SPRINGER BRIEFS IN EARTH SYSTEM SCIENCES

Manuel E. Pardo Echarte
Osvaldo Rodríguez Morán

Unconventional Methods for Oil & Gas Exploration in Cuba

The Redox Complex

Springer

SpringerBriefs in Earth System Sciences

Series editors

Jorge Rabassa, Ushuaia, Argentina
Gerrit Lohmann, Bremen, Germany
Justus Notholt, Bremen, Germany
Lawrence A. Mysak, Montreal, Canada
Vikram Unnithan, Bremen, Germany

More information about this series at http://www.springer.com/series/10032

Manuel E. Pardo Echarte
Osvaldo Rodríguez Morán

Unconventional Methods for Oil & Gas Exploration in Cuba

The Redox Complex

Springer

Manuel E. Pardo Echarte
Scientific-Research Unit Exploration
Centro de Investigaciones del Petróleo
El Cerro, La Habana
Cuba

Osvaldo Rodríguez Morán
Scientific-Research Unit Exploration
Centro de Investigaciones del Petróleo
El Cerro, La Habana
Cuba

There are instances where we have been unable to trace or contact the copyright holders. If notified the publisher will be pleased to rectify any errors or omissions at the earliest opportunity.

ISSN 2191-589X ISSN 2191-5903 (electronic)
SpringerBriefs in Earth System Sciences
ISBN 978-3-319-28015-8 ISBN 978-3-319-28017-2 (eBook)
DOI 10.1007/978-3-319-28017-2

Library of Congress Control Number: 2015958320

© The Author(s) 2016
This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made.

Printed on acid-free paper

This Springer imprint is published by SpringerNature
The registered company is Springer International Publishing AG Switzerland

Foreword

As a rule worldwide, the first, and many of the most important oil discoveries have been made following the method of drilling near springs, asphalt deposits or oil seeps, based on the assumption that some hydrocarbons of an oil-gas accumulation migrate to the surface vertically. Special attention deserves the known microleakages or microseeps given its relationship with well-preserved hydrocarbon accumulations at depth. The probable mechanisms consider the vertical rise of gas bubbles colloidal size through the interconnected system of microfractures, cracks and bedding planes, all filled with water in the subsoil. Floating leads these bubbles to the surface almost vertically. As the light hydrocarbon rise, the bacterial oxidation produced as by—products carbon dioxide acid and hydrogen sulfide. For its part, the carbonic acid reacts with the clay, destroying minerals, while creating secondary carbonate mineralization and silicification. Both result in making the surrounding surface materials denser and erosion resistant, with an effect on the increase of seismic velocity on the accumulation and the formation of erosional topographic maximum. Meanwhile, the destruction of clay minerals by the acids mentioned releases potassium from rocks which is leached by groundwater and surface water. However, the thorium remains relatively stable in its original distribution within the insoluble heavy minerals. Thus, it becomes evident that the ratio of attributes K/eTh is informative (for their minimum values) of the environment affected by the process described above. Additionally, this relationship offers the opportunity to eliminate a number of undesirable effects on spectrometric measurements (influence of lithology, moisture, vegetation and measurement geometry). On the role of sulfhydric, its own presence conditions the formation of a column of reducing environment (minimum of Redox Potential) on accumulation. This reducing environment favors, in turn, converting the non-magnetic iron minerals in more stable magnetic diagenetic varieties as magnetite, maghemite, pyrrhotite and griegita all responsible for the increase (maximum) of Magnetic Susceptibility of rocks and soils on the occurrence, which explains the observed inverse correlation between attributes (minimum of Redox Potential and maximum of Magnetic Susceptibility) and justifies the integration of methods.

Oil-gas unconventional geophysical-geochemical exploration techniques, among which is the *Redox Complex*, are indicative of physical—chemical processes and/or environmental changes taking place in the upper section directly on the occurrences conditioned by diffusion halos of light hydrocarbons and other satellites elements (metal ions) that reach the surface. These techniques are used as a complement to conventional prospecting complex with the purpose of assisting in the reduction of areas and/or selection of the most favorable geological testing targets, thereby increasing the effectiveness of geological investigations.

The antecedent in the use of the referred techniques back to the decades of the forties and fifties, where aerial radiometry to map hydrocarbon deposits (minimum total counting on the areas of production) was used. In the seventies, the methods airborne gammaspectrometric high sensitivity (minimum potassium), aeromagnetic (micromagnetic anomalies) and Magnetic Susceptibility of soils (maximum) applied to oil exploration were developed. In Cuba, the application of these techniques has its antecedent in the work of Alfonso Roche and Pardo (1993) in which the possibility of remote mapping potentially producing areas, revealed by lows of K/eTh relationship, and verify the oil-gas nature of these anomalies, specifying their limits on land by the conjugate expression of minimum of Redox Potential and maximum of Magnetic Susceptibility of soils. Industrial accumulations of hydrocarbons studied (Varadero, Cantel and Pina oil fields), revealed by lows of K/eTh relationship to values lower than 0.1 are expressed by minimum of Redox Potential in soils with amplitude between 30 and 80 mV, whose epicenters match the apical part of the structures, being reflected the direction of its sinking by the lower flank gradient. For antiforms, the Redox anomaly has a maximum relative over its axial part, coinciding the epicenters approximately with the limit water/oil. Soil magnetic susceptibility, as a rule, is less informative, even though, in some cases their maximum may be diagnostic of the production structure position.

In any country it is essential the ongoing assessment of hydrocarbon potential for the renewal of the exploratory oil policy and strategy of its economic development. This is supported by the increased acquisition of new geological, geophysical, geochemical and other data and the constant refinement of the criteria and methods of oil exploration, which provide a plenty of important information. In recent decades unconventional exploration methods have come to harmoniously complement traditional methods, by virtue of improving outcomes for oil exploration.

The *Redox Complex* (Redox Potential, Magnetic Susceptibility, Spectral Reflectance and Soil Geochemistry) is a complex of unconventional exploration techniques, used for indirect detection and evaluation of various objects of metal nature, which is based on the *Geochemical Principle of Vertical Migration of Metal Ions*. It is a genuine Cuban combination of techniques. It has been applied in various fields (Oil, Metal Minerals, Environment and Archaeology) since 1997, initially rudimentary and subsequently incorporating new theoretical—practical elements in their work. So, the *Redox Complex* has been used to elucidate the structure and nature of hydrocarbon prospects in Cuba, mainly in the Northern Fringe of heavy crude and Central Basin. This complex of unconventional exploration techniques has well identified its possibilities and limitations, making it

more objective and credible results. Although the available applications are still statistically insufficient as experimental foundation of empirical regularities formulated mathematically, however, they allow, a priori, envision a better future for this complex of exploration methods.

The reader will find in this essay, the most important insights and results related to the *Redox Complex*. The contribution of its principal author has been decisive in obtaining them. His expert status in the acquisition and interpretation of the data in this complex of unconventional exploration techniques has led to it for an important place in the work of oil exploration in Cuba.

Dr. Evelio Linares Cala
Head of Regional Geology and Geological Survey Department
Oil Research Center