IV.—Notes on the Growth of Soil.

By G. H. Kinahan, M.R.I.A., etc., etc.

PREVIOUS to writing "Suggestions on Denudation,"[2] I had not seen Mr. Darwin's paper "On the Formation of Soil;"[3] since then, having read this essay, it appears to me that instead of Darwin proving "the disappearance of stones, etc., needs no growth of soil," he advocates in a great measure the statement put forward in "Suggestions on Denudation." For Darwin clearly proves that any foreign substance placed on grass land will be gradually covered up *by a growth of soil over it.* This soil, however, he seems to believe to be entirely due to the labour of earth-worms, who excavate in the ground under the foreign substance and deposit over it. From this it would appear that this eminent observer considers that the *total thickness* of the soil is not increased upwards by mould formed from vegetable decay, but that all is taken from below the foreign substance and placed above it,[4] thereby adding to the thickness of the upper stratum of the mould and diminishing the thickness of the portion below the foreign substance. This, within certain limits, may be correct; but can anyone assert that the decay of the yearly growth of vegetable matter is *nil*, and that it cannot possibly add its mite,

[1] The Belemnite, which I have stated in my lists as *B. semicanaliculatus* (non de Blain.) is without doubt the *B. Brunswicensis* v. Stromb. During a recent visit to Germany for the purpose of studying the Neocomien strata of that country, I received much very kind assistance from several geologists, and especially from M. Von Strombeck.—J. W. J.

[2] Geol. Mag. No. 57, Vol. VI. p. 109.

[3] Trans. of the Geol. Soc. 2nd series. Vol. v. p. 505, *et seq.*

[4] Although not actually stated, it seems to be inferred that the soil increases in thickness downwards, the worms burrowing into the subsoil and thereby changing its nature. This subject will hereafter be referred to.

no matter how small, to the thickness of the soil? If the above is the case, how can we account for the growth of peat bogs in Ireland and other countries? On the site of all peat bogs (or the bogs in the low flat country) there originally was vegetable soil, in which trees and lesser plants grew;—on this, by the decay of the vegetable matter, a spongy soil was formed that retarded the drainage, and was well fitted for the growth of such mosses as the *Sphagnum*, which began to luxuriate. The earthworms, it is probable, helped to form the vegetable mould in the first instance, but after the drainage was stopped they could not inhabit the place, therefore their part in the work ceased and only the decay of the successive growth of the plants could add to the surface. The growth of the bogs has been ably treated by Portlock in the Memoirs of the Ordnance Survey of Londonderry, and by Nimmo and Griffith in their "Bog Report,"—therefore it is unnecessary to enter further into the subject. Even from Darwin's examples it would appear evident that the growth of soil cannot alone be due to worms; for spread a layer of lime on a field and the worm, to quote that Author, "is unable to swallow coarse particles, and the finer earth lying beneath would be removed by a slow process to the surface." Thus eventually all the matter that could be reduced small enough to be swallowed by the worms would be brought above the lime, and only the pebbles and fragments of stones left below; so that above there ought to be only this fine earth, while below there ought to be only gravel and sand. This is the result that ought to occur if to the worms alone is due the vegetable soil; but if they worked in conjunction with the decay of the vegetables, and principally in the soil due to that decay, there would be a continual shifting of a soil in which few pebbles ever existed. This, however, would necessitate the surface of the subsoil remaining permanent,—a subject, the consideration of which must be deferred till further on in these notes.

Nearly all the examples put forward by Darwin were observed in rich highly cultivated ground where earthworms abound, therefore the growth of the worm-formed soil must have been more rapid than would ordinarily be the case, and the part added, through the decay of the vegetable matter, may not have been very apparent; Nevertheless, in one instance, he seems to prove that the vegetable decay, not the earthworms, buried the foreign substances; namely, that of the boggy field which was covered over with a coat of gravel, and in two years and a half afterwards, there was a peaty layer three-fourths of an inch thick grown over it. Very similar instances occur, and may be examined in many places in Ireland among the reclaimed cutaway bogs, or as they are locally called *Moors*. These moors are generally tilled for a few years previous to being laid down in grass, after which a coat of marl or gravel is spread on them. If they are to be kept in good heart more gravel or marl from time to time must be applied to them, and the drainage attended to; but if they are neglected, as is too often the case, they will attempt to return to their former state, and in a short time a

layer of peaty soil will grow on the marl or gravel. It is not uncommon in these moors, if a section is opened through them, to see one, two, or even three of these layers of foreign matter, pointing out the number of times the moor was "brought in," and afterwards allowed to run wild.

Any one acquainted with bogs well knows that earthworms cannot live in them. They will be found in reclaimed moors in the made soil, both while they are in tillage and grass land, but once the original boggy nature again predominates they disappear, so that they cannot assist in making the upper stratum of soil above the gravel ; moreover, if this upper stratum is examined, it will be found to be of the same plaity or rudely laminated structure, similar to that of all bogs that grow from the successive layers of decayed vegetable matter.

Those conversant with highly cultivated rich grass land, can scarcely have failed to remark the enormous worm-work that yearly goes on, but this is not the case in all lands, for in many (not all) over chalk and limestone there is little or no worm-work, and also in poor sandy soils or in 'slob-land' newly reclaimed from the sea. On many chalk and limestone lands as mentioned in "Suggestions on denudation," "stones grow," but in poor sandy soils or in slob-land, although it may be the work of time, yet eventually there will be a surface soil formed by the decay of the vegetable matter, and all the stone will be covered up by the growth of the soil. In such soils at the beginning of the growth of the vegetable clothing, earth worms will be rare ; in fact they cannot live without organic food, therefore until the vegetable life began they could not exist. As the vegetable soil increases, so will the earthworms, showing that the two agents work together, also that the growth of the vegetable soil is due, not only to its decay, but also to the worm-work ; when the soil becomes rich, the latter agents do the major part of their work, but while it was poor, they could do little or none, owing to the paucity of their number, so that to vegetable decay was due the growth of the first mould.

Lands with a permanent turf or sod, that has remained untilled for ages, may be used either as pasture or the grass may be cut to dry into hay. If the surface soil were due only to the earthworms, apparently, in a field all of which has the same fertility, subsoil, etc., if a part is used as permanent pasture, while from the rest hay is always cut, the condition of the whole ought to be similar, and there would be a gradual increase of the mould of the same. This, however, is well known to the farmer not to be the case, for the surface will increase on the pasture-land, but not on the permanent meadow, except the latter is cut early enough to allow of a second growth or "after grass," which is left to rot on the ground. To counteract the injurious effect of removing all the vegetation, which naturally should decay on it, from the meadow-land, the land has to be top-dressed with foreign substances ; moreover, all farmers state that mowing machines are harder on meadow-land than hand mowing, because the latter do not or cannot cut as close as the former, and

for similar reasons horses are harder on grass land than either sheep or cows. It may be said that on pasture land the vegetable products are not allowed to decay. In one sense they are not, but if they are eaten off by the cattle they are returned again to the surface, their fertility being increased from their having been used as animal food.

In a comparison between meadow and pasture land, the "hand joined in hand" work of vegetation and of the earthworm appears conspicuous. Examine a meadow field after the hay is cut, and the worm-works will be found to be few and far between, but if the after-grass is allowed to rot on the land, and during that process the field is examined, worms will be found working everywhere among the decaying vegetable matter; and in the pasture-land there will be a hundred worms for every one in the meadow-land, the largest portion being found under and associated with the decayed vegetable matter in the droppings from the cattle.

Although, as previously stated, Darwin seems to infer that the thickness of the mould does not increase upward, that is, its height is not added to by an increase from the decay of the vegetable matter, although the full thickness may be increased by the earthworms working up part of the subsoil; yet in no instance is a fact put forward that would favour such a supposition. But on the other hand, facts may be stated which apparently would prove that it does increase upwards. To give a homely instance. Previous to the introduction of wire railings, the usual fencing in parks and pleasure grounds were iron hurdles with double knee-shaped legs. When the hurdles were placed in position, they were forced down till the knees were on a level with the surface of the ground, but in a few years the knees were not only covered, but a greater or less thickness of soil had grown over them. A stone, a piece of crockery, or some such substance, although not probable, might possibly sink bodily with the whole surface of the ground as the earth was excavated from below by the earthworms, and carried up by the same agents to be placed on the surface; but this could scarcely be the case with a railing half a mile or more long, and yet over every knee I have observed an equal growth of mould. But if there is an increase upwards in the thickness of the soil due to vegetable decay, it would be natural to expect that each knee of the different hurdles should be gradually and at the same time covered.

Darwin brings forward a startling fact in favour of the burrowing powers of the earthworm, in his quotation from Mr. W. Lindsay Carnegie's letter, however that may possibly be an exceptional case; for in the alluvial earth, forming some of the flats adjoining rivers in Ireland, such as that along the Little Brusna, the river which divides Tipperary from the King's County, I have, during the arterial drainage works in operation nearly twenty years ago, observed the burrows of the earthworms at great depths, but usually they seem incapable of penetrating into the ordinary sub-soils that occur in Ireland. The gravelly sub-soils formed by the Esker or post-drift gravels ought to be soft enough for them to work into, yet I never remember remarking a worm-burrow in them. The

usual sub-soil, the limy Boulder-clay drift they never burrow in, and a sub-soil frequent in some places, namely, a stratum of bog-iron-ore, they could not possibly enter; yet over all these different kinds of sub-soil the surface mould increases if the land is laid down in permanent grass. The beginning of the soil forming the land over a subsoil of bog-iron-ore, cannot possibly be due to anything but chemical action and vegetable decay, as no worm-work could have been done; and if in such an instance a surface soil can be formed without their aid, why is it that similar work does not go on in other places? Moreover, in such places the work is carried on under most adverse circumstances, for every one ought to know that a bare surface of limonite is not a very favourable place for vegetation, and usually it appears due to the decay of the water lodged on the surface, with perhaps a slight disintegration of the underlying mineral, from which are generated lichens and mosses, and eventually a peaty soil. It, however, is added to very gradually, for in dry weather, there being no depth of earth, the vegetation is withered away.

Land that for years has been tilled to one depth will have a surface to its sub-soil like a road, and this is so well known, that to counteract it sub-soiling has been introduced. If such land is laid down in grass and subsequently again broken up, the surface of the sub-soil, caused by the former tilling, will be found intact; but the depth of the mould will have increased in proportion to the number of years it has remained under grass. This increase cannot take place below, as the old sub-soil surface still remains, therefore the mould must have increased in thickness upwards, and necessarily by the decay of the vegetable substances. It may be said that this is an exceptional case; for naturally this road-like surface would not be formed over the subsoil. However, if the thickness of the mould increases downwards, is it not remarkable that over each different kind of sub-soil the thickness of the vegetable mould should be so uniform? Naturally the mould is only a few inches thick over gravel, a little thicker over clay, a good depth over a sub-soil formed of a combination of clay and sand, more especially if it is limey, while over an alluvial sub-soil it may be any depth; unless, indeed, that *chemico-fluvial* denudation in each several case has removed an exact equivalent from the surface for the increase below; but this is highly improbable.

Before leaving the subject it should be mentioned that there are remarkable facts in connection with the decay of drift and its change into silt, that may bear on the growth of soil. One of these is well exemplified in a river that is partly subterraneous and partly sub-aerial; flowing partly between banks of Boulder-clay-drift and disappearing, not in an open vent, but through a filter formed of the insoluable parts of the drift. Such a stream, during floods, wears and cuts away the drift banks, and when it dries up there is a thick coat of fine silt over the natural filter; while in the bed of the stream there will not be blocks and fragments of rock in due proportion to those that were in the drift denuded away during the

previous winter, and consequently much less than the quantity that ought to have been left as a residue from all the mass of the drift carried away.[1] From this it would appear that some drift can, in a way not yet explained, change into fine silt, the blocks and fragments of stone disappearing, and in some such way it might be possible that the stony residue from the worm-formed mould might also disappear, and thereby the thickness of soil be increased from below; however, against this idea still remains the facts stated as to the thicknesses of the mould over the different kinds of sub-soils.

From the above notice it appears that the writer cannot agree with Mr. Darwin in believing that in the formation of the surface mould "the whole operation is due to the digestive powers of the common earthworm." But although Darwin disagrees with him in this particular, yet *all the observations of this eminent Naturalist go to prove that in grass land chemico-fluvial denudation is stopped*, unless, indeed, part of the worm-formed earth is carried off by that denudent. The latter, however, could scarcely be possible (save in some exceptional case), for if this agent so acted, it must reduce the quantity of the worm-formed earth, which otherwise would be much more considerable than at present.