Fluorspar Resources of Africa

GEOLOGICAL SURVEY BULLETIN 1487

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By RALPH E. VAN ALSTINE *and* PAUL G. SCHRUBEN

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Geologic setting, production, reserves, outlook for future supply, and relation of fluorspar deposits to rift structures and carbonatites

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CONVERSION FACTORS

Metric unit		Inch-Pound equivalent
Length		
millimeter (mm)	= 0.03937	inch (in)
meter (m)	= 3.28	feet (ft)
kilometer (km)	= .62	mile (mi)
Area		
square meter (m^2)	= 10.76	square feet (ft^2)
square kilometer (km^2)	= .386	square mile (mi^2)
hectare (ha)	= 2.47	acres
Volume		
cubic centimeter (cm^3)	= 0.061	cubic inch (in^3)
liter (L)	= 61.03	cubic inches
cubic meter (m^3)	= 35.31	cubic feet (ft^3)
cubic meter	= .00081	acre-foot (acre-ft)
cubic hectometer (hm^3)	=810.7	acre-feet
liter	= 2.113	pints (pt)
liter	= 1.06	quarts (qt)
liter	= .26	gallon (gal)
cubic meter	= .00026	million gallons (Mgal or 10^6 gal)
cubic meter	= 6.290	barrels (bbl) (1 bbl=42 gal)
Weight		
gram (g)	= 0.035	ounce, avoirdupois (oz avdp)
gram	= .0022	pound, avoirdupois (lb avdp)
metric tons (t)	= 1.102	tons, short (2,000 lb)
metric tons	= 0.9842	ton, long (2,240 lb)
Specific combinations		
kilogram per square centimeter (kg/cm^2)	= 0.96	atmosphere (atm)
kilogram per square centimeter	= .98	bar (0.9869 atm)
cubic meter per second (m^3/s)	= 35.3	cubic feet per second (ft^3/s)

Metric unit		Inch-Pound equivalent
Specific combinations—Continued		
liter per second (L/s)	= .0353	cubic foot per second
cubic meter per second per square kilometer [$(m^3/s)/km^2$]	= 91.47	cubic feet per second per square mile [$(ft^3/s)/mi^2$]
meter per day (m/d)	= 3.28	feet per day (hydraulic conductivity) (ft/d)
meter per kilometer (m/km)	= 5.28	feet per mile (ft/mi)
kilometer per hour (km/h)	= .9113	foot per second (ft/s)
meter per second (m/s)	= 3.28	feet per second
meter squared per day (m^2/d)	= 10.764	feet squared per day (ft^2/d) (transmissivity)
cubic meter per second (m^3/s)	= 22.826	million gallons per day (Mgal/d)
cubic meter per minute (m^3/min)	=264.2	gallons per minute (gal/min)
liter per second (L/s)	= 15.85	gallons per minute
liter per second per meter [(L/s)/m]	= 4.83	gallons per minute per foot [(gal/min)/ft]
kilometer per hour (km/h)	= .62	mile per hour (mi/h)
meter per second (m/s)	= 2.237	miles per hour
gram per cubic centimeter (g/cm^3)	= 62.43	pounds per cubic foot (lb/ft^3)
gram per square centimeter (g/cm^2)	= 2.048	pounds per square foot (lb/ft^2)
gram per square centimeter	= .0142	pound per square inch (lb/in^2)
Temperature		
degree Celsius (°C)	= 1.8	degrees Fahrenheit (°F)
degrees Celsius (temperature)	=[(1.8×°C)+32]	degrees Fahrenheit

FLUORSPAR RESOURCES OF AFRICA

By RALPH E. VAN ALSTINE and PAUL G. SCHRUBEN

ABSTRACT

Africa is becoming one of the world's leading producers and exporters of fluorspar. This compilation is timely because of the increased amounts of African fluorspar imported by the United States. From 1975 through 1977, imports of African fluorspar increased from 4 percent of our total fluorspar imports to 22 percent, or from about 39,000 to about 199,000 metric tons.

Fluorspar ore, as mined in Africa, averages about 22 percent CaF_2. It is beneficiated into metallurgical, ceramic, or acid grade for the steel, aluminum, ceramic, and chemical industries.

Fluorspar veins are worked in Egypt, Morocco, and South Africa, but manto fluorspar deposits in carbonate rocks are much more productive in South Africa, Kenya, and Morocco. Pipelike bodies of fluorspar have been worked in South Africa and Namibia. Stockworks of fluorspar in granite are mined extensively in South Africa. Fluorite-bearing carbonatites are reported from Angola, Kenya, Morocco, Mozambique, Namibia, South Africa, Tanzania, and Uganda. Fluorite has been reported in 24 of the 115 carbonatites in Africa, but large commercial-grade fluorspar deposits in or associated with carbonatites have been reported only in the Okorusu district of Namibia.

Fluorspar production from Africa through 1976 totals about 3.5 million metric tons. Approximately 88 percent of this total was produced since 1960, and 80 percent originated in South Africa. In 1976, about 83 percent of African fluorspar production was exported.

Estimated African fluorspar reserves of proved and probable ore total about 192 million metric tons and average 22 percent CaF_2. South Africa accounts for about 86 percent of this total and ranks first in world reserves of fluorspar. These reserve estimates for Africa are taken from reports published in 1976 or later.

Africa is able to provide an increasing and a major share of the world's fluorspar supply. South Africa is the only substantial consumer of fluorspar in Africa, and most of the African fluorspar production will continue to be available for export.

Geological conditions are favorable for the discovery of additional large fluorspar deposits. The most promising places to search are in and near carbonatites and alkaline and highly silicic igneous rocks, especially where adjacent rocks consist of readily replaceable limestone or dolomite. The carbonatites and other intrusive bodies are in regions of tension marked by abyssal or subcrustal fractures, rifts, block faults, grabens, and mainly vertical movements. Saline lakes and playas of the rift valleys of Africa may contain fluorine minerals of commercial importance. Fluorine hot springs near the rifts, and also the eroded carbonatites and alkaline and silicic igneous rocks rich in fluorine, contributed fluorine to the basins. Possibly fluorite will be found in Cenozoic tuffaceous lake beds near the rift zones.

INTRODUCTION

Africa is becoming one of the world's leading producers and exporters of fluorspar. In 1977, about 22 percent of the 900,000 t (metric tons) of fluorspar imported into the United States came from Africa. This study is timely because of the increased amounts of African fluorspar exported to the United States, which consumes about 20 percent of the world's annual production of about 5 million metric tons.

In recent years, United States imports of fluorspar from Africa originated chiefly in South Africa (source of 89 percent of our African imports in 1977) and in Kenya, Morocco, and Tunisia. From 1975 through 1977 imports of African fluorspar increased from 4 percent of our total fluorspar imports to 22 percent, or from about 39,000 t to about 199,000 t. African fluorspar production in the past 10 years has increased 4.5 times. In view of these facts, the present study was undertaken to appraise the fluorspar resources of Africa, to examine possibilities of increased production and exports, and to consider the effects of such an increase upon the worldwide fluorspar industry.

This report is a compilation of information from published literature and data in the files of the U.S. Geological Survey. The text, tables, and map, where possible, give the name of the deposit or district, location, geologic environment, resources, grade, and sources of data. The references cited are the publications used in preparing this compilation and are those considered most helpful in appraising areas in Africa that contain fluorspar resources.

In industry, fluorspar ore must contain enough of the mineral fluorite (CaF_2), usually more than 20 percent, to be of commercial interest. Fluorite is 48.7 percent fluorine and 51.3 percent calcium. Its industrial value is due mostly to the fluorine content, and it is the chief source of that element. Fluorspar is used mainly in making hydrofluoric acid, fluorocarbons, and other fluorine chemicals; in manufacturing artificial cryolite and aluminum fluoride for the aluminum industry; as a flux in the steel, iron foundry, and ferroalloy industries; and in the ceramic industry.

Fluorspar, as mined in open pits and underground workings in Africa, averages about 22 percent CaF_2. It is beneficiated generally by heavy-media or flotation processes into metallurgical, ceramic, or acid grade. Metallurgical-grade fluorspar, chiefly for the steel industry, contains at least 60 effective percent CaF_2 (effective percentage of CaF_2 is determined by multiplying the silica percentage in the analysis by 2.5 and subtracting this number from the CaF_2 percentage in the analysis). Much metallurgical-grade fluorspar now comes in the form of pellets or briquets because of their convenience and controlled physical properties and chemical composition. Ceramic grades of fluorspar, used for making pottery, glass, fiberglass, opal glass, and enamels, contain 85–96 percent CaF_2. Acid-grade fluorspar, used by the chemical and aluminum industries, contains at least 97 percent CaF_2.

The price of acid-grade filter cake produced by flotation in South Africa was quoted at $97–$102 a short ton (Engineering and Mining Journal, 1978); however, acid-grade fluorspar exported in 1976 averaged about 57 rands ($66) a metric ton (Gössling, 1978, p. 34), the rand being equivalent to $1.15, (U.S. dollars) in 1978. In the United States, the price for acid-grade and ceramic-grade fluorspar ranges from $95 to $115 a short ton, and that for the metallurgical-grade pellets or briquets, 70 percent effective CaF_2, ranges from $83 to $91 a short ton (Engineering and Mining Journal, 1978).

GEOLOGIC ENVIRONMENTS AND TYPES OF FLUORSPAR DEPOSITS

Fluorite is a fairly soft (hardness of 4 on the Mohs scale) and moderately heavy (sp gr, 3.1) isometric mineral that is generally associated with quartz, chalcedony, calcite, or barite; sphalerite and galena are the most common sulfide minerals in fluorspar deposits. Fluorite occurs in a variety of colors, and ranges from large crystals having cubic, octahedral, or dodecahedral forms to fine-grained material having no crystal faces. The fine-grained material may have earthy, botryoidal, reniform, mammillary, and stalactitic structures. Fluorite in tuffaceous lake beds of Western United States is so fine grained that it can be distinguished only with an electron microscope or X-ray. This type of material in a deposit near Rome, Italy, (Spada, 1969) is about to be worked commercially.

Fluorspar occurs throughout the world in a great variety of geologic environments and types of deposits. Epigenetic fluorspar deposits commonly coincide with regions of low gravity and zones of high heat flow, igneous activity, and hydrothermal effects (Shawe and others, 1976). The tectonic environment consists chiefly of tensional and deep-seated normal fault zones. The most common types of fluorspar deposits in the world are veins; mantos (bedded layers, stratabound, or stratiform); pipelike bodies (including mineralized diatremes and cryptovolcanic structures) and stockworks; contact zones and greisens; pegmatites and carbonatites; disseminated deposits in granites, syenites, volcanic rocks, and tuffaceous lake beds; and residual deposits derived from the weathering of any of the above types. Highly silicic and alkalic igneous rocks are common associates of fluorspar deposits, but any type of rock may be the host rock for the actual deposit; limestone and dolomite are most favorable. At some localities limestone or dolomite has been strongly fractured, veined, or made cavernous by ground water, and ore solutions have deposited fluorite in the open spaces or as replacements of the wall rocks.

Most large concentrations of fluorspar are associated with continental rifts and lineaments throughout the world (Van Alstine, 1976). These structures and fluorspar deposits are of various geologic ages but commonly are of Cenozoic age. Evidently large volumes of fluorine leaked upward from the lower crust or mantle along the rifts and formed the deposits. In Africa fluorspar deposits, ranging in age from Precambrian through Tertiary, are along or near the rift systems, from north to south, in Egypt, Somalia, Uganda, Kenya, Tanzania, Malawi, Mozambique, and South Africa (pl. 1).

Plate 1 shows 76 fluorite localities in 19 countries. Many of these deposits are associated with carbonatites, alkaline intrusive and extrusive rocks, and highly silicic igneous rocks. In South Africa a rift zone projects south from the Great Dyke of Rhodesia, past a swarm of satellite dikes in the Limpopo Belt (Jones and others, 1975), and to the Bushveld Complex. An east-trending arcuate fracture zone connects the Bushveld Complex centers of intrusion (Verwoerd, 1967, p. 282 and fig. 19). Near the intersection of these two Precambrian structures are many intrusions of highly silicic rocks, alkaline rocks, and carbonatites and what may be the largest concentration of fluorspar in the world. The fluorspar mineralization is also considered to be of Precambrian age and related to a late phase of the Bushveld granite. Similarly, fluorite is associated with alkaline rocks, carbonatites, and north-trending or northeast-trending young rifts in eastern and central Africa, in Namibia (South West Africa), and in Angola and is associated with major fault zones in the Atlas Mountains of Morocco and Tunisia.

As shown in table 1, all types of fluorspar deposits described in the preceding paragraphs are in Africa. Table 1 gives selected information on 76 fluorite localities in 19 countries. At present, fluorspar veins actively being mined are in Egypt, Morocco, and South Africa. Mantos or bedded layers of fluorspar in carbonate rocks form large deposits in Kenya, Morocco, and the Marico district of South Africa. Pipelike bodies of fluorspar are exemplified by deposits in the Marico and Kromdraai districts of South Africa and in the Garub deposit of Namibia. Stockworks of fluorspar in granite are mined extensively at the Buffalo Mine in South Africa. Contact zones containing fluorspar are found in Morocco and South Africa. Greisen with fluorite, tin, tantalum, and columbium occurs in Jurassic granite in Nigeria. Pegmatites in Egypt, South Africa, Uganda, and Zaire contain fluorite but not in commercial quantities. Fluorite-bearing carbonatites associated with alkaline intrusive rocks are reported from Angola, Kenya, Malawi, Morocco, Mozambique, Namibia, South Africa, Tanzania, and Uganda. In South Africa, deposits of fluorspar are found disseminated in silicic granite in the Bushveld Complex and disseminated in alkaline intrusive rocks near Pretoria and Pilanesburg. Residual deposits derived from the weathering of stratiform replacement deposits in dolomite have yielded a small amount of fluorspar in the Marico district of South Africa.

TABLE 1.—*Fluorite in Africa*

[Identified on pl. 1 by an italic number]

No. on pl. 1	Mining district or locality	Latitude (approximate	Longitude (approximate)	Geology	Remarks	References
			Algeria			
1	Saharan Hoggar	23°00′ N.	6°30° E.	Fluorite vein with pitchblende in Precambrian silicified granite.		DeKun, 1965.
			Angola			
1	Coola	12°31′ S.	15°16′E.	Fluorite veins, lenticular bodies, and replacements in carbonatite complex.	Fluorite associated with barite, quartz, and iron oxides.	Lapido-Loureiro, 1973.
2	Tchivira	14°19′ S.	13°53′ E.	Fluorite in vugs and disseminated in feldspar-carbonatite rock.	Discovered in 1966.	Do.
			Egypt			
1	Igla, Nabih, Nuweibeh, Abu Dabbab, El Mueilha tin-tungsten deposits.	25°15′ N.	34°35′ E.	Fluorite in quartz veins and pegmatites containing wolframite, cassiterite, and topaz; in Precambrian granitic and metamorphic rocks.	Near east margin of Great Rift system.	Amin, 1947; DeKun, 1965.
			Kenya			
1	Kerio Valley area (Elgeyo-Marakwet, Baringo, and other deposits near Eldoret; also Kamnaon, Chof, and Kimwarer deposits).	0°18′ N.–0°24′ N.	35°35′ E.–35°38′ E.	Fluorspar veins in Miocene volcanic rocks and Precambrian gneisses and replacement deposits in Precambrian crystalline limestone associated with faults of the Rift Valley system; epithermal.	Reserves 6 million metric tons proved, 4 million metric tons probable, 6 million metric tons inferred, all 50 percent CaF_2. Metallurgical-grade production by gravity separation began in 1972. Flotation plant (100,000 t per year). Continental Ore Corp. and Assoc.	Mining Magazine, 1972a; Nyambok and Gaciri, 1975; Reed and Clarke, 1976.
2	Kakamaga-Margoli area	0°10′ N.	34°44′ E.	Fluorite in gold veins near Precambrian granite.		DeKun, 1965.
3	Rata area	0°03′ S.	34°32′ E.	Fluorite in gold-bearing veins in Precambrian rocks.		Do.
4	Homa-Ruri-Rangwa-Sokolo area.	0°31′ S.	34°20′ E.	Fluorite disseminated in carbonatites in Miocene alkaline intrusive rocks.		DeKun, 1965; Tuttle and Gittins, 1966; Le Bas, 1977.

TABLE 1.—*Fluorite in Africa*—Continued

No. on pl. 1	Mining district or locality	Latitude (approximate)	Longitude (approximate)	Geology	Remarks	References
				Malawi		
1	Chilwa Island	15°19′ S.	35°36′ E.	Fluorite layers in carbonatite in alkaline ring complex of Jurassic and Cretaceous age near rift zone.	Several layers 2 m thick, as much as 50 m long, and 25 percent fluorite.	Garson, 1965.
2	Nkalonje	15°34′ S.	35°42′ E.	Fluorite disseminated in carbonatite complex (Jurassic and Cretaceous) near rift zone.	Quartz-fluorite layer 0.3 m thick in brecciated fenite. Explored in 1972 by Reynolds International.	Garson, 1965; Manos, 1977.
3	Songwe	15°40′ S.	35°50′ E.	do	Apatite-fluorite rock in talus. Boulders as much as 0.6 m across, some 75 percent fluorite. Explored by Reynolds International in 1973.	Do.
4	Nsengwa	15°24′ S.	30°44′ E.	do	Quartz-carbonatite, 0.6 m thick, contains as much as 50 percent fluorite.	Garson, 1965
5	Kangkankunde	15°07′ S.	34°55′ E.	Fluorite veins associated with carbonatite complex (Jurassic and Cretaceous) near rift zone; locally containing monazite, pyrochlore, florencite, and bastnaesite.	Quartz-fluorite bodies cut Precambrian marble and adjacent brecciated fenitized gneiss over an area 60×9 m; <10 percent to 50 percent fluorite.	Garson, 1965; Smith, 1956.
				Morocco		
1	Ceuta area	35°54′ N.	5°22′ W.	Fluorite gangue in lead-zinc veins chiefly in Permian limestone.		Morocco Service Géologique, 1969.
2	Chaouene area	35°08′ N.	5°04′ W.	do		Do.
3	Rio Bades-Casualidad area	35°10′ N.	4°07′ W.	do		Do.
4	Melilla area (Providencia deposit).	35°15′ N.	2°57′ W.	Fluorite with opal, gypsum, and montmorillonite disseminated in altered upper Tertiary rhyolite.		DeKun, 1965.
5	Ouezzane area	34°43′ N.	5°40′ W.	Fluorite gangue in lead-zinc vein between Triassic and Eocene beds.		Agard and Morin, 1951.

6	Jebel Tirremi deposit near Taourirt).	34°26′ N.	3°00′ W.	Fluorite veins and massive replacement deposits containing quartz, calcite, barite, and local sulfides in Jurassic limestone cut by Tertiary alkaline intrusive rocks.	Veins as much as 2 m thick contain 85-90 percent CaF_2. Reserves about 1 million metric tons.	Agard and Morin, 1951; DeKun, 1965; Stowasser, 1976.
7	Achèmeche area (El Hammam and other deposits)	33°34′ N.	5°50′ W.	Fluorite veins containing quartz and calcite in Carboniferous limestone belt 11 km long near upper Paleozoic granite; nearby fluorspar veins (Bergamou, Gouaida, and Moufrès South) contain galena, pyrite, and pyrrhotite.	Veins as much as 8 m thick. Proved reserves 3 million metric tons 62 percent CaF_2; probable reserves 2 million metric tons 50 percent CaF_2. Flotation plant (60,000 t per year).	Agard and Morin, 1951; Chermette, 1958; DeKun, 1965; Industrial Minerals 1970b, 1971; Stowasser, 1976.
8	Jebel Zrahina deposit ______	32°52′ N.	5°56′ W.	Fluorite vein in Paleozoic shale between limestone beds near contact with upper Paleozoic granite.	________________________________	Agard and Morin, 1951; Chermette, 1958.
9	Azegour molybdenum mine__	31°10′ N.	8°18′ W.	Fluorite in molybdenum, copper, uranium contact-metamorphic deposit in Paleozoic limestone near granite intrusive rock; accompanied by garnet, amphibole, pyrite, molybdenite, chalcopyrite, scheelite, and pitchblende.	________________________________	Agard and Morin, 1951; Permingeat, 1957.
10	Tamazert ________________	32°30′ N.	4°54′ W.	Fluorite disseminated in carbonatite complex also containing calcite, celestite, strontianite, witherite, barite, apatite, vermiculite, pyrochlore, sulfides, and possibly monazite.	Carbonatites form dikes and irregular masses cutting Liassic limestones of the High Atlas Mountains.	Tuttle and Gittins, 1966.
				Mozambique		
1	Chioco-Djanguire area ______	16°24′ S.	32°35′ E.	Fluorite-quartz veins chiefly in Precambrian gneiss; some veins in basaltic and rhyolitic rocks.	Reserves containing more than 35 percent CaF_2 – known, 71,000 t; probable 95,000 t; possible 532,000 t. Bethlehem Steel and affiliates	Chermette 1964; U.S. Bureau of Mines, 1973; Jolly, 1977.
2	Changara (Mount Domba) area.	16°46′ S.	33°02′ E.	Fluorite-quartz veins along fault between Precambrian basement complex and Cretaceous sandstone and conglomerate.	________________________________	Chermette, 1964; U.S. Bureau of Mines, 1973.
3	Canxixe (Mount Geramo) area southwest of Chemba.	17°38′ S.	34°13′ E.	Fluorite-quartz veins chiefly in Precambrian gneiss and granite; some in basalt and Karroo and post-Karroo sediments.	Reserves of 160,000 t containing more than 35 percent CaF_2. Continental Ore Corp. and affiliates in 1967.	Chermette, 1964.
4	Macossa (Mount Djalira) area.	17°56′ S.	34°12′ E.	Fluorite-quartz veins in Precambrian gneiss and granulite; calcite and chalcedony locally present.	Reserves of 43,000 t containing more than 35 percent CaF_2.	Do.

TABLE 1.—*Fluorite in Africa*—Continued

No. on pl. 1	Mining district or locality	Latitude (approximate	Longitude (approximate)	Geology	Remarks	References
				Mozambique—Continued		
5	Mount Muambe	16°34′ S.	34°12′ E.	Fluorite disseminated in Jurassic(?) carbonatite complex.		Mozambique Serviços de Geologia Minas, 1974.
6	Xiluvo	19°15′ S.	34°04′ E.	Fluorite in vugs in carbonatized volcanic breccia cut by carbonatite.		Heinrich, 1966; Tuttle and Gittins, 1966.
				Namibia (South West Africa)		
1	Okorusu-Marburg area, Otjiwarongo district.	20°06′ S.	16°46′ E.	Fluorite, quartz, apatite, hematite, and titaniferous magnetite replacing Precambrian limestone and ankeritic carbonatite in Precambrian graywacke faulted, brecciated, and domed up around margin of a nepheline syenite plug. Also veins of fluorite and apatite.	Reserves of 8 million metric tons 50 percent CaF_2, 20 percent SiO_2, and 7-15 percent apatite. Another estimate, 10 million metric tons 35 percent CaF_2. Small production of metallurgical-grade fluorspar before 1964. Deposits controlled by South African Steel Corp. and Tsumeb Corp. associated with Bethlehem Steel Corp.	U.S. Bureau of Mines, 1951; Chermette, 1964; Hodge, 1973; Chermette, 1976; Verwoerd, 1967; Heinrich, 1966; Tuttle and Gittins, 1966; Van Zijl, 1962.
2	Arandis area (Steipelmann tin mine).	20°20′ E.	13°50′ E.	Fluorite, cassiterite, and sulfides in pipe in Precambrian limestone.		Sainsbury, 1964.
3	Kohero tin deposit and vicinity.	21°15′ S.	15°35′ E.	Fluorite in 0.3 m vein between tin-bearing pegmatite and Precambrian granite. Fluorite disseminated in pegmatites and quartz-tourmaline-wolframite veins.		Haughton and others, 1939.
4	Omburo deposit	21°15′ S.	16°25′ E.	Fluorite-quartz vein in marble lentils in a pendant in a Precambrian granite massif.	Production began in 1973 from flotation plant, 25,000 t per year capacity. Closed in 1975 by Gypsum Industries of South Africa.	Chermette, 1964; Hodge, 1973.
5	Kuibis (Aukam) deposit	26°48′ S.	16°50′ E.	Fluorspar in irregular veins in Precambrian granite.		Chermette, 1964.

6	Garub deposit, Warmbad district.	27°05′ S.	18°42′ E.	Inclined breccia pipe of fluorspar in Precambrian granite gneiss, associated with galena, chalcopyrite, barite, quartz, and calcite.	Production of about 1,900 t of fluorspar.	Chermette, 1964; Verwoerd, 1967.
			Nigeria			
1	Jos and Bukuru districts-	9°55′ N.	8°48′ E.	Fluorite, cryolite, topaz, pyrochlore, cassiterite, columbite, tantalite, wolframite, and sulfides in stockworks and greisens in Jurassic biotite and riebeckite soda-granites.	----------------------------------	Beer, 1952; Jacobson and others, 1958; Sainsbury, 1969; Orajaka, 1973.
2	Akwan and Arufu lead-zinc deposits.	7°50′ N.	9°12′ E.	Fluorite associated with galena, sphalerite, calcite, siderite, barite, and quartz in veins in Cretaceous limestone.	Deposits in Benue trough, near rift zone.	Farrington, 1952; Orajaka, 1973.
			Somalia			
1	Bihendulah Range deposits.	10°10′ N.	45°08′ E.	Fluorite associated with barite and quartz in veins cutting Precambrian gneiss.	----------------------------------	DeKun, 1965.
			South Africa			
1	Grobbelaars Hoek deposit.	23°18′ S.	28°25′ E.	Veins of fluorite cut by quartz in Bushveld granite of Precambrian age.	----------------------------------	DeKun, 1965.
2	Leeuwbosch lead-fluorspar deposit.	24°28′ S.	27°25′ E.	Veins of fluorite and galena in Precambrian dolomite.	----------------------------------	Do.
3	Rietfontein-Ruigtepoort area.	24°45° S.	27°48′ E.	Veins of fluorite, chlorite, specularite, and quartz in post-Karroo normal faults; quartz-fluorite lenses and pipes in quartz-chlorite greisen in Bushveld granite.	Nearby tin deposits associated with alkaline intrusive rocks have fluorite as a gangue mineral, especially near Rooiberg. Small flotation plant, 25,000 t per year capacity, at Ruigtepoort.	Do.
4	Zwartkloof and other deposits west of Warmbad.	24°36′ S.	28°00′ E.	Veins of fluorite and ankerite in Precambrian felsite; locally containing chalcopyrite, pyrite, and sphalerite.	Deposits in northeast-trending belt 40 km long. Resources of 5 million metric tons 14 percent CaF_2. Flotation plant, capacity of 50,000 t of filter cake per year. Production in 1971, first full year of operation of Zwartkloof mine was 43,000 t; mine closed in 1973 because ore grade was too low.	DeKun, 1965; Industrial Minerals, 1970a, and South African Mining and Engineering Journal, 1970; Jolly, 1976; Crocker and Martini, 1976.

TABLE 1.—*Fluorite in Africa*—Continued

No. on pl. 1	Mining district or locality	Latitude (approximate	Longitude (approximate)	Geology	Remarks	References
				South Africa—Continued		
5	Vischgat deposit	24°33′ S.	28°36′ E.	Veins of fluorite in Bushveld granite, felsite, and pyroclastic rocks.		DeKun, 1965; Engineering and Mining Journal, 1972a, b.
6	Buffalo mine, Buffelsfontein.	24°28′ S.	28°40′ E.	Fluorspar stockworks and veins as much as 0.6 m thick in leptite roof pendants in Bushveld granite; locally associated with monazite, allanite, and bastnaesite.	Reserves of 60 million metric tons 16 percent CaF_2 in five orebodies. Flotation and heavy-media plant with capacity of 150,000 t of filter cake per year.	Holz, 1960; U.S. Bureau of Mines, 1970; Mining Magazine, 1972b; Holz, 1972; Mining Magazine, 1973; Watson and Snyman, 1975; Crocker and Martini, 1976.
7	Marico-Zeerust-Ottoshoop district (Wintershoek, Witkop, Rhenosterfontein, Buffelshoek, Gubbins mine, Oog van Malmanie).	25°42′ S.–25°50′ S.	26°02′ E.–26°08′ E.	Fluorspar mantos, pipes, veins, and irregular bodies replacing Precambrian dolomite; locally containing manganese oxides, sphalerite, galena, pyrite, chalcopyrite, pyrrhotite, tremolite, and talc.	Deposits in zone 60 km long. High-grade bodies worked out; reserves 80–100 million metric tons 15 percent CaF_2. Chemspar Limited (Phelps Dodge) and Marico Fluorspar Ltd. (U.S. Steel Corp.) have flotation plants with capacities of 100,000 t and 170,000 t per year, respectively.	DeVilliers, 1959; Engineering and Mining Journal, 1972b, p. 194; Martini, 1976; Crocker and Martini 1976; Button, 1976 Von Gruenewaldt, 1977.
8	Pilanesberg district (Wydhoek and other deposits).	25°14′ S.	27°05′ E.	Fluorite associated with feldspar and apatite in veins in foyaite alkaline intrusive of the western Bushveld.	At Wydhoek, veins as much as 5 m thick contain fluorite, apatite, and feldspar.	DeVilliers, 1959; DeKun, 1965.
9	Slipfontein deposit	25°05′ S.	27°15′ E.	Fluorite ring in quartz pipe in Bushveld granite.		DeVilliers, 1959.
10	Kromdraai and other deposits southwest of Marble Hall.	25°17′ S.	28°38′ E.	Fluorite pipe containing hematite and manganese oxides in felsite, basalt, and agglomerate of Precambrian age; associated with Bushveld granite.	Kromdraai deposit covers area of 110×64 m; reserves of 20 million metric tons 30 percent CaF_2. Vergenoeg Mining Co. flotation plant, capacity of 95,000 t of filter cake per year.	DeVilliers, 1959; Chermette, 1964; DeKun, 1965; Crocker and Martini, 1976.

11	Pretoria district	25°33′ S.	28°24′ E.	Fluorite, apatite, and pyrite in breccia in volcanic rocks and carbonatite (Roodeplaat) and veins in alkaline intrusive bodies (Walmansthal and Leeuwfontein) of Precambrian age.		DeVilliers, 1959.
12	Hlabisa district, Natal.	28°08′ S.	31°54′ E.	Fluorite-quartz stockworks in early Precambrian granite and post-Carboniferous sandstone, shale, and tillite.	Deposits in belt 19×20 km; some veins several km long. Reserves 400,000 t 35 percent CaF_2.	Kent and others, 1943; DeVilliers, 1959; Chermette, 1964; Crocker and Martini, 1976.
13	Dyasonklip-Kenhardt district.	28°36′ S.–29°24′ S	21°10′ E.–21°12′ E.	Fluorite veins with calcite, chalcedony, galena, and pyrite in quartz-rich breccia zones in Precambrian granite and gneiss.	Mineralized breccia zones as much as 3 m thick; high grade and moderate reserves.	DeVilliers, 1959; Hugo, 1963.
14	Onseepkans-Styerkraal area.	28°50′ S.	19°30′ E.	Fluorite veins and pockets in pegmatites in Precambrian granite; locally associated with scheelite.		DeVilliers, 1959; DeKun, 1965.
15	Richtersveld deposits	28°30′ S.	17°00′ E.	Small deposits of fluorite in limestone near Precambrian granite and in gneiss.		Kent and others, 1943; DeVilliers, 1959.
16	Palabora (Loolekop)	23°40′ S.	31°20′ E.	Fluorite is a minor constituent of magnetite-rich carbonatite of the Palabora Complex, which cuts early Precambrian granite and gneiss.	Carbonatite yields apatite, iron ore, vermiculite, calcite, and copper.	Verwoerd, 1967; Heinrich, 1966; Tuttle and Gittins, 1966.
17	Glenover	23°50′ S.	27°24′ E.	Veins containing fluorite, barite, quartz, calcite, dolomite, pyrite, and specularite cut dolomitic carbonatite. Fluorite disseminated in apatite in phosphate breccia.	Veins average 0.3 m in thickness. Carbonatite is mined for phosphate.	Verwoerd, 1967; Tuttle and Gittins, 1966.
18	Goudini	25°05′ S.	26°20′ E.	Veinlets of fluorite, calcite, and rutile cut ankeritic carbonatite. Fluorite streaks in carbonatite dikes. Fluorite-dolomite veins.		Do.
19	Kruidfontein	25°12′ S.	27°25′ E.	Fluorite disseminated in carbonatite dikes and irregular bodies. Fluorite-barite veins cut brecciated banded ironstone.		Verwoerd, 1967; Heinrich, 1966; Tuttle and Gittins, 1966.

Southern Rhodesia

1	Tinde deposit, Wankie district.	18°19′ S.	27°06′ E.	Fluorite veins and fluorite-quartz-chalcedony veins in Precambrian granite.	About 3 km of strike length of veins known in 1968; 600 m explored, average width of 5 m. Proved reserves 200,000 t.	DeKun 1965; Mining Journal, 1968; Minos, 1978.

TABLE 1.—*Fluorite in Africa*—Continued

No. on pl. 1	Mining district or locality	Latitude (approximate	Longitude (approximate)	Geology	Remarks	References
				Sudan		
1	Jebel Semeih deposit	12°44′ N.	30°50′ E.	Fluorite associated with quartz in veins, joints, and irregular patches in silicic granitic rock of Precambrian age.	Discovered in 1935. One quartz-fluorite vein, 123 m long and 7 m wide, contains 11–42 percent CaF_2, 56–86 percent SiO_2, and less than 1 percent $CaCO_3$. Reserves 100,000 to 300,000 t.	Sudan Geological Survey, unpub. rep., 1972; Whiteman, 1971, p. 19–20.
2	Jebel Dumbeir deposit	12°35′ N.	30°48′ E.	Fluorite veins in fractured and faulted Precambrian slate, quartzite, marble, hornblende syenite, and red soda granite; genetically associated with the red soda granite. Fluorite also replaces marble, impregnates quartzite, and is disseminated in red soda granite and hornblende syenite.	Discovered in 1971. Veins, 25 cm to 5 m thick, contain as much as 95 percent CaF_2 and less than 1 percent each of $SiO_2$and $CaCO_3$. Fluorite disseminations and impregnations contain less than 2 percent CaF_2. Reportedly associated with carbonatite.	Sudan Geological Survey, unpub. rep., 1972; Whiteman, 1971, p. 19–20; Vail, 1978, p. 52.
				Swaziland		
1	Hlatikulu deposite	27°00′ S.	31°18′ E.	Fluorite-chalcedony-quartz-opal veins 0.3–1.5 m thick in Precambrian granite gneiss; fluorite in tin and molybdenum deposits nearby.	Reserves of 1,600 t	DeKun, 1965.
				Tanzania		
1	Mbeya deposits (Panda Hill and Sengeri Hill)	8°59′ S.	33°14′ E.	Fluorite, pyrochlore, columbite, magnetite, cassiterite, barite, and sulfide deposits in carbonatite (Jurassic) in explosion vent and outer ring-dike of extinct volcano (Panda); accompanied by alkaline intrusive rocks and next to rift valley.	Fluorite veins cut carbonatite dikes at Sengeri Hill.	Fawley and James, 1955; Heinrich, 1966.
2	Ngualla	7°44′ S.	32°42′ E.	Fluorite in carbonatite dikelets and in veins containing quartz, calcite, barite, chalcopyrite, and galena.		Heinrich, 1966; Tuttle and Gittins, 1966.
				Tunisia		
1	Djebel Sidi Abiod, Cap Bon.	37°02′ N.	10°02′ E.	Fluorite prospect in Tertiary sedimentary rocks.		U.S. Bureau of Mines, 1953.

2	Zaghouan area (Hammam Zriba, Djebilet el Kohol, Djebel Staa, Djebel Ouest, and Hammam Djedidi deposits).	36°24′ N.	10°08′ E.	Fluorite veins and manto, or stratiform, replacement deposits in Jurassic and Liassic limestones near major fault zone; locally associated with barite, celestite, galena, or sphalerite. Manto deposits contain 17–53 percent CaF_2.	Hammam Zriba replacement deposit traced about 2 km; 1–7 m thick; proved reserves of 6 million metric tons at 50 percent CaF_2. For area, proved, probable, and possible reserves of 10 million metric tons. Two flotation plants (50,000 and 5,000 t per year). Industrie Chemique de Fluor, Reynolds International and Associates.	U.S. Bureau of Mines, 1953; Sainfeld, 1956; Chermette, 1958; U.S. Bureau of Mines, 1972; Hodge, 1973; Thibieroz, 1974; Merwin, 1976.
3	Bou Jaber deposit	35°45′ N.	8°23′ E.	Fluorite and barite in Cretaceous limestone.		Sainfeld, 1956.
				Uganda		
1	Singo deposits	0°40′ N.	32°00′ E.	Fluorite associated with tungsten in Precambrian pegmatites.		DeKun, 1965.
2	Mubende deposits	0°34′ N.	31°24′ E.	Fluorite in Precambrian granite		Do.
3	Buswale deposits	0°23′ N.	33°54′ E.	Fluorite in Precambrian granite		Do.
4	Bukusu	0°50′ N.	34°18′ E.	Fluorite disseminated in calcite carbonatite and in veins cutting it.		Heinrich, 1966.
5	Tororo	0°42′ N.	34°12′ E.	Fluorite disseminated in calcite carbonatite.		Heinrich, 1966; Tuttle and Gittins, 1966.
				Zaire		
1	Wanie-Rukula	0°12′ N.	25°36′ E.	Fluorite in Triassic limestone		DeKun, 1965.
2	Mokama	2°37′ S.	26°08′ E.	Fluorite in tungsten-tin veins and pegmatites in Precambrian granite.		Do.
3	Kamituga district, Kibukira Mountain region.	3°04′ S.	28°06′ E.	Fluorite in gold veins containing pyrite, arsenopyrite, apatite, chlorite, zoisite, and garnet in Precambrian rocks.		Do.
4	Kakontwe	10°59′ S.	26°40′ E.	Fluorite in Precambrian limestone		Do.
				Zambia		
1	Kariba	16°25′ S.	28°47′ E.	Fluorite, feldspar, and amethyst in veins cutting Precambrian gneiss on fault block between two major normal faults.	Very small production began in 1973.	Hitchon, 1957.

The deposits range in size from mere occurrences of fluorite to the deposits of the Marico district, South Africa, which contain more than 80 million metric tons of fluorspar ore (about 13.5 million metric tons of CaF_2) and may be the largest fluorspar deposit in the world. Table 1 gives reserve figures for many of the deposits, and plate 1 shows by size of the symbols whether a fluorspar deposit is large (>1 million metric tons), medium (1,000,000–50,000 t), or small (< 50,000 t). A medium-size deposit in Africa might have about 100,000 t of contained CaF_2, which is slightly less than 10 percent of the tonnage consumed annually in the United States. Plate 1 shows few medium-size deposits, which are all veins or stockworks and pipes; their scarcity probably results from the lack of exploration and development work at many of the small deposits shown or from the lack of published information.

The nine large deposits are in South Africa (Marico, Buffalo, Kromdraai, Zwartkloof), Namibia (Okorusu), Kenya (Kerio Valley), Morocco (El Hammam, Jebel Tirremi), and Tunisia (Zaghouan). These major deposits occur as mantos or replacements, veins, or stockworks and pipes.

FLUORSPAR PRODUCTION AND EXPORTS

Fluorspar mining on a large scale in Africa is a relatively young and

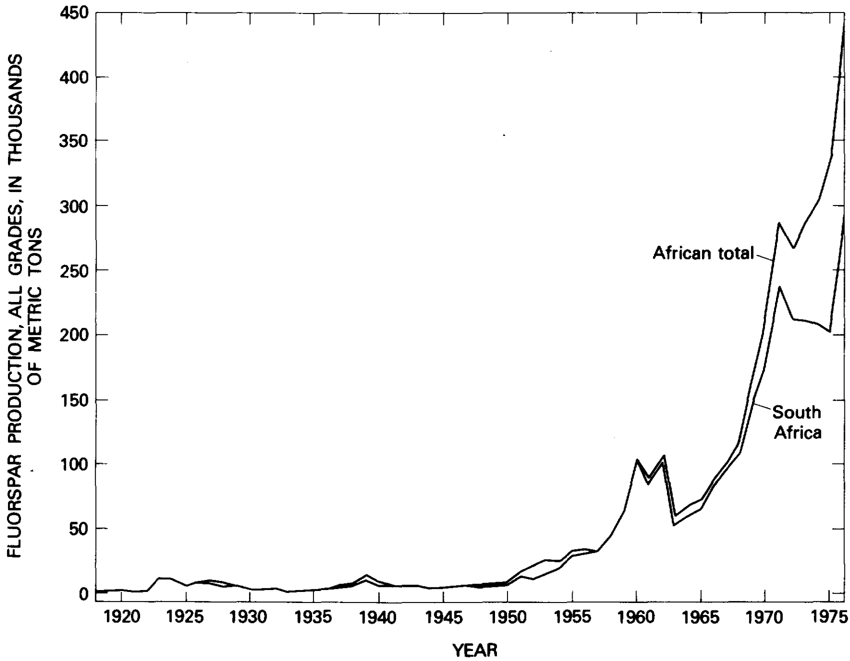

FIGURE 1.–Comparison of fluorspar production from South Africa with total African fluorspar production, 1918–76.

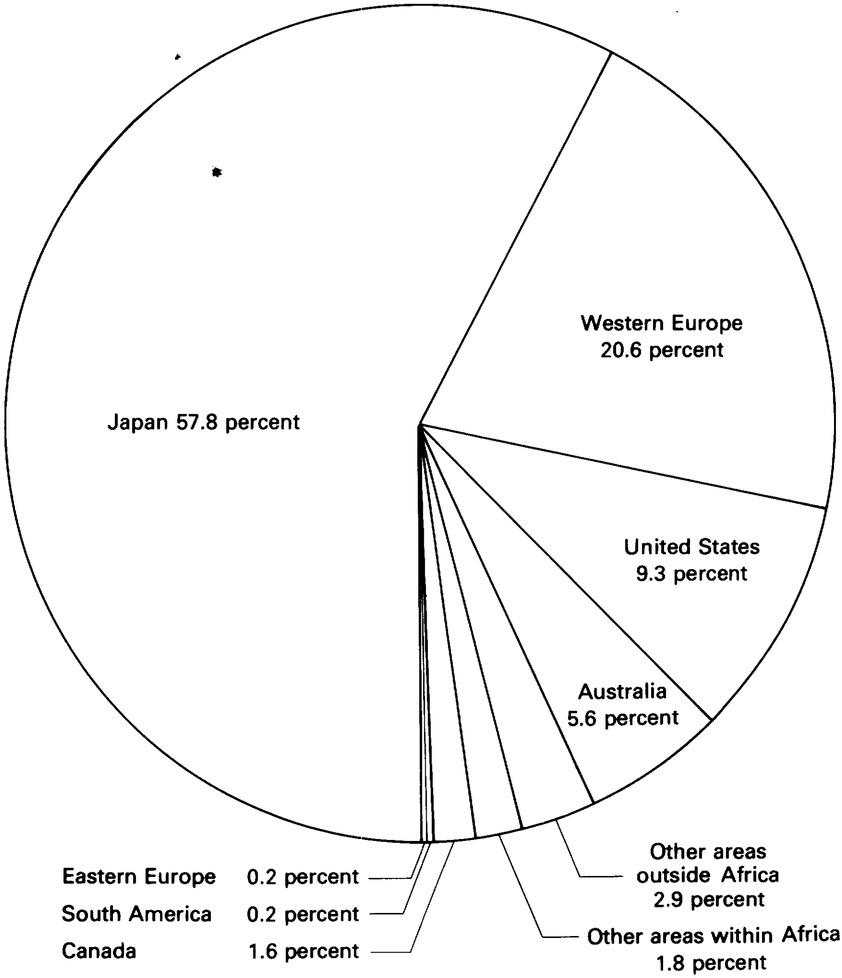

FIGURE 2.—African fluorspar exports 1958–73 by area of destination.

growing industry (see table 2); production is expected to increase. African production began in 1918 in the Zeerust area of South Africa but did not exceed an annual rate of 100,000 t until 1960 (fig. 1). Fluorspar production from Africa through 1976 totals about 3.5 million metric tons. Approximately 88 percent of this total was produced since 1960, and 80 percent originated in South Africa. About 83 percent of African fluorspar production in 1976 was exported. Figure 2 shows the destination of African fluorspar exports between 1958 and 1973. Fluorspar production in Africa in 1976 amounted to 453,115 t, about 10 percent of the world output. South African fluorspar production in 1976 was 290,718 t or about 6 percent of the world production, as com-

TABLE 2.—*Selected data on African fluorspar production through 1976*

[Most of the data are from the U.S. Bureau of Mines, Mineral Resources of the United States, 1925–31, and Minerals Yearbooks, 1932–75. Short tons converted to metric tons]

Country	Productive years	Total production (metric tons)	Year of maximum production	Maximum annual production (metric tons)	Percent exported in 1974
Egypt	1970–76	6,797	1973	1,509	0.0
Kenya	1968–76	239,116	1976	75,027	96.2
Morocco	[1]1948–76	148,018	1976	51,450	28.9
Namibia	[1]1927–63	18,317	1952	4,418	.0
South Africa	1918–76	2,836,137	1976	290,718	59.5
Southern Rhodesia	[1]1938–76	5,583	1956	855	.0
Tunisia	[1]1937–76	291,609	1973	46,600	90.3
Zambia	1973–76	969	1975	499	.0
Total	-------	3,546,546	----	------	---

[1]Intermittent.

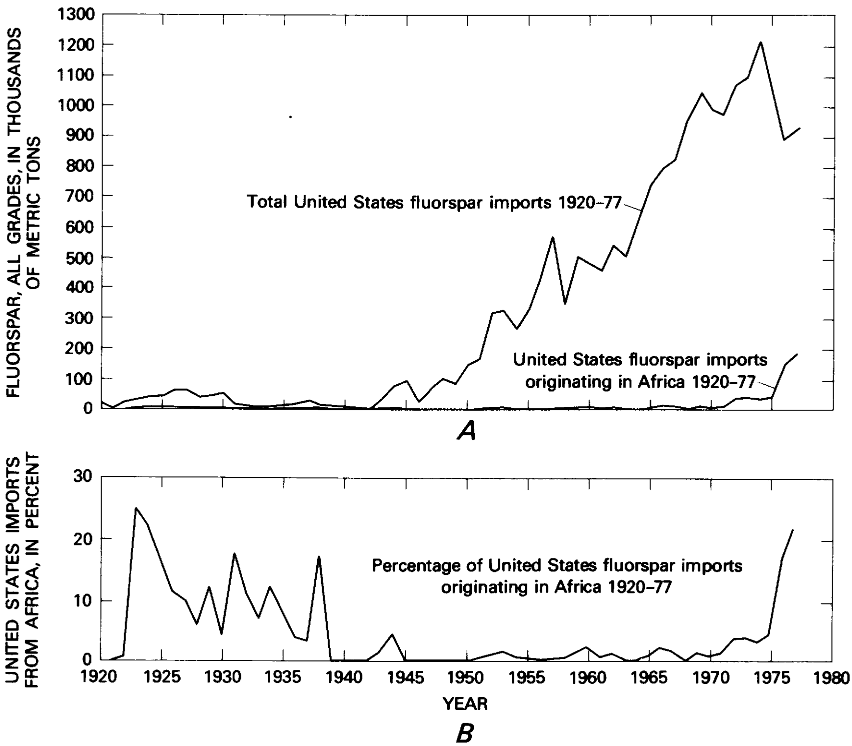

FIGURE 3.—Amount of fluorspar imported by the United States. *A*, Total imports of fluorspar; imports of fluorspar from Africa. *B*, The percentage of imports of fluorspar from Africa, 1920–77.

pared with United States production of about 169,000 t in that year.

Figure 3 shows the total U.S. imports of fluorspar, U.S. imports of fluorspar from Africa, and the percentage of U.S. imports of fluorspar from Africa for the years 1920 through 1977. The sharp increase in our fluorspar imports from Africa since 1975 is impressive and reflects our greater reliance upon South Africa as a source.

FLUORSPAR RESERVES

Estimates of African fluorspar reserves of proved and probable ore total about 192 million metric tons, averaging 22 percent CaF_2. South Africa accounts for about 86 percent of this total and ranks first in world reserves of fluorspar. These estimates are taken from reports published in 1976 or later and are shown by country and district in table 1. Table 3 shows the estimates of combined proved and probable, and also possible, fluorspar ore reserves by country.

The total reserves,when calculated as 35 percent CaF_2 or equivalent, are about 40 percent of the fluorspar reserves of the world, although most world reserve figures do not include estimates for fluorspar deposits averaging much lower than 30 percent CaF_2. The large size of some South African deposits and the low production costs permit large-scale mining of reserves that are of a lower grade than can be mined elsewhere. According to a Stanford Research Institute estimate, the cost in South Africa to produce one ton of acid-grade concentrate from a low-grade fluorspar ore is $55 compared with a cost of $94 in the United States (Quan, 1978, p. 20–21).

The African deposits are not described in the literature in sufficient detail to evaluate these reserve estimates or to make estimates of other categories of fluorspar resources.

TABLE 3.—*African fluorspar reserves, in millions of metric tons*

Country	Proved and probable ore	Percentage of total	Possible ore	Approximate grade (percent CaF_2)
Kenya	10	5.2	6	50
Morocco	6	3.1	2	50
Mozambique	.4	.2	.5	35
Namibia	6	3.1	2	50
South Africa	[1]160.4	83.3	41	17
Tunisia	9	4.7	3	50
Others [2]	.7	.4	.3	35
Totals	192.5	100.0	54.8	--
Average grade	-----	----	---	22

[1] Compares with 157 million metric tons of measured ore reserves containing 20 percent CaF_2 estimated by Gössling (1978).

[2] Chiefly Southern Rhodesia and Sudan.

OUTLOOK FOR FUTURE SUPPLY

Africa is able to provide an increasingly significant share of the world's fluorspar supply. The extensive reserves of proved and probable ore are equivalent to about a 75-year supply at the 1976 rate of production, although the largest deposit, the Marico district, South Africa, probably will not be depleted during that period. Geological conditions are favorable for the discovery of additional major deposits.

Until steel, aluminum, and fluorine chemical industries are developed in more African countries, most of the African fluorspar will continue to be available for export. South Africa, the only substantial consumer of fluorspar in Africa, in 1976 used only about 39,000 t.

An annual growth rate for African fluorspar production cannot be reliably predicted, even for the next few years, mainly because of worldwide recession, decreasing production of fluorocarbons for aerosol use, decrease in use of fluorides in the aluminum industry, and the growing use of fluorine from phosphate rock. The capacity of existing fluorspar plants in Africa is about 755,000 t of fluorspar per year (table 1). This capacity would permit a possible increase in production of about 60 percent above the 1976 rate. Gössling (*in* Industrial Minerals, 1979) predicted that the South African fluorspar industry will continue expansion over the next 7 years to an annual production level of 560,000 t, that 85–90 percent will be exported, and that South Africa will become the world's largest fluorspar producer.

Increased production and exports of lower-cost fluorspar from Africa probably will have adverse effects upon the world fluorspar industry. Some smaller higher-cost mining operations may be closed, unless demand for fluorspar grows at a faster rate. World demand for fluorspar should increase as economic conditions improve and as developing countries require a fluorspar supply for any new steel, aluminum, or fluorine chemical industries.

SEARCH FOR ADDITIONAL DEPOSITS

The most promising places to search for new deposits in Africa are near the major deposits and in the areas having the most numerous deposits (pl.1). Areas near carbonatites, alkaline and highly silicic igneous rocks, and adjacent rocks, especially where there may be readily replaceable carbonate rocks, are the most favorable sites for large deposits containing more than 1 million tons of fluorspar. The areas of carbonatites and other alkaline extrusive and intrusive bodies commonly are in regions of tension marked by abyssal or subcrustal fractures, rifts, block faults, grabens, and mainly vertical movement (Mitchell and Garson, 1976).

Carbonatites are more abundant in Africa than in any other continent. Africa has about three times more deposits than does Asia, the continent in second-place (Heinrich, 1966). Fluorite has been reported in 24 of the 115 carbonatite localities of Africa shown on plate 1. Probably careful search of the other 91 carbonatite localities would increase the number of known localities that are associated with fluorite, possibly some containing commercial deposits. Most of the list of carbonatite localities (table 4) was obtained from publications by Pecora (1956), Smith (1956), Garson (1965), Heinrich (1966), Tuttle and Gittins (1966), Verwoerd (1967), Lapido-Loureiro (1973), Blanchot (1975), and Le Bas (1977).

The only extensive fluorspar deposit of commercial grade associated with carbonatites in Africa is the Okorusu deposit in Namibia (Van Zijl, 1962), but other carbonatites also contain fluorite and are considered to be possible sources of commercial fluorspar. Carbonatites of Africa may also contain valuable deposits of pyrochlore (a fluoroniobite of calcium and sodium), phosphate, vermiculite, calcite, barite, nepheline, strontianite, thorium, uranium, rare earths, titanium, magnetite, copper, and zirconium. The fluorite may occur in vugs, layers, and disseminated in the carbonatite or adjacent rocks; in late-stage replacement deposits in carbonatite, alkaline intrusive rock, or country rock; or in veins containing quartz, calcite, barite, apatite, and sulfide minerals. Fluorine minerals, other than fluorite, found in carbonatites include pyrochlore, fluorapatite, fluorphlogopite, bastnaesite, and sellaite (MgF_2).

Carbonatites occur in alkaline petrologic provinces and in Africa range in age from Precambrian to Holocene. They are generally small bodies compared with other masses of igneous rock, but because they commonly are circular or elliptical domed features rising above the surrounding terrain, most should be detectable on aerial photographs or satellite imagery. Probably many more carbonatites and fluorspar deposits will be found in Africa, for much of the continent has not been geologically mapped in detail, and in large areas, the bedrock is concealed by wind-blown sand and other surficial deposits.

Le Bas (1977) recognized the following four-stage sequence of intrusions in the formation of carbonatites: (1) magmatic sövitic carbonatite consisting of coarse-grained calcite; (2) minor intrusions of alvikitic carbonatite consisting of fine-grained ferroan calcite, apatite, magnetite, limonite, and goethite; (3) ferruginous dark-colored carbonite containing fluorite; and (4) low-temperature veins of calcite carbonatite containing fluorite, barite, and quartz. Fluorite may have formed in any of the four stages, but deposits of commercial quantity and grade most likely formed during the last two stages.

Alkaline petrologic provinces of Africa, in which carbonatites or fluorite deposits have not yet been reported to be associated with the alkaline rocks, are found in Chad, Ethiopia, Malagasy Republic, Mali, Niger, and Somalia (Beer, 1952). Alkaline igneous rocks were reported

TABLE 4.—*Carbonatite localities of Africa*

[Italics indicate that fluorite has been reported with the carbonatites]

ANGOLA

1. Cuacra
2. Catanda
3. Capuia
4. Bailundo
5. Monte Verde
6. *Coola*
7. Chianga
8. Longonjo
9. Capunda
10. Bonga
11. *Tchivira*
12. Virulundo
13. Morro Vermelho
14. Lupongola (Chitado)

ETHIOPIA

1. Bishoftu

KENYA

1. Tinderet
2. Buru
3. *Homa*
4. *Rangwa*
5. *Ruri*
6. *Sokolo*
7. Mrima

MALAWI

1. Lake Malombe vents
2. Kadongosi
3. Chaumbwi
4. Nailuwa
5. *Kangankunde*
6. Kalambo Stream
7. Mongolowe
8. Palula
9. Kapiri
10. Mtsimukwe
11. *Chilwa Island*
12. *Nsengwa*
13. Tundulu
14. *Nkalonje*
15. *Songwe*
16. Bangala
17. Namangali

MALI

1. Adrar Tadhak

MAURITANIA

1. Richat
2. Tabrinkout
3. Akjoujt
4. Legleitat

MOROCCO

1. *Tamazert*

MOZAMBIQUE

1. Lipuche
2. Cone Negose
3. *Muambe*
4. Chuara
5. Chandava
6. *Xiluvo*
7. Cura

NAMIBIA

1. Swartbooisdrif
2. Epembe
3. *Okorusu*
4. Ondurakorume
5. Kalkfeld
6. Osongombo
7. Brukkaros
8. Chamais

SOMALIA

1. Darkainle

SOUTH AFRICA

1. *Palabora (Loolekop)*
2. *Glenover*
3. Magnet Heights
4. Spitskop
5. Nooitgedacht
6. *Goudini*
7. *Kruidfontein*
8. Bulhoek
9. Tweeriver
10. Zoutpan
11. *Roodeplaat*
12. Derdepoort
13. Salpeterkop

SOUTHERN RHODESIA

1. Katete Hill
2. Dorowa
3. Shawa
4. Chishanya

TANZANIA

1. Mosonik
2. Oldoinyo Lengai
3. Kerimasi
4. Sadiman
5. Meru
6. Burko
7. Monduli-Arusha
8. Oldoinyo Dili

TABLE 4.—*Carbonatite localities of Africa*—Continued

TANZANIA—Continued

9. Essimingor
10. Galappo
11. Basotu
12. Hanang and Balangida
13. Sangu
14. Wigu Hill
15. Maji Ya Weta
16. *Ngualla*
17. Luhombero
18. Songwe Scarp
19. Musensi
20. *Mbeya (Panda and Sengeri)*
21. Nachendazwaya

UGANDA

1. Toror Hills
2. Napak
3. Lolekek
4. Budeda
5. *Bukusu*
6. Fort Portal
7. *Tororo*
8. Sukulu

ZAIRE

1. Bingu
2. Lueshe
3. Kawezi

ZAMBIA

1. Nkombwa
2. Kaluwe
3. Nachomba
4. Mwambuto
5. Chasweta

in about 80 percent of the 19 African countries having fluorite deposits (table 1). The alkaline rocks include nepheline syenites, foyaites, syenites, ijolites, fenites, and riebeckite granites. The riebeckite granites and other alkaline granites of Nigeria contain a variety of fluorine minerals, including accessory fluorite, cryolite, thomsenolite, topaz, pyrochlore, and riebeckite; there has been no production of fluorspar there, but cassiterite and columbite have been recovered from the decomposed granite (Williams and others, 1956).

Saline lakes and playas of the rift valleys of Africa may contain fluorine minerals of commercial importance. Fluorine hot springs near the rifts, hydrothermal solutions, and also the eroded carbonatites and associated alkaline and silicic intrusive and extrusive rocks rich in fluorine may have contributed fluorine to the basins. Saline water from Lakes Hannington, Magadi, Nakuru, and Elmenteita, all in the rift valley of southwestern Kenya, contain 1,170, 1,270, 1,400, and 1,627 parts per million of fluorine, respectively (Baker, 1958, p. 58; Hay, 1966, p. 33). Lake Magadi has large commercial deposits of trona that locally contains as much as 22 percent villiaumite (NaF) and 6 percent fluorite (Sheppard and Gude, 1969, p. D73). Possibly fluorite will be found in an environment of Cenozoic tuffaceous lake beds near the rift zones; deposits of this type occur in Pleistocene sediments near Rome, Italy (Spada, 1969), some beds averaging 55 percent CaF_2, and in Pliocene beds of lower grade near Rome, Ore., (Sheppard and Gude, 1969) and Eastgate, Nev. (Sheppard and Gude, 1976).

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