Int. J. of Geol. & Earth Sci., 2018

International Journal of Geology and Earth Sciences

ISSN 2395-647X www.ijges.com
Vol. 4, No. 1, March 2018
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Research Paper

GEOLOGICAL, GEOCHEMICAL AND GEOELECTRICAL PROSPECTING FOR ORE MINERAL RESOURCES IN GARATU, NORTH CENTRAL NIGERIA

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Received on: 7th January, 2018 Accepted on: 25th February, 2018

Gindira Mine is located in Garatu town, within North Central Nigerian basement complex. Profit from the mine is now waning, and sustaining mining activity requires defining new mine prospects in the town. The new prospects were defined by interpreting Global Digital Elevation Model (GDEM), elemental composition data of foliated rocks acquired using Energy Dispersive Fluorimeter (EDXRF) equipment, Electrical Resistivity (ER), Spontaneous Potential (SP) and Induced Polarisation (IP) sounding data. Dextrally faulted lineaments observed on GDEM are schist and amphibolite with granite and granodiorite intrusions. Elemental composition analysis revealed concentration of gold, nickel, zinc and cobalt are above 400 ppm between longitudes E6.400° to E6.410° and latitudes N9.468° to N9.471°. Copper coexists with gold in concentration above 300 ppm in the southeastern part. The ore minerals are disseminated within rock outcrops. Their subsurface occurrence is indicated by coincidence of 18 to 32 ms IP values with 20 to 30 mv SP values within low ER interval. Massive ore minerals are probably indicated by -90 mv SP values associated with 19.65 Ωm ER within 7 m half current electrode spacing at E6.397° and latitude N9.470° location. Generated new mining prospects are between (1) longitudes E6.400° to E6.410° and latitudes N9.460° to N9.477° and (2) longitudes E6.400° to E6.415° and latitudes N9.480° to N9.495°.

Keywords: New mine prospects, Ore minerals, Elemental composition

INTRODUCTION

Panning is one of the methods for mining gold. It is common to find people mining by panning for gold along stream channels within central Nigeria basement complex, in an attempt to eke out a living for their household. Sustained success requires that new panning sites are found as returns from existing ones begin to diminish. The search for new panning sites is commonly attempted by shifting panning activity to regolith and stream sediment in the neighbourhood of rock outcrops near old mines. This is blind chance

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search because it is unguided by geoscience data. The success from such efforts has been fortuitous. Returns from panning activity can be boosted if systematically acquired geoscience data guide the search for new panning sites. Besides, geochemical data can reveal the presence of other ore metals that are unknown to the local miners. One of such panning sites with declined returns is Gindira Gold Mine located within latitudes N9°29'5'' to N9°29'7'' and longitudes E6°24'45" to E6°29'47", in Garatu town in North Central Nigerian basement complex. Sustainability of mining activity in Garatu thus requires employing systematically acquired geoscience data to delineate new mineralised areas. This is essentially generating new mining prospects that would become new mining sites. Such data is hitherto unavailable for Garatu. As a result of the given circumstances, this study was conducted to acquire and analyse geological, geochemical and geoelectrical data to delineate areas with possible ore mineralization in Garatu.

The study was conducted within latitudes N9°28'0'' (N9.466°) to N9°30'0'' (N9.50°) and longitudes E6°23'0'' (E6.383°) to E°25'0'' (E6.416°) of Garatu town in North Central Nigeria basement complex (Figure 1). This covers 16 km^2 areal extent, and is part of Bida Topographic Sheet 184 NE. This area includes an old mining site called Gindira Gold Mine, where mining activity is at very low ebb because of much diminished returns.

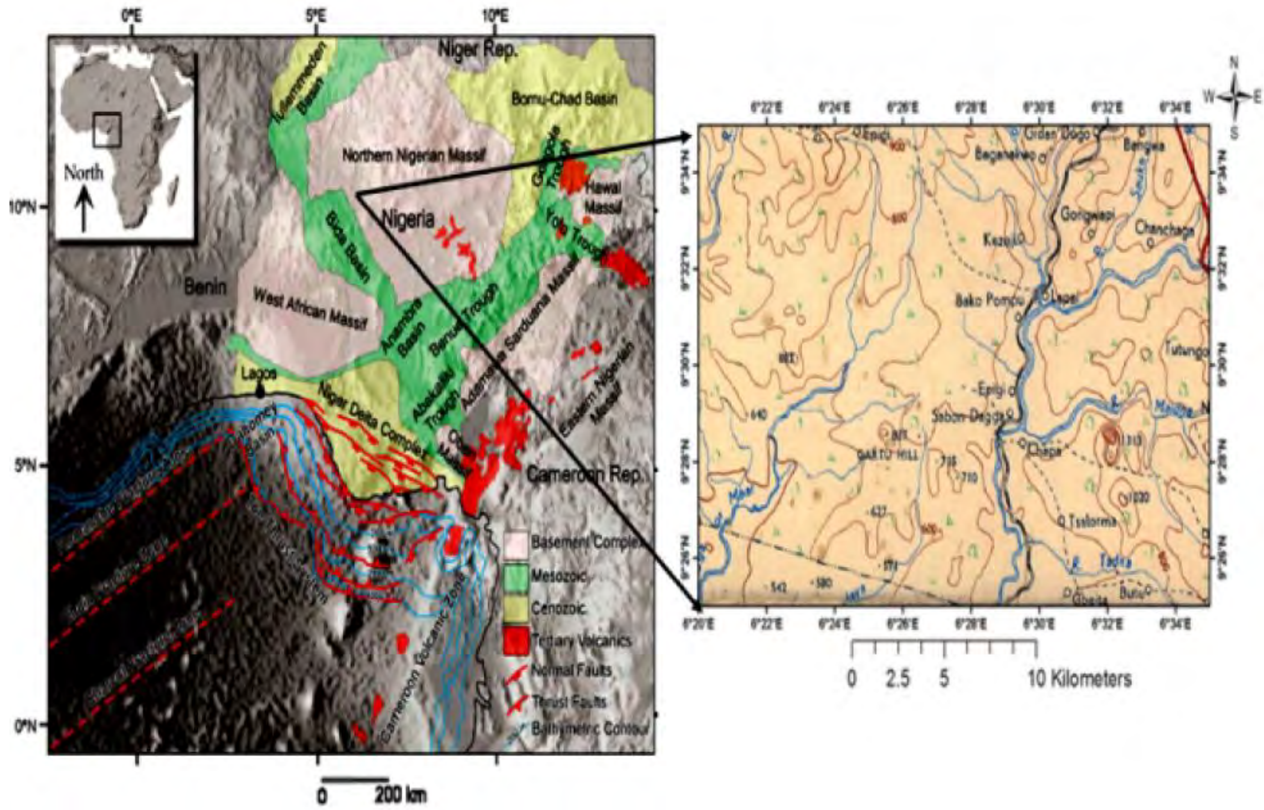
Bateman (1981), Guibert and Park (1986) and Nelson (2012) described ore mineral resource as a body of rock that bears economic concentration of one or more metals. Such metals include gold (Au), silver (Ag), tin (Sn), copper (Cu), lead (Pb), zinc (Zn), cobalt (Co), iron (Fe), nickel (Ni), and chromium (Cr). Keary and Brooks (1988) differentiated massive ores from disseminated ones. They considered a massive ore deposit to be a single mass with over 50% mineral component and a minimum cross sectional area of 100 m^2. Pardo *et al.* (2012) remarked that ore bodies of disseminated minerals contain less than 20% mineral content, which is fine grained and occurs as specks and veinlets throughout the host rock body. Ralph (2016) reported that Au occurs in quartz veins in sizes that are invisible to naked eyes to sizes that are visible large aggregates. Wright *et al.* (1985) reported that Cu, Pb, and Zn ores exist within the vicinity of igneous intrusives in schist formations. Ajibade *et al.* (2008) reported some Au mineralisation hosted within Ushama Schist and Kushaka Schist in north central Nigeria basement complex.

Metallogenesis is driven by igneous activity, irrespective of whether the ore metals are deposited in hydrothermal veins, in pegmatites or concentrated in minerals that separated during magmatic crystallization. Effective exploration and exploitation of ore mineral resources hinge upon integrated application of geological, geochemical and geophysical data. The search for ore mineral resources begins with area selection using regional geological knowledge, followed by careful geological mapping, geochemical sampling, geophysics and drilling (Maclaurin, 1996). Bahiru and Woldai (2016) employed surface geological mapping to build relationships between lithology and structure to assess controls on gold mineralization in Buhweju area of Uganda. They established a cluster of gold occurrences associated with high lineament density at Kitata mine site.

Geochemical exploration is any method of exploration that employs systematic measurements of one or more chemical properties of a naturally occurring material (rock, soil, stream and lake sediment, vegetation). Xuejing and Xueqiu (1991) employed geochemical analysis of stream sediments to discover hundreds of new gold occurrences in China, on the basis of a regional anomaly outlined on a threshold of 2 to 4 ppm. Some of the occurrences are now producing mines. However, geochemical indications should be validated by geophysical investigations. Ako *et al.* (1978) reported that electrical resistivity, spontaneous potential and electromagnetic data indicated absence of massive or disseminated sulphide body where reconnaissance geochemical studies indicate sulphide mineralization in Ifewara area of southwestern Nigeria. Ore mineral exploration is now preferably conducted using integrated surface geological, geochemical and geophysical methods. Ariyibi (2011) employed coincident electromagnetic, magnetic and geochemical anomalies to reveal subsurface Zn-Pb-Cr sulphide deposits within amphibolites in Ilesha area of southwestern Nigeria. Peterson and Patelke (2014) reported that grid-based geological mapping, bedrock sampling, ground geophysics and soil geochemistry were employed in mineral exploration for lode gold deposits in Vermilion district of northeastern Minesota.

Many workers (Parasnis, 1986; Keller and Frischknecht, 1966; Ako *et al,* 1978; Lowrie, 1997; Kearey *et al.,* 2002; Salmirine and Turunen, 2007; Musset and Khan, 2009; and Pardo *et al.,* 2012) employ geoelectrical methods to prospect for ore mineral resources because many ore minerals are electrically conductive, unlike their generally resistive host rocks. Electrical resistivity and spontaneous potential methods were first successfully employed to prospect for ore minerals in the 1900's by Schlumberger brothers. From that time, the methods have detected numerous ore bodies such as Kimheden ore body at Skellefte in northern Sweeden, copper ore at Chalkidili in northern Greece and sulphide orebody at Sariyer in Turkey (Reynolds, 2011). Disseminated ore minerals are isolated single crystals separated from each other by resistive gangue minerals (Keller and Frischknecht, 1966). Resistivity anomalies require continuous conductors such as massive orebodies, and cannot be generated by disseminated orebodies (Lowrie, 1997). Disseminated orebodies are prospected for using induced polararisation method since the late 1940s (Dobrin and Savit, 1988). Some of the successes in induced polarisation prospecting are Kalgoorlie ore field in western Australia (Telford *et al.,* 2001), Gortdrum copper-silver deposit in Ireland (Seigel, 1962), copper-gold orebody within Malmfalten ore district in Sweden in (Malmquist and Parasnis,1972; and Rezvani, 2015) and copper mountain deposit in Quebec in Canada (Hallof, 1966). Moreira *et al.* (2016) employed DC resistivity and IP to ascertain continuity of gold lodes in Rio Grande, southern Brazil. Unuevho *et al.* (2016) combined digital elevation model with surface geological mapping and geoelectrical data to prospect for ore minerals in Kundu, north central Nigeria basememt complex. They interpreted spontaneous potential values between +20 and +40 mv to indicate possible ore mineral bearing quartz veins and pegmatite bodies, when associated with IP values greater than 10 ms. They also interpreted SP values in the neighbourhood of -100 mv to indicate possible subsurface massive ore minerals, when characterized by resistivity values lower than 150 Ωm. Their interpretation is in conformity with geoelectrical characterization of massive ore minerals, and ore minerals disseminated in

Figure 1: Location Map of the Study Area



pegmatite dikes and quartz veins given by Parasnis (1986), Lowrie (1997), Kearey *et al.* (2002), Salmirine and Turunen (2007) and Musset and Khan (2009).

MATERIALS AND METHODS

Equipment employed in this study comprise geologic hammer, compass clinometer, Geographic Positioning System (GPS), Energy Dispersive Fluorimeter (EDXRF) and Abem SAS 1000 Terrameter. The software comprises Arcmap GIS, rockwork, Microsoft excel, suffer 11 and Win Resist. The entire method is pivoted on exploration concept of Arbenz (1976), which states that exploration is a venture into the unknown that employs interpolation, extrapolation and comparison to predict subsurface rock content before drilling. Garatu town's 50 m resolution Global Digital Elevation Model (GDEM), generated from Advanced Space Borne Thermal Emission and Reflection Radiometer (ASTER), was obtained from https://reverb.echo.nasa.gov. The GDEM was georeferenced and processed into hillshade view using *Arcmap GIS*. Linear and conical features were identified on the GDEM. Laterally displaced lineaments were inferred to be fractures, and the conical features were inferred to be igneous intrusives. Surface geological mapping was conducted to establish the lithologies of the lineaments and conical features. Strike, dip amount and dip direction of foliated rocks were measured using compass clinometer. Direction of joints were measured and plotted into Rosette diagram using *Rockworks.* The geologic map for the area was produced on a scale of 1:20,000. Thirty fresh rock samples were collected from different outcrops during the field mapping. The geographic coordinates of the outcrops were determined using the *etrex Garmin* type of the GPS. Twelve fresh samples of foliated rocks were selected from vicinity of igneous intrusives, and analysed for elemental composition using EDXRF at the National Agency for Science and Engineering (NASENI) in Akure, southwestern Nigeria. The spatial concentration map for Au, Ni, Cu, Zn, Co and sulphur (S) were plotted using *suffer 11.* The economic significance of the concentration for each metal was assessed by multiplying their respective crustal abundance value with their enrichment factor.

Six locations in the neighbourhood of areas with appreciable metals' concentration, were selected for geoelectrical sounding. The geoelectrical sounding comprised Electrical Resistivity (ER), Spontaneous Potential (SP), and Induced Polarisation (IP). Schlumberger field electrode array was employed. The sounding traverse and measurement electrodes were laid along rock foliation strike, NNE. This would minimize effect of lithologic variation along dip direction on the measurements. Electrical resistivity values were plotted against half current electrode spacing on log-log graphs, using *Microsoft excel*. Low resistivity intervals bounded above and below by higher resistivity values were inferred to be fractured intervals. Values of SP and IP were plotted against half current electrode spacing, using *Microsoft excel*. Fractured intervals with SP values in neighbourhood of -100 mv were interpreted to be massive ore deposits. Fractured intervals with SP values between +20 and +40 mv and IP values above 10 ms were inferred to be quartzite veins and pegmatite dikes with disseminated ore minerals.

RESULTS AND DISCUSSION

Figure 2 is the interpreted hillshade view of ASTER's terrain model (GDEM) for Garatu town. The hillshade view reveals lineaments trending NNE, which are laterally displaced by NNW-SSE oriented dextral fault trace on the east. The lineaments and fault trace are less conspicuous on the west where the study area is located. Surface geological mapping revealed that the lineaments are schist and amphibolite. The conical features are granite and granodiorite outcrops. Localized pegmatite outcrops are also present, as shown on the geological map (Figure 3). The schist and amphibolite belong to the younger metasediments. The schist is part of the Kushaka Schist belt. The schist and amphibolite

Figure 2: Hillshade View of Garatu's Terrain Elevation Model, GDEM

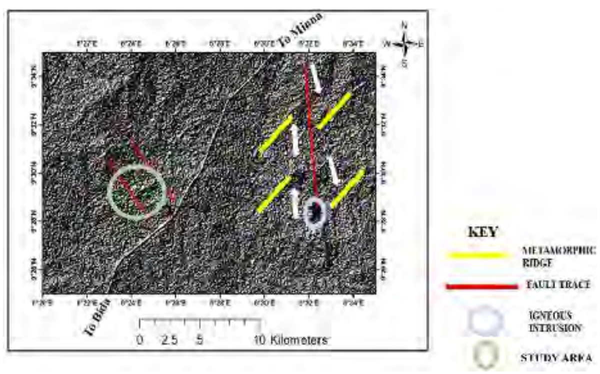
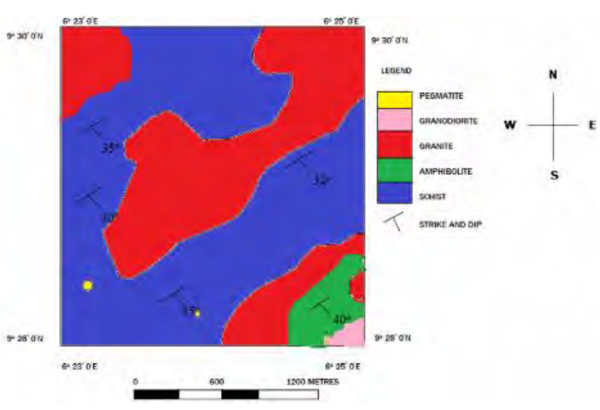


Figure 3: Geological Map of the Study Area



dip between 30 and 40 degrees eastwards. Their strike direction is NNE-SSW. The granite and granodiorite belong to the rocks called Older Granite in Nigeria. They intruded into the core of the schist.

Figure 4 is an outcrop of granite with schist xenoliths that indicate that granite intruded into the schist, which predates it. Figure 5 is an outcrop of granite with a network of surface fractures. Figure 6 is an outcrop of amphibolite with folded quartzo-feldspathic vein and granitic intrusion. Minor quartzite outcrop is shown in Figure 7.

Figure 4: Granite Outcrop (Location E6°24'40'', N9°28'32'') with Schist Xenoliths (by the Compass Clinometer)

Figure 5: Highly Fractured Granite Outcrop (LocationE 6°24'52'', N9°29'48'')

Figure 6: Outcrop of Amphibolite (Location E 6°24'26'', N9°28'32'') with Folded Quartzo-Feldspathic Vein (Indicated by the Compass Clinometer) and Granitic Intrusion on the East

Figure 7: Quartzite Outcrop at Location E6°23'20'', N9°29'31''

Tables 1 and 2 respectively shows elemental concentrations of the metals in the analysed rock samples in parts per million (ppm) and in percentage(%). The respective economic threshold value for the metals is given in Table 3. Apart from samples from locations 1, 10 and 15, their concentration largely exceeds their economic threshold value.

Figure 8 shows spatial concentration map, in ppm, of Au in the studied part of Garatu. The Au

Table 1: Metallic Elemental Concentrations (ppm) of Metals and Sulphur Within Garatu Area, North Central Nigeria

S. No.	Samples Location	Longitude (Easting)	Latitude (Northing)	Gold (ppm)	Nickel (ppm)	Copper (ppm)	Sulphur (ppm)	Zinc (ppm)	Cobalt (ppm)
1	1	6°24'53"	9°28'14"	0	320	268	3350	630	207
2	2	6°24'52"	9°28'22"	788	350	220	3241	706	180
3	5	6°24'40"	9°28'32"	272	298	276	2316	676	229
4	6	6°24'27"	9°28'30"	803	438	241	6252	781	486
5	7	6°24'26"	9°28'32"	992	365	268	4426	657	794
6	10	6°24'03"	9°28'12"	0	573	156	7716	832	375
7	13	6°24'37"	9°29'02"	414	508	252	56527	487	1015
8	14	6°24'52"	9°28'06"	129	403	196	3866	505	133
9	15	6°24'57"	9°29'12"	0	387	227	2598	593	368
10	28	6°23'16"	9°29'55"	810	209	222	3250	615	468
11	30	6°23'17"	9°29'32"	189	168	414	13369	444	331
12	34	6°23'06"	9°28'08"	0	384	0	3215	666	0

Table 2: Metallic Elemental Concentrations (%) of Metals and Sulphur Within Garatu Area, North Central Nigeria

S. No.	Samples Location	Longitude	Latitude	Gold (%)	Nickel (%)	Copper (%)	Sulphur (%)	Zinc (%)	Cobalt (%)
1	1	6°24'53"	9°28'14"	0	0.32	0.27	3.35	0.63	0.21
2	2	6°24'52"	9°28'22"	0.79	0.35	0.22	3.24	0.71	0.18
3	5	6°24'40"	9°28'32"	0.27	0.3	0.28	2.32	0.68	0.23
4	6	6°24'27"	9°28'30"	0.8	0.44	0.24	6.25	0.78	0.486
5	7	6°24'26"	9°28'32"	0.99	0.37	0.27	4.43	0.66	0.79
6	10	6°24'03"	9°28'12"	0	0.57	0.16	7.72	0.83	0.38
7	13	6°24'37"	9°29'02"	0.41	0.51	0.25	56.53	0.49	1.02
8	14	6°24'52"	9°28'06"	0.13	0.4	0.2	3.87	0.51	0.13
9	15	6°24'57"	9°29'12"	0	0.39	0.23	2.6	0.59	0.37
10	28	6°23'16"	9°29'55"	0.81	0.21	0.22	3.25	0.62	0.47
11	30	6°23'17"	9°29'32"	0.19	0.17	0.41	13.37	0.44	0.33
12	34	6°23'06"	9°28'08"	0.00s	0.38	0	3.22	0.67	0

concentration is generally higher than the economic threshold value of 0.001 ppm by a factor of hundreds of thousands. The concentration is highest in the southern to central

Table 3: Average Crustal Concentration, Enrichment Factor, and Economic Threshold Values for Some Metals

Element	Symbol	Average Crustal Concentration (%)	Enrichment Factor	Economic Threshold Value (%)
Gold	Au	0.0000002	4600-5000	0.00092-0.001
Zinc	Zn	0.0082	300	2.46
Nickel	Ni	0.008	130	1.04
Copper	Cu	0.0058	100-200	0.58-1.16
Cobalt	Co	0.002	200-1000	0.4-2

Figure 8: Spatial of Au Concentration in ppm

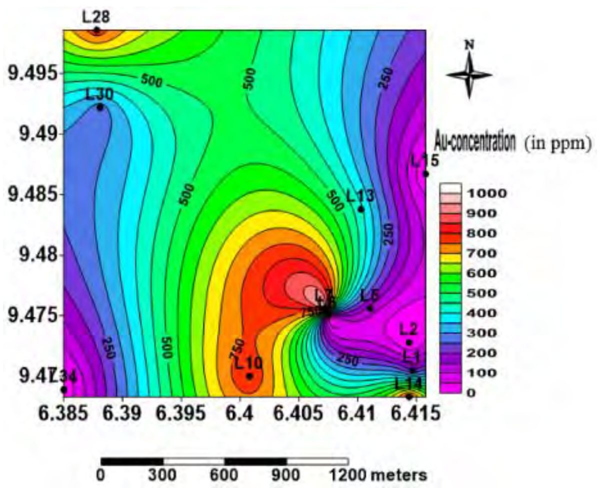
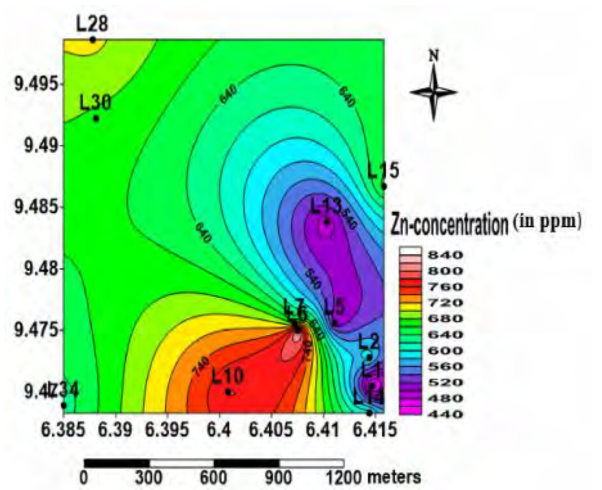


Figure 9: Spatial of Zn Concentration in ppm



part between longitudes E6.397° to E6.407° and latitudes N9.468° to N9.483°, where it is above 600 ppm. Such concentration also exist in the

Figure 10: Spatial of Ni Concentration in ppm

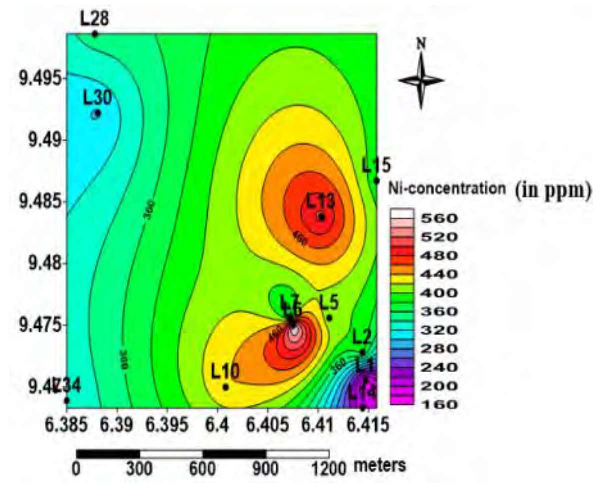
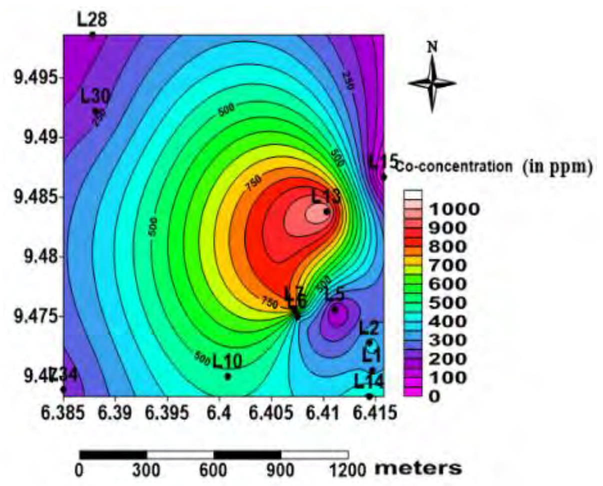


Figure 11: Spatial of Ni Concentration in ppm



north western part (longitudes E6.385° to E6.390° and latitudes N9.497° to N9.498°) and in south eastern part (longitudes E6.413° to E6.416° and latitudes N9.468° to N9.467°). Figure 9 is the spatial concentration map of Zn in ppm. The concentration of Zn is also above 600 ppm in the southern part of the studied area in Garatu, between longitudes E6.393° to E6.407° and latitudes N9.468° to N9.477°. Similar concentration of Zn exists in north western part of the area (between longitudes E6.385° to E6.387° and latitudes N9.497° to N9.498°). The Zn ore minerals appear to coexist with Au because their concentration is highest in the same area (between longitudes E6.397° to E6.407° and latitudes N9.468° to N9.477°), apart from the south east. Figure 10 is the spatial concentration map of Ni in ppm. Ni, Zn, and Au have their highest concentration in the southern part of the town, within longitudes E6.400° to E6.407° and latitudes N9.468° to N9.476°. Ni also shows high concentration, above 400 ppm in the eastern part of the town, between E6.403° to E6.413° and latitudes N9.480° to N9.492°. Figure 11 is the areal concentration map for Co. Cobalt occurs in concentration above 700 ppm in the eastern part within longitudes E6.400° to E6.410° and latitudes N9.475° to N9.487°. This area of high Co concentration coincides with the high concentration area of Ni in the eastern apart. This

Figure 12: Spatial of S Concentration in ppm

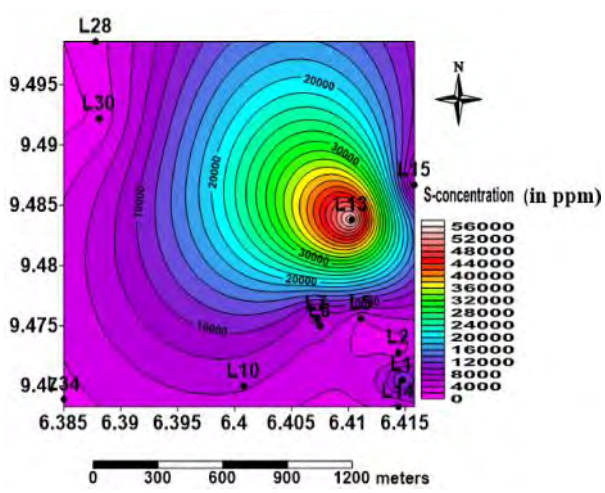
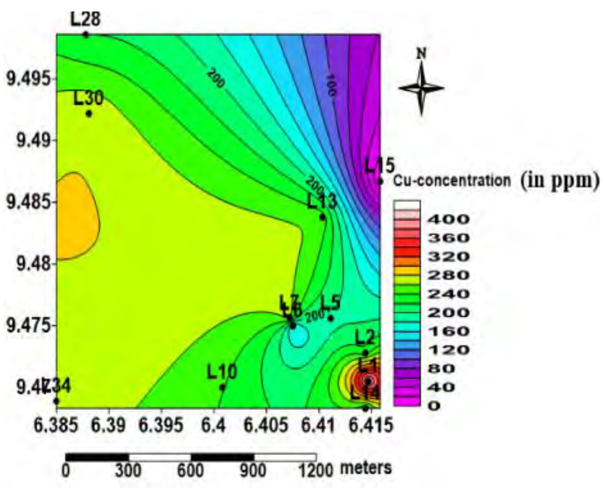


Figure 13: Spatial of Cu Concentration in ppm



indicates that Ni and Co coexist in the eastern part. Co also displays significant concentration in the south eastern part (in the vicinity of L14), which indicates it coexist with Cu as a minor component of Au ore. Figure 12 is the concentration map of sulphur in ppm in the area. There is very high concentration of sulphur (above 36000 ppm) in the vicinity of L13 in the eastern part of the area (longitudes E6.400° to E6.415° and latitudes N9.480° to N9.490°). The very high concentration of Co and Ni in this area suggests that Co and Ni exist as sulphide in the eastern part. Ni is found in mafic igneous rocks. This suggests that mafic igneous rocks might be the protolith of the schist bearing Ni. Figure 13 is the spatial concentration map of Cu in ppm in Garatu. The concentration is above 280 ppm in the west (longitudes E6.385° to E6.39° and latitudes N9.48° to N9.487°) and in the south eastern part. Miners at Gindira mining site in the south eastern part have been mining only Au, unaware of the Cu deposit. The Cu probably coexist with Au as native metals in the south eastern part. It definitely does not exist as sulphides because of absence of sulphur indications in the west and south eastern parts it exists in high concentration.

Table 4 is the summary of the geochemical coexistence of the metals in Garatu. On the outcrops, the minerals exist as fine grains dispersed within rock matrix, pegmatite dykes,

Table 4: Summary of Geochemically Coexisting Ore Metals in Garatu

Location	Longitude	Latitude	Elements
6 and 7	E6.405°	N9.475°	Au, Zn, Ni, Co, Sulphur
10	E6.400°	N9.470°	Au, Zn, Ni
13	E.410°	N9.485°	Ni, Co, Sulphur
14	E6.415°	N9.468°	Au, Zn
28	E6.387°	N9.497°	Au, Zn
30	E6.387°	N9.493°	Cu

Table 5: Geoelectrical Data from the Vicinity of L2 (Longitude E6.415° and Latitude N9.473°)

AB/2	RES	SP	IP
1	385.76	-7.08	0.39
1.5	379.81	-7.086	0.74
2	352.2	-7.071	1
3	308.88	-6.925	1.21
5	330.92	-6.507	1.53
7	360.97	6.097	6.23
10	392.93	18.69	18.69
15	442.13	18.78	18.78
20	526.96	18.79	18.79
25	437.14	18.81	18.81
30	434.07	23.98	18.82
40	454.77	30.34	30.34
50	499.6	30.54	30.54
60	664.5	30.66	30.66
70	710.28	30.69	30.69
80	926.19	30.38	30.38
100	728.65	31.5	31.5

Table 6: Geoelectrical Data from 30 m South of L30 (Longitude E6.389° and Latitude N9.492°)

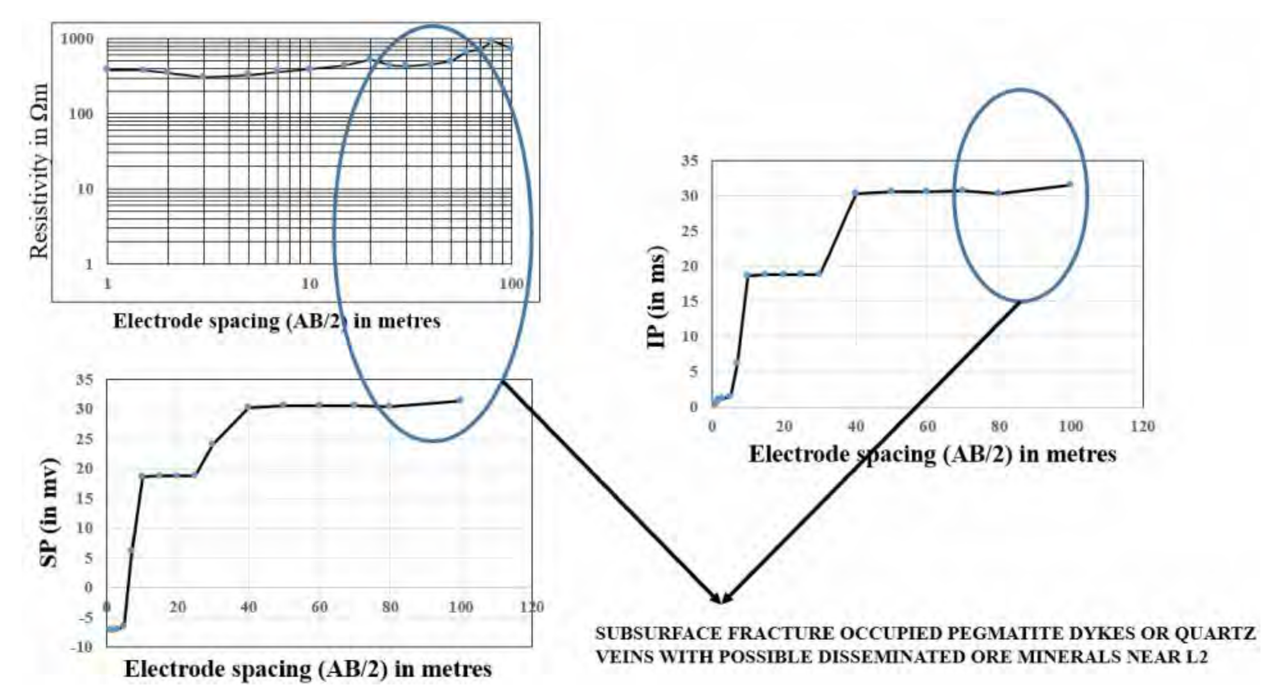
AB/2	RES	SP	IP
1	59.34	-25.49	1.41
2	53.06	-24.18	1.39
3	59.3	-23.75	1.64
4.5	73.62	30.55	1.87
7	109.74	21.79	2.04
10	157.99	19.42	2.35
15	241.47	16.28	2.42
20	433.27	11.92	1.89
30	389.39	36.31	6.45

Table 7: Geoelectrical Data Acquired Near L7 (Longitude E6.405° and Latitude N9.480°)

AB/2 (m)	Resistivity (Ω m)	SP (mv)
1	37.34	82.94
1.5	48.12	85.36
2	52.65	85.72
3	63.1	82.12
7	54.91	61.38
10	52.79	49.43
15	18.69	29.74
20	7.08	31.14
25	91.24	31.02
30	257.1	30.8
40	199.11	53.32
50	109.32	-82.92
60	144.79	-82.13
70	204.49	-82.32
80	273.95	-82.45
100	273.99	-82.65

and quartz veins. Table 5 is the geoelectrical data acquired in the vicinity of L2 (longitude E6.415°

Figure 14: Graphical Illustration of Possible Pegmatite and Quartz Vein Hosteddisseminated Ore Mineral (Indicative Resistivity, SP and IP Values (Longitude E6.145°; Latitude 9.473°)



and latitude N9.473°) near Gindira gold mine in L14. The graphical plot of the data is given as Figure 14. An interval of low resistivity values sandwiched between high resistivity values within 25 to 30 m half current electrode spacing (AB/2) indicates subsurface fracture interval. Similar fracture interval is indicated between 80 to 100 m AB/2. Values of SP are between 20 and 32 mv in these intervals, and thus indicate pegmatite dykes or quartz veins. Values of IP in these intervals are between 18 and 32 ms, which are indications of possible disseminated minerals.

Table 6 is the geoelectrical data acquired within 30 m south of L30 (longitude E 6.389° and latitude N9.492°).

Figure 15 is the graphical plot of the data. The resistivity values indicate presence of subsurface fracture interval between 20 to 30 metres depth. The SP values indicate presence of pegmatite dykes or quartz veins within the interval. Induced plolarisation value of 6.45 ms indicate possible ore minerals within the pegmatite and quartz veins.

Tables 7 and 8 are geoelectrical data acquired near L7 (longitude E 6.405° and latitude N9.480°) and L28 (longitude E 6.387° and latitude N9.497°). The graphical plot of the geoelectrical data from the vicinity of L7 (longitude E 6.405° and latitude N9.480°) is Figure 16. Resistivity and SP values indicate possible subsurface massive ore mineral deposits between 80 and 100 m depth. The

Table 8: Geoelectrical Data Acquired Near L10 (Longitude E6.397° and Latitude N9.470°)

AB/2 (m)	Resistivity (t m)	SP (mv)
1	35.71	-11.92
2	29.33	-10.65
3	13.88	-9.79
4.5	194.06	-0.17
7	19.65	-99.49

Figure 15: Graphical Illustration of Possible Pegmatite and Quartz Vein Hosted Disseminated Ore Mineral Indicative Resistivity, SP and IP Values (Longitude E6.389°; Latitude 9.492°)

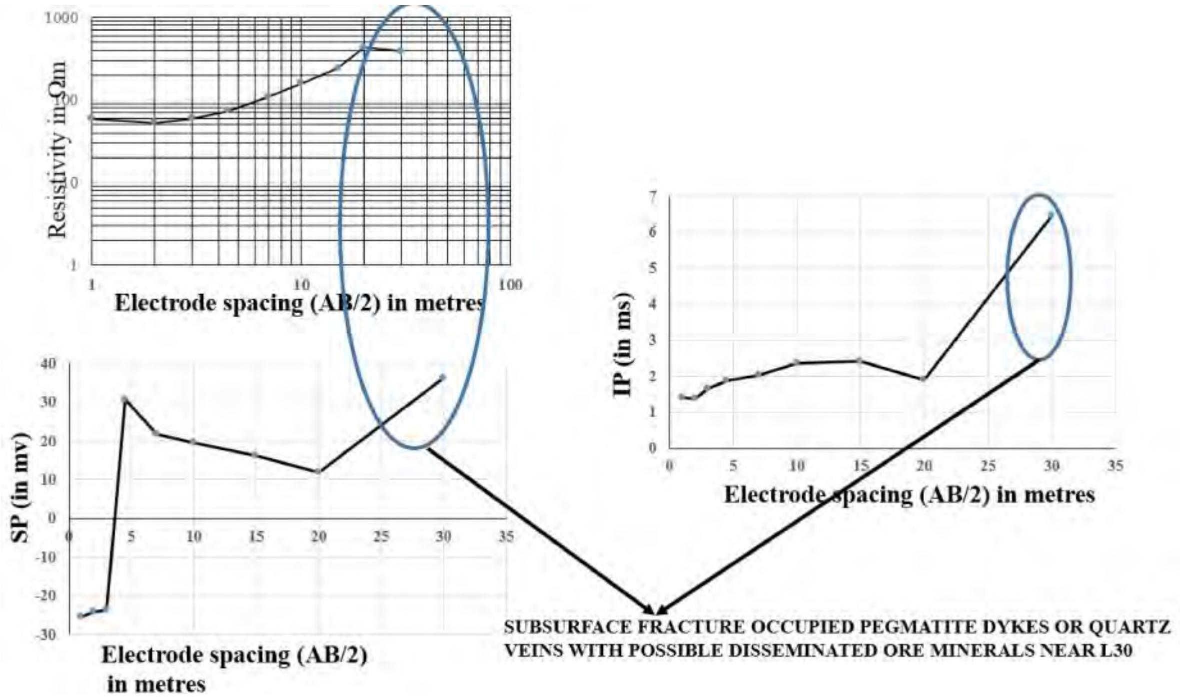


Figure 16: Graphical Illustration of Possible Massive Ore Mineral Indicative Resistivity and SP Values (Longitude E6.405°; Latitude 9.480°) Near L7

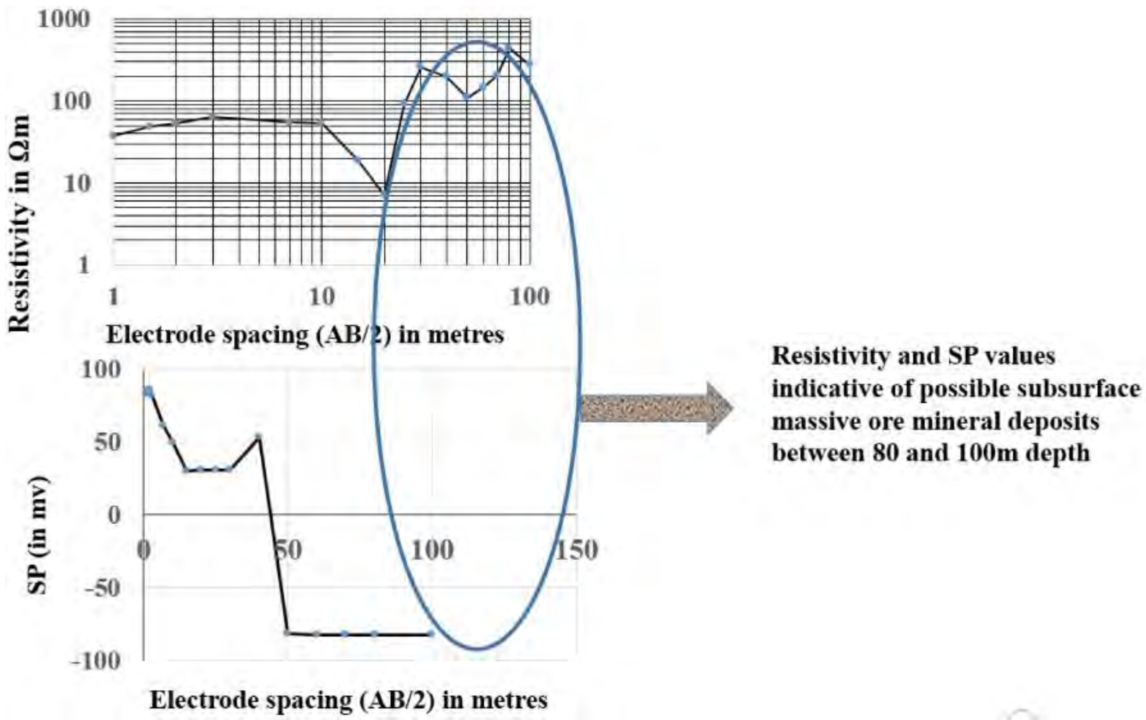
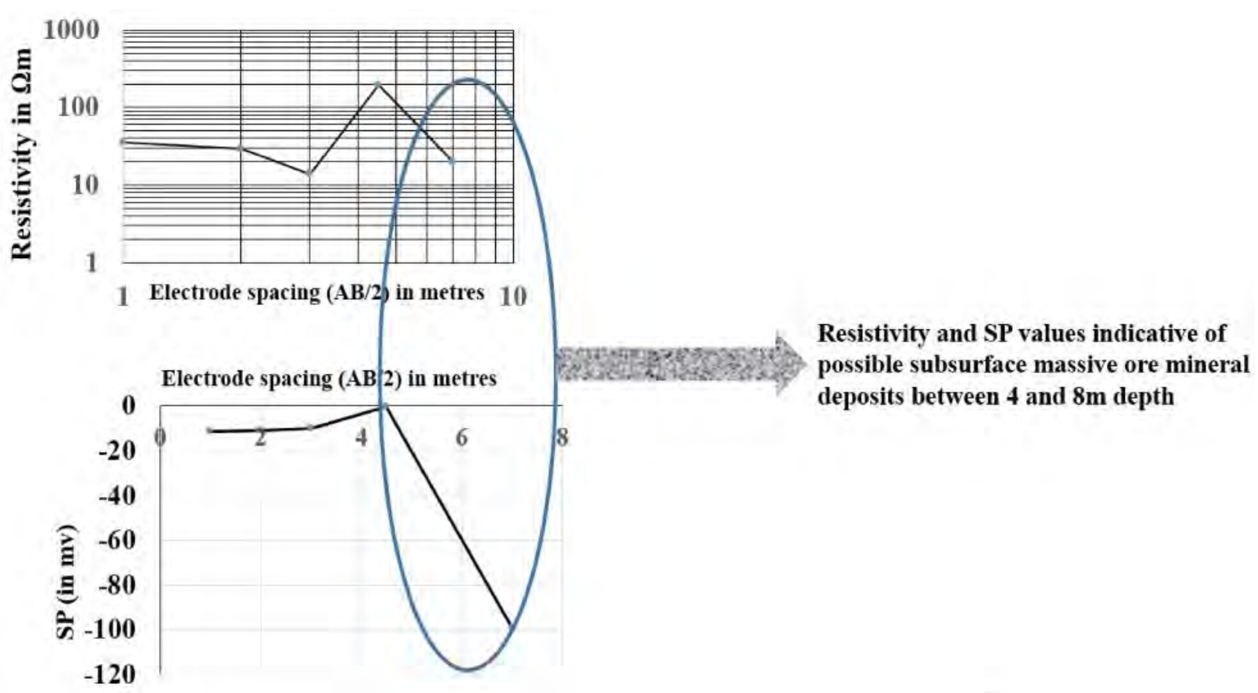


Figure 17: Graphical Illustration of Possible Massive Ore Mineral Indicative Resistivity and SP Values (Longitude E6.397°; Latitude 9.470°) Near L10



geolectrical measurements were discontinued at this location because negative resistivity values were recorded repeatedly after numerous measurement attempts. This could be due to the presence of massive conductive ore minerals in the subsurface. The geoelectrical measurement equipment recorded positive resistivity values at all other locations.

The graphical plot of the geoelectrical data from the vicinity of L10 (longitude E 6.397° and latitude N9.470°) is Figure 17. Resistivity and SP values indicate possible subsurface massive ore mineral deposits between 4 and 8 m depth.

CONCLUSION AND RECOMMENDATION

In the attempt to generate mining prospects outside Gindira Gold Mine in Garatu, dextrally faulted lineaments were identified on hillshade view of the town's GDEM. Surface geological mapping revealed that the lineaments are outcrops of schist and amphibolite, which were intruded by granite and granodorite. Elemental composition analysis of schist and amphibolite samples from igneous intrusions' vicinity, conducted using EDXRF equipment, revealed the presence of gold, nickel, copper, zinc and cobalt in concentrations above their respective economic threshold values. Gold concentration is higher than 600 ppm in northwestern and southeastern investigated parts of Garatu. Gold coexists with copper in concentration higher than 300 ppm in the southeastern part. Nickel coexists with gold, zinc, and cobalt in concentration higher than 400 ppm between longitudes E6.400° to E6.410° latitudes N9.468° to N9.477°. Sulphur, cobalt and nickel respectively exist in concentration higher than 30,000 ppm, 700 ppm, and 400 ppm in the eastern part. This is an indication that cobalt and nickel exists as sulphides in the east. The minerals are generally disseminated as grains invisible to the unaided eye within the rock matrix, pegmatite and quartz veins. Occurrence of disseminated ore minerals in subsurface pegmatite and quartz veins is indicated by the coincidence of IP values between 18 and 32 ms with SP values between 20 and 32 mv within low resistivity interval. The coincidence of disseminated ore minerals indicative geoelectrical values occurred at half electrode spacing from 25 to 30 m at (1) longitude E6.415° and latitude N9.473° and (2) longitude E6.405° and latitude N9.470°.

Probable subsurface massive ore minerals were indicated by $\geq$ -80 mv SP values within low resistivity (109 to 199 Ωm) interval from half current electrode spacing of 30 to 50 m, at longitude E6.377° and latitude N9.470°. Subsurface massive ore minerals were also indicated by -90 mv SP value associated with low resistivity (19.65 Ωm) interval at 7 m half electrode spacing, at longitude E6.397° and latitude N9.470°. The combination of elemental composition and geoelectrical data enabled the generation of two main prospects at locations (1) longitudes E6.400° and E6.410° to latitudes N9.468° and N9.470°; and (2) longitudes E6.400° and E6.415° to latitudes N9.480° and N9.495°.

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