stitial clay, and generally lower oil saturations than the thinly interbedded sand and shale. The cross-bedded sands contain the highest oil saturations and form the largest and most continuous reservoir. Oil saturations are commonly lower in the marine sands of the Bluesky Formation where glauconite, clastic carbonate, and local carbonate cement combine to reduce porosity and permeability.

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Paleocene (Midway) Continental Shelf Deposits, Rio Grande Embayment, Texas

The Midway Group has been considered a monotonous section of marine shale which was deposited on the continental shelf during the initial Cenozoic transgression. However, recent studies show the Midway to be a complex group of sediments deposited in environments ranging from deltaic to bathyal.

Sedimentary rocks of the Midway Group crop out along the northern and western edges of the Rio Grand embayment. Siltstones deposited as a beach occur in the northwest corner of the Rio Grande embayment in Uvalde County, Texas. To the east and south, richly fossiliferous carbonate rocks indicate a nearshore shallow-marine environment. Basinward, the Midway Group grades into shale deposited on the shallow continental shelf. Sandstones, up to 10 ft (3 m) thick, occur intermittently throughout the shale. These shallow-marine sands are most likely derived by longshore currents paralleling the coast.

Sandstone in the Midway is increasingly abundant toward the shelf edge near Laredo, Texas. The sand was probably deposited as barrier islands and shallow-marine shelf sands. The source of the sand was probably to the east. Significant quantities of gas have been discovered in these sandstones near Laredo in both the United States and Mexico.

Recent gas discoveries have been made in the Midway rocks of eastern Texas which were deposited in deltaic to bathyal environments. It appears that a delta prograded over the shallow continental shelf, and sediments were deposited on the shelf edge and upper slope. Sands from the delta complex were probably carried by longshore currents to the south and deposited near the shelf edge in the vicinity of Laredo.

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Two Controls of Sand-Wave Size: Dynamic Equilibrium Processes and Kinematic Depositional-Erosional Processes

Studies in flumes and estuaries have shown that the average size of dunes or sand waves in equilibrium with the flow that generated them is controlled primarily by flow velocity, depth, and sediment size. Equilibrium sand-wave height and wavelength increases with flow velocity, for a constant depth and sediment size, until flows become transitional with the upper flat-bed phase.

Additional non-equilibrium processes operate at a site of deposition. Sand is deposited on lee slopes of sand waves more rapidly than it is eroded from stoss slopes. The balance of the sand, that part deposited at the base of lee slopes but not subsequently eroded at the upstream stoss slopes, is left behind. Bed forms decrease in size as sand is thus removed from circulation unless either (1) sediment transported in suspension from outside the depositional area is trapped by sand waves as rapidly as sediment is removed, or (2) sand waves merge to form larger ones.

Sand waves in nonequilibrium flows, where neither of these two processes operates, should show a change in cross-sectional area proportional to the change in the sediment-transport rate. Sand-wave cross-sectional area is observed to be proportional to the sediment-transport rate raised to a power of 0.5 to 2 in equilibrium flows that are not transitional with upper flat beds, and where depth and sediment size are constant. Consequently, where depth is constant, both equilibrium and nonequilibrium processes tend to keep sand-wave cross-sectional area approximately proportional to sediment-transport rates. Where depth changes downcurrent, the two processes may conflict, and the response of the bed will have to be determined experimentally.

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Mechanisms Controlling Porosity in Red River (Upper Ordovician) Carbonate Reservoir, Cabin Creek Field, Montana

Cabin Creek field, on the Cedar Creek anticline in southeastern Montana, produces oil from Mississippian, Silurian, and Ordovician carbonate rocks. The major producing reservoir is the Upper Ordovician Red River Formation.

The Red River of Cabin Creek field is a 500-ft (152 m) thick limestone-dolomite sequence; the upper Red River consists of several cycles of uniformly thick peritidal shelf carbonate rocks. Favorable porosity is restricted to the dolomites; the limestones are nonporous and serve as cap rocks. Porosity and permeability are controlled both by dolomitization and by silica and anhydrite cements. Lateral and vertical variations of dolomitization are mainly responsible for variations in reservoir properties and effective pay thickness. Average porosity is 13%, with a maximum of 25%. Production is from porosity zones in the upper 150 ft (45 m) of the Red River.

Upper Red River limestones consist of biomicrite-wackestones which contain diverse faunal assemblages, and are interpreted as shallow, open-marine shelf deposits. The limestones are pelletal in part, poorly bedded, burrowed, stylolitic, with widespread dolomitic mottling. Producing dolomite zones consist of two distinct facies. The lower facies, interpreted as subtidal, consists of biomicrite-wackestone and skeletal dolomite with moldic porosity. The upper facies, interpreted as intertidal, consists of wavy-laminated, unfossiliferous, microcrystalline dolomite with intercrystalline porosity. The upper facies is abruptly truncated by overlying pelletal limestone and (locally) thin black shale. Con-