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Problems in Turbidite Research: A Need for COMFAN

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Abstract

Comparison of modern submarine fans and ancient turbidite sequences is still in its infancy, mainly because of the incompatibility of study approaches. Research on modern fan systems mainly deals with morphologic aspects and surficial sediments, while observations on ancient turbidite formations are mostly directed to vertical sequences. The lack of a common data set also results from different scales of observation.

To review the current status of modern and ancient turbidite research, an international group of specialists formed COMFAN (Committee on Fans) and met in September 1982 at the Gulf Research and Development Company research facilities in Pennsylvania.

Introduction

Exploration for energy resources in the deep-water areas of continental margins has necessitated increased offshore research on turbidite environments; turbidites are the dominant sediment type of the extensive continental rise areas and include many of the slope-basin deposits on active margins. Thus, published studies on modern deep-water basins, and the wide variety of turbidite and related deposits that fill them, continue to increase in number. Work on modern and ancient turbidite sequences in the last two decades has resulted in a variety of depositional models. Unfortunately, models based on individual modern submarine fan systems are commonly inapplicable to many of the widely disparate types of turbidite systems found in either modern or ancient basins. Furthermore, models based on ancient turbidite systems tend to show more differences from than commonalities with those based on modern deep-water turbidite basins. The inappropriate application of many of these models to poorly exposed and/or inadequately mapped deposits (modern and ancient) compounds an already confusing situation.

The lack of common ground between models for modern and ancient turbidite deposits has resulted in a nonuniform application of models, facies distinctions, morphologic criteria, and depositional processes. As a net result, nonspecialists are increasingly confused, and specialists directly involved in turbidite research remain unable to resolve the differences among various sedimentation models.

Definition of Problems

Data Types and Scale Relations

The differences in both scale of observation and data-acquisition methods [1] result in the lack of a common data set for comparing modern and ancient submarine fans. Observations from outcropping ancient fans provide details of bed thickness, composition, grain size, and sedimentary structures. Detailed sections from several meters to hundreds of meters in thickness are available, and individual beds can be followed laterally across the width of the outcrop. Correlation between outcrops, however, requires basinwide marker beds, which rarely occur. Correlation of depositional events represented by single layers, packets of layers, or laterally equivalent facies across an ancient submarine fan is typically beyond the resolution of biostratigraphic control. For most ancient systems, one cannot reconstruct the sea-floor relief at the time of deposition of any given bed, and structural complication and erosion commonly prevent reconstruction of the original shape and extent of the deposits. Source area(s) can rarely be defined adequately.

For modern fans, the available data-acquisition techniques and resulting data sets generally do not overlap in scale and resolution (Fig. 1). Both the sediment source area(s) and morphology of the system can be defined. Acoustic-reflec-

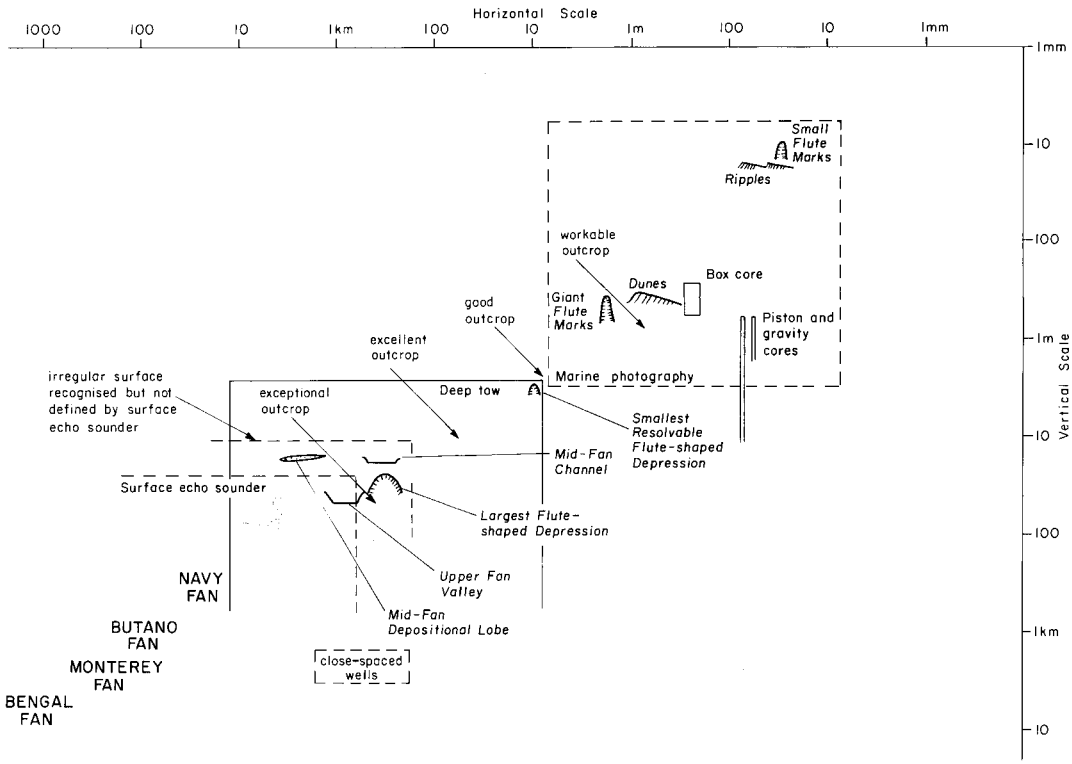

Figure 1. Horizontal and vertical scale comparison for modern submarine-fan data sets with sedimentologic observations based on outcrop studies of ancient turbidite deposits; modified from Normark and others [1]. Nondeep-tow systems are capable of resolving features in areas noted by dashed lines.

tion profiling methods enable us to define details of the fan surface, total thickness of the deposit, and lateral variation of internal structure; in short, acoustic facies distinctions can be made. However, the detail of such distinction and depth of observation vary widely among the systems used. Acoustic systems that scan the sea bottom from near the sea surface, including even the modern multibeam techniques, are unable to resolve vertical relief of less than 10 m or horizontal dimensions of less than 100 m in deep water. Sediment characteristics are known only from core samples that are short (generally less than 15 m), narrow (<10 cm), and commonly deformed by the coring process itself. Little is known about the internal makeup of modern submarine fans because sedimentary structures are inadequately resolved in the narrow core samples, and vertical sequences cannot be studied because of the shortness of the cores. Thus, correlation of beds and erosional surfaces between core sites is normally impossible.

This brief review indicates that there is little common ground for observations from modern and ancient turbidite systems (Fig. 1). For example, channels observed in large outcrops that are several hundred meters across probably could not be recognized on a modern fan without the use of deeply towed narrow-beam sounding systems or special intermediate-range side-scanning sonar techniques that have only been available for the last two years. Thus, the channel and valley features observed from outcrop studies are frequently one or two orders of magnitude smaller than channels observed on modern fans. Such problems of comparison are further complicated by commonly overlooked limitations on the use of certain types of data. Differential compaction of mud and sand during lithogenesis obscures the original topographic character of ancient fans, and the use of morphologic terminology tends to be misleading. Acoustic definition of sedimentary layers (reflectors) using reflection-profiling systems is limited, and the minimum spacing of reflectors, which in some cases do not correspond with distinct lithologic boundaries, is commonly greater than the length of core samples recovered from modern fans; therefore, acoustic facies cannot be confidently correlated with sedimentary facies. These are only a few of the general types of limitation produced by the methods of observation. Failure to recognize the limitations resulting from the various types of data make comparison of modern and ancient systems nearly meaningless at this time.

Morphometric Emphasis Versus Sedimentary Facies

Fans and related turbidite sediments occur as distinct morphological features in modern basins. These features, in some cases, can be further split into a number of subenvironments that are also primarily defined on their morphological characteristics. When comparing ancient turbidite sequences with modern morphological features, like fans or specific fan subdivisions, the actual comparison is made between sedimentary rocks (or derived facies) and the morphology of a modern fan together with a scant indication of surficial sediment cover. Such a comparison is limited by several factors.

(1) There is no unanimity in the application of the term *fan*. Turbidite deposition that forms a fan-shaped deposit generally results from long-term active turbidite deposition related to a point source, generally a canyon or major river delta, and occurring within an unconfined basin of low relief. However, many cases of modern turbidite sedimentation involve the infilling of narrow, irregular, and structurally active depressions and thus do not result in the formation of a distinct fan morphology. This dichotomy in morphologic expression of submarine turbidites must be equally common in ancient sequences. The first limitation in comparing modern fans with ancient turbidite sequences results, therefore, from the nonexplicit relation between a distinct fan morphology and other types of turbidite accumulation.

(2) Although channel and lobe features have been defined for ancient turbidite sequences, equating these features to morphologically defined channels and lobes on modern fans may be misleading. It is better therefore to describe ancient turbidite sequences without specific morphologic connotations.

(3) The original morphology and the physiographic subdivisions of an ancient clastic environment can only be inferred from the geometry of the resulting sandstone bodies. Unfortunately, entire turbidite sandstone bodies can rarely be seen in outcrop. Typically, both exposed and subsurface ancient turbidite deposits can only be studied in vertical sequences. Therefore, vertical facies-sequence analysis has been widely used to infer the geometry of turbidite sandstone bodies from vertical variations in thickness of sandstone beds, sand-to-shale ratio, texture, and other significant facies characteristics. Much confusion has arisen from the popular application of these concepts, especially in cases where the interpretation of specific depositional environments of ancient fan systems is based on only a few sections.

(4) Thickening and/or coarsening- and thinning- and/or fining-upward sequences have been widely and often successfully used to recognize channel-fill and lobe deposits similar to modern distributary channels and mouth bars in fluvially dominated deltas. However, the actual validity of these trends as environmental indicators and their meaning in terms of accretion and progradation processes have never been tested by sufficiently deep cores in modern fan systems. In addition, much confusion exists about the criteria and even the terminology that should be used to establish these sequences, resulting in highly inconsistent usage.

Work on ancient fans has focused particularly on channel-fill and lobe deposits because they are generally very distinct in terms of texture and sedimentary structures. The former generally have been assigned an inner- or middle-fan environment, the latter a middle- or outer-fan environment. The size of the exposures is generally too small to determine the width, depth, and internal structure of a channel precisely or to assign the exposed sequence to a specific type of channel as seen in modern settings. Lobes in ancient sequences are primarily recognized by their lack of basal channeling. Therefore, some very broad channel-fill sequences could be mistaken for lobes. *Lobe* is a very confusing term because it applies to specific modern features (such as a suprafan) as well as to nonchannelized ancient sandstone bodies that are the analogs of modern lobes only in some cases.

COMFAN Goals

The COMFAN (*COM*mittee on *FAN*s) project was conceived to (1) review the current status of modern and ancient turbidite research from fan and nonfan settings, (2) identify the primary areas of confusion and nonuniform uses of terminology, processes concepts, and data types, (3) present the most recent (generally unpublished) results of turbidite research by active specialists for modern and ancient systems, (4) critically review and if necessary modify the proposed Deep Sea Drilling Project program on the Mississippi Fan, and (5) where possible, recognize and define specific criteria such as facies types, morphologic features, morphometric zonations, sediment distribution, and depositional processes that can be applied to both fan and nonfan turbidite environments. The approach was not designed to resolve differences between existing sedimentation "models" but to provide a reliable means for understanding the full range of turbidite deposits and turbidity current processes. The number of participants (18), and thereby the number of turbidite systems discussed, was kept sufficiently small to foster active discussion by all as each topic was brought into focus.

The first COMFAN meeting was held in Harmarville near Pittsburgh, Pennsylvania, 7–10 September, 1982, and was hosted by Gulf Research and Development Company. Sixteen of the authors of the papers reviewed in this issue were present at the meeting.

This special issue of GEO-MARINE LETTERS presents a review of 23 submarine turbidite systems: 13 modern and 10 ancient. To the greatest extent possible, we have attempted to provide the same basic data compilations for each system to facilitate comparison. The key parameters have been summarized in a comprehensive table [2] and in schematic drawings to emphasize the differences in scale, types of observation, and amount of data available for each study. The volume has been subdivided into three sections. The first presents studies of modern submarine fans ranging from 16 km to 2500 km in length and covering a wide range of fan morphologies. The second section includes studies of ancient turbidite sequences with clear indications that they were fan-

shaped deposits when formed. The last section reviews ancient turbidite sequences for which fan-related features are not clearly recognized or where sedimentation was confined to a narrow, tectonically deforming trough. In the latter case, tectonic processes control deposition, and fan morphology and internal structure do not form.

No attempt has been made to fit these depositional systems into model types or to modify existing models. At this stage, COMFAN activities focus on providing comparable data bases for comparison of fans. The last chapter does, however, attempt to evaluate how well the first COMFAN meeting was able to achieve the defined objectives.

References

[1] Normark, W. R., Piper, D. J. W., and Hess, G. R., 1979. Distributary channels, sand lobes, and mesotopography of Navy Submarine Fan, California Borderland, with applications to ancient fan sediments. Sedimentology, v. 26, pp. 749–774.

[2] Normark, W. R., Barnes, N. E., 1983.

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