

18. *On some SUPERFICIAL DEPOSITS in CUTCH.* By the Rev. J. F. BLAKE, M.A., F.G.S. (Read February 3rd, 1897.)

[Abridged.¹]

DURING a recent visit to Cutch for the purpose of studying the Jurassic² rocks there exposed, my attention was naturally attracted to a number of superficial deposits, which in some cases concealed, and in others were associated with, the solid rocks beneath. I cannot pretend to have made an exhaustive study of them, as I have only examined such parts as may be found in the Jurassic area; but these have suggested certain theories of their origin, which I have not seen proposed elsewhere, and as these theories depend on observations which I do not find recorded, it may at least be hoped that an account of such observations may throw light on the origin of the deposits. The matters with which I propose to deal may be classed under the following heads:—

- (1) Subrecent concrete.
- (2) The boulder-beds associated with this concrete.
- (3) Infratrappean grits.
- (4) Laterite.
- (5) Alluvium and Ran.

Of all these, except No. 2, there are to be found brief descriptions in Mr. A. B. Wynne's memoir on the geology of Cutch,³ but, as a rule, that author does not venture on any suggestion as to their origin, and in no case does he appeal to the particular causes to which I have been led to refer them.

(1) The Subrecent Concrete.

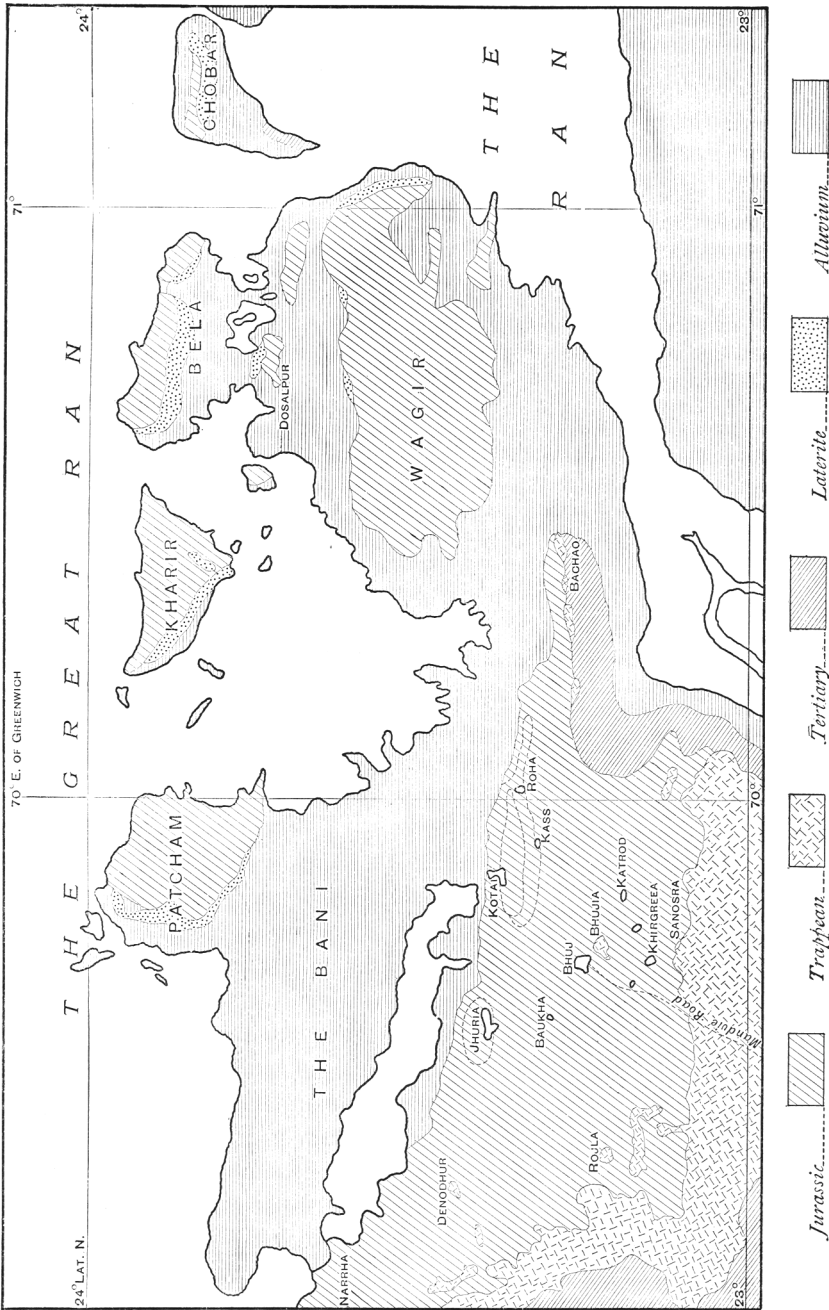
Under this name Mr. Wynne describes some remarkable deposits of which he writes as follows:—‘Very generally distributed over the hilly country is the subrecent calcareous deposit already alluded to. The white sandstones of which it consists are sometimes sufficiently coherent to be used for building, and it is very commonly burnt for lime all over the province. No fossils have ever been found in it, but on some slabs from the deposit in Western Cutch tracks of crustacea or of annelids have been observed. It is not limited to a uniform level in its various situations, having been met with in the low ground at the foot of the hills bordering the Runn, as well as high in their glens. Its aspect is always very much the same, though its texture is varied, being sometimes conglomeratic or finely oolitic, and generally it presents some oblique lamination.’⁴

¹ [By the omission of that portion of the paper in which the quartzite-reefs and their mode of formation were discussed.]

² Throughout this memoir I use the word ‘Jurassic’ for all the rocks so coloured on Mr. Wynne's map, without prejudging the question as to how many of them may be, as some certainly are, of Neocomian age.

³ Mem. Geol. Surv. India, vol. ix, pt. i. (1872).

⁴ *Ibid.* p. 81.



[For the Survey spelling of some of the names on this Map, see text.]

This description, which is the fullest in the memoir, does not in any way indicate the author's view of their origin. Indeed he elsewhere says: 'The . . . subrecent deposits, except in their most superficial portions, contain no evidence as to the conditions under which they were accumulated.'¹

Although in one sense it is true that they are very generally distributed, there are only ten definite localities where these deposits are sufficiently important to be noticed. Of these one is said to be of 'quartz-gravel,' and is thus, as will be seen, of a character different from the rest. There are also six other localities where I have noticed them, making in all fifteen to be considered, situated as follows:—1. The northern slopes of the Kala Dongar, in Patcham.² 2. The summit of the Gora Dongar, north of Andhou. 3. In the glens at a considerable elevation in Bela. 4. On the northern flanks of the Habo Hills, near Kotae. 5. Below Roha Hill. 6. High up on the Kas scarp. 7. On the south side of the Jhurio Hills. 8. In the valleys of Varar Hill. 9. At Baukha, where it is quarried. 10. On Bhujia Hill. 11. At the base of Katrod Hill. 12. In the Katrod Hills between Ler and Jadura. 13. In a valley north-west of Godpur. 14. On the Mandvi road, where it is quarried. 15. At the base of the trap-escarpment at Khedoi. It will be observed that the deposits are all very local, and usually associated with some hill. They appear also to be absent or inconspicuous on the western side of Cutch. (See Map, opposite.)

If we examine now more closely their mode of occurrence, some remarkable peculiarities become obvious, which should be some guide as to their origin. Thus the Kala Dongar Hills³ have a steep escarpment on their northern side, and the slopes below have usually a direction parallel to it, but near the western end there is a projection of high ground forming a kind of bay which opens on the west, and it is in the angle of this bay that the subrecent concrete is found. In the Gora Dongar, north of Andhou, a broad open valley is formed by a dome of Jurassic rocks, the eastern side of which is bounded by an escarpment of limestone rising towards the north. Near the summit the continuity of this escarpment is broken, and we find a narrow recess of which the mouth faces west. It is on the two flanks of this recess that the concrete occurs, occupying nearly the highest level in the neighbourhood, which, from the figures given on the Trigonometrical Survey map, must be some 560 feet above the level of the Ran. In the glens of Bela these deposits lie, as noted, at a high level. On the northern flanks of the Habo Hills the principal part lies on the southern slope of an outlying scarp, and reaches a height of 300 feet above the Ran. In

¹ Mem. Geol. Surv. India, vol. ix. pt. i. (1872) p. 85.

² The spelling of the names is in all cases that found on the Trigonometrical Survey Maps; but the local pronunciation, as given by Mr. Wynne's names, is often very different, unaccented *a* being pronounced as a short *u*, and *d*, *l*, and *r* being often interchangeable.

³ The Kala Dongar Hills run along the northern half of Patcham, and the Gora Dongar Hills along the southern half.

the three localities south of the same hills the occurrence is very instructive. Here a long east-and-west valley is bounded on the north side by gently sloping surfaces, and on the other or south side by a long and very uniform escarpment. This, however, is broken at one place where the pass over the summit crosses, and shows a kind of notch in the outline, which is the only spot where the subrecent concrete occurs. It here reaches its highest elevation, being not more than 100 feet below the summit of the escarpment, and therefore about 700 feet above the level of the Ran. Towards the east the valley closes in, and we reach the watershed below some high hills. It is on the west side of this watershed that the greater part of these deposits of concrete occurs, while there is very little on the east (see fig. 10 in Mr. Wynne's memoir). On the south side of the Jhurio Hills there is a fairly continuous encircling scarp which faces north. The main drainage of the southern slopes of the inner hills escapes through a gorge in this scarp, which at one time was fairly broad, but is now nearly choked up by the concrete, while within the scarp we find the concrete spreading out as a thick white mantle over a square mile of the slopes beyond. Notwithstanding this, the outer slopes of the scarp, up to within a few hundred yards of the gorge, are quite bare, the solid rocks being everywhere visible. At Bhujia Hill the deposit is found in a semicircular valley which opens on the south. Between Ler and Jadura there is a long east-and-west valley, opening to the east, and this is almost entirely bare; but at one place a basaltic dyke crosses the valley like a wall, and on the west side of it the concrete is piled up in places to its summit. A similar phenomenon may be seen in the valley north-west of Godpur. Where the Mandvi road crosses the Charwar range, it traverses in one place a valley whose streams run west, and in this valley we find the concrete on the north side resting against the Jurassic prominences as seen near the Mandvi road. Farther east the locality Khedoi, where Mr. Wynne records this concrete, is situated in a semicircle eroded back from the general line of the trap-escarpment.

In structure these deposits are very uniform. Leaving out of consideration for the present the large stones derived from the nearest solid rocks, which they sometimes contain, they consist of fine particles very slightly agglutinated, so that a blow of the hammer shatters them to dust. Some southern varieties, however, are tougher, and are used for building, while on reaching the extreme north-east in Bela we find them scarcely consolidated at all. They are for the most part obliquely laminated, and in this case the slope of the laminae in the part of the deposit nearest to the solid rock is in the direction of that rock.

In composition the majority are mostly white sand, cemented only with calcareous matter. In the more southerly exposures there are calcareous particles also, but I have not seen any that are truly oolitic. The complete rounding of the particles gives the rock that appearance, especially in the deposit near Kotae, but on examination they appear to be organic fragments, and there are white specks

which consist of little-worn miliolines. These organisms belong, of course, to the deposit itself; but the concrete is in the habit of enclosing what it finds on the spot. Thus at Bhujia Hill it is full of the fragments of trap that have fallen from the summit; on the Kas scarp it encloses the little *Buliminus* which is now living in the district, and in Bela it is said to enclose human bones, though it is not stated definitely that the deposit there was undisturbed.

Such are the facts with which we have to deal in attempting to discover the origin of these curious deposits. Their constant association with hills, and their occurrence in the glens, might suggest at first that they are a rainwash, more or less transported by rapidly descending water, on account of their lamination. But this seems impossible. In some cases, no doubt, the solid rocks might yield the sand, but it would be ferruginous, not white, and such sandstone-rocks would yield very little calcareous matter. But in other cases there is no sand in the neighbourhood at all. Thus in the Gora Dongar all the hills are of limestone, and the deposits are at the very summit. The same may be said of the deposit in the Jhurio Hills and in Bela, while the miliolines at Kotae cannot possibly be of local derivation. Moreover, the deposits lie on a great variety of rocks, and yet have an uniform character. We may therefore dismiss this explanation.

Another alternative is that they are marine deposits. This would involve a depression in quite recent times of 700 feet or more, and would in no way account for their peculiar local distribution, nor for their lamination. One might also expect marine shells when delicate *Bulimini* and tiny miliolines have been preserved. But greater than all other difficulties is that of their loose porous character. So far as my experience goes, no deposits that have been laid down in water are of similar character. The water invariably aids the particles in packing together at their closest, and with such materials as these they would form a solid rock.¹

There remains, so far as I can see, but one other alternative, and that is that they are æolian in origin, and this will, I think, be found to account for all their peculiarities. It would need, however, a strong wind to raise sand up to 700 feet in one place and 560 feet in another, and carry the miliolines from the nearest sea. We must therefore enquire whether there are such winds in Cutch.

The Meteorological Office in Simla publishes every day a series of observations showing, amongst other things, the average rate per hour for the last 24 hours, and the direction of the wind at 8 A.M. We cannot gather from this what was the direction of the wind at other times, for if the direction has changed the time of the change is not recorded; but by assuming that the direction at 8 A.M. is the same as that for 12 hours before and 12 hours after, we may arrive

¹ Mr. Wynne (*op. cit.* p. 103) speaks of a small patch of littoral concrete full of shell-casts on the northern side of Patcham, about 20 feet above the Ran; but he does not classify this with the 'subrecent concrete,' which he says is unfossiliferous.

at a rough estimate of the average direction and speed. Taking the year 1895, and treating the records in this way, it appears that the air travels at Bhuj, in the various directions, at an average rate of $10\frac{1}{2}$ miles per hour for the whole year. But at the end of this time, the air is not found to have returned upon itself. According to the records, a particle of air which travelled constantly with the wind would find itself at the end of the year 66,000 miles to the east and 9600 miles to the north of its initial position. These figures, of course, are merely indicative of general results, the meaning being that there is, on the whole, a constant passage of air in one direction, from a little to the south of west, at a rate of $7\frac{2}{3}$ miles per hour.

We shall form, however, a better idea of the action and power of the wind by examining the records in detail. There were, in the first place, only 40 occasions in the year when there was any east in the wind at all, and the total velocity of such winds was only $12\frac{1}{2}$ per cent. of that of the westerly winds. Again, for the greater part of the year the winds are not excessive, but out of the 140 days between April 25th and September 11th, no less than 90 days' gales are recorded, 7 of which are specially recorded as dust-storms. If now we confine ourselves to these dates of gale we find that the average velocity was 20 miles per hour, and the average direction about 20° south of west. The velocity exceeded in six cases 30 miles per hour. This is an average for 24 hours, and, as gales do not continue to have a constant velocity for so long, there must have been not infrequent times when the wind was moving at 40 miles per hour. The complete records for other years I have not been able to consult, but there is no reason to believe that 1895 had a maximum of wind, nor are we sure that the present winds as a whole are equal in intensity to those of some period of the past. We have, therefore, good reason to believe that there is adequate force available to do the work required.

Moreover, similar work is now being done, as witness the dust-storms for which Cutch is famous. As, however, the gales blow from the west, it is important to know what happens in that direction, and on consulting the Meteorological Reports above quoted we find that there were no fewer than 55 dust-storms recorded at Karachi during 1895, mostly under westerly winds, and in the other stations next north and north-east of Cutch 53 dust-storms and 53 dust-hazes, which latter may be taken to mean the transport of the finer particles of dust. It is obvious, therefore, that the passage of fine sand, etc., across the country is a widespread phenomenon.

We have evidence also that the sand thus carried travels with great velocity, for, as shown on p. 456 of the 2nd edition (1893) of Blanford & Medlicott's 'Geology of India,' there are in Sind two types of sandhills—one lying transverse to the prevailing winds and the other parallel to them, the direction here being about 30° south of west. Now it is only necessary to study the drifting of snow to see that, while comparatively gentle winds make transverse drift, the snow that is borne along tumultuously by the wind lies, when

the wind drops, in long straggling lines parallel to the course it has taken. These longitudinal sand-dunes, therefore, indicate a great velocity of wind in the desert north of the Ran, so that we are not surprised to learn that some of them, even without the aid of any inclined plane of solid rock below, are able to attain a height of 400 to 500 feet. That the same phenomena are found in Cutch itself may be gathered from the fact that in speaking of the sand-dunes along the southern coast Mr. Wynne says that they have a bearing of about 20° south of west,¹ which is exactly the average direction, as seen above, of the strongest winds. From personal observation I can only say that at Mandvi, after the close of the monsoon season, when the sea had calmed down enough for steamers to call, the wind was constantly blinding with sand and the pier was all buried in a dune. That large areas of Cutch are now covered with still drifting sand is pointed out by Mr. Wynne.²

The cause assigned being thus found adequate for the work, we must next enquire how far it explains the special phenomena noted above. As it was the distribution of the deposits that suggested the cause, this must be taken first. Now all the localities may be described as spots where a wind coming from the west or south would be stopped by an obstacle, or where a shelter-spot exists in a long scarp. Thus in the Kala Dongar the wind would be stopped by a projecting high land, below Roha Hill by a watershed, below Bhujia Hill by the hill itself, between Ler and Jadura, and also N.W. of Godpur, by projecting dykes, and on the Mandvi road by the Jurassic escarpments. On the other hand shelter-spots occur above Andhou on the Gora Dongar, on the flanks of Habo Hills, on the Kas scarp, on the south side of the Jhurio Hills, and at Khedoi on the trap-escarpment. In some other places, as along the north side of the Katrod Hills, and apparently at Baukha, the deposit makes no feature on the surface, being level with the ground, and thus probably fills originally existing hollows. To this latter category must also be assigned the various glens in which the deposits less abundantly occur.

It is thus seen that the horizontal distribution is exactly what it ought to be. In the vertical direction, where the deposits occur at high levels inland the main valleys are also high, so that there is not a great difference of level; but in the case of the Gora Dongar, where the deposits are 560 feet above the neighbouring Ran, there is a gradual rocky slope all the way, leading up to the hollow where they lie. In the case of the Kas scarp the west wind would be hemmed in by lofty hills into a gradually narrowing valley, so that its force would be greatly increased.

The lamination may at first sight seem a difficulty in the way of the proposed explanation, but it is not so. The principal dust-bearing gales are in the hot season, and these will leave a deposit of sand or calcareous dust upon any preexisting surface. Then the succeeding rains, which are not often so heavy in Cutch as to wash

¹ Mem. Geol. Surv. India, vol. ix. pt. i. (1872) p. 82.

² *Ibid.* p. 12.

such deposits away, will cement the particles together at once, as they do the flood-deposits along the riversides. Thus each lamina will represent a season's work. That the laminæ should dip towards the rock on which the concrete rests, on the side nearest to the rock, is what we should expect in a wind-blown deposit. For when sand is blown against an obstacle it is thrown back again and the wind has to pass away on either side, so that in such places we always find an intervening valley between the mound and the obstacle, the surface of the mound thus sloping towards the obstacle.

The loose porous character of the deposits, as already pointed out, is against their aqueous origin, but is what we should expect in an æolian formation, only so far subjected to water that it has been rained upon. The uniformity of general character over a wide area, independently of the rock below, is thus fully accounted for. The more calcareous composition of the southern deposits is due to the fact that the materials here are mostly derived from the sea (hence the milioline also), while farther north the dust is reinforced by the breaking-up of the Jurassic sandstones. The enclosure of the local rocks and of the local *Buliminus* is quite natural, the dust finding its way into the interstices of whatever was lying on the ground.¹

(2) The Associated Boulder Beds.

These are not mentioned by Mr. Wynne, unless he refers to them in the passage quoted above, when he writes of the concrete that it is 'sometimes conglomeratic' (*op. cit.* p. 81). As no æolian deposit can be in itself conglomeratic, these boulder-beds require explanation.

I will first describe the three localities where I have observed these beds. The first is in the banks of a river running out from the Habo Hills at Fulae near Kotae, where the subrecent concrete has been above recorded. Here we find the following section (see fig. 1).

The bed of the river and about 4 to 6 feet of the vertical sides are composed of Oxfordian shales dipping at a very high angle. Their surface, except for the river-erosion, is nearly flat, and immediately on the top lies a 5-foot bed of rounded and subangular stones, from the size of a quarto book downwards, embedded in a fine loamy material without any stratification. The boulders lie irregularly jumbled together, with a tendency, however, for the long axes to lie horizontally, so that the deposit has very much the aspect of a boulder-clay. Over this comes 7 to 8 feet of false-bedded concrete, and then follows another boulder-bed 5 to 12 feet thick up to the top of the cliff, in which the boulders are smaller, about the usual size of coals in a scuttle. All the boulders, so far as observed, can be matched in the neighbouring hills. The stratification is approximately horizontal; but the boulders only commence some way down stream, away from the outer slopes of the hills

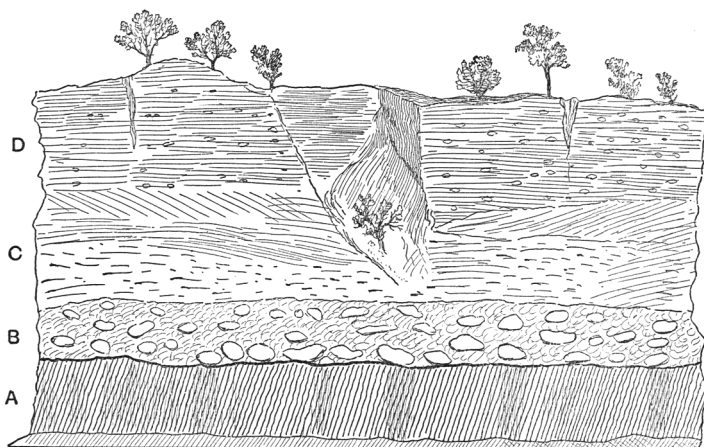
¹ If this be the true origin of the calcareous surface-deposits of Cutch, it is probably also the origin of the foraminiferous rock of Porbandar, which too is local and is backed by a range of felsite-hills on the north and east.

and below the spot where the *Miliola*-bearing concrete is seen resting directly on the Jurassic rocks.

The second locality is on the south side of the Jhurio Hills, in the concrete-filled gorge and beyond. The description of these deposits would be practically a repetition of the last—only the thicknesses are somewhat greater, and the bed-rock is not reached in the stream-bottom, where the boulders are seen in the sides.

The third locality is a more remarkable one, namely, that on the north side of the Kala Dongar in Patcham. It was here that the boulder-beds were first noticed and called loudly for some explanation. At this spot there are marked on the map of the Trigonometrical Survey two long projecting elevations running out at right angles from the Jurassic escarpment, where it is coated with the

Fig. 1.—Section on stream west of Kotae.



A = Oxfordian.
B = Boulder-bed.

C = False-bedded concrete.
D = Smaller-boulder-bed.

subrecent concrete. These no doubt were originally one, the end having been eroded along the dividing watercourse. Their length is $\frac{9}{10}$ mile, the united breadth $\frac{1}{2}$ mile, and their elevation (not marked on the map) is perhaps 100 to 150 feet above the plain. They have the general aspect of the tip-heaps of a cyclopean railway-embankment in course of construction. As seen weathered on the surface they are covered with large fragments of rock from $\frac{1}{2}$ cwt. downwards, more or less rounded, but not scratched, and all to be apparently matched in the neighbouring Jurassic hills. Where a section is seen the matrix is rubbly, more or less tufaceous, and tough enough to form a cliff. At the base of the valley laterite is found, and the long mounds appear to rest upon it.

In the first two localities the stratification in alternate boulder- and non-boulder-bearing beds may be without discussion assigned to the action of the streams when they were depositing and not eroding, but in all three cases the difficulty is to account for the carriage of the large stones and their promiscuous heaping together. The principal agents that have been supposed to possess sufficient transporting power are ice, torrents, and sea-waves. In a place where the present range of temperature is between 70° and 120° , it is scarcely feasible to call in the aid of ice, and certainly sea-waves are out of the question. In the first two localities, where the boulder-beds fill up the bottom of valleys at the end of gorges leading out from lofty domes, the bottom beds may be fairly ascribed to the force of the water, with or without further aid; but those which overlie the soft concrete could scarcely, one would think, be borne along in so rapid a torrent that they could not even be sorted, without that torrent eroding the surface below.

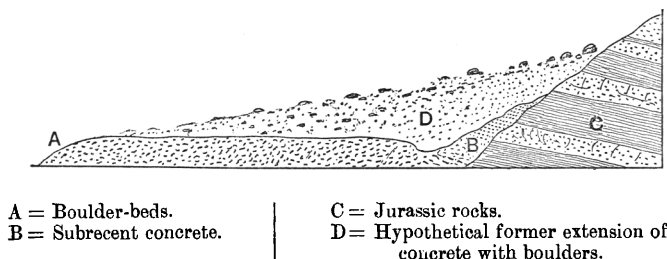
For the third locality, however, there seems no possibility of calling in the aid of a torrent, as there is no gathering-ground for the water. The whole history of the deposit must at the outside be confined within an area of $1\frac{3}{4}$ square miles on which no longer line than $2\frac{1}{2}$ miles can be drawn, with a maximum difference of elevation of 1150 feet. But the mounds point in the direction of the scarp only $1\frac{1}{4}$ miles distant and whose highest point is only 640 feet above their surface, and for three-quarters of this distance the boulders occur. Nor do they fill up a valley, but form mounds on a flat surface. The only area whence the water could be obtained to form a torrent would thus be the slopes of the hills opposite the mounds, with an average fall of only 320 feet. This appears to me quite inadequate to produce a torrent sufficient to carry large stones over a nearly level surface for $\frac{3}{10}$ mile. If we take the longer oblique line and greater height the difficulty is found to be not lessened but increased.

In the 29th volume (1873) of the Journal of this Society, p. 493, Dr. W. T. Blanford describes similar deposits on a far larger scale in Persia. Here there are boulder-ridges extending for 5 to 10 miles from the foot of the hills, with a fall of their upper surface in that distance of 1000 to 2000 feet. He says that the large fragments are commonest near places where small streams issue from the higher ranges, but the mounds increase in quantity towards the north and east, where the rainfall is less. I thought that this last fact would have led the author to enunciate the theory which I am about to expound, but he argues only that there must have been a greater rainfall in past times, and that lakes were thus produced—without saying how even then these boulders could have been transported for 5 to 10 miles with so little fall.

In Cutch these boulder-beds occur only where there are deposits of æolian origin, and in Persia they are most abundant where there is less rain and therefore presumably more dry sand to be blown about, so that some connexion between the two is suggested. It appears to me that, if we suppose that at one time there was more

blown sand present, so as to make a greater slope, the weathered blocks which fell on it from the hills would, under the influence of the rains saturating the sand below, slip gently forward along the slope, supported by the underlying sand, till they reached their farthest destination without sinking to the bottom. Thus the æolian deposits have served as the carrier (see fig. 2).

Fig. 2.—*Boulder-beds in the north of Patcham.*



This explanation is analogous to that made use of by Sir Wyville Thomson to account for the forward motion of the stone-river in the Falkland Islands,¹ and, if it be a true one, it is possible that it may in some cases account for deposits of loose blocks which have been referred to glacial action. There will always be antagonism between this process and the running away of the water in definite channels, and at last, when the slope of the æolian deposits became too low, the growth of the mounds would cease and the streams would begin to sensibly denude the deposits, and even cut channels in the bed-rock. It might be thought that all along the rain would wash the sand away and let the boulders drop, but we see that as a matter of fact it does not; besides which, the boulder itself protects the sand below it, as in the case of earth-pillars, and what is washed away above or below will be replaced by the next dust-storm.

(3) Infratrappean Grits.

These deposits, lying as they do below the traps, cannot in strictness be called superficial, but it will be seen that they were probably of that character—that is, deposited on the land before the traps were poured on the top of them. This is what Mr. Wynne says of them:—‘These form a peculiar, soft, loosely granular, and obscurely stratified group of earthy and sandy rocks, largely composed of trappean materials . . . [they] are frequently associated with the base of the stratified traps, but they also occur in separate patches over the country, and sometimes at a considerable distance from them. They are clearly beneath the trap in some localities; in others they fill up hollows in the Jurassic beds, the planes of stratification not

¹ ‘Nature,’ vol. xv. (1876) p. 359.

being conformable even to the surfaces of the hollows which they occupy.'¹

In the detailed description, however, I can find only eight places where they are recorded, namely, west of Bhachau, Bhujia Hill, two places north of Katrod, Rhojla Hill, 'Khirgreea,' Rampur, and Lakhapur. The letter *d* by which they are indicated is also marked on the map at Sanosra and west of Mundhan. Of these, one of the localities obviously represents, by the description, some fault-rock only; that at Lakhapur and west of Mundhan is related to an intrusive mass of igneous rock which the deposits do not underlie, but merely abut against, so that they may possibly belong to the subrecent concrete. Of the deposit at Rampur, it is stated that 'it may have been the basal portion of the trap series.' It is not connected with the trap of the neighbourhood, and consists of 'scoriaceous lumps of trap mixed with sand, etc.,' so that this also may be an old variety of subrecent concrete. Of the other deposit north of Katrod, we read that beneath the trap is 'a hard bed of black ferruginous grit;' it therefore contains no trap-fragments, and may perhaps be dismissed as doubtful. There remain, therefore, five spots where peculiar deposits are actually found below the traps, with a sixth at Artara, unrecorded by Mr. Wynne, and in no case are they large enough to map.²

These six may also be grouped together, for those at Artara and at Sanosra are of the same character, and those at Khirgreea and Rhojla Hills are described as similar to that at Bhujia Hill. There are thus, with that west of Bhachau, three types of such deposits.

I have thought it necessary to thus analyse the evidence on account of the statement that they are 'largely composed of trappean materials,' which is difficult to understand if they are *infra*- and therefore presumably pre-trappean.

We will first examine the deposits on Bhujia Hill. The following are the only two sentences in Mr. Wynne's memoir which give us his description of them:—'To the eastward from beneath the highest summits, the basalt is underlaid by, and intercalated with, a rapidly increasing mass of soft, ? ashy, sandy rock of greenish-yellow colour, passing in places into a hard siliceous trappoid sandstone of coarse texture, containing fragments of woody plants. . . . From Bhoojia to the conical sandstone-hill on which Soorul temple stands and near the latter, the subtrappean grits are occasionally seen; the trappean blotches and interstitial portions weathered out into little cavities on the surface of the rock, which sometimes occupies pockets or wide fissure-like spaces in the underlying Jurassic beds.'³ With this description I am in perfect agreement, but the accompanying map and section do not correspond to it, and I am at a loss to understand

¹ Mem. Geol. Surv. India, vol. ix, pt. i. (1872) p. 56.

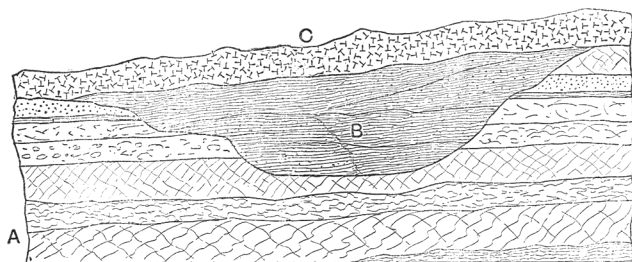
² On Mr. Wynne's map there is marked a considerable expanse of *infra*-trappean rocks in the neighbourhood of Bhachau, but there is evidently something wrong here. A distinct unexplained colour is inserted, and the details do not correspond with the text. Moreover, the deposits are not overlain by the traps.

³ *Op. cit.* p. 168.

them. It will be seen that, beyond calling some of the rocks ‘? ashy’ and ‘trappoid’ and speaking of ‘trappean blotches,’ the author speaks of nothing but grits. It is true that in some parts they are so much and so irregularly discoloured, apparently by infiltration, that they then bear a superficial resemblance to some rocks of volcanic origin, but their essentially gritty nature is unaltered.

The best exposure is on the northern slope of the hill, where the section shown in fig. 3 is seen. Here the bulk of the hill is com-

Fig. 3.—*Infratrappean grits at Bhujia Hill.*



A = Jurassic rocks.
B = Infratrappean grits.

C = Trap.

posed of the Jurassic sandstones, which on the western side rise up and meet the capping of basalt. East of this junction there comes in rapidly a series of thick beds of very porous character, all of which are laminated, but not conformably to the base on which they lie. Their porous character gives them a very ‘ashy’ appearance—that is, the appearance of fine *débris* deposited in the open air; but they are almost entirely composed of sand-grains lying in a loose matrix of finer dust, and are so like some of the samples of subrecent concrete that without labels they can scarcely be distinguished in hand-specimens. The laminae run up to and meet the basalt above, and as we pass eastward the deposit becomes thinner till the basalt and Jurassic sandstones come together again. The other patches referred to as lying in the open hollows are generally darker and more compact, but they are still sandy. The isolation of this and similar deposits at Khirgreea and Rhojla; its occurrence in a shelter-spot on an old Jurassic hill; its porous character and sandy composition, all point to an *æolian* origin, representing as they do the same conditions as those represented by the subrecent concrete.

The second type of deposit at Sanosra, due south of Bhuj, and at Artara, between the Jurassic rocks and the trap, is simply a collection of stones derived from the rocks below, cemented by finer material, and lying in hollows over which the trap passes: that is to say, it is the surface-*débris* of the land on which the lava was poured out.

The section west of Bhachau, which appears to show a third type, I have not seen, as at the place where alone I was able, from lack of more time, to examine the trap, it was lying directly on the Jurassic rocks, showing, as pointed out by Mr. Wynne, the very local character of the subtrappean group. I therefore copy here the description in the memoir (p. 136) of the beds referred with a query to this group, as taken from Mr. Fedden's note-book :—

| | Feet. |
|---|-------|
| '7. Brecciated and conglomeratic bed, lower part almost wholly of pink lava? | 3 |
| 6. Yellow sandstone | 2 |
| 5. Conglomeratic and concretionary bed of pale lavender and pink lava?, with large pebbles of hornstone, fragments of yellow clay, and fine sandstone | 1-4 |
| 4. Hard, yellow and pinkish, gritty sandstone | 5' |

It will be seen from this description that the only ingredients which could not be derived from the Jurassic rocks are the fragments of 'pale lavender and pink lava?' I think it is very doubtful whether these are really volcanic fragments. Even Mr. Fedden queries them, and as the large area south of Bhachau, mapped as trap, is now seen in the cuttings of the new road to be entirely lateritic, it is more probable that the fragments here noted are also of that character. Perhaps, however, it comes to the same thing if laterite is derived from trap, in which case the basalt of Bhachau must be one of the later flows. The stratification also of these deposits indicates the agency of water, so that we may perhaps sum up as follows :—

The subtrappean rocks are all superficial deposits on the pre-trappean land-surface, those at Artara and Sanosra being the ordinary results of weathering : those at Bhachau, the washing-down of similar debris onto a lower, water-covered level ; and those of Bhujia Hill, etc., æolian drift.

Taking this last in connexion with the subrecent concrete, we have thus a record of the constancy of the meteorological conditions in Cutch, from recent times as far back as the Cretaceous epoch.

(4) The Laterite.

The deposits hitherto dealt with are on a small scale and more or less peculiar to Cutch, but those which remain to be discussed are widely distributed in this part of India.

The various deposits which in different parts of India have gone by the name of laterite are, with exceptions, superficial in origin. As, however, the term has been so widely applied that the only definition which will cover all the varieties is that it is a very ferruginous rock of peculiar character, it follows that the rocks included under this definition may be of many origins and of many ages. All the laterites of Cutch are classed and mapped by Mr. Wynne as 'sub-Nummulitic,' so that they stand, with those of

the Nerbudda valley near Surat, as the only laterites which lie below well-defined marine deposits.

That there are lateritic beds below and associated with the Nummulitic Series in Cutch admits of no dispute; but those whose age can thus be proved all lie on the south side of the trap-escarpment and rest immediately on the trap itself, where there can be little doubt that the lower red earthy varieties are the products of decomposition *in situ*. It is with an entirely distinct area that I am concerned, where the laterite is separated from the trap by miles of intervening Jurassic rocks and Ran, and is overlain by nothing but alluvium. That these also are sub-Nummulitic depends on the assumption that all the lateritic deposits in a province as large as Cutch must necessarily be of the same age—an assumption which does not appear to me to be warranted.

The superficial group of laterite is found only on the southern and western margins of the Ran islands and along the northern border (and eastern also according to Mr. Wynne) of Wagir. In the course of this range it is found lying on various members of the Jurassic series. In the north of Patcham it lies on the oldest, in the north of Wagir on the youngest, and on intervening members at other places.

This distribution indicates, I think, a later age than the Nummulitic rocks, for these latter rest upon the decomposition-products of the trap, which do not require long to form, and they nowhere extend to the Jurassic rocks, as they surely must have done, if these had been already denuded to any great extent. Whereas, before these laterites were produced, not only must the lowest Jurassics have been exposed by denudation, but the general contour of the country must have been not far different from what it is at present. The only indication of age that I can quote is that they underlie the boulder-beds in Patcham.

The laterite here is a sort of gravelly deposit, the pieces being of fantastic shapes with a crinkly surface. They are dark red or black in colour, and consist of concretionary and stringy ferruginous matter, more or less closely sprinkled with sand-grains. The several pieces often interosculate into a vacuous spongy mass, in which case the rock so closely resembles some of the higher members of the Jurassic series as to be undistinguishable in hand-specimens. In certain well-defined spots, the surface of the ground is covered with small, irregularly-shaped, and obviously detrital agates, sometimes white and sometimes tinged yellow and red. These ferruginous beds are frequently seen to overlie well-stratified, soft, white sandstones and earthy beds, which are tinged with pink and purple by the infiltration from the laterite, as seen by the stalactitic form of the coloured parts (see fig. 1, p. 69 of Mr. Wynne's memoir).

Deposits of this kind are mostly found at levels relatively low, as compared with the surrounding Jurassics, and they seem to be limited to a level lower than about 120 feet above the Ran. They are only found inland at spots which would become lakes if the water-level were restored to that height.

From the preceding observations we may safely conclude that

- (i) This laterite and its associates were formed in water.
- (ii) They are not the result of the decomposition of any rock *in situ*.

- (iii) They are detrital in origin.

- (iv) They were formed at a time when the surface of the country was not very different from what it is at the present day, but when the water-level was 120 feet or more higher than now.

As to the source of the detritus, the materials of the sandstones, etc., might easily be procured from the higher Jurassic rocks, and the iron of the laterite itself could be found abundantly in the same beds or in the lower Jurassics—though possibly not in a state suited for solution. But we cannot derive the agates thence, and agates and iron probably came together. Agates are abundant in certain of the lower flows of trap, and to such rocks we must look for the source of the laterite. Now, as the ‘stratified traps’ are flows without pipes, and in the Jurassic area to the north of them there are several pipes without flows, it has been natural to connect the one with the other; and if the southern traps were emitted from these pipes, there must have been flows also to the north. Here, however, is a sharp anticlinal visibly bringing in the higher Jurassics, so that the relics of such flows would now be hidden beneath the Ran; and it is from the degradation of these flows that we may best seek the source of the laterites. This would account for their occurrence on the north side, but not on the south side of the inner Ran.

In the absence of any organic remains, it is impossible to say whether they are marine or lacustrine deposits. Their resemblance to the higher Jurassic rocks which have associated plant-beds points to the latter, in which case we may call in the aid of vegetation, as suggested by McGee and by Mallet; but as there are other deposits which have a similar distribution, and yet contain remains of apparently marine shells, and as moreover a depression is easier to imagine than a barrier, the former becomes at least equally probable.

(5) The Alluvium and Ran.

The area marked as alluvium on Mr. Wynne’s map is a very large one. It occupies no less than 800 square miles. A large portion of it, however, lies along the southern margin of the province, overlying fossiliferous Tertiary rocks, and it is to this portion that I think Mr. Wynne’s description must especially apply, when he says that ‘it is the result of the degradation of the local rocks, consisting largely of materials derived from the Tertiary beds, frequently mingled with travelled fragments brought by rivers from the hills.’ On this part of the alluvial area I have nothing to say, but of those parts which are in relation to the Jurassic rocks the above is scarcely a suitable description. In these I have found no evidence that the materials are specially of local origin or of Tertiary derivation, and no travelled fragments have been any-

where seen by me. The history, in fact, of these portions must be somewhat exceptional and instructive.

The alluvium comes into relation with the Jurassic rocks (except in the lateritic and a few other, possibly marine, patches of similar age, which have contributed no recognizable elements to it) in the broad flat area which joins the mainland of Cutch, north of Bhachau, to Wagir, continues round the western and northern sides of that district and unites it to Bela, skirts the south-western sides of the islands of Kharir and Patcham, and forms patches here and there along the northern coast of Cutch proper. With the deposits of this area must be classed about 650 square miles of lower-lying land, still occasionally flooded, known as the Bani, which lies in the middle of the area between the mainland and Patcham; and the deposits on the floor of the Ran, which may be divided into the inner Ran, south of the islands, and the outer or Great Ran, north of them. All these areas pass insensibly into each other, being merely distinguished by the relative heights of an undulating surface above the general level of the sea.

In the area mapped as alluvium there are parts which become muddy in the rains, and these pass gradually into Ran; but a larger portion is sandy soil, which soon becomes dry, including vast tracts where the sand is all loose and where no amount of rain can remain for an hour on the surface.

The characteristic deposit of the Bani is a very fine micaceous silt, and the surface is dotted over with groups of trees which stand round the margins of artificial tanks, or near the wells which are known to be abundant here. The surface of the Ran, in the wet season, is everywhere covered with the slimiest of muds, on which the camels can scarce maintain a foothold; but this is probably underlain by a firmer, perhaps sandier deposit, as below the first two or three inches the ground is firm and may be easily traversed while covered with water.

Before attempting the history of this strange area, attention must be drawn to the further features which may help to elucidate it. One of the most important of these is the aspect of the Ran where the alluvial deposits are absent. It has been shown long ago by Dr. Blanford¹ that both the Ran and the sandy desert on the north of it may be reasonably concluded to have been formerly occupied by the sea, and the latter to have been since more or less choked by blown sand. Mr. Wynne² quotes the numerous statements that have been made that the Ran was navigable and provided with various ports within the period covered by native traditions, though, in describing the Kharir cliffs (p. 106), he appears to be doubtful of the geological evidences. In one place in Patcham (*op. cit.* p. 27) he quotes a deposit with 'marine shells nearly 20 feet above the Runn' as 'traces of this old sea'; but elsewhere he states that these 'shells' are casts and may be 'very new Tertiary.' They are therefore no evidence

¹ Journ. Asiat. Soc. Bengal, vol. xlv. pt. ii. (1876) p. 26.

² Mem. Geol. Surv. India, vol. ix. pt. i. (1872) p. 26.

that before the sea left in comparatively recent times it stood 20 feet higher than the present surface or the Ran.

Standing by the edge of the Great Ran, on the northern shore of Patcham, Kharir, or Bela, one might fancy oneself looking over flats which have just been deserted by the tide. Save for the absence of the scraps of sea-wrack and the greater firmness of the mud, there is little to distinguish the appearance from that which might be seen along the coast of Brittany and Normandy between St. Malo and Mont St.-Michel. Here, too, are the clean-swept foreshore, the low cliffs on its landward margin,¹ the broken tumbled masses on the slopes, and the frowning scarps above, all recalling the aspect, though wilder in type, of the Undercliff of the Isle of Wight, where the lie of the strata also is the same as it is here. But, since the formation of the laterites and other minor deposits, there is no evidence that the sea has stood at a higher level than when it washed the low cliffs that now edge the Ran.

Why then has the sea departed, as it were yesterday, and left its bed to be dried up by the sun? Two explanations are possible: either the sea has been dammed out of the area by deposits on its surface, or the land has relatively risen. If the former were the sole explanation, the level of the borders of the Ran would still be uniform. But, according to the figures on the Trigonometrical Survey maps, it would require a depression of about 30 feet to bring the sea-water to the edge of the inner Ran along the northern shores of the mainland, whereas on the edge of the eastern side of Kharir it would require no more than 5 or 6 feet. The land therefore must have risen unequally, which is not an improbable counterpoise to the depression that has taken place over the Sindree basin.

But that deposits also have taken place and that the peculiarities of the Ran result from these will, I think, appear probable from what follows:—In the first place the Ran proper is extraordinarily level; this may be seen from the figures on the Trigonometrical Survey map, where, over wide areas, we find 1, 3, 5, 4, 8, 11, 12 feet, showing a difference of very few feet, and I have myself ridden over 10 miles of it in the rainy season with water on it almost all the way of never greater depth than the knees of the coolies. Yet, beneath the lofty scarps of Patcham and Kharir with their broken undercliff, the shores are swept quite clean, and the débris must have been carried away when these shores were in the making, and when the small cliffs, sometimes 30 feet in height, were being worn away. Now, in such a shallow sea as the Ran would be if the water returned no waves or currents could originate, nor would the harbours, of which tradition tells, be restored, and I conclude that in former times the bottom must have been deeper and have been since filled up.

¹ I do not specially quote in this connexion the curiously worn cliff figured by Mr. Wynne as 'sea-cliff,' because it happens to be composed of irregularly hardened sandstone which even inland weathers into similar fantastic shapes, as near Mundhan.

Again, the Ran is traversed by no rivers; some of those from the northern side of the mainland reach its edge, and the projecting higher alluvial land in their neighbourhood may be taken to represent their deltas. But the great majority begin and end without reaching it. At the lower end they break up into constantly subdividing branches, which dwindle away to nothing. In this latter case all the water which runs even during the heaviest rains is absorbed by the porous soil, and sinks in before it can reach the Ran; in the former case the quantity and velocity of the water are too great for this to be entirely effected, and the remaining water spreads out in a broad sheet on the surface, and so helps to flood the Ran. In the higher parts of the Bani, and in the alluvial area west of Wagir, there are a number of short nullahs, which begin and end in the middle of a flat surface, and sometimes follow each other in a broken line. They indicate the course of underground streams, the roofs of which have fallen in and exposed them in places. Such an underground course must be due to the original valley being filled in with loose and porous material, into which the water sinks. This it may be actually seen to do with great rapidity. I have known 4 inches of rain to fall in the course of a night, and the rivers to be torrential in the morning, but before evening to be all dry again; and one can watch the water sinking in on the bottom of their beds.

The nature and origin of these deposits can also, I think, be determined. With regard to the Bani, as it is separated both from the mainland (except at the two extremities) and from Patcham by an area of Ran, it can hardly be 'a bank formed . . . by the discharge of the Cutch streams,' while the fine micaceous silt of which it is composed could scarcely be obtained from thence. Its composition and the power which it has of retaining water indicate rather that it is a relic of the sea-bottom, corresponding perhaps to a higher level of the submerged bed-rocks. The highest part of the alluvial area between Wagir and the mainland lies in the direct line of an anticlinal which passes from one area to the other, and is doubtless continuous. This may have originated the higher level here.

With these two exceptions, the whole of the features may be put down to the wind and rain. The importance of the former may be argued from the wide sheets of loose sand that lie to the west of Wagir and on the south-western edges of the islands. These are comparatively scarce on the margin of the mainland, and entirely absent along the northern island-coasts: that is, these sands occur where the prevailing strong winds will be stopped and are lacking on the lee of high grounds. Moreover, the rivers that reach the Ran on the north side of the mainland (with one exception where there is higher Tertiary ground to the west) are deflected to the west by the accumulation of sand, etc., on the east; hence the distribution of this sand may be assigned to the wind. Nevertheless, much of the fine dust that is carried by the gales must fall *en route* and beyond the lee of the hills. Here, however, it will be covered by water during the rains, and the finer particles will come

to the surface and form the mud, but the ground as a whole will be fairly firm.

The amount of deposit from rivers must be comparatively, if not very, small. What they bring down must for the most part be left behind when the water sinks in, and then be distributed by the wind. It is only when the rainfall is very heavy, 2 or more inches in 24 hours, that it can escape on to the more impervious Ran, and in this case it will make a comparatively small part of what has fallen there directly from the clouds, for the depth of water there is so immediately sensitive to the fall of rain that it cannot depend for its principal supply on remote sources. The only material that the rivers succeed in bringing directly to the Ran will be of the finest mud, and it will be uniformly spread.

From these causes I believe that the whole depression of the Ran has become shallower, just as the Sindree basin to the east has become more contracted, and in course of time all the surface will become 'alluvial' soil. There are no satisfactory means of ascertaining whether such a diminution of the Ran is now actually in progress, the older maps being only approximate. Nevertheless all comparisons tend in that direction. Thus the western end of the Bani is marked on the old maps as surrounded by Ran, but as joining the mainland by a wide area now under cultivation in the new. The northern edge of the Bani is also separated by Ran from Patcham in the old maps, but I found little or no mud there after 4 inches of rain, while the Ran on the south side was under water. Mr. Wynne mentions places where the Ran is very soft, as between Patcham and Kharir; but it is reported as perfectly passable now. Mr. Wynne also goes out of his way to correct the statement that Bela is joined by alluvium to Wagir; and though no doubt in the dry season, when both are barren, it may be difficult to distinguish alluvium from Ran, I can scarcely think he could have done this, if so many trees had then found root in it as are now to be seen growing in the area. But on the lee of the hills there is certainly no change—the cliffs of Kharir are to-day exactly as he drew them.

It will be seen from the above that the main geological agent in Cutch is now, and for long ages past has been, the wind. The heat of the sun expands the surface-rocks, the rain disintegrates them; but the wind denudes, cleaning them in one place and covering them in another. If this be so, we can scarcely admit with Mr. Wynne that 'the question of how the alluvial plains of India were formed is not cleared up by anything observed in Cutch'; but we may adopt, with a slight modification, another statement of his, that to whatever causes the great plains of Sind and the Ran are due the coast-plains of Western India may also be ascribed. These, indeed, with their wide distribution of thick unstratified deposits of fine soil over areas inaccessible to rivers, and their abundance of kunkur gathered from disseminated calcareous particles, seemed to bespeak an æolian origin, even before a visit to Cutch rendered the activity of the wind in this quarter of the globe an observable fact. Doubtless much of the material is brought down in the first instance

by the Indus and other rivers, but from the neighbourhood of their mouths this has been blown about in an easterly and northerly direction, and has thus afforded a constantly renewed source of fresh fertility.

DISCUSSION.

Dr. W. T. BLANFORD expressed his satisfaction that some of the peculiar formations of Western India had been examined by an English geologist of experience. Indian geologists appreciated the value of independent criticism. Taking the deposits, which varied greatly in geological age, in the order in which they had been treated by the Author, the speaker said that his own knowledge of the subrecent concrete, the Miliolite of Dr. Carter, was small, but the fact that the rock was said to be so calcareous that it was in many places burnt into lime was difficult to reconcile with a purely æolian origin. The deposits described by the Author as boulder-beds doubtless belonged to the subaerial accumulations so enormously developed in Central Asia, Cutch being on the edge of the great dry region in which disintegration is in excess of transporting power, and the rainfall only suffices to carry detritus, including boulders, to a lower level, not to wash it down to the sea. With the so-called quartzite-reefs the speaker was unacquainted. The infratrappean grits were possibly part of a similar formation occurring at the base of the Deccan traps throughout the Nerbudda valley and elsewhere, and known as Lameta Beds. These often contained small rolled quartz-pebbles. The laterites of Cutch were principally of Eocene age, but it was very probable that lateritic deposits of more recent origin also occurred. Some of the peculiarities of the rock were that the two principal types—that supposed to be due, in part at least, to alteration of other rocks, and that which was unquestionably of detrital origin—were remarkably similar, and that the rock is easily reconsolidated from the detritus of an earlier laterite. The Ran must formerly have been much deeper, and according to tradition was navigable; but as late as the time of Alexander the Great the Indus flowed into the western part, and silt must have been deposited with great rapidity. Even now silt-laden water from the sea is driven up the channels on both sides of Cutch in the south-west monsoon, and from this and other causes deposits take place constantly. The high elevation of the Ran alluvium near the land-area of Cutch may be due to rainwash.

Mr. E. A. MARTIN regretted that he could not quite understand how the quartzite-reefs could have been formed in the manner suggested. It seemed to him that if this pseudo-stratified rock were formed by the action of the prevalent south-westerly winds, there would not be that thinning-out arrangement on the north-east and east which the diagram appeared to show. If, however, the occasional winds from the opposite direction were also to be taken into account, the force of the theory was more apparent, and then the prevalence of one wind more than another would be shown by the north-easterly trend of the apices of the beds where the dovetailing took place.

Mr. LAMPLUGH was glad that the Author had called attention to the phenomena of dry erosion, as he had touched the fringe of an important subject which had not yet received its due recognition from the geologists of this country. Over vast areas in various parts of the world the surface-drainage was at present insufficient to remove the detritus brought down the slopes by atmospheric agencies, and the waste-material consequently accumulated around the hills and partially buried them. The speaker had been greatly impressed by these phenomena in Arizona, where, as Dr. Blanford had just remarked with respect to another region, the rocky ground often stood out like islands above the vast spreads of loose material.

Mr. VAUGHAN CORNISH said that the power of the winds in the locality dealt with in Mr. Blake's paper was undoubtedly adequate to carry sand to the situations described; and that, with regard to the calcareous nature of the subrecent concrete which Dr. Blanford regarded as a difficulty, the blown sand of Hale in Cornwall might be cited in support of the Author's views. This was largely composed of shell-fragments, and he had observed that it was more mobile under the action of wind than the ordinary quartz-sand of the sea-shore. Referring to the boulder-beds, he said that the travel of boulders presented some curious features, which he was at present examining. For example, a large boulder travelled badly on fine sand because the sand was readily displaced, and the boulder sank. Conversely, little pebbles travelled with difficulty over a bed of boulders because they were caught in the hollows, and with difficulty surmounted the humps of the rough surface. The best condition for the transport of large boulders, and of blocks or slabs of stone, appeared to be when the bed was composed of pebbles large enough to form a hard floor, but not so large as to allow the boulder to catch in the pits of the surface. It seemed, therefore, that to every size of boulder there should correspond a particular size of pebbles over which the boulder could be transported with the minimum effort.

The AUTHOR, in replying, remarked that the infratrappean grits were, in his view, of entirely local origin and not to be compared, except in point of time, with any deposits elsewhere; while the presence of a single quartz-pebble in them would be destructive of his account of their origin. He admitted that there were laterites in Cutch of Eocene age. Those examined by him, however, which were far more widely spread, gave no indication of age, but were certainly neither derived from the rocks on which they rested nor produced by the reconstruction of such as were so derived. He very much doubted the usual statement that water was driven on to the Ran from the Indus-mouth by the monsoon. He had ridden over part of it towards the end of an exceptionally rainy season, and there was less water on it than the rain that had fallen. Moreover, the strongest winds in Cutch blow in the hot season, but the Ran is not flooded till the rain has fallen. He agreed with Mr. Lamplugh that the study of the phenomena of denudation by aerial agencies in the tropics was a new experience for an English geologist.