INTRODUCTION

Towards the close of Mesozioc era there was a great volcanic activity over large parts of the Peninsular India with intermittent outburst of lava flows resulting into the formation of volcanic plateau called as the "Deccan Traps". The Peninsular region lying between the rivers Narmada and Cauvery is traditionally referred to as Deccan or Dakshinpath (Mahabale, 1966). Since the major rock type found in Deccan is 'Trap', the region is called as "Deccan Trap Country". The characteristic low, flat topped hills of basalt which are commonly seen in this region represent the weathered surfaces of these lava beds.

The Deccan Trap today occupies an area of about 520,000 square kilometers covering large parts of Maharashtra, Gujarat, Madhya Pradesh, Karnataka and Andhra Pradesh. The thickness of the trap varies. It is about 20 meters near Belgaum, where the traps end on southern side. Near Amarkantak and Surguja an eastern limit of the traps, the thickness is about 150 meters, whereas in Kachchh they are 750 meters thick. The Deccan Trap Country forms one of the most ancient land masses of the globe, while the eastern and southern parts are believed to have existed as a land surface ever since the original crust was formed. The central and western parts are much younger, resulting directly over the eroded surface of the old formations.

During the considerable interval of time elapsed between successive lava flows, there came in to existence some rivers and fresh water lakes in the depressions and in places there was obstruction to drainage. The fluviatile and lacustrine deposits formed in them are intercalated with the lava flows and are of small horizontal extent, generally 0.5 to 3 meters in thickness, sometimes only 0.15 meters thick. They are known as **Intertrappean beds.**

These beds are highly fossiliferous and in them are preserved the remains of plants and animals that lived during the period intervening the successive lava flows. They comprise cherts, impure limestones and pyroclastic materials. The Deccan Traps have been divided in to three groups – Upper, Middle and Lower with the Infratrappean beds or Lameta beds at their base.

Upper Traps (450 meter thick) - Exposed in Maharashtra and Gujarat containing numerous Intertrappean beds and beds of volcanic ash.

Middle Traps (1200 meter thick) - Exposed mostly in Madhya Pradesh and parts of Maharashtra; containing few or none Intertrappean beds but have ash beds in the upper parts.

Lower Traps (150 meter thick) - Exposed in eastern parts of Madhya Pradesh; while they are totally lacking in the Middle Traps as seen near Pune, Matheran, Mahabaleshwar and other areas. This may probably be due to lack of time between the successive lava flows which did not allow the plants and animals to colonize the surface.

Deccan Intertrappean Beds

India is quite rich in Cretaceous - Tertiary fossiliferous exposures which are spreaded throughout the Deccan Trap Country. Most of the exposures belong to the Deccan Intertrappeans Series, the Cuddalore Series of south India, Tippam Series of Eastern India, Lower Siwalik beds of Northern India and Dupi-Tila Series of NEFA. In age, this ranges from Upper Cretaceous to Mio-Pliocene period. Apart from these, small exposures at Neyveli in South Arcot district, Tamil Nadu; Warkalai in Travancore, Kerala; Ratnagiri and Sindhudurg areas in Maharashtra; Palana in Bikaner, Rajasthan; Dandot in Punjab and others have yielded very rich mega and micro flora.

In the Deccan Intertrappean Series more than 50 fossliferous localities are known scattered in the vast area of Deccan Plateau from Rajahmundry in South India, Kapurdi beds of Rajasthan and number of exposures in Maharashtra, Madhya Pradesh, Karnataka and Gujarat States. Usually the localities are exposed on the slopes of the hills, in small patches, very rarely forming extensive bands or at the nala and hillock cuttings and sometimes in the open fields.

Some well known localities are as follows:

Maharashtra: Mumbai (Worli and Malabar Hills), Nagpur (Sitabardi), Takli, Mahurzari, Bharatwada, Nawargaon, Maragsur, Sindhivihira, Kondhali, Dongargaon.

Madhya Pradesh: Jabalpur, Sagar, Mothi, Mohgaonkalan, Amajhiri, Keria, Seoni, Sitapuri, Sausar, Samnapur, Parapani, Mohgaon-Palasundar, Ghughua (Mandla), Umaria, Silther, Chabi Deori, Bhama, Nandgaon, Barbaspur, Padwar, Ranipur.

Andhra Pradesh: Vikarabad, Rajahmundry (Dudukur, Pangidi, Kateru, Bomorru), Malchalma (District Medak).

Rajasthan: Kapurdi, Bikaner, Barmer, Jaisalmer.

Gujarat: Ghala, Chotila, Bamanbor, Morvi, Ninama, Anjar, Panandhro, Serdi, Matanomadh, Baranda, Goylea, Mokra, Mothala, Kothara, Jatawara, Naliya, Vinjhan, Sandhan, Baraia Mota, Dhaneti, Kanaiyabe, Naiya Dhun, Banaskatha.

Karnataka: Gurmatkal (District Gulbarga).

The Deccan Intertrappean flora.

Very huge quantity of work has been done on the palaeofloristic composition from the Deccan Intertrappean beds of India. The flora of the Deccan Intertrappean beds often been spoken as one unit which is heterogeneous. It consists many ecological facies. The flora was initially reported by the clergymen and military officers in the British Army such as Sleeman, Malcomson, Buist, Carter, Hislop, Nicolls, Stoliczka and Schenk. However, the systematic floral investigation was done only after the discovery of the classical intertrappean locality of Mohgaonkalan in Chhindwara district of Madhya Pradesh by Professor K.P. Rode, a Geologist of the Banaras Hindu University in 1929-30. The flora was later on studied in detail for its botanical affinity by Professor Birbal Sahni at Lucknow University. Lateron many more Intertrappean exposures were discovered and studied systematically by number of workers like Dr. K.R.Surange, Dr. R.N.Lakhanpal, Dr.Uttam Prakash, Dr. B.S.Trivedi, Professor T.S.Mahabale, Dr. Shyamala Chitaley, Dr. N.V.Biradar, Dr. A.R.Kulkarni, Dr. G.V.Patil, Dr. M.B.Bande, Dr. S.D.Bonde, Dr. K.Ambwani, Dr. A.K.Ghosh, Dr. Manju Banerjee and others who worked at different centers like University of Poona, M.A.C.S. Research Institute; Institute of Science, Nagpur; Shivaji University, Kolhapur; University of Calcutta; University of Bombay; Holkar College, Indore, besides Lucknow University and Birbal Sahni Institute of Palaeobotany, Lucknow. Lakhanpal (1970, 1973), Bande *et al.* (1988), Bande (1992) appraised the Intertrappean flora. Bande *et al.* (1988) analysed the flora into following smaller assemblages on the basis of the phylogenetic and geological compositions as

1) Rajahmundry assemblage

2) Nagpur –Chhindwara assemblage

3) Bombay – Malabar –Worli assemblage and Mandla assemblage.

(I) Rajahmundry floristic composition.

The Rajahmundry assemblage is mainly dominated by a number of algal taxa of estuarine habitat and thirteen species of charophytic gyrogonites (Pia, Rao and Rao, 1937; Rao, Rao and Pia, 1938 Rao and Rao, 1939, Chandra, Deb and Mukherjee, 1989). Important algal genera are *Helimeda, Dissocladella, Terquemella, Acetabularia, Neomeris, Holosporella* and *Acicularia.* Mahabale and Rao (1973) reported three gymnospermous woods, viz., *Taxaçeoxylon kateruense* Mahabale and Rao, *Dadoxylon barakarense* Surnge and Saxena and *Mesembrioxylon fusiformis* Sahni represernting families Taxaceae, Araucariaceae and Podocarpaceae; *Rhizypalmoxylon sundaram* Mahabale and Rao, *Palmoxylon sundaram* showing affinities with extant genus *Cocos* and *Sonneratioxylon dudukurense* Rao and Ramanujam indicate the mangrove habitat. The evidence of esturine algae, *Cocos* and *Sonneratia* indicate near-shore conditions around Rajahmundry at the time when these beds were deposited. The presence of Podocarpaceae is not surprising as the family is known to occur even today at lower altitudes. However, identification of taxaceous wood needs verification as Taxaceae is confined to the upland regions only.

Intertrappeans near Nawargaon in Wardha district of Maharashtra contain a rich floral assemblage. It is difficult to assess its relationship with the Nagpur-Chhindwara assemblage at present. The fossils include five species of *Palmoxylon,* palm petiole *Palmocaulon hyphaeneoides* similar to that of *Hyphaene* and dicotyledonous woods showing affinities with the genera *Evodia* (Rutaceae), *Amoora* (Meliaceae), *Ardisia* (Myrsinaceae), *Sonneratia* (Sonneratiaceae), *Heterophragma* (Bignoniaceae), *Gmelina* (Verbenaceae), *Phyllanthus* (Euphorbiaceae), *Aristolochia* (Bande, 1987) and *Anamirta* of Menispermaceae (Bonde, 1997). This floral assemblage is akin to a humid tropical flora as presently seen in the Western Ghats.

(II) Nagpur-Chhindwara floristic composition.

The important fossiliferous localities are Mohgaonkalan and Keria situated near Chhindwara and Sausar, Mahurzari and Takli near Nagpur. Many fossil taxa are common to these localities. Very rich flora has been documented from these exposures. The important floral elements in the major groups are as follows:

Algae - Fresh water elements are represented by *Spirogyrites, Oedogonites* and *Westiellopsis* from Mohgaonkalan and *Ulothrix*-like filaments from Sausar (Shukla, 1950; Dwivedi, 1959; Sahni and Rao, 1943; Biradar, 1977). Sahni and Rao (1943) described *Chara sausari* which is the only fossil record of oogonium of a *Chara* with attached vegetative parts. Charophytic gyrogonites, viz., *Platichara raoi*, *P. sahnii* and *Microchara* sp. have been described from the Gitti Khadan area near Nagpur (Bhatia and Mannikeri, 1976). Bande, Prakash and Bonde (1981) described marine algae *Peyssonnelia antiqua* and *Distichoplax raoi* from Mohgaonkalan and *Solenopora* sp. (Mehrotra, 1989). These elements have a phytogeographical significance.

Fungi - Some of the fungal forms described here are *Shuklania* (Dwivedi, 1965), *Diplodia rodei* (Mahabale, 1969) and *Tetracoccosporium* from Mohgaonkalan and *Paleosordaria, Perisoracites varians* from Sausar and *Palaeophora mohgaoensis* Singhai from Mohgaonkalan (Sahni and Rao, 1943; Chitaley and Patil, 1972; Lakhanpal *et al.*, 1967; Paradkar, 1974; Biradar and Mahabale, 1974; Singhai, 1978) and others have added more taxa to this list.

Bryophytes - The record of bryophytes is very meager. It may be perhaps due to the fragile nature of the thallus and reproductive organs. An anthocerotaceous capsule *Shuklanites deccanii* has been described by Singhai (1975) from Mohgaonkalan. *Riccia chitaleyi* has been identified by Sheikh and Kapgate (1982).

Pteridophytes - The pteridophytic elements in this assemblage are mainly composed of fresh water ferns. The important genera are *Azolla* (Sahni, 1941; Trivedi and Verma, 1971; Patil and Upadhye, 1980), *Rodeites* (Sahni, 1943; Chitaley and Paradkar, 1972, 1973), *Marsilea* (Upadhye and Patil, 1979) and *Salvinia* (Mahabale, 1950). *Rodeites* probably has affinities with the south American fern *Regnellidium*. Chitaley and Sheikh (1972) described *Surangea mohgaoense,* a pteridophytic fructification from Mohgaonkalan. A strobilus resembling that of *Selaginella* has been reported from Mohgaonkalan (Singh and Patil, 1979) and *Acrostichum intertrappeum* Bonde and Kumaran (2002) is a mangrove fern reported from Nawargaon intertrappeans which indicate definite occurrence of sea arm in and around Wardha, Nagpur and Chhindwara area.

Gymnosperms - The gymnosperms are mostly represented by cones, e.g., *Takliostrobus alatus, Indostrobus bifidolepis, Pitystrobus crassitesta* (Sahni, 1931) and *Mohgaostrobus sahnii* (Prakash, 1961). *P. crassitesta* shows affinities to the family Abietineae. The other two cones exhibit characters of Abietineae as well as Podocarpaceae. *M. sahnii* shows affinities with the Araucariaceae. Chitaley and Sheikh (1973) recorded *Harrisostrobus intertrappea,* a cone with uncertain affinities from Mohgaonkalan. Fossil wood of Araucariaceae has also been reported from this area (Lakhanpal, Prakash and Bande, 1977).

Angiosperms - Major bulk of the floristic elements of the Deccan Intertrappean Series and later horizons belongs to the Angiosperms or flowering plants comprising both the groups, the Monocotyledons and the Dicotyledons. The Monocotyledons are represented by the families Agavaceae, Amaryllidaceae, Araceae, Arecaceae (Palmae), Cannaceae, Cyclanthaceae, Cyperaceae, Heliconiacaeae, Liliaceae, Marantaceae, Musaceae, Pandanaceae, Poaceae (Gramineae), Smilacaceae, Sparganiaceae, Typhaceae, Xyridaceae and Zingiberaceae (Bonde, 2008).

Monocotyledons - *Palmoxylon (Cocos) sundaram* (Sahni, 1946; Bonde *et al.*, 2004) is a reconstructed 4.5 meter tall palm stem axis with rooting base comparable to *Cocos nucifera* L. Biradar and Bonde (1990) reconstructed the plant of *Cyclanthodendron sahnii* Sahni and Surange and suggested its affinity with Scitamineae (Zingiberales) combining the characters of Musaceae, Heliconiaceae and Strelitziaceae instead of Cyclanthaceae, Pandanaceae or Palmae. *Mahabalea phytelephantoides* Bonde (in press) is a 15 cm tall permineralized juvenile palm axis with adventitious roots, short obconical stem crowned with a rosette of leaves in trimerous phyllotaxy suggesting its affinity with *Phytelephas* which is restricted now to Northern South America and *Appamahabalea uhli* Bonde (in press) is a 46 cm tall matured soboliferous acaulescent palm comparable to *Phoenix* L.

Palms, which dominate the woody monocotyledonous flora in fossils are represented by number of organ genera for stem, root, leaf, inflorescence axis, rachilla, flower, fruit, seed and pollen grains. Permineralized woody monocotyledonous stems are generally assigned to the organ genus *Palmoxylon* Schenk (1882) established for woods presumably belonging to the palms. There are about 200 species throughout the world including 74 species from India. Large number of species of *Palmoxylon* may be parts belonging to outer or inner, basal or apical region of the stem or some times parts of leaf or inflorescence axis established on the basis of anatomical characters such as form and distribution of fibrovascular bundles, type of sclerenchyma, number of metaxylem vessels, size and shape of phloem, presence of fiber bundles, nature of ground tissue, structure of vessel endplate, etc; which are highly variable even within one genus. (Stenzel, 1904; Sahni, 1943, 1964; Mahabale, 1958). These characters are highly variable even within the genus and species of Arecaceae. Until one is familiar with and takes into account the variability of these characters in different parts of the same species and in different species in the genus and tests it statistically, the applicability of these characters in the resolution of *Palmoxylon* to natural genera has a limited scope.

Sahni (1943) in an attempt to resolve the organ genus *Palmoxylon* to natural genera formulated a combined system of classification for palms by Mohl (1845) and Stenzel (1904) based upon external morphology and shape of sclerenchyma as seen in cross section. Knowledge of morpho-taxonomy and anatomy of these members is required for the resolution of the organ genera erected for different plant organs. Moreover, *Palmoxylon* might comprise many natural genera of Palmae/Aracaceae as it is a very large family of woody plants comprising 212 genera and 2779 species distributed in 5 subfamilies (Uhl and Dransfield, 1987). Some of the species of *Palmoxylon* as well could be other monocotyledons belonging to the families Agavaceae, Araceae, Boryaceae, Cannaceae, Cyperaceae, Heliconiaceae, Musaceae, Pandanaceae, Poaceae, Velloziaceae, Zingiberaceae and others.

The palm roots are described under the genus *Rhizopalmoxylon* Gothan (1942). There are 13 species reported from the world. *R. sundaram* Mahabale and Rao (1973), *R. borassoides* Awasthi *et al.* (1996), *R. singulare* Bonde *et al.* (2009), A root comparable to *Nypa* (Verma, 1974 and a borassoid root (Ambwani, 1981) have also been reported. The other monocotyledonous roots are *Hygrorhizos deccanii* Trivedi, Srivastava and Bajpai (1985) comparable to *Hygrorhiza* (Family – Poaceae), *Velamenorhizos intertrappeanum* Barlinge and Paradkar (1978) showing affinities with Araceae, Arecaceae and Orchidaceae, *Aerorhizos harrisii* Chitaley (1968) showing affinities with aquatic plants and a root comparable to *Eichhornia* (Family – Pontederiaceae). A combined system suggested by Bonde *et al.* (in press) based upon terminologies used by Mahabale and Udwadia (1960) and Seubert (1997) will be feasible to resolve the artificial genus *Rhizopalmoxylon* Gothan. *R. borassoides* Awasthi *et al.* (1996) is a palm root comparable to extant palm genus *Borassus. R. singulare* Bonde *et al.* (2009) is aerial mantle of coralloid roots comparable to *Hyphaene dichotoma* Furtado and *Phoenix sylvestris* L.,*Sabalocaulon* Trivedi and Verma, *Parapalmocaulon* Bonde, *Phoenicicaulon* Bonde *et al.* are the petioles; *Palmostroboxylon* Biradar and Bonde is an inflorescence axis; *Arecoideostrobus* Bonde is a rachilla; *Cocos sahnii* Kaul (1951) and *C. pantii* Mishra (2003); *Hyphaeneocarpon* Bande *et al.* (1982) and *Nypa* aff. *fruticans* Wurmb (*Nypa burtini* [Brongniart] Ettingshausen; Emended by Tralau, 1964). (=*Nipadites compressus* Rode, 1933; Sahni, 1937; =*Nipadites hindi* Rode, 1933, Sahni, 1937; =*Nipa sahnii* Lakhanpal, 1952; =*Nipadites* sp. Bhattacharya, 1967) are the fruits comparable with those of *Cocos, Hyphaene* and *Nypa* respectively. *Eugeissonocarpon* Shinde and Kulkarni (1986), *Arecoidocarpon* Bonde (1990) are the fruits comparable to *Eugeissona* and *Areca* respectively. *Deccananthus savitrii* Chitaley and Kate (1974) is a flower showing its affinity with Palmae. Mahabale (1978) considers Indo-African region as one of the centre of the origin of coconut (*Cocos nucifera* L.). Occurrence of *Cocos, Hyphaene, Phoenix, Nypa, Pandanus* and other coastal/marine elements in the Deccan Intertrappean sediments suggest the transgression of sea arm in Central India (Sahni, 1946; Kaul, 1951, Bande *et al.*, 1981, 1982; Bande, 1992; Bonde and Kumaran, 2002; Bonde *et al.*, 2004, 2008; Chitaley and Nambudiri, 1995).

Cyclanthodendron sahnii (Sahni and Surange, 1953; Biradar and Bonde, 1990) is a rhizomatous soboliferous scitamineous plant of medium height (2-3 meters) having woody aerial continuation covered with overlapping leaves in two ranks with petiole *Heliconiaites intertrappea*, pseudostem *Musocaulon indicum* and fruits *Tricoccites trigonum*. *Musostrobocaulon skutchii* Bonde (2008) is a musaceous inflorescence axis with a sheath. *Musophyllum indicum* Prakash *et al.* (1979) is a Musaceous leaf whereas *Cannaites intertrappea* Trivedi and Verma (1971) is a pseudostem of *Canna*. *Musa cardiospermum* Jain (1963) is a triangular multiseeded syncarpous berry comparable to the seeded banana fruit. However, the fruit exhibits several differences from extant *Musa* such as lack of laticifers in the pericarp, absence of perianth remnants at the fruit apex and a single row of seeds in each locule of the fruit. It requires further work for its affinities with *Musa* or other members of Scitamineae (Manchester and Kress, 1993). *Pandanus eocenicus* (Guleria and Lakhanpal, 1984) a leaf, *Pandanusocarpon umariense* (Bonde, 1990) a fruit and *Pandanaceoxylon kulkarnii* (Patil and Datar, 2002) is a rhizome of Pandanaceae. However, the rhizome, *Pandanaceoxylon kulkarnii* appears to be a rhizome of Scitamineae or Araceae. It needs reinvestigation in the light of the work done by Cheadle and Uhl (1948) and French and Tomlinson (1980, 1981, 1981a, 1981b, 1981c, 1983, 1984; Tomlinson, 1969).

Viracarpon Sahni is a pedunculate, spiny, aggregate fructification consisting an unbranched central axis bearing densely arranged, sessile, ebracteate, hexangular fruits with single seed in each locule, arranged in longitudinal rows; ovary inferior, outer wall of ovary extends upwards in six perianth lobes, forming a cup like structure, free apically and connate basally with a vertical ridge running the entire length of the middle of the inner surface of each lobe, margin of lobes thickened, inside of the lobes densely covered with long hairs. These combined characters are not known in any of the extant family. *Viracarpon* may represent an extinct family. Further work on vegetative parts associated with *Viracarpon* would help to come nearer to its relationship with the extant members. *Rhodospathodendron tomlinsonii* Bonde (2000) is a viny aerial axis resembling *Rhodospatha* of Araceae. *Rhizocaulities palaeocenicus* Mehrotra (2003) is a rhizome comparable to *Aglaonema* Schott. However, it looks like a rhizome of Zingiberaceae. *Glycerioxylon mohgaoensis* Trivedi and Bajpai (1982) is a gramineous culm comparable to *Glyceria*. *Festucophyllites intertrppeaense* Patil and Singh (1984) and *Elymus deccanensis* Patil and Singh (1984) are the pseudostems comparable to hydrophytic member *Festuca ovina* L. and *Elymus* L. respectively. *Culmites eleusineoides* Bonde (1986) is a stem with thin culm, swollen node and dormant bud comparable to *Eleusine* Gaertn. *Graminocarpon mohgaoense* Chitaley and Sheikh (1971) and *G. stellatus* Dutta and Ambwani (2005) are the caryopsis type of grains. Poaceae is considered to be originated in the Upper Cretaceous period based upon the occurrences of generalized modern appearing grasses (Wolfe *et al.*, 1989), fossil pollen record (Linder, 1986) and phytoliths extracted from the coprolites of Titanosaur sauropods (Prasad *et al.*, 2005).

Cyperaceoxylon intertrappeum Chitaley and Patel (1970) is a Cyperaceous axis with stem, roots and leafsheaths. Whereas *Scirpusoxylon indicum* Shete (1989) is a rhizome comparable to *Scirpus* L. *Cyperaceocarpon sahnii* Dutta and Ambwani (2005a) is an achene type of fruit.

Eriospermocormus indicus Bonde (2005) is a liliaceous corm comparable to *Eriospermum* Jacq. The family Liliaceae is also represented by the inflorescence with inaperturate, monosulcate to trichotomosulcate pollen grains resembling *Matanomadhiasulcites* (Bonde and Kumaran, 1993). *Monocotylostrobus bracteatus* (Lakhanpal *et al.*, 1982; Bande, 1993) is a inflorescence showing its resemblance with Liliaceae and Palmae. *Neyvelia awasthii* Reddy (1995) is an axis comparable to *Dracaena* Vand. ex L. of Agavaceae. A wood comparable to *Dracaena* has also been reported earlier from the same horizon (Ambwani, 1982, 1999).

The occurrence of *Sparganium* Mahabale (1953) in the Deccan Intertrappean beds is doubtful as it is a temperate element and requires further work.

Dicotyledons – They are well-represented by a number of woods, flowers and fruits. Bande *et al.* 1988 analysed the dicotyledonous woods from the Deccan Intertrappean Beds which have been assigned to the families Annonaceae, Nymphaeaceae, Flacourtiaceae, Guttifereae, Dipterocarpaceae, Sterculiaceae, Tiliaceae, Elaeocarpaceae, Rutaceae, Simaroubaceae, Burseraceae, Meliaceae, Icacinaceae, Celastraceae, Rhamnaceae, Ampelidaceae, Sapindaceae, Hippocastanaceae, Anacardiaceae, Caesalpinaceae, Mimosaceae, Papilionaceae, Hemmamelidaceae, Combretaceae, Myrtaceae, Lecythidaceae, Lythraceae, Sonneratiaceae, Trapaceae, Datiscaceae, Menispermaceae, Myrsinaceae, Ebenaceae, Oleaceae, Bignoniaceae, Acanthaceae, Verbenaceae, Aristolochiaceae, Lauraceae, Euphorbiaceae and Moraceae. The most common wood is *Ailanthoxylon.* The other known genera are *Simarouboxylon, Boswellioxylon, Bridelioxylon, Mallotoxylon, Tetrameleoxylon, etc.*

from Keria and *Grewioxylon, Elacarpoxylon, Leeoxylon, Barringtonioxylon, etc.* from Mahurzari (Prakash, 1973). *Aeschynomenoxylon* is comparable to the extant genus *Aeschynomene* indicative of a marshy habitat. A peduncle showing affinities to the aquatic family Nymphaeaceae is also described as *Nymphaeocaulon intertrappeum* Trivedi *et al.* (1970). The flower *Sahnianthus parijae* (Shukla, 1944; Chitaley, 1955) and the fruit *Enigmocarpon parigae*(Sahni and Rode,1937) have affinities with *Sonneratia apetala* and *Sonneratia acidia* (Mahabale and Deshpande,1957). Other noteworthy flowers and fruits are *Sahnipushpam* (Shukla, 1950), *Chitaleypushpam* (Paradkar, 1973), *Harrisocarpon* (Chitaley and Nambudari, 1973), *Raoanthus intertrappea* (Chitaley and Patel, 1975) and *Sahniocarpon* (Chitaley and Patil, 1973). The affinities of these taxa are not known. It is most essential to decipher correct affinities of fossil taxa after a detailed comparative analysis with extant forms before fossil plant evidences can be used for palaeovegetational and palaeoclimatic reconstructions. Doubtful assignments, therefore, are eliminated in this discussion after critical assessment. Fossil taxa attributed to *Sparganium* (Mahabale, 1953), *Vitex* (Ingle, 1972), *Machilus* (Ingale, 1974) *Pangium* (Trivedi and Shrivastava, 1982) and *Canna* (Trivedi and Verma, 1970) are not considered tenable. It is always necessary to use as guideline phytogeographical associations before concluding on the affinities of fossil taxa. Floral elements like *Canna* and *Aesculus* do not fit in to the overall floral composition of the assemblage from which they have been described. Superficial resemblances must generally be evaluated to avoid major phytogeographical inferences. The Deccan Intertrappean flora indicates a distinctive tropical climate with more humidity than today. The presence of forms like distinctive marine algae *Peyssonnelia, Distichoplax* and *Solenopora;* mangrove and near coast elements like *Nypa, Cocos, Sonneratia* and such other elements authenticates marine and near shore conditions. Fresh water lakes and ponds supporting algal growth, water ferns and aquatic angiosperms are postulated to be present in the vicinity. The evidence of *Aeschynomene* suggests the occurrence of fresh water marshes in the vicinity. The entire scenario viewed as a whole depicts deltaic sedimentation involving fresh- water bodies, estuarine regimes as well as sand bars and coastal vegetation. *Simarouboxylon* and *Rodeites* which bear resemblance with tropical American genera *Simarouba* and *Regnellidium* deserve special attention. The affinities of these fossils are not proved beyond doubt. Further study is needed to confirm the presence of South American floral element in this flora. *Cyclanthodendron* is now proved to be a member of Zingiberales showing combination of characters of members of the families Strelitziaceae, Musaceae and Heliconiaceae (Biradar and Bonde, 1990). This floral assemblage is akin to a humid tropical flora as presently seen in the Western Ghats.

(III) Bombay-Malabar-Worli floristic composition

The Deccan Intertrappean beds of this area contain fresh water tortoise *Hydrapsis* (*Platmeys*) *leith,* frog *Rana pusilla* (*=Indobatrachus pusillus*) and three species of Cyprides (Crustaceae), the common being *Cypris submarginata.* Very few plant fossils have been reported which include wood of bamboo, leaflets similar to those of *Acacia* and seed similar to *Artabotrys* (Carter,1857). A fossil wood of Podocarpaceae has also been recorded (Bande and Prakash, 1984). This fossil locality is totally destroyed because of urbanization in Mumbai area since long time.

(IV) Mandla floristic composition

Extensive palaeobotanical studies on the Deccan Intertrappean localities in the Mandla district have substantially added to our knowledge on the Deccan Intertrappean floras (Awasthi *et al.* 1996; Bande and Khatri, 1980; Bande and Prakash, 1982, 1984; Bande *et al.*, 1986; Mehrotra *et al.*, 1984; Mehrotra, 1987a,b,c). The monocotyledons are exclusively represented by woods of palms and pandans. The fruits have been attributed to the modern branched palm *Hyphaene dichotoma* Furtado and *Pandanus* sp. The other identified palms show affinities with *Phoenix, Phytelephas, Corypha, Cocos, Nypa, Areca, Livistona, Chrysalidocarpus,* etc. The dicotyledonous assemblage is composed of *Polyalthia, Homalium, Hydnocarpus, Garcinia, Sterculia, Grewia, Elaeocarpus, Echincarpus, Atlantia-Limonia, Bursera, Canarium, Otonephelium, Gomphandra, Stemonurus, Heynea, Aglaia, Walsura, Dracontomelium, Ailanthus, Zizyphus, Lophopetalum, Artocarpus, Syzygium, Eucalyptus, Melaleuca- Tristania, Barringtonia, Sonneratia, Bischofia, Dryopetes* and others. This assemblage is also suggestive of a humid tropical climate. Recently Chate (2009) in his thesis described five new species of *Palmoxylon* as *P.phytelephantoides, P. arecoides, P.kaulii, P.chitaleyi, P.calamoides;* two new species of

Rhizopalmoxylon as *R.gothanii* and *R.mahabalei.* A new palm petiole, *Raphiocaulon biradarii,* first record of a branched stem of *Hyphaene deccanii,* a new species of juvenile palm axis as *Mahabalea acaulis,* a rhizome of pandanaceae as *Pandanaceoxylon zimmermannii,* a new fruit of *Sabal* as *Sabalocarpon indicum,* seeds of *Phytelephas* and leaf impressions of *Phoenicites* species and *Sabalites* species. The present work is the further continuation of the flora of Mandla assemblage. Bande and Prakash (1982) reconstructed the palaeoclimate and palaeogeography of central India during Intertrappean period. Their analysis is based upon the floral assemblages of Wardha-Nagpur-Chhindwara and Mandla region based on the evidence of fossils comparable modern genera such as *Tetrameles, Grewia, Elaeocarpus, Ailanthus, Barringtonia, Hyphaene, Polyalthia, Homalium, Hydnocarpus, Garcinia, Sterculia, Atalantia, Gomphandra, Heynea, Dracontomelum, Syzygium* occur today in the evergreen to semievergreen forests of Western Ghats and northeast India. It is envisaged that a similar type of vegetation and climate in central India existed during the deposition of Deccan Intertrappean sediments. It has been postulated that the area enjoyed a humid tropical climate and an annual rainfall of over 2,000 mm. The evidences bring forth a postulation of an equatorial position of peninsular India and presence of sea in near vicinity. The second postulation is supported by the occurrence of fossils of *Peyssonelia* and *Distichoplax, Nypa, Cocos, Areca, Phoenix Sonneratia, Barringtonia,* etc. in the Nagpur Chhindwara assemblage. The absence of Western Ghats as the main barrier in the path of the south-west monsoon currents was perhaps another important factor responsible for the occurrence of this type of climate in Central India during the late Cretaceous to early Tertiary period. The florule of Mohgaonkalan is primarily of angiospermous with a predominance of dicots, palms and other monocotyledons. However, the other groups present in lesser quantities like the members of algae, fungi, bryophytes, pteridophytes and gymnosperms are also significant for palaeofloristic diversity and some of them have phytogeographic and phylogenetic significance. Occurrence of *Azolla, Salvinia, Rodeites, Sparganium, Nypa, Eichhornia, Canna, Musa* and members of other land plants indicate that the florule of Mohgaonkalan was aquatic with which neighbouring plants were also preserved. The fossils at Mothi, District Sagar indicate that it belongs to Nagpur-Chhindwara Flora (Gamre, 2002).

The fossil plants of Bombay area are distinct from those of other localities. Similarly, plant remains of Rajahmundry area are also characteristic for their aquatic charophytic and other algal forms which thrive in brackish waters of estuary. This distinctiveness of the flora is further supported by Taxaceous and Podocarpaceous wood findings by Mahabale and Rao (1973) and Mahabale and Satyanarayana (1977).

Age of the Deccan Traps

The geological age of the Deccan Traps has long been a matter of discussion since the time Malcomson (1837). It has been discussed by several Geologists and the Palaeobotanists. There are different opinions amongst the scientists whether the Deccan Traps are Late Cretaceous or Early Tertiary in age. It was originally regarded Early Tertiary (Malcomson, 1837: *In*: Carter, 1857; Hislop, 1853; Hislop and Hunter, 1855; Oldham, 1871). The later workers, however, considered it as Upper Cretaceous (Blanford, 1867, 1880; Medlicott and Blanford, 1879; Oldhm, 1893; Matley, 1921). On the palaeobotanical evidences it is shown as belonging to Eocene age (Sahni, 1934, 1937, 1938, 1940, 1941, 1943; Sahni, Srivastava and Rao, 1934, Rao, 1936, 1950; Rao and Rao, 1936, 1939; Sahni and Rode, 1937; Sahni and Rao,1943; Mahabale, 1950, 1953). Crookshank (1937) adopted Tertiary view for the Deccan Traps. On the basis of petrological, chemical and radioactive studies, Dubey (1937, *In*: Rao, 1950) was of the opinion that the greater part of the Deccan Traps belonged to the early Tertiary. Wadia (1957) considers Deccan Traps of the Danian Stage of the uppermost Cretaceous, on the basis of external evidence and Eocene age based upon the palaeontological evidences such as fossil fishes, palms and foraminifers. Krishnan (1960, 1973) considers the Deccan Traps ranging from Uppermost Cretaceous to earliest Eocene in Gujarat and Eocene in age in rest of the Deccan Trap area.

The commencement of the Deccan Trap activity can be deduced by the study of Infra-trappeans along the eastern margin of the Deccan Trap Province where older traps are known. The Intertrappean beds were deposited in shallow depressions on the surface of each flow during quiscent intervals. The surface during this deposition was sufficiently cool for the luxuriant vegetation the intertrappeans hold as well as molluscas, crustaceas, fishes and algae that have been recovered from these sediments. Vertebrate assemblage is represented by tetraodontid fishes, batoids, holosteans and teleosts, frogs, snakes and crocodiles.

The Infra-trappean beds are only confined to a few localities, while Intertrappeans are common and have been discovered from many localities. The Infra-trappeans are most valuable to ascertain the age of the Deccan Trap eruption.

Geological Evidences bring forward that the Deccan volcanism covered a fairly long span of time. The flows in Kachchh Basin are considered to have erupted during the Aptian and Palaeocene epochs. Deccan Trap flows resting on Bagh Beds in Narmada Valley and Lameta Beds in Jabalpur have evidences to prove that the flows in these areas are subsequent to Middle Cretaceous and Turonian respectively. The intercalated *Cardita beaumonti* beds among the basaltic flows of Rajkot are suggestive of volcanism being operative in this region during upper Cretaceous-Danian period. Nummulitic beds of Surat and Bharuch, overlying the trap, point to the eruptions in pre-Eocene times while the trap of Chhindwara overlying the lime stone beds suggests a post-lower Eocene activity (Alexander, 1981). In Rajahmundry area, the traps overlie marine Cretaceous sand stone and contain sedimentary horizons of distinct Eocene affinity (Pascoe, 1964). These facts clearly indicate the commencement of extrusion of trap after the Cenomanian period extended up to the Eocene period.The deep bore holes in the Deccan Traps occur below the Eocene in the Cambay basin. They are immediately overlaid by 'trap-wash', carbonaceous clays and pyretic and lateritic clays which are known to be of Palaeocene age. This leads to the inference that the Palaeocene beds were deposited on the Traps. It is, therefore, believed that the traps are slightly older than Palaeocene. The Deccan Trap found in some wells of the Cambay Basin and in the off-shore of the West coast points to Cretaceous and Eocene age (Sastri, 1981). The youngest of the Deccan basalt in Cambay Basin is not likely to be younger than 60m.y. (Ramnathan, 1981).

Radiometric and palaeomagnetic evidences

Alexander (1981) records K/Ar ages for basalt samples from Sagar, Dhandhuka, Koyna and Dohad. K/Ar ages for two Deccan trap dykes, one from Saurashtra and another from Pachmadhi in Madhya Pradesh are also reported. K/Ar ages of the Deccan Trap flows of Sagar range from 50 to 41.7 m.y. Basalts on the Koyna on the southern margin of the Deccan Trap outcrop record an age of 31.1 ± 1.0 m.y., while that from Dohad and also in western India record an age of 37.7 ± 1.2

m.y. The topmost flow of the 37 flow sequence of the Dhandhuka bore hole in western India is dated as 62.7 ± 2.05 m.y. However, flow no.5 towards the bottom of the sequence at a depth of 488 m is dated as 61.3 ± 2.0 m.y. while one from Saurashtra is dated as 46 ± 1.5 m.y. This data bring forth that the volcanic activity around Sagar extended from 50-41.7 m.y. while that at Koyna and Dohad the age of the trap is much younger-31.1 and 37.3 m.y. respectively. The oldest date available is 101.7 m.y. from Dhandhuka (Alexander, 1981).Venkateshan *et al.* (1986) have dated the lava flows from different elevations from a 1250 m thick exposed section near Mahabaleshwar. The ages obtained are: 72 ± 1 m.y. (50 m above main sea level), 68 ± 0.6 m.y. and 65 ± 2 m.y. This indicate that the Deccan Trap volcanism stretches widely on either side of the conventionally accepted 65-60 m.y. datum line. In most of the cases the trap dates do not belong to the immediate vicinity of localities from where plant fossils are known to occur. This necessitates interpolation of dates in postulation with the stratigraphic correlation of the fossiliferous intertrappean beds.

The available radiometric evidences for the Rajmahal Trap suggests that they are older than the Deccan Traps dated 109-69 m.y. on the basis of K/Ar determination (Mc Dougall and McElhinny,1970; Agarwal and Rama,1976). Alexander (1981) considers Rajmahal volcanic activity coeval with the basal Deccan Trap depositions.

Palaeomagnetic Evidences

Irving (1956), Clegg *et al.* (1956), Deutsch *et al.* (1958) carried out palaeo-magnetic studies on the Deccan Traps. Deutsch *et al.* (1959) and Sahasrabudhe (1963) observed one reversal geomagnetic polarity during Deccan Trap volcanism. Murty (1973), however, felt that some of the traps may show more than one reversals. Dalrymple *et al.* (1967) and Heirtzler *et al.* (1968) consider many more reversals. However, they observed that the geomagnetic field with frequent reversed polarity since Cretaceous period. On the basis of this frequent field reversal model and the simple two-zone polarity, McElhinny (1968) concluded that the total time of this extrusion did not exceed 5m.y. He also showed that the variations of the palaeomagnetic pole positions of the two groups of the traps (varying by 172°-180°) represents the same axis of rotation and that the scatter of pole position prints are due to secular variations. According to him, the pole position has not changed during the entire period of the Deccan volcanism and the reference point (Nagpur) was virtually stationary at 30° south latitude. Wellman and McElhinny (1970) think that the entire of the Deccan Traps were poured out in 5m.y. as several basalts from western India are in the range of 65-60m.y. (K/Ar dating). This observation was also supported by Kaneoka and Haramura (1973) on the basis of their K/Ar dates younger than 65-60 m.y. ranges were invariably ascribed to Argon loss as was done in the work of Rama (1968). One reversal model could be true for some limited areas but can not be applied to the entire Deccan Trap Province. Kono *et al.* (1972) have restricted this one reversal model to the Western Ghats. Further studies (Pal, 1975; Pal and Bhimasankaram, 1971a; Pal *et al.,* 1971; Wensink, 1972) on the Deccan Traps suggested that the geomagnetic polarity inversions occurred several times during eruptions of the Deccan lavas. According to Pal (1975), a minimum of 6-7 reversals are clearly indicated in the entire Deccan province. Studies on the Sagar lava suggest that the geomagnetic field had reversedits polarity twice during the volcanic episode (Pal and Bhimasankaram, 1971b). On these grounds, Pal (1975) has suggested that the trap eruptions continued during the time interval of 70-40m.y. The present K/Ar data is in line with this thinking although the suggested duration of eruption is much higher. The stratigraphical position of Nawargaon and other Deccan Intertrappen exposures in Central India indicate latest Maastrichtian age (Uppermost Cretaceous) to the Deccan Traps.

Stratigraphic evidences

The stratigraphic position of the entire Deccan Intertrappeans indicates latest Maastrichtian age to the entire Deccan Intertrappean exposures contrary to the previous age assignment of early Tertiary. The entire Deccan volcanic episode is more or less synchronous event on the basis of palaeomagnetic, stratigraphy, gepchronology and radiomagnetic dates (Baksi, 1987; Alexander, 1988; Courtillot *et al.* 1986, 1988; Duncan and Pyle, 1988; Pande *et al.,* 1988; Vandamme *et al.,* 1991). An *Aquilapollenties*-associated palynoflora (Prakash *et al.,* 1990; Mathur and Sharma, 1990; Sahni *et al.,* 1996; Kumaran *et al.* 1997), a contemporaneous charophytic flora (Bhatia *et al.,* 1990; Chandra *et al.,* 1989), the megaflora of Intertrappean localities need to be reappraised for their exact biostratigraphic and phytogeographic implications. The palaeopalynofloral assemblage supports the view. The recent investigation of an occurrence of *Acrostichum intertrappeum* Bonde and Kumaran (2002) from the Nawargaon Intertrapeans along with earlier known costal and marine floral elements and palaeontological evidence suggests prevalence of costal and marine environment around Nagpur-Wardha area during the Deccan Intertrappeans.

The entire Deccan volcanic episode is more or less synchronous event on the basis of palaeomagnetic, stratigraphic, geochronological and radiometric dates. In fact, a concerted and systematic collecting and sampling of Intertrappean strata are needed for meaningful stratigraphic and evaluations of palaeobotanical, palynological and palaeontological data of the different exposures from the Deccan Trap Country.

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