immediately covering grits, was at that time undergoing denudation. The Labrador volcanic breccias, as they have been called, bear witness to the fact that during their accumulation the covering grits were being largely demolished, the granite sparingly, if at all. Now, assuming these breccias to be Permian, would it not be possible to trace the gradual uncovering of the Western granites by the character of the débris found throughout the newer beds of the Red Sandstones? A very arduous task, no doubt, but an interesting one. Then the schorlaceous rocks of such distant localities as Teignmouth, Budleigh Salterton, and the Midlands, should be carefully compared. Perhaps the first question to get answered is—Is there any region known, except the West of England, which produces crystalline schorlaceous rocks crammed with chlorides; and fine grits, saturated, so to speak, with tourmaline?

I need not say what a very important bearing these tourmalinized grits have on the volcanic theory of Dartmoor. Were the Dartmoor rocks first exposed to denudation, the once plutonic tourmalinized grits; or were they the higher lavas and ashes of a volcano? They cannot very well have been both. Then how are we to reconcile the apparently early appearance of these covering grits in the conglomerates with the famous Cattledown hypersthene-andesites found by the late Mr. R. N. Worth, and referred by him to an ancient Dartmoor volcano? Dartmoor is a wondrous easy problem if we suppress inconvenient evidence. But hear all sides, and it is a tough nut to crack.

In conclusion, I cannot refrain from expressing my admiration of the pertinacity with which my friends, Messrs. Somervail and Lowe, have so continuously attacked the Culm conglomerates. These granitic fragments are entirely new facts, and facts which may lead to a good many more, and one real new fact about Dartmoor is worth a volume of theories, however large such volume may be.

V.—ON THE COURSES OF THE LANDWASSER AND THE LANDQUART.

By A. VAUGHAN JENNINGS, F.L.S., F.G.S.

CASES of relatively recent change in the courses of rivers, due to the invasion of their valleys by neighbouring and more rapidly working streams and the consequent diversion of their waters, have been investigated of late years by an increasing number of geologists in different countries. Such phenomena are, of course, most frequent in mountain districts, and the Swiss Alps have yielded many examples of greater or less certainty. Some cases are evident and undeniable; others are difficult to decide upon, and need careful consideration of all available evidence; while in yet other instances it is possible that statements as to the occurrence of such changes have been accepted on inadequate authority. The generally received opinion as to the present and past relationship of the Landwasser and the Landquart can certainly not be included in the last category, but neither can it, I think, be rightly placed in the first.

The Landquart is a river of Northern Graubunden which now flows from the glaciers of the Silvretta group northward and

westward through the fertile Prätigau to join the Rhine between Chur and Ragaz. Near the village of Klosters, where the narrower valley of its mountain course widens into the ampler trough of the Prätigau, it receives two tributaries. From the north flows into it the Schlappina, rising behind the rugged mass of the Eastern Rätikon; on the south opens a side valley, which, when followed up, is found to lead to the saddle that now closes the northern end of the famous 'valley' of Davos. The stream which apparently

*I. Former drainage of the Davos district
according to Prof. Heim.*

descends from this saddle proves to be formed by the union of two, one from the east and one from the west,¹ but there is none flowing directly from the broad pine-clad divide between Wolfgang and the Drusatch Alp. On the south side of this curious 'Kulm' lies the deep Davoser See, and into the long, almost level alluvial area which succeeds it flow three rivers—the Fluëla, the Dischma, and the Sertig. The Fluëla and the Dischma enter near together below the south end of the lake, and form, with the insignificant outflow

¹ The streams are the Mönchalpbach and the Stützbach; the result of their confluence I have called the Lareterbach,¹ but find that on some maps it is called the Stützbach down to Klosters.

of the lake, the origin of the Landwasser. Five miles below the lake, but only at a level of thirty metres below its surface, the Landwasser is joined by the Sertig, which flows also northward and westward from its source among the snows of the Ducan. Thus reinforced the Landwasser flows on past Frauenkirch and Glaris, and through the Züge gorge, finally joining the Albula, and so in time also reaching the Rhine.

II. *Present drainage of the Davao district.*

Scale 1:250,000

Professor Heim considers that this distribution of the two rivers and their tributaries does not represent the original drainage conditions of the area. He is of opinion that the valley of the Landwasser once extended northward above the present site of Klosters, and that its river was continuous with that rising at the head of the Schlappinathal.¹ The western side of this valley consisted of a rock-wall continuous with the masses now remaining on either side of the Prätigau—the Mädrihorn and Calanda on the north and the Casanna and Cotschna on the south. This wall, on the hypothesis in question, was cut through by the head waters of

¹ "Mechanismus der Gebirgsbildung," p. 321.

the river which then occupied the Prätigau, and was eroding its source more rapidly than the ancient Landwasser could deepen its bed. The result was that the latter was cut into by the former, and its waters, with those of its upper tributaries, diverted into the channel of the pirate stream.

This theory has, I believe, been accepted by geologists in general both in Switzerland and elsewhere. It has been incorporated by Professor Tarnuzzer in his revised edition of Theobald's "*Naturbilder aus der Rhätischen Alpen*," and it has been made widely known to English readers by its inclusion in Sir John Lubbock's "*Scenery of Switzerland*."¹

It may seem rash to question a view put forward by so high an authority and so strongly supported; but as I have already to some extent committed myself to an opinion on the subject,² it is perhaps both justifiable and advisable that I should point out the considerations which, during several months' study of the district, have seemed to me to weigh against its too ready acceptance.

The conditions which, according to the hypothesis, existed before the diversion of the ancient 'Landwasser' are shown in Fig. 1. Even at first sight there seems here something different from the usual type of river origin. There is an absence of the tree-like structure, of the oblique convergence of tributaries that one associates with the upper waters of a drainage system, while the northward trend of the main feeders from the east seems distinctly exceptional.

Leaving these difficulties aside, however, for the present, and observing the sources from which the river would have been supplied, it is evident that the ancient 'Landwasser' must have possessed a current of considerable volume and great erosive power. The present Landwasser, fed from the mountains of the Scaletta and Ducan districts, is no mean excavating agent in the Frauenkirch-Filisur valley, but its predecessor would have had in addition the whole force of the 'Upper Landquart,' the drainage of the snow and icefields of the great Silvretta group. We may therefore be reasonably sure that such a river would be rapidly deepening its channel and tending to add to the relative height of its western wall.

The question then arises as to the nature of the stream on the other side of this barrier, and whether it is likely to have had the erosive force requisite even to keep pace with its powerful neighbour. It is difficult to imagine that such can have been the case. The lower Landquart is supplied by numerous streams from the side valleys of the Prätigau, but these enter it approximately at right angles from north or south, and their representatives at that time could have taken no part in the denudation of the transverse cliff-like outcrops at the head of the system. When the rock ridge stretched across from the Mädrishorn to the Casanna the head waters of the Landquart would have been only the little rivulets rising on the western face of the ridge of itself. The Landquart between Klosters and Serneus owes its existence, according to the theory

¹ London, 1898, p. 190. ² Quart. Journ. Geol. Soc., vol. liv; August, 1898.

itself, to the removal of the barrier ridge, and cannot therefore be regarded as the cause of that removal. There were doubtless small streams at work on the east side of the ridge (as suggested by the dotted lines in Fig. 1), but it is difficult to understand how there could have been any river describable as the former 'Landquart' engaged in its destruction.

The conditions which then existed may be paralleled at the present day by the source of the Plessur, a short distance to the south. This river is an important one in the Schanfigg valley after the lateral influx of the Fondeier and the Arosa-wasser: its upper waters are insignificant, and originate in a rivulet between the Weissfluh and the Schiahorn. The limestone ridge of the Schiahorn and Kupfenfluh here occupies just the same position in relation to the Davos and Plessur valleys that the ancient ridge at Klosters did to the Landwasser and Prätigau. Between the two mountains the ridge is lowered where it is traversed by the Strela Pass, but there is practically no running water at work on the western face at this point, and no evidence of denudation except that of atmospheric agents and the cutting of the Schiabach on the east. Sir John Lubbock,¹ it is true, suggests that "It is possible that in the distant future the Landwasser may be still further robbed of its territory. The waters of the Davos Lake, the Fluela, the Dischma, and the Kuhalphthal now take a very circuitous route to Chur, and it is not impossible that they may be captured and carried off by the Plessur."

Such a change may appear conceivable when considered only with the aid of sketch-maps, but I venture to think that anyone who carefully observes the contours or studies the locality in person, will find it very difficult to imagine its possibility. At its lowest the limestone ridge is 2,000 feet above the Landwasser at Davos, and, as pointed out above, is suffering no specially rapid denudation. On the other hand, the Landwasser is a considerable current which under normal conditions would be constantly lowering its level and so relatively adding to the height of the divide between it and the Plessur basin. It seems to me that a similar condition of things would have existed in the Klosters neighbourhood according to Professor Heim's theory.

It may be argued that some geological peculiarity of the district may have contributed to a rapid destruction of the ridge. It is true that the neighbourhood is one of complex structure—of the rapid thinning of some strata, and of folds and faults, torsion and overthrust. The hypothetical ancient 'Landwasser,' however, seems to have followed its own course independent of the disturbed strike of the strata and uninfluenced by the variety of rocks through which it cut, and we have no reason for supposing any special conditions that would have assisted its rival. Had there been any important line of weakness running east and west, the north-and-south course of the Landwasser would scarcely have been in the first instance established.

¹ "Scenery of Switzerland," p. 192.

Again, a study of the geological map may suggest that the rapid back-cutting of the Landquart was due to the more rapid erosion of the grey Bündner Schiefer of the Prätigau, in comparison with that of the crystalline rocks, limestones, etc., which formed the bed of the 'Landwasser.' The grey Bündner Schiefer, however, lay only at the base of the ridge, and it is the through-cutting of the ridge itself that is the difficulty. It was only after the cutting of the ridge that the Landquart would in the critical area have arrived at the underlying shales, and this brings us to a consideration of the nature of the ridge itself.

Although the district is a difficult one, owing to its being the point at which the simple outcrop-line of stratified works running south-east to Klosters from the Scesaplana district passes into the complex folds traceable near Davos, yet a study of the present outcrops of the various formations gives us a fairly accurate idea of what must have been the structure. Its most conspicuous feature was doubtless the band of 'Hauptdolomit' now seen to form the Casanna on the south of the Prätigau and the Calanda on the north. A line drawn from the present top of the former, doubtless then considerably higher, to the upper limit of limestone on the latter gives a height above the sea of 2,650 metres. This would be about 4,800 feet above the present level of Klosters, and 2,800 feet above the Drusatch Alp. The limestone series was accompanied by a greater or less thickness of Verrucano and Casanna Schiefer, with probably a band of serpentine; and the whole series was thrust over the grey Bündner Schiefer, which dipped south and east below it. Above the limestone and its associated rocks there was in all probability a capping of the schists and gneisses belonging to the older crystalline series, such as now overlies it to a vast thickness on the Eastern Rhätikon, and still remain to form the peak of the Mädrishorn. What may have been the thickness of this crystalline covering it is impossible to say. Even, however, if we suppose it to have been removed before the period under consideration there would still remain a barrier of a height and constitution to render it a formidable task for a few rivulets to attempt in competition with the forceful river on its further side.

Lastly, when one considers that the ancient 'Landwasser' represented not only the combined Schlappina, Upper Landquart, and Landwasser of to-day, but almost certainly a far greater volume of water owing to the wider extent of the snow and ice-fields on the eastern mountains—a difference of conditions that would not have had proportionate effect on the Calanda-Cotschna ridge—the inequality between the two agencies at work becomes still more conspicuously marked.

Such are some of the difficulties which, it seems to me, one must overcome before accepting Professor Heim's view. When we endeavour to get an idea of the bed of the ancient 'Landwasser,' and attempt to derive from it the present conditions between Klosters and the Davos-Glaris region, we meet with considerations no less

difficult to reconcile. To appreciate these it is necessary to observe some of the peculiarities of the Davos 'valley.'

If we follow up the Lareterbach from Klosters we find it descends in a steep valley with solid rock on the east and a great accumulation of moraine and detrital material on the west. Some three miles up, near Laret, it curves west, and is seen to descend from the pass between the Casanna and the Todtalp. Just below this bend it receives the Mönchalpbach, flowing from the Pisch glacier on the east, but there is no stream descending in the middle line of the valley. Half a mile south of the Stützbach is Wolfgang, the 'Kulm' of the Davos 'valley,' 1,634 metres above the sea, or 425 above Klosters. West of Wolfgang is the serpentine mass of the Todtalp, lying back at some distance but with a great talus-fan at its foot, which spreads over the Kulm and has apparently forced southward the stream of the Todtalpbach. East of Wolfgang lies the remarkable rounded and tree-covered elevation which stretches transversely across the valley and reaches a height of 1,776 metres at the Drusatch Alp, where it abuts against the schists and gneisses of the Hörnli.

The southern slopes of this ridge descend to the Davoser See, which is a mile in length and about half as much in width. While popular tradition as to the depth of the lake is undoubtedly exaggerated, the evidence of sounding and of calculation from the slopes of the surrounding mountains, leaves no doubt that the bottom is some 150 metres below the surface at the deepest point, about a third of the length from the north end. The south end shallows rapidly and terminates in the low-lying meadows around Dorf, which in turn are continued into the alluvial flat stretching on past Davos Platz. Into these meadows flows the Fluela, and its now canalized course, turning southward and receiving the little stream issuing from the lake, forms the origin of the Landwasser of to-day. Increased in volume by the influx of the Dischma, the Landwasser flows on, with but little drop, to Frauenkirch. Here it lies on the western side of the valley, and on the east a vast accumulation of detrital material marks the mouth of the incurrent Sertig. This mass presents a steep bank 30 metres high to the river, and is cut out above into the wide flat terraces of the Wildboden and Junkersboden. The level of these terraces is just the same as the present level of the lake, so that the height of their terminal bank represents the total fall of the Landwasser in the first five miles of its course. Below Frauenkirch the river, no longer canalized, pursues a winding course past Spinabad, Glaris, and Monstein, and then plunges into the gorge of the Züge. As far as Glaris it is flanked on the west by great masses of detrital material, but soon after passing that village it flows practically on its true rock bed.

In a paper published last year¹ I called attention in greater detail to these general features of the Davos area, and also pointed out—

¹ Vaughan Jennings, "On the Structure of the Davos Valley": *Quart. Journ. Geol. Soc.*, vol. liv (1898).

(1) That the Landwasser was not running as at present when the detrital fan opposite Frauenkirch accumulated, since a portion of that fan still exists on the west side of the valley, separated from the main mass by a subsequent down-cutting.

(2) That as the whole bed of the Upper Landwasser lies on alluvial and detrital material its present course gives no indication of the real contour of the rock-floor; and the latter may, and probably does, slope northward.

(3) That a comparison of the slopes of the mountain sides at a series of points along the Davos area also gives support to this suggestion.

(4) That the ice-movement in the district was certainly northward.

(5) That solid rock *in situ* cannot be found on the Wolfgang-Drusatch ridge, and that this feature in the landscape probably consists entirely of moraine material, mainly ice-borne from the Todtalp.

The conclusions which I based on these observations were as follows:—(1) That in Pre-Glacial times the Fluela, the Dischma, and perhaps the Sertig, flowed northward into the Landquart. (2) That in Post-Glacial times the presence of the Wolfgang-Drusatch mass and the detrital accumulation round Clavadel and Frauenkirch—then, as I have shown, far greater than now—caused the formation of a lake between these two points, probably with an outflow over Wolfgang. (3) That in time the work of the Landwasser below Frauenkirch, and perhaps of the Sertig also, so weakened the southern dam as to cause an outflow of the lake in that direction, carrying with it the waters of the Fluela and Dischma.

In making these suggestions I did not fully realize the extent to which they were connected with the whole question of the past history of the rivers; nor did it occur to me that some geologists would be willing to accept the idea of the former northward flow of the eastern tributaries, while still holding not only to Professor Heim's view but also to a belief in a solid rock ridge between Wolfgang and Drusatcha. I may, therefore, perhaps be allowed to say something in support of the conclusions I then arrived at before pointing out their bearing on the main question under consideration.

It has been objected by some that the detrital accumulations opposite Frauenkirch are mainly of a fluvatile character, and as a whole are not of sufficiently compact and massive character to have held up the waters of a great lake. We have exposed here, however, only what is probably a fringe of lighter material round the edges of a mass of coarser detritus. There are abundant examples near Clavadel of large rock-fragments ice-borne down the Sertig valley. It is also by no means necessary to suppose that the southern dam was merely a transverse barrier at this point. It is very probable that the whole valley was choked with débris as far south as Monstein. The enormous thickness of detritus full of ice-borne blocks which occurs at that village doubtless once crossed the Landwasser valley and abutted against the western cliffs of the Züge. In the same way the banks and terraces of the Langmatter

district are cut out of a mass that probably once stretched across the valley, and was heaped up against the slopes of the Rinnerhorn. We have here an amply sufficient amount of material to have supported the lake. The *fact* of the former southerly extension of the lake is generally accepted and perhaps undeniable,¹ but there seems no other way of accounting for its existence than that here suggested.

Secondly, as to the nature of the Wolfgang-Drusatch barrier. When I made the suggestion above referred to I based my conclusions on physiographic grounds only. The form and position of the mass and its overgrown character, offering a striking contrast to the bare and weathered Todtalp of which it has been regarded as an extension, suggest anything but an ancient ridge of rock exposed to denudation since Pre-Glacial times. It is evident that an immense amount of material must have been removed from the east of the Todtalp; yet we do not find great accumulations of serpentine in the lower valleys. Evidence of extensive glaciation is, as Theobald specially noticed, abundant on the upper Todtalp slopes. What, then, is more natural than to suppose that the removed material was piled up in this position? Added to this, the difficulty of in any other way accounting for the lake and other features of the valley seemed to me conclusive.

Since then I have spent some months in studying the solid geology of the neighbourhood² and find that the results of this totally different line of inquiry are confirmatory of my former opinion. Thus the serpentine band undoubtedly occupies a constant position between certain rocks: it follows, that is, the strike of all the other formations. Its outcrop runs from between the Schiahorn and the Weissfluh down the Meierhoferthäli, and obliquely across by Wolfgang to Laret; it reappears on the east of the Lareterthal at Rüti, and crosses the Upper Landquart valley to Monbiel. The line of strike thus *excludes the whole of the Wolfgang-Drusatch barrier*. If that mass were composed of rock *in situ* it would not be of serpentine, but of crystalline schists, limestone, and 'verrucano'; a continuation of the rocks of the Dörfliberg and

¹ I have been several times asked what date may be attributed to the former extension of the lake towards Frauenkirch, but I am not aware of any evidence on which conclusions can be based. The infilling of the old lake by detritus from the mountain sides and material brought down by the streams must have been going on since its earliest days, but it is probable that the final disappearance of standing water from parts of the Davos level is a very recent matter. The peat at the southern end seems modern, and above the Davos-Frauenkirch road the talus slopes contain a considerable quantity of peaty material near the surface. At the northern end, I am told that the Fluela discharged into the lake within the memory of those still living. It is said also that the Romans used the Fluela Pass as a route between the Prätigau and the Engadine, and the finding of Roman remains at Drusatcha suggests that they traversed the ridge at that point and passed round the shoulder of the Seehorn. This is not likely to have been their route if they could have crossed in the neighbourhood of Dorf. The name Wolfgang itself is said to represent the fact that the ridge formed the path of wolves from the eastern mountains, and this also seems to suggest that the foot of the Fluela valley was recently closed by the waters of the lake.

² The results of this survey are embodied in a paper read before the Geological Society on May 10th, 1899.

of those which are seen on the east bank of the lake and which reappear north of the Mönchalpthal.

Returning now to the question of the course of the ancient Landwasser, I have endeavoured in Fig. 3 to represent in diagram its possible changes of position in relation to the Davos area.

If we imagine the Schlappinathal brought into line with the Laret-Landwasser valley, we obtain the present surface contour here shown. If we take a point near the source of the Schlappina and draw a line to the point near Glaris where the Landwasser now flows on solid rock, we may get an idea of what might have been the river-bed had the ancient Landwasser persisted to the present day. The lines A and A' drawn parallel to this at different heights may therefore represent its course at different remote periods. The cutting away of the western ridge may be represented by a succession of notches, B, B'. On the supposition that this cutting was more rapid than the lowering of the river-bed there would have come a time when one of the notches reached the line A, A', and the Landwasser was consequently diverted into the Prätigau.

Subsequently the new river, the Landquart, widened its valley, till this gradually approximated to its present size, represented diagrammatically by C, C'. At the same time the Schlappina on the north would be progressively lowering its level and nearing its present position. On the south it may be supposed that the stream representing the present Lareterbach would have lowered its bed through a succession of stages represented by D and D'. The result of this would be the production of a watershed between it and the basin of the remaining Landwasser; there would be a ridge or divide just where, as a matter of fact, there is a deep lake. If the Wolfgang-Drusatch ridge were of solid rock *in situ* it might at first sight be thought to satisfy the required conditions, but it is evident that its sudden drop of 350 metres on the south could not be attributed to erosion by the Landwasser. This brings us to the most important point of all: the striking fact that the bottom of the lake is *actually lower than the bed of the Landwasser at Glaris*.

It seems so impossible to reconcile this fact with any view but that which supposes a northerly slope of the rock-floor of the valley, that it appears scarcely necessary to pursue the subject further, and we may summarize the results of our whole inquiry somewhat as follows:—

(1) The theory of the former origin of the Landwasser in the Schlappinathal is not tenable if the Wolfgang-Drusatch ridge is solid.

(2) If this ridge is an accumulation of Glacial age the hypothesis may be still tenable, but only on the supposition that after the diversion of the Landwasser, the Flüela and Dischma were also turned northward and produced a rock-bed sloping toward Klosters from some watershed south of Davos.

(3) This second possibility does not, however, dispose of any of the difficulties attending the cutting of the Casanna-Mädrishorn

ridge, and under these circumstances it seems natural to suggest that after all the Fluela, Dischma, and Sertig, as well as the Schlappina, may have been original tributaries of the Landquart.

In this case there is no longer any difficulty in understanding the cutting of the mountain barrier just mentioned. The old river system would have had a much more usual character and would naturally take its place among similar systems in the surrounding mountains.¹ And lastly, if we accept this view, we are no longer at a loss to explain the anomalous physiographic features of the Davos valley, but, on the other hand, are in a position to offer a simple solution of its problems.

REVIEWS.

I. — REMARKS ON THE HELIOLITIDÆ. By G. LINDSTRÖM. Kong. Svenska Vetenskaps-Akad. Handlingar, Bd. xxxii, No. 1. 4to; 140 pp., 12 plates. (Stockholm, 1899.)

UNDER the above modest title Professor Lindström has brought out a very important work dealing with the Heliolitidæ, a well-known family of Palæozoic Corals. At first intended as a review of the Swedish species merely, the scope of the work was afterwards enlarged, so that it now comprises a critical description of nearly all the known forms of this family, and it may be considered as a monograph of the group. The value of this work to the palæontologist depends not so much on the descriptions given of new and rare forms as on the very thorough and complete manner in which the author has investigated the structure of known species, by means of microscopic sections, and by this means establishing the detailed features by which one species may be distinguished from another. The characters assigned to the earlier known forms of this group were very frequently limited to those shown on the surface merely, and as these are in many instances very similar in species having a different internal structure, much confusion has consequently resulted. The author has spared no pains to ascertain the microscopic structural characters of the types of the known species, and these are represented with marvellous fidelity in the magnificent series of plates accompanying the memoir, and thereby much of the uncertainty respecting these species will be removed.

The earliest horizon on which the Heliolitidæ make their appearance is nearly at the summit of the Lower Silurian (Ordovician), none having been found below the Bala beds in England or the Wesenburg beds of Estland, whilst their highest limit is the lowest beds of the Upper Devonian. They have a very wide geographical distribution, as they are found in most countries

¹ Thus, the direction of the Fluela, Dischma, and Sertig is exactly the same as that of the eastern tributaries of the Inn, such as the Bernina and Chamuera. Again, their relationship to the present Lareterbach and the Landquart may be exactly paralleled north of the Rhätikon by the conditions existing between the Valzavenz and Vergalda, the Gargellenthal and the Montafun.