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Mineralization and Exploration Perspectives in the Oudiane Elkharoub Zone, Birimian Domain, Reguibat Shield, Mauritania

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Abstract

The Oudiane Elkharoub Zone is one of the major areas of the Reguibat Shield due to its position in the extreme northeast of the Birimian formation (dated between 1.6 and 2.7 Ga) within the Reguibat Shield, coupled with its closeness to with the Archean Domain in the Shield's southern portion and with the Taoudeni Basin to the east. The results of field mapping, together with chemical (Fire Assay) and XRF (fluorescence spectrometer X-ray) analyses, shows significant Au, Ag, Cu, Pb, Mn, Cr, Ni, Th and Y anomalies in samples taken from the Oudiane Elkharoub Zone. The results of those analyses will allow us to build a geochemistry maps for the anomalous metal for the study area, understand the relationships between different rock units and the mineralization and the mineralization control and their style, such as structural or lithological control. This context reflects a structural control of the Mineralization according to the conducted analyses and the observation on the field. The mineralization auriferous mainly hosted in quartz vein or quartz-carbonate vein with sulfide (pyrrhotite and pyrite) alteration.

Keywords

Oudiane Elkharoub, Reguibat Shield, Birimian, Anomalies, Mineralization, XRF, Fire Assay

1. Introduction

The West African Craton is subdivided into three distinct domains (Figure 1), [1] [2] [3] [4]. 1) In the north the Reguibat Shield outcropping in Mauritania, Algeria, and Morocco, constituted by Archean formations (3.0 - 2.7 Ga) and Paleoproterozoic (~2 Ga). 2) In the South the Man or Leo Shield formed by the Archean series of the Liberian Shield and the Paleoproterozoic formation of the Baoule-Mossi Domain covering Ghana, Ivory Coast, Guinea, southern Mali, Burkina Faso, western Niger, these Paleoproterozoic formations are generally referred to as Birimian. 3). In an intermediate position between the two dorsal, two buttonholes, the Kayes buttonholes in western Mali and the Kedougou Buttnhole located on either side of the border Senegales-Malian, these buttonholes are formed exclusively by Birimian series.

There are five principal geological entities within the borders of Mauritania (**Figure 2**). One of these, the Reguibat Shield, is located to the north of the country. It hosts Archean and Paleoproterozoic metamorphic sequences and granites that form the northwestern limit of the West African Craton (WAC) [7] [8]. Further to the south, the Craton's margins coincide with the Mauritanide Belt (**Figure 2**), a Hercynian tectonic belt consisting of Neoproterozoic and Paleozoic metamorphosed sediments and volcanoclastic formations, including

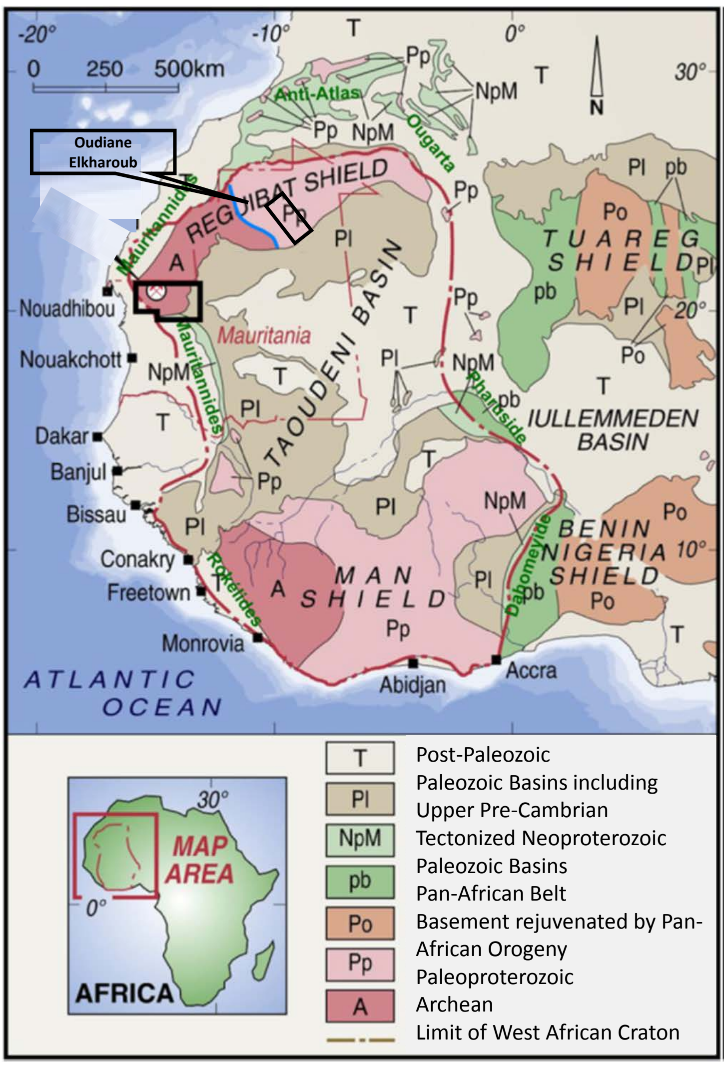


Figure 1. Geology of the West African Craton. Modified from [5] [6].

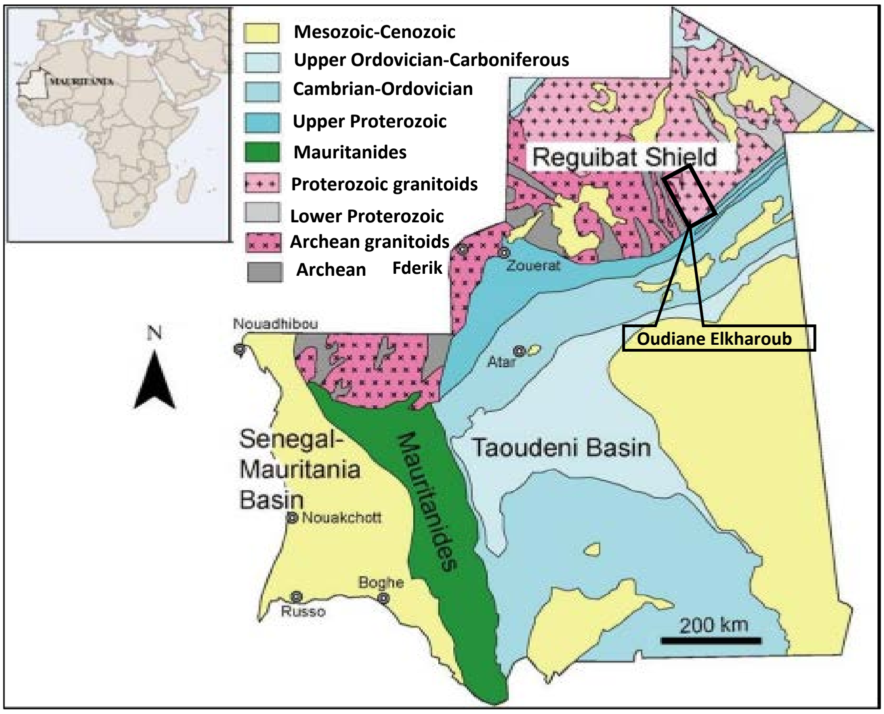


Figure 2. Mauritania's geological map.

parts of the underlying basement [9]. To the east of the Mauritanide Belt lies the vast Mesoproterozoic [10] to-Paleozoic Taoudeni Basin. Finally, to the west lies the northern limit of Mauritania-Senegal-Gambia-Conakry basin, a Mesozoic-Cenozoic continental margin-type basin that overlies a Paleozoic (and probably Archean) basement.

Mauritania is a significant source for gold, iron and copper ores in Africa continent. It was the second-highest ranked exporter and producer of iron in Africa in 2012, being preceded only by South Africa. In addition to iron, Mauritania also produces cement, copper, crude oil, gaz, gold, gypsum, quartz, salt and steel [11].

The Birimian terrains (2156 ± 10 to 2067 ± 12 Ma) of the West Africa Craton are one of enormous interest, both for their fundamental potential in terms of geological research and in terms of mining. Indeed, they are some of the oldest lands in the Craton, and are affected by important orogenies. The Birimian rocks host many gold deposits and occurrences of the West Africa Craton. They were formed and accreted during the Eburnean orogenic cycle, which took place between 2.25 Ga and 1.80 Ga. The Birimian hosts some of the main types of such deposits in West Africa Craton, and these are directly associated with granitic plutons. This type of environment is, in turn, the supplier of relevant metals such as Au, Ag, Pb and Zn, which are associated with many types of deposits (copper porphyries, perigranitic veins, skarns, etc.). As such, they are major economic targets. In addition, perigranitic deposits contain gold, which has become the subject of abundant and extensive geological discussion, leading to varied and novel terminologies. The Mauritanian Birimian terrains are, however, yet to be properly known.

The study Zone is located in the Gallaman in the central part of Reguibat Shield (**Figure 3**), which has been stable since about 1700 Ma [1] and dominates the north third of Mauritania's geological surface. This choice is based on the fact that despite the scare amount of research on the study zone, as a part of Reguibat Shield, the Oudiane Elkharoub Zone has the same characteristics as the lager area it constitutes, possessing many precious and base metals. The objective is to figure out the anomalies for precious and base metals and define the type of mineralization (Auriferous, Polymetallic etc.). This work contributes on the one side to a better understanding and planning of subsequent research activities and exploration, on the side to improvement of geological knowledge on Oudiane Elkharoub Zone which presents all the specificity to host all type of mineralization.

2. Geological Overview of the Oudiane Elkharoub Zone

As mentioned above, the Oudiane Elkharoub Zone is in the so-called Ghallaman Group, in the central part of the Reguibat Shield (**Figure 3**). Rocci [1] has described the occurrences of leptynite, pyroxene gneisses (a diopside gneiss and diospide + hyperstene gneiss) and amphibolite, as well as much rarer outcrops of cipolins and two-mica gneisses.

According to [1] [12] [13] [14], the Temmimichate Group differs from the Ghallaman Group given the omnipresence of granulitic gneiss. The author indicates that the sebkhat of Ghallaman Group correspond to all outcrop of metamorphic rocks located to the east of large sebkhas of the same name within it. Rocci note the presence of the following: two meca gneisses, amphibolite, pyroxene gneiss and leptynite. The group of sebkhas at the Oudiane Elkharoub Zone emerges in series of sumeridian depressions that converge in their descension from the Alous Tmar hills. For [1] [15], they differ very clearly from the previous sabkhas due to the great homogeneity of the facies that compose them, as well as to the existence of aluminous-to-hyperaluminous gneisses. The observation on field mapping coupled with the local geophysical map show a geological and structural complexity in the study zone (**Figure 4**) that reinforces its significance to be an interesting zone to hosting the mineralization. Moreover, its location is particularly special, seen, as it is set between two batholiths with different age: to the west, it is the tmemeimichat Ghallaman granitoid (dated 2150 - 2100 Ma) and to the east the Yetti granitoids (dated 2050 - 1995 Ma) [16]. All these geological and structural complexity make a good argument for the discovery of large deposits in Oudiane Elkharoub zone.

3. Material and Methods

The Oudiane Elkharoub Zone (location coordinate: 542,250, 2,611,070) is located within the central eastern part of Reguibat Shield, in the administrative region (Willaya) of Tiriss Zemmour 450 km to the northeast of an Iron deposit (Kediat Ijil, exploiting by National Industrial and Mining Company, (SNIM) in the city of Zeouarat, northern Mauritania (**Figure 5**).

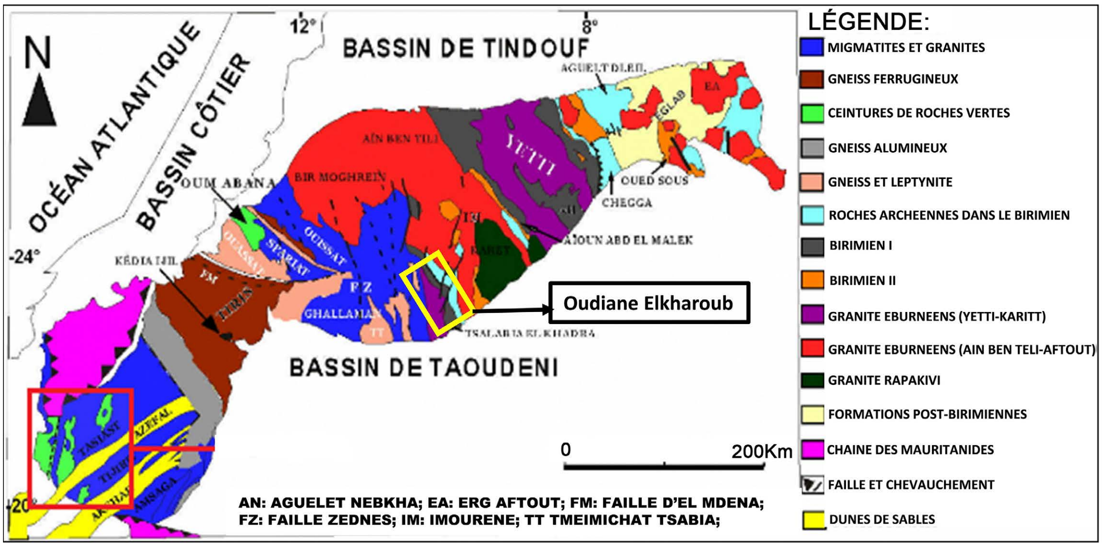


Figure 3. Reguibat Shield lithostratigraphic Units modified after [17].

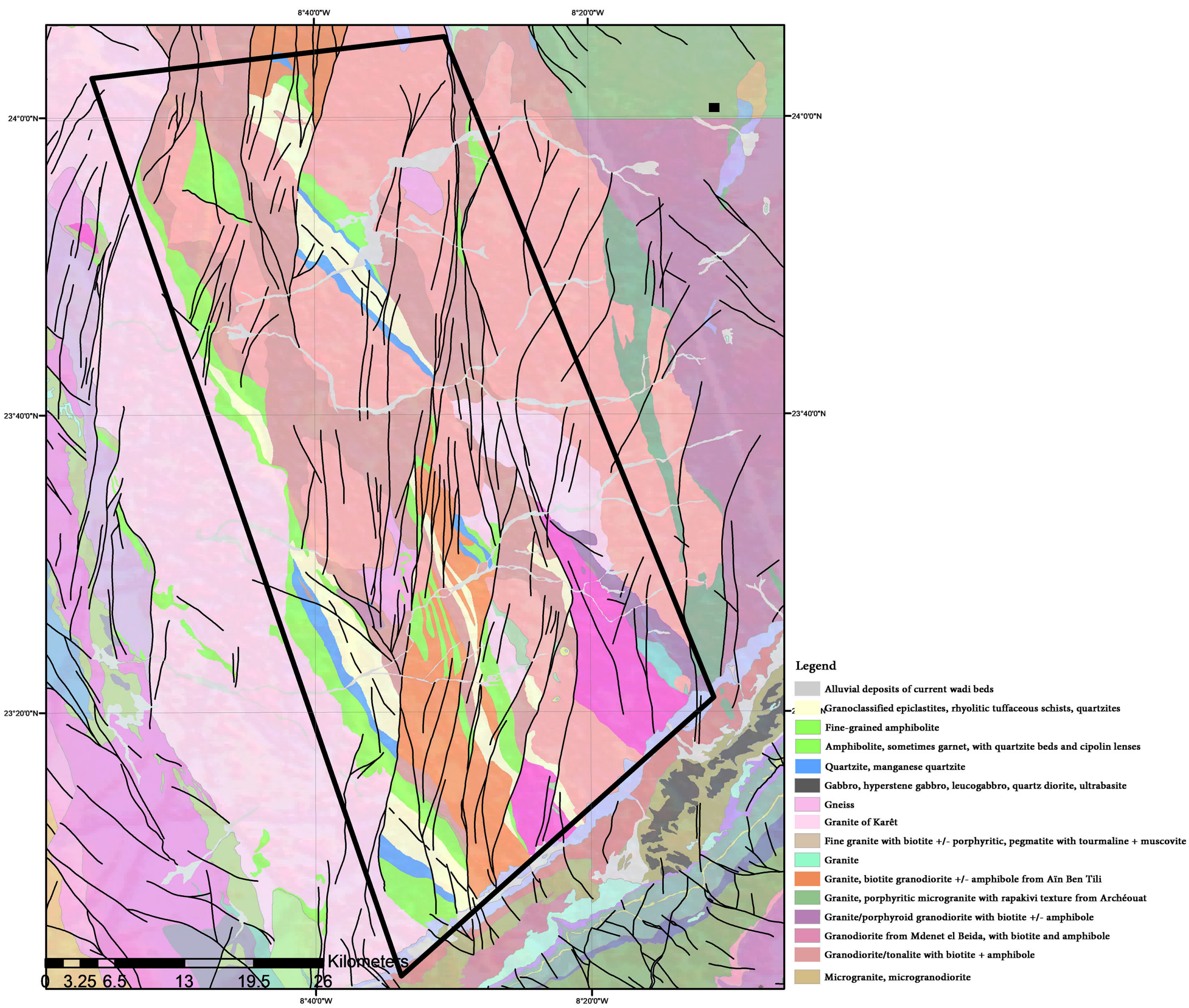


Figure 4. Geological and structural map of Oudine Elkharoub after [13] [14] [15] [16].

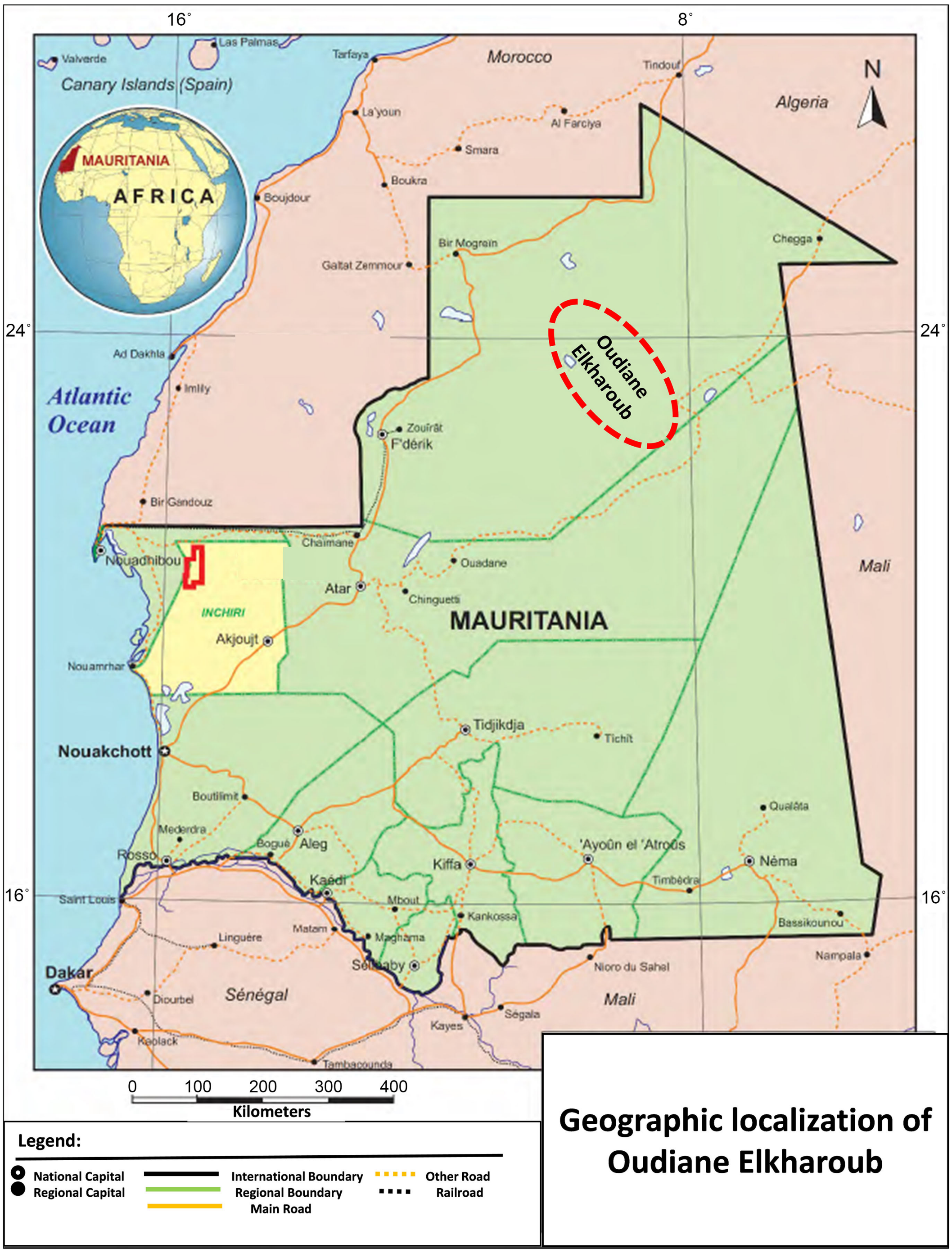


Figure 5. Placement of Oudiane Elkharoub.

Several comparisons between mapping and sampling were carried out during the study. The purpose of this juxtaposition was to conduct a metallogenic study of area, discover anomalies, and generate a new geological map based on field mapping, control and mineralization (precious and base metals…) style as well as on the relationships between host rocks and the mineralization themselves.

A total number of 66 samples were collected from various outcrops in the field (**Figure 6**). Sixteen samples were analyzed at the MSALABS (is a Global company

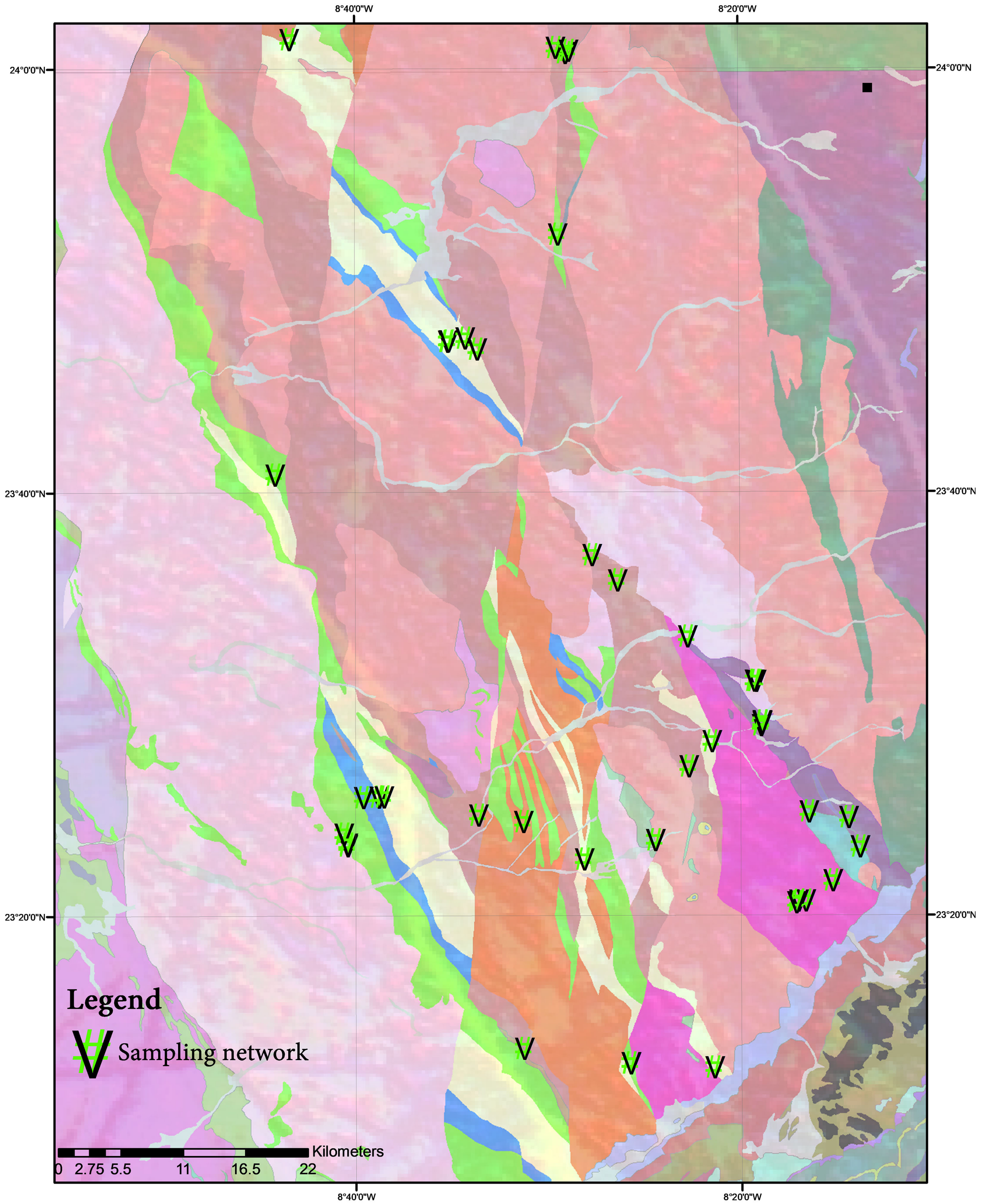


Figure 6. Samples localization in Oudiane Elkharoub.

providing analytical services to the mining industry, with advanced instrumentation, and an experienced team with a client-focused approach, MS Analytical provides full-service solution, from early stage of exploration to the projects, that have advanced to the process development stage), who employed the Fire as their standard analytical method for gold detection, (According the MSALABS, Fire assay method is to quantitatively determine the content of precious metals by adding flux to smelt ores and metallurgical products. This method has the advantages of good sampling representativeness, wide applicability, and good enrichment effect. It is an important means for the chemical analysis of gold and precious metals). A Fluorescence Spectrometer X-ray was utilized to analyze all samples at the National Agency of Geological Research and Mining Heritage in Mauritania. The interpretation of the geological map, in turn, employed software such as Argis and QGIS. While ioGAS and Microsft Excel were used to shed, light on the results and build anomaly maps and graphs.

4. Results

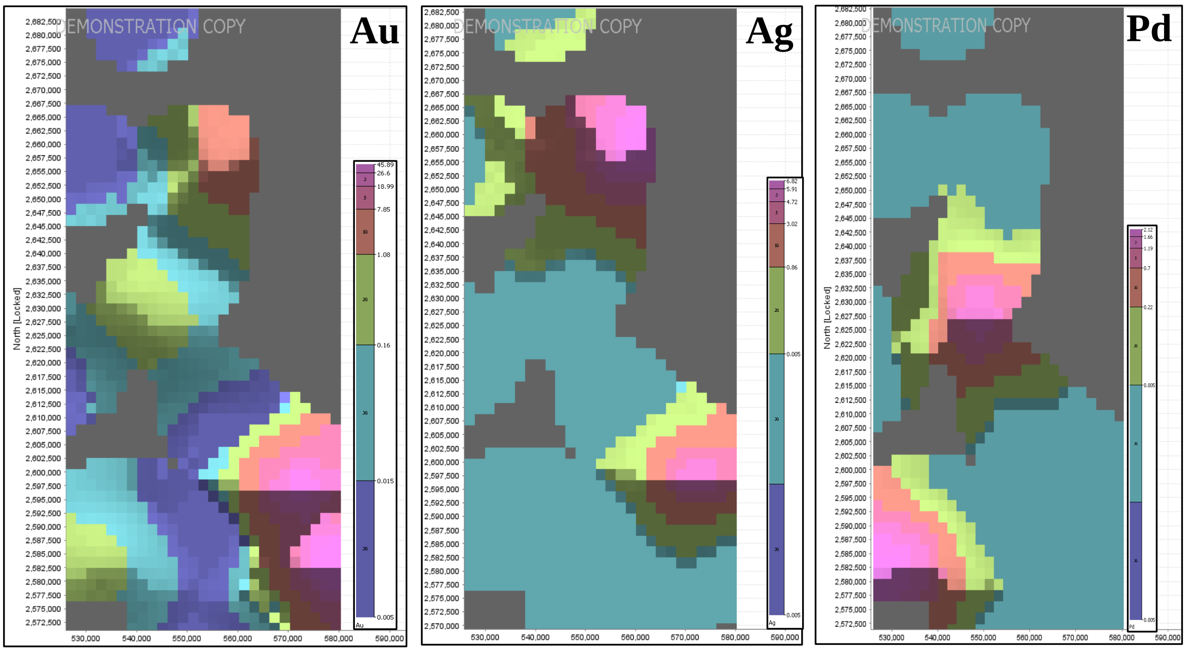
The analytical results **Table 1**, together with on-site observations, indicate samples to have anomalies for certain precious (Au, Ag and Pd) and base (Cu, Zn and Pb) metals and Mn, Cr, Ni, Th and Y. gold ranges from 0.13 ppm to 117.52 ppm, silver between 2.54 ppm to 11.85 ppm and palladium, between 1.67 ppm to 2.12 ppm (**Figure 7**). As for the base metals (Cu, Zn and Pb), copper ranges from 100 ppm to 1709 ppm; Zinc from 3.97 ppm to 228 ppm; and lead , from 2.5 ppm to 83.74 ppm (**Figure 8**). In the case of case of chromium and nickel, these vary respectively, between 10 ppm - 1085.70 ppm and 8.5 ppm - 432.54 ppm. Manganese highly anomalous reaches 2417.48 ppm (**Figure 9**). Thorium ranged between 1.17 ppm to 12.92 ppm, Yttrium ranged between 1 ppm to 34 ppm and finally Arsenic ranged between 10.29 ppm to 240.67 ppm.

Table 1. Samples results.

Sample ID	Ag	Au	Cr	Cu	Mn	Ni	Pb	Th	Y	Zn
OE10	0.005	1.36	27.5232	45.4393	270.9986	0.005	0.005	0.005	1.4684	0.005
OE10-ENCAI	0.005	0.005	29.8433	243.3325	2289.013	61.2951	5.297	0.005	15.401	13.7923
OE14	6.9057	2.25	79.5303	693.3807	62.2939	0.005	83.7474	0.005	0.005	90.1214
OE14-ENCAI	0.005	0.005	42.7951	136.41	717.8161	50.6571	13.2393	0.005	8.1859	97.7388
OE16	0.005	0.36	26.1641	34.4989	0.005	0.005	0.005	0.005	0.005	0.005
OE17	0.005	0.2	24.2802	30.3441	0.005	12.6625	0.005	3.3803	0.005	0.005
OE33	0.005	2.57	0.005	1709.96	23.1477	28.5918	0.005	0.005	0.005	12.8733
OE37	0.005	4.38	67.0601	186.1111	121.0175	14.6781	68.9216	0.005	1.9738	5.7495
OE42	0.005	61.14	36.3294	46.0599	84.5639	0.005	9.3708	0.005	0.005	3.9714
OE42-ENCAI	0.005	0.06	20.0856	100.5458	589.2131	80.0113	10.0801	0.005	9.8413	61.2381
OE50	0.005	117.52	25.2439	55.6692	109.2389	63.6598	5.5701	0.005	0.005	0.005
OE50-ENCAI	0.005	0.13	344.0486	162.8941	1124.211	137.6787	6.7345	0.005	11.9574	78.8173
OE59	0.005	0.23	24.7122	33.584	81.2043	37.151	0.005	0.005	0.005	0.005

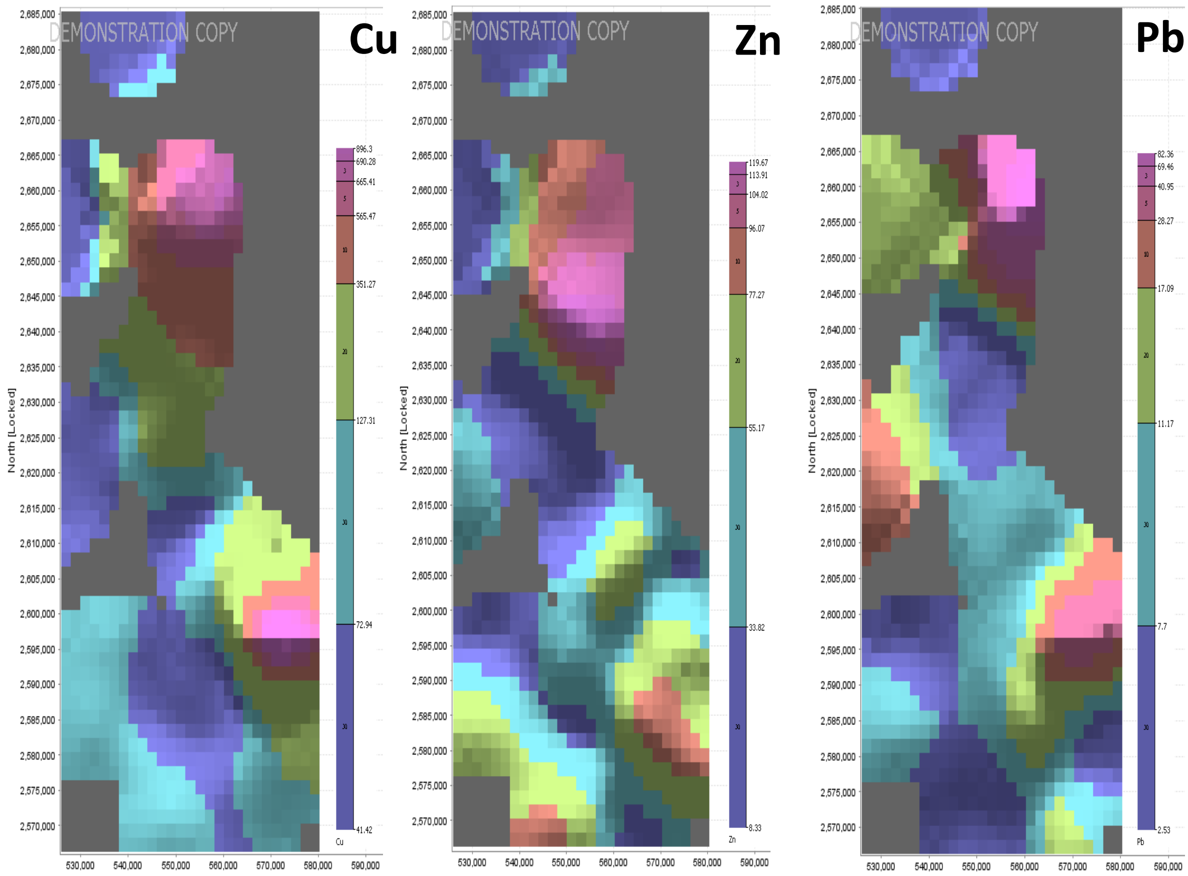
Continued

OE67	0.005	0.07	42.6882	170.845	2017.725	84.1828	8.9452	0.005	24.8859	24.5165
OE69	0.005	0.08	71.799	106.7663	225.5692	17.8532	6.4563	0.005	0.005	0.005
OE84	0.005	0.29	32.6693	41.5728	0.005	0.005	0.005	0.005	0.005	0.005
OE85	0.005	0.03	29.5044	36.5425	0.005	9.1358	3.232	2.9876	0.005	0.005
OE85-ENCAI	0.005	0.005	15.2419	36.602	20.4062	21.6565	10.4831	1.1722	0.005	24.57
OE88	0.005	0.05	45.474	86.1969	0.005	14.9155	5.7983	0.005	0.005	0.005
OE88 ENCAI	0.005	0.005	15.0622	107.6978	0.005	8.5285	0.005	0.005	0.005	0.005
S2	0.005	0.005	42.1432	41.4182	268.5283	0.005	16.1651	9.0472	21.04	21.8492
S3	0.005	0.005	348.4071	382.1282	1203.73	380.0439	5.4634	0.005	32.9017	122.0528
S11	0.005	0.005	26.2083	70.9306	122.888	16.7247	9.4631	0.005	1.1411	11.756
S18	0.005	0.005	35.3379	45.7626	129.7779	16.0023	4.5424	0.005	1.366	31.3163
S19	0.005	0.005	16.7348	43.4087	159.8886	0.005	21.7739	3.5066	3.5778	44.3161
S21	2.5487	0.005	88.3431	652.3611	946.8886	126.8275	9.5173	0.005	13.3466	93.3718
S24	0.005	0.005	0.005	41.7771	121.383	0.005	8.4757	0.005	2.3524	6.7348
S25	0.005	0.005	27.7253	82.9174	882.0612	48.7866	10.0108	1.7318	18.0823	78.4237
S27	0.005	0.005	71.0692	262.287	1271.09	104.4279	5.7605	0.005	5.5711	77.8351
S30	0.005	0.005	27.5148	53.7788	116.9871	0.005	13.7157	0.005	5.023	10.4074
S32	0.005	0.005	22.7311	42.3792	39.0403	0.005	17.0176	1.3929	12.6144	3.5143
S40	0.005	0.005	25.7538	85.7577	669.8025	56.5737	4.097	0.005	10.7144	89.7479
S46	0.005	0.005	142.7775	175.4171	1029.913	87.4817	7.6923	0.005	15.1985	92.1908
S53	0.005	0.005	63.9121	133.3731	1202.809	55.8193	5.1204	0.005	16.3386	90.0671
S57	0.005	0.005	19.0676	35.7888	136.7717	0.005	4.6777	1.7015	4.3825	24.2372
S75	0.005	0.005	68.6401	76.497	127.4254	29.8168	15.1934	10.1541	20.8665	18.7354
S76	0.005	0.005	1085.702	56.7375	254.2213	41.7168	2.8037	0.005	3.9246	40.2565
S77	0.005	0.005	11.5115	36.0054	214.1969	0.005	4.3905	0.005	11.7756	11.4359
S79	0.005	0.005	335.2001	114.6356	637.128	238.554	2.516	0.005	16.2511	81.8734
S83	0.005	0.005	141.4274	126.4468	144.0971	107.9857	2.7642	0.005	34.0036	75.9766
S89	0.005	0.005	11.3329	39.2687	0.005	0.005	0.005	0.005	0.005	0.005
S90	0.005	0.005	586.2482	100.8001	421.9692	230.1904	4.8931	0.005	4.3846	33.595
S93	0.005	0.005	10.5829	28.155	213.0948	15.2961	7.3607	4.0562	26.3558	21.9085
S94	0.005	0.005	431.2798	87.9362	2417.483	432.5457	9.3515	0.005	10.6815	75.9188
S96	0.005	0.005	18.2151	35.6214	62.8036	0.005	7.9058	2.8495	2.6944	8.7834
S102	0.005	0.005	46.4182	45.176	494.2766	9.0456	16.3096	7.0386	23.8888	92.4399
S104	0.005	0.005	59.3047	45.9952	428.0808	23.9622	10.2186	5.0261	13.5669	34.9142
S105	0.005	0.005	44.6562	44.4372	127.7386	16.606	11.1934	12.9268	45.032	41.9123
S109	0.005	0.005	26.0468	37.5626	55.0815	0.005	4.21	0.005	1.0507	4.1171
SHR-ENC	0.005	0.005	11.2415	84.6211	1408.735	103.9474	32.2086	0.005	7.4726	228.0789
SHR-QVN	11.8568	11.319	17.0128	27.2315	0.005	0.005	0.005	0.005	0.005	0.005



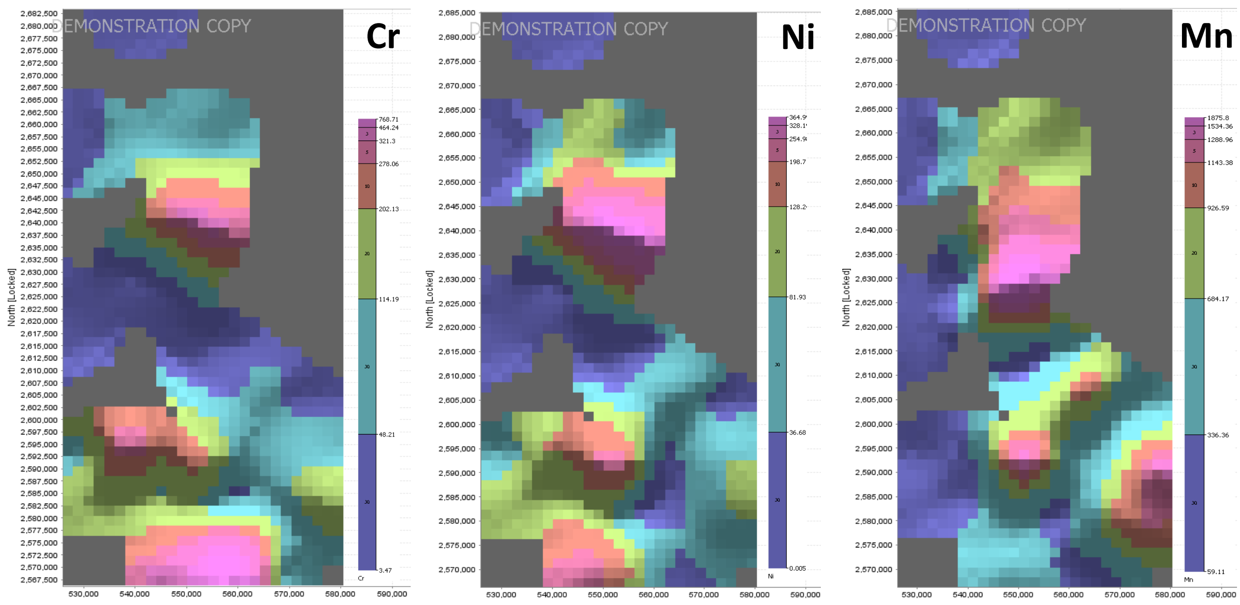
(a) (b) (c)

Figure 7. Map showing the anomalies: [(a) gold, (b) silver and (c) palladium].



(a) (b) (c)

Figure 8. Maps showing the anomalies: [(a) copper, (b) zinc and (c) lead].



(a) (b) (c)

Figure 9. Maps showing the anomalies: [(a) chromium, (b) nickel and (c) manganese].

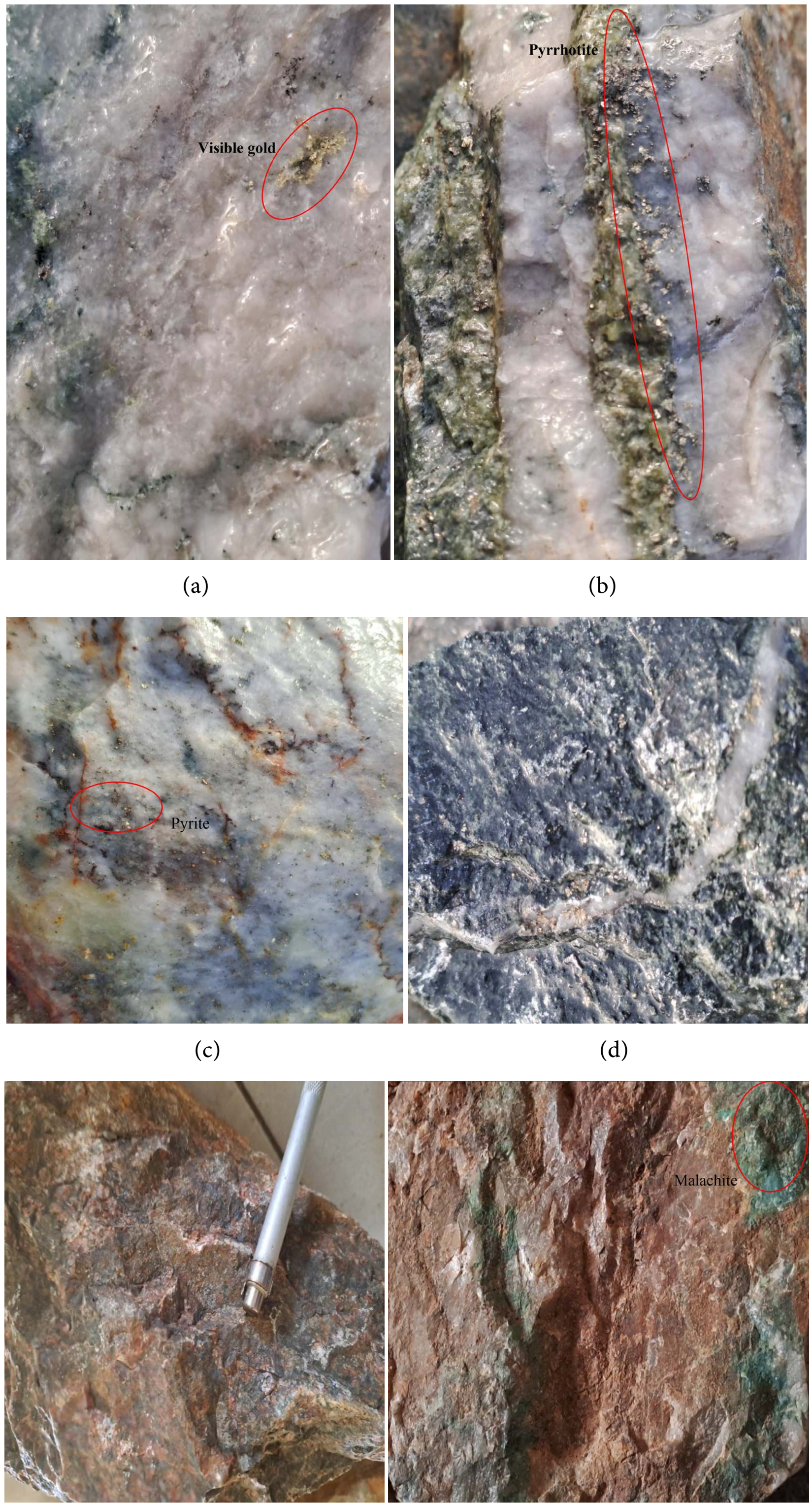
All these values represent very important targets for the exploration of Au, Ag, Pd, Cu, Zn, Pb, Mn, Ni, Cr, Y, and thorium in Oudiane Elkharoub.

The results show that among all samples, those with spatial correlations between gold, silver, copper, zinc and lead are OE14 and OE42 Table 1. The positive results of precious and base metals cans be explained by the intense level of alteration for sulfides in the samples (Figures 10(a)-(f)), which are also clearly visible one the field, seen in the outcropping rocks, thus enabling the observation of gold in the existing quartz veins (Figure 10(a)).

On-site observation also indicated there are two generations of quartz veins the first is parallel with the foliation of host rocks, whilst the second intersects the host rocks foliation, both host mineralization. The chemical analysis of the host rock was only undertaken for gold and did not show any anomalies occurring within, only inside the quartz veins with sulfide alteration (mainly Pyrrhotite, pyrite) and tourmaline that control the mineralization of god inside the shearing zone.

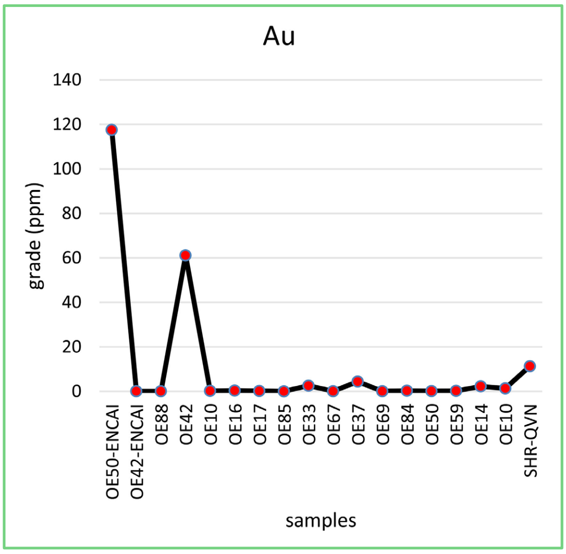
The Chromium anomalies are associated with mafic rocks, especially amphibolite, while the anomalies of manganese are associated with quartzite and gabbro; there are a good spatial correlation between gold and manganese especially in the sample OE10 (quartzite). Good spatial correlation between Nickel, Manganese, copper, yttrium, lead and Chromium in the sample S94 (Gabbro).

Noteworthy is the spatial correlation between gold anomalies and silver, copper, zinc, manganese and lead (Figures 11(a)-(j)) that possess a higher anomaly. According to on-site observation and both chemical and XRF analyses, we can affirm that the presence of polymetallic mineralization in Oudiane Elkharoub Zone is a common occurrence.

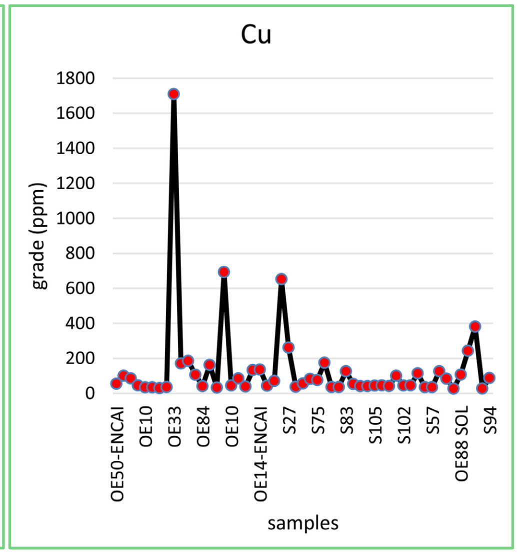


(a) (b) (c) (d) (e) (f)

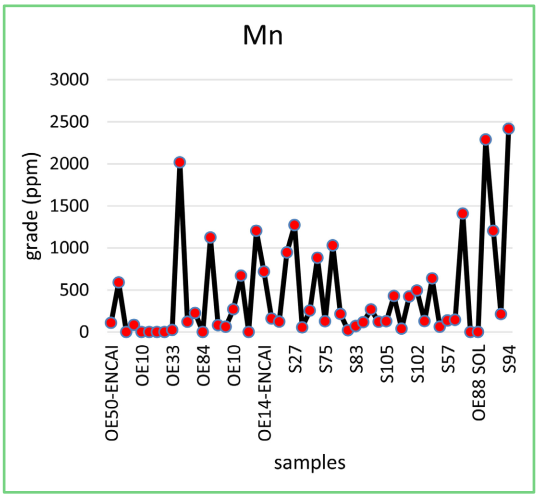
Figure 10. (a). Quartz vein with visible gold, pyrrhotite and pyrite from field. (b). Quartz vein with Pyrite and pyrrhotite from the field. (c). Quartz vein with Pyrite, pyrrhotite and iron oxide from the field. (d). amphibolite with sulfide and host quartz veinulle. (e). Quartz vein with and iron oxide from the field. (f). Quartz vein with sulfide and malachite from field.


Au
140
120
100
80
60
40
20
0
grade (ppm)
OE50-ENCAI
OE42-ENCAI
OE88
OE42
OE10
OE16
OE17
OE85
OE33
OE67
OE37
OE69
OE84
OE50
OE59
OE14
OE10
SHR-QVN
samples

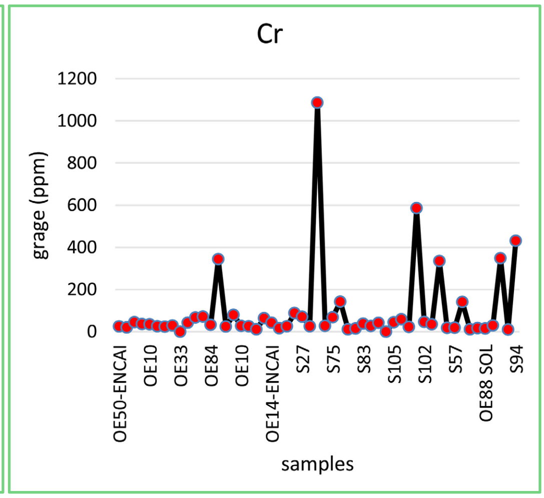
(a)


Cu
1800
1600
1400
1200
1000
800
600
400
200
0
grade (ppm)
OE50-ENCAI
OE10
OE33
OE84
OE10
OE14-ENCAI
S27
S75
S83
S105
S102
S57
OE88 SOL
S94
samples

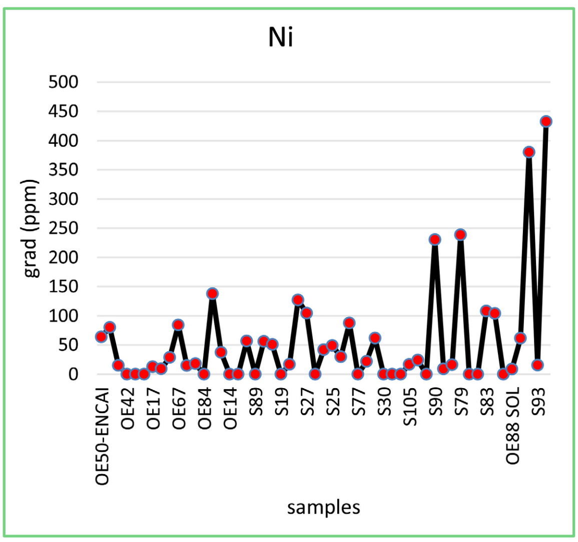
(b)


Mn
3000
2500
2000
1500
1000
500
0
grade (ppm)
OE50-ENCAI
OE10
OE33
OE84
OE10
OE14-ENCAI
S27
S75
S83
S105
S102
S57
OE88 SOL
S94
samples

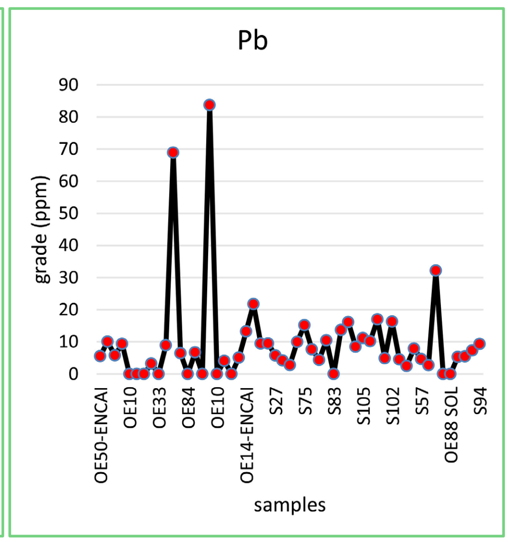
(c)


Cr
1200
1000
800
600
400
200
0
grage (ppm)
OE50-ENCAI
OE10
OE33
OE84
OE10
OE14-ENCAI
S27
S75
S83
S105
S102
S57
OE88 SOL
S94
samples

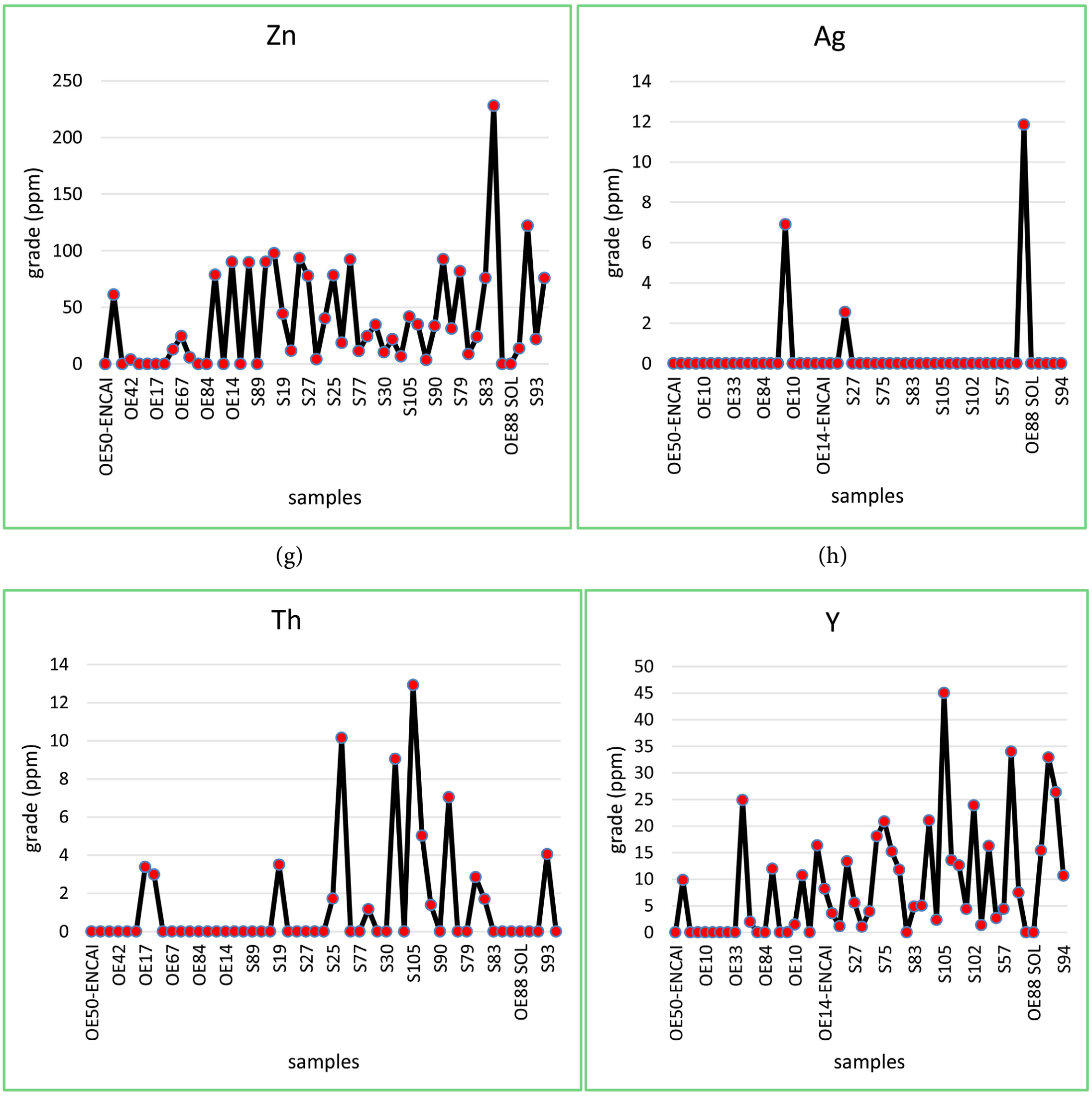
(d)


Ni
500
450
400
350
300
250
200
150
100
50
0
grad (ppm)
OE50-ENCAI
OE42
OE17
OE67
OE84
OE14
S89
S19
S27
S25
S77
S30
S105
S90
S79
S83
OE88 SOL
S93
samples

(e)


Pb
90
80
70
60
50
40
30
20
10
0
grade (ppm)
OE50-ENCAI
OE10
OE33
OE84
OE10
OE14-ENCAI
S27
S75
S83
S105
S102
S57
OE88 SOL
S94
samples

(f)



(i) (j)

Figure 11. (a). Au spatial distribution in the all samples. (b). Cu spatial distribution in the all samples. (c). Mn spatial distribution in all samples. (d). Cr spatial distribution in the all samples. (e). Ni spatial distribution in all samples. (f). Pb spatial distribution in the all samples. (g). Zn spatial distribution in the all samples. (h). Ag spatial distribution in the all samples. (i). Th spatial distribution in the all samples. (j). Y spatial distribution in the all samples.

The compilation of the geological, geophysical, both chemical and XRF analyses and the interpretation of field mappings showed that the existing mineralization is controlled by the structure (shear zone) that intersects the different lithology, indeed, hydrothermal fluids would use the shear zone along with faults and fractures as pathways for their circulation and for the mineralization's precipitation. However, the current stage in our model's implementation requires more investment and further prospection work.

5. Discussion

The comparison between the southern and northern portions of the Birimian formation in the West African Craton points to a few important factors. There is a significant spatial distribution of deposits in the southern Birimian part; the Paleoproterozoic terrane to the south of the West African Craton (**Figure 12**) is intensely mineralized in various economically important commodities and therefore must be described in further detail. The terrane consists of the Baoule-Mossi domain [2], the Kedougou-Kenieba. As well as Kayes and Anosongo inliers, comprising relicts of Archean rocks set in a granite-greenstone terrane. Such domains are composed of Paleoproterozoic volcano-sedimentary sequences that underwent reworking during the Eburnean Orogeny [18] [19]. The basement rocks contain linear, volcano-sedimentary and volcano-plutonic greenstone belts.

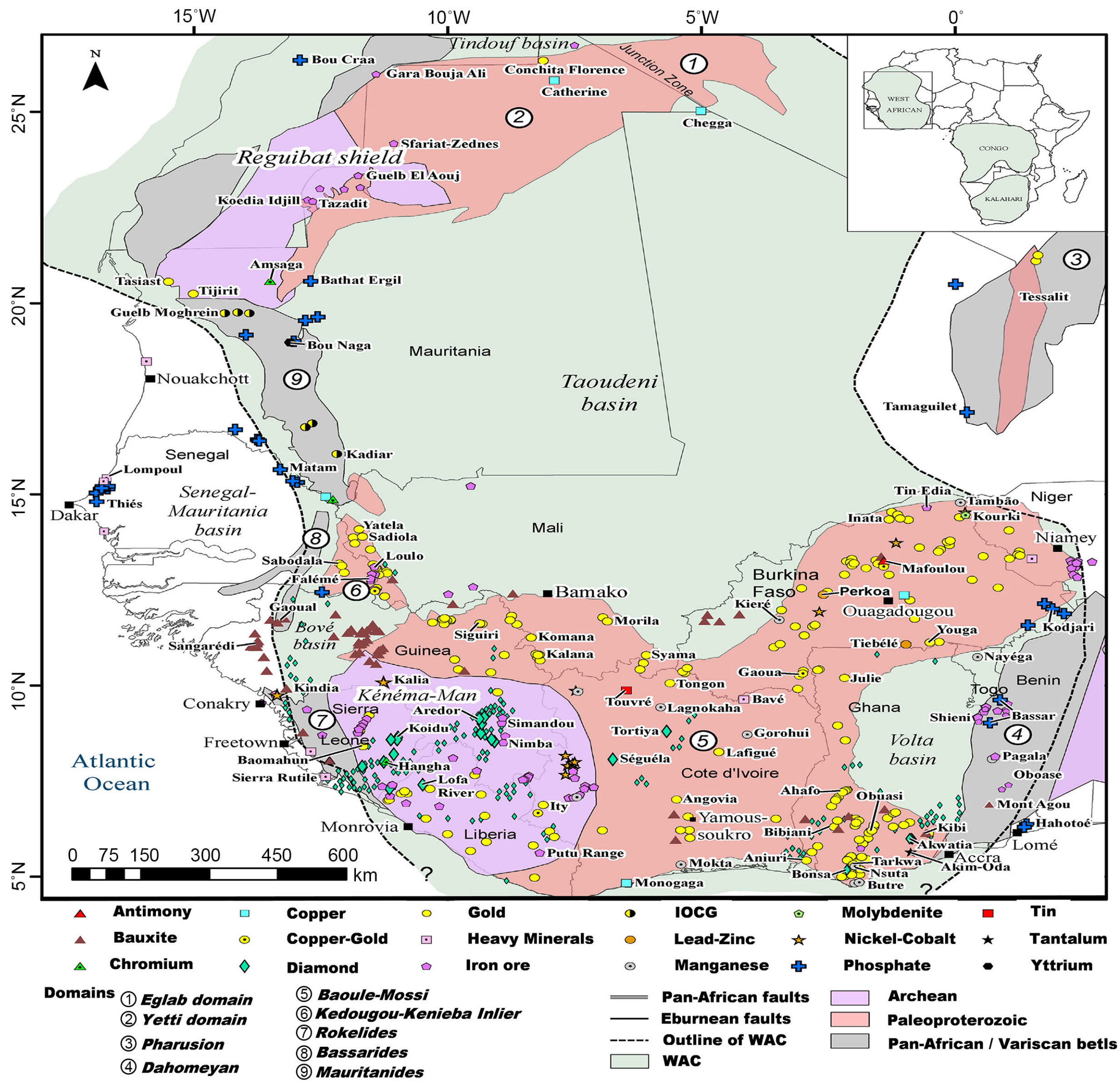


Figure 12. A simplified map of the West African Craton that highlights the distribution of all known mineral deposits listed in the WAMDD. A dashed line indicates the limit of the Craton; the map is modified after [29] [30] [31] and [32].

The diverse structural architecture of Birimian greenstone belts can also be seen inside the Baoule-Mossi domain. Such belts are linear in form and metamorphosed to lower-greenschist-to-ampibibolite facies, depending on their distance from the granitoid intrusions. Numerous studies on the Eburnean granitoids indicate they were emplaced around 2178 - 2176 Ma (U-Pb) in the Ghanaian Aahanti Belt [18], 2090 - 2070 Ma in eastern Guinea [19], 2076 ± 16 Ma in the Mauritania Eglab Shield [20], 2160 - 2080 Ma in the Kedougou-Kenieba inlier, located in Senegal and Mali [21], and around 2181 - 2117 Ma in northeast Burkina Faso [22]. These Eburnean granitoids are typical ovoid in form or crop up as composite batholiths, which constitute ca. 70% of the birimian terane, with a composition that range from TTGs to leucogranite [11]. Some granitoids crosscut the region's volcanic belts, whereas others intrude the Paleoproterozoic basins or older gneissic complexes.

Birimian supracrustal rock sequences are uncomfortably overlain by Neoproterozoic and Cambrian, continental-to-glacial sedimentary rocks in the east. As in the Baoule-Mossi terrane, three major tectonic events have been defined for the region [23]-[28]. In conclusion, the geological and structural context in northern part of Birimian (which our study Zone belongs) is very similar to the Birimian deposits in the southern part of Birimian domain, and the source of mineralization is the same.

6. Conclusions

The results of chemical and XRF analyses have demonstrated the existence of mineralized zone in gold, copper, zinc, lead, manganese, chromium, nickel, silver, thorium and yttrium, in Oudiane Elkharoub Zone all to the southeast portion of the study zone and with high-grade anomalies. This kind of mineralization essentially found in chlorite-rich diorite, sheared amphibolite, mafic rocks and quartzite. The anomalies, in turn, can be interpreted as resulting from the abundance of sulfide and malachite in the outcropping rocks (quartz vein and host rocks).

There is an important correlation between the sheared zone observed on-site and the mineralization itself. The mineralization's trend follows an N-S direction, with slight deviation.

The contribution of values denounced by the anomalies of polymetallic elements indicates spatial correlations between the existing gold, copper, manganese, zinc, and lead. A few samples demonstrate spatial correlations between their base metal (copper, zinc and lead) and manganese, while others do so for their base metals and their nickel and chromium.

In Oudiane Elkharoub zone, quartz veins are generated with two different size and orientations, and both of them host mineralization occurrences in more than one host rocks. This aspect of our study zone is also observed in the analyzed region of birimian domain in its southern part: from an economic point of view, the southern part of the West Africa Craton contains gold, copper, zinc, silver, lead and manganese all actively explored and mined within the Birimian terrane [28]. The particular positioning of Oudiane Elkharoub Zone between two batholitic granitoids with different ages is one of the strongest parameters for the interest in this district [33]. Furthermore, the main gold mine in the West African Craton is associated with Eburnean orogeny.

Therefore, the northern section of the Birimian Domain in West Africa Craton requires further study and exploration investment to have the same commodities in southern part of Birimian, given both have the same geological and structural characteristics.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Rocci, G. (1966) Essai d'interprétation des mesures géochronologique de la structure de l'Ouest africain. *Science Terre*, **10**, 3-4.

[2] Bessoles, B. (1977) Géologie de l'Afrique: Le craton ouest africain. http://pascal-francis.inist.fr/vibad/index.php?action=getRecordDetail&idt=PASCALGEODEBRGM7720312661

[3] Potrel, A. (1994) Evolution tectono-métamorphique d'un segment de croûte continentale archéenne. Exemple de l'Amsaga (R.I. Mauritanie), Dorsale Réguibat (Craton Ouest Africain). Ph.D. Thesis, Université Rennes, Rennes. https://theses.hal.science/tel-00675134/

[4] Traore, D.Y. (2017) Etude Metallogenique du district aurifère de Syama (Mali): Analyse comparative de gisement situes sur un même structure lithosphérique éburnéenne. Ph.D. Thesis, Université Paul Sabatier—Toulouse III, Toulouse. https://theses.hal.science/tel-01900948/

[5] Fabre, J. (2005) Géologie du Sahara occidental et central. Série/Reeks: Tervuren African Geosciences Collection, MRAC Tervuren, Belgique.

[6] Sims, J. (2019) Tasiast Project Mauritania National Instrument 43-101 Technical Report. https://s2.q4cdn.com/496390694/files/doc_downloads/technical_reports/2019/Kinross-Tasiast-NI-43-101-Technical-Report-Oct-2019-FINAL.pdf

[7] Ennih, N. and Liegeois, J.P. (2008) The Boundaries of the West African Craton. Geological Society, London. https://doi.org/10.1144/SP297.0

[8] Heron, K. (2016) Origine et évolution de la Ceinture Verte Mesarchéenne d'Aoueouat et la minéralisation aurifère associée. Ph.D. Thesis, Department of Geology, School of Natural Sciences, Trinity College, Dublin.

[9] Villeneuve, M. (2008) Review of the Orogenic Belts on the Western Side of the West African Craton: The Bassarides, Rokelides and Mauritanides. Geological Society, London. https://doi.org/10.1144/SP297.8

[10] Kah, L.C., Bartley, J.K. and Teal, D.A. (2005) Chemostratigraphy of the Late Mesoproterozoic Atar Group, Taoudeni Basin, Mauritania: Muted Isotopic Variability, Facies Correlation, and Global Isotopic Trends. *Precambrian Research*, **200-203**, 82-103. https://doi.org/10.1016/j.precamres.2012.01.011

[11] Taib, M. (2012) The Mineral Industry of Mauritania. USGS Minerals Yearbook.

[12] Ould Abdivall Taleb. (1994) Caractérisation pétrographique et géochimique du plutonisme birimien de la dorsale Reguibat (Mauritanie, Afrique de l'Ouest). Ph.D. Thesis, Henri Poincaré University, Nancy. https://hal.univ-lorraine.fr/tel-01747477

[13] Thieblemont, D., Lahondere, D., Goujou, C., Roger, J., Metour, J., Marchand, J., Gatta, B., Hadi, M., Diabira, F.B. and Thiam, B. (2003) Carte géologique a 1/200,000 du Nord de la Mauritanie, 14 coupure. Nouakchott.

[14] Lahondere, D., Thieblemont, D., Goujou, J.C., Roger, J., Moussine-Pouchkine, A., Le Metour, J., Cocherie, A. and Guerrot, C. (2003) Notice explicative des cartes géologiques et gitologiques a 1/200 000 et 1/500 000 du Nord de la Mauritanie. DMG, Ministère des Mines et de l'Industrie, Nouakchott.

[15] Lahondere, D., Rogger, J., Thieblemont, D., Goujou, J.C., Marchand, J., Bronner, G. and Le Metour, J. (2003) Notice explicative des cartes géologiques a 1/500,000 du Nord de la Mauritanie, 9 coupures. DMG, Ministère des Mines et de l'Industrie, Nouakchott.

[16] Finn, C.A. and Horton, J.D. (2012) U.S Geological Survey Administrative Report. Carol. A Ministère du pétrole, de l'énergie et des mines.

[17] Bronner, *et al.* (1992) Reguibat Shield lithostratigraphic Units.

[18] Hirdes, W., Saager, R. and Leube, A. (1988) New Structural Radiometric and Mineralogical Aspects of the Aubearing Tarkwaian Group of Ghana. *Bicentennial Gold*, **88**, 146-148.

[19] Egal, E., Thieblemont, D., Lahondere, D., Guerrot, C., Costea, C.A., Iliescu, D., Delor, C., Goujou, J.C., Lafon, J.M., Tegyey, M., Diaby, S. and Kolie, P. (2002) Late Eburnean Granitization and Tectonics Along the Western and Northwestern Margin of the Archean Kénéma—Man Domain (Guinea, West Africa Craton). *Precambrian Research*, **117**, 57-84. https://doi.org/10.1016/S0301-9268(02)00060-8

[20] Potrel, A., Peucat, J. and Fanning, C. (1998) Archean Crustal Evolution of West African Craton: Example of Amsaga Area (Reguibat Rise). U-Pb and Sm-Nd Evidence for Crustal Growth and Recycling. *Precambrian Research*, **90**, 107-117. https://doi.org/10.1016/S0301-9268(98)00044-8

[21] Dioh, E., Beziat, D., Debat, P., Gregoire, M. and Ngom, M. (2006) Diversity of the Paleoproterozoic Granitoids of the Kedougou Inlier (Eastern Senegal): Petrographical and Geochemical Constraints. *Journal of African Earth Science*, **44**, 351-371. https://doi.org/10.1016/j.jafrearsci.2005.11.024

[22] Tapsoba, B., Lo, C.H., Jahn, B.M., Chung, S.L., Wenmenga, U. and Iizukac, Y. (2012) Chemical and Sr-Nd Isotopic Compositions and Zircon U-Pb Ages of the Birimian Granitoids from NE Burkina Faso, West African Craton: Implications on the Geodynamic Setting and Crustal Evolution. *Precambrian Research*, **224**, 364-

396. https://doi.org/10.1016/j.precamres.2012.09.013

[23] Leube, A., Hirdes, W., Mauer, R. and Kesse. G.O. (1990) The Early Proterozoic Birimian Suergroup of Ghana and Some Aspects of Its Associated Gold Mineralization. *Precambrian Research*, **46**, 139-165. https://doi.org/10.1016/0301-9268(90)90070-7

[24] Ledru, M., Eko N'Dong, J., Johan, V., Prian, J.P., Coste, B. and Haccard, D. (1989) Structural and Metamorphic Evolution of Gabon Orogenic Belt: Collision Tectonics in Lower Proterozoic. *Precambrian Research*, **44**, 227-241. https://doi.org/10.1016/0301-9268(89)90046-6

[25] Ledru, P., Milesi, J.P., Feybesse, J.L., Dommanget, A., Johan, V., Diallo. M. and Vinchon, C. (1989) Tectonique transcurrente et évolution polycyclique darts le Birrimien, Protérozoïque inferieur du Sénégal-Malli (Afrique de l'Ouest). *Earth Sciences*, **308**, 117-122. http://pascal-francis.inist.fr/vibad/index.php?action=getRecordDetail&idt=7144601

[26] Ledru, P., Lasserre, J.L., Manier, E. and Mercier, D. (1991) Le protérozoïque inferieure du craton guyanais: Révision de la lithologie, tectonique transcurrente et dynamisme des bassins sédimentaire. *Bulletin de la Société Géologique de France*, **162**, 627-636. https://doi.org/10.2113/gssgfbull.162.4.627

[27] Ledru, P., Pons, J., Milési, J.P., Feybesse, J.L. and Johan, V. (1991) Transcurrent Tectonics and Polycyclic Evolution in Lower Proterozoic of Senegal-Mali. *Precambrian Research*, **50**, 337-354. https://doi.org/10.1016/0301-9268(91)90028-9

[28] Milési, J.P., Ledru, P., Feybesse, J.L., Dommanget, A. and Marcoux, E. (1992) Early Proterozoic Ore Deposits and Tectonics of the Birimian Orogenic Belt, West Africa. *Precambrian Research*, **58**, 305-344. https://doi.org/10.1016/0301-9268(92)90123-6

[29] Feybesse, J.L., Milesi, J.P., Johan, V., Dommanget, A., Calvez, J.Y., Boher, M. and Abouchami, W. (1989) La limite Archéen-Protérozoïque inferieur de l'Afrique de l'Ouest une zone de chevauchements majeure antérieure a l'accident de Sassandra; l'exemple des régions d'Odienné et de Touba (Côte-d'Ivoire). *Earth Sciences*, **309**, 1847-1853. http://pascal-francis.inist.fr/vibad/index.php?action=getRecordDetail&idt=6621460

[30] Schodield, D.I. and Gillespie, M.R. (2007) A Tectonic Interpretation of Eburnean Terrane: Outliers in the Reguibat Shield, Mauritania. *Journal of African Earth Sciences*, **49**, 179-186. https://doi.org/10.1016/j.jafrearsci.2007.08.006

[31] Markwitz, V., Hein, K.A.A., Jessell, M.W. and Miller, J. (2015) Metallogenenic Portfolio of the West African Craton. *Ore Geology Reviews*, **78**, 558-563. https://www.researchgate.net/publication/283563455_Metallogenic_portfolio_of_the_West_Africa_craton https://doi.org/10.1016/j.oregeorev.2015.10.024

[32] Markwitza, V., Heinb, K.A.A. and Millerc, J. (2016) Compilation of West African Mineral Deposits: Spatial Distribution and Mineral Endowment. *Precambrian Research*, **274**, 61-81. https://doi.org/10.1016/j.precamres.2015.05.028

[33] Metour, J. (2003) Carte géologique a 1/500,000 du Nord de la Mauritanie, 9 coupures. DMG, Ministère des Mines et de l'Industrie, Nouakchott.