

# XV.

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## ON THE MINERAL PRODUCTIONS

OF THAT PART OF THE

HIMALAYA MOUNTAINS,

LYING BETWEEN THE SATLAJ AND THE KÁLI (GÁGRA) RIVERS;

*Considered in an economical point of view: including an Account of the Mines,  
and methods of working them, with suggestions for their Improvement.*

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BY CAPTAIN J. D. HERBERT, 9th REGT. B. N. I.

*Late Sup. Min. Survey, and Assist. to the Sur. Genl. of India.*

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THE survey of the mountains, of which I have had the superintendence, having been brought to a close, by order of Government, I have, in the selection and arrangement of my materials for the formation of a final Report, thought that the accompanying paper on the mineral productions of that tract might be acceptable to the Society. It forms a communication intelligible in itself, and independent of the other details; while it is not of a length to fatigue the attention. A subject as yet untouched by any pen, it may be not even without its interest.

The metallic ores are the principal productions considered in an economical point of view, and the details relating to them, including an

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account

account of the mines and the method of working them, constitute the larger portion of the paper. I have added such suggestions as have occurred to me, for the improvement of the more obviously defective processes. But possessing little (if any) knowledge of practical mining, it is very possible that my suggestions may not be always improvements. The reader will take them for so much as they are worth, and no more.

As the subject is a popular one, I shall not affect any precision or refinement of method, but endeavour to communicate the little I know in the most intelligible form I can; guided only by convenience as to the order in which I shall notice the different substances. They may be divided, then, into two sections—the first to consist of those which do not furnish metal, the latter, including all the metallic ores.

## I.

Of minerals, not useful to the metallurgist, though otherwise productive, the following are found :

1. Sulphur.
2. Green Sulphate of Iron.
3. Alum.
4. Bitumen.
5. Graphite.
6. Gypsum.
7. Limestone, and
8. Potstone, or Indurated Talc.

I shall bestow a few words on each of these, and then proceed to the second section, comprising the Metallic Minerals.

1.—*Sulphur.*

1.—*Sulphur.*

This substance appears to deserve the first notice, if it be only for its value as an ingredient in the manufacture of gun-powder. During the late war, its price rose to £30 per ton in Europe, and it would seem a subject not unworthy of attention, to ascertain in what quantity and at what price we could draw it from our own provinces. There are several sources of supply within these mountains; but it is to be feared that the expence of carriage would neutralise any profit to be expected from the more remotely situated of these. It is found in the deposits of hot springs, occurring in the bed of the *Rámgangá*, and of the *Garjía* rivers; in the province of *Kamáun*, mixed with carbonate of lime, from which it is readily separable by a subliming heat.—It occurs in considerable quantity in some of the galleries of the lead mines at *Mywár*, on the *Tóns*, in *Jaunsár*.—It may also be obtained in the first roasting of copper pyrites, as is practised at the *PARYS'* works in Anglesea, or of the ores of Galena, as was effected in the lead mines of Cronebane, in Ireland. It is not easy, without further enquiry, to estimate correctly the amount derivable from these several sources. Doubtless it would be considerable, and probably greater than any demand likely to arise immediately.

2.—*Green Sulphate of Iron.*

In connection with the deposits of sulphur and carbonate of lime occurring at the hot springs, there are also found extensive surfaces covered with an efflorescence of green sulphate of iron. This substance might be further obtained, in any quantity, from the iron pyrites of the mines. The conversion of the sulphuret into the sulphate is effected by reducing it to small pieces, exposing it to the air, and occasionally sprinkling it with water; operations requiring little labor, and involving no other expence.

3.—*Alum.*

Alum has not (as far as I know,) been yet found in Europe, otherwise than associated with the argillaceous schists. In America, however, a notice lately appeared, to which some degree of interest seemed to attach, of its having been found in micaceous schist. Our mountains afford another example of this fact. Near *Almórah*, in the bed of the *Cosilla*, it may be seen as an extensive efflorescence on mica slate, and it is probable that, by quarrying and lixiviating the rock, profitable quantities of the mineral might be obtained. From observations made when I was occupied in other duties, and not so precise as to the exact nature of the mineral, I think it probable that there are many similar examples of its occurrence, and that it is by no means rare in our mountains.

4.—*Bitumen.*

Bitumen occurs, but in no great quantity, if we may judge from the price it bears. It exudes from the crevices of a lime-stone rock, on the summit of the range between the *Sarjú* and the *Rámgangá*. On exposure to the air it hardens. It is used by the natives as a medicine.

5.—*Graphite.*

This substance has been found in round nodules of sizes, from one to three inches in diameter, scattered on the summit of a ridge composed of a highly carburetted micaceous schist. No bed, or mass *in situ* has been yet observed; but there is little doubt of the existence of such from considering the character of the rock, combined with the mode of occurrence of the mineral. Many of the nodules are more or less contaminated with quartz and mica, while, in one specimen, there were portions of quartz that had much the appearance of veins.

Almost

Almost all the nodules have more or less of the metallic lustre on the outside, owing to the degree of friction they have undergone. But the fracture surface is always dull; the composition being, apparently, fine earthy. On being rubbed or cut, it recovers its polish. That the absence of lustre on the fracture is dependent on its state of aggregation or composition, as mineralogists call it, seems further probable from its extreme porousness. One specimen, by some trials, appeared to absorb one-fourth of its bulk of water.

The specific gravity of those specimens apparently most free from foreign contamination, varied from 2.21 to 2.26. There is little doubt that, in the case of a mineral like graphite, the specific gravity is a valid test of its purity. It is interesting, then, to compare these values with that generally assigned by the best authorities. Amongst the older writers, there is such a range of results as warrant their rejection altogether. Professor MOHS, one of our best modern authorities, assigns 1.8 to 2.1 as the limits—HAUY 2.089, as an actual determination. SCHRADER again, who undertook a particular examination of the graphites from different countries, states the specific gravity of English specimens, remarkably pure, and one of them from Borrodale, at 2.32 to 2.46. However this may be, the mountain graphite is, certainly, of inferior quality—although I have succeeded in manufacturing a very tolerable pencil from it, and even in cutting out a small cylinder, such as is used in the patent pencil cases. It is also to be noted, that the graphite in England undergoes the preparatory operation of being boiled in oil. It is possible that such a process may considerably improve the quality of the mineral.

The uses of graphite are not confined to the construction of pencils, and there is a demand for very inferior qualities of the article. Advertising to the increasing employment of steam engines, it may be safely said that

that a sufficient quantity of even the quality yet found, would not be without its value. It is well known to be the very best anti-attrition application for metallic surfaces, when mixed with tallow, or other greasy substances. A mixture of this kind is useful, too, as a preservative from rust for articles of cast iron, and it is equally found to improve their appearance.

#### 6.—*Gypsum.*

Of the more bulky articles, Gypsum, of the discovery and geological relations of which an account is given in another part of this volume, is doubtless the most valuable. Its pure white color and granular composition, fit it for works of ornament. It is, however, probable, that its chief use in this country, for some time, would be as convertible into Plaster of Paris, and affording a material for cornices and ornamental work, to the banishment of the very rude productions of this kind we have hitherto put up with. There is, perhaps, sufficient quantity of it to answer any demand, likely immediately to arise. When the Government House was last repaired, it was considered desirable to obtain a sufficiency for the purpose above indicated; but the fact of its occurrence within our mountain provinces was not known at that time. As it is within fifty or sixty miles of water-carriage, it might be expected to pay for its transport.

#### 7.—*Limestone.*

Marble is the rock next in value. Although it is not found of very brilliant colours, yet it is not deficient in beauty, and might, I think, be found to defray the expences of working. It is indubitably superior to the very coarse marbles of the western provinces. A white dolomite, of a fine grain, approaching to compact, is found in many places. A variety, exactly answering to the description of the Iona marble,

marble, occurs at no great distance from the plains, and would certainly be admired. Another, at no great distance, is a flesh-colored dolomite, with purple clouded delineations, which, to judge from hand specimens that have been worked and polished, promises well. All the preceding are fine grained, almost compact. A marble of a more crystalline grain is found on the road to *Bhadreenath*, above the *Bishen Ganga*. This is a large mass; but, perhaps, too far from the plains to be of any value. Rolled pieces of crystalline limestone are found in many of the torrents within the zone of greatest elevation, proving that beds of this rock are, or were to be found within that tract.

8.—*Potstone, (Indurated Talc.)*

This rock may be substituted for many of the purposes of the former. It admits of considerable, though not equal polish, and in its great sectility, and the consequent facility of shaping it, there is an advantage. It may be cut with a knife, and by means of chisels, rasps, and files, may have any delicacy of ornament impressed on it. It may be turned in the lathe, and in this way are formed in Europe vessels, which are used for preparing food, having the advantage of standing the most intense heat: as a material for small furnaces and crucibles, it is valuable on this account. In ornamental work, its inferiority of polish and peculiar oily lustre, prevent its emulating marble—yet it is not without its beauty and its correlative gem—the chrysolite, which has something of the same peculiarity of appearance, is highly valued. So well are the uses of this stone understood in Europe, that at *Chiavenna* in *Italy*, it is said, a very considerable trade is carried on in articles manufactured from it, amounting to forty thousand piastres yearly. In *Ireland*, where, as in these mountains, it has been found in a primary formation, containing also copper, it forms a profitable article to the proprietors of the mines.

Serpentine, a mineral nearly allied to potstone, has not yet been found, except as an ingredient in other rocks. On the other side of the *Káli* river, (the boundary of the British authority,) it is found in sufficient quantity. The natives apply it to the same uses as we do, i. e. ornaments, and small utensils of various descriptions. I have seen a very beautiful specimen—the handle of a small knife in a *Khúkeri*, sent as a present. I have myself two large specimens of a very good quality, obtained through the kind assistance of Mr. TRAILL, the Civil Commissioner.

#### 9.—*Granite.*

By a certain latitude of expression, granite, though not exactly a mineral, may be ranked under the head of mineral productions. There is a very beautiful porphyritic grey granite close to the cantonment of *Almorah*, which would furnish fine ornamental pillars, or slabs of any size, and to any extent. Under this head also may be noticed, a variety of toadstone, which has been found in fragments, and the original mass of which is doubtless to be detected. It has a greenish grey basis, with white crystals interspersed, and when polished, has rather a beautiful appearance.

#### 10.—*Borax.*

Borax, though not occurring within the British tract, yet as forming a valuable article of commerce, should not be omitted. The whole supply of the European market passes through these mountains. It is found in a lake, which would appear from some accounts, to have the power of reproducing it. It is sold at the *Bagésvar* Fair, (twenty-three miles from *Almorah*,) in two states, picked and unpicked. The first consists entirely of

of crystals, varying in length from one, to one-eighth of an inch. These crystals are very flat hexagonal prisms, with trihedral summits. They are of an oil green color, and nearly, if not quite, opaque. In the other state, it contains a good deal of Borax-dust, which consists either of very minute crystals, or of fragments, broken off the larger crystals, of the sand, or earth, forming the substratum of the lake, from which it is procured, and (not unfrequently) of impurities, with which it is fraudulently adulterated. The picked Borax (or larger crystals,) is, itself, very far from being pure, and the method of purifying it, is said in England, to be a secret confined to a few—I could perceive no difficulty, beyond the length of time required for the deposition of the peculiar matter by which it is contaminated. I have found Borax of one solution, perfectly equal to the purposes of the arts. When pure, it is quite transparent, and nearly colorless. It is an article of such great utility, (for its actual uses are limited by the high price it bears) that it appears desirable the purification might be performed on the spot instead of transporting it to such a distance in its impure state, thereby enhancing the price. Indeed, owing to the high duty, which amounts to a prohibition, the price of Borax, in the *Calcutta* market, whether raw or purified, is the same, viz. fourteen to seventeen rupees a maund. At *Bagésvar* it is five rupees.

The preceding details are sufficiently meagre, but this must necessarily be the case as none of the substances found in our own provinces, have yet been sought for as articles of commerce: so that, except the mere fact of their occurrence, there is little to communicate. In the following Section, which includes an account of the mines worked, I shall be more full; though I fear there may still remain many deficiencies, and many particulars of interest to be supplied.

## II.—METALLIC

## II.—METALLIC PRODUCTIONS.

The metallic productions of the mountain provinces, though hitherto inconsiderable, as far at least as regards the quantity of metal raised, might, it is probable, under judicious management, become profitable enough to repay any attention bestowed upon them. No mine of the precious metals has yet, it is true, been found within the limits of the British authority, although the discovery of such beyond the frontiers is said to be far from rare. There are, however, circumstances which seem to indicate the existence of gold within the limits of the British tract. Several of the mountain rivers which have their sources within this tract are known to furnish gold; and, though the produce at any particular spot be scanty, yet when we consider the whole extent of surface from which the metal is obtainable, the quantity is far from inconsiderable. At all events, the fact furnishes proof of the actual occurrence of gold in some part of the strata which these rivers traverse. In the case of the *Rám-gangá*, the supply is traced to a tributary stream, called the *Béni Gangá*, which has its rise in the lower mountains, as it is only below the confluence of the two that the sands are found productive. In that of the *Sona Nadi*, it is still more limited, as that stream has a very short course wholly within the *Patlí Dún*. And with regard to the *Alakanandá*, I may mention that I have a specimen of granite, I obtained at *Kédárnáth*, one of the sources of that river, in which occurs a speck of native gold. Considering, indeed, all the circumstances of the case, it is, I think, far from improbable, that gold will yet be found in its native matrix within our mountains.\*

Of

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\* Such a discovery is, however, more likely to be the effect of accident at some distant period, when the progress of population and improvement together shall have left scarcely a spot unexplored. That a systematic search holds out few hopes will be evident from considering the history of gold mines all over the world. How fruitless the most prudently conducted examination of a tract positively known to contain gold, and in some quantity, may turn out, is to be seen in the detail of the proceedings adopted in Ireland, to trace the gold found in diluvial gravel in the County Wicklow, to its parent source. The reason of this, as well as of the inferior productiveness in general

Of copper, lead, and iron, the metals next in value, there is no deficiency; or I should rather say, there ought not to be any; for the actual produce in any of these metals, is trifling in quantity, and inferior in quality. There are many considerations which combine to prove that the mountain tract, extending from the *Setlej* to the *Brahmapútra*, is rich in copper. With regard to iron, it may be said to constitute a considerable part of the country; either as a constituent of rocks, in the form of ironstone, or in the numerous and extensive beds of the better defined ores. Lead also is found in abundance; and is worked as well as the two preceding in many places, and with considerable profit. With regard to the other metals, little is known. Antimony is found, combined with lead and sulphur; but the ore is not worked. Manganese has been detected as entering, in small quantity, into the composition of one of the iron ores. Perhaps, were its characters and value known to the miners, it might be discovered. Arsenic, in the state of sulphuret, is imported from beyond the frontier; but I have not heard that it has been found within our provinces. Of the rarer and less extensively useful metals, it is impossible to pronounce with certainty. There is, of course, a probability, that some of them which may be said to be geologically connected with the existing formations, will be found. Nor does their non-occurrence hitherto, militate against that probability; when it is considered, that their properties and value are alike unknown amongst those with whom the task of discovery has hitherto rested.

The metals which yield revenue; are COPPER, LEAD, and IRON. The GOLD obtained from the sand of rivers; paid during the *Gorkhali* rule, a small

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of mines of the precious metals, may be found in their comparatively small produce, thereby occasioning an expence in searching for or raising them, which, in most cases, more than balances their superiority of value. It is the accidental discovery where no expence has been incurred, or the falling on a rich vein in a mine already worked which constitutes the prizes in this lottery. For one who makes his fortune, hundreds lose.

small duty ; but the amount was too trifling to render its continuance expedient, and it was accordingly abolished by the Commissioner. I think, however, the amount of metal obtained from this source, might be increased by attempting the operation on a larger scale. Hitherto the work of an unassisted individual ; who has neither means or inclination to do more, than will earn his daily pittance ; and who compelled to execute every part of the process himself, necessarily loses time, and does nothing well ; it is not to be wondered that the produce has been trifling. Mercury is used for the final separation of the gold ; but it is driven off again in an open vessel, and consequently lost. On the small scale on which they work, this is not felt to be a loss. The common account is, that a man's daily labor will earn him two annas : but this estimate is certainly much under the truth.

The method followed is abundantly obvious. The gravel in which the gold-dust is always found ; and which in some rivers is the superficial deposit, in others, lies under a bed of sand ; is collected in heaps, and washed on a stage, or imperfect riddle, made of bamboos. The pebbles of any size are retained by this, and then rejected ; while the sand which passes through the interstices, is carefully preserved. When a sufficient quantity is collected, it is put into a wooden trough, of about three, to five, feet in length, and a foot broad : being filled with water, the whole is agitated by the hand, and such a degree of inclination skilfully given, as shall carry off all the lighter particles ; leaving a heavy black sand, behind. It is in this sand, that the particles of gold are found. It is triturated with quick-silver, which takes up the gold ; and the amalgam being separated from the still remaining impurities, is set over a fire to evaporate the mercury : the gold remaining behind, in the vessel.

Of the mines, at present, worked in these mountains ; those which yield COPPER, are undoubtedly the most important. With regard to the

IRON

IRON mines, although they do not hold out an equal prospect of immediate advantage ; yet there is little doubt, but that the revenue derivable from them also, might be much augmented ; and, with very little modification of the present processes. Eventually, they may be found the most valuable of all ; but this must be the result of a state of things, not in existence at present. The LEAD mines are next in importance ; and judging from their former value, (which was greater than the total amount of all the mines of whatever metal at the present day;) they would seem to be, even not much less worthy of attention.

### 1.—*The Copper Mines.*

There are seven copper mines ; or I should say, seven places where copper ores are extracted ; for at some of them, the mines or excavations, are very numerous. These seven localities, with the rent they pay, are as follows :

Dhanpúr,* .. ..	} 1200 Rupees per annum.
Dhóbri, .. ..	
Gangóli, .. ..	} 1000
Síra, .. ..	
Pókrí, .. ..	600
Khari, .. ..	40
Shór Gurang, ..	50

None of these are very advantageously situated, considering the expence of carriage in the mountains. But as buffaloes† may be extensively employed

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\* The localities of these mines, and of the other minerals, will be indicated in the Geological Map, which I hope soon to lay before the Society.

† An average Buffalo will carry two maunds, with great ease, up the steepest ascents.

employed on good roads ; and the breed appears to thrive in these provinces ; it seems easy to obviate any objection, arising from the present difficulties of transport.

Of the probable value of these mines, it is difficult to form any thing like a correct idea ; owing to the miserably contracted scale on which they have been, hitherto, worked. The chief thing of course to be considered is, the productiveness of the several veins or beds of ore ; for supposing the quality of the metal sufficiently improved, there is little fear of a market being wanting.\* It is not, however, easy, to obtain precise information on this subject : for the mines themselves are inaccessible to a European ; or indeed to any, but people who, from their childhood, are accustomed to penetrate them. They resemble, as Mr. TRAILL has observed ; rather the burrow of an animal, than the path of a human being. For this reason, it is impossible to speak, from actual observation, as to the productiveness of any particular repository of ore ; and all we can do is, to form probable guesses. In *Chili*, it would appear, that the average produce of about 500 mines, is six tons each annually. From considering the rent of our *Kemáun* mines ; and the price of copper (two rupees a seer ; ) allowing also, that the produce is double the rent ; we shall have only one ton, for the amount yielded by the *Dhanpúr* mine : and half a ton each, for those of *Gangóli*, *Síra*, and *Pókri*. The others, are too small to be worth considering. Supposing then that these four mines, have naturally an equal average of ore, with those of *South America* ; we see that there is great room for improvement, and a fair prospect of advantage. On the average of six tons for each of these four mines ; *Kemáun* would yield  
 twenty-four

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\* It appears by Captain Hall's work on South America, that notwithstanding the quantity of Copper thrown into the market by the Hon'ble Company ; the greater part of the produce of the mines of Chili, (3000 tons annually) finds its way to the Calcutta market.

twenty-four tons annually, instead of two and half as at present : and the revenue ought to encrease in the same proportion ; that is, from 2700, to 27000 annually. But this is not all. There is little doubt of the existence of the ore in many other places : and were an improved system to be introduced, and the value of the metal consequently to rise in the market ; a stimulus to investigation would be given, which might reasonably be expected to lead to the discovery of other sources of the ore, at present unknown.\*

The principal mine, in point of value, *Dhanpúr*, owes its rank in the scale, not only to the great value of the ore yielded ; but also to the nature of the rock in which it is situated. This rock, a red dolomite, is of such consistence, as to require seldom, if ever, any props for the support of the roof ; and scarcely any additional expence, after the gallery or chamber is once excavated. Whereas, in the others, the rock is often so tender as to require timbers for its support ; and even so supported, it fails every year in the rainy season ; when a new expence is to be again incurred, without the prospect of any immediate advantage. This, is more particularly the case, with the *Pókrí* mines. In the *Dhanpúr* mine, the work once effected, there is no occasion to repeat it ; and every foot of excavation made good, is a permanent acquisition. An equally important advantage is, the continuance of the working season all the year round.

The compact structure of the rock, or perhaps the great elevation of the mine, and its proximity to the summit of the mountain ; gives it  
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\* I am told that the mine at *Pókrí*, called the *Ráj Khán*, yielded one year 50,000 Rupees : and at *Dhanpúr*, it is known that in consequence of an earthquake which shook the mine and laid open new veins of ore ; the profits of the lessee were, that year, very considerable. Every one who travels in the mountains, must be struck with the numerous indications which present themselves of the existence of this metal. While writing this paper, a new vein of ore has been discovered, and leave asked to work it.

another superiority which is no inconsiderable one : a freedom from water, and consequently, from the expence and trouble of drainage. One of the effects of this advantage is, that the miners have been enabled to follow the deposit of the ore, in all its ramifications and changes of direction : and the interior of this mine, presents quite a different appearance from that of others ; being a succession of chambers, situated at various levels, and in various directions.

The ore is of that kind called **GREY COPPER** ; (the *Fahlerz* of the Germans.) Many species, chemically speaking, perfectly distinct, have been confounded under this name. Four at least are certain—one of which contains iron as well as copper ; two, iron and arsenic, but in different proportions ; and the fourth, iron and antimony. They are all sulphurets, and the yield of copper is from thirty to fifty per cent ; that is of the pure mineral : for no working ore, can ever be expected to give that proportion. The *Dhanpúr* ore, is the most valuable of the four : and contains fifty per cent. of copper ; besides iron, and sulphur. It is always amorphous, either massive or disseminated. **GREEN CARBONATE** is sometimes found, but in no quantity.

The *Pókri* mine, or mines, are situated in a talcose schist : which on one side, passes into a talcose gneiss ; and on the other, into a chloritic schist. All these rocks are so soft, and even rotten ; as to have rendered vain every precaution of the miner : and the galleries excavated, have been constantly subject to accidents. When I visited the place ; they had all fallen in : and, there was no lessee. I was unable, therefore, to procure proper specimens : and can only judge from the imperfect indications observed, in examining the rubbish of the mine. These seemed to point to, **VITREOUS**, and, **PURPLE COPPER** ; the two most valuable of the sulphurets : the former, yielding eighty per cent. metal. The  
waters

waters from this mine were observed to be impregnated with SULPHATE OF COPPER.

The *Sira*, and *Gangóli* mines, are situated in beds of indurated talc, or potstone; which are again, enclosed in dolomite. Occasionally the former, occasionally the latter rock, forms the roof, and sides, of the mine. The dolomite, has a large crystalline grain; and great tenacity; and forms a perfectly durable work, when excavated. It is not so, however, with the other: at least, not always. When massive, it is, I believe, to be depended on: and it has then, a great recommendation in its extreme sectility; and the ease with which it is worked. But it occurs, sometimes, of such inferior consistence; having much the appearance of re-united debris; as to require support: and to occasion much inconvenience, and even, danger.

The ore, at each of these places, is COPPER PYRITES. I have never seen any crystallised specimens. It is accompanied by IRON PYRITES: which is occasionally found in the pentagonal dodecahedron; but most commonly, in such irregular and anomalous forms, as are with difficulty, describable.\* I have observed specimens also of GREY COPPER: but in small quantity. The working ore is, no doubt, copper pyrites; and the quantity of copper it contains, may be taken at thirty-five per cent. This is, of course, to be understood, as before remarked, of the pure mineral: uncontaminated by the matrix.

The KHARI, and SHÓR GURANG mines, are similarly situated—the ore produced, is in so small a quantity, as not to require any lengthened notice. I have observed GREY COPPER, COPPER PYRITES, and CARBONATE OF COPPER: chiefly, if not always, disseminated. An important advantage, which all  
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\* Possibly composite forms.

the mountain ores, I have yet seen, possess ; is a freedom from any mixture or combination of arsenic : a metal which, above all others, deteriorates the quality of the copper ; and is most difficult to remove.

The method of working these mines, is, with the exception of that at *Dhanpúr*, (which has already been described) as follows. A gallery, or passage, is cut into the face of the hill ; with such slight declivity outwards, as is sufficient to carry off the water. Where the rock may happen to require it ; frames of timber, rudely, and even carelessly constructed, are set up : to support the roof and sides ; and save the miner, from being crushed. Accidents, however, do happen : and men are, sometimes, lost. The size, or section of the gallery, is always small : in those parts, where the hardness of the rock, occasions any difficulty in working it ; scarcely sufficient to admit a person, in a creeping posture. In no place, will it admit of an erect position.

The ore, as well as the rock, is detached by means of a very inefficient pick : and by chisels, or cutters ; and hammers.—It is removed from the mine ; on skins, drawn along the floor of the gallery, by boys. In some mines, great part of this work must be performed in a creeping posture. The ore being delivered at the mouth of the mine ; is reduced to small fragments, by the hand. At *Dhanpúr*, however, this work is done by the *panchakki*, or water mill. It is next roasted in an open fire, or forge hearth ; the fuel being charcoal ; and the heat occasionally urged by two air bags or skins, which are alternately shut and opened by the hand. After being thus imperfectly roasted, it is smelted : but for this important operation, the same forge hearth is made to serve ; and the process is repeated, till the metal is sufficiently refined. I do not know of any flux being used ; to accelerate the scorification, and separation, of the less valuable metals.

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The whole system, thus briefly described; is evidently, extremely rude, and inefficient. Worse methods, I do not think, could well be devised. They are, however, the natural result of the contracted views and want of enterprise, of the native character. It would, probably, be difficult to convince them; that any system of working, requiring an increase of outlay; could possibly be equally advantageous. It is hardly to be expected, therefore, that they will ever adopt any improvements of this kind: until at least, they can have the proof of direct experience; in favor of the greater profit, they may bring. Any important amelioration of the system, must then proceed either from the Government, or from some European capitalist: and when the advantage of the new methods shall be clearly seen in an increased produce, and improved quality of metal; it is possible that then, but not till then, the mountaineer also, may begin to adopt them.

In England, the copper mines present a scene, perhaps, the first in the world, (except in the coal-mines of the same country) for commercial enterprise, scientific combination and mechanical skill. Such a system has been the growth of circumstances; and is only fitted to those circumstances, and to that country, in which it originated. To attempt working these mines, on any thing like a similar scale; would be absurd: at least, before the productiveness of the several repositories of the ore, be clearly ascertained; and facilities of transport created, which do not at present exist. But, there are many modifications and improvements, which seem perfectly fitted to the state of things in the mountains; and which would involve little additional expence to the present outlay. In fact, there seems a wide interval, between the Chilian and English systems; while the modifications here contemplated, would probably, stop short of, even, the former. Supposing the expediency of such improvements, or a part of them generally admitted; they must, I think, to have justice done them, be introduced under the orders of government, in some mine, the lease of which

may be retained for the necessary period. They would, at least, have the good effect of enabling us to obtain better data; for judging, whether or not, any further improvements and extension of the system, would be advisable. In the former case, experienced and practical people might be invited from England; for the purpose of improving the various operations of mining, roasting, smelting, refining the ore, &c.

The improvements which appear to me suited to the actual condition of things are as follows. The present narrow and inaccessible galleries should be enlarged; so as to admit, not only of an erect position, but of a man's working with effect, in them. This, of course, only applies to such as furnish a sufficient supply of ore; or to new galleries just commenced. Vertical shafts should be sunk when advisable, so as to admit of the ore being followed with effect. In many cases, however, this would be perfectly impossible; from the nature of the mountain, in which the mine is situated. Strong and effective timbers should be put up, for the support of the rock, when at all likely to fail: and to effect all these purposes, proper tools, made of good iron; and not the inferior kind, at present used; should be provided. The method of splitting rocks, by the wedge; and by blasting; might be introduced with advantage: and generally, such other practical improvements, as, though readily suggesting themselves on the spot, are not easy to be enumerated connectedly.

With regard to the drainage; the present system is, perhaps, the cheapest that could be devised, as far as it goes: but it is only calculated to meet, one, of many numerous cases occurring in practice. Should the ore be situated below the level of the mouth of the mine; some method is then required to raise the water, which will flow into the new excavation, to that level, at which it may flow out. At present, I am inclined to think, that much valuable ore is lost; owing to the  
difficulties

difficulties which present themselves, when the bed or vein sinks to an inferior level. And it is certainly, to the absence of water, in the *Dhanpúr* mine; and the consequent facility of following the ore, in all its deviations; that its higher value in the scale, is mainly owing. Simple methods of raising water, might then, I think, be advantageously employed: such as the endless chain of water pots, used in the upper provinces; or a pump, or set of pumps, to be worked by manual labor. In raising water or any weight; where great power is required; one of the most useful mechanical inventions, is the double capstan: a contrivance, which is at once, eminently cheap, simple, and efficacious. In many cases, where the deposit of ore has a downward direction; a second gallery, at a lower level, may be conveniently established: probably, in most cases, this method of double galleries might be advantageous. A great progress must be made in the system here contemplated; before a Steam Engine, even of small power, could be introduced with any thing like a prospect of profit.

I have mentioned the principal points of improvement in working the ore. In delivering it from the mine; wheel barrows; or still better, sledges on four wheels, should be adopted; instead of the skins at present used. It seems, however, doubtful, whether the introduction of goats, to draw such sledges, would be any improvement. They are used extensively in the upper mountains, for carrying burthens.

In reducing the ore to fragments; the *Dhanpúr* miners employ the *Panchakí*, or water mill. When water is present, no better plan (I mean consistent with the economy here contemplated,) can be devised; when water is not to be had, in sufficient abundance; a simple arrangement of stampers, might be preferable to the method of doing it, by the hammer.

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It is, however, in the roasting, and smelting operation, that the greatest room for improvement is to be found; and the greatest prospect of advantage from a change; as the immediate effect of this would be, to raise the value of the metal produced. For the present open hearths, and air bags; I would substitute a system of reverberatory furnaces; of different draughts, for the two different processes, of roasting and smelting. An excellent material for constructing them is at hand, in the rock, I have called potstone. Perfectly compact, and equal to any resistance; infusible in the strongest heat; while it is so soft as to be cut with a knife; it is difficult, even to imagine, any substance better fitted for such work. It might be advisable, in an economical point of view, to construct the roasting furnaces in such a manner, as to collect the sulphur at present lost; an object not difficult to be effected.

Even the introduction of the simple blast furnace used in Chili, (and nothing can be simpler) would be an immense improvement. It is of a circular shape; similar to a lime kiln; and covered with a dome, to confine and concentrate the heat. The ore is arranged in it, in alternate layers with the fuel, which is wood; and being lighted, it continues burning for a considerable time. When required; the heat is urged by a double pair of bellows, worked by a crank, turned by a water mill. The mere substitution of an efficient bellows, for the air bags, used at present, would be no trifling advantage gained; but I am of opinion, that a wind furnace is greatly preferable to all these half measures, in the saving of manual labor. Nor is it so much more expensive, even at the outset, as might be imagined.

The methods of reduction practised in England; where, certainly, the subject is best understood; vary with the ore, and even with the establishment: but the differences are trifling, and affect only the minor details. The two great objects to be effected, are—first, by a properly regulated heat to drive

drive off the volatile ingredients, sulphur, and arsenic; and to oxidate the iron, thereby promoting the fusibility of the ore, and consequent separation of the copper from the scoria when in fusion: and, secondly, by an intense and properly directed fusing heat, to effect the vitrification of the impurities; which thus form a slag at the top, and are skimmed off, while the metal sinks down in a comparatively pure state. To promote this vitrification of the ingredients, occasional additions are made to the ore, as the case may seem to require; though, in general, the run of the ores is such, as to require little beyond a few slags of an old smelting. Calcareous flux has been used at some works; and this is at hand in the mountains. A most valuable and effective flux, for the reduction of ores, in the small way, (for experiment) is borax. Whether it might not be used on the large scale, here, where it is so much cheaper than in Europe; may require some consideration, and some practical trials.

The operations of roasting and smelting are repeated several times—each smelting being followed by a roasting—to expedite which effect; the copper is after each smelting, but the last, let into water to be granulated. This separation of the metal into such small parts, assists of course, the calcining power of the furnace, and the work is more speedily effected than if performed on the mass. After the last smelting comes the process of refining, or poling, as it is technically called. It consists in keeping the copper in a melted state, covered with charcoal; and introducing from time to time a wooden pole into the melted metal; which causes considerable ebullition, owing to the evolution of gaseous matter. It is occasionally assayed, in order to judge how the process is going on; by taking out a small portion, allowing it to cool, and breaking it in the vice. By the colour and general appearance of the fractured surface; a judgment is formed, as to whether the poling has proceeded far enough. This operation which gives the metal that perfect appearance, always looked for in the market; is

unknown to the mountaineer. It is probable, that it would materially improve the quality; or at least, the appearance of the article.

Lead is sometimes used, both in Hungary, and England, to expedite the previous operations of the refinery. The oxides of this metal, are amongst the most powerful vitrifiers known: as such they are effectual in the assay and refinement of the precious metals; and as such they may be used also with copper: but the process requires attention, as if not stopped in time, or too much lead added; the copper itself will be oxidated and vitrified. Applied with proper caution, it would, no doubt, be a most useful material to the mountaineer; and the occurrence of this metal, in the vicinity of the copper mines, obviates every objection on the score of expence.

On the supposition of Government establishing an experimental mine; I would propose that all the different processes of mining, extracting the ore, removing it, for pounding, roasting, smelting, refining, &c. should be performed by the job, and not by the day. This, which is one of the most important improvements in modern management, is particularly necessary on a new experiment; because it makes it the interest of the people employed, to co-operate with, instead of endeavouring to thwart us: the implements, tools, apparatus, furnaces, &c. to be all furnished at the expence of Government; and a given tale established for the different kinds of rock and ore, both for removal from the mine, and for the calcining and smelting of the latter.

## 2.—*The Iron Mines.*

The foregoing includes all that immediately suggests itself, as feasible improvement in the management of the copper mines: I have proposed,

posed, I think, no charge that would not, in a very short time, more than repay the expence incurred. With regard to the iron mines, I shall also mention a few particulars ; which, if attended to, would materially increase the revenue derivable from them also. I am informed by the Commissioner that the united rent of these mines, which are very numerous, does not exceed the sum of 1500 Rupees per annum ; while the iron is of the very worst quality, and yet bears a price, in the Almora\* Bazar, not much less than that of the best English iron, deliverable at Bareilly.

The process of manufacturing iron from its ores, is so far different from that of copper ; in as much as, none but the *oxides* of the former metal are ever employed. In the copper ores (that is, in those which occur in any quantity;) the metal is combined with sulphur : which can be only driven off by repeated roastings ; employing such a draught of air as to acidify it, the more effectually to separate it, in the latter stages. In the iron ores ; the metal is united to oxygen ; and mixed with various earthy impurities. In reducing these ores then, there are three distinct points to be attended to—First, the provision of a substance, which shall effectually take the oxygen from the ore ; leaving the metal mixed, only with its earthy constituents : 2ndly, The proportioning the flux used, to those earthy ingredients ; so as to ensure a complete vitrification of them, and separation from, the metallic particles : and 3dly, A sufficient heat, to fuse the latter ; that the separation, and reduction, may be more complete. The first point is attained, by using a sufficient quantity of charcoal, in the reduction of the ores ; the second, by adding, as the ore may require it, limestone or other flux ; and the third point is only to be effected, by  
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\* Almorah, 8 seers, 1 Rupee—Gwalior iron, good, soft, 6 seers—at Moradabad, hill iron ditto but hard, good for *fouras*—Swedish steel, 2 seers—English cast, 2½—English iron, bar, 4—in flat bars, 4½.

using a powerful blast furnace. Though it be, no doubt, possible to construct wind furnaces, of such draught as should smelt iron; still it is, I believe, more economical, as well as more certain, to trust only to a powerful blast.

The mountaineer reduces his iron ores in the manner already described for the copper ores. But from the imperfection of the method, the great waste of heat and non-employment of a proper flux in refractory ores, the iron is never smelted, but comes out of the furnace in porous knobs very much the size and shape of the original pieces of ore. These might, however, with proper management, be manufactured into a saleable iron; but the miner is contented with selling them in this state to the blacksmiths who, again, are very sparing in labor when shaping them into the pigs in which they are finally sold in the bazar.

In as far as such a lazy process may be compared with one which furnished metal of the very best quality, we may say the mode practised in the mountains is similar in its general features to the ancient methods which prevailed in Europe. These have, however, long been superseded by more economical processes, each of which is adapted to the particular kind of fuel and ore of the country in which it is employed. The English method, which employs coal as the fuel, does not require to be considered here; but the Swedish, in which charcoal is the fuel used, appears from this circumstance, from the simplicity of the apparatus and the small outlay of capital required, particularly fitted for these provinces, and not unworthy of attention and encouragement from the Government. It is well known that the superiority of the Swedish iron over the English, is mainly owing to the nature of the fuel used; although it is *also* true that the Swedish ore is chiefly, if not entirely, of the first quality—MAGNETIC IRON ORE. The former advantage ought also to hold in the case of the mountain iron; but none  
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of the working ores, it must be confessed, that I have yet examined, excepting one, is of the same species, as the Swedish.

Specimens, however, of this ore have been found in different places ; and it is very probable that it does exist in sufficient quantity, to become an object of consideration to the Government. The *Bundelkhand* iron, which is said to be one of the best after that from *Gwalior*, is manufactured from the red oxide. The *Gwalior* ore I have never seen ; but conclude it to be of the magnetic species, from a circumstance I recollect being mentioned by Captain GERARD, when surveying that country, of an unusual deviation of the magnetic needle. The mountain iron would, however, if carefully manufactured, have a sufficiently fair market, without any chance of being interfered with by either of those other kinds : and even supposing that the common ores should hold out little inducement to expend much on improvements in their reduction ; still in the one known source of the magnetic ore, there is, apparently, a sufficient supply to authorize at least an experiment on a small scale.

It may, perhaps, be said, that a full improvement of the quality of this iron, would interfere with the sale of English iron : but it appears to me, that it would chiefly supply the place of the Swedish in the market ; which is known to be in great request amongst the natives, under the name of “ *Francese Loha.*” English iron has not an extensive sale in India ; even in England it is now well established, that all the best steel is manufactured from Swedish iron. English bar iron, however, bears a higher price than the *Gwalior* iron ; though the latter is more extensively used amongst the natives. The former is sold at *Moradabad*, for  $4\frac{1}{2}$  seers the Rupee ; the latter at 6 seers. The mountain iron sells on the spot for 8 seers generally, that is about £14 a ton, which was the highest wholesale price to which the English iron attained during the war ; at

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sent it is little more than £10. The mountain iron could be afforded at a much cheaper rate.

The chief points, in which improvement is desirable, will be evident from what I have stated (Art. 30). The erection of proper blast furnaces; the judicious employment of fluxes; and a more careful system of manufacture; are all that is required to raise the quality of the metal, according to the ore used, either to a standard with the English iron or the Swedish. In the erection of blast furnaces, there seems no difficulty in a country where water is to be commanded at every turn. Limestone, one of the fluxes most used, is at hand; and all that seems required is a careful superintendence, to shew the advantage of the new methods in the first instance.

These being once established, it appears probable they would be generally adopted, when the object is to furnish so generally useful a metal in a purer and more workable state. I have said nothing of the process required for bringing the fused metal into a malleable condition, as it offers no difficulty. Water may here also be advantageously used as the moving power for the great sledge hammers, with which the fused metal is to be beaten.

The iron ores all belong, with the exception of those of two mines, to the species called RED OXIDE (*fer oligiste* of HAUY). This is a peroxyde of iron; containing, in its best-defined type, seventy per cent. iron, and thirty, oxygen. The working ore, however, often contains earthy impurities, which reduce the proportion as low as fifty per cent. of metal.—RED HEMATITE, a variety of this species occurs in a very extensive bed in Gneiss at *Dhaniakót*, on the *Cosillah*. It frequently contains small veins of MICACEOUS IRON ore of a highly splendent lustre. At *Ramgár*, on the road  
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from *Bhamáori* to *Almórah*, it passes into the variety called SCALY IRON ORE, consisting of loosely cohering glimmering particles of a steel grey or iron black color, strongly soiling and feeling unctuous to the touch. These beds, though distant many miles, are, I think, connected beneath, and from one and the same deposit.—Both of these varieties are said to yield very good iron; the first, particularly. COMPACT RED IRON ORE, occurs in a clay slate containing beds of lime-stone at *Katsári*, on the *Rám-ganga*, in masses composed apparently of fragments more or less angular, reunited by a stalagmitic incrustation. The iron manufactured from it is esteemed the best in the province of *Kamáun*. It is the only ore which has any adjunct of calcareous matter; and to this adjustment of the flux by nature, is attributable, I think, the superiority of the iron produced. Near *Kalsi* on the *Jemna*, there is an extensive bed of SPECULAR IRON ORE. The specimens which I have examined were fine granular, approaching to compact.

In *Chawgarka* purgunnah, one of the excepted mines, the ore is the YELLOW (or *hydrated*) OXIDE. It is of two varieties, the ochry and compact. The former sometimes contains octahedral crystals of magnetic iron ore, and in the neighbourhood of the mine, on the summit of a small hill, there occur rolled pieces, composed of grains of quartz, and small octahedral crystals of this mineral, cemented together. These pieces are magnets, and have each two poles. The ores of this mine contain manganese in small proportion, and would, consequently, afford a very good steel; as it is to the alloy of this metal that the superiority of the steel manufactured from some of the brown iron stones, is generally attributed. The other exception is the mine at *Sil*, in *Biseher*, where a mica slate occurs with disseminated crystals, or grains of MAGNETIC IRON ORE; in such quantity, as in favorable specimens, to equal half the weight, or one-third the bulk. Some pieces of this slate have a specific gravity of 3,45. That of the ore itself is 4,8. The stone is reduced to powder by hand mills; and by means of  
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a running stream, all the impurities are separated. There remains a black sand; which however still contains about a fifth of its weight of impurities: this is smelted with charcoal, into a porous mass; which imperfectly beaten, is sold to the lower mountaineers at the rate of eight and a half seers for the Rupee. The iron is said to be of excellent quality, and is in great demand for *Khúkerís*. This is the mine at which I think it very desirable some improvements should be attempted, as holding out a fairer prospect of advantage. There does not appear to be any reason why this ore, if carefully reduced, should not furnish an iron fully equal to the Swedish. The supply, too, is sufficient to justify the expectation of a considerable addition to the revenue. At present, the people state the produce of manufactured iron as not exceeding three hundred Rupees; but from the flourishing and substantial appearance of the village, I should think it must greatly exceed this sum.

### 3.—*The Lead Mines.*

The LEAD MINES are numerous, and the supply of ore from some of them has been considerable. The most valuable are situated on the river *Tonse*, at no great distance from the *Dehra Dún*. There are three places where works, to some extent, have been, and are carried on; *Aiyar*, *Máiyar*, and *Boréla*. The first-named place is on the right bank of the river below the village of *Bhatnór*, and within the limits of *Sirmúr*. The other two are on the left bank, and are in *Jaúnsár*, one of the mountain purgunnahs retained by Government; the superintendence of which, is vested in the Officer commanding at *Déhra*. The *Boréla* mine formerly paid two thousand rupees yearly; the *Máiyar* one, four thousand: the present rents are six hundred and fifty; and one thousand. The mines were always included in the assessment for revenue; and latterly owing to their alleged non-productiveness, the sum assessed has been limited to the  
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mere land tax of the mine at *Aíyar*. I could not learn any particulars regarding the rent, the people being uncommunicative.\*

With regard to the truth of their assertion, that these mines have ceased to be profitable, it is very difficult to judge. They are still worked, which is a presumption against it, but without a personal examination of the several galleries, and they are exceedingly numerous, it is difficult to say positively whether this assertion be correct or otherwise. I have however little doubt but they might be made productive, by a more enlarged and perfect system of work; and I found this opinion on the great number of excavations, clearly proving the original abundance of the ore. It is not likely, that the several veins or beds, have been exhausted by a system of mining which admits of no ventilation; and has no galleries, exceeding probably two hundred yards in length. At all events some trials, and a closer examination, would seem to be advisable; particularly when it is considered that there has been a falling off in the revenue, amounting to upwards of four thousand rupees yearly. To offer the mines to the highest bidder, would not be likely to elicit any light on the subject. It is not probable that any mountaineer could be got to undertake the work in opposition to those residing on the spot,† and having the advantage of experience.

The mine at *Bhatnór* is situated in clay slate. The rock where the mine penetrates is so tender and fragmentary, as when removed from the mine to have all the appearance of angular debris. Owing to this circumstance, the roof of the mine, as well as the sides, have occasion  
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\* The village belongs to the Rájah of *Sirmúr*.

† On account of the difficulties a stranger (if a native) would have to contend with; there would be, most probably, an organised opposition of the whole neighbourhood, to thwart him.

to be strengthened by timbers. Notwithstanding which, they sometimes fall in, and the miners are killed.

The ore is found, as I said, occasionally in quartz veins in the clay slate; occasionally in the slate itself. The ore at *Máiyar* also occurs in a clay slate; that at *Boréla*, in a bed of lime-stone, situated in the clay slate. At each of these places the rock is sufficiently firm to afford the greatest security, and no propping or timbers are required; but the labor of excavation is greater. At *Bhatnór*, owing to the softness of the ground, the galleries are roomy; and will allow of an upright position: at the other places, they are similar to the copper mines; low, narrow, and tortuous. The supply of ore has evidently been considerable, for the number of these galleries is quite surprising: at *Boréla*, I was told they exceeded eighty; and I see no reason to think that the statement is too high.

At all three places the ore is the same, a steel grey FINE GRANULAR GALENA, having a specific gravity of 7,2; at *Máiyar* it is accompanied by IRON PYRITES, and in one gallery by SULPHUR. The mode of reducing these ores, is precisely the same as that already described for the copper ores; the sulphur being allowed to go to waste. Similar improvements suggest themselves as advisable; though as the metal is so much cheaper, and the process of reduction so much more facile, they do not appear to be so imperiously called for, as an amelioration of the system of working the copper. A singular fact is, that the ore and reduced metal sell, by weight, for the same price at *Kálsi*, the nearest town. I could not learn the reason of this; but suppose that the produce of sulphur, pays the expence of reducing the ore.

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