U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

PREFACE TO PRELIMINARY GEOLOGY REPORTS FOR THE COOPERATIVE MONTEREY ORGANIC GEOCHEMISTRY STUDY, SANTA MARIA AND SANTA BARBARA-VENTURA BASINS, CALIFORNIA

by

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Open-File Report 92-539-A

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1992

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INTRODUCTION

This report provides preliminary geologic background and research data for the Cooperative Monterey Organic Geochemistry Study (CMOGS), a study involving researchers jointly examining rock and oil samples from the Santa Maria and Santa Barbara areas of California. CMOGS was initiated during a Division of Geochemistry field trip to the Monterey Formation along the Santa Barbara coast, California, in conjunction with the American Chemical Society Meeting in Anaheim (September 1986), and was initially organized in June 1987 at the Society of Economic Paleontologists and Mineralogists Organic Geochemistry Research Group Meeting in Los Angeles. Samples were distributed in 1988 and 1989, study workshops were held in August 1990 and September 1991 in Ventura, California, and a joint publication is in progress.

STUDY MATERIALS

The study mainly involves research and analysis on splits of 22 rock samples and 11 oils. Rock samples (designated KG-1 to KG-20, KG-22, and KG-24) are from two sections (see Plate 1, Chapter B, this report): (1) Naples Beach, Santa Barbara coastal area (KG-1 to KG-13); and (2) Lions Head, Santa Maria area (KG-14 to KG-20, KG-22, and KG-24). The 13 rock samples from Naples Beach include 9 samples from the Monterey Formation, and 2 samples from each of the overlying Sisquoc Formation and underlying Rincon Shale. The 9 rock samples from Lions Head are all from the Monterey Formation. For details on the rock samples, see Chapter C (this report). Of the 11 oil samples, 2 are from the Santa Barbara Channel, 8 are from the onshore Santa Maria basin, and 1 is from the offshore Santa Maria basin (for details see Chapter F, this report).

PURPOSE OF STUDY

The original purpose of the study was to explore the organic matter depositional system of the Monterey Formation of the Santa Barbara coastal area in view of inconsistencies with widely held concepts about factors influencing total organic carbon (TOC) distribution (Isaacs, 1987). The widely held concepts are that TOC is more abundant with higher surface productivity, with higher sedimentation rate, and with lower bottom-water oxygen. The inconsistencies are that TOC in this area correlates inversely with all geologic indicators of surface productivity, correlates inversely with sedimentation rate, and is not highest in strata interpreted as representing lowest bottom-water oxygen. The sample set that was designed to explore these inconsistencies was the set KG-1 to KG-13 from Naples, a set which represents all major stratigraphic divisions within and

adjacent to the Monterey in the most thermally immature surface section available. In this set, for example, both the highest productivity and the most rapid sedimentation as interpreted geologically are represented by KG-12 and KG-13 (both Sisquoc samples) which have the lowest TOC (0.9-1.0%) of the set. Conversely, both the least productivity and slowest sedimentation as interpreted geologically are represented by KG-1 and KG-4 which have the highest TOC (>10%) in the set. Inasmuch as the abundant organic matter of the Monterey is generally attributed to diatom-rich strata rapidly deposited in an anoxic setting, these detailed relations raise questions about the source, deposition, and early diagenesis of organic matter in the Monterey Formation in this area. Might these questions have wider relevance?

Another purpose of the study, added in the early organizational stages, was to explore the maturity and oil generation characteristics of the Monterey Formation. Many questions about these characteristics had been raised in the literature during the early 1980s as a result of oil discoveries that seemed anomalous in terms of existing maturation models. Questions were raised, for example, about the effect of sulfur on the time of maturation, the difficulties of interpreting Rock-Eval and vitrinite reflectance data, the possibility of a subset of strata being the main oil-source, distinguishing biodegradation from immaturity, and so forth. The two sample sets that focus on these questions are: (a) KG-14 to KG-20, KG-22, and KG-24 from Lions Head (the most mature surface section available), a set designed to explore lithologic or stratigraphic control of organic matter maturation or maturation parameters; and (b) the 11 oils, a set designed to represent the maximum variety of oils within the region, including several pairs of high and low gravity oils from the same field. In order to explore a fuller sequence of maturity, a deep well from offshore Santa Maria (OCS 315-1 well) was added to the study after the 1990 workshop for selected participants specially interested in maturation.

An implicit purpose throughout the history of the study has been to explore the consistency and inter-relatedness of different kinds of evidence about very basic concepts, for example anoxia. Commonly, anoxia is inferred from one or more parameters that have been empirically related in one or more localities to the observed environmental condition of anoxia in the presentday, or to another parameter interpreted as an indicator of anoxia. Are these necessary connections or inadvertent ones controlled by some other factor that is frequently (but not necessarily) associated with anoxia? Are different kinds of evidence consistent when applied to the same sample set? If not, could some parameters record different thresholds of oxygen or are the parameters inconsistent in a more basic way? What is actually meant by anoxia? low in oxygen? free of oxygen? Does the term refer to the pore water? the bottom water? the water column?

Looked at from a slightly different perspective, a related opportunity of the study is to explore the value of intensive cross-disciplinary analysis of single samples. Might this not reveal new understanding of the organic geochemical variability sometimes observed in closely spaced samples and often regarded as "noise"? An example could be KG-4, which has now been shown to have an anomalously negative carbon isotope ratio ($\delta^{13}C$ = -13) in the calcite of the benthic foraminifera. In the ordinary way of sampling, carbon isotope ratios would not have been determined on KG-4, but rather on adjacent beds with more

abundant foraminifera, concealing the anomalous value in this specific sample. Does sample-specific information lend significant insight to organic matter characteristics that would otherwise be inaccessible? Another example might be maturity indicators. Many organic matter parameters have historically been proposed as maturity indicators only to be later revealed as being significantly influenced by lithotype or etc. Rather than simply dismissing such parameters as poor maturity indicators, might it not be possible to explore their relation to lithotype etc. with the aim of developing a maturity indicator that was, albeit complex, nevertheless highly useful?

As CMOGS evolved, an opportunity that developed was to educate geologists about both the power and limitations of organic geochemistry. Most geologists are unaware of the recent explosion in techniques and capabilities of organic geochemistry, and depend on the simplest of data (TOC and Rock-Eval) to interpret the depositional characteristics, maturity, and source potential of the rocks they are studying. Are these data mainly misinformative? Could the average geologist do better? If so, what? By providing comprehensive results in a well-integrated interdisciplinary study, might not major progress be made in giving geologists more effective tools for their research on organic matter?

Another opportunity that developed during the study was to educate organic geochemists about the limitations of geology, geologic frameworks, and geologic evidence. Much organic geochemical interpretation depends very heavily on geologic frameworks, but these frameworks have to be viewed in the context of the enormous scale, spatial variability, and fragmentary record that geologists have to deal with. What are the criteria that geologists use as evidence for generalities that organic geochemists often take for granted, such as "upwelling deposit", "anoxic sediment", "formation", "basin"? What do they really mean, and how certain are the interpretations? How can the evidence be appropriately evaluated?

PRELIMINARY GEOLOGY REPORTS

The purpose of the preliminary geology reports is to provide geologic background and preliminary research data to study participants to help with interpretation of organic geochemical data. Since the intention of the study is to re-evaluate many presumptions, it seemed appropriate to provide a geologic background which did not categorically adopt one of many possible geologic interpretations. Thus the various chapters of this report attempt to clarify the geologic objectives and interpretive possibilities for each sample, and at the same time leave much of the geologic framework open so as to make clear the level of uncertainty.

Chapter B of this report is the *Preliminary Geologic Background*, which places the Monterey Formation of the sampled sections in the broader perspective of the Monterey Formation as a whole and modern quasi-analogs. The chapter also outlines the distribution of total organic carbon in the area, and describes various interpretations of local paleoenvironmental conditions.

Chapter C, *Preliminary Rock Sample Data*, provides preliminary geology data on the study rock samples, and describes the purposes and questions embedded in the selection of each sample. Chapter D, *Preliminary Correlation and Age*, provides tentative stratigraphic positions and age assignments for the study samples.

Chapter E, *Geologic Handbook*, defines major geologic terms and illustrates them with discussion focused on the geology pertinent to the study. Also discussed are some of the basic oceanographic and environmental concepts, such as anoxia, being explored in the study.

Chapter F, *Preliminary Petroleum Geology Background*, provides a review of the local petroleum geology (source rocks, reservoir rocks, traps, generative areas and timing of trapping). Also included are tables showing production and reservoir characteristics of oil and gas fields in the area, and well histories for the study oil samples.

STUDY PARTICIPANTS

Participants in the Cooperative Monterey Organic Geochemistry Study include Jürgen Rullkötter, University of Oldenburg (formerly of KFA, Julich), Federal Republic of Germany; Barry J. Katz and Rae A. Royle, Texaco Exploration and Production Technology Division, Houston, Texas; Nils Telnaes and Trond Hanesand, Norsk Hydro Research Center, Bergen, Norway; Jan W. de Leeuw, and Stefan Schouten, Delft Technical University, Netherlands; Michael D. Lewan, J. David King, and Paul G. Lillis, U.S. Geological Survey, Denver, Colorado; Daniel M. Jarvie, Humble Instruments and Services, Humble, Texas; Eric Michael, Conoco Exploration Research and Services, Ponca City, Oklahoma; David K. Baskin and Martin Schoell, Chevron Oil Field Research Company, La Habra, California; Alain Yves Huc, J. Martigny, and S. Belin, Institut Français du Pétrole, Rueil-Malmaison, France; P. Sundararaman, Chevron Canada Resources, Calgary, Canada; Roger E. Summons, Bureau of Mineral Resources, Canberra, Australia; Geoffrey D. Abbott, Gavin A. D. Law, and B. Bennett, University of Newcastle, U.K.; Suhas G. Talukdar, DGSI, The Woodlands, Texas; Arndt Schimmelmann, Scripps Institution of Oceanography, University of California San Diego; Lo ten Haven, Total Scientific and Technical Center, Saint Rémy lès Chevreuse, France; Joseph A. Curiale and Bruce W. Bromley, Unocal Science and Technology Division, Brea, California; Amane Waseda, Japex Research Center, Chiba, Japan; Maria R. B. Loureiro, Federal University of Rio de Janeiro, Brazil; Lee L. Lundell, Arco Exploration and Production Technology, Plano, Texas; Theodore P. Goldstein, Mobil Research and Development Corporation, Princeton, New Jersey; Doreen Zaback, Indiana University, Bloomington; Hans H. Richnow, University of Hamburg, Federal Republic of Germany; Wilson L. Orr, Mobil Dallas Research Lab, Dallas, Texas; and Clare E. Reimers, University of Alaska Fairbanks.

Geologic data and discussion has been provided to the study by Caroline M. Isaacs, Janice H. Tomson, David Z. Piper, and John A. Barron, U.S. Geological Survey, Menlo Park, California; Richard M. Pollastro, and Marilyn E. Tennyson, U.S. Geological Survey,

Denver, Colorado; Robert G. Arends, Mary Lou Cotton, and Mark V. Filewicz, Unocal Corporation, Ventura, California; Benjamin P. Flower and James P. Kennett, University of California Santa Barbara; and Timothy R. Baumgartner of CICESE (Centro de Investigación Científica y de Educación Superior de Ensenada), Ensenada, Mexico.

STUDY ACKNOWLEDGMENTS

Many people have contributed to the Cooperative Monterey Organic Geochemistry Study. Invaluable organizational leadership for the project in its initial stages was provided by David J. Curry then of Sun Exploration and Production Company, now of Exxon Production Research (Houston, Texas). Many valuable suggestions and counsel were also provided by Neil F. Petersen of Worldwide Geosciences (Houston, Texas).

In selecting the study rock samples, Thane H. McCulloh of Mobil Oil Company (Dallas, Texas) provided important suggestions and encouragement. For collecting the study rock samples, I wish to acknowledge the many weeks of arduous labor and laborious assistance contributed by Janice H. Tomson now of Long Beach City College (Long Beach, California). Much appreciated help in supplemental sampling and resampling was also provided by Richard "Spike" Hubbard of Long Beach City College, and a geology class from Long Beach City College.

In selecting the study oil samples, both Neil F. Petersen and Charles E. Katherman of Katherman Exploration (Santa Maria, California) provided counsel and important suggestions. In obtaining the study oil samples, I appreciate help by Gregg H. Blake of Unocal Corporation (Ventura, California), David Cole of Unocal Corporation (Orcutt, California), C. Michael Clayton of Texaco (Denver, Colorado), Courtney Isselhardt and F.C. Spizale of Texaco U.S.A. (Ventura, California), Frank Getz (consultant, Whittier CA), Matthias Peterson of Conoco (Ponca City, Oklahoma), Robert O'Brien of Conoco (Santa Maria, California), Robert Chase of Conoco (Ventura, California), William J. M. Bazeley formerly of Arco Oil and Gas Company (Bakersfield, California), Lee Lundell of Arco Exploration and Production Technology (Plano, Texas), and Margaret H. Pytte of Chevron U.S.A. (San Ramon, California). For their generous help in transporting the study oil samples, I thank Colin F. Williams and S. Peter Galanis of the U.S. Geological Survey (Menlo Park, California), and Allan L. Schweitzer of Nippon Electric Company (Princeton, New Jersey).

Processing, homogenizing, distributing, and archiving both the rock and oil samples for the study was done by Paul G. Lillis and J. David King of the U.S. Geological Survey (Denver, Colorado), and I particularly thank David for volunteering to be responsible for this arduous but important task.

Helpful advice and useful suggestions during intermediate stages of the project were provided by many. I particularly thank Neil F. Petersen; Michael D. Lewan then of Amoco Production Company, now of the U.S. Geological Survey (Denver, Colorado); and Simon C. Brassell then of Stanford University, now of Indiana University (Bloomington, Indiana) for many valuable discussions.

For assistance with the logistics of the study workshops, Janice H. Tomson is most gratefully acknowledged. Susan Lewis and Robert A. Ballog of Unocal Corporation (Ventura, California) also provided much time and effort to arrangements for the first workshop. For permission to conduct workshop field trips, I thank Vandenberg Air Force Base, George Wilson of the Dos Pueblos Ranch, and Robert Manning of Celite Corporation (Lompoc, California). I also thank Michael Boston of Celite Corporation for conducting a field trip of the diatomite mine.

Valuable assistance in obtaining financial support and sponsorship for study workshops was provided by Andrew L. Colb, Joseph E. Rogers Jr., and Dorothy H. Pierce of the American Chemical Society (Washington, D.C.); Courtney Isselhardt; Robert A. Ballog; Donald F. Gautier of the U.S. Geological Survey (Denver, Colorado); and Gary W. Hill of the U.S. Geological Survey (Reston, Virginia). For financial support of study workshops, I also acknowledge the U.S. Geological Survey, the Donors of the Petroleum Research Fund administered by the American Chemical Society, and the Coast Geological Society in Ventura, California.

Finally, I particularly wish to thank my brother Kenneth H. Z. Isaacs for his exceptionally generous and invaluable counsel throughout the project. For their many contributions, discussions, and assistance to the study, I also thank my friend Steven R. Chambers of Erler & Kalinowski (San Mateo, California), Margaret A. Keller of the U.S. Geological Survey (Menlo Park, California), and Prof. Jürgen Rullkötter of the University of Oldenburg (Oldenburg, Federal Republic of Germany).

CHAPTER ACKNOWLEDGMENTS

For invaluable discussions contributing to the statement of study purpose, I particularly thank Kenneth H. Z. Isaacs and Steven R. Chambers. Kenneth J. Bird and Margaret A. Keller, both of the U.S. Geological Survey (Menlo Park, California) reviewed preliminary versions of the chapter.

REFERENCE

Isaacs, C. M., 1987, Sources and deposition of organic matter in the Monterey Formation, south-central coastal basins of California, U.S.A., *in* Meyer, R. F., ed., *Exploration for Heavy Crude Oil and Natural Bitumen*: American Association of Petroleum Geologists Studies in Geology 25, p. 193-205.