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Gold mineralisation in the Surselva region, Canton Grisons, Switzerland

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Abstract The Tavetsch Zwischenmassif and neighbouring Gotthard Massif in the Surselva region host 18 gold-bearing sulphide occurrences which have been investigated for the present study. In the Surselva region, the main rock constituting the Tavetsch Zwischenmassif (TZM) is a polymetamorphic sericite schist, which is accompanied by subordinate muscovite-sericite gneiss. The entire tectonic unit is affected by a strong vertical schistosity, which parallels its NE-SW elongation. The main ore minerals in these gold occurrences are pyrite, pyrrhotite and arsenopyrite. The mineralisation occurs in millimetric stringers and veinlets, everywhere concordant with the schistosity. Native gold is present as small particles measuring 2–50 μm, and generally associated with pyrite. Average grades are variable, but approximate 4–7 g/t Au, with several occurrences attaining 14 g/t Au. Silver contents of the gold are on the order of 20 wt%. A "bonanza" occurrence consists of a quartz vein coated by 1.4 kg of native gold. The origin of the gold is unknown. On the assumption that the sericite schists are derived from original felsic volcanic tuffs, the gold-bearing sulphides may have been introduced during pre-Alpine magmatism.

Keywords Surselva · Tavetsch Zwischenmassif · Sericite Schist · Gold · Silver

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Resumaziun Il massiv intermediar da Tujetsch ed il vischinant massiv dal Gottard en Surselva cumpiglian deschdotg giaschaments da sulfid cun aur ch'èn vegnids examinads per quest studi. En la regiun da la Surselva sa cumpona il grip principal dal massiv intermediar da Tujetsch da crap plattì sericit polimetamorfic accumpagnà da gnais sutordinà cun muscovit e sericit. L'entira unitad tectonica demussa ina ferma structura da crap plattì verticala che va parallelamain cun sia elongaziun nordost-sidvest. En quests giaschaments dad aur domineschan ils metals pirit, pirhotit ed arsenopirit. La mineralisaziun succeda en passagls ed avainas da grondezza millimetrica, dapertut en concordanza cun la structura dal crap plattì. Aur nativ cumpara, en general ensemen cun pirit, en pitschnas particlas d'ina grondezza da 2–50 μm. Il cuntegn d'aur variescha enturn 4–7 g/t, cun plirs giaschaments fin 14 g/t. Il cuntegn d'argient da l'aur munta a 20 wt%. In giaschament "bonanza" consista d'ina avaina da quarz cuverta dad 1.4 kg aur nativ. L'origin da l'aur n'è betg enconuschent. Mess il cas ch'il crap plattì sericit derivia oriundamain da tufs vulcanics felsics, èsi pussaivel ch'ils sulfids cun aur èn vegnids introducids durant il magmatissem prealpin.

Introduction

The Surselva region, part of the western Grisons Canton, comprises the entire valley through which the Rein Anteriur flows from its source near Sedrun to the village of Trun. Disentis/Mustér, at an elevation of 1,130 m, is the centre of the Surselva region (Fig. 1). It is connected eastwards by road and railway to Chur, the capital of Grisons Canton, and westwards, also by road and rail,

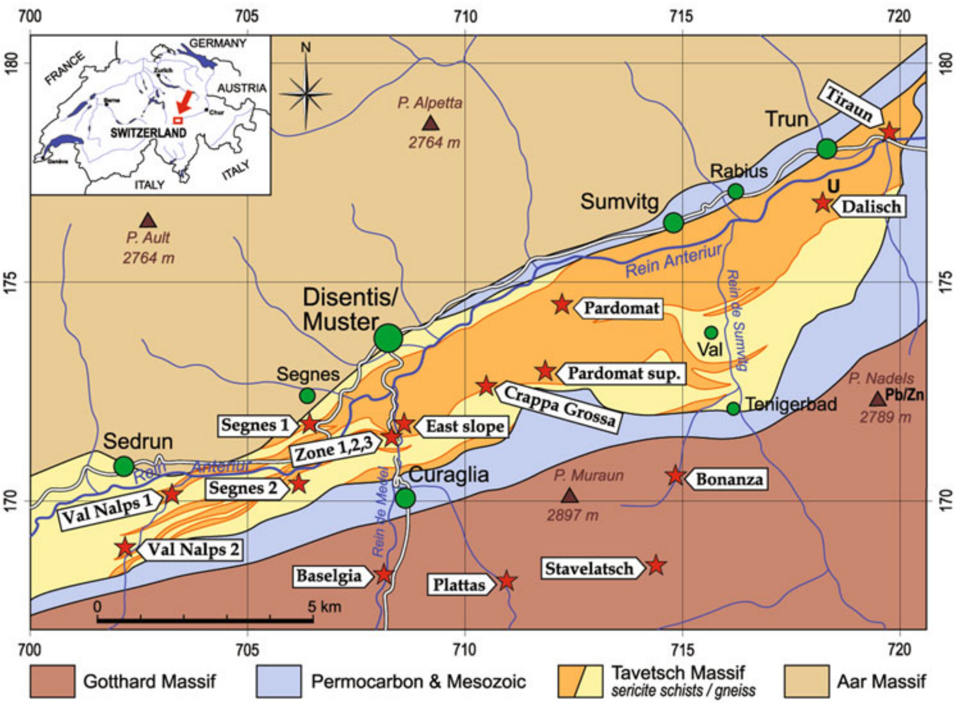

Fig. 1 Regional geology and gold occurrences (*red stars*) in the Surselva region

through the Oberalp pass to Andermatt and the Gotthard pass. A road towards the south connects the Surselva via the Lukmanier pass to the Tessin Canton, the southern Italian speaking part of Switzerland. The climate of the region is characterised by warm summers and thick winter snow cover. The language spoken in Surselva is Romansh, the fourth Swiss national language. Hence all geographical names herein are written in Romansh (Surselva means the "High Forest").

Gold in Surselva was briefly mentioned in several publications, but did not attract any particular attention (Niggli 1944; Stalder et al. 1973; Kramers 1973; Rykart and Hotz 1979). In 1986, gold-bearing rock units were discovered jointly in sulphide-bearing sericite schists in the Lukmanier gorge by D. Knopf, a Swiss geologist and K. Naert, manager of Narex, a Canadian junior exploration company (Fig. 1; zones 1, 2, and 3). Soon afterwards, Narex began work in the mineralised area, including drilling (Knopf et al. 1989). The company ceased exploration activities after two years, apparently because of the low gold prices prevailing at the time.

At about the same time, the alluvial gold deposit in the Lukmanier gorge, which had been known for many years, became more widely known and attracted many enthusiastic amateur gold panners during the summertime. It is by far the largest gold placer in Switzerland, and is now listed as a regional tourist attraction.

Detailed geological mapping was carried out in the region between Sedrun and Disentis/Mustér and in the Lukmanier gorge, and high-grade gold samples grading 8–14 g/t were collected (Fig. 1, East Slope; Della Valle and Haldemann 1991). During the same period, the central part of the Tavetsch Zwischenmassif (TZM) was also studied (Böhm 1991).

Fig. 2 The "bonanza" native gold-quartz veinlet occurrence (photograph courtesy of Bündner Naturmuseum, Chur)

In 2000, René Reichmuth, a prospector, made an important discovery in Val Vallesa, southwest of Teniger Bad (Fig. 2, "bonanza"). A small quartz vein was entirely covered by 1.4 kg of native gold, the largest gold find in Switzerland.

In 2005, minAlp, a newly formed, Geneva-based, Swiss exploration company, obtained exploration licences from the five Surselva municipalities (minAlp is an abbreviation in Romansh for mineira Alpina, "Alpine mining"). The company carried out fieldwork for three years, locating another high-grade zone assaying about 14 g/t Au to the southwest of Disentis/Mustér (Fig. 1, Crappa Grossa).

In 2009, minAlp was purchased by Murray Brook Minerals, a Toronto-based junior exploration company, thereby becoming a fully owned subsidiary. Further exploration activities are been envisaged by the Canadian owners.

Regional geological setting

From north to south, three major tectonic units can be distinguished in the western Swiss Alps (Labhart 1999; Fig. 1): (1) the Variscan (or Hercynian) Central Aar Massif, composed of granites, granitoids and polymetamorphic basement rocks; (2) the TZM, a highly sheared unit trending practically east–west and mainly composed of highly sheared sericite schists and gneisses with some minor intrusions. This unit contains practically all the gold occurrences described in this article; (3) the Variscan (or Hercynian) Central Gotthard Massif, with its complex metamorphic and granitic formations and related sedimentary rocks (Mercolli et al. 1994).

The Tavetsch Zwischenmassif (TZM)

The TZM, a tectonic unit bracketed between the Aar Massif to the north and the Gotthard Massif to the south, occupies a large part of the Surselva region (Canton Grisons), mainly on the southern side of the Upper Rhein river. The massif extends for >30 km, with a width of 2–3 km between Sedrun to the west and Trun to the east (Labhart 1977; Trümpy 1980). The TZM is affected by a penetrative schistosity, which was developed during the Variscan orogeny and further reactivated during the Alpine orogeny (Voll 1976; Mayerat 1986).

The following lithological units compose the TZM (Labhart 1999):

1. muscovite and sericite schists and gneisses, quartzo-feldspathic gneisses and schistose gneisses, leucogneisses, (microcline) augen gneisses;
2. chlorite schists and gneisses, biotite-chlorite gneisses, amphibolites, diorite; and
3. serpentinites, talc schists and associated dolomitic rocks, and pegmatites.

The first two units, described in more detail below, constitute >95% of the TZM. The third group of lithologies is of secondary importance and not related to the gold mineralisation; hence, it is not further described.

Sericite schist

Sericite is a fine-grained variety of muscovite. The sericite schists are soft and brittle and, since much of the Surselva region is covered by Quaternary morainic material, scree and soil, they crop out uncommonly and over restricted areas only. Although mineralised sericite schist may be sampled locally, it can almost never be followed and sampled continuously along strike. Hence, resource assessment is impossible without trenching and drilling.

The main minerals in the sericite schists are sericite, muscovite, quartz and feldspar, with tourmaline, commonly associated with sulphides, fuchsite (Cr-muscovite), apatite, leucoxene, zircon, magnetite, ilmenite, monazite, carbonates (mainly magnesite) present as accessories.

In the field, three main varieties of sericite schist are observed, which are not regularly distributed, and are commonly interspersed with each other: (1) coarse grained, with predominant muscovite; (2) fine grained, with predominant sericite; and (3) fine grained and silica-enriched, which is more resistant to erosion, has predominant sericite and disseminated sulphides and, hence, develops a limonitic or gossanous patina of brown-coloured iron hydroxides (Fig. 3). The reddish to light brown colour of the latter facies constitutes an important and easily recognizable indicator for exploration.

The Variscan and Alpine metamorphism and fabric development have largely obliterated the protolith of the sericite schist. In the first regional studies, and again recently, they have been considered as sediment-derived (Niggli 1944; Stalder et al. 1973; Labhart 1999). However, in recent years, they have generally been considered as

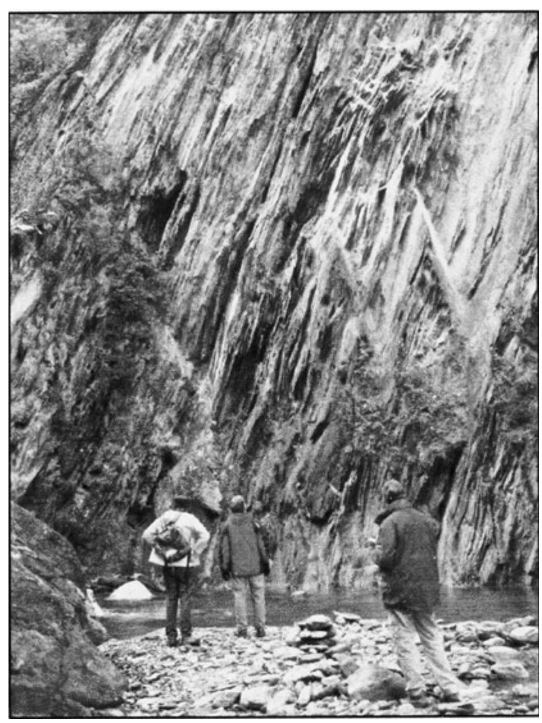

Fig. 3 Mineralised, steeply dipping sericite schists, characterised by a typical brownish limonitic patina, *dark grey* on the picture (Rein de Medel river bed, Lukmanier gorge)

metamorphosed felsic tuffs (Jaffé 1989; Bonanomi 1989; Della Valle and Haldemann 1991; Böhm 1991).

Sericite gneiss

The TZM has frequently been considered as lithologically homogeneous, consisting mainly of sericite schists because of their presence in the Lukmanier gorge, the only more or less continuous outcrop and the most accessible one of the TZM. The mineralogical composition of sericite gneiss is similar to that of the schists, but generally richer in albite. Their chemical compositions are also similar (Table 1).

Recent mapping has shown the regional importance of different gneiss units. In the region between Val Nalps, near Sedrun (Fig. 1) and the Lukmanier gorge, four gneiss bodies extending for over 6 km are intercalated with sericite schist. The bodies terminate just before the Lukmanier gorge, where the sericite schists predominate (Della Valle and Haldemann 1991). Another important gneiss body occurs in the Rein de Sumvitg region (Fig. 1), with its centre in the hamlet of Val, 1.5 km north of Teniger Bad. The body is largely massive, with its width attaining 2 km (Böhm 1991), and continues on the eastern flank of the Val Sumvitg. In this part of the TZM, the gneisses are more intensely deformed, with the development of coarse augen gneiss containing microcline crystals measuring 1–2 cm in length. Muscovite and augen gneiss are important components of the western- and southernmost TZM, south of Trun and Tiraun (Kramers 1973).

It is estimated that the gneisses comprise at least 20–30% of the TZM. Insufficient information precludes determination of whether the gneisses are derived from originally igneous or sedimentary rocks, although some previous authors have considered them as paragneisses (Niggli 1944; Kramers 1973).

The sulphide mineralisation is generally restricted to the sericite schists and has not been observed in the gneisses.

Table 1 X-ray fluorescence major element oxide analysis of a typical sericite schist (sample 2) and a mineralised sericite schist (sample 7); Lukmanier gorge, after Böhm (1991)

Sample no.	7	2
SiO_2	63.67	70.22
TiO_2	0.75	0.38
Al_2O_3	16.32	16.04
$Fe_2O_3 + FeO$	4.29	2.47
MnO	0.09	0.00
MgO	1.83	0.75
CaO	1.80	0.26
Na_2O	0.08	1.71
K_2O	5.06	5.41
P_2O_5	0.20	0.23
$H_2O + CO_2$	5.07	2.15
Cr_2O_3	0.01	0.00
Total	99.17	99.62

Gold occurrences

Alluvial gold

A small gold placer, the largest in Switzerland, occurs in the Rein de Medel river bed, at the entrance of the Lukmanier gorge, near the camping site south of Disentis/Mustér (Pfander and Jans 2004; Schweizerische Goldwaschervereinigung 2009). The alluvial gold particles are generally small, but several nuggets weighing >10 g, and two of 101.6 and 125 g, with a silver content of 20 wt% have been found (Hofmann 1999). The origin of the placer gold has not been studied, but it may well be derived from in situ gold which is known in the same region (Fig. 1, zones 2, 3 and East slope).

Alluvial gold is not restricted to the Rein de Medel, but occurs in many of the streams in the region. Narex carried out a panning survey of all the streamlets on the south side of the Rein Anteriur, between Disentis/Mustér and Sedrun (Fig. 1). In all the panned concentrates, gold flakes were encountered. Alluvial gold has also been reported from Val Nalps, Val Sumvitg and Val Velesz, with samples from these localities deposited at the Natural History Museum in Bern.

A gold placer occurs in the Tscharbach near Obersaxen, 9 km SSW of Trun, well outside the TZM "sensu stricto" (Schweizerische Goldwaschervereinigung 2009). The source of its gold nuggets is unknown, but is believed to be located in the nearby Gotthard Massif.

The Sumvitg gold "bonanza"

In 2000, René Reichmuth discovered a quartz vein, which was covered with native gold particles several millimeters thick (Fig. 2; Gurtner 2001). The vein, measuring 1–4 × 30 × 100 cm^3, was almost entirely hidden on the side of a small streamlet in Val Vallesa, southwest of Tenigerbad, in a region with few outcrops and mostly covered by unconsolidated Quaternary sediments. The host rock of the gold-bearing quartz vein is Gotthard gneiss (B. Hofmann, personal communication 2009), and the locality lies within the Gotthard Massif. The total estimated weight of the gold is 1.4 kg, including a silver content of 20 wt% (B. Hofmann, personal communication 2009). The sample was divided into several pieces and sold to museums and private collectors at undisclosed prices. The largest piece is exhibited in the mineralogical section of the Bündner Naturmuseum in Chur (Fig. 2).

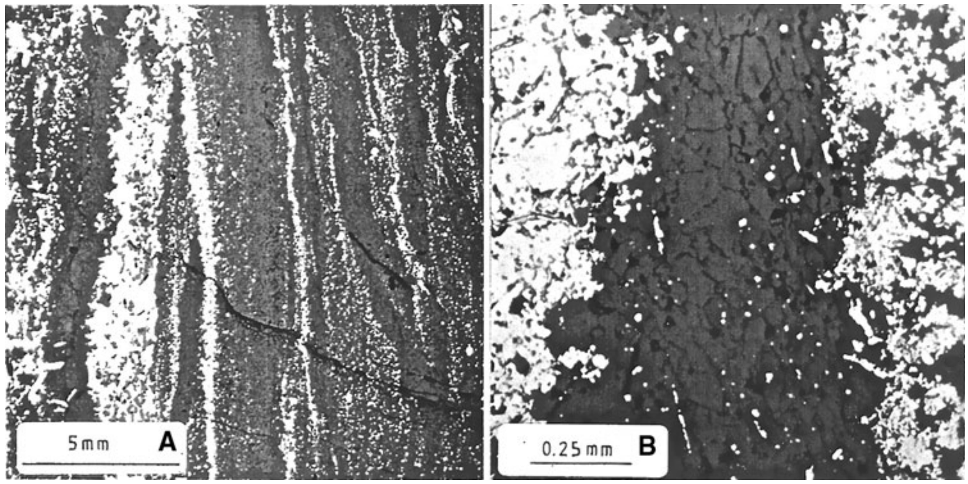

Fig. 4 **a** Polished sericite schist sample showing concordant banded sulphide veinlets (after Böhm 1991). **b** Close-up of a pyrite veinlet (*left*) and a pyrrhotite veinlet (*right*)

The remarkable "bonanza" occurrence is by far the largest native gold discovery in Switzerland, at least during recent times. The origin of such a large native gold mass is difficult to assess. A relationship with late Alpine hydrothermal fluid circulation may be hypothesised, but the passage of such fluids has not been documented previously in the Surselva region. With the present state of knowledge, an older Hercynian origin should also not be ruled out. Two skilled prospectors have operated over the last 10 years in the region, but no further find of similar nature has been reported.

Gold in association with sericite schists

Gold mineralisation in sericite schists occurs throughout the Surselva region, and can generally be recognised in the field by the development of brownish limonitic coatings. Sixteen gold-bearing sericite schists occurrences have been discovered and described by different teams over the last 25 years (Fig. 1; Kramers 1973; Bonanomi 1989; Knopf et al. 1989; Jaffé 1989; Böhm 1991; Della Valle and Haldemann 1991). The main opaque minerals in these occurrences are pyrite (gold-bearing), pyrrhotite and arsenopyrite, with chalcopyrite, tetrahedrite, löllingite, galena, sphalerite, monazite, rutile, ilmenite, boulangerite and ullmanite in accessory amounts.

The following paragenetic sequence has been suggested (Della Valle and Haldemann 1991; Böhm 1991): pyrrhotite, pyrite replacing pyrrhotite, pyrite with inclusions of gold (and subordinate silver), Pb, Sb, Cu and Zn minerals, arsenopyrite (gold-bearing?) replacing iron sulphides, late pyrite without gold and other inclusions, tourmaline replacing mainly pyrite, and late carbonates.

The ore minerals occur in millimetric layers concordant within the sericite schists (Fig. 4). Sulphide contents of the most intensely mineralised schists vary between 5 and 20 vol.%. Massive sulphides are extremely uncommon and limited in extent. The sulphides occur locally in thin stringers a few centimeters wide, commonly associated with quartz veinlets. By far the best and easiest accessible mineralised outcrops are located on the western side of Lukmanier gorge, along the road from Disentis/Mustér south to the Lukmanier pass, and in the river bed of the Rein de Medel (Fig. 3).

Three mineralised zones are readily visible along the road south of Disentis/Mustér in east-striking, vertically dipping sericite schists. On this road, and in the Rein de Medel river bed, the first mineralised zone is located near the bridge crossing the Rein Anteriur. Approximately 200 m south of the bridge is zone 2, approximately 100 m wide, which commences with a small cliff of typical limonitic sericite schist, named the "discovery point" by Narex (Fig. 5). After a 500 m barren zone, mineralised zone 3 is also about 100 m wide.

Considerable thought was given to the possibility of an originally single mineralised zone that may have been dismembered during orogenic movements through a sequence of recumbent folds to give the three discrete mineralised zones that are currently observed. However, detailed observations along the road and in the river bed failed to substantiate the hypothesis.

On initial inspection of the regional map (Fig. 1), it is tempting to assume that the Rein de Medel and the Rein de Sumvitg are caused by weakness zones or even major faults crossing the regional TZM schistosity almost at right angle. However, no evidence for such structural features is observed in the river beds, in which bedrock exposures are good to excellent. The steep eastern side of the Lukmanier gorge has been surveyed only in a preliminary fashion, because climbing skills and the necessary safety measures would be required.

The three most southerly gold occurrences in the Gotthard Massif deserve special comment. Platta was known by Narex, but Stavelatsch and Baselgia were only discovered

Fig. 5 The Narex gold discovery site with fresh, whitish sericite schists, partly covered by a brownish limonitic patina, *dark grey* on the picture (Lukmanier pass road, at the entrance to the Lukmanier gorge)

recently by minAlp (Fig. 1). These three localities, which appear to be aligned, are identical to most of the gold showings in the TZM, consisting of disseminated, gold-bearing sulphides in sericite schists. Their location in the Gotthard Massif raises a difficult question whether the TZM is not an independent tectonic unit but simply the most northerly part of the Gotthard Massif. This challenging regional problem is beyond the purpose of the present study.

Gold particles

Examinations with the scanning electron microscope indicate that gold is associated mainly with pyrite as minute particles ranging in size from 2–4 μm, but locally attaining 100 μm (Fig. 6). An association with tetrahedrite has been reported, but not yet confirmed (Della Valle and Haldemann 1991). The results of these studies indicate that the gold may be refractory, requiring chemical treatment for extraction. To avoid the problems associated with a nugget effect, careful sampling procedures need to be applied.

Exploration drilling results

Narex drilled 17 holes, for a total length of >3,000 m. The main localities tested are in the Rein de Medel, in the

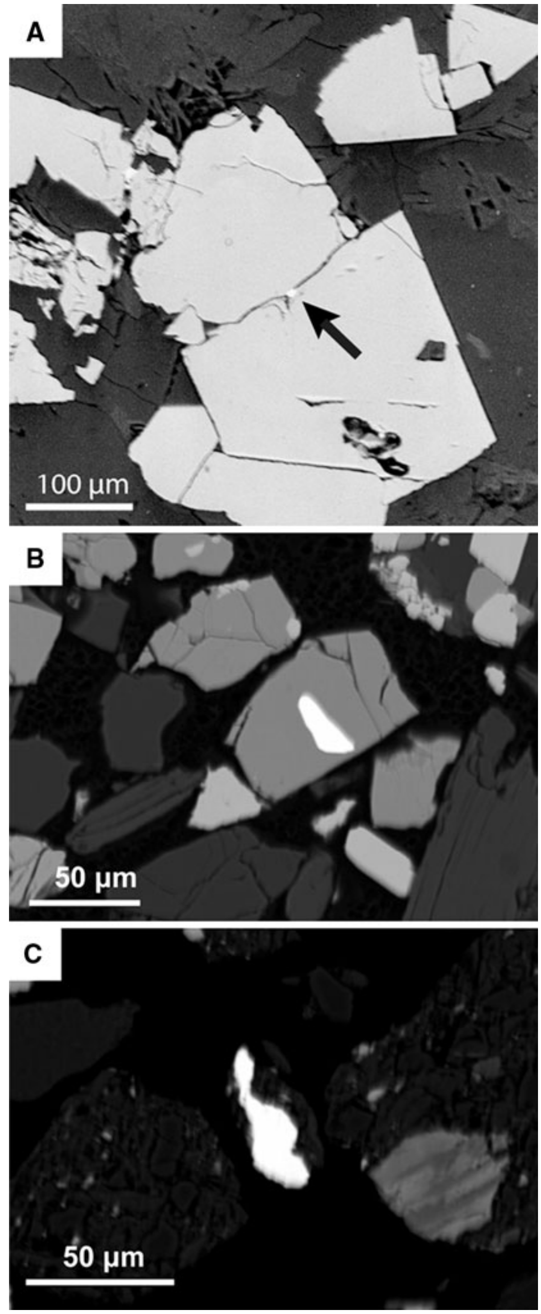

Fig. 6 Scanning electron microscope photomicrographs of native gold particles. **a** Gold particle in a fracture cutting a pyrite crystal; **b** Gold inclusion in pyrite; **c** Elongate gold particle hosted by sericite schist. The elongate form may reflect the strong regional schistosity

Lukmanier gorge (7 holes) and west of the hamlet of Mompe Medel, 600 m west of the Lukmanier road (7 holes; Fig. 1). In the river bed, the holes were drilled mainly from a single location, in a fan-like pattern, in order to intersect the vertically dipping sericite schists at different angles. Apparently, no drilling was performed on the eastern side of the Lukmanier gorge. In Mompe Medel, drilling was conducted to test the possibility of gold

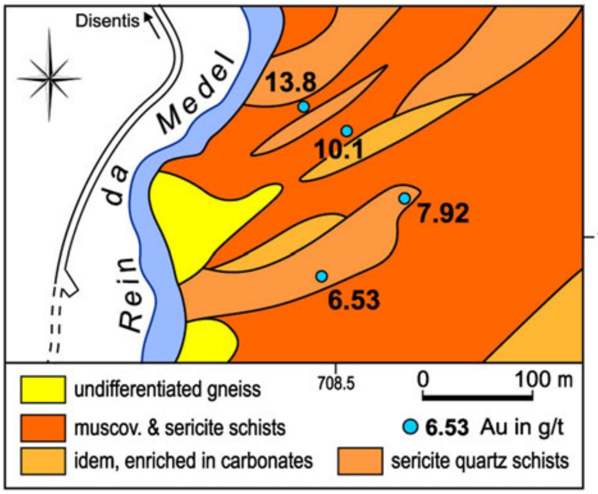

Fig. 7 High grade gold-bearing occurrences in the East slope (Lower Lukmanier Gorge, Fig. 1), after Della Valle and Haldemann 1991

enrichment at the contact between the sericite schists and a small ultramafic body. Results were negative (Narex, personal communication 1989), but core logs are not available. Relatively low gold values, ranging from 1–4 g/t, are present in many drill holes over widths that rarely exceed 1 m. The conclusion is that a high-grade ore body is not evident.

Surface gold and silver grades

Grab samples weighing 1–2 kg were taken consistently at right angle to the local strike.

Gold

Gold values in outcrop grab samples vary from one occurrence to another. They vary generally between 4 and 7 g/t Au.

At the eastern end of the TZM, near and south of Trun, the tenors are particularly low, on the order of 1–2 g/t Au (Fig. 1). These tenors are based only on two analyses of 1 and 2 g per sample (Kramers 1973, p. 49). The two results can hardly be considered as representative. An accurate resembling of the zone followed by standard analytical procedures should be undertaken.

The relations between the Surselva gold occurrences and the sizeable uranium mineralisation in the Trun region (Kramers 1973) have not been studied.

No gold values are reported from the Pb/Zn showing of Alp Nadels, 5 km south of Trun (Friedlaender 1930).

Only two occurrences exhibit encouraging "high" values: Crapa Grossa with 14 g/t Au, and the East slope with three values of 8, 10 and 14 g/t Au over a 100 m interval (Figs. 1, 7) The distance between these two occurrences is only 2 km along strike, and the zone between them needs to be examined carefully.

Three of the four gold-bearing samples in the East slope were collected in quartz blocs, which may not be "in situ". In these blocs, gold is associated with coarse pyrite and in one case also with arsenopyrite (Table 2). This kind of mineralisation is unusual in Surselva, and requires further investigations, albeit under difficult field work conditions.

The significant presence of carbonates within and in vicinity of the East slope gold occurrences (Fig. 7) may be interpreted as the result of the formation of an incipient hydrothermal alteration halo. Narex has already mentioned in passing the existence of a similar alteration halo in other parts of the Lukmanier gorge (Knopf et al. 1989, p. 293).

Silver

Scanning electron microscope study of gold particles reveals that all three types of gold occurrence described have high silver contents, ranging from 20–35 wt% Ag, and in one case attaining 50 wt% Ag: a newly recognised feature of the Surselva gold mineralisation.

Metallogenic model

With the scarce information available it is not possible to establish a definitive metallogenic model or a resource. If the current interpretation of the sericite schists as metamorphosed felsic volcanic tuffs is accepted, the gold-bearing sulphides could be related to the initial volcanic activity. Several characteristics of the Surselva gold mineralisation, including the possible link to pre-Alpine felsic tuffs, and the sulphide-rich nature, are notably different from the well-known Monte Rosa gold belt situated in Piemont, Italy, in the southern part of the Monte Rosa

Table 2 High-grade gold-bearing values and their geological setting in the East slope occurrence (Fig. 7), Lower Lukmanier gorge, after Della Valle and Haldemann 1991

g/t Au	6.53	7.92	10.10	13.90
Lithology	Pyrite-bearing sericite schist	Quartz vein with coarse pyrite, in bloc	Quartz vein with coarse pyrite, in bloc	Quartz vein with coarse pyrite and arsenopyrite, in bloc

nappe of the northwestern Alps. These deposits are of late-Alpine (Oligocene) age. Their tectonic setting is also markedly different, as they are hosted by the Penninic nappes (Pettke et al. 1999).

Conclusions

In just a few decades, the Surselva has developed from a region with some minor and little-noticed gold flakes into a potentially significant gold district. The geological map (Fig. 1) reveals 18 discrete gold occurrences, 14 in the TZM unit and the remaining 4 in the Gotthard unit. With the exception of the placer deposit, the East slope occurrence and the "bonanza", the gold is strictly lithologically controlled, as it is everywhere associated with sulphide-bearing sericite schists.

The exceptional "bonanza" occurrence, in which 1.4 kg gold accumulated on a surface of <1 m^2, is unique in Switzerland and metallogenically puzzling. For both spatial and quantitative reasons, it seems impossible to derive the "bonanza" gold occurrence from the other surface occurrences in the region. Hence, future exploration ventures face the challenging task to identify the source ore body of the bonanza occurrence.

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