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Gold in Switzerland

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Vorwort der Schweizerischen Geotechnischen Kommission

Die Zeitschrift *Economic Geology* publizierte in ihrem Vol. 84, 1989, einen Beitrag von Prof. F. C. Jaffé mit dem Titel "Gold in Switzerland". Die Schweizerische Geotechnische Kommission freut sich, dass es möglich wurde, diese Arbeit auch in ihre Publikationsreihe der "Kleineren Mitteilungen" aufzunehmen. Für das Entgegenkommen sei dem Autor und der Redaktion der Zeitschrift *Economic Geology* herzlich gedankt.

Nach einem kurzen Überblick über die Geologie der Schweiz nimmt der Autor Bezug auf die zahlreichen Goldvorkommen in den verschiedenen geologischen Einheiten. Die primären Goldlagerstätten werden ausführlich beschrieben, wobei speziell die Vorkommen von Disentis, wo in jüngster Zeit Prospektionsarbeiten laufen, einen Schwerpunkt bilden. Ebenso wird der Golddistrikt des Malcantone in den Südalpen detailliert beschrieben, wogegen - entsprechend ihrer Bedeutung - die alluvialen Vorkommen nur kurz gestreift sind. Literaturhinweise erleichtern aber hier, wie auch in den Hauptkapiteln, den raschen Zugriff zu den entsprechenden Daten.

In ihrer Vollständigkeit und Übersichtlichkeit ergänzt diese Zusammenstellung der Goldlagerstätten die verschiedenen Veröffentlichungen über die Vorkommen mineralischer Rohstoffe in der Schweiz, welche seit langer Zeit von der Geotechnischen Kommission unterstützt oder ausgeführt werden.

Für den Inhalt von Text und Figuren ist der Autor allein verantwortlich.

Zürich, Juli 1991

Der Präsident der Schweizerischen
Geotechnischen Kommission

C. Schindler

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GOLD IN SWITZERLAND

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Introduction

Although Switzerland is a small country, it has a diversified and complicated geologic structure. From north to south, it can be divided into the following main units (Fig. 1):

1. The Jura, essentially a suite of Mesozoic sedimentary rocks, arranged in rather simply folded and faulted structures.
2. The Molasse basin, a Tertiary postorogenic sedimentary-rock sequence, consisting mainly of sandstones, shales, and conglomerates, formed through the erosion of the Alpine rocks during and mainly after their uplift. The Molasse basin is partially covered by extensive Quaternary glacial and fluvioglacial formations.
3. The calcareous Alps, essentially a sequence of Mesozoic sedimentary rocks which were strongly dislocated during the Alpine orogeny and now form classic overthrusts (Helvetic, Ultrahelvetic, and Prealpes nappes).
4. The Hercynian massifs, in particular the Mont Blanc-Aiguilles Rouges massif in western Switzerland, extending into France and Italy, and the Aar-Gotthard massif, its equivalent in the central part of the country. These massifs consist of a central granite core and a surrounding suite of crystalline schists formed during metamorphic events in relation to the Hercynian and probably the Caledonian orogeny.
5. The Penninic and Austroalpine Alps, consisting of a complicated sequence of sedimentary, volcanic, and mainly metamorphic rocks of Precambrian (?), Paleozoic, and Mesozoic age. These rocks were severely deformed during the Alpine orogeny and have formed large overthrusts, such as the St. Bernard and the Dent Blanche nappes.
6. The southern Alps, a small stable basement unit, not very well represented in Switzerland. Metamorphic rocks, formed at least partially during the Caledonian orogeny, are overlain by sedimentary rocks, essentially of Mesozoic age.

For further details, the reader is referred to geological handbooks of which Trumpy's (1980) is the most recent and modern.

Numerous small ore deposits occur in Switzerland, many of which have been mined on a small scale in the past, mainly for iron, base metals, nickel-cobalt, molybdenite, gold, and silver (Jaffé, 1986). None of these deposits is economic under present conditions.

The main purpose of this communication is to present and discuss available information on alluvial and primary gold deposits in Switzerland in relation to their geologic environment.

Alluvial Gold

Alluvial gold is known from different localities in Quaternary and Tertiary sediments of the Molasse basin.

Around Geneva, placer gold in the Allondon River is due to secondary concentrations of particles already contained in morainic material (Pittard, 1936). During the latest glaciation, this material was transported westward and northward from gold-bearing regions in the Alps. In recent years, amateur gold washers have been increasingly active in other fluvial deposits of the Geneva area.

Placer deposits also occur in the Tertiary Molasse conglomerates, which were formed through the erosion and resedimentation of the Alpine range. Small gold-bearing placers in the Napf region (Canton Luzern) occur where local streams and rivers intersect the Napf conglomerate fan (Schmid, 1973).

Hofmann (1985) has described in detail numerous similar occurrences in eastern Switzerland and has discussed in detail their origin and age of formation.

Swiss placers are small, low grade, and uneconomic in fairly populated agricultural regions with stringent environmental regulations. Historic production figures, available only for the Napf region, do not exceed a total of 30 kg.

Primary Gold

Gold mining operations, albeit on a small scale, have been recorded from the Middle Ages onward for all the deposits which will be described in this communication, with the exception of the Disentis deposit, which has been discovered recently.

The calcareous Alps: Calanda, Grisons

The abandoned Calanda gold mine was described in the last century (Kenngott, 1866) and is constantly referred to, although past-production has been insignificant (70 gold coins at the beginning of the 19th century).

Calanda is located in the Rhine valley, in the autochthonous Helvetic sequence, which in this region is slightly sheared and metamorphosed. Narrow discordant quartz veins confirming gold-bearing pyrite intersect sedimentary units of Triassic to Jurassic

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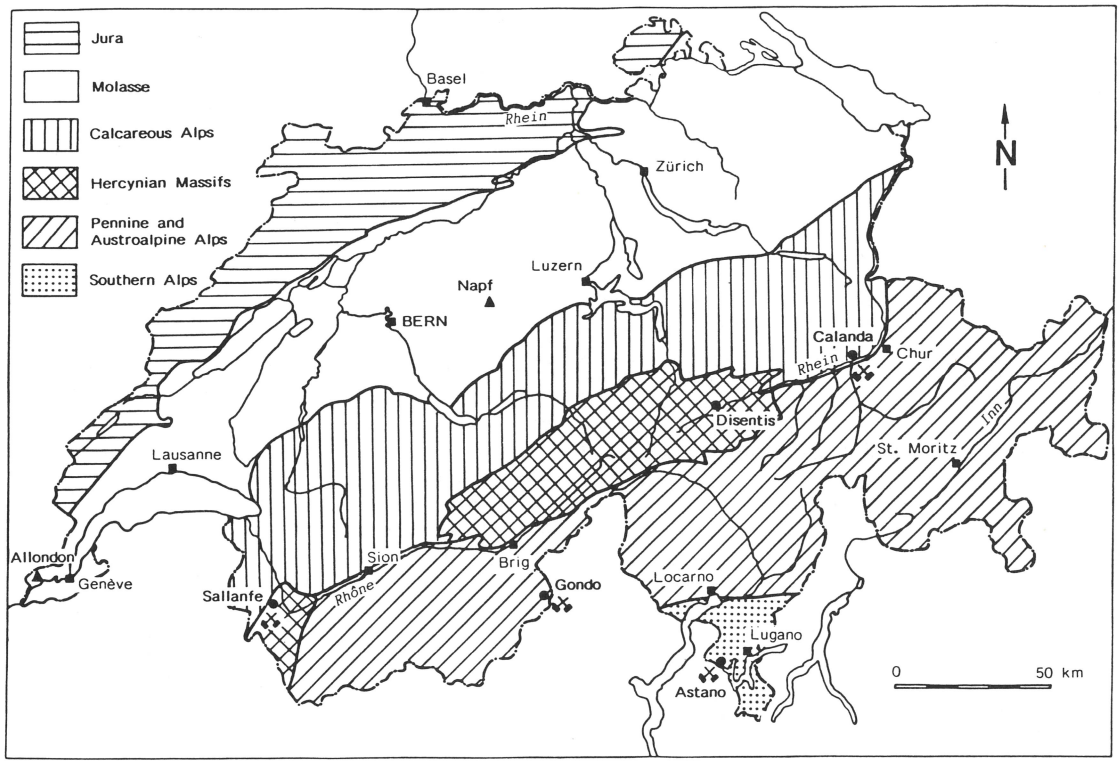


FIG. 1. Gold deposits of Switzerland. ▲ = placers deposits; ● = primary gold deposits, all of which are abandoned mines, except the newly discovered Disentis deposit; ■ = city site; ⚒ = mine location.

(Dogger) age. The emplacement of the veins took place toward the end of the Alpine orogeny (Cadisch, 1939). Sheelite is occasionally associated with gold-bearing veins (Bächtiger, 1967; Bächtiger et al., 1972).

The Hercynian domain: Salanfe, Wallis, and Disentis, Grisons

The Salanfe gold district is located at an elevation of approximately 2,100 m, within the metamorphic basement of the Aiguilles Rouges Hercynian massif. The ore zone is very close to the overlying transgressive Triassic sediments (Rickenbach and von Känel, 1953; Woodtli et al., 1987).

The great variety of gneisses which occur in the region have been interpreted to be the result of complex metamorphic processes. The ore zone is associated exclusively with elongated lenses of skarns, marbles, and graphitic quartzites contained in biotite gneisses (Fig. 2). The known ore zone is clearly strata bound. Mineralization occurs essentially at the roof of the skarn zone, immediately at the contact with the marbles. It has been recognized over a length of 1 km, with a general north-northeast strike.

Arsenopyrite, lollingite, and pyrite are the main ore minerals, with some accessory scheelite. Gold is mostly associated with the arsenic-bearing minerals. The diameter of gold particles, of irregular form and size, ranges from 10 to 20 μm (Rickenbach and von Känel, 1953).

The Salanfe deposit was mined irregularly from 1904 until 1928, but no reliable production figures exist from this period. Gold grade was high, apparently reaching over 20 g/metric ton. These grades have been confirmed by the underground sampling in abandoned stopes and pillars of the Robert mine (Woodtli et al., 1987, p. 122) which was undertaken during the UROMINE mineral exploration project.

Several geochemical and geophysical surveys were carried out in the area (Wagner and Wellhauser, 1965; Koehn, 1966). A comprehensive study was completed recently within the framework of the UROMINE exploration projet (Woodtli et al., 1987). The potential for additional ore reserves is considered to be interesting, and drill targets for the underground continuation of known orebodies have been outlined.

The recently discovered gold mineralization in the Disentis regions occurs in the Tavetscher Zwischen-

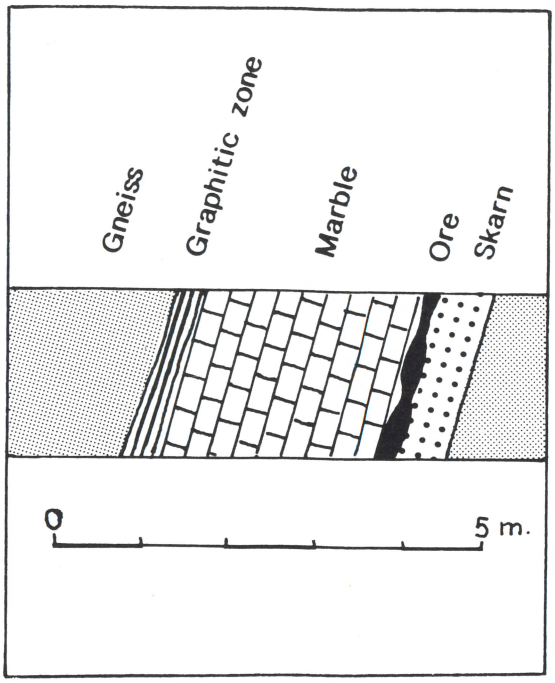


FIG. 2. Cross section of the Salanfe gold deposit (simplified after Woodtli et al., 1987).

massif, a metamorphic unit of Hercynian age (Jäger et al., 1961) located mainly to the south of the Vorderrhein valley. This unit is 35 km long and 2 to 5 km wide. It occurs between the Hercynian massifs of the Aar to the north and of the Gotthard to the south, and it is separated from these two units by a thin and discontinuous sedimentary zone (Niggli, 1944; Labhart, 1977; Pfifner, 1985; Wyss, 1986). In a generally mountainous region, the Tavetscher Zwischenmassif is without a distinct morphological expression.

The Tavetscher Zwischenmassif is composed mainly of sericite schists and gneisses, which have been considered traditionally as metasedimentary rocks but which have been recently reinterpreted as the metamorphic equivalent of acid tuffaceous rocks. Tourmaline and fuchsite are interesting accessory minerals. Amphibolites, at times interfingered with the acid rocks, are less frequent. Ultrabasic, mainly talc-serpentine-bearing rocks, occur as small and heavily sheared lenses. They are generally associated with quartz-carbonate rocks containing dolomite, ankerite, and magnesite.

Three phases of deformation have been described (Mayerat, 1985, 1986). In the first phase, which is older than the Alpine metamorphism, a very regular ductile penetrative schistosity was developed, parallel to the contacts of different rock types, with formation of small folds. Shearing has triggered a dextral displacement in the massif. A crenulation schistosity, contemporaneous with Alpine metamorphism, was formed during the second phase. Finally, kinks with irregular orientation and a general dip to the east appear in a third phase.

On a broader scale, the Tavetscher Zwischenmassif may well be interpreted as a megashear zone with a dextral displacement.

In the Disentis region, the presence of isolated showings of free gold was probably known for many years by "Strahlers," local prospectors and small-scale miners of quartz crystals and of associated minerals in Alpine vugs. No mention of gold can be found in

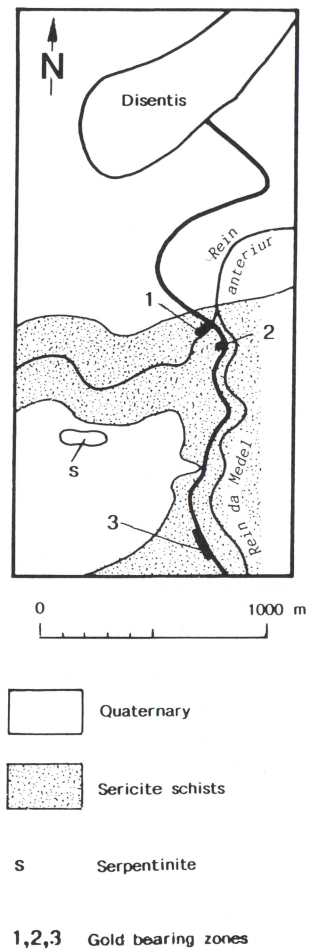


FIG. 3. Gold-bearing zones south of Disentis, along the Lukmanier road (simplified after Niggli, 1944; and Bundesamt für Landestopographie, 1987).

older publications, although the presence of sulfides was duly recorded (Kenngott, 1866; Friedlaender, 1930). The first published record of gold appeared in Niggli's thesis (1944, p. 169), in which several gold-bearing localities such as the Lukmanierschlucht and the Sedrun region were mentioned in passing. The same occurrences were described in more detail by Parker (1973). Free gold has been recently observed in small Alpine vugs along the Disentis-Sedrun road, but the outcrop has disappeared during subsequent road construction (Ryckart and Hotz, 1979).

No primary gold mining is known to have occurred in the Disentis area. Occasional alluvial gold washing has taken place in the Medelser Rhine.

In 1985, gold was rediscovered in the Lukmanierschlucht (Lukmanier gorge), in which nearly vertical sericite schists are well exposed along the Lukmanier pass road, immediately to the south of the bridge over the Rein anterior (Fig. 3). Conspicuous, iron-stained (or gossanous) zones are visible over 50 m. They are due to the intense weathering of thin stringers of pyrite which are associated with arsenopyrite and occasionally with minor amounts of other sulfides (Figs. 4 and 5). Locally, sampling has indicated gold grades of 2 to 4 g/metric ton.

The presence of disseminated gold along the Lukmanier pass road triggered intensive exploration in the area. In 1986, the Minera Val d'Aur S.A. obtained exploration rights from the communes of Disentis, Medels, Sedrun, Somvix, and Trun. Exploration has been carried out by mapping, geochemical soil surveys, as well as airborne and ground geophysics. Almost 4,000 m of core obtained by diamond drilling was logged and sampled. The main discovery emerging from this exploration project is the existence of three discrete gold-bearing zones within the sericite schists. These zones are subvertical and parallel to the regional east-west strike. Zones 1 and 2 are approximately 30 to 40 m wide, with a distance of 100 m between the two zones. Zone 3, which starts 700 m south of zone 2, is approximately 200 m wide. All three zones are open on both ends along strike and at depth.

At depth the three zones are characterized by a strong hydrothermal alteration. Silicification is prevalent and is accompanied by an intensive carbonate alteration, with the formation of calcite, ankerite, dolomite, and magnesite (up to 11% Mg).

Lensoid and irregularly banded massive and disseminated sulfide horizons occur in the three zones. In the southern most zone (zone 3), sulfides are associated with graphite and cherts. In order of decreasing frequence, the most common metallic minerals in these zones are the following: pyrite, pyrrhotite, arsenopyrite, and magnetite. The accessory minerals are stibnite, bismuthinite, sphalerite, galena, ilmenite, tetrahedrite, and chalcopyrite. In other mineralizations of the Disentis area, Weibel and Köppel (1962) have argued that stibnite was erroneously described instead of an assemblage of jamesonite and boulangerite.

Gold grades are reported to be irregular, on the order of 2 to 3 g/metric ton, but locally up to 7 g/metric ton. Large tonnages of this low-grade ore have been blocked out, and work is still in progress in the whole area.

The region of Trun, a village also located in the Vorderhein (or Rein anterior) valley approximately 11 km east of Disentis, has been studied in some detail in relation to its uranium-bearing mineralization, which also occurs in Tavetscher Zwischenmassif rocks (Kramers, 1973). In some polished sections minute

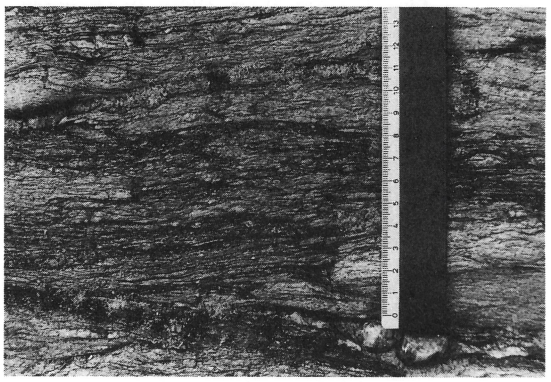


FIG. 4. Disentis, Grisons. Gold-bearing zone 2. Sericite schists (white) with characteristic gossanous alteration (dark gray).

FIG. 5. Disentis, Grisons. Gold-bearing zone 3. Sericite schists (light gray) with stringers of slightly graphitic sulfides (dark gray).

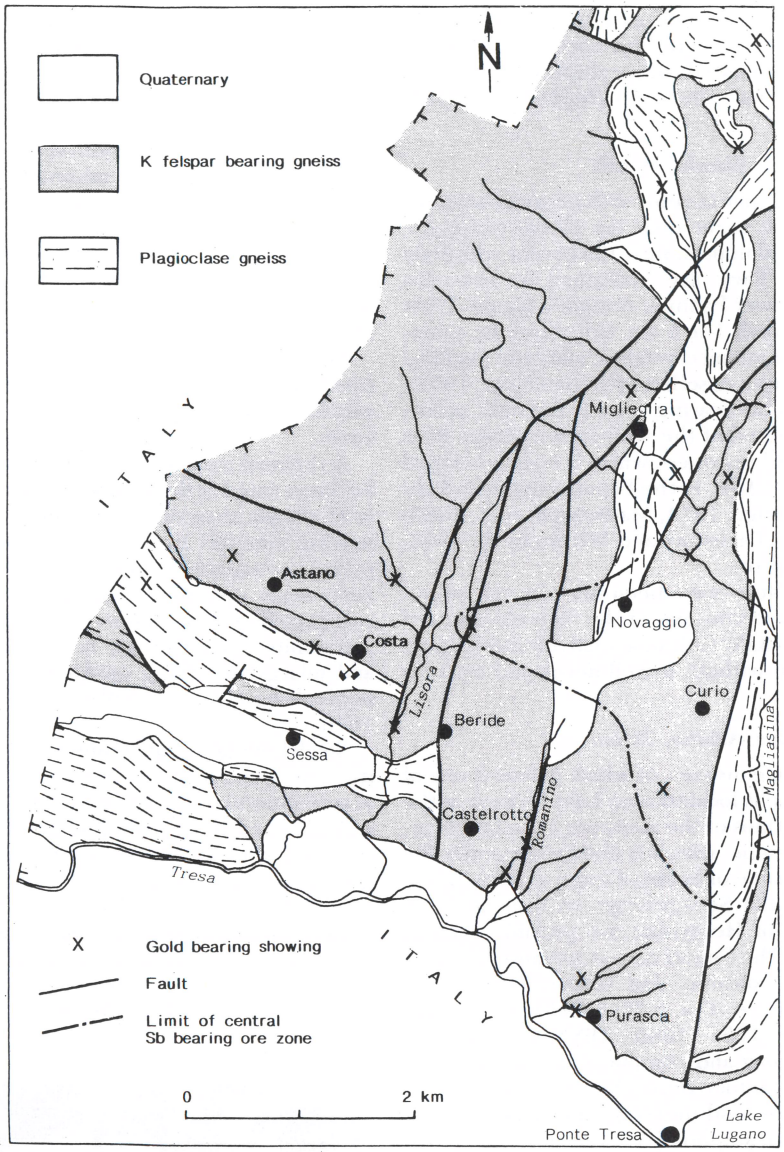


FIG. 6. Gold showings of the Malcantone region, 10 km southwest of Lugano (simplified after Koppel, 1966).

gold particles, with a diameter of a few microns, are associated with pyrite, disseminated pitchblende, cobaltite, and linnaeite. Field evidence is not sufficient as yet to determine whether the Trun gold occurrences can be correlated along the strike with those in the Disentis area.

The main interest of the Disentis prospect lies in the fact that in a few years the area, which was known only for occasional and insignificant gold specks, has developed into an important exploration target. At present more information is needed for a better understanding of the emplacement of gold-bearing mineralization, its age, and its structural control. Studies in this direction are in progress. Some similarities with the Hemlo deposit (Ontario, Canada) have been tentatively suggested as a working hypothesis (David

Bell, pers. commun.), such as a sheared metasedimentary and metavolcanic host rock, tabular steep orebodies, disseminated mineralization type, and strong hydrothermal alteration (Burk et al., 1986; Kuhns, 1986).

The Penninic Alps: Gondo, Wallis

Pyrite-bearing quartz veins with irregular amounts of gold and silver occur near the village of Gondo, south of the Simplon pass, near the border with Italy (Gysin, 1930). They are contained in two-mica gneisses of the lower Pennine Antigorio nappe. Their width rarely exceeds 1 to 2 cm. Schapbachite, a mineral composed of mixed crystals of matildite ($AgBiS_2$) and galena, has been described (Grünenfelder, 1957).

The Gondo gold-bearing area is the only occurrence in Switzerland of the well-known Monte Rosa metallogenic gold province, which is well developed south of the Swiss Alps, in the Piemont region in Italy (Omenetto and Brigo, 1974; Mastrangelo et al., 1983; Diamond, 1986; Diamond and Wiedenbeck, 1986; Curti, 1987a and b).

Past mining efforts have been sporadic and unsuccessful, partly also because of the high elevation of the area, (1,000–3,000 m), in a relatively inaccessible mountain region without a well-developed road infrastructure.

The Southern Alps: Astano, Ticino

The Malcantone district, of which Astano is one of the main villages, is located near Lake Lugano in the basement formations of the southern Alps. In this region the Ceneri zone, which is also known under the wider regional name of Strona-Ceneri zone, is an important unit of the Seengebirge, an ancient metamorphic region of Hercynian and possibly even of Caledonian age. The Ceneri zone is composed of rocks of sedimentary, volcanic, and volcanoclastic origin with clear evidence of a polyphased metamorphic history (Graeter, 1951; Zingg, 1983; Cummings et al., 1987). The long and complicated structural evolution of the Malcantone region has not been analyzed as yet by modern field methods. So-called "Schlingen" or folds with amplitudes in the kilometer range and with steeply dipping fold axes are common (Reinhard, 1953).

The principal rock type in the Malcantone district is an alkali feldspar gneiss. Two-mica and plagioclase gneisses, the latter associated with amphibolite layers, are also frequent. Shear zones of regional significance are generally oriented north-south (Fig. 6).

In the Malcantone district, the occurrence of over 20 sulfide showings has been reported over a surface of approximately 25 km^2 (Dubois, 1931; Burford, 1933; Köppel 1966). Generally they are small and poorly exposed, partly because of a heavy Quaternary fluvioglacial cover. They have generally been described as veinlike bodies, all of which are contained in or are associated with local and regional faults and shear zones. Several are also closely associated with small lamprophyre dikes, which were probably emplaced in shear zones (DuBois, 1931; Bearth, 1932). More detailed work is required in order to ascertain whether this interesting association has not only a spatial but also a metallogenic significance. The most common minerals are pyrite and arsenopyrite, with smaller amounts of pyrrhotite, chalcopyrite, sphalerite, galena, and gold (Fig. 7). Quartz-carbonate assemblages are generally the dominant gangue minerals. Tourmaline and barite occur sporadically.

Sericitization, chloritization, ankeritization, and silicification are typical wall-rock alteration types in relation to the mineralized veins in faults and shear zones.

A regional zonal distribution of the mineralization has been noted in the Malcantone district. In a central or Miglieglia zone, of approximately 4 km^2, antimony-bearing minerals are associated with the prevailing pyrite-arsenopyrite paragenesis (Figs. 8 and 9). In this zone many antimony-bearing minerals have been recognized: native antimony, stibnite, berthierite, jamesonite, boulangerite, tetrahedrite, pyrargyrite, and miargyrite. Many oxidation products of these minerals have also been identified (Bachmann et al., 1986).

Small but high-grade mineralized clusters with visible gold grains up to 2 mm in diameter are composed of several antimony-bearing sulfosalts, as well as pyrite and arsenopyrite. These gold grains are not visible, even with a hand lens, in weathered or broken hand specimens, but become clearly visible as soon as the specimen is cut and polished (Figs. 8 and 9).

In the outer or Astano zone, in which pyrite and arsenopyrite are the main ore minerals, many showings contain 1 to 2 g/metric ton of gold.

The major deposit of the outer zone, and for that

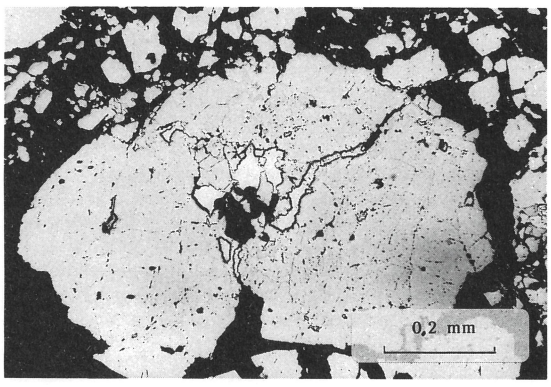
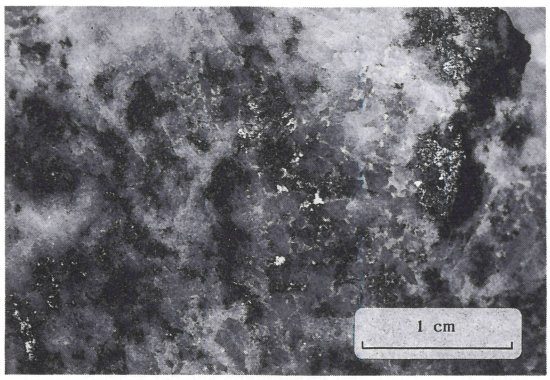


FIG. 7. Astano, Ticino. Gold veinlet in pyrite crystal.



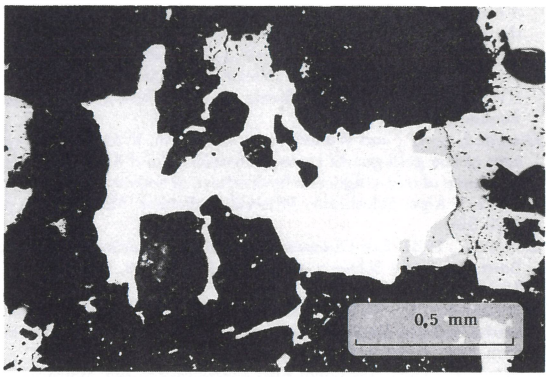


FIG. 8. Miglieglia, Ticino. Visible gold (white) accompanied by tetrahedrite (dark gray) in a quartz-carbonate matrix (light gray).

FIG. 9. Miglieglia, Ticino. Gold (white); tetrahedrite (light gray) in quartz matrix (dark gray).

matter the whole Malcantone district, is the abandoned Costa mine, 1 km southeast of Astano. The deposit is located on a shear zone, which can be followed in the field and by geophysical methods for over 1,200 m. Underground mining operations ceased at the beginning of World War II. Past production is believed to be small, mainly from high-grade ore. Grades of over 20 g/metric ton of gold have been sampled recently on surface and in underground pillars. Metallurgical tests indicate that gold is associated mainly with arsenopyrite (47%) and to a lesser extent with galena (26%), pyrite (11%), and sphalerite (7%). Free gold is also present (9%).

Conclusions

The highly diversified geologic environments in which the various known Swiss gold deposits occur do not permit the formulation of a uniform and comprehensive metallogenic theory. Is the gold potential of Switzerland limited to the extent of known prospects, or, on the contrary, can unknown deposits expect to be found? A somewhat optimistic outlook does not find its justification only in the recent case history of the Disentis area, but recent studies of the Pennine Alps indicate that gold values are associated with several small sulfide deposits in the Turtmantal district, 25 km west of Brig, Canton Wallis (Della Valle, 1988).

The growing need for a modern study of the nature, genesis, and potential of Swiss gold deposits has been recognized by the Swiss National Science Foundation, which has recently granted the University of Geneva the funds necessary for a research project in this field.

Acknowledgments

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