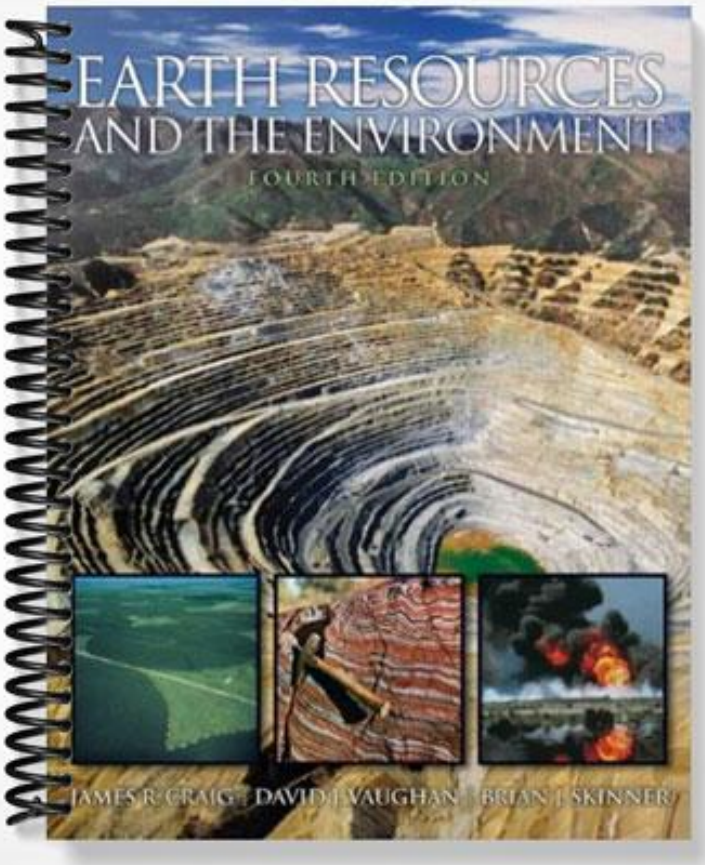
SOLUTIONS MANUAL



Earth Resources and the Environment

Fourth Edition

INSTRUCTOR'S MANUAL

James R. Craig

PREFACE

We are pleased that you are planning or considering the use of the fourth edition of our textbook, *Earth Resources and the Environment* in your class. This new edition has been retitled from *Resources of the Earth: Origin, Use and Environmental Impact* to better reflect increased environmental emphasis without sacrificing the content dealing with Earth resources. The writing of this book has been premised on the two quotations cited in the preface and in Part 1 of the book. They state:

"Our entire society rests upon—and is dependent upon—our water, our land, our forests, and our minerals. How we use these resources influences our health, security, economy, and well-being." —John F. Kennedy, February 23, 1961

"It is important for the future voter to appreciate the realities of our resource—environment situation as it is to be able to read the ballot. I believe that our principal hope is in education." —Paul B. Barton, November 7, 1979

To these, I add one more:

"A man's mind, once stretched by a new idea, can never return to its original dimension." —Oliver Wendell Holmes

It is the belief of these authors that there has never been a greater need for the citizens of all nations to recognize the dependencies that our modern societies have on Earth's mineral resources. This is an era of both rapid population growth and of rapid change in the technological use of resources. These factors create increasing demands on the resources of a finite Earth. Furthermore, it becomes ever more important to realize that the resource availability is not merely a question of the geochemical abundance of an element or mineral, but is also dependent on economic, political, and environmental factors, many of which are beyond the control of geologists and engineers. All of these factors lead to complex relationships that are understood by relatively few people.

It is also vitally important that today's students learn about the impacts that resource extraction and usage have on the environment. They should be aware that "Earth is our only home" now and in the foreseeable future. Consequently, the exploitation of resources needs to be coupled with an awareness of all environmental consequences, immediate and long-term, local and global. We currently live with consequences of many activities carried out in the past and we want to be careful not to repeat the mistakes of the past.

We have written *Earth Resources and the Environment* in the hope of providing an interesting and informative text that will raise the general level of knowledge and understanding of students. This Instructor's Manual has been prepared as an aid to you as you endeavor to teach your students. I have organized it following the structure of the textbook and have included a statement of the objective of each chapter, the approach employed, an outline of major topics, a listing of topics that might be used for in-class discussion and/or term papers, and a variety of questions (more than 500 multiple-choice and approximately 230 essay) that might be used in the preparation of quizzes or exams. Please do keep in mind that changes in usage, technology, politics, and economics may alter the validity of some answers provided for multiple-choice exam questions.

The fourth edition of *Earth Resources and the Environment* has retained a "parts" concept in which we have incorporated an overarching discussion at the beginning of each pair of chapters. These "parts" discussions are intended to better tie together related issues and to better offer an explanation of how the issues in the chapters fit into the larger scheme of Earth resources. Reading these "parts" before the chapters will help the students understand the overall goals of the following chapters and help them frame a more comprehensive view of Earth resources in general.

The third edition of *Earth Resources and the Environment* contains two to four "boxes," or self-contained discussions in each of the first 12 chapters. These are intended to help the students recognize and understand specific issues or events that have been important in human development and in the use of mineral resources.

In previous editions of this Instructor's Manual, I included an annotated list of references that dealt with the topics of each chapter. However, experience has shown that (1) many of the original web sites are no longer maintained. (2) many old web sites contain only out-of-date information, (3) there are countless new web sites and more being added regularly, and (4) most computers have very effective search engines that readily locate the most informative web sites. Accordingly, I believe that it is better today for students to enter the vast information world using their search engines and then to be a bit judicious when it comes to choosing data sources. To help in this regard, I have included some logical key words to use in any search.

There has been little problem with most resource production and usage data. On the other hand, there has been considerable controversy over some environmental data and interpretations. Hence, students need to be especially careful of sites that try to take only one side of "hot-button" issues. Sometimes political correctness must be considered. As a result, some governmental web sites have changed "global warming" to "climate change" because it has a more neutral sound. There are literally mountains of information available on the Internet. Most is accurate, but urge students to use a critical eye when extracting data or the opinions of others.

I do not presume to tell you how to teach your course, but I do, in the following discussions, try to offer some useful hints based on writing *Earth Resources and the Environment* and based on 30 years of teaching this course to more than 15,000 students. Thus, for each chapter, I offer a brief narrative on the major topics and attempt to point out the most important relationships and trends.

For more than 20 years, I have supplemented regular topical lectures with resource-related daily news items that come from newspapers and news magazines. This activity has proven to be very successful in demonstrating to students that the resource issues about which they are studying, have daily, and often unanticipated, impacts upon their lives. Furthermore, because the news articles are written for public interest and information rather than for a science class, they frequently contain reference to non-geologic aspects of issues. Hence, the news articles commonly demonstrate the complexity of life and the need to integrate information from nongeologic perspectives. An additional benefit of the use of such articles is that nonscience students taking the course often see relationships to their own majors and interests that are related to the issues of resources. I long used the *Wall Street Journal*, many local and regional papers, and current major magazines as sources of articles. Commonly, students have contributed articles from their hometown papers as well. My experience has been that there have been many more articles available than I could use. Of course, to the extent I discussed the articles in class, they also became part of the course, and were incorporated into exams.

The fourth edition of the textbook incorporates, as an Appendix, a calendar of resource-related events, listed day by day through the year; this demonstrates that every day is the anniversary of some resource issue that has affected peoples' lives. We desire that students not view this text or your course as merely a historical account of what has happened, but rather as a commentary of an ongoing and unfinished drama in which they are players.

CHAPTER 1. MINERALS: THE FOUNDATIONS OF SOCIETY

Objectives

Part 1 and the initial chapter have been written with the express objective of setting the scene for the subsequent chapters. Thus, they are intended to demonstrate the "complex network;" that is, the fact that nearly all resources are used in conjunction with many others. They also attempt to point out the importance of human population as a major force in the increasing use of resources and to trace the history of population increase. Another intent is to provide definitions for the terms "resource" and "reserve" so that the students have a clear understanding of types of parameters that control the exploitation of mineral commodities. The final intent is to show that our exploitation of resources has immediate and local, as well as long-term and often global, consequences in terms of our environment. We have only one planet on which we can live, so we need to be careful about activities that degrade the environment.

Approach

In the opening sections of this book, the approach is to demonstrate the great dependence we have on the mineral products of the earth and to point out the complexities of their use. Human population, as a driving force for increasing mineral production, is followed over the past 6000 years and is projected, on the basis of the latest demographic figures, to an ultimate value of about 12 billion. It is as important for the students to recognize the differences in population growth rates and resource demands between modern technological societies and lesser developed societies as it is to see total population figures.

The standard definitions of "resource" and "reserve" are provided, both verbally and in diagram form, so that the students have a proper basis on which to base the world's capabilities to meet future needs.

Major Topics

The World's Resource Needs
Population Growth: The Force that Drives Consumption
Materials We Use
Consequences of Resource Exploitation
Resources, Reserves, and Ores
Where Do Earth Resources Come From?
Box 1.1: CO_2 and the Greenhouse Effect
Box1.2: The Lessons of Busang and Bre-X

Possible Topics for Discussion and/or Reports

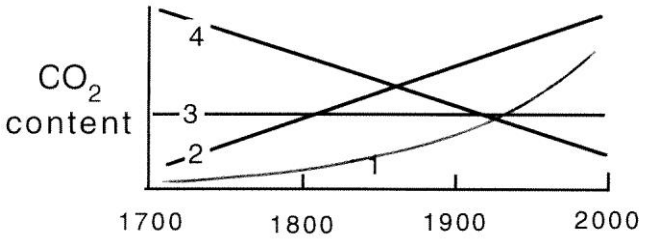
1. Impact of the Black Death on Human Population
2. The Earth's Ultimate Carrying Capacity
3. The Changing Nature of Resource Consumption
4. How Many People Have Ever Lived?
5. The Economic Controls of Mineral Resources
6. The Nature of Society if We Did Not Extract Mineral Resources from the Earth 7. Changes in the Carbon Dioxide Content of Earth's Atmosphere and Its Consequences

Sample Quiz Questions

1. Why is it not possible to consider the uses of each resource individually?
2. As an example of the complex interactions of resource usage, please describe the involvement of the varied types of mineral resources in the preparation of a loaf of bread.
3. Briefly describe the pattern of human population increase over the past 6000 years.
4. What was the only period of major world population decline, and what was its cause?
5. Why did human population begin to increase so rapidly at about the end of the sixteenth century?
6. How do the rates of population growth in individual countries correlate with their standards of living?
7. What are the current projections of the world's ultimate stable human population?
8. Draw "age–sex" pyramids to illustrate the populations of a typical lesser developed country and a typical technologically developed country.
9. Discuss the differences between renewable and nonrenewable resources.
10. On a simple *x*–*y* diagram, draw curves that illustrate the amounts of a typical nonrenewable and a typical renewable resource remaining to be extracted as time goes by.
11. What limits the amount of renewable resources available in any one year?
12. What is generally understood by the term "abundant metal"? Cite three examples.
13. What are the two major sources of energy driving the activities we see on the face of Earth? Which of these is most visible to us?
14. What is geochemical cycling?
15. Illustrate, in a simple schematic diagram, the geochemical cycle for carbon.
16. How do human activities affect the carbon cycle?
17. How are "resources" different from "reserves"?
18. What factors determine how much of the resources are also reserves?
19. How has the amount of carbon dioxide in Earth's atmosphere changed since the late 1950s?
20. What are the likely consequences of continuing increases in the carbon dioxide content of the atmosphere?

Multiple-Choice Questions (Answers Indicated by *)

1. The CO_2 level in the atmosphere over the past 300 years is best represented by curve #: (1)*



2. The current world population of: (1) 2 billion; (2) 3 billion; (3) 4 billion;

   (4)* 6.5 billion; (5) 8 billion . . . is expected to rise until it stabilizes. . .

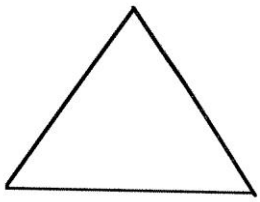
3. . . . at about (1) 8 billion; (2)* 12 billion; (3) 15 billion; (4) 33 billion; (5) 100 billion.

4. The value of an "ore" depends upon: (1) grade + location; (2) grade + location + mineralogy; (3) grade + location + market value; (4) grade + mineralogy + market value; (5)* grade + location + mineralogy + market value.

5. The amount of "reserve" of any commodity: (1)* depends upon the market value; (2) is fixed; (3) is always decreasing; (4) is always rising; (5) is never known.

6. The largest drop in world population occurred in: (1) 1066 as a result of the Norman Conquest; (2)* 1348 as a result of the Plague; (3) 1492 as a result of the introduction of measles into the Americas; (4) 1861 during the American Civil War; (5) 1918 as a result of World War I.

7. An age–sex pyramid with the shape shown below:



   (1) is representative of developed nations;
   (2) is representative of developing nations;
   (3) indicates a stable population;
   (4) indicates a growing population;
   (5) (1) and (3);
   (6)* (2) and (4).

8. The most populous country on Earth is: (1) the United States; (2) India; (3)* China; (4) Russia; (5) Pakistan.

9. Nonrenewable resources are: (1) finite in finite time; (2) infinite in infinite time; (3) finite in infinite time; (4) infinite in finite time; (5) (1) and (2;) (6)* (1) and (3); (7) (2) and (4).

10. Renewable resources are: (1) finite in finite time; (2) infinite in infinite time; (3) finite in infinite time; (4) infinite in finite time; (5)* (1) and (2); (6) (1) and (3); (7) (2) and (4).

11. The quantity of reserves of a given resource: (1) is always decreasing; (2) is never really known; (3) varies inversely with the sale price of the commodity; (4)* often rises and falls on a day-to-day basis; (5) (1) and (2); (6) (1) and (3).

12. The original energy source for renewable resources is: (1) gravity; (2) radioactivity within the earth; (3) the rotational energy of Earth; (4)* the Sun; (5) the oceans.

13. Reserves compared to resources of a mineral commodity are: (1) always the same; (2) always larger; (3)* always smaller; (4) not related.

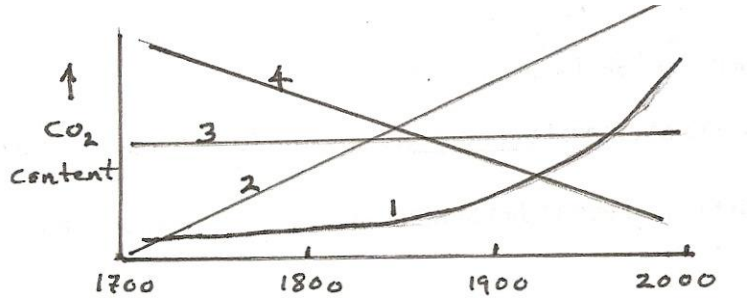
14. The rate of the increase in the use of mineral resources has been: (1)* greater than; (2) equal to; (3) less than . . . the rate of population increase.

15. The rate of population increase in a country is, in general: (1) proportional to; (2) independent of; (3)* inversely proportional to . . . its standard of living.

16. Most of the chemical elements that we use in modern society are extracted from: (1) the atmosphere; (2) the oceans; (3) plants; (4)* mined ores.

17. The age–sex pyramid of a country with a stable or very slowly growing population is shaped like which diagram below? (3)*

18. The age–sex pyramid of a country with a very rapidly growing population is shaped like which diagram below? (1)*



19. The principal atmospheric gas that could affect Earth's temperature is considered to be: (1) methane; (2) nitrogen; (3) oxygen; (4)* carbon dioxide; (5) nitrous oxide.

20. The principal cause for the change in the amount of this gas in Earth's atmosphere in the past 200 years has been: (1) the internal combustion engine; (2) the cutting down of forests; (3)* the burning of fossil fuels; (4) the increased numbers of humans breathing; (5) the solar UV conversion of nitrogen into this gas.

21. Which of the following has increased at the most rapid rate over the past 50 years? (1) world population; (2) irrigated land area in the world; (3) the number of tractors used in agriculture in the world; (4) the total amount of food produced in the world; (5)* the amount of fertilizer used in the world.

22. The primary point of "The Lessons of Busang and Bre-X" is that: (1) the largest gold deposits occur in Southeast Asia; (2) the largest gold deposits form in porphyry-type intrusions at

subducting plate boundaries; (3) most announcements about gold discoveries are false; (4)* it is still easy to be fooled by credible-sounding reports of wealth; (5) the largest mines often create the greatest amounts of pollution.

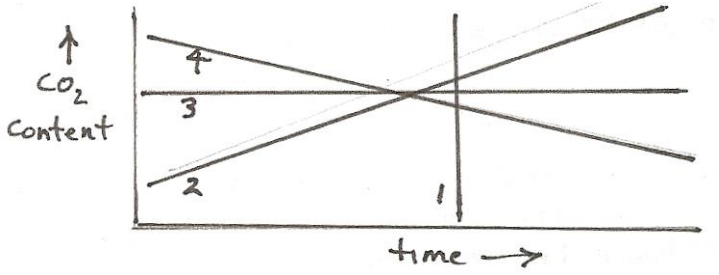
23. If the United States is going to live up to its commitment in the Kyoto Protocol and subsequent agreements, it will have to (meaning what specifically must be done to do what it said it would do): (1) reduce its total energy use; (2) reduce its total water consumption; (3) reduce its consumption of oil; (4)* reduce its carbon dioxide emissions; (5) reduce its emissions of radiation from all nuclear sources.

24. The principal concern of any significant rise in the amount of carbon dioxide in Earth's atmosphere is: (1) the slowing of the growth of plants; (2) a rise in the ozone level in Earth's atmosphere; (3)* a rise in Earth's temperature; (4) a reduction in the amount of oxygen in Earth's atmosphere; (5) an increase in the UV radiation reaching Earth.

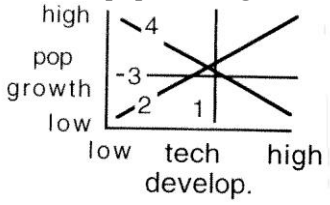
25. Canaries were once widely used in mines in order to: (1) test if there was too much radiation; (2) test if there was too much radon; (3)* test if the air was breathable; (4) warn for high-pitched noises associated with rock failure; (5) test for unhealthy levels of humidity in the air.

26. The primary difference between "resources" and "reserves" is: (1) that mining of reserves is profitable, whereas the mining of resources is not; (2) that reserves are generally of higher grade; (3) that the volume of resources is usually greater than that of reserves; (4) that mineral concentrations must be accessible if they are to be listed as reserves; (5)* all of the above.

27. In the diagram below, which curve best describes the trend in the amount of carbon dioxide in Earth's atmosphere if humans were not influencing the atmosphere? (*#3)

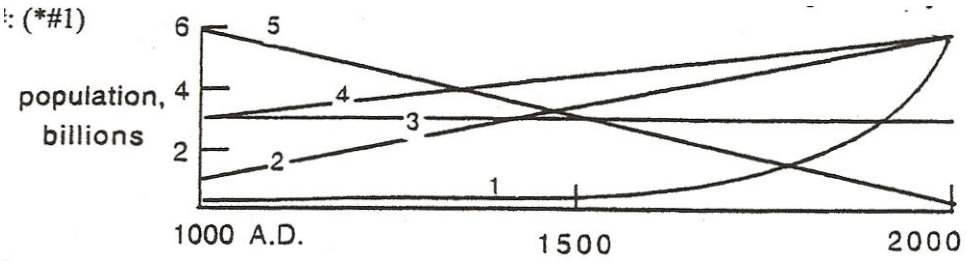


28. The curve that best shows the relationship between a country's degree of technological development and its rate of population growth is #:(*4)



29. The degree to which the United States is dependent on other countries for its mineral resource needs: (1) is less than 20 percent for most materials; (2) is about 50 percent for most materials; (3) is about 70 percent for most materials; (4)* ranges from 0 to 100 percent depending on the materials; (5) is nearly 100 percent for most materials.

30. The curve that best represents the change in human population over the past 1000 years is #: (*1)



31. During photosynthesis, plants take in: (1) CO_2 and give off N_2; (2) N_2 and give off CO_2; (3) O_2 and give off CO_2; (4)* CO_2 and give off O_2; (5) CO and give off O_2.

32. In general, the quantity of a "reserve:" (1) is much larger than the quantity of a "resource;" (2) is much smaller than the quantity of a "resource;" (3) changes on a day-to-day basis; (4) remains essentially fixed for long periods of time; (5) is much affected by changes in the market value; (6) (2) and (4); (7) (1), (3), and (4); (8)* (2), (3), and (5).

33. In general, the quantity of a "resource:" (1) is much larger than the quantity of a "reserve;" (2) is much smaller than the quantity of a "reserve;" (3) changes on a day-to-day basis; (4) remains essentially fixed for long periods of time; (5) is much affected by changes in the market value; (6)* (1) and (4); (7) (1), (3), and (4); (8) (2), (3), and (5).

34. Mineral resources often assume significant political importance because: (1) they are irregularly distributed geologically; (2) they are irregularly distributed geographically; (3) they are necessary or important; (4) each type is more or less uniformly distributed across the earth's surface; (5)* (2) and (3).

Internet Information Search Terms

The listing given below is intended to provide a few starting points for students who wish to find additional information on the Internet. Insertion of these terms in a computer search engine will provide information and lead to the discovery of many additional sources.

Search Terms:

Population, census, global warming, greenhouse gases, climate change, Statistical Abstract of the United States, United Nations, U.S. Geological Survey, mineral resources, age–sex pyramids, population clock, and Mineral Commodity Summaries

CHAPTER 2. PLATE TECTONICS AND THE ORIGINS OF MINERAL RESOURCES

Objectives

Two important perspectives for students are as follows:
1. All Earth's resources are created by one or more geological processes.
2. All geological processes are forming, destroying, or modifying some of Earth's resources.
The primary objective of this chapter is to provide a relatively simple overview of the principal geological processes involved in the formation and distribution of Earth's resources. There is greater emphasis on the role of plate tectonics than in the previous edition. This includes the present plate position as well as the specific processes that have been active. Many of Earth's resources were formed in the past, and the movement of plates has now altered their geographic positions on Earth's surface. Furthermore, it is implicit that resources are not random in their distribution, but rather that they occur in association with certain types of rocks and types of geological environments. Simplistically stated, "If one has the right kinds of rocks, one may well have the specific kinds of resources that tend to be associated with those rocks."

Approach

The students who enroll in courses dealing with Earth's resources and the environment may come with backgrounds that range widely in terms of their levels of exposure to geology. Many students have not had prior geology courses and therefore, have little knowledge of the processes that form resources; many others have had courses in physical geology that focused on Earth's surface processes with little discussion of resources. This chapter attempts to strike a balance that can effectively serve both groups of students. Hence, it strives to offer students, with no prior background, a very basic understanding of the major geological processes that affect resources. At the same time, we hope that it will refresh the memories of students who have had physical geology and emphasize that many of the processes they studied before were also making the resources they use every day. The condensation of the discussion of resource-forming processes into one chapter requires that all are treated rather superficially and incompletely. Nevertheless, we have felt that some brief overview helps the students in their understanding of the origins and distribution of resources. Additional discussions of processes relevant to specific resources remain in the individual chapters.

There is no single way to approach the variety of geologic processes involved in resource formation; hence, we have made some arbitrary choices in the order of discussion. We have tried to stress that the resources are integral parts of large dynamic cycles of earth processes that we call "the rock cycle." Furthermore, for every chemical element and resource, there are identifiable cycles in which they are transported, concentrated and dispersed. The approach we have employed is organized according to the following outline:

— Subsurface Igneous and Metamorphic Processes

Formation of Granites and Other Relatively Silica-Rich Rocks
Formation of Basalts and Other Relatively Silica-Poor Rocks
Regional Metamorphism
Contact Metamorphism

— Surface Processes
Weathering and Erosion
Evaporation

— Shallow Subsurface and Diagenetic Processes
— Marine Processes

The emphasis throughout is on the manner in which each of the processes produces, modifies, or destroys resources. The discussions are necessarily brief and intended to help the students recognize the connections between resources and the various components of the rock cycle. We invite the course instructors to expand on the presentations in the text.

We have included "boxes," one on "Fluid Inclusions" and the other on "Placer Deposits: Panning Gold and Mining Gravel." Fluid inclusions provide good examples of how some very small features can provide extremely valuable information to help decipher the origins of resources. Placer deposits demonstrate that running water concentrates resources as valuable as gold and as common as sand and gravel. The discussion further points out that, despite the value of placer gold and its importance in the discovery of gold fields, sand and gravel are generally much more important in terms of volume used and in terms of value. An additional “box” on seabed ownership is intended to help students understand the complexities of mineral resource ownership when they lie under oceans beyond normally recognized jurisdictions.

Major Topics

Introduction
Plate Tectonics
Subsurface Igneous and Metamorphic Processes
    Formation of Granites and Other Relatively Silica-Rich Rocks
    Fluid Inclusions
    Formation of Basalts and Other Relatively Silica-Poor Rocks
    Regional Metamorphism
    Contact Metamorphism
Surface Processes
    Weathering and Erosion
    Placer Deposits: Panning Gold and Mining Gravel
    Evaporation
Shallow Subsurface and Diagenetic Processes
Marine Processes
Box 2.1: Fluid Inclusions
Box 2.2: Placer Deposits: Panning Gold and Mining Gravel
Box 2.3: Seabed Ownership

Possible Topics for Discussion and/or Reports

1. The Internal Structure of Earth
2. The Types of Resources Associated with Acidic (or Granitic) Igneous Rocks
3. The Types of Resources Associated with Basic (or Basaltic) Igneous Rocks
4. The Genesis of Resources by Weathering and Erosion
5. The Genesis of Resources by the Evaporation of Seawater and/or Fresh Water

6. Earth Resources Formed in the Marine Environment

7. Earth Resources Formed as a Result of Metamorphism

8. The Origins of Fossil Fuels

9. The Relationship of the Water Table to the Land Surface

10. Fluid Inclusions and Their Utility in Understanding the Origins of Rocks

Sample Quiz Questions

1. How does the intrusion of large basaltic bodies (low silica magmas) lead to the formation of resources and what kinds of resources?

2. What kinds of resources form in association with granitic (high silica magmas) intrusions and how?

3. How have the world's principal resources of chromium and platinum formed?

4. How and where have the world's largest copper deposits formed?

5. How have the world's principal precious-metal and base, metal-bearing veins formed?

6. How have placer gold deposits formed?

7. How does weathering form resources?

8. What resources are derived from the oceans?

9. What are fluid inclusions and how are they useful in understanding the origins of rocks?

10. What kinds of resources are formed by regional metamorphism?

11. What are hydrothermal fluids?

12. What is the source of the heat within Earth?

Multiple-Choice Questions (Answers Indicated by *)

AUTHOR: Please note that #24 through end in this numbered list need to be aligned with other numbers. I could not get the numbers to align properly; please adjust as needed.

1. Chromite layers form: (1) in deeply weathered soils; (2) from hydrothermal fluids; (3)* in large basaltic intrusions; (4) as a result of contact metamorphism; (5) where the mineral grains precipitate as layers in deltas.

2. Precious- and base-metal vein deposits generally form: (1) where meteoric waters percolate down along fractures; (2) in large basaltic intrusions; (3) as a result of deep weathering; (4) from fluids escaping from Earth's mantle; (5)* from hydrothermal fluids.

3. The gold found in placer deposits: (1) dissolved out of average rocks and then crystallized around small grains of pyrite; (2) was dissolved out of average rocks and then was crystallized by bacterial activity; (3) forms where gold-bearing hydrothermal fluids flow into the streams; (4)* are grains weathered out of preexisting deposits and washed down the streams; (5) are the residual fragments of human-made gold objects.

4. The principal mineral comprising the mid-latitude beaches along the coasts of most continents is: (1) calcite; (2)* quartz; (3) orthoclase feldspar; (4) olivine; (5) plagioclase feldspar.

5. The reefs and beach sands, such as those found in the Bahamas, forming in tropical seas are composed nearly entirely of: (1)* calcite; (2) quartz; (3) orthoclase feldspar; (4) olivine; (5) plagioclase feldspar.

6. The principal mineral deposited when seawater evaporates is: (1) quartz; (2) calcite; (3) gypsum; (4)* halite; (5) orthoclase feldspar.

7. Marbles form as a result of: (1) the crystallization of granites; (2) the crystallization of basalts; (3) the metamorphism of coal; (4)* the metamorphism of limestone; (5) the evaporation of seawater.

8. The fossil fuels (coal, oil, and natural gas) form: (1) where hydrothermal fluids pass along fractures; (2) as precipitates in large basaltic intrusions; (3)* where organic matter is trapped in sediments; (4) where organic matter is dissolved in groundwater and is redeposited along bedding planes; (5) as the result of the evaporation of seawater.

9. Deep tropical weathering of rocks and soils has led to the formation of the major ores of: (1) copper; (2)*aluminum; (3) gold; (4) lead; (5) zinc.

10. The quartz sand that forms most mid-latitude beaches: (1) results from the breakup of clam and oyster shells; (2) crystallizes from seawater; (3)* is composed of grains weathered out of rocks on the continents; (4) is composed of fragments of ocean-floor basalts; (5) is silica precipitated by certain kinds of bacteria in the wave zones.

11. Most groundwater that can be extracted from wells: (1) has seeped into the ground from rivers and lakes; (2) has seeped into the ground from the oceans; (3)* has seeped into the ground from rainwater; (4) is the result of hydrothermal fluids that are rising upward from igneous intrusions; (5) was initially trapped in the sediments as seawater.

12. Modern day "black smokers" are essentially the precursors of what we now see as: (1) oil deposits; (2) coal beds; (3) iron ores; (4) vein deposits; (5) diamond pipes; (6)* volcanogenic massive sulfide deposits.

13. Regional metamorphism of mudstones and shales generally results in the formation of: (1) coal beds; (2)* slates; (3) marbles; (4) oil shales; (5) dolomites.

14. Contact metamorphic ore deposits generally form best where intrusions cut across: (1) shales; (2)* limestones; (3) sandstones; (4) basalts; (5) schists.

15. The initial source of most of the elements in evaporite minerals that precipitate from water bodies, such as the Great Salt Lake or the Dead Sea, is: (1) seawater; (2) the atmosphere; (3) hydrothermal fluids; (4) groundwater; (5)* chemical weathering of rocks.

16. Coal beds form as the result of: (1) hydrothermal fluids; (2) the burial of marine organic matter; (3)* the burial of terrestrial organic matter; (4) the crystallization of basalts; (5) the metamorphism of limestones.

17. Petroleum forms: (1) hydrothermal fluids; (2)* the burial of marine organic matter; (3) the burial of terrestrial organic matter; (4) the crystallization of basalts; (5) the metamorphism of limestones.

18. Large metal-bearing porphyry deposits typically form: (1) at spreading plate boundaries; (2)* at subducting plate boundaries; (3) in the centers of large continental plates; (4) within thick sequences of lava flows; (5) in regional metamorphic terrains.

19. Fluid inclusions: (1) are small lakes; (2) are small pools of oil that form in coal beds; (3) are droplets of fluids trapped in minerals; (4) can often yield information about the conditions under which they form; (5) (2) and (4); (6)* (3) and (4).

20. Pegmatites generally form: (1) in basalt flows; (2)* in granitic intrusions; (3) in large basaltic intrusions; (4) in contact metamorphic zones; (5) in regionally metamorphic rocks.

21. Large-bedded phosphate deposits: (1) result from the evaporation of seawater; (2) result from the replacement of limestones during contact metamorphism; (3)* form on shallow continental shelves; (4) form as a result of deep weathering; (5) crystallize in large igneous intrusions.

22. Gossans: (1) form as a result of contact metamorphism; (2) form as a result of the weathering of sulfide minerals; (3) are useful as exploration guides for ore deposits; (4) are good ores of aluminum; (5) (1) and (4); (6)* (2) and (3).

23. What is the principal source of the heat in Earth's interior? (1) the Sun; (2) residual heat from when Earth was pulled out of the Sun; (3)* radioactive decay; (4) the gravitational pull of the Sun; (5) the friction of the convection cells in the mantle.

24. Salt domes may rise from thick salt beds and then migrate up through sediments because: (1) they trap helium; (2) they slowly dissolve the overlying sediments; (3) the salt has a higher density than the overlying elements; (4)* the salt has a lower density than the overlying sediments; (5) of granitic intrusions that force it upward.

25. Fluid inclusions have proven to be especially useful in the study of mineral resources because they can provide information about: (1) the age of minerals; (2) the radioactivity of deposits; (3) the principal types of pollution that could occur as a result of mining; (4)* the solutions from which the minerals formed; (5) the grade of the deposits; (6) how much reserve remains in a deposit.

26. Black smokers form most often: (1) at subduction zones; (2)* at spreading plate boundaries; (3) in the centers of continental plates; (4) at the centers of oceanic plates; (5) where volcanoes cut through coal-bearing sedimentary beds.

27. Large porphyritic intrusions, rich in copper and gold, have formed: (1) during high-grade

metamorphism; (2) at oceanic plate spreading boundaries; (3)* at plate subduction zones; (4) where basalts have intruded into the crust; (5) in the centers of oceanic plates.

28. The only widely used mineral resource that did not form in Earth's crust: (1) is coal; (2) is gold; (3) is silver; (4) are emeralds; (5)* is diamond.

29. Placer accumulation has served to be an important means of forming reserves of: (1)* gold; (2) silver; (3) copper; (4) aluminum; (5) zinc.

Please correlate the resource with the mode of formation listed at the left

30.	Evaporation of seawater (*3)	(1) chromium
31.	Metamorphism of common marine sediments (*6)	(2) gold
32.	Crystallization of large basaltic intrusions (*1)	(3) halite
33.	Intense tropical weathering and leaching (*7)	(4) sand
34.	Hot water flowing outward from granites (*2)	(5) coal
35.	Accumulation and burial of land plants (*5)	(6) marble
36.	Decomposition and erosion of average rocks (*4)	(7) bauxite

37. The thick salt beds that occur under parts of the Gulf Coastal region of the United States formed as the result of: (1) replacement of limestones by magmatic fluids; (2)* evaporation of seawater; (3) crystallization.

Internet Information Sources

The listing of search terms given below is intended to provide some starting points for those who wish to find more information on the topics covered in this chapter. Insertion of these terms into any computer search engine will yield numerous results and lead to many additional terms worth pursuing.

Search Terms:

Physical geology, history of resources, California Gold Rush, Industrial Revolution, U.S. Geological Survey, mineral resources, OPEC, DeBeers, consumer price index, U.S. National Stockpile, stone age, copper age, bronze age, iron age, fluid inclusions, placer deposits, plate tectonics, subduction zones, volcanogenic massive sulfides, vein deposits, chromite deposits, and hydrothermal veins