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CUT-AND-FILL MINING AS PRACTICED IN THE U.S.--AN OVERVIEW

by

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INTRODUCTION

Cut-and-fill (C/F) mining here is defined as methods where backfill is required for ground support. Bulk underground mining methods such as caving, sublevel stoping, blasthole stoping, and shrinkage stoping often involve backfilling, but only after a stope is worked out, not as a cyclic part of the mining system. Mining generally proceeds by mining horizontal slices either overhand or underhand, and backfilling, generally with deslimed mill tailings, but in some mines with waste rock or gravel (from surface). C/F is also used for pillar recovery.

Supplementary ground support may be provided by timber, shotcrete, or liner plates in area of raises; and bolts, timber, remnant pillars, or planned pillars in stopes. Cemented fill may be used for part or all of the backfill. Timber and steel mats with cemented fill are required in undercut methods.

IMPORTANCE AND EXTENT (1979 STATISTICS)

In the U.S., nonferrous metal ores are the most dependent on C/F mining. C/F mining is singularly a most important source of silver ores. U.S. mine production supplied about 20 percent of total domestic demand for a value in 1979 of $408 million. The Coeur d'Alene mining district

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(State of Idaho, NW U.S.) produces over 40 percent of this, all C/F mining. The State of Colorado is another substantial producer of silver ores from C/F mining. Remaining domestic mine production of silver is generally a secondary product of Pb/Zn/Cu or Mo mining.

C/F mining is an important source of Pb/Zn ores. The U.S. is about 90 percent self sufficient in Pb, valued at $549 million. Ten percent of this is from C/F mining in the Coeur d'Alene mining district. Domestic mine production of Zn, valued at $215 million has supplied 38 percent of total demand; of this New Jersey and Idaho supplied 12 percent, each, of domestic production from C/F mining.

Cu ore from C/F mining comes from the State of Arizona, mainly the Superior mine, producting approximately $70 million in Cu.

The Homestake mine, largest U.S. underground gold mine, produced $165 million of $275 million total U.S. mine production. A substantial portion of Homestake production is from C/F mining. Gold, as a secondary product, comes from other C/F mines. Many small C/F gold mines with unavailable production records exist.

The use of backfill in uranium mines is increasing. Antimony, bismuth, and cadmium--minor but important commodities--are all secondary products to milling and refining Pb/Zn ores, thus are substantially dependent to a large extent on C/F mining.

METHOD AND VARIATIONS

C/F mining is a selective mining method resulting in maximum recovery with minimum dilution. The vein is developed along the strike length in 200- to 400-foot blocks or stopes and vertical lifts of 160 to 200 feet. The level development is either on the vein or parallel to the vein with crosscuts intersecting the vein at right angles. Chutes, manways, and haulageways are established in the center of the blocks. Mining then proceeds by blasting horizontal cuts in both directions from the chutes. As blasting continues to the outer limits of the stope, the broken ore is transferred to the raise area. When a complete horizontal cut has been made, the stope is filled and the mining cycle repeated.

Development

Two basic methods are used: (1) development of the level haulage drift within the vein, or (2) development of the haulage drift paralleling the vein in the foot or hanging wall with crosscuts intersecting the vein perpendicularly at 200- to 400-foot intervals. If the vein is relatively straight, then development on the vein is feasible; although excessive ground pressures may necessitate the leaving of a sill pillar, and highly fractured or "heavy" ground will require timbering. Development on the vein has the advantage of reducing capital outlay and waste-handling problems since the mined rock has value, but removal of the sill pillar is costly and time consuming. Also, where no sill pillar is left, excessive timbering and subsequent level repair is a drawback. Development in either the foot or hanging wall is the more common procedure and offers greater flexibility in overall development of consecutive stoping blocks by partially disassociating the level development from stoping.

Chutes, manways, and service compartments comprise the next stage of development and are established in a variety of ways. They provide for access, ventilation, and muck removal. Raise borers may be used to estab- ventilation, access, and service from level to level. These are normally reamed with a 5- or 6-foot cutterhead and may either be left bald or lined with liner plate, depending upon ground conditions. The use of an Alimak[2] raise climber is another effective method of driving a raise

[2] Reference to specific equipment or trade names does not imply endorsement by the Bureau of Mines.

from level to level. The size usually is 7-foot square. This will accommodate square-set timber which is later installed if required. Conventional raising is still used. This method is used to establish two-compartment timbered raises from level to level. Subsequent chutes and access ways to the stope mining horizon are established by conventional raising practices.

Stoping

Overhand stoping is prevalent, but underhand C/F is being used increasingly. Initially (overhand), a cut has to be taken to undercut the ore block. Once the first cut has been completed, the stope is prepared for fill by installing the chutes and manways to within a few feet of the stope back. All the openings to the level below are sealed and the stope is filled. Mucking and drilling equipment are then moved up and breasting down or backdrilling of the vein commences.

Underhand C/F mining is applicable to conditions in which either wall rock or the vein is too unconsolidated to permit safe mining by conventional C/F methods. Mining starts immediately below the level, bounding the upper limit of the stope. A cut from 10 to 14 feet in depth is mined along the strike in each direction from the ore pass. A mat must be laid, generally consisting of caps hitched into hang and foot walls, and overlain with stringers and reinforcing mesh. Fill adjacent to the mat must be cemented. The result is a safely designed back for the subsequent cut.

PROBLEMS

Problem areas related directly to C/F mine exploitation concern productivity, ground control, and ventilation.

Productivity

C/F mining is characteristically a labor-intensive method--benefits are derived from "clean" mining, that is, near total extraction with minimal dilution. This has depended on skilled miners working on a bonus pay system. Substantive increases in productivity can only be accomplished by increased mechanization. Older mines must work within the constraints of existing development and installed mine plant capacities (ventilation, hoisting, etc.). New mines must be developed in the initial stages to optimize use of mechanized equipment. In both cases, mechanization requires heavy capital investment.

The successful development of new continuous mining machines that can excavate hard materials is the key to the development of integrated and continuous systems and, ultimately, truly low cost C/F mining. Further development of equipment for hydraulic transporting and hoisting would enable increased use of existing loading capacities and eliminate the cyclical nature of current hoisting operations. Possibilities also exist for a continuous mining process by coupling hydraulic transporting-hoisting methods with hydraulic or solution mining systems.

Ground Control

All elements of ground support become increasing problems as older mines go to great depths. Rock bursts are a major problem in the Coeur d'Alene mining district. Required are advances in rock engineering principles and rock mechanics instrumentation that will facilitate safer, more economical mine design, and the construction of predictive models to forecast rock mass behavior over a period of time. Instrumentation could enable the development of monitoring and warning systems for potentially unstable mine areas. Definitive manuals (not texts) that relate rock mechanics principles to actual design practices are needed. Published case histories of real design situations would serve as sample applications.

Ventilation

Ventilation problems, like ground control problems, increase dramatically with both increased depth and lateral extent. These problems are compounded with the use of diesel equipment. C/F mining in the U.S. is into the mile plus depths requiring innovative air cooling systems to maintain productivity.

Monitors to sample critical atmospheric contaminants continuously, and suitable for mounting on machines, are needed. A computerized monitoring system is being developed now for coal mining. Equivalent systems could be developed for sampling other unique mine environments that contain such contaminants as radon gas and diesel exhaust fumes. Improved exhaust scrubbers for diesel-powered equipment are needed. There is a need for improved filtering devices for the radioactive daughter products (alpha, beta, and gamma emission particles) and radon gas.

BuMines Research

Bureau of Mines research related to C/F mining is extensive in the areas of stope fill, rock mechanics, artificial support, and rock-burst control. Fill research programs involve densification, dewatering, and physical properties of fill. Rock mechanics programs involve extensive use of finite-element techniques, in situ stress measurement, and instrumentation system design. Artificial support programs concern continuous lining systems, vastly improved rock-bolting systems, and replacement materials for timber. More recently, programs are developing unique underground mining machinery.

Future

C/F mining systems with adaptations should be the mining methods of the future. The significance of C/F mining related to the need to increase the domestic production of some commodities (see "Importance") is self-evident. This method is the only system that can maintain opening integrity at great depths. It is readily adaptable to mechanization in new mines and will become generally more cost-effective as environmental considerations become more stringent and need arises to mine previously uneconomic deposits. C/F systems will be inherent to any advanced underground methods utilizing continuous mining machinery or hydraulic transport.

Three other important factors insure the need for increased C/F mining:

1. Environment: The method is environmentally ideal. All mining activity is underground, and equipment maintenance and primary milling facilities may readily be placed underground resulting in only minimal surface structure. Waste disposal is minimized since the bulk of waste material is returned underground. Subsidence, of course, is nonexistent since only the desired openings are made and then filled.

2. Safety: The system is inherently safe. Mining is always "under control," with relatively small amounts of material broken at a time. This is in contrast to caving systems requiring "controlled failure" of masses of unpredictiable rock, or the large openings encountered in blast-hole methods.

3. Selectivity and recovery: It is a precise system, any desired grade may be maintained and the method is applicable to any configuration of ore body. Nearly 100 percent of extraction may be accomplished--pillars are readily retrieved with second mining.