- XVI. *The Geognosy of Scottish Tourmalines.* By J. G. GOODCHILD of the Geological Survey, F.G.S., F.Z.S., PRESIDENT, Custodian of the Collections of Scottish Geology and Mineralogy in the Edinburgh Museum of Science and Art.

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AN extensive series of specimens containing Tourmaline forms part of the Scottish Mineral Collection which has been under my charge in the Edinburgh Museum of Science and Art during the past thirteen years. As these specimens present some features of more than a purely mineralogical interest some notes upon them may well be placed before this Society.

Tourmaline is essentially a Rhombohedral Boron-Aluminium Subsilicate, which contains either Magnesium or Iron, or else an Alkali. It may be regarded as a name for a small group of subsilicates of somewhat diverse composition, in which Boron, in the proportion, in some cases, of nearly thirteen per cent., is combined with Aluminium, and with other bases. Thus there are recognised Alkali Tourmalines, Iron Tourmalines, Magnesium Tourmalines, and even Chromium Tourmalines. Fluorine and Lithium occur too in so many cases that they may almost be regarded in the light of essential constituents.

There are about thirty native Boron compounds known, of which twenty-five or so are borates of the metals. Only two of the thirty have hitherto been recorded from Scotland: the other besides Tourmaline being Datolite. As its composition may be said to be various, so is its colour, which may range through greater part of the scale, or, on the other hand, the colour may be absent altogether. The Tourmalines which contain much iron are usually dark in colour, or even black, and in this latter case they are opaque.

The most usual and characteristic habit of Tourmaline crystals is that of elongated prisms, trigonal in cross section, each side of the prism presenting the appearance of being more or less rounded. This is due to an oscillatory combination of the unit prism $m, 10\bar{1}0$, with other prisms lying near to it, which also gives rise to a very characteristic longitudinal striation. Quite commonly three or even more forms in the prism zone are combined in this way. Terminated crystals are of very rare occurrence in Scotland, and are found only where the mineral has finished its growth in a cavity with one end of the crystal free. In all other cases the crystals may be described as

idiomorphic in the prismatic zone, and allotriomorphic at their ends. It may be remarked here that this is only one case of very many amongst minerals in which crystals of elongated habit retain their own form in the direction of least extension, and lose it earliest in the direction in which growth has been most rapid. In the present case this fact is remarkable, seeing that the very same minerals which constitute the matrix of the Tourmalines are hindered in their growth by the prism faces of the Tourmaline, which therefore in that direction impresses its form upon its neighbouring minerals; while, at the ends of the crystal the converse occurs, and the matrix impresses the Tourmaline. If this curious phenomenon were confined to the mineral here specially under notice less might be thought of it; but that is not the case. Many other minerals which tend to assume elongated forms behave in exactly the same manner.

The next point for consideration is the habitat of Tourmaline. Usually the matrix in which it occurs is in rocks which were primarily of eruptive origin, formed at great depths below the surface. In the majority of cases it occurs with highly silicated minerals, and, indeed, Quartz is associated with it in every case of the great many I have yet had an opportunity of examining.

It occurs most commonly in rocks which have undergone more or less change by causes of a mechanical nature. These may vary in effect, from the simple cases where a slight crush has been caused by the contraction of the outer parts of an eruptive mass as a result of differential cooling and contraction during consolidation; and may extend to the extreme cases of deformation, which seem always to accompany the upheaval of great continental masses. Deep below the surface which is undergoing upheaval the cores of the great earthfolds must always be the parts of the Earth's crust which are subjected most to the effects of dynamic metamorphism. It is within these cores that Tourmaline chiefly occurs. It is found in them in mechanically deformed rocks of almost every grade, from the simple "short" or granulitic phase of alteration, through the various schistose stages, to the stage at which recrystallisation has set in. It may be said to occur most commonly in connection with those interesting types of rock structure which are collectively referred to as pegmatites, and which form the *nidus* of so many species of minerals of interest. Here, perhaps, it may be as well to define what I understand by the term pegmatite, especially as the definitions given in text-books are in every case at fault. Pegmatites are coarse-grained, local, aggregations of rock-forming minerals, chiefly of Quartz and various silicates, which are intimately

related in composition to the matrix in which they occur, and into which they grade by decrease in the size of their several constituents. They differ from Aplites in not being more highly-silicated than their enclosing mass, and they differ also from intrusive masses not only in their being identical in composition with that of their matrix, but in never showing anything approaching a well defined line of separation, and in never showing the signs of "chilled edges" which nearly always characterise intrusive masses.

So far as *composition* is concerned these pegmatites may be of any kind, from ultra acid even to ultra basic. So I have long employed the term Granite Pegmatite, Syenite Pegmatite, Diorite Pegmatite, Gabbro Pegmatite, etc., in arranging the Rock Collection in the Edinburgh Museum, and I think the terms referred to were first used there. In like manner has the term Aplite been used by Mr Harker, so that we have Granite Aplites, Gabbro Aplites, Picrite Aplites (like those I described some years ago in these Transactions, from the Picrite of Barnton, near Edinburgh). The structure is characteristically granitic, but it often passes into that of a more or less well-marked graphic character. As regards the origin of these rocks a word may be said here. I have long held that pegmatites represent the effects of a local relief of pressure, which has taken place while the rocks in which they occur have been at a high temperature, which has been caused by dynamic metamorphism, and the resulting conversion of the energy of motion into that of heat and chemical action. Water has been present—concentrated sea-water, perhaps. The alkalies in this have facilitated the solution of the silicates, which has commenced directly a local relief of pressure has taken place. The stages in the development of pegmatites seem to be, first, the evolution of heat by dynamic causes; and next, the formation of granulitic structure when the rocks have become "short in the grain" through a repetition of these dynamic effects. After that, if the temperature is raised by the heat evolved from dynamic action upon contiguous masses, and this takes place in the presence of water, migration of rock material ensues, and augen are formed wherever a local relief of pressure takes place. These augen, in their turn, aggregate into the pegmatites whose origin is under consideration. Finally, pegmatite bands may extend and coalesce, and so give rise to gneiss or even to the magma of eruptive rocks. Pegmatites, on this view of their origin, have arisen through dynamic causes. The graphic structure so commonly seen in them is connected with consolidation under slightly less pressure than is necessary for the development of granitic structure of the normal kind.

Now, as already stated, Tourmaline is rarely found in any rocks but those which afford clear evidence of having been subjected to dynamic causes. Whether they occur in pegmatites, as they do usually, or whether they are associated with parts of great eruptive masses which have consolidated after being affected by the movements resulting from the shrinkage of the cooling mass, the evidence points to the same conclusion. That is, the origin of Tourmaline is in some way connected with dynamic causes. Not only is this the case, but it can be proved in a very large number of cases that the formation of the Tourmaline was completed at a late stage in the history of the development of the dynamic effects, but before the final consolidation. This is shown by the fact that the matrix enveloping the mineral under consideration shows much more strongly marked evidences of crushing than the Tourmaline itself does. Furthermore, it is evident that, after the Tourmaline had consolidated, differential movements which previously affected its matrix have been repeated, but to an extent less marked than before. This is evidenced by the fact that the Tourmalines (Scottish examples, at all events) are invariably bent and fractured, though manifestly they have suffered less than their matrix as a whole. Lastly, the fractures are mended, in all cases, with crystalline Quartz, which is not unusually accompanied by both felspar and mica, all three of which must therefore be of later origin than the fractures in which they have crystallised.

It may be remarked here that every specimen of the fifty or more exhibited in the Scottish Mineral Collection, which come from about all parts of the kingdom, affords evidence of the sequence mentioned.

When we come to seek for an explanation of these facts so many difficulties arise that they seem to forbid any one to even make the attempt. These, however, are the facts: some day their consideration by the light afforded by evidence collected over a much wider area may help us to understand their history better than we are able to do at present. One of the questions that will have to be answered in this connection will be: "Where did the Boron come from?" Did it arise from below? Is it one of the results of the concentration of the many substances held in solution by sea-water? Is it one of the constituents of the magma left over after all the rest had been used up in the formation of the matrix? Or is it due to some other, as yet unsuspected cause?

Whatever proves to be the origin of Tourmaline I am confident that the search for answers to these questions will lead to an improved insight into the geognosy not only of the

Tourmaline, but also that of the enigmatical rocks in which it occurs.

It may be well here to summarise the chief points noticed in this paper: (1) Tourmaline is usually a secondary mineral associated with highly silicated rocks which have undergone mechanical deformation. (2) Its initial stage dates from a late period in the history of the dynamic changes, but the crystals had completed their growth before the movement quite ceased. (3) They were next fractured and bent; possibly also their ends were partially absorbed and rendered allotriomorphic to the matrix there at this stage. (4) These events happened prior to the final consolidation of some granitic material, because Quartz, Felspar and Mica fill the interspaces between the broken portions of the crystals of Tourmaline.

Is all this quite in accordance with the currently-received views regarding the origin of the eruptive rocks and gneisses? I think it is not.

Lastly: Scottish Tourmalines, as already mentioned above, very rarely show crystalline terminations. In the few cases represented in the Scottish Mineral Collection in which they do so, I have determined the forms and drawn the crystals. The figures below represent these. These figures are, in each case, accompanied by their respective registration-marks, which will enable anyone to identify the originals.

FIGURES OF SCOTTISH TOURMALINES.