which merit a fuller treatment than I am able to give. I have, however, indicated them in footnotes in the body of the paper and have attempted to discuss them so far as I can.

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A NOTE ON THE PLIO-PLEISTOCENE BOUNDARY IN THE SIWALIK SERIES OF INDIA AND IN JAVA

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ABSTRACT. The definition of a boundary between the Pliocene and the Pleistocene in India has been a subject for much debate, as it has in other parts of Asia. The authors agree with the definition of the beginning of the Pleistocene period adopted at the 18th session of the International Geological Congress in 1948, where it was decided that "the lower Pleistocene should include as its basal member in the type area the... Villafranchian." In India the primitive elephant *Archidiskodon,* a characteristic Villafranchian genus, first appears in the Tatrot zone of the Siwalik series. However, certain other genera characteristic of the Villafranchian, such as *Equus* and *Leptobos,* have not been found below the Pinjor zone of the Siwalik series. When a complete survey of the Tatrot fauna is made it is found that there are nine holdovers from the distinctly Pliocene Dhok Pathan zone into the Tatrot, while six genera in the Tatrot may be considered as newcomers. Consequently the Tatrot appears to be truly transitional between the Pliocene Dhok Pathan and the Pleistocene Pinjor.

AT the 1948 session of the International Geological Congress in Great Britain[1] it was unanimously agreed that "the Lower Pleistocene should include as its basal member in the type area the Calabrian formation (marine) together with its terrestrial equivalent the Villafranchian."

The Villafranchian (Haug, 1908-1911, p. 1767) is defined by a widespread mammalian fauna characterized by the first appearance on several continents of *Archidiskodon, Equus,* and advanced bovines (*Leptobos*). Some of the implications of the definition recommended have been discussed by King and Oakley (1949, p. 186) who venture to state that the Pinjor stage of the Upper Siwaliks as well as the Djetis beds of Java are equivalent to the Villafranchian and hence basal Pleistocene. In other words, the Plio-Pleistocene boundary, according to their statement would have to be placed between the Tatrot zone and the Pinjor zone of the Siwalik series, and between the Kali Glagah beds and the Djetis beds in Java.

This is exactly what has been advocated by Pilgrim (1938, p. 479) and Von Koenigswald (1935; 1940, p. 77; 1950,

[1] International Geological Congress, Report of the Eighteenth Session, Great Britain 1948, Part I, General Proceedings, London, 1950, p. 214.

p. 93). In Java it has been the usage of the Geological Survey to regard the base of the Poetjangan beds as the base of the Pleistocene, and the Poetjangan beds contain the Djetis fauna of Von Koenigswald.

However, in the meantime a different view became prevalent through the writings of De Terra and Teilhard de Chardin (1936, p. 822), Lewis (1937, p. 192), Colbert (1940, p. 9; 1942, p. 1454; 1943, p. 426), Paterson (1941, p. 413), and Movius (1944, p. 84; 1949, pp. 346-347). All of these six authorities assign to the Tatrot zone a place just within the Pleistocene, and, with it, the Tjidjoelang plus Kali Glagah faunas of Java which have always been correlated with the Tatrot fauna of the Siwaliks.

Lewis (1937, p. 198) states that the genus *Archidiskodon* is represented at the type locality at Tatrot, thus establishing the fact that *Archidiskodon* appears earlier than *Equus* in the Siwalik system. Von Koenigswald's record of *Archidiskodon* from the Tjidjoelang plus Kali Glagah faunas of Java (Von Koenigswald, 1940, p. 74; 1950, p. 92) certainly is in favor of the view, so often expressed, that the Tjidjoelang and Kali Glagah faunas of Java should be regarded as Villafranchian, hence Pleistocene (Hooijer, 1950, p. 37). Von Koenigswald (1950, p. 93), however, states that he cannot accept this because the Tjidjoelang fauna "is associated with the marine Cheribonian fauna of Oostingh, which by all standards is of pliocene age."

Equus does not occur in Java except as introduced by Man. This genus makes its first appearance in the Pinjor zone as far as the Siwalik series is concerned[2].

Leptobos is found in the Siwaliks only in the Pinjor zone (Pilgrim, 1939, p. 7), while in Java this genus is represented in the Djetis fauna exclusively (Von Koenigswald, 1935, p. 7; 1940, p. 61) unless the skulls collected in Java by Dubois

[2] Lewis (1937, p. 198) writes that *Equus* first appears in the Tatrot formation, but Lewis's Tatrot formation is the Tatrot zone plus the Pinjor zone of Pilgrim and later writers, none of whom follows Lewis in uniting these two zone faunas. Although Pilgrim (1938, p. 446) had remarked upon the apparent absence of *Equus* from the Tatrot zone, Lewis's remark gave rise to some confusion; and subsequent to Lewis's paper *Equus* is stated to occur in the Tatrot zone by Von Koenigswald (1940, p. 74), Paterson (1941, p. 414), and Colbert (1943, p. 427). However, present evidence indicates that the first appearance of *Equus* is in the Pinjor zone.

(1908) do not belong to the Djetis fauna, a point that unfortunately cannot be definitely settled.

It has been stated by one of us (Colbert, 1943, p. 426) that the Villafranchian aspect of the Tatrot fauna is strong. As far as known at the time (Colbert, 1935, pp. 29-36; Pilgrim, 1939, pp. 5-7) only three Tatrot genera, *viz.*, *Ramapithecus*, *Dorcatherium*, and *Proamphibos*, failed to persist into the Pinjor[3], so that the Tatrot fauna seemed to be rather closely related to the succeeding Pinjor fauna which possesses *Archidiskodon*, *Equus*, *Leptobos*, etc.

The record of *Archidiskodon* from the Tatrot fauna by Lewis, (1937, p. 198) made us curious to see whether the Tatrot fauna might not be richer than was known thus far from the London, Calcutta, and New York Siwalik collections. We are much indebted to Dr. J. T. Gregory of the Peabody Museum of Yale University for his kind permission to restudy some of the fossil mammals collected by the Yale North India Expedition of 1931-1933. The examination of this collection proved to be very rewarding indeed: the list of mammal genera comprising the Tatrot fauna now appears to be more than twice as long as was known before, including *Archidiskodon* which, although recorded as from the Tatrot type locality already by Lewis (1937), apparently has been considered as absent from the Tatrot subsequently by Pilgrim (1938, p. 446; 1944, p. 32) and one of us (Colbert, 1942, p. 1448).

The complete list of Tatrot zone mammal genera as known at this moment is given in chart 1, in which the distribution of these genera in the Lower, Middle, and Upper Siwalik zones is also noted.

We have been able to add fourteen genera to the short list of Tatrot mammals. Not less than seven out of these newly added genera, *viz.*, *Paramachaerodus*, *Propotamochoerus*, *Hyosus*, *Hydaspitherium* (?), *Tragocerus*, *Selenoportax* and *Gazella* (?), do not pass from the Tatrot into the Pinjor, making a total of ten non-persistent Tatrot genera out of a total of twenty-four. Until now we knew of three non-persist-

[3] *Gazella* and *Hemibos* were mentioned as occurring with the Tatrot fauna by De Terra and Teilhard de Chardin (1936, p. 810), but for some reason or another, these genera have not been marked as from the Tatrot by Pilgrim (1939, pp. 5 and 7). *Gazella* would also have been a non-persistent Tatrot genus, which is difficult to believe since the genus is recent and still lives in India.

ent Tatrot genera out of ten (*viz.*, *Ramapithecus*, *Dorcatherium*, and *Proamphibos*), giving a percentage that does not differ significantly from the ten out of twenty-four, which we now have obtained.

On the other hand there are six genera that make their first Siwalik appearance in the Tatrot, *viz.*, *Ramapithecus*, *Pentalophodon*, *Archidiskodon*, *Sivachoerus*, *Potamochoerus*, and *Hemibos* c.q.*Bos*[4].

Thus, out of the twenty-four genera of mammals known from the Tatrot zone, nine are holdovers from the Dhok Pathan zone and do not persist into the Pinjor stage, while six genera are to be considered as newcomers. The remaining nine genera continue from the Dhok Pathan into the Pinjor.

CHART 1

Distribution of Tatrot zone genera through the Siwalik zones

	Lower Siwaliks		Middle Siwaliks		Upper Siwaliks		
	Kamlial zone	Chinji zone	Nagri zone	Dhok Pathan zone	Tatrot zone	Pinjor zone	Boulder Conglomerate zone
Ramapithecus					x		
Paramachaerodus				x	x		
Pentalophodon					x	x	
Stegodon				x	x	x	
Archidiskodon					x	x	
Hipparion		x	x	x	x	x	
Rhinoceros				x	x	x	
Tetraconodon		x	x	x	x	x	
Sivachoerus					x	x	
Propotamochoerus		x	x	x	x		
Potamochoerus					x	x	
Hyosus				x	x		
Hippohyus			x	x	x	x	
Dicoryphochoerus		x	x	x	x	x	
Sus			x	x	x	x	
Merycopotamus				x	x	x	
Hippopotamus				x	x	x	
Dorcatherium		x	x	x	x		
Hydaspitherium (?)				x	x		
Tragocerus				x	x		
Selenoportax			x	x	x		
Proamphibos				x	x		
Hemibos c.q. *Bos*					x	x	x
Gazella (?)		x		x	x		

[4] For the genus *Ramapithecus* this is its last appearance in the Siwalik series at the same time; *Ramapithecus* is not of great value in faunal comparisons, since the limits admitted to fossil Primate genera are very narrow.

One would perhaps be inclined to think that these figures indicate a more distinct break in the faunal succession between the Tatrot and the Pinjor than exists immediately below the Tatrot, and that consequently the Plio-Pleistocene boundary might better be drawn between the Tatrot and the Pinjor. However, the "invasion" of *Archidiskodon* had already taken place at least by Tatrot times[5]. Moreover, two of the "holdovers" from the Dhok Pathan, *viz.*, *Hydaspitherium* and *Gazella*, could not be identified by us with absolute certainty, and can better be left out of account here. Thus the ratio of the number of holdovers to that of the newcomers in the Tatrot zone fauna can be given as 7 to 6.

To the best of our present knowledge the Tatrot zone serves equally well, from the standpoint of the vertebrate paleontologist, as the beginning of a period as it would do as the end of one. We can only repeat what has already been said some years ago by one of us (Colbert, 1942, p. 1446), that the Tatrot is possibly transitional between the Upper Pliocene and the Lower Pleistocene. The same holds, mutatis mutandis, for the Tjidjoelang and Kali Glagah faunas of Java. No grounds are apparently present to consider these latter faunas, which contain *Archidiskodon* (Von Koenigswald, 1950, p. 92), as Plaisancian and Astian respectively (Von Koenigswald, 1950, p. 94), which would implicate a set of proboscideans far more primitive than those of which these Javan faunas give evidence.

[5] As very correctly remarked by Hopwood (1938, p. 473), it is difficult to apply the principle of simultaneously immigrating forms when dealing with areas at or near the (supposed) center of evolution of a given group.

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ESSAY REVIEW

LA TECTONIQUE D'ECOULEMENT PAR GRAVITE; GRAVITY GLIDING TECTONICS*

During the past decade or a little more, a set of ideas called collectively "la tectonique d'écoulement" has become prominent in Alpine, especially West Alpine, geology. According to these ideas, the far travel of some of the Alpine nappes or thrust sheets, for example the famous Préalpes, need not be explained entirely by shortening under tangential pressure but can be ascribed, at least in part, to gravitational sliding of the forward parts of the nappes down slopes from structural highs that were at the same time topographic highs. These ideas are not wholly new, as indeed their proponents clearly state, but the application of them has been more broad and thorough than before, and thus it constitutes a new departure.

The repercussions of these ideas have been reaching North American geologists lately, especially by the medium of personal contacts established at the International Geological Congress in Great Britain in 1948. The Editors of this Journal had indeed arranged for Professor Gagnebin of the University of Lausanne, one of the principal proponents of the new views, to prepare a general article on the subject for American readers, but unhappily his untimely death intervened. The present note is designed to call attention to an extremely interesting and well balanced symposium on gravity gliding tectonics, arranged by Dr. L. U. de Sitter, Professor of Geology at Leiden, and published in *Geologie en Mijnbouw,* the organ of the Netherlands Geological and Mining Engineering Society, for December 1950 (Jaargang 12, nieuwe serie, no. 12, pp. 329-365). From this symposium, structural geologists not conversant with recent work in the Alps can obtain a very satisfactory general understanding of the present status of the matter. Five of the six papers in the symposium are in French, but van Bemmelen's is in English.

In a short introduction to the symposium, de Sitter points out that the proponents of gravity gliding tectonics, like the proponents of most new sets of ideas, include both moderates and extremists, and he has neatly balanced the two points of view in the invited papers. The moderate position is set forth in a long article by Tercier on the Swiss Alps (containing the only adequate bibliography in the symposium) and a shorter one by de Sitter on a part of the Italian Alps (a sort of supplement to his report on the same area, reviewed in this Journal, September 1950, vol. 248, pp. 669-670). According to them, gravitational sliding may help greatly

*The primary meaning of the verb écouler is flow, but in the present context it corresponds rather to the English glide or the German gleiten.