Timing, Controls and Tectonic Context of Gold Mineralisation in the Southern Uplands-Down-Longford Terrane, Caledonides, Scotland and Ireland.

Samuel Rice, Simon Cuthbert and Andrew hursthouse

Exploration Geosciences Group, School of Science, University of the West of Scotland, Paisley, Scotland, UK.

samuel.rice@uws.ac.uk

Introduction

Development of a global genetic model for gold mineralisation in orogenic belts has been inhibited by the difficulties of constraining and interpreting the tectonic assembly of such belts [11]. In particular, controversy persists over the origins of mineralising fluids and metals [18, 23]. In some cases mineralising fluids could be of entirely metamorphic origin [10, 18]. However, evidence of magmatic fluids is not uncommon [19, 24]. Furthermore, it is now recognised that there are significant mineralogical and geochemical similarities between lode-gold deposits in collisional settings and epithermal and porphyry deposits in the forearc regions of convergent margins [13, 19].

Geological context

The Southern Upland-Down-Longford Terrane (SUDLT; Fig. 1) is well-studied and its geotectonic interpretation largely resolved [22]. Dominantly Ordovician greywacke turbidites in the north represent a forearc accretionary complex. Silurian turbidites in the south represent a syn-collisional foreland basin fold-and-thrust-belt [22].

Gold mineralisation

Gold-bearing lodes are a conjugate pair of D_3 strike-slip faults trending ~NW-SE and ~N-S transverse to the NE-SW D_1 Caledonoid structural grain (Fig. 3) [1, 2, 9, 14, 17]: Gold mineralisation was probably coeval with initiation of strike-slip faulting. Auriferous veins exhibit phyllic alteration haloes: Mineralisation was synchronous with peak hydrothermal alteration (Fig. 2) [14, 17]. The hydrothermal alteration is related to porphyritic granodiorite intrusions: Zoned phyllic and propylitic alteration is developed in brecciated turbiditic greywackes above granodiorite sheets at Black Stockarton Moor (Figs. 1, 2) [3]. The same alteration style is associated with auriferous veins in diorite and granodiorite at Glenhead and Hare Hill (Fig. 1) [2, 14]. This is consistent with exsolution of a magmatic-hydrothermal fluid during final cooling of the intrusions (Fig. 4). Zoned alteration assemblages are developed around gold lodes remote from known igneous intrusions [9, 17]. Heat, fluid and metals could have derived from intrusions and carried gold along D_3 fault zones (Fig. 4). Very low metamorphic grade (prehnite-pumpellyite facies) indicates burial < 5 km (Fig. 5): continental collision was 'soft' [15]. A significant volume of metamorphic-derived fluids seems unlikely.

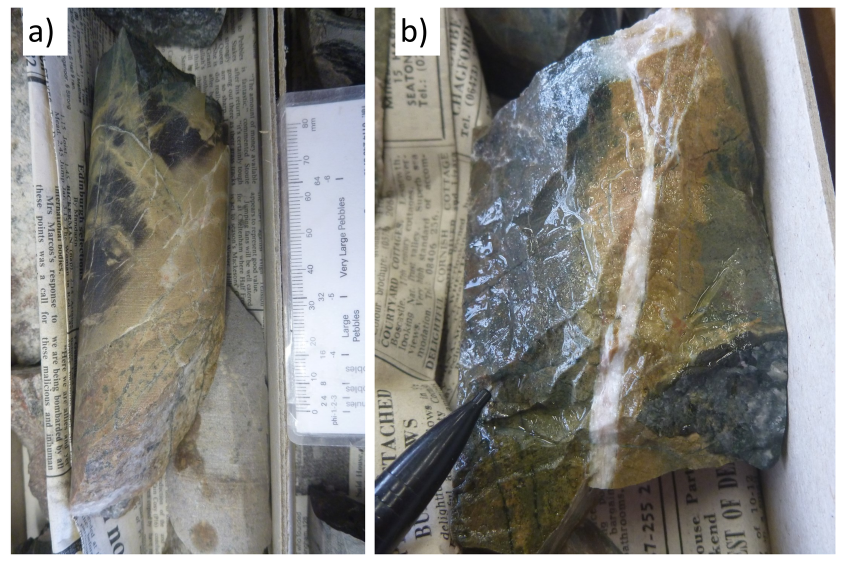

Figure 2: Examples of hydrothermal alteration and veining around porphyritic granodiorite intrusions in drill core from Black Stockarton Moor ; a) sericitised greywacke immediately above a granodiorite contact @221 m in BH7; b) sericite halo around quartz vein above granodiorite sheet @193 m in BH7.

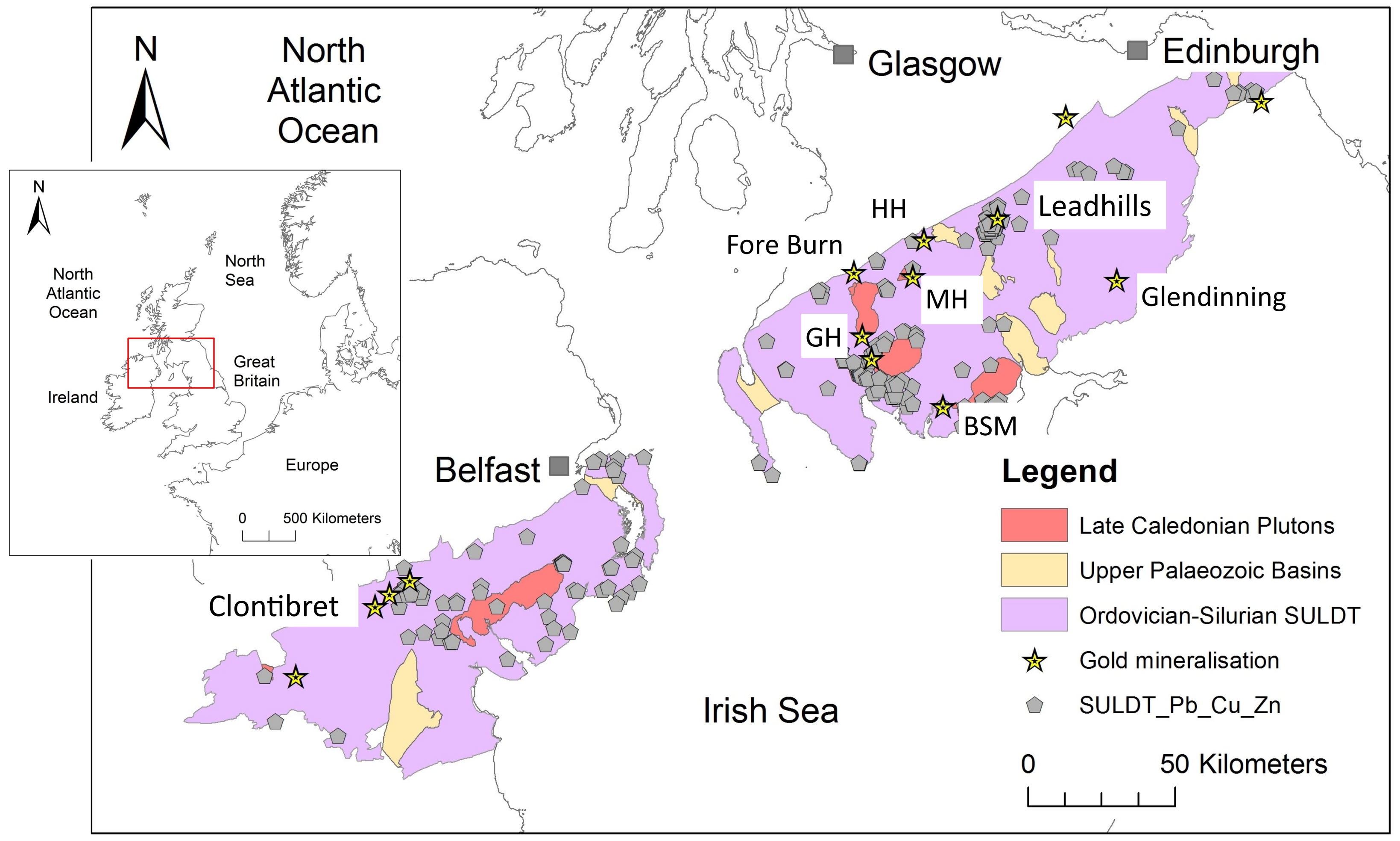

Figure 1: Au and Pb-Zn-Cu occurrences and simplified geology of the SULDT. GH: Glenhead; MH: Moorbrock Hill; HH: Hare Hill; BSM: Black Stockarton Moor. BGS Digital Data Licence No. 2015/162 BGS ©NERC.

Clontibret	Fore Burn	Moorbrock Hill	Glenhead	Hare Hill
25 g/t (for 2.5 m)	50 g/t (for 0.9 m)	4.9 g/t (for 10 m)	5.9 g/t	5 g/t

Table 1: Examples of gold grades in the SUDLT [2, 4, 5, 6, 14].

Relative age constraints

D_3 strike-slip faults are broadly contemporaneous with lamprophyric dykes 395 and 418 Ma (K-Ar and Rb-Sr methods) [20]. Hydrothermal alteration and Cu-Au mineralisation are related to granodiorite sheets at Black Stockarton Moor (Fig. 2) hosted by ~428 Ma turbidites and cut by the 410 ± 6 Ma Criffel Pluton (zircon U/Pb age) [16] [3]. Gold mineralisation is broadly coeval with emplacement of granodiorite at Hare Hill and Glenhead at 408 ± 2 Ma (K-Ar age) [21]. Gold mineralisation therefore, most probably occurred between ~418 and ~410 Ma, i.e. during the Scandian Event of the Caledonian Orogeny.

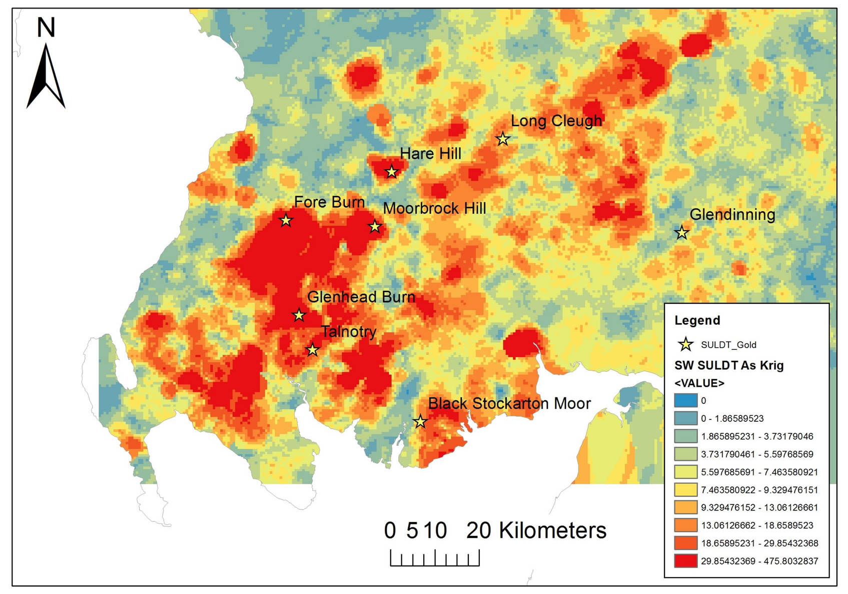

Figure 5: Interpolated map of arsenic in stream sediments in SW Scotland. BGS Licence 2015/063GC ED. ©NERC .

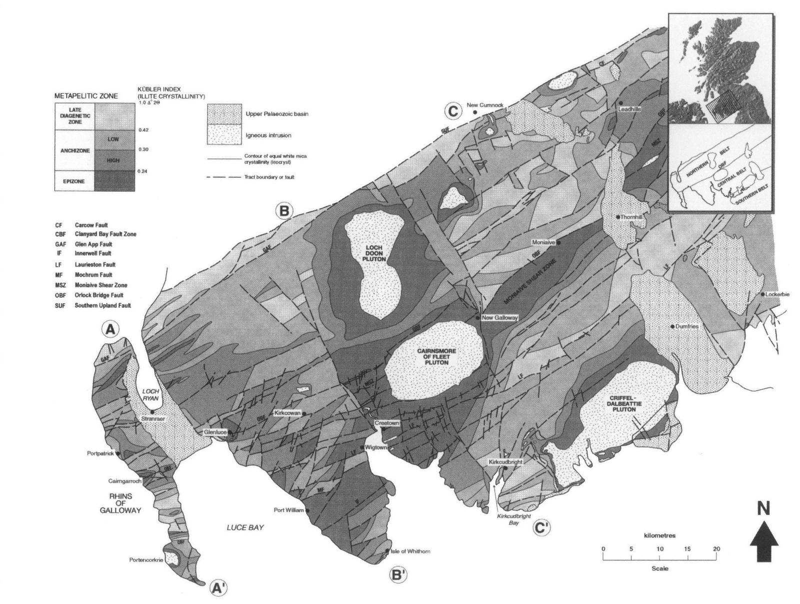

Figure 6: Map of metamorphic grades in SW Scotland after Merriman and Roberts, 2001.

Conclusions

- Gold mineralisation shortly post-dates the youngest sedimentation in the foreland basin ~20 My and arrival of the Avalonian continental margin at the northward subducting trench [22].
- Mineralisation was synchronous with peak hydrothermal alteration and emplacement of intermediate to felsic intrusions and related basic lamprophyres.
- Magmatism and mineralisation occurred during a transition from regional orthogonal compression to sinistral strike-slip shear (Fig. 4) [8].
- Very low regional metamorphic grade indicates that collision was soft and that magma is likely to have played an important role in conveying heat and possibly fluids, sulphur and metals from the deep crust.
- This suggests that magmatic-hydrothermal ore-forming processes generally attributed to epithermal settings in forearc regions of active margins could operate in collisional orogenic settings to create structurally-hosted vein gold deposits commonly attributed to metamorphic-derived fluids.

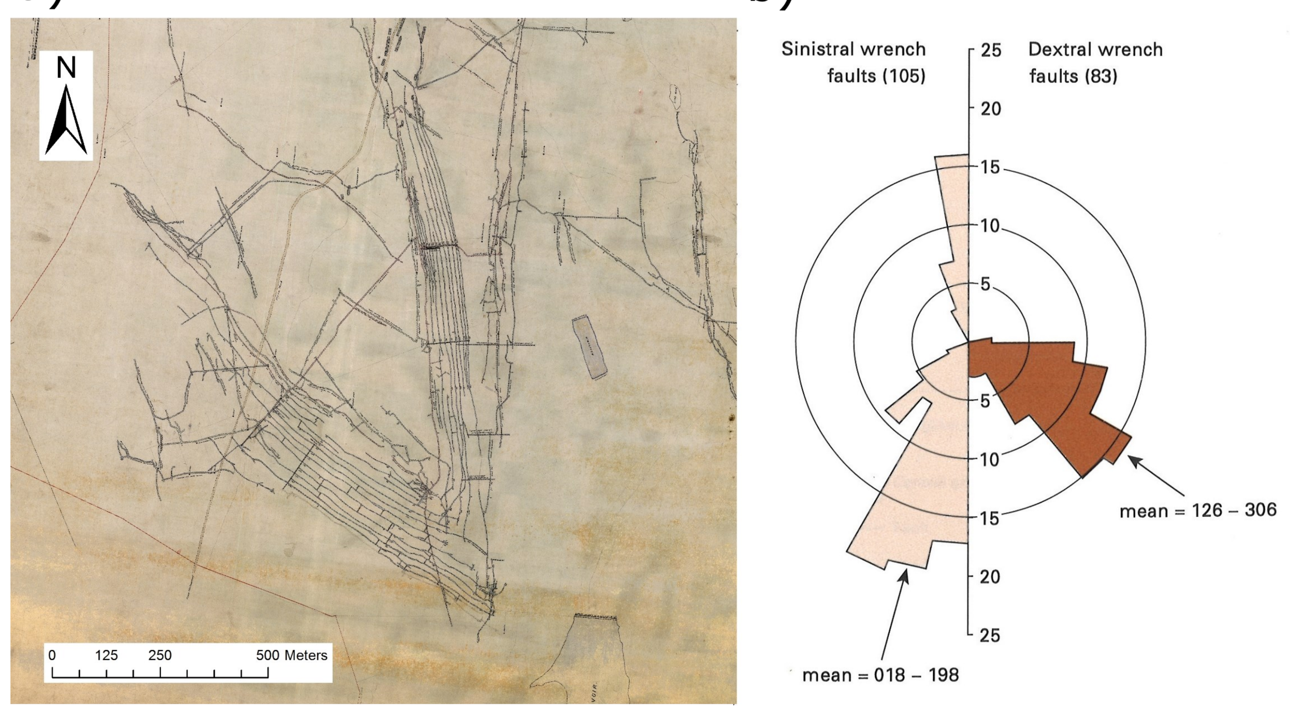

Figure 3: a) Plan of abandoned underground lead mines at Leadhills, Copyright BGS NERC; b) Rose diagram of D_3 strike-slip faults from Galloway (after Stone et al., 1995).

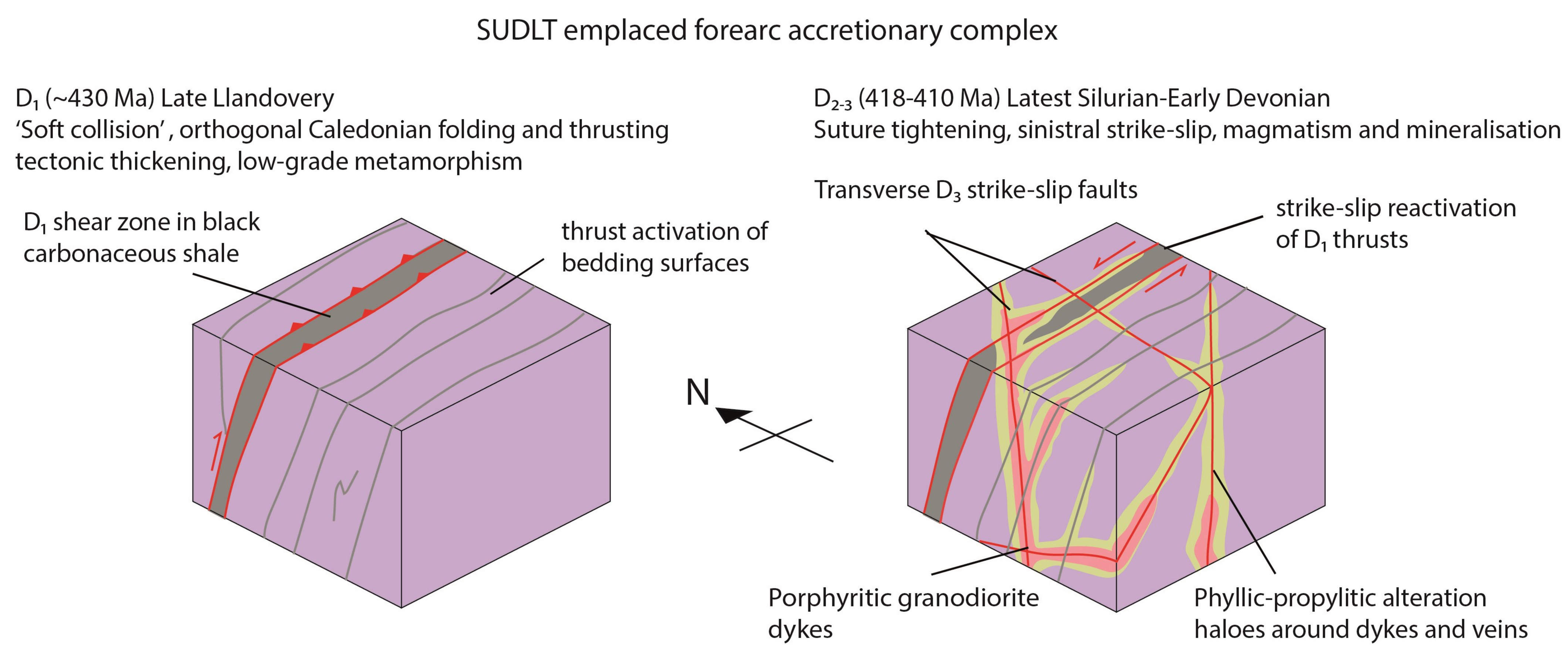

Figure 4: Schematic block models illustrating the structural and metallogenic development of the SULDT.

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