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ASSESSMENT OF SOLID MINERALS AND ELEMENTAL COMPOSITION OF ROCKS AND SOIL SAMPLES FROM SUKUR HILLS, MADAGALI, NIGERIA

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ABSTRACT

Mineral exploration is a critical component of any economy, and comprehensive geoscience data of a location provides critical information about the location's mineral exploration potential. This study evaluates the mineral composition of the rocks and soil samples from the area covering the Sukur Hill in Madagali, to provide geoscience insight of the area. Untapped rock and soil samples were obtained from five locations and labeled as follows: Sukur east rock (SER), Sukur north rock (SNR), Sukur south rock (SSR), Sukur center rock (SCR) and Sukur west rock (SWR), as well as Sukur east soil (SES), Sukur north soil (SNS), Sukur south soil (SSS), Sukur center soil (SCS) and Sukur west soil (SWS) respectively. X-ray diffraction (XRD) was used for the identification of solid minerals while X- ray florescence (XRF) was used for the analyses of the elemental oxides. Six minerals were found in the sample locations, according to the spectroscopic analysis. These include: albite, annite, kaolinite, microcline, orthoclase, and quartz. Quartz (36.6 - 100%) was recorded in all locations of the area, while annite (4%) and orthoclase (33%) were only recorded in SER and SCR respectively. The soil samples from the area shows the presence of albite, annite, kaolinite, microcline, montmorillonite, quartz, rutile, tremolite, zircon, phlogopite and calcite. The major and minor elemental oxides in rock samples studied follow the order $SiO_2 > Fe_2O_3 > Al_2O_3 > K_2O > SO_3 > CaO$, and $BaO > TiO_2 > P_2O_5 > ZnO > MnO$ respectively, while the major and minor elemental oxides in soil samples follow the order $SiO_2 > Al_2O_3 > Fe_2O_3 > CaO > K_2O > MgO > SO_3$, and $P_2O_5 > TiO_2 > BaO > Zr\ O_2 > MnO > Rb_2O$, respectively. The elemental oxides recorded in this study compliments the minerals identified in the area. The overall results from this study makes valuable contributions to the mineral deposit assay of the area and this will provide handy information for future exploration.

Keywords: *Elemental Oxides; Minerals; Rocks; Soil; XRD; XRF*

INTRODUCTION

Nigeria grew through revenue from agricultural products before the discovery of crude petroleum in 1964, among many other valuable natural resources in the country. Since the discovery, the nation has moved towards a mono-economy system, as the economy of the nation continued to be majorly bench-marked by the price of crude oil. The development of Nigeria has therefore been handicapped due to the single dependence on oil wealth at the expense of all other naturally abundant resources including agricultural and minerals lying throughout the landscape of the country. Considering global events such as the economic melt-down that in 2008 [1], COVID-19, unpredictable emergence and shift in world political powers and emergence of new oil producing nations, which have recurrently influence the prices of crude oil, and the fact that crude oil deposits are depletable, the Nigerian monolithic economy will continue to face challenges with sustainability. The dwindling world market price of crude oil makes it obvious that for Nigeria to be able to sustain its economy, the oil revenue must be used to develop the other sectors of the economy such as agriculture, solid minerals, manufacturing and infrastructure [2]. Rocks are minerals and these are commonly found everywhere in Nigeria. In the earth, on top of the earth to create mountains, and at the bottom of the oceans, rocks can be found. Granite and basalt are two of the main types of rock that make up the crust of the Planet. One mineral predominates in the composition of some minerals. For instance, the sedimentary rock known as limestone is almost completely made up of the mineral calcite. Numerous minerals are found in other rocks, and the particular minerals that make up a rock can vary greatly from one rock to another [3]. Some crystals, like quartz, mica, or feldspar, are widespread, while others have only been discovered in a small number of places on Earth. Quartz, feldspar, mica, chlorite, kaolin, calcite, epidote, olivine, augite, hornblende, magnetite, hematite, and limestone make up the overwhelming majority of the rocks that make up the crust of the earth [4].

Chemical composition is the primary identity of every mineral or rock. The most prevalent mineral in limestone is calcite, which is composed of calcium carbonate. Sandstones and some other igneous rocks with significant silica content frequently contain quartz. The mode of origin of the rock and the phases it went through to arrive at its current state are the two main factors that are of equal importance in determining the nature of the rock-forming minerals [3, 5–6]. Even though two rock masses may share the same overall composition, their mineral assemblages may be completely distinct. Granite is a rock formed by the consolidation of molten magma under extreme pressure and temperature, with the mineral composition remaining constant. Some of these original minerals, like quartz and white mica, are relatively stable and stay unaffected when exposed to moisture, carbonic acid, and other agents at the typical temperatures of the earth's surface. Other original minerals weather or decay and are replaced by new combinations. The rock collapses into a loose, incoherent earthy mass that can be viewed as sand or soil as a result of these changes, which are accompanied by disintegration [3–4, 6].

Robust geoscience data are very necessary for future mining and metallurgical processes. The mineral assay of rocks and other forms of mineral deposits in Adamawa State has been well reported in the literature [2, 7-10]. However, these reports call for further research into the wide and untouched rocks and other minerals deposits in the State, so as to make further reports in the build-up to a comprehensive geoscience data of the State. The aim of the study is to provide wider report on the mineral deposits in Adamawa State, by investigating the mineral composition of the rocks and soil samples from Sukur hills in Madagali local government of Adamawa state. The minerals in the rock and soil samples in this location were analyzed using X-ray Diffraction Spectroscopy (XRD), and Xray fluorescence spectroscopy (XRF) was used to analyze the elemental oxides corroborating the presence of the minerals in the samples.

MATERIALS AND METHODS

Materials

The materials and apparatus that were used in this study include: stearic acid, hand anger, pestle and mortar, hammer and chisel, spatula, soil thief, weighing balance, crucibles, and polyethene bags.

Study Area

The area earmarked for the study is Sukur cultural land scape, it is a UNESCO first African cultural landscape with geographical coordinates Latitude10 46” 00 N and 13 45”09 N, Longitude 13 33 “35 E and 13 34 13” E (Figure 1). Sukur is located in Madagali Local Government Area of Adamawa State, Nigeria. The cultural landscape has many spiritual, aesthetic, political and archaeological qualities characterized by the use of stone to define administrative space as in the architecture of the Hidis palace, spiritual spaces as the shrines and graveyards.

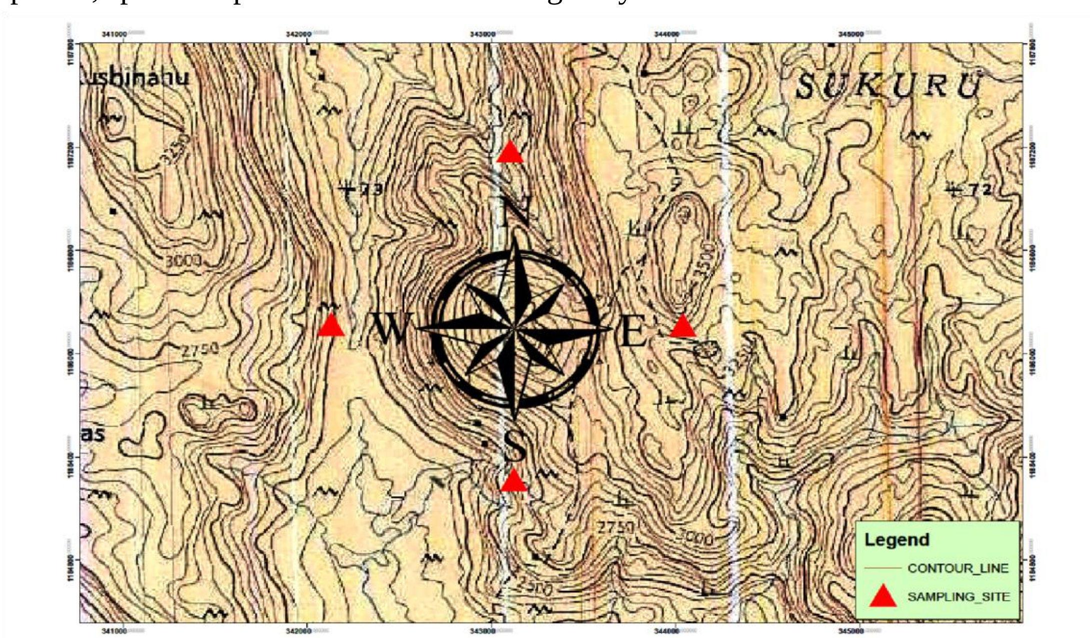

Figure 1: Topography mapping of Sukur hill indicating the sampling sites

Sampling

The Sukur Hills was divided into five locations in order to make sure that samples so collected represent the areas granitic nature. The sample locations and their codes are as follows:

1.	Sukur East Rock	SER
2.	Sukur North Rock	SNR
3.	Sukur South Rock	SSR
4.	Sukur Center Rock	SCR

5.	Sukur West Rock	SWR
6.	Sukur East Soil	SES
7.	Sukur North Soil	SNS
8.	Sukur South Soil	SSS
9.	Sukur Center Soil	SCS
10.	Sukur West Soil	SWS

Sample Preparation

The rock sampling was collected with the aid of a chisel used to dig deep into the rock and obtain unweathered samples of the rock [2]. The rock samples when collected were carefully wrapped in clean paper bags and kept in a polyethylene bag. Each sample was weighed (300 g), and labeled before they were moved to the laboratory for further preparations. The soil samples were collected using a soil thief which penetrates to about 50 cm depth and the soil so collected is transferred into a polyethene bag and labeled. Before analysis the rock and soil samples were thoroughly washed, dried in the sun and then crushed and ground to fine powder.

X-ray Diffraction Spectroscopy (XRD) Analysis

The samples were analyzed using a Rayon X-ray diffraction spectrophotometer (XRD) [PANanalytical Empyrean, Netherlands], at the Nigerian Geological Survey Agency, Kaduna, Nigeria. The method reported by Dutrous and Clark [11], as detailed in our previous work [2], was also adopted in this study. Information about the compound name, chemical formula, density, and crystal structure of minerals identified were provided from equipment library.

X-ray Fluorescence Spectroscopy (XRF) Analysis

X-ray fluorescence spectroscopy analysis was also carried out using Energy Dispersive X-Ray fluorescence (EDXRF) spectrometer of model miniPal 4 PANanaltical. The detailed procedure was also reported in our previous study [2].

RESULTS AND DISCUSSION

Mineral Components of Rock and Soil Samples

Rocks are typical natural mixtures of minerals. X-ray diffraction is a very useful analytical technique in the identification of the constituents of a solid mineral bulk based on the unique crystallography of each constituent solid mineral in the bulk [12-13]. Figure 2[(a) – (e)] presents the XRD spectra of rock samples from the different sampling locations in the study area. The percentage composition of each solid mineral in each sample is also presented on the XRD spectra. Table 1 complementarily present the compound names, chemical formula, and the crystal system of the minerals identified in Figure 2[(a) – (e)]. The results showed that Sukur hill rock is rich with quartz, as the mineral takes more than 35% composition of all the rock samples collected in the area. The highest quartz was recorded in SNR (100%) while the least was recorded in SER (36.6%). The dominance of quartz in the area agrees with some previous studies on rocks in Adamawa state Nigeria [14-15]. Quartz is highly resistant to mineral weathering [4, 16]. Hence, it is the typical remnant mineral in most tropical rocks. Microcline and Kaolinite were recorded in three locations; hence these follow quartz in order of abundance in the studied area. Microcline was recorded at SER (31.7%), SSR (14%) and SWR (40.6 %). Kaolinite was recorded at SSR (8.0%), SCR (14%) and SWR (7.9 %). Albite was recorded in two locations (SER: 27.7% and SSR 17. 0%), while Annite and Orthoclase were recorded only at SER (4.0%) and SCR (33.0%) respectively.

Figure 3[(a) – (e)] presents the XRD spectra of the soil samples from different locations of the study area. Table 1 presents the compound names, chemical formular, and the crystal system of the minerals identified in Figure 3[(a) – (e)]. Quartz was also the most abundant mineral in the soil samples from the study area, as it was found in all soil samples from all the studied locations except Sukur north. Albite and microcline were recorded in three of the five studied locations; hence, these followed quarts in order of mineral abundance in the area. Contrary to the results from the rock samples, orthoclase (recorded in SCR) was not recorded in soil samples, while tremolite, phlogopite, montmorillonite, calcite, rutile and zircon which were recorded in the soil samples were not present in the rock samples. This inferred that the soil in the area is not majorly constituted by the weathering of the rocks in the area. Table 3 present a comparison of the minerals recorded in the rock and soil samples obtained from the different locations of the study area.

Quartz is used in making glass, especially for the fabrication of electromagnetic radiation window in optical instruments [17]. Microcline is used industrially in the production of glass and reinforcing agent in the fabrication of ceramic products and ornamental lapidary material [18]. Albite is an alternative source of elemental sodium. Albite has been fused and used as geologic fluid and as a solvent for rutile (titanium oxide) [19]. Kaolinite is used in catalysis; it is of remarkable geological importance as it stabilizes mechanical properties of sediments [20]. Tremolite occurs as a result of contact metamorphism of calcium and magnesium rich siliceous sedimentary rocks and in greenschist facies metamorphic rocks derived from ultramafic or magnesium carbonate bearing rocks. Tremolite is an indicator of metamorphic grade since at high temperatures it converts to diopside [21]. Montmorillonite is used in the oil drilling industry as a component of drilling mud, making the mud slurry viscous, which helps in keeping the drill bit cool and removing drilled solids. It is also used as a soil additive to hold soil water in drought-prone areas [22-23]. Rutile a (tetragonal) and anatase also (tetragonal) the two among the three crystalline polymorphs of titanium oxide in existence, the other being brookite (orthorhombic) [24]. While rutile is the most stable phase, anatase is a metastable phase and transform to rutile upon heating [25]. The majority of the applications of TiO_2 are strongly influenced by the crystalline phase.

Rutile phase has been widely used for pigment materials because of its chemical stability [26]. Zircon can be found in a variety of hues, such as reddish brown, yellow, green, blue, gray, and white. Heat treatment can occasionally alter the color of zircons. By heating to 800–1,000 °C, ordinary brown zircons can be changed into translucent and blue ones. Zircon is a frequent component of most sands and endures in sedimentary deposits due to its hardness, durability, and chemical inertness. The decorative ceramics business has been known to use zircon, which is primarily used as an opacifier [21, 27].

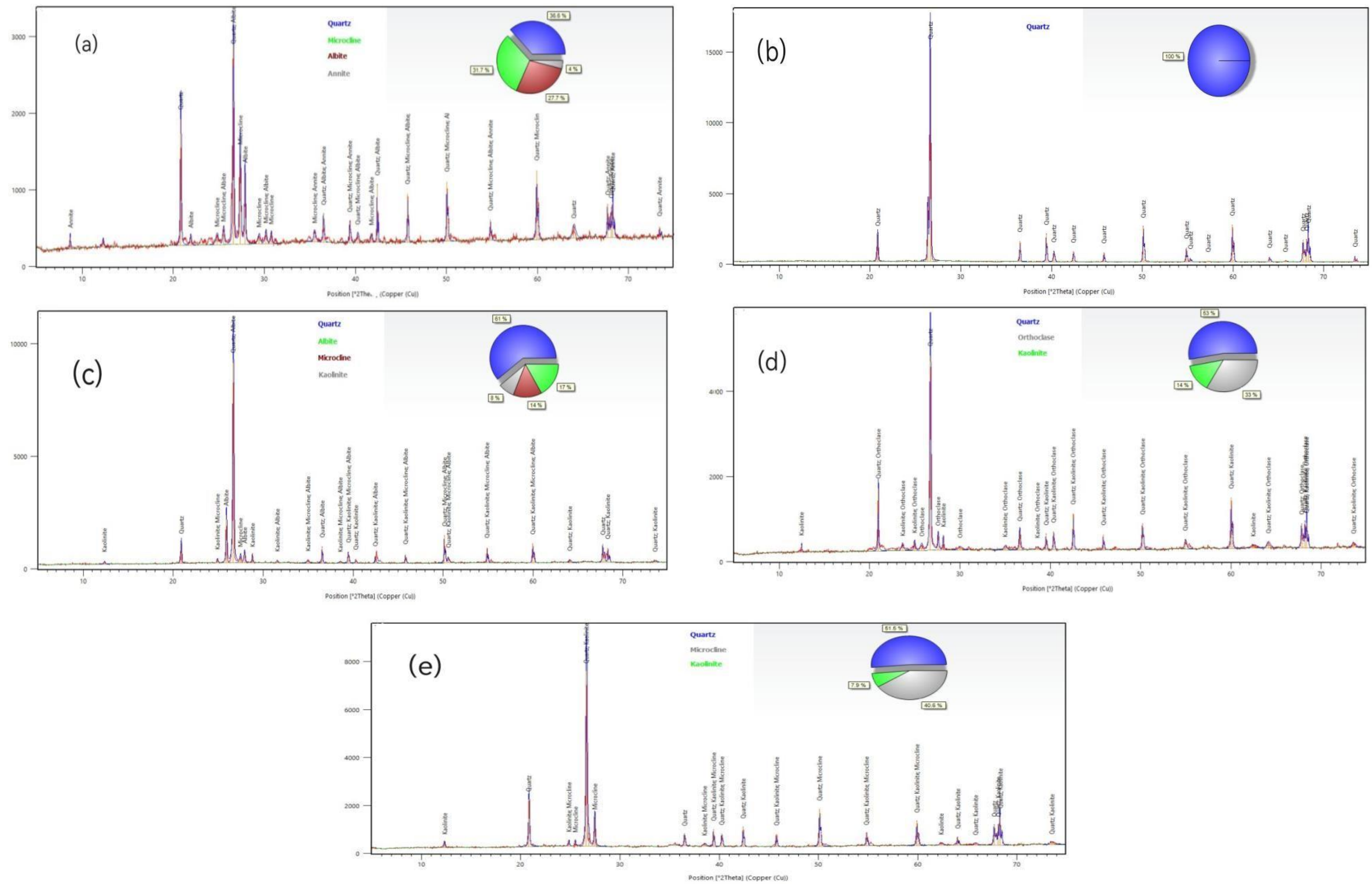

Figure 2: X-ray diffraction spectrums of (a) SER (b) SNR (c) SSR (d) SCR (e) SWR

Table 1: Minerals identified in the rock samples from Sukur Hills

Location	Minerals Identified	Compound Name	Chemical Formula	Density g/cm^3	Crystal System	% Composition
SER	Quartz	Silicon Oxide	$Si_{3.0}\ O_{6.0}$	3.87	Hexagonal	36.6
	Microcline	Potassium Sodium Aluminium Silicate	$K_{1.90}\ Na_{0.10}\ AL_{2.0}\ Si_{6.0}\ O_{16.0}$	2.56	Anorthic	31.7
	Albite	Sodium Aluminium Silicate	$Na_{2.0}\ AL_{2.0}\ Si_{6.0}\ O_{16.0}$	2.62	Anorthic	27.7
	Annite	Potassium Aluminium Iron Magnesium Silicate Hydroxide	$AL_{3.42}\ Si_{5.12}\ Mg_{0.24}\ Fe_{4.74}\ Ti_{0.06}\ Mn_{0.06}\ K_{2.0}\ O_{23.92}\ F_{0.08}\ H_{3.80}$	3.21	Monoclinic	4.0
SNR	Quartz	Silicon Oxide	$Si_{3.0}\ O_{6.0}$	2.65	Hexagonal	100.0
SSR	Quartz	Silicon Oxide	$Si_{3.0}\ O_{6.0}$	2.65	Hexagonal	61.0
	Albite	Sodium Aluminium Silicate	$Na_{1.90}\ Ca_{0.04}\ Si_{5.96}\ Al_{2.04}\ O_{16.0}$	2.62	Anorthic	17.0
	Microcline	Potassium Sodium Aluminium Silicate	$K_{1.90}\ Na_{0.01}\ Al_{2.0}\ Si_{6.0}\ O_{16.0}$	2.56	Anorthic	14.0
	Kaolinite	Aluminium Silicate Hydroxide	$Al_{2.0}\ Si_{2.0}\ O_{9.0}\ H_{4.0}$	2.61	Anorthic	8.0
SCR	Quartz	Silicon Oxide	$Si_{3.0}\ O_{6.0}$	2.65	Hexagonal	53.0
	Orthoclase	Potassium Aluminium Silicate	$K_{4.0}\ Si_{12}\ Al_{4}\ O_{32.0}$	2.57	Monoclinic	33.0
	Kaolinite	Aluminium Silicate Hydroxide	$Al_{2.0}\ Si_{2.0}\ O_{9.0}\ H_{4.0}$	2.61	Anorthic	14.0
SWR	Quartz	Silicon Oxide	$Si_{3.0}\ O_{6.0}$	2.65	Hexagonal	51.5
	Microcline	Potassium Sodium Aluminium Silicate	$K_{1.90}\ Na_{0.10}\ Al_{2.0}\ Si_{6.0}\ O_{16.0}$	2.56	Anorthic	40.6
	Kaolinite	Aluminium Silicate Hydroxide	$Al_{2.0}\ Si_{2.0}\ O_{9.0}\ H_{4.0}$	2.61	Anorthic	7.9

Key: Sukur east rock =SER, Sukur north rock =SNR, Sukur south rock =SSR, Sukur center rock =SCR and Sukur west rock =SWR

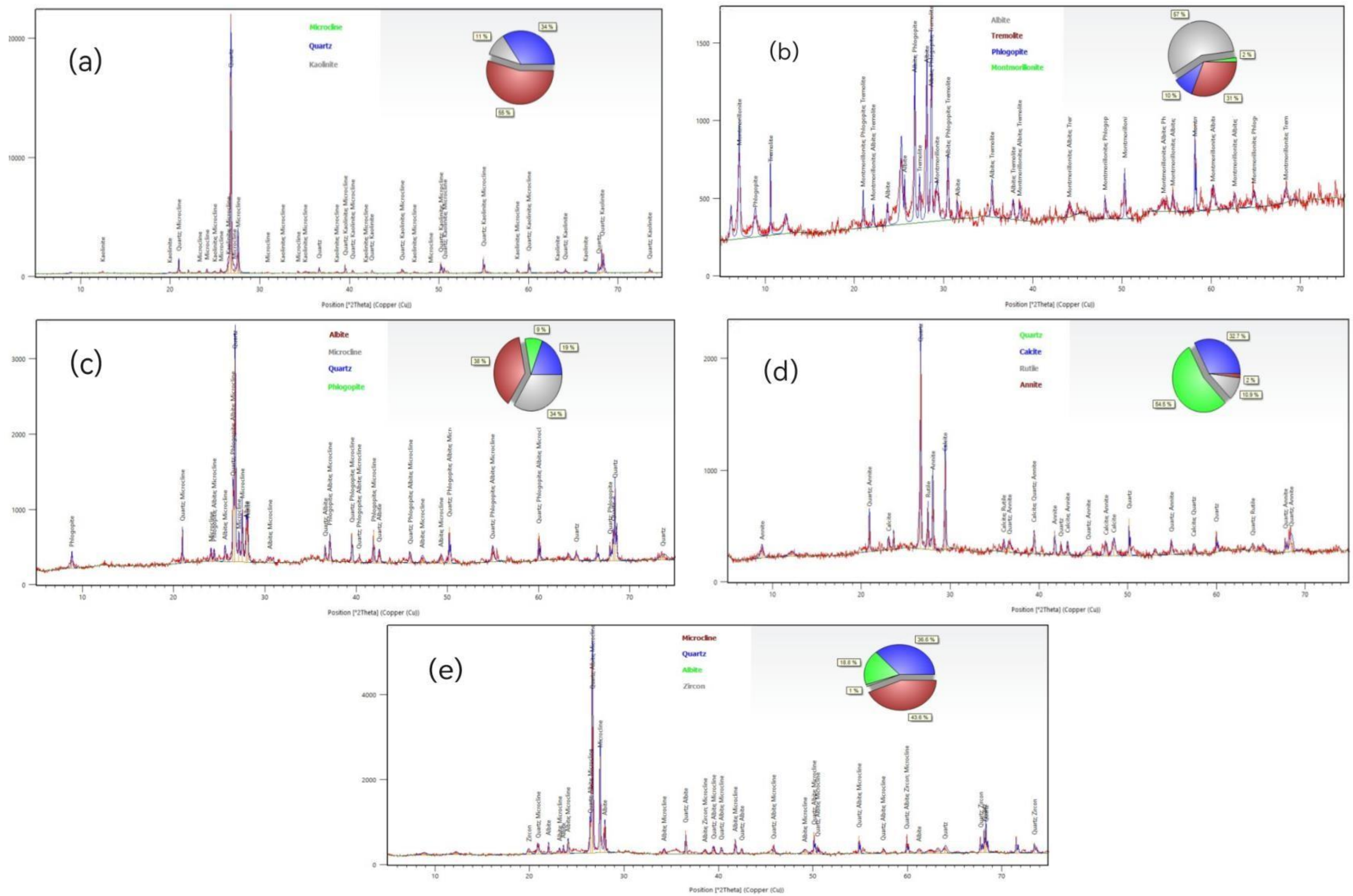

Figure 3: X-ray diffraction spectra of (a) SES (b) SNS (c) SSS (d) SCS (e) SWS

Table 2: Minerals identified in the soil samples from Sukur Hills

Location	Minerals Identified	Compound Name	Chemical Formula	Density G/Cm^3	Crystal System	% Composition
SES	Microcline	Potassium Aluminium Silicate	$K_{1.9}$ $Na_{0.1}$ $Al_{2.0}$ $Si_{6.0}$ $O_{16.0}$	2.56	Anorthic	55.0
	Quartz	Silicon Oxide	$Si_{3.0}$ $O_{6.0}$	2.65	Hexagonal	34.0
	Kaolinite	Aluminium Silicate Hydroxide	$Al_{2.0}$ $Si_{2.0}$ $O_{9.0}$ $H_{4.0}$	2.61	Anorthic	11.0
SNS	Albite	Sodium Aluminium Silicate	$Na_{2.0}$ $Al_{2.0}$ $Si_{6.0}$ $O_{16.0}$	2.68	Anorthic	57.0
	Tremolite	Calcium Magnesium Silicate Hydroxide	$Mg_{9.90}$ $Fe_{0.10}$ $Ca_{4.0}$ $Si_{16.0}$ $O_{48.0}$ $H_{4.0}$	2.98	Monoclinic	31.0
	Phlogopite	Potassium Magnesium Iron Aluminium Silicate	$K_{1.74}$ $Na_{0.12}$ $Mg_{3.0}$ $Fe_{2.22}$ $Ti_{0.78}$ $Al_{2.16}$ $Si_{5.84}$ $O_{24.0}$	3.07	Monoclinic	10.0
	Montmorillonite	Sodium Magnesium Aluminium Silicate Hydroxide Hydrate	$Na_{0.3}$ (Al Mg) $Si_{4.0}$ O_{10} OH_2. $6H_2O$	2.65	Hexagonal	01.0
SSS	Albite	Sodium Aluminium Silicate	$Na_{2.0}$ $Al_{2.0}$ $Si_{6.0}$ $O_{16.0}$	2.68	Anorthic	38.0
	Microcline	Potassium Aluminium Silicate	$K_{1.9}$ $Na_{0.1}$ $Al_{2.0}$ $Si_{6.0}$ $O_{16.0}$	2.56	Anorthic	34.0
	Quartz	Silicon Oxide	Si_3 $O_{6.0}$	2.65	Hexagonal	19.0
	Phlogopite	Potassium Magnesium Iron Flora Aluminium Silicate	$K_{1.84}$ $Na_{0.08}$ $Mg_{3.12}$ $Fe_{2.34}$ $Ti_{0.29}$ $Mr_{0.12}$ $Si_{5.94}$ $Al_{2.01}$ $O_{22.12}$ $F_{1.88}$	3.12	Monoclinic	09.0
SCS	Quartz	Silicon Oxide	$Si_{3.0}$ $O_{6.0}$	2.64	Hexagonal	54.5
	Calcite	Calcium Carbonate	$Ca_{6.0}C_{6.0}$ $O_{18.0}$	2.71	Hexagonal	32.7
	Rutile	Titanium Oxide	$Ti_{2.0}$ $O_{4.0}$	4.25	Tetragonal	10.8
	Annite	Potassium Iron Aluminium Silicate	$Si_{5.1}$ $Al_{6.9}$ $Fe_{6.0}$ $K_{1.98}$ $Na_{0.02}$ O_{24}	3.69	Monoclinic	02.0
SWS	Microcline	Potassium Aluminium Silicate	$K_{1.9}$ $Na_{0.10}$ $Al_{2.0}$ $Si_{6.0}$ $O_{16.0}$	2.56	Anorthic	43.6
	Quartz	Silicon Oxide	$Si_{3.0}$ $O_{6.0}$	2.64	Hexagonal	36.6
	Albite	Sodium Aluminium Silicate	$Na_{1.96}$ $Ca_{0.04}$ $Si_{5.96}$ $Al_{2.04}$ $O_{16.0}$	2.62	Anorthic	18.8
	Zircon	Zirconium Silicate	$Zr_{4.0}$ $Si_{4.0}$ $O_{16.0}$	4.67	Tetragonal	10.0

Key: Sukur east soil =SES, Sukur north soil =SNS, Sukur south soil =SSS, Sukur center soil =SCS and Sukur west soil =SWS

Table 3: Comparisons of minerals and their percentage composition in the rock and soil samples obtained from the same location.

Location	Minerals Identified	Mineral composition in samples (%)	
		Rock	**Soil**
Sukur East	Microcline	31.7	55.0 ↑
	Quartz	36.6 ↑	34.0
	Kaolinite	-	11.0
	Albite	27.7	-
	Annite	4.0	-
Sukur North	Albite	-	57.0
	Tremolite	-	31.0
	Phlogopite	-	10.0
	Montmorillonite	-	01.0
	Quartz	100	-
Sukur South	Albite	17	38.0 ↑
	Microcline	14	34.0 ↑
	Kaolinite	8	-
	Quartz	61 ↑	19.0
	Phlogopite	-	09.0
Sukur Center	Quartz	53.0	54.5 ↑
	Orthoclase	33.0	-
	Kaolinite	14.0	-
	Calcite	-	32.7
	Rutile	-	10.8
	Annite	-	02.0
Sukur West	Microcline	40.6	43.6 ↑
	Quartz	51.5 ↑	36.6
	Kaolinite	7.9	-
	Albite	-	18.8
	Zircon	-	10.0

- = Not found; ↑ = higher

Elemental Oxides Constituents of Rock and Soil Samples

X-ray florescence (XRF) is an excellent technique used to identify elements and their oxides based on the unique characteristics of energy emitted by the species after excitation by an incident X-ray [28]. Major and minor elemental oxides constituted in the rock samples are presented Table 3 and 4.

The results show that SiO_2, Al_2O_3, Fe_2O_3, K_2O, SO_3 and CaO exist at all the locations in variable quantities. The sequence appears as thus; $SiO_2 > Fe_2O_3 > Al_2O_3 > K_2O > SO_3 > CaO$. SiO_2 is the most abundant with the range of 54.28 and 91.35 %. Fe $_2O_3$ with the range of 1.15 and 18.9 2 %, Al_2O_3 within 4.49 and 14.90 % and SO_3 has 0.38 and 3.91 %. The location SNR where XRD showed 100 % quartz was also revealed in the XRF results with 91.35 % SiO_2. The results are comparable with results reported rock samples from Hong, Adamawa state by Tadzabia et al. [10]. For the minor elemental oxides (Table 4), BaO dominates at one location SSR. This shows that in addition to minerals recorded in the location (Figure 2(c) and Table 1), traces of barite are also present in the location. The presence of minor elemental oxides followed the order BaO > TiO_2 > P_2O_5 > MnO > ZrO_2, and these shows order of minerals in trace amounts in the rock samples.

The results of major and minor elemental oxides in the soil samples are presented in Table 5 and 6. Based on their range, presence of major elemental oxides follow the order SiO_2 > Al_2O_3 > Fe_2O_3 > CaO> K_2O > MgO > SO_3.The oxides appeared in the following ranges SiO_2 appeared within 41.37-62.18 %, Al_2O_3 between 13.57-21.76 %, Fe_2O_3 7.8-16.76 %, CaO 1.09- 20.46 %, K_2O 3.77-7.24 %, MgO1.8- 4.4 % and SO_3 within 0.47-1.26 %. Na_2O was detected at STS only. These results are also comparable with the those reported for some soil samples [29]. For the minor elemental oxides, P_2O_5 was detected at all the locations with the highest appearance of 3.88 % at STS while others are less than 1%. TiO_2 also appeared at all the locations with the highest percentage of 1.86 % at SNS. Chlorine also appeared at all the locations with the highest percentage of 0.65 % at SSS. Barium oxide was detected in few places with the highest percentage of 1.56 % at SSS. ZrO_2 also appeared at all the locations with highest appearance of 0.27 % at STS. MnO was detected at all the locations of the area with the highest value of 0.28 % at SNS.

Table 3: Percentage composition of major elemental oxides in rock samples

Location	SiO_2	Al_2O_3	Fe_2O_3	CaO	SO_3	K_2O
SER	56.59	13.5	18.92	1.38	0.47	6.1
SNR	91.35	4.49	1.15	0.24	0.42	1.05
SSR	54.28	11.28	14.98	0.7	3.91	3.86
SCR	62.68	14.71	13.85	0.39	0.43	5.48
SWR	62.46	14.9	14.79	0.36	0.38	4.73
Range	54.28	4.49	1.15	0.24	0.38	1.05
	91.35	14.9	18.92	1.38	3.91	6.1

Key: Sukur east rock =SER, Sukur north rock =SNR, Sukur south rock =SSR, Sukur center rock =SCR and Sukur west rock =SWR

Table 4: Percentage composition of minor elemental oxides in rock samples

Location	TiO_2	BaO	P_2O_5	ZrO_2	MnO
SER	1.1	0.15	0.36	0.33	0.36
SNR	0.16	-	0.69	0.05	-
SSR	-	9.28	0.42	0.27	0.29
SCR	1.0	-	0.39	0.32	0.18
SWR	0.99	-	0.38	0.28	0.18
Range	0.16	0.15	0.36	0.05	0.18
	1.1	9.28	0.69	0.33	0.36

Key: Sukur east rock =SER, Sukur north rock =SNR, Sukur south rock =SSR, Sukur center rock =SCR and Sukur west rock =SWR

Table 5: Percentage composition of major elemental oxides in soil samples

Location	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O
SES	62.18	17.43	7.8	1.09	-	1.26	7.24	-
SNS	48.27	17.2	16.76	5.46	4.4	0.47	3.77	-
SSS	52.52	16.32	12.46	2.93	2.6	0.7	6.78	-
SCS	41.37	13.57	9.18	20.46	2.5	0.57	4.81	0.9
SWS	55.53	21.33	7.82	2.43	1.8	0.96	7.09	-
Range	41.37	13.57	7.8	1.09	1.8	0.47	3.77	
	62.18	21.33	16.76	20.46	4.4	1.26	7.24	0.9

Key: Sukur east soil =SES, Sukur north soil =SNS, Sukur south soil =SSS, Sukur center soil =SCS and Sukur west soil =SWS

Table 6: Percentage composition of minor elemental oxides in soil samples

Location	TiO_2	BaO	P_2O_5	ZrO_2	Rb_2O	MnO
SES	1.39	-	0.74	0.16	0.05	0.08
SNS	1.86	-	0.53	0.09	-	0.28
SSS	1.63	1.56	0.87	0.26	0.06	0.18
STS	1.29	0.1	3.88	0.27	0.07	0.18
SWS	1.4	-	0.72	0.16	0.06	0.09
Range	1.29	0.1	0.53	0.09	0.05	0.08
	1.86	1.56	3.88	0.27	0.07	0.28

Key: Sukur east soil =SES, Sukur north soil =SNS, Sukur south soil =SSS, Sukur center soil =SCS and Sukur west soil =SWS

CONCLUSION

The rock and soil samples collected from the five locations of the Sukur hills constitute minerals including; quartz, microcline, kaolinite, annite, albite, tremolite, phlogopite, montmorillonite, calcite, rutile and zircon. In accordance with most studies, quartz remains the most abundant mineral in the area. Some mineral such as tremolite, phlogopite, montmorillonite, calcite, rutile and zircon which were recorded in the soil samples alone, and these indicated that the soil in the area is not majorly formed from the weathering of the rocks. The results of the elemental oxides show that the abundance of major elemental oxides followed the order SiO_2 > Fe_2O_3 Al_2O_3 > K_2O > SO_3 > CaO > Na_2O. In the Soil samples, major oxides abundance followed the order SiO_2 > Al_2O_3 > Fe_2O_3 > CaO > K_2O > MgO > SO_3. The major elemental oxide composition in the locations mirrored the minerals identified. The results will present useful information about the mineral deposit in the study area, and this will serve good purpose in future exploration.

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