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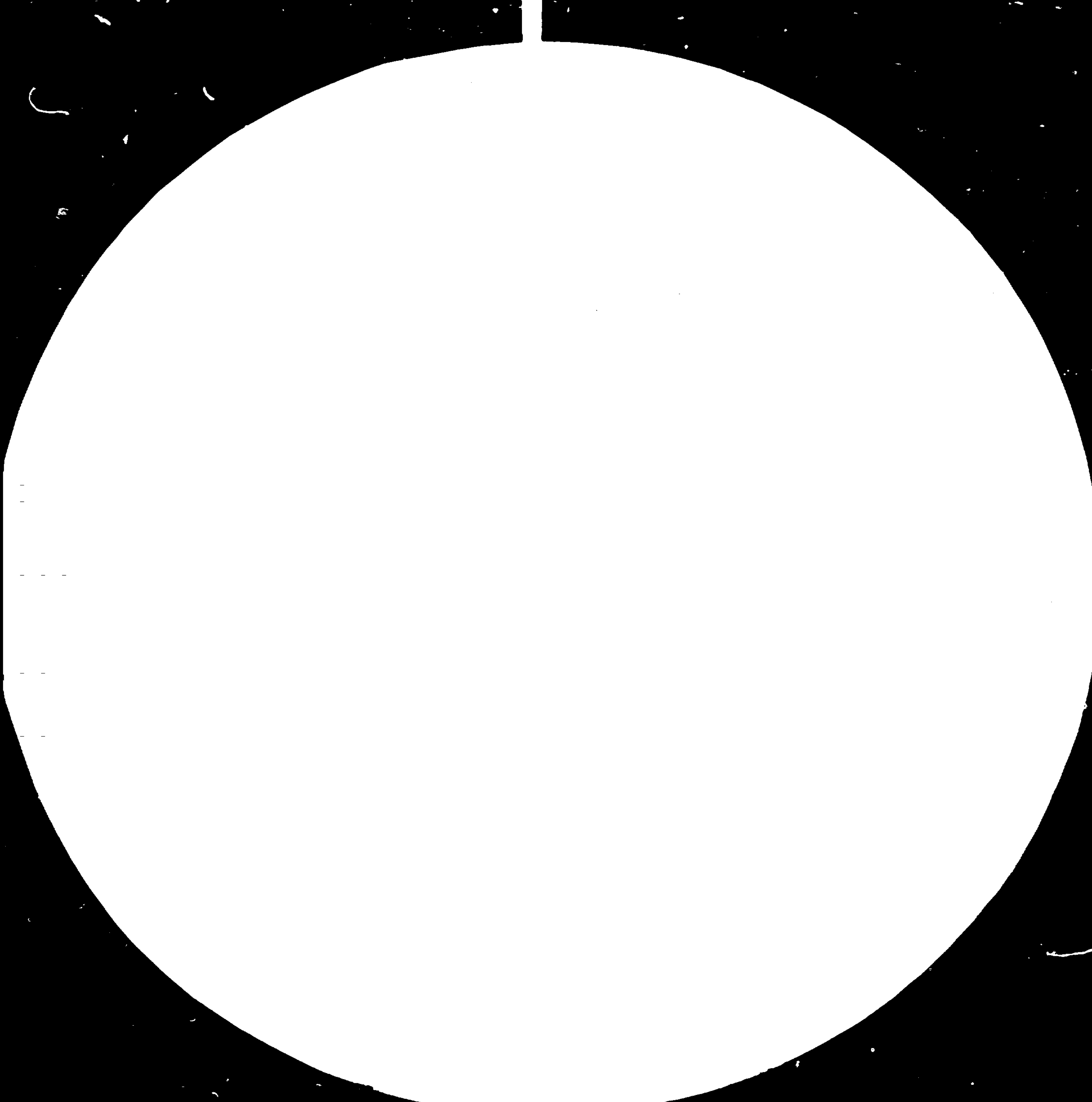

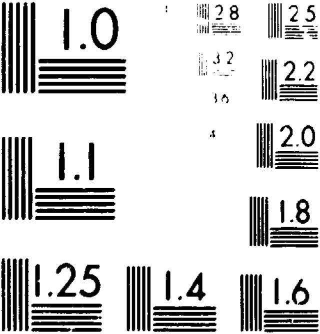
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OTHER NON-METALLIC RAW MATERIALS

By: M. Kužvart +

2807

+ Department of Mineral Deposits, Charles University, Prague, Czechoslovakia

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1. mode of occurence
2. world's largest deposits
3. where to look for new deposits and recommendations for further geological survey
4. principles of exploitation
5. basic data on world reserves (a), and output (b)
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OTHER NON-METALLIC RAW MATERIALS

M. Kužvart

I. INTRODUCTION

Other non-metallic raw materials for ceramics, refractories, building materials and other industries include all industrial minerals and rocks with the exception of quartz crystals and other quartz raw materials, bentonite, clays, kaolin, perlite, gypsum, limestone and light aggregate, which are dealt with in special lectures.

In this lecture we shall describe the occurence and use of following ceramic raw materials: feldspars, wollastonite and leucophyllite.

Refractory raw materials:

A. Alumine-silica raw materials (see special lecture):
   (a) kaolin: 1. siliceous (with quartz), in molochite resistant up to 1770°C;
   2. bauxitic (with kaolinite and hydrated alumina)
   (b) fire-clay: 1. plastic clay (= soft clay, bond clay);
   2. flint clay (= hard clay)
   (c) "ball-clay": plastic clay for bonding of other more refractory components

   Main mineral: kaolinite ($Al_2O_3 . 2 SiO_2 . 2 H_2O$)
   Products: chamotte - resistant up to 1630 - 1750°C
   hard porcelain - resistant up to 1670-1730°C
   (both contain less than 50 % Al_2O_3)

B. High-alumina raw materials:
   (a) aluminous laterite and bauxite - mixture of gibbsite ($Al_2O_3 . 3 H_2O$), boehmite, and diaspore (both $Al_2O_3 . H_2O$); should contain less than 2,5 % Fe_2O_3 and 3,5 % TiO_2; calcined bauxite contains up to 85 % Al_2O_3.
   (b) diaspore and/or gibbsite clay. Hydrated alumina must be calcined before further use.
   (c) andalusite, kyanite, sillimanite (all have the composition $Al_2O_3 . SiO_2$), kyanite heated to 1100 - 1480°C is converted to mullite, resistant up to 1810°C.

(d) corundum and synthetic corundum (fused and sintered alumina, produced from high-alumina bauxite), resistant up to 2050°C.

(e) synthetic mullite ($3\ Al_2O_3 \cdot 2\ SiO_2$) made from high-alumina clay (natural or artificial, i.e. washed kaolin) or from sillimanite, andalusite, kyanite, dumortierite, or topaz.

Product: high-alumina brick with 50 - 90 % and more Al_2O_3.

C. Silica raw materials:

(a) pure silica sand (SiO_2), resistant up to 1710°C

(b) quartzite (ganister type)

Product: silica brick (called "dinas" brick in Europe).

D. Basic raw materials:

(a) magnesite ($MgCO_3$)

(b) brucite and synthetic magnesium hydroxide produced from sea water (both $Mg(OH)_2$)

(c) dolomite ($CaCO_3 \cdot MgCO_3$)

(d) chromite ($Cr_2O_3 \cdot FeO$), resistant up to 2000°C

(e) forsterite (Mg_2SiO_4), resistant up to 1905°C, with some Fe_2SiO_4 (fayalit) which lowers the melting point of the mixture (i.e. the mineral olivine) to about 1700°C.

Raw materials under (a) through (c) require preliminary dead burning to get rid of CO_2 and OH . MgO and $Cr_2O_3 \cdot FeO$ are combined to magnesite-chrome (m. prevails over ch.) and chrome-magnesite bricks by burning to 1700°C. Dead burned (to 1450°C) magnesite (MgO) is used as "magnesite" or "periclase" for manufacture of bricks. The theoretical melting point of periclase is 2800°C.

Product: basic brick.

E. Special refractory raw materials:

(a) pure oxides:

1. zirconium as the mineral baddeleyit ZrO_2 or produced from zircon $ZrSiO_4$, melting point 2500°C;
2. ThO_2 from monazite (melting point 2700°C);
3. BeO from beryl (melting point 2200°C).

(b) refractory minerals: flake graphite (C), resistant up to $3700^{o}C$ in a reducing atmosphere; steatite $3\ MgO \cdot 4\ SiO_2 \cdot H_2O$, resistant up to $1370 - 1540^{o}C$.

(c) synthetic minerals:

1. carbides: SiC, resistant up to $1700^{o}C$, W_2C- constituent of thermal shields of spacecrafts, B_4C
2. borides: ZrB, melting point $6000^{o}F$
3. nitrides: BN borazon (diamond hardness, resistant up to $1900^{o}C$ in oxidation atmosphere), AlN, Si_3N_4.

The principal trends in the use of refractory materials have resulted in a decline in the use of clay and silica types and an increase in the consumption of basic and high-alumina refractories. The formerly acceptable chrome/ /magnesite basic bricks are being replaced by new types of magnesite and magnesite/chrome bricks and these now comprise 55 % of basic brick deliveries (excluding dolomite bricks) compared with only 31 per cent in 1960 in the UK. In the area of alumina refractories, firebrick has given way to more expensive, higher quality bricks containing over 40 % alumina. There has also been a growing preference for the more easily installed monolithic refractories at the expense of traditional brick and shapes.

Such changes in refractory usage have primarilly been a result of improved blast furnace performance, the shift from silica to basic refractories in open hearth rooves and the rapid growth of the basic oxygen steelmaking process at the expense of the open hearth process.

Building raw materials comprise marly and siliceous correction material for cement, brick raw materials, stone for aggregate (gravel and crushed stone) and building stone.

Raw materials for glass production involve glass sand, fonolite, and minor components (soda, sodium, nitrate, limestone, feldspar, dolomite); for chemical industry - sulfur, fluorite, barite, borates, salts, limestone a.o.; for metallurgical industry - fluorite, quartzite, limestone, magnesite, foundry sands; for optical industry - quartz, fluorite a.o.; for electronical industry - talc, mica, quartz a.o.; for agriculture - phosphates, sodium nitrate, limestone, dolomite, potassium salts; for production of abrasives - quartz, pumice, perlite, corundum and emery, diamond, antiabrasives - molten basalt; for heat-and acustic isolations - chrysotile asbestos, perlite, vermiculite, mineral wool (molten basalt or marly limestone, clay or glass); for fillers - diatomite, asbestos, kaolin, limestone, talc, barite, bentonite, zeolites, mica, perlite, pumice, vermiculite a.o.; for filters - amphibole asbestos, zeolites, diatomite, expanded perlite; for pigments - - ochres, umbras.

II. GENESIS OF DEPOSITS OF INDUSTRIAL MINERALS AND ROCKS

Geologic criteria, which guide the prospector to a yet unknown deposit, depend to a high degree on the conditions and processes of its formation. Hence, a brief survey of the origins of the above-mentioned non metallic raw materials is necessary.

A. Deposits formed with the help of inner terrestrial forces: (a) igneous and (b) metamorphic.

(a) Igneous deposits comprise those completely enclosed in bodies of deep seated igneous rocks: 1. magmatic deposits (feldspars, mica, forsterite); 2. volcanic deposits (basalt, perlite, zeolites), and deposits which crystallized closer to the Earth surface from hot solutions and gases liberated during the long process of magma cooling - 3. hydrothermal deposits (asbestos, barite, beryl, brucite, fluorite, magnesite, quartz, talc and steatite, and kaolin).

(b) High pressure and temperature prevalent in deeper parts of the Earth's crust transformed carbonaceous beds in graphite, and beds with higher alumina content (similar to kaolins, clays, and bauxites - see below) to kyanite, sillimanite, andalusite, in exceptional cases to corundum and emery. All these deposits - and wollastonite, leucophyllite - belong to the metamorphic type.

B. Deposits formed on or near to the Earth surface where the rocks formed by the internal forces meet in unceasing struggle with processes of decay, destruction, and removal of their products under the influence of atmosphere, hydrosphere, and the biosphere. Here also we can distinguish two main groups of deposits:

(a) deposits formed by weathering of rocks (kaolin, Al-laterite, "amorphous" magnesite, vermiculite, bentonite, ochres, loams), and

(b) deposits formed after transport by sedimentation of weathered rocks (= sedimentary deposits):

1. placers (zircon, monazit with high ThO_2)
2. clastic sediments (clays of all types, shales, bedded bauxites, sands, gravels, quartzites)
3. organogenous deposits (limestone, diatomite, dolomite, sulfur, phosphates)
4. chemogenous deposits (salts, borates, gypsum).

Igneous and metamorphic deposits (A; (a), (b) can be found in moutain ranges and in their roots, if they are ancient enough to have undergone thorough erosion and levelling. Deposits of the weathering crust (B; (a)) can be expected to form only on levelled surfaces of ancient massives (e.g. Africa except Maghreb and Cape province), where the weathering agents (rain-water with dissolved organic and inorganic matter under tropical conditions) acted undisturbed by movements of the Earth's crust on the destruction of rocks for millions of years. Sedimentary deposits (B; (b)), if still young, can be found in the river valleys cutting into granites,or on the beaches (placers - B;(b),1.), or as part of beds that formed the bottom of ancient fresh-water lakes (e.g. all refractory clays, many deposits of diatomite) or seas and salt lakes (e.g. bauxites, some sands and quartzites, i.e. clastic sediments - B;(b),2.).

Organogenous sedimentary deposits (B;(b),3.) were formed from the skelets of many small dead organisms which formed extensive, thick beds on the sea-floor, e.g. diatomites, or from decaying organic matter which changed the sea environment to one suited to biochemical deposition of dolomite.

Chemogenous deposits (B,b,4) were formed by evaporation of sea water in extremely arid climate.

III. AN ALPHABETICAL SURVEY OF INDUSTRIAL MINERALS

Possibility of beneficiation of refractory and other mineral raw materials see Table 1, Figures I and II; its financial effect see Table 2.

Arrangement of each chapter on a mineral raw material:

1. mode of occurence
2. world's largest deposit
3. where to look for new deposits and recomendations for further geological survey
4. principles of exploitation of deposits
5. basic data on world reserves (a), output (b) 1/
6. utilisation of the raw material
7. countries with possible new discoveries in Africa (AF), Latin America (LA), Middle East (ME), Far East (FE).

A n d a l u s i t e $Al_2O_3 . SiO_2$

less important than kyanite of the same composition.

1. Contacts of argillaceous and micaceous slates with granite; lenses and pockets in pegmatites. Both types are a source of placers in beach sands and river sediments.
2. White Mountain (Mono County, California, USA); Marico District (Transwaal, South Africa) - placer 0,3 m thick.
3. In andalusite-bearing slates in areas formed by granites intruding argillaceous sediments. By studying heavy minerals obtained by panning of river- or beach-sands.
4. Placer deposits are easy and cheap to work by various types of rockers, jiggers, etc.
5. (a) Transwaal 400,000 t
6. refractories

1/ 1 long ton = 1.016048 metric ton
1 short ton = 0.9072 metric ton
1 metric ton = 1.10 short ton
1 long ton = 1.12 short ton
1 short ton = 0.894 long ton

Asbestos $Mg_3(Si_2O_5)(OH)_4$

1. cross fiber veinlets of chrysotile asbestos in serpentinite
2. Thetford belt in Quebec (Canada) - 50% of world production; serpentinized peridotite with 4,5% of asbestes in veinlets 10-100 mm thick.
   Bazhenovo in the Urals Mts. (USSR) - serpentinized peridotite with 4-6% of asbestos in veinlets 60-80 mm thick.
   Shabani (Zimbabwe) - serpentinised dunite
3. In dark ultramafic rocks (peridotites, dunites) in mountain ranges. By magnetometric method, trenches, diamond drilling (with recovery of asbestos fibers from the drilling mud).
4. Open-pit quarrying or shrinkage stoping, sublevel stoping and block caving.
5. a) Canada 100 mil.sh.t., Europe 70 mil.sh.t., Africa 36 mil.sh.
   b) thousand metric tons

Country	1970	1971	1972	1973	1974	1975
Canada	1508	1483	1530	1690	1644	1037
USSR	1070	1150	1220	1280	1360	1900
Brazil	376	403	474	819		
South Africa	287	319	321	333	335	355
China	170	160	200	210	150	150
Italy	119	119	133	149	148	147
USA	114	119	119	136	102	89
World total	4250	4340	4430	5180	5140	5080

6. Refractory textiles, clutch facing, brake lining, asbestos-cement products, isolations a.o.
7. LA: Brasil; ME: Saudi Arabia; FE: Indonesia; Australia.

Barite $BaSO_4$

1. (a) hydrotermal veins of irregular bodies, (b) sedimentary beds or (c) blocs around weathered outcrops of both
2. (a) Magnet Cove (Arkansas, U.S.A.).
   (b) Meggen (Westphalen, Federal Republic Germany)
   (c) Washington County (Missouri, U.S.A.)
3. in all types of rocks close to acid granitoids; panning for heavy mineral concentrates, dyeing of barite grains; shafts, drilling.

4. types (a) and (b) - mostly underground mining, type (c) - open pit.
5. (a) milion short tons of barium content: U.S.A. 230, Mexico 120, Brasil 75, China 75, West Germany 50.

(b) short tons

	1970	1971	1972	1973
USA	854 132	825 000	906 000	1 104 000
FRG	454 798	450 693	406 434	359 910
USSR	314 000	331 000	342 000	356 000
Italy	239 555	222 144	200 365	183 500
Mexico	351 738	308 362	288 147	281 372
Ireland	177 000	216 160	257 356	275 500
China	165 000	154 000	171 000	182 000
Peru	143 295	113 004	226 000	237 000
Canada	147 251	120 765	77 261	98 000
Korea North	132 000	132 000	132 000	132 000
World total	4133 976	4113 982	4361 578	4760 700

6. weighting agent for muds in rotary drilling, manufacture of glass, industrial filler, extender; pigments, absorption of gamma radiation.
7. It can be expected that high-grade reserves will be discovered in many coutries.

B o r a t e s

colemanit $Ca_2B_6O_{11} \cdot 5\ H_2O$, pandermit $Ca_4B_{10}O_{19} \cdot 7\ H_2O$, sassolin H_3BO_3 a.o.

1. Chemical sediments (a) in arid basins of playa type, and (b) in the upper part of salt deposits, (c) volcanic gases (sassolin)
2. (a) Kramer (California, U.S.A.) - claystones with boron minerals on an area of 0,8 x 3 km; Searles Lake (California U.S.A.); Bandirma (Turkey)
   (b) Stassfurt (East Germany)
   (c) Toscana (Italy)
3. potential sources of boron: contacts of igneous rocks with dolomites, limestones and magnesites; sea water.
4. Mostly open pit, type (c) - condensation of vapours
5. (a) milion short tons of boron content: U.S.A. 20, U.S.S.R. [illegible]0, Turkey 20, China 10, Argentina 5, Chile 5

(b) production of borates, metric and short tons

	1972	1973	1974	
USA	1121 COC	1225 000	1185 000	s.t. boron minerals
Turkey	622 444	525 588	1038 588	m.t. dtto
USSR	75 000	75 000	80 000	m.t. B_2O_3 content
Argentina	52 438	63 380	74 095	boron minerals m.t.
Chile	2 250	1 532	968	borates,crude (m.t.)

6. fiber glass, ceramic glazes, detergents, food preservatives extra hard abrasives, nuclear reactor control rods and shields

C o r u n d u m Al_2O_3

1,2. (a) Disseminated crystals in rocks formed by regional or contact metamorphism
(b) Lenses in desilicated pegmatites (Transwaal, Rep.of S.Africa).
(c) Lenses in nepheline syenite, sometimes with sillimanite (Renfrew County, Ontario, Canada).
(d) Placers
(e) Emery, a mixture of corundum and magnetite (Izmir, Turkey).

3. Metamorphosed bauxites; contacts of pegmatites with basic rocks. Study of the position of paleo-equators is necessary.
4. Primary deposits are mined by underground methods. Enrichment through crushing, sieving, and handling on shaking screens.
5. (a) No data.
(b) Production of corundum (metric tons)

	1972	1973	1974
India	391	266	335
Egypt	294	269	275
USSR	7 000	7 000	7 COO

6. abrasives
7. AF: Rhodesia; Mozambique; Malawi; Tanzania; ME: Iran; Turkey; LA: Uruguay.

F e l d s p a r s $(K,Na)AlSi_2O_8$

1. (a) pegmatite veins and lenses;
   (b) intrusive massives;
   (c) sands
2. (a) New England (U.S.A.), Karelia (U.S.S.R.) - thickness 3-25 m, length X00 m.
   (b) alaskite (Spruce Pine, N.Carolina, U.S.A.), albitite (Aksoran, Kas.S.S.R), aplite (Küre Köy, Bilecik, Turkey), felsite, porphyry, nepheline syenite (Blue Mt.,Canada)
   (c) dune sands (California, U.S.A); river sands (Halámky, Czechoslovakia)
3. intrusive massives and rivers draining them
4. open - pit
5. (a) vast
   (b)

short tons	1970	1971	1972	1973
USA	726 069	742 810	732 439	791 900
FRG	456 634	389 789	385 198	338 432
USSR	274 400	276 000	287 000	298 000
Italy	195 258	212 192	193 805	209 657
France	132 160	212 000	162 000	165 000
Norway	143 360	223 530	220 000	220 000
Mexico	91 300	109 506	108 426	107 042
World total	2627 180	2815 046	2305 349	2794 005

6. glass, procelain, enamel, tile, dinnerware, engobes, frits,
7. almost all countries

F l u o r i t e CaF_2

1. (a) hydrothermal veins and irregular bodies;
   (b) pegmatites
2. (a) Cave in Rock (Illinois, U.S.A.) - subhorizontal bodies 1-5 m thick, 70-500 m long, 15-70 m wide. Coahuila (Mexico)
   (b) Kasakhstan (U.S.S.R) - crystals in cavities
3. Acid intrusives and their roof; prospecting for eluvial placers or hydrochemical prospecting using the fluoride electrode
4. underground exploitation (shrinkage stoping, open stoping,

room - and-pillar), rarely open pit quarrying

5. (a) million short tons: USA 60 , Mexico 100, Europe 100, Asia and Oceania 100, Africa 40

(b)

short tons	1970	1971	1972	1973
Mexico	1078 594	1301 779	1149 039	1196 992
USSR	450 000	460 000	470 000	490 000
Spain	376 621	370 091	444 290	430 000
Thailand	350 785	471 235	412 915	377 079
France	320 000	270 792	320 000	330 000
Italy	318 861	325 833	305 244	359 630
China	300 000	280 000	280 000	280 000
UK	213 044	232 500	219 300	220 000
USA	269 221	272 071	250 347	248 601
South Af.	190 693	203 497	232 374	231 842
Canada	136 800	80 000	179 700	151 000
Czechoslov.	90 000	100 000	100 000	137 000
World total	4597 008	5013 290	4974 333	4927 849

6. Chemical, steel and ceramic industries.

G r a p h i t e C

soft black flaky mineral; artificially produced from petroleum coke.

1. Graphite originates:
   (a) in magmatic rocks as nepheline syenites (Botogol, USSR) or pegmatites (Buckingham, Canada), in their contacts with carbonates (Grenville, Canada), or in high-temperature veins (Ceylon);
   (b) in metamorphic rocks during regional of contact metamorphism of carbonaceous shales (southern Bohemia) or coal seams (Sonora, Mexico)
2. Sri Lanka-veins of flake graphite up to 2 m thick. Malagasy - 4 to 11 % of graphite with flakes 1 to 3 mm in layers 3 to 30 m thick and thousands of m long in gneisses.
3. Flaky graphite can be found in veins and in metamorphic deposits. Crystalline massives are to be studied. Black

outcrops of veins and seams of graphite can be located by means of aerogeological mapping and delimitated by means of electrical resistivity, self-potential or radiometrical geophysical methods. Sinking of pits, boring and exploration through galleries is necessary to estimate the reserves.

4. In tropical coutries it is sometimes possible to work residually-enriched outcrops of poor graphite seams or graphite gneisses (e.g. Madagaskar). Underground mining is inevitable in other cases. Maintenance of shafts and galleries in slippery graphite is often very difficult. Graphite is crushed, flotated, sometimes refined chemically (up to 99,9 % C). For refractory purposes at least 85 % C in graphite is required.

5. (a) No data.
(b)

metric tons	1970	1971	1972	1973	1974	1975
USSR	75 300	80 000	80 000	85 000	90 000	90 000
Mexico	55 648	50 916	55 110	65 392	62 551	60 814
USA	29 854	35 536	43 340	56 653	59 002	49 081
Korea,N.	75 000	75 000	75 000	75 000	77 000	77 000
Korea,S.	59 530	72 515	40 768	43 604	104 861	47 232
China	30 000	30 000	30 000	30 000	40 000	50 000
Austria	24 000	21 000	18 777	17 211	29 555	30 586
FRG	16 406	12 688	11 348	13 525	16 485	13 557
Czechosl.	12 929	13 457	13 300	15 306	15 082	15 036
Madagask.	18 312	20 116	18 320	13 963	17 280	17 774
Brazil	11 200	23 709	27 347	25 784	28 625	-
World total	448 955	478 580	456 962	482 298	597 627	544 313

6. Foundry facings (" amorphous" graphite), batteries, bearings, brake linings, crucibles (flake graphite), lubricants, pencils, packings, refractories

K y a n i t e $Al_2O_3 \cdot SiO_2$

1. Originates at high pressures under conditions of deep regional metamorphism from argillaceous sediments with high alumina contents, occurs as disseminated crystals in mica--schists, gneisses, and quartzites, with possible later segregation into pockets and lenses under the influence

of contact metamorphism. Kyanite lenses and pockets occur also in pegmatites and quartz veins. Sometimes accumulates in river- and beach-placers.

2. Baker Mountain near Pamplin (Virginia, USA) - 30-40 % kyanite in rock. Lapso-Buru (Singhbum District, Orissa, India) - massive kyanite with 10 % corundum.
3. Found by studying heavy minerals in river- and beach-sands in metamorphic massives with acid intrusions; associated with placers, residual boulders, and primary outcrops which build low ridges.
4. Mining by open cut methods using blasting. The ore is crushed, cobbed, and hand-sorted, sometimes flotated, fired, separated magnetically. The concentrate is pre-calcined.
5. (a) India - 3,790.000 t (1971); Botswana - 30.000 t; Guayana - 2,200.000 t (1973); Austria (Wipp Valley) - several mil.tons.

   (b) Production of kyanite (short tons)

	1950	1955	1966	1968	1970	1971
USA	16,000	28,000	cannot be disclosed			
India	29,747	13,206	63,670 (m.t)	70,945 (m.t)	119,120 (m.t)	62,960 (m.t)
Kenya	12,845	3,031				

6. refractory mortars, cements and castables
7. AF: Botswana (Halfway Kop); Malawi (Ncheu, Kapiridimba); Uganda; Tanzania; Angola; Liberia (Grand Bassa Country); LA: Surinam (Boschland); FE: Mayurbhanj State (India) - several mil. tons of dumortierite 8 Al_2O_3 . B_2O_3 . 6 SiO_2 . H_2O; Lapso Buru (Kharsawam, India) - topaz 2 Al_2O_3 . 2 $Al(F,OH)_3$. 3 SiO_2 .

M a g n e s i t e $MgCO_3$

(a) crystalline and (b) cryptocrystalline ("amorphous").

1. (a) In large irregular bodies in dolomites;

   (b) I. either in lenses or veins with dolomite; II. in concretions and boulders in weathered serpentinite; III. in sediments with dolomite.
2. (a) Košice (Czechoslovakia) several bodies tens of meters

thick and hundreds of meters long;

(b) I. Euboia (Greece);

II. Khalilovo (Urals, USSR);

III. Needles (California, USA) - a bed 4 m thick, 800 m long, 900 m broad.

3. (a) Areas of dynamic geological activity built by crystalline carbonate rocks;

(b) serpentinite massives. In both cases: outcrops are first located, then sampled and drilled to find their thickness.

4. Mining by open-pit methods if possible, otherwise by underground methods of the room-and-pillar type, possibly first by the former, then by the latter.

5. (a) million tons magnesium content: China 1150, North Korea 820, USSR 800, India 50, Czechoslovakia 30

(b) thousand metric tons

	1970	1971	1972	1973	1974	1975
Kenya	0	0	1	2	10	17
S.Afrika	84	79	69	80	105	61
Sudan	-	-	-	-	-	-
China	1000	1000	1000	1000	1000	1000
India	755	915	922	1069	1347	1426
Iran	4	4	4	4	16	16
N.Korea	1630	1720	1720	1700	1700	1700
Pakistan	1	1	0	3	[illegible]	2
Turkey	300	362	336	351	3[illegible]	[illegible]1
Austria	24	20	19	22	[illegible]	36
Czechosl.	2928	3062	2996	2734	2816	2885
Greece	755	915	922	1069	1347	1426
Poland	39	22	36	22	24	27
Spain	222	258	273	240	265	342
USSR	1420	1450	1500	1710	1750	1800
Yugoslavia	512	493	422	384	464	485
Brazil	216	233	277	275	366	439
Mexico	8	12	21	29	22	40
World total	11130	11510	11300	1270	12170	12340

Annual production (1972) of magnesium from seawater and brines: USA (300,000 tons seawater, and Great Salt Lake), USSR (100,000 t - Sivash, Crimea), Japan

(420,000 t), GB (250,000 t, Italy (6,000 t), Norway (80,000 t), Canada (30,000, Mexico (50,000), Iceland (107,000 t $MgCl_2$). Product on of magnesite from dolomite planned in Hungary.

6. refractories, chemical industr pulp and paper
7. AF: Tanzania (Same, 4 mil. t); ME: Saudi Arabia (40 mil.t); FE: India (Tamil Nadu; Uttar P adesh - Almora district 7,9 mil. t; Mysore); Nepal (Kh idhunga - 180 mil.t).

M i c a

$K_2Al_4(Si_6Al_2O_{20})$ $(OH,F)_4$- muscov te

$K_2(Mg,Fe)_6$ $(Si_6Al_2O_{20})$ $(OH,F)_4$ phlogopite

1. muscovite: (a) granite pegmatit ; phlogopite: (b) hydrothermal veins in Precambrian s elds
2. (a) Bihar (India); Karelia and ola Peninsula (U.S.S.R.); (b) Slyudyanka (U.S.S.R.);
3. prospecting for pegmatites in tamorphic rocks close to acid granitoid intrusions; exp ration by underground workings.
4. open pit quarrying by hydrauli method or power shovels; underground mining - blasting small charges
5. (a) no data
   (b)

metric tons	1970	1971	1 72	1973	1974	1975
USA	107813	115289	13[illegible]63	139110	124262	122093
USSR	37000	38000	39[illegible]00	40000	41000	42000
India	16589	15099	1[illegible]73	13830	13804	11501
S.Afrika	7562	7160	[illegible]47	6009	2696	2511
Norway	4348	3478	[illegible]90	4445	4160	7455
Argentina	1404	3256	[illegible]56	2940	3197	3330
World total	189312	197850	21[illegible]11	224259	202396	200195

6. insulators in electronic, telev sion and radio equipment

O l i v i n e (forst rite Mg_2SiO_4)

1. Rock-forming mineral of ultraba ic rocks such as dunites.
2. Aaheim and Norddal (Norway).
3. Ultrabasic crystalline massives usually controlled by deep faults.

4. Quarrying by blasting, loading by power-shovel.
5. (a) Aaheim - 2 miliard tons
   (b) Norway 1970 - 140,000 metric tons, 1972 - 250,000 metric tons
6. refractories
7. AF: Bushveld Complex (Rep. of S. Africa).

S i l l i m a n i t e $Al_2O_3 \cdot SiO_2$

1. Originates as prismatic crystals or fibrous masses at high temperatures in the presence of fluorine during regional or contact metamorphism, or both. Occurs in schists, gneisses, hornfels, and in placers.
2. Sona Pahar (Khasi Hills, Assam, India) - sillimanite + + corundum; Cape Province (Rep. of S. Africa).
3. see kyanite. Massive sillimanite is sawn into glass tank blocks.
4. Economic content of sillimanite in schist - 10 %.
5. (a) USA - tens of millions of tons; Namaqualand - 2.5 mil. t (sillimanite + corundum); Assam - 238,000 t.
   (b) Production of sillimanite (metric tons)

	1972	1973	1974
India	4 046	3 138	2 917
Egypt	9 476	19 317	13 091
Australia	575	642	700

6. see kyanite

S u l f u r (S)

1. (a) volcanic deposits on the crater walls and floors
   (b) biochemical-sedimentary bedded deposits
   (c) gypsum cap rock of salt domes
   (d) natural gas and petroleum
   (e) pyrite (hydrothermal or sedimentary)
2. (a) Siretoko Iosan (Hokkaido, Japan)
   (b) Tarnobrzeg (Poland)
   (c) Gulf Coast (U.S.A.)
   (d) Alberta (Canada), France
   (e) Rio Tinto (Spain)

3. young fold belts (a,b,c) and their foredeeps (d)
4. open pit or Frasch method (b,c)
5. (a) million long tons: Canada 1500, Near East 900, U.S.A. 630, U.S.S.R. 600, Mexico 150, Poland 80, Japan 60
   (b)

th.m.t.	1970	1971	1972	1973	1974	1975
USA	7196	7138	7407	7727	8028	7326
Poland	2683	2713	2927	3545	4093	4771
USSR	1120	2100	2200	2300	2400	2500
Mexico	1381	1178	944	1608	2322	2164
Irak	-	-	137	395	610	650
China	130	130	130	130	130	130
Finland	-	-	11	123	100	84
Italy	63	72	91	80	64	73
Japan	146	96	17	16	16	16
Czechosl.	7	5	2	5	7	10

   Recovered sulfur from natural gas (1972 mil.metric.tons): Canada 7,25, France 1,75.
6. sulfuric acid; sulfur asphalt for paving, inpregnations, building materials
7. LA: Cordilleras, ME: Taurides and Iranides, FE: East Asia mountain ranges

T a l c and s t e a t i t e $Mg_3(Si_4O_{10})(OH)_2$

1. (a) In or on contact of magnesite and dolomite with country rock, as lenses and veins;
   (b) in serpentinites (mostly as soapstone, i.e. with aklinolite, carbonates, chlorites etc.).
2. (a) Manchuria (China); Inyo Mountains (California, USA)- up to 17 m thick and 300 m long lenses on the contact of quartzite and dolomite
   (b) Shabry, Urals (U.S.S.R.)
3. In sheared and fractured metamorphic rocks with intercalations of magnesite and dolomite. Prospecting by geophysical methods, sinking of pits, drilling.
4. Underground mining with difficult maintenance of the shafts, galleries, and chambers because of the slippery charakter of talc and steatite.

5. (a) milion short tons: U.S.A. 800, Asia and Oceania 500, Europe 250, Africa 25, South America 25

(b) Production of talc, steatite, soapstone and related minerals (short tons)

	1971	1972	1973
Botswana	143	-	-
Egypt	6968	8518	8500
S.Africa	12975	11926	13055
Swaziland-pyrophyllite	225	119	139
Burma	237	240	141
China	165000	165000	165000
India	208094	209189	228344
Japan	1731827	1661114	1723540
Korea-N	99000	110000	120000
Korea-S	234185	259867	248257
Pakistan (soapstone)	5200	4846	4390
Philippines	1452	1110	1801
Taiwan	43036	27328	25490
Austria	100995	91725	101638
Finland	110979	99568	120928
France	279579	250548	285363
FRG	32692	34743	33000
Greece	2045	2200	2200
Hungary	17600	17600	17600
Italy	152936	163607	161539
Norway	85092	85000	85000
Portugal	1405	1327	1224
Romania	63000	63000	66000
Spain	44911	44000	44000
Sweden	26505	29107	33000
USSR	420000	430000	440000
UK	13228	17637	18000
Canada	65562	80946	110000
Mexico	1889	3450	2324
USA	1037297	1107404	1246534
Argentina	54881	40827	44000
Brazil - talc	143000	143000	143000
Chile	1938	2021	1938
Colombia	2177	2477	992

	1971	1972	1973
Paraguay	176	243	276
Peru	1057	1100	1100
Uruguay-ground talc	939	1458	2201
Australia	52774	61891	62000
World total	5221214	5240750	5666181

6. electro-ceramics, cosmetics, ceramics, filler in paper, plastics and rubber industries, paints
7. AF: Egypt (between Nile and Red Sea); Zambia (Lilaya and Chipata - 300,000 t); FE: Nepal (Kharidhunga - 300,000 t).

W o l l a s t o n i t e $CaSiO_3$

1. in metamorphic rocks
   (a) on a contact of limestone with intrusive rock, or (b) in regional metamorphosed rocks
2. (a) Willsburough (New York state, U.S.A.), Lapperanta (Finland)
   (b) Little Maria Mts. (California, U.S.A.)
   Synthetic w. is produced in Denmark from sand and chalk (trade mark Synopal), Italy, U.S.A., Germany, and U.S.S.R.
3. see 1., and in carbonatites
4. open pit
5. (a) world: 90 mil. tons
   (b) Production of wollastonite (metric tons)

	1972	1973	1974
India	3326	476	947
Kenya	-	55	100
Finland	6491	6547	9118
Mexiko	559	1593	1984

6. ceramics (reduces warping and cracking), paints, plastics,
7. see 1., and wollastonite in carbonatites: AF: East African rift, LA: Brazil

Z e o l i t e s

are cristalline hydrated alkalin alumosilicates with ion exchange capacity and interconnected cavities in the structural lattice

1. alteration of volcanic glass by water

2. Itaya (Fukushima, Japan) - thickness 100m; Bouie (Arizona, U.S.A.)
3. homogenous fine-grained rocks in volcanic complexes
4. open pit
5. (a) vast reserves in U.S.A., Japan, FRG, Italy, Yugoslavia Hungary, Bulgaria, Mexico
   (b) see 5 a: 300.000 metric tons per year
6. pozzolanic cement and concrete, lightweight aggregate, filler in paper, ion-exchange processes, oxygen separation from air, animal nutrition, agriculture, gas adsorption and catalysis, dimension stone

Z i r c o n e $ZrSiO_4$ with some hafnium

in placers sometimes occurs together with baddeleyit ZrO_2 (Minas Geraes, Brazil), often with monazite $(Ce,La,Th)PO_4$ (Espirito Santo, Brazil); ilmenite $FeTiO_3$, and rutile TiO_2 (Victoria and New South Wales, Australia).

1. Beach placers fed by inland crystalline rocks (granites, granitic pegmatites, granodiorites, nepheline syenite pegmatites) with zircon as accessory mineral. The rocks underwent deep weathering (e.g. laterization) on peneplain followed by uplift, rapid erosion of newly formed high mountains near the sea and quick immersion in the sea of weathered rocks with heavy minerals.
2. Australia, eastern coast in a length of 100 miles between Bollina (N.S.W.) and Stradbroke Island (Queensland): 44-70 % zircon in heavy mineral concentrate (with 15-30 % each rutile and ilmenite); Florida (USA), elevated sand bars on the coast near Yacksonville and St. John's River (15,000 tons per year of zircon); Turkey, Black-Sea coast near Shile - black sand 7-14 cm thick with 10 % zircon (88 % of grains smaller than 0.2 mm).
3. Shores with vertical movement, built by acid and alkaline intrusions, that weathered deeply thus releasing the heavy minerals. Loci: alongshore sand bars extending from headland to headland.
4. Removal of overburden by bulldozer, selective hand loading into trucks, separation of heavy minerals from silica sand on Wilfley tables and spirals, electromagnetic and electro-

static separation of zircon and rutile (non-magnetic) from magnetite and ilmenite.

5. (a) Australia, Brazil, India: 10 mil. t of Zr-minerals; North Stradbroke Island (Australia): 1 % of zircon in sand dunes 700 feet thick on a 107 square miles area. USA deposits: 5 - 15 mil. t of Zr-minerals: Trail Ridge (Florida): 2,520,000 tons of zircon, Pulmaddai and Kokkelai deposits: 210,000 t of zircon. Urugababa near Durban (Rep. of S.Africa): 200,000 t of zircon.

(b) Production of zirconium concentrate (short tons)

	1970	1971	1972	1973
Australia	424902	455195	397042	393336
Brazil	4483	4596	5046	5100
Sri Lanka	-	153	33	31
Malagasy R.	3	3	15	15
Malaysia	948	2803	2216	2200
Thailand	953	1682	403	440
India	7649	9924	12000	12000
S.Africa	432	1091	745	2180

6. refractories, foundry sand, ferroalloys, glazes, enamels, paints,pharmaceuthicals; hafnium: nuclear reactors

7. AF: coast of Sierra Leone, Senegal, Egypt (Rosetta-Damietta, Borallus); FE: coast of India (Travancore, Cochin); eastern shore of Australia; LA: Uruguay: black sands 6 m thick with 2.5 % heavy minerals on the Atlantic coast at Aguas Dulces (3 mil. t of heavy minerals, 5 % zircon, 0.6 % monazite); coast of Brazil (Rio Grande del Norte).

IV. AN ALPHABETICAL SURVEY OF INDUSTRIAL ROCKS

B a u x i t e (A) and alumina-rich laterite (B)

rock composed of gibbsite ($Al_2O_3 \cdot 3\ H_2O$), boehmite and/or diaspore (both $Al_2O_3 \cdot H_2O$) with admixture of kaolinite,quartz, hematite, goethite, rutile, and others.

1.A. (a) Beds and lenses in sediments (mostly limestones);
(b) Pockets in limestones (bauxite fills the sinkholes);
(c) Detrital deposits;
all types are washed-over Al-laterites

1.B. Residue on rocks with low silica contents formed by ancient or recent tropical weathering in savannah with alternating dry and rain seasons.

2.A. (a) Tikhvin near Leningrad (USSR) - beds with 35-55 % Al_2O_3, 15-25 % Fe_2O_3, 10-25 % SiO_2

(b) Jamaica - gibbsite, 46-50 % Al_2O_3, 10-20 % Fe_2O_3, 1-2 % SiO_2

(c) India (at the foot of the weathered trapps)

2.B. Surinam - gibbsite - bearing Al-laterite with up to 57 % Al_2O_3, 8-12 % Fe_2O_3, 2-3 % SiO_2

3.A. Mostly in tropical and subtropical zones - fossil or recent - where limestones occur.

3.B. laterites of Neogene age sometimes build top hardpan on inselbergs in contemporary tropical belts. Prospecting for laterites: by paleogeomorphological studies; following the flow fragments; drilling and test-pitting.

4. Stripping of overburden by scrapers, open-pit quarrying by blasting and power shovel, crushing, washing (to remove clay), drying and calcining in rotary kilns.

5. (a) 1 to 2.5 miliard tons on the Earth: Jamaica 19.7 %; Guinea 14.8 %; Ghana 10.8 %; Hungary 7.4 %; Australia 7.4 %; Guayana 3.2 %; Malawi 3 %; Surinam 2.5 %; India 2.5 %; Brazil 2 %.

(b) Production of bauxite (in thousands of metric tons)

	1970	1971	1972	1973	1974	1975
Jamaica	12106	12543	12989	13489	15224	11304
Australia	8294	11043	13697	14702	18545	22205
USSR	4300	4100	4200	4300	4300	4400
Surinam	6011	6717	6777	6718	6863	4751
France	2992	3117	3281	3299	2938	2563
Guinea	2490	2630	2600	3800	7600	8406
USA	2562	2458	2235	2324	2408	2199
Yugoslavia	2098	1959	2197	2167	2370	2306
India	1374	1517	1684	1297	1114	1274
Indonesia	1229	1238	1276	1229	1290	993
Malaysia	1139	978	1077	1143	948	704
Guyana	4413	4234	3727	3622	3606	3830
Domin.Rep.	1083	1032	1087	1086	1196	785
Haiti	673	715	725	779	793	523
Sierra L.	443	590	692	704	693	727

	1970	1971	1972	1973	1974	1975
China	500	550	550	760	970	970
Brasil	510	566	765	849	858	969
Ghana	342	329	340	356	365	325
Turkey	52	153	471	352	665	558
Mosambique	7	8	5	6	5	2
World total	57940	62560	66170	69270	79180	76470

6. alumina, aluminum, refractories
7. AF: Mozambique; Upper Volta (Kaya-Kongoussi; Bobo-Dioulasso); Malagasy (Menentenina); Malawi (Mulen Mts.); Cameroon (Minim Martap - 1.5 mld.tons);
   LA: Dominican Rep.; Colombia (Cauca Deparment); Haiti; Costa Rica (San Isidro; Carthago province);
   FE: Sarawak; Maleysia; Solomon Islands (Wagina Island; Rennell Island - ? 100 mil.t 47-48 % Al_2O_3); Fiji

D i a t o m i t e

low density sedimentary rock consisting of fossilized shells of siliceous algae - diatoms. Mineralogical composition - opal.

1. Beds of sedimentary origin with tuffs and tuffites of contemporary volcanism, mostly Neogene and Quaternary.
2. Lompoc (California, USA) - thickness 250 m.
3. Neogene and Quaternary strata with volcanic ash. Exploration by sinking of shafts and drilling holes.
4. Working by electric or diesel shovels or rooters powered by tractors or bulldozers. Drying and coarse milling, calcination.
5. (a) No data.
   (b) Production of diatomite (short tons)

	1970	1971	1972	1973
USA	597636	535318	576089	608906
USSR	410000	410000	420000	430000
France	190000	185703	190000	190000
FRG	100924	97787	63985	50700
Italy	66000	65000	65000	65000
Denmark diatomite	22000	22000	22000	22000
Denmark moler	240000	240000	240000	240000
Spain	20000	20211	22000	22000
W.total	1766308	1706917	1700109	1738498

	1970	1971	1972	1973
Argentina	9070	10568	10600	10600
Peru	2821	4162	4400	4400
Kenya	1765	1543	1997	137
Egypt	2504	2480	1839	1900

6. filtration, filler, mild abrasive, sourc of silica
7. AF: Nigeria (Potiskum); Rep. of South Africa (Ermelo and Prieska districts); LA: Brazil; Chile; Colombia (Quesnel); Costa Rica; Mexico; ME: Turkey; FE: Korea; Japan.

Dolomite $CaCO_3 \cdot MgCO_3$

1. (a) Sedimentary beds interstratified with limestones.
   (b) Hydrothermal-metasomatic masses with crystalline magnesite.
2. In almost all coutries, huge deposits.
3. (a) In Paleozoic and Mesozoic sediments.
   (b) see crystalline magnesite
   By localition of the outcrop, digging trenches and drilling holes.
4. Open-cast mining by means of blasting; loading by power shovel.
5. (a) No data - huge reserves
   (b) Belgium, Italy, Norway, Spain, and other coutries
6. Aggregate, special cement and lime, refractories, removal of sulfur oxides from stack gases, neutralisation of acid waters and soils, filler of rubber, glass, ceramic and chemical industries.

Glass and foundry sands

glass sands: most quartz grains 0,1-0,3 mm in diameter, and Fe_2O_3 content less than 0,04 %; foundry sands: quartz grains and 5-10 % of clay substance; if missing (in pure sands) bentonite or organic compounds should be added

1. sedimentary complexes with sands, and sandstones
2. almost in all coutries
3. shallow sea or lake sediments, recent of ancient
4. open pit quarrying, sometimes by hydraulic method

Note: for production of green or brown bottle glass fonolite with more than 15 % of $Na_2O + K_2O$ can be used

L e u k o p h y l l i t e

composition: quartz, sericite, talc, leuchtenbergite

1. hydrothermally altered fractured zones in granitoids
2. Austria
3. granitoids close to talc and magnesite deposits
4. mostly underground mining
5. no data
6. filler in paints, rubber, paper; wall-tiles, utility and sanitary ware (leuk. lowers the burning temperature)

M i n e r a l p i g m e n t s

yellow: ochres; red: hematite; brown: umbers; black: magnetite, pyrolusite

1. weathered iron-or manganese - bearing rocks, or their washed-over and sedimented derivatives
2. almost in all coutries
3. see 1
4. open pit quarrying

P e t r u r g i c b a s a l t
(for melting and casting)

1. volcanic areas
2. Czechoslovakia, U.S.S.R., F.R.G., Japan, Poland, Bulgaria
3. basalts with composition:

SiO_2	43,5-47,0 %	MnC	0,2-0,3 %
TiO_2	2,0- 3,5 %	MgC	8,0-11,0 %
Al_2C_3	11,0-13,0 %	Cao	10,0-12,C %
Fe_2O_3	4,0-7,0 %	Na_2O	2,0-3,5 %
FeO	5,0-8,0 %	K_2O	1,0-2,0 %
		P_2O_5	0,5 - 1,0 %

4. open pit quarrying, mostly selective
5. no data
6. anticorrosive pipes and their bends, floor-tiles, various casts; mineral wool, refractory isolations

Phosphates

composition: mostly apatite $Ca_5(PO_4)_3 \cdot (F,Cl)$

1. (a) marine shelf sediments
   (b) phosphate pebbles - re-worked deposits of type (a)
   (c) residual and infiltration deposits
2. (a) Khouribga (Morocco), Hahotoe (Togo)
   (b) Florida (U.S.A.)
   (c) Tennessee (U.S.A.)
3. (a) in complexes with black bituminous shales; by radiometric method (0,02 % and more of U_3O_8 in some phosphates); hint for prospecting: fluorosis of cattle.
   (b) weathering crust, soils above limestones with accessory phosphates
4. mostly open pit quarrying
5. (a) miliard short tons: Morocco 60, U.S.A. 7, U.S.S.R. 4, western part of Sahara 3,7; Australia 3, Tunisia 2
   (b)

th.m.tons	1970	1971	1972	1973	1974	1975
USA	35143	35277	37041	38226	41446	44285
USSR	17800	19000	19700	21250	22500	24120
Morocco	11424	12030	15105	17077	19750	14119
Tunisia	2969	3162	3986	3473	3826	3512
China	1700	2200	2600	3000	3000	3400
Nauru	2200	1913	1906	2323	2288	1535
Senegal	998	1454	1250	1533	1472	1600
W.Sahara		33	150	696	2168	3300
World total	81800	84600	90900	99300	116900	118500

6. fertilizers, chemical industry
7. AF: Libya; LA: Mexico (Baja California), Peru; ME: Turkey, Iran, Saudi Arabia;

Salts

(A) rock salt NaCl, (B) potassium salts: sylvite KCl, carnallite $KCl.MgSO_4 \cdot 11\ H_2O$, a.o.

1. recent of ancient beds (or ancient domes) originated by evaporation of saline waters (sea, lake, playa, lagoon, salina , sabkha) in arid climate;
   (A) mass of the deposits; (B) upper part of approx. 20 % of salt deposits

2. (A) Zechstein (Germany); Alberta (Canada); Danakil lowland (Ethiopia); domes: Gulf Coast (U.S.A.)

   (B) Stassfurt (Germany); Kama (U.S.S.R.); Delaware Basin (N.Mexico, U.S.A.)

3. around salt springs and outcrops of gypsum; by gravimetry and sesmic methods; gamma logging of drill cores for ^{40}K; careful drilling

4. room - and - pillar

5. (a) world ocean: 4.5 milion cubic miles of salts; vast reserves of rock salt in almost all coutries with the only major exception of Japan. Potassium salts, miliard short tons K_2O: U.S.S.R. 55; Canada 55; West Germany 11, East Germany 10; U.S.A. 0,5; Israel and Jordan 2.

   (b) (A) rock salt (thousand metric tons)

	1970	1971	1972	1973	1974	1975
USA	41636	39986	40843	39834	42217	37222
China	15600	16500	18000	19960	25400	29940
USSR	12428	11968	12228	12860	13356	14300
F.R.G.	10511	9009	8282	9077	11497	9500
India	5588	5426	6521	6864	5918	
Canada	4862	5028	4914	5048	5447	5156
France	5664	5495	5237	6117	5995	5347
Australia	2054	3774	3503	3671	4683	5057
Mexico	4063	4703	5060	4319	5470	3803
UK	9188	9348	9734	8374	8283	7630
Italy	4359	4382	3836	3707	4006	3191
Romania	2862	2948	3147	3296	3923	3833
Poland	2904	2962	3010	3078	3295	3524
Metherlands	2371	3167	2803	3059	3387	
GDR	2180	2221	2187	2286	2338	2430
Czechoslov.	42	40	41	40	41	39
World total	144000	143380	147400	151400	164700	159200

(B) potassium salts (K_2O content) thousand metric tons

	1970	1971	1972	1973	1974	1975
USSR	4087	4807	5433	5900	6100	6050
Canada	3103	3629	3494	4453	5776	4850
GRD	2419	2445	2458	2556	2864	3019
FRG	2420	2815	2845	2975	3090	2607
USA	2476	2347	2412	2361	2315	2314
France	1904	2000	1760	2263	2275	2085
World total	18230	20100	20700	22640	24600	23200

6. (A) source of sodium and chlorine, nutrient, preservative, freezing point depressant, metalurgical processing;
   (B) chemical industry, fertilizers, glass, ceramics, textiles, paints, detergents, a.o.

V. BUILDING RAW MATERIALS

Marly and siliceous correction materials for cement
(A) argillaceous limestones and marls with 60-80% $CaCO_3$,
(B) loams, clays, shales, weathered igneous rocks, sands

1. (A) shallow-water marine sediments;
   (B) various types of sediments and residual deposits
2. common in all countries
3. close to the planned cement factory
4. open-pit quarrying
5. (a) vast reserves
   (b) production of cement in milion short tons (1973): U.S.S.R. 120; Japan 94; U.S.A. 87,5; West Germany 45; Italy 40; France 38; China 34; Spain 24,5; U.K.22; Poland 17;
6. for correcting of hydraulic module of the raw material

$$\frac{CaO}{SiO_2 + Al_2O_3 + Fe_2O_3}$$ to values between 1,7 and 2,2;

other modules and coefficients are also used.

Brick raw materials

(A) plastic (clay) component: loams, clays, shales, weathered claystones, loess

(B) non-plastic (clastic) component: aleurites, sands, sandstones, loess, aleuropelitic residues of various weathered rocks

1. various kinds of rocks (see A,B) outcropping on the surface
2. common in all countries
3. close to the market; exploration by shallow bore-holes or shafts
4. open-pit
5. (a) vast reserves; (b) utilisation in all countries but no data available

Stone for aggregate

(A) gravel and sand, (B) crushed stone

1. (A) river and glacial sediments, (B) granites, basalts, porphyrites, greywackes, granulites a.o.
2. common in almost all countries
3. close to the market; exploration by shallow bore-holes or shafts
4. open-pit
5. (a) vast in almost all countries

   (b) thousand metric tons

	1970	1971	1972	1973	1974	1975
USA	1300457	1264011	1254050	1422990	1311800	1138650
FRG	140108	144567	145652	136167	145156	125672
Australia	61020	63412	63346	65557	70785	74652
Italy	41848	41502	44177	49378	53800	– (excluding gravel)
Czechosl.	32728	35983	38820	41567	45065	47602
Poland	14610	17532	22047	27275	33350	39738
N.Zealand	26872	25879	27712	29252	27580	22664
Hungary	21119	23530	23112	24218	24034	27670

6. concrete (85-90% gravel + 10-15% cement) for construction: highway, residential, commercial

Building stone

for structural support (rough construction stone: retaining walls, seawalls, bridge work a.o.), ashlar, dimension (cut) stone (curtain, walls, veneer, roofing slate, floor tile, monumental stone), ornamental use

1. masses or beds of granite, diorite, limestone, marble, greenstone, sandstone, slate
2. common in many countries
3. mostly in old shields and consolidated platforms that had undergone tectonic movements long ago
4. quarries
5. (a) no data; (b) dimension stone: world 1974 38,8 miliard short tons

VI. CONCLUSIONS

The finding, exploration, and working of deposits of nonmetallic raw materials in developing countries.

A. A preliminary marketing feasibility study must answer the following questions:
   (a) is there a potential market for nonmetallics in the country?
   (b) what is the cost of imported industrial minerals and rocks
   (c) will there be any possibility for exports of nonmetallics and their products to adjoining countries in the remote future?
   (d) are there, in general, suitable raw materials in the country?

B. Should the comparison of item sub A. favour establishing relevant industry, the following steps should be taken:
   (a) inquiry at the local Geological Survey on the raw material basis of industrial minerals and rocks individual deposits must be sufficient for at least 25 years

of planned production;

(b) should there be insufficient information, a thorough prospection must be planned, if necessary with the help of foreign experts - one geologist and one mineralogist-technologist.

C. The prospecting team can consist of a geologist, mineralogist-technologist, geological assistant (a technician with knowledge of local languages), several workers for digging trenches and shallow shafts, drilling of shallow bores (e.g. by a hand-drill of mackintosh type), for exploration and sampling of clays, kaolins, bauxites, etc., one foreman skilled in blasting hard rocks, one passenger car with driver, another car of a landrover (jeep, GAZ) type with driver.

D. Prospecting for many kinds of nonmetallic raw materials is usually carried out in a four-stage sequence (Table 3):

(a) Preliminary prospecting of the whole territory in question on the basis of published data and unpublished reports of the local Geological Survey, Public Works Department, Water Supply Department, etc. Information from local authorities and individual citizens should also be taken in consideration. Small samples (0.X kg) are taken at widely spaced regular intervals over the deposit or its part.

(b) Preliminary examination of the samples is carried out in the respective capital or in any town with facilities rendering it possible to carry out simple enrichment tests, such as sieving or panning of the placers with refractory heavy minerals, firing tests of clays and kaolins, chemical analyses of carbonate and silicate rocks and minerals, mineralogical examination of the samples by means of a polarizing microscope, thermal methods, X-ray diffraction, etc.

(c) Those deposits which proved to justify further investigation from the point of view of quality are revisited, explored by a network of dense exploration workings (trenches, shafts, bores) and large samples are taken (X tons from each deposit). The reserves of deposits are evaluated according to the usual standards assuming that the visible reserves will cover production for at least 10 years, probable reserves for 15 years and possible reserves for another 25 years.

(d) The large samples are studied thoroughly either in the respective coutry or in an industrial country, usually the one which supplies the technological equipment. Pilot-plant experiments with the large samples are necessary.

E. Erection of a plant (cement, ceramic, glass, refractories etc.) near the bulk raw material deposits and close to the market follows. Technical assistance continues during the first months of production. Rational developing of the mineral deposits requires removal of the overburden and innerburden outside the limits of the demonstrated reserves.

F. Most industrial countries are capable of rendering the technical assistance required - geological and technological: e.g. super-powers, minor powers, countries of intermediate size, as well as small countries such as Switzerland, Austria, and Czechoslovakia, and, of course, the United Nations Development Program, Department for Transport and Geology (New York) or the United Nations Industrial Development Organization (Vienna).

VII. LITERATURE

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Fig.1. Typical sizes of raw industrial minerals, their products and size change equipment

Ranges shown are approximate

KEY: ↘ Feed ✱ Product

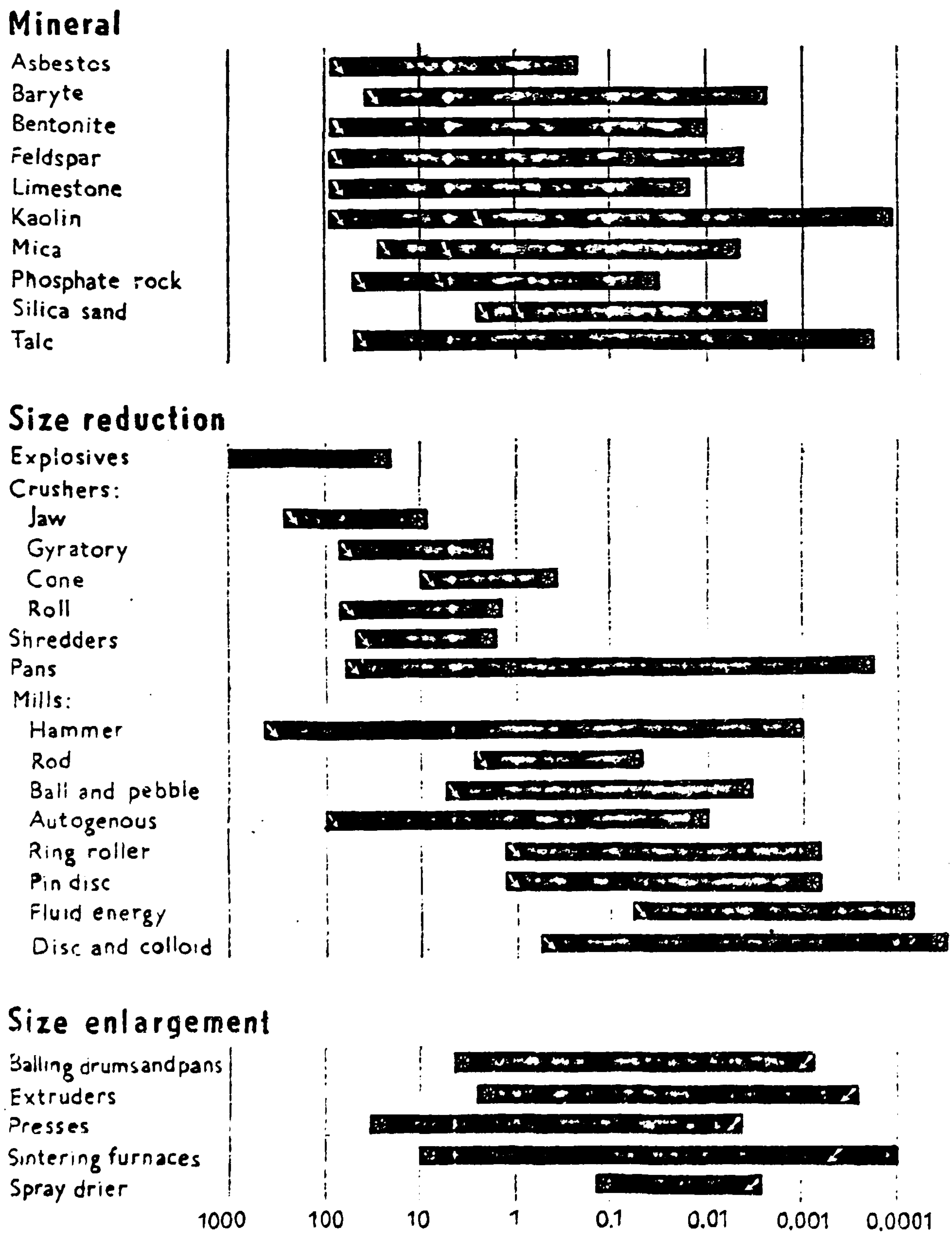

Figure II. Applicability of industrial minerals separation methods

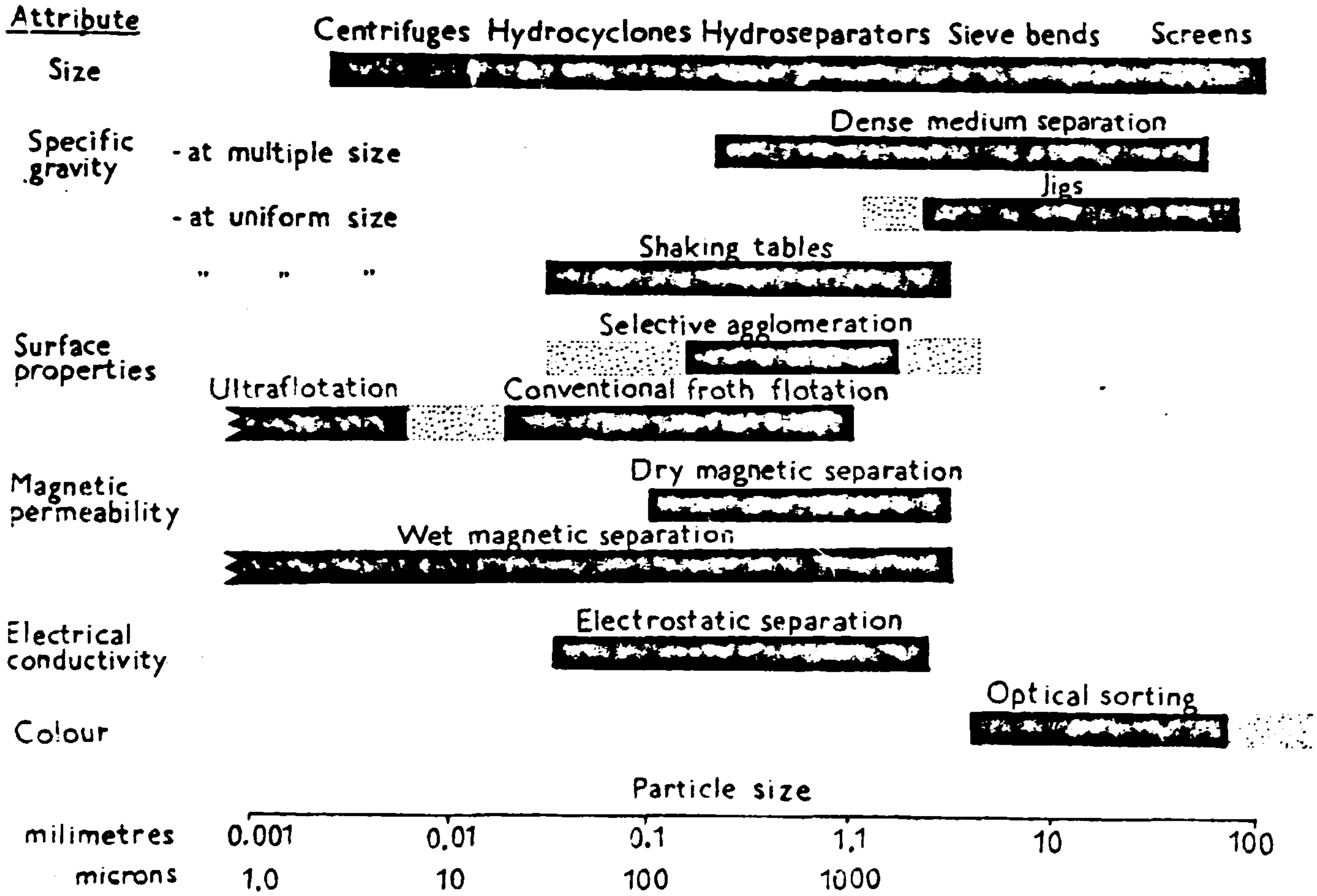

Table 1. Separation methods for some industrial minerals (9)

Separation method: Basis	Separation method: Technique	Asbestos	Barite	Borate	Chalk	Clay, common	Clay, china	Corundum	Cryolite	Diamond	Diatomite	Dolomite	Feldspar	Fluorspar	Garnet	Graphite	Gypsum	Kyanite	Limestone	Marble	Magnesite	Mica	Nitrate	Phosphate rock	Potash	Pumice	Pyro-phyllite	Ilmenite	Quartz silica sand	Salines	Sand & gravel	Crushed stone	Sulphur	Talc	Vermiculite
Size and Shape	Hand picking		+		+			+	+	+			+	+		+		+		+	+	+				+				+		+		+	+
	Scrubber							+		+												+							+		+	+			
	Log washer		+				+							+										+					+	+	+	+			
	Screens	+		+		+	+	+	+	+	+	+			+	+	+		+				+	+		+			+			+			
	Bowl				+		+																	+							+				
	Screw washer					+						+							+															+	+
	Aspirator	+														+																			
Specific Gravity	Sink-float													+	+	+	+				+														
	Hydrocyclone dense medium									+																		+							
	Jig		+					+	+	+				+	+																				
	Table		+	+			+		+					+	+			+						+	+			+							
	Humpreys Spiral																										+								
Surface Properties	Froth flotation		+				+						+	+	+	+		+			+			+					+				+		
	Grease tabling									+															+										
Electrical	Electrostatic												+																						
	Electromagnetic							+	+	+			+		+			+						+											
Miscellaneous	Colour sorting																			+															
	Solution																						+		+					+					
	Distillation																																+		
	Decrepitation			+				+	+																										

Table 2. Effects of processing on costs (1970) of industrial minerals

mineral	selling price £ per ton		ratio (2):(1)
	raw (1)	treated (2)	
bauxite	16	49	3.1
barite	15	44	2.9
ball clay	5	10	2.0
feldspar	8	17	2.1
ilmenite, rutile	13	75	5.7
magnesite	7	25	3.6
olivine (forsterite)	5	15	3.0
perlite	15	75	5.0
kaolin	5	30	6.0
silica sand	3	10	3.3
Fuller's earth	4	17	4.2

Table 3. Example of capital and time requirements of a mineral processing plant project

stage	expenses (per cent of the total cost)	time requirement (in months)	
(a) preliminary feasibility study (I): marketing	0.5	1-2	
(b) preliminary prospecting and sampling of all known and newly found occurences of mineral raw materials in the country	1	overlap 3	3-4
(c) preliminary examination of small samples taken during stage (b)	0.5	1-2	
(d) contract for the project			
(e) exploration, estimation of reserves and bulk sampling of prospects with demanded quality	3	6	
(f) pilot-plant experiments	1.5	3-5	
(g) feasibility study (II): 1.quality,possible use,and reserves of the deposits,transport,water,and energy supply, labour,etc.; 2.technological study on the basis of pilot-plant expeziments	3	3-4	
(h) authorization to build	-	2	
(i) detailed mechanical and technological design, project for buildings	6	overlap 6	17
(j) construction of the buildings; delivery of the technological equipment	38	overlap 15	
(k) cost and fitting of the technological equipment (cost of fitting=approx.12% of the value of the machines)	46	12-16	
(l) start up	0.5	2	
Total	100 %	47-56 months	

"Overlap" indicates that several stages can run simultaneously