C. 930–I

U.S. GEOLOGICAL SURVEY CIRCULAR 930–I

International Strategic Minerals Inventory Summary Report—Lithium

Prepared as a cooperative effort among earth-science and mineral-resource agencies of Australia, Canada, the Federal Republic of Germany, the Republic of South Africa, the United Kingdom, and the United States of America

Geologic Time Scale

Age			Million years before present
Holocene	Quaternary	CENOZOIC	0.01
Pleistocene			2
Pliocene	Tertiary		5
Miocene			24
Oligocene			38
Eocene			55
Paleocene			63
Late Cretaceous	Cretaceous	MESOZOIC	96
Early Cretaceous			138
Jurassic			205
Triassic			~240
Permian		PALEOZOIC	290
Pennsylvanian	Carboniferous		~330
Mississippian			360
Devonian			410
Silurian			435
Ordovician			500
Cambrian			~570
PRECAMBRIAN	Late Proterozoic	PROTEROZOIC	900
	Middle Proterozoic		1600
	Early Proterozoic		2500
		ARCHEAN	

International Strategic Minerals Inventory Summary Report—Lithium

By Terrance F. Anstett, Ulrich H. Krauss, Joyce A.Ober, and Helmut W. Schmidt

U.S. GEOLOGICAL SURVEY CIRCULAR 930-I

Prepared as a cooperative effort among earth-science and mineral-resource agencies of Australia, Canada, the Federal Republic of Germany, the Republic of South Africa, the United Kingdom, and the United States of America

1990

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, Jr., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

UNITED STATES GOVERNMENT PRINTING OFFICE: 1990

Free on application to the
Books and Open-File Reports Section
U.S. Geological Survey
Federal Center, Box 25425
Denver, CO 80225

Library of Congress Cataloging in Publication Data

International strategic minerals inventory summary report—Lithium / Terrance F. Anstett ... [et al.].
p. ; cm. — (Geological Survey circular ; 930–I)
Includes bibliographical references.
Supt. of Docs. no.: I 19.4/2:930–I
1. Lithium. 2. Strategic materials. I. Anstett, T.F. (Terrance F.) II. Series.
TN490.L5157 1990
333.8'5499—dc20 CIP

FOREWORD

Earth-science and mineral-resource agencies from several countries started the International Strategic Minerals Inventory in order to gather cooperatively information about major sources of strategic mineral raw materials. This circular summarizes inventory information about major deposits of lithium, one of the mineral commodities selected for the inventory.

The report was prepared by Terrance F. Anstett and Joyce A. Ober of the U.S. Bureau of Mines (USBM) and Ulrich H. Krauss and Helmut W. Schmidt of the Federal Institute of Geosciences and Natural Resources (BGR) of the Federal Republic of Germany. It was edited by David M. Sutphin and transcribed by Dorothy J. Manley of the U.S. Geological Survey (USGS).

Lithium inventory information was compiled by Terrance F. Anstett, Derik Cloete, Geological Survey of South Africa; Ulrich H. Krauss (chief compiler), and Ian McNaught, Australian Bureau of Mineral Resources. Additional contributions to the report were made by Sigrid Asher-Bolinder, USGS; Aldo F. Barsotti, USBM; John H. DeYoung, Jr., USGS; Christoph Kippenberger, BGR; W. David Sinclair, Energy, Mines and Resources Canada (EMR), Geological Survey of Canada; and Antony B.T. Werner (EMR), Mineral Policy Sector.

Director

CONTENTS

ILLUSTRATIONS

TABLES

INTERNATIONAL STRATEGIC MINERALS INVENTORY SUMMARY REPORT

LITHIUM

By Terrance F. Anstett,[1] Ulrich H. Krauss,[2] Joyce A. Ober,[1] and Helmut W. Schmidt[2]

ABSTRACT

Major world resources of lithium are described in this summary report of information in the International Strategic Minerals Inventory (ISMI). ISMI is a cooperative data-collection effort of earth-science and mineral-resource agencies in Australia, Canada, the Federal Republic of Germany, the Republic of South Africa, the United Kingdom, and the United States of America. Part I of this report presents an overview of the resources and potential supply of lithium on the basis of inventory information; Part II contains tables of some of the geologic information and mineral-resource information and production data collected by ISMI participants.

In terms of lithium-resource availability, present economically viable resources are more than sufficient to meet likely demand in the foreseeable future. In times of excess capacity such as currently exist, some pegmatite operations cannot compete with brine operations, which are less costly. A further production shift from pegmatites to brines will result in the concentration of supply in a few countries such as Chile and the United States. This shift would lead to the dependence of industrialized countries on deliveries from these sources.

PART I—OVERVIEW

INTRODUCTION

The reliability of future supplies of so-called strategic minerals is of concern to many nations. This widespread concern has led to duplication of effort in the gathering of information on the world's major sources of strategic mineral materials. With the aim of pooling such information, a cooperative program named International Strategic Minerals Inventory (ISMI) was started in 1981 by officials of the governments of the United States, Canada, and the Federal Republic of Germany. It was subsequently joined by the Republic of South Africa, Australia, and the United Kingdom.

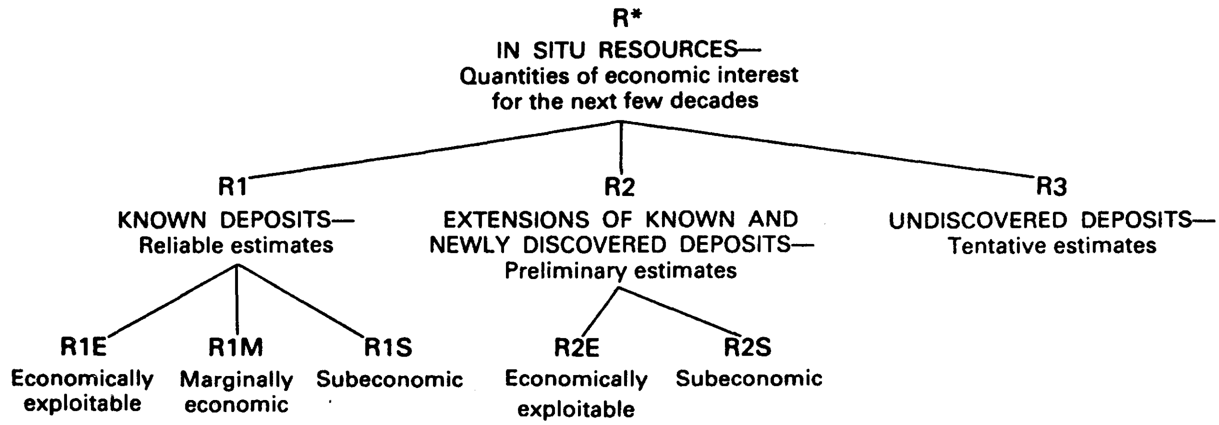
The objective of ISMI reports is to make publicly available, in convenient form, nonproprietary data and characteristics of major deposits of strategic mineral commodities for policy considerations in regard to the short-term, medium-term, and long-term world supply. Part I of this report provides a summary statement of the data compiled and an overview of the supply aspects of lithium in a format designed to be of benefit to policy analysts and geologists. Knowledge of the geologic aspects of mineral resources is essential in order to discover and develop mineral deposits. However, technical, financial, and political decisions must be made, and often transportation and marketing systems must be constructed before ore can be mined and processed and the products transported to the consumer; the technical, financial, and political aspects of mineral-resource development are not specifically addressed in this report. The report addresses the primary stages in the supply process for lithium and includes some considerations of lithium demand.

The term "strategic minerals" is imprecise. It generally refers to mineral ore and derivative products that come largely or entirely from foreign sources, that are difficult to replace, and that are important to the nation's economy, in particular to its defense industry.

Manuscript approved for publication June 20, 1989.

[1] U.S. Bureau of Mines (Terrance Anstett, deceased).

[2] Federal Institute for Geosciences and Natural Resources of the Federal Republic of Germany.



***The capital "R" denotes resources *in situ*; a lowercase "r" expresses the corresponding *recoverable* resources for each category and subcategory. Thus, r1E is the recoverable equivalent of R1E. This report deals only with R1 and R2, not with R3.**

FIGURE 1. United Nations resource categories used in this report (modified from Schanz, 1980, p. 313).

Usually, the term implies a nation's perception of vulnerability to supply disruptions and of a need to safeguard its industries from the repercussions of a loss of supplies.

Because a mineral that is strategic to one country may not be strategic to another, no one list of strategic minerals can be prepared. The ISMI Working Group decided to commence with chromium, manganese, nickel, and phosphate. All of these studies, plus the study of platinum-group metals, cobalt, titanium, and natural graphite have now been published. Additional studies on lithium (this report), vanadium, tungsten, tin, and zirconium have been subsequently undertaken.

The data in the ISMI lithium inventory, some of which are presented in Part II of this report, were collected from April 1987 to September 1988. The report was submitted for review and publication in March 1989. The information used was the best available in various agencies of the participating countries that contributed to the preparation of this report. Those agencies were the Bureau of Mines and the Geological Survey of the U.S. Department of the Interior; the Geological Survey and the Mineral Policy Sector of the Canadian Department of Energy, Mines and Resources; the Federal Institute for Geosciences and Natural Resources of the Federal Republic of Germany; the Geological Survey and the Minerals Bureau of the Department of Mineral and Energy Affairs of South Africa; the Bureau of Mineral Resources, Geology and Geophysics of the Australian Department of Primary Industries and Energy; and the British Geological Survey, a component of the Natural Environment Research Council of the United Kingdom.

No geologic definition of a deposit (or district) is used for compiling records for this report. Deposits (or districts) are selected for the inventory on the basis of their present or expected future contribution to world supply. Records of all deposits compiled by ISMI participants meet this general "major deposit" criterion and are included in the inventory.[3] Because the assignment of a specific number of records to the lithium resources of a district or even of a nation was not done with the same detail by all compilers, comparisons among numbers of lithium records in different geographic areas or among numbers of lithium records and those records of other commodities reported on in this series are not meaningful.

The ISMI record collection and this report on lithium have adopted the international classification system for mineral resources recommended by the United Nations Group of Experts on Definitions and Terminology for Mineral Resources (United Nations Economic and Social Council, 1979; Schanz, 1980). The terms, definitions, and resource categories of this system were established in 1979 to facilitate international exchange of mineral-resource data; the Group of Experts sought a system that would be compatible with the several systems already in use in several countries. Figure 1 shows the U.N. resource classification used in

[3] No information is provided on deposits that were once significant but whose resources are now considered to be depleted.

this report. This report focuses on category R1, which covers reliable estimates of tonnages and grades of known deposits. The familiar term "reserves," which many would consider to be equivalent to r1E or R1E, has been interpreted inconsistently and thus has been deliberately avoided in the U.N. classification.

It should be noted that generally until a deposit has been extensively explored or mined, its size and grade are imperfectly defined. In many cases, actual deposit size will prove to be significantly larger, sometimes even several times larger, than was thought when the decision to mine was made. Experts with a sound knowledge of a deposit and its geologic setting might infer that the deposit extends beyond the bounds reliably established up to that time. Tonnage estimates for such inferred extensions fall into category R2. For major deposits, ISMI records show R2 estimates in the few cases for which they are readily available. Category R3, postulated but undiscovered resources, is not dealt with in this report.

Mining recovery from an ore body depends on individual conditions and may vary considerably, typically in the range of 75 to 90 percent for underground mining; that is, 10 to 25 percent of the in-place resources cannot be extracted.

USES AND SUPPLY ASPECTS

Lithium, a silvery white metal, is the lightest solid element at normal temperatures. Its chemical symbol is Li, and its atomic number is 3. Lithium belongs to the alkali metal group. Some physical and chemical properties of lithium are listed in table 1.

End uses.—Lithium possesses a unique combination of chemical and physical properties. For this reason, it is being used in an increasing number of manufacturing processes, mostly in the form of lithium compounds and mineral concentrates and to a lesser extent in its elemental form. Some of these compounds find application as ingredients in final products and others as additives that do not change the final product but that make the production process more efficient. Table 2 shows the lithium content of important lithium chemicals and their primary uses. Several aspects of lithium uses and supply are especially noteworthy:

- Addition of lithium carbonate (Li_2CO_3, having 18.8 percent lithium) or lithium ores to ceramics and glass is currently the world's leading consumption of lithium. Glass and ceramics produced with lithium have high strength and low thermal expansion, and lithium replaces toxic lead in enamels and glazes. The presence of lithia (Li_2O, having 46.5 percent lithium) in glass and ceramics also reduces melting temperatures, thereby reducing energy consumption and increasing production (Carroll and Angelo, 1983). High-grade lithium-mineral concentrates having low iron content are gaining popularity as raw materials in the container and bottle-glass industry. While providing the lithia needed for the extra strength it imparts, the ores are also a source of alumina and silica, both necessary ingredients in glass.
- The aluminum industry is another large consumer of lithium. Lithium carbonate is added to the aluminum salt bath of aluminum potlines to increase the electrical conductivity and to lower the temperature of the bath, resulting in increased cell capacity and reduced power consumption (Cheney, 1983). Aluminum companies are also beginning to produce aluminum-lithium alloys that could be used in the aircraft and aerospace industries. These alloys con-

TABLE 1.—*Properties of lithium*

[Source: Weast, 1987]

Naturally occurring isotopes	^6Li	^7Li
Atomic weight	6.015	7.016
Relative abundance (percent)	7.42	92.58
Average atomic weight	6.941	
Density (g/cm^3 at 20 °C)	.534	
Melting point (°C)	180.54	
Boiling point (°C)	1,342	
Mohs hardness	.6	
Valence	1	

TABLE 2.—*Chemical composition and uses of common lithium compounds*

Compound	Chemical formula	Percent lithium	Main end uses
Lithium carbonate	Li_2CO_3	18.8	Aluminum electrolysis, ceramics, and glass. Starting material for all other lithium compounds and ensuing products.
Lithium hydroxide monohydrate	$LiOH{\bullet}H_2O$	16.5	Lubricants, additive in Ni-Fe batteries, and air conditioning.
Lithium chloride	LiCl	16.4	Production of lithium metal, air conditioning, dehumidification, welding fluxes, and production of butyllithium.
Lithium hypochlorite	LiOCl	11.9	Bleaches and sanitizers.
Butyllithium	$n\text{-}C_4H_9Li$	10.8	Catalyst for synthetic rubber production.
Lithium stearate	$LiC_{18}H_{35}O_2$	2.3	High-temperature and water-resistant lubricants and greases.

tain 2 to 3 percent lithium by weight and when used for wing and fuselage skins in aircraft can reduce the weight and hence increase fuel economy or payload without compromising strength or flexibility (Sanders, 1980). This market, however, is not clearly established.

- Lithium soaps prepared from lithium hydroxide monohydrate ($LiOH \cdot H_2O$, having 16.5 percent lithium) are used in a large percentage of lubricating greases. Lithium greases are water resistant, resist oxidation, perform well over extreme temperature ranges, and form a stable grease on resolidification after melting (American Metal Market, 1972).
- Lithium salts of bromine (LiBr) and chlorine (LiCl), containing 8.0 and 16.4 percent lithium, respectively, are used in industrial air conditioning and dehumidification systems. Solutions containing either lithium salt absorb water vapor from the air, cool it, and, in the process, destroy airborne microorganisms, mold, and bacteria (Engineering News Record, 1983).
- One use of lithium is in high-energy batteries having lithium anodes, an application with growth potential. These batteries have more energy per unit weight and a longer shelf life than conventional alkaline batteries and operate dependably over a large temperature range. Lithium is used for anodes, and lithium compounds are used as electrolytes in primary batteries which are nonrechargeable. Lithium is also used in some secondary, or rechargeable, batteries (Bro and others, 1987).
- Small quantities of lithium compounds are used as material for absorption of carbon dioxide in air purifiers, in sanitizers and bleaches, as catalysts in the synthesis of high-performance rubbers and plastics, and to improve fiber properties and to reduce pollution in the manufacturing of synthetic textiles. Lithium carbonate is used medically to treat manic-depressive mental disorders.
- In the future, lithium may be used as a coolant or as a source of fuel in nuclear-fusion reactors. Although not currently feasible, if such technology were developed by the beginning of the next century, a significant increase in demand for lithium could result.

Estimates of current world lithium production patterns are presented in figure 2.

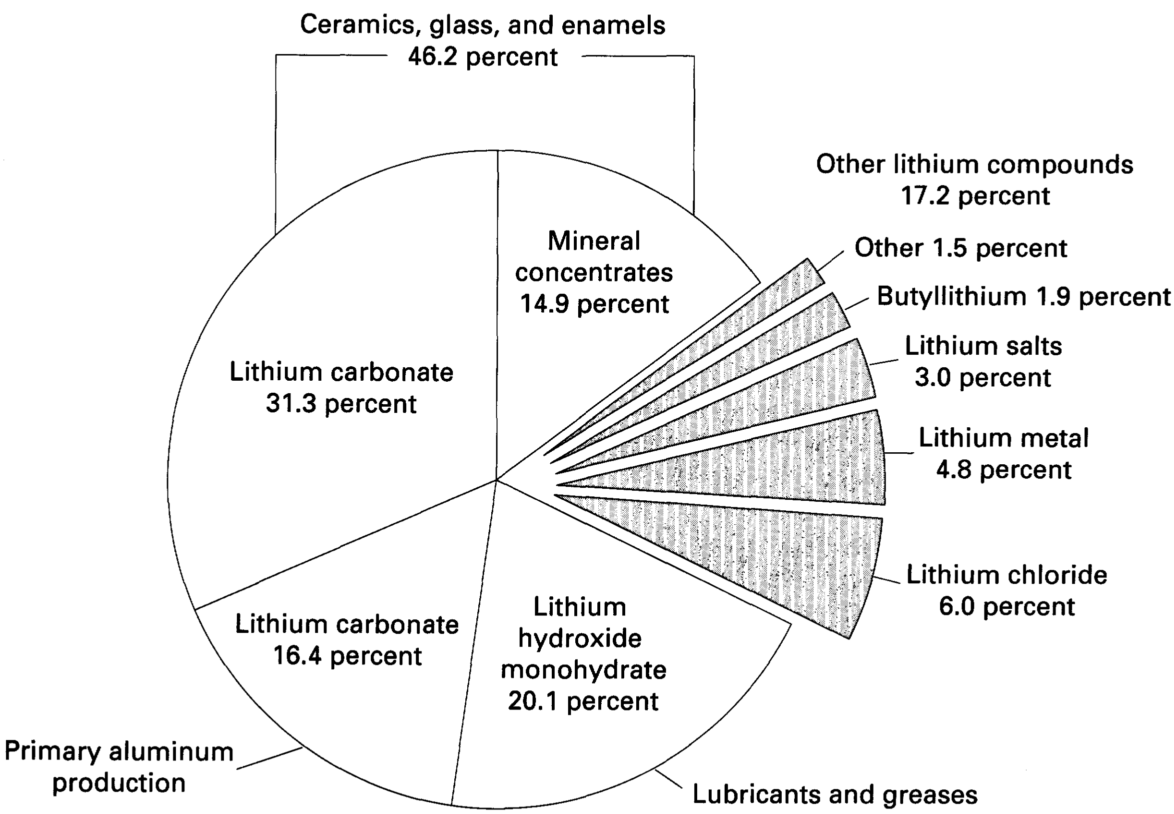


FIGURE 2. Estimated world lithium demand by product type. (Totals do not add to 100 percent due to rounding.)

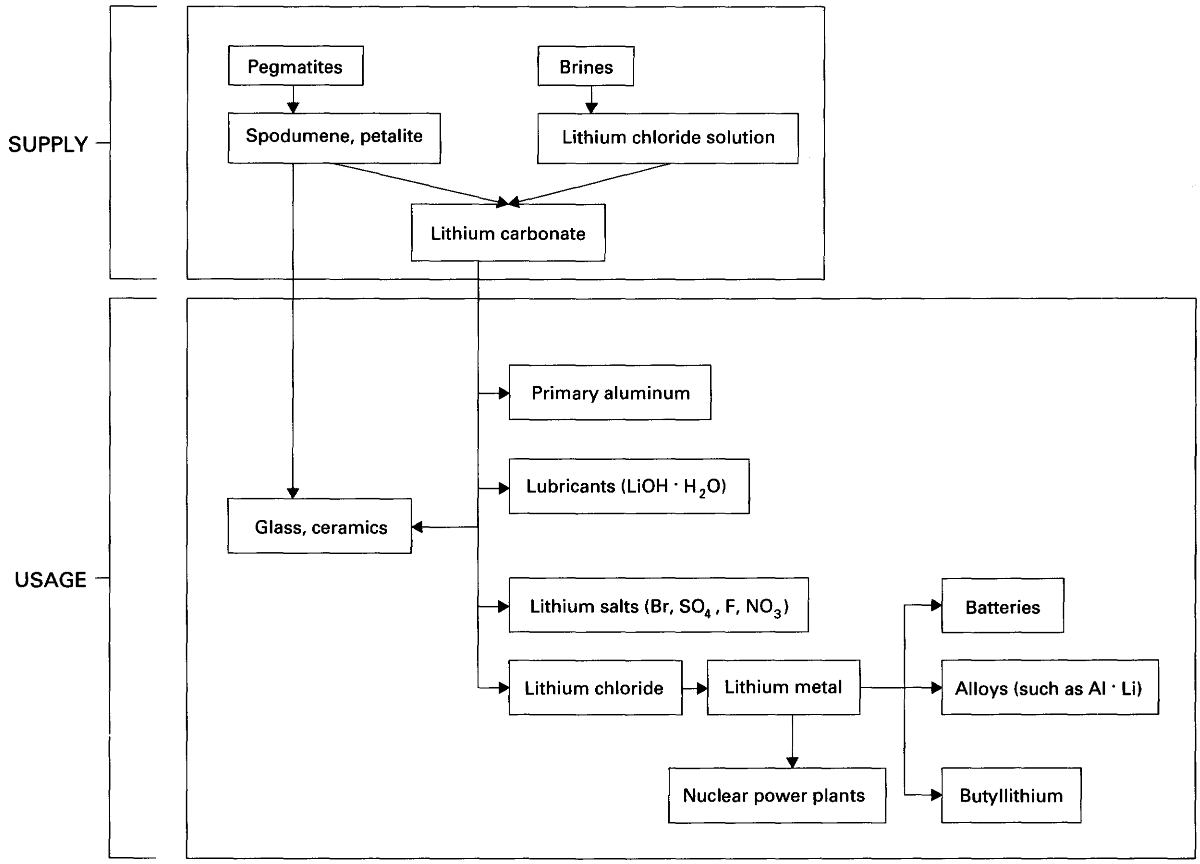


FIGURE 3. Lithium materials flow.

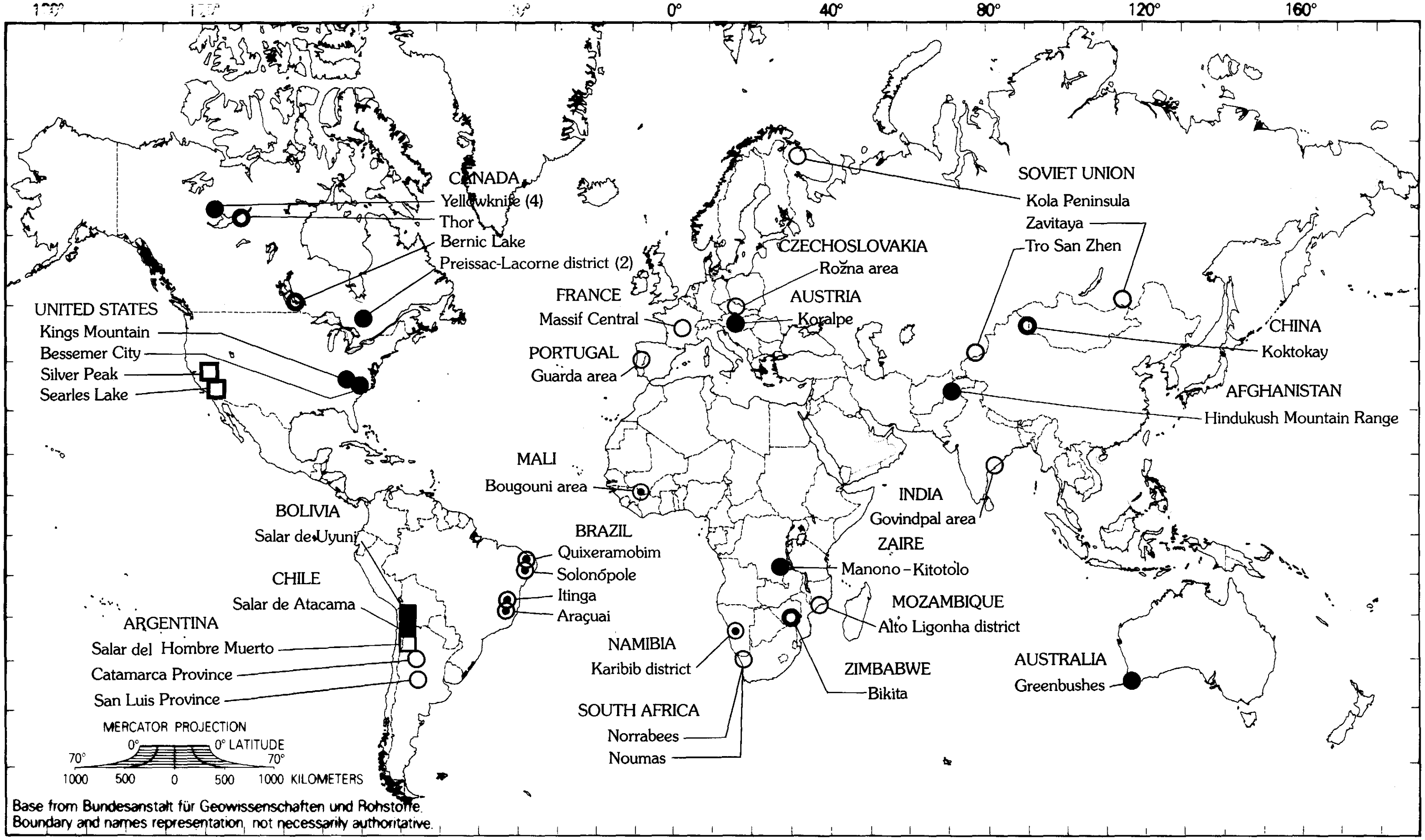
Figure 3 shows the materials flow from pegmatites and brines to the major products. Materials flow is an important factor in the economics of the lithium market, because for all products except glass and ceramics, lithium carbonate is the main intermediate chemical.

The largest consumption of lithium occurs in the glass, ceramics, and enamel industry, followed by the lubricants and grease industry and the primary aluminum industry. These three segments represent more than 80 percent of total lithium consumption. More than 46 percent of total consumption is in the glass, ceramics, and enamels industry, which is the only major sector using natural mineral concentrate. Lithium carbonate or downstream lithium compounds are required as starting materials in more than 85 percent of total lithium consumption.

DISTRIBUTION OF LITHIUM DEPOSITS AND DISTRICTS

Many lithium occurrences are known throughout the world. Only about 15 deposits are currently producing; however, several others are available for future development. Locations of producing deposits and other important world occurrences are shown in figure 4.

Four types of lithium enrichments (deposits) can be distinguished: pegmatites, brines, greisenized granites, and lithium-rich clays such as hectorite and saporite and stevensite. Major lithium deposits in this report are either pegmatite or brine deposits, although significant lithium resources in clays are known (Industrial Minerals, 1987, p. 25). Greisenized granites, once a major source of lithium, are no longer important in western countries. They may still be mined in the Soviet Union at Sherlovaya Gora and also in the Transbaikalia region. Figure 4 shows the locations of 29 pegmatite deposits, representing 34 inventory records, and 5 locations of brine deposits, representing 5 inventory records. Figure 4 also indicates the size of the deposits or deposit groups at each location. There are two very large (greater than 1 million metric tons of contained lithium in total reported resources) locations and inventory records, both of which are brines. The eight large (from 100,000 to 1



EXPLANATION

Geologic deposit type

Brine

Resources (metric tons of lithium contained in reported R1 and R2 categories)

- ■ >1,000,000
- ▣ 10,000 - 100,000
- □ Unreported

Pegmatite

Resources (metric tons of lithium contained in reported R1 and R2 categories)

- ● 100,000 - 1,000,000
- ◉ 10,000 - 100,000
- ⊙ <10,000
- ○ Unreported

FIGURE 4. Location, deposit type, and estimated resources of major lithium deposits and districts in the world. Numbers in parentheses indicate numbers of records (deposits and districts) for each location. Location names are from table 11 of Part II.

million metric tons of contained lithium in total reported resources) locations represent 12 inventory records all of which are pegmatite deposits. The six medium (from 10,000 to 100,000 metric tons of contained lithium in total reported resources) locations represent six inventory records (four pegmatite deposits and two brine deposits), and the six small (less than 10,000 metric tons of contained lithium in total reported resources) locations represent a like number of pegmatite deposits. The sizes of 12 pegmatite deposits and 1 brine deposit, represented by 11 map symbols, are unreported.

Pegmatites.—Lithium-bearing pegmatite deposits are widespread throughout the world and can be divided into two categories: zoned or unzoned. Zoned deposits contain spodumene and other economically important lithium minerals such as petalite, lepidolite, eucryptite, and amblygonite (see table 3) that are segregated into a series of different compositions and textures (Norton, 1973, p. 367). A typical pegmatite deposit contains about 20 percent spodumene, 41 percent feldspar, 32 percent quartz, 6 percent muscovite, and 1 percent trace minerals (Ferrell, 1985a, p. 463). In such pegmatites, spodumene crystals may be over 3 feet in length. Low-iron spodumene concentrates are produced mainly from zoned pegmatites. Bikita, Zimbabwe, which produces petalite with some spodumene, lepidolite, and amblygonite, and Manono-Kitotolo, Zaire, are localities having large zoned pegmatite deposits.

Unzoned pegmatite deposits contain spodumene that is evenly distributed throughout; the rock is said to be homogeneous. Unzoned pegmatites are by far the most important pegmatitic source of spodumene, which may make up to 25 percent of the rock. Deposits of this type include the Kings Mountain and Bessemer City operations in the United States and Koralpe in Austria.

Lithium pegmatite deposits generally range from 1 to 50 million metric tons of ore containing from 0.59 to 1.36 percent lithium. They are mined mostly from the surface, although the mine at Bernic Lake, Canada, is worked from underground. Grinding, crushing, and flotation produce concentrates of 75 to 80 percent spodumene, with feldspar, quartz, and mica byproducts. Production of lithium carbonate is completed by use of a sulfuric acid process and reaction with sodium carbonate. Total carbonate recovery yields 55 to 70 percent of the contained lithium.

Brines.—Like other alkali metals, lithium is dissolved through chemical weathering. In closed basins, especially in areas of high evaporation, lithium may be concentrated in subsurface brines or in specialized clay minerals. Lithium-rich brines are generally associated with desert basins in areas of rocks of Tertiary to Holocene ages. Some investigators suggest, implicitly, that geothermal activity may make brines a renewable resource. However, significant regeneration does not occur within the timespan of economic planning.

The size of major brine deposits generally ranges from 200 million to 1.3 billion metric tons, and the grade ranges from 0.015 to 0.125 percent lithium. Brine deposits in the ISMI lithium inventory are Salar de Hombre Muerto, Argentina; Salar de Uyuni, Bolivia; Salar de Atacama, Chile; and Silver Peak and Searles Lake in the United States.

At Silver Peak, lithium brines are exploited by pumping them to solar evaporation ponds in which they are concentrated by a factor of about 20. This process produces a chloride solution containing about 0.6 percent lithium from which lithium carbonate is precipitated by the addition of soda ash (Ferrell, 1985a, p. 464). Byproducts of brine operations are commonly boron and (or) potassium.

LITHIUM RESOURCES

Mineral resources normally are assessed and classified in different categories of geologic assurance and economic recoverability. Unfortunately, it is not possible to appraise lithium resources in this way as it would

TABLE 3.—*Chemical formulas and lithium content of lithium-bearing minerals*
[After Norton, 1973, p. 367]

Mineral	Chemical formula	Theoretical content (percent)		Contents of commercial concentrates (percent)	
		Li	Li_2O	Li	Li_2O
Spodumene	$Li_2O \cdot Al_2O_3 \cdot 4SiO_2$	3.73	8.03	2.6–3.5	[1]5.5–7.5
Petalite	$Li_2O \cdot Al_2O_3 \cdot 8SiO_2$	2.27	4.88	1.7–2.2	3.6–4.7
Eucryptite	$Li_2O \cdot Al_2O_3 \cdot 2SiO_2$	5.51	11.86	2.1–3.0	5.5–6.5
Amblygonite	$2Li(F,OH) \cdot Al_2O_3 \cdot P_2O_5$	4.69–4.76	10.1–10.24	3.5–4.4	7.5–9.5
Lepidolite	$KLi_2AlSi_4O_{10}(F,OH,O)$	≤3.58	≤7.70	1.5–3.3	[2]3.3–7.0

[1] A glass-grade spodumene concentrate containing 4.5 percent Li_2O is available from one producer.

[2] Lepidolite concentrates, once a major source of lithium, have declined in importance because they emit environmentally harmful fluorides during processing. However, some lepidolite concentrates are an important source of rubidium.

TABLE 4.—*Lithium resources in the world's major deposits and districts, by geologic deposit type and resource category*

[Resource figures are in thousand metric tons of contained lithium; figures may not add to totals shown due to rounding; figures in parentheses are percentages of world total]

Geologic deposit type[1]	No. of records	R1E[2]	All other R1 and R2[3]
Pegmatites	34	1,320 (85)	1,080 (9)
Brines	5	232 (15)	10,436 (91)
Total	39	1,552 (100)	11,516 (100)

[1] Deposit types of the world's major lithium deposits are shown in figure 4 and in table 11 of Part II.

[2] Reliable estimates from identified deposits with economically exploitable resources (fig. 1).

[3] That is, resources in the R1M, R1S, R2E, and R2S categories (fig. 1).

involve comparison of brine and pegmatite deposits that possess different economic and technological characteristics. It is appropriate, therefore, to assess brine and pegmatite resources separately. Estimated resources for the world's major lithium pegmatite and brine deposits and districts are shown in table 4.

Brines.—In western countries, lithium is presently recovered at two brine operations: Silver Peak (Clayton Valley), Nevada, in the United States and Salar de Atacama in Chile. There are reports indicating that similar deposits may be worked in the Soviet Union in the Minusinsk area and in China in the Tsaidam Basin, but no details are available.

Several other brine deposits have been identified in Argentina, Bolivia, Chile, and in the Western United States. Some of them have been investigated, and studies are underway for development of new brine operations in Bolivia and Chile that may recover boron and potassium as well as lithium. Enormous quantities of lithium are contained in brines, but probably only a small portion of these resources will be recoverable.

An attempt is made in table 5 to divide the lithium resources of major brine deposits into categories—identified economic resource (R1E) figures are from company reports. These R1E resources may increase considerably if major investments are granted for the development of new operations such as Salar de Uyuni in Bolivia and the AMAX–MOLYMET project in the northern Salar de Atacama in Chile.

Pegmatites.—Lithium-bearing pegmatites are known to occur in many countries, and huge quantities of lithium-bearing pegmatites have been identified. At present, however, less than 10 to 15 pegmatite deposits are being mined for lithium in market economy countries. From published data about major operations, it is estimated that in these countries about 90.4 million metric tons of recoverable (r1E) pegmatitic ore, mostly spodumene from 97.9 million metric tons of in-place (R1E) material, can be mined with current technology and under present-day economic conditions. A total of about 22 million metric tons of concentrates, containing about 670 thousand metric tons of lithium, can be extracted assuming a 75- to 80-percent rate of recovery from the recoverable ore. Additionally, at least another 200,000 metric tons of contained lithium are estimated to be available in centrally planned economy countries from similar deposits, such as the Koktokay deposits in China and the Zavitaya and Tro San Zhen deposits in the Soviet Union. A major portion of the currently r1E pegmatite resources will become marginal (r1M) or subeconomic (r1S) as additional capacities from brine deposits come on stream.

Table 6 summarizes R1E and r1E resource estimates for pegmatites. Although data on marginal, subeconomic, and inferred resources are incomplete and inconsistent, table 7 gives estimated grades and tonnages. It is believed that continued work on this inventory will not produce significantly better figures.

LITHIUM PRODUCTION

Lithium is produced from natural brines, pegmatites, and possibly greisens in more than 12 countries.

TABLE 5.—*Lithium resources of three major brine deposits in market economy countries*

[Resources are in thousand metric tons; categories are explained in figure 1. Figures may not add to totals shown due to rounding. N.r.=Not reported. Countries where major lithium deposits and districts occur are, by economic category: market economy countries—Afghanistan, Argentina, Australia, Austria, Bolivia, Brazil, Canada, Chile, France, India, Mali, Mozambique, Namibia, Portugal, South Africa, the United States, Zaire, and Zimbabwe; and centrally planned economy countries—China, Czechoslovakia, and the Soviet Union. Market economy countries are defined as all countries that are not centrally planned economy countries]

Deposit	R1	Grade (percent lithium)	Lithium content R1E	R1M	R1S	Total	R2
Silver Peak (United States)	240,000	0.033	30	35	14	79	36
Salar de Atacama (Chile)	1,300,000	.125	201	1,099	325	1,625	2,675
Salar de Uyuni (Bolivia)	505,000	.025	N.r.	101	25	126	5,374
Total	2,045,000	.090 (avg)	232	1,235	364	1,830	8,085

TABLE 6.—*Known economically exploitable (R1E) and recoverable (r1E) lithium resources in pegmatite deposits and districts, listed by country*

[Resources are in thousand metric tons. Figures may not add to totals shown due to rounding. N.r.=Not reported; Countries where major lithium deposits and districts occur are, by economic category: market economy countries—Afghanistan, Argentina, Australia, Austria, Bolivia, Brazil, Canada, Chile, France, India, Mali, Mozambique, Namibia, Portugal, South Africa, the United States, Zaire, and Zimbabwe; and centrally planned economy countries—China, Czechoslovakia, and the Soviet Union. Market economy countries are defined as all countries that are not centrally planned economy countries]

Country	Identified economic resources (R1E)[1] (thousand metric tons)	Average grade (percent lithium)	Lithium content (thousand metric tons)	Recoverable lithium (r1E)[2] (thousand metric tons)
Market economy countries				
Argentina	40	0.60	0.2	0.2
Australia	41,900	1.36	569.8	[3]313.0
Brazil	215	1.92	4.1	3.3
Canada	6,600	1.28	84.5	68.0
United States	45,000	.67	301.5	240.5
Zimbabwe	4,100	1.35	55.4	44.3
Total	97,855		1,015.5	669.3
Centrally planned economy countries				
China	N.r.	N.r.	N.r.	70.0
Soviet Union	N.r.	N.r.	N.r.	130.0
Total	N.r.	N.r.	305	200.0
World total	N.r.	N.r.	1,320	869.3

[1] Reliable estimates from identified deposits with economically exploitable resources (fig. 1).
[2] Reliable estimates of lithium recoverable from R1E resources.
[3] Low recovery historically.

TABLE 7.—*Known in-place marginal and subeconomic lithium resources in pegmatite deposits and districts, listed by country*

[Resource figures are in thousand metric tons. Figures may not add to totals shown due to rounding. N.r.=Not reported]

Country	In-place material[1] R1M+R1S+R2 (thousand metric tons)	Average grade (percent lithium)	Contained lithium (thousand metric tons) R1M+R1S	Contained lithium (thousand metric tons) R2
Austria	13,000	0.65	84.50	N.r.
Brazil	100	3.96	3.96	N.r.
Canada	76,000	.63	478.80	N.r.
France	500	.70	3.50	N.r.
Mali	1,000	.56	N.r.	5.6
Namibia	900	.93	8.37	N.r.
United States	900	.56	5.04	N.r.
Zaire	50,000	.98	305.64	184.36
Total	142,400		889.81	189.96

[1] Categories are defined in figure 1.

Not all of these countries disclose figures about their production. For more than 75 percent of world production, it is necessary to make estimates and assumptions. The United States, representing over 60 percent of the world total production, can provide no official production figures. Virtually no information is available regarding production in centrally planned economy countries, especially the Soviet Union.

Despite such incomplete information, it is estimated that in the past several years world lithium production averaged about 7,000 metric tons annually. About 25 percent of the world total originated in centrally planned economy countries, specifically China and the Soviet Union. In the 7 years from 1980 to 1986, market economy countries produced between 67 percent and 76 percent of the world total. Of that percentage, the

TABLE 8.—*Mine production of lithium by country, 1980 to 1986*

[Figures are in metric tons of contained lithium. Figures may not add to totals shown due to rounding. N.r.=None reported. * = Estimated. Sources: Ferrell (1985b), Searles (1987), and Ober (1988). Countries where major lithium deposits and districts occur are, by economic category: market economy countries—Afghanistan, Argentina, Australia, Austria, Bolivia, Brazil, Canada, Chile, France, India, Mali, Mozambique, Namibia, Portugal, South Africa, the United States, Zaïre, and Zimbabwe; and centrally planned economy countries—China, Czechoslovakia, and the Soviet Union. Market economy countries are defined as all countries that are not centrally planned economy countries]

Country	Source of lithium[1]	1980	1981	1982	1983	1984	1985	1986
Market economy countries								
Argentina	Not specified	2	1	3	4	1	1	1
Australia	Spodumene	N.r.	1	3	81	217	363	357
Brazil	Amblygonite, lepidolite, petalite, spodumene.	58	57	56	43	19	20	33
Canada	Spodumene	N.r.	N.r.	N.r.	N.r.	3	10	16
Chile	Brine	N.r.	N.r.	N.r.	N.r.	396	847	837
Namibia	Not specified	N.r.	23	19	14	16	36	23
Portugal	Lepidolite	7	6	6	4	7	1	N.r.
Rwanda	Amblygonite	1	N.r.	N.r.	N.r.	N.r.	N.r.	N.r.
United States*	Spodumene and brine	4,792	4,922	3,468	4,450	4,992	4,200	3,805
Zimbabwe	Not specified	405	111	194	357	425	530	534
Total		5,265	5,121	3,749	4,953	6,076	6,008	5,606
Centrally planned economy countries								
China*	Not specified	390	390	420	555	835	835	835
Soviet Union*	Not specified	1,250	1,250	1,350	1,350	1,350	1,350	1,350
World total		6,905	6,761	5,519	6,858	8,261	8,193	7,791

[1] See table 3 for chemical formulas and lithium content of minerals.

portion of production from developing countries[4] rose from 7 percent at the beginning of the decade to about 18 percent in 1986. Mine-production estimates are given in table 8.

The most striking feature in this table is the high concentration of production among a few countries such as United States, the Soviet Union, China, and Zimbabwe. In the last 2 or 3 years, however, new production facilities have been developed in Australia, Canada, and Chile. This has led to a more diversified supply, although the concentration of the supply in a small number of countries remains significant.

Production capacity.—In 1986, world production of lithium was about 7,800 metric tons, about 73 percent of world production capacity. Table 9 shows estimated production capacity for various important world lithium producers. For several operations, including those in Brazil, China, the Soviet Union, and Zimbabwe, actual capacities are not known. Figures shown in table 9 are based on recent production levels.

[4] In this report, developing countries that produce lithium are Argentina, Brazil, Chile, Namibia, Portugal, Rwanda, and Zimbabwe. The World Bank (1986, p. 180–81) classifies these countries (except for Namibia) as low- and middle-income economy countries on the basis of gross national product per capita and other criteria.

Of the total 10,520 metric tons of world lithium production capacity, United States operations account for the largest portion, almost 6,000 metric tons, or about 54 percent. However, Cyprus-Foote Mineral Company's Kings Mountain operation in North Carolina, with a production capacity of 1,540 metric tons or 14 percent of the total, is currently on care-and-maintenance status and is unlikely to again produce significant amounts of lithium unless prices and demand increase substantially.

Brine operations, which are expected to become an increasingly important source of lithium, presently account for 2,560 metric tons capacity, or 24 percent of the world total.

Production costs.—The small number of lithium producers worldwide, and the fact that brines and pegmatites have widely varying economic and technological attributes, makes it neither possible, nor desirable, to present average production costs among the various producers. Furthermore, in countries such as China certain costs, specifically transportation and wages, are not directly attributable to the operation, so that total production costs are not reflected in the sales price. A brief discussion of some important cost considerations is warranted.

TABLE 9.—*Production capacities of major lithium operations*
[N.a.=Not applicable]

Country	Operation	Operator	Major products	Capacity (metric tons lithium)
Australia	Lithium Australia Limited (formerly Greenbushes)	Lithium Australia Limited	Spodumene	510
Brazil	Aracuai-Itinga	Arqueana de Minérios e Metais Limitada.	Petalite, spodumene amblygonite, lepidolite.	60
Canada	Bernic Lake	Tantalum Mining Corporation	Spodumene	200
Chile	Salar de Atacama*	Cyprus-Foote Mineral Company	Lithium carbonate	1,360
China	Not available	Chinese government	Spodumene	700
Soviet Union	Not available	Soviet government	Lithium chemicals and metal	1,350
United States	Kings Mountain (currently on care-and-maintenance status).	Cyprus-Foote Mineral Company	Spodumene	1,540
	Silver Peak*	Cyprus-Foote Mineral Company	Lithium carbonate	1,200
	Bessemer City	Lithium Corporation of America	Lithium chemicals, metal, and lithium carbonate.	3,070
Zimbabwe	Bikita	Bikita Minerals Limited	Lithium carbonate, petalite, spodumene.	530
Total	N.a.	N.a.	N.a.	10,520

*Brine operations.

Lithium carbonate is produced from both brines and pegmatites. In terms of the cost to obtain lithium carbonate, brines are significantly less expensive. Although there are only a few operations from which to compare figures, and individual component costs vary from operation to operation, the total cost of producing lithium carbonate from a brine source is estimated to be roughly 75 percent of the cost of producing it from a pegmatite deposit.

With respect to individual processing costs for a typical open-pit pegmatite mine in the United States, an average cost breakdown has been estimated. The cost of mining is approximately equal to the cost of crushing and beneficiation with each constituting about 16 to 17 percent of the total processing costs. The remainder is attributable to chemical processing.

Competition among operations producing the same products such as lithium carbonate or spodumene concentrates is an important factor in determining market share. However, there is increasing competition between lithium carbonate producers and concentrate producers to supply certain markets. In the manufacture of ceramics and glass, the use of spodumene and petalite concentrates instead of lithium carbonate may result in cost savings and technological advantages. It is estimated that demand for 4,535 metric tons of lithium carbonate equivalent in the glass and ceramics industry is currently met by concentrate producers. In the future, another 3,200 to 3,600 metric tons of lithium carbonate equivalent may be supplied through concentrates.

ASPECTS OF FUTURE LITHIUM SUPPLY AND DEMAND

Although the recent decline of the world manufacturing economy has resulted in lower lithium consumption, there are several prospects for growth in the demand for lithium.

- In the ceramics and glass industry, lithium is starting to be used in container glass; previously lithium was used almost exclusively in shock-resistant glassware.
- New applications may be found in the manufacture of aluminum, a major lithium-demand sector. Older potlines use lithium to increase energy efficiency, but new energy-efficient potlines may use lithium to remove impurities from the melt, hence enhancing environmental control.
- The consumption of lithium in batteries is relatively minor, but the prospects for future growth are favorable.
- Use of aluminum-lithium alloys in the aircraft industry has been widely publicized, but at present major growth in this area has yet to occur.

In 1985, lithium producers were operating at approximately 70 percent of capacity, and the U.S. Bureau of Mines forecasted that lithium demand would

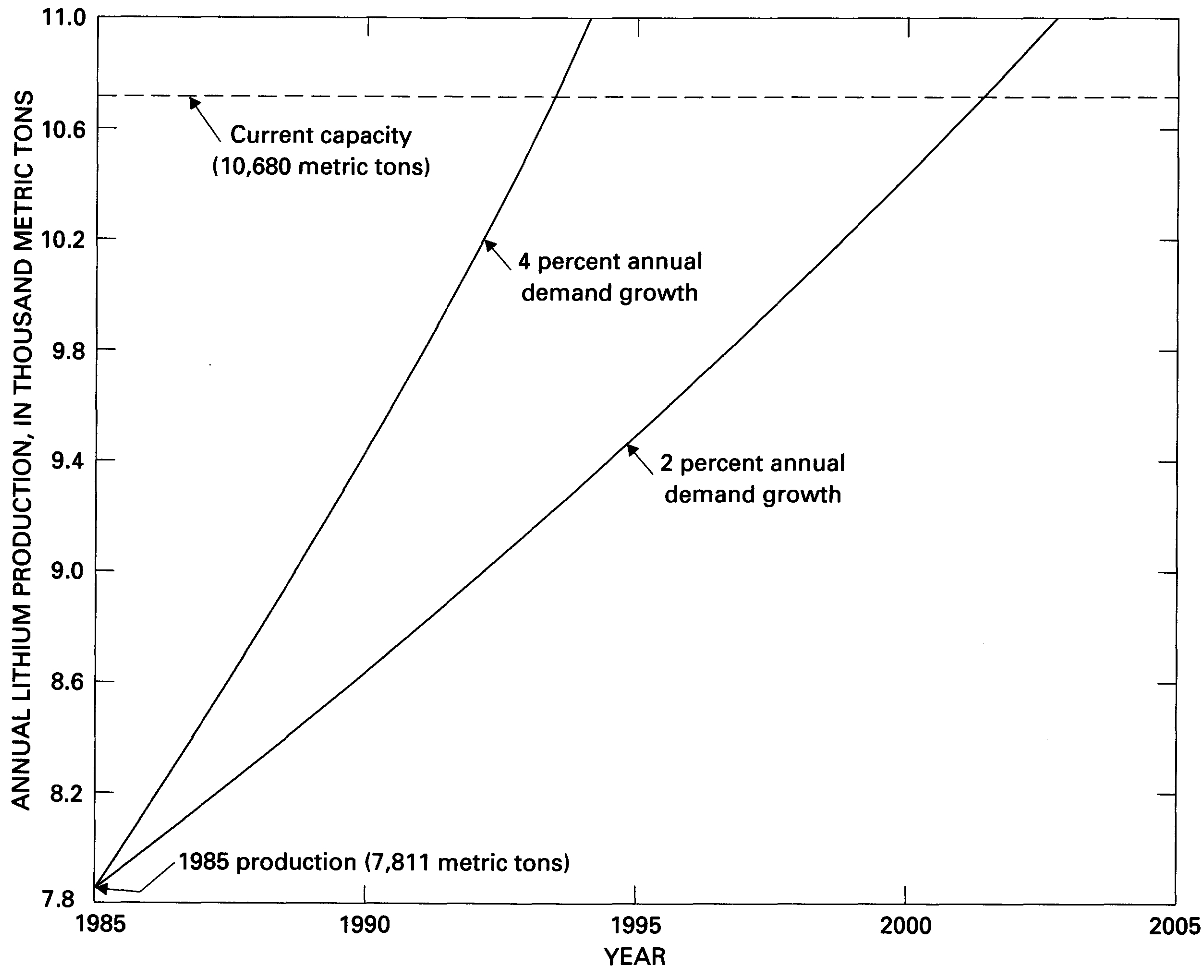


FIGURE 5. Present lithium production capacities and possible future demand.

grow at 4.5 percent annually (Ferrell, 1985a, p. 469). Although the aluminum industry seems to be recovering from a recent slump, and there are prospects for future growth in some sectors, it is estimated that the growth of lithium demand will be somewhat lower than was previously predicted, probably on the order of 2 percent to 4 percent. Figure 5 compares two demand scenarios (2 percent and 4 percent) with current production capacity. At 4-percent growth, capacity is sufficient to fill demand until approximately 1995; at 2-percent growth, capacity can meet expected demand until approximately 2005.

In the United States, however, Cyprus-Foote Mineral Company's Kings Mountain operation, with an annual production potential of 1,540 metric tons, was placed on standby in mid-1986, suggesting that prices are not high enough to allow development of additional pegmatite deposits. Unless special production incentives are made available to prospective operators of undeveloped pegmatites, it is unlikely that other pegmatites will be developed in the near future. A recent survey (Bleiwas and Coffman, 1986) evaluated seven undeveloped Canadian pegmatite deposits containing a total of 76 million metric tons of mineralized material averaging 0.63 percent Li_2O. Lithium recovery from the least costly of these potential operations would be approximately two to three times more expensive than from the Bernic Lake operation.

Although use of spodumene and petalite concentrates in place of lithium carbonate in glass and ceramics manufacturing may result in an increasing share of concentrate production to that market sector, it seems that current concentrate producers will be capable of meeting that demand. Furthermore, within the lithium carbonate sector, it is possible that producers will shift some production to brines, from which lithium carbonate can be produced at lower cost than from pegmatites.

TABLE 10.—*Plans for expanding operations and for establishing new production facilities*

[Capacity figures are in metric tons per year]

Operation or proposed operation	Deposit type	1985 capacity (metric tons lithium)	Projected capacity (metric tons lithium)	Projected years of completion of new capacity
	Australia			
Lithium Australia Limited (formerly Greenbushes) Lithium Australia Limited	Pegmatite	510	1,045	1990–91
	Chile			
Salar de Atacama AMAX–MOLYMET	Brine	0	2,800	1992
Salar de Atacama Cyprus-Foote Mineral Company	Brine	1,360	1,704	1990

Table 10 shows recent and proposed future capacity of lithium operations for which expansion and developments have been announced or projected. By the early 1990's, there could exist nearly an additional 4,000 metric tons of annual lithium production capacity if these plans are implemented.

Present and probable future production of lithium from major deposits included in the International Strategic Minerals Inventory are shown in figure 6 (p. 26).

CONCLUSIONS

In terms of lithium-resource availability, present economically viable resources are more than sufficient to meet likely demand in the foreseeable future. In times of excess capacity such as currently exist, some pegmatite operations cannot compete with the lower costs of brine operations. Thus, there is an increasing tendency to develop new brine operations instead of pegmatite operations. A notable exception is the recent development of pegmatites by Lithium Australia Limited, which offers low-iron lithium concentrates to the glass and ceramics industry.

A further production shift from pegmatites to brines will result in the concentration of supply in a few countries such as Chile and the United States. This could lead to dependence of industrialized countries on deliveries from these sources.

PART II—SELECTED INVENTORY INFORMATION FOR LITHIUM DEPOSITS AND DISTRICTS

Tables 11 and 12 contain information from the International Strategic Minerals Inventory record forms for lithium deposits and districts. Only selected items of information about the location and geology (table 11) and mineral production and resources (table 12) of the deposits are listed here; some of this information has been abbreviated.

Summary descriptions and data are presented in the table as they were reported in the inventory records. For instance, significant digits for amounts of production or resources have been maintained as reported. Data that were reported in units other than metric tons have been converted to metric tons for comparability. Some of the data in the table are more aggregated than in the inventory records, such as cumulative production totals that for some mines have been reported by year or by groups of years. Some of the abbreviations used in the inventory records have been used in these tables; they are explained in the headnotes.

TABLE 11.—*Selected geologic and location information*

Host rock may include some or all of the following items (separated

Age abbreviations and prefixes:

Cenozoic	CEN	Triassic	TRI	Proterozoic	PROT	Late	L
Tertiary	TERT	Paleozoic	PAL	Huronian	HUR		
Cretaceous	CRET	Carboniferous	CARB	Archean	ARCH		
Jurassic	JUR	Precambrian	PREC	Early	E		

Other abbreviations:

--, Not reported on the ISMI record form

Site name	Latitude	Longitude	Deposit type	Host rock	Age of mineralization
Afghanistan					
Hindukush Mountain Range	35° 14′N.	70° 44′E.	Pegmatite	---	---
Argentina					
Catamarca Province	28° 40′S.	65° 31′W.	Pegmatite, zoned	Mica schist, quartzites; Crystalline basement; LPROT–EPAL.	LPROT–EPAL
San Luis Province	32° 53′S.	65° 39′W.	----do.------------	----do.------------	LPROT–EPAL
Salar del Hombre Muerto	25° 00′S.	67° 00′W.	Brine	---	CEN
Australia					
Lithium Australia Limited (formerly Greenbushes) (Western Australia)	33° 51′S.	116° 04′E.	Pegmatite, zoned	Quartzites, gneisses; Balingup metamorphic belt; ARCH.	ARCH
Austria					
Koralpe (Kärnten)	46° 50′N.	14° 58′E.	Pegmatite, unzoned	Garnet-mica schist	---
Bolivia					
Salar de Uyuni	20° 30′S.	67° 30′W.	Brine (hydrothermal?)	---	CRET–TERT
Brazil					
Solonopole (Ceara)	05° 44′S.	39° 05′W.	Pegmatite	---	PREC
Itinga (Minas Gerais)	16° 30′S.	41° 54′W.	----do.------------	Garnet-mica schist	PREC
Araçuai (Minas Gerais)	16° 43′S.	41° 56′W.	----do.------------	----do.------------	PREC
Quixeramobim (Ceará)	05° 23′S.	39° 09′W.	----do.------------	Granite	PREC
Canada					
Bernic Lake (Manitoba)	50° 25′N.	95° 27′W.	Pegmatite, zoned	Amphibolites; Rice Lake group; ARCH. Metaconglomerate; Rich Lake group; ARCH.	PREC (ARCH?)
Preissac-Lacorne district (Quebec)					
Authier	48° 22′N.	78° 12′W.	Pegmatite	---	PREC (ARCH?)
Quebec Lithium Lacorne	48° 24′N.	77° 49′W.	Pegmatite, unzoned	Amphibolized green-stone; Keewatin; ARCH.	PREC (ARCH?)
Yellowknife area (Northwest Territories)					
Big	62° 30′N.	114° 00′W.	Pegmatite	Meta-andesites, metabasalts, meta-sediments, Yellow-knife supergroup; PREC.	EPROT (HUR)
Fi (Hidden Lake)	62° 41′N.	113° 30′W.	----do.------------	----do.------------	EPROT (HUR)

from ISMI records for lithium deposits and districts

by semicolons): main host rock type, formation name, and host rock age.

Abbreviations for mineral names (after Longe and others, 1978, p. 63–66 and some additions):

Albite	ALBT	Fluorite	FLRT	Microcline	MCCL	Spodumene	SPDM
Amblygonite	AMBG	Garnet	GRNT	Muscovite	MSCV	Tantalite	TNTL
Beryl	BRYL	Halite	HLIT	Petalite	PETL	Tourmaline	TRML
Cassiterite	CSTR	Hubnerite	HBNR	Plagioclase	PLGC	Ulexite	ULXT
Columbite	CLMB	Lepidolite	LPDL	Pollucite	PLCT	Zinnwaldite	ZWLD
Feldspar	FLDP	Mica	MICA	Quartz	QRTZ		

Tectonic setting	Local environment	Principal mineral assemblages	Comments	Reference
		Afghanistan—Continued		
---	---	SPDM; BRYL; MCCL; QRTZ; TRML.	Nilau-Kulam, Parun. Major portion of spodumene is gem quality.	Rossovskii and others (1976).
		Argentina—Continued		
Crystalline basement.	---	SPDM; AMBG; MCCL; PLGC; QRTZ.	Includes La Herumbrada, Juan Carlos, Refilljos del Mar, Ipizca, and Sta. Gertrudis.	Angelelli (1984).
----do.------------	---	SPDM; AMBG; MCCL; PLGC; QRTZ.	Includes La Viquita, Teresida, San Rolando, and Geminis.	---
---	---	HLIT; ULXT	Recent investigation to evaluate possibilities for lithium recovery.	Angelelli (1984).
		Australia—Continued		
Yilgarn block	Balingup metamorphic belt.	SPDM; QRTZ; FLDP; TRML	Mineral assemblage is of lithium zone only.	Hatcher and Elliott (1986).
		Austria—Continued		
Alpine orogen crystalline core	---	SPDM; QRTZ; FLDP	Deposit includes 3 tabular and lens-shaped pegmatite bodies within a series of garnet-mica schists.	---
		Bolivia—Continued		
Antiplano Boliviano.	---	---	---	---
		Brazil—Continued		
---	---	AMBG	---	Filho (1985).
São Francisco craton.	Faixa de dobramentos Araçüaí.	PETL; AMBG; SPDM	---	Afgoüni and Silva Sá (1978).
----do.------------	----do.------------	PETL	---	Do.
---	---	LPDL	---	Do.
		Canada-Continued		
Canadian shield	Bird River formation (Greenstone belt).	SPDM; AMBG; PETL; LPDL; MCCL; ALBT; QRTZ.	Mineral assemblages are for lithium zone only. Mine was a major tantalum producer until 1983.	Crouse and Cerny (1972), Energy, Mines and Resources Canada (1986).
----do.------------	---	MCCL; ALBT; QRTZ; SPDM	---	Energy, Mines and Resources Canada (1986).
Canadian shield, Superior Province.	Lacorne batholith, Manneville fault.	MCCL; ALBT; QRTZ; SPDM	Numerous parallel spodumene-bearing dikes lie within a 600-m- wide band.	Mulligan (1965; 1969), Energy, Mines and Resources Canada (1986).
Canadian shield	---	SPDM; QRTZ	---	Energy, Mines and Resources Canada (1986).
----do.------------	---	SPDM; QRTZ	---	Lasmanis (1978).

TABLE 11.—*Selected geologic and location information from ISMI*

Site name	Latitude	Longitude	Deposit type	Host rock	Age of mineralization
			Canada—Continued		
Jim (Hidden Lake)	62° 34′N.	114° 31′W.	Pegmatite	Meta-andesites, metabasalts, metasediments, Yellowknife supergroup; PREC.	EPROT (HUR)
Vo	62° 51′N.	114° 28′W.	----do.------------	----do.------------	EPROT (HUR)
Thor	62° 26′N.	112° 11′W.	----do.------------	Granodiorite, metaclastites; Yellowknife supergroup PREC.	EPROT (HUR)
			Chile		
Salar de Atacama (Antofagasta Province).	23° 15′S.	68° 15′W.	Brine	Evaporites	QUAT
			China		
Koktokay (Xinjiang-Uygur)	47° 15′N.	89° 37′E.	Pegmatite, zoned	Gabbro, granite; LTRI–JUR.	LTRI–JUR
			Czechoslovakia		
Rožna area (Moravia)	49° 22′N.	16° 02′E.	Pegmatite; greisen?	---	---
			France		
Massif Central (Allier Department)	46° 14′N.	02° 42′E.	Pegmatite; greisen	Granites; Massif granitique d'Echassières. Gneisses; Sioule series.	CARB?
			India		
Govindpal area (Madhya Pradesh)	18° 42′N.	81° 54′E.	Pegmatite, zoned	---	---
			Mali		
Bougouni area	11° 25′N.	07° 28′W.	Pegmatite	Two-mica granites. Mica-schists.	PREC
			Mozambique		
Alto Ligonha district	16° 00′S.	38° 00′E.	Pegmatite, zoned	---	LPROT–EPAL
			Namibia		
Karibib district	22° 09′S.	16° 00′E.	Pegmatite, zoned	Metasediments; Karibib formation; PREC. Granite; Salem suite; PREC.	PREC
			Portugal		
Guarda area	40° 30′N.	07° 20′W.	Pegmatite, greisen?	---	---
			South Africa		
Noumas (Cape Province)	28° 57′S.	17° 44′E.	Pegmatite, zoned	Granodiorite; Vioolsdrif suite.	PREC
Norrabees (Cape Province)	28° 57′S.	17° 59′E.	----do.------------	Gneiss, metasediments; Horn formation; PREC. Red granite; Hangoor suite; PREC.	PREC

records for lithium deposits and districts—Continued

Tectonic setting	Local environment	Principal mineral assemblages	Comments	Reference
		Canada—Continued		
Canadian shield	---	SPDM; QRTZ	---	Lasmanis (1978).
----do.------------	---	SPDM; QRTZ	---	Do.
----do.------------	---	SPDM; QRTZ	---	Do.
		Chile—Continued		
Andean Cordillera	Atacama downwarp (bolsón).	---	r1E refers to SCL portion only	Foote Mineral Company (1987), Bleiwas and Coffman (1986), Stoertz and Ericksen (1974).
		China—Continued		
---	---	ALBT; SPDM; QRTZ; TNTL; PLCT; LPDL.	Mineral assemblage is of lithium zone only.	---
		Czechoslovakia—Continued		
---	---	LPDL	---	---
		France—Continued		
---	---	LPDL; AMBG; QRTZ; MCCL; CSTR; CLMB; HBNR.	Echassières, Montebras, and La Chèze deposits.	Aubert (1969).
		India—Continued		
---	---	FLDP; QRTZ; MICA; LPDL; ZWLD; AMBG; SPDM; CSTR; TNTL; GRNT; BRYL; FLRT.	Pegmatites in granites, metasediments, and metabasic rocks.	Singh and Muskerjee (1985).
		Mali-Continued		
---	---	QRTZ; MCCL; ALBT; MSCV; SPDM.	Includes Sinsinkouro, Gouanala, Dialakoro, and Kola.	Traoré and Méloux (1978).
		Mozambique—Continued		
---	---	LPDL; AMBG; SPDM; PLCT; BRYL; MCCL; QRTZ; PLGC; MSCV.	Includes Nahipa, Inchope, Muiane Morrua, and Nahora.	Lopes Nuñes (1973), Hutchison and Claus (1956).
		Namibia—Continued		
Metasediments with intrusive granites (Damara sequence).	Geosyncline	PETL; QRTZ; ALBT; AMBG; CLMB; TNTL; LPDL.	Pegmatites are linked to granite intrusives.	Roering and Gevers (1964).
		Portugal—Continued		
---	---	LPDL; AMBG	---	Aubert (1963).
		South Africa—Continued		
Namaqua mobile belt.	Pegmatite belt	SPDM; ALBT; QRTZ	Spodumene mineralization is confined to the second intermediate zone.	Schutte (1972).
----do.------------	----do.------------	ALBT; SPDM; QRTZ; MCCL	---	Do.

TABLE 11.—*Selected geologic and location information from ISMI*

Site name	Latitude	Longitude	Deposit type	Host rock	Age of mineralization
Soviet Union					
Kola Peninsula (RFSR)	67° N. (approx location)	37° E.	Pegmatite	---	PREC
Tro San Zhen (Kirgiz SSR)	42° N. (approx location)	77° E.	----do.------------	---	TRI?
Zavitaya (Chita Oblast)	51° N. (approx location)	115° E.	----do.------------	---	PREC
United States					
North Carolina Tin-Spodumene Belt					
Kings Mountain	35° 15′N.	81° 21′W.	Pegmatite, unzoned	Amphibolite, schist; Blacksburg Formation LPROT–CAM. Quartz Monzonite; Cherryville quartz monzonite; DEV–MISS.	PREC
Bessemer City	35° 20′N.	81° 10′W.	----do.------------	----do.------------	PREC
Silver Peak (Nevada)	37° 45′N.	117° 38′W.	Brine	Clay, silt, sand, evaporites; Esmeralda Formation.	CRET–TERT
Searles Lake (California)	35° 46′N.	117° 24′W.	----do.------------	Salt, mud	CRET–TERT
Zaire					
Manono-Kitotolo (Shaba)	07° 19′S.	27° 27′E.	Pegmatite, zoned	Mica schist; Kibara system; PREC. Quartzite; Kibara system; PREC.	PREC
Zimbabwe					
Bikita (Masvingo district)	19° 57′S.	31° 26′E.	Pegmatite, zoned	Epidiorites; Victoria greenstone belt; ARCH. Banded ironstones; Victoria greenstone belt; ARCH.	ARCH

Tectonic setting	Local environment	Principal mineral assemblages	Comments	Reference
		Soviet Union—Continued		
---	---	SPDM; LPDL	---	---
---	---	SPDM	---	---
		United States—Continued		
---	Kings Mountain belt.	SPDM; MCCL; QRTZ; ALBT; MSCV.	Deposit is near border between Kings Mountain and Inner Piedmont belts.	Foote Mineral Company (1987), Horton (1981), Bleiwas and Coffman (1986).
---	Kings Mountain and Inner Piedmont belts.	SPDM; MCCL; QRTZ; ALBT; MSCV.	---	---
---	---	---	Brines located in a closed evaporite basin.	Foote Mineral Company (1987), Davis and Vine (1979).
---	---	---	---	Kesler (1960), Rykken (1976).
		Zaire—Continued		
---	---	SPDM; CSTR; CLMB; ALBT; QRTZ; MICA.	Not a lithium producer at present	Angermeier and others (1974), Varlamoff (1968).
		Zimbabwe—Continued		
---	Victoria greenstone belt.	PETL; SPDM; LPDL; QRTZ; ALBT.	Mineralization includes spodumene-quartz intergrowth which is chemically equivalent to petalite.	Bleiwas and Coffman (1986), Cooper (1964).

Abbreviations used throughout this table include:

---, Not reported on the ISMI record form.

Mining method abbreviations:

S, surface mining; U, underground mining; and N, not presently being mined.

Commodities provides a listing of commodities or prospective commodities and their activity status (separated by semicolons). Activity status abbreviations: C, current production; N, no production; and P, past production.

Annual production includes some or all of the following items (separated by semicolons): production in thousand metric tons of material mined (unless other processing stage is indicated); grade of reported material; and year of production (or range of years used to estimate average annual production).

Site name	Year of discovery	Mining method; status	Year of first production	Commodities	Annual production (thousand metric tons)
			Afghanistan		
Hindukush Mountain Range	---	---	---	Li	---
			Argentina		
Catamarca Province	---	S; intermittent production.	1964	Li; Be	---
San Luis Province	---	----do.------------	---	----do.------------	---
Salar del Hombre Muerto	---	N; no production	---	K, N; B, C; Li, N	---
			Australia		
Lithium Australia Limited (formerly Greenbushes) (Western Australia)	1978–79	S; active	1983 (Li)	Li, C; Ta, C; Nb,C; Sn, C, kaolin or kaolinitic clay C.	5; 7.5 percent Li_2O in spodumene concentrates; 1983–84 13.2; 7.5 percent Li_2O in spodumene concentrates; 1984–85.
			Austria		
Koralpe (Kärnten)	---	U?; no production	---	Li, N	---
			Bolivia		
Salar de Uyuni	1976	N; no production	---	Li; B; K	---
			Brazil		
Solonopole (Ceara)	---	N; past production	---	Li, P	---
Itinga (Minas Gerais)	---	S; active	---	Li, C	2.1; 4 percent Li_2O; 1986 (combined production for Itinga and Aracuai).
Araçuai (Minas Gerais)	---	----do.------------	---	Li, C	(Included with total for Itinga.)
Quixeramobim (Ceará)	---	N; past production	---	Li, P	---
			Canada		
Bernic Lake (Manitoba)	1929	U; active	1984 (Li)	Ta, P; Li, C; Cs, C; Tb, C; Sn, P.	0.082; 7.25 percent Li_2O 1984. 0.276; 7.25 percent Li_2O; 1985. 0.830; 7.05 percent Li_2O; 1986.
Preissac-Lacome district (Quebec)					
Authier	---	N; no production	---	Li, N	---
Quebec Lithium Lacorne	---	U; past production	1955	Li, P	40; 5 percent Li_2O; 1956–59
Yellowknife area (Northwest Territories)					
Big	---	N; no production	---	---	---
Fi (Hidden Lake)	---	----do.------------	---	---	---
Jim (Hidden Lake)	---	----do.------------	---	---	---
Vo	---	----do.------------	---	---	---
Thor	1974–76	----do.------------	---	---	---

from ISMI records for lithium deposits and districts

Cumulative production includes some or all of the following items (separated by semicolons): production in thousand metric tons of material mined (unless other processing stage is indicated); grade of reported material; and years for reported cumulative production.

Resources includes, for various resource categories, some or all of the following items (separated by semicolons): resource in thousand metric tons; U.N. resource classification (United Nations Economic and Social Council, 1979; Schanz, 1980); grade (unless resource is specified as contained metal); and year of estimate. Grades reported for mining properties often are the grade of mill feed, while for undeveloped properties, in-place grades are usually reported. Dilution in the mill feed grades may be about 15 percent for underground mining.

Cumulative production (thousand metric tons)	Resources (thousand metric tons)	Comments
	Afghanistan—Continued	
---	Large?	---
	Argentina—Continued	
---	---	---
---	---	---
---	---	Property is being evaluated.
	Australia—Continued	
29; 7.5 percent LiO_2; 1983–86.	41,900; 1.48 percent Li; R1E; 1986	Deposit has large tonnage, high grade resources with potential for additional resources and is emerging as a major producer.
	Austria—Continued	
---	13,000; 0.77 percent Li; R1M+R1S; 1986	Property is being evaluated; deposit is in a recreational area.
	Bolivia—Continued	
---	5,000; Li metal; R1M+R1S; 1983	Feasibility study is planned by Industria Minera Teirra Ltda.
	Brazil—Continued	
---	90.2; 3.96 percent Li: R1M; 1984	---
---	95.1; 2.35 percent Li; R1E; 1984	Production is mostly petalite.
---	80.1; 1.17 percent Li; R1E; 1984	---
---	4.4; 0.68 percent Li; R1M+R1S; 1984	---
	Canada—Continued	
---	5,900; 1.24 percent Li; R1E; 1986	Tanco pegmatite was discovered accidentally in a single drill hole while exploring small tin-bearing pegmatites. Deposit was not outlined until 1955.
---	5,800; 0.53 percent Li; R1S; 1977	---
---	18,000; 0.60 percent Li; R1S; 1986	---
---	7,200; 0.68 percent Li; R1S; 1986	14 pegmatites in the area have been studied in detail. They contain 49 million metric tons of rock averaging 1.40 percent Li_2O.
---	13,900; 0.55 percent Li; R1S; 1986	Extensive glaciation has removed most of the overburden leaving continuous exposures.
---	3,800; 0.58 percent Li; R1S; 1986	---
---	3,100; 0.69 percent Li; R1S; 1986	---
---	8,400; 0.70 percent Li; R1S; 1986	Flotation tests gave an 80-percent recovery rate and a concentration grade of 6 percent Li_2O.

TABLE 12.—*Selected production and mineral-resource information from ISMI*

Site name	Year of discovery	Mining method; status	Year of first production	Commodities	Annual production (thousand metric tons)
			Chile		
Salar de Atacama (Antofagasta Province).	1960	Pumping, evaporation; active.	1984	Li, C; K, C	2.11; 99.5 percent $LiCO_3$; 1984. 4.508; 99.5 percent $LiCO_3$; 1985. 7.332; 99.5 percent $LiCO_3$; 1988.
			China		
Koktokay (Xinjiang-Uygur)	1942	S; active	1946	Li, C; Be, C; Ta,C; Nb, C; Cs, C.	---
			Czechoslovakia		
Rožna area (Moravia)	---	---	---	---	---
			France		
Massif Central (Allier Department)	---	N; no production	---	Li, N	---
			India		
Govindpal area (Madhya Pradesh)	---	---	---	---	---
			Mali		
Bougouni area	---	N; no production	---	Li, N	---
			Mozambique		
Alto Ligonha district	---	U, S?; intermittent production.	---	Li C; Be, C; Ta, C; Cs, C; Rb, C.	0.013; amblygonite concentrates; 1970. 0.024; lepidolite concentrates; 1970.
			Namibia		
Karibib district	1927	S; intermittent production	1945	Li, C; Be, C	8.4; 3.99 percent Li_2O; 1956.
			Portugal		
Guarda area	---	Active	---	Li, C	---
			South Africa		
Noumas (Cape Province)	---	S, U?; intermittent production.	---	Li, C	---
Norrabees (Cape Province)	---	S; intermittent production	---	Li, C	---
			Soviet Union		
Kola Peninsula (RFSR)	---	---	---	---	---
Tro San Zhen (Kirgiz SSR)	---	---	---	---	---
Zavitaya (Chita Oblast)	---	---	---	---	---
			United States		
North Carolina Tin-Spodumene Belt					
Kings Mountain	1930's	S; standby	1950's	Li, C; feldspar, C; mica, C; crushed stone, C; Sn, N; Ta, N.	83.9; 1.5 percent Li_2O; 1986. 0.953; 40.4 percent Li_2O; 1986.
Bessemer City	---	S; active	Early 1960's	Li, C; Be, N	2.771; Li in carbonate; 1980. 2.744; Li in carbonate; 1979.
Silver Peak (Nevada)	Early 1900's.	Pumping, evaporation; active.	1967	Li, C	1.171; Li in carbonate; 1980. 1.023; Li in carbonate; 1979.

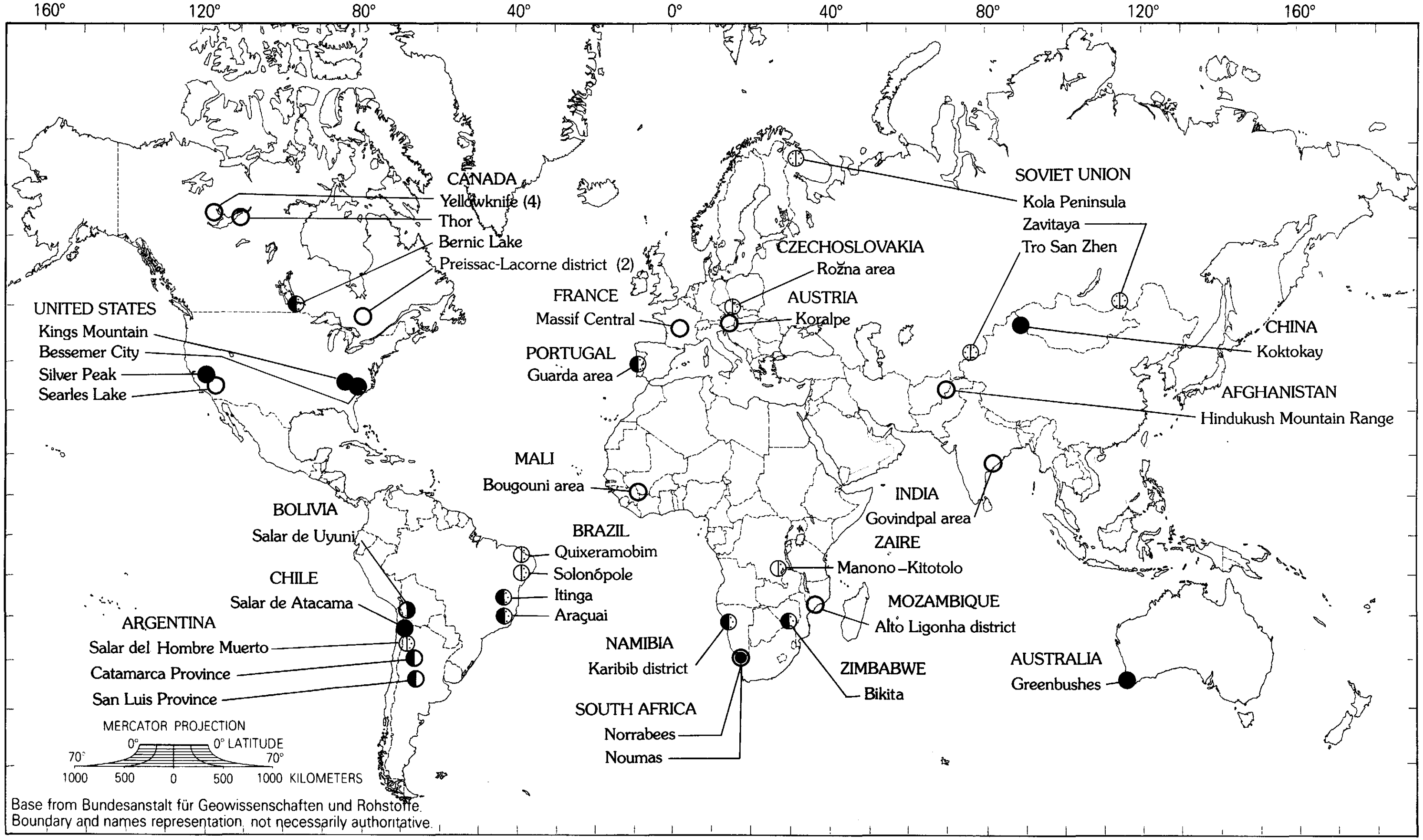
Cumulative production (thousand metric tons)	Resources (thousand metric tons)	Comments
	Chile—Continued	
---	201.4; Li metal; r1e; 1986. 1,424; Li metal; r1M+r1S; 1986.	Operation actually producing is SCL near Chepica del Salar.
	China—Continued	
---	>5,000; 0.7 percent Li; R1E; 1987	---
	Czechoslovakia—Continued	
---	---	---
	France—Continued	
---	---	---
	India—Continued	
---	---	---
	Mali—Continued	
0.059; amblygonite concentrates; 1956–70. 0.033; spodumene concentrates; 1956–70.	266; 3.02 percent Li; R1M+R1S; 1978	---
	Mozambique—Continued	
---	---	---
	Namibia—Continued	
---	100; >1.4 percent Li; R1E; 1951	---
	Portugal—Continued	
---	---	---
	South Africa—Continued	
---	30; grade not reported; R1M; 1968	---
---	---	---
	Soviet Union—Continued	
---	---	---
---	---	---
---	---	---
	United States—Continued	
1,241.431; 1.47 percent LiO_2; 1975–81.	21,682; 0.7 percent Li; R1M; 1986	---
15.972; Li in carbonate; 1974–80.	23,300; 0.65 percent Li; R1E; 1986	---
11.786; Li in carbonate; 1970–80.	30.4; Li metal; r1E; 1986	Total area of evaporation ponds is about 16 km^2. Lithium grades are diminishing significantly in brines.

TABLE 12.—*Selected production and mineral-resource information from ISMI*

Site name	Year of discovery	Mining method; status	Year of first production	Commodities	Annual production (thousand metric tons)
			United States—Continued		
Searles Lake (California)	---	Pumping, evaporation; past production.	About 1938.	Li, P	---
			Zaire		
Manono-Kitotolo (Shaba)	1911	S; active	1919 (Sn)	Li,N; Sn, C; Ta, C; Nb, C.	---
			Zimbabwe		
Bikita (Masvingo district)	1909	S; active	1952–53 (Li).	Li, C; Be, C; Ta, C; Sn, C; Cs, C; Rb, C.	133.557; Li ore; 1986. 26.964; petalite concentrate; 1986.

records for lithium deposits and districts—Continued

Cumulative production (thousand metric tons)	Resources (thousand metric tons)	Comments
	United States—Continued	
1.985; ore; 1967–78	31.6; Li metal; r1S; 1960	---
	Zaire—Continued	
780.0; pegmatite ore; 1951–56.	31,500; 0.98 percent Li; R1M + R1S; 1986	Not a lithium producer at present. High transport costs are a limiting factor.
	Zimbabwe—Continued	
---	3,800; 1.35 percent Li;R1E; 1986	New beneficiation system and reworking of tailings have substantially improved workability.



EXPLANATION

- Active or intermittent producer in 1986; probably a significant producer in 2025
- Active or intermittent producer in 1986; probably an insignificant producer in 2025
- Active or intermittent producer in 1986; information insufficient to permit any forecast as to future production
- No production in 1986 or 1986 production not reported; probably a significant producer in 2025
- No production in 1986 or 1986 production not reported; probably an insignificant producer or exhausted by 2025
- No production in 1986 or 1986 production not reported; information insufficient to permit any forecast as to future production
- Present (1986) status not reported; information insufficient to permit any forecast as to future production

Figure 6. Major lithium deposits and districts, their present production status, and their probable production status in 2025. Numbers in parentheses indicate the number of records (deposits and districts) for each location. Location names are from tables 11 and 12.

REFERENCES CITED

Afgoûni, K., and Silva Sá, J.H., 1978, Lithium ore in Brazil, *in* Penner, S.S., ed., Lithium—Needs and resources, proceedings of a symposium: Energy, v. 3, no. 3, p. 247–253.

American Metal Market, 1972, Humble unveils lithium grease: American Metal Market, v. 79, no. 70, p. 12.

Angelelli, Victorio, 1984, Yacimientos metaliferos de la República Argentina [Metallic deposits of Argentina]: Comisión Investigaciones Cientifícas Provincia de Buenos Aires, Instituto Geologia Aplicada, 2 volumes, 704 p.

Angermeier, H.-O., Krauss, Ulrich, Kruszona, Manfred, and Schmidt, Helmut, 1974, Rohstoffwirtschaftliche Länderberichte, v. 3. Zaire: Hannover, Bundesanstalt für Geowissenschaften und Rohstaffe, 120 p.

Aubert, Georges, 1963, Le lithium: France, Bureau de Recherches Géologiques et Minières Bulletin, no. 2, p. 23–93.

———1969, Les coupoles granitiques de Montebras et d'Échassières (Massif Central français) et la genèse de leurs minéralisations en étain, lithium, tungstène et béryllium: France, Bureau de Recherches Géologiques et Minières, Mémoires no. 46, 345 p.

Bleiwas, D.I., and Coffman, J.S., 1986, Lithium availability—A minerals availability appraisal: U.S. Bureau of Mines Information Circular 9102, 23 p.

Bro, P., Gabano, J.P., Takehara, Z., and Yamamoto, O., 1987, The future of lithium batteries (round table discussion): Journal of Power Sources, v. 20, p. 245–356.

Carroll, H.R., and Angelo, J.J., 1983, Adding lithium can improve melting-forming performance: Glass Industry, v. 64, no. 11, p. 14–18.

Cheney, R.G., 1983, The lithium advantage in making aluminum: Foote Mineral Company, Foote Prints, v. 46, no. 2, p. 14–26.

Cooper, D.G., 1964, The geology of the Bikita pegmatite, *in* Haughton, S.H., ed., The geology of some ore deposits in southern Africa, v. 2: Geological Society of South Africa, p. 441–461.

Crouse, R.A., and Cerny, P., 1972, The Tanco pegmatite at Bernic Lake, Manitoba; I, Geology and paragenesis: Canadian Mineralogist, v. 11, part 3, p. 591–608.

Davis, J.R., and Vine, J.D., 1979, Stratigraphic and tectonic setting of the lithium brine field, Clayton Valley, Nevada, *in* Newman, G.W., ed., Basin and Range symposium and Great Basin field conference: Denver, Colo., Rocky Mountain Association of Geology, p. 421–430.

Energy, Mines and Resources Canada, 1986, Lithium—An imported mineral commodity: Energy, Mines and Resources Canada Mineral Bulletin MR 212, 46 p.

Engineering News Record, 1983, Dessicant cooling arrives: Engineering News Record, v. 210, no. 20, p. 18.

Ferrell, J.E., 1985a, Lithium, *in* U.S. Bureau of Mines, Mineral Facts and Problems, 1985 edition: U.S. Bureau of Mines Bulletin 675, p. 461–470.

———1985b, Lithium, *in* U.S. Bureau of Mines Minerals Yearbook 1984, Volume I, Metals and Minerals: Washington, D.C., U.S. Government Printing Office, p. 607–613.

Filho, L.C.D., 1985, Litio, *in* Departamento Nacional da Produção Mineral, Sumário Mineral 1985: Brasília, Ministério das Minas e Energia, p. 64–65.

Foote Mineral Company, 1987, Form 10–K—Annual report pursuant to section 13 or 15(d) of the Securities and Exchange Commission, for the fiscal year ended Dec. 31, 1986: Exton, Penn., Commission File No. 1–4064, 57 p.

Hatcher, M.I., and Elliott, A.V., 1986, Greenbushes—A new world source of lithium: Industrial Minerals, 7th Industrial Minerals International Congress, Monte Carlo, v. 1, p. 217–232.

Horton, J.W., Jr., 1981, Shear zone between the inner Piedmont and Kings Mountain belts in the Carolinas: Geology, v. 9, no. 1, p. 28–33.

Hutchison, R.W., and Claus, R.J., 1956, Pegmatite deposits, Alto Ligonha, Portuguese East Africa: Economic Geology, v. 51, no. 8, p. 757–780.

Industrial Minerals, 1987, Lithium—No shortage in supply: Industrial Minerals, no. 237, p. 22–39.

Kesler, T.L., 1960, Lithium raw materials, *in* Gillson, J.L., editor in-chief, Industrial minerals and rocks (nonmetallics other than fuels), 3d ed.: New York, The American Institute of Mining, Metallurgical, and Petroleum Engineers, Seeley W. Mudd series, p. 521–531.

Lasmanis, R., 1978, Lithium resources in the Yellowknife area, Northwest Territories, Canada, *in* Penner, S.S., ed., Lithium—Needs and resources, proceedings of a symposium: Energy, v. 3, no. 3, p. 399–407.

Longe, R.V., and others, 1978, Computer-based files on mineral deposits—Guidelines and recommended standards for data content [prepared by the Mineral Deposits Working Committee, National Advisary Committee on Research in the Geological Sciences]: Canada Geological Survey Paper 78–26, 72 p.

Lopes Nuñes, J.E., 1973, Contribution à l'étude minéralogique et géochimique des pegmatites du Mozambique: Sciences de la Terre, Mèmoire no. 26, 261 p.

Mulligan, Robert, 1965, Geology of Canadian lithium deposits: Geological Survey of Canada, Economic Geology Report, no. 21, 131 p.

———1969, Metallogeny of the region adjacent to the northern part of the Cassiar batholith, Yukon Territory and British Columbia (Parts of 104 O, P, and 105 B): Geological Survey of Canada Paper 68–70, 13 p.

Norton, J.J., 1973, Lithium, cesium, and rubidium—The rare alkali metals, *in* Brobst, D.A., and Pratt, W.P., eds., United States Mineral Resources: U.S. Geological Survey Professional Paper 820, p. 365–378.

Ober, J.A., 1988, Lithium, *in* U.S. Bureau of Mines Minerals Yearbook 1986, Volume I, Metals and Minerals: Washington, D.C., U.S. Government Printing Office, p. 619–625.

Roering, C., and Gevers, T.W., 1964, Lithium and beryllium-bearing pegmatites in the Karibib district, South West Africa [Namibia], *in* Haughton, S.H., ed., The geology of some ore deposits in southern Africa, v. 2: Geological Society of South Africa, p. 463–495.

Rossovskii, L.N., Chmyrev, V.M., Yeremenko, G.K., and others, 1976, Geologiya i usloviya formirovaniya spodumenovykh mestorozhdeniy Gindukusha (Afghanistan) [Geology and conditions of formation of spodumene deposits in Hindu Kush, Afghanistan]: Geologiya Rudnykh Mestorozhdeniy (Akademiya Nauk SSSR), v. 43, no. 6, p. 19–33.

Rykken, L.E., 1976, Lithium production from Searles Valley, *in* Vine, J.D., ed., Lithium resources and requirements by the year 2000: U.S. Geological Survey Professional Paper 1005, p. 33–34.

Sanders, T.H., Jr., 1980, Al-Li-X alloys—An overview, *in* Proceedings of the First International Aluminum-Lithium Conference: The Metallurgical Society of the American Institute of Mining, Metallurgical, and Petroleum Engineers, p. 62–67.

Schanz, J.J., 1980, The United Nations' endeavor to standardize mineral resource classification: Natural Resources Forum, v. 4., no. 3, p. 307–313.

Schutte, I.C., 1972, The main pegmatites of the area between Steinkopf, Vioolsdrif and Goodhouse, Namaqualand: Geological Survey of South Africa Memoir 60, 15 p.

Searles, J.P., 1987, Lithium, *in* U.S. Bureau of Mines Minerals Yearbook 1985, Volume I, Metals and Minerals: Washington, D.C., U.S. Government Printing Office, p. 607–613.

Singh, Satyendra, and Muskerjee, N.K., 1985, Some observations on the mineralized pegmatites of the Govindpal-Tongpal region, District Bastar, M.P., *in* Proceedings of Indian Geological Congress, IVth session, Bhattacharya, A.K., ed., *in the collection* Current trends in geology, v. 7–8: New Delhi, Today and Tomorrow's Printers and Publishers, p. 277–289.

Stoertz, G.E., and Ericksen, G.E., 1974, Geology of salars in northern Chile: U.S. Geological Survey Professional Paper 811, 65 p.

Traoré, H., and Méloux, J., 1978, Plan mineral de la République du Mali: Bamako, République la Géologie et des Mines, 649 p.

United Nations Economic and Social Council, 1979, The international classification of mineral resources—Report of the Group of Experts on Definitions and Terminology for Mineral Resources: United Nations document E/C.7/104, 28 p. including annexes.

Varlamoff, N., 1968, Die Beryll-und Lithiumpegmatite Rwandas, des Kongo und Madagaskars [Beryllium and lithium pegmatites of Rwanda, the Congo, and Madagascar]: Zeitschrift für Erzbergbau und Metallhuttenwesen, v. 21, no. 6, p. 261–269.

Weast, R.C., ed., 1987, CRC handbook of chemistry and physics: Boca Raton, Florida, CRC Press, Inc., 2416 p.

World Bank, 1986, World development report 1986: New York, Oxford University Press, 256 p.

ADDITIONAL REFERENCES ON LITHIUM RESOURCES

Bauer, R.J., 1978, Lithium and Lithium-Verbindungen, *in* Ullmann's Encyklopaedie der technischen Chemie: Weinheim, New York, Verlag Chemie, v. 16, p. 261–277.

Lithium Corporation of America, 1985, Lithium: Gastonia, North Carolina, Lithium Corporation of America, 18 p.

Penner, S.S., ed., 1978, Lithium—Needs and resources, proceedings of a symposium held in Corning, New York: New York, Pergamon Press, 418 p.

Roskill Information Services, 1975, The economics of lithium: London, Roskill Information Services, 138 p.

Vine, J.D., 1976, Lithium resources and requirements by the year 2000: U.S. Geological Survey Professional Paper 1005, 162 p.

INTERNATIONAL STRATEGIC MINERALS INVENTORY

PARTICIPATING AGENCIES

Australia
Bureau of Mineral Resources,
Geology and Geophysics

Canada
Energy, Mines and Resources Canada
Mineral Policy Sector
Geological Survey of Canada

Federal Republic of Germany
Bundesanstalt für Geowissenschaften
und Rohstoffe

South Africa
Minerals Bureau
Geological Survey

United Kingdom
British Geological Survey

United States
Bureau of Mines
Geological Survey

SUMMARY REPORTS

This circular is one of several reports on selected mineral commodities to be published in the U.S. Geological Survey 930 series. The circulars published to date are listed below; year of publication is shown in parentheses. Copies are available free on application to The Books and Open-File Reports Section, U.S. Geological Survey, Federal Center, Box 25425, Denver, CO 80225–0046 U.S.A.

930–A. Manganese (1984)
930–B. Chromium (1984)
930–C. Phosphate (1984)
930–D. Nickel (1985)
930–E. Platinum-Group Metals (1986)
930–F. Cobalt (1987)
930–G. Titanium (1988)
930–H. Graphite (1988)
930–I. Lithium (1990)

Requests for copies of International Strategic Minerals Inventory summary reports and for further information may also be addressed to:

Ian R. McLeod
Chief Commodity Geologist
Minerals Resource Assessment Branch
Bureau of Mineral Resources
P.O. Box 378
Canberra City, A.C.T. 2601
AUSTRALIA

A. Ignatow
Director, Rare and Minor Metals Division
Mineral Policy Sector
Energy, Mines & Resources Canada
460 O'Connor Street–Room 630
Ottawa, Ontario, K1A 0E4
CANADA

Distribution Branch
Bundesanstalt für Geowissenschaften
und Rohstoffe
Postfach 51 01 53
D–3000 Hannover 51
FEDERAL REPUBLIC OF GERMANY

Chief Director, Minerals Bureau
Private Bag X4
Braamfontein 2017
REPUBLIC OF SOUTH AFRICA

Richard N. Crockett
Head, Mineral Intelligence Programme
British Geological Survey
Keyworth
Nottingham NG12 5GG
UNITED KINGDOM

Anstett and others—INTERNATIONAL STRATEGIC MINERALS REPORT—LITHIUM—U.S. Geological Survey Circular 930–I