



Physicochemical weathering conditions of the characteristic white soil horizon at Al Firjah area and it's vicinity in North Kordofan State, Central Sudan.

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Abstract

Mineral deposits and valuable materials are deposited, concentrated, and purified by natural processes during long or short time, chemical weathering reactions is a major one.

Satellite images exhibit distinct white horizon of high reflectance. Investigation of this phenomenon reveals that these areas were associated with the distal reaches of the major part of the drainage system. Exposures of the basement rocks include metasediments marl, marble, and other silicate rocks (granite, granodiorite, meta andesite,....etc) at high land where the proximal reaches of the drainage system. These rock were subjected to chemical disintegration process of hydrolysis for silicate constituent and dissolution for carbonate constituent and consequently these material were transported by the drainage system as colloidal (kaolinite) and dissolved material (calcium cation and bicarbonate), eventually these material were deposited due to evaporation at flash delta to form the kaolinite carbonate soil at Alfirjah area and it's vicinity.

Field observations in addition to rock and soil sample analysis forearm the above mentioned hypothesis.

Keywords; Physicochemical Weathering, Industrial Materials, Northern Kordofan, Sudan.

Introduction

Some aspects of the geology of Kordofan were described by Whiteman (1971) and Vail (1978), they reported on the lithological variations of the Precambrian basement rocks. Roberson Research International (RRI) and the Geological Researches Authority of the Sudan (GRAS) (1988) compiled a geological map of the North Kordofan State (to the scale of 1:800.000)

and outlined the regional distribution of the rock facies in the area.

Schandelmeier *et al.* (1991) identify structurally lower and an older sequence (high grade sequence) consisting of poly metamorphosed and deformed orthogneisses and paragneisses with minor inliers of amphibolites and calc-silicate rocks. These rock unit are of lower to middle Proterozoic age (Harms *et al.*, 1990). The low grade

rocks and their deformations are considered to be of Late Proterozoic age Schandelmeier and Richter (1991). They are comparable with the low grade Pan-African metasediments further north of Ummbadir at the JabelRahib area NW Sudan Abdel Rahman *et. al.* (1990). The continuation of favorable Late Proterozoic structures from the Arabian-Nubian Shield into the foreland region west of the Nile (e.g. Dam EtTor Shear Zone of Eastern Bayuda is proposed by Abdel Rahman (1993). Sami Omer (1997) studied the metamorphic evolution in Sodari- ummbadir area. El Rasheed *et. al.* (2000) studied the highly mineralized quartzite and quartz veins in Sodari Shear Zone (SSZ) and conclude that the shear zone controls the mode of occurrence of sulfides mineralization and associated precious metals.

Integrated geological, geochemical and remote sensing investigations revealed a mineralization of base metal sulfides of Cu and Zn, with Au and Ag in the late Pan-African structures in central Sudan Abdel Rahman and ELMahi (2006).

A comparative study on various sulfide rich mineralization, North Kordofan state has been made by Mohamed Ali, *et. al.* (2011), and suggested island arc environment to these mineralization. El Hassan (2014) study the geological and geochemical criteria for mineralization in Al firjah area.

Study area

The study area is located in the northern part of North Kordofan State, central Sudan

which covers Sodari, El Markh, and El Firjah localities, Fig (1). El Firjah which represents the central part of the study area lies at about 38 kilometers north of Sodari and about 67 kilometer southwest of El Markh.

The region is characterized mainly by long dry-hot summer, minor dry winter, and a short rainy season, only from July to September. It reflects typical desert to semi desert conditions.

Physiographic

The landscape of the area is shaped by relatively moderate relief ridges and hilly chains with almost gentle slopes. These are mainly composed of highly sheared acid metavolcanic ridges, syn-tectonic intrusive bodies and post-tectonic granitic stocks. These hills are tabular to elongate in shape towards the NE-SW and E-W directions, while decreasing to the south to form low lying out crops and large sandy plains with sand dunes and kaolin deposits.

The most prominent topographic features are the ridges that associated to the major shear zones which broadly control the drainage system of the whole region Fig (2). The main drainage pattern is represented by many wadis and khors, the most important of which are Wadi Umm Dam, Wadi El Nuwaiq, Wadi El Gambrawi, Wadi El Mezaibit, Wadi Umm Sharrow, and Wadi El Jamama Fig (3). These are recharged with many tributaries from hills and high relief areas to constitute sub-dentric to dendritic pattern. The overall drainage system attitude is from the high altitudes in the north east to low-lying areas in the southwest running parallel to shear zone

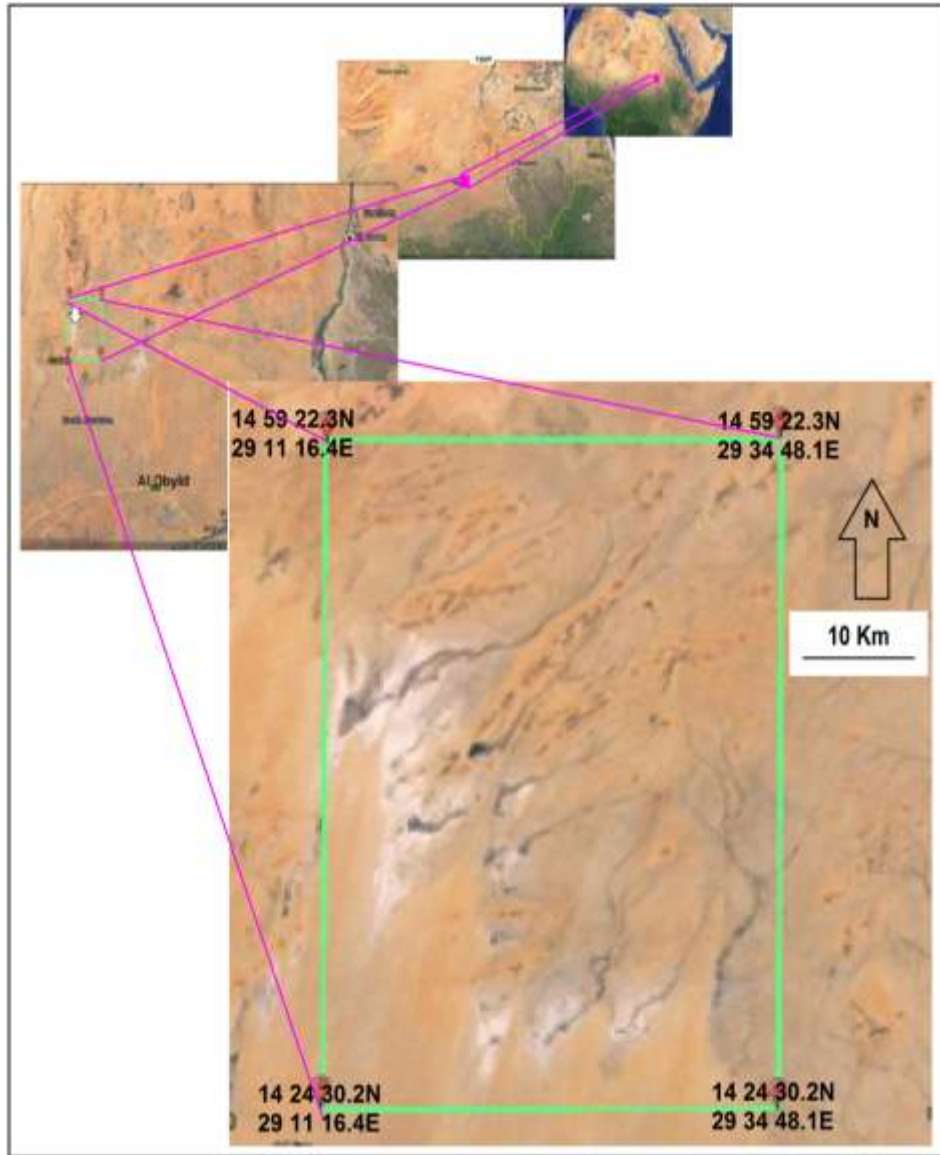


Fig (1): Lands at image sketch map of the study area.

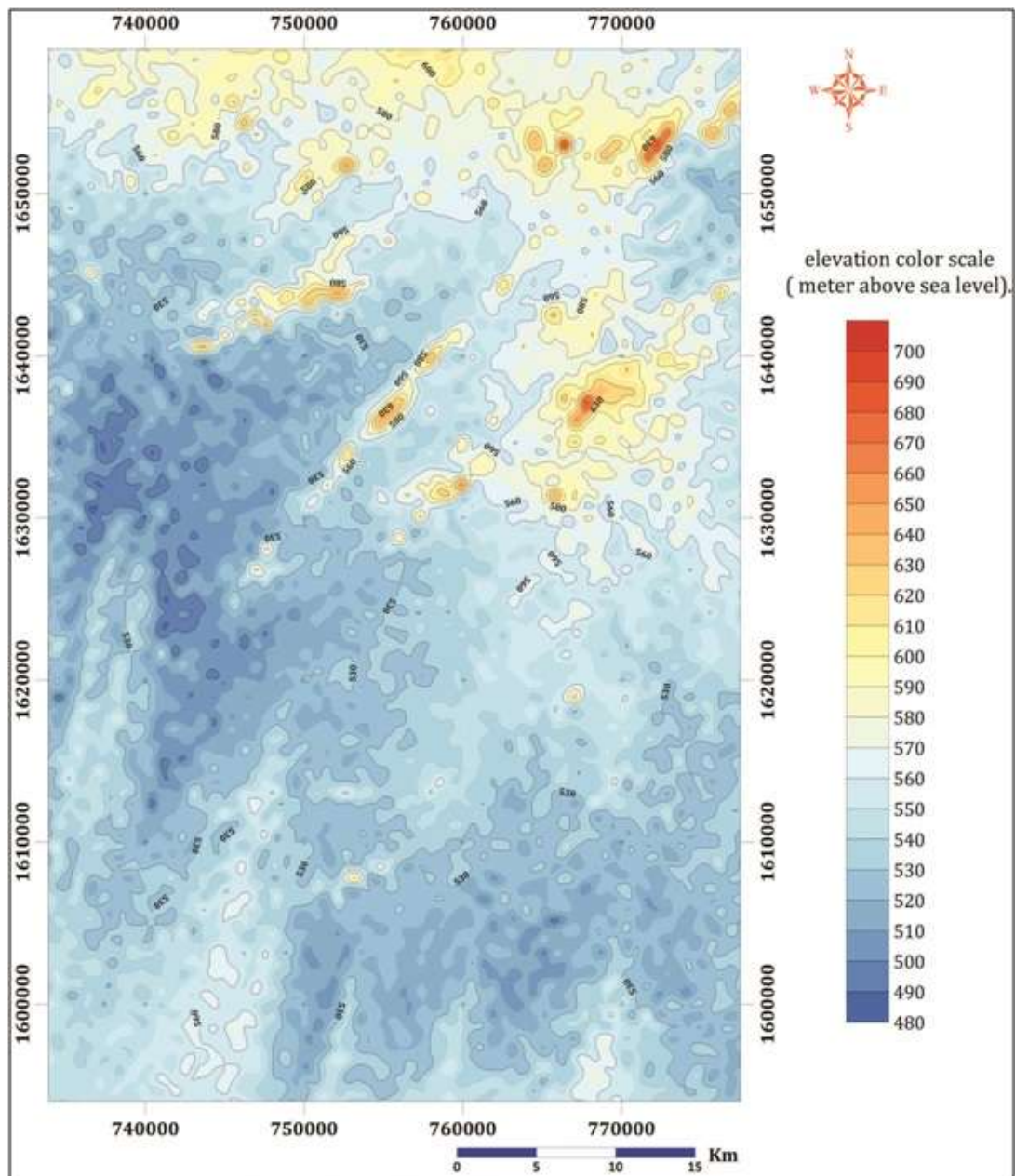


Fig (2): Topographic contour map of the study area.

Geology and Structures

The geology of the area is formed up of a lower group of high-grade migmatitic-gneisses, of both igneous and sedimentary origin, associated with bodies of tholeiitic ultrabasic rocks that are interpreted as wandering slaps of an oceanic crust EL Hassan 2014. The upper group of the

basement complex in the area is formed of metamorphosed volcano-sedimentary sequence occur as roof pendants on top of the syntectonic granitic complexes. The oldest known rocks in the study area are the partially migmatized gneisses. These rocks are supposed to be of Proterozoic age. These were followed by the intrusion of the

syntectonic granitic complexes possibly during, or slightly before, the above mentioned Pan-African tectono-metamorphic event. They were affected by, and accompanied, UBSZ. These complexes have rose up the temperatures of the country rocks and caused contact metamorphism that is superimposed on the regional metamorphism.

The metavolcanic are comparable to those of Ariab belt in the Red Sea Hills that gave an age of about 730 Ma. They are metamorphosed in the green schist facies of metamorphism in the epizone and were affected by SSZ.

Later shearing occurred during crustal uplift and seems to have been accompanied by a retrogressive phase of metamorphism to the level of the green schist facies in the epizone. Then the intrusion of the post tectonic granites, syenite, and gabbro which emplaced during a vast igneous activity that took place about 450 Ma known elsewhere in the Sudan (Vail 1985).

The deposition of the Nubian Sandstone Formation took place during the Cretaceous age through period of igneous activities quiescence.

Both Quaternary chemical and physical weathering and erosion processes have led to the formation of a thin loose cover of sand, wadi deposits, and residual soils Fig (3).

Tectonic evolution

The depositional setting and structural style the North Kordofan Belt in central Sudan is similar to the Jebel Rahib Belt, except that, here, ophiolites has not been found. Among the intrusive granitoids, a tourmaline bearing granite has been dated at about 590Ma. Late Pan-African shear zones, which are sealed by mica-bearing pegmatites, have yielded

ages of about 560Ma, Thomas Schlüter (2005).

El Hassan (2014) encountered complex deformed ultrabasic and basic igneous rocks of tholeiitic affinity such as: gabbro, olivine norite, and tholeiitic ultrabasic rocks of scapolite metapyroxenite. These rock units were interpreted as wondering slaps of an oceanic crust until further ophiolitic members are discovered. Similarly, meta-volcano-sedimentary sequences that are exposed at the intersection region where SSZ offset UBSZ are interpreted as part of the newly formed oceanic crust in Ummbadir –Sodari shear zone.

The deformation regime and the metamorphic evolution of the study area resembles, to a great extent, those regimes described in the juvenile Pan-African rocks in the Arabian Nubian Shield mentioned by Dawood(1980), Elsamani(2010), etc. . The initial compressive ductile regime resulted in successive ductile strains of folding and refolding which is fulfilled by ductile and brittle shearing phases. These are typical D2, D3, and D4 described by Schandelmeier and Richter (1991) in the study area. However, this brings further prove of Pan -African geotectonic evolution rather than a reworked older Sahara Meta-Craton crustal type. Schandelmeier et al., (1991) agree with Harms et al. (1990) that the oldest exposed basement rocks in the study area are of lower to middle Proterozoic age. The tectono-metamorphic events and their deformations are considered to be of Late Proterozoic age. Therefore they are comparable to the Pan-African formations further north of Ummbadir at the Jabel Rahib area of NW Sudan (Abdel Rahman *et.al.*, 1990).

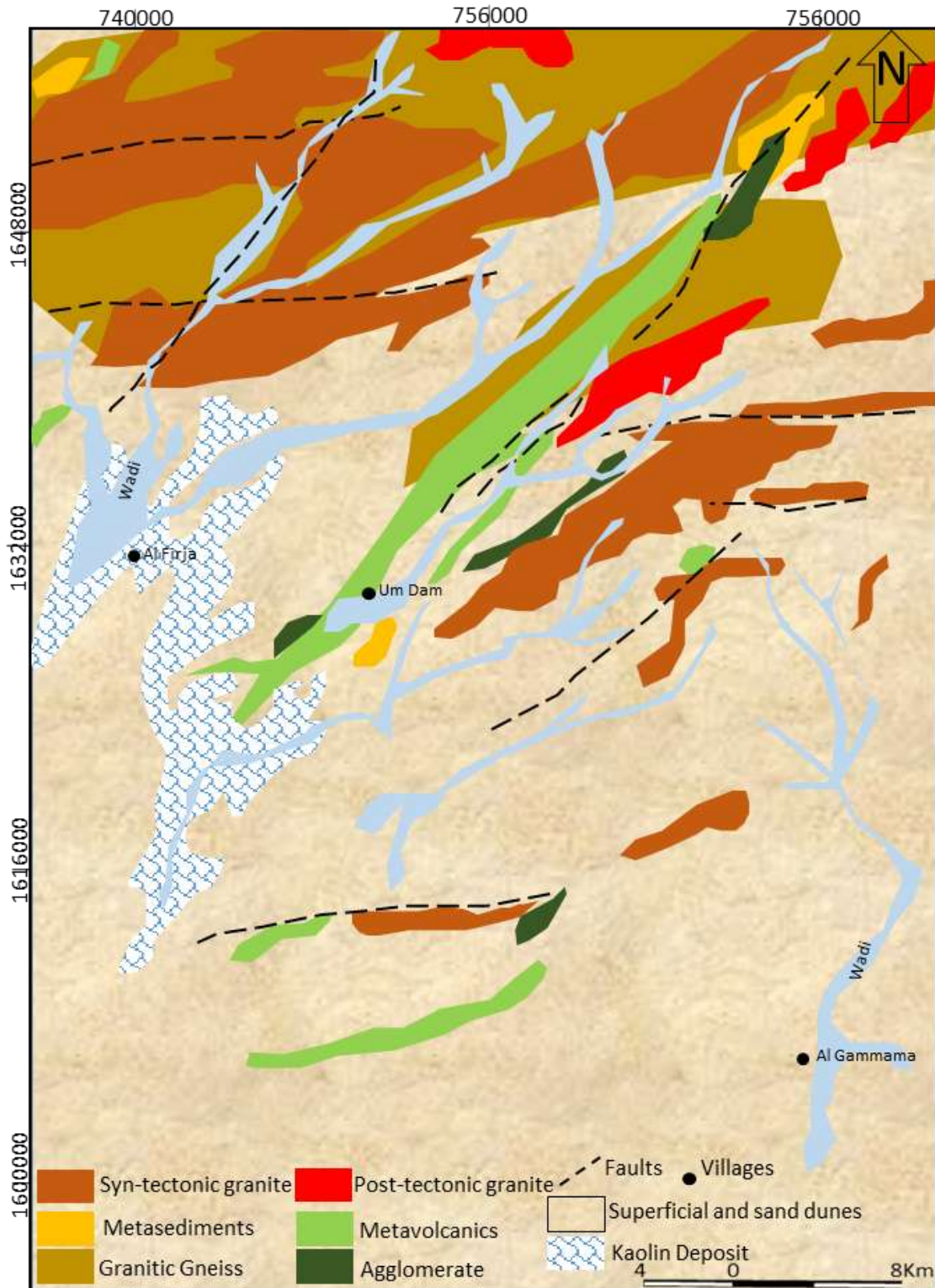


Fig (3): Detail geological map of the study area after El Hassan (2014).

Material and Method

The main objective of the study is

- To interpret the physicochemical weathering conditions that are control the formation of the white soil horizon in the study area using different techniques of remote sensing, geological mapping, and geochemical investigations
- To elaboration the economic value and significant of such soil deposits

The applied methods of investigation during the present work are enrolled under three main subdivisions Office work, Field work, and Laboratory work.

The first step after literature review is the preparation of a base map of the study area. This step requires processing of a satellite image (landsat-8 OLI). The image has been prepared from scene (path 175/ Raw 50) at the scale of 1:250.000 and 30meter pixel size. The band combination of the image has been set 7, 4, 2 in Red, Green, and Blue respectively that highlighted different phenomena, for instance, the drainage system, different lithological units, and the structural lineaments Plate (3).

Field work performed that involved regional geology survey. In addition, forty sample from rock exposure were collected, twenty samples were chosen as reprehensive to basement exposure in the study area to be investigated under polarized microscope via preparation of thin section at Al Neelain University rock preparation laboratories, that help in Lands at image classification processing to produce the final geological map.

Collecting of two target soil samples which were subjected later to chemical analysis. Initial sample preparation is conducted at Global Group Enterprises for Mining laboratory in order to prepare portable

package, which was then sent to Al-Amri Laboratories –Jeddah - Kingdom of Saudi Arabia in order to be analyzed. The analyzed standard major oxides include in order the following:

SiO₂, Al₂O₃, Fe₂O₃, TiO₂, CaO, MgO, K₂O, Mn O₂, Cr₂O₃, P₂O₅, and (LOI) Lost On Ignition using XRF via Lithium Borate Fusion. The only one exception here is Na₂O, which is analyzed by AAS via four acid digestions (HCl/HNO₃/HClO₄/HF). The results of the major oxides analysis are expressed in weight percent (wt %).

Result and Discussion

Industrial material in the study area

These are rocks and nonmetallic mineral occurrences that have economic importance and can be used directly without major processing as industrial material like carbonate rocks and kaolinite residual soils that are used as raw materials in many industries.

Marbles and marls are frequently exposed at many localities in the study area mainly at the north eastern and south eastern region Plate (1). In addition, unique white soil horizons characterize the study area, which may constitute addition economic preference to the area.

Marbles and marls

Marbles are exposed as minor low line out crops to the north east and south west of the study area with dark impurities most probably of ferric minerals and other transitional elements. Other rock units that are related to the marble in many localities are marls, i.e. carbonate with considerable amount of clay minerals Table (1) and Fig (4.5).

Table (1): Metasediments chemical analysis (Marl).

Oxide	Concentration (%)
SiO ₂	41.07
TiO ₂	1.17
Al ₂ O ₃	19.01
Fe ₂ O ₃	14.67
MnO	0.12
MgO	7.18
CaO	15.06
Na ₂ O	0.84
K ₂ O	0.09
P ₂ O ₅	0.01
Cr ₂ O ₃	0.01
LOI	0.83



Plate (1): Marble in north east area.

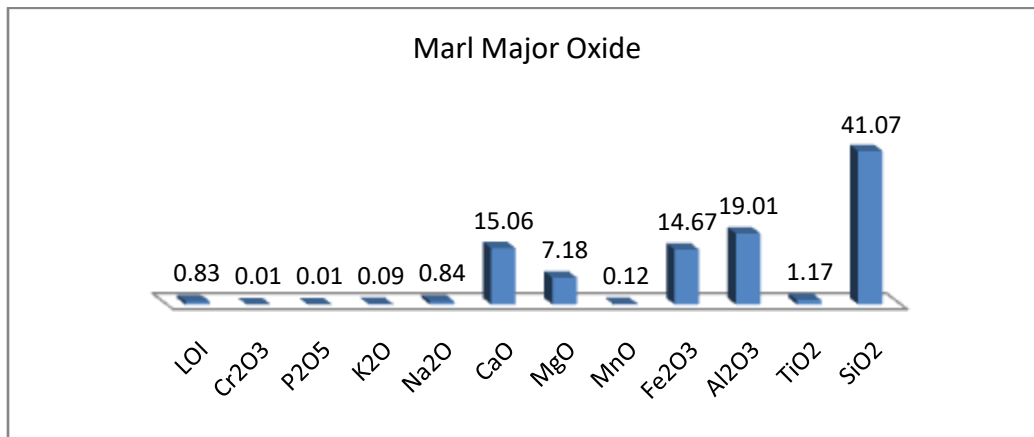


Fig (4): Histogram represents the major oxide constituent of marl as weight percent.

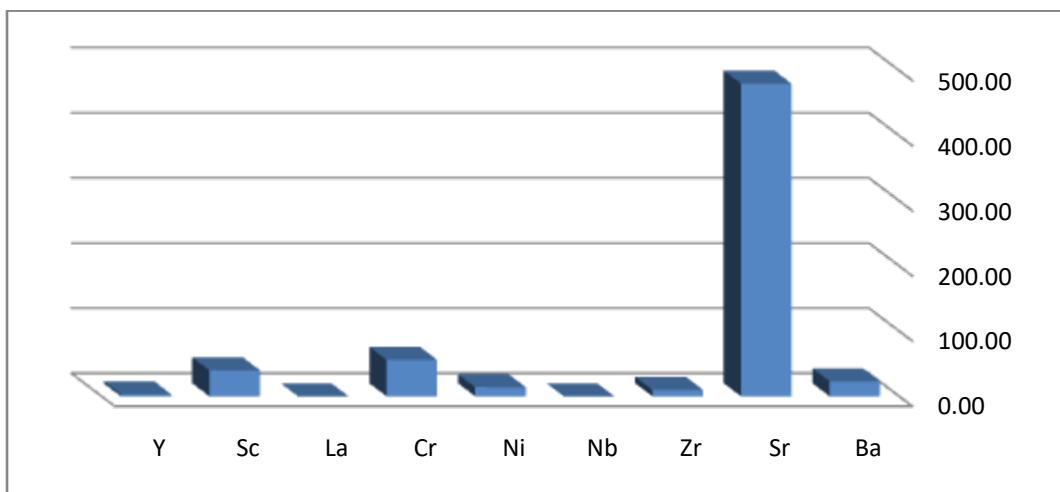
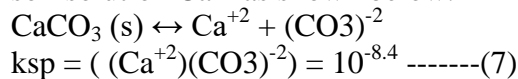


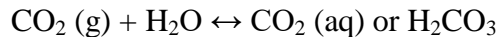
Fig (5): Histogram represents trace element constituent of marl ppm.

That means CaCO_3 re-dissolves with increasing CO_2 concentration in the gaseous phase. However, in soils with relatively high concentrations of Ca^{+2} and limited water content, reaction (5) is favored and reaction (6) is suppressed. When CaCO_3 is present in soils at high concentrations, say several percent, then it controls both soil pH and soil solution Ca^{+2} as shown below.



Carbonate species in soil solution

CO_2 dissolves in water to form a weak acid, H_2CO_3 .



The solubility of CO_2 and other gases is governed by Henry’s law, which relates the partial pressure of a gas to its concentration in solution.

$$KH = (\text{H}_2\text{CO}_3) / \text{PCO}_2 = 10^{-1.5} \text{ -----(8)}$$

H_2CO_3 , however, doesn’t stay as it is, but it dissociates into $(\text{HCO}_3)^{-1}$ and $(\text{CO}_3)^{-2}$ ions as the pH increases .

The concentrations of various ions can be calculated from these equations by assuming a value for P_{CO_2} . From these equations, acidity of rain water can be calculated by assuming that rain is in equilibrium with CO_2 of the atmosphere ($\text{P}_{\text{CO}_2} = 0.00038$). pH of such water would be around 5.6-5.7.

The above mentioned four process (A,B,C, and D) were responsible for the formation of

the characteristic soil horizon Fig (4) and Plate (2) that formed at the distal reaches of wadi Nuwaiq and El-Gambarawi in addition to other minor Khors at El-Firjah to form El-Firjah swamp in autumn season and evaporate in summer season, as a consequence carbonate minerals formed and as a result of the hydrolysis processes of feldspar the clay minerals (kaolinite), gibbsite, and hematite are formed Table (2) and Fig (6).

Table (2): Exhibit bulk chemical composition of soil at El Firjah swam area note the high percentage of lime, silica, LOI, and alumina.

Oxide concentration in%	Soil sample A	Soil sample B
SiO_2	13.05	28.87
TiO_2	0.01	0.20
Al_2O_3	1.30	4.18
Fe_2O_3	0.57	1.75
MnO_2	0.04	0.07
MgO	2.30	2.85
CaO	43.79	31.66
Na_2O	0.05	0.25
K_2O	0.12	0.47
P_2O_5	0.05	0.10
Cr_2O_3	<0.01	<0.01
LOI	37.9	29.29
Total	99.2	99.69

This phenomenon is repeated in the entire region in many other regions where potential industrial soil horizon is accumulated, and still is going to be forming year after year.

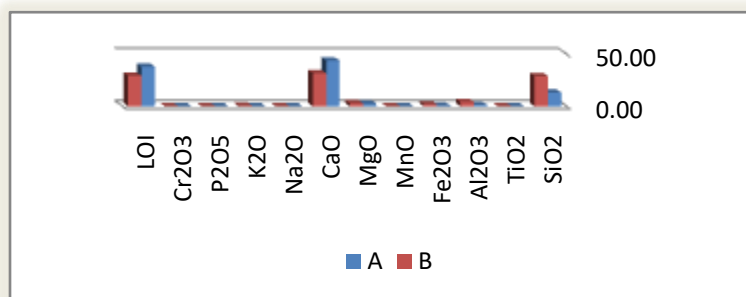


Fig (6): Histogram represents chemical analysis of soil horizon at El- Firjah Swam area (two samples a & b) note the high percentage of lime, silica, LOI.



Plate (2): Exhibits the carbonate kaolintic soil at El-Firjah swam area at dry season, note the shell of Gastropoda at the right photo.

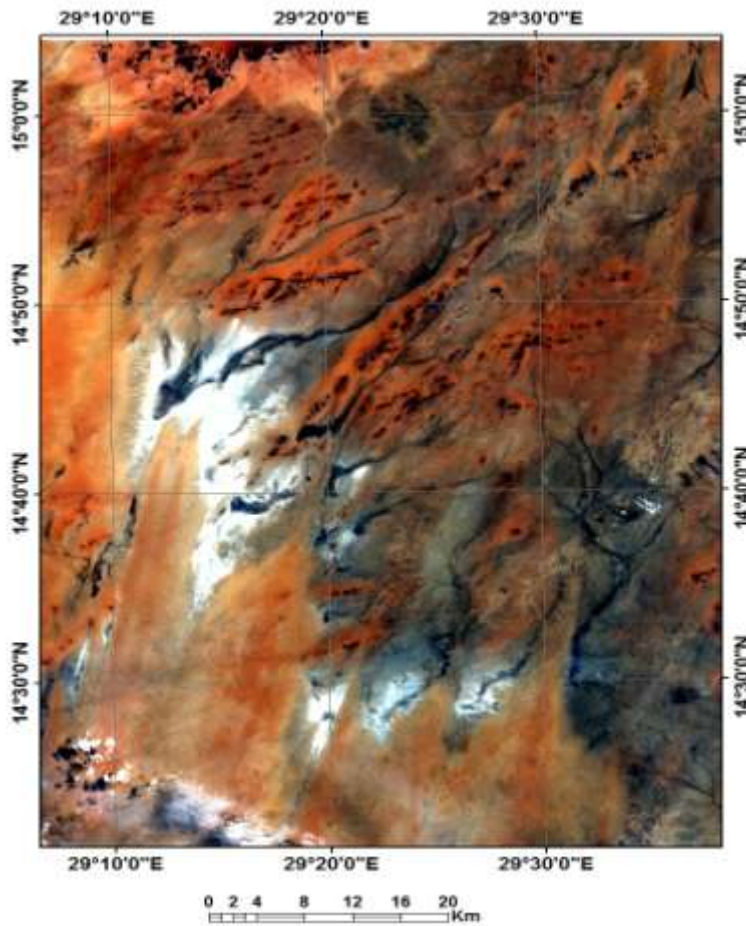


Plate (3): ETM⁺(742) band composite image exhibits the characteristic soil horizon at El-Firjah swam area.

Conclusion

Basement metasediments carbonate rock (marble and marl) in addition to silicate rock exposure at upstream areas (wadi Nuwaiq and wadi El Gambarawi) at high land in the study area were subjected to extensive chemical reaction to produce suspended material mainly kaolinite as product of hydrolysis of feldspar mineral from granite granodiorite meta andesite ..etc. equation (1 and 2). The second major chemical process is the dissolution of carbonate mineral from marble and marl.

The weathering product i.e. both suspended materials (clay mineral), and the dissolved materials mainly (Ca^{++} , and HCO_3) were transported by the above mentioned wadis to downstream flash delta area and deposited by settle down processes in El Firjahswam (Gastropoda) and eventually due to evaporation in summer to produce the characteristic white soil horizon in the study area.

This soil has economic importance since it constitutes somewhat pure material concentrated by physicochemical processes.

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