STRONTIUM ISOTOPE (\(^{87}\text{Sr}/^{86}\text{Sr}\)) CHEMISTRY IN PRODUCED OIL FIELD WATERS: THE IEA CO\(_2\) MONITORING AND STORAGE PROJECT

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Abstract: EnCana’s CO\(_2\) injection EOR project at Weyburn Saskatchewan (Canada) is the focal point of a multi-faceted research program, sponsored by the IEA GHG R&D and numerous international industrial and government partners. More than yearly strontium isotope, trace element and dissolved gas surveys were conducted by INGV in conjunction with the thrice yearly borehole fluid sampling trips performed by the Canadian partners. This paper focuses on the Sr isotope monitoring. Approximately 25 samples were collected over three years for \(^{87}\text{Sr}/^{86}\text{Sr}\) analyses. At Weyburn, a water-alternating-gas (WAG) EOR technique is used to inject water and CO\(_2\) into the Mississippian Midale reservoir. \(^{87}\text{Sr}/^{86}\text{Sr}\) ratios for produced fluids fall between 0.7077 and 0.7082, consistent with published values for Mississippian fluids and carbonate minerals. A small \(^{87}\text{Sr}/^{86}\text{Sr}\) component of this produced fluid is derived from waters of the Cretaceous Mannville aquifer, which has been used for water-flooding EOR since 1959. The progressively more positive Sr isotope trend from 2001 to 2003 may be due to: 1) a smaller Mannville aquifer component in the water flooding process; and/or 2) the dissolution of Mississippian host rocks during the ongoing CO\(_2\) injection. Evidence that \(^{87}\text{Sr}/^{86}\text{Sr}\) values are approaching those of Mississippian host-rock values may point towards zones of carbonate dissolution as a result of continuing CO\(_2\) injection. This hypothesis is strengthened by i) \(^{81}\text{C}\) data; ii) preliminary “gross composition” of dissolved gases (H\(_2\)S, CO\(_2\), CH\(_4\), He, H\(_2\)) and iii) by trace elements data.

Key words: CO\(_2\) geological storage monitoring, EOR Weyburn oil field brines, Sr isotopes.

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1. INTRODUCTION

The Weyburn oil field, presently owned and operated by EnCana Resources, is located approximately 120 km SE of Regina (Canada). After the discovery of the field in 1954 and its primary depletion in middle 1964, other tools were exploited, such as horizontal wells and water flooding. Since August 2000, CO₂-Enhanced Oil Recovery (EOR) has also been performed, with around 5000 tons/day of CO₂ being injected within the Mississippian Midale Beds oil reservoir at a depth of 1300-1500 m. The “Phase A1” early injection area currently comprises around 90 oil producers, 30 water injectors and 30 CO₂ injection wells (Wilson & Monea, 2004; Tian et al., 2004). Recent studies (Tian et al., 2004) stated that after 3 years of CO₂ injection oil production increases have been relatively slow, with responses only in 30 wells and increases in the average oil production per well from around 6 to 11 m³/day and an increase in the Gas/Oil Ratio of the Phase A1 area from around 20 to 33 m³/m³. The CO₂-storage efficiency decreases with an increase in the amount of CO₂ produced together with oil and water. Apart from industrial exploitation, the EnCana CO₂ injection EOR project at Weyburn is the focal point of a multi-faceted research program to “co-optimise” CO₂-EOR production and CO₂-geological storage within the framework of the Kyoto Protocol. This work is sponsored by the IEA GHG R&D and numerous international industrial and government partners, including the European Community (Riding & Rochelle, 2005).

Together with reflection seismic monitoring of the evolution of CO₂ distribution at depth (recent papers on http://www.uregina.ca/ghgt7/), the geochemical monitoring tools are mainly: i) soil gas geochemistry, to discover and monitor possible CO₂ surface leakage (Jones et al., 2005) - this tool is particularly important in geo-dynamic areas where the risk assessment of CO₂ geological storage sites must be very accurate (Quattrocchi, 2003, 2004); and ii) deep-reservoir fluid geochemistry (Gunter et al., 2000; Quattrocchi et al., 2004; Perkins et al., 2004, Shevelier et al. 2004). In the Weyburn case, we are dealing with a 3-phase reservoir (water-gas-oil) requiring complex chemical equilibria, diffusion and thermodynamic models (Nitao, 1996; Czernichowski-Lauriol et al., 2001; Quattrocchi et al., 2003; Chapoy et al., 2004; Tian et al., 2004, Le Nidre and Gaus, 2004).

INGV has conducted geochemical monitoring experiments from pre-injection (“Baseline”, B0, August 2000) to the present day (September, 2004, see Appendix). The purpose of produced fluid and gas monitoring was to identify and ultimately quantify water-gas-rock reactions in the reservoir; in this paper we are focusing on the Sr isotope results. These data may help in reconstructing the evolution of the fluid reservoir prior to and during the injections stages (after Sunwall and Pushkar, 1979; Smalley et al., 1988). At