The Codell Sandstone Member of the Carlile Shale is a new exploration target for oil and gas in the northern Denver basin. The Codell interval ranges in thickness from a wedge edge to approximately 100 ft (30.5 m), the average being 15 to 20 ft (4.5 to 6.1 m). The Codell is well developed in the southern Denver basin, is absent in a broad northeast-trending area in the central Denver basin, and is sporadically developed in the northern Denver basin.

The variation in geographic distribution and thickness results from regional unconformities at the base and top of the Codell. The Carlile Shale (50 to 200 ft, 15.3 to 61 m), in the Denver basin and marginal outcrop area, has four members which, in ascending order, are the Fairport Chalk, Blue Hill Shale, Codell Sandstone, and Juana Lopez Limestone. The unconformity at the base of the Codell Sandstone member has a hiatus which increases in magnitude to the west across the basin. The sandstone is transitional with the underlying Blue Hill in central Kansas, but overlies Fairport equivalents in most of the Denver basin and the underlying Greenhorn Formation along the northwest flank of the basin. The unconformity at the top of the Codell places the Fort Hays Limestone Member of the Niobrara in erosional contact with either the thin (1 to 3 ft, 0.3 to 0.9 m) Juana Lopez or the Codell.

Outcrop and core studies clearly show three types of sandstones which developed during sea level changes in late Turonian and early Coniacian time. The Codell is related to processes in three different environmental settings:

1. The marine (or shoreline) bars have a transitional base with the underlying Blue Hill Shale Member. The sandstones have good porosity and permeability and a sheetlike distribution. These sandstones occur in Kansas and the southern Denver basin and are not currently productive of petroleum.
2. Tight bioturbated and reworked marine shelf sandstones generally are without a central-bar facies. These sands may also be associated with thin, irregular, relict, or palimpsest shelf deposits which locally are coarse grained and conglomeratic. Recent petroleum discoveries have been made in this sandstone facies in the west-central part of the Denver basin. Productive depths range from 4,000 to 8,000 ft (1,219 to 2,438 m). Net pay ranges from 3 to 25 ft (0.9 to 7.6 m). Porosities range from 8 to 24%. Permeabilities are generally less than 0.5 md. Trapping of petroleum appears to be stratigraphic.
3. Tight sandstones of marine (?) origin fill large scour depressions (valleys?) which were eroded into underlying Fairport or Greenhorn strata. Although these sandstones are the thickest found in the Codell, they are generally tight and occur mainly in the Wyoming portion of the basin. Only minor production has been found in this facies.

Variation in thickness and reservoir quality is related to original environmental control, paleostructure which locally influenced the unconformities, fracturing, and diagenesis. Where fracturing is important to reservoir quality, the Codell and overlying Fort Hays Limestone may be a co-mingled reservoir.

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Potential New Sources of Water for Energy Resource Development in Northwestern Colorado

Northwestern Colorado contains the largest reserves of shale oil in the world and the coal beds of the area are some of the most extensive in the United States. Development of the oil shale and coal may require large supplies of water and may therefore create additional demands on the surface-water resources of the region. The availability of ground water, however, is not well known. The Eocene Green River Formation in the Piceance basin has been estimated to contain several million acre-ft of ground water that generally is chemically suitable for most uses, and the ground-water resources of all northwestern Colorado probably are much larger.

Preliminary studies indicate that large quantities of water may be available in the Mississippian Leadville Limestone on the southern, western, and northern flanks of the White River Uplift. The Leadville is about 200 ft (6 m) thick, has solution openings, and is very permeable at least in places. Much of this permeability, as evidenced by the extensive paleokarst topography throughout most of western Colorado, had developed by the beginning of the Pennsylvanian Period. The Leadville yields water to at least 100 springs and probably forms a major aquifer system that would yield calcium carbonate type water to shallow wells on the flanks of the White River Uplift. The quantity of ground water in storage in the Leadville Limestone in the western one-half of the White River Uplift area may exceed 10 million acre-ft. Exploratory drilling and testing of the Leadville Limestone to depths of 2,000 ft (600 m) are needed to evaluate the potential of this aquifer for providing large supplies of water.

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Solubility of Crude Oil in Methane as Function of Temperature and Pressure

The solubility of a whole crude oil (44° API) in methane has been measured (with water present) at temperatures of 50° to 250°C and pressures of 740 to 14,852 psi, as have the solubilities of two high molecular weight petroleum distillation fractions at temperatures of 50° to 250°C and pressures of 4,482 to 25,266 psi. This was done to evaluate the gaseous solution mechanism for primary petroleum migration. Both increases in pressure and temperature increase the solubility of crude oil and petroleum distillation fractions in methane, the effect of pressure being greater than that of temperature.

The data of this study, compared to previous work in dry systems, show that the presence of water in the system greatly increases the solubility of crude oil in methane. The presence of water also drastically lowers the temperature and pressure conditions required for cosolubility.

Qualitative analyses of the crude oil solute samples showed that with increases in temperature and especially pressure, the solute condensate became essentially identical to the original crude oil. The n-paraffin distributions (as well as overall composition) of the solute condensates are controlled by the temperature and pressure of solution and exsolution, as well as by the composition of the original starting material. It appears possible that primary migration of gaseous solution could "strip" a source rock of crude oil-like components leaving behind a bitumen totally unlike the migrated crude oil. The data of this study demonstrate that previous criticisms of primary petroleum migration by gaseous solution are invalid: that primary migration by gaseous solution cannot occur based on the inadequacy of methane to dissolve sufficient volumes of crude oil or to dissolve the highest molecular weight components of petroleum (tars and asphaltenes).

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