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Spectral remote sensing for onshore seepage characterization: A critical overview

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Abstract

In this article, we overview the application of spectral remote sensing data collected by multi-, and hyperspectral instruments in the visible-near infrared (VNIR), short-wave infrared (SWIR), and longwave infrared (LWIR) wavelengths for characterization of seepage systems as an exploration indicator of subsurface hydrocarbon (HC) accumulations. Two seepage systems namely macro-, and microseepage are recognized. A macroseepage is defined as visible indications of oil and gas on the surface and in the air detectable directly by a remote sensing approach. A microseepage is defined as invisible traces of light HCs in soils and sediments that are detectable by its secondary footprints in the strata, hence an indirect remote sensing target. Based on these broad categories, firstly, a comprehensive set of well-described and reliable remote sensing case studies available in the literature are thoroughly reviewed and then systematically assessed as regards the methodological shortcomings and scantiness in data gathering, processing, and interpretation. The work subsequently attempts to go through seminal papers published on microseepage concept and interrelated geochemical and geophysical techniques, exhumed HC reservoirs, lab-based spectroscopic analysis of petroleum and other related disciplines from a remote sensing standpoint. The aim is to enrich the discussion and highlight the still unexplored capabilities of this technique in accomplishing exploration objectives using the concept of seepage system. Aspects of seepage phenomenon in environmental pollution and uncertainties associated with their role in global warming are also underlined. This work benefits from illustrative products generated over two study areas located in the Ventura Basin, State of California, USA and the Tucano Basin, State of Bahia, Brazil known to host distinctive macro-, and microseepage systems, respectively. In conclusion, we recommend further research over a diverse range of seepage systems and advocate for a mature conceptual model for microseepage phenomenon.

Keywords: seepage; microseepage system; hydrocarbon; gas-plume; onshore; spectroscopy; remote sensing; exploration; environment; methane budget.

1. Introduction

A large portion of hydrocarbon (HC) traps is not perfectly sealed and thus, their accumulations leak to the surface over time. When the surface manifestation of oil and gas is clearly visible by naked eye, it is termed as *macroseepage*, whereas the traces of invisible light HCs in near-surface soils and sedimentary rocks (sediments henceforth), which are only detectable by analytical methods and careful geochemical sampling, is called *microseepage* (Horvitz, 1985; Tedesco, 1995). Historically, seepage and HC accumulations have been tied together and, as a result, a large number of the world's oil and gas fields have been explored by drilling in the immediate area of a seep (Hunt, 1996; Yergin, 1992). In modern exploration programs, *macroseeps* are typically regarded as direct clues for the existence of mature source rock(s) and a compelling evidence for the formation of a petroleum system in a given sedimentary basin (Magoon and Beaumont,