PAPERS ON IRON AND STEEL

V.—THE BESSEMER PROCESS (*continued*)

IN the previous papers I have described the phenomena presented during the different stages of the blow, and have endeavoured to explain the chemical actions upon which they depend. The next stage, that of adding the molten spiegeleisen to the iron which has been fully acted upon by the blast, also presents some interesting phenomena which have not hitherto been fully examined.

In a paper on "Burnt Iron and Burnt Steel," read before the Chemical Society 6th April last,* I showed that the "burnt iron" of the workman is really what its name implies, viz., iron which has been more or less oxidised throughout its substance, and that "burnt steel" is quite different,—that the presence of combined carbon in sufficient quantity effectually protects iron from oxidation by heat.

These conclusions are strikingly illustrated in the Bessemer process. In spite of the excessively high temperature and the abundant supply of oxygen during the blast producing most violent combustion of the material in the converter, I have found no "burnt iron" during the early or middle stages of the blow. This only appears at quite the latter stages when the carbon is nearly all burnt out. At the termination of the blow, the material left in the converter is burnt iron of a very exaggerated type in all cases where the burning out of the carbon has been carried to its full extent.

Mr. Bessemer failed in his attempts to produce malleable iron by his process, and all subsequent attempts have equally failed, even when the very finest qualities of hæmatite pig-iron have been used. I am not aware that any explanation of this has yet been given, but have no doubt that it depends upon the principle above stated, viz., that some combined carbon is absolutely necessary to preserve the iron from oxidation, and thus, as the carbon is removed, the iron begins to oxidise throughout, and we have an incoherent mixture of iron and particles of oxides, which crushes under the hammer or the rolls, is neither malleable nor ductile.

The degree of rottenness depends upon the extent to which the blow has been carried, and the iron thus produced varies from a quality which simply cracks at the edges when hammered or rolled, to a mass that crushes into granules like a piece of coarse sandstone. If inattention or some hitch in the machinery prevents the immediate turning over of the converter, and the blow is continued a few minutes too long, the amount of oxidation is so considerable that the mass in the converter loses its fluidity, and becomes a spongy and pasty mixture of melted iron and infusible oxide, which is rather troublesome to the manufacturer.

By the simple method described in the paper above-referred to, I have been able at once to detect the presence of entangled particles of oxide in the midst of the iron remaining in the converter at the end of the blow. They are even visible on the fracture of overblown iron.

The presence of this free oxide explains some otherwise inexplicable phenomena which accompany the pouring of the spiegeleisen. A furious ebullition of the molten metal takes place, jets of burning carbonic oxide spurt up violently from all parts of the surface; the converter is filled with the blue flame which pours forth from its mouth, producing the weird illumination I have already described. The outpouring flame so completely occupies the whole dimensions of the mouth of the converter, that no air can possibly enter, and thus all the oxygen required for the combustion which is going on must be derived from the material inside the converter. Some of the carbon of the spiegeleisen is thus burning at the expense of the oxide of the original charge, and this oxide is thereby reduced.

The sole function usually attributed to the spiegeleisen is that of converting the iron into steel; but if the above be correct, it performs, in addition to this, the important service of reducing the free oxide of the rotten burnt iron, and thereby rendering it malleable. We shall now understand why Mr. Bessemer and others have failed to produce malleable iron by directly oxidising the silicon, carbon, &c., of the pig-iron in the converter. It may be asked how then does the puddler remove the carbon from pig iron? My answer is simply that he does it by a far less violent process of oxidation; that towards the end of his work when the iron is "coming to nature," *i.e.*, when the proportion of protecting carbon has become very small, he takes especial precautions by closing the dampers, and otherwise diminishes the rate of oxidation as much as possible, and thus he is able to work down to less than $\frac{1}{10}$ per cent. of carbon without burning his iron.

The more violent oxidising agency of the Bessemer blast demands a greater quantity of carbon for the protection of the iron, and accordingly it is found that about 0·25 per cent. is the minimum limit of carbon which is practically obtainable without sacrifice of malleability. I have determined the carbon of many hundreds of samples of Bessemer steel which has been specially made as "mild" as possible, where it was a primary object to reach the minimum proportion of carbon, and have never found any sound metal to contain less than 0·20 per cent. The usual range of this (which is sometimes called "Bessemer metal" being scarcely steel although not true iron) is from 0·25 to 0·30 per cent. of carbon. I do not here speak of the limits of absolute possibility, but of the practical limits of the process as at present conducted.

I should add that, in the course of subsequent working the proportion of carbon is reduced, but the extent of this reduction is very variable, depending on the number of re-heatings, the amount of surface exposed, and the kind of furnace in which the reheating is conducted. By using a reducing flame the oxidation of the carbon may be wholly prevented, but in the ordinary reheating or mill furnace and in the exposure of rolling, &c., a certain amount of oxidation commonly occurs. Rails and tyres usually contain two or three hundredths per cent. less than the ingots from which they were made, thin plates and sheets lose a larger proportion, even as much as one-tenth per cent. in extreme instances. I have removed the whole of the carbon from the surface of a hard steel plate by exposing it for several days to the low red heat of an annealing furnace.

W. MATTIEU WILLIAMS

* An abstract of this paper will be found in NATURE, April 20, p. 497.

THE CAUSE OF LOW BAROMETER IN THE POLAR REGIONS AND IN THE CENTRAL PART OF CYCLONES

IN none of the treatises on Meteorology or Physical Geography is there to be found any satisfactory explanation of the observed low barometer in the polar regions, or in the centre of a cyclone. Observations show that in the Antarctic region there is a permanent depression of more than one inch below the average height nearer the equator, and in the Arctic region a depression of about half that amount; and also that for several days frequently the barometric pressure of the central part of a cyclone is one or two inches less than that of the exterior part. Mr. Buchan, in his excellent treatise on Meteorology, attributes the low barometer in the polar regions to the effect of the vapour in the atmosphere. If the amount of vapour in the polar regions was greater than in the equatorial, this effect, so far as it would go, would be in the right direction; but just the reverse is the case; for it is well known that the amount of vapour in the warm equatorial region is much in excess of that in the cold polar regions. Attempts have also been made, without success, to account for the depression in cyclones by the effect of centrifugal force.

By whatever cause so great a difference in the barometric pressure in the different regions might be produced, it may be shown from the principles of dynamics that the equilibrium would be restored in a very short time, if there was not some constant force tending to drive the atmosphere from the polar regions towards the equator, or from the centre of the cyclone to the exterior, and to keep it in that position. Such a force may be found in the influence of the earth's rotation. In a paper by the writer in the *Mathematical Monthly* in 1860, published in Cambridge, U.S., a full abstract of which was also published in the January No. of *Silliman's Journal* for 1861, the following very important principle was demonstrated:—In whatever direction a body moves on the surface of the earth, there is a force arising from the influence of the earth's rotation, which tends to deflect the body to the right in the northern hemisphere, and to the left in the southern hemisphere. This force, which is the key to the explanation of many phenomena in connection with the winds and currents of the ocean, does not seem to be understood by meteorologists and writers on physical geography. We see it frequently stated that the drift of rivers and currents of the ocean running north or south always tends to the right in our hemisphere, and that a railroad car running north or south presses to the right; and this is the case. But the same is true, and to exactly the same amount, of a current or of a railroad car running east or west, or in any other direction.

The amount of this deflecting force, when the velocity of the body is small in comparison with that of the earth's rotation, is expressed by $2 \cdot \frac{1}{289} \cdot \frac{v}{n} \cos \theta \, g$; in which v is the lineal velocity of the body relatively to the earth's surface, n that of the earth's rotation at the equator, θ the angle of polar distance, and g the force of gravity. If the velocity is expressed in miles per hour, the expression in round numbers becomes $\frac{v \cos \theta}{150{,}000} g$; that is, for each mile of velocity per hour, the force is $\frac{1}{150{,}000}$ of gravity, multiplied into the cosine of the polar distance. Hence a railroad car on the parallel of 45° north, running in any direction at the rate of forty miles per hour, presses to the right with a force equal to about $\frac{1}{5{,}000}$ part of its weight.

The effect of this deflecting force upon what Mr. Stevenson calls the barometric gradient is easily estimated. Since the strata of equal pressure of the atmosphere, so far as this force is concerned, must be perpendicular to the resultant of this force and gravity, the sine of inclination of any such stratum to the earth's surface must be $\frac{v \cos \theta}{150{,}000}$, and the change in barometric pressure for any given distance is equal to the weight of a column of atmosphere of a height equal to the change of level of the stratum of equal pressure, and of a density equal to that at the earth's surface. The barometric gradient, then, as expressed by Mr. Stevenson, for any distance d expressed in miles is $\frac{v \cos \theta \, d}{5 \times 150{,}000} \times 30$ inches; putting five miles for the height of a homogeneous atmosphere, and thirty inches for the pressure at the earth's surface. Round numbers are used throughout, since it is only the order of the effects we wish to determine, and not their exact amount.

According to all observations, there is a steady and very strong wind blowing all around the earth in the middle and higher latitudes of the southern hemisphere, with a velocity of at least twenty-five or thirty miles per hour at the surface of the ocean, and this is perhaps much greater in the upper strata of the atmosphere. If at the parallel of 50° we suppose the velocity of the wind v to be thirty miles per hour, the preceding expression of the barometric gradient for a distance d of 5° or 350 miles, using the cosine of 40°, is 0·33 inches of mercury. By reference to § 113 of Mr. Buchan's Meteorology, it will be seen that the barometric gradient for that parallel is only 0·28 inches for 5° of latitude, and that this is about the maximum gradient in the southern hemisphere. Hence a velocity less than 30 miles per hour at the surface of the sea, especially if we suppose that it increases in the higher regions, is sufficient to account for this maximum barometric gradient; and, according to observations, 20 or 30 miles per hour for the wind in that region is no unreasonable assumption. The eastward velocity of the wind in the different latitudes being known, and, consequently, the corresponding barometric gradients, the difference of barometric pressure between any parallel near the pole and one toward the equator, is readily obtained by integration. As the wind near the equator is toward the west the deflecting force there is *toward* instead of *from* the pole, and hence the greatest barometric pressure is about the parallel of 30°, and there is a slight depression at the equator. The deflecting force and the consequent depression are small, then, on account of the small value of θ near the equator.

Since there is more land and mountain ranges in the northern than in the southern hemisphere to obstruct the eastward motion of the atmosphere, its velocity is not so great, and consequently the polar depression is much less there than in the southern hemisphere. According to Mr. Buchan the barometric depression in the Arctic regions is much greater in the northern part of both the Atlantic and Pacific oceans, than it is in the same latitudes on the continents. The explanation of this is, that the eastward velocity of the atmosphere over the oceans being much greater than it is on the continents, where it is obstructed more by friction and mountain ranges, the force driving the atmosphere from the poles toward the equator is less, and consequently the barometric pressure is less in the northern part of both oceans than it is on the continents in the same latitudes.

Upon the relative strength of the forces tending to drive the atmosphere from the poles towards the equator, depend the positions of the equatorial and the tropical calm belts. This force being strongest in the southern hemisphere on account of less resistance from friction and mountain ranges, the mean position of the equatorial calm belt is a little north of the equator, and the positions of the others a little farther north than they would otherwise be. The prime motive power also in both hemispheres being the difference of density of the atmosphere between the polar and the equatorial regions, arising from a difference of temperature and of the amount of aqueous vapour, during our summer when this difference is less than the average in the northern hemisphere, and greater in the southern, these calm belts are forced a little north of their mean positions. Of course, just the reverse of this happens during our winter; hence we have an explanation of the annual variations of the positions of these belts.

In the case of cyclones, the atmosphere at the earth's surface being forced in from all sides towards the centre, by the force arising from a difference of density of the atmosphere in the central and exterior parts, it cannot, on account of the deflecting force which has been explained, move toward the centre, without, at the same time, receiving a gyratory motion around that centre. Neither can it have a gyratory motion without also having a motion towards that centre, since in that case there would be no force to overcome the frictions of gyration. Hence, neither the radial theory of Espy, nor the strictly gyrating theory of Reid and others, can be true, though either of them may be approximately so in special cases. But the gyratory part of the motion is not caused by the motion of the atmosphere from the north and south only toward the centre of the cyclone, as stated by Mr. Buchan and others, but equally by the different parts moving in from all sides, since in whatever direction they move toward the centre there is the same deflecting force, either to the right or the left according to the hemisphere.

The motion of the atmosphere being in a spiral toward and around the centre of the cyclone, the deflecting force depending upon the earth's rotation, at right angles to the direction of motion, being resolved in the directions of the radius of gyration and tangent, the latter overcomes the friction of gyration, and the former causes a pressure from the centre, decreasing the height of the strata of equal pressure in the cyclone, and consequently diminishing the barometric pressure. The barometric gradient of a cyclone is estimated in precisely the same way as in the case of the hemispheres, using for v the lineal velocity of gyration obtained by resolving the real motion into the directions of the tangent of gyration and of the radius. It has been seen that a velocity of 30 miles per hour gives a barometric gradient of $\frac{1}{3}$ of an inch in 350 miles on the parallel of 50. A gyratory velocity therefore of 100 miles per hour would give a barometric gradient of one inch of mercury in about 300 miles. The velocities of gyration being known at all distances from the centre of motion, and consequently the barometric gradients, the difference of barometric pressure between the centre and the exterior, so far as it depends upon the gyratory motion, may be obtained by integration. The effect of the centrifugal force of the gyrations is generally only a very small quantity of a second order, in comparison with the other, and the effect of it is entirely insensible, except in the case of small tornadoes, when the gyrations are very rapid close around the centre.

In all the preceding estimates of the barometric gradient, it should be understood that the results belong merely to the force depending upon the earth's rotation, and to this must be added the part belonging to a difference of density of the atmosphere, which in the case of cyclones increases the gradient, but diminishes it in the case of the hemisphere. For the general motions of each hemisphere form a cyclone, with the pole as a centre; but having the denser instead of the rarer portion of the atmosphere at that centre. Hence the motions in any vertical plane through the centre are reversed, and it becomes what has been called an anti-cyclone.

Cambridge, Mass. WM. FERREL

RECENT MOA REMAINS IN NEW ZEALAND

II.

THE Moa's neck with the integuments attached, the discovery of which was announced in my communication dated April 3, has since then been forwarded to this Museum for examination by Dr. Thompson, and the following particulars may not be without interest to your readers.

The total length of the specimen is 16·5 inches, and includes the first dorsal and last six cervical vertebræ with the integuments and shrivelled tissues enveloping them on the left side. The surfaces of the bones on the right side, where not covered by the integuments, are free from all membranes and other tissues, but are quite perfect and in good preservation, without being in the least degree mineralised.

The margin of the fragment of skin is sharply defined along the dorsal edge, but elsewhere it is soft, easily pulverised, and passes into adipocere.

The circumference of the neck of the bird at the upper part of the specimen appears to have been about 18 inches, and the thickness of the skin about $\frac{3}{16}$ of an inch.

The only indication of the kind of matrix in which it had been imbedded was a fine micaceous sand, which covered every part of the specimen like dust, there being no clay or other adherent matrix. On removing this sand with a soft brush from the skin, it was discovered to be of a dirty red-brown colour, and to form deep tranverse folds, especially towards the upper part. The surface is roughened by elevated conical papillæ, from the apex of some of which springs a slender transparent feather barrel, never longer than half an inch. On the dorsal surface a few of these quills still carry fragments of the webs, some being 2 inches in length. From these it appears that the colour of the feather barbs was chesnut-red, as in Apterix Australis, but that each barrel had two equal plumules to each quill, as in the Emu and Cassowary, and in this respect differed from the Apterix, the feathers of which have not even an accessary plumule. On the other hand the barbs of the webs of the feathers do not seem to be soft and downy towards the base as in the Emu.

From the direction of the stumps of the feathers, it is evident that the portion of the neck which has been preserved is that contained within the trunk of the body, and which, in the natural position, has a downward slope, the conical end of the specimen being where the upward sweep of the neck of the bird commenced, which accounts for the absence of the trachea with its hard bony rings, none of which are found among the soft parts which have been preserved.

The integument was easily removed by dividing the few threads of dried tissue by which it was attached. The shrivelled-up soft parts thus displayed could not be clearly distinguished, but may be grouped as follows:—1. A strong band of ligamentous tissue connecting the spinous processes. 2. Inter-vertebral muscles and ligaments. 3. A sheath diverging from the lower part as if to enclose the thorax. The only bone besides the vertebræ was attached to this sheath by its tip, the other extremity being articulated to the first dorsal.

Respecting the nature of the circumstances to which this remarkable specimen owes its preservation, I can only conjecture that the body of the bird must for a considerable period have lain on its side in water or a swamp, and that the portion immersed was thoroughly macerated, while the exposed parts were desiccated and shrivelled up; and that subsequently the whole remains were embedded in dry sand.

As a fact of some interest connected with the history of the Moa, I should mention that in December last, Archdeacon Williams informed me of the discovery of a series of enormous bird-foot marks on the surface of a layer of sand beneath a bed of alluvium at Poverty Bay. The specimens he collected for me have unfortunately gone astray, but others have been placed in the Museums in Auckland and Napier, and I have just seen a pencil rubbing from the latter, taken by Mr. Cockburn Hood, which leaves no doubt that they are the footprints of a bird like the smaller-sized species of Dinornis, the largest of these footprints being about eight inches in length.

JAMES HECTOR

Colonial Museum, Wellington, New Zealand, May 15

[We exceedingly regret that we are unable to reproduce woodcuts of the beautiful illustrations by which Dr. Hector's article is accompanied.—ED.]

NOTES

WE are glad to learn that our anticipations last week with reference to the Australian observations of the Total Solar Eclipse of December next are being realised. The Royal Society of New South Wales is organising an expedition to Cape Sidmouth, a little south of Cape York. The President of the Royal Society of London has arranged that a few instruments of the newest construction shall be sent out from this country.

IT perhaps is not so generally known as it ought to be that the Emperor of Brazil, now in this country, is an enthusiastic astronomer, and has an appreciation of the value of science which places him in the highest rank among reigning sovereigns. During the last week he has visited the Royal and Mr. Huggins's Observatory, and in a long interview with Mr. Lockyer has discussed the bearings of the recent solar discoveries.