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Review

A new tectonic and temporal framework for the Tanzanian Shield: Implications for gold metallogeny and undiscovered endowment

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ABSTRACT

The lack of new gold discoveries in recent times has prompted suggestions that Tanzania is mature or approaching maturity, in terms of gold exploration. New tectonic–metallogenic subdivisions proposed in this study are used to explain gold-endowment, assess gold exploration maturity, and suggest the potential for new discoveries from the following three regions: 1) the Lake Victoria Region, comprising the gold-endowed East Lake Victoria and Lake Nyanza Superterranes of <2.85 Ga greenschist–amphibolite facies granitoid-greenstone terranes in >3.11 Ga continental crust. These superterranes are separated by the gold-poor, Mwanza–Lake Eyasi Superterrane, comprising deeply eroded and/or exhumed terranes of gneissic-granulite belts and widespread granitoid plutons; 2) the Central Tanzania Region, comprising the Moyowosi–Manyoni Superterrane, which is largely composed of granitoid and migmatitic–gneissic terranes, and the Dodoma Basement and Dodoma Schist Superterranes, these are underlain by extensive, >3.2 Ga migmatitic-gneisses and granitoid belts with interspersed, relatively narrow, <2.85 Ga greenschist–amphibolite facies greenstone and schist belts. The Central Tanzania Region also includes the East Ubendian–Mtera Superterrane, comprising the East Ubendian Terrane of predominantly Paleoproterozoic belts with cryptic Archean age components, and the ~2.85–3.0 Ga Isanga–Mtera Terrane of thrust-transported migmatitic ortho- and para-gneisses; and 3) Proterozoic Tanzania Regions, comprising various Archean terranes which were once sutured to the Tanzania Craton prior to later Proterozoic orogenic and tectonic events that separated them from the craton and thermally reworked them. These include the Archean Nyakahura–Burigi Terrane in the Northwestern Tanzania Proterozoic Orogen and the Kilindi–Handeni Superterrane in the Southern East African Orogen of Tanzania.

The major metallogenic significance of the new tectonic subdivisions is the recognition of under-explored belts: 1) in the gold-endowed East Lake Victoria and Lake Nyanza Superterranes, Lake Victoria Region. Here deeply weathered belts in the Musoma–Kilimafedha, Kahama–Mwadui and Nzega–Sekenke Terranes and belts, situated in tectono-thermally reworked crustal blocks such as the Iaida–Haidon, Singida–Mayamaya and Mara–Mobrama Terranes, are predicted to be prospective; 2) in the Dodoma Basement Superterrane, Central Tanzania Region, where relatively thin, juvenile granitoid-greenstone belts, similar to the ~2815–2660 Ma Mazoka Belt in the Undewa–Ilangali Terrane, contain small-scale gold systems with analogous terrane-scale geologic settings and evolution histories to those of gold-hosting greenstone belts in the Sukumaland Terrane, Lake Victoria Region. The overall geologic–geometric setting of the greenstone belts in the Central Tanzania Region (Mazoka-type) is comparable to those of the gold-hosting juvenile granitoid-greenstone belts in the South West and Youanmi Terranes, Yilgarn Craton, Western Australia, and North Superior and North Caribou Superterrane, northwestern Superior Craton, Canada; and 3) in the Proterozoic Tanzanian Regions, where terranes that lie in close geographic proximity and regional strike extension to the gold-endowed Lake Nyanza Superterrane are likely to be most prospective. They include the Archean Nyakahura–Burigi Terrane in unroofed thrust windows of the Mesoproterozoic Karagwe–Ankolean Belt of northwestern Tanzania, and the Kilindi–Handeni Superterrane where Archean proto-crust has been reworked by Pan-African tectonothermal events in the Southern East African Orogen.

1. Introduction

Cratons with well-endowed Neoarchean superterranes world-wide are becoming depleted of gold resources as traditional gold districts approach exploration maturity (Goldfarb et al., 2009).

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Although some gold provinces contain several world-class (>100 t Au), one or more giants (>300 or >500 t Au) and rare super-giants (>10,000 t Au) as well as numerous small orogenic gold deposits (Bierlein et al., 2006; Jaireth and Huston, 2010; and references therein), other provinces appear to host only small deposits. The Tanzanian Craton already hosts some world-class to giant gold deposits (referred to as very-large deposits in this paper), but exploration in recent times has so far failed to provide new discoveries. Viewing this as a scale-dependent problem, Groves (2009) explains the lack of discoveries in recent times as being partly a result of ineffective targeting criteria developed from deposit-scale forensic research studies, undertaken mainly on very large gold deposits. This is because both small and very-large orogenic gold deposits are characterised by similar deposit-scale geological, geochemical and genetic features. Instead, Bierlein et al. (2006) and Leahy et al. (2005) suggest that very-large orogenic gold systems are selectively developed in specific terranes that have suitable geologic–tectonic settings, controlled in space and time by lithospheric-scale tectonic processes. In these orogenic gold systems, superterrane boundaries constitute first-order structures that control crustal-scale plumbing systems of mantle-derived magma and hydrothermal fluids from deeper crustal levels to terrane- and domain-scale depositional sites (Goldfarb et al., 2005; Phillips and Powell, 2010; Ridley et al., 1996).

In some goldfields, gold-prospective provinces are linked to other controlling factors such as major lithospheric instabilities following catastrophic events (e.g. slab detachment, roll-back and ridge subduction) in the crust overlying the sub-continental lithospheric mantle (SCLM: Leahy et al., 2005; Bierlein et al., 2006) and delamination of the lower crust (Czarnota et al., 2010a). These events, which produce high-heat flow in the lithosphere and thus provide access to magmas and hydrothermal fluids, are part of global periods of crustal growth, including specific periods of intense felsic granitoid magmatism, which are more-or-less synchronous with peak gold mineralization events (Goldfarb et al., 2001, 2005). The age of these events and their nature are largely constrained by U–Pb geochronology, and Sm–Nd and Lu–Hf isotopic fingerprinting (Belousova et al., 2009).

Revised superterrane boundaries, based on regional to district-scale solid geological maps produced in this study, represent the spatial extent of contiguous crustal blocks with diverse geologic–tectonic frameworks. They are subdivided in hierarchical order into superterranes, terranes and domains, consistent with the approach of Myers (1990, 1997) and Swager (1997). The metallogenic equivalents of these tectonic subdivisions are goldfields, provinces and camps. The tectonic–metallogenic subdivisions introduced are used elsewhere in well-researched and systematically explored provinces of the Yilgarn Craton, Western Australia (Blewett et al., 2010a, 2010b; Czarnota et al., 2010a; Kositcin et al., 2008; Krapež and Barley, 2008; Robert et al., 2005; and references therein), and in the Superior Craton (Ayer et al., 2010; Percival, 2007; Percival et al., 2001; Robert et al., 2005; and references therein), to explain gold-endowments (e.g. Jaireth and Huston, 2010; Figs. 7 and 14) and assist in targeting of new orogenic gold districts and/or camps.

A similar approach is used herein: 1) to explain potential additional gold-endowment of the Lake Victoria Region, where exploration has been presumed to be mature or approaching maturity (Figs. 1, 2 and 4); and 2) to explain the exploration potential of some of the apparently poorly endowed provinces in the Central Tanzania Region and Southern East African Orogen (Figs. 3, 10, and 11).

2. Review of existing geologic–tectonic subdivisions

2.1. Regional geological maps

Three regional geological maps of Tanzania are used to illustrate advances in understanding of the geologic–tectonic subdivisions and flanking mobile belts, and their implications to gold exploration of Tanzania. These are: 1) The Geological Map of Tanzania of Quennell (1956: Fig. 1); 2) The Lake Victoria Goldfields Map of Barth (1990: Fig. 2); and 3) The Geological and Mineral Deposits Map of Tanzania by the BRGM et al. (2004: Fig. 5). The superterrane-scale boundaries interpreted are draped on to these maps to explain endowment and exploration potential, and not the respective shortcomings and/or similarities between the new and old maps.

2.1.1. Geological map of Quennell (1956)

The map of Quennell (1956) shows the older, Early-Archean Dodoman System overlain by the Nyanzian and Kavirondian Systems (Tanzania Craton), flanked by the Late Archean Usagaran and Ubendian Mobile Belts (Stockley, 1936; Grantham et al., 1945; McConnell, 1945; Quennell et al., 1956). The Dodoman System comprises basement rocks of interleaved concordant granitoids, migmatites and schist belts in widespread belts of tonalite–trondhjemite–granodiorite (TTG) and their gneissic equivalents (e.g. Quarter Degree Sheets (QDS) 161, 162, 178, 179). According to Quennell (1956), the Early-Archean crust forms the basement to greenstone belts in the Singida–Geita and East Lake Region Belts (i.e. the Lake Victoria Goldfields of Barth, 1990; Fig. 2). According to Harpum (1970) and Kimambo (1984), greenstones in those belts were formed as roof pendants. They crop out as linear belts where juxtaposed against granitoids and gneisses and as isolated patches where deeply weathered. The boundaries between the Early-Archean craton and the Late-Archean mobile belts are defined by deformation-metamorphic transitions from the craton into: 1) high-grade metamorphic rocks (e.g. Pan-African/Mozambique Belts: Holmes, 1951; Shackleton, 1986); 2) strongly folded and thrusted sedimentary belts (e.g. Karagwe–Ankolean Belt: Cahen et al., 1984); and 3) poly-deformed high-grade metamorphic rocks intruded by a high-density of granitoids (e.g. Ubendian Mobile Belt: Lenoir et al., 1994).

In summary, the geological map of Quennell (1956) was produced at a time when regional-scale geological controls on gold deposits were considered to be less important for targeting than more detailed belt to deposit-scale controls. This is demonstrated by the amount of detailed and high-quality geological, structural, mineral deposits/occurrences data documented on available 1:125,000 and 1:100,000 scale geological maps in Quarter Degree Sheets mapped between the 1930s and 1960s (e.g. Tanzania, 2005, Fig. 6).

2.1.2. Geological map of Barth (1990)

The 1:500,000 scale geological map of Barth (1990) was produced from geological compilation of 1:125,000 and 1:100,000 scale QDS maps available from the Geological Survey of Tanzania (Tanzania, 2005). The map shows the geology and selected mineral deposits of the Lake Victoria Goldfields. Barth (1990) subdivides the geology of this region from older to younger, into Archean granitoid shield, Archean greenstone belt, Proterozoic–Late Archean intrusive rocks, and Proterozoic and Cenozoic rocks including regolith, and Recent and proto-lake sediments. Structural data on the map of Barth (1990) include only magnetic lineaments and mafic, including gabbroic, dykes.

The map of Barth (1990) was produced during the onset of modern exploration in Tanzania, and, as such, it highlights BIFs and late basins from other greenstones and associated regolith, and linear belts of late-kinematic granitoids in extensive granitoid-gneiss basement. The map clearly shows many gold prospects and old mines, although their spatial relationship with structures cannot be interpreted from the map. This is despite the fact that the importance of structural controls on lode-gold deposits was already known in 1990 (e.g. Groves and Phillips, 1987; Kerrich, 1989).

2.1.3. Geological map of the BRGM et al. (2004)

The map of BRGM et al. (2004) draws much from the work of Pinna et al. (1996) and Pinna et al. (2004b). Their work explains the formation of the Precambrian Shield of Tanzania from the oldest Archean basement, through to the Paleoproterozoic Ubendian and Neoproterozoic Mozambique Belt (see Fig. 5, for a simplified legend, this study;