

Using Geochemical Methods to Prospecting Mineralization for Gold and Associated Minerals in Hamra Sheikh area- Sodari Locality- North Kordofan State- Sudan (March 2023 To October ,2023AD)

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Abstract:

This study was conducted in Hamrat El Sheik area Sodari locality, North Kordofan State march, 2023. The study was intended to the geology and the mineralization of gold in the area. The main objective is to investigate the relationship between the geological structures of the gold bearing rocks and the mineralization in Hamrat El Sheik area . The secondary data was collected from reports, researches and studies related to the study area this objective of the study was achieved , The importance of this study lies in exploring the gold ores that are abundant in the study area , which are expected to contribute to developing the local resources of the region increasing the national income of Sudan in general from foreign currencies that the state treasury needs , This study relied on the descriptive analytical approach . The primary data included field visits and sampling from Jebel El Zaraf . Five of the collected rock samples were chemically analyzed using the Inductively Coupled Plasma (ICP) and Atomic Absorption Spectrometry (AAS) . While the other five rock samples were cut in thin sections and studied using petro graphic microscope .The The most important findings of this study are : obtained from the petro graphic study showed that the gold bearing rocks are characterized

by shear zone structures. The gold mineralization in the area is linked to quartz veins, which differ in trends and dimensions . Chemical analysis revealed that the gold concentration varies in values between 0.076 ppm in sample Z9 in medium 0.086 ppm in Z5 5.339 ppm in sample Z2. On the other hand, the other elements such as Zn, Co, Cr, Ni, Fe show Variable concentrations with regard to that of Au. The study suggested some recommendations that detailed investigations are needed for better understanding of the type of gold mineralization in El Sheik area and in the other part of North Kordofan State where the artisanal gold mining activity is practiced by local miners.

Keywords Geochemical Methods , Mineralization ,For Gold , Associated Minerals ,Hamrat El sheik, North Kordofan .

استخدام الأساليب الكيميائية للاستكشاف السطحي لمعدن الذهب والمعادن المصاحبة له في منطقة حمرة الشيخ - محلية سودري ولاية شمال كردفان - السودان

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المستخلص :

أجريت هذه الدراسة بمنطقة حمرة الشيخ في ولاية شمال كردفان في شهر مارس وحتي أكتوبر 2023م بهدف معرفة علاقة التراكيب الجيولوجية والتمعدن في الصخور الحاوية على معدن الذهب في منطقة حمرة الشيخ وقد تحقق ذلك الهدف وتكمن أهمية هذه الدراسة في الكشف عن خامات الذهب والعناصر المصاحبة له في منطقة الدراسة والذي من المتوقع أن يسهم في تنمية الموارد المحلية للمنطقة المستهدفة بالدراسة لتواجد خامات الذهب فيها بكثرة وكذلك زيادة الدخل القومي للسودان عموماً من العملات الأجنبية التي تحتاجها خزينة الدولة واعتمدت هذه الدراسة علي المنهج الوصفي التحليلي تم جمع المعلومات الثانوية لهذه الدراسة من التقارير والبحوث والدراسات المتعلقة بمنطقة الدراسة وتضمنت المعلومات الأولية تلك التي تم جمعها في الزيارة الميدانية والعينات الصخرية من منجم جبل الزراف تم التحليل الكيميائي لعدد خمسة عينات باستخدام طريقة البلازما بالحث وجهاز الامتصاص الذرى وتم قطع وعمل الشرائح الزجاجية للخمسة عينات الأخرى ودراستها بالمجهر واهم النتائج التي خلصت لها هذه الدراسة كالأتي أظهرت نتائج الدراسة المجهرية أن الصخور الحاوية للذهب هي أحزمة قص ويمتاز

معدن الذهب بارتباطه بعروق الكوارتز التي تختلف في شكلها وابعادها بينما أوضحت نتائج التحليل الكيميائي بأن تركيز الذهب يختلف في قيمته والتي تتباين وتتنحصر بين 670.0 جزء من المليون Z9 وإلى 933.5 جزء من المليون كحد اعلي في العينة Z2 العينة في ومن جهة أخرى فأن تراكيز العناصر الأخرى مثل الزنك والكروم والنحاس والنيكل والحديد أظهرت تغيراً واضحاً مقارنة بتركيز عنصر الذهب . توصى الدراسة إلى إجراء بحث تفصيلي دقيق لمعرفة جيولوجية منطقة حمرة الشيخ وأجزاء أخرى بولاية شمال كردفان ودراسة العلاقة بتمعدن الذهب في المناطق التي يتم فيها التعدين التقليدي للذهب والذي تتم ممارسته بواسطة المعدنين المحليين بالمنطقة .

الكلمات المفتاحية: استخدام الأساليب الكيميائية , الكشف السطحي عن الذهب والمعادن المصاحبة , منطقة حمرة الشيخ كردفان

1. *Introduction :*

Historically Sudan has known gold mining since the era of Paranoiac kingdoms in the third Century BC.

This activity continued since then throughout. The period of Napata and Kush kingdoms in the Nubian Desert and Red Sea hills.

After these periods, the tribes of Bela, migrant Arabs and Nubians continuer gold mining through tracing the paranoiac mining sites. There is are similar gold mining activities at the areas of Bani Sharigol which extended to around 200 years in the area currently known as Southern Blue Nile Close to the Sudanese. Ethiopian borders. Studies point .

Out that gold mining using modern methods has only started at the begging of the nineteenth century in the Red Sea hills and Nubian Desert.

During the period 1900 to 1953 the gold mining witnessed intensified activity through introduction of modern equipment and technology by the Bntish. indicate the production of more than 10 tons of gold during this period. other side, there is no statistics on traditional mining activities in the country. This is due to the intermittent nature of the activity and its mobility besides it wide spreading in rural and desert .

During the last twenty years, the gold intensified as a parallel activity to other traditional activities such as agriculture and graz-

ing in the countryside as the agricultural seasons Witness instability in Production and sometimes failure, thousands of citizens turned to gold mining. There are no precise figures, but the number of indigenous miners is estimated at more than five hundred thousand tons.

The Widespread of this activity is due to high gold prices and improved communications roads and others. This activity has contributed to creation of job opportunities that helped in combating poverty.

Due to the importance of gold during this period this activity should be organized and controlled for preserving environment and resources for the coming generations.

Despite the fact that traditional mining is known for centuries in Sudan, the equipment and tools used are primitive and did not go beyond primary digging tools, wooden dishes and recently aluminum dishes and washing basins for washing the ore with water and then Picking up the pellets. In this process, and that improved through introduction of mercury, the sieving results did not go beyond 30 -40%- of gold available there. Even with the introduction of grind mills ,the percent of extracted gold.

Despite the primary the produced amount of gold is quite significant There is a long and complex Production marketing relationship. middle and gold traders entered into the cycle and became the funders for process an important tool in the traditional production which is the metal detector has been introduced at the end of 2009.

Now days there are hundreds of citizens searching for the metal in the Nubian Desert West Red Sea Hills, North and South Kordofan in area originally licensed to mining companies It is worth mentioning that all these operations are carried outside the Mineral Returns Development Law of 2007.

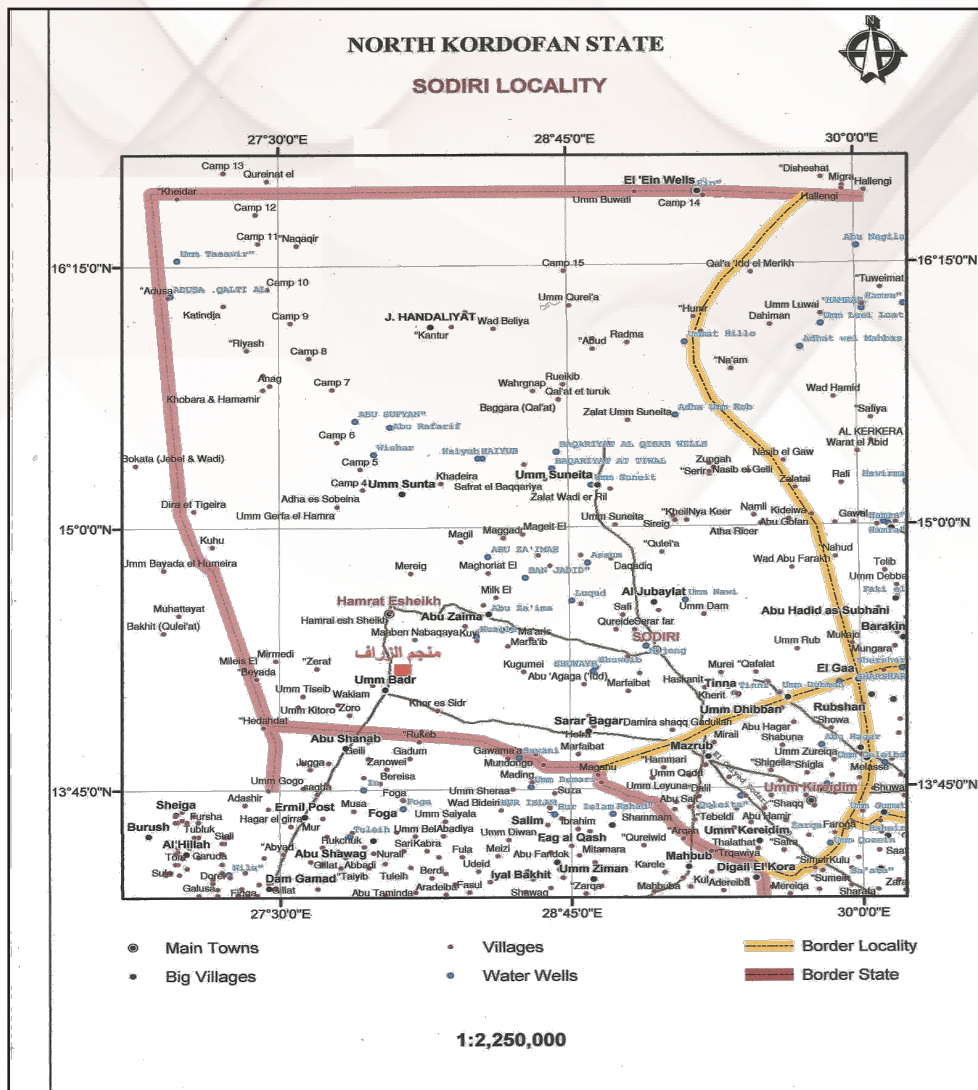


Fig. (1): Location Map of the Study Area . (Elobied Ordnance Office March 2014).

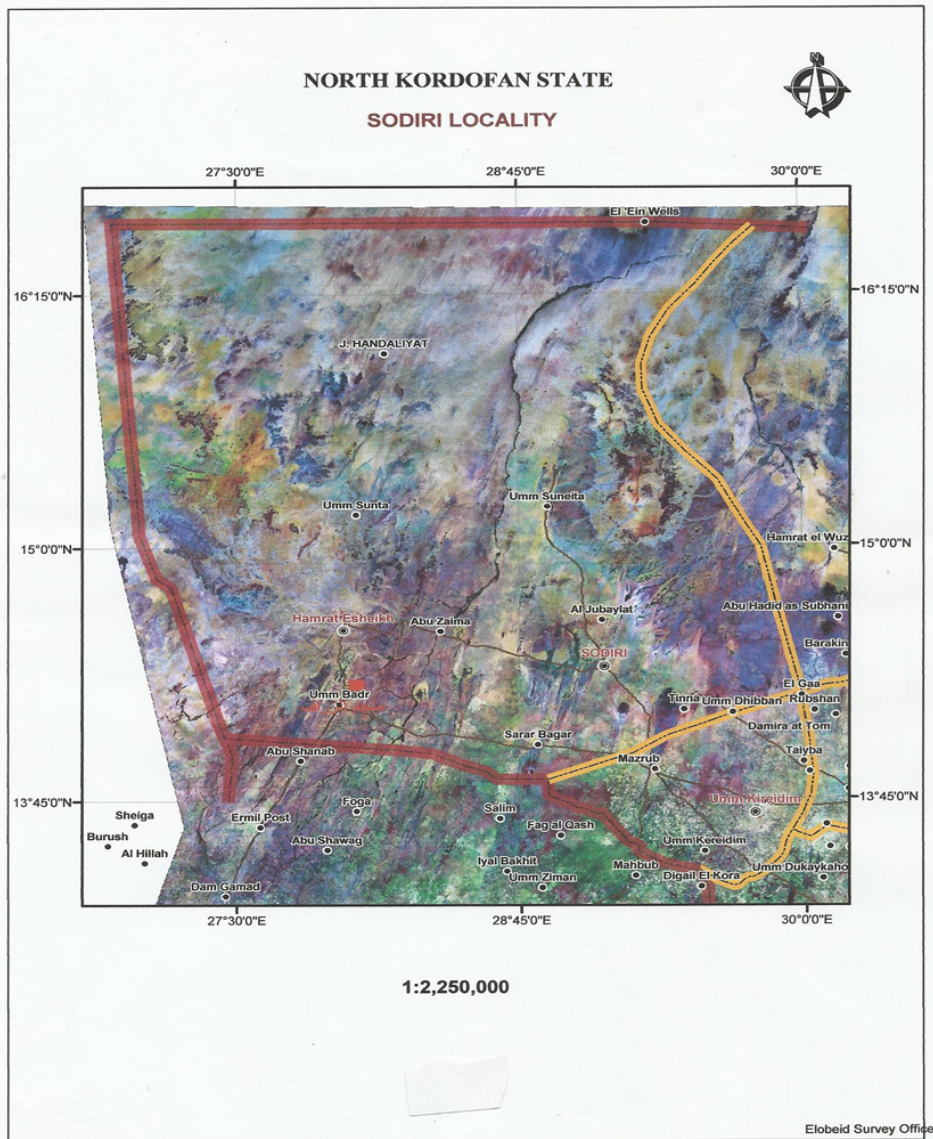


Fig . (2) : Aerial photograph of the Study Area . (Elobied Ordnance Office March 2014).

2. Objectives Of The Study :

Already known area of gold mineralization were selected for this experimental study the main objective is reveal qualitative

Geochemical investigation criteria which can be applied for study area of similar climatic, geochemical and geotectonic environments.

The main objectives of the study are:

1. To investigate rocks of basement complex exposed in the study area using different techniques geochemical investigations.
2. prospecting for gold and associated minerals in order to areas and layers of gold mineralization.
3. To contribute to elaboration of the tectonic setting and evolution of basement complex.
4. Determination focus in grams per ton concentrate of other minerals in the study area and its relationship between gold and other minerals.

3. Materials And Methods :

To undertake this study the following work should be done

3.1 Office Work

It is necessary for geochemical investigation; it is based on literature review so as to highlight the general concepts and to review the previous studies of the gold mineralization in Sudan.

3.2 Field Work

Geological survey should be done to collect information about the geology of the study area. Description of different rock units and collection of chips and rock samples are also one of the activities of this geological survey. Stream sediments and soil samples are to be collected from different auriferous quartz vein areas.

3.3 Laboratory Work

It is composed of three parts:

3.4 Part One

Preparing thin sections and studying the Petrogenesis of the rocks under the polarized microscope. In this part information will

be collected about the mineral composition, mineral assemblages, textures, micro structures and degree of alteration of the rocks.

3.5 Part Two

Preparing polish section to determine micro structures of the ores.

3.6 Part Three

Chemical analysis of the collected rock samples should be done using X-ray Fluorescence (XRF) method. The results of the analysis are going to show the concentration of the major oxides (Si, Fe, Mg, Ca, Mn, Na and K) the minor and rare earth elements (REE) and the gold coherent elements such as As, Cu, Pb, Zn, Ni, Co and Ba .

4. field and Laboratory methods

The fieldwork was facilitated by GPS , existing maps , native guides Some vein quartz

i) In El Hamrat Area

Shear Zone respectively. The first two (D1& D2) were accompanied by m1 metamorphism and m2 retrograde amphibolites metamorphism respectively (Abdel Rah man et al., 1999).

The pronounced regional trends of foliation in the basement rock generally range between 030° to 035 ° in Umm Bader and 060 ° - 067 ° in Sodari. The shear zones developed parallel to thin foliation have acted as conduits, and solutions passing through them have precipitated silica, gold, iron and manganese oxides (BICHAN, 1981).

In the study area there are zones of kaolinisation and solidification witness to the passage of large quantities of hydrothermal fluids . These zones are associated with tensional fracture in granite and

heavily ferruginous quartzite . The emplacement of chalcedonic quartz and the kaolinisation of feldspar is related to episodic movement along the main shears which caused repeated re-opening of the en Chelan fractures (Bridges et al , 1979

Association of geology and mineralization

Abdurrahman and others (1999) identified four primary sources of gold in Umm Bader area . These are :

- ferruginous quartz in high grade acid gneisses ;
- shear zone-related smoky quartz veins in graphitic schist's and slates;
- tourmalines intrusive-related quartz veins in meta-sediments; and
- very limited shear zone-related Cu-Au mineralization in low grade basic volcanic .

In El Hamrat area the gold mineralization is mainly associated with tourmaline-bearing quartz veins in granite and highly sheared meta-sediments . The auriferous host rocks to quartz veins probably means that gold was precipitated from iron-rich hydrothermal solutions passing through open fractures .

However, the geology and tectonics of the survey areas are reminiscent of the geological setting of Baeda Desert where vein-typed deposits are developed in tensional fractures associated with regional shears .

The low grade sequence of Umm Bader Belt is comparable with Pan African rift-type basins in adjacent areas with clastics sediments and subordinate volcanic and volcano clastics rocks .

These basins might represent re-entrants of the major Pan African oceans from the east or independent rift basins in the foreland of the Arabian Nubian Shield . These belts have been subjected to a multi-phasal deformation dominated by ductile and brittle shear zones that formed lineaments of regional extent (e.g. Umm Bader Shear Zone) . The latter , normally transport mineralizing fluids (KERRICH, 1986) leading to the formation of large deposits (1985) .

Similar situation has been observed in the Red Sea Hills of eastern Sudan where shear zones controlled the localization of gold and associated elements(1990) .

Heavy mineral prospecting revealed the existence of alluvial gold which, may relate to four different primary sources in the Umm Bader Belt .These are: Ferruginous quartz veins in high grade acid gneisses; Tourmalines intrusive-related quartz veins in meta sediments; shear Zone related Smokey quartz veins in graphitic schist's and slates; and very limited shear Zone related Cu-Au mineralization in low grade basic volcanic.

Chemical analyses of rock samples from the four different settings gave values between 100 and 600 ppb (0.1 to 0.6g/t) Au. Although these values are low, they are still comparable with results of mineralized veins from other areas like Eastern Baeda Desert where dilution of gold in the upper part of the veins might be due to leaching by weathering processes. Some samples have been selected to be analyzed abroad for gold and other elements to have a clear picture of the mineral associations and the type of

mine rations. Its recommended short term low budget exploration and mapping Programs must continue in North Kordofan especially in areas.

Northeast and southeast of El Hamrat where low grade meta sediments and possibly associated volcanic may exist.

Further work including geological mapping, geochemical sampling, and trenching is needed to produce more information on the potentiality of newly discovered occurrences.

Workable placer gold deposits may exist where alluvial gold has been observed in heavy concentrates from areas like the flat plain north of Wadi Umm Amid, which is densely covered by boulders of the Smokey quartz .

Safari and aided darning areas gave between 0.2 to 0.6 ppm of gold, thus confirming that the veins are auriferous .

The pervasive tourmalinization observed in the region might be due to intense hydrothermal activity related to the Syntectonic granitic emplacements as already mentioned in this report.

5. *The geological field work was carried :*

The geological field work duration is from 22 April to 25 April Regional geological survey and mapping in scale 1:250 000 Seventy five representative rock specimens were collected during this field work.

Laboratory investigations Maps compilation. Geological information collected during the field work were correlated and a geological map was compiled at The National Remote Sensing Authority (NRSC) The regional geological map in scale 1:250

000 was reduced to scale 1:500 000 and the detailed map in scale 1:700 000 was superimposed on the regional ones.

MAP printed by using ARC/INFO – GIS (Geographic Information System) and then Corel draw 5 and 6 software programmers'

6. *Present investigations :*

The present investigations are phased in the following sequence :-

- 1- Pre-field work phase .
- 2- Field- work phase .
- 3- Laboratory- work phase .

Figure (3) Schematically illustrates the phases of this work During the execution of the above outlined phases the following materials and methods were used ;-

1. Land sat images . MSS (Multi-Spectral Scanner) hard copies and negative . Paths 175 and 176 – Row 50 , band 5 . acquired in 20 Feb 1975 Hard copies of scale 1;250 000, negative scenes of scale 1;1000 000
2. Selected strips of aerial photographs of scale 1;70 00 and 1;40 000
3. Topographic maps of arils of scale 1;250 000 (Sadri sheet – ND 35 H and El Hamrat sheet – ND 35 G of scale 1;250 000) .
4. Polarized microscope . photomicrograph device and a number of 5 thin sections prepared from 10 representative rock specimens .

7. *petro graphic investigations :*

Petro graphic investigations were carried out on 5 thin sections, using polarized microscope . mineral assemblages and tex-

tural manifestations were determined. Then photomicrographs of representative lithologies were produced.

8. Geochemical analysis :

Rock samples were prepared by the conventional methods, samples were cleaned, fragmented and crushed manually in mortar, then ground by electric mortar. Five samples were selected for the geochemical analysis. The geochemical analysis was carried out X-ray fluorescence spectrometer on pressed powdered samples at the Geochemical Laboratories – Technical University of Berlin – Germany. Major, minor and trace elements were determined in forty rock specimens.

Determination of the loss on ignition (LOI) was performed at the Chemistry Department – University of Khartoum for more information about the method of determination of LOI see appendix I.

9. Statistical treatment of geochemical data :

A software programmer New pet(C)1989, for rock – geochemistry data handling and plotting discrimination diagrams was used to display the chemical characteristics and tectonic settings of the lithological units in the study area.

5. X-ray fluorescence spectrometer analyzer (XRF) .
6. LBM compatible computer .
7. Software's .

The Laboratory methods included sieving of the soil samples by electric shaker, chemical analyses of the soil, quartz vein and hard rock samples by A.A.S, Thin sectioning and microscopic petrography, magnetic and electromagnetic separations of the

heavy mineral concentrates . All these operations were performed in the laboratories of the Geological Research Authority of the Sudan (GRAS) . the results of the treatment of the various samples are as follows:

- The original sizes of the 5 soil samples were sifted down selected for chemical analysis . the elements analyzed for included gold , silver , copper , zinc, cobalt and nickel .
- All the 5 quartz vein and the 5 hard rock samples were crushed , milled and analyzed only for gold .
- 61 thin sections were made for petrography study .
- 35 stream sediment samples were panned in the field and their concentrates subjected to binocular examination , magnetic and electromagnetic separations .

The scientific and exemplified way of died mining to keep the nature free and the developing . That is to avoid the bad effect and the drawbacks of destroying our nature .This why the ancient romantic poets said – Civilization destroys nature . Eventually Sudan should be aware of these dangers and set good example for saving the nature life .

10. Ore Genesis:

From description of polished section Samples illustrate the general characteristics of the ore mineral associations, and textures from samples collected from the quartz veins, and cherts that are exposed in the central part of the study area.

the polished sections of these samples have been found to include several epigenetic sulfide minerals associated with gold such as:

pyrite (FeS_2), Chalcopyrite (CuFeS_2) Arsenopyrite (FeAsS), Native Copper (Cu), Chalcocite (Cu_2S) Sphalerite (Zn, FeS) Bornite (Cu_3FeS_4) Azurite ($\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$) Malachite ($\text{Cu}_2\text{CO}_3(\text{OH})_2$) Pyrrhotite (Fe_7S_8), Magnetite (Fe_3O_4), Hematite (Fe_2O_3) Goethite ($\text{FeO}(\text{OH})$) and quartz as the principal gangue mineral.

The mineral association can be classified into two assemblages as follows:

1- Fe-As Sulfide minerals assemblage: (pyrite, arsenopyrite and pyrrhotite).

2- Cu-Pb-Zn sulfide minerals assemblage: (native copper, chalcocite, chalcopyrite, galena, sphalerite, malachite, Bornite and azurite). Gold is found to occur either as independent grains or in association with arsenopyrite and pyrite, in the quartz veins and in the chert.

Field observations and studying of thin and polished sections indicate meso epithermal gold mineralization as epigenetic gold mineralization (vein lode type) Occurring largely in quartz veins, quartz stringers and chert which emplaced within basement rocks such as diorites along; NE, ENE, E-W shear joints, fractures and faults zones.

The supergene enrichment zone associated with quartz veins occur as small halos distributed around the mineralization zones with ages related to volcanism, shearing or similar to post igneous activities in the region.

11. Discussion of Structures and Metamorphism:

The strike of the planner structures is NE and NEE, controlled by OBSZ and SSZ respectively. Schandelmeier and Richter (1991) assigned four major deformational episodes that have affected the basement complex rock units of the Ombadir and Sodari areas. These four major deformational episodes are referred to here as

D1, D2, D3, and D4.

D1: The first phase of deformation (D1) is a Late Proterozoic deformational episode that has resulted in isoclinal folding in the high-grade Migmatitic gneissic basement units and the meta sedimentary belt of Ombadir.

D2: The second phase of deformation is a Late Pan-African deformational episode (D2) that is manifested in numerous N020 striking ductile shear zones, where the older granite was synchronously deformed while being intruded. (D2) refolded the earlier structures of (D1) especially the meta sediments of the Ombadir belt

D3: The third phase of deformation is the Latest Pan-African deformational episode (D3) resulted in the OBSZ is expressed in form of 60 km wide system of sub parallel brittle shear zones which cross-cut all previously described ductile fabrics of Ombadir belt. These shear zones are generally made up of cataclastics and fault breccias. The strike of the master faults trend about N051Oblique, cross-cutting relationship with regional NNE trending fold and shear structures suggest that OBSZ faults developed during intensive late Pan-African crustal shortening. Late Pan-African shearing in the meta sedimentary belt of Ombadir provides an example of brittle deformation of the upper crust which can also be observed in many other parts of NE Africa. This shearing marked the final compressive deformation which affected the entire area between the Tibesti Mountains (Libya, Chad) and the Arabian-Nubian Shield (Saudi-Arabia, Egypt, Sudan) and which terminated the Pan-African evolution in NE Africa Schandelmeier (1991).

D4: The fourth phase of deformation is the Late Carboniferous to Triassic deformational episode (D4). It is a brittle dextral shearing reactivation event in Ombadir and Jebel Nehud areas.

In Sodari area the sinistral shearing extensively reactivated the structures of the previous episodes of deformation, exploiting part of the anisotropic zones of weakness.

Sodari shear zone (SSZ) is a large wrench fault zone which is extremely conspicuous on satellite images. The master fault of this shear zone can be traced by ridges and narrow depressions which line up in an approximately N35° 40° direction for about 200 km. The D4 sense of shearing along the SSZ can be determined unambiguously as sinistral, due to two specific structural features that occur along the shear zone denoted by a large and a small circle in which is manifested in left-lateral transtension and transpression structures respectively.

The stress regimes, which caused regional shearing in the Ombadi and Sodari areas during late Carboniferous to Triassic period, utilized part of the fault patterns generated during major episodes of the Pan-African deformation (D2, D3). In other words, many of the fault fabrics of the Phanerozoic shear zones in central North Kordofan were generated by reactivation tectonics. Close genetic relationship between within-plate shearing and alkaline igneous activity is suggested.

12. Conclusion:

Hamrat El sheik Area considered as a part of the Arabian – Nubian Shield. The lithology's in this region are late Proterozoic gneisses, folded supracrustal metavolcaniclastics.

Relatively younger granitic intrusions and felsic ring dikes have been emplaced along fractures and major systems.

Detailed studies of the geology and associated wall – rock alteration suggest that gold mineralization is shear related and characterized by green schist facies mineral assemblage. The mineralization is characterized by gold – bearing quartz veins containing

pyrite, arsenopyrite and iron oxides. Gangue minerals include quartz, calcite, K-feldspar. The auriferous quartz reefs are variable in color and size and textures include massive and banded. The width of the veins range from a few centimeters (stringers, vein lets) to greater than 1.5 m. It usually occur as discontinuous isolated patches due to pinch and swell. The veins are preferably hosted in calc – silicates.

Shearing processes and retrograde metamorphism are associated with remobilizing gold in the quartz veins and red posting it in structural traps. The spatial distribution of Abu Zaima auriferous reefs, the zonal nature of associated wall – rock alteration and the structural and litho logical evidence suggest that the mineralization is related to episodic fluid flux during deformation. The deposition of gold was retrograde metamorphism and the fault reactivation along the shear zone.

The gold occur as free gold in quartz or as dissemination in fluids. Gold also occur as placers structurally – controlled auriferous quartz vein mineralization in *Hamrat El sheik* area.

The geochemical, litho logical, structural and mineralogical features as well as the style of wall rock alteration of the quartz veins suggest that it best classified as reflecting an organic gold deposit type. Next point explain that:

- Deposited tectonic disruption due to repeated deformational cycles complex display the following criteria characteristic for ophiolitic complex
 - i- Full range of litho logic assemblage: (layered gabbros Pyroxenes, pillowed basalts and calc-silicates)..
 - ii- Regional structural position and internal structure: the complex is aback arc marginal basin with linear trail concordant coinciding with the general regional geological strike.
 - iii- Characteristic mineral and element assemblages usually

associated with pod form deposits, sulphides of Ni, Cu, Pb (occurring as anomalous element content disseminated in Pyroxenes).

Native Au, PGE, Alloys (forming within the nickel sulphides). The anomalous elements content of the above mentioned metals are found to be specially enriched in cap rock. Out of the above mentioned minerals and elements and only chromites and talc are now being mined in small scale.

- Stream sediment sampling method (heavy concentrated-black sands- mineralogical method) and litho chemical method (secondary dispersion) proved to be useful tools for detailed prospecting to reveal secondary haloes, blind and/or ore convened showings.

The results obtained from field observations confirmed the poly metamorphic nature in the study area, thus consolidating the ideas forwarded by Different litho logical units displaying various metamorphic ranks, indicated from their mineral assemblages, textural and structural . The deformational and remobilization processes in the study area are manifested in the migmatitic gneisses and amphibolites structural fabrics which denote that the area under consideration was subjected to ploy-phase or ploy-episode deformational history.

The hornblende schist's of J. Abu Retag represent anomalous variety of hornblende schist's. Characterized by the presence of large K-feldspar crystals following the metamorphic foliation and displaying high gamma ray readings which could be ascribed to content in the large K-feldspar crystals. This rock type is not reported in previous investigations. The hornblende schist's are organized in a linear belt with the other meta sedimentary rocks in J. Abu Retag, with and regional trends that conform with the described regional trend of the Northern Zalingi Folded Zone and the Central African Shear Zone

It is pertinent to mention that the amphibolites and hornblende schist's are encountered as pockets or small linear belts within the meta sedimentary rocks, such modes of occurrence could denote prevalence of anomalous P-T conditions in some localities. Meta gabbros reflect varying degrees of incipient metamorphism (partial epidotization, carbonitization, serisitization, albitization, saussuritization, etc.), whereas the syn- to late-tectonic granites display structural and textural features that testify to their formation during tectonics (slickenside surfaces, intense silicification and toumalinization processes).

Some felsitic rocks have extruded syn-cinematically while others superseded the shearing episodes in the study area. Field evidences confirm their pre-Nubian age as recorded previously .

Petro graphic investigations authenticated field observations and clearly indicated that the study area is a poly metamorphic terrain, composed of different litho logical units described in the lithostratigraphic sequences in The mineral assemblage of the Migmatitic gneisses (Quartz - K-feldspar orthoclase and microcline-partite) plagioclase of upper amphibolites facies. These rocks are highly deformed and subjected to retrogressive processes as manifested in plates (8) and (9) {features that lend support the re-activation and remobilization of the forwarded by Schandelmeier. et al. (1987a. 1987b. 1990) and Harms, et al. (1990).

Minerals assemblages of the amphibolites, hornblende schist's and the diopsidic-forsterite marbles denote medium grade metamorphism (epidotite-amphibolites facies) However, the large crystals of K-feldspar in the hornblende schist's seem to be blastoporphritic crystals these crystals preceded the tectonic episode since the crystals are fragmented and display various degrees of retrogresses processes as shown features are interpreted as an indication of poly metamorphic history. The microscopic examinations of the chlorite schist's, graphitic schist's, meceaceous quartz-

ite's, marbles indicate that these meta sediments have mineral assemblages characteristic of low-grade metamorphism of green schist facies. Lithologies and the different metamorphic ranks displayed by the meta sediments in the study area are similar to the metamorphic processes .

The tectonic implications of the above described metamorphic evolution of the area may be summarized as follows:

The Migmatitic gneisses in the study area seem to belong to the high-grade continental carbonic gneisses in north west Sudan and south east Egypt which constitute the oldest rock unit which were described by Rocky, (1965) as "the Nile Craton". Sjeandelmeier, et al. (1987a) redefined this area and coined the name "The East Saharan Craton" (ESC). Kroner .(1977) regarded the Nile Craton as a continuation of the Congo Craton and termed it the Sahara-Congo Carton. While Black and Lie'geois (1993) argued that this Craton was a Craton before the Pan African episode, but was totally remobilized during it, and named it the Central Saharan Ghost Craton [quoted from Schandelmeier, et al. 1987].

However, our field and laboratory investigations clearly show that these gneisses have undergone severe deformation and remobilization, findings compatible with the ideas of Schandelmeier, et al. (1990) about the ESC, hence may, probably, have the same geologic and tectonic evolution history. The reactivation of the ESC produced numerous small rift basins which hosted the present low-grade meta sedimentary pile. Dynamic metamorphism within the shear zones exemplifies the last tectonic episode in the area.

- 1- It seems reasonable to conclude that the study area is belongs to the remobilized East Saharan Craton of Pre-Pan African age, wherein a ploy metamorphic terrain is produced that high-grade Migmatitic gneisses (upper amphibolites Facies)

which represent the old crustal material that is overlain unconformable by Sodari – Umm Bader intercontinental supracrustal meta sedimentary belt of low- to medium-grade metamorphism (green schist and lower-amphibolites facies).

2- The overall tectonic event in the study area is represented by three deformational episodes labeled D1 D2 and D3, which have extensional, compression and shearing characteristics consecutively These episodes are:-

- D1 Produced the rift basins that received the sedimentary pile formed by the post D1 erosion- devotional cycle.
- D2 Is of compression nature, triggered the low-grade metamorphic phase “M2” and brought the isoclinal folds in the amphibolites.
- D3 Created the cataclysmic metamorphic transformations along the shear zones in the area of study.

3- The outlined metamorphic phases in Sodari – Om Bader area are separated in time, space and rank:

Miss of late Achaean to early Proterozoic age, affected the deepest and oldest rocks in the Basement Complex Formations produced the Migmatitic gneisses, rank high-grade metamorphism (upper amphibolites facies).

M2 Probably of Pan-African age according to Abdel Rahman, et al (1990), affected the sedimentary pile and produced the various meta sediments described previously, rank low- to medium-grade metamorphism (green schist and lower-amphibolites facies).

M3 of late Carboniferous – Triassic age according to Schan-

delmeier and Richter (1991), created catalectic metamorphism along shear zones (brecciating, mylonitization associated with hydrothermal processes), rank low-grade metamorphism (green schist facies)

4. Pock geochemical investigations have distinctly revealed that the precursor igneous materials of the ortho-metamorphosed rocks in Sodari – Ombadir area exemplify within plate continental crust magmatic. Thus excluding any relation to plate margins.
5. Fracture systems in the Basement Complex rocks are deemed to be the favorable sites for groundwater accumulation, whereas shear zones represent the conduits for hydrothermal solutions rich in mineralization, presence of intensive tomalinization processes is convincing evidence.
6. It is envisaged that geothermal barometric and investigations would be of value in the determination of the P-T conditions and age of the outlined deformational episodes and metamorphic phases. Such an exercise is essential for correlating the present findings with the well established concepts regarding

The oxidized ores of exposed sulfide deposits on land are common! enriched in gold, in a zone of secondary Cu-sulphides or Fe-rich gossans. Supergene enrichment of gold in this environment is commonly attributed to the exposure of sulphides to oxidation by near-surface groundwater, following uplift and erosion. However, high concentrations of secondary gold have been found in oxidized shipside deposits on the modern as e.g. in hydrothermal field of the Mid-Atlantic Ridge. This observation suggests that high concentration of secondary gold may occur in ancient deposits that have never been exposed to surface weathering on land.

. The gold-rich ochres contain coarse-grained native gold in a matrix of Fe-oxides and parasite and have been interpreted to be the fossil analogues of gold.

The mineralized massive barites are distally located relative to the massive ship side deposits and the gossans. The best example in the area occurrences which are hosted by acid volcanic and contain about 1.5 and 60ppm Au on average ,respectively (Table 5). Gold occurs as fine disseminations in barite, pyrite and quartz. Wall rock alteration is extensively developed and the host rocks are also mineralized. New occurrences of massive pyrite have been found in the Abu Zaima belt within mineralized structures, hosted by acid volcanic and volcano clastics rocks. The mineralization in the area is controlled by a shear zone that contains a number of meter-scale lenses of massive, compacted fine-grained barite associated with disseminated copper sulfides in its hanging wall. No Fe-gossans have been found in the area. Gold content.-of one analyzed sample (i insignificant, but the wall rock (Å contains up to 59 ppm to 1.5 ppm Au (Table 5). The mineralized massive barite lenses in to the same phases of deformation as the host rocks.

Hamrat El sheik area considered as part of the Arabian – Nubian Shield . The lethargies in this region are late Proterozoic gneisses , folded supracrustal metavolcanicclastics and turbidity assemblage . Relatively younger granitic and Felsic ring dike have been emplaced along fracures and major systems .

Detailed studies of the geology and associated wall- rock alteration suggest that gold mineralization is shear –related monsoonal , and characterized by green schist facies mineral assemblages . The mineralization is characterized by gold – bearing quartz veins containing pyrite , arsenopyrite , chalcopyrite , pyrrotite , and iron oxides .

The conclusions which have been drawn as the result of this Experimental work are given as shown in systematic order based on the actual Stages usually adopted lo conduct geological investigations leadingtowaeds finding gold deposits i.e. defining geological criteria which encourage prospecting, to define potential

targets (in this study geochemical anomalies and finally dissection or detailed prospection-preliminary exploration of revealed secondary dispersion geochemical patterns.

13. Recommendations:

- Sudan covers a big surface area and has diversified geology which merges with neighboring African countries
- Sudan has a huge mineral potential waiting to be explored / evaluated and developed.
- Infrastructure is developing and the environment of investment is encouraging.
- Invitation is extended to investors to visit and explore Sudan, and to invest in the mineral sector.
- The traditional mining provides job Opportunities and improves the economical status thus help in poverty combating.
- The export gold provides foreign currency and contributes to the increase of GDP It expands the area for explorations and reveals important hidden indicators for gold presence.

14 .*REFERENCES:*

- (1) Abdel Rahman F. M. (1993): Geochemical and geotectonic of the metallogeny of Selected ophiolite Complexes from the Sudan. Ben. Geowiss Abh. (A) 159, 103 pp., Berlin.
- (2) Abdel Salam, M. G., and Dawoud, A. S. (1991): The Kabus ophiolitic melange Sudan, and its bearing on the Western boundary of the Nubian Shield, Journal of the Geological Society, London 148, P. 83-92 .
- (3) Ahmed, M., Solomon, M., Walshe J.L. (1987): Mineralogical and Geochemical studies of Emperor gold Telluride Deposit, Fiji., Econ. Geol. V. 82, P. 345-37
- (4) Almond F.1.. (1982): Relationships of mineral deposits and Lineament analysis of the of the Red Sea Region., Northern Sudan. Adv. Space. Res. 3, P. 71-79,
- (5) Almond. C'., Kher, O.M., and Poole, S. (1984): Alkaline basalt in, volcanism in northern Sudan: Comparison of the Bayuda and Gedaref areas Jour. African., Bartli. Sd., Vol.2, No.3, P. 33-245.
- (6) Almond. C., Ahmed F. I., and Shaddad M. Z. (1984): Setting of gold mineralization in the Northern , Red Sea JilJç of the Sudan Econ Geol. Vol. 79, P 3 89-392
- (7) Almond D. C., (1982): New ideas on the geological history of the Basement Complex of northern Sudan. Sudan notes and Records, V. 59, P.i6136
- (8) Almond D. C., (1979): Younger Complexes of the Sudan In AI-Shante Evolution and numerical.

- (9) Almond D. C., Kalloran., McCormack M., Vail, J. R. (1977): Concentration of Younger granite complexes and small Cenozoic Volcanic fields in the Bayuda Desert Sudan. 20th. Ann. Rep. Res. Inst. Afro. Geol. Univ. Leeds: P. 61-65; Leeds
- (10) Almond D. C., (1974): the composition of basaltic lava from Bayuda Sudan, and their place in the Cenozoic of North Africa Bull. Volcano 38, 2: P. 5-360.
- (11) Almond D. C., Almed D. C., (1969): An excursion to the Bayuda Volcanic field of North Sudan Bull Volcano 33: P. 9-565
- (12) Aloub, O.A., and El samani (1991): ' the geology of gold deposit in the Red Sea Hills of the Sudan , Pan- Africa, Tectonic, Metamorphic Models Geol. Res. Authority of the Sudan (GRAS) Bulletin No. 39 Addis Ababa (1990): Gold Mineralization in Kapeota and Lurid areas, Eq. region Region Southern Sudan (Unpubl) Ph.D. thesis (Belgium) Bakheit A. K. (1991): Geochemical , and Structural Control of Sulfide- gold mineralization in Ariab Mineral district, Red Sea Hills-Sudan, Ph. D., thesis (unpubl.).
- (13) Barth, H., Besang, C., Lenz, H., and Mainhold, K.D. (1983): Results of petrological Investigations and Rb/Sr age determinations on the non-organic igneous ring complexes in the Bayuda Desert, Sudan., Geol. 16. 115 I, p. 3—34; Hannover.
- (14) Barth, H., and Mainhold, K. D. (1981): Geological map of Bayuda Desert 1:250000. Hannover (Bundesanst. F. Geowiss., and Rohstoffe); Khartoum (Geol. and Mineral. Resour. Dept.).
- (15) Barth, H., and Meinhold, K. 1). (1979): Sudanese German Exploration project. Technical Report, part 1; Mineral pros-

- pecting in the Blaynda Desert., Vol. A. (Investigation of mineral potential 336, P., Vol. 13: Annex
- (16) (Geochemical data). I inpubi . Rep., BGR, Hannover.
 - (17) Berhe, M. S. (1990): Ophiolite in Northeast and East Africa:
 - (18) implication for Proterozoic crustal growth. Jour. Gcol. Soc. London, V. 147, P. 41-57.
 - (19) Bonnemaïson, M. and Marcoux., B. (1 990): Auriferous mineralization in some Shear zone :a three stage model of metallogenesis, Miner. Dep. 25, P. 96-104.
 - (20) Boniface Geo export Roma. (I 986): Reconnaissance Primary mid Alluvial Gold Deposits along the Nile Valley, report No. 3inHydrogeological studies and investigation in North Sudan.
 - (21) Bow depend Turner D.C (1 974) Per alkaline and associated Gold is found to Occur either as independent grains or in association with arsenopyrite and pyrite, in the quartz veins and in the chert.
 - (22) Field observations and studying of thin and polished sections indicate mesoepithermal gold mineralization as epigenetic gold mineralization (vein lode type) Occurring largely in quartz veins, quartz stringers and chert which emplaced within basement rocks such as diorites along; NE, ENE, E-W shear joints, fractures and faults zones.
 - (23) The supergene enrichment zone associated with quartz veins occur as smallhalos distributed around the mineralization zones with ages related to volcanism, shearing or similar to post igneous activities in the region.
 - (24) Abdel Rah man, E. M., Mathis, G. and Ute, A., 1994:

- Mineral potentials in terrane. Red sea Hills. Sudan- An integrated training and research approach; The Geological Research Authority of the Sudan (GRAS). Bulletin No 41.
- (25) Abdel Salam, M. G. and Dawoud, A. S., 1991: The Kabus ophiolite mélangé, Sudan and its bearing on the western boundary of the Nubian Shield: Journal of the Geological Society. London. Vol. 148. pp. 83 – 92. printed in Northern Ireland.
- (26) Al Biely, A. I., 1983: The Wildenstein Specularite Deposits. Carinthia. Austria. Geology. Metamorphism and Genesis; (unpublished Ph. D. thesis). Leaven Mining University – Leaven Austria.
- (27) Al Biely, A. I. Farwa, A. G. and Gasim El Sid, E., 1986: Geological geophysical and hydro geological investigations in North Kordofan. Sudan: (unpublished report) University of Khartoum.
- (28) Al Biely, A. I., Khidir, S. O. and Mohamed, A. H. A., 1996a: Geological remote sensing investigations in North Kordofan State – Sudan. Proceedings of the Eleventh Thematic Conference and Workshops on Applied Geologic Remote Sensing Las Vegas. Nevada – USA.
- (29) Al Biely, A. I., Mohamed, A. H. A., Khidir, S. O and Abdel hammed, N., 1996b: An information system for the utility of the ephemeral tributaries west of the Nile Valley in Sudan Based on remote sensing and geologic techniques. Proceedings of the Eleventh Thematic Conference and Workshops on Applied Geologic
- (30) Remote Sensing Las Vegas. Nevada – USA.
- (31) Almond, D. C., 1983: The concepts of “Pan-African episode” and “Mozambique Belt” in relation to the geology of east and north-east Africa. Bull. Fac. Earth Sci. King Abdul-Aziz Univ., 6. pp. 71 – 87.

- (32) Barth, H. and Meinhold, H. D., 1979: Mineral prospecting in the Baeda Desert; Part I. vol. A. Investigations of mineral potentials: Technical Cooperation. Project No. 75. 7038.0 Sudanese German Exploration Project. Hannover. Berliner Geowiss. Abh. A., 50. pp. 7 – 21. Berlin – Germany.
- (33) Dawoud, A. S., 1980: Structural and metamorphic solution of the area south-west of Abu Hammed. Nile Province. Sudan. (unpublished Ph. D Thesis) University of Khartoum.
- (34) El Nadi, A. H., 1980: The geology of keg El Kheil. Damik and Umm Dugo igneous complexes. Nubba mountains. Sudan. (unpublished M. Sc. Thesis) University of Khartoum.
- (35) El Nadi, A. H., 1983: The geology of the late Precambrian meta vocations. Red Sea Hills. NE Sudan; (unpublished Ph. D. Thesis).
- (36) El Netiefa, A. M. A. H., 1991: Inorganic magmatic in the Sudan: Petrology and Petro genesis of some Alkaline Complexes from Northern Kordofan Province. Sudan. (unpublished M. Phil thesis). Polytechnic. England.
- (37) Floyd, P. A. and Winchester, J. A., 1975: Magma type and tectonic setting discrimination using immobile elements: Earth and Planetary Science Letters. (27). pp. 211-218. North-Holland publishing company.
- (38) Floyd, P, A. and Winchester. J. A. 1978: Identification of altered and metamorphosed volcanic rocks using immobile elements: chemical Geology. 21. P. 291-306.
- (39) Harms, U. Schandelmeier. H. and Derbyshire. D. P. F. 1990: Pan – African reworked early / middle Proterozoic crust in NE Africa west of the Nile: Sr and Nd isotope evidence: journal of Geological Society. London Vail 147 PP. 854-872 printed in Northern Ireland.

- (40) Huth, A. Franz, G and Schandelmeier, H. 1984: Magmatic and metamorphic rocks of the NW Sudan: A reconnaissance survey. Berliner geowissenschaftliche Abh. (A). 50.pp. 7-21. Berlin.
- (41) Ibrahim, A. E. Binger. C. J. and Fairlead. J. D. 1996: Lithosphere extension northwest of the central African shear Zone in Sudan from potential field studies. Tectonophysics. 255. PP 79- 97.
- (42) Irvine, T. N and Baragar, W. R. A. 1971: A Guide to the chemical classification of the common volcanic rock. Canadian Journal of Earth science 8.
- (43) Johann sin, A. 1939: A descriptive petrography of the igneous rocks: Vol. 1 University of Chicago press. USA.
- (44) Kherks, J, Lie'geois, W. 1987: Crustal evolution of the Northern Kibaran belt. Eastern and Central Africa. in Kroner. A (ed) Proterozoic lithosphere Evolution Geodynamics series Vol. 17.
- (45) Kroner, A, 1993: The pan African belts of Northern and Eastern Africa. Madagascar. South India Sri Lanka and East Antarctica: Terrene amalgamation during formation of the supercontinent: in Schandelmeier (eds) Geoscientific Research in Northeast Africa Baklava, Rotterdam.
- (46) Leake, B. E., 1964: The Chemical Distinction between Ortho-and Para-amphibolites: J. Petrology. 5. pp. 238 – 245.
- (47) Mohamed: A. H. A., Al Biely A. and Zen I. A M., 1996: Geological Mapping of mega-Structures in Northeast Africa Using NOAA Image. Proceeding of the Eleventh Thematic Conference and Workshops on Applied Geologic Remote Sensing, Las Vegas. Nevada- USA.
- (48) Muller-Sohnius, D. and Horn, P., 1994: K-Ar dating of ring complexes and
- (49) fault systems in Northern Kordofan. Sudan: Evidence for independent magmatic and tectonic activity.

- (50) Pearce, J. A. and Can, J. R., 1971: Ophiolite origin investigated by discrimination analysis using Ti, Zr and Y: Earth and Planetary Science Letters. (12). pp. 339 – 349.
- (51) Pearce, J. A. and Can, J. R., 1973: Tectonic setting of basic volcanic rocks determined using Trace elements analysis: Earth and Planetary Science Letters. (19). pp. 290 – 300. North-Holland Publishing Company.
- (52) Pearce, J. A. and Gate, G. H., 1977: Identification of ore-deposition environment from trace element geochemistry of associated igneous rocks: Geology. Soc. London Spec. publ. 7. pp. 14 – 24 London.
- (53) Pearce, J. A., German, B. E. and Burkett, T. C., 1975: The TiO₂-K₂O-P₂O₅ diagram: A method of discriminating between oceanic and nonoceanic basalts: Earth and Planetary Science Letters. (24). pp. 419 – 245. North-Holland Publishing Company.
- (54) Rise, A. C., Shackelton, R. M. and Dawoud, A. S., 1985: Geochemistry and tectonics of the NE Baeda Desert. N Sudan: Implications for the western margin of the late Proterozoic fold belt of the NE African: Precambrian Research, 30. pp. 43 – 62.
- (55) Rods. H. G., Hassan, A. and Warden, L., 1963: Availability of groundwater in Kordofan Province. Sudan. Bulletin No. 12. Geological Survey Department of Sudan.
- (56) Schandelmeier. H. and Harms, U., 1987: The Northern Zalingi Fold Zone: An international mobile belt of mid-Proterozoic age in NE Africa?: in Matches and Schandelmeier (eds). Current research in Africa earth science Baklava. Rotterdam. Netherlands. Schandelmeier, H. and Pudlo. D., 1990: The Central African Fault Zone (CAFZ) in Sudan- A possible continental transform fault. Berliner Geowiss. Abh. A. 120. 1. pp. 31 – 44. Berlin.

- (57) Schandelmeier. H. and Richter. A., 1991: Brittle shear deformation in Northern Kordofan. Sudan: Late. Carboniferous to Triassic reactivation of Precambrian fault systems: *Journal of Structural Geology*. Vail 13. No 6. pp. 711 – 720. Printed in Great Britain.
- (58) Schandelmeier. H. Huth, A., Harms, U., Franz, G. and Bernie, R., 1987a: The East Saharan Craton in Southern Egypt and Northern Sudan: Lithology and structural development: *Berliner Geowiss. Abh. A.*, 75. pp. 25 – 48. Berlin.
- (59) Schandelmeier. H., Richter. A., and Harms, U., 1987: Proterozoic deformation of East Saharan Craton in south-east Libya. South Egypt and north Sudan: *Tectonophysics*. 140. pp. 233 – 246. Elsevier Science Publishers B.V. Amsterdam. Netherlands.
- (60) Schandelmeier. H., Derbyshire, D.P.F., Harms, U. and Richter. A., 1988: The East Saharan Craton: Evidence for pre- pan-African crust in NE Africa west of the Nile; in: Richard. O. Grayling and Samar El Gaby (eds). *The Pan-African Belt of Northeast Africa and Adjacent areas Chapter 3*. *Wie weg*. Schandelmeier. H., Richter. A., Harms, U. and Abdel Rahman, E. M., 1990: Lithology and structure of the late Proterozoic Jebel Rehab Fold- and Thrust belt (NW Sudan); *Berliner Geowiss. Abh. A.* 120.1. pp. 15 – 30. Berlin – Germany.
- (61) Stern, R.J., 1994: Arc assembly and continental collision in the Neoproterozoic East African Orogeny: Implication for the consolidation of Gondwanaland: *Annul. Rev. Earth Planet. Sci.* 22. pp. 319 – 351. *Kea*. Rotterdam. Netherlands.
- (62) Stern, R.J., Kroner, A., Bender, R., Reichmann and Dawoud, A. S. 1994: Precambrian Basements around Wade Halva. Sudan: A new perspective on the East Saharan Craton. *Geol. Rundsch.* 83. pp. 564 – 577.

- (63) Strojexport 1976: Geophysical geological and hydro geological research of Kordofan Province. Rural water Corporation (unpublished report).
- (64) Vail, J. R., 1971: Geological reconnaissance in part of Berber District. Northern Province. Sudan. Geological Survey Department. Sudan Bulletin N. 18.
- (65) Vail, J. R., 1973: Outline of the geology of the Nubba Mountains and vicinity. Southern Kordofan Province. Sudan Geological Survey Department. Sudan Bulletin N. 23.
- (66) Vail, J. R., 1986: Outline of the geochronology and tectonic units of the Basement Complex of the north-east Africa. Proc. R. Soc. Lund. A350. pp. 127 – 141. London.
- (67) Vail, J. R., 1978: Outline of the geology and mineral deposits of the Democratic Republic of the Sudan and adjacent areas – Overseas Nd Miner. Retour. No 49. pp. 67. London.