

The Nature and Significance of certain 'Late' Veins of South-west Cornwall which are characterised by the presence of Potash Feldspar

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SYNOPSIS

VEINS containing K-feldspar are common in South-west Cornwall and about 50 localities in which they occur are noted. Partial analyses of a number of the feldspars are given and the paragenesis of the felspathic veins is discussed. Zones of vein feldspars appear to halo 'emanative centres' and so the presence of the silicate in drill core, outcrops, and dumps of abandoned mines facilitates the search for tin deposits.

It is thought that whilst most of the felspathic veins examined were developed during the phase of ore-genesis immediately following the emplacement of the Permo-Carboniferous granite, some may be of Jurassic or Tertiary age, and so K/A age determinations of certain material are necessary.

Finally, in view of the widespread occurrence of K-feldspar in veins in South-west Cornwall and in other broadly similar metallogenetic provinces, and because the granites of the study area have been subject to extensive late potash metasomatism, it is concluded that adularia associated with stratiform submarine hydrothermal deposits may owe its origin to potassium introduced by juvenile solutions.

INTRODUCTION.

This paper is an interim report on the nature and significance of certain 'late' veins of South-west Cornwall which contain potash feldspars.

Veins of the type under discussion, which most geologists would not now term pegmatites, although some of the local miners do, and which are not replacement veins containing relict feldspars [such as have been noted in South Crofty Mine by Webb and described by him (1946)], are surprisingly common in the tin and copper fields of South-west Cornwall, and, indeed, in those of the remainder of the County, yet, strangely, they have received far less attention than they merit. Cronshaw (1920-21) mentions that feldspar occurs in some of the South Crofty Mine veins as also does Dines (1956, pp.317-326) who, in addition, notes that the mineral is to be found in some of the lodes of certain other Cornish mines including East Pool (op. cit., pp.326-333) and the St. Day United Mines (op. cit., p.424). Davison (1920) records its presence in the

wolframite/loellingite deposit of Castle-an-Dinas, whilst Garnett (1963) notes that it occurs in certain of the Geevor Mine lodes and he establishes its position in the local paragenetic sequence. The present writer (Hosking, 1953-54) observes that feldspar is a component of the greisen-bordered cassiterite/wolframite veins of St. Michael's Mount, and in a later paper (1962) he suggests that the disposition of veins containing potash feldspar facilitates the mapping of the buried upper portions of the batholith of the South-west. To Russell, however, must be given the credit for having made the greatest number of detailed recordings of specific veins in Cornwall of the type under review, although it must be remarked that he was primarily concerned with the rare species which they contained. Brief details of some of the feldspar-bearing veins described by Russell from the study area follow :

ia. **Wheal Metal, Breage** (1913, p.18).

"Black tetrahedra of blende are attached to yellow-white, part kaolinised *orthoclase*, with which are associated chlorite and a little quartz. Bertrandite is implanted on the sphalerite and also occupies cavities in the feldspar."

iib. **Wheal Metal** (1913, p.20).

In the 162 fm. level on Wheal Metal lode, west of the Metal Engine Shaft, wood-tin was found "with ordinary crystalline cassiterite, quartz, chlorite, chalcedony, dolomite, *orthoclase*, and pyrite".

iii. **Stamps and Jowl Lawn, Wheal Cock, St. Just** (1920, pp.20-21).

"... phenacite crystals occur either attached to yellowish, iron-stained quartz or are embedded in a loosely-coherent, scaly brownish-green, partially altered chlorite, whilst associated with them are pale wax-yellow, bipyramidal crystals of scheelite, and small, black, prismatic crystals of cassiterite (sparable tin), and also a few minute crystals of *orthoclase* of adularia habit."

Carrick Du Mine, St. Ives (1910, p.378).

"In one case heulandite forms a coating on a mass of quartz, pink *orthoclase*, chalybite and chalcopyrite — evidently true lode material."

The present writer has to date established about 50 localities in South-west Cornwall (fig. 1) and a further considerable number elsewhere in the south-west of England where 'late vein' potash feldspar occurs. As such material is often to be found on the dumps of the abandoned mines (especially those worked primarily for tin and/or copper), and as the mineral is readily recognised in the hand specimen, one wonders why it should have been so frequently omitted by competent mineralogists and geologists from their descriptions of the Cornish mineral deposits. Could it be that they

were embarrassed by the presence of feldspar in lodes: did the mineral prompt the asking of questions concerning the validity of those theories of ore-genesis which they embraced and did not wish to see destroyed: was this why they generally failed to record it? What other reason can there be?

NATURE OF THE 'LATE VEIN' FELDSPAR.

The feldspars under review are usually pink but on rare occasions they are white or cream in colour (as at the Garth Mine locally at St. Michael's Mount, and Relistian, where both pink and white aggregates are closely associated). Frequently, at least they display an adularia habit, and this habit has been invariably displayed by feldspars lining druses in veins (such as in those found on the dumps of Wheal Edward, Carn Camborne, and in situ at Priest's Cove, Penlee Quarry and South Crofty Mine). That the adularia was deposited by agents moving through open systems is clearly indicated by a specimen from the No. 4 lode at the 335 ft horizon of South Crofty Mine (collected by P. Garrett, Esq., and kindly lent to the writer) on which pink adularia crystals are attached to the stoss sides of quartz crystals whose asymmetrical character further establishes the general environment in which the minerals present crystallised. (It is not irrelevant to mention that chlorite occurs in the cores of the large quartz crystals and that the adularia is encrusted with small quartz crystals to which are attached a few small cubes of pyrite.)

In thin section the vein feldspars rarely display sodic feldspar 'inclusions', but vacuoles containing both liquid and gas are generally abundant.

KEY TO MAP (Fig. 1)

No.	No.
1. Priest's Cove.	20. Crenver and Abraham Mine.
2. Botallack cliff section.	21. Binner Downs Mine.
3. Geevor Mine.	22. Rosewarne Mines.
4. Porthglaze Cove.	23. Relistian Mine.
5. Trenwith Mine.	24. Herland Mine.
6. Carbis Bay Mines.	25. Wheal Alfred.
7. Ding Dong Mine.	26. East Rosewarne/Duffield.
8. Garth Mine.	27. Trevaskis Mine.
9. Wherry Mine.	28. St. Andrew Mine.
10. Penlee Quarry.	29. Gwithian (Wheal Emily).
11. St. Michael's Mount.	30. North Cliffs Tunnel.
12. Bolton Mine.	31. Violet Seton Mine area.
13. West Fortune Mine.	32. Dolcoath Mine.
14. Tolvadden Mine.	33. Roskear section of South Crofty.
15. Trevean porphyry dyke.	34. South Crofty Mine.
16. Penberthy Croft.	35. East Pool Mine.
17. Enys Wheal Virgin.	36. Carnhot Mine area.
18. Wheal Reeth.	37. Nangiles/Wheal Jane area.
19. Wheal Vor/Wheal Metal.	38. Porkellis Mine.

As yet 2V values for the Cornish vein feldspars have not been determined, but it is pertinent to note that Stemprok (1964) in a most stimulating and informative paper on potash feldspars in veins, particularly, but not entirely, in the tin/tungsten ones of the Krusné Hory Mountains, includes a diagram (op. cit., p.17) after Smith and MacKenzie (1959) on which he has plotted the 2V values of certain vein feldspars against their composition, and he observes (pp.16-17) that the plots "distinctly show that the prevailing part of feldspars in tin and tungsten veins occupies an intermediate position between the maximum microcline and typical orthoclase. According to the 2V values in the sense of Spencer (footnote) they may be termed as adularia. Even though the feldspars marked in the diagram came from very different ore districts, their points show a rather good coincidence. If we take into consideration that the chemical composition of some of them was influenced by posterior albitisation, the slight dispersion of points along the X axis can be easily explained". (The above mentioned diagram is fig. 2 of this paper.)

Concentrates of vein feldspar for analysis were obtained by subjecting crushed samples to hand picking under a binocular microscope: for various reasons it was not convenient to use more sophisticated methods of separation. Potash and soda were determined by flame photometry (using an Eel instrument) whilst tin, copper, arsenic, tungsten and molybdenum were determined by means of semi-quantitative rapid colorimetric methods designed primarily for applied geochemical studies. The results of this work appear in Table I, and invite the following comments:—

i. In all but two cases the feldspars are characterised by very high K_2O/Na_2O ratios, and the two exceptions are probably due in part, at least, to late albitisation.

ii. All but the Gwithian sample are from areas known to possess tin-bearing lodes (though some of the latter are distinctly richer in this element than others) yet despite this the tin-content of the feldspars may be very low, and when it is not so it is due, beyond reasonable doubt, to cassiterite which has been laid down in the feldspar by replacement, etc., during the period of lode development. Similar statements can be made, of equal validity, about the other elements which have been investigated.

It is, however, relevant to note that anomalous concentrations of 'ore elements' in these, and similar samples, are valuable indications of the presence of lodes in the vicinity which may be of economic importance, and they also give a clue to the nature of the

FOOTNOTE: —Spencer (1937) believes that without considering differences in habit differentiation between orthoclase and adularia can be effected by optical methods because the average 2V of orthoclase is $25-50^\circ$ whilst that of adularia is $50-70^\circ$.

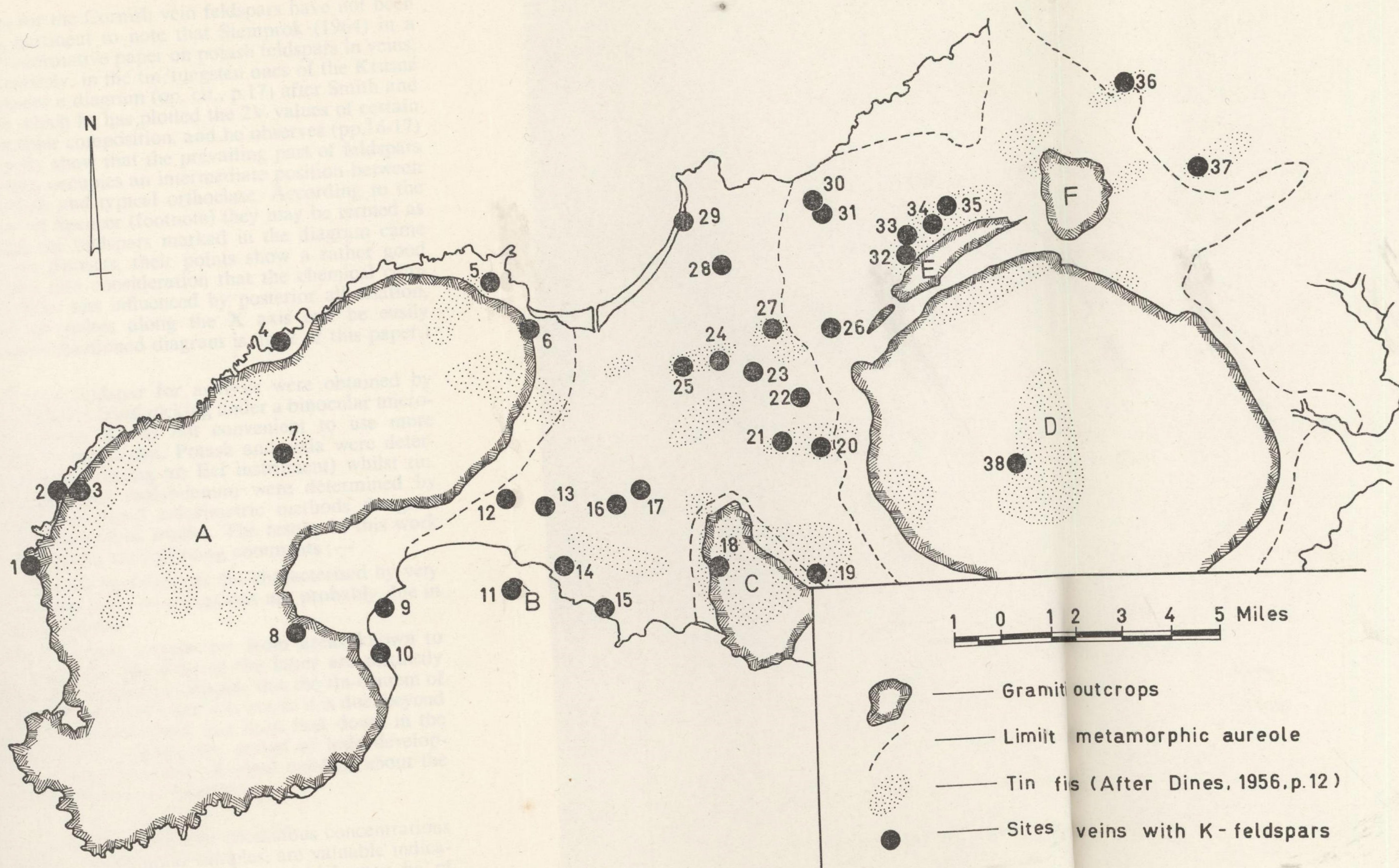


FIG. 1

Table 1
Partial Analysis of certain Cornish 'Vein' Feldspars

Locality	Per Cent		Parts per Million				
	K ₂ O	Na ₂ O	Sn	Cu	As	W	Mo
Gwithian ...	14.88	0.81	<1.5	<5	50	20	6.2
South Crofty, Complex Lode ...	13.44	0.54	40	<5	25	16	2
South Crofty, 3 A, B, C zone ...	16.08	1.35	<1.5	<5	75	4	<
Enys Wh. Virgin...	15.48	0.40	1.5	5	25	4	1
East Pool ...	14.64	0.80	<1.5	<5	75	<4	3
Hawskwood Mine..	15.36	1.56	<1.5	<5	n.d.	n.d.	n.d.
South Crofty, Roskear Section ...	5.04	8.09	2.5	5	300	<4	1
South Crofty, Roskear Section ...	13.92	3.78	<1.5	20	25	8	4
Crenver and Abraham Mine ...	15.72	0.40	<1.5	<5	50	8	1
Binner Downs ...	6.27	5.80	<2.5	5	250	8	1
Wh. Violet Seton...	14.88	0.40	2.5	n.d.	n.d.	n.d.	n.d.

(Analysts : Lee and Mohu)

mineralisation. These facts might facilitate prospection when, for example, felspathic vein material, lacking ore minerals which are not visible to the naked eye (or even under the microscope), is found in outcrops, on the waste dumps of abandoned prospects, or in a diamond drill core. The Gwithian material serves to illustrate this. It, together with many similar specimens, was collected from the site of the long abandoned, unsuccessful, and little documented Wheal Emily which, in 1859, produced 169 tons of copper ore and "raised 25 tons of zinc ore and 75 tons of 73 per cent lead ore" (Dines, 1956, p.149.) Here lode development took place along zones in which fracture and brecciation occurred on a number of occasions during the period of mineralisation. The order of deposition, judging by material found on the dumps, was quartz, feldspar, chlorite, chalcopyrite and sphalerite, galena, pyrite and siderite. It is important to point out that because new fractures were constantly developing throughout the period of lode genesis whilst early ones were not always opened during the later mineral deposition stages, it is common to find vein specimens lacking some of the minerals noted above: for example, veins consisting solely of quartz and feldspar are abundant.

Despite the anomalously high tungsten and molybdenum content of the Gwithian feldspar no minerals containing either of these elements as essential components have ever been recorded from the area. However, their presence in high trace amounts in the material analyzed suggests that hypothermal deposits might occur in the vicinity, and that they do has been supported by the fact that an intact but very fragile specimen of geniculately twinned cassiterite was recovered by the writer in concentrates from just above bed-rock in a sand-filled valley about half a mile to the south-west during evaluation of the tin-content of the Gwithian/Hayle beach sands by methods involving Banka drilling. Clearly this specimen was of local origin.

HABITAT OF THE FELSPATHIC VEINS.

Veins containing potash feldspar occur in all the major lithologic units of the study area. They have been noted in the granite of South Crofty, East Pool, Porkellis and Geevor Mines; in the porphyry dyke of the Wherry Mine; in the greenstones of Penlee Quarry (near Newlyn) and of Tolvadden Mine dump (near Marazion), and in the killas of the dumps of Penberthy Croft, Enys Wheal Virgin, Gwithian and Trenwith Mine (St. Ives). It is also worth mentioning that pink feldspar also occurs in veins in the calc flinta of the Mulberry Mine area of Central Cornwall.

NATURE OF THE VEINS. (Figs. 3-15.)

Potash feldspar is generally one of the earliest minerals to be deposited in the veins developed during the period of ore-genesis and is found in the mineralogically and structurally simple ones and in those which are mineralogically and structurally complex.

Although veinlets consisting solely of feldspar occur, it is much more usual to find veins containing this mineral in association with one or more other species. Of all the combinations the quartz/feldspar one is the commonest. In these the feldspar may fringe the walls (as in certain beach pebbles from Carbis Bay and in some specimens from Tolvadden dump), fringe both walls and country rock fragments in brecciated bodies (as at Penlee Quarry, Gwithian, Wheal Trenwith and Penberthy Croft), form a reticulate texture (as at Penberthy Croft, Enys Wheal Virgin and Gwithian) or a mottled one (as at Enys Wheal Virgin and Gwithian), and occur in part as irregularly shaped masses in the 'middle' of the vein (as at South Crofty Mine). In addition it may occur with quartz in irregularly shaped replacement 'pods' in the walls of feldspar-bearing veins (as at Penberthy Croft) and as narrow bands which, alternating with quartz ones, produce a texture which although it might be tempting to call a degraded colloform one, is, in all probability, simply a crustified one of the general type most commonly encountered in Cornwall in barren crosscourses, and elsewhere in epithermal

deposits : the only Cornish examples of the last type known to the writer were collected by him from Wheal Alfred dumps (near Hayle). Finally, disseminated potash feldspar may be formed at the expense of greisen and an example of this has been described earlier by the writer from St. Michael's Mount (Hosking, 1953-54).

Many of the textures noted above may also be seen in veins which have a more complex history of development, but in some cases the feldspar pattern has been modified by vein-forming processes which post-dated the formation of this silicate. On occasion the feldspar is virtually confined to early veinlets within the country rock fragments of a major vein (as in some of the Gwithian material) whilst some of the Complex Lode material of the Robinson's Section of South Crofty Mine consists essentially of bands of quartz containing irregularly shaped masses of pink feldspar alternating with bands consisting largely of wolframite and arsenopyrite and minor amounts of other sulphides.

Many different minerals may occur in the feldspathic veins and the combinations encountered are many. At Gwithian chlorite has been deposited after the feldspar and in part replaces it : at Wheals Edward and Owles plenakite, cassiterite, and chalcopryrite are associates, and on occasion, and together with quartz and adularia, line druses in the veins : at Tryphina dump a specimen consisting of feldspar, quartz, cassiterite and blue chalcedony was found by the writer ; locally at South Crofty (as noted above) and East Pool Mines, abundant wolframite and arsenopyrite are accompanied by quartz and pink feldspar. These examples do not exhaust the types but they serve to indicate the diverse character of the group : further variations of the theme which were noted by Russell have already been described.

PARAGENESIS AND AGE OF THE FELSPATHIC VEINS.

In the overwhelming majority of the feldspathic veins examined by the writer quartz is the first of the vein minerals to be deposited and this is followed by a single generation of feldspar which commonly, though not invariably, has formed by local replacement of the earlier species (which in some instances, as in the case of the Penberthy Croft "wallrock" pods, noted earlier, was itself a replacement product. That vein feldspar was sometimes deposited directly from mineralising agents is established by its occurrence in druses, and particularly by the nature of the specimen from South Crofty Mine which was collected by Mr. Garrett and which has already been described. The crustified material, described earlier, from Wheal Alfred, however, suggests that on occasion rhythmic deposition of quartz and feldspar may occur.

In the mineralogically more complex feldspathic veins the paragenesis becomes less easy to determine. Whilst there is no doubt that the feldspar preceded the wolframite and arsenopyrite in the

early veins of South Crofty Mine, there is some doubt about the order of deposition of the feldspar and wolframite in the Middle Lode of the adjoining East Pool Mine : certainly a specimen of this material which the writer examined some years ago (see fig. 11) did not provide a unique answer to this problem, and Dewey and Dines (1923, p.17) state that in this lode "the wolfram is intergrown with microcline feldspar". Garnett (1963), after a number of years of study of the Geevor lodes, concluded that a number of important lode-mineral-forming events preceded the deposition of the feldspar. Briefly, he recognises the following phases of mineralisation there :-

1. Main wall-rock alteration. (Reddening of the feldspars, greisenisation, etc.)
2. Impregnation of wall-rock by arsenopyrite, pyrite and chalcopyrite.
3. Development of cassiterite by replacement.
4. Infilling with tourmaline.
5. Deposition of *feldspar* and arsenopyrite.
6. Deposition of quartz and cassiterite.
7. Deposition of tourmaline and cassiterite.
8. Deposition of chlorite and cassiterite.
9. Deposition of cassiterite, chalcopyrite, pyrite and green fluorite.
10. Deposition of chalcopyrite, chalcocite and sphalerite.
11. Deposition of quartz and purple fluorite.
12. Deposition of calcite and siderite.
13. Deposition of quartz and jasper.

Elsewhere (Garnett, 1962, pp.346-347) remarks that "the first major movements and dislocation of the potential lode fissures, and the surrounding joints, permitted the formation of openings with a maximum width of about six inches. Arsenopyrite and salmon-pink feldspar immediately filled the cavities". He further notes that "the composition of the feldspar, which is occasionally massive . . . is uncertain owing to its eventual, almost complete replacement by quartz and sometimes cassiterite. Preliminary work indicates that the feldspar is orthoclase, and it either forms as laths . . . or possesses an adularia habit . . . Early tourmaline was brecciated and recemented . . . by the feldspar-arsenopyrite association. The arsenopyrite often succeeds the feldspar . . . and partly replaces it."

Only in a comparatively small number of cases has it been possible to establish directly, and with some degree of precision, when, during the period in which major and minor granitic bodies (including pegmatites) and lodes were formed, the feldspathic veins commenced development. At St. Michael's Mount, Cligga, South Crofty, Geevor and Porkellis the feldspar occurs in veins bordered by greisen which predates the vein filling. Whilst the feldspathic veins are earlier than certain cassiterite/chlorite/quartz/fluorite lodes at

South Crofty and are intersected and faulted by the latter, at Michael's Mount greisen-bordered felspathic veins intersect simple granite pegmatites.

The adularia habit, which so frequently characterises the 'vein feldspar' is never seen in the granite pegmatites, nor does the form possess an abundance of sodic plagioclase inclusions which permit the feldspars of the pegmatites to be termed microcline microperthite.

Felspathic veins in the killas are never bordered by metamorphosed wall-rock as pegmatites are. The bulk of the available evidence suggests, then, that generally, at least, veins containing feldspar commenced development after the pegmatites and before the major phase of cassiterite deposition. However, on occasions quartz/pink feldspar veins were formed after the tin lodes had been developed, and the writer collected a few months ago several specimens from a recently established waste-rock dump near the Robinson Shaft of South Crofty Mine which clearly demonstrate this. One sample in particular (fig. 14) consists of a portion of lode, composed of tourmaline, chlorite, cassiterite and quartz and bordered by chloritised granite, which is intersected by a narrow quartz/pink feldspar vein which post-dates all the other mineral components. Limited studies have already demonstrated that some of the Cornish lodes contain mineral components of Jurassic and Tertiary ages, but no one has seriously suggested that the bulk of the minerals of the hypothermal lodes were not deposited during the final stages of the emplacement of the Permo-Carboniferous granite and immediately after. It is generally thought that the Jurassic and Tertiary mineralising agents probably added little to the hypothermal lodes: rather they effected limited mobilisation and redeposition of lode material (footnote).

In view of the above observations it is possible that the post-cassiterite, etc., felspathic veins of South Crofty may be Jurassic or Tertiary in age. However it is unwise to jump at such a conclusion, because differentiation leading to the 'release' of ore-forming agents probably takes place at many centres within the consolidating batholith, and the stage of differentiation reached at one centre at a point in time is likely to be somewhat different from that reached in another. Thus, the South Crofty material described above could owe its character to the fact that it is composed of minerals laid down by agents derived from two centres and in one of these differentiation had occurred earlier than in the other. There

FOOTNOTE :—Whilst it is likely that the mesothermal lodes whose strike is approximately to those of neighbouring hypothermal lodes consist largely of minerals which were deposited during the final stages of the 'Permo-Carboniferous' phase of mineralisation, it may be that the 'cross-coursing' lead/zinc/etc., lodes are distinctly younger. On the other hand the antimony lead/zinc veins of North-east Cornwall, which are spatially closely related to Devonian spilites, may pre-date the granite and the tin lodes.

is the further possibility that the late feldspar may owe its presence essentially to potassium liberated during chloritisation of the feldspars of the granite host. In this connection it is worth noting that Barabanov (1961) considers the adularia in the wolframite-bearing veins of the Bukuka and Belukha deposits of Eastern Transbaikalia to have originated from the mobilisation of the components of granitic host-rock microcline.

In addition, the possibility that potash feldspar might be deposited on more than one occasion during one major cycle of mineralisation cannot be disregarded. Indeed, according to Stempok (1964, p.15) Povilaitis claims that in the molybdenum/tungsten deposit of Dzhida in Western Transbaikalia microcline "was deposited during four stages of mineralization, the whole cycle of metallization being divided into nine stages", and that "for each stage the different chemical composition of potash feldspars is characteristic as well as the 2V values".

The crustified quartz/pink adularia specimen (fig. 8) from Wheal Alfred (which has been noted earlier) is also of particular interest when one is considering the 'absolute' age of the felspathic veins of the study area. Texturally it is atypical of the Cornish hypothermal deposits, and from a textural, not a mineralogical point of view, it is much more reminiscent of some of the crosscourse material, such as can be collected, for example, at South Crofty Mine. It is possible, therefore, that this specimen contains 'young' feldspar — say of Jurassic or Tertiary age.

From what has gone before it must be obvious that when we contemplate the history of the Cornish ore-deposits we are still, as it were, peering through a glass darkly. To get the record straight more events must be dated, and amongst the minerals whose birth-days can be established with a useful degree of precision are the potash feldspars, and some specimens worthy of particular attention have been described in this paper (footnote).

FURTHER OBSERVATIONS RE THE DISTRIBUTION OF FELSPATHIC VEINS.

There is good reason for believing everywhere in the study area where granite is not exposed it underlies the sediments, and elsewhere the writer (Hosking, 1962) has presented evidence in support

FOOTNOTE :—Dating can be achieved because c. 11% of the K^{40} present captures an orbital electron and becomes A^{40} (argon). The half-life of this K^{40} fraction is 11,850 million years. The remaining 89% of the K^{40} present loses beta particles and becomes Ca^{40} . Because of the great abundance of Ca^{40} in nature "the minute additions contributed by potassium are generally lost beyond recognition" and so this change is of "very limited value for dating purposes". Because of losses of argon from the feldspar only the minimum age of the latter can be established by K—A dating. For further details see Carr and Kulp (1957, Schaeffer and Zähringer (1966), Holmes (1965, chapt. XIII), and Rankama (1956, chapt. 25).

of the view that the original surface of the batholith was ornamented by ridges which were locally surmounted by cusps, and that the centres of mineralisation (Dines' 'emanative centres') were approximately coincident with these cusps. The emanative centres are the centres of the primary tin zones and of the concentric, but, in plan more extensive, copper ones. The writer believes that the potash vein-feldspar also occurs in zones which are *broadly* co-extensive with the tin zones although he appreciates the fact that evidence from some areas of limited extent could be advanced in support of the contention that the feldspar zone is smaller than the associated tin one, whilst from others, evidence in favour of the opposite view could be cited. Thus, the fact that feldspar tends to favour the deeper portions of the tin lodes at Geevor supports the first view, whilst the fact that at Gwithian felspathic veins occur in killas which shows no signs of thermal metamorphism supports the second. (When considering the Gwithian evidence it is well to remember that because the felspathic veins occur in killas which has not been thermally metamorphosed this does not automatically mean that they are outside the tin zone: economically important cassiterite-bearing veins may occur outside the metamorphic aureole — they do so locally in the St. Agnes area: the 1 in. Geological Survey map bears witness to this!)

If then there is a broad spatial relationship between potash vein-feldspar and cassiterite in stanniferous provinces, when the silicate is found during prospecting it can be regarded as an indicator of the likely presence of tin lodes in the area.

In order, however, to prevent the 'picture' of the distribution of potash vein-feldspar in the South-west of Cornwall from becoming grossly distorted it must be pointed out that although vein-feldspar may be much in evidence in certain sections of a tin mine it may be restricted to certain parts of a lode and there may be many lodes which appear to be devoid of the mineral. Its distribution at Geevor Mine has already been referred to, whilst at South Crofty Mine it is largely restricted to the earliest of the lodes, namely those which are also characterised by the presence of wolframite and arsenopyrite and the virtual absence of cassiterite (footnote). Furthermore, whilst scores of specimens of felspathic veins have been collected in a short space of time from some mine dumps (for example, at Enys Wheal Virgin, Penberthy Croft and Gwithian) other dumps have only yielded one specimen, or at best a few, or none at all, after a prolonged search: the vast dumps of Polbero Tin Mine, near St. Agnes, fall into the last category.

Of course, failure to find vein-feldspar on a dump does not mean that the latter contains none: after all, only the superficial parts are

FOOTNOTE:—At South Croft swarms of tin-rich veins occur within somewhat more extensive felspathic vein swarms, and so for many years particular attention is paid to any unworked block of ground which yields drill core containing samples of the latter.

examined adequately. On the other hand, the dump of a tin mine may be devoid of vein feldspar because the felspathic portions of the lodes were not reached during mining; because the felspathic veins occurred in ground which was sub-economic; because the felspathic parts were confined to the ore which was milled. The dump may also lack vein feldspar because it was nowhere deposited in the area: it would probably be quite wrong to think that cassiterite could not be deposited without feldspar being deposited also in the neighbourhood: after all, what mineral except quartz is a constant companion of this tin species? It is also important to note that evidence from both the operating mines and the many thousands of feet of diamond drill core which have been obtained from tin fields in the study area during the past few years indicate that potash feldspar forms only a modest percentage of the total vein components, and this fact naturally limits its use as an aid during prospecting.

Finally it is becoming ever more apparent that potash feldspar, often pink, and with an adularia habit, is frequently present in hypothermal deposits associated with granitic rocks throughout the world. Stempok (1964) has noted a number of European and extra-European examples, and recently Garnett (1966, p.B256) has figured an example of the long known quartz/feldspar/cassiterite veins of Pelepahkanan (Johore, Malaya). To these the writer can add examples from Panasqueira (the Portuguese wolframite mine), the Rooiberg tin field of South Africa, and from the Richi tin lode of Nigeria (see figs. 16-20).

Adularia feldspar is also known to occur in notable amounts in sediments including those associated with some of the stratiform deposits — notably those of the Zambian Copperbelt and of Mount Isa (Australia), and there is good reason for believing that this silicate can be formed in a number of ways: in some instances it may be, as Davidson (1967, p.B57) suggests, that the adularia "is an end-phase of a complex diagenetic-metamorphic sequence of zeolitization . . . reached only at depth in hypersaline intra-stratal environments" and usually involving "an overhead load of several thousand feet of strata". However, in view of the common occurrence of feldspar in epigenetic veins in many metallogenic provinces, and because much of the granite in the South-west has been subject to widespread late potash metasomatism, it would seem that in some instances not only the heavy metals of stratiform ore deposits, but also the potassium of the feldspar in neighbouring beds, might have been derived from juvenile fluids.

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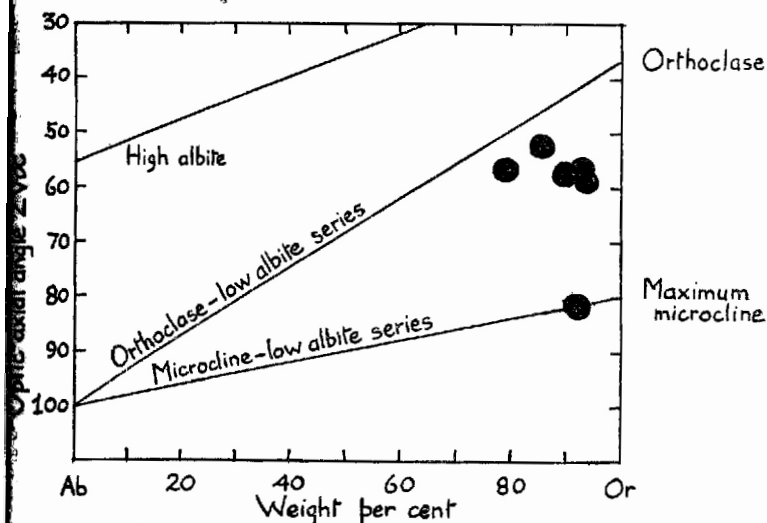


FIG. 2

- FIG. 3. A quartz/pink feldspar replacement vein intersecting a fragment of slate (black) embedded in a quartz matrix. Enys Wheal Virgin. Q.= quartz; F.= feldspar.
- FIG. 4. Portion of a vein consisting of pink feldspar which has replaced quartz and is itself locally replaced by quartz and chlorite. Country rock is slate hornfels. Dump near Roskear Shaft. Quartz, white; feldspar, lined; quartz/chlorite, stippled.
- FIG. 5. Portion of the cliff section at Priest's Cove showing the relationship between pink feldspar (black) which has replaced a quartz vein (stippled) and slate hornfels (white) and the fissure along which the feldspar-forming components moved.
- FIG. 6. Portion of a brecciated drusy vein in chloritised killas from Trenwith Mine dump. Pink feldspar lines the walls of the vein, invests killas fragments and occurs as irregularly shaped aggregates in the quartz core. The feldspar is locally fringed by 'replacement' chlorite. Some of the druses are lined with cassiterite, and chalcocopyrite. Somewhat diagrammatic. K.= chloritised killas; P.F.= pink feldspar; C.= chlorite; Q.= quartz; D.= druse.
- FIG. 7. Portion of brecciated vein consisting of somewhat leached fragments of dolerite hornfels (black), rimmed by pink feldspar (stippled) in a quartz matrix. Penlee Quarry.
- FIG. 8. Portion of a crustified vein from Wheal Alfred dump, consisting of alternate bands of pink feldspar (black) and very fine-grained quartz (white).
- FIG. 9. Portion of a vein, c. 2.5 in. wide, in a biotite slate hornfels boulder at Priest's Cove (near St. Just). The vein consists of black tourmaline crystals (Tm) whose long axes are perpendicular to the walls, pink feldspar (P.F.), together with minor amounts of pink fluorite (Fl.) and arsenopyrite (Apy.).
- FIG. 10. A quartz/feldspar/wolframite vein near the Shaft Section, 260 fathom level, South Crofty Mine. Q.= quartz; F.= pink feldspar; W.= wolframite; Fl.= fluorite; G.= granite; Gn.= greisen; S.= late chlorite stringers. (After Webb, 1947.)

- FIG. 11. A specimen of quartz/feldspar/wolframite from the Middle Lo East Pool Mine. W.= wolframite (black); P.F.= pink-orange feldspar; S.= sericite; Q.= quartz.
- FIG. 12. Portion of a brecciated vein in dark-green chloritised killas from the dump at Penberthy Croft. The walls of the vein and the killas fragments are locally fringed with aggregates of pink feldspar, while masses of dark-brown cassiterite occur in the quartz matrix. The slate fragments are cut by a quartz/chlorite stringer. Locally the wall has been silicified, and elsewhere quartz/feldspar replacement pods occur in the killas. Q.= quartz; P.F.= pink feldspar; C.= cassiterite (black); Ch.= chlorite; C.S.= chloritised killas; S.S.= silicified killas; P.= quartz/feldspar pods; X = killas fragments.
- FIG. 13. A specimen (collected by J. Trembath, Esq.) from the Footwall Branch Lode, at Level 10, Geevor Mine.
1 = Very silicified granite with highly kaolinised feldspar and wolframite after feldspar (K) and sulphide aggregates (S) — pyrite and minor chalcopryrite. 2 = Chlorite 'parting'. 3 = Comby quartz with small central druse (D) and intersected by 'partings' of malachite (M). 4 = Fluorite (F). 5 = A fine-grained quartz/chlorite band. 6 = A band of fine-grained chlorite. 7 = White fluorite (Fl). 8 = Red feldspar with chlorite stringers. 9 is the same as 6. 10 = Granite wall rock, with pink feldspars, which is locally 'cut' by a black tourmaline/quartz vein (11).
- FIG. 14. Specimen collected from a dump near Robinson Shaft, South Crofty Mine. It consists, essentially, of a portion of a lode and the associated granite wall-rock intersected by a late vein (L.Q./F.) consisting of quartz (Q.) and pink feldspar (black). The lode is composed of quartz (Q.), chlorite (Cl.), tourmaline (Tm.), pink feldspar (F.) and cassiterite (small circles with a central spot). The granite near the lode has been converted to quartz and chlorite (Q./Cl.) whilst further away the groundmass is somewhat chloritised and the large feldspars (F.P.) are pink.
- FIG. 15. A portion of a specimen from Tryphina Mine dump consisting of quartz (Q.), deep-brown, massive cassiterite (Ca.), deep-red feldspar (D.R.F.), pink feldspar (P.F.) and pale-blue chalcedony (Ch.).
- FIG. 16. A vein at Bridge Winze, Rooiberg, South Africa, consisting of white cassiterite (black), pyrite (Py.) and red feldspar (R.F.) in a matrix of white ankerite (Ank.). The wallrock is arkose which, in the vicinity of the vein, is very chloritised.
- FIG. 17. Specimen from A3, Rooiberg Mine, South Africa, consisting essentially of alternate bands of pink adularia (P.F.) and dark cassiterite (black). The bands 'follow' the bedding of the arkosic country rock. The feldspar bands consist of aggregates of lath-like crystals c.0.3 in. long: isolated feldspars also occur within the cassiterite masses.
- FIG. 18. A banded vein from Lower Spruit, Leeuwpoort, South Africa. The bands are of quartz (Q.), massive pyrite (Py.) and massive cassiterite with isolated crystals of red feldspar (Ca. + R.F.). The wallrock is slate-like.
- FIG. 19. Detail of the M.D. Lode, Rio Rita, S. Africa, 230 ft. from the surface in the 140 ft. drive south, showing red 'orthoclase' (R.F.) fringed with cassiterite (Ca.) which having been brecciated was cemented by buff ankerite (B.F.).
- FIG. 20. Portion of the vein at L2 P4 13E. in Beralt Mine, Portugal. The vein, which is in 'schist', is here c. 1 ft. wide, has selvages of white mica (M.) and consists of pink feldspar (P.F.), arsenopyrite (Ap.), wolframite (W.) and coarse white mica (C.M.) in a quartz matrix. Elsewhere in this vein cassiterite, a little chalcopryrite and siderite occur. The feldspar appears to have developed at the intersection of the fractures A. and A₁.



FIG 3

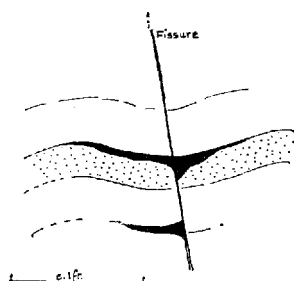


FIG 5

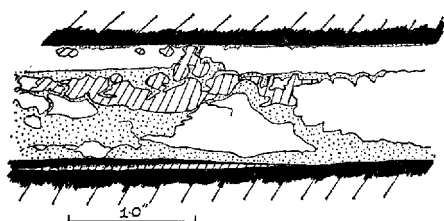


FIG 4

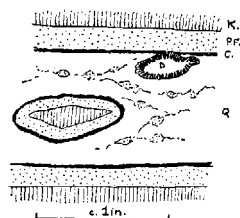


FIG 6

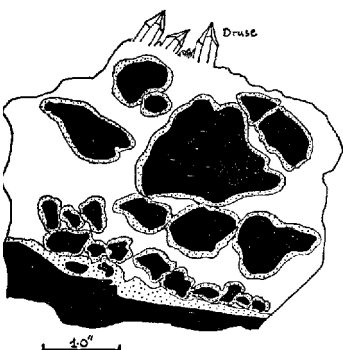


FIG 7

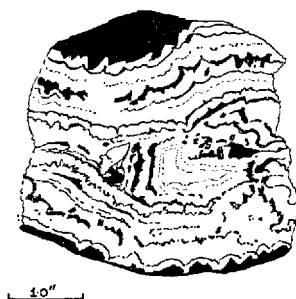


FIG 8

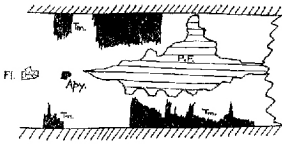


FIG 9

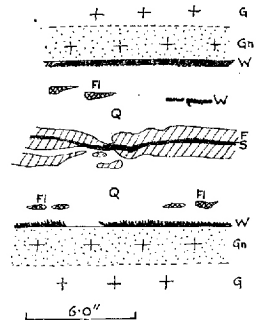


FIG 10

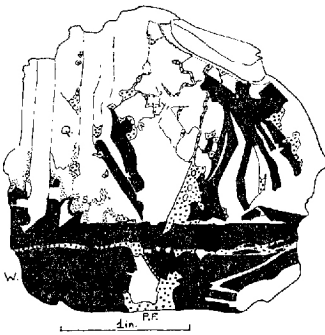


FIG 11

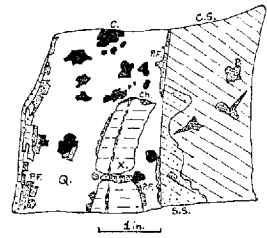


FIG 12

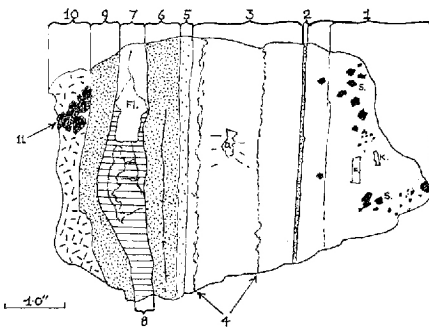


FIG 13

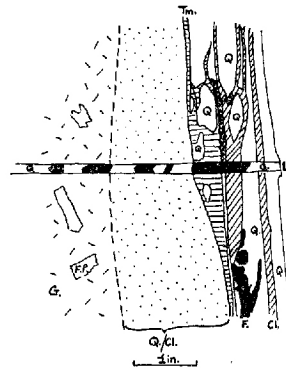


FIG 14

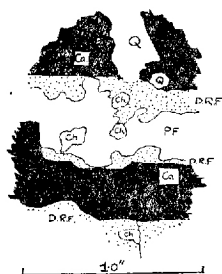


Fig 15

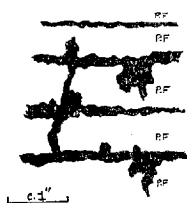


Fig 17

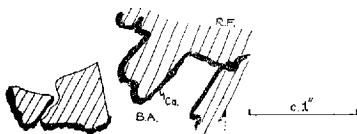


Fig 19

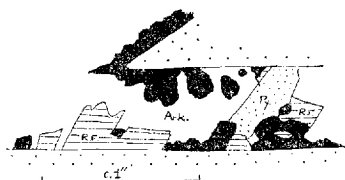


Fig 16

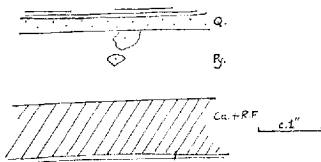


Fig 18

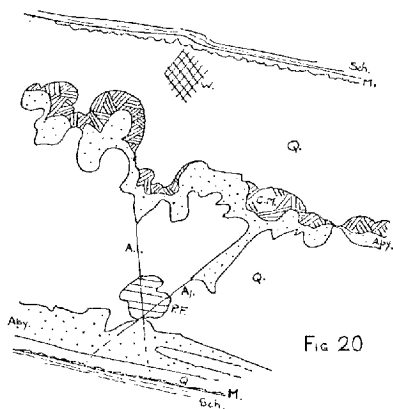


Fig 20