Petrographic investigation and geochemical survey of rocks in Inteet area (Nile River State, Sudan)

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Abstract. The aim of the work is to estimate the Inteet area for search for gold mineralization. This area is located between Umm Trambishi and Alsalam area in Nile River State, Sudan. Surrounding territory is a gold-mining region, in which there are known deposits with estimated resources, as well as promising places where local prospecting is carried out. For a preliminary assessment of the prospects of the site is necessary to conduct geological and geochemical studies. Evaluation of the geological environment was carried out both during field work and with a petrographic microscope. 11 thin sections of rock samples have been prepared and petrographically investigated under polarized microscope the mineral compositions, textures, microstructures, degree of alteration and metamorphism have been studied. Geochemical studies were conducted on 32 samples from 25 sampling points. The main results of petrographic investigation and geochemical survey show the presence of hydrothermal alteration zones, which are associated with a high content of elements-indicators of gold mineralization. In general, the territory can be assessed as promising, but requiring further exploration and assessment work.

1. Introduction
The object of study is the Inteet area. It’s a part of Alibediyya area Nile River state, Sudan (figure 1). The distance from Khartoum to the study area is about 400 km. The Inteet area is located between Umm Trambishi and Alsalam area. The economic importance of the territory is the presence of a number of gold mineralization zones [1-3], of which Alsalam and Umm Trambishi ore conceder as the main deposit. We have focused on study area about (800x450) to study the geology and gold mineralization in it, since the area already prospected by artisanal mining by locals [4].

Figure 1. Location map of the study area.
The main goal of research is the initial assessment of the mineral prospecting in the Inteet area [5, 6]. The main objectives of the study are petrographic investigation of rocks and geochemical survey.

2. Methods

2.1. Petrographic investigation
During the field work samples of rocks were collected. 11 thin sections have been prepared from them at Khartoum University Laboratory of cutting and preparation of thin sections. Petrographic microscope allows investigate the mineral compositions, textures, microstructures, degree of alteration and metamorphism of rocks [7]. The main results of petrographic investigation shown in the article.

2.2. Geochemical survey
32 samples were collecting after remove the soil horizon this is was done by drilling to about 1-2 m approximately to reach the bed rocks plate. The total of pits that drilled are 25 pits, and from each pit we collected chip samples for geochemical analyses, but in certain pits we mainly need two samples (in case of presence of Quartz vein cutting across the bed rock) one sample from quartz vein and the others from bedrock. The collected samples had been prepared in form of powder for geochemical analyses and analyzed by Atomic Absorption Spectroscopy (AAS). The results of laboratory research were studied by statistical and graphical analysis [8-11], that shown in the article.

3. Results

3.1. Geology of the area
The geology of Inteet area is the same of Alibediyya area and it mostly covered by super facial deposits (1-2 m - from drilling), that covered the volcano-sedimentary sequence and low grade schistosed rocks which are not exposed in the surface the description of these volcano sedimentary sequence [12, 13] will be shown below from petrographic study. Some outcrops of quartz and Chert have been found in the area. But there is no existing of ophiolite mafic-ultra mafic. Granitic outcrops are also distributed in the area. The area also influenced by the shear zones and also affected by the four phases of deformation, these very clearly in volcano sedimentary units.

3.2. Petrographic studies
Elven chip samples and out crops were collected from the area and thin sections are prepared and studded under polarized microscope [7] (figure 2-9). The description is shown below.

![Figure 2. Photos of petrographic thin sections A1 (aX2.5, bX10): Hydrothermally altered metasediment (quartz-sericite-chlorite schist.) a: shows quartz, sericite chlorite assemblage & b: shows quartz, chlorite and epidote.](image)
Thin section A1 (figure 2). The specimen shows medium-grained texture. Composed mainly of Quartz and feldspar (alkali-feldspar and plagioclase) Quartz is seemed to be of two generations (primary quartz and secondary quartz which is coarser than primary one due to silicification). Sericite is found after Feldspars. Muscovite is also detected. Considerable amount of chlorite is detected together with epidote aggregates. The secondary quartz Sericite, chlorite and epidote is due to hydrothermal activities (silicification, sericitization, chloritization and epidotization respectively). Iron oxides, zircon, and ilmenite are accessories. The rock is deformed and highly affected by hydrothermal alterations. The specimen is meta-sediment (quartz-sericite-chlorite schist).

Figure 3. Photos of petrographic thin sections A2 (aX10&bX10): Hydrothermally altered Metasediment (quartz-chlorite talc schist) show quartz veinlet across quartz, chlorite and talc assemblages.

Thin section A2 (figure 3). The specimen is intensively weathered, hydrothermally altered and deformed. Quartz is detected together with some feldspar and also as vein and veinlets across the section. Chlorite and talc are found in considerable amount. Accessories are iron oxides. The rock is Metasediment highly chloritized talc schist.

Thin section A3 (figure 4). The rock consists mainly of quartz and feldspars (alkali feldspar and some plagioclase). The feldspars are highly sericitized and kaolintized Muscovite and chlorite are recognized that intensively affected by deformation and forming what is called pressure shadow texture (brittle minerals bent around the harder one like quartz and pyrite). Pyrite is found in considerable amount due hydrothermal activities. The rock is hydrothermally altered metasediment (quartz-chlorite pyritic schist).

Thin section A4 (figure 5). The specimen is coarse-grained leucocratic containing mainly quartz and feldspar (alkali feldspar) constituting more than 85% of the total feldspars the remaining is plagioclase. Muscovite and biotite are also recognized together with epidote. Hornblende is detected as minor constituent. Iron oxides (mainly magnetite), zircon and apatite are accessories. The feldspar is highly kaolinitized. The specimen is weathered and metamorphosed and it has composition of granitic gneiss.

Thin section A5 (figure 6). In the specimen feldspars are dominant mainly plagioclase and some alkali feldspar. The Feldspars and some quartz are forming the fine groundmass. The quartz is recognized as primary (phenocrest and groundmass) and secondary constituent (amygdaloidal and veinlets). Some of the plagioclases are altered to Sericite. Chlorite and some epidote are recognized as secondary components due to hydrothermal alteration. Sulphides and iron oxides are accessories. The rock is hydrothermally altered meta-volcanic (quartz chlorite schist).

Thin section A6 (figure 7). The slide is mainly consist of quartz (coarse to medium grained) about more than 95% of the section with minor iron oxides and sulphide. The specimen is ferruginous meta-chert.
Figure 4. Photos of petrographic thin sections A3 (aX2.5 & bX10): the quartz-chlorite pyritic schist shows chlorite and muscovite shaded the quartz and pyrite grains.

Figure 5. Photos of petrographic thin sections A4 (a X2.5 & bX2.5) a: coarse-grained rock containing mainly quartz and feldspar (alkali feldspar) and hornblende, biotite and iron oxides; b: show coarse.

Thin section A7 (figure 8). The rock is granular in texture that mainly composed of quartz, alkali feldspar (mainly microcline) and plagioclase that highly sericitized and kaolinitized in addition to considerable amount of muscovite and biotite. Iron oxides and apatite are accessories. The rock has composition of granite.

Thin section A8 (figure 9). The specimen is composed mainly of quartz more than 98% in addition to iron oxides. The specimen is quartz vein.

The description shows that the host rocks specimens are meta-sediment to meta-volcanic rocks in composition, that highly deformed weathered and affected by hydrothermal alterations. The hydrothermal processes affected the area are silicification, sericitization, chloritization, epidotization and pyritization. These host rocks are intruded by granitic to granitic gneiss and in some part granodiorite. Quartz vein is also found cutting across the host rocks. Chert and meta-chert are also detected in the area.

And therefore is a region hydro thermal solution, this means the presence of mineralization and economic ores.
Figure 6. Photos of petrographic thin sections A5 (a X2.5 & X10): quartz chlorite schist with some grains of epidote. The hydrothermal activities cause silicification and chloritization.

Figure 7. Photos of petrographic thin sections A6 (aX2.5 & bX10): Meta-Chert shows quartz with minor iron oxides and sulphides.

Figure 8. Photos of petrographic thin sections A7 (aX2.5 & bX10): shows granitic rock with quartz and feldspars and micas.
Figure 9. Photos of petrographic thin sections A8 (ax2.5 &bX10): quartz vein.

3.3. Geochemical survey
Chip samples have been taken during the field work. The results of laboratory research (AAS) were studied by statistical and graphical analysis [14], that shown in the article. Statistical analysis shown that Au, Ag, Cu and Pb are more informative for area assessment. The result of (Au, Ag, Cu and Pb) was used in ArcGIS to construct monoelemental maps (isoconcentration maps) to locate the zones of geochemical anomalies (figure 10). Analysis of the contrast of anomalies and the spatial combination of haloes of dispersion of elements with geological elements showed a high perspective of the area. [15-16].

4. Discussion
The cut-off grade is the level of mineral in an ore below which it is not economically feasible to mine it which is 0.25ppm. In the study area the geochemical analysis gives the values of gold in ppm these values are plot as isoconcentration map made to explain the location of high gold anomaly. From Au isoconcentration map the high anomaly appeared to be concentrated in southern west part of the area in point (89611) the anomaly is 0.45 ppm found in the chert cutting the meta-sediments.

There are other samples near the range and also in the southern west part (points 89601, 89610, 89612, 89615 and 89616) the meta sediments and have an anomaly of (0.21 ppm) which may give a higher values if there have been from higher depth.

The lowest anomaly concentration in the north and northern east of the area the rest of the points found in Meta sediments.

From Ag isoconcentration map the high anomaly appeared to be concentrated in south, centre and the northern-east in points (89604, 89605, 89618, 89623, 89631and 89632) the anomalies are range between (1.5 – 2.2) ppm.

From Cu isoconcentration map the high anomaly appeared to be concentrated in west and north in points (89608, 89623, 89630 and 89623) the anomalies are range between (95 – 140) ppm.

From Pb isoconcentration map the high anomaly appeared to be concentrated in most of the area except part of southern west and northern east in points (89604, 89613, 89615, 89618, 89621, 89622, 89623, 89624, 89625, 89627, 89630 and 89631) the anomalies are range between (11.5 – 16.5) ppm.

5. Conclusions
Petrographic study showed that the host rocks specimens are meta-sediment to meta-volcanic rocks in composition, that highly deformed weathered and affected by hydrothermal alterations. The hydrothermal processes affected the area are silicification, sericitization, chloritization, epidotization and pyritization.
The geochemical analysis showed that the (Ag, Cu and Pb) can be considered as associated elements with the gold. The southern west part of the area consists of high anomalies (0.45-0.21) ppm and the meta-sediments cutting by the chert.

Therefore, the detected rock changes indicates the presence of hydrothermal systems that are of potential interest for the search for gold mineralization. The parameters of geochemical anomalies and their spatial location indicates the presence of gold mineralization in the southern west part of the study area.

Recommendation. The Inteet area is one of the rich areas by gold mineral, but in spite of some difficulties like lake of power sources, water sources and telecommunication.

Therefor this study recommends the following: digging trenches in the southern west part of the study area in high-geochemical anomalies to identify the direction of gold depositional; encouragement the mining in the area; enhancement the mining process for better result; preserve the environment during mining; development of methods of analysis for pathfinder elements (As, Hg, etc.).
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