II.—On the Sand-grains in Micaceous Gneiss from the St. Gothard Tunnel; and on some other Difficulties raised by Prof. Bonney.

By Dr. F. M. Stapff.

FROM the "Annals of British Geology," 1892, No. 533, p. 294, I find that Prof. T. Bonney doubts the occurrence of sand-grains in the Guspis micaceous gneiss,[1] as stated by me in various reports on the geology of the St. Gothard Tunnel, and repeated on p. 17 of my "Remarks on Prof. Bonney's paper on the Crystalline Schists and their relation to the Mesozoic rocks in the Lepontine Alps."[2] The question being of some general interest, and not only of importance for the comprehension and classification of the crystalline schists in the Lepontine Alps, I think it desirable to repeat here the *observed facts*, and to present to the notice of the readers of the Geological Magazine some *autotype prints* of the rock in question. I am the only geologist who has seen these beds in situ, when they were opened by the St. Gothard Tunnel; and it would be rather difficult for anyone to make out their outcrops along the line of profile through the Guspis Valley and below the actual moraine of the St. Anna glacier, without taking into consideration the faults and thrusts in this tract, which are indicated on my geological map of the St. Gothard Railway and on the profile of the tunnel.

I beg leave to quote a passage from the geological records kept during the construction of the St. Gothard Tunnel (Geologische Durchschnitte und Tabellen über den grossen Gotthard-tunnel; Spezialbeilage zu den Berichten des Schweizerischen Bundesrathes ueber den Gang der Gotthardbahnunternehmung, 1874–1882; Zürich Orell Füssli), which refers to the bed No. 130; 7262, 4 m. from the northern entry (*loc. cit.* p. 178–9) :—

"No. 130; 1879, Sept. 4th; *ditto* (fine-grained rather dense gneiss) *with sandy quartz-grains*; 7262, 4 to 7278, 3 m.; false-stratification 20 W. and 77 E. to 5 E. and 64 W., average 11 W. and 82 W. Samples taken at 7262, 4. Fine-grained, rather dense, micaceous gneiss, rough, almost tufaceous (but not porous), of reddish-grey colour and confused parallel structure, which is indicated by shreds of brown mica. In this groundmass grains of *quartz* and *felspar* of the size of a peppercorn and smaller are disseminated, whence the rock assumes a porphyritic structure. Some crystalline outlines of dull, whitish, faintly glittering *felspar* may plainly be recognized. The grains of *glassy* and milky quartz show an iridescent, glossy, conchoidal fracture; they are *rounded*, with some crystal facets here and there; enveloped by thin mica-films (macroscopically visible), which can readily be loosened and picked out from the groundmass. The presence of *calcspar* is indicated by effervescence, especially around the quartz-grains; other *accessory minerals* are: *pyrites* and rarely minute fragments of *tourmaline*.

[1] See Correspondence, Geol. Mag. 1892, p. 90.

[2] Geological Magazine, January, 1892, Dec. III. Vol. IX. pp. 6–21.

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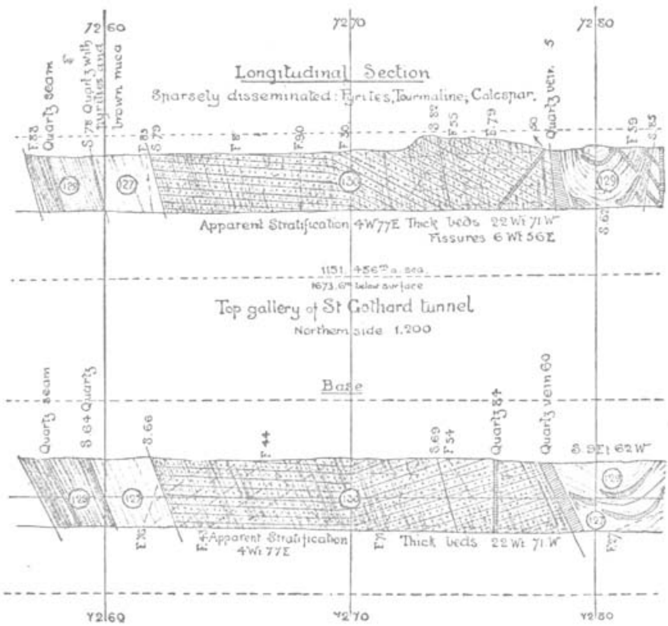
Microscopic observations.—The contours of the larger quartz-grains (as far as they have not been broken out by the grinding operations) are rough but not splintery; the grains are partially wrapped in some longer pellicles or shorter split scales of brown mica. Other grains are surrounded by a garland of fine mica films, which occasionally seem to extend into the quartz-grains. *Calcspar,* together with occasional quartz splinters, is deposited in these mica envelopes, and is attached to the sandy quartz-grains without visible traces of abrasion. Each sandy quartz-grain forms *a single individual,* which is almost always fractured, with or without slight dislocation and torsion of the fragments. The cracks are often covered by a brownish-green substance. In the interior of the quartz-grains may be observed some *microscopic inclusions* of *opaque dust,* specks of *pyrites,* some of *mica,* a few small *lacunæ* (pores), and some short thin *colourless needles.* Here and there a fern-like figure is dimly seen, perhaps indicating the face of a microscopic crack, rather than any microlithic material. Most of the *plagioclastic felspar* is twinned, and the fine twin-striations are visible (in polarized light) though the felspar is in a state of advanced decomposition and intermixed with clusters of *mica scales,* which veil the striations. Though the outlines of the felspars are not so distinct as those of the quartz-grains, they are yet better defined and more clearly individualized than those of the ordinary crushed felspars in the micaceous gneiss; and thus they convey the impression of being porphyritic inclusions rather than indigenous constituents of the micaceous gneiss. The groundmass surrounding the grains of quartz and plagioclase is a compressed mixture of *quartz, felspar* and *two kinds of mica,* the films of which induce an indistinct parallel structure. A little *calcspar* also makes its appearance, partly in isolated granules, partly in larger groups of polysynthetic twins, which are cross-barred with the other minerals, so that it sometimes appears to be a constituent mineral, and sometimes a later-formed accessory cement. Microscopic accessories are *pyrites* (also *pyrrhotine*) in irregular masses, grains, and small crystal groups; and minute, but easily recognized, fragments of *tourmaline.* (So far microscopy.)

This rock appears to be one of the most curious from the interior of the St. Gothard massif. If it really be psammitic, as one may suppose from the foregoing, then all the stratified beds bored through in this massif must also be of sedimentary origin. It recalls to mind the *sericite slates* of the Ursern Valley, with their *glossy sand-grains*; a similar, though less characteristic, rock occurs at 5560–5600 m. from the southern entry. On newly-opened wall-surfaces in the gallery, the quartz-grains appeared to be arranged like *pearls in strings* (scarcely visible in hand-specimens); the strings did not agree with the *parallel structure* of the rock, but rather with its false-bedding (or secondary schistosity); and hence the interpretation of this feature, and of the rock itself, becomes still more complicated. At its margins the bed No. 130 is penetrated by compact veins of quartz and felspar, and further on it passes over into the ordinary micaceous gneiss. . . . ."

To this almost verbal translation I add Fig. 1, a copy from my *original survey sheets* (deposited in the archives of the St. Gothard R. R., Lucerne), after which the plate xxx. (northern side) of the "Geologische Durchschnitte" has been arranged and lithographed. It shows a longitudinal section and a base view of the bed No. 130, as exposed in the top gallery of the tunnel between 7260 and

Fig. 1.



7280 m. N. (Particulars, which are not relevant to the present question, are omitted.) The *parallel structure* of the rock (S. on drawing), as indicated by the orientation of the mica scales, the course of the parallel quartz-bands, and the boundary faces of the bed, strikes and dips N.E. and S.E., as is commonly the case on the north side of the St. Gothard; whilst the *supposed stratification* ("mock" or "false stratification") is directed N.N.W., dipping W. and E.; and the *quartz-grains are disposed in the same direction.* Having been accustomed to regard the "false stratification" wherever it was met with in the St. Gothard as "secondary," I cannot help confessing that the arrangement of the quartz-grains, in accordance with the "secondary stratification," would witness against the sedimentary origin of the bed in question. But this testimony is at once overborne and reversed if we conceive that this *stratification to all appearance* (beds between limiting faces) *is here the original one,* and that the parallel structure (S. of drawing) of the rock is a secondary phenomenon. Hand-specimens of the rock *support* this opinion, as the mica pellicles are fitted and *stretched* so as to indicate a *linear*

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rather than a *plane* parallelism; but recently-exposed large faces of the rock allowed a more satisfactory decision to be arrived at.

As some 70 examples (belonging to as many St. Gothard Collections) of the rock in question are preserved in different Museums, it would not be difficult for anyone to examine its petrographical details. I give here (Fig. 2, natural size) an autotypic print of a

Fig. 2.—Natural size. Micaceous gneiss with sand-grains. Bed 130 (north) St. Gothard Tunnel.

polished face, which has recently been cut from a specimen in the direction of its most visible "parallel structure," as indicated by the mica; but some wavy undulating bands on the design indicate another orientation, which almost agrees with the trend of the imbedded quartz-grains. The quartz-grains (white spots on drawing) are, by their shape and lustre, easily recognized and distinguished from the felspar grains, and I cannot give a better description of their form, size, number and distribution, than can be seen in the figure.

The autotypic figures 3 and 4, which are taken by microphotography from my original thin slices (described in the "Geologische Durchschnitte und Tabellen" beforenamed) reproduce respectively *a grain of quartz* and *a grain of felspar* magnified 16–17 times. In order to show the *marginal lines* between the groundmass and the imbedded grains as clearly as possible, I have taken the photograph by polarized light; but by this method other particulars have been obscured or are not shown.

The quartz of the grains is apparently different from the constituent quartz of the enveloping micaceous gneiss. The former agrees with the quartz crystals occurring in *porphyries*, the latter with the quartz in *granites* and *gneisses*. Each quartz-grain of our rock forms a single crystallographic individual, which is frequently split, in one direction by a few clear parallel fissures, and in other directions by single irregular cracks. Sometimes the fragments of the fractured grain have not been at all dislocated, and then the polarization colour is homogeneous throughout the whole grain; in

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some other cases there has been an insignificant displacement, and this is the case with the quartz-grain here figured; but these quartz-grains *never* present such a brilliant, polymorphous and polychromatic variegated mosaic as the small particles of quartz which enter into the constitution of the micaceous gneiss. Their polarization colours are somewhat dull, and fade away concentrically from the interior outwards, just as in the case of quartz crystals in porphyries.

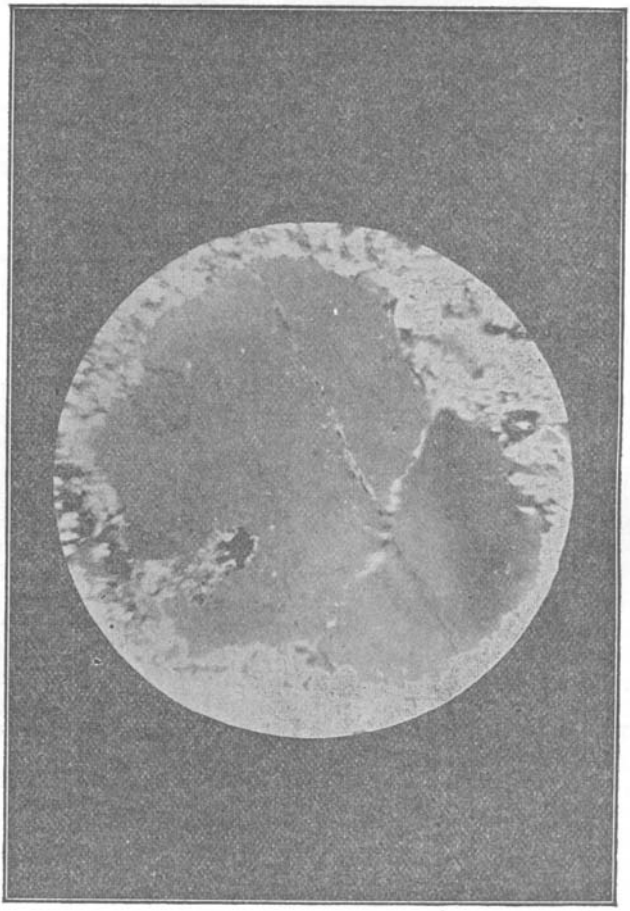

FIG. 3.—Quartz-grain in micaceous gneiss, No. 130 (north) St. Gothard Tunnel. Enlarged 16–17 times. Photographed in polarized light.

The *microlithic* (and other) *inclusions* in the quartz-grains are larger but neither so frequent nor so varied as those in the magmatic quartz-splinters. The thin, colourless, brilliant prismatic needles—not visible in figure—and the rhombic sections,[1] seemed to offer a special character since they were missing in the magmatic quartz-splinters; but later I found them also in the *holes* from which the quartz-grains had been broken out (abundantly), and finally outside the edge of the thin slice (rarely); whilst they were *wanting in another freshly-made microscopic section.* They seem *not to be connected with the material of the rock.* Some few microscopic scales of *brown mica* are deposited *on the cracks* in the quartz-grains; they appear to be later deposits and not inclusions in the crystallizing quartz. But some doubt may arise with regard to rare microscopic patches of brown mica and quartz, *i.e.* of the *enveloping material,* which appear to be inclusions, though they may quite as well be deposited above or below the grains, or they may be terminal points of lateral inclusions in bays of the quartz-grains (see figure). Small (microscopic) granules of *calcspar* likewise occur on *cracks* traversing the quartz-grains; and without doubt they have been deposited there *à posteriori,* just as well as the calcspar on the margin of the grains. The same cannot so decidedly be said about the granules of calcspar, which are interwoven in the texture of the micaceous gneiss; the less so, as they proved to be *dolomitic.*

The shape of the quartz-grains is always *roundish polygonal;* short, straight fragmentary edges of a crystal are interrupted or connected by curves and small fracture-lines; but the outline is by no means fringed by filaments or threads entering and losing themselves in the enveloping material. No regularity whatever can be recognized in the crystallographic orientation of the grains, either with respect to each other or towards the surrounding minerals; the different quartz-grains exhibit very different orientations and individual colours when the slice is moved between unaltered Nicols. And just as little can any *fluidal structure* be noticed around the grains. Short segments are wrapped up in extended pellicles of mica, which stick close to the outline of the grain and leave but little room for the deposition of other mineral particles; for the rest, small brown mica scales intermixed, to form a minute mosaic, with broken quartz (and some grains of felspar, calcspar, etc.) environ the foreign quartz-grains; and it is seen that the mica pellicles are twisted around the quartz-grains in such a way that longitudinal and cross-sections alternate in one and the same profile. Hence the cavity from which a quartz-grain has broken out seems to be lined by a cuticle of brown mica; but, if that same cuticle is cut through, the sections vary very considerably at different places.

The demarcation line between a quartz-grain and its envelope is seldom quite clean and smooth. Microscopically seen it is, for the most part, rough, and small pellicles of mica and granules of quartz are attached to it (squeezed in, to all appearance); just as we see

[1] Mentioned in the translation from the Geol. Durchschnitte und Tabellen.

sand-grains and gravel encrusting the corrugated surface of a pebble. The cracks and fissures are sometimes enlarged at the surface of the bay, which allows the surrounding material to invade the grain.

The *felspar-grains*, of which one is reproduced on Fig. 4, are in part *polysynthetic twins*, in part *single* or *twofold* individuals. It is not easy to determine particular felspar species in view of the

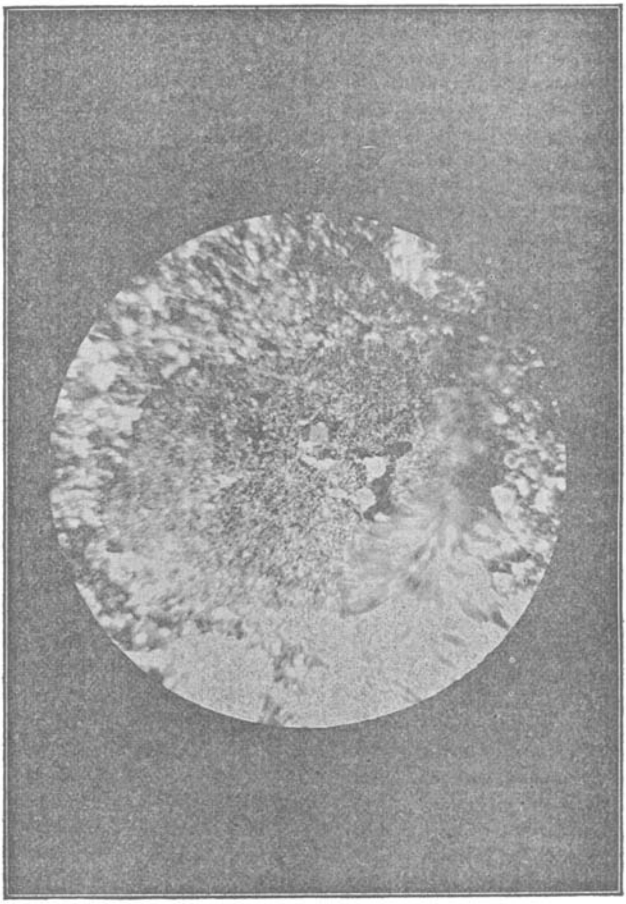

Fig. 4.—Felspar-grain in micaceous gneiss, No. 130 (north) St. Gothard Tunnel. Enlarged 16–17 times. Photographed in polarized light.

extent to which they are decomposed; but even with the naked eye one can observe that some of the felspar-grains are greenish, dull, lustreless, striped and dusty (*kaolin*); whilst others are white or limpid, fresh and glossy. Commonly they present the outlines of

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crystals, but sometimes they are rounded; or they are split, broken and torn, as felspars in the squeezed St. Gothard gneisses so often are; and hereby we learn that the same felspar simultaneously makes its appearance as an ordinary constituent of the micaceous gneiss *and* as a porphyritic inclusion in the same.

The figured grain is porphyritic though rounded. It shows no twin stripes in polarized light, and its mass is almost replaced by clusters of pellicles of *potash mica* and *kaolin*. Small *quartz-grains* and other microliths accompany the mica in the decomposed felspar, which I need not further mention.

The outline of this grain of felspar—and of others similar—is not so well defined as that of the quartz-grains (Fig. 3), and to all appearance it has coalesced with the surrounding materials; a white margin indicating in some cases the zone of intermixture.

In spite of the roundish contours of many of the felspar-grains, I am *not* inclined to consider them to be grains of felspar *sand*. The occurrence of porphyritic segregated felspar in gneissic rocks is by no means unusual; and this may be the case in the quartzitic micaceous gneiss No. 130, where the lesser part of the felspar is intermixed with the other constituent minerals, and the greater is segregated.

The preceding observations put beyond every doubt that the *quartz-grains are foreign bodies:* their material is not identical with that of the constituent quartz of the micaceous gneiss, nor are there any transitions between the two kinds; each quartz-grain is an individual, loosely imbedded in the groundmass and easily picked out of it. Some of the apparent inclusions in the quartz-grains are *later depositions* on cracks, others are *squeezed in from the outside*, and with regard to the nature of others some doubt may be reasonably entertained. The question now is: have we to deal with *sand-grains* imbedded in an (originally) *sedimentary psammitic rock;* or with a kind of *quartz-porphyry*, the groundmass of which has been decomposed in such a way that it is now a micaceous gneiss? This second view is supported by the nature of the quartz-grains, and their association with porphyritic felspar-grains; whilst it is contradicted by the actual nature of the enveloping magma, by the lack of fluidal structure, by the arrangement of the grains in accordance with the bedding of the rock (Fig. 1)—*facts which corroborate the belief in the sedimentary origin of the bed.*

Prof. Bonney doubts also "*the occurrence of organisms in the Altkirche marble*"; but I question whether many share his opinion after seeing the autotype figures of the bodies in question, which are published in the GEOLOGICAL MAGAZINE (1892, Dec. III. Vol. IX. p. 16),[1] with a footnote by the Editor (p. 17): "hand-specimens of these St. Gothard rocks are preserved in the Mineralogical Collection of the British Museum, and sections taken from the one marked No. 43 show precisely similar structures to those in the accompanying figure.—EDIT. GEOL. MAG."

[1] Reproduced by Professor J. F. Blake, in his Annals of Geology for 1892, p. 293.

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"The reference of the Piora schists to the *Carboniferous* appears (to Prof. Bonney) to be only a hypothesis"—but, as a fact, I have not made such a reference. I have not dealt with his Piora schists, and would not say anything about them but (GEOLOGICAL MAGAZINE, *loc. cit.* p. 9) "that they belong to the second of my groups (that of the grey garnet schists) and his 'Val Tremola schists' to the third and fourth group (green, black felspathic mica schists, and amphibolic rocks)." What I have mentioned about the geological age of *these* (*my own*) groups is restricted to the following lines in the GEOLOGICAL MAGAZINE, p. 7: "If this parallelization be correct, and the metamorphosed sedimentary rocks of the Ursern Valley properly determined, then we may draw the conclusion that the series of the originally sedimentary rocks on the south side of the St. Gothard begins, at the bottom of the Ticino Valley, with *Jurassic* deposits and includes *Carboniferous* at about 1833 m.[1] inside the mountain, counted from the mouth of the tunnel." *Ibid.* p. 10: "The beds, in which disthene and kindred minerals can be recognized at a glance[2] . . . . . are usually connected with the calc-mica schists and black garnet schists, but it would be premature to assert that certain geological horizons in the grey mica schists are characterized by the appearance of disthene, etc." *Ibid.* p. 19: "5 The rocks belonging to the fifth series (on my geological map of the R.R. line), viz. dolomites, grey and green mica schists . . . . have been characterized in § I.–III., where it is pointed out that they extend from the *Carboniferous to the Jurassic* age."

I have nowhere advanced the hypothesis imputed to me by Prof. Bonney that his Piora schists (*my grey mica schists of the St. Gothard Tunnel*) *belong to the Carboniferous*; and, comparing the Geological Map of the railway line (Explanation on the title-page), the designation *Carbon* (?) will be found exclusively behind the references for: "Quarzglimmerschiefer mit Chloritglimmerschiefer-lagen, North, Pl. V."; "Schwarze phyllitische (chloritische) Schiefer mit Kalk—Quarzit—Gneiss-streifen (Oberalpstrasse)."

On the summary profile (title-page) the designation "*Carbon*" (?) is restricted to the black schists of the Oberalpstrasse, on the north side; to the black (and green) schists on the south side, *inwards from* 1100 or 1200 m. as mentioned above; and to the well-known *Manno grits.*

In the bathrologic review (on the same sheet of the map) the schists belonging to V., viz. "Granat-Amphibol-Paragonit-Chlorit-Sericit-Kalk-Glimmerschiefer," are designated as "Archacische[3]-Mesolithische Lückenbüsser."

[1] My "grey garnet schists" (*sint* Prof. Bonney's Piora schists) are reckoned from 90–1142 m.; my "black and green garnet mica schists" from 1142–1833 m. (GEOLOGICAL MAGAZINE, *loc. cit.* p. 9).

[2] *Sint* Prof. Bonney's "Piora schists."

[3] In the GEOLOGICAL MAGAZINE (*loc. cit.* p. 19) I have freely confessed that the reference to *Archæan* was a mistake of mine.

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