goons, bays, and estuaries up to 8 mi wide. Regional studies indicate that barrier morphology and texture and composition of beach sediment, although largely unrelated to modern rivers, are related to the distribution of sand-rich late Pleistocene facies on the inner continental shelf. For example, Matagorda Peninsula, near the Brazos River, is narrow, receding, and has a high oyster-shell content.

Narrow, regressive barriers occur where Pleistocene strand plains are absent, where Pleistocene deltas are mud-rich, and in Pleistocene interdeltaic areas. These regressive barriers have a high shell content (dominantly estuarine species), and varying amounts of caliche, siderite, beach rock, and sandstone fragment gravel. Beaches retreat 7–40 ft/yr in erosional areas. Dunes are rare on narrow barriers, and shell ramps extend several hundred feet bayward ending abruptly as steep avalanche faces.

Terrigenous sand is the dominant sediment type of wide barriers such as Matagorda Island; no modern stream contributes sand to this barrier. Broad barriers develop where sand-rich Pleistocene deltas and strand plains are present and the sand budget is large. Morphologic features of these barriers are fore-island dunes, beach ridges, and broad barrier flats. Beach ridges, indicating rapid accretion, are characteristic of the older barrier segments. Today, fore-island dunes, suggesting cessation of accretion, are relatively well developed on these barriers.

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EVIDENCE OF MIGRATING HYDROCARBONS IN DEEP SEA DRILLING PROJECT CORES

To date the Deep Sea Drilling Project has revealed migrated liquid hydrocarbons in 3 widely separate areas of the globe. The first occurrence was the highly publicized, visually observed accumulation of immature petroleum in sediments on the Challenger Knoll in the Gulf of Mexico. Subsequent to the discovery of this obvious saturation, chemical analyses revealed 2 more possible examples of migration. The first was a low-grade bitumen saturation in a thin porous zone in Pleistocene sediments on the Shatsky Rise in the western Pacific Ocean. The second and latest was a small but geochemically significant quantity of wet gas and gasoline-range hydrocarbon that apparently seeped upward into Miocene rocks in the Balearic basin of the western Mediterranean Sea. These migrated hydrocarbons—in addition to the methane gas commonly encountered in deep ocean cores—reveal that hydrocarbon source beds are present, and that liquids as well as gases have begun to migrate, at least locally, in deep-ocean sediments.

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ANATOMY OF DISTRIBUTARY CHANNEL-FILL DEPOSITS IN RECENT MUD DELTAS

Recent distributary channel-fill deposits (of various sizes) were studied in three mud-rich deltas of the Gulf Coast: the Mississippi, the Colorado-Matagorda, and the Trinity. Although the deltas differ markedly in size, they show similar geomorphology, depositional processes, and patterns of sand accumulation. Data were obtained from 2 major sources: (1) continuously cored borings with electric logs to study the depositional sequence of filled channels, and (2) fathometer surveys to study bed forms in modern channels.

Deposition within distributary channels reflects major depositional stages during the development of the channel. A complete depositional sequence consists, from the base upward, of an active-channel fill (deposited when the channel carried its full flow), a partial-abandonment fill (flow through the channel was reduced), and an abandoned-channel fill (deposited in essentially a still-standing body of water when channel was abandoned).

There is good agreement between cross bedding direction and sand-body elongation, *i.e.*, crossbedding foresets dip downstream parallel with the channel axis. The dip azimuths for accretion beds in the upper part of the channel are too variable in their orientation to be useful trend indicators. The shoestring channel-fill deposits generally trend subnormal to the regional depositional strike, but can show a wide directional scatter.

Because delta channels scour 20–200 ft below sea level, channel-fill sands are commonly positioned stratigraphically lower than their contemporaneous delta-front sands. Although distributary channel-fill and point-bar sands show a similar sedimentary sequence, some sedimentologic and stratigraphic features are helpful in distinguishing the 2 sand types.

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GEOCHEMICAL STUDY OF CRUDE OILS FROM GHADAMES BASIN, WESTERN LIBYA

Twenty-five crude oils from the Ghadames basin, western Libya, were analyzed to distinguish genetically distinct oil families and to attempt identification of different geologic processes that have affected the oils. The oils came from reservoirs ranging in age from Cambrian to Triassic. The samples were analyzed by mass spectrometry to identify molecular types of compounds present and to determine the stable carbon isotope values for the heavy saturate and heavy aromatic fractions. Gas chromatography was used to analyze the light gasoline fractions and the heavy saturate fractions of the oils.

Significant differences were noted between oils from different parts of the basin. At least 4 different Paleozoic oil families were distinguished. The oils from Triassic reservoirs appear to have migrated from Paleozoic strata. Alteration of some of the oils by water flushing and by bacterial degradation is evident. A study of the hydrodynamic flow of formation waters in the major reservoir zones supports the chemical evidence that flushing has affected the compositions of some of the oils.

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JOHANNES WALTHER'S LAW OF CORRELATION (OR SUCCESSION) OF FACIES

The writings of Johannes Walther (1860–1937) have been neglected in the west and his law of the correlation (or succession) of facies has been ignored or misstated in many text books of stratigraphy. Walther should be recognized as a pioneer stratigrapher-sedimentologist, important both as a world traveler and explorer of modern sedimentary environments (deserts, reefs, laterites) and as a theorist. His main theoretical contributions were his championing of the

actualistic method for the study of fossils and sedimentary rocks and his founding of the science of comparative lithology. Comparative lithology was seen by Walther as the analogue for sedimentary rocks of comparative anatomy for fossils. It has been neglected in the western world until the recent revival of the concept of facies models.

Walther's law was the key concept within comparative lithology, and was originally stated as follows: "The various deposits of the same facies areas and similarly the sum of the rocks of different facies areas are formed beside each other in space, though in cross-section we see them lying on top of each other. As with biotopes, it is a basic statement of far-reaching significance that only those facies and facies areas can be superimposed primarily which can be observed beside each other at the present time."

In Russia, Walther's writings appear to have had a far greater influence than they have in Europe and America. They have been partly responsible for the development there of "lithology" as a branch of the geological sciences separate from stratigraphy or petrology.

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PLEISTOCENE ICE-RAFTED PEBBLE ABUNDANCE, EASTERN NORTH ATLANTIC OCEAN

Detailed examination of a suite of 8 deep-sea cores collected by USNS *Kane*, north of 48°N lat., in the eastern North Atlantic Ocean indicates an unusually high abundance of coarser than sand-size-rafted debris. An average of 3 pebbles per core, each weighing greater than 8 g, characterizes the suite. In fact, the average weight for all pebbles found was 30 g. Assuming that these averages are compatible for the rest of the eastern North Atlantic, and assuming an average age of 300,000 years for the 8 cores, it has been calculated that over 2.6×10^{13} metric tons of coarse debris has been transported from Europe, Iceland, and the Faeroe Islands by ice-rafting since late middle Pleistocene time. If coarse debris represents a total of only 20% of all ice-rafted sediment, then in the eastern North Atlantic, over 1.3×10^{14} metric tons of sediment has been ice-rafted in the last 300,000 years.

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EVALUATING SOURCE BEDS FOR PETROLEUM

Geochemists have made considerable progress in recent years in evaluating source beds for crude oil and natural gas. Petroleum is generated from disseminated sedimentary organic matter by thermochemical processes. A certain amount of time and temperature (thermal energy) is essential to produce the thermal cracking reactions causing the generation of petroleum. As the temperature is raised, the time for the reactions to occur is decreased. The same thermochemical processes that result in the generation of oil and hydrocarbon gases also contribute to the maturation and the ultimate destruction of oil and natural gas. Methane and graphite are the stable end products of these reactions. The exposure time-temperature relations necessary for the generation of petroleum and its expulsion from the source bed have been determined with sufficient accuracy from geochemical data to permit predictions of the approximate stage of generation or diagenesis in advance of sample analysis. Also, the conditions under which oil and condensate are thermally destroyed have been reasonably well established from empirical data. Geochemists are gradually improving their understanding of the factors that control source-bed performance. Factors such as the minimum amount and quality of organic matter necessary for effective oil source beds have been quantified rather accurately.

A balanced program includes evaluation of both the extractable organic matter and the residual organic matter in a source bed. The evaluation of extractable organic matter includes conventional analyses of organic carbon, total extractable organic matter, and extractable hydrocarbons. Evaluation of the extractable organic matter and extractable hydrocarbons include the study of heavy (C_{15}-C_{30}) hydrocarbon distributions and infrared spectra. Elemental analysis of carbon, hydrogen, nitrogen, and oxygen is a method used to investigate the diagenetic (carbonization) stage of residual organic matter. Pyrolysis techniques have been developed to investigate organic matter from the standpoint of its remaining generating capability.

Examples from the literature confirm that, in general, young source beds must be exposed to sustained higher temperatures than old source beds to attain peak generation. If 2 source beds of the same age and with identical burial histories were subjected to significantly and uniformly different temperatures, the hotter would be in a more advanced stage of organic matter diagenesis.

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FACTORS WHICH MAY AFFECT OCCURRENCE OF GAS IN SAN JUAN AND UINTA BASINS, ROCKY MOUNTAINS

The San Juan basin, northwestern New Mexico, has long produced methane gas which commonly carries sufficient liquids to yield high BTU values. With this production, however, there have been wells which produced only carbon dioxide, or such large quantities of nitrogen as to be of very little economic value.

Early production came largely from the Dakota sandstones (Cretaceous) the gases of which contain an average of 80% methane and 15% higher hydrocarbons. Nitrogen and carbon dioxide average less than 3% and 1% respectively, yielding an average BTU of 1,194.

Later exploration has proved extensive gas reserves in the uppermost sequence of Upper Cretaceous sandstones, where the gases average 85% methane and 12% higher hydrocarbons. Nitrogen and carbon dioxide values are 1% or less and BTU values average 1,133.

Deeper exploration has shown a plethora of problems in the occurrence of gas in this basin. Gas from Permian, Pennsylvanian, and Mississippian reservoirs shows quantities of hydrocarbons much lower than in shallower formations, and nitrogen content as high as 81%. These nitrogen-rich gases carry some of the highest percentages of helium in the entire basin, from 3% to as high as 7.5%, although the production and reserves of Paleozoic rocks are several orders of magnitude smaller than those of the Cretaceous.

Characteristics of the gases in each group or sequence of formations are presented as related to depth of production. Economic factors may be evaluated on the basis of production from different zones at deeper