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OBSERVATIONS ON SEVERAL MINES IN THE CENTRAL PART OF INDIA, WITH AN ACCOUNT OF THE INDIAN MODE OF MANUFACTURING IRON AND PLANS OF THE MACHINERY & IMPLEMENTS : circa 1829

An oppertinity afforded by the Government of Bengal in 1828-9, having enabled me to examine several iron mines in the central part of India, and to make experiments on the Indian mode of manufacturing iron, I beg to offer the result of my observations to the Hon'ble court of directors of the East India Company and I desire more particularly to draw the attention to the simple forge and refinery, by means of which the process of smelting and decarbonization is performed.

These mines are situated in the districts of Jabalpur, Baragaon, Panna, Katola, and Sagur, in the bed of a great central channel, which intersects the heart of India; and their localities are as follows.

IRON MINES OF JABALPUR

In the district of Jabalpur the best mines are at Aggeriya, Gatna, Baila, Magaila, Jowli, Imliya, and Baragaon, and (p 2) the ore (NO 12) of the first four, is micaceous, resembling in its less oxidated condition Iron Glance; at Aggeriya, Gatna and Baila it is interstratified with sandstone, and exploited by small hill capped with laterite; but at the other places, it is in fragments, buried in feruginous gravelly clay, about five or six feet below the surface; it melts easily; and on actual experiment, 170 sers of ore, smelted by 140 of charcoal, produced 70 sers of crude iron en masset, in ten hours, which is equal to 40 per cent; the ore of Magaila is less oxidated than the others; it slightly affects the needle when heated, and sometimes crystallizes; its streak is cherry red, and from its hardness, it is principally smelted for steel.

Laterite is a term given by Dr Buchanan to a species of iron clay very prevalent in India.

The same kind of ore (No 13) still less oxidated, is in great abundance, interstratified with quartz sandstone, and forms mountain masses, exhibiting a variety of contortions, as in the Lori hills; in this state, it is shining, splendent, and even glittering, but it is never smelted, because there is better ore on the same spot.

The ore of Jowli (No 15) is the ochrey variety of red oxide, it is almost a pure oxide, (p 3) and affords a good pigment; it soils the fingers deeply, and its stain on cloth is difficult to wash out; it melts more easily than the former, and on actual experiment 185 sers, smelted by 165 of charcoal, produced 77 sers of crude iron én masset, in something less than ten hours, which is nearly 42 per cent; it is associated with a compact variety, (No 16 & 17) which appears to contain specular ore, from the blood red colour reflected from its small crystals when fresh from the mine; it lies near the border of a range of trap hills, and is clearly a deposite, or a vein, in the fissure of a rock resembling hornstone (No 18) which has probably been thus changed by contact with the trap.

South of the river Nermada near the village of Dangrai, the micaceous variety (No 19) is found in thicker laminae, interstratified with quartz sandstone, which separates into rhomboids; it is extracted by breaking the rock, but its iron is bad, and as it scarcely repays the expence and labour, it is rarely smelted.

The general character of the ore of these mines appears to range in the class, (p 4) which the Comte de Bournon denominates fer oxyde au maximum; the micaceous kind is at times so highly

IOR: MSS Eur D 154: by Major James Franlin, Bengal Army, F.R.S. MRAS (received from secretary May 19th 1835)

Oxidated, that it is nearly pulverulent, and the ochrey variety is almost a pure oxide; the compact species is rare, and fibrous hematitte (No 19) is still more scarce; in every instance it is found near the surface, and all the varieties, except that of Magaila, yield excellent malleable iron.

IRON MINES OF BARAGAON; LAMTERA, & EMLIYA

The mines of Baragaon, Lamtera and Emliya in the pergunnah of Belhari, are situated on the north side of the valley, and is remarkably that near this ridge, there is a change in the nature of the ore; it lies near the surface imbedded in ferruginous sandy clay, and is unconnected with any rock, though the subjacent stratum is sandstone; in the two first of these mines, the ore is granular, argillaceous (No 20) in globular grains, about the size of a pea, which are cemented together into a solid mass, by ferruginous clay; the other is the lenticular variety of the same kind of ore (No 21) differing from the former in the size and (p 5) and flatness of its pieces; but its cement is of the same nature, only less hard, and the nodules of ore being more easily separated, appears to give it a superiority over that of Baragaon, the grains of which not being divisible, its ore is perhaps affected by some vitiating property contained in the cement, the metal being very brittle.

IRON MINES OF THE DISTRICT OF PANNA

The best mines of the Panna district are near Brijpur, the ore is common argillaceous lying in a thin stratum, between beds of reddle and yellow earth (No 22) the former below, and the other above it; both these earths adhere slightly to the tongue, and fall to pieces in water, but do not form a paste, the former dissolves rapidly, the latter after a slight ebullition falls first in flakes, and finally into powder; on calcination the yellow earth assumes a lively colour - like English red, and they both would form useful pigments; the ore yields bad and brittle iron; but there is another kind of red ore exploited and smelted at the village of Simmeriya which produces better metal. (p 6)

IRON MINES OF THE DISTRICT OF KATOLA

The district of Panna produces diamonds, and the tract in which they are found, borders on the iron mines of Katola; the Ken (?) river being the boundary between them; and though this circumstance is foreign to my present object, it is at least curious, as it may perhaps serve to shew, the connexion, between the gem and ferruginous matter: the iron mines of Katola are in a cluster (@) of hills which extend between the Ken and Dessan rivers, and the ore, with one exception only, consists of varieties of the red oxide, its changes being from the most compact form, having a metallic lustre, into common argillaceous, according to the quantum of clay associated with it, the nature of which will be best understood from the specimens which are sent herewith.

@ NOTE: see the map which accompanies this paper.

Commencing from the Ken river and proceeding westward, the first mine is in the Pandua hill (No 23) but as it is nearly exhausted, I pass on to those of Amrownia, Majgaon, and Motehi; the ore of the first and second of these places (No 24) resembles that of Deora to be described hereafter, and that of the third (No 25) is in the form of water worn pebbles of various sizes, which are (p 7) imbedded in feruginous sandy clay; the mines are situated near the foot of the Bindachel hills which are here composed of sandstone conglomerate, and capped with the newer horizontal sandstone, which every where is uppermost in this range; the iron stone pebbles are about fifteen feet below the surface, and are intermixed with blocks, and fragments of sandstone, the whole bearing evident marks of attrition; the metal made from them is not esteemed.

Next in succession still proceeding westward, are the mines of Deora, the ore of which (No 26) is of two kinds, one compact with a metallic lustre, and the other containing a large portion of clay; the second of these is found high up in the hills, and in a vein, or deposite, immediately below the upper sandstone; it yields very good malleable iron, not brittle like that of Motehi, but such as may be drawn into thin plates without bursting.

About five miles farther west are the mines of Kotah, but the iron is bad, and I therefore pass on to the more clebrated mines of this district, viz those of Saigerh and Chandrapura, which are situated on the crest of the Bindachel range, and near the point where the waters (p 8) separate; in this respect they correspond with the mines of Baragaon and Emliya before mentioned, and like them also, the ore (No 27 & 28) differs both in nature and character, from all the other ores of this district; it lies in a thin vein, in ferruginous sandy, or gravelly clay - very near the surface; and its streak, in some specimens is yellow, in others yellowish brown, whilst that of all the other ores is red; in general appearance, it somewhat resembles the ore of Baragaon, but the grains are not so perfectly formed; its iron is excellent, possessing tenacity and malleability in a high degree far excelling every other description of iron produced in this district; coal shale crops out in its neighbourhood, and in all probability coal exists near the mines, but with all these advantages, the want of water carriage will ever prevent them from becoming more valuable than they now are.

West of the above, are the mines of Piperiya, Rejkoi, and Kanjra, the ore of the former (No 29) is something like that of Saigerh, and is usually mixed with the other two, to correct them; that of Rejkoi (No 30) being nearly compact, and that of Kanjra (No 31) containing/more argile. / (p 9)

Next in succession, still proceeding westward, is the Chapar hills near the town of Bajna which abounds in iron, and viewed at a distance it appears as if blackened by fire; its base is surrounded by protrusions of greenstone, and its stratification appeared to me to exhibit marks of derangement; at the foot of it is a cavern, and a chasm, filled with water to the depth of 220 feet, and an isolated fragment in its neighbourhood seems to have been separated from its parent mountain by violence; these appearances are very striking, and furnish grounds for speculation, but my present business is with its mines, which are situated at Bajna, Keritanga, and Suka, near to Surajpura; the ore of all which is nearly compact; the former (No 32) is on the summit of the hill, in large amorphous masses, the ore appearing to have penetrated the sandstone rock from a fissure of which it is excavated; the second (No 33) is a vein, in S (L)yenite about half way up the hill, and the third (No 34) is in a small adjoining colline; there are some rounded pebbles of iron stone - dug out of ferruginous clay near the village of Bhojpura - but they closely resemble those of Motehi and deserve no further notice. (p 10)

The last of the mines of this district are at Serwa, Hirapur, Tighora, and Mandewra, the former of which is in a small colline near the village, and the ore (No 35) does not appear to deserve notice; that of the latter (No 36) is of the same kind; but the ore of Hirapur is rich, and its iron in great request; it is also cheaper, and being situated on a good road it is often purchased in its crude state, and carried elsewhere to refine.

There are other iron mines still further west which are situated in a similar cluster of hills between the Dessan and Jamni rivers, as at Weldana, Sarai, Dhori &c.- and towards the north west iron abounds in every part of the hills from the mines of Katola to those of Gualior.

The Katola mines extend from the Ken to the Dessan rivers, and it is remarkable that the ore is confined to the cluster of hills, which lie between those points - never being found northwards of them - and only in a few instances, in the sandstone range south of them; this cluster, like the detached hills of Callinger and Adjygerh, have all the appearanace of having once formed part of the great range; their bases are all composed of Syenite (?) or Syenitic Granite, and their caps of (p 11) sandstone, and there is strong reason to conclude that the iron ore, here found, is an associate of the latter rock;- with one exception only - it consists, as I have stated above, of varieties of the red oxide, and in no instance have I found it affect the needle, unless it is heated, and even in that case, it is the compact variety alone, which does affect it slightly; its principal vitiating constituent is clay - which the native smelters do not manage well - and/perhaps is the reason /this of their obtaining so little produce; the refiners also have bad usages in their refining process in common with other parts of India, and though it cannot be said that they are unable to make good iron if they please, yet it is a fact that they have an objection to make it good for bazaar sale, except in the shape of culinary or other utensils which yield a better profit; their furnaces both large and small, and also their refineries, are exactly the same as those of Tendukaira in form, and the only difference in their process consists in keeping the wind tubes separate, as at Jabalpur.

IRON MINES OF THE SAGAR DISTRICT

From the Katola mines, I shall proceed up the Hirapur pass and ascend the table land, which being entirely composed of sandstone, and trap rocks, is not rich in iron ore; (p 12) there are however a few spots where it is found in the Sagur district, but as it is not wrought in any part, to an extent sufficient to attract notice, I pass on to the mines of Tendukaira.

TENDUKAIRA

The Tendukaira mines are situated in a more westwardly position of the same valley, as those of Jabalpur, and are about one mile and a half distant from the village Tendukaira; they are near a low range of hills composed of stratified quartz rock which evidently contains felspar, and this rock is the gaugue (?) (No 1) of the ore; at times it assumes the character of hornstone, and when contiguous to the ore, it is penetrated by numerous x slender veins, which although filled with the oxide of iron are very different from ordinary clendritic (?) appearances, as they are always in shoots, intersecting each other, and never arborescent (?), and it seems quite impossible that they could have been produced by infiltration.

The ore is never found near the surface as at Jabalpur but always about 30 feet below it, and in large massesx, or beds, in cavaties between the strata of the rock, which in some cases seems to have sustained violence; it is the brown hydro-oxide, both fibrous, and compact; but the former is by far the most prevailing; its general character, and (p 13) appearance is opaque, and earthy, but when it has a metallic lustre, its fibres are beautifully fine, and constantly radiated; its most common form is irregular concentric ~~lamina~~ lamellae, the lamellae of which are separated by a different colour, usually yellow, or yellowish brown; it is sometimes, though very rarely, crystallised, sometimes also it is mamillary and botryoidal (?) but I have not met with any other imitative form; it contains manganese and silex, but sulphur is its principal vitiating constituent; its produce will be shewn hereafter; but here it may be observed, that it yields most excellent malleable iron, fit for all uses, and also steel at nearly the same price as iron; there are five distinguishing names for it, which I shall give in the terms used by the native miners annexing thereto - their European synonims: Gulkoo (No 2) includes all the water-worn pebbles which are imbedded in diluvuial gravel between the alluvium and the rock, under which the ore lies; it is a mixed and bad kind of ore.

Surma (No 4) is distinguished by its red appearance and is usually found mixed with the above, (p 14) it perhaps contains arsenic and is always carefully picked out, and thrown away; Peera (No 3) or yellow ore, is the yellowish brown variety - always intermixed with the other kinds, and marking by its difference of colour their concentric lamellae form, it rarely occurs separate, its streak is yellow.

Kala (No 5) or black ore, is the compact earthy brown oxide, always dark coloured, generally approaching to black, sometimes but very rarely metallic (No 6) and crystallised (No 7) its streak is brown, and it is a very good kind of ore; Devi Sahi (No 8) or variegated, is the concentric lamellar variety (No 10 & 11) streaked with the yellow oxide; it has a fibrous tendency though opake, but sometimes it is metallic as Hemate (No 9), and in this case its fibres are extremely fine, and of a silky lustre, its streak is yellowish brown and it is reckoned the best kind of ore, producing most abundantly, good malleable iron, and also tolerably good steel.

CHARCOAL

Charcoal is universally used in India for smelting iron, as the natives have no knowledge of coal, nor could they use it with their present refineries, because they are totally inadequate to the reduction of highly carbonised metal; they are fully aware of the effect of certain kinds of wood on the quality of iron (p 25) and know from experience those which are best suited for their purpose; but as they cannot always obtain the trees they prefer - they use a mixure for their smelting process, excluding only such as are notoriously pernicious; but in their refineries they use exclusively taak (?), mowa, or bamboo, to the last of which they give the preference; in their preparation of it, they are expert from habit and no men are able to make better charcoal; they usually allow a month for drying the wood after felling, and their method of piling it, for burning, is in conical heaps; the remainder of the process being exactly similar to the practice of Europe.

FURNACES

Their smelting furnaces, though rude in appearance, are nevertheless very exact in their interior proportions, and it has often surprised me to see men who are unquestionably ignorant of their principle, construct them with precision, in so simple a manner; their unit of measure is the breadth of a middle sized man's finger; 24 of which constitute their large and 20 small cubit; thus there is a constant ratio of 6 to 5 prevailing throughout these furnaces, nor is it of the least consequence, that their dimensions are larger or smaller, so long as all the parts (p 16) are in the same proportion; the length of these measures is on an average 19-20 English inches for the large cubit, and 16 English inches for the small one.

As they have no standard measure their fingers, their span, and their arm (?) are substituted by which a piece of stick is measured which they use in practice; neither is the division of the cubit necessary though the large one is supposed to be divided into six parts and the small one into five, of four fingers each - as the measurement is invariably ascertained by their fingers; the length of these parts is on an average 3-20 English inches.

GEOMETRICAL CONSTRUCTION OF THE FURNACE

To construct the outlines of the furnace geometrically (Pålte 1, fig 1 and 2) rule an indefinite line A.B. which suppose equal to a large cubit of 24 digits or 19-20 English inches, and divide it into 6 parts; at C erect a perpendicular, then from C to E set off 6 parts and it will mark the central point of the greatest bulge, and consequently the point of greatest heat; next, from E to F set off 6 more points, and it will mark the point of cremation (?); then again from F to G, 6 parts more, will mark the line, where it is necessary to recharge the (p 17) furnace, after the burden has sunk thus low, and from G to D - two parts more; will give the perpendicular height of the furnace, in 20 parts equal to 5 feet four inches of English measure.

To complete the figure, rule lines parallel to the base, through the points E,F,G, and D, and from D, fig 1, set off three parts to the left hand for the top; bisect it at I, bisect also the bottom at H, draw H,L, right angled at K, and it will be the oblique axis of the furnace (fig 1. K I) bisecting all the parallels corresponding with CD (fig 2)- then make the parallels ~~corresponding with~~ AB six parts,- E six parts - F five parts, and D three parts, rule lines through all these points, and the geometrical outline will be completed, the sum of the parallels in parts, corresponding with those of the perpendicular.

PRACTICAL CONSTRUCTION OF THE FURNACE

To construct it practically - dig a fosse 3 feet deep in the annexed form (Plate 3, fig 2) the semicircular part of which contains the furnace walls B, the walls CCC being composed of unburnt bricks of large dimensions; the first structure is rude, preserving only an approximation to the required form, the interior being afterwards cut away; a large stone capable of containing heat is placed at the bottom; and in this state it is suffered to remain until thoroughly dry; the next operation is performed by a more skilful artist who cuts away the interior, and plasters it with clay, using the measures above described to adjust its dimensions; he first finishes the top, and from the centre of the back part of it, he drops a plummet, to ascertain the spot where the centre of the ~~first~~ front part of the stone is to rest; this plummet line corresponds with the perpendicular CD of the geometrical figures 1 and 2 - and thus he obtains (p 18) not only the required obliquity of the furnace, but the points most essential for the adjustment of all the rest.

When the furnace is thus far prepared it is again suffered to dry, and in the mean time, other appendages called by the Indian smelters Gudaira, Pachar, Garrairi, and Akaira (names which have no synonimes in the English language), are constructed; the Akaira in particular is a most extraordinary implement (Plate 1, figs 4 & 5; and Plate 2 fig 1); externally viewed it is a clumsy mass of clay enveloping the wind tubes (Plate 1,fig9) but when it is considered that the complete fusion of this mass, and the perfect completion of the smelting process must be simultaneous results , the implement becomes the most important of all appendages; thus for instance if it is too small, or too large, its effect will immediately be perceived ; in the

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NOTE: It may here be observed the nature of the clay is a material point with regard to this implement, and at Tendukaira it is well adapted,being near the great trap-range, and reposing on a mass of cretaceous limestone belonging to the trase family; in all probability therefore it contains a small portion of lime; a few small grains of wacken (?) may also be observed in it and in addition to these Kodo straw being mixed with it the potash derived from these materials facilitates the fusion of its , whilst the lime renders it a fusible compound, the ingredients of which are well ported, and seem to be well adapted former case the masset of crude iron will be full of impurity, and in the latter the iron will be consumed, and if it cracks during the operation of smelting, there is no remedy for such an accident - short of dismantling the furnace and commencing the work again.

I found after numerous experiments that its mean length should be $4\frac{1}{2}$ parts, its mean breadth 3 parts its mean thickness $1\frac{1}{2}$ parts and it is somewhat remarkable that the product of these dimensions, should exactly equal a twentieth part of the cubic contents of the furnace when fitted for use; this coincidence may arise from the peculiar nature of the clay of Tendukaira, the ingredients of which are well assorted, but the rule will nevertheless apply generally - because clay by admixure is susceptible of being rendered amenable to rule; and therefore this implement will be found (p 19) in all Indian furnaces to have (or by tempering the clay may be made to have) the same corresponding dimensions.

The Guddaira is a wedge of clay used to adjust the vertical position of the Akaira when placed in the furnace; and the pachar is an oblong plate of clay, used in walling (?) up the orefice after the Akaira is placed, and adjusted; these figures and dimensiond are given in Plate 1 - fig 7 &8 ; the Gurairy (plate 1, fig 6) is a convex plate of clay, perforated with holes and used as a grate - through which the scoria are drawn off.

When the appendages are ready and the furnace thoroughly dry, it is prepared for use in the following manner.- the front part is walled up from Akaira to the top (the top) to the line SS (plate 1 fig 1 & 3) which line is ascertained by thw small cubit; one end being placed at D, the other will measure CB and CS (fig 1) - the grate is next put in, its lower edge resting upon the edge of the stone; and the space is filled - with a mixture of pulverised cow dung and kodo straw - up to the dotted line (plate 1 fig 1) upon which is placed the Akaira; its sides being every where $1\frac{1}{2}$ parts distant from the walls of the furnace - as represented in Plate 1 -fig 4 and Plate 2 -fig 1; where a,b,c,d, are the walls of the furnace, and 5 fig: 5 and 1 (plus) fig: 4 the Akaira; the Gudaira or wedge, is next introduced in order to adjust its vertical angle (plate 1 fig 1) and this being placed satisfactorily, the Pachar is inserted and the whole has then the appearance represented in Plate 1, fig 3, where No 5,6,7 and 8, are the Akaira, Gudaira, Pachar, and Garrairi; nothing now remains but to the whole with clay, leaving the ends of the wind tubes open to receive the bellows.

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BELLOWS

The bellows are as singular in their construction ad the Akaira, and are worked by the hand; they are made of a single goat skin, the dimensions of which ought to be 7 parts in breadth when doubled and 8 parts in length; such proportions being required for circular bellows of 5 parts diameter, and which when worked by a man of ordinary strength will rise 6 parts in height - having $11\frac{1}{2}$ circular folds; the wooden nozzle through which the blast is conveyed into the furnace surfaces the Akaira in its complex nature, and so little is its principle understood - that the art of making it was once lost at Tendukaira, and was again restored by the smelters of Katola.

Construction of the Nozzle of the Bellows

To construct its figure geometrically, rule a line AB equal 3 parts (Plate 2 fig 2) divide it into four, giving one of those

NOTE: The broad end $3\frac{1}{2}$ the narrow end $2\frac{1}{2}$, the mean of which is 3 parts. These dimensions do not greatly differ from those of the native smelters, on the contrary they are founded on the mean of all the measures I could procure - and the difference consists in their being regular and fixed while those of the natives are [illegible] govern by caprice.

dividions to each of the legs, and two for the space in the center; set off a perpendicular from C to D equal 3 parts; bisect it and the middle point will mark the apex of the central angle; then through the point D rule a line parallel to AB and from it as a centre set off each way ¾ of a part making together 1½ parts; divide it also into four, giving one of each to the legs, and two for the space in the center as before; and then by ruling lines to connect all these points, the outline will be complete; the exterior of the implement is plain but the interior is complex and cannot be described except by a reference to Plate 2: fig 3 which represents it, divided in the middle, to shew its internal structure.

This curious appendage is fastened to the bellows by leathern thongs, and the blast is forced through it at an angle of 24° degrees but when it is luted to the wind tubes of the Akaira, the blast enters the furnace at an angle of 12° degrees, both vertically (@) and horizontally - because these tubes are placed so as to reduce that angle; (p 21) Plate 2 fig 1 (plus) represents the whole apparatus luted together and placed in the furnace the walls of which are marked a.b.c.d, and it exhibits at one view, the whole of the mechanism of this complex machinery; the furnace when closed up with clay, and the bellows luted in, is represented entire in Plate 3 and 4; the dotted lines shewing the chimney - the outer walls, B a mound of earth to strengthen the walls, C an upper chimney of moveable bricks, D planks laid across the trench to support the bellows and the man who works them, E a stone supporting one end of the plank, F forked branches supporting an iron bar on which the other end of the planks rests, and G a simple apparatus for preventing the bellows from rising from the planks when they are worked.

The above description is not founded on theoretical conclusions; the measurements given are derived from taking the mean of several and the results were proved in furnaces under my own superintendance; the coincidences of the several parts are very striking, thus for instance, the perpendicular and parallel lines of the geometrical outline are equal in quantity (Plate 1, fig 2); and the top-bulge and bottom being 3 - 6 and 4½ parts respectively, shew that the furnace is exactly constructed, and that it corresponds well enough with the most regular furnaces of Europe (Plate 1, fig 1); it is also curious, though perhaps of no importance to observe, that the mean of numbers, being squared and multiplied by the terms of the perpendicular or axis, give the cubic area of the furnace, and shew that it is twenty times larger than the cubic content, of the Akaira; the angle of the blast is also worthy of notice, as well as the simplicity by which both it and the obliquity of the furnace is obtained; all these serve to shew that the original plan of this singular furnace must have been the work of advanced intelligence, and that its geometrical proportions have been preserved by simple measures; hence though its original form may be changed by caprice or ignorance, its principle never can be lost so long as hands a-nd fingers remain. (p 22)

REFINERIES

The refinery is as rude in its appearance, and as novel in its construction as the furnace, to which it seems to have been purposely adapted; two refineries being required for one smelting furnace; to construct it they use the small cubit of 20 digits, or what is still more available, the span or distance between the tips of the thumb and little finger of a middle sized man when extended without force, two such spans being considered

(@) NOTE: The vertical angle is obtained by means of the wedge the thickness of which is adapted to the angle of 12° degrees, and the horizantal angle is obtained by keeping the ends of the wind tubes a certain number of fingers breadth as under when imbedded in the Akaira. These quantities never differ much.

equal to the cubit; the first process is to arrange a number of square unburnt bricks, as in the ground plan (plate 5 fig 1) in which a.a.a.a are the wallxs - is the chimney - B the refinery furnace, C the seat of the refiner, and D the anvil; see also (fig 2) for a side view of it - divided in the middle for the purpose of shewing the interior structure, in which is a piece of crude iron under the process of decarbonization; the dimensions of the chimney are not material - but it is usually about one cubit broad, one deep and six in length; the oval part where the operator sits is altogether a fanciful appendage, being merely a mound of earth in which a log of wood is inserted for receiving the anvil - and its elevation serves the further purpose of giving the workmen a purchase (?) in using the hammer; when the walls of the chimney are finished, the top is covered with unburnt bricks of an oval shape, flat below and convex above and these are luted together by a plastering of clay - (fig 3) is a front view - shewing the opening of the furnace and Plate 6 exhibits the refinery complete, with the refiner at work on his seat, the bellows man plying the bellows, and various implements lying about - A the outside of the chimney - B a mound of earth to strengthen its walls - C the refining furnace - D a piece of crude iron undergoing the process decarbonization (in dotted lines) - E the bellowsman plying the bellows - F the refiner with an iron spitle in his hand (p 23) regulating the operation (the dotted lines shewing the interior of the furnace) - G a thick plate of iron plated at the bottom of the refinery (in dotted lines)- H a forge for the hammerman - I the anvil - K implements, and L a heap of charcoal.

The furnace of the refinery is the only part which requires skill in its construction, and this is usually done by the operator himself; its geometrical outline is represented (Plate 5 fig 4) and its construction is as follows. Rule a line AB equal five parts, divide it into six - set off four of these divisions for the top - let fall a perpendicular from the center C - set off three divisions from C to D for the depth - rule a line through D - parallel to AB and make it two divisions, now rule the outline - bisect the perpendicular and the centre parallel will be equal to three divisions.

The center parallel is the most important part of the furnace and next to it is the accurate adjustment of the angle of the blast; I have frequently seen the Indian refiners obliged to discontinue their work on account of some error in this point; the usual measure for the former is the span above mentioned applied both longitudinally and transversely as in Plate 5 fig 1-B where a ground plan of the furnace is exhibited - the inner circle of which corresponds with the center parallel of fig 4 - this measure never differs much from 8 inches, and that quantity may be assumed as a fair average; - the outer circle of the same figure is indefinite - the space between the two - being merely a slope, chamfering (?) from the inner edge, and gradually expanding, until it is lost in the sides of the furnace, so that in fact it is reverberatory; with regard to the blast, it is absolutely necessary that it should be directed, at an angle of (p 24) about 12 degrees, upon the opposite edge of the inner circle or to the point C fig 1-B-; the natives have no instruments to enable them to do this exactly but the working of the furnace soon tells them where there is an error and they know well enough how to correct; - the bellows resemble those of the smelting furnace, but instead of the wooden nozzle, they are furnished with long eron tubes - as in Plate 5 fig 5 which are so placed, that the angle of the blast thrown through them is 24 degrees, the same as that of the wooden nozzle.

SMELTING FURNACE

Plate 7: fig 1 and 2 represent the front and back view of a small circular smelting furnace, which is very common in India - its measurementsx may be taken from the scale of the Plate either in parts or inches; the bellows are the same as fig 5: Plate 5 and the form of the interior or chimney is exhibited by dotted lines; fig 3 and 4 of the same plate shew another description of refinery used chiefly for decarbonizing large masses for the manufacture of anvils &c worked by two pairs of bellows - this refinery might be more extensively applied; such as for the manufacture of , or other heavy work (@). Fig 5 is a small field black-smith's forge, constructed of the same kind of oval bricks, as those which are used for covering in the refinery, and luted together by clay; this apparatus may be constructed in half an hour; and is a useful field smithy; fig 6 is a tube of clay, used in the refinery to preserve the end of the bellows - fig 7 is atube of the same kind used in the small circular furnaces.

MODE OF SMELTING AND REFINING

In the process of their manufacture the Indian smelters use charcoal only; the ore is broken into pieces about the size of a walnut, but it is not washed, nor is it roasted although it is known to contain a large quantity (p 25) of sulphur which might be dissipated by that method; they commence by filling the chimney of the furnace with charcoal which they suffer to burn until all moisture is expelled; they throw in a small bucket of ore, and upon it a larger one of charcoal, after which the burden is allowed to sink as low as the line G (Plate 1: fig 1 and 2) when it is again charged - and afterwards ore and charcoal are alternately given in the same proportions until the operation is complete; the scoria begin to to flow within the space of an hour, and by that time, it is known whether the furnace will wok well or ill - the scoria being a sure indication; it is let out by piercing the grate with an iron spike, and the orifice is again closed with clay as soon as it is drawn off; the bellows are worked by three men - who take it by turns; and they should be kept constantly playing until the process is compleated; the time of which is ascertained by introducing a hooked piece of iron through the wind tubes, into the furnace, which shews how much of the Akaira remains; for as I have shewn before, it is indispensably necessary that this appendage should be totally fused before the operation is complete, and when this is the case, it would be useless to continue longer, because the furnace would cease to work properly; it usually continues 12 hours but much depends on the bellows-man, and also on the working of the furnace.

The metal is never completely melted by this process - the heterogeneous mixture of the ore alone is fused and thrown off in scoria, and the iron being freed from it falls by its superior gravity to the bottom of the furnace, and there coagulates into a (p 25) mass or masset; it is never very highly carbonized, and sometimes it is partially malleable even in its crude state; when the process is finished, the bellows are removed; the front part of the furnace demolished; and the red hot masset dragged out, and divided by large before it has time to cool, hence it happens that the parts of the furnace thus broken up, require daily renewal.

This completes the business of the smelting furnace - the process of decarbonization being performed in the refinery, and

(@) NOTE: The refinery is convertible into a blacksmith's forge by taking out the iron plate and building up a wall in the middle so as to destroy the reverberating effect.

Plate 6: fig D, represents half a masset - properly placed in a refinery and undergoing that operation; as it becomes decarbonized, it drops into the hollow of the furnace upon the plate of iron G - and when a sufficient quantity has accumulated, it ~~it~~ is taken out and hammered into more circular lumps which are seen in every bazar; the charcoal used in the operation is always of hard wood, such as teak (sectona grandis ?) Mowa (fana Latifolia ?) or bamboo; this is the part of the manufacture in which the Indian manufacturers play tricks; for in the first place they do not allow time for the crude mass to become properly decarbonized and then again they have a most pernicious practice of knocking off corners and small pieces from the masset in its crude state into the decarboni~~zation~~ -zing fluid (?), and instead of waiting patiently until the whole of the masset is decarbonized they often throw in large lumps at the end of the process, mixing all these crude pieces with the other so that the cheat cannot be detected except on trial; thus they not only shorten the time of the operation, and thereby use less fuel, but contrive by this nefarious (p 27) practice to sell a large portion of their crude iron at the same price as the malleable; they are also very sparing in their hammering lest they should force out too much of the Vitreous Oxide (?) and thereby reduce the weight; so that upon the whole there seem to be causes which have justly affected the reputation of Indian iron - but as they are repairable errors, they ought rather to be placed to the account of the perversity of Indiah habits - than arrayed against that fair repute to which the Indian metal under different management might lay claim.

PRODUCE

The produce of the ore of <u>Tendukaira</u> varied from 36 to 40 per cent - but as it was upon the whole nearer to 40 than 36 - I ~~am~~ am quite safe in fixing the average at 38 per cent; I tried by roasting the ore to obtain a greater quantity but without effect, neither was I satisfied with its result in another point of view, as will be shewn hereafter; with regard to charcoal the consumption varied according to its quality - or, in accordance with the working of the furnace. The following diary contains a statement of the daily produce of four smelting furnaces, from which I assumed a mean, as a fair proof of their power of production. They were under my own superintendance from the 30th April to 6th June 1827 which is beyond/question the most /all unfavorable portion of the year ~~for~~ for smelting iron, and the result therefore is the more enhanced in value. (p 28) (@) ..(p 29)

From this statement it appears that each furnace yielded upon an average about 18½ <u>Panchseri</u>, and that every hundred sers of crude metal yielded 63 sers of malleable iron; the total of the produce therefore is as follows: the ore yielded 38 per cent - the crude metal 63 per cent - and the malleable iron yielded 56 per cent when wrought up into bars fit for use in a suspension bridge - as will be shewn in the following paragraph.

QUALITY OF THE IRON

The iron was made over to Captain Presgrave of the Sagar Mint (an officer very capable of judging with regard to its quality). He wrought it up into bars and rods for an iron suspension bridge on which he was then employed and the following is his report to understand which it is necessary to refer to the note below. @@@

(@) Statement of p 28 on separate sheet.

@@ The furnaces all varied in their produce but the mean is 18½ Panchseri - a Panchseri is 5 sers - eight of which or 40 sers are equal to a maund.

@@@ NOTE: I tried all the descriptions of ore and made experiments on roasting it - the result of which could only be ascertained by making the iron; the first   marks constituted the bulk of the quantity submitted for trial, and their iron result may be safely taken as a fair average; the other three are the result of my experiments on roasting the ore -previous to

"The first six marks, afford bar iron (as far as my knowledge allows me to judge) of most excellent quality, possessing all the desirable properties of malleability, ductility at different temperatures and of tenacity for all of which I think it can not be surpassed by the best Swedish irón; the second description consisting of the three last numbers in the accompanying statement has produced very good bars, but in forging and working it up, the iron appears somewhat harder, probably from its still containing a portion of carbon; the different marks varied in yielding from 50 to 60¼ per cent in bars, the average from the whole being rather more than 55¾ per cent."

It is necessary to add that the bar iron mentioned above, is not (@) common bar iron - but highly wrought bars, for use in a suspension bridge; the hardness alluded to in the three last numbers, was evidently occasioned by the metal "still retaining a portion of carbon", and it is worthy of remark that this quality was confined to those specimens, the ore of which had been roasted. (@@)

COST OF THE IRON

The cost of the iron was as follows. The excavation of a mine cost 30-12 Nagpur or 25 Calcutta Sicca Rupees; the construction of four smelting furnaces, two refineries, and one small round furnace, cost 34-12 Nagpur or 30 Sicca Rupees; and the purchase of skins and manufacture of seven pairs of circular bellows cost 30-5 Nagpur or about 25 Sicca Rupees - total of outlay 80 Sicca Rupees; but as my experiment lasted only five weeks, and the above outlay was calculated to last (p 30) a whole season, a portion of it only is chargeable to the cost of the above iron; the hammers, anvils and other implements of iron, not being perishable articles - are chargeáble only for reasonable repairs; thus the proper proportion of outlay is 15 Rupees, and the expence (@@@) of working the furnace was 441-0 Nagpur or 375 Sicca Rupees, the total of cost therefore for 225 maunds of malleable iron was 390 Sicca Rupees, or one rupee 12 annas per maund.

The iron was weighed by the standard of Nagpur - the maund of which place is about 3 lbs avoirdupois less than the factory maund of Calcutta; hence its weight is about 71 lbs 10 Ozs avoirdupois, and 31¼ Nagpur maunds are nearly equal to one English ton; the value of the Calcutta Sicca Rupee is usually reckoned at 2 shillings and hence the cost of a ton weight of malleable iron in English money was five pounds nine shillings, and five pence, or in round numbers- five pounds ten shillings.

(@) The common English bar iron yields about 70 per cent of such highly wrought bars.

(@@) NOTE: The roasting of iron ore, previous to smelting is supposed to repay with advantage, the additional expence it occasions; and the reason of its ill success with me I can only explain as follows: The furnaces of Europe are I believe in general perpendicular that is - the ore and fuel fall perpendicularly and consequently (p 30) descent is more rapid; but in India the furnaces are oblique, and the descent of ore and fuel more gradual and hence sufficient time is gained for dissipating sulphur, (or other volatile ingrdients) before it reaches the póint of greatest heat; this appears to be the fact as the chimneys of these furnaces are always coated with sulphur; it would seem also that the metal acquires more carbon under the effect of both operations than the Indian refinery, constituted as it now is, can dispose of - and hence the hardness of the last three marks as observed by Captain Presgrave.

(@@@) STATEMENT OF EXPENCE

6 Men for each Smelting Furnace or 24 for @ from 30th April to 6th June or 1¼ months at 4 Rs/p.m (each)	120- 0
Charcoal for the Furnace for the same period	134- 0
For digging ore	14- 2
Carriage of ore	15- 5
Carriage of charcoal	14- 9
Headman	6- 0
Total for Smelting	304- 0

CONCLUSION

It was my intention to have compared this little furnace with some of the minor furnaces of Europe - but as my knowledge of the latter must have been derived from books, I prefer giving facts derived from actual experiment, and leave the comparison to those who are better able to make it; the quantity of crude metal smelted in my four furnaces from the 30th April to the 6th June, was 354½ maunds, and its cost was 304 Nagpur or 260 Calcutta Sicca Rupees - hence its cost per maund was 11¾ annas, or two pounds, six shillings per English ton - and the produce per week of four furnaces was 71 maunds or 2¼ English tons.

These data shew the cost of the iron both in its crude and malleable state and Captain,now Coll Presgrave's report gives the latter so fair a character that it may be useful to follow up that report by another obtained from the Calcutta Mint on some places of Jowli and Ageriya iron which were wrought up to the state of English bar iron - and submitted to trial - the substance o f the report is as follows:

"A piece of the Jowli iron being broken shewed about half the surface of a fine blue tough (p 30) appearance, the other half had a very brittle appearance of a glassy white colour resembling what the smiths in England call cold-short; this piece 1 inch broad and ¾ inch thick was put into a clam and a lever applied to it; it twisted with a fair resistance, and bore one revolution in 6 inches without shewing a fracture; it was then warmed and a hole punched through it, which it bore in a way that would have been expected in a piece of good English iron and better than the general run of English iron purchased in the bazar would have borne it. An eye being turned at each end, the space of 10 inches long so drawn down to one third of an inch square, and dead weight scale fashion without the use of the lever applied and in the length of six inches it elongated:

1/10th	of an inch	with	3378 lbs
2/10th	"	"	3624
3/10th	"	"	4795
5/10th	"	"	5127

and drew itself to near a point and broke with 5246.

A piece of the Ageriya iron on being broke,shewed a small portion of its fracture light blue tough vein, the remainder silvery white, shewing very fine particles, and was what the smiths in England would say had an inferior appearance, it was 1⅛ (?) inch broad by ⅞ inch thick, and was twisted cold one revolution in 6 inches without shewing a fracture and appeared to be much stronger (to the twist in proportion) than the above piece from Jowli, though much softer; it was then heated, and punched which it bore in a manner sufficient to give it the character of very fair average iron; an eye being then turned at each end, the space of ten inches long was drawn down to one third and dead weight scale fashion without the use of the lever, applied and in the length of six inches - it elongated 1/20 of an inch, with 4748 lbs, and made a square break with 5376 lbs.

Though the Ageriya piece gave no notice of its approaching failure, whilst suspending a weight; yet when brought to the bend, it shewed itself possessed of the power of elongating, and bore more bend without shewing a fracture than the piece of Jowli and stood the bend better than the general run of English iron purchased in the bazar."

The above statement was addressed to Captain Forbes, superintendent of the hon'ble Company's steam engines and machinery, to whom I applied to obtain a trial and the experiments were all made by one of (p 32) the most able and practical men of the Mint - named Thomas Pigg.

Having now exhausted all my information which was obtained from actual experiment and impartial trial and proof I shall conclude with the following remarks - viz: that the Indian forge is able to make crude metal, for two pounds six shillings, and good malleable iron for five pounds ten shillings per English ton; it is moreover susceptible of improvements; it requires but little outlay; it is portable; and may be transported from place to place, the implements being the only things necessary to carry; it may be erected in places which combine the advantages of proximity of ore and fuel and where other furnaces requiring a large supply of water cannot be set up - and it may be erected for temporary purposes and abandoned when the object is fulfilled without material loss, the furnaces being the only part which would be lost and their cost is about 6 shillings each.

The employment of so simple a forge in England would be absurd - but considering it an instrument adapted to the existing condition of the country where it is used - it assumes a different character - for such is the cheapness of labour and fuel that I question whether any other furnace would compete with it - and if by improvement it can be made capable of working on a larger scale1 arsenal materials, materials for bridges and other heavy work - it certainly is an object worthy of attention, as a great saving of expence might be effected by its use.

(signed: Jas Franklin
Major of Bengal Cavalry)

Continuation of footnote "Statement of Expence" (p 30 in MSS)

6 Men for each Smelting Furnace or 24 for 4 furnaces from 30th April to 6th June, or 1¼ month at 4 Rs each per mensem.	120- 0
Charcoal for the Furnace for the same period	134- 0
For digging ore	14- 2
Carriage of ore	15- 5
Carriage of charcoal	14- 9
Head Man	6- 0
Total Cost of Smelting	304- 0

1 Lohar Mistry at 8 and five Lohars at 4 (Rs) per mensem for each Refinery: this sum doubled for two and for a period of five weeks is	70- 0
Teakwood Charcoal for the Refineries	63- 0
Head Man	4- 0
Total Cost of Refining	137- 0
Total Cost of Smelting	304- 0
TOTAL EXPENCE	441- 0

(Note: see diary page 28)