

Cactus and Dinosaurs: did they coexist?

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While orchids are the most important and most varied family of plants on Earth, they are surprisingly missing in the fossil collections. Also, there are, until now, no fossils known for cacti.

Like for Orchids, the lack of cactus fossil data would be sufficient “evidence” of the recent appearance of these families on the planet. But a recent discovery comes to upset this popular misconception and could apply to cactus very well ... A fascinating investigation on the real origin of Cactaceae is still to begin.

• REALITY or FICTION?

While visiting the Arizona-Sonora Museum in the 80s, near Tucson in Arizona, I bought a book for children on dinosaurs. These enormous reptiles from the Jurassic were depicted there, evolving among unknown, disappeared plants, but also cacti of the region! I was somewhat surprised, but this memory remained as no more than a amazing anecdote ...

The family of Cactaceae is certainly much more older than we have been led to believe for a long time. I accepted this adage as no evidence existed to contradict the fact that fossils of cactus were non-existent, therefore they are recent. So, as it said in many books or articles about this family, they probably appeared at the end of the Tertiary (Cenozoic) era, and are together with Orchids, are one of the most recent family plants on the Earth. More recently, an average of 19.1 – 3.1 M.yrs. was proposed for Cactaceae (Ocampo & Columbus 2010).

Nevertheless, something does not fit in this assertion. As there is no evidence that cacti are of recent appearance, with the same logic, there are no evidences of the opposite. The lack of fossilization of these plants, their seeds or their pollen does not disprove they could be of a much older origin.

Then, I found the excellent work of the Dr Phil Maxwell (see bibliography), on the origin and the distribution of ***Rhipsalis***: I had come to the same conclusions, and it rapidly became very interesting, indeed fascinating, but always still remaining obscure. Dismissal of the most plausible of the theories for divergent distribution of ***Rhipsalis*** i.e. that of human introduction is said to be improbable.

The theory that birds would have transported in their feathers or digestive system, seeds of a single species of ***Rhipsalis*** from America to Africa and finally dropping them then in a good place after thousands of kilometres must not be considered as serious for different reasons:

- the distance about 3000 km between South America and west coast of Africa is not browsed by migratory birds, only some lost constipated (in order to retain the seeds on such a route) albatross which does not usually eat the fruit of ***Rhipsalis***, and are not either going to perch in the forests...

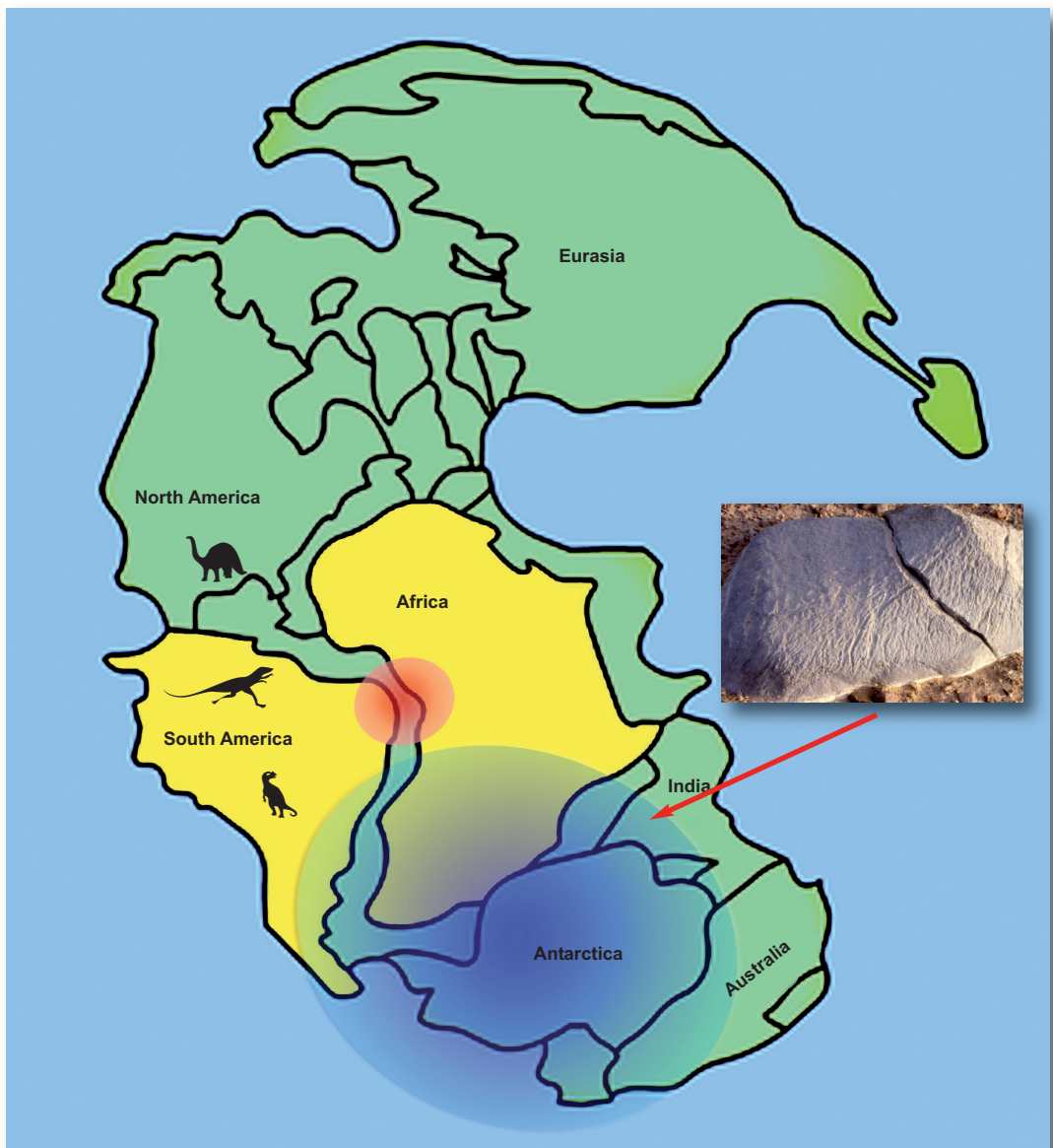
- the ***Rhipsalis*** which we find in Africa (but also in Madagascar, Mauritius, La Reunion, Comoro Islands, Mascareignes, Seychelles and Sri Lanka differ from those growing in America.



- why, when there are so many cactus genera with juicy and attractive fruit for birds, only a ***Rhipsalis*** has been singled out as the only cactus in the improbable ornithophilous dispersal? Melocactus would have been a stronger and better candidate in this “Game of Chance”...

Rhipsalis baccifera habitat, La Reunion.

(photo : JL)

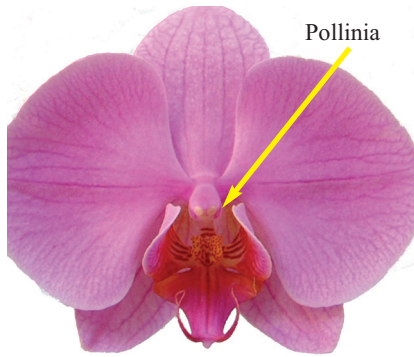


We can find glaciation vestiges of the Pangaea (blue circles) south of the presumed *Rhipsalis* center of biodiversification (red circle). Photo : a rock covered with glacial scars in the Thar desert, Rajasthan, India.
(map & photo : J.L.).

- if this improbable scenario would nevertheless have taken place, it should be because in ancient times, the American and African continents were much closer to each other i.e before the great the division of Gondwanaland and the drift of continents. The beginning of the separation of Africa and America is situated near the lower Cretaceous, so, approximately 130 million years ago...

But then, did *Rhipsalis* (or its ancestor) already exist?..

• PALEOZOOLOGY and PALEOBOTANY, the answer?



According to paleobotanists, Angiosperms (among which we find the family of Cactaceae, was already present on the Earth during lower Cretaceous and probably before, with possible fossil remains which would go back, according to Shields (1988, in Maxwell) from average Jurassic (Bathonian: between 168 and 166 M.yrs.).

Anthophilous insects previous to Cretaceous were discovered in Late Jurassic rocks in Liaoning Province of northeast China, with a fossil of a short-horned fly (*Brachycera*), with a long

proboscis adapted to feed on nectar and dated from the Upper Jurassic (between 150 and 143 M.yrs.). The most ancient Lepidopteran is dated from the lower Jurassic. Thus, in conclusion (Shields, 1988) flowering plants appeared towards the end of the Triassic era, at the beginning of the Jurassic (approximately 205 M.yrs.).

Some authors, like Crane (1995), advanced that their origin would be during the Upper Triassic (between 225-205 M.yrs.), at a time when dinosaurs, the first mammals, and doubtless, also birds appeared ...

• TOWARDS NEW DISCOVERIES

In 2000, a bee fossil in amber was discovered in the Dominican Republic, in a mine of the Mountain range northeast of Santiago. It arrived, by means of a private collector, at the Museum of Comparative Zoology of Harvard laboratory in 2005. It was not the first time, as another bee was also previously found (Wille & Chandler 1964).

But the piece of amber, dated 15 to 20 million years, contained two pollinariums (or pollinies) of orchid attached at the abdomen of a worker bee, the whole in very good state of conservation.

Santiago Ramirez, of the University of Harvard, Cambridge (Massachusetts, United States), as well as the other authors of the discovery gave to this unknown orchid, the name of *Meliorchis caribea*, and identified the bee, belonging to the species *Proplebeia dominicana*, characterized by being stingless.

We thus have henceforth a means to reconstitute the phylogenetic tree of the orchids. With about 25 000 known species worldwide, we could imagine that they needed more time than what is generally allowed (at the end of the Tertiary) to spread and diversify...

Moreover, the Dr Maxwell quotes with justice, that Léon Croizat had well asserted before everybody: "The most widely distributed member of a group of organisms with limited powers of dispersal will be the oldest member of that group." But he was not taken seriously. It was only in the 70s, when the theory of plate tectonics was accepted by practically the whole scientific world that his article, although still debated, took on

all its importance.

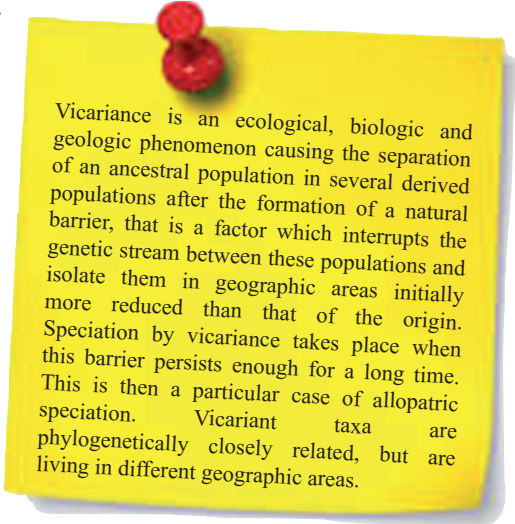
Ramirez adds that they took advantage of this discovery to realize a family tree based on DNA sequences: "Because we knew the whereabouts of the fossil, we used its age to calibrate the molecular clock. And because no other fossil orchid was known up to now, we calculated the age of the modern orchids from that of *Meliorchis*."

So, the scientists of Harvard arrived to the conclusion that the common ancestor of the actual orchids was growing somewhere in America 76 to 84 million years ago. The obtained results suggest that the dramatic radiation of orchids began shortly after the mass extinctions which marked the passage of the secondary era to the tertiary era, some 65 million years ago, and of which dinosaurs are the most remarkable victims.

Still going a little farther and applying the method of the molecular clock, they estimated the age of the main branches within the family of Orchids. To their surprise, they found that certain groups of modern orchids, including the well-known genus *Vanilla*, evolved very early during the rise of the plant family.

One of the largest plant families of the New World and its distribution through the continent has to lead to the same conclusion: it would have been necessary more than some small thousands or even million years to arrive to such a biodiversity and a similar scattering. Following Croizat, the Dr Maxwell resumes the term of *vicariance* to explain the phenomenon of dispersal and evolution of the *Rhipsalis*.

I think that we can perfectly extrapolate this hypothesis to the remaining members of Cactaceae. I shall add, although mainly against the generally accepted theories, that it is completely plausible that cacti were born on the African part of Gondwanaland, but diversified in America, instead of seeing a sort " of escapee " of the family from America, with *Rhipsalis* scattering towards the Old World... Considered as a single species, *Rhipsalis baccifera* can nevertheless be diploid, tetraploid or even octoploid. Maxwell thinks that they are in fact very different species, and treats them as separate taxa.



Vicariance is an ecological, biologic and geologic phenomenon causing the separation of an ancestral population in several derived populations after the formation of a natural barrier, that is a factor which interrupts the genetic stream between these populations and isolate them in geographic areas initially more reduced than that of the origin. Speciation by vicariance takes place when this barrier persists enough for a long time. This is then a particular case of allopatric speciation. Vicariant taxa are phylogenetically closely related, but are living in different geographic areas.

Barthlott (1979) suggested that cactus appeared during Cretaceous, but he added that when South America and Africa separated, there were no plants such as *Rhipsalis*. How can he be so sure of that?

Leuenberger (1986) suggested a likely origin of the family in the northwest of South America towards the end of the Cretaceous, far from the closest point where the continent was in contact with Africa (now the northeast of Brazil and Gabon).

For Maxwell, *Rhipsalis* appeared during the Jurassic, before the separation between Madagascar and Africa, that is from 180 to 160 M.yrs., parts of Gondwanaland which remained close to each other one (and maybe even in contact) much later, allowing

Échelle du Temps					
Million years	Geological Eras	Period	Epoch	Evolution of Life	Apparition of Life (M.A.)
4000	Precambrian	Archean		bacteria	3500
2500		Proterozoic		blue algae cells with nucleus blue algae colonies	3200 2800 2500
570	Primary or palaeozoic	Cambrian		invertebrate shells	560
510		Ordovician			
438		Silurian		first vertebrate (fish) first amphibian	450 360
410		Devonian		first reptile	320
355		Carboniferous			
290		Permian		first dinosaur	230
250	Secondary or mesozoic	Trias			180
205		Jurassic		first cactus ? first mammals	65
135		Cretaceous		extinction of dinosaurs	
65	Tertiary	Palaeogene	Palaeocene	first equid (ancestral horse)	55
53		Neogene	Eocene		50
37			Oligocene.	expansion of mammals	4
23			Miocene	australopithecus	
5			Pliocene		
1,6	Quaternary		Pleistocene	evolution of man	0,035
0,012			Holocene	modern man	



certainly some exchanges of plants and animals. The narrow neck of land connecting at present day North and South America, is of much more recent appearance, towards Pliocene (approximately 3.5-3.1 M.yrs.). Moreover, we find there that a single species of ***Rhipsalis***, ***R. micrantha*** lives in Costa Rica, but is normally spread in Venezuela, Colombia, Equator and Peru.

If it is possible that Rhipsalideae (***Rhipsalis***, ***Hatiora***, ***Lepismium*** and ***Schlumbergera***) represents an “evolutionary cul-de-sac”, although effective, and appeared very early and remained practically confined to the trees, Maxwell thinks rather than ***Rhipsalis***, and more exactly members of the group ***R. baccifera*** are ancestral to all other Cactoideae, excepting Hylocereenae. He brings even “all grist to the mill”, because it seems very improbable that non spiny, epiphytic plants could evolved towards spiny , spherical or columnar plants growing at ground level, even by having a lot of time to do that... Nevertheless, Maxwell clarifies that ***R. baccifera*** and the other members of this group are also epilithic, and at the juvenile stage, they wear bristles and have ribs!

• POSSIBLE SCENARIO

The theoretical scenario could be the following one: during the Cretaceous period, Cactoideae began to occupy various arid and semi-arid habitats and they diversified at the same time as radiation took place, creating adaptive forms in term of morphology,

photosynthesis and storage of the nutriment, then the occupation of very different territories, mountains, deserts, tropical and humid zones or cold regions etc. took place from this period and continues even today under our eyes with a reticulate evolution, which allows the hybridization of sometimes phylogenetically distant genera and the conquest of new lands for new taxa. However, others disappear for reasons of ecological and, or climatic pressure (e.g. one of the parents of ***Geohintonia mexicana*** would have disappeared for that reason, or this new taxon would have been born because of this pressure on one of its parents?).

Finally, last point which seems to me fundamental in the evolution of the family: would it be possible that we look for a common ancestor which does not exist, and that on the contrary, two lineages (or more?) occupied, the one, South America, the other one, North America, both continents being still divided, not connected yet?

Actually, leaving apart the Opuntioideae which we find from Canada down to Patagonia, the rest of Cactaceae is distinguished by different genera, which are only found in North America, eg. ***Ferocactus***, ***Mammillaria***, ***Coryphantha***, ***Echinocereus***, ***Pachycereus***, meanwhile others occupied a part of South America without ever reaching North America: ***Melocactus***, ***Gymnocalycium***, ***Parodia***, ***Pilosocereus***, ***Trichocereus*** for

example. The dispersal of these genera shows that some of them managed until recently to cross (apparently towards Pliocene) from one to another continent: ***Melocactus*** arrived from South America up to Mexico, however ***Mammillaria*** took two different paths from Mexico where the diversification is considerable for this genus: it managed to come down to the North of South America (Colombia, Venezuela), but also went up to the United States.



The answer could be in the cacti which we find in Central America: these taxa were able to appear only lately, from their parents arrived from Mexico, the Caribbean islands, Colombia or Venezuela, where similar taxa exist.

Thus, the attractive scenario bringing together cacti and dinosaurs would be a reality more than plausible, but only these last ones were not able to resist a drastic climate change that underwent the New World towards the end of the Cretaceous era. Cacti like ***Pachycereus pringlei***, capable of withstanding cold down -12°C while in their habitat of origin, the average temperatures are $+18^{\circ}\text{C}$ (absolute minimum in Loreto $+5.4^{\circ}\text{C}$ in

January, 1971) are the possible evidences for several species of plants of Baja California, of a memory of the cold which existed when this region was partially covered by the ices of the south pole.

The study of cacti is an open, fascinating subject, but still full of uncertainties and mysteries. We only can imagine one of the last apatosaurus (ex brontosaurus) looking desperately for food in a landscape becoming arid little by little, so precipitating the extinction of this species, but obliging the cacti to adapt themselves to this new climatic scheme which would finally be favorable to them.

Text and photos: JL

a web page to visit: <http://rhipsalis.com/maxwell.htm>

Note of the trad.: there is a parallel example which has only recently been understood. The ancestral stock of *Aloe*, *Haworthia*, etc. does not exist in Africa but Australia (the first continent to break from Pangeae). This is why we now know that *Aloe* derived from Xanthorrhoeaceae.

Ray Stephenson.

BIBLIOGRAPHICAL REFERENCES:

- Crane P.R., Friis E.M., Runsgaard Pederson K. 1995. *The origin and early diversification of angiosperms*. Nature 374: 27-33.
- Gibson, A. C. & Nobel P. S. 1986. *The Cactus Primer*. Harvard University Press, Cambridge, 286 pp.
- Leuenberger, B. E. 1986. *Pereskia*. Memoirs of the New York Botanical Garden 41 : 1-140.
- Maxwell, Phil. 1998. *The Rhipsalis Riddle – or the day the cacti came down from the trees, Part 1*. New Zealand Cact. & Succ. Journal, 51:4 129-140.
- Maxwell, Phil. 1999a. *The Rhipsalis Riddle – or the day the cacti came down from the trees, Part 1*. New Zealand Cact. & Succ. Journal, 52:1 19-25.
- Maxwell, Phil. 1999b. *The Rhipsalis Riddle – or the day the cacti came down from the trees, Part 1*. New Zealand Cact. & Succ. Journal, 52:2 52-62.
- Ocampo, G. & Columbus, J. T. 2010. *Molecular phylogenetics of suborder Cactineae (Caryophyllales), including insights into photosynthetic diversification and historical biogeography*. Am. J. Bot. **97**: 1827-1847.
- Ramirez S.R, Gravendeel B., Singer R.B., Marshall C.R., Pierce N.E. 2007. *Dating the origin of the Orchidaceae from a fossil orchid with its pollinator*. Nature 30;448(7157):1042-5.
- Shields, O. 1988. *Mesozoic history and neontology of Lepidoptera in relation to Trichoptera, Mecoptera, and angiosperms*. Journal of Paleontology 62: 251-258.
- Schlumpberger Boris O. 2012. *A Survey on Pollination modes in Cacti and a potential Key innovation*. In Evolution of Plant-Pollinator Relationships, Ed. S. Patiny. Cambride University Press.
- Wille A. & Chandler L. C. 1964. *A new stingless bee from the tertiary amber of the Dominican Republic (Hymenoptera; Meliponini)*. Rev. Biol. Trop., 12(2) : 187-195.

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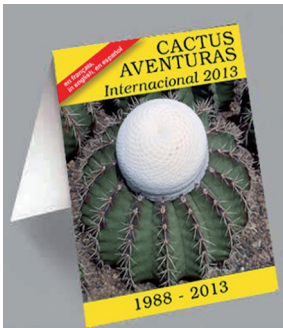


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