Matthews, 1984
"DYNAMIC STRATIGRAPHY"

The Present as the Key to the Past

2

The major tenet of this book is that late Cenozoic processes and history provide model that will help us to understand the details of earth history recorded by th stratigraphic record. Sediments are being deposited today in a wide variety of en vironments. We must study them in detail and learn to infer the depositional en vironment of ancient sediments by analogy with Recent sediments. With recognitio of depositional environment comes a whole series of insights concerning the proc esses that must have been active and the sequence of events required to produce certain stratigraphic sequence.

As often happens with such statements, "the present as the key to the past' sounds deceptively simple. In fact, this approach requires sufficient sophisticatio that we shall have to cover a large amount of background material (Parts II anc III) before we can come to grips with the major subject matter of the book (Part IV and V). In the meantime, the following discussion is offered as a simplifiec overview of how the environmental approach can make the stratigraphic recorc come alive in our minds.

A Rational Approach to Sandstone, Shale, and Limestone

Figure 2.1 depicts a stratigraphic sequence that commonly occurs, with varying dimensions, throughout the stratigraphic record. Figure 2.2 portrays lithologic correlation of three measured sections containing this sequence of lithologies. In early stratigraphic work, there was a tendency to equate lithology with time. With this simple view of the stratigraphic record, a geologist of the old school might have looked at Figures 2.1 and 2.2 and written a scenario of earth history that would read as follows: "A time" of deformation and peneplanation was followed by "a time" of marine sandstone deposition. (The quotation marks are added for special significance in later discussions.) The sandy nature of this basal marine unit indicates that nearby mountains stood high at "this time." As the mountains became worn down, "the time" of sandstone deposition gave way to "a time" of marine shale deposition. As the sources of clastic sediment supply became completely peneplained, there came "a time" of marine carbonate deposition. Subsequent to the deposition of the marine limestone, there was "a time" of tectonic rejuvenation of the source area, leading once again to deposition of marine shale and finally to deposition of marine sandstone.

The preceding outline of earth history is probably a well-reasoned *ad hoc* explanation of the data. This is the so-called "layer-cake" approach to stratigraphy. Things may have happened just that way. We cannot argue conclusively against it on the basis of the limited amount of data presented. On the other hand, this explanation does not fit our study of Recent sediments. Thus, we are led to ask if the data contained in Figures 2.1 and 2.2 could be equally well explained in terms of processes and products with which we are familiar from studying Recent sediments.

Figure 2.3 presents an exceedingly simplified and generalized schematic cross section of a situation common in Recent sedimentation. Scale of the model and depth relationship among the sediment types may vary widely. On the one hand, Figure 2.3 may generally describe the transition from intertidal deltaic sediments to globigerina ooze accumulating in oceanic depths. On the other hand, in some Recent environments, the transition from clastics to carbonates may involve little or no

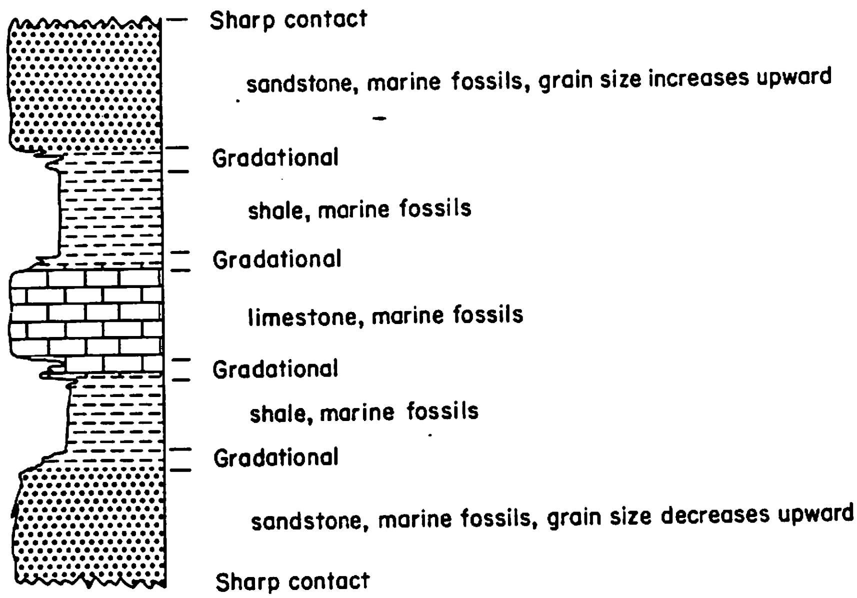

Figure 2.1 Common sequential relationships among sandstone, shale, and limestone.

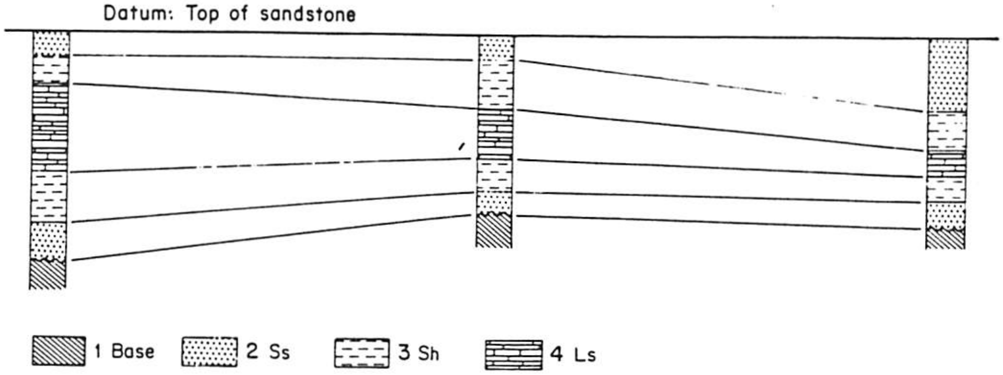

Figure 2.2 Lithologic correlation of three measured sections, displaying variations on the general sedimentary sequence depicted in Figure 2.1. Pattern (1) represents basement rock; (2), sandstone; (3), shale; and (4), limestone. By the *ad hoc* model discussed in the text, each lithology may be taken to represent "a time" in earth history: "a time" of sandstone sedimentation, "a time" of shale sedimentation, and so on.

change in water dèpth. For the moment, let us accept the following discussion as a reasonable and moderate generalization useful only to convey an initial feeling of security. As we move into Part IV, we shall develop more specific models based on specific examples of Recent sedimentation.

Marine sands are commonly high-energy nearshore deposits: deltas, beaches, and the like. Marine shales usually occur in deeper waters seaward of the high-energy nearshore sand deposits. Still farther seaward, beyond the influence of clay input from the land area, clear-water carbonate sedimentation occurs. Here, in the absence of a high influx of terrigenous clay, carbonate-secreting organisms such as foraminifers, molluscs, corals, bryozoa, and calcareous algae produce biogenic accumulations of calcium carbonate that are quite similar to limestones of the stratigraphic record.

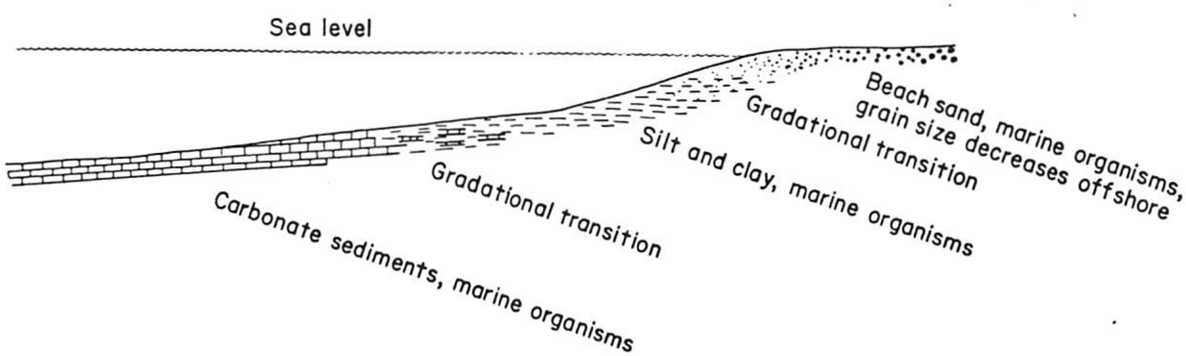

Figure 2.3 Hypothetical cross section depicting a common relationship among sand, clay, and carbonate sediments in the Recent epoch.

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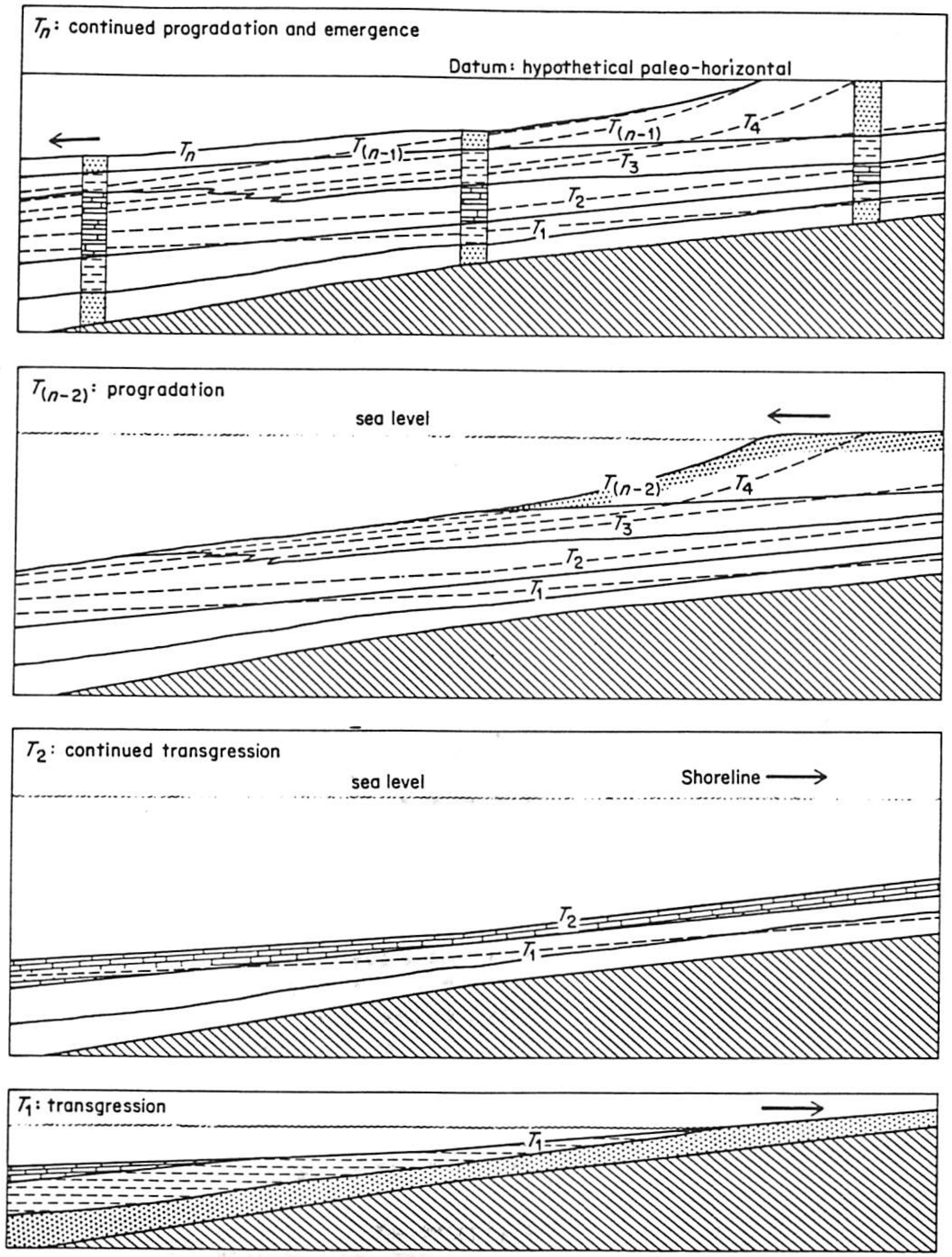

Figure 2.4 Dynamic model for the generation of the stratigraphic sections depicted in Figure 2.2. Transgression and regression superimposed upon the general model of Figure 2.3 generates an alternate hypothesis concerning the earth history recorded by the sections. The sequence of events begins with transgression at time T_1. Note that time lines T_1 through T_{n-1} cut across sediment types. Throughout the deposition of the entire sequence, sand, shale, and limestone are all being deposited somewhere within the model.

To the modern sedimentologist, therefore, Figure 2.2 might suggest transgression followed by regression. As the sea level rises, the site of high-energy sand accumulation might be expected to move landward. Likewise, the environments of shale and limestone deposition would migrate landward. Thus, marine sandstone becomes overlain by marine shale, which in turn becomes overlain by marine limestone. With subsequent regression, shale comes to overlie limestone, and the sandstone in turn comes to overlie shale. Such a reinterpretation of the data in Figures 2.1 and 2.2 are given in Figure 2.4.

Note that the two interpretations of each set of data are quite different. For the present time, suffice it to say that the interpretation given in Figures 2.3 and 2.4 "makes sedimentologic sense" in that all sediment types exist at the same time, whereas the previous interpretation of "a time" of sand, "a time" of clay sedimentation, and so forth seems rather foreign to the sedimentologist familiar with the Recent epoch. In subsequent chapters, we shall discuss additional sedimentological criteria that might indicate more clearly how we should interpret the earth's history as recorded by stratigraphic sequences.

Sedimentation Rates and the Stratigraphic Record

Although the preceding examination of a hypothetical stratigraphic example encourages our trying to understand stratigraphy in terms of Recent sedimentation, comparison of Recent sedimentation rates with the thickness of the total stratigraphic record complicates the problem. Consider, for example, sedimentation rates in Recent calcium carbonate environments. Reasonable rates for Recent shallow-water calcium carbonate vertical accumulation rates are from 0.1 to 1 meter per 1000 years. Similar deposits occur in Mississippian through Permian strata over much of the central United States. Mississippian through the Permian periods represent approximately 10^8 years. Thus, application of Recent sedimentation rates would suggest that some 10^4 to 10^5 meters of sediment should have accumulated within that time. In reality, these sediments seldom exceed 10^3 meters in thickness. Thus, we have a problem. During the late Paleozoic, there could have been 10 to 100 times as much sediment accumulation as is actually recorded.

Another way of fitting Recent sedimentation data to stratigraphic record is by considering the lengths of time represented by the Recent and by the classical stratigraphic units of Ancient deposits. Recent shallow-marine sedimentation began some 5000 years ago as the post-Wisconsin transgression brought sea level up to approximately where it now stands. From our knowledge of sedimentation dynamics within 5000 years, we must attempt to build models that will apply to the stratigraphic record. In contrast, biostratigraphic zonation of Ancient rock sequences usually provides us with working units of geologic time that are on the order of 1 to 10 million years long. If the processes involved in Recent sedimentation are indeed responsible for the sedimentation of stratigraphic units representing 1 to 10 million years, then we must suspect (1) that our Recent sedimentation model has barely begun to run its course, or (2) that our Recent sedimentation model has been repeated over and over again within a single biostratigraphic interval, or (3) that the record is missing for large portions of many biostratigraphic intervals, or (4) some combination of (1), (2), and (3).

Thus, understanding the stratigraphic record in terms of Recent sedimentation will not be as simple as we might have originally anticipated. To begin with, we must study the Recent sediments as we see them today. Next, we must seek to understand the dynamics of Recent sedimentation over the short time interval for which it has been operating. Then we must construct a dynamic model that will extend Recent sediment models to a time scale appropriate to the stratigraphic record. Finally, we must apply these models to the stratigraphic record in an iterative fashion; that is, crude models leading to an improved understanding of the stratigraphic record, which in turn leads to an improved model, which in turn leads to still a better understanding of the stratigraphic record, and so on. These four activities are treated in Parts IV and V. But first we must organize the materials and dynamics with which we shall be dealing. This organization is the subject of Parts II and III.

Selected References

IMBRIE, J., and N. NEWELL (eds.). 1964. Approaches to paleoecology. John Wiley & Sons, New York. 432 p.
Collection of topical papers. Fairly advanced level.

LAPORTE, L. F. 1968. Ancient environments. Prentice-Hall, Inc., Englewood Cliffs, N. J. 115 p.
Introductory treatment of analogies between Recent sediments and Ancient sedimentary rocks.

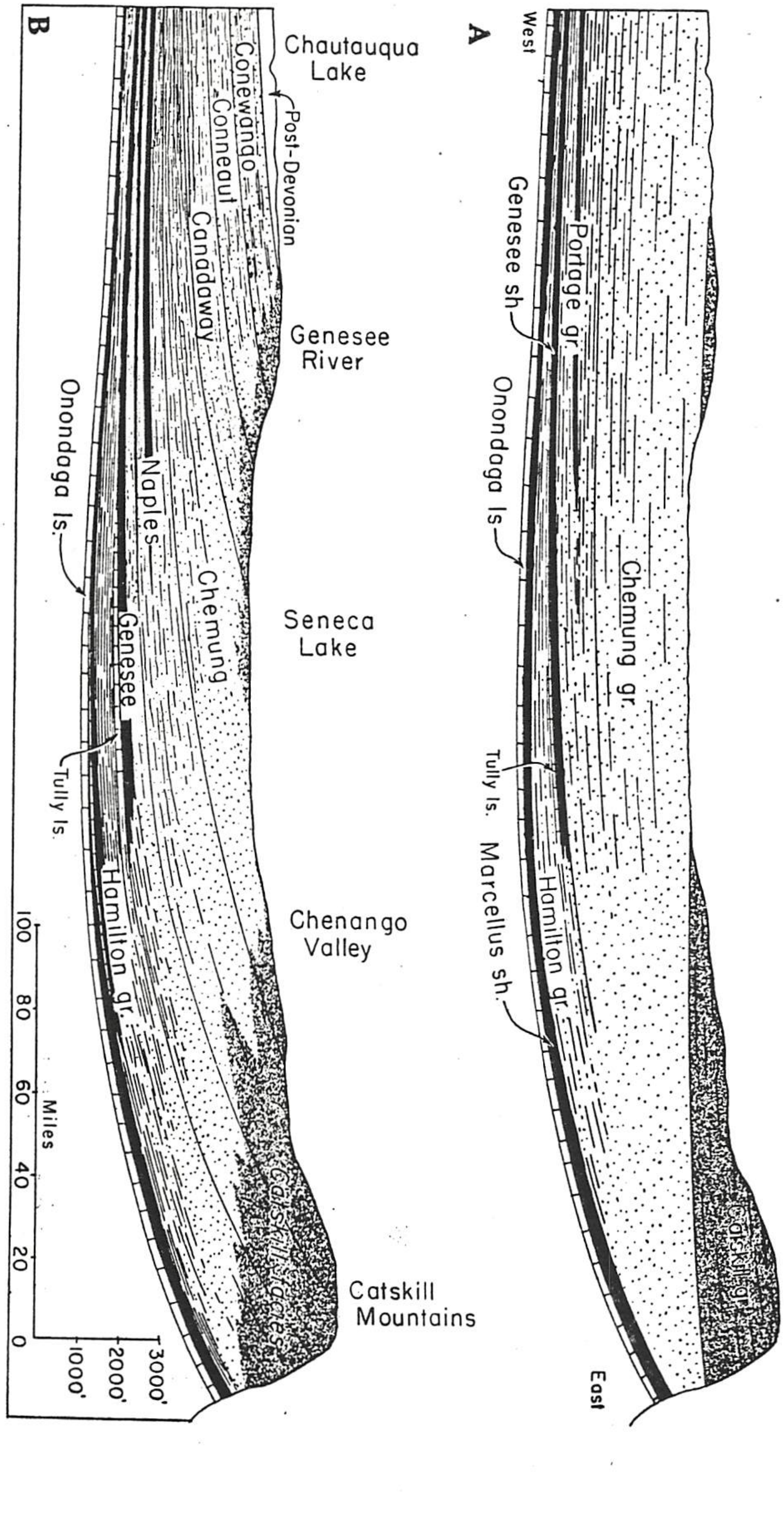

Figure 71. East–west sections across the Catskill Delta (Devonian) in southern New York. A, interpretation of Middle and Upper Devonian stratigraphy current before about 1930. B, present interpretation following the work of Chadwick and Cooper. Stratification lines indicate supposedly isochronous deposits.

NEW VIEW

OLD LAYER CAKE VIEW

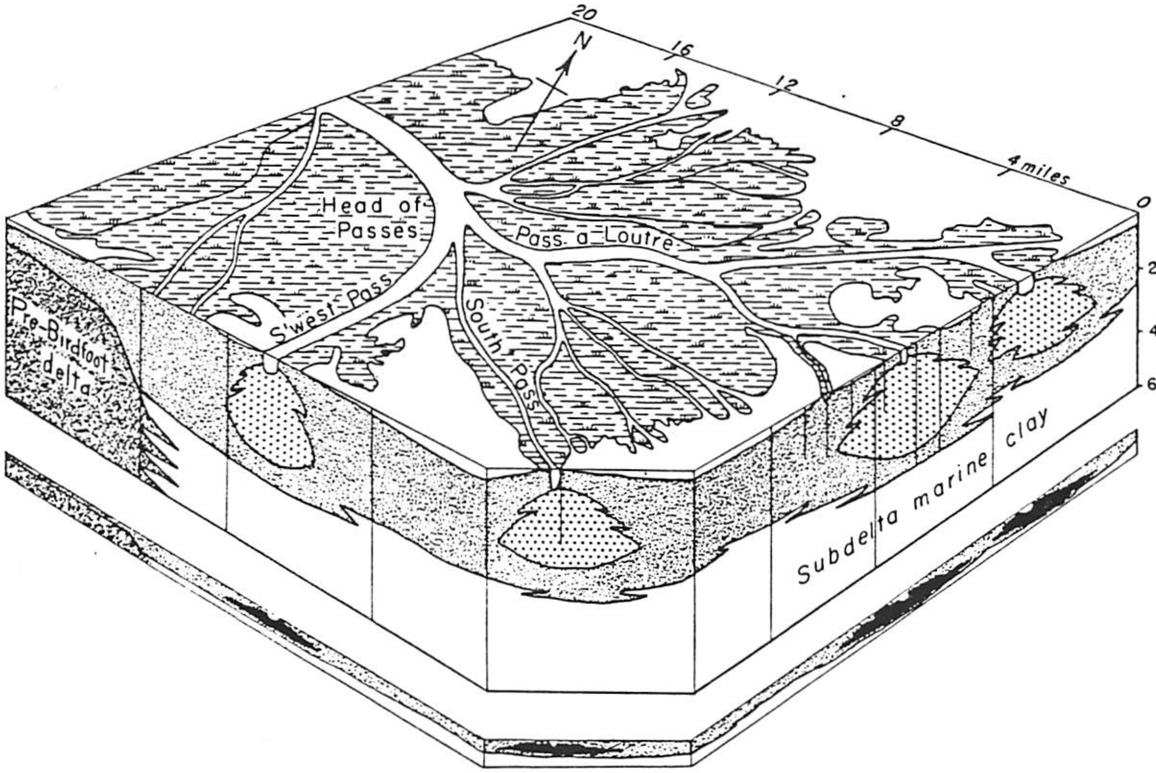

Figure 31. Block diagram of the Birdfoot subdelta, modified from Fisk and others (1954). Linear sand bodies made by main distributaries shown in open stipple on main diagram (vertical exaggeration about 30), in black on cross section below (vertical exaggeration about 5).

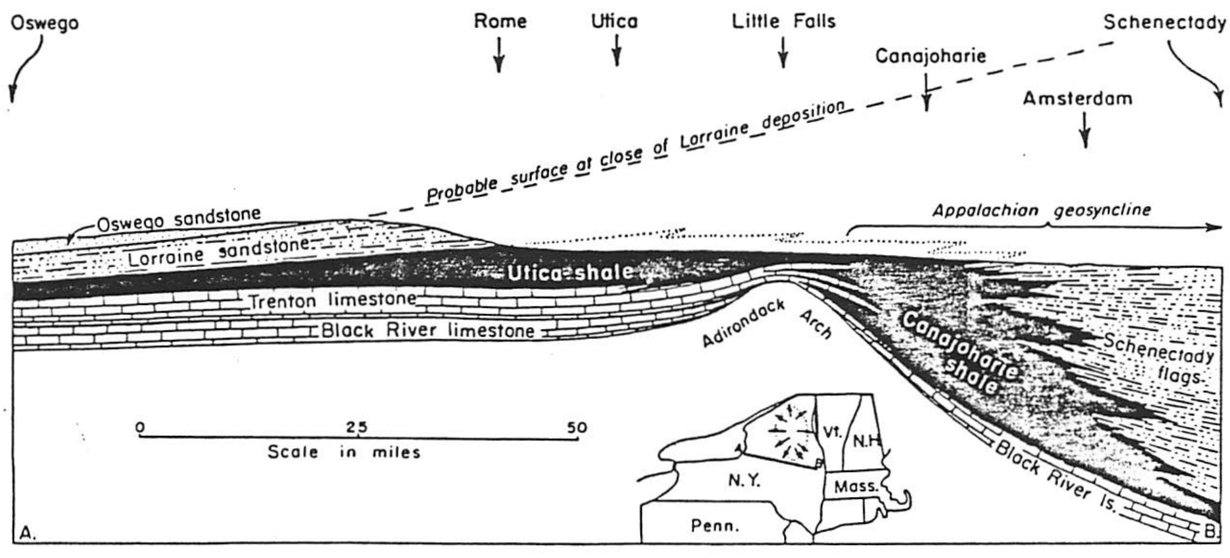

Figure 72. East–west section of the Middle and Upper Ordovician formations from central New York to Albany.

youngest Devonian rocks in the state, are as old as the lower part of the Upper Devonian in the western part of the state, which is in turn overlain by many hundreds of feet of younger Devonian rocks, divided into three great groups.

discussion.) This sequence was recognized both in north-central New York east of Oswego on Lake Ontario and in the lower Mohawk Valley west of Schenectady. But Ruedemann, by zoning the graptolites in detail, was able to show that

From Dunbar & Rogers

TABLE 18. CLASSIFICATION OF STRATIGRAPHIC UNITS PROPOSED BY SCHENCK AND MULLER (1941).

Geologic-Time Units	Time-Stratigraphic Units	Rock-Stratigraphic Units
Era Period Epoch Age	System Series Stage Zone	Group Formation Member, etc. Bed, etc.

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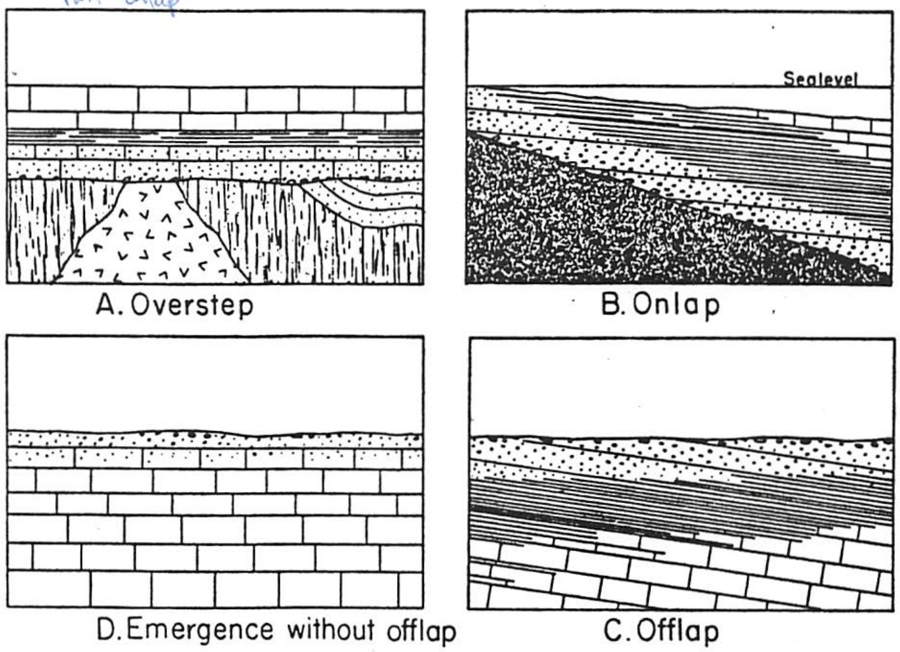


Figure 74. Idealized types of marine facies relations.

all layers are time transgressive

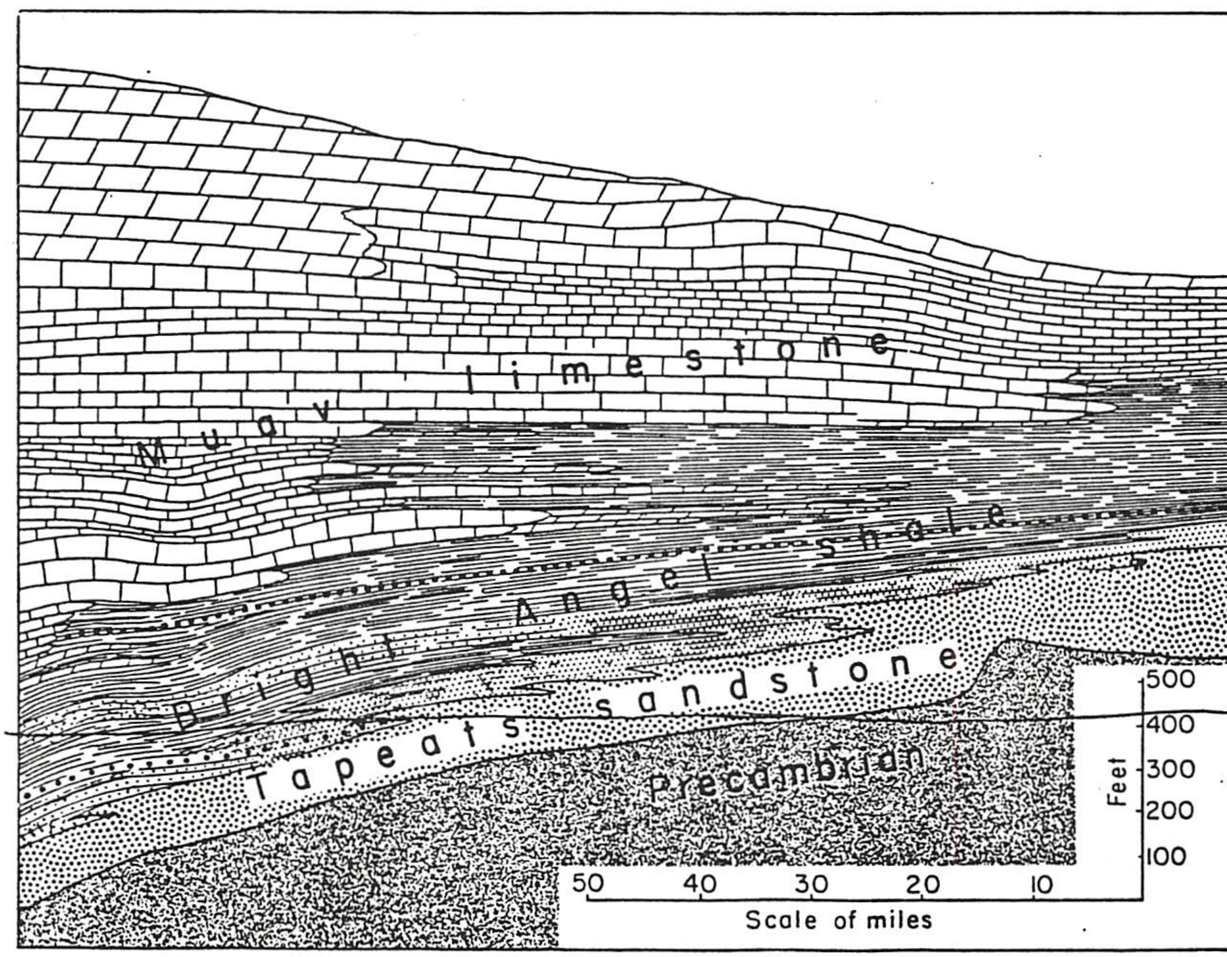
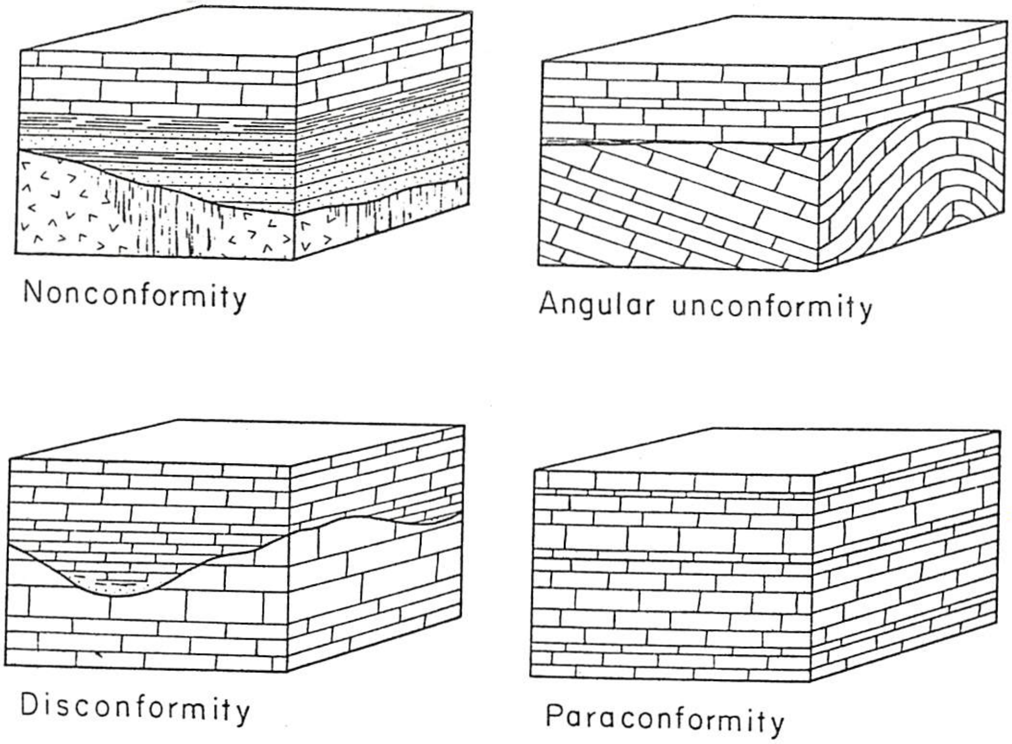


Figure 73. East–west section of the Cambrian formations exposed in the Grand Canyon of the Colorado in northwestern Arizona. After McKee (1945a). Stratification lines indicate isochronous deposits. The row of heavy round dots shows the position of a high lower Cambrian (*Olenellus*) faunal zone; the row of heavy square dots shows the position of a low Middle Cambrian (*Glossopleura*) zone.



← most of stratigraphic record is absent

Figure 57. The four types of unconformity.

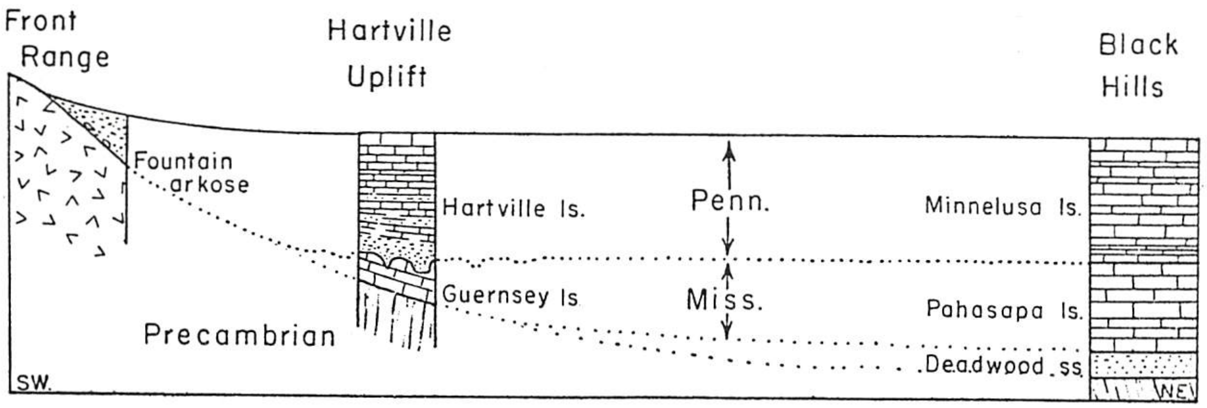


Figure 62. Variable expression of the great unconformity at the base of the Pennsylvanian System in southeastern Wyoming: nonconformity to SW (left), disconformity in center, paraconformity to NE (right).

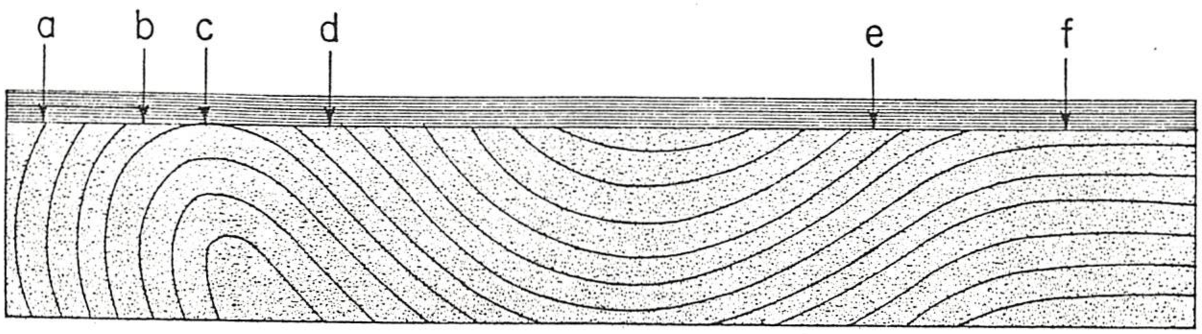


Figure 64. Diagram of an angular unconformity between folded and non-folded beds, showing variation in the angular discordance according to position on the folds.

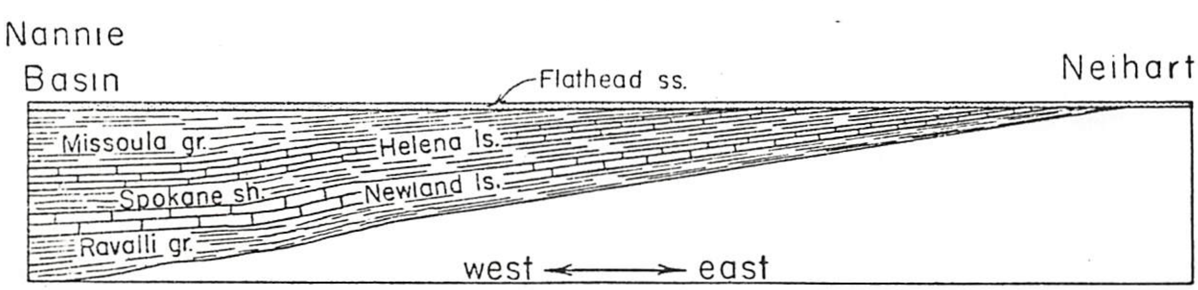


Figure 66. . Stratigraphic section from Nannie Basin to Neihart, Montana, showing regional unconformity between the Belt group (Precambrian) and the Flathead sandstone (Middle Cambrian). Length of section about 125 miles. After Deiss (1935).

ESS 141 FINAL FIELD PROBLEM 24 November 1986

Yonose Basin

STOPS

1. Oakfield Formation in Sherman Oaks.
2. Millbrook Formation in Sherman Oaks.
3. Stunt Formation at Saddle Peak.
4. Stunt Formation at sign 1.27.
5. Mailbox Formation at the mailboxes.
6. Concrete Ramp Formation at the concrete ramp.
7. Mulholland Formation on Mulholland Highway.
8. Mulholland Formation on Mulholland Highway.

RULES

The above information designates the units you will observe at each stop. The attached map and stratigraphic chart provide geometric and chronologic constraints on relations among the units. Your job is to reconstruct as much of the basin history as possible using only the information provided, as well as general references on depositional systems. Additional copies of the base map will be provided for your use. The following steps should be taken sequentially in order to arrive at your final destination.

1. At each stop, take careful note of all relevant features that you observe in the allotted time. Use your time efficiently to make the observations that will allow proper interpretation of depositional environments and systems. Take careful notes for later reference. You will not have a second chance to see any of the outcrops (you are not permitted to return to the outcrops on your own)!

2. As you gather data at each stop, begin formulating multiple working hypotheses to explain your observations in the context of the map and stratigraphic chart.

3. At the end of the day or soon thereafter, reread your notes and modify your interpretations to account for all of the information.

4. You may use any references that occur on the course reading list, but YOU MAY NOT CONSULT ANY OTHER REFERENCES!

5. Turn in to me by Monday 8 December 1986 (11:30 AM [start of final exam]), the following:

   a. A maximum of five doubly spaced typed pages of a report that includes a one-paragraph description of each stop, discussion of possible relations among the stops, and a summary of basin history, with possible causes and effects. Include a reference list as needed.
   b. Two paleogeographic/paleotectonic maps (using the base maps) for Middle Miocene and Late Miocene.
   c. A generalized geohistory diagram for the east

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GEOLOGICAL NOTES

A SCRUTINY OF THE ABSTRACT, II[1]

KENNETH K. LANDES[2]
Ann Arbor, Michigan

ABSTRACT

A partial biography of the writer is given. The inadequate abstract is discussed. What should be covered by an abstract is considered. The importance of the abstract is described. Dictionary definitions of "abstract" are quoted. At the conclusion a revised abstract is presented.

For many years I have been annoyed by the inadequate abstract. This became acute while I was serving a term as editor of the *Bulletin* of The American Association of Petroleum Geologists. In addition to returning manuscripts to authors for rewriting of abstracts, I also took 30 minutes in which to lower my ire by writing, "A Scrutiny of the Abstract."[1] This little squib has had a fantastic distribution. If only one of my scientific outpourings would do as well! Now the editorial board of the Association has requested a revision. This is it.

The inadequate abstract is illustrated at the top of the page. The passive voice is positively screaming at the reader! It is an outline, with each item in the outline expanded into a sentence. The reader is told what the paper is about, but not what it contributes. Such abstracts are merely overgrown titles. They are produced by writers who are either (1) beginners, (2) lazy, or (3) have not written the paper yet.

To many writers the preparation of an abstract is an unwanted chore required at the last minute by an editor or insisted upon even before the paper has been written by a deadline-bedeviled program chairman. However, in terms of market reached, the abstract is *the most important part of the paper*. For every individual who reads or listens to your entire paper, from 10 to 500 will read the abstract.

If you are presenting a paper before a learned society, the abstract alone may appear in a pre-convention issue of the society journal as well as in the convention program; it may also be run by trade journals. The abstract which accompanies a published paper will most certainly reappear in abstract journals in various languages, and perhaps in company internal circulars as well. It is much better to please than to antagonize this great audience. Papers written for oral presentation should be *completed prior to the deadline for the abstract*, so that the abstract can be prepared from the written paper and not from raw ideas gestating in the writer's mind.

My dictionary describes an abstract as "a summary of a statement, document, speech, etc. . . ." and that which *concentrates in itself the essential information* of a paper or article. The definition I prefer has been set in italics. May all writers learn the art (it is not easy) of preparing an abstract containing the *essential information* in their compositions. With this goal in mind, I append an abstract that should be an improvement over the one appearing at the beginning of this discussion.

ABSTRACT

The abstract is of utmost importance, for it is read by 10 to 500 times more people than hear or read the entire article. It should not be a mere recital of the subjects covered. Expressions such as "is discussed" and "is described" should *never* be included! The abstract should be a condensation and concentration of the *essential information* in the paper.

[1] Revised from K. K. Landes' "A Scrutiny of the Abstract," first published in the *Bulletin* in 1951 (*Bulletin*, v. 35, no. 7, p. 1660). Manuscript received, June 3, 1966; accepted, June 10, 1966.
Editor's note: this abstract is published together with The Royal Society's "Guide for Preparation and Publication of Abstracts" to give *Bulletin* authors two viewpoints on the writing of abstracts.

[2] Professor of geology and mineralogy, University of Michigan. Past editor of the *Bulletin*.