



Regional patterns in the geochemistry of oil-field water, southern San Joaquin Valley, California, USA



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ABSTRACT

Chemical and isotopic data for water co-extracted with hydrocarbons in oil and gas fields are commonly used to examine the source of the formation water and possible impacts on groundwater in areas of oil and gas development. Understanding the geochemical variability of oil-field water could help to evaluate its origin and delineate possible contamination of shallow aquifers in cases where oil-field water is released to the environment. Here we report geochemical and multiple isotope (H, C, O, Sr, Ra) data from 22 oil wells, three sources of produced water that are disposed of in injection wells, and two surface disposal ponds in four oil fields in the southern San Joaquin Valley, California (Fruitvale, Lost Hills, North and South Belridge). Correlations between Cl and $\delta^{18}\text{O}$, as well as other ions, and gradual increases in salinity with depth, indicate dilution of one or more saline end-members by meteoric water. The saline end-members, represented by deep samples (610 m–2621 m) in three oil-bearing zones, are characterized by Na–Cl composition, near-seawater Cl concentrations (median 20,000 mg/L), enriched $\delta^{18}\text{O}$ – H_2O (median 3.4‰), high ammonium (up to 460 mg-N/L), and relatively high radium activity ($^{226}\text{Ra} + ^{228}\text{Ra} = 12.3$ Bq/L). The deepest sample has low Na/Cl (0.74), high Ca/Mg (5.0), and low $^{87}\text{Sr}/^{86}\text{Sr}$ (0.7063), whereas the shallower samples have higher Na/Cl (0.86–1.2), Ca/Mg near 1, and higher $^{87}\text{Sr}/^{86}\text{Sr}$ (~0.7083). The data are consistent with an original seawater source being modified by various depth and lithology dependent diagenetic processes. Dilution by meteoric water occurs naturally on the east side of the valley, and in association with water-injection activities on the west side. Meteoric-water flushing, particularly on the east side, results in lower solute concentrations (minimum total dissolved solids 2730 mg/L) and total radium (minimum 0.27 Bq/L) in oil-field water, and promotes biodegradation of dissolved organic carbon and hydrocarbon gases like propane. Acetate concentrations and $\delta^{13}\text{C}$ of dissolved inorganic carbon indicate biogenic methane production occurs in some shallow oil zones. Natural and human processes produce substantial variability in the geochemistry of oil-field water that should be considered when evaluating mixing between oil-field waters and groundwater. The variability could result in uncertainty as to detecting the potential source and impact of oil-field water on groundwater.

1. Introduction

Substantial recent research has examined the potential effects of oil and gas production activities on groundwater quality (Kharaka and Otton, 2007; Darrah et al., 2014; Humez et al., 2016; Schloemer et al., 2016; Wen et al., 2016; McMahon et al., 2017; Nicot et al., 2017; Zheng

et al., 2017; Kulongoski et al., 2018). Quantifying mixing between groundwater and fluids from hydrocarbon reservoirs requires an understanding of the geochemical signatures of the end-member waters. Oil-field water consists of a complex mixture of inorganic and organic chemicals; therefore, measuring geochemical tracers with a range of chemical and physical properties could be advantageous to

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