# Distribution of Salt and Potash Deposits: Present and Potential Effect on Potash Economics and Exploration

Eugene C. Pendery
*Continental Oil Company*
*Denver, Colorado*

## ABSTRACT

*Commercial utilization of saline deposits plays important role in our mineral economy, with 67 Free World potash production at about 28 llion tons KCl and Free World salt production at out 110 million tons. Present and projected pply/demand relationships of potash are illus- ted and indicate that production of this com- dity must continue to increase.*

*An increasingly important industrial utilization saline deposits is liquid (primarily hydrocarbon) derground storage. In 1967, storage capacity was excess of 125 million barrels. Location of suit- le saline deposits for storage purposes will be- me even more important for the following rea- s.*

*(1) Five to ten times cheaper than conventional ove-ground storage;*

*(2) Increasing scarcity of real estate in populated as;*

*(3) Conservationist and beautification move- nts.*

*Geographic and geologic distribution and occur- ce of saline deposits are discussed and illus- ted. These studies demonstrate that saline osits underlie surprisingly large areas of the -shield Continental land masses. Location of se deposits, especially in populated areas, will ome more and more important as demand ws for salt, potash, storage facilities and other s.*

*Depending on the product or end use desired, logic, geographic, economic, and market param- s essentially eliminate certain saline basins as prospective exploration and/or exploitation targets.*

## INTRODUCTION

Commercial utilization of saline deposits plays an important role in our mineral economy. In 1967 the industry produced about 28 million tons of muriate of potash and about 110 million tons of sodium chloride. In addition, other industrial utilization of halite deposits, such as underground liquid storage caverns, continued to increase.

This paper reviews various economic aspects of the potash industry as well as the distribution of saline basins and potash occurrences. These data enable the combined economic-geologic influence on potash exploration to be predicted.

Details regarding utilization of saline deposits for underground storage and waste disposal are the subject of another paper of the Third Salt Symposium. Moreover, data relating to economics of the salt industry is the subject of a paper in this symposium by W.E. Dickinson. Many of the following comments regarding potash economics and exploration are applicable to the salt industry and to the other industrial applications or utilization of saline deposits. The writer would like to especially thank Mr. J.R. Shah who provided supply-demand and transportation forecasts as shown in Figures 1 through 3.

## POTASH SUPPLY/DEMAND

Much consternation has been generated lately regarding an impending potash "glut" created by new mines being brought on-stream in Canada.

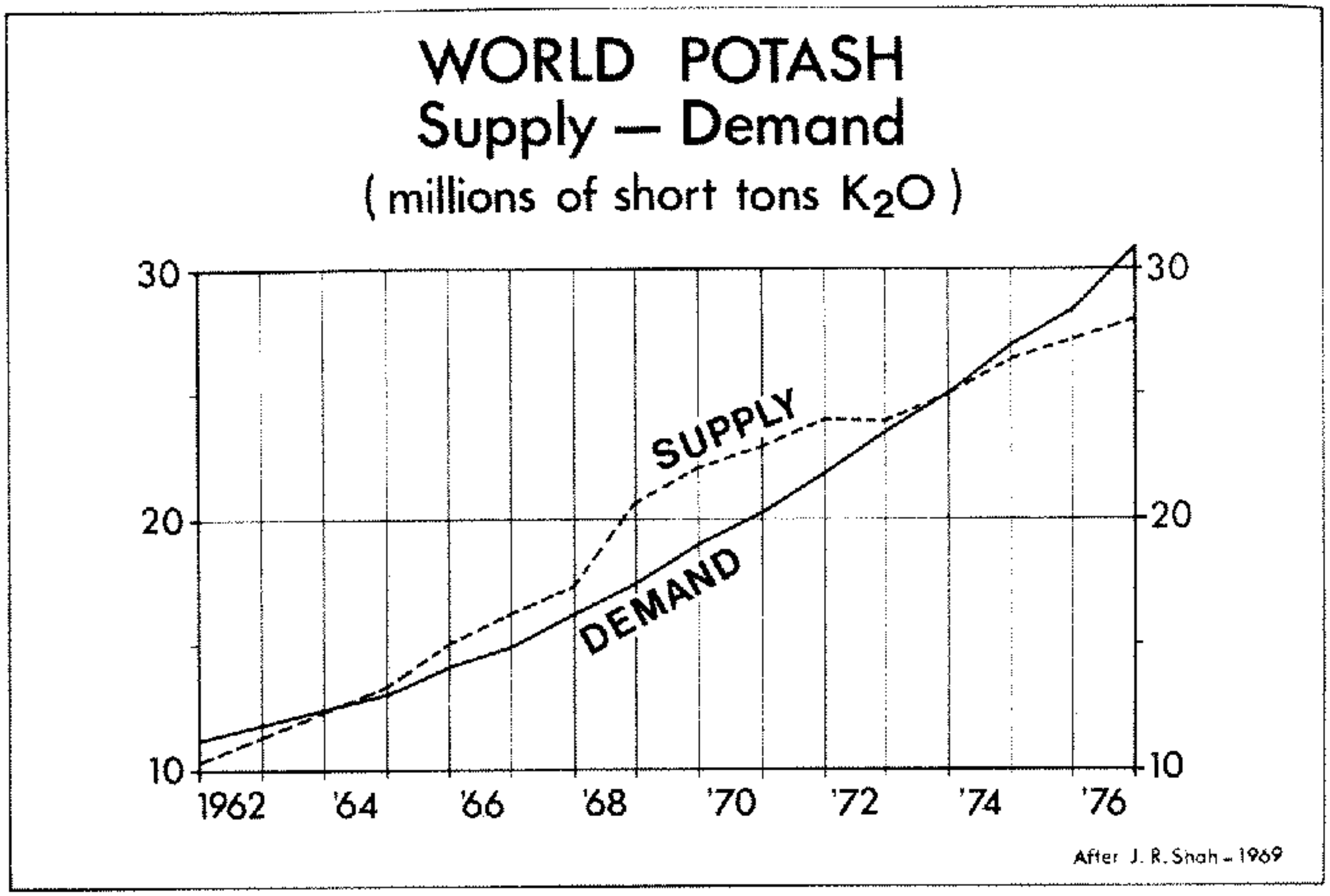


Figure 1.

Figure 1 illustrates what the writer considers to be a "cautiously optimistic" outlook on the world supply-demand relationship. Even on a casual glance one might wonder why potash prices have plunged 40 to 50 percent in the past two years while capacity utilization is forecast to remain about 80 percent.

The outlook for potash demand appears strong throughout the forecast period. Based upon continued awareness of the need for potash on soils and rapid growth in consumption in Communist Bloc and underdeveloped countries, it is predicted that future demand for potash will maintain a 7.5 percent growth rate. On the supply side, it is predicted that productive capacity should increase about 75 percent by 1977. About one-half the increase will result from new Canadian mines, while most of the remaining expansion will take place in the Communist Bloc.

The supply curve was based upon the following parameters:

(1) By 1977, Canada will have ten mines in operation with an annual capacity of about 8.2 million S.T. $K_2O$.

(2) The Canadian forecast projects only those mines under construction at the present time. Recently announced, delayed, or rumored projects are not expected to come on-stream within the forecast period.

(3) U.S. capacity is expected to decline by at least one-third.

(4) The forecast includes new capacity in the Congo, United Kingdom, Peru, Jordan, and Australia.

(5) Also included are increased capacities in West Germany, East Germany, and Russia.

(6) Ethiopian production is not expected before 1977.

Based upon the above premises, it is predicted that capacity utilization will reach a low of about

**Table 1**

**World Supply/Demand—Potash***
**(Million S.T. $K_2O$)**

| YEAR | DEMAND | SUPPLY | CAPACITY UTILIZATION (%) |
|---|---|---|---|
| 1965/66 | 14.1 | 15.0 | 94 |
| 66/67 | 14.9 | 16.2 | 92 |
| 67/68 | 16.2 | 17.2 | 94 |
| 68/69 | 17.4 | 20.6 | 84 |
| 69/70 | 19.0 | 22.0 | 86 |
| 70/71 | 20.2 | 22.8 | 89 |
| 71/72 | 21.8 | 23.9 | 91 |
| 72/73 | 23.4 | 24.3 | 96 |
| 73/74 | 25.0 | 25.0 | 100 |
| 74/75 | 26.9 | 26.3 | 102 |
| 75/76 | 28.8 | 27.1 | 106 |
| 76/77 | 30.8 | 27.9 | 110 |

*After J.R. Shah, 1969

80-85 percent during the 1969-1970 period and gradually increase to approximate balance about 1974-1975.

Two depressing factors could influence the supply/demand outlook. It is estimated that Canadian mines can be expanded by at least 3.0 million S.T. $K_2O$ per year by addition of mill capacities alone. Expansions within this category could maintain an approximate supply-demand balance throughout the forecast period. Another imponderable is whether or not the Communist Bloc will create large surpluses and hence become a much larger net exporter. Time alone will answer this question. On the other hand it should be mentioned that by 1977 the addition of a two million ton mine will only increase overall capacity by six to seven percent, which is equivalent to the annual growth in demand.

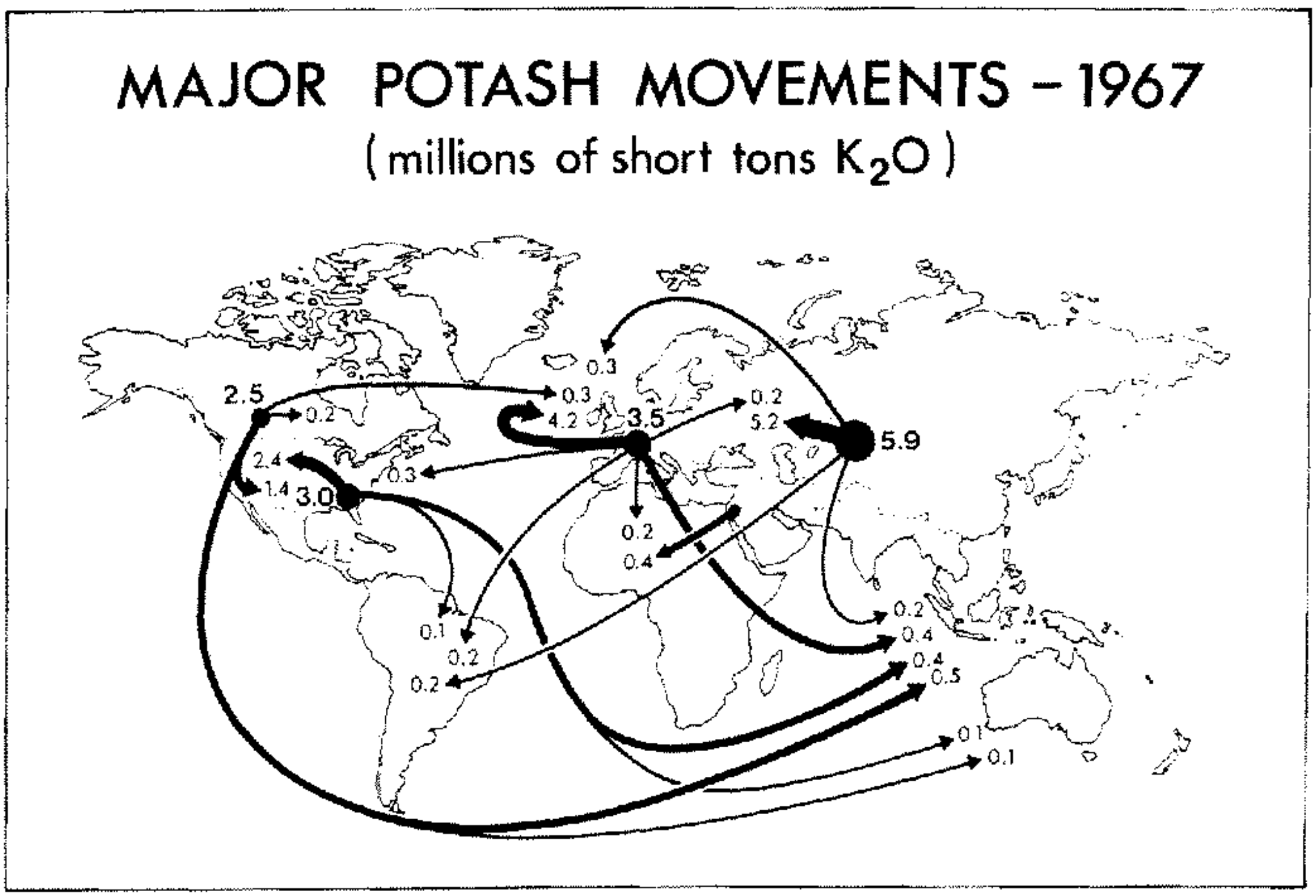


Figure 2.

## MAJOR POTASH MOVEMENT

A comparison of present and projected movement of potash provide insight to changing and enlarging supply centers. The four major producing areas and movement therefrom for 1967 are illustrated on Figure 2. Of significance is the fact that most production is consumed relatively near supply centers. Table 2 shows 1967 movements and projected supply-consumption patterns for 1975.

Projected movements by 1975 show a distinct departure from 1967 (Fig. 3). The Communist Bloc is projected to become a larger net exporter, and Canada must export about 7.5 million S.T. $K_2O$ per year. About 60 percent of that tonnage is

**Table 2**

**Major Potash Movements*** **(Million S.T. $K_2O$)**

**1967**

| TO/FROM | U.S. | CANADA | WESTERN EUROPE | IRON CURTAIN | TOTAL |
|---|---|---|---|---|---|
| U.S. | 2.4 | 1.4 | 0.3 | - | 4.1 |
| Canada | - | 0.2 | - | - | 0.2 |
| Other America | 0.1 | - | 0.2 | 0.2 | 0.5 |
| W. Europe | - | 0.3 | 4.2 | 0.3 | 4.8 |
| Asia | 0.4 | 0.5 | 0.4 | 0.2 | 1.5 |
| Africa | - | - | 0.2 | - | 0.2 |
| Oceania | 0.1 | 0.1 | - | - | 0.2 |
| Iron Curtain | - | - | 0.2 | 5.2 | 5.4 |
| TOTAL | 3.0 | 2.5 | 5.5 | 5.9 | 16.9 |

**1975**

| TO/FROM | U.S. | CANADA | WESTERN EUROPE | AFRICA | OTHER | IRON CURTAIN | TOTAL |
|---|---|---|---|---|---|---|---|
| U.S. | 2.5 | 4.2 | - | 0.1 | - | - | 6.8 |
| Canada | - | 0.3 | - | - | - | - | 0.3 |
| Other America | 0.1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 | 0.9 |
| W. Europe | - | 0.9 | 5.7 | 0.1 | 0.4 | 0.4 | 7.5 |
| Asia | 0.2 | 1.7 | - | - | 0.5 | 0.4 | 2.8 |
| Africa | - | 0.1 | 0.4 | 0.1 | - | - | 0.6 |
| Oceania | - | 0.3 | - | - | 0.1 | - | 0.4 |
| Com. Block | - | - | 0.2 | - | 0.1 | 9.2 | 9.5 |
| TOTAL | 2.8 | 7.7 | 6.4 | 0.5 | 1.2 | 10.2 | 28.8 |

*After J.R. Shah, 1969

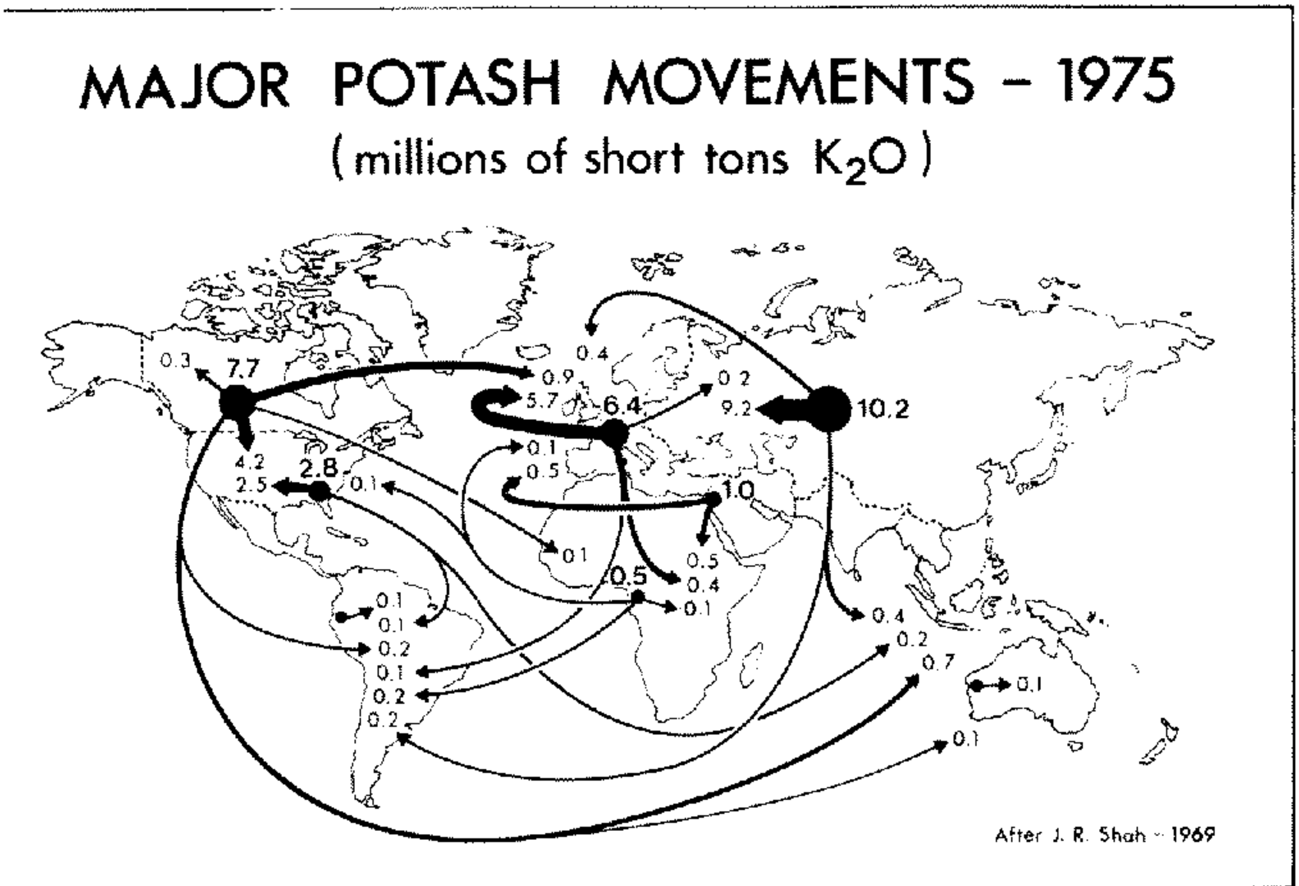


Figure 3.

dicted to move into the United States. This data of particular importance at the world market-ce as Canada will be competing with supply nts such as the Congo and United Kingdom, :h of which command a substantial overland nsportation advantage by virtue of location near e water. Significance of transportation costs in rall economics will be discussed in succeeding agraphs.

## GEOGRAPHIC DISTRIBUTION OF SALINE DEPOSITS

Vith these supply-demand and transportation terns in mind, let us examine the location of ne basins and point out known potash occur-ces. Saline deposits are widely distributed und the Earth. Saline (meaning halite and/or :em salt deposits for the purposes of this paper) e been identified on every major continent ex-t Antarctica and have been ascribed to all logic periods, including the Precambrian.

Many excellent studies and compilations of geology and distribution of saline deposits have been published. The author has borrowed most heavily from these works and wishes to especially acknowledge contributions by Lotze, Borchert and Muir, Lefond, Hite, Halbouty, and Ivanov. Figures 4 through 8, illustrating distribution of salines, are essentially compilations of these and other publications appearing throughout the literature.

Distribution of saline deposits of Precambrian through Devonian age are illustrated on Figure 4. Deposits are especially widespread across the North American, Asian, and Australian continents.

The valid identification of Precambrian age halite occurrences is always somewhat of a problem because age determinations are based primarily upon stratigraphic position rather than reliable fossil or radiometric dating methods. Recent opinions favor Precambrian age for deposits in Central Australia, the Persian Gulf, and southwestern Pakistan.

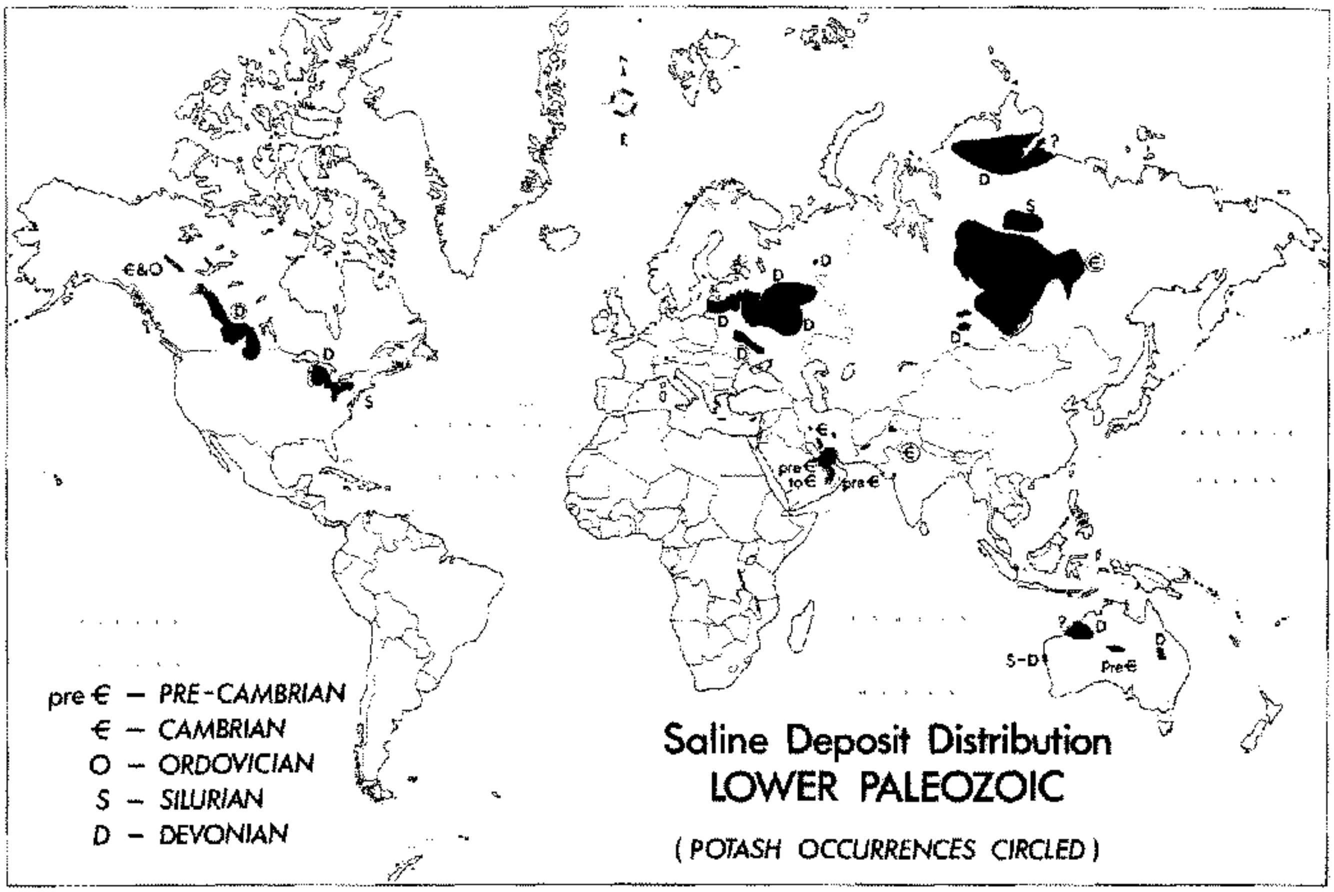


Figure 4.

Cambrian deposits have been identified in the Middle East, Pakistan, the USSR, and possibly northern Canada. Potash mineralization has been noted in the Pakistani salt ranges (personal communication, C. Jones, May, 1968); however, by far the most extensive evaporite basin in the world is located in Siberia. Potash deposition is reported from the southern portion of the basin.

Very few saline sediments have been recognized in the Ordovician system. The McKenzie Basin in the Northwest Territories, Canada, is the only reported occurrence (Hite, 1967, p. 17). Even this occurrence may be Cambrian in age (Fig. 4).

Silurian evaporites occur in the Michigan Basin, United States, and in Siberia, USSR (Ivanov, 1960). Recently discovered halite occurrences in the Carvarvan Basin, Western Australia, have not been accurately dated, but are believed to be Silurian or Devonian in age.

Devonian saline deposits are very extensive and have been identified on the North American, Asian, and Australian continents. Two of the world's largest commercial potash deposits, located in Saskatchewan, Canada, and southeastern USSR are Devonian in age (Fig. 4).

Figure 5 illustrates the distribution of Upper Paleozoic saline occurrences (Mississippian, Pennsylvanian, and Permian). Mississippian deposits have been identified in North Central and Eastern United States and in the Maritime Provinces of Canada. Other deposits of Mississippian age may occur in South Central USSR (Ivanov, 1960) and on the Arctic Islands (J.D. Sproule, personal communication, 1966). Potash has been identified from occurrences located in the Maritime Provinces.

Although not widespread on a worldwide basis, extensive saline deposits of Pennsylvanian age are noted in the Paradox Basin, United States, and in the Amazon Basin, Brazil. The Paradox Basin contains huge amounts of potash.

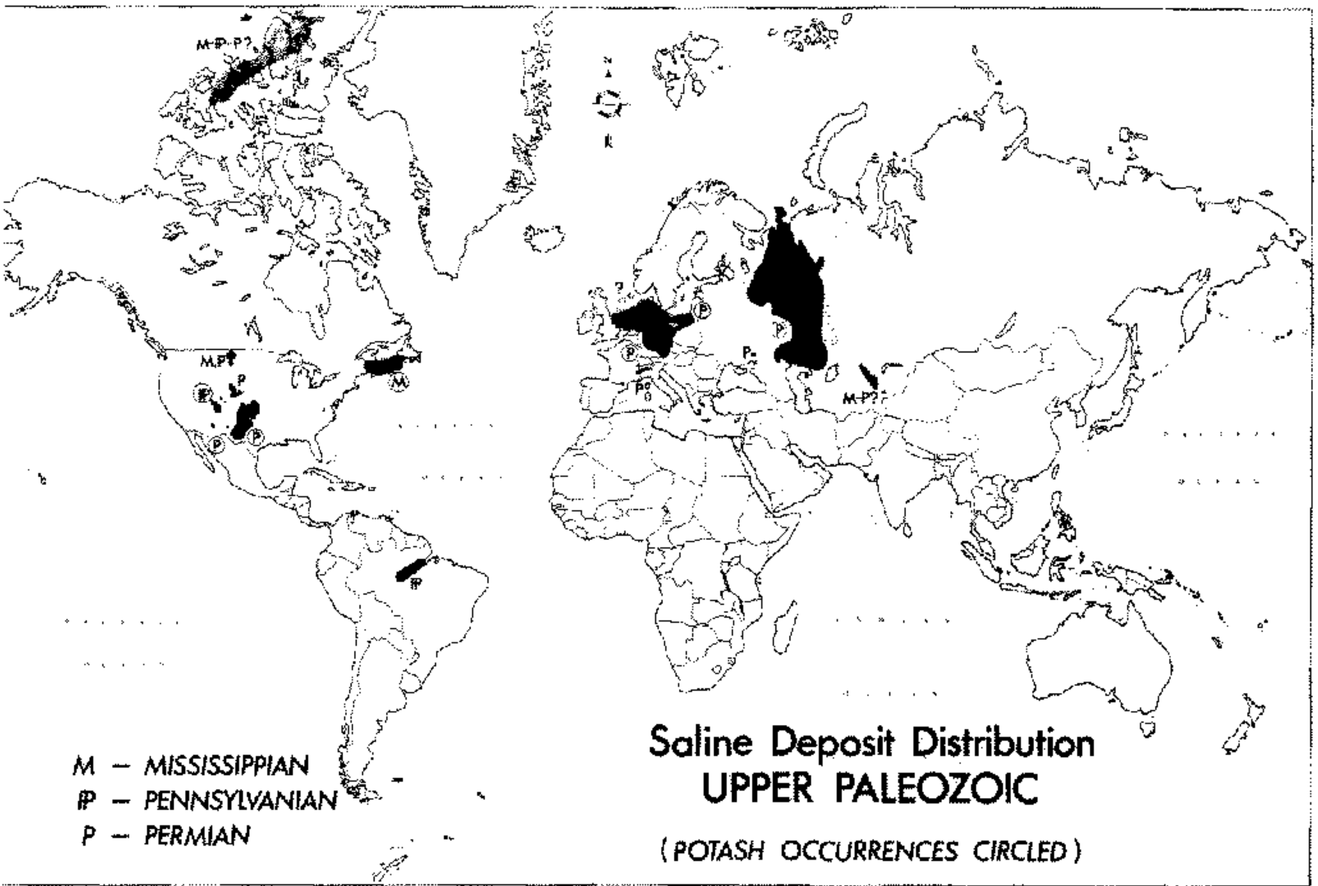


Figure 5.

Certainly the most important of all evaporite ges is the Permian Period, both from the stand- oint of areal extent and thickness and from the tandpoint of deposition and preservation of bit- ern saline sediments. It is almost redundant to cite he Permian producing areas such as the Permian lasin, United States; the Zechstein Basin, Europe; nd the potash deposits of several basins in the JSSR. Areal extent of the Zechstein deposits, robably the most extensively known and studied vaporite deposits in the world, is still not defined n the North Sea area. Zechstein deposits in the Jnited Kingdom, although recognized for years, re only now being developed.

Saline deposit distribution for the Triassic and urassic are shown on Figure 6. Triassic deposits re especially widespread across Europe and north- vestern Africa. Occurrences have also been re- orted in Peru, Somalia, China, and Tanzania. The Tanzanian deposits may be Jurassic in age. Potash ccurrences have been noted in several of the sub- asins in Morocco.

One of the world's largest evaporite deposits occurs around (and possibly across) the western portion of the Gulf of Mexico. Because of diapir- ism and extreme depth to undisturbed evaporite beds, even the age of these deposits is debatable. Most students favor a Jurassic age determination. Minor amounts and traces of potash have been re- ported from the United States and Tehuantepec portions of the Gulf Coastal Basin. Jurassic salt also occurs in the western United States, the USSR, the Middle East, and in Thailand.

Distribution of Cretaceous and Tertiary saline deposits are illustrated in Figure 7. Cretaceous occurrences have been noted in Central America and the Caribbean, Argentina, and Brazil; also China, Libya, Morocco, and West Central Africa. Most important from a commercial standpoint are potash occurrences of Brazil and West Central Africa. The Congo deposits are under development, and occurrences in Angola and Brazil are currently being investigated.

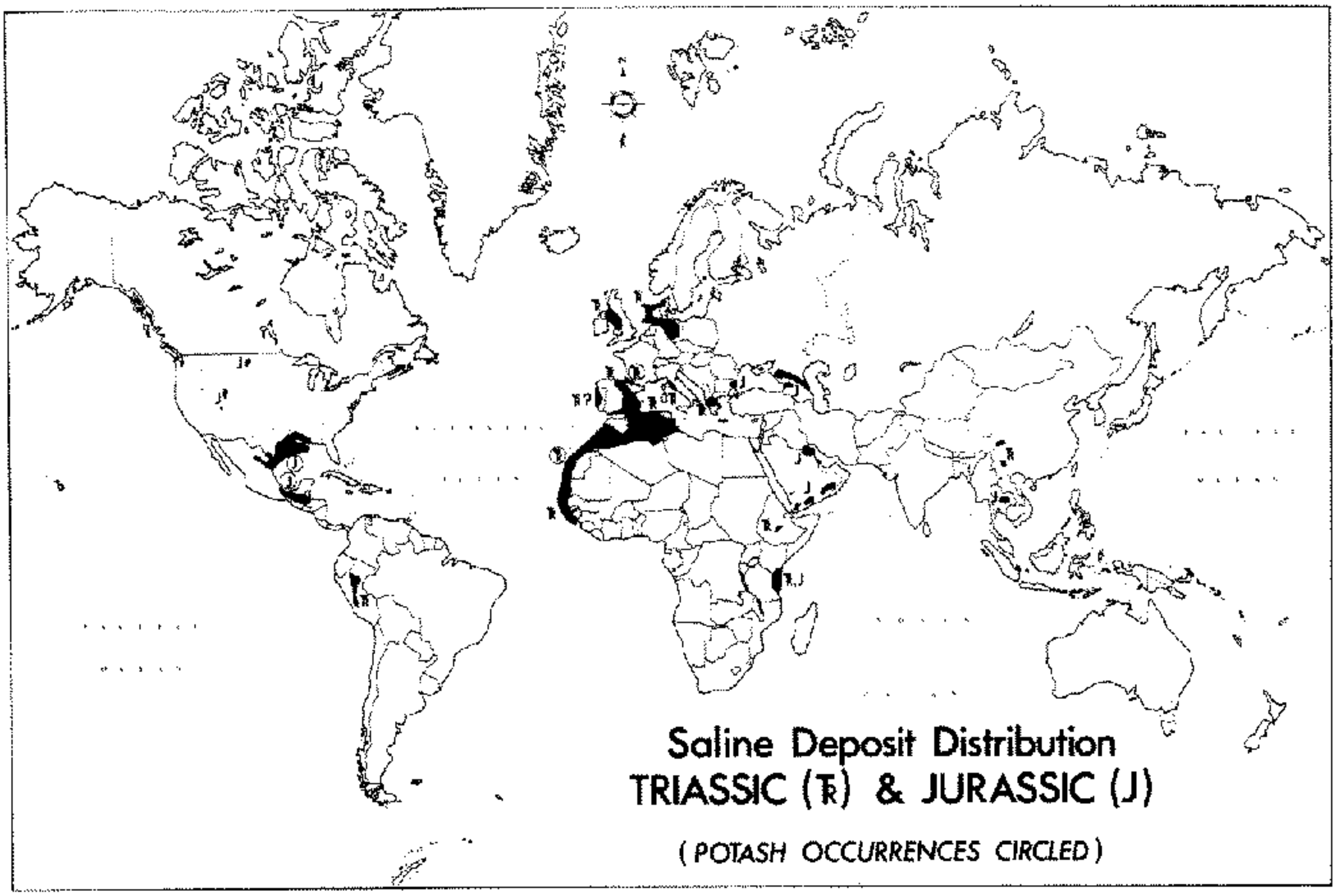


Figure 6.

As noted in Figure 7, Tertiary evaporite deposition was common across Europe and Asia Minor. Extensive deposits are associated with various rift systems and small, narrow tectonic belts. Potash has been discovered in many of these basins and is being produced in Spain, France, Sicily, and Russia. Recent potash discoveries include Ethiopia and saline sediments underlying the Dead Sea. Potash deposits along the flanks of the Carpathian Mountains have also received recent scrutiny.

The preceding review of the geographic distribution and age of saline deposits has been brief and unquestionably inaccurate in some instances because regional geologic data are lacking in many areas. However, these maps illustrate that:

(1) A surprisingly large portion of the continental land masses are underlain by saline deposits (Fig. 8).

(2) Contrary to most industrial opinion, potash occurrences are found in many saline basins. Since a relatively small portion of the world's saline basins are extensively known, the question naturally arises as to the probability of additional discoveries. Statistics alone dictate new discoveries as additional data becomes available.

## FUTURE OF POTASH EXPLORATION

Figure 8 shows that a very large proportion of the world's potash production is achieved from inland basins, all of which suffer overland transportation disadvantages to some extent or another when competing at the marketplace. When operating costs, capital charges, transportation costs (and hopefully a modest profit) are integrated, a final competitive market price is established. It is the responsibility of the economic geologist to restrict venture capital outlays to prospects that will lead to development of competitive properties. Therefore, exploration must be directed toward:

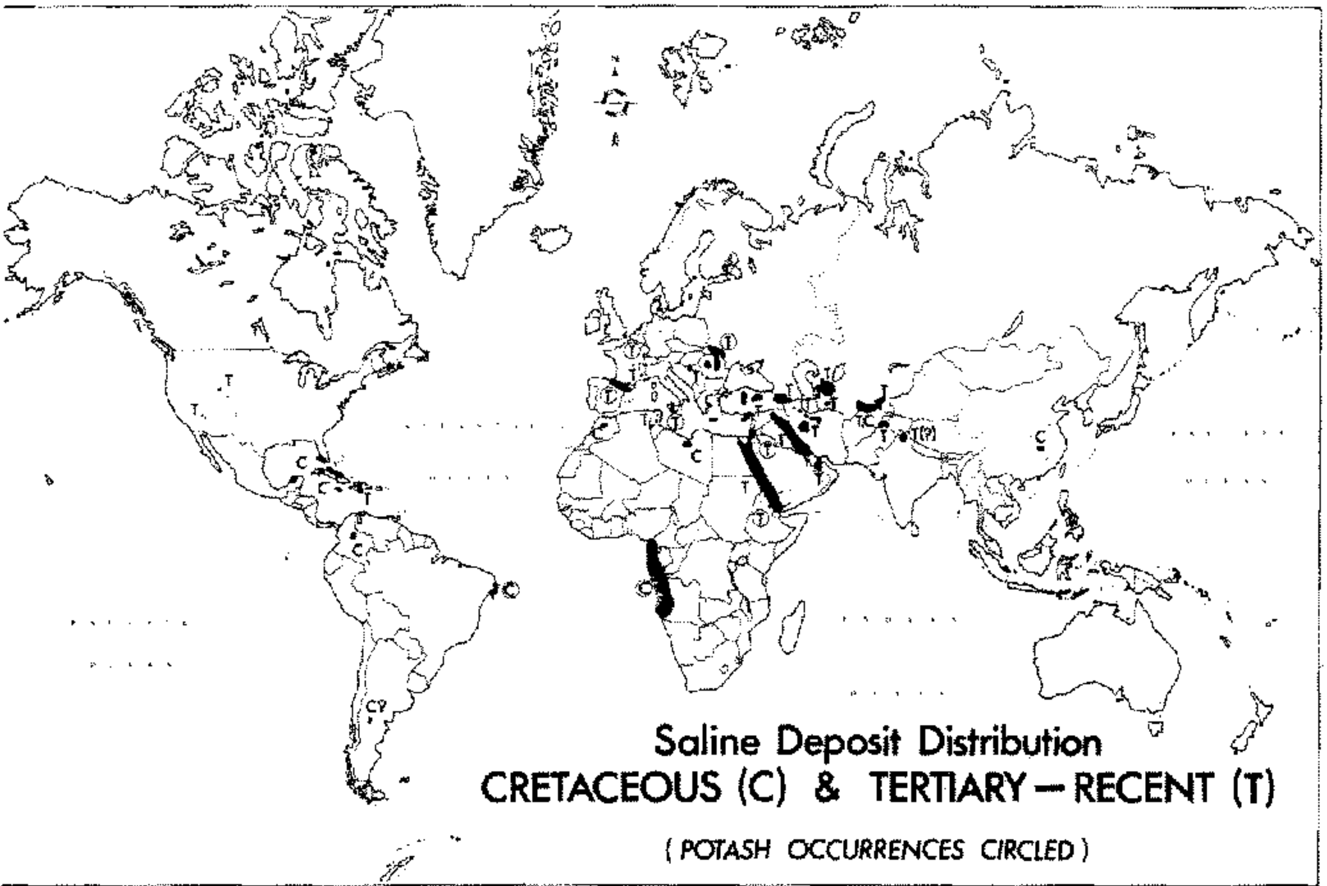


Figure 7.

(1) Deposits that are shallow and high grade which will equal or compete with low operating cost producers such as Canada.

(2) Geographic locations which will not impose large outlays of capital to combat severe climatic conditions or cause extensive construction of railways, townsites, or ports.

(3) Political aspects which must be evaluated in project economics. Internal strife within a particular country or closure of transportation avenues can lead to rather undesirable economic results.

(4) Transportation costs which contribute (or hinder) a large proportion of delivered market price. Therefore, exploration should be directed towards areas that will not be at a distinct transportation disadvantage to established producers.

The importance of these elementary statements strike home when seeking large-volume, low-price commodities such as salt and potash. In effect, economic parameters create a geographic, political, and transportation grid within which exploration programs must be patterned.

For example, a very high-grade potash deposit in the interior of Africa, which could produce at low operating costs, might not support high capital and transportation costs for development and production. Conversely, a shallow, low-to-medium grade deposit located either near deep-water and/or consuming areas might well be an extremely lucrative economic venture even at today's prices.

With these thoughts in mind, let us reexamine Figure 3. Notice that all of the major producing areas, with the exception of the United Kingdom, Congo, Israel-Jordan, Peru, and Australia, are located somewhat inland. For example, despite slurry pipelines, unit trains, or other transportation innovations, it would appear that Canada will have a several dollar disadvantage to producers located near tide water. Remember also that the world needs ever increasing amounts of potash. Therefore, it would appear that despite today's low

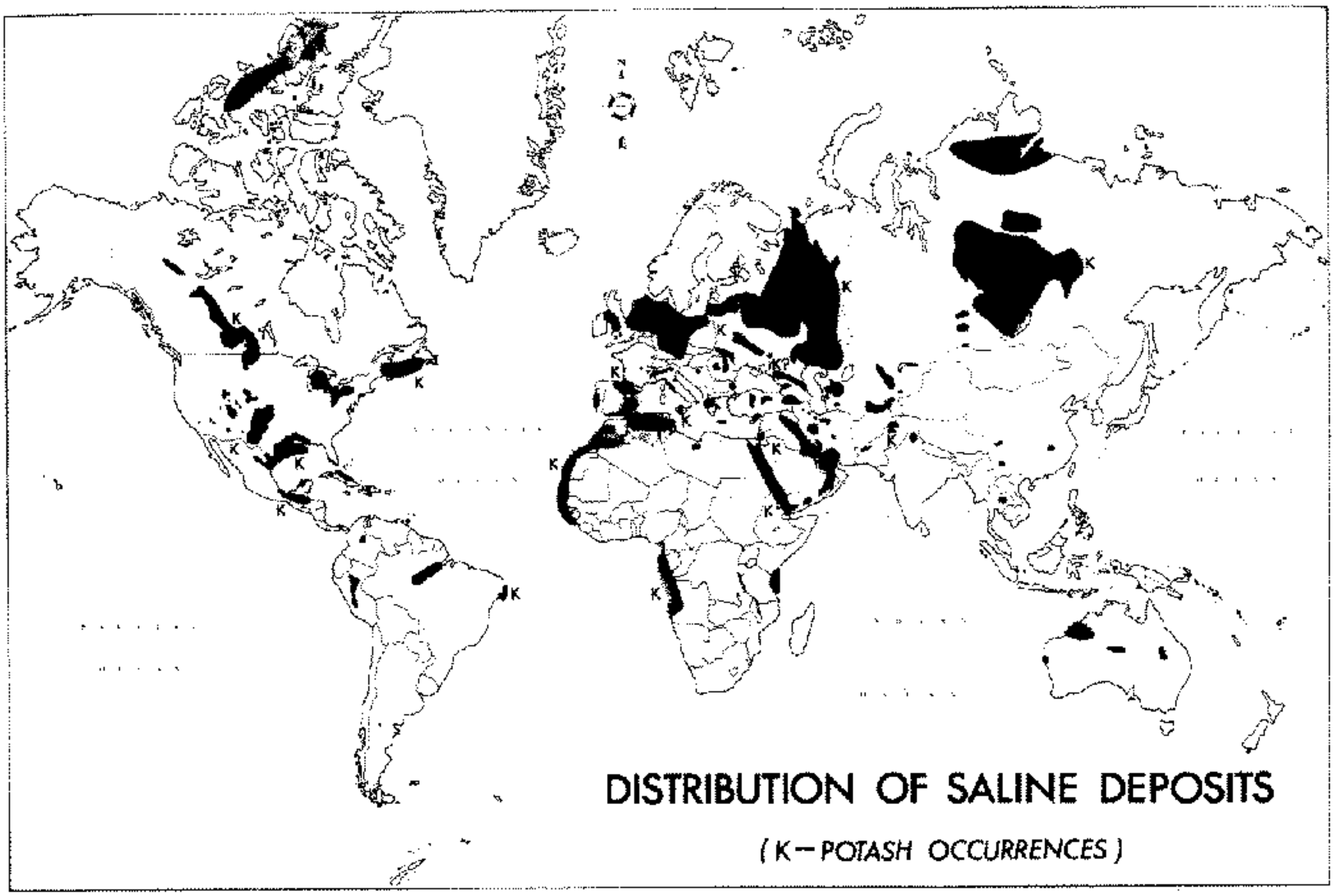


Figure 8.

potash prices and low capacity utilization, that long-range plans should incorporate exploration programs for potash in areas that will at least compete with established producers. Successful discoveries of reserves near consuming areas or in saline basins near deep-water ports solve many transportation and market problems. For example, note the Far East-Oceania market. How would you or your company like to discover a property with a several dollar overall delivered sales price advantage into this region? There are many unexplored salt basins that could contain potash which would satisfy these conditions. The exploration will not be cheap; however, the rewards could be great.

## REFERENCES

Borchert, H., and Muir, R.O., 1964, Salt Deposits: D. Van Nostrand Company, Ltd., London, 338 p.

Braunstein, J., and O'Brien, G.D., (eds.), 1968, Diapirism and Diapirs, a symposium: Am. Assoc. Petroleum Geologists, Mem. 8, 444 p.

British Sulphur Corporation, 1967, World Survey of Potash: British Sulphur Corp., Ltd., London, 93 p.

Castillon, M., and Larios, J.P., 1963, Salt deposits of the Isthmus of Tehuantepec: *in* No. Ohio Geol. Soc. Symposium on salt, p. 263-280.

Halbouty, M.T., 1967, Salt domes—Gulf Region, United States and Mexico: Gulf Publishing Co., Houston, 425 p.

Hite, R.J., 1967, Distribution and Geologic Habitat of Marine Halite and Associated Potash Deposits: U.S. Geol. Survey Open-file Report, 41 p.

itute of Petroleum, 1965, Salt Basins around Africa: Proc. of Inst. of Petroleum and Geol. Soc., London, 122 p.

nov, A.A., 1960, Geologiya galogennykh otlozheniy (formatsiy) SSSR: Trudy Vsesoyuznogo Naucho-Issledovatel skogo Gedogicheskogo nstituta (VSEGEI) Ministerstva Gedogii i Okhrany Nedr SSSR Novaya Seriys Tom 35.

shnan, M.S., 1963, Geology of the salt deposits n Punjab Salt Range, Pakistan (abs.): Geol. Soc. Am., Spec. Paper 73, p. 276-277.

mbein, W.C., 1951, Occurrence and lithologic associations of evaporites in the United States: Jour. Sed. Petrology, v. 21, p. 63-81.

ond, S.J., 1969, World Salt Resources: Plenum Press, N.Y., 536 p.

tze, F., 1964, The distribution of evaporites in pace and time: *in* A.E.M. Nairn, ed., Problems n Palaeoclimatology, Proc. of NATO palaeoclimates conf., Univ. of Newcastle-upon-Tyne, 1963, p. 491-507.

Lotze, F., 1957, Steinsalz und Kalisalze v. 1 (allgemein-geologischer teil), Zweite Auflage (neubearbeitet): Berlin, Gebruder Borntraeger, 465 p.

Murray, G.E., 1961, Geology of the Atlantic and Gulf Coastal Province of North America: Harper and Row, N.Y., 692 p.

Pearson, W.J., 1963, Salt deposits of Canada: *in* No. Ohio Geol. Soc. Symposium on Salt, p. 197-239.

Pierce, W.G., and Rich, E.I., 1962, Summary of rock salt deposits in the United States as possible storage sites for radioactive waste materials: U.S. Geol. Survey Bull. 1148, 91 p.

Rios, J.M., 1963, Materiales salinos del suelo Espanol: Inst. Geol. y Minero de Espana, Mem. 64, Madrid, 161 p.

Scruton, P.C., 1953, Deposition of evaporites: Am. Assoc. Petroleum Geologists Bull., v. 37, no. 11, p. 2498-2512.