Spatial analysis of gold mineralization information from GSWA's abandoned mine sites database

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Abstract

Selectively extracted data from GSWA's inventory of abandoned mine sites can be processed to form pseudocolour drapes that portray both bedrock and alluvial–colluvial gold-mineralization patterns. Case studies from Norseman and Widgiemooltha illustrate how these patterns, when combined with historical gold production data, can be used to define exploration targets. The Widgiemooltha example demonstrates how geological attributes that are now routinely recorded can assist in understanding controls on bedrock gold mineralization, and in prospectivity mapping.

KEYWORDS: Western Australia, Norseman, Widgiemooltha, abandoned mines, mineralization, mineral exploration, placer deposits, gold, GIS, spatial data.

Introduction

The Geological Survey of Western Australia's (GSWA's) Western Australian inventory of abandoned mine sites (WABMINES) is a comprehensive digital database, growing by about 25 000 records per annum, that provides baseline data, including photographs, on abandoned mining-related features in Western Australia (Ormsby et al., 2003). Included in this information in recent years are the geological descriptions of all types of former mine workings from small prospecting pits to major shafts and opencuts (GSWA, 2004, 2005).

Overall, about 40% of the known 11 411 abandoned mine sites in Western Australia have been documented, and the vast majority of these sites produced gold. The WABMINES database now aims to include every mining-related feature within the surveyed areas, and currently has more than 138 000 records and 34 000 digital photographs.

Spatial analysis of mineralization trends

Abandoned shallow gold workings and shafts commonly follow bedrock-mineralized features such as quartz veins. They once formed the equivalent of a drillhole for exploration purposes, with the difference being that each working was commonly excavated on the surface outcrop of a vein that produced visible gold from dollying. With continued encouragement, these workings were extended to follow the dip and strike of the mineralization.

The dense number of features in some mineralized areas makes the WABMINES database ideal for spatially analysing 2D mineralization trends using geographic information software. The objective of this analysis is the identification of new exploration targets from the distribution of abandoned mine and prospect workings. This analysis is based on the recently released 'Inventory of abandoned mine sites: progress 1999–2004' digital dataset (GSWA, 2005).

Methodology

To examine bedrock gold-mineralization patterns, field data collected from shallow workings, shafts, collapsed shafts, rehabilitated shafts, open stopes, and former workings located from historical maps and other sources (under infrastructure and some rehabilitated features) were selected from WABMINES for a particular region. Non-gold workings and mechanically excavated features were excluded. Depth ranges estimated in the field were assigned average depths, and original depths for collapsed shafts were inferred from the height of the waste material (bund) that surrounds the feature. Average depths were applied to rehabilitated workings, and to workings that are now either beneath waste dumps or have been removed by opencuts (under infrastructure), where the original depths were unknown. Because the actual depth of any working more than 20 m deep is normally not known (they are recorded as >20 m), all depths in this category were attributed a value of 25 m.

The other main types of abandoned gold workings are those that follow surficial alluvial, colluvial, or eluvial deposits. In the areas covered by the inventory to date, this type of working commonly resulted from panning or dry blower sampling in areas downslope or downstream from bedrock gold mineralization. All workings of alluvial, colluvial, eluvial, or 'deep lead' origin were noted in the 'MINE_NOTE' field, and were selected from WABMINES to examine 'alluvial' gold-mineralization patterns.

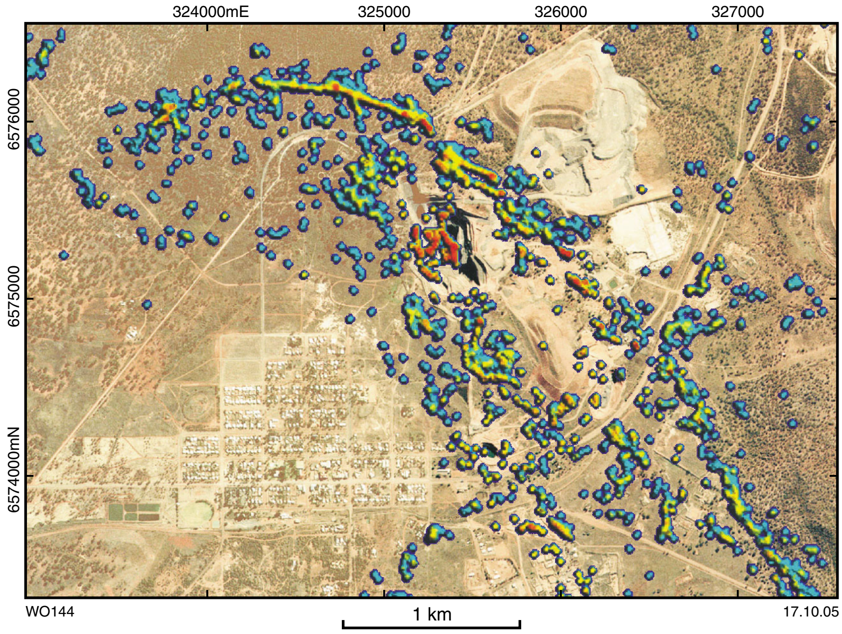

Figure 1. Bedrock gold working depth – density drape on an orthophotograph for the Coolgardie region. The deepest workings are shown in reddish tones, and the areas with a higher surface concentration of workings are shown in higher relief

Creating pseudocolour drapes

ArcGIS Spatial Analyst software was used to generate raster images of the surface concentration of workings (density), and of working depth via the neighbourhood statistics function. The working density images were produced by calculating the sum of points within a 20 m search radius, with an output cell size of 10 × 10 m. This resulted in both an amplified and smoothed output. The same approach was used for summing the depth of the workings, rather than calculating the mean, so that depth variations were accentuated, yet still reflected a component of working density. Three-dimensional pseudocolour drapes of working depth (in colour) over density (as elevation) were generated using ER Mapper software (Fig. 1).

Exploration target generation

For bedrock gold, mineralization structures were interpreted using the bedrock working depth – density drape. Polylines were created in ArcMap to follow the 'ridge lines' on the drape. Buffers were then created to approximate the width of most of the depth–density drape trend lines, and to encompass the relevant pre-1985 gold production sites from the Western Australian mines and mineral deposits information database (MINEDEX database MH sites). The total historical gold production was calculated for each buffer from the MINEDEX production statistics, and was attributed to that buffer. The buffers now represented bedrock gold mineralization structures, and were colour coded to reflect total cumulative gold production.

Exploration targets can be generated from abandoned mine sites data in a number of ways including:

a) examining the relationships between the major historical production structures and more recent mining activity (e.g. opencuts), and identifying similar patterns in areas with no recent exploration or mining activity;
b) identifying mineralization structures with relatively high historical production, but no recent exploration or mining activity;
c) using targets generated by a) or b) above as templates to identify other areas that share similar characteristics in the WABMINES database;
d) by interpreting geological controls on mineralization structures with known high historical production, and identifying other areas with these controls.

Case study — Norseman

Figure 2 shows the bedrock working depth – density drape for the Norseman region. An area east of the township was selected that covered most of the historical gold production in the district. Mineralization structures were interpreted using the drape, and the surface projections of the major gold-producing reefs (adapted from Thomas et al., 1990). The structures were then given a 60 m-wide buffer to cover the majority of relevant workings and associated MINEDEX MH sites. After attributing the buffers with historical gold production (from MINEDEX and Thomas et al., 1990), it became clear that the most gold has been produced from north-trending structures (Fig. 3). The clear definition of north-trending structures highlighted their intersections with major crosscutting structures and the location of a number of recent opencuts near these intersections. Intersections of these structures were used to define the surface projections of exploration targets at the northern end of the Norseman reef, and along the Mount Barker structure (Fig. 3). A similar process was carried out for the minor

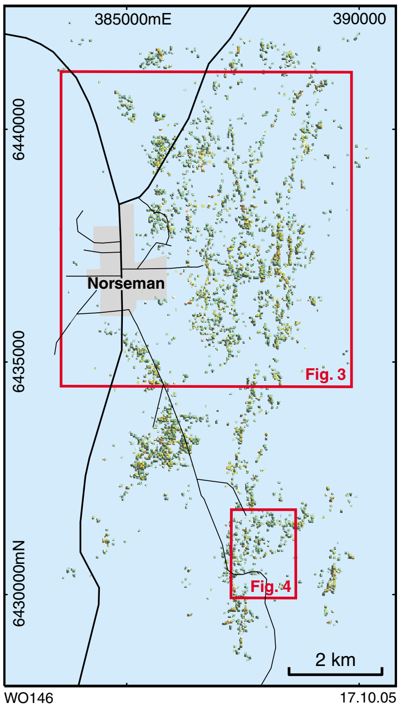

Figure 2. Bedrock gold working depth – density drape for the Norseman region, showing the locations of the areas covered by Figures 3 and 4

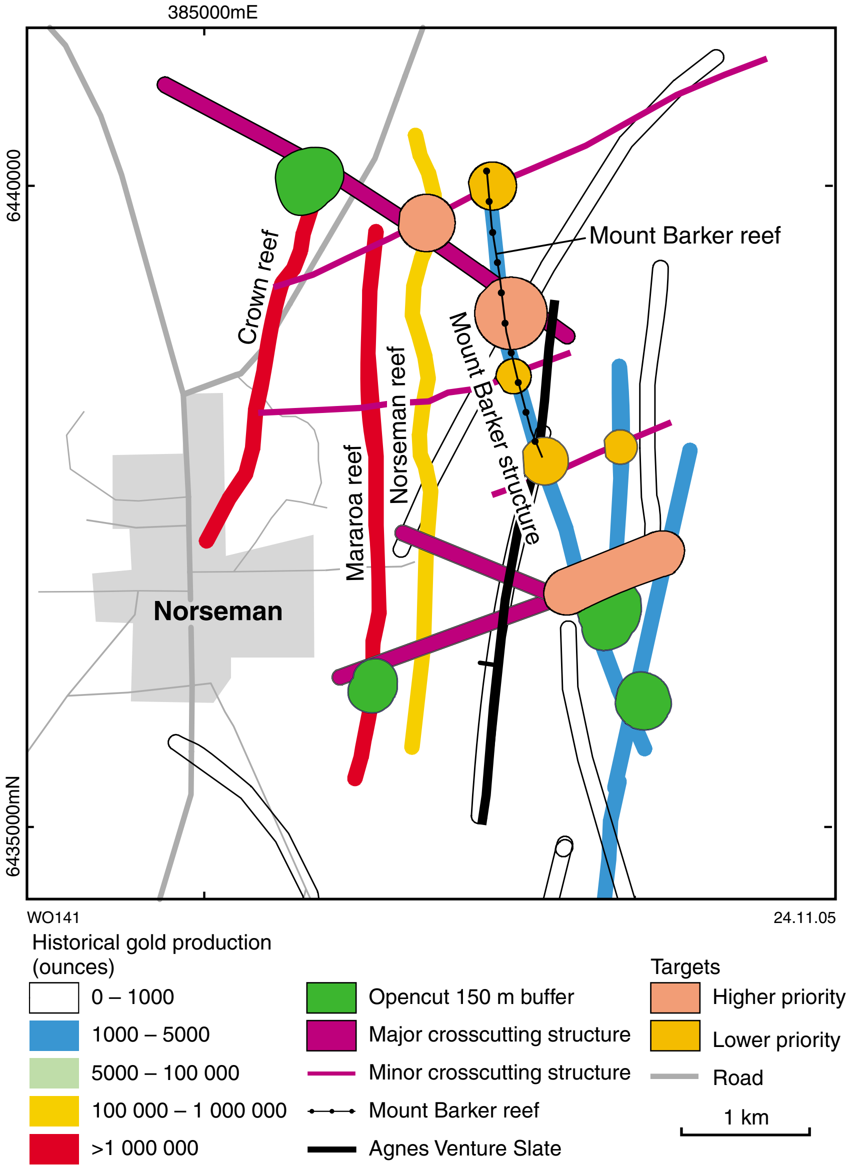

Figure 3. Major bedrock gold-mineralization structures in the Norseman region showing exploration targets

crosscutting structures, with further lower priority targets identified at the intersections of these structures with the major north-trending structures.

The Mount Barker trend was shown to be of similar length to the other major producing reefs, extending about 2.5 km further south of the previously mapped 'Mount Barker reef' (Fig. 3). Historical gold production up to 2.4 km south of the mapped reef suggests the potential for stratigraphically deeper targets beneath the west-dipping 'Agnes Venture Slate' that has been previously thought to mark the eastern boundary of known gold mineralization in this district.

Alluvial–colluvial workings south of Norseman were portrayed as a working depth – density drape (Fig. 4). Like the bedrock workings, many of the alluvial–colluvial workings are along linear trend lines. These trends differ from the bedrock trends in that they reflect areas of downslope redistribution of gold along past and present drainages, rather than primary mineralization structures. The bedrock source of the alluvial–colluvial gold can commonly be inferred from the upslope origin of these lines of workings.

Case study — Widgiemooltha

Like Norseman, bedrock gold mineralization structures were interpreted using the working depth – density drape. In this case, 20 m-wide buffers were generated to cover the majority of associated workings, and associated MINEDEX MH sites. The buffers were again attributed with historical gold production data from the MINEDEX MH sites. Where structures intersect near a MINEDEX site, the production was attributed to the dominant northwesterly structure. Figure 5 depicts historical gold production for both mineralization structures and MINEDEX sites. Three centres of past gold production stood out: Flinders, Cardiff Castle, and Mount. Cardiff Castle and Mount have been

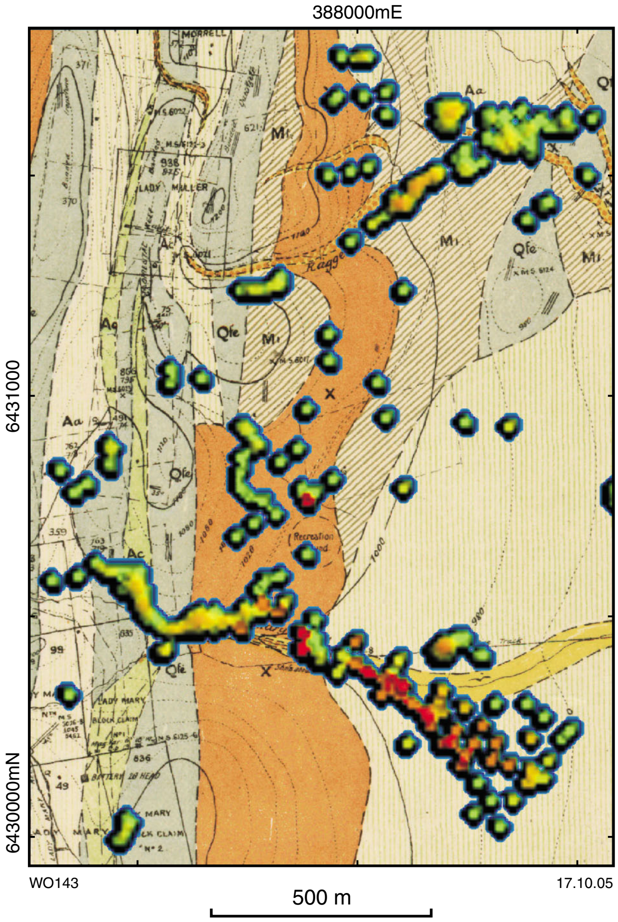

Figure 4. 'Alluvial' gold working depth – density image for the Lady Miller to Lady Mary region, about 7 km southeast of Norseman. The deepest workings are shown in reddish tones, and the areas with a higher surface concentration of workings are shown in higher relief. The base map is from Campbell (1906)

recently explored and mined, but Flinders has received little attention. The majority of gold production in the Flinders area was attributed to a 660 m-long, northwesterly trending 'target' structure.

Specific geological comments in the bedrock gold-mineralization dataset (such as rock type, strike of veins and associated workings, quartz occurrence, foliation, and accessory minerals) were extracted into additional fields and numerically coded for further analysis. Where there were multiple entries such as rock type, a hierarchy was established to ensure that the most relevant lithology (e.g. a marker horizon such as banded iron-formation) was coded. Raster images were then generated using neighbourhood statistics for each of the additional fields (attributes), using the same parameters as for depth and density.

The 'target' structure was intersected with the point layers for each attribute to identify key target characteristics. A selection was made for points both within and outside the 'target' structure, and statistics were examined for each. Natural breaks and various numbers of classes were used to select a threshold value for depth and quartz occurrence that set the target apart from the remainder of the population. Some target characteristics such as rock type, tourmaline occurrence, and foliation were examined visually and have a positive correlation with the target.

Separate binary raster layers were generated for each of the permissive characteristics (e.g. each cell with a depth greater than 12 m was given a value of '1', else '0'), and were added together using the raster calculator in Spatial Analyst. Each layer was given the same weighting. The resultant raster image highlighted other areas with the same permissive characteristics, and hence was a form of prospectivity map. A pseudocolour drape was then created using the same process as for the working depth – density drape, except that 'prospectivity' was shown as colour draped over a 'prospectivity' elevation layer (Fig. 6).

The prospectivity map highlighted a second 'look alike' target area southwest of the previous target at Flinders. Consequently, two areas of exploration interest were clearly defined spatially in the Flinders region. Elevated 'prospectivity' values were also recorded around the Darlek opencut about 1.5 km southeast of Flinders (Fig. 6).

Conclusions

The examples from Norseman and Widgiemooltha illustrate how selective extraction and processing of WABMINES data enables the visualization of both bedrock and alluvial–colluvial gold-mineralization patterns. When combined with historical production information, these mineralization patterns can be used for targeting in areas with significant historical mining activity.

The increased geological information from some of the recent WABMINES data can be extracted and combined to produce prospectivity maps. These data can also provide insights to both regional and local controls on mineralization, as well as providing detailed information on the geological setting at the prospect scale. The extrapolation of regional mineralization controls has the potential to identify targets in areas with surficial cover, especially if used in combination with other detailed proprietary geological, geophysical, and geochemical datasets.

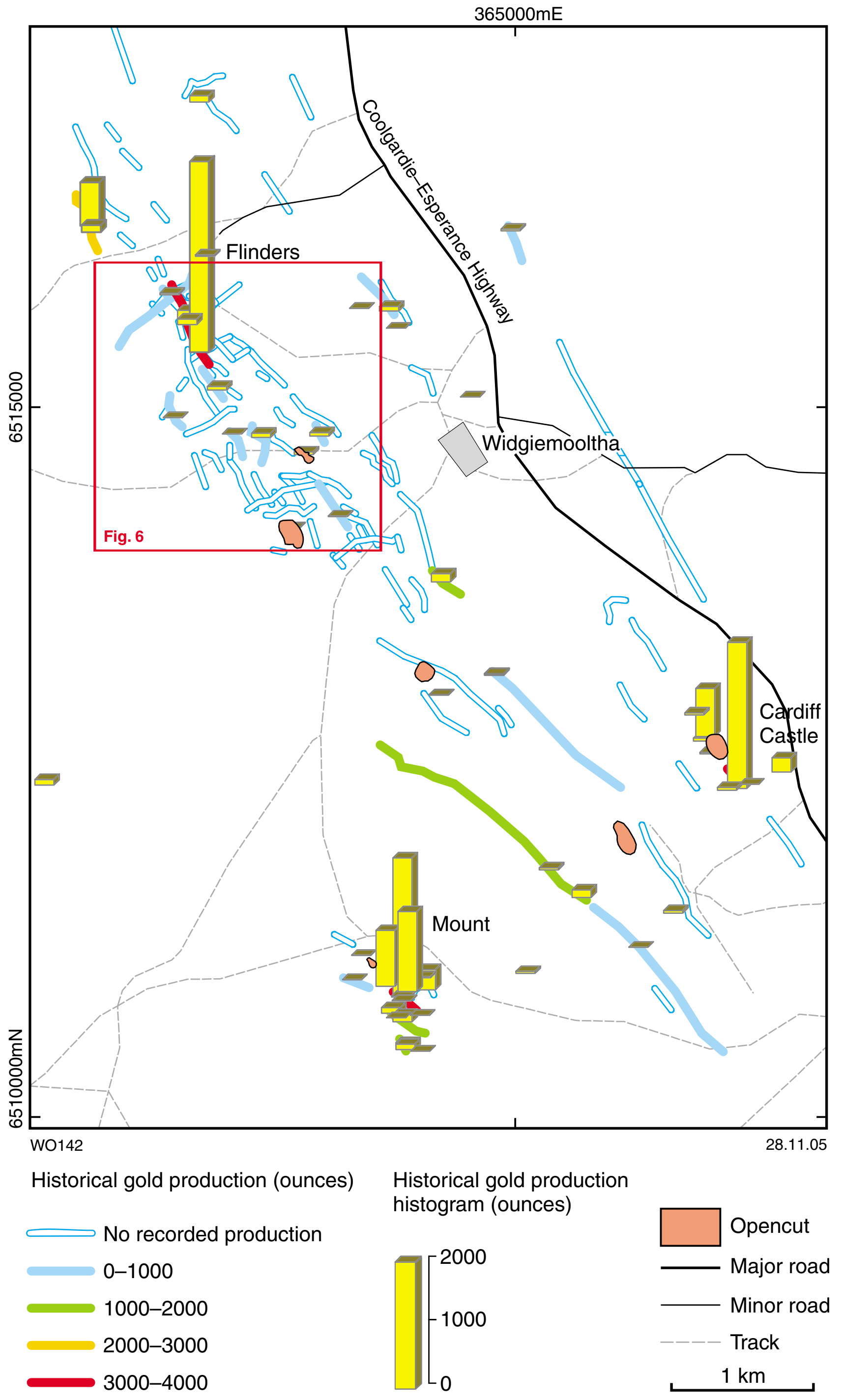

Figure 5. Historical gold production in the Widgiemooltha region shown as coloured mineralization structures, and histograms on MINEDEX MH sites. The Flinders area is highlighted as having had significant previous production and no recent mining development

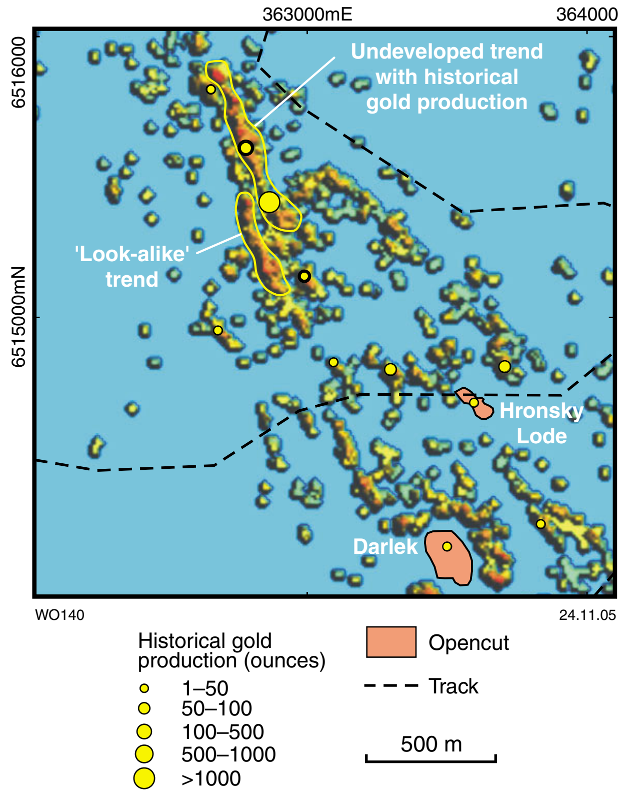

***Figure 6.** Prospectivity map of the Flinders area, located about 2 km west-northwest of Widgiemooltha. Areas with a high prospectivity are shown in reddish tones and with higher relief*

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