$^{40}Ar/^{39}Ar$ dating of pyrite from gold deposits in low grade terranes.

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SUMMARY

$^{40}Ar/^{39}Ar$ dating of fine-grained white micas from gold deposits, formed under low-grade metamorphic conditions, is often complicated by multiple mica populations, recoil loss/redistribution of $^{39}Ar_K$ and loss of ^{40}Ar. Recent studies have suggested that pyrite armours enclosed mica inclusions against argon loss and, therefore, may provide improved age information in low grade terranes.

This premise is tested by applying the $^{40}Ar/^{39}Ar$ pyrite dating method to three gold deposits in Victoria, namely Stawell, Fosterville and Walhalla. These analyses indicate that, although pyrite behaves as a partially closed system, the method is able to 'see through' younger hydrothermal overprints. At the same time, $^{40}Ar/^{39}Ar$ analyses of pyrite from the Fosterville gold mine failed to constrain the timing of gold deposition due to the encapsulation of detrital mica grains by the pyrite. These results emphasize the importance of petrological control on sample selection and combining $^{40}Ar/^{39}Ar$ analyses of pyrite and matrix mica.

Key words: geochronology, $^{40}Ar/^{39}Ar$, pyrite. gold

INTRODUCTION

The timing of gold mineralisation associated with low-grade metamorphic terranes is often difficult to constrain due to the paucity of suitable minerals for U-Pb geochronology and the fine-grained nature of the white micas usually available for $^{40}Ar/^{39}Ar$ dating. $^{40}Ar/^{39}Ar$ analyses of fine-grained micas typically yields discordant apparent age spectra due to factors such as multiple mica populations (e.g. cleavage-forming white micas plus detrital micas), recoil loss and/or redistribution of $^{39}Ar_K$, excess argon contamination and ^{40}Ar loss (e.g. Fergusson and Phillips, 2001).

In a recent study, Smith et al. (2001) analysed pyrite grains from basalts and speculated that pyrite may armour encapsulated mica inclusions, thus preventing ^{40}Ar loss and negating the effects of $^{39}Ar_K$ recoil. Phillips and Miller (2006) showed that pyrite, containing coarse white mica inclusions, behaves as a partially closed system with respect to argon loss. Nonetheless, this work also demonstrated that multiple laser probe analyses of single pyrite grains provides improved age constraints on gold mineralisation compared to analyses of matrix white mica. Importantly, the pyrite dating method is able to 'see through' younger overprinting events that reset or partially reset matrix micas.

In this study, we test the application of the pyrite dating method to three Victorian gold deposits formed during low metamorphic grades; namely the Stawell, Fosterville and Walhalla gold deposits.

METHOD AND RESULTS

Samples were collected from well-characterised gold lodes associated with the Stawell, Fosterville and Walhalla deposits. All three localities contain gold-bearing pyrite and associated cleavage-forming fine-grained white micas, both in the matrix and as inclusions in pyrite. Pyrite and matrix white mica separates were prepared for $^{40}Ar/^{39}Ar$ dating from the three deposits. In the case of the Stawell deposit, the pyrite-bearing sample was collected within the thermal aureole of the younger Stawell pluton.

The samples were irradiated in position 5c of the McMaster University nuclear reactor, Canada, together with the fluence monitor GA1550 (age = 98.8 ± 0.5 Ma; Renne et al., 1998). $^{40}Ar/^{39}Ar$ step-heating analyses were undertaken on a VG3600 or VG5400 mass spectrometer equipped with a Daly detector. Analytical procedures followed those described by Phillips and Miller (2006) and Reid et al. (2005). Decay constants are those of Steiger and Jager (1977). Unless otherwise stated, uncertainties are reported at the one sigma level.

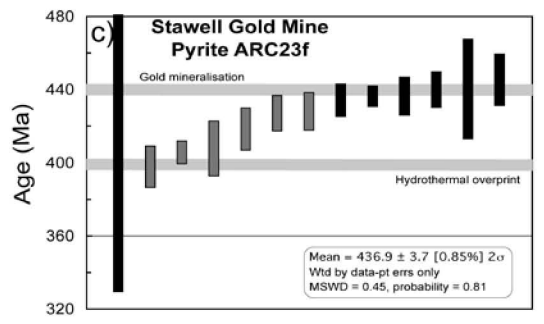

Figure 1. Diagram showing $^{40}Ar/^{39}Ar$ age results obtained from the high temperature heating steps of single pyrite grains from sample JM-23f, Stawell gold mine. Each bar represents a single grain analysis, with the height of each bar reflecting ±2σ uncertainties. Also plotted are the ages of gold mineralisation (~440 Ma) and the matrix micas (~400 Ma).

Matrix white mica from the ~440 Ma Stawell gold deposit yielded a discordant age spectrum with a total-gas age of ~400 Ma, attributed to hydrothermal overprinting related to intrusion of the Stawell granite. Single pyrite grains from the same sample produced high temperature ages ranging from ~400 Ma to ~440 Ma (Fig. 1). Matrix mica from the Walhalla deposit sample also produced a discordant age spectrum, indicative of recoil loss/redistribution of $^{39}Ar_K$, with a total-gas age of 370 ± 3 Ma. A similar age of 367 ± 2 Ma was obtained from mica-bearing pyrite from the same Walhalla sample. $^{40}Ar/^{39}Ar$ step-heating analyses of white mica from a hydrothermally overprinted dyke in the Fosterville gold mine gave an age ~370 Ma, whereas laser probe analyses of detrital muscovite grains from the ore zone gave ages of ~500 Ma. Single pyrite grains from the Fosterville ore zone sample produced intermediate apparent ages ranging from ~450 to 480 Ma.

CONCLUSIONS

The $^{40}Ar/^{39}Ar$ ages obtained from the Stawell pyrite grains confirms previous results that pyrite behaves as a variably closed system with respect to loss of ^{40}Ar and $^{39}Ar_K$. However, multiple analyses of pyrite grains from a single sample provide improved constraints on the timing of gold deposition. Importantly, the pyrite dating method appears capable of 'seeing through' younger overprint events.

The concordance of matrix mica and pyrite ages from the Walhalla sample suggests that this system has remained undisturbed since the time of gold mineralisation at ~370 Ma.

In contrast to the other localities, pyrite from the ~370 Ma Fosterville deposit contains a mixture of matrix and detrital mica inclusions, the latter being unaffected by hydrothermal alteration and overgrowth by pyrite. This suggests that careful petrological characterisation of pyrite samples is important for selecting suitable material for the pyrite dating method.

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