Gold and silver in the Dartmoor granite.

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Introduction.

Gold and silver have been detected not only in the peculiar facies of the granite occurring on Bittleford Down,[1] but also in the normal grey biotite-granite of numerous tor- and quarry-localities; several hand-specimens of granite showing minute flakes of visible gold have been collected.

The modes of occurrence of gold on Dartmoor, the environment of the granite from which specimens showing visible gold have been taken, and the gold-silver content of the granite generally have been investigated in some detail, with the results described below.

Occurrences of gold and silver.

Previous to the identification of gold and silver in the Bittleford pegmatite, detrital gold had been identified in only four out of about 120 samples of stream-sand and 'head' examined at an early stage of this work. Though the number of samples which have yielded gold now totals seven, the total yield of the metal from such samples is only a few milligrams.

In following up this identification, considerable attention was paid to vein-quartz, blocks of which may be met with on the surface of the moor along almost every traverse. Minute specks of gold have been detected in only two of the numerous blocks broken up and examined on the ground. The following occurrences, however, deserve mention.

On a well-developed crystal of vein-quartz collected a few years ago

[1] A. Brammall and H. F. Harwood, The occurrence of a gold-bearing pegmatite on Dartmoor. Min. Mag., 1924, vol. 20, pp. 201–211.

by Miss I. M. McCrea (late of Newnham College) somewhere in the vicinity of the Vittifer mines and acquired by the author, the latter observed several minute flakes of gold embedded in patches of earthy haematite coating the specimen. The exact source of this crystal has not been traced, though the author and his colleagues Dr. H. F. Harwood and Mr. J. G. C. Leech have made a thorough search of the locality.

In a water-clear crystal of cavity-quartz found by Mr. P. G. Stevens on the top of North Hessary Tor, the finder detected several minute inclusions which he identified as particles of gold, this identification being confirmed by the author.

A scrutiny of 'heavy mineral' concentrates from fresh crushed granites was more fruitful. Though gold was detected in only three samples of normal tor-granite, minute particles of it were identified in concentrates from several specimens of the Bittleford pegmatite. The occurrence at this locality has already been described.[1] Assays of representative samples of the pegmatite and of the sulphidic ore-grains extracted from the rock revealed the constant presence of both gold and silver (see table on page 19).

Visible gold has been noted in several hand-specimens of normal grey biotite-granite. Two occurrences, in east and west Dartmoor respectively, are here described.

Welstor Cross quarry, near Buckland Beacon, east Dartmoor.—This quarry is traversed by several veins of compact granular quartz striking nearly east-west and dipping north (at 35°–42°), these directions agreeing with the strike and dip respectively of one of the main joint-systems developed at this locality. The main quartz-vein is about 8 inches thick; the others are much thinner. The thickest vein shows occasional nests of radiating tourmaline and isolated patches of felspar. No vughs have been observed. It may be regarded as an extreme (leucocratic) modification of the granite. No visible gold has yet been detected in this vein-quartz.

Minute film-like flakes of gold forming an aggregate visible to the naked eye (see fig. 1, p. 16) were found on the fracture-surface of a large block of the normal granite taken by the author from a bench about 4 feet above the main quartz-vein. This fracture-surface is highly irregular; it exposes fresh granite quite free from iron-staining, oxides of manganese, and other secondary minerals, and cannot reasonably be regarded as a joint-plane. The flakes (up to 1·2 millimetres long) shown

[1] loc. cit.

in fig. 1 lie on a fracture-surface across plagioclase. They are curiously fluted, the direction of fluting being approximately parallel to the outcrops of twin-lamellae discernible with difficulty. The interior of the block was explored in the laboratory by breaking up the specimen between the jaws of a rock-crusher. Similar clusters of still more minute flakes were detected on two of the fragments so obtained. These clusters occur about the margins of, and also on, orthoclase phenocrysts which are only feebly discoloured by iron-staining. A few flakes are intimately associated with minute patches of limonitic material doubt-

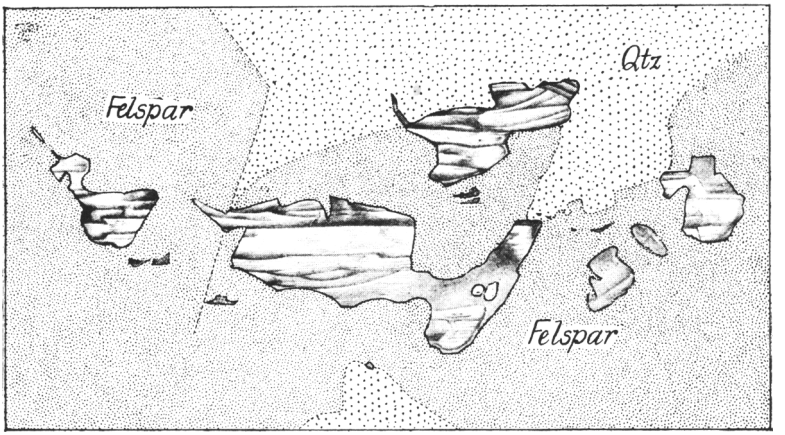

FIG. 1. Showing fluted film-like flakes of gold in plagioclase exposed on the fracture-surface of a granite specimen from Welstor Cross quarry. The largest flake is about 1·2 millimetres long. The direction of fluting appears to be closely related to the strike of the twin-lamellae. (Flakes drawn by Dr. O. M. B. Bulman).

less representing altered iron sulphide gossan on a small scale. Only two blocks showing visible gold were found at this quarry during the course of several visits occupying in all about ten hours. An assay of representative material collected indiscriminately from the quarry revealed only a minute trace of gold and silver.

Small quarry near cottage immediately south of Vixen Tor, west Dartmoor.—The joints at this locality include a nearly vertical system striking west-south-west and apparently related to a quarry-face of pneumatolysed granite and to thin erratic quartz-schorl stringers. Pneumatolytic effects extend also along narrow zones below, and roughly parallel to, the quarry-benches. The quarried rock is fresh grey

biotite-granite apparently quite normal. Visible gold was first detected in a specimen of this granite by Mr. P. G. Stevens. After a prolonged search by him and the author jointly, five similar specimens were found.

On the first specimen taken, numerous minute flakes of gold are visible with the aid of a pocket-lens. Two of the flakes are definitely embedded in groundmass quartz; others lie along or across the cleavage-planes of felspar. A few only are associated with microscopic crusts of iron oxide. The surfaces carrying these flakes are highly irregular and unlikely to be related to any of the joints affecting the quarried rock.

On other specimens, most of the flakes are intimately associated with gossan-like crusts of iron oxide.

Representative material collected indiscriminately at the quarry was assayed, the values found, per long ton (2,240 lb.), being 6·3 grains (0·00004 %) of gold and 38·1 grains (0·00024 %) of silver.

Evidence in favour of the primary character of the gold and silver.

The possibility that the gold at the Vixen Tor locality may have been introduced into the granite by processes incidental to local pneumatolysis was tested by an assay of a fair sample of the reddened pneumatolysed granite flanking the quarry-benches. The assay yielded not even a trace of gold, and only 8·8 grains of silver per ton (0·00005 %).

The frequent association of minute flakes of gold with iron oxide suggested the desirability of assaying the iron sulphide present in the granite. The content of sulphide, however, was too small to justify the cost of materials necessary to separate it from the crushed rock in quantity adequate for an assay.

On the other hand, minute crystals of pyrites separated from the granite of the Prison quarry, Princetown, are identical in habit with the pyrites occurring as well-formed interpenetrant pyritohedra (up to ½ inch in diameter) in a matrix of decomposed and haematite-stained granite forming a zone of 'bad rock' in the Merrivale quarry. The latter occurrence of vein-pyrites is almost certainly syngenetic with the Princetown granite, which, however, differs considerably from the Merrivale and Vixen Tor facies. The vein-pyrites yielded on assay (per ton) only 1·6 grains (0·00001 %) of gold, but 125·3 grains (0·0008 %) of silver.

If this gold value is not considerably exceeded by that of the pyrites in the granite of the Vixen Tor quarry, it seems improbable that altering pyrites can be the sole, or even the main, source of the visible gold in this granite. As certain of the joint-planes at this locality carry manganese-rich dendrites, sometimes associated with arsenopyrite, autunite, haematite, and schorl, a typical sample of manganese-incrustation taken at the Merrivale quarry was assayed: it yielded (per ton) 9·6 grains (0·00006 %) of gold and 72·7 grains (0·00046 %) of silver. On the other hand, an assay of the Merrivale granite itself yielded (per ton) 3·6 grains (0·00002 %) of gold and 106·2 grains (0·00067 %) of silver. These figures afford no ground for assuming that the gold and silver found in the granite were introduced by waters circulating in the joint-planes. The converse—that the gold and silver present in the joint-plane incrustation were extracted from the granite—is at least possible.

Following the identification of two minute particles of gold in mounted 'heavy mineral' concentrates from the Princetown granite, this rock was assayed, and yielded (per ton) 6·0 grains (0·00003 %) of gold and 156·8 grains (0·001 %) of silver.

On the basis of values ascertained for the Merrivale vein-pyrites, the figures for the Princetown granite are perplexing, unless other constituent minerals besides pyrites carry gold and silver. A thorough examination of numerous samples of the Princetown granite failed to detect a single flake of gold in association with either the quartz or the felspar. There remained therefore the biotite. About 40 grams of biotite were separated from the granite and assayed: the values found (per ton) were only 1·5 grains (0·000007 %) of gold, but 108 grains (0·00069 %) of silver.

A calculation based on the content of biotite and pyrites in the granite showed either that the pyrites was much richer in gold and silver than the Merrivale vein-pyrites, or that the major constituents, quartz and felspar, also enclosed finely divided particles of the metals. The quarry occurrences of visible gold described on pages 15–17 render the latter alternative highly probable.

That both metals are primary and indigenous to the granite is further suggested by the results of assays of tor- and quarry-granites from other parts of the moor. The assay-results as a whole are given in the following table, which incorporates the values for the Bittleford pegmatite and also the results of assays of St. Austell granites kindly communicated to the author by his colleague Mr. J. G. C. Leech.

Assay-values for gold and silver in granites.

	Gold. (Grains per ton of 2,240 lb.)	Silver. (Grains per ton of 2,240 lb.)
Dartmoor Granites:		
Normal tor-granites:[2]		
Birch Tor	nil	20·4
Bonehill Rocks	2·4	1·2
Greator Rocks	1·2	9·6
Northcombe, Widecombe	1·2	54·0
Normal quarry-granites:[2]		
Cold East Cross quarry	1·6	10·4
Haytor: east quarry	trace	6·0
Haytor: west quarry	1·2	6·0
Merrivale quarry	3·6	106·2
Princetown: Prison quarry	6·0	156·8
Vixen Tor quarry	6·3	38·1
Welstor Cross quarry	trace	trace
Miscellaneous:[2]		
Biotite, Princetown granite	1·5	108·0
Graphic granite, Hameldown	trace	9·6
Pegmatite, Ponsworthy	trace	16·8
Pneumatolysed (red) granite, Vixen Tor quarry	nil	8·8
Manganese-rich deposits on joint-planes, Merrivale quarry	9·6	72·7
Vein-pyrites, Merrivale quarry	1·5	125·3
Bittleford Pegmatite[3]	218·4	360·0
	156·0	33·6
	129·6	264·0
	93·6	55·2
	38·6	14·4
	21·6	170·4
	16·8	40·8
	14·4	187·2
	12·0	16·8
	9·6	26·4
	7·2	28·8
St. Austell Granites:[2]		
China-stone	1·0	97·4
Colcerrow type	4·8	56·6
Prideaux type	2·4	27·8
Californian Granites[4]	1·6	120·0
	2·1	19·1
	1·8	14·7
Nevadan Granite[4]	17·7	87·6

[1] Note: 24 grains per ton (2,240 lb.) = 1,530 milligrams per metric ton.

[2] Assayed by C. W. Dannatt, Lecturer, Royal School of Mines, who reported also that in each case the cupel showed a slight green stain indicating traces of copper.

[3] Assayed by B. W. Holman, Assistant-Professor, Royal School of Mines.

[4] Cited by F. W. Clarke, Data of Geochemistry, 1911, pp. 613–614.

Conclusions.

From the occurrence of visible gold as inclusions in both quartz and felspar, and from the presence of both gold and silver (the latter in quite appreciable quantity) in biotite, the primary character of the two metals may be reasonably inferred.

The closest examination of vein-quartz, and the assays of vein-pyrites, incrustations on joints, and pneumatolysed rock, afford no grounds for attributing the gold-silver content of the granite either to the diffusion of siliceous or other solutions, or to the production of pyritous veins, or to processes incidental to pneumatolysis.

On the other hand, the occurrences described and the numerous assays made of apparently barren granites support the conclusion that both metals are intimately associated with both the earlier and the later products of crystallization from the granitic magma direct, and that they are primary.

Numerous occurrences of primary gold in granite are on record.[1] A. Lacroix quotes C. F. Lincoln (1911) in respect of fifteen such occurrences, and describes the occurrence of the metal in pegmatite. G. P. Merrill observed gold embedded in the quartz and felspar of a Mexican (Sonora) granite. The Dartmoor occurrences are closely comparable to those described by L. Wagoner for three Californian and one Nevadan granite. Wagoner's assay-figures are appended to the table given on p. 19.

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[1] For references to literature, see Min. Mag., 1924, vol. 20, p. 210, and F. W. Clarke's Data of Geochemistry.