

DID TERMITES PROVIDE PHOSPHORUS FOR OCEAN PHOSPHORITES AND BONE DEVELOPMENT IN THE CRETACEOUS?

By Charles E. Weber, MS

1908 Country Club Road, Hendersonville, NC 28739, USA

1 828 692 5816 isoptera@att.net

ABSTRACT

It is the proposal of this article that the development of the ability to build a layer of phosphorus rich earth over plants by termites in order to smother them and thus harvest the fungi that grow there, caused the decline in size, bone, armor, and teeth of savanna vertebrates. This happened because of the nature of the sheet erosion that took place. Also resulting was deposition of ocean phosphorites, anoxic bottom water, large ocean reptiles, and Ammonite decline. Therefore paleontologists should analyze the soil profiles associated with fossils for phosphorus in order to get as full a picture as possible.

KEYWORDS

termites; phosphorite; phosphorus; bone; teeth; soil; erosion; ammonite

DISCUSSION

The Amitermitinae subfamily of the Termitidae family of termites [now merged with the Termitinae] have evolved the ability to form a phosphorus rich [possibly by phosphorus in the termite's saliva (Weber 1993, p111)] earthen sheath over plants cemented with their saliva. They also use the above smothering technique as a subfamily to use dung, dead grass, dead herbs, rotten wood, bark, debris, seeds, and the surface tissue of woody plants (MacKay, et al 1985) (Hill 1942). This has enabled them to lose most of their cellulose digestive microorganisms. This use of earth may be an adaptation of an earlier use of saliva to entangle enemies (Noirot 1970). They probably evolved first in Australia because that continent has the most species at present and it is there that the first ocean phosphorites appeared. Emerson believes they have arisen in Southeast Asia (Emerson 1955). They are most successful in savanna regions, probably because their earth works are not resistant to erosion, so they need a dry season. The exposed position of the earth works results in severe sheet erosion and thus loss of phosphorus from the soil (Weber 1993). Their present distribution indicates that they were almost certainly present in the Cretaceous. Their upland habitat combined with their short mating flights low in numbers that head to the ground instinctively probably helps explain why there are no fossil wings from the Cretaceous.

Modern Amitermitinae make large colonies that can bore down dozens of meters to reach a water table, which last is probably the reason they can inhabit desert and monsoon regions. Probably what made larger colonies eventually possible was the ability to have more than one reproductive in each colony, as many as one hundred. The ability

to synthesize nitrogen (Schaefer 1981) must enhance their success considerably also. Modern species from Amitermitinae have evolved mono- and sesquiterpenes including several unique cyclic ethers (Prestwick 1983), which probably play a role in defense and could conceivably assist in stimulating fungi. These many complicated compounds imply a long time of evolution. Even more indicative of a very long evolution time is a very low queen to worker class ratio, inbreeding inside the colonies, and life span of queens that can be well over ten years compared to short lives of most other insects other than ants, which lengthens the time it takes to evolve. Since the now very numerous Termitidae family had differentiated in such widely separated areas as South America, Africa, and Australia during the Cretaceous, their progenitors must surely go far back into the Jurassic at least. It is easy to believe primitive Termitidae species going back to the upper Jurassic and thus making this thesis possible.

Before the close of the Jurassic phosphorites began to appear in marine deposits again after the Triassic discontinuance from the Permian depositions. In the early Cretaceous there manifested a series of pulses of phosphorus ocean deposition of increasing magnitude in the greensand glauconite [ferrous iron clay] beds. There was widespread marine phosphogenesis middle early Valanginian to early Hauterivian early to early middle late Aptian, latest Aptian and earliest Albian (Follmi, et al, 1994 p742,743). It was in Australia where phosphorites first appeared, since this is where phosphate deposits were clustered in late Jurassic and early Cretaceous (Cook 1984 p251, map).

North American soils had low phosphorus in higher up soils in late Cretaceous (Retallack 1994), about one fifth of the amount in African soils in the Miocene (Retallack 1994) (Retallack, et al 1995). A few hundred thousand years after the iridium spike signaled an impact at the close of the Cretaceous there was a rise of ocean phosphorites to double that in the late Cretaceous that lasted to the end of the Eocene (Zhou and Kyte 1992). I suspect that this resulted from an additional spread of Amitermitinae around most of the world's savannas at that time. They would have had to have migrated to North America early. This would have been possible since the land bridge at or above the Aleutian Islands warmed up assisted by an Arctic Ocean, which may have been as warm as six degrees centigrade in winter as determined by leaf design (Herman and Spicer 1996). There was a spike of temperature in mid Cretaceous (Huber 1998), the Arctic Ocean going up to 27 degrees centigrade in the Coniacian [93.5 million years ago] (Jenkyns, et al 2004) possibly partly from trees in the high Arctic (Otto-Bleiser 1997)

The likely circumstance is that ants which could hunt in packs were absent from Cretaceous savannas since that type are not cosmopolitan even today. Primitive ants make up only 1% of the Cretaceous insect fossils (Holldobler and Spicer 1990, p23). There were only two individuals out of thousands in the Alberta, Canadian Amber while in the Tertiary ants were among the most abundant fossils (Wilson 1987). However there were very few fossil insects in the Cretaceous anyway (Carpenter 1953 p268), especially in the tropics, so the presence of higher ants on the savannas is open. However it is very likely the lack of ants made Amitermitinae and other termites still virtually unopposed in savanna areas during the Cretaceous. Present day termites and ants are dramatically

successful. They make up three fourths of the entire insect biomass in the Brazilian rain forest [Holldobler & Wilson 1990, p566] and may be as much as 95% of the insect biomass in the Cameroon rain forest (Bignell et al 1997, p110). It is highly probable that termites were even more successful on some of the Cretaceous and all of the Paleocene savannas, and had even more affect on the environment than they do today since ants that hunt in packs are a late development outside of South American rain forests and none are cosmopolitan.

North American vertebrates declined some in bone and armor across the Cretaceous especially on the savannas. Even so, animals that probably lived on or near flood plains with firm soil such as the web-footed duck billed Dinosaurs, which are Hadrosaurs, remained fairly large up until almost the close of the Cretaceous, possibly partly because soil borne termites can not live on flood plains (Bown 1983) and those flood plains were no doubt deposition areas for some of the upland erosion sediments. However, large Dinosaurs lost diversity, probably because of the diminished areas of very fertile soil, as Amitermitinae became more efficient. By the end of the Cretaceous Ceratopsia made up 80% of the dinosaurs while duckbilled Dinosaurs made up most of the rest (Bakker 1986). One reason why Ceratopsia seemed to be more numerous is that their fossils are primarily found in swampy areas (Retallack 1997). This is understandable since they were adapted to a frontal defense and could stand and fight on soft soils. A Tyrannosaur would not dare to attack them from the front. Even a poorly aimed thrust of that huge horn into its thin ribs would have been disastrous. They would not be required to run fast in soft soils while the duck billed dinosaurs must have had to outrun predators and keep them at bay with whippings from their tail and so would have had to be on hard ground or have access to a river from a firm bank. Also, there may not have been as many areas of hard ground left fertile enough to sustain the duckbill dinosaurs. It is also possible that they lived in water like hippopotami.

It may also be part of the reason why birds lost their teeth as soon as early Cretaceous in China (How , et al 1995) even though marine birds retained them until late Cretaceous. However, ingestion by the reproductive alates of soil and humus eating termites [there are very many humus eating species in the Amitermitinae (Krishna 1970, p51) and other humus eating Termitidae] may have been the primary reason the birds lost teeth, because of the phosphorus binding attribute of laterites and bauxites in the gut (Weber 1993, p115). Pterosaurs also lost teeth and would have been even more affected by an insect diet since they were thought to be able to fly at 40% of adult weight (Hazelhurst and Bayner 1992), which would imply an insect diet for the young. Evolution toward lightness can not explain it because stones in the gizzards of birds are also heavy and teeth are very valuable and can be very small. Pterosaurs did increase in size (Hone and Benton 2007), but this was probably because birds took over the small size niche or because Pterosaurs' low wing loading (Hazelhurst and Bayner 1992) meant aerial predation or maybe scavenging by adults.

CONCLUSION

It may be that part of the decline of ammonites near the end of the Cretaceous (Paul 1990) was because the rise in ocean phosphorus gave their competitors, the fish, a

relative advantage since the ammonites used a calcium carbonate shell. Also anoxic conditions on the sea floor, which tends to follow an excess of phosphorus, may have been hard on a bottom dwelling creature (Harries 1993). Ammonites almost completely disappeared by the Paleocene, although this may also have been also related to a considerable extent to the pH and/or calcium status arising from enormous loss of calcium in Foraminous shells and other shells. There is an excellent chance that evolution of the ability to smother plants and debris with phosphorus rich earthworks by Amitermitinae caused a great decline in tropical phosphorus soil fertility, which continues unabated until the present in Australia. If so, it could explain the low Cretaceous phosphorus soil fertility, the formation of ocean phosphorites then, the anoxic bottom waters, large ocean vertebrates at the same time that land savanna vertebrates declined in size, armor, and teeth especially in Australia and East Asia, and then North America, and the decline in the Ammonites.

REFERENCES

- Bakker, R.T., 1986. *The Dinosaur Heresies*. Wm. Morrow and Co. NY.
- Bown, T.M., Kraus, M.J., 1983. Ichnofossils of the alluvial Wildwood formation (lower Eocene). *Paleogeography Paleoclimatology Paleoecology* 43; 95-128.
- Bignell, D.E., Eggleton, P., Nunes, L., Thomas, K.L., 1997. Termites as mediators of carbon fluxes in tropical forest: budgets for carbon dioxide and methane emissions. In: Watt, A.D., Stork, N.E., Hunter, M.D., (eds), *Forests and Insects*, pp109-133 Chapman & Hall, London.
- Carpenter, F.M., 1953. The Geological history of insects. *American Science*. 4; 256-270.
- Cook, P.J., 1984. Spatial and temporal controls on the formation of phosphate deposits a review P242-274 in: Nriagu, J.O., Moore, P.B., (eds.), *Phosphate Minerals*. Springer Verlag Berlin NY
- Föllmi, K.B., Weissert, H., Bisping, M., Funk, H., 1994, Phosphogenesis, carbon-isotope stratigraphy, and carbonate-platform evolution along the Lower Cretaceous northern Tethyan margin. *Geological Society of America Bulletin*, Boulder, 106, 729–746.
- Harries, P.J., 1993. Dynamics of survival and recovery following the Cenomanian-Turonian (Upper Cretaceous) mass extinction event. *Cretaceous Research*, v. 14, 563-583.
- Hazelhurst, G.A., Rayner, J.A., 1992 Flight Characteristics of Triassic and Jurassic Pterosauria: An Appraisal Based on Wing Shape. *Paleobiology* 18, 447-463.

- Herman, A.B., Spicer, R.A. 1996. Paleobotanical evidence for a warm Cretaceous Arctic Ocean. *Nature* 380; 330 or 331-333.
- Hill, G.F., 1942. *Termites (Isoptera) From The Australian Region*. H.E. Daw, Govt. Printer, Melbourne, Austr.
- Holldobler, B., Wilson, E.O., 1990. *The Ants*. Belknap Press of Harvard University Press, Cambridge.
- Hone, D.W.E., Benton M.J., 2007, Cope's rule at different taxonomic levels. *Journal of Evolutionary Biology* 20, 1164-1170.
- How, L., Zhou, Z., Martin, L.D., Feduccia, A., 1995. A beaked bird from Jurassic China, *Nature* 377:616-618.
- Huber, B.T., 1998. Tropical paradise at the poles? *Science* 282: 2199-2200.
- Jenkyns, H.C., Forster, A., Schouten, S., Damste, J.S.S., 2004. High temperatures in the late Cretaceous ocean. *Nature* 432; 888-892.
- Krishna, K., 1970. Taxonomy, phylogeny, and distribution of termites p127-150 in: Krishna, K., Weesner, F.M., (eds.), *Biology Of Termites*, Vol II Academic Press NY.
- MacKay, W.P., Blizzard, J.H., Miller, J.J., Whitford, W.G. 1985. Analysis of above ground gallery construction by the subterranean termite *Gnathamitermes tubiformans* (Isoptera: Termitidae). *Environmental Entomology*. 14; 470-474.
- Noirot, C., 1970. The nests of termites. P 73-125 in: Krishna, K., Weesner, F.M., (eds.), *Biology Of Termites*, vol. II, Academic Press.
- Otto-Bleisner, B.L., 1997. Upchurch Jr. GR Vegetation induced warming of high latitude regions during the late Cretaceous period. *Nature* 385; 804807.
- Paul, R.C., 1990. Patterns of evolution and extinction in invertebrates. in; Allen, K.C., Briggs, (eds.), *Evolution And The Fossil Record* p99-121.
- Prestwick, G.D., 1983. Chemical systematics of termite exocrine secretions. *Annual Review of Ecol. Systems*. 14; 287-311.
- Retallack, G.J. 1994. A pedotype approach to latest Cretaceous and earliest Tertiary paleosols in eastern Montana. *Bull. Geol. Soc. Am.* 106; 1377-1397. GSA Depository item .9425.
- Retallack, G.J., Bestland, E.A., Dugas, D.P. 1995. Miocene paleosols and habitats of proconsul on Rusinga Island, Kenya. *J. Human Evolution* 29; 53-91.

Retallack, G.J., 1997. Dinosaurs and dirt. In: Wolby, D.L., in; Dinofest International: Proceedings of a symposium held at Arizona State University, Wolby DL Stump E Rosenberg G (eds) Society of Vertebrate Paleontology Academy of Natural Sciences, Philadelphia.

Schaefer, D.A. Whitford, W.G., 1981. Nutrient cycling by the subterranean termite *Gnathamitermes tubiformans* in a Chihuahuan desert ecosystem. *Oecologia* 48; 277-283.

Weber, C.E., 1993. Cretaceous termites and soil phosphorus. *Journal of Soil Biology and Ecology*. 13, 108-121. on p 115.

Wilson, E.O. 1987. The earliest known ants; an analysis of the Cretaceous species and an inference concerning their social organization. *Paleobiology* 13; 44-53.

Zhou, L., Kyte, F.T., 1992. Sedimentation history of the South Pacific pelagic clay province over the last 85 million years inferred from the geochemistry of deep sea drilling project hole 596. *Paleoceanography* 7; 441-465.