THE DEPOSITIONAL SYSTEM CONCEPT, WITH A SELECTIVE, ANNOTATED BIBLIOGRAPHY

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INTRODUCTION

Detailed mapping of surficial sediments is becoming more and more important, both to geologists who want to understand the geologic development of an area and to specialists in a variety of other disciplines who are finding increasing need for a useful inventory of the natural framework of an area.

This bibliography is designed to serve geologists as a basic reference to the depositional system concept of mapping sediments and as a source of specific applications of the concept in the Middle Atlantic and Virginia Coastal Plain area.

In the future, depositional systems defined by surface mapping will likely be of value for fully interpreting the sparse, but growing, amount of subsurface data in the Coastal Plain.

DEPOSITIONAL SYSTEM CONCEPT

Many geologic investigations involve strata, or layers, of sedimentary rocks or loose, unconsolidated sediments. According to one classification, a layer may be defined as a geologic formation if it has a uniform composition, a generally tabular geometry, and lateral continuity. Lateral continuity, or mappability, is regarded as a test of the validity of the definition of a geologic formation (American Commission On Stratigraphic Nomenclature, 1970, p. 6). In addition, it is often assumed that such layers are the same age throughout much of their lateral extent, are of nearly uniform thickness, and were originally formed as horizontal layers.

Lateral persistence can usually be safely assumed for marine formations deposited well within a basin or in a cratonic area. Gross physical characteristics of depositional environments in these settings tend to be uniform and laterally persistent, qualities reflected in the resulting strata.

Sediments deposited at the edges of depositional basins, however, are noted for their lack of lateral persistence and for their abrupt changes in facies and thickness. These characteristics reflect abrupt changes

both in the physical characteristics of the depositional environments along the edge of a basin and in the active processes which affected the sediments during their depositional history.

Basin-edge variability seems to be a characteristic of both terrigenous and carbonate sediments. Terrigenous deltaic deposits bordering the Paleozoic Appalachian basin show abrupt changes in facies (Ferm, 1970, p. 253, Fig. 9) and deposits on the edge of a Paleozoic carbonate basin show steep initial dips and abrupt changes in thickness (Adams and others, 1951, p. 2606, Fig. 3). Deposits on the edge of the Tertiary Gulf Coast geosyncline illustrate the problems in defining a "formation" there (Curtis, 1970, p. 296, Fig. 2).

For many years, geologists have studied areas where sediments are now being deposited, in an effort to better understand how various sedimentary rocks were formed in the past. Most of the areas studied are along present coast lines. Sediments deposited in coastal environments exhibit the same variability in their properties that is shown by ancient basin-edge deposits.

Time-stratigraphic subdivision of basin-edge deposits on a paleontologic basis is often unsatisfactory because

the abrupt lateral changes in depositional environments limit lateral persistence of fossils and seriously weaken methods of subdivision dependent upon uniform composition, a particular geometry, and lateral persistence of strata.

In an effort to provide a meaningful method of subdividing modern sediments, to systematically organize the growing volume of data from studies of these sediments, and to provide a basis for applying these data to interpretation of ancient rocks, the concept of depositional systems has evolved.

Although the name "depositional systems" is rather new, the concept is not, and can be found expressed in the literature at least as far back as the 1950's. Only in recent years, however, has the concept been more fully developed and the scope of its applicability more fully explored.

Active processes that affected sediments during their depositional history have sometimes been generally categorized as "marine", "fluvial", "deltaic", or some similar genetic term. Sediments deposited in various individual environments can be grouped into parallel categories depending upon the kind of active processes that affected the sediments. Such a process-defined category and its included sediments are a depositional system. As introduced

by Fisher and McGowen (1967, p. 106) and restated by Brown and Fisher (1970, p. 10), a depositional system is a large-scale group of genetically related facies defined by physical parameters that, ideally, are related to the active processes that formed each facies. Emphasis is placed on those physical characteristics that, in combination, are distinctive of individual depositional environments and the active processes that prevailed in those environments.

In practice, there is a certain amount of choice involved in defining a given depositional system. This is a valuable characteristic of the concept because it allows flexibility in adapting to specific situations of varying geologic setting, varying scale, and varying levels of knowledge. At the same time, specific depositional systems of any scale are defined by tangible, physical criteria that reflect the genesis of each depositional system.

Studies of modern sediments provide a way to predict the geometry and individual facies components of depositional systems in ancient rocks (for example, Fisher and McGowen, 1969, p. 53, Fig. 12). Conversely, sequential changes through time, documented in older depositional systems, can be used to predict future behavior of modern counterparts (for example, Kraft, 1971, p. 199, Fig. 106).

The concept of depositional systems relates the active processes that affected sediments during their depositional history and the physical features of the resulting deposits which reflect those processes, namely, the internal sedimentary characteristics and the external geometry and geomorphology.

If the original external geometries of sedimentary bodies can be observed, appropriate depositional systems can be defined geomorphically and rapidly mapped at a reconnaissance level. The internal sedimentary characteristics of each facies can then be reasonably inferred on the basis of many studies of modern sediments, such as summarized by Visher (1965). This approach has been used successfully in the subsurface for mapping rocks as old as Pennsylvanian (Brown, 1969), and at the surface for mapping Quaternary sediments.

If the original external geometries of sedimentary bodies can no longer be readily observed, then field examination is necessary to determine the internal sedimentary characteristics and the vertical variation in these characteristics at different geographic locations. Detailed columnar sections reflect the geographic as well as stratigraphic distribution of facies (Visher, 1965, p. 41, Kraft, 1971, p. 84). Once the internal sedimentary

sequences are known, it is possible to infer the geometries and geographic distributions of facies and thus, the depositional systems. This approach has been used successfully in surface mapping of rocks as old as Cambrian? (McGowen and Groat, 1971).

The annotated bibliography in Appendix I has three types of entries, indicated by the following numbers in the margin to the left of each entry:

1. Original or recent papers describing entire depositional systems and dealing with applications of the depositional system concept.
2. Recent papers describing specific depositional environments and component facies of various depositional systems.
3. Papers describing depositional systems, component facies, or applications of the depositional system concept in the Middle Atlantic and Virginia Coastal Plain area.

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Adams, J. E. and others, 1951, Starved Pennsylvanian Midland basin: Am. Assoc. Petroleum Geologists Bull., vol. 35, p. 2600-2607.

American Commission on Stratigraphic Nomenclature, 1970, Code of stratigraphic nomenclature: Tulsa, Am. Assoc. Petroleum Geologists, 22 p.

Brown, L. F., Jr., 1969, Geometry and distribution of fluvial and deltaic sandstones (Pennsylvanian and Permain), North-Central Texas: Texas Bureau Econ. Geol., Geol. Circ. 69-4, 47 p.

Brown, L. F., Jr. and Fisher, W. L., 1970, An approach to environmental geology with examples from the Texas coastal zone, in Young, Keith, conv., Environmental geology: Washington, Am. Geol. Institute.

Curtis, D. M., 1970, Miocene deltaic sedimentation, Louisiana Gulf Coast, in Morgan, J. P., ed., Deltaic sedimentation modern and ancient: Soc. Econ. Paleon. and Min., Spec. Publ. 15, p. 293-308.

Ferm, J. C., 1970, Allegheny deltaic deposits, in Morgan, J. P., ed., Deltaic sedimentation modern and ancient: Soc. Econ. Paleon. and Min., Spec. Publ. 15, p. 246-255.

Fisher, W. L. and McGowen, J. H., 1967, Depositional systems in the Wilcox Group of Texas and their relationship to occurrence of oil and gas: Gulf Coast Assoc. of Geol. Soc. Trans., vol. 17, p. 105-125.

Fisher, W. L. and McGowen, J. H., 1969, Depositional systems in the Wilcox Group (Eocene) of Texas and their relation to occurrence of oil and gas: Am. Assoc. Petroleum Geologists Bull., vol. 53, p. 30-54. A slightly modified and more readily available version of the preceding paper.

Kraft, J. C., 1971, A guide to the geology of Delaware's coastal environments: College of Marine Studies, Univ. of Delaware, 220 p.

McGowen, J. H. and Groat, C. G., 1971, Van Horn sandstone, West Texas: An alluvial fan model for mineral exploration: Texas Bureau Econ. Geol., Rept. Invest. 72, 57 p.

Visher, G. S., 1965, Use of vertical profile in environmental reconstruction: Am. Assoc. Petroleum Geologists Bull., vol. 49, p. 41-61.

APPENDIX I

ANNOTATED BIBLIOGRAPHY

Three types of entries are indicated by the following numbers in the margin to the left of each entry:

1. Original or recent papers describing entire depositional systems and dealing with applications of the depositional system concept.
2. Recent papers describing specific depositional environments and component facies of various depositional systems.
3. Papers describing depositional systems, component facies, or applications of the depositional system concept in the Middle Atlantic and Virginia Coastal Plain area.

1, 2 Allen, J. R. L., 1965, Late Quaternary Niger delta, and adjacent areas: sedimentary environments and lithofacies: Am. Assoc. Petroleum Geologists Bull., vol. 49, p. 547-600.

Internal sedimentary characteristics of facies may vary within a single environment because of differences in the supplied sediment. It is preferable to define sedimentary

environments in terms of unique associations of active processes, which do not vary. Sedimentary environments are classified into super-environments (depositional systems), environments, and sub-environments (individual component facies). Detailed descriptions of the sedimentary characteristics of each facies are given and are interpreted in terms of the active processes of each depositional system.

2 Bernard, H. A. and others, 1970, Recent sediments of southeast Texas: Texas Bureau Econ. Geol., Guidebook 11, 16 p. Internal sedimentary characteristics are well-illustrated and described in detail for individual facies belonging to fluvial, deltaic, coastal interdeltaic, and marine depositional systems associated with a marine regressive shore zone. Individual facies are assembled into characteristic vertical sequences for each depositional system and are interpreted in terms of active processes that deposited the sediments. Extensive material describing the Galveston barrier island complex and the Quaternary geology of the northwest Gulf of Mexico in similar fashion is appended.

3 Boggess, D. H. and others, 1964, Water table, surface drainage, and engineering soils map of the Rehoboth Beach area,

Delaware: U. S. Geological Survey, Hydrologic Investigations Atlas HA-109.

Soils derived from sediments of fluvial and coastal marine depositional systems are shown on a map and the physical properties of interest to engineers are tabulated. Understanding the dynamics of the depositional systems and the internal and external characteristics of the resulting deposits makes it possible to selectively locate bore holes for obtaining data and to interpolate physical properties between bore holes with some assurance.

1, 2 Brown, L. F., Jr., 1969, Geometry and distribution of fluvial and deltaic sandstones (Pennsylvanian and Permian), North-Central Texas: Texas Bureau Econ. Geol., Geol. Circ. 69-4, 47 p.

Fluvial, deltaic, interdeltaic, and shelf depositional systems are defined on the basis of external geometries and stratigraphic arrangement of individual facies, plus internal sedimentary characteristics, from both surface and subsurface data. A depositional model, showing relationships between the four depositional systems, is derived to explain the distribution of sandstones that are important as objectives in oil exploration and as conduits for subsurface movement of

naturally-occurring and introduced fluids. "Dip-fed sandstone" is introduced as a general name for elongate fluvial and deltaic sands deposited parallel to the depositional dip. A very brief discussion is included of the shortcomings of formal stratigraphic classification for this type of study.

1,2 Fisher, W. L. and McGowen, J. H., 1967, Depositional systems in the Wilcox Group of Texas and their relationship to occurrence of oil and gas: Gulf Coast Assoc. Geol. Socs. Trans., vol. 17, p. 105-125. A slightly modified version is reprinted in Am. Assoc. Petroleum Geologists Bull., 1969, vol. 53, p. 30-54.

One of the first papers to use the phrase "depositional system". Seven depositional systems are defined from surface and subsurface data and the component facies of each are described in terms of their physical characteristics. Stratigraphic and geographic aspects, and their effects on the occurrence of oil and gas, are discussed for each depositional system.

3 Hansen, H. J., 1971, Transmissivity tracts in the Coastal Plain aquifers of Maryland: Southeastern Geology, vol. 13, p. 127-149.

Physical characteristics of the formations of the Maryland Coastal Plain are reviewed from previous work. The formations are grouped into fluvio-deltaic, fluvio-marine, and marine depositional systems on the basis of origins interpreted from these physical characteristics. The external geometry of each depositional system is shown to affect the regional occurrence of groundwater.

3 Jordan, R. R., 1964, Columbia (Pleistocene) sediments of Delaware: Delaware Geol. Sur., Bull. 12, 69 p.

Surficial deposits are described in terms of their internal sedimentary characteristics at a number of locations. Geographic variation of these characteristics and limited data on external geometries are used to define fluvial, shoreline complex, and estuarine depositional systems. These depositional systems make it possible to relate various facies to each other, to predict general distribution of facies in areas of no data, and to reconstruct the geologic history of the sediments.

1, 2 Kolb, C. R. and Van Lopik, J. R., 1966, Depositional environments of the Mississippi River deltaic plain - southeastern Louisiana, in Shirley, M. L., ed., Deltas in their geologic

framework: Houston, Houston Geological Society, p. 17-61.

Individual facies of four depositional systems are defined by internal sedimentary characteristics and external geometries, and are described in detail. The distinctive physical properties of each facies are related to its geologic origin. Knowledge of the dynamics of each depositional system and the resulting physical properties of each facies makes it possible to selectively locate fewer bore holes to obtain a given amount of data and to knowingly interpolate physical properties between bore holes.

2, 3 Kraft, J. C., 1971, A guide to the geology of Delaware's coastal environments: College of Marine Studies, Univ. of Delaware, 220 p.

Stratigraphic distribution of facies in a marine transgressive shore zone is determined in individual borings. The facies are described in terms of their internal sedimentary characteristics. Vertical sequences of facies reflect geographic sequences of facies, as determined from multiple bore holes. Physical properties and distribution of facies are used to interpret active processes influencing the shore zone during

the Holocene, to reconstruct the sequential development of a transgressive shore zone, and to extrapolate to possible future changes.

2 McGowen, J. H. and Groat, C. G., 1971, Van Horn sandstone, West Texas: An alluvial fan model for mineral exploration: Texas Bureau Econ. Geol., Rept. Invest. 72, 57 p. Internal sedimentary characteristics are interpreted in terms of active processes operating during deposition of the sediments. Stratigraphic and geographic distribution of these sedimentary characteristics is the basis for a process-defined depositional model (depositional system) of alluvial fan formation by fluvial processes next to a highland source area. Occurrence of heavy minerals is genetically related to the depositional model to serve as a guide for exploring other, similar deposits.

3 Owens, J. P. and Sohl, N. F., 1969, Shelf and deltaic paleoenvironments in the Cretaceous-Tertiary formations of the New Jersey Coastal Plain, in Subitzky, S., ed., Geology of selected areas in New Jersey and eastern Pennsylvania: New Brunswick, New Jersey, Rutgers Univ. Press, p. 235-278.

Deltaic and marine shelf depositional systems are subdivided into sedimentary environments on the basis of active processes and gross physical characteristics of corresponding facies. Individual component facies of each formation are defined in terms of compositions, internal sedimentary structures, and external geometries, and are assigned a position within a conceptual depositional model to emphasize the relationships between facies, and between depositional systems.

1, 3 Schlee, John, 1957, Upland gravels of southern Maryland: Geol. Soc. America Bull., vol. 68, p. 1371-1410.

A detailed petrographic description of a fluvial depositional system, emphasizing stratigraphic and geographic variations of internal sedimentary characteristics. An early paper, profitable to re-read in light of more recent studies of fluvial sediments and processes.

2, 3 Schubel, J. R., conv., 1971, The estuarine environment: estuaries and estuarine sedimentation: Washington, Am. Geol. Institute.

Estuaries are presented as a continuous spectrum of gradational types. Emphasis is on active processes and the reflection of these processes in various physical characteristics

for each type of estuary. Data are drawn largely from upper Chesapeake Bay.

2, 3 Stanley, D. J., conv., 1969, The new concepts of continental margin sedimentation: Washington, Am. Geol. Institute.

Lecture 2, "Shore zone sand bodies", by J. R. Curray and lecture 4, "Inner shelf sedimentation", by D. J. P. Swift emphasize active processes and external geometries of individual facies in nearshore marine depositional systems. Swift discusses the idea of equilibrium between the parts of a depositional system, which has important geologic implications. Abundant data from the Middle Atlantic coastal area are included.

1, 2 Visher, G. S., 1965, Use of vertical profile in environmental reconstruction: Am. Assoc. Petroleum Geologists Bull., vol. 49, p. 41-61.

A limited number of sequential sedimentary processes, such as transgression and regression, are recognized. Each unique sedimentary process produces a characteristic sequence of depositional environments that are reflected in characteristic stratigraphic sequences of facies. Individual

facies are described in terms of physical characteristics, including faunal content. Stratigraphic sequences are used to infer the geographic distribution and geometry of component facies for six different depositional systems.