Journal of African Earth Sciences 109 (2015) 143–153

Contents lists available at ScienceDirect

Journal of African Earth Sciences

journal homepage: www.elsevier.com/locate/jafrearsci

Identifying pathfinder elements from termite mound samples for gold exploration in regolith complex terrain of the Lawra belt, NW Ghana

Emmanuel Arhin [a,*], Samson Boadi [a], Millicent Captain Esoah [b]

[a] University for Development Studies, Faculty of Applied Sciences, Department of Earth and Environmental Sciences, P.O. Box 24, Navrongo, Ghana
[b] University for Development Studies, Faculty of Applied Sciences, Department of Applied Biology, P.O. Box 24, Navrongo, Ghana

ARTICLE INFO

Article history:
Received 27 November 2014
Received in revised form 22 May 2015
Accepted 25 May 2015
Available online 3 June 2015

Keywords:
Termite mound
Bivariate and multivariate analysis
Pathfinder elements
Concealed gold deposits

ABSTRACT

It is difficult to detect gold mineralization under cover of complex regolith comprising widespread ferruginous duricrust, extensive redistributed depositional and patchy residual materials of relict and erosional units by using gold (Au) analytical technique at Lawra belt. Commonly in these areas, the cover materials mask geochemical gold (Au) response to gold deposits under cover. Termite mound samples were collected from residually weathered materials. Fire assay (FA–AAS) was used to determine gold in the termiteria whereas the concentrations of the chalcophile and other selected elements were determined by XRF technique. The geochemical data were analyzed using bivariate and multivariate analysis to establish relationships among elements. Pearson correlation shows that Au, As, Zn, Mo and Cu have moderate to strong correlations. Factor analysis explained 91.53% of the total variance of the data through four factors. Factors 2 and 3 that constituted about 23% of the total variance of the data explained have elements associations with Au and that the elements in these factors are appropriate pathfinder elements. Spatial geochemical distribution of Au only detected small and erratic Au anomaly. Contrastingly the identified pathfinder elements using bivariate and multivariate analysis delineated broader anomalous areas that included gold (Au) anomaly detected by FA–AAS analytical technique. Hidden anomalies in the thick regolith overburden are detectable by the identified pathfinder elements. As and Zn were therefore identified as pathfinder elements suitable for defining Au mineralization in complex regolith environments.

1. Introduction

Exposed gold (Au) deposits have been discovered (Butt, 2004) and lack of discoveries at covered terrains in the past two decades (Blain, 2000; Hronsky, 2009; Mckeith et al., 2010). Many regolith researchers that the lack of discoveries were due to misunderstanding of the regolith environments where the exploration surveys were conducted (Arhin and Nude, 2009; Wang et al., 1995, 2007; Anand et al., 2001). The regolith at the Lawra belt is complex and thus affects the geochemical expressions in the surface regolith due to the evolved and evolving characteristics of surface regolith materials (Arhin and Nude, 2009). Identifying pathfinder elements in complex regolith was demonstrated to be unreliable by Nude et al. (2012). However, Affam and Arhin (2006) recognized termite mounds as a good geochemical sample media for gold exploration, and its validation has been confirmed by Arhin and Nude (2010) in northern Ghana. The termiteria are formed from materials burrowed from deep seated environments upwards by termites and are residual in character. The termite mound samples are relate to underlying mineralization more than the soils which are affected by surface processes especially in complex regolith terrains. Dilution and enhancement of gold in surface regolith at the Lawra belt (Arhin and Nude, 2009) are controlled in part by the regolith–landform evolution, thus determination of pathfinder elements of termite mound samples for gold exploration is necessary.

Termiteria at Lawra belt average about 5 m high and occur as preserved or eroded relict mounds of various sizes (Arhin and Nude, 2010). Height of termiteria is directly proportional to the depth of burrowed materials from sub surface environment. Fractions of bedrock mineralization will be expressed in the termiteria. Sampling them and identifying pathfinder elements are applied to Au exploration in complex regolith terrain. Concentrations of Au and other elements in termite mounds from known Au mineralized areas to non-mineralized Au areas were determined. In less complex regolith terrains Au anomalies expressed in soils were generally relate to the underlying mineralization. On the contrary, the study area is overlain by complex regolith where Au signatures in soils appear unrelated to the

* Corresponding author.
E-mail address: lordarhin@gmail.com (E. Arhin).

http://dx.doi.org/10.1016/j.jafrearsci.2015.05.022
1464-343X/

underlying mineralization. The evolved and evolving characteristics of the regolith and landscape modifications by the surface processes result in the disorderly distribution of the regolith materials. The processes that modify the regolith and the landscape also affect the geochemistry in the surface environment. Evidence of regolith complexity implications on gold geochemical surveys are shown by high and robust surface Au anomalies with no bedrock mineralization (Arhin and Nude, 2009; Griffis et al., 2002). The complex regolith results in the mobilization and redistribution of Au, and has considerable significance to the surface signature of mineralization (Butt, 1989; Gray et al., 1992). Hence considering the mobility of Au in complex regolith environment such as the study area, the application of pathfinder elements is vital. Many exploration companies worked in this area had to discontinue exploration survey when pathfinder elements were not used (Griffis et al., 2002). Reversing the unsuccessful exploration surveys in the study area requires the use of the identified elements, most of these elements are appropriate than others when detecting the concealed gold anomalies in the complex regolith terrain. This paper therefore seeks to identify pathfinder elements from termite mound samples to support gold exploration in the complex regolith terrain of the Lawra belt.

2. Location, geology and regolith of the study area

2.1. Location and geology

The study area is 700 km northwest of Accra, the national capital. It is located in the Lawra Birimian belt in northern Ghana (Kesse, 1985) and its detailed regional geology is shown in Fig. 1. The area is underlain by rocks of the Birimian Supergroup. Most of the metavolcanic rocks are metamorphosed lavas and pyroclastic rocks (greenstones), comprising basalts, andesite, rhyolites, dolerites that are intruded at places by gabbros (Leube et al., 1990; Liegeois et al., 1991; Hirdes et al., 1992; Doumbia et al., 1998; Oberthuer et al., 1998; Egal et al., 2002; Gasquet et al., 2003; Naba et al., 2004; Feybesse et al., 2006). The metasedimentary units consist of phyllite, sericite-schist and metagreywacke that are locally intruded by felsic and mafic dykes. Intruding the metasedimentary and the volcanic suites of rocks are small discordant to semi-discordant, late or post-tectonic soda-rich hornblende–biotite granites or granodiorites that grade into quartz diorite and hornblende diorite (Hirdes et al., 1996). These are referred to as belt granitoids and are generally massive but in shear zones they are strongly foliated. The basin granitoids are large concordant and syntectonic batholitic granitoids commonly banded and foliated. The basin granitoids are two-mica potassic granitoids, containing both biotite and muscovite, with the biotite dominating (Leube et al., 1990). These rocks are generally isoclinally folded, with dips usually greater than 50°. The general foliation in the rocks is N–NNE to S–SSW. Sheared and brecciated quartz veins are extensively developed. Zones of shearing and faulting are locally presented in all the rocks but more pronounced in the soft metasedimentary rocks adjacent to intrusive units (Leube et al., 1990).

2.2. Regolith of the study area

The regolith of the study area is characterized by deep weathering profile, which is well preserved or locally truncated. The laterites and depositional covers are extensively distributed. Most of the low-lying areas are covered by sheet wash deposits, which are characterized by thin layers of colluvium and are interspersed with alluvial deposits. The upland areas are marked generally by scree that decreases in fragment size down-slope. The topography is low and undulating at some places with isolated hills (Arhin and Nude, 2009). Most of the Lawra belt rises gently between elevations of 100 m and 250 m above mean sea level (Meyertons, 1976). The landscape areas that are characterized by lateritic profiles are capped by hardpans. The hill slopes and high pediments are marked by scree, consisting of small fragments of visibly mineralized and altered rock that decrease in fragment size down-slope. Lateritic duricrust that commonly occurs at the topographic highs is formed from in situ weathered materials cemented together by Fe-oxide and clay minerals and thus shows equigranular groundmass. The transported regolith is found generally at low pediments, low-lying areas and around drainage catchment areas. Ferruginous duricrust and sediments are widespread at low pediments and sometimes in stream basins (Nude and Arhin, 2009). They are characterized by rounded and sub-rounded lithic and quartz clasts. Sometimes mature or older laterite is found embedded in an immature or younger laterite with different weathering histories, demonstrating the older laterite was transported. In addition certain areas have been overlain by indurated saprolite and usually appear silicified. The erosional areas that expose the saprolite are generally uncommon.

3. Termites and termite mounds

3.1. Termites

Termites are insects that belong to the family 'Termitidae' and the order 'Isoptera'. In the mound individual termites have their positions in the colony either as workers, soldiers, or reproducers (Eggleton et al., 2008). Termites perform several activities that qualify them as soil engineers. They collect organic material as food source and for nest construction. The collected materials are transported to the nest and are altered during digestion. During the transportation corridors are built in the soil which is later covered by termite-made sheeting. Termites also transport inorganic materials for construction purposes. The building of galleries and nests influences the physical soil properties. In general, galleries and hunting holes enhance the porosity of the soil (Elkins et al., 1986; Basppa and Rajagopal, 1991; Mando et al., 1996) and thus reduce the bulk density (Arsad, 1982). The results of termites burrowing the soils whilst bring materials upwards from the deep seated environments induce higher infiltration rates (Elkins et al., 1986; Mando et al., 1996; Leonard and Rajot, 2001). Indications from Lee and Wood (1971) and Coventry et al. (1988) suggest termites bring materials at depths of 8.5 m, 23 m, and up to 70 m. Termites generally collect soil particles and minerals from the underlying rocks and thus transfer the geochemistry of the underlying rocks and mineralization to the termiteria. Therefore anomalies expressed by sampling termite mounds represent site-specific or in-situ mineralization (D'Orey, 1975; Kebede, 2004), as the materials sampled are usually from the subsurface and generally unaffected by surficial processes. Work by Gleeson and Poulin (1989) and Kebede (2004) validate the direct relationship between the concentration of metals in termite mounds and their contents as the elements migrating from the underlying substrate. The motivation of sampling termite mounds is based on the assumption that the mound building activity results in an upward transfer of clay, silt, sand and fine metal grain particles to the surface, a process opposite to leaching, which often results in significant mobilization and dispersion of trace elements (Roquin et al., 1991; Chatuta and Direng, 2000).

3.2. Termite mound

Termite mounds or termiteria are surface mounds built from materials sourced from bedrocks at or near the water table below