Welsh Slate and the Penrhyn Quarry.

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GENERAL.

North Wales has long been famous for the high quality and the immense quantities of slate it has produced. As much as 20 years ago there were 100 quarries in North Wales. The total output of Welsh slate for the year 1906 is given as 379,806 tons, valued at £1,047,917. Australia in the same year imported from the United Kingdom 4,085 tons, of which the invoiced value was £4 13s. 7d. per ton.

The two principal slate series of North Wales lie on opposite sides of the Snowdon Range, in Carnarvon and Merioneth. The former, which is more or less highly tilted, extends from Conway (on the north-east), *viâ* Bethesda, Llanberis, and Mantlle Valley to Pwllheli, where it is cut off by a granite intrusion, though it is believed to continue again in Ireland. The total length given above is over 20 miles. The latter series, which is horizontal, is chiefly developed about Festiniog. The Carnarvon slate being stronger, is generally preferred to, and brings a higher price than, Merioneth, which is often pyritous.

The rock is obtained both by open cut and by underground excavation, 30 per cent. of the output for 1906 being credited to 33 mines, of which the largest is at Festiniog. There is a large quarry in the vicinity of Carnarvon, but the Penrhyn, near Bangor, is the largest in the world, wherefore a brief account of the methods in vogue there may therefore be of interest. It is to be understood, nevertheless, that the writer's visit was far too hurried for anything like an exhaustive account to be prepared.

FIG. 1.—PART OF THE PENRHYN QUARRY. [*Photo.*, *L.C.B.*

(SHOWING SHELTER-HOUSES ON DIFFERENT GALLERIES AND A LITTLE OF THE GREAT LAND SLIDE, ON THE LEFT.)

LOCATION AND OWNERSHIP.

The Penrhyn Quarry is located on the eastern flank of Tronllwyd, a high conical mountain overlooking the River Otwen, and about $1\frac{1}{2}$ mile west of Bethesda, the terminus of a short branch railway from Bangor (a Cathedral town at the north-eastern entrance to the Menai Straits, and one of the largest centres of population in North Wales).

The quarry is directly connected by a tramway with a spur of the Bethesda Railway, and is about 5 miles from Bangor. Lord Penrhyn, the proprietor of the quarry, has a chief manager (Mr. Young) stationed at the shipping port, and a local "agent" (Mr. Davis) at the quarry.

OUTPUT.

Mr. Young has informed me that the annual output amounts to about 100,000 tons. He was unable to state the value; but, judging from the figures for the whole of Carnarvon, it could not have been much below £3 per ton, and for purposes of calculation good slate rock in the quarry is held to be worth £1 to £2 per ton. The Bethesda Quarry was said,* in 1876, to be paying a profit of from £100,000 to £150,000 per annum, when the output was 120,000 tons per annum, and valued at £3 per ton.

The slate shipped comprises roofing slate of various sizes (12 x 6 to 24 x 14, and larger if required), school slates (from the smaller blocks), mantle-pieces, cisterns, gravestones, and billiard-tables.

EXTENT AND EXPLOITATION.

The quarry covers an area of, approximately, 120 acres, being $\frac{3}{4}$-mile in greatest length and $\frac{1}{2}$-mile in width. From the bottom to the upper edge on the hill-side is a total of 1,200 ft., but from the lower lip to the bottom is only 550 ft., owing to the steep slope of the mountain.

The quarry resembles a somewhat irregularly shaped and elongated Roman amphitheatre, for the sides rise in a series of steps, each 20 yds. high. The platforms (now numbering 20), on which the men work, are locally known as "galleries," and are about 10 yds. wide. The width of the galleries should theoretically be equal to the vertical distance between them, but should never be less than one-half that height. The danger of having the platforms too narrow was attested by a landslip in the early forties. The general stope of the inner side of the quarry had been left so steep that a large part of the mountain above came away, and even yet all the débris has not yet been removed, while some trouble is given by the water which percolates down through it. The galleries are all worked simultaneously out from the centre, and, as the bottom of the pit thus becomes larger, a new pit is started in it, forming at the same time a new gallery.

A certain proportion (known as a "bargain," and from 4 to 6 yds. wide) of each gallery is allotted to each crew of three men and a boy, who blast down the face above, by means of black powder, dynamite being employed only in bad rock. All drilling in the slates is by double-handed drills, but machine-drills are employed in working through dykes. On all the galleries there are cabins (built of slabs of slate, timber, and shingles), to which the men retire for shelter during blasting, which takes place at certain definite hours, and of which warning is given by the hoisting of a red flag to the accompaniment of a bugle call. The slate falls on to the gallery, on which a tram-line has been laid, and is run out on light wooden trucks.

The galleries below the lower lip of the quarry are connected by tunnels, 7 ft. high and 12 ft. wide, and none more than 600 ft. in length, with a series of shafts, each about 15 ft. in diameter and between 120 and 400 ft. in depth. Up these all material is raised to the main surface gallery by means of water balances. (See below.)

From this main gallery all waste is now carried up a steep incline to a stack, the rope haulage being driven by water power. Formerly the waste was simply run out in the trucks and dumped into the valley, but presumably the large quantity of comparatively valuable

* "Slate Quarrying." By Morgan Richards.

arable land being eaten up has had to be considered. Indeed, among the most noticeable features of a slate quarry of any size are the huge dumps or waste heaps, those at the Penrhyn Quarry containing many millions of tons of stone. One of the causes of waste in the past has been the practice of paying the quarrymen so much per ton of rock removed, in addition to payment for slates made. Slate is still destroyed every time the rock is dislodged from above the galleries, and, even though the dressers are wonderfully expert, the waste from each shed is of some volume in a single day. A second cause of waste operating at a few quarries is the vertical (instead of stepped) sides, a method formerly preferred in Mantlle Valley. The great fall here results in the breaking up of most of the blocks; and, in addition to the absolute loss of the stone, a higher percentage has to be paid the quarrymen. Great waste is said to occur by working slate underground in the large proportion of the rock required to be left for supports.

Very little water enters the Penrhyn Quarry by soakage, and most of the surface water is caught in drains on the various galleries. What water does find its way down is pumped to a drainage tunnel 210 ft. above the present bottom. This tunnel is a mile in length, and empties into the River Otwen on the north.

MEN EMPLOYED.

A total of over 2,000 men are employed here, all on one shift, beginning at 7 a.m. and ending at 5·30 p.m. (with one hour for lunch). The general manager states that during good times the number of employees would reach 3,000. The employees comprise quarrymen, dressers, rock-men, wagoners, and labourers, besides loaders, markers, weighers, a few mechanics, engineers, &c. The labourers and rock-men are paid by the day, per ton or per yard of material removed; and the quarrymen receive so much (a "standard" price) per 1,000 slates produced from a given "bargain" or tribute, with perhaps poundage added. The standard price may vary between 2s. 6d. and £2 per 1,000, according to size, while the selling price will be nine or ten times these figures. This does not all represent profit, for "poundage," amounting to from 5s. to £5 per £ of the standard price, has always to be paid the quarrymen to allow for bad ground.

I understand that quarrymen receive about £5 per month, and that slate-makers make 4s. or 5s. per day, but unfortunately can give no information *re* costs on the authority of the manager. No horses are kept at the quarry, all trucking along galleries being done by men and boys, but locomotives are in use outside the quarry.

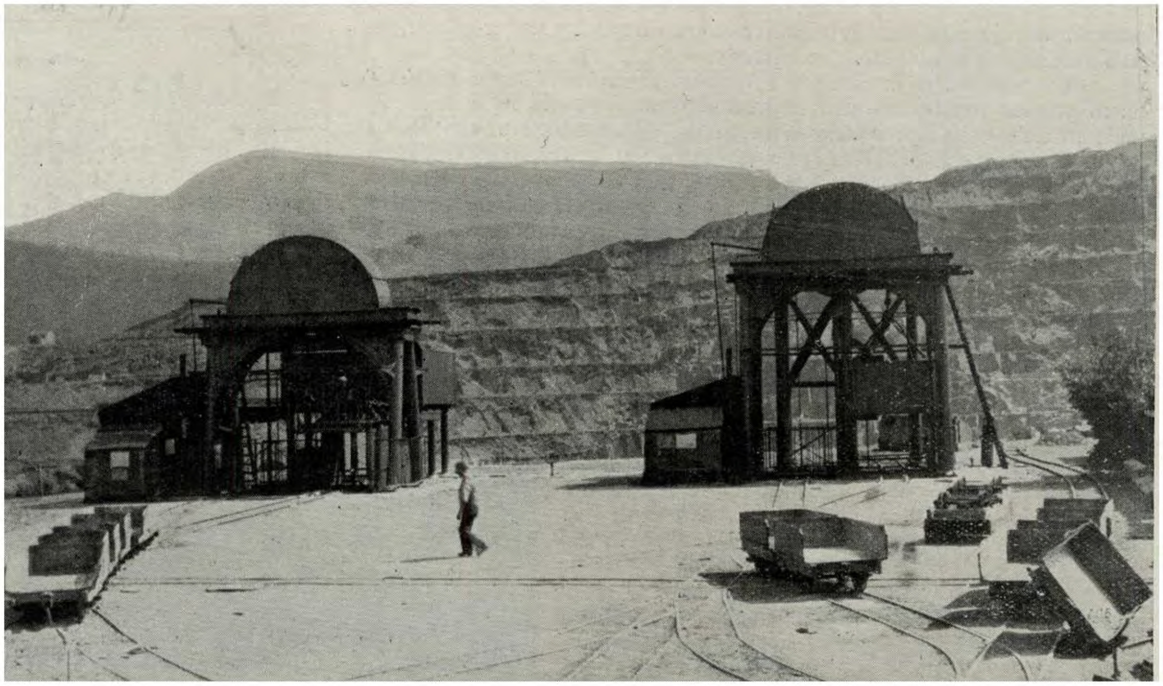
MACHINERY AND MECHANICAL APPLIANCES.

One is surprised at the small number of mechanical appliances seen at the quarry. With the exception of the 14 small locomotives on the main gallery and a 10-in. auxiliary pump in the drainage tunnel, the only steam-driven appliances are three Ingersol-Sergeant drills, which are supplied with steam from small boilers carried on trucks. These are capable of drilling a hole 16 ft. deep, and with a diameter decreasing from 3 ft. to 2 ft. 6 in. in 1½ hours, on an average, the charge of powder being 35 lb. per hole. They are very seldom used except when a dyke has to be penetrated.

All other mechanical energy required is supplied by water-power. The water, taken from the Otwen River below a lake of the same name, 4 miles distant, is brought to the quarry in a race or in fluming 2 ft. 6 in. wide and 18 in. deep. The fluming is built of 2-in. planks, clamped together by ½-in. round iron rods fitted with brackets.

The most important of the water-driven appliances are the "balances," each of which comprises a pair of iron cages, 10 ft. long and 5 ft. wide. These are suspended by a flat wire rope (6 in. wide and 1 in. thick) working over a 10-ft. pulley wheel, and attached to the cages by heavy chains, and they are connected beneath by a heavy balance chain. They are controlled by a hand-power band-break, working on the pulley. Each cage has a cistern, 4 ft. deep, either above or below, into which, when at the surface, sufficient water to counterbalance the weight of passenger or truck in the cage below is run. The inlet nozzle at the surface, and the discharging valve when at the shaft bottom, are both worked by a man who is stationed in a cabin at the surface, and who is in communication with the lower station by speaking tube and whistle. The reservoir at the top of each shaft is also of iron plates, and is supported about 10 ft. above the ground on cast-iron columns. An interesting safety appliance is the gate at the brace of the shaft, which slides on iron runners, and which is lifted by a projecting arm catching the top of the cage.

Water is raised from the quarry bottom to the drainage tunnel (200 ft. above) by ordinary bucket pumps, six driven by two hydraulic engines and two driven by a turbine with water under a pressure of 60 lb. per sq. in. The turbine, a Gilke's form, 16 in. in diameter, makes 800 revolutions per minute, to reduce which worn gearing is employed. The two pumps are worked by 5-ft. beams from the one axle, and have a 4-ft. stroke, with 15-in. suction pipe; and they raise a total of 650 gallons per minute. Each hydraulic engine (Amos and Francis patent) has an inclined water cylinder, 12 in. in diameter, and is fed by ordinary slide-valves. The piston makes 14 strokes of 4 ft. per minute, and drives the three 15-in. pumps from a crank shaft, so raising 600 to 650 gallons per minute. These engines were installed about the middle of last century, and have given no trouble whatever. They require little attention, and the loss of energy is not of importance where cheap water-power is available.



[*Photo.*, L.C.B.

FIG. 2.—WATER-BALANCES AND THE QUARRY IN THE BACK-GROUND.

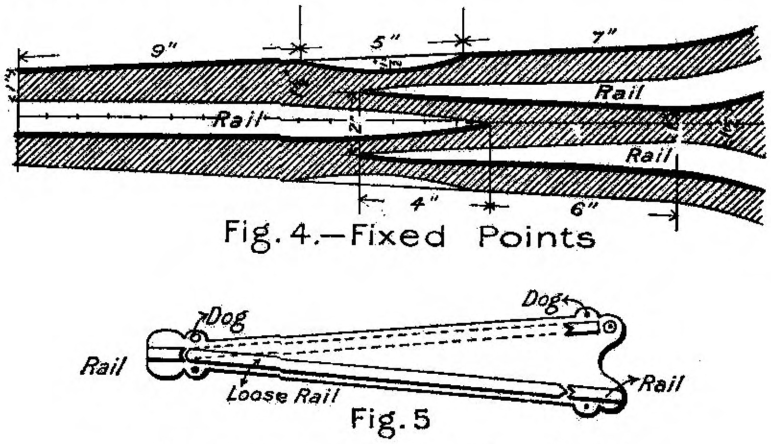
It is understood that the circular saws at the mill are driven by water-power, but these were not visited.

Some 200 tripod hand-winches are in service on the galleries, in handling the heavier blocks of slate, and, owing to the former large percentage of accidents from runaway handles, the manager has had them all specially fitted with a locking-gear and band-break, allowing of the handles being removed when the stone is sufficiently raised. (See photo.)

So many tram-lines are in use that special attention has here to be given to the matter of rails. Where the lines have to be frequently moved, round rails are commonly used. These are bent at the ends, and fit into iron sleeper sockets. Again, instead of having iron turning plates, so common in Australian mines, two systems of points are employed, the one a fixed casting (Fig. 4), and the other a cast bed with a moveable rail (Fig. 5).

Dressing.

The roofing slates are split and squared, as described below, at the quarry, but the school slate works, in which blocks are split, squared, smoothed, and framed, are at Port Penrhyn. The grave-



FIGS. 4 AND 5.—POINTS FOR LIGHT RAILS.

stones, &c., are cut out by circular saws, driven by water-wheels, at the mills about ½-mile from the quarry.

One reason for limiting the vertical distance between galleries is to prevent the breaking up of the slate in the fall to the bottom; but, in spite of all precautions, much the greater part of the bed is wasted. The good boulders are split into slabs by the quarrymen, on the galleries on which they have fallen, and these are then trucked to the dressing sheds, each about 10 ft. square, the long rows of which on the quarry bank remind one forcibly of ancient British shelters, being wholly built of slate slabs. The only fittings are a rough bench, a few tools, and the squaring guillotine. Here two of the partners in the bargain (two men, or one man and a boy) split and cut the slabs, which may be up to 6 ft. in length, 18 in. in width, and many inches wide. They are first split with a broad-edged chisel into several slabs, each about 1½ in. thick, and then the resulting sheets are "cut." This operation is performed by notching one edge to a depth of 2 in., standing the slab on a narrow chip of slate, and striking the opposite edge to that notched with a heavy wooden mallet, the result being that in the majority of cases the slab cracks straight across as desired. *One of the trimmers, when several slabs* have been broken up, proceeds to split the resulting blocks, with wide-edged chisels and wooden mallets. The trimmers affirm that they are able to split the best blue slate as thin as paper, but the buyers require the slates to be at least ⅛-in. in thickness. When the slates are of the required thickness, the second trimmer squares them up roughly with a long-bladed bent-handled heavy knife, and finally in a Francis machine, which consists of a steel blade, 5 ft. long and 3 in. wide, worked by a foot-plate across a straight edge against a spiral spring. (See photo.)

At some quarries circular saws are used for cutting up the blocks, the result being a great saving in slate, for even the most expert dresser cannot always break slabs as desired. Mechanical splitters have also been introduced at some quarries, but none were seen at the Penrhyn Quarry.

Geology.

The slate beds worked at Bethesda are of Cambrian age, and lie between the Harlech grits above and volcanics below. They dip about 60 deg. to the south-east, and have a total thickness of between 2,500 and 3,000 ft.

The complete section is as below:—

Harlech grits	Lava, grits and mud
Green slate	Hard red slate
Soft purple slate	Hard blue slate
Hard grey slate (three beds)	*Volcanics.*
Old Penrhyn blue slate	

The old Penrhyn blue bed, the main one, is 200 ft. thick, and has yielded a quarter of the total shipments. Mr. Davis states that it is, on the whole, the purest, being free from iron sulphides, and it is undoubtedly the best paying, especially for slabs. It has been found that the cleavage of this slate improves as depth is attained, the finest slate now coming from the bottom of the quarry.

The hard blue bed is worked chiefly for roofing slate, though the splitters affirm the "soft" blue slate to be more permanent (offering greater resistance to frost), and being more fissile than the "rough" or sandy slate, which yields nothing less than ½-in. in thickness. The uppermost green bed often contains much pyrite or marcasite, and is then useless.

The cleavage is vertical, making an angle of about 30 deg. with the bedding, which is to be distinguished only by differences in colour and texture of the various strata, and possibly by lenticular quartz-calcite veins. A peculiar fact is that cleavage decreases if the slate be exposed for even a short time. It is said that a block of the best slate, a few inches in thickness, cannot be split after a few hours' exposure to the hot sun or a frosty wind.

Faults are rather numerous, and many nearly vertical diabase dykes intersect the beds, generally at right angles to the cleavage. *The dykes are cross-veined with calcite and quartz, which in places* contains much specular iron.

Education of Coal Miners.—The Lehigh Valley Coal Company, U.S.A., is inaugurating a school for miners which will give the rank and file of mine employees the opportunity to learn mining from experts. They are to be taught not only mining practice, but how to protect themselves, and, furthermore, are instructed in the engineering problems met in their daily work. The school is to be located at Lost Creek, Penn. It consists of a regulation school room and a reference room well stocked with mining periodicals and books. It is expected that this educational work will materially lessen accidents due to carelessness and ignorance. If this venture proves successful, the company plans to establish about a dozen similar schools in the different mining districts. The company's aim is to produce men *trained in the theory and practice of mining, and thus fill positions* of responsibility. A report of each man's progress is to be made, and those winning the highest marks will be selected for promotion.

FIG. 3.—SAFETY HAND-WINCH. [*Photo., L.C.B.*

Improvement in Mine Ventilation.

Until recent years it was the general opinion of mining engineers (says the "Mining World," Chicago) that the fans required for ventilation must necessarily be of large diameters. When, however, the turbine or multivane mine fan was invented, it became evident that this opinion needed modification.

The first installation where the Sirocco multivane fan was used proved the maker's claims, that a 75-in. fan of the double-inlet type not only does the work of two other fans, whose aggregate diameters amounted to ten and one-half times that of the Sirocco, but delivered a 12 per cent. larger volume of air. On another mine a 77-in. Sirocco is replacing a fan measuring 44 ft. in diameter, while many others of less than 100 in. are replacing fans of the old type measuring 30 to 40 ft.

Interesting as this question of reduced diameter undoubtedly is from the mechanical standpoint, it would be of little value if it could not show some advantageous features when considered also from a commercial aspect. The chief advantage of fans of small diameter lies in the fact that they can be run at comparatively high speeds, making it possible to couple them directly to motors or engines which develop the required power at high speed.

The first cost of the motor or engine is consequently very much lower than in the case of a slow-running fan, which often could not be direct-coupled, owing to slow speed necessitating the use of a large-size motor or engine with the proportionate increase in cost.

The reduced dimensions of the high-speed fans lead to a marked economy in the cost of erection, owing to the small amount of brickwork and masonry necessary to provide their housing, and this fact is clearly evidenced when taking the actual space occupied by the fan-wheels into consideration. Thus, taking an actual installation as an example, where a wheel occupying a space of 325 cu. ft. is replacing another occupying 15,000 cu. ft., it is obvious that the amount of brickwork required to enclose the former is very much less than that needed for the latter. An additional saving is frequently effected in the reduced size of the engine and motor-house, due to the use of a high speed in place of a low speed, and consequently a machine of larger dimensions.

Although the Sirocco multivane fans are small in diameter they are capable of fulfilling large duties, as is borne out by a number of installations. Instances may be noted where a double-inlet fan 119 in. in diameter is capable of passing 300,000 cu. ft. per minute at 3-in. water gauge, while another measuring 140 in. can deliver 375,000 cu. ft. per minute at 4-in. water gauge. Furthermore, one of these fans is now in course of construction which will have an output of 500,000 cu. ft. at 6-in. water gauge, and will be direct-coupled to a motor of 1,000-h.p.

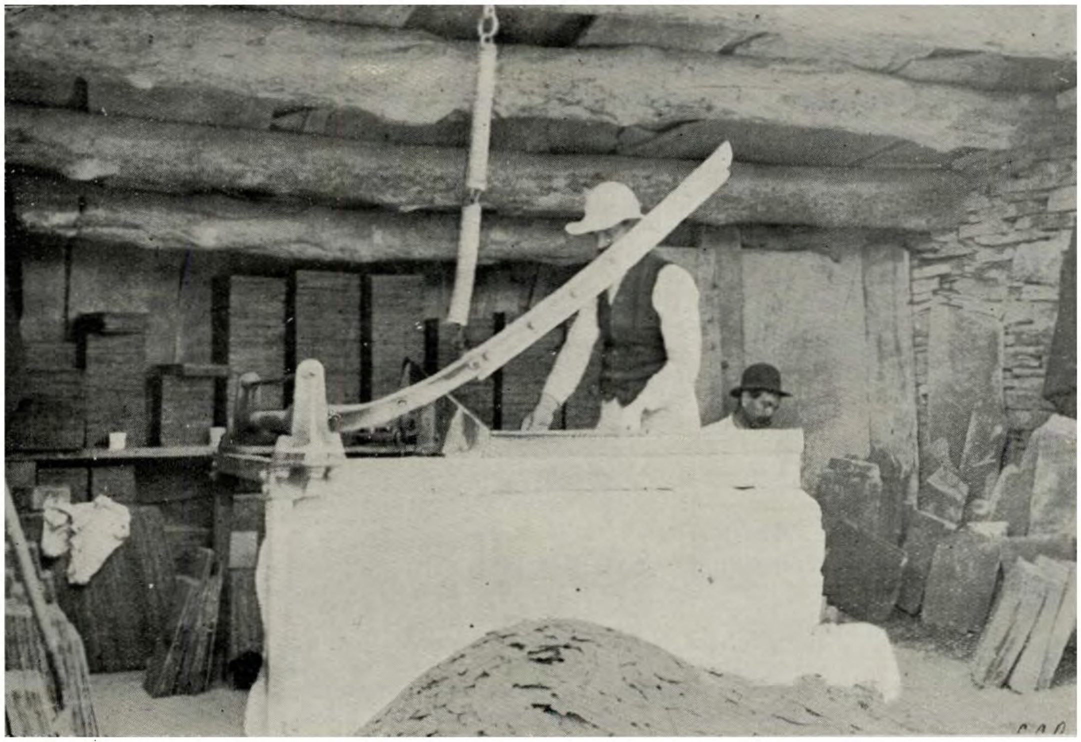
It is argued sometimes that the slow-speed fans of large diameters show far better efficiencies than the smaller high-speed types. This, however, cannot be the case, considering that a turbine fan is able to give an efficiency of more than 70 per cent. when tested under actual working conditions in mines.

The change that has been brought about in mine ventilation by the introduction of the multivane fan not only counts for economy, it counts also for increased safety and efficiency.

THE advantages of mineral over vegetable or animal lubricating oils are:—(1) They are much cheaper; (2) they do not become thick or gummy from exposure to the air; (3) they do not corrode metals; (4) they are capable of being separated into many grades, from the lightest to the heaviest cylinder oil; (5) they are free from the danger of spontaneous combustion, as they have a low cold test.

Gilsonite.

Gilsonite is the most abundant of all the known hard asphalt substances in the United States. It is found in north-eastern Utah, in Uinta and Wasatch counties, where it occurs in vertical gash veins or fissures, cutting across nearly flat Tertiary rocks. The veins of gilsonite bear in general north-west south-east directions, and vary in width from thin stringers to several feet. At one locality a vein 18 ft. thick has been reported. The same vein extends for several miles with thicknesses varying from 4 ft. to 12 ft. The horizontal length of some of these veins is known to be many miles, but their vertical depth as a rule is unknown. The best known of the thicker deposits of gilsonite in Utah are in the central part of the Uinta basin, on both sides of White River valley. Notable localities are near Dragon and on the north side of White River, near the Colorado State line. Other important deposits are at Pariette, near Fort Duchesne, and north-west of Fort Duchesne. Some of the gilsonite veins in Utah, in White River valley, extend into Colorado. Veins of similar species of asphalt occur in Willow Creek valley, near the north side of Middle Park, in Grand county, Colorado.—"Mining Science."



[Photo., L.U.B.

FIG. 6.—FRANCIS SLATE-TRIMMING MACHINE, AND THE SPLITTER AT WORK, PENRHYN QUARRY.

An Interesting Hoisting Record.—The Superior Coal Company, of Gillespie, Ill., under the management of J. W. Miller, operates three shaft mines. None of these mines have been in operation more than four years, and yet each makes a daily output of over 3,000 tons. Two days' work at each mine recently gave the following results:—

No. 1—24th Aug. ...	3,270 tons	No. 2—26th Aug. ...	3,015 tons
No. 1—25th Aug. ..	3,276 ,,	No. 3—25th Aug. ...	3,601 ,,
No. 2—25th Aug. ...	3,019 ,,	No. 3—26th Aug. ...	3,619 ,,

The total for the three mines, two days' work at each, was 19,800 tons. This is an average of 3,300 tons per day of eight hours for each mine. Each of these mines is about 350 ft. deep, and is equipped with 24 by 36 in. first-motion hoisting engines, with cylindrical drums 7 ft. in diameter, built by the Litchfield Foundry and Machine Company, of Litchfield, Illinois.

IT is stated that the best method for estimating arsenic and antimony is by the distillation method; and for bismuth the method depending upon the brown coloration produced by dissolving bismuth iodide in potassium iodide.