RC. 930–H

U.S. GEOLOGICAL SURVEY CIRCULAR 930–H

International Strategic Minerals Inventory Summary Report—Natural Graphite

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

Major geologic age units

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

International Strategic Minerals Inventory Summary Report—Natural Graphite

By Ulrich H. Krauss, Helmut W. Schmidt,
Harold A. Taylor, Jr., *and* David M. Sutphin

U.S. GEOLOGICAL SURVEY CIRCULAR 930-H

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

1988

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

Library of Congress Cataloging in Publication Data

Natural graphite.

(U.S. Geological Survey circular ; 930–H)
"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."
Bibliography: p.
Supt. of Docs. no.: I 19.4/2:930–H
1. Graphite. I. Krauss, Ulrich H. II. Series:
U.S. Geological Survey circular; 930–H.
TN845.N34 1989 553.8′6 88–600318

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

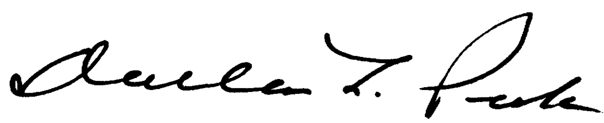
FOREWORD

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 graphite, one of the mineral commodities selected for the inventory.

The report was prepared by Ulrich H. Krauss and Helmut W. Schmidt of the Federal Institute for Geosciences and Natural Resources (BGR) of the Federal Republic of Germany, Harold A. Taylor, Jr., of the U.S. Bureau of Mines, and David M. Sutphin of the U.S. Geological Survey (USGS). It was edited by Richard N. Crockett of the British Geological Survey (BGS).

Graphite inventory information was compiled by Ulrich H. Krauss (chief compiler), Manfried Krusona, and Henning G. Saam (BGR); Y. J. Lepinis and Michel Prud'homme of the Canadian Department of Energy, Mines and Resources (EMR), Mineral Policy Sector (MPS); Roy R. Towner, Australian Bureau of Mineral Resources (BMR); Ian Goldberg, South African Department of Mineral and Energy Affairs (MEA), Minerals Bureau; Erik C. I. Hammerbeck, MEA, Geological Survey; and James A. Calkins, USGS.

Additional contributions to the report were made by Lee C. Ranford, BMR; Richard N. Crockett, BGS; Antony B. T. Werner and Jan Zwartendyk, EMR, MPS; and James A. Calkins and John H. DeYoung, Jr., USGS.



Director

CONTENTS

ILLUSTRATIONS

TABLES

INTERNATIONAL STRATEGIC MINERALS INVENTORY SUMMARY REPORT

NATURAL GRAPHITE

By **Ulrich H. Krauss,[1] Helmut W. Schmidt,[1] Harold A. Taylor, Jr.,[2]** *and* **David M. Sutphin[3]**

ABSTRACT

Natural graphite is a crystalline mineral of pure carbon which normally occurs in the form of platelet-shaped crystals. It has important properties, such as chemical inertness, low thermal expansion, and lubricity, that make it almost irreplaceable for certain uses such as refractories and steelmaking. Graphite ore types are crystalline (flake and lump) or "amorphous" (cryptocrystalline). Refractory applications use the largest total amount of natural graphite, while the most important use of crystalline graphite is in crucibles for handling molten metals.

All graphite deposits being mined today are found in the following metamorphic environments: (1) contact metamorphosed coal generally is a source of amorphous graphite; (2) disseminated crystalline flake graphite comes from syngenetic metasediments; and (3) crystalline lump graphite is found in epigenetic veins in high-grade metamorphic regions. Graphite may also occur as a trace mineral in ultrabasic rocks and pegmatites, but these are economically insignificant.

The world's identified economically exploitable resources of crystalline graphite in major deposits are estimated to be about 9.7 million metric tons of concentrate. In-place resources of amorphous graphite are about 11.5 million metric tons. Of these, less than 2 percent of the crystalline ore and less than 1 percent of the amorphous ore are in western industrial countries. World mining production of natural graphite rose from 347,000 metric tons in 1973 to 659,000 metric tons in 1986, while the proportion produced by central economy countries increased from about 50 percent for the period from 1973 to 1978 to more than 64 percent in 1979 to 1986. It is estimated that crystalline flake graphite accounts for at least 180,000 metric tons of total annual world mining production of natural graphite, and amorphous graphite makes up the rest.

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 short-term, medium-term, and long-term world supply. This report provides a summary statement of the data compiled and an overview of the supply aspects of

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

[2]U.S. Bureau of Mines.

[3]U.S. Geological Survey.

natural graphite 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 infrastructure 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 natural graphite and includes only peripheral considerations of natural graphite 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 a nation's economy, in particular to its defense industry. 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 studies of platinum-group metals, cobalt, and titanium have now been published. Additional studies on graphite (this report), vanadium, tin, tungsten, lithium, and zirconium have been subsequently undertaken.

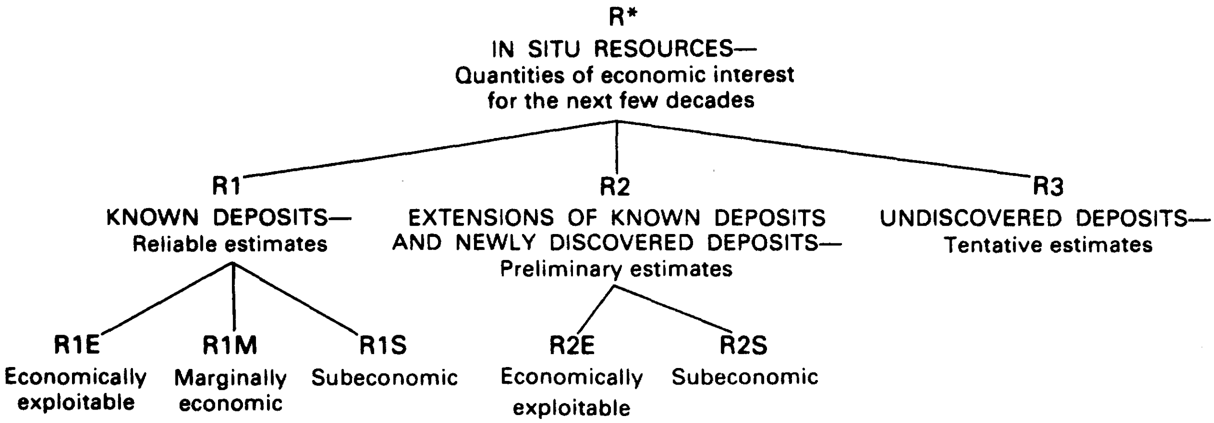
The data in the ISMI natural graphite inventory were collected from April 1984 to August 1985. The report was submitted for review in November 1987. The information used was the best available in various agencies of the countries that contributed to the preparation of this report. Those agencies were the Bureau of Mines and the Geological Survey of the U.S. Department of the Interior; the Geological Survey of Canada 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.

Deposits (or districts) are selected for the inventory on the basis of their present or expected future contribution to world supply. Records for all deposits compiled by ISMI participants meet this general "major deposit" criterion and are included in the inventory.[4]

The ISMI record collection and this report on natural graphite 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 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, deposit size will prove to be significantly larger, sometimes even several times larger, than was established 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

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



*The capital "R" denotes resources *in situ*; a lower case "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).

metal mining; that is, 10 to 25 percent of the in-place resources cannot be extracted.

USES AND SUPPLY ASPECTS

Graphite is one of two naturally occurring crystalline forms of carbon; the other is diamond. Graphite occurs as a mineral (natural graphite), but it can also be produced synthetically (as synthetic graphite, electrographite, or manufactured graphite). Sometimes, for example in melting of iron ore or ferroalloys, it is a byproduct. In accordance with the goal of the International Strategic Minerals Inventory, this report deals only with natural graphite.

THE MINERAL GRAPHITE

Graphite usually occurs in the form of platelet-shaped crystals, although needle forms have been observed in deposits such as those in Sri Lanka. The crystal lattice of graphite consists of layers of hexagonally arranged carbon atoms. The two structural varieties of graphite, 2H and 3R, result from the manner in which these layers are stacked (fig. 2). Variety 3R is rarer than 2H, but the two often occur together. Graphite variety 3R, which makes up as much as 30 percent of some occurrences, is important in some applications. The platelet form and excellent basal cleavage of most graphite is due to its structure of layers of continuous networks of planar hexagonal rings. The physical properties of graphite are listed in table 1.

Only a very small proportion of the carbon in the Earth's crust is present in elementary form as either graphite or diamond. Most carbon is contained in carbonate rocks, such as limestone, and in organic matter, bituminous rock, and fossil fuels. A schematic diagram of the geochemical cycle of carbon and the processes that can lead to the formation of graphite is shown in figure 3.

Nearly all nonelementary carbon in the Earth's crust and probably most graphite is biogenic in origin. Nonbiogenic carbon, of juvenile origin, can be identified in a few cases: examples of such carbon are diamond; graphite in basic and ultrabasic rocks, in meteorites, and in some pegmatites; some carbon dioxide present in volcanic gases; and carbon in certain carbonates found in hydrothermal veins and in carbonatites.

TABLE 1.—*Physical properties of graphite*

Color: Dark steel gray to iron black; metallic luster
Streak: Gray to black
Hardness (Mohs's scale): ½ to 1
Density (g/cm^3): 2.09 to 2.26
Melting point: about 3,550 °C
Lubricity (ratio of force required to induce gliding and compression force perpendicular to gliding plane): 0.15.
Thermal conductivity at room temperature (watt/cm °C):
a axis: 4.0
c axis: 0.8
Thermal expansion coefficient (temperature range 0 to 800 °C):
a axis: -1×10^{-7}/°C
c axis: 140×10^{-7}/°C
Electrical resistivity at room temperature (ohm cm$\times10^{4}$):
a axis: 1 to 100
c axis: 10,000

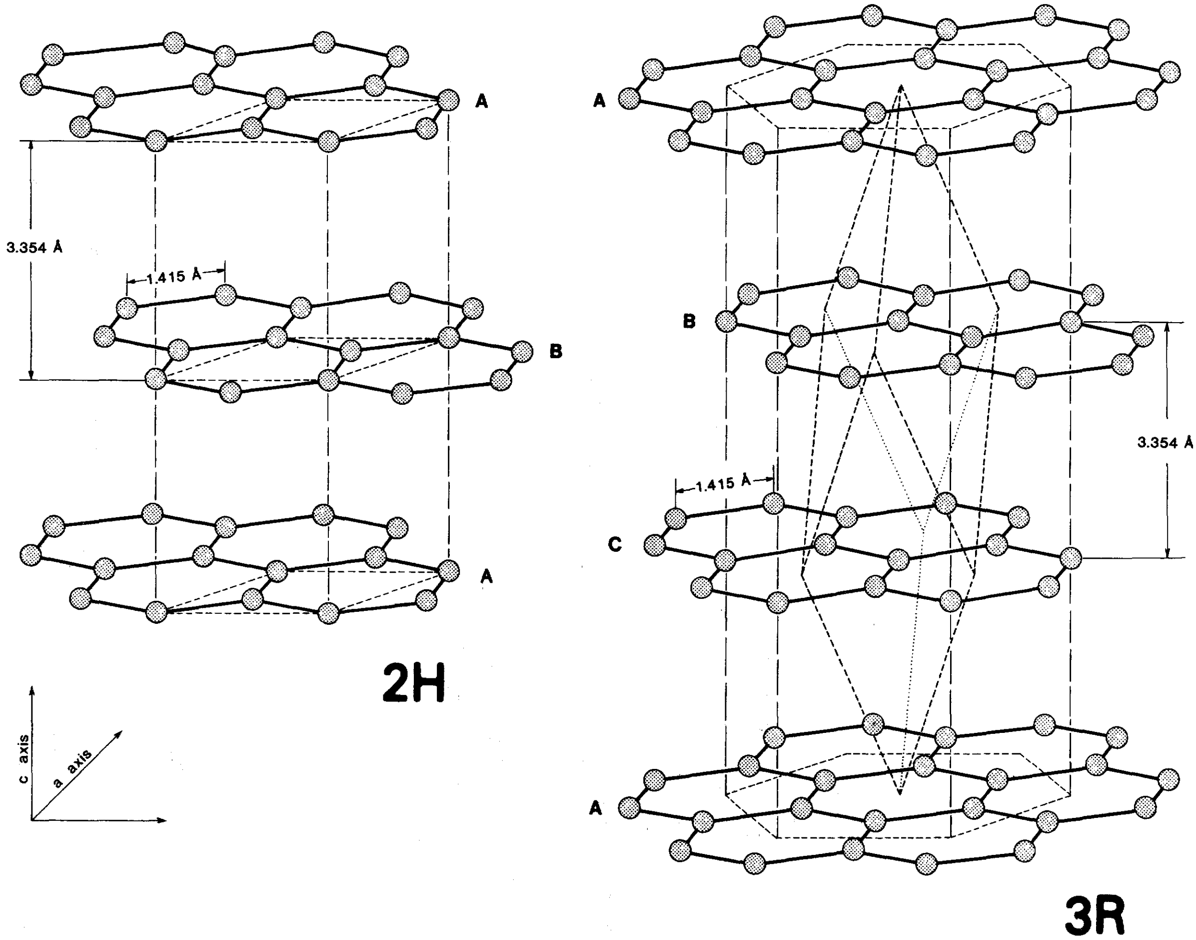


FIGURE 2.—Arrangement of carbon atoms in the hexagonal (2H) and rhombohedral (3R) unit cells.

NOMENCLATURE, COMMODITY SUBTYPES, AND QUALITY CRITERIA

Terms used in industry for the ores and concentrates from different types of graphite deposits as well as the main processing methods are compiled in table 2. Unfortunately, some expressions are used in more than one sense. The term "amorphous" graphite is a misnomer commonly used in industry for "cryptocrystalline" or "microcrystalline" graphite that can only be distinguished with the aid of a microscope. Misunderstanding may further result because the terms "crystalline" and "amorphous" are used ambiguously. For example, fine-grained graphite concentrates ("dust" or "flying dust" with a crystal size of >200 mesh) are defined as "amorphous graphite" in some trade statistics. A useful boundary between crystalline and amorphous graphite is the resolution capability of the unaided human eye: 0.04–0.07 mm, or 400 to 200 mesh. The crystal size of amorphous graphite (0.0001–0.01 mm) is normally well below this limit. Therefore, in

TABLE 2.—*Varieties of graphite and main processing methods*

Ore type (other terms sometimes used)	Processing beneficiation	Finished products	
		Percent fixed carbon	Form
Disseminated flake (crystalline graphite).	Crushing, screening, wet grinding, flotation, chemical purification.	75-90	Flake concentrates (>8 to >200 Tyler mesh).
Lump (vein graphite, massive ores, plumbago).	Hand sorting, washing screening, winnowing.		Concentrates:
		90-98	Lump
		85-90	Chip
		55-85	Dust
		50-90	Flying dust.
Amorphous (black lead).	Handpicking, crushing, screening, air classification.	45-90 (avg 80)	Amorphous graphite.

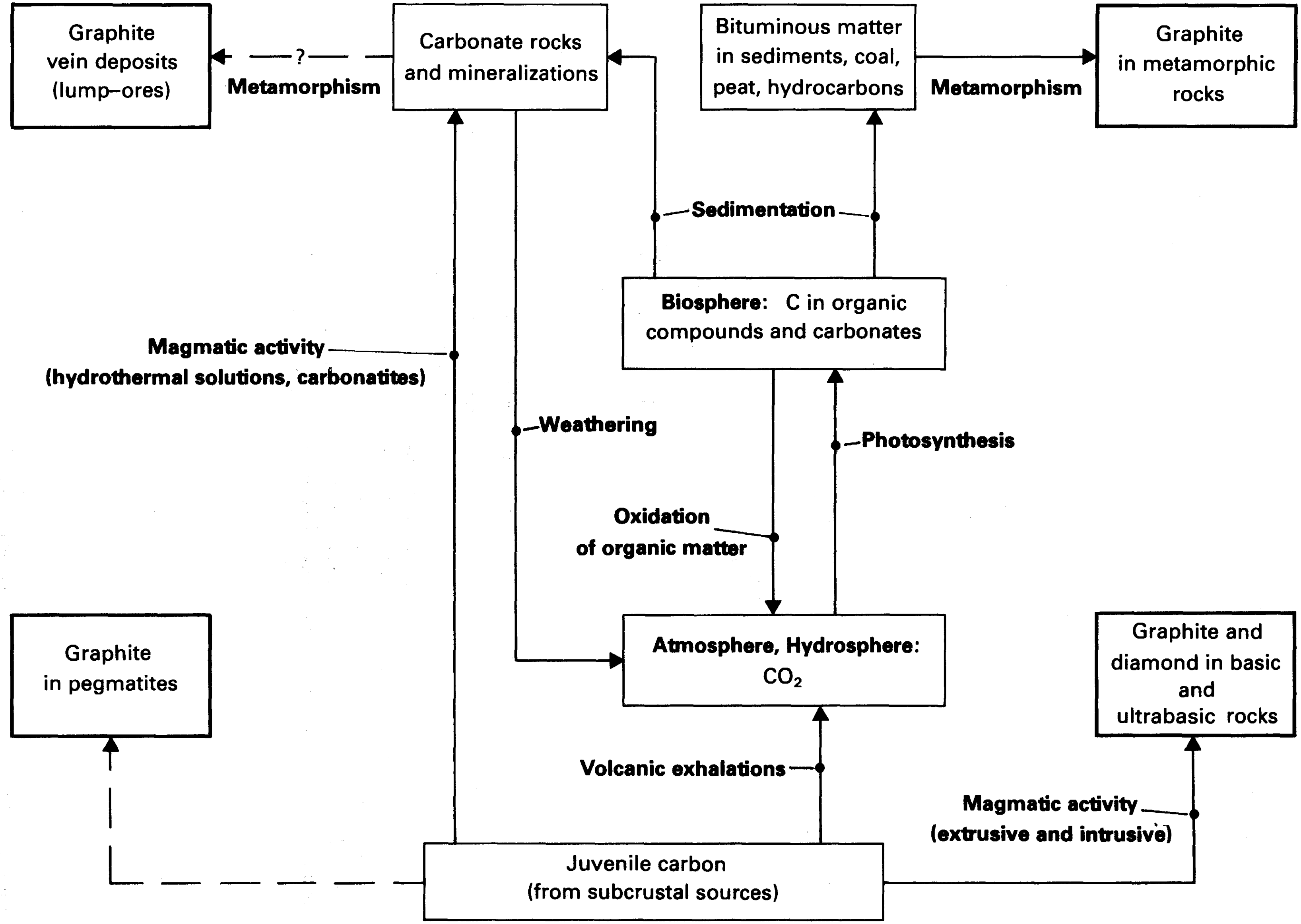


FIGURE 3.—The geochemistry of carbon.

TABLE 3.—*Major chemical, physical, and mineralogical properties that affect the suitability of graphite to industrial applications*

Chemical	Physical	Mineralogical
Chemical analysis of ore or concentrate	Bulk density of concentrates	Grain size.
• Content of graphitic carbon (fixed carbon, percent FC).	Flakiness	Crystal size.
• Ash content	Toughness, tenacity	Crystal form, boundaries.
• Type and amount of volatile matter.		
• Content of sulphur and phosphorus.	Gliding properties, lubricity	Presence of gangue minerals (especially sulfides and abrasive silicates).
Chemistry of the ash		Mineral composition of the ash.

such amorphous graphite, individual crystals cannot be distinguished, and the metallic luster typical of crystalline graphite is not present.

The major physical, chemical, and mineralogical properties given in table 3 provide important criteria for the suitability of a graphite or graphite ore for industrial applications. Detailed descriptions of the properties and the methods of determining them are given in special monographs, such as Mantell (1968) or Reynolds (1968). The applicability of a particular graphite product for a specific use is normally investigated in semi-industrial pilot tests.

USES OF NATURAL GRAPHITE

Although there are materials that may be able to compete with graphite in a few applications, the unique combination of physical and chemical properties (table 4) which qualify graph-

TABLE 4.—*Properties qualifying natural graphite for industrial applications and possibilities for substitution*

Use	Refractories	Low thermal expansion	Heat conductivity	Electrical conductivity	Chemical inertness	Surface properties, lubricity	Color	Carbon content	Substitution	Competitive materials	Remarks
Batteries				+	+				Possible	Manufactured graphite	—
Brake linings		+	+			+			—	—	—
Carbon products (such as electrical brushes)				+		+		+	Possible	Manufactured graphite	—
Crucibles, retorts, stoppers, sleeves, and nozzles	+	+	+		+	+			—	—	Quantity of suitable graphite is decreasing.
Foundries	+				+	+			Possible	Scrap of manufactured graphite, calcined coke, olivine, zircon.	—
Lubricants	+	+	+		+	+			Sometimes possible	Greases, molybdenite	Major uses in applications where greases or molybdenite would not withstand thermal and chemical conditions.
Pencils						+	+		—	Manufactured graphite	—
Refractories	+	+	+		+	+			—	—	Quantity of suitable graphite is decreasing.
Rubber						+			Possible	Talc	—
Steelmaking								+	Possible	Coal, scrap of manufactured graphite.	—

ite (especially crystalline flake) for industrial applications generally excludes the possibility of substitution by other materials.

Demand for natural graphite in the United States according to type (crystalline or amorphous) and use in selected years from 1960 to 1986 is given in table 5. Corresponding figures are not available for other countries. It may be assumed, however, that aside from steel production, a similar structure exists in the other western industrial countries. Graphite consumption appears to be a function of level of industrial development within individual countries. High-grade graphite is in demand for specialized applications, but specifications are less critical for most heavy industrial purposes.

As seen in table 5, the following structure is probable for graphite demand in industrial countries for 1986: more amorphous graphite is used than crystalline graphite, and the heaviest demand for graphite occurs in refractories (31 percent), followed by foundries, brake linings, and lubricants (each with about 11 percent), and steelmaking crucibles, batteries, and pencils (with about 6 percent each). Other uses, including carbon products, powdered metals, and rubber, account for the remainder.

Crucibles, retorts, stoppers, sleeves, and nozzles.—In the United States (table 5), the most important application for crystalline flake graphite was for crucibles and related products such as retorts, stoppers, sleeves, and nozzles; recently, however, refractory applications have taken precedence. Use of crucibles has been dropping as metal production has declined, as larger crucibles have replaced smaller crucibles, and as bulk melting has removed the need for a crucible. Also, the amount of graphite used in crucibles has been reduced with the partial shift from the traditional clay-graphite crucible to the silicon carbide-graphite crucible that uses less graphite. Growth in production of steel-related continuous-casting ware, such as alumina/graphite shrouds, has partly offset lack of demand for graphite for crucibles and will probably lead to the crucibles and related products regaining some of their market share. Western industrial countries are following these U.S. trends. However, if crucible-using metal production increases, use of graphite in crucibles could also rise. In other countries, use in crucibles remains the major application, or one of two major applications, for crystalline flake graphite.

Foundry applications.—Graphite's use as a facing is by far its most important application in the foundry. In this application, graphite and a small amount of clay, which serves as a suspension agent, are mixed in a carrier, such as water, alcohol, or a chlorinated hydrocarbon, to produce a paintlike foundry facing. This facing is applied as a thin coating to mold surfaces thus providing a clean and easy mold release of the metal casting. Both amorphous graphite and low-quality crystalline flake graphite can be used; however, synthetic graphite powder, coke, talc, mica, or zircon may be substituted.

Refractories.—In the United States (table 5), the major application for amorphous and crystalline flake graphite is now in refractories where it increases durability, erosion resistance, thermal-shock resistance, and thermal conductivity. The growth in refractory-related use of amorphous graphite occurred earlier, while the growth in this use of crystalline flake graphite was mostly after 1980. While sizable amounts of amorphous graphite are used in shaped refractories such as bricks,

TABLE 5.—*Demand for natural graphite in the United States by type and use; selected years 1960-86*

[Source: U.S. Bureau of Mines, unpublished data. Figures are in thousand metric tons and may not add to totals due to rounding. *=less than 500 metric tons. N.r.=None reported]

Use	1960			1970			1980			1986		
	Crystalline	Amorphous	Total	Crystalline	Amorphous	Total	Crystalline	Amorphous	Total	Crystalline	Amorphous	Total
Batteries	N.r.	1	1	1	*	1	2	*	2	2	*	2
Brake linings	1	*	1	*	1	1	1	2	3	1	3	4
Crucibles, retorts, stoppers, sleeves, and nozzles	3	N.r.	3	5	N.r.	5	5	N.r.	5	2	N.r.	2
Foundries	2	21	23	3	13	15	1	6	7	1	3	4
Lubricants	4	2	5	*	5	5	1	2	3	1	3	4
Pencils	1	1	2	1	1	2	2	*	2	2	*	2
Refractories	N.r.	4	4	*	6	6	5	9	14	6	5	11
Steelmaking	N.r.	5	5	1	4	5	*	7	7	*	2	2
Other	1	N.r.	1	3	5	7	2	4	6	2	2	4
Total	11	34	45	13	34	46	18	30	48	17	18	35

much more is used in plastic and castable (unshaped) refractories, principally gunning and ramming mixes. Almost all the crystalline flake graphite for refractory applications goes into carbon-magnesite brick. This trend results from the development of new techniques and processes in iron and steel production, beginning with the commercial appearance of gunning and slinging several decades ago and then development of carbon-magnesite brick almost a decade ago. Since newer plants operate at higher temperatures and under more extreme conditions, refractories had to be upgraded. Changes will continue, as shown by the recent appearance of new alumina/graphite refractories and flame gunning and flame spraying. New applications are expected to lead to an overall increase in graphite consumption.

Other advanced industrialized countries are believed to have a similar use pattern, although western Europe appears to consume a higher proportion of crystalline flake graphite than the United States.

Steel production.—Graphite has several uses in steel production. In the United States, these applications include recarburizing (increasing the carbon content of steel), use as a material around stopper rods or around nozzles when hot metal is poured into an ingot mold, and even use in the mix for making steel parts by powdered metallurgy. Recarburizing can be accomplished by using petroleum coke, synthetic graphite powder or scrap, and anthracite, in addition to natural graphite. The lowest priced form of pure carbon is usually the one used. Thus, usage can shift from natural to synthetic graphite or petroleum coke and back. In the United States, natural graphite presently has only a minor part of the recarburizing market. More than 10 times as much synthetic graphite is used for recarburizing, and very large amounts of petroleum coke are also used. Practice varies from country to country; Japan is said to use large amounts of amorphous graphite in recarburizing. A few countries, such as Austria and North Korea, use low-grade graphite instead of coke in blast furnaces.

Lubricants.—Graphite's properties allow it to be used as an excellent lubricant, either as a dry powder or mixed with oil or water. Owing to the unique combination of this lubricating effect with other physical and chemical properties that persist even at high temperatures (for example, low chemical reactivity, low coefficient of thermal expansion, high thermal conductivity, and low friction coefficient), natural graphite is irreplaceable for applications in which other lubricants such as molybdenum disulfide would degrade. Graphite used as a lubricant should be of high purity (>97 percent carbon) and free from abrasive components. Mostly synthetic and natural crystalline flake graphite and some Sri Lankan lump graphite are used for this purpose.

DISTRIBUTION OF GRAPHITE DEPOSITS AND DISTRICTS

The world map in figure 4 shows the location of 90 major natural graphite deposits and districts in the ISMI graphite inventory. Names and numbers of the individual deposits are listed in table 12 of Part II.

Graphite occurs in two distinctly different geologic environments: (1) as a result of metamorphism and (2) in basic or ultrabasic rocks as phenocrysts (flakes). All flake, lump and chip, and amorphous graphite deposits being mined today are the products of metamorphism. Minable occurrences of graphite in basic or ultrabasic rocks are unknown.

Metamorphic environments may produce either syngenetic or epigenetic graphite deposits. Characteristics of graphite from metamorphic rocks are listed in table 6. Syngenetic graphite mineralization is known in practically all metasedimentary sequences associated with both regional and contact metamorphism. The origin of syngenetic graphite has been generally accepted for at least 100 years. Syngenetic deposits are composed of graphitized coal beds or other highly carbonaceous sedimentary rocks or graphite in other metasediments such as schists, gneisses, and marbles.

Graphitized coals form when coal is converted to fine-grained (amorphous) graphite by contact metamorphism from the emplacement of igneous rocks in close proximity to coal-bearing rocks (Weis and others, 1981). Such graphite, which sometimes shows a gradation from coal to graphite along strike and often contains relict anthracite, may be composed of 45 percent to over 90 percent fixed carbon. Examples of graphitized coal deposits include deposits of amorphous graphite such as those in Sonora, Mexico; Kureika, Siberia; Kaiserberg, Steinmark, Austria; Pinerolo, Italy; most of the occurrences in Korea; and the

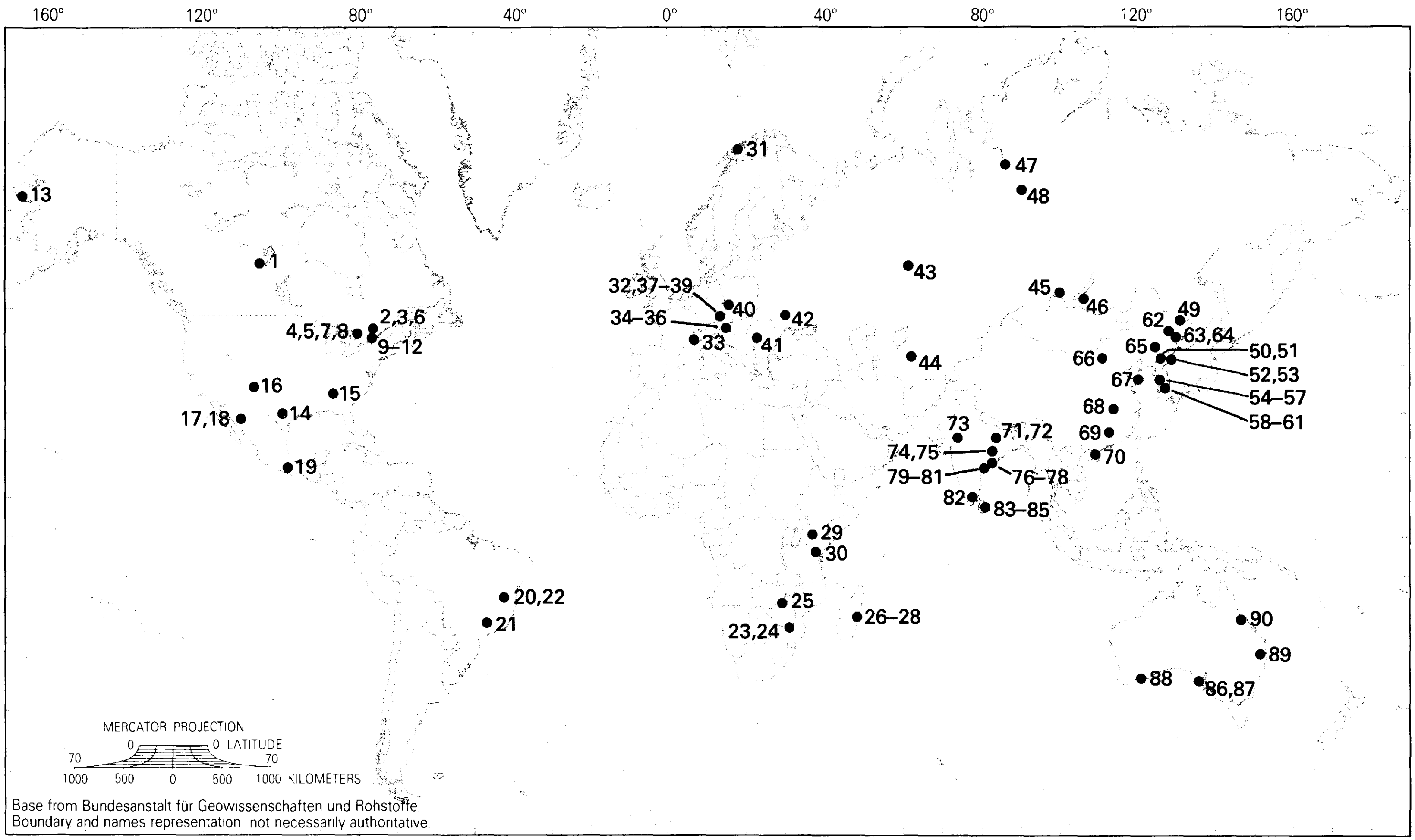


Figure 4.—Location of major graphite deposits and districts in the world. Numbers refer to site numbers in table 12 of Part II.

TABLE 6.—*Characteristics of types of graphite ore from metamorphic environments*

Characteristic	Ore type: Crystalline graphite — Disseminated flake	Ore type: Crystalline graphite — Lump ore	Ore type: "Amorphous" graphite
Description of ores (crystallinity, crystal size).	Well-developed crystal platelets (grain size greater than 0.04 mm disseminated or segregated) displaying metallic luster disseminated in metamorphic rocks (gneisses, quartzites, marbles).	Interlocking aggregrates of coarse graphite crystals.	Microcrystalline (grain size less than 0.004 mm, 400 mesh) aggregates, earthy black, rarely displaying submetallic or metallic luster of graphite. Aggregates may contain nongraphitized carbonaceous material (such as anthracite).
Grade (percent carbon).	5 to 30 percent fixed carbon	Up to over 98 percent fixed carbon.	40 to 85 percent fixed carbon; dependent on carbon content of parent coal.
Ore body	Tabular, rarely lenticular; locally as irregular bodies in hinge zones of folds.	Veins (comb structure at margins) generally crosscutting structures related to metamorphism; stockworks, vugs, and nests.	Seams, often folded and faulted.
Geologic environment and setting.	Syngenetic graphite deposits; regionally metamorphosed metasediment sequences and migmatitic terranes.	Epigenetic deposits; regionally metamorphosed (granulitic, charnockitic) rocks. Contact metasomatic origin has been proposed for some deposits (such as Botogol'sk).	Syngenetic deposits of metamorphosed coal seams near younger igneous rocks (contact metamorphism) or in regional metamorphic terranes.
Examples			
	Madagascar deposits, Skaland (Norway), Kropfmüehl (Germany), and Reindeer Lake (Canada).	Sri Lanka deposits, Botogol'sk (Soviet Union), and Dillon (Montana, United States).	Sonora deposits (Mexico), Kureika (Soviet Union), Pinerolo (Italy), Kaiserberg-Trieben (Austria), Malonga-Mutale and Mtubatuba (South Africa), and deposits in North Korea.

occurrences of the metamorphosed Ecca coal in South Africa.

Syngenetic graphite deposits in siliceous metasediments and, to a lesser extent marbles, are the major commercial sources of crystalline flake graphite; these deposits may also contain amorphous graphite. They form when original detrital organic material is graphitized during regional metamorphism of the host shales, sandstones, and limestones (Weis and others, 1981). Syngenetic graphite is an accessory or trace mineral in practically all metasedimentary sequences associated with both regional and contact metamorphism. Examples of syngenetic graphite deposits in siliceous metasediments and marbles are Reindeer Lake, Saskatchewan; Burnett, Texas; Ashland, Alabama; Kigluiak Range, Alaska; deposits in Madagascar; deposits in Kenya; Kropfmühl, Bavaria; and Czeskey Krumlov, Czechoslovakia.

Epigenetic deposits are rare and are of three types: fracture-filling veins, replacements, and metamorphic segregations (Weis and others, 1981). Of these, the vein deposits of Sri Lanka are the most important economically. The United States has graphite vein deposits of scientific interest at Dillon, Montana; Ticonderoga, New York; and in New Hampshire. The exhausted Borrowdale deposit in Cumberland, United Kingdom, is thought to have been a replacement deposit (Strens, 1965).

In Sri Lanka, the deposits are in high-grade metamorphic rocks of Archean age (greater than 2,500 m.y. old). The graphite commonly occurs as fracture fillings, especially in openings related to structural disturbances that postdate the high-grade metamorphism. Some of this graphite is extremely high grade, having over 99 percent fixed carbon. Graphite from these deposits is marketed as "lump graphite" (chips, dust, and flying dust).

The origin of vein graphite deposits has long been questioned (Winchell, 1911; and Bastin, 1910, 1912) and is chronicled briefly by Silva (1987). There is no doubt that the carbon in graphite veins has been transported.

Explanations offered for the origin of vein graphite include migration in the solid state into rock openings (Erdosh, 1970), formation from the release of carbon from the chemical breakdown of carbonate rocks during metamorphism (Salotti and others, 1971), or mobilization in the semifluid state aided by magmatic fluids (Dissanayake, 1981). The debate about the origin of vein graphite continues. Recently, Rumble and Hoering (1986), Katz (1987), and Silva (1987) have suggested that these deposits formed from hydrothermal fluids, as do veins in metallic mineral deposits, but they disagree on the source of the carbon. Rumble and Hoering propose that metamorphism of biogenic material in common sediments produced aqueous fluids that transported carbon, in the form of methane and carbon dioxide, into fluid-filled cracks. Graphite precipitated along vein walls when fluids having different ratios of methane and carbon dioxide were mixed.

Katz (1987) and Silva (1987) suggest that Sri Lankan vein graphite formed under high-pressure and high-temperature metamorphic conditions. Katz postulated a deep-seated origin for the carbon with only minor biogenic contributions, while Silva suggested the graphite at Bogala mine originated from a mixing of pegmatitic fluids with those generated during decarbonation of siliceous marbles. Possible problems with these suggestions are (1) it would appear that the reactions suggested by Rumble and Hoering would require movement of methane and carbon dioxide from cooler to hotter environments and (2) the processes proposed by both Katz and Silva appear to require high pressure and temperature environments, but the veins are post-high-grade deformation and metamorphism.

Graphite is not susceptible to weathering. As a consequence, the weathering of graphite-bearing metamorphic rocks may lead to secondary enrichment because of the gradual separation of the graphite from silicate gangue material and any sulfides present. Such zones of alteration above primary graphite occurrences are especially good for mining the crystalline flake variety. As a result of weathering, the zones can usually be mined in open pits and the ore processed to high-grade graphite concentrate at low cost.

Apart from the deposits shown in figure 4 and listed in table 12 of Part II, minor deposits and occurrences are known in Argentina, Burma, Mongolia, Mozambique, Pakistan, Spain, the Sudan, Tanzania, Thailand, Turkey, and Uruguay. It proved impossible to collect information in the case of numerous deposits and small mines in certain countries, especially China, India, Mozambique, North and South Korea, and Zambia. It is believed that the deposits included in the inventory represent more than 90 percent of world production and certainly more than 75 percent of known world resources.

NATURAL GRAPHITE RESOURCES

The value of graphite, like most industrial nonmetallic mineral commodities, depends at least as much on accessibility and acquisition, processing and transportation costs, consumer habits, perceptions regarding the applicability of various forms of graphite and graphite substitutes, and current political conditions as it does on such things as physical form, purity, nature of impurities, and the like.

World graphite resource figures by country have not been published, and it is likely that such figures have been calculated for only a few countries. Reliable resource estimates for individual occurrences are available only in exceptional cases, such as for certain Canadian deposits. Often, statements like "the recognized and presumed resources should be sufficient for several decades at the present rate of use," are the most precise estimates found in published sources. Also, recent availability of Soviet and Chinese data is responsible for a portion of apparent changes in graphite resources, production, and consumption over the last several years.

Tables 7 and 8 contain information on in-place and recoverable resources compiled for the ISMI graphite inventory and also include some conservative estimates. As with any commodity, calculation of recoverable product, by applying recovery rates for the appropriate processing technology, gives an insight into the resource and supply situation.

Bearing in mind that the figures for in-place resources are often gross approximations and that sophisticated statistical calculations thus would give only an unjustified appearance of accuracy, the following general points may be made:

- Mining recovery rates are about 90 percent and 65 to 75 percent in open-pit and underground operations, respectively.
- During the beneficiation of amorphous graphite ores, recovery rates often exceed 90 percent.

TABLE 7.—*Resources of crystalline graphite by country, continent, and economic grouping*

[Resource categories (R1E, R1M, and so on) are defined in figure 1. Figures in boldface type represent values for the entire R2 or r2 categories, respectively, without assignment to economic and subeconomic categories. Figures are in thousand metric tons of ore (R) or concentrates (r). *=Western industrial countries; other Western World countries are classified as developing countries. N.r.=Not reported]

	Tonnage of identified resources, in place					Tonnage of recoverable concentrates[1]					
				R2						r2	
Country	R1E	R1M	R1S	E	S	r1E*	Percent of world r1E	r1M	r1S	E	S
Fixed carbon, grade range in percent	4-30	4-20	3-14	3-8, Sometimes up to 25		85-90		85-90	85-90	85-90	85-90
WESTERN WORLD											
North and South America											
*Canada	453	3,800	90	N.r.	2,900	36	0.4	230	5	N.r.	140
*United States	N.r.	700	N.r.	N.r.	23,804	N.r.		21	N.r.	N.r.	528
Mexico	4,400	N.r.	N.r.	13,400	N.r.	106	1.1	N.r.	N.r.	322	
Brazil[2]	6,416	4,500	N.r.	16,000	20,000	500	5.2	500	N.r.	1,000	1,800
Other (Argentina, Uruguay)	N.r.	N.r.	N.r.	N.r.	1,000	N.r.		N.r.	N.r.	(3)	
Total	11,269	9,000	90	77,104		642	6.6	751	5	3,790	
Africa											
Zimbabwe	5,000	N.r.	N.r.	N.r.		600	6.2	N.r.	N.r.	1,200	N.r.
Madagascar	23,000	N.r.	N.r.	2,522,000		980	10.1	N.r.	N.r.	180,000	
Kenya	N.r.	N.r.	N.r.	1,200		N.r.		N.r.	N.r.	95	N.r.
Other (Tanzania)	N.r.	N.r.	N.r.	N.r.		N.r.		N.r.	N.r.	N.r.	
Total	28,000	N.r.	N.r.	2,523,200		1,580	16.3	N.r.	N.r.	181,295	
Europe											
*Norway	720	N.r.	N.r.	150	N.r.	200	2.1	N.r.	N.r.	40	N.r.
*West Germany	650	N.r.	N.r.	1,000	N.r.	130	1.3	90	N.r.	600	
*Austria	1,000	N.r.	N.r.	N.r.		270[4]	2.8	N.r.	N.r.	800	
Total	2,370	N.r.	N.r.	1,150		600	6.2	90	N.r.	1,440	
Asia											
Turkey	180	300	200	N.r.		10	0.1	12	5	N.r.	
India	6,000	N.r.	N.r.	33,000	132,000	736	7.6	N.r.	N.r.	4,400	6,000
Sri Lanka[5]	100	N.r.	N.r.	300		50	0.5	N.r.	N.r.	150	N.r.
South Korea	2,200	800	1,000	11,600		160	1.7	34	20	620	
Other (Burma, Thailand, Pakistan)	N.r.	N.r.	N.r.	1,000	N.r.	N.r.		N.r.	N.r.	(3)	
Total	8,480	1,100	1,200	177,900		956	9.9	46	25	11,170	
Australia											
*Australia	13	N.r.	63	4	45	2	0.0	N.r.	7	3	
WESTERN WORLD TOTAL	50,132	10,100	1,353	2,779,403		3,780	39.0	1,209	37	197,698	
CENTRAL ECONOMY COUNTRIES											
Czechoslovakia	3,900	4,200	4,600	N.r.		900	9.3	840	580	N.r.	
Soviet Union	25,600	28,400	N.r.	26,000		1,800	18.6	2,000	N.r.	5,000	
China	100,000	127,000	(3)	N.r.		2,500	25.8	5,000	N.r.	4,000	
North Korea	6,000	N.r.	(3)	N.r.		700	7.2	300	N.r.	1,000	
Other (Mongolia, Vietnam)	N.r.	N.r.	(3)	N.r.		N.r.		N.r.	N.r.	1,000	
Total	135,500	159,600	4,600	26,000		5,900	61.0	8,140	580	11,000	
WORLD TOTAL	185,632	169,700	5,953	2,805,403		9,680	100.0	9,027	617	208,698	
ECONOMIC GROUPING											
Western industrial countries	2,836	4,500	153	26,704		638	6.6	341	12	2,111	
Developing countries	47,296	5,600	1,200	2,752,699		3,142	32.4	546	25	195,587	
Central economy countries	135,500	159,600	4,600	26,000		5,900	61.0	8,140	580	11,000	

[1] Taking into account both mining losses and benefication losses.

[2] Resources are tentatively classified; for official Brazilian figures see table 12.

[3] Insufficient data to allow estimation.

[4] No concentrate production; ores are used for sinter feed.

[5] High-grade ore, 50-60 percent fixed carbon.

TABLE 8.—*Economically recoverable resources of crystalline graphite by economic class of country and resource category*

[Resource figures are in thousand metric tons of graphite recoverable in concentrate form and may not add to totals due to rounding. Figures in parentheses are percent of column totals]

Economic class[1]	Number of countries	Resource category			
		r1E[2]		All other r1 and r2[3]	
Low-income	6	4,266	(44.1)	200,645	(91.9)
Lower middle-income	3	1,310	(13.5)	2,517	(1.2)
Upper middle-income	3	766	(7.9)	4,296	(2.0)
Industrial market	6	638	(6.6)	2,464	(1.1)
Eastern European nonmarket	2	2,700	(27.9)	8,420	(3.9)
Totals	20	9,680	(100)	218,342	(100)

[1] Classification based principally on GNP per capita and, in some instances, other distinguishing characteristics (World Bank, 1986, p. 180–181). Countries having recoverable resources of crystalline graphite (see table 7) are, by class: low-income economies—China, India, Kenya, Madagascar, Sri Lanka, Vietnam; lower middle-income economies—North Korea, Turkey, Zimbabwe; upper middle-income economies—Brazil, Mexico, South Korea; industrial market economies—Australia, Austria, Canada, Norway, the United States, West Germany; eastern European nonmarket economies—Czechoslovakia, the Soviet Union. A sixth economic class, high-income oil exporters, is not listed because those countries do not have identified major crystalline graphite deposits.

[2] Reliable estimates of economically recoverable resources in known deposits (fig. 1).

[3] Includes recoverable resource categories r1M, r1S, r2E, and r2S (fig. 1).

- Recovery rates for the beneficiation of crystalline flake graphite ores containing 15 to 30 percent fixed carbon are about 90 percent. Considerably lower recovery rates may apply in the beneficiation of lower grade ores.

CRYSTALLINE GRAPHITE RESOURCES

Known world resources of recoverable crystalline graphite considered to warrant economic exploitation (r1E) are equivalent to 9.7 million metric tons of graphite concentrate (table 7). Recoverable resources that have been thoroughly investigated but that are at present marginally economic (r1M) or subeconomic (r1S) are estimated to be equivalent to nearly 10 million metric tons of concentrate; while recoverable inferred (r2) resources are estimated to be about 209 million metric tons of concentrate equivalent, only part of which would be economic.

As seen in table 8, about two-thirds of global r1E crystalline graphite resources are concentrated in the 12 countries composing the low- and middle-income economy classes. The eastern European nonmarket economy class has over one-fourth of these world resources. Only about 7 percent of these resources are in industrial market economy countries. Large r1E resources in central economy countries, such as China and the Soviet Union, however, are in low-grade (3–5 percent) ore which would possibly not be economically workable in western industrial market economy countries.

AMORPHOUS GRAPHITE RESOURCES

The world's three main sources of amorphous graphite are the metamorphosed coal deposits in Sonora, Mexico; the metamorphosed Tunguska coal deposits in Siberia, Soviet Union; and the large graphite province stretching from Inner Mongolia, China, into North and South Korea. Other deposits, such as those in Austria and Czechoslovakia, are small in comparison. Additional, possibly major, resources of amorphous graphite exist in the metamorphosed Ecca coal of South Africa. World resources of economically workable (R1E) amorphous graphite amount to about 11.5 million metric tons; while inferred resources (R2), most of which are in Siberia, are estimated to be about 600 million metric tons (table 9). These resources have grades in the range of 40 to 90 percent fixed carbon, averaging about 80 percent. No refining is needed for most uses.

NATURAL GRAPHITE PRODUCTION

As seen in table 10, world production of graphite increased from about 347,000 metric tons in 1973 to about 659,000 metric tons in 1986. There are, however, considerable uncertainties inherent in such figures. Sources such as U.S. Bureau of Mines' Minerals Yearbook and British Geological Survey's World Mineral Statistics often are not clear as to whether the estimated figures represent ore or concentrate, which may differ by a factor of 10 or more. This uncertainty makes it difficult to reach detailed assessments concerning the distribution of production in individual countries and of production trends among country groups; we do not attempt to make such assessments here. Despite these limitations, however, two observations may be made from table 10:

(1) The proportion of world mining production by the centrally planned economy countries has increased significantly from about 50 percent in the period from 1973 to 1978 to more than 63 percent for 1979 to 1984 and

(2) the proportion of Western World production by western industrial countries and develop-

TABLE 9.—*Resources of amorphous graphite by country, continent, and economic grouping*

[Figures are in thousand metric tons and may not add to totals due to rounding. * = Western industrial countries; other Western World countries are classified as developing countries. N.r. = Not reported. (e) = estimate]

Country	Resource category		
	R1E	R1M+R1S	R2
WESTERN WORLD			
North America			
*United States	N.r.	1,000	N.r.
Mexico	3,000	N.r.	10,000
Total	3,000	1,000	10,000
Africa			
South Africa	50(e)	N.r.	1,000
Other (Morocco)	N.r.	N.r.	N.r.
Total	50	N.r.	1,000
Europe			
*Italy	N.r.	N.r.	N.r.
*Austria	50	N.r.	1,000
Total	50	N.r.	1,000
Asia			
South Korea	3,000	17,000	25,000
Other (India, Pakistan)	N.r.	N.r.	N.r.
Total	3,000	17,000	25,000
Australia			
*Australia	N.r.	N.r.	N.r.
WESTERN WORLD TOTAL	6,100	18,000	37,000
CENTRAL ECONOMY COUNTRIES			
Czechoslovakia	52	224	740
Romania	300	N.r.	N.r.
Soviet Union	1,000	20,000	540,000
China	3,000(e)	[1] 300,000	N.r.North
Korea	1,000(e)	10,000(e)	20,000(e)
Total	5,352	330,224	560,740
WORLD TOTAL	11,452	348,224	597,740
ECONOMIC GROUPING			
Western industrial countries	50	1,000	1,000
Developing countries	6,050	17,000	36,000
Central economy countries	5,352	330,224	560,740

[1]Recent observations suggest that this may be fine-grained crystalline flake rather than amorphous graphite.

ing countries has remained constant at about 27 percent and 73 percent, respectively.

In 1986, the three leading graphite-producing countries accounted for 62 percent of production. China, the largest producer, accounted for about 35 percent of natural graphite production; the Soviet Union, the second largest producer, about 17 percent; and South Korea, the third largest producer, about 10 percent. Some countries, such as Madagascar, Sri Lanka, and Zimbabwe, although accounting for a relatively small proportion of total production, are important suppliers of high-grade graphite.

Annual mine production by economic class of country (World Bank, 1986, p. 180–181) for the period from 1973 to 1986 is given in table 11 and figure 5. The proportion of annual mine production attributed to low-income economy countries rose significantly during the period as a consequence of major expansions in production, especially in China and India. For the same period, the share contributed by upper middle-income economy countries and industrial market economy countries decreased, as did the absolute quantities produced in these countries. The decrease in production in the upper middle-income economy

TABLE 10.—*Mine production of graphite by country, continent, and economic grouping, 1973-86*

[Source: [United Kingdom] Institute of Geological Sciences, 1978-83; [United Kingdom] British Geological Survey, 1984-86. Figures are in thousand metric tons and may not add to totals shown due to rounding. *=Western industrial countries; other Western World countries are classified as developing countries. p=Preliminary, W=Withheld, company proprietary; N.r.=Not reported]

Country	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985p	1986p
WESTERN WORLD														
Europe														
*West Germany	13.5	16.5	13.6	14.0	13.5	11.9	10.3	11.3	10.4	10.6	12.0	12.4	12.8	13.2
*Italy	4.2	2.4	1.5	3.8	3.8	4.1	4.1	4.0	3.5	3.2	2.3	N.r.	N.r.	N.r.
*Norway	6.9	9.7	8.9	9.1	9.1	11.2	11.9	10.4	6.9	7.5	8.1	10.1	2.3	N.r.
*Austria	17.2	29.5	30.6	33.1	35.3	40.5	40.5	36.7	23.8	24.5	40.4	43.8	30.8	35.0
Turkey	N.r.	N.r.	N.r.	N.r.	N.r.	N.r.	0.2	0.2	N.r.	3.4	4.8	4.5	N.r.	N.r.
Total	41.8	58.1	54.6	60.0	61.7	67.7	67.0	62.5	44.7	49.1	67.6	70.8	45.9	48.2
Asia														
Burma	0.2	0.3	0.1	0.2	0.1	0.3	0.3	0.4	1.4	0.3	0.3	0.2	0.2	0.2
India	4.3	5.1	5.9	7.8	11.6	14.5	13.9	14.7	20.2	13.1	13.6	13.0	9.4	10.3
South Korea[1]	43.6	104.9	47.2	41.7	66.0	56.3	56.7	60.6	34.9	27.0	33.3	58.6	71.5	67.0
Sri Lanka	7.8	9.4	10.4	8.3	8.9	10.5	9.4	7.8	7.6	8.8	5.8	5.6	7.4	7.3
Thailand	N.r.	N.r.	N.r.	.0	.0	.0	N.r.	2.1	1.8	.6	.0	N.r.	N.r.	N.r.
Total	55.9	119.8	63.7	58.0	86.6	81.6	80.3	85.6	65.9	49.7	53.0	77.4	88.5	84.5
Africa														
Madagascar	14.0	17.3	17.8	17.4	15.7	16.6	14.2	12.3	13.3	15.4	13.5	14.0	14.0	14.0
*South Africa	1.0	1.6	.5	.5	.9	.6	.4	N.r.	N.r	N.r	N.r	N.r	N.r	N.r
Zimbabwe	N.r.	N.r.	N.r.	5.0	3.0	5.7	5.7	7.4	11.2	8.2	19.9	12.3	10.0	9.1
Total	15.0	18.8	18.3	22.9	19.6	22.9	20.4	19.6	24.6	23.6	33.4	26.3	24.4	23.1
North America														
Mexico[2]	65.4	62.6	60.8	60.3	58.4	52.3	50.9	44.9	42.3	36.2	44.3	41.5	35.4	37.3
*Canada	N.r.	N.r.	N.r.	N.r.	N.r.	N.r.	N.r.	1.0	4.0	N.r.	1.2	0.0	N.r.	N.r.
*United States	W	W	W	N.r.	N.r.	N.r.	N.r.	N.r.	N.r.	N.r.	N.r.	N.r.	N.r.	N.r.
Total	65.4	62.6	60.8	60.3	58.4	52.3	50.9	45.9	46.3	36.2	45.5	41.5	35.4	37.3
South America														
Argentina	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brazil[3]	2.8	5.5	5.3	6.0	9.2	10.4	10.9	21.3	17.5	15.4	16.5	30.0	27.2	28.8
Total	2.9	5.6	5.3	6.1	9.3	10.4	10.9	21.3	17.5	15.4	16.5	30.0	27.2	28.8
WESTERN WORLD TOTAL	181.0	264.8	202.7	207.4	235.6	234.8	229.4	234.8	198.9	173.9	216.0	246.8	221.4	221.9
CENTRAL ECONOMY COUNTRIES														
Romania	6.0	6.0	6.0	6.0	6.0	11.3	12.4	12.5	12.5	12.5	12.6	12.4	12.0	12.0
Czechoslovakia[4]	25.0	39.0	45.2	33.8	49.2	46.4	51.0	50.7	54.0	55.0	60.0	60.0	60.0	60.0
Soviet Union	85.3	90.7	90.7	95.3	95.3	100.0	100.0	100.0	105.0	105.0	110.0	110.0	110.0	110.0
China	29.9	40.8	49.9	49.9	59.9	79.8	182.3	159.7	184.2	185.1	185.1	185.0	200.0	230.0
North Korea	20.0	20.0	20.0	20.0	20.0	20.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Total	166.2	196.5	211.8	204.9	230.3	257.6	370.7	347.9	380.7	382.6	392.7	392.4	407.0	437.0
WORLD TOTAL	347.2	461.4	414.4	412.3	465.3	492.3	600.1	582.7	579.6	556.5	608.7	638.4	628.4	658.9
ECONOMIC GROUPING														
Western industrial countries	42.8	59.6	55.1	60.5	62.6	68.3	67.2	63.3	48.7	45.7	64.0	66.3	45.9	48.2
Developing countries	138.2	205.2	147.6	146.9	173.0	166.5	162.2	171.6	150.2	128.2	152.0	179.7	175.5	173.7
Central economy countries	166.2	196.5	211.8	204.9	230.3	257.6	370.7	347.9	380.7	382.6	392.7	392.4	407.0	437.0

[1] South Korea, amorphous and crystalline graphite. Production of crystalline graphite 1973: 892; 1974: 1,660; 1975: 2,339; 1976: 3,413; 1977: 3,446; 1978: 2,534; 1979: 2,453; 1980: 1,429; 1981: 842; 1982: 627; 1983: 695.

[2] Mexico, amorphous and crystalline graphite since 1980. Production of crystalline graphite 1980: 348; 1981: 1,152; 1982: 1,804; 1983: 1,658.

[3] Brazil, figures refer to concentrate produced. In addition to this, a 14-percent fixed carbon ore is mined near Itauna/MG (about 13,000 metric tons in 1984) and shipped directly to local consumers.

[4] Czechoslovakia, mine output of ores originating from operations in Bohemia (crystalline graphite) and Moravia (microcrystalline, amorphous graphite). Mine output in Bohemia 1975: 30,158 and 1980: 37,597. Some figures on concentrate production of Czechoslovakia 1978: 13,630; 1979: 14,600; 1980: 15,700; 1981: 20,317; 1982: 21,977; 1983: 26,666.

TABLE 11.—*Average annual production of graphite by economic class of country, 1973-86*

[Figures are in thousand metric tons and may not add to totals due to rounding. Figures in parentheses are percent of column totals]

Economic class[1]	No. of countries	Average annual production 1973-78		1979-84		1985-86	
Low-income	5	84.5	(19.7)	216.8	(36.7)	246.3	(38.3)
Lower middle-income	4	22.3	(5.2)	38.7	(6.6)	34.8	(5.4)
Upper middle-income	5	125.7	(29.3)	105.5	(17.9)	133.6	(20.8)
Industrial market	6	57.3	(13.3)	57.0	(9.7)	47.1	(7.3)
Eastern European nonmarket	3	139.5	(32.5)	172.6	(29.2)	182.0	(28.3)
Total	23	429.4	(100)	590.6	(100)	643.7	(100)

[1] Classification based principally on GNP per capita and, in some instances, other distinguishing characteristics (World Bank, 1986, p. 180-81). Countries having annual production of graphite (see table 10) are, by class: low-income economies—Burma, China, India, Madagascar, Sri Lanka; lower middle-income economies—North Korea, Thailand, Turkey, Zimbabwe; upper middle-income economies—Argentina, Brazil, Mexico, South Africa, South Korea; industrial market economies—Austria, Canada, Italy, Norway, the United States, West Germany; eastern European nonmarket economies—Czechoslovakia, Romania, the Soviet Union. A sixth economic class, high-income oil exporters, is not listed because those countries did not have graphite production between 1973 and 1986.

countries (which includes Mexico and South Korea) was partly a consequence of the depressed market for amorphous graphite.

A shortcoming in the production figures is that classification by graphite product type, crystalline or amorphous, is available only for a few countries. Goosens (1982) estimated that in 1976 only about 8 percent of world mining production, or about 37,000 metric tons, was crystalline flake graphite. A rough estimate based on the production figures for each country having deposits of crystalline graphite indicates a possible annual

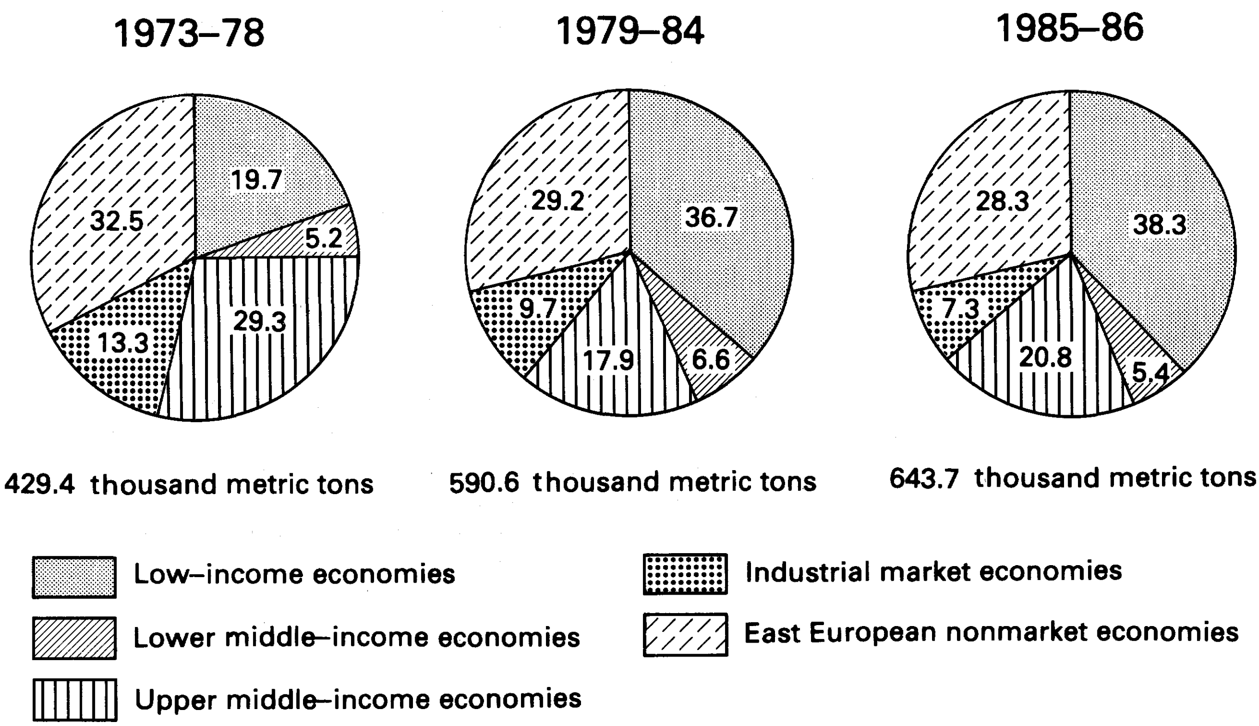


FIGURE 5.—Distribution of world graphite production, 1973-78, 1979-84, and 1985-86 by economic class of country. Economic classes are modified from the World Bank (1986, p. 180-81) classification which is based principally on GNP per capita and, in some instances, other distinguishing characteristics. Countries having annual production of graphite (see table 10) are, by class: low-income economies—Burma, China, India, Madagascar, Sri Lanka; lower middle-income economies—North Korea, Thailand, Turkey, Zimbabwe; upper middle-income economies—Argentina, Brazil, Mexico, South Africa, South Korea; industrial market economies—Austria, Canada, Italy, Norway, the United States, West Germany; eastern European nonmarket economies—Czechoslovakia, Romania, the Soviet Union. A sixth economic class, high-income oil exporters, is not listed because those countries did not have graphite production between 1973 and 1986.

world production of flake graphite of at least 180,000 metric tons. At the present annual rate of production, it may be assumed that there will be no exhaustion of flake graphite resources in the foreseeable future.

While the information is incomplete, it is known that the main producers of crystalline graphite concentrates are China, North Korea, India, Brazil, and Madagascar, each of which provides more than 10 percent of the total and collectively about 60 percent. Sri Lanka, the Soviet Union, Norway, Zimbabwe, and Czechoslovakia each account for 5 to 10 percent of world crystalline graphite production and together produce 33 percent of the total. Annual world production of top quality crystalline graphite concentrates recently has been about 80,000 metric tons. Such high-priced grades are produced by Madagascar, Sri Lanka, Brazil, China, and the Federal Republic of Germany.

CONCLUSIONS

Natural graphite is strategic because of its use in crucibles and refractories related to metal production and because of the uneven global distribution of economically workable graphite resources. The main types of natural graphite are crystalline flake, crystalline lump, and amorphous. Each type of graphite has its individual set of characteristics and uses and originates from a specific type of deposit.

There are no equally suitable substitutes for crystalline flake graphite in applications such as crucibles and carbon-magnesite bricks. The quantities consumed are fairly large and in several applications are growing. In-place world resources of recoverable crystalline flake graphite in economically workable deposits are enormous, equivalent to 9.7 million metric tons of concentrate, compared with a current consumption of an estimated 180,000 metric tons of concentrate; only a small percentage of these resources, however, is in industrial market economy countries, but these countries do have sizable uneconomic and inferred resources.

Amorphous graphite competes with other materials such as coal or manufactured graphite in certain major applications such as steel production. Price determines whether graphite or a competitive material is used. In-place world resources of economically minable ore of natural amorphous graphite are about 11.5 million metric tons with an additional 950 million metric tons of marginal, subeconomic, and inferred resources. The main economically exploitable resources of amorphous graphite are in Mexico, South Korea, and China. Together these countries have about 80 percent of world economic resources and over one-third of the remaining reported uneconomic and inferred resources of amorphous graphite.

PART II—SELECTED INVENTORY INFORMATION FOR NATURAL GRAPHITE DEPOSITS AND DISTRICTS

Table 12 contains information from the International Strategic Minerals Inventory record forms for natural graphite deposits and districts. Only selected items of information about the geology, mineral production, and resources of the deposits are listed here; some of this information has been abbreviated because of space limitations.

Summary descriptions and data are presented in the table as closely as possible to the way that they were reported in the inventory records. 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 record forms have been used in this table; they are explained in the headnotes.

TABLE 12.—*Selected information from*

Site name: Numbers in parentheses (1 through 90) correspond to deposits shown in figure 4.

Ore type: Flake=crystalline, disseminated flakes; Lump=crystalline, lump ore.

Site name (no.)	Latitude	Longitude	Ore type	Mining method
		CANADA		
Pollon Lake (1)	56° 23′N.	103° 07′W.	Flake	---
Graphex (2)	46° 08′N.	75° 33′W.	----- do.	Surface
Orwell (3)	46° 21′N.	75° 33′W.	----- do.	---
Todd property (4)	45° 34′N.	79° 27′W.	----- do.	---
Ryerson (5)	45° 35′N.	79° 32′W.	----- do.	---
North American mine (6)	45° 31′N.	75° 33′W.	----- do.	---
Graphite Lake (7)	45° 43′N.	79° 04′W.	----- do.	---
Coronation (8)	45° 17′N.	77° 56′W.	----- do.	---
Cornell property (9)	44° 44′N.	76° 09′W.	----- do.	---
Timmins mine (10)	44° 44′N.	76° 18′W.	----- do.	---
Globe graphite mine (11)	44° 51′N.	76° 09′W.	----- do.	---
Kirkham graphite property (12)	44° 33′N.	76° 34′W.	----- do.	---
		UNITED STATES		
Kigluaik Mountains, Alaska (13)	65° 02′N.	165° 32′W.	Flake	---
Burnet-Llano district, Texas (14)	30° 47′N.	98° 21′W.	----- do.	---
Clay, Coosa, Chilton Counties, Alabama (15)	33° 16′N.	85° 50′W.	----- do.	---
Raton deposit, New Mexico (16)	36° 50′N.	104° 32′W.	Amorphous	---
		MEXICO		
Lourdes (17)	28° 36′N.	110° 30′W.	Amorphous	Underground
Tonichi (18)	28° 37′N.	109° 34′W.	----- do.	---
Telixtlahuaca (19)	17° 20′N.	96° 52′W.	Flake, weathering	Surface
		BRAZIL		
Pedra Azul (20)	15° 53′S.	41° 08′W.	Flake, weathering	Surface
Itapecerica (21)	20° 26′S.	45° 08′W.	----- do.	----- do.
Itanhem (22)	17° 06′S.	40° 21′W.	Lump	----- do.

ISMI records for graphite deposits and districts

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 Nation's Economic and Social Council, 1979; Schanz, 1980); grade (FC=fixed carbon). A comment on resources may also be included.

---, not available.

Status	Resources	Reference
	CANADA—Continued	
Inactive	1,633; R1M; 10.3 percent FC	Guliov (1984).
Active	453.5; R1E; 10 percent FC	Lamarche (1976, 1981).
Planned producer	1,757; R1M+R1S+R2S; 7.2 percent FC	Northern Miner (1982, 1983).
Inactive	3,000; R2S; 3.2 percent FC	Villard (1982), Villard and Garland 1983).
----- do.	---	Do.
Past producer	---	Spence (1920).
Inactive	Large	Davidson (1982), Papertzian and Kingston (1982).
----- do.	---	Meyn (1982, 1983).
----- do.	907; R2S; 10 percent FC	Hewitt (1965), Stone (1960).
Past producer	206.2; R1M; 6 percent FC. 454; R1M+R1S+R2S.	Kingston and Papertzian (1984), Industrial Minerals (1982).
----- do.	91; R1S; 8 percent FC	Papertzian and Kingston (1982), Spence (1920).
Inactive	194; R1M; 10.8 percent FC. 272; R2S; 10 percent FC.	Do.
	UNITED STATES—Continued	
Past producer	65; R2S; 52 percent FC	Sainsbury (1969), Coats (1944).
----- do.	400; R2E; 5 percent FC	Cameron and Weis (1960), Paige (1911).
----- do.	300; R2E	Prouty (1923), Clemmer and others (1941).
Inactive	---	Lee (1913, 1924).
	MEXICO—Continued	
Active	900; R1E; 75-80 percent FC. 2,000; R2E; 75-80 percent FC.	Weis and Salas (1978).
----- do.	2,000; R1E	Do.
----- do.	4,400; R1E; 4 percent FC. 13,400; R1M.	Zamora Montero (1975).
	BRAZIL—Continued	
Active	26,800; R1E; 11.9 percent FC. 20,300; R2E.	Guimarães (1973).
----- do.	383; R1E; 15.7 percent FC. 210; R2E.	Do.
---	2.778; R1E; 40 percent FC	Do.

TABLE 12.—*Selected information from ISMI records*

Site name (no.)	Latitude	Longitude	Ore type	Mining method
		SOUTH AFRICA		
Gumbu graphite mine (23)	22° 19′S.	30° 40′E.	Flake	---
Malonga graphite mine (24)	22° 39′S.	30° 53′E.	Amorphous	Surface
		ZIMBABWE		
Lynx mine (25)	16° 36′S.	29° 26′E.	Flake	Underground
		MADAGASCAR		
Vatomandry area (26)	19° 21′S.	49° 01′E.	Flake, weathering	Surface
Ambatomitamba-Sahanovo area (27)	18° 21′S.	49° 06′E.	do.	do.
Perinet-Ambatovy area (28)	18° 56′S.	48° 27′E.	do.	do.
		KENYA		
Oldoinyo-Nyiro (29)	00° 45′N.	37° 00′E.	Flake, weathering	---
Chawia (30)	03° 28′S.	38° 23′E.	do.	Surface
		NORWAY		
Skaland-Senja (31)	69° 27′N.	17° 17′E.	Flake	Underground
		FEDERAL REPUBLIC OF GERMANY		
Kropfmuehl (32)	48° 37′N.	13° 39′E.	Flake	Underground
		ITALY		
Pinerolo (33)	44° 53′N.	07° 19′E.	Amorphous	---
		AUSTRIA		
Doppl-Muehldorf-Zettlitz (34)	48° 23′N.	15° 27′E.	Flake	Surface
Kaisersberg (35)	47° 21′N.	15° 04′E.	Amorphous	Underground
Trieben (36)	47° 29′N.	14° 30′E.	do.	do.
		CZECHOSLOVAKIA		
Cesky Krumlov (37)	48° 48′N.	14° 19′E.	Flake	Underground
Mestsky-Vrch (38)	48° 51′N.	14° 18′E.	do.	do.
Kolledeye (39)	49° 13′N.	14° 27′E.	do.	Surface and underground
Velke Vbrno-Konstantin (40)	50° 08′N.	17° 20′ E.	Amorphous	Surface
		ROMANIA		
Baia de Fier (41)	45° 14′N.	23° 45′E.	Amorphous	Surface and underground

for graphite deposits and districts—Continued

Status	Resources (thousand metric tons)	Reference
	SOUTH AFRICA—Continued	
Past producer	---	Whiteside (1976), Wilke (1969).
Active	---	Do.
	ZIMBABWE—Continued	
Active	600; r1E; 80-82 percent FC (huge additional resources).	Taupitz (1973), Stagman (1978).
	MADAGASCAR—Continued	
Active	2,000; R1+R2; 7 percent FC	Rantoanina (1962), Rasoamahenina (1966).
----- do. -----------------------	2,000; R1E+R1M; 5-10 percent FC	Chantraine (1968).
----- do. -----------------------	---	Rantoanina (1962), Rasoamahenina (1966).
	KENYA—Continued	
Planned producer	---	Pohl and Horkel (1980), Pulfrey (1969).
Past producer	1,200; R2; 13 percent FC	Pohl and Horkel (1980), Stewart (1963).
	NORWAY—Continued	
Active	180; r1E; 84-88 percent FC	Doughty (1975).
	FEDERAL REPUBLIC OF GERMANY—Continued	
Active	300; R1E; 20-30 percent FC (estimate)	Töpper (1961), von Guttenberg (1974).
	ITALY—Continued	
Past producer	Depleted	---
	AUSTRIA—Continued	
Active	1,000; R1E	Kuzvart (1984).
----- do. -----------------------	50; R1E; 40-90 percent FC. 1,000; R2E; 40-90 percent FC.	Klar (1957), Metz (1938, 1940).
----- do. -----------------------	---	Do.
	CZECHOSLOVAKIA—Continued	
Active	15-17 percent FC	Kuzvart (1984), Stutzer (1911), Formanek and others (1963).
Planned producer	50; r1E; 80 percent FC. 530; R1E; 15 percent FC (estimate).	Do.
----- do. -----------------------	12 percent FC	Do.
Active	2,000; R1+R2; 30 percent FC. 200; r1E; 40-60 percent FC (estimate).	Do.
	ROMANIA—Continued	
Active	300; R1E; 32 percent FC. 58; r1E; 70 percent FC (estimate).	Wagner (1977), Panu and others (1967).

TABLE 12.—*Selected information from ISMI records*

Site name (no.)	Latitude	Longitude	Ore type	Mining method
		SOVIET UNION		
Zaval'e (42)	48° 12'N.	30° 02'E.	Flake, weathering	Surface
Tayginsk (43)	55° 38'N.	60° 39'E.	Flake	----- do.
Taskazgan (44)	40° 49'N.	63° 23'E.	Crystalline (flake or lump?)	----- do.
Botogolsk (45)	52° 28'N.	100° 45'E.	Lump, flake	Underground
Boyarsk (46)	51° 51'N.	106° 06'E.	Flake	---
Kureyka (47)	66° 29'N.	87° 10'E.	Amorphous	Surface and underground
Noginskoje (48)	64° 30'N.	91° 15'E.	----- do.	Underground
Soyusnoye (49)	47° 55'N.	130° 56'E.	Flake	Surface
		NORTH KOREA		
Kanggye deposits (50)	40° 58'N.	126° 36'E.	Crystalline (flake or lump?)	Surface
Kaechon (51)	39° 40'N.	125° 58'E.	Amorphous	----- do.
Songjin deposits (52)	40° 40'N.	129° 12'E.	Flake	---
Yonghung deposits (53)	39° 50'N.	127° 26'E.	Amorphous	Surface and underground
		SOUTH KOREA		
Gun-Ja (54)	37° 21'N.	126° 49'E.	Flake, weathering	Surface
Shihung (55)	37° 10'N.	126° 45'E.	----- do.	----- do.
Pyongtack (56)	37° 02'N.	127° 28'E.	----- do.	----- do.
Yongwon (57)	36° 55'N.	127° 40'E.	----- do.	----- do.
Taehung (58)	36° 35'N.	126° 55'E.	Flake	---
Pongmyong (59)	36° 43'N.	128° 09'E.	Amorphous	---
Wolmyong (60)	36° 25'N.	127° 45'E.	----- do.	Underground
Kaerim (61)	36° 15'N.	128° 20'E.	----- do.	---
		CHINA		
Heling (62)	46° 19'N.	129° 33'E.	Amorphous	---
Jixi (Liu Mao) (63)	45° 17'N.	131° 00'E.	----- do.	Surface
Xing He (64)	40° 53'N.	113° 53'E.	Flake	---
Panshi (65)	43° 07'N.	125° 59'E.	Amorphous	Underground
Hohot (66)	40° 49'N.	111° 37'E.	Crystalline (flake or lump?)	Surface
Shandong Peninsula (67)	36° 50'N.	120° 40'E.	Flake	----- do.

for graphite deposits and districts—Continued

Status	Resources (thousand metric tons)	Reference
	SOVIET UNION—Continued	
Active	38,000; R1+R2; 5-6 percent FC (estimate)	Korzhinskiy and others (1978), Shpak (1972).
----- do. ----------------------	1,116; R1+R2; 2.4-3 percent FC	Kuzakov (1979), Kuzvart (1984).
----- do. ----------------------	7,000; R1E; 11 percent FC. 13,000; R2.	Baranov and Kromskaya (1983).
----- do. ----------------------	Small	Conolly (1975), Lobozova and others (1971).
Inactive	Huge; 5 percent FC	Kuzakov (1979), Kuzvart (1984).
Intermittent producer	9,785; R1M. 87,000; R2E; 80-95 percent FC.	Britan and Rubanov (1972).
Active	1,000; R1E. 10,000; R1M; 85 percent FC	Kuzakov (1979), Kuzvart (1984).
----- do. ----------------------	8,200; R1E; 15-20 percent FC	Onikhimovskiy and others (1976).
	NORTH KOREA—Continued	
Active	---	Gallagher and others (1962).
----- do. ----------------------	---	Do.
----- do. ----------------------	100; r1E (estimate of concentrate)	Do.
----- do. ----------------------	---	Do.
	SOUTH KOREA—Continued	
Active	---	Kim and others (1972).
----- do. ----------------------	1,300; R1+R2; 3.5 percent FC	Do.
----- do. ----------------------	707; R1+R2; 2.4 percent FC	Do.
----- do. ----------------------	40; R1+R2; 11.7-14.6 percent FC	Do.
----- do. ----------------------	---	Do.
----- do. ----------------------	15,000; R1E (estimate). 10,000; R1M+R1S (estimate). 12,000; R2E (estimate).	Gallagher and others (1962), Kim and others (1972).
----- do. ----------------------	---	Do.
----- do. ----------------------	150; R1E; 85 percent FC (1944 estimate)	Do.
	CHINA—Continued	
Active	---	Zhaoyang and Yantang (1984), Vei Chow (1946).
Inactive	300,000; R1E; 85 percent FC (suitable for surface operation).	Do.
Active	Major producer in Inner Mongolia	Do.
----- do. ----------------------	1,000; R1+R2 (1942 estimate)	Do.
----- do. ----------------------	---	Do.
----- do. ----------------------	2,000; r1E. 2,000; r1M+r1S. 5,900; r2 (estimate of run of mill ores is 4-5 percent FC).	Do.

TABLE 12.—*Selected information from ISMI records*

Site name (no.)	Latitude	Longitude	Ore type	Mining method
		CHINA—Continued		
Honan deposits (68)	32° 36′N.	113° 53′E.	---	---
Hunan (69)	26° 00′N.	113° 00′E.	Amorphous	Underground
Haikou (70)	20° 05′N.	110° 25′E.	---	Surface
		INDIA		
Khamdih (71)	23° 58′N.	84° 13′E.	Flake, lump	Surface
Sokra (72)	23° 58′N.	84° 08′E.	----- do.	----- do.
Tamatia mines (73)	23° 37′N.	74° 30′E.	Flake	----- do.
Sargipali area (74)	20° 54′N.	83° 05′E.	Flake, lump	----- do.
Dandatapa area (75)	20° 48′N.	84° 36′E.	----- do.	----- do.
Titlagarh area (76)	20° 12′N.	83° 22′E.	----- do.	----- do.
Tumdibandh-Phulbani area (77)	19° 50′N.	83° 38′E.	----- do.	----- do.
Srikakulam (78)	18° 20′N.	83° 06′E.	----- do.	---
Visakhapatnam (79)	18° 01′N.	82° 56′E.	----- do.	Surface
East Godavari (80)	17° 23′N.	81° 51′E.	----- do.	----- do.
Khammam (81)	17° 23′N.	81° 20′E.	----- do.	Surface and underground
Madurai (82)	10° 04′N.	77° 50′E.	----- do.	Surface
		SRI LANKA		
Kahatagaha-Kolongaha (83)	07° 34′N.	80° 32′E.	Lump	Underground
Bogala (84)	07° 08′N.	80° 17′E.	----- do.	----- do.
Rangala (85)	07° 07′N.	80° 20′E.	----- do.	----- do.
		AUSTRALIA		
Uley mine (86)	34° 48′S.	135° 42′E.	Flake, weathering	Surface and underground
Koppio (87)	34° 25′S.	135° 54′E.	Amorphous?	----- do.
Munglinup River (88)	33° 30′S.	120° 51′E.	Flake	----- do.
Undercliff (89)	28° 39′S.	152° 12′E.	Amorphous	Surface
Jack's Creek (90)	20° 40′S.	147° 52′E.	----- do.	Surface and underground

for graphite deposits and districts—Continued

Status	Resources (thousand metric tons)	Reference
	CHINA—Continued	
Active	---	Zhaoyang and Yantang (1984), Vei Chow (1946).
----- do. ----------------------	---	Do.
----- do. ----------------------	---	Do.
	INDIA—Continued	
Active	---	Geological Survey of India (1974b), Banerjee and others (1980).
----- do. ----------------------	---	Do.
----- do. ----------------------	1,120; R1M+R2E; 14.1 percent FC	Geological Survey of India (1977).
----- do. ----------------------	---	Geological Survey of India (1974a), Krishna-Rao and others (1971).
----- do. ----------------------	---	Do.
----- do. ----------------------	---	Do.
----- do. ----------------------	---	Do.
---	---	Geological Survey of India (1975).
Active	---	Geological Survey of India (1975), Malleswara Rao (1973).
----- do. ----------------------	---	Geological Survey of India (1975).
----- do. ----------------------	---	Do.
----- do. ----------------------	130; R1E; 19.5 percent FC (estimate)	Geological Survey of India (1974c), Paramasivan and Srinivasan (1973).
	SRI LANKA—Continued	
Active	---	Herath (1975), Fernando (1950).
----- do. ----------------------	52; R1E	Dobner and others (1978), Herath (1975).
----- do. ----------------------	---	Herath (1975), Fernando (1950).
	AUSTRALIA—Continued	
Past producer	13; R1E; 15.7 percent FC. 63; R1S 7; r1S.	Gourlay (1965), Johns (1961).
----- do. ----------------------	4; R2E; 12.2 percent FC. 15; R2S.	Gourlay (1965), Broadhurst and Armstrong (1945).
----- do. ----------------------	30; R2S; 25 percent FC	Carter (1976), Sofoulis and Connolly (1957), Ellis (1944).
----- do. ----------------------	32 percent FC	Haditsch (1979), Hamilton and others (1971).
----- do. ----------------------	---	Cribbs (1976).

REFERENCES CITED

Banerjee, B., Chatterjee, C.N., and Choudhury, S.S., 1980, Graphite deposits in the Precambrian of Palamau, Bihar: Metals and Minerals Review, v. 19, no. 8, p. 6-12.

Baranov, V.V., and Kromskaya, K.M., 1983, Graphite, *in* Kozlovskiy, E.A., ed., Poleznye iskopaemye—Grafit: Moscow, Nedra, Geologija SSSR, v. XXIII, no. 3, Industrial Minerals, p. 132-135.

Bastin, E.S., 1910, The origin of certain Adirondack graphite deposits: Economic Geology, v. 5, p. 134-157.

——— 1912, The graphite deposits of Ceylon [Sri Lanka]—A review of present knowledge with a description of a similar deposit near Dillon, Montana: Economic Geology, v. 7, p. 410-443.

Britan, I.V., and Rubanov, N.I., 1972, Kureyskoje Mestorozhdenye Grafita [the Kureyka graphite deposit]: Razvedka i Okhrana Nedr, no. 9, p. 10-13.

Broadhurst, E., and Armstrong, A.T., 1945, Koppio graphite mine: South Australia Mining Review, no. 82, p. 93-109.

Cameron, E.N., and Weis, P.L., 1960, Strategic graphite—A survey: U.S. Geological Survey Bulletin 1082-E, p. 201-321.

Carter, J.T., 1976, Graphite in Western Australia, *in* Knight, C.L., ed., Economic geology of Australia and Papua New Guinea, v. 4. Industrial minerals and rocks: Australasian Institute of Mining and Metallurgy, no. 8, p. 198.

Chantraine, Jean, 1968, Géologic et prospection de la région Ambohimahasoa-Fianarantsoa-Ifanadiana: Madagascar, Travaux du Bureau Géologique, no. 127, 29 p.

Clemmer, J.B., Smith, R.W., Clemmons, B.H., and Stacy, R.H., 1941, Flotation of weathered Alabama graphitic schists for crucible flake: Alabama Geological Survey Bulletin 49, 101 p.

Coats, R.R., 1944, Graphite deposits on the north side of the Kigluaik Mountains, Seward Peninsula, Alaska: U.S. Geological Survey Open-File Report, 10 p.

Conolly, Violet, 1975, Siberia today and tomorrow—A study of economic resources, problems, and achievements: London, Collins, 248 p.

Cribbs, H.G.S., 1976, Graphite in Queensland, *in* Knight, C.L., ed., Economic geology of Australia and Papua New Guinea, v. 4. Industrial minerals and rocks: Australasian Institute of Mining and Metallurgy, no. 8, p. 155.

Davidson, A., 1982, Graphite occurrences in the Algonquin region, Grenville Province, Ontario: Geological Survey of Canada Open-File Report 870, 7 p.

Dissanayake, C.B., 1981, The origin of graphite in Sri Lanka: Organic Geochemistry, v. 3, no. 1/2, p. 1-7.

Dobner, Albert, Graf, Wolfgang, Hahn-Weinheimer, Paula, and Hirner, Alfred, 1978, Stable carbon isotopes of graphite from Bogala mine, Sri Lanka: Lithos, v. 11, no. 3, p. 251-255.

Doughty, C., 1975, Graphit-Gewinnung in Norwegin: Concentrates, no. 1, p. 5-7.

Ellis, H.A., 1944, The Munglinup graphite deposits: Western Australia, Annual Report of the Geological Survey, p. 65-66.

Erdosh, G., 1970, Geology of Bogala mine, Ceylon [Sri Lanka] and the origin of vein-type graphite: Mineralium Deposita, v. 5, no. 4, p. 375-382.

Fernando, L.J.D., 1950, The geology and mineral deposits of Ceylon [Sri Lanka]: London, Imperial Institute, 25 p. [Reprinted from the Bulletin of the Imperial Institute, 1948, v. 46, no. 2-4, p. 303-325.]

Formanek, Josef, Krizek, Jaroslav, and Stephan, Karel, 1963, Graphite, mining, beneficiation and usage in industry [Original in Czechoslovakian]: Praha, Statni nakl. technicke literatury, 131 p.

Gallagher, David, Klepper, M.R., Overstreet, W.C., and Sample, R.D., 1962, Mineral resources of Korea: U.S. Geological Survey Open-File Report 646, 2239 p.

Geological Survey of India, 1974a, Geology and mineral resources of the states of India, Part III. Orissa: Geological Survey of India, Miscellaneous publication no. 30, 51 p.

——— 1974b, Geology and mineral resources of the states of India, Part V. Bihar: Geological Survey of India, Miscellaneous publication no. 30, 34 p.

——— 1974c, Geology and mineral resources of the states of India, Part IV. Tamil Nadu and Pondicherry: Geological Survey of India, Miscellaneous publication no. 30, 28 p.

——— 1975, Geology and mineral resources of the states of India, Part VIII. Andhra Pradesh: Geological Survey of India, Miscellaneous publication no. 30, 51 p.

——— 1977, Geology and mineral resources of the states of India, Part XII. Rajasthan: Geological Survey of India, Miscellaneous publication no. 30, 75 p.

Goosens, P.J., 1982, Graphite deposits of the Precambrian and their mining development, *in* Natural Resources and Energy Division, United Nations Department of Technical Co-operation for Development, The development potential of Precambrian mineral deposits: New York, Pergamon Press, p. 123-155.

Gourlay, A.J.C., 1965, Graphite, *in* McLeod, I.R., ed., The Australian mineral industry—The mineral deposits: Australia, Bureau of Mineral Resources and Geophysics Bulletin 72, p. 289-295.

Guimarães, M.A., 1973, Perfil analitico da grafita: [Brazil] Departmento Nacional da Producão Mineral, no. 16, 22 p.

Guliov, P., 1984, Saskatchewan—Industrial minerals in Canada, review of recent developments: Industrial Minerals, no. 200 (May), p. 93-105.

Haditsch, J.G., 1979, Lagerstätten fester mineralischer Rohstoffe in Österreich und ihre Bedeutung, Grundlagen der Rohstoffversorgung, v. 2: Vienna, Bundesministerium für Handel, Gewerbe, und Industrie, p. 31-32.

Hamilton, L.H., Ramsden, A.R., and Stephens, J.F., 1971, Fossiliferous graphite from Undercliff, New South Wales: Journal of the Geological Society of Australia, v. 17, pt. 2, p. 31-38.

Herath, J.W., 1975, Mineral resources of Sri Lanka: [Republic of Sri Lanka] Geological Survey Department, Economic Bulletin, no. 2, 72 p.

Hewitt, D.F., 1965, Graphite in Ontario: Ontario Department of Mines, Industrial Mineral Report no. 20, 66 p.

Industrial Minerals, 1982, Canada—Flake graphite prospects: Industrial Minerals, no. 173 (Feb), p. 9-11.

Johns, R.K., 1961, Geology and mineral resources of Southern Eyre Peninsula: Geological Survey of South Australia Bulletin 31, p. 69-74.

Katz, M.B., 1987, Graphite deposits of Sri Lanka—A consequence of granulite facies metamorphism: Mineralium Deposita, v. 22, no. 1, p. 18-25.

Kim, H.K., John, Y.W., and Kang, W.S., 1972, Mineral requirements for Korea's industrialization—Patterns of require-

ments and availabilities: Korean Institute of Mineral and Mining Engineers, 153 p.
Kingston, P.W., and Papertzian, V.C., 1984: Report of activities 1983—Regional and resident geologists, *in* Kustra, C.R., ed., Report of activities 1983, regional and resident geologists: Ontario Geological Survey, Miscellaneous Paper 117, p. 221-229.
Klar, Gustav, 1957, Die wichtigsten Graphitvorkommen der Welt: Erzmetall, v. 10, no. 6, p. 5.
Korzhinskiy, A.F., Mamchur, G.P., and Kostin, V.A., 1978, K-Ar age of the mineral formation stages of the Zaval'e graphite deposit (Ukrainian Shield): Dopovidi Akademiia Nauk Ukrainskoi, Seria B, no. 1, p. 14-18.
Krishna-Rao, M., Chowdhurry, G.S., and Narasimhan, K.S., 1971, Petrography and beneficiation characteristics of graphite deposits of Orissa: India, Journal of Mines, Metals and Fuels, v. 19, no. 3, p. 63-64.
Kuzakov, M.G., 1979, Der Untertagebau von kleinen Lagerstatten (Glimmer, Graphit, Talk) in der UdSSR [Underground working of inextensive deposits of scarce nonmetallic minerals (mica, graphite, talc) in the U.S.S.R.]: World Mining Congress, 10th, Istanbul, v. II, no. 2, p. II1-II21.
Kuzvart, Milos, ed., 1984, Industrial minerals and rocks, *in* Developments in economic geology, no. 18: Amsterdam, Elsevier Science Publishing Company, 454 p.
Lamarche, R.Y., 1976, Rapports des géologues résidents 1975, Part A: Quebec, Department of Natural Resources, p. 12-14.
——— 1981, Rapports des géologues résidents 1981: Quebec, Ministére des Richesses Naturelles, DPV 868, p. 97.
Lee, W.T., 1913, Graphite near Raton, New Mexico: U.S. Geological Survey Bulletin 530, p. 371-374.
——— 1924, Coal resources of the Raton coal field: U.S. Geological Survey Bulletin 52, p. 47-48, 71-78.
Lobozova, R.V., Vinogradov, V.I., and Lebedev, V.S., 1971, Genesis of Botogolsk graphite from data on isotopic composition of carbon: Geologiia Rudnykh Mestorozhdenii, v. 13, no. 4, p. 50-55.
Malleswara Rao, V., 1973, Beneficiation of graphite from Visakhapatnam district: Journal of the Indian Academy of Geoscience, v. 16, no. 2, p. 77-81.
Mantell, C.L., 1968, Carbon and graphite handbook: New York, Interscience Publishers, 538 p.
Metz, Karl, 1938, Die Geologie der Grauwackenzone von Leoben bis Mautern: Austria, Geologische Bundesanstalt, Jahrbuch, v. 88, no. 1-2, p. 165-193.
——— 1940, Die Geologie der Grauwackenzone von Mautern bis Trieben: Vienna, Mitteilungen der Reichsstelle für Bodenforschung, v. 1, no. 3, p. 161-220.
Meyn, H.D., 1982, 1982 Report of the Bancroft resident geologist, *in* Kustra, C.R., ed., Report of activities, regional and resident geologists 1982: Ontario Geological Survey, Miscellaneous Paper 107, p. 169-179.
——— 1983, Report of activities 1983—Bancroft resident geologist, Algonguin Region, *in* Kustra, C.R., ed., Report of activities 1983, regional and resident geologists: Ontario Geological Survey, Miscellaneous Paper 117, p. 209-217.
Northern Miner, 1982, Orwell to begin drilling program: Northern Miner, v. 68, no. 36 (Nov 11), p. 7.
——— 1983, Orwell seeking $12 M financing for big new Quebec graphite mine: Northern Miner, v. 69, no. 26 (Sept. 1), p. 15.
Onikhimovskiy, V.V., Daatsko, Y.K., and Leontovich, A.A., eds., 1976, Khabarovskiy kray i Amurskaya oblast—Poleznyye isokopayemyye [The Khabarovsk Territory and Amur Province—Mineral resources]: Geologiya SSSR, v. 19, no. 2, 271 p.
Paige, Sidney, 1911, Mineral resources of the Llano-Burnet region, Texas: U.S. Geological Survey Bulletin 450, p. 77-81.
Panu, I.H., Georgescu, B., and Oprescu, A., 1967, Research regarding beneficiation of graphite-bearing rocks in Ribari and Ungurelo areas: Romania, Dari de Seama Sedintelor, v. 54, no. 3, p. 492-493.
Papertzian, V.C., and Kingston, P.W., 1982, Graphite development potential in eastern Ontario: Ontario Geological Survey Open-File Report 5377, p. 27-31.
Paramasivan, T.S., and Srinivasan, R., 1973, Graphite deposits of Tamil Nadu: Mineral Research, v. 5, p. 20-23.
Pohl, W., and Horkel, A., 1980, Notes on the geology and mineral resources of the Mtito Andei-Taita area (southern Kenya): Mitteilungen der Osterreichischen Geologischen Gesellschaft, v. 73, p. 135-152.
Prouty, W.F., 1923, Geology and mineral resources of Clay County, with special reference to the graphite industry: Alabama Geological Survey, County Report 1, 190 p.
Pulfrey, William, 1969, The geology and mineral resources of Kenya [2d edition by John Walsh]: Geological Survey of Kenya, Bulletin no. 9, 34 p.
Rantoanina, Maurice, 1962, Prospection et géologie des feuilles Moramanga-Lakato: Madagascar, Travaux du Bureau Géologique, no. 111, 38 p.
Rasoamahenina, J.A., 1966, Considérations sur la géologie génerale et les gisements de graphite de Tamatave et Moramanga, *in* Razafiniparany, A., Rapport annuel du Service Géologique pour l'annee 1966: Madagascar, Service Géologique, p. 47-64.
Reynolds, W.N., 1968, Physical properties of graphite: London, Elsevier Publishing, 193 p.
Rumble, Douglas, III, and Hoering, T.C., 1986, Carbon isotope geochemistry of graphite vein deposits from New Hampshire, U.S.A.: Geochimica et Cosmochimica Acta, v. 50, no. 6, p. 1239-1247.
Sainsbury, C.L., 1969, Geology and ore deposits of the Central York Mountains, western Seward Peninsula, Alaska: U.S. Geological Survey Bulletin 1287, 101 p.
Salotti, C.A., Heinrich, E.W., and Giardini, A.A., 1971, Abiotic carbon and the formation of graphite deposits: Economic Geology, v. 66, no. 7, p. 929-932.
Schanz, J.J., Jr., 1980, The United Nations' endeavor to standardize mineral resource classification: Natural Resources Forum, v. 4, no. 3, p. 307-313.
Shpak, P.F., 1972, Syr'yevye resursy Ukrainskoy S.S.R [Mineral resources of the Ukrainian S.S.R.]: Sovetskaya Geologiya, no. 8, p. 3-9.
Silva, K.K.M.W., 1987, Mineralization and wall-rock alteration at the Bogala graphite deposit, Bulathkohupitiya, Sri Lanka: Economic Geology, v. 82, no. 7, p. 1710-1722.
Sofoulis, J., and Connolly, R.R., 1957, Report on Munglinup River graphite deposits, Eucla Division, W.A.: Geological Survey of Western Australia, Bulletin 112, p. 30-40.

Spence, H.S., 1920, Graphite: Canada, Department of Mines, Mines Branch, Publication no. 511, 202 p. [56 plates].
Stagman, J.G., 1978, An outline of the geology of Rhodesia: Rhodesia Geological Survey Bulletin, no. 80, 126 p.
Stewart, A.L., 1963, Graphite in Kenya: [Kenya] Ministry of Natural Resources, Geological Survey of Kenya Bulletin, no. 6, 72 p.
Stone, W.J.D., 1960, Concentration of graphite from the Perth area of Ontario, Canada: Department of Mines and Technical Surveys, Mines Branch, Investigation Report 60-65, 7 p.
Strens, R.J.G., 1965, The graphite deposit at Seathwait in Borrowdale, Cumberland, England: Geological Magazine, v. 102, no. 5, p. 393-406.
Stutzer, Otto, 1911, Die wichtigsten Lagerstatten der "Nicht-Erze," v. I. Graphit, Diamant, Schwefel, Phosphat: Berlin, Borntraeger, 474 p.
Taupitz, K.C., 1973, Der Bergbau Rhodesiens: Glückauf, v. 109, no. 26, p. 1275-1286.
Taylor, H.A., Jr., 1988, Graphite, in U.S. Bureau of Mines, Mineral commodity summaries 1988: Washington, D.C., U.S. Government Printing Office, p. 64-65.
Töpper, Wolfgang, 1961, Beitrag zum Mineralbestand und zur Geochemie der der Graphitlagerstätte Kropmühl-Pfaffenreuth bei Passau, Donau: Ph. D. thesis, Technischen Universität Berlin, 107 p.
[United Kingdom] British Geological Survey, 1984-86, World mineral statistics [1978-86]—Production, exports, imports: Her Majesty's Stationery Office, 3 v.
[United Kingdom] Institute of Geological Sciences, 1978-83, World mineral statistics [1970-81]—Production, exports, imports: Her Majesty's Stationery Office, 8 v. (Continued by British Geological Survey, World mineral statistics.)
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.
U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, 5 p.
Vei Chow, Juan, 1946, Mineral resources of China: Economic Geology, v. 41, no. 4, pt. 2, p. 399-474.
Villard, D.J., 1982, 1982 Report of the Huntsville resident geologist, *in* Kustra, C.R., ed., Report of activities 1982, Regional and resident geologists: Ontario Geological Survey, Miscellaneous Paper 107, p. 166-167.
Villard, D.J., and Garland, M., 1983, Report of activities 1983—Huntsville resident geologist area, Algonguin Region, *in* Kustra, C.R., ed., Report of activities 1983, Regional and resident geologists, Ontario Geological Survey, Miscellaneous Paper 117, p. 204-208.
von Guttenberg, Reinhard, 1974, Stoffbestand und Metamorphose von Gesteinen der buten Süerie am Sdrand des Passauer Waldes: München, Ph. D. dissertation, Ludwig Maximilians Univesität, 108 p.
Wagner, Hermann, 1977, Rohstoffwirtschaftliche Länderberichte, XIII. Rumanien [Romania]: Hannover, (Germany, Federal Republic), Bundesanstalt für Geowissenschaften und Rohstoffe, 176 p.
Weis, P.L., Friedman, I., and Gleason, J.P., 1981, The origin of epigenetic graphite—Evidence from isotopes: Geochimica et Cosmochimica Acta, v. 45, no. 12, p. 2325-2332.
Weis, P.L., and Salas, G.A., 1978, Estimating reserves of amorphous graphite in Sonora, Mexico: Engineering and Mining Journal, v. 179, no. 10, p. 123-128.
Whiteside, H.C.M., 1976, Graphite, *in* Coetzee, C.B., ed., Mineral resources of the Republic of South Africa: South Africa Geological Survey Handbook no. 7, 5th edition, p. 365-367.
Wilke, D.P., 1969, Grafietafsettings noord van die Soutpansberg, Transvaal [Graphite deposits north of the Soutpansberg, Transvaal]: [South Africa] Department of Mines, Geological Survey Bulletin 51, 60 p.
Winchell, A.N., 1911, A theory of granite formation: Economic Geology, v. 6, p. 218-230.
World Bank, 1986, World development report 1986: New York, Oxford University Press, 256 p.
Zamora Montero, Salvador, 1975, Geologia de los yacimientos de grafito cristalino en el estado de Oaxaca: Mexico, Consejo de Recursos Naturales Seminario Interno Anual sobre Exploracion Geologico-Minera, v. 5 (Dec.), p. 311-352.
Zhaoyang, H., and Yantang, Y., 1984, Development and utilization of industrial minerals in China, *in* Clarke, G.M., ed., Proceedings—Industrial Minerals International Congress, no. 6, p. HZ1-HZ13.

ADDITIONAL REFERENCES ON NATURAL GRAPHITE RESOURCES

Acharya, B.C., and Dash, B., 1980, Distribution of graphite deposits in Orissa and its relation with regional geology: Metals and Minerals Review, v. 19, no. 7, p. 1-3.
Ahnert, E.E., 1929, Mineral resources of north Manchuria: Geological Survey of China, series A, no. 7, 262 p.
Bates, R.L., 1969, Geology of the industrial rocks and minerals, 2d ed., New York, Dover Publications, Inc., 459 p.
Besairie, Henri, 1956, Carte minière et des indices de Madagascar (scale 1:1,500,000): Tananarive, Service Geologique.
——— 1961, Les ressources minérales de Madagascar: Tananarive, Annales Géologiques de Madagascar, part 30, 116 p.
——— 1966, Gites mineraux de Madagascar [chapter on graphite p. 187-219]: Tananarive, Annales Géologiques de Madagascar, part 34, 437 p.
——— 1970, Description géologique du massif ancien de Madagascar, v. 5. Le Sud: Tananarive, Documentation Bureau Géologique, no. 177e.
——— 1973, Precis de géologie Malgache: Tananarive, Annales Géologiques de Madagascar, part 36, 141 p.
Blackman, L.C.F., ed., 1970, Modern aspects of graphite technology: New York, London, Academic Press, 320 p.
Canada, Department of Energy, Mines and Resources, Mineral Policy Sector: National Mineral Inventory and Resource Files.
de Silva, P.H.D.H., ed., 1967, An introduction to the geology of Ceylon [Sri Lanka]: National Museums of Ceylon Publication, 324 p.
Dickerman, Nelson, 1948, Mineral resources of China: U.S. Bureau of Mines, Foreign Minerals Survey, v. 2, no. 7, 266 p.
Dickson, Ted, 1984, Korean industrial minerals—A brief summary: Industrial Minerals, no. 202 (July), p. 57-61.

Fogg, C.T., and Boyle, E.H., Jr., 1987, Flake and high-crystalline graphite availability—Market economy countries: U.S. Bureau of Mines Information Circular 9122, 40 p.
Goosens, P.J., 1979, Graphite deposits of the Precambrian and their mining development: Moscow, August, 25 p.
——— 1983, Precambrian mineral deposits and their metallogeny: Musée Royal del' Afrique Centrale Tervuren, Belgigue, Annales, Série IN 8, Sciences Géologiques, no. 89, 97 p.
Harben, P.W., and Bates, R.L., 1984, Geology of the nonmetallics: New York, Metals Bulletin Inc., 392 p.
Harrington, G.L., 1919, Graphite mining in Seward Peninsula: U.S. Geological Survey Bulletin 692, p. 363-367.
Hill, W.B., 1986, China—A source of flake graphite for the refractories industry: 7th Industrial Minerals International Congress, p. 181-189.
Industrial Minerals, 1976, Natural graphite retains traditional markets: Industrial Minerals, no. 109 (Oct.), p. 17-37.
Johnstone, S.J., 1954, Minerals for the chemical and allied industries: New York, London, Wiley, 692 p.
Kanungo, S.C., 1976, Graphite mineralization in Titlagarh-Graphite-Belt, Bolangir and Kalahandi districts Orissa: Indian Minerals, v. 30, no. 4, p. 1-6.
Kegler, J., 1981, Potential und Entwicklung des Bergbaus in Simbabwe: Erzmetall, v. 34, no. 10, p. 530-535.
Klar, Gustav, 1964, Steirische graphite: Verlag Styria, 149 p.
Korea, Republic, 1968, The development of mineral resources in Korea (1965-1967): Seoul, United Nations, ECAFE Sub-committee on Mineral Resources Development, seventh session, 35 p.
Krishnaswamy, Subbier, 1979, India's mineral resources, 2d edition: New Delhi, Oxford and IBH Publishing, 658 p. Larios, J.P., 1965, El Grafito: Mineria y Metalurgia, no. 33, p. 75-90.
Larios, J.P., 1965, El grafito: Mineria y Metalurgia, no. 33, p. 75-90.
Mason, J.E., and Theuri, F.G., 1980, Industrial development in Kenya, *in* Coope, B.M., ed., Proceedings of the 4th Industrial Minerals International Congress: Surrey [England], Industrial Minerals, Metal Bulletin Group, p. 111-128.
Minerals and Metals Review, 1983, Kenya advances small-scale mining: Minerals and Metals Review, v. 22, no. 3, p. 15-16.
Moffit, F.H., 1913, Geology of the Nome and Grand Central quadrangles, Alaska: U.S. Geological Survey Bulletin 533, p. 135-136.
Northern Miner, 1976, Saskatchewan Mining Development Corp. in joint venture on graphite mine: Northern Miner, v. 62, no. 36 (Nov 18), p. 17.
Parkinson, J., 1947, Outlines of the geology of the Mtito Andei-Tsavo area: Geological Survey of Kenya, report no. 13, 43 p.
Pawlowski, K., 1980, Structural investigations of industrial graphites: Prace Mineralogiczne, no. 60, 87 p.
Petrov, V.P., ed., 1984, Non-metallic minerals of the USSR: Moscow, Nedra, 405 p.
Pettifer, L., 1980, Natural graphite, the dawn of tight markets: Industrial Minerals, no. 156 (Sept.), p. 19-39.
Québec Ministère de L'Énergie et des Ressources, Service du Potential Mineral, Fiche de Gîte Mineral no. 315/5-25.
Roskill Information Services, 1972, Carbon and graphite: London, Roskill Information Services, 324 p.
Schanz, J.J., Jr., Werner, A.B.T., and Mroczek, R.J., 1961, Final report on graphite market research: University Park, Pennsylvania, Pennsylvania State University, College of Mineral Industries, 22 p.
Shackleton, R.M., 1946, Geology of the country between Nanyuki and Maralal: Geological Survey of Kenya, Report no. 11, 54 p.
Tartarinov, P.M., ed., 1934, Kurs nerudnych mestorozhdeniy [course on "non-ore" deposits]: Moscow, parts 1 and 2, 932 p.
——— 1969, Kurs mestorozhdeniy nemetalicheskikh poleznykh iskopayemykh; Moscow, Izd. Nedra, 472 p.
Taylor, H.A., Jr., 1980, Graphite, *in* U.S. Bureau of Mines Bulletin 671, Mineral facts and problems, 1980 edition: Washington, D.C., U.S. Government Printing Office, p. 383-394.
——— 1985, Graphite (preprint), U.S. Bureau of Mines Bulletin 675, Mineral facts and problems, 1985 edition: Washington, D.C., U.S. Government Printing Office p. 1-10.
Tichy, L., and Voda, O., 1983, Grafit, *in* Kuzvart, M., ed., Loziska nerudnich surovin CSR: Praha, Univerzita Karlova, p. 39-58.
U.S. Bureau of Mines, 1948, Foreign minerals survey—Mineral resources of China: Washington, D.C., unpublished report.
Vos, M.A., 1982, Industrial mineral studies: Ontario Geological Survey, Summary of fieldwork 1982, Miscellaneous Paper 106, p. 226.
Weis, P.L., 1973, Graphite, *in* Brobst, D.A., and Pratt, W.P., eds., United States mineral resources: U.S. Geological Survey Professional Paper 820, p. 277-283.
Wijayananda, N.P., and Jayawardena, D.E. deS., 1983, Some aspects of the geology of graphite mineralization in Sri Lanka: Institution of Mining and Metallurgy, Transactions, Section B, May, p. B93-B97.
Wijesekera, Nalin, 1984, Mineral exploration in Sri Lanka: Mining Magazine, v. 150, no. 5, p. 464-467.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1988 - 201-933 - 226/80039

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. Natural Graphite (1988)

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
Resource Assessment Division
Bureau of Mineral Resources
P.O. Box 378
Canberra City, A.C.T. 2601
AUSTRALIA

J. Zwartendyk
Director, Resource Evaluation Division
Mineral Policy Sector
Energy, Mines & Resources Canada
580 Booth Street
Ottawa, Ontario K1A OE4
CANADA

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

Ian Goldberg
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

Krauss and others—INTERNATIONAL STRATEGIC MINERALS INVENTORY—NATURAL GRAPHITE—U.S. Geological Survey Circular 930–H