The Western Ghats is one among the 35 global hotspots of biodiversity and it lies in the western part of peninsular India in a series of hills stretching over a distance of 1,600 km from north to south and covering an area of about 1,60,000 sq.km. It harbours very rich flora and fauna and there are records of over 4,000 species of flowering plants with 38% endemics, 330 butterflies with 11% endemics, 156 reptiles with 62% endemics, 508 birds with 4% endemics, 120 mammals with 12% endemics, 289 fishes with 41% endemics and 135 amphibians with 75% endemics (http://wgbis.ces.iisc.ernet.in/biodiversity/pubs/ces_tr/TR122/index.htm). The rich biodiversity coupled with higher endemism is due to the humid tropical climate, topographical and geological characteristics, and geographical isolation (Arabian Sea to the west and the semiarid Deccan Plateau to the east). The Western Ghats forms an important watershed for the entire peninsular India, being the source of 37 west flowing rivers and three major east flowing rivers and their numerous tributaries.

Western Ghats belongs to the great peninsular India which swam following the break-up of the super-continent Gondwana towards Mainland Eurasia. The concomitant formation with the Deccan Volcanism is responsible for the floral and faunal massing over several million years. This is evident from the occurrence of some of the relicts of Gondwana in Western Ghats. In this regard, the current issue provides vital information towards the understanding of floral massing of Western Ghats.

Floral massing of Western Ghats

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India with four diversity hotspots (among 35 global hotspots) flaunts a very unique floral and faunal assemblages. It harbours 17,527 flowering plants belonging to 2984 genera and 247 families; of which more than six thousand species are endemic (35.3% of total flowering plants from India). On the other hand, the country has 246 globally threatened floral species (i.e. 2.9% of the global estimations) (4th National Report to the CBD, 2009). The history of this biological wealth could be interrelated with Gondwana when India had been a component of the larger supercontinent from Cambrian (Geological Time Scale, Table 1).

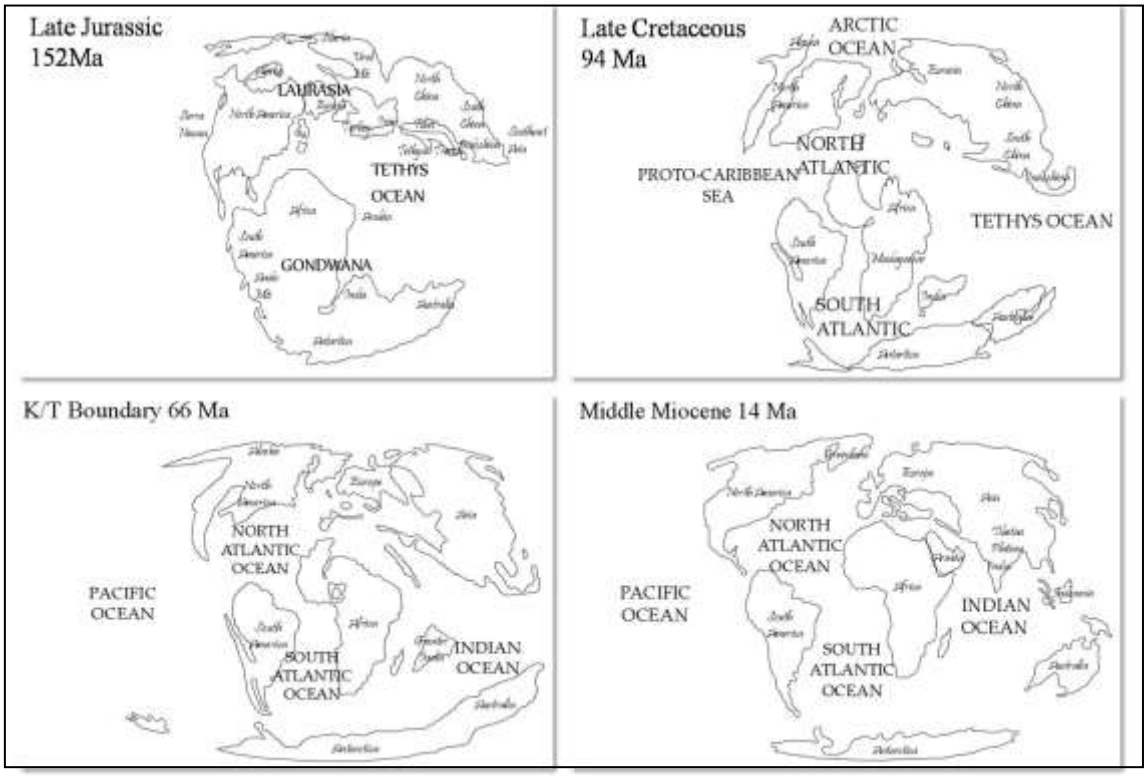

Fig 1. *Gondwana breakup and movement of Indian Peninsular fragment towards Eurasia, the numbers indicate respective time of occurrence in terms of million years ago (ma); (drawing based on Scotese 2001)*

In early Cretaceous the great continent fragmented into several pieces of landmasses and commenced receding away from each other. India was one such landmass headed towards north as it moved away from the other neighbours. The floating mass carried several Gondwana elements while on northward journey and these primed the initial evolution of biota across Indian subcontinent (Figure 1). Following the suturing of Indian mass to the Eurasia, there had been other events causing major biotic enrichment, e.g. climatic oscillations and geologic catastrophe. Deccan volcanism happened during ***Cretaceous-Tertiary boundary*** perhaps drove extirpation of a significant portion of floral gifts from Gondwana. In addition to geologic catastrophe, the impact of climatic oscillation had been quite severe. From the amalgamation of Indian mass to Asia, over the millions of years, throughout Eocene, Oligocene and Miocene the dispersal of biotic elements continued from neighbouring countries e.g. China-Tibet, Malaysia, Mediterranean, East Africa that gradually sculpted the finer melange of biotic elements. The final strokes had been given by Quaternary climatic perturbation i.e. so-called Ice age that exerted final impetus to floral evolution leading to extinction as well as revamping of biota. In a nutshell, there had been climatic and geologic factors which acted as prodigious selective force and filtered out the relicts of Gondwana and dispersed neighbouring elements. However, the history of floral evolution had been very enigmatic due to severity and complexity of the events and reconstruction of the past warrants an integration of disciplines e.g. geology, paleoecology, climatology, palynology, genetics.

Western Ghats, geologically an escarpment from south to north and spread across five states of southern India is a hotspot and holds a significant fraction of Indian biodiversity (Table 2).

Attributes	Hotspots			
	Himalaya	Indo-Burma	**W.Ghats and Sri Lanka**	Sundaland
Hotspot original extent (km^2)	741,706	2,373,057	**189,611**	1501,063
Hotspot vegetation remaining (km^2)	185,427	118,653	**43,611**	10,0571
Endemic plant species	3,160	7,000	**3,049**	15,000
Human population density people/km^2)	123	134	**261**	153
Area protected (km^2)	112,578	235,758	**26,130**	179,723

Table 2. Attributes of biodiversity hotspots from India (taken from 4th national report CBD)

Western Ghats belongs to the great peninsular India which swam following the break-up of the super-continent Gondwana towards Mainland Eurasia. The history of this escarpment says its concomitant formation with the Deccan Volcanism and later floral and faunal massing over several million years. However, the riddle stays alive, whether Western Ghats still retains some of the relicts of Gondwana, if so, today's floral legacy may be a diaspora of both Gondwana as well as members arrived from neighbouring or distant countries and flourished later.

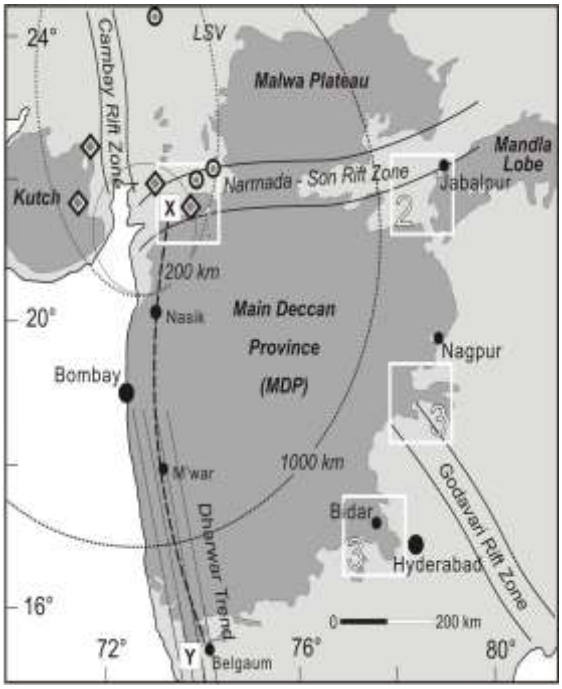

Figure 2: Shaded areas represent the current areas of expanse of Deccan trap. Cross section line X - Y follows the Western Ghats escarpment where the lava succession is best exposed. Numbers 1 -3 (square boxes) indicate the localities of key sedimentary successions. (http://www.geosociety.org/news/pr/07-59.htm

A closer examination of the literature describes that while on long northern cruise of Indian ferry, growth and expansion of tropical forests had been in full swing and the same continued perhaps until Deccan volcanism broke out (Morley, 2003) (Figure 2). Prior to that, tropical forest perhaps had almost expanded and established throughout. The survival of Gondwanan relicts and resurrection of tropical biota rest on the attributes of Deccan volcanism *(timing),* the time period and the spatial extent of its

Era	Period	Epoch	Characteristic organisms	Duration (m.y.)	Began (m.y.) ago
Cenozoic	Quaternary	Recent		Last 5,000 years	
		Pleistocene	Redistribution of floras according to retreat and advance of glaciers. Woody mammoth and giant bison. Appearance of modern human.	2.5	2.5
	Tertiary	Pliocene	Mastodons, camels, horses and cats.	4.5	7
		Miocene	Establishment of present day forest associations. Grazing mammals and apelike creatures.	19	26
		Oligocene	Widespread occurrence of now relic taxa (*Metasequoia, Cercidiphyllum*), true cats, dogs, rodents and rhinoceroses.	12	38
		Eocene	Many old generas of angiosperms became extinct with new modern types appearing. All modern orders of mammals present; first horses.	16	54
		Paleocene	Angiosperms continued, first lemurs; some modern groups of birds	11	65
Mesozoic	Cretaceous	Upper	Angiosperms rise to dominance. Monocots and dicots present. Modern group of insects;	76	
		Lower			

			first pouched and placental mammals; extinction of giant land and marine reptiles.			141
	Jurassic	Upper Middle lower	Rise of higher insects and birds. Dinosaurs abundant.		54	195
	Triassic	Upper Middle Lower	Diversification of conifers and ferns. First mammals, rise of the dinosaurs.		30	225
Paleozoic	Permian	Upper Lower	Extinction of arborescent lycopsids and sphenopsids. Diversification of reptiles		55	280
	Carboniferous	Pennsylvalian	Upper Middle Lower	Origin of confers, reptiles, diversification of amphibians,	45	325
		Mississippian	Upper Lower	Spread of amphibians, sharks, and bony fish. Insects evolved wings.	20	345
	Devonian	Upper Middle Lower	Diversification of vascular plants, all major groups except angiosperms, diversification of fishes, origin of amphibians.		50	395
	Silurian	Upper Lower	First vascular plants. Scorpions and millipeds, first air-breathing animals. Brachiopods, corals and eurypterids		40	435
	Ordovician	Upper Lower	Green and red algae, First vertebrates, variety of marine invertebrates		65	500
	Cambrian	Upper Middle Lower	Cyanophytes, green and red algae, marine invertebrates,		70	570
Precambrian			Growth of cyanophytes, red algae, bacteria and possibly green algae.		4,130	4700

Table 1. Geological time scale (taken from "Paleobotany and evolution of plants" by W. N. Stewart and G. W. Rothwell, Cambridge University Press,2005)

Effect, which is the key driving force behind mass extinction of significant fraction of biota. Currently, in absence of detail stratigraphic records, the effect of Cretaceous volcanism on the extinction of Gondwanan elements is mostly contentious. However, reviewing the spatial extent of the volcanism it seems probable that it has mostly enveloped today's Maharashtra, Gujarat perhaps extending to north of Karnataka sparing a larger fraction of the southern most part which may have the chance to serve as refugia. These are areas where Gondwana relicts or old migrants from Afro-Madagascar might find their refuge to tide over unfavourable condition; upon onset of the favourable period gradually propagated and established in newer patch. There has been growing evidence on southern Western Ghats as refugia during the volcanism, mostly from faunal groups (Joshi and Karanth, 2013). In addition, post-volcanism period perhaps during late Paleocene and Early Eocene rain forest refugial presence is quite conspicuous from the plethora of fossil records (Prasad et al. 2008). In short, it seems that biotic refugia survived in southern Western Ghats, may be in isolated pockets which later served as biological pump to recharge biota across the larger part of the escarpment.

Independently of the old lineages from the super-continent, Western Ghats had presumably been massed by a diverse floral forms from the neighbouring countries or continents. This had commenced from the middle Cretaceous when India was very close to Africa and almost hooked to Madagascar which facilitated the biotic exchange between them (Figure 3). Pollen records of various plant families makes the case of biotic exchange between India and Madagascar stronger (Morley 2003). It was facilitated by the formation of transient land-bridges acting as stepping stones for colonisation (Ali and Aitchison, 2008).

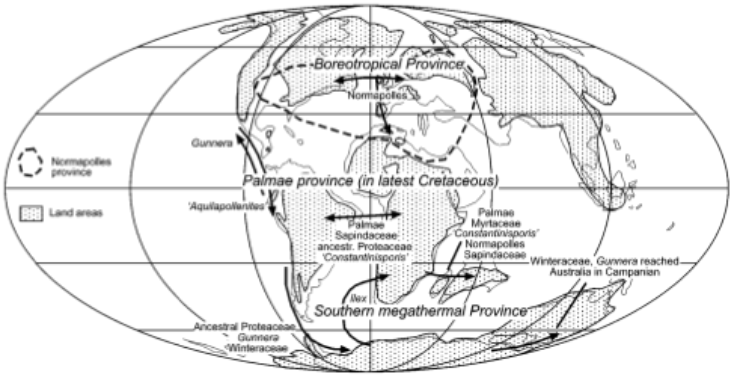

Figure 3: Late Cretaceous paleogeography and dispersal routes of various floral elements (Smith et al. 1994)

Malayan elements in the Western Ghats includes Myrtaceae, Guttiferae, Melastomataceae, Dipertocarpaceae (Mani 1974). The most dominant forms include *Dipterocarpus, Vateria, Hopea, Syzygium, Eugenia, Melastoma.* There is an iconic palm member endemic to WG, *Benitnckia condapanna*. The list may include Myristicaeae, Bambusoideae etc. (Fact sheet 1). These members mostly have their centers of diversity in Malayan archipelago and around. The dispersal into India perhaps had happened during Eocene, Oligocene, and Miocene times. There could be common migration routes through the north-eastern corridor; or even the case of long distance trans-oceanic dispersal of certain elements is also possible. However, the conspicuous presence of many remnant conspecific or sister lineages across north-east may strengthen the possibility of a dispersal route facilitating plant migration.

Foothills of Himalaya shelter a few cold-loving members which are found at the middle to higher elevation across WG and Nilgiris; e.g Ericaceae, Asteraceae, Rubiaceae. These are the lineages which perhaps invaded WG from north and established, the colonization perhaps maintained the continuous vegetation cover through the central India. However, fragmentation due to change in climate change during Quaternary period majorly delinked the floral connection existed. The discontinuous distribution of these biotic elements today portrays a pattern called central Indian disjunction and evokes of relictual absence of a few shared taxa in once-lush cover maintained perhaps during the pre-Quatarenary times.

Several lineages are abundant across Western Ghats e.g. *Hernandia, Lindenbergia, Pittosporum, Acrotrema, Gomphandra, Nothopodytes, Sarcostigma, Hydnocarpus*etc. which have their congeners in Africa or South America. In addition, there are members of Orchidaceae, Poaceae

(Andropogoneae) which also occur in Africa. These perhaps resurrect the ancient Gondwanan link i.e. relicts imbibed with the signatures of past events and depict independent evolution of several families shared among the participating countries of Gondwana super-continent. So, these taxa retain the Gondwana heritage perhaps were able to tide over the unfavourable periods of Deccan volcanism restricting themselves in isolated refugia. In contrast, with growing cases of long-distance trans-oceanic dispersal from various families, the chance of migration from distant place and establishment of a few taxa can not be ruled out.

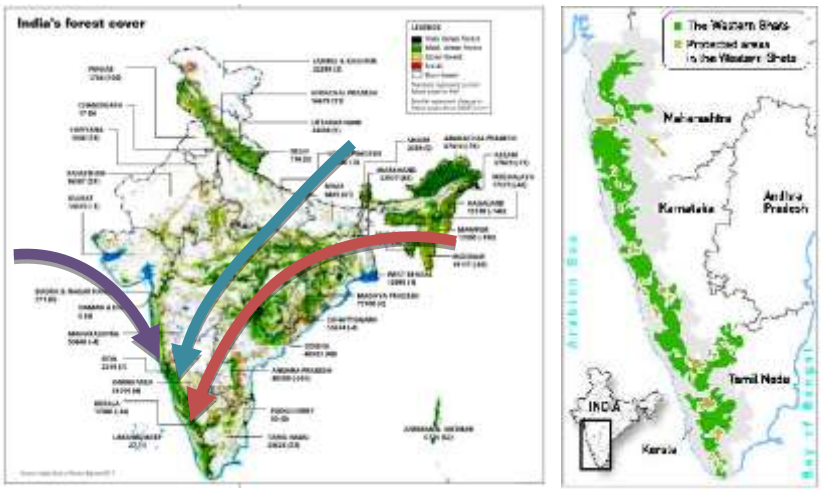

Figure 4: schematic representation of probable dispersal routes of flora over the evolutionary timescale

In summary, the evolutionary history of enormous floral diversity of Western Ghats appears as highly complicated. It seems that it has been primarily crafted by gifts from Gondwana, and later enriched by plethora of dispersal events over millions of years (Figure 4). Many taxa may have arrived from Afro-Madagascar when India was lying close enough to support biotic exchange. Others could have been following the route through north-eastern landscapes leaving their sisters in Malaya. A few invaded from north and foothills of Himalaya or even from further north i.e. Qinghai Tibetan Plateau. In addition, trans-oceanic dispersal of floating seeds or fruits traversing boundaries of seas and oceans also contributed majorly to floral enrichment throughout the world, and Western Ghats may not be an exception (de Quieroz 2005). Not the least, yet another key period in earth's history that governed major rearrangement of distribution of biota is the Quaternary age; long term changes in earth's orbit caused a massive climatic and geological upheaval i.e. repeated glaciations and deglaciations. This in turn recreated the distribution pattern, fuelled diversification and lastly speciation. In a nutshell, it appears that over millions of years, a melange of climatic and geological factors together with dispersal gave rise to major floral diversity of Western Ghats. In order to

decipher the complex web of movements, an understanding of the age of the members, their relations with global congeners, and past dispersal routes are complementary to each other.

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