On the Polysynthetic Structure of some Porphyritic Quartz Crystals in a Quartz-felsite.

By Major-General C. A. McMahon, F.G.S.

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BEFORE describing some features of special interest in the micro-porphyritic quartz crystals of an Indian felsite, it may be as well to say a few words, by way of preface, regarding the rock itself.

About 85 miles to the north-west of the town of Delhi, in the peninsula of India, a hill rises abruptly from the plain to the height of 630 feet. It is one of a series of similar elevations separated from each other by some miles of sandy soil which strike the traveller with their resemblance to a group of islands in a tempestuous sea—an idea greatly favoured by the long swelling waves into which the sand is thrown by the strong westerly winds which prevail in that region during the greater part of the year.

The dip of the rocks of which the hill of Tushám is composed is nearly vertical; those on the eastern flank consist of chiastolite schists; and they are succeeded, as you proceed towards the west, first by pale grey argillaceous beds traversed in all directions by bright red ferruginous bands, and then by felsites that compose the centre and western side of the ridge.

Granite and quartz-porphyry intrude into the felsites at different points, and a granite-porphyry, that closely approximates to a true granite, forms the substance of neighbouring hills.

Some 250 miles and more to the south-west of Tushám Dr. Blanford some years ago discovered felsites in Bálmir, in some respects resembling those of Tushám, which are associated with beds of unmistakable volcanic ash.

The Mallání beds of Bálmir, and the felsites of Tushám, are probably rocks of extreme antiquity; but as they occur in isolated outcrops their precise age in both cases is unknown.

In the thin slices of one of the Tushám felsites several of the porphyritic quartz crystals when examined between crossed nicols present the tessellated appearance peculiar to the polysynthetic structure, being made up of countless quartz grains of microscopic size. These crystals are set in a structureless felsitic groundmass.

The porphyritic quartzes of the felsites and quartz-porphyries of Tushám are corroded in the way familiar to the student of rocks of this class. In some, the original outline has been more or less completely destroyed; in a few the crystallographic form has remained nearly intact; whilst in others the outline is partly sharp and partly blurred. Some crystals seem to have been on the point of disappearing altogether; some have had their corners rounded off and part of their substance eaten away, whilst some have only yielded here and there; fragments of free quartz, in the last mentioned cases, however, seem to have been on the verge of being floated off from their parent crystals when the process of re-solution was arrested by the cooling and consolidation of the rock.

The polysynthetic structure of these quartz-crystals is not the only point to be noted in them. The crystals that exhibit this structure appear to have been extensively schillerized. Red and brown oxides of iron, and other material, have been freely introduced, and numerous strings of a flaky colourless substance, that I believe to be a species of mica, have been formed in them.

It is noteworthy that these wavy strings, though not exactly parallel to each other, maintain a common direction within each quartz-crystal undisturbed by the micro-grains into which it is subdivided. In one of the members of a group of crystals the micro-grains of quartz show a disposition to elongation in the same direction as the micaceous strings. I have attempted to show this in my plate; but as regards the exact shape of the micro-grains depicted therein I do not pretend to minute accuracy.

Dr. Sorby in one of his classical papers stated that "the quartz of thin-foliated gneiss and mica-schist differs from that of granite in having a far less simple optical structure, and in being often more or less flattened in the plane of foliation. Instead of the larger portions of quartz being made up of a few comparatively large crystals, they are frequently composed of very many, closely dovetailed together, as if formed *in situ*."[1] Other petrologists have gone even further, and apparently accept the polysynthetic structure as evidence of a metamorphic in contradistinction to an igneous origin. The latter conclusion is, I venture to suggest, an erroneous one. Micro-granules of quartz are no doubt characteristic of schists, but they are not confined to rocks of clastic origin. The eruptive

[1] *Q. J. G. S.* Vol. XXXVI., Anniv. Address, p. 48.

granites of the Himalayas, to the study of which I have devoted some time in past years, abound in polysynthetic grains of quartz. If the canon of interpretation alluded to were to be applied to the crystals now in question, we should have to regard these quartz-crystals as fragments of schists included in the felsite. The strings of micro-crystalline mica might seem to support this contention; but an advocate of this theory would, I think, find some difficulty in accounting for the striking crystallographic outlines of these fragments. Some petrologists, on the other hand, appear to consider the presence of polysynthetic structure in quartz as evidence of mechanical pressure; and when they see quartz grains elongated in the same general direction, they regard the circumstance as an indication of plastic deformation. But, in the case before us, all argument regarding plastic deformation seems to be put out of court by the fact that the Tushám rocks give no evidence of crushing either in the field or under the microscope. None of these felsites, or the granites in their neighbourhood, give the least indication of even incipient foliation.

The polysynthetic structure of these quartz-crystals must be accounted for in some other way than by an appeal to plastic deformation.

The inclusion of portions of the groundmass in the porphyritic crystals of quartz-porphyries has long been recognised as a characteristic of rocks of that class; and the explanation given by M. M. Fouqué and Michel Lévy, in their *Minéralogie micrographique* is, that these quartz-crystals were formed in the magma in an early stage in the history of the rock, and subsequently underwent partial re-solution.

Evidence that the inclusion of portions of the groundmass in the quartz crystals of the Tushám quartz-porphyry was not, like the glass inclusions in the minerals of some lavas, due to the entanglement of the base consequent on rapid cooling after the eruption of the rock, but that it was due to corrosion, is, I think, furnished by the Tushám rock itself. "The matrix," to quote from one of my Indian papers,[1] "of a hand specimen taken from the thin tongue protruded" from the main dyke "into the adjacent rocks is perfectly compact, even when viewed with a powerful pocket lens, whereas that taken from the body of the dyke appears, under the same lens, to be micro-granitic rather than compact—a difference attributable, I presume, to the fact that the thin tongue cooled more rapidly than the main dyke. If the porphyritic crystals were formed after the intrusion of the quartz-porphyry, one would expect to see a marked difference between those in the tongue and those in the main dyke, correspond-

[1] *Records Geol. Surv. India*, Vol. XVII. p. 108.

ing to the difference observable in the matrix of the specimens from the two localities. One would, also, expect to see inclusions of the groundmass more common, and crystallographic outlines less frequent in the former than in the latter. No such difference, however, is to be discerned. Sharp, well-defined crystallographic outlines are not rare in the quartz of the specimen from the tongue; whilst the crystals in the main dyke are quite as much corroded as any in the tongue."

The commonly accepted explanation of the cause of the inclusion of portions of the groundmass in the quartz of quartz-porphyries suggests, I think, an explanation of their polysynthetic structure. These crystals were, I suppose, formed whilst the uncooled igneous rock was at rest below the earth's crust. Movement towards the surface then took place, probably in connection with volcanic action; pressure was relieved; the melting point was consequently lowered, and a re-melting or re-solution of the porphyritic crystals commenced. The first stages of this process consisted in the schillerization of the quartz-crystals. Extraneous mineral matter penetrated from the matrix into the quartz-crystals along "planes of chemical weakness," to borrow the admirable term used by Professor Judd, and the ferruginous patches and flakes and strings of mica now to be seen[1] in them were introduced. In the gradual progress of the magma upwards, pressure was still further relieved, and the tendency to re-melt was increased. Some of the crystals appear to have nearly succumbed to this influence and to have been almost completely assimilated—remnants of them, however, may I think be still detected in patches here and there. Some crystals yielded less readily than others, and in the case of those under description the process of re-melting was suddenly arrested by their having been poured out on the surface, or moved into a position between comparatively less heated rocks, where the process of cooling and consolidation set in.

A rapid transition from a condition of heat verging on the melting point to one in which the loss of heat was rapid, must have caused considerable internal strain; and it is to this internal strain at the moment of consolidation that I attribute the formation of the polysynthetic structure of the crystals now exhibited.

Another explanation may be suggested. It seems possible that this structure may be an indication of the commotion into which the molecules of quartz were thrown, and the breaking up of old ties which took place when the melting point was almost reached, but I incline towards the first explanation.

[1] As the polysynthetic structure and the schillerization could not be shown together without confusion, I have not attempted to illustrate them.

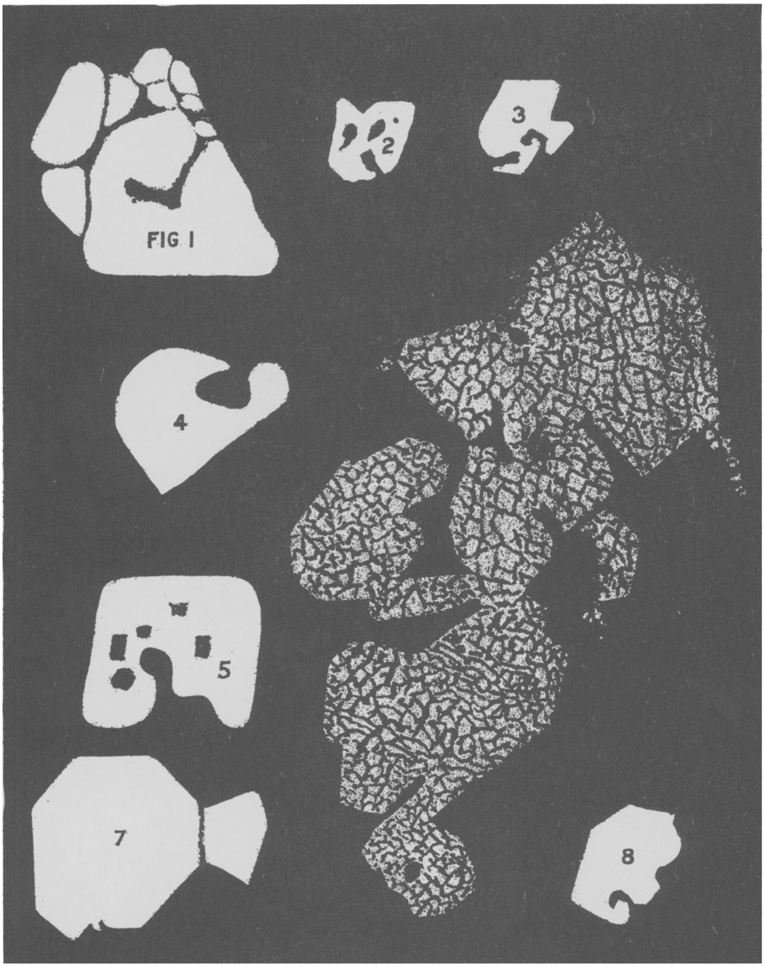
I may mention in connection with this subject, that I have specimens of complex felspar crystals, or rather groups of crystals, which occur in a lava from the crater walls of Monte Somma, Naples (collected by myself), which may, I think, be explained in the same way. Sections of these compound crystals in thin slices under the microscope are lozenge-shaped, though the outer boundary of each lozenge is broken by the projecting ends of minute felspar crystals. These felspar corporations appear to have originally grown as single bodies, for they exhibit along their outer margins a strongly developed zonal structure, and contain countless inclusions of devitrified glass arranged in elliptical lines in symmetry with the oval shapes of the lozenges. Notwithstanding these symmetrically grouped "stone" inclusions and the zonal lines, however, each lozenge is subdivided into a great number of minute felspar crystals, many of which are visibly triclinic. These micro-crystals do not interfere with the symmetrical allignment of the bands of devitrified glass, and consequently each corporate body, with its corporate symmetry, must have been formed before it was broken up into these minute crystals of felspar. On the other hand, the fact that the unbroken ends of these micro-crystals project into the magma, indicates that the modification of internal structure imposed on those corporate bodies subsequent to their formation, took place when the rock was still in a plastic condition.

EXPLANATION OF PLATE II.

Fig. 1. A rounded and corroded quartz-crystal subdivided into seven quartz-grains oriented in different directions. These grains are, with one exception, directly related to the outlines of the internal corrosions. The only exception is the large inclusion of the groundmass seen in the centre of the largest micro-grain.

Figs. 2, 3, 4, 5, 7, 8, are illustrations of corroded quartz-crystals that are not subdivided into micro-grains.

Fig. 6. Porphyritic quartz compounded of several quartz-crystals, each of which is subdivided into numerous micro-grains of quartz, the optic axes of which are oriented in different directions. The crystals are corroded in places, and portions of the substance of the quartz seem to have been on the point of floating off into the magma when the rock began to cool and consolidate. The thin slices contain other similar crystals which are not represented in the plate. Some of these present sharp crystallographic outlines; others have completely lost their shapes and seem on the point of being absorbed into the matrix.



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To illustrate Major-General McMahon's Paper on "The Polysynthetic Structure of some Porphyritic Quartz Crystals in a Quartz-Felsite."