

GLEANINGS

IN

SCIENCE.

No. 12.—December, 1829.

1. *On the Introduction of the Iron Chain Suspension Bridge into the Himmaláya Mountains.*

Those of your readers who have visited our hill provinces to the north-west, scarcely require to be told, that they constitute, perhaps, the most rugged and difficult country in the world. The difficulties of intercommunication are indeed very great, and no doubt, oppose a serious obstacle to the improvement of the people. In the Alps of Europe, which naturally are, probably, not much better, there yet have been formed magnificent roads in various directions, so as to render the labour of traversing the country comparatively easy, and thus to unite places apparently separated by nature. There arches of stone facilitate the passage from one precipice to another; bridges convey the traveller over, otherwise, impassable torrents; and where the nature of the rock forbids the attempt to construct a road, galleries are excavated through the very body of the mountain, and by a safe, though dark and dismal transit, render passable routes, where nature had seemed to fix an insurmountable barrier. In our northern mountains, again, with a few trifling exceptions, all is as it came from the hand of nature. Yet the Alps of Europe cannot be put in competition for value with our mountain provinces. They owe these improvements, rather to the circumstance of their being the high road into one of the finest countries in Europe, than to any settled plan of improvement, or to any well understood view of developing the resources of the country. Schemes of conquest, and projects of ambition have, perhaps, oftener prompted such works (and this in every country) than the more useful calculations of the political economist. But whatever the motives, the works are a positive gain: the destruction of the barrier against invasion, being more than compensated for by the increased facility of communication with the neighbouring countries. The sword will yet, it is to be hoped, be stayed in its ravages, by obstacles more difficult to be surmounted than "Alp or Appennine;" and in the mean time, the mutual intercourse of nations, as it affords to suffering humanity the principal solace for its destructive rage, so will it be mainly instrumental in forwarding that state of things in which, (if the prophecy be ever literally fulfilled,) "the swords shall be converted into plough shares, and the spears into pruning hooks."

Facility of communication within itself, and with neighbouring countries, is certainly one of the first steps in the improvement of a nation. What rank the people of our mountain provinces would have held in the scale of wealth and civilization, if their country had been more accessible, and they less shut up in their rugged hills, it were vain to conjecture; but it may safely be said, that a country with such resources could not have remained stationary at so low an ebb under such circumstances. With one of the finest climates in the world as it regards health; with a soil certainly not below the average, and having the great advantage of a cheap irrigation; with so many valuable natural productions, both vegetable and mineral; there seems only wanting improved means of intercourse within itself, and with the neighbouring countries of Thibet and Hindoostan, to raise it far above its present level. With a surface equal to nearly half of England; with such a range of cultivated productions as the vine, wheat, rice, hemp, flax, cotton, sugar, and opium; with copper, lead and iron mines; with inexhaustible forests, that include almost every production of the tropics or the temperate zone, the bambœ, the oak, the cedar (probably the

three most valuable trees); the richest and most extensive pasturages; situated so conveniently for trade, between two countries, mutually in want of each other's productions, this tract does not yet yield a revenue of perhaps £30,000. Can it be doubted, but that good roads and bridges would do much for such a country?

Unfortunately, however, the people are too poor to undertake any thing of this kind themselves. These works must indeed in every country be the result of a certain degree of national prosperity, on which they again react; producing an accelerated progress. To carry into effect extensive schemes of public utility, requires capital; and this is unfortunately an element of improvement as much a desideratum in these countries, as the execution of the projects which can only be secured by it. In Europe the first impulse is given by the great landed proprietors and capitalists, who have their remuneration, the former in the improved value of their estates, the latter in the return made by the employment of their capital. In India we have no proprietors of land but the Government, nor any capitalists capable of comprehending the full value of projects of public utility, still less of rising to the conception of so paradoxical a thing (to them) as public spirit. It is by the Government, and by them only, that such works can be expected to be undertaken; and I may add, that in the double capacity of rulers, and landed proprietors, it is their interest to engage in them. Nothing can be clearer than that improved facilities of intercommunication allow of a country's resources being fully developed. As internal and external commerce increases; with it increase the wealth and comforts of the people. Population then takes a start, and with it must increase the productions of the agriculturist. Land acquires a new value, corresponding to the increased demand for its produce, and the means of the consumers to purchase. Thence a direct interest as landed proprietors; while as rulers, it is sufficiently obvious, that the more prosperous the commerce and agriculture of a country, the more productive will its revenue be; its revenue, I mean, as composed of ordinary taxes. In America it has been found, that the revenue has steadily increased with the development of her resources; and it will be even found, that the rate of increase in the line of roads, taken as a single element of national improvement, corresponds *pari passu* with that of the revenue.

The value of a proper system of intercommunication, as a step in the improvement of a country, is indeed so fully acknowledged, as to stand in no need of illustration; were it a doubtful question, the practice of that magnificent people the Romans, might serve to reassure us. Even our Mogul predecessors could discover this truth, and their best princes made the construction of roads and bridges a principal object of their care. It is remarkable, how little we have done, when our means of accomplishing so much are taken into consideration. By a laudable innovation on the established maxims of a cruel justice, we have sparingly administered the punishment of death; and have in all, but the very heaviest offences, commuted that punishment for labour on the roads; our delinquents are therefore collected in prisons all over the country, and in considerable numbers. As their punishment is expressly declared to be **LABOUR ON THE ROADS**, and as their numbers are very great, the stranger might naturally conclude, that our roads, at least in the plain country, must be excellent. Our residents can tell a different story, particularly those who have travelled much; in no country on the face of the globe is the state of the roads so truly disgraceful, or so little indicative of the rule of an enlightened people. This is a truth the more provoking, because so little expenditure of labour would suffice to ensure all that is wanted*.

The utility of a few good lines of road in a mountainous country, is, if possible, more directly obvious, at least to the traveller, than in the plain country. But if roads are useful, bridges may be said to be absolutely necessary; for without them, there can be no intercourse whatever in a country so completely intersected by rivers; by rivers that are very seldom fordable, and never navigable. Ferries in such rivers are entirely out of the question; without bridges, therefore, the people must be confined to the narrow spots on which they were born, and all inter-

* I should be sorry to be so far misunderstood in any of these remarks, as to have it supposed, I mean to impute blame to any one; either to the officers of Government or to the Government itself. It is as far from possibility, that one man should be able to do the work of ten, as that 5 or 600 Europeans, be their intelligence, zeal, and activity, what they may, should be able to govern and perfectly manage in all its details, a country so extensive as this subject to our sway. The wonder is, that it has been done so well. The fault is in the system.

change of commodities, or other intercourse must cease. To give some idea of the number of impassable torrents by which the face of the country is covered, I may mention that on the road from Bhamári to Almórah, a distance of 44 miles, there are required in the rainy season three bridges. In the road from Almórah to Petórahgerh (40 miles), there are required two bridges all the year round. In the road from Petórahgerh to Lóhu-ghát (18 miles), one bridge all the year round. These are all military roads, and as the communication must be kept open, the fact is, that these bridges have been erected at the expense of Government.

The people of these hills, every where aware of the value of intercommunication, have exerted themselves to facilitate it, but their efforts, like their means, have been circumscribed; and, in general, their bridges have been rude and inefficient in a degree commensurate with their poverty. Their most simple erection is a single rope, or rather several ropes gathered together, stretched across a river, on which slides a wooden block, to which the traveller, being attached, is pulled across. This is a disagreeable, though not a dangerous method of crossing a river; but it is exceedingly tedious, and laborious to the attendants at the bridge; and has this capital objection, that cattle cannot pass such a bridge; they are necessarily dragged through the foaming torrent, where if they escape the two-fold danger of drowning or being dashed to pieces against the rocks, they are fortunate. Yet as even the worst communication is better than none, and as the poverty of the people cannot afford better, these bridges are numerous in the hills.

The next step, is the bridge of ropes, which is a little, and only a little better; being merely a huge rope ladder as it were, stretched across the river, on the spokes or steps of which the traveller has to pick a precarious footing, assisted by the two lateral ropes which he holds to steady himself. This kind of passage of a river is scarcely less disagreeable than the other; it is a little less tedious, and involves little labour on the part of the attendants; but it has the same disadvantage of being impassable to cattle. These bridges are generally made of rope, manufactured from the fibres (bark) of the *Málsan*, (*Bauhinia scandens*) a gigantic climber common in the mountains. It is a rope of great toughness; but exposed as it is, without any defence, to the action of the sun and atmosphere, it does not last many years. Instances have occurred of these bridges giving way, and the unfortunate passengers being lost.

The third step is the wooden bridge, and this alone is, perhaps, entitled to the name or capable of answering the purposes of a bridge. It is, however, of various degrees of efficiency, and some of its ruder and less expensive forms, are indeed scarcely preferable to the preceding arrangement. But whatever the care bestowed in its construction, one principle guides the workmen; a principle which shows little mechanical ingenuity on the part of these people, and which is the very opposite to that which directed the construction of the celebrated bridge in Europe, at Schaffhausen, over the Rhine. Instead of disposing their timber in a light frame work, judiciously opposing tension to stress, they use massy and heavy beams, the support of which, when the bridge exceeds a certain span, forms a great difficulty in the erection of such bridges. They are in fact only kept in their places by a heavy mass of stones and earth placed on them, and even this weight is not always a match for the great length of lever combined with the weight of the bridge itself, particularly when extra loaded by passengers; any twist or warping of the beams too, immediately weaken such a bridge. These objections will be better understood by considering the following short description of the mode of construction. A row of massy beams about 18 ft. in length, are laid in a direction, slanting upwards, on each bank, with not more than 6 feet projecting over. On these a second tier of beams, 6 ft. longer, is laid, the extra 6ft. projecting beyond the ends of the lower tier: a third and fourth tier, and even more, are added, each projecting 6ft. beyond the inferior tier, till the vacant space in the middle is so far reduced as to allow of spars being laid across it. The ends of the projecting beams are then secured by masses of stones and earth, as above noticed, and the whole is planked over and railed. Such a construction does not require its faults to be pointed out. Were it necessary, nothing could show them in a clearer light, than the very narrow limits to which such a bridge applies. A span of 100 feet is not without its difficulties. To erect one of 190 feet was considered a great triumph, and I believe no one thinks it possible to apply this construction to a bridge with a span of 250 feet.

It will be supposed that the bridges erected by order of our Government, mentioned in one of the preceding paragraphs, were on a superior principle; and that an opportunity was taken of showing the people the inferiority of their method of con-

struction, as compared with those which the genius of improvement had so fully developed in Europe. It may, therefore, surprise your readers to be told, that so far from it, no attempt was made to bring to the consideration of the question any of the resources of modern science, or even of the most ordinary mechanical skill; and that, content to follow where we should have led, we blindly adopted the above clumsy and ill-contrived bridge, and that the six bridges mentioned, as necessary for keeping open the communication on the military roads, were all built on this model. In the usual course of things, experience at last made us wiser, so far at least as to be aware of the great expense of these bridges, both in original cost and repairs; and also in want of durability. About this time, the Shakespearian rope bridge, had attracted a good deal of attention, and those who, from travelling in the mountains, had personal experience of the want of bridges, as well as of the greatness of such a want, began to hope that such a bridge would be a great boon to these people; and being, as it was said, so cheap, might come even within their own means to erect them in various remote parts of the country. Having also a general resemblance in principle to their own rope-ladder-bridge, it was thought that they might the more easily understand and appreciate such a bridge, than one requiring greater mechanical skill, or resources of art less available in their remote situation.

In a short time, several of these bridges were erected in various quarters, some at the expense of Rájahs, and some at the expense of Government; they were considered, we believe, to be a decided improvement on the wooden bridge above described; as being more convenient, more economical, and less confined as to the limit of span; and in fact, it was generally thought that this was the best adapted form of bridge that could be devised for these provinces; and that the introduction of it into such a country, was a real benefit. A little more experience showed the fallacy of this opinion. The durability of the rope was found to be less than half that of timber, while the expense of attending to the former, proved to be considerable. An establishment was required to tighten the ropes; to watch that none of the iron-work should be stolen, or ropes wilfully destroyed; and where the nature of the torrent would allow it, for taking them down during the dry months. In this latter case, a store-room was required in which to lodge the ropes. In considering all these particulars, it appeared that the difference of expense, which on a first view was 4 to 1, dwindled down as low as 8 to 5; while the greater security and convenience of the wooden bridges, was thought to be more than a balance for this small difference of expense. The Shakespearian bridge began now to be considered only fit for the smaller rivers, or for those situations where wood was not to be had; and for the larger spans the *sanga* was thought best adapted.

There were still some who could not but think the *sanga* or wooden bridge a very unskilful structure, and who wondered that European sciences could devise no better. The quantity of timber used in these bridges is enormous, and might certainly, if judiciously disposed, support four times the weight they are capable of bearing. It is indeed truly surprising that the subject of carpentry and framing of timber should be so little understood or appreciated, as to permit of such structures being erected under European superintendance. It being, however, taken for granted that these were the best wooden bridges, (although the plate and description of the Schaffhausen bridge, which is in every Encyclopædia, might have proved the contrary,) every new project for erecting bridges of a different material attracted the more attention; and this, assisted by the judicious puffery of the Calcutta newspapers, was the great secret of the short lived popularity of the Shakespearian. The late Mr. Adam, when residing at Almórah, took great interest in the question; and his attention being drawn to an account in one of the scientific journals, of a bridge erected at Geneva, constructed entirely of iron-wire, he thought at first that such a bridge might be preferable to any yet tried in the mountains. A gentleman there, I believe, wrote to Calcutta for some iron-wire, to try the experiment; but I never heard the result, further, than that it was found too expensive a delicacy for the mountains, where from the number required, economy was a primary consideration. At length the iron-chain suspension-bridge was proposed, and this invention, so useful and so generally applied in Europe, promises to be not less so in these mountains. For economy, for durability, and portability, it has no equal. It requires scarcely any attention or repairs, and is applicable to the largest spans. The following extract from Mr. Ainger's lectures, at the Royal Institution, puts the subject in so clear a light, that I shall make no apology for giving the whole passage.

"The most striking circumstance in these bridges, is their great economy, as compared with ordinary or what are called insistent bridges. That economy arises from the power of a suspension-bridge to vary its curve, so as to adapt it to any variation or partial excess in its load; in consequence of which, the strength of the

chains may be with great precision adjusted to any required strain, and no more : while in insistent bridges, the liability of the arch to a fatal derangement of its form from partial or excessive pressure, requires an enormous increase of weight, and of strength beyond what is requisite for the mere support of its load, supposing it were uniformly distributed.

“ Iron, independently of its cheapness and extensive diffusion, is singularly and admirably adapted for the construction of suspension bridges. When it is considered that the greater part of the weight of these bridges arises from the chains themselves, it is evident, that the best material for this purpose is that which has great tenacity with small weight, and thus we find that iron is at the same time the most tenacious, and excepting tin, the lightest of the common metals. A square inch of good iron requires about 28 tons to separate it, and it will not be stretched or otherwise affected with less than half that weight.” Mr. Ainger goes on to say, “ Where, however, economy and portability are important objects, rope bridges will be found advantageous, and they have been during the last few years extensively introduced into British India by Mr. Shakespear, the Post Master General at Calcutta. They have produced great benefit in facilitating the transport of troops and baggage, as well as of merchandise and the mails. One of these bridges, 160 ft. in length, is so light and portable, that it has been several times set up and removed in a few hours.” The reader will presently see, that, in giving this opinion, Mr. Ainger was not acquainted with the real value of the Shakespearian bridge.

The merit, I believe, of first pointing out clearly the great superiority of the iron chain bridge over any that had yet been constructed of wood or rope, belongs to the present superintendent of that department. In 1828, nine bridges were sent up for the military roads about Almórah, before mentioned. The span was from 80 to 190ft. and the cost only 5,256 Rs. being an average of 584 Rs. for each bridge. Sundry spare articles, amounting in the whole to 707 Rs. increased the above average 78 Rs. making it 626. One of these bridges alone, the 190 ft. span, cost Government, when constructed of wood, 10,000 Rs. and what is still more to the purpose, it was, in less than three years, condemned by a committee as unserviceable. Their opinion was justified by the result; for the following year, two unfortunate men, having ventured to cross in spite of the repeated public notices that had been given, the bridge gave way, and they were lost. I believe the smallest of those bridges, as made of wood, did not cost less than 3000 Rs. and probably on an average, one with another, they cost 5000, or eight times the price of the iron chain bridges, which will probably last five times as long. The Shakespearian bridge was found to have in economy, only the advantage of 5 to 8; so that the iron-chain bridges will be five times cheaper than these, contrary to Mr. Ainger's and the inventor's opinions. On this subject I propose to enter into a little detail.

The strength of iron has been found, by experiment, to be nearly SEVEN TIMES greater than that of the freshest hemp rope (of European manufacture). The weight then of two bridges of equal strength of iron and hemp, should be nearly equal, *i. e.* while dry. In practice, however, it is found that so many additional pieces are required in a rope bridge, as ties, slings, braces, &c. as to raise the weight of the rope bridge to double that of the iron, strength for strength. This in itself is a serious objection, independent of its reference to economy. The price of wrought iron is found to be from 10 to 12 Rs. per factory maund; that of good European hempen rope is 21 Rs. per cwt. or 56 seers, equal to about 16 Rs. per maund. We see therefore, that even on the supposition of equal weights, rope is dearer by one-third than iron: if we take double the weight of rope, as shown above to be necessary, a bridge of rope will be nearly three times the cost of one of iron.

Now, supposing a rope-bridge will last four years, (and this I think is a favourable supposition,) an iron one will last ten*; and as it costs only a little more than ONE-THIRD, the price is evidently more economical in the ratio of nearly six to one. It may however be said, that Europe hemp is dear, and that a cheaper material is on the spot (the *Malsan* rope), the adoption of which, would make a great difference in this estimate. I shall therefore, as the best answer to this objection, and as a means of showing the great superiority of iron, here compare two estimates, the one showing the expense of a bridge of 165 ft. span to be constructed of rope, manufactured in the hills; the other of an iron-chain bridge of the same span. That the latter estimate is not too favourable, will appear by the details I shall presently bring forward of what *has been actually done*.

* The duration of an iron bridge is assumed as above, to allow of every advantage to the rope-bridge in the comparison; but I believe, I might safely have said 20 instead of 10.

be carried without any difficulty on the worstroads. A coil of 4½ or 5½ inch rope, the weight of which would be probably five or six cwt. is not so easily disposed of.

In point of durability, including attention and repairs, the advantage is equally great; a chain-bridge once properly erected, requires little or no care, and the expense is confined to an annual cost of paint, or coal tar; either of which, will effectually preserve iron for many years, however inclement the weather to which it may be exposed. The rope-bridges which were erected in Kamáún, on the contrary, required constant attention, and the maintenance of an extensive establishment, as well for tightening the ropes, as to preserve them from intentional mutilation. During eight months of the year, they were wholly removed and lodged in storerooms. Yet with all these precautions they are not expected to last in the hills above two seasons. In convenience, therefore, as well as in actual safety, iron must be always superior to rope, which from its flexibility, however well secured or supported by guys, is ill adapted for bridges. This is so obvious that it is unnecessary to insist more on it.

Thus we see that in economy, whether as regards prime cost, expence of carriage, expence of management, or durability, iron has a great and manifest advantage over rope as a material for bridges. In point of convenience, whether as regards facility of carriage, durability, or as requiring little attention, it is also greatly superior. The erection of bridges every year, and their reconstruction every two years, would be a seriously inconvenient arrangement, even were it not an expensive one. Lastly, there can be little doubt of its being the most safe material, in as much as it is, strength for strength, only half the weight; being scarcely subject to deterioration from exposure, it is not liable suddenly to become insecure in consequence of any unusual or unseasonable weather, or casual inferiority of material; and lastly, not being subject to the stretching and tightening of rope, it is not liable to suffer from any change in the figure of the bridge, or alteration of strain on the parts.

The above points have been so clearly established, and are now so generally admitted, that there is every prospect of this bridge being extensively introduced within the hills; and doubtless, it is one of the greatest boons the mountaineers have yet received from their European masters. Tables have been furnished, by which any engineer or executive officer may at once determine the expense of these bridges, according to their span and the weight they are required to carry. The following are the particulars of three different sizes which may, we think, be interesting to many.

Dim. of bridge.		Section of iron for chains.	Probable weight of finished iron work.	Prob. Exp. of iron work deliverable at the H. C. yard.	Estimated weight of platform.	Load at 20 lbs. pr. square foot.	Equivalent to men.
Length.	Breadth.						
ft.	ft.	Sq. inch.	Fy. mds.	Sa. Rs.	lbs.	lbs.	
100	6	2	30 to 35	360	5,000	12,000	80
150	6	3	40 to 50	480	7,500	18,000	120
200	6	4	60 to 70	720	10,000	24,000	160

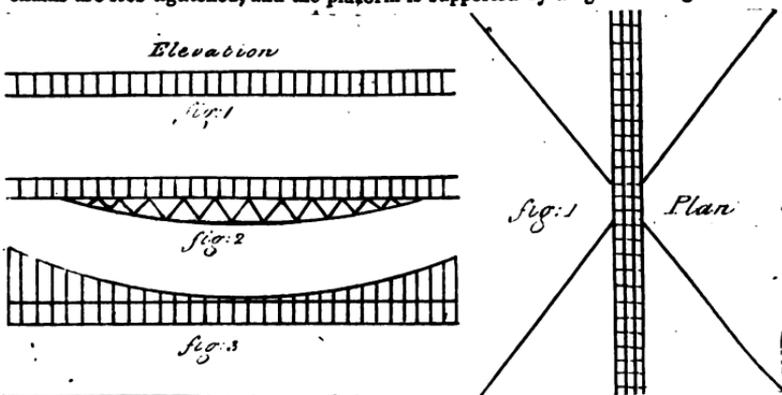
Note 1. For retired and less frequented situations, lighter bridges might be constructed at, probable, one quarter the above expense; the loads allowed for these being ample, and such as are not likely to be placed on any but military bridges.

Note 2. In order to facilitate the carriage of the iron, the bars can be made of any length considered most convenient, so as to admit of the whole being carried by hill porters if necessary; multiplying the numbers of joints must of course increase the expense in some measure; the above estimate supposes the bars not less than 10 ft. in length. Such a bar having a sectional area of one inch, would weigh 27 to 30 lbs.

Note 3. In calculating the comparative expense of iron, with that of any other material, the former may be assumed to last 20 years, at the expiration of which time, it might still be available for bridges of smaller span, or would at least be valuable and sell as old iron to be wrought up again. Its durability, however, will greatly depend upon its being occasionally cleaned and fresh painted or tarred.

It will be useful to mark also the several modifications of form of which the iron-bridge is susceptible. The most obvious and secure against vibratory motion, as well as the most economical, is that represented in the accompanying elevation fig. 1. next page. The chains are carried straight across.

The second, (Fig. 2,) which is applicable to greater spans, is nearly the same. The chains are less tightened, and the platform is supported by a light framing.



In the 3rd form, (Fig. 3,) fulcra or piers are erected, over which the chains are suspended. The platform is then attached to them by vertically suspended rods; the path or roadway passing between the supports. This form is applicable to the largest spans.

When the breadth of the stream is considerable, and the depth not very great, economy and safety will be best consulted by multiplying the number of curves, and having one or more supports in the bed of the stream: vibratory motion must naturally be expected where the length of chain is considerable and the platform narrow; but this may be obviated by applying horizontal chain guys in the manner represented in figure 1.

A MOUNTAINEER.

II. On some Petrified Shells found in the Gawilgerh Range of Hills, in April 1823. By the late H. W. Voysey, Esq. Assistant Surgeon His Majesty's 67th Foot.

[From the Asiatic Researches, vol. xvii. pt. i.]

This remarkable range of hills is called, by Arrowsmith, in his last map, the Bindih, or Bindachull (Vindhya or Vindhyachala) hills. The same name is, however, given to a lofty range of hills on the left bank of the Godáveri, as it passes through Gondwána, and also to those near Guálior. I shall, therefore, distinguish them by the name of the Gáwilgerh range, particularly as, after repeated enquiries, I have never been able to discover that they were as above designated, either by the inhabitants of those hills or of the neighboring plains. They take their rise at the confluence of the Purna and Tapti rivers, and running nearly E. and by N. terminate at a short distance beyond the sources of the Tapti and Wardor. To the southward, they are bounded by the valley of Berar; and to the north, by the course of the Tapti. The length of the range is about one hundred and sixty English miles, and average breadth, from twenty to twenty-five miles.

On the Southward side they rise abruptly from the extensive plain of Berar, the average height of which is one thousand feet above the level of the sea, and tower above it to the height of two and three thousand feet. The descent to the bed of the Tapti is equally rapid, although the Northern is less elevated than the Southern side of the range. The outline of the land is generally flat, but much broken by ravines, and by groupes of flattened summits, and isolated conoidal frustra. The summits and the flat land are generally remarkably destitute of trees, but thickly covered by long grass:—in the ravines and passes of the mountains the forest is very thick, and, in many places, almost impervious. The inhabitants are principally Goanás, whose language, manners, and customs differ remarkably from those of the Hindus. At present, their chief occupation is hunting, and