Journal of Unconventional Oil and Gas Resources 13 (2016) 1–31

Contents lists available at ScienceDirect

Journal of Unconventional Oil and Gas Resources

journal homepage: www.elsevier.com/locate/juogr

Review

Organic geochemical applications to the exploration for source-rock reservoirs – A review

Joseph A. Curiale [a,*], John B. Curtis [b]

[a] Chevron Energy Technology Company, United States
[b] Colorado School of Mines & GeoMark Research, Ltd., United States

ARTICLE INFO

Article history:
Received 13 February 2015
Revised 11 October 2015
Accepted 27 October 2015
Available online 7 November 2015

Keywords:
Source rock
Petroleum geochemistry
Source-rock reservoirs
Organic matter
Geochemical methods

ABSTRACT

Source-rock reservoirs are fine-grained petroleum source rocks from which liquid and gaseous hydrocarbons may be produced following fracture stimulation. A major factor that allows such a source rock to function well as a reservoir is its organic matter – specifically the quantity, quality and thermal maturity of that organic matter as it occurs within the source-rock reservoir. Here we review the published literature to assess the current status of geochemical measurement and data interpretation of organic matter in these reservoirs, and how workers have applied this information in the exploration for this reservoir type. Our focus is on the chemical and geochemical characteristics of source-rock reservoirs, with emphasis on the isotopic and molecular characteristics of their hydrocarbon fluids and solid organic matter. Special consideration is given to geochemical analytical methods particularly appropriate to the organic matter in this reservoir type. Our discussions of published studies focus on three areas: (a) source rock characteristics – organic matter quantity, quality and maturity; (b) thermally-induced cracking of kerogen, oil, condensate and gas; and (c) natural gas stable carbon isotopic anomalies often observed in shale plays. Conceptual approaches and practical applications are addressed in equal measure, and our assessment of future directions and unsolved problems is provided.

Contents

* Corresponding author at: Chevron Energy Technology Company, 1500 Louisiana Street, Houston, TX 77002, United States.
E-mail address: joecuriale1@gmail.com (J.A. Curiale).

http://dx.doi.org/10.1016/j.juogr.2015.10.001
2213-3976/

Introduction and concepts

Overview

The presence and character of the source rock for oil and gas is the most critical risk element in petroleum exploration, whether the target is a conventional play or an unconventional source-rock reservoir play. It is the only element which, if absent, excludes the occurrence of oil or gas. The conceptual shift from dealing with four distinct risk elements – source, reservoir, trap, seal – to considering source and reservoir as a unified component in so-called shale plays has revolutionized 21st century petroleum exploration, and with it the question of organic matter character and distribution in fine-grained rocks.

Source-rock reservoirs contain sufficient organic matter to generate petroleum and sufficient porosity and adsorption sites to retain that petroleum. Terminologies used to describe this type of reservoir and the plays involved have varied considerably over the past decade (Passey et al., 2010, and references cited therein; Cander, 2012). For our purposes, we will use the term "source-rock reservoir" as recently proposed by Hart et al. (2013): "source-rock reservoirs are fine-grained petroleum source rocks... having geomechanical properties that allow those rocks to produce hydrocarbons at economic rates after stimulation by hydraulic fracturing". We intend for this usage to encompass the range from 'pure' unconventional systems (e.g., Barnett gas play) to 'hybrid' systems (e.g., Bakken liquids play) (Williams, 2013). Several lithologies and sub-lithologies satisfy this definition, although the current literature (and industry) focus remains on mudrocks, *sensu stricto* (Passey et al., 2010). While we will use the term "source-rock reservoir" throughout this review, other terms used here will conform to current usage, including common phrases such as "gas shales", "shale plays" and "liquids plays". This review deals with (a) the application of organic geochemistry to the exploration for source-rock reservoirs and (b) the composition of organic matter contained in these reservoirs.

Definitions

We consider petroleum to be an organic molecular continuum encompassing gas, liquid and solid phases. Thus, although we will refer to the chemical composition of individual phases, we generally attempt to treat the organic matter of source-rock reservoirs as part of a continuum, rather than rigorously separating our discussion into play types according to phase.

Furthermore, we consider the origin of petroleum, broadly considered, to be a settled issue: it is a product of thermal generation over geologic time from disseminated organic matter syndepositionally accumulated in sedimentary rocks (Tissot and Welte, 1984; Hunt, 1979). Therefore, while the reader is welcome to investigate proposed origins of gas and oil by catalysis at temperatures below those of thermal scission (Sheiko et al., 2006; Mango et al., 2009; Mango and Jarvie, 2009, 2010) or from abiotic sources, either from the crust or mantle (Etiope and Sherwood Lollar, 2013, and references cited therein), our focus is solely on the thermal origin.

Lastly, we note that terms such as 'asphaltene', 'bitumen' and 'kerogen' are traditionally defined operationally, and in our view they have less relevance inside the rock than after they have been removed from the rock. We will define each term as it arises, and discuss compositions accordingly. We refer to solid organic matter at standard temperatures and pressures (STP: 25 °C and 1 atm) within source-rock reservoirs as either kerogen or solid bitumen. Solid bitumen rendered insoluble in organic solvents (due to elevated temperatures) is termed pyrobitumen, after Abraham (1920).

Scope

The emphasis of this review is narrow: organic chemical and geochemical approaches and their application to exploration for source-rock reservoirs. We will examine the elemental, isotopic and molecular composition of the organic matter in source-rock reservoirs, with a focus on the ultimate impact of its composition on petroleum characteristics. This approach will involve both the solvent-soluble (petroleum, bitumen) and solvent-insoluble (kerogen, pyrobitumen) organic matter in the source-rock reservoir, and the chemical changes that this organic matter undergoes from initial deposition through generation of petroleum.

The confined focus of this review inevitably leaves several subjects out of scope, many of which have been reviewed elsewhere. Although we will mention current plays in the context of discussing specifics of their hydrocarbon charge component, for detailed descriptions of the geology and general petroleum systems of these plays the reader is referred to a wide range of peer-reviewed and gray literature, as well as the summaries in Hart Energy's Unconventional Playbook Series (www.ugcenter.com). Additionally, many play-types designated elsewhere as 'unconventional' are out of scope here. These include tight sands, heavy oil, coal bed methane, tar sands, so-called oil shales, and marine and arctic hydrates. Likewise, and similarly out of scope,