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# Leaves of two species of *Terminalia* L. (family: *Combretaceae*) from the Eocene sediments of Gurha Lignite Mine, Bikaner District, Rajasthan, India

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## ABSTRACT

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The lignite deposits possess almost all plant groups either in form of macro-remains comprising complete/ fragmented remains of leaves, stems, fructifications, etc. or micro-remains such as spores and pollen. The present paper deals with fossil leaves of two species of *Terminalia* L., viz. *T. chebula* (Gaertn.) Retz. 1789 and *T. bellirica* (Gaertn.) Roxb.1805 (family *Combretaceae*). Palaeoecological conditions of the area in Rajasthan during the Eocene are also discussed.

**Keywords:** *Terminalia* L., *Combretaceae*, Eocene, Gurha Lignite Mine, Rajasthan, India.

## INTRODUCTION

Lignite deposits can be found in open-pit mines or subsurface (approximately 20–30 m below ground level) deposits at a number of locations in western Rajasthan, including Palana, Barsinghsar, Gurha, Giral, Matasukh, etc. Rao and Vimal (1950, 1952), Sah and Kar (1974), Singh and Dogra (1988), Kar (1995), Ambwani and Singh (1996), Kar and Sharma (2001), Tripathi et al. (2008) and Harsh and Shekhawat (2018, 2020, 2022a, 2022b) carried out palynological studies on the Early Tertiary sediments of Rajasthan. Rao and Misra (1949) reported, for the first time, discovery of oil-bearing fresh and brackish water alga *Botryococcus braunii* Kütz. from the Palana lignite sequence. Pollen and spores from Palana lignite were described by Rao and Vimal (1950, 1952) and Sah and Kar (1974). Harsh and Sharma (1992) examined a carbonized piece of Palana wood and determined its inorganic and organic composition. Tripathi et al. (1998) reported many plant microfossils from Barsinghsar lignite. Algal filaments, fungal hyphae, sporangia, spores, cuticles, pollen grains, as well as unusual kinds of seeds and fructification, are among these microfossils.

## MATERIAL AND METHODS

More than 15 leaf impression specimens have been gathered from the overburden of the Gurha lignite mine for the current study (Lat. 27.5229° N, Long.

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72.52269° E). It is located about 70 km southwest of Bikaner City (Figure 1). The size of leaves varies significantly, ranging from 0.8 to 3 cm in width and 15 to 21 cm in length. The majority of leaves are grayish in colour. Detailed morphological features of leaf impressions were studied under EISCO Stereo binocular microscope. Herbarium sheets from the Botanical Survey of India, Jodhpur, and from Dungar Post-Graduate College, Bikaner, were used to compare fossil leaves with their modern counterparts. Most of the studied specimens exhibited close resemblance with contemporary modern leaves. Along with photograph of the fossil leaves, photographs of comparable modern leaves with identical morphological characteristics were also obtained at the same magnification.

The Canon 1100d DSLR camera was used to capture the images of the leaf impressions displaying diverse morphological characteristics. With the aid of an objective lens, reflected light, and pictures, these fossils were observed. With the use of clear peels (such as Fevicol and Quick Fix) mounted on slides for microscopic examination, the microscopic structure of the surface (cuticle and stomata) of impressions was also analyzed. However, in order to identify these leaves, criteria proposed by Hickey (1973, 1974), Dilcher (1974), Melville (1976), Ash et al. (1999) and LAWG (1999) were followed and compared with works like Dickinson et al. (1987), Agarwal (1991, 2002) and Ambwani (1991).

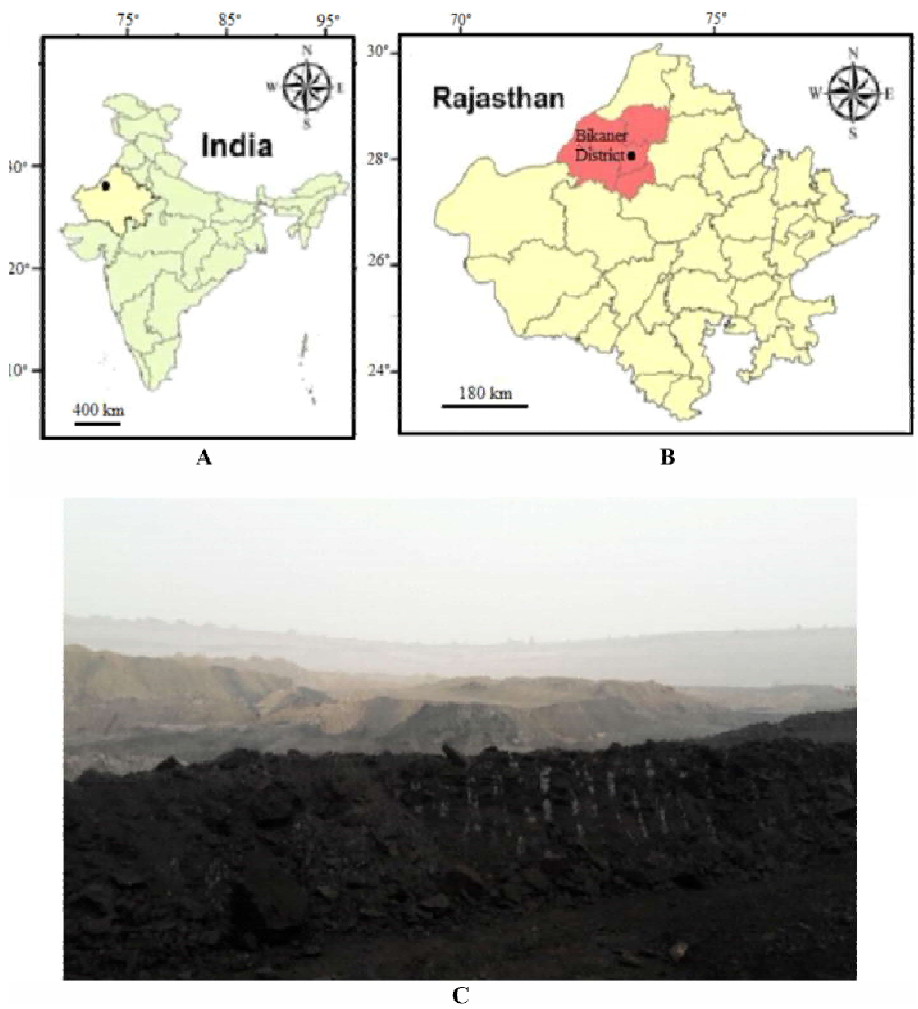


**Figure 1. A.** Map of India showing location of Rajasthan. **B.** Map of Rajasthan showing location of Bikaner District. **C.** Fossil locality (Gurha lignite mine), Bikaner District, Rajasthan, India.

## DESCRIPTION OF FOSSIL LEAVES

**Kingdom:** *Plantae* Haeckel

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

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

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

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

**Genus:** *Terminalia* (Gaertn.) Retz.

***Terminalia chebula*** (Gaertn.) Retz. 1789

Figure 2.1–3

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

**Number of specimen:** One.

**Description (leaf):** Leaf symmetrical, elliptical, preserved size 9 × 4.9 cm ( L/W ratio 2:1), microphyll (one side area 16.8 $cm^2$), apex acuminate, base broken, margin entire, petiole not preserved, venation pinnate semi-craspedodromous type, primary vein (1°) single, prominent, stout, almost straight, secondary veins (2°) 9 pairs, angle of divergence about 30 to 60° narrow to moderately acute,1 to 1.4 cm apart from each other, uniformly curved up, unbranched, inter-secondary veins not visible, tertiary veins (3°) not visible.

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

**Modern affinity and comparison:** Important characteristics of the fossil leaf such as elliptical shape, semi-craspedodromous venation, and uniformly curved up indicate their affinity with the modern leaves of *Terminalia* of family Combretaceae. Leaf was compared with a number of species of modern leaves of *Terminalia* like *Terminalia alata, T. arjuna, T. chebula, T. crenulata, T. paniculata* and *T. bellirica*. The comparison was also made with the published fossil species of *Terminalia*, viz. *Terminalia obovata* N. Awasthi & R.C. Mehrotra 1995, *Terminalia palaeocatappa* N. Awasthi & R.C. Mehrotra 1995, *Terminalia neyveliensis* An. Agarwal 2002 and *Terminalia praechebula* An. Agarwal 2005. A critical examination of fossil leaf and comparison with modern species indicate that the leaves of *Terminalia chebula* (BSI Jodhpur sheet no. 33211) closely resemble with the fossils.

**Remarks:** The present leaf impression is identical to *Terminalia chebula* described from Dholwani Herbal Garden, Sabarkantha District, Gujarat, India; hence this fossil leaf is identified as *Terminalia chebula*. *Terminalia chebula* is a large deciduous tree, 8–20 m high, with bark dark brownish-grey, fissured, young parts tomentose. Leaves alternate, long petiole, 7.5–12 × 4–10.5 cm, elliptical-oblong or ovate-oblong, rounded at both ends at length glabrous.

***Terminalia bellirica*** (Gaertn.) Roxb.1805

Figure 2.4–6

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

**Number of specimen:** One.

**Description:** Leaf symmetrical, elliptic, preserved size 5.5 × 3.5 cm ( L/W ratio 2:1 ), microphyll (one side area 10.56 $cm^2$), apex broken, base obtuse, margin entire, petiole not preserved, venation pinnate craspedodromous type, primary vein (1°) single, prominent, massive, curved, secondary veins (2°) 3 to 4 pairs, angle of divergence is about 40 to 50°, 1.5 to 1.8 cm apart from each other, uniformly curved up, oppositely arranged, inter-secondary veins simple, tertiary veins (3°) fine, clearly visible.

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

**Modern affinity and comparison:** The fossil leaf is characterized by its elliptic shape, obtuse base, and oppositely secondary veins with a 50° angle of divergence, these features are found in the modern leaves of *Terminalia* of the family Combretaceae. Leaf was compared with a number of species of modern leaves of *Terminalia* like *Terminalia alata, T. arjuna, T. chebula, T. crenulata, T. paniculata, T. bellirica*. The comparison was also made with the published fossil species of *Terminalia*, viz. *Terminalia obovata* N. Awasthi & R.C. Mehrotra 1995, *Terminalia*

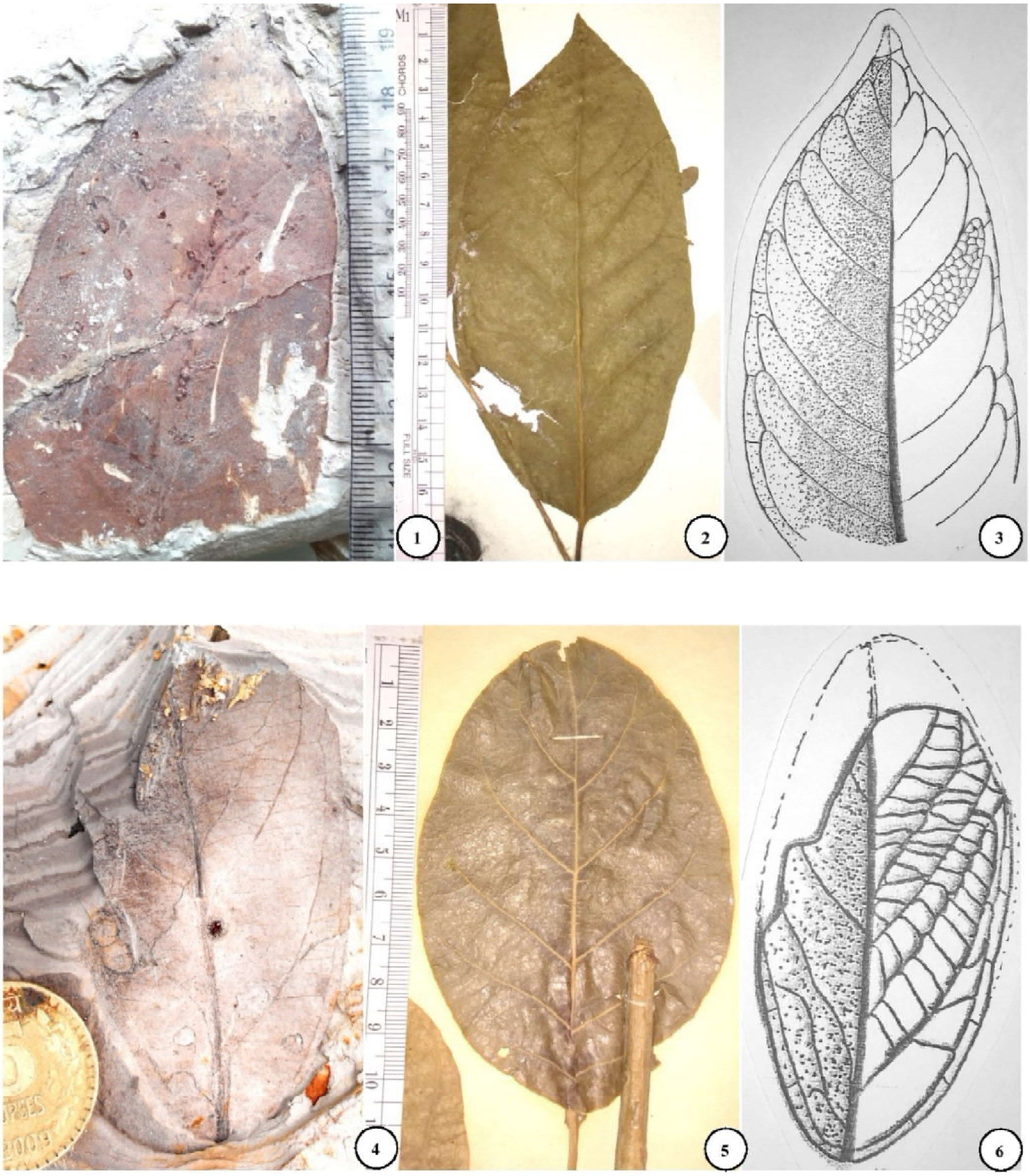


**Figure 2. 1–3.** ***Terminalia chebula*** (Gaertn.) Retz. **1.** Fossil leaf showing shape, size and venation pattern. ×0.9. **2**. Modern leaf showing resemblance in similar shape, size and venation pattern. ×0.67. **3.** Text figure of fossil leaf showing clear pattern of venation up to 3° veins. ×0.9. **4–6.** ***Terminalia bellirica*** (Gaertn.) Roxb**.** **4.** Fossil leaf showing shape, size and venation pattern. ×1.1. **5.** Modern leaf showing resemblance in similar shape, size and venation pattern. ×1. **6.** Text figure of fossil leaf showing clear pattern of venation up to 3° veins. ×1.1

*palaeocatappa* N. Awasthi & R.C. Mehrotra 1995, *Terminalia neyveliensis* An. Agarwal 2002 and *Terminalia praechebula* An. Agarwal 2005.

**Remarks:** A critical examination of the fossil leaf and comparison indicate that the leaves of *Terminalia bellirica* (Botanical Survey of India, Jodhpur sheet no 5047) closely resemble with the fossil leaf. It is described from Aravalli Hills, Pali District, Rajasthan hence this fossil leaf is identified as *Terminalia bellirica*. *Terminalia bellirica* is a deciduous tree, 10–30 m high, bark dark grey, leaves 5–25 × 2.5–15 cm, broadly obovate, cuneate, glabrous coriaceous.

## PALAEOECOLOGY

It is evident that the plants exhibit significant habitat variation from the data on fossil plants found in the Eocene sediments of Rajasthan. As evidence of the marine conditions in this region, the extinct remains of *Cocos* (Kaul 1951), *Mesua* and *Garcinia* (Lakhanpal & Bose 1951, Lakhanpal 1964) as well as palm pollen, *Barringtonia* and *Rhizophora* (Sah & Kar 1972, Lakhanpal 1974), etc. are found there. The presence of marine fish fossil, echinoderms fossils (Barooah 1950, Hora 1952, Singh 1952, Bhatia 1977, Das Gupta 1977) and other evidence supports this view.

However, the megafossils discovered, such as the broad and large-sized dicot plant leaves from Barmer, *Mangiferoxylon* and *Glutoxylon* from Jaisalmer, *Cassia fistula* and *Cassia angustifolia* from Gurha, Bikaner, and the current collection of dicot leaves described here, favour the presence of a warm and humid climate but definitely not marine conditions in the western shelf of Rajasthan.

## RESULT

The plant fossil data indicate that there were both low-lying and high-lying regions during the Eocene. In the former, the sea presumably encroached on the land, rather deeply, creating a gulf-like formation. The flora recorded includes *Mesua, Garcinia, Rhizophora*, and other species occurring in low-lying areas. Even though it was humid and warm in the 'upland' parts, there was little influence from the 'sea gulf', which is why broad and large-sized leaves may be seen in some Eocene locales on the western shelf of Rajasthan.


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