Kimberley Basin gold

by L. Y. Hassan

Abstract

Visible gold in stream-sediment samples, and soil anomalies with up to 16 ppm gold, were reported from the Oombulgurri area in the northeast Kimberley Basin in 2002. The anomalies are associated with a large area of argillic and hematitic alteration. The alteration assemblage, together with an association with quartz veins with epithermal textures, suggests that the mineralization is epithermal. The anomalies are near the intersection of northerly, northwesterly, and/or northeasterly trending faults. Auriferous quartz veins were first reported in the southern Kimberley Basin by William Fitzgerald in 1907, and there are a few other historic accounts of gold mineralization in the Kimberley Basin. By analogy with the epithermal fluorite and base metal mineralization at Speewah in the east Kimberley, it is proposed that the gold mineralization in the Kimberley Basin could be related to carbonatites and associated alkaline igneous rocks and could be as young as Miocene. An alternative model is that the mineralization formed during high heat flow associated with rifting during the Devonian–Carboniferous.

KEYWORDS: gold, mineralization, epithermal deposits, alteration, faults, carbonatite, Kimberley Basin.

Introduction

The discovery of gold at 88 Creek in the Oombulgurri area in the northeast Kimberley Basin (Fig. 1) was announced by Striker Resources NL (Striker) in January 2002, following the delineation of a large area of argillic alteration during an airborne hyperspectral scanning survey carried out by DeBeers Australia Exploration Ltd, and the recovery of gold grains during sampling for diamond indicator minerals (Striker Resources NL, 2002a). Striker took up the gold rights on the tenements and subsequently recovered 88 grains of gold from one stream-sediment sample, giving the 88 Creek Prospect (Fig. 1) its name. In September 2002, Striker announced that it had confirmed a new gold province in the north Kimberley (Striker Resources NL, 2002b). However, the gold potential of the Kimberley Basin had been recognized by Fitzgerald (1905) almost a century earlier.

Regional geology

The Kimberley Basin is situated in the northern part of Western Australia. The basin contains predominantly sedimentary rocks (sandstone with minor siltstone, shale, and dolomite) and mafic igneous rocks (the Carson Volcanics) of the Palaeoproterozoic Kimberley Group (Fig. 1), which was deposited within a broad, semi-enclosed, shallow-marine basin. The Kimberley Group unconformably and disconformably overlies sedimentary rocks of the Palaeoproterozoic Speewah Group and both groups are intruded by the c. 1790 Ma Hart Dolerite (Thorne et al., 1999). The Kimberley and Speewah Basins are flanked by metamorphic rocks and granites of the Palaeoproterozoic Lamboo and Hooper Complexes. A more detailed description of the geology of the Kimberley Basin is given in Hassan (2000, in press) and Ruddock (2003).

Historic gold occurrences

In 1905, William Fitzgerald[1] accompanied surveyor Chas Crossland on a government expedition to the west Kimberley. Fitzgerald was employed to assess the agricultural potential of the area, but he also described the geology and botany of the areas he passed through and collected rock and botanical specimens. Fitzgerald (1905, 1907) noted the presence of probable auriferous quartz veins in the Carson Volcanics over a wide area, and submitted samples to E. S. Simpson, the Government Mineralogist and Assayer, for gold assay. A sample from a westerly trending, 1.5 m-wide quartz

[1] Although referred to in the geological literature as a botanist, Fitzgerald studied geology at the School of Mines in Tasmania and learnt botany later by corresponding with the famous Australian botanist Ferdinand von Mueller (Hall, 1978).

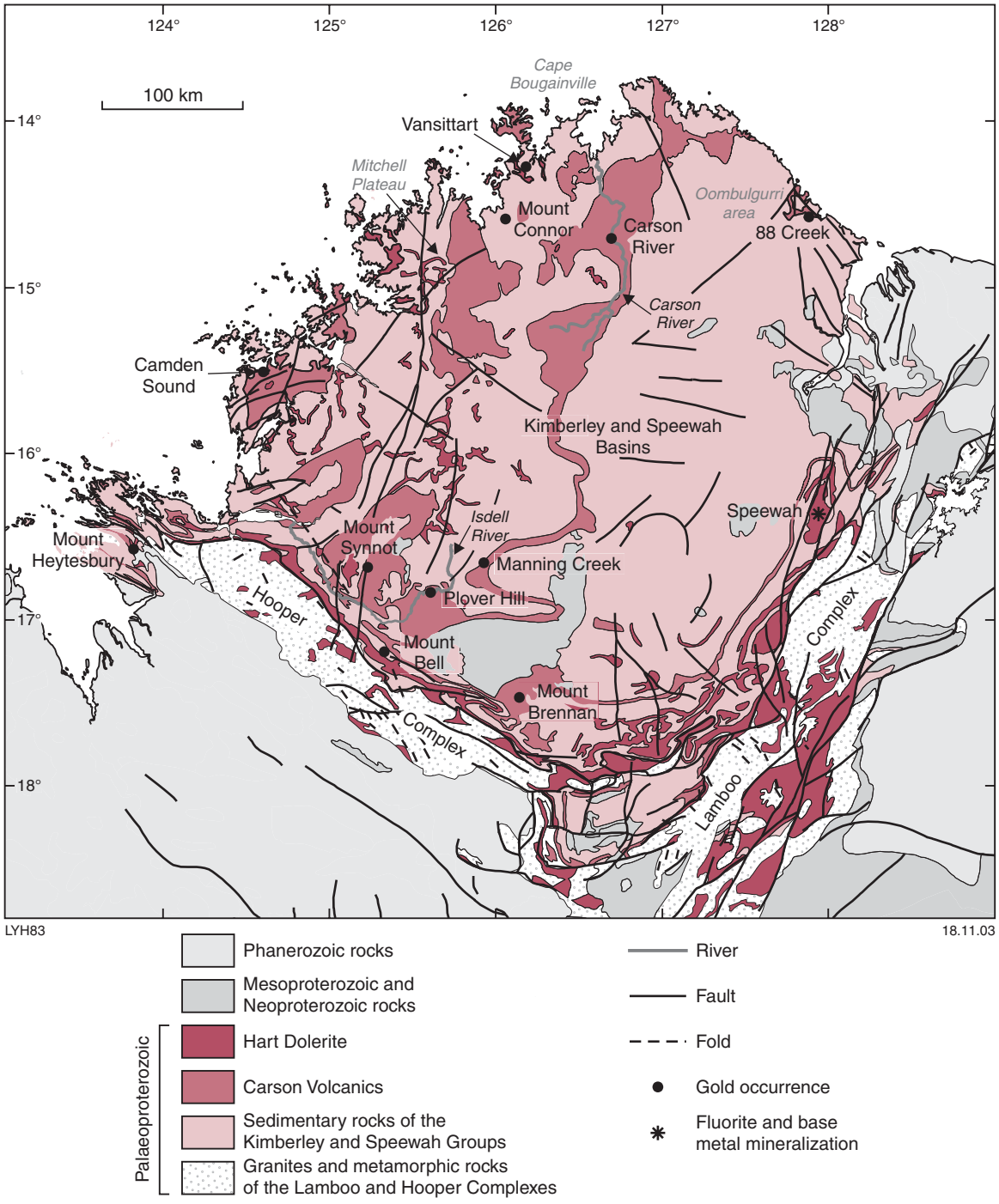

Figure 1. Simplified geological map of the Kimberley Basin showing the location of known and reputed gold occurrences and the Speewah fluorite and base metal mineralization

reef from the Isdell River near Plover Hill[1] (Fig. 1) assayed 71.0 g/t Au (2 oz 5 dwt 18 grs). Other assayed samples included quartz from a reef adjacent to a westerly trending dolerite dyke in Manning Creek (12.3 g/t Au), and pyritic quartz from a major northerly trending quartz body at Mount Synnot (2 g/t Au; Fitzgerald, 1907). Fitzgerald (1905, 1907) also reported auriferous quartz reefs, veins, and stringers associated with abundant hematite and limonite on the lower slopes of Mount Brennan. Samples from three of the larger reefs at Mount Brennan assayed between 1.3 and 2.5 g/t Au. These locations are shown on Figure 1. Fitzgerald (1907) stated that the results 'demonstrate conclusively that at least a portion of the Kimberley basalts constitute a gold-bearing area'.

Intriguingly, until recently, Fitzgerald's discovery of gold in the west Kimberley appears to have been overlooked by prospectors and geologists. Maitland (1919) makes no mention of gold in the west Kimberley in his summary of gold occurrences in Western Australia, even though he was Government Geologist at the time of Fitzgerald's discovery. Harms (1959) dismissed persistent reports of gold in the Kimberley Basin as pyrite in the Carson Volcanics and appeared unaware of the high assays obtained by Fitzgerald, even though Harms cited Fitzgerald's (1907) report in his bibliography. There is also no mention of Fitzgerald's gold discoveries in the explanatory notes for CHARNLEY (Gellatly and Halligan, 1971; Gellatly et al., 1974) or LANSDOWNE* (Gellatly and Derrick, 1967; Gellatly et al., 1975).

There are a few other early reports of gold in the Kimberley Basin. A convict named Wildman claimed he found eight gold nuggets near Camden Sound (Fig. 1) in 1856. When it was confirmed that he had sold gold nuggets in London, an expedition was sent to search for gold but none was found; however, Scholl, who established a government settlement on the Glenelg River, reported finding indications of gold whilst exploring the country between Camden Sound and the King Leopold Ranges in 1865 (Battye, 1915). A report in the Victorian Naturalist in 1886 stated that there was 'every indication of gold' in the valley of the Carson River (Fig. 1). Prospector Charlie James reported finding gold in a series of ferruginous quartz veins from rough country north of Mount Heytesbury (Fig. 1; Sunday Times, 1909a,b,c).

Recent exploration in the Kimberley Basin

Prior to 2002, with the exception of a Temporary Reserve for bauxite on the Mitchell Plateau and mining leases for bauxite at Cape Bougainville, most of the tenements over the Kimberley Basin were held for diamond exploration. Some gold was reported during routine diamond indicator sampling: Faustus Nominees Pty Ltd and Lental Pty Ltd (1996) reported panning significant gold from Vansittart and Mount Connor (Fig. 1). Century Metals and Mining NL (1987) reported a rock-chip sample assaying 0.5 ppm Au from the Isdell River area, but did not give coordinates. In addition, low-grade gold values (1.03 m at 0.69 ppm Au, between 126 and 127 m, and 0.9 m at 0.64 ppm Au, between 432.1 and 433.0 m) were reported from a vertical diamond drillhole (DD88MB2), drilled by CRA Exploration in hematitic sandstone of the King Leopold Sandstone at Mount Bell near the southern margin of the basin (Hamdorf, 1989).

Following the announcement by Striker of gold and hydrothermal alteration in the Oombulgurri area, and the awareness of the possible significance of Fitzgerald's discoveries, many applications for exploration licences have been lodged (Fig. 2). Striker's gold interests over the Kimberley Basin were to be floated on the Australian Stock Exchange (Napier Minerals Ltd, 2003), but the float has subsequently been withdrawn. Striker had not located the veins described by Fitzgerald (1905, 1907) at the time the Napier Minerals prospectus was compiled, although they had found veins with anomalous levels of copper and lead (Fig. 3) and a stream-sediment sample containing 139 ppb Au (Garlick, 2003).

Oombulgurri mineralization

The Oombulgurri area is characterized by widespread argillic alteration with zones of dickite, paragonite, and pyrophyllite identified using De Beers Airborne Multispectral Scanner (Striker Resources NL, 2002a; Garlick, 2003). Although surficial iron oxides are widespread in the Kimberley Basin, Garlick (2003) reported a specific association of iron oxide alteration (hematite) with gold mineralization in the Oombulgurri area. Epithermal textures, such as colloidal banding, are common in quartz veins (Fig. 4), but the highest gold concentration to date from these veins is 491 ppb Au (Striker Resources NL, 2002b). Three areas with anomalous gold values have been defined from soil sampling over a northwesterly trending strike length of 12 km: 88 Creek, Epithermal Creek, and Magnesite Creek. Soil samples containing up to 16 ppm Au have been reported (Striker Resources NL, 2002c; Garlick, 2003). There is generally no correlation of base metal and pathfinder elements with gold, although thallium and uranium anomalies extend over parts of the strongest gold anomalies and there are isolated arsenic and tungsten anomalies associated with the gold anomalies (Garlick, 2003). Optical

[1] Fitzgerald (1907) described the location as adjacent to the Isdell River and almost opposite Plover Hill, but, according to his diary (Fitzgerald, 1905), Fitzgerald only travelled 10 miles (16.7 km) down the Isdell River from Graces Knob on the day he found the quartz vein. Since the vein was in Carson Volcanics, the sample probably came from north of Plover Hill, possibly from a point where a weak easterly trending photolineament is visible. Fitzgerald made a map showing the agricultural potential of the area, which may have shown his sample locations. The map was supposed to have been included with his 1907 report but was omitted. An old Lands Department file in the State Archives (5843-1906) indicates that 270 copies of the map were printed in 1908, but no copies have been preserved in the State Archives.

* Capitalized names refer to standard 1:250 000 map sheets

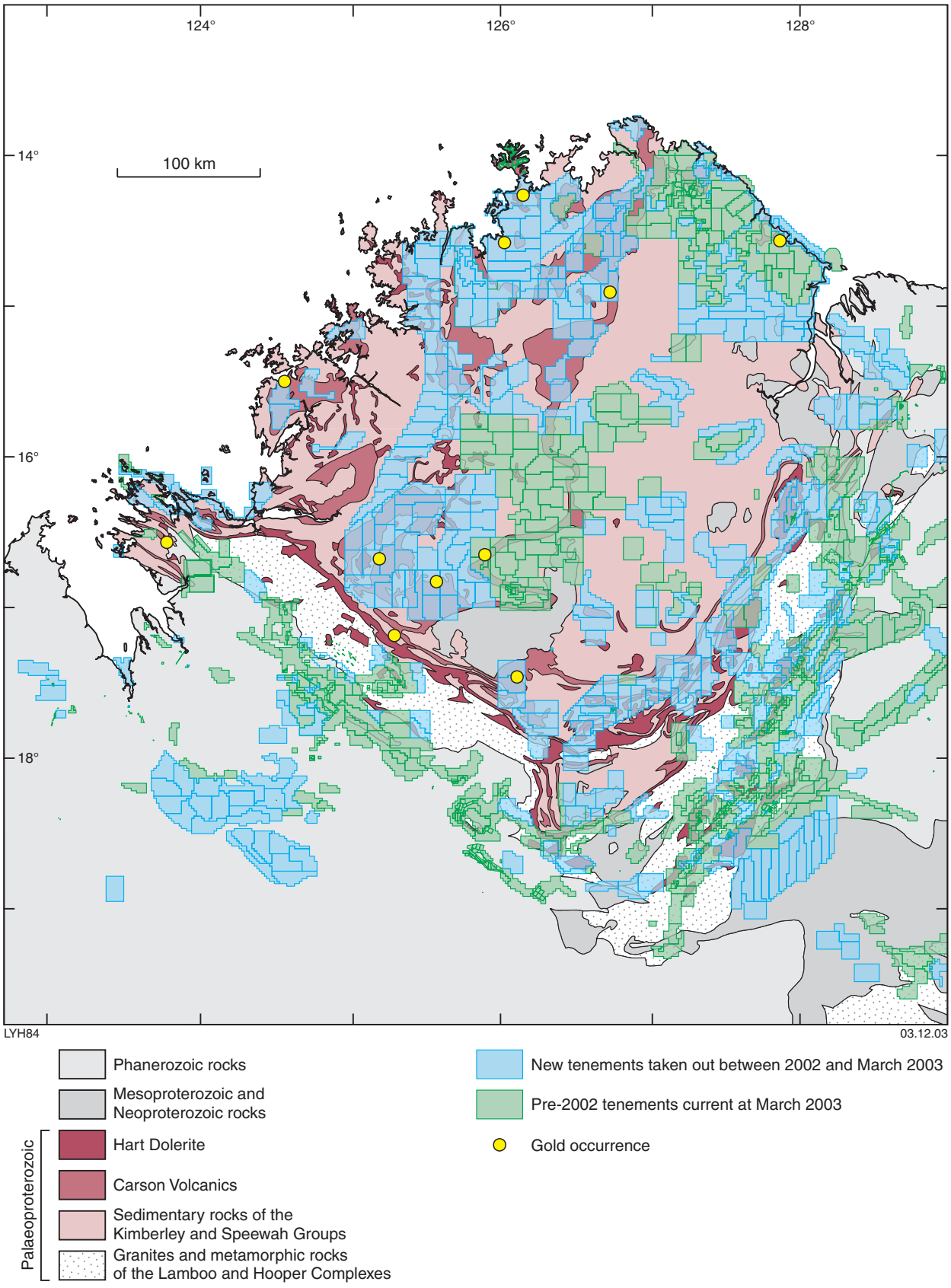

Figure 2. Pre-2002 and 2002–2003 tenements superimposed on a simplified geological map of the Kimberley Basin

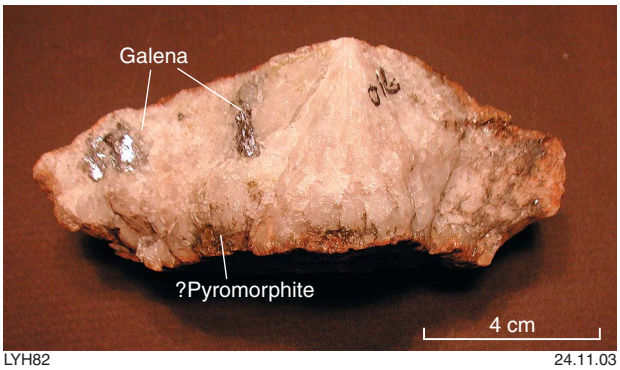

Figure 3. Quartz vein with galena and an olive-green mineral, which is probably pyromorphite; found by Striker Resources southwest of Plover Hill

and scanning-electron microscope studies of the gold grains from 88 Creek indicate that the grains have not been transported very far — they show little mechanical damage, have quartz, calcite, and aluminium oxides attached, and are irregular or xenomorphic in form suggesting they are primary. The 88 Creek soil anomaly has been tested by 48 reverse circulation drillholes. Drilling at the time of prospectus compilation resulted in a best intersection of 1 m at 1.4 ppm Au; this low-grade mineralization is hosted by Warton Sandstone containing quartz micro-veins, phyllosilicate alteration, and disseminated pyrite (Garlick, 2003).

Gold genesis

The presence of quartz veins with epithermal textures (Striker Resources, 2002b) and the widespread argillic alteration suggest an epithermal origin for the gold mineralization in the Oombulgurri area. However, there is no obvious igneous event associated with the mineralization, and the age of mineralization is uncertain. Three models for the mineralization are considered below:

1. Striker/Napier Minerals' model, in which a Phanerozoic granite body provides the heat source.
2. A carbonatite complex as the source of heat and fluids.
3. Rifting and high heat flow associated with continental breakup as a source of fluids.

Phanerozoic granite model

Garlick (2003) proposed a model for the gold mineralization in the Oombulgurri area, whereby a buried igneous intrusion generated a heat cell that focused gold-bearing fluids along near-vertical conduits where northerly, northwesterly, and possibly north-easterly trending faults intersected. Garlick (2003) questioned that the Kimberley Basin is a relatively stable area cratonized in the Palaeoproterozoic, as his proposed model requires that there has been intrusive activity after the deposition of the Palaeoproterozoic Kimberley Group.

There is a prominent magnetic high, 50 km in diameter, in the north-eastern part of the Kimberley Basin (Fig. 5). It may be interpreted to lie on the same trend as a series of offshore magnetic anomalies along a major rift zone known as NW1 (O'Brien et al., 1999), located between the Browse and Bonaparte Basins (Fig. 5). O'Brien et al. (1999) interpreted these magnetic anomalies as mafic igneous intrusions that could be Permian or Mesozoic in age and possibly related to continental breakup. They could, however, also be interpreted as volcanic rocks; Burmah Oil Company of Australia Ltd (1968) reported an intersection of Upper Jurassic volcanic rocks in petroleum well Ashmore Reef 1 (Fig. 5). Napier Minerals' preferred model for the epithermal mineralization in the Oombulgurri area is that the large magnetic anomaly represents a

Figure 4. Laminated epithermal quartz vein (photograph by Striker Resources)

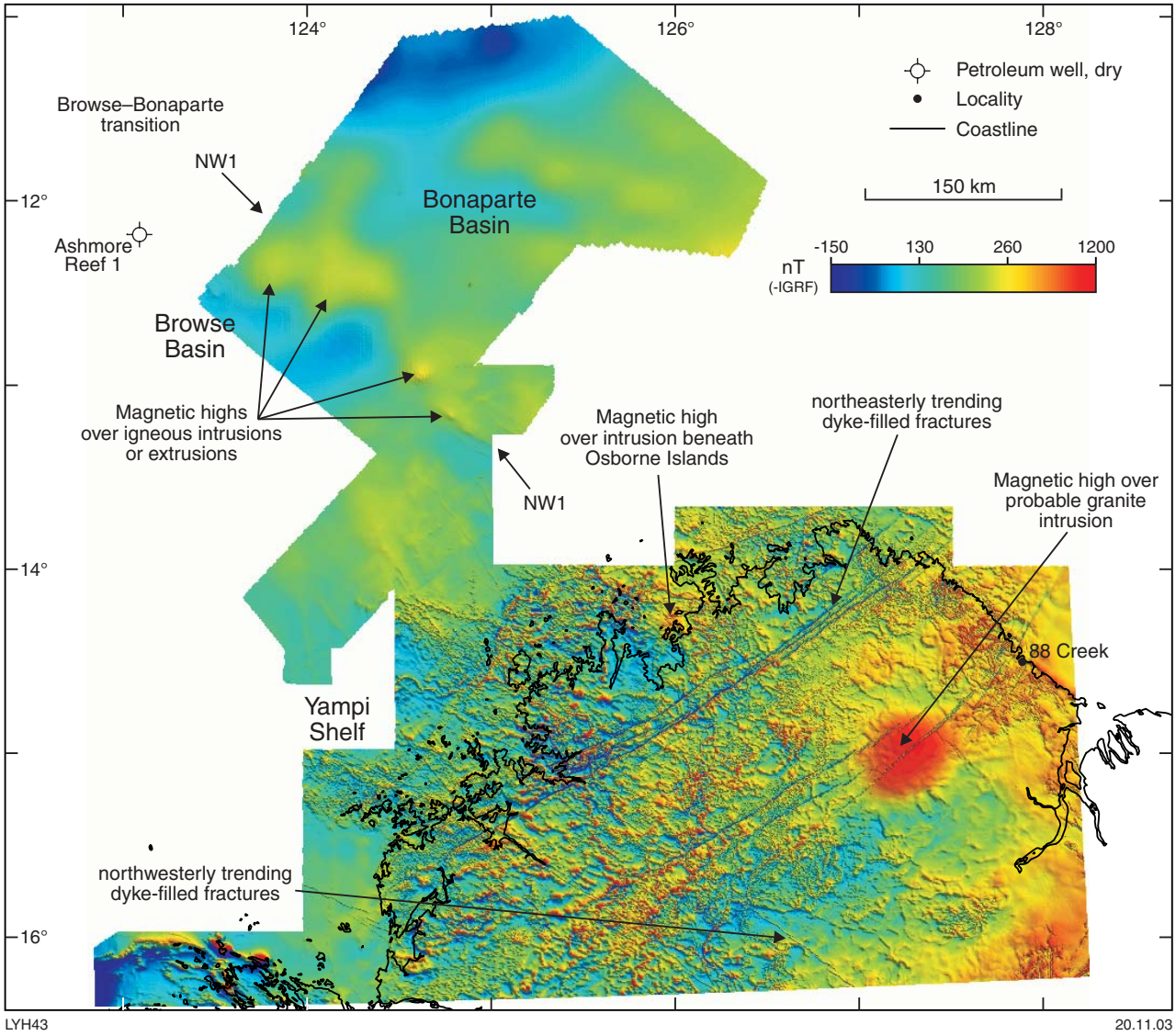

Figure 5. Total magnetic intensity image showing intrusions or extrusions along the Browse–Bonaparte rift zone (NW1) and intrusions along the same trend in the north Kimberley; note also the northwesterly and northeasterly trending dyke-filled fractures (modified from O'Brien et al., 1999 and Gunn and Meixner, 1998)

Phanerozoic granite body related to the intrusions along NW1, and that the granite has introduced mineralizing fluids into the overlying sedimentary pile (Garlick, 2003). However, Garlick (2003) noted that, alternatively, the anomaly could represent a magnetic granite in the underlying Archaean basement. The modelling of Gunn and Meixner (1998) suggests that the large magnetic anomaly is a magnetic granite in the basement, unconformably overlain by about 5 km of Kimberley and Speewah Basin rocks. If this modelling is correct, then the magnetic granite could not have played any role in the Oombulgurri mineralization. Furthermore, it seems unlikely that an intrusion 80 km southwest of the 88 Creek prospect could have resulted in the zoned alteration observed in the area.

Carbonatite model

Epithermal mineralization is known from the Speewah area in the east Kimberley (Hassan, 2000), where fluorite and base metal veins are hosted predominantly by sills of the Hart Dolerite and sedimentary rocks of the Speewah Group. A carbonatite dyke and a hydrothermal–tectonic breccia are associated with the fluorite at West Ridge to the west of the main Speewah deposits (Alvin, 1993). Quartz syenite, diorite, and quartz–feldspar porphyry rubble have been found in a soil-covered area. One of the fluorite veins cuts the Antrim Plateau Volcanics, indicating that the mineralization is younger than Cambrian. Galena from base metal and fluorite veins at Speewah has

given model lead ages of between 15 and 131 Ma, and direct Sm–Nd dating of the veins gave an age of 120 Ma (Alvin, 1993). On the basis of aeromagnetic data and aerial photographs, Rogers (1998) identified circular and curvilinear structures inferred to be ring structures within the Speewah Dome. Rogers (1998) suggested that fractures related to caldera collapse, resurgence, and subsequent rifting could have acted as pathways for hydrothermal fluids and that the carbonatite and associated alkaline rocks might have been the source of the fluids. Only minor gold mineralization has been found in association with base metal and fluorite veins at Speewah, but Rogers (1998) suggested that there could be rich epithermal gold mineralization at depth. Gold enrichment (up to 3.8 g/t) has been reported from weathered carbonatite pyroclastics of the Kruidfontein Volcanic Complex in South Africa (Pirajno et al., 1995). Groves and Vielreicher (2000) interpreted the Palabora carbonatite in South Africa, from which gold is produced as a by-product, as an end member of the iron oxide – copper–gold deposit group. No carbonatites are known from the Oombulgurri area, but since carbonatites may be small and poorly exposed, it is possible that they are present in the Oombulgurri area and other parts of the Kimberley Basin but have not yet been recognized.

Century Metals and Mining NL (1987) searched for diamonds in the vicinity of Plover Hill during 1986–87 on the basis of a prospector's report of a roughly circular occurrence of carbonated agglomerate; it would be worthwhile locating this to determine if it is a carbonatite. This company also named Pegmatite Creek, a tributary of the Isdell River near Plover Hill, so it is possible there are unmapped intrusions in the area that could be a source of ore fluids. A previously unmapped rhyolite porphyry was located in 2003 from Prince Regent (Donaldson, M. O., 2003, written comm.); however, it is not known whether this is related to the Palaeoproterozoic Wotjulum Porphyry, which outcrops 230 km to the west, or is a younger intrusive.

Rifting model

Another possible source of epithermal activity and mineralization is rifting and high heat flow associated with continental breakup, without any associated igneous activity. Such a model was postulated for the Late Permian – Early Cretaceous epithermal gold deposits at Donnybrook in the southwest of Western Australia (Hassan, 1998).

The Oombulgurri gold occurrences are found near the intersection of northerly, northwesterly, and/or northeasterly trending faults (Garlick, 2003), suggesting faults have played a significant role in focusing mineralization. However, there are few age constraints on the faults. The northeasterly and northwesterly trending faults in the Kimberley Basin were interpreted by Gunn and Meixner (1998) to be extensional faults related to a phase of Devonian–Carboniferous rifting. However, some of the faults could be deep-seated crustal structures that were initiated in the Palaeoproterozoic and reactivated many times, similar to the northeasterly trending faults in the Lamboo Complex of the east Kimberley (Tyler et al., 1995). Positively magnetized dykes have intruded some of the northwesterly trending faults; one of these, the Milliwindi Dyke near the southern margin of the Kimberley Basin, has a SHRIMP zircon age of 513 ± 12 Ma (Hanley and Wingate, 2000). The Miocene lamproites in the west Kimberley are localized along inferred northwesterly trending faults (Smith, 1984). The c. 800 Ma kimberlites in the north Kimberley generally have a northeasterly trend (Jacques et al., 1986), including the kimberlites at Seppelt, which lie along northeasterly trending fractures (Striker Resources NL, 2002c). Negatively magnetized dykes intrude northeasterly trending faults, but no dates are available for them. The age of the northerly trending faults is unknown.

West Kimberley deposits

The genesis of the gold mineralization in the west Kimberley is even less certain. Fitzgerald (1907) described the quartz reefs near Plover Hill as 'true fissure reefs', but from his description it is impossible to determine whether the veins are epithermal or mesothermal. At both Plover Hill and Manning Creek, the quartz veins are between or along the wall of easterly trending mafic dykes (Fitzgerald, 1907), suggesting that the veins are syn- or post-dyke in age. According to Fitzgerald (1907), most of the quartz reefs at Mount Brennan also have an easterly trend. In contrast, the pyritic quartz found by Fitzgerald at Mount Synnot is associated with a major northerly trending fault that is visible on Landsat images. Fitzgerald (1905, 1907) noted that there are abundant iron oxides in the Mount Brennan area, both in sandstone and quartzite on the ridges, and in mafic volcanic rocks farther down the slope, where there are masses of hematite and limonite together with quartz veins containing specular hematite.

Conclusions

Epithermal gold mineralization in the Oombulgurri area is associated with an extensive zone of argillic and hematitic alteration, and exists near the intersection of major faults. It is not certain whether the mineralization found by Fitzgerald (1905, 1907) and other early explorers in the west Kimberley is epithermal or mesothermal, or how it relates to the Oombulgurri mineralization. However, as in the Oombulgurri area, at least some of the mineralization described by Fitzgerald is associated with major faults. Hematite alteration is also present at Mount Brennan. If the mineralization found by Fitzgerald is related to that at Oombulgurri, then the Kimberley Basin gold province was discovered nearly 100 years ago. By analogy with the epithermal fluorite and base metal mineralization at Speewah, it is possible that carbonatites and associated alkaline rocks could be a source of heat and fluids, and the gold mineralization in the Kimberley Basin could be as young as Miocene. Another possibility is that the mineralization is related to high heat flow during rifting in the Devonian–Carboniferous. Additional fieldwork may assist in evaluating

these models. If auriferous quartz veins are intersected during diamond drilling, fluid-inclusion studies would provide information on the temperature of deposition and the composition of the ore-forming fluids. A more detailed study of the alteration assemblages would also assist in determining the conditions of ore formation.

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