Introduction
Geological mapping makes an important contribution to orebody knowledge during the evaluation of structurally controlled gold veins. Key geological issues that can be resolved from mapping, include: vein geometry (attitude and shape); internal architecture (mineralogy, alteration types and patterns, small-scale continuity effects, ore shoot controls, grade distribution, etc); and post-mineralisation modification, which in turn lead to the resolution of structural controls and timing.

Orebody knowledge comprises an understanding of mineralization characteristics relevant to evaluation, mining, processing and environmental issues. These include ore and waste rock mineralogy, geological/structural controls, grade distribution and variability, ore hardness and geotechnical properties, etc. These characteristics show different degrees of variability that are often not realised. Any limitations in their interpretation and modeling are likely to increase the resource risk. Orebody knowledge must be developed to the level that is required to allow the identification and assessment of potential risks. If orebody knowledge is strong, then realistic expectations and likely risks can be defined and appropriate management strategies put into place.

A major challenge during the evaluation of structurally controlled gold veins is determining and managing their inherently high risk profile. Risk relates to issues of grade and geological continuity and ultimately their effect on grade and tonnage estimates. In particular, vein attitude, geometry and internal architecture are important features that need to be understood. In addition, issues of erratic grade distribution leading to a high to extreme nugget effect pervade. Structural geological studies support evaluation and accord with the JORC (2004) and other reporting codes, which require geology to be considered during estimation and classification.34

The Dolgellau gold belt has been subject to renewed interest as a result of the rising gold price over the last few years. The area is characterised by poorly mineralized veins with very local, but extremely rich pockets yielding up to 200 oz/t Au. The host reef systems are ribbon veins emplaced in a Cambrian greywacke black shale sequence.

In December 2008, a 125 km² Crown Exploration Licence was issued to Victorian Gold Limited. This is the first time that the entire gold belt has been held by one company. After an initial exploration and evaluation programme, the target is to produce sufficient gold metal to manufacture jewellery for a specialist Welsh product, which raises a substantial premium above the spot price.53

This paper builds on previous work by the authors and presents results that were derived from regional surface mapping and detailed surface and underground mapping, supported by historical data.16,18,24,44,45. It stresses the needs for geological application in vein systems and discusses relevant practical issues. Examples are presented from the Dolgellau gold belt and implications for similar systems discussed.

Geological mapping
Role of geological mapping
A geological map is the primary means of presenting data on structural, lithological, alteration and mineralization features.5 It presents a selection of field observations and is...
useful to the extent that it permits prediction of those things which cannot be observed. Maps are prepared by geologists on the basis of the data available to them and are primarily designed for use by geologically trained professionals, though may also be used by other professionals (e.g. mining or geotechnical engineers).

In the context of mining, surface and underground geological mapping is used to support exploration, evaluation and exploitation. In advanced projects (i.e. under evaluation or in production), mapping forms a basis for understanding the orebody and is a foundation of 3D geological and resource modeling. Mapping should be undertaken in close collaboration with sampling programmes to ensure maximum addition to orebody knowledge.

Mapping as conditioning data
Mapping plays a conditioning role to support drill based evaluation. In greenfield and brownfield projects, drilling can be the sole method for evaluation. Where historical data, accessible former workings and/or surface exposure are present, mapping permits the local geology and mineralisation to be understood in more detail. Table I shows the three critical mineralized body characteristics that can often be resolved by mapping.

A shortcoming of mapping is that it can be restricted to a relatively flat plane and hence is a 2D representation. Surface mapping across variable topography yields a better 3D understanding, providing good exposure exists. Underground mine mapping, over two or more levels, provides very good 3D resolution, and can be improved where raises between levels and/or stopes can be mapped.

Low density drilling often results in a ‘data gap’ where certain features cannot be resolved through lack of information. For example, where a vein contains small high grade gold pockets on a scale of less than 10 m, then a drilling grid of 30 m by 30 m is unlikely to resolve the pockets (e.g. the Dolgellau gold-belt). Elsewhere, historical mapping and written accounts may yield information on the size (geometry) and architecture of ore shoots to support modern evaluation (e.g. Charters Towers & Chewton gold projects, Australia). These are issues of not being able to define internal architecture (small scale effects) at a given drill spacing, however, global continuity, and to some extent geometry, will be resolved. In another example, a structure that shows rapid changes in vein width (pinch and swell) over a distance of 5 m similarly will not be resolved by a 30 m by 30 m spacing. Subtle changes in vein dip may not be identified by wide spaced drilling and could have a local material effect during mining (e.g. Nalunaq mine, Greenland). In this case, the issue is with resolving vein attitude and indicates a need for underground development.

Vein complexity also has a material effect on the ‘data gap’. For example, if a stockwork (or spur) vein system is drilled, then core samples will be biased if drilling passes down dip (parallel to) a specific (or dominant) vein set which may or may not be gold bearing. In this case, the data gap relates to internal architecture and introduces the effect of the orientation of a discrete vein set(s). Drilling down dip also provides a strong bias on vein thickness and sample grade.

In the previous cases, the existence of geological mapping would have provided the geologist with an understanding of vein features, scales and variability, effectively conditioning data to aid drill interpretation. The data gap directly relates to geological risk and, therefore, must be considered in the context of resource estimation and reporting.

**Dolgellau gold-belt**

**Introduction**

The gold belt is located close to the town of Dolgellau, in the County of Gwynedd (formerly Merionethshire), north Wales - some 360 km by road from London, England (Figure 1). It lies within the southern part of the Snowdonia National Park. Elevations within the area range from sea level to 400 m, local relief ranges from 200 m to 300 m (Figure 2).

**History of mining and exploration**

The history of the Dolgellau gold belt has been described

![Figure 1. Gold belt location and setting in Wales. Post Ordovician cover rocks not ornamented and small outcrops of pre-Cambrian rocks not shown](image)
Early mining (late eighteenth to early nineteenth century) in the district was for lead (silver-bearing galena) and copper (chalcopyrite) in quartz veins. Gold was first identified in 1844 in lead ores at East Cwm Hesian with many very small deposits found and worked between 1853 and 1862. The Gwynfynydd (estimated production ~50,000 oz Au) and Clogau (estimated production ~100,000 oz Au) mines are the only ones with a lengthy record of production and are also the only mines to be operated in the late twentieth century (Figure 3). Cefn Coch and Castell Carn Dochan mines were worked intermittently, but produced only a fraction of the Gwynfynydd or Clogau output. Other mines operated for a few years producing a few ounces to 300 oz Au from 5 t to 300 t of gold bearing quartz.
From sixty-nine mine/trial sites reported by Foster-Smith; sixty were known or suspected to target gold, thirty-nine sites produced evidence of gold, nineteen produced some gold, but only two were significant producers. The occurrence of gold, as very small high grade pockets in sections of very low grade quartz, reflects the limited production and life of many mines in the region.

Recent mining activity has been restricted to the Gwynfynydd and Clogau mines. Gwynfynydd was operated by Gwynfynydd Gold Limited between 1981 and 1989 when a rich, narrow vein was recovered from the footwall by Gwynfynydd Gold Limited between 1981 and 1989 to produce gold for jewellery manufacture. Clogau has been worked intermittently on an artisanal basis during this time. Both mines are currently being re-evaluated by Victorian Gold Limited.

Exploration in the nineteenth century was undertaken by drives and cross-cuts in the vicinity of surface quartz exposure. Quartz locally forms upstanding tor like ridges (e.g. Cefn Coch and the hilltop exposures at Gwynfynydd) and is exposed in some rivers and streams (e.g. Afon Mawddach near Gwynfynydd and Afon Wnion). Most quartz exposures were investigated in this period. Later exploration was also undertaken by drives and cross-cuts within existing mines.

In the later twentieth century, regional mineral reconnaissance was undertaken by the British Geological Survey (‘BGS’). Stream sediment, water and bedrock geochemistry and magnetic, electromagnetic and radiometric aerial surveys were done. This work improved general understanding of the geology, but sampling and/or traverse lines were too coarse to be relevant to reef scale exploration.

Geological setting

Regional geology
The Dolgellau gold belt occurs in Cambrian strata around the southeast and eastern margins of the Harlech Dome, a 25 km diameter inlier in the northern parts of the Lower Palaeozoic Welsh Basin (Figures 1 and 3). The Cambrian sequence rests unconformably on late Proterozoic basement dominated by volcanic sequences. Regional geology is summarised from Howells.

The lower Palaeozoic Welsh basin was a sedimentary basin near the northern margin of Avalonia. Sedimentation extended from the Cambrian through to Early Devonian time, being terminated by the Acadian Orogeny during final closure of the Iapetus Ocean. The Cambrian fill is dominated by turbidite sandstone sequences in the lower parts and by interbedded mudstone/siltstone formations in the upper parts (Table II). Several carbonaceous mudstone horizons are present, including the Clogau Formation. Local unconformities were developed during the early Ordovician and are associated with faulting and some north-south trending folds.

The Ordovician is characterised by major accumulations of volcanic rocks and the emplacement of associated sills and dykes. The Rhobell Fawr volcanic centre (Tremadocian), Arenig, Aran and Cader Idris volcanic centres (Arenig to early Caradocian) and Snowdon volcanic centre (Caradocian) are adjacent to various sectors of the gold belt. Silurian turbidite sandstones and mudstones bury this sequence, with major depositional centres east and south of the Dolgellau area.

Acadian (early Devonian) deformation resulted in the development of north-south to northeast-southwest trending, upright folds. A regional cleavage is slightly oblique to the fold axial traces. Peak metamorphism associated with the deformation locally reaches low greenschist facies. Uplift and erosion were largely completed by the late Devonian.

Gold mineralization

Dolgellau style of mineralisation
The Dolgellau gold veins are of the mesothermal and turbidite hosted quartz carbonate or slate-belt types. They show many similarities to other slate-belt deposits such as those in Australia (Central Victoria), Canada (Nova Scotia and Meguma), China (Guizhou) and New Zealand (Otago).

The veins display an extreme nugget effect (>75%), exacerbated by the presence of coarse gold particles

<table>
<thead>
<tr>
<th>Geological age</th>
<th>Lithostratigraphy</th>
<th>Lithology</th>
<th>G</th>
<th>Py</th>
<th>C</th>
<th>S</th>
<th>M</th>
<th>Po</th>
<th>Au in veins</th>
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<tbody>
<tr>
<td>Ordovician</td>
<td>Ail Llwyd Fm</td>
<td>Arenite</td>
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<td>Rhobell Gp</td>
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<tr>
<td>Cambrian</td>
<td>Dol-cyn-afon Fm</td>
<td>Mudstone</td>
<td>Y</td>
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<td>Pfestinow Fm</td>
<td>Fine arenite</td>
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<td>R</td>
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<td></td>
<td>Dolgellau Fm</td>
<td>Mudstone</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<td><strong>Main gold vein hosting horizons</strong></td>
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Table II
Summary of local host sequence with diagenetic/metamorphic opaque phases in the Cambrian sediments and gold in veins. G: graphite; Py: pyrite; C: chalcopyrite; S: sphalerite; M: marcasite; Po: pyrrhotite. \([Y: present; N: absent; R: rare\] Table derived from Shepherd and Allen. **Main gold vein hosting horizons**

WORLD GOLD CONFERENCE 2009
The gold bearing quartz veins

The general geological setting of the gold-belt is well established.\cite{4,3,30,32,38,44,52} Mineralization occurs in northeast-southwest to east-northeast - west-southwest trending quartz veins. These are commonly located along normal faults. The veins are planar and oblique to the trend of the later Acadian folds and cleavage. Minor, northwest-southeast and east-west trending sets of quartz veins also occur in the district.

Post cleavage mineralization is characterized by crustified calcite marcasite veins that cut cleavage, minor folds and syn cleavage extension veins.\cite{39,44} These veins are easily distinguished from the earlier auriferous quartz veins.

The host reef systems are ‘pinch and swell’ ribbon veins that contain up to sixteen component veins, of which none or only one may contain gold (Figure 4). Vein mineralogy and texture has been described by various workers.\cite{5,30,39,45,52} Quartz is the dominant mineral, often close to 100% (Figure 5). Carbonates, white mica and chlorites form the other non sulphide components. Sulphides, pyrite, marcasite, pyrrhotite, arsenopyrite, galena and sphalerite are present in variable proportions (Figures 5 and 6). Minor telluride minerals are reported in the Clogau veins. Gold is predominantly coarse grained and visible.

Hand specimen scale texture reflects the primary crystallisation events, but thin/polished sections show extensive evidence of deformation and annealing as a result of Acadian events. Primary columnar or comb textures dominate quartz (Figure 5). Sphalerite can form conspicuous cauliflower like masses where undeformed. Secondary equigranular textures dominate the sulphides (Figure 6).

Figure 4. Gwynfynydd gold mine footwall section of the Chidlaw Lode (Link Zone) on No 6 Level. The reef shows a classic book and ribbon structure with single episodes of opening represented by quartz veins separated by screens of black shale. The high grade gold bearing vein (FLV) is not present at this point; the gross reef grade is sub 0.5 g/t Au

Figure 5. Block from tip of East Cwm Hesian mine. Textural variation, wall rock screen and contacts in three little deformed quartz veins. V3 cuts V2, time relations of V1 are unknown. AS, axial suture; C, axial carbonate fill; CT, vein contact surfaces; NQ narrow columnar quartz; QS, granular sand sized quartz; TQ, thick columnar quartz with local terminations; SS sediment screen

Figure 6. Deformed quartz vein showing deformed quartz (white) and granular textured galena (dark grey and silver) from river exposure at East Cwm Hesian mine. M, mica veneer on quartz grain boundary; P1, pyrite cube; P2 pyrite anhedral; Q1/2 slightly bent coarse columnar quartz with millimetre scale irregularity against galena; Q3 oblique section of quartz column showing ragged, mm scale, margin against granular sulphide; S granular aggregates of sphalerite
Pyrite shows extensive fracturing reflecting deformation of the more ductile host quartz. Gold occurs in pore spaces and grain boundaries in primary textures. Secondary gold lies in an intergranular position or along fractures.

**Recent geological research**

The Dolgellau gold belt has been the subject of research and development activity since the 1980s. The veins were the subject of a series of studies in stable isotope geochemistry and of volatile materials in fluid inclusions. This work was primarily concerned with conditions of deposition, but also looked at the practical application of fluid inclusion studies in gold exploration. The study presented evidence to support the role of carbonaceous material (within the Clogau Formation: Table II) in the precipitation of gold in quartz veins.

A new model for the structural development of the region was presented in 1999, interpretations of the timing of reef emplacement relative to the Acadian cleavage forming event showed a pre cleavage age for gold and base metal veins. Studies undertaken during 1994 to 1999 at Gwynfynydd lead to various discourses related to sampling high nugget coarse gold systems. A primary geological control for the nugget effect was demonstrated at Gwynfynydd mine for the first time, having implications for gold vein systems globally. Continuity risk in gold veins was discussed in the light of work at Clogau mine. More recently, the importance of gold particle issues and clustering effects on sampling was demonstrated, based partly on work undertaken at Gwynfynydd.

**Mapping in the Dolgellau gold-belt**

Systematic regional mapping by Matley and Wilson at 1:10 560 scale provided a map of the outcrop of the quartz veins and placed the veins in a formalised stratigraphical context. This work was published in Matley and Wilson and forms the basis of the current BGS 1:50,000 scale geological map. Peripheral areas are covered by more recent mapping, mostly published at 1:50 000 scale. Some surface geological mapping at 1:10 560 scale was undertaken by Gilbey, which produced most detailed surface maps of the vein systems. Underground geological mapping is restricted to accessible parts of the Clogau and Gwynfynydd mines between 1980 and 1999, mostly undertaken by the authors.

During 1999 to 2009, the authors undertook detailed mapping of the internal structure of veins exposed in outcrop and exploration trenches. This work was intended to determine the detailed architecture of the ribbon veins and provide a basis for evaluating historical records of the occurrence of gold pockets.

**Regional mapping and gross structural and stratigraphic control**

**Introduction**

The Dolgellau gold belt forms a 26 km by 6 km arc around the southeast and eastern margins of the Harlech Dome, but quartz vein systems are found in all exposed sectors of the dome (Figure 3). Quartz veins occur on the entire southeast margin of the dome, but gold is rare towards the coast. Quartz veins are present, but much less common, along the northeast and north sectors of the dome. The original western margin of the dome is not seen, being truncated by the Mochras Fault and buried by Mesozoic and Palaeogene sediments. Veins are absent (or not reported) from the central parts of the dome.

**Stratigraphic controls of quartz and gold distribution**

The majority of quartz vein systems cut the Gamlan, Clogau and Maentwrog Formations and the outcrop of these formations, controls the arcuate form of the gold-belt (Figures I and 3; Table II). Rare examples cut the underlying Barmouth, Hafotty and Rhinog Formations. Veins are absent from the overlying Ffestiniog Flags Formation and Dolgellau Formation in most of the area. Veins cutting higher stratigraphic levels are restricted to three areas: around Afon Gamallt mine (Ffestiniog Formation - Llanvirn); east and west of the outcrop of the Rhobell Fawr Volcanic Formation (Ffestiniog and Dolgellau Formations) and the southwest coastal zone (Ffestiniog Formation - Llanvirn). Veins are not reported within the Rhobell Volcanic Group itself. A solitary mine, Castell Carn Dochan, occurs in much younger Ordovician (Caradocian) volcanic rocks and overlying dark mudstones.

The quartz veins are most auriferous where they intersect the Clogau Formation, a pyritic and graphitic black mudstone (Figure 3 and Table II). Veins extending up into the Maentwrog Formation, grey silty mudstones with minor siltstones with some greywacke and black mudstone intercalations, also yield gold (e.g. New/Main Vein at Gwynfynydd and East Cwm Hesian: Figure 7). Significant gold mineralization in the Clogau Formation is restricted to the short sector between Clogau and Gwynfynydd. Commercial amounts of gold were not found in veins in younger Ffestiniog Flags Formation (flagstones) or in the black shales of the Dolgellau Formation.

The base of the Clogau Formation is generally cited as the lower limit to significant gold accumulation but some gold is reported from veins cutting the upper part of the Gamlan
Table III

Geometry, architecture and post mineralization modification characteristics of the Cefn Coch, Clogau, Gwynfynydd, Maestryfer and Tyn’y Llwyn vein systems. Data sources include current and historical surface and underground geological mapping and other historical data

<table>
<thead>
<tr>
<th>Deposit (principal mapping sources)</th>
<th>Geometry</th>
<th>Architecture</th>
<th>Post-mineralisation modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cefn Coch [surface mapping]</td>
<td>Tabular lode zone containing series of often parallel quartz veins with linking structures. Global continuity of 1.5 km. Local changes in strike up to ±40° and dip up to ±60°. Pinch and swell on individual veins ranging from 1.5 m to a few cm.</td>
<td>Book and ribbon structure with zones of massive to brecciated quartz. Quartz dominated mineralization with sulphides. High grade gold shoots reported to be controlled by vein intersections.</td>
<td>Cross-faulting with lateral displacement to 20 m. Late low angle and steep quartz veins and masses. Intra-vein faulting bearing marcasite calcite in fill, with &lt;10 m lateral displacement.</td>
</tr>
<tr>
<td>Clogau [surface and underground mapping]</td>
<td>Tabular vein system with localized splits and branches. Global system continuity of 1 km, with local vein continuity of &lt;300 m. Local changes in strike up to ±40° and dip to ±10°. Marked pinch and swell, with vein locally absent. Mean vein width around 1.2 m.</td>
<td>Book and ribbon structure. Quartz dominated mineralization with sulphides. Gold associated with galena and telluride minerals. High-grade gold shoots controlled by vein branches and intersection with greystone bodies.</td>
<td>Cross-faulting with lateral displacement to 100 m. Late low angle and steep quartz veins and masses. Clogau stone dykes emplaced along parts of the vein system. Intra vein faulting with &lt;10 m lateral displacement.</td>
</tr>
<tr>
<td>Gwynfynydd [surface and underground mapping]</td>
<td>Tabular vein system with minor splits and branches. Global system continuity of 1 km, with local vein continuity of &lt;300 m. Local changes in strike up to ±40° and dip to ±45°. Pinch and swell, but gross vein highly continuous.</td>
<td>Book and ribbon structure. Quartz dominated mineralization with sulphides. No detailed information on gold localization, though known to be related to vein splits and juxtaposition with greystone bodies.</td>
<td>Cross-faulting with lateral displacement to 300 m. Late low angle and steep quartz veins and masses. Intra-vein faulting bearing marcasite-calcite in-fill, with &lt;10 m lateral displacement.</td>
</tr>
<tr>
<td>Maestryfer [surface and underground mapping]</td>
<td>Tabular vein system with localized splits and branches. Global system continuity of 1 km, but local continuity &lt;300 m. Local changes in strike up to ±40°. Marked pinch and swell, with vein locally absent or very thin.</td>
<td>Book and ribbon structure. Quartz dominated mineralization with sulphides. No detailed information on gold localization, though known to be related to vein splits and juxtaposition with greystone bodies.</td>
<td>Cross-faulting with lateral displacement to &lt;10 m lateral displacement.</td>
</tr>
<tr>
<td>Tyn’y Llwyn (Wnion) [surface and trench mapping]</td>
<td>Tabular vein system with localized splits and branches. Global system continuity of 1 km, but local continuity &lt;20 m. Local changes in strike up to ±40°. Marked pinch and swell, with vein locally absent or very thin.</td>
<td>Book and ribbon and pinch and swell structure. Quartz dominated mineralization with sulphides. No information on gold localization.</td>
<td>Cross-faulting with lateral displacement to 25 m. Late quartz veins and masses. Intra vein faulting with &lt;10 m lateral displacement.</td>
</tr>
</tbody>
</table>

Formation (e.g. St David’s, Pennaen and eastern end of Clogau). Gold is not reported from the rare veins in the greywacke dominated sequence below the Galman Formation.

Gold is reported from stream sediments in the outcrop areas of the Galman, Clogau and Lower Maentwrog Formations on the northern margin of the dome. Some quartz veins occur here, but none are identified as sources of gold.

The stratigraphic control of gold is also seen in single, continuous vein systems at Clogau/St David’s and Gwynfynydd. At Clogau/St David’s the vein system is found in Clogau Formation at surface but is traced down into Galman Formation in the mine. Gold production decreased downwards in both sections of the mine although gold was produced from below the Clogau Formation. At Gwynfynydd (Figure 7) the quartz vein systems can be traced from the Hafotty-Rhinog Formation boundary to the lower part of the Maentwrog Formation. Gold production was from the segments in the Clogau and Maentwrog Formations, black mudstones being present in the local Maentwrog sequence.

Stratigraphy is an important control on the distribution of gold mineralization and the region provided a model for the role of black shales in localizing gold precipitation. However the relationship is not simple:

- the area of significant gold mineralization is much smaller than the area with quartz veins
- long segments of Clogau Formation black shales are cut by quartz veins without commercial gold
- gold-bearing quartz veins occur locally below the Clogau Formation
- gold-bearing, but non-commercial, quartz veins occur in latest Cambrian and early Ordovician strata.

The distribution of gold is effectively summarised as starting close to the base of the Clogau Formation and extending upwards irregularly and with decreasing intensity into higher Cambrian and locally early Ordovician strata.

**Regional structural controls of quartz and gold distribution**

*Harlech dome development and mineralization*

The Harlech dome exposes a 4 km sequence of Cambrian rocks and had a former cover of Ordovician and (probably) Silurian rocks (Figure 1). This substantial structural relief is the cumulative result of Ordovician and Silurian differential subsidence and Acadian deformation. The early
Associated with a Cu-Mo-Au porphyry system.

Related to the Rhobell Fawr volcanic centre, which is extensively invaded by ‘greenstone’sills and sheets that different sectors of the dome have slightly different of gold (Figure 3). The regional mapping by BGS shows around the rest of the dome contain insignificant amounts of gold. The regional mapping by BGS shows that different sectors of the dome have slightly different structural features and Ordovician burial history.

The main gold belt sector dips systematically southeast. It is extensively invaded by ‘greenstone’sills and sheets related to the Rhobell Fawr volcanic centre, which is associated with a Cu-Mo-Au porphyry system. The sector lies up dip from the major Ordovician volcanic accumulations and gabbroic sill complexes of Cader Idris and the Aran Mountains. It lies across the axis of sparse northwest-southeast dyke swarm of Ordovician age. The northeast sector of the dome has complex pattern of dip and fault displacement. It is invaded by post Tremadoc sub-volcanic domes. The north sector dips systematically north or northwest below the thick Caradocian volcanics of the Snowdon Centre. Early Ordovician volcanic deposits are limited. The sector is crossed by the northwest-southeast dyke swarm and a small granitic pluton underlies the northeast end.

These observations focus exploration attention on the proven Clogau to Gwynfynydd sector of the gold belt. They show that it has a distinct geological setting, but the way in which the setting controls mineralisation is unknown. Four significant questions are posed which are relevant to long-term regional exploration, but relatively unimportant to short-term, mine-scale investigation:

- do quartz veins really fail to penetrate the lowest Cambrian strata? This has implications for the fluid flow directions and source of fluids in the veins;
- can the mineralization be dated more precisely relative to Ordovician volcanic eruptive centres and sedimentary depocentres? Provides information about stage of burial of Cambrian rocks and diagenetic conditions during mineralization. May guide exploration in younger Ordovician rocks, c.f. Castell Carn Dochan mine;
- can the controls on the observed restriction of the gold belt to the southeast and east sector be determined and used to re-assess potential in the other sectors, e.g. role of surrounding volcanic centres and differential subsidence associated with accumulation of Ordovician and Silurian sequences;
- do carbonaceous mudstones at higher stratigraphic levels (e.g. the Cambrian Dolgellau Formation and Ordovician Nod Glas Formation) form potential exploration targets?

These questions are the subject of current research.

**Gross features of vein systems: relationship with faults and gross continuity**

Vein systems are commonly located on, or adjacent to, northeast to east-northeast trending normal faults. This is apparent from the regional mapping (Figure 7), detailed surface mapping and mapping underground at Clogau and Gwynfynydd. Faults and veins may have downthrow on either the north or south sides, but tend to occur in groups with common downthrows (Figure 7). The faults with largest displacements, e.g. Pystyll y Cain Fault south of Gwynfynydd (Figure 7), are unminalizeried or only locally mineralized.

Vein systems are traceable along strike for up to 1.5 km in the well-explored areas (Clogau, Cefn Coch and Gwynfynydd; Figures 2, 7, 8 and Table III). Individual quartz vein packages are continuous for several metres up to a few hundred m. Vein systems may be a single tabular mass of quartz or sub parallel groups of quartz veining separated by wall rock. They can show branching or en echelon offsets (Figure 8). The veins are not continuously exposed and the mapped traces reflect both exposed vein and inferred vein. The patterns shown in these maps require verification, i.e. re-mapping.

Information on the vertical extent of individual vein packages is only available for Clogau and Gwynfynydd where quartz is proved through to 150 m in underground workings.

Northerly trending faults appear to bound domains in the mineralization at regional and local scales. Regionally, the richest part of the gold belt lies between the Craiglaseithin fault and the Caedeon Bodlyn fault (Figure 3). On the local scale, veins may appear to terminate, or be offset, at minor members of the north-south fault set (Bryntirion Fault at Clogau and faults east and west of the Voel set of veins—

**Figure 8. Clogau, Cefn Coch and Winion-Voel lode outcrop patterns and relationship with stratigraphy and north-south faults. These are abstracted from 1:10 560 mapping in Gilbey and show more complex patterns than are seen on 1:50 000 maps.**
Figure 8a and b). Exposure control of mapped relationships at the junctions between north-south faults and the vein systems have not been verified at present.

The Bryntirion fault (Figures 2 and 8a) is exposed underground at Clogau. Underground mapping at Gwynfyndyd shows that the north-south Trawsfynydd fault postdates the quartz veins. The displaced continuation of mined mineralization is likely at depth across some faults.

Future surface mapping will aim to:
- Check gross vein continuity, identify terminations and locate unexposed gaps in data
- Check branching/braiding patterns in vein systems
- Clarify nature of intersections with north-south faults
- Determine sedimentary wall rock lithology and structural relationships of any ‘greenstones’
- Compare surface and underground mapping at Clogau, Gwynfyndyd and any other accessible workings.

Detailed vein architecture

Introduction

The critical problem in the Dolgellau gold belt is to locate very small, but rich, gold pockets that are dispersed in the host low grade quartz veins. Rich pockets vary in length from less than 1 m to approximately 10 m. Understanding the factors that control pocket location requires identification of their site within the host vein architecture.

Six factors have been cited as indicators of pockets:
- Host rocks in Clogau Formation
- Presence of greenstones, with ore pockets below or associated with the line of intersection
- Intersections or branching (or splitting) of veins
- Intersections of cross fractures (sometimes quartz mineralised) with the main vein
- Intra vein shearing in carbonaceous shale host (specifically Gwynfyndyd)
- Location on or in footwall of main quartz vein (specifically Gwynfyndyd).

Factors (1) to (3) were considered significant during nineteenth century mining, and factor (4) was added later in a review of Clogau and Gwynfyndyd based on recent research. Factors (5) and (6) are reported from Gwynfyndyd and may be of local significance only. Factor (4) is reputed to be applicable in the Cefn Coch and Clogau mines.

Detailed mapping of the internal vein architecture and the relationships between veins and faults and greenstones is required to evaluate these factors. The results of some recent detailed mapping are presented and discussed in the context of historical data and the factors suggested as controlling gold pockets.

Recent detailed mapping of trenches and natural exposure

Available mapping is restricted to sites of recent underground activity at Clogau and Gwynfyndyd. Most of these maps only show the gross quartz distribution though reports note that quartz is present as ribbon veins (e.g. examples of mapping at Clogau reproduced as Figures 6 and 7 in Dominy and Platten). Most mapping at Gwynfyndyd also shows gross quartz form and distribution, but with detailed maps from the 1981 to 1989 period of working giving some information on internal structure (e.g. 6 Level plan used as the basis of Figure 7 in Platten and Dominy).

Recent unpublished surface mapping by the authors (1999-2009) has focussed on determining the continuity in vein systems and investigating the arrangement and continuity of the individual veins. This is intended to provide a basis for evaluation of both the nineteenth century reports of rich gold occurrences and more recent, twentieth century mine mapping.

Aspects of gross continuity for vein systems are illustrated in Figures 9 and 10 for sites in an area of small nineteenth century mines southwest of Cefn Coch. The gross quartz shows rapid variations in thickness, changing from 1 m to centimetre scale over 5 m strike lengths. Discrete quartz segments are traced 12 m and 16 m along strike in Figure 9, and 4 m and >7 m in Figure 10. The segments are offset, left stepping in the case of northwest system in Figure 9 and right stepping in the case of Figure 10. Low angle quartz veins, the northeast system, are associated with truncation of the main vein at the northeast end of Figure 9. These features may indicate the reason for very limited development of the mines, if work was abandoned at the tapered end of a quartz vein mass.

Figure 10 shows the relationship between vein offsets and steps in the margin of a greenstone sill. At vein offsets [B] and [C] the greenstone shows a step with similar sense. The quartz vein, however, shows a small number of narrow veins linking the main segments at these offsets suggesting
that the greenstone steps may pre date and therefore, control the position of the main vein offsets. It could not be determined if the greenstone steps were the result of original greenstone emplacement or later, small, transverse faults that predated vein emplacement.

Internal structures within the vein systems have been investigated. Individual quartz veins can be identified with confidence where they are separated by wall rock screens. Individual screens taper but, if continuous, can be traced when their thickness is reduced to 1 mm. Where screens are absent, planar surfaces marked by abrupt textural changes in the quartz can identify component veins. These may be abrupt changes in scale of columns or comb texture in quartz or changes between column texture and much finer grained matte surfaced quartz (Figures 5 and 11). Textural changes of this type are most reliable as indicators of vein contacts when they continue or lie on strike of contacts marked by wall rock screens.

Figures 12 and 13 illustrate examples of the internal architecture of some ribbon veins, Figure 12 is an exposure above one of the nineteenth century rich stopes in the Chidlaw Lode at Gwynfynydd and Figure 13 illustrates the internal structure of the southeast system in Figure 9.

Figure 12 lies a few metres west-southwest of a branch in the worked veins. The veins 1 to 7 are exposed on pillars in the old stope below but it is not known which may represent the host structure to the historical rich gold pockets. Veins 11 to 17 lie on line of strike of the old workings to the east, also reported to yield gold. There are 17 individual veins recognized, relative time relations are only indicated for veins 6 and 7, which appear to be terminated by the much thicker veins 6 and 9.
GEOLOGICAL MAPPING IN THE EVALUATION OF STRUCTURALLY CONTROLLED GOLD VEINS

Figure 13. Tyn’y Llwyn veins internal structure: screens, contacts and vein branching from segments of the southeast vein shown in Figure 9

Figure 14. Tyn’y Llwyn vein branching from the far southwest end of the southeast vein system shown in Figure 9. Arrows show dilation direction inferred from matching wall irregularities in vein walls

underground mapping at Maestryfer demonstrates the relatively discontinuous nature of the vein system and small scale continuity of individual, constituent veins. Traces of visible gold have been reported recently from the No 6 and No 8 Lodes. During the 1990s, a 10 m vertical shaft was sunk within a vein split on the No 6 Lode. The shaft followed two parallel, but converging veins hosted in greenstone, but no gold was located. The extent of the shaft however, fell short of its target depth of 20 m. The limited development of the historical adits opened in this area may reflect the small scale discontinuity shown in the mapping. High grade gold mineralization was recorded from an adit on the No 6 Lode between 1855 and 1862 (Mining Journal, 1855-1893). The vein was 1.2 m in width, with gold being recovered from a 5 cm vein. Visible gold-bearing quartz graded at 168 oz/t Au; whereas apparently barren quartz graded around 5 oz/t Au.

Tyn’y Llwyn
The detailed mapping demonstrates the discontinuous nature of the vein systems and the very small scale, a few metres, of continuity in individual veins at the sites near Tyn’y Llwyn (Figures 9, 10, 13 and 14). No gold was observed. The limited development of the historical adits opened in this area may reflect the small scale discontinuity shown in the mapped trenches. The only recorded production in this area was from the Union mine, which between 1889 and 1894, yielded 145 t ore for 38 oz Au (8.1 g/t Au). The mine was re opened during 1889 to 1890, and produced 100 tons of ore yielding 3 oz Au (0.9 g/t Au).

Gwynfynydd
The rich footwall vein worked in the Chidlaw Lode (Link Zone) in the 1980’s and 1990’s (Figure 15) is in a similar position to the rich zone worked in the nineteenth century (Figure 12). The extremely rich portion in Figure 15 occurs as a discrete vein below the footwall of the mass of ribbon quartz marking the main vein structure. The visible portion of the footwall vein was approximately 12 m with the very gold rich section 6 m long. The footwall vein converges westwards with the main vein footwall. The available mapping record does not indicate if this vein runs along the

Applications to earlier less detailed mapping

Maestryfer
Located 3 km east of Clogau, surface and limited
main vein footwall, cuts the main vein or is cut by the main vein. The patterns shown by individual veins in Figure 13 suggest that vein components are more likely, but not certain, to converge than intersect.

Figure 12 shows seventeen veins of which seven are greater than approx 8 cm thick. The Chidlaw Lode in 6 Level shows ten quartz veins >8 cm and an unspecified number of narrow veins. Both sites are in sections of vein with gold in the footwall, the 6 Level site being just above the gold rich site illustrated in Figure 15. Comparison of the two sites indicates that in a single traverse 1 in 7 to 10 veins >8 cm may be rich in gold, but only 1 in 17 of all veins is potentially ore bearing. This gives an indicator of the potential of gold in single vein sections.

A plan of the Chidlaw Lode (Link Zone) in 6 Level allows it to be divided into three zones (Figure 7 in Platten and Dominy) although individual vein elements had not been mapped. A central set of quartz galena carbonate veins can be distinguished from a hanging wall set of quartz veins, a division that is traceable for 65 m though the site. Comparing this with the patterns shown by individual veins in Figure 13 suggests that component veins may be more continuous at Gwynfynydd although this would need to be tested by re mapping.

The complex New/Main Vein structure at Gwynfynydd (Figures 7 and 16) may also be compared with pattern shown in Figures 9 and 13. These suggest that in the New/Main structure: component veins of the eastern massive quartz body diverge westwards but individual veins do not ‘split’ and the fan pattern is built of successive increments rather than the results of intersection between two vein systems. This would require testing, but may place the historically, worked gold pockets into a clearer geological context and test the relevance of vein splits/intersections as indicators of gold pockets. The footwall localization of gold in the New/Main structure appears less important than in the Chidlaw Lode.

Clogau

Hall reports two sites at Clogau where there is some indication of the shape and dimensions of gold rich pockets in nineteen century accounts. These can be interpreted in the context of local surface vein exposure showing at least six veins between 0.1 m to 1.0 m thick and the patterns seen in Figures 12 and 13.

The reopening of the St Davids discovery site in 1859 is well documented and produced around 800 kg of quartz with very abundant gold. The lode was 0.75 m to 0.9 m wide. A ‘rib’ of calcareous material 5 cm to 10 cm thick in the lode carried abundant visible gold for 5 cm to 8 cm. The ‘rib’ is likely to represent a single component vein in the ribbon veined lode. A second patch 0.3 m high and 8 cm to 10 cm wide was ‘abundantly impregnated with minute particles of fine yellow gold’. This elongate patch may also represent a single vein, but it is not known if it is the same vein as the first patch.

At the junction between Paraffin and Main Lodes in Clogau, a 1.8 m long by 1.4 m high by 23 cm thick mass of quartz produced 500 oz. The plate like form and dimensions suggest that this represents a segment of one of the thicker component veins in the lode.

Gold pockets are reported at other sites, but although well located in the plane of the reef, are poorly located in the vein system cross section and it is not known if they occupy a single component vein or a group of veins. The original discovery site is typical. Hall quotes Calvert describing the initial discovery at St David’s from material in the mine office: ‘large blocks of some hundredweights. …showing gold all over, beautifully disseminated…’. The larger individual veins could produce blocks of this weight but so could masses of the thinner ribbon veins. Dominy and Platten illustrate pockets associated with the base of sills and ‘branches’, in the vein system where the position in cross section is unknown. In the case of the pockets at ‘branches’ the internal structure at the site is unknown. Is it like the small branches seen in Figures 9 and 13 to 16 or is some different pattern present?

Comments on factors controlling rich pockets

None of the factors cited in the literature have universal application although they are all known or reported at one or more sites. The Clogau Formation graphic mudstones are present at Clogau and Gwynfynydd but gold is found in veins at other stratigraphic levels. Greenstone sills (2) are common in the Clogau Formation between the Clogau and Gwynfynydd mines yet there has been only minor gold production between the two main mines. Branching (3) at different scales is similarly a common feature (Figures 8, 9, 13 to 16) in the region, with gold production noted from Clogau and Gwynfynydd. However, vein branching has not always resulted in the localization of gold. Recent exploration at Maestryfyr involved a shaft being sunk on a branch that failed to reveal any gold mineralization. The significance of the cross fractures (4) is uncertain as the nature of them is obscure. Some possible examples of transverse structures are seen in trench maps, Figures 9, 10 and 13. Factor (5) has not been clearly identified by the authors. The footwall vein site (6) is well established locally at Gwynfynydd (Figures 12 and 15), but not elsewhere.
The utility of these factors needs to be assessed by study of a much larger number of sites where they control gold pockets and at sites where they are not associated with significant gold. The increased understanding of branching resulting from mapping shows that similar studies may improve the understanding of the other factors. At present, only sites without gold or where the gold has been removed are available for study.

**Discussion**

**General**

It is well known that structurally controlled high nugget gold quartz veins generally possess a moderate high to extreme high resource risk. Key components of resource risk are grade and geological continuity, which relate to uncertainty in vein architecture at different scales. In addition, variable vein geometry and post-mineralization features can contribute. Any evaluation must collect geological information, which includes diamond drill core logging and surface and/or underground mapping. It should then be possible to achieve a level of geological prediction on which realistic resource definition can be based.

Development of deposit geological knowledge, i.e. orebody knowledge, allows expectations to be set. For example, it should be obvious to an operator that a structurally complex, geometrically variable, high nugget system bearing coarse gold will be both difficult to evaluate and exploit. This poses the question: does the operator really have an appetite for this level of uncertainty and risk?

The economic reward, however, could be very high. Geological knowledge lead by mapping will help to set project expectations and planning (Table IV and V).

Geological mapping that supports structural interpretation leads to the definition of continuity and mineralization controls, and a key part of geological risk reduction and reporting resources. For example, where continuous surface (or underground) mapping data is absent, then the definition of resources from drilling data alone may be difficult. If a drill spacing of 30 m by 30 m cannot be shown to resolve internal architecture (e.g. small-scale continuity), then Indicated Mineral Resources may not be defined. However, if the drill data can be conditioned with mapping data, then, this level of classification may be possible.

**Dolgellau gold belt**

A review of existing regional and local mapping sets out the geological context of the gold belt. Detailed mapping is shown to begin to answer questions about the geometry, internal architecture and post mineralization modification in these vein systems (Table III).

However, there remain many unanswered questions about the detailed factors controlling gold distribution. As new gold pockets are found, then it is essential that their context in the structure of the host vein system is carefully mapped if they are to provide useful information to guide further exploration.

The Dolgellau vein systems can be provisionally classified into three types based on their broadly differing continuity characteristics (Table IV). This classification

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**Table IV**

Continuity classification for Dolgellau gold veins

<table>
<thead>
<tr>
<th>Continuity type</th>
<th>Example vein</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1: Continuous</td>
<td>Cefn Coch &amp; Gwynfynydd</td>
<td>Host fault zone and quartz vein up to 1 km. Veins locally displaced by cross faults and late quartz veins.</td>
</tr>
<tr>
<td>Type 2: Semi continuous</td>
<td>Clogas &amp; Maestryfer</td>
<td>Host fault zone up to 1 km. Vein segments range from &lt;100 m up to few 100 m's. Fault blanks/gouge separate vein segments. Veins locally displaced by cross faults and late quartz veins.</td>
</tr>
<tr>
<td>Type 3: Discontinuous</td>
<td>Tyn’y Llwyn</td>
<td>Host fault zone up to 1 km. Vein segments generally less than 20 m. Fault blanks separate vein segments. Veins locally displaced by cross faults and late quartz veins.</td>
</tr>
</tbody>
</table>

Figure 16. Detailed structure of the New Main vein system at Gwynfynydd mine on the 6 Level (redrawn and simplified from Ashton5).

The southern margin of the quartz marks the main fault plane, the central and northern leaves of quartz lie on faults with much smaller displacement.
leads to the definition of characteristics that indicate evaluation needs (Table V). In general terms, the more continuous quartz veins (Type 1) can be globally defined by drilling (50 m by 50 m), whereas in the case of discontinuous veins (Type 3) a wide spaced drilling grid (50 m by 50 m) will resolve the gross fault zone continuity, but may not locate quartz vein segments. Where veins are intersected in Type 3 systems (to some extent also in Type 2), the assumption of quartz continuity between holes is likely to be flawed. In all cases, the small scale structures (mostly <20 m) that carry high grade gold, require underground development, a fine drill grid (<5 m by 5 m) and/or surface mapping to resolve.

It must be considered, that like many extreme nugget effect systems, Dolgellau veins cannot be evaluated using diamond drilling unless unrealistic spacings are used (e.g. <5 m by 5 m). Any drilling undertaken is in an attempt to resolve geological features and not grade. Drilling aims to identify certain geological features (e.g. stratigraphy, presence of greenstone bodies, quartz veins, etc) than can be used to evaluate the grade potential (e.g. ore shoot) of the target zone. Only closely sampled mapped underground development will resolve grade continuity.19,20

From a gold grade localization perspective, there are, generally, three levels of complexity that can be recognized in both Dolgellau and other systems globally:

• Gold distribution (internal architecture) in the host structure may be controlled by textural development of the vein minerals to give an irregular distribution. This has been proven in Dolgellau, where vein textures are seen to control gold particle distribution and hence the local nugget effect.23,45
• Primary shape and dimensions (geometry) of the host vein are principally controlled by slip directions and initial fracture shape. Fracture pattern and deformation style may be controlled by the behaviour of the rest of the vein structures and its host rock. Veins in the gold belt are grossly controlled by geomechanical variability within the host shale and localized intersection with massive greenstone bodies.16,24
• Relationship of the gold rich vein(s) to the whole structure (internal architecture) can be affected by late deformation, minor igneous intrusions, etc. Late faults, barren quartz veining and Clogau Stone dykes have an effect of both diluting and displacing primary gold distribution in Dolgellau.16,24

Dolgellau veins are a high risk style of mineralization due to the relatively small size of the ore shoots (tens m scale) and highly localized (<10 m scale) gold pockets, therein. On the macro-scale, the occurrence of individual ore shoots is controlled by the gross reef structure crossing greenstone sills and/or vein splits/branches. The high risk nature of the deposit only permits the definition of relatively small resources (less than 10 000 t) after drilling and/or underground development. Potential economic viability is gained through the use of gold for a jewellery product, which carries a substantial premium on the bullion price.

### Conclusion

This contribution indicates that high quality geological mapping contributes to orebody knowledge and underpins the management of resource risk in structurally controlled gold veins. If geological (and grade) continuity issues can be determined early in a project life, it will permit the technical team to define realistic deposit expectations and milestones. The level of investment required to resolve geology (and grade) is often high, and can involve underground development supported by diamond drilling. This is the price that an operator must be prepared to pay if they wish to work within structurally controlled vein systems and maintain a sensible level of risk reduction. A strong geological understanding should form the base of all resource estimates. Beyond evaluation, mapping supports grade control during production and dynamic review of the geological model. The key message from this paper is ‘geological mapping adds significantly to orebody knowledge, in addition to reducing project/resource risk’.

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### Table V

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<thead>
<tr>
<th>Continuity type</th>
<th>Evaluation characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1: Continuous</td>
<td>Host fault zone and vein gross continuity can be defined from wide spaced drilling to 50 m by 50 m.</td>
</tr>
<tr>
<td>Resolution of gold bearing</td>
<td>Vein to define resources require underground development, surface trenching and/or drill spacing &lt;10 m by 10 m.</td>
</tr>
<tr>
<td>Type 2: Semi continuous</td>
<td>Host fault zone gross continuity can be defined from wide spaced drilling to 50 m by 50 m.</td>
</tr>
<tr>
<td></td>
<td>Vein segment continuity may be defined from 50 m by 50 m to 20 m by 20 m drilling dependent upon segment scale.</td>
</tr>
<tr>
<td></td>
<td>Resolution of gold bearing vein to define resources require underground development, surface trenching and/or a drill spacing &lt;10 m by 10 m.</td>
</tr>
<tr>
<td>Type 3: Discontinuous</td>
<td>Host fault zone gross continuity can be defined from wide spaced drilling to 50 m by 50 m.</td>
</tr>
<tr>
<td></td>
<td>Vein segment continuity may be defined from 10 m by 10 m to 5 m by 5 m drilling dependent upon segment scale.</td>
</tr>
<tr>
<td></td>
<td>Resolution of gold bearing vein to define resources require underground development, surface trenching and/or a drill spacing &lt;5 m by 5 m.</td>
</tr>
</tbody>
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References


41. MINING JOURNAL. Various entries in the London Mining Journal published during the period 1855 to 1893 pertaining to development and production in the Dolgellau gold-belt.

42. MORRISON, T.A. Gold Mining in Western Merioneth. Merioneth Historical and Record Society, Llandysul. 1975. 98 pp.

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