
[The paper now published, completes a series of notes of a journey to the Spiti Valley, undertaken on account of the Asiatic Society, by Capt. Hutton, 37th Regt. N. I. It was with those which have already appeared placed at the disposal of the Editor of this Journal by the Committee of Papers. The results of the author's geological observations have induced the adoption of theories, upon which the Editor is only competent to remark in so far as the identification of the opinions of a publisher is concerned with those of any writer, to whom he is enabled to offer a medium of communicating his views to the public.

In the belief that hardly any novel theory could be broached, which would be unproductive of good results, (if not by its intrinsic merits, at any rate by the consequence of the discussion it might excite,) the Editor has great pleasure in giving publicity to this paper, for the views contained in which the author is alone answerable.]

The valley of the Sutledge is that portion of the western Himalaya which, as its name implies, forms the tract of country through which the river Sutledge flows.

The term valley is however scarcely applicable to it, since it is strictly speaking nothing more than a deep and rugged mountain glen, of more than ordinary sternness and magnificence, often affording from the abrupt rise of its rocky sides, a mere channel for the roaring torrent which winds its irresistible and headlong course along its sheltered bed.

On either side rise high and snow-clad peaks, forming along the river's course two mighty walls, whose dark and furrowed sides proclaim the constant warfare which is waged by frost and heat alternately.

Villages are numerous along the river's course, sometimes placed near the water's level, at others raised high above it on the mountain's side, surrounded by their cultivation cut in steppes, and sheltered by the stern and frowning cliffs which raise their hoary summit far above it.

In the lower part of the valley, commencing from Rampore downwards, to below Kotghur, vast beds of rolled and water-worn stones are seen accumulated on the river's banks, and rising high above the water's present level. Such deposits evidently owe their origin to the eddies or back waters of some far mightier stream than that exhibited by the Sutledge in the present day, even at its greatest height, and must undoubtedly have been formed by the rush of water attendant on the outburst of some enormous lake or lakes in the higher portions of the hills.
These deposits extend in many places along both banks of the river, and appear to have been formerly one solid mass of debris, which as the waters gradually disappeared, have become divided by the current of the stream.

These are for the most part situated at those places where the Sutledge takes a rapid turn, and have been evidently thrown up within the elbow by the eddies, or back waters.

On the surface of these broad and flat alluvial deposits, now flourishes an abundant cultivation, consisting of barley, wheat, rice, tobacco, poppies, &c. which being situated high above the river's level, are irrigated by the minor streams, which are furnished from the heights above them.

Higher up the river's course the valley narrows, and forming in many parts a mural cliff on either bank, gives a mere passage to the foaming stream, which rushes with a hoarse and deafening roar over the boulders which obstruct its progress, and dash its waters in muddy waves on high. Some hundred feet above the stream the hills are clothed with dense and stately woods of oaks and various sorts of pines, among which the "Ree," producing the edible seed called by the people "Neoza," is in great abundance. Above the belt of wood, are seen to rise huge rocky spires, along the rugged line of mountains, bare of all vegetation, and crowned by everlasting snows. From these snow-clad heights are furnished numerous streams, which rushing downwards in a sheet of foam, furrow the mountains sides with minor glens, and join the Sutledge as it rolls along below. Now and then the forests cease, and wide grassy tracts succeed, affording pasture to multitudes of goats and sheep; while here and there the whole hill side has slipped away, and left a mural height of precipitous and crumbling rocks, which are annually precipitated into the depths below by the expansive powers of the frost and snow.

The general features presented by the Geology of these hills, may be briefly and summarily comprised in the following observations:—

The main or central range of the Himalya or true snowy mountains, runs in a general direction from East-South-East to West-North-West, sending off branches or spurs in every direction, intersected or divided everywhere by deep and precipitous valleys, whose narrow bed or bottom almost invariably serves as the channel of some mountain torrent or rivulet, whose waters are supplied from the snowy heights above. Where the sides of these valleys are of sufficient elevation to retain the snow throughout the year, these rivulets receive a neverfailing supply of water; but, on the other hand, if the enclosing walls are of moderate or medium elevation, the valleys are often dry for several months together.
The valleys, it must be borne in mind, are not to be attributed, as some have contended, to the gradual wear and tear of the weather, and the streams which now drain through them, but have been formed by the convulsive uprise and disruption of the lofty mountains which form their sides; the glen or valley being thus a mere ravine or trough lying between them, and furnishing often just room sufficient for the passage of an insignificant stream.

The existence of the valley is not therefore to be attributed to the abrations caused by the constant action of the waters; but, on the other hand, the presence of the rivers and streams within them is entirely owing to the configuration of the mountains, which furnishing on the heights vast beds of snow, are ever sending down supplies, which naturally gather in the hollow troughs below, and gradually wind their way to form a junction with some larger stream, which in its turn seeks out the noble rivers of the plains.

It would therefore appear, that the existence of these hill streams is altogether owing to the previous formation of the valleys by the uprise of mountain ridges, the intervention of a glen or khud being the natural consequence of disruption in a range, or the sudden alteration of direction of the upheaving power, thus often causing ranges to intersect or to run parallel with each other. Thus the valleys are in no wise the consequence of the unceasing action of the streams, which now find a fitting channel in their depths.

In the present day, these glens usually communicate or open into some other, and the waters gradually escape, but doubtless time has been when their enclosing barriers were continuous, and numerous lakes were formed, until the weight of waters accumulated from the melting of the snows, burst through the rocky walls and so escaped. This is indeed a fact and no wild theory, for the people of different parts of the hills still hold traditions of such events. Dr. Gerard, I think it is, who mentions, that the natives informed him the valley of the Bups was once closed at the lower extremity, and contained a lake, traces of which may still be seen along the banks of the present stream. A similar lake once occupied the glen in which the town of Soongnum now stands, and thick alluvial deposits containing rounded pebbles may still be seen in some of the higher parts of it; from the lower portion they have been swept away by the out-rush of the waters.

Of this, however, I shall speak again hereafter. The dip of the strata is, as might be expected in such a vast and often confused assemblage of mountains, excessively variable; and although previous travellers have uniformly insisted much on a N.E. dip, it will be quite as often found
to lie in an opposite direction. The prevailing inclination of the strata may therefore be said to be N.E. or S.W. It is, however, remarkable that the latter dip, although perceptible on both sides of the snowy range, is more prevalent on the northern than on the southern side. It has also been pointed out as matter of astonishment, that while one aspect of the mountains presents a gradual and shelving face, rich in soils and forest scenery, the opposite exposure is, on the contrary, found to present a bare and often mural cliff. This, however, is no just cause for astonishment, as the circumstance where it occurs is simply owing to the outcrop of the strata being on the precipitous side, while the dip of the other forms a more shelving slope. But this circumstance is by no means confined to any one direction in particular, for the outcrop of strata is no more prevalent on the northern than on the southern or any other exposure. It may, however, be taken as a general feature in all mountains, that while the dip or inclined position of the strata gives on the one face a shelving surface for the growth of plants, the other face or outcrop must necessarily be rugged and nearly barren, as furnishing by its precipitousness no resting place for soils. In this respect the Himalya does not differ from other mountain ranges. Travellers, however, having no knowledge of geology, and witnessing these facts, have sought to solve the problem by bringing to their aid supposed peculiarities of soil, of aspect, or of climate.

Viewed at a distance from the plains of India, these hills appear to form one long continuous chain or ridge, entirely clothed with everlasting snows, and this line has been designated by way of pre-eminence or distinction, by the name of the "snowy range," or "region of perpetual snows." Arrived within the mountains, and perched aloft upon the summit of some portion of this mighty range, the traveller is surprised to find that what he had been led to consider one continuous field of snow, is nothing more than a vast assemblage of scattered and far distant peaks, approximated apparently by the distance at which they were wont to be viewed into one wide-extending line, and forming component parts of the same snow-clad range.

He is surprised to find the greater portion of that line to be absolutely devoid of snow during several months of the year, except within the deep and sheltered glens, to which the rays of the summer sun can only penetrate for a few short hours during each day, and where frost resumes its sway the moment his beams are withdrawn or intercepted by some towering peak.

Far beyond the ridge which he has hitherto been accustomed to distinguish as the snowy range, he now beholds gigantic and frowning masses clothed in the winter garment, rising often in isolated peaks to
an elevation exceeding that of the main or central chain on which he stands.

Around him, far and wide, he beholds these rugged and awe-inspiring peaks rising pre-eminently grand amidst the sea of mountains by which he is surrounded, and he now first learns that the line of snow he has witnessed from the plains, is the wintery sheet which envelopes these often widely separated masses, but which to the eye of the far-off observer, have become blended by the distance into one long line of continuous snowy peaks.

The central range, and all the hills, with the exception of these loftiest peaks and some deep secluded glens, usually lose the sheet of snows during the period that the monsoon is raging in the plains. It is at this season that the snows send down the greatest supplies of water to the rivers, commencing about the end of May and continuing till September, when the frosts again arrest the dissolving snows, and the mountains once more put on the pure and dazzling robes of winter, and continue thus enveloped in one sheet of snows until the approach of summer again relieves them.

No sooner has the wintery garment disappeared, than a fine rich sward at once springs up, almost as if by magic, so rapid is the vegetation in these high tracts,—affording abundant pasture to the flocks and herds, which then range over them to the height of 15,000 feet above the sea.

This smiling and verdant state of things is, however, unhappily of short duration, appearing like the transient gleam of sunshine that often precedes the fiercest storm, yielding in the space of two short months to the drifting whirlwind and wreaths of snow, that soon enshroud the whole in cold and dreary solitude.

Journeying from Kotgurh, in the lower hills, towards the Spiti valley, the geological formations which came under my observation from that station to the frontiers of Tartary, were exclusively of the primary class.

Commencing at Kotgurh, and crossing the brow of the hill above Kaypoo, we find strata of mica and hornblende schists, jutting up through the surface, interspersed with veins and nodules of quartz.

These veins are often found to contain iron disseminated in small thin scales resembling mica, and in such cases the quartz is generally in a state of decomposition. This ore pays no duty to Government, and the mines, if indeed such they can be called, are seldom worked, being so unproductive, that out of 14 lbs. weight of the rough ore only 2 lbs. of iron, and that impure, can be procured.

Veins and masses of coarse primitive calc spar or carbonate of lime are also seen to accompany the mica slate. These rocks continue, with an
occasional bed of porphyritic gneiss, until we reach Rampore, half a mile beyond which a fine white granular quartz occurs, underlying mica slate.

These strata dip strongly to the N. E., and are seen on either side of the river, by which they appear to have been transversely divided, the lower end dipping down on the right bank, while the upper portion forms a high mountain on the left.

I say these strata have been apparently divided by the Sutledge, which now flows through them, because such in reality has not been the case; but the bed of the river lying through them, is entirely attributable to the disruption of the strata at this point having formed a fitting channel for the waters to escape through to the plains.

(See plate)—Fig. 1.


The surface of this quartz rock takes a yellowish rusty hue when exposed to the weather, but when freshly fractured, it is of a pure white, somewhat resembling Carrara marble in appearance, but of a coarser texture.

Onwards from Rampore, the mica schist is seen in several varieties, sometimes appearing to be composed entirely of mica, at others containing a predominance of quartz; in these cases the strata are either soft and crumbling, from the mica scaling off, or very hard and flinty, from the quantity of quartz.

Silty mica passing into chlorite schist is abundant near Goura, and from its soapy and decomposing nature, the whole rock has in many places slipt away altogether, leaving a constantly decomposing cliff, from which in wet weather large masses are constantly falling.

Further on, the mica is seen to contain numerous small crystals of hornblende, which cause it to pass gradually into hornblende schists. Garnets of small size occur occasionally imbedded in the mica, which also contains masses of white quartz, in which beautiful crystals of cyanite are interspersed, varying in shade from pale sea green to bright blue.

The characteristic rocks, however, from Kotgurth to Sarahun are mica and hornblende slates, frequently alternating with each other, and imbedding blocks of porphyritic gneiss and white quartz.

From Sarahun the gneiss begins to shew itself as the prevailing rock, and occurs both common, red, and porphyritic;—mica slate and hornblende are also frequent, and when they come in contact, the mica often becomes jet black.
A few miles from Sarahun, on the right bank of the river, an interesting appearance presents itself in the disposition of the strata. The dip which up to this point has been pretty uniformly to the N. E., now gradually rises, and preserving for a short distance a nearly horizontal position, at last lifts itself abruptly, and dips back again to the S. W. at the same angle of about 45°.

From this disposition of the strata it becomes evident, that they have been lifted or upheaved at both ends, from the horizontal position they once had, by some volcanic force. The lowest strata exposed to view at this spot are on the right bank of the river, nearly even with the water, and form a complete arch immediately under those strata which dip to the N. E. I annex a slight sketch made on the spot, which will serve to show the position of the rocks, better than a description. (See plate)—Fig. 2.

Beyond this, as we approach Traada, a fine white granite is observed, containing large scales or crystals of mica, and farther on still, about Nachar, white felspar becomes abundant, imbedding the same mica crystals, and forming the first division of the granite of some geological writers. Quartz also occasionally entered into its composition and formed true granite, with which were found hornblende and mica slates, porphyritic and granitic gneiss. In some instances where the hornblende and granite were in contact, the mica of the latter rock assumed a black and glossy appearance, producing a variety of granite of some beauty.

Proceeding from Nachar, the road passes over formations similar to those already mentioned, and a few miles lead down to the Sutledge, which is crossed by a good broad Sangho. At this point the rocks rise abruptly in huge masses on either side, confining the river to narrower limits, and affording a mere passage for its waters.

These rocks are of gneiss, and the stratification which previously had often been indistinctly discernible, now ceased altogether, and the beds presented a shattered and amorphous mass,—a circumstance by no means of rare occurrence among this class of rocks.

From the sangho to Chergong the road still continues along the bank of the river over beds of boulders and broken rocks of every size, consisting of granite, gneiss, mica, and hornblende slates. Here too cyanite again occurred in quartz, and crystals of crysoberyl (?) in granite.

From Chergong to Meeroo the strata of gneiss are often laid bare by the descent of streams from the snows above, and the dip is seen falling to the N. E. at about the usual angle of 45°. Beyond this place occur thick beds of mica slate, containing garnets in profusion, and often, from the decomposition of the rock, the whole road is strewn with garnets of various sizes. Beneath this bed occurs one of white quartz rock, which is seen rising from the edge of the Sutledge to about 3,000 feet in thickness.
Near Chini, the mica slate contains occasional small crystals of cyanite, and sometimes passes into chlorite slate.

A short distance from Chini, the whole hill side has slipped down into the Sutledge, from the action of frost and snow, and the cliff now towers up from the banks of the river, presenting a sheer and perpendicular wall of between six and seven thousand feet in height. This vast mass is composed throughout of gneiss, and the road, which is a mere scaffolding, passes along the face of it, at 4,000 feet above the Sutledge, which is seen foaming below.

From this to the village of Leepee, the formation is pretty nearly the same, consisting of granite, gneiss, hornblende, mica, and quartz.

The granite about Punggee, Rarung, and Junggee, contains a large proportion of hornblende, and at Rarung it is also seen to assume a brick red colour, often traversed with veins of quartz, both red, amber, and white. The red granite appears only in masses imbedded in a yellowish variety, which is the true rock, and which towards Leepee gives place to gneiss and mica slate. Above the last mentioned rock commences the first bed of argillaceous slates, which continues interstratified with greywacke schists to the top of Roonung Pass. The alternations of these strata are frequent, sometimes the one and sometimes the other rock prevailing in thickness.

These beds are evidently the first indication of the transition, or lowest secondary formation of geologists, and extending across or through the Roonung Pass, downwards to Soongnum, they are seen to support strata of compact greywacke, and beds of quartzose rock, apparently analogous to and holding the place of the old red sandstone of Europe.

The town of Soongnum stands in a valley immediately between the Roonung Pass in its front and the Hungrung Pass in its rear. In front, the range of hills which form the right side of the Rushkoolung valley are composed of an argillaceous series, consisting of clay stones and greywacke slates, of different textures and degrees of induration, and dipping to the S.W. The strata in the rear of the town, forming the left bank, dip, on the contrary, to the N. E. and are composed of greywacke slates, compact greywacke, old red sandstone, and a superior stratum of limestone and greywacke. These towards the summit of the range gradually change their dip, and rise up again to the S.W., the whole being surmounted by a bed of dark blue secondary limestone, containing portions of clay and silex. This formation extends along both sides of the Rushkoolung valley, even to the Manerung Pass above Manes in Spiti, a distance of about seventeen miles. About seven miles from Soongnum, copper veins occur in their strata of white quartz rock, and veinous quartz, lying occasionally between, or ramifying through, the greywacke and old red sandstone. The
last mentioned rock varies much in colour and in texture, the lowest stratum being white, and scarcely distinguishable from quartz rock, but changing gradually to a faint tinge of pink, becoming deeper as it passes upwards, until its colour is of a dull purplish hue.

These strata are sometimes separated by a very thin layer of soft whitish marl. The crest of the Hungrung Pass is 14,837 feet above the level of the sea, and is composed of dark blue limestone. The range on which this Pass is situated divides Kunawur from Hungrung,—a district inhabited by Tartars, who are subject to Bussaher.

Descending from the Pass to the village of Hungo, the road passes over numerous alternations of blue limestone and greywacke slates, resting upon white quartz, which lower down gradually passes into a greenish variety of the same rock.

These strata all dip to the S.W., and are probably an outcrop of those which run in a N.E. direction from behind Soongnum, and thus shew the effects of what may be termed a double upheavement, or lifting of the same strata at two different points. The lofty granitic peaks which tower up to the right of the Pass, at once shew that they have been instrumental in forming the S.W. dip, and it is more than probable that the same rock might be discovered also protruding through the strata on the opposite exposure.

The following partly imaginary section of Hungrung, may serve to explain my meaning:—

(See plate)—Fig. 3.

Supposed Section of Hungrung Mountain.

Strata of greywacke slates are met with for a few miles after leaving Hungo; but they disappear as we approach Leeo, or rather, from the great descent of the road, they are left far above, while the base of the mountain is found to be a dark coloured gneiss, traversed and intersected in every direction by veins of white quartz.

Leeo stands in a kind of basin, surrounded on all sides by lofty hills of granite and the same dark gneiss; but the lower parts of them are overlaid by strata of the secondary series, consisting chiefly of greywacke and shales. On the sides of the surrounding hills exist strong indications of the former presence of a lake, in the lines of water-worn stones and pebbles that now rest many hundred feet above the river Lee.

These appearances were long since pointed out by Dr. Gerard, who though knowing nothing of geology, was at once forcibly struck with
the conviction, that nothing but the former presence of deep waters could account for the phenomena here so plainly exposed to view.

In his conjectures on this head, that enterprising and unwearying traveller was undoubtedly correct.

In the bed of the Lee, where it is crossed by a wooden sangho, a thick bed of white quartz rock is seen dipping to the S.W., and as we mount the hill in the direction of Chungo, beds of boulders, and disjointed masses of granite, gneiss, and mica slates hurled from above, are passed over, now in many places overlying the secondary slates.

At the village of Chungo, which is the last on the left bank of the Lee, under the government of Bussaher, the most decided indications of the former presence of a deep lake again occur. To the eastward of the level patch on which the village and its cultivation stands, rise three lofty and rugged mountains, whose shattered sides present sections of the same strata as those noticed at Leeo: namely, deep beds of dark gneiss and mica slates intersected by granitic and quartz veins of various thickness; these strata dip down towards the west, and as they approach the village, are lost beneath the vast accumulations of alluvial soils, which here, as at Leeo, mark the former presence of deep and tranquil waters.

To the southward these deposits consist almost entirely of thick beds of clay, sands, and boulders of every size, rising high above the level of the village; while to the NNE. are again presented the same alluvial deposits of a greater thickness, and accompanied in addition by a deep and extensive bed of a pure white and friable gypsum. This bed is perhaps a most valuable discovery in a geological point of view, as tending to show the nature of the waters from which it was precipitated. This thick gypsumous bed is overlaid by the sands, clays, and boulders, which have already been noticed. At the fort of Skialkur, on the opposite or right bank of the river, about 3½ miles from the village of Chungo, this gypsum is likewise seen overlying the transition series of alternating slates and sandstones.

These deposits are now at the height of 2,000 to 2,500 feet above the present level of the river's course, or at an elevation of 12,000 to 12,500 feet above the level of the sea.

The three mountain peaks of gneiss, which rise up to the eastward of Chungo, are divided from each other by narrow glens, through which streams flow down to join the sea, between which and the base of these mountains, the whole alluvial deposits have been swept away, and the present cultivated plain of Chungo is therefore situated far below the surrounding alluvium, which rises like walls on either side of it.

As we proceed from Chungo towards Spiti, the road lies at first over the alluvial accumulations above-mentioned, for two or three miles, when from
the abrupt nature of the primary rocks that are hence met with, they cease to exist, except far below where a wide and shelving plain lies along the river's side, and which is entirely composed of them. From the point where the road leaves them behind, for a distance of six miles, the strata are again of mica, slate, and gneiss, varied with the same curious veins of granite and quartz as those of Leeo and Chungo. At this point the mountains are separated by a rapid river called the Paratee, which runs down from Chinese Tartary and joins the Spiti near Skialkur. Here the primary series may be said to disappear, and the Spiti road crossing the Paratee by a natural bridge of stone, which is formed of several large masses of gneiss fallen from above, and wedged firmly together over the stream, brings the traveller at once upon the secondary class. The lowest strata are therefore just perceptible where the waters cut their way through, and we thus catch a glimpse of the gneiss of the opposite bank, above which occurs a talcose schist, white quartz rock, and clay slate, dipping to the S. W. Above these are alluvial deposits similar to those of Chungo, and extending for a mile or two inland from the river, forming a flattened plain, on which stands "Kewrick," the first village of Chinese Tartary. Here again a portion of the deposit has been swept away by a descending stream, exactly as at Chungo. It is worthy of remark, that all these alluvial deposits are the deepest and most extensive where the surrounding hills have the most gradual slope, and where they retire so as to form recesses; while on the contrary, as might be expected, where the dip of the strata is rapid or acute, scarcely any trace is left of the former existence of a lake, because the deposit has been swept away by the outrush of the escaping waters.

These accumulations are likewise the most extensive at the lower end of the Spiti valley, where alone the gypsum is to be found. To this fact I would beg to call special attention, as it will be hereafter alluded to, and prove of some importance in the explanation of these diluvial and alluvial deposits.

From Kewrick the road runs over hills, which are entirely of the secondary class, being frequent alternations of the same rocks, as greywacke and claystones, limestones, and sandstones, and in one or two instances a trap of greenstone is also seen, both stratified and amorphous.

From Kewrick to the village of Larree, which is the first inhabited place in Spiti, we travel first for four miles over the edges of strata of clay slates and accumulations of debris. From the decomposing state of these strata, caused the effects of weather and a portion of alum, which causes them to scale off in soft flakes, the whole of the hills on either side of the Spiti river have a charred and blackened aspect, which combined with their arid and barren nature, gives a sad and melancholy appearance to the country, by no means cheering to the weary traveller.
The dip of the strata is now uniformly to the S.W., and generally at an angle of 45°, though here and there they rise abruptly to a nearly vertical position, denoting an excess of the upheaving forces from below. As we approach Larree after crossing the Gew river, the bed of which is of greywacke slate, we come upon a thick stratum of pure white quartz rock, which appears to be a continuation of the same rock which was seen at Leeo on the opposite side of the range; in contact with this, and immediately resting upon it, is another bed of siliceous rock, which passes gradually into thin strata of flinty slate. Upon this rests clay slate, which then alternates frequently with greywacke and sandstones. Further on we perceive masses of gypseous breccia formed of angular fragments of argillaceous schists, encrusted or cemented together by gypsum. This rock, if it be entitled to the name, owes its origin to the same waters which deposited the gypsum beds of Chungo and Skialkur; it is found overlying the edges of the true strata from which it has been formed, and occurs in rude and mis-shapen masses. To this breccia I would also call attention, as serving to shew a change in the waters of the lake, or at all events a decrease in the proportion of their saline properties. Farther on still, and nearly opposite the village of Somra, a stratum of trap is seen to occur between shales above and sandstone below; it is conformable to the true strata with which it is clearly interstratified, not causing any dislocation of the series. Beyond Larree, however, the same rock occurs again, in one place interstratified with greywacke and dark blue limestone, at another running up vertically in an amorphous mass through the strata, which it first dislocates and then overlies. In this case, the strata on either side of the Spiti dip to the S.W., while the rocks through which the trap has more immediately passed or been injected, are thrown boldly and abruptly from the usual course to the westward. The strata on the opposite side of the river are at the same time raised from the angle of 45° nearly to a horizontal position, and after some twisting of the strata, again with apparent difficulty regain their wonted S.W. dip. Here it is evident that the trap in question has been the molten vein whose struggles to burst upwards through the superincumbent weight of strata has been the agent which has thrown them into their present inclined positions, and in its upward course has first become partially interstratified with those which possessed the least induration or means of resistance, and then finally, as it burst through all obstacles, flowed over them in a broad sheet of molten matter, which as it cooled assumed the present solid and compact texture.

Of such having been the fact, we observe proof in the vein of vertical trap acting as a support, or upright as it were, from which the strata now incline and dip downwards.
As, however, trap is known to possess, "in a general sense, the universal common character of being unstratified, and posterior to the rocks with which it is connected," it becomes necessary in here stating, that it is conformable to and interstratified with those of the secondary series, to offer a few theoretical remarks on the probable means by which this partial stratification has been produced.

The interstratification of this rock, where it occurs, is of very inconsiderable extent, when compared with that of those with which it is associated, possessing by no means the wide and almost universal range of the primary and secondary series, but being on the contrary, "in a great measure limited to particular spots, more or less extensive, and to be, if separately considered, partial and independent productions."†

Let us then suppose that these secondary strata were once (which in fact they really were) horizontal deposits from the waters, which it is generally supposed were instrumental to the formation of the series to which they belong.

We shall thus perceive them to have been deep unconsolidated masses of sands, covered by muddy layers, which we now term shales. The struggles of the molten matter to procure access to the surface would, from the heat and pressure engendered by its upward course, have the effect of vitrifying and indurating the sands through which it forced a passage, and of converting them into strata of sandstone, while the shale or muddy deposit next in succession being lighter and less massive than the stream of trap, would probably rise and yield a passage between itself and the sandstone for the molten matter to form a stratum, somewhat in the same manner as oil would give place to a stream of water if injected through a tube or aperture below it.

The muddy deposit, however, being hardened by contact with the lava and by the general pressure of the uprising strata, would burst as the sandstone had already done, and yield a passage to the trap, which flowed through and overspread them at the surface.

Should it be contended that the outburst of a stream of lava such as that I have described the trap to have been, would have expended itself in a shower of ashes or cinders, rather than have assumed the stratiform structure it now exhibits, I would remind the reader that the secondary rocks are supposed to have been deposited in the bosom of a tranquil water, and that that water formed either extensive lakes or portions of the sea.
The upheaving lava current had therefore not only the weight of the superimposed deposits, but the pressure likewise of an enormous volume of water. It becomes more than probable, therefore, that this aqueous pressure would effectually check the tendency to produce cinders and ashes, and thus as the stream poured upwards through the deposits and came in contact with the waters, the molten matter would extend itself along the bottom of the lake, and thus overlie the secondary strata, as in the present instance.

For farther information on this subject, I would refer the reader to De la Beche's Geological Manual, where will be found some very just and apposite remarks on the point in question.

"It being by no means probable," he says, "that the density of sea water beneath any depth which we can reasonably assign to the ocean, would be such as to render it of greater specific gravity than liquid lava ejected from a volcanic rent, situated beneath the sea, it would follow that so long as the lava continued in a state of fusion, it would arrange itself horizontally beneath the fluid of inferior specific gravity." The question then arises, how long a body of lava in fusion would remain fluid beneath the waters of the sea? The particles of water in contact with the incandescent lava would become greatly heated, and consequently, from their decreased specific gravity, would immediately rise: their places being supplied from above by particles of greater density and less temperature. Thus a cooling process would be established on the upper surface of the lava, rendering it solid.

Now as the particles of fluid lava would be prevented from moving upwards by the solid matter above, pressed down by its own gravity and the superincumbent water, they would escape laterally, where not only the cooling process would be less rapid, from the well-known difficulty of heated water moving otherwise than perpendicularly upwards, but where also the power of the fluid lava to escape resistance would be greatest. (See plate)—Fig. 4. Let a be a volcanic rent, through which liquid lava is propelled upwards in the direction d f: the lava being of greater specific gravity than the water b h e c it would tend to arrange itself horizontally in the directions d b d c The surface b d c having become solid, the lava would escape from the sides b and c, spreading in a sheet or tabular mass around; and this effect would continue so long as the propelling power at a was sufficient to overcome the resistance opposed to the progress of the lava, or until the termination of the eruption, if that should first happen."

This clearly stated theoretic problem may now be successfully reduced to practice, and will correctly and exactly apply to the phenomenon under


consideration. The truth therefore of De la Beche's proposition will be at once established.

(See plate)—Fig. 5. Let us suppose these now inclined strata to be in their original horizontal position, and 2 and 3 forming beds of unconsolidated sandy and muddy deposits beneath the waters of the lake or sea a c e h.

Then a a a a, &c. is a vein of lava or molten trap, which in its endeavours to find vent, upraises and bursts through the solid primary series denoted at 1.

By the heat and pressure thus engendered, the lava indurates the sand at 2, and converting it into sandstone, breaks through it also, and is thus brought in contact with the muddy deposits represented at 3. This deposit being of a specific gravity inferior to the stream of lava, is naturally displaced and forced to contract and furnish room for a stratum of trap at a a a.

The heat and pressure, however, continuing, speedily and almost on the instant, converts the muddy deposit into shale or slate clay. And the lava current bursting through it and the superior stratum of limestone, comes at length to the surface, and in contact with the waters. Here then commences the facts detailed theoretically by De la Beche, as already quoted, and the stratum of trap spread over the surface of the now inclined and consolidated strata of deposits; while the waters of the lake or sea being displaced by the upheavalment, effected an escape through the various channels afforded by the disruption of the uprising strata.

It may possibly be objected that the occurrence of a compact stratum of limestone above the shale, and in contact with the trap, will at once invalidate the theory here proposed, from its being a known fact, that when heat is applied to calcareous matter, the carbonic acid is driven off, and the remaining lime rendered infusible.

I shall endeavour therefore to obviate such an objection, by quoting and establishing a theory long since propounded by Dr. Hutton, which at the time of its proposition was looked upon as an ingenious, but perfectly untenable, doctrine.

"He had asserted that calcareous rocks, like every other, had been subjected to the action of heat. But it was well known that when heat was applied to this class of rocks the carbonic acid was driven off in the shape of gas, and the remaining quicklime become infusible. Dr. Hutton indeed had answered this by suggesting, that the pressure of the superincumbent ocean was sufficient to confine the carbonic acid, and to cause it to act as a flux on the quicklime. His theory, however ingenious, was so abundantly gratuitous, that it by no means satisfied even his own disciples. After Dr. Hutton's death, Sir James Hall ascertained by numerous experi-
ments that carbonate of lime might readily be fused when exposed to heat, if it were at the same time under a pressure not greater than Dr. Hutton's theory required, or about a mile and a half of sea."*

Now it is easily perceptible, that the result of these experiments is in exact accordance with the effects which the theory here proposed would give rise to.

We have supposed that the present solid strata were once soft and aqueous deposits beneath a vast depth of waters; we thus perceive a beautiful and conclusive illustration of Dr. Hutton's theory in the fact, that when the heat generated by the pressure and condensation from below acted on the superior calcareous stratum at 4, that very stratum was then actually subject to the pressure of the superincumbent waters at A C E H, which by preventing the escape of the carbonic acid gas, and causing it to act as a flux upon the quicklime, converted the stratum, as Dr. Hutton had suggested, into the compact state which it now exhibits.

As theoretic speculations, however just, and however much in accordance with the phenomena observable, they may prove to be, may nevertheless be deemed misplaced in a paper of this kind, I shall leave the subject for a more fitting occasion, and now pass on to a consideration of the remaining facts exhibited in the strata of the Spiti valley.

From Kewrick to the village of Leedung, the strata may be said to be of the same description, namely, talcose schist, quartz rock, greywacke slates, clay slates, sandstone shales and trap, all except the last alternating frequently with each other.

A precise description of each rock belongs rather to the department of the mineralogists than to that of the geologists, and I therefore content myself with pointing out the series rather than individual species, in order that I may hasten on to the theory which the appearances presented suggest.

Passing therefore from Larree via Pokh to the fort of Dunkur, we find the strata to consist of the same alternations of rocks as those already mentioned; but at this latter spot the appearances denote a struggle for the direction of the dip, which merits some attention. The range of hills running along the right bank of the Spiti opposite to Dunkur have a N. W. by W., and S. E. and by E. direction, and at four miles below the fort the strata dip uniformly to the S. W. From that point, however, or near the village of Maness, it would seem that an upheavement had taken place through or along the centre of the range, causing the superior strata to assume a pent or roof-like appearance, throwing them on one side with

* Journal of Science, p. 4.
an acute dip to the N. E., while the opposite side preserved the S. W. direction at a less acute angle. In such cases where a section is obtained by a water course, the strata forming the heart or interior of the range are seen twisted in every grotesque direction. These strata consist of thick beds of argillaceous schists and sandstones, and what strikes one as singular in their disposition is, that the upheavement has had the effect of throwing the outcrop of the sandstone, or superior stratum dipping to the S.W., higher than the portion which falls to the N.E. Thus the joining of the strata is not at the summit of the range, but the rocks of the N.E. side are seen lying against those of the opposite direction, whose upper edge, or outcrop, juts out above them. \(\text{See plate}\)—Fig. 6.

Passing on from Dunkur we come to the Lingtee river, which joins the Spiti.

Here again a double upheavement of the strata appears to have taken place, which will be better understood by a reference to the annexed sketch, and which may serve as an example in all similar cases. \(\text{See plate}\)—Fig. 7.

On the right bank of the Spiti, the strata fall acutely to the river in a N. E. direction, as already pointed out, while on the left bank, although they at first dip to the same direction, they are seen first gradually to rise to a nearly horizontal position, and then to dip backwards again to the S. W. This occurs on the left bank of the Spiti and the right bank of the Lingtee at the point where the two rivers meet.

On the left of the Lingtee the strata first dip to the N. E., and then after many extraordinary twists and contortions, yield, as it were reluctantly, to the contrary dip, which turns them back to their old and proper direction of S.W.

In all these cases it will be found that the rocks are rent asunder, and the disruption now forms deep \textit{khugs} or glens, through which at present a stream or river descends.

About six miles from Dunkur stands the village of Leedung, where the strata consist, in an ascending order, of greywacke and clay slates, dark blue limestone shales, limestone and sandstone, repeated in many alternations.

Leedung stands at the height of 12,037 feet above the sea, and the strata just mentioned rise precipitously above it to the height of from 3,000 to 6,000 feet more, or to 15,000 and 18,000 feet above the sea. The highest stratum here appeared to be of sandstone, resting upon shale.

To the N.E. of this village rises a Pass, which has an elevation of 15,247 feet, and here along its summit, where the streams which descend
from the snows have worn numerous channels through the loose and decomposing *shales*, occur the fossils which were long ago discovered by Dr. Gerard. These consist of various species of *ammonites, belemnites, orthocerasites arca*, and some others; but all partaking of the same decomposing nature as the *shales* in which they occur, so that it is next to impossible to procure a perfect specimen, or to prevent its falling to pieces if obtained.

The *limestones* which here alternate in the series, are sometimes wholly composed of shells, and are of a dark grey colour, while at the height of 14,712 feet occurs a bed of a whitish grey colour, and almost free from shells, but embedding large rounded masses of various sizes, which when broken are found to be composed wholly of the dark shell *limestone* already mentioned.

Among these hills there is great confusion in the direction of the dip, the strata sometimes inclining to the S.W. or N. E., while at others they are N.N.W., and to almost every point of the compass. These masses are, however, generally limited to small extent, and appear like fragments torn from the true or main direction by the force of the upheaving agent. These strata extend along the range for many miles farther up the valley, but no fossils were apparent at any place, except on the heights above Leadung and Larra. They exist, however, in the form of shell *limestone* along the range immediately leading from the lake Chummorareel; but at this season the whole range lay so deeply buried in snow, that the route was impracticable, and I was obliged reluctantly to quit the fossil site, not half satisfied with its investigation.

From the nature of the rocks in this part of the valley, and the reports of those who have visited lake Chummorareel, I should feel strongly inclined to believe that it is situated among the *Lias clays*. Puttee Ram, the Tartar wusser, who has often visited the spot, assured me that the lake was surrounded by high hills composed of *earth* of various colours, red, yellow, blue, &c. and that the country around was all of similar *clays*, and not composed of rocks like the lower parts of Spiti, although sometimes above the hills of clay, large masses of stone were also found.

Such a description, all rough though it be, would lead one to expect the *Lias* beds resting on the red *marl*, and surmounted by the *sandstone* series above the *oolite*. The subject, I am sorry to think, must thus far remain obscure, until some more fortunate traveller shall venture upon those interesting scenes.

From this slight sketch it will be seen that the geological series from Kotgurh to the neighbourhood of Soongnum, in Kunawur, is that of the primary class; while thence, to the head of the Spiti valley, we find,
with slight interruption, the transition or lowest secondary series containing fossil exuviae of marine Mollusca.

From the point of junction of the Spiti and Sutledge to the head of the Spiti valley, we find everything indicating the former presence of an extensive lake. These indications consist in beds of friable or earthy gypsum, clays, sand, and rolled pebbles now left high in horizontal strata above the course of the river at the present day.

These accumulations are also seen to be the thickest and most extensive at the lower end of the valley, where the mountains form recesses, and where the slope is the most gradual. We find the gypsum beds alone at the lower end, and we also find them growing thinner and dying out as they approach the higher and narrower part of the valley, until at last their presence is only to be traced in the incrustations of other rocks.

The clays and sands which have been deposited upon these beds are, on the other hand, universal throughout the valley wherever they could find a resting place, and they pass on after the gypsum has ceased up to the higher portion of Spiti, where at length they yield to pebbles and boulders.

I have called attention to these facts, because I shall presently show by what means such an arrangement has taken place.

It will, however, first be necessary to state the theory which these appearances suggest, and then to show how the phenomena presented to our view, are in accordance with that theory.

Theory of the Spiti Valley.

We have already seen that the valley bears every appearance of having been at some remote period the bed of an extensive lake, which at length, by the accumulations of its waters, and its enormous pressure upon the rocky barriers which confined it at the lower extremity of the valley, burst forth with irresistible power and devastating effects down into the district of Kunawur. I shall endeavour to trace in detail the circumstances which may have led to this outburst of the Spiti waters.

The first formation of such a lake may have occurred from one of three distinct causes, namely:

First. If we allow the existence of these vast mountains previous to the flood, the lake may have accumulated in the bosom of the valley from the melting of antediluvian snows, and thus, (supposing the Mosaic narrative to be correct,) it will be seen, that although originally composed of fresh waters, it must have changed its nature and become salt at the period of its submersion by the deluge; and again in after years, when that deluge
had subsided, it would have gradually regained its freshness, and parted
with its saline properties by the constant accession of streams from the
beds of snow surrounding it.

Secondly. If these mountain ranges were formed at no remoter period
than that assigned to the subsidence of the Mosaic deluge, the lake may have
been formed simply by the accumulation of the snow streams from the
heights above, since that last grand catastrophe.

And, Thirdly. If suppose these mountains to have been upheaved by sub-
marine volcanic agency during the convulsions attendant on the subsidence of
the deluge, we may assign the origin of the lake to the enclosing or retaining
of the oceanic waters, as the ranges rose upwards from beneath the waves.

I shall presently speak of the most probable of these three causes, and
in the mean time taking for granted the former existence of the lake, pro-
ceed to show by what means it has disappeared.

The walls of the valley, then, we must suppose to have been at one pe-
riod continuous, without an outlet; thus forming an extensive basin con-
taining a lake of water, which from its vast expanse and magnitude, might
have been almost termed an inland sea.

The surrounding barriers of this lake rearing their heads aloft to an el-
evation of from 16,000 to 20,000 feet and upwards above the level of the
present sea, were then, as they still continue to be, the never-failing
receptacles of eternal snows, which furnished streams of ever-running
waters, all emptying themselves into the broad lake beneath.

This constant increase would of course in a little time cause the waters to
rise, and overflow that portion of their bounds which attained the least
elevation, and accordingly we find it actually to have been so at the con-
fluence of the present stream with the river Sutledge.

This overflowing would at first proceed quietly, and with a gently exert-
ed force; but as the action of the never-ceasing stream gradually carved a
deeper channel over the rock, a greater body of water would flow down,
bursting through and tearing away blocks of increasing magnitude, until
its weight and constant action having loosened and undermined the bank,
the massive barrier which had hitherto sustained this enormous weight,
now weakened by the repeated loss of its various supports and out-posts as
it were, would at length give way before the overpowering pressure of
the waters, and yield them a passage to the vales below.

Bursting with headlong fury through this, its long sought aperture,
what devastation must have attended the downward passage of such a bo-
dy of water! Huge fragments of rocks, together with the soils and pro-
ductions of whole districts through which the torrent rushed, must have
been swept off before it, and have been deposited at various distances from
their original sites, where combining with other soils, they would form
strata peculiar to those situations.

It is probable that these sudden overwhelmings of the district now called Kunawur, may have happened more than once, both from this and from other lakes; for although the Spiti lake had burst through its rocky barriers and found an outlet for the superabundant waters, it would merely have expended itself to a level with the opening it had made, at which point it would again remain until the accumulating supplies from the snow-clad peaks above, and the never-ceasing flow and action of the waters upon the already ruptured rocks, should again have brought about a similar outpouring of its waves, and thus would the lake gradually sink by the same never-failing means, from level to level, until its whole body of waters was expended, and so leave those trickling and apparently insignificant snow streams which had ultimately caused its expulsion from the valley, not only to usurp its former bed, but to form by their united waters the present river Spiti.

From these facts a question naturally arises, as to the probable source from whence the vast beds of marine exuviae found in the higher portions of this valley have been derived, and the answer to it must entirely depend upon the origin we assign to the lake itself. That is, if these mountains and the lake were in existence before the Mosaic deluge took place, it will follow, that the quality of the waters must have undergone a change from fresh to salt by the influx of the ocean, and it might on this account be contended by some that the marine shells rising with the waters, were here left living when that ocean again subsided to its proper bed; that as from that period the waters of the lake would gradually part with their saline properties, as the snows around continued to pour down their limpid streams, causing the lake again to resume its pristine freshness, it becomes evident that those marine animals, exclusively formed and adapted for an existence in salt waters, could only have survived there for a short time, and would then have been deposited in one vast accumulation. But had this been the case, the exuviae must have belonged to species still existing in the seas, whereas we find them all to be the spoils of extinct animals; and again, had such been the case, they would have been imbedded in strata of the tertiary formation, whereas, we find them in those of the secondary deposits, which are referrible to a period long antecedent to the Mosaic flood.

Thus, we must at once abandon this first position.

Secondly. If we suppose that the lake was formed at and by the deluge, and afterwards by the constant accession of snow water became fresh,—the effect, as regards the marine deposits, will still be the same; and consequently this second supposition must be abandoned likewise.
As it is therefore evident that the presence of the fossils can be attributed to neither of these sources, we are at once led to the conclusion, that the vast ranges of the Himalyan mountains were not in existence previous to the Mosaic deluge, but that the rocks and strata which they now exhibit were at that time horizontal, and forming part of the bed of the antediluvian ocean. Of this I shall adduce positive geological proof in the sequel.

The fossils therefore which are found imbedded in these higher tracts, did not become extinct at the deluge, but at a period long previous to that great event, when the secondary formations in which they occur were deposited, and which period though hitherto passed by unnoticed by writers on geology, is nevertheless clearly pointed out by the sacred historian.

In order more satisfactorily to ascertain the causes by which animals once living in the depths of ocean have been left imbedded in rocks now towering to a height of more than 16,000 feet above its present level, and at a distance of many hundred miles from it, it will be necessary to skim lightly over the events which have occurred on the surface of our globe from the time of its creation, until that last catastrophe to which these mountains owe their existence. "Geologists," says Cuvier, "have hitherto assigned but two revolutions to account for the phenomena which the strata of the earth now exhibit, namely, the creation, and the deluge, which he rightly thinks are insufficient, although he erroneously pronounces them to have been numerous." Nor is it surprising that he should have deemed them inadequate to account for such phenomena, since the first of these periods was no revolution at all, but occurred before the vegetable and animal races, whose remains constitute the chief phenomena of our strata, were created, and therefore it could have been in no wise instrumental either to their destruction or deposition. It is, moreover evident, that this first revolution of geologists could in reality be no revolution, but a creation! A revolution must imply the overthrow or upsetting of an already established order of things; while here in this first period we know that there was no overthrow, but a setting in order of things which had not as yet existed; therefore it was a creation, or calling into being an order of things which subsequently in after years was to be overthrown through the disobedience of created beings.

The separation therefore of land and sea, by which our earth was first called into existence, can be looked upon as only a creation, and such indeed it is termed by the sacred historian, for he tells us that in the beginning the materials from which our land was to be formed were called into being, and that on the third day, the interim being occupied in perfecting other arrangements all tending towards its welfare, the earth was separated from the waters, and its existence commenced. True, the record mentions two and only two distinct revolutions, but the Mosaic, equally with the
mineral geologist, has disregarded and passed over the first of them which occurred, not during but subsequent to the Creation, when man first transgressed the commandment of his Maker, and drew down, in consequence, the curse of an offended God upon the earth and its productions. Thus it would appear, that geologists are right in referring the fossil exuviae of the secondary strata to a revolution long prior to that of the deluge, and they have only erred in not assigning to it the actual period pointed out by the record.

The second revolution, or deluge, is too clearly marked, and its consequences too obvious to escape the notice of any one; but the historian enters into no details of the means by which the first was effected, although he clearly points out the effect of it. This difference in the seeming importance of the two revolutions may have arisen from the fact that the first did not, like the second, involve the loss of life to the human race, and therefore the record is content to point it out merely by its effects, leaving us at liberty to infer the causes.

Asserting therefore, with the inspired historian, that our planet, together with all its goodly furnishing of vegetable and animal life was created and finished in the space of six days, each of the same duration as these of our present computation, and that on the sixth and last day the progenitors of the human race were also created, and were consequentlly contemporaneous with the whole animal kingdom, as constituted before the fall, I shall endeavour to point out the period when, in my opinion, the marine animals, whose exuviae are imbedded in the secondary strata of the Spiti valley, ceased to exist.

Within the limits, however, which it is found necessary to assign to the present paper, it cannot be expected that I should much enlarge upon the time at which, or the causes by which this first great change in the temperature of our earth occurred, and I shall therefore pass it over with a slight allusion only, and with the less regret, since I hope at no distance of time to lay before the Society a theory of the changes which have taken place on the surface of the earth, from creation to the present time.

If in succeeding ages a writer were to state that the various countries of our present earth had suddenly undergone a great change for the worse in the prolificness and character of their vegetation, would not our posterity justly look upon it as an indication of a well marked revolution and change of temperature?

And would they not naturally seek for a corresponding change and loss in the genera and species of the animate classes?

Assuredly they might reasonably do so; then why do not we, who have a parallel case presented to us in the pages of Holy Writ, seek for traces of
that loss of animal life which must ever be a consequence of any great change or loss in the temperature and vegetation of the earth?

Such a revolution, although no details are given of its operations, is clearly implied in the effects which are recorded in this simple language of Scripture:

"And unto Adam, he said, Because thou hast hearkened unto the voice of thy wife, and hast eaten of the tree of which I commanded thee, saying thou shalt not eat of it:—Cursed is the ground for thy sake;—in sorrow shalt thou eat of it all the days of thy life;—thorns also and thistles shall it bring forth to thee; and thou shalt eat the herb of the field. In the sweat of thy face shalt thou eat bread, until thou return unto the ground; for out of it wast thou taken; for dust thou art, and unto dust shalt thou return."

That earth which had hitherto profusely yielded, freely and gratuitously, its choicest productions, now shrinking beneath the frown of Him, before whose wrath all nature trembles, refused to supply even the common necessaries of life, unless wooed into compliance by the sweat of man's brow, and the toil and labour of his hands.

Can a more convincing proof be required of a change of temperature, and of the first great revolution on the earth?

Or, can it be thought necessary to assign to the fossils of the secondary strata a more remote period than this, in all probability, the first few months of man's existence upon the globe?

Should such proof be required, it may at once be derived from the character of the fossil flora of the earth's strata, which although now abundantly found in northern latitudes, is wholly of a tropical form, and consequently the temperature of those countries must undoubtedly have been much higher formerly than at present.

It is unnecessary to enlarge here upon the several means which were instrumental to this change, and enough has been said to show, that to this epoch I would refer the extinction, and imbedding in the secondary deposits of the exuviae now under consideration, and it therefore only remains to state, that these marine formations as they are termed, remained in the bosom of the deep until the period of the second revolution or Mosaic deluge, when the mountains in which they now occur were upraised, for the purpose of throwing back the waters from the surface of the earth into their proper beds; to serve as agents, from their accumulations

* That is—"by labour."

† I am well aware, that many will object to this, that man did not exist upon the earth until long after the period here spoken of; but I shall be able hereafter to give proof that such doctrine is not only unfounded, but actually opposed to facts.
of snow, in reducing still more the temperature of the earth, and in furnishing those supplies to the rivers and streams, which are so essential to the welfare of organised creation; and, lastly, perhaps it may be added, to stand forth with their imbedded fossils as eternal and convincing monuments of man's fall and punishment, and of the truths so simply stated in the Scriptures.

My own opinions lead me to conclude, that when the waters of the ocean had risen over, and, as in the beginning again enclosed the earth in its cold embrace, and had effected the punitory offices for which it was permitted to transgress its bound, the lofty mountain ranges which now adorn the surface of our earth were successively upheaved through the agency of submarine volcanic powers, forming in the depths of ocean vast indentations or depressions, corresponding in magnitude to the masses which were upheaved upon the opposite surface, and into which depressions or vacuities, by the laws of nature still in force, the waters would have rushed or risen, forced down as they were by the pressure of the superincumbent atmosphere, and thus as each successive upheavement took place, the waters being drawn downwards would have again retired from the surface of the earth, into the place appointed to receive them; the same as on that third creative day when, as recorded in the Scriptures, they were commanded "to gather themselves together, that the dry land might appear."

Nor does this theory of submarine upheavements appear to be unsupported by the opinions of able geologists, for we find in the words of Dr. Buckland, "that trachyte and lava being ejected through apertures in granite, prove that the source of volcanic fires is wholly unconnected with the pseudo-volcanic results of the combustion of coal, bitumen, or sulphur, in stratified formations, and is seated deep beneath the primary rocks."

Among the vast mountain ranges which were then upheaved, the Himalya stands pre-eminent, and as it rose towering upwards from beneath the waters of the deluge, the lake in question, and doubtless many more, may have been borne on high enclosed among its loftiest ridges. If such were the case, its waters which at first were salt, would afterwards have become fresh, from the cause already stated. Or if no such lake were borne aloft, then must it have accumulated in after times from the snows above, until bursting through the barriers of gneiss, which had hitherto confined it, the valley would have been left nearly as we find it in the present day.

The solution of the problem must therefore be sought for in the strata and appearances which the valley now exhibits.

* For an illustration of this, see Fig. 5.
Those phenomena and appearances have already been stated, and it therefore now only remains to show, that they are precisely in accordance with the theory proposed, and prove it to be correct.

When the vast ranges of the Himalya burst upward through the watery shroud which had hitherto enclosed the earth, the lofty ridges which surrounded the lake became at once the eternal reservoirs of everlasting snows, from which numerous streams descended, as in the present day.

The waters of the lake itself were salt, being taken from the ocean, and they gradually yielded to the streams which descended from the heights, until they became first brackish, and finally fresh.

The largest body of water which was supplied from the snows was that of the Spiti river, and to its current are partly attributable the appearances of the present valley.

Let us then look well to the mode of operation.

The lake was salt or marine; its waters after the agitation caused by the upheavement had ceased became tranquil, and as their nature began immediately to undergo a change from the influx of the snow streams, a deposit from its waters commenced. That deposit I hold to be the bed of friable or earthy gypsum.

The reason why it occurs at the lower end of the lake is this:—The downward rush of the Spiti waters from the heights of the Paralassa range, caused a strong current to advance far onwards into the valley, where it became less and less rapid, till it died away, or was checked by the body of water below.

Thus we may at once perceive, that while the fresh waters usurped the upper portion of the valley, the middle and lower parts were occupied by brackish and salt waters respectively—a circumstance that may be fully understood by observing the confluence of a large river with a gulf or any part of the sea. The river is fresh, the junction brackish, and the ocean salt.

The gypsum or sulphate of lime would therefore naturally be precipitated in the greatest quantities at the lower end of the valley, where the waters were the saltiest, and the bed would gradually become thinner as it advanced into the intermediate part where the lake was brackish, and it would be wanting altogether in the upper part where the waters were fresh. This is precisely the fact, for the upper end or head of the Spiti valley is free from the gypsum deposit, while towards the middle we find the rocks often incrusted with it, or forming with fragments of shale and other rocks a gypsum breccia, which becomes less crystalline as it advances to the lower end of the district, where it yields to the thick beds or deposit of friable gypsum.
While this deposit was precipitating from the changing waters of the lake, the streams from the snows were bringing in large quantities of fine alluvial particles, such as sands and clays, and water-worn stones of various size.

These were deposited above the gypsum of the lower end of the valley, and passing on after that had ceased, reached to the upper end of Spiti. This too, is seen to be the fact, for the beds of clay are found not only covering the gypsum to a great depth, but also occupying its place at the upper extremity of the district.

At the same time, the waters carried onwards an uniform solution of clays, which they precipitated throughout the valley, the heavier stones and boulders were forming beds at the points where the streams fell into the lake. A reference to the annexed section will show the order and disposition of the various deposits which this valley contains, and serve to illustrate the foregoing remarks:—

__(See plate) Fig. 8.__

Section of the Spiti Valley.

Let 3. 3. represent the fall or present line of descent of the river Spiti from Leedung 12,037 feet, to Chungo 9897 feet above the sea.

It will be at once apparent that the waters of the lake must have had an increasing depth towards the lower end of the district, and that they were fresh about A;—brackish about B;—and salt at C. The gypsum was therefore, deposited at the lower end, and is represented as lying within the triangle 2. 2. 3.

At the same time, above this marine formation a thick stratum of alluvial deposits took place, forming a fresh water formation throughout the valley, as represented within 1.1. 2. 2.

The height at 1. on the left hand is 12,037 feet at the village of Leedung, and the corresponding elevation at 1. on the right hand is the height of the aqueous deposit about Chungreesing above Chungo, which is also 12,037 feet, thus beautifully exhibiting the line of the former surface of the alluvium.

Above this the waters rose and filled the valley, till they procured egress at the lower end, beyond Leeo.

Thus from the appearance of the district we gather, that it has once been the bed of an extensive marine lake, whose waters having at length burst through their barriers, have escaped by the channel of the Sutledge.

This fact I consider to be indisputable, and it leads at once to a satisfactory explanation of the origin of the deep alluvial deposits of clays,
Fig. 8
Section of the Stick Valley
sands, and pebbles now seen in the lower parts of the valley of the Sutledge, to which allusion has been made in the commencement of this paper.

Having now, I trust, satisfactorily showed how the theory proposed, and the facts observable, are in accordance, it only remains, before bringing the subject to a close, to take a brief and rapid glance at the geological formations of the lower hills from Kotgurh to the foot of the mountains.

Taking that station, therefore, again as a starting point, and proceeding towards Simla, we find the formation to consist principally of mica and clay slates, the one constantly fading into the other, and occurring in frequent alternations.—Quartz veins are numerous interspersed in the beds of mica, which is sometimes of a soft and scaly nature, containing but little quartz,—at others hard and compact, exhibiting little trace of the mica.

The mountain of Huttoo, which rises near Nagkunda to the height of 10,656 feet of elevation above the sea, is composed of mica slate and gneiss, while its summit exhibits some rugged peaks of granite jutting upwards through the strata.

The soils which occur from Kotgurh to Simla, are formed chiefly from the decomposition of the clay and mica slates, with the addition often of a rich vegetable mould.

Descending from Simla towards Subathoo, the primitive formations again yield to the secondary series, exhibiting dark blue limestones and many alternations of slate clay of different colours; dull-greenish, yellowish, and purple. The latter is also seen as the post or matrix of a quartz-ose breccia composed of angular fragments of white quartz.

Around Subathoo the change becomes the most decided, and the strata are there seen in perfection, consisting of the usual thick beds of clays and maries, varied with veins of gypsum, and resting on a red marle, apparently analogous to the red marle of England. The strata are here often upheaved nearly to a vertical position, and thick beds of shell limestone* are found alternating with thinner strata of compact limestones, containing casias of bivalve shells, similar to the “Venus angularis” of the European strata. Large specimens of Ostra also occur, as well as compact strata, almost entirely composed of small species of the fresh-water genera, Melania and Poludina.

The presence of these last prove again, beyond a doubt, that fresh water must have occupied eventually the basins in which the marine strata of the secondary series were deposited, and leads to the supposition, that nearly the same causes were instrumental to the formation of that series, as we have just shown to have been conducive to the deposition of the diluvium and alluvium of the Spiti valley.

* Strata composed almost entirely of shells.
Above these various alternations we find the *oolite*, with its strata of *sandstones*.

Captain P. Gerard of the Invalids, informed me that his brother, the late Dr. Gerard, had once discovered some *Ammonites* in the valley below Subathoo, but although I procured and fractured several of the dark rounded balls in which they often occur, I was not fortunate enough to meet with a specimen of the shell.

About eight miles from Subathoo, in an easterly direction, are rocks of a greyish *limestone*, rising above the *lias* and *oolitic* formation. Immediately underlying this are several strata separated by layers of flints of various forms, and imposed upon these, the *limestone* is first of all stratified and dipping in the same direction, namely, to the S. W.; but the superior portion of the beds rises in shattered and *amorphous* masses, giving a picturesque and beautiful appearance to the range. This *limestone* is quarried and used for economical purposes; it is of two kinds, one being of a pale dirty white or greyish colour, and is the stone from which the *lime* is procured, the other being darker and harder, emitting a strong sulphurous fetid smell when fractured. This latter is little used, and appears to hold the lighter coloured variety imbedded in it in large masses.

The geological position of this *limestone*, coupled with the remarkable occurrence of layers of rounded and kidney-shaped flints, leads to the supposition, that it may be analogous to the chalk formation of Europe, and if so, it will follow, that the vast ranges of the Himalya, so long supposed to exhibit strata of *gneiss* and *mica schists* alone, will be found to present formations entirely analogous to those of other mountainous countries, even from the *granite* upwards to the *alluvium*, at present in course of deposition and accumulation.

The range on which Subathoo stands, exhibits another example of the effects of what I have termed a *double upheavement*.

Seen from the dak bungalow of Chamier, the outcrop of the *sandstone* strata is seen dipping towards the N. Eastward, while the same rocks from which they have been torn, dip on the Chamier side of the Glen, towards the S. Westward.

But the N. Easterly dip is not the true direction, for we see again on the opposite side of the same range, that the strata dip likewise to the S. W.

Therefore, the deep valley or glen between the Subathoo and Chamier ranges is the line of disruption of the strata, causing them, as it were, to dip outward on either hand.

From Subathoo downwards to the foot of the hills, the strata belong to the *lias* formation, and gradually fade away until they yield at
length to the sandstones of the tertiary series, in which, at various places from Nahn to Buddee, the fossil exuviae of extinct quadrupeds are found.

This, although but a faint and meagre outline of the geology of the noble ranges of the western Himalaya, is nevertheless sufficient to point out the formations which occur from the base of the mountains to Spiti and Ludäk, and is as much as could be done in a hasty tour over so extensive a field. I shall now, therefore, draw this somewhat lengthy paper to a close, by alluding to the means by which the imbedded exuviae of these formations have been brought to light in these latter days.

I have already stated, that the fall of man is the true period to which the loss of the fossil marine Mollusca of the Spiti and Subathoo fields is to be referred.

At the time of their extinction, the secondary strata in which they are imbedded were under course of deposition in horizontal beds, beneath the bosom of a tranquil water, and thus they remained for a period of many years after.

The increasing depravity of the human race, once more called down the vengeance of an offended God, and brought about the second and last grand revolution which the earth has experienced, namely, the Mosaic deluge.

That catastrophe was the means by which the destruction of the large terrestrial mammalia of the tertiary strata was effected.

When, therefore, the waters had performed the punitory offices for which they were allowed to transgress their bounds, the mountains of the Himalaya were caused, among others, to rise upwards by some vast volcanic or upheaving agent, in order to throw back the ocean from the earth, and gather it again into the place appointed to receive it.

By that upheavement the primary series of the Snowy Range was thrust aloft in torn and ragged spires, while the secondary strata of Spiti and Subathoo then first rose upwards from their horizontal plane to the inclined position which they now possess. Consequent on the uprise of this secondary series was also that of the tertiary beds, and thus we find one single geological revolution to be the sole agent in upheaving the strata of three widely distinct and separate formations.

The Snowy Range or true Himalaya, is composed entirely of rocks belonging to the primary series, while to the north and south of it are found resting on its sides, strata of the secondary formations disposed at high angles from the horizon, and usually rich in the exuviae of marine and lacustrine Mollusca; while on the southern exposure, forming the base of the hills, and resting on the secondary rocks, occur the tertiary or diluvian beds, which the successful researches of Messrs. Falconer, Durand, and others, in
the present day, have proved to be so rich in the exuviae of the now extinct forms which once inhabited these countries. Whether this last series occurs also on the northern side, is a point for future investigation; but as fossil bones are sometimes brought down by native travellers from the Tartar hills beyond Almorah, it would seem that similar phenomena are to be expected there.

The inclined position both of the secondary and tertiary series, is clearly attributable to the outbreak of the primary rocks from beneath or through them and furnishes to the inquiring mind, a sure and beautiful guide by which the period when these vast mountain ranges first rose upwards to adorn our earth, may be satisfactorily and positively determined. The conclusion, therefore, to be drawn from the facts observable in these strata, are all strictly in accordance with the rules of geological reasoning, and I shall therefore now bring the subject to a close, by endeavouring to show the reasoning and existing facts to be in unison, and thus fix the period to which must be referred the stupendous and never-fading monuments of Almighty power, exhibited in the vast upheavements of the Himalyan range.

It is a fact accepted and admitted by geology as indisputable, that where one series of rocks having a horizontal position is found to rest upon another whose strata are inclined, it amounts to positive certainty, that the deposition of the former took place subsequent to the upheaving of the latter; and vice versa, where both series are found, the one resting on the other at high angles with the horizon, that the deposition of the superior strata took place previous to the upheavement of those by which they are supported.

Resting on the primary rocks of the Snowy Range, we find on either side the strata of the secondary series thrown into an inclined position by the upheavement of the granite and its usual accompaniments of gneiss and mica slates, proving by their inclined position, according to the above reasoning, that they were deposited previous to the outburst of the former through them.

Again we perceive, that resting on the secondary rocks the tertiary or diluvial strata of the Siwalik range have also an inclined position, consequent on the upheavement of the primary and secondary series, and therefore, that they too, by a parity of reasoning, were deposited previous to the upheavement of the two former.

Now the tertiary or diluvial strata containing the fossil exuviae of extinct terrestrial Mammalia are clearly attributable to the effects of the last great revolution which our earth has undergone, and consequently, we derive from the phenomena, presented to our notice in the various formations of the Himalyan mountains, sure and decided data for determining the period of
Fig. 9.

Imaginary Section of the Himalaya, showing how the upheavalment of the Primary Strata at 4. 1. 1. would cause the inclined position of the Secondary Strata at 2. 2. and the Tertiary deposits at 3. 4. Alluvium of the Plains.
their first upheaval, which period the facts adduced enable us to assign to the first subsidence of the waters of the Mosaic deluge.—(See plate) Fig. 9.)

We may suppose, therefore, that when the ocean had been permitted to transgress its bounds, and had again enveloped the earth as in the time before the third creative day, or separation of land and water; and had by its devastating effects fulfilled to the utmost the dreadful doom assigned to all organised creation, the vast and imposing ranges of the Himalya and other mountains were caused to burst upwards by volcanic agents from below, as a means of throwing back the waters from the earth into those bounds appointed to receive them, and also to furnish, by their subsequent accumulations of everlasting snows, a never-failing reservoir from which the rivers of the plains were to be supplied with waters to fertilize the soil; which plains, had the mountains been of inferior elevation, would for ever have remained barren and desolate, except during the prevalence of the periodical monsoon; for it is apparent, that in the hot climates of the eastern world, no snows could have rested upon mountains of a lesser altitude sufficiently long to afford a never-failing supply of waters for irrigation.

Thus, even in the ordering of a mountain range, and the furnishing of wintery snows, is the wisdom and unvarying goodness of the Great First Cause, made manifest to the minds of his inquiring creatures.

To enter at length into the means by which these revolutions took place, and the reasons why they were allowed, belongs more properly to a system or theory of geology than to a paper professing to be merely an outline of the geological formations of a limited district.

I shall, therefore, for the present, leave the question in this imperfect form with less regret, since I purpose ere long, (should circumstances befriend me,) to lay before the Society and the Public a theory, which I would fain believe worthy of their most serious and attentive consideration.

Candahar,
19th July, 1840.