

Asbestos in South Africa*

by H.P. HART†

SYNOPSIS

After a brief account of the history of asbestos, this paper reviews the types and characteristics of asbestos and its occurrence in the world (mainly the USSR, Canada, and South Africa). The types of asbestos mined in South Africa are discussed, as are its primary applications.

Asbestos production in South Africa is detailed in relation to that of the rest of the world, and the mining and extraction techniques are described. The main mining operations in South Africa are then described, and this is followed by a discussion of the health hazards associated with asbestos and the ways in which they are combated.

The review ends with an account of the methods used to rehabilitate the environment in asbestos-mining areas, and a brief discussion of the short- and long-term prospects for asbestos.

SAMEVATTING

Na 'n kort verslag oor die geskiedenis van asbes gee hierdie referaat 'n oorsig oor die soorte asbes en die eienskappe daarvan asook die voorkoms van asbes in die wêreld (hoofsaaklik in die USSR, Kanada en Suid-Afrika). Vervolgens word die soorte asbes wat in Suid-Afrika ontgin word en die primêre aanwendings daarvan, bespreek.

Asbesproduksie in Suid-Afrika word uiteengesit in verhouding tot dié in die res van die wêreld en die ontginnings- en ekstraksietegniese word beskryf. Daarna word die vernaamste ontginningsbedrywighede in Suid-Afrika beskryf en dit word gevolg deur 'n bespreking van die gesondheidsgevaare verbonde aan asbes en die maniere waarop hulle bekamp word.

Die oorsig eindig met 'n verslag oor die metodes wat gebruik word om die omgewing in gebiede waar asbes ontgin word, te rehabiliteer en 'n kort bespreking van die lang- en korttermynvooruitsigte vir asbes.

HISTORY

Asbestos is not only one of the most widely used minerals known to man, it is also one of the oldest. It was already in use more than 2000 years ago in China, Egypt, and Greece, and its name—derived from the Greek for 'inextinguishable flame'—indicates one of its earliest applications: as a virtually indestructible wick for oil lamps. (This fireproof quality is still one of its most useful characteristics.)

In the early days, asbestos was a curiosity rather than a commercial product, and was used mainly by the rich. Reports dating back to AD 79 indicate that shrouds of asbestos were used in royal cremations to preserve the ashes, and it is believed that the emperor Charlemagne had an asbestos cloak in the ninth century. Marco Polo came across fire-resistant cloth made from asbestos during his travels in the East in the thirteenth century, and it was apparently the Chinese who re-introduced the mineral to Europe when a merchant exhibited an asbestos handkerchief to the Royal Society in London in 1676.

Commercial production of asbestos began in earnest in the 1850s, at the height of the industrial revolution. Demand for the mineral increased rapidly, particularly in response to the need for insulation materials for steam engines. In 1860, large deposits of asbestos were found in Canada and, as the search for what was then hailed as a 'miracle fibre' spread wider, deposits were also found

in Russia, Italy, and Cyprus. In the early years of this century, asbestos was also found in South Africa and what is now Zimbabwe.

Asbestos mining in South Africa began in earnest in the 1930s. In the following decades, it attracted a multitude of big and small companies, and even individuals. Mining and production methods were crude, with the fibre being separated from the ore by hand, and in some cases the 'mines' were literally spade-and-wheelbarrow operations run by farmers who had found deposits on their land.

By 1981, the foreign companies had withdrawn from active asbestos mining in South Africa, and a long series of mergers and acquisitions had reduced the number of major producers to two: The Griqualand Exploration & Finance Company (Gefco) and Msauli Asbes. Gefco produces the amphiboles crocidolite and amosite—commonly known as blue and brown asbestos—in the north-western Cape and in the north-eastern Transvaal. Msauli produces chrysotile, or white asbestos, in the KaNgwane homeland near Barberton.

TYPES AND CHARACTERISTICS OF ASBESTOS

Asbestos is a generic name for six naturally occurring asbestiform or fibrous minerals from the amphibole and serpentine group of rock-forming minerals. Chrysotile (white asbestos) is the only fibrous form of serpentine, but is by a very wide margin the most abundant and widely distributed of all the asbestiform minerals throughout the world. The asbestiform varieties of minerals belonging to the amphibole group are crocidolite (blue) after riebeckite; and amosite (brown) after grunerite. Another fibrous amphibole mineral, anthophyllite, has been used

* In view of the popularity of our Metal Review Series of papers, which are still being published from time to time, we shall be publishing a series of Mineral Reviews. This is the first paper in the Mineral Review series.

† The Griqualand Exploration & Finance Co. Ltd, P.O. Box 10505, Johannesburg 2000.

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as asbestos but today is of little importance. The amphiboles tremolite and actinolite may be fibrous and are sometimes regarded as asbestos, but neither is of commercial significance.

The chemical compositions of the four most important asbestos minerals are as follows:

<i>Chrysotile</i> $\text{Mg}_3[(\text{OH})_4\text{Si}_2\text{O}_5]_2$	Hydrated magnesium silicate
<i>Crocidolite</i> $\text{Na}_2\text{Fe}_3[(\text{OH})\text{Si}_4\text{O}_{11}]_2$	Complex sodium-iron silicate
<i>Amosite</i> $\text{MgFe}_6[(\text{OH})\text{Si}_4\text{O}_{11}]_2$	Iron-magnesium silicate
<i>Anthophyllite</i> $(\text{Mg},\text{Fe})_7[(\text{OH})\text{Si}_4\text{O}_{11}]_2$	Magnesium silicate with variable iron.

The asbestos minerals are products of metamorphism. They occur in narrow veins as 'cross fibre' extending from wall to wall, or as 'slip fibre' roughly parallel to the vein walls. 'Mass fibre' is an aggregate of variously oriented fibres, commonly in radial arrangement.

Amphibole asbestos differs radically from the other major variety of asbestos—the serpentine-group mineral chrysotile—in structure, chemistry, and physical properties.

About 95 per cent of the world's production of asbestos is the chrysotile variety. The mineral occurs in veinlet form in green massive serpentinite as a silky cross fibre. The length of the fibre depends on the width of the vein and rarely exceeds 12 mm. Chrysotile-bearing veins commonly occur as a complex stockwork and extend throughout the serpentinite host rock.

Crocidolite asbestos occurs predominantly as laterally continuous cross-fibre seams, and ranges in thickness from 3 to 150 mm. These seams lie parallel to the banding in the banded iron formation host and, although laterally continuous over many metres, normally have lenticular terminations. Slip and distorted fibre are occasionally found in areas affected by strong structural deformation.

Amosite, a commercial name derived from the initial letters Asbestos Mines of South Africa, is found mainly in well-developed cross-fibre seams interlayered with the host banded iron formations. Amosite tends to occur as considerably longer fibres than those of any other type of asbestos. The fibre length averages between 10 and 40 mm, some being up to 300 mm in length in certain reefs in the Penge area. The distribution of fibres within the individual bands is jagged or wavy, with dog-toothed structures common throughout.

Asbestos-bearing formations are widely distributed in the earth's crust. Commercial deposits of asbestos are associated with four groups of rock formations:

- Alpine-type ultramafic rocks, including ophiolites, as in the chrysotile of eastern North America and California, the USSR, the Italian Alps, New South Wales (Australia), and Cyprus
- Stratiform ultramafic intrusions as in the chrysotile of the Transvaal, Swaziland, and Zimbabwe

- Banded ironstone as in the amosite of the Transvaal and the crocidolite of the Cape Province
- Serpentinized dolomitic limestone as in Arizona and the Transvaal.

The various types of asbestos are extremely important industrial minerals. The essential requirements are that the fibres should be easily separable, soft, and flexible, and at the same time possess a fairly high tensile strength. Other desirable properties are incombustibility, and resistance to heat, acids, and various chemical solutions.

Chrysotile's important physical properties and its resistance to heat and tensile strength render the fibre suitable for spinning and weaving. The commodity is most commonly used for asbestos textiles, friction linings and facings, and asbestos-cement and insulation products.

Crocidolite is characterized by high tensile strength, acid resistance, and harshness in wet mix. Long-fibre crocidolite is woven into fabrics that are used for boiler lagging, acid-resistant packings, and gaskets. The principal use of the shorter crocidolite fibres is in the manufacture of asbestos-cement products.

Amosite is unsurpassed among asbestos as regards length of fibre. Its resistance to acids and sea-water is greater than that of chrysotile, and it fuses at a much higher temperature than crocidolite. However, it is somewhat more brittle than either of these. It is used in blanket form for felted insulation in high-temperature applications. In compacted form, it is applied as a covering for marine turbines, jet engines, and similar applications. More recently, amosite has also found application in the asbestos-cement industry.

OCCURRENCE OF ASBESTOS WORLDWIDE

The world's known asbestos reserves (Table I) are located mainly in Canada and the USSR, with smaller fibre reserves reported from South Africa, Brazil, Zimbabwe, Italy, China, Greece, the USA, Swaziland, Cyprus, Turkey, Columbia, Japan, North Korea, Bulgaria, Australia, and Egypt.

Asbestos production is dominated by the USSR and Canada, which together account for almost 70 per cent of the world's supply. All but 5 per cent of the asbestos produced is chrysotile, the South African production of crocidolite and amosite making up the balance, as shown in Table II.

USSR

Most of the chrysotile deposits in the USSR are associated with ultrabasic rocks, with a small percentage found in dolomite. The most important deposits are in the south-central and southern Ural mountains in the Sverdlovsk region, which account for more than half of the Soviet output. Other occurrences of asbestos are located in the Kustanay region of the Kazakh SSR and the Akdovurak area in the Tuva SSR.

The USSR is the world's leading producer of asbestos. Their latest five-year plan foresaw an increase in production from about 2 Mt in 1981 to 2,22 Mt of fibre in 1985.

Canada

Canada's asbestos fibre occurs broadly in an eastern and a western belt.

TABLE I
WORLD RESERVES OF ASBESTOS

Country	Type	Proven reserves* t × 10 ⁶	World		Market economies	
			%	Rank†	%	Rank
Canada	Chrysotile	48,0	35,6	1	51,6	1
USA	Chrysotile					
	Anthophyllite	8,2	6,1	3	8,8	2
RSA	Chrysotile					
	Amosite					
	Crocidolite	7,8	5,8	4	8,4	3
Australia	Chrysotile					
	Amosite	6,9	5,1	5	7,4	4
Zimbabwe	Chrysotile	5,0	3,7	6	5,4	5
Italy	Chrysotile					
	Anthophyllite	4,4	3,3	7	4,7	6
Brazil	Chrysotile	4,0	3,0	8	4,3	7
Yugoslavia	Chrysotile	2,0	1,5	9	2,2	8
Greece	Chrysotile	1,4	1,0	10	1,5	9
Other market economies‡	Chrysotile					
	Amosite	5,3	3,9		5,6	
Total market economies		93,0	69,0		100	
Centrally planned economies§	Chrysotile					
	Anthophyllite	41,9	31,0			
Total world		134,9	100			

* Contained fibre

† The USSR, with 38,7 % market economies, is believed to rank 2nd

‡ Cyprus, India, Swaziland, Colombia, New Zealand, Turkey, Mexico, Venezuela, Korea R, Argentina, and Egypt

§ USSR, China, Bulgaria, Mocambique

TABLE II
WORLD PRODUCTION OF ASBESTOS*, 1984

Country	Production kt	World		Market economies	
		%	Rank	%	Rank
Canada	838,0	20,1	2	49,3	1
RSA†	167,4	4,7	3	11,6	2
Zimbabwe	165,4	3,9	4	9,7	3
Italy	147,3	3,5	6	8,7	4
Brazil	136,1	3,3	7	8,0	5
USA	57,4	1,4	8	3,4	6
Greece	45,7	1,1	9	2,7	7
Turkey	29,9	0,7	10	1,8	8
Swaziland	25,8	0,6	11	1,5	9
India	25,1	0,6	12	1,5	10
Other market economies‡	30,5	0,7		1,8	
Total market economies		1698,7	40,8		
USSR	2300,00	55,3	1		
China	160,0	3,8	5		
Other centrally planned economies§	0,6	0,01			
Total world		4159,3	100		

* BGS World Mineral Statistics, 1980-1984

† Minerals Bureau of South Africa

‡ Cyprus, Egypt, Japan, Korea R, Mocambique, Taiwan, Turkey, Yugoslavia

§ Bulgaria, Czechoslovakia

The Eastern Belt

This is the most important asbestos-producing area in Canada and is confined to a belt of partly serpentinized ultramafic rocks stretching from the Baie Verte district of Newfoundland, through the Thetford Mines, Black Lake, and Asbestos district of Quebec, to the Belvidere Mountains in Vermont. This belt is part of the lower Palaeozoic ophiolites of the northern Appalachians. The serpentinized ultramafic bodies have been subjected to faulting and intense shearing, creating the ideal environment for asbestos development.

The Western Belt

The Western Belt, found in British Columbia, forms part of the Mississippian ultramafic bodies in the 110 km long chain of the McDame intrusives. Most of the ultramafic rocks have been altered to serpentinite and contain chrysotile, although only the Cassiar body is regarded as commercial.

South Africa

South Africa is in a unique position in that it is the only country in the world that has reserves of and produces all three principal varieties of asbestos: chrysotile,

crocidolite, and amosite. Indeed, significant deposits containing the last two varieties are almost unknown elsewhere in the world. South Africa's fibre reserves, at present computed as 7,8 Mt, remain the third-biggest in the western world after Canada and the USSR.

The localities of the asbestos fields in South Africa are shown in Fig. 1.

Chrysotile Asbestos

In South Africa, chrysotile deposits are invariably associated with serpentinites. These can conveniently be divided into two geological types: those which have been emplaced as ultrabasic intrusives in rocks of Swazian age with subsequent metamorphism, and those in dolomite of the Malmani Subgroup, which probably resulted from thermal metamorphism by diabase sills of chemically suitable zones in the dolomite.

There are many deposits of chrysotile in the Transvaal and Natal. However, the most important are those located in the Barberton areas of the eastern Transvaal, where the chrysotile bodies are hosted in ultramafic intrusions within the Swartkoppies Formation, which is part of the Onverwacht Group of rocks.

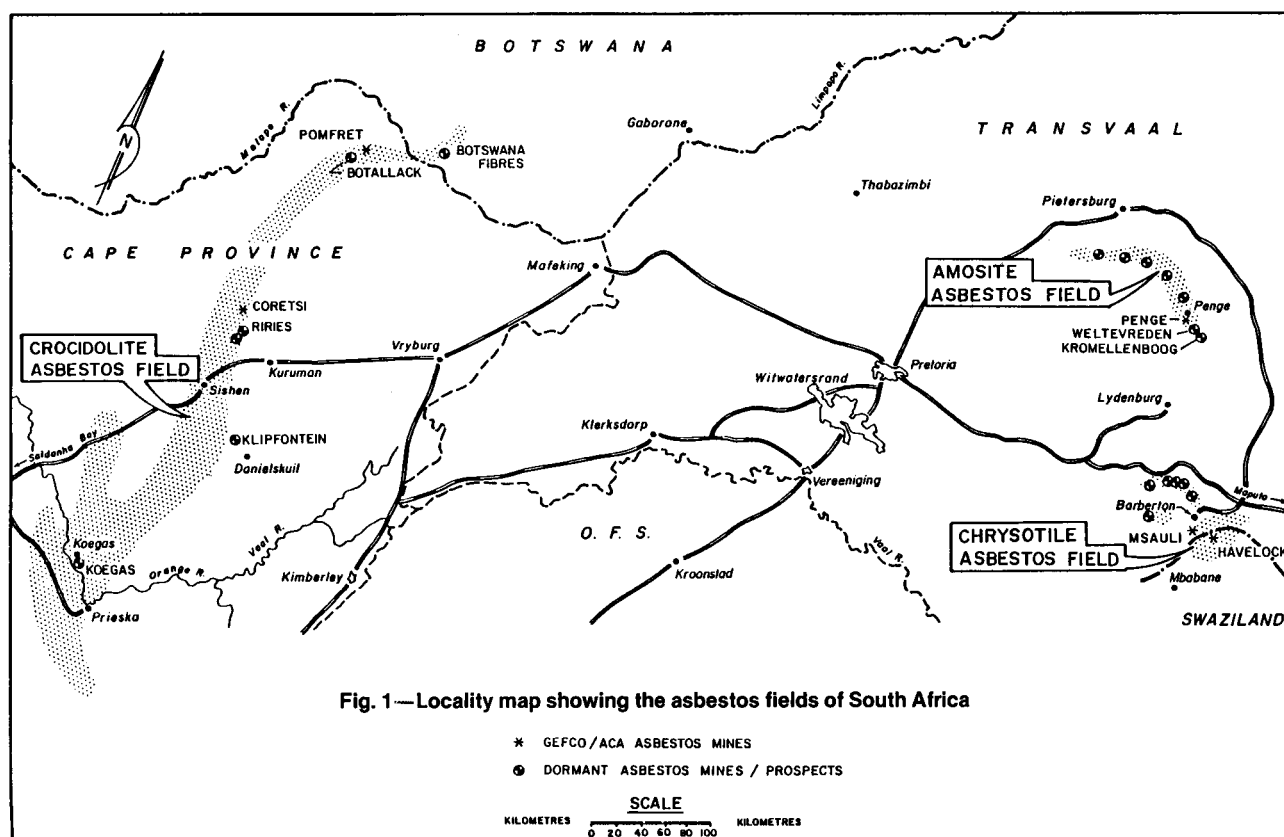


Fig. 1—Locality map showing the asbestos fields of South Africa

Although some chrysotile deposits in serpentinized dolomite have been worked in the past, they are not currently of economic value.

Amphibole Asbestos

Crocidolite occurs mainly in the Transvaal and the Cape Province. Amosite is found almost exclusively in the Transvaal. A few occurrences of both minerals outside these areas are of little importance.

The Transvaal Crocidolite-Amosite Field occupies portions of the Pietersburg and Letaba districts, and extends from Chuniespoort in the west to the Steelpoort River in the east, a distance of some 90 km. In this region, the asbestos is confined to the banded ironstone of the Penge Formation of the Chuniespoort Group. Both amosite and crocidolite occur in the western part of the area, but the concentration of crocidolite decreases rapidly west of the Mohlaptse River, with the result that only amosite is found in the vicinity and southeast of Penge.

The shortest crocidolite fibre of economic importance found in the area is about 3 mm, and the longest about 100 mm. On average, the length of the fibres ranges between 10 and 25 mm. Amosite fibres are in the main longer, and range from 30 to 150 mm in most places, with fibres commonly up to 100 mm and, in exceptional cases, as much as 300 mm.

The Cape Crocidolite Field lies mainly in Griqualand West, and extends northwards along a line from 50 km south of Prieska, on the Orange River, past Griquatown and Kuruman, to its presently known northern-most occurrence—in Botswana, approximately 40 km to the north of the South Africa-Botswana border—a distance of about 450 km.

The crocidolite is developed in banded ironstone of the Asbestos Hills Formation of the Griquatown Group. It generally occurs in seams of cross-fibre that range in thickness from less than a millimetre to about 50 mm; the maximum fibre length is about 150 mm.

Anthophyllite and tremolite are found in xenoliths of serpentinite, gneiss, and pyroxenite in granite and schist of Swazian age in the northern Transvaal and central Natal. Some of the deposits have been exploited, but the reserves are insignificant.

Reserves

The present proven fibre reserves of amphibole asbestos are sufficient to meet long-term objectives. Exploration for additional fibre reserves is a costly undertaking because of the high costs of drilling in banded ironstone, the sparseness of surface outcrops (there is extensive sand cover), and the adverse topography. These factors rule against the evaluation of potential fibre areas decades ahead of actual mining operations. However, the latest available information gives South Africa's reserves of extractable fibres of all types as some 8 Mt. The resources of amosite are considerable and of crocidolite, very large.

PRIMARY APPLICATIONS

Because of its unique and useful characteristics—chemical, electrical, and thermal neutrality, fibrous strength, fire resistance, and sound absorption—asbestos is used in a wide variety of everyday products, as shown in Table III. More than three-quarters of all the asbestos mined is used in the manufacture of asbestos-cement products, such as prefabricated wall sections, corrugated roof sections and tiles, water pipes and tanks, and such house-

hold goods as garden furniture and flower pots. Asbestos is an important component of friction products, such as clutch plates and brake pads for cars. It is woven into material that is used for heat- and fire-resistant clothing such as that worn by foundry workers and firemen. It is also used for wrap-around pipe insulation and electrical insulation. It enhances the structural strength of the plastics used in battery cases, and can also be found in heaters, ovens, toasters, hairdryers, and polyvinyl chloride (PVC) floor tiles.

TABLE III
MAIN USES OF ASBESTOS

Major end-use	Product
Friction products	Clutch facings Disc-brake pads Brake drums
Distribution of water or other liquids	Asbestos-cement pipes
Fire-, heat-, or noise-resistant walls in low-cost housing	Asbestos-cement sheets
Attachment of bonded modules to high-temperature surfaces, or patching	Refractory asbestos-cement
Roofing	Roofing felts Roofing paper Tiles and shingles
Thermal insulation in furnaces	Asbestos pulp
Compression packings and sealing devices in fluid processing and power equipment	Asbestos textile Asbestos woven into yarn, tape, or braid
Pipe insulation	Asbestos textile Asbestos woven into cloth, tape, rope, braid, sleeving, blankets, or mats
Protective clothing	Asbestos textile Asbestos woven into cloth, blankets, or mats
Electrical insulation	Asbestos textile Asbestos woven into cloth, rope, braids, or yarn
Pipe seals	Asbestos gaskets
Additives	Plastics Coatings: paint, caulk sealings
Liquid filtration	Filters

ASBESTOS PRODUCTION IN SOUTH AFRICA

As shown in Table II, South Africa ranks as the world's third-largest producer of asbestos, after the USSR and Canada.

The production of asbestos in South Africa increased by 73,5 per cent in the period 1960 to 1980. Since 1980, however, the production rate has declined by some 20 per cent as a result of a drop in world demand, as shown in Table IV.

The vast bulk of South African asbestos is exported, and the decrease in demand in several of its major overseas markets reflects the detrimental effects of the worldwide economic recession in the first half of the 1980s,

TABLE IV
PRODUCTION OF ASBESTOS FIBRE IN SOUTH AFRICA

Year	Type, kt			kt
	Chrysotile	Amosite	Crocidolite	
1960	26,73	62,25	70,51	159,49
1965	35,28	73,23	109,86	218,37
1970	52,80	97,38	137,23	287,41
1975	99,75	88,41	164,73	352,89
1977	111,58	66,98	200,97	379,53
1978	79,51	40,53	118,15	276,74
1980	106,94	51,65	118,15	276,74
1981	76,77	56,83	102,34	235,94
1982	81,13	43,45	87,23	211,81
1983	93,02	40,66	87,44	221,12
1984	75,41	33,24	58,74	167,39
1985	91,65	37,86	34,07	163,58

TABLE V
DESTINATION OF SOUTH AFRICA'S ASBESTOS EXPORTS, 1985
(by mass)

Region	Chrysotile		Amosite		Crocidolite		Total asbestos	
	%	Rank	%	Rank	%	Rank	%	Rank
Europe	0,86	2	15,45	2	50,78	1	15,67	2
N. America	0,02	5	0,43	5	20,41	2	4,71	3
S. America	Nil		0,46	4	1,09	7	0,36	6
Africa	0,83	3	Nil		3,76	5	1,29	5
Middle East	0,19	4	0,69	3	15,63	3	3,78	4
Far East	98,10	1	82,97	1	6,94	4	73,89	1
Oceania	Nil		Nil		1,39	6	0,30	7
Total world	100		100		100		100	

TABLE VI
NON-GOLD MINERAL EXPORTS FROM SOUTH AFRICA, 1985

Commodity	Value in 1985 R × 10 ³	Projected for 1986 R × 10 ³
Coal	3 092 516	2 699 048
Diamonds	417 690	612 607
Copper	328 579	362 500
Iron ore	319 254	338 095
Manganese ore	243 877	272 738
Chromium ore	146 988	148 570
<i>Asbestos</i>	98 539	108 750
Nickel	82 789	74 763
Silver	74 454	78 290
Fluorspar	52 003	53 048

as well as the impact of environmental and health lobbies aimed at reducing, and even eliminating, the use of asbestos. The export destinations of South African asbestos are shown in Table V.

The comparatively small local market for asbestos increased by 236 per cent from 1960 to 1970. Since then, the domestic demand has fluctuated, reflecting the fortunes of the building and construction sectors of the market.

In spite of the decline in its markets, asbestos still ranks seventh among South Africa's non-gold mineral exports, as shown in Table VI.

MINING AND EXTRACTION TECHNIQUES IN SOUTH AFRICA

The methods used in the mining of asbestos depend on the type of orebody to be mined. Chrysotile normally occurs in massive-stockwork orebodies or thick lenses that dip steeply (55 to 65 degrees). Both crocidolite and amosite occur in flat, thin (1 to 4 m), tabular orebodies. Crocidolite in the Kuruman and Pomfret areas occurs in oval-shaped orebodies with a length of approximately 1200 m and a width of 300 m (the ratio in the northern sector is 1:2 or 2:3, and in the southern sector 1:4 or 1:5), dipping between 7 and 10 degrees to the west. The amosite deposit in the Penge area dips at approximately 17 to 20 degrees, and the orebodies are lenticular and spaced out over a strike length of considerable distance.

Mining Methods

Stoping Widths Below 1,5 m

On both the amosite and crocidolite mines in South Africa, the normal scraper-cleaning methods of mining are employed. Face and strike scraping with centre gullies is used to scrape the ore to the orepasses on the main tramming levels, from where it is transported to the shafts. Support is by means of pipesticks with strike and dip stonewalls. A typical mine layout is shown in Fig. 2.

Owing to the soft nature of the amosite fibre, every effort is made not to drill and blast within the bands of fibre. Consequently, the waste portion of the face is blasted first, and cleaned and packed. The remaining fibre is then 'softly' blasted out with pop-holes above and

below the waste cut.

Water is normally used for dust suppression, but all endeavours are made to prevent water collecting in dams or pools through which the ore has to be scraped. This is because the mud, dust, and graphite collect within the free-fibre portion of the ore and cause problems when the minus 200 portion of the dust is being removed from the fiberized material in the mill. On the amosite mine, the average stoping width is 0,9 m.

The crocidolite mines also try not to drill holes for blasting within the fibre bands. Owing to the strength, hardness, and abrasiveness of the ore, and the occurrence of riebeckite (massed microscopic fibre) within the fibre bands, the drilling of a 1,2 m hole with normal 42 mm tungsten carbide-tipped steel may take up to half an hour. The grade of tungsten used in the steel is of great importance.

Anfex is used as the blasting medium, with safety fuse igniter cord and detonators.

Stoping Widths Above 1,5 m

Here the bord-and-pillar method (Fig. 3) is normally employed, with 3 m by 3 m pillars and 6 m bords, giving an extraction of 89 per cent. At a stoping width of beyond 2,5 m height, the bords are stepped with a cut of 1,2 m height taken against the hangingwall for 2 m depth, and the remaining footwall is lifted afterwards.

Cleaning is done by 2 t shovel, low-profile front-end

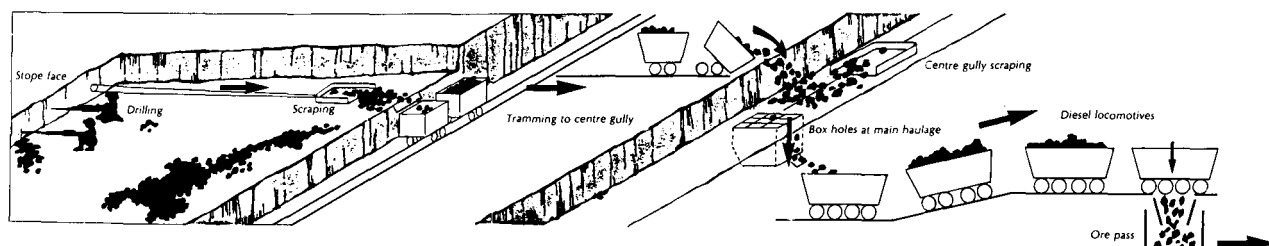


Fig. 2—The layout of a typical asbestos mine

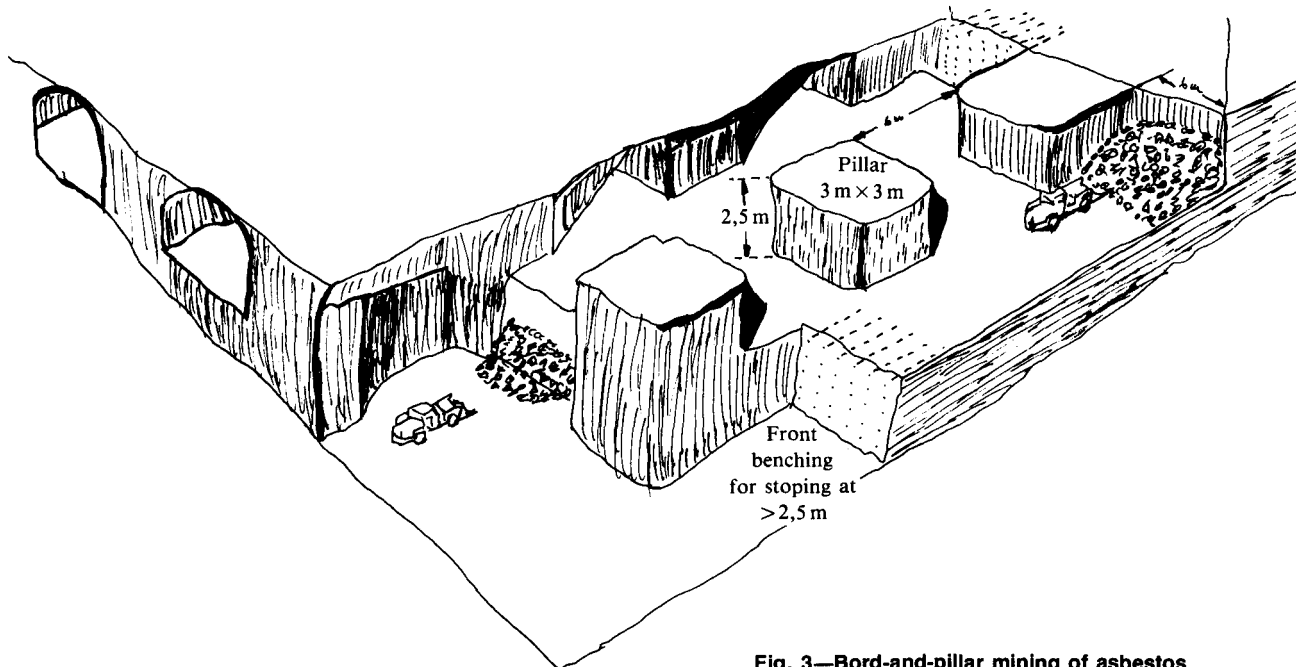


Fig. 3—Bord-and-pillar mining of asbestos

loaders into either tractor-trailer units of 10 t capacity or 20 t hauling units, which haul the ore to boxholes delivering into footwall haulages along which ore is transported by 4 or 6 t hoppers and diesel locos to the shafts. Smaller 1 t load-haul-dump trucks are also employed.

Ventilation is controlled by strike stonewall or brattices between the pillars.

The crocidolite mines each produce approximately 30 to 35 kt of ore per month.

Massive Orebodies

The massive deposits are serpentinite orebodies that were mined in the early 1960s as openpit operations. At present, as the orebodies extend to depth, they have narrowed into oval lenses of approximately 250 to 400 m in length and 30 to 75 m in width.

These orebodies are mined by sub-level caving (Fig. 4) with levels 10 to 15 m apart, and the ore is drawn off from ring-drill drives that are retreated to either hanging- or footwall depending on the strength of the contact rocks. As the ore is drawn off, waste fill from the surface migrates into the voids.

The ore is loaded by means of compressed air loaders into 1.5 t cars, which are handtrammed to orepasses leading onto a tramming level. Also used are 1 t low-profile load-haul-dump trucks, which load directly into orepasses.

The mine produces about 75 kt of ore per month.

Extraction

The basic present-day extraction method (Fig. 5) used to separate the fibres from their host rock is a dry-milling process (Fig. 6). The ore is reduced in a series of crushing and milling stages. After each crushing stage, the liberated fibre is airlifted off the vibrating screens to cyclones and cleaning machines to extract the dust. The screen 'overs' are mostly milled by hammer mills, after which the liberated fibres are again airlifted. Within the process, the fibres are screened into grades that basically have fibres of different lengths.

In the case of crocidolite and amosite fibres, the fibres are bagged into 50 kg bags (Fig. 7). The bags are then pressure-baled (Fig. 8) into 1.2 t bales that can be containerized. The chrysotile fibres are pressure-packed into individual 50 kg bags, which are palletized for conveyance in containers.

Flow of Ore in Crocidolite and Amosite Mines

The ore from underground, which should have a moisture content of not more than 15 per cent, is screened to separate the fines (minus 20 mm). The fines are diverted into a separate circuit in which they are washed to remove the dust and grit. They are then dewatered and dried in dryers before being deposited in the mill bins.

The dryers are of a rotary and/or fluid-bed type and coal-fired, operating in the region of 600°C. The capacity of these dryers is from 15 to 25 t/h, and they lower the moisture content by approximately 10 per cent at this feed rate.

The plus 20 mm fraction follows its own circuit, where it is screened into two or three size fractions. Primary waste sorting is done on the plus 100 mm fraction, and the remaining material is crushed to about 50 mm. The

50 mm material is waste or reef-sorted, depending on the grade of the material, on the secondary sorting belts. The sorted material is then crushed down to 10 mm in cone crushers prior to being deposited in the mill bins. At this stage, much of the fibre has been liberated.

The free fibres in both the fines and the coarse fractions are lifted off immediately upon entering the mill circuit.

In the mill, the rock and fibre are milled, airlifted, cleaned, and screened in a series of hammer mills, flail trommels, cyclones, and de-dusting units. In the hammer mills, the fibre is fiberized, i.e. the fibres are separated to various degrees of fiberization.

Dust extraction (Fig. 9) takes place from every machine where dust is generated, and all the conveyors and screens are enclosed and subjected to negative pressure to prevent dust and/or fibre entering the ambient atmosphere.

In the milling process, the fibre is screened into its various grades. The grades differ by the length of fibres, and are the basic grades of fibre produced.

These basic grades are bagged by screw baggers, and the bags are weighed to contain 50 kg and are pressure-baled in 1.2 t bales. The bales are enclosed in plastic covers before being containerized for transportation to local or overseas customers.

Flow of Ore in Chrysotile Mines

Ore from underground is fed direct to the mill and is not subjected to sorting. In the mill, it is treated in basically the same way as for the crocidolite and amosite, except that it is pressure-packed into 50 kg rectangular bags. These small bags are palletized into 1.2 t pallets and covered with plastic for transportation to the end-users in containers.

MAJOR MINING OPERATIONS IN SOUTH AFRICA

There are 8 asbestos mines in South Africa at present. Chrysotile ores are worked at Msauli, Kaapsehoop, and Stella Mines in the Barberton area, crocidolite at Pomfret, Coretsi, Wandrag, and Emmarentia in the north-western Cape Province, and amosite at Penge in the northeastern Transvaal. Not all the mines are necessarily in operation at the same time.

The Companies

The Griqualand Exploration & Finance Company Limited

This company was incorporated in the United Kingdom in 1895 as The African Saltpetre Company Ltd, and acquired certain rights and properties in the northwestern Cape Province. The company's affairs were reported as being in a very unfavourable state in 1897, and the then chairman, Mr F.P.T. Struben, visited its holdings and recommended to his board that an area of 80 square miles should be retained since it appeared to be highly mineralized.

During 1905-1906, a small royalty was received from asbestos recovered on the company's properties. Mr Struben, with considerable vision, advised the board in 1908 to prospect the area with boreholes. However, owing to the primitive and rudimentary mining equipment and the extremely hard rock formations (ironstones), the results were very disappointing for the next 20 years.

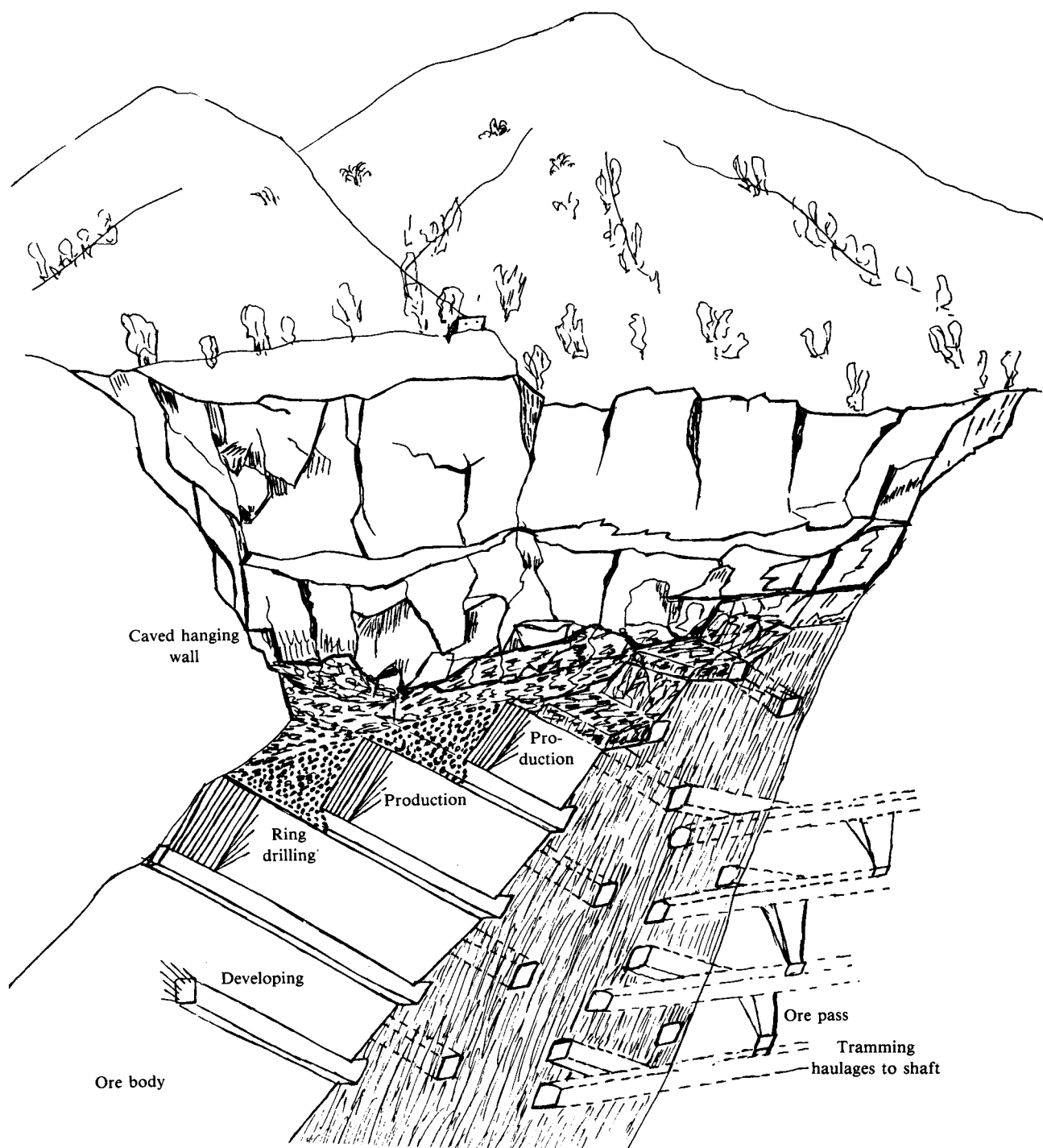


Fig. 4—Sub-level caving as used in the mining of asbestos

In 1923, it was decided that the company itself should exploit the asbestos deposits. Four years later it was re-organized and its name changed to the Griqualand Exploration & Finance Company Limited.

In 1928 the asbestos production increased to 300 t for the year from the farms Elandsfontein and Kranshoek. In 1936, Bretby was purchased, and in 1946 leases were secured over the farms Riries and Mount Vera, as well as the Gamopedi Reserve. Sales of the asbestos were channelled through the Central Asbestos Company in London and, with the advent of the Second World War, Central Asbestos became a full subsidiary of Gefco.

During 1962 the controlling interest in the company passed to South Africa, and in 1965 the Johannesburg Stock Exchange granted a listing of the company's shares. In 1965 Gefco acquired a controlling interest in two companies previously owned by The Hans Merensky Trust, thereby acquiring two additional producing mines and prospecting rights over 17 500 ha.

In January 1981, the company took over the asbestos interests of the entire production facilities for blue asbestos within the boundaries of the Republic of South Africa and Bophuthatswana, stretching from Koegas, on the banks of the Orange River, in the south to Pomfret,

Fig. 5—The schematic flow of a typical asbestos recovery plant

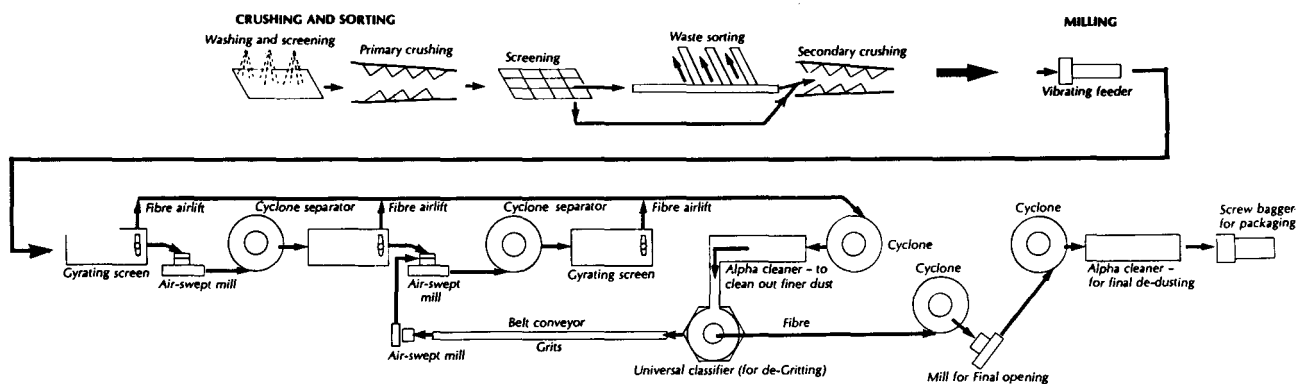
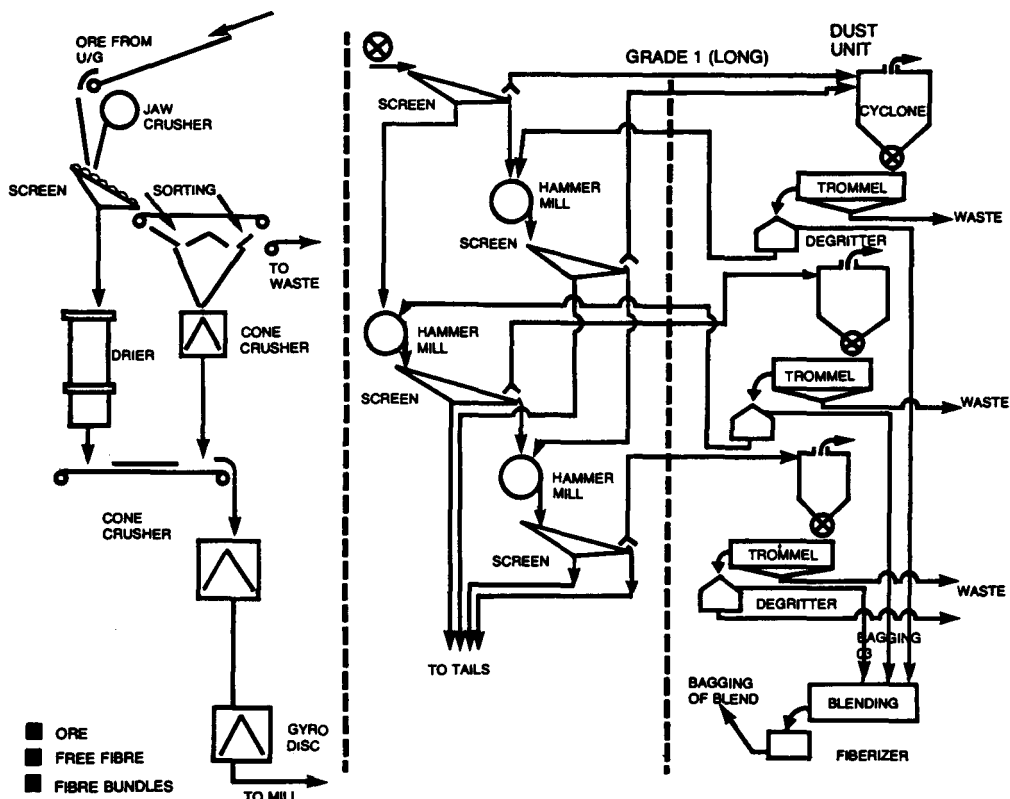


Fig. 6—The crushing and sorting of asbestos

on the Botswana border, in the north, as well as the amosite mines in the eastern Transvaal.

Msauli Asbes Beperk

In 1942 the Diepgezet Asbestos Works produced its first 148 t of chrysotile asbestos on the farm Diepgezet. During 1943 this company exchanged its assets in its claim area for an interest in African Chrysotile Asbestos (Pty) Limited (ACA). In 1951 control over ACA passed to Msauli Asbestos Mining & Exploration Company Limited, a new company that obtained a stock-exchange listing shortly afterwards. Some ten years later, Federale Mynbou acquired a substantial interest in this company, and the name was changed to Msauli Asbes Beperk.

From 1944 onwards, production grew steadily from the opencast workings, and in 1969 one of the most modern

asbestos mills in the world was commissioned on the mine at a cost of more than R4 million.

The Mines

Gefco

At present Gefco produces blue asbestos from the Coretsi farms, with a blending plant on Riries. Coretsi lies within the borders of the Bophuthatswana national state. Numerous small deposits occur on these farms and each is served by its own vertical shaft system, the ore being delivered to the most accessible mill and blending plant.

There are two mills on the farm Whitebank, one on Klipfontein, a mill and blending plant on Owendale, and a mill and blending plant at Elcor. Sorting plants are situated on Coretsi, Whitebank, and Owendale.

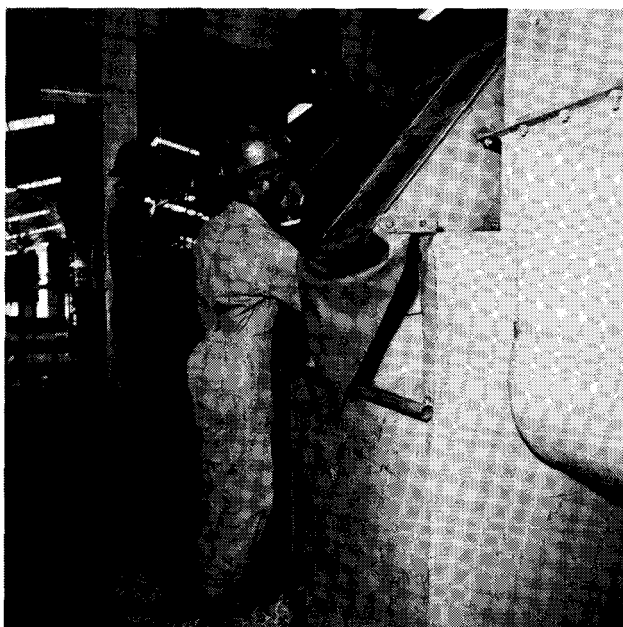


Fig. 7—Mill bagging section

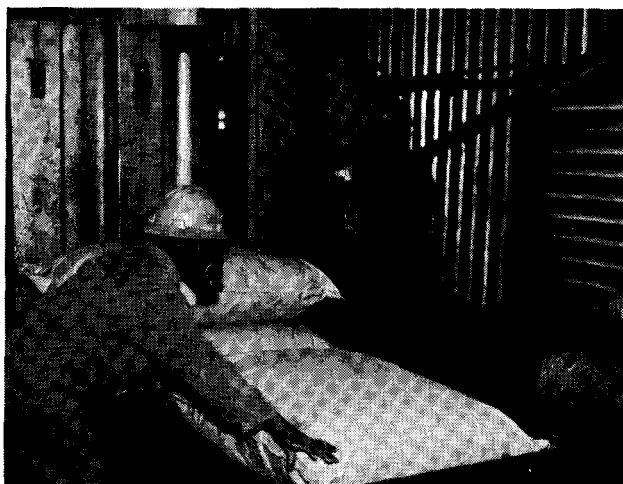


Fig. 8—Pressure-balling

The stoping methods are conventional bord-and-pillar (Fig. 3) with 2 m by 2 m or 3 m by 3 m pillars and 6 m bords. The stoping widths vary from 0,8 to 3,5 m. Drilling is done by Seco S23 rock drills, drilling 1,5 m by 25 mm holes. Blasting is done with 60 per cent Dynagel, capped fuse, and igniter cord. Cleaning is done by scrapers and/or load-haul-dump units.

All the mine employees are housed in company houses in the town of Kuruman, and the mine offices are also situated in the town.

The finished product is transported by road to the company's warehouse at Hotazel, from where it is railed to local customers and to the coast for export.

Pomfret

The Mine, also owned by Gefco, is situated in the Kalahari approximately 200 km northwest of Vryburg and 450 km to the west of Johannesburg. It has its own township, where all employees are housed, and has its own hospital with a medical practitioner and hospital

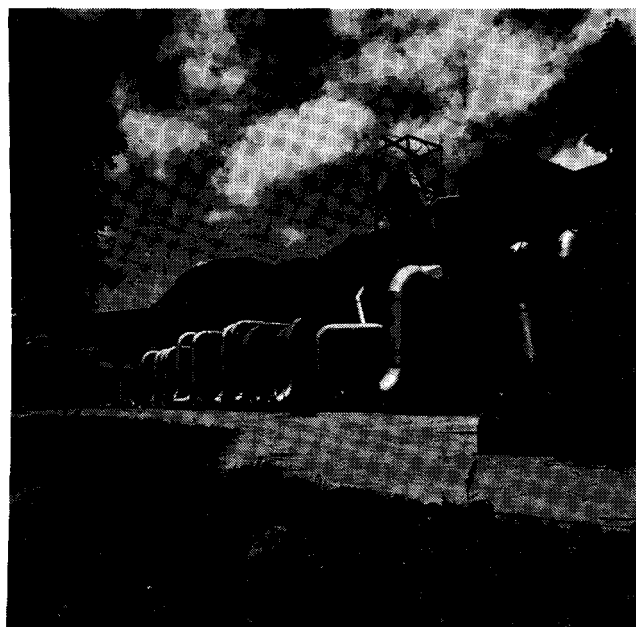


Fig. 9—Dust-extraction air fans at the mill complex

staff. A wide variety of recreational facilities are available for the employees.

This Mine was originally started by the Cape Asbestos Company in 1926 based on the work done by the famous South African geologist A.L. Hall in 1918. Another equally well-known South African geologist, A.L. du Toit, then did geological work for the Cape Asbestos Company on the farms Gosike, Cheddar, and Botallack. Production started on Pomfret in 1927 at the rate of 4 t per month.

During 1944, A.L. du Toit was again commissioned by the Cape Asbestos Company to re-examine the workings in the Pomfret area. He identified three main deposits and recommended the opening up of no. 3 deposit. In 1949 the production was 300 t per annum. In 1954 Du Toit's suggestion was followed, and soon afterwards no. 2 deposit was delineated, which led to the first sizable ore reserves being established.

Control of the operating company (Cape Asbestos) passed to Cape Industries Ltd of London for a period during the 1970s, and thereafter reverted to T.C. Lands in South Africa. In 1981 Gefco acquired the Mine.

It has two of the most modern asbestos mills in the industry, with the unique feature that the mills are built around a central plenum into which all the dust from the machinery is extracted. This makes for short dust ducts and minimum maintenance. The mills are operated from a central control panel from where the process can be followed on a mimic panel.

The underground workings are highly mechanized, with 3 m by 3 m pillars and 6 m bords, being cleaned with load-haul-dump trucks at stoping widths of up to 4 m. A 2,3 km long conveyor transports the ore from underground to the surface bins in front of the sorting plant.

The finished product is transported by road to Vryburg, from where it is despatched by rail to customers all over the world and locally.

Penge

This Gefco-owned Mine (Fig. 10) is situated in the pic-

turesque mountainland of the Transvaal Lowveld, approximately 40 km north of Burgersfort, and lies within the boundaries of the Lebowa homeland. All the employees are housed in the mine township which consists of approximately 150 houses, 3 hostels, single quarters, recreational facilities, and a mine-staffed hospital. It is the only amosite-asbestos mine in the world, and dates back to the 1890s, when the deposits at nearby Kromellenboog and Weltevreden were discovered.

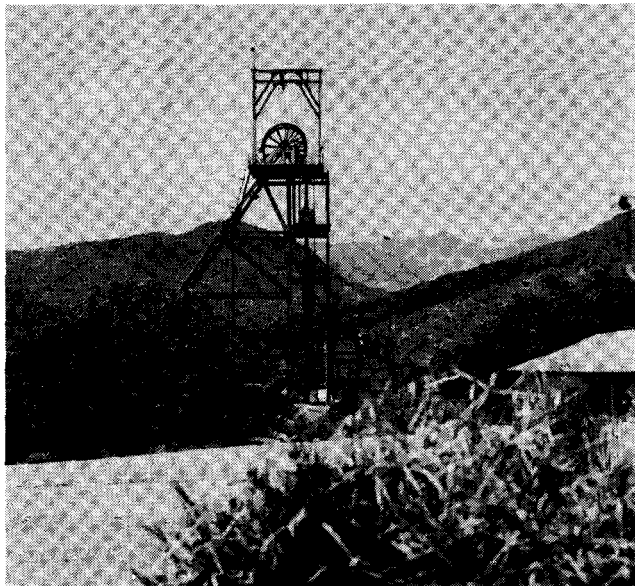


Fig. 10—The headgear at Penge Mine

The orebody extends over a strike distance of 15 km, and varies from 1 to 1,5 m in height. There are three horizons that are exploitable. It is mined on the gully-scraper system. Because of the geographical situation of the mill, the ore is hauled underground over long distances to the shaft adjacent to the mill for sorting and milling. The finished product is transported by road to the Mine warehouse at Apiesdoorn siding, from where it is railed.

Msauli

This Mine is situated in the upper region of the valley at the confluence of the Msauli and Komati Rivers, near the South Africa–Swaziland boundary. This boundary lies on the mountain range just east of the Mine. As the crow flies, the Mine lies about 15 km south of Barberton, but it is 35 km by road.

There is a township on the Mine, with houses, single quarters, hostels, recreational facilities, and all the amenities necessary for a township. A mine hospital with medical personnel is maintained by the Mine.

Originally, the Msauli River traversed the orebody, and its course was altered artificially to divert the water from the Mine. The Mine started as an opencast mine, but is now an underground operation, mining on a sublevel caving system. At present, a subvertical shaft is being constructed to exploit the deeper levels of the Mine.

Ore is transported to a vertical shaft tipping on surface into an aerial ropeway, which transports the ore across the Msauli River to the mill. The finished product is transported in containers to a depot at Kaapmuiden

for despatch.

ASBESTOS AND HEALTH

Asbestos fibres present a health hazard when the recovery process has inadequate dust control. Inhalation of high concentrations of fibre over a number of years may lead to a scarring of the lung tissue, a condition that is known as asbestosis; in a severe form, it causes shortness of breath, which is aggravated in smokers. Scarring of the lung lining gives rise to pleural plaques, which do not produce any disability unless they are very extensive.

There is also an association between asbestos inhalation and malignancy of the lung, or bronchial cancer. The risk is greatly enhanced among smokers. A rare asbestos-related disease is mesothelioma, a malignancy of the lining of the lung or the peritoneum. This disease was once exclusively identified with asbestos, but it is now accepted that it must also have other origins.

Over the years, the asbestos-mining industry has made great progress in its efforts to contain all possible health hazards at its mines and mills, and in their environments (Figs. 11 and 12). As an example, in the 1950s the dust counts ran at hundreds of asbestos fibres per millilitre of air; today, a standard of 2 fibres per millilitre applies to the work areas. The environmental standard is a hundredth of that figure—0,02 fibre per millilitre—and this applies to living quarters, mine townships, and mine surroundings. These standards, which were introduced on 1st January, 1984, are in line with current international limits.

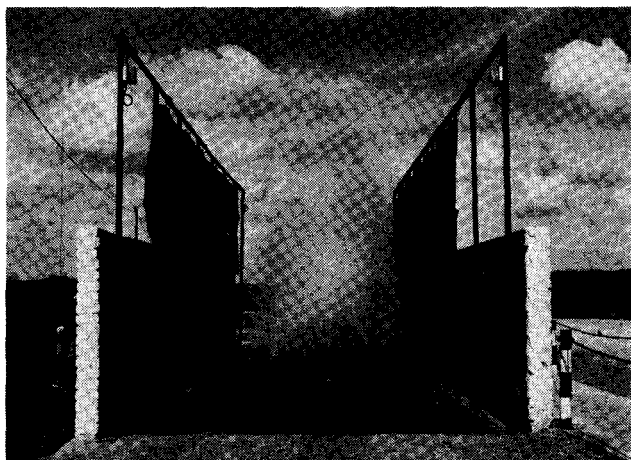


Fig. 11—To ensure that asbestos fibres from the mines and mills are not conveyed into surrounding areas, all vehicles leaving the mine property are washed in spray baths

Gefco and Msauli are already improving upon the statutory standard and, as the latest analysis of work places and mine townships shows, some 70 per cent of the employees are now exposed to dust counts of less than 1 fibre per millilitre. This improvement has been achieved by the establishment of new mills and the development of new milling techniques; the introduction of improved mining methods designed to suppress underground dust; the installation of ore-washing systems and of more effective dust-extraction and filtration equipment in the mills. The sun-drying of washed fibre—the only stage of the process where dust control could still be difficult—has virtually been eliminated.

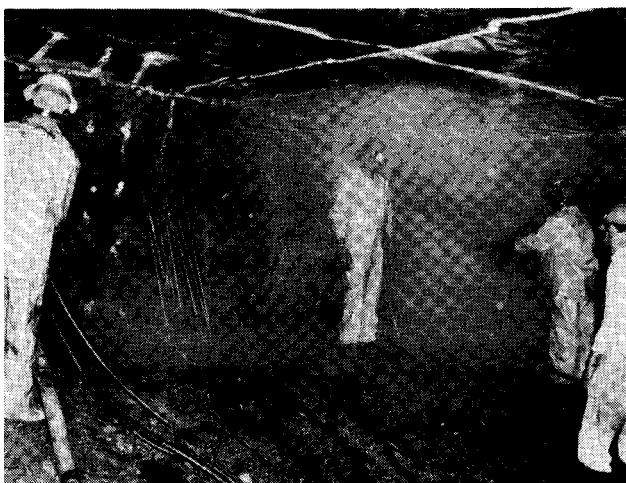


Fig. 12—Improvements in wet-mining methods have helped to reduce the levels of asbestos dust even further

There have also been significant improvements in the handling of the final product, which is now packed in dust-proof bags, palletized, shrinkwrapped, and often containerized before being dispatched from the mines. Employees are provided with respirators for use in emergencies (Figs 13 and 14) and when dust is unavoidably created in repair and maintenance work. In the few specifically demarcated areas where dust levels could exceed the prescribed standards, the wearing of respirators is compulsory.

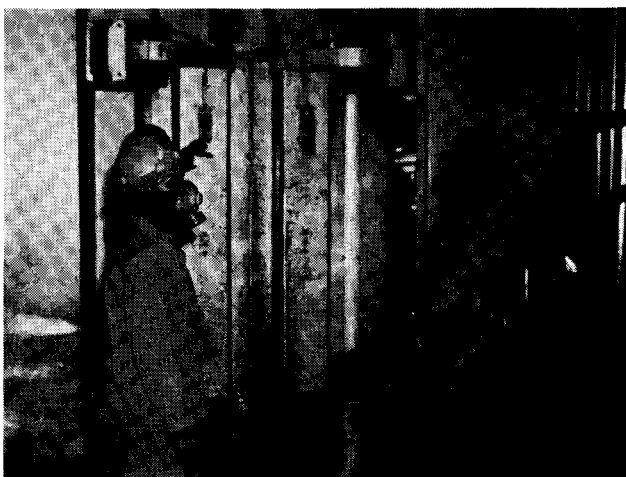


Fig. 13—Employees are provided with respirators for use in emergencies and when dust is unavoidably created in repair and maintenance work

In all, Gefco and Msauli have spent some R20 million on improving their working conditions and on environmental clean-up measures over the past six years.

To ensure that dust levels at and around the mines and mills remain below the prescribed limits, Gefco and Msauli operate a comprehensive monitoring programme. Readings of the air quality are taken in all areas at least once a month, with frequent spot checks in between. A variety of internationally accepted measuring instruments is used to obtain measurements of personal exposure and static samples (Fig. 15). The mines report their dust counts to management on a monthly basis, and once a quarter these results are submitted to the Government

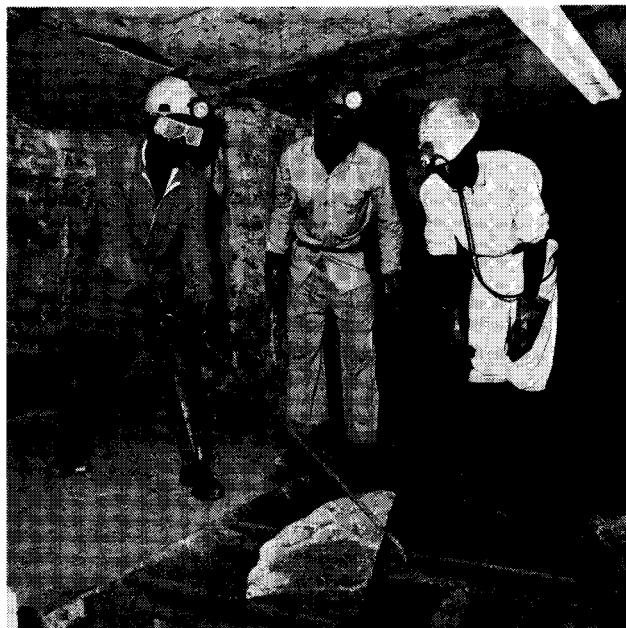


Fig. 14—All workers are issued with the protective clothing required for their jobs

Mining Engineer, whose staff control the mines' reports by taking their own readings. In addition to keeping a close watch on air quality, the mines keep their employees under regular medical surveillance. Employees receive a thorough clinical and X-ray examination on engagement, at regular intervals, and when they leave service.

All prospective employees are given a comprehensive briefing about the dust hazard when they join (Figs. 16 and 17). The induction programme, which includes audio-visual and other specialized communication techniques, covers the dangers of handling asbestos incorrectly, the steps taken by Gefco and Msauli to control dust and prevent pollution, and the contribution the employees can make. Only at the end of this course are they finally offered employment.



Fig. 15—Fibre quality and dust levels are carefully monitored in modern, well-equipped laboratories



Fig. 16—Prospective workers are briefed comprehensively about the dust hazard, and how it can be controlled, before they are employed

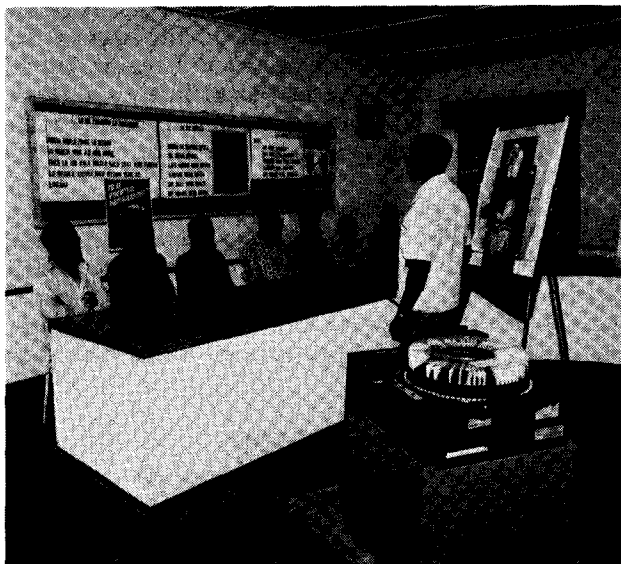


Fig. 17—All newly appointed workers undergo intensive classroom and on-the-job training

The question arises as to why, if the current control measures are effective, numerous cases of asbestos-linked disease are still being identified. The answer to this question lies in the long latency period in the development of a malignancy. This period from the exposure to asbestos to the onset of the disease varies between 20 and 50 years, and malignancies that are now being diagnosed are the result of exposure before the controls that now exist were instituted.

While cases contracted before the current controls were introduced may still be diagnosed into the next century, the current occupational risk from asbestos is minimal and the risk to the general public virtually non-existent. Many scientists, in fact, believe that asbestos-related diseases will in due course disappear altogether as a result of the safety measures being taken at present.

ENVIRONMENTAL CONTROL

Because of the large amount of waste and tailings produced during mining operations, as well as the recent implementation of the Mines and Works Act and Regulations, it was decided to appoint the PU-NTC Research Institute for Reclamation Ecology as consultant with regard to the rehabilitation of asbestos-producing localities in South Africa. The approach to rehabilitation can basically be described as an individualistic approach since it is based on individual case studies for each and every locality that needs to be rehabilitated.

The Institute started with reclamation research during the early 1960s and developed reclamation programmes for the Department of Transport on a nationwide scale. This involvement exposed the Institute to basically all the major types of vegetation and soil in South Africa.

It soon became clear that, owing to the tremendous climatic diversity in South Africa, only a small percentage of the commercially available seeds can be included in seed mixtures for the re-vegetation of areas, since the plants are not suited to the diverse South African (in many cases extreme) environmental conditions. A uniform seed cocktail cannot be used countrywide, since plants are adapted to certain environmental parameters and cannot live outside their tolerances.

- Most commercial seeds originate in Europe and the USA in cool climatic and high rainfall conditions and are available because of an agricultural demand.
- Many reclamation efforts fail because fertilizing and maintenance are not based on chemical analyses of the soil, which would reveal plant nutritional deficiencies and/or abnormalities.
- The methods and techniques used to keep topsoil in place on steep slopes are inadequate.
- The removal, storage, and handling of topsoil, etc. are generally inadequate.

Based on these and other findings, various experiments were designed to test the hypothesis that seed mixes must include those of local species, and soil rectification must be done according to nutritional deficiencies and/or abnormalities. Positive results were obtained in all the experiments.

From these studies, a broad strategy was developed, which is followed for every project. However, as each disturbed area requires different treatment from that suitable for other areas owing to variations in soil and environmental conditions, an individualistic approach had to be followed.

The main aspects of the approach are as follows.

- A detailed study is made of the vegetation in the vicinity of the disturbed area to determine the role of each species in the community, with special attention to their rehabilitation potential, which includes:
 - potential to invade bare areas
 - drought resistance
 - seed production, germination, and establishment in poor conditions
 - recovery after fire, etc.
- Seed and/or vegetative reproduction material is collected, and nurseries are established if needed.
- Representative soil samples are collected for physical and chemical analysis.

- Based on the analyses, the soil is improved chemically and/or physically.
- Pot experiments are conducted in greenhouses and outside.
- Trials are conducted on site and are monitored, preferably for three growing seasons.
- Seeds of the selected species are produced on one of the seven seed-production farms if they are not yet represented in the collection.
- A rehabilitation programme is drawn up.
- During implementation, the Institute acts as consultants or physically implements the planting, etc. if the client so desires.
- The project is normally followed by a two-year monitoring period and, if needed, a light maintenance programme.

As a result of the Institute's involvement, successful rehabilitation programmes are under way at Kuruman, Warrendale, Pomfret, Prieska, Bewaarskloof, and Kromellenbogen, while research is still underway at Msauli.

It is generally recommended that all slopes should be flattened to about 18 degrees. Dumps are covered with about 400 mm of topsoil containing 70 per cent rocky material (coarser than soil) before seeding. A different seed cocktail is prepared for each climatic region, and includes the seed of species that are adapted to the local environment.

The following unpalatable and impenetrable species were used at Bewaarskloof since the trampling and grazing of rehabilitated asbestos dumps must be minimized: *Euphorbia tirucalli* (Kraalmelkbos), *Sansevieria* species (Bowstring), *Euphorbia cooperi* (Tree Euphorbia-Naboom), *Euphorbia ingens* (Candelabra Euphorbia), *Aloe* species, *Acacia* species such as *A. schweinfurthii* (Creeping Acacia), *A. mellifera* var. *detinens* (Noebusch), *A. erubescens* (Blouhaakdoring), and *A. fleckii* (Bladdoring).

After this planting, the implementation of re-vegetation started at Bewaarskloof (1986) under the guidance of Professor J.J.P. van Wyk, Director of the Institute. Up to 160 people are permanently occupied in flattening, covering, and planting operations.

Since the beginning of these operations, thirty dumps/localities have been rehabilitated, while another fifty still

remain to be done. It is estimated that, at the present rate, the Institute, Gefco, the Department of Mineral and Energy Affairs, and the Lebowa Government will be involved in this rehabilitation for the next ten to fifteen years.

SHORT- AND LONG-TERM PROSPECTS FOR ASBESTOS

The demand for asbestos has decreased over the past decade, and South African production has declined to some 40 per cent of its 1977 peak as a result of the elimination of hazardous applications. However, the elimination of potentially dangerous products and practices will ultimately benefit the producers and the manufacturers, as well as the users.

Asbestos is now mainly used in asbestos-cement mixes for the production of sheets and piping for building materials, water reticulation, and sewage and drainage systems. Because of its distinctive properties, it cannot be replaced effectively or economically in these applications.

It has been fairly widely accepted that asbestos can be mined and used safely provided strict controls are maintained. The International Labour Organisation and the European Economic Community have both introduced safety codes, but neither has banned asbestos. The situation in the USA is more fluid. The Environmental Protection Agency has called for a ban on asbestos, but this is being opposed by the Occupational Safety and Health Agency as well as by the industry, which is confident that the proposed ban will be replaced by regulations for controlled use.

Attempts to replace asbestos with substitute fibres have met with limited success mainly because no single substitute material has the same combination of properties as asbestos fibres. Recently, epidemiological research indicated that many man-made mineral fibres have potential health hazards equal to or even worse than those associated with asbestos.

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New publication

● *Gold and silver recovery innovations*, by Randol International Limited (21578 Mountsfield Drive, Golden, Colorado, 80401 USA), 1987. 11 vols., over 7000 pp. US\$4000 (US\$550 per set for extra copies).

This report gives the results of a worldwide survey of all aspects of gold and silver recovery, particularly innovative processes, concepts, and equipment that are useful to the industry. The survey focuses on practical rather

than theoretical aspects. Special attention is paid to the treatment of refractory ores, heap leaching in new environments, carbon-in-pulp improvements, and how to live within new regulatory constraints, as well as the recovery of incremental resources from effluents, etc. This is a report for operators, plant designers, and managers, and would also be useful in the selection of directions for R&D.