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K-Ar Radiometric ages of the gold-quartz veins at Brusson, Val d'Ayas, NW Italy: Evidence of mid-Oligocene hydrothermal activity in the Northwestern Alps

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Abstract

The Brusson gold-quartz veins belong to the Monte Rosa Gold District, an extensive province of hydrothermal mineralization in the Western Alps. K-Ar radiometric analyses of hydrothermal muscovites yield formation ages of 33.3. ± 1.4 and 30.7 ± 1.4 Ma, in agreement with field evidence that ore deposition post-dated the latest phase of Alpine metamorphism in the Western Alps. Biotite from a lamprophyre that is cross-cut by the gold veins gives a K-Ar radiometric age of 32.7 ± 1.4 Ma. These data show that hydrothermal activity took place during uplift and cooling of the Western Alps, some 4 to 8 Ma after the local metamorphic peak. The timing of gold mineralization coincides with the intrusion of syeno-monzonitic stocks along the internal margin of the northwestern Alps. This coincidence in ages, while not excluding other genetic hypotheses, supports a long held theory that formation of the gold deposits may be related to late-Alpine magmatism.

Keywords: Gold-quartz veins, metamorphism, K-Ar dating, Western Alps.

Introduction

Gold-bearing quartz veins occur sporadically over a 130 km length of the western Alpine arc, from Simplon (near the Swiss border) in the north to Gran Paradiso (Italy), in the south. Similarities in their mineral parageneses and epigenetic structural relationships unify these occurrences as a single metallogenic province, named by HUTTENLOCHER (1934) as the "Monte Rosa Gold District". Early workers showed that the mineralization post-dates the climax of the Meso-Alpine metamorphic event in the northwestern Alps, but apart from this "late-Alpine" age, the timing of ore formation was unknown. With interest in the formation of these deposits renewed (e.g. RICHARD, 1981; DIAMOND, 1986; CURTI, in prep.), more precise age determinations are required to constrain ge-

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netic models. This paper presents new age data on one of the southern vein occurrences in the Monte Rosa District, the gold deposits at Brusson in Val d'Ayas, NW Italy.

Field constraints on the age of gold mineralization

The Brusson locality comprises a swarm of well over a hundred quartz-carbonate-sulphide veins (Fig. 1) that were earlier mined for their gold content (COLOMBA, 1907; REINHOLD, 1916; HUTTENLOCHER, 1934; STELLA, 1943). The veins are hosted by folded augen-gneisses and metasediments of the Arcesa-Brusson Unit (an equivalent of the Penninic Monte Rosa Nappe), and by metabasites and serpentinites of the overlying Piemonte Ophiolite Nappe (NOVARESE, 1903; DAL PIAZ et al., 1972). Each of the wallrock lithologies shows mineralogic evidence of a greenschist-facies metamorphic overprint that is attributed to the Meso-Alpine phase of the Alpine Orogeny (DAL PIAZ and ERNST, 1978).

As the Brusson gold veins and their accompanying wallrock alteration haloes discordantly cross-cut all the metamorphic fold structures, planar fabrics and mineral assemblages, REINHOLD (1916) deduced a late-Alpine age for the gold mineralization. HUTTENLOCHER (1934) and STELLA (1943) recognized the same age constraint throughout the Monte Rosa Gold District. Radiometric dating by HUNZIKER and BEARTH (1969) and HUNZIKER (1974) has since revealed that Meso-Alpine metamorphism in the Brusson area reached its thermal peak between 36 und 40 Ma. This time interval therefore sets an upper limit on the age of the gold deposits.

At the Crête di Naie mine (Fig. 1), REINHOLD (1916) noted that offshoots of a gold-bearing quartz vein penetrate an adjacent "minette" lamprophyre dike. The dike itself is otherwise undeformed and it cuts vertically through folded serpentinites and metabasites of the Zermatt-Saas Ophiolites. Although absolute ages were, of course, unavailable to Reinhold, there is no doubt regarding his interpretation that emplacement of the lamprophyre preceded gold mineralization (compare RICHARD, 1981). Consistent with this relative timing, the dike rock shows sharply-bounded metasomatic reaction zones along its contacts with the hydrothermal quartz vein. As in other hostrock lithologies in the Brusson area, such reaction zones show the complete replacement of wallrock biotite by hydrothermal white-mica, dolomite and pyrite (DIAMOND, 1986).

RICHARD (1981) pointed out that the Crête di Naie lamprophyre is chemically comparable to the discordant dikes that occur elsewhere in Val d'Ayas. One of these high-K lamprophyres was dated by DAL PIAZ et al. (1973), yielding a K–Ar whole-rock age of 31.6 ± 1.3 Ma. By implication, this age places an even lower limit on the maximum age of the gold veins.

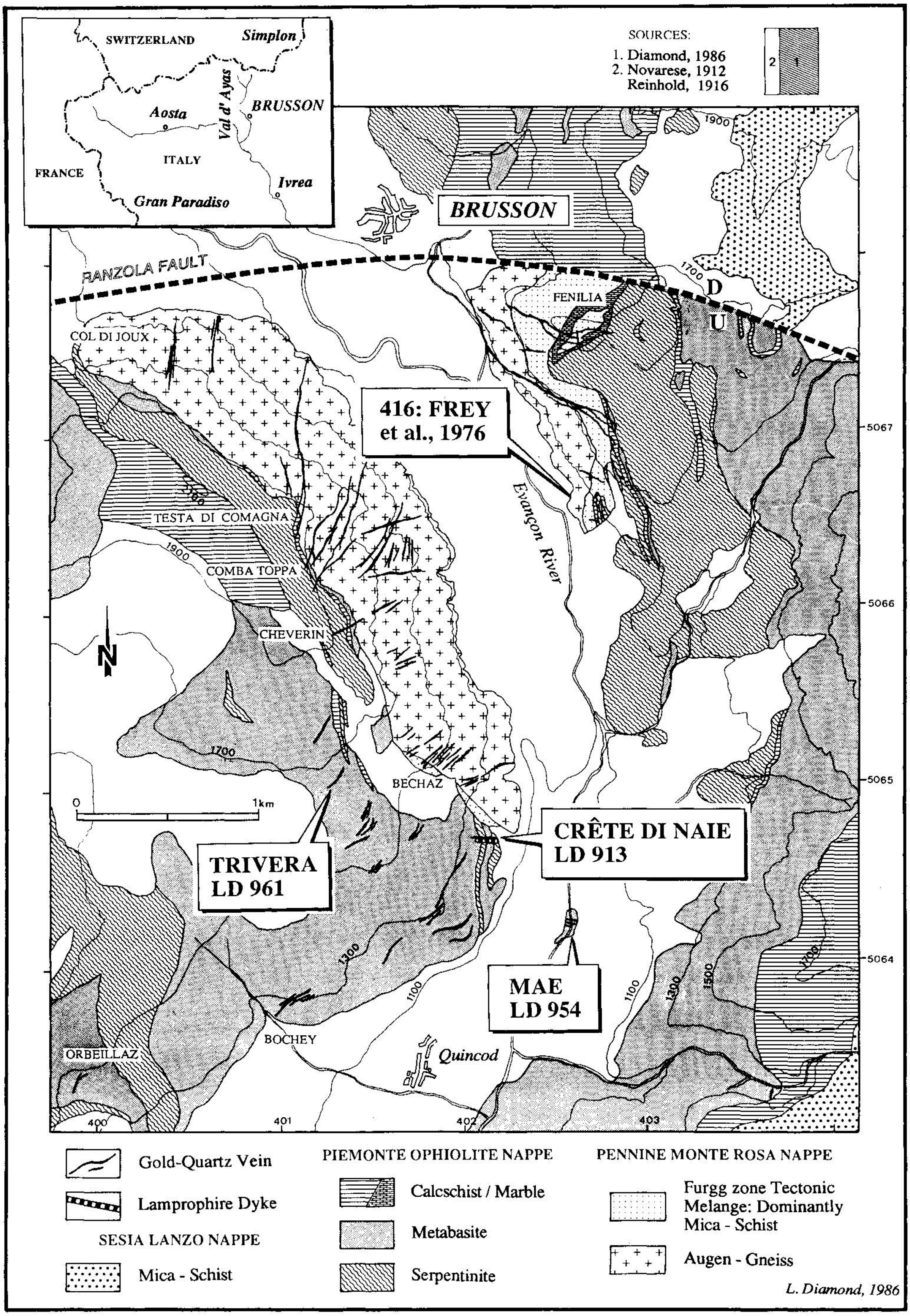

Fig. 1 Geological map of the Brusson area showing the location of major gold veins. The micas dated in this study were taken from the hydrothermal veins at Mae and Trivera and from the Crête di Naie lamprophyre dike. Sample 416 is the granitic augen-gneiss investigated by FREY et al., 1976.

A complementary minimum age bracket is not so obvious from field relations. Evidence of cross-cutting (DIAMOND, 1986) suggests that movement along the Ranzola fault (Fig. 1) post-dated vein formation, however, the precise age of displacement is not known. BALDELLI et al. (1985) provide no justification for the Oligocene age they assign to the fault, hence there seems to be no argument against the Ranzola Fault being considerably younger. A plausible assumption, for example, is that the fault is related to major Late Miocene displacements along the Cavanese and Insubric Lines (LAUBSCHER, 1983).

Radiometric age determination of gold mineralization

The age constraints drawn from field observations leave a wide time interval, spanning perhaps 20 million years, during which gold mineralization could have taken place. To better resolve the chronology of the hydrothermal event, three mica samples were collected for K–Ar radiometric age determinations.

Coarse-grained biotite was separated for analysis from the lamprophyre dike at Crête di Naie. The sample was taken from within a mine adit and it was checked by thin-section microscopy to ensure that no traces of gold-related hydrothermal alteration were present. As the mica that occurs in the cross-cutting quartz vein proved too fine-grained and impure for dating purposes, two coarse-grained separates of white phengitic muscovite were extracted from the nearby hydrothermal gold veins at Trivera and Mae (Fig. 1). The paragenetic, textural and chemical characteristics of these micas are described by DIAMOND (1986).

ANALYTICAL METHOD

High-purity mineral separates for analysis were concentrated by standard techniques. In order to minimize the presence of any atmospheric argon, each sample series was heated at 200 °C for six hours. Argon was extracted by total fusion at 1700 °C followed by purification in an all-metal extraction line. Radiogenic argon concentrations were determined by the peak height method, using known quantities of purified atmospheric argon for calibration. For each of the three samples investigated, two independent mineral aliquots were analysed for both their argon concentrations and isotopic compositions (Table 1). The argon error estimates take into account corrections for uncertainties in mass spectrometer precision, isotope blanks and sample weight. Multiple runs of the hornblende standard MMhb-1 gave reproducible results (radiogenic ^{40}Ar = 3.60×10^{-5} cm^{3}gm^{-1}), approximately 1% below the interlaboratory standard value. No correction for this deviation has been incorporated in the data presented here.

Potassium concentrations were determined by isotope dilution, and a precision of 2% (1 σ) was arbitrarily assigned to each result so as to allow for possible sample inhomogeneity (Table 1). Ion exchange chemistry was used to separate potassium prior to mass spectrometer analysis.

SAMPLE NUMBER	MINERAL	GRAIN SIZE (µm)	Wt. (mg)	Ar36	Ar40	Ar40Rad	Ar40 (%Rad)	K (%)	CALC. AGE (Ma)
				(1.0E-8 cm3g-1)					
LD961	Muscovite	50 - 300	16.6	2.989	1919.	1036±24	54	8.82	30.0±1.4
LD961	Muscovite	50 - 300	12.7	0.350	1136.	1033±12	91	8.82	29.9±1.2
LD961	Muscovite	300 - 500	28.6	0.313	1182.	1090±12	92	8.83	31.5±1.4
LD961	Muscovite	300 - 500	32.7	0.140	1131.	1090±12	96	8.83	31.5±1.4
LD954	Muscovite	300 - 500	8.1	0.398	1077.	959±12	89	7.32	33.4±1.4
LD954	Muscovite	300 - 500	7.2	0.356	1057.	952±12	90	7.32	33.2±1.4
LD913	Biotite	300 - 500	21.6	0.366	1106.	998±12	90	7.78	32.7±1.4
LD913	Biotite	300 - 500	30.1	0.277	1082.	1000±12	92	7.78	32.8±1.4

Tab. 1 K–Ar isotope analyses and calculated ages of hydrothermal phengitic muscovite and dike biotite (errors given are 2σ estimates).
Sample localities:
LD961: Trivera hydrothermal gold vein (GR: 0135/6495).
LD954: Mae hydrothermal gold vein (GR: 0262/6429).
LD913: Crête di Naie lamprophyre dike (GR: 0216/6471).
Grid References apply to Sheet 29 CHALLANT of the Map of Italy (Series M8 91, scale 1:25000: Inst. Geog. Militare d'Italia, 4th edition, 1970).

Absolute ages (Table 1) were calculated from the measured isotopic compositions by use of the decay constants and isotope ratios recommended by the IUGS subcommission on Geochronology (STEIGER and JÄGER, 1977). Estimates of precision given in the Table represent the 2σ confidence level, incorporating uncertainties in both argon and potassium concentrations.

INTERPRETATION OF RESULTS

Replicate K–Ar analyses of biotite from the lamprophyre gave an apparent age of 32.7 ± 1.4 Ma (sample LD913: Table 1, Fig. 2). Within analytical uncertainty, this age is identical to that of the other dated dike in Val d'Ayas (i.e. 31.6 ± 1.3 Ma; DAL PIAZ et al., 1973). Interestingly, replicate analyses of the hydrothermal vein muscovites yielded ages that overlap the biotite age, i.e. 30.7 ± 1.4 Ma for Trivera (LD961) and 33.3 + 1.4 Ma for the Mae locality (LD954).

Mineralogic, fluid inclusion and stable-isotope evidence presented by DIAMOND (1986) has established that the hydrothermal micas must have precipitated at temperatures between 230 and 300 °C. Now because (i) the blocking temperature of the K–Ar isotopic system within phengitic white micas is approximately 350 °C (PURDY and JÄGER, 1976) and (ii) the hydrothermal vein minerals have suffered no metamorphic or significant deformational perturbations following their initial precipitation, the calculated radiometric ages of the phengitic muscovites are interpreted here as formation ages of the gold mineralization (Fig. 2).

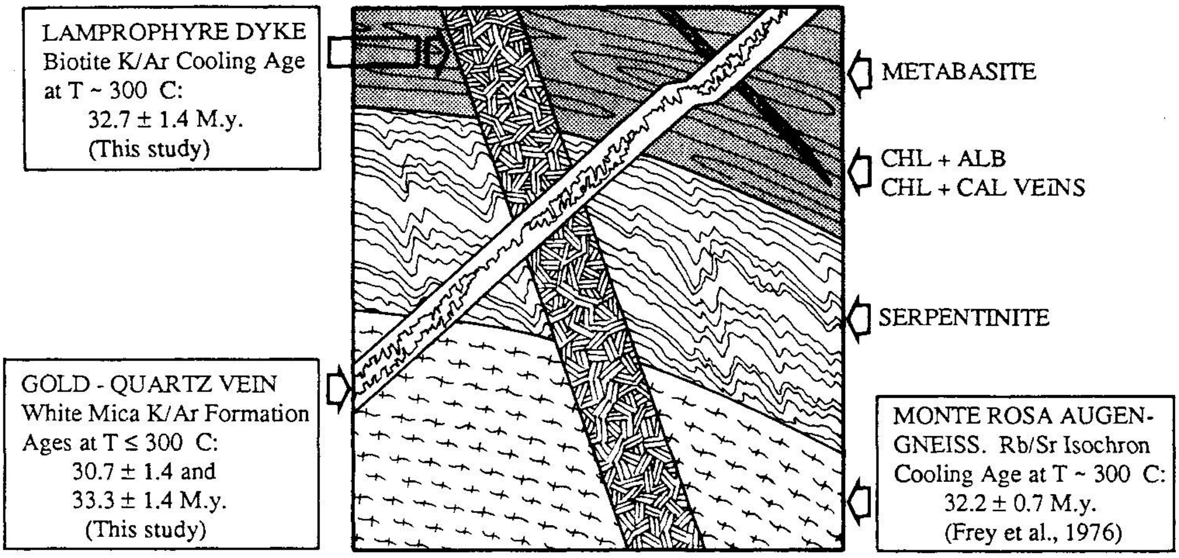

Fig. 2 Schematic summary of field relations and radiometric ages of the Brusson gold veins. The geometric configuration of the rock units has been deduced from mutually consistent observations at several outcrops.

While it cannot be rigorously excluded, it seems unlikely that the calculated ages are partial artifacts of excess initial argon. If anything, the difference in ages determined for two size fractions of sample LD961 suggests grain-size-dependent argon loss. In this instance, however, because the difference is comparable to the analytical uncertainties, the net effect on the age data is considered minor.

As the estimated blocking temperature of the K–Ar system in biotite is around 300 °C (PURDY and JÄGER, 1976) the 32.8 ± 1.0 Ma apparent age of the lamprophyre could represent either a cooling or a formation age (Fig. 2). The latter case poses no conflict with the field requirement that gold mineralization must post-date dike intrusion, since a time margin of up to 2.2 Ma is permitted by uncertainties implicit in the age determinations (Table 1).

In view of the fact that precipitation of the hydrothermal micas took place near the blocking temperature of the K–Ar and Rb–Sr isotopic systems in biotite, we would expect metamorphic biotite in the unaltered countryrocks to show cooling ages similar to the muscovite formation ages obtained in this study. This is indeed the case. Rb–Sr isotopic analysis of the Arcesa-Brusson augen-gneiss by FREY et al. (1976: their sample 416) revealed a 32.2 ± 0.7 Ma cooling age for biotite and other greenschist facies minerals (epidote, garnet, K-feldspar, plagioclase). Within the resolution of the radiometric method, this isochron age is indistinguishable from the ages determined here. It thus appears that the available radiometric data are consistent with each other, and with the constraints on relative timing set by field observations.

Timing of gold mineralization with respect to regional geological events

Our new radiometric data, coupled with those of HUNZIKER and BEARTH (1969) and HUNZIKER (1974), indicate that hydrothermal activity at Brusson took place some 4 to 8 million years after the peak of greenschist-facies metamorphism, a time when the northwestern Alps were undergoing rapid uplift, erosion and concomitant cooling (DAL PIAZ et al., 1972; LAUBSCHER, 1983).

In searching for clues as to the origin of the gold deposits we note a very suggestive coincidence. Whereas the influence of regional metamorphism was rapidly waning during the mid-Oligocene, hydrothermal activity at Brusson was virtually contemporaneous with the 28–32 Ma old intrusion of syeno-monzonitic stocks at Biella and Traversella (KRUMMENACHER and EVEREDEN, 1960; CARRARO and FERRARA, 1968; HUNZIKER and BEARTH, 1969; SCHEURING et al., 1974) and with the widespread emplacement of lamprophyric and andesitic dikes in the northwestern Alps (DAL PIAZ et al., 1979, DAL PIAZ and VENTURELLI, 1983; BIGIOGGERO et al., 1983). The Biella stock, lying 18 km to the east of Brusson, is clearly too distant to have played a direct role in ore generation, however, it is worth emphasizing that the extent of mid-Oligocene intrusive bodies beneath the northwestern Alps remains completely unknown. Thus, while the new radiometric ages do not rule out other genetic hypotheses, such as the generation of gold-bearing fluids strictly by metamorphic processes, this remarkable coincidence in ages lends new support to the proposal of HUTTENLOCHER (1934), that the gold veins of the Western Alps may be genetically related to the late-Alpine phase of intrusive activity.

Conclusions

This study has shown that:

1) The hydrothermal gold-quartz veins at Brusson formed during the mid-Oligocene, approximately 32 million years ago.
2) The formation ages obtained from radiometric data are consistent with the

field constraints that ore deposition at Brusson took place after the local peak of Meso-Alpine greenschist-facies metamorphism.

3) Within the error limits of the radiometric analyses, the cooling ages of potassic lamprophyre dikes in Val d'Ayas are identical to the formation ages of the gold veins. However, the field evidence that one of the dikes is cross-cut by a gold vein indicates that mineralization occurred shortly after dike intrusion.
4) Within the resolution of the radiometric method, the timing of hydrothermal mineralization at Brusson coincides with the intrusion of syeno-monzonitic stocks and potassic lamprophyres along the southeastern (internal) margin of the northwestern Alps. While other genetic hypotheses are not contradicted by this result, the coincidence in ages strengthens the possibility, proposed by Huttenlocher in 1934, that the gold deposits of the Monte Rosa District are genetically related to late-Alpine magmatism.

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