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The grainsize and associations of gold from the Henty Prospect

by R. S. Bottrill

Abstract

Examination of a small suite of gold-bearing sections from Renison Goldfields' Henty Prospect indicated gold to be abundant in patches in some samples. The gold is relatively fine grained and occurs in various associations (quartz-carbonate and pyrite-base metal sulphide mainly) but may be largely free-milling after reasonably fine grinding. Relatively little gold is likely to be locked in pyrite. Gold appears to have been introduced in varying forms and remobilised in part.

INTRODUCTION

A small suite of samples from the Henty Prospect (380150 mE, 5363950 mN), held by Renison Goldfields Exploration P/L, was examined for an investigation into the paragenesis and size distribution of the enclosed gold. The samples were selected by Goldfields. Eight samples (with both polished and thin sections) were examined, and four were found to contain surprisingly abundant, microscopically visible, gold grains. Sample details are shown in Table 1. It must be stressed that the results of this work are limited by the small number of samples studied, which may not be entirely representative of the orebody.

The mineralisation has been described in a number of unpublished company reports for Renison Goldfields Pty Ltd, most recently by Arnold (1988) and Newnham and Roberts (1988). The mineralisation is poorly exposed on the surface, and has been principally described from drill logs. Most of the mineralisation is considered by Arnold to occur in quartz-phyric pyroclastic-rich Lower Tyndall Group rocks, overprinted with a mylonitic schistosity and post-mylonitic brecciation, and is within the Henty Fault Zone. He considers the mineralisation to be stratabound, predating the schistosity, and to be represented principally by disseminated pyrite and base metal sulphide in fragmental volcanic rocks (pebbly epiclastics?) with minor massive sulphide and sulphidic veining. Newnham and Roberts (1988) noted high gold values to be very erratic and, largely based on drill logs and assays, four major types of mineralisation were postulated:

1. Massive pyrite with high Au, As, Ag and Bi (low base metal sulphide)

2. Quartz-carbonate veins with high Au, Ag and Bi (low base metal sulphide)

3. Base metal sulphide zone with Pb, Zn and Au

4. A copper zone with gold

Metallurgical studies have shown poor recovery of gold from massive pyrite but good recovery from quartz-carbonate-sulphide ores (Newnham and Roberts, 1988). Fine gold in pyrite may cause this problem but previous petrological studies have correlated poorly with assay results, and thus have been somewhat inconclusive (Newnham and Roberts, 1988).

GENERAL PETROLOGICAL DESCRIPTIONS

PS 50728, HFZ 5, 426'6", (GFE No. 11137)

This is a veined and brecciated pyritic quartz-carbonate rock, with small amounts of sericite and chalcopyrite, and traces of galena and gold. Veins have a similar mineralogy to the clasts, but are coarser. The gold occurs in pyrite, quartz and base metal sulphides in a late-stage pyritic vein, with minor sericite, quartz and carbonate. The approximate mineralogy is:

Quartz	60%	cherty to vein-style
Carbonate	25%	?siderite
Pyrite	9%	fine to coarse grained
Sericite	5%	
Chalcopyrite	1%	medium grained
Galena	tr.	
Gold	tr.	

PS 50729, HFZ 5, 424'9" (GFE No. 11138)

This is a veined and banded pyritic quartz-carbonate rock similar to the above, but less brecciated and more sulphidic. Most gold occurs with quartz and/or carbonate and/or mica, but some is associated with pyrite and other sulphides. The approximate mineralogy is:

Quartz	50%	chalcedonic to cherty and vein-style
Carbonate	25%	? siderite
Pyrite	10%	fine to medium grained
Sericite	5%	
Chalcopyrite	5%	fine grained
Galena	5%	fine grained
Sphalerite	tr.	relatively coarse grained
Bi minerals	tr.	
Gold	tr.	

PS 52902, HP4, 235.6 m (GFE No. 16780)

This is a highly sheared pyritic quartz-sericite rock, with recrystallised quartz phenocrysts and quartz aggregates (± pyrite, sericite and apatite) probably representing boudinaged veins, in a sericitic matrix with fine pyrite. Most base metal sulphides and gold are intergranular to pyrite. The approximate mineralogy is:

Quartz	50%	cherty to vein-style
Pyrite	20%	fine to coarse grained, euhedral and brecciated
Sericite	20%	
Chalcopyrite	10%	coarse grained
Galena	tr.	

Sphalerite	tr.	
Bi minerals	tr.	intergrown with galena
Tetrahedrite ?	tr.	
Pyrrhotite	tr.	in pyrite cores
Gold	tr.	with gold and base metal sulphides

PS 52903, HP4, 259.35 m (GFE No. 16780)

This is a sheared, sericitic, pyritic quartz-carbonate rock, with boudinaged quartz-carbonate-sulphide veins and recrystallised quartz microphenocrysts in a sericitic matrix with disseminated pyrite. Most gold occurs with quartz and/or carbonate and/or white mica, but some is associated with pyrite, chalcopyrite and other sulphides. The approximate mineralogy is:

Quartz	50%	cherty to vein-style
Carbonate	25%	? ankerite, fine grained + chalcopyrite, gold
Pyrite	5%	colloform to euhedral
Sericite	10%	
Chalcopyrite	10%	fine grained
Galena	tr.	
Sphalerite	tr.	
Tetrahedrite	tr.	
Gold	tr.	

Detailed examination of sections H50730 (HFZ5, 422' 2", GFE No. 11139), H50731 (HFZ5, 420' 6", GFE No. 11140), H50732 (HFZ5, 421' 6", GFE No. 11141), and H50733 (HFZ5 , 423' 9", GFE No. 11142) revealed no visible gold.

In summary the rocks all appear to be sheared and veined volcaniclastics which have been carbonitised, sericitised, pyritised and silicified. Base metals and gold occur mainly in boudinaged quartz veins. Where gold occurs in the sections it is typically present as patches of scattered fine grains, often very abundant (see fig. 1–8). The gold occurs in two main associations: quartz and carbonate; and base metal sulphides with pyrite. Gold in pyrite and mica are relatively minor associations. Plates 1 to 8 illustrate these associations, which are discussed in more detail below. One gold association probably represents the second type of mineralisation described by Newnham and Roberts (1988), i.e. quartz-carbonate veins, but it is uncertain to which category the other association belongs, and what degree of overlap exists between the ore types.

DISTRIBUTION OF GOLD-ASSOCIATIONS AND ASSOCIATES

The eight samples described above were used for a detailed study of the gold distribution. The grain size and associates were recorded for every gold grain observed in systematic traverses of the entire surface of each polished section, at 20× magnification. These data were used to determine the distribution by volume of gold in various associations, and are summarised in Table 1 and Figures 1 and 2.

Table 1 indicates the existence of two main gold parageneses, prominent in different sections: a nonsulphide±base metal sulphide paragenesis in sections H50729 and H52903; and a pyrite-base metal sulphide paragenesis in sections H50728 and H52902 (and of minor importance in H50729). There is also a pyrite-only (i.e. enclosed entirely in pyrite) paragenesis present in all samples, which is always volumetrically insignificant, but is numerically significant in section H50728.

A more detailed look at the associates enables us to subdivide the parageneses further. A gold-sericite association is important in section H50729 but most of the gold in the gold-nonsulphide association occurs with quartz and/or carbonate. The most important base metal sulphide associate of gold is chalcopyrite, except in H50728, where galena is slightly dominant. This section is also notable for the significant amount of gold in "primary" inclusions (i.e. totally enclosed in gold, 'py1' on the tables and figures), most of which are associated with galena and chalcopyrite. In the other sections almost all of the pyrite-associated gold is "secondary", i.e. in cracks and grain boundaries of pyrite ('py2' on the tables and figures).

The summary (average) column in Table 1 indicates the most important paragenesis in these sections is gold-quartz, followed by gold-pyrite-chalcopyrite.

SIZE DISTRIBUTION OF GOLD

The measured grain sizes of gold were used to determine the size distribution of gold in these sections. The results exhibit complex distributions, indicating several populations, and the results were broken down by association in an attempt to elucidate the interpretations. The results are shown in Table 2 and Figures 4 to 8. The average volume mean diameter is the size of a particle with the average volume for the population, giving a more realistic indication of the size distribution. Half of the total gold should be coarser, and half finer, than this size. The average volume mean diameter of gold in these samples is 14 mm.

The size distribution for gold in the nonsulphide-only association (the largest group, fig. 4) is complex, probably trimodal. The mode is <1.6 μm (primary gold grains?) but there are peaks in the ranges ≥4,<6.3 μm and ≥10,<16 μm. The latter probably represents the gold with mica, but the significance of the intermediate peak is uncertain (perhaps representing recrystallisation at grain boundaries?).

Figure 5 shows the base metal sulphide–nonsulphide association to have a relatively normal distribution, with a mode ≥6.3,<10 μm. The slight shoulder in the range ≥25,<40 μm is probably not statistically significant. The base metal sulphide only and base metal sulphide-nonsulphide-pyrite associations are not statistically significant but the former are all <4 μm and the latter all ≥4 μm. This reflects the fact that coarser grains are more likely to be in contact with more phases.

Figure 6 shows the distribution for the pyrite-only association to be skewed towards lower values (most <6.3 μm) with two peaks of population: ≥1.6,<2.5 μm and ≥4,<6.3 μm. This, as in the nonsulphide-only association, may indicate slight recrystallisation or annealing. The base metal sulphide-pyrite association shows a relatively normal distribution, but is skewed to coarser grain sizes, and has a mode of ≥10,<16 μm. The pyrite-nonsulphide association has a complex distribution with a mode of ≥4,<6.3 μm and a large shoulder towards the coarser grain sizes. There is also a peak in ≥1.6,<2.5 μm, perhaps reflecting primary gold with nonsulphide inclusions in pyrite.

Figures 7 and 8 indicate the average volume mean diameters for gold with different associations and associates. Figure 7 shows the average volume mean diameter for each association. Gold in the base metal sulphide-pyrite and base metal sulphide-pyrite-nonsulphide associations is distinctly larger than average, while gold with pyrite-only or base metal sulphide only is much finer. Other associations are close to average. Figure 8 indicates that gold with mica, chalcopyrite or galena, or as "secondary" grains with pyrite, is all relatively coarse grained, while gold with carbonate, sphalerite or bismuth minerals, or as "primary" inclusions in pyrite, is all relatively fine grained

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SUMMARY AND METALLURGICAL IMPLICATIONS

The distribution of gold in these samples is very erratic and complex. The gold all appears to have been introduced in quartz-carbonate-sulphide veins, but it may be considered to occur in four distinct associations:

1. "Primary" gold in pyrite (relatively fine-grained inclusions, partly with galena, chalcopyrite and/or nonsulphides, see fig. 2 to 7).

2. "Secondary" gold in fractures in (or along grain boundaries to) pyrite, with chalcopyrite, galena and/or nonsulphides (relatively coarse grained and the secondmost important paragenesis, see fig. 1, 2 and 3).

3. Gold in quartz and/or carbonate, often with chalcopyrite (medium grained and the most important paragenesis, see fig. 1, 2 and 3).

4. Gold with mica (relatively coarse grained)

The gold appears to have been introduced in several different forms. The gold in pyrite is a very common mode of occurrence in most gold deposits, and may indicate adsorption of gold onto growing pyrite crystals (Joralemon, 1971; Springer, 1983), with later exsolution and/or coarsening during recrystallisation, followed by migration into lower energy sites in fractures and at grain boundaries. The gold in quartz-carbonate±chalcopyrite aggregates appears to result from recrystallisation of some sort of colloid, perhaps derived from oxidation of an organic complex (Radtke and Scheiner, 1970). The gold with mica has probably recrystallised from clays or hydromicas, which are known to absorb gold under some conditions (Ahlrichs, 1981; Elevatorski, 1984; Bakken *et al.*, 1987). These postulated origins for gold all imply rather low temperature introduction of gold, followed by later low-grade metamorphism causing some remobilisation and recrystallisation.

The gold is rather fine grained overall, about half (by volume) being less than 14 mm, but grains are very abundant in patches. No grains larger than 60 mm were observed.

The metallurgical response of this ore can be postulated from the mineralogy, although it will depend upon the local characteristics of crushing behaviour of the various minerals and ores. The ore will require crushing relatively finely to liberate most of the gold—probably 40 µm or less. Most of the gold is present on grain boundaries; only pyrite-bound gold is likely to prove very difficult to recover at this degree of comminution, and this appears to be a very minor proportion of the gold. It must be stressed again that these interpretations assume the samples studied are reasonably representative. About half of the gold would probably be recovered with galena and sphalerite by sulphide flotation, with only a little gold lost in pyrite concentrates. This gold may be best recovered with the other metals during smelting. Most of the gold in the quartz-carbonate association is likely to be lost to tailings in flotation circuits, due to its fine size, and bulk cyanide leaching will be necessary as it is likely to represent about half of the gold resource. The gold in mica may be coarse enough for recovery by flotation or direct gravity concentration.

Further detailed studies of the mineralogy and distribution of the various types of gold are strongly recommended before extensive pilot plant metallurgy be carried out.

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[8 December 1988]

Sample No.	H50728	H50729	H52902	H52903	Total
No. of Grains	96	299	27	281	703
Tot.Vol. (µm3)	379527	1076308	208866	284646	1949347
Associations					**Average**
Pyrite only	2.70	0.58	0.05	0.75	0.96
NS only	12.53	70.07	0.00	78.19	52.55
BMS only	0.00	0.00	0.00	0.01	0.00
Pyrite+NS	4.38	5.59	0.00	1.10	4.10
BMS+NS	0.89	10.67	1.96	9.24	7.63
Pyrite+BMS	79.36	11.61	97.99	0.00	32.36
Pyrite+BMS+NS	0.13	1.47	0.00	10.72	2.40
Associates					**Average**
Py1	20.84	0.67	0.67	0.66	4.60
Py2	65.74	18.58	97.37	11.90	35.23
Galena	64.41	2.69	3.05	3.05	14.80
Chalcopyrite	52.92	20.98	17.13	17.13	26.22
Sphalerite & OS	0.40	0.10	0.40	0.40	0.23
Quartz	17.94	83.22	1.96	70.09	59.89
Carbonate	0.00	38.44	0.00	25.33	24.93
Mica	0.00	31.85	0.00	0.58	17.67

Table 1. Distribution by volume percent of gold in the various samples, with different associations and associates. Note that percentages for associates do not add up to 100% because of overlap. Abbreviations: Tot. Vol.: Total volume of gold observed (cubic µm); BMS: Base metal sulphide; NS: nonsulphide; Py1: "primary" gold in pyrite (see text); Py2: "secondary" gold in pyrite; OS: other sulphides and related minerals.

Sample No.	H50728	H50729	H52902	H52903	Average
AVM	15.81 (96)	15.33 (299)	19.78 (27)	10.04 (281)	14.05 (703)
Associations					
Pyrite only	8.76 (45)	10.11 (6)	3.21 (3)	7.07 (6)	8.45 (60)
NS only	16.29 (11)	14.45 (250)	- (0)	9.91 (229)	12.37 (490)
BMS only	- (0)	2.00 (1)	- (0)	2.41 (2)	2.27 (3)
Pyrite+NS	14.93 (5)	15.24 (17)	- (0)	6.21 (13)	11.84 (35)
BMS+NS	15.00 (1)	17.62 (21)	15.99 (1)	9.79 (28)	13.24 (51)
Pyrite+BMS	20.43 (33)	39.68 (2)	20.72 (23)	- (0)	21.21 (58)
Pyrite+BMS+NS	8.00 (1)	19.93 (2)	- (0)	21.66 (3)	18.81 (6)
Associates					
Py1	13.12 (35)	9.66 (8)	5.86 (7)	7.78 (4)	11.27 (54)
Py2	17.20 (49)	21.92 (19)	22.04 (19)	12.35 (18)	18.10 (105)
Galena	20.12 (30)	16.89 (6)	20.39 (20)	12.95 (4)	19.41 (60)
Chalcopyrite	27.18 (10)	23.23 (18)	27.10 (9)	12.03 (28)	19.55 (65)
Sphalerite & OS	9.11 (2)	8.00 (2)	14.90 (3)	8.25 (2)	10.60 (9)
Quartz	15.58 (18)	16.12 (214)	15.99 (1)	9.96 (202)	13.23 (435)
Carbonate	- (0)	13.75 (159)	- (0)	8.42 (121)	11.45 (280)
Mica	- (0)	20.13 (42)	- (0)	7.46 (4)	19.03 (46)

Table 2. Grain size (average volume mean, see text) of gold in the various samples, with different associations and associates. Brackets indicate numbers of grains. AVM: Average volume mean diameter; for other abbreviations see Table 1.

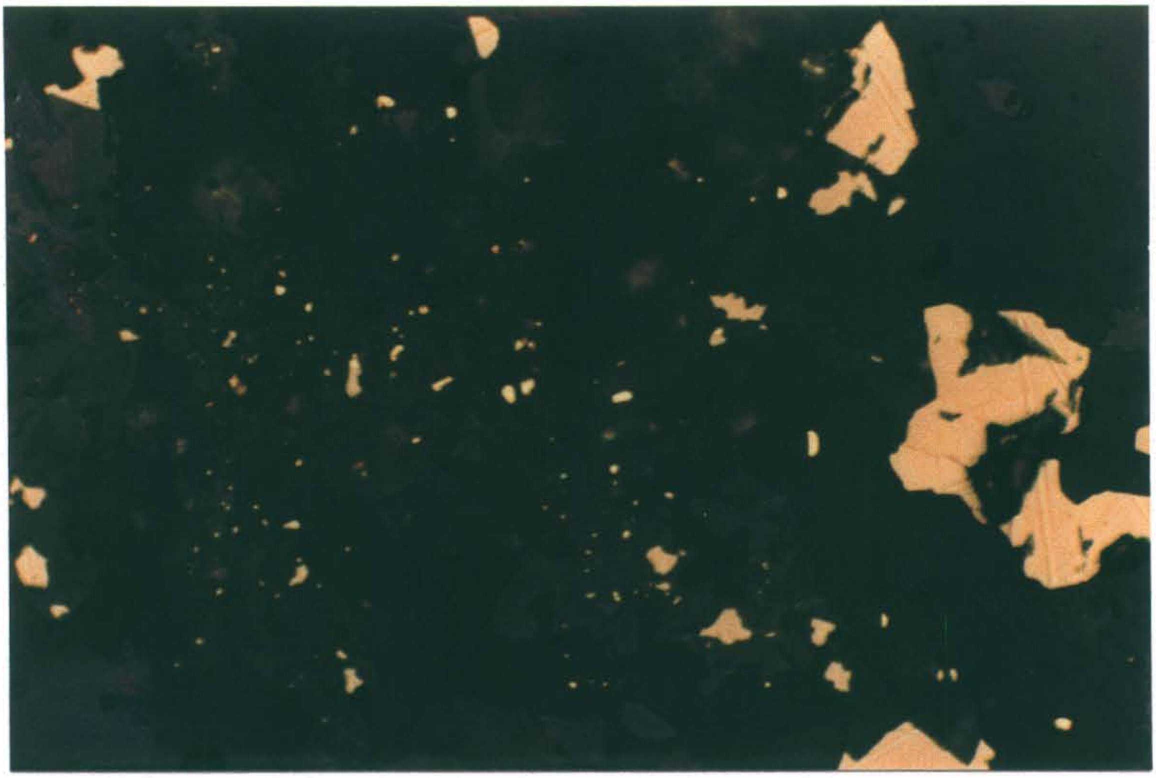

Plate 1 Fine gold and chalcopyrite in granular quartz-carbonate. PPRL (Plane polarised reflected light), FOV (Field of view) 560X375 μm. Sample H50729.

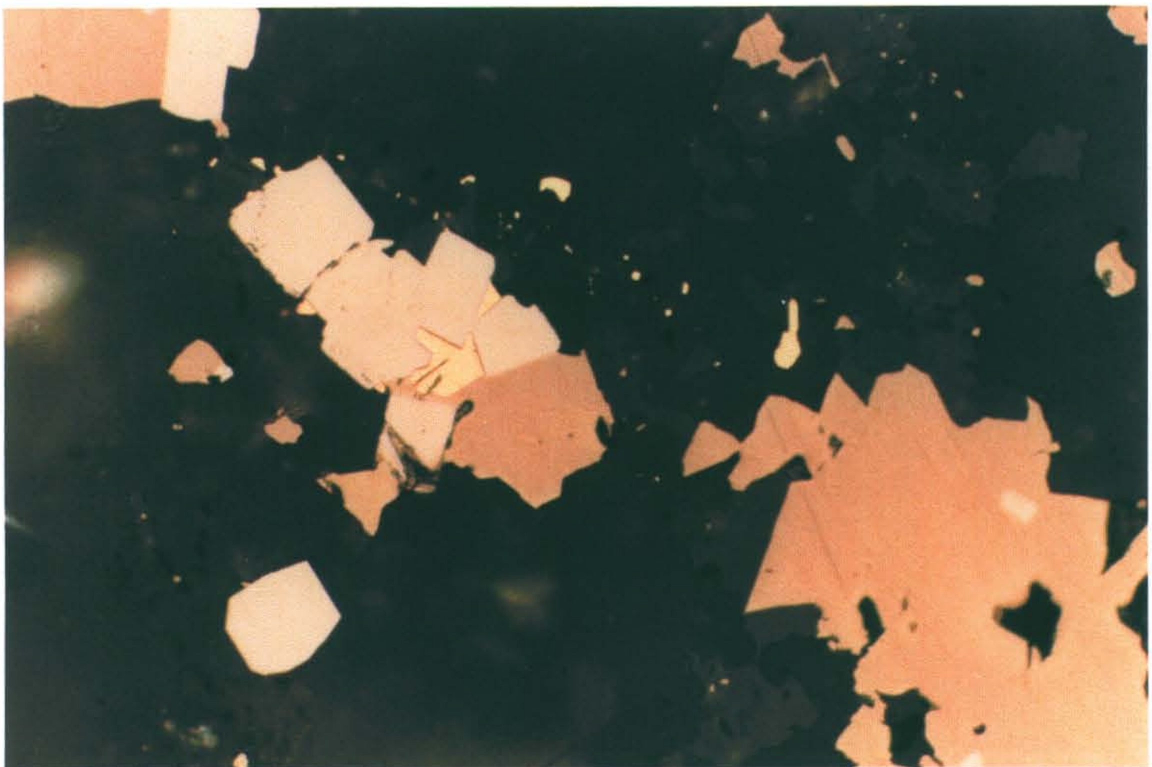

Plate 2. Fine gold and chalcopyrite in granular quartz-carbonate, with some coarse gold with chalcopyrite and pyrite. PPRL, FOV : 560X375 μm. Sample H50729.

5 cm

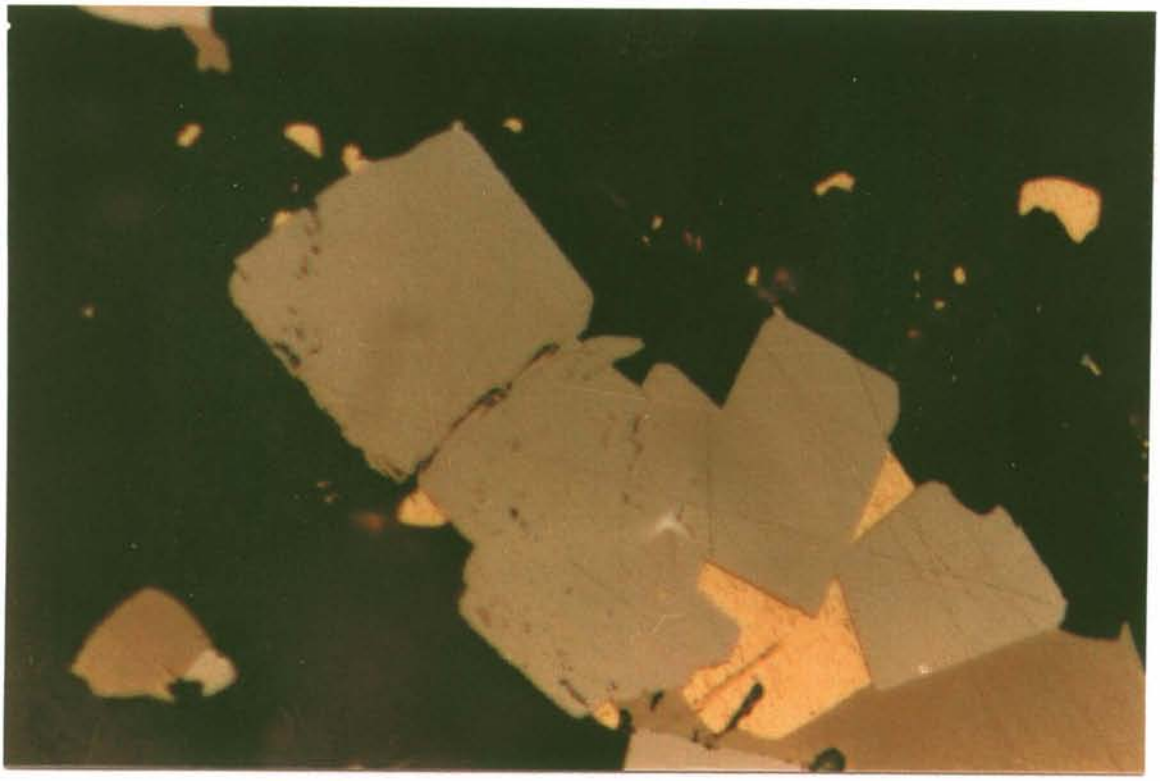

Plate 3. Coarse gold (about 25µm) with pyrite-chalcopyrite and fine gold and chalcopyrite in granular quartz-carbonate. PPRL), FOV: 220X150 µm. Sample H50729.

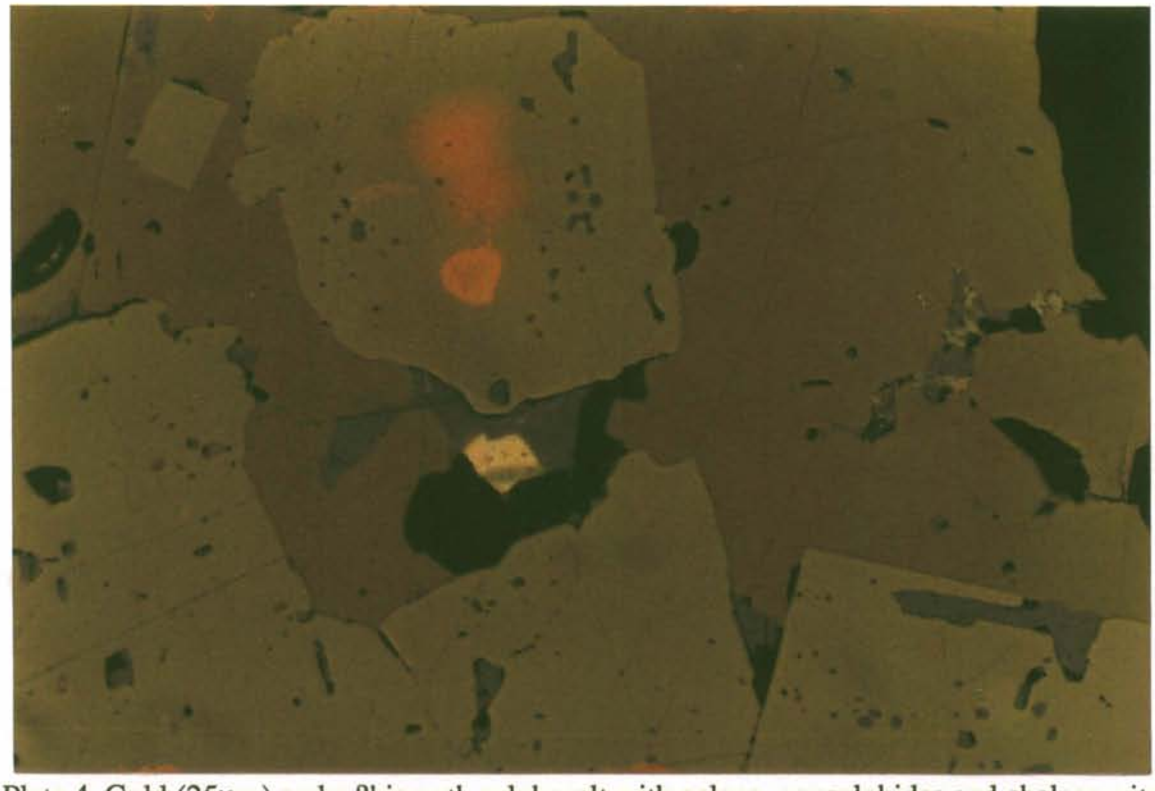

Plate 4. Gold (25µm) and a ?bismuth sulphosalt with galena, nonsulphides and chalcopyrite, intergranular to pyrite. PPRL, oil immersion, FOV: 350X230 µm. Sample H52902.

5 cm

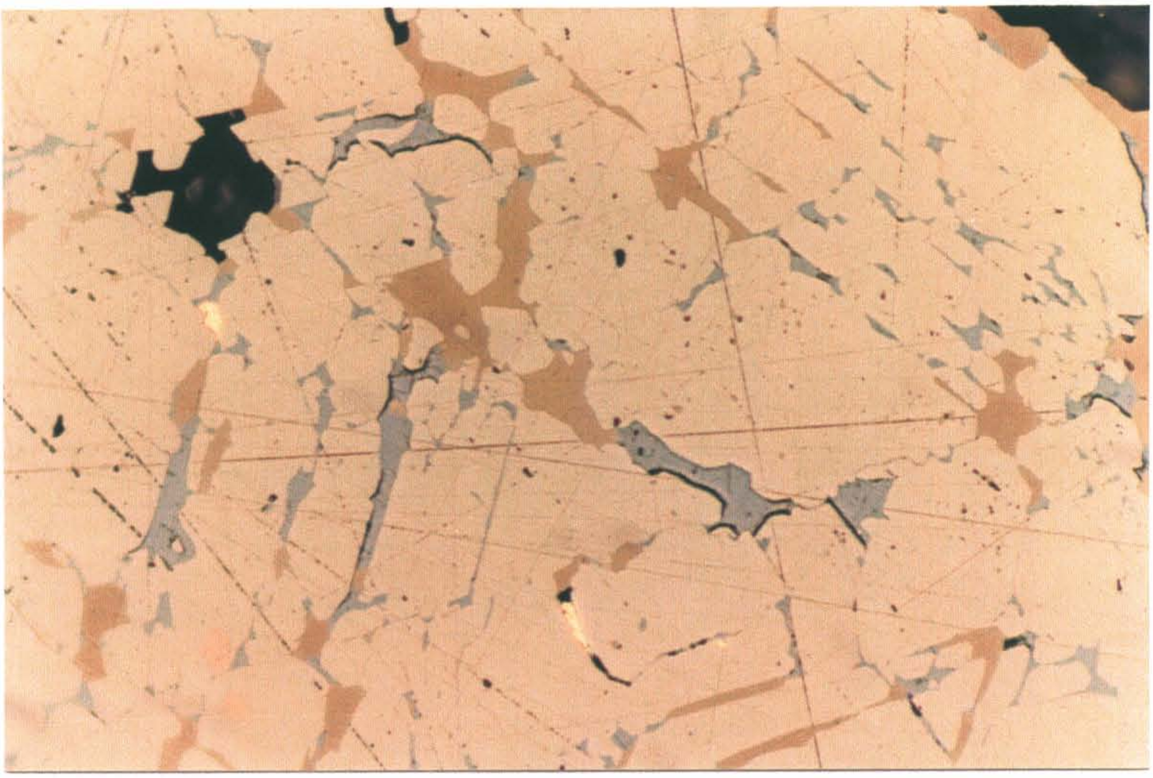

Plate 5. Gold (to about 15μm) with galena, nonsulphides and chalcopyrite, intergranular to skeletal (recrystallised framboidal?) pyrite. PPRL, oil immersion, FOV: 350X230 μm. Sample H52902.

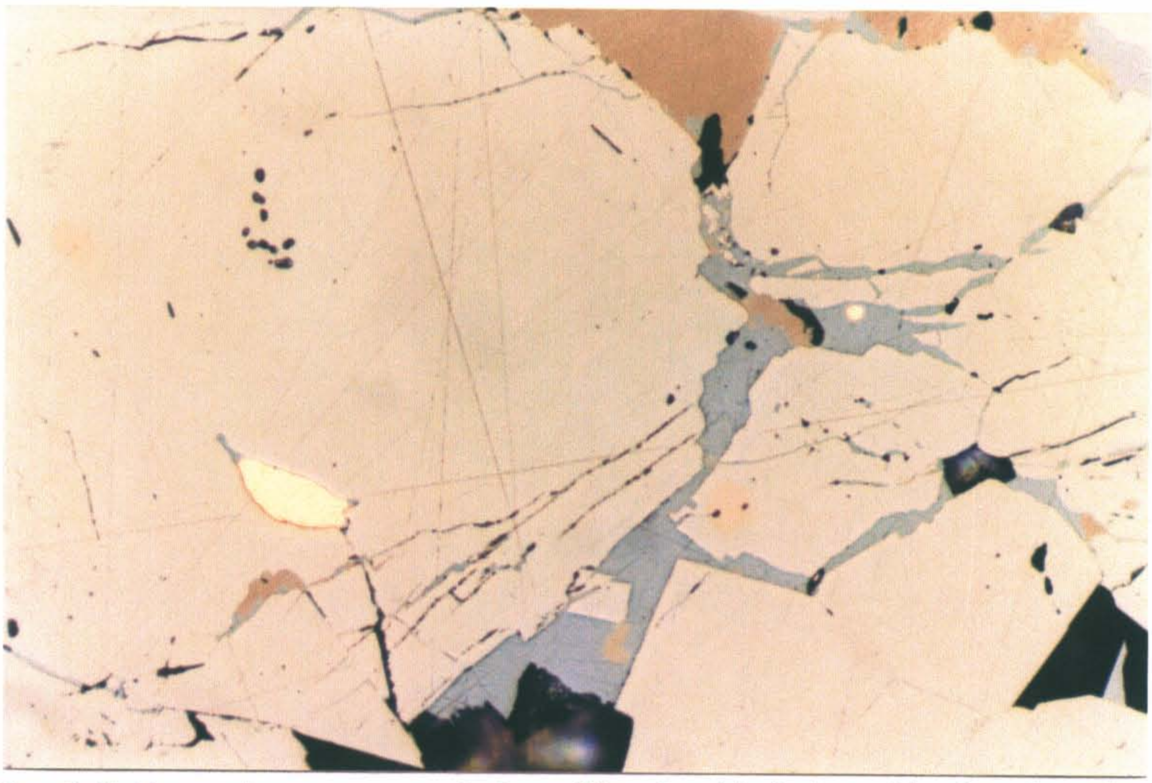

Plate 6. Gold occurring as an unusually large (50μm long) inclusion, with galena, in pyrite and as an 8μm gold grain in a galena-filled fracture in pyrite. PPRL, oil immersion, FOV: 350X230 μm. Sample H50728.

5 cm

Plate 7. Gold occurring as "primary" inclusions (to about 5µm) ± galena, in pyrite, and in a healed fracture. PPRL, oil immersion, FOV: 90X60 µm. Sample H50728.

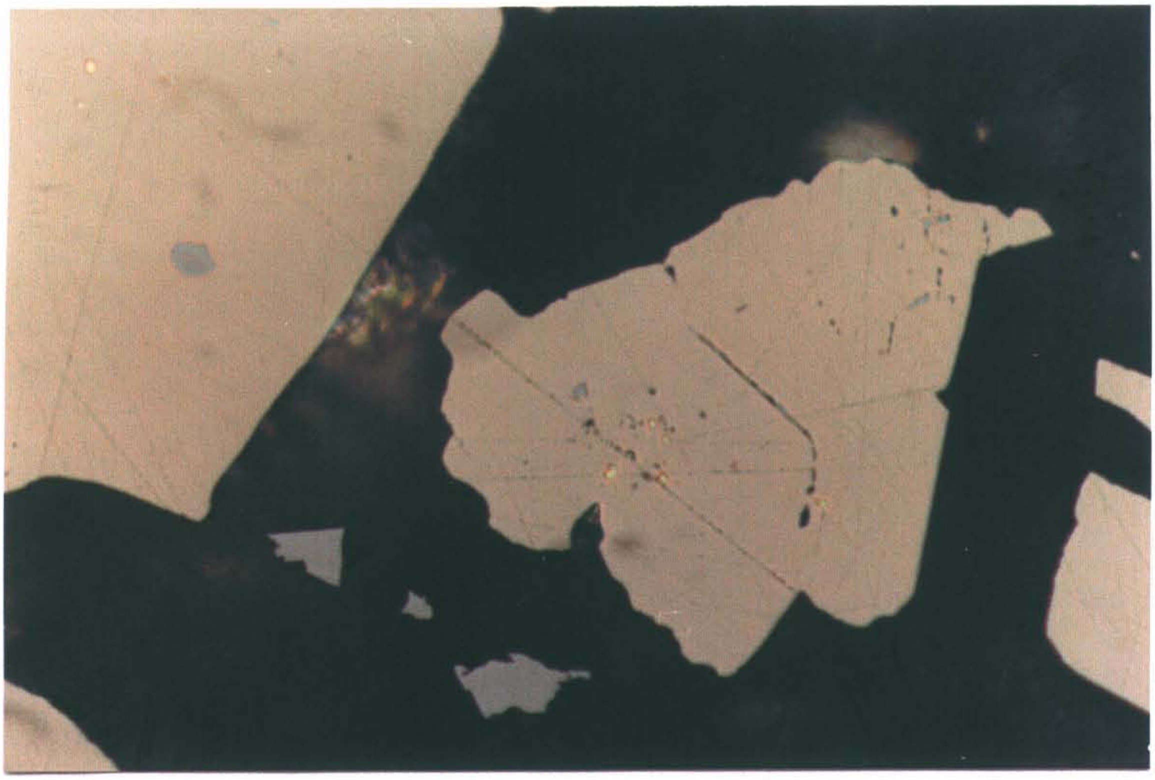

Plate 8. Gold occurring as fine primary inclusions (to about 2µm) in the core of a brecciated pyrite crystal. PPRL, FOV: 220X150 µm. Sample H50728.

5 cm

Fig. 1. Distribution of gold between different associations. See Table 1 for abbreviations.

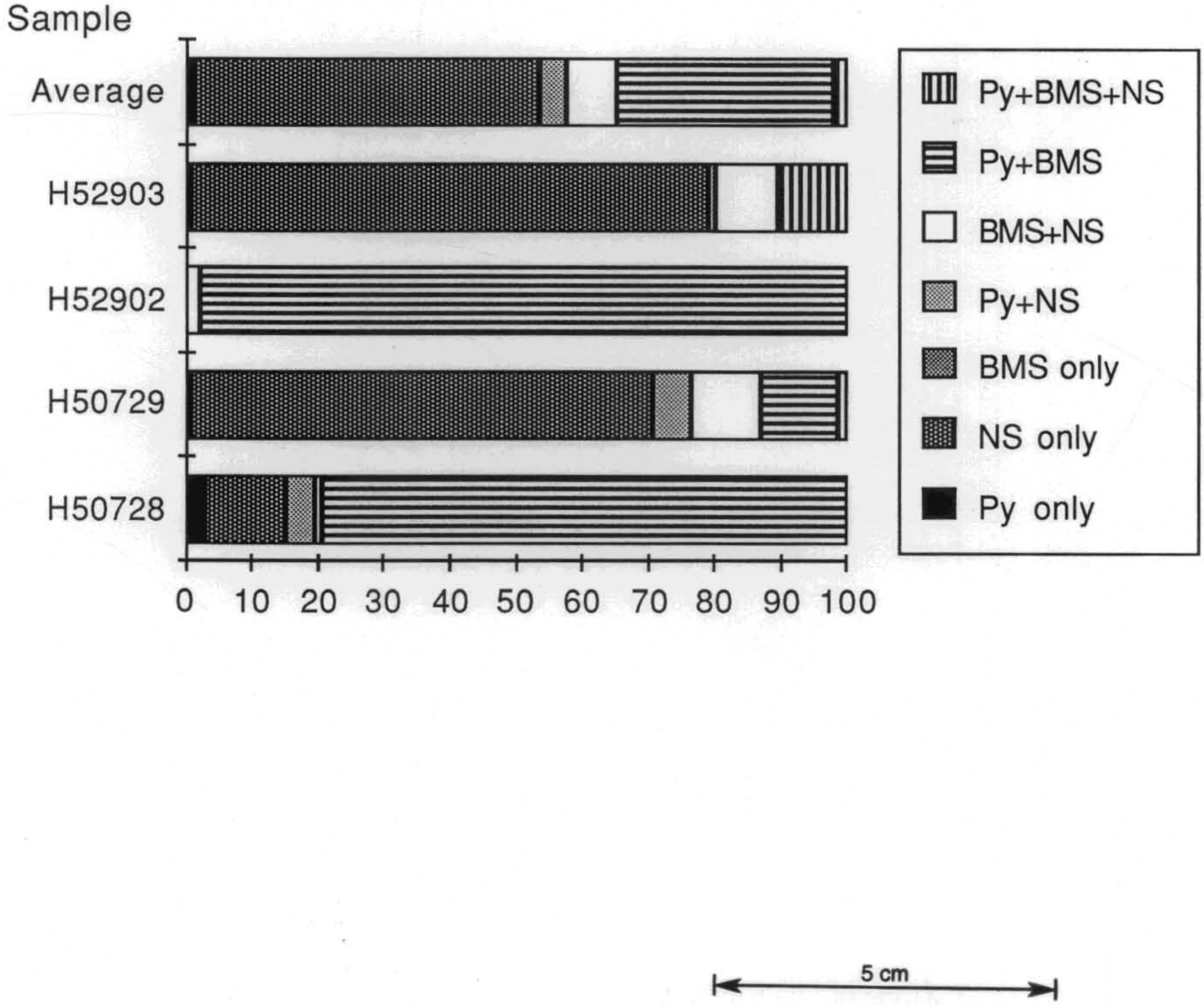

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Fig. 2. Distribution of gold with different associates

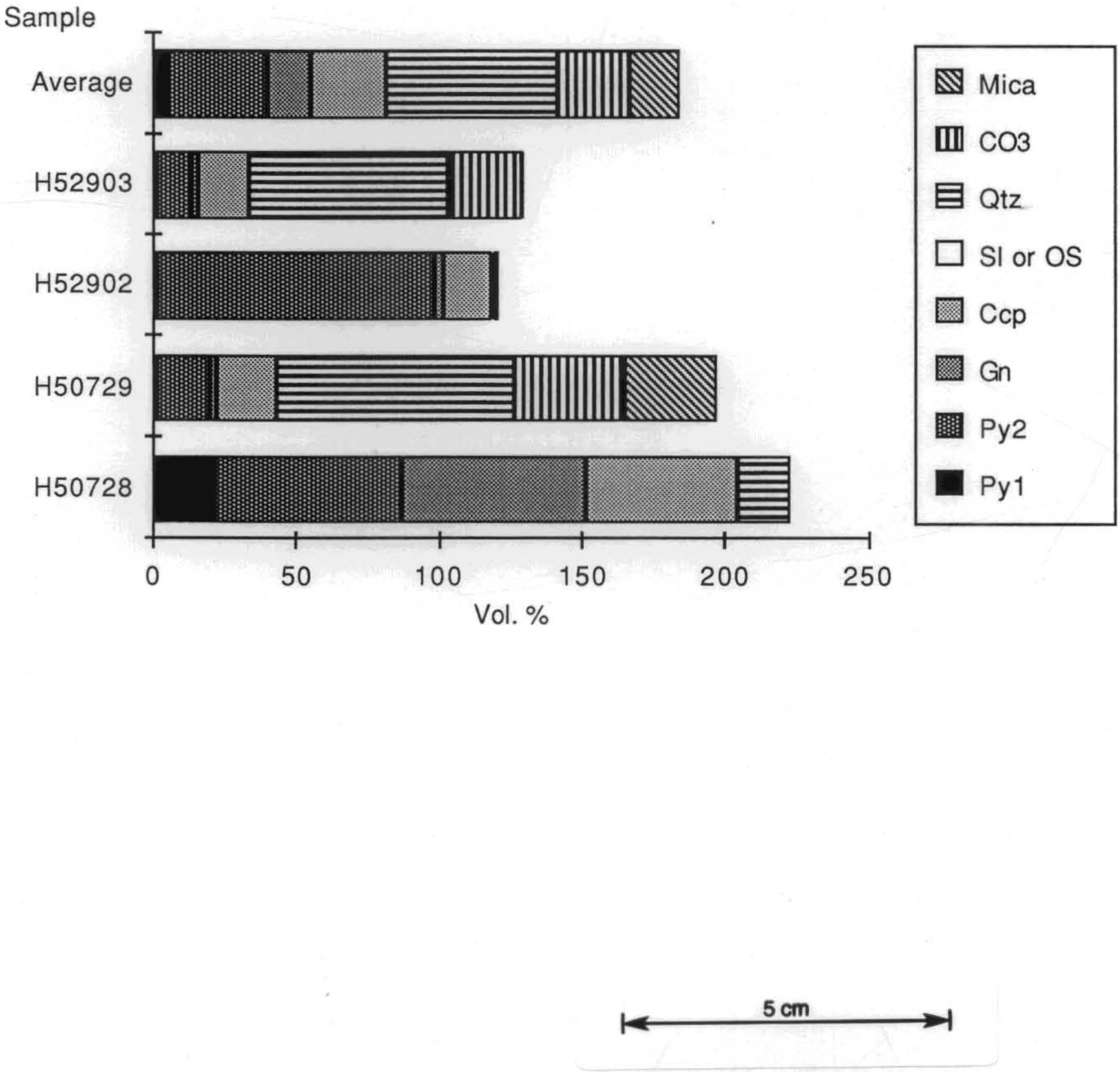


Fig. 3. Size distribution of gold within each sample.

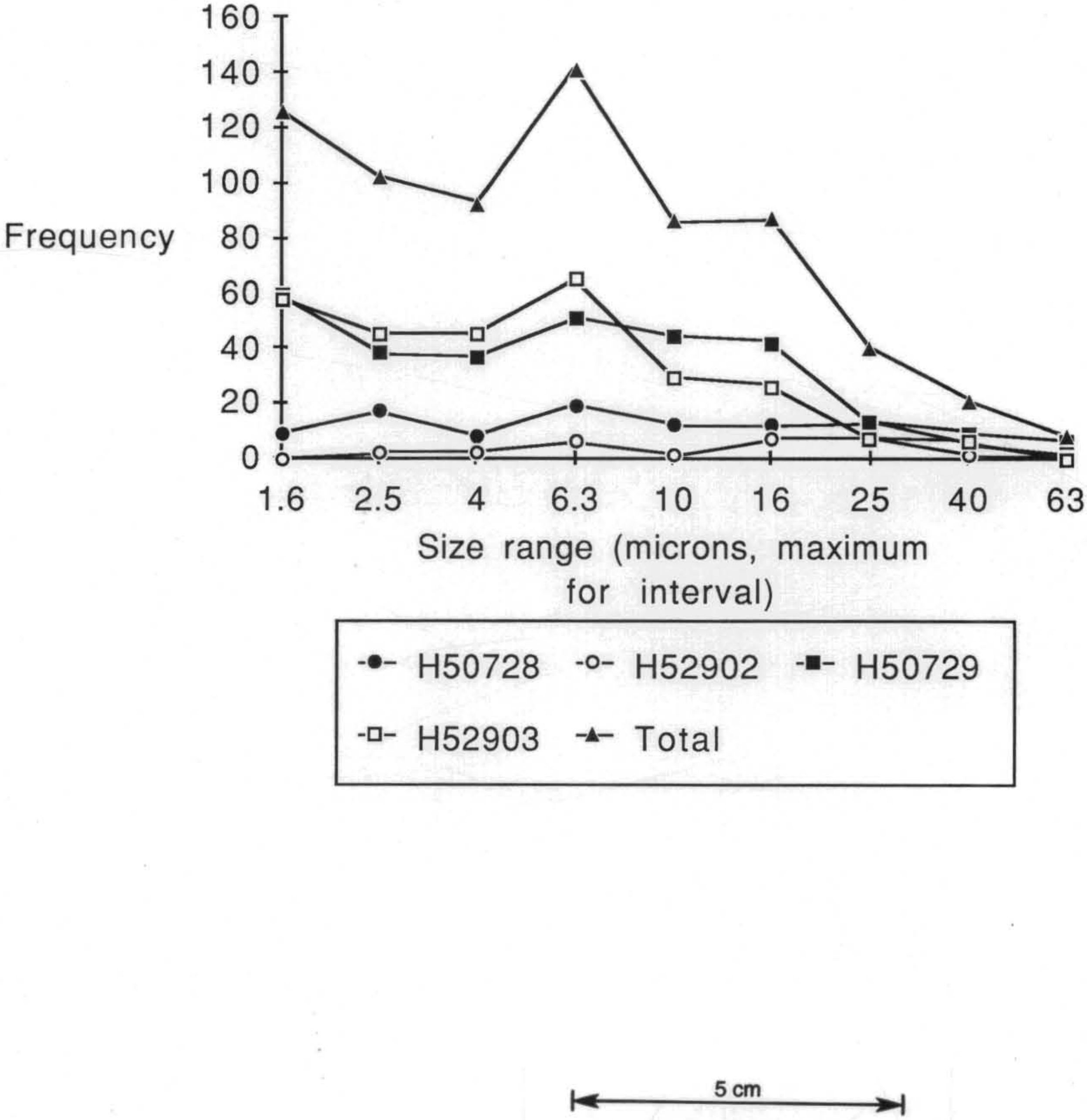
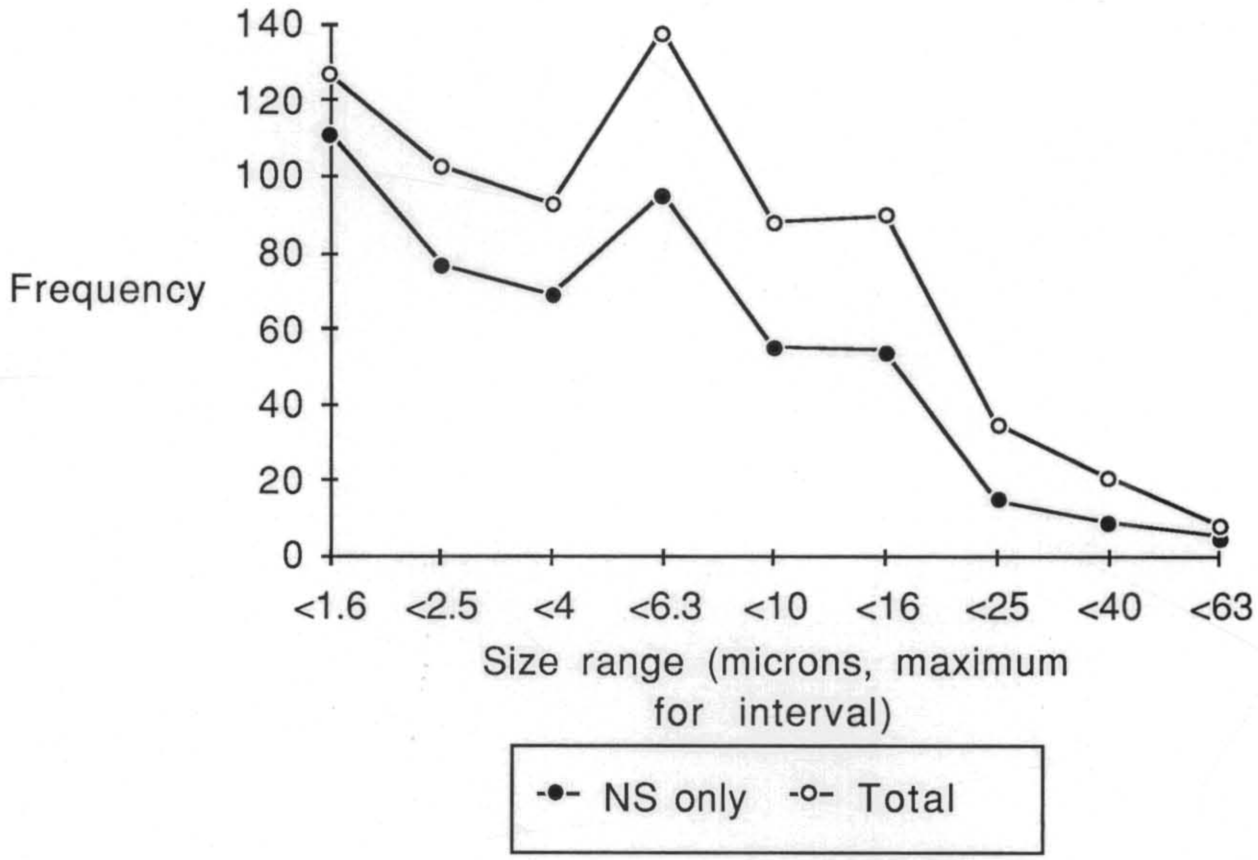


Fig. 4. Size distribution of gold in the nonsulphide-only association, and in total.



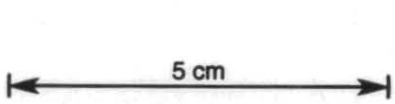
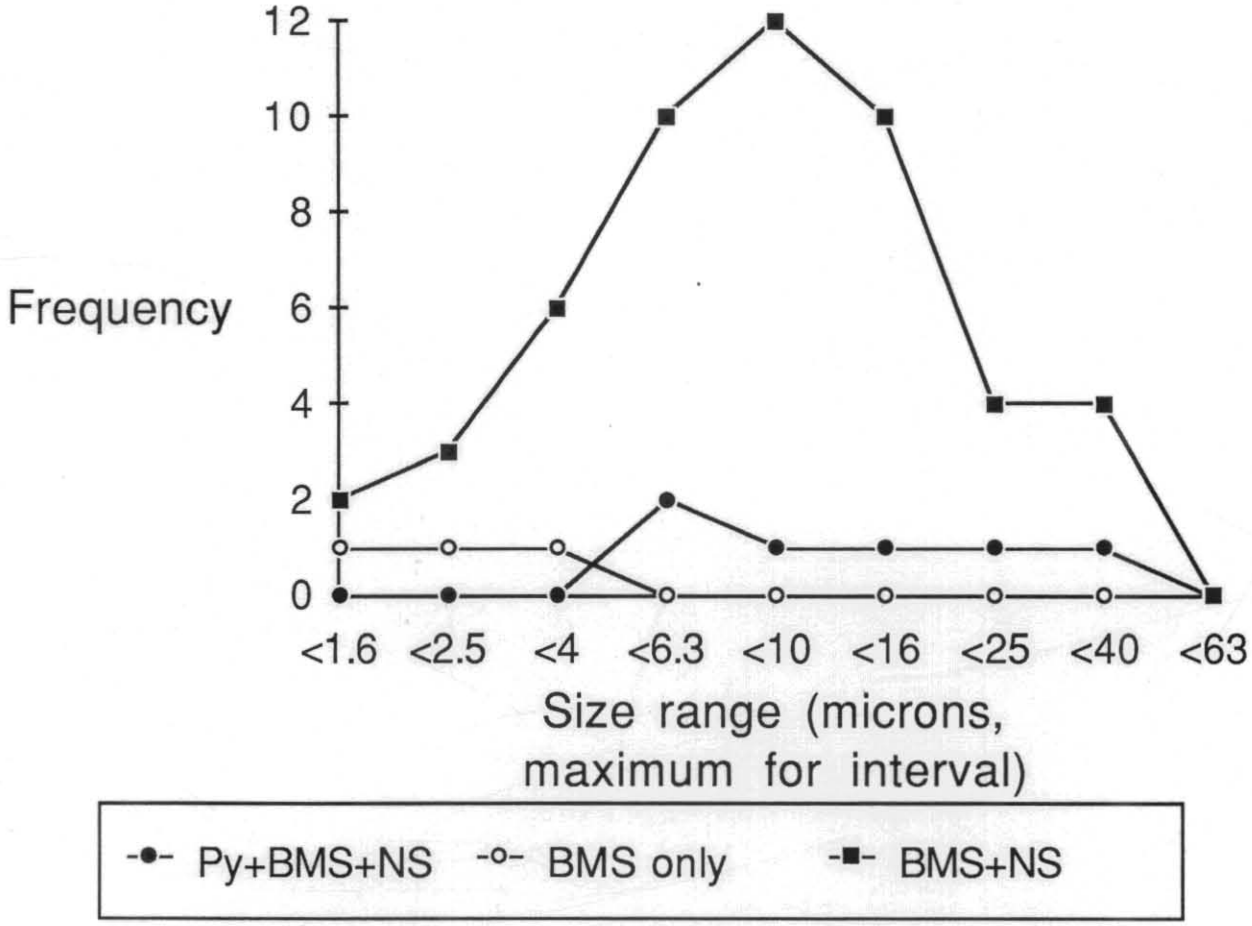


Fig. 5. Size distribution of gold in various associations



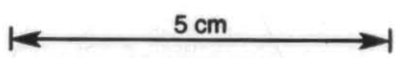


Fig. 6. Size distribution of gold in various associations

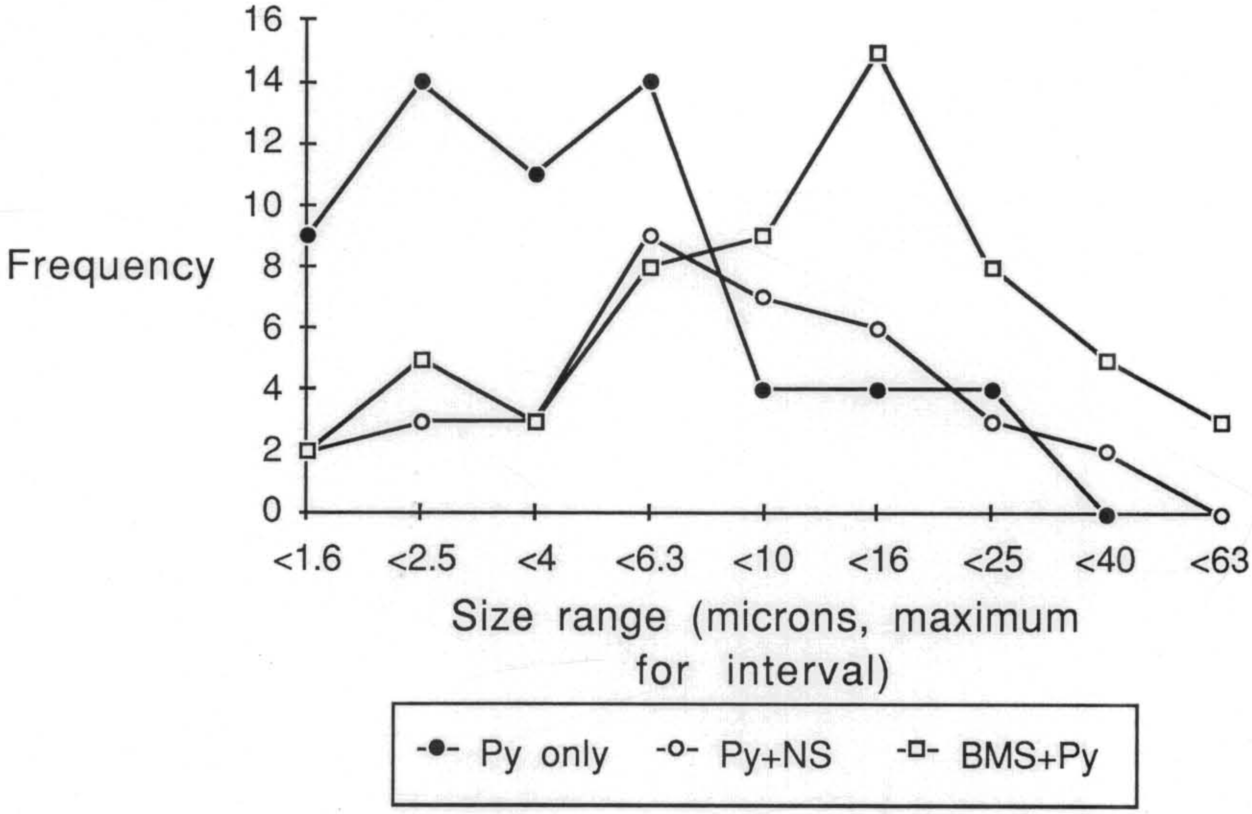
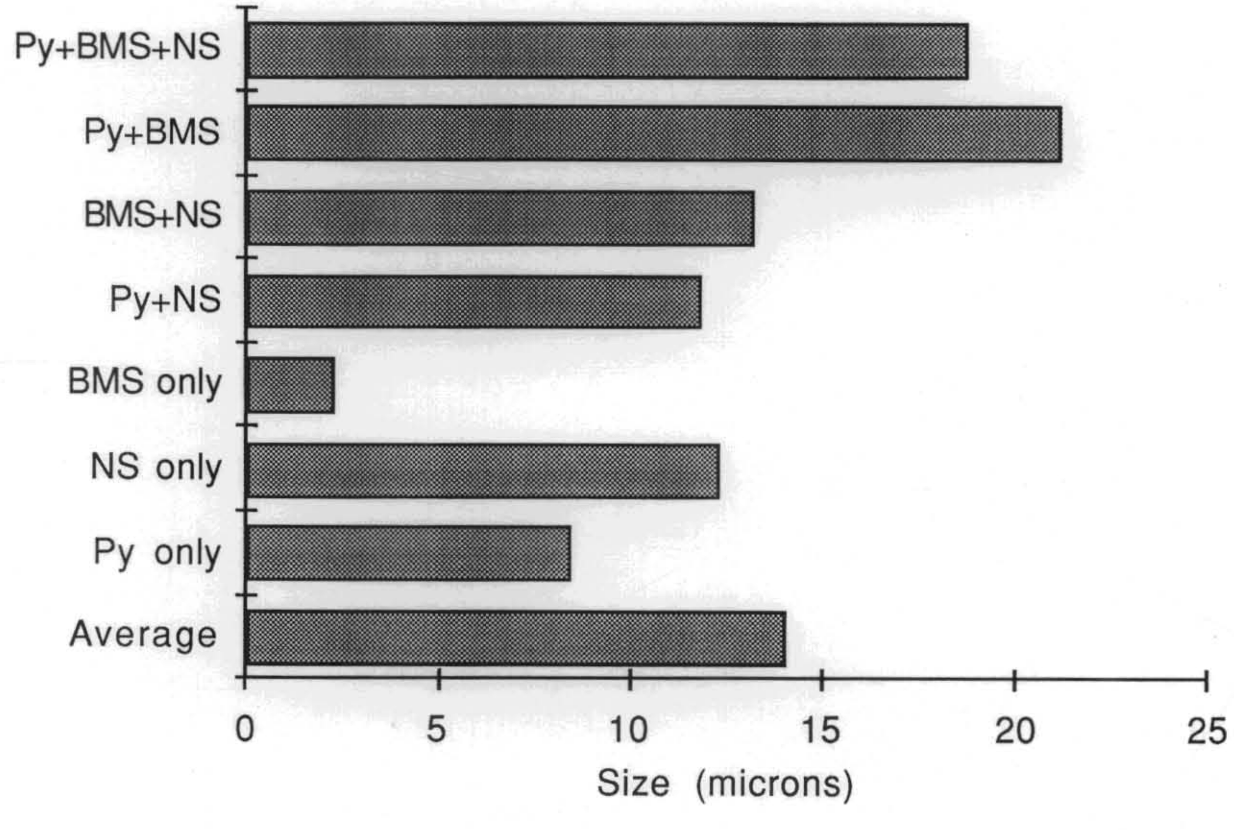


Fig. 7. Average volume mean diameter of gold in various associations



5 cm

Fig. 8. Average volume mean diameter of gold with various associates