Occurrences of elaterate pollen from the Lower Cretaceous of Ghana: Implications for biostratigraphy and palaeoclimatology

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ABSTRACT

Elaterate pollen with elater-like protruberances including *Elaterocolpites castelaini*, *Elaterosporites klaszii*, *E. protensus*, *E. verrucatus*, *Elateropollenites jardinei*, *Galaeocornea causea*, *G. clavis*, *Sofrepites legouxae*, have been recovered from the 1S-3AX well in the offshore Tano Basin. The assemblage has been interpreted as Albian - Cenomanian age, and is indicative of an arid to semi-arid palaeoclimatic conditions for these periods in the Tano Basin. Similar species have been interpreted as Albian – Cenomanian in other localities within the Africa-South America (ASA) province and thus allows for a palynostratigraphic correlation with these localities in the ASA province.

***Keywords***: Elater-bearing pollen; palaeoclimate; Albian; Cenomanian; Tano Basin

1. INTRODUCTION

A total of 39 cutting samples have been obtained and analysed from the offshore Tano 1S-3AX well in the Tano Basin (Fig. 1). The Mesozoic to tertiary rocks of the basin occur on the eastern side of a crescent-shaped basin which is located along the coast of the Atlantic Ocean. The basin extends to the southeastern corners of Cote I'voire and continues into the Gulf of Guinea. The Tano Basin began its tectonic-sedimentary life as an extensional rift basin modified by wrench tectonism. This rifting was initiated by complex movements due to the separation of the continents of South America and Africa. This was most likely initiated in the Barremian and Aptian times. It is thought that movement along a series of transform faults including faults in the Romanche Fault Zone during this continental separation led to the development of the large rift basin in the Tano area (Davies, 1989). As a result of these movements, by Aptian - early Albian time, a large rift basin had developed in the Tano Basin area. This was followed in middle - late Albian times by widespread deposition of shallow marine sandstones and shales with minor limestone in the area. General evidence suggests that final separation on the continents took place in latest Albian (Davies 1989). It is speculated that, a thermal anomaly with subsequent uplift occurred at the margin of the newly created African and Brazilian continental plates in the Tano area. This uplift occurred in late Albian time and may be the plate tectonic model for the development of the Tano structural trend. This paper presents the occurrences of elater-bearing species including *Elaterocolpites*

castelaini, Elaterosporites klaszii, E. protensus, E. verrucatus, Elateropollenites jardinei, Galaeocornea causea, G. clavis, Sofrepites legouxae, in the Tano basin and also provides updated information on their occurrence in some parts of the Africa-South America (ASA) province (Fig. 2).
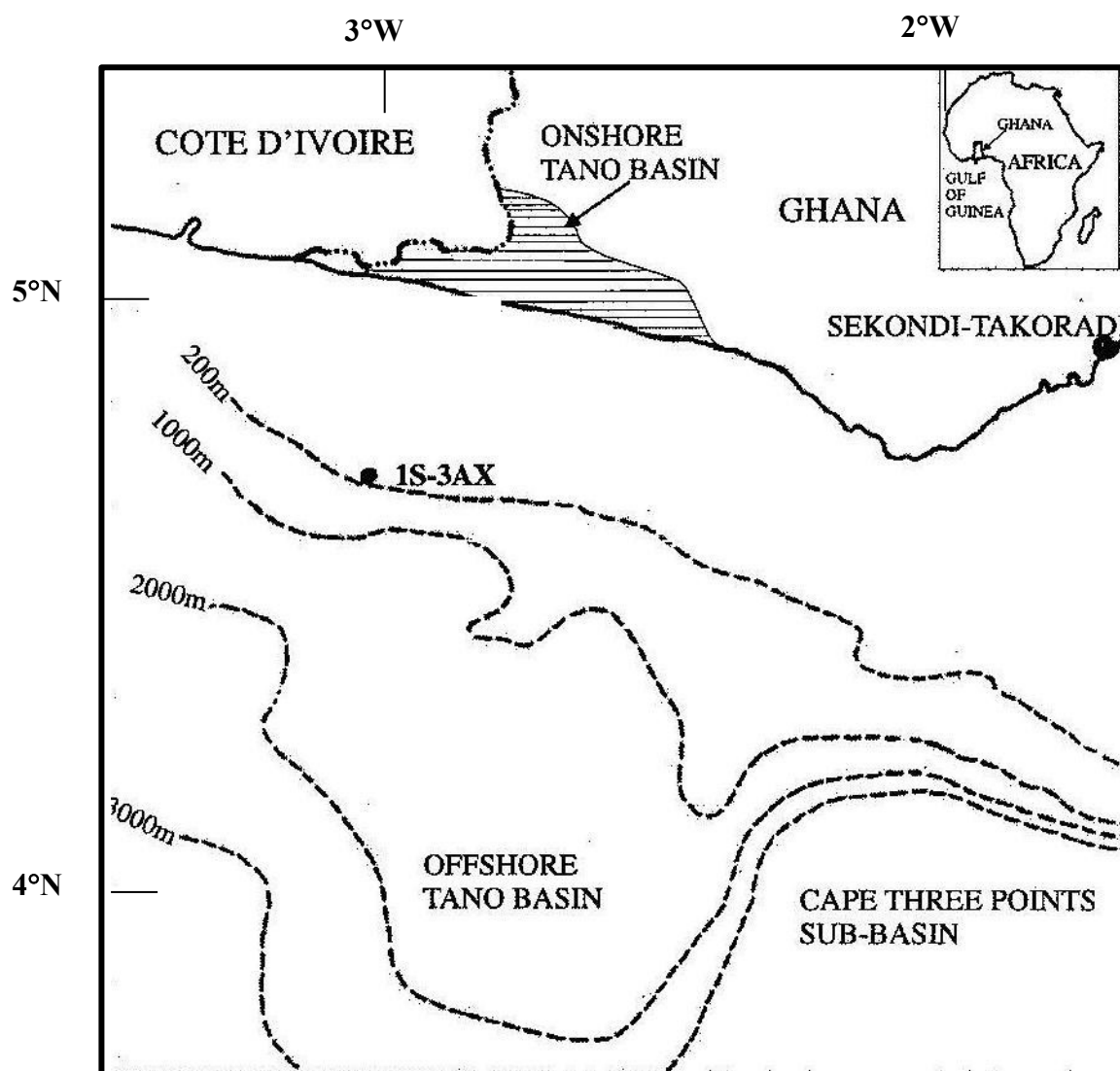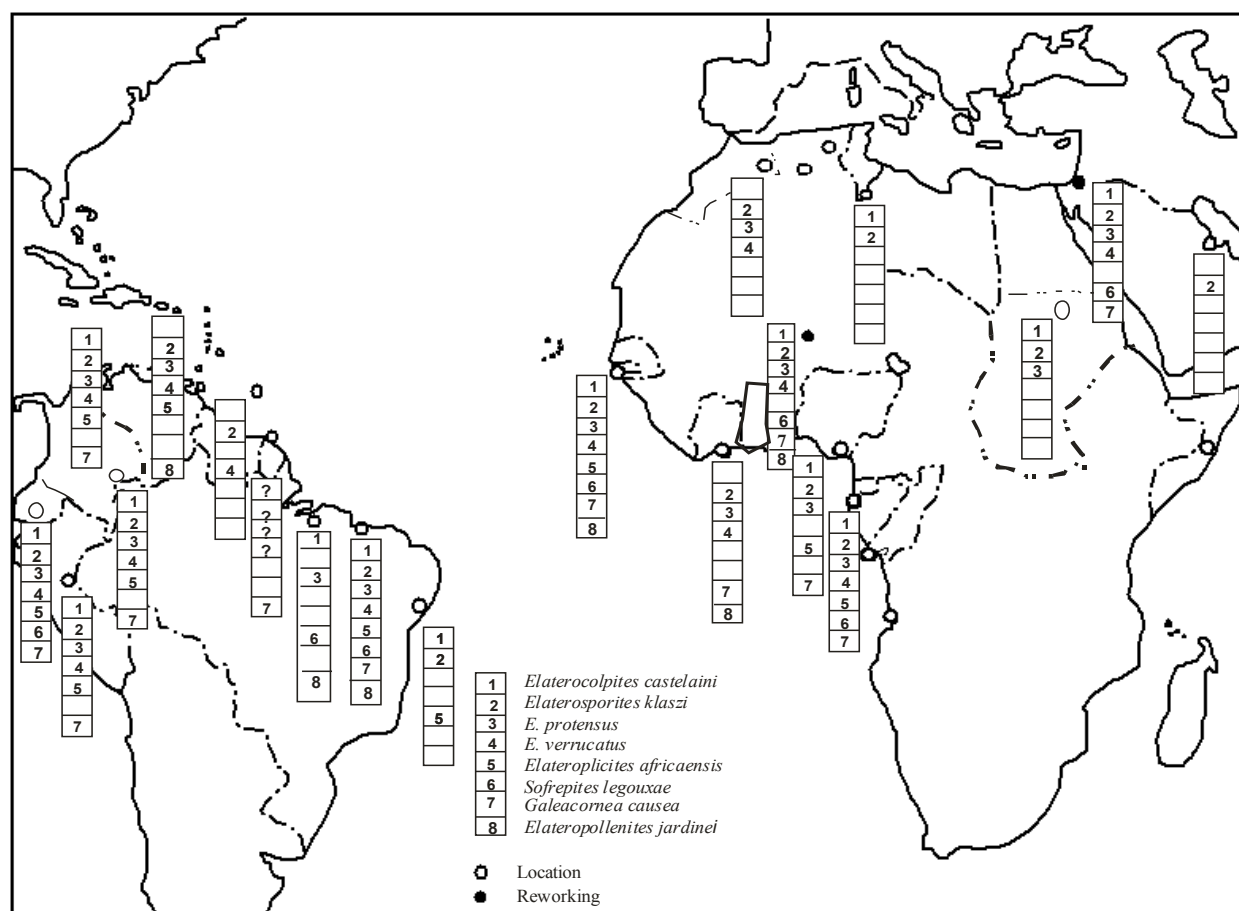

Fig. 1. Map of Tano Basin showing the offshore 1X-3AX well
(Modified after GNPC Offshore Activity Map, 1994).
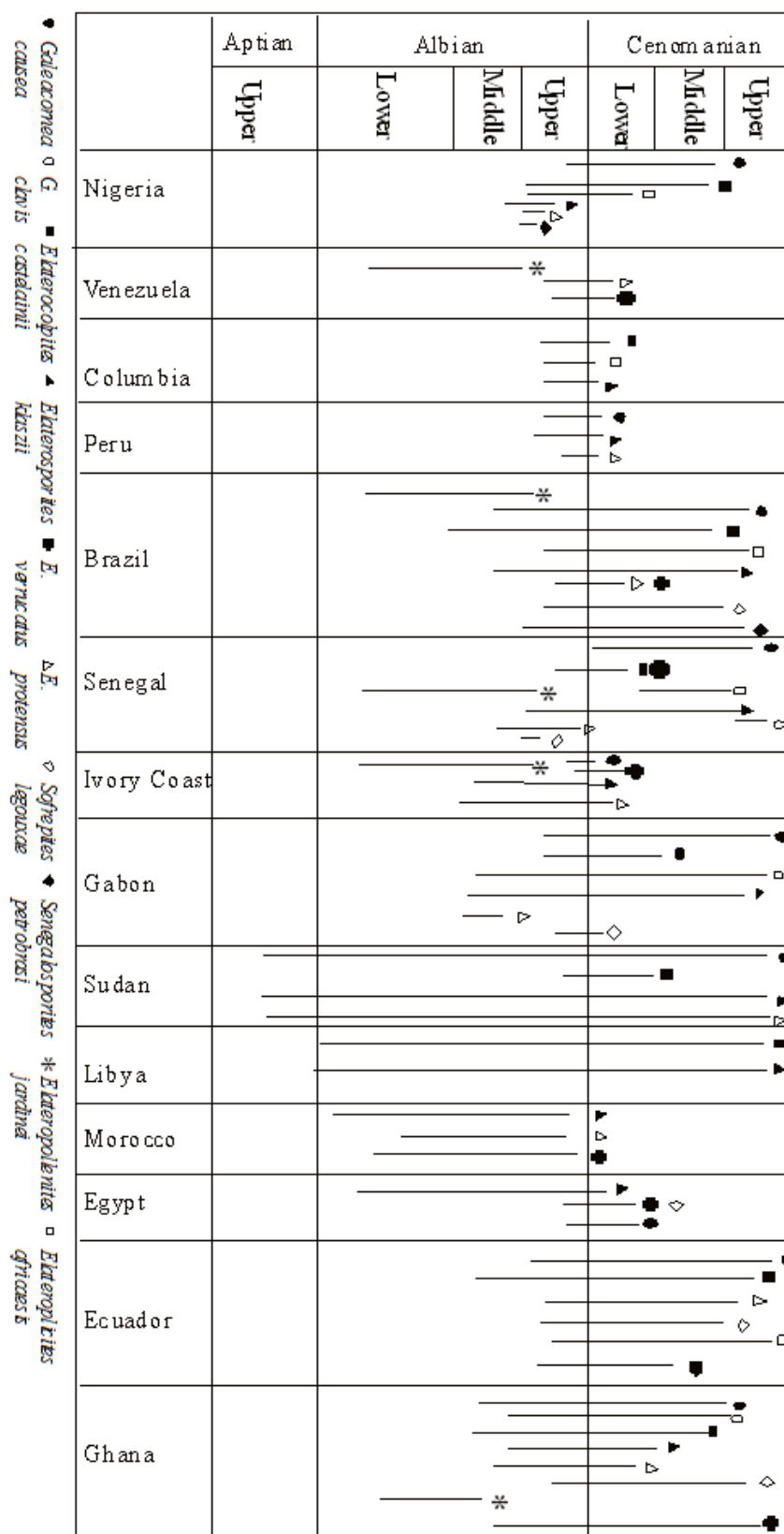
Fig. 2. Comparison between Ghanaian elater-bearing species and those of other localities within the palynofloral province (Modified after Abubakar er al., 2006). Information on Venezuela (Muller et al., 1987), Morocco (Bettar and Meon, 2006), Egypt (Mahmoud, 1998; Aboul Ela and Mahrous, 1992), Ecuador (Dino et al., 1999) has been added.

2. MATERIALS AND METHODS

The specimens studied have been obtained from the Albian – Cenomanian section of well 1S-3AX in the Tano Basin. The samples were mainly shales, sandstones and some limestones Samples were processed using standard laboratory techniques for the extraction of palynomorphs from sediments (Phipps and Playford, 1984). This involved the use of hydrochloric (HCl) (10 %) and hydrofluoric (HF) (40 %) acids to digest and remove the carbonates and silicates from the rock samples respectively. The residue was then sieved through a 10 μm nylon sieve, and the organic matter separated using zinc bromide solution. Slides were then prepared from shrew mounts of organic matter in polyvinyl alcohol (PVA) and cured in ultra violet light for light microscopy and photomicrography.

1 Elaterocolpites castelaini
2 Elaterosporites klaszi
3 E. protensus
4 E. verrucatus
5 Elateroplicites africaensis
6 Sofrepites legouxae
7 Galeacornea causea
8 Elateropollenites jardinei

◘ Location
● Reworking

Fig. 3. Distribution chart of elater-bearing forms (Modified after Herngreen, 1975 with added contributions from Ecuador, Venezuela, Colombia, Morocco, Nigeria, Sudan, and Ghana.

3. RESULTS

3. 1. Pollen fossil

The distribution of the elater-bearing pollen species recovered from the stratigraphic column from well have been shown in Fig 4. They include *Elaterosporites protensus*, *E. verrucatus*, *E. klazsii*, *Elaterocolpites castelaini*, *Elateropollenites jardinei*, *Galeacornea, causea, Sofrepites legouxae.*
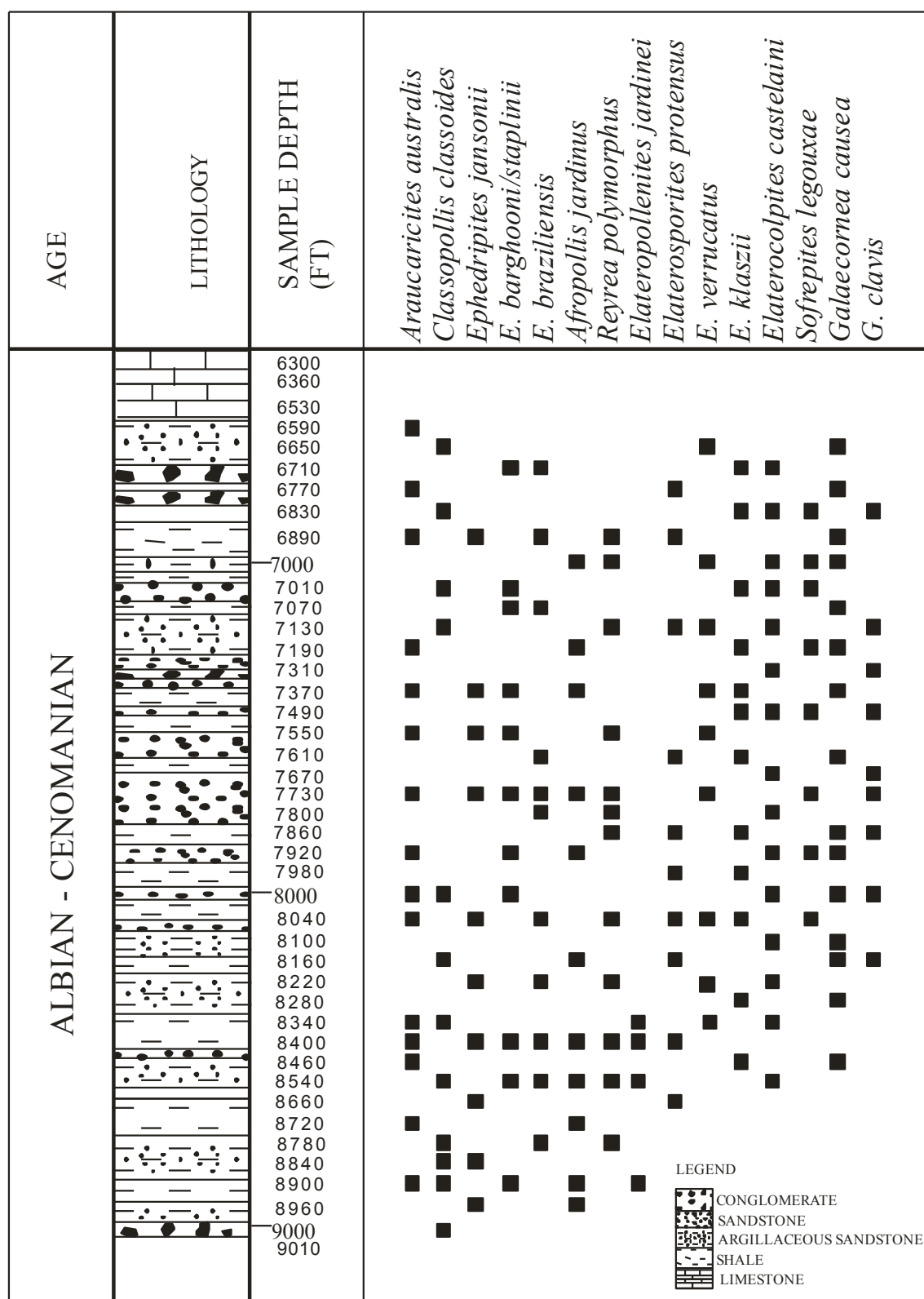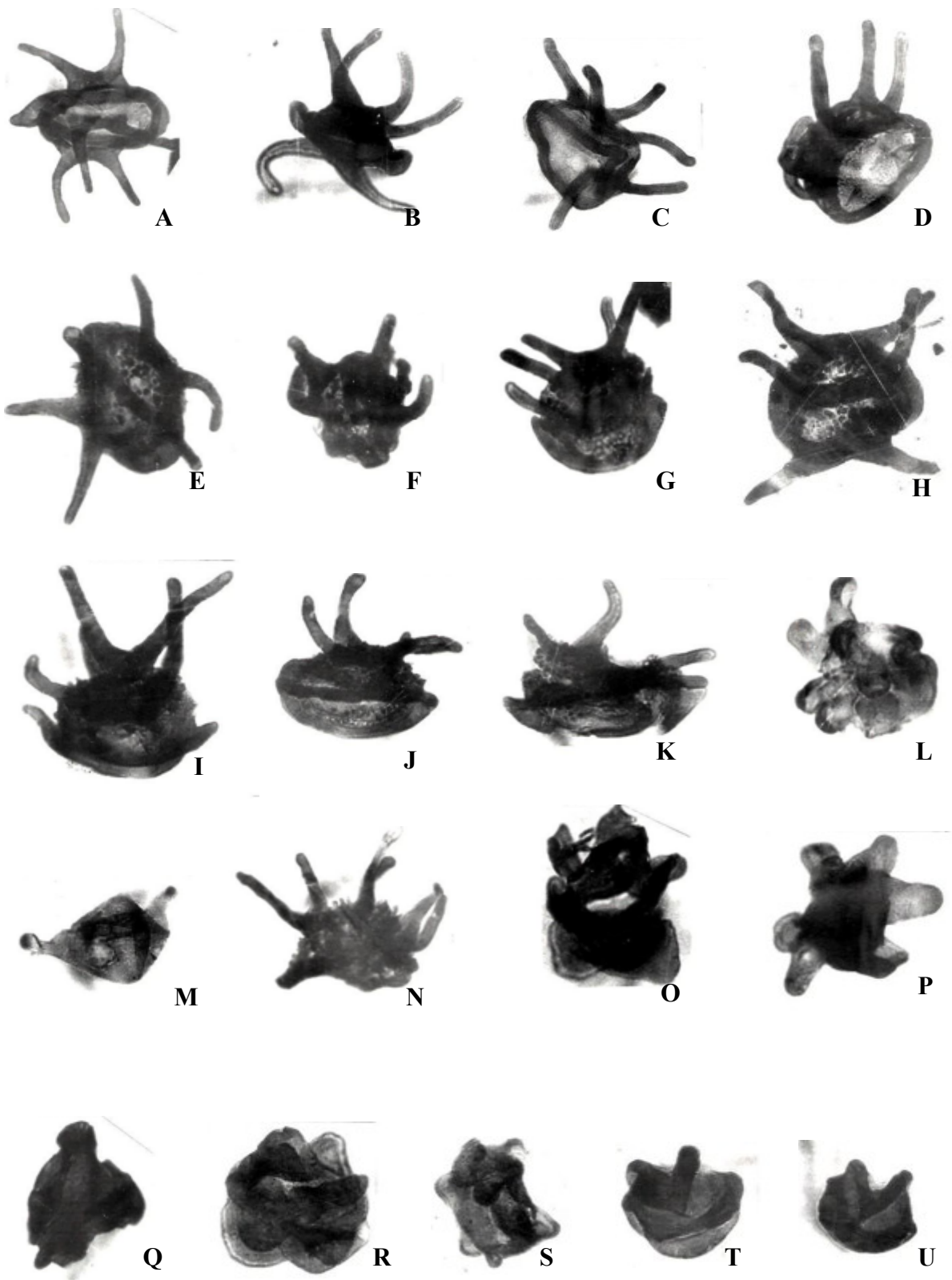
Fig. 4. Stratigraphic column of 1S-3AX well showing the distribution of elater-bearing pollen and other stratigraphically relevant palynomorphs.

PLATE 1

A   B   C   D

E   F   G   H

I   J   K   L

M   N   O   P

Q   R   S   T   U

Explanation to Plate 1
All figures X 660 unless otherwise stated.
Figure.
A, B, C, D. Elaterosporites klaszii (Jardiné and Magloire) Jardiné, 1967
E, F, G, H. *Elaterosporites verrucatus* (Jardiné and Magloire) Jardiné,   1967
I, J, K, N.   *Elaterosporites protensus* (Jardiné and Magloire) Jardiné 1967
L, P.   *Elaterocolpites castelaini* forma B Jardiné, 1967
S.   *Elaterocolpites castelaini* forma A Jardiné, 1967
M.   *Elateropollenites jardinei* Herngreen, 1973
O, R.   *Galaeocornea causea* Stover, 1963
T, U.   *Galaeocornea clavis* Stover, 1963
Q.   *Sofrepites legouxae* Jardiné, 1967

Selected Systematics

For nomenclature and rules on priority and typification, the International Code of Botanical Nomenclature [(ICBN) Stafleu et al., 1978] is followed.
Genus *Elateropollenites* Herngreen, 1973
Elateropollenites jardinei Herngreen, 1973
Plate 1, Figure M.
Dimensions: (34-36) x (43-45) μ, mean 35 x 44 μ. (5 specimens measured)
Length of appendages 5-12 μ, mean 8 μ.
Width at base 3-6 μ, mean 5 μ
Remarks: Specimen has three appendages which give the body a lobate habitus. It is also ornamented with thin striae more or less parallel to the body. *Elateropollenites* differs from *Elaterocolpites* which possesses 10 appendages and also from *Elaterosporites* which has 3 pairs of U -shaped appendages. It has not been recorded from post - Middle Albian sediments.
Genus *Elaterocolpites* Jardiné and Magloire, 1965
Elaterocolpites castelaini Jardiné and Magloire, 1965, forma B Jardiné 1967
Plate 1, Figure L, P,
Dimension: (30-34) x (37-42) μ, mean 32 x 40 μ. (8 species measured)
Length of appendages 15-30 μ, mean 22 μ
Width at base 7-12 μ, mean 10 μ
Remarks: Specimens bear 10 short cylindrical, simple appendages with more or less parallel sides and terminating in free, blunt rounded apices. In some cases vestiges of annular band surround the spore body. Most of the specimens observed are similar to *Elaterocolpites castelaini,* forma B of Jardiné (1967). It differs from the forma A (Pl. 1, Fig. S) by its longer parallel sided appendages. Appendages of forma A are either clavate or gemmate.
Genus *Elaterosporites* Jardiné, 1967
Elaterosporites protensus (Jardiné and Magloire) Jardiné, 1967
Plate 1, Figure I, J, K, N
Dimension: (42-55) x (30-45) μ, mean 50 x 38 μ. (12 specimens measured)
Length of appendages 22-50 μ, mean 35 μ
Width at base 5-8 μ, mean 7 μ.
Remarks: Specimen has elliptical to subspherical central body with a strongly convex distal face, thick exine and ornamented with spines (5-7 μ long, 2.5 μ wide at base). It also bears 3 pairs of U-shaped cylindrical appendages of almost equal lengths.

Elaterosporites verrucatus (Jardiné and Magloire) Jardiné, 1967
Plate 1, Figure E, F, G, H

Dimension: (37-50) x (50-57) μ, mean 42 x 54 μ (15 specimens measured)
Length of appendages 25-37 μ, mean 31 μ
Width at base 5-8 μ, mean 7 μ.
Remarks: This species differs from *E. protensus* only by ornamentation. *E. verrucatus* has verrucate ornamentation, much lower in height (2.5-3) μ and also loosely packed on distal face as well as bigger appendages.

Elaterosporites klaszii (Jardiné and Magloire) Jardiné, 1967
Plate 1, Figure A, B, C, D

Dimension: (30-48) x (50-60) μ, mean 40 x 55 μ. (12 specimens measured)
Length of appendages 25-37 μ, mean 32 μ.
Width at base 5-9 μ, mean 7 μ.
Remarks: This species differs from other forms of *Elaterosporites* by its smooth or punctate membrane, and the frequent expansion and detachment from the central body of an annular band similar to the appendages of the distal face.

Genus *Galeacornea* Stover, 1963
Galeacornea clavis Stover, 1963
Plate 1, Figure T, U

Dimension: (37-42) x (25-30) μ, mean 40 x 28 μ. (4 specimens measured)
Length of appendages 12-25 μ, mean 20 μ
Width at base 4-6 μ, mean 5 μ.
Remarks: This specimen is characterised by a Y - shaped horn on the distal surface. A single stem supports the "V" of the "Y". This attribute of the specimen is similar to the original description of the species by Stover (1963). It differs from *G. causea* in possessing a distal horn or appendage, a zona of uniform width that is concentric to the equatorial outline of the body and that lies in a plane.

Galeacornea causea Stover, 1963
Plate 1, Figure O, R

Dimension: (35-48) x (25-35) μ, mean 42 x 30 μ. (10 specimens measured)
Length of appendages 25-40 μ, mean 35 μ.
Width of appendages 3-6 μ, mean 5 μ
Remarks: *G. causea* differs from other forms of *G. clavis* in possessing zona of variable width, long axis of the zona oblique to that of the body and possessing a distal flap instead of a horn or appendage.

Genus *Sofrepites* Jardiné, 1967
Sofrepites legouxae Jardiné, 1967
Plate 1, Figure Q

Dimensions (25-42) x (18-34) μ, mean 35-26 μ   (5 specimen measured)
Length of appendage 10-18 μ, mean 15 μ
Width at base 5-8 μ, mean 6 μ
Remarks: S. legouxae possesses ellipsoidal body with elliptical to subcircular outline with 2 or 3 appendages of somewhat equal lengths. Exine is psilate to granulate.

Reported Occurrences

Elaterocolpites castalainii has been reported from middle Albian – middle Cenomanian in Brazil (Herngreen, 1973, 1975, Dino et al., 1990); late Albian- early Cenomanian in Dongola

region in northern Sudan (Schrank, 1990), Gabon and Senegal (Jardiné, 1967), Colombia (Herngreen & Jiminez, 1990), Egypt (Zobaa et al., 2013), late Albian – late Cenomanian in Senegal (Jardine & Magloire, 1965), Albian in Gabon (Boltenhagen, 1965), Albian in Libya (Thusu and Van der Eem, 1985), late Albian – middle Cenomanian in Nigeria (Abubakar et al., 2006, 2011).

Elateropollenites jardinei has been recorded in early Albian – middle Albian in Brazil (Regali and Viana, 1989; Herngreen, 1973, 1975; Dino et al., 1999), Venezuela (Muller et al., 1987), midddle Albian in Ivory Coast (Jardiné and Magloire, 1965)

Elaterosporites klazii has been recorded from has been reported from Albian – Cenomanian of Libya (Batten & Uwins, 1985), Albian of Morocco (Bettar & Meon, 2006), late Albian – early Cenomanian of northern Sudan (Schrank, 1990), Egypt (Zobaa et al., 2013), late Albian in Nigeria (Abubakar et al., 2006, 2011), early Albian - early Cenomanain of Brazil (Herngreen, 1975), early Albian – early Cenomanian of Eygpt (Mahmoud & Deaf, 2007), middle Albian – late Cenomanian in Gabon (Doukaga, 1980) and Senegal (Jardiné, 1967). Herngreen and Dueǹas-Jimenez (1990) have reported *E. klazii* from the late Albian – early Cenomanian in Peru and Colombia.

Elaterosporites protensus has been reported from the Albian of Morocco (Bettar & Meon, 2006), late Albian of Nigeria (Abubakar et al., 2006, 2011), middle – late Albian of Senegal (Jardiné, 1967), middle Albian in Gabon (Doukaga, 1980), late Albian – early Cenomanian of Brazil (Herngreen, 1973, 1975), Peru (Herngreen and Dueǹas-Jimenez, 1990) and Venezuela (Muller et al., 1987), middle Albian – early Cenomanian of Cote d'Ivoire (Jardiné, 1967).

Elaterosporites verrucatus occurs in the Albian of Morocco (Bettar & Meon, 2006), late Albian – early Cenomanian of Brazil (Herngreen, 1973, 1975), Senegal and Cote d'Ivoire (Jardiné et Magloire, 1965), and Venezuela (Muller et al., 1987), Egypt (Shrank and Ibrahim, 1995).

Elateropollenites jardinei has been reported from early to middle Albian rocks of Brazil (Herngreen, 1973, 1975; Regali and Viana, 1989), Senegal and Cote d'Ivoire (Jardine et Magloire, 1965), Venezuela (Muller et al., 1987).

Galaecornea causea has been reported from late Albian – early Cenomanian of Brazil (Herngreen, 1973, 1975), Albian – Turonian of Guinea Bissau and Senegal (Stover, 1964), late – early Cenomanian of Senegal and Gabon (Jardiné and Magloire, 1965; Jardiné, 1967), Albian – Cenomanian of Peru (Brenner, 1968), late Albian – early Cenomanian of Egypt (Mahmoud, 1998; Shrank and Ibrahim, 1995; Aboul Ela and Mahrous, 1992; Zobaa et al., 2013), late Cenomanian of Nigeria (2011).

Sofrepites legouxae has been recorded from late Albian – early Cenomanian rocks of Brazil (Herngreen, 1973, 1975; Herngreen et al., 1996), Gabon (Jardiné, 1967), Eygpt (Mahmoud, 1998; Mahmoud and Moawad 1999; Aboul Ela and Mahrous, 1992), late Albian of Senegal (Jardiné, 1967).

4. DISCUSSIONS AND CONCLUSIONS

The elater-bearing pollen have been attributed to the Albian - Cenomanian Elaterate Province of Africa South America (ASA). This concept was introduced by Herngreen (1975) and has been also referred to as Northern Gondwana Province (Brenner, 1976) and *Elaterosporties* phytoprovince (Srivastava, 1981).

Their unique morphology with protuberances characterise this otherwise heterogeneous group of pollen grains with and short stratigraphic range. They appeared in the lower Albian sediments of the low latitude region, diversified, became numerically important in the upper Albian – Cenomanian and died out at the end of Cenomanian, which saw rapid diversification and rise to dominance of the angiosperms (Herngreen et al. 1996; Vallati, 2013). The elater pollen have attracted the attention of palynologists and has contributed to their application in palynostratigraphy and paleobiogeography (Schrank, 2001). According to Vallati (2013), the morphological characteristics of these grains are unknown from extant pollen grains and up to now in situ specimens have not found. A probable ephedroid affinity for the elaterates has been proposed (Shrank, 2001; Dino et al.1999; Crane, 1988). The ranges of other associated palynomorphs in the assemblage point to an Albian – Cenomanian age.

These include; *Afropollis jardinus* (Aptian – lower Cenomanian) (Herngreen 1973, 1975; Doyle et al., 1982), *Reyea polymorphus* (lower Albian – Middle Albian) (Herngreen 1973, 1975; Masure et al., 1998), *Perotriletes pannuceus* (Albian – Cenomanian) (Brenner, 1968), *Classopollis* spp. (early Aptian – late Cenomanian) (Schrank and Ibrahim, 1995).

The distribution of the characteristic elements of this province paralleled the palaeolatitude and the axis of the Elaterate Province approximates the palaeoequator (Herngreen, 1998; Dino et al., 1999). The province is recognized in ASA region, Middle East, (Fig 3) and recently Bahamas islands, China and Papua New Guinea (Herngreen, 1996, 1998; Dueǹas-Jimenez, 1990). According to Herngreen (1998), their presence suggests that climate was the main controlling factor of the geographical extent of the province. This phytogeographic belt is characterized by the presence of elater-bearing species and related forms which are restricted to the province, variety of polyplicate forms (ephedroids, etc), absence of bi and trisaccate gymnosperous pollen, scarcity of fern spores and the presence of angiospermous pollen.

The presence of elaterate pollen have been interpreted as indicating arid – semi arid palaeoclimatic conditions (Herngreen and Dueǹas-Jimenez, 1990; Herngreen et al., 1996; Schrank, 2001). But because of the unknown botanical affinities, and taking into account wall stratification and ultrastructural compartibility of the elaterates (*Sofrepites*, *Elateroplicites*, *Elaterosporites*) with that of *Ephedripites* and other Cretaceous polyplicates, Dino et al., (1999) suggested that elaterates and polyplicates are botanically related. Dino et al., (1990) thus intimated that palaeoclimatic factor controlling the distribution of the elater pollen may be obtained from knowledge of associated vegetation and the types of environment they inhabited. They also opined that associated plant fossil provided a perspective of the vegetation and the enclosing sediments reflect the interaction of physiographic/biotic processes in the region.

The associated plant fossils (*Classopollis*, ephedroids) with the elaterates in our materials are similar to that of Dino et al., (1990) and Schrank (2001), which suggests that a hot-arid to semi-arid climatic condition must have prevailed during deposition of the Albian – Cenomanian sediments in the Tano Basin. Mahmoud and Deaf (2007), Dino et al., (1999) and Schrank (2001) have reported that *Afropollis* and Elaterate pollen parent plants flourished in humid coastal plains. The presence therefore of the *Afropollis* pollen in the samples

investigated here suggests that similar conditions prevailed in Ghana during the Albian – Cenomanian time.

The continental breakup, drift and initiation of new oceans worldwide were experienced during the Cretaceous period. The opening of the South Atlantic Ocean, which separated South America from Africa, was initiated by crustal thinning and thermodynamic uplifts during the Late Jurassic. According to Dino et al., (1999), which is reiterated by Abubakar et al., (2006), the elater-bearing plants were found in dry zones under warm climates, and that their diversification and abundance were the response to climatic changes associated with the opening and enlargement of the northern parts of the South Atlantic ocean in the latest Aptian to early Albian, which came to a close during the late Albian – Cenomanian time. Dino et al., (1990) also opined that, the widening and deepening of the South Atlantic Ocean at the close of Cenomanian, resulting in temperature drop, culminated in the disappearance of the elaterate pollen from the stratigraphic record.

Contrary to the Brazilian and Equadorian basins, where Dino et al., (1990) have reported that the earliest appearance and highest diversity and frequency levels of the elaterates seem to coincide with the transgressive event during the late Albian – Cenomanaian time, the elaterates in this study, reached their maximum diversity and frequency levels in fluvial and lacustrine continental facies. This observation supports Abubakar's (2006) suggestion that the appearance and subsequent abundance of the elaterates is evolutionary and palaeoclimatic in nature and that the palaeoclimatic influence may not necessarily be related to the opening of the northern part of the southern Atlantic Ocean, as suggested by Dino et al., (1990).

Overlying the Cenomanian fluvial/lacustrine facies are the limestones which is as a result of deposition in open marine waters which is devoid of the elater pollen. This supports the suggestion of Dino et al., (1990) that the elater pollen disappeared as a result of climatic fluctuations or perturbations during the onset of deeper and more marine conditions as the South American Atlantic Ocean widened at the close of the Cenomanian.

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