fertilizer prices and to restrict fertilizer use. This does not apply to South Africa where fertilizer prices have not risen as rapidly as in other countries and agricultural products have increased in value to a greater extent than nutrients.

(c) Many soils are inherently high in potassium and scientific research has led to more selective potash application being practised. This is particularly characteristic of South Africa where large areas of farmland have been proved to contain adequate amounts of potash.

(d) A failure on the part of fertilizer manufacturers to pass on price reductions to the farmer.

(e) The failure on the part of potash producers to promote the use of potash in agriculture.

2 Large stocks in producing countries overhanging the market despite lower production levels (the average World potash production-capacity utilization in 1974/75 was about 85 per cent).

3 A sustained increase in both production capacity and production by the U S S R, and its export drive to countries traditionally supplied by the West.

As a result of these combined factors, a buyers' market seems to be well established for the foreseeable future, with poor prospects for producers, especially those situated in the Western countries. The price could well fall further before it rises, and even then can be expected to do little more than follow the World inflation rate.
(Other Sources: Keyes, 1975; Botha, 1976; *Ind. Miner.*, Mar. 1971b).

South Africa-Occurrences

South Africa has no known deposits of water-soluble potassium minerals. Potential sources of potash, however, include minerals such as phlogopite mica, sericite, glauconite, and alkaline igneous rocks such as syenite and ijolite. All these minerals contain less potassium than ores currently exploited overseas and require more expensive processing for the extraction of the potash i e, the formation of potassium chloride or sulphate for use as fertilizer. The strategic implications of South Africa's reliance on imports, and the desirability of reducing expenditure on them, are factors which have contributed to the investigations that have been undertaken into the exploitation of local raw materials. Phalaborwa phlogopite, which has received more attention than any other raw material because it has one of the highest K_2O contents, is a co-product of another mining operation and appears to be more easily decomposed than the other possible materials.

Phalaborwa phlogopite

Phlogopite mica is concentrated in a pipe-like body in the northern part of the Phalaborwa pyroxenite, and constitues between 10 and 20 per cent of the entire pyroxenite ore body which is mined for vermiculite by the Palabora Mining Company (PMC), and for phosphate by the Phosphate Development Corporation (Foskor). Resources are estimated at some 200 x 10^6 t of contained K_2O to a depth of 1 000 m. The area is already mined for vermiculite, an alteration product of phlogopite, and the mica is at present largely discarded as a waste product. Phlogopite, in a finely ground state and mixed with other gangue material, is also discarded onto the Foskor slimedams after the phosphate has been removed. The possible separation of the mica has been investigated without any significant success.

Extraction of potash from phlogopite

In 1968 the South African National Institute for Metallurgy investigated the recovery of potash from a sample of Phalaborwa phlogopite (Dicks & McCulloch, 1968). The analysis of the sample is given in Table 4. Approximately 95 per cent of the K_2O was found to be soluble in water after the sample (ground to $< 35 > 60$ mesh) had been reacted at 900 °C for one hour with a mixture of calcium carbonate and calcium sulphate. By using this process 5 t of lime (R5,00), 5 t of gypsum (R5,00), 10 t of phlogopite (R25,00) and 6 t of coal (R30,00) are required to produce 1 t of K_2O valued at R52,00. The process was thus hopelessly uneconomic, when based on the cost of raw material and reagents alone, although calcium carbonate is available locally as a waste product from copper production and gypsum from a local phosphoric acid plant. Potash has risen in price considerably since 1968 (R58 per t of K_2O) but treatment and raw-material costs appear to have risen in proportion. It would thus appear that for the extraction of potassium compounds only the proposed process may be no more economic today than in 1968.

Phlogopite, however, in addition to potassium, contains 14,4 per cent alumina, and 22,8 per cent magnesia. Refractory-grade magnesite and aluminium oxide for aluminium production are also entirely imported and are also strategic raw materials for South Africa. It is therefore possible that the economics of a process for the extraction of all three raw materials could be more favourable than one for potash alone. Silica, comprising 39,2 per cent of the mica may prove to be an additional co-product. A viable process has still to be developed and demonstrated.

TABLE 4 Analysis of potential sources of potash in South Africa

Constituent, %	Phalaborwa phlogopite	Phalaborwa syenites	Pilanesberg and Spitskop alkaline complexes	Sericite	Marine glauconite
K_2O	11,0	10–12	4	7–10	9
Al_2O_3	14,4	13–16	19	23–30	
SiO_2	39,2				
Fe_2O_3	5,6				
TiO_2	1,0				
Na_2O	0,1				
MgO	22,8				
CaO	n d				
Loss on ignition	4,7				

n d not determined

Phalaborwa syenites

The area surrounding the carbonatite complex is intruded with numerous dykes of nepheline syenite having a K_2O content of 10 to 12 per cent, and an Al_2O_3 content of 13 to 16 per cent. The recovery of both elements has been considered but the rock is hard and would have to be mined, so that the costs of ore recovery and comminution are likely to be considerably higher than in the case of phlogopite. The reserves are not known accurately, but they are very large.

Pilanesberg and Spitskop alkaline complexes

The rock of greatest importance in these complexes is ijolite which occurs as dykes and sills. The average K_2O content is 4 per cent and the rock also contains about 19 per cent alumina, a possible co-product. It is hard and requires mining, and the reserves are thought to be relatively small.

Sericite

This occurs in layers in the Dominion Reef system, interbedded with lavas and sediments. It has a content of K_2O of 7 to 10 per cent and a content of Al_2O_3 of 23 to 30 per cent. The reserves of 1,2 million t are inadequate for the establishment of an industry.

Glauconite

Glauconite (a hydrous silicate of potassium, iron, and aluminium) occurs as sedimentary beds in northern Zululand, and marine glauconite and phosphorite have been found at many locations along the South African coast.

Localized but highly concentrated deposits of glauconite occur on the outer-continental shelf off the west coast of South Africa, and on the middle shelf west of Port Elizabeth. The highest concentrations (96 per cent glauconite) have been recorded in an outer shelf between Saldanha Bay and Cape Point and have a K_2O content of about 9 per cent. The deposit off Cape Town represents a reserve of $0,7 \times 10^9$ t K_2O. The deposit occurs at depths of 200 to 500 metres and is considered to be one of the richest marine deposits in the World. Ocean mining at such depths is not undertaken at present, and cost estimates are not encouraging for the exploitation of these deposits.

Sea water

Evaporation of sea water can proceed to about 90 per cent completion with the precipitation of only calcium (or calcium-magnesium) carbonate, and calcium sulphate. Further evaporation results in the precipitation of sodium chloride, followed by gypsum, and finally complex salts of potassium and magnesium, together with further sodium chloride. A plant for the recovery of K_2O as a co-product of sodium chloride recovery from sea water at a rate of 150 000 t of K_2O per annum would require a salt production of more than 10 times the current salt consumption in South Africa.

A typical analysis of water from the open Indian Ocean is given in Table 5.

TABLE 5 Typical analysis of water from the open Indian Ocean (Hugo, 1974)

Hypothetical combination	Concentration
Potassium sulphate	1,327
Sodium chloride	26,442
Sodium bromide	0,326
Magnesium chloride	4,450
Magnesium sulphate	1,104
Calcium sulphate	1,622
Calcium carbonate	0,014
Iron oxide	0,003
Total salts	35,288
Specific gravity	1,019
	($2,7^{o}$Bé)

Bé = Baumé

TABLE 6 Country of origin of South African potash imports (Fraction of total imports, %)

Country	1974	1975	1976
France	{90	49	41
West Germany		33	28
Israel	10	15	15*
Canada	0	3	16
Total	100	100	100

* Expected to increase substantially during 1977.

Imports

South African potash imports have declined from 169 000 t K_2O in 1973, to about 154 000 t in 1976. This is due to over-buying and stock-piling during 1973 and 1974 (in common with world consumers); to the subsequent resistance to the increased fertilizer prices on the part of farmers; to the effect of the economic slowdown, and to greatly reduced exports of mixed fertilizers.

As shown in Table 6, about 40 per cent of South Africa's potash imports are supplied by France, and the balance by West Germany, Israel, and Canada. The French supplies are not necessarily produced in France but are distributed from sources of supply in other countries for whom French companies act as agents, or have an interest in the foreign producing company. Potassium chloride accounts for between 80 and 90 per cent of imports (Table 7), and potassium sulphate, supplied by France and Germany, accounts for the balance. Small amounts of potassium magnesium sulphate and potassium nitrate are supplied by West Germany and Israel respectively.

Consumption

South African consumption of potash for fertilizer increased from 34 000 t K_2O in 1960 to 133 000 t in 1976 (Figure 4) representing an average annual growth rate of 8,9 per cent over this period. If it is assumed that future consumption will increase at the same rate, South African consumption would amount to some 200 000 tonnes of K_2O by 1985. The downturn during 1975–1976 indicates that a slowdown in the growth rate is possible.

Because of its lower price and higher potassium content, potassium chloride is preferred to the sulphate and accounts for about 92 per cent of the total potash consumption (Table 8). Potassium sulphate, accounting for about 7 per cent of the potash consumption, and potassium nitrate, are used for crops which are sensitive to chlorides, e g, tobacco. Only potassium chloride and potassium sulphate are used in mixed fertilizers. During 1975, 87 per cent of the potash consumed was used for blending with other fertilizer raw materials, mainly nitrates and phosphates.

Almost 60 per cent of the potash consumed is used in the cultivation of maize and sugar cane, with Natal and Transvaal being responsible for almost 70 per cent of the total potash consumption.

Re-exports

South Africa's imports of potash exceed consumption (Figure 4) because of re-exports to countries in Southern Africa. Exports of mixed fertilizer virtually ceased in mid-1976 mainly because, according to the fertilizer companies, South African producers can no longer compete with the Western European suppliers, who were able to reduce prices following the great price reductions on World markets.

TABLE 7 . South African imports of potash according to type (thousand t K_2O)

Type	1974		1975		1976	
	Mass	Fraction of total %	Mass	Fraction of total %	Mass	Fraction of total %
KC1	142,9	87,9	147,0	81,1	130,1	85,6
K_2SO_4	18,1	11,1	32,0	17,7	18,6	12,2
$K_2SO_4.2MgSO_4$	0,7	0,4	0,3	0,2	0,8	0,5
KNO_3	0,9	0,6	1,9	1,0	2,5	1,7
Total	162,6	100,0	181,2	100,0	152,2	100,0

TABLE 8 South African consumption of potash according to type (thousand t K_2O)

Type	1974		1975		1976[e]	
	Mass	Fraction of total %	Mass	Fraction of total %	Mass	Fraction of total %
KC1	124,9	91,7	116,9	92,0	121,0	91,0
K_2SO_4	9,9	7,2	8,8	6,9	9,0	6,8
$K_2SO_4.2MgSO_4$	0,5	0,4	0,5	0,4	0,5	0,4
KNO_3	0,9	0,7	0,9	0,7	2,5	1,9
Total	136,2	100,0	127,1	100,0	133,0	100,0

e = Estimate

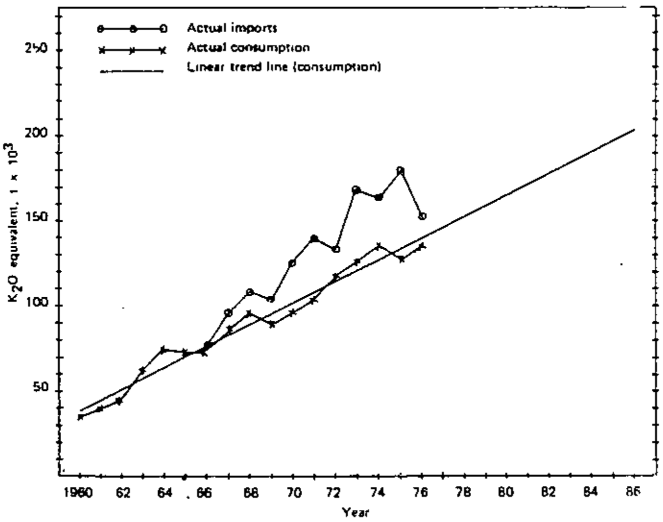

FIG 4 South African imports and consumption of potash for fertilizer use

Prices

The selling prices of potash in South Africa remained fairly constant from 1950 to 1974 (Figure 5). From February 1975 a dramatic price increase of some 80 per cent became effective although a decrease of about 10 per cent was allowed from September 1975, and a further decrease of about 13 per cent from February 1977. This compared with a World price increase of about 80 per cent during 1974 and the first half of 1975, and a decrease of about 40 per cent by the end of 1976. The retail selling prices are controlled by the Government and are determined by the Department of Industries in consultation with the fertilizer companies to allow for a specified profit margin.

The price of potassium sulphate is about 50 per cent higher than that of potassium chloride on an equivalent K_2O basis.

TABLE 9 Approximate costs of potash landed at a South African harbour (R/t of K_2O equivalent)

Year	Type	
	KC1	K_2SO_4
1973	63	97
1974	73–97	119–145
First half 1975	150–160	241–258
1975	147	242
1976	145	256
1977	110	219

The cost of landed potash at the South African coast is at present about R66/t of standard grade KC1 (R110/t of K_2O) and about R105/t of K_2SO_4 (R219/t of K_2O), compared to about R38/t of KC1, and R47/t of K_2SO_4 during 1973 (before the dramatic increase in World prices) and about R95/t of KC1 and R135/t of K_2SO_4 during the first half of 1975 when World potash prices peaked (Table 9).

The average annual South African landed prices of potassium chloride are superimposed on the graph of the World KC1 prices in Figure 3.

Conclusions

World situation

1. World reserves of potash at 1974 price levels are estimated at 10 000 million t of K_2O of which 45 per cent is located in Canada.

2. The abnormally high growth rate of World potash production in 1974 was not matched by a corresponding increase in consumption, which still remains depressed.

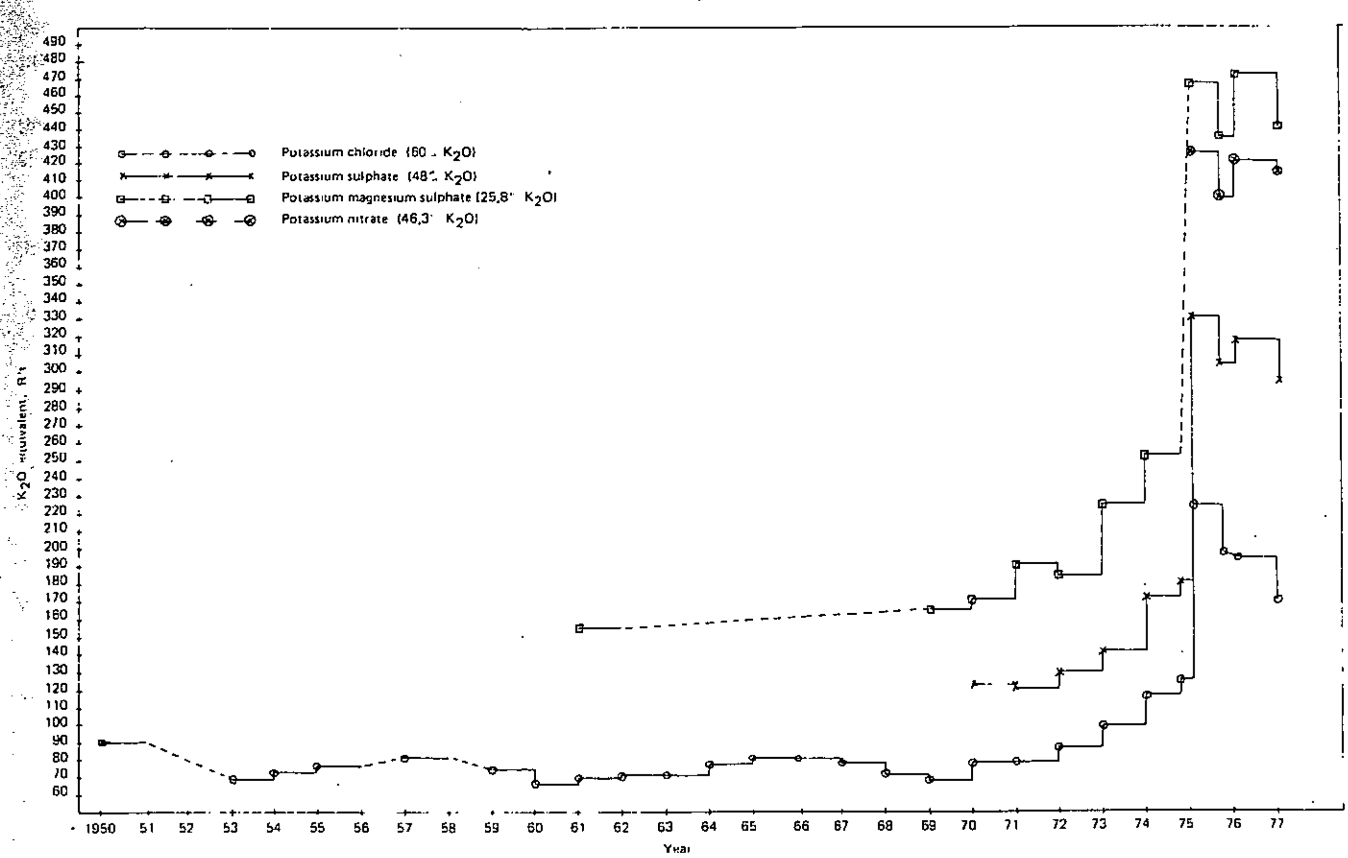

FIG 5 *South African gross selling price of potassium fertilizers*

3 The U S S R and Canada are the World's two largest potash producers and together account for more than half of the World production. Canada, producing virtually all its potash for export, and the U S S R, planning almost to double its production during the coming 4 years and committed to the export of most of the additional production, hold the key to future developments in the potash World market.

4 World potash prices have decreased from the peak reached in 1975, back to the lower levels of 1974, and the price in real terms is not expected to increase in the short to medium term.

South African situation

1 South Africa depends entirely on imports for her supplies of potash. The commodity is therefore considered a strategic raw material and possibilities for rendering the country self-sufficient have been investigated.

2 South Africa has no known deposits of water-soluble potassium minerals. Of the known occurrences of potassium minerals, Phalaborwa phlogopite is considered to be the most promising for local potash production. Although the recovery only of potash from this source appears to be uneconomic, the economics of extracting co-products such as alumina, magnesium, and silica in addition to potash, could be more favourable and should be investigated.

3 The consumption of potash as a fertilizer was 133 000 t K_2O in 1976 and is expected to reach 200 000 t by 1985.

4 Re-exports of potash, blended as mixed fertilizer, virtually ceased during 1976 and this together with more judicious use of potash as fertilizer and consumer resistance to the increased prices, contributed to the recent decline in potash imports.

References

ADAMS, S.S., 1975. Potash. *In*: American Inst. of Mining, Metallurgical and Petroleum Engineers Inc. 1975. *Industrial Minerals and Rocks. 4th Ed.* Port City Press, Baltimore, USA.

BOTHA, J.C., 1976. The Economics of the Potassium Industry. *Minerals Bureau Report No 1.* Johannesburg.

BRITISH SULPHUR CORPORATION. *Statistical Supplement.* No 8, Nov/Dec 1973; No 9, May/June 1974; No 12, Nov/Dec 1975; No 13, May/June 1976; No 14 Nov/Dec 1976.

DICKS, L.W.R. & McCULLOCH, H.W., 1968. The recovery of potassium from phlogopite. *National Institute of Mettalurgy, Report No 298.* Johannesburg.

EUR. CHEM. NEWS, 1976. Vol. 29, No 756, 4.

FERTILIZER INT., No 75, Sep 1975.

FERTILIZER INT., No 82, Apr 1976.

FERTILIZER INT., No 92, Feb 1977.

HUGO, P.J., 1974. Salt in the Republic of South Africa. *Memoir 65,* Government Printer, Pretoria.

IND. MINER., No 41, Feb 1971, World Potash Producers.

IND. MINER., No 42, Mar 1971a, World Potash Producers – 2.

IND. MINER., No 42, Mar 1971b, Potash today – 2: The impact of Canada.

IND. MINER., No 78, Mar 1974 Potash today : The market recovers.

IND. MINER., No 80, May 1974, Potash today – 2.

IND. MINER., No 87, Dec 1974, Sua Pan on shelf.

KEYES, W.F., 1975. Potash. *Reprint from*: US Bureau of Mines, *Mineral Facts and Problems.* US Government Printing Office, Washington.

KEYES, W.F., 1976a. Potash. *Reprint from*: US Bureau of Mines, *The 1974 Minerals Yearbook.* US Government Printing Office, Washington.

KEYES, W.F., 1976b. Potash. *In*: US Bureau of Mines, *Commodity Data Summaries 1976.* US Government Printing Office, Washington.

LEWIS, R.W., 1970. Potassium. *In*: US Bureau of Mines, *Mineral Facts and Problems.* US Government Printing Office, Washington.

MIN. J., MINING ANNUAL REVIEW, 1976. London, 295.

NOTHOLT, A.J.G., 1976. Potash. *Mineral Dossier No 16.* Her Majesty's Stationery Office, London.

PHOSPHORUS AND POTASSIUM. No 76, Mar/Apr 1975, 13–14.

PHOSPHORUS AND POTASSIUM. No 77, May/June 1975, 18.

PHOSPHORUS AND POTASSIUM. No 82, Mar/Apr 1976, 7.

PHOSPHORUS AND POTASSIUM. No 83, May/June 1976, 13–14.

PHOSPHORUS AND POTASSIUM. No 84, July/Aug 1976, 12.

PHOSPHORUS AND POTASSIUM. No 85, Sep/Oct 1976, 11.

PHOSPHORUS AND POTASSIUM. No 86, Nov/Dec 1976, Carnallite – a brighter future CPC?

WLD. MIN., Jul 1976. Longwall potash in Soviet Union. Vol. 29, No 8.