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(HONOURS)

The Indian Gondwana Flora

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The Indian Gondwana System

The term "Gondwana" (meaning "the land of the Gonds[1]") was coined by H.B. Medlicott in an unpublished work of 1872 while referring to geological formations in Central India. This was later published by Otokar Feistmantel (1876) who gave these rocks the status of a geological system—**the Gondwana System**. C.S. Fox (1931) showed that the **Gondwana Period** started from Upper Carboniferous (315 Ma)[2] and extended up to Lower Cretaceous (135 Ma).

The Gondwana System in Indian Geology refers to the massive (*c*. 6-7 km thick), largely **sub-aerial terrestrial deposits**[3] mostly found along the **major river systems**[4] of **peninsular India**[5] in the form of fossil-rich (and frequently coal-bearing) **sedimentary rocks**[6] which are older than the Vindhya System[7], ranging from Upper Carboniferous to Lower Cretaceous (a timespan of *c*. 180 million years), and which rests **unconformably** on an ancient basement of mostly Archaeozoic[8] **igneous rocks**[9] in the form of a **slowly-sinking faulted trough** with little or no **folding** or **tilting**.

Gondwanaland: The Southern Supercontinent

The term "**Gondwanaland**" referring to a **southern supercontinent** that existed from late Palaeozoic to late Mesozoic was introduced by Eduard Suess (1885) who discovered rocks with minerals and fossils similar to the Indian Gondwana System in distant geographical areas of the southern hemisphere: *viz*. South America, South Africa, Australia, Antarctica and Madagascar. Three scientific theories tried to explain the similarities in their palaeoclimate, palaeoflora and palaeofauna: the existence in the geological past of **land bridges**, **volcanic island chains** or a **supercontinent** (*i.e.* Gondwanaland). Based on the last idea, Alfred Wegener (1912) and A.L. du Toit (1937) developed the theory of **continental drift** of the relative movement of continents "drifting" across the oceans. Arthur Holmes (1944) later provided a much-needed mechanism for this idea which was finally subsumed by the theory of **plate tectonics** of the movement of continents as part of the Earth's **tectonic plates** that was scientifically established in the 1950s. The Earth's original supercontinent **Pangea**, surrounded by the universal ocean **Panthalassa**, fragmented during late Palaeozoic (the second mountain-building **Hercynian orogeny**) into the northern **Laurasia** and the southern Gondwanaland supercontinents, separated by a sea **Tethys**. Laurasia soon split into **Euramerica**, **Angaraland** and **Cathaysia**. Gondwanaland, much later during late Mesozoic (the third mountain-building **Alpine orogeny**), finally broke up and drifted apart to form the now distant continents that were once part of it.

[1] The ancient Kingdom of the Gonds, an aboriginal tribe still found in Central India.
[2] Mega-annum (Ma) for million (10^6) years before present.
[3] Continental deposits that are predominantly fluviatile but lacustrine at the base; minor marine intercalations are also present at the base and at the top.
[4] Damodar, Mahanadi and Godavari river systems.
[5] Extra-peninsular minor deposits found in Gujarat, Rajasthan, Punjab, Kashmir and Assam.
[6] Conglomerate, sandstone and shale.
[7] 900—1,400 Ma.
[8] 2,500—4,000 Ma.
[9] Gneiss and schist.

Three-Fold Classification of the Indian Gondwana System

There are diverse opinions regarding the classification of the Indian Gondwana System. According to Medlicott (1879), Oldham (1893) and Fox (1931) the Indian Gondwana system has two divisions: **Lower Gondwana** and **Upper Gondwana**. This view is called the **bipartite** or **two-fold classification**. However, based on the similarities between the upper part of the lower division and the lower part of the upper division, Feistmantel (1880), Vrendenburg (1910) and Wadia (1926) divided this system into three divisions by introducing a new division (**Middle Gondwana**) between the two previous ones. This, the **tripartite** or **three-fold classification**, stratigraphically fits well with the **International Standard Scale**[10] (Table 1). The rocks of Middle Gondwana can be separated from those of Lower Gondwana and Upper Gondwana not only by **discordance** in their **minerals** and **fossils**, but also due to the presence of **unconformities**.

The fossil flora of the **Indian Gondwana System** is not only rich but also the most important in India. The three divisions of the Gondwana System of Indian have distinctive index fossils[11] (Table 1), all in the form of leaf impression fossils, after which their characteristic fossil floras have been named. The **Lower Gondwana flora** is called the *Glossopteris* flora after its index fossil—*Glossopteris* spp.[12] The **Upper Gondwana flora** is similarly called the *Ptilophyllum* flora after its index fossil—*Ptilophyllum* spp.[13] The rocks of the Middle Gondwana bear an admixture of both along with its own elements. This **Middle Gondwana flora** is called the *Dicroidium* flora after its index fossil—*Dicroidium* spp.[14]

Table 1: Brief Stratigraphy of the Indian Gondwana System

Division	**Time Period (Ma)**	**Geological Formation**	**International Standard Scale**			**Index Fossil**
			Epoch	**Period**	**Era**	
Upper Gondwana	135-195	Umia	Lower	Cretaceous	Mesozoic	*Ptilophyllum* spp.
		Jabalpur	Upper	Jurassic		
		Kota	Middle			
		Rajmahal	Lower			
Middle Gondwana	195-225	Maleri	Upper	Triassic		*Dicroidium* spp.
		Panchmari	Middle			
		Parsora	Lower			
		Panchet				
Lower Gondwana	255-315	Raniganj	Upper	Permian	Palaeozoic	*Glossopteris* spp.
		Kulti	Middle			
		Barakar	Lower			
		Karharbari				
		Talchir	Upper	Carboniferous		

Mega-annum (Ma) or million (10^6) years before present.
(Modified from Gangulee and Kar, 1989).

[10] The Geological Time Scale.
[11] Fossil indicating the geological age of the stratum in which it is present.
[12] Glossopterid foliage.
[13] Cycadeoid foliage.
[14] Caytonioid foliage.

The Lower Gondwana Flora

The fossil flora of Lower Gondwana division is called the ***Glossopteris* flora**. Lower Gondwana ranges from Upper Carboniferous to Permian and consists of the **Talchir Fm.** (Upper Carboniferous) at the base, followed by **Karharbari Fm**. and **Barakar Fm.** (Lower Permian), **Kulti Fm.** (Middle Permian) and **Raniganj Fm.** (Upper Permian). These rocks are characterized by the presence of the index fossil—fronds of *Glossopteris* spp. There is evidence of **glaciation** resulting in poor vegetation during Upper Carboniferous (Talchir Fm.). Localized marine deposits are also present here. The glaciation destroyed the previous *Rachiopteris* flora and a new Permo-Carboniferous flora (*Glossopteris* flora) developed during the subsequent **warm and humid** climate which supported luxuriant vegetation in the form of **coal forests** during Permian (the **Coal Measures** of Karharbari Fm., Barakar Fm. and Raniganj Fm) except in the middle (the **Barren Measure** of Kulti Fm.) when the climate became **hot and dry** and the coal forests disappeared. Permian coal deposits were formed *ex situ* at the river estuaries.

The *Glossopteris* flora of Lower Gondwana was dominated by **primitive pteridophytes and gymnosperms** in the form of **arborescent ferns** and **glossopterids**. The fossil pteridophytes include the **arborescent lycopods**[15] (e.g. *Cyclodendron leslii*), **sphenophylls**[16] (e.g. *Sphenophyllum speciosum*), **horsetails**[17] (e.g. *Schizoneura gondwanensis*, *Phyllotheca indica* and *Raniganjia bengalensis*), **ferns**[18] (e.g. *Pteychocarpus srivastavae*) and numerous **unclassified ferns** (e.g. *Gondwanidium vallidum*). The fossil gymnosperms include the enigmatic **glossopterids**[19] (e.g. *Glossopteris indica*, *G. conspicua*, *G. retifera*, *Gangamopteris cyclopteroides*, *Vertebraria indica*, *Ottokaria bengalensis*), **seed ferns**[20] (e.g. *Palaeovittaria kurzii*), **cycads**[21] (e.g. *Taeniopteris danaeoides*), **ginkgoes**[22] (e.g. *Rhipidiopsis ginkgoides*), **primitive conifers**[23] (e.g. *Samaropsis raniganjensis*, *Noeggerathiopsis hisolpi*) and **transitional conifers**[24] (e.g. *Buriadia sewardiana*).

The Middle Gondwana Flora

The characteristic fossil flora of Middle Gondwana division is called the ***Dicroidium* flora**. Middle Gondwana corresponding with the Triassic period consists of the **Panchet Fm.** and **Parsora Fm.** (Lower Triassic) at the base, followed by **Panchmari Fm.** (Middle Triassic) and **Maleri Fm.** (Upper Triassic). These rocks are characterized by the index fossil—fronds of *Dicroidium* spp. Traces of the previous *Glossopteris* flora are present in the oldest rocks (Panchet Fm.). Hence, in the two-fold classification this is included in Lower Gondwana. There is evidence of **glaciation** during early Triassic (Panchet Fm.) This destroyed the remains of the

[15] Lepidodendrales.
[16] Sphenophyllales.
[17] Equisetales.
[18] Filicopsida.
[19] Glossopteridales.
[20] Cycadofilicales (= Pteridospermales).
[21] Cycadales
[22] Ginkgoales
[23] Cordaitales
[24] Voltziales

previous *Glossopteris* flora. A new, characteristic Triassic flora (*Dicroidium* flora) developed during the **hot and dry** climate which followed, supporting only scanty vegetation during the rest of Triassic. The characteristic plant fossils of this division are mostly restricted to the Parsora Fm (Lower Triassic). The rocks of the Panchmari Fm. (Middle Triassic) and Maleri Fm. (Upper Triassic) are mostly **without plant fossils**. No coal or marine deposits are present.

The *Dicroidium* flora of Middle Gondwana represents a transformation in the floral composition and was dominated by **transitional pteridophytes and gymnosperms** in the form of **herbaceous ferns** and **caytonioids**. The fossil bryophytes are represented by a moss[25] (*Capsulites gondwanensis*). The fossil pteridophytes include the **herbaceous lycopods**[26] (e.g. *Lycopodites gracilis*), **horsetails** (e.g. *Neocalamites foxii*), **ferns** (e.g. *Danaeopsis gracilis*) and **unclassified ferns** (e.g. *Cyclopteris pachyrachis*). The fossil gymnosperms include the enigmatic **caytonioids**[27] (e.g. *Dicroidium odontopteroides*, *D. hughesii* and *D. sahnii*) and **primitive conifers** (e.g. *Noeggerathiopsis hisolpi*).

The Upper Gondwana Flora

The fossil flora of Upper Gondwana division is called the ***Ptilophyllum* flora**. Upper Gondwana ranges from Jurassic to Lower Cretaceous and consists of the **Rajmahal Fm.** (Lower Jurassic), **Kota Fm.** (Middle Jurassic) and **Jabalpur Fm.** (Upper Jurassic), with the **Umia Fm.** (Lower Cretaceous) at the top. These rocks are characterized by the presence of the index fossil—fronds of *Ptilophyllum* spp. Extreme drought during late Triassic (Panchmari Fm. and Maleri Fm) destroyed the previous *Dicroidium* flora. A new Jurassic flora (*Ptilophyllum* flora) developed with the return of a moderate climate which supported vegetation much more luxuriant than Middle Gondwana. However, no coal forests developed and coal deposits are absent. Localized marine deposits are present in Lower Cretaceous rocks (Umia Fm.).

The *Ptilophyllum* flora of Upper Gondwana was dominated by **modern pteridophytes and gymnosperms** in the form of **herbaceous ferns**, **cycadeoids** and **modern conifers**. Traces of **angiosperms** are also present in the Umia Fm. (Lower Cretaceous). The fossil pteridophytes include the **herbaceous lycopods** (*e.g. Lycoxylon indicum*), **quillworts**[28] (*e.g. Isoetites indicus*), **horsetails** (*e.g. Equisetites rajmahalensis*), **ferns** (*e.g. Osmundites sahnii*) and many **unclassified ferns** (*e.g. Alethopteris medlicottii*). The fossil gymnosperms are diverse and include the **seed ferns** (*e.g. Pachypteris specifica*), **caytonioids** (*e.g. Sagenopteris bambanii*), **cycads**[29] (*e.g. Zamia proximus*, *Nilssonia rajmahalensis*), **cycadeoids**[30] (*e.g. Ptilophyllum cutchensis*, *Otozamites bengalensis*, *Dictyozamites indicus*, *Bucklandia indica*, *Williamsonia sewardiana*), **pentoxylates**[31] (*Pentoxylon sahnii*), **ginkgoes** (*e.g. Ginkgo crassipes*) and **modern conifers**[32] (*e.g. Elatocladus jabalpurensis*, *Araucarites cutchensis*, *Taxites mehatii*). The fossil angiosperms are represented by a palm stem (*Palmoxylon mathuri*).

[25] Bryopsida.
[26] Lycopodiales.
[27] Caytoniales.
[28] Isoetales.
[29] Cycadales and Nilssoniales.
[30] Cycadeoidales (= Bennettitales).
[31] Pentoxylales.
[32] Coniferales and Taxales.

Further Reading

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