

THE VEIN SYSTEM OF ST. MICHAEL'S MOUNT, CORNWALL

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Abstract

In this preliminary study, general geological features of St. Michael's Mount are described briefly and it is noted that several important characteristics of the hypothermal and/or pneumatolytic veins and their associated greisen bands have been ignored by earlier writers. These neglected features are dealt with in detail, old theories of the genesis of the St. Michael's Mount hypothermal veins are shown to be inadequate and a new one is proposed.

St. Michael's Mount, which is situated in Mount's Bay immediately to the south of Marazion, has received considerable attention from geologists for more than a century, and a number have devoted papers to it. The most up-to-date and adequate of these is by E. H. Davison (1920). However, although Davison described the greisen-bordered veins occurring there in some detail he has not mentioned a number of characteristics which are important clues to their genesis. The major purpose of this paper, therefore, is to describe these hitherto neglected features and to discuss the genesis of the veins in the light of present knowledge.

GENERAL GEOLOGY

St. Michael's Mount consists essentially of a steep mass of granite, rising more than 200 ft. above sea-level, and mantled on the north by comparatively gently-sloping thermally metamorphosed slate. In plan the junction between these major components is an E.—W. arc which is concave towards the south.

Slate.

All the slate on the island has been thermally metamorphosed and as the granite/slate junction is approached spotted slate tends to give way to andalusite — and biotite-hornfels. Locally, slate adjacent to the granite has been feldspathised. Quartz-tourmaline hornfels is comparatively rare and only occurs near some of the early quartz/tourmaline veins.

As the effects of thermal metamorphism die out between the island and the mainland it is probable that the granite dips steeply to the north. The writer has suggested elsewhere (Hosking, 1949) that the Mount may be the highest part of an undulating granite ridge extending from the Land's End to the Godolphin Mass.

Granite.

Much of the granite is porphyritic and consists of comparatively large crystals of potash feldspar and quartz embedded in a fine-grained matrix of quartz, orthoclase, perthite, albite-oligoclase, muscovite and tourmaline. Accessory fluorite, topaz, biotite, zircon, apatite, magnetite, and even cassiterite, are sometimes seen in thin sections. Towards the south the granite has a more normal texture and is richer in biotite.

A curious granite variant, characterised by the presence of "fleur-de-lys" feldspar aggregates which are crudely orientated along N.N.W.—S.S.E. lines, is also to be seen along the southern fore-shore where it takes the form of a sill-like mass.

Examination of boulders indicates that thin alternating bands of pegmatite and aplite occur locally between the hornfels and the granite. These were probably developed in structural traps during the initial stages of consolidation of the granite magma.

The granite, as a whole, is intersected by three major systems of joints. Two of these are vertical and strike approximately 23° W. of N. and 30° N. of E. respectively, whilst the third — the system of floor joints — is nearly horizontal.

Minor Granitic Bodies.

In the vicinity of the granite/slate junctions there are numerous granitic vein-like bodies.

Probably some of the fine-grained granite veins — containing, on occasion, small lenticular masses of pegmatite — are apophyses of the major mass, but many of the aplites and pegmatites on the Mount were formed after the superficial portions (at least) of the granite had consolidated and, with rare exceptions, they strike along approximately E.N.E.—W.S.W. lines parallel to one of the major joint systems of the granite and to the later-developed cassiterite/wolframite veins.

Probably the earliest pegmatites to be formed within the consolidated granite were certain mineralogically simple, feldspar-rich, vertical, lenticular bodies now exposed on the western side of the Mount. Somewhat later a series of essentially parallel-sided, near-vertical veins composed almost entirely of large feldspar crystals whose long axes are orientated more-or-less at right-angles to the walls were developed, and these are also seen on the western side of

the island. It is quite clear that these bodies were formed before the phase of greisenizing (which is discussed later) as some of them are crossed by greisen-bordered veins.

After the formation of greisen bands a further limited number of felspar/quartz veins were developed — usually in and around the fissures through which the greisen-forming agents had moved and at the same time the greisen was locally feldspathised beyond the veins.

PNEUMATOLYTIC AND/OR HYDROTHERMAL VEINS

The pneumatolytic and/or hydrothermal veins reach their maximum development along the granite platform on the southern side of the island but they *do* extend into the hornfels.

Within the granite any given portion of a vein is usually, *but not invariably*, fringed on one or both sides by greisen.

The vein system, which strikes about 20° to the north of east, is parallel to one of the major sets of vertical joints of the granite. Many of the veins in the granite show a marked parallelism of strike over considerable distances, but branching does occur, especially along the west-central portion of the platform. Here branches — often differing in strike by about 30 degrees from the major veins — not only link the latter, but also join small, normal-trending gash-veins to them. (Fig. 1.) Occasionally small off-shoots emerge from the larger veins along strikes which differ appreciably from those of the parents' and then gradually assume the normal trend.

In plan the veins vary in thickness from a fraction of an inch to about six inches, but their average is only one or two inches, and some of them display remarkable variations in thickness within a distance of a few feet. Sometimes a vein — say an inch wide — tapers extremely rapidly to about an eighth of an inch, and then, after maintaining this width for a few feet, rapidly opens out to its original width. (Figs. 2-6.)

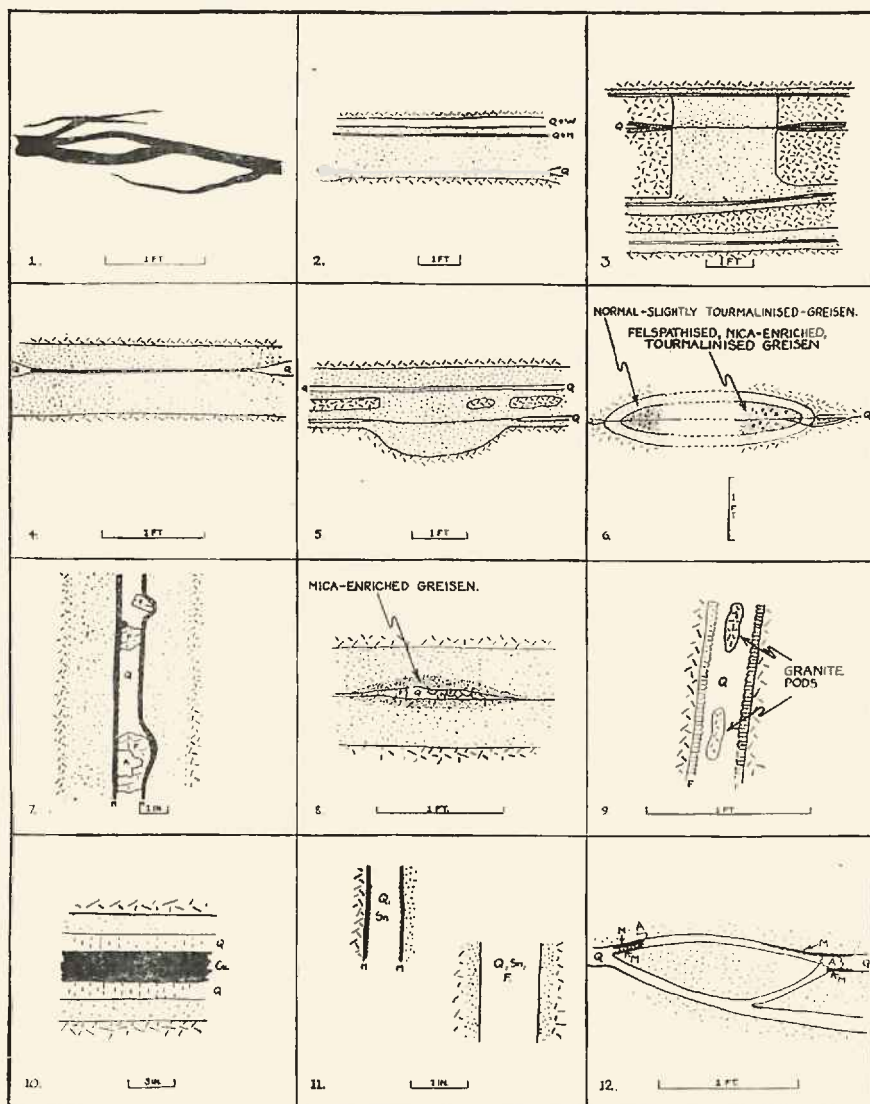
Over the limited dip sections which are visible the veins never display any very marked change in width, nor do they deviate from the vertical to any noticeable extent. However, a vein which is exposed in a small inlet on the western side of the Mount is characterised by two bulges in which crystals of felspar are accommodated. (Fig. 7.)

DESCRIPTION OF PLATE 1

A = apatite : Cu = copper-bearing minerals : F = feldspar :
M = mica : Q = quartz : Sn = cassiterite : W = wolframite.

- FIG. 1. The form, in plan, of a portion of a greisen-bordered vein-system on the central part of the platform.
- FIG. 2. Part of the vein system on the central portion of the platform showing a wolframite-bearing vein bordered only on one side by greisen ; also a narrow, multi-mineralic part of another vein.
- FIG. 3. A greisen "chimney". Central part of platform.
- FIG. 4. A narrow multi-mineralic part of a vein. Central portion of platform.
- FIG. 5. A part of the vein system on the central part of the platform, showing granite pods in the greisen and a prominent greisen bulge adjacent to a presumably early, multi-mineralic, portion of a vein.
- FIG. 6. One of a number of greisen pods on the western side of the platform which consists of an inner feldspathic, tourmalinised, mica-enriched zone, and an outer envelope consisting of slightly tourmalinised — but otherwise normal — greisen. The pod surrounds a narrow, multi-mineralic part of a vein.
- FIG. 7. Section of a vein in a gully on the west fore-shore, showing feldspars occupying curious bulges, and also the close spatial relationship between the feldspar and the apatite masses.
- FIG. 8. A lenticular section of a quartz/feldspar vein which occurs on the central part of the platform, and which is bordered by mica-enriched greisen.
- FIG. 9. A section of a curious, presumably early, pink-feldspar-bordered vein containing granite pods which occurs on the western part of the platform.
- FIG. 10. The general structural characters of the presumably late copper-bearing veins of the west-central part of the platform.
- FIG. 11. Two sections of veins from the western part of the platform. The one is unusual in that only one side is bordered by greisen. The other is the normal type and is bordered on both sides by greisen bands of approximately the same widths.
- FIG. 12. A plan view of some members of the vein system on the central part of the platform, showing an interesting mica/apatite spatial relationship.

PLATE I: FIGS. 1-12



GRANITE

GREISEN

On the same side a vertical greisen-bordered, normal striking vein—which contains cassiterite and wolframite—*appears* to be intersected by a greisen-edged, barren quartz vein which has developed along the plane of a floor joint. However, the precise age relationship between these two is not clear and no other similar examples have been seen on the Mount.

Whilst there are clear indications that some of the veins are of the replacement type, it is possible that others — the later ones in particular — may have developed partly — or even entirely — in open spaces formed by the thrusting apart of the walls of fissures by the ascending mineralising agents. There is no evidence — such as slickensides, brecciation, etc. — of any marked horizontal or vertical displacement of the walls of the veins during any phase of their genesis.

Vein minerals.

The following mineral species have been recorded by Davison (1920, p.317) as occurring in the veins and associated greisen of the Mount :—Quartz, mica (mostly a lithium-bearing variety), pinite, orthoclase, tourmaline, topaz, fluorite, beryl, apatite, albite, chalcopyrite and oxidation products, sphalerite, cassiterite, wolframite, stannite, molybdenite and uranite. Sir Arthur Russell (private communication) thought it probable that varlamoffite (an oxidation product of stannite) might also occur there and this has been confirmed by the writer.

Whilst most of the species noted by Davison have been seen there by the writer (and, in addition, arsenopyrite), he has not yet completed the studies necessary to include a detailed account of the mineral paragenesis in this paper. However, the general sequence of primary deposition within the veins is silicates and apatite, cassiterite and wolframite, and the copper-containing sulphides. Arsenopyrite may well have been deposited early, but this cannot be proved at this stage, whilst beryl, fluorite, molybdenite, sphalerite and primary uranium minerals must needs be omitted because they have not yet been found by the writer. Quartz was deposited intermittently before, during and after the phase of heavy-mineral development.

Distribution characteristics of some of the vein minerals.

The distribution characteristics of the minerals in the veins are of considerable importance when attempting to unravel the genesis

of these bodies and therefore they are now considered. An account of the mineralogy, etc., of the spatially associated greisen bands is deferred, for convenience, until later.

Mica, topaz, apatite and tourmaline.

Mica — usually pale-coloured, but sometimes fox-brown, and often lithium-bearing — forms selvages along portions of many of the veins and is, therefore, an early mineral. Occasionally, however, druses within the quartz vein-matrix are lined with small flakes of either white sericite or yellow gilbertite which are clearly younger than the mica of the selvages.

Sometimes a mica selvedge ceases abruptly as the vein passes from one rock-type to another. Thus, in the vicinity of the eastern granite-“slate” contact a particular vein possesses marked mica selvages whilst in the hornfels immediately to the east of a fine-grained granite tongue. Within the tongue the vein lacks these selvages, and what is even more remarkable, they are also absent from the vein when it passes from the granite body into the hornfels immediately to the west. The writer cannot suggest an entirely satisfactory explanation for this curious phenomenon. Obviously variation in reaction between a given mineralising solution and wall-rocks of different compositions cannot be the cause, and one can only conclude that during the phase of mica development the western limit of the local path of ascending mineralising agents coincided with the western junction between the granite tongue and the hornfels.

In those extremely narrow portions of veins, which are noted earlier, strongly developed mica selvages occur even though they are lacking in the immediately adjacent parts. (Fig. 8.) Furthermore, it must be noted that these narrow portions invariably contain a considerable number of mineral species which are absent from the adjoining wider parts. Conversely, the narrow portions often contain little or no quartz, whilst this mineral is the major, and often the sole constituent of the wider parts. This distribution pattern can be explained if it is assumed that during the initial phases of vein development open fissures only existed along those portions which are now extremely narrow and that subsequently they were closed — by the deposition of minerals in them — and further fissures developed along the prolongation of their strikes. Support for this

suggestion is to be found on the western side of the granite platform where narrow, mica-selvedged, multi-mineralic parts of veins occur within a number of E.—W. oriented greisen pods whilst the wider quartz-filled parts are confined to the adjacent, unaltered granite. (Fig. 6.) Furthermore, some of the distribution patterns of mineral species within the veins along the southern platform suggest that the development of any given vein involved the ascent of mineralising agents through a number of fissures which were, at any rate, discontinuous along the present, near-horizontal, granite surface. Thus, apatite occurs in some of the wider veins solely where there is a mica selvedge. (Fig. 12.)

Topaz crystals, rarely, if ever, exceeding a quarter of an inch in length, are often much in evidence in those narrow portions of veins — mentioned above — which are characterised by an imposing number of species. The mineral is, in the writer's experience, never seen in quantity elsewhere in the veins, but is often visible in thin-sections of the greisen.

Apatite is also often present in the narrow multi-mineralic parts of veins and it is occasionally seen in the wider portions where it is commonly found accompanying feldspars, although, as noted above, it is sometimes spatially related to mica selvedges. The apatites are invariably prismatic in habit and those seen *in situ* by the writer are zoned in various shades of pale-green. However, a specimen, reputed to have been collected from the Mount, and now in the museum of the Camborne School of Metalliferous Mining, consists of pale-blue prismatic crystals scattered over greisen.

Tourmaline is a rare constituent of the hypothermal veins and is confined to some of the very narrow multi-mineralic parts. During its deposition the associated greisen was also sometimes tourmalinised. It is undoubtedly an early vein mineral and conceivably the tourmaline cores occasionally seen in the pegmatites may be of the same age.

Feldspar.

Feldspar becomes progressively commoner as the vein system is traced from east to west. Usually it occurs as isolated aggregates of white or yellowish crystals which developed after the mica-selvedged. An extraordinary example of a mica-selvedged vein containing feldspars which occupy bulges has been noted earlier.

(Fig. 7.) These curious bulges are almost certainly due to local replacement of greisen by "vein" feldspar and mica. This view is supported by the fact that elsewhere on the Mount unquestionable feldspathisation and mica enrichment of the greisen have taken place: these phenomena are discussed later. (This vein, which in addition contains cassiterite and wolframite set in a quartz matrix, is of further interest in that masses of apatite are associated with some of the feldspar aggregates and appear to pre-date the latter.)

Veins from about an eighth to a quarter of an inch wide and consisting essentially of quartz and yellowish feldspar are not uncommon in the western and west-central parts of the granite platform. These are usually bordered along one or both sides by greisen and in one instance the greisen immediately adjacent to the vein is locally highly enriched in mica. (Fig. 8.)

In the granite on the western side a dip section of a remarkable 4-inch-wide vein may be seen which possesses selvages of feldspars with their long axes orientated at right-angles to the walls. The quartz core of this vein — which elsewhere encloses cassiterite and wolframite — contains two granite pods here. No greisen is associated with this body, which exhibits characteristics between those of a pegmatite and a hypothermal (or pneumatolytic) vein and is, as far as the Mount is concerned, structurally unique. (Fig. 9.) Its manner of formation is not clear.

All the obvious vein feldspar may be broadly classified as orthoclase. It is probable that the albite that Davison records was seen by him in the narrow multi-mineralic parts although the present writer has not yet identified it in any of these nor elsewhere in the veins.

Cassiterite and wolframite.

Cassiterite appears to be most highly concentrated in the west-central portion of the granite platform where the veins are most numerous and the greisen is most intense. To the west of this zone cassiterite is more frequently seen than wolframite although most of the veins contain little but quartz. In the east-central zone the veins are less numerous but wider than those to the west and consist essentially of quartz in which scattered aggregates of wolframite crystals are embedded. Cassiterite is comparatively rare there although both it and wolframite tend to become relatively more abundant in the vicinity of the eastern granite/killas junction.

Within the extremely narrow but mineralogically complex parts of veins, already noted, cassiterite is often, but wolfram rarely, much in evidence. This marked association of cassiterite with demonstrably early gangue minerals suggests that it was deposited before wolframite. That cassiterite usually occurs adjacent to the walls — or mica selvedge — of a vein, whilst wolframite tends to be distributed throughout the central part is a further indication that cassiterite is probably the earlier mineral. Further evidence in support of the belief that cassiterite deposition pre-dates that of wolframite is the fact that whilst cassiterite is often found in the greisen, and sometimes in the granite, wolframite is never — so far as the writer is aware. However, no exposure has yet been found on the Mount which establishes beyond doubt that cassiterite *was* the earlier mineral to be formed, nor that there was only one phase of cassiterite and wolframite deposition.

Sulphides and sulpharsenides.

Chalcopyrite and stannite appear to be confined to a few veins in the west-central part of the platform where their presence is advertised by green secondary products which stain the veins and adjacent rocks. These veins possess a unique internal structure, as far as the Mount is concerned, in that they consist of somewhat comby peripheral quartz bands which are separated by a central band of copper species — together with some pale-brown cassiterite and wolframite — embedded in quartz. (Fig. 10.) These veins are bordered by greisen. The anomalous structure and mineral content of these veins suggest that they may be the products of a second phase of mineralisation which post-dated that which gave rise to the normal veins on the island and which was due to agents derived from another source. On the other hand they may simply be essentially post-greisen/pre-cassiterite quartz veins which were subsequently re-opened during the phase of cassiterite/wolframite deposition and remained open during the subsequent phase of sulphide deposition.

Arsenopyrite is extremely rare on the Mount and has only been found by the writer in a few veins on the western side of the Mount where it occurs in a quartz matrix. It is, therefore, impossible to determine its position in the sequence of vein-mineral deposition with any degree of certainty, but as it occurs randomly distributed in the wider parts of the "normal" veins, just as the wolframite is, it may well have been deposited at about the same time as the latter.

The significance of mineralogical and structural differences between the veins.

It has already been noted that mineralogical and structural differences displayed by a given vein along its strike suggest that only parts of the vein were open at any given time. Likewise consideration of mineralogical and structural differences shown by adjacent veins in strike and dip sections indicate that whilst one was locally open another just a foot or so away was closed. Thus the copper-bearing veins, noted above, are adjacent to "normal" veins which are structurally and mineralogically quite different from the former. The vein — noted earlier — whose dip section shows felspar occupying bulges, and which contains apatite, is within a few feet of several other veins which contain neither felspar nor apatite. Scores of other convincing examples could be sited in support of the above contention.

Greisen.

Most of the E.—W. trending veins — regardless of their mineralogic composition — are bordered on one or both sides by greisen when in the major granite mass and also when they transect granitic bodies in the slate.

The mineralogic characteristics of the normal greisen — which merges laterally into essentially unaltered granite — has been described by Davison (1920, p.316) as follows :—It " is composed of quartz, gilbertite mica, muscovite mica, tourmaline and topaz. Under the microscope the quartz is seen to be crowded with inclusions, negative crystals, and irregular spaces containing liquid with gas bubbles are especially common but the liquid seldom contains any crystals : small crystals of apatite, cassiterite, and muscovite also occur. The quartz shows outlines which do not agree with the present crystal form, there has evidently been absorption and recrystallisation to a considerable extent. The mica is at times faintly pleochroic but most of it is colourless . . . and contains inclusions of apatite, tourmaline and rutile. It was one of the first essential minerals to crystallise out. There is abundance of topaz which contains numerous black dusty inclusions which spread from the topaz through contiguous minerals, its shows typical cleavage and sends tongues into the minerals round it. Tourmaline is also abundant . . . in places it shows a corroded outline and is penetrated by other minerals notably by quartz and topaz : it contains haloed inclusions of zircon and inclusions of apatite and iron oxide."

The spatial relationships between the veins and the greisen are most interesting and are enumerated below :—

(i) Apart from certain demonstrably early pegmatite and quartz veins, there are a number of others — or portions thereof — which are lacking greisen borders despite the fact that there is reason to believe that they are contemporaneous with those which are associated with greisen. (Fig. 6.)

(ii) Greisen may border only one side of a vertical vein, or may be very much thicker on one side than on the other, even though the granite is identical on both sides. (Figs. 2, 3 and 11.) However, in the central part of the platform most of the veins are centrally disposed with respect to their associated greisen. (Fig. 11.) That this phenomenon is most marked along that part of the platform which is most accessible — and, therefore, most likely to be examined — is doubtless why some have assumed that only this greisen/vein relationship exists on the Mount.

The major fact which emerges from (i) and (ii) is that the greisen bands were developed *before* the veins which are spatially related to them.

The greisen/vein age relationship of the Mount is not without parallel. Coteló Neiva (1944, pp.120-125) describes and figures a cassiterite/wolframite stockwork at Bejanca (Portugal) which is superimposed upon a portion of a granite mass in which a series of greisen lenses had developed earlier. Although the stockwork is largely confined to two of the lenses the predominant strike directions of the veins differ very considerably from that of the greisen and the veins extend for considerable distances into the unaltered granite.

(iii) Whilst the width of the greisen bands often bears no relationship to that of the spatially related vein nor to its contents, greisenizing is commonly most marked in the vicinity of those extremely narrow, multi-mineralic parts of veins which have already been discussed. (Figs. 3, 5 and 6.) This suggests that whilst some paths of the mineralising agents remained open throughout most — if not all — of the period during which greisen could be developed, others did not become available until this period was partly over.

(iv) The width of a given greisen band may change abruptly as it is traced across the contact between one type of granitic rock

and another. Thus greisenizing is often much less intense in pegmatite and aplite than in the normal granite.* Furthermore, that part of a vein which transects a granitic tongue in the hornfels is often bordered by greisen.

(v) On rare occasions a feldspathised greisen may occur between the vein and a normal greisen zone. Thus, in the granite on the western side of the Mount a quartz vein (about $\frac{1}{8}$ -inch wide) rapidly narrows to an extremely thin vein which is selvaged by mica and contains an abundance of topaz. This very thin portion — which is about four yards long — eventually opens out again until it is about $\frac{1}{8}$ -inch wide and this consists solely of quartz. Whilst the comparatively wide quartz portions are not bordered by greisen, the narrow part is sheathed by an inner zone — ellipsoidal in plan — containing relatively coarse flakes of mica, feldspar crystals (about $\frac{1}{8}$ -inch long); quartz, topaz, and a little tourmaline. This zone is surrounded by another of slightly tourmalinised — but otherwise normal — greisen. (Fig. 6.) (It may be noted that this is the largest of a number of similar and neighbouring structures.)

That the greisen bands bordering certain essentially feldspar/quartz veins are locally extremely rich in mica has been noted earlier.

These facts suggest — among other things — that the period of greisen formation was followed by the ascent of mineralising agents which were initially capable of replacing the greisen by tourmaline and then by feldspar and mica. However, with time the reactivity of these — and subsequent — agents decreased so that they could only deposit minerals in open fissures or replace the greisen in the comparatively close vicinity of fissures — micro, or otherwise. Whether this decline in reactivity was due simply to a decrease in the temperature of the mineralising agents, or partly — or entirely — to their changing chemical character, is unknown.

* An interesting example of preferential greisenizing is to be seen in a small boulder collected by the writer from the foreshore of the Mount. In it a mica-selvaged vein has developed along the junction between normal microgranite and one possessing feldspar phenocrysts orientated at right-angles to the junction. The vein is bordered — for the most part — by narrow greisen bands, but locally the feldspar phenocrysts — which are outside these bands — have also been greisenized.

The marked increase in the width of the veins on leaving the greisen pods can only be accounted for — in the writer's opinion — by assuming that the parts in the granite were developed by replacement when the fissures within the pods were closed.

Vein Genesis.

It has usually been stated, or implied, that the lodes of St. Michael's Mount were formed essentially as follows :—When the granite crust had consolidated open fissures were developed along planes of maximum weakness as a result of regional stress, contraction associated with the cooling of the granite, or gas-pressure. Solutions and/or gases then ascended along these fissures and deposited quartz, cassiterite, wolframite, etc., within them in a manner which indicated that the character of the vein-forming agents was changing with time. At the same time as the minerals were being deposited within the fissures the adjacent granite was being converted to greisen. (Davison, for example, concludes that " it is evident that the agency which gave rise to these greisen veins was also the means of bringing up the metallic minerals which all seem to be of the same period as the alteration minerals ".) (1920, p.320.)

Theories of the above type cannot be entirely correct as they do not take into account the greisen/vein relationships, neither do they explain the shapes of the veins in plan, nor the distribution characteristics of the minerals composing the veins.

In order to account for the observed facts the writer suggests that the geological history of St. Michael's Mount in general — and of the veins in particular — was as follows :—

In Permo-Carboniferous times an arcuate granite ridge with a markedly undulating surface was emplaced between the contemporaneous Land's End and Godolphin granite masses. (This is suggested by the lode and porphyry dyke pattern in the Penzance-Prah Sands zone.) The highest point of this ridge is the St. Michael's Mount mass. Here, during the early phases of granite emplacement, the adjacent slates were thermally metamorphosed and a few small quartz and quartz/tourmaline veins were developed in them. (Similar bodies, which owe their formation to the escape of flux-rich fractions from the invading magma, may be seen in the Tremearne coastal section, near Porthleven.) At about the same time slight pegmatic

and aplo-granitic bands were laid-down in structural traps, and when the more superficial portions of the granite-proper had more-or-less consolidated a somewhat differentiated magmatic fraction was emplaced which crystallised as a fairly fine-grained granite containing aggregates of "fleur-de-lys" feldspar phenocrysts. This stage was followed by one in which simple, vein-like, feldspar-rich pegmatites (and to some minor extent, aplites) were formed. The earlier of these are remarkably sinuous, whilst the later are near-vertical and possess a strike which is essentially the same as the later hydrothermal and/or pneumatolytic veins. Undoubtedly the earlier pegmatites were formed by replacement, but the later ones may have developed — at least to some extent — within open fissures.

Towards the end of the pegmatite phase mineralising agents migrated along a series of vertical fissures — the earliest of which were of very limited length — and converted the granite to greisen for an equal distance on either side of the passage-ways.

As time progressed the micro-fissures along which the greisen-forming agents had moved were used by chemically different mineral-forming liquids and/or gases, but further fissures were also opened along planes within the greisen bands which did not coincide with those of the earlier micro-fissures, and to some minor extent others were opened in the greisen-free granite. Certainly some of the post-greisen veins were formed largely by replacement of greisen (and locally granite) but others — the later ones in particular — may have developed largely — or even entirely — within open spaces formed essentially by the thrusting apart of the walls of micro-fissures by the ascending mineralising agents.

The earliest post-greisen veins possess strong pegmatite affinities. They contain appreciable quantities of feldspar — together with mica — and on occasion the agents responsible for their formation locally converted the greisen to a mica-rich variety and sometimes caused it to be tourmalinised and feldspathised. Towards the end of this phase—and immediately after it—considerable amounts of mica, apatite, topaz and quartz were laid down largely in and around a number of narrow fissures of very limited extent which — in some cases — had remained open since the commencement of greisen development. Subsequently further fissures developed along the prolongation of the strikes of these earlier multi-mineralic veins, both within the greisen and the granite, and mineralising agents

ascended along these and caused the development of replacement veins consisting essentially of quartz. With time a succession of new fractures was initiated — largely in the greisen — but to some extent in the hornfels and even in the granite. It seems likely that the walls of these fractures were thrust apart by the increased pressure of the mineralising agents — as suggested above — so that these later, and often comparatively wide veins which contain the bulk of the cassiterite, wolframite, and copper-bearing sulphides were developed essentially in open spaces from mineralising agents whose character was changing progressively with time.

The physical and chemical nature of the heavy-mineral-forming agents can only be guessed at. It is possible that the cassiterite was deposited as a result of the reaction between stannic fluoride and steam in accordance with the equation $\text{SnF}_4 + 2\text{H}_2\text{O} = \text{SnO}_2 + 4\text{HF}$, and that the hydrofluoric acid so liberated was used largely in the development of topaz and mica. However, the paucity of topaz in the larger wolframite-rich veins, and the comparatively small quantity of fluorine which is likely to be accommodated in the micas occurring there, make it unlikely that wolframite was formed by a reaction involving tungstic fluoride. Of course, it might be argued that the fluoride *was* involved and that the liberated hydrofluoric acid migrated to higher horizons where it was fixed as, for example, fluorite which has since been removed by erosion. However, as tungstic fluoride boils at 19°C . it is a very improbable ore-forming agent. It is unlikely that either the tin or the tungsten was transported to the site of deposition as sulphide or arsenide as there is an almost complete lack of contemporaneous minerals containing these anions. However, again it might be argued that the anionic fractions migrated to higher horizons. Finally there is the attractive possibility that the tin and tungsten were carried in solution as sodium and/or potassium stannate and tungstate respectively and that the alkali ions liberated during the deposition of cassiterite and wolframite were utilised principally in the formation of micas. The feasibility of this suggestion cannot be entirely gauged until further chemical and mineralogical studies of these deposits have been completed.

In conclusion it must be stated that the characteristics of the greisen-associated, cassiterite/wolframite veins of Cornwall generally — and of St. Michael's Mount particularly — differ so much from

those of the tin/tungsten lodes of major economic importance, that it is probable that the two are not quite as closely related — from a genetical point-of-view — as has generally been believed. Briefly, the writer is of the opinion that the greisen-associated veins may owe their origin to the action of mineralising agents liberated during the consolidation of the granite bosses with which they are spatially closely related, whereas the comparatively large tourmalinised and/or chloritised lodes which are encountered, for example, in the South Crofty Mine, Camborne, may have been derived from material which emanated from considerable depth and which accumulated during the consolidation of the core of the batholith.

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