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THE OCCURRENCE AND CHEMICAL COMPOSITION OF GYPSUM AT CHAM IN THE YOLA ARM OF THE UPPER BENUE TROUGH, N. E. NIGERIA

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ABSTRACT

Investigation of the occurrence and chemical composition of gypsum deposits at Cham and its environs from outcrop sections of the Jessu Formation in the Yola Arm of the Upper Benue Trough have been carried out. The studies show that the gypsum occurs displacively within grey to black parallel laminated shale as thin laminae (1-3mm) along the shale laminae and discontinuously along minor fractures within the shale beds indicating diagenetic occurrence in the host shale. Chemical analysis of the gypsum reveals that the percentage purity ranges from 81.07 – 95.05% indicating high grade and suitable for industrial use (construction, medical, agriculture, etc).

KEY WORDS: Upper Benue Trough, Yola Arm, Jessu Formation, Gypsum, Diagenesis

INTRODUCTION

Cham area is located within the Dadiya Syncline in the Yola Arm of the Upper Benue Trough northeastern Nigeria (Figure 1). The Jessu Formation in the Yola Arm of the Upper Benue Trough represents mid -upper Turonian sediments deposited during the regressive phase of the Late Cenomanian–Early Turonian transgression in the Benue Trough (Carter et al, 1963; Enu, 1980; Allix, 1983; Mamman, 1998; Zaborski, 2003)(Figure 1). The Jessu Formation comprises alternating sequence of gray to brown shale, gray to light brown sandy mudstones with subordinate fine grain sandstones (Carter et al., 1963; Mamman, 1998; Akande and Ojo, 2001). Gypsum occurrence has been reported from the Guyuk area in the Senonian sediments (Sukuliye and Numanha Formations) in the Yola Arm of the Upper Benue Trough (Ntekim, 1999) and the Fika shales in the Borno Basin (Isah, 1995). Isah (1995) and Ntekim (1999) suggest that gypsum occur in Fika shale and the Senonian sediments (Sukuliye and Numanha Formations) as primary deposits formed by precipitation of calcium sulphate from sea water through the brine–mixing hypothesis (Raup, 1970, 1982).

Sillo and Okunsenogu (1994) studied the Adoka Gypsum and reported that it has 88.4% purity compared to the imported Moroccan gypsum with 70.5% purity. He suggests that the Adoka gypsum is a better retarder of cement setting compared to Moroccan gypsum.

Ntekim (1999) reported three mappable gypsum deposits in Guyuk area at Dukul, Gunda and Lamza with purity rating of 47%, 75% and 73% $CaSO_4$ $2HO_2$ respectively. According to him those with low purity (high impurities) are due to the high imput of clastic materials during their deposition. Isah (1995), from studies of the chemical composition of gypsum from Fika shales at Mada and Nafada show that they are of high purity (76.66% and 76.99%) respectively. These compare well with imported gypsum from Spain and Morocco. The main aim of this work is to study the nature of occurrence and the chemical composition of gypsum deposits in the Cretaceous sediments at Cham and adjacent areas. This is done in order to understand the origin of the gypsum in the area and evaluate its industrial quality.

Stratigraphy

The study area (Cham) is part of the Yola Arm of the Upper Benue Trough, northeastern Nigeria (Figure 1). The Yola Arm is covered by continental and marine Cretaceous (Aptian-Early Santonian) deposits with total thickness of 3-4 km (Carter et al., 1963; Ofoegbu, 1988; Shemang et al., 1998; Benkhelil, 1989; Allix, 1983; Mamman, 1998; Zaborski, 2003). The various sedimentary sequences in the Yola Arm of the Upper Benue Trough are; Bima, Yolde, Dukul, Jessu, Sukuliye, Numanha and Lamja Formations (Carter et al., 1963).The stratigraphy is summarized table 1.

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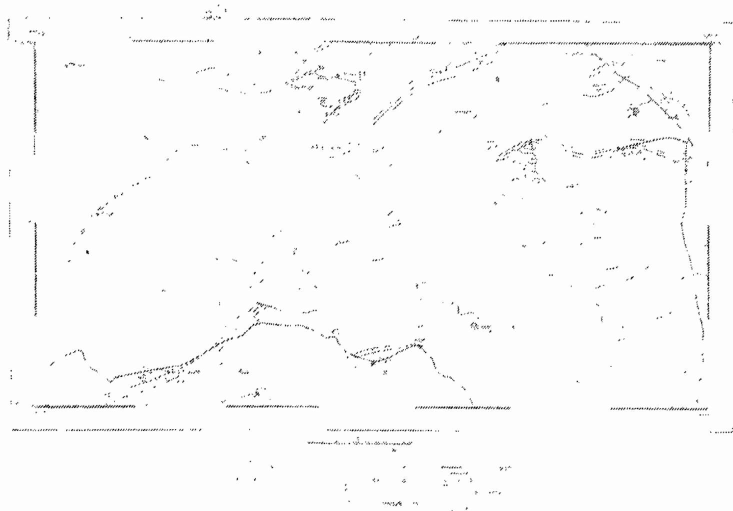

FIG. 1: GEOLOGICAL MAP OF DADIYA SYNCLINE, YOLA ARM OF THE UPPER BENUE TROUGH SHOWING THE SAMPLING

Bima Sandstone

The Bima Sandstone is the oldest sedimentary sequence in the entire Upper Benue Trough and overlies the undulating Basement Complex unconformably. It is generally a fining-upward continental successions with overall thickness of close to 2000m (Carter et al., 1963 and Guiraud, 1990). It comprises of basal boulder conglomeratic alluvial fan/debris flow deposits, gravelly arkoses of the braided river, medium to coarse grained sandstones with lenses of gray, red and purple mudstones, shales and paleosols (Guiraud, 1990; Braide 1992). On the basis of palynomorphs the formation is Aptian to Albian in age.

TABLE 1: STRATIGRAPHIC SUCCESSION OF CRETACEOUS AND CENOZOIC SEDIMENTS AND VOLCANICS IN UPPER BENUE TROUGH [MODIFIED FROM PETTERS (1978)]

AGE		YOLA ARM (DADIYA)	GONGOLA ARM (PINDIGA-GOMBE)
PLEISTOCENE			BIU BASALTS
PLIOCENE			
MIOCENE			
OLIGOCENE		LONGUDA BASALTS	
EOCENE			
PALEOCENE			KERRI-KERRI FORMATION
MAASTRICHTIAN			GOMBE SANDSTONE
CAMPANIAN			
SANTONIAN			
CONIACIAN		LAMJA SANDSTONE NUMANHA FORMATION SUKULIYE FORMATION	PINDIGA FORMATION
TURONIAN	UPPER	JESSU FORMATION	
	LOWER	DUKUL FORMATION	
CENOMANIAN		YOLDE FORMATION	
APTIAN – ALBIAN		BIMA SANDSTONE	
PRECAMBRIAN		BASEMENT COMPLEX	

Yolde Formation

The Yolde Formation is a transitional deposits between the dominantly continental Bima sandstone and the dominantly marine sequences (Dukul, Jesssu, Sukuliye, Numanha and Lamja Formations) (Carter et al.,1963). It comprises of medium grain parallel to cross bedded sandstone (quartzarenite), passing upward into fine grain parallel bedded, sometimes bioturbated and calcareous sandstones, mudstones, shales and limestones (Carter et al., 1963). The formation was deposited in littoral to sublittoral environments and is said to be late Albian to late Cenomanian in age (Lawal and Moulade, 1986).

Dukul Formation

The Dukul Formation represents the basal part of the full marine sequences in the Yola Arm of the Upper Benue Trough. It comprises of limestone, marlstone, mudstone and shale intercalatios (Carter et al., 1963; Enu, 1980; Allix, 1983; Akande and Ojo, 2000; Mamman, 1998). The formation was deposited in open marine shelf environment and lower Turonian in age (Reyment, 1980; Allix, 1983; Akande and Ojo, 2004; Mamman, 1998).

Jessu Formation

The Jessu Formation was deposited during the mid-Turonian regressive phase of the late Cenomanian-Turonian maximum transgression which affected the whole of the Benue Trough. It comprises of alternating sequences of shales (gypsiferous and non gypsiferous), siltstones, mudstones and fine to medium grain sandstones (Carter et al., 1963; Allix, 1983; Akande and Ojo, 2004). Allix (1983) suggest that the formation was deposited in a shallow muddy shelf sometimes subject to open marine conditions.

Senonian Sequence

The Senonian sequence (Sukuliye, Numanha and Lamja Formations) in the Yola Arm are regarded by Carter et al. (1963) to be 3 separate units, superposed, and represent the entire interval from Coniacian to Maastrichtian. Petters (1978), Odebode and Enu (1986), and Odebode (1987) regarded them as partial lateral equivalents, all of Coniacian age and representing environments ranging from marine to continental. Allix (1983) noted their superposition but regarded them as elements of a deltaic system prograding eastwards into a shallow sea during the Coniacian.

Sukuliye Formation

The Sukuliye Formation comprises mainly of gray to black shale with numerous thin bands of hard gray fossiliferous limestone. Allix (1983) interpreted the Sukuliye Formation as prodeltaic in origin and refered to it lower to middle Coniacian in age based on presence of Coniacian ammonites.

Numanha Formation

The Numanha Shale comprises mainly of gray to black shale which are gypsiferous, with occasional limestone. The shale beds are frequently intercalated by green to yellow or brown laminated siltstones (Carter et al., 1963; Allix, 1983). Allix (1983) regarded the Numanha Shale to have been deposited in shallow marine environments ranging from delta front to lagoonal environments.

Lamja Sandstone

The Lamja sandstone have only outcrop at the eastern margin of the Longuda plateau (Carter et al., 1963), It comprises of shale, siltstones (carbonaceous and noncarbonaceous), fine grain sandstones, low rank coal 24cm thick and bioclastic oyester rich limestone (Allix, 1983). Carter et al. (1963) dated the formation as Maastrichtian in age based on the presence of the bivalve *Pycnodonte vesicularis Lamarck* in the uppermost limestone bed. However, Allix, (1983), Odebode and Enu (1986) and Odebode (1987) dated it as Coniacian in age based on palynoflora. Allix (1983) interpreted the Lamja sandstone as deltaic deposit, while Odebode and Enu (1986) and Odebode (1987) suggested continental paleoenvironment with few minor marine incursions. The formation is overlain by the Tertiary Longuda basaltic flows in the Yola Arm of the Upper Benue Trough.

METHODS

This work involves mapping of the study area locating outcrop sections where gypsiferous units are well exposed. Three outcrop sections of the Jessu Formation were studied and samples of gypsums were taken from the 3 sections for chemical analysis. The elemental concentrations of major ions in oxide was done using high energy dispersive x-ray fluorescence spectrophotometer (EDXRF) lab-X3500 equipped with computer at the Ashaka Cement Company factory Gombe State. The gypsum samples were washed clean and freed from impurities like clay particles and then pulverized into fine powder of size less than 125μm. 20 grams of the powdered gypsum samples was mixed with 0.4 gram of stearic acid powder which acted as a binding acid or buffer so as not to allow the sample to disperse or scatter away. The aluminium cup of the x-ray machine 4cm in diameter was half filled with stearic acid powder followed by the addition of the finely ground sample powder. The cup was put into hydraulic pump compression machine and compressed at 200KN for 10 seconds which form pellet. The pellet was put into the x-ray fluorescence spectrometer sample holder and then into the loading position of the XRF and measure unknown sample was selected and entered into the computer and the programme desired was entered. The results are displayed after 70-80 seconds on the PC screen and was printed on the spectrophotometer printer in % oxides of elements in the samples (Table 2).

RESULTS AND DISCUSSION

Lithology and occurrence of gypsum

Mona Section

The Mona section outcrops 10km SW of Cham along stream channel and totals 9m in thickness. It comprises dark gray to black shale. Gypsums occur in all the beds and the amount increases with depth (Figure 2 and 3). Gypsum occur within the shale as thin laminae (1-3mm) discontinuously parallel to subparallel and cross-cutting forms along sub-vertical to vertical tiny fractures (Figure 3). Very thin films of shale as mere partings on the laminae surfaces of the

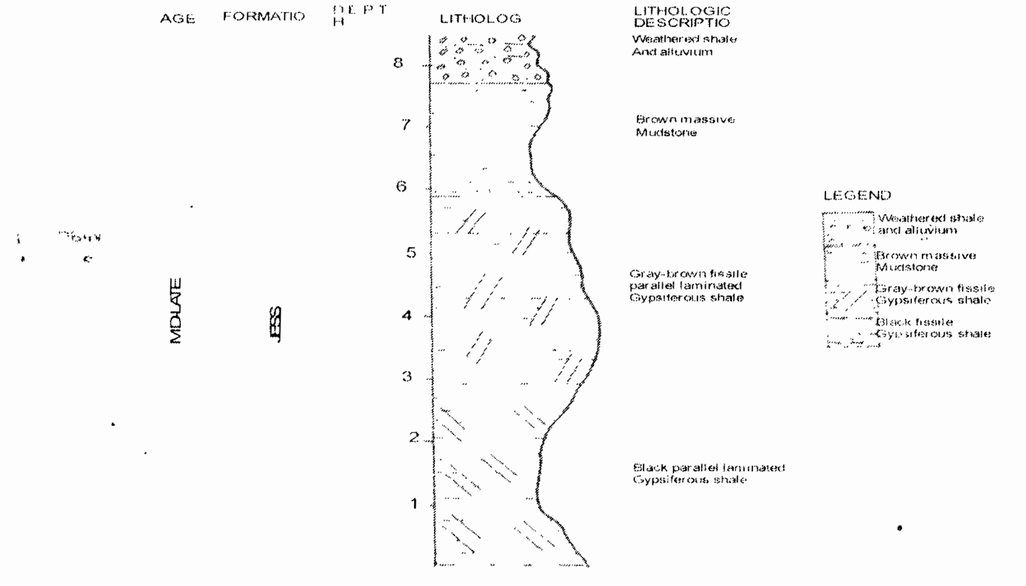

FIG. 2: LITHOLOGIC SECTION OF THE JESSU FORMATION AT MONA SHOWING GYPSIFEROUS SHALE

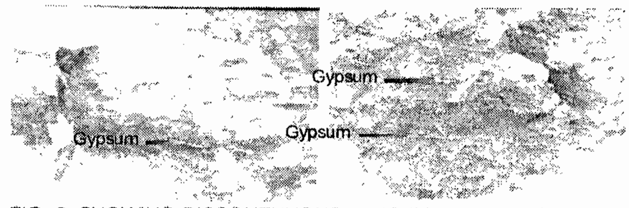

FIG. 3: SHOWING DISCONTNUOUS GYPSUM LAMINAE AS FRACTURE INFILLINGS WITHIN THICK SHALEOF THE JESSU

gypsums are observed indicating the diagenetic displacive growth of the gypsum poikilotically around the shale (Shearman,1966;Murray,1964;Tucker,1982). According to Louncks and Longman (1982), the tiny fractures within the shale along which the gypsums precipitated formed from hydraulic fracturing of the shale resulting from a high pressure created by the interstitial water squeezed out of the compacting mudstones.

Majority of the gypsums are transparent and flaky, but some are translucent due to the presence of impurities. Chemical analyses of gypsum samples from this section show high purity (81-86%). The slightly high amount of silica, aluminium and iron 10.86%, 5.20% and 3.72% respectively are an indication of high impurities (Table 2).

Cham section

The Cham section outcrops 4km NW of Cham town and totals 9m in thickness. The exposed section comprises siltstone, gypsiferous shale (6m), massive mudstone (1.5m) and light gray nongypsiferous shale (Figure 4). The mode of occurrence of gypsum in shale of this section is similar to that of Mona section.

Chemical analyses of gypsum from this section show a purity of 92.05% (Table 2) far above the British standard (1971) of 90%.

TABLE 2: CHEMICAL COMPOSITION OF GYPSUM FROM JESSU, MONA AND CHAM (%).

ELEMENTS	CS_1	MG_1	MG_2	JE_1	JE_2
SiO_2	3.47	10.86	6.45	0.81	2.60
Al_2O_3	1.43	5.20	2.76	0.24	1.23
Fe_2O_3	1.28	1.90	3.72	0.06	0.28
CaO	29.63	26.21	27.99	30.08	29.22
SO_3	42.82	37.71	40.0	44.56	43.01
K_2O	0.13	0.27	0.20	0.05	0.10
Na_2O	0.05	0.04	0.05	0.08	0.08
COMB.Water	19.27	16.97	18.00	21.17	20.24
MgO	0.03	0.23	0.08	0.67	0.71
$MgCO_3$	0.07	0.53	0.16	1.40	1.49
% PURITY	92.05	81.07	86.01	95.81	92.47

CS_1 = Gypsum from Cham
MG_1 = Gypsum within Black Shale from Mona.
MG_2 = Gypsum within Purple Shale from Mona.
JE_1 & JE_2 = Gypsum from gray shales at Jessu Village

Jessu village

Shallow outcrops (>1m) of gray shale expose gypsums which occur in laminae forms (2-3mm) discontinuously, parallel to sub parallel to the laminae plane of the host shale. Jessu village is about 8km NE of Cham town. Chemical analyses of gypsum from the Jessu vllage show purity of 92.47-95.81% (Table2) and lesser amount of impurities.

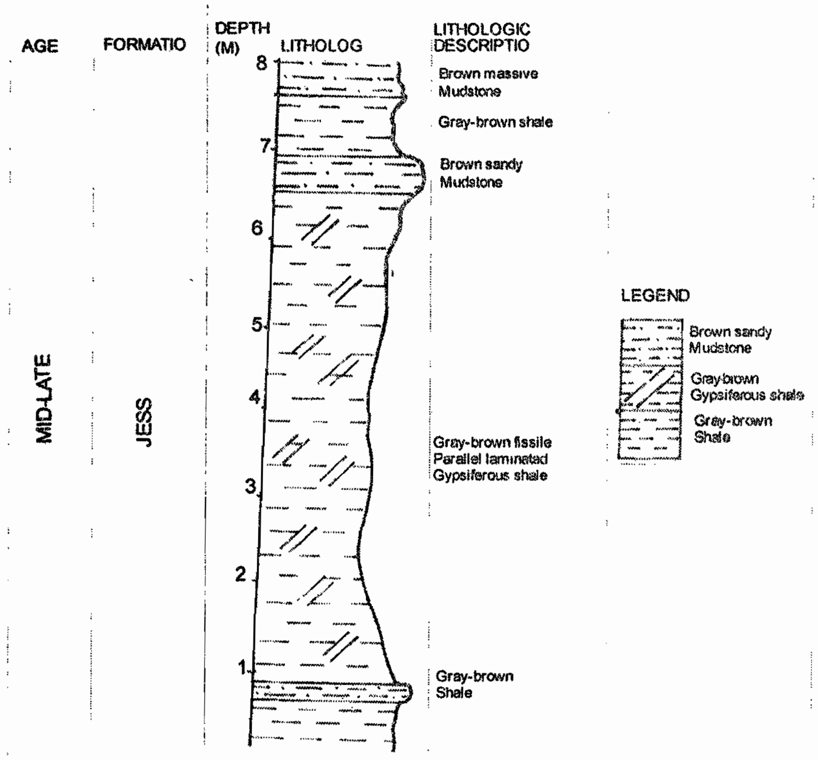

FIG. 4: LITHOLOGIC SECTION OF THE JESSU FORMATION AT CHAM SHOWING GYPSIFEROUS SHALE.

Origin and Industrial quality of the gypsums

The nature of field occurrence of gypsums from Cham area suggest diagenetic mode of origin. However, what are the sources of the calcium and sulphate ions from which the gypsums precipitated?

Scott (1984), shows that gypsum with high amount of Cao (lime) indicate that their source is from limestone. The calcium ions could have come from the dissolution of calcareous shells or tests of fossils present in the shale. This is evidenced from the absence of calcareous foraminiferas and presence of only the impressions of the shells of the dwarf bivalves on the laminae surfaces of the host shale (Mamman work in progress) after the calcareous shells have been dissolved. Another source of calcium ions are from dolomitization of the limestone concretions and nodules within the gypsiferous shale (Figure 3). Petrographic studies of the nodules show that they comprise of sparry dolomitic limestone (Mamman work in progress). Folk et al (1974) show that dolomitization of limestone through replacement of calcium (Ca^{2+}) by magnesium (Mg^{2+}) makes calcium available and reacts with sulphate ions (SO_4^{2-}) in interstitial fluids to form gypsums according to the following equations (Murray, 1964)

$CaCO_3(solid) + Mg^{2+}(aq) = CaMg(CO_3)_2(solid) + Ca^{2+}(aq)$
(limestone) (dolomite)

$Ca^{2+} + SO_4^{2-} + 2H_2O \rightarrow CaSO_4 . 2H_2O$
(gypsum)

Similar processes of dolomitization and formation of gypsum and anhydrite have been observed at the Trucial Coast of the Arabian Gulf (Evans et al., 1969).

Industrial quality of the Gypsums

The physical and chemical standards required for indusrial quality of gypsum depends on the end use. Chemical analysis of the gypsum deposits from Cham and environs show that purity ranges from 81%-95% far above British standards (1977) of 77% and that of imported gypsum from Spain (76%) ands Morocco (70%). It also has a better purity than gypsums reported from Fika shale (76%) (RMRDC, 2001), Nafada (75%) and Mada (76%)(Isah, 1995), Adoka, Benue State (88%).

However, the gypsums from Cham has high impurities compared to those mentioned above. They are best suited for the production of Portland cement (requires purity of ≥ 60%), because cement producers can tolerate relatively large amounts of clay impurities (since clay is a component of the raw material mix). Gypsum for chalk, glass, ceramics and plaster of paris (POP) require much higher purity upto more than 90% (Table 3).

Table 3: Chemical specification of gypsum in the chalk, glass, ceramics and POP industries (RMRDC, 2001).

SiO_2	0.39%	CaO	32.2%
Al_2O_3	0.02%	MgO	0.41%
Fe_2O_3	0.09%	L.O.I	21.01%
SO_3	45.42%	Others	0.35%

Because of the high purity of gypsum required in the manufacturing of glass, ceramics, chalk and POP, the gypsums from Cham need to undergo beneficiation and processing.

For agricultural purposes, gypsum is beneficial because of the presence of two elements; calcium and sulphur. Their quantity in gypsum determines its grade (South Australia formulated regulation 201 of 1999). Regulation 201 defines four grades of gypsum:

Premium; minimum of 90% gypsum or 16.7% sulphur
Grade 1; minimum of 81% gypsum or 15% sulphur
Grade 2; minimum of 67% gypsum or 12.5% sulphur
Grade 3; minimum of 54% gypsum or 10.6% sulphur

Gypsums most suitable for agricultural purposes are fine grain (0.075mm), have 81 – 90% purity and 5 – 16% sulphur (Roessler, 1987). Calcium replaces sodium ions in clay soils and makes it become more friable. This allows easy movement of water and nutrients in the soil and better soil aeration which make the crops grow better. While the sulphur content of Gypsum aids the setting of flowers in crops and hence better yields. Gypsum from Cham with purity ranging from 81.07%-95.81% falls within the required purity for use in agriculture.

CONCLUSION

Gypsum occur in Cham area in large amount, and the mode of origin is diagenetic as evidenced by the discontinuous or inpersistent occurrence within the host shales as very thin laminae (1-3mm). Also the displacive growth patterns along the shale laminae and within vertical to sub-vertical tiny fractures are evidence of diagenetic growth. Chemical analyses of the gypsums show that they are of high purity (81.07-95.81% with varied levels of impurities; SiO_2 (2.60%-10.86%), Al_2O_3 (0.24%-5.2%), Fe_2O_3 (0.06%-3.72%). Such high impurities are due to the poikilotic growth of the gypsums round the host shales and thus enclosing them within its laminae. The gypsums can be used in cement manufacturing without undergoing further beneficiation and reprocessing. While for other industrial uses (chalk, crayons, glass, ceramics, POP, etc) the gypsums must undergo beneficiation and processing.

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