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Leaves of *Terminalia* L. and *Anogeissus* (DC.) Wall. ex Guill. & Perr. (family: *Combretaceae*) from the Eocene sediments of Gurha Lignite Mine, Bikaner District, Rajasthan, India

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ABSTRACT

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Almost all plant groups are represented in the lignite deposits of Rajasthan, either as spores-pollen, fragments of various parts of plants, or as whole vegetative and fertile forms. In the present paper, leaves of *Terminalia alata* B. Heyne ex Roth and *Anogeissus sericea* Brandis (family: *Combretaceae*) are described from the Eocene sediments of Gurha Lignite Mine, Bikaner District, Rajasthan, India. The palaeoecological setting of this area in Rajasthan during the Eocene is also discussed.

Keywords: *Anogeissus*, *Terminalia, Combretaceae*, Eocene, Gurha lignite mine, Rajasthan, India.

INTRODUCTION

There are several open-pit and subsurface (20–30 m below ground level) lignite mines, notably at Palana, Barsinghsar, Gurha, Giral, Matasukh, etc. in western Rajasthan. Sah and Kar (1974), Singh and Dogra (1988), Kar (1995), Ambwani and Singh (1996), Kar and Sharma (2001), Tripathi et al. (2008), Harsh and Shekhawat (2018, 2020, 2022, 2023) studied plant fossils from Bikaner-Nagaur Basin. The oil-bearing fresh and brackish water alga *Botryococcus braunii* Kütz. was recorded from the Palana lignite (Rao & Misra 1949). Rao and Vimal (1950, 1952) and Sah and Kar (1974) described pollen and spores from the Palana lignite. Harsh and Sharma (1992) investigated a sample of carbonized Palana wood and identified inorganic and organic components. Tripathi et al. (1998) reported several plant microfossils in the Barsinghsar lignite. These microfossils include algal filaments, fungal hyphae, sporangia, spores, cuticles, pollen grains, odd types of seeds, and fructifications.

MATERIAL AND METHODS

For the present study, 15 leaf impression specimens were collected from the overburden of Gurha lignite

Figure 1. Map of Rajasthan showing location of Bikaner District.

mine (Lat. 27.5229ºN, Long. 72.52269ºE), about 70 km southwest of Bikaner City (Figure 1). The dimensions of leaves vary widely. It ranges between 15 and 21 cm and between 0.8 and 3 cm. Most of the leaves are grey in colour. We employed the herbarium sheets from the Botanical Survey of India (B.S.I.), Jodhpur, and the Dungar Post-Graduate College, Bikaner, to morphologically analyze the leaf impressions and contrast them with various contemporary leaves. It was found that the vast majority of the samples closely resembled modern leaves. A photograph of comparable contemporary leaves with the same morphological traits was also taken at the same magnification, in addition to those of the fossil leaves.

The photographs of the leaf impressions demonstrating various morphological traits were taken using a Canon 1100d DSLR camera. These fossils were seen using an objective lens, reflected light, and photographs. The microscopic structure of the surface (cuticle and stomata) of impressions was also examined using transparent peels (such as Fevicol and Quick Fix) put on microscope slides. However, criteria suggested by Hickey (1973, 1974, 1979), Dilcher (1974), Melville (1976), Ash et al. (1999), and LAWG (1999) were adhered to identify these leaves. These criteria were then compared with works by Dickinson et al. (1987), Agarwal (1991, 2002) and Ambwani (1991).

DESCRIPTION OF FOSSIL LEAVES

Phylum: ***Tracheophyta*** Kenrick & Crane

Class: ***Magnoliopsida*** Cronquist et al.

Order: ***Myrtales*** Juss. ex Bercht. & J. Presl

Family: ***Combretaceae*** R. Br.

Genus: ***Terminalia*** L.

Terminalia alata B. Heyne ex Roth

Figure 2.1–6

Material: The present specimen is a well-preserved leaf impression. There is no trace of any cuticle preserved on the impression.

Number of specimens: Three

Description: Leaves symmetrical, narrow elliptical, preserved size 6 × 2.6 cm and 5.7 × 3.2 cm, 4 × 2.4 cm (L/W ratio 3:1), microphyll (one side area 6–10 cm^2), apex and base broken, seemly obtuse apex and acute base, margin entire, petiole not preserved, venation pinnate craspedodromous type, primary vein (1º) single, prominent, stout, almost straight, secondary veins (2º) 11 to 12 pairs visible, angle of divergence about 45 to 50º moderately acute, 0.4 to 0.7 cm apart from each other, uniformly curved up, inter-secondary veins very fine, tertiary veins (3º) very fine not clearly visible.

Figure 2. 1–6. ***Terminalia alata*** B. Heyne ex Roth. **1, 4.** Fossil leaf showing shape, size and venation pattern. (a ×1.4), (d ×1.2). **2, 5.** Modern leaves showing resemblance in similar shape, size and venation pattern. (b ×1.4), (e ×1.2). **3, 6.** Hand diagram of fossil leaf showing clear pattern of venation up to 3^0 veins. (c ×1.4), (f ×1.2). **7–9.** ***Anogeissus sericea*** **var. 7.** Fossil leaf showing shape, size and venation pattern. ×0.85. **8.** Modern leaves showing resemblance in similar shape, size and venation pattern. ×0.75. **9.** Hand diagram of fossil leaf showing a clear pattern of venation up to 3^0 veins. ×0.85

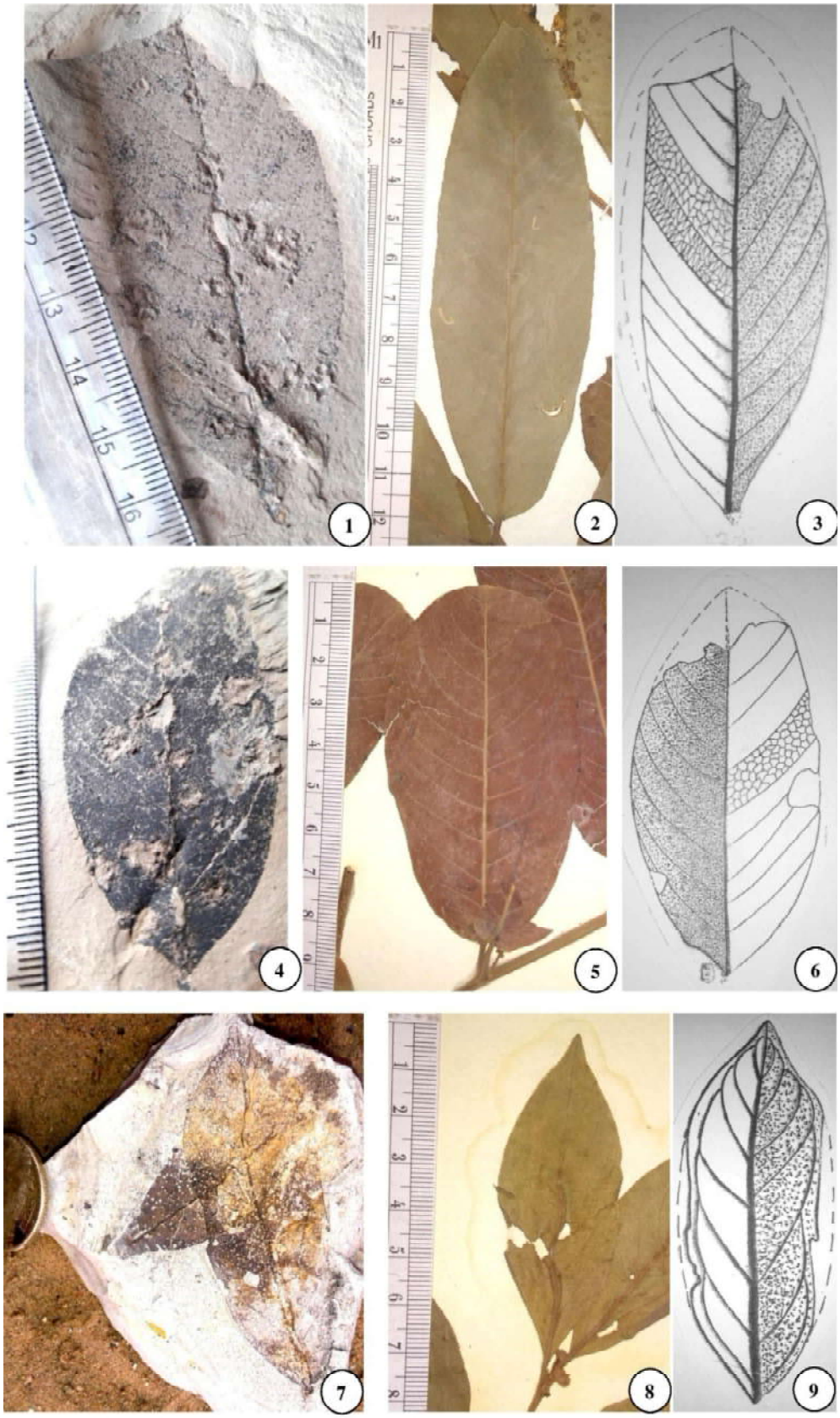

Figure 2

Location and age: Gurha, Bikaner District, Rajasthan, India; Eocene.

Modern affinity and comparison: The important characteristics of the fossil leaves such as elliptic shape, craspedodromous venation and closely spaced secondaries with nearly right angle of divergence indicate their close affinity with the modern leaves of *Terminalia* of *Combretaceae*. Leaf was compared with leaves of several modern species of *Terminalia* viz. *Terminalia alata, T. arjuna, T. chebula, T. crenulata, T. paniculata* and *T. bellirica*. Comparison was also made with the published fossil leaves of *Terminalia*, viz. *Terminalia obovata* (Awasthi & Mehrotra 1995), *Terminalia palaeocatappa* (Awasthi & Mehrotra 1995), *Terminalia neyveliensis* (Agarwal 2002) and *Terminalia praechebula* (Agarwal 2005). A critical examination of fossil leaves and comparison indicate that the leaves of *Terminalia alata* (BSI Jodhpur sheet no. 39468, 19903, 25795) show closest resemblance with the fossils. The present leaf impression is identical to *Terminalia alata* described from Patan District. Gujarat India hence leaf is identified as *Terminalia alata.*

The modern taxon *Terminalia alata*, with which the fossils show close affinity, is a deciduous tree, 20–35 m high, with dark cracked bark. Leaves opposite, 10 × 5 cm, elliptic-lanceolate or obovate, acute, emarginated, entire.

Genus: ***Anogeissus*** (DC.) Wall. ex Guill. & Perr.

Anogeissus sericea Brandis

Figure 2.7–9

Material: The present specimen is a well-preserved leaf impression. There is no trace of any cuticle preserved on the impression.

Number of specimens: One

Description: Leaf symmetrical, narrow oblong shape, preserved size 8 × 2.9 cm (L/W ratio 3:1), microphyll (one side area 10.36 cm^2), apex acuminate, base obtuse, margin entire, petiole not preserved, venation pinnate camptodromous type, primary vein (1º) single, prominent, massive, straight, secondary veins (2º) 6 to 7 pairs, angle of divergence is 55º, mordantly acute, uniformly curved up, oppositely arranged, unbranded, inter-secondary veins not visible, tertiary veins (3º) not visible.

Location and age: Gurha, Bikaner District, Rajasthan, India; Eocene.

Modern affinity and comparison: The distinguishing features of the present fossil leaf are a narrow oblong shape and closely spaced and uniformly arranged secondaries. Such features are found in the modern leaves of *Anogeissus sericea* of the family *Combretaceae*. Leaf was compared with modern leaves of *Anogeissus* (viz. *Anogeissus sericea*, *A. latifolia*, *A. pendula*, *A. coronata*) indicating that the leaves of *Anogeissus sericea* (BSI Jodhpur sheet no. 19568). Comparison was also made with the published species of *Anogeissusoxylon*. A critical examination of fossil leaves and comparison indicate that the leaves of *Anogeissus sericea* show closest resemblance with the fossils.

The present leaf impression is identical to *Anogeissus sericea* described from Gurushikher, Mount Abu district Rajasthan, India hence this fossil leaf is identified as *Anogeissus sericea.* Plants of this species are moderate- sized trees, with pendulous branches, leaves 2–5.5 × 1.5–3 cm, acute or acuminate, occasionally obtuse or almost truncate, sometimes mucronulate, nerves 4–6 petiole.

PALAEOECOLOGY

The information on the fossil plants discovered in the Tertiary strata of Rajasthan shows that the plants exhibit significant habitat variety. The extinct remains of *Cocos*, *Mesua*, and *Garcinia* in Kapurdi, along with palm pollen, *Barringtonia*, *Rhizophora*, etc., are

evidence of the presence of marine conditions in this area. This hypothesis is supported by the existence of marine fish and echinoderm fossils, and other data.

The broad and large-sized dicot plant leaves from Barmer, *Mangiferoxylon* and *Glutoxylon* from Jaisalmer, *Cassia fistula* and *Cassia angustifolia* from Gurha in Bikaner, as well as the current collection of dicot leaves described here, however, support the presence of a warm and humid climate but unquestionably not marine conditions in the western shelf of Rajasthan.

RESULT

During the Tertiary Period, there were both low-lying and high-lying zones. In the former, a gulf-like feature was probably formed when the sea encroached quite deeply on the land. In the low-lying areas, several plant species, including *Mesua*, *Garcinia*, *Rhizophora*, etc. were present. Although it was warm and humid in the "upland" regions, there was little effect from the "sea gulf," which is why some Eocene locations on Rajasthan's western shelf may have had broad and large-sized leaves.

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