The Comparative Method in Stratigraphy: the Beginning and End of an Ice Age

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Glaciation should now be treated as a regularly repetitive process, not as an irregular process through geologic time. If so, the changes in volume of the world ocean (glacio-eustasy) may be expected to account primarily for the major advances and retreats of the sea (the "pulsations" of Grabau) that are global and characteristic of all continental platforms (cratonic margins). These larger cycles, best termed *stages* (equivalent to the "megacycles" or "megacyclothems" of Moore, and to the "mesothems" of Ramsbottom), resemble the Quaternary Model, whether comparison is made with sedimentary cycles of the Paleozoic, Mesozoic, or Tertiary. Conversely, the Quaternary may be considered as a stage (or megacyclothem), seemingly composed of six couplet-cyclothems that diminish in intensity toward the present. Unconformities are taken to occur at glacial maxima, representing twelve (six-double) glaciations; whereas the strong soils are interpreted as interglacials and the weak soils as interstadials. We should be approaching the end of the Quaternary Stage, if the model is the same as for earlier stages, but does that not mean that we should expect the next one to begin soon after?

The comparison of this Quaternary Model with earlier stages should be considered as both a powerful new research tool and as a theory. As a topic, it may be a new scientific discipline, *Comparative Stratigraphy*. If these concepts prove to be valid, the causes for glaciation should be sought in the Sun, and diminishing cyclicity (cyclic sedimentation) should be tested for a possible relation to a damped-Fourier series. However, we should build on the Tradition, not toss it aside.

† † †

INTRODUCTION

It is becoming increasingly evident that glaciation, like other physical processes, is an integral part of much, if not all, of the decipherable history of the earth, and not limited to just the latest or selected other chapters of that record. This is a view developed by the author in a 1959 lecture to the geological-research staff of the Jersey Production Research Company (later Exxon), in Tulsa; with continued search of the literature and field relations, now for more than four decades, the concept is believed to be demonstrable. However, it requires progressive documentation, and only a selection of the pertinent literature is presented here (*see* "References"), not all favorable.

Simply stated, the application of the comparative method to stratigraphy, comparing the history of the Great Ice Age (Quaternary) with that of earlier geologic time, is suggested as a new scientific discipline, *Comparative Stratigraphy*. It should offer a fresh approach to some of the problems to be considered in this and related symposia or conferences, such as providing partial answers to the questions, "Are Ice Ages ordinary or extraordinary episodes?" and "When does an Ice Age begin and end?" To evaluate the importance of the comparative approach, one has only to examine its revolutionary effect in the development of Comparative Anatomy, dating from the middle of the sixteenth century when Pierre Belon (1555) first compared the bones of Man and the Bird.

COMPARATIVE STRATIGRAPHY

A basic Quaternary Model of sedimentation has been suggested (Stout, 1971, 1973, 1977; Schultz and Stout, 1945, 1948, 1977) that seems to be capable of indefinite extension backward into the pre-Quaternary, and to be recognizable in global, cyclic-sedimentational patterns (as in the Paleozoic, Mesozoic, and Tertiary). In some respects it is not greatly different from the concept of "causal biostratigraphy" which has been defined as follows:

> Causal biostratigraphy means an approach to stratigraphic problems based on ecosystem analysis of interrelations between geological events and organic evolution. The succession of ecosystems is controlled mainly by climatic cycles. (Krassilov, 1974:173).

However, the comparative approach is less restrictive in that it allows any segment or segments of the stratigraphic record (stage or megacyclothem, or mesothem) to be compared with any other(s), and especially with the Quaternary (Pleistocene, and Recent). It is thus both actualistic and uniformitarian (Rudwick, 1969), being a powerful geological-research method as well as a scientific theory that can be investigated in depth.

The Quaternary Model was established initially (Schultz and Stout, 1945, 1948, 1977) upon the cut-and-fill nature of valley-fills in the Central Great Plains, mainly in Nebraska and adjacent states, but correlation with the Gulf Coastal Plain is evident (Barnes and Eifler, 1971; Fisk and McFarlan, 1955; Akers and Holck, 1957, modified by Poag, 1969, 1971, 1973). Figure 1 illustrates the author's interpretation of this succession as consisting of six-couplet glaciations, with twelve important glaciations (including a "double Illinoian") in the entire Quaternary, of diminishing character toward the present. Unconformities are taken to occur at glacial maxima, with the strong *terminal* soils interpreted as interglacials and the weaker *intermediate* soils as interstadials. The pattern nearly duplicates that seen in the Late Carboniferous and "Permian" megacyclothems of Nebraska and Kansas, as well as in the older Paleozoic, Mesozoic, and Tertiary of the Northern Midcontinent.

PALEOZOIC CYCLES

Such major episodes of transgression and regression were termed "pulsations" by Grabau in 1933 in an address before the International Geological Congress and were made the subject of a major work (1936-1945) and one popular summary ("The Rhythm of the Ages") intended to document these through the entire geologic record, beginning with the Cambrian. Grabau did publish several thousand pages in many rare volumes under difficult war-time conditions in Peking, in confinement and ill health in his later years, but at his death in 1946 he had published only the Early Paleozoic "pulsations" through the Ordovician. The last volume known to me was published in 1945 (Vol. 5, Pt. 2, Fascicule 1) on "The Ordovician of the St. Lawrence and of the Appalachian Geosynclines," with 395 pages. Grabau's death marked also the virtual end of his great "Pulsation Theory," the beginning of which he described in the second edition of the first volume of 1936, on "The Lower and Middle Cambrian Pulsations":

> The *Pulsation Theory* was formulated in 1933 and presented before the International Geological Congress held that year in Washington, D.C. It developed from the correlation of the facts accumulated during more than thirty years of field studies in many parts of the world, and from the survey of the literature. This led to the invariable conclusion that the major transgressions indicated by the progressive overlap of the strata were essentially synchronous in all continents, while the major regressions indicated by progressive off-lap of strata, also took place concurrently in all parts of the world, and that moreover transgression and regression alternated in rhythmic succession throughout at least the Paleozoic Era. This rhythmic succession and the essential simultaneousness of the transgressions as well as the regressions in all the continents, indicates a periodic rise and fall of the sea-level, a slow pulsatory movement, due apparently to alternate swelling and contraction of the sea-bottom. It is this to which the name *pulsation* has been applied, each *transgressive series* representing the positive half of the pulsation, while the succeeding *regressive series* represents the negative half. Regression of the sea may further be followed by *emergent* phenomena such as erosion and the development of emergent deposits such as continental sediments and volcanic outpourings and intrusions. Finally, it became apparent that the major tectonic movements differentiated and dated by Stille and his school, correlate with the periods of emergence, that is, represent interpulsation phenomena. This seems to justify Stille's assumption of a causal relation between the two types of phenomena. (Grabau, 1936, 1:iv).

Sedimentary cycles that emphasized overlap had bee described by Grabau (1906) some thirty years earlier, but th concept seems to date from Lavoisier (1789) as a basic princ ple (Carozzi, 1965) or even earlier in some of its aspect (Wegmann and others *In* Schneer, 1969). Indeed, Lamarc (1802) expressed very similar views to those of Lavoisier s that by the beginning of last century these ideas may be co sidered as established. Carboniferous cycles had been describe first in 1809 in the English Pennines, according to Dunha (*In* Allen, 1950), and it is of interest that repetitive strata i the Coal Measures of England were considered as characterist when the Carboniferous was defined as a system.

The term "megacyclothem" was introduced by Moo (1936, 1950) for a grouping of "successive sedimentary cycl which exhibits regularity of occurrence in sequence, each co stituent cyclothem being marked by some distinctive charact or characters," and which are "exceptionally well shown Upper Pennsylvanian rocks of Kansas" and Nebraska. Figu 2 illustrates the author's interpretation of many of these meg cyclothems; eleven of the eighteen or more studied by st dents and myself in the Pennsylvanian-"Permian" of Nebras and Kansas are shown, arranged side by side for ease in co parison. The author's ideal megacyclothem (at left in Fig. differs from that of Moore in that six-couplet cyclothems a recognized in each, instead of five-complex cyclothems, a the basal ones are seemingly the best developed (stronge although obviously occurring axially in drowned-valleys. T ideal, when compared with the cyclic patterns recognized Illinois and adjacent states, differs in that two "Illinois-typ cyclothems would make up one megacyclothem of "Kans Nebraska-type." In other words, the "Illinois-type" cycloth

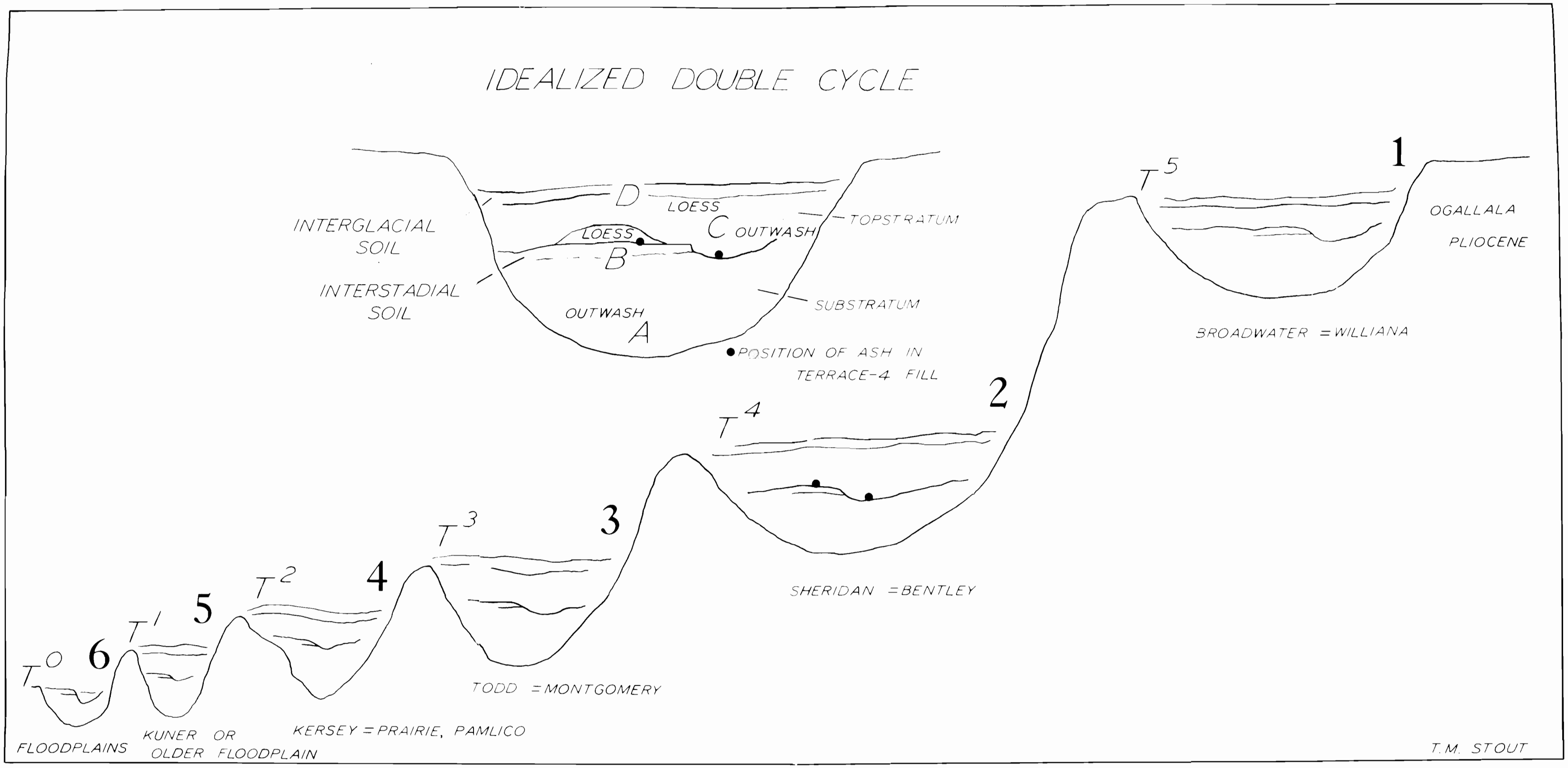

Figure 1. Quaternary valley-fills (terraces) in the Central Great Plains of Nebraska and adjacent states. Six progressively weaker *double cycles* or *valley-fills* are recognized in the periglacial areas, the last of which is incomplete. Each double cycle consists of a *substratum* (A–B) and overlying *topstratum* (C–D), separated by an unconformity that is weaker than either the initial or terminal unconformity. The double cycle is initiated by the erosion that is the only record outside the glaciated regions of the onset of glaciation and the coincident drop of sea level (ultimate and controlling base levels). The outwash or equivalent sediment (A) marks the initial melting of the ice, and the *interstadial* soil (B) indicates the temporary restoration of conditions like those of the present. The second glacial (stadial) episode is shown by the interstadial unconformity, with relatively thin loess deposited seasonally and locally, mostly marginal to and over the generally frozen or dry stream courses. With the waning of glaciation, the second outwash or its equivalent (C) is deposited in the valleys, and the transition to the long *interglacial* terminal episode is marked by thick loess and weak soils, culminating in a thicker and stronger soil profile (D). Correlations with the marine benches of the Lower Mississippi River and Gulf Coastal Plain are suggested here. The older valley-fills represent the longest times, becoming progressively quickened toward the present (Stout and others, 1965, 1971).

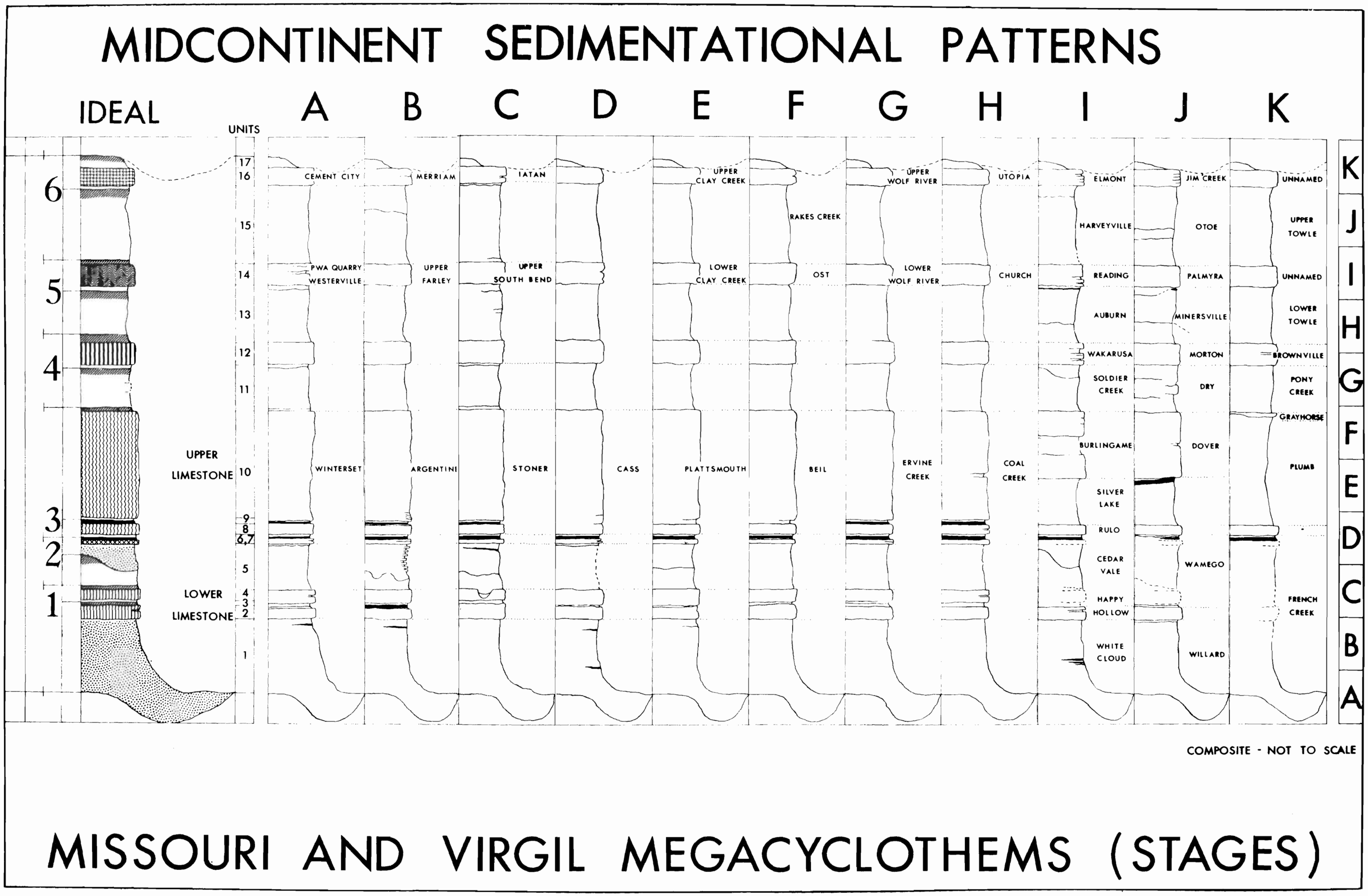

Figure 2. Megacyclothems (stages/groups) of the Missouri and Virgil Series, Late Carboniferous, in the Northern Midcontinent (Nebraska and Kansas). Eleven successional megacyclothems (A–K) are shown side by side for ease in comparison, and not to scale, with only the principal names retained. The ideal megacyclothem (at left) consists of six couplet-cyclothems, the weakest at the top. Each cyclothem is interpreted somewhat as in Figure 1, with a *substatum* and *topstratum* separated by a weaker unconformity than the initial and terminal breaks. The intermediate soil (red bed, or equivalent coal or black shale) is weaker than the terminal one. Transgressive episodes, including a full-marine phase or phases, represent the rise of sea level (glacio-eustasy), but the regressive episodes were rapid drops of sea … Each megacyclothem is characterized ideally by 17 sequential lithologic units before repetition follows a major unconformity.

equals one-half of a megacyclothem, but the latter term is not used in the official cyclic classification of Illinois or Missouri. Although the author does not agree exactly with Moore or with present Kansas workers regarding either the boundaries or interpretation of many Nebraska-Kansas megacyclothems, we would have less disagreement if we referred to Moore's (1936) type megacyclothem, based in large part on Nebraska exposures.

Unconformities of regional importance separate all or nearly all of the Nebraska-Kansas megacyclothems as they are traced in a southerly direction toward Oklahoma, and there are less significant unconformities separating and within cyclothems (Fig. 2). Soils also punctuate the sequence. It is perhaps useful to recall here two comments by Ramsbottom (1977: 281) with respect to such unconformity-bounded stratigraphical units:

> The notion that the stratigraphical record contains primarily a record of the rise and fall of sea level in relation to the continents has a long and honourable history in geology. . . .
>
> It was not by accident that these ideas came first from the central United States, for that area has remained so stable for so long that they can still be demonstrated most easily there. . . .

Comparison of British Carboniferous successions with those in other regions of western Europe as well as with those in Russia and the United States led Ramsbottom (1977, 1973, 1978) to introduce the term "mesothem" for numerous "major eustatic cycles of transgression and regression" in the Dinantian and Namurian. He states (1977:261) that "A brief survey suggests that these cycles are widely applicable in the northern hemisphere and are of eustatic origin," and that "The stage boundaries correspond closely with the boundaries of the major cycles. . . ."

Favoring a stage classification, Ramsbottom (1973:596; also 1977:285) remarks, "The primary division of a series is into stages, and it is here suggested that each major cycle should form a stage, which would have effectively chronostratigraphical boundaries." Further, he notes (1973:588-589) that among the essential features of eustatic cyclicity (according to Bott and Johnson, 1967:426-428) ". . . there are many indications at each major cycle boundary of erosion, karsts, non-sequences and of evaporation and dessication in the extremely shallow waters around the margins of the areas of deposition."

One major stage boundary may be that between the Mississippian and Pennsylvanian (Ramsbottom, 1977; see also Brenckle et al., 1977) as an international biostratigraphic datum, which Ramsbottom believes may mark a climatic change "at some level in the middle of the Namurian." At any rate, in his earlier paper Ramsbottom (1973) made correlation with several parts of the classical Mississippian in the Upper Mississippi Valley near Saint Louis where American workers have long known there are regional unconformities that can be identified in many other parts of North America. An example is the Osage-Meramec break (Laudon, 1948).

Carboniferous cyclic sedimentation has traditionally been recognized to begin with the Chester cycles, in the upper part of the Mississippian in the Illinois Basin. Fortunately, we have an excellent regional study of these Chester cycles (Swann, 1964), in which the sea shifted back and forth over a distance of 600-900 miles, surely due to glacio-eustatic rise and fall. But we must now think of the entire Carboniferous and Permian sedimentational record as dominantly controlled by glacio-eustasy, although basinal subsidence and some local uplifts were probably also always present.

That glaciations may have affected Late Paleozoic sedimentation everywhere was first proposed by Wanless and Shepard (1936) and later emphasized by Wheeler and Murray (1957) in contrast to Weller's (1956) argument supporting diastrophic control. There have been several excellent reviews of the problems (Elam and Chuber, 1972; Duff, Hallam, and Walton, 1967; Merriam, 1964), but many authors seem now to be favorable to Late Paleozoic eustasy. For surveys of the evidence on Late Paleozoic glaciations, the summaries of Wanless and Cannon (1966), Wanless (*In* Elam and Chuber, 1972), and Crowell and Frakes (1972, and other papers), are adequate to show not only widespread glaciation but also possible migration of ice centers (including Antarctica). The work of Bowen (1958) suggests multiple glaciation and deglaciation in eastern Australia during the Late Paleozoic, for he remarks that "at least 51 tills occur in approximately 3000 feet (sequence incomplete, base missing) of glacial and outwash deposits." There is an enormous literatuie on "Gondwana glaciation," which may extend back far in the Paleozoic.

At this point, some of the evidence regarding glacio-eustatic interpretations of sediments of Early and Medial Paleozoic Age requires brief mention. For example, Lochman-Balk (1970, and other papers) studied the Late Cambrian faunal and lithofacies patterns on the North American Craton and recognized several synchronous regressions and transgressions "attributable to eustatic sea level change." She interpreted the cause of the faunal changes and of the regressions to be "a deterioration of world climate." (See also the data of Ivanova, 1975).

A similar conclusion was reached by Berry and Boucot (1973, and other papers) and by Sheehan (1973), that there was glacio-eustatic control of Late Ordovician-Early Silurian platform sedimentation and faunal changes. Now that end-Ordovician glaciation has been proven for at least the Saharan region of North Africa (Fairbridge, 1970, 1974; Allen, 1977), this interpretation seems to be acceptable generally. Lately, Dennison (1976) has attempted to explain the Appalachian

Queenston Delta as "related to eustatic sea-level drop accompanying Late Ordovician glaciation centred in Africa." Perhaps the older, pre-Cincinnatian Paleozoic cyclic sediments in the Upper Mississippi Valley (Ostrom *In* Merriam, 1964; Dapples, 1955; Suhm, MS. 1970) and elsewhere, including those of Kansas and Nebraska, are best explained by this mechanism.

Deltas, both modern and ancient, have been much studied in late years (Van Straaten, 1964), but the Devonian Catskill Delta of New York constitutes an example of cyclic sedimentation that is very similar to that of the Late Paleozoic megacyclothems of Kansas and Nebraska. This is also true for the pre-Catskill Devonian and Silurian of New York (Dennison and Head, 1975).

MESOZOIC CYCLES

The boundary between the Permian and Triassic has long been known as the approximate time of extinction of many groups of organisms (Newell, 1966), but the eustatic sea-level change then has been only recently discussed (Forney, 1975). Regarding the faunal crisis and a slightly modified boundary, Tozer (1969:348) comments:

> The nature of the faunal break that takes place at or near the boundary between Permian and Triassic has provoked considerable discussion. In most, if not all areas, the boundary between marine Permian and Triassic rocks is abrupt and apparently marks a break in sedimentation. There is general agreement that many groups of marine invertebrates became extinct near or at the level of this boundary. From reviewing the evidence it seems that the base of the Triassic precisely marks this faunal change. For marine faunas the boundary between Paleozoic and Mesozoic rocks apparently marks a world-wide, although as yet unexplained catastrophic event. . . .

The Permo-Triassic of southern Germany displays numerous Violet Horizons that have been identified as ancient soils or "paleosols" (Ortlam, 1966, and other papers; Gwinner, 1955). These are very interesting from a cyclic viewpoint for the Bunter Cycle (Ortlam, 1966:73, Table 1; Gwinner, 1955: Figs. 1-8) again duplicates the Late Paleozoic megacyclothem of Kansas and Nebraska, even to the presence of the widespread Violet Horizons (red beds) that seem to be ancient soils.

Eustatic cyclicity is likewise characteristic of the Jurassic (Hallam, 1961, 1963, 1969, 1978) and Cretaceous (Figs. 3-4). The Wealden megacyclothems, with the associated soils or extensive horsetail reedswamps, have been described in great detail in a memoir (Allen, 1959) on the Early Cretaceous, Valanginian to Aptian, of the Anglo-Paris Basin. All that is missing from his reconstruction of the Wealden environment is the presence of the numerous dinosaurs *(Iguanodon)*, some of large size, that populated the swamps and coast plain from Britain to Belgium and even as far north as Spit bergen.

The so-called "Comanchean" (Trinity-Fredericksbur Washita) in the later part of the Early Cretaceous allows th recognition in Texas of three megacyclothems or stages th are nearly of ideal type since each of the three stages is ve similar to the other (Murray, 1961). The Washita equivale of Kansas and Nebraska is the "Dakota," which has been th subject of much local study and has been traced into th Black Hills and Front Range to tie in with the units describ by Waagé. It is also very much like the Late Paleozoic meg cyclothems but best treated as a stage or group (Fig. 3).

Figure 4 shows the similar four stages/groups (meg cyclothems) of the Late Cretaceous of Nebraska and adjace states: Benton, Niobrara, Pierre, and Laramie. The literatu on these is vast, but special attention should be given to t global correlations that are implicit in the work of Hanco (1975), DeGraw (1975), Hart and Tarling (1974), Kauffm (1970a and b, 1972), and Kauffman and Hazel (1977). The i teresting work of Nagappa (1959) on the Cretaceous-Eoce transgressions and regressions in the India-Pakistan-Bur region can be studied to advantage to realize the truly glo extent of these major episodes. They can be picked up alm everywhere where there is an adequate literature, but espe ally in western Europe and the Gulf Coastal Plain (Murr 1961, for example). These extend up into the Tertiary (Stan 1921; Vella, 1967) and Quaternary.

CENOZOIC CYCLES

Figure 5 shows the Great Plains Tertiary and Quatern record, and Figures 6-7 exhibit the author's view as to intercontinental correlations from the base of the Oligoc to the present through the Northern Hemisphere. There w major extinctions at the Eocene-Oligocene boundary (wh there is now proven glaciation, see especially Cavelier, M 1976) as well as at the end of the White River, Arikaree, H ingford, and Ogallala stages/groups. Major erosion follo significant soil development at the end of each stage/gr interpreted as a time of important drought and probably c in the Great Plains (Schultz and Stout, 1977). It is furt postulated that these may be eventually defined as also time renewed glaciation in terms of the world glacio-eustatic re and in deep-sea cores (see the September 20, 1977 issue of *Journal of Geophysical Research* and Hayes, 1977, for s maries of some of the new work on the deep-sea data).

But attention needs to be given also to the climatic on the lands. In Iceland, for example (Gladenkov, 1 Epshteyn, 1978; McDougall and Wensink, 1966), the w water, Coralline-Crag equivalent is overlain by the colder Crag equivalent that is associated with what may be consid

EARLY CRETACEOUS

	W. EUROPE - BEDS	- LOCALITIES -	U.S. GULF, ATL.	INTERIOR	PACIFIC
EARLY CRETACEOUS	LATE ALBIAN		BUDA WASHITA CHEYENNE	JANSSEN "DAKOTA" LYTLE, LAKOTA	
	MEDIAL ALBIAN		FREDERICKS-BURG		
	EARLY ALBIAN LATE APTIAN		TRINITY		
	EARLY APTIAN BARREMIAN		NUEVO LEÓN		
	HAUTERIVIAN VALANGINIAN		DURANGO		

Figure 3. Stages/groups (megacyclothems) of the Early Cretaceous. The names used in Nebraska and adjacent states are shown in the "Interior" column. Double-lines separate the stages.

LATE CRETACEOUS

	W. EUROPE - BEDS	- LOCALITIES -	U.S. GULF, ATL.	INTERIOR	PACIFIC
LATE CRETACEOUS	MAASTRICHTIAN		NAVARRO	LANCE LARAMIE FOX HILLS	
	CAMPANIAN		TAYLOR	PIERRE	
	SANTONIAN CONIACIAN		AUSTIN RAPIDES	NIOBRARA	
	TURONIAN CENOMANIAN		EAGLE FORD WOODBINE •TUSCALOOSA DEXTER	BENTON GURLEY OR "D"	

T. M. Stout

Figure 4. Stages/groups (megacyclothems) of the Late Cretaceous. The names used in Nebraska and adjacent states are shown in the "Interior" column. Double-lines separate the stages.

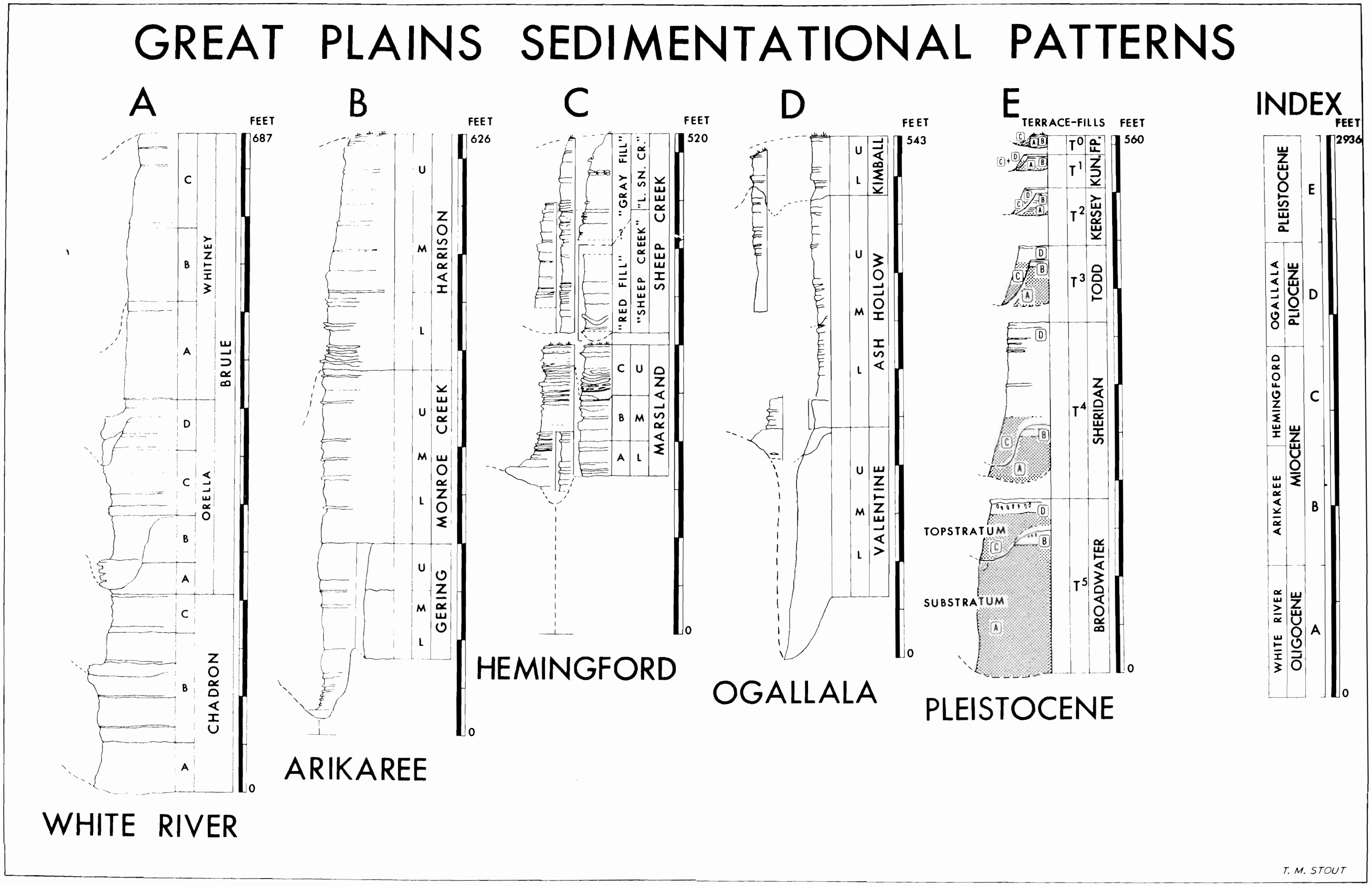

Figure 5. Stages/groups (megacyclothems) of the Central Great Plains Tertiary and Quaternary: White River (Oligocene), Arikaree (Early Miocene), Hemingford (Late Miocene), Ogallala (Pliocene), and Pleistocene, here including Recent (collectively, the Quaternary). These are arranged side by side for comparison of soils and unconformities with the Quaternary Model (E). Abbreviations: "L. SN. CR."–Lower Snake Creek; KUN.–Kuner; FP.–Floodplains; L–Lower; M–Middle; and U–Upper. From guide books (Stout and others, 1965, 1971).

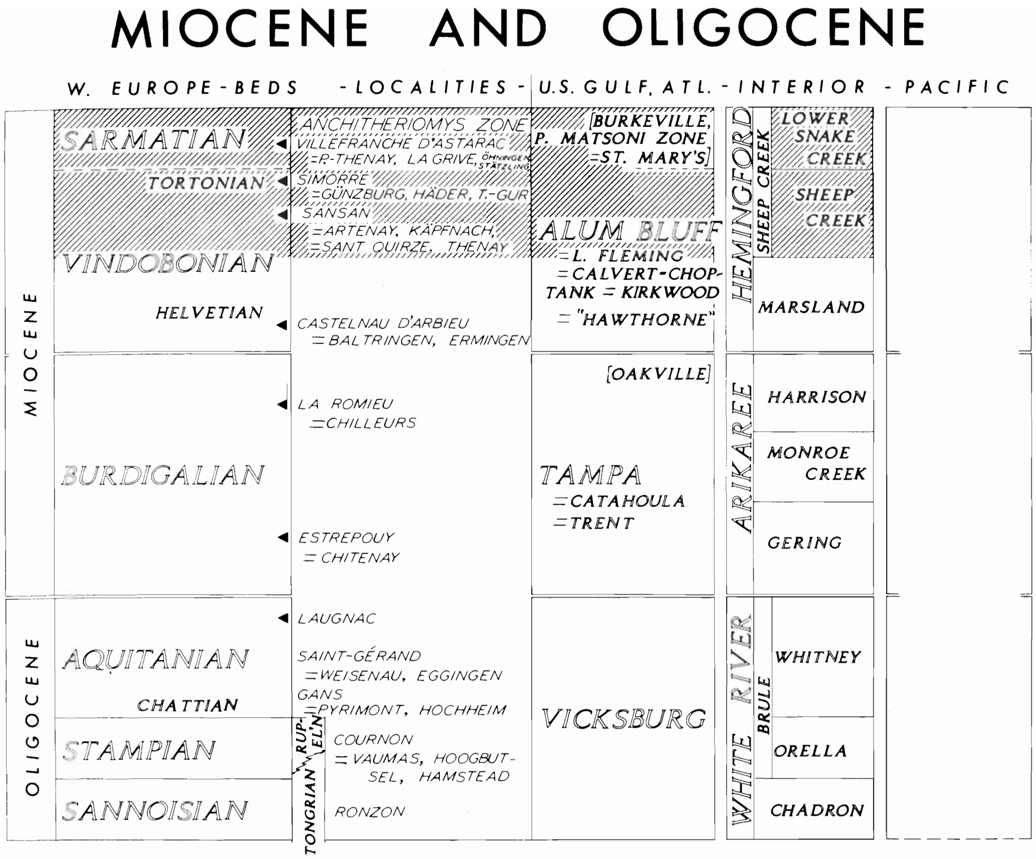

Figure 6. Stages/groups (megacyclothems) of the Oligocene and Miocene, each separated by double-lines. The *Anchitheriomys* Zone (restricted) which marks the Miocene-Pliocene boundary is shaded; it is now known to extend up into the Valentine in Nebraska. The names used in Nebraska and adjacent states are shown in the "Interior" column.

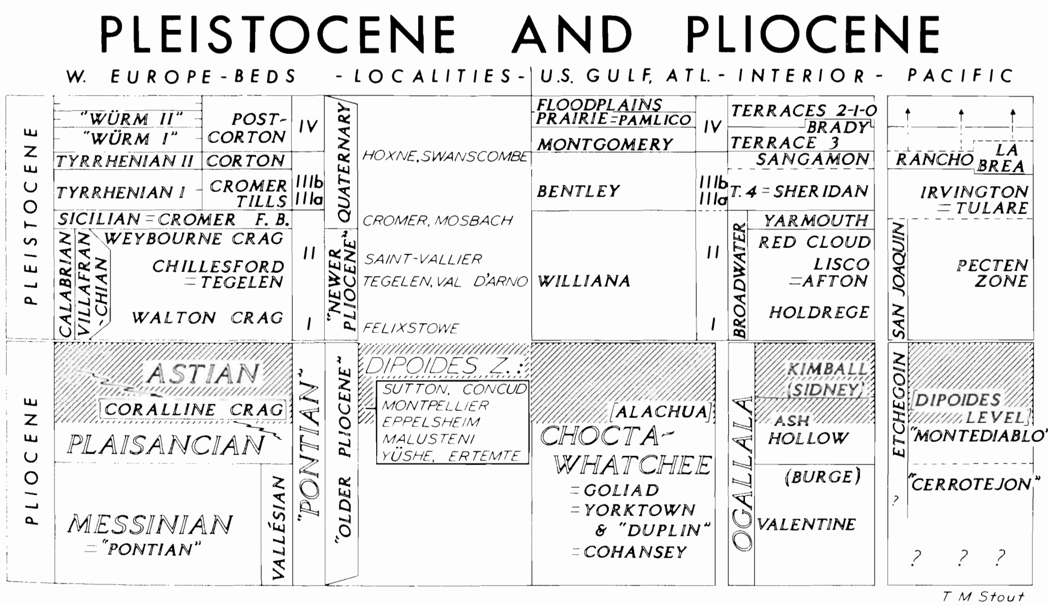

Figure 7. Stages/groups (megacyclothems) of the Pliocene and Pleistocene, here including Recent (collectively, the Quaternary) separated by double-lines. The *Dipoides* Zone (restricted) which marks the Pliocene-Quaternary boundary is shaded. The *Anchitheriomys* Zone (see Fig. 6) is now known to extend upwardly into the Valentine of Nebraska. The names used in Nebraska and adjacent states are shown in the "Interior" column. Abbreviations: I–Günz-I (Nebraskan); II–Günz-II (Kansan); IIIa–Mindel (Older Illinoian, or Illinoian I); IIIb–Riss (Younger Illinoian, or Illinoian II); and IV–Weichsel or Würm (Wisconsin). (Stout and others, 1965).

as the first glaciation of the Quaternary. This correlates, in my opinion, with the Reuver-Pretiglian break in the Netherlands (see Zagwijn, 1974, for background) and with the unconformity below the Early Villafranchian site of Perrier-Étouaires (Bout, 1970, 1960; Brun, 1974; Goër de Hervé, 1974) in central France that has been dated as before 3.3 million years. This is approximately the time of the First Patagonian Glaciation (Mercer, 1976) and about the time of initiation (3.2 million years) of early Northern Hemisphere glaciation according to Shackleton and Opdyke (1977), from oxygen isotope and paleomagnetic evidence.

SUMMARY

The data of Figures 5-7 are carried over in expanded form to Figure 8, where the right half of the diagram may be considered to represent North America and the left half Eurasia at the Bering Land Bridge. The Roman numerals, V–I, may be taken in ascending order as White River (Oligocene), Arikaree (Early Miocene), Hemingford (Late Miocene), Ogallala (Pliocene), and Quaternary (Pleistocene with Recent), as projected from the New World to the Old World at the Bering Corridor. The lower arrow indicates the *Anchitheriom* datum, from a fossil beaver that defines the Miocene-Plioce boundary in the Northern Hemisphere, and the upper arr the *Dipoides*-datum, from another fossil beaver that defi the Pliocene-Quaternary boundary, both according to t author's researches. The transgressive-regressive movements the sea may be taken as diminishing episodes of positi negative glacio-eustasy (Werth, 1952; Pratt and Dill, 197 possibly representing a damped-Fourier series within ea stage/group. (See also Vail et al., 1974).

Finally, Table I considers the Quaternary as a sta group or megacyclothem composed of six-couplet episodes diminishing glaciation and deglaciation, twelve in the ent Quaternary. If valid as a model, we would seem to be now a proaching the end of the Quaternary Ice Age, which beg after Ogallala (Pliocene) time, perhaps about 3.3 or 3.2 milli years ago. However, there seems to be no need to toss asi the Tradition and to substitute arbitrary numbers ("gold spikes" of Ager, 1973), for there appear to be natural brea These seem to have been associated with climatic chan possibly induced by the same solar engine, which with t moon, has left its mark upon all life—even upon us.

TABLE I

Revised Classification of the Quaternary
(From Stout, 1973)

	Substages (Cyclothems)			Great Plains (Formations)	Gulf Coast (Formation
	6	t # / s ##	* *	Floodplain (T^0, T^{00})	Floodplain (=Alluvium)
	5	t # / s ##	* *	Kuner (T^1)	Older Floodplain (=Deweyville)
	4	t # / s ##	*	Kersey (T^2)	Prairie (=Beaumont)
			*		
Quaternary Stage/Group (Megacyclothem)	3	t # / s ##	*	Todd (T^3)	Montgomery
		# Sangamon	*		
	2	t / s ##	*	Sheridan (T^4)	Bentley
		#	*		
	1	t / s ##	*	Broadwater (T^5)	Williana (=Willis)
			*		

s = substratum; t = topstratum; * = glacial; # = interglacial; ## = interstadial

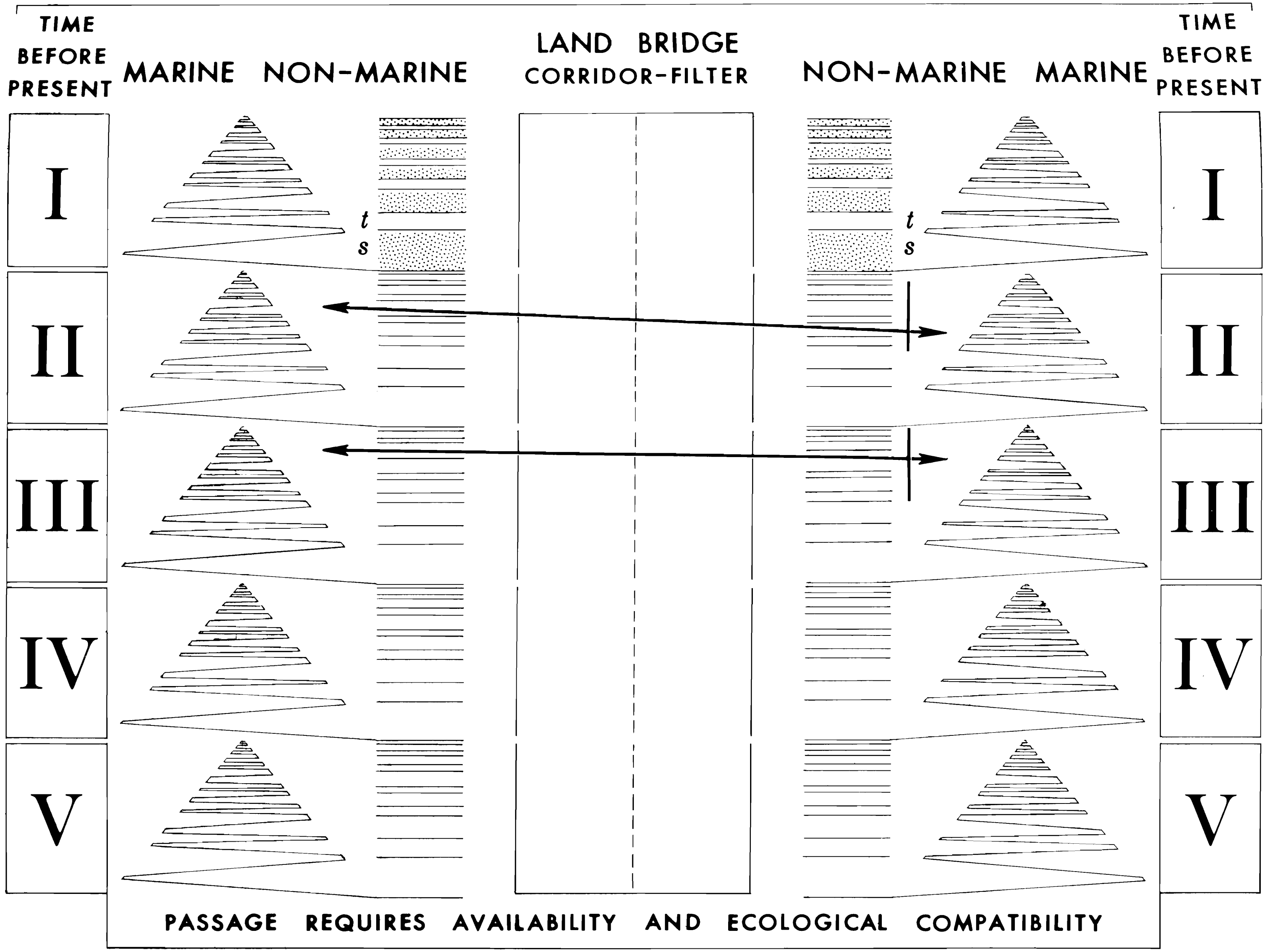

Figure 8. Idealized relations for migration and interchange across a Land Bridge; here the Bering Corridor-Filter Land Bridge is taken to separate the New World (North America, at right) from the Old World (Eurasia, at left). Abbreviations: I–Quaternary; II–Pliocene; III–Late Miocene; IV–Early Miocene; V–Oligocene; s–substratum; and t-topstratum. The schematic shifts of the sea level (transgressions and regressions) due to glacio-eustasy are shown by the jagged lines. The lower arrow shows the *Anchitheriomys* Zone, defining the Miocene-Pliocene boundary, and the upper arrow the *Dipoides* Zone, defining the Pliocene-Quaternary boundary. (For background on the Bering Land Bridge, see Hopkins, 1973).

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