MODERN PHYSICAL GEOLOGY

Updated Version

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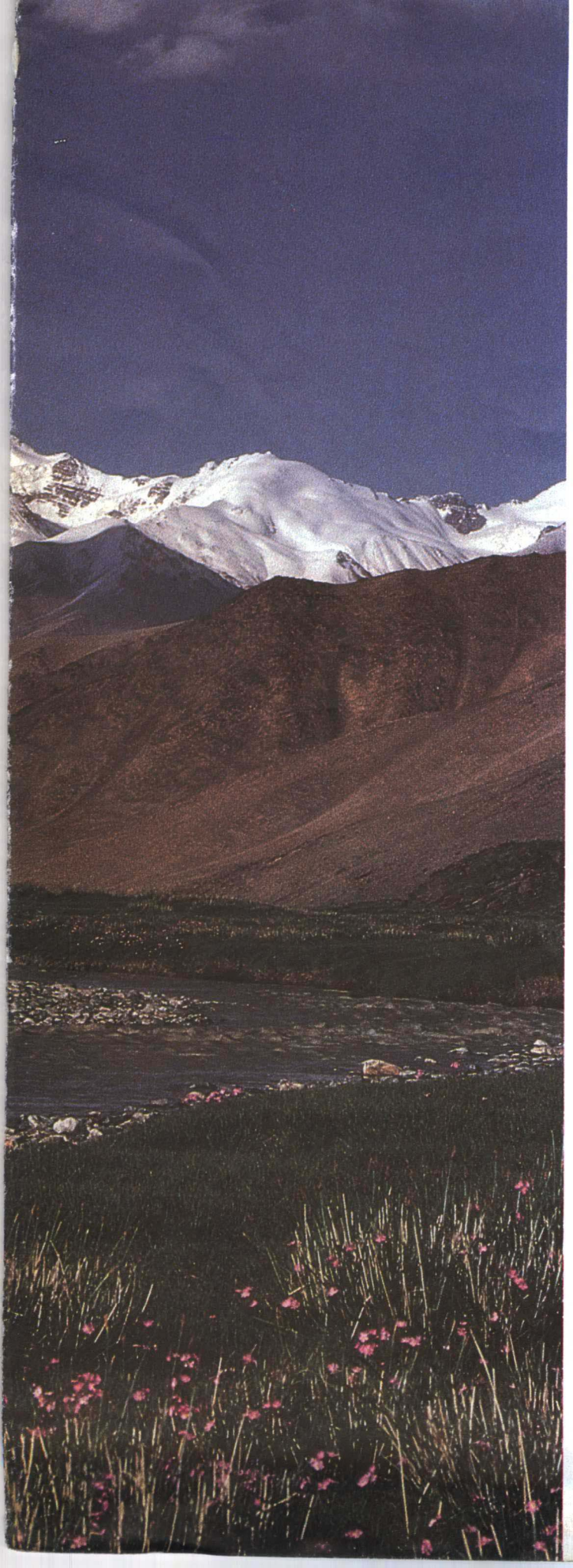

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UPDATED VERSION

Saunders College Publishing
Philadelphia Fort Worth Chicago
San Francisco Montreal Toronto
London Sydney Tokyo

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Updated version, 1993.

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Frontispiece: Pamir Mountains, China (© Galen Rowell/Mountain Light Photography)
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Printed in the United States of America

MODERN PHYSICAL GEOLOGY

ISBN 0-03-096910-7

Library of Congress Catalog Card Number: 90–052891

2345 063 987654321

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PREFACE

The primary purpose of this book is to provide students who have had little or no science background with an understanding and appreciation of geology. Every day we walk, bicycle, or drive across landscapes that were created by geological processes. Even people who live in cities can see evidence of such activity in parks and road cuts and in the shapes of river valleys, lake shores, or coastlines. Although they are less familiar to many of us, lofty mountain ranges, fertile prairies, and massive glaciers are parts of our world and are familiar through travel, books, television, and film. Every year we read about tragic loss of life and property that occurs when volcanoes erupt or earthquakes topple buildings and destroy cities or villages. Our water, air, and climate are also influenced and affected by geological change.

This book, and the introductory geology course that it accompanies, will enable a student to see and understand the Earth as a geologist does. We believe that an understanding of geology tremendously enhances one's enjoyment of the beauty of the natural world. To foster that enjoyment and to make the study of geology tangible and directly relevant, we have included a chapter entitled "Geologic Evolution of North America." This chapter summarizes many of the principles introduced in previous chapters and relates them to the geology and origin of North America, and to each part of our continent. It answers the question: How did the landscape outside my window evolve? Instead of looking at the mountains in one of our National Parks and thinking simply that they are pretty, a student will have an understanding of how and when they formed.

In this book we describe and explain the Earth as an integrated system of geological processes and events. Humans are part of this system and an important interrelationship exists between human activities and geological processes. Many of these connections are obvious, such as the impact of earthquakes and volcanoes on human settlement or the relationships between industrial development and the availability of fuel and mineral resources.

More recently, other relationships between humans and their physical environments have become important in the study of geology, for example, the effects that agricultural systems have on groundwater reserves and the short- and long-term results of man's attempts to channel rivers and to control coastal erosion. Modern physical geology textbooks must address these as environmental issues without advocating any particular philosophy, as these issues are also aspects of science that are relevant to our lives. Therefore, with these concepts in mind, we have written a book that teaches us modern physical geology and relates geology to contemporary issues and problems, particularly environmental issues.

One of the most important features of any textbook is the manner in which it develops its material so that each subject builds a foundation for the next. To this end, our approach is to introduce a discussion of geological *processes* first, followed by descriptions of the geological results of those processes. For example, sedimentary rocks are introduced only after weathering is taught. This type of sequential development, from fundamental processes to the consequences of these processes, is pursued throughout the book.

We recognize that while some students in introductory geology courses have a background in chemistry and physics, others do not. The overall aim of this text is to portray geological processes and events accurately, but in a language and style that is readily understood by students with little or no college-level science background. We have included necessary background material on the nature and structure of atoms, on fundamental physical forces, and on other topics as the need arises.

Finally, we feel that it is not sufficient to teach science as a set of facts to be learned and memorized. The study of geology is made vital by descriptions of the manner in which theories were developed. Thus when a theory is presented, we explain some of the crucial experiments and thought processes that led to the development of the idea.

Teaching Options and Sequence of Topics

This book is divided into four units,

Unit I: The Earth, Its Origin and Its Materials
Unit II: Earthquakes and Plate Tectonics

Unit III: Surface Processes
Unit IV: Special Topics in Geology

Some instructors may prefer to introduce surface processes before tectonics. We have included a brief introduction of plate tectonics in Chapter 1 so surface processes can be taught before tectonics without loss of continuity. The special topics in geology—mineral resources and planetary geology—can be taught separately or alternatively; portions of these chapters can be incorporated with topics taught earlier in the book. Alternate sequences are proposed in the Instructors Guide.

Special Features

Updated Version

A modern textbook must be up to date, not only to convey accurate information, but to remind the student that science is dynamic. If students go beyond this elementary course in geology and become geologists, they must understand that information and interpretations change. To convey the spirit of geology as a career, we strive to recognize debate throughout the book and to provide recent data and theories. We have made significant changes in this updated version to reflect recent articles in the literature.

Special Topics

Discussions of interesting, but nonessential, topics are presented throughout the book in the form of special topics, which are set aside and highlighted in color. These topics are not essential to the sequential development of each chapter, and they can be included or omitted at the discretion of the instructor. However, we feel that by providing geological anecdotes or interesting ideas that reinforce the main topic, the student is drawn into the chapter by specific examples, and at the same time the examples serve to reinforce the basic concepts. Three types of special topics are included. FOCUS ON boxes cover interesting topics such as "Pegmatite, The World's Largest Crystals." PHYSICAL GEOLOGY AND THE ENVIRONMENT boxes cover environmental topics such as "Groundwater Contamination from Disposal of Radioactive Wastes." Finally, short MEMORY DEVICES aid the student by introducing the roots of words and the relationships between the roots and the modern definition.

Unique Chapters

We have included a chapter titled, *Fossils, Evolution and Extinction* because paleontology is an integral part of geology and the study of fossils is useful in interpreting and dating sedimentary rocks. Although other introductory texts omit this topic, we feel that it is a fascinating and relevant part of modern physical geology. In Chapter 14, *Geologic Evolution of North America,* the geology learned in the thirteen previous chapters is integrated and used to discuss the origin and development of North America. Geology is made alive by bringing it home to the landscapes in the students' backyards.

Use of Analogies

Many geological processes occur beneath the Earth's surface where they cannot be directly observed. Some occur so slowly that even if we could see them the changes would not be detectable over many human lifespans. However, all of these processes can be clearly understood through the use of examples and analogies. This book emphasizes familiar examples and analogies to explain geological processes that cannot be experienced directly.

Chapter Review Material

Important words are highlighted in bold type in the text. These KEY WORDS are then listed at the end of each chapter for review purposes. In addition, a short SUMMARY is provided at the end of each chapter.

Questions

Two types of questions are included in the end-of-chapter material. The REVIEW QUESTIONS can be answered in a straightforward manner from the material in the text. On the other hand, DISCUSSION QUESTIONS challenge students to apply what they have learned to the analysis of situations not directly presented in the text. Often there is no single correct answer to these questions. Instead, they are intended to provoke thought and discussion among students.

Glossary and Appendix

A glossary of geological terms is provided at the end of the book. In almost all cases, we use definitions given in the *Dictionary of Geological Terms*, published by the American Geological Institute. We recom-

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mend this excellent and inexpensive paperback to the student who wants a comprehensive glossary of geology. In addition, appendices cover mineral classification and identification, metric units, the elements, and rock symbols.

Interviews

Students often wonder, what type of life would I lead if I decided to make geology my career? Who would I work and trade ideas with? What intellectual rewards would make my life challenging? In order to open a window into geology as a profession, we have interviewed three prominent geologists whose research and theories are discussed in the book. These interviews include a brief look at both their professional and personal lives and are included to encourage students to look closely at a career in geology.

Ancillaries

This text is accompanied by an extensive set of support materials.

Study Guide

The Study Guide, written by Vicki Harder of Texas A&M University, provides review and study aids to further enhance the students' understanding of the text. The Study Guide includes an overview for each chapter, learning objectives, a detailed chapter outline, a chapter summary, key words and review questions and answers.

Instructors Manual

The Instructors Manual, written by the authors of the text, provides teaching goals, alternate sequences of topics, answers to discussion questions and a short bibliography.

Overhead Transparencies

A set of 150 overhead transparencies includes four-color illustrations and photographs from the text for use in the classroom or the laboratory.

35mm Slides

A set of five hundred 35mm slides of the text's illustrations and photographs are available for use in the classroom or the laboratory.

Acknowledgments

We have not worked alone. The manuscript has been extensively reviewed at several stages and the numerous careful criticisms have helped shape the book and ensure accuracy:

Dave Alt, *University of Montana*
Joan Baldwin, *El Camino College*
Phillip Banks, *Case Western Reserve University*
Robert E. Behling, *West Virginia University*
Donald M. Burt, *Arizona State University*
Gary Byerly, *Louisiana State University*
F. Howard Campbell III, *James Madison University*
Mario V. Caputo, *Mississippi State University*
Larry E. Davis, *Washington State University*
Don Fisher, *Pennsylvania State University*
Roberto Garza, *San Antonio College*
Fred Goldstein, *Trenton State College*
Bryan Gregor, *Wright State University*
Vicki Harder, *Texas A&M University*
Donald W. Hyndman, *University of Montana*
Jim Mazzullo, *Texas A&M University*
Howard Mooers, *University of Minnesota*
John E. Mylroie, *Mississippi State University*
James F. Petersen, *Southwest Texas State University*
Jennifer S. Prouty, *Corpus Christi State University*
Bruce Rueger, *Colby College*
James W. Sears, *University of Montana*
Steven D. Sheriff, *University of Montana*
George D. Stanley Jr., *University of Montana*
Daniel A. Sundeen, *University of Southern Mississippi*
Charles P. Thornton, *Pennsylvania State University*
Alfred Traverse, *Pennsylvania State University*
Peter W. Whaley, *Murray State University*

Geology is a visual science. We can readily observe rocks and landforms on the Earth's surface. Although we cannot see internal processes in action, these events can be visualized through the artist's eye. George Kelvin has painted many of the superb illustrations in this book and he has been a pleasure to work with. We would also like to thank Larry Davis, Don Hyndman, Dewey Moore, and Roberto Garza for contributing excellent photographs.

We are especially grateful to Don Hyndman, Paul Hoffman, and Jack Horner for providing us with insightful interviews.

We would never have been able to produce this book without professional support both here in Montana and at the offices of Saunders College Publishing. Thanks to Christine Seashore and Eloise Thompson for finding photographs, contributing personal photographs, and for logistic collaboration. Special thanks to John Vondeling, our Publisher. One of us, Jonathan Turk, has worked with John Vondeling for over twenty years and has developed a long-lasting friendship and a superb professional relationship with him. Christine Connelly, Developmental Editor, Anne Gibby, Project Editor, Christine Schueler, Art Director, and Kathy Walker, Copy Editor have all worked hard and efficiently to produce the finished project.

Graham R. Thompson
Missoula, Montana

Jonathan Turk
Darby, Montana

September 1992

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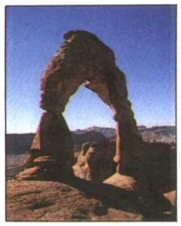
The Earth: Its Origin and Its Materials



UNIT III
Surface Processes

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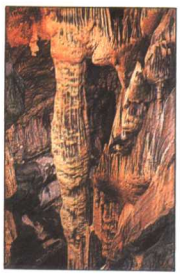

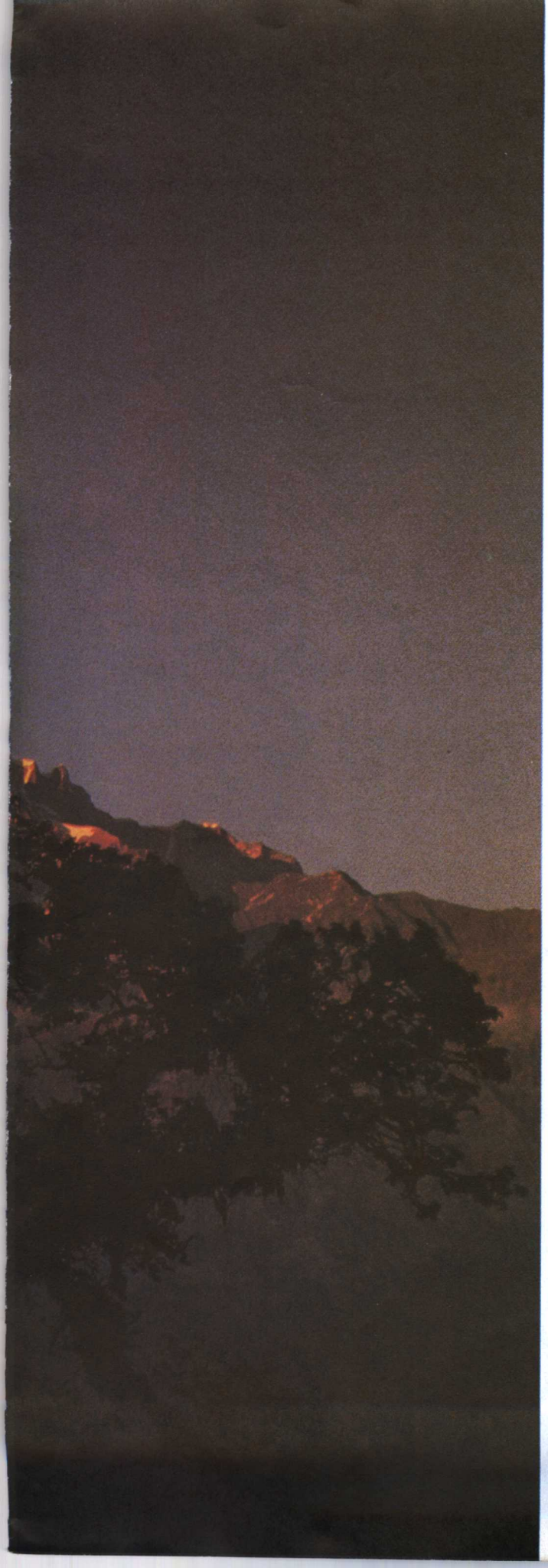

UNIT I
The Earth: Its Origin and Its Materials

The Earth and the Study of Geology

Minerals and Rocks

Igneous Rocks

Plutons and Volcanoes

Weathering and Soils

Sediments and Sedimentary Rocks

Metamorphic Rocks

Fossils, Evolution, and Extinction

Geologic Time and How It Is Measured

Sunset on Machupuhare in Nepal (Galen Rowell/Mountain Light Photography)

The Earth and the Study of Geology 1

OUTLINE

Imagine yourself on a rocky beach, walking toward the surf. You can see, hear, and feel the movement of the wind and the water. But you do not see the cliffs move, and the Earth doesn't shake under your feet. The solid Earth seems to be a firm base beneath the blowing winds and the breaking waves. However, this apparent immobility is deceptive—the Earth's crust is actually dynamic, not static. Continents slowly shift position, mountains rise, and then they are eroded away. These motions escape most casual observations because they are generally slow, although every year volcanic eruptions, earthquakes, and other types of rapid movement do occur in many places on our planet.

1.1 The Science of Geology

The science of geology is the study of the Earth: the materials that it is made of, the various physical and chemical changes that occur on its surface and in its interior, and the history of the planet and its life forms from its origin to the present.

As you can see from this definition, geology is a broad topic. Geologists seek to understand both the interior and the surface of the Earth. They study the Earth as it exists today and look backward at its past history. No single person can become an expert in all aspects of geology. Therefore the science is subdivided into a wide variety of specialties. Some of these specialties are suggested by our original definition.

The Earth's Materials

Most of the Earth is composed of solid **rocks**. Even a casual observer will notice that not all rocks are alike—some are soft, others are harder. They come in a wide variety of colors. Some appear to be

West coast of Costa Rica.

made of tiny bits and pieces of different substances stuck together, while others look homogeneous. One important aspect of geology is the study of rocks, their composition, structure, and origin. Rocks are not necessarily pure substances, rather many are composed of aggregates of one or more chemical compounds called **minerals**. The study of the formation, occurrence, properties, and compositions of minerals is an important specialty in geology.

Geology is interesting for its own sake simply because we humans are curious creatures and wonder about the world around us. If you drive along a highway or walk through the woods, your experience will be more interesting if you understand the processes that led to the formation of the rocks, minerals, and landforms that you see. In addition, geology has a wide variety of practical applications. Our technological world depends on a continuing supply of fossil fuels—coal, petroleum, and natural gas—and mineral resources such as metals, sand and gravel, certain fertilizers, and limestone (for the manufacture of cement). Many professional geologists spend their lifetimes exploring for valuable deposits of these materials.

The Earth's Physical and Chemical Changes

Most of us have seen water running over the surface of the ground after a heavy rainstorm. If you watch closely, you will notice that the flowing water dislodges tiny grains of soil and carries them downslope. After a few hours of heavy rain, an exposed hillside may become scarred by a series of tiny gullies. If you look at the shape of these gullies, you will see that they are similar to large-scale landforms such as mountain valleys and canyons. If you stretch your imagination over a great length of time, you can imagine how moving water has carved the surface of our planet. Some geologists study physical and chemical changes that occur on or near the surface. These changes are caused by streams, underground water, ocean waves, moving ice, wind, gravity, and the action of chemical compounds. Again, both theoretical and practical questions are routinely encountered. Why are desert landscapes different from those in humid climates? or How do river valleys change over the course of millennia? Many practical questions concern the interaction between surface processes and human development. Is a flood likely to destroy a housing development in this valley? How will acid rain affect lakes in a specific region? Will the acids be neutralized by the soil, or will they accumulate and kill fish in lakes and streams?

Some geologists study earthquakes and others study volcanoes. Still others try to learn about the Earth's magnetic field or the transfer of heat from the interior to the surface. Interior processes are responsible for the forces that lift mountains and

Offshore drilling platform. (Courtesy Sun Oil.)

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