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RESEARCH ARTICLE

GIS BASED APROACH TO OPTIMIZATION OF EXPLORATION DRILLING FOR LIRHANDA GOLD EXPLORATION PROJECT, WESTERN KENYA.

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ABSTRACT

In an effort to realize commercial gold mining in Western Kenya, its exploration has been done over the years and recently in 2015, a gold resource worth 1.31 Million ounces of gold worth 1.65 billion US Dollars was announced by Acacia Exploration Company in the Lirhanda Corridor of Western part of Kenya. In addition, Acacia gold Ltd reported mineralised zones on the neighbouring prospects, approximately one kilometre away from the Acacia prospect, but stated that at that stage the material remained unclassified due to drill density and the need to further understand the controls on the mineralisation and its continuity. Further exploration and research has been proposed to move this existing target mineralisation into the “Inferred Resource” category and to expand the scale of the targeted mineralisation by exploring areas of the neighbouring prospects, which are large gold in-soil anomalies with positive initial drill results. According to results provided by Acacia Exploration Kenya from their drilling program, the main zones of gold mineralisation at Acacia prospect are hosted by sheared pillow and sheared massive basalts of the mafic volcanic unit. They are associated with quartz, quartz-carbonate and quartz-vanadium mica veinlets and sulphide mineralisation is present in the form of pyrite, pyrrhotite, sphalerite, arsenopyrite, and molybdenite Sometimes minor graphite and native gold are also recorded within the zones. The Acacia and Bushiangala prospects mineralisation style is classified as orogenic, shear-zone-hosted quartz-carbonate vein subtype, as defined by Robert et al. 2007. In this study, an attempt has been made to derive a GIS model from preliminary exploration data for identifying targets which will be consistent to Acacia findings and use such to reduce exploration expenditure in the future exploration programs in the area. This study, employing interpolation and data integration techniques provided by the GIS software, utilised preliminary exploration data obtained from geophysical, remote sensing and soil geochemical surveys together with the available supporting geology to identify more prospective areas during gold exploration. After Validation the more prospective locations for drilling were found to be those within mudstones, conglomerates and andesite lithologies as well as along the interpreted magnetic targets and fault lines and are therefore hereby referred to as the optimum signatures for gold mineralization in Lirhanda corridor. The possible geochemical signatures are Fe-*Nb*-*As*-Mo-Cu-Zn-Au, Fe-Cu-Zn-Au, Fe-*As*-Cu-Zn-Au. These indications lead to what Acacia had previously established and hence such a model is important to define drilling targets with more certainty. This optimization technique may be applied for exploration optimisation in other goldfields in Kenya and other countries, which occur in similar geological settings.

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INTRODUCTION

Exploration drilling is a key step in the mineral exploration to trace the lateral and vertical extent of any mineralization and to define as accurately as possible the valuable mineral content of any occurrence.

The drilling stage is required to understand the nature of the subsurface. To model the 3D geometry of an ore deposit, core drill data is important and hence necessitating the need for drilling stage (Racic and Millis, 2006). Owing to the expensive nature of the drilling stage, optimization is necessary towards reduced cost of the whole exploration process (Saikia and Sarkar, 2006). Successful drilling exercises often do not come without disappointments; some drill holes return no intercepts as planned or expected and this could possibly be as a result of

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wrong location of the drill holes as a result of miss interpretation of the continuity of the mineral deposit. The question that arises therefore is where to position these drill holes. In other words, what should be the optimum drill hole location for adequate exploration of a deposit for evaluation purposes? Hence the optimization of exploration drilling. The use of the surface exploration data to generate a geostatistical model of the subsurface is one of the many ways that can help to infer the continuity, geometry and the extent of mineralization in an effort to increase the confidence level of the subsurface, prior to making drilling decisions (Modeling, Mineral and Targets, 2009). Some of the documented models are descriptive, conceptual, genetic, mineral Deposit/Belt, ore body, grade-tonnage, empirical, exploration and predictive modelling which is a mathematical technique used to forecast the prognostic mineral deposits, metal resources and expected areas likely to host mineralization. Geochemistry plays an important role in cases particularly where deposits are exposed, and geophysics aids discovery in some cases where the discoveries are concealed (Chapman and Mortensen, 2006). During the drilling process, monitoring and re-evaluation of the mineralization data is done and this becomes the basis of deciding when to stop or continue drilling.

The mining of gold in Kenya can be traced back to 1882 when the first gold was discovered at Lolgorian, western Kenya on the border of the Rift Valley and Nyanza provinces. However, it wasn’t sufficient to necessitate commercial mining. In an effort to realize commercial mining therefore, gold exploration has been done in the Western part of Kenya over the years. Recently in 2015, 1.31 Million ounces of gold worth 1.65 billion US Dollars was estimated by Acacia Exploration Company in the Lirhanda Corridor of Western part of Kenya. In addition, Acacia gold Ltd reported mineralised zones on the neighbouring prospects, approximately one kilometre away from the Acacia prospect, but stated that at that stage the material remained unclassified due to drill density and the need to further understand the controls on the mineralisation and its continuity. This prospect therefore did not amount to a mineral reserve and could therefore not be economically exploited. To move this existing target mineralisation into the “Inferred Resource” category, exploration of the neighbouring prospects in Lirhanda corridor, which were found to have large gold in-soil anomalies with positive initial drill results, is necessary. There is therefore a need to establish a predictive model for the gold mineralization within this locality, which can be used primarily for expanding the exploration drilling for Lirhanda corridor exploration project and also for future exploration within the same belt.

The use of GIS based geostatistical approach has in the past successfully delivered positive results in optimizing exploration processes. This has often been accomplished by means of predictive maps that arose as a result of combination of preliminary exploration data (data from remote sensing, geophysical and geochemical surveys). Exploration drilling stage which demands the highest value of exploration budget if optimized, will significantly lead to a reduced exploration expense. This paper therefore has attempted to propose the use of the GIS based geostatistical approach to accomplish the objective of optimizing the exploration drilling by utilization of preliminary exploration data in optimizing drilling locations within Lirhanda corridor and involves creation of a digital database for the four sets of data for ease of handling them in GIS software.

METHOD AND RESOURCES

The approaches and the resources for achieving the set objective are outlined. The methodology involves an integrated approach to treating different exploration data to come up with a conclusive evidence of the underlying mineralization. To better understand the nature of the deposit and the geostatistical approach to use, a review of literature pertinent to the geochemistry, geophysics, geology of gold deposits and geostatistical methods was done.

The following data was sourced from various sources

- Geological setting and mineralisation data; Regional and Local geology of Lirhanda corridor including lithologies, alteration, structures and mineralisation were obtained from the Ministry of Mining.
- Data on host rock alteration and alteration due to gold mineralization which involves spectral maps of Lirhanda corridor-western Kenya was obtained from the Regional Centre of Mapping of Resources for Development (RCMRD)
- Surface exploration data (both geophysical and geochemical) was obtained from Acacia Exploration Kenya (AEK) and the quarterly reports submitted to the Ministry of Mining.
- Drilling, reverse circulation drilling and diamond drilling data from (AEK) and quarterly reports submitted to the Ministry of Mining.
- Subsequently, the following major steps (Figure 1) were performed on the available data;
- Image processing and enhancement: ERDAS software was used to enhance the LANDSAT imagery and the geological map of the study area.
- Creation of a digital database: GIS software was then used to create a digital data base; this was achieved by doing on–screen digitization of the interpolated geochemical maps, Landsat image of the study area and on the geological map of the area.
- Intermediate maps: LANDSAT and geological maps were integrated in GIS software to generate an updated geological map of the study area with well-defined geologic boundaries while sets of digitized element concentration maps from the interpolated geochemical data were overlain at different transparencies to generate intermediate maps [7].
- Furthermore, the following steps (Figure 2), which are necessary to obtain a predictive map of the study area, were undertaken (though not be detailed in this paper).
- The updated geologic map and the geochemical intermediate map are overlain to generate a predictive map.
- Model validation by using data from SL267 were utilised as well as drilling of preselected locations from the predictive map to test the success of the model [9-11].

Data and software: The following sets of data were utilised in the GIS software to generate digital database which in turn was used to generate the intermediate and final prospective/predictive maps.

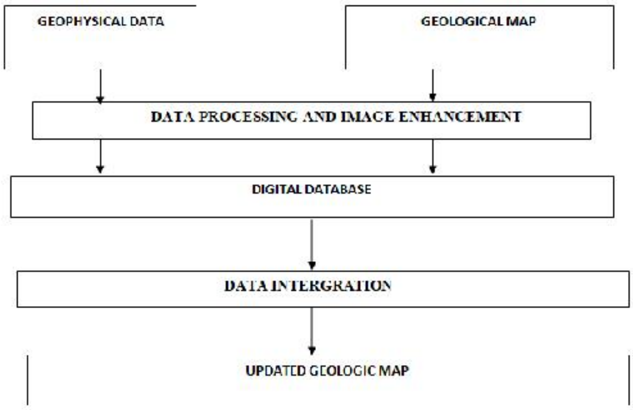


Figure 1. Methodology for generating intermediate geologic map

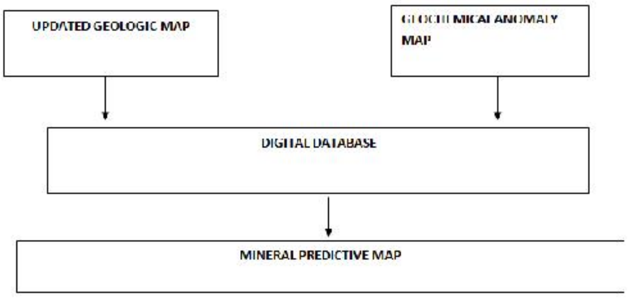
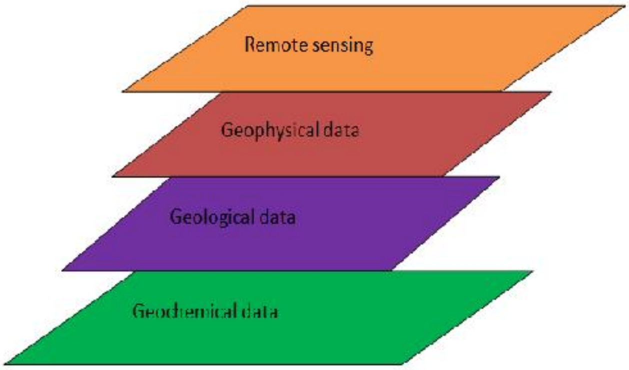


Figure 2. Methodology for generating mineral predictive map



Software used

- ARGIS was used to interpolate and digitize the data maps
- ERDAS was used for image enhancement and correction. Image enhancement techniques are applied to the selected subset of the Landsat data for the study area.

Data Pre-processing

Checking for reliability of geochemical: The available geochemical data was obtained from NITON XRF analyses. Parallel sample analysis was done in the laboratory to check the consistency of the results and test the reliability of the NITON XRF data. NITON XRF and Laboratory results correlated well (Figure 3) for indicator elements and were effective in defining known (drilled) base metal mineralisation at Bumbo area, which was the area selected for orientation survey.

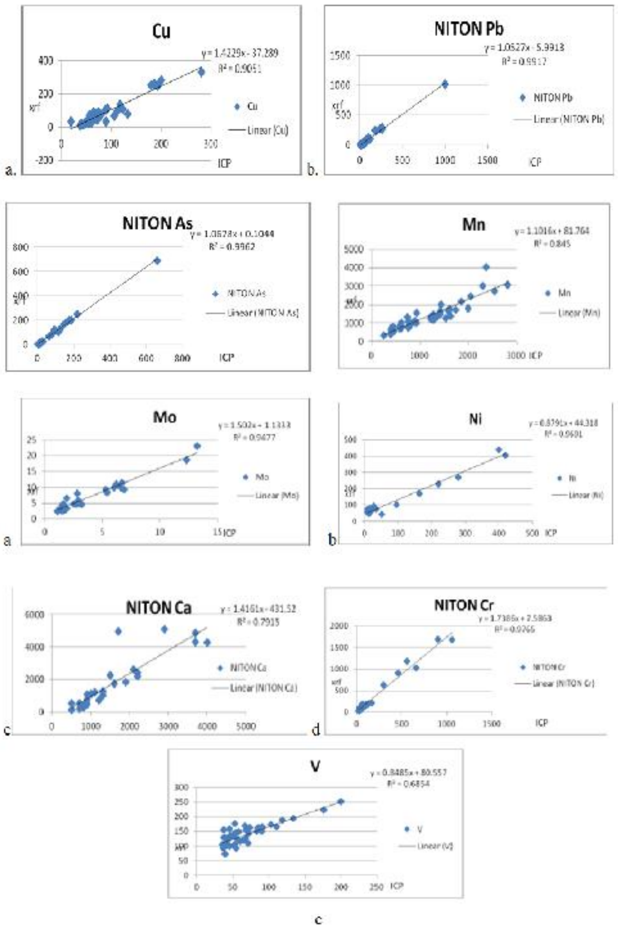
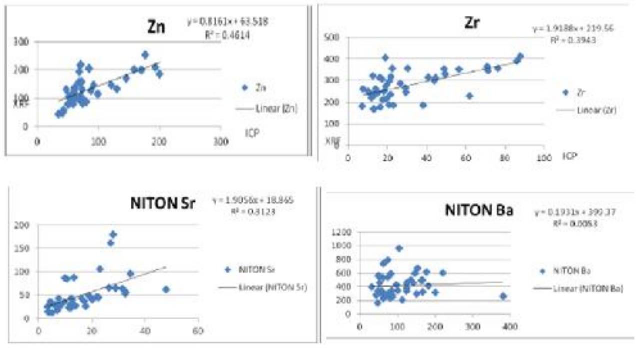


Figure 3. a,b,c,d,e shows Correlation of NITON XRF results with Laboratory results

As observed, compared Cu values show correlation and are within range, .As, Pb, Ni and Mo values show almost a perfect match, Mn values show that correlation are within range while Cr values have a constant trend. XRF Fe shows a trend however has a higher value, while Ca are almost equal for lower concentration samples. XRF Zn, Zr, Sr and Ba show poor correlation with lab results (Figure 4).



Evidently, NITON XRF can be used reliably to determine geochemical trends in soils from both prospects on elements such as Cu, As, Pb, Mn, Mo, Ni, and Cr. Fe can also be used but concentration level should be noted. Zn being a mobile element is affected presumably by the matrix effect. Elements such as Zr, Ba, and Sr have a poor correlation with laboratory results therefore more calibration is required.

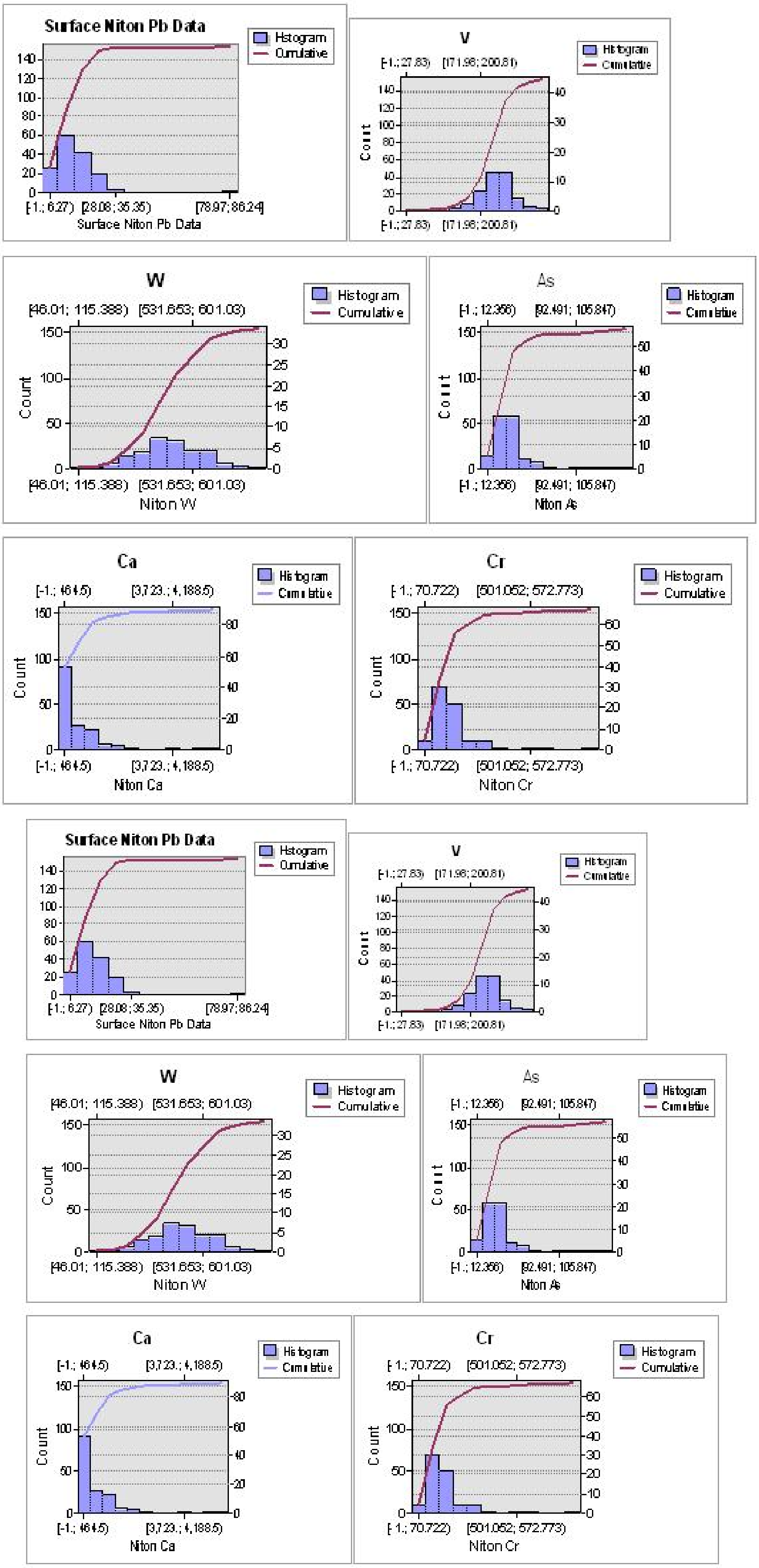


Figure 5. Statistical distributions of select elements

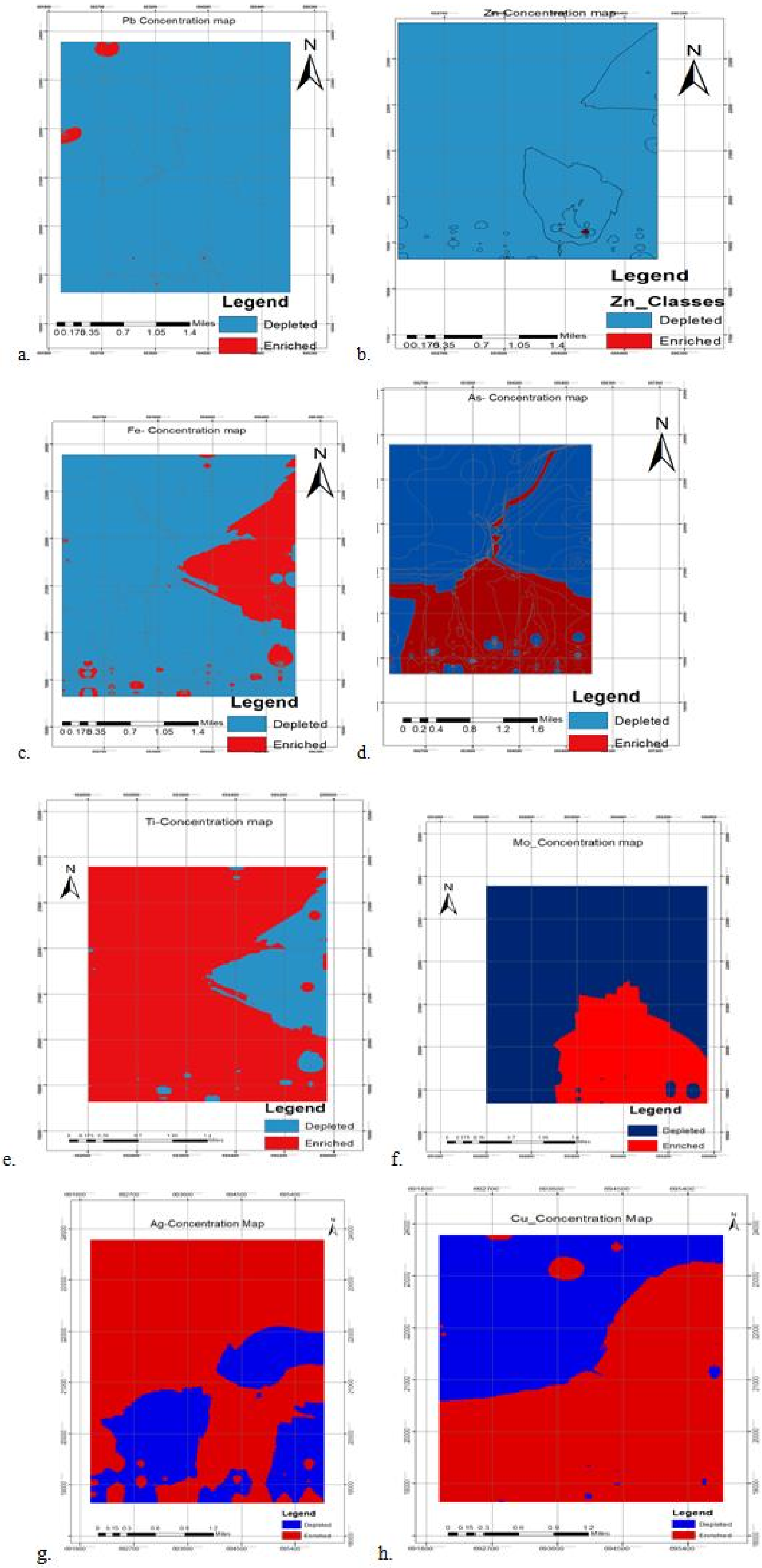


Figure 6: IDW Interpolation of a) Pb, b)Zn, c) Fe, d) As, e) Ti, f) Mo, g) Ag, and h) Cu within SL266

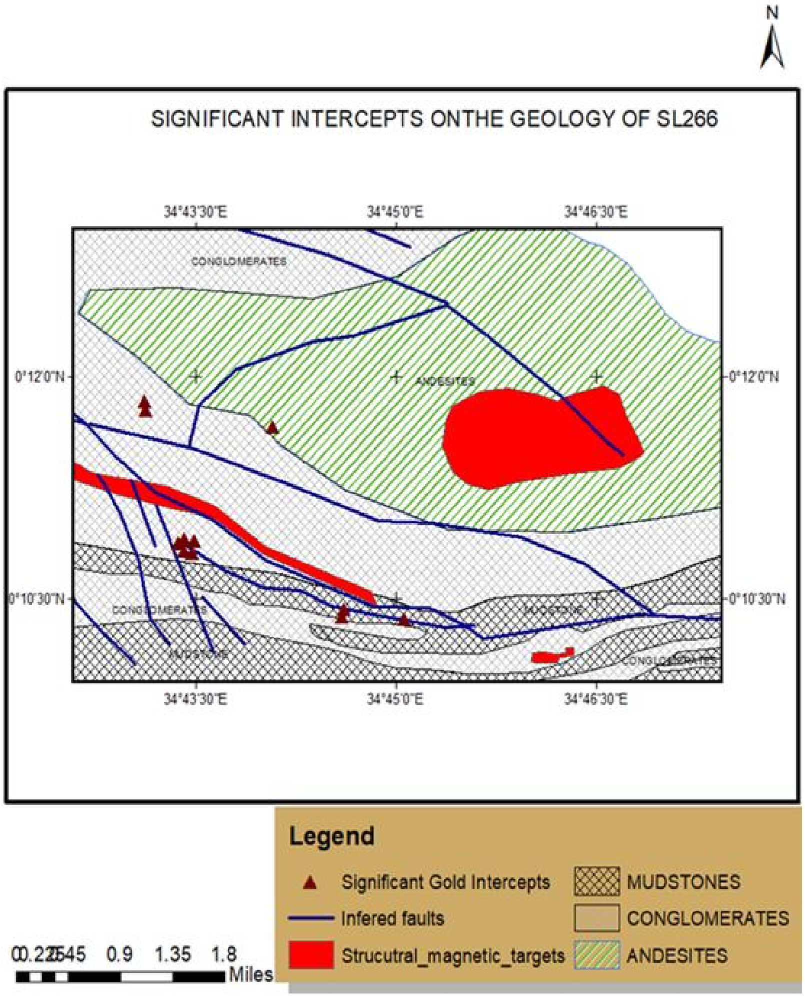


Figure 7. Updated geology map

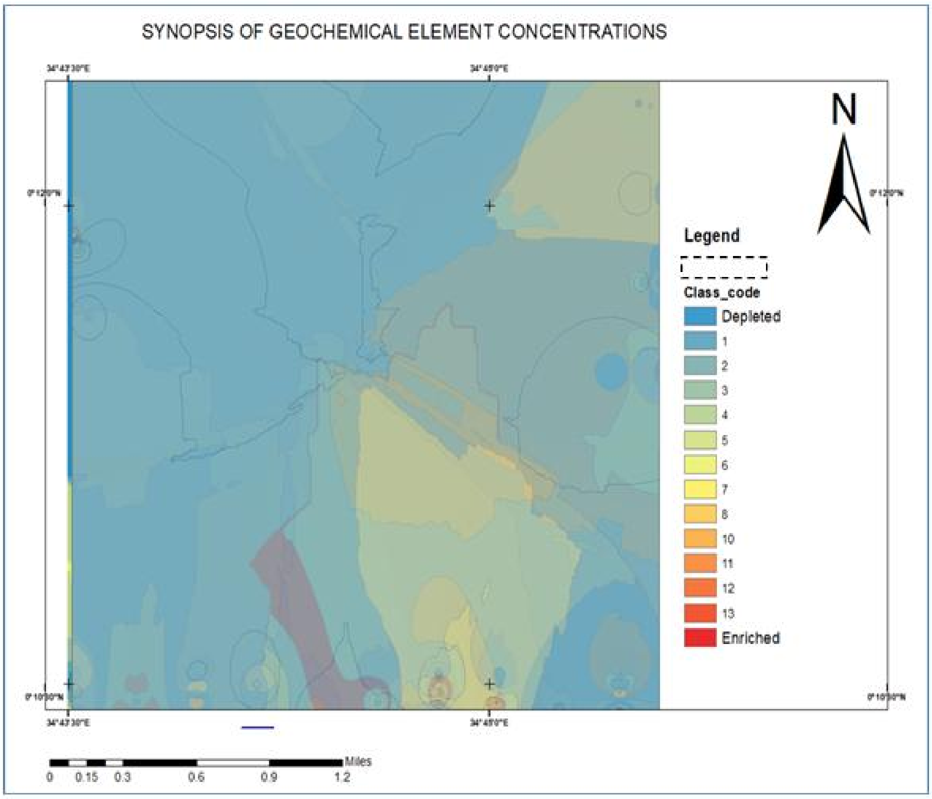


Figure 8. Synopsis of Cu, Mo, Zn, Pb, Fe, As and Ba element concentrations superimposed at different transparencies

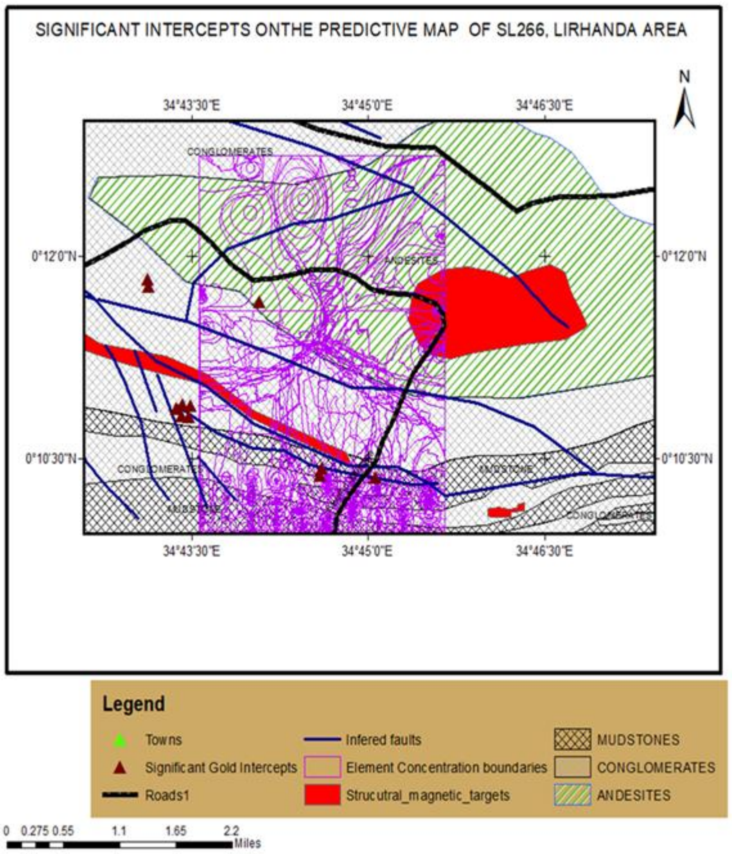


Figure 9. Spatial correlation of all datasets in relation to geology and structures hereby Gold predictive map of the study area showing element enrichment superimposed on the updated geological map

Checking for data statistical distribution: The geochemical data for indicator elements was thereafter first treated statistically with respect to gold intercepts primarily for the purpose of identifying mineralization processes based on statistical and spatial variations of indicator elements (Grunsky, Wilkinson and Harris, 2000). To treat the numerical geochemical data statistically, it was evaluated to characterize statistical distributions by use of cumulative frequency histograms (Harris *et al.*, 1999) (Grunsky, Wilkinson and Harris, 2000)(Harris, Wilkinson and Bernier, 2001) forming the basis for further analysis, which includes methods for separating anomalous geochemical concentrations from background and methods for visualizing the spatial characteristics of the data. Graphical inspection is a necessary step as the first step in data analysis (Wang *et al.*, 2013).

Graphical techniques were used to examine the distribution of univariate data to give the first impression of the distribution of the data (Zuo, Carranza and Wang, 2016)(Analysis and Geochemical, 2009).

The geochemical soil sample data were first plotted as frequency histograms to inspect the distribution of data. Figure 5 is graphical representation of some elements from Surface Niton XRF data for SL266. The data shows skewed distribution and therefore the a non-parametric treatment of data was adapted. IDW method was found to be more robust and suitable for huge geochemical data. The geostatistical tool of the GIS software was utilised to generate element concentration maps which were then digitized along concentration boundaries to create a geochemical database.

Creation of Geodatabase

The creation of geodatabase involved

- Creation of geochemical database and
- Digitization of geological map and the interpreted geophysical data.

Creation of geochemical database: This was achieved by interpolation of geochemical data to element concentration maps and digitization of the same. Based on the statistical distributions observed, the elements do not follow a normal distribution therefore the method adopted for interpolating the geochemical data was based on that fact. IDW method of interpolation was utilised to generate concentration maps (Figure 6). This tool makes use of the measured values surrounding the prediction location to predict a value for any unsampled location, based on the assumption that samples that are close to one another are more alike than those that are farther apart. The predicted value is limited to the range of the values used to interpolate. Because IDW is a weighted distance average, the average cannot be greater than the highest or less than the lowest input. Therefore, it cannot create ridges or valleys if these extremes have not already been sampled. IDW can produce a bull's-eye effect around data locations. Unlike other interpolation methods such as Kriging, IDW does not make explicit assumptions about the statistical properties of the input data. IDW is often used when the input data does not meet the statistical assumptions of more advanced interpolation methods. This method is well-suited to be used with very large input datasets.

Digitization of data maps: The geology data and interpreted geophysical data were also digitized and superimposed as.to produce an updated geology map (Figure 7) Indicating significant gold targets. Note that Landsat Imagery was not utilised because it was discovered that the area is dominated by vegetation cover hence not possible to map the outcrops and alterations .Geochemical maps concentration maps were also digitized along concentration boundaries and superimposed to obtain a synoptic concentration map. (Figure 8)

Data integration: To assist in following the interpretation of the soil geochemical data, boundaries of the geochemical map, produced from the digitization of interpolated geochemical map are superimposed on those produced from geophysical map, Landsat TM and geology data sets i.e the updated geology map (Sadeghi, Billay and Carranza, 2015) for better and reliable results. The gold intercepts obtained from the exploration blocks is therefore superimposed on the resulting map. The first step in data integration involves creation of intermediate maps from each set of data. Figure 8 shows an intermediate enrichment map for the selected elements because gold is characterised by enrichment of some indicator elements and depletion of others.

RESULTS

The resulting digitized concentration maps for selected elements are shown with emphasis on element concentration and depletion. Superimposing the geochemical concentration boundary map on the updated geology map resulted to a predictive map for gold targeting and for locating drill holes. An evaluation of the buffer regions for range of element concentrations, geology, proximity to interpreted structures and interpreted targets and intercepted gold intercepts helped generate criteria for using the available data for optimally locating drill holes and hence gold targets. (Figure 9)

CONCLUSSION

The interpolation of geochemical data resulting to concentration map shows that there are pairs of elements that display spatial correlation while the updated geology map acting as an intermediate map shows the correlation of interpreted geophysical structures and geology of the study area. The two therefore form a basis for generation of a predictive map for gold exploration. A review of earlier work done in the region , integration of the intermediate maps from the different data sets and model validation are major steps towards creation of a complete predictive model for a reliable gold exploration in Lirhanda Corridor. From such the following conclusions were possible.

- The associated geology and geophysical interpreted targets as well as structural features lie proximal to gold intercepts encountered.
- Preliminary exploration data can be utilised appropriately to understand the subsurface and optimize drilling locations hence reducing the exploration expenditure.
- The more prospective locations for drilling are those reflecting a coincidence in supporting geology, fault lines and within the proximity to interpreted magnetic targets. These locations are within mudstones, conglomerates and andesite lithologies as well as along the interpreted magnetic targets and fault lines and are therefore hereby referred to as the optimum signatures for gold mineralization in Lirhanda corridor. The possible geochemical signatures are Fe-*Nb*-*As*-*W*-Cu-Zn-Au, Fe-Cu-Zn-Au, Fe-*As*-Cu-Zn-Au.

Recommendation

- Towards the realisization of the emerging Machine Learning technology in gold exploration, this work recommends further validation from similar gold occurrences across the world.
- This technique can be used to improve the livelihood of thousands of gold artisanal miners in Kakamega region who currently rely on traditional methods to locate their shafts.

REFERENCES

Analysis, E. and Geochemical, O. F. 2009. ‘Chapter 3: Exploratory Analysis of Geochemical Anomalies’, *Handbook of Exploration and Environmental Geochemistry*, 11, pp. 51–84. doi: 10.1016/S1874-273409. 70007-5.

Chapman, R. J. and Mortensen, J. K. 2006. ‘Application of microchemical characterization of placer gold grains to exploration for epithermal gold mineralization in regions of poor exposure’, *Journal of Geochemical Exploration*, 911–3. , pp. 1–26. doi: 10.1016/j.gexplo.2005.12.004.

Grunsky, E. C., Wilkinson, L. and Harris, J. R. 2000. ‘Effective use and interpretation of lithogeochemical data in regional mineral exploration programs: Application of Geographic Information Systems GIS. technology’, *Ore Geology Reviews*, 163–4. , pp. 107–143. doi: S0169-136899. 00027-X.

Harris, J. R. *et al.* 1999. ‘Techniques for analysis and visualization of lithogeochemical data with applications to the Swayze greenstone belt, Ontario’, *Journal of Geochemical Exploration*, 671–3. , pp. 301–334. doi: 10.1016/S0375-674299. 00077-1.

Harris, J. R., Wilkinson, L. and Bernier, M. 2001. ‘Analysis of geochemical data for mineral exploration using a GIS — A case study from the Swayze greenstone belt, northern Ontario, Canada’, *Geological Society, London, Special Publications*, 1851. , pp. 165–200. doi: 10.1144/GSL.SP.2001.185.01.08.

Modeling, P., Mineral, O. F. and Targets, E. 2009. ‘Chapter 1: Predictive Modeling of Mineral Exploration Targets’, *Handbook of Exploration and Environmental Geochemistry*, 11, pp. 3–21. doi: 10.1016/S1874-273409. 70005-1.

Racic, L. and Millis, T. 2006. ‘Mapping the subsurface for mineral exploration’, *First Break*, 247. , pp. 57–62.

Sadeghi, M., Billay, A. and Carranza, E. J. M. 2015. *Analysis and mapping of soil geochemical anomalies: Implications for bedrock mapping and gold exploration in Giyani area, South Africa*, *Journal of Geochemical Exploration*. Elsevier B.V. doi: 10.1016/j.gexplo.2014.11.018.

Saikia, K. and Sarkar, B. C. 2006. ‘Saikia’, *Transactions - Institution of Mining and Metallurgy. Section B: Applied*

Earth Science, 1151. , pp. 13–22. doi: 10.1179/174327506X102787.

Wang, C. *et al*. 2013. ‘Characterization of primary geochemical haloes for gold exploration at the Huanxiangwa gold deposit, China’, *Journal of Geochemical Exploration*. Elsevier B.V., 124, pp. 40–58. doi: 10.1016/j.gexplo.2012.07.011.

Zuo, R., Carranza, E. J. M. and Wang, J. 2016. ‘Spatial analysis and visualization of exploration geochemical data’, *Earth-Science Reviews*. Elsevier B.V., 158, pp. 9–18. doi: 10.1016/j.earscirev.2016.04.006.

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