

Geochemistry of Oil-Field Waters from Northern Gulf of Mexico Basin

Detailed chemical analyses of 120 formation-water samples from 25 oil and gas fields in coastal Texas and Louisiana show that the salinity of water in the geopressed zones ranges from about 10,000 to 270,000 mg/L dissolved solids and may be higher or lower than the salinity of water in the overlying normally pressured zones. All the waters are of the Na-Cl type; Na generally constitutes more than 90% of the total cations and Cl constitutes more than 90% and up to 99.8% of the total anions. Ca concentrations increase with increasing salinity and bicarbonate increases with decreasing Ca concentrations. Magnesium and sulfate concentrations are generally low. The concentrations of copper, lead, and other heavy metals are generally less than 10 $\mu\text{g/L}$.

Hydraulic fluid potentials and δD and $\delta^{18}\text{O}$ values indicate that the formation waters are most probably modified connate waters representing the original marine water of deposition. The chemistry of these waters, however, is markedly different from that of ocean water. The differences in composition are shown to result from (1) interaction of the waters with evaporites, (2) interaction of the waters with minerals and organic matter present in the enclosing sedimentary rocks, and (3) membrane-squeezing and membrane-filtration properties of shales.

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Stable Carbon Isotopes in Oil-Field Waters and Origin of Carbon Dioxide

The $\delta^{13}\text{C}$ values of dissolved HCO_3^- in 75 water samples from 15 oil and gas fields were determined in a study of the source of carbon dioxide of the dissolved species and the carbonate cements that modify the porosity and permeability of many petroleum reservoir rocks. The fields are located in the San Joaquin Valley, California, and the Houston-Galveston and Corpus Christi areas of Texas. The reservoir rocks are sandstones ranging in age from Eocene through Miocene. The $\delta^{13}\text{C}$ values of total HCO_3^- indicate that the carbon in the dissolved carbonate species and carbonate cements is mainly of organic origin.

The range of $\delta^{13}\text{C}$ values for the HCO_3^- of these waters is -20 to 28 permil relative to the PDB standard. This wide range of values is explained by three mechanisms. Microbiologic degradation of organic matter appears to be the dominant process controlling the extremely low and high $\delta^{13}\text{C}$ values (-20 to 28 permil) of HCO_3^- in the shallow production zones where the subsurface temperatures are less than 80°C . The extremely low $\delta^{13}\text{C}$ values are obtained in waters where the concentration of SO_4 is more than 25 mg/L and probably result from the degradation of organic acid anions by sulfate-reducing bacteria ($\text{SO}_4^{2-} + \text{CH}_3\text{COO}^- \rightarrow 2\text{HCO}_3^- + \text{HS}^-$). The high $\delta^{13}\text{C}$ values probably result from the degradation of acetate by methanogenic bacteria ($\text{CH}_3\text{COO}^- + \text{H}_2\text{O} \rightleftharpoons \text{HCO}_3^- + \text{CH}_4$).

For samples from production zones with subsurface

temperatures greater than 80°C , thermal decarboxylation of short-chain aliphatic acid anions (principally acetate) to produce CO_2 and CH_4 is probably the major source of CO_2 . The $\delta^{13}\text{C}$ values of HCO_3^- for waters from zones with temperatures greater than 100°C result from isotopic equilibration between CO_2 and CH_4 . At these high temperatures, $\delta^{13}\text{C}$ values of HCO_3^- decrease with increasing temperatures and decreasing concentrations of these acid anions.

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Deposition of Marble Falls Formation, Central Texas

The Marble Falls Formation (Lower Pennsylvanian) records normal marine conditions and widespread limestone deposition over the Llano uplift and the adjacent Concho platform in Texas. Examination of depositional environments of the outcropping Marble Falls facilitates interpretation of the oil-producing Lower Pennsylvanian shelf and shelf-edge carbonate rocks along the western margin of the Fort Worth basin.

Most of the outcropping Marble Falls can be divided into two units separated by an unconformity. Lower Marble Falls is entirely Morrowan. Upper Marble Falls becomes younger westward: Morrowan in the east and Atokan in the west.

Marble Falls deposition began with establishment of an open marine platform centered at the Llano uplift. Incipient calcarenite shoals developed at some slight break in slope. The northeast part of the platform resembled the modern Bahamian Platform, although platform-off platform relief was less than 9 m. Platform margins were approximately coincident with present outcrops on the north and east sides of the Llano uplift.

The upper Marble Falls was deposited primarily as algal buildups and calcarenite shoals and as shale and spiculitic biomicrite in topographic lows. While the older lower Marble Falls Platform was subaerially exposed, deposition continued on the off-platform shelf adjacent to the rapidly filling Fort Worth basin. Progressive subsidence of the old platform allowed these facies to onlap the erosional surface. Strawn deltas simultaneously prograded across the upper Marble Falls shelf from the east. Marine energy levels and depositional relief were less than during deposition of the lower Marble Falls.

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Statfjord Field, North Sea Giant

Statfjord, the largest single oil field in the North Sea, is located on the United Kingdom-Norwegian boundary between 61 and $61^\circ 30'$ N lat. About 11% of the field extends into United Kingdom waters. Its discovery, in March 1974, was based on interpretation of seismic reflection surveys and extrapolation of a productive regional trend. Two principle sandstone reservoirs, Middle Jurassic Brent and Lower Jurassic to Upper Triassic Statfjord, contain reserves on the order of 3 billion bbl within a productive area of approximately 20,000 acres (8,094 ha.). Reservoir properties are excellent with permeabilities in darcys. The field extends northeastward 15.5 mi (24.9 km) and averages 2.5 mi (4 km) in width.