Gold occurrence, mineral textures and ore fluid properties at the Viper (Sappes) epithermal Au–Ag–Cu orebody, Thrace, Greece

SP Kilias, M Paktsevanoglou, M Giampouras, A Stavropoulou, D Apeiranthiti, I Mitsis
National and Kapodistrian University of Athens, Fac. Geology and Geoenvironment, 157 84, Athens, Greece

J Naden, SJ Kemp, TJ Shepherd
British Geological Survey, Keyworth, Nottingham, NG12 5GG UK

T Koutles
Thrace Minerals S.A. 74, Papadima Str., PC 69300, Sappes, Rodopi, Greece

C Michael
IGME, Regional Branch of Eastern Macedonia and Thrace, Brokoumi 30, Xanthi 671 00, Greece

C Christidis
Aristotle University of Thessaloniki, Faculty of Sciences, School of Geology, 541 24 Thessaloniki, Greece

Abstract. Optical and electron microscopy studies coupled with Laser ablation analyses of pyrite and enargite of the Viper orebody at the Sappes gold prospect in Thrace, north-east Greece show that it has a number of characteristics in common with high sulfidation (HS) epithermal mineralisation. These include hypogene alunite, vuggy quartz and pyrite+enargite as the dominant sulfides. However, it also exhibits features that are not typical: (i) mineralization is flat-lying rather than an upwardly flaring vertical pipe-like structure more typical of HS mineralisation; (ii) high grade (>30 g/t) sections of drill core have an illitic pattern of alteration more characteristic of low-sulfidation mineralisation; (iii) areas of colloform–banded and chalcedonic quartz suggest intermediate and low sulfidation epithermal mineralisation and these can also be correlated with high-grade intersections, and (iv) the co-precipitation of gold with pyrite and enargite. Fluid inclusion data indicate salinities of 1.5 to 5.3 wt % NaCl eq. and homogenization temperatures ranging from 156 to 266°C.

It is suggested that the Viper orebody is the result of recurring low-sulfidation argillic alteration, and auriferous high-sulfidation advanced argillic alteration events. The distribution of gold appears to be controlled by secondary porosity caused by multi-stage hydrothermal brecciation and widespread void-development.

Keywords. Pyrite, enargite, gold, high-sulfidation, epithermal, fluid inclusion, Greece

1 Introduction

The Viper orebody at the Sappes gold prospect in Thrace–north-east Greece (Fig. 1), is a high-grade Au–Ag–Cu deposit (280 kt @ 19.5 g/t Au; 9 g/t Ag; 0.4 % Cu—Glory Resources, 2012). The economic mineralization forms a northwesterly-trending, elongate "blind", flat-lying ~ 60 m thick orebody, and has estimated dimensions of 550 by 1310 m, at a depth of approximately 200–240 m below the current surface. Hydrothermal ore occurs as multi-stage silicified hydrothermal breccias, and disseminations in stockwork quartz veinlets and vug-fillings, within altered calc-alkaline to high–K Miocene andesitic–dacitic volcanic rocks. The host volcanics were extruded in a small volcano-sedimentary basin developed at the contact between the Rhodope metamorphic core complex and the Circum-Rhodope belt (Voudouris 2006, and references therein). It is classified as a high-sulfidation (HS) epithermal deposit (Arribas 1995; Cooke and Simmons 2000; Hedenquist et al. 2000) with an oxidation overprint.

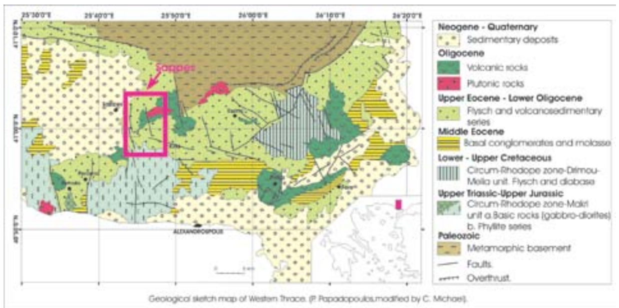

Figure 1. Geological map showing the location of the Sappes gold prospect.

2 Alteration and Mineralogy

In terms of alteration, optical microscopy study and portable infrared mineral analyser PIMA and XRD analyses of drill core identify the apparent superposition of at least two events of gold/electrum-associated advanced argillic alteration (AAA) and one stage of argillic alteration and silicification (AAS), which are strongly correlated with hydrothermal breccias and veinlets (Fig 2). Stage I AAA is pervasive and characterized by quartz, alunite, and pyrite, with localized kaolinite/dickite. The alunite forms flaky assemblages, fine-grained clusters, euhedral coarse grains and irregular tabular to bladed grains. Stage II AAA overprints previously altered rocks and is confined to crosscutting crustiform-banded quartz–alunite–woodhousite–svenbergite–pyrite veinlets and their haloes, and vugs. Alunite occurs as fine-grained clusters, pseudocubic crystals and rosettes in open vugs, whereas kaolinite/dickite may locally fill all types of cavities. AAS alteration is characterized by illite (sericite), quartz and pyrite without alunite, in pseudomorphs after feldspar (plagioclase) crystals. Its relationship to both stages of AAA is unclear, although, crosscutting relationships suggest that at least stage II AAA post-dated argillic alteration.

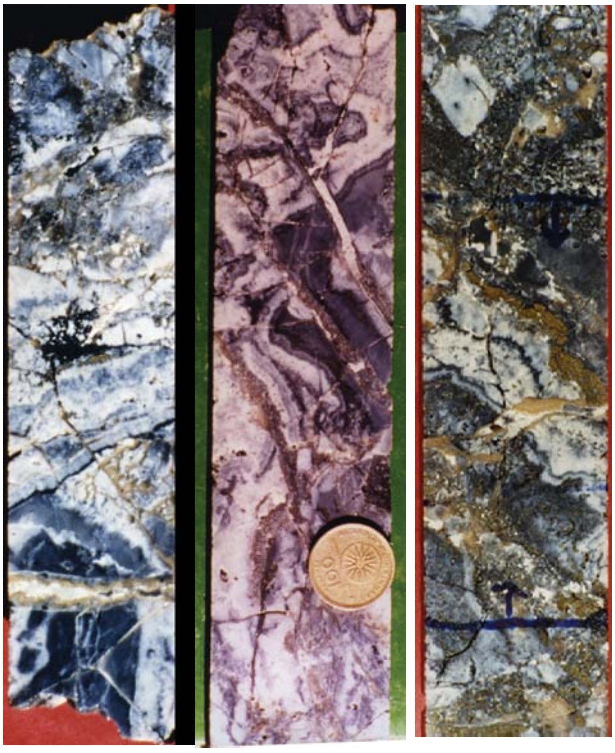

Figure 2. Drill core from a high-grade ore zone showing repeated silicification and alteration events

At the microscopic scale a variety of complex Pb–Bi–Cu sulfosalts, tellurides and selenides are intimately associated with gold. Based on optical microscopy, SEM-EDS and Laser ablation ICP-MS studies, there are at least three major modes of occurrence for micron-sized gold at Viper (Fig. 3) that in decreasing order of abundance include: (i) readily liberated and discrete free native gold/electrum grains, intergrown with metallic minerals, quartz and alunite; (ii) discrete free native gold/electrum grains either enclosed in sulfides (i.e. pyrite, enargite, goldfieldite), in random position, or along growth zones in pyrite; and (iii) sub-micron to micron-sized inclusions or chemically held gold within, pyrite and enargite. Enargite constitutes the most important and widespread Cu-ore mineral, comprising more than 30 per cent of the total sulfide content. Enargite is commonly intergrown with its polytype luzonite and with variable amounts of mainly pyrite, Pb–Bi–Cu sulfosalts, tellurides and selenides, gold, quartz, alunite, kaolinite/dickite. Elongate prismatic crystals are common and found in druse-like cavities in breccias and veinlets. The bulk of Au–Ag–Cu mineralization is invariably associated with AAA assemblages. Silica textures associated with high-grade gold ore include colloform-banded plumose quartz, colloform-banded jigsaw quartz, ghost-sphere and moss-textured quartz, and to a lesser extend feathery/flamboyant textured quartz and spider quartz–veinlets and are indicative of rapid deposition, such as might occur during boiling (sensu Moncada et al. 2012) The textures that are most closely associated with elevated concentrations of Au are colloform-banded plumose quartz, and/or colloform-banded jigsaw quartz.

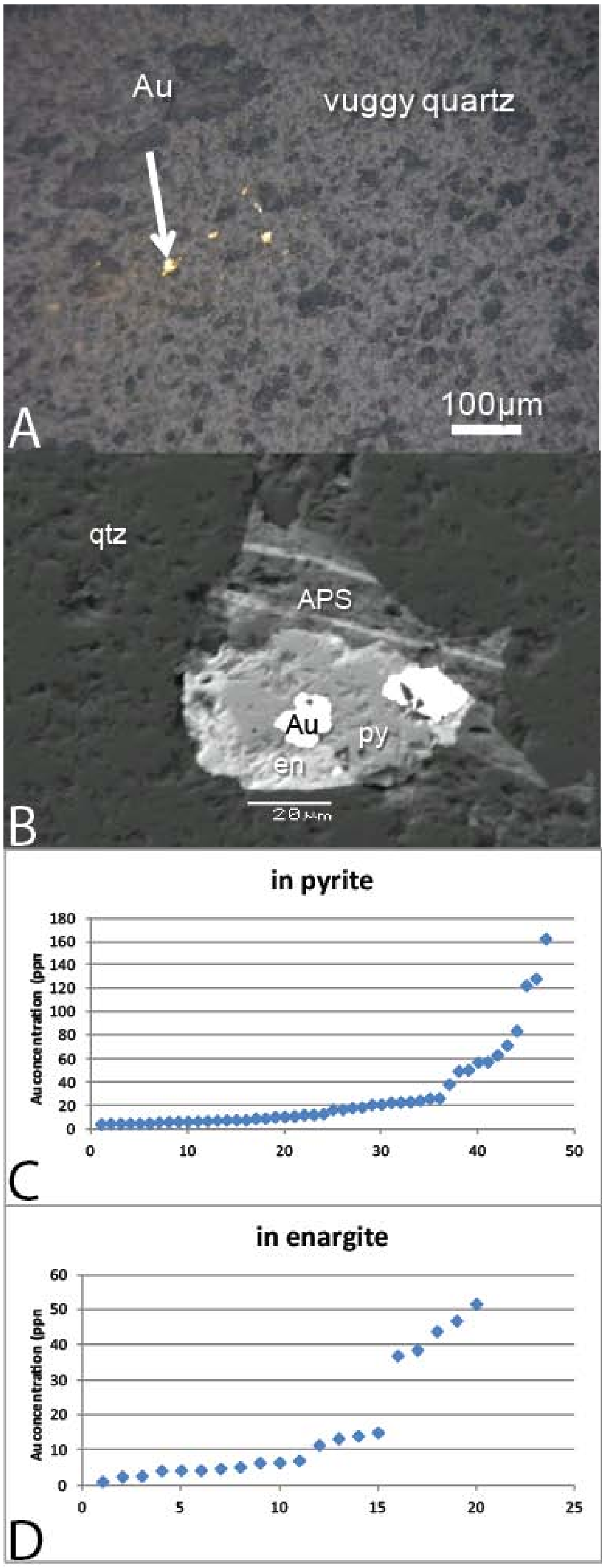

Figure 3. Different types of gold occurrence A: free gold; B: discrete free native gold/electrum grains enclosed in a microassemblage of pyrite, enargite and an alumina-phosphate sulfate (APS) mineral; C and D: Concentration of gold in sulfides and sulfosalts determined by laser ablation ICP-MS.

2 Fluid Inclusion Microthermometry

Preliminary microthermometric measurements (Fig. 4) of primary aqueous liquid-rich fluid inclusions in auriferous plumose and jigsaw quartz from breccias and veinlets in high-grade (>11–63.4 g/t) intersections have salinities of 1.5 to 5.3 wt% NaCl eq. and liquid homogenization temperatures ranging from 155.9° to 266°C, with most values between 178° and 244°C (Fig. X). They coexist with low-density vapor-phase inclusions, suggesting low-pressure conditions. Boiling could have resulted in gold deposition, but precipitation of pyrite and enargite in response to rapid cooling of the system may have been the main control on deposition of pyrite- and enargite-hosted gold.

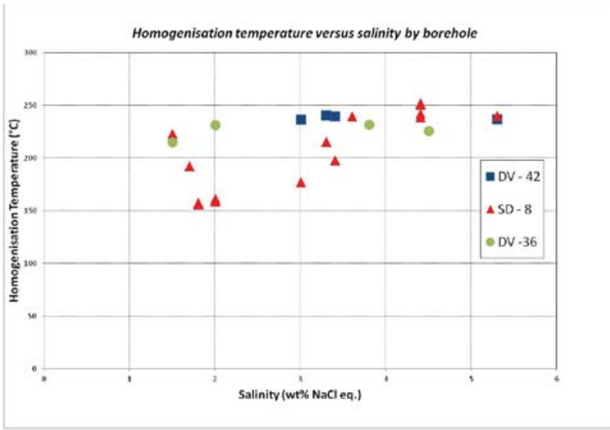

Figure 4. Preliminary fluid inclusion data

2 Discussion and Conclusions

Although similar in many respects to classic high-sulfidation epithermal deposits, the Viper deposit ~~it~~ has some atypical features: (i) drilling shows that the mineralization is flat-lying rather than an upwardly flaring vertical pipe-like structure more typical of HS mineralisation; (ii) PIMA analyses show that high grade (>30 g/t) sections of drill core have an illitic pattern of alteration more characteristic of low-sulfidation mineralisation; (iii) some sections of drill core show significant development of colloform–banded and chalcedonic quartz, typical of intermediate and low-sulfidation epithermal systems, rather than vuggy quartz. Furthermore, this can be correlated with high-grade (>30 g/t) intersections, and (iv) the co-precipitation of gold with pyrite and enargite as indicated by pyrite- and enargite-hosted gold inclusions the Laser ablation analyses (Figs. X and X).

An important feature of the Viper deposit is the apparent superposition of possibly recurring “low sulfidation” argillic alteration, and auriferous high-sulfidation AAA events. Gold and associated metals are interpreted to have been transported and deposited by magmatic fluids. In general, the distribution of the gold grade seems to be controlled by secondary porosity caused by multi-stage hydrothermal brecciation and widespread void-development.

Acknowledgements

JN publishes with permission of the Executive Director, British Geological Survey (NERC).

References

Arribas A Jr (1995) Characteristics of high-sulfidation epithermal deposits and their relation to magmatic fluid. In: Thompson JFH (ed) Magmas, Fluids, and Ore Deposits. Min Assoc Canada Short Course 23: 419–454

Christofides G, Pecskay, Z, Eleftheriadis G, Soldatos T, Koroneos A, (2004) The Tertiary Evros volcanic rocks (Thrace, northeastern Greece): Petrology and K/Ar geochronology. Geologica Carpathica, 55: 397–409

Cooke, D.R., and Simmons, S.F., (2000) Characteristics and genesis of epithermal gold deposits: Reviews in Economic Geology, 13:241-244.

Glory Resources (2012) website http://www.gloryresources.com.au; accessed Nov 2012

Hedenquist JW, Arribas AR, Gonzalez-Urien E (2000) Exploration for epithermal gold deposits. Rev Econ Geol 13: 245–277

Moncada, D., Mutchler, S., Nieto, A., Reynolds, T.J., Rimstid, J.D., Bodnar, R.J. (2012) Mineral textures and fluid inclusion petrography of the epithermal Ag–Au deposits at Guanajuato, Mexico: Application to exploration. Journal of Geochemical Exploration 114:20-35.

Voudouris P, A comparative mineralogical study of Te-rich magmatic-hydrothermal systems in northeastern Greece. Mineralogy and Petrology, 87: 241-275.