(*Paper No. 2741.*)

“Transporting and Dressing Iron Ore at Cabarceno, Spain.”

By FREDERICK KENSINGTON, Assoc. M. Inst. C.E.

It is unnecessary to dwell on the importance of Spanish iron ore to English smelters, especially the mineral which is obtained from the provinces of Biscay and Santander. The deposits of iron in those provinces appear to occupy a position in the Upper Jurassic formation, or between that and the corresponding greensands of England, and are the products of replacement, that is, sparry or spathose ores, being the primary mineral from which the Limonites have been produced and redeposited by the action of oxygen and water; but there exist, especially in the province of Santander, other deposits, the origin of which it is not so easy to explain. Along the southern margin of the Bay of Santander, a ridge of limestone mountains rises to a considerable altitude, and south of this ridge again, between it and a further range, is a more or less broken and irregular valley. Allowing for the contour of the mountains (the spurs of the Pyrenees have a general east and west direction in this district), extending from Solares through Cabarceno and Obregon to Guarnizo, and embracing an area of about 90 square miles, the general level of this valley is 600 to 700 feet above the level of the sea, the Jurassic or Neocomian limestone being here covered by surface deposits of soft argillaceous drift, containing Limonite interspersed in the clay in pieces varying from several tons in weight to that of fine grains of sand, by far the greater quantity, however, being of the size of shingle or gravel. The amount of ore varies between 5 per cent. and 40 per cent. by weight of the clay with which it is associated; and these deposits have been proved to overlies the limestone 180 feet thick in some places, whilst in others they are not more than 2 feet thick. The presence of these clays containing iron is, however, by no means limited to the valley; in some places extensive deposits are found between spurs of the limestone or in deep basins far up the side of the mountain, upwards of 1,200 feet above the level of the sea.

It is a curious fact that the ore found is of two distinct varieties,

one part consisting of heavy water-worn pebbles, boulders, and shingle of hard compact nature, containing 58 per cent. to 59 per cent. of metallic iron, and the other of soft porous pieces of Rubio similar to that of the Bilbao district, evidently the result of replacement—these pieces containing more silica, less metallic iron, and being much lighter than the boulders and pebbles. It is not difficult to trace the boulders and pebbles as the result of glacial drift of the Pleistocene age; but this drift must have occurred at long intervals of time, as there is evidence of lakes having existed, with their margins at many levels, and it is possible to follow a shore of iron shingle or gravel in many directions, whilst interspersed throughout occurs the rubio ore bearing no trace of travel—the whole presenting a most interesting geological problem. The existence of these deposits of iron ore in the Santander district have been long known, but until it became evident that Bilbao could not long maintain the large annual output, no one seemed interested in working this district. A little of it was occasionally riddled or sifted out of the surrounding earths by the landowners, and a few cargoes were sent to Rotterdam, Philadelphia, and the Middlesbrough district, but the result was unsatisfactory; the ore contained too much clay, was dirty, and little liked by the ironmasters, while the expenses attending its preparation for the market and transport rendered it impossible to compete with the Bilbao ores.

Practical men saw at once that if this mineral was ever to be worked at a profit it must be on a large scale, and that some cheap expeditious plan must be adopted to separate the mineral from the surrounding clay. The only means of doing this effectually was by washing, and here the first difficulty occurred, as the district did not contain sufficient water for the purpose. After many experiments and trials for determining the value of the Cabarceno district, it was found that generally the amount of iron contained in the clay was about 460 to 490 tons in 1,000 cubic metres of “wash-dirt,” or about 6 cwt. in a cubic yard; while places were cut into whence more than 15 cwt. was extracted.

With regard to the quality of the ironstone, but little variation existed. A large number of samples were washed by hand, and were afterwards dried at 100° C., and were analyzed with the following results:—

	Per cent.
Metallic iron	59·50
Silica	1·70
Sulphur	0·08
Phosphoric acid (= 0·038 per cent. of phosphorus)	0·08

The ore proved remarkably rich in iron, being in that respect at least 4 per cent. above the average of the ordinary rubio ores exported from Bilbao; the silica was low, $7\frac{1}{2}$ per cent. being a usual amount in unwashed samples. The phosphoric acid disclosed by the analysis was rather high, but it should be borne in mind that washing iron ore increases by the removal of all soluble earthy matter the percentage of all the remaining ingredients, whether good or bad. Further, these being surface tests, the mineral would probably be affected by the phosphoric acid associated with decaying animal and vegetable matter which is always present on the mountain sides, and would be conveyed to the iron by the surface-water. Samples subsequently taken from a pit 25 feet deep gave results as under:—

	Per cent.
Metallic iron	58·99
Manganese	0·30
Silica (insoluble)	4·50
Alumina	0·28
Sulphur	0·10
Phosphoric acid	0·02
Oxygen, &c.	35·80
	<hr/> 100·00 <hr/>

An average of five cargoes sent to Germany at the end of 1892 gave—

	Per cent
Metallic iron	57·17
Phosphoric acid	0·047
Sulphur	0·044
Silica	2·41

In this last analysis, though the amount of phosphoric acid is satisfactory, it will be seen that the metallic iron has decreased, but it must not be forgotten that this is a cargo analysis, and that the iron was washed by machinery, and, being a bulk sample, represents more accurately the commercial value of the deposits.

A company was formed in 1889 to work a concession of 500 acres in the district of Cabarceno, to erect efficient washing-machinery, and to construct a line of railway from this place to the margin of the bay and there erect the necessary ore-cleaning plant. The first consideration was the method by which large quantities of mineral earth could be transported to the washing-floors on the shore of the bay, the ground being separated from the latter by a hill 1,166 feet high, situated at a distance of rather more than 3 miles in a direct line south; it was necessary either

to cross this hill or to run round the foot of it, either on the east or west side, in which case a line of railway over 13 miles in length would have been required. It was decided to construct a line of chain railway over the top of this mountain, and, on the completion of the survey, it was found that the level of the mineral ground on the south side of Peña Carbargo was 493 feet above the level of the bay on the north side—a decided advantage in power being thus secured for the line, though not sufficient to enable the trucks to be drawn up without the assistance of steam-power on the south side.

Commencing the ascent of the mountain from the north side, the road was divided into six sections—A and G being the terminal points, whilst at B, C, D, E and F were angles where the change of direction was provided for by a chain

Figs. 1.

Scale $\frac{1}{2}$ inch = 1 foot.

passing round toothed wheels, *Figs. 1*. The lengths of the several sections are—

	Metres.
A	840
B	273
C	387
D	820
E	470
F	490

At F, 105 metres above the mine level, it was found that an excess of power existed—from gravitation on north side—equivalent to 12 HP. over that required to draw up the empty trucks, and here it was decided to erect a steam-engine capable of raising the trucks to that station from the terminus G; this engine is horizontal, having a 16-inch cylinder with a 20-inch stroke, geared to the toothed wheels of the angle, which make 50 revolu-

tions per minute. It is geared so as to give the chain a speed of $2\frac{1}{2}$ miles per hour, steam being supplied by a Cornish boiler, 21 feet long and 6 feet in diameter. The gradients throughout the line are steep. In section D they are as much as 1 in $2\frac{1}{2}$ in some places. The length of the line is 3,280 metres, the trucks are placed at a distance of 20 metres apart, and the line is capable of bringing over the mountain between 800 and 1,000 tons of mineral earth in twelve hours. The speed on the north side is regulated by brake-bands passing round brake-wheels, *Figs. 2*, placed over the top of the claw-wheels which carry the chain, these again being surmounted by a horizontal toothed-wheel acting on a large fan-brake. The result obtained may be considered satisfactory, 800 to 1,000 tons being raised 500 feet

Figs. 2. Scale $\frac{3}{8}$ inch = 1 foot.

high and carried a distance of 3,280 metres with the aid of an engine of 24 HP., by the expenditure of 19 cwt. of fuel, the cost of haulage being rather over 1*d.* per ton per mile, including all charges. The gauge of the line is 18 inches throughout, the size of the bodies of the wagons being 3 feet 6 inches by 2 feet 6 inches by 1 foot 8 inches. The size of the chains varies between $1\frac{1}{8}$ inch and $1\frac{5}{8}$ inch, the total weight of chain being 80 tons. The total cost of the 3,280 metres of line, fully equipped with five hundred and fifty wagons, was approximately £9,500. The level across the valley from station G—terminus of chain-railway—distance one mile, to the iron deposits is worked by locomotives of the platform vertical-boiler type on an 18-inch gauge line.

The washing-machinery in which the mineral earth is treated consists of three wrought-iron drums, *Fig. 3*, 6 feet 6 inches in

diameter and 15 feet long, fitted with an internal worm of 1 foot pitch, making 12 revolutions per minute. These drums are fitted with longitudinal lifters, 4 inches broad, at intervals of 12 inches between the worm, which alternately lift and drop the mineral earth. One end of the drum is partially closed, leaving room for the earth to enter, while the other is raised in conical form to allow the mineral to pass out at that end while retaining a certain depth of water in the drum. The mineral earth is fed into the partially-closed end of the drum at the rate of about 6 cubic feet per minute, accompanied by about 80 gallons of water during the same time.

The revolving drum washes and separates the mineral which is

Fig. 3.

Scale $\frac{3}{8}$ inch = 1 foot.

propelled forward by the action of the internal worm, while the mud is discharged at the end at which the earth enters, the mineral being delivered into wagons at the conical end, in traversing which it is met by a powerful spray of water, which washes it completely clean—the quantity of water thus used being about 70 gallons per minute. The weight of the drums, fully loaded and running, is 10 tons each. They revolve on cast-steel rings on steel rollers fitted in cast-steel cradles, the motion being imparted by a pinion acting on a spur-ring bolted to the body of the drum and worked by means of pinion-and-mitre wheels from the line shaft. Each drum is capable of producing 70 to 100 tons of

perfectly clean iron from the mineral earth in ten hours, the amount of mud or clay left in the ore never exceeding 2 per cent.

The salt water used for washing the mineral is drawn direct from the bay by a pump, having two bucket plungers of 12 inches diameter and 14 inches stroke, fitted with india-rubber annular grid valves, revolving at the rate of 40 revolutions per minute. This pump is driven by a 12-inch belt from the intermediate shaft, and raises the water 10 feet, throwing it 15 feet above the pump-chamber. The whole of the machinery is driven by a horizontal surface-condensing engine, having a 24-inch cylinder with a 3-foot stroke. The air-pump works direct off the piston tail-rod, the water passing through the condenser before going into the drum, and a 24-inch vacuum is obtained. The steam is supplied by a Lancashire double-flue boiler—fitted with Galloway tubes—7 feet in diameter and 22 feet long, the steam-pressure being 50 lbs. per square inch.

In the first year of the company's work 23,000 tons of washed ore was turned out, giving 57 per cent. of metallic iron when dried at 100° Centigrade, while in the present year (1893) it is expected that 40,000 tons will be produced. Two other undertakings of the same description have lately been started, and it is proposed to erect machinery in the Bilbao district to wash the dump heaps, which, as already stated, contain valuable mineral.

The cost of this mineral f.o.b. is about 4s. per ton exclusive of Royalty and administration charges, but it should be possible to reduce this. The cost of production must in all cases of this kind depend greatly on the quantity turned out, there being a certain establishment charge whether the output is 1 or 20,000 tons. However, putting the output at 40,000 tons per year and the value of the mineral earths washed at 460 tons to 490 tons per 1,000 cubic metres, the cost is as near as possible 4s. f.o.b.—this amount representing the cost of digging at the mine, the cost of carriage of "wash-dirt" to the washers, washing the mineral, conveyance to the port, quay dues and cost of putting on board.

The refuse mud is collected in large tanks constructed on the marshes in the Bay of Santander, and in addition to the profit on the mineral it is expected that a considerable return will be forthcoming from the reclaimed land. The whole of the works were designed by the Author, under whose direction they were constructed.

The Paper is accompanied by 13 drawings and a photograph, from which the *Figs.* in the text have been prepared.