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Australian Government
Geoscience Australia

PROSPECTS LOOK GOOD in north Queensland

New datasets available for gold prospectors in northern Queensland

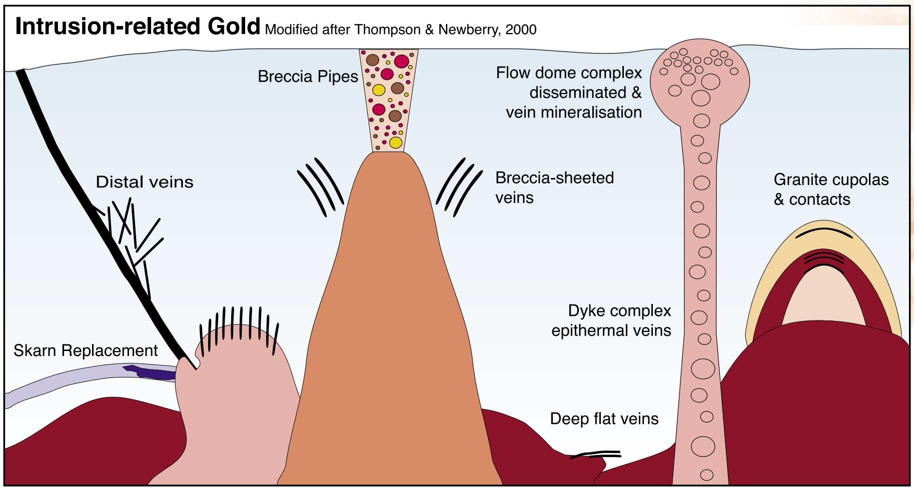

Figure 1. Generalised model for IRG systems. Modified from Thompson & Newberry (2000), to include breccia pipe (Kidston, Qld: Baker & Andrew 1981) and granite carapace (Timbarra, NSW: Mustard 2001) styles.

Table 1. Selected characteristics of intrusion-related gold deposits

Characteristics of IRG systems	Indicators of favourable areas undercovers
Porphyry Cu–Au generally absent	
Continental sedimentary assemblage, especially, carbonaceous or carbonate-bearing	Typically reduced to strongly reduced aeromagnetic signature
Often metaluminous, calc-alkaline, I-type granodiorite to granite, but range of compositions	Aeromagnetic and gravity signatures indicating granites
Typically high crustal levels at time of mineralisation	Indirect evidence such as presence of dyke swarms, particularly when associated with individual granites. Presence of texturally variable granites, including porphyries.
Fractionated granite compositions, with evidence for volatiles (e.g. miaroles, pegmatite, pebble dykes)	Zoned aeromagnetic signatures may indicate fractionation. F in groundwater. F, U, Th anomalies in geochemical data (e.g. stream sediment data). F and U mineral occurrences. Radiometric signatures elevated in K, Th and U (where outcrop exists)
Weakly oxidised to weakly reduced oxidation states	Aeromagnetic and gravity signatures for granites. Weakly oxidised granites readily apparent when intrusive into sedimentary sequences.
Bi, Mo, W, Sn, U, Au, Ag metallogenic signature	Mineral occurrence data—Bi, Mo in particular
May have lateral mineral zonation; W +/– Mo, Sn, Bi, Au > Au, As, Sb > Zn, Pb, Ag	Mineral occurrence data
May have vertical mineral zonation; Bi increases, As, Sb decrease with depth	

Source: Characteristics of IRG systems modified from Thompson et al (1999), Lang & Baker (2001) and Blevin (GA Report, in review).

David Champion

Geoscience Australia is releasing updated datasets of various metallogenic parameters for intrusive and country rock units in north Queensland to assist the exploration industry's search for intrusion-related mineralisation systems.

The work is part of the 'Felsic Igneous Rocks of Australia' project to compile and synthesise publicly available regional datasets of the Tasmanides of eastern Australia, and follows the release of datasets for Tasmania (a joint Geoscience Australia – Mineral Resources Tasmania product, see *Ausgeo News 74*).

Intrusion-related gold systems

Work in the past decade has identified a class of gold deposits associated with felsic intrusions—igneous rocks with high levels of quartz or feldspar. This has consolidated a variety of previously recognised intrusion-related mineralisation under the one mineral system, known as intrusion-related gold (IRG). See figure 1 and table 1, and also Thompson et al (1999).

Broad styles are included within IRG mineral systems. They range from those proximal to granites (e.g. greisen, disseminated gold, skarns) to more distal and controversial styles, such as breccias, and vein systems (figure 1) where the relationship with granites is equivocal. Although model development for IRGs has been largely based on North American deposits, well-studied Australian examples include Timbarra (Mustard 2001), Kidston (Baker & Andrew 1991) and Red Dome (see Blevin 2004).

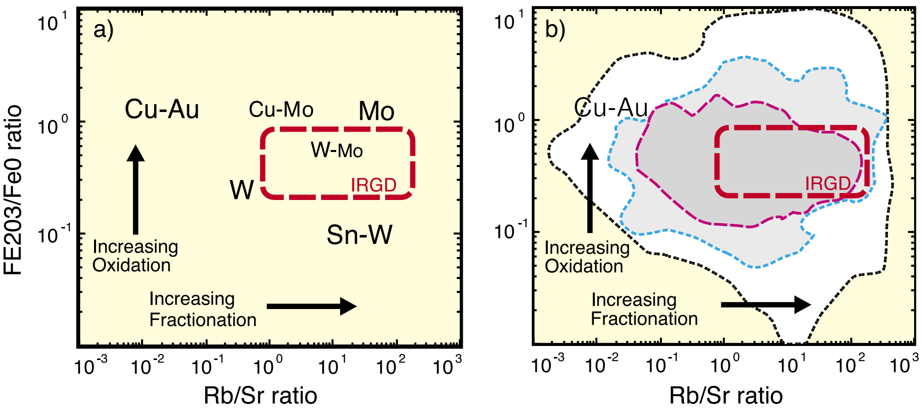

Figure 2. **(a)** Relationship between the oxidation state (calculated using total rock Fe_2O_3/FeO ratio) and the degree of evolution (calculated using total rock Rb/Sr ratio) of granites, and related metallogenic associations, as documented by Blevin et al (1996) and Blevin (2004). 9. **(b)** Oxidation-evolution plot contoured using available geochemical data for north Queensland granites. The bulk of the geochemical data falls within the dark grey contour (pink line), strongly overlapping with the suggested field (Blevin 2004) for IRG.

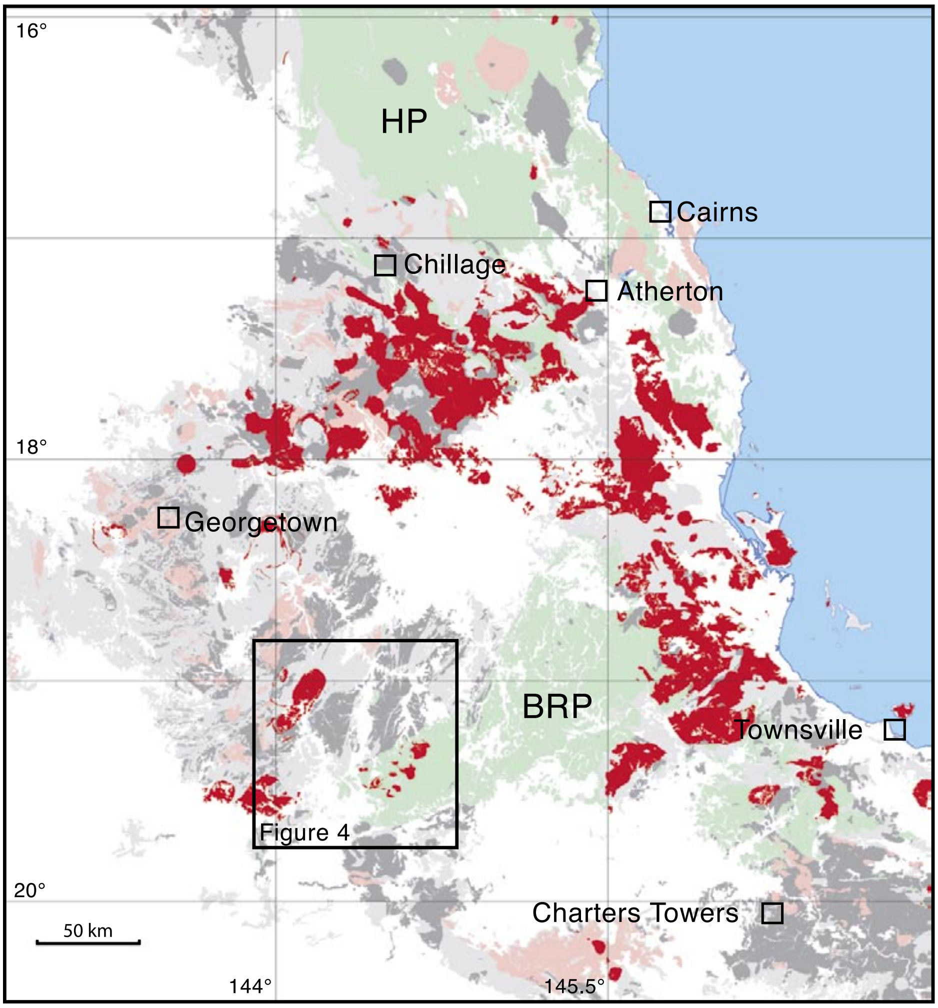

Figure 3. Distribution of North Queensland granites with favourable oxidation and fractionation characteristics for potential IRG mineralisation (i.e. those inside the IRG box in figure 2). Carboniferous to Permian I-type granites shown in red, other granites in pink; granites with non-favourable characteristics in dark grey; non-granites in light grey; Mesozoic and younger cover rocks in white. Major Palaeozoic basins, including the Hodgkinson Province (HP) and Broken River Province (BRP) shown in light green. Black box marks location of figure 4.

One of the central tenets of studies of granite-related mineralisation has been the recognised role of variations in granite properties such as oxidation state, as initially recognised by Burnham & Ohmoto (1980) and Ishihara (1981).

Blevin and co-workers (Blevin et al 1996, Blevin 2004), and more recently others (e.g. Thompson et al 1999), have documented the relationship between the degree of fractionation and the oxidation state of the associated intrusives and commodity-types in granite-related mineralisation systems. This simple but powerful relationship (figure 2) can be utilised predictively. Champion & Mackenzie (1994) demonstrated the very strong correlation between tin occurrences in north Queensland and reduced, strongly fractionated granites, regardless of age, granite type or other characteristics.

A similar approach can be utilised for IRGs, though their parameters are less certain. Most are clearly associated with evolved felsic intrusives. This is particularly true for Australian deposits, such as Timbarra (Mustard 2001), but probably less so for northern American deposits (e.g. Hart et al 2004).

Most controversy concerns the relative oxidation state of the intrusives. Early IRG models emphasised the mildly to moderately reduced nature of the granites, based on aeromagnetic signatures, whole rock Fe_2O_3/FeO ratios, magnetic susceptibility measurements, and the lack of modal primary magnetite (e.g. Thompson et al 1999).

This contrasts with reported data for Australian IRGs, which are commonly weakly to moderately oxidised, largely just above the Far North Queensland buffer (see Blevin 2004). The presence of titanite (if primary) in at least some of northern American granites associated with IRGs (e.g. Hart et al 2004) is also more consistent with a weakly oxidised (though magnetite-free) nature. Accordingly, we have followed the interpretation of Blevin (2004; see figure 2), an interpretation now also largely supported by Baker et al (2005).

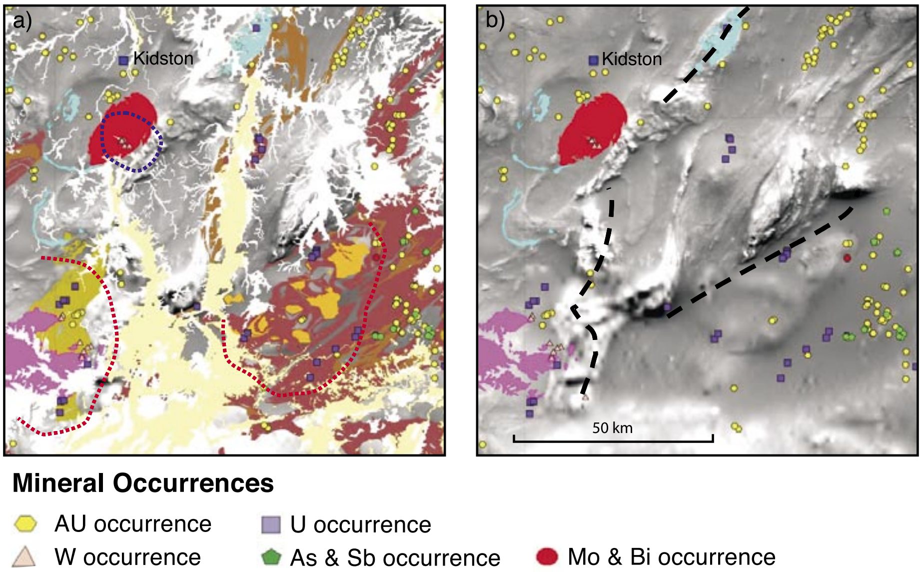

Figure 4. Geology of the Kidston region. **(a)** Mineral occurrence data and selected geology superimposed on regional aeromagnetic data. Broad metallogenic zoning centred around the fractionated, weakly oxidised granites (in red, blue, pink and ochre), is evident in the mineral occurrence data. Geology shown also includes high-level granites and porphyries (ochre), graphitic and carbonate-bearing sediments (browns), and cover rocks (Tertiary—yellow, Quaternary—white). **(b)** TMI aeromagentic image of the region showing the presence of major structures and a buried granite within the Broken River Province.

As part of the Felsic Igneous Rocks of Australia project, we have been compiling and synthesising various lithological, mineralogical, geochemical and metallogenic parameters for intrusive and country rock units of eastern Australia. One of the chief and first aims is compilation and interpretation of chemical-based metallogenic parameters for the granites, using characteristics identified by Blevin and other workers. The simplest first-pass approach has been to use the granite data in combination with the oxidation and degree-of-evolution parameters as defined by Blevin (2004; figure 2).

The north Queensland region (figure 3), has been the site of voluminous, episodic granite magmatism and associated volcanism, ranging in age from Mesoproterozoic (~1550 Ma), Silurian–Devonian (430–380 Ma), to Carboniferous–Permian (330–250 Ma). Magmatism of the most recent of these periods was the most voluminous and widespread, and is associated with a period of intense mineralisation, much of it probably granite-related (e.g. Bain & Draper 1997).

More than 650 intrusive units (Proterozoic to Permian) have been recognised in the region, with reliable geochemical data (in digital format) available for 375 units. Geochemical data from these units has been plotted (contoured) on the oxidation–fractionation diagram of Blevin (2004; figure 2), from which a number of points are illustrated.

First, it is evident that the granites collectively span a range of compositions, encompassing various metallogenic associations, consistent with what is known for this strongly mineralised region.

Second, it is evident that only a few of the granites have characteristics considered conducive for the granite-related copper–gold class of deposits (such as Cadia, New South Wales), potentially explaining the apparent dearth of significant deposits of such styles within the region. This is also consistent with the low potassium–rubidium ratios (< 400) of the north Queensland granites in the region, in contrast to the elevated values found with copper–gold associated granites elsewhere (Blevin 2004).

Third, and possibly most important, it is clear that a high percentage of the granites in north Queensland for which data exists have characteristics considered conducive for IRG-style mineralisation. Of approximately 300 granite units that fall within the IRG field of Blevin (2004), the majority (75%) are I-type and Carboniferous to Permian (figure 3), the age of most mineralisation in the region. Importantly, some 60% of these latter granites belong to just three granite supersuites: the well-endowed I-type Ootann, O'Briens Creek and Oweenee supersuites.

General models for the IRG system also highlight the importance of continental sedimentary assemblages as host rocks, especially those with carbonaceous- or carbonate-bearing units (table 1). When this is included as an additional selection parameter for north Queensland, only the western part of Hodgkinson Province and the eastern half of the Broken River Province (figure 3) emerge as prospective regions. Although these are sites of the major Palaeozoic basins in the region, it should be noted that one of the largest gold deposits in the region—Kidston—does not fall within these basins (figure 3).

Under cover/blind mineralisation

Two obvious features of Figure 3 are the amount of reasonable outcrop in the north Queensland region and, paradoxically, the extent of post-Permian cover for much of the region. Both offer additional exploration potential. It is evident that potential IRG-style mineralisation may be present beneath shallow cover along the north–south spine of the IRG-potential granites, in the northwest (west of Herberton, north of Georgetown) and in the southwest (south and southwest of Georgetown). Additional potential (buried) mineralisation, however, also exists in regions of good outcrop as blind deposits, related to buried granites. One potential example of this has been identified in the region just south of Kidston (figure 4).

As well as listing the general characteristics of IRG-style mineralisation, table 1 also documents how these characteristics may be recognised under cover or as blind deposits. Chief amongst these are geophysical characteristics, such as aeromagnetic and gravity data, recognised buried granites (especially those weakly oxidised or magnetically zoned, which may indicate fractionation), dyke swarms (which may also indicate buried granites and/or high crustal levels), and structural pathways.

Other important features include the presence of important pathfinder elements, especially bismuth and molybdenum, highlighting the importance of mineral occurrence databases. Other, more subtle, indicators could include recognised zoning in mineral occurrences (table 1), or possibly groundwater chemistry (such as presence of fluorine, uranium etc.), which may indicate strongly fractionated granites at depth.

Within the Kidston region (figure 4), favourable indicators include:

- presence of buried granites (as indicated by aeromagnetic data)
- abundant hypabyssal intrusions indicative of relatively shallow crustal levels
- presence of major faults
- bismuth and molybdenum occurrences
- presence of apparent broad mineral zoning from proximal uranium, molybdenum, tungsten, bismuth or tin to more distal gold or antimony
- presence of carbonate and graphitic horizons in the local country rocks
- proximity to known deposits of the IRG-style (Kidston).

Conclusions

The granite geochemistry of the north Queensland region shows many intrusives with characteristics considered conducive to IRG-style mineralisation. This is consistent with known occurrences of such deposits in the region but also reveals considerable potential for further discoveries.

Most of the favourable granites appear to belong to just three granite supersuites—the I-type Carboniferous to Permian Ootann, O'Briens Creek and Oweenee supersuites. Of these, the Ootann Supersuite is considered particularly favourable. Exploration should not only focus on regions under shallow cover but also on outcrop areas where buried granites (and potential for blind mineralisation) occur.

Acknowledgments

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