Thermal History of Sedimentary Basins
Nancy D. Naeser    Thane H. McCulloh
Editors

Thermal History of Sedimentary Basins
Methods and Case Histories

With 197 Illustrations

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The collection of papers in this volume is a direct result of the Society of Economic Paleontologists and Mineralogists Research Symposium on “Thermal History of Sedimentary Basins: Methods and Case Histories” held as part of the American Association of Petroleum Geologists Annual Convention in New Orleans in March 1985. The original goal of the symposium was to provide a forum where specialists from a variety of disciplines could present their views of methods that can be used to study the thermal history of a sedimentary basin or an important portion of a basin. An explicit part of that goal was to illustrate each method by presentation of a case history application. The original goal is addressed by the chapters in this volume, each of which emphasizes a somewhat different approach and gives field data in one way or another to illustrate the practical usefulness of the method.

The significance of our relative ignorance of the thermal conductivities of sedimentary rocks, especially shales, in efforts to understand or model sedimentary basin thermal histories and maturation levels is a major thrust of the chapter by Blackwell and Steele.

Creaney focuses on variations in kerogen composition in source rocks of different depositional environments and the degree to which these chemically distinct kerogens respond differently to progressive burial heating. Molecular indicators of thermal maturity from kerogen and kerogen extract are the principal subject of the chapter by Curiale, Larter, Sweeney, and Bromley. They review this subject against a broad background of the more commonly measured bulk thermal maturity parameters such as Rock-Eval pyrolysis data and vitrinite reflectance. In particular, they examine specific aromatization reactions relative to measured “maturity levels” with appropriate concerns about reaction kinetics and heating rates.

Bulk organic matter maturities (mainly vitrinite reflectance) from many localities that are classified as burial diagenesis, geothermal system, or contact metamorphic environments are examined by Barker in terms of maximum temperature, exposure time, and reaction rates. He concludes that maximum temperature reached is the overwhelmingly dominant control and that reaction time spent at temperatures only slightly lower than the maximum can be neglected.
Empirical chemical thermometers based on the compositions of the dissolved substances in waters from oil wells, hot springs, and geothermal wells can be used to estimate the subsurface reservoir temperatures from the surface to depths corresponding to 350°C, according to Kharaka and Mariner. Estimates are within 10°C of measured values for reservoir temperatures higher than about 70°C. A new Mg-Li geothermometer is presented and recommended for all subsurface water (except those from gas wells).

Determination of paleotemperatures from measurements made on fluid inclusions in diagenetic minerals is the subject of an up-to-date review by Burruss, in which a pointed discussion is presented of the problems posed by reequilibration of early diagenetic fluid inclusions under deeper burial pressure-temperature conditions.

Pytte and Reynolds assemble and discuss data from six selected sites where duration of time near peak temperature can be estimated for the smectite to illite transformation. An empirical kinetic reaction model is fit to the data and adequately describes the smectite to illite reaction extent for conditions that range from volcanic contact alteration to long-term burial diagenesis under low-temperature conditions. Temperature is the dominant control on reaction progress (provided the chemistry of the system permits reaction).

The use of 40Ar/39Ar age spectrum analysis of detrital low-temperature potassium feldspar from buried clastic sequences as a means to trace the thermal evolution of a sedimentary basin is the subject of the chapter by Harrison and Burke. Data from the southernmost San Joaquin basin, California, the Albuquerque basin section of the Rio Grande Rift, New Mexico, and the southern Viking Graben of the North Sea basin are used to illustrate the technique.

Naeser, Naeser, and McCulloh discuss fission-track dating of detrital apatite and zircon from clastic sequences as a method of defining the overall temperature-time history of a basin. In addition, localized temperature anomalies, the sediment provenance, and the sedimentation record of the basin can be analyzed. They illustrate the method with studies in the San Joaquin basin, California, and the Green River basin, Wyoming.

Green, Duddy, Gleadow, and Lovering also discuss the application of fission tracks to basin studies, but they emphasize the importance of using the shortening of fission tracks in apatite, and the resulting variation in mean track length and track length distribution, with progressive annealing as a paleotemperature indicator. They illustrate this with data from wells in the Otway basin, Australia.

Feinstein, Kohn, and Eyal have combined vitrinite reflectance and fission-track data to reconstruct the thermal history recorded in folded rocks of a discontinuous succession of Early Permian to Tertiary age in southern Israel. According to the authors, following a brief intense Jurassic thermal episode, the coalification process “froze,” despite progressive burial, reflecting a thermal decay since Early Cretaceous time.

Armagnac, Bucci, Kendall, and Lerche present a method of using the variation in vitrinite reflectance with depth in a well to estimate the thickness of sediment removed at unconformities. They illustrate use of the
method in wells in the National Petroleum Reserve of Alaska and in a well in the Rharb basin, Morocco.

A one-dimensional finite-element modeling procedure is used by Issler and Beaumont to study the postrifting thermal and subsidence history of the Labrador continental margin, northeastern Canada. Model-derived temperatures are used to predict vitrinite reflectance and the progress of selected aromatization-isomerization biomarker compound reactions. Preliminary results from seven wells show overall good agreement with observations of maturity measures, crustal thickness (refraction), corrected bottom-hole temperatures, and paleobathymetry and stratigraphy.

McDonald, von Rosenberg, Jines, Burke, and Uhler use a two-dimensional, transient, finite-difference modeling procedure to derive the time-temperature history of sedimentary basins. The model simulates processes that occur during basin evolution, including subsidence, sedimentation, uplift and erosion, internal heat generation, surface temperature variations, magmatic activity, faulting, and changes in sediment thermal conductivity with burial. Use of the model is illustrated for a hypothetical Late Cenozoic basin.

A steady-state two-dimensional, finite-difference, numerical modeling procedure is used by Hagen and Surdam to examine the thermal evolution of the northern Bighorn basin, Wyoming and Montana. Integration of this thermal evolution model with time-temperature reconstructions derived from basin geology results in temperature histories for Cretaceous hydrocarbon source rocks.

Heasler and Surdam use their previously proposed thermal model for coastal California as a basis for modeling hydrocarbon maturation in Miocene Monterey Formation source rocks of the Pismo and Santa Maria basins. The authors use the model to predict the level of thermal exposure necessary to generate high API gravity crude oil in the rocks.

We would like to thank all of the authors and the reviewers of the chapters in this volume. Their conscientious work has made the volume possible. We thank Dale Issler and Christopher Beaumont for permission to use a modified version of one of their figures as the cover illustration. We would also like to thank Tom Kostick, U.S. Geological Survey, Denver, for preparing the cover illustration and for helping to modify a number of illustrations in the volume. Nancy Naeser wishes to thank Ian Mackenzie, New Zealand Department of Scientific and Industrial Research, for the early training in editing that made working on this volume so much easier.

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Thane H. McCulloh
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Contributors

CHARLENE ARMAGNAC
Department of Geology, University of South Carolina, Columbia, South Carolina 29208, USA

CHARLES E. BARKER
United States Geological Survey, Denver, Colorado 80225, USA

CHRISTOPHER BEAUMONT
Oceanography Department, Dalhousie University, Halifax, Nova Scotia B3H 4J1, Canada

DAVID D. BLACKWELL
Department of Geological Sciences, Southern Methodist University, Dallas, Texas 75275, USA

BRUCE W. BROMLEY
Unocal Science and Technology Division, Unocal Corporation, Brea, California 92621, USA

JAMES BUCCI
Department of Geology, University of South Carolina, Columbia, South Carolina 29208, USA

KEVIN BURKE
Department of Geosciences, University of Houston, Houston, Texas 77004, USA

W. H. BURKE, JR.
Mobil Research and Development Corporation, Dallas, Texas 75381, USA

ROBERT C. BURRUS
United States Geological Survey, Denver, Colorado 80225, USA

STEPHEN CREANEY
Esso Resources (Canada) Ltd., Calgary, Alberta T2P 0H6, Canada
Contributors

JOSEPH A. CURIALE
Unocal Science and Technology Division, Unocal Corporation, Brea, California 92621, USA

IAN R. DUDDY
Geotrack International, Department of Geology, University of Melbourne, Parkville, Victoria 3052, Australia

MOSHE EYAL
Department of Geology and Mineralogy, Ben Gurion University of the Negev, Beer Sheva 84105, Israel

SHIMON FEINSTEIN
Department of Geology and Mineralogy, Ben Gurion University of the Negev, Beer Sheva 84105, Israel

ANDREW J.W. GLEADOW
Department of Geology, La Trobe University, Bundoora, Victoria 3083, Australia

PAUL F. GREEN
Geotrack International, Department of Geology, University of Melbourne, Parkville, Victoria 3052, Australia

E. SVEN HAGEN
Pecten International Company, Houston, Texas 77001, USA

T. MARK HARRISON
Department of Geological Sciences, State University of New York at Albany, Albany, New York 12222, USA

HENRY P. HEASLER
Department of Geology and Geophysics, University of Wyoming, Laramie, Wyoming 82071, USA

DALE R. ISSLER
Institute of Sedimentary and Petroleum Geology, Calgary, Alberta T2L 2A7, Canada

W. R. JINES
Mobil Research and Development Corporation, Dallas, Texas 75381, USA

CHRISTOPHER G. ST. C. KENDALL
Department of Geology, University of South Carolina, Columbia, South Carolina 29208, USA

YOUSIF K. KHARAKA
United States Geological Survey, Menlo Park, California 94025, USA
BARRY P. KOHN
Department of Geology and Mineralogy, Ben Gurion University of the Negev, Beer Sheva 84105, Israel

STEPHEN R. LARTER
Institut for Geology, Department of Geology, University of Oslo, Blindern, N-0316 Oslo 3, Norway

IAN LERCHE
Department of Geology, University of South Carolina, Columbia, South Carolina 29208, USA

JOHN F. LOVERING
Department of Geology, Flinders University, Bedford Park, South Australia 5042, Australia

ROBERT H. MARINER
United States Geological Survey, Menlo Park, California 94025, USA

THANE H. MCCULLOCH
Mobil Exploration and Producing Services, Inc., Dallas, Texas 75265-0232, USA

A. E. MCDONALD
Mobil Research and Development Corporation, Dallas, Texas 75381, USA

CHARLES W. NAESER
United States Geological Survey, Denver, Colorado 80225, USA

NANCY D. NAESER
United States Geological Survey, Denver, Colorado 80225, USA

A. M. PYTTE
Chevron Overseas Petroleum Inc., San Ramon, California 94583-0946, USA

R. C. REYNOLDS
Department of Earth Sciences, Dartmouth College, Hanover, New Hampshire 03755, USA

JOHN L. STEELE
Department of Geological Sciences, Southern Methodist University, Dallas, Texas 75275, USA

RONALD C. SURDAM
Department of Geology and Geophysics, University of Wyoming, Laramie, Wyoming 82071, USA
ROBERT E. SWEENEY
Unocal Science and Technology Division, Unocal Corporation, Brea, California 92621, USA

L. M. UHLER, JR.
Mobil Research and Development Corporation, Dallas, Texas 75381, USA

D. U. VON ROSENBERG
Mobil Research and Development Corporation, Dallas, Texas 75381, USA