

steam; for this propensity of the steam to absorb heat, or rather of the metal to part with it, must obviously be greater the higher the temperature of the boiler and its appendages, that is, the higher the original pressure of the steam. No wonder, then, that equal weights of steam, at first so different in density and temperature, should, when equally dilated, and received in equal quantities of cold water, produce equal rises of temperature; as is shown somewhat differently in the *Philosophical Magazine* for July 1826, p. 38. It would, however, be running still farther into the opposite extreme to suppose that equal *volumes* of saturated steam should, at different temperatures, contain equal quantities of heat. There is no reason to doubt that the more dense volume will always be found to contain more heat, though, from what we have just shown, this cannot increase in so high a ratio as the density does, because that would be precisely Clement's doctrine over again.

Observations on the Loamy Deposit called "Loess" of the Basin of the Rhine. By CHARLES LYELL, Esq. F. R. S. Foreign Secretary to the Geological Society, &c.* Communicated by the Author.

DURING the last summer, I had opportunities of examining the remarkable deposit called by the Germans "Loess," in several parts of the valley of the Rhine, between Cologne and Heidelberg, and also in some parts of the country of Baden, Darmstadt, Wurtemberg and Nassau. The observations made during this tour have caused me to modify some of the opinions which I formerly entertained and published respecting the probable origin and mode of deposition of this formation, and its relation to the newest volcanic products of the Lower Eifel. As much has been already written on this subject, I shall confine myself in this notice to what I saw during my late excursion, and shall give my observations nearly in the order in which I made them, pointing out afterwards the general conclusions to which they appear to me to lead.

* Read before the Geological Society of London, May 7th 1834.

It may be as well to state, that the Loess consists of a pulverulent loam of a yellowish grey colour, containing a certain quantity of carbonate of lime, according to Leonhard about a sixth part. When not associated with gravel it exhibits no signs of stratification. It contains almost everywhere imbedded terrestrial and aquatic shells of species still living in Europe, which have usually lost their colour, but are for the most part entire.

The Loess is found with its usual characters reposing here and there upon the gravel of the plains of the Rhine at Bonn, where I first examined it with attention, and patches of it are seen of much greater thickness on the flanks of the Siebengebirge, on the right bank, and at a corresponding height near the summit of the low hills which border the plain on the opposite bank. In all these localities terrestrial shells, chiefly *Helix* and *Pupa*, are by far the most abundant.

I employed a collector for a fortnight in obtaining shells from a deposit of Loess of considerable thickness, which is laid open on the right bank of the Rhine about a mile and a half below Bonn. The individual shells procured in an entire state amounted to 217 in number, not a seventh part of which were of aquatic species. The proportions were as follows :

Terrestrial—*Helix* 167, *Pupa* and *Clausilia* 18; 185 individuals; *Aquatic*—*Lymnea* 17, *Paludina* 10, *Planorbis* 5; 32 individuals;—217.

In order to compare these fossils with such shells as are now drifted down by the Rhine, I made a collection of the latter at low water from the mud and sand of the shore of the river for several miles above and below Bonn. Along the beach is a line of rubbish composed of small pieces of drift wood, leaves, weeds, sand, and other matter, cast up principally by the large waves raised by the steam-packets, as they cut through the water. Here the greater number of drift shells occur, and I collected 273 individuals which were in the following proportions.

Terrestrial—*Helix* 133, *Pupa* and *Clausilia* 12, *Bulimus* 2; 147 individuals; *Aquatic*—*Paludina* 48, *Planorbis* 34, *Neritina* 28, *Lymnea* and *Succinea* 5, *Unio* 6, *Ancylus* 3, *Cyclas* 2; 126 individuals;—273.

If I may be allowed to draw any general conclusion from this comparison, it would appear that, in the waters of the Rhine,

as in the loess, the drift-shells belong chiefly to terrestrial species, and in both the great mass of the shells are referable to the same genera, the principal difference consisting in the absence from the loess of species of the genera *neritina*, *ancylus*, and *unio*. The only bivalve-shells I ever happened to meet with in the loess, were *Cyclas fontinalis*, *Drap* *.

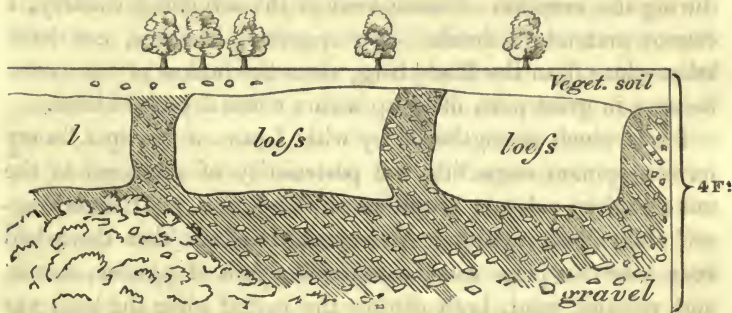
It may be well to observe here, that, in some places where the bank of the river is wholly or partly composed of loess, the fossil shells are often washed out, and may be found entire on the shore; and they might, in such cases, unless great caution were used, be confounded with the more modern shells drifted down by the Rhine. I was careful to guard against this source of error, by collecting chiefly from spots far from the loess, and by rejecting those which, by their want of colour, or by the circumstance of their being filled with loess, resembled the general characters of the fossils. The colour of the more modern specimens affords in general a safe criterion for distinguishing them from the fossils; and I feel sure that there was scarcely any intermixture in the sets above compared, or only two or three *lymnea*, at least, were doubtful.

The greater part of the shells drifted by the Rhine agree specifically with those which are buried in the loess; and if I had enlarged my collection, the correspondence would no doubt have been much more perfect, for the shells of the loess vary in different localities, and those now brought down by the Rhine probably vary equally at different seasons. As the drift shells of the Rhine agree with those of the loess, so the sediment of that river bears a very close resemblance to loess. This was first pointed out to me by Professor Noegerath, and it has lately been confirmed by Mr Horner's experiments on the quantity and nature of the solid matter brought down in the waters of the Rhine at

* I found several specimens of this with both valves entire, together with *Valvata piscinalis*, in the interior of an individual of the *Lymnea ovata*, in loess at Odenau, near Bruchsal. Hard calcareous concretions, in the same loess, contained shells of recent *helix* and *clausilia*, which were thus embedded in solid limestone. In the third volume of my *Principles of Geology*, Appendix, p. 58, I included *Cyclas palustris*, and *C. lacustris*, *Drap.* in a list of loess shells; but I afterwards ascertained that they had been brought to the spot in mud used to fertilize the soil. Probably they are to be found in loess.

Bonn*. The circumstance must, in part, be ascribed to the rapid degradation of loess, which is constantly going on throughout the valleys drained by the Rhine and its tributaries, but it also shews that the waste of other rocks in the same districts produces a sediment very similar in its nature to loess.

It is well known that the loess rests on the gravel of the plain of the Rhine. This superposition is well seen on the left bank of that river, about a mile above Bonn, where the loess fills up hollows in the gravel, and presents the appearance represented in the annexed sketch.



I conceive, that in this instance, small rills or torrents must first have furrowed the upper beds of gravel, leaving small trenches with vertical and occasionally overhanging walls, and then the waters holding loamy sediment in suspension must tranquilly have overflowed the spot and thrown down the loess until it first filled up the cavities, and then formed a continuous overlying mass.

The next subject to which my attention was called on my way from Bonn to Mayence, was the relations of the loess to some of the more modern volcanic formations of the Lower Eifel.

The volcanic hill called the Roderberg, situated on the left bank of the Rhine, about four miles above Bonn, and immediately opposite the celebrated Drachenfels, is well known. From the perfect form of the crater at its summit, and the appearance of its scoriæ, it has always been supposed to owe its origin to one of the most modern eruptions of this country. In the mid-

* See Proceedings of Geological Society 1834.

dle of the crater is a farm-house, where a well was sunk in July 1833: at that time I visited the spot in company with Mr Horner, and we found, to our great surprise, that the materials passed through were loess, covered by a small bed of cinders and cindery loam. The mass of pure loess was 65 feet in thickness. How much deeper it extended was not ascertained. We did not find any shells, but we were only able to examine a small quantity of loess which had been taken from the well. The usual calcareous concretions were in abundance. Whether the overlying cinders were alluvial or showered down from the air during the eruption of some vent in the adjoining country, I cannot pretend to decide. No eruption, however, can have taken place from the Roderberg, since the hollow of the crater became, in great part, filled up with a dense deposit of loess.

I was much strengthened by what I saw on this spot, in my former opinion respecting the posteriority of the loess to the more modern volcanic eruptions of the Eifel; yet I found myself obliged, on revisiting Andernach, to admit that there had been near that place some considerable falls of pumice, scoriæ, and volcanic sand, both during the period when the loess was forming, and since its formation. I am aware how easily pumice and other light volcanic matters may be drifted during heavy rains, and that the waters capable of depositing the loess might easily have washed away such transportable matter, had any of it been already strewed over the land before the loess was formed. In that case some alternations of volcanic cinders and loess might undoubtedly have been caused, even though all volcanic eruptions had ceased before the deposition of loess began. With due regard to these views, I compared with attention the appearances near Andernach with those which I had seen in the neighbourhood of active volcanoes, and concluded, contrary to my original idea, that some volcanoes must have been in activity while the formation of loess was still going on. In the hollow way called the Kirchweg, immediately above Andernach, the loess, having its usual characters, is still seen, with here and there an included fragment of pumice, or a small quartz pebble. I collected several shells from it, and Mr Steininger gave me a list of species which he procured from the spot. The thickness of the loess in this and other adjoining places (as in the high road

from Andernach to Mayen) is from 15 to 30 feet. In one place the loess is clearly exposed, resting upon volcanic matter, and at the junction it alternates with it. Small portions of pure loess are there entangled in black volcanic matter. In many other sections, the same loess is seen covered with beds of pumice, trassy pumiceous sand, and small dark volcanic cinders, forming upon the whole a mass from 10 to 15 feet in thickness, and very like that which covers Pompeii. There is, in this instance, no loess intermixed, nor any alternation at the point of junction, as might have been expected, if the volcanic matter had been washed over the loess by running water. At one place in the Kirchweg I observed, in a perpendicular section, an aggregate of small fragments of pumice resting on loess. The latter had wasted away, so that the incumbent mass of pumice was undermined and overhanging. It thus exhibited its under surface, projecting several feet from the face of the precipice, and it appeared flat and even like the ceiling of a room, shewing that there was an abrupt passage from loess to the pumice. It may also be seen, on comparing several sections, that before this shower of pumice fell, the loess already formed the slope of a hill descending towards the valley of the Rhine, just as it does now where no volcanic superstratum has been spread over it. I conceive, therefore, that the valley of the Rhine had assumed its actual shape, and that the loess had been considerably denuded, before the occurrence of the eruption which produced the great bed of pumice near Andernach.

I think it unnecessary to give more details respecting the sections near Andernach, because some of them have been faithfully described by Mr Steininger, Dr Hibbert *, and others; and these geologists have declared their conviction that some of the volcanic eruptions were contemporaneous with, and others subsequent to, the deposition of the loess.

On descending the hill to the village of Plaidt, on the road from Ochtendung, at the distance of about four miles from Andernach, I saw loam resembling loess covered with eight feet of volcanic matter, consisting of stratified beds of pumice, dark volcanic sand, lapilli, &c. I found no shells in this loam.

* See Hibbert's extinct Volcanoes of Neuwied, p. 221.

I conjectured that its height was about 600 feet above the level of the Rhine.

From Andernach I proceeded to Neuwied, and from thence across a plain covered with pumice to Sayn. Near the latter place, I saw the loess forming a terrace on the flanks of the hills composed of greywacke, and at a lower level the country is covered with volcanic ejections, which, according to M. von Oeynhausien, are clearly seen in some sections to overlie the loess, a fact which I had not time to verify.

From Sayn I proceeded to Mayence, where the country on the left bank of the Rhine is composed of tertiary limestone, with green and white marls. This formation is overtopped by loess, and both are cut off abruptly in the escarpment which the high land presents towards the Rhine at Mayence, Oppenheim, and other places.

The tertiary formation must here have undergone considerable denudation since the loess was superimposed. In an excursion through part of the Duchy of Darmstadt by Mayence, Oppenheim, Alzey, Flonheim, Eppelsheim and Worms, I found the loess spread almost everywhere over the country, and the inferior tertiary strata and secondary red sandstone only exposed to view in valleys, or where the country begins to rise towards the base of the Donnersberg.

At Heidelberg Professor Bronn, who has devoted much time to the study of the loess, told me that he is persuaded that the loess was not formed suddenly by a transient flood, but gradually by successive deposition. The absence of all appearance of stratification, which formerly led me and others to a different conclusion, is owing, he thinks, chiefly to the homogeneous nature of the loamy deposit. In some places he has seen calcareous concretions forming horizontal lines, marking the greater quantity of calcareous matter which was thrown down when some of the layers were accumulated. I had formerly imagined that the loess must have subsided suddenly from a flow of muddy water, like the Moya of the South American volcanoes, in the same manner as I believe the unstratified trass of the Rhine volcanoes to have been formed; but I am now convinced that Professor Bronn's view of the subject is more correct. Among other places, the signs of successive deposition are well

seen in the deep gravel pits at the Manheim gate of Heidelberg, where the following section is exposed.

1. Vegetable soil with gravel.
2. Loess without any appearance of stratification, and with land and fresh-water shells.
3. Loess and gravel in alternating layers.
4. Sandy loess with shells.
5. Coarse gravel and loamy sand in horizontal strata, from one to two feet in thickness.

This section shews that, after the loess with shells (No. 4.) had been deposited, alternate strata of gravel and loess accumulated to the thickness of 12 feet, and then pure loess.

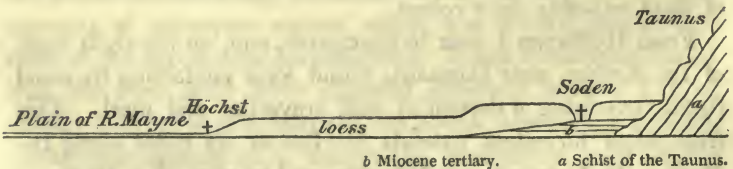
In travelling from Heidelberg to Heilbronn, by Wiesenbach and Sinsheim, a country composed of the bunter-sandstein, muschelkalk, and keuper of the Germans, I found the loess at various heights filled with both land and fresh water or amphibious shells,—the *Succinea elongata* generally equalling or surpassing in the number of individuals all the accompanying land-shells. I collected 158 shells from the loess between Heidelberg and Heilbronn, of which 80 belonged to *Succinea minuta*, 68 to the genus *Helix*, and 10 to the genus *Pupa*. Heilbronn is nearly 500 feet above the level of the sea, and M. Titot of Heilbronn informed me, that some of the loess on the hills near Heilbronn lies about 300 feet above the Neckar. If this is the case, the height of the loess must sometimes be more than 800 feet above the sea. Part of the district here alluded to, is within a few miles of that elevated table-land above the Bergstrasse between Wiesloch and Bruchsal, which I had visited the year before, where the loess attains the thickness of 200 feet and upwards, and contains a great variety of recent shells, many of them retaining their colour.

From Heilbronn I went to Stuttgart, and, on the right bank of the Neckar, near Canstadt, found loess containing its usual fossils, overlying a deposit of tuff, travertin, and marl. This fresh water formation extends for five or six miles along the Neckar, by Canstadt and Münster, and in part of it Professor Jäger has found the remains of a tortoise, and some plants which appear to be of extinct species.

Whether the overlying loess is connected in age with the tra-

vertin, I was unable to determine; but I was told by naturalists at Stuttgart, that the land-shells of the travertin were of recent species, and the same as those in the loess. From Stuttgart I went to Göppingen and Boll in Wurtemberg, and between the last two places saw loess resting on lias, after which I met with no more of it in the course of a tour by Heidenheim, Steinheim, Wasser Alfingen, Nordlingen, Solenhofen, Pappenheim, Ellingen, Nuremberg, Pegnitz, Bayreuth, the cave-district round Muggendorf, and thence to Forchheim and Bamberg. Between Bamberg and Wurtzburg, in the valley of the Mayn, I again found the loess, at Dettelbach, of a somewhat redder tint than in Wurtemberg, but exhibiting the same want of stratification, and containing the same terrestrial and aquatic shells, especially Pupa and Succinea. The loess near Dettelbach is seen not only in the Valley of the Mayn, but on the hills of muschelkalk, five or six hundred feet above the valley, where its redder tint is probably, in part, derived from the degradation of the red bunter sandstein.

In the Spessart, and in the country immediately around Aschaffenburg, I observed no loess. The road which leads from Frankfort to the foot of the Taunus, passes first over the low flat plain of the Mayn, which is covered with yellow sand, for the most part very barren. (See section, No. 2.) At Höchst, on the Mayn, is a higher platform, composed of loess, and here the soil is extremely fertile. This platform afterwards rises to a still greater height between Höchst and Soden, which last town is situated in a valley cut through the loess, at the bottom of which the subjacent tertiary strata of the Mayence formation are laid open. On quitting Soden, I ascended the steep flanks of the Taunus mountains, and saw no loess. (See diagram, No. 2.)

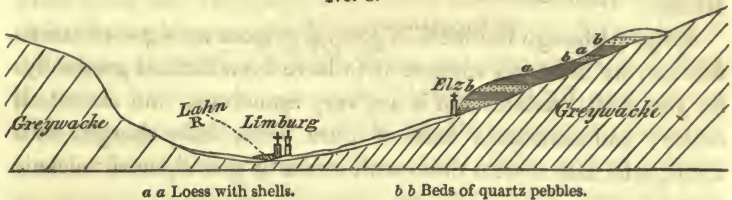


I then crossed the highest part of the Taunus, where the greywacke passes into crystalline schists, and from thence descended towards Esch and Walsdorf, where the more ordinary greywacke

of the Rhine, a yellow argillaceous and sandy rock, is very generally concealed under a deep covering of loam, which appears to have resulted from the decomposition of this greywacke, and not to have been transported from any distance. This loam has precisely the ordinary colour of the loess, and contains a great quantity of quartz pebbles.

The same alluvium is very general in the Westerwald, especially on the surface of that high table-land around Altenkirchen, Uckerath, and between that place and Siegburg, a district lying immediately behind the Siebengebirge.

No. 3.



The principal river which intersects the table-land of Nassau is the Lahn, which I crossed at Limburg, about twenty miles above its junction with the Rhine. The road from Limburg to Freilingen passes first by Elz. On the north of this village is a hill, which forms one boundary of the valley of the Lahn, and here loess is seen with all its usual characters, with many land and fresh-water shells; and alternating, as at Heidelberg, with gravel. I observed, in particular, a horizontal layer of white quartz pebbles, a foot and a half in thickness, resting on a mass of loess fifteen feet thick, and covered by another bed of loess five feet in thickness; the loess, in both situations, including in it entire shells. Following the road, I found the slope of the hill above to consist of horizontal beds of quartz pebbles, which have a base of loess. Hence it appears that the valley of the Lahn, which is excavated through highly inclined greywacke, has, at some period since its excavation, been partially filled up with beds of gravel, alternating with loess, a great part of which has since been removed by denudation. (See Section, No. 3.) It appears that, during the accumulation of the mass, fine loam was sometimes thrown down, containing unbroken shells, then gravel, and then again the shelly loam.

On a review of the observations above mentioned, it appears

to me that the following conclusions may be legitimately deduced:—

1st, The loess is of the same mineral nature as the yellow calcareous sediment with which the waters of the Rhine are now commonly charged.]

2dly, The fossil shells, contained in the loess, are all of recent species, consisting partly of land and partly of fresh-water shells.

3dly, The number of individuals belonging to land species usually predominates greatly over the aquatic, and this seems now to be the case with the modern shells drifted down by the Rhine.

4thly, Although the loess in general evinces no signs of stratification, we must yet suppose it to have been formed gradually, for the shells contained in it are very numerous, and almost all entire; and sometimes beds of pure loess, fully charged with shells, alternate several times with strata of gravel, or of volcanic matter.

5thly, Although, in general, the loess overlies every formation, including the gravel of the plains of the Rhine, and the volcanic rocks, which have the most modern aspect, yet in some cases, as at Andernach, the volcanic matter is so interstratified as to indicate that some eruptions occurred during the deposition of loess.

These inferences seem to me sufficiently clear; but if asked to account for the manner in which the loess, considering it as a fluvatile or lacustrine formation, was brought into the places which it now occupies, I must confess that the more I have studied the subject the more difficult I have found it to form a satisfactory theory.

If we begin to study the loess near Strasburg, we see large masses of it at the foot of the Vosges, on one side of the great plain of the Rhine, and at the base of the mountains of the Black Forest, on the other side. The intervening plains exhibit here and there remnants only of the same formation resting on gravel, for the loess has evidently suffered great denudation; valleys having been hollowed out in it, and small ridges of intervening hills formed, much like those seen on the surface of older horizontal tertiary formations. On following the loess from Strasburg to Mayence; we may trace it covering the rocks

of every age along the borders of the great plain of the Rhine, and we naturally incline at first to suppose that a vast lake has existed, of which the barrier may have been somewhere near Bingen, formed by the union of the mountains of the Hunsrück and Taunus, before the deep and picturesque gorge of the Rhine, between Bingen and Bonn, had been opened, or occasioned by the choking up of that gorge by lava or ejections from the volcanoes bordering the Rhine below Bingen. Of this lake, the valleys of the Neckar and the Mayn would have formed two great bays. According to this hypothesis, the depth of water must have been sufficient to have allowed a loamy sediment to be thrown down not only on the gravel of the Rhine, but at the height of 600 feet or more above that level, on the boundary heights. Afterwards, we must suppose that an opening was made through the barrier, and the lacustrine sediment denuded, until at length the original valleys of the Rhine and its tributaries were re-excavated, and small patches only of loess left here and there.

But this explanation is not sufficient, for when we pass from Bingen to the country of Neuwied, we find masses of the same loess rising to considerable heights above the Rhine, so that we require another lake, or we must remove the barrier of the great lake farther down than Andernach. If we then suppose it to have been in some of the narrowest parts of the great gorge between Andernach and Bonn, we again encounter a similar objection; for, on examining the Siebengebirge, we discover the loess at great heights on its flanks, as also on the opposite hills behind Poppelsdorf; and we are then under the necessity of constructing an imaginary dam, many hundred feet in height, which should stretch across a wide part of the plain below Cologne. Even if we are prepared to assume the former existence of one or more such barriers, we have still to assign adequate causes for their removal.

It is clear that no theory can account for the position of the loess, which does not admit great revolutions in the physical geography of the country now drained by the Rhine and its tributaries, within a very modern geological period, when all the existing testacea inhabited the country.

It seems also indispensable to assume that some barriers have

existed, for those waters must have been at rest from which the loess, with its unbroken shells, was thrown down as sediment. Probably the relative levels of different parts of the country now covered by loess, have been altered by the elevation of some tracts, and the depression of others, since the loess was formed. In order to possess data for speculating on this point, we must have more accurate observations on the highest levels which the loess ever attains above the Rhine and above the sea.

This singular formation is so homogeneous in its mineral character, whether it rests on gravel, volcanic matter, granite, red sandstone, or any other rock, that it cannot be compared to the local alluviums which different rivers and torrents may have produced in various parts of the same hydrographical basin. It may not all have been deposited at one time, or in one vast lake; but it seems to have been derived from some common source, as from the sediment of one great river like the Rhine, continuing to overflow a certain district, and always bringing down the same kind of sediment.

I subjoin a list of the fossil shells which I collected myself, from the loess of the various districts which I have mentioned in this paper.

<i>Helix fruticum,</i>	Drap.	<i>Pupa tridens,</i>	Drap.
<i>arbustorum,</i>	ib.	<i>lubrica.</i>	-
<i>pomatia,</i>	ib.	<i>Clausilia bidens,</i>	ib.
<i>nemoralis,</i>	ib.	<i>plicata,</i>	ib.
<i>hortensis,</i>	ib.	<i>Achatina acicula,</i>	ib.
<i>ericetorum,</i>	ib.	<i>Succinea amphibia,</i>	ib.
<i>carthusianella,</i>	ib.	<i>elongata,</i>	ib.
<i>plebeium,</i>	ib.	<i>Planorbis marginata,</i>	ib.
<i>obvoluta,</i>	ib.	<i>carinata,</i>	ib.
<i>pulchella,</i>	ib.	<i>Lymnea auricularis,</i>	ib.
<i>Pupa muscorum,</i>	Mont.	<i>ovata,</i>	ib.
(<i>marginata,</i> Drap.)		<i>Valvata piscinalis,</i>	ib.
<i>dolium,</i>	Drap.	<i>Cyclas fontinalis,</i>	ib.
<i>frumentum,</i>	ib.		