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GEOLOGY, WATER TYPES AND FACIE EVOLUTION OF THE OHAOZARA SALINE LAKE AREAS OF EBONYI STATE, NIGERIA

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Abstract: *Geological and Hydrochemical investigation of Okposi and Uburu Saline spring Areas of Ohaozara and Environs of Ebonyi State has been carried out. The study area is underlain by shales which vary from light to dark grey in colour, fine grained sandstone and mudstone which belong to the Asu River Group and the Ezeaku Shale, (Albian and Turonian respectively). Results of hydrochemical analysis revealed that* Ca^{2+}, Mg^{2+}, Fe^{2+}, Na^{+} *(cations),* Cl^{-}, SO_4^{2-}, NO_3^{-}, HCO_3^{-} *(anions) and* Br^{-}, Mn^{2+}, F^{-}, I^{-}, Al^{3+}, Mo^{2+}, Co^{2+}, Hg^{2+}, Cr^{3+}, Ni^{2+}, Cd^{2+}, Ag^{+} and Mn^{2+} *are the main geochemical constituents. Water facie evolution shows three water types namely, the calcium bicarbonate facies in the northern parts and sodium chloride facies with sodium/potassium bicarbonate facies in the southern parts. Groundwater flow pattern reveals predominance of recharge and discharge at the northern and southern parts respectively.*

Index Terms: Hydrochemical, Water types, Facies, Asu River Group and Ezeaku Group.

I. INTRODUCTION

Water is the most common solvent. Geographically, it covers about 71% of the entire area of the earth's surface and it is found in oceans, streams, seas, rivers, lakes, ponds, springs and underground (Ogunji et al, 2004). Biologically, water makes up a large proportion of the total body fluid system. The domestic, industrial, agricultural and recreational uses of water have been on the increase.

Water pollution resulting from artificial and natural sources has always been the problem militating against municipal, rural and general water supply in Nigeria. The pollutant sources have either been from improper refuse disposal, contaminants in host rock or natural processes of volcanism and water transportation processes beneath the earth. This is pertinent, as water during its movement and storage in aquifers, tends to dissolve minerals in their host rocks. Other possible sources of dissolved chemical and biological constituents in water include residues and leachates of metals from mining, agricultural fertilizers and organic inputs and outputs, disposal of radioactive wastes materials and sewage disposal. Higher concentrations of these constituents above toloratable standards tend to render the water unwholesome for any type of use (Freeze and Cherry, 1979). Obasi and Akudinobi (2013) and Egboka and Uma (1985) have carried out the assessment of the chemical constituent of the available water resources in the area and showed the major and minor constituents of the water resources of the area. This work is aimed at classifying the water resources of the area in terms of their hydrochemical facies, based on the distribution and amount of dissolved hydrochemical facies. Recommendations on the best option on management/utilization of water resources in the area by comparing the results of the study with global water quality guidelines will be made.

II. The Study Area

The study area covers Uburu and Okposi and environs in Ohaozara and Onicha Local Government Areas of Ebonyi State. (Fig.1.0). Geographically, the area is located between latitudes $6^{0}00^{I}$N and $6^{0}10^{I}$N, and longitudes $7^{0}42^{I}50^{II}$E and $7^{0}52^{I}50^{II}$E. The area extends from Isu in the North to Okposi in the South. Laterally, it extends from Asumgbom through Okposi and Uburu, and bounded by Umuka. Major villages within the study area include Uburu, Okposi, Umuka, Ndiagu-Onicha, Eneagu, Isuachara, Onicha – Uburu, Nkwegu-Isu, Obina and Umuniko.

Saline springs and lakes occur within a relatively narrow belt, which extends in a northeast-south- southwest direction. This include the Okposi Salt Lake (06° 02.23 N, 007° 48.337 E) and the Uburu Salt Lake (06° 02.971 N, 007° 44.799 E) (Obasi and Akudinobi, 2013). Surface drainage in the study area is irregular and consists originally of a number of small ephemeral streams. The streams generally flow in the north-south direction (Fig.2.0) into the Asu River, which is about 15Km south of the study area. Asu River controls the drainage of the study area. Flow of the Asu River during the dry season is near zero, implying a negligible base flow contribution. Other rivers and smaller streams, which contribute to the drainage, are Asumgbom River, River Atte, River Azuu, River Ovum, River Enu and River Oshi.

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Fig. 2: Map study area showing water sample locations

III. METHOD OF STUDY

Geologic field mapping was carried out to determine the geology of the area. Strikes and dips of beds were measured, and rock samples were collected for laboratory investigation. Water samples were also collected. A total of twenty- eight (28) Water samples were collected from groundwater and surface water sources for hydrochemical analysis. Twenty (20) samples were collected from boreholes while eight (8) were collected from surface sources (Fig 2.0). Temperature, electrical conductivity and pH were measured using a digital meter. Laboratory analysis for the concentration of major ions comprising Ca^{2+}, Mg^{2+}, Fe^{2+}, Na^{+}, $S0_4^{2+}$, $N0_3^{-}$, Cl^{-}, $HC0_3^{-}$ and $C0_3^{2-}$ was done using DR 2010 spectrophotometer. The results were analyzed and compared with the World Health Organization (WHO) standards for water quality.

IV. GEOLOGY OF THE STUDY AREA

The study area is underlain by the Asu River Group and the Ezeaku Formation (Fig 3.0). The Asu River Group is the oldest sedimentary rock in southeastern Nigeria (Simpson, 1954). It is exposed variously in the Abakaliki area where they are often referred to as the Abakaliki Shale. These rocks are overlain by the Ezeaku Formation, as there is no evidence to suggest the break between the Asu River Group and the Ezeaku Shale, although the junction has not been seen (Simpson, 1954). The area is predominantly underlain by shale, sandstones, siltstones, sandy shale and limestone. Based on the lithologic, structural and stratigraphic positions, three broad lithostratigraphic units have been recognized. These are:Unit A: the light-gray shale; unit B: the sandstone/siltstone; and unit C; the dark-gray shale, (Table 1.0, Fig.3). These units strike in the NE-SW direction and dip in the Southeast (SE) direction, with dips ranging between 17^0 - 45^0.

UNIT A: **The Light-Grey Shale Unit** covers a greater portion of the study area, predominantly the Western parts. The unit is composed of light-grey shale, which weathers into brownish shale. The shales are often pyritic, fossiliferous, easily fragmented, laminated, fissile and generally micaceous. This unit is also composed of fine-grained micaceous sandstones and sandy shale.

UNIT B: **The Sandstone/Siltstone Unit** overlie the light-grey shale unit although the contact is gradational. The unit is composed of whitish, fine to medium grained consolidated sandstone, siltstone and mudstone. The sandstone is well bedded, calcareous and highly indurated. The outcrops are massive in some places. These sandstones are intercalated with very fine whitish to greyish siltstones and mudstones, which occupy the lower parts of the unit.

UNIT C: **Dark-Grey Shale Unit** is predominant in the eastern part of the study area. The unit is composed of dark-grey, flaggy shale. These shales are highly indurated and calcareous. This is due to high content of organic matter. This unit is also composed of dark-grey calcareous limestones facie, interbedded with calcareous fine grained sandstone. These limestones occur as thin interbeds in the shale.

V. Results and Discussion

Ca^{2+} values of the study area ranges between 0.01mg/l-1.22mg/l, except in the Okposi salt lake where it increased excessively to 274.5mg/l.

Iron mostly occurs in the form of ferrous bicarbonates ($Fe(HC0_3)_2$), ferrous sulphate ($FeS0_4$), or ferrous chloride ($FeCl_2$), especially when it occurs in acidic surface water (Back and Hanshaw, 1971). The values of iron (Fe^{2+}) in the area ranges between 0 to 0.07mg/l, and the maximum value was recorded in the Uburu salt lake. However, the boreholes have low Fe^{2+} content. The Fe^{2+} content indicates a uniform value for all the aquifer units. The analysis revealed that the magnesium ion concentration in water samples in the area ranges between 0.34-2.62mg/l for the boreholes while that of surface water is also on that average, but the Okposi salt lake is excessively high, having a value of 990mg/l.

Potassium (K^+) and sodium (Na^+) are present in natural waters in low concentrations. They occur in plant and animal matters, and may be introduced to the environment as sewages, industrial effluents, agricultural fertilizers and other farm inputs. All these are leached into natural waters, contributing to concentrations in natural waters.

The concentration of HCO_3 ions ranges between 0.34mg/l-2.82mg/l for the boreholes and about the same range for the surface waters except for the Okposi salt lake with about 1204.5mg/l. This indicates a high level of hardness for the salt lake. The concentration of sulphate in the study area ranges between 0m/l to 3.0mg/l. The concentration of Cl^- in the study area is excessively high in some places. This includes the Ahia Ochie boreholes (927mg/l), Okposi Ukwu borehole (822mg/l), and Ndiagu Onicha (528mg/l). Other boreholes in the area have low concentrations (between 0.62-5.6mg/l). The Cl^- concentration values in the surface water samples are also high (between 235.5mg/l– 679.0mg/l). The areas of higher concentrations are areas closer to the salt lakes, and within the fractured shale aquifer units, while those in the sandstone/siltstone aquifers are low. These high concentrations may be due to leachate from the brine loaded bedrocks and halite mineralization, which is not far from the area. It might also be as a result of sewage disposal. The concentration of $N0_3$ in the study area ranges from 0 mg/l (in many places) to 0.30 mg/l (the highest value). This concentration is high due to excessive use of agricultural fertilizers and nitrogenous waste dumping in the area.

Water Types, Hydrochemical Sequence and Facie Evolution

Results of hydrochemical analysis are used to determine the cummulative impacts or concentrations of certain constituents in water. The distribution and concentration of chemical constituents in natural waters is controlled by a number of factors including geology, amount of water supply, vegetation and climate (Todd, 1980). Egboka, et al, (1993), enumerated five major factors that can influence the distribution of the aqueous species in groundwater. These include:

a. Diagenetic processes of recrystallization, dolomatization and cementation;
b. The existence of geological structures (such as fractures, fissures, joints, bedding planes, lithologic boundaries and solution cavities);
c. Chemical mass-transfer, which is controlled by mass balance;
d. Thermodynamic variables related to physicochemical environment, ande.
e. Hydrodynamic factors (such as flow pattern, permeability, hydraulic gradient) which govern the flow path and discharge.

TABLE 1.0 STRATIGRAPHY OF THE STUDY AREA.

AGE	FORMATION	UNIT	LITHOFACIES
TURONIAN	EZEAKU	C: DARK-GREY SHALES	Dark, Flaggy and hard shales. Contains minor bands of sandstones. With highly calcareous indurated limestones.
		B: SANDSTONE/SILTSTONE	Sandstones, whitish and calcareous. Siltstones are also whitish and interbedded with mudstones.
ALBIAN	ASU RIVER GROUP	A: LIGHT-GREY SHALES	Shales, light grey in colour, contains finegrained micaceous sandstones and sandy shales.

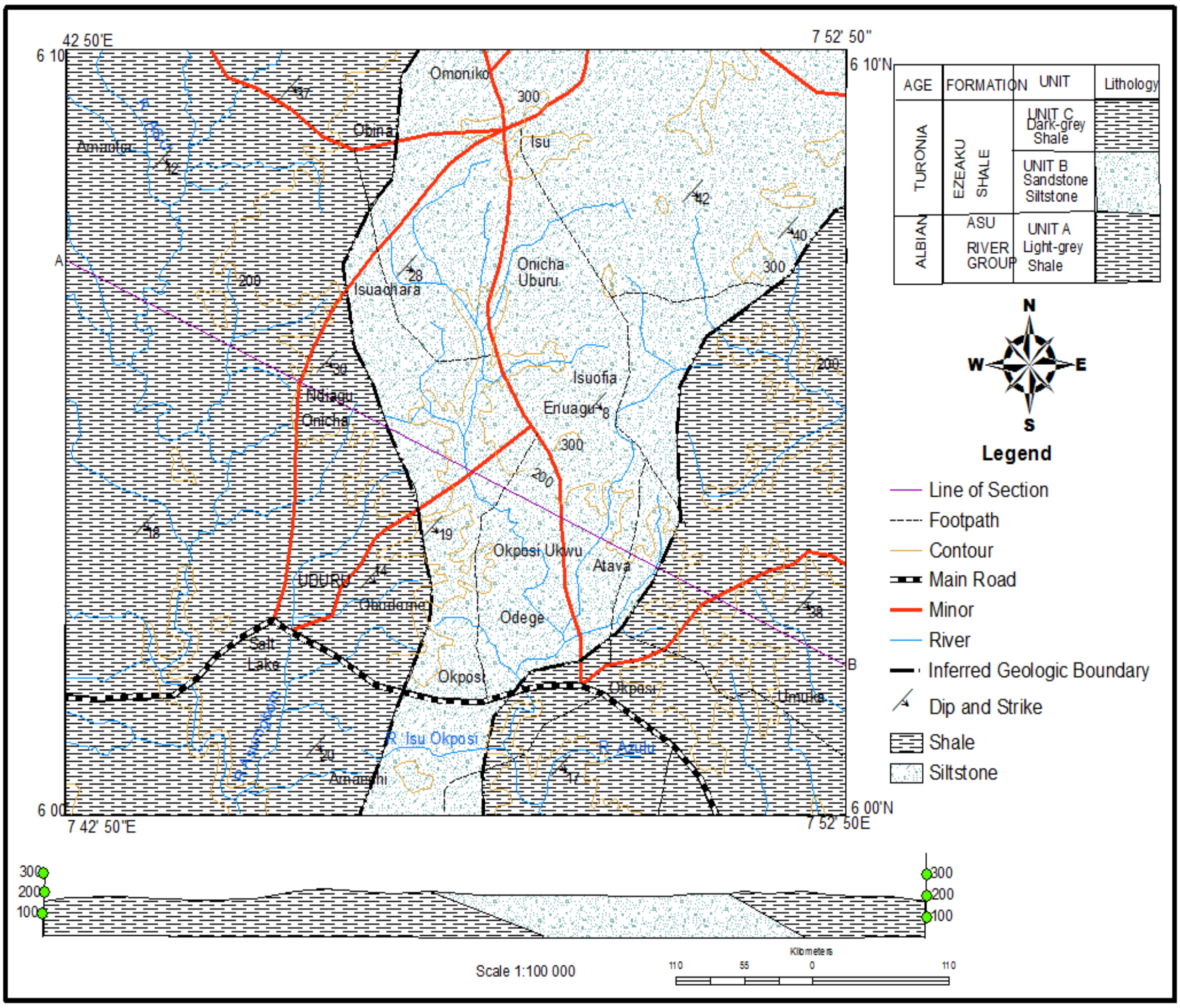

Fig. 3: Geologic map of Okposi-Uburu And environs

TABLE 2.0: CONCENTRATION OF PHYSICAL PARAMETERS IN WATER SAMPLES ANALYZED

SAMPLE LOCATION	SAMPLE NO	Colour	p^H (mg/l)	Electrical Conductivity (µScm)	Turbidity (mg/l)	Total Dissolved Solid (TDS) (mg/l)
Okposi salt lake	OP/09/L2	5.00	11.50	527.10	10.00	497,700.00
Uburu salt lake	OP/09/L5	10.00	10.60	13.00	23.00	129,600.00
Ahia Ochie Uburu	OP/09/L6	30.00	9.60	2.10	149.00	699.00
Okposi Ukwu	OP/09/L10	10.00	9.40	1.92	158.00	928.00
Nkwegu-Isu	OP/09/L11	18.00	7.50	0.18	10.00	96.00
Omoniko	OP/09/L12	9.00	7.30	0.19	28.00	86.00
Hand dug wel (Ameachi)l okosi	OP/09/L3	15	8.4	0.12	48	53.00
Isuachara onicha	OP/09/L7	10	8.3	0.21	11	98
Onicha Uburu	OP/09/L8	10	8.2	0.23	15	102
Atavo Okposi	OP/09/L9	10	8.0	0.22	37	110
Umuka	OP/09/L13	17	8.2	2.00	148	284
Ndiagu Onicha	OP/09/L14	10	9.4	2.06	1800	80
River Atta (Okposi)	Op/09/L1	5	9.4	4.38	18	1510
River Asumgbom (Uburu)	Op/09/L4	5	8.5	0.18	15	81

TABLE 3.0: CONCENTRATION OF MAJOR CATIONS AND ANIONS IN WATER SAMPLES ANALYZED

S/N	SAMPLE LOCATION	SAMPLE NUMBER.	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	$Na^{+} + k^{+}$ (mg/l)	Fe^{2+} (mg/l)	Cl^{-} (mg/l)	No_3 (mg/l)	So_4^{2-} (mg/l)	HCO_3^{-} (mg/l)
1	Ahia Ochie Uburu	OP/09/L6	0.00	0.34	68.20	0.01	927.00	0.00	1.00	0.34
2	Atavo Okposi	OP/09/L9	0.02	2.62	54.9	0.02	0.01	0.00	1.00	2.82
3	Hand dug wel (Ameachi)l okosi	OP/09/L3	0.82	0.48	17.8	0.04	0.01	0.03	1.00	1.3
4	Isuachara onicha	OP/09/L7	0.02	2.1	10	0.01	0.1	0.00	0.00	2.1
5	Ndiagu Onicha	OP/09/L14	0.02	2.00	18	0.01	0.1	0.01	0.00	1.58
6	Nkwegu-Isu	OP/09/L11	0.02	1.98	3.05	0.01	0.84	0.00	0.00	2.00
7	Okposi salt lake	OP/09/L2	274.50	990.00	1805.00	0.01	679.00	0.30	1.00	1204.50
8	Okposi Ukwu	OP/09/L10	0.87	0.38	7.00	0.01	822.00	0.00	1.58	096.00
9	Omoniko	OP/09/L12	0.02	1.50	1.05	0.00	0.62	0.12	0.98	1.86
10	Onicha Uburu	OP/09/L8	0.01	2.2	8	0.01	0.11	0.00	0.00	2.24
11	River Asumgbom (Uburu)	Op/09/L4	1.22	3.02	52.1	0.01	0	0.12	3.00	4.24
12	River Atta (Okposi)	Op/09/L1	0.14	1.41	78.3	0	235.5	0.03	1.00	1.55
13	Uburu salt lake	OP/09/L5	0.02	1.87	2,280.00	0.07	5,160.00	0.01	0.00	1.89
14	Umuka	OP/09/L13	0.22	2.08	48.8	0.02	4.90	0.00	0.00	2.46

TABLE 4: CONCENTRATION OF HALOGENS IN SOME OF THE WATER SAMPLES ANALYZED

SMAPLE LOCATION	SAMPLE NUMBER	Bromide (mg/l)	Chloride (mg/l)	Flouride (mg/l)	Iodine (mg/l)
Okposi salt lake	$OP/09/L_2$	643.50	679.000	1.030	1014.000
Uburu salt lake	$OP/09/L_5$	1.06	5,160.000	0.500	0.001
Ahia Ochie Uburu	$OP/09/L_6$	0.88	927.000	0.000	1.180
Okposi Ukwu	$OP/09/L_{10}$	0.90	822.000	0.000	1.900
Nkwegu-Isu	$OP/09/L_{11}$	0.05	0.840	0.060	0.020
Omoniko	$OP/09/L_{12}$	0.07	0.620	0.040	0.010
Hand dug wel (Ameachi)l okosi	OP/09/L3	0.44	3.2	0.00	0.67
Isuachara onicha	OP/09/L7	0.06	0.9	0.08	0.04
Onicha Uburu	OP/09/L8	0.07	2.4	0.07	0.04
Atavo Okposi	OP/09/L9	0.86	5.6	0.58	1.45
Umuka	OP/09/L13	0.78	4.9	0.54	1.24
Ndiagu Onicha	OP/09/L14	1.00	528	0.08	0.03
River Atta (Okposi)	Op/09/L1	0.69	236	0.09	1.25
River Asumgbom (Uburu)	Op/09/L4	0.02	2.8	0.2	0.06

Hems (1989) also showed that rock deposits (geology) impose its chemistry on the groundwater system. These factors enhance inter/intra aquifer transfer of the chemical species in solution, giving rise to the formation of mixed groundwater of varying composition.

The evolutionary trend of hydrochemical facies in groundwater system reveals a sequence from bicarbonate to sulphate and chloride stages. These processes proceed very gradually since diffusion is a very slow process. This accounts for pockets of sulphate and bicarbonate waters in some places like Isu and Ndiagu Onicha respectively. The anion evolution sequence and the tendency for Total Dissolved Solute (TDS) to increase along the groundwater flow paths define the flow history of the water. The hydrogeochemical facies map (Fig 6) shows the various geochemical facies present in the study area. This depicts calcium bicarbornate facies at the northern parts and sodium chloride facies at the southern part with pockets of sodium facies in Umunuka – Okposi, Ezi-Okposi and Enuagu. The geochemical facies are inherent in the bedrocks. The calcium bicarbonate facies migrates from the carbonate – rich sandstones/siltstones and shales which underline the northern part while the sodium chloride facies in the southern parts emanates from the brine–loaded bedrocks and weathered/fractured shales which underlie the Okposi and Uburu area. Figure 4 is a tri-linear diagram of water types in the study area which shows the various percentage composition of major cations and anions contain in water. It shows high compositions of Cl^{-}, Ca^{2+}, CO_3^{-} + HCO_3^{-} and Na + K with low compoitions of Mg^{2+} and SO_4^{2-}. This composition is imperative for the classification of the water into three water types ie

a. Calcium bicarbonate
b. Sodium chloride and
c. Sodium/potassium bicarbonate.

Fig 5 shows the classification of the main anions and cations facies in terms of their major ionic percentage. This result shows that in the study area the
dominant cation types are calcium(Ca^{+}) and sodium (Na^{+}) while the dominant

anions are the bicarbonate (HCO_3) and chloride (Cl^-) ions. In comparison with the tri-linear diagram, this result shows that although magnesium (Mg^+) and sulphate (SO_4^-) ions occur in the study area, they are minimal and do not occur as the dominant ions.

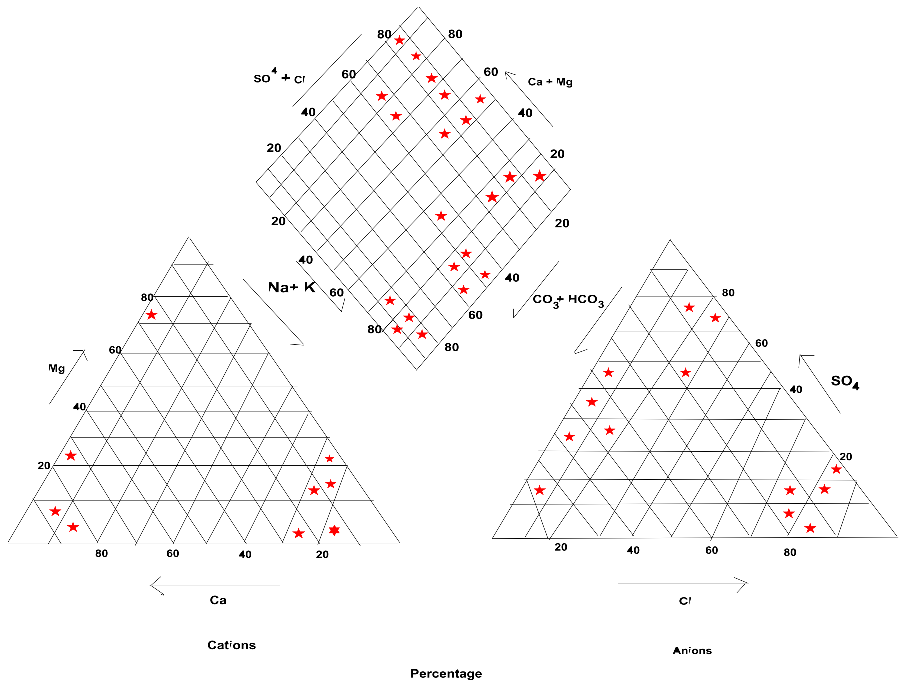

FIG 4.0 TRILINEAR DIAGRAM SHOWING WATER TYPES IN THE STUDY AREA.

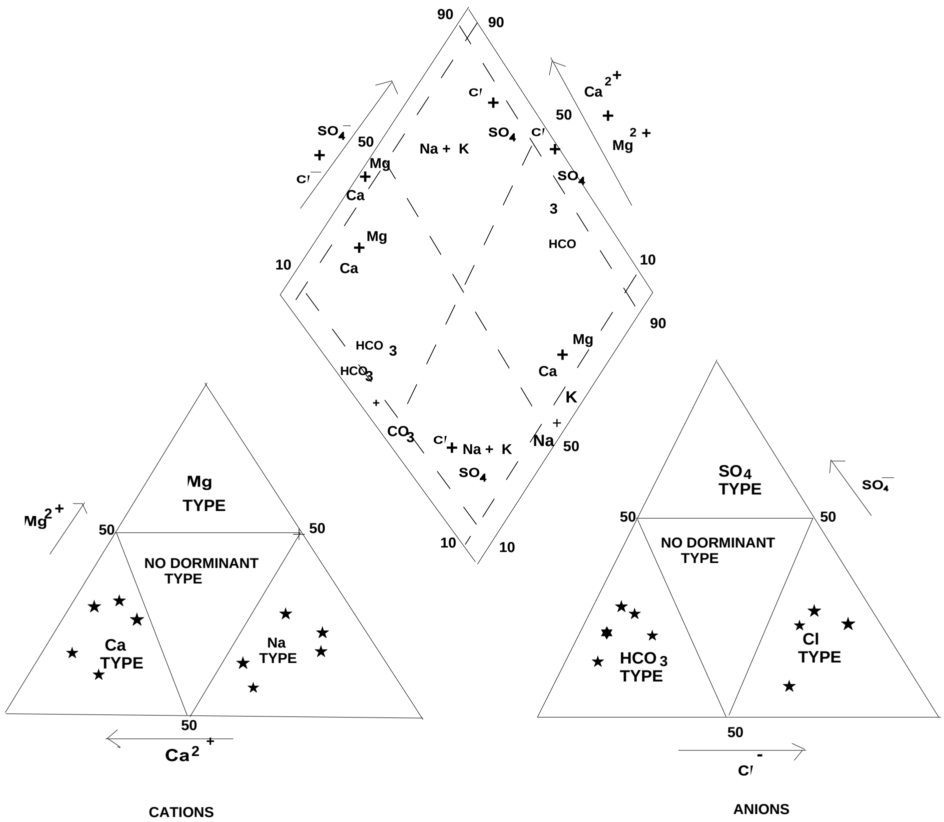

FIG 5.0 CLASSIFICATION OF ANIONS AND CATIONS FACIES IN TERMS OF MAJOR IONIC PERCENTAGE AND WATER TYPES, (AFTER MORGAN AND WINNER, 1962; BACK 1962.

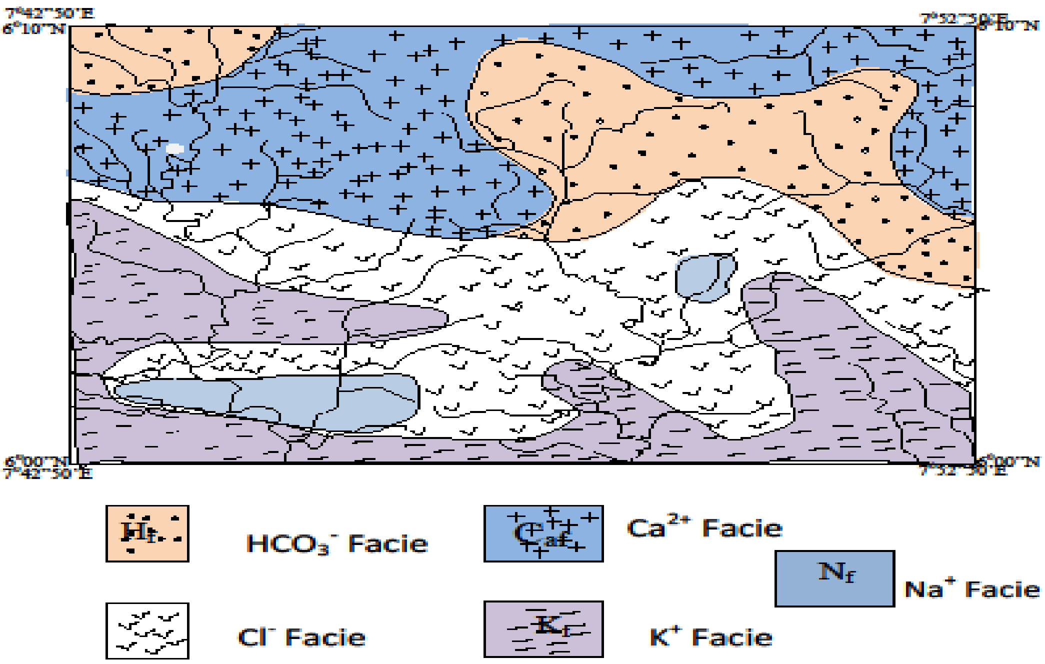

Fig 6: WATER TYPES AND THEIR HYDROCHEMICAL FACIES.

VI. SUMMARY AND CONCLUSION

The Geology and Hydrochemical investigation of Okposi and Uburu areas of Ohaozara and Environs of Ebonyi state was carried out.

Geologically, the area is underlain by shale, sandstones, siltstones and sandy shale. These sediments belong to the Asu River Group and Ezeaku Formation deposited in the Albian and Turonian times respectively. The salt waters may have been trapped during the regressive phases that occurred within these periods. They migrate through veins, faults and fractures, which characterize the sediments.
The concentration of the major cations such as Ca^{2+}, Mg^{2+}, Fe^{2+}, K^{+}, Na^{+}, and anions such as SO_4^{-}, HCO_3^{-}, CO_3^{2-}, Cl^{-}, and NO_3^{-}. Cl^{-} falls above the WHO recommended standard. This is linked to the high salinity of water resources in the area. There is high concentration of Ca^{2+} and HCO_3^{-}, low concentrations of Mg^{2+} and SO_4^{2-} in the recharge areas, while high concentration of Na^{+}, Cl^{-}, K^{+} and HCO^{-}_3 predominate in the discharge areas.

Hydrogeochemical classification of the water types indicates prevalence of calcium bicarbonate water in the northern parts, while sodium chloride and sodium/potassium bicarbonate waters exist in the southern parts of the study area. The distribution of these chemical constituents in the water resources of the area is in line with the groundwater flow pattern in the Cross River Basin and hydrochemical facies evolutionary trend. This study also shows that, the geology of the area has much effect on the hydrochemistry of the area.

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