Reef rims were flanked by steeply dipping marginal-slope deposits that descended to depths up to several hundred meters. These deposits include debris flows, huge allochthonous reef blocks, scheck breccias, and reefal tongues and bioherms built primarily by sponges and algae.

Platform margins are classified as advancing, retreating, upright backstepping, and roll-over types. Advancing margins are typical of the Famennian reef complexes; the others occur principally in the Frasnian and Givetian, where they are often associated with platform-margin unconformities resulting from submarine erosion or margin collapse.

The reefs and slowly deposited parts of the marginal-slope facies were subject to pervasive early submarine cementation by fibrous high-magnesium calcite (now radiaxial spar). The strongly cemented reef limestones formed rigid wave-resistant rims to the platforms. Fracturing of these limestones, probably largely associated with earthquake shaking, gave rise to extensive networks of neptunian dikes and sills, and to the collapse of some sections of the margins. Such collapses in turn initiated debris flows and the deposition of allochthonous reef blocks on the adjoining marginal slopes.

The reef complexes are being explored extensively for lead-zinc deposits in outcrop and oil in the subsurface. A significant oil discovery was made in a Famennian platform margin (the Blina field) in 1981.

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Neptunian Dikes and Sills in Devonian Reef Complexes of Canning Basin, Western Australia

Neptunian dikes and sills are conspicuous features of early-cemented limestones in Devonian reef complexes of the Canning basin. They are sedimentary fillings of fissures formed by fracturing of the limestones soon after deposition, and are most abundant in the reef subfacies, but also occur in some back-reef and marginal-slope deposits.

The dikes and sills were filled with contemporary sediment (including oolite, peloid grainstone, biomicrite, and calcareous sandstone), encrusting organisms (*Renalcis* and stromatolites), and early radiaxial calcite cement. Some of the sediment is dolomitized or mineralized. Some dikes contain concentrically coated balls of radiaxial calcite up to 0.3 m (1 ft) across. Sediment in the dikes and sills was cemented rapidly, and repeated refracturing and infilling occurred during brief intervals. The largest dikes are up to 6 km (3.5 mi) long, 20 m (65 ft) wide, and originally extended more than 80 m (260 ft) below the surface. However, most are less than 100 m (330 ft) long and 5 cm (2 in.) wide. Neptunian sills are up to 0.8 m (2.5 ft) thick. The principal strike directions of major dikes approximately parallel the original reef fronts of underlying basement ridges. Lateral extension through the development of fissures amounted to as much as 6.5%, and averaged about 3% in measured reef sections. The fissures allowed circulation of large volumes of seawater to considerable depth within the reef complexes, and must have played a significant role in early diagenesis.

Fissuring probably resulted from earthquake shaking, differential compaction of underlying sediments, and slippage along bedding planes, especially in the steeply dipping marginal-slope deposits.

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Uncertain Future of Natural Gas Production in U.S. Lower 48 States

The Office of Technology Assessment (OTA), an analytic support agency of the United States Congress, has examined the process of forecasting future supplies of conventional, domestically produced natural gas in the U.S. lower 48 states to the year 2000. Its investigation focused particularly on the technical sources of uncertainty, including the incomplete geologic understanding of the remaining resources and the difficulties involved in properly interpreting and extrapolating past trends in natural gas discovery. The OTA examined the arguments developed by supply "optimists" and "pessimists" regarding both the size of the recoverable resource base and the speed with which new resources can be discovered and produced. As part of the investigation, resource-base estimates, ranging from those of H. King Hubbert and Richard Nehring to those of the U.S. Geological Survey and the Potential Gas Committee, were reviewed and compared.

The OTA concluded that the credible ranges of estimates for lower-48 resources and future production potential are very wide—400 to 900 tcf for the remaining recoverable resources of conventional gas at near-current prices and technology, and 9-19 tcf/yr for the year 2000 production under the same price and technology conditions.

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Timing of Saddle Dolomite in Tuscaloosa Formation, Mississippi

Saddle (baroque) dolomites are characterized by curved crystal faces and sweeping extinction patterns. They are associated with hydrocarbons, sulfates, and base-metal mineralization, and occur as void-filling cements or replacement minerals. Most described saddle dolomites are from carbonates and are interpreted as a diagenetic product that formed under high temperatures during deep burial.

Saddle dolomites are present as nodular, poikilotopic cements in sandstones from a core of the Tuscaloosa Formation in southern Mississippi. The Tuscaloosa, a major oil producer in the area, consists of a series of fluvial/deltaic sands and shales. The sandstone is a fine to medium-grained lithic arenite whose grains are coated with isopachous layers of authigenic chlorite, which petrographic evidence indicates was precipitated at relatively shallow depths. The interrelationships of the chlorite rims and the saddle dolomite cements indicate that some of the dolomites were precipitated before the chlorite rims and that others formed shortly after the chlorite. This suggests that the saddle dolomites grew concurrently with the chlorite during a relatively early, shallow diagenetic event and not during deep burial.

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Sedimentation of an Upper Pennsylvanian Phylloid Algal Mound Complex, Hueco Mountains, El Paso County, Texas

A Late Pennsylvanian mixed carbonate-clastic sequence is exposed in the Hueco Mountains of west Texas. The sequence begins with deposition of a progradational fan-delta system and marine and tidal-flat carbonates. This unit is dominated by calclithite and shale with minor interbeds of shallow-water calcareous mudstone and wackestone. Shallow-water spiculites are commonly associated with these limestones. A thick carbonate unit composed predominantly of limestone overlies the clastics; it was deposited during or just after a major local transgression. The carbonate sediments were deposited on the submerged delta platform in the following sequence: (1) colonization of the shallow platform by rugose corals and early (or syndepositional) cementation of the zone; (2) establishment of shallow-water dasycladacean algal flats; (3) increasing domination of the environment by phylloid algae in response to increasing water depth; (4) accretion of phylloid algal sediments and formation of mounds (directly overlying the dasycladacean algal flats are a number of small mounds formed by accelerated sedimentation within phylloids algal "meadows." The high productivity of the phylloid algae and their sediment-trapping ability allowed sedimentation to keep up with sea level rise. Large bioherms resulted, but because of the difference in accretion rates of various mounds, some grew while others were buried by more successful neighbors); and (5) reestablishment of shallow-water dasycladacean algal flats as a result of shoaling of mound crests and subsequent increased sedimentation in deeper, quieter water on the lee side of the mound complex.

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Nature of Fort Chadbourne Fault System and its Relation to Petroleum Potential of Wilberns Formation (Upper Cambrian) of West-Central Texas

The Wilberns Formation (Upper Cambrian) in the subsurface of west-central Texas is composed predominantly of sandstone units. Subsurface mapping of the Wilberns shows the sandstones to be persistent through-

out most of the study area. The Fort Chadbourne fault system is a linear zone of deformation trending from Sutton County northward into northeastern Nolan County. This structural zone contains uplifted and faulted Wilberns Formation. En echelon faults and folds as the predominant structures along the Fort Chadbourne fault system suggest wrench faulting. The orientation of these faults (north-south) and folds (northeast-southwest) suggests that the wrench system had left-lateral movement that was produced from compressive forces active during the Ouachita orogeny.

Based on thin-section analyses of core samples, the general paragenetic sequence for the upper sandstone units of the Wilberns Formation consists of at least 4 diagenetic stages: (1) reduction of primary porosity and development of quartz overgrowths resulting from burial and compaction; (2) precipitation of dolomite cement into remaining pore space; (3) dissolution of calcareous material and development of secondary porosity in response to uplift and exposure; and (4) precipitation of hematite, pyrite, and clays as pore lining and pore fill after reburial (hydrocarbon migration probably occurred during this stage).

This sequence of diagenetic events is responsible for the excellent reservoir quality of the sandstone units within the Wilberns Formation found along the Fort Chadbourne fault system.

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Petrographic and Trace Element Analysis of Nonreef Silurian Carbonates, Northern Lower Michigan

Carbonate sediments of the northern reef trend in Michigan have been the subject of serious scientific scrutiny since the discovery of significant hydrocarbon reservoirs in pinnacle reefs in the late 1960s and early 1970s. The reef trend is a complex of reef and nonreef carbonate facies capped by an evaporite/carbonate sequence. The reef and the evaporite/carbonate sequence have been extensively described and discussed over the last decade. However, the nonreef (interreef) facies has received little more than brief descriptions throughout this time. As these nonreef carbonates are virtually barren of hydrocarbons, their analysis has been neglected.

Most exploration for pinnacle reefs centers around geophysical techniques; however, it should be considered that patterns of textural or geochemical gradients may occur between the reef masses and surrounding nonreef deposits. This study examines, in detail, the petrographic and geochemical character of these nonreef (interreef) sediments. These characteristics can provide additional data and a potential exploration tool for determining the spatial facies relationship between pinnacle reefs and interreef carbonates in the Michigan northern reef trend.

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Reservoir Volume and Production Decline Programs for the IBM-PC

Two programs useful for geologists and engineers in calculating reservoir volumes, setting up well and field production schedules, and projecting production decline have been written for the IBM-PC. Both programs are "user friendly" with simple full-screen data entry, and output to screen, printer, or diskette file for use by other programs. The programs are written in BASIC. Minimum system requirements are 128K RAM, one disk drive, monochrome monitor, and MS-DOS 1.1.

PXVOLUME calculates reservoir volume using input data consisting of contour values, measured areas within the contours, and reservoir isochore information. Output includes net reservoir volume above each contour. The program will interpolate or extrapolate areas and volumes for contour levels for which areas have not been measured, such as gas-oil and hydrocarbon-water contacts. Gas-cap and oil-reservoir volumes will be calculated and output separately if the gas column is provided.

PXDECLIN is designed primarily for use in estimating production profiles for prospects or individual wells, but may also be used for projections based on actual production data. The user is given a choice of production parameters to input, and remaining parameters are calculated. Hyperbolic, exponential, or harmonic decline may be specified, and decline rates may be either entered or calculated. Specifically, the "b" exponent for hyperbolic decline will be determined without any requirement for estimation or curve matching. Output consists of production profiles by month, quarter, or year, and both input and calculated production parameters, such as daily rates, cumulative production, production life, and the "b" exponent and "a" factor.

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Neogene Paleogeography of Western Snake River Plain, Idaho and Oregon

Analysis of Miocene through Pleistocene siliciclastic and volcaniclastic sequences in the western Snake River Plain of Idaho and Oregon allows detailed paleogeographic reconstruction of sedimentation associated with the development of a rapidly subsiding continental basin. Extensional tectonism was accompanied by voluminous outpourings of basaltic and silicic volcanic material. These in turn were reworked basinward by marginal alluvial fan–braided stream networks into basin-center fluviolacustrine systems. Episodic influxes of both felsic and basaltic tephra are recorded in fossiliferous lacustrine silt and claystones of the Poison Creek and Chalk Hills Formations, radiometrically bracketed between 12.5 to 5 m.y.B.P. Basinward-fining facies indicate deposition in a large lacustrine complex fed by at least 2 major fluvial systems. Complex interfingering of coarse-grained strandline deposits with offshore fine-grained sediments suggests repeated expansion and contraction of the lake system and record the dynamic interplay between basin tectonism and sedimentation. A major unconformity and presence of extensive interbasinal basaltic volcanism (Banbury Basalt) reflects draining of this lacustrine system and renewed extensional tectonism in the basin approximately 4 m.y.B.P. Reestablishment of a major fluviolacustrine complex is represented by deposits of the Pliocene-Pleistocene Glenns Ferry Formation (4-1.8 m.y.B.P.). The fossiliferous mudstone, sandstone, and conglomerate represent alluvial fan, meandering stream, flood-basin, and lake margin systems. Interbedded with these are a series of basaltic tuffs and flows reflecting continuing volcanism along the basin margin and basin center. Continued structural adjustments along high-angle normal faults that bound the basin are indicated by stratigraphic relationships as well as the style of fluvial sedimentation. Periods of rapid basin subsidence are recorded by thin, discontinuous channel sandstone encased by thick overbank siltstone and claystone. More stable periods allowed development of sheet-like channel sandstone with subordinate amounts of overbank fines. Basin-wide structural adjustments have continued to the present, as indicated by the incisement of these Neogene deposits by the modern Snake River.

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Depositional Control on Red Clinton Sandstone Production, Holmes County, Ohio

The Clinton sandstone (Silurian:Albion) is a major producing horizon throughout eastern Ohio. It accounts for 75% of total drilling activity in the state in recent years. The middle member of the Clinton, the Red, has caused problems for drillers in Holmes County, Ohio; rapid changes in thickness and porosity create wide differentials in production between closely spaced adjacent wells. A detailed analysis of Red Clinton variation in this area would be helpful for better direction of exploration and development programs.

On the basis of more than 1,100 drillers' and geophysical logs, structural, isopach, and porosity interpretations were assembled for the Red Clinton in Holmes County. Data analysis indicates that the Red Clinton is arranged in a number of multiple bar systems trending east-west to northeast-southwest throughout the county. Production statistics show that thickness and porosity of the Red Clinton is relatively good in the cleaner bar sands, whereas thinner, finer grained, more argillaceous interbar sands yield poorer producers or dry holes. Use of this depositional model clarifies the nature of controls on directional variation in thickness and porosity in the Clinton and facilitates prediction of production trends.