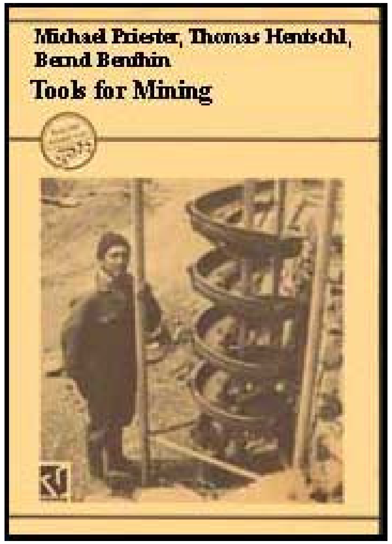

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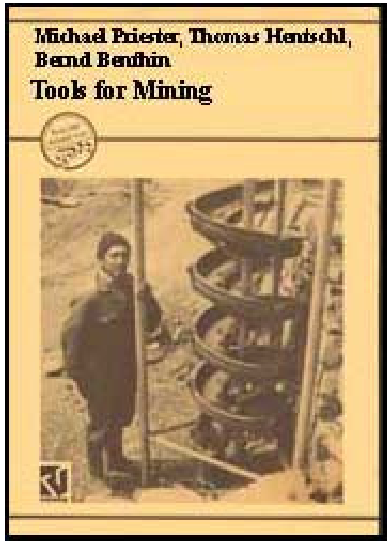

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Metalmecanica Milag - Millan
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45067,4 1202

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28 32 85,28 62 97,28 62 98, Fax 32 66 66 Telex 25793

Mineral Deposits,
81 Ashmore Road, Southport, Qld.4215, Australia,
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Mineral Equipment, Inc.
Precious Metals Extraction (PMX), 3740 Rocklin Road, Rocklin, CA 95677,
California, USA,
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Mainzer Strae 118,6200 Wiesbaden, Germany
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Netter
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Oliver Manufacturing Company,
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Pfister & Langhanss,
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52 1755,51 5944

Rife Hydraulic Engine Man.,
PB 367, Millburn, New Jersey 07041, USA

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Salzgitter,
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Wilfley Mining Machinery Co. Ltd.,
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Zutta Hermanos,
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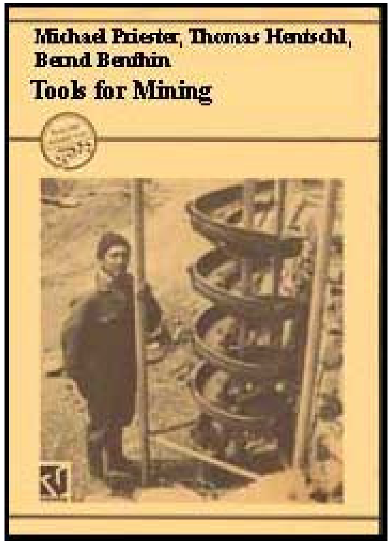

Michael Priester, Thomas Hentschl, Bernd Benthin
Tools for Mining

List of abbreviations

A.D.	Anno Domini
AGID	Association of Geoscientists for International Development
AKW	Amberger Kaolinwerke
approx.	Aproximate
B.C.	Before Christ
BGR	German Federal Institute for Geosciences and Raw Material
cif	Cost insurance freight
COMIBOL	Coorporacion Minera de Bolivia
Coop.	Cooperative
Cord.	Cordillera
CSMRI	Colorado School of Mines
DAV	German Alpine Club
DBM	German Mines Museum

DDR	German Democrate Republic
DE	German Patent
Dept.	Departamento
DM	Deutsch Mark
e.g.	Exempli grati (lat. = for instance)
E/MJ	Engineering Mining Journal
Ed.	Edition
EP	European Patente
etc.	Etcetera
Fig.	Figure(s)
fob.	Free on board
FONEM	Fondo Nacional de Exploracion Minera, La Paz
GATE	German Appropiate Technology Exchange
GFK	Glasfaserverstarkter Kunststoff (glass fibre-reinforced synthetic)
GTZ	Gesellschaft fur Technische Zusammenarbeit (German Technical Cooperation)
KfW	Kreditanstalt fur Wiederaufbau
KHD	Klockner Humboldt Deutz
LA	Latin-America
M.S.L.	Mean Sea Level
MAK	Maximale Arbeitsplatzkonzentration (maximum concentration at work place)
max.	Maximum
min.	Minimum
MWSt	Mehrwertsteuer (value added taxes)

MWSt	Mehrwertsteuer (value added taxes)
NE	Nichteisen (non-ferrous)
No.	Number
P,	Page
PAAC	Programa de Asistencia Agrobioenergetica al Campesino
PE	Polyethylene
PGM	Platin Group Metals
PVC	Polyviniychlorid
R+D	Research and Development
RFA	X-rayfluorescentanalyses
SKAT	Schweizerische Kontaktstelle fur Angepate Technik (Swiss Contact Agency for Appropriate Technology)
SM	Schwermineral (heavy mineral)
TMM	Taller Metal Mecanico
TZ	Technische Zusammenarbeit (Technical Cooperation)
US $	American Dollar
UV	Ultra-violet
VDI	Verein Deutscher Ingenieure (Association of German Engineers)
VITA	Volunteers in Technical Assistance
WHO	World Heath Organisation

PHYSICAL QUANTITIES, SIMBOLS OF FORMULAE AND UNITS

"	Inch, approx. 2.5 cm
%	Per-cen

%	Per cent
‘	Foot, approx. 30 cm
<	Smaller then
>	Bigger then
	Difference
A	Ampere
a	Year
W	Width
bar	Bar-pressure
Be	Beaume
C	Degree Celsius
cd	Candela, measurement for degree of luminosity
cm	Centimetre
cm^3	Cubic centimetre
d	Diameter, density
D	Diameter, Depth
die	Diameter
En	Electrons' potential
F	Force
f (...)	Function of
ft.	Foot
g	Earth acceleration, 9.81 m/sec^2
g	Gramme

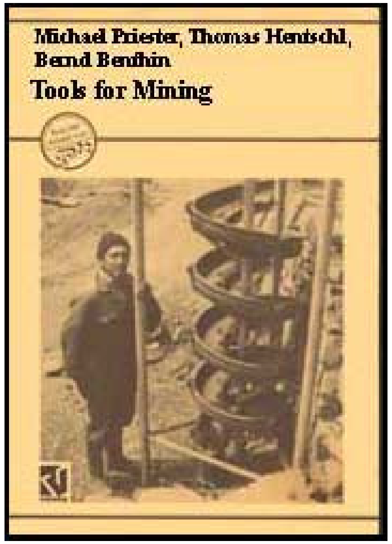
G	Weight
h	Hour
H	Height
HP	Horse-Power
in	Inch
kg	Kilogramme
km	Kilometre
KW	Kilowatts
I	Litre
L	Length
lb.	Libra = pound
m	Metre
M	Man
m^3	Cubic metre
min-1 Per minute	
min.	Minute
mm	Milimetre
MP	Intermediary (middle) product
MS	Man Shift
Mstat	Statistical moment
μ	Micro
μm	Micro meter
n	Amount

n	Amount
N	Newton
oz	Ounze
p	Pressure
pH	Negative decadic log of hydrogen ions or proton concentration
ppb	Parts per billion
ppm	Parts per million
q	Constant factor
R, r	Radius
rpm	Revolutions per minute
sec.	Second
t	Metric ton
TMF	Tonelade metrica fina
v	Speed
V	Voltage
W	Watt
E	Sum
0	Diameter
°	Degree
°C	Degree Celsius

CHEMICAL SYMBOLS

Ag Silver

Al	Aluminium
Au	Gold
Bi	Bismuth
C	Carbon
Ca	Calcium
Cd	Cadmium
Cu	Copper
Fe	Iron
H	Hydrogen
Hg	Mercury
M^{2+}	Metalion with double valence
N	Nitrogen
O	Oxygen
Pb	Lead
S	Sulphur
Sb	Antimony
Si	Silicon
Sn	Tin
W	Tungsten
Zn	Zin



Tools for Mining: Techniques and Processes for Small Scale Mining (GTZ, 1993, 538 p.)

Guide to the user

This technical handbook on small-scale mining in developing countries serves as a general source of information and as a planning and consulting guide for mining, exploration and beneficiation engineers as well as other technical-staff members of planning and consulting companies and organizations both in developing and in developed countries. Although the handbook caters to the special needs of small-scale mining in Latin American countries, incorporating particularly the traditional techniques employed in countries in the Andean region, it has a worldwide application. Included in this handbook are also guidelines for craftsmen and artisans and their affiliated consulting organizations who are interested in

diversifying their product line.

Prerequisites for the successful application of this handbook include a technical knowledge on the part of the reader, as well as the ability to think abstractly and the capability to understand and interpret technical sketches and drawings.

Due to the large quantity of information which has emerged from the complex array of mining activities, a structuring of the data is crucial to ensure the convenient use of the handbook. The handbook covers all basic information about mining, in particular focusing on the extraction and beneficiation of ores, precious metals, coal, salt, industrial minerals, and precious stones. Since the selection of mining and processing equipment relies more upon specific operational data, such as production rate and the degree of mechanization, rather than the type of mineral being extracted, the information given in this handbook is divided into five main chapters according to the following five categories: Analysis, Underground Mining, Surface Mining, Beneficiation and Energy.

Each of these five chapters includes an introduction containing definitions, problem areas, environmental and health risks, and organizational advice. This is followed by a presentation of technical information on individual techniques and procedures, which in some cases is divided into specific work categories. Each of these techniques is summarized in a technical outline containing a compact presentation of the technical data, costs, and conditions and restrictions of application. Especially with regard to the conditions for application, the evaluation of these techniques is based on more subjective criteria; for example, service and maintenance costs can only be approximated in a small-scale mining handbook through comparison with costs for equipment which perform comparable

functions. As a result, these evaluations cannot be universally correlated with each other.

The degree of environmental impact is presented on a linear scale, providing an initial basis for defining the technology's effect on the environment. Negative environmental effects through the depletion of mineral resources, or those associated with the supplying of energy, were not taken into consideration here; these effects are discussed in the chapter on Energy. Those techniques that are energy intensive and cannot utilize regenerative sources of energy are included in the environmental impact evaluation. Damage to the environment caused by the manufacture of spare parts for mining equipment are not considered here unless the production pertains to major machinery components. The environmental material-balance sheet for reagents has, however, been incorporated into the data analysis for the most part.

The section on suitability for local production examines the possibilities for manufacturing at the local level. The investigation does not focus on manufacturing by the mines directly, but rather production in non-mining industries such as wood, metal and other special machine-manufacturing shops which, due to the fact that they do not belong to the mining sector, are not equipped with special machines or special knowledge in the manufacture of such mining equipment. Besides providing information on the local conditions required for machine manufacturers, the handbook also includes photos, drawings and simple dimensioning aids. Every technical outline has a numbered title and name of the technique or technology, mining sector and work category, enabling rapid identification and classification of the technique or technology according to its area of application.

The technical section of the handbook also includes names of manufacturers and bibliography for further information. Abbreviations used in the handbook are explained in the List of Abbreviations.

A Subject Index is provided at the end of the handbook to assist the reader in quickly locating particular text subjects within the work-organization and technical sections.

Those mineral resources which require special mining or processing techniques are presented in the handbook separately:

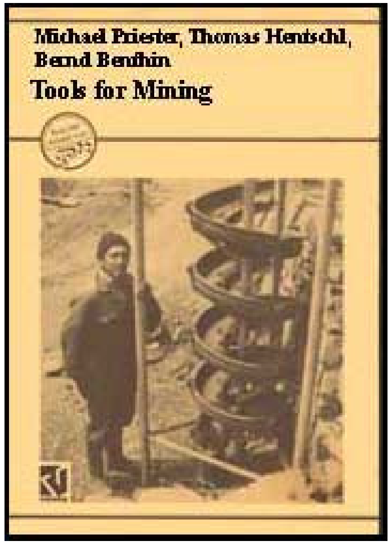
- industrial minerals extraction in the chapter on Surface Mining, since this primarily involves the mining of bulk materials. The techniques presented in Chapter D are suitable for the processing of raw materials for industrial and construction purposes, and can normally be used without difficulty.

- techniques for diamond processing are presented in Chapter D, whereby sorting of raw materials is the main difficulty since in some cases the feed material contains significantly less than 1 g/ton valuable mineral.

- gold beneficiation is also contained in the section on beneficiation and processing. This additionally includes information concerning the problems and risks of contamination in the amalgamation process as well as a collection of flowsheets from various gold-processing plants. Special separation techniques for gold extraction are described in Subchapter 15. Crushing, classification and some sorting processes employed in gold beneficiation are not gold-specific techniques and are therefore found in a beneficiation of the handbook. The mining of gold,

whether surface or underground, likewise does not need to be addressed separately.

Some of the described modern techniques for smallscale mining are under patent protection in case of local production. The valid legal requirements must be considered.



Tools for Mining: Techniques and Processes for Small Scale Mining (GTZ, 1993, 538 p.)

Introduction

The role of small-scale mining worldwide, both in developed and developing countries, should not be underestimated. It must be taken into consideration that the definition "small-scale mining" varies greatly from country to country. The criteria used here are cost of investment (less than 1,000,000- US$), number of employees (up to 100 employees), crude ore production rate (less than 100,000 t/a), annual sales, size of the mining concession, amount of reserves, or a combination of these individual criteria. These criteria are still under discussion, and uniform guidelines based on objective criteria have not yet been established.

Consequently small-scale mining in developing countries is defined by subjective criteria, some of which characterize this sector as a craft-activity:

- the absence or low degree of mechanization due to a high proportion of heavy manual labor,

- low safety standards,

- poorly-trained personnel,

- lack of technical personnel in the plant, resulting in deficient planning in both mining and processing activities,

- comparatively poor utilization of resources due to nonselective mining of high-grade ores and poor recovery,

- low pay scale,

- low work productivity,

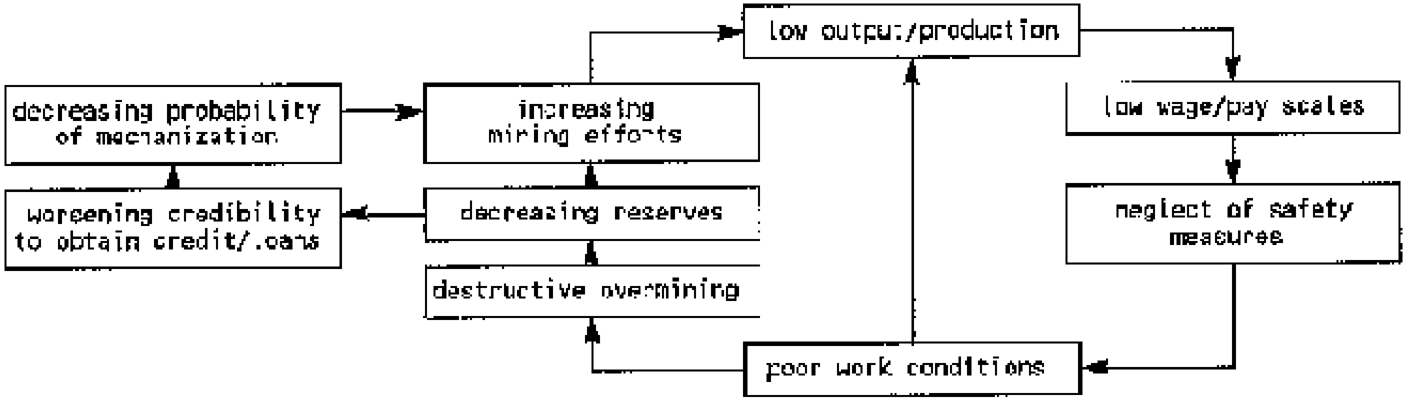
- periods of non-continuous mining, as a result of mining only seasonally or when world market prices reach a certain minimum level,

- insufficient consideration of environmental impact

- chronic lack of capital,

- some illegal operations due to mining without concession rights.

In general, the situation in small-scale mining can be characterized as a vicious circle that, without external assistance, can hardly be broken:



Figure

Despite the difficult conditions that beset small-scale mining, the industry holds a substantial position in mining worldwide. Of the total world mining production, a considerable proportion is accounted for by small-scale mining.

Table: Precentage of Total World Production of Selected Raw Materials/Minerals represented by Small-Scale Mining (Source: Noetstaller)

Metals				**Industrial minerals**			
beryllium	100 %	iron	12 %	fluorite	90 %	barite	60 %
mercury	90 %	lead	11 %	graphite	90 %	sand and gravel	30 %
tungsten	80 %	zinc	11 %	talc	90 %	stones for building	30 %
chrome	50 %	cobalt	10 %	vermiculite	90 %	salt	20 %
antimony	45 %	gold	10 %	pumice	90 %	coal	20 %
manganese	18 %	silver	10 %	feldespar	80 %	asbestos	10 %
tin	15 %	copper	8 %	clay	75 %	phosphate	10 %
				gypsum	70 %		

For many developing countries throughout the world, small-scale mining provides an important source of income as well as a significant source of foreign monetary exchange.

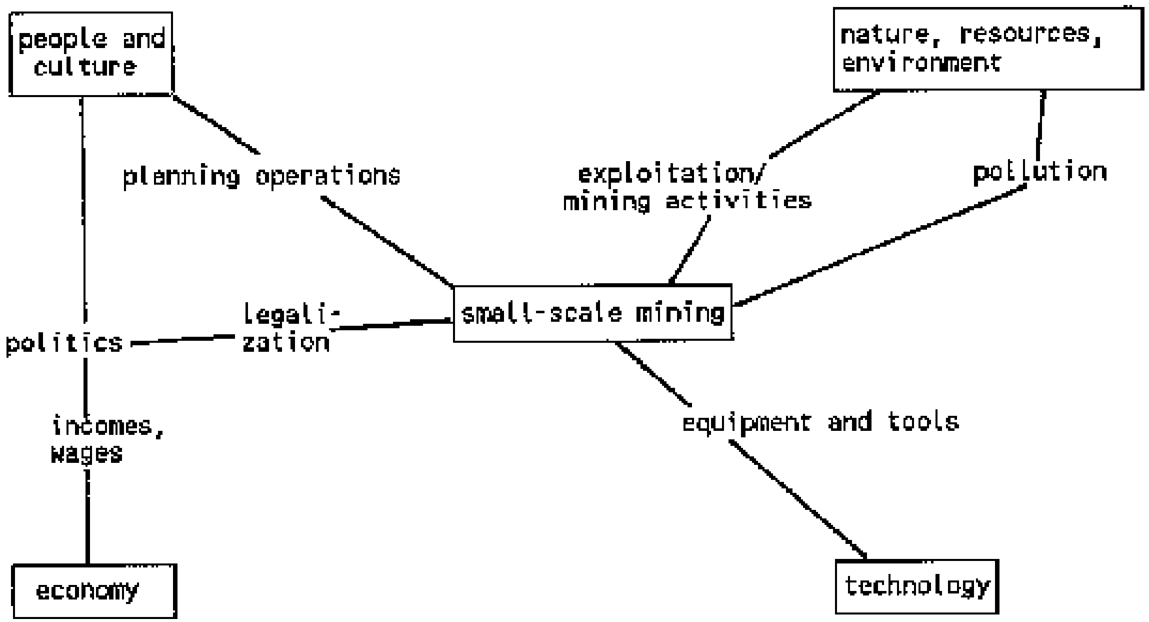
Table: The Most Important Small-Scale Mining Countries and Coresponding Minerals Processed (Source: Noetstaller)

Country	**Raw Material mined by Small-Scale Mining**
Latin America	
Argentine	antimony, asbestos, beryl, lithium, mercury, bismuth, tungsten
Bolivia	antimony, lead, gold, sulphur, silver, tungsten, zinc, tin
Brazil	beryl, chromite, gold, precious stones, titanium, tin
Chile	barite, lead, gold, copper, manganese, mercury, sulphur, coal

Dominican Republic	gold
Guatemala	antimony, lead, mica, manganese, tin, tungsten
Colombia	antimony, lead, chromite, precious stones, iron, gold, coal, platinum mercury, zinc,
Cuba	copper, manganese, pyrite
Mexico	fluorite, mercury, sulphur, uranium, tin
Peru	antimony, lead, diatomite, gold, copper, manganese, molybdenum, silver, bismuth, zinc, tin
Venezuela	asbestos, diamonds, gold
Ecuador	gold
Asia	
Myanmar	antimony, manganese, tin, tungsten
China	antimony, iron, coal, tin, tungsten
India	barite, borates, iron, mica, coal, manganese, tin
Indonesia	gold, tin
Iran	barite, lead, copper, zinc
Malaysia	gold, iron, manganese, zinc, tin, tungsten
Papua-New Guinea	gold
Philippines	chromite, gold, coal, copper, silver, zinc
Thailand	antimony, tin, tungsten
Turkey	lead, chromite, copper, magnesite, mercury, zinc

Africa	
Algeria	antimony, barite, diatomite, mercury, zinc
Ethiopia	gold, manganese, platinum
Gabon	gold
Ghana	diamonds, gold
Kenya	beryl, precious stones, gold, copper, silver
Lesotho	diamonds
Liberia	diamonds, gold
Madagaskar	gold, rare earth, bismuth
Morocco	antimony, barite, lead, manganese, zinc, tin
Nigeria	asbestos, barite, lead, gold, zinc, tin
Rwanda	beryl, gold, tin, tungsten
Sierra Leone	diamonds
Tunesia	lead, mercury, zinc
Tanzania	diamonds, mica, gold, magnesite, precious stones, tin, tungsten
Uganda	beryl, bismuth, tungsten
Central African Rep.	diamonds, gold
Zimbabwe	antimony, beryl, chromite, precious stones, mica, gold, copper, lithium, manganese, silver

Small-scale mining activities and mine workers have an integral interrelationship with their surroundings -nature, culture and people, technology and economy: mining disturbs nature through the depletion of its natural resources and its deleterious impact on the environment, which it is dependent upon for its energy and raw materials. Mining on the one hand, and culture and people on the other, have greatly influenced each other since prehistoric times: mining activities provided culturally significant metals and precious stones; mining has always, still to this day, led the way for rural and technological development. Mining, with its tools and equipment, utilizes this technology to generate income through the materials it produces. This interrelationship can be depicted as follows:



Figure

A comprehensive promotion of small-scale mining must consider the social suitability, assessed needs, profitability and environmental compatibility; only

then can subsequent improvements in the working conditions of small-scale miners be achieved. In particular, the following measures are essential:

Table: Catalogue of possible Promotion Measures for the various Stages of Production

	On-site technical and organizational consultation	**Research and development**	**Policy on raw materials**
Exploration	**Training** in: - analysis - deposit geology and mineralogy - geological mapping	**Development** of appropriate: - methods of analysis - instrument kits	National **assistance** through: - regional exploration programs - providing suitable maps - service facilities - reducing bureaucratic requirements
Mining, Exploitation	**Training** in organization and implementation of: - exploration activities - safety measures - mining operation	**Development** of appropriate: - mining methods and equipment - haulage facilities - safety procedures	**Implementation** of: - security and health control - technical advice

	- mecanization - training in the operation of machines	- ventilation methods	**Devising** a social security system for small-scale mining
Beneficiation	**Training** in: - operation of machines - planning, operation, optimization and supervision of beneficiation plants - water management - handling/treatment of chemicals which are hazardous to health and the environment	**Development** of appropriate: - crushing and grinding equipment - beneficiation techniques and machines for small-scale mining, e.g.: - mobile systems - heap leaching - flotation - mechanization of equipment - analysis of concentrates	Promotion **and construction** of: - central processing plants - infrastructure for - transportation - water source facilities
Marketing, Investments	**Training** in: - plant management - marketing - accounting - profitability calculations	**Development** of appropriate: - credit schemes for small-scale mining - organizational structures - advertising	formulation of raw material policy suited to small-scale mining -

	- credit/loan facilitation - cooperatives		debureaucratization - legalizing small mines - government purchase of products at market prices - management consulting - credit and tax incentives

The objective of this technical handbook on small-scale mining is to provide technical alternatives and organizational improvements for small-scale mining. The goal of these technical innovations is to assist the small-scale mining industry in numerous ways in solving its problems; specifically, this can be accomplished by:

- improving operational success by increasing mine output,
- job generation with low specific cost,
- improving the quality of social and economic living conditions,
- increasing production through semi-mechanization[1)] using regenerative sources of energy,
- improving job safety, and
- minimizing environmental impact.

[1)]Semi-mecanization is defined here as a form of mechanization in which only

individual steps of the total mining and beneficiation operations are mechyanized (e.g. mechanization of the crushing process by use of a breaker). Additionally, semi-mechanization also defines an operation in which the control and feeding of the machine are performed entirely manually.

The techniques or methods discussed in this handbook are summarized according to five categories: analysis, surface and underground mining, beneficiation, and energy supply. In addition to purely technical solutions, the handbook also provides alternatives for improvement of organizational problems typical to small-scale mining. In conjunction with that, historical mining machines, modern small-scale mining equipment, and traditional techniques were examined within the scope of the investigation. The integration of the historical, modern and traditional elements serves as the basis here for the development of an appropriate technology.

This technology is aimed not only at the small-scale miners themselves. The majority of the mining and dressing techniques identified to be applicable for small-scale mining, due to their suitability for local production, offer various approaches to the promotion of crafts and small manufacturing industries.

The craftsmen and the small to medium-scale manufacturers can especially profit from the production of machines and facilities for the small-scale mining industry and resulting diversification of product lines when

- competetive products do not yet exist on the local market, and

- if the local market for mining and processing equipment is protected from the

import market as a result of, amongst others, import duties, shortage of foreign exchange, and high transportation costs.

Small-scale craftmen or manufacturers associated with the mining industry can:

- deliver faster and cheaper

- more accurately meet the customers needs

- benefit from the relationship to become independent and self-organized

- shorten repair and maintenance time, which is especially important in seasonal small-scale mining operations.

The following results are expected from the application of the recommended technical and organizational improvements for small-scale mining in developing countries:

- local production of equipment for appropriate mining and beneficiation technology by craftshops and small-scale manufacturers. This would be developed to meet demand within the country itself and, in addition, could lead to the intensification of a South-South cooperation

- consultancy for small-scale mining operations, accompanied by installation of appropriate equipment, support for adaption developments, etc.

- educational measures; training of small-scale mining personnel, planners and consultants in suitable educational facilities, for example in the areas of analysis,

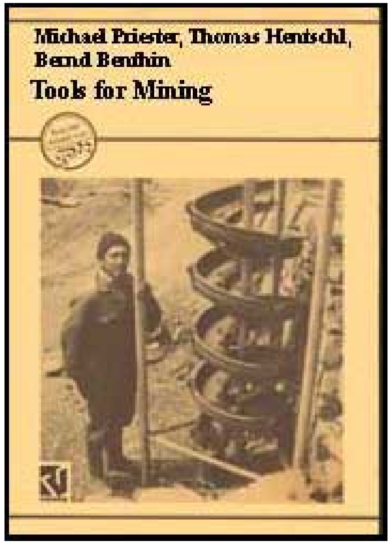
geology, mineral-deposit geology, work organization and techniques in mining and beneficiation, work safety, marketing and economics

- development of new concepts for environmentally and economically advantageous energy supply systems, such as the use of renewable energy sources

- development and implementation of environmental protection measures in small-scale mining (e.g. decreasing the amount of lumber needed for mine supports, reducing or even eliminating mercury emissions in the gold amalgamation process, addressing problems of cyanide-leaching in gold-ore processing, reducing contamination of waste water by, for example, reagents from flotation processing or slurry effluents from beneficiation operations).

The effects of such a politically-instigated developmental program would include creating and securing jobs in the non-agricultural sector, qualifying workers in the mining and craft industries, import-substitution of raw materials in the industrial, energy, and agricultural sectors, substituting locally- manufactured for imported machinery and equipment, as well as contributing to regional development.

As a whole, these measures lead to the internalizing of costs and income in the areas influenced by mining i.e. the mines themselves, the craft and manufacturing industries, as well as the suppliers of raw materials.



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A. Analysis

A.1. Definition

The section on analysis includes the determination of the chemical and physical properties of soil, rock and ore samples as well as of concentrates, middlings and tailings from beneficiation processing. The analytical procedure used here consists of the following four steps:

1. sampling,
2. chemical or physical analysis of sample material,
3. classification and statistical analysis of data, and
4. interpretation of the results.

The application of analytical procedures in the small-scale mining industry are particularly significant for prospecting, exploration, quality control during mining, beneficiation, marketing and environmental protection.

A.2. Initial conditions and problem areas

Small-scale mining in developing countries suffers from a lack of knowledge concerning crude ore reserves as well as product composition. The situation is worsened by the fact that ihomogeneous mineralization exists, especially in deposits of sub-volcanic genesis as are characteristic of the Andean region. As a result, variations in mineralization occur within small proximities with regard to both geological relationships and mineralogical and geo-chemical compositions. A good example of this can be seen in Bolivian tin deposits, where the tin source can be Cassiterite (for chemical composition see Table), Cylindrite, Teallite or Frankeite (three Sulfostannates) or Stannite. Knowledge of the entire geological relationship is critical for planning. not only the mining procedure but especially the beneficiation processing.

The composition of concentrates is frequently not known by the small-scale mining operators, which can be disadvantageous for selling the products. Impurities in the concentrates result in lower prices for the product following high penalty deductions assessed by the buyers or the beneficiation plant, and further impairing the marketing of profitable by-products. The Cascabel Mine in Bolivia (Dept. La Paz) serves as an example, which, despite higher lead, silver and tin contents in its concentrates, is only able to market its products with great difficulty, suffering large penalty assessments (price discounts) due to abnormally high levels of mercury contamination. These mineralization problems occur not

only in the primary vein ore deposits, but are also present in placer deposits; deficient product knowledge is the reason why valuable platinum contents in alluvial gold deposits (e.g. in Colombia) are not being mined and consequently not being separately marketed.

Another characteristic problem of small-scale mining in developing countries is the questionable credibility of the analyses, which, as a rule, are performed by the buyer himself. Control checks have shown that results of the analyses are being manipulated to the advantage of the buyer and to the disadvantage of the small-scale mine operators. Primarily, the silver contents were given as too low, and the residual moisture levels as too high, which is difficult to prove in the absence of control measures.

The resulting conclusion is that the small-scale mining industry needs to implement its own control program. In addition to quality control during mining (grade control) and beneficiation and marketing planning, analytical procedures suitable for small-scale mining are also important for prospecting and exploration activities.

The use of centralized analytical methods becomes inconvenient or even impossible for small-scale mining due to the location-dependency of stationary analytical techniques, and the lack of infrastructure in the remotely-located, isolated small-scale mining operations.

The need exists within the small-scale mining industry for a simple, portable analyitical procedure. The main criteria should include low cost and quick performance with limited equipment and time requirements while avoiding

unnecessary measuring precision. The extent to which the analytical results are representative and are reproducable is determined more through the quality and preciseness of the sampling rather than the application of the most optimal method of analysis. An analysis which is precise to several places behind the decimal point is worthless when an improper sampling procedure results in inaccurate figures in front of the decimal point.

The lack of simple analysing procedures for smallscale mining is not limited just to developing countries; this is an area calling for research-anddevelopment efforts.

A.2.1 SAMPLING

The sampling procedure is of primary importance for the technical planning of mining and beneficiation operations. However, a very precise and exact analysis is of no value if the sample being analyzed is not representative. A sample is representative of its original geologic environment only when the same chemical, mineralogical and physical relationships characteristic of the specific geologic area are exhibited in the sample. These relationships are defined by the mineral or element distribution, humidity, granulation and grain-size distribution, permeability, etc. When a waste dump, mineral deposit or beneficiation product is analyzed, it is not possible to examine the entire dump or deposit, or the total product quantity, but only portions of the whole. Proper conclusions can only be made from these sampled portions when they are representative of the whole.

In the testing of a pile of crude ore, for example, it is not sufficient to take only one chunk of ore from the pile, which may be representative of only the country-rock or the mineralization itself. An analysis of this sample alone would result in

erroneous conclusions concerning the metal-content of the deposit in general. Several sampling techniques which consistently produce representative results are discussed below:

Bulk sampling is employed for the sampling of loose fine-to-coarse-grained materials, such as in the analysis of tailings, waste dumps, products, and crude ores. Numerous smaller samples are taken from a number of various arbitrary locations throughout the material pile without preference to any particularly richer or poorer regions. The sampling procedure should not only include numerous different sample locations but should also ensure that the grain-size of the samples also vary, in that samples of the finer fractions and the fines are also collected along with the large pieces of ore. In so doing, the sample volume or quantity should always be at least ten times greater than that of the largest individual sample in order to assure that the effects of classification, whether from deposition in the pile or from selectivity during blasting, are statistically compensated.

Channel sampling is a method of sampling exposed in-situ ore-bodies. In this procedure, sample material is obtained from a groove, constant in width and depth, cut into the rock over a specific length, for example from the hanging wall to the foot wall across the width of the face during drifting; for example, a slit 10-cm in height and 5-cm in depth is cut out along the entire stope width with the sample material being collected on a tarp spread on the roadway floor below.

In-situ ore bodies can also be tested by grab sampling. Over the affected sample area, for example the area of the face, numerous equally-sized samples are randomly taken by hammering, digging or prying off loosened chunks without any

locational preference for richer or poorer zones of mineralization. This sampling method is considerably easier to carry out than channel sampling, especially in hard ore bodies.

Cuttings-sampling recovers sample material from the washed drill dust or drill cuttings which are produced during drill-and-blast drifting and mining. As a result, the collected sample material originates not just from exposed surfaces, but rather represents a three-dimensional sampling area when an entire drilling-grid is sampled. An additional advantage of this method is that the sample material already exists in a finely-comminuted form.

In order to avoid systematic causes of errors, sampling should always be conducted by only one and the same person.

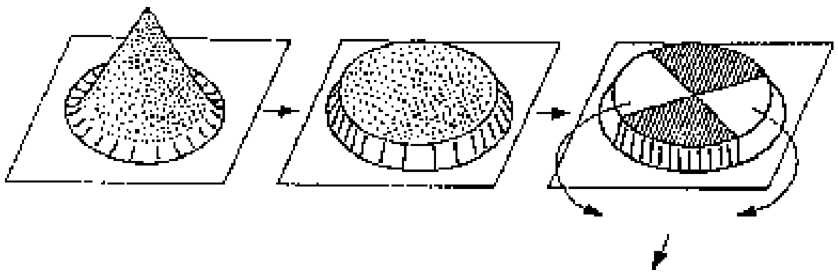

Fig.: Manual quartering of sample material by mixing, coning, mixing, flattening, quartering, and discarding of two opposite-lying quarters. Source: Schroll

For further treatment larger-sized samples are crushed and subsequently quartered. This is performed by heaping the crushed sample material into a cone, thoroughly mixing it several times via shovelling, and again heaping it into a cone by pouring. The cone is then pressed or stomped flat, and the resulting flat cone base is divided into four equal segments. Two of the quarters, located opposite

one another, are analogously processed further, while the remaining two quarters are discarded. This procedure is repeated as often as required until the desired sample quantity has been reached. The conical pouring of the sample material assures the homogeneity of the sample.

The homogeneity of ores, alluvial deposits, tailings or other mined waste, and the degree to which the samples are representative, is particularly important where the element or mineral-content is low. This occurs in discrete aggregates, where the valuable mineral exists as separate grains independent of the mineralized matrix. An important example is gold. Gold analysis demands values of a magnitude of less than 1 g/t. Gold particles can appear as gold glitters or nuggets with individual weights of up to more than 1 9. If, for example, one ton of crude ore which has only a single 1-9 gold nugget is analyzed by using 100kg of sample material which happens to contain this nugget, the results will indicate 10 9 of gold/l, which of course is too high. Statistically, in 9 out of 10 cases the nugget would not be contained in a 100-kg crudeore sample, so that the gold content is then assessed at 0 g/t. This effect is known as the nugget effect and requires, in such cases, multiple samples of large quantities. The more nonhomogeneous the sample material, the higher the number of samples required in order to obtain a statistical median value which approaches the true value for the material as a whole.

A.2.2 MINERALOGICAL EXAMINATION

Under certain conditions, an optical measuring or visual estimation of the ore content underground can serve as a substitute for an analysis. The prerequisites for this are:

- a relatively high proportion of ore minerals in the total material, since only then is the measured or estimated value of sufficient accuracy, and

- high visibility of the ore mineral under the conditions of examination. This requires clean working faces or sampling surfaces, perhaps involving the use of artificial methods to improve visibility, for example with ultra-violet lamps to detect mineral luminescence.

The visual evaluation is significant in lead-zinc mining in hydrothermal deposits with classic vein patterns. As a rule, testing is combined in this case with geological mapping of the hanging or footwalls. In so doing, the total width of the wall and the width of the ore veins are measured onto one profile. The profile must run vertically along the strike and dip of the vein; otherwise the values appear unrealistically high. If the profile is divided into several fragments, the sum of the individual vein thicknesses can be determined (for example, 25 cm galena, 15 cm sphalerite over a thickness of 175 cm). From this information, the volumetric proportion of the various ore minerals can be calculated. When the densities of each ore mineral and host rock are included, the total weight proportion of the ore minerals can then be established. With this information, and the additional knowledge of the metal content in each ore mineral, the metal-content distribution (% by weight) of the sampled profile can be determined. The incorporation of correction factors to account for mineral intergrowths, etc., can increase the accuracy of this method. This form of sampling or testing has proven itself even in highly mechanized operations in industrialized countries where it competes against modern procedures, such as portable X-ray fluorescent analysis.

Another mining sector which employs optical evaluation is scheelite mining,

where the mine face is irradiated with an ultra-violet lamp which induces fluorescence of the scheelite.

As is true for sampling procedures, a high degree of accuracy in the optical test results can only be attained through disciplined work procedures and a great deal of experience.

A.2.3 ADVANTAGES OF MINIMIZING ACCURACY

All analysing procedures and evaluation methods exhibit a linear relationship between degree of accuracy and the cost of analysis, or, in other words, the more accurate the analysis, the more complex the equipment and the higher the costs. The lower the detection limit of the analytical method, i.e. the smaller the analyzed value is, the more expensive the analysis will be. Looking at this fact, it is absolutely necessary from an economical standpoint that the small-scale mining industry employs the cheapest method of analysing available within the desired accuracy and metal-content limits.

A.2.4 DETERMINATION OF ELEMENT DISTRIBUTION IN RAW ORE AND CONCENTRATES

Lack of knowledge about the contents of the different elements in raw ore, mine waste and concentrates is frequently the cause for the inefficient or uneconomic performance of small-scale mining operations. As a rule, only the contents of the desired metals in the ore and concentrate are examined. Consequently, the causes for undesired metal contents in the products, and subsequent penalty assessments, are not known by the small-scale miner. Additionally the accounting

statements from the ore buyer do not explicitly indicate the reasons for penalty deductions. Commercially marketable byproducts also remain unidentified.

A number of various contaminating metals and elements which may be present in the mine products lead to penalties, assessed by the smelters in the form of price reduction, when the content of these metals exceed a maximum tolerance level. These elements, their maximum tolerance limits, and the penalty amounts are established by the smelting standards, varying according to smelting process, market situation and buyer. Consequently, a definite statement concerning these elements and tolerance limits cannot be made; however, as a general reference, the following table lists some critical elements which are deleterious to non-ferrous metal ore concentrates:

As a rule, non-ferrous metal smelters penalize:	
Bi	In almost all concentrates
Hg	in almost all concentrates
S	in concentrates of valuable oxide minerals
As	in Pb-Ag-concentrates
Cu	in Pb-Ag-concentrates
Cd	in Pb-Ag-concentrates
Se	in almost all concentrates

Penalties can lead to a considerable decrease in profit for small-scale mining operations. Therefore, knowledge of the element and trace-element distribution should be obtained, as much as possible, before initiating any mining activities or

planning the beneficiation plant in order to establish a marketing strategy.

Similar to the deleterious metals, element contents which would be worth recovering and marketing in the form of by-products are also often overlooked; for example, zircon sand from alluvial deposits, gold-containing pyrite and arsenopyrite from complex sulphide veins. Here, as well, a knowledge of the element distribution prior to the start of any mining activities is crucial in order to formulate an optimal marketing strategy.

The practice of performing complete analyses on a concentrate sample and on a mixed raw-ore sample, conducted by a competent laboratory for the purpose of determining the contents of all relevant metals, trace-elements and cations, should become standard procedure for the small-scale mining industry. Governmental support of these needs, for example by providing inexpensive analyses, would significantly contribute to promoting the small-scale mining industry.

The performing of mineral analyses also serves an important function from an environmental-protection viewpoint by identifying environmentally-damaging components such as sulfur in coal, residual mercury in gold tailings, cyanide and arsenic contents in mining wastes, etc.

A.2.5 DETERMINATION OF THE VALUABLE-MINERAL SOURCE

In addition to a purely geochemical examination of the raw materials, a mineralogical knowledge, especially of the valuable-mineral sources, is of major priority in small-scale mining. Since beneficiation processing in small-scale mining

usually leaves the material components of the minerals unchanged, this identification of the valuable-mineral source is particularly important for planning and marketing. This can be accomplished through microscopic examination of polished sections, which enables experienced microscope analysts to quickly and easily semi-quantitatively recognize segregations, trace element minerals, etc.

The question, for example, of whether silver appears as a silver mineral or as a lattice element of lead or zinc minerals can strongly influence the beneficiation, marketing and profitability of a mining operation.

Equally important is the mineralogical composition of the raw material in primary gold deposits, in which the gold can occur as free gold or bound to pyrite or arsenopyrite as "refractory ore".

Whatever the situation, it is essential that the major ore minerals can be marketed. Some ore deposits produce main valuable minerals which are sellable only with great difficulty, if at all; such as the complex ore deposits with spienles sulfades (antimony and arsenic) as the metal source.

<table>
<tr><td colspan="2">One example is the Taricoya Mine in Bolivia, whose raw ore reserves are relatively promising according to FONEM, as here shown in the Table:</td></tr>
<tr><td>Pb: 3.45 %</td><td>Ag: 379 g/t</td></tr>
<tr><td>Sb: 6.48 %</td><td>Au: 7 g/t</td></tr>
<tr><td colspan="2">However, because the main ore mineral is composed of specular jamsonite ($Pb_4FeSb_6S_{14}$) selling the concentrates is very difficult.</td></tr>
</table>

The above example shows that the results of mineralogical studies play an important role in determining whether or not an ore deposit can be mined profitably using the simple mining methods characteristic of small-scale mining.

A.2.6 OTHER RAW MATERIAL STUDIES

In addition to chemical and mineralogical composition, other characteristic data are also important, depending upon the material, for the analysis of raw mineral reserves. Examples are:

- ash content' thermal value, sulfur content, caking capacity, etc. for fossil fuels (coal, peat);
- compressive strength of a cube, cleavability and permeability for construction materials;
- swelling characteristic for certain clays (vermiculite);
- weaving characteristic for asbestos;
- coloration for pigment raw materials (barite, kaolin);
- grain sizes for many raw materials (large grain size for graphite and mica, fine grain size for kaolin;
- hardness for grinding material (corundum, garnet).

The following table presents a list of essential ore minerals including primary physical characteristics and types of veins and host rocks.

Table: Characteristics of Ore Minerals including Vein Types, Gangue or Matrix, Asociated Minerals and Host Rocks:

Name	Composition	Content of valuable	Density	Tennnacity

Name	Composition	Content of valuable minerals	Density	Tenacity 1)
Ordinary lead-zinc mineralization:				
galena	PbS	Pb: 86.6 %	7.2-7.6	4
sphalerite	ZnS	Zn: 67.0 %	3.9-4.1	2
wurtzite	ZnS	Zn: 67.0 %	4.0-4.1	2
greenockite	CdS		4.8	*
cerussite	$PbCO_3$	Pb: 77.5 %	6.4-6.6	1
anglesite	$PbSO_4$	Pb: 68.3 %	6.3-6.4	1
smithsonite	$ZnCO_3$	Zn: 52.1 %	4.0-4.5	2
Mixed lead-silver-zinc-gold mineralization:				
bournonite	$CuPbSbS_3$	Pb: 42 %	5.75.9	3
boulangerite	$Pb_5Sb_4S_{11}$	Pb: 55 %	5.9-6.5	2
jamesonite	$Pb_4FeSb_6S_{14}$	Pb: 40 %	5.6	4
tetrahedrite	$Cu_{12}Sb_4S_{13}$	Ag: up to 19 %	4.6-5.1	2
free silver	Ag	Ag: up to 100 %	10.1-11.1	6
stephanite	Ag_5SbS_4	Ag: 68 %	6.2-6.4	2-4
argentite	Ag_2S	Ag: 87 %	7.2-7.4	6
proustite	Ag_3AsS_3	Ag: 65 %	5.6	2
pyrargyrite	Ag_3SbS_3	Ag: 60 %	5.8	2

petzite	Ag_3AuTe_2	Ag: 41.8 %		
		Au: 25.4 %	8.7-9.1	5
free gold	Au	Au: up to 100 %	15.5-19.3	6
copper minerals:				
free copper	Cu	Cu: up to 100 %	8.5-9.0	6
covellite	CuS	Cu: 66.5 %	4.6-4.8	4
chalcocite	Cu_2S	Cu: 79.9 %	5.5-5.8	4
bornite	Cu_5FeS_4	Cu: 63 %	4.9-5.3	2-4
chalcopyrite	$CuFeS_2$	Cu: 34.7 %	4.1-4.3	3
enargite	Cu_3AsS_4	Cu: 48 %	4.4-4.5	2
cuprite	Cu_2O	Cu: 88.8 %	6.1	2
malachite	$Cu_2(OH)_2CO_3$	Cu: 57 %	4.0-4.1	
azurite	$CU_2(OH/CO_3)_2$ Cu: 55 %	3.8	2	
tin minerals:				
cassiterite	SnO_2	Sn: 78.1 %	6.8-7.1	2
teallite	$PbSnS_2$	Sn: 30%	6.4	4
franckeite	$Pb_5Sn_3Sb_2S_{14}$ Sn: 17 %	59	4	
stannite	Cu_2FeSnS_4	Sn: 27.5 %	4.3-4.5	2

stannite	Cu_2FeSnS_4	Sn: 27.5 %	4.3-4.5	2
antimony minerals:				
antimonite	Sb_2S_3	Sb: 71.4 %	4.6-4.7	4
antimonochre	$Sb_2O_3(H_2O)$	Sb: var.	5.6-6.6	**
bismuth minerals:				
free bismuth	Bi	Bi: up to 100 %	9.7-9.8	2
bismuthinite	Bi_2S_3	Bi: 81 %	6.8	4
bismuthochre/bismite	Bi_2O_3	6.7-7.5	**	
tungsten minerals:				
scheelite	$CaWO_4$	W: 63.8 %	6.1	2
wolframite	$(Fe,Mn)WO_4$	WO3: 76 %	7.1-7.5	2
ferberite	$FeWO_4$	WO3: 76.4 %	7.5	2
huebrerite	$MnWO_4$	WO3: 76.6 %	7.1	2
tungstic ochre/tungstite	$WO_2(OH)_2$	4.0-4.5	**	
additional and accompanying minerals:				
realgar	As_4S_4	As: 70 %	3.6	
orpiment	As_2S_3	As: 61 %	35	
molybdenite	MoS_2	Mo: 60 %	4.6-5.0	
pyrite	FeS_2		5.0-5.2	

pyrrhotite	FeS		4.6-4.8	
haematite	Fe_2O_3		4.9--5.3	
arsenopyrite	FeAsS		5.9-6.2	
limonite	FeOOH		aprooox.4	
jarosite	$KFe_3((OH)_6/(SO_4)_2)$	3.1-3.3		
argentojarosite	$AgFe_3((OH)_6/(SO_4)_2)$	?		
plumbojarosite	$PbFe_6((OH)_6/(SO_4)_2)$	?		

[1)] Tenacity characterizes brittleness or breaking characteristics of the mineral

Explanation of tenacity/Remarks:

1 very brittle
2 brittle
3 less brittle
4 mild
5 ductile
6 very ductile
* exists as fine intergrowths
** exists in pulverized form due to weathering
1) Tenacity characterizes brittleness or breaking characteristics of the mineral

Table: Characteristics of Ore Minerals including Vein Types, Gangue or Matrix, Associated Minerals and Host Rocks:

Name	Composition	Density
quartz	SiO_2	2.6-2.7
calcite	$CaCO_3$	2.6-2.8
siderite	$FeCO_3$	3.7-3.9
dolomite	$CaMg(CO_3)_2$	2.8-2.9
fluorite	CaF_2	3.1-3.2
barite	$BaSO_4$	4.3-4.7
vivianite	$Fe_3PO_4\ 8H_2O$	2.6-2.7
apatite	$Ca_5(F,Cl,OH)(PO_4)_3$	2.9-3.1
epidote	$(Ca_2Fe)(AI_2O)(OH)Si_2O_7SiO_4$	3.4-3.5
tourmaline	Complex boron-hydroxylic silicate	3.0-3.1
orthoclase	$(K,Na)AISi_3O_8$	2.5-2.7
plagioclase	$(Ca,Na)(Al,Si)_4O_8$	2.6-2.7
alunite	$KAI_3(OH)_6(SO_4)_2$	2.6-2.9

HOST ROCK

Name	Density

granite	2.6-2.7
diorite	2.8-2.9
syenite	2.6-2.8
dacite	2.6-2.7
andecite	2.5-2.6
trachyte	2.6-2.8
basalt	2.7-3.2
porphyry	2.7-2.9
gneiss	2.4-2.7
quartzite	2.3-2.6
sandstone	2.2-2.5
clay shale	2.6-2.7

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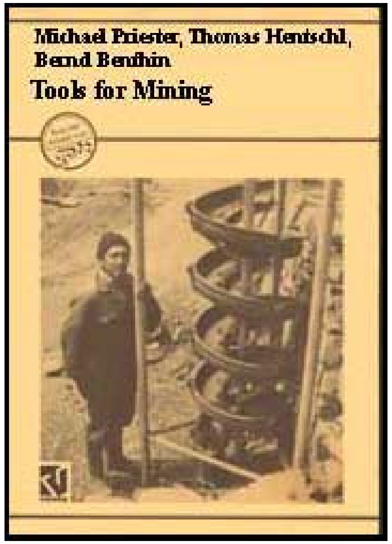

Tools for Mining: Techniques and Processes for Small Scale Mining (GTZ, 1993, 538 p.)

Technical Chapter 1: Analysis

1.1 Blow pipe assaying

General Ore Mining
Analysis

germ.:	Lotrohrprobierkunde
span.:	analisis con soplete
Manufacturer:	Krantz

TECHNICAL DATA:	
Dimensions:	approx. 20 - 25 cm long, pointed nozzle with 0.4 - 0.5 mm jet of platinum

	or nickel
Weight:	approx. 50 grams
Degree of Mechanization:	not mechanized
Form of Driving Energy:	either blown by mouth or
Alternative Forms:	driven by compressed air
Mode of Operation:	intermittent
Materials for operation:	
Type:	charcoal, clay vessel, glass tube, fuel Na_2CO_3 (soda) $K_2C_2O_2$
(sorrel-	salt) $Na_2B_4Ox7 \times 10\ H_2O$ (borax) $Na(NHg)HPO_4 \times 4H_2O$(microcosmic salt)
ECONOMIC DATA:	
Investment Costs:	blowpipe approx. 30 DM
Operating Costs:	predominantly determined by cost of reagents and labor costs
Related costs:	very accurate weighing scale (to ± 0.1 mg), lineal scale for determinin small silver and gold grains, magnifying lens

CONDITIONS OF APPLICATION:

Operating Expenditure:	low |————|———| high
Maintenance Expenditure:	low |———|————| high
Personnel Requirements:	highly experienced analyst
Type of Analysis:	semi-quantitative and qualitative
Accuracy of Results:	+ 2 g/t for Au and Ag
On-site Performability:	Ag, Au, Cu, Pb, Bi, Sn, Co, Ni, Hg can be determined quantitatively
Replaces other equipment:	all other analytical-chemical methods such as RFA, liquid chemicals
Regional Distribution:	previously widely-distributed sampling and analyzing method in industrialized countries; has since been replaced by new methods.
Operating Experience:	very good |———|————| bad
Environmental Impact:	low |———|————| very high
Suitability for Local Production:	very good |————|———| bad
	Parts of the blowpipe and the heater, possibly the stand as well as the small-scale compressor could be locally produced.

Lifespan: very long |———|————| very short

Bibliography, Source: Plattner, Wehrle, Kest, Kolbeck, Frick-Dausch

OPERATING PRINCIPLE:

Blowpipe analysis is a multiple-step procedure for qualitatively or semi-quantitatively determining the individual elements contained within a small quantity of sample. The process involves dry thermal procedures, sometimes in combination with wet testing methods. The sample is heated in an open or half-closed pipe, melted to a bead with borax ($Na_2B_4O_7 \times 10\ H_2O$) or microcosmic salt ($NaNH_4HPO_4 \times 4\ H_2O$) under oxidizing and reducing conditions, burned directly in a flame to determine flame color, or heated with coal under oxidizing and reducing conditions. A small flame torch serves as the energy source, which is intensified by blowing into it through a tapered tube, the blowpipe. The discoloration of smelt, sublimate, corona or flame in each particular assay or experiment, together with any distinct odors and/or reactions which may appear, provide Information on the chemical composition of the sample.

REMARKS:

Of importance is a waterbag, which is an extension of the pipe for collecting condensed water, to prevent It being expelled during blowing.

Lamps with cotton wick and rape-oil, paraffin, tree oil and mixtures of alcohol (spirits) with gasoline (benzine) or oil of turpentine are suitable.

Polished pieces of charcoal of approx. 30 × 30 × 40 mm are employed as a base. If charcoal is not available, the foundation or base can be prepared using coal dust and starch paste.

In 1670, Erasmus Bartholin conducted the first scientific research on the use of the blowpipe. A homogeneous air current can be achieved during blowing by connecting the blowpipe to an available compressed air line. If this is not possible, a pumped-up tire, for example from a wheel barrow or automobile, can be used as a compressed air tank.

The advantages of blowpipe analysis are the simplicity of both the determination and the required equipment. Samples can be analyzed very quickly and comparatively accurately, which is particularly important in an operating mine. Special sample preparation, such as extensive crushing, etc. are not necessary.

The analysis methods, which appear complex in their description, can be greatly simplified when standard assays are conducted on known metals.

SUITABILITY FOR SMALL-SCALE MINING:

Semi-quantitative and qualitative analytical technique requiring simple and low-cost equipment; demands, however, a highly-experienced operator. In metal mining, the blowpipe analysis is suitable for grade control and for assaying during prospecting and exploration.

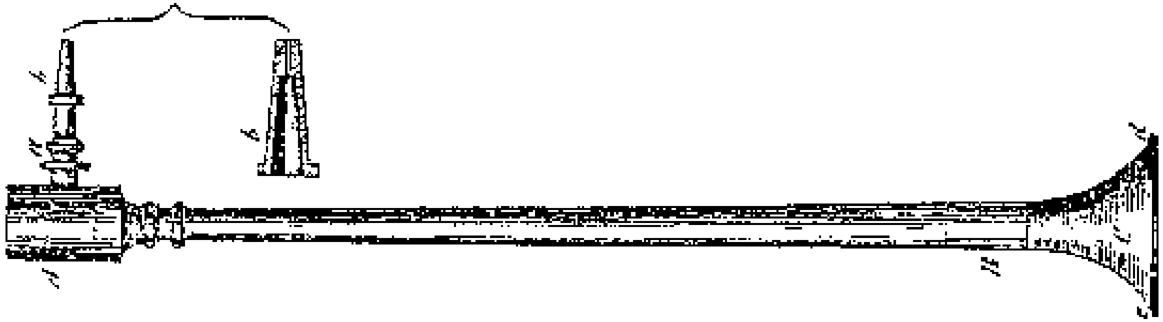

Fig.: View of blowpipe with changeable precious-metal nozzle (above left). Source: Frick-Dausch

Table: The primary chemical reactions of blowpipe analysis. Source: Frick-Dausch

A. Heating of the substance in a half-closed pipe

1. A distillate develops: water.

2.
A pure white sublimate develops:
Salts of ammonia: simultaneous occurrence of NH3 odor.
Mercury chloride: melts, evaporates and condenses in a needle-like form.
Mercury all-chloride: sublimates without melting; hot sublimate is yellow, cold is white.
Arsenic tri-oxide: fine-crystalline white sublimate.
Antimony tri-oxide: melts to a yellow liquid and sublimates at higher temperatures.

3.
A coloured sublimate develops:

Arsenic and high-grade arsenic ores: mirror of arsenic, garlic odor.
Antimony: mirror of antimony.
Arsenic sulphides, arsenopyrite: hot sublimate is dark, cold varies from yellow to red.
Antimony sulphides: at higher temperatures; hot sublimate is black, cold is red-brown.
Sulphur: melts easily, condenses as a yellow sublimate.
Mercury sulphide: black sublimate which when rubbed with a match changes only very slowly into a red modification.
Mercury grey sublimate from metallic mercury.

4.
A gas develops:
Oxygen: from chlorates and peroxides.
Carbon all-oxide: from carbonates and bi-carbonates. CO_2-gas put into lime water produces a white precipitate, which then dissipates when acidified with HCI, contrary to $CaSO_4$.
Ammonia: from salts of ammonia
Hydrogen sulphide: from water-bearing sulphides.

B. Heating in a half-closed pipe with potassium-bisulphate
Nitrate and nitrite form NO_2.
Bromides emit red-brown bromine vapors.
Iodides release violet-colored iodine vapors.
Chlorides form hydrogen chloride.

C. Heating in a pipe open on both sides (calcination test)
Free sulphur and metal sulphides form SO_2.
Tellurium emits white smoke, which partially condenses.
Selenium sublimates black, on the upper edge often reddish, Selenium odor.
Arsenic substances emit white, volatile, cristalline arsenic tri-oxide.

D. Bead test

a) Borax bead: borax $Na_2B_4O_7$ 10 H_2O

Borax bead

Coloring element	Oxidation bead		Reduction bead	
	hot	**cold**	**hot**	**cold**
Mn	violet[1)]	red-violet	colorless	colorless
Ni	violet (recognizeable only for a short time)	red-brown	cooolorless or	colorless or grey[2)]
				grey
Co	blue	blue	blue	blue
Cu	green	blue-green to light blue	colorless	sealing-tax red opaque[3)]
Vd	yellowish	green-yellowish	brownish	lllight greenish
Cr	dark yellow to red	green	green	green

Cr	dark yellow to red	green	green	green
U	yellow-red	yellowish	green[4)]	green[4)]
Mo	yellowish[5)]	colorless	yellow	light brown-yellow
Wo	yellow to colorless	colorless	yellow	light brown-yellow
Ti	yellowish	colorless	yellow-brown	yellow-brown
Fe	yellow-red	yellow to colorless	greenish	greenish

1) black when solution is too strong

2) from finely-divided metallic nickel

3) easy to produce with tin, highly characteristic

4) when saturation is too strong and by whirling, greenish-black and muddy

5) only in a very pure oxidizing flame completely free of reducing components

b) Phosphor salt test; phosphor salt (= microcosmic salt) $NaNH_4HPO_4 \times 4H_2O$

Phosphor salt bead

coloring element	oxidation bead		reduction bead	
	hot	cold	hot	cold

	hot	**cold**	**hot**	**cold**
Mn	violet	violet	colorless	colorless
Co	blue	blue	blue	blue
Cu	green	blue-green to light blue	colorless to greenish	sealing-wax red opaque[1]
Mo	yellowish[2]	colorless[2]	brownish-green	green
Cr	red, then dirty green, finally clear green	as with oxidation bead, but colors more intense		
Vd	dark yellow	yellow	brownish	green
U	yellow	yellow-green	dirty green	green
Ti	yellowish to colorless	colorless	yellow	violet[3]
Wo	yellowish to colorless	colorless	dirty green	blue[4]
Ni	reddish-brown	yellow to reddish-yellow	reddish to yellowish with $SnCl_2$ grey and muddy	
Fe	red-yellow, then green-yellow, finally brownish		like oxidation bead, but colors less intense	

1) with the help of tin

2) only in a very pure oxidizing flame completely free of reducing components

3) calcined with a trace of ferro sulphate, blood red; very sensitive!

4) with a trace of ferro sulphate, blood red; also very sensitive (e.g. wolframite!).

With $SnCl_2$ and without Fe-additive, dark green.

E. Flame coloration

Yellow flame:	sodium
Reddish-yellow flame:	calcium
Red flame: lithium;	strontium

Differentiation between Li and Sr:
LiCl is more volatile than $SrCI_2$. LiCI develops at once and does not last.
Green flame: barium: yellowish-red lasting coloration.

Boric acid: very sensitive when sample is mixed with CaF_2 and H_2SO_4; evaporates as BF_3
Copper nitrate: pure green (copper chloride: blue).
Phosphoric acid: light bluish-green, especially after moistening the sample with H_2SO_4.

Blue flame: copper chloride.

Selenium: selenium odor.

Violet flame: potassium; rubidium; caesium.

Separation of Na and K: viewed through a cobalt glass, the light from Na fades, and the potassium flame appears purple-violet.

F. Sample with cobalt solution

The sample is soaked with a cobalt solution (1:10) and heated on a magnesia stick in the oxidizing flame.
Blue coloration: silicic acid and silicates: light blue.

alumina: dark blue (Thenard's-blue).

Green coloration: zinc oxide, pure green (Rinnmann's-green).

Tin oxide: blue-green.

G. Soda-saltpeter-melt

Light yellow melt: chrome.
Light reddish-yellow melt: uranium.

Vanadium produces a very pale-yellowish-colored melt; colorless when cold.
Ferro oxide does not go into solution.

Greenish-blue melt: manganese.
Testing for: molybdenum, tungsten, vanadium, columbium, titanium

> **The soda-salpeter-melt is rubbed with water in a flask filtered, and the filtrate is acidified with H_2SO_4. A piece of metallic zinc is soaked in the solution for a longer period of time.**

Tungsten: The solution slowly turns sky-blue
Molybdenum: solution slowly turns brownish-black.
Vanadium: solution becomes light blue, then later green. If the sulphuric solution is treated with hydrogen peroxide, vanadium causes a yellow-brown coloration.
Columbium: the dry mass is treated with concentrated H_2SO_4. When cooled, the solution is poured into a threefold volume of water and zinc is added. In the presence of columbium the solution first becomes blue and then changes to a turbid brownish-black
Titanium: present if a white powder, which slowly turns violet, precipitates out when an aqueous solution of the melt is acidified.
Special reaction for titanium: potassium bisulphate bead is dissolved in water and hydrogen peroxide is added; if the solution becomes brownish-yellow, titanium is present.
To test for manganese, alcohol is added to an aqueous solution of the melt and the precipitated manganese dioxide is filtered off. In the presence of chrome, testing for the other metals according to the described method is not possible.

H. Testing on Coal

1. Sublimates

Yellow sublimate: hot - dark yellow lead, bismuth (often bead).
White sublimate: hot - yellow zinc; when moistened with cobalt nitrate and strongly annealed: green.Blue sublimate: cadmium.
White sublimate, adhering to sample: tin (involatile).
White sublimate: hot - yellow. molybdenum. When a reducing flame is briefly held over a molybdenum sublimate, perpendicular to longitudinal direction of coal, a dark blue band of Mo_3O_2 develops in the middle of the white sublimate. Highly characteristic.
Brownish sublimate: silver (silver bead).
Grey sublimate and odorous fumes: selenium.
White sublimate and arsenic odor: arsenic.
White sublimate, slightly volatile and thick fumes: antimony.

2. Reduction with soda

White bead: silver, lead, bismuth, antimony, tin.

Colored bead: copper, gold.

Grey metallic spangle: iron, nickel, cobalt (magnetic) and platinum metals (non-magnetic).
Important special samples: sulphur (Hepar test). The substance is melted with soda under reducing conditions and placed on a thin sheet of silver. After moistening, a brownish-black coating develops on the silver sheet in the presence of sulphur.

Flourine: heating of the sample substance in a lead crucible with SiO_2 and H_2SO_4 (Browning test, see below).

Tellurium: when tellurium ores are slightly warmed with concentrated H_2SO_4, the sulphuric acid turns red.

Uranium: the sample substance is first melted with soda, then with saltpeter; the melt is mixed with water to a pulp, which is then placed on a filter; acetic acid and solution of ferro potassium cyanide are added, which produces a brownish-red spot in the presence of uranium.

Silicic acid and flourine: Browning Test: the sample is mixed with calcium chloride and sulphuric acid to a pulp in a thimble-shaped lead crucible which is then covered by a lead lid with a hole in the middle. A wet piece of black filter paper (available by Schleicher and Schull) is placed over the hole, and a second, standard filter paper (wet and folded) is placed on top to keep the black paper wet. Following warming of the crucible in a water bath for about 10 minutes, silicon flouride escapes which hydrolytically dissociates during deposition of white silicic acid when it comes in contact with the moisture of the black filter paper. Upon completion of testing, the presence of silicic acid in the sample is revealed by a white spot on the black filter paper where it covers the hole in the lid. Very characteristic and highly sensitive. The procedure can also be used to test for flourine by mixing the sample substance with silicic acid and sulphuric acid. Boric acid can be disruptive since it similarly volatilizes.

1.2 Pycnometer

General Ore Mining Analysis

engl.: specific gravity bottle
germ.: Pyknometer
span.: picnometro (densimetro)

TECHNICAL DATA:	
Dimensions:	available in volumes from approx. 10 ml to 1,000 ml
Weight: 50 ml-size:	16 grams
Extent of Mechanization:	not mechanized
Mode of Operation:	intermittent
Throughput/Performance:	approx. 10 - 12 measurements/h
Operating Materials:	
Type:	water
ECONOMIC DATA:	
Investment Costs:	30 to 100 DM
Operating Costs:	predominantly labor cost
Related Costs:	weighing scale with minimum accuracy of ±0.1g, cost approx. 200 DM

CONDITIONS OF APPLICATION:

Operating low I———I————I high

Operating Expenditure:	low |———|—————| high
Maintenance Expenditure:	low |———|—————| high
Personnel Requirements:	experience in collecting and evaluating test data
Type of Analysis:	quantitative/qualitative
Accuracy of Results:	dependent weighing accuracy.
Time Requirement:	approx. 5 min.
On-site Performability:	pycnometric determination of density through the use of mechanical scales can easily be performed in the field, especially when at least 10 g of material is available for testing. The weighed sample for determining density should be dry and must be insoluble in a medium (e.g. water).
Operating Experience:	very good |———|—————| bad
Environmental Impact:	low |———|—————| very high
Suitability for Local Production:	very good |—————|———| bad

Precision instrument made of glass which cannot be manufactured

locally; the mechanical scale also cannot, in most instances, be locally manufactured.

Lifespan: very long |———|————| very short

OPERATING PRINCIPLE:

The pycnometer determines the density or specific weight of insoluble mineral fragments or powder. It is a carefully calibrated, very precise volumetric measuring apparatus. Three weighings to determine the density are taken as follows:

- with the dry, empty container (tare)
- with the container filled with dry mineral sample and
- with the container including sample filled with water in the absence of bubbles

The density is determined according to the following formula:

$$\sigma[\frac{gr}{cm^3}] = \frac{\text{weight(container + sample)[g]} - \text{weight(container / tara)[g]}}{\text{volume}[cm^3] + \text{weight(container + sample)[g]} - \text{weight(container + sample + water)[g]}}$$

SPECIAL APPLICATIONS:

Determination of mineral density (mineral-identification method) and determination of beneficiation product densities.

REMARKS:

The accuracy of determination is particularly high when the differential quantities

to be measured are not too small, such as when the pycnometer is half-full with sample material.

This measuring method, which measures density to an accuracy of ±0.1 g/m³ and therefore meets mining requirements, necessitates only minor equipment expenditures. A mechanical weighing scale accurate to ±0.1 g has been proven sufficient and enables this method to be applied in the field.

SUITABILITY FOR SMALL-SCALE MINING:

Pycnometer assaying is a simple and accurate method for determining density and is therefore well-suited for the evaluation of product quality and for mineral determination.

1.3 Manual magnetic separator by Dr A. Wilke

Metal Mining
General Analysis

germ.:	Handmagnetscheider nach Dr. Wilke
span.:	separador magnetico manual segun Dr. A. Wilke, separador magnetico manual
Producer:	Krantz

TECHNICAL DATA:	
Dimensions:	Dia: approx. 3 cm, H: approx. 8 cm
Weight:	approx. 150 g
Externa power needs:	none, due to permanent magnet

Throughput/Performance:	for example, 30 min required for the quantitative separation of a 5-g heavy-mineral sample into five portions of differing magnetic susceptibility
Technical Efficiency:	relatively high selectivity
Operating Materials:	none .
ECONOMIC DATA:	
Investment Costs:	approx. 200 DM
Operating Costs:	no operating materials, therefore only labor costs
Related Costs:	for quantitative determination: weighing scale

CONDITIONS OF APPLICATION:

Operating Expenditure:		low |———|————| high
Maintenance Expenditure:		low |———|————| high
Location Requirements:	none	
Sample Requirements:	sample must be dry and dissociated.	
Period of Analysis:	several minutes	
Accuracy:	quantitative analysis is possible with liberated sample material. Probability of error ± 10 %	
Regional Distribution:	not yet employed in small-scale mining in South America	
Operating Experience:		very good |———|————| bad

Operating Experience:	very good |———|———| bad
Environmental Impact:	low |———|—————| very high
Suitability for Local Production:	very good |—————|———| bad
Under What Conditions:	requires a very strong, homogeneous permanent magnet and good membrane material.
Lifespan:	very long |———|—————| very short

Bibliography, Source: Manufacturer information

OPERATING PRINCIPLE:

The pocket magnetic separator by A. Wilke is made of a strong, cylindrical permanent magnet with a cylindrical pole gap which can be moved up and down in a brass container by means of a pull rod. The container is covered by a transparent graduated plastic tube with increments in millimeters, and by means of screwing can be adjusted within this plastic tube to change the height of the magnetic surface above the sample material being separated. In this way the separation capability of the magnetic separator is varied, being greatest at the greatest height and smallest at the smallest height (thus biotite is Just barely separable).

To perform the analysis, the sample is thinly spread over a smooth, non-magnetic plate (glass, wood) and magnetically separated over the entire surface by placing the magnetic separator on the plate. The magnetic particles are attracted by and adhere to the magnet. The magnetic separator is then placed on another plate, and the enclosed magnet is lifted by the pull rod, resulting in the release of the magnetic particles. Starting with the minerals exhibiting the highest magnetic

susceptibility, the magnetic separator can selectively separate a number of different magnetic fractions. Weighing the entire sample and the products can provide quantitative results when the sample material is completely analyzed.

AREAS OF APPLICATION:

Apparatus for selective separation of magnetic components of mineral sands, ground minerals and ores (beneficiation products).
Generation of monomineralic specimen for microscopic and chemical analysis.
Quantitative determination of composition of mineral mixtures.

Highly magnetic substances which can be separated:
Magnetite, maghemite, franklinite, pyrrhotine;
Moderately or weakly magnetic substances:
arsenopyrite, chromite, hematite, ilmenite, limonite, manganite, wolframite, rhodochrosite, garnet, amphiboles and pyroxenes.

DESIGN INSTRUCTIONS:

In addition to its analytical application, locally-manufactured pocket magnetic separators can be used in beneficiation for the purpose of recleaning concentrates, for example to separate out magnetic heavy-mineral particles from precious metal concentrates. Loud-speaker magnets (strong permanent magnets), placed in a plastic container and calibrated with distance washers made of cardboard, paper, wood, plastic or similar material, are suitable for this purpose.

SUITABILITY FOR SMALL-SCALE MINING:

Pocket magnetic separators are ideally suited for quick quantitative determination of magnetic mineral contents in raw ores and beneficiation products.

The simplest magnetic separators are well suited, depending upon the situation, for recleaning concentrates by removing magnetic components.

1.4 Quick-test-strips merckoquant

General Ore Mining Analysis

germ.:	Schnellteststreifen Merckoquant
span.:	tire de prueba rapida Merckoquant
Manufacturer:	Merck

TECHNICAL DATA:	
Dimensions:	Dia 3 cm, H: approx. 10 cm for 100 test-strips
Weight:	approx. 100 - 150 g
Throughput/Performance:	one analysis per test-strip
ECONOMIC DATA:	
Investment Costs:	between 20 and 35 DM/100 quick-test-strips
Operating Costs:	none
Related Costs:	laboratory equipment to bring mineral samples into solution: mortar, acids, glass flasks and possibly an alcohol burner for quantitative analyses; analytical balance for samples in an

	aqueous solution.

CONDITIONS OF APPLICATION:

Operating Expenditure:	low |———|—————| high
Maintenance Expenditure:	low |———|—————| high
Personnel Requirements:	highly precise weighing scale necessary for quantitative determination
Location Requirements:	none
Sample Requirements:	sample must be completely dissolved in an aqueous solution.
Duration of Analysis:	several seconds
Accuracy of Analysis:	varies depending upon the type of substances being analyzed; values for arsenic, for example, are accurate to ±0.1 ppm, for pH-values to 0.5 pH.
Regional Distribution:	not widely distributed to date.
Operator Experience:	very good |———|—————| bad
Environmental Impact:	low |————————| very high
	depending upon type and degree of sample preparation (sample solution).

depending upon type and degree of sample preparation (sample solution).

Suitability for Local Production:		very good |————|———| bad
	not possible	

Bibliography, Source: Manufacturer information

OPERATING PRINCIPLE:

Merckoquant quick-test-strips consist of plastic strips which have a sealed test-zone on one end impregnated with reagents, buffers and other compounds. These provide a quick preliminary identification in the range 2 1 mg/l (ppm). Application involves dipping the reaction-zone end into the aqueous sample solution for 1 to 2 seconds, and then comparing it to a color scale (included with the strips).

AREAS OF APPLICATION:

For quick determination of metal-contents in water (environmental impact assessments), raw-ore solutions, beneficiation products, etc. Control of reagents during simple cyanide leaching of gold.

REMARKS:

The following can be determined:

arsenic:	0.1 - 3 ppm
cobalt:	10 - 1000 ppm

copper:	10	- 300 ppm
molybdenum:	5	- 250 ppm
nickel:	10	- 500 ppm
silver:	0.5	- 10 g/l
zinc:	10	- 250 ppm
tin:	10	- 200 ppm
Total hardness:	4	- 25
pH-value:	0	- 14

Solutions which are too highly concentrated can be diluted with distilled water until the measureable concentration range is reached.

SUITABILITY FOR SMALL-SCALE MINING:

Highly suitable for environmental impact assessment (water) in that it provides fast and location-independent analysis and is very simple to use; unsuitable for raw-material analysis due to substantial difficulties in sample preparation.

1.5 Rifflebox

Metal Mining General Analysing

germ.:	Riffelteiler
span.:	partidor de muestras acanalado

Manufacturer: Haver + Boecker, Siebtechnik

TECHNICAL DATA:

Dimensions:	approx. 30 cm H × 60 cm W × 30 cm D
Weight:	approx. 2 - 5 kg depending on thickness of material
External power needs:	not mechanized
Throughput/Performance:	several hundred kg/in
Technical Efficiency:	good representation of sub-samples

ECONOMIC DATA:

Investment Costs:	300 to 1200 DM for equipment manufactured in the FRG; approx. 100 DM when locally manufactured
Operating Costs:	labor costs only
Related Costs:	none

CONDITIONS OF APPLICATION:

Operating Expenditure:	low |———|—————| high
Maintenance Expenditure:	low |———|—————| high
Location Requirements:	none
Sample Requirements:	sample must be crushed to a size less than half the riffle width.
Duration of Separation:	very short
Replaces other Equipment:	mechanized sample-divider
Regional Distribution:	already distributed in the laboratories of organizations involved with small-scale mining.

Operating Experience:		very good |———|————| bad
Environmental Impact:		low |———|————| very high
Suitability for Local Production:		very good |———|————| bad
Under What Conditions:	ordinary metal-working shops	
Lifespan:		very long |———|————| very short

Bibliography, Source: Schroll, manufacturer information

OPERATING PRINCIPLE:

The sample-divider directs the sample material over riffles which alternately distribute the sample to one side or the other, thereby guiding it into two separate compartments; the sample material of one container is then retained for testing, that of the other is discarded.

AREAS OF APPLICATION:

Sample preparation through a stepwise halving of sample material from individual or composite samples of raw-ores from ore-vein or alluvial deposits, or of beneficiation products.

REMARKS:

Riffleboxes are very simple dividers which are known for their success in producing highly representative sub-samples.

SUITABILITY FOR SMALL-SCALE MINING:

Riffleboxes are highly suitable for small-scale mining application especially since they can be locally manufactured and because they offer an easily-operable method for improving sample preparation, which increases the analytical accuracy associated with small-scale mining.

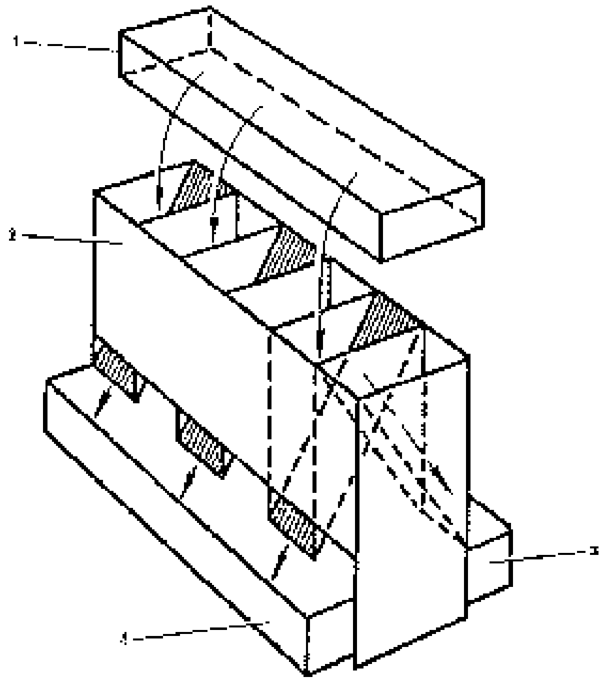

Fig: Physical Principle of the Rifflebox. Source: Lauer

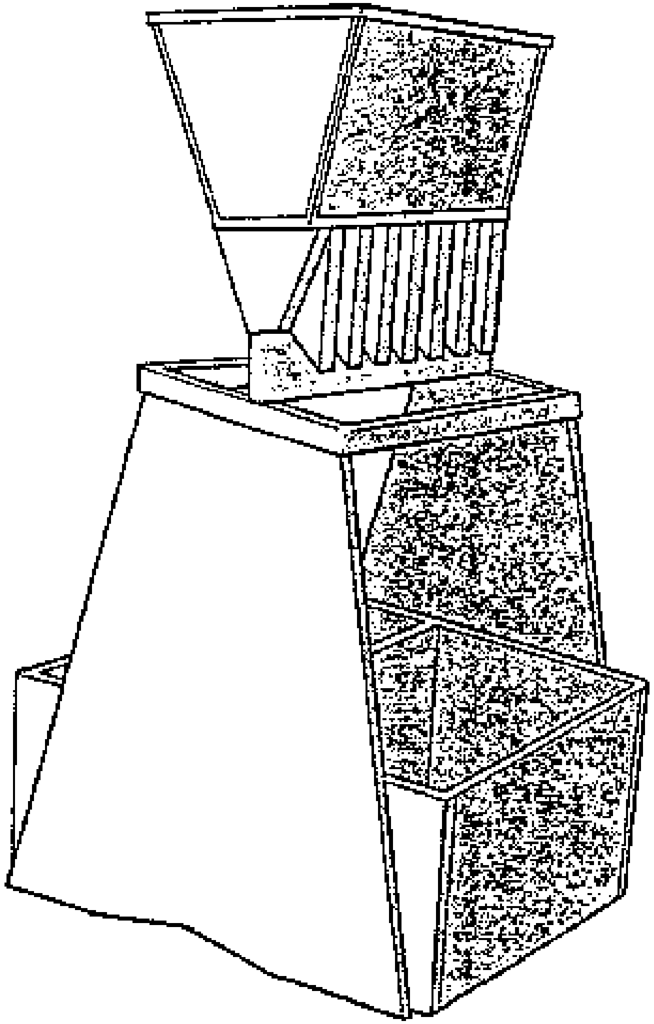

Fig.: Rifflebox for example preparation. Source: Armstrong

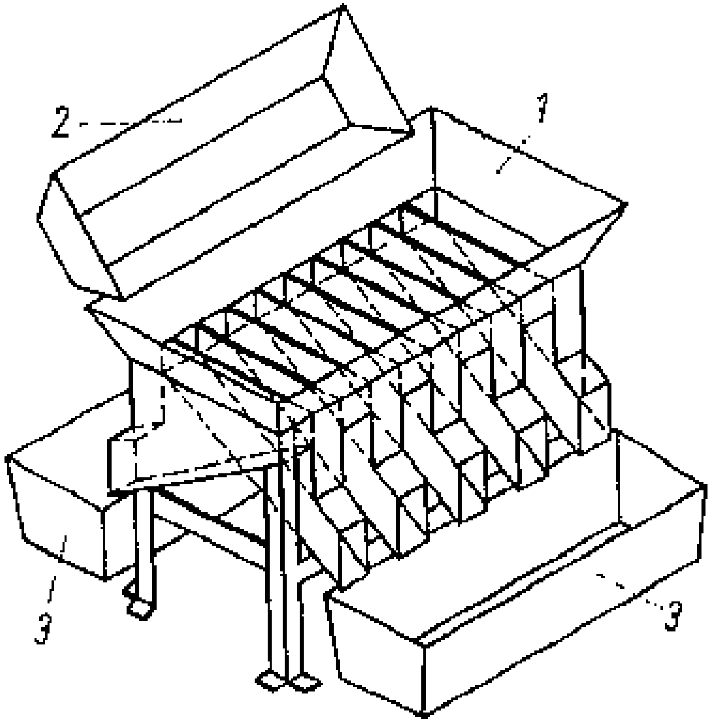

Fig.: Rifflebox with (1) sample divider, (2) feed tray and (3) receiving tray, from Schubert.

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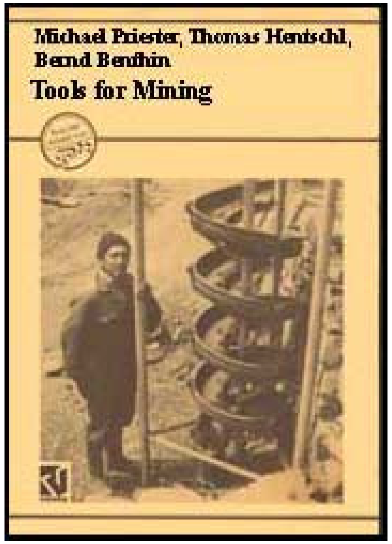


B.3. Organizational measures

B.4 Environmental and health aspects

Tools for Mining: Techniques and Processes for Small Scale Mining (GTZ, 1993, 538 p.)

B. Underground mining

B.1. Definition

Underground mining includes all aspects of raw mineral extraction by man assisted by the use of technical aids. In addition to the activities involving mining and haulage, it also includes exploration and provision of the necessary infrastructure as well as all measures for the miner's safety. Included among these are:

- drilling - drainage
- blasting - ventilation
- loading - lighting

- haulage - roof support.

The frequently-used small-scale mining method in developing countries, characterized as a shallow digging or excavating (cateo), can be regarded as a transitory form of open-pit mining.

Deposit exploration in small-scale mining in Latin America and other developing countries is performed using underground mining development methods (tunnelling), due to the comparatively high cost of core drilling.

B.2. Existing situation and problem areas

Small-scale mining in the developing countries extracts raw ores from extremely varying deposit types. The following ore-deposit types can be considered suitable for small-scale mining methods:

- **alluvial or placer deposits,**
- **oxidation zones,**
- **magmatic hydrothermal vein ore deposits with defined veins (which, however, frequently contain complex mineralizations as a result of extreme telescoping),**
- **pegmatite veins,**
- **low-sulphide gold-quartz-veins,**

- veins with high-grade gold-containing sulphides (which can be enriched into a sulphide concentrate by flotation),

- pneumatolytic and metasomatic deposits.

In can generally be stated that in small-scale mining the individual mineralized parts or excavations are of small dimension. The mine buildings are sometimes so small that the use of technical improve meets in the form of standardized, mechaninized mining equipment is impossible. An example of this is the large tungsten deposit Kami in Bolivia, where numerous small veinlets and associated difficulties in mechanizing the operation have led to a predominantly manual extraction of the ore.

Besides the purely technical problems accompanying nonmechanized mining, small-scale mines, particularly the cooperative mining operations (span: Cooperativas Mineras), also encounter a multitude of organizational difficulties, namely;

- inappropriate extracting/ mining methods,
- low degree of division of labor,
- lack of coordinated efforts.

The organizational problems are especially apparent in the structure devided in "cuadrillas", typically four-man mining teams in the cooperatives. At the Cooperativa Minera Progreso in Kami, it could be observed that every cuadrilla in the cooperative was given the right to mine the portion of the deposit extending above or below of 15 meters drift. This results in unplanned, irregular and totally

varying mining activities which have limited advance rates due to the lack of ventilation, supports, etc.

These technical and organizational deficits are responsible for the especially low specific performance rates characteristic of small-scale mining in developing countries. As a result, many small mines, although rich in ore, must be classified as economically marginal operations.

These economical inefficiencies lead to further problems specific to small-scale mining:

- Insufficient safety measures. Deficient cash availability has caused mine operators to save on expenses, particularly in the areas of ventilation and support, as well as in supplying safety equipment for miners.

- The economic problems of miners' families force the women and children to work in the mines (see photo). While women, due to tradition and religious beliefs, are only allowed to work above ground, i.e. in the beneficiation processing activities, children as young as 10 - 12 years old are already working underground mining the ore. These children frequently work in extremely small holes which are inaccessible to adult miners.

- The high exploitation costs and related costs incurred in poorly-organized, manual small-scale underground mining force the operators to more selectively mine only the high-grade zones in the vein. This screening-out method of mining (= highgrading) which follows only the rich portions of ore veins is a form of destructive exploitation which can

lead to substantial macro-economic damages. In areas where poorer deposits become inaccessible or are abandoned due to destructive exploitation of rich ores, a later mining becomes technically difficult or if not impossible. Even under changing economic conditions (as for example higher world market prices for mineral resources), the deposits that have been destroyed through exploitation mining practices still may not be mineable. This situation applies only to unorganized small-scale mining of large deposits; the unique macro-economic value of small-scale mining lies in its ability to adapt to small deposits which could not be mined by any other organinized form of mining.

A further goal of the handbook "Tools for Mining" is to help solve the problems associated with small-scale underground mining. Recommended work-organization improvements are presented below which can benefit small-scale mining operators without requiring additional investment costs:

- lowering the cut-off grade,
- extending the life-span of the deposits,
- improving work conditions (increased safety, elimination of child labor practices),
- improving mine productivity,
- increasing incomes, and
- stimulating the economy through job security.

B.3. Organizational measures

B.3.1 USE OF GRAVITY TO REDUCE HANDLING

Small-scale mining frequently employs inefficient loading and transport methods. Loose material is rehandled a number of times through reloading, redumping, relocating. Particularly primitive and unproductive are the mining methods practiced in the small-scale mining cooperatives where the miners are organized into small mining teams (cuadrilla) which work from the haulage level downward. In these mines, hoists are the standard form of ore transport (see photo, Technical Outline 9.1), sometimes being found every 15 - 20 meters. This is a situation in which changes in mining procedures in order to increase production, listed below as a three-fold concept, are not only logical but also necessary:

1. **A reorganization which incorporates division of work duties (job specialization) should be established.**

2. **A mining procedure should be chosen which employs gravity to increase the efficiency of loading and transport activities.**

3. **Shaft haulage should be centralized where possible; this involves planning and driving of haulage drifts for the transport of raw ore to the haulage shaft or blind shaft.**

A planned loading procedure through the use of loading platforms, raise chutes and bunkers can significantly increase mine productivity and reduce loading and transportation costs. Furthermore, a centralization of shaft haulage can simplify a mechanization of the hoisting equipment.

B.3.2 BACKFILL WITH HAND-PICKED ROCKS

Another method for reducing haulage costs is the hand-sorting of waste rocks underground for further use as packing or backfill material in the excavations. In deposits where portions of unmineralized hanging or foot wall also need to be mined, hand sorting can significantly decrease the volume of raw-ore to be transported. Although hand-sorting in small-scale underground mines in developing countries is a frequent occurrence (see photo, bottom), the sorted-out waste material is not always used in the excavations for backfill, but rather hauled separately out of the mine and deposited on the surface. A change in this practice could contribute significantly to lowering transport costs, improving safety at the mining face and, especially in the small manually-operated mines, alleviating drift and shaft haulage activities. Aside from these, a systematic back-filling can also contribute towards improving the ventilation in the mine, for example by filling in old man (abandoned) workings and thereby preventing short circuits in the ventilation flow.

B.3.3 DIVISION OF LABOR IN UNDERGROUND MINING

One basic organizational deficiency in small-scale mining is the frequent lack of work specialization. Especially the cooperatives' "cuadrilla" work procedures repeatedly lead to difficulties due to the parallellism or duplication of work performed by these small mining teams. As a result, a continuous working operation is not possible, and due to economic and organizational necessities, the work activities are limited to a few critical areas. Mining, haulage and beneficiation are performed sequentially, and other essential tasks are negelected

for the present time; as a result, work activities such as development of deposits (even where this is possible internally inside the ore-body structure), timbering and maintenance of galleries (see photo) are not performed.

This has the following effects:

- **lack of safety in the mining operations**

- **a steadily worsening mineral-reserves situation which further lowers the ability of the operations to receive credits and further impedes potential investment through exploration funds (e.g. from the Fondo Nacional de Exploracion Minera, FONEM, Bolivia).**

These problems can be countered by a systematic division of labor in the mining operations. This normally requires, however, that the existing distrust first be eliminated. This lack of confidence has been the primary cause of failure so far for numerous projects which attempted to promote a cooperative work system, despite the fact that a concept incorporating rotating job responsibilities not only contains components for specialized training, but also most ideally encompasses the cooperative idea.

Furthermore, a system of work specialization could also facilitate essential planning and coordination activities such as ventilation, supply of energy, mine planning and mine safety.

The introduction of work specialization should include the negociation of personnel salaries based on performance or productivity.

B.3.4 COST REDUCTION IN DRILLING, BLASTING, MAULING, CRUSHING

Depending upon deposit geology and existing mechanization and equipment both on the surface and underground, possibilities exist for reducing costs for drilling, blasting, hauling and crushing. The following relationships regulate potential savings within these cost categories:

fewer drill holes per drilling round (lower drilling costs) produces coarser material (higher crushing costs), stronger explosives (higher blasting costs) results in fewer and/or smaller drill holes (lower drilling costs), electrical milk-second detonator (higher detonator costs) yields finer-grained material (lower loading and crushing costs).

In mines with defined veins without impregnation zones, coarser mined materials can make the hand-sorting or backfilling work easier. Optimization possibilities are dependent on the specific mineralization conditions and the technical capabilities of the mine operation.

B.3.5 SELECTING AN APPROPRIATE STOPING METHOD

The primary deficiency in underground mining operations is the lack of mine planning. As a rule, a type of exploitation mining in the form of irregular excavating or room-and-pillar mining is practiced without any prior planning. This results in lower recovery, lack of safety, and adverse macroeconomic effects due

to a partial destruction of the deposits. The different mining methods can be classified according to the type of mine development and support and roof-control measures as follows:

Table: Main Classification of Mining Methods

Mining Method	**Roof Control**		
	with pillars	**with backfilling**	**with roof caving**
Longwall type (50 m and longer advancing face)		longwall mining inclined cut-and-fill mining overhand stoping cut-and-fill stoping	longwall mining
drift type (2-4 m face width, gallery driving)		drift stoping cut-and-fill stoping cross cut stoping	cross cut stoping
room-and-pillar type (drifts separated by pillars which are mined in retreat)		pillar mining cross-cut stoping	pillar mining sublevel caving cross cut stoping

panel type (large axially-expanding rooms extending to mine limits boundary)	panel mining room-and-pillar mining breast stoping		panel mining room and pillar stoping stall pillar stoping glory hole sublevel stoping
block type(excavation chamber not open or visible)		block caving with square sets	block caving

In the following sections, mining methods are presented (according to Stoces) which, under the special conditions of small-scale mining in the Andean region, contribute to lowering costs, increasing productivity, improving the use of resources (through higher recovery) and decreasing the effort required to extract the ore (consequently increasing mine safety).

Pillar mining

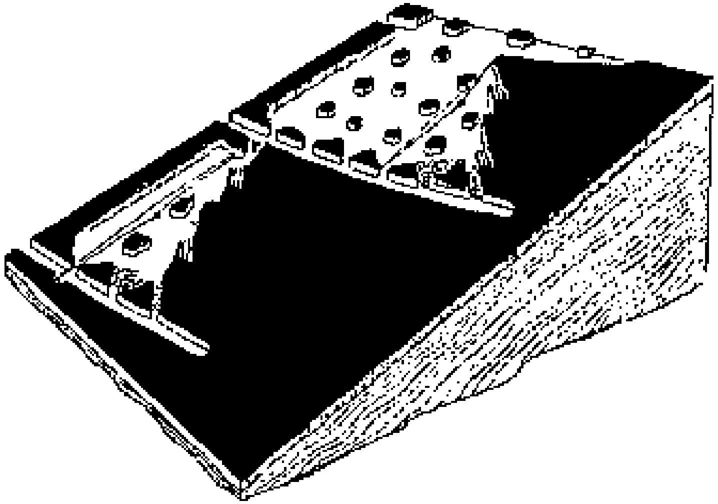


Fig.: Development of pillar mining in an inclined deposit. Source: Stoces

Pillar mining is characterized by irregular forms and arrangements of the excavation chambers, determined by the characteristics of the deposit, the chambers being separated by pillars of varying shapes to support the roof.

It can be applied in deposits with competent mineral and host rock.

Room-and-pillar method

Fig.: Room-and-pillar method. Source: Stoces

This mining method is characterized by the development of parallel headings which resemble long drifts in their form and dimensions. The width of the

headings depends upon the competence of the host rock and can reach 10 meters; the height can total up to 3 meters.

The individual headings are laid out either parallel to each other, or either perpendicularly or diagonally crossing each other. Support pillars are left between the headings to support the roof. The roof and floor of the headings usually correlate with the hanging and foot walls of the vein being mined; in some cases, however, the mineralization may extend beyond the upper and lower heading boundaries.

This mining method can be applied in flat or slightly-inclined deposits with competent ore and country-rock.

Panel mining

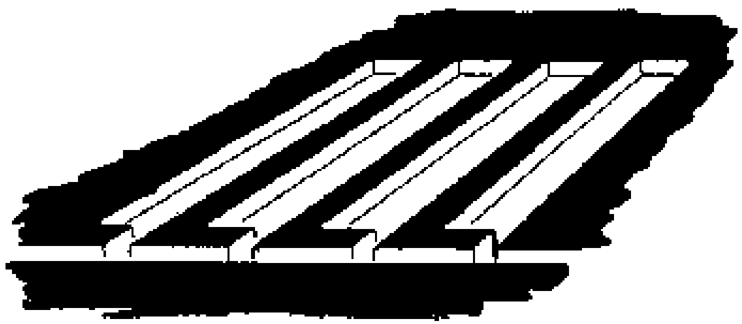


Fig.: Panel mining. Source: Stoces

Within the deposits, only the narrow, long panels are mined, the valuable mineral contained in the support pillars between panels is left unmined. The deposit is normally developed by a main gallery from which other drifts branch off. These drifts are then widened into panels, leaving a stretch of unwidened drift between

the main gallery and the panel for support reasons.

This method of mining is characterized by the construction of panels of regular, mostly rectangular shape. These panels are usually larger than headings, being developed according to preplanned, defined measurements.

Support pillars are left between the panels, consisting of either a solid wall (without cross-cuts), or a row of singular pillars (separated by cross-cuts connecting adjacent panels), depending on the method of ecavation employed.

In gently-dipping deposits, either the hanging wall and foot wall, or portions of the mineralized ore itself, form the roof and floor of the panels. In steeply-dipping or massive deposits, the mineralization can extend beyond the chamber boundaries in all directions. The panels can be mined by various methods, for example, a full advance to the final dimension, or with overhand or bench stoping, with or without backfilling or roof caving.

Panel mining can be applied in thick and massive deposits with competent mineral and host rock regardless of dip.

Shrinkage stoping

The blasting is performed from small chambers in the roof of the stope itself which are sunk from the overlying drifts.

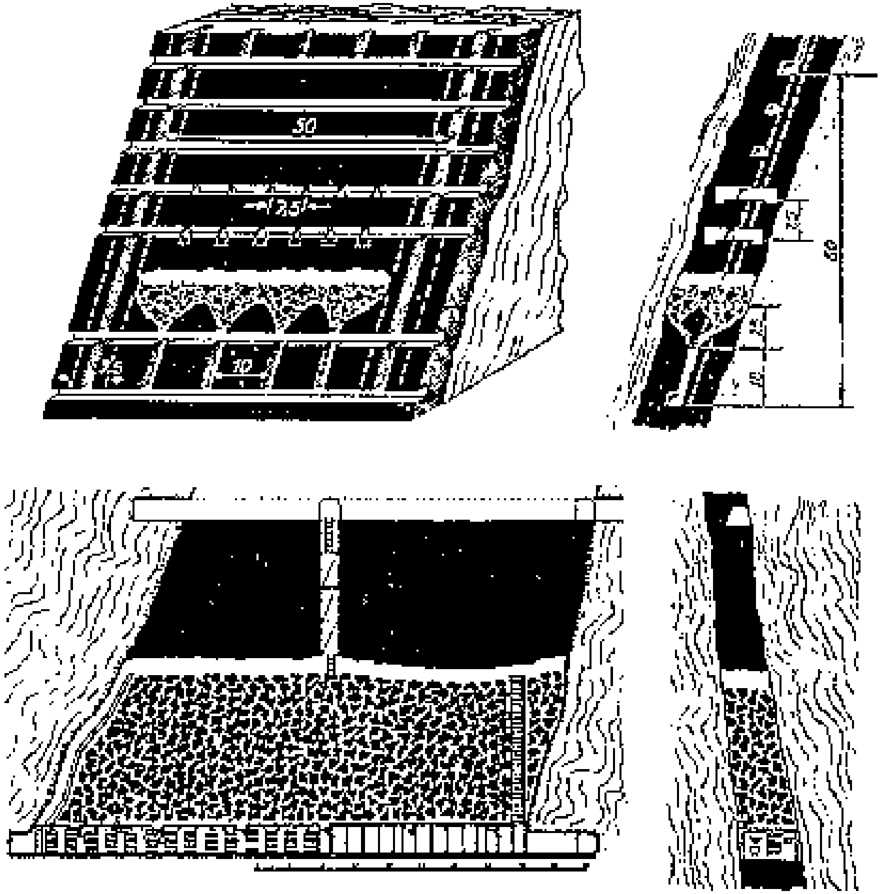


Fig.: Shrinkage stope. Source: Stoces

With this procedure, the extracted ores are stored in the excavation chamber for the duration of mining of the individual slopes. The advantages of shrinkage stoping lie in the fact that no support measures are required and recovery is very high. Shrinkage stoping in small-scale mining in the Andean region is particularly suitable where local conditions permit only seasonal execution of certain processing steps; for example where there is a lack of processing water during the dry season, so that raw-ore beneficiation can only be performed in those months

with sufficient rainfall.

Sub-level stoping

Sub-level stoping is an irregular form of panel mining.

This method is characterized by the blasting of large chambers, varying in size depending upon the structure and stability of the deposit and the host rock, and therefore, contrary to panel mining, not precisely defined prior to mining. The excavation chamber must be designed so that gravitational forces alone enable the blasted ore to slide down out of the chamber. Only in rare exceptions (for example, in particularly competent host rock) in only slightly inclined deposits, can a scraper be installed to assist in removing the blasted ore from the chamber.

The stoping, contrary to that in the panel stoping method, does not occur within the chamber itself, but rather at the chamber perimeter, either from horizontal sublevels or through long drillholes, since for safety reasons the chamber may not be entered.

The sublevel stoping can be performed either with roof-caving or with backfilling. It is applicable in steeply-diping deposits of lesser or greater thickness, and in flatter, more massive deposits where a required minimum stope height of around 15 meters can be realized.

A sufficient host-rock stability is important since the stopes can only be worked as long as they remain open. Due to the specified minimum sizes of the chambers and the corresponding greater degree of mechanization, sublevel stoping cannot be considered suitable for small-scale mining.

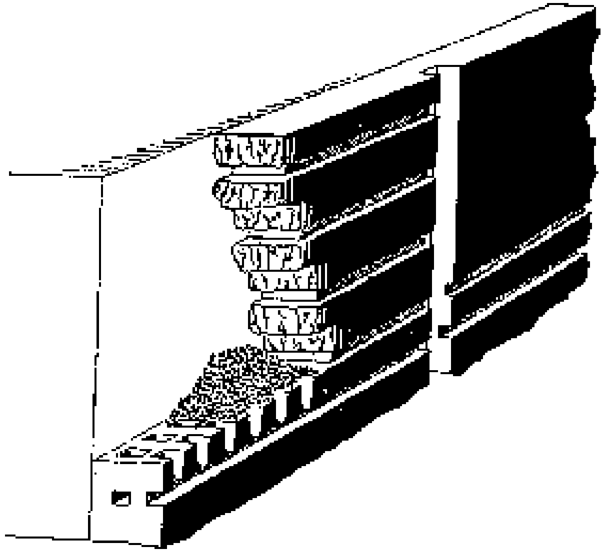


Fig.: Sublevel stoping. Source: Stoces.

Sublevel stoping (sublevel widening and sublevel caving). When competent ore is being mined from sublevel drifts, then mining from the lower sublevels can proceed.

Cut-and-fill stoping

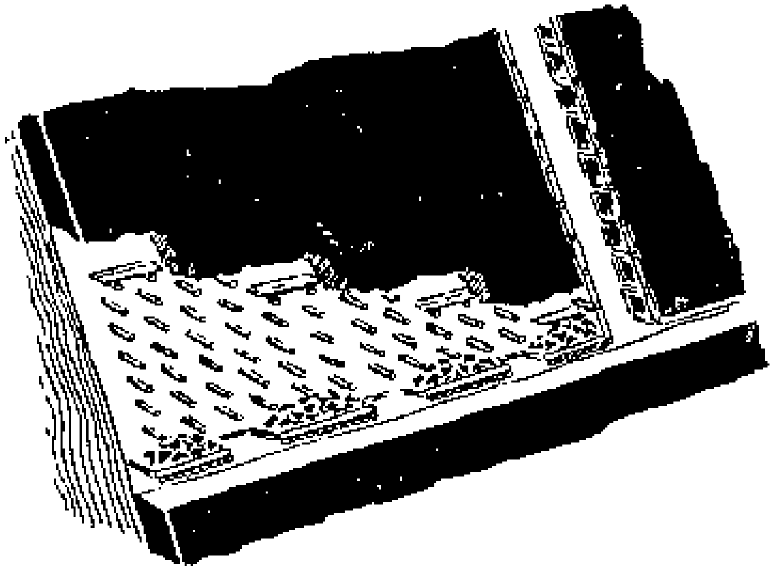
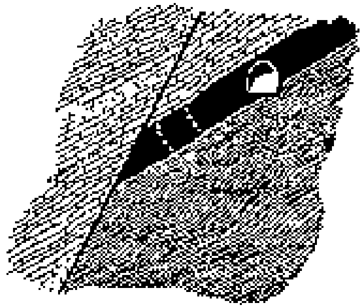


Fig.: One-Sided cut-and-fill stoping of overhand faces with brace support. Source: Stoces.

This type of stoping is defined primarily according to the type of advance and not the shape of the excavated chamber. The overhand stope, which aside from bench stoping is the oldest form of mining, is characterized by the arrangement of the overhand-stope faces in a step-like pattern of advance whereby each stope cuts into the roof of the preceding stope. The floor of the stope generally is constructed with backfill' although in rare cases square sets are employed for chamber support.

Bench stoping (Underhand stoping)



Figure

Bench stoping is sometimes employed for mining smaller regions of deposits which lie below the haulage level where it would be uneconomical to develop additional levels.

Fig.: Bench (or underhand) stoping. Source: Stoces

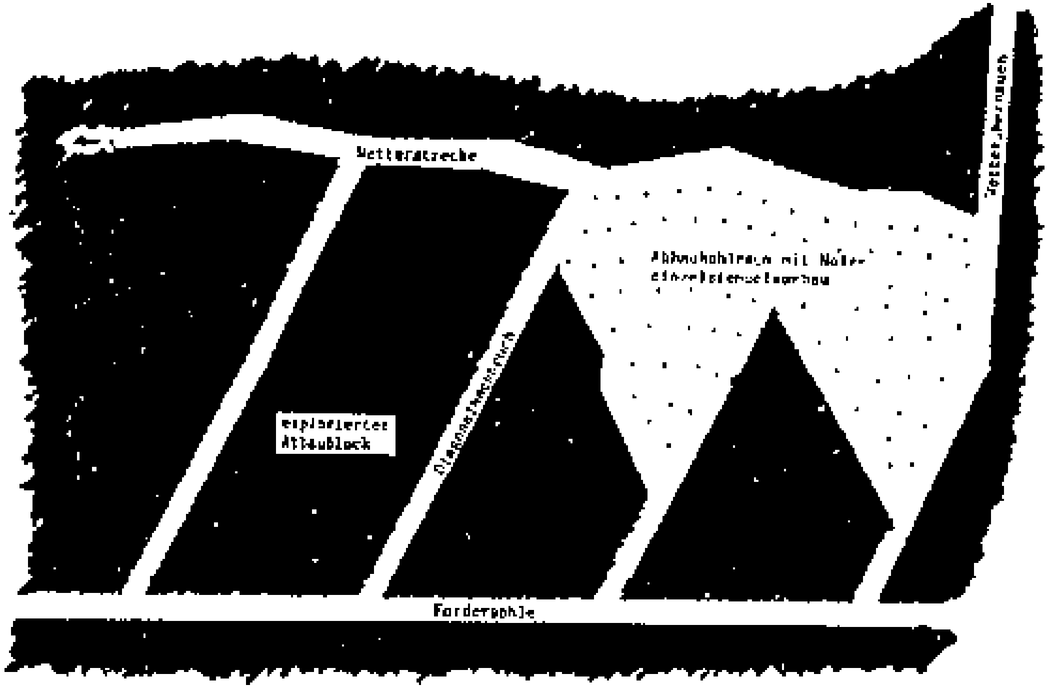


Fig.: underground bench stoping or glory-hole mining in a steeply-dipplig coal mine in Checua Region, Cundinamarca, Colombia.

This mining method is the graphic opposite of overhand stoping. Here also, the type of development rather than cavity shape characterizes this mining method. The step-like stoping advances in such a manner that each face mines the floor of the preceding one.

In more massive deposits, the bench stoping develops into an underground glory-hole mining without backfill. It is applicable in deposits of smaller thickness and steep dip, and also as underground glory-hole mining in more massive deposits.

Inclined cut-and-fill mining is differentiated from the regular cut-and-fill method only by the inclined position of the face, which occurs as a result of applying this

stoping method in steeply dipping deposits.

This method is only applied in steeply-dipping seamlike deposits of smaller thickness.

Inclined cut-and-fill mining

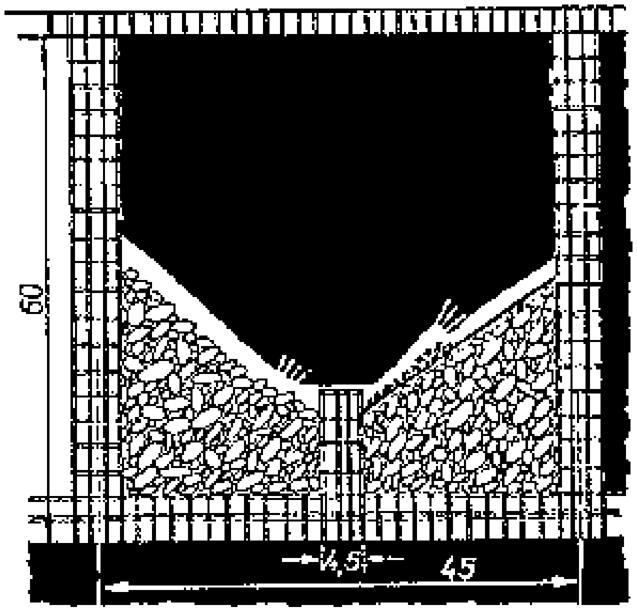


Fig.: Example of double-sided inclined cut-and-fill mining. Source: Stoces

Sub-level caving

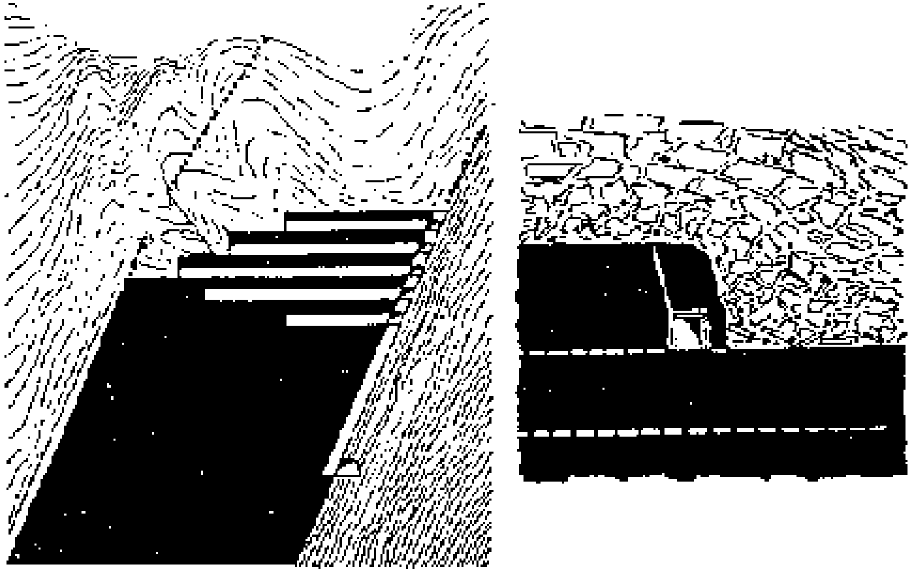


Fig.: Sub-level caving. Source: Stoces

This form of stoping is characterized by the drifting of underground sub-levels, aligned underneath each other, separated by vertical distances of two to three times the height of the roadway. Mining progresses, as the name implies, from the top downwards, followed by caving which automatically also advances downward from sublevel to sub-level.

At each sublevel, the mineral is mined by a two-step form of "small panel mining" as follows:

advance mining involving the driving of individual parallel headings (similar to drifts in height and width), which is then immediately followed by retreat mining whereby the in-situ mineral above the sub-level is mined and the pillars between the drifts simultaneously weakened to the furthest extent possible. The stoping can be performed either sequentially, one sublevel after the next, or

simultaneously with several staggered sublevels in deposits of sufficient thickness.

The sub-level caving method is predominantly applied in steeply inclined deposits, of smaller or greater thickness, or in rare cases in thick flat deposits.

A comparison of the various mining methods with regard to their technical and economic characteristics is presented below:

In any case, the application of a systematic mining method leads to a reduction in costs and improved mine saftey compared to the visual mining methods currently being used. The selection of one of the above-mentioned mining methods must give serious consideration according to the deposit characteristics.

Table: Compasion of the essential mining parameters of the major mining methods

Mining Costs:		**Productivity per man:**	
(low)	panel mining	(high)	panel mining
	pillar mining		pillar mining
|	abandoned pillar mining	|	abandoneeed pillar mining
|	shrinkage stoping	|	shrinkage stoping
|	overhand cut-and-fill	|	overhand cut-and-fill
|	bench stoping	|	sublevel caving
↓	sublevel caving	↓	inclined cut-and-fill
(high)	inclined cut-and-fill	(low)	bench stoping

(high)	inclined cut-and-fill	(low)	bench stoping
Recovery		**Preparation:**	
(high)	cut-and-fill mining	(low)	panel mining
	shrinkage stoping		pillar mining
|	sublevel caving	|	abandoneeed pillar mining
|	pillar mining	|	bench stoping
|	abandoned pillar mining	|	cut-and-fill mining
|	panel mining	|	shrinkage stoping
↓		↓	sublevel caving
Timber Consumption:		**Ore Dilution:**	
(low)	panel mining	(low)	panel mining
	abandoned pillar mining		abandoned pillar mining
|	pillar mining	|	pillar mining
|	shrinkage stoping	|	shrinkage stoping
|	bench stoping	|	cut-and-fill mining
|	cut-and-fill mining	|	bench stoping
↓	inclined cut-and-fill mining.	↓	sublevel stoping(high)
(high)	sublevel caving	(high)	Number of drills

B.3.6 DEVELOPMENT OF FURTHER PORTIONS OF THE DEPOSIT

A factor worth considering for increasing the economically mineable reserves is

the possibility of developing parallel mineable seams or areas of the deposit. In the small-scale mining industry in developing countries, exploration of the mined areas of the deposit is only performed where very massive seams or veins are being mined. Only in a few mines are the mine workings designed to accommodate mining of parallel seams or veins. This would be especially favorable, from an economic-geology point of view, for operations where steeply to moderately-inclined seams or veins are being mined, since the steep country-rock layers between the mineralized seams or veins could be penetrated by horizontal cross-cuts. Furthermore, cross-cuts could be driven through the country-rock simultaneously with the ongoing mining activities.

From a mining perspective, the development of parallel seams offers the following advantages:

- **simplification of ventilation**
- **centralization of haulage**
- **reduction of exploration and extraction costs**
- **avoidance of water supply and drainage problems.**

The mining of parallel seams or veins also permits a postponement of development at greater depths, which characteristically encounters substantial technical difficulties such as advancing into water-bearing levels, higher mining costs due to greater ground pressure, or higher transport costs due to longer haulage distances.

Without exception, the development of the mine should begin with the upper seams or veins, especially in flat or moderately-inclined strata. The mining of

underlying seams occurs only after mining and caving of the upper seams has been completed. Only in this way can damage to overlying mineable seams be avoided, caused by fracturing or caving of the roof of the underlying mined seams which results in the overlying seams becoming incompetent and therefore unsuitable for mining. A fracturing and caving of the exposed rock surfaces also in large mined stopes as well can affect the competency of massive country-rock over a distance of several hundred meters. As a result, complete portions of the overlying veins or seams can fracture or cave, rendering them in any event unsuitable for mining. Given this fact, the mining of only one mineralization, for example the thickest seam, can under certain conditions cause major irreversible damage to the economy as a whole.

On the one hand, mine operators should be motivated through consulting efforts to design their mine workings to accommodate parallel mining activities, even if this results, under the circumstances, in temporary economic disadvantages such as postponement in the mining of explored sections. On the other hand, it remains to be investigated whether a small revolving fund with pre-financing capabilities for the purpose of developing the cross-cuts traversing the country-rock could offer sufficient support to the mines in their exploration activities.

B.4 Environmental and health aspects

Mining activities adversely affect the environment both underground and on the surface by polluting air and water.

a) Air Pollution: Contamination of the mine air in small-scale mining of non-iron metallic ores in developing countries is not, as a rule, due to natural causes.

Radon emission from host rock and natural radioactivity which occurs, for example, in uranium mining, firedamp gas from methane emission which occurs in coal mining, or CO_2 blow outs which occur in salt mining can be disregarded. The main causes of mine-air contamination are man-made, produced by gas emissions from mechanized diesel equipment and vehicles, by oil aerosols generated by direct oiling of compressed-air equipment, and also by blasting fumes. As a result of the explosive reaction of blasting materials, highly toxic nitrous gases are released. To solve these air-quality problems, artificial ventilation is employed, which in small-scale mines in developing countries is often employed insufficiently and operated inadequately. Standard values for minimum air volume should be incorporated here according to the specifications applicable in Europe:

$6m^3$ / man × min plus
3-$6m^3$/ PS × min for diesel equipment underground.

In addition, high dust levels further contaminate the mine-air. Quartz-containing country-rock is particularly problematic, in that the respirable quartz fines cause the lung disease silicosis. These respirable dusts are generated during drilling and blasting activities. Wet drilling, wearing of masks, and sprinkling of blasted muck are attempts to minimize these problems. In general, growing mechanization increases dust levels and the associated health hazards.

b) Water Pollution: Contrary to mine-air pollution underground, pollution of mine water directly affects the above-ground ecosystem. Almost without exception, the vein deposits in smaller non-ferrous metal ore mines contain more or less high proportions of sulphide ore minerals or other accompanying minerals. In

permeable zones of the vein mineralization, soluble sulfate compounds are formed through oxidation processes (partially stimulated by microbial calatytic reactions); in combination with water these compounds form sulphuric-acidic mine water. The pH-value of this acidic water can reach levels below pH 2. Besides being acidic and containing high levels of sulfates, these waters form solutions containing high levels of heavy metals, some of which are toxic. Furthermore, these waters may also be contaminated with oil from diesel-operated equipment and lubrication of compressed-air machine-tools. One lifer of oil poisons one million lifers of water. This polluted water becomes hazardous when it ends up on the surface or when it comes into contact with the ground water. Serious impacts on unstable, vulnerable ecosystems, for example in the semi-arid high Andean region, cannot be ruled out. Surface water not only serves as processing water for mining and beneficiation, but is also used as a source for drinking water and for irrigation purposes.

Quantitative statements regarding the degree of environmental impact cannot be made since measurement values of pollution levels outside regions of greater population density in developing countries are not available. Measures to alleviate this deficiency are greatly needed.

In addition, general deficiencies are apparent in terms of work safety, namely:

- **noise protection during drilling or other mining and transport activities is rare**

- **safety shoes and helmets (see photo) are not standard equipment**

- no safety measures are provided during personnel transport

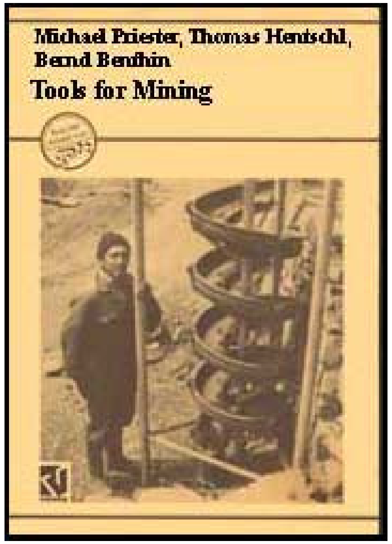
- safety measures during blasting operations (for example, detonating fuses are too short, etc.) are lacking

- lighting is inadequate (e.g. candles).

The cause for this deplorable state of affairs is not the negligence or mentality of the miners but rather the result of economic pressures.

Increased mine productivity and improvements in ore beneficiation should, above all, also place priority on the implementation and financing of miner health and safety measures.

c) Destruction of Trees and Forests: Lumbering for purposes is one of the major causes of massive destruction of forests in Latin America and elsewhere. This can be countered by application of cheaper, reusable support elements (individual props, such as railroad ties; see technical chapter).



2.1 Safety kit

Tools for Mining: Techniques and Processes for Small Scale Mining (GTZ, 1993, 538 p.)

Technical Chapter 2: Safety Techniques

TECHNIQUES APPLIED IN UNDERGROUND MINING

2.1 Safety kit

General Ore Mininig
Underground Mining Safety Technology

Mining and work safety, especially in small-scale mining in developing countries, are sensitive areas frequently characterized by major deficiencies due to cost factors or negligence. The following section presents the safety-equipment components for small-scale mining, categorized according to personnel equipment

and general mine equipment. The personal safety equipment should ideally consist of the following:

Helmet - serves as the primary protection from head injuries caused, for example, by falling stones and debris, roof-falls or supports. Mining helmets are made of thermoplastic, such as PE, or fiber-reinforced synthetic resin and are predominantly produced in the developing countries. They have an adjustable inset mounted inside the helmet, with several centimeters of space left in between to accommodate a first-aid kit. The external helmet surface is affixed with a fastener for a cap lamp. The cost of one helmet ranges between 10 and 20 DM.

Safety shoes - with steel-reinforced cap and sole to protect against crushing of the toes or cutting of the foot from sharp objects. In dry working areas leather shoes are preferable, and rubber boots in wet or moist working areas. Locally-manufactured boots are available in most of the mining countries. The cost for one pair varies between 20 and 40 DM.

Ear protectors - against health-damaging noise levels such as those produced by pneumatic drilling. They are available either in the form of a head-piece with attached ear-covers, or in a simpler and cheaper form as absorptive foam-plastic ear plugs which are independently placed directly into the ear.

The following safety items are also necessary, depending upon the type of potential dangers present in the particular work-area:

Shinbone protector - protects against shinbone injuries. It consists of a hard plastic shield placed over the clothing on the shinbone and fastended with two

straps.

Hand gloves - to protect hands and fingers from injury.

Protective goggles/glasses - to be worn when danger of eye injuries exists due to flying objects, stone splitters or other particles (e.g. dust from drilling or grinding activities).

Face Mask/Oxygen Mask - with replaceable filter which is placed over the mouth and nose. Especially dangerous is air-transmittable stone dust, which can cut the pulmonary alveolus in the lungs when inhaled. This disease, known as silicosis or "mal de mines", is the most common occupational disease in mining. Dry drilling, blasting and caving are activities which produce extreme amounts of stone dust, requiring not only the use of breathing masks for personal protection, but also sprinkling of the dust sources with water. In less dangerous working areas where smaller levels of dust are prevalent, a soft cloth tied over the mouth and nose frequently serves as a temporary protection.

Knee protectors/Knee shoes - these are only needed as protection in drifts of low roof height where longer stretches need to be travelled via crawling. Knee shoes are made of rubber (sometimes from parts of car tires) and fastened in place with an attached rubber belt.

Filter-Self-rescuer - In some branches of mining, particularly coal and certain salt deposits, dangers to the miner exist in the form of toxic or explosive gas emissions from the country-rock during mining underground. In salt deposits, especially those of tectonic or vulcanic origin, the accumulation of CO_2-gas under

conditions of high ground pressure can lead to a sudden explosion. CO_2 is a toxic, odourless, respiration-inhibiting gas which is heavier than air and therefore collects in the deepest locations. Since the danger of gas explosion is the greatest when the country-rock is loosened by blasting, it is standard practice that blasting in underground salt mines occur during shift change in the absence of mining personnel. As a protection again these gases, every miner carries a filter-self-rescuer which allows him to escape from the toxic fumes to the surface in the event of an explosion. In coal mining, the occurrence of underground fires can likewise lead to the danger of high levels of CO and CO_2 gas in the mine air, use of the filter-self-rescuer offers protection against these gases during escape as well. CO and methane gas, emitted from the seam or country-rock, are both explosive as fire damp in certain concentrations. In order to avoid mine gas explosions, flameproof electrical equipment, permissable explosives, continual measurement of the gas content in the mine air, and extensive ventilation of the gob are necessary. Coal dust can also become explosive when present in whirling air vortexes.

Gas Measuring Devices - to measure mine gas concentrations. Measuring appratuses are available on the market either as small rechargeable electrical meters for taking single or continual measurements, or as larger measuring devices equipped with a graduated pipe and bellow pump for taking single measurements.

For the first device, the investment costs are higher, whereas for the second, the operating costs are higher. For the Indirect measurement of methane gas, gasoline safety lamps can also be used (see 6.1).

The mine safety equipment should include the following items:

Personnel tags - small numbered metal tags which hang on a check-in/check-out board near the shaft or mine entrance. One side of the board holds the tokens for those workers currently in the mine, the other side for miners who are not in the mine at the time. Every miner has a tag with his own number or name, and personally hangs it on the appropriate board every time he enters or leaves the mine. In the event of an accident, or prior to blasting, this personnel-control system allows immediate determination of which workers are currently in the mine.

Scaling rods · a basic component of the safety equipment in underground mining, used to pry off loose rock pieces from the roof and headings caused by blasting or the effects of ground-pressure. Scaling rods, like crow bars, are applied by inserting the tip in the fracture between the loosened portion and the country-rock, and prying until the loose rock falls. Old drill-rods with a sharpened tip can be employed as scaling bars in small openings or drifts, whereas lighter, longer aluminum pipes with a chisel tip are used in larger cavities. Fundamentally, scaling should be performed after every blasting round before any other activity is undertaken. Thereby, the blasted debris provides easier access to the roof. These simple safety precautions significantly Increase work safety, decreasing the risk of accidents.

First-Aid Kit - with an assortment of medicines and adhesive plasters, bandages and splints for treatment of injuries.

Stretcher - to rescue injured miners.

Gas Protection Equipment - for use by the mine-rescue team in emergency situations, these are practical in small-scale mining In developing countries only if miners are trained in mine-rescue operations. This safety measure, however, is frequently not implemented by the individual mine operators in developing countries.