VI.—NOTES ON RUSSIAN GEOLOGY.¹

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III. THE BLACK EARTH.

IN a previous paper on the Loess of S. Russia, I endeavoured to discuss its character and origin, and to compare the facts observed with the results obtained by many students of the latest phases of our earth's history. In so doing I overlooked two articles on this subject, which appeared in the GEOLOGICAL MAGAZINE for 1882, and embodied the views held by Baron von Richthofen and Sir H. Howorth respectively. These may be briefly considered ere we turn to a special examination of the structure and relations of the Black Earth. An examination of Sir H. Howorth's statements reveals serious points of disagreement between the theories previously or subsequently suggested, and those which he himself holds. At the outset (*loc. cit.* p. 12) Sir Henry remarks: "Loess is not found in S. Russia, nor yet in the flat country bordering." Such a proposition would be deeply resented by the geologists of that country, and has unconsciously on my part received its answer in my previous paper, where I have shown Loess to be one of the most striking deposits of some of its southern governments, and that it presents all the most important features mentioned as characteristic by Baron von Richthofen.

But Sir Henry goes further, and having successively attempted to crush the various views held on this subject, propounds a theory of his own, which may be considered in the light of the results obtained from the particular district under discussion. The proposition practically may be stated thus: The Loess is a subterranean or volcanic product, which has been subsequently distributed by diluvial action.

This suggestion is also extended to the Black Earth, which, it is stated, is distributed about an apparently recently disturbed mountain focus, viz. the Southern Urals. So far is this from being the case that the Kharkov government, where some of the finest Black Earth districts exist, is 1000 miles from the above mountains, and over 500 miles from the Carpathian range. In reality the country is practically undisturbed, the Tertiary and Cretaceous beds having so small a dip, that the slight rolling of the strata is only observable when the conditions along a line of over fifty miles are passed in review.

Further, there are no traces of volcanic action in any of these central districts. The nearest exposures of eruptive rocks are probably the Carboniferous andesites and rhyolites of the south of the Ekaterinoslav government, the diabases (probably very old) in the W. of the same province, and the basalt mass rising through the Chalk of Central Poland.

Finally, if the Loess were of volcanic origin, it would contain traces of minerals, and possibly of structures produced under such conditions. Such evidence is not only wanting, but is *à priori* im-

¹ For No. I. Cretaceous, see GEOL. MAG. September, 1892; No. II. the Loess, see GEOL. MAG. December, 1892.

probable. Under these circumstances the prime cause operating, according to Sir H. Howorth, in the production of Loess and Black Earth appears entirely inadequate. At the same time, Sir Henry is to be thanked for the number of facts which he has brought together after undoubtedly long and careful reading, though the interpretations he has put upon them may frequently be open to much adverse criticism.

The second theory, that of Baron von Richthofen, is set forth clearly in the same volume as the above (pp. 293–305), and further study of his views, there brought together in a small compass, only serves to strengthen my belief in the great value of his contribution to this subject.

It is not necessary here to repeat how completely the vast majority of the conclusions formulated by him with regard to the Loess have been proved to be applicable to the sandy clay of S. Russia. Further, wherever we find unbroken land-shells, and remains of a typical steppe fauna, there the presence of Loess will have, in all probability, to be attributed to the action of wind.

Baron von Richthofen points out that there are two great classes of places where the dust of continents will rest permanently, and continue to accumulate through ages:

“The first includes the central regions of continents, where the water has no drainage towards the sea, but is collected in inland basins, from whence it gradually disappears by evaporation.” (For further details see p. 298.)

“The second comprises such regions as the prairies, savannas, llanos, pampas, and *steppes*, where there is an alternation of a dry and a rainy season. Where this occurs the amount of dust put in motion and distributed through atmospheric agency can reach enormous proportions.” Such conditions are in a measure prevalent in S. Russia, where a very dry summer frequently succeeds the long winter snows, and an autumnal rainy period follows the summer droughts.

As regards the original glacial origin of the Loess advocated by me, Baron von Richthofen fully agrees in regarding it as partly resulting from glacial trituration. Indeed, he came to the conclusion (“China,” vol. ii. p. 748) that the time of the deposition of the Loess as a steppe formation in Central Asia coincides with the Glacial era in Europe, and in Germany it appears to have been formed after the first, and before (or during) the second glaciation.

Practically, then, the differences between the views held by Baron von Richthofen, and those which I have been led to adopt, are reduced to a minimum. Indeed, one cannot but be struck with the keen appreciation of every point of importance shown by him in his classical treatises. In my previous paper I failed to comprehend how fully he had discussed the subject in its various bearings, and desire here to tender an apology for my unwitting misrepresentation.

Subsequent to the publication of my paper in the *GEOL. MAG.* December, 1892, Prof. Dokoutchaieff of St. Petersburg published a note in the *Bulletin Soc. Géol. Belge*, January, 1893, on the Loess

of S. Russia, in which he rejects the æolian theory, and advocates that of glacial origin.

He considers the deposit under several heads :

1. The Loess may be of glacial, marine, lacustro-fluvial, eluvial, or diluvial origin.

2. The fine-grained Loess of the Poltava or Nijni-Novgorod type, of uniform structure throughout its thickness (except where a few small erratic blocks are present in its lower portions), and containing terrestrial or marsh-living organisms only ; this Loess, covering the watersheds and ancient slopes, is of *exclusively glacial origin*, and represents the finer constituents of the glacial mud deposited over a country already covered with vegetation, and inhabited by the typical rodents of the steppes (as the *Alactaga*, the *Spermophilus*, the *Arctomys*, and the *Lagomys*) ; by the Mammoth and Rhinoceros, and occasionally by the Beaver.

3. A similar Loess occurs sporadically as little islands throughout the whole of the districts bearing traces of glaciation, sometimes in the inferior sands containing erratic blocks, and sometimes in the northern brown clays ; but they become less frequent as we approach the sources of the Russo-Scandinavian glacier.

The Glacial Loess occurs principally (1) at the S. and S.E. limits of the glacier itself, and (2) in that part of the open country immediately contiguous to its probable boundary. In the first case it may cover all the watersheds ; in the second it will only be in those districts where the absolute height is inferior to that of the most elevated points of the neighbourhood occupied by deposits of erratic blocks. For example, in the government of Poltava the maximum height of these deposits above sea-level is 210 metres, consequently in the whole of the lower basin of the Dnieper it should only occur at heights less than 210 metres.

4. One of the most characteristic peculiarities of the Glacial Loess is the presence of the dark-grey glacial mud, forming a definite but interrupted layer, frequently attaining a thickness of over two metres. It is distributed in patches, containing many large grains of quartz, and sometimes calcareous inclusions. The humus percentage is 3.

5. In the eastern wing of the glacier, that of the Don, the Loess is a stratified, coarse, and somewhat porous clay, of a brown-grey colour, but its origin is similar to that previously mentioned.

6. The typical Loess is absent, and cannot in general exist on the very ancient portions of the earth's crust. Exceptions occur along the whole of the Dnieper Valley, at the exterior limits of the glacier, and on the littoral of the Sea of Azov, where marine are interstratified with glacial deposits ; Loess possessing the type characteristics also occurs in the south of Poland.

7. The Asiatic Loess is in all probability partly glacial in origin, but may be also eluvial, diluvial, or alluvial ; only in isolated regions, occupying ravines of greater or less depth, will it be distinctly of æolian derivation. Prof. Dokoutchaieff would also remove the Loess of W. Europe from the æolian category.

8. The diluvial deposits of the government of Poltava are divisible into three horizons: (1) A fresh-water marl at the base; (2) Red clay; (3) Loess; all these, however, passing gradually into one another, whether in respect of organic remains, stratigraphical position, or lithological character. There is no evidence especially favourable to the conception of more than one Glacial epoch.

9. Seeing then that the typical Loess is, in the government of Poltava, restricted to the region of inferior morainic deposits, and only extends beyond them to a slight extent; viewing the fact that it is completely analogous to glacial mud occurring in purely morainic deposits, erratic blocks also being sometimes found at its base; bearing in mind also that Loess may be found below the brown morainic clays—the Loess must be considered as a glacial mud deposited from glacial waters.

This valuable contribution to the discussion of the origin of Loess comes from the pen of a distinguished geologist, who possesses a wide knowledge of the superficial deposits of Central Russia and the Poltava government. It seems to be the case that the theory adopted by an observer depends very much on the district in which he first studies its characters. Those who examine it along the boundary of the old Russo-Scandinavian glacier, a boundary indicated by morainic clays containing rocks of Finnish origin, are at once led to regard the Loess as a product of glacial activities. It immediately overlies the Boulder-clay, is stratified at the base, and clings closely to the ancient line of ice-action. Others, travelling over the southern steppe-land, would be struck by the tremendous activity of the varying wind-currents, giving rise to innumerable dust-clouds, and would not fail (now that Baron von Richthofen has called attention to the importance of these phenomena) to regard these remarkable deposits as resulting from æolian action, a conclusion which would be greatly strengthened by the discovery of perfect terrestrial mollusca, and the presence of a true steppe fauna.

As to the glacial origin of some types of Loess, most students of the subject are now in agreement, and it has, as above stated, been conceded by Baron von Richthofen himself, that such may be the case.

But it is by no means restricted to the boundary of the glaciated area. It extends all along the right bank of the Dnieper, and is said to be very marked on the banks of the Don. It appears, therefore, that when the general drainage directions of the country were first marked out, the flooded waters carried the fine glacial silt with them, and it was only on the establishment of conditions similar to those now prevailing that the rivers, confined to narrower channels, were engaged in denuding the deposit which their ancestral streams had assisted to transport.

Whilst on many points we are in full agreement, Professor Dokoutchaieff scarcely does justice to the vast importance of æolian activities operating during the many years that have elapsed since steppe-conditions came into existence.

After a reconsideration of the literature of the subject, I find no

reason to modify the propositions submitted more than a year ago (*GEOL. MAG.* December, 1892). These are: I. That the Russian Loess was originally the fine mud derived by the triturating action of the ancient glacier. This view has been still more strongly urged by Prof. Dokoutchaieff. II. That it was deposited by slowly-moving waters (this would embrace the aspect adopted by Prof. Armachevsky), and was distributed by rivers in flood. This latter action would account for the great southward extension of the Loess along the valleys of the Dnieper and the Don, and would by inference suggest that the general courses of these two great streams were already marked out. The thick deposits in the Danube and Rhine valleys may be explained in the same way. Here, let me say, seems to be the time for considering that mighty diluvial change, the Deluge, which has left its mark on the old historical records and traditions of so many nations. Sir H. Howorth weakens his argument by introducing prime causes, which, it is to be feared, he will have great difficulty in proving; but as one deeply interested in modern as well as ancient history, I should be delighted if he could bring our geological data and the monumental references into perfect accord. Only by a frank acceptance of a Glacial period in some limited form, will he be able to attack the serried ranks of the Uniformitarians with some hope of success, but combining the results due to its melting, and the changes in the mountain-structure of E. Europe, he may yet hope to carry on a not unsuccessful warfare. III. The glacial and diluvial actions were mainly restricted to the earlier periods of post-Glacial history, and determined the general geographical relationships of the Loess; but it was not long ere the wind became the redistributive factor, and, acting through long years, established those numerous characteristic features which can only be explained by means of an æolian theory of origin.

Having now briefly reconsidered some of the theories with regard to the origin of the Loess, let us now turn to the study of the Black Earth as it is developed in S. Russia. It has long attracted the attention of geological observers, not only on account of its striking appearance, but also because of its rich fertility as a soil. Its wide distribution has been specially noted by Sir R. Murchison ("Russia and the Urals," p. 557), where he says: "Its N. limit is a waving line, passing from near Kieff to Tchernigov, a little to the S. of Lichvin along the 54° latitude line, then advances E. to 57° N. latitude, and occupies the left bank of the Volga between Nijni Novgorod and Kazan. It is also abundant on the Kama and Ufa." Its wide occurrence in Siberia is then noted, as also its presence on plateaux more than 1000 feet above sea-level in the Bashkir country, and on both flanks of the S. Urals. "It does not occur much in the space occupied by the Aralo-Caspian beds, nor is it found S. of the granitic axis. It lies on rocks of all ages and is found at very different levels. The northern drift is succeeded, if not actually overlapped, by the Black Earth." It has, in reality, a far greater western extension than has been ascribed to it in the above lines, and I

have noticed it not only in the Jitomir district, about a hundred miles to the W. of Kieff, but also in passing from Russia into Austrian Poland. The last locality at which it was actually observed by me was Jaroslavl, a town situated on the railway between Cracow and the old city of Premysl. Beyond that point Loess alone seemed to be the prevalent surface deposit. The first point of importance is the close connection existing between the Loess and the Black Earth. Murchison included both deposits under the common term *Tchernozem*; but this latter, in the truest sense of the term, should be restricted to the upper strata, rich in humus contents. Schmidt regards it as practically identical with Loess (*Zeits. Deutsch. Geol. Ges.* vol. xxix. p. 830-31). Richthofen states: "The black colour, which is proper to the uppermost layer only, appears to result solely from the formation of vegetable mould, the deeper portions showing the brown colour of the Loess, together with its structure, although this appears to be less perfect than in the former case." Personal observation has left no shadow of a doubt on my mind as to the intimate connection between these two types of deposit. Reference has already been made as to the gradual passage from pure Loess to Black Earth observed in a ravine at Kharkov, and an example of the interlamination of the two at their point of junction has been cited from Bielgorod.

But these cases, developed on a small scale at the above localities, may attain much greater proportions. Repeatedly the dark brown humus-bearing bed forms distinct lenticular patches (often 3 or 4 feet in thickness at the centre and extending some little distance in a horizontal direction) running through the yellow clay.

The further and final stage is attained when the Black Earth forms a distinctly marked stratum, actually overlain by a true Loess. This is beautifully observed in the ravine near the railway station at Kieff, where a thick layer of Black Earth is overlain by some seven feet of Loess.

But the inter-relationships of the two deposits are still further brought out if a closer examination be made of the materials composing them. Not only does Black Earth agree with Loess in its superficial position, its existence at most varying level, its occasionally purely local development, but it possesses the same want of consistency when rubbed in the fingers. The chemical composition is in most respects similar. Thus Loess may be said to be composed of pure silica in the form of sand-grains, clays, calcareous constituents (as concretions frequently), and oxide of iron, acting as a colouring material. Compare with this the analysis of Black Earth made by Mr. H. Phillips for Murchison's work:

Silica	...	...	...	...	...	...	...	...	69.8
Alumina	...	...	...	...	...	...	...	...	13.5
Lime	...	...	...	...	...	...	...	...	1.6
Oxide of Iron	...	...	...	...	...	...	...	...	0.7
Organic Matter	...	...	...	...	...	...	...	...	6.4
Traces of Organic Matter	H ₂ SO ₄ , Cl., etc.	...	...	...	...	...	...	...	1.7

The amount of silica is always very noticeable. The high percentage is due to the large number of polished sand-grains always present in samples of Tchernozem. These, however, vary greatly in size, from the grains $\frac{1}{8}$ of an inch in diameter already mentioned from Bielgorod, down to particles almost invisible to the naked eye. The variations appear in some respects, to follow the rule, that the further south the deposit the smaller the sand-grains contained in it. It would require a close examination of a large number of samples before this could be established as an absolutely proved fact.

In doing so, particular care must be taken to select the specimen from an uncultivated spot. This is now a somewhat difficult task, so much of the steppe-land having been brought under cultivation. Examination and enquiry have both, however, led to the same result—the deeper the earth from the surface the more sand-grains does it contain. Both in character, position, chemical analysis, and history, the Black Earth is thus intimately connected with the Loess, and is due to special circumstances affecting the latter.

A historical review of the whole subject is of particular interest, as showing the various possibilities which have been brought forward to account for these soils, the treeless prairies and steppes, and the sharp distinctions between present geographical conditions in N. and S. Russia. At the same time a remarkable parallelism is to be observed between the theories propounded in America, and those which have from time to time been enunciated by Russian geologists. In the Journ. Poltava Agricult. Soc. February–May, 1891, Prof. Krasnov has given an admirable summary of the latest position of these discussions as viewed from Russian standpoints. Many of his conclusions have struck me as being of such general interest that it may be advisable to include them in the present discussion, especially as they are at present practically buried in a local Russian journal. Pallas was one of the first to consider the origin of the Tchernozem. He, in common with later observers, regarded it as having been formed on the bed of a gradually-dying sea, the water-plants and other organisms of which, rotting in contact with the atmosphere, formed its mass, and gave rise to its richness in nitrogenous products.

Murchison (*loc. cit.*) considered it as not having been formed *in situ*, but derived from the disintegration of the Black Jurassic shale, which is found in the more northern districts of the empire. He held that powerful currents had acted as the transporting agents, though no reason was assigned for the production of this rush of tumultuous waters. At the present day ice-action explains all these varied results in a more reasonable manner.

Ruprecht seems to have gone half-way in regarding the Black Earth as of grassy origin, though he still held the view that the boulders strewing the northern parts of the country had been brought thither by ice-bergs.

But, with the acceptance of the theory propounded by Nikitin, Krapotkine, and Inostranzeff, that a great fresh-water sea did not cover N. Russia, but rather that a huge ice-sheet spread over the face of the country, a new aspect was obviously given to the discussion, and it was sought to explain the phenomena by other means.

The former presence of forests was naturally regarded as necessary to account for the formation of such a soil, if all aqueous action were rigidly excluded. Thus, Bogdanoff and Polimpsest considered the Black Earth to be the humus resulting from prehistoric woods, cut down by hordes of nomads. For the extensive character of such forests they sought to find evidence in the works of Herodotus.

In his work *Melpomene*, Book IV., Herodotus gives some very concise descriptions of the nature of the country lying between the Dnieper (Borysthenes) and Don (Tanais). He appears, indeed, to have made this region an object of special research. For instance, it is expressly stated that the Androphages (inhabiting Volhynia) lived northward of a region of vast deserts (the great Loess-covered plains east of the Dnieper). In another place it is stated that the entire country occupied by the nomadic Scythians is without trees. (This is evidently the district we are specially considering.) And this is still more forcibly emphasized when considering the country N. of the Azov Sea. The country of the Sauromates commences at the extremity of the Palus Mæotis, and occupies the country that lies to the north; a fifteen days' journey is required to traverse it; *one sees there neither wild nor fruit-bearing trees*. Beyond this is the country of the Budins, where trees are in abundance.

It is also interesting to note that to the north of the country between the Dnieper and Don, only marshes and land without inhabitants were believed to exist.

Far, therefore, from proving the existence of former forests, Herodotus strongly argues in favour of the desert character of these regions, and indeed further cites Scythian traditions which fully confirm the view that this country was treeless ever since the earliest historical records were written.

It is necessary to emphasize these points, because some support might be lent to the opposite view, if the remarkable statements made by Mr. Floyer regarding the former fertility of many of the Egyptian wadis be considered.

The discussion in America has run to a large extent on absolutely parallel lines, and Mr. J. W. Rodway (*Geographical Journal*, March, 1894) has shortly resumed the views propounded, and arrived at a conclusion differing in no respect from the one now enunciated, viz. the areas in question never were timbered.

Mr. Miller Christy, in a paper read before the British Association, held that the absence of the trees was due to prairie fires, in general started by Indian tribes. But, as Mr. Rodway points out, these fires only affect the stems and branches, leaving the roots of the trees entirely untouched. That these splendid plains have not borne these growths for many centuries past, is shown by the fact, long ago observed by Murchison, that traces of root-fibres are altogether absent.

Prof. Krasnov also argues that woods do not form Tchernozem. On the contrary, they form a subsoil in which the component parts are of the size of nuts, of an ashy-grey colour, and poorer in humus than the Black Earth proper. In addition, this soil bears traces of

the roots of trees, at the same time possessing considerable powers of resistance to pressure, that is, failing to crumble readily when rubbed between the fingers.

Researches in the Nijni Novgorod and Poltava governments prove that a hundred years after the cutting down of the forests the soil still preserves its original character. If woods be not the source of the rich deposit, the present character of the steppe areas may serve to furnish a solution to the problem. There are still some districts not yet touched by the agriculturist, where the virgin soil produces a rank vegetation, luxuriant or sparse according to the amount of rainfall. A notable growth is a peculiarly wiry grass, that blunts the edge of the sharpest scythe. On the great plains E. of the Dnieper, in the region not devoted to the cultivation of cereals, Euphorbiaceous plants and Compositæ largely predominate. Indeed, so favourable is the soil for the growth of the latter, that one of the Thistles, *Xanthium spinosum*, (introduced some thirty years ago with the Bohemian settlers) has become a widespread pest, and threatens even to supplant the indigenous flora.

In travelling over these plains, I early came to the conclusion that the decomposition of these plant-remains, and the intimate intermixture of a portion of their protoplasmic contents with the particles of the Loess soil, were the true causes of the formation of Black Earth. In the autumn the dried stems which roll over the steppe, often bound together in large bundles, bear witness to the large amount of plant-waste which must then go on. At the same time the roots remain in the soil, giving rise to great matted fibrous layers which prevent the penetration of water to the lower levels. Indeed, there are circumstances in which such roots may attain the thickness of a man's thumb. Many of them will probably undergo decomposition, but, thanks to the fine-grained character of the soil, the materials necessary for the production of the humus would be concentrated rather than diffused through it.

Von Richthofen (*loc. cit.* p. 300) remarks: "The Black Earth of Southern Russia is growing (owing to dust transported by wind action). The black colour, which is proper to the uppermost layer only, appears to result solely from the formation of vegetable mould, the deeper portions showing the brown colour of the Loess, together with its structure, although this appears to be less perfect than in the former case."

Prof. Lewakowsky, of Kharkov University, has approached this interesting subject from the chemical point of view. He finds that the organic matters form, at a shallow depth, definite chemical combinations with the soil constituents, alumina, iron oxides, and calcium compounds. These compounds are exposed to the oxydizing action of the air, becoming gradually of darker tints, till eventually they form the Tchernozem itself. He explains the absence of Black Earth in forest regions as follows: The soluble organic materials which are prevented from passing into the soil, owing to the thick deposit of fallen leaves, undergo changes under the influence of the atmosphere, and become insoluble or even burnt by its oxydizing

action. I would suggest that in all probability, even if these materials did sink into the ground, its loose constitution would prevent the formation of any deposit as rich as Black Earth. Owing to the matting of the roots above-mentioned, it is always necessary to remove the upper layer of black soil round any spot where trees are to be planted. Mr. Christy has maintained that trees on the treeless plains grow readily. Mr. Rodway admits this to be true in part. For Russia, I may venture to go further, and say that Black Earth is in many respects absolutely inimical to the growth of wood or forest.

(To be continued in our next Number.)

VII.—REMARKS ON MR. MELLARD READE'S ARTICLE "ON THE RESULTS OF UNSYMMETRICAL COOLING AND REDISTRIBUTION OF TEMPERATURE IN A SHRINKING GLOBE AS APPLIED TO THE ORIGIN OF MOUNTAIN RANGES."

By A. VAUGHAN, B.A., B.Sc.

[Addendum to paper on Corrugations of Earth's Surface.]

AFTER I had written the above dissertation and sent it for publication my attention was kindly drawn to a paper, dealing with the same subject, communicated by Mr. T. Mellard Reade, C.E., F.G.S., to the Liverpool Physical Society, and since republished in the May number of the *GEOL. MAG.* for this year (p. 203).

As I was not aware, when engaged upon my own paper, of the views which Mr. Reade had expressed, I feel that some discussion of the theory put forward by that writer is of necessity demanded. Since, however, Mr. Reade's views are extremely antagonistic to those which I have already endeavoured to explain, such discussion will find its most convenient place as a brief addendum to what I have already written.

Mr. Reade's paper opens with a statement of some results arrived at by Lord Kelvin in his classical paper on the "Cooling of the Earth"; since the utmost importance is necessarily attached to the conclusions arrived at by so eminent a physicist, it is very important that such results should be quoted correctly, and also that their statement should be accompanied by a short exposition of the assumptions on which they are based. I propose then, in the first place, to point out, as plainly and briefly as possible, the method of reasoning employed and the data assumed in Lord Kelvin's essay; this I regard as especially necessary, because Mr. Reade not only mis-states some of the most important results, but also invests them with a rigidity to which the writer expressly lays no claim.

The essence of the employment of Fourier's equations depends upon assuming that we are dealing with nothing but the *conduction* of heat from point to point. Thus, no heat must be supposed to be used up or evolved in changing the physical state of the material under consideration; for example, we cannot suppose that any large portion of the mass has, during the time we are considering,