depths of 500 ft (152 m) or less. The gas-bearing aquifer is underlain by gas-bearing, low-permeability sandstones of Early Cretaceous age that form the Wattenberg field. It contains reserves of natural gas at depths of 7,500 to 8,500 ft (2,285 to 2,590 m) but requires massive hydraulic stimulation to provide economic flow rates.

Gases from the water wells are generally dry ($C_1/C_{1-5} > 0.99$) and enriched in the light isotope ^{12}C ($\delta^{13}C_1$ values range from -73 to -70 ppt). These gases are interpreted to be of biogenic origin that are being or have been generated in an anoxic, sulfate-free environment within the aquifer system. The probable source of carbon is the organic matter originally deposited with the Upper Cretaceous sediments.

In an area north of Milton Lake, coinciding with a region containing higher amounts of dissolved sulfate in ground water, methane is generally not detected in ground water. Water from wells in this region has a putrid odor and probably contains hydrogen sulfide resulting from microbial sulfate reduction. The absence of methane is probably explained by the fact that methanogenesis generally is not concurrent with the process of sulfate reduction and usually begins after dissolved sulfate is removed from ground water.

Gases from the Wattenberg field, coming from considerably greater depths than those from the water wells, are distinctly different from most of the water-well gas in both chemical and isotopic composition. They contain significant amounts of heavier hydrocarbons (C_1/C_{1-5} values range from 0.83 to 0.87) and are isotopically heavier ($\delta^{13}C_1$ values range from -49 to -43 ppt). The chemical and isotopic composition of the gases indicate that they are thermogenic in origin and were generated by thermal cracking processes during intermediate stages of thermal maturity in the deeper part of the Denver basin. This interpretation is consistent with the level of maturation determined by source rock studies.

Occasionally, gases from water wells are almost identical in both chemical and isotopic composition to gases produced from the underlying Wattenberg field in the immediate area. These gases are also interpreted to be of thermogenic origin and probably migrated from deeper reservoirs.

RICH, DAVID W., Sabine Production Co., Denver, CO

Porosity Types in Limestones

A suite of selected oolitic limestones ranging in age from Devonian to Pleistocene was studied petrographically with light microscopy and SEM observation of resin pore casts, and petrophysically with measurements of porosity, gas and liquid permeability, and with mercury injection capillary pressure curves. A new genetic classification of porosity types and related processes in oolitic limestones is presented which is based on the chronological order of their occurrence in the natural history of the rock, following the terminology and concepts of Choquette and Pray.

The 11 subdivisions of the proposed classification are: *Primary Porosity*: pre-deposition, deposition; *Secondary Porosity*: eogenetic dissolution, eogenetic drusy cementation, eogenetic compaction, mesogenetic cementation, mesogenetic dissolution, mesogenetic compaction, late mesogenetic cementation, telogenetic recrystallization and telogenetic dissolution. Furthermore, it is possible to subdivide the investigated samples into five evolutionary stages showing the gradual reduction of primary porosity mainly through cementation, and into six stages showing the modification of secondary porosity mainly through dissolution.

Concurrently, 11 laboratory experiments were performed in which samples of a tightly cemented Mississippian oolitic calcarenite were submitted to simulated burial conditions, and undersaturated carbonic acid solution was forced to pass through them. The result was selective dissolution of the ooid cortical layers, with the sparite cement preserved undissolved. It is concluded that oomoldic porosity can result from textural variation between components and does not necessarily imply that the ooids had an unstable mineralogy.

The understanding of the complex time and space relationships between the different types of porosity in oolitic limestones is critical for reconstructing their depositional-diagenetic history and for evaluating their economic importance as potential hydrocarbon reservoirs.

RINE, J. M., and R. W. TILLMAN, Cities Service Co., Exploration and Production Research, Tulsa, OK and W. L. STUBBLEFIELD, National Oceanic and Atmospheric Administration, Miami, FL

Lithologic Comparison of Two Linear Sand Ridges from Nearshore and Middle Portions of New Jersey Continental Shelf, U.S.A.

Two linear sand ridges from the nearshore and middle portions of the New Jersey continental shelf were sampled using a vibracore system and box corer. Lithologic descriptions were made of the cores based on epoxy peels, X-ray radiographs, and impregnated core slabs. The cores were sampled for grain-size analysis. Box cores sampled lithologies and relative abundance of physical and biogenic structures found in the upper 25 to 46 cm (9.8 to 18.1 in.) of the sediment. Bottom topographies were established using 3.5 kHz data.

The nearshore sand ridge sampled (74°22′W, 39°19′N) exceeded 5 km (3 mi) in length and ranged up to 2 km (1.2 mi) in width and had a relief of 6 to 10 m (20 to 33 ft). A mid-shelf ridge (74°08′W, 39°09′N), nearly 4 km (2.5 mi) long and up to 1 km (0.6 mi) wide, with a relief of 10 to 11 m (33 to 36 ft) was also studied.

The vibracores averaged 6 m (20 ft) of penetration and in excess of 95% recovery, and although partially deformed as a result of the coring procedure, revealed three general lithologic units which may be common to both ridges.

At the base of many of the cores, nonskeletal mud and poorly sorted sand are present; some of the interlayered sands and muds contain laminations and abundant pebbles. Overlying this unit in the nearshore ridge is a shell-rich mud and sand interval that is for the most part massive (bioturbated). This lithology was also recovered in one core from the middle shelf ridge. C-14 dates taken from the shell-rich units indicate that the middle and nearshore ridges are of different ages.

The top unit in all the cores is a fine to medium-grained sand, here termed the upper ridge sand. This unit, similar in both ridges, consists of stacked beds ranging from 3 to 71 cm (1.2 to 28 in.) in thickness, and generally coarsens upward. This unit in the nearshore ridge system has a slightly coarser mean grain-size range (150 to 400 μ) than the mid-shelf ridge (130 to 350 μ). Both ridges contain some alternating laminated and nonlaminated bed sequences. C-14 dates from the upper ridge sand units are indecisive in establishing whether the upper units in the nearshore and middle shelf are time equivalent. Nearshore box cores which only penetrate the upper ridge sand from 25 to 46 cm (9.8 to 18.1 in.) contain well-developed ripples and cross-bedding; physical structures dominate. The middle shelf box cores are dominantly burrowed sand and are muddier than nearshore box cores.