Available online at www.sciencedirect.com
SCIENCE DIRECT®
Journal of Hydrology 317 (2006) 202–220
Journal of Hydrology
www.elsevier.com/locate/jhydrol

Hydrochemical-isotopic tendencies to define hydraulic mobility of formation water at the Samaria-Sitio Grande oil field, Mexico

Peter Birkle[a,*], Marisela Angulo[b], Santos Lima[b]

[a]*Instituto de Investigaciones Eléctricas, Gerencia de Geotermia, Av. Reforms 113, Col. Palmire, Cuernavaca, Morelos, México*
[b]*PEMEX-Exploración y Producción, Diseño de Explotación Cactus-Níspero Sitio Grande, Zona Industrial S/N, Reforma, Chiapas, México*

Received 5 January 2004; revised 10 May 2005; accepted 25 May 2005

Abstract

The chemical (major elements) and isotopic (^{2}H, ^{3}H, ^{13}C,^{18}O) composition of formation water is presented for the Sitio Grande oilfield, SE-Mexico, extracted from 28 production wells from the carbonate reservoir at a depth between 3585 and 4545 m.b.s.l. The linear $\delta^{18}O/\delta D$-trend explains the formation of reservoir water as part of three subsequent stages: a) the evaporation of marine water at the surface, causing enrichment of both, $\delta^{18}O$ and δD-values, b) a reversal trend with decreasing $\delta^{18}O$-and δD-ratios by the extreme evaporation of brines and, c) the subsequent mixing with isotopically depleted meteoric water.

A SW-NE directed flow direction of deep groundwater systems is indicated by parallel-oriented isoline trends of stable isotope ratios and conservative elements, supported by the dominance of parallel directed microfractures and extensional faults, and by tracer test results. The arrival of artificial tritium, three years after tracer injection in the well SG-85, reflects a) the importance of long-term monitoring of tracer tests, and b) an estimated flow velocity of 2.2×10^{-5} m/s. As the arrival of the tracer was detected exclusively in three production wells towards the SW of the injection site, lateral migration of groundwater occurs mainly along defined, channel-like conducts with a narrow dispersion angle of 39 °. Surface water, injected as part of an enhanced oil recovery program, was not detected in the production zone by chemical and isotopic methods. This fact is not a proof for lacking hydraulic conductivity, as the large reservoir size and the termination of the injection program in 1996 could have caused a complete dilution of the injected fluids.

Restricted vertical flow movement between reservoir layers and insignificant temperature-dependent reaction processes is indicated by the heterogeneous distribution of $\delta^{18}O$-and Cl-values throughout the groundwater column of most reservoir zones. Little influence of water-rock interaction, such as Ca-Mg exchange processes between formation water and host rock is reflected by the heterogeneous abundance of calcium in the liquid phase in both, dolomite-free and dolomitized carbonate host rock layers.

Keywords: Oil reservoir; Formation water; Stable isotopes; Tracer tests; Hydraulic communication; Geochemical processes

* Corresponding author. Fax: +52 777 362 38 04.
E-mail address: birkle@iie.org.mx (P. Birkle).

0022-1694/$ - see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.jhydrol.2005.05.018

1. Introduction

The Activo Samaria-Sitio Grande oil field is located in the southern production region (Región Sur) of the Mexican National Oil Company (PEMEX) between the States of Tabasco and Chiapas. The production area with a lateral extension of 200 km^2 is subdivided into the Cactus, Níspero, Río Nuevo and Sitio Grande camps (Fig. 1), producing from a depth between 3500 and 4500 mbsl. Since 1972, a total of 116 drilled wells produced a total of 522.6 Millions of barrels (MMBLS) of crude oil and 952,600 Millions of cubic feet of gas with an average daily production of 16,103 barrels of crude oil and 31.21 Millions of cubic feet of gas (up to February 2001) (Aguilar, 2001a). An additional volume of 82.16 MMBLS of produced formation water, representing 9.5% of the total volume of exploited reservoir fluids, causes economic losses by decreasing oil production rates.

In general, formation water is distributed throughout the reservoir. Major water accumulations are observed in the N-and E-part of the Níspero zone and S-and SE-section of the Cactus reservoir (water invaded wells in Fig. 2), characterized by rising water/oil contact levels and the necessity to close water-flooded production wells. Some of the invaded

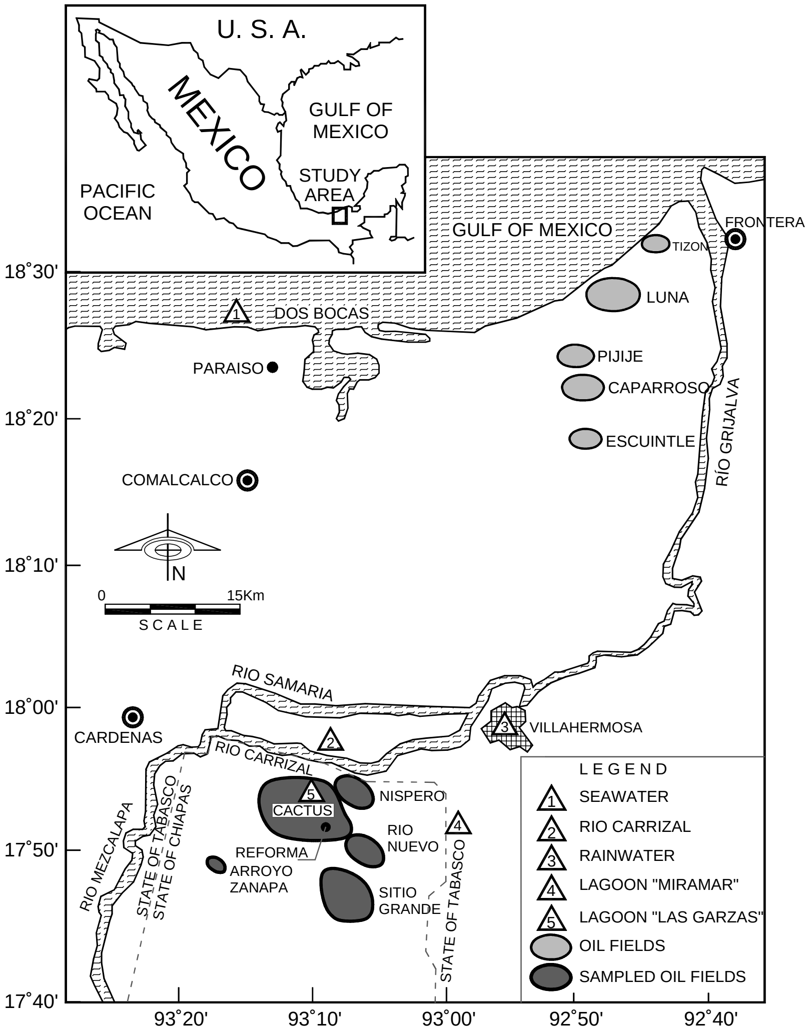

Fig. 1. Regional map of SE-Mexico with studied oil fields and sampled surface samples.