were delivered from the continental interiors onto the young passive margins. In time, river drainage became increasingly focused, concentrating detrital sediment supply at the mouths of a few large rivers. Very large supplies of detrital sediment require large, high uplifts such as those caused by subduction of young, hot ocean crust or by continental collision.

Large sediment supplies also require drainage basins with relatively constant slope; so that sediment erosion, throughput, and delivery to the ocean margin are efficient. The result is rapid sedimentation of deltaic complexes containing an abundance of organic carbon. During most of earth history, there are no large, high uplifts, and carbonate rocks become more important in the continental margins.

In contrast to the point inputs of detrital sediments, the supply of carbonate has been from the oceanic reservoir and is diffuse. Carbonate deposition dominates the continental shelves in all warm regions where the detrital sediment input is not extremely large. Carbonate shelves become cemented, resisting erosion, so they build up until the shelf edge approximates highstands of sea level. Detrital shelves become adjusted to lowstands of sea level with the shelf breaks typically many tens of meters below the low sea level.

The clastic-carbonate shelf-slope-rise system operates to promote bypassing of detrital materials into deep water in the subtropics and tropics, with sharp facies contrasts. In higher latitudes, carbonate may be a significant proportion of the continental margin material, but facies changes are usually much more gradual.

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Application of Database Management to Biostratigraphy

The nature of biostratigraphic data presents major problems that are not considered by most computerized database-management systems. These problems include the variety of ways that paleontologists record data, the reluctance of many paleontologists to use the computer, the need to change the database to reflect the current state of biostratigraphy, and the need to separate the paleontologic information from interpretive and nonpaleontologic information. With regard to the first problem, the level of paleontologic measurement (e.g., presence-absence, qualitative assessments of abundance, or counts) should be retained for each sample; yet the system should be designed so that data with varying levels of measurement can be reduced to their lowest form allowing comparisons among samples with different levels of measurement. For example, in a series of wells to be correlated, a combination of presence-absence information, qualitative assessments, and counts of fossils may be present. In this example, one wants the opportunity to automatically reduce all data to presence-absence form and correlate the wells.

The second problem presented to the management of biostratigraphic data is the reluctance of paleontologists to utilize the computer. To minimize this problem, the database-management software must be designed to run as efficiently and simply as possible so each user feels that the system was designed specifically for him. In addition, the design of the system should be flexible enough so that the user can request minor modifications in the system to meet his own needs.

With regard to the final problem, paleontologic data must be separated from both interpretative (e.g., zonal and age assignments) and nonpaleontologic (e.g., formational assignments) information. It is highly desirable to assign quality factors to the data, so that high-quality data is distinguishable from data produced in a quick-and-dirty fashion.

Many of these problems have been resolved using an efficient, relational database-management system designed for a variety of paleontologic and related data linked with a series of biostratigraphic applications programs. The internal structure of the database as well as the applications programs are hidden from the user, who only sees a series of panels that allow easy, efficient execution of the entire package. This package expedites report writing, analysis of data from a single well, regional synthesis of data from many wells and outcrops, and integration of biostratigraphic data with other types of geologic information.

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Ocean Margin Drilling Project Data Synthesis off Eastern North America: 28 to 36 Degrees North Latitude

An atlas of geological and geophysical maps has been compiled for the east coast of the North American continent covering an area from well onshore to the ocean crust, and from 28 to 36° N as part of the Ocean Margin Drilling Project.

Included in the atlas are maps of the depth to continental and oceanic basement, depth to the top of Lower and Middle Jurassic (reflectors J_M/J_2 and J_S/J_2), to the top of Jurassic (reflectors J/J_1), to the top of Neocomian (reflector Beta), to the top of Cretaceous (reflector A*), to the top of Paleogene (reflector A_u), and to the top of lower Miocene (reflector X). Isopach maps between these reflectors and between them and the seafloor are also included. Contours are two-way travel time with a contour interval of 0.25 to 1 sec.

The atlas also contains a tectonic map of basement, a pre-Quaternary geologic map, and lithofacies maps for six time slices.

There are geophysical maps of magnetic and gravity anomalies and compressional wave velocities in sediments and basement.

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Evolution of Sedimentary Basins

Simple extensional models that involve stretching by listric faulting in the brittle upper crust and plastic flow in the lower lithosphere have been shown to account for the subsidence history of various sedimentary basins, continental shelves, and the Central graben in the North Sea. The case where extension thins the crust by a different amount from the subcrustal lithosphere has been considered by several authors, but their treatment of two-layer extension is overly complicated and partly incomplete. In this paper, we present a simplified analysis of the two-layer extensional model for the elementary case in which extension is instantaneous, the crust is thinned by a different amount from the subcrustal lithosphere, the effects of radioactivity and dike intrusion are ignored, and local isostatic compensation is assumed at all times. We show how the thinning parameters can be obtained from the subsidence data through the use of a simple and powerful method of data analysis. We show that conservation of mass during a process of non-uniform extension implies that much greater thicknesses of sediment can be deposited in a young basin than in the case of uniform extension of both crust and subcrustal lithosphere. Further, we show that such an extensional process produces significant uplift of the flanks of a graben and that, as a result of erosion of the uplifted areas, the effective area of the basin can be increased as much as 25 to 30%, depending on the rate of erosion, compared to the area that would have been created by a process of uniform extension. Finally, we consider the forces of uplift on the flanks in the situation where the crust is treated as a thin elastic plate floating on a fluid upper mantle, the graben is bounded by two major normal faults, and there is subcrustal thinning under the flanks. We show that such normal faults produce uplift of the flanks and that this uplift can be significantly increased by the subcrustal thinning. Both kinds of forces give rise to uplift which can, in certain places, be misinterpreted as pre-rift doming. However, the uplift and erosion on the flanks of the graben associated with nonvertical faulting does not introduce significant error into the calculation of extensional parameters from subsidence analysis of a cross section of a basin.

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Sedimentation in Pull-Apart Basins—Modern Examples from Eastern Turkey

Well-exposed ancient pull-apart basin deposits have the following characteristics in common: (1) great stratigraphic thickness relative to basin size, (2) high rate of sedimentation, (3) asymmetry of sediment thickness and facies pattern, (4) organization of the facies into marginal fault-bounded fanglomerates and central flood-basin and lacustrine deposits, and (5) textural cycles that reflect tectonic activity and evolution. The relationship between basin deposits and boundary faults is usually well defined. However, many pull-apart basin deposits are deformed and their boundary faults are usually no longer active. Understanding of sedimentation in ancient pull-apart basins suffers from a limited knowledge about the original depositional and structural setting. In an attempt to develop a more comprehensive understanding of sedimentation in pull-apart basins, we examine the fault and depositional systems of two modern, active pull-apart basins in eastern Turkey.

The Erzincan pull-apart basin overlies the North Anatolian fault, a right-lateral, 1,200-km (745 mi) long intracontinental transform fault. It is 50 by 13 km (31 by 8 mi) and rhomboidal. Boundary strike-slip faults define sharp, steep, and relatively undissected mountain fronts. These active faults are characterized by an overlap of 32 km (20 mi) and a separation of 13 km (8 mi). Sedimentation within the basin is controlled by: (1) an axial fluvial system (the upper Euphrates River) associated with a broad flood plain/salt marsh, and (2) alluvial fans that prograde transversely from the boundary mountain fronts. Small calcalkaline volcanic cones intrude and overlie these sediments along subsidiary strike-slip faults within the basin. Aluvial fans are well-developed along the northern mountain front. They are steep, composed of fluvial and debris flow facies, and prograde over fluvial plain/salt marsh deposits. Along the southern mountain front alluvial fans have coalesced into a gently sloping alluvial apron composed of fluvial facies. These features suggest that the northern fault margin has probably been more recently active than the southern fault margin.

The Lake Hazar pull-apart basin overlies the East Anatolian fault, a left-lateral, 450-km (280 mi) long intracontinental transform fault. It is 25 by 7 km (16 by 4 mi), rhomboidal, and forms an asymmetric half-graben in cross section with its deepest part to the south. Boundary strike-slip faults form sharp, steep mountain fronts and are characterized by a separation of 3 km (1.9 mi) and an overlap of about 5 km (3.1 mi). Sedimentation within the basin is controlled by: (1) an axial fluvial system which enters the basin longitudinally and forms a large (5.1 km^2 [2 mi^2]), low-gradient (1.1°) fan delta which is composed of interbedded fluvial and lacustrine facies, and (2) lateral fluvial systems that enter the basin transversely and form small (0.03 to 0.23 km^2 [0.01 to 0.09 mi^2]), steep (2.5° to 8.5°) fan deltas composed of interbedded fluvial and debris flow facies.

The Erzincan and Lake Hazar pull-apart basins present an "instantaneous" structural and depositional picture of pull-apart basin evolution and provide a basis of comparison with ancient pull-apart basin deposits.

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Case History of Langley Deep Field in Lea County, New Mexico

In May 1978, ARCO Oil and Gas Co. completed the Langley Deep Unit 1 well in Lea County, New Mexico, discovering a deep gas field with production from 2 horizons. The discovery well produces gas from a northwest-southeast trending anticline that has a reverse fault at the Ellenburger formation on the northeast flank of the structure. This reverse fault generated an anticlinal feature in the upthrown block on the east flank of the Delaware basin that is the reservoir for the Langley Deep field Devonian strata, and the fault is the possible trap at the Ellenburger formation.

This discovery was the result of an ongoing seismic program that started with a regional group shoot in 1968 on the Central Basin platform and the Delaware basin in Lea County, New Mexico. This survey obtained data that has at best only short discontinuous reflectors in the present area of interest. It could be used only to obtain dips of unknown geologic horizons. ARCO Oil and Gas Co. has been in additional group shoots or has acquired seismic data in each year from 1973 through 1981 in the Delaware basin and Central Basin platform of New Mexico. Each vintage is an improvement in the quality of the section in terms of both the continuity of events and resolution of events. New acquisition and processing techniques contribute to the enhancement of the data. Even though better record sections are obtained with each succesive vintage, the improvement is limited in each case. The most improvement in record section quality is between the data acquired in 1968 and 1973.

The exploration play developed when data acquired in 1973 was reprocessed in 1975 including diffraction migration, which clearly demonstrated the presence of the critical east dip on Devonian and older formations. Subsequent seismic programs define the limits of the closure. The 1978 discovery well confirmed the existence of the seismic structure. Seven wells have been drilled to date on the Langley Deep seismic feature. Six wells have been completed and are producing gas from Devonian and Ellenburger formations. The seventh well had shows but is considered noncommercial. The only other deep well on the structure was drilled in 1962 to Conoco Inc. to the Ellenburger formation on the northern end of the Langley Deep feature, but was over 500 ft (150 m) lower at the Devonian formation when compared with the shallowest penetrations of these formations on the Langley Deep structure.

The success of finding the Langley Deep field is due to recognizing that the potential for finding reservoirs exists in the no-data zones on seismic. By continually investigating and searching for the causes of the no-data zones, new and improved acquisition and processing techniques revealed a gas field that would never have been found if exploration stopped after the initial efforts to define the subsurface. The continued efforts to specify the subsurface along the western edge of the Central Basin platform and eastern edge of the Delaware basin not only resulted in the discovery of the Langley Deep field, but also renewed interest of the majors and independents in this area. Conoco Inc., ARCO Oil and Gas Co., and Shell Oil Co. have drilled additional deep