VALIDATION OF GIS BASED APPROACH OF OPTIMALLY LOCATING EXPLORATION TARGETS DURING GOLD EXPLORATION IN KAKAMEGA, WESTERN KENYA.

Abstract

When a new borehole is drilled during mineral exploration, it needs to be located in the field at a location that will hit a mineral target yet not interfere with the exploration budget. Due to the heterogeneity in field properties, there may be places where drill holes need to be located close from each other or further apart. Drilling is also time-dependent in that the entire exploration program is legally and technically time bound. To complicate the issue further, the placement of the borehole must also consider the decision as to direction of inclination. [1]

The choice of the drill holes locations, spacings, orientations and patterns during gold exploration is based on the knowledge of the continuity, strike and dip of the subsurface mineralization. Geological, geochemical and geophysical nature of the surface environment obtained through respective exploration methods as reflected in anomalies in a particular locality individually do not sufficiently define the subsurface nature of mineralization which is the basis for the drilling decisions. [2]

An exploration model that outlines the criteria for making drilling decisions has been the key deficiency in gold exploration in western Kenya. An attempt to overcome this problem was proposed and defined by Mutua et al. (2018) where data from preliminary surface exploration methods was used in a GIS based optimization approach for exploration drilling.

This study therefore seeks to validate the criteria defined by Mutua et al. (2018) where he postulated that the nature of surface environment in relation to the subsurface for Lirhanda corridor gold prospect can be used in generating a predictive model giving recognition to the geological aspect in defining mineralized blocks. His approach involved a check on the available geochemical, geophysical and geological data related to gold mineralization and correlating them to the subsurface environment to generate a consistent link. This therefore set a reliable base for the model validation which can then be performed to the defined 'geologic' blocks to optimize drill hole locations and hence a validated optimum model for making drilling decisions and a guide in further gold exploration within Lirhanda corridor

[1] Güyagüler Baris, 'Optimization of Well Placement and Assessment of Uncertainty'.
[2] Dindi and Maneno, 'Geological and Geophysical Characteristics of Massive Sulphide Deposits: A Case Study of the Lirhanda Massive Sulphide Deposit of Western Kenya'.

and other similar occurrences. The research validates the reliability of remote sensing, geophysical, geochemical and geological data in identification of gold mineralization.

Key words: Validation, Drilling, Targets, Model, Exploration, Optimization

Intoduction

The objective of any gold exploration company is to operate at the minimum costs possible. While almost all mineral exploration involves drilling to precisely establish the mineral resource located, drilling generally represents the largest single cost associated with mineral exploration and the delineation of an ore deposit once it has been discovered. Decisions on where to drill, how to drill and when to start and stop drilling are critical and are influenced by the level of certainty or uncertainty of the sought mineral. Due to the expensive nature of the exploration drilling; clear, certain projections and rapid reporting are needed for accurate drill hole locations to achieve timely decisions before and during the drilling exercise, there is also need for a projected model at a more local scale [3]. This is to ensure that surface to near surface information can be correlated to the subsurface gold occurrence to make these critical drilling decisions.

Presently, distinctive exploration models have been documented for many types of deposits, and different elements show characteristic patterns of enhancement or depletion with proximity to mineralization [4]. Nevertheless, although many typical deposits display similar regional-scale controls and commonly occur in the same camps, they differ in styles of mineralization, metal association, interpreted crustal levels of emplacement and relative age. The Western region of Kenya has revealed gold potential since 1953 [5] and has been a target for exploration. However, not much could be shown from these long-time efforts until recently in 2015 when Acacia mining identified considerable and possibility of more deposits in the area. Primarily because there is no developed robust exploration model for gold in this area, it has been difficult to locate the deposits. Furthermore most of the original old gold mines were abandoned as dangerous holes covered with vegetation. The exploration company

[3] Holliday and Cooke, 'Advances in Geological Models and Exploration Methods for Copper ± Gold Porphyry Deposits'.
[4] McClenaghan, 'Indicator Mineral Methods in Mineral Exploration'.
[5] Tosdal, 'Paper Number : 3938 Geology of the Archean Busia-Kakamega Greenstone Belt , Western Kenya'.

has therefore called for more research to be done to help in further exploration of this very high gold potential area.

It was therefore necessary to use the available exploration data to establish the relationship between surface and the subsurface of Lirhanda area. This will assist in the understanding of the occurrence of the gold deposit hence the development of an optimum model for effectively locating such deposits with ease and optimizing drill location. Such model having been proposed and done, is hereby validated by use of GIS based procedures to identify the conformity of the validation area to that of the previously defined criteria.

Methodology

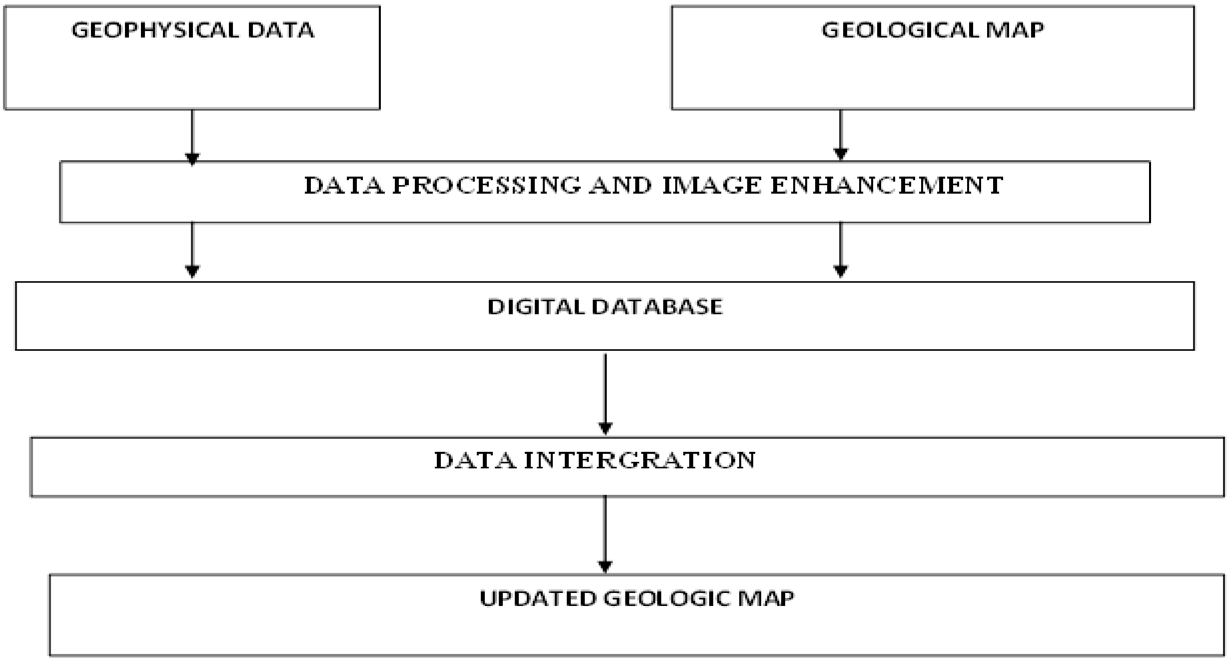
Data-based approach involves the build-up of a voluminous database containing various geoscientific data [6]). The database used often in this approach contains remotely sensed data, geophysical, geological and geochemical exploration data. A meaningful geostatistical interpolation and intergration techniques on exploration data with careful attention to geological controls on mineralization provide more reliable block by block mineral prospects. Understanding the geological character of a mineral deposit as thoroughly as possible is an essential base on which to build an estimate of mineral inventory [7]

The methodology initially used to define the criteria for optimal drill holes involved an integrated approach in treatment of exploration data to come up with a conclusive evidence of the underlying mineralization as shown in figure 1.1

Step 1.

[6] (Harris et al., 2001)

[7] Soltani and Hezarkhani, 'Proposed Algorithm for Optimization of Directional Additional Exploratory Drill Holes and Computer Coding'.



Step 2.

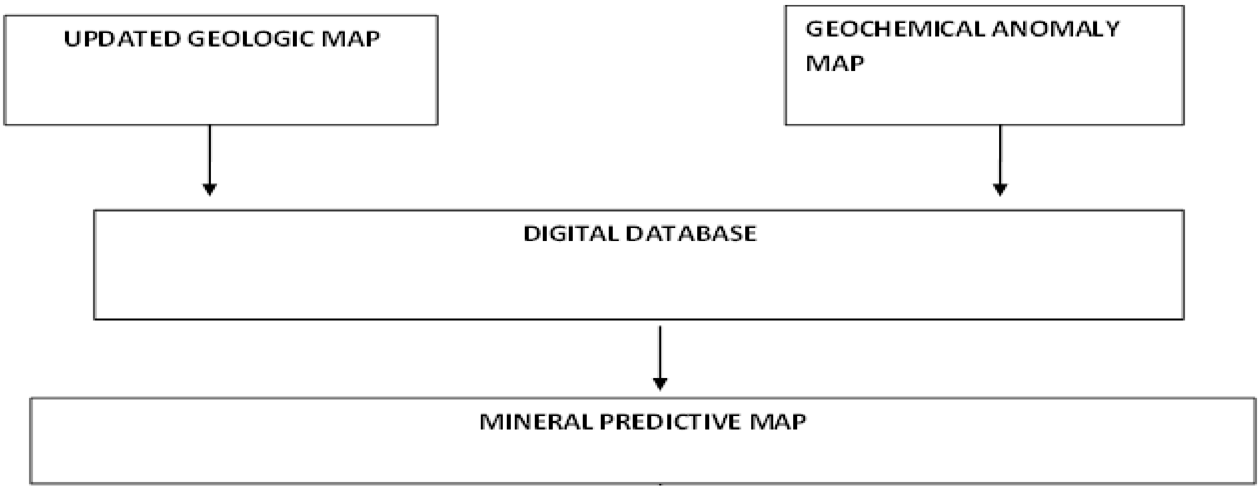


Figure1.1: Methodology chart for validation process

The result of step one and two which have been published in another work are displayed in figure 1.2 and are used in this case to portray the criteria modelled by the author, hereby being validated.

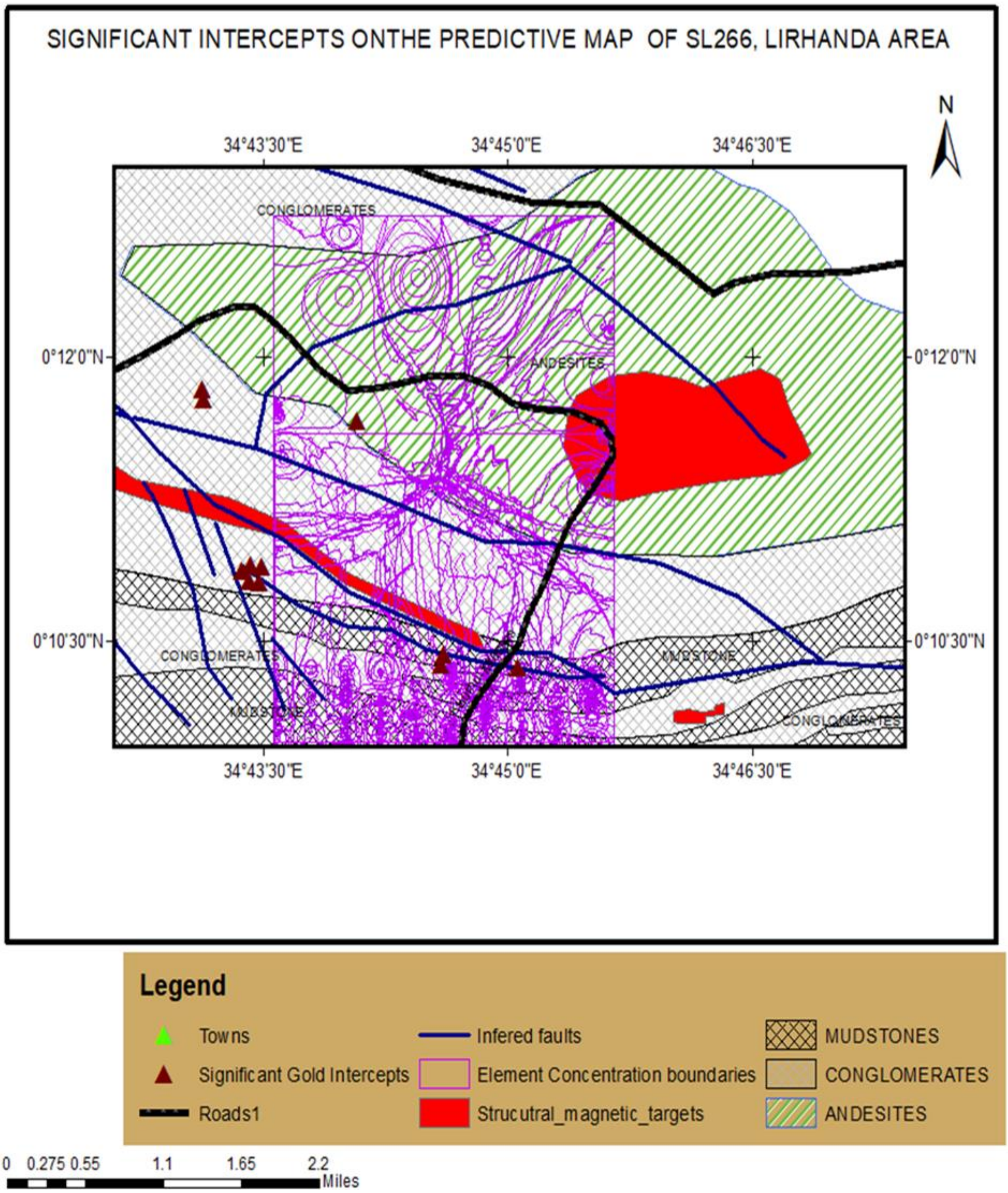


Figure 1.2: Spatial correlation of all datasets in relation to geology and structures hereby Gold predictive map of the study area showing element enrichment superimposed on the updated geological map.(after Mutua, 2018)

Figure 1.2 defines the optimum drilling locations during gold exploration in this area as those within the proximity to interpreted magnetic targets as well as within mudstones, conglomerates and andesite lithologies and along the interpreted magnetic targets and fault lines. The purpose of this validation procedure is therefore to confirm the defined criteria.

Step 3

Model Validation

To test the consistency of the criteria defined by Mutua et al. (2018), drilling and/or sampling at preselected locations from the predictive map to test the success of the model were necessary. A location of known geological and geophysical data was selected and tested for compliance to gold mineralization. The SL266 geochemical soil samples by AEK used in the generation of this projected model were collected from within mudstones, conglomerates and andesites as well as from within the proximity of interpreted structural controls and magnetic targets. For consistency therefore, samples points were preselected from the map from locations with similar geology and structural features as those of SL266 BY AEK (figure 1.2) which were in support of gold mineralization. The coordinates for these sample locations were calculated from the GIS software. Results are displayed for a region sharing geology with SL266. Fifteen Samples were collected at different depths from shafts proximal to these preselected sampling points within Isulu and Bushiangala areas. They were then tested for Fe, Sb, Cd, Hg, Bi, Ag, Mo, As, W, Pb, Cu, Zn and Sn using AAS method at the Ministry of Mining laboratories. Spatial distribution of samples shows the underlying geology from which these samples were selected. NB. Negative values show no detected elements.

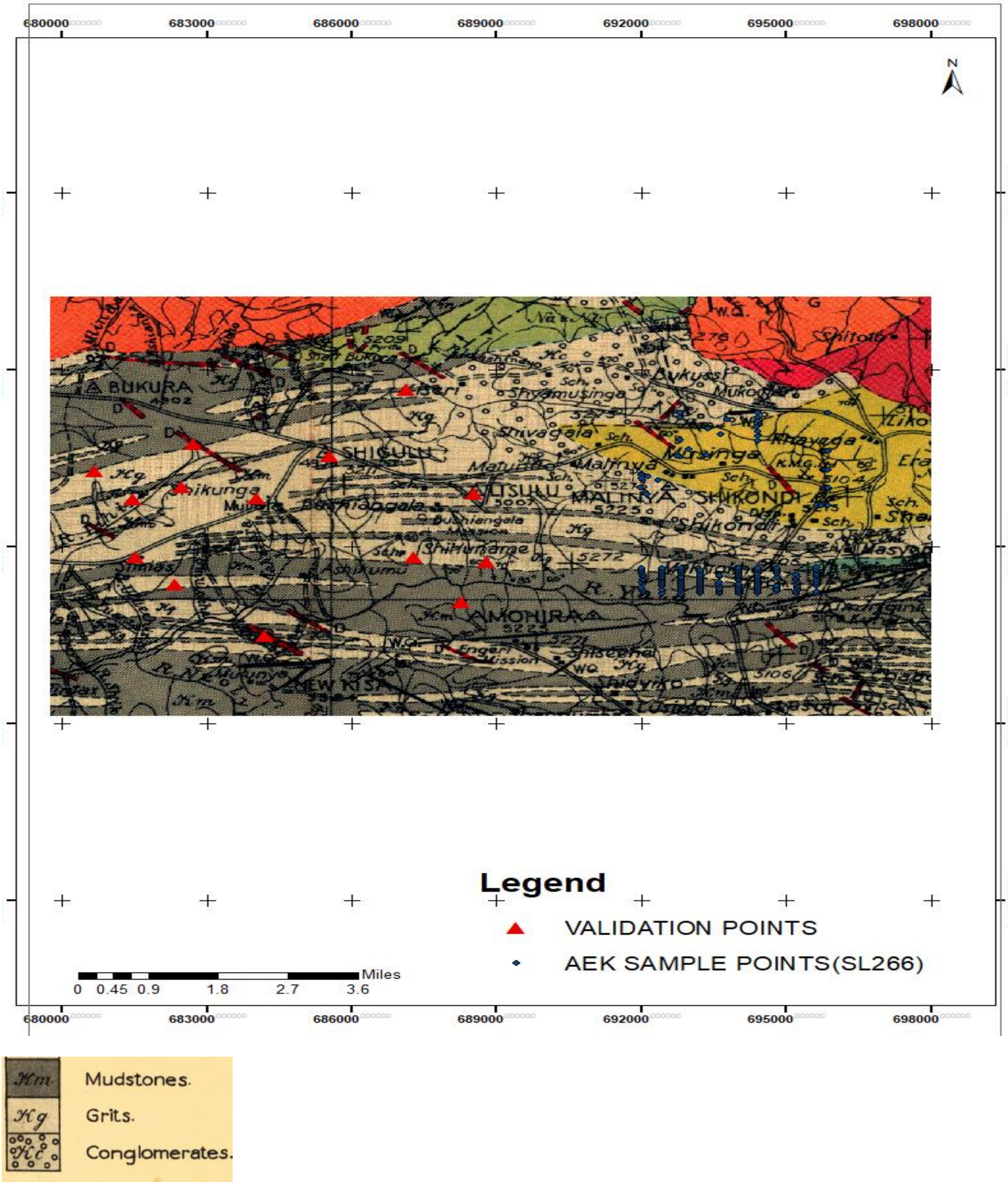


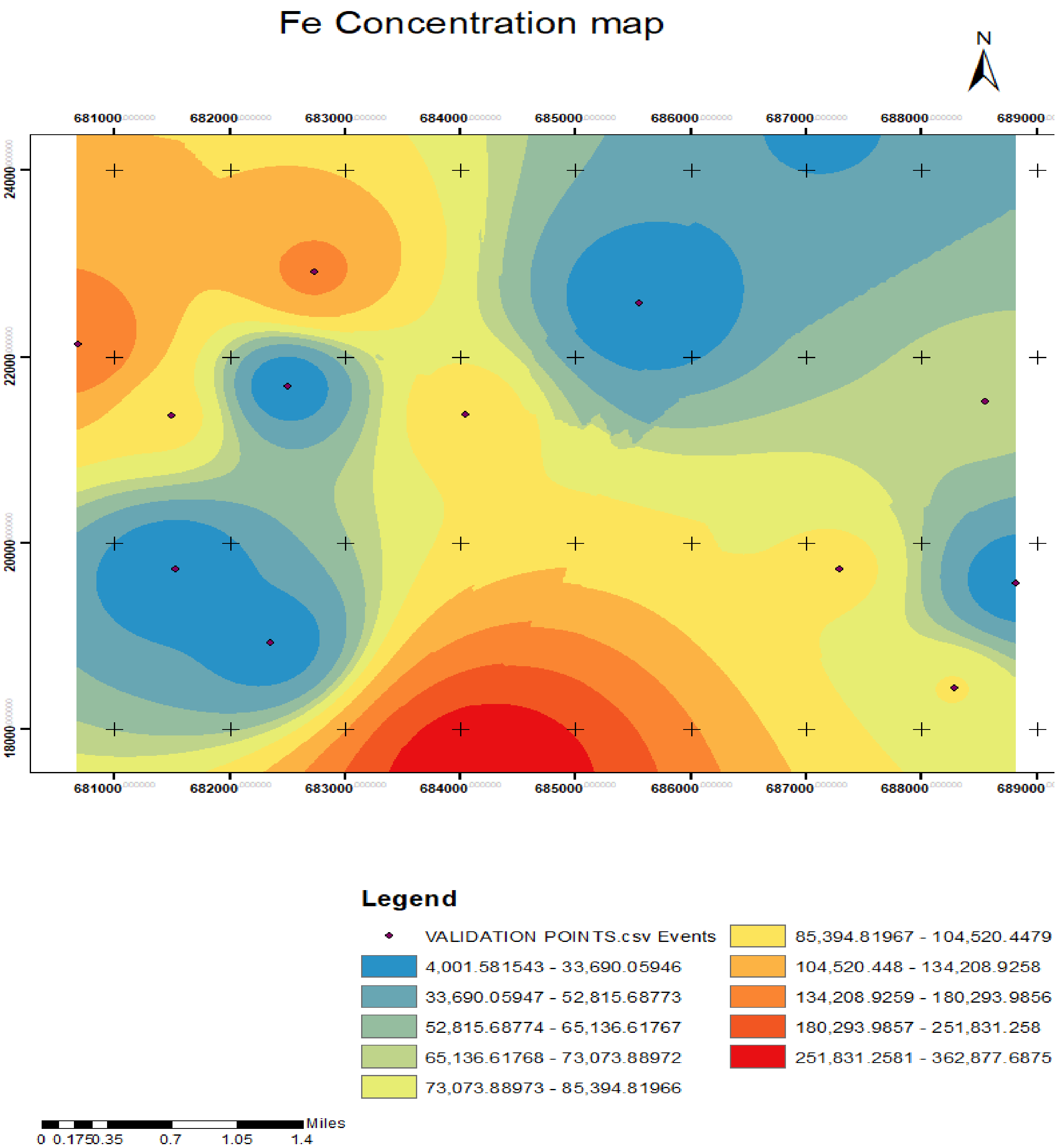
Figure1.3: Spatial distribution of validation points vs. AEK sampling points with respect to the geology (Extracted from Huddlestone, 1953)

Table 1: AAS results from study area (ppm)

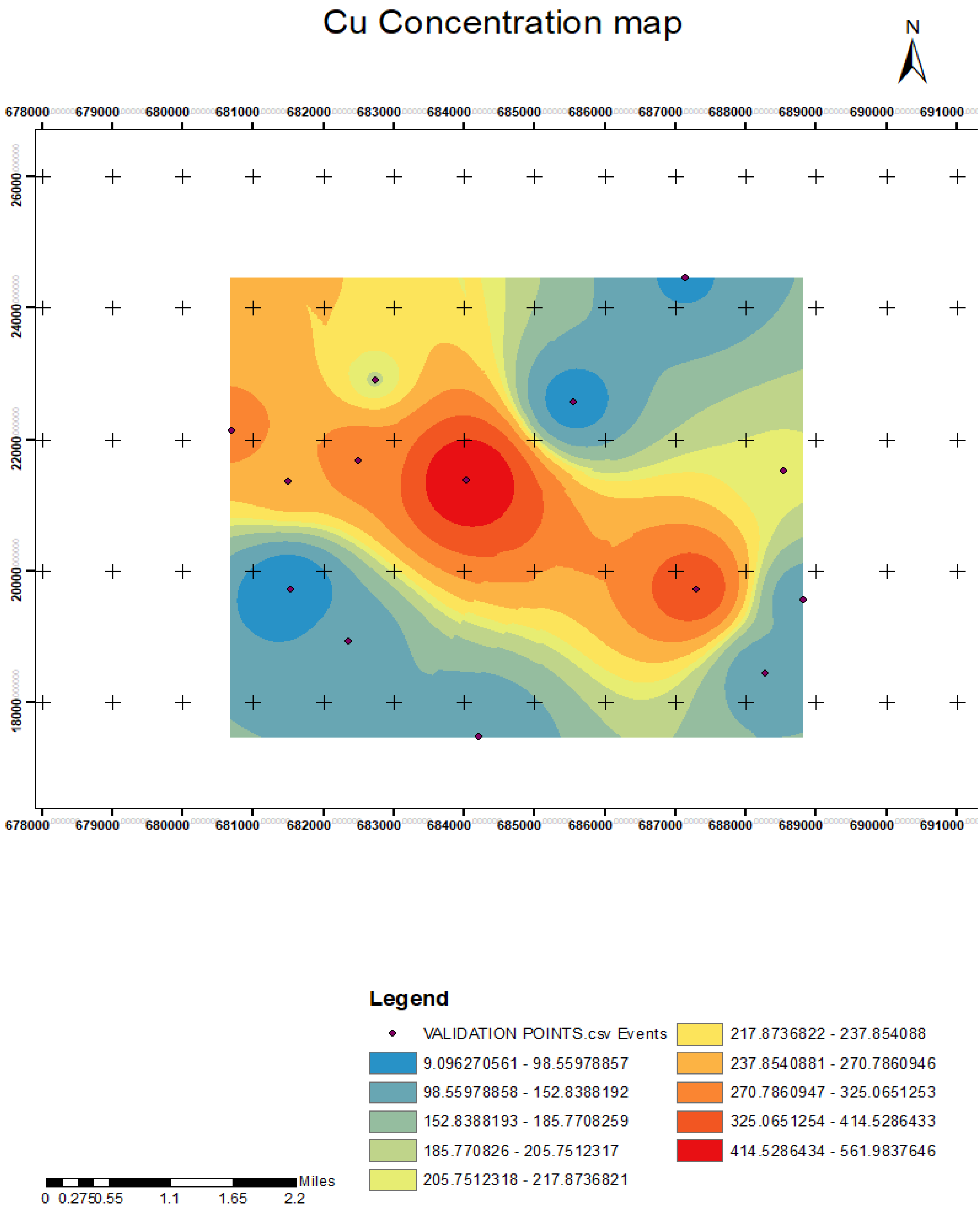
Sample code	x	Y	Fe	Sb	Cd	Hg	Bi	Ag	Mo	As	W	Pb	Cu	Zn	Sn	Au
A	688278	18445.27	86120	-1	-1	-1	-1	-1	-1	18	-1	-1	115.06	201.8	-1	7.99
B	688814.5	19568.46	14684	-1	-1	-1	-1	-1	-1	-1	-1	-1	117.3	98	-1	6.73
C	687288.9	19719.33	90732	-1	-1	-1	-1	-1	20	-1	-1	54.08	386	100.4	-1	8.06
D	688546.2	21513.08	69325	-1	-1	-1	-1	-1	-1	11.04	-1	-1	210	76.04	-1	13.55
E	685545.5	22569.22	8360	-1	-1	-1	-1	-1	58	27.08	-1	-1	58	78.98	-1	38.58
F	687138.1	24446.79	30580	-1	-1	-1	-1	-1	-1	21.06	-1	-1	89.01	82.34	-1	10.35
G	682343.5	18931.42	15380	-1	-1	-1	-1	-1	10.5	20.04	-1	-1	116.4	198.9	-1	8.08
H	681522.1	19719.33	3980	-1	-1	-1	-1	-1	22	-1	-1	-1	9.03	9.08	-1	8.22
I	681488.6	21362.21	91560	-1	-1	-1	-1	-1	34	9.04	-1	-1	260	189	-1	5.87
J	680683.9	22133.35	172890	-1	-1	-1	-1	-1	-1	1160	38.02	-1	290.04	486.07	420	7.22
J2	682494.4	21680.72	10205	-1	-1	-1	-1	-1	26.89	-1	1489	-1	301.04	756	-1	19.41
K	684036.7	21378.97	98600	-1	-1	-1	-1	-1	938	26.48	12.01	0.8	562	499	-1	27.35
L	682729.1	22904.5	144840	-1	-1	-1	-1	-1	-1	1320	26.78	119.24	204	401	-1	11.28
M	684204.3	17472.95	362884	-1	-1	-1	-1	-1	131	496	9.04	242	101	620	-1	6.52

Performing geostatistical interpolation of the above data yielded the following integral maps.

IDW Validation Maps



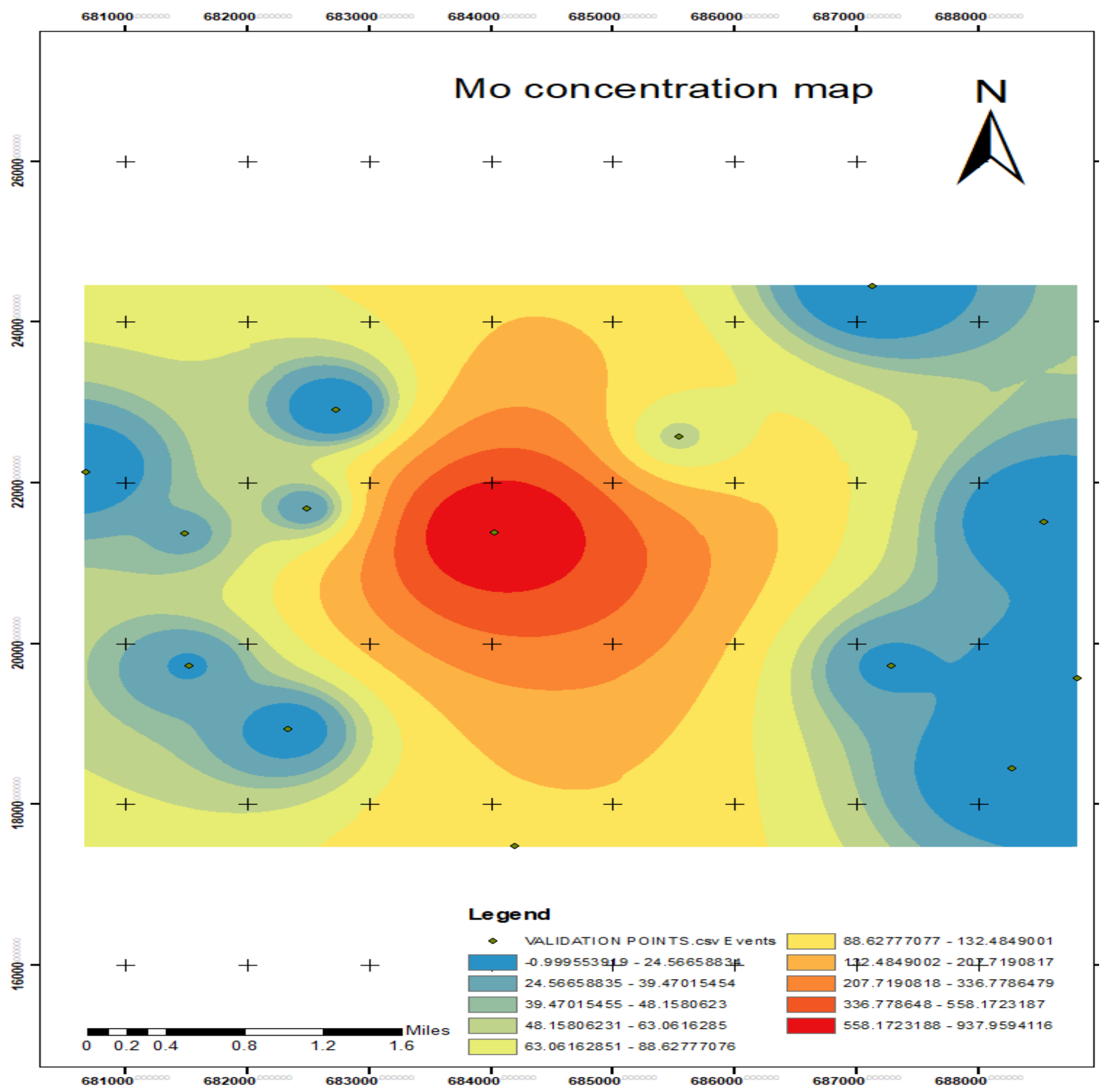
a)

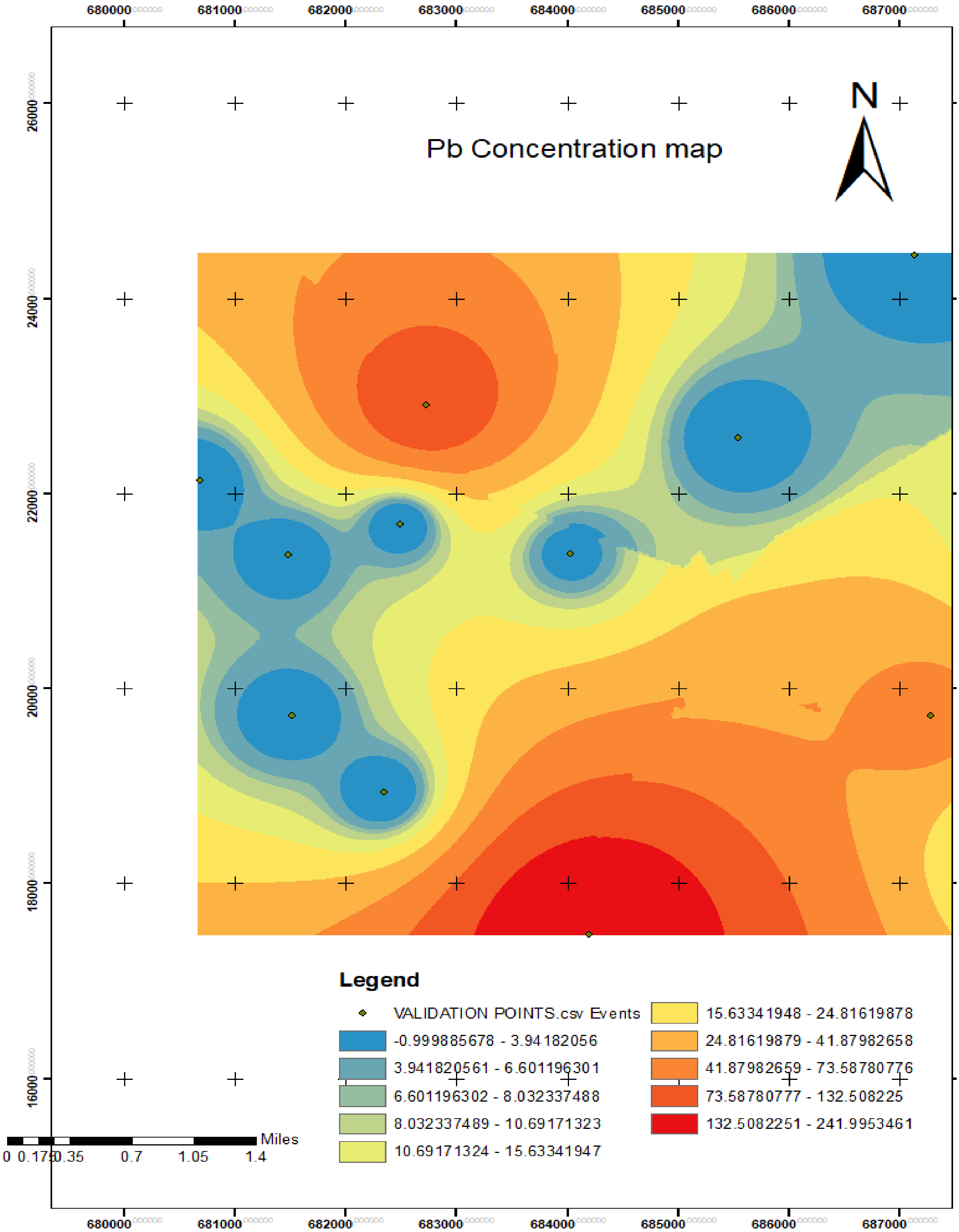


Cu Concentration map
N
678000
679000
680000
681000
682000
683000
684000
685000
686000
687000
688000
689000
690000
691000
26000
24000
22000
20000
18000
Legend
VALIDATION POINTS.csv Events
9.096270561 - 98.55978857
98.55978858 - 152.8388192
152.8388193 - 185.7708259
185.770826 - 205.7512317
205.7512318 - 217.8736821
217.8736822 - 237.854088
237.8540881 - 270.7860946
270.7860947 - 325.0651253
325.0651254 - 414.5286433
414.5286434 - 561.9837646
Miles
0 0.275 0.55 1.1 1.65 2.2

b)

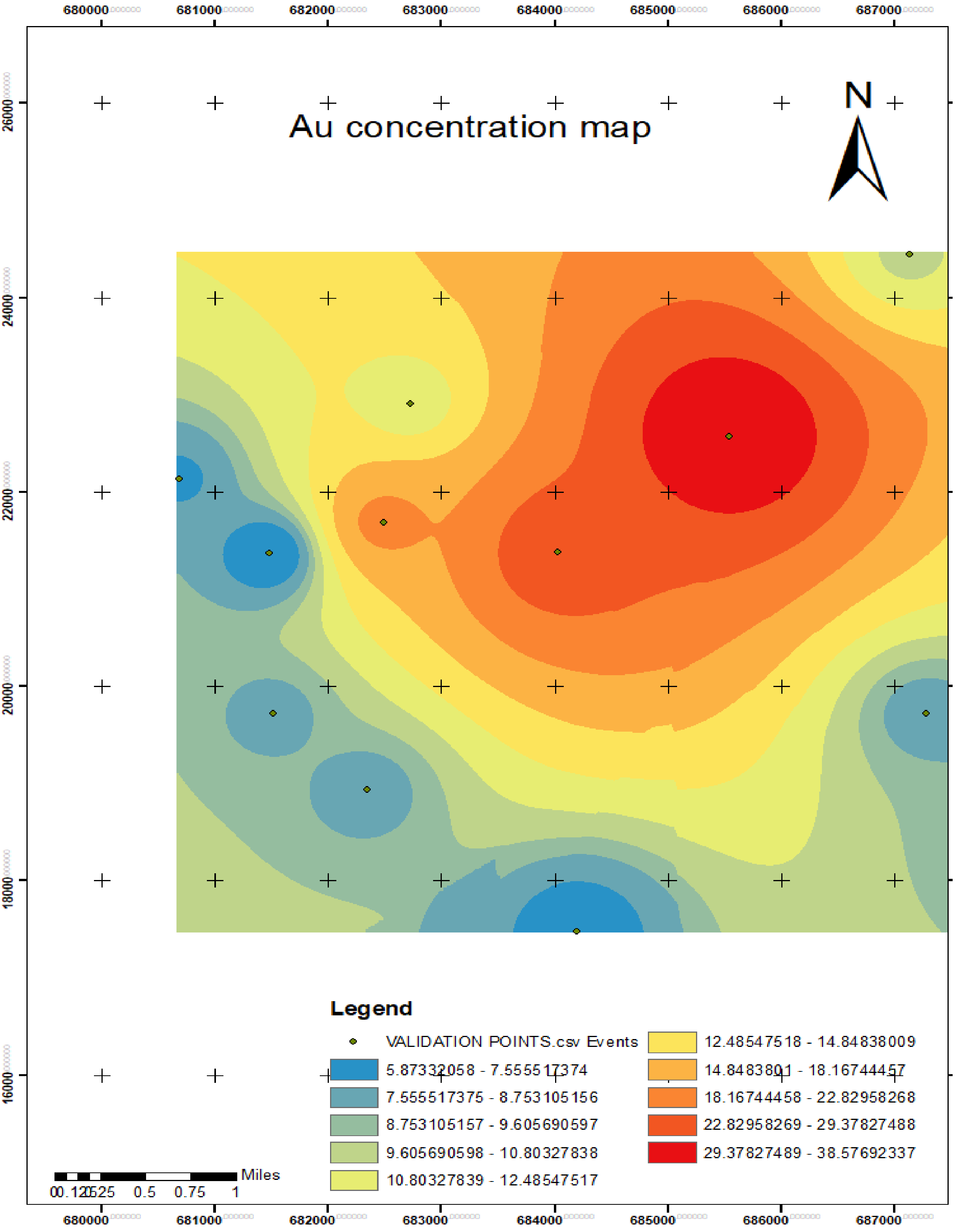
c)


Mo concentration map
N
681000
682000
683000
684000
685000
686000
687000
688000
26000
24000
22000
20000
18000
16000
Legend
VALIDATION POINTS.csv Events
-0.999553919 - 24.56658834
24.56658835 - 39.47015454
39.47015455 - 48.1580623
48.15806231 - 63.06162851
63.06162851 - 88.62777076
88.62777077 - 132.4849001
132.4849002 - 207.7190817
207.7190818 - 336.7786479
336.778648 - 558.1723187
558.1723188 - 937.9594116
0 0.2 0.4 0.8 1.2 1.6
Miles



Pb Concentration map
N
Legend
VALIDATION POINTS.csv Events
-0.999885678 - 3.94182056
3.941820561 - 6.601196301
6.601196302 - 8.032337488
8.032337489 - 10.69171323
10.69171324 - 15.63341947
15.63341948 - 24.81619878
24.81619879 - 41.87982658
41.87982659 - 73.58780776
73.58780777 - 132.508225
132.5082251 - 241.9953461
Miles
0 0.175 0.35 0.7 1.05 1.4
680000
681000
682000
683000
684000
685000
686000
687000
26000
24000
22000
20000
18000
16000

d)



e)

Figure 1.4: Spatial correlation of a) Fe, (b) Cu, (c)Mo, (d) Pb and (e)Au within validation area.

Cu, Ag, Mo, Pb and Au were observed to be significantly concentrated over the validation area suggesting the possibility of sulphide mineralization within the area. Figure 1.4 is a summary of the above concentration maps displayed at 70% transparency over the geology of the area to ascertain the selection criteria used to select drill locations. It is evident from the map that those locations showing enrichment lie within the Mudstone, andesite and conglomerate lithologies as well as well as along the inferred fault lines. The element concentrations also show a trend suggesting the trend of possible mineralization. A close look into the synoptic map reveals a dense concentration of element classes which also is an agreement to the defined criteria.

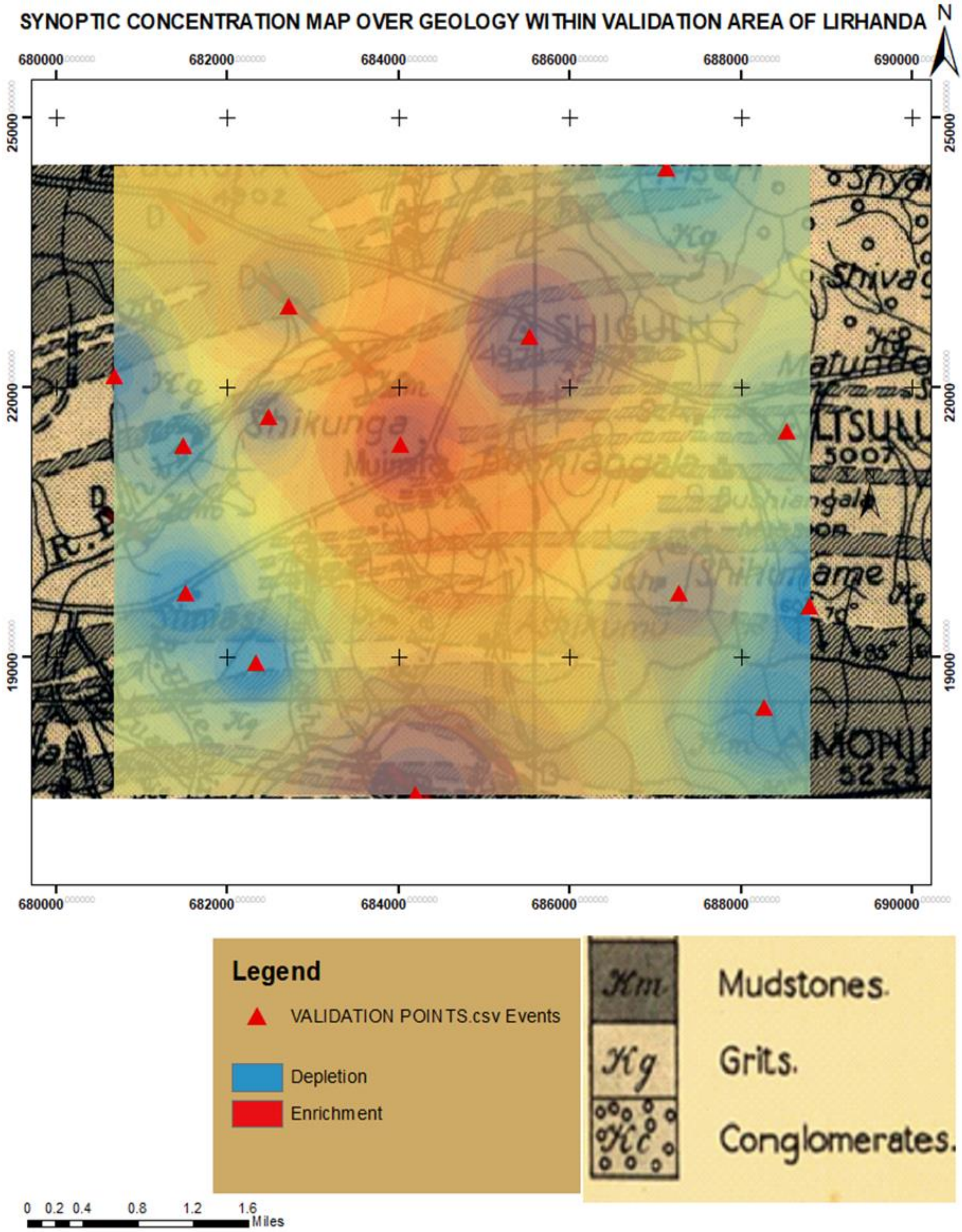


Figure 1.5: Synoptic element concentration map within Validation area of Lirhanda corridor

Visual inspection of the concentration maps in figure 1.4, clearly shows that the base metals except for the silver are spatially correlated with enrichments trending North-south and NW - SE diagonal of the sampled area. This is the area characterised by the interpreted intrusions in the same direction of enrichment and also by the mudstones, conglomerates and andesite lithologies. This relates well to the defined criteria as in (figure 1.2).

Conclusions

To have exploration drilling done at a minimum cost possible within Lirhanda gold exploration project by AEK, a research to optimise drilling locations using the available surface exploration data was invited, conducted and hereby validated. A GIS based interpolation technique for the geochemical data and spatially relating it to the geological and geophysical data was employed. Surface Niton XRF data was primarily used to generate concentration maps for different pathfinder elements within the special licence area SL266 of the Lirhanda gold project. A digital geochemical database was created from these maps using the GIS software and then superimposed on digital features created from the geophysical and geological data sets. Preselected points and areas which showed more positive spatial correlation of all the three data sets and which were defined to be optimum as drill locations in this project area were successfully validated and the following conclusions were made;

- Base metal and low grade gold intercepts were encountered at the preselected points, that is ‘‘optimal drill locations’’. There were pyrite intercepts but low gold intercepts encountered as revealed by the results from existing shafts which fall within the preselected ‘‘optimum locations’’.
- Existing shafts proximal to the preselected drill locations which were used for sample collection revealed mineralized quartz veins indicative of gold mineralization.
- The associated geology and geophysical interpreted targets as well as structural features of those areas which indicated possible mineralization showed similarity to those of the preselected drill location.
- The defined criteria is a very appropriate replacement of the trial and error methods by the artisanal miners in Kakamega who have previously used the landmarks left during the pre-colonial era to locate their shafts which most often ended up a disappointment.
- 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 were confirmed to be 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.

- Together with previous research done on the same area, this work can be used to indirectly reduce unnecessary drill holes and determine when to stop or continue drilling. The selected drilling points can be used to determine whether there is a sulphide mineralization which could be gold. Decision to stop drilling exercise can be made on the basis of the type of sulphide mineralization encountered.

Recommendations

Based on the findings of this study during the validation exercise, the following recommendations were made;

- To optimize the drilling exercise in the same area the company in charge has to priotize on the preselected areas defined by this research work to help them know when to proceed or stop exploration drilling.
- Further Model validation by drilling on the more prospective areas to determine compliance to the sulphide mineralization which would in turn help determines gold mineralization.
- Adapt the defined criteria to help artisanal miners to locate their shafts with an improved certainty. Artisanal miners from Kakamega area have for a long time used traditional methods to locate their shafts.
- Further validation to be done by visual inspection of superimposed gold intercepts on data maps from SL277 and SL265 special license areas to confirm the defined criteria for drill hole location.

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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