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Research Article

Use of Multi-Media Sampling as Integrated Approach to Surficial Geochemical Sampling for Gold in Regional Reconnaissance Surveys in Parts of the Ashanti Belt, Southwest Ghana

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Abstract: This study compared the conventional method used in surficial geochemical sampling to multimedia sampling method during reconnaissance surveys in gold exploration. The use of the conventional method in regional reconnaissance exploration surveys whereby surficial geochemical sampling is done step-wise, first by sampling stream sediments followed by rock chips then soils and other regolith materials in the search and defining of prospective targets of gold mineralization appears inefficient in geological environments characterized by complex regolith and landform modifications. However, multi-media geochemical sampling which involves the simultaneous sampling of different geochemical samples appears a better alternative and eliminates false and erratic anomalies often associated with the sampling of a single medium. Multi-media samples comprising rock chips, scree, termite mounds and lateritic lags, were collected simultaneously to support stream sediments in parts of the Ashanti belt in the Birimian of southwest Ghana, which is characterized by complex regolith and landform modifications. The most prospective targets among the three anomalous zones defined by the stream survey were better pronounced with the support of the other media, based on the consistency in significant gold contents in those samples. Gold assay values from the multi-media samples ranked the Manso East target as the most prospective and the Manso Northwest target being least prospective due to the inconsistent gold assay values in the different media. Thus the integration of the gold assay values from the various media defined real and prospective geochemical gold targets better than in the conventional method in which sampling of different media was done in stages. Unlike the conventional method, the multi-media survey provided gold results that showed regional, proximal and *in-situ* anomalies simultaneously. Multi-media geochemical survey therefore, appears to be a reliable method that can be used in regional surficial geochemical exploration for gold in areas characterized by hidden anomalies.

Keywords: Exploration, geochemical sampling, Ghana, gold, multi-media samples

INTRODUCTION

In Ghana and many parts of West Africa, the conventional method of regional reconnaissance exploration for gold (Au) follows a systematic practice of collecting samples from streams draining the gold bearing areas to define broad anomalous targets. These regional targets are then followed up to confirm the defined anomalies by sampling rock exposures, regolith materials and soils, sub-surface samples from trenches; and followed possibly by Reverse Circulation (RC) exploratory drilling to understand the distribution and concentration of the mineral. This conventional approach was efficient in the discovery of some major gold producing mines in Ghana. For example the Obuasi mines (Anglogold-Ashanti Ltd.), Tarkwa mines (Goldfields-Ghana), Chirano mines (Redback mining company), Ahafo Kenyasi mines and Akyem projects (Newmont Ghana gold) were founded using the conventional method.

However, the use of the conventional method in which sampling is done step-wise in the search and defining of prospective gold targets appears inefficient in the present day exploration programs. This is because prospective gold targets which are significantly mineralized and therefore, relatively easy to find, appear to have been exhausted over the years, leaving deposits in geological environments that are characterized by complex regolith and landform modifications (Arhin and Nude, 2009; Bolster, 1999; Butt and Zeegers, 1992). This problem is indicated by the slow spate of finding new major gold deposits during the last two decades worldwide. For example, in the case of Ghana, several producing gold mines were

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discovered up to the 1990s, but since then, only two gold producing mines have been founded in addition to the existing ones. Reported cases in Ghana indicate that many exploration companies have abandoned their exploration surveys for the lack of detecting workable gold targets for follow up, especially in areas under cover with buried mineralization (Griffis *et al*., 2002) where conventional method of gold exploration was employed. It therefore, appears that modifications of exploration methodologies are required in areas of complex regolith; and the understanding of landform changes and the regolith are necessary in the interpretation of geochemical data.

In this contribution to the efforts of gold exploration in Ghana, we used multi-media sampling technique in surficial geochemical sampling for gold in parts of the Ashanti gold bearing belt where previous works failed to delineate gold occurrence that merit follow up work to conclusion. We sampled rock exposures and scree samples alongside other regolith materials comprising termite mounds and lateritic lags, in support of the stream sediment samples during a single survey. The results show the method to be an efficient and cost effective approach to surficial geochemical sampling for gold.

GEOLOGICAL SETTING AND REGOLITH

Geological setting: The study area, which is underlain by rocks of the Paleoproterozoic Birimian Super group, is located in the southeastern tip of the Ashanti volcanic belt and the regional geology is shown in Fig. 1. The Ashanti volcanic belt is one of the six parallel greenstone belts found in the Birimian of Ghana; all these belts are associated with gold mineralization (Kesse, 1985). The Birimian rocks in Ghana have been described by several workers including (Junner, 1935, 1940; Kesse, 1985; Milési *et al*., 1989; Leube *et al*., 1990). The rocks comprise metavolcanic and metasedimentary rocks. The metavolcanic rocks are chiefly metamorphosed lavas and pyroclastic rocks (greenstones) comprising basalts andesites, rhyolites, dolerites that are intruded at places by gabbros. Elsewhere the rocks consist of dark grey to greenish grey, weakly foliated mafic volcanic rocks, partially assimilated with melanocratic relicts (xenoliths) in close association with granitoids. The metasedimentary units consist of phyllite, sericite-schist and metagreywacke which are locally intruded by felsic and mafic dykes. Zones of shearing and faulting are locally present in all the rocks but more pronounced in the soft metasedimentary rocks adjacent to the intrusive units (Leube *et al*., 1990).

Intruding the Birimian rocks are migmatitic bodies and porphyritic granitoids that have generally been classified into two broad categories. These are a hornblende-rich varieties that are closely associated with the metavolcanic rocks and known as the 'Dixcove' or 'belt' type; and mica-rich varieties which tend to border the volcanic belt and are in the metasediment units and referred to as 'Cape Coast' or 'basin' type granites (Leube *et al*., 1990; Taylor *et al*., 1992; Hirdes *et al*., 1992). The belt granitoids are small discordant to semi-discordant, late or post-tectonic soda-rich hornblende-biotite granites or granodiorites which grade into quartz diorite and hornblende diorite. They are generally massive but in shear zones they are strongly foliated. The basin granitiods are large concordant and syn-tectonic batholitic granitoids, commonly banded and foliated; they are two-mica

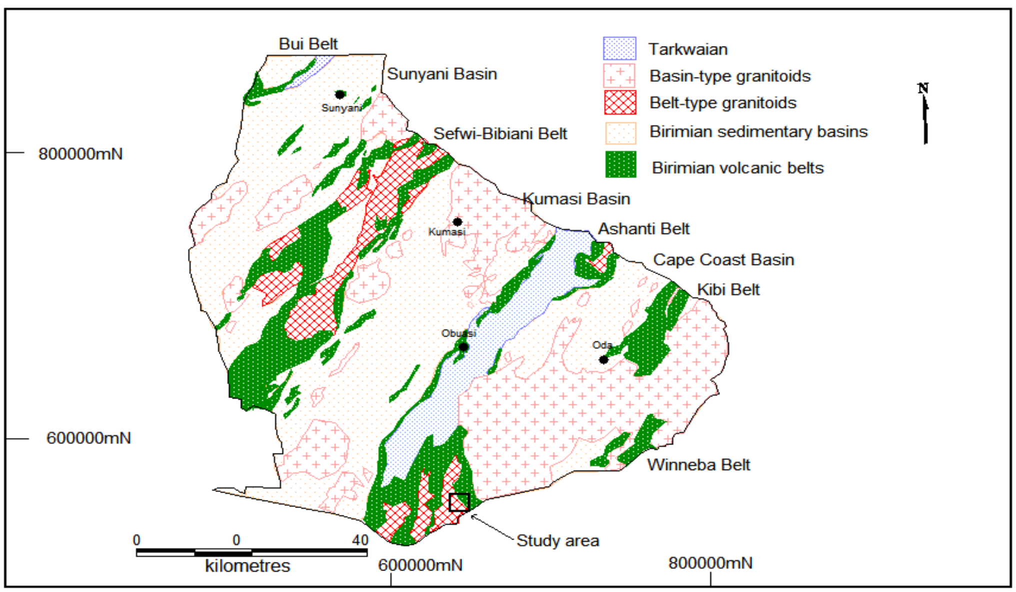

Fig. 1: Regional geological map of parts of southern Ghana showing the rock units and the study area

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 50º. Sheared and brecciated quartz veins are extensively developed.

Regolith: The regolith in the area is characterized by a deep weathering profile, which is preserved and truncated at places and with widespread lateralization that has surface veneer of pisoliths. The hill slopes are marked by scree, consisting of small fragments of visibly mineralized and altered rock, which decrease in fragment size down-slope. Preserved and eroded relict termite mounds of various structures and colorations are interspersed on the hill slopes and over the flat and undulating areas. The area generally has alluvial plains with dendritic stream channels.

Gold mineralization: In Ghana, the volcanic belts and their associated rocks are known to host gold mineralization (Junner, 1940; Kesse, 1985; Ntiamoah-Agyakwa, 1979; Leube *et al*., 1990; Melcher, 1995). The extensive faults and fissure zones are the most important structural features which control Birimian gold mineralization (Ntiamoah-Agyakwa, 1979; Dzigbodi-Adjimah, 1993; Mücke and Dzigbodi-Adjimah, 1994). The gold in the Birirmian occurs in the form of quartz reefs and in sulphide ores (Junner, 1940; Kesse, 1985). In the quartz reefs, gold occurs alongside chalcopyrite, sphalerite, galena and bournovite, whereas in the sulphide ores, gold occurs with aresenopyrite, pyrite and pyrrhotite.

Sampling and gold analysis:

Sampling: The study area was traversed on existing grid lines of 250×50 m and also by the aid of footpaths. During the exploration survey, five different types of geochemical media samples were collected during a single survey. These comprise stream sediments, rock chips, scree at the foot of hills, termite mounds and lateritic lags. The sample points for the stream sediments and the hilly areas were predetermined from the topographical maps using GIS MapInfo-Software and the coordinates uploaded into a Global Positioning System (GPS) receiver. While traversing to either the stream or the hill site; the rock exposures, screes, termite mounds and the lateritic lags found along the traverse and the vicinity were sampled and labeled separately. The stream sediment samples were collected from the active stream channel where clay-silt fractions predominate. Composite samples were also collected from the other media. Representative samples comprising 34 stream sediments, 14 rock chips, 37 scree samples, 12 termite mounds and 6 laterite lags were analyzed for gold.

Gold analysis: The samples were analyzed for gold by Fire Assay-Atomic Absorption Spectrometry (FA-AAS) at a commercial laboratory operated by SGS Mineral Services at Tarkwa, Ghana. FA-AAS was chosen, first, due to the nature of the occurrence of gold in the Birimian, which is often in the form of sulphide ores and second, the method is generally accepted as a dependable analytical method for gold (Delaney and Fletcher, 1999; Juvonen and Kontas, 1999). The analytical procedure described by Nude and Arhin (2009), involves two consecutive metallurgical separations that consist of lead fire assay followed by determination of gold by atomic absorption spectrometry. Representative samples of the rock and the scree were jaw crushed and pulverized to 90% passing 75 µm. The stream sediment samples were dried, homogenized and sieved to -125 µm. The termite mound samples were disaggregated and the lateritic lag samples were crushed and each pulverized to -125 µm. Fifty grams charge of each sample was dissolved in a molten flux and fused in a graphite furnace at 1100ºC. The obtained lead button was removed by cupellation at 950ºC. The resultant gold prill was digested with aqua regia mixture and the solution was analyzed by Varian 55B atomic absorption spectrometer with air-acetylene burner and a lamp current of 4 mA at a detection limit set at <5 ppb. Gold standards were prepared from 1000 ppm stock solution with 10% HCl matrix. Replicate analyses of standards and field-split duplicates were used to estimate analytical precision and relative errors according to the quality control procedures of SGS Mineral Service Laboratories.

RESULTS AND DISCUSSION

Based on previous study in southern Ghana (Griffis *et al*., 2002), gold assay value of 50 ppb was considered significant for all the media and areas with such values and higher have been considered anomalous in this study. On the basis of this cut-off value in gold contents together with the catchment areas of the streams, three stream anomalous zones were delineated. These are the Edum Banso, Manso Northwest and Manso East targets (Fig. 2). The gold contents in the various media which fall within the anomalous gold targets zones defined by the stream sediments are shown in Table 1. Gold values in the stream sediments which fall below the cut-off 50 ppb, grade have been excluded from this table.

At Edum Banso target (Fig. 3), gold contents in the two rock chips sampled are 23 and 403 ppb; at Manso Northwest target the only rock chip sampled assayed at 10 ppb and at the Manso East target the rock chips are significantly high with values ranging from 270 to 1100 ppb (Table 1). In this (Fig. 3), the Edum Banso and Manso East targets defined by the stream survey were confirmed by the significant gold contents in the rock chip samples, although gold contents in the

Table 1: Fire Assay-Atomic Absorption Spectrometry (FA-AAS) analyses of gold contents (ppb) in the multimedia samples from the anomalous gold target zones

Target	UTM-E	UTM-N	Au (ppb)	Sample medium
Edum banso	624259.87	559569.46	100.00	Stream sediment
	624193.63	560198.72	141.00	Stream sediment
	624635.22	560022.09	52.00	Stream sediment
	623553.32	559094.75	58.00	Stream sediment
	623531.25	561578.68	87.00	Stream sediment
	632 750.00	563797.00	23.00	Rock
	623 815.00	561366.00	405.00	Rock
	625080.39	560160.98	100.00	Scree
	625199.92	561794.65	108.00	Scree
	624751.66	562252.88	115.00	Scree
	624462.77	561216.89	150.00	Scree
	625189.96	560539.51	50.00	Scree
	624 323.00	559255.00	210.00	Termite mound
	623 815.00	559573.00	89.00	Laterite
Manso NW	627527.63	563002.81	171.00	Stream sediment
	626368.45	563102.17	85.00	Stream sediment
	626688.61	562362.50	100.00	Stream sediment
	627792.52	564095.74	50.00	Stream sediment
	627 212.00	563468.00	10.00	Rock
	625976.91	563717.16	10.00	Scree
	625976.91	563398.43	21.00	Scree
	625498.77	563298.82	45.00	Scree
	626544.71	562760.90	45.00	Scree
	627769.97	563637.51	29.00	Scree
	625,409.11	562711.10	20.00	Scree
	626,096.45	562103.46	50.00	Scree
	625 877.00	562761.00	50.00	Termite mound
	626 774.00	562094.00	5.00	Termite mound
	627 342.00	562621.00	9.00	Laterite
Manso east	630972.03	562704.73	65.00	Stream sediment
	630629.79	561655.97	105.00	Stream sediment
	631766.88	560783.82	200.00	Stream sediment
	630673.96	559017.47	85.00	Stream sediment
	631976.63	557670.63	150.00	Stream sediment
	632 631.00	560689.00	500.00	Rock
	632 406.00	559165.00	1100.00	Rock
	632 810.00	558 910.00	270.00	Rock
	631 157.00	559 653.00	385.00	Termite mound
	632 153.00	559 314.00	386.00	Termite mound
	631 500.00	560 808.00	23.00	Termite mound
	631 824.00	558 199.00	20.00	Laterite
	632 332.00	561 276.00	108.00	Laterite

Gold values shown in this table are from the anomalous zones defined originally by the stream sediments

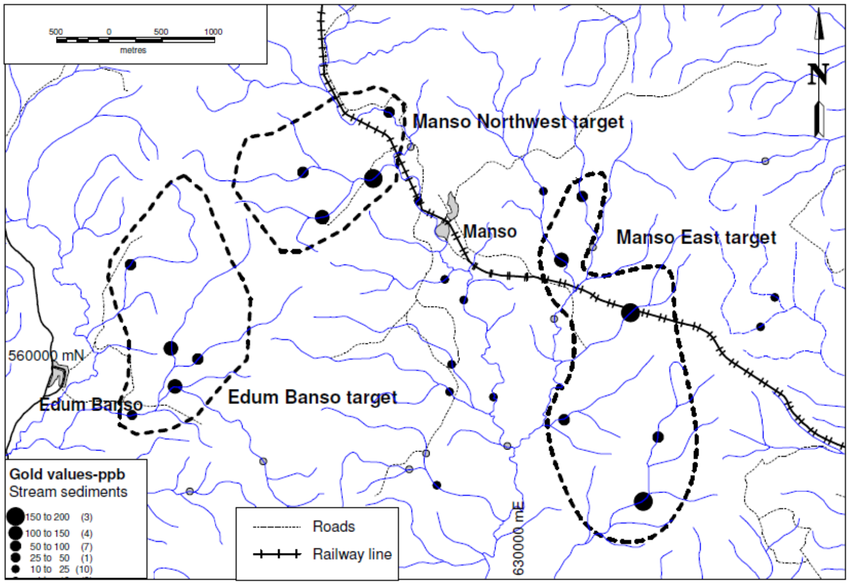

Fig. 2: Anomalous target zones delineated from the distribution of gold contents in the stream sediments

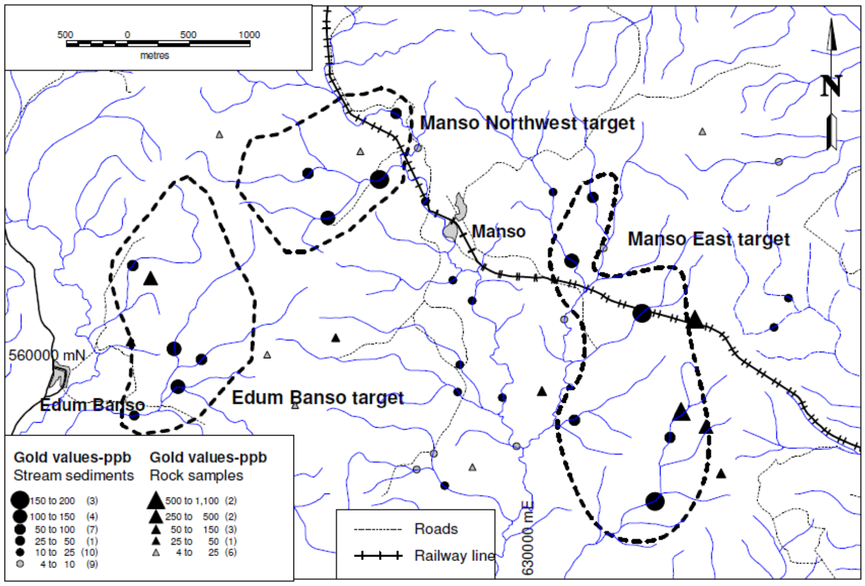

Fig. 3: Gold content distribution in the rock chips integrated with the gold contents in the stream sediments. Anomalous targets are based on gold contents in the stream sediments

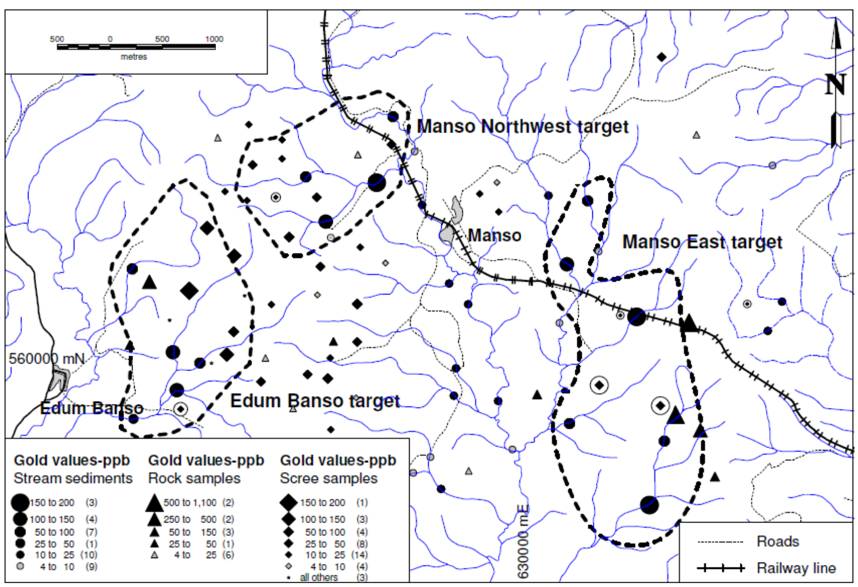

Fig. 4: Gold content distribution in the scree samples integrated with gold contents in the stream sediment and rock samples. Anomalous targets are based on gold contents in the stream sediments

rock chips from the Manso East target were relatively higher. However, the rock chip from the Manso Northwest target which returned gold assay value of 10 ppb, appear insignificant and generally down-graded that target.

From Fig. 4, gold contents in the scree samples which were superimposed on the stream sediment targets confirmed the prospectivity of the anomalous stream targets at Edum Banso and Manso East. Again the scree samples from Manso Northwest target which range from 10 to 50 ppb (Table 1) are relatively low. This is in addition to the weak anomalous gold contents in the rock chips from this target.

It is also noted from Fig. 5 that the stream sediment anomaly in Manso East was enhanced as the gold assay values (23-386 ppb, Table 1) in the termite mounds were integrated with those in stream sediment, the rock chips and the scree samples. Whereas the stream target at Edum Banso did not show any significant enhancement when the gold contents in the termite mound samples were added to these samples, the Manso Northwest target became relatively insignificant

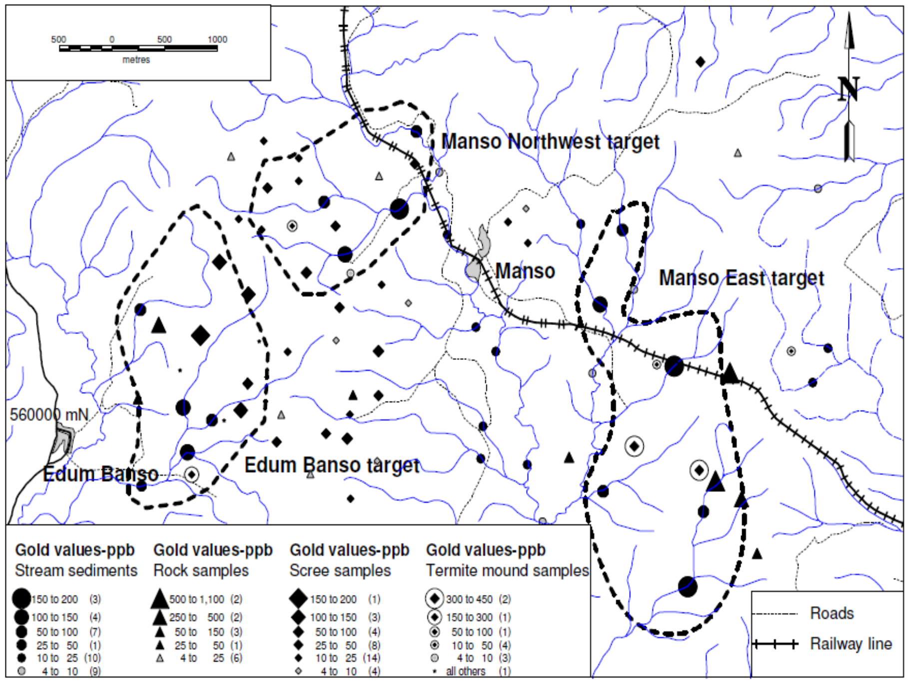

Fig. 5: Gold content distribution in the termite mound samples integrated with gold contents in the stream sediment, rock and the scree samples. Anomalous targets are based on gold contents in the stream sediments

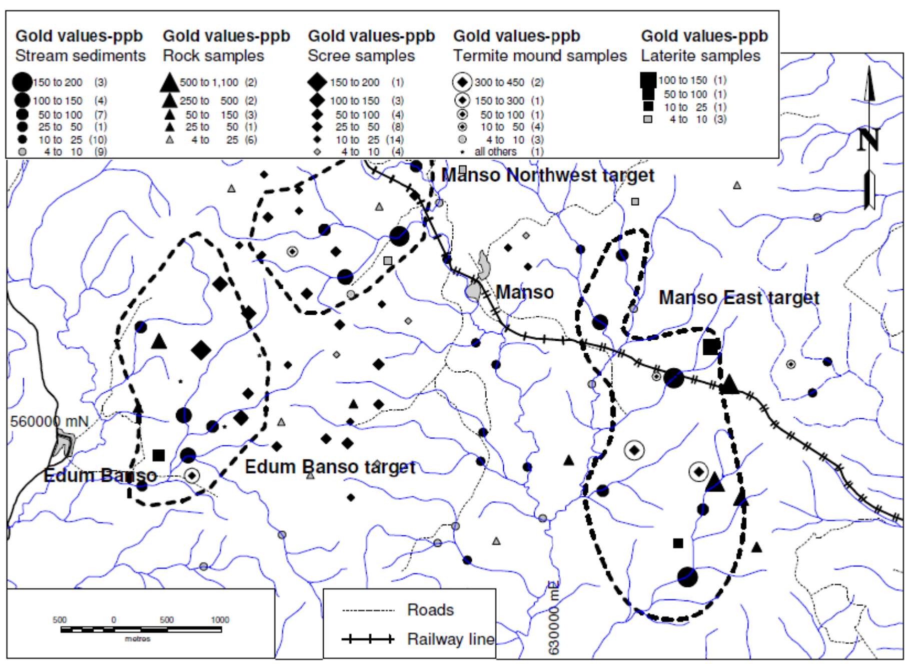

Fig. 6: Integrated gold values from all the media, namely the stream sediments, rock, scree, termite mound and laterite samples. Anomalous targets are based on gold contents in the stream sediments

due to the low gold values (5-50 ppb, Table 1) in the termite mound samples. A similar trend is seen in Fig. 6 as the gold contents from the laterite samples were added to all the other media. In this Figure (Fig. 6) the significant gold anomalies defined by the stream sediments and supported by the rock chips, scree and termite mound samples at Edum Banso and Manso East were clearly re-confirmed and more pronounced. Unlike the latter two targets, the weak Manso Northwest target from the other media has been further subdued by the addition of the gold values in the laterite samples from this target.

It appears that the Manso Northwest target which was initially delineated based on the significant gold contents in the stream sediment samples is likely to be a false anomaly, arising from erratic gold contents in the stream sediments. In the conventional technique for surficial exploration for gold, all the three targets defined by stream sediments survey as seen in Fig. 3 would normally be followed up with further work, preferably with soil sampling. This is not the case from this study, as the integration of gold results from all the media has indicated that the initial anomaly defined by the streams are likely to be erratic and possibly false in some cases. In case mineralization in the Manso Northwest target is masked by the thick regolith for which the gold response in the regolith materials are weak, the gold response in termite mound samples from the area should be relatively pronounced and detect the concealed mineralization. This is because materials sampled from the termite mounds are usually from the subsurface (Petts *et al*., 2009) unaffected generally by surficial processes (Gleeson and Poulin, 1989). It therefore, appears that the Manso Northwest target is anomalously weak with respect to gold and based on these results the area is not a priority and does not merit follow up work with soil sampling.

Implications for regional surficial geochemical exploration for gold: Previous studies in Ghana including the study area, have shown that sediment supplies to stream channels are often disturbed by continuous logging, agricultural and illicit mining activities often resulting in wide flood plains and the decoupling of the stream channels (Nude and Arhin, 2009). These factors are impediments to the use of stream sediments as an initial sample medium to determine the continuity of the exploration survey. This is because areas of complex regolith and landform modifications are likely to be associated with false and erratic gold anomalies (Arhin and Nude, 2009; Fletcher, 1997; Butt and Zeegers, 1992). Therefore, regional reconnaissance geochemical survey for gold in such areas may require the sampling of multiple media and integrating the gold results of all the sampled media, regarding each sample as a supporting medium. This will aid in the delineation of the most prospective anomalous targets for follow up.

It is known that stream sediment geochemistry is based on the assumption that samples collected from streams are representative of the products of weathering upstream from the sampling site and therefore, stream sediment values define regional gold targets. The gold values in the rock chips show bedrock mineralization and mineralization obtained by sampling termite mounds represent site specific (Affam and Arhin, 2006; Kebede, 2004) or *in-situ* anomaly (D'Orey, 1975). Gold contents in the scree and pisolithic samples define proximal targets whose source can easily be traced nearby. From the above, multi-media sampling provide information that represent regional, proximal, site specific or *in-situ* anomalies that can be detected simultaneously during a single exploration survey. In such cases exploration decision will be relatively easy because the geochemical assay values can be better interpreted and regional anomalies can be separated from proximal and site specific anomalies. It therefore, appears that the most prospective and real gold targets can be reliably delineated by sampling multiple media and integrating the gold values.

CONCLUSION

The conventional method of exploration using stream sediment surveys as first step in the search of gold has been successful in areas where the stream drainage systems are well developed and landform modifications are not complex. But in areas characterized by complex regolith and decoupled streams, the systematic conventional method of exploration is often associated with erratic gold values and the missing of potential gold anomalies. As such false anomalies are often followed up only to be abandoned later, resulting in huge sums of money spent over non-existent gold anomalies. This study has shown that the sampling of different media such as rock exposures, screes, termite mounds and lateritic lags during a single survey in support of the stream sediments, may eliminate false anomalies that usually result from sampling a single medium and better define the exact anomalous targets under cover or in areas with regolith complexities.

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