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FLUORSPAR MINING IN DERBYSHIRE

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Abstract: Laporte Minerals' Glebe Mines and its independent ore suppliers extract, by both underground and surface mining, about 420,000 tonnes per year of fluorspar-bearing ores, which are treated at the Cavendish Mill near Stoney Middleton in Derbyshire, within the Peak District National Park. The ore is processed to produce 75,000 tonnes per year of "Acid Grade" fluorspar plus by-products.

INTRODUCTION

Vein minerals from the Derbyshire orefield have been extracted and processed for lead from Roman times. Glebe Mines has mined and processed fluorspar since 1938, eleven years before the National Park was created. Laporte acquired the company in 1959. Cavendish Mill was opened in 1965.

Ore is supplied to the mill from three types of operation: the Company's own underground mines; opencast ore quarried by sub-contractors on properties where Laporte has obtained the mining rights, and opencast ore bought from independent suppliers ("tributers"). The practical economics of mill operation require this mix of high quality underground ore with the lower grade opencast.

GEOLOGY

Fluorspar mineralization is mostly to be found on the eastern side of the Derbyshire dome. The deposits are of fissure vein type and are restricted stratigraphically to Visean limestones of the Carboniferous System in a structurally controlled environment. Fluoridization of limestone in fractured or well jointed zones has also given rise to replacement deposits.

The dome-like limestone structure is exposed over an area of approximately 520 km² and is flanked, except to the south, by overlying shales and grits. The limestone contains interbedded impervious contemporaneous volcanic rocks. The volcanics occur as tuffs and lavas, locally called 'toadstone' when encountered in the fluorspar workings. Vein mineralization is largely confined to the limestone but may be attenuated or cut off at these volcanic horizons. In cases where the toadstones are thick, these effectively form a lower boundary to mineral extraction. Veins do not extend into the shales and gritstone which form a barren cap to orebodies extending east beyond the limestone outcrop. The workable depth of vein is usually about 100m. Veins can vary in width between 1.5 and 12 m over relatively short strike lengths. They are composed of varying proportions of fluorspar, barite, calcite and galena.

Dr Bramley is General Manager of Laporte Minerals, Stoney Middleton. This paper was originally presented at the 14th Congress of the Council of Mining and Metallurgical Institutions, organised by the IMM and held at Edinburgh from 2-6 July 1990. This version is reproduced from the Mining Magazine (Vol. 163, No. 5, of November 1990) with permission. The photographs, which were not published previously, are provided by H.M. Parker.

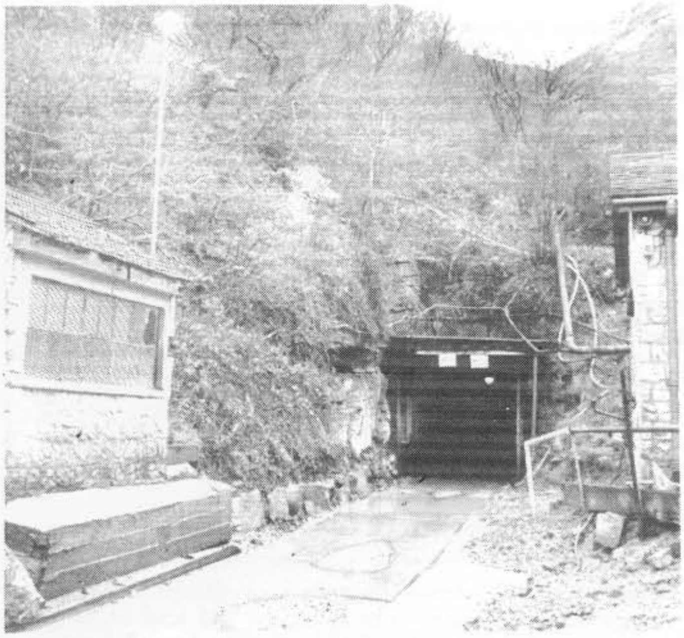
UNDERGROUND MINING

Glebe has operated underground mines in two major vein structures: Hucklow Edge and Longstone Edge Veins, to the north and south respectively of Cavendish Mill. Both veins were extensively worked by the old lead miner but their characteristics differ. Mining in Hucklow Edge Vein is where the limestone is capped by shale and gritstone, whereas on Longstone Edge the vein outcrops and was first extensively worked opencast. The Longstone Edge Vein mineralization is thus more weathered and structurally less competent.

Ladywash Mine exploited Hucklow Edge and associated veins until 1979. Operations ceased because the in-vein sub-level stoping mining methods then in use had become unsafe, due to the incompetence of the vein. Furthermore, the overlying weak shale strata had collapsed in a number of places with two deleterious effects: mixed with the ore it had rendered the mill froth flotation process inoperable, and the collapse had caused subsidence holes in the sensitive landscape of the Hucklow Edge escarpment. Ladywash Mine had also become uneconomic because it was worked from a 220 m deep shaft of only 1 tonne per wind hoisting capacity geared to narrow underground haulage.

Extensive reserves remained along strike to the west of

Ladywash Mine on Eyam Edge soon after closure.



Sallet Hole No. 1 mine, which uses trackless haulage.

Ladywash Mine workings and development of a new mine, Milldam Mine, to exploit these is now well advanced.

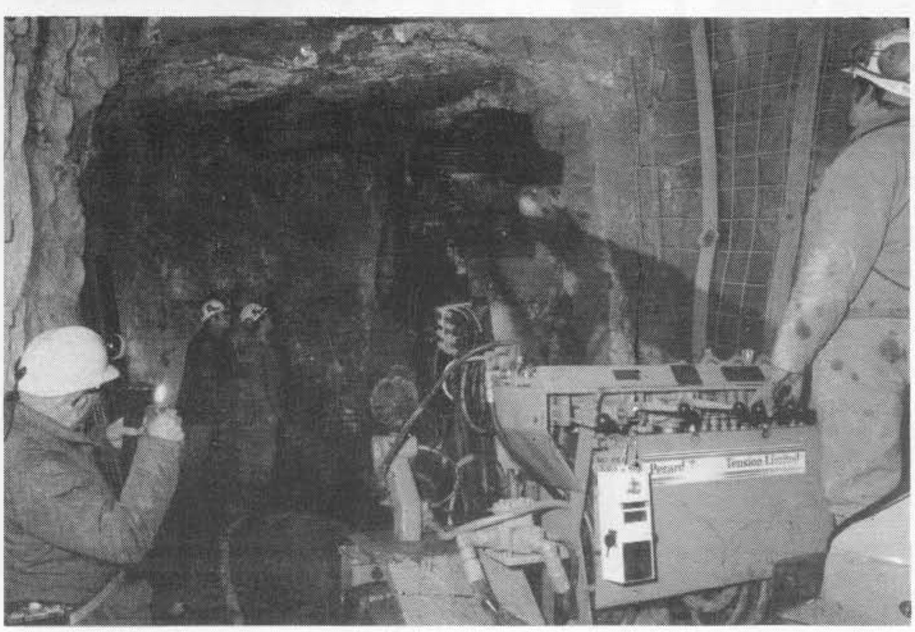
Access to the vein is now provided by a 1 in 8 drift downwards from just below the exposed shale-limestone contact. Mining will be by a modification of the trackless method currently in use under Longstone Edge as described below.

Sallet Hole Mine was opened in 1965, since when it has exploited the ore below opencast depth over a strike length of some 3.5 km. The mining method has been long-hole caving (to surface) based on haulage drives in limestone parallel to the vein (Fig. 1). The mine is trackless based on Eimco 912 LHDs and 6 tonnes tractor/trailer units.

The tractor/trailer units are a customized design based on standard agricultural tractors sized to fit roadway dimensions of 3.3 m square with appropriate clearances. The choice of tractor ensures the ready local availability of spares. Long-hole rigs are diesel-hydraulic, one having the option of electric power. Single boom hydraulic rigs are used for headings.

Current practice is to cave no more than a vertical interval of 25 m in order to control stoping and prevent wallrock dilution. Accurate placement of the long-hole fans is important; care is taken that the mineralization encountered in each hole is recorded and the hole charged accordingly. Long holes are normally charged with Gelamex, Cordtex igniter cord and electrically detonated. Headings in limestone are driven using 2 m drill rods, with an average "pull" of 1.8 m. Again, nitroglycerine explosive is used although it is planned to change to ammonium nitrate/fuel oil (ANFO) in the future. Current productivity at Sallet Hole Mine, from a total mining workforce of 38, is 24 m of development plus 1748 tonnes of ore per man per year.

Milldam Mine is still in the primary development stage. The mining method to be used, shown schematically in Fig. 2, is "concrete pillar stoping". Parallel drives and cross-cuts will be constructed to a very similar layout to that at Sallet Hole. Stoping is planned to be in 25 m high panels of 9 m strike length. This plan is based on an assumed vein width of 2.5-3 m and the dimensions may be varied according to circumstances found along strike.



(left) The new Milldam Mine on Hucklow Edge - carefully driven below ground level for environmental reasons.

(bottom) Driving the main adit in Milldam.

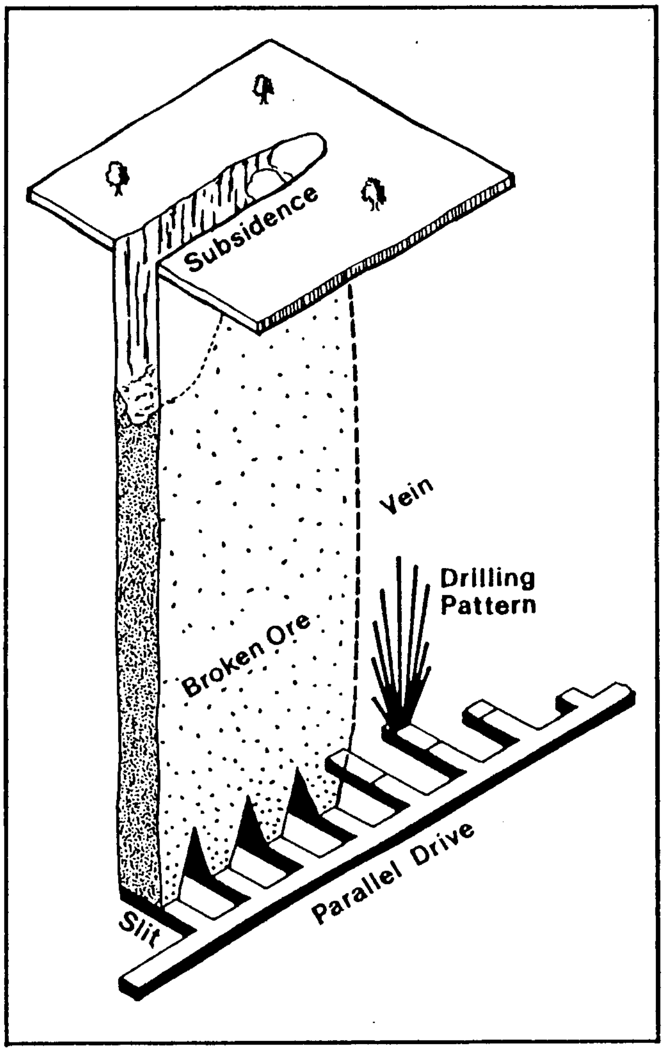


Fig 1. The stoping method currently in use at Sallet Hole Mine.

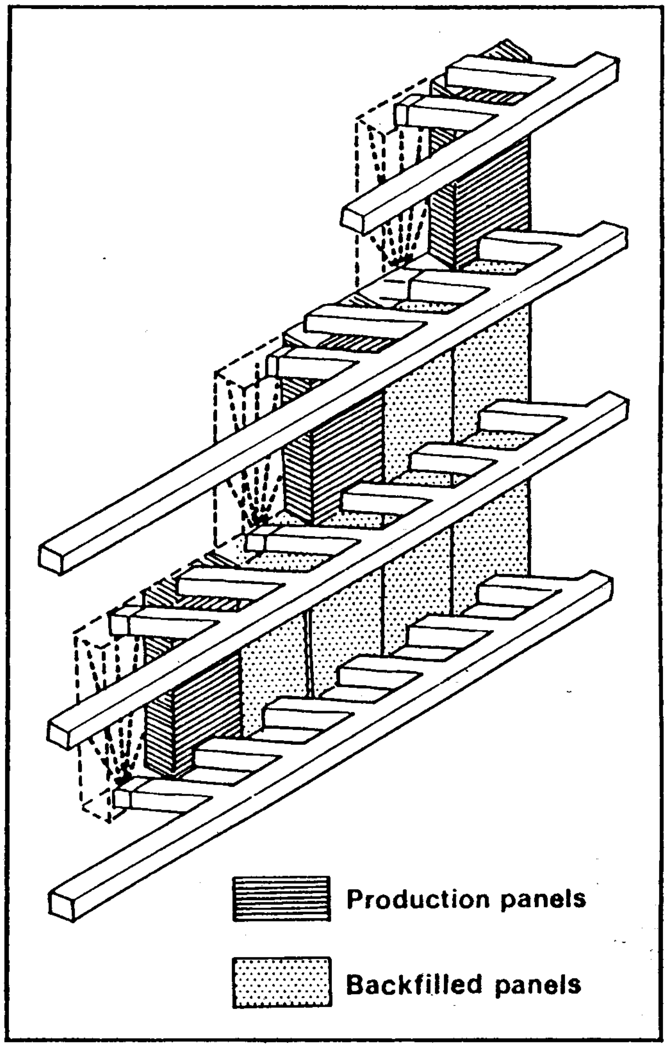


Fig 2. The proposed stoping method to be used at Milldam Mine.

Diamond drilling from the primary development drive has already found vein widths which in places exceed 11 m. Stoping is planned to commence at the lowest horizon, above the toadstone, with access from two parallel drives spaced 25 m vertically apart. Exhausted stopes will be backfilled before proceeding to stope the next 25 m depth of vein above. Backfill will be composed of roughly equal proportions of heading stone (from the parallel drives and crosscuts) and unclassified mill tailings containing 6% Portland cement. This method has been tested and proved in Sallet Hole Mine where it has been shown that unstoped vein can be extracted cleanly adjacent to a backfilled panel.

Sallet Hole Mine is scheduled to produce, in 1990, 73,000 tonnes (dry wt) of ore containing 45-50% CaF_2. When Milldam Mine is brought into production during the course of next year it will be worked at a similar rate.

SURFACE ORE SUPPLY

About half of the 340,000 t of surface ore milled each year comes from opencast operations sub-contracted by the company. The other half is ore produced by tributers which is bought over the mill weighbridge for prices related to fluorspar content. The control of surface ore quality is most important, particularly because most surface ore is in the grade range of 20-27% CaF_2 about half the underground ore grade. This difference in quality is largely because the majority of opencast operations are working replacement orebodies, as the classical fissure-vein deposits accessible for surface working are now depleted.

MILLING

The mill is run on a continuous shift basis for between 225 and 228 days a year in scheduled campaigns of between 6 and 8 days using only 3 shift crews. The operating rota provides for maintenance on weekdays rather than at weekends. Prior to 1982 it was manned by 4 shift crews and ran 7 days a week with a monthly maintenance shutdown of 1 or 2 days. The present running pattern was the result of a decision to shed low-profit sales volume in favour of a significant saving in fixed costs. Subsequent experience has demonstrated the further benefit of steadier running with far fewer unscheduled stoppages.

All ore supply to the mill is delivered by road, on weekdays only, on to a central blending and reserve stockpile. A total of 12-14 different ore sources can be delivering to this stockpile at any one time. Close manual sampling of individual lorry loads together with rapid determination of grades is necessary to maintain the required control of ore quality.

Ore assay results are transmitted throughout the day by telephone or radio to management in the field, because

(above) Cavendish Mill near Stoney Middleton - the processing plant and offices.

(below) Wemco flotation cells in the mill.

visual estimation of ore quality can often be misleading, even with experienced loading machine operators. Feedback from the laboratory to source must be as fast as possible. The standard method of ore analysis is by neutron activation using equipment developed in conjunction with the Atomic Energy Research Establishment (A.E.R.E.), Harwell, in the early 1970s.

Fluorspar, barite and silica are separately determined. Since 1986 this method has incorporated electronic control and computer print-out of results.

ORE PREPARATION

A blended mix of ores is fed from the stockpile using a wheeled loader to a small storage hopper. A variable speed apron feeder and conveyor belt feeds an open-circuit wet operated 0.9m x 0.6m Parker jaw crusher set at 90mm. This feeds a twin boom 12.2 m long by 1.1 m diameter logwasher, from which the bath material flows over a coarse trash screen and a fine trommel (for wood and vegetation removal). It is further washed (and -15mm material removed) on a rubber decked vibratory screen. The screen oversize is then crushed in a closed circuit APK 50 Hazemag impact crusher. Tramp metal is initially removed by electromagnet and metal detection equipment. A double-deck Niagara vibratory screen removes -18 mm material and returns +37 mm material to the crusher. The +18 mm -37 mm middlings are rejected at this stage as a low mineral content waste and sold as roadstone. This represents a removal of some 10-12% of total ore feed.

Dewatering of the logwasher bath overflow and the -18mm fraction from the logwasher and Niagara screens is carried out in a Harleyfield Hydrosand Elutriator and a Sandor-wheel Dewaterer. The finer -0.5mm pulp is pumped to a bank of six 230 mm Lintatex rubber lined desliming cyclones with 19 mm ceramic spigots. Some 15% of overall ore feed reports to the cyclone overflow, 50% of this is -7 micron material. The cyclone overflow accounts for around 4-5% loss of total plant fluorspar input.

Commissioning of improvements to the desliming cyclone circuit commenced in February 1990. A bank of 50 x 75 mm Mozley cyclones has been added to treat the overflow from the original desliming circuit. Because of the very small spigot diameter of these secondary cyclones (5 mm) it has been necessary to install a fixed wedge-wire detrashing screen ahead of the desliming section. This new circuit has resulted in an overall improvement in recovery of 2-3%. The cyclone underflow is stored in agitated tanks and accounts for approximately half of the feed to the mill flotation circuit.

HEAVY MEDIA SEPARATION

The +0.5 mm -18 mm fraction from dewatering is stored in a 200 tonne bin ahead of a Sala DynaWhirlPool (DWP) separator plant. Feed is at a controlled rate of 40-45 tonnes per hour to a bucket elevator. This feeds a Wemco 2-stage attrition machine to remove any residual clays. The feed then cascades over a wedge-wire screen to a rubber-decked vibratory screen with high intensity wash water which removes already enriched -3 mm fines. These are separately collected in a 0.9 m Wemco spiral classifier. The +3 mm -18 mm fraction feeds the 300 mm diam. DWP unit. An operating media density of 2.70 to 2.76 is maintained with an approximate 1.5 to 2 parts magnetite to 1 part milled ferrosilicon. A separation efficiency of 90-94% fluorspar recovery is typical. The DWP products transfer to a common wash and drain vibratory screen where residual media is collected and transferred to the magnetic separators. Media loss is of the order of 350 g/t feed to the separator unit.

Both the fine sands and the product from the separator are conveyed to a 250 tonne storage bin ahead of the ball mill flotation circuit. This represents the other half of the feed to the circuit.

MILL AND FLOTATION

The 2.4 m diameter by 2.7 m Dunford rubber lined discharge grate mill is fed from the upgraded heavy media stone and sands. A 1.8 m diameter Denver spiral classifier operates in closed circuit with the mill.

The deslime cyclone underflow is also fed to the classifier and enables any oversize from this source to be returned to the mill. The mill operates with 50 mm forged low carbon steel balls and a discharge density of 65-68% solids. The primary grind is controlled in the range 15-22% +150 microns. This enables a high degree of liberation and minimizes any overgrinding of the softer barite. Fresh water is used for the grinding and flotation section. The feed to flotation is typically 32-34% solids.

With one exception (the Denver lead cleaner) all the flotation cells are Wemco machines incorporating 1 + 1 mechanisms. The fluorspar rougher cells are each of 2.8 m^3 capacity, all other cells being 2 m^3.

The first stage of the circuit is lead sulphide and oxide rougher flotation. It is carried out at neutral pH (typically 7-8) in a single bank of cells. A single cleaner produces a 65/70% concentrate. Lead removal, apart from its by-product cash value, is essential because metallic sulphides reporting to the fluorspar concentrate will result in elemental sulphur precipitation during the manufacture of hydrofluoric acid. Conventional flotation for a typically 2 parts sulphide to 1 part oxide/carbonate feed is used. The circuit also scavenges small quantities of pyrites and zinc blende. Regrettably, precious metal levels are low with only silver values detectable (35-40 gramme per tonne concentrate).

A stage fluorspar rougher operation incorporates a small (2.4 m x 1.2 m) Dunfold overflow regrind mill fed from the underflow of a Linatex 450mm cyclone. Feed to the rougher is 40-45% CaF_2 and typically produces a 85-90% CaF_2 concentrate which proceeds to a four stage cleaner circuit. The circuit is operated at a pH of around 10.2 and at ambient temperature.

Apart from the temperature and the flotation of fluorspar before barite, the flotation techniques are conventional. Because calcium carbonate is the main host rock, rather than silica, there is a tendency for fine calcitic slimes to float readily, particularly in warm weather. For this reason the best performance is most often obtained during the winter months. Final concentrate grade is 97.4-97.8% CaF_2 and it is a relatively coarse product. Size is typically 10-12% +150 microns and 38-42% -45 microns.

Soda ash pH modification is a fully automatic bulk reagent mixing and closed circuit system. Other reagents are fed from troughs through rotating disc and cup feeders thence by gravity to the conditioning tanks. Oleic acid, the fluorspar collector, is fed heated but without emulsification. Different grades are used in summer and winter; a less selective and less viscous material usually being preferred in winter months. Dextrine and mimosa extract are used in the fluorspar circuit as depressants for silica and calcite. Dextrine is solubilized with caustic soda prior to dilution with water. The mimosa extract (or quebracho on the rare occasions when greater calcite selectivity is required) is also used in a water solution.

Fluorspar flotation recoveries have averaged 94-95% over the last 3 years, some 2% higher than previously. This is due to improved control, flowsheet and reagent development, and steadier plant operation with the campaigned runs established in 1982.

Cyclone dewatering and desliming is carried out prior to barite flotation. The circuit currently comprises a bank of 8 x 120 mm and two banks of 16 x 50 mm Mozley cyclones (incorporating 1.5 mm detrashing screens) with approximately 45% feed pulp density to two banks of roughers and two cleaners.

The three final cleaner concentrate products are pumped to dewatering thickeners ahead of rotary drum vacuum filters. The fluorspar thickener is 15.2 m diameter, and the barytes and lead thickeners 9.1 m and 7.6 m diameter respectively.

DEWATERING AND DRYING

The fluorspar concentrate is fed to a 23 m^2 Stockdale drum filter and produces a wetcake of around 9% moisture. The

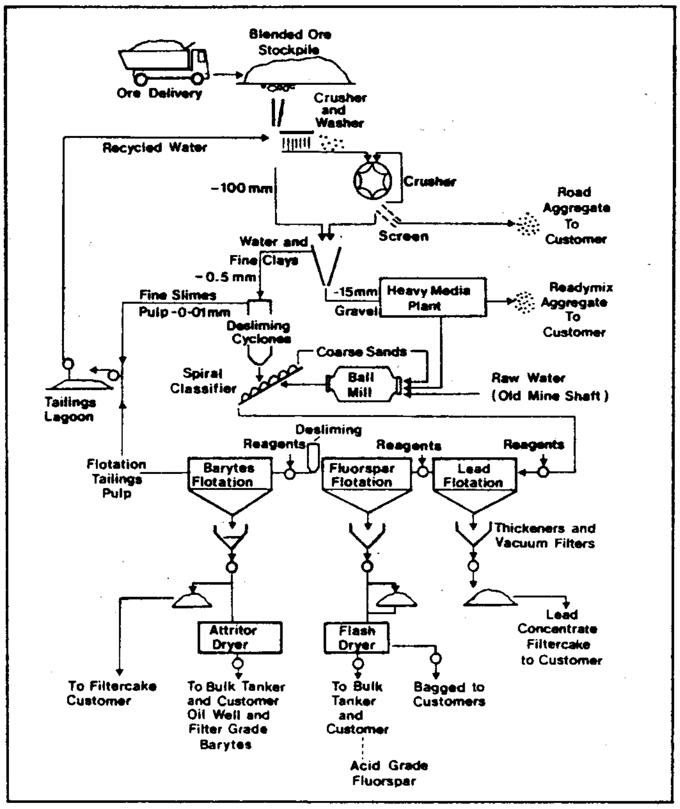


Fig 3. A schematic flowsheet for the Cavendish Mill.

barite is filtered on a 12 m^2 Stockdale filter and the lead on a 5 m^2 Stockdale filter. The fluorspar and barite filtercake production is weighed by belt weightometer.

Almost all of the fluorspar filtercake is dried in a Rema 550 tonnes per day thermo-venturi "flash" dryer. The dryer feed is either from the plant supplemented by backfed material from the filtercake warehouse, or from the warehouse direct. The dryer is fired with gas oil.

A small dried barite demand is met using a 16A Alfred Herbert Atritor dryer. Most of the barite concentrate and all of the lead concentrates are sold as filtercakes.

TAILINGS DISPOSAL

The flotation tailings are combined with the desliming circuit overflow and pumped to the tailings lagoon as a suspension of 5-6% solids. A polyelectrolyte flocculant is added before distribution around the lagoon with the result that the settled tailings are mainly composed of flocs of mixed particle size distribution. The resultant minimal particle size segregation in the beached tailings confers a stability which is particularly advantageous in subsequent handling of this material.

The tailings lagoon is sited at the head of a shallow valley and is retained by an earth wall engineered to comply with the 1930 Reservoirs Act. Because the lagoon sits on potentially fissured limestone, the vegetated topsoil was left in situ beneath the areas designated for tailings deposition. As the level of the lagoon rises it is the clear supernatant water which is first to advance up the valley slopes, revealing leaks which can then be plugged from the shoreline with a mixture of clay, soil and crushed stone. Leakage of tailings slurry to the underground strata is illegal.

Tailings are dug from exposed beaches for several uses: when required as mine backfill; as the major constituent of "artificial soil" (as noted below), and to form coffer dams within the lagoon area as a means of forming terracing above the operating level.

ENVIRONMENT

The environmental constraints of operating in a National Park are significant items on management's agenda. The individual opencast sites are usually restricted in size by the extent of the orebodies, fragmentation of mineral ownership or by Planning Permission limits. Ten or more such operations can be active at any one time but their life is often no more than one or two years. Thus there is frequent need to seek planning permissions for new sites and success depends upon a good reputation as a responsible operator with high standards of restoration.

Planning permission for Milldam Mine was obtained in 1986 with the imposition of 52 separate Planning Conditions. The mine compound, adjacent to the village of Great Hucklow, has been landscaped to prevent neighbouring noise levels exceeding 45 dB. The visual evidence of industrial activity is also effectively concealed.

About 150,000 tonnes of fine tailings are deposited in the Blakedon Hollow tailings lagoon each year. Planning Permission for this facility was granted in 1975. Two other tailings lagoon areas were completely filled in 1972 and 1978. Both have been restored: one to grazing and one as a bird sanctuary with hide, and have been visited by restoration specialists from all over the world.

Opencast excavations are generally restored to conform with the surrounding landscape. There is very little topsoil on the Derbyshire limestone moors and it can often be impractical to store it for subsequent use in restoration. Successful use has been made of an artificial topsoil mixed on site from about 10 parts mill tailings with 1 part of sewage sludge. Mixing of the constituents can be carried out by the bulldozer used to spread the tipped lorry loads. The majority of ore lorry traffic to the mill, approximately 150 return journeys per day, is local and avoids residential areas. Planning permissions for surface ore sites, however, often contain conditions specifying the route to be taken to reach Cavendish Mill.

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