

Source-rock kinetics: new methods of determining them, and novel applications to hydrocarbon exploration, especially unconventional

Although source-rock kinetics have been widely used in basin modeling for more than 20 years, recent technical developments have greatly increased the utility of kinetics data. Source-rock kinetics can now be used for a variety of purposes not imagined only a few years ago. These new applications are extremely valuable in both conventional and unconventional exploration.

Traditional methods of measuring kinetics were slow and expensive. One new method increases the speed of laboratory analysis by a factor of approximately 20, resulting in major reductions in cost and in acquisition time. In addition, kinetics can now be determined at even lower cost for samples for which appropriate archived Rock-Eval or Source-Rock-Analyzer data are available. Studies can even be carried out using a combination of archived and newly generated pyrolysis data. The use of archived data can greatly relieve the burden of acquiring samples where acquisition is expensive, difficult, or impossible. Finally, the kinetics obtained by the new method are more reliable and have less chance of being significantly in error than kinetics determined by the traditional method.

Kinetic data include the mean activation energy (Mean E_a) and the shape of the activation-energy distribution, but can also include a split of the hydrocarbons into liquid and gas products. Mean E_a values are conceptually similar to T_{max} values, in that they are both derived from the Rock-Eval S_2 peak, but are superior in that they take into account the entire S_2 curve rather than simply the maximum. Kinetic data are normally used in conjunction with TOC and Rock-Eval data, as well as with other types of geochemical data, such as biomarkers. Kinetic data can also be integrated into sequence-stratigraphic interpretations.

The lower cost of kinetics data strongly encourages acquisition of large data bases of kinetics. These data bases can then be used not only to provide more-reliable kinetics for basin modeling (the traditional application), but also to identify distinct organofacies within a single source layer, and as a direct indicator of the progress of hydrocarbon generation. Source-rock kinetics can be easily linked to Transformation Ratio and vitrinite reflectance (R_o) values via relationships that are uniquely calibrated for each kerogen.

Exploration applications include (1) defining distinct organofacies within a single source layer, showing both vertical and horizontal variation, and thus permitting high-grading of a kitchen area according to kerogen quality; (2) mapping R_o values calculated from the kinetic data to aid in calibrating thermal history in basin models; and (3) mapping Transformation Ratios to indicate the actual progress of hydrocarbon generation across an area of interest. Kinetic data can supplement R_o data where R_o data are available and confident, or they can replace R_o data where vitrinite is absent or where R_o measurements are unreliable (e.g., R_o suppression, Lower Paleozoic rocks where vitrinite is absent, carbonates where vitrinite is scarce or absent).

Specific applications to conventional exploration include defining source-rock facies and the hydrocarbon kitchen, with a view to later integrating this information with a migration scenario. Applications in unconventional exploration are somewhat different: since little or no migration is

anticipated, one must know precisely where the kitchen is. Mean E_a is extremely valuable in precisely identifying kitchens. Criteria for defining a kitchen can be adjusted to meet specific exploration needs, such as the requirement of having oil with high GOR and high API gravity.

RESUME

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PERSONAL

Date of birth: July 29, 1945

Age: 67

Marital status: Married

Hobbies and interests: soccer, triathlons, canoeing, reading, writing, languages, stamp collecting, genealogy

EDUCATION

B.A. 1967 DePauw University (Greencastle, Indiana, USA)
Major: Chemistry

Ph.D. 1971 Stanford University (Stanford, California, USA)
Major: Physical organic chemistry

LANGUAGES

Native speaker:	English
Fluency:	Spanish, German
Reading knowledge:	Russian, French, Portuguese
Moderate speaking ability:	Japanese

AWARDS AND HONORS

Phi Beta Kappa (1967)

National Science Foundation Graduate Fellowship (1967-1971)

Alexander von Humboldt Foundation Fellowship (1971-1972)

Latin American Teaching Fellowship (1972-1973)

Shipboard Organic Geochemist, Deep Sea Drilling Project,

Legs 58 and 80 (12/77-2/78 and 6/81-7/81)

Invited keynote speaker, AASP, Dallas (1979)

Associate Editor, Bulletin of the American Association of Petroleum Geologists
(1981-1988)

J.C. Sproule Award, American Association of Petroleum Geologists (1982)

Adjunct Professor, Colorado School of Mines

Dept. of Chemistry and Geochemistry (1/80-5/80; 8/86-5/87)

Dept. of Geology (8/88-7/89)

AWARDS AND HONORS (continued)

Adjunct faculty member, University of Texas at Dallas

Dept. of Geology (4/81-4/84)

Invited keynote speaker, Geological Society of Malaysia Petroleum Seminar (1991)

Selected as AAPG International Distinguished Lecturer (1992)

Visiting lecturer, Department of Petroleum Geoscience, Universiti Brunei

Darussalam, Brunei (1995-2006)

Invited keynote speaker, Geological Society of the Philippines Conference on Borneo and Palawan (1999)

Invited keynote speaker, Ecopetrol Jornadas de Geoquímica (2001)

Session chairman, EAGE, Tunis (2003)

Invited keynote speaker, Ecopetrol Exploration Symposium (2005)

Visiting lecturer, Department of Petroleum Geoscience, Chulalongkorn University (2009-present)

Rocky Mountain Association of Geologists Outstanding Scientist Award (2012)

PROFESSIONAL INTERESTS

- Application of geochemistry in oil exploration, especially

Integrated regional geological/geochemical studies

Maturity modeling

Basin modeling

Oil correlations

Biomarkers

- Training and continuing education for petroleum geologists

- Research in development of better numerical basin models

PROFESSIONAL ACTIVITIES

Member: American Association of Petroleum Geologists (1981-present)

Nominating committee, organic geochemistry division of The Geochemical Society (1979-1982; chairman, 1982)

Co-chairman, SEPM technical session, AAPG National Convention, Dallas (1983)

Convenor, AAPG Research conference, Denver (1987)

Convenor, Group meetings on sensitivity analysis in basin modeling,

Houston and Aberdeen (1991)

Co-chairman, International Geological Congress technical session, Kyoto (1992)

PUBLICATION SUMMARY:

5 books, about 85 articles and book chapters, 3 book reviews, about 25 abstracts, 1 translation

WORK EXPERIENCE: (Full-time permanent positions)

Geochemical consultant, Dallas, Denver, and Chiba, Japan (8/83-present)

Duties:

- Interpretation of geochemical data and execution of modeling studies for petroleum exploration (Algeria, Argentina, Australia, Bahrain, Bangladesh, Cambodia, China, Colombia, Denmark, Egypt, Equatorial Guinea, Gabon, Greece, India, Indonesia, Iran, Japan, Jordan, Kenya, Libya, Malaysia, Mauritania, Morocco, Myanmar, New Zealand, Norway, Oman, Pakistan, Papua New Guinea, Peru, Saudi Arabia, Sudan, Syria, Thailand, Tunisia, Turkmenistan, USA, Uzbekistan, Venezuela, Vietnam, Yemen).
- Development of software for maturity modeling and basin modeling.
- Research in numerical basin-modeling techniques.
- Hands-on training of personnel through collaborative projects.
- Development and teaching of short courses (Introductory Petroleum Geochemistry, Advanced Petroleum Geochemistry, Maturity Modeling and Basin Modeling, Advanced Maturity Modeling) in Australia, Brunei, Canada, Chile, Colombia, Denmark, Egypt, Greece, Hungary, India, Indonesia, Italy, Japan, Malaysia, Mexico, Morocco, Papua New Guinea, Philippines, South Africa, Spain, Thailand, UK, USA.

Visiting Professor of Geochemistry, Colorado School of Mines, Golden, Colorado (8/87-5/88)

Duties:

- Teaching of undergraduate chemistry courses and graduate geochemistry and geology courses.
- Thesis advisor for two Ph.D. students.

Manager of regional studies, Exlog/Brown & Ruth Laboratories, Denver (10/84-8/86)

Duties:

- In charge of designing and executing regional studies, and or recruiting, hiring, and training staff to accomplish this objective.
- Marketing and client-contact responsibilities.
- Teaching of short courses in geochemistry (Egypt, USA, Spain, Morocco).

Senior staff geologist, Applied Geochemistry Group, Mobil Exploration and Producing Services, Inc., Dallas (2/82-7/83)

Duties:

- Consultant to exploration teams on geochemical problems in Peru, Alaska North Slope, Bering Sea, North Sea, Atlantic rift basins, Angola.
- Development of Mobil's probabilistic model for hydrocarbon generation and migration.

Senior research geochemist, Mobil Oil Field Research Laboratory, Dallas (2/80-2/82)

Duties:

Research in predicting organic richness, biomarkers as maturity parameters.
Responsible for developing and teaching Mobil's "Geochemical Exploration" course.

Assistant and Associate Professor of Geochemistry, Colorado School of Mines, Golden, Colorado (8/76-2/80)

Duties:

Teaching of undergraduate courses (general and organic chemistry) and graduate courses (organic geochemistry and petroleum geochemistry).
Thesis advisor for four M.Sc. students.
Varsity soccer and cross-country ski coach.

Research chemist, Chevron Oil Field Research Company, La Habra, California (8/73-7/76)

Duties:

Research in carbon-isotope fractionation and in kinetic parameters of petroleum generation.
Responsible for technical service projects.

Professor of Chemistry, Universidad Católica, Valparaíso, Chile and Organic Geochemist, Empresa Nacional del Petróleo (ENAP), Concón, Chile (4/72-4/73)

Duties:

Teaching, supervision of one senior thesis.
Research on source-rock evaluation and oil correlation in the Magallanes Basin.

Post-doctoral fellow, Geochemisches Institut, Universität Göttingen, Göttingen, West Germany (6/71-4/72)

Duties:

Studying organic geochemistry of evaporites.