GEOLOGICAL CONDITIONS IN BRAZIL AT THE END OF THE CRETACEOUS AND IDEAS ABOUT THE PROBLEM OF DINOSAUR EXTINCTIONS

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ABSTRACT Geological conditions in Brazil at the end of the Cretaceous are here presented, bearing in mind the problem of dinosaur extinctions. The Cretaceous is extensively developed over a large part of Brazil, which is particularly significant, since the country comprises half of South America. Theories concerning the extinction of dinosaurs fall into two categories in the geological literature, one relying on some sort of extraterrestrial interference and the other relying on phenomena intrinsic to the Earth itself. The most favoured theory calls upon the development of harsh climatic conditions on Earth as the cause of extinctions. Geological conditions in Brazil at the end of the Cretaceous bespeak against this theory as the harshest conditions during the Cretaceous prevailed during Aptian to Cenomanian times without causing mass extinctions similar to those attributed to the end of the period. A theory that relies on the intrinsic biologic nature of the being in the process of extinction is favored herein.

RESUMO Neste trabalho são tratados de forma sucinta as condições geológicas do Brasil no fim do Cretáceo, conhecidas até o momento. Tais condições geológicas são relacionadas ao problema das extinções orgânicas do fim do período, em especial dos dinossauros. O Cretáceo brasileiro é importante neste particular por se desenvolver extensamente no Brasil, país que cobre aproximadamente metade da América do Sul. As teorias sobre as extinções orgânicas são divididas em duas categorias, uma apelando para forças extraterrestres e a outra para forças com sede no planeta. A teoria mais em voga considera o desenvolvimento de climas rigorosos como a causa das extinções. As condições geológicas no Brasil no fim do Cretáceo não foram tão rigorosas quanto condições ocorrentes no meio do período (Aptiano a Cenomaniano), as quais não provocaram as extinções em massa do fim do período. A teoria que considera as extinções como intrinsecamente ligadas aos processos biológicos é aqui favorecida.

INTRODUCTION Recently the problem of organic extinctions was taken up by K. J. Hsü in his address as retiring president of the International Association of Sedimentologists (Hsü 1983). Naturally, as Hsü himself states at the end of his address, there is undisputed agreement among geologists that "a chance combination of multiple factors may have set the pace for the tempo and mode of evolution". Hsü follows Alvarez *et al.* (1980) who favor the possibility of a rare event, such as the impact of a large meteorite, as the trigger for mass extinction. Hsü uses the expression "actualistic catastrophism" for these rare though devastating events. The presence of clays in Late Cretaceous-Early Tertiary boundary beds in many deep water cherts, taken as suggestive of mass mortality after an impact event (Hsü *et al.* 1982), is interpreted in a different way by Surlyk and Johansen (1982), however. Officer and Drake (in Angier 1985) believe that the levels of arsenic and antimony in these clays correspond to decidedly terrestrial, not cosmic concentrations. Clemens (in Angier 1985) states that the layer of iridium and the bones of the last surviving dinosaurs were too far apart to share any meaningful connection. A "nuclear winter" killing off the dinosaurs would not cause the killing off other beings, principally the dicotyledonous plants that flourished through the Cretaceous and the Cenozoic?

As is implicit in Hsü's address (1983), the changes in terrestrial environments, whether of terrestrial origin or due to extraterrestrial influences, are the ultimate cause for

biologic extinctions. As a matter of fact, the terrestrial environments are continuously changing so that biologic extinctions are as intrinsic an attribute of life as is death. Life itself is constantly creating conditions favorable or unfavorable to its further development, as for instance, the conditions created by the development of green-plant (O_2 -liberating) photosynthesis which favored the development of eukaryotic life (Cloud 1976) or the unfavorable conditions to many species of wild life created during the ascent of Man.

Even though "actualistic catastrophism" cannot be disregarded, it has to be demonstrated, and the so-called mass extinctions may be explained in a different way, using the observed facts in biologic and human sciences. Relationships among humans and social beings are influenced by "social environments", and the patterns of life in society change with time just as life changes with physical-chemical environmental changes. The difference between "social environmental changes" and "biologic environmental change" is the rate of change involved in each. In the case of human societies, rate is fast, as changes are directly observed and registered as History. Many examples can be cited of social classes which became so attached to their ways of life that they were unable to adapt to new ways of life. For instance, most members of the French and Russian aristocracies, after the respective revolutions, were unable to cope with the new times. Several writers have put it forth with great elegance. For instance, the Brazilian author

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Jorge Amado (1971) tells the saga of the settlers of lands suited for cacao plantations in southern Bahia. The settlers' peculiar concept of ethics was surpassed by further evolution of the local society. Another example, the drama of the Sicilian prince of the House of the Leopard and the changes of time are magistrally narrated by Lampedusa (1958). It is hard for organisms well adapted to a specific environment to try to live in another world. It is like Don Quixote's mishaps while trying to live in El Cid's world.

Nowadays we are witnesses to the extinction of many wild animal and plant species unable to cope with encroaching civilization. In fact, the only constant in nature is change. The very existence of biostratigraphy proves that extinctions are not exclusive of some short-duration time intervals. The rates of extinctions greater than the "Lyellian rate" (Hsü 1983), attained at about the same time for groups of unrelated species, could be explained as the result of similar sequences of genetic mutations, involving at roughly similar paces, eventually reaching a situation in which further genetic mutations no longer produced organism adaptation to new environmental conditions; that is "racial senility", or perhaps better stated, "genetic inadaptiveness". The similar paces of the genetic changes could then produce such a situation at about the same time, for unrelated groups of organisms. It could be a fatalistic end of the line, previously "written into" the respective genetic codes.

It must be remembered that "sudden" and "simultaneous", often quoted in the discussions of the so-called mass extinctions, are misleading as when taken in a geological sense and could represent a great span of time indeed when compared with an organism's lifetime.

THE CRETACEOUS BRAZILIAN RECORD The Brazilian Cretaceous sedimentary record attests to a Great Aptian episode of aridity covering an area of up to 4×10^6 km² from the Paraná and São Francisco interior basins to the present northern and eastern coastal strip, including the present eastern and northeastern continental shelf. The remainder of Brazil lacks a sedimentary record of this age so that this area may have been even greater.

These widespread dry environments may have continued into Albian and even Cenomanian time with minor wet climate fluctuations (Carozzi *et al.* 1973; Castro *et al.* 1982; Dias-Brito, 1982; Falkenheim *et al.* 1981; Lima 1983; Lima *et al.* 1980; Petri 1983; Petri & Fulfaro 1981; Ramos 1980; Soares *et al.* 1980; Suguio & Barcelos 1983). According to Lima (1983), after the Cenomanian, an amelioration of the climates occurred, and such extensive dry climates have never recurred since. Thus, there is nothing whatsoever in the climatic record of Brazil that might explain dinosaur extinctions at the end of the Cretaceous.

In spite of the absence of detailed studies of the Latest Cretaceous-Earliest Tertiary boundary in Brazil with respect to possible evidence of presumed impact of an extra-terrestrial body (for instance, a possibility of Ir-anomalies in clays), we favor a different interpretation for mass extinction.

Latest Cretaceous and Earliest Tertiary sediments in many eastern and northeastern Brazilian coastal basins were developed as clastic deltaic lobes prograding over continental shelf limestones. The long axes of the deltaic lobes are

Figure 1 - Paleogeographic map of Brazil during Alagoas (aptian) times

often approximately colinear with the axes of present rivers. Such is the case for instance, for the deltaic lobe developed on and offshore from the mouth of the present São Francisco river, the largest river running across the Sergipe-Alagoas basin. Coincidentally, this latest Cretaceous-Earliest Tertiary deltaic lobe is the thickest of the deltaic lobes of this basin (Fischer *et al.* 1973, Gama Jr. 1976).

Similar deltaic lobes occur in the Jequitinhonha and Espírito Santo basins. Red beds began to form in the Latest Cretaceous on the Continental side of the Campos basin and kept on forming during the Tertiary, thus suggesting hot, rainy and dry seasons on the continent. The Carapebus submarine cone developed in this basin during this time, suggesting the presence of great rivers along the coast. Thick clastic wedges formed red beds from the continent into Santos basin.

Figure 2 - Second degree residual map from a trend surface analysis of Latest Cretaceous - Earliest Tertiary deltaic lobes in Sergipe-Alagoas basin (After Gama Jr. 1976). As seen in the figure, the deltaic lobes are closely connected with the mouth of the larger rivers of the region. The thickest lobe is connected with the largest river (S. Francisco). This situation suggests that in the Latest Cretaceous, the present drainage were already established.

Further to the south in Pelotas basin similar clastic wedges didn't form red beds but gray beds, suggesting a different climatic situation.

The similarities of all these basins seem to indicate that by Latest Cretaceous times the present drainage pattern was essentially established for most of the Brazilian territory, and the predominantly prograding (offlap) pattern of sedimentation suggests predominantly humid climates on the continent at least in the neighbourhood of the coastal basins.

Palynologic evidence suggests tropical to subtropical climates during the Cretaceous in Brazil and a relative cooling toward the end of the period, but not enough to alter the essentially tropical climate (Lima 1983). If this is true, the statement that a warming of up to 10°C at the end of the period would restrain the development of the dinosaurs or even interfere in their reproduction, favoring the exclusive development of males (Hsü 1983) does not hold up. At any rate, such supposedly warmer temperatures would not interfere with the marine organisms which also died out during these times.

CONCLUSION We believe in simultaneous "genetic inadaptiveness" to explain the extinctions of many strains during geological times. By "genetic inadaptiveness" we mean the inability of strains to cope with the ever changing environments. Extra-terrestrial body impacts may have influenced in this change but are not essential to explain mass extinctions.

Figure 3A - Recife-João Pessoa and Sergipe-Alagoas basins during Latest Cretaceous times

Figure 3B - Profile AB (see fig. 3A)

Figure 4 – Paleogeographic map of Brazil during maestrichtian times

	Fan deposits going down highlands from NE, N and NW in a dry climate (Bauru basin)
	Fanglomerate clastic wedges adjacent to the great faults of the western border of Limoeiro graben (Amazonas mouth basin) and Serrado Mar range (S.M.R.)
	Submarine fan, proximal and distal facies (DF) in Santos basin.
	Piedmont and fluvio-lacustrine environment with mudfilled and limestone lakes (Acre basin)
	CSC-Carapebus submarine cone
	Volcanic tuffs
	Deltaic lobes
	Submarine Canyon
	Alkaline lavas volcanoes
	Limestone shelf
	Submarine fan
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PP	- Parí platform	PRD	- Present Rio Doce river
ISH	- Ilha Santana high	SC	- Submarine Canyon
T	- Turbidites	SB	- Starved basin in bathyal realm
FUSA	- Ferrer-Urbano Santos arch	CP	- Campos platform
LL	- Law land	FI	- Florianópolis high
PJR	- Present Jequitinhonha river		

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