drawings, which were exhibited on a large screen by means of the oxyhydrogen light. These consisted chiefly of phenomena characterising the *Glacier Epoch*, such as, glaciers, moraines, ice-tables, crevasses, ice-caverns, scratched and polished surfaces of rock (roches moutonnées), perched blocks, and the many varied and beautiful geometrical forms assumed by snow-crystals.

The invited company numbered considerably over *seventeen hundred* ladies and gentlemen, and included the élite of the city and neighbourhood. By the permission of the Colonel and Officers of the "6th Royal Warwickshire," the excellent band of that regiment was in attendance, under the able conductorship of Herr F. Beyer, and contributed largely to the enjoyment of the evening. The Society was indebted to Mr William Nelson for the loan of the illustrations and apparatus necessary for the exhibition by oxyhydrogen light.

The *Conversazione* (the *third* given by the Society) was most successful in all respects, and proved to be one of the best ever given in Edinburgh.

Thursday, 6th February 1868.

Dr PAGE, President, in the Chair.

The following Communication was read :—

On the Granite of Shap, in Westmoreland. By HENRY ALLEYNE NICHOLSON, Esq., D.Sc., M.B., F.G.S. Read by Mr CHARLES P. NICOLSON.

About four miles to the south of the village of Shap, in Westmoreland, there occurs a mass of granite, which has been long known to geologists by the enormous number and wide distribution of the erratic blocks which have been derived from it. It breaks through the highest beds of the green slates and porphyries of the Lake district, and is of comparatively small superficial extent, forming but two elevations of any note, viz., Wasdale Crag, and Wasdale Pike. It is, however, remarkable for its peculiar mineral character, for the glacial phenomena which it presents, and for the great alterations which it produces in the contiguous rocks, belonging both to the green slates and porphyries, and to the Conistone series. As to the date of its production nothing can be positively stated, except that it is certainly posterior to the formation of the green slates, and prior to the deposition of the Old Red Sandstone, the conglomerates of which are well exhibited in the adjoining valley of the Birbeck, and contain fragments of its harder portions, along with crystals of flesh-coloured felspar. Not improbably it was formed in the

interval which intervened between the deposition of the Coniston and the Ludlow Rocks. At any rate, it is the youngest granite in the Lake district, no other having been found to exist above the green slate series.

Mineral Character.

When unaltered by contact with the neighbouring rocks, the Shap granite is extremely well marked and peculiar in its mineral structure. The base is formed of crystalline quartz and white felspar, in which are scattered numerous plates of black mica and oblong crystals of pink felspar. These latter are the distinguishing feature in the granite, from their great number and comparatively gigantic size—not unfrequently attaining a length of one to nearly two inches. The felspar of the base is usually white; but in some places it is greenish, apparently from the presence of oligo-clase. The large crystals of flesh-coloured felspar consist of ortho-clase. Dark-green masses of fine grain, from rapid crystallisation, occur here and there. They are the “heathen” of Scotch quarrymen, and interfere a good deal with the value of the stone for artistic purposes.

*Changes produced at the Junction of the Granite with the
Neighbouring Rocks.*

The above are the normal characters of the Shap granite, when no disturbing element is present; but very considerable alterations take place in it where it comes into contact with the rocks through which it breaks, these latter being at the same time greatly metamorphosed. In no place are these phenomena better observed than in a little stream near Scale Head farm, a short distance to the west of Wasdale Crag. The section in question was first noticed by Professor Harkness and myself, in the summer of 1867, and was described by us in a paper read before the Geological Section of the British Association at Dundee. The granite here comes into direct contact with the Coniston limestone, no members of the green-slate series being apparently interposed between the two, and it is altered through a zone of about fifty yards in breadth, when it assumes its normal appearance. Immediately beneath the limestone the granite is converted into a greyish felspathic crystalline rock, which passes shortly into a pink compact felstone. This in turn graduates into a very fine-grained granite, in which the large crystals of flesh-coloured felspar, which are usually present, have entirely disappeared; and, lastly, the ordinary variety of Shap granite is reached, some bands of imperfectly crystalline compact felspar being still found in it. The Coniston limestone, on the other hand, is seen with its ordinary dip and strike, but converted into a crystalline marble, or into a granular rock, striped with alternating bands of

white and brown. This latter appearance is the usual one, and is due to a segregation of the calcareous and aluminous constituents of the limestone produced by the heat of the granite, the white layers being composed of nearly pure carbonate of lime, and the brown of felspar. The Coniston shales and flags lying above the limestone are also displayed in their proper position, and are metamorphosed sometimes into a flinty chert or hornstone, sometimes into a quartzy grit.

The Coniston limestone and flags are again seen in contact with the granite, as long ago pointed out by Sedgwick, in the neighbourhood of Shap Wells. Here, however, the section is poor, and the limestone is much broken, and even brecciated. In other portions of its circumference the granitic mass comes into contact, not with the Coniston group, but with the underlying series of the green slates and porphyries, and here also the changes are well marked and instructive. The phenomena in question were first made out by Professor Harkness and myself in 1865, at Stockdale, in Long Sleddale; but a much better exhibition of the same was subsequently examined by us at Harrop Pike.

At Stockdale, in Long Sleddale, and its tributary Arncoside Beck, there is an excellent section of the top of the green slates, and the base of the Coniston series. The granite itself is not visible; but the highest beds of the green-slate series, consisting here of bedded felspathic ashes, are traversed by a vein of hard pink felstone proceeding from the granite. The felspathic ashes in contact with the vein are metamorphosed for a distance of two or three feet, but they are a good deal decomposed, and consist of numerous concretionary masses imbedded in a felspathic matrix. These concretions, when broken, at first sight closely resemble agates, and are composed of beautifully foliated pink felspar, arranged in alternate lighter and darker laminæ of great thinness. The altered band is succeeded by unchanged bedded felspathic ashes, which are in turn directly and conformably overlaid by the Coniston limestone, a thin bed (2 to 3 feet) of a volcanic breccia intervening in one place between the two.

At Harrop Pike, on its southern side, essentially the same phenomena are exhibited, but on a larger scale, and in much greater perfection. Here, as in the last-named locality, the granite itself is not seen, and here there are no signs of any granitic vein. The metamorphism which is observed must, therefore, be due either to the granite being but a short distance beneath the surface, or to its having overflowed, and having been subsequently removed by denudation—the former hypothesis being the most probable. In this locality, a large mass of bedded felspathic ashes is exposed, but they are found entirely to have lost their ordinary character, and to be metamorphosed into an exquisitely foliated felspathic rock, the folia

being alternately pink and white, and of extreme tenuity. These altered ash-beds attain a very considerable thickness, and must be immediately surmounted by the Coniston limestone; but the latter is not exhibited. They repose upon a band of dark shales, interlaced with felspathic ashes, the latter being sometimes fine-grained, sometimes almost of the nature of a breccia, but not being in any way altered. The shales, however, show marked traces of metamorphic action, being considerably indurated, and containing numerous nodules of bright red jasper. These shale beds are doubtless the representatives of the "Dufton Shales" beneath the Pennine Chain (see *Harkness' Quart. Journ. Geol. Soc.* vol. xxi.), and are therefore the direct continuation of the fossiliferous band at the top of the green slates and porphyries, which was described by Prof. Harkness and myself as occurring in the Lake district (*Quart. Journ. Geol. Soc.* vol. xxii.)

Glacial Phenomena.

Wasdale Crag has long been known as affording the most convincing proofs of the action of glaciers and icebergs in the north of England, but it is not my intention to do more than notice these very briefly.

The Crag itself is very beautifully and extensively moutonnée, and in some places is scored by glacial striations, which have a W.S.W. and E.N.E. direction. Owing to the rapid weathering of granite, these striæ, however, are only visible on surfaces which have been recently laid bare. The lower part of the crag is covered by glacial drift, composed of granitic detritus, and containing pebbles of the Coniston flags and grits, of porphyry, and of the granite itself.

The erratic blocks of the Shap granite are distributed in enormous numbers over the whole country to the south and east of the crag; but they are too well known to require any description. Owing to the very well-marked mineral characters of the rock, boulders of it can be infallibly recognised; and they have been traced over the Pennine Chain by the pass of Stainmoor (1500 feet in height) as far as the eastern seaboard of Yorkshire, a distance of about 60 miles.

General Conclusions.

As regards the general conclusions to be drawn from a study of the Shap granite, I may remark, in the *first* place, that the phenomena above described lead almost inevitably to the belief that the granite of Wasdale Crag must have been produced by igneous action. In using the term "igneous," I do not, of course, overlook the co-operation of water; and there is no real impropriety in the expression, since we know that water plays an essential part in the production even of the recent

volcanic rocks. To avoid ambiguity, however, the term "hydro-igneous," suggested by Mr David Forbes, may advantageously be employed. It appears then, certain that the Shap granite is of hydro-igneous origin, as shown by its breaking through the stratified rocks, into which it sends numerous veins; by its being itself altered in mineral character at the line of contact with the beds through which it bursts; and by the fact that these latter show all the ordinary effects produced by being subjected to a powerful source of heat.

Secondly, The conclusion which I have just stated is borne out by the occurrence of phenomena similar to those above described in connection with all the other granites of the Lake district.

Thirdly, It is noticeable as a singular, if not easily explicable, fact, that all the various granitic masses of Cumberland and Westmoreland are strictly confined to a given horizon in the series of stratified rocks. They none of them, namely, transgress the upper limits of the green slates and porphyries, in which group they most frequently occur, though some of the smaller exposures are found in connection with the underlying group of the Skiddaw slates. The vast series of the Conistone rocks is not known to exhibit a single granitic boss, and the same is true of the Ludlow beds. It appears, then, that all the granites of the two counties either underlie or directly penetrate a series of rocks, in which there is ample evidence of contemporaneous igneous activity; since the green slates and porphyries consist almost entirely of felspathic ashes with interbedded traps and porphyries. This fact, if understood, would probably throw some light upon the much-vexed question of the origin of granite; but our present knowledge is not sufficient to enable us to come to any decided conclusion.

Fourthly, Neither the Shap granite, nor any other granite in the Lake district, can be shown to be in any way connected with any axis of elevation or disturbance. The Shap granite, like that of the Caldew valley, does not derange the inclination or relative position of the rocks through which it breaks, and, therefore, cannot be said to form a "mineral axis."

Finally, In stating my decided conviction, that the granites of Cumberland and Westmoreland are truly eruptive or igneous rocks, I would at the same time state, that I do not affirm that *all* granites have a similar origin. It is perfectly possible that some granites may be due to "hydro-thermalism," in the ordinary acceptation of the word; that is to say, that they may be simply the extreme term of the metamorphic series. This view, however, obtains little countenance from the phenomena observed in the Lake district, and I should be inclined to believe that it is applicable to fewer and to less decided and conspicuous cases than is supposed by some eminent geologists.