TECHNICAL DIGEST

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NAGPUR

EXPLORATION

Camera for Borehole Inspection

It is reported that the North American based Company Knopafex has recently introduced the BH-170 colour camera system for borehole inspection work in geological and mining fields. It has important features of remote focussing, an electronic iris and variable lighting system. A wheel system keeps the camera in the middle of the borehole and an optional rotating mirror assembly provides direct examination of the sides of the boreholes.

This camera can examine boreholes over 305 m. The controller, housed in a portable aluminium case, monitors camera, light power and power supply. The unit has a built-in VCR and colour monitor.

(Mining Magazine, July, 1989,p. 66)

MINING

Rampura-Agucha Mining Complex

Situated in Bhilwara District in Rajasthan and connected by a 13 km road from Rupaheli Railway Station on Ajmer-Chittorgarh-Ratlam metre gauge railway line, Rampura-Agucha complex is a part of Rs.617 crore HZL Integrated Project which consists of this mining complex and Chanderiya Lead Zinc Smelter near Chittorgarh.

The cost involved in the mines and concentrator at Agucha will be around Rs. 167 crores. The project is likely to be completed by May, 1991.

The total lease area is around 1,200 hect. out of which about 750 hect. have been acquired. In addition, 74-hect. area has been acquired outside lease area for housing colony at 7 km away from the mine.

45 million tonnes of ore are amenable by openpit mining extending up to 220 m from the surface. Reserves beyond 220 m depth may be mined economically by underground method. In situ zinc and lead grades are 13.48% and 1.93% respectively. Major design parameters of the pit are as follows :

Surface MRL	:	390 mtr.
Open-pit bottom	:	170 mtr.
Minimum-width at bottom	:	50 mtr.
Hangwall slope	:	48^{o}
Footwall slope	:	38^{o}
Haulage ramp width (on footwall)	:	20 mtr.

Ore exploitation is planned by heavy earth-moving equipments like front-end loaders (10 m^3), rotary drill machines (225mm), electric shovels (4.6 m^3) and 50 T dumpers with the use of software for day-to-day mine-planning and equipment scheduling at designed rate of extraction of 3,000 tonnes per day. Openpit reserves may last for more than 45 years with an average waste : ore ratio as 4.14 : 1. During life of the mine 160 million tonnes of waste dump will be produced. An Environment Management Plan of the mine has been prepared by WS Atkins International, England, in association with MECON India Ltd. and Environment Committee Centre, Udaipur.

Mercury Mining in Spain

Few mines anywhere can be as high grade as the mercury mines of Almaden in South-West Spain. Vein material analyses 20% Hg and run-of-mine feed to the roaster is 5% Hg, more than five times the grade of any other mercury mine. The almost pure cinnabar(mercury sulphide) ore glows a vivid vermillion and sweats native mercury from its pores.

Almaden produces 12 lakh kg to 13 lakh kg of mercury (35,000 to 40,000 flasks) every year. This production is about half the world's requirements. Almaden's reserves and capacity could easily produce all the world's needs, if the market permitted.

The State owned Almaden complex consists of the original Almaden underground mine, which was worked from 7th Century B.C., a new underground mine at Las Cuevas (opened in 1986), an open pit operation, primary processing facilities for production of mercury metal and two plants for production of mercury oxides and chemicals.

At the original Almaden mine there are three veins, approximately 4m, 5m and 8m to 10m in width, separated by about 10m thick waste rocks. From the past the mine has been worked manually by cut-and-fill method, where broken ores are funneled through timbered raises in the fill to boxholes and mine cars on extraction level. Because of high operating cost and health problems encountered on account of silicosis and mercury poisoning, Almaden switched over to Vertical Crater Retreat (VCR) mining which was pioneered in Spain in 1970s. After this change no new mercury poisoning has occurred. All the current production comes from the new Las Cuevas underground mine and Entredicho open pit.

VCR at Las Cuevas

Las Cuevas, situated 12 km north of Almaden, started production from 1986. VCR method of stoping is followed here. The mine has ore reserve of 140,000 mt at a grade of 5% Hg. Ore body has a strike length of 100 m with widths varying from 4 to 5 m and a depth up to 185m.

There is a spiral ramp as access to the mine with concrete flooring. There are four main levels driven in the footwall. From the footwall drives cross-cuts are driven into the ore zone and a room is excavated for the drill rig which forms the top of the stope. Holes are drilled down to a similar room on the extraction level below. 165 mm holes are drilled on a 3m x 3m pattern using DTH hammer. Holes between the levels are drilled with extreme care.

Only 2% deviation over 50m represents a maximum displacement of 1m at the base, which on a 3m x 3m pattern can have a major effect on fragmentation. Concrete is therefore poured on the stope floor to form a solid base to which the drill can be securely anchored.

(Engineering & Mining Journal, February,1989/Vol.190, No.2, p. 24)

Hydraulic Mining

English China Clays, one of the world leaders in Kaolin mining, produces 3 million tonnes of clay per annum using hydraulic monitors to wash clay from decomposed granite host rock. Mines are worked with 1:7 ore to waste ratio with 50% of the waste material being quartz sand. Each working pit has three to four hydraulic monitoring stations. After mining, the sand and clay gravitate to the pit sump. Subsequently sand removal is done by a simple decantation sand beach system or by using spiral classifiers. These are now being replaced with 'bucket wheel' classifiers fitted with variable speed drives. The cut point on the classifier is 250 microns and minus 250 microns slurry is classified further to minus 53 microns for removal of coarse mica particles in 355 mm (14 in) cyclones. Cyclone overflow is taken to a 43 m diameter thickener where a flocculant is added. The thickener under flow is then pumped into centralised refinery plant.

In the refinery, raw slurry is deflocculated and sized in either hydroseparators or in centrifuges. Multistage hydrocyclones are now also in use. Whereas clay particles as large as 35 microns used to be lost in this process, ECC now using flotation with fatty acid collects 60% of

these particles from refining residues. This is a major advance in the refining process, as it maximises clay recoveries. The clay product is thickened, reflocculated and bleached with sodium hydrosulphite to remove any iron present. Moisture is then removed in a pressure filtration and gas-fired dry process, which gives a moisture content of 10%.

(International Mining, November, 1989, p.30)

Ocean Mining

In its bid to establish deep-sea mining rights, South Korea plans to invest $30 million, the minimum amount that must be spent under the U.N. codes for territorial claims to be valid, in deep-sea mining by 1992. Of this amount $3 million will be spent on research and the rest on building an exploration vessel.

South Korea's area of interest is a 75,000 sq km region south-east of Hawaii, where reserves are estimated at 100 million tonnes of manganese nodules, which could yield 3 million tonnes of manganese, cobalt, nickel and copper annually. The country imports an estimated $1 billion worth of these metals every year.

(Minerals & Metals Review,Vol.XVI,No.5,May 1990, p.15)

MACHINERY - EQUIPMENT

New Drill Rig Developed in Australia

A drill rig based on Komatsu Hydraulic Excavator has been developed and is under use at Cosmo Gold Mine, Australia with good results. The rig consists of 19 tonne Komatsu PC 200 hydraulic excavators with Montabert CPA 480 drill attachments and Ingersol Rand compressors. A Melbourne-based company, Drilling Equipment (DE) produced the concept and designed the necessary attachments and fittings.

It is reported that the new CPA-Komatsu unit drills 600 metres per shift compared to 300 metres a shift with an hydraulic rig and 100 metres a shift with a crawler-type rig. The Komatsu rigs are single pass units which drill to a depth of six metres at an angle of 20 degrees from vertical. It is also reported that they are quicker and can reach into tight corners in the pit. Mounting drill on a hydraulic excavator also provides for improved operator visibility and comfort. The hydraulic excavator drill rigs operate at various levels in the pit, drilling into hard oxide materials and hard dolerites.

(Australian Mining,November,1989,Vol. 81,No.11, p.66)

DTH Sampling Hammer

A new down the hole hammer drill for geological sampling has been developed in U.K. incorporating independent internal flushing system. Improved quality of sample recovery as compared to reverse circulation methods normally in use is claimed. In this exploration drill, a suction is created at the bit face to get high volume recoveries with no sample contamination.

While drilling, it is understood, there is no loss of circulation in voids/fractures with continuous sampling through various geological conditions. A continuous air flow passing through the flushing jet into the sample tube maintains flushing all the time-even when the piston is not operating. It is reported, higher penetration speed is achieved at high pressure with technically advanced piston and bit design.

The drilling system is stated to be very effective in faulted or highly fractured ground, porous rock units and old underground mine workings.

(Mining Magazine,July 1989, p.69)

MINERAL PROCESSING

Metprotech - A Fine Milling Process

A new concept of grinding in a stirred ball mill against the age old conventional ball mill in a horizontal position has been developed. The development of the metprotech ultra fine milling process started in 1982 and has proved its efficiency in laboratory and pilot plant scale. Finally a commercial plant was set up in July, 1988 at New Consort Gold Mine in Transvaal, South Africa.

The pilot scale stirred ball mill has a chamber 450 mm

diameter with a height of 900 mm. The slurry is fed into bottom of the mill, with the media being retained by a slotted screen, the slots being 1.5 x 25 mm. The slurry passes upwards through the mill and discharges through a peripheral slotted screen. The grinding medium consists of 700 kg of steel balls. The grinding medium is stirred by 15 pairs of arms with a swept diameter of 400 mm, each set at 90 degrees to the lower pair. The shaft is rotated at a speed, which resulted in a tip of 2.66 m/sec.

The low speed stirred ball mill has been identified as being most suitable for the application of ultra fine milling of gold bearing ores which has rapid grinding rates, low energy consumption and better dissolution rates of gold compared with other milling practices available. The very rapid rates of dissolution that are achieved when cyanide is added to the mill feed in metprotech mill are resulted from good mass transfer conditions, small particle size of liberated gold and absence of any surface coating occurring on the gold particles.

(Minerals & Metals Review, May 1990, Vol.XV,No.5, p.20)

Advanced Leaching Technology - Recovery of Gold

Over the past decade, boom in gold mining has been aided by the development of advanced leaching technology permitting recovery of gold from very low grade ore.

Use of carefully controlled solution of sodium cyanide to leach ore containing finely disseminated gold, either in vats or in heaps, is now the primary method for recovering gold from low grade ore. The ore volumes involved in this method are between 5 and 15 tonnes of ore, which are processed to yield one ounce of gold in vat leaching and typically between 15 and 50 tonnes in heap leaching.

Cyanide in the form of salt sodium cyanide (NaCN) is preferred for leaching as in aqueous solution at a pH above 10 gold is readily soluble. In mining operations alkalinity of the solutions is kept high, and by proper safety procedures threat of cyanide to human health is removed by preventing its escape to the environment.

In sunlight it is easily decomposed through a variety of chemical and biological reactions into carbon and nitrogen compounds. To protect underlying ground water and to prevent loss of cyanide reagents, mining companies have used impermeable liners under leach heaps, in solution ponds and often in tailing ponds.

(Mining Journal,Vol.314,No.8069, May 4, 1990, p.358)

ENVIRONMENT

State-of-the Art Tailing Facility

Jamestown open pit gold mine is operating in the foothills of western Sierras, California. Average daily mill throughput is 6,100 tonnes of ore with a grade of 2.26 gms/tonne. Jamestown tailing facility is designed for zero discharge and no waste escapes into the ground water and adjacent stream system.

Thickened mill tailings are pumped to the tailings area as a 50% solids mixtures. To prevent seepage into ground water, the bottom of the facility and that inside of the embankment are lined with an impervious 0.61m clay layer. A series of perforated pipes run beneath the clay layer to relieve any potential upward pressure from ground water.

A 15.24 cms gravel layer through which another series of perforated pipes run is placed on top of the clay layer. Called LCRS, or Leachate Collection and Recovery System, these pipes reclaim any water not lost to evaporation or tailing run-off and collect it in a nearby pond lined with double high density impervious polystrene, for re-use in the mill.

(Canadian Mining Journal,Vol.110,No.12, December 1989, p.25)

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EXPLORATION

Improving Sample Recovery

Poor core recovery or lost samples, can make an exploration team's task very difficult, if not impossible. In an attempt to improve the core recovery in a strongly fractured rock within a silicified zone, Golconda Resources, a Canadian Company, has adopted to 'Bulroc' reverse circulation system, which the company reports, has improved the sample recovery vastly.

The reverse circulation drilling technique employs a dual wall drill pipe and the drilling medium, usually high pressure air, is channeled down to bit, between the outer and inner tubes. At the bit end, the air picks up the cuttings and returns up the centre tube with surface. As the sample passes through the centre of the system after it has been collected and immediately transported to surface, contamination is minimised. Additionally, drilling speeds can be up to five times faster in reverse circulation than for diamond core drilling.

Advantages of the reverse circulation system include speed and the ability to work without water which is often a problem when core drilling in remote areas. It is reported the system can provide accurate sample even in broken ground, through voids or where the hole intersects workings.

(INTERNATIONAL MINING, JULY, 1990, P.32).

MINING

Malanjkhand Copper Project

Malanjkhand Copper Project, located in district Balaghat, Madhya Pradesh produced 2 million tonnes of copper ore during the year 1989-90 , representing 100% capacity utilisation, highest achieved so far by the unit. Ore milling of 19.56 Lakh Tonnes was done. The project carried out a total excavation of 4.2 million cubic metres in the year 1989-90. As development backlog has accumulated, two contracts are awarded to outside agencies to clear 7.5 million cubic metres.

Bishimetal Exploration Company (BME), Japan has been engaged for preparing feasibility reports for expanding mining, milling and smelting capacities. Exploratory drilling is under progress under the Japanese experts. Indian Bureau of Mines has also taken up the job of conducting Laboratory and Pilot Plant beneficiation test on four samples and recovery of molybdenum from Copper concentrate. On successful commissioning of five instream analyser in one flotation circuit, analyser stations were being extended to cover all the four circuits so that process automation can be introduced to optimise process recoveries.

Bio-leaching studies on lean ore dumps at Malanjkhand have been interesting. The management has taken up acid leaching of oxide ore yielding copper of 92-95% purity with 80% recovery. The base of leaching pad (175 m x 75 m size) is consolidated by a heavy roller followed by spreading a sand bed, giving it a gentle slope (1 in 20) with provision of channels all around the pad for natural flow of liquor. The entire pad including channel ways are covered with HDP rubber sheet to prevent any loss of 'leach liquor' reagent. Sized oxide ore (+ 1.3 cm - 7.5 cm) is spread over the leach pad to a height of about 3 m. For first 3-4 days stacked ore is wetted by sprinkling concentrated sulphuric acid. After allowing to cure for 8 days, progressively weaker sulphuric acid solution (150 - 200 gms of H_2SO_4/lit) is continuously sprinkled over the stack for another 35 days. In one lift of 3 m, about 33000 tonnes of oxide ore can be treated. A pad is designed to accommodate 3 lifts, which will ultimately treat about 1 lakh tonnes. Altogether there will be 5 leaching pads which will treat the entire 4,70,000 tonnes of oxide ore generated during the last 5 years.

Sulphuric acid reacting with the copper ore trickles down to bottom of heap and is collected in leach liquor tanks.

From tanks the leach liquor is pumped into launder, which is loaded with scraps of iron, on which copper gets deposited. High pressure water jets vibrating the launder at regular intervals separates the deposited copper. This is termed as 'cement copper'. In the process 75% of sulphuric acid is re-used. The average production of 'cement copper' is reportedly 2 tonnes per day.

(ANNUAL REPORT OF H.C.LTD.; 1989-90; P.3, 9 AND RECORD NOTE ON VISIT TO THE MINES).

Dexing Copper Mine, China

Dexing copper mine situated in Jiangxi Province, China started operating in 1958. The capacity of mine production has been increased from 300 to 42,000 TPD during 1988-89. A further phase of expansion is underway, as a result of which total excavation by the year 1993 will be 80 mt/y including 33 mt/y ore production. The average grade of copper ore is 0.46% Cu. The geological reserve for the whole mine has been calculated as 1500 Mt with a cut off grade of 0.3% Cu. The reserves of copper metal are put at 6.4 Mt, molybdenum 250,000 t, sulphur 26 Mt, gold 240 t and silver 2,800 t.

In designing the mine, the floating cone method was employed for calculation of the optimum mining outline. The principal parameters of the proposed pit will be, pit mouth 2.3 km x 2.4 km; elevation of the highest bench, 470 m.; bottom elevation, 220 m; final slope angle, between 36° and 46°. Present capacity of the pit is 30,000 tonnes of copper ore per day. A normal drilling, blasting, shovel loading and truck-haulage system is used. Within the pit there are two primary crushing installations, where 122 cms and 137 cm gyratory crushers have been installed.

By 1993, the major equipment in the mine will be 251 mm rotary drills, 13 units; 13 m^3 to 17^3 electric shovels, 9 units; 154 t electric wheel trucks, 49 units; bull dozers, 320 to 770 HP, 22 units; 12 t explosive trucks, 4 units.

There are three concentrators at the mine, which are under expansion programmes and the total capacity of concentrators will be 1000,000 TPD. Primary crushed ore from the pit subsequently goes through secondary and tertiary heavy-duty cone crushers to reduce the particle size to 80% - 7mm, before passing to eight 5500 HP (4100 KW)) 5.5 m diamter x 8.53 m long overflow type mills. The application of such a "more crushing, less grinding" process reportedly has the advantages of less investment, higher efficiency, lower operating costs and saving of energy.

(MINING MAGAZINE, APRIL, 1990; P.287)

EQUIPMENT

High-Tech Analyser for Exploration

The $400,000 Inductively Coupled Plasma Mass Spectrometer (ICPMS), which measures more accurately than I.C.P.U. units in fractional ppb ranges was commissioned at the State Chemistry Laboratory, South Australia. The instrument has a capacity to analyse more than 40,000 samples in a year. By introducing samples into a highly ionised plasma, the instrument is able to measure down to 0.01 parts per billion, the level at which most trace elements are present. It can also pin-point the level of precious metals and indicator elements with great sensitivity and accuracy, which helps geologists to determine accurately precise locations for exploration.

The ICPMS works by spraying the sample in liquid or solution form into a zone preheated to 7000°C, where atoms are ionised. These charged atoms are then sucked into a mass spectrometer which separates and counts the idividual atoms.

The instrument can analyse trace metals impurities in ultra pure metals, perform noble metal analysis and undertake trace element characterisation of ore bodies.

(AUSTRALIAN MINING; AUGUST 1990; P.24)

High Density Pump at Grund Mine

For minimising mining loss and preventing dilution of ore, adoption of back-filling techniques in underground mining are considered useful.

The fill material used must be highly competent. Environmental and economic considerations also favour use of back-fill consisting of mill tailings including ultra fine fractions. Pneumatic fill requires coarse and dry material, while hydraulic fill is impeded by inclusion of ultra fines. Typical densities for back-fill are 1.6 for pneumatic and 1.7 for hydraulic fill. In contrast, high density pumped back-fill includes all size fractions and its density of 2.1 approaches that of structural concrete with low compressibility and early bearing strength.

Preussag AG Metall of Goslar, Germany has developed after considerable experiments, the Preussag Pmped fill method at Grund lead-zinc mine, where sub-vertical veins were exploited at a depth of 750-850 m. This pumped fill includes not only flotation tailings with all the contained fines but also an HMS reject sized 2 mm to 30 mm, so that the water content is only 12-14% by weight, which is total-

ly absorbed by fill material. Cement is injected pneumatically into the pipe line near the stope. The amount of cement added, however, depends on the required compressive strength. The back-fill is mixed on surface and pumped 500 m down a shaft, then 1300 m horizontally to a booster pump and from there into stopes over 250-350 m down and extending upto 1000 m on the level. As a result of its specially engineered rheological properties, the pumped-fill can reportedly be safely left in the distribution pipes during the week-end breaks from mining operations.

(MINING JOURNAL ; OCTOBER 1990; P.260)

Chromite Recovery Using Physical Concentration Process

In order to improve the domestic resources, test work in the USBM was conduted on low grade ores assaying 5% to 20% Cr_2O_3 or more with a Cr:Fe ratio of 2.8:1 adopting simple ore dressing process operations.

In the process, different techniques were adopted like tabling by wet and dry methods, magnetic and electrostatic separation, flotation and gravity methods.

It was observed that magnetic and electrostatic separation methods are less effective than tabling or flotation. The flotation was again generally less effective than tabling as much loss was reported in the slimes. Recoveries from tabling were also low because of fine liberation of chromite.

Benefication by gravity techniques, however, indicated that concentrate of 52% Cr_2O_3 with a recovery of 80% would be obtained. Efforts were made to adopt the age-old conventional Humphrey's spiral and the latest Reichert Tray concentraton to improve the results. It has been reported that Pilot plant results are even better than those of laboratory tests.

Chromite ore from Salem district, Tamil Nadu has also been subjected to gravity separation in the tests carried out by Indian Bureau of Mines. However recovery was not satisfactory enough.

(USBM PUBLICATION/RI/93000 & CHROMITE MONOGRAPH PUBLISHED BY IBM)

MINERAL PROCESSING

Lab-Scale Flotation System

A continuous Froth Flotation system for laboratory use, known as the 'Flexi-Float', has been developed by Met-tech International Pvt. Ltd. of Republic of South Africa. The equipment can replace locked-cycle batch flotation testing and establish accurate data and simulate plant configurations before conducting full scale plant operations. Each unit measuring 5 m x 2 m x 2 m is designed as compact, robust and fully transportable equipment on a steel frame, and is complete with :

- Stock tank with variable speed feed pump.
- Flotation tank with eight compartments and necessary air flow controls.
- Two variables speed drives for the flotation tank machines so that roughers and cleaners can be driven at different speeds.
- For froth handlings, variable-speed scraper paddles, transfer pumps and launder sprays.
- Reagent feed systems, conditoners and control pannel.

A numb r of different circuits can be simulated. Units can also be designed to meet specific requirements with variations.

It has been claimed that 'Flexi-Float' will have many useful and interesting applications at research laboratories, universitites and mine concentrator plants, and will make major contributions to the efficient concentration and beneficiation of base metals, industrial minerals etc.

(MINING JOURNAL; 9.11.90; Pg.359)

Non -toxic Recovery

Prior to the introduction of cyanide process in 1890, gravity concentration and amalgamation were the main processes for the recovery of gold.

A relatively new comer to gravity separation technology is the centrifugal concentrator, two types of which have come into use recently - the Knelson concentrator and the Mozley multi-gravity separator. Both these machines depend on centrifugal force to enhance gravity and hence to obtain better performance than in other wet gravity separators such as sluices, jigs and tables.

The Knelson concentrator has a stepped bowl that rotates about a vertical axis and develops about 60 G. Water is added with the feed and is also injected into the bowl to fluidise the material being treated. It operates in the size range 6 mm to 50 microns, and has been used chiefly on gold alluvial and hard rock ores. It is a batch operated machine, and the commerical unit is reported to occupy a 1.5 m cube, having a capacity of $25 m^3/h$.

The multi-gravity separator has a cylindrical surface that rotates about a horizontal axis, the inner surface forming the separating deck. The machine develops 24 G; water is added with the feed and into the drum. A shaking motion is imparted to the drum and scrapers direct products into launders.

Both these centrifugal machines show considerable promise and with further usage should have an important place in recovery of gold without the use of cyanides.

Gold has been recovered from concentrates by amalgamation since ancient times. Now direct smelting is also possible as an alternative. If carefully controlled, gravity concentration in conjuction with flotation and direct smelting can be a substitute for cyanidation and amalgamation for a large number of simple ores.

(INTERNATIONAL MINING; OCT., 1990; P.29)

ENVIRONMENT

Migratory Birds - a Problem In Nevada

Ducks and other migratory birds were not seen before the development of gold mining operations in Nevada. With the opening of each gold mine migratory water and shore birds started landing in the tailing ponds and died by the hundred because of cyanides in the water. Local miners have tried a number of ways to prevent the birds from landing but without any success.

Nevada Departments of Wildlife (NDOW) decided that all existing and new mines should have a permit specifying the means of bird protection to be used. By law, all ponds were decided to be netted or neutralized to non-toxic levels. At Paradise Peak, a 50 mm mesh polypropylene net was secured in two directions on air- craft cable and anchored by barrels floating on the pond surface. Alternative waterways were created on which birds could land safely. One such system was followed in Buckhorn Mine, south of Carlin where an old water course was dammed.

Environmentalists hope that in future mines will be designed with enclosed systems in which cynide solutions are not stored in the open. Also more thought will be given to providing alternative pond areas, which the birds can use.

(MINING MAGAZINE; SEPTEMBER, 1990; P.144)

Vibration - A Subtle Enemy to Industry

Above or below ground, all mining equipment under use vibrates in varying degrees and frequencies. Whether a person uses a jack-hammer drill, drives a dumper or operates any kind of 'digger', the human body is subjected to vibration. Up-down, forward-backward, left-right, buffeting, bumping, shaking or any combination of these, can go right through the persons body tissues and may result in physical and mental problems.

Some of the more common vibration related ailments are : herniated disc, lumbago, damage to backs, joints, abdomen, increased pulse/respiratory rates, heart problems, and adverse effects on nerves. Prolonged exposure may impair visual acuity and narrow the field of vision. In short, vibration can be a real safety hazard to its workers together with adverse effects on productivity.

The Australian mining industry is, therefore, investigating into whole of the body vibration problems with all seriousness. Engineers have studied the sources and with much success have designed dampening devices to arrest vibration. Manufacturers have designed suspension 'cuches' to protect the operator from receiving vibrations.

Driving postures for an operator in the cab of any machine, the height of the seat and position in relation to the control plays a vital role to avoid effects of vibration. Angle between upper thigh and trunk is also an important factor. These are matters of ergonomic research study. So far it has not been possible to design a lumber support which is likely to suit every operator.

Research is underway to find out ways and means to reduce vibrations. Areas that are being covered are automation with remote control, machine tool design, seating, dampening, and so on. To reduce vibration, timely maintenance of equipments are also important. Vipac, the famed consulting engineers for vibration analysis have been involved with the whole body vibration study for the industry.

(AUSTRALIAN MINING; JULY, 1990; Pg.20)

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EXPLORATION

Conditional Simulation

Estimation of potential ore reserves is commonly made by measuring the surface area contained with a predefined anomaly, calculating a volume of anomalous rock and assigning a value to the area. Elimination of the uncertainties created by scattered and often disparate data sets would require exhaustive sampling during assessment. This is not economically feasible or desirable. To quantify the prospect and evaluate the uncertainty more accurately, a conditional spatial simulation has been devised. The spatial simulation can be constrained to honour all sample data and is therefore called a conditional simulation.

The method of conditional simulation is easily implemented on the personal computer when the Lu decomposition algorithm of Davis (1987) is employed. This algorithm is fairly compact, yet can generate moderate–sized simulations in a few minutes on a 80286 or 80386 based personal computer. The application of conditional simulation is to generate possible ore inventories from a limited amount of exploration sampling.

The simulation can then be examined to decide if the potential inventories are sufficiently attractive to proceed with further exploration.

With a minimum of sample data, it is possible to simulate the possible outcome for exploration success. The results of the simulation allow an assessment of the risk of a given project. Furthermore, if multiple projects are assessed in this fashion, minimum risk–maximum reward types of exploration strategies may be developed.

(MINING ENGINEERING; February, 1991; p.223)

MINING

Asia's Largest Bauxite Mine

"Panchpatmali" means five flat–topped hills. These hills hold the world's largest single–capping bauxite deposit. With reserves around 377 million tonnes, Panchpatmali can be easily compared to Boke in Guinea & Weipa of Australia.

This high–level lateritic bauxite deposit occurs as a capping over the plateau top 1204 m above sea level. It has been formed by residual weathering of parent rock Khondalite of Eastern Ghat series. The deposit extends over a length of 21 km in a general NNE–SSE direction and attains an average width of 800 metres.

The fully mechanised Panchpatmali mine owned by M/s. NALCO is designed to produce 2.4 million tonnes of bauxite per year, which is more than 60% of India's total bauxite production. The average grade of bauxite is Al_2O_3–44.6%, SiO_2–2.3%.

The overburden measuring up to 3 metres in thickness is ripped almost entirely by 700 HP CAT D–10 ripper–dozer. Drilling and blasting in ore–zone is carried out with 150 mm dia. holes drilled by track–mounted rotary blasthole drills in grids of 4.7 m x 4.7 m. Site mixed ANFO explosive is used for blasting. At the mine top, a single stream double roll toothed crusher of 900 TPH capacity crushes the ore from 85% minus 800 mm down to 85% minus 150 mm.

The mine design concept is in keeping with the latest trends in the world. NALCO has introduced the concept of geostatistics, deposit modelling, mine modelling, operation simulation and computerised mine planning from the initial stage of mine design. Here, NALCO has employed a new mining system, i.e. trench mining, in which bauxite mining is carried out by developing parallel trenches of varying widths and staggered faces, where the trench normally has an advance direction along the axis of the plateau. The levels of the trenches vary depending upon the thickness of bauxite. These trenches are planned in such a way that they follow the contour and topography of the plateau of bauxite without much loss or dilution.

The mine plan features natural drainage in the mines without causing common pollution problems. Transportation of bauxite from the Panchpatmali mine to the alumina refinery, having an altitude difference of 340 m over a very

difficult undulating terrain is by a single flight conveyor, 16 km, the longest in the world.

Over the last 7 years NALCO has made 4.9 lakh nos. plantation over an area of 288.54 ha. The survival rate is on an average 74% whereas in slope it is around 85%. The slopes are being dressed into terraced benches and planted with lemon grass and Sissal plants.

NALCO is making 10–15 m wide barrier all along the periphery on the hill to ensure the safety of men and machinery, as well as to conceal the mining activities from external views. This prevents spillage of muddy water from the mines to the slopes. Afforestation to create the peripherial barrier of areas on the plateau is under active consideration of the company.

Total area covered by pits/quarries and dumps in the mine is 60 ha. and 70 ha. respectively. So far NALCO has reclaimed only 2 ha. area.

(MINERALS & METALS REVIEW; ANNUAL 1990)

Plasma Blasting

Engineers at Norande Technology Centre (NTC), Canada are now engaged in a most exciting project of blasting hard rock using electrical, rather than, chemical energy. This project, when successfully incorporated into a continuous drill–blast mixing machine, could radically change the way ore bodies are mined. The technology is so advanced, it is reported, that such a machine could be available within about five years.

The concept is simple. A large amount of electrical energy is stored in capacitors and then delivered in a few brief microseconds to an electrolyte confined at the end of a relatively short, 30 – to 50 – cm deep borehole. This large amount of electrical power turns the electrolyte into a high–temperature, high–pressure ionized gas or plasma–with pressures as high as 2 gigapascals–which quickly expands to break the rock.

The Principal Scientist engaged on the project claims that designing a machine to accomplish this feat has taken about five years of intensive research.

The machine relies on three pieces of technology which have only recently been developed: a bank of highly efficient electrical capacitors developed in the U.S. for the Strategic Defence Initiative; a proprietary high–current switching device which sends stored–up energy rushing to the borehole electrode at the rate of 200 mega watts per microsecond; and the coaxial electrode which is subjected to tremendous forces.

The long–term goal is to develop a continuous mining machine that would drill, blast and muck in underground hardrock mines at the rate of 200 tonnes per shift. Not only would such a machine reduce mining costs to about $ 10 per tonne, but also yield considerable savings in ground support costs since blast damage to the surrounding rock (overbreak) would be limited.

(CANADIAN MINING JOURNAL; April 1991; pp. 19, 21–23)

SMALL–SCALE MINING

Chinaclay

Chinaclay/kaolin is an essential raw material for ceramic, textile, paper, medicine, etc. Improvement in brightness of chinaclay requires expertise and considerable investment and is not always successful, but it is possible otherwise to add value to chinaclay by levigation.

Depending on the nature of crude material, refining by levigation can yield about one tonne of washed clay for every 2 to 6 tonnes of crude. Silica sand minerals found associated with chinaclay some times can also be beneficiated and marketed to add further value to the composite minerals.

Details on investments, machinery/equipment required by small entrepreneurs for the purpose and useful information on facilities for processing/analysis, etc. are available for ready reference.

(NISM NEWS BULLETIN; No.2; July 1991; pp.1–7)

Stone Deposits in West Bengal

Stone aggregate has good potentiality in West Bengal and principal localities have been identified in Birbhum, Purulia and Burdwan districts. In Purulia district over 100 stone crushing units and quarries are operating, which have given a face lift to the area and livelihood for about 10,000 persons.

The stone material has a tremendous export potential to the neighbouring Bangladesh, which is devoid of hard material rock, and is therefore a matter of great interest for entrepreneurs. It is reported that the Indian Railway Construction Company (IRCON) has bagged a project to modernise Railways in Bangladesh and requirement of stone for ballast would be up to 2 million tonnes per year.

(NISM NEWS BULLETIN; No. 2, July 1991; pp. 1–7).

NON–FERROUS TECHNOLOGY

Non–ferrous Metal Smelting : Isasmelt

A new smelting process, "Isasmelt" which offers significant saving in energy, is the joint outcome of a fifteen–year research work by Mount Isa Mines Limited and Australia's Commonwealth Scientific Industrial Research Organisation (CSIRO) to improve the efficiency of the bath smelting of non–ferrous metals.

Essentially, Isasmelt is a process for smelting of non–ferrous metals. It employs a static cylindrical reactor and a submerged Sirosmelt lance to provide turbulent slag baths. The result is a high intensity smelting process which is readily controlled. The process can operate effectively with either oil or gas. A $–65 million lead Isasmelt plant is currently under construction at Mount Isa in Queensland, Australia. Mount Isa Mines Ltd. has collaborated with CSIRO in the development of Isasmelt technology since 1977. In September, 1983 a 5t/hr. pilot plant was commissioned to continue the studies.

The Isasmelt lead process is a continuous two–stage process for the production of crude lead from concentrate. It is based on the use of a top entry submerged Sirosmelt lance to produce turbulent baths in which high intensity smelting and reduction reactions can occur. The process involves oxidizing the concentrate in the first stage to produce a high lead slag. The slag is tapped continuously and transferred down a launder to a second furnace, where it is reduced with coal. The crude lead is further processed in a conventional forehearth.

The advancement of Isasmelt lead process has been paralleled in the copper stream by the development of Isasmelt reactor technology for the commercial smelting of copper concentrates.

(MINING MAGAZINE; July 1990; pp. 34–38.)

SOPHISTICATED ANALYTICAL INSTRUMENT

Electron Spectroscopy for Chemical Analysis (ESCA)

It is a surface analysis technique that provides chemical analysis at depths ranging from 10 to 50 A^{o}. The method involves irradiation of the solid sample in high vacuum with monoenergetic soft X–rays (MgH α or Alk α (x–rays) and sorting the emitted X–rays by energy. The spectrum obtained is a plot of the number of emitted electrons per energy interval versus their binding energy. Each element (with the exception of hydrogen and helium) has a characteristic set of electron binding energies that can be used to identify the element. Moreover ESCA can often differentiate between chemical environment or valence states of any given element.

ESCA has been extensively used in the minerals and metal industry. Flotation responses of sulphide minerals and the amount of collector adsorption have been shown to be dependent upon the state of oxidation of the sulfide mineral surface. ESCA has been used to characterise the surfaces of galena, sphalenite, chalcopyrite, etc. Surface analyses were made after comminution in air and comminution in a nitrogen atmosphere and after adsorption of xanthate or dithiophosphate collector. Analyses were also made after treating with modifiers. Most of the sulphide samples ground in air and aqueous environments showed signs of sulphur or sulfate formation. ESCA was also used to investigate the effect of dissolved species from natural and synthetic sulphide minerals in the surface chemical composition in selective flocculation systems.

(MINERALS & METALLURGICAL PROCESSING; May 1990; pp. 94–99.)

MINERAL LEGISLATION

Hazardous Asbestos

Asbestos is an ingredient in as many as thousand industrial products but exposure to its dust has been identified as the cause of crippling and some time pulmonary diseases. Occupationally the dangers appear to be even present at every stage of production of asbestos, when the asbestos fibres are released in the air in the processes of extraction, grinding and manufacture of various products.

Asbestos industry in India employs over 7,000 people, situated in Andhra Pradesh, Maharashtra, Gujarat, Tamil Nadu and Haryana. Asbestos is a hydrous silicate containing magnesium, iron, sodium and calcium characterised by fibrous structure. The naked eye may not be able to see small fibres of asbestos entering the human body. The dust enters through nose and settles in the air sacks of lungs causing 'Asbestosis'.

One way of fighting Asbestosis, according to ILO report, is to report the exposure of workers by specifying the concentration of air–borne asbestos fibres at the work places itself. Periodical check–up of workers exposed to asbestos is also a must. The convention on safety in the use of asbestos adopted at 1986 ILO Session has stipulated that National Laws should lay down specific technical hazards and special rules/procedures including authorisation for use of asbestos.

The Government of India has brought asbestos and asbestos based products within the licensing purview irrespective of investment level and scales of operation.

The decision to impose licensing restriction on this industry has been taken in view of the hazards workers are exposed in the asbestos industry.

(YOJANA; June, 15, 1991; pp. 11–12)

Ruling on refund of illegal levy

The Supreme Court gave a ruling in appeals filed by M/s. Orissa Cement Limited, M/s. Tata Iron & Steel Company Limited, The Orient Papers and Industries Limited and a number of public sector undertakings, which had challenged the cess levied by the State of Orissa, Bihar & M.P.

The levy of cess on the basis of royalty derived from mining lands by these states was declared as beyond the legislative competence of State Legislatures. In the matter of refund of amounts collected by impugned cess, the court preferred to declare the cess ultravires and has ordered the refunds prospectively from the dates of judgments by concerned High Courts and the Supreme Court.

(THE ECONOMIC TIMES; New Delhi; 12.6.1991)

ENVIRONMENT

An Environmental Audit Can Reduce Liability

Environmental audit is a tool, one can use to reduce current or potential liability. It helps to assess the risks and potential liabilities of existing waste management practices and site operations in general. There are basically three steps to an environmental audit – Site audit, Existing facilities audit and Management audit.

Site audit is to identify whether there is specific contamination problem at a site, which normally poses an environmental or public health risks. It also identifies other related issues like uncontrolled erosion and damage to rare flora, etc. Site audit helps for further investigation and remedial measures and also provides cost estimates for correcting site problems to the acceptable limits.

Existing facilities audits concentrate on regulatory compliance of activities on a particular site. The objective of an existing facilities audit is to achieve environmentally acceptable and viable operation.

Management audits are concerned with the organisation and quality assurance aspects of operations from environmental perspective. Information handling, reporting and feed–back mechanisms are reviewed in the context of the management frame work.

It also reviews the responsibility and authority for the environmental issues which affect the company's operation. The implementation of environmental practices are monitored and reviewed.

An environmental audit has to be performed for objective assessment or environmental risks by an independent third party, which minimises any bias.

Early identification of potential problems suggesting cost effective and environmentally acceptable solutions for the management can provide a significant public image and market advantage by presenting a 'green' operation. And if a company can show through correct management procedures that it has a good track record of environmental compliance, then obiviously insurers and financiers should look on more favourably.

(AUSTRALIAN MINING; March 1991; p.50)

Red Mud Disposal

The Alumina plant of NALCO at Damanjodi (capacity of the plant 0.8 Mt. per annum) generates 2,350 tonnes of red mud per day which is disposed of in the Red mud pond by adopting wet disposal systems. The NALCO experience however reveals that this wet disposal system is not the right solution for Damanjodi area having higher precipitation (2150 mm per year) and low rate of evaporation (650 mm per year).

Negative aspects of wet disposal system are found to be high investment costs of building dams with low rate of caustic recovery and creating large volume of pollutted water with likelihood of overflow and seepage.

In view of these difficulties, dry disposal system for red mud either by filteration or through deep thickening is envisaged by NALCO, as a long range solution of the problem. Dry disposal system can reduce the soda loss and also eliminate pollution hazards. The land already acquired by NALCO for the ponds, it is understood, will be more than sufficient for additional 50 years life even after the full expansion. Further the dry mud can be utilised for manufacturing bricks, PVC pipes, roof sheets, etc.

(NALCO; SOUVENIR ON WORLD ENVIRONMENT DAY; 5th June, 1990, p.8)

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EXPLORATION

Improved Remote Sensing Techniques

ERS-1 satellite was designed to study the ocean and climate rather than geology. But the satellite will still pick up information over land, especially as the main microwave radar instrument is not blocked by clouds. Light for each picture element received by these satellites can be split into seven different wavebands, ranging through the visible and infrared enough for a rough spectral analysis of surface minerals.

The second new development is an improved airborne imaging spectrometer capable of splitting up visible light,from the ultraviolet through to the infrared, into more than 200 channels. Airborne scanners have been in use for sometime. The Geoscan unit can analyse incoming images into 26 adjustable wave bands and is usually set to scan for changes in the mineralogy and crystallography of surface clays and silicas. Surface variations in minerals can indicate the site of underwater deposits. The unit's main use is a means of accurate mapping of surface geology and geochemistry. A brief change in infrared radiation could indicate a fault. The Geoscan unit has been used to check on the extent of oil spills.

Magnetic surveys look for surface variations in the earth's magnetic field as a pointer to the presence of a metallic ore body. Electromagnetic surveys try to induce signals from ore bodies while radiological surveys shoot the ground with a radio signal and note when, or if, the signal bounces back. Gamma ray scans are useful as the amount of background radiation in any region varies with the type of rocks present.

Aerodata has developed a number of techniques including constructing contour maps of magnetic field strengths, complete with shadows from an artificial rain to aid the recognition of distinctive features. The PIMA II now being marketted by Integrated Spectronics, is a hand-held spectrometer which can be used for identifying rocks, minerals and soils in the field.

Drilling as the final means of deciding where to mine cannot be replaced by none of the advanced techniques described above. The increasing knowledge and improving techniques of remote sensing however, will help reduce the amount of field work necessary to identify an economic ore body.

(Australian Mining, July 1991, p. 16.)

Geophysical Exploration

Geophysical prospecting methods are continually being refined for use in exploration programmes.

Doyle of Western Australia has shown as to how geophysical methods can be of value through the association of gold with particular host rocks, marker beds, or structures which are of unusual magnetization, density, electric polarization or conductivity. Useful markers may be magnetic dolerites, banded iron formations, magnetic shales, conductive and/or polarizable pyrites, or other sulphides detectable by I.P. and resistive silicified zones.

Shading methods were useful for enhancing weak directional anomalies in the aeromagnetic data. Multidirectional, shaded-relief images produced by overlying three coloured, shaded relief images were useful for the analysis of anomalies associated with structure. Vertical gravity derivative images, and vertical magnetic derivative images of the shear zone clarified structural trends. Composite images using three different geophysical parameters show correlations between magnetic, gravity and radiometric data which can be related to the geology. Subtle variations in uranium, thorium and potassium concentrations

determined by gamma-ray spectrametry cause effective displays using ternary radio-element images.

Application of the use of digital image processing and integration of geo-physical data sets provided to develop exploration models from airborne electromagnetic (EM), and very low frequency electro-magnetics (VLF-EM) data collected over an area in NW Arizona with uranium metallised breccia pipes. Apparent resistivity and overburden thickness were derived from the EM measurements using half-space models. A number of standard digital image processing techniques were supplied to the data.

Normal Potential Field Methods

Most existing techniques for potential field data enhancement and interpretation require data on horizontal plane, although in ground surveys they are collected on an irregular surface. Pilkington and Urquhart describe a method of reducing such data to a horizontal plane by computing an equivalent source distribution that models the observed field on a mirror image of the observation surface. This surface is then replaced by a horizontal plane and the effect of the equivalent sources is computed on the required horizontal level. This calculated field approximates the field reduced to a horizontal plane. The technique is illustrated with two dimensional synthetic data examples in which the maximum errors occur in areas of steep topographic gradients and increased magnetic field intensity. The approach is also applied to a portion of a helicopter borne aeromagnetic survey from the Gaspe region in Quebec, Canada, where the results are horizontal shifting of anomaly maximum by up to 150m and changes in anomaly amplitudes of up to 100nT.

(Mining Annual Review,1991, p.179)

MINING

Moly from Sierrita

Cyprus Minerals Co. is the leading U.S. producer of molybdenum, as well as the nation's second largest copper miner.

The adjacent Sierrita and Twin Buttes open pits in south central Arizona are run as one consolidated operations whose output was 122,086 t of copper in concentrate in 1990. It is the third largest moly mine in the world. It has the largest moly roaster facility in the world, and the largest ferric chloride leach plant. It is also North America's only producer of Rhenium.

The complete Cyprus Sierrita Corporation mining potential currently comprises three open pits at Sierrita-Sierrita, Esperanza and Ocotillos; two pits at Twin Buttes- West and East, and future possible underground operations at Twin Buttes, Ocotillo, named after a local cactus, has high moly grade and low copper. It is not operating currently .

Total reserves as on Ist January 1990 were 556 million tonnes at a grade of 0.34% Cu and 0.037% Mo, and a stripping ratio of 0.88:1. The current production rate is a total of 275,000 t/day, of which 100,000 t is ore (82,000 t from the Sierrita pits and the rest from Twin Buttes).

At present, Esperanza is the primary source of ore. There is a fleet of three P & H 2300 shovels, three P & H 2100 shovels and 14 Caterpillar 789 trucks. In addition, Sierrita recently took delivery of the world's first Cat 994, the largest production wheel loader in the world, which is equipped with high-lift arms and a massive $16m^3$ bucket. Sierrita operates Cat 793, 217 t trucks. It was also the first mine anywhere to introduce in-pit crushing.

(Mining Magazine, July 1991, p.5)

Hydro Borehole Mining Introduced

In Poland Hydro borehole mining system has been successfully experimented which although limited to selective conditions, has the advantages of being a low capital cost, non-complex, environmentally acceptable method of extracting ore from deposits which could not be economically mined in traditional ways.

This method is said to be suitable for mining lignite, sulphur, bauxite, uranium, and even gold and is particularly effective in areas of newly developed deposits where high volumes of underground water are present. Also it has been found applicable where other alternatives such as Frasch's method (used for melting and pumping sulphur ore) or underground leaching are not possible for a variety of reasons.

Hydro borehole mining is presently being tested on a seam of kaolin 60m deep. Mainly a drill rig (650 mm diameter), two high pressure pumps, air compressor, electric generator (about 1 MW), and 20 t crane have been used. Personnel includes four to six men for operation and supervision.

In essence, a large diameter hole is drilled to the bottom of a mineral deposit and after lining the borehole, special piping with water jetting equipment mounted on sliding collars is assembled down the hole. Water is pumped at high pressure through

monitor jets to excavate the deposit, and air pressure above is used to force the slurried ore to the surface.

This method has minimal impact at the surface since the tailing can be pumped back in closed circuit - not into the surrounding countryside and since water can be reused, a relatively small amount of process water needs to be replenished during operation.
(Australian Mining, May 1991; p.62).

Blasthole Drill Datalogger System for Mining

The first Stratalogger Plus drill recorder systems have recently completed 12 months of field usage, and systems are operating at mines in five countries. The stratalogger plus is a recent addition to the product line of monitoring and recording instrumentation for blasthole and exploration drills - which includes the Drilling Efficiency Indicator and Stratalogger.

The Stratalogger Plus logs all drilling parameters and inputs from an operator's terminal. Using Stratalogger Plus software, the logged data can be translated into a variety of standard reports. Included are production reports, as well as detailed hole profiles. This data can be used for recognition of strata passed through and assists in blast design.
(Mining Journal; July 26, 1991; p.69)

MINERAL PROCESSING

Vertical Grinding Mills - New Concept

The tower mill or vertical stirred ball mill is an unusual grinding system that is specially suited for fine-grinding applications. Material is reduced in size through the process of abrasion in a stationary cylindrical grinding chamber which is filled up with a vertical column of grinding balls. Rotation of the screw stirs balls inside the mill. Feed enters at the top and particles make their way down through the ball charge against a rising stream of water. The greater depth of balls than in an equivalent ball mill gives greater ball-to-ball pressures and contributes to grinding efficiency. Apart from space savings of the vertical design, power savings are said to be 30 to 40% compared to a conventional ball mill.

In general, compared to a tumbling mill in the same application, manufacturers claim the following principal advantages for vertical mills:

*Lower installation costs

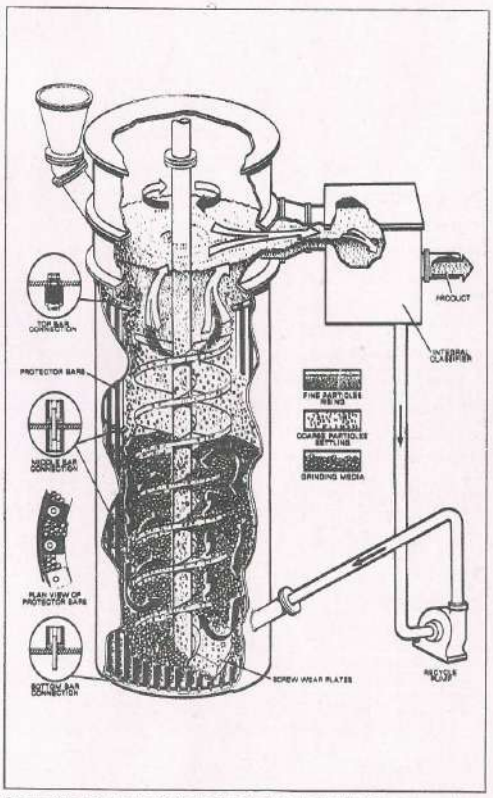
*Lower operating costs

*Higher energy efficiency

*Less floor space

*Less overgrinding

The tower mill was first developed in Japan in the 1950s. Today, following subsequent licensing agreements, company takeovers, and technical developments, two companies offer such grinding systems-Mineral Processing Systems Inc. (MPSI of the Boliden Allis group) produces its VertiMill while Kubota Corp. (with Japanese parent group) offers its Tower Mill. The illustration (of an MPSI VertiMill)shows the general operating principles of tower mills.



Operating principle of the vertical stirred ball mill, diagram courtesy MPSI VertiMill.

(Engineering & Mining Journal, April 1991; p.38)

Peroxide-assisted Gold Leaching

The latest step in the chemical optimization of cyanidations is the use of hydrogen peroxide as a liquid oxidant. The peroxide-assisted leach (PAL) sys-

tem allows the use of this strong oxidant in cyanidation while avoiding a reaction between H_2O_2 and cyanide. The availability of H_2O_2 in cyanidation significantly accelerates the extraction kinetics compared to standard technology which uses compressed air or oxygen as oxidant. The main field of PAL application is the processing of sulphide ores, which are strongly oxygen and cyanide-consuming. In contrast to standard acration technology, the PAL process works very efficiently and economically on this ore type.Increased gold recoveries (usually 5-20%) and reduced cyanide consumption of up to 50% have been reported. The PAL process was first introduced to the mining industry some three years ago and seven mines are currently using this technology.

As oxide orebodies are mined out and more sulphide gold ores must be mined, it is likely that PAL will become increasingly used in cyanidation.

PAL is now used at several mines in Australia, South Africa, and more recently, North America.

(Engineering & Mining Journal, June, 1991)

Compact Concentrators for Gold Recovery

Based in Langley, British Columbia, Canada, Knelson Gold Concentrators Inc. makes a range of compact and portable concentration systems which are highly effective in recovering gold from both placer and hard rocks deposits. The concentrators have been improved and upgraded to the extent that they are now used in over 50 countries world wide and recoveries of free gold exceed 96%. Knelson concentrators are particularly effective in recovering fine particles, of the order less than 1 micron.

The operational principle is gravitational enhancement created by highspeed centrifugal force. Slurry is introduced into the rotating one piece polyurethane ribbed inner cone which is rotated at high speed generating a force 60 "G". The heavier materials are trapped in the ribs of the cone while lighter particles are carried by the water flow out of the top. Compaction of the concentrating bed is prevented by injecting water through a series of graduated perforations in the cone wall. This water keeps the concentrating bed fluidized, so that even microscopic gold particles can be recovered under the high force.

Durable, low cost and easy to operate the Knelson concentrator is offered in 5 models which can be applied in bench scale lab and pilot plant testing through to full-scale production.

[Mining Journal; July 26, 1991; p.69]

MINING MACHINERY

Komatsu Adopts Australian - Made Buckets

Japanese earthmoving manufacturer Komatsu has taken significant local production initiative and adopted locally produced buckets and ground tools for all new Komatsu wheel loaders.

Komatsu, Australia has produced motor graders in Australia since April, 1988. In July 1989, it started designing and production of wheel loader buckets locally. Since Jan. 1st 1991 it has designed and produced its own line of buckets for hydraulic excavators. This offers superior quality to other systems and has the advantages like:

* Vertical locking for easy installation and/or removal.

* A nose-shaped design gives improved strength.

*Increased tool life due to more cast metal in wear areas and hence reduces cost.

*Re-usable lock and pin which reduce costs.

*Time proven tool shapes for Australian Conditions, including standard, rock abrasion and penetration.

(Australian Mining; June 1991; p. 68)

Large-Hole Drilling Aids Underground Productivity

Introduction of Atlas Copco's new longhole production drilling system - the Simba H4000 with the new COP 4050 hydraulic rock drill - marks the successful conclusion of an extensive development project to increase output in long-hole production drilling.

The new COP 4050 is a 390 Kg heavy top hammer rock drill with an impact power output of up to 40 kW and is intended for drilling large holes from 89 to 127 mm.

The COP 4050 can reportedly drill almost as straight holes at twice the speed and can be used with conventional drill rods, drill tubes or a combination of both.

Impact and power levels can readily be adjusted to prevailing rock conditions, contributing to good hole quality and longer drill steel life. The COP 4050 offers increased productivity in underground mining.

Features include:

* Hydraulic recoil absorption mechanism

* Slim-line piston

* Adjustable stroke length and impact rate

* Powerful rotation mechanisms with double hydraulic rotation motors

* Front head in corrosion-proof materials.

To take advantage of the new drill's productivity, a new series of Simba rigs designated Simba H4000 has been designed. The rigs include a new hydraulic tube breaking mechanism with total control over tube breaking. The risk of losing the drill string is minimized and tube life increased. This results in an increase in improved drilling economy.

(Mining Journal, London, May 3, 1991; p.335)

MINERAL ECONOMICS

The World Availability of Cobalt

Cobalt is used to poduce alloys that have heat and wear resistance, high strength and superior magnetic properties. It also has numerous non-metallic applications.

According to estimates of countries studied, Zaire, Philippines, Zambia, Indonesia, Canada and the U.S.A. have the largest demonstrated cobalt resources, accounting for over 90% of the potentially recoverable cobalt. However, a significant part of the resources of the Indonesia, the Philippines and the USA are in non-producing nickel deposits that can only be recovered at long- term nickel costs higher than the January 1990 nickel market price. Resources estimates are considered to be very conservative. Resources in Zaire, Canada and the Pacific Islands are specifically much larger than estimates provided in the study, but have not been proven at demonstrated level, or data are not currently available for inclusion in this analysis. Development of new nickel operations in China, Cuba and now defunct USSR will increase world capacity to where all anticipated cobalt requirements will probably be met beyond 2000, barring any supply problems in Central Africa.

(Natural Resources Forum; May 1991; pp. 100-109).

ENVIRONMENT

Metal Mines Respond to Environmental Concern

The metal mining industry is preparing to establish an International Council on Metals and the Environment (ICME), a global response to mounting pressures for better health and environmental protection. The ICME can help develop industry consensus on strategies to promote the safe production, use, recycling and disposal of metals. It plans to foster cooperation on policies and programmes with major inter-governmental organisation including the U.N. Environment programmes, the ILO and the Paris based Organisation for Economic Cooperation and Development. The ICME will collaborate on environmental issues with the International Lead Zinc Research Organisation, the Nickel Producers Environmental Research Association, the Australian Mineral Industry Research Association and other commodity and industry groups.

All of these linkages are expected to enhance the ICME's influence and credibility with governments and the public worldwide. The global environmental network welcomed the emergence of a central body in the world resource industry, with which crucial questions like energy efficiency in mining and metallurgy, recycling and reuse of materials and the global stewardship of metals can be discussed.

(Australian Mining; April 1991; p.22)

Scarcity of Natural Resources and the Implications for Sustainable Development

The idea of sustainable development has much popular appeal, but conflicts with centuries of economic theory about how limited land and natural resources constrain the growth of economies and populations. Much of that doctrine, especially that in the Malthusian tradition, is contradicted by historical experience, but the modern threat of environmental degradation raises new questions about whether growth can be sustained. Many of those new problems result from biases in economic organisations and institutions against so-called environmental resources. Marketed resource commodities like minerals and timber are protected by the incentives of owners and suppliers to conserve them, enhance them and find new sources, and by the incentives of users to economize on their demands and find cheaper susbstitutes. Together, these forces have been sufficient to offset depletion and render resources less scarce over time. The same forces are not at work on environmental resources like water and air, so they are over-used and degraded as demands grow. However, promising opportunities exist to develop property rights and economic incentives to encourage users of environmental resources to protect them, and these are likely to be more effective in harmonizing economic activity with the environment than purely regulatory policies.

(Natural Resources Forum; February, 1991; pp. 74-79).

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TECHNICAL DIGEST

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EXPLORATION

Digital Mapping in Burundi, Africa

Operating in Africa for exploration or exploitation is not unlike anywhere else in the world. The methods employed are using standard Computer-Aided Design(CAD) software. Relative to Geographic Information Systems(GIS) or many other digital mapping packages, CAD is much easier to use and significantly cheaper. Most of the work required is routine data input, and for production of maps, CAD is excellent. Users of CAD mostly do not appreciate the full analytical capability of their own system for use in many aspects of the mining industry.

GIS is essentially an analytical tool. It is a system for integrating different map sets and interrogating them. GISs also hold information on a sample point which can be read into a "tabular" database for interrogation for use in statistical analysis and reports. GIS does analytical statistics on multi-variate datasets in a transparent fashion.

Digital Mapping Process

A standard CAD system was used as a basis for the mapping in Burundi. Firstly, it is easy to use. Secondly, not having a number of computer experts available, it is useful to have a number of publications available by independent authors that can describe how to use the system in greater detail than the manual. Thirdly, the ability to customize the system to suit local needs could easily be done on site. Fourthly, the cost was appropriate to the scale of the project.

The project consisted initially of exploration in the concession area covering NE Burundi. This area was sufficiently large to justify the purchase of satellite imagery and produce false colour composites written to film for geological interpretation. Images used generally ranged in scale between 1:200,000 and 1:25,000.

The most important job is to digitize useful data and rectify them to a common grid.

In addition, areas, distances and volumes can be readily obtained in metric system. For this job "rubber sheeting" algorithms are essential. They will tell what errors are. For instance, a 1:50,000 scale map should have a planimetric accuracy of 20 m. One must then use non-linear warping to get that data to below 20 m. Once these data are in a common grid system, and rectified to within known errors, the geologist can begin to decipher the different datasets. The data are all stored as different layers in the computer and can be analysed accordingly. Many intermediate digital map products were important for field mapping to generate the geological map. The digital maps made field work much more efficient and spotted relationships essential to the programme that could not have been obtained by standard analogue methods. With all the surface data, 3D models of the ore zones can be generated. This model is ready for designing a drilling programme. Once the orebody is defined, the same plans and 3D models can be used to insert ore treatment plant designs, collect data from pumping tests for geohydrology, design tailing dams and design appropriate environmental safeguards.

(Mining Magazine; February 1992; p. 86)

MINING

Doubling Productivity at Kamioka Mine, Japan

The Kamioka mine in the eastern Japan operated by Kamioka Mining & Smelting Co. Ltd has exploited a complex zinc-lead-silver orebody. There are two zinc and lead mines at Kamioka, namely Tochibora and Mozumi mines, separated by a distance of 12 km. Combined output from the two is 4,555 t/d ore grading 15 g/t Ag, 0.40% Pb and 4.41% Zn.Kamioka accounts for some 40% of Japanese zinc production.

Massive irregular orebodies have been mined by means of sublevel stoping, induced block caving and cut-and-fill at Tochibora and mainly cut-and-fill at Mozumi; the latter is much the smaller operation.

The equipment at Tochibora is managed under a 'productive maintenance' concept. The overall result is high availability and low total maintenance costs. Equipment operates with minimum downtime.

The eight Tamrock HS 205D Minimatic drill rigs are equipped with Tamrock hydraulic chain feeds and ZRU 700 hydraulic universal booms. The two

Tamrock H 395-24 Robolts are equipped with the optional high-pressure washing system. The Tamrock drills are reported to have consistently drilled 7,000 m/month over the past two years whereas the older pneumatic rigs could accomplish only 3,200 m/month. More than 650 m is being achieved with each bit as compared to 300 m on the pneumatics, while rod life is up from 600 m to over 1,400 m in a rock with a typical compressive strength of 150 to 200 MPa.

The cut-and-fill stopes measure 5 m high x 20 m long; each blast produces 1,050 t (350 cu m). Tamrock Minimatics with 3.5 to 4.5 m feed carry out drilling, and following blasting, loading and hauling is by LHD (6.5 cu m buckets); two of these units are fitted with a remote control system.

At Tochibora, introduction of a large ANFO charging unit and an electric charging unit has contributed much to the overall productivity increase.

Drilling, charging, loading and backfilling operations are carried out individually by operators specializing in each particular operation. Each crew is responsible for 15 to 20 faces and operates the equipment minimizing downtime. Rock bolting is also done on the crew system.

Kamioka management recognizes that in the future further automation and use of electrically-powered equipment will be necessary to maintain the competitiveness of the mine.

(Mining Magazine; February'92; p. 61)

Maricunga– the World's Next Great Gold Province

Maricunga in Chile has been described as "the world's next great gold province". The long-term significance of the Maricunga district is that the existing mines and prospects are merely the most obvious outcroppings of porphyry gold mineralization in a swathe of territory stretching from La Serena all the way into southern Peru.

El Hueso Chile's First Gold Heap Leach

El Hueso is the first heap-leach gold mine in Chile. It is situated at an altitude of 3,900 m and 23 km by road southeast of the Potrerillos smelter. The El Hueso claims were drilled by Codelco's El Salvador Division from 1981 onwards. The proven and probable reserves stood at 16 million tonnes grading 1.68 g/t gold. Production in 1990 was 2,069.55 kg.

El Hueso is a disseminated gold deposit about 600 x 100 m in area with an oxidized zone about 90 m deep. The host rocks are Jurassic limestones and Eocene volcanics which have been intruded by quartz-feldspar. Apart from free gold, there is hematite, jarosite, and isolated occurrences of cinnabar and realgar.

Tamrock Zoomtraks drill 114.3 mm dia holes on a 3 x 6.5 m pattern and blasted rock is selectively loaded by 3.44 cu m and 5.35 cu m backhoes. Production averages 30,000 t/d, 365 days a year. This consists of about 6,200 t/d high-grade (over 0.8 g/t gold) and 3,000 t/d low-grade (0.4-0.8 g/t gold) ore. Material currently considered waste; less than 0.2 g/t and 0.2 to 0.4 g/t, is tipped onto separate dumps. Loading and hauling are done under contract.

High-grade and low-grade ores are treated separately. High-grade,averaging 1.4 g/t gold, is crushed in three open-circuit stages to minus 13 mm, mixed with lime and cyanide, and transported to the leach pads. Cyanide consumption is 0.6 kg/t and is all added onto the final crusher conveyor belt. Barren solution adjusted with sodium hydroxide to the correct pH is used for spraying.

Bulldozers were originally used to build the heaps but have been replaced by backhoes. The Poclain 400 backhoes stand on the platform of ore dumped by the trucks, lift it up, and pour it down the face of the heap. The method provides compaction-free heaps.

The geotextiles under the 4-m-high heaps have textured surfaces to provide superior adhesion to the ground. El Hueso is in an earthquake-prone zone and many of the heaps are constructed on slopes. A triple lining is used; a base of geotextile followed by polyethylene sheet and a top layer of geotextile.

Heaps are left to cure for four days before sprinkling begins. Thereafter, an average 40 to 50 days are required to reach 75% recovery.

Once leached, the heaps are removed and fresh ones laid. Leached ore is discarded either on dumps, or if it is still of sufficiently high-grade, secondary leach dumps. Low-grade ore running 0.4 to 0.8 g/t gold is directly dump leached for an average recovery of 40%. These dumps are never removed. Fresh low grade ore is simply dumped on top. Cyanide consumption in this circuit averages 0.4 kg/t.

Solution pumping capacity for both high- and low-grade sections is 300 cu m/hr for an average distribution of 7 liter/sq m. Pregnant liquor typically runs 0.9 to 1.0 ppm gold. Sub-grade pregnant liquor is recirculated until it reaches the required loading. Barren solution runs less than 0.05 ppm gold.

(Engineering & Mining Journal; October 1991; p. 33).

MINING MACHINERY

Electric or Mechanical ?

Consideration of the correct haulage system for any open pit cannot, obviously, just be restricted to selecting the appropriate truck power train. Many other criteria come into play, including tyres, brakes, dispatch systems and payload monitoring. In certain applications, the mechanical drive units out perform the electric units at appreciably lower costs but only because of the conditions,and vice versa.

Steep downhill hauls (down loaded and back empty) are an excellent application for mechanical drive units as the speed of a mechanical truck up a hill empty far exceeds that of an electric drive truck. Similar arguments may be made for electric drive trucks out of a deep pit, or for long hauls, etc.

The drive line component costs vary dramatically between the type of unit because of the type of application.

In the final analysis, the operator has to choose the most suitable option for the pit design and conditions to be encountered. Familiarity will continue to have a major influence in future as will be existing experience and skills.

Now mechanical drive trucks are gaining an increasingly significant market share. Caterpillar's market figures (Mining Magazine; August,1991; p.50) show that units of 85t capacity and above were split 54% electric drive and 46% mechanical back in 1980. By 1989 that split had taken a major turn in favour of mechanical drive, with electric showing only 27%. Similarly, in 1980 all 120t and above trucks were electric drive, but by 1989 mechanical drive units had taken 39% of the market.

The Pros and Cons

In order to overcome the electric drive advantage (lower operating cost and fuel consumption), the mechanical drive system must have a faster cycle and higher productivity. If the haul road is not long or flat enough, this advantage may not be overcome. Electric drive is still the choice in the 170 to 190t range, unless technology develops lighter components with an operating cost similar to the electric drive's.

Caterpillar would certainly take issue on the higher fuel consumption of mechanicals. Its complete truck fleet, up to the 218t-793, is mechanical drive.

There have been substantial improvements in mechanical transmissions over recent years, including the application of electronic controls, clutch modulation, downshift inhibition, pressure regulation modulation and the use of pressure reducing valves. They also point to similar improvements in electric drive systems including microprocessor controls, significant reduction in mechanical components, the switch to alternator systems, improved retarding characteristics and other measures to improve system performance and reliability.The decision between the two options is site-specific and that mine operators must carefully analyse the pros and cons.

The comparisons used in arguments some 20 years ago are still valid, and electric drive offers substantial advantages over mechanical drive, particularly at the upper end of the truck size range.

Needs for the Future

Fancier electronics and monitoring systems, while important, should not take the place of common sense engineering. Equipment manufacturers often lose sight of this and in an effort to decrease costs actually increase them to the mining companies, as the mining companies must pay for research and development indirectly through higher capital and, often, operating costs.

Developing and refining present technology before going into 'new' technology should be an important consideration.

The greatest call for the future was for further development and improvement of in-pit crushing and conveying systems. The next was for larger trucks for over 300t capacity. In addition, some supporters, called for work on driverless trucks haulage systems to be speeded up. Better fuel efficiency was another common desire.

Trolley assist also had its main field of influence in Southern Africa with major systems installed at Grootegeluk.

In contrast to those calling for more work on in-pit crushing and conveying, it is felt that the industry requires to pursue development of electrical assist means for trucks because of its flexibility and low initial capital requirement as in comparison to in-pit crushing/conveying.

The continuous surface mining as it is being developed for hard rock mines by such companies as Krupp and Voest Alpine, also polled significant interest. It is cheaper alternatives to truck haulage, such as conveyor haulage without the need to crush first. Effective continuous surface mining machines will certainly translate into changes in haulage philosophy. (Mining Magazine; February 1992; p. 64).

MINERAL BENEFICIATION

New Simple Test for Flotability

The test is based on Dr.Chudacek's discovery that in an intensely agitated closed-system, particle/bubble equilibrium is established quickly and does not change with additional agitation. Equilibrium is, however, strongly dependent on agitation intensity.

A pneumatically driven reciprocating agitator called "EMDEE Microflot Agitator" has been developed to provide defined agitation for a pre-selected period. This microflot agitator can determine the flotability of an ore by a simple direct experiment using very small sample 0.1 to 20 g/test.

In this method, reagent-added pulp is conditioned by a magnetic stirrer in a centrifuge tube. After conditioning, the tube is agitated in the EMDEE Microflot Agitator for 20 cycles at 120 m/sec to establish the pulp/ froth equilibrium. This takes about 3.5 seconds. The froth is removed by vacuum suction into another centrifuge tube. Upto six froth concentrates can be removed in succession to calculate the flotability spectrum of the ore sample.
(Engineering & Mining Journal, February, 1992).

New Developments in Dewatering

Due to large distances involved in the transportation of mineral concentrates, the mining & mineral-processing industry is constantly searching for better, more effective methods for dewatering. A recent development in the field of concentrate dewatering is the use of a series of discs made out of a patented microporous sintered–alumina material as capillary action filters.

Capillary action technology was originally developed in Finland for the paper-making industry. It is now found more suitable for liquid/solid filtration in the mineral industry. The chemical inertness of discs makes suitable for the filtration of most water-based slimes. Each disc is constructed from a number of sectoral plates consisting of a permeable core to collect filtrate during dewatering.

As the discs rotate in the slurry, the dewatering process begins immediately without external force as the liquids are drawn into the micropores. Solids accumulate on the outside of the plates creating a very dry, uniform cake. Cake solids are discharged at the end of discs' rotation by scrapers.

Now these dewatering discs made by Outomec improve solid/liquid separation eliminating the need for filter cloth.

(Engineering & Mining Journal; February 1992)

ENVIRONMENT

Woodlawn Mine Overcomes Water Management Problems

Woodlawn Mine, located on the NSW southern tablelands, has extracted and processed 8 million tonnes of ore since 1977. Until 1987, mining operations were exclusively open cut and more than 80 million tonnes of waste rock was produced and placed in a dump alongside the open pit. The sulphide waste rock, on exposure to air oxidises and reacts with water to produce a sulphuric acid solution rich in heavy metals.

The mine management has always followed the requirements of the clean Water Act where all polluted water is contained in and evaporated from tailings and evaporation dams. During the "water management crisis", polluted runoff from the waste rock dump was being produced in quantities that far exceeded the rate of water being lost by evaporation. In 1988, the mine received nearly double the annual average rainfall. In normal dry months when most evaporation occurs, more than 200 mm of rain fell. Over March and April 1989, the mine received a further 281 mm of rain. By April 1989, the mine's capacity to store polluted water was under severe strain.

A major crisis was averted by the construction of additional dams during breaks in the rain, the treatment and recycling of waste water, strategic pumping of waste water between dams and the open cut pit, and the separation and release of clean water from the mine.

Typical of this commitment is the annual review of environmental management carried out by a committee of representatives from the mine and from government regulatory and advisory authorities. A committee has streamlined the role of the regulatory authorities and ensured good communication on all mine environmental issues. Commencement of underground mining in 1986 and cessation of open cut mining in 1988 provided the opportunity to the company for improving the long-term water balance situation. The waste rock dump was the major source of polluted runoff water from the mine operations.

The Soil Conservation Service has a long history of involvement in conservation and water management programmes; all monitoring programmes have provided very positive results – no water is entering the waste rock material, and surface and groundwater tests are coming up clean.

While mining is the major enterprise carried out on the 3,238 ha Woodlawn Mine property, 2,428 ha of the property is devoted to farming. The mine runs 5,500 merino sheep, 350 Hereford cattle and 450 deer directly adjacent to the mine. The mine has a 180 ha pine forest, planted in 1974 and 1975 and now undergoing its first thinning, in preparation for saw logging in years to come.

According to mine management, the farm runs side-by-side with the mine as a fully commercial and sustainable operation.

The commitment of the company to sound environmental management is reflected in the management of the farm. The mine and the farm help each other with technology and skills. Farm staff know about pastures and weed control and can assist the mine in its revegetation programmes. Mining and agriculture, combined, earn most of Australia's export income, which, in turn, provides Australia with its high standard of living. While each industry has different needs and uses for the land, both industries have a right to operate and both industries have areas of common ground, on issues of national significance.

(Australian Mining; August 1991; p. 12).

Significant New Arrivals in IBM Library

TECHNOLOGY TRANSFER, by Dr. K.S.U. Menon,
(First Printed-1990, Reprinted-1991),
Goldline Publishers,
(Prop. Goldline Engineering Pvt. Ltd.),
Vikas Chambers, Vikas Marg, V-136, Shakarpur,
Delhi-110 092.

GEOLOGICAL SURVEY OF JAPAN (Vol.21)
Shunso Ishihara, Director,
Higashi 1-chome, Tsukuba-shi, Ibaraki-ken,
305, Japan.

IMPACT OF MINING ON ENVIRONMENT,
by R.K.Trivedy & M.P.Sinha
(Printed in 1990)
Published by S.B. Nangia for Ashish Publishing House,
8/81, Punjabi Bagh,
New Delhi-110 026.

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EXPLORATION

Geophysical Exploration

Resistivity methods

Electrical resistivity methods have been used with considerable success for many years in mineral exploration programmes despite the limitations in the methods of data analysis.

Shima of the Oyo Geotechnical Institute in Japan proposes a new method using alpha centres in which potential and conductivity can be calculated very quickly and the distribution of conductivity can be obtained as a continuous function that closely corresponds to the actual ground and so is suitable for automatic analysis of resistivity structures. He uses the method to identify the form and distribution of lava in the ground and also to investigate the distribution of intrusive rock and alteration in a steep mountainous area.

In resistivity soundings, interpretations can really only be made in areas of flat topography underlain by horizontal homogeneous layers. Molano, Salamanca and van Overmeeren have developed the GEA-58, a geoelectrical instrument which can make continuous soundings along a profile with any co-linear electrode configuration. They use the finite-difference and finite-element methods to model complex earth resistivity distributions in 2-D, in order to calculate apparent resistivity responses to any co-linear current electrode distribution in terrains where the earth resistivities do not vary along the strike.

The execution and interpretation of resistivity soundings are always challenging. The topography is never flat and the lines are never straight. Zohdy and Bisdorf of the USGS overcame these problems very elegantly in their Schlumberger soundings to explore the geothermal potential of the Medicine Lake area of Northern California. They expanded the array along the winding roads and the measured resistivities were corrected using the geometric factor for the exact geometry instead of that for the linear array. These works proved (a) the distances from the current electrodes to the centre of the array are equal, and (b) the proper geometric factor is used to calculate the apparent resistivity. They used the data to produce resistivity maps and cross-sections to identify geothermal targets. The procedures are exactly applicable to mineral targets.

Tong and Yang of Taiwan have been looking at the problem of incorporating topography into 2-D resistivity inversion. Their method is based on the finite-element method and their iterative inversion scheme is derived from the second order Marquardt damped least-squares method. The algorithm has been tested on both synthetic and field resistivity data with topography incorporated explicitly into the inversion model. Their theoretical and field studies indicate that the technique is exceptionally efficient and is a great improvement on conventional interpretation schemes.

(Mining Annual Review; 1991; p 180)

MINING

Planned Bench 'Robbing' Increases Ore Recovery

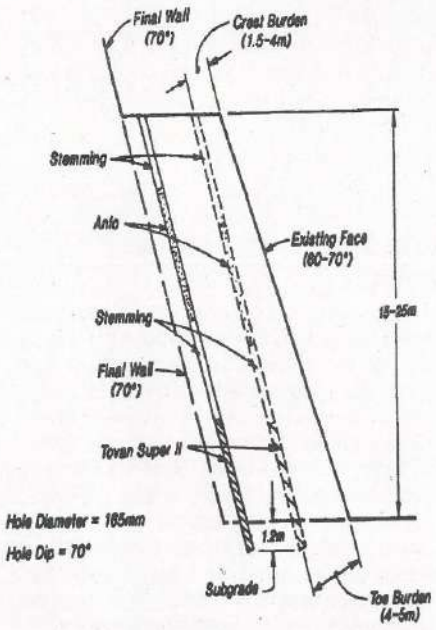
As mineable reserves are depleted, underground mine operators attempt to recover additional ore by 'robbing' selected pillars and extracting barrier pillars between stopes. Similarly, open pit operators can 'rob' additional ore of lower benches of a completed ultimate pit. Equity Silver Open Pit Mine in north-central British Columbia successfully demonstrated such robbing of bench pillars without compromising with safety.

The ore body occurs in a competent volcaniclastic and monozonite intrusive rock that exhibits unconfined compressive strength of the order of 100 to 200 MPa. The pit had already reached its

ultimate size-850 metres long and 650 metres wide at the crest and about 240 metres deep with overall ultimate pit slope angles varying from 40 to 54°. The benches were 15 to 25 m high (at a slope angle of 60 to 70°) and 6 to 10 m wide.

The mine commenced production in 1980 and by 1991, it produced 83.9 million kg of copper concentrates, 2.2 million kg of silver and 15,000 kg of gold, average production of waste and ore being about 21,500 tpd at a stripping ratio of 1.5 : 1. In 1991, the management identified about 140,000 tonnes of high grade ore locked in the waste bench beyond the limits of the designed ultimate pit slope. The material averaged 0.30 % copper, 146 g of silver and 1.2 g of gold per tonne. A preliminary feasibility study established the economic viability of recovering this high grade ore which was not included in the original mine plan. The geotechnical aspects of 'robbing' the above ore was entrusted to a consultant, Golder Associates.

It was visualized that complete removal of the 15 to 25 m high bench from the bottom of the pit would create a single combined bench, about 30 to 50 m high. Nevertheless, considering the total depth of the quarry (240 m), it was also visualized that it would not appreciably increase the overall slope angle. However, small-scale structural failures were apprehended which would not jeopardize the overall slope stability.



The bench robbing operation took only about 8 weeks to complete. The important parameters of the operation are given below:

(i) Mining in a retreating manner such that the operators would not have to pass under 30 to 50 m 'unstable' high wall.

(ii) Continuous monitoring of the slope stability and ground vibration; the vibration velocities were observed to be below 300 mm/second which was within the safe limits.

(iii) Drilling and blasting operations designed for a well-fragmented, low profile muckpile and to minimize damage to the existing bench walls at upper levels. The blastholes (165 mm) were drilled at an angle 70° (i.e. parallel to the final high wall) with burden of 1.5 to 5 m and spacing of 5 to 7 m (*see* sketch). Adoption of a relatively higher powder factor (0.65 kg per m^3) achieved the desired fragmentation. Use of decked charges in long holes to reduce the charge weight per delay could minimize overbreak and ground vibrations.

While the inter-hole delay was achieved by 25 ms detonators, 157 ms and 190 ms down-the-hole nonelectric delays were used in the upper and the lower decks, respectively.

(iv) As a matter of additional safety, the existing front-end loader was converted to remote control operations.

(Canadian Mining Journal; April 1992; p. 32)

MINING MACHINERY

Largest Mechanical Drive Wheel Loader

Designed for fast and efficient loading of mining trucks, the 'Dresser-4000' wheel loader was recently introduced by the Haulpak Division at its US mining centre. Said to be the largest mechanical drive wheel loader in the industry, it is offered with either a standard or highlift linkage system.

There is a choice of six buckets, ranging from 30.6 m^3 light material bucket to 10 m^3 heavy material model. The wheel loader gives high productivity. It has an advanced power train of modular design which reduces downtime. Constant operation at 1,900 rpm gives long engine life. The modulating clutch increases efficiency by apportioning power as needed, thus maximizing the hydraulic power for digging. Built-in modulating retarding reduces dependence on the service brakes. These are all-wheel wet disc brakes with spring apply/hydraulic release for emergencies.

Structural aspects include "z bar" loader linkage geometry to produce ideal rollback, maximize breakout and improve lift forces. High quality, high yield strength steel and castings have been used for all structures and the box-beam boom design gives increased strength with less weight. A central autolube system extends the service interval resulting in higher production.

Regarding the hydraulics, conservatively rated high pressure pumps ensure high performance and long life. The 2-speed system provides infinitely variable fingertip control. Other notable features include a quiet and comfortable airconditioned cab, and the loader's longer wheel-base gives better fore/aft stability.

(Mining Journal; Oct. 18, 1991; p. 292)

MINERAL BENEFICIATION

Hydraulic Shaking Tables

A new look is given to veteran gravity separator in the form of shaking table. The newly developed shaking table is provided with hydraulic drive, versatile with a more or less unlimited choice of forward and backward motions. Therefore, the same table can be adapted for the separation of both coarse sands and fine slimes.

The hydraulic shaking table does not require special foundations.The deck is isolated from the rectangular steel support frame by air cushions to prevent transmission of dynamic forces to the foundations.

The table deck is made of 50 mm thick aluminium sandwich plate with a honeycomb structure which reduces the weight of a 3.5 x 1.3 m deck to less than 80 kg. The deck which includes the riffles is covered with single sheet of cast polyurethane or rubber.

(Engineering & Mining Journal; Nov. 1991; p. 34)

Gold Recovery from Refractory Gold Ores

Refractory gold ores do not yield high recovery of gold when treated by conventional grinding and cyanidation technology. Refractory gold ores may be classified into the following groups:

a) Ores in which gold is finely locked within other minerals such as pyrite and arsenopyrite.

b) Gold compounds especially those of antimony, bismuth and tellurium which are poorly soluble.

c) Gold ores having carbonaceous gangue, yielding low recoveries.

There are a number of processes for the pretreatment and recovery of gold from refractory ores. These methods are i) roasting, ii) double oxidation, iii) pressure oxidation, and iv) bio-leaching.

Roasting has been used for several decades but there are a number of disadvantages to the process due to air pollution, high cost of recovery, etc. Pressure oxidation, a new technology, has become more effective for refractory gold ores.

Dr. W.T. Yen, Department of Mining, Queen's University has developed a commercial pressure oxidation process after working for nearly ten years on this problem.

Dr. Yen's process is a one-stage process and it eliminates the need for neutralization and cyanidation. An acidic hypochlorite solution is added to the autoclave for pressure oxidation and extraction of the gold at the same time. Gold extraction by pressure oxidation is rapid and complete.

(Canadian Mining Journal; April, 1991; pp. 16 & 18; Asia Pacific Mining; August/Sept. 1990; p. 38)

Gravity-Magnetic Separation

The conventional gravity separators are modified with the addition of magnets to enhance recovery of magnetic and weakly magnetic minerals by combined gravity-magnetic separation. A significant improvement in the efficiency of separation occurred with the addition of magnets compared with conventional gravity separation.

A Reichert cone and spiral gravity separator were modified by addition of special magnets placed so that the attractive magnetic and gravitational forces acted together. The tests showed the following results:

i) Proper placement of the magnets with the correct magnetic field intensities is essential for achieving optimum results.

ii) Under similar feed conditions, addition of magnets to a spiral or Reichert cone improved the recovery of magnetic and weakly magnetic minerals.

iii) On iron ore, the magnetic spiral increased the recovery of both magnetite and hematite.

Iron ore, chromite, wolframite, heavy mineral sands, etc. could benefit by retrofitting conventional gravity separators with magnets.

(Engineering & Mining Journal; June 1991; p. 16)

ENVIRONMENT

Lunar Environment

The Moon is a fascinating but alien place. The environment is hostile and drastically different from one we are used to on the Earth. For successful mining and processing material on the Moon, the effect of hostile lunar environment should be taken into consideration while deciding the method of mining

technology and the design of equipment. The 'Apollo Lunar Modules' and associated equipment which were exposed to the lunar environment for twenty years have revealed the following interesting facts about the lunar environment.

Surface Materials

The lunar soil is a global veneer of debris generated from underlying bedrock by meteorite impacts. It contains rock and mineral fragments and highly porous agglutinates which are produced by micrometeorite impacts into the lunar soil. Since single grain of minerals is rare, mineral separation techniques might be ineffective. The depth of the lunar soil ranges from 2 to 30 metres.

The lunar soil is an excellent insulator. The upper few hundred metres of the Moon have been intensely fragmented by meteorite impacts. In the heavily cratered highlands and regions underlying mere basalt flows, the fragmental region extends for at least a few kilometers. Consequently, it might be difficult to find extensive areas of intact bedrock.

Surface Temperature

The Moon completes one revolution in 27.3 Earth days and therefore days and nights last almost two weeks. Surface temperature changes drastically from dawn to noon to dusk. Therefore, designing lunar structures which are subject to severe thermal expansion and contraction in a day-and-night cycle of 27.3 Earth days is a big problem.

Atmosphere

The lunar atmosphere is a collisionless gas with total night time concentration at only 3×10^{-13} molecules/m^3. At night, the Moon's atmosphere is composed chiefly of H_2, He and other noble gases which are derived from the solar wind. Although no daytime measurements of gas concentration could be made due to instrument limitations, enhancements in the levels of CO_2 and CH_4, for a short time before sun rise indicates that these gases were being desorbed at sun rise.

Radiation Environment

The Moon has smaller magnetic field and it has nearly absent atmosphere. There are three courses of radiations : (1) high energy galactic cosmic rays, (2) solar flare particles, and (3) solar wind particles. The combination of high flux and energy makes solar flare particles most dangerous to people working on lunar surface. Although there are hazards to personnel, most mining and processing equipment can be designed to mitigate the damaging effects of radiation.

Micrometeorite Flux

The lack of a significant atmosphere on the Moon allows even the tiniest particles to impact with their full cosmic velocities, ten to several tens of km/sec. These minute impactors could damage cameras which would be the 'vision sensors' in teleoperated devices.

Seismic Stability

Lunar seismic activity is drastically less than terrestrial seismicity. Lunar seismographs detected only 500 quakes per year as compared to about 10,000 detectable quakes that occur each year on the Earth. Therefore, the Moon provides a more stable platform than the Earth for building structures. There are two main categories of lunar seismic signals, i.e. (i) deep moon-quakes, and (ii) shallow moon-quakes. Most of the moon-quakes fall under the former category and occur at depth 700 to 1,100 km. These deep moon-quakes are related to tidal forces inside the Moon. Shallow quakes which originate at depth ranging from 50 to 200 km occur less frequently, only about five per year.

Mining on the Moon

Before any mining technology and equipment design is arrived at, the likely extent of degradation of such equipment to be caused by long-term exposure to micrometeorite bombardment, solar and cosmic radiation, thermal cycling as well as vacuum on the lunar surface is to be clearly understood so as to mitigate damage to such components at a permanent 'base' on the Moon. Large-scale testing of systems will be required before these are actually deployed. This is especially true for earth-moving equipment such as front-end-loaders, vehicles and conveyor belt system. The test must be done in a simulated lunar environment using simulated lunar soil.

(Advanced Materials; p. 23)

Significant Arrivals in IBM Library, Nagpur

INDUSTRIAL MINERALS, GEOLOGY & WORLD DEPOSITS 1990. Publisher : Industrial Mineral Division, Metal Bulletin PLC, London, Price - Rs. 3248/-

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MINING

New Techniques for Mining Steep Narrow Ore Bodies

Small quantities of ore contained in a narrow ore body hardly justifies investment on expensive machinery/equipment. Consequently, traditional labour-intensive mining methods, are quite common. However, the need to improve efficiency and to lower production costs are still of paramount importance, particularly where labour costs are high. Thus, in 1984, a research programme was initiated in Sweden to investigate the feasibility of adopting mechanised mining techniques to a narrow steeply dipping ore body. It was carried out as a full scale mining project in the Zuikgruvan Zinc-lead Mine in Central Sweden owned by a Belgian company. The mine produced 750,000 tonnes of ore annually and several ore bodies, all steeply dipping at about 75°, and less than 4 m in width, were mined here. The strike length within the test area was 130 m; the depth of the ore block was 49 m and it contained 23,000 tonnes of ore.

A plan for mining with sub-level stoping (sub-levels at 13 m vertical intervals) was prepared. The ore body was divided into three slices which gave a maximum length of 9 m for long hole drilling. The lowest level was prepared for draw point loading with LHD loaders. A shaft was made for connecting the loading level and the three sub-levels ; the shaft was equipped with an Alimak hoist for transport of men and materials.

Atlas Copco was assigned the design and manufacture of a drill rig. The TRAKKER, a crawler-mounted drill rig with an overall width of 1.1 m, was made. It was equipped with a pneumatic rock drill and telescopic feed for drilling 3.4 m deep holes. During this period, a completely new drill rig for mining narrow ore bodies called the 'Boomer 104' was commercially manufactured by Atlas Copco and already introduced in mines. The 'Boomer 104' can drill both horizontally and vertically without reconnections. Its total width is 1.22 m to match a 0.8 m^3 LHD loader. The upper part of the rig's profile is sloping inwards to facilitate working in stopes with inclined walls due to steep dip of the orebody.

Drilling provision was an important factor for the success of the project. This was achieved with an advanced instrument made by a Norwegian Company, DIREKTOR. It was also the case with blasting which had to be done carefully to minimise over break and dilution.

The productivity of the mechanised mining technique, as applied in this particular mine, was twice that achieved with traditional cut-and-fill method. Its success depended on two main factors, viz. availability of narrow-built equipment and ability to achieve high precision in long hole drilling.

A computer model for cost estimation in narrow vein mining has been developed at the Lulea University of Technology, Sweden. The model includes ore reserves estimation including ore losses and waste rock dilution based on statistical treatment of ore width. Cost analysis is based on probabilistic calculation by simulation techniques.

The programme 'VEIN COST' cost analysis includes statistical calculations and the results in terms of expected value (mean) and standard deviations for production cost, revenue and profit under given conditions.

(XV World Mining Congress ; Vol.I ; May, 92; pp 165-173)

Mining in Space : Concepts and Issues

On July 20, 1989 - the 20th anniversary of the 1st Apollo Moon landing - the United States announced a new National Space Exploration

Initiative (SEI). Consequently, the USBM believe that mining community should play a strong role in implementing a R & D programme for exploiting lunar and other space resources. Many mining and processing concepts have been suggested, even though the choices may be narrowed down to one or two which are very likely to be successful.

Exploring space beyond the Moon requires bases outside the earth's atmosphere and gravitational pull. To maintain a permanent lunar base, vital resources must be mined and processed near the base. Adequate supply of oxygen and hydrogen (for life support and fuel) as well as construction materials poses a challenge.

Mining/processing equipment and techniques presently used on Earth will not function in space without significant changes due to the following reasons :

* Terrestrial mining and processing methods are energy-intensive; energy will be very difficult and expensive to produce in space.

* Large labour force required for mining on the Earth will not be available in space requiring automation, computer control, etc.

* Terrestrial mining equipment is too heavy to be transported to the Moon.

* The operating environment in space imposes severe restrictions on equipment design and presents major operational difficulties like dust, extreme temperature fluctuation, radiation hazards, etc.

* The equipment should need very little maintenance.

Very little engineering data is available for potential mining and processing sites which renders the development of lunar mining and processing technology even more difficult. The technology for extracting lunar resources has to be developed as a system. In addition, excavation components of the initial mining system must be designed to perform a variety of related constructions and tasks.

Two workshops on 'Mining and Construction in Space' have since been co-sponsored by the USBM, and the Bureau has completed a preliminary assessment of the lunar mining technology and scope of mining methods have been broadened to include many innovative concepts. Equipment options conceived to be deployed in early surface mining excavation activities are load-haul-dump (LHD) machine which may be provided with a ripper to loosen the soil, or a fixed excavating machine, or a mobile excavator loader, with truck haulage in the last two cases. For underground mining and tunneling, second generation mining and/or excavation equipment may have to be designed. Excavation concepts proposed for underground mining include (1) mechanical rock excavation - possibly using a boom-mounted, drill - split device (2) drill - blast rock breakage and (3) Thermal rock fragmentation.

(XV World Mining Congress; Vol. I; May, 1992; pp. 43-49.)

Future Deep Sea-bed Mining of Poly-metallic Nodules

In the course of 43 expeditions totaling 1235 days at sea, 5500 nodule samples were collected using samplers or corers and 45,000 chemical analyses performed; more than 120,000 photographs of the seabed were taken.

Untill 1980, topography of the sea-bed was mapped by conventional echo-sounders when a multi - narrow-beam echo-sounder was used. The detailed relief was then studied using a high definition lateral scanning sonar, especially built for the purpose and the main relief features thus found were then "visited". The physical environment of ore mining was studied over several months using ocean currentometers, temperature and salinity sensors and measurement buoys for oceano-meteorological parameters (waves, wind, etc.) linked to 'Argos' Satellite.

Simultaneously with this exploratory work, studies were being carried out into various operational mining systems.

Later, from 1980 to 1983, studies were made for mining by free shuttles, which were, however, proved to be uneconomical. A programme was then oriented towards the study of a pump-based system fitted with a motorized collector which could overcome sea-bed obstacles, Studies have also been carried out into the metallurgical processing of nodules, and three processes i.e. ammonia leaching, sulphuric leaching, and direct smelting have been closely examined.

Untill 1976, it was intended to recover only three metals, namely nickel, copper and cobalt. Recovery of manganese was found feasible by smelting or sulphuric leaching and it was therefore added to this list.

The pioneer area allocated to France by the Preparatory Commission for the International Sea-bed Authority in December, 1987, located in the

center of the North Pacific, has a total surface area of 75,000 km^2, the average depth being 4800 m. The nodules are in the form of small brown, slightly flattened balls, between 2.5 and 10 cm in diameter, and they rest embedded in the surface sediment with a very low shear strength (approx. 5 kilo pascal), and a high water content (200%). The metal content of the nodules is about 30% Mn, 6% Fe, 1.37% Ni, 1.25% Cu and 0.25% Co. On the basis of available data on the spatial distribution of the nodules, a two dimensional map of abundance of nodules and the slope of the sea-bed can be drawn using geostatistical simulation. This representation of a potential deposit facilitated development of a mining system consisting of a collector, a flexible hose, a rigid steel pipe about 4800 m long, and a semi- submersible "Catamaran" type platform. The transfer from the surface platform to the ore carriers (ships) is by lifting a dense medium (60% solid) through a 300 m long flexible pipe.

(XV World Mining Congress; Vol. II., May, 92; pp. 1301-1309.)

Trend of Open-pit Iron Ore Mining in erstwhile USSR

In the USSR, 87% value of the raw ore mineral in 1990 was accomplished by open-pit method. In the past decade, while the average depth of mining progressed from 150 m to 200 m, the average rock hardness and yield of large-sized materials increased, and the raw ore iron content decreased by 2%. In coming years, the existing ore production level is likely to be maintained by deep level development where the weighted average depth is expected to reach 300 to 330 m, of course, with added cost. An increase in mining depth by 100 m leads to an estimated increase of 25 to 30% cost per ton which, in turn, is contributed by 50 to 56% towards transportation and 25 to 27% towards drilling and blasting operations.

Effective exploitation of iron ore deposits at great depth will be done through increase of high wall slope angles by using temporary rock pillars and increased bench height upto 20 to 30 m; the latter also improves the economy of open-pit mining.

For deep open-pit mines, there is a trend to change over to cyclical and continuous method (CCM) with increased efficiency. At open-pits of the 9 mining and processing integrated works, fifteen CCM units, each with a capacity of 10 to 22 mty, treated about 170-180 mt. of rock/year. By this method, over 1200 mt. of rock mass including about 900 mt. of iron ore have been extracted.

The most significant trend in open-pit mining is the in-pit primary ore crushing and its transportation by trucks/conveyors. This is based on drilling and blasting operation followed by loading into trucks using excavators and then conveying to in-pit (portable) crushing and transferring points (CTP) equipped with a set of crushers. Railway transport units transfer the waste rock to outside dump yards. This method in openpit iron ore mines results in 20 to 30% cutting of operating costs on transportation, reduces overall ore mining cost by 10 to 15%, and improves ecological conditions, besides leading to an increased labour productivity by 20 to 25%. Moreover, use of portable crushing plant reduces the volumes of both constructional activities and stone drivages.

Since the share of expenses in rock mass transportation at some mines reaches as high as 60% of mining costs, one of the major trends in deep open-pit mining is the development on transport system. The most effective means for exploitation at deep open-pits are railway traction which are widespread at the USSR iron ore mines. Large scale of production, favourable ecological conditions and relatively low transportation cost led to further evolution of railway transport system. Augmentation of railway transport system at deep levels is carried out by change over to heavy gauges of tracks at transport inclines as well as by construction of in-pit tunnels, the main disadvantages, however, being the high capital cost and long construction period. At Sarbaiskij Open-pit Mine, for example, railway transport system was extended upto a depth of 280 m. With completion of the second tunnel, the working depth is likely to extend further upto 320 m.

Another trend in deep open-pit mining is air normalisation by effective suppression of dust and gas emission at sources, installing air conditioning systems in cabins of mining equipments, and introducing rational means of artificial ventilation for the whole mine. Increased attention to land reclamation is also a welcome trend and the USSR mining industry foresees to reclaim 900 to 1000 ha area annually.

(XV World Mining Congress; Vol. I; May 1992, pp.15-23.)

Mining Technology for the 21st Century

While the basic mining processes of breaking the rock either by manual labour or by machineries will undergo little change, computers are likely to take over a large share of the mining activities with resultant increased efficiency.

To eliminate the negative aspects of mineral extraction and to reduce environmental damage, USBM has been pursuing 'in-situ mining' and 'borehole slurry mining'.

In-situ (solution) mining or leaching will be the expected mining method for new mines in the next century, that will eliminate the cyclic operations like drilling, blasting and mucking. In this method, weak solvents are pumped down through a series of wells. As the solvents pass through, they dissolve the target metal(s) which collects in recovery wells for subsequent delivery to the processing plant. Centuries ago, the method was used in Rio Tinto in Spain to recover the naturally leached copper. In 21st century, however, with the help of computers, the flow rates in the pipelines will be monitored from a remote corner, adjusting the pumping pressure. Environmental specialists will be able to check the solutions moving away from the desired path between wells and correct the alternate schedule.

* In-situ leaching has several advantages:

* Rock is left in place after exhausting the ore bodies,

* Dumps of waste rocks are eliminated; there will be no tailing pond,

* Metals may be recovered by treating the solutions chemically.

USBM's current research work is expected to provide 'in-situ mining' technology for copper and manganese ores. Mining engineers in the 21st century are expected to design mines for stope leaching and also to retrieve metals from the old worked out mines and abandoned deposits.

Borehole slurry mining, using high pressure water jet to excavate ore from a borehole, should become widespread in the next century. Excavated ore-formed slurry is pumped to a beneficiation plant to recover the mineral concentrates, returning the tailing to the mine site back into the excavated cavities in the underground. This saves energy and minimises environmental pollution. The USBM has evaluated pilot - scale borehole slurry mining for coal, uranium, phosphates and tar sands.

While rock cutting machines will be designed with special bits which will easily cut rock according to a computer - assisted programme, microwave radiation will 'soften' any hard rock for easy cutting and sophisticated rock mechanics programme will take over the work of mine design.

By the mid 21st century, mining for nodules and deep sea mount crusts for critical metals, such as cobalt, nickel and manganese,may be done using remotely operated system. Ship-board processing will help extracting the desired minerals from the material retrieved from the sea floor. This will yield an environmentally safe waste material that can be put back to the sea floor.

Even, mining on the Moon may become a reality in the next century. Miners of the lunar base will require oxygen and water that may be more economical to produce there than transported from the earth.

(XV World Mining Congress : Vol.1; May 1992; pp.35-41)

About Fankou, the Largest Lead-Zinc-Silver Mine of China

Fankou lead-zinc Mine, located in suburb of Shaoguan in South China, is the largest Pb-Zn-Ag concentrate producer in China. In this mine, a main shaft and two service shafts have been sunk in the deposit, besides three ventilation shafts. Side dumping mine cars pulled by electric locos are used for level haulage. Ore is crushed in the underground, hoisted by skips and transported by a ropeway (1.4 km) to the concentrator.

The Karst aquifer of Upper Middle Carboniferous limestone and dolomite overlie the deposit. As early stage of mine excavation experienced repeated accidents of water inrushes, mud floods, etc. a scheme for shallow interception was adopted on the basis of hydrogeological studies and clusters of drainage holes were drilled, both from underground drifts and surface. Groundwater pumpage includes both the polluted water from stopes and drainage water from karst aquifer.

Due to the high grade of ore, the overlying karst aquifer and necessity to prevent subsidence, backfill is essential. Rooms and pillars are arranged perpendicular to the strike. Mined out rooms are first backfilled with cemented material to form an artificial sill and then filled with loose material. 'Cut and fill', 'mechanised cut and fill panel' and 'modified VCR' methods are adopted for stoping.

The Fankou ore is a complex type of lead-zinc-silver deposit; the mineral particles are fine and unevenly distributed, particle sizes being 0.04 to 1.0 mm for galena, 0.2 to 1.5 mm for sphalerite and 0.05 to 0.4 mm for pyrite with galena and sphalerite being closely intergrown. The floatability of unactivized sphalerite is, however, poor.

The mine takes enough care to protect the environment. Cyanide and sodium aerofloat were replaced by better reagents so as to eliminate poisonous source. While waste rocks are used for backfilling, the waste water is treated to meet the national effluent criteria. Sufficient noise control measures have been taken by putting rubber liners in mills. Noise absorption devices are used in exhaust ventilation shafts to bring down the noise level to 85 db. About 30% of the total mine area has been brought under afforestation, the rate of survival being reportedly about 94%.

(XV World Mining Congress; Vol. II, May, 1992; pp. 917-926.)

CONSERVATION

Development, Utilisation and Conservation of Minerals in China

China, though rich in mineral resources in general, has more of low grade and less of high grade minerals. The "Mineral Resources Law" of the country requires that the state shall practice the policy of unified planning, rational distribution, comprehensive exploration, rational exploitation, and comprehensive utilisation.

So far as non-ferrous metallic minerals are concerned, about 70% of the 400 state-operated mines have conducted comprehensive utilisation of ten kinds of minerals to different extent. Majority of the combined mining, ore dressing and refinery enterprises have attempted comprehensive recovery of valuable elements, even though recoveries achieved have lagged behind the world standards. Some of the large mining companies in China have, however, achieved remarkable economic results after comprehensive utilisation.

Iron ores in China contain elements like vanadium, titanium, rare earth, tin and copper. But the comprehensive utilisation of iron ores in China is at a low level as in many steel and iron complexes ; only vanadium and titanium are recovered. While the recovery of titanium is often less than 10%, that of vanadium slag (containing 15% V_2O_5) is only about 40%. However, in one mine of Hubei Province, substantial quantities of copper, gold and concentrates of cobalt can be recovered per year. In the process of refining, while zinc, tin, cadmium and bismuth are recovered from smoke dust, cobalt is recovered from furnace slag.

Apart from coal, China is very rich in non-metallic mineral resources also of which more than ten minerals hold leading positions in the world, but they are mostly sold as raw minerals.

For rational development, utilisation and effective preservation of China's mineral resources, the following steps are called for,

* Intensive education and improvement of the sense of rational development and utilisation of mineral resources.

* Good planning of mineral resource development and macro control of the development and utilisation of mineral resources. Details for short-term and medium-term development as well as long-term preservation need be specified.

* Comprehensive management of mineral resources.

* Greater use of mineral saving technologies.

* Rigorous implementation of "Mineral Resources Law" of the country.

(XV World Mining Congress ; Vol. II; May, 92; pp.1501-1506)

MINERAL BENEFICIATION

Acid Leaching of Beleida Copper Oxides, Germany

Acid leaching of copper ore has been practised in Germany since the16th century. During the 20th century, further efforts were made to adopt copper hydrometallurgy to meet the current economic need. In case of copper oxide ores of Beleida, the leaching methods tested are : dynamic leaching heap leaching, in situ leaching, static vat leaching, and thin layer leaching.

Dynamic leaching is an interesting process with regard to metal recovery. 'Heap leaching' and 'static vat leaching' with copper recovery through filtering have not been satisfactory as a lot of slime is produced by the ore. Thin layer leaching consists of sintering the ore with concentrated sulphuric acid. Besides the above, the 'digestion washing decantive technique' - a variation of 'vat leaching' has proved to be a quicker process.

During research for the treatment of Beleida ore, sulphuric acid was chosen as a leaching agent, the main reasons for the choice being the moderate price of sulphuric acid, less corrosion problems and the possibilities of producing copper sulphate. One such method, namely the 'DWD (ONA-REMINEX) method consists of keeping ore immersed in an acid solution. It provides a more homogeneous spreading

of the reagents within the ore, cuts down on water evaporation, and gets rid of acid fog.

After a -10 mm blending, the ore is submerged in an acid solution in an ONA reactor for treatment in seven phases. The waste is sent over some curve sifters to complete the washing phase and to eliminate the water of lumps travelling on the conveyor belt on their way to waste heap. Any matter getting through the curve sifters is sent in a thickener for the recovery of copper solutions. The ticketed slime is pumped out to the dike. The solutions contain an average of 9 gm/l of copper.

The process can be applied to moderately carbonated ores that present problems such as slime production. This is also used for treatment of non-porous ores. It has technical advantages such as greater and quicker copper recovery, loss of liquid due to negligible impregnation and a high copper content in the effluent solution.

Currently, grinding at 5 mm instead of 10 mm is being considered in order to increase the production of copper dissolution. On a pilot scale, grinding at 5 mm enabled 10 points gain in metal production.

(XV World Mining Congress ; Vol. II; May 1992; pp.789-799)

ENVIRONMENT

Environment Aspects Concerning Closure of Mines in Finland

The mining industry in Finland is relatively young as compared to most other European countries. Further, most mine life spans have been quite short and their metal contents rather poor. The most active period was during the seventies when several limestone and other mines were in operation. At the end of this century, only a few mines, including some gold and sulphide ore mines, may be in operation.

Provisions of four major acts are to be complied with when a mine is to be closed down. They are : the Mining Act, the Water Act, the Waste Management Act, and the Dam Safety Act. The Mining Act stipulates that the mine site has to pass general safety conditions like sealing of all mine entries, and fencing of open pits and areas on the surface in which subsidence may take place. Where future use of the areas on surface for housing or industrial purposes is envisaged, authorities concerned may require determination of magnitude and continuity of past mining subsidence precisely.

The waste dumps and tailings disposal areas will have to be landscaped. In Finland, a closed mine may gradually get filled with water. The waters flowing from the mines, which may contain heavy metals, are the mine water and that percolating from waste dumps and tailings disposal areas. The formation and spread of these waters is prevented by covering or neutralising the areas and the water. These actions may continue years after closure of the mine in accordance with the Water Act.

According to the Waste Management Act, other solid or liquid wastes must be delivered to the designated places on the eve of closure of a mine. The act also prohibits littering which means that all extra scrap and refuse must be cleaned away. Hazardous wastes have to be delivered to a hazardous waste treatment plant before closing a mine.

The Dam Safety Act requires that all tailing disposal ponds and other basins must be emptied and that the dams must be discharged.

The environmental effects of underground mines which are on the verge of closure or have already been closed down are subsidences on the surface above the areas stoped out. Seepage of water has complicated the problem further.

A possible environmental problem on the surface is dissolution of heavy metals caused by sulphate developing from oxidation of sulphides caused by water and air. In order to prevent this phenomenon, the tailing disposal area and pyritic waste dumps are covered with a 30 cm thick layer of moraine, clay or sod.

So far there have not been any major environmental problems in Finnish mines, as the duration of mining activities have been rather short, and as the mines have been abandoned only recently. Oxidation and metal dissolution from mines closed in fifties have been observed. Finnish authorities have just started examining the problems so as to adopt suitable abatement measures for closing and already closed mines.

(XV World Mining Congress; Vol.II ; May 92 ; pp.1055-1063).

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EXPLORATION

Diamonds in Arctic Canada

After diamond discovery in India (1700s), Brazil and Africa (1800s), Russia and Australia (mid-1900s), it is now the turn of Canada.

Following the discovery of uneconomic deposits of Kimberlites to the west of the Mackenzie River area of Mackenzie District of Northwest Territories (NWT) of Canada and also in alluvial material near Blackwater Lake around 1980, two Canadian geologists initiated a systematic heavy-mineral sampling programme. The same was concentrated encompassing the central part of the Archean Slave Structural Province. This led to the discovery of diamonds at Lac de Gras area, 210 km south of the Arctic Circle and 320 km north-east of Yellowknife, capital of the NWT.

Then in 1990, a joint venture agreement was formed between Dia Met Minerals Ltd. and BHP Utah Mining Ltd. to pursue the exploration further. In October 1991, they struck a fairly rich Kimberlite beneath Pointe Lake, a body of water about 24 ha in size.

In February/March 1992, BHP/Dia Met drilled 32 vertical, wide diameter reverse circulation holes on Pointe Lake and collected 160 t cuttings. Since summer/fall of 1992, three companies, namely BHP/Dia Met, Monoprops, and Kennecott - Aber - Southern Era-Commonwealth Consortium continued the exploration at Lac De Gras, which led to the discovery of several Kimberlites. While further work will reportedly continue in 1993, the Kimberlites confirmed to date provide a meaningful starting point to suggest that Kimberlites will in time be found over much larger area.

(Mining Magazine; December 1992; pp. 379-383).

Lithologic Mapping in Vegetated Terrains

In approaching the idea of using remote sensing techniques for lithologic mapping in vegetated terrains, one must, of necessity, cross discipline boundaries.In leaving the relatively straight forward situations of mechanical weathering, little soil development, and low vegetation cover that are obtained in arid areas, the researcher faces an interweaving of ecological,geological, pedological, and botanical factors that must be unravelled in order to interpret and understand remote sensing data. Whereas the primary objective might be the extraction of geological information, ecological understanding follows naturally in the process.

The geological remote sensing community is aware of the potential, as well as the complications, associated with geobotanical remote sensing mapping efforts.And whereas efforts are made to remove the spectral contribution of vegetation, primarily in areas of low vegetation, in order to leave as residual the lithologic information of interest when attempting lithologic mapping.The vegetation present even in nominally vegetated areas indicates the overall ecological potential of an area given its climatic and edaphic conditions.The vegetation should not be disregarded but, rather, should be understood.Only in this way can remote sensing mapping efforts in heavily vegetated areas progress to the status of a useful geological technique.

In most cases, geobotanical remote sensing mapping efforts will involve collaboration among researchers having complementary specializations. For example, the areal extent of terrestrial biomes is not well documented, and the global information that is available is from limited study sites. The available information is complicated further by the dynamic nature of the spatial distribution of vegetation as a result of desertification or clearcutting. Lithologic mapping efforts that attempt to use and understand

the vegetation information cannot help but expand understanding of the global biome distribution by contributing to the knowledge of small sites.

Knowledge of the relationships between type and the distribution of tree species within different biomes, as well as how such relationships might differ among biomes, also can contribute to the understanding of the dynamics of biome ecosystems. In each of these biomes, it was found vegetation-bedrock associations that were of potential use for lithologic mapping using remotely sensed data.
(Episode; Vol.15, No.1; March, 1992; p. 85.).

Monitoring Recent Active Tectonic Activity for Satellite Data

In 1987 the CNRS-INSU, a French research funding organization, created the Tectoscope-Positionement programme for promoting the use of high spatial resolution satellite data (SPOT)and positioning systems in tectonic studies.

The 10-m size of the pixel allows precise mapping of fault traces and a good estimate of horizontal offsets. A horizontal displacement rate that is higher than 1 cm/y leads to significant offsets of landforms, such as rivers and drainage patters, moraines, and glacier valleys, after only a few thousand years, and these offsets can be observed and measured on SPOT images. If the age of landform can be estimated reasonably, a displacement rate can be obtained. Good illustrations of this method have been given in a map showing the displacement rates of faults in Asia. These data combined with classic field observations and measurements and an analysis of focal mechanisms are essential for understanding contemporary strain fields.

France's SPOT satellite also offers the possibility for obtaining stereographic pairs of images that help us to make a three dimensional analysis of surface structures at various scales. This is especially useful where the topography is controlled directly by deformation and is not altered strongly by erosion. The project also incorporated previous results determined from the Global Positioning System. These data, in addition to classic geodesy and paleomagnetism studies, have been used to assess the recent, active deformation, in the Afar triangle.
(Episode; March 1992; Vol. 15; No. 1; p. 83)

MINING

La Aurora : Dawn of New Mining Era at Charcas, Mexico

Charcas with an average output of 85,000 mt/year zinc concerntrate is the leading zinc producer of the IMMSA group in Mexico. With the principal primafy minerals, sphalerite, galena, chalcopyrite and pyrite, mining first started on the outcrops of the Leones and Santa Isabel veins as early as 1583. Silver was recovered from the upper oxidized zones. By 1870, the oxide ores had been depleted, so the only available ore source was sulphide ore. With the innovations in the technology the company started its first flotation plant in 1911.

With the taking over of the full charge in 1974, IMMSA group concentrated more on exploration. Today Charcas has reserves of 17 million mt. ore, grading 60 gm/mt silver, 0.41% lead, 0.22% copper and 5.41% zinc. Two types of concentrates, viz.lead @ 7000 mt/y which also contains copper, silver and zinc @ 85,000 mt/y, are produced.

The mine operates three separate vein sections interconnecting, San Bartolo,Rey Y Reina and La Aurora. San Bartolo being the oldest, it has very limited reserve. It produces at the rate of 500 mt/day by cut-and-fill stoping. Rey Y Reina section produces 2000 mt/day while La Aurora, the youngest of the three sections, contributes at the rate of 1000 mt/day ore from its mechanised room and pillar operations.

The deposit of La Aurora dips at 30^0 and is variable in width, maximum up to 50m. The deposit is 400m long and extends over 300 m vertically. A complex ramp was first developed in the footwall orebody. Access ramps at 6m vertical interval was driven. Ore is mined by room and pillar mining, using a 12m square room 6 m square pillar.

First heading is driven for a size 3.5mx 3.5m and is then widened out to 12m width. The horizontal drilling is used to mine downwards in succession to the footwall. Extracting three 6 m benches in this way presents no problems as far as the pillar stabililty is concerned. The La Aurora section has three jumbos for both development and benching. Of these Secoma mercury 14 is equipped with a standard development boom and Hydrastar 300 hydraulic drifter and has been very useful in advance development headings.

In the section each 300 cubic metre bench blast produces 900 mt ore with an intention to increase the production capacity to 2000 mt/day.After the mining of the stope to the footwall, it is filled with both development waste and mill tailings.The tailings from both the concentrators are combined and classified.The sand fraction is returned underground as fill at 85% solids. Fill passes are raisebored from the surface into each stope block. The central access

ramp is then recovered and filled before the next stage of mining starts upwards from the surface of the fill.At this stage about 20 m of ore remains in the hanging wall.

The mine has a mixed fleet of LHDs and 5 underground trucks of Jarvis Clark JDT 426 for haulage of the ore.

(Engineering & Mining Journal; May 1992; pp. 16 F- 16 H)

MINING MACHINERY

Flexible Mobile Conveyor - a new Addition to 'In-pit' Crushing System

Nordbeg Australia has introduced a mobile conveying system, 'Lokolink', as they call it, to carry the crushed material from mobile self-propelled 'in-pit' crusher to stationary secondary crusher, installed outside the pit. The 'Lokolink' system comprises 36 m long sections of electrically powered, wheel mounted belt conveyors, and can handle material sizes up to 400 mm @ 300 to 1200 tph. The conveyor is fabricated from tubular steel in a lattice construction. Each section weighs about 10 t and can operate at a maximum inclination of $\pm 8^{o}$. Adjacent sections can operate at any angle within a 300^{o} arc, in relation to each other,thereby adding much flexibility to the system. Each section keeps a minimum ground clearance of 1.8m.

Being mobile, the conveyor system can easily follow the primary crusher as it moves along the mine face or retreats to a safe distance from the face during blasting. The conveyors can be moved, section by section, or in combination of two or three sections, using the motive power of the in-pit primary crusher itself or from other external mobile plants. Conveyor belts upto as much as 1200 mm wide have been used for the system.

The first such 'Lokolink', installed at a limestone quarry in U.K. transporting 150 mm size crushed ore @ 600 tpa, has successfully replaced 35 t payload dumpers, thereby improving economy of the transport system.

(Australian Mining; Jan/Feb.,1993, p. 56)

Rock Breaking by Hydraulic Hammers

Increasing public pressure to reduce shock waves, noise, dust and physical risks involved in the use of explosives has led the users to think for the fast and efficient hydraulic hammers breaking oversize rock and to cut rock directly from the mine faces. The use of hammer/excavator combination for the purpose has proved to be popular.

After obtaining the first patent for the hydraulic hammer in 1963, Krupp manufactured machine operated hydraulic breaker HM400 1967. Krupp then slowly developed its hammer design. Hammers available in the market are powered on the impact stroke by oil, by gas and by a combination of oil and gas.

Hydraulic hammers, ranging from 50 to 5000 kg, act under very high stress to strike against the material to be broken under enormous bending loads which are frequently imposed on the chisel. The vibration loading on the chisel is also compounded by high mechanical stresses. For this the chisel has to be made to very high standards of material, manufacture and heat treatment.

The problem like seizure of working of the chisel in its bushing has been improved by using automatic lubrication system. Like the chisel, fasteners are also required to be designed to the high standard of material selection, manufacture and heat treatment. These hydraulic hammers produce noise from 75 to 105 dBA which is under the continual improvement with their R & D work. Use of vibration insulation on the hammers to reduce the strain on the machine operation is another noble step taken to reduce the environmental problems.

One such G 100 hammer, designed by Rammer for primary excavation work in quarries and tunnelling has a maximum hydraulic power input capacity of 96 KW. A noise-damped version of the G 100, the 'G 100 city' is specially suitable for working in built up areas.

Maintenance of these hammers is easier. G 100 hammer can also be modified for use underwater.

(The Century Cement Limestone mine in Raipur district and Arasmeta Limestone mine in Bilaspur district, both in Madhya Pradesh, are known to have used hydraulic hammers (imported) as attachment with CK 90 Poclain hydraulic excavators.)

(World Mining Equipment; Feb. 1993; pp. 22-24.

Kvernex Bolt-on Wear Part System

Kvernex bolt-on wear part systems which are made from special abrasion resistant steel was found to be very appropriate to excavator buckets. The Kvernex system comprises a front plate or plates welded on to the bucket, and the teeth or other wear parts (which may be reversible) are bolted on to high performance bolts.

Kvernex wear parts result in good penetration and last two to three times more than their conventional counterparts. After it wears out, the part can be replaced or reversed depending upon the condition.

Kvernex system along with its parts has been fitted to buckets with operating weight from mini size up to 100 t. The wear parts, fitted with 60 mm high tensile bolts, are heat treated which normally give following life :

Centre teeth	-	1,616 hrs.
Outer teeth	-	3,358 hrs.
Shrouds	-	4,430 hrs.

In a case study out of total 5,869 hrs., no downtime due to bucket problems has been experienced.

On a trial run where Kvernex system was fitted to a 10.6 m^3 bucket on an O & K RH120 at the Titania mine at Tellnes, south-west Norway, the machine loads about 3 million t/y of granite overburden into five 130t Komatsu HD 1200 M trucks.

In another small scale development of Kvernex system, it was found that its welded-in section could reduce the cost of making a bucket by 15%. Successful trials have been completed with trenching buckets from 300-900 mm fitted to JCB and Cat machines.

(World Mining Equipment, Dec. 1992; pp. 17-18)

Modern Dewatering Pumps

Grindex AB of Sweden, since 1960, has set new standards in performance and efficiency in different ranges of portable dewatering pumps.

Through its continuous development, the company has seven models of drainage pumps with capacities up to 14,000 litres/min. and heads of 100 m.

Grindex submersible pumps have combined many features for strength and durability. Surveillance of Motors and Rotation system provides three way motor protection for improved performance :

* Use of the special ROTASENSE device ensures that the pump always works in the correct direction.

*In the event of power failure in any one of the three phases the pump stops immediately, but will restart automatically when the fault is repaired.

*The pump has high security from overheating.

In the absence of constant flow of water at source, when pump begins to 'snore', a special 'air cooling valve' opens. It thus allows the impeller of the pump to act as a fan and circulate cooling air to the motor, bearings and seals, which allows the pump to run dry. Float switches, mounted on to the pump, are regulated by the Surveillance of Motor and Rotation system, help controlling the level of water in some dewatering system.

(World Mining Equipment; Feb.1993; p. 3)

ROCK MECHANICS

Yieldable Supports for Controlled Deformation

Rock movements, although unwanted, are recognised as a necessary evil and often a desirable phenomenon for stress release. Indeed, the magnitude of deformation itself is a measure of the existing level of safety. With principal objectives of (1) controlled stress release, (2) a safety indicator, and (3) an economic support system, yieldable supports provide roof support, though temporary, adequate enough for mining activities.

In addition to their standard properties, i.e. yield, ultimate strength and elongation, the axially loaded elements in yieldable support system must have values relative to their maximum deformation capacity, and a load deformation curve indicating the 'unlocking' load.

'Dywidag system' offers such an yieldable roof bolt. The yieldable bolts are distinguished by their variable load deformation curves, thus allowing the user to select properties which best suit a particular problem. It comprises a hot rolled bar with sliding nut which deforms the bar while sliding without affecting its ultimate strength. As load on the bolt reaches the pre-determined level (the unlocking load), the sliding nut encounters a stop nut, after which the anchorage attains the full capacity of the bolt before breaking. The magnitude of allowable deformation can be pre-determined by either choosing an appropriate length of bar extension or adjusting the position of the stop nut. A visual inspection of the distance between the sliding nut and the stop nut provides valuable information concerning the amount of rock-mass deformation.

High roof stresses can be released if controlled deformation along shear planes can occur without disintegration of the rock mass, and yieldable roof bolts do provide an appropriate solution to such problems.

(Engineering & Mining Journal; December, 1992; p. 34)

MINERAL BENEFICIATION

Gold Recovery by High Gravity Concentration

Worldwide gravity separation is responsible for concentrating a greater tonnage of minerals. A new gravity concentrator "Falcon Concentrator" is now being tested to recover ultrafine gold. This new concentrator can develop much higher centrifugal force of about 340 G (340 times of normal gravity). In contrast the well known Knelson concentrator produces only about 60 G.

Pulp is delivered to the small diameter of the cone and centrifugal force immediately separates the pulp into its two components - water and solids.

The solids are pinned to the cone wall forming a compact blanket. Because of the solids it moves progressively towards the larger diameter and ultimately to discharge. During this upward and outward progression, the blanket of solids diminishes in thickness.

Light particles are drawn into the pulp stream by the overlying layer of fast-moving water and pass out with the tailings. The heavy minerals are retained on the cone wall and accumulate in a cylindrical end-part of the cone which is so moulded to retain them.

In the batch mode, the machine will run from half-an-hour to two hours, the rpm of the cone is then reduced to coasting speed and concentrates flushed to discharge using an internal spray bar.

(Canadian Mining Journal; April 1992; p. 21)

Zinc Production - The Warner Process

The arrival of a completely new route from ore to zinc metal is a rare event for the zinc industry. The route described here has been extensively researched and is now ready to be taken on through to commercialisation. The route is applicable to all sulphidic deposits and the principal objective is to raise the added value of the minesite products. The key to the new route is the Warner Process. The process is used in conjunction with standard or existing ore milling and permits metal to be made at the site.

THE WARNER PROCESS

The Warner Process was invented by Professor Noel Warner of the University of Birmingham, U.K. and has been developed under his direction at the University over the past ten years. Two particular features of it distinguish it from all other routes from ore to metal :

Zinc sulphides are converted to zinc metal by the reaction :-

$$ZnS + 2Cu \text{-------} Zn + Cu_2S$$

This takes place at temperature of about 1,200° C. This route is unique amongst zinc smelting processes, in that it does not go via an oxide phase to metal and thus does not require the purchase of large amounts of energy (as electric power or metallurgical coke) for reducing the dioxide to metal.

Heat released in oxidation of copper and iron sulphides is sufficient to sustain the whole operation. The heat is transferred from the oxidation zone to the non-oxidising melting zone by circulating liquid copper matte.

These two features together mean that there is no need, as at present, to locate the metal-producing facilities where large source of low cost energy are available - metal production can supply of feed or the product markets or the environmental requirements. The economic potential for the zinc industry in this new freedom in location should be welcome.

It is also a feature that by melting the feed under non-oxidising conditions a slag is formed of the gangue minerals which is low in zinc (1%). A higher ratio of gangue to zinc minerals can thus be tolerated than is permitted in zinc concentrates for shipment to distant smelters. This in turn permits a flotation mill to be operated for high recovery with little penalty on lower concentrate grade. Iron sulphides in the ore are a source of heat from the oxidising zone so that high iron infeed is not a limitation; iron is discharged as a second slag. Iron slags are easier to dispose of cleanly than leach residues.

(Mining Magazine; January, 1992; pp. 15-17)

MINERAL PROCESSING

Modular Processing Plants

Modular processing plants are trailor mounted plants which are transportable. These modular beneficiation or processing plants are small scale plants which are convenient and cost effective. These are prefabricated plant modules, usually for installation in remote locations.

The modular construction can cut the capital cost by upto 20% and shorten the construction time by as much as 50%. Another advantage is the higher salvage value of a modular plant. Machines in a conventional stationary plant are difficult to relocate

when the plant is shutdown, while modular plants can easily be removed and refabricated. Modular plants are also very advantageous to move and work in locations with severe climatic conditions.

A number of international companies manufacture and supply modular plants. Some of them are :

1. Birtley Engineering Limited.
2. Carpco Inc.
3. Dowding Reynard & Association (Pty) Ltd.
4. IHC Holland NV.
5. Knelson Gold Concentrators Inc.
6. Mineral Deposits Limited.
7. Placer Recovery Systems, Inc.
8. Richards Engineering Limited.
9. Sala International, Allis Mineral Systems.
10. Separation Products Ltd.
11. Van Eck & Lurie (Pty) Ltd.

(Mining Magazine; July 1992; pp. 37 to 43)

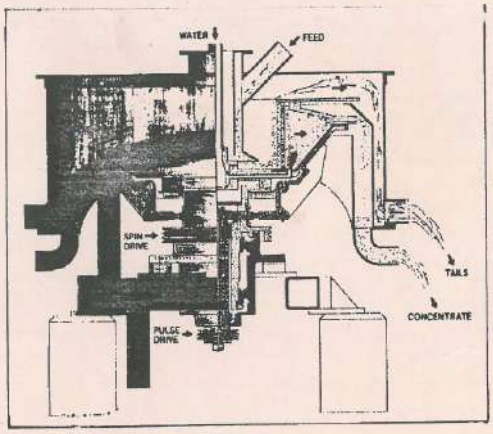
Kelsey Jig

This is a gravity separation device. Its concept incorporates all the parameters of a conventional jig plus the ability to vary apparent gravitational field.

In essence, the Kelsey jig takes a conventional jig and spins it in a centrifuge. The ability to change the apparent gravitational field enhances recovery of minerals in the fine size ranges. This is achieved by variable speed control of a spinning rotor, inside which a parabolic shaped screen is spun co-axially together with the rotor. The screen is lined inside with "ragging" material which is spread evenly over the inside surface of the screen. Feed pulp is introduced through a fixed control annular pipe. Variations in feed rates and ore size range do not have an adverse effect on jig operation.

Kelsey centrifugal jigs offer high recoveries in 5 to 500 micron size range, extended recovery ranges, etc., and is much suited in off-shore and dredge type operations. Models range from the largest capacity 150 tph down to the bench-scale models for laboratory testing. Minerals currently being treated in the jig include tin, beach sands, gold, iron ore, coal, platinum, lead and manganese.

(Mining Magazine; August, 1992; p.114)



Schematic diagram of the model J650 Kelsey Centrifugal Jig

ENVIRONMENT

Environmental Impact of Mining in Ghana

The Ghanian Environmental Protection Council (EPC) issued draft guidelines for Environment Impact Assessment (EIA) in July 1989. Since then each proposal for a new mine is required to be accompanied by an EIA. The Mineral Commission of Ghana has in turn required that EIA of each new mine be approved by the EPC as precondition of its recommendation to the Land and Natural Resources for the grant of mining lease.

A draft National Environmental Policy was prepared and six committees including one on "Mining, Industry and Hazardous Chemicals" were appointed to assist in the development of national Environment Action Plan which was formulated in 1990.

However, a formal framework and guidelines regarding the conduct of mining companies in environmental matters do not exist. In order to remedy the omission, the Government commissioned a study on the Effect of Mining on the Environment, as a part of the Rehabilitation Programme of the Mining Sector. The study was undertaken under the auspices of the Mineral Commission in November/December 1990.

It was found that the total disturbance to land caused directly by the existing to large mines was about 0.025 per cent of the country's surface area.Over the years of mining operation, damage to land was equivalent to one third of the current annual rate of deforestation, and was therefore, extremely small since all new mines are surface mines, there will be higher ratios of land loss.

Only one of the established mines was found to have implemented rehabilitation measures since its inception.

Dust, sulphur dioxide and arsenic trioxides were found to be the only significant mining related effects on air quality.The effects of serious water pollution were observed down stream of two of the mines where there were no effective pollution controls.

(Natural Resources Forum; Feb.1992; pp. 49-53)

The Berlin Guidelines

A series of discussions in the Berlin Round Table conference expressed that worldwide long-term economic development can be achieved through sustainable development policies.This should comprise a balance of economic, socio-cultural and environmental protection measures. Sustainable mining activities under apropriate environmental guidelines are based on the interaction between industry, governments and the public.Their goal was directed towards optimizing economic development while minimizing environmental degradation.

Addressed to the Mineral Sector

Government, mining companies and the minerals industries should as a minimum,

i) recognize environmental management as a high priority area,

ii) establish environmental accountability in industry and government,

iii)encourage to recognize individual responsibility for environment management,

iv) ensure active participation on environmental aspects of all phases of mining activities,

v) Seek to provide funds to improve environmental performance,

vi) adopt risk analysis land risk management in the development, design and operation of mining activities,

vii) reinforce the infrastructure, information system service, training and skills in environmental management,

viii) recognize the linkages between ecology, socio-cultural conditions and human health and safety,

ix) evaluate and adopt policies to encounter the reduction of pollutant emmissions and the introduction of innovative technology,

x) explore the possibility to reduce trans-boundary technology,

xi) encourage long-term mining investment by having clear environmental standards with stable and predictable environmental criteria and procedures.

Addressed to Development Assistance Agencies

In developing nations multinational and bilateral assistance agencies can play an essential role in environmental management. While according high priority to the mitigation of environmental degradation associated with mining they should intimate special support to improve environmental capacities.

In supporting mining projects, agencies should also take into account the,

* rehabilitation of displaced population
* environmental history of the country
* large scale impact on socio-cultural patterns
* overall economic balance of the project vis-a-vis its total environmental impact.
* impact on other natural resources and ecologically sensitive areas.

Agencies should promote conferences and policy research on environmental management practices and technologies and ensure the dissemination of this information. They should support and promote regional co-operative programmes to achieve sustainable development of mineral resources. Environmentally safe methods of mining should be adopted. Agencies should also increase and co-ordinate their assistance to developing nations in the field of environmental policies management.

('INTERNATIONAL ROUND TABLE CONFERENCE ON MINING & ENVIRONMENT'; Jointly organised by UNDESD and the Development Policy Forum of the German Foundation for International Development in Berlin; June 1991)

Tara's Environmental Success

Tara is an underground zinc-lead mine in Ireland sited in a rural residential area of population 16,000 and adjacent to productive farmland. The orebody itself lies at the confluence of two rivers. The first Environment Impact Study was carried out in 1971 much earlier to the commencement of production in 1977. Since the commencement of mining activity, the mine has operated within the imposed constraints. Out of 70,000 blasts since 1973, each one of which was monitored, there have been marginal infringements only in 0.01 per cent cases. There have been changes in the ownership of the mine but the original principals have been adhered to.

The first phase of comprehensive environmental audit was completed by an independent environment development group. Phase two of the audit was to complete in 1992. Tara, through the years has consistently maintained its position at the leading edge of environmental technology and has pioneered many aspects of monitoring particularly vibrations, noise, effluent discharge, tailings, revegetation, soil and herbage surveys. Constant updating of environmental control system has been special features.

Tara mine has received accolade of the 1991 Sunday Independent/Ulster Bank Environmental Award, in recognition of its continuing commitment to environmental preservation and protection.

(Mining Magazine; June 1992; pp. 343 - 344)

OUR FORTHCOMING PUBLICATIONS

1. Bulletin on Precious & Semiprecious Stones, Volume I : Diamond.
2. Bulletin on Precious & Semiprecious Stones, Volume II : Coloured Gemstones.

RECENT ARRIVALS IN CENTRAL LIBRARY, IBM (As on 30-6-1993)

Publications

1. U.K. World Mineral Statistics, Vol. I & II, 1986-90
2. U.S.B.M. Minerals Yearbook Vol. I &III, 1990 which include -
   i) Minerals in World Economy
   ii) Mineral Industry of Middle East
   iii) Mineral Industry of Asia & Pacific
   iv) Mineral Industry of Africa
   v) Mineral Industry of Europe
3. Indian Petroleum & Natural Gas Statistics, 1990-91
4. Facilities, Incentives, Policies & Procedures for 100% Export Oriented Units
5. Gem & Jewellery Yearbook 1991-92
6. Introduction to Mineral Economics

Reports/Souvenir

1. Beneficiation & Industrial Utilization of some Fertilizer Minerals of Madhya Pradesh - Progress Report No. 2 (Sponsored by Department of Mines, Government of India) Issued by Regional Research Laboratory, Bhopal.
2. Mine Environment & Mineral Conservation Week 1993.- Souvenir
3. Report on Preliminary Investigation for Tungsten, Nagpur District (Saongi Block)
4. Report on Preliminary Investigation for Tungsten, Nagpur District (Borkipeth Block)
5. Report on Primary Tin in Bathapara Block, Bastar District, Madhya Pradesh

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EXPLORATION

Tanzania's Geological Mapping

Tanzania's geological and mineral database has been assembled over the past 60 years. About 70% of the country is covered by geological mapping on scales of 1:125,000 or larger, and the whole country has been covered by airborne magnetics, radiometrics and VLF-EM. Countrywide aerial photography and gravity data are also available. Most of the information is available from the Mineral Resources Department at Dodoma.

For the purpose of geological mapping, Tanzania has been divided into 322 quarter - degree quadrangles; of these, 233 have been mapped on a scale of 1:125,000. The remaining are available in draft form. Topographic maps covering the whole country on the same quarter - degree grid have also been produced.

A complete airborne geophysical survey was carried out in the late 1970s. Magnetic, VLF-EM and rediometric data were gathered, from which a series of 1:100,000 maps covering all 322 sheets has been prepared. Each sheet is covered by nine maps showing different data.

Gravity data are concentrated in a number of specific areas which also include the coastal basins. The Mineral Resources Department also maintains a core library that contains cores and chip samples from nearly 100 drilling programmes.

(Mining Journal; April, 1993; pp. 3-4).

Cooperative Earth Observations For Environmental Applications

World governments and industries will expand resource development, along with its incumbent environmental impact, in order to accommodate a global population that will go up by 30 percent by the year 2010. Earth Observation Satellites have demonstrated their capabilities for mapping world resources and for monitoring global environmental changes. Industrialized, satellite-producing countries are developing advanced Polar-Orbiting Platforms such as the Earth Observing System (EOS) of the U.S. National Aeronautics and Space Agency Administration(NASA) and similar systems of the European space and Japan.

These systems will conduct extensive satellite observations of the Earth for resource development, as well as for global change studies. This will lead to better environmental management policies for both governments and industry. These EOS programmes will create extensive volumes of electro-optical, microwave, and radar satellite data in massive digital data bases that will be used for basic scientific and applied research in geology, hydrology, agriculture, oceanography, meteorology and environmental science. Data-base management, information extraction and user access to data are major issues now under review.

Subsequent to the initial proposals for the Polar Orbiting Platforms, their use in providing long-term measuring and monitoring capabilities for studying global environmental changes and man's impact upon these changes has become the centerpiece in the growing international popularity of the concept of "Mission to Planet Earth". A major thrust for the use of these data is the U.S. Government's "Global Change Research Programme", is to be prepared annually by the Committee on Earth and Environmental Science (CEES).

The resource industries, such as the petroleum, mining, agriculture, timber and fishing industries, contribute to man's impact on natural global change. Thus industry has a major stake in the U.S Global Change Research Programme. The Geosat

committee working with the CES in order to develop the linkage mechanisms for establishing cooperative industry-government-academic research on the applications of earth observations for global change studies and environmental management. As a first step, the Geosat committee is working to inventory current industry research that will determine where industry and government cooperative initiatives might best begin.

(Episode ; Vol 15, No.1 ; March, 92; p. 85).

MINING

Rampura-Agucha Mine of HZL

Located at a distance of 225 km by road southwest of Jaipur, the present deposit of Rampura - Agucha was discovered by a state geologist way back in 1977. Drilling and proving the ore body first started by the Hindustan Zinc Ltd. in February 1980 and subsequently by SNC, Canada in March 1982.

With the initial development work started in November, 1988 at Rampura-Agucha for an open pit mine, the first ore production began in March 1991.

The general strike of this shallow-depth deposit is NE-SW, stretches along 1.2 km long and the dips near the surface are fairly steep towards the southeast. Based on the 18,095 m of surface drilling in 133 boreholes which covered an area of 1,550 m along strike and 370 m vertical depth, the proved reserve was estimated to be 39.18 million tonnes. The grade was analysed as 1.90% lead and 13.28% zinc. The probable and possible reserves were subsequently estimated as 13.8 million tonnes and 10.7 million tonnes respectively.

MINING

The present extent of the openpit is 1,400 m long by 600 m wide by 40 m deep, while the planned ultimate pit will be 1,600 m long by 700 m wide by 250 m deep.

The pit is worked in 10 m benches using a berm width of 6.4 m. The face inclination of individual bench is 70^{o} while the overall pit slopes are 36^{o} on the footwall side and 40^{o} on the hanging wall side. The gradient of the haul road has been maintained at 1 in 16. 165 mm diameter six DTH drills of 395 hp each is employed to drill 11.5 m deep holes with a spacing being 4m x 4m in hard rock and 5m x 5m in soft rock. About 66% of the hole depth is charged with explosive. Electric detonation is used. The overall powder factor achieved is 0.185 kg/t. The blast hole samples are analysed and accordingly blending plans are prepared. Average ROM grades are maintained at 1.66% pb, 12.00% zn. The mine is operated in two shifts/day and the ROM production is on an average, 900,000 t/y of ore and 1,400,000 m^3/y of waste.

Five BEML (Bharat Earth Movers Limited) PC 650 (410 hp) hydraulic excavators are used for loading. These are equipped as back-hoes fitted with 2.8 m^3 buckets and two as front shovels with 3.8m^3 buckets. Haulage is undertaken by a fleet of 16 Haulpack LW 50 trucks. Average haul distances are 1,500 m with ore, 2,000 m with waste.

Supporting equipment are four BEML D-355, three track dozers, one BEML wheeled dozer, one HM/2071 front end loader; two BEML 1NS WS water sprinkler trucks and two BEML GO-650-R-2 motor graders. The grade of feed to the mill is controlled by blending.

PROCESSING

ROM ore is crushed in a primary gyratory crusher to (-) 150 mm(90%) and then stockpiled. Ore drawn from this pile is sent through standard cone secondary crusher via a double deck vibrating screen. Primary grinding is arranged in two parallel streams. Fine ore (-) 19mm which is stacked in fine ore bins is delivered to two primary wet grinding rod and ball mills. The slurry discharge is sent for classification, the coarse under flow from both the stages of cyclones being returned to the ball mills. The final hydrocyclone overflow from both grinding streams passes to the lead conditioner ahead of flotation.

Pulp from lead conditioner is sent to a single flotation stream consisting of scavenger flotation cells followed by cleaning cells. Lead scavenger concentrate and tails are subjected to further grinding.

The lead circuit tailings go to zinc conditioner and then to scavenger flotation cells followed by cleaning. The cleaned zinc concerntrate is fed to thickeners and filters for dewatering. Zinc cleaner tailings are further cleaned while zinc scavenger concentrates and cleaner scavenger concentrates are reground and recirculated to the zinc conditioners.

(Mining Magazine ; Dec.,1992 ; pp. 372-375)

PROCESS CONTROL

Treatment of Acid Mine Waste Waters

Disposing of large volume of acid mine wastewaters at times poses problem when it is to discharge to the nearest river following appropriate treatment. Depending upon the conditions for the discharge, raising the pH to within a range 6 - 9 and

reducing the concentration of metal to milligram per litre levels or lower is usually required.

CHEMICAL PRECIPITATION

Most of the mine waste waters can be precipitated as an insoluble hydroxide in the pH range 8.5 - 10. There are three main options to consider for chemical precipitation.

LIME

Lime is usually added as a hydrated lime [$Ca(OH)_2$] slurry in a 2- stage mixing tank prior to settlement in circular mechanically- scrapped clarifiers. A typical arrangement is shown in Fig.1

Settled sludge can be pumped to a tailings pond for consolidation and storage. If this is not available the sludge will require thickening by gravity prior to mechanical dewatering with a filter-belt or filter-plate press, the former (Fig. 2) being more appropriate to handle the large quantities of sludge generated and to minimise the number of presses required.

Where iron removal is required, an aeration facility must be part of the mixing/lime addition process in order to oxidise ferrous iron to ferric and maximise the efficiency of iron removal.

LIMESTONE/LIME

Limestone is a cheaper material than lime and so there are economic advantages in using it for raising the pH. In areas where it is available, limestone ($CaCO_3$) may be used to raise the pH initially to 4.0 - 4.5 in a first-stage reactor, lime then added in a second reactor to raise the pH to the desired value of around 9 prior to settlement. Limestone is ineffective for raising the pH to levels higher than 4-5.

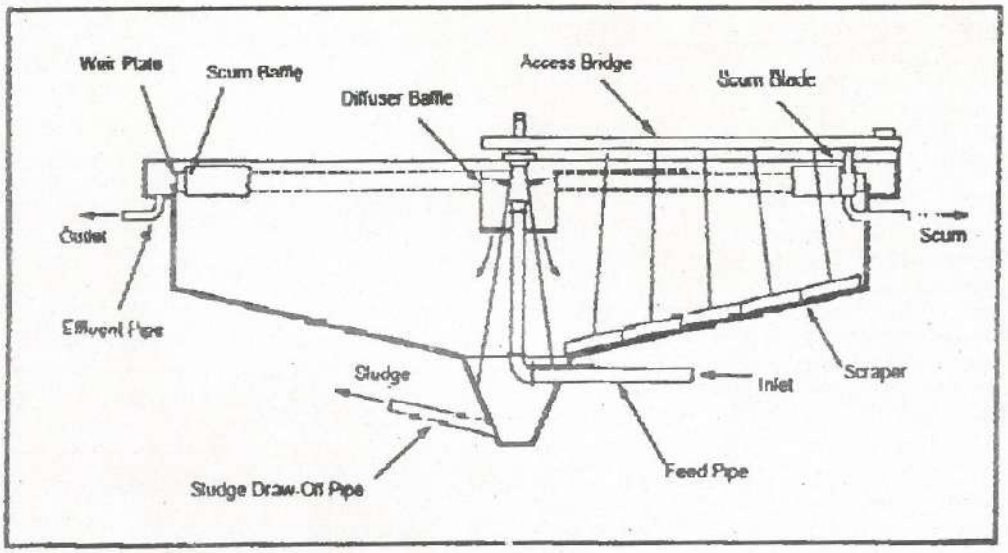
LIME/SODIUM SULPHIDE

Since the majority of materials will already have been removed in the lime precipitation stage, the required dosage will be considerably smaller. An aeration facility following filtration is still required.

pH CORRECTION

The provision for acid addition to achieve an effluent standard within a pH range of 6 - 9 for final pH correction is often necessary. Sulphuric acid can be used for this purpose as it is usually cheaper than

Figure 1 : Radial-Flow Clarifier with Half-Bridge Scraper



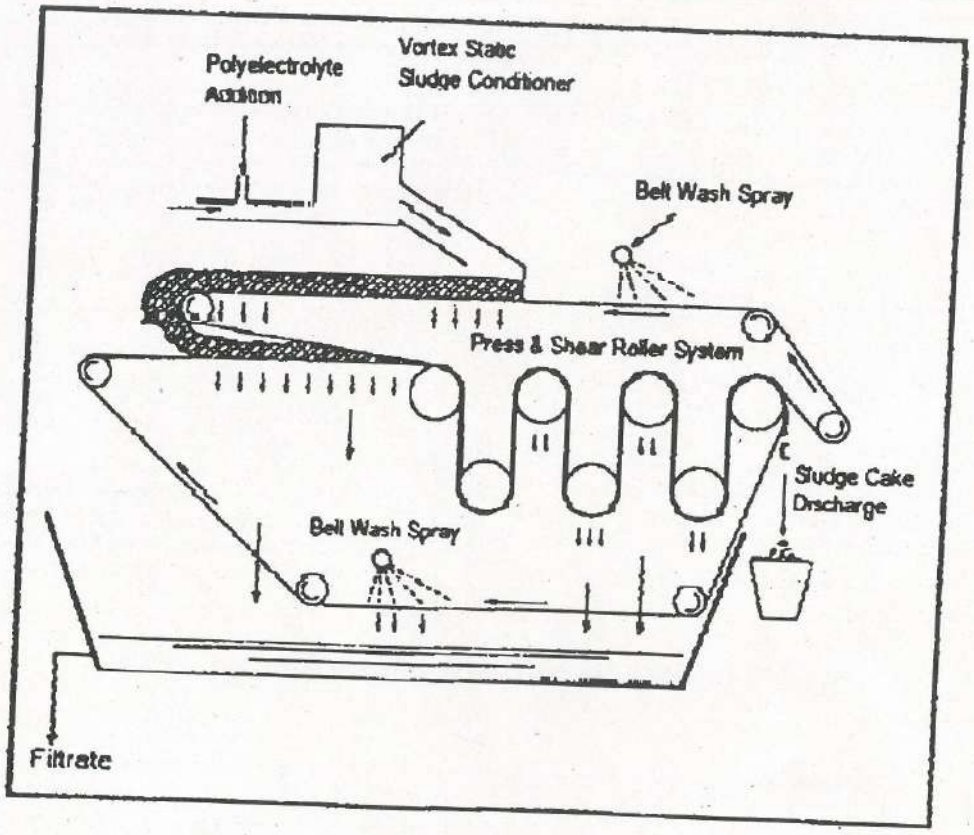


Figure 2 : Filter-Belt Press

hydrochloric acid. Depending upon what subsequent treatment processes are selected (if necessary) and particularly whether there is a sulphate limit imposed addition of carbon dioxide (by the submerged combustion of propane within a small reaction tank) is a cost-effective alternative to increasing an already high sulphate level.

FILTRATION

Not all the insoluble metal-precipitate will be removed in the clarificatio . stage. Dual media (sand/anthracite) rapid-gravity downflow filters with in-line addition of a small dose of flocculant (polyelectrolyte), can be expected to remove 50% of the major portion of finely divided residual insoluble material.

With a small sodium sulphide dose added as well, some additional removal to around 90% of the primary settled waste water insoluble metal load can be expected. Periodic air scour and back-wash of each filter is required, back-wash liquors being pumped back to the head of the plant for further treatment.

TREATED EFFLUENT QUALITY

Where conventional chemical precipitation is practised on waste water containing a wide range of heavy metals present in double and treble-figure concentrations, an effluent quality within a total heavy metals standard of 10 mg/l and 5 mg/l respectively is generally obtainable following

settlement and subsequent rapid- gravity filtration; a significantly higher quality cannot, however, be expected. A 30 mg/l suspended solids limit is also generally achievable after settlement.

Where only a few individual metals (for which standards have been set) have appreciable concentrations, a corresponding reduced total heavy metals quality within 5 mg/l after settlement and say, 3 mg/1 following conventional filtration is considered to be a practicable expectation.

To achieve higher standards with chemical precipitation is impossible without resorting to more sophisticated and costly treatment systems.

(World Mining Equipment; June, 1993 ; pp. 36-37)

India's Largest Copper Smelter

India's largest Copper Smelter is being built at Ratnagiri, Maharashtra and this is the first in private sector.

The plant will incorporate an Isasmelt furnace and Isa Process technology and have an initial capacity of 60,000 t/yr. The plant is scheduled to start up towards the end of 1994. Brisbane-based MIM Holdings Ltd, is providing the core technologies for Sterlite Industries (India) Ltd.

Mount Isa International Pvt.Ltd. will act as agents for Sterlite Industries in the procurement of copper concentrates from various sources, international and domestic.

Concentrate from the storage area will be conveyed to proportioning bins and blended with coal and fluxes(limestone and silica) and pelletised. Pelletised feed will be conveyed to the Isasmelt furnace and smelted with oxygen-enriched air, using oil as ancillary fuel. The oxygen will be generated on site in a plant owned by Sterlite.

Three Peirce-Smith converters will be installed in the aisle serviced by a 50 t crane. The converters will produce blister copper, including remelted anode scrap. The blister will be refined in two anode furnaces and cast as 348 kg anodes on a 28 mould rotary casting wheel. The anodes will be transferred to the electro-refinery to be turned into cathode grade copper.

Gas containing SO_2 from the Isamelt furnace is cooled in a water- spray tower and cleaned in an electrostatic precipitator. A similar system is used to cool and clean converter gas. The two streams are mixed and fed to a sulphuric acid plant. A phosphoric acid plant is being planned for the Ratnagiri site to utilise most of the sulphuric acid production.

All aspects of the plant are being designed to conform to the environmental standards specified by the state authorities.

(Mining Magazine ; April, 1993; pp: 198-199)

MINING MACHINERY

Largest Mine-haul Truck Introduced

M/s. Marathon Le Tourneau has stepped into a new phase by producing 290 metric ton capacity Titan 3320 mine haul truck, the largest mine-haul truck in the world.

The eight-tyre, three axle concept truck is designed to utilize proven component technology while affording vehicle balance during operation. The unique two-axle, four-tyre steering and four-tyre, single-axle drive are claimed to provide the optimum design configuration.

A new Marathon Le Tourneau "F-series" traction motor, designed specially for the Titan 3320 and rated at 2000 hp (1492 KW) makes this single-drive axle concept to become a reality.

The Titan 3320 will be available with a choice of twin Cummins diesels rated at 1600 hp (1194 KW) each, twin Detroit Diesels rated at 1600 hp (1194 KW) each, or a single MTU diesel engine rated at up to 3200 hp (2387 KW), and a choice of gear ratios to allow power application to be matched to mine requirements. The truck is 17.56 m long and will use eight 44.00 R 57 size tyres.

The Titan 3320 mine-haul truck can be equipped with the Marathon Le Tourneau Vital Signs monitor and Digital Diagnostic systems.

(Engineering and Mining Journal; January, 1993; p. 36).

Braking for the World's Largest Mine Winder

For the Vaal Reefs gold mine in South Africa, the local company Dorbyl Heavy Engineering manufactured what is said to be the world's largest mine winder. The double drum winder is designed to raise and lower a weight equivalent to 16 family cars through a distance of almost 2.5 kilometres. The all-important brakes were manufactured by Twiflex.

The design parameters for the mighty winder are impressive :

- Drum width	2.2 metres
- Payload	16,000 kg.
- Depth wind	2,450 metres
- Rope of speed	19.2 m/s^2
- Max. static rope tension	550 kN
- Total inertia	3,332,000 kg. m
- Motor rating(Ward Leonard Feedback Sys.)	7.2 MW DC
- Calculated RMS power	6.93 MW

Twiflex employed a total of 12 off VMS type disc brake calipers, acting on two discs 6.8 metres in diameter. Each of the calipers weighs approximately 500 kg and is applied by means of direct acting springs. The mine winder disc brakes are hydraulically controlled which in turn applies direct force to a friction pad against a disc. In mine winder disc brake technology, each caliper module contains a disc spring pack which provides direct mechanical force to a friction pad against a disc. The brake is then released by applying hydraulic pressure to a piston and cylinder arrangement which compresses the spring pack. Controlled braking can be achieved by varying the hydraulic pressure to each caliper.

Oil pressure for the braking system is supplied by three hydraulic power packs which provide independent control systems to ensure safety in the event of a single system failing to ON or OFF.

When considering selection for mine winder disc brakes, it is necessary to design a system that will statiscally hold twice the weight of the cables and fully loaded skip at the bottom of the mine shaft. This maximum braking torque requirement clearly provides a braking force in excess of the requirements for normal retardation and holding, hence the need for a control system that accurately regulates the degree of hydraulic pressure needed for optimum retardation. It has a total pad area of 2.64 m^2 acting on brake discs 70 mm thick.

(World Mining Equipment; June 1993; pp. 10-11)

ENVIRONMENT

Advances in Mine Reclamation

BRIDGE HILL RIDGE SAND MINE, AUSTRALIA

When Bridge Hill Ridge project was announced for a 2,000t/h sand operations, there were objections from environment point of view. On account of the fact that the proposed mine was to make a 360 m (approx.) wide passage for over 19 km. through a forest of eucalyptus and blackbutt trees. After protracted negotiations, the company agreed to mine only half the area that it originally wanted. For nine years since 1974 the mine operated at 50,000 t/d.

The mine has received the 1991 Award for Environmental Excellence by the Mineral Advisory Council, NSW Government, Australia. Since mining was stopped in 1983, the rehabilitation was so good that it is not possible to locate the past dredging excavation operations. The key to success of rehabilitation was the quick placement of topsoil to recontoured areas before it lost its viability. In order to protect against erosion and wind action, quick-growing of sterile hybrid sorghum crop was carried out. Mesh fencing and use of harvesting machine was also resorted to.

Overall, about 227 ha. of high dune ridges have been excavated, restored and rehabilitated.

FOSKOR TAILING WORK, SOUTH AFRICA

A major mine rehabilitation project work is under progress in a phosphate mine in northern Transval. The objective of the rehabilitation project is to transfer two unsightly phosphate tailings dumps into tree and grass covered hills so that they blend into the local topography.

Rehabilitation work involves transportation of about 1,200 tpd of top soil over 8 km. to be spread over an area of 1,300 to 2,000 m^2. It will take 8 years to complete rehabilitation of first 360 ha dump and 17 years to complete the second 998 ha dump. The dumps have 17 per cent gradient and 120 m. height. This will need 1.6 Mt of gravel and topsoil (at 50:50 ratio) for the rehabilitation of first dump alone.

(Mining Magazine ; June, 1992 ; pp: 334 - 338)

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Exploration

EXPLORATION IN BURKINA FASO

The prospect for short term development in the important Perkoa base metal project in Burkina Faso took a new base of life with the detailed exploration carried out by the state Bureau of Mines and Geology (BUMIGEB) and assisted by both the World Bank and the UNDP. This defined a reserve of 5.6 million tons of gold. For numerous other mineral occurrences the Government has a five year plan extending from 1991-95. Its objective include an increase in exploration with following priorities :-

* Production of manganese, zinc and especially gold;
* Further studies on six main projects;
* Mapping and regional exploration;
* Revision to the mining investment code, and
* Establishment of a central gold recovery plant.

The UNDP has supported exploration projects since the mid-1960s. Its earliest work involved a study on a copper occurrence at Gaoua, and this was followed by exploration in the Boromo and Hounde greenstone belts, an evaluation of the Tambao manganese deposit, assistance to artisanal gold miners, an airborne geophysical survey over the centre and southeast of the country and, most recently, assistance with the drafting of the new mining investment code.

The Tambao manganese deposit located 340 km northeast of Ouagadougou, was previously explored between 1960 and 1976. It consists of four manganese bearing beds hosted between Precambrian volcano-sedimentary rocks and granites. It grades over 50% manganese, with low phosphorous and minimal sulphur.

Several gold properties are under investigation. The French Company SIREXM and the Government have a 70:30 joint venture to explore and develop the Essakane and Guibare gold properties, both of which are artisanal mining sites. The joint venture, CE MOB, has installed a tailings retreatment plant at Essakane, and is planning to heap leach 120,000 t/y of ore grading 4.5 g/t gold.

(Mining Journal ; 13, Aug. 1993 ; p.6.)

Mining Scenario

PERUVIAN COPPER

About half the value of Peru's export is contributed by the country's mining sector. Peruvian mining is faced with serious challenges like exchange rate appreciation which has led to rising costs, uncertain prospects in the international prices of some commodities.

In 1991, Peru ranked seventh in the world in copper production as mine output rose to 3,82,000 t, the highest since 1987 and the value of copper exports totalled $ 755 million. The second largest mineral commodity in terms of value was zinc as mine production in 1991 rose to 6,28,000 t of zinc-in-concentrate. Peru was fourth leading supplier of zinc with a total export value at $ 340 million. Lead output of 200,000 t in 1991 placed the country sixth amongst all producers; lead export were valued at $ 169 million.

Examples of the geological setting of a number of the major deposits illustrate the wide diversity of deposit in Peru.

CERRO VERDE

Mineralisation at Cerro Verde consists of two porphyry copper deposits, separated at the surface by

a low-grade zone. The principal primary ore is chalcopyrite. The supergene enrichment blanket, which formed part of the reserve for the first stage of Cerro Verde production is up to 140 m thick. Total reserves are quoted as 797.0 Mt at 0.68% Cu.

CUAJONE

The deposit at Cuajone forms the basis of one of Southern Peru Copper Corporation's (SPCC) operations. The principal copper mineral is chalcopyrite. Supergene enrichment has proved important, the enrichment blanket extending to a depth of 20 m. Original reserves were 22 Mt of oxide ore at 1.3% Cu and 426 Mt of sulphide ore at 1.0% Cu and 0.013% Mo.

TOQUEPALA

Copper mineralisation at Toquepala is associated with a dacite porphyry stock. A substantial thickness of secondary enriched mineralisation (up to 150 m) covered the deposit. Chalcopyrite is the principal copper mineral. Initial reserves were 509 Mt grading 0.86% Cu and 0.013% Mo.

QUELLAVECO

Quellaveco is also a typical porphyry copper deposit. The primary mineralisation, is overlain by a supergene enrichment blanket averaging 50 m thick. Mineralisation in this zone consists of chalcocite, covellite and chalcopyrite. Reserves are estimated at 178 Mt of primary sulphide mineralisation at 0.68% Cu and 215 Mt of secondary mineralisation at 0.99% Cu.

CERRO DE PASCO

Cerro de Pasco has been an important mining area for over 350 years. Originally worked for silver, the deposits formed the basis for the first large-scale copper production at the beginning of this century and now produce base metals and silver. Principal copper minerals are enargite, luzonite, chalcopyrite and chalcocite, with zinc and lead in sphalerite and galena. Reserves are 33 Mt grading 9.5% Zn, 3.5% Pb, 112 g/t Ag and minor copper.

ANTAMINA

This is a contact metasomatic skarn deposit, formed during emplacement of a monzonite intrusion. The skarn zone has an average thickness of 150 m, and consists of granatite, calc-silicates and ores containing zinc, copper, silver and molybdenum. Proven and probable reserves total 165.9 Mt at 1.3% Cu, 1.1% Zn, 0.04 % Mo and 16 g/t Ag.

LA GRANJA

La Granj is a disseminated copper deposit. Three zoned mineral associations have been identified. Primary sulphide mineralisation consists of pyrite and chalcopyrite. A secondary sulphide zone contains chalcocite, covellite and pyrite accompanied by enargite, tennantite, bornite and molybdenite, while the oxidation zone consists of ferrous oxides and hydroxides. Probable reserves have been estimated to be 318.9 Mt grading 0.78% Cu, 5 g/t Ag and 0.015% Mo.

TINTAYA

Tintaya is a skarn copper deposit, first discovered in the early 1900 and brought into production in 1985. The deposit contained 10 Mt of oxide ores grading 2.2% Cu and 41 Mt of sulphides at 2.0% Cu. Remaining reserves are 20 Mt of sulphide ore. The ore also contains 0.6 g/t gold and 1 g/t Ag. The principal ore minerals are chalcopyrite and bornite; there is minor secondary enrichment.

MINING IN PERU

State controlled mining has played a significant role in the Peruvian economy over recent decades. A few well-known companies such as Minero Peru, Centromin, Hierro Peru, Tintya and SPCC account for about two-thirds of mine output. The remaining one-third of minerals are produced by some 1,000 small and medium-sized companies engaged in mining operations.

SPCC is the largest single copper producer in the country , reporting 1991 output of 248,000 t of fine copper from its mines at Toquepala and Cuajone. Technical improvements at the two concentrators bring copper output to 283,000 t annually in 1993.

At present, Peruvian copper production is dominated by SPCC which accounts for 60% of national output, followed by the state companies Tintaya (13%), Centromin (11%) and Minero Peru (9%). The balance is mined by 30 private Peruvian companies. Minero Peru operates the country 's only copper refinery at Ilo, next to the SPCC smelter.

ILO REFINERY

Minero Peru's copper refinery was established to refine blister copper from SPCC's smelter. Production during 1991 was 1,73,000 t of copper cathodes, 48.54 t of silver and 85.92 kg of gold. The refinery produces 99.99% Cu cathodes from its two major units, an anode plant and an electrolytic plant. During the period 1976-1991, production totalled over 2 Mt of copper cathodes, 299,000 kg of refined silver and 497 kg of refined gold.

(Mining Magazine ; April 1993 ; pp :181-184)

Mining Machinery

SURFACE LOADING

Electric cable shovels typically carry 5-7% of their operating weight in bucket. With 93-95% of their weight in support capacity, these units are designed for durability. Hydraulic front shovels carry 8-11% of the operating weight as payload. Wheel loaders carry 18-21% of operating weight as payload. Given comparably sized buckets, a cable shovel weighs four times as much as a wheel loader; a hydraulic front shovel weighs about twice as much as a wheel loader.

Hydraulic shovels and wheel loaders are generally considered to have economic lives in the 30,000-60,000 hour range. Turning to the size of loading tools, 240 st [218 t] trucks are now common and 300 st trucks are anticipated in the near future. Harnischfeger, Marion and Bucyrus-Erie all have cable shovels swinging 80 st/pass, and appear prepared to go to 100 st/pass if a 300 st truck class should come into being. A limited number of hydraulic front shovels in the 40-60 st/pass range are at work around the world.

Considering the choice between hydraulic excavators and wheel loaders, controlled dumping of material into the truck is one of the influencing aspects. Dumping heavy boulders into the empty truck can cause damage. Reach and dump height also play a considerable role in truck repair costs. One further aspect in reducing the cost of truck wear and tear is the visibility that the operator has over and into the truck.

MOBILITY

Versatility and mobility are other important considerations. In one minute a cable shovel will travel about 21 m, a hydraulic shovel about 37 m and a wheel loader about 370 m. Mobility is a key factor in choosing wheel loaders. Mines are beginning to recognize that if floor conditions are bad enough to tear up wheel loader tyres, they will also damage expensive truck tyres as they roll in under a shovel.

BREAKOUT FORCE

A cable shovel offers about 50% more breakout force than hydraulic excavators with comparably sized buckets. Given comparably sized bucket capacities, a hydraulic shovel and a wheel loader will show approximately the same breakout force ; a front shovel bucket is typically half the width of a wheel loader bucket, on a breakout-force-per-linear measurement the shovel can apply twice as much as the comparably sized wheel loader.

The listing below shows bucket fill factors in production rock face conditions as calculated by Caterpillar, based on hundreds of actual field measurements :-

Cable shovels	90-100%
Hydraulic front shovels	80-85%
Hydraulic backhoes	100%
Caterpillar wheel loaders	100-115%
Other wheel loaders	85-95%

POWER AND FUEL

In developed countries, electricity is usually available to mines to power cable shovels. In less developed areas, such a power source may not be an option. Diesel powered hydraulic shovels consume less fuel per hour than wheel loaders because shovels swing only their upper mass to load, while wheel loaders move the entire machine. The cable shovel has safer operator position with higher cab location.

ELECTRIC CABLE SHOVELS

Quite apart from the choice between the various units, each type of loading equipment has developed added productivity and efficiency. Thus loading fleets can be reduced and optimised. To improve on shovel loading efficiency which relates to performance availability, productivity and its cost of operation, both the machine and its use must be evaluated. The quality of performance must be dissected and individual contributory factors evaluated to improve the overall operation.

HYDRAULIC EXCAVATORS

The hydraulic shovel/excavator is not as well suited to hard rock and high tonnage applications as the cable shovel. The majority of hydraulic shovel applications have been in softer, often stratified materials such as coal and industrial minerals. Where selective excavation is necessary, hydraulic backhoes are a preferred tool since the operator has direct sight to the point of excavation and is able to distinguish between mineral and waste entering the bucket.

Factors favouring hydraulic excavators include :

Hard digging
Poorly shot material

Selective loading
Wet jagged floor
Pitching floor
Single face operation

Harnischfeger, a manufacturer of both cable and hydraulic shovels, points to some other advantages of hydraulic excavators that include prying capabilities, increased gradeability, low ground bearing pressure (lighter weight), unitised construction, reduced time and costs and faster erection.

(Mining Magazine ; May 1993 ; pp : 230-235)

Mineral Processing

AIR - SEPARATION - A VIABLE TECHNOLOGY

Experience of some alluvial wet process operators is that wet alluvial plants operating in Australia were inefficient, wasteful of resources, costly and environmentally unfriendly.

A small team in Cairns, N. Queensland, Australia, has developed successfully dry processing plant for heavy minerals. They developed air-bed rotary air-concentrator. The plant is able to handle a wide range of feed from fine particles to 12 mm. large throughout and continuous flow of concentrates. The plant is processing 80 m^3/hr. and todate over 750,000 m^3 ore was processed.

The feed after passing though a grizzly for elimination of over size, goes to rotary concentrators. As the material works its way outwards across the beds of the concentrators, air is pushed through the bed so that heavy particles percolate downwards and are drawn off to cells below. Lighter material finally discharges off the edge of the concentrator. The concentrator ratio achieved 300:1, is very high.

The concentrate is transported by a truck to a small scale wet treatmcnt gold recovery plant where amalgamation technique is used.

(Mining Magazine ; May 93 ; p. 251 - 253)

Environment

ENVIRONMENTAL IMPACT ASSESSMENT USING GEOGRAPHICAL INFORMATION SYSTEM

Environmental planning is a form to improve decision making. Its purpose is to ensure for an environmentally sound and sustainable project. Automatic Geographical Information System (GIS) is a more accurate of the all Environmental Impact Assessment (EIA) methods that are currently in use. Two GIS packages viz. PC GRAM and PC ARC/INFO have been utilised for environment assessment study.

The case study for the environmental assessment was selected from Korba area (MP). The environmental scenario in the Korba area became complex due to the presence of thermal power stations and other auxiliary industries. Two super thermal power plants belonging to NTPC and MPEB have been added on the west bank of Hasdeo river. Balco power house is coming up adjacent to NTPC.

Due to the extensive opencast mining deforestation, disturbance of land alongwith the inhabitants and associated environmental pollution are inevitable. Environmental Impact Assessment has become a major issue for any project to safeguard against this pollution. Based on the importance to environmental planning systematic assessment of environmental parameter was emphasised.

Ambient air observations were collected from four ambient air stations selected in and around the project considering the prevailing wind direction and topography of the area. The location of monitoring stations and data was taken up for analysis. It allows surface to be modeled than the same can be used to derive an isolines of air quality parameters.

Various interpolation methods were available for estimation of pollution concentration at unsampled points, of which Kriging is the widely used method. The Environmental Sensitive Index (ESI) is estimated based on the methodology of weighted index on GIS analysis.

(International Seminar 4 th Asian Mining : MGMI, Calcutta ; Dec.,1993.)

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EXPLORATION

Possible Extension at Niugini's Red Dome

Exploration results from the two latest diamond drill holes in Niugini Mining's NW Mungana, Australia showed an all oxidised gold intersection of 22 m grading 10.3 gm/t from 126 m depth, including 16 m of 13.8 gm/t from 128 m. The second hole intersected 17 m of oxide mineralisation from 99 m which averaged 2.8 gm/t gold, 1090 gm/t silver, 8.1% Cu, 5.8% Pb and 0.5% Zn, followed by 7 m of sulphide mineralisation from 136 m, which graded 1.3 gm/t gold, 362 gm/t silver, 14.2% Pb and 0.7% Zn over a true width of 15 m. This could extend the life of its nearby Red Dome operation. Till date, near surface mineralisation has identified over a 400 m strike length and remains open in both directions and at depth.

Currently, Niugini has undertaken a voluminous waste stripping programme at Red Dome to expose 2 Mt of additional reserves to be sufficient to feed the mill until early 1997.

(Mining Magazine; Sept. 1993; p. 161)

Exploration Round up by Wyoming's Geological Survey

Wyoming's Geological Survey has summarised the results of several unusual and unrecognised silver, gold anomalies in southern Wyoming. The two years of study resulted in the identification of gold-silver anomalies in coal seams near Kemmerer that appears to be similar to some disseminated gold deposits in Nevada and widespread concentration of gold along northern flank of Medicine Bow Mountains. Results of 54 stream-sediment samples taken along the flank of the Medicine Bow Mountains yielded values from 0 to 256 ppm gold of this panned concentrates and 24 samples showed good results of visible gold. A rock chip sample in Quaking Asp Mountain yielded 0-0.115 ppm gold, 4-65ppm Cu, 5-690 ppm zinc, 2-51 ppm lead, 0-29 ppm molybdenum, 0-0.70 ppm mercury, and 5.5-1430 ppm arsenic.

In other areas, studies were carried out where the massive lead- zinc-silver sulphide mineralisation in the Sierra Madre, and platinum, palladium and gold anomalies in the Lake Owen Complex situated in Medicine Bow Mountains. Lake Owen Complex's samples of magnetite result into 7.79% TiO_2, 73.66% Fe_2O_3, 0.21% V, 900 ppm Cr_2O_3 and 0.139 ppm Au+Pt+Pd. Broadway samples results contained 0.02-8.17% zinc, 0.30-5.66% lead, 0.05-1.82% Cu, 0.1-3.3 ppm gold and 0.2-12.18 oz/st silver.

(Engineering and Mining Journal; June 1993; p. 13)

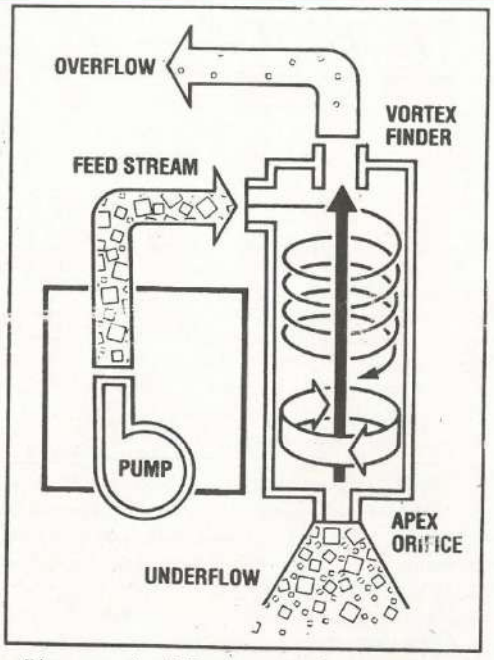
MINERAL PROCESSING

Flat Bottom Cyclones

Grinding mill efficiency is strongly influenced by the quantity and quality of the circulating load. When a mill is initially equipped, the cyclones are selected to produce a desired grind. In order for operators to increase mill output, a coarser grind must be acceptable. To produce a coarser separation, cyclone feed density need be increased. In a vertically mounted cyclone configuration, however, this reduces cyclone efficiency resulting in an increase of bypass fines to the cyclone underflow.

In recent years vertically mounted cyclones have been replaced with horizontally mounted cyclones and flat bottom cyclones.

Flat bottom cyclones, which are also known as circulating bed cyclones or circulating bed classifiers, have a cylindrically, shaped body and a completely flat or 'bowl'-shaped bottom as shown in the following diagram.



Diagrammatic of flat bottom cyclone operation

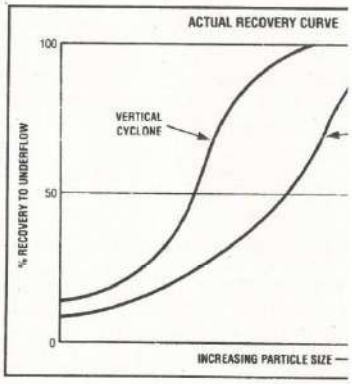
Centrifugal force causes the coarser solids to move down and along the cylinder wall forming a circulating bed in the bottom bowl section. Finer solids drawn to the centre of the cyclone in the rising air/slurry core discharge out of the overflow. The coarse solids discharge out of the underflow through the apex which is located in the centre of the bowl.

The flat bottom cyclone produces a coarser separation than a conventional vertical cyclone due to the abrupt directional change of the slurry in the bottom section.

When compared typical actual recovery curves for a vertical cyclone, and a flat bottom cyclone of the same diameter on the same cyclone feed the separation of the flat bottom cyclone is coarser and the recovery curve is flatter than the vertical cyclone.

The coarser separation for the flat bottom cyclone requires additional dilution water. The resulting lower cyclone feed density improves cyclone efficiency since it decreases the amounts of bypass fines material in the cyclone underflow. Flat bottom cyclones produce consistently high density cyclone underflow.

A disadvantage of flat bottom cyclones is that the rotating bed of coarse solids circulating in the bowl section causes grooving in the bowl and apex. Flat



Actual recovery curve showing perform vertical and flat bottom cyclones.

bottom cyclones also have flatter effi than vertical cyclones in a coarse gr This lower efficiency leads to more c in the cyclone overflow, which can r recovery in flotation.

Horizontal or flat bottom cycl considered for ball mill circuits with a (-) 150 microns or coarser. In most cas cyclones will be the optimum cho cyclones will still be recommended in c circuits with high overflow density re to meet other special design needs.

(World Mining Equipment; Sept., 1993; pp:21-

ORE DRESSING

New Flotation Reagents Copper Oxides

The Lakefield Research, Ontario developed new reagents for th oxide, oxide/sulphide and sulphide cop complex gangue compositions. The n have been tested on the following ore t

- oxide ores containing malachite or + chrysocolla
- mixed copper ores containing mal cuprite, chalcocite and covellite

- copper-gold ores containing native copper, chalcocite and malachite

- copper-gold ores containing gold, chalcocite, malachite, azurite and chrysocolla.

In the new line of collectors, sodium di-isobutyl or sodium di- isoamyl dithiophosphate collectors and their mixtures can be modified with a suitable chelating agent such as guanidine or quinoline. The reaction products provide excellent collectors for mixed and oxide copper minerals. These collectors are usually added with xanthate, depending on the type of ore being treated.

(Mining Magazines: August, 1993: p. 101)

MINING

Dynatec's Long Round Technology Improve Shaft Development

Dynatec has pursued productivity improvements through the use of long rounds in shaft sinking and lateral development. The concept of longer rounds was developed by Dynatec on the Craig Shaft Sinking Project (RETC, 1991). This technology was subsequently used to sink the two shafts at Aur Resources.

CRAIG SHAFT SINKING DESIGN

In analyzing the performance data, the criteria for high speed shaft sinking can be classified in three distinct functions: mucking, drilling and blasting, and lining and equipping.

While the Ansil vent shaft sunk to 1360 m in 361 days by Dynatec in North America, was only a 4m diameter concrete-lined shaft, the Craig Shaft's diameter at 6.3 m is more than double that size on a volume basis. For the Craig shaft, a shaft mucking capacity exceeding 100 t/h was required. This prompted the use of the stage-mounted cactus grab.

To reduce the shaft bottom crew and the associated labour costs, the shaft sinking system was designed around a drill jumbo. It required to equip the shaft simultaneously with sinking led to choosing a burn-cut rather than a V-cut. Since the burn-cut does not throw the muck, the need to move the stage was virtually eliminated. However, in drilling a burn-cut with a series of small holes, it is necessary that these holes be parallel if the cut is to shatter properly and break to the bottom. This problem was solved by using ITH drill to create a large diameter cut. This makes the round easier to break.

The 4.6 m hoist allowed for 12.5 t buckets that facilitated high production rates for the shaft mucking operations.

The stage was a five-deck, 50 t working platform suspended on three, single-drum winches that were electrically synchronized for simultaneous operation.

Emergency exit from the shaft was provided by a man-hoisting winch located in the hoist room. Emergency power was available from a diesel generator.

The concrete forms were suspended on eight Dwidag hanging rods. Pouring was accomplished using concrete buckets with a concrete distribution system mounted on the stage. The concrete was introduced into the system from the concrete buckets at the top deck.

Steel installation was conducted from the top deck. To make a safe work platform, hinged doors were used to close the bucket holes in each stage's top deck.

PROBLEMS ENCOUNTERED AND RESOLVED

The primary problem with the Craig shaft sinking system was the crew's inexperience with electric hydraulic drill jumbos for shaft sinking operations.

To further complicate matters, the use of a small crew made bottom cleaning difficult. Thus, the Dynavac vacuum system was developed for the final bottom cleaning before drilling.

Initially, due to the equipment congestion at the shaft bottom, the jumbo drilling and the ITH hammer drilling were not conducted simultaneously as had been planned. The problem was solved by removing two of the jumbo's hammers with Montabert model HC 80.

One problem in using an electric hydraulic drill jumbo and transferring high voltage power to the sinking stage is the presence of high moisture levels from water leaking into the shaft. Dyantec installed three water rings between the surface and the first level. With these water rings and some grouting conducted during the initial sinking the shaft was virtually dry. A dry shaft is better for the mine's long-term operation.

(Mining Engineering: November 1993; pp:1368-1373)

ENVIRONMENT

Hayden Hill Living in Harmony

Amex Gold's new gold mine at Hayden Hill in northern California started production from its opencast mining operation. Ore is delivered from the pit to a closed circuit crushing plant. Ore is heap leached at the rate of 4 to 6 Mt/year.

The Hayden Hill Reclamation Plan submitted initially was refined over the period. With the five members project steering committee plan of operations for Hayden Hill was submitted in August 1989.

Reclamation planning and implementation will be carried out concurrently with mining operations. The major part of the plan will be initiated after the termination of mining operations. The goal for general reclamation at Hayden Hill is to reclaim the site to a stable, functioning ecosystem to allow the same land uses as currently exist and to ensure that the reclaimed areas are visually and functionally compatible with the surrounding topography. The reclamation approach and procedures were developed for the site-specific conditions on the property. The reclaimed landscape will contain areas of low mountain shrub vegetation.

Where areas cannot be revegetated within a reasonable time period, these will be stabilised to provide habitat for raptor and wildlife species.

ACHIEVEMENTS

At Sleeper open-pit gold mine, a netting system to keep birds out of solution ponds was designed by the company's engineers. The netting system is being used at Hayden Hill.

Sleeper had been very successful in creating a wetlands area. This experience was helpful at Hayden Hill. The wetlands area now has an impressive wildlife population whereas previously the ponds had poorly-developed plant cummunities and low-quality grazing.

In the mine itself, sodium lignosulphonate, a cellulose and sugar product, is used to control dust on access and haul roads. When the mine's operational life is over, each catch bench in the openpit will be covered with 152 mm of topsoil and will be vegetated. A fogger system reduces dust in the crushing plant and Hayden Hill was amongst the first mines in the world to use Nordberg's Waterflush crushing technology, which cuts power consumption, dust emission and noise levels.

(Mining Environmental Management; Sept., 1993; pp. 6-7)

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EXPLORATION

DEEP HOLE DIRECTIONAL DIAMOND DRILLING

The need based deep hole directional diamond drilling in mineral exploration has benefited the industry, as near-surface exploration targets are becoming rarer and near-surface mineral deposits are depleted.

Accurate surveying of the hole determines current position at any given depth and at any given time. Electronic borehole surveying instruments now available are more accurate and efficient to use. A combination of down-the hole motors and controlled drilling has been used to drill targets in the Mount Isa Mines to vertical depths of up to 2,000 m. A suitable drilling fluid was necessary for the deep directional drilling programme to be a success and at the same time to be economically viable. In order to minimise friction between the drill rods and the hole wall and between the drill rods and the upper section of the casing, it was important that a good coating of grease be maintained on the rod string.

Drilling design

The initial drillhole design was determined from:-

* the optimum intersection to test the target
* drill site limitations due to access
* the geology between the collar and the target

With the target depth in excess of 1,500 m and the steeply west dipping Mount Isa Group bedding, a steeply dipping drillhole lifting at depth to the east was considered the optimum approach to testing the target. Unfortunately drill site access is limited to immediately west of the target in the rugged hills of the Surprise Creek Formation. This constrained the drill sites to further west in the Bortala Formation.

The drill path steepened over the first 400 m, corkscrewing gradually to the east and then slowly lifting to the east through the Holly Fault and Surprise Creek Formation. After drilling the Mount Isa Fault the drill string was reduced from HQ to NQ. The NQ resumed lifting to around 35 degree through the Eastern Volcanics to intersect the Paroo Fault and continued through the Mount Isa Group testing the target. As the project advanced, there was continuing refinement of the geometry of the Paroo Fault and target depth. Wedging of the existing drillhole was considered appropriate for further testing to ensure cost efficiency.

Downhole geophysics

Downhole EM test is routinely carried out on surface exploration holes to assist in detection of in-hole and off-hole conductive bodies. A probe is lowered below the target area and measurements are recorded at regular intervals.

Grouting

All drillholes are routinely grouted to prevent mine and ground water passage into stopes or hydraullic sand fill to drain into access development. With exploration drilling in proximity to the mine, drillholes are grouted/cemented where potential development may occur in the future. Cementing of drillholes at depths in excess of 1,500 m presents many interesting challenges.

(Mining Magazine; December 1993; pp : 299-302)

MARINE DIAMOND EXPLORATION

Alluvial Mining Co. Ltd., a subsidiary of Royal Boskalis Westminster, UK, with long experience in mapping and mining of marine deposits of gold, diamonds and rutiles in many parts of the world over, is about to begin a major diamond prospecting project in South West African Coast. The company

contracted the Namibian Mineral Corporation (NAMCO) and have been granted major marine diamond concessions off Namibia to carry out a comprehensive minerals survey covering 5,600 line km over Luderitz Bay and Hottentots Bay.

The work is to recover seabed grab samples of potential diamond bearing sediments and 6 m seabed cores at selected sites for geophysical study. The geotechnical team will be working in water depths from less than 10 m to 200 m.

For pilot mining and on-stream extraction, Alluvial Mining has experienced to work with remotely-operated dredge vehicle systems.

(World Mining Equipments; January 94; p-10)

MINING

THE RICHES OF PORGERA

Porgera, located in Enga Province at 220 km WNE of Mount Hagen, in the Central Highlands of Papua New Guinea recently marked its 100th mt gold production. The mine itself straddles a ridge rising from 2200 m - 2700 m altitude.

The mine is based on the zone 7 gold deposit which is an epithermal orebody hosted by metamorphosed sediments and associated with a diorite intrusive. There are four main types of mineralisation, of which the high-grade native gold and electrum in brecciated ore is the main ore type mined from underground which is centred on the Roamane fault zone. The ore deposit has a strike length of 4 km and is typically 12 m thick. About 1 km of this is mineralised and the present workings cover about 350 m of this strike.

In 1992 the total resource was estimated at 118 M mt grading 4.7 g/mt at a 1.5 g/mt cut-off. Openpit reserves are 45.63 M mt at 5 g/mt and underground reserves 5.04 M mt at 15.2 g/mt as on 1.1.1993.

Underground mine

The access to the underground mine is through two adits; one at 28 level (2,280 m above sea level) and the second one on 40 level (2,400 m above sea level). There are eight main levels from 18 level to 40 level at 30 and also at 50 m intervals. Main support in permanent developments is provided by fully grouted rebar.

A bottom slicing method, locally known as Modified Vertical Retreat is the main mining method followed and series of stopes developed between the hanging wall and footwall drives which are separated by a distance of 15-50 m. Depending on the distance there may be several stopes across a given area. Stopes are 15 m wide along strike, an average 20 m wide across strike, and 30 m high. Stope access is by a single cross-cut on both the drill and extraction level. The initial free face for blasting is provided by a raise bore hole in the centre of the stope. A Tamrock Solo 1006 then drills a series of radiating holes which are fired in a series of horizontal lifts. Normally three lifts are required for a 30 m high stope.

Primary stopes are taken out and backfilled, followed by extraction of the adjacent intermediate pillars, or secondary stopes. Main support for the stope backs is provided by 10 m long twin 15.2 mm dia. fully-grouted cable bolts.

The mine requires 3,000 mt/d backfill and there are two underground backfill stations where crushed waste is mixed with cement slurry. Crushed waste grading 100% minus 100 mm and 25% (-) 10 mm is conveyed to the 40 level adit and the stations. 55% cement slurry is batch mixed and pumped to a second hopper above the backfill truck loading point. Both the aggregate and cement hoppers are opened simultaneously during loading so that vigorous mixing takes place during loading. Cement slurry addition is 5%. Eimco 426 and 430 trucks fitted with special lipped beds to reduce spillage are used for both backfill and waste transport.

Hoists and Conveyors

Ore is mucked from the stopes by remote control LHDs to one of three ore passess and crushed by a 107 x 122 cm jaw crusher and then hoisted 200 m to surface by a vertical Flexowall belt hoist. The hoist is driven by two 150 kw motors and has a capacity of 350 mt/hr with a belt speed 2 m/sec. The flexible overland conveyor carries ore from the hoist to the crushing plant and returns backfill to the mine. This conveyor runs along the base of Mount Waruwari which is covered in a deep layer of colluvium moving downhill at a rate of several metres a year. The area also lies immediately below the edge of the openpit and waste rock and devegetation have made the colluvium prone to slides.

The conveyor is run through a series of linked pontoons which effectively float on the unstable ground. As the underlying ground moves, the conveyor also moves and is periodically jacked back into an approximately straight line. The twin belts (ore up and backfill down) ride in cradles which can move in a vertical plane to accommodate horizontal flexing.

Open pit

The open pit contributes around one third of mill input. Ore ranges in grade from 3 to 13 g/mt gold with 0.5-2% sulphur and averages 7 g/mt. Mining is normally on 10 m benches although 5 m benches are taken when necessary. Two Ingersoll-Rand rigs, a

DM 45 and a DM 25-SPH both fitted with 165 mm DTH hammers are used for all production drilling. Grade control holes between blast holes are drilled by Tamrok 1000. Loading equipments consist of three Liebherr 994 excavators, two Liebherr 974 excavators, and a Cat 992C wheel loader. A fleet of 16 Cat-777 trucks are used for haulage. Wastage is transported to the engineered dumps to the west of the pit and ore hauled downhill to the crusher.

The crushing facilities incorporate for the production of backfill and construction aggregate. Crushed underground ore transported by the flexible overland conveyor is diverted directly to the coarse ore stockpile. Open pit ore is crushed by a 107 cm Fuller gyratory crusher and conveyed to the stockpile. The first belt which receives both underground ore and gyratory crusher product is reversible. This enables waste from surface or underground to be diverted to the aggregate plant which produces three products of minus 10 mm ,minus 35 mm. plus 10 mm and minus 100 plus 25 mm.

(Engineering and Mining Journal; Nov. 1993; pp. 24-31)

GLENBROOK NICKEL - THE ONLY U S NICKEL PRODUCER

Glenbrook Nickel Co. is the only nickel smelter and the only active nickel mine in the United States. In 1989, the company purchased and recommissioned a southwestern project, Oregon with adjacent mine and the smelter near Riddle. In 1989, nickel price was riding high between $ 2.30 and $ 2.70 per kg., whereas in 1993, the price of nickel hovers around $ 1.13/kg. The company stressed more on increasing smelter production to reduce operating cost.

Operation

The Ugine reduction process is used in smelter of the company to produce ferronickel (50% Fe and 50% Ni) and the company sells its products solely to the stainless steel industry, which accounts for more than two-third of the world's nickel consumption. During its operation in pre-July 1993, the smelter near Riddle used to work on a blend of feeds, with 60% soft ore from adjacent Nickel Mountain deposit. Eventually, the ore from New Caledonila will provide all the smelter's feed. With an average depth of 18.3 m and a hilltop altitude the mine is worked by opencast method with shovels and 18 wheel belly-dump trucks. Each can carry 24.9 t of material at 25% moisture.

The material is first hauled down to a dryer and then to the screening - crushing plant where it is sized, crushed and screened. About 38% to 40% of the dry weight is rejected at this point and the remaining fines are sent to storage bins for delivery to the smelter.

Environment

The deposits natural soils lack potassium, trees planted at the mine site grow more slowly than those on surrounding hillsides. Glenbrook plans to provide more trees for the area through its own nursery stock. There is already a small creek running through Glenbrook's land functions as a nursery of different type.

A local conservation group operating under the Salmon and Trout Enhancement Protgram (STEP) that raises fingerlings from eggs that are released in the local rivers.

(Mining Engineering; Sept. 1993; p. 1139)

ENVIRONMENT

ENVIRONMENTAL IMPACT OF MINING IN TROPICAL FOREST - A CASE STUDY

To achieve the incompatible objective of development, it is essential that complex nature of the impact a mine has on the environment is understood and most damaging effects are identified. The strategies are established to protect the environment while developing valuable resources. In the case of mining impact assessment the scope of the study must include :

- Air quality (dust and gaseous emission)
- Ground water and surface water contamination
- Soil contamination
- Noise and vibration
- Physical Encroachment (of the mine and its transport links)
- Effects on protected areas and special habitats
- Socio-economic aspects (including local development)
- Rehabilitation and after-care of old mine sites.

The associated plant viz. crushers, concentrators and generators etc. produce noise, dust and gaseous emissions whilst dumps and tailings ponds covering larger areas, cause ground water contamination, surface drainage problems and dust problems.

A joint study has been taken up by Earth Resources Centre, University of Exeter, UK and Department of Mining, VRCE, Nagpur and understand the effect of mining on tropical forest in Central India. This is a belt of mineralisation stretching from the manganese mining district NE of Nagpur to the copper mineralisation adjacent to the Kanha National Park and focussing on the Malanjkhand Copper mine of M/s HCL in Madhya

Pradesh and the Dongri Buzurg manganese mine of M/s MOIL in Maharashtra. Operations at both these places are by opencast method.

Among the 40,000 trees planted at Malanjkhand mostly are teak. A variety of species like eucalyptus, acacia, karanji, jhinia and babool in addition to teak are being planted at Dongri Buzurg. It is expected to grow a healthy forest on worked out areas and waste dumps, as in the case of Tirodi mine of M/s. MOIL.

At Malanjkhand, most of the lands occupied by mining was formerly cleared for agriculture. Here the tailing disposal site is adjacent to the forest. Possible ground water contamination at this place and blasting noise and vibration study over a radius of 7 km from the part of the study.

Forest surrounding the Malanjkhand mine extends in all directions and supports a small tiger population even beyond the boundary of the Kanha National Park which is an important tiger reserve. At Dongri Buzurg mine which is surrounded by forest leopards are seen close to the fence, where langur monkeys are seen within the mine.

The socio-economic impact on human environment is more obvious and significant on local communities since mines provide essential employment in rural areas.

(Mining Environmental Management; Sept. 1993; pp. 20-21)

MINING EQUIPMENT

ELECTRICALLY POWERED NEW DEMAG SHOVEL IN OPERATION

The electrically powered Demag H485-SE hydraulic mining shovel is the largest hydraulic shovel. With a bucket capacity of 33 m^3 it takes three passes to load 172 t truck at Pinto Valley mine of Magma Copper Company in USA. There are nineteen 172 t trucks and two 154 t trucks. Each working truck hauls 20 to 25 loads per eight hour shift. The fast cycling H485-SE has a 2.1 MN digging force. In the seven-days-a-week, 24 hours a day mine operation schedule, the shovel achieves 96% availability.

The undercarriage tracks are 1500 mm wide for superior stability and is powered by a hydraulic drive system with a travel speed of 2.25 km/hr. Demag's 'Hydropilot' three-circuit hydraulic system directs priority delivery to the excavator's two swing pumps for short working cycles. When braking the swing motion, the total oil volume is redirected to the work circuits. The cab of this Demag shovel places the operator 8.2 m above the pit floor. Excellent accessibility of all components facilitates servicing and maintenance jobs on major components.

Mines outside the US that are currently using H485 shovels include a CVRD iron ore mine in Brazil.

(Mining Engineering; January, 1994; p-17)

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EXPLORATION

Diamond Exploration using IRS Data in Panna (M.P.) and Wajrakarur (A.P.) Areas

There are two regions in India of known diamond bearing kimberlites of which one in central India near the town of Panna in Madhya Pradesh and another in south India near the village of Wajrakarur in Andhra Pradesh. The latter has a history of large scale diamond mining in alluvial deposits, and is reported to have produced two of the best diamonds, namely Kohinoor and the Regent. Diamonds in these areas are associated with two types of deposits : (a) primary deposit - kimberlite pipes, and (b) secondary deposit - conglomerate beds, river terraces and older alluvium or palaeo channel belt. The concentration of diamonds in the known kimberlites of Wajrakarur area, however, does not seem to account for such large alluvial deposits to explain the fact that diamonds are frequently picked up at the surface over a very large stretch in this area.

Finding kimberlites in these regions is difficult for a number of reasons. One reason is that they are quite small in size; another is that their degree of weathering is highly variable.

STUDY AREA

The study area covering about 1,30,000 ha around Panna town, situated in Madhya Pradesh has been taken for present investigation. The area falls between 24°30′ - 24°50′ N latitude and 80°00′-80°20′E longitude. The major river in the area is Ken.

The Wajrakarur area situated in Anantapur district, Andhra Pradesh, covering about 1,30,000 ha was also taken for the present investigation. It is bounded by 14°45′ - 15°05′N latitude and 77°15′-77°25′E longitude. The area covers the villages of Wajrakarur, Uravakonda, Venkatampalli and Latavaram. The area is physiographically mild undulating terrain and is drained by Pennar river.

METHODOLOGY

IRS, LISS-II data was used for digital analysis in both the areas. Evaluating several band combinations, false colour composites with band 4 in red, band 3 in green and band 1 in blue were generated for exploration study. The known kimberlite pipe locations were identified using earlier studies in the area. The colour balancing technique was adopted by balancing blue in band 1 and red in band 4, since band 1 has slight penetration into water and moist soil, and band 4 (infrared) indicating differences between soils. While using this technique, small distinct spots similar to the known kimberlite dimensions were mapped and correlated with FCC. It was known that some of the spots correspond to small tanks which were later eliminated.

Several band ratios were performed in the anomalous zones, out of which ratio 4/2 yielded better enhancement of known kimberlites as well as new possible target locations. The remote sensing anomalies derived from digital image processing were used for detailed field verification and geophysical correlations by the Mineral Exploration Corporation Ltd., Nagpur.

Visual interpretation techniques were employed for delineation of secondary deposits. The palaeochannels, river terraces and conglomerate beds were demarcated along upstream side of Krishna river from Vijayawada town as possible locations for diamond prospecting using IRS LISS-II data.

CONCLUSIONS

In this investigation, remote sensing techniques provided very useful information for kimberlite explorations. Lithological and structural information derived from IRS, LISS-II data in Panna (M.P) area

indicated that the lineaments trending N60°-80° and N 120° approximately, may have more influence on the known kimberlite pipes. N 13°, N 60° and N 94° trending lineaments influenced the kimberlite activities in Wajrakarur (A.P) area. The remote sensing anomalies derived from digital image processing have been correlated with the geophysical data, and it was found that two locations near pipe 1 and 6 have encouraging results.

(National Natural Resources Management System, Bangalore - a new perspective; pp : 407-411)

MINING

Australian Mineral Sands

The Australian Mineral sands industry produces around 35% of the world's rutile, 50% of the zircon, 40% of the high-grade ilmenite, and a substantial portion of the world's synthetic rutile. The world market for mineral sands products is currently depressed.

Rutile is an important titanium dioxide material and ilmenite a feed material for the production of synthetic rutile or titanium dioxide slag. Paint, paper and plastics consume more than 90% of the world's production of titanium dioxide derived from rutile, ilmenite, and synthetic rutile.

Rutile is economically more attractive than ilmenite since it contains 96% TiO_2. The price of ilmenite has been steady at $A90-95/mt bulk concentrates containing 54% TiO_2.

Rutile and synthetic rutile are converted to titanium dioxide pigment by either a chloride or sulphate-based process. The chloride route, being more environmentally acceptable, is becoming the preferred process.

Zircon is used in ceramics, refractories, and foundry applications. The price of zircon has been dramatically affected by production in South Africa and lower demand.

TECHNICAL DEVELOPMENTS

Dredging

In the past, dredging systems in the mineral-sand industry were usually based on the conventional rose-shaped cutterhead cutter unit. The conventional cutterhead unit however, does have a number of serious drawbacks when operating in materials other than free-flowing sand. The cutting action with a curved cutting-edge contacting the dredge face is inefficient.

In recent years the major additions to dredge fleets in the Australian mineral sands industry have been bucketwheel suction dredges. The bucketwheel uses a different cutting principle. The cutting edge is a straight edge enabling the cut material to move cleanly over the cutter into the interior cavity. This allows simple extraction by the ladder-mounted dredge pump.

Dry mining

Although dredging has an operating-cost advantage, factors such as difficulty of dredging the particular materials and the initial cost of new dredging equipment can convince that dry-mining methods would be more suitable. Standard earth-moving equipment such as bulldozers, scrapers, wheel loaders and trucks can provide a workable alternative to dredging.

An advantage of dry mining is the ability to mix the plant feed to suit the treatment plant's separation capabilities.

(E&MJ ; January, 1994; pp : 56, 60)

MINERAL TRANSPORTATION

Limestone Transportation by Capsule Pipeline

Environmentally-friendly pneumatic transportation of limestone by capsule pipeline to a cement plant 3.2 km. away has proved the ideal solution at Karasawa mine in Japan. The technology was originally introduced from the former Soviet Union two decades ago. Sumitomo Metal Industries along with other Japanese Companies has developed the Pneumatic Capsule Pipe line System (PCPS).

This capsule pipeline system has been in operation since 1983, transporting limestone at a rate of 2.1 Mt/y between Sumitomo Cement Co.'s Karasawa open pit mine and its Tochigi cement plant. Since commencing operation the system has been in continuous use averaging 7,200 h/y.

The limestone was originally transported from mine to plant by surface railway. Rail transport capacity was limited and had difficulty in keeping pace with mine production increases.

Studies were undertaken to assess the relative merits of belt conveyor systems and pneumatic capsule transport as possible alternatives.

Other considerations were the noise and vibration problems. Belt conveyor noise and vibration could be controlled by using pipe girder, low-noise rubber and firm foundation. The noise level was reduced to about 20 dB by burying the pipeline, and capsule vibration in transit was controlled by using thick rubber tyre and pipe connection gap control.

CAPSULE SYSTEM AT KARASAWA

The major component of the system is the 998 mm diameter, 3,180 m long steel pipeline which has the considerable advantage of being virtually maintenance-free.

The limestone is transported in trains consisting of three capsules connected together. Each capsule has two five-wheel assemblies at either end of its body. The equally-spaced wheels are all mounted on a trunnion bearing at the central axis of the capsule. As the centre of gravity of the capsule body is below the point of rotation, the capsule body will remain stable, preventing cargo spillage, while the wheel assemblies are set at a small angle, allowing them to spiral in motion, thereby evenly distributing tyre wear. The specially-designed solid rubber tyres minimise noise and vibration along the pipeline route. These tyres have very long life, averaging 250,000 km before replacement.

As the capsules move in three-capsule trains, two sets of connectors are used to connect three capsules. Each end of the capsule train is fitted with a hydraulic shock-absorber to cushion the impact.

The capsule body is open at the top and divided into three compartments, each compartment fitted with a bottom flap which opens to discharge the limestone. Although the capsules appear to be circular in cross-section, they have vertical walls to prevent adhesion of clay which occurs on the surface of the limestone and thus facilitate discharging.

Once the trains operate in a continuous stream, they are loaded or unloaded with limestone with the capsule motion controlled by a chain conveyor. Once the trains exit the loading or unloading station, the connecting link between trains is released and each train is sequentially inserted in the launching device.

Both loading and unloading stations are fully automatic in operation. Limestone from the mine, crushed to fist-sized lumps is fed via conveyor into a hopper which feeds a batcher turntable from which it is loaded into the capsule.

At the unloading station, some 3 km away, whilst the capsule trains are still in motion, the three bottom flaps of each capsule open and close consecutively, discharging the limestone.

Both ends of the pipelines are fitted with dual roots blowers to minimise the effect of a rapid pressure increase when a capsule train is accelerated in the launch tube.

A centralized control system at the loading end manned by one person monitors the entire system operation continuously, while the unloading end is unmanned except when personnel are involved in capsule maintenance and repair.

As the capsules are open at the top, a small amount of dust blows off the surface of the limestone during transit through the pipeline by the small amplitude of the air current.

TROUBLE-FREE OPERATION

The system at Karasawa has operated for nine years without any serious problems. Energy requirements are about 2.5 kWh/t, it operated 16 h/day every day in 8 h shifts.

OTHER/FUTURE PCPS INSTALLATIONS

The PCPS has also been applied for spoil removal during drivage of the Akima railway tunnel in Japan. The PCPS should have increasing impact for a number of reasons : it is clean, safe and has no adverse effects on the environment; it is ideal for continuous mass transport; it is adaptable to many load types and situations; it is independent of the weather; the pipeline, which represents the major investment, is maintenance-free; and labour productivity is extremely high. In addition to limestone, materials which can be handled by PCPS include ores, sand and gravel, coal, cement and waste materials such as mine tailings.

(Mining Magazine ; December, 1993 ; pp : 294 - 298)

MINERAL CLASSIFICATION

Industrial Minerals and Rocks Classification

Since 1951, attempts have been made in the past, to classify industrial minerals and rocks for analysis. Subsequently, in 1960, economic and geologic criteria was used for classifying non-metallic minerals.

End use classifications of industrial minerals and rocks are difficult to develop. An informal working group, consisting of professionals from 13 countries formed the Industrial Minerals International Working Group (IMIWG) in 1991 to work on a voluntary basis, on important issues in the field of industrial minerals and rocks. IMIWG members from Canada, Denmark, Germany, Norway, Spain, Sweden, the UK, and the USA identified the major uses for industrial minerals in their respective countries.

The responses indicated that there were substantial differences in the understanding and applications of end use definitions, which render statements on end uses incomparable between one country and the other. This is because :

1. End use classification schemes have evolved over time as information needs and industrial consumption patterns have changed.

2. End use classifications reflect the importance of different end uses in the country's economy, the manufacturing sector, or to the particular mineral's industry.

3. Respondents differed on the definition of end use. In some cases, end use referred to a mineral's use in a final product, thereby corresponding to the proper use of the word.

By structuring the classification, category definitions were made less ambiguous, thus making it possible to compare the results of different studies. In the past, comparisons often were made between categories that were not equivalent because of the lack of structure in existing end use classifications. Since this proposed classification is the first step towards developing internationally acceptable end use classifications, there is still much work to do.

A global hierarchically structured classification applicable for all types of end uses of all types of industrial minerals and rocks will be formidable. Any internationally agreeable end use classification will have to be developed more by consensus than what is right or wrong.

(Industrial Minerals; April 1994; pp : 65-67)

ORE DRESSING

Ultra-fine Grinding of Minerals

A new micronizing technology with applications in the minerals industry, based on the use of compressed air has been developed by OY Finnpulva AB. The Pulva FP opposed jet milling process which produces fine powder from hard and soft materials. The Jet milling process too can reduce the moisture content of the processed material. The energy consumption can be 50-70% lower than that of conventional micronizing processes.

Homogeneous, clean powders with a large specific area are needed in the building and processing industries as well as for medical pharmaceutical, food processing, and other applications. For example, fine minerals improve the quality of paper, and the colouring capacity of pigments increases when the pigment powders are fine. Some of the latest applications of powders are the use of minerals as fillers for plastics, and the use of ceremic powders to imporve the wearing qualities of various materials.

In the Finnpulva opposed jet mill system, the particles to be ground are accelerated to a high velocity in specially designed acceleration nozzles by using compressed air. The jets are directed to a small space where the raw material particles collide and this collision is the main contributor to the grinding process. Milling efficiency is considerably better and energy consumption lower than conventional jet milling. After grinding the kinetic energy of the carrier gas and the solid particles are utilized in the classifier to separate the fine and coarse fractions by centrifugal force. Coarse fractions can be returned to the mill for regrinding or used as a separate product.

The first laboratory machine was manufactured in the early 1980 and was used successfully for grinding talc, dolomite blast furnace slag and pigments.

The energy consumption of the new technology is 100-400 Kwh/min. Depending on the capacity and the application, the investment costs of the mill are 0.5 to 2 M FMK and the pay-back period is 2 to 5 years.

(Engineering and Mining Journal; June 1993; pp: 41-42)

Sample Reducer and Splitter from Tyler

The particle analysis and fine screening division of W.S. Tyler Inc. has anounced the development of the Tyler 16 to 1 sample reducer, which it is claimed greatly reduces the time and labour normally expended in obtaining representative samples of ten pounds or over, with maximum particle sizes of approximately 1.27 cm (0.5 in.). From just one passing of material through the splitter, a fraction of one-sixteenth can be obtained at one go. Subsequently, by passing the reduced sample through the splitter a second time, it is possible to obtain a representative sample from an original sample. Tyler claims that the splitter can reduce a large sample into a more manageable size for sieve testing whilst still retaining the same proportion of fines and coarse fractions in the final sample.

(Industrial Minerals; Jan 1994; p :64)

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