3. Arsenopyrite-rich quartz veins hosted by metabasalts (Bernheim group of mines).

The cumulative gold production of these mines up to 1984 was 31,761, 1160, 527, and 1888 kg, respectively (Bartholomew 1990).

This work aims firstly to provide basic mineralogical and geochemical data for the different types of deposits, all of which are in close proximity to each other. Secondly, the genetic relationships between the various styles of mineralization are discussed with the aim of formulating a metallogenetic model.

Regional geology

Regional aspects are described in detail in part I (Blenkinsop et al. this issue). Basically, the Harare-Bindura-Shamva greenstone belt is surrounded by various granitoid complexes that intrude the volcano-sedimentary sequences. The centre of the greenstone belt is occupied by the Chinamora Igneous Complex which comprises a series of gneissic tonalite-granodiorite plutons, associated migmatitic injection gneiss and the immense, probably tabular, body of the later Chinamora porphyritic granite (Baldock et al. 1991). The lithologies of the greenstone belt are regarded as correlatives of the Bulawayan Group and are constrained in age to younger than 2.86 Ga, the age of the gneissic "basement", and older than the Sesombi-type tonalite/granodiorite intrusives which were deformed between 2.68–2.62 Ga (Baldock et al. 1991).

The earliest sequence within the greenstone belt is the Iron Mask Formation, which partly surrounds and overlies the later Chinamora Igneous Complex. The Iron Mask Formation comprises a succession of metamorphosed felsic volcanics and associated metasediments including prominent bands of sulfide-facies iron-formation, phyllites, meta-arenites and quartzose schists.

The Iron Mask Formation is overlain by the Arcturus Formation which consists mainly of tholeiitic basalts, locally with pillow-structures, and subordinate iron-formations and chert bands.

The Mount Hampden Formation, which overlies the metabasalt sequence, comprises graphitic to tuffaceous meta-argillites, or phyllites, representing fine-grained deep water sediments. They are accompanied by bands of iron-formation and cherts. Locally, some limestone deposits are present.

The Passaford Formation is the stratigraphically uppermost and most complex sequence mainly comprising felsic metavolcanics and metasediments varying from quartzites to reworked volcaniclastics and wackes. In the area investigated in this study, the greenstone belt lithologies are metamorphosed to greenschist facies conditions.

Late Archean granitoids outside the greenstone belt (external group) mainly comprise the extensive Chilimanzi suite with ages clustering around 2.6 Ga (Vinyu 1994). Internal granitoid stocks within the greenstone belt have been dated by U/Pb zircon techniques at 2664 ± 15 Ma (Jumbo granodiorite), 2649 ± 6 Ma (Bindura granodiorite), and 2618 ± 6 Ma (Glendale tonalite) by Vinyu et al. (1996). Notably, only the older two granitoids have significant gold mineralization associated with them (i.e. Mazowe and Freda-Rebecca mine, respectively).

Mine geology

The following descriptions are based on the work of Ferguson and Wilson (1937), Tomschi et al. (1986), Tomschi (1987), Baldock et al. (1991), Höppner and Oberthür (1994), Hein et al. (1995) and recent field observations. Figure 1 shows the localities of the mines within the gold field.

Mazowe Mine

Mazowe Mine is a merger of several formerly independent mines of which the old Jumbo mine was the single most important producer. A total production of 31,761 kg of gold was declared between 1890 and 1984. Host rocks to the mineralization are the Jumbo granodiorite stock and the slightly earlier, comagmatic Jumbo quartz-feldspar porphyry, both intrusive into mainly metadacites and metasediments of the Passaford and Mount Hampden Formations. The ore bodies are found in subparallel, planar shear zones striking nearly E–W and dipping 25–45°N. The major ore bodies, formerly independent mines, are known (from S to N) as the Carn Brae, Birthday, Nucleus, Jumbo, Connaught, Bojum, Bucks, SOS, and Flowing Bowl reefs, which are separated on outcrop by between 100 and 300 m and can be followed for about 500 to 1500 m along strike (see Fig. 5 of Blenkinsop et al. this issue). The major sections of the E–W striking reefs are hosted in the Jumbo granodiorite stock, but also extend eastwards into the Jumbo porphyry and greenstones. The reefs are exposed by underground mining which presently extends down to the 28th level (about 900 m below the shaft collar). The reefs have average widths of 20 cm but commonly split into mineralized stringer-zones some 30–60 cm wide which may join again or cross to adjoining reefs.

The ores are dominated by pyrite, which is often massive, quartz and rarer carbonate, which together form veins usually a few centimetres wide. Gold is mainly associated with the pyrite, and to a lesser degree with quartz. Contacts of the veins with the granodiorite or porphyry country rocks are sharp, and little sign of hydrothermal alteration is obvious in the adjoining rocks. Thin sericite selvages may be developed, and up to 1 cm wide scheelite veinlets, lenses or pockets locally accompany the reefs on both their hanging and footwall contacts.

Bernheim Mine

The "Bernheim Group" includes a number mines in close proximity to each other and with similar geology and ore mineralogy. Access to the workings is possible via the 160 m deep Lonrho shaft, situated about 1 km SW of Alice mine. Crosscuts have exposed the Rothschild and Bernheim reefs to the N, and the Highland Chief and Gardner-Williams reefs to the S (see Fig. 8 of Blenkinsop et al. this issue). Samples were collected from the latter two reefs and from the stockpile.

The country rocks consist of locally porphyritic metabasalts, metatuff and interbedded slaty bands of the Arcturus Formation. The reefs occupy WNW-trending shear zones dipping 70–80°SSE. They consist of dark grey quartz veins, usually about 0.5 m wide, which tend to pinch. Abundant, locally massive or disseminated arsenopyrite, pyrrhotite and pyrite may comprise 5–10% of the ore. Scheelite was reported from the Rothschild Parallel reef (Ferguson and Wilson 1937) but was not detected in the samples of the present study.

Stori's Golden Shaft and Alice mines

Stori's Golden Shaft and the adjacent Alice mine are very similar in their ore types and are thus described together. In contrast to the producing Stori's mine, Alice mine is dormant and only a limited number of samples were obtained from recent prospecting activities.

The ore bodies at Stori's Golden Shaft mine occupy shear zones in locally pillowed metabasalt of the Arcturus Formation. The reefs mainly consist of auriferous quartz with ubiquitous, locally coarse (up to 1 cm in diameter) scheelite and minor calcite.

The Stori's Main Reef tends to be arcuate and convex to the north. It dips 58–68°N and NE, has been exposed down to the 9th level (ca. 300 m below shaft collar), and it is most fully developed on the 6th level where it has been exposed for 224 m along strike (see Fig. 10 of Blenkinsop et al. this issue). The quartz veining is very irregular and ranges in width from less than 10 mm to 2 m. Locally, the reef divides into scores of veinlets, and splaying has molybdenite, and rare gold. Bluish and greenish copper stainings are visible in the open pit.

Structural controls on gold mineralization

For an in-depth structural analysis, the reader is referred to the accompanying work (Blenkinsop et al. this issue). Briefly, mineralization in the Mazowe group of mines is hosted in shear zones which contain narrow quartz ± sulfide veins. Mineralization and quartz veining was syn-tectonic. At the Mazowe mine itself, seven major subparallel shear zones dip gently to the north, and have a dominantly reverse movement. At Bernheim mine, the major shear zones dip steeply SSW, and have gently plunging slickenside lineations and dextral-reverse shear senses. Subvertical dextral shear zones with the same strike occur at Stori's Golden Shaft mine, together with sinistral shear zones dipping to the ENE and NW. The major shear zones in all the mines are compatible with a northerly shortening direction. The structural analysis, therefore, shows that mineralization in all the mines of the Mazowe area is likely to be part of a single tectonic event. The northerly shortening direction is also the shortening direction of a minor late Archean D2/D3 deformation event. The mineralization cannot be related to any regional shear zones, or to strains that may have resulted from intrusion of the late Archean granitoids.

Ore mineralogy

Mazowe mine

Pyrite is the dominant sulfide (> 95% of the ore minerals). It occurs in the form of massive and layered ores, of which both fine- (grain diameters < 50 μm) and coarse-grained (mm-size) varieties are present. The pyrite grains are compact, homogeneous, and idiomorphic to hypidiomorphic in shape. They usually form aggregates that are locally fractured. Pyrrhotite, sphalerite, chalcopyrite, galena, arsenopyrite and cobaltite are present in minor quantities in the ores. Gold recoveries of > 90% are achieved by a combination of gravity separation and cyanide leaching, indicating that gold is present in a particulate form. Gold occurs as roundish inclusions (5–30 μm in diameter) in pyrite or in rarer instances in gangue, and as thin films along grain contacts or cracks in pyrite. Occasionally, gold also forms large (up to 200 μm in diameter), irregular grains in pyrite or gangue. Silver contents of the gold, analyzed by microprobe, range between 7 and 20 wt% Ag (Tomschi 1987; $n = 121$) in gold grains of different samples collected throughout the mine. The silver contents of gold vary in an unsystematic manner with little correlation with depth or from one reef to the other.

A late association of a number of Bi-minerals is notable in the ores, namely native bismuth, bismuthinite, tetradymite (Bi_2Te_2S), cosalite ($Pb_2Bi_2S_5$) with distinct Ag contents (0.49–1.95 wt% Ag, $n = 10$), joseite A (Bi_4TeS_2) and ingodite (Bi_2TeS) (Table 1, Fig. 2). The presence of native Bi, which has a melting point of 271.5 °C, sets an upper temperature limit for the formation of this specific paragenesis. Scheelite mainly occurs as thin veinlets or oval grains along the selvages of the veins, both at their hangingwall and footwall contacts.

Bernheim mine

The sulfide-rich ores from the Highland Chief and Gardner-Williams reefs are dominated by arsenopyrite (>80% of the sulfides). Other sulfides include chalcopyrite, pyrrhotite, pyrite, and sphalerite, in approximate order of abundance. Arsenopyrite either occurs as needle-shaped crystals, several millimetres in length, or as numerous smaller grains forming aggregates, or in rather massive ores. Gold grades usually correlate with arsenopyrite contents. Accordingly, microscopic gold of variable shapes and sizes (up to some 100 μm large) is found along grain contacts, in cracks, and as individual grains in gangue close to arsenopyrite.

Stori's Golden Shaft and Alice mines

The ores essentially comprise quartz veins with free gold of variable grain size. Fine-grained, chert-like quartz from Stori's reef contains numerous grains of gold (diameters from < 10 to 50 μm) having roundish to drop-like shapes which are disseminated throughout the quartz matrix or arranged in subparallel trails. The gold grains are occasionally intergrown with pyrite, chalcopyrite and pyrrhotite. In coarser varieties of quartz, gold may be visible and reaches millimetre and rarely centimetre-sizes. It is present in the form of irregular grains, filigree aggregates or thin foils. In the veins, sulfides are generally rare while scheelite is found throughout Stori's Golden Shaft mine. Local sulfide-rich ores (2-level east, 9-level at Stori's Golden Shaft mine) are usually gold-poor. The sulfide assemblage in these ores comprises chalcopyrite, pyrrhotite, pyrite, and subordinate arsenopyrite and sphalerite. Scheelite is usually dispersed in the quartz veins and was observed in all the major quartz vein ores at Stori's Golden Shaft mine. Individual scheelite crystals may reach centimetre-size. The close spatial association of gold with scheelite (Fig. 2c) indicates contemporaneous deposition of gold and scheelite. Vein selvages often carry abundant fine grained rutile and/or titanite.

To summarize, the major ore mineralogical features of the granodiorite hosted mineralization at Mazowe mine is pyrite rich, and gold grades correlate with sulfide contents. In contrast, arsenopyrite is the dominant sulfide at Bernheim mine. The mineralization at Stori's Golden Shaft and Alice mines is characterized by quartz reefs poor in sulfides.

Vein mineralogy and fluid inclusion studies

Samples and analytical procedures

Fluid inclusions were investigated in samples from the mines of the Mazowe area by applying microthermometry, Raman spectroscopy, and SEM-EDX techniques. The samples from the Mazowe mine cover the major mineralized structures, i.e. the Nucleus, the Birthday, and the Connaught Reefs. Samples from the Alice mine are from the Alice Reef, 2-level, and the North Reef, 2-level. The Bernheim mine samples were collected on the stockpile, and the samples from Stori's Golden Shaft mine are from the by-pass east (1-level), Patrick's Reef (3-level), and Stori's Reef (3-level). Microthermometry was performed using a FLUIDINC heating and freezing stage calibrated with a commercial set of synthetic fluid-inclusion standards. A RAMANOR U-1000 served for routine Raman analysis of gaseous and solid phases. Electron microscopy was carried out on a Cambridge INSTRUMENTS-SEM (Stereoscan 250 MK3) with a coupled EDX equipment using pure Co and Kakanui pyroxene as standards. Isochores have been constructed from the equations of Holloway (1981), Bowers and Helgeson (1983), Zhang and Frantz (1987) and Brown and Lamb (1989) using the software package FLINCOR (Brown 1989).

Vein mineralogy

The silicate parageneses of the mineralized structures are largely similar in the individual deposits which are therefore discussed together.

Quartz is the major constituent of the veins. Mineralization commonly starts with an early quartz with frequently developed fibrous, crack-seal textures indicating precipitation during rapid extensional opening of the shear veins in an overall brittle regime. Bow-shaped