GEOSPATIAL PROFILING FOR THRESHOLD MAPPING OF HYDROTHERMAL ALTERATION WITHIN KUSHAKA SCHIST BELT, NORTH CENTRAL NIGERIA: IMPLICATIONS FOR MINERAL EXPLORATION

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Abstract

Determining thresholds are very useful in hydrothermal alteration mapping because of their association with mineral deposits. Thus, quantifying the degree of association can serve as a reliable way of separating highly to less altered zones. This can be achieved through knowledge of the threshold values. The aim of the study is to propose a new and more effective method for defining thresholds from spatial profiles in thematic images. To achieve this, band ratio technique and threshold mapping of the study area were carried out. The band ratio method was used to delineate clay alteration by dividing band 5 on band 7. Ten (10) profiles were generated within the study area and the maximum and minimum threshold were determined. The results showed a close agreement between the thresholds values using spatial profiling method with the values computed from other established method of threshold determination. It is also important to note that known gold mineralization points in the study area were observed to occur within the highly clay altered zones. Therefore, spatial profiling technique can be regarded as a valid method for determining threshold values in thematic images.

KEYWORDS: Threshold, band ratio, spatial profiling, thematic images, hydrothermal alterations.

INTRODUCTION

The concept of remote sensing applied to mineral exploration makes use of identification of alteration zones from well processed satellite images. In simplifying this concept, it is believed that hydrothermal alteration zones are generally associated with mineral deposits (Pour and Hashim, 2015). If this is true, the higher the degree of alterations, the greater the tendency of finding mineral deposits. Quantifying the degree of alteration can also serve as a reliable way of separating highly altered areas from less altered ones. Thus, defining a threshold value can be very useful in such endeavors. In mineral exploration, threshold is a term use to signify a specific value that effectively separate high and low data value of fundamentally different character that reflect different causes (Sinclair, 1974). The term is usually applied to a value that distinguishes between the upper or anomalous dataset from lower or background datasets (Sinclair 1974). Determination of threshold values have been carried out for different types of geoscience related datasets ranging from geochemical, geophysical, remote sensing and environmental studies using a variety of statistical techniques. (Sinclair, 1974; Aramesh *et al.*, 2014, Chang, 1995). This study is aimed at inventing a new method for defining thresholds from spatial profiles in thematic images. Spatial profiling method for threshold determination is targeted towards determining maximum and minimum threshold values by constructing profiles across very high and very low altered zones.

REGIONAL GEOLOGY OF THE STUDY AREA:

The study area is situated within the latitudes 10° 33' 32.7"N to 10° 39' 50"N and longitudes 6° 38' 38"E to 6° 43' 40"E (Fig. 1). According to Black (1980), it is located within the Nigerian Basement Complex which form parts of the Pan African mobile belts. It occupies the reactivated region that results from plate collision between the passive continental margin of the West African craton and the active Pharusian continental margin affected by the Pan African Orogeny (Burke and Dewey; 1972, Dada 2006). Lithologically, the Nigerian Basement Complex can be sub divided into Migmatite Gneiss Complex (MGC), the Older Metasediments, the Younger Metasediments and the Older Granites. The

Migmatite gneiss complex is the oldest rock units of the Basement Complex, it is dated as Birrimian in age (about 2500Ma). It is believed to be of sedimentary origin but was later profoundly altered under metamorphic and granitic conditions (McCurry 1970, 1976). It comprises of Archean polycyclic grey gneiss of granodiorite to tonalitic composition and is considered to be the Basement Sensu Stricto (Rahaman 1988, Dada 2006).

The Older meta-sediments (aged between 1100-900Ma) are among the earliest rocks form on the Nigerian Basement Complex, initially of sedimentary origin with a more extensive distribution. The Older meta-sediments have undergone prolonged, repeated metamorphism and now occurs as quartzites, mudrock and other calcareous relics of highly altered clay sediments and igneous rocks. The Younger Metasediments, which range in age between 850-700Ma are late pelites (represented by phyllites, muscovites schists and biotite schists) with quartzites forming the dominant ridge severally in most parts of the belts. Some belts contain ferrugineous and banded quartzites, spassetite-bearing quartzites, conglomerates, horizon marbles and calc-silicates.

The Older Granites of Nigeria dated 750-450Ma (Burke and Dewey, 1972; Turner, 1983) are widely spread throughout the basement complex and occurs as large circular masses. They consist of a wide spectrum of rocks which vary in composition form tonalite through granodiorite to granite, syenite and charnokitic rocks (Truswell *et al.*, 1963). The granitoids have been emplaced into both the migmatite-gneiss complex and the schist belts. The north-south linear aggregation of many large batholiths within the Basement Complex suggests that they may be related to deep-seated pre-existing plutonic episodes controlled by deep mantle structures (Ogezi, 1977).

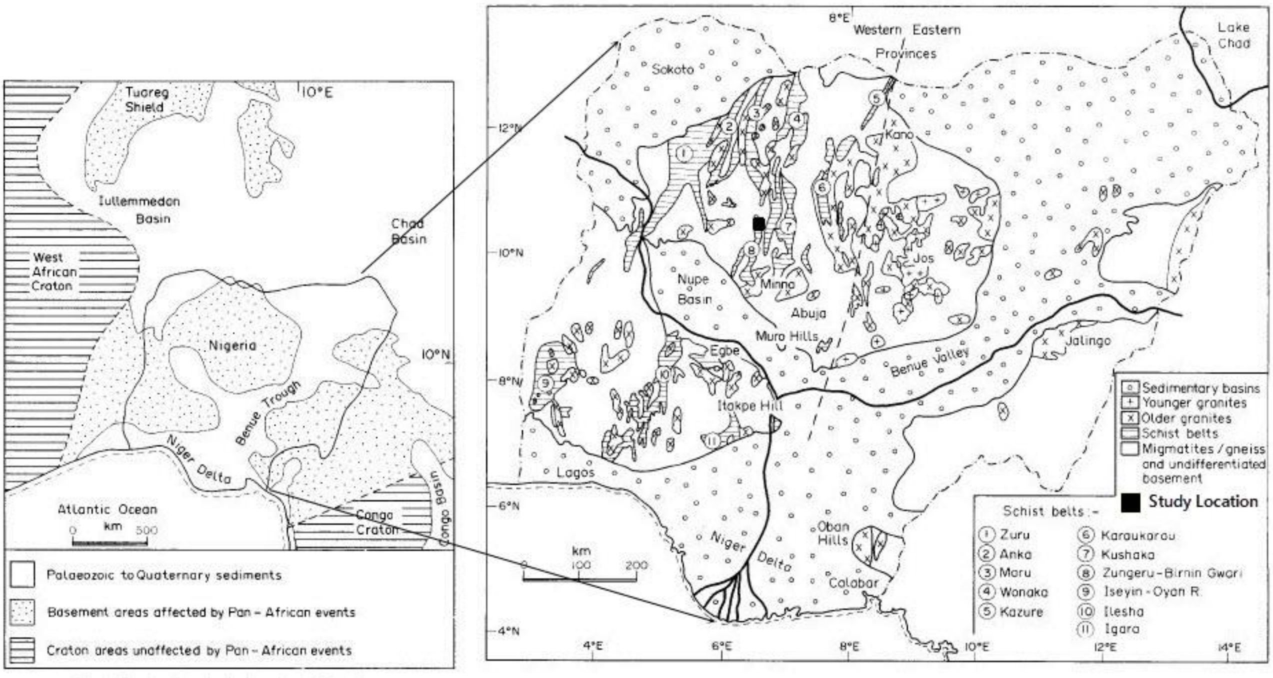


Figure 1: Regional Geology of the Study area (Modified after Woakes et,al. 1987)

METHODS:

Band Ratio:

This is an image processing method where digital numbers (brightness values) of one band is divided by that of another band. It corresponds to the peak of high and low reflectance curves (Pour and Hashim, 2015). The technique improves the contrast and enhances compositional information while suppressing less useful information like earth's surface and topographic shadow, thus highlighting some features that cannot be seen in raw data (Sabins, 1999; Vander Meer, 2004; Ali and Pour, 2014). Since gold mineralization within the study area is associated with clay alterations, a band ratio image 5/7 was generated to show the intensity of the clay alterations from dark to white. The dark colour represents low clay alteration while the white represents high clay alterations (Fig. 2A). For better display, ENVI 4.5 color tool was used to display these variations in clay alteration intensity from blue which represents low to red which represents high zones (Figure, 2b).

RESULTS:

Gold mineralization within the study area is known to be associated with clay alterations, band ratio image 5/7 generated displayed the intensity of the clay alterations from dark to white (Figure 2A). The dark color represents low clay alteration while the white represents high clay alterations (Fig. 2A). For better display, ENVI 4.5 color tool was used to display these variations in clay alteration intensity from blue which represents low to red which represents high zones (Figure, 2B).

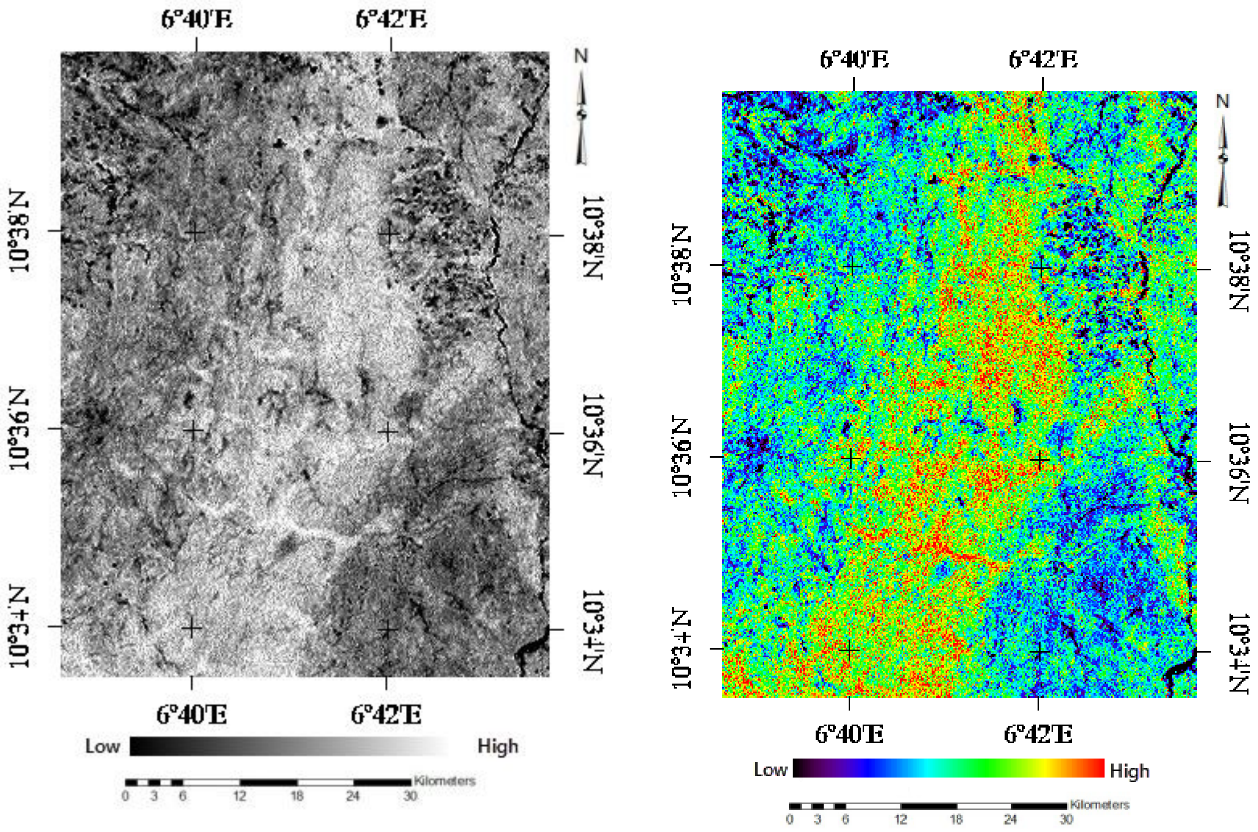
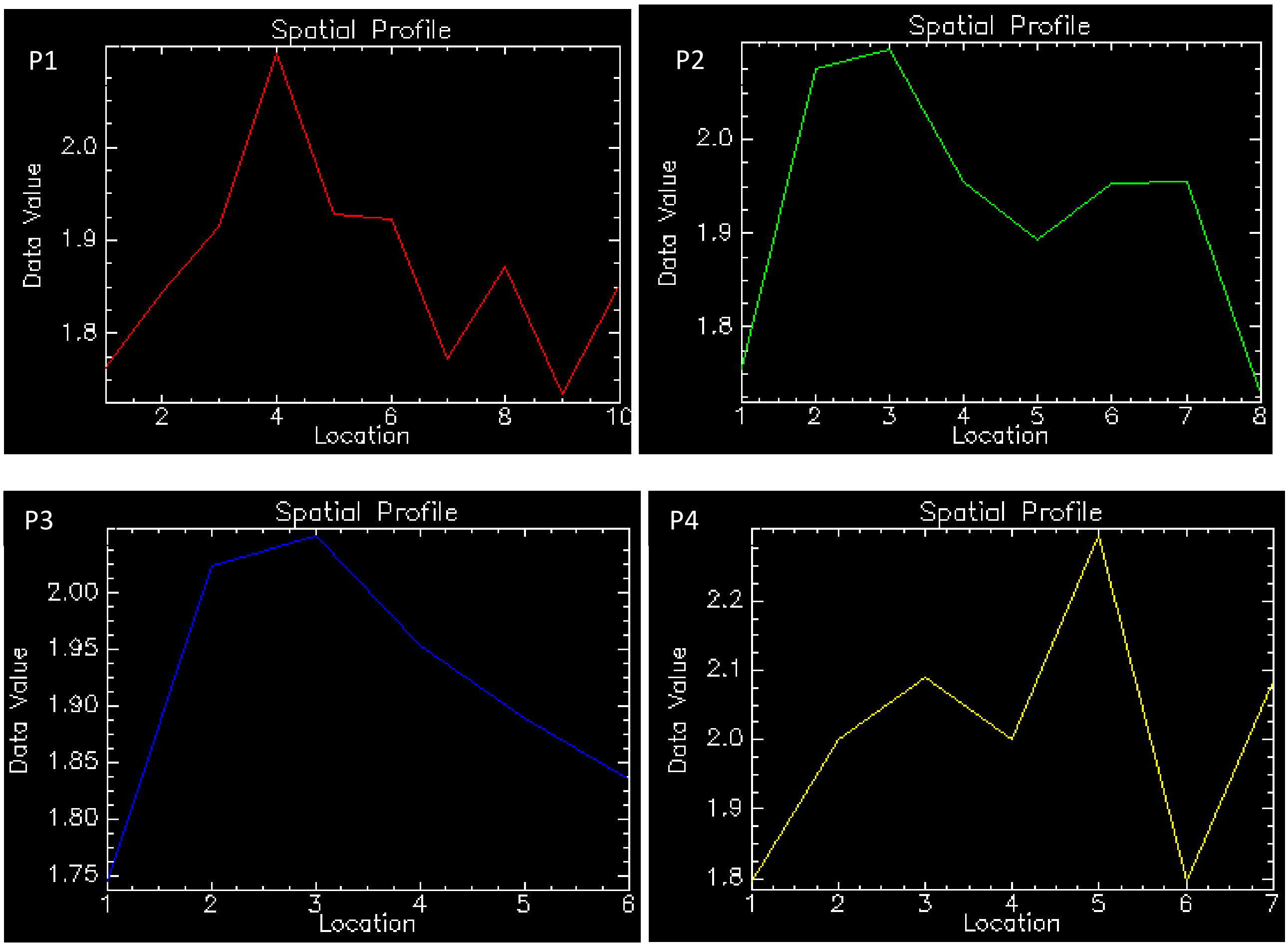


Figure 2: Band ratio image 5/7 displaying clay alterations A = Black and white image
B = Colour image.

Threshold Mapping: Threshold mapping involves finding that value which separates regions of high and low alteration from background. In this study, 10 profiles each were constructed from anomalous high and low altered zones.

Maximum Threshold Mapping

For determining the maximum threshold value, 10 micro profiles were constructed across highly altered zones within the study area (Figure 3). From these profiles, the maximum reflectance value for all the 10 profiles were extracted, summed and the mean calculated (Table 1). The mean value was assumed to be the maximum threshold value. The maximum threshold value was then used to segregate and delineate highly altered areas within the study location (Figure 4).



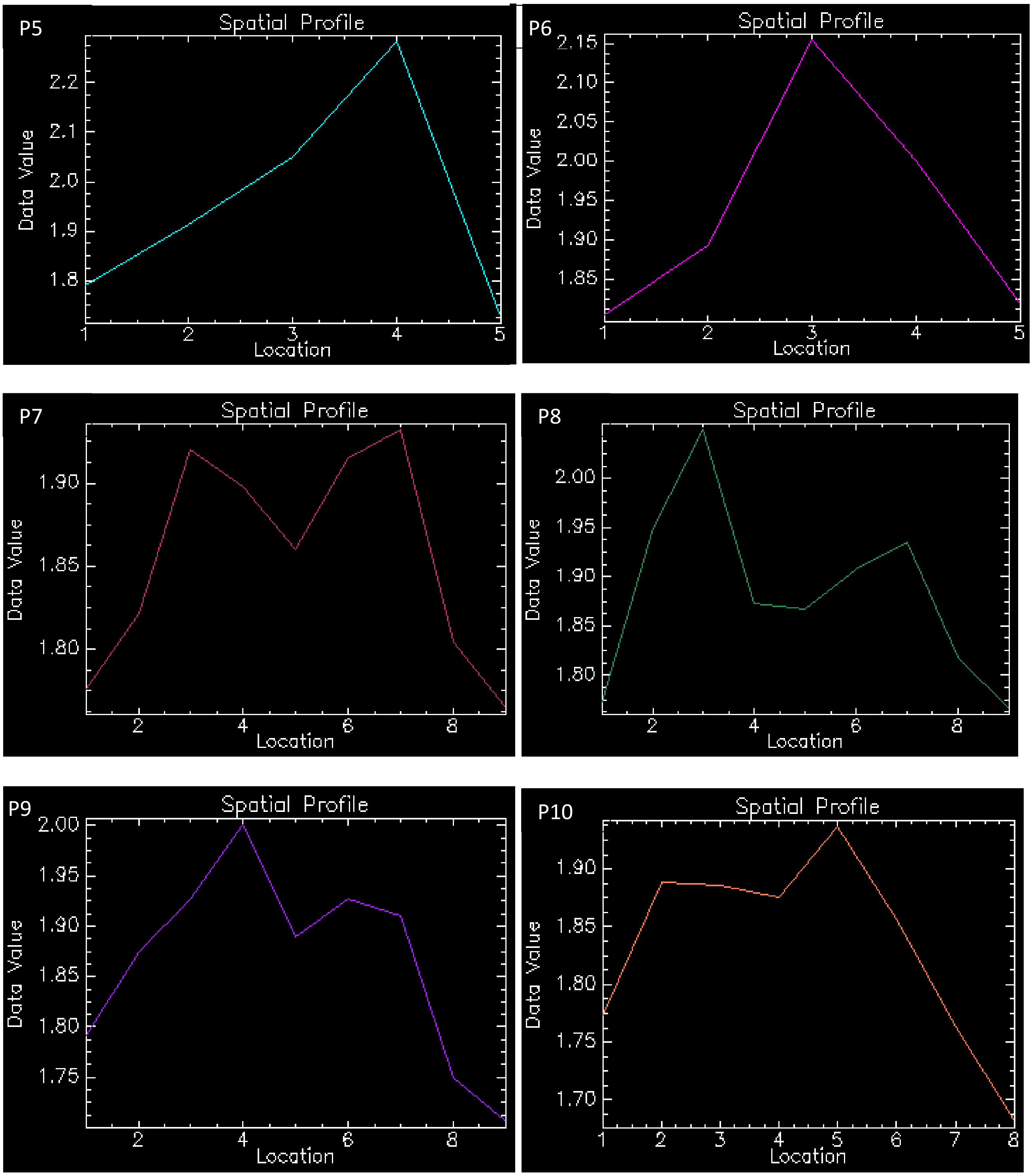


Figure 3: Spectral Profiles across high anomalous zones within the study area (within Kushaka Schist belt)

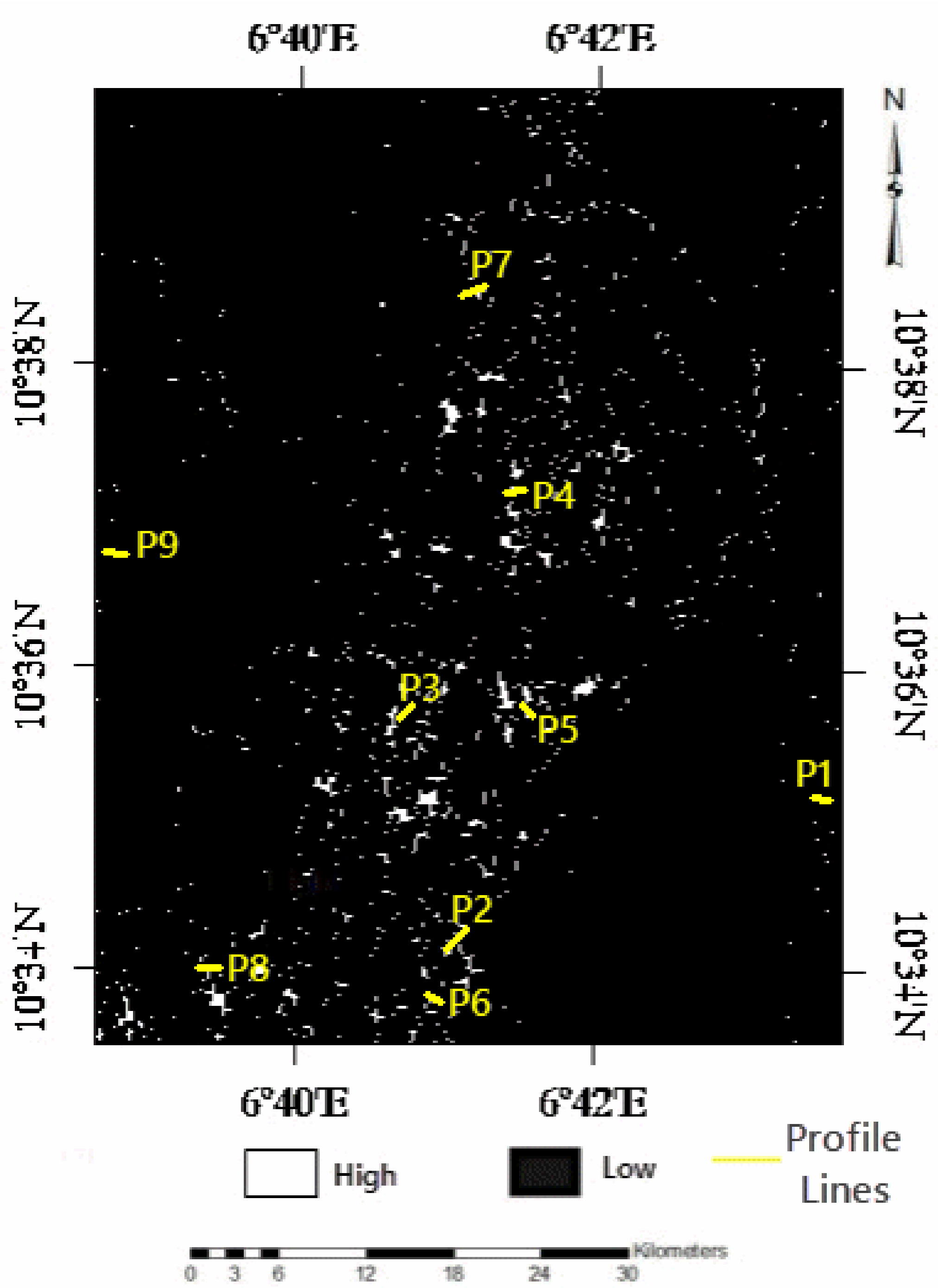
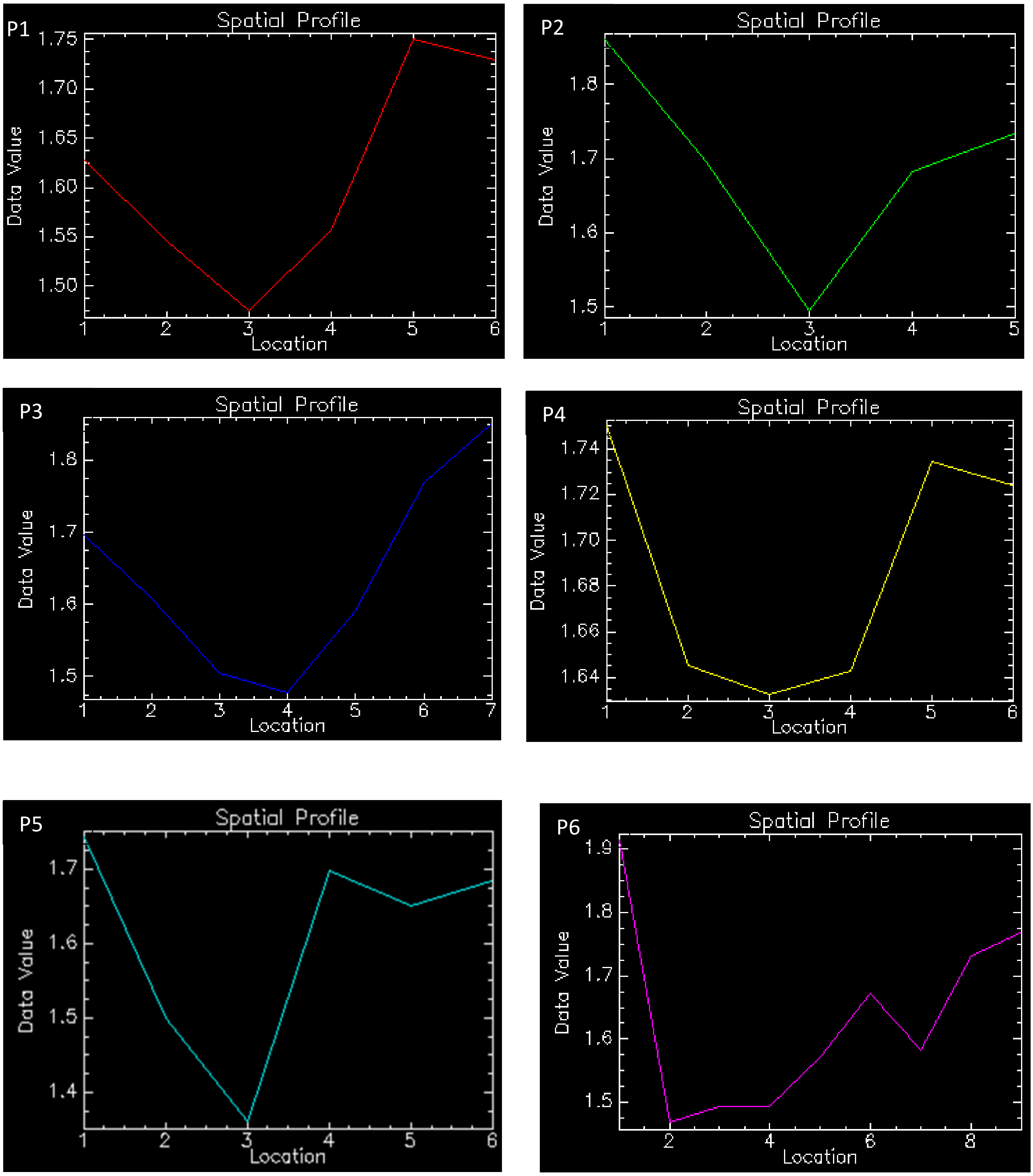


Figure 4: High threshold zones for the study area

Minimum Threshold Mapping

Constructing 10 profiles across least altered areas (Figure 5) and extraction of their minimum values (Table 1) was the first step toward calculation of minimum Threshold. The minimum values, their summed and calculated threshold is presented on Table 1. Using the minimum value to segregate low altered zones, it was observed that the least altered zones within the study area dominates the eastern and western part of the study area (Figure 6).



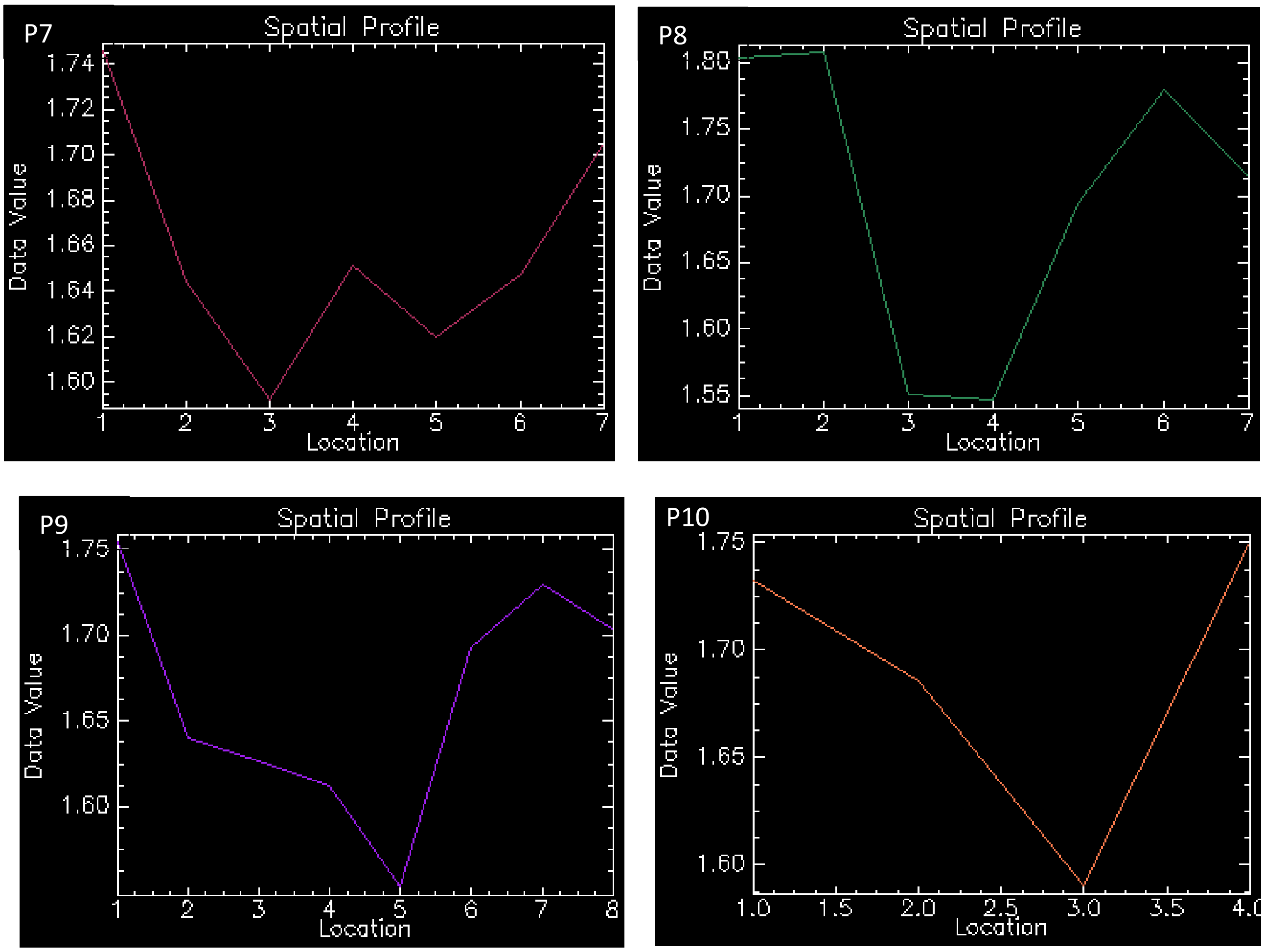


Figure 5: Spectral profile across low anomalous zones within the study area (within Kushaka Schist belt)

Table 1: Threshold statistics for altered imagery along profiles

	P1	P 2	P 3	P4	P 5	P 6	P7	P8	P9	P10	STD	Total	Threshold
Max	2.1	2.09	2.05	2.29	2.28	2.15	1.932	1.95	2	1.94	0.313	20.782	2.078
Min	1.55	1.5	1.48	1.63	1.36	1.47	1.59	1.55	1.55	1.59	4.14	15.27	1.527

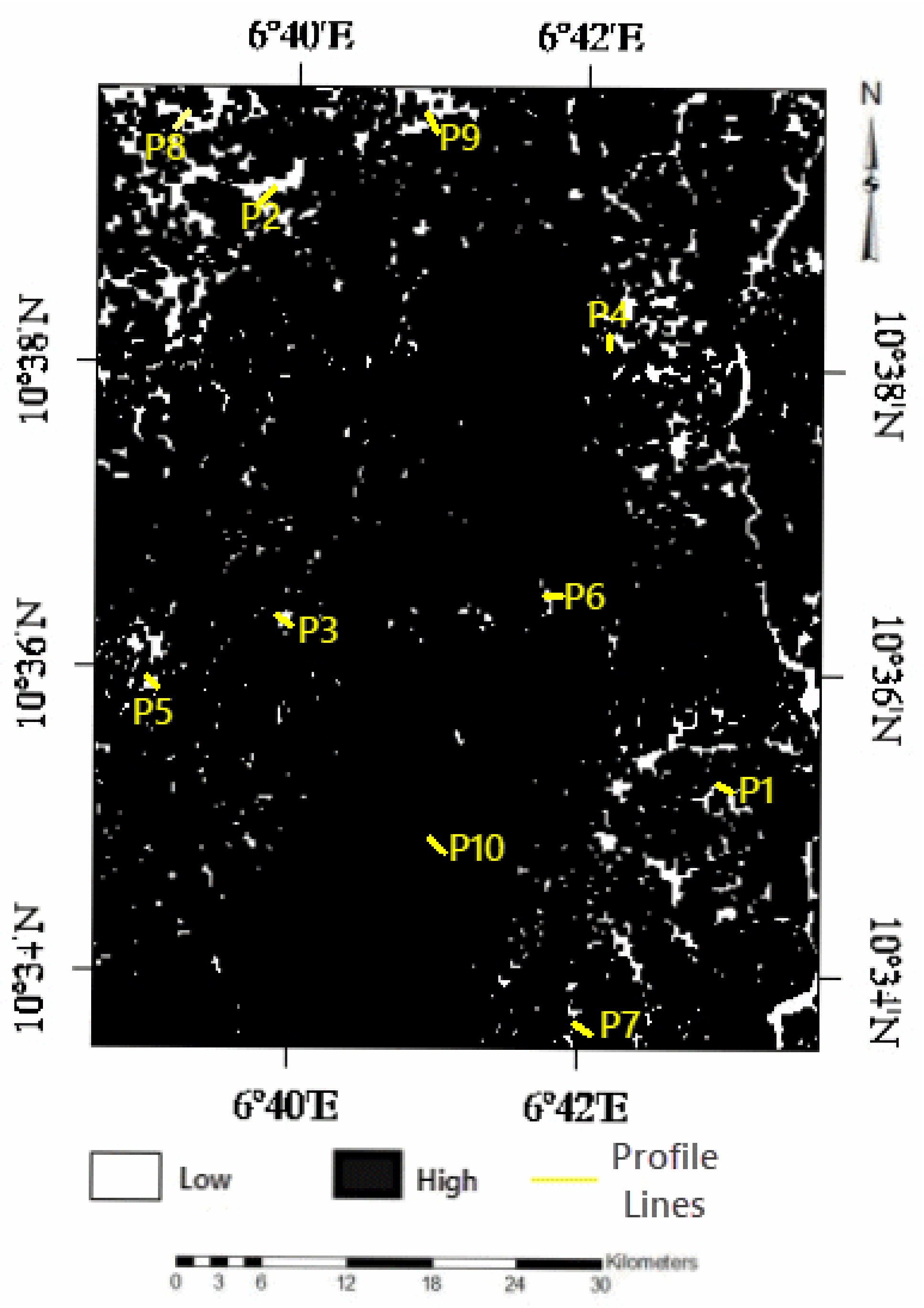


Figure 6: Low threshold zones within the study area

Validation of Threshold Method

The validation of spatial profiling method for calculating threshold values for any geodata set were carried out by comparing threshold values obtained from spatial profiling method to threshold values computed using other established methods. For convinence, the spatial profiling threshold values were compared to a known mathematical method for calculating the threshold as stated below.

$$Maximum\ Threshold = Mean + 2*\ Standard\ deviation$$

$$Minimun\ Threshold = Mean - 2*\ Standard\ deviation$$

The comparison of threshold values from both methods are presented in Table 2.

Table 2: Threshold validation for spatial profiling

S/N	**Threshold**	**Method**	**Result**
1	Maximum Threshold	Maximum Spatial Profiling	2.078
		Mean + 2* Standard deviation	2.06
2	Mininmum Threshold	Minimum Spatial Profiling	1.527
		Mean – 2* Standard Deviation	1.5

Implications of spatial profilling technique for Mineral exploration

Mineral exploration deals with the search for mineralisation within a particular area. Thus Remote sensing technique is highly valuable in exploration programs because of its ability to map not just alterations types associated with mineralisation but also the degree of alteration. Therefore the higher the degree of alteration the greater the chances of finding a mineral deposit (Sinclair, 1974). Mapping the degree of alteration is possible by defining threshold values and using these values for segregating delineating areas of low, moderate and high alterations (Figure 7). Before carrying out such a task, the knowledge of alterations associated with mineralisation in these areas must be known. This study has proven that gold mineralisation is associated with clay alteration. Further more, clay alteration from satellite imagery was quantified using threshold values derived from spatial profiling method. Known zones of gold mineraliation were plotted to establish relationship between clay alteration and gold mineralisation.

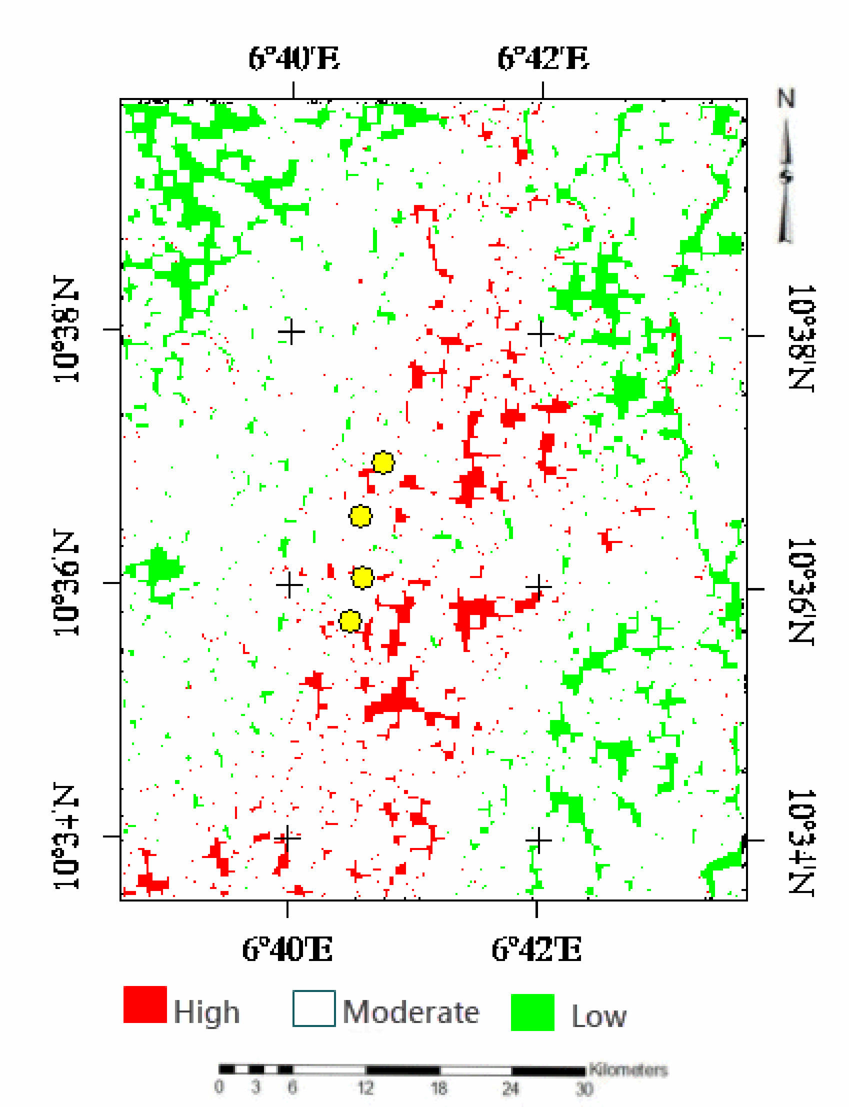


Figure 7: Relationship between gold mineralisation and alterations within the study area

DISCUSSION

There are several methods of threshold determination. Iterative Mean ±2SD statistical method (as applied in Galuszka, 2007; Hawkes and Webb, 1962), the Box-plot method (as applied in Turkey, 1997), the Fence method (as applied in Schwertman and Silva, 2007; Schwertman et al., 2004) and so many other techniques including the probability graph, univariate analysis, multivariate analysis of Stanley and Sinclair, 1989, multifractal models (as applied in Cheng and Aterberg, 1996, Aterberg et al., 1996) have also been widely used in threshold determination (Bolviken et al., 1992; Cheng et al., 1996). Unlike some of the methods mentioned above, this method which is a new and inovative method of threshold determination, does not require full statiscal details but detail knowledge of high and low signal input zones. It also has addition advantage when using thematic images as high and low zones can easily be identify and isolated for threshold determination. The use of remote sensing in mapping mineral deposits associated with alteration becomes easier when threshold values are defined and used to segregate highly altered zones from low altered zones. The rationale behind this method relies on the fact that mineralisation tend to increase with the degree of alteration. From this study, it was observed that the spatial profile method is an alternative method for defining and quantifying geo-data set within any thematic layer of interest. This is evident from the close simillarities of threshold values computed from standard techniques to those obtained using spatial profile method. Applying the computed values to a well processed band ratio imagery was able to define regions of low and high alteration within the study area. The resulting imagery revealed that the highly altered zones dominates the central part of the study area along a N-S trend and it is being flanked by a low altered zone. Zones of intermediate alterations are peppered throughout the study area. Well known zones of gold mineralisation within the study area all plotted within the highly altered zones confirming location of gold mineralisation within the highly altered zones.

CONCLUSION

The spatial profile method for defining threshold values in any geoscience dataset is valid and effective especially for data displayed in thematic layer format. Application of this method for mapping hydrothermal alteration have proved to be very effective in defining zones of high alterations within the study area. A close correlation has been shown to exist between highly altered zones and known mineralisation points within the study area. Spatially, the highly altered zones assumed a general N-S trend within the central part of the study area. Therefore the higher and the degree of alteration the greater the chances of finding a mineral deposit. Mapping the degree of alteration is possible by defining threshold values and using these values for segregating delineating areas of low, moderate and high alterations. The study established that known gold mineralization points in the study area were observed to occur within the highly altered clay alteration zones.

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