Early Eocene (~50 m. y.) legume fruits from Rajasthan

The early Eocene (55–52 Ma) is one of the most biologically diverse intervals associated with extensive migration of biota from one land to another in the earth's history[1]. This epoch has witnessed exceptionally warm temperature recorded in global deep marine environments[2–8], though Shukla *et. al.*[9] have recently suggested cooler early Eocene temperature regime for the terrestrial biome on the basis of CLAMP analysis. The north-moving Indian subcontinent is said to be subducted beneath the Eurasian plate at this juncture[10], and the biota of each land mass marked its own way to move far and wide. To study these changes in deep time we have collected several plant fossils from the Gurha lignite mine (27.87398°N, 72.86709°E) in Rajasthan. Our collection contains several legume (family Fabaceae) fruits of which two are systematically described here.

Fabaceae, the third largest family of angiosperms[11], includes more than 19,000 species distributed throughout the globe from deserts of high latitudes to seasonally dry and wet tropical forests of equatorial regions[12]. Taxonomically, the family has been divided into three subfamilies, namely Caesalpinioideae, Mimosoideae and Papilionoideae (Faboideae)[13]. Molecular data suggest that Fabales and Cucurbitales got separated at 84 Ma and age of Fabaceae was estimated as 74–79 Ma (refs 14, 15). The earliest definite fossil record of legume is from the late Paleocene of Wyoming, USA (ca. 56 m.y. ago). From India, the Cenozoic records of fossil fruits have been listed by Srivastava and Mehrotra[16]. Recently, Khan and Bera[17] recorded some more legume fruits from the Siwalik sediments of Eastern Himalaya.

The Gurha lignite mine is situated ~75 km WSW of Bikaner, Rajasthan (Figure 1 *a*). The lignite of this mine belongs to the Palana Formation (early Eocene) exposed near Kolayat and Nagaur areas. The stratigraphic details of the mine can be found in Shukla *et al.*[9] (Figure 1 *b*). This is a new mine and only a fossil leaf of *Uvaria* L. has been described from the region[18].

The fossil fruits were identified either by consulting systematic legume literature[11,19,20], or by direct examination of available preserved specimens of extant plants at the herbarium of Central National Herbarium (CNH), Howrah, and Forest Research Institute (FRI), Dehradun. The type specimens are housed in the museum of the Birbal Sahni Institute of Palaeosciences, Lucknow.

Order: Fabales
Family: Fabaceae
Subfamily: Caesalpinioideae
Genus: *Leguminocarpon* Goeppert[21]
Leguminocarpon saracoides Shukla and Mehrotra, sp. nov.
(Figure 2 *a* and *e*)
Holotype: Specimen no. BSIP 40815.

Diagnosis: Fruit legume, flat, chartaceous in texture, slightly curved, symmetrical, indehiscent, elliptic in shape; preserved length 4.9 cm, width 2.8 cm; thickness of dorsal and ventral margin 2.0 and 0.5 mm respectively; apex acute; base acute; surface with regular, parallel to reticulate, fine wavy veinlets arising at 90°; septa absent.

Remarks: The above features of the fossil fruit show its similarity with modern fruits of the family Fabaceae. For further identification, a large number of extant genera of the family was examined at various herbaria. Initially, the fossil fruit was found to be close to the genera *Caesalpinia* L., *Butea* Roxb. ex Willd., *Millettia* Wight and Arn. and *Saraca* L. Detailed comparison revealed its close similarity with the fruits of *Saraca*, particularly *Saraca asoca* (Roxb.) Wilde (Figure 2 *b*). The fossil fruit can be easily separated from the rest mainly in shape and nature of veinlets.

Several legume fruits were described from the Cenozoic sediments of India[16,17]. Being usually similar in appearance, the

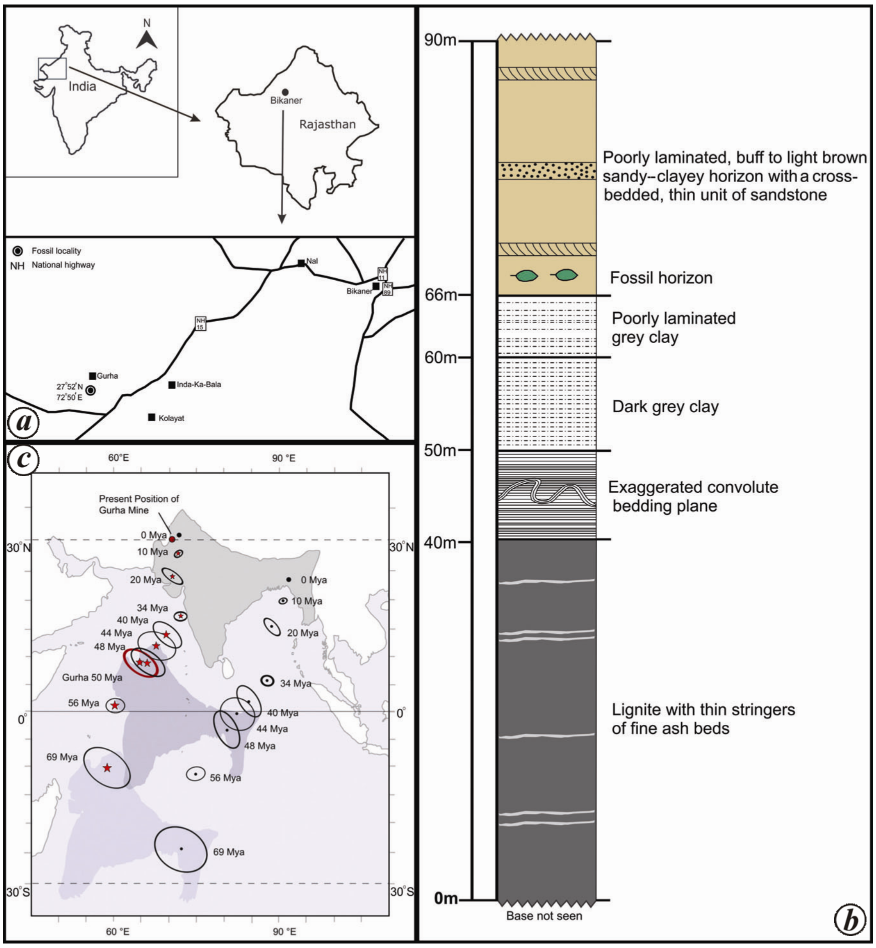

Figure 1. ***a***, Map showing the fossil locality. ***b***, Generalized litholog showing the fossiliferous horizon. ***c***, Map showing the early Eocene location of the Gurha Mine, Rajasthan, based on Molnar and Stock[10]. The position of northwestern India (red star) shows the rate of northward migration of the country through time as well as its rotation in an anticlockwise direction.

fossil legume fruits are generally described under the organ genus *Leguminocarpon*[21]. We have compared our fossil with these fruits and found that three of them, i.e. *Dalbergia sissoo*[22], *Buteocarpon awasthii*[16] and *B. oligocenicum*[16] show some resemblance to our fossil. *D. sissoo* has a curved shape, *B. awasthii* has oblique veinlets, while *B. oligocenicum* possesses curved shape and attenuate apex. As the present fossil is not identical to any known fossil fruit, it has been kept under a new specific epithet, i.e. *Leguminocarpon saracoides* sp. nov. The specific name is after the nearest modern comparable genus *Saraca*.

Subfamily: Faboideae
Genus: *Leguminocarpon*[21]
Leguminocarpon cajanoides Shukla and Mehrotra, sp. nov.
(Figure 2 *c* and *f*)
Holotype: Specimen no. BSIP 40816.

Diagnosis: Fruit legume, flat, oblong in shape, appearing chartaceous in texture, straight, symmetrical, indehiscent; preserved length 4.2 cm, width 2.3 cm; thickness of dorsal and ventral margin 1.1 and 0.8 mm respectively; apex acuminate; base slightly broken; veinlets fine; septa present, seemingly six in number, horizontal to slightly oblique, 7–9 mm apart; mark or impression of seeds visible at places.

Remarks: The shape, size and other morphological features of the fossil fruit indicate its close similarity with the extant fruits of the family Fabaceae. We have compared our fossil fruit with various modern genera of the family and found it to be close to *Acacia* Mill., *Albizia* Durazz. and *Cajanus* Adans. Detailed comparison revealed close affinity of the fossil fruit with genus *Cajanus*. Though fruits of various species of this genus are more or less similar, we found our fossil to be more close to *Cajanus crassus* (King) Maesen (Figure 2 *d*). The other two genera were found to be different, as in *Acacia* the shape of the fruit is elliptic in contrast to oblong shape of the fossil, whereas apex of *Albizia* is more acuminate than that in the fossil.

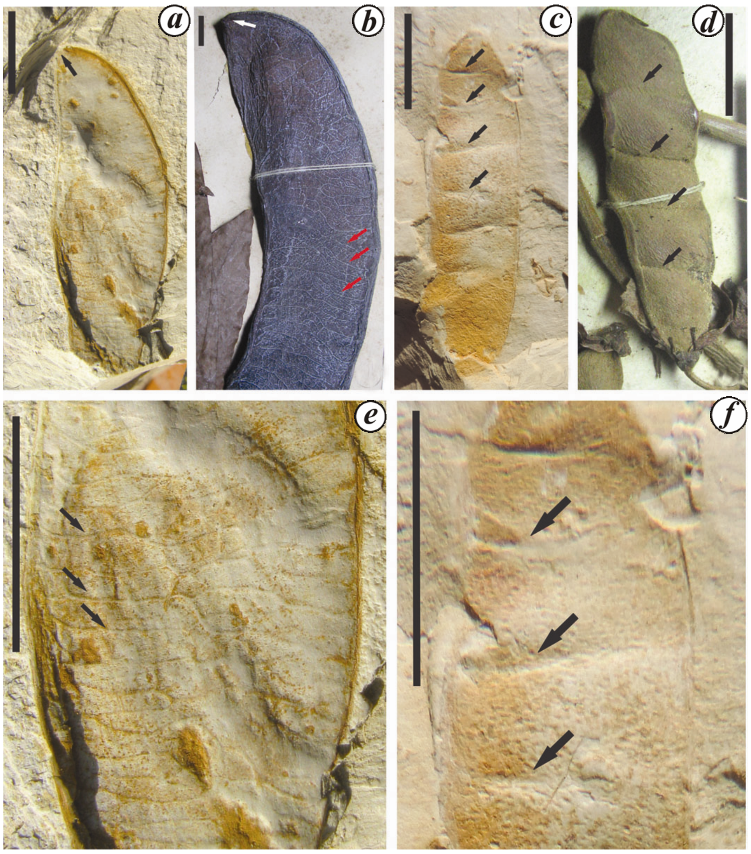

Figure 2. ***a***, *Leguminocarpon saracoides* sp. nov. showing shape and size (arrow indicates the tip). ***b***, *Saraca asoca* showing similar shape and size (arrow indicates the tip). ***c***, *L. cajanoides* sp. nov. showing shape and size (arrows indicate septa). ***d***, *Cajanus crassus* showing similar shape and size (arrows indicate septa). ***e***, A part of *L. saracoides* showing veinlets indicated by arrows. ***f***, A part of *L. cajanoides* showing septa indicated by arrows (scale = 1 cm).

The present fossil was also compared with the already known fossil fruits from India. Among those described only two, i.e. *Mastertia neoassamica* Khan and Bera[17] and *Acacia miocatechuoides* Khan and Bera[17] possess septa like the present fossil fruit. Nevertheless, both of them were found to be different from the present fossil in having lesser number of septa. As the present fossil fruit is different from the already known fossils, it is described under a new specific epithet, i.e. *Leguminocarpon cajanoides* sp. nov. The specific name is after the modern comparable genus.

Palaeoenvironmental reconstruction is based on the NLR (nearest living relative) method which assumes that the physiognomy and climatic tolerance of the modern equivalent could be representative of its comparable fossil. *Saraca asoca* (also known as Ashoka tree), one of the NLRs of our fossil, is a rainforest tree of distinctly warm humid climate. This tree is native to India and grows up to an altitude of 750 m in the central and eastern Himalayas. It is also distributed in the central areas of the Deccan plateau as well as the middle section of the Western Ghats in the western coastal zone of the Indian subcontinent. *Cajanus crassus*, another NLR of our fossil, though restricted to tropical Asia is also found in some parts of temperate Asia. Presence of the family Fabaceae, along with other taxa known from the Gurha lignite mine indicates the prevalence of humid forest with a marked dry season in the locality. This result is in congruence with the reconstruction based on CLAMP[9], which measured the ratio of precipitation during the three wettest months (3-WET) to that during the three driest months (3-DRY) as 11.8 : 1. According to studies[23,24], a ratio greater than 6:1 is indicative of a monsoon regime.

The palaeoequatorial position (Figure 1 *c*) of the Indian subcontinent during the early Eocene (~50 Ma) was at ~9°N, which favoured the growth of rainforests[10]. These forests are now restricted to a small pocket in south India in the form of the Western Ghats[25]. At present, Rajasthan is the driest region in India. Movement of the Indian plate from the equator to further north shifted India away from the influence of the Intertropical Convergence Zone and caused a change in the land and sea distribution as well as uplift of the Himalaya and the Tibetan Plateau[5,26–29]. The cumulative effect of all these changes might be responsible for weakening of the monsoon over Rajasthan, causing massive changes in the biota[9,18,25].

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Pallas's or Great Black-headed gull's (*Larus ichthyaetus*) feeding preference for toxic Lunartail puffer (*Lagocephalus lunaris*)

More than any other group of seabirds, gulls exploit a wide variety of food types and have evolved highly diversified foraging methods and habitats[1]. This has been demonstrated among gulls, both in the family as a whole and within each species, and at all times of the year. As a long-distance migrant, gulls, especially in the non-breeding season, spend more time on large water bodies along the coasts or in the open ocean; as a result they flourish on fish and marine invertebrates as their diet. Gulls in general are thus opportunistic and omnivorous.

Pallas's gull *Larus ichthyaetus* Pallas, 1773, chiefly feeds on fish and particularly on dead fish[1]. Other feeds include crustaceans, insects and small mammals, less often birds and their eggs, reptiles and seeds[2]. The Pallas's gull has an extremely large distributional range. Breeding range of this species extends from the Danube Delta in Romania eastwards across large areas of Central Asia to western China, where the lakes of the Qinghai–Tibet plateau hold most of the Chinese breeding population[3]. The migratory route of this gull is from Central Asia to coastal Bengal, encompassing diverse biome extending from the inland freshwater ponds, lakes to marine saline water[4]. The Bay of Bengal, with extensive areas of coastal mudflats, is an important wintering site for Pallas's gull and other species of gulls, from early November to mid-March[5]. A Pallas's gull captured and marked in China has been recovered in Assam, India, indicating that it may possibly be using many places in India as stopover sites[4–6]. Gulls feeding on a toxic fish species have not been documented, but there are reports on how the predators learn to avoid such toxic prey[7–11]. Nevertheless, an emerging alternative view is that predators should not entirely neglect toxic prey as long as this could increase their opportunity to gain energy[12–15]. A novel toxin-based optimal diet model was developed on the basis of data on prey abundance, diet choice, local survival and number of red knots[16]. Here we report instances of Pallas's gull feeding on toxic Lunartail puffer, *Lagocephalus lunaris*.

Pallas's gulls were observed from December 2013 (post-monsoon) to May 2014 (pre-monsoon) around the coastal