

Less than a century ago the site of Southport was marked only by a few fishermen's huts in a cleared space in these sand hills.

The hamlet was called South Hawes and was situated in the parish of Meols, a place of some antiquity, which still contains the "mother church" of Southport. The district was well described by Jamieson in 1636, in his *Iter Lancastrensi* (Cheetham Soc. Ed.) :—

"Ormeschurch and ye Meales
Are our next journey. We direct no weales
Of state to hinder our delight. Ye guize
Of those chuffe sands which doe in mountains rise
On shore tis pleasure to behould, which Hoes
Are called in Worold : windie tempest blows
Them up in heapes."

"Worold" is the hundred of Wirral, the northern promontory of Cheshire, which is similarly fringed by *Sand Dunes*, villages in which are still called "Great" and "Little Meols." The name is found in "Ravensmeols," a destroyed village on the Lancashire coast, and the name "meol" also occurs in the names of villages on the coast of Iceland, where Dunes of volcanic sand occur.

VI.—ON A SUPPOSED CASE OF METAMORPHISM IN AN ALPINE ROCK OF CARBONIFEROUS AGE.¹

By PROF. T. G. BONNEY, M.A., F.R.S.

A FEW years since it would have been flat heresy to assert that a very clear proof would be necessary before we could accept a crystalline schist as the metamorphosed representative of a rock of Palæozoic age. Yet at the present time many who have made a special study of this branch of petrology would not hesitate to go thus far, and some would even declare that we do not know of any completely metamorphic rock which is not of Archæan age. Certainly the stock instances of metamorphism in Wales, and especially in Anglesey, in Cornwall, in Leicestershire, in Worcestershire, have utterly broken down on careful study. Outside the English Geological Survey probably no person who can use a microscope believes that the schists of Anglesey are altered Cambrian, or that the slates of this age are melted down into the quartz-porphyry of Llyn Padarn. It is becoming evident that even the metamorphic fastnesses of the Highlands are in danger, and that at any rate even there the realm of "altered Lower Silurian" will be grievously curtailed. Startling facts are now and then adduced by the defenders of what we may call the 'established' (*i.e.* non-progressive) geology; fossils are said to have occurred in crystalline non-calcareous rocks, Calamites in gneiss, Trilobites in mica-schist, and so on; but those who are familiar with the molecular changes which take place in the formation of such rocks as these will require the clearest evidence before they can accept statements so antecedently improbable.

It may be worth while then to describe the result of my examination of a deposit in the Western Alps, which is often quoted as an example of metamorphism in a later Palæozoic rock. The subject

¹ Read before Section C, British Association, Southport Meeting, 1883.

is not novel, for the Poudingue de Valorsine, as the deposit is called, has been noticed by geologists again and again since the days of De Saussure, who described it with his usual accuracy; but when I state that more than one geologist of importance holds that the rock exhibits a considerable amount of metamorphism, I may be pardoned for directing attention to it. The Poudingue de Valorsine is a conglomerate, often of considerable thickness, at the base of the Carboniferous series in the Western Alps. For its distribution and the literature of the subject I may refer to Prof. Favre's classic work—*Recherches géologiques de la Savoie*, etc. I have examined this conglomerate, especially in the neighbourhood of Vernayaz. All authors agree that it contains fragments of gneiss and various schists with vein quartz. De Saussure, however, states that he did not find "any schist (*i.e.* slate) simply argillaceous or any limestone." It should, however, be mentioned that he is not speaking quite of the same locality as I describe, though he had probably seen it, and his remark appears intended to be general.

The conglomerate, together with a grit and dark slate, which in aspect resembles some of the Bala slates of Wales, occurs on the left bank of the Rhone, near Vernayaz and the opening of the famous Gorge de Trient. This last has been excavated in a hard gneiss, and the beautiful Pissevache cascade a little further down the valley is precipitated over a similar rock. Between the two, all seemingly interstratified, and now in an almost vertical position, come the conglomerate, grit, and slate of the Carboniferous series. Of course the last is simply caught in a great fold of the earlier rock, after the usual Alpine fashion, and there has perhaps also been some further disturbance of the nature of faulting. But as no one disputes that the gneiss and the conglomerate differ greatly in age, it is needless to enter into details on this point. The conglomerate crops out along the winding road which leads from the level of the Rhone to the elevated bed of the Val de Trient, and can be traced for a very considerable distance up the latter valley.

The conglomerate passes into and is interbanded with grits, and these are succeeded by slate, as may be well seen during the above-named ascent. The transition from the supposed metamorphic rock to the only mechanically altered is so rapid, that our suspicions as to the former may well be aroused. The fragments in it are generally subangular, of various sizes, commonly up to 2 or 3 inches in diameter, but occasionally as much as 5 or 6 inches. The materials are chiefly vein-quartz, gneiss, mica-schist, and a purplish argillite. The proportions of these rocks vary somewhat, as might be expected. The gneiss is a rather fine-grained one, with silvery mica; it belongs to the same group as that exposed in the immediate neighbourhood—that which in the Alps usually occurs some distance above the coarse granitoid gneisses or protogines—the lowest known rocks of the district—and the large group of variable schists, part of which is the Pietra Verde group of some authors. Silvery mica, however, seems more abundant in the fragments than in the rocks which occur *in situ*. The mica-schist is one of the ordinary strongish mica-

schists, which are associated with or rather higher in position than the above gneiss. The purplish slaty rock is much less common than the other, but it is indubitable, and shows no sign of metamorphism. The matrix is a dark leaden-grey colour, composed of scales of mica, mostly silvery, with a variable amount of quartz; it often weathers a bright iron-brown; the scales lie rather parallel one with another, and the whole mass undoubtedly looks extremely like a rather tender and somewhat massive mica-schist. The extremely sharp boundaries of the fragments however have a suspicious appearance, and in order to account for the presence of argillite among them, we must credit the metamorphic agents with very selective action indeed.

But the more we examine the rock even in the field, the more we become convinced that the metamorphic aspect is illusory, and that the mica scales are exogenous and not endogenous. Microscopic examination fully confirms this. The rock consists of the following minerals—1. *Quartz* in single subangular grains and granular aggregates evidently derived from a mica-schist or gneiss. 2. *Mica*: the greater part is a white mica, with silvery lustre, showing brilliant chromatic polarization, resembling that common especially in the more silvery mica-schists of the Alps; the remainder is a dull brownish mica, evidently somewhat altered. 3. A granular, somewhat earthy-looking mineral, sometimes pretty evidently replacing fragments of felspar, which is also more or less disseminated among the other constituents. Examined with the two Nicols it shows a peculiar scaly to granular speckling, very familiar to those who have investigated rocks of similar nature to this, as an alteration product of felspar,¹ though it is not easy to assign to it a definite name. There is the usual dark dust—ferrite or opacite—and a few grains of a black mineral, probably iron peroxide: also one or two grains of a clear brown, strongly dichroic mineral, probably tourmaline.² It is evident from the structure of the rock that it is of fragmental origin, and practically unaltered, only such micro-mineralogical changes having taken place as are usual in Palæozoic or even more recent rocks. The rock obviously has been greatly compressed, and the result of this has been to give a general parallelism to the mica flakes and so enhance the resemblance to a foliated rock, but of metamorphism in the technical sense of the word there is no trace.

Below the Pissevache fall, where some of the gneiss is so crushed that without microscopic examination it is impossible to say whether it has been crushed *in situ* or is a compressed arkose, we find an infold of a flinty greenish rock. The cliffs make examination difficult or impossible, and my knowledge of it is mainly derived from fallen blocks. It appears to vary from a very compact flinty-looking greenish-grey rock, with slight indications of cleavage (rather like some of the siliceous argillites or "hornstones" not uncommon in the older rocks of Britain), to a more granular and micaceous rock,

¹ It may be worth noting that in some *remanié* rocks the felspar is no longer recognizable, in others it is excellently preserved.

² This mineral has been noticed in the fragments.

presenting some resemblance to a *remanié* gneiss much compressed. One great block showed distinct interbanding of the compacter and more micaceous varieties, but the former is the more abundant. Prof. Favre considers this rock to belong to the Carboniferous series, though, as is needful, he expresses himself with caution. I have examined microscopically one of the coarsest and one of the finest varieties, and though they have no very direct bearing on the main questions of this paper, may record the result, as it is rather curious. The coarser fragment is so like a crushed gneiss that were it not for the label I could not distinguish it. Even under the microscope this resemblance is maintained; so much that I should not have liked to express a positive opinion from a single slide. The chief minerals are quartz, felspar, orthoclastic and plagioclastic, rather decomposed but recognizable, and mica, brown and white, the former in this case rather predominating. Not seldom two things are certain: that the minerals are associated as in the original gneiss, and that they have been broken *in situ*. I conclude then that we have here a seam made up largely of comparatively unrolled gneiss fragments, subsequently subjected to enormous pressure which has cracked some and welded all together. The structure of the compact flinty "argillite" is even more remarkable. I expected to find the usual minutely granular aspect of this rock, specks or fragments of clear quartz in a slightly earthy base, full of ill-defined crystallites. On the contrary, we see a fairly well-defined fragmental structure, in a minutely granular ground-mass into which the fragments seem sometimes to melt away. Crossing the Nicols a good deal of the minute filmy mineral, often called sericite, becomes visible, with the usual sub-parallel rootlet-like arrangement, common in schistose rocks. This of course is of the nature of foliation, but it is a change which in rocks of proper chemical composition readily takes place under pressure, and is as far away from the true foliation of a gneiss or mica-schist, to use a rough illustration, as the caterpillar is from the butterfly. Crossing the Nicols, the sericite becomes more conspicuous, being most highly coloured when the general direction of the fibres makes an angle of about 45° with the vibration planes of the Nicols, but the clastic aspect of the slide becomes far less marked. Many fragments are wholly replaced by a chalcedonic structure, speckly-translucent granules interspersed among darker, others are traversed by irregular bands showing this structure; the edges of most appear to melt through it into the surrounding ground-mass, so that not seldom one might reasonably have doubted whether the apparent fragments were not rather segregations.

On inserting a quartz-plate, the original structure is not only restored, but rendered far more distinct. It is then evident that even this remarkably compact and homogeneous looking rock has been made up to a large extent of fragments, sometimes as much as 0.06" in diameter, of quartz and felspar derived from a gneiss (I do not see any fragmental mica in the slide). This material has been subjected to immense pressure, the quartz grains have been broken, the felspar crushed; from the latter and from the inter-

spersed earthy dust, minute micaceous minerals have been formed, and the free silica been deposited as chalcedonic quartz or perhaps sometimes opal—and as the result a rock is produced to the eye indistinguishable from one of those formed from similar mineral matter much more finely divided.

In conclusion, I will venture upon two remarks. One, that no inferences with regard to metamorphism can be accepted until they have been fully confirmed by the evidence of the microscope, and in this particular branch of investigation the observer must be contented to serve a rather long apprenticeship. The other, that in the Val Orsine conglomerate we have distinct proof that the principal Alpine metamorphism occurred long before the Carboniferous period. When that conglomerate was deposited, the rocks from which it was derived and on which it rested were schists and gneisses not materially differing from those which now form the great central masses of the Alps. Go where you will in the Western, Central, and the greater part of the Eastern Alps (for of all these I can speak from personal knowledge), you pass abruptly from the comparatively unmetamorphosed rock, whose age you know, to a highly metamorphosed rock, of which you can only say that it is immensely older. Further, in the latter series you can trace a certain lithological and stratigraphical sequence, which leads upwards through a series of groups, how far separable I will not now attempt to say, from the coarse granitoid gneisses and protogines to the topmost well-stratified, but still truly metamorphic, schists; so that we seem justified in demanding very clear evidence before we can accept any of the crystalline foliated rocks of the Alps as of Devonian or Silurian age, even if we carry the latter group to the lowest limit of the late Sir R. Murchison.

VII.—NOTE ON THE NAGELFLUE OF THE RIGI AND ROSSBERG.¹

By PROF. T. G. BONNEY, F.R.S., F.G.S.

THE remarkable conglomerate, called nagelflue, which fringes a considerable extent of the northern district of the Swiss Alps, and in places forms almost mountain masses rising some 5000 feet above the sea, has already received much attention from geologists. One might then fear to handle a subject almost as well worn as its pebbles. Still there are one or two points to which in the present state of our knowledge it may be worth while to call attention.

During the last quarter of a century I have frequently passed over the beautiful sub-Alpine district of Switzerland in which the nagelflue and the molasse are the dominant rocks, the former affording the bolder, the latter the gentler scenery of the region; but last summer I devoted three or four days to a special examination of the great masses of nagelflue in the neighbourhood of the Rigi. I examined this mountain on both sides, and spent some time in investigating the vast blocks which fell from the Rossberg and overwhelmed the ill-fated village of Goldau. Without lingering

¹ Read before Section C, British Association, at Southport Meeting, 1883.