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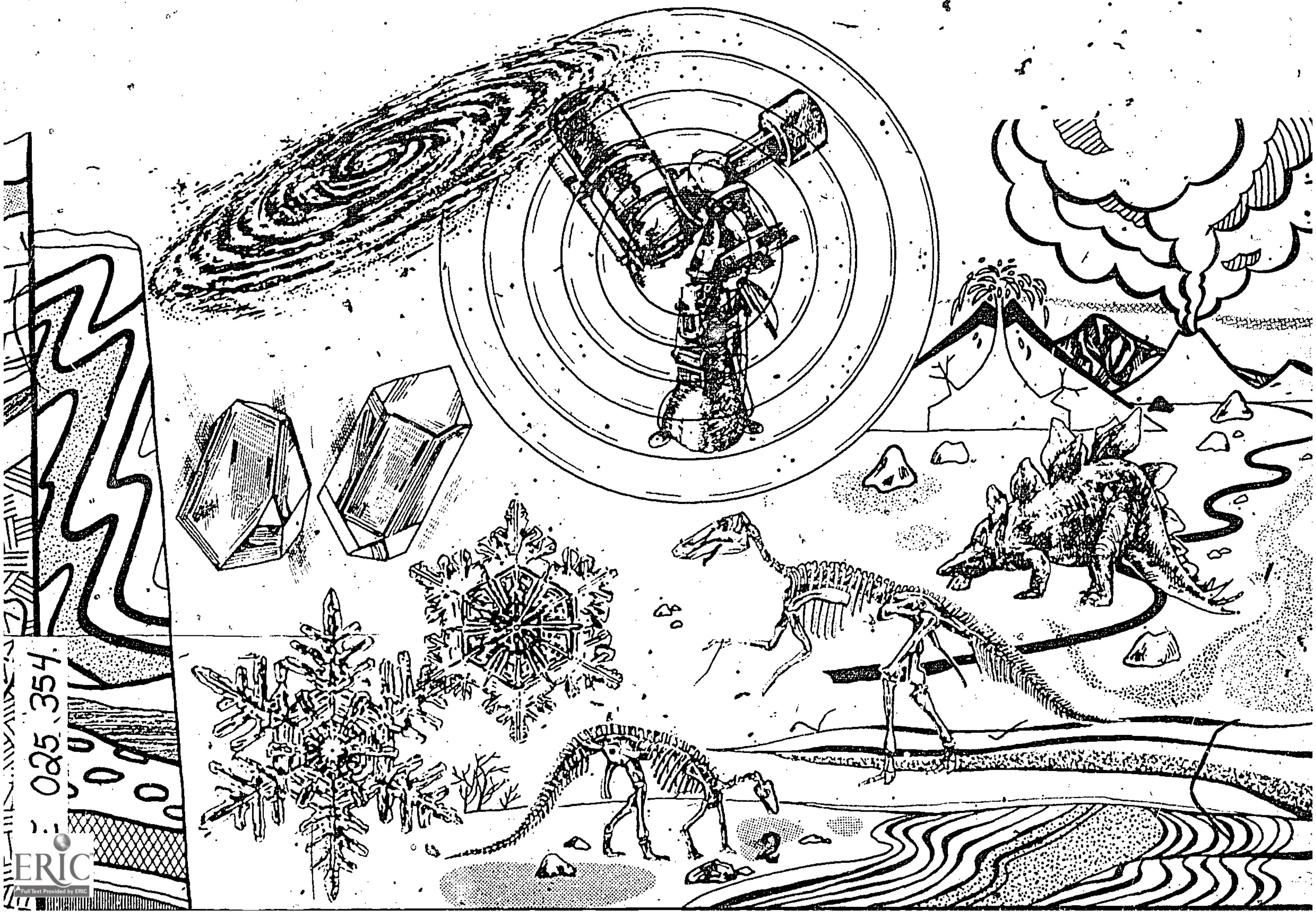
ABSTRACT

This publication, developed by the Ministry of Education, Province of British Columbia, Canada, is a teaching guide for the Earth Science 11 course. The course is intended to provide secondary school students with the background and desire to investigate their earth, its materials and its processes. The guide consists of four sections. Section A is concerned with astronomical sciences. It includes three units: stellar systems, solar systems and the third planet. Section B is concerned with geological sciences. It also includes three units. Section C is concerned with oceanographic and atmospheric sciences. It includes two units: the oceans and the atmospheric science. Section D is concerned with renewable and non-renewable earth resources. Learning outcomes, suggested activities and investigations, a list of references, and scope and sequence of the units are also included in each section. A list of equipment and supplies, audiovisual materials, supplementary reference texts and prescribed textbooks are presented in the appendix. An introduction including the purpose of the course is also presented. (HM)

EARTH SCIENCE 11



PROVINCE OF BRITISH COLUMBIA

MINISTRY OF EDUCATION

DIVISION OF EDUCATIONAL PROGRAMS — SCHOOLS

CURRICULUM DEVELOPMENT BRANCH

EARTH SCIENCE 11

VICTORIA, B.C.
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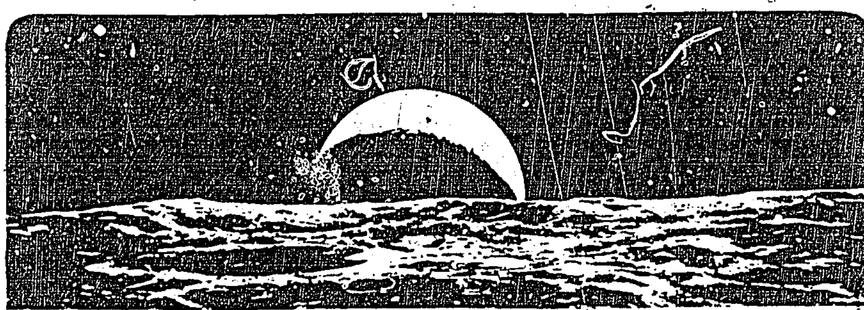

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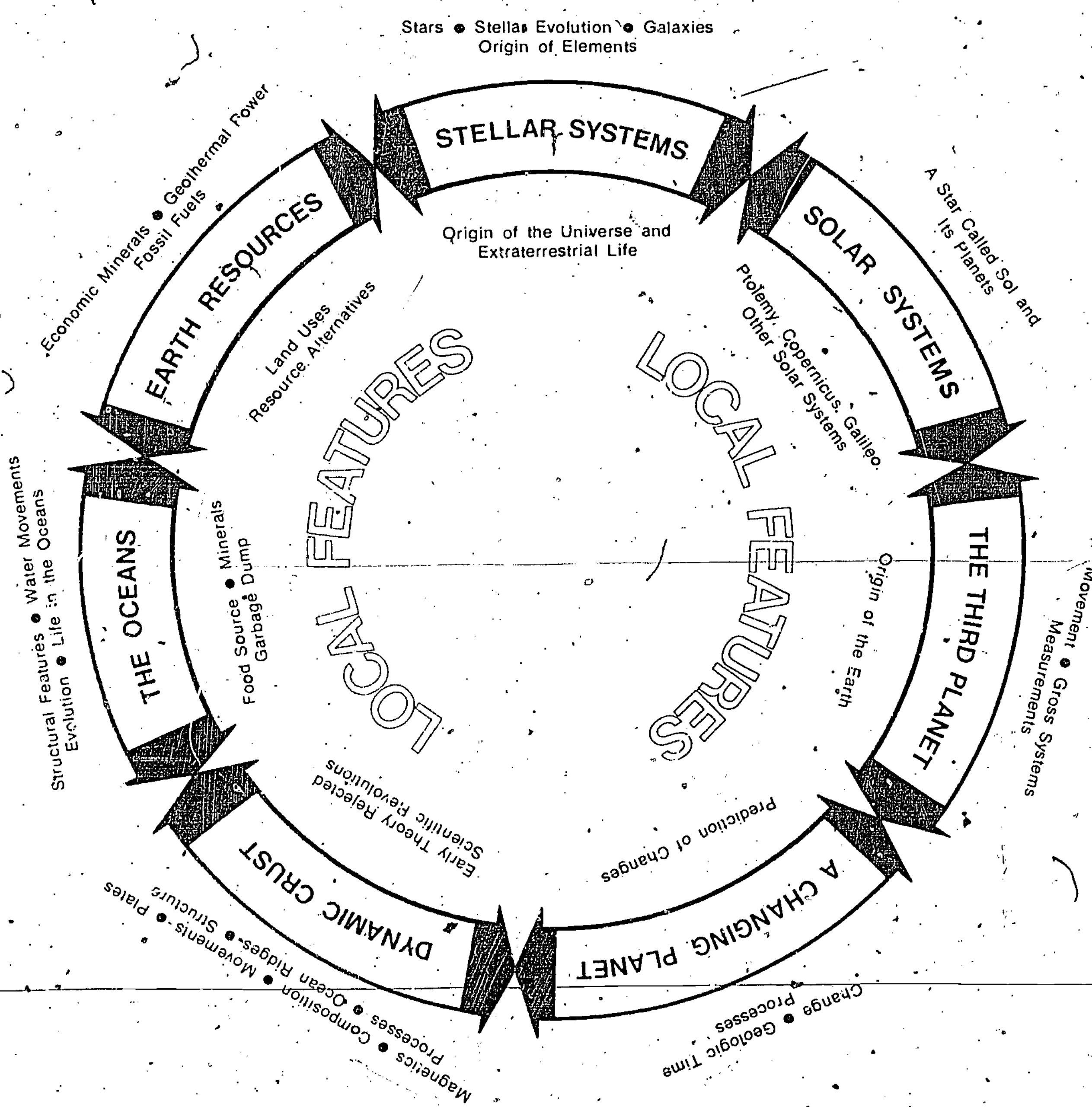
MAJOR THEMES

INQUIRY PREDICTION

UNIVERSALITY of
CHANGE

UNIFORMITY of
PROCESS ENERGY FLOW TIME & SPACE SCALE

CONSERVATION of
MASS & ENERGY



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Introduction

PART I — PURPOSE OF THE COURSE

Historians of science, notably T.S. Kuhn, have suggested that major scientific discoveries frequently occur as slow metamorphoses rather than unique events. Such a slow metamorphosis is presently responsible for an entirely new way of viewing our earth, its processes and its history.

Kuhn (1970) describes the maturation of a science as tangential groups of studies being united by a major theory which is consistent with a large body of observations. Copernican astronomy, Newtonian physics and Lavoisier's oxygen theory of combustion are some excellent examples of revolutionary theories that have emerged in response to a breakdown in the ability of previously held beliefs to explain a growing body of observations. It is the appearance of such new theories, termed paradigms by Kuhn, which allows the correlation, integration and explanation of observed puzzles and anomalous data, thus allowing science to progress to the point where a new paradigm becomes necessary.

Such a point was reached in the earth sciences in the late 1950's. Maps and oceanographic charts produced for nuclear submarines began to show that the seventy percent of the earth's surface which lay below the oceans was not the flat, uncomplicated place that it had once been thought to be. Vast mountain ranges and deep trenches were among the most impressive structures of a topography quite unlike anything observed on the land surface of the earth. P.J. Coney (1970) states that perhaps the most startling discovery resulting from the explosion in oceanographic research has been the fact that the OCEANIC RISE is one of the major features of our planet. It is a system of adjoining rifts, which circles the globe like the seams on a baseball. Such major features of our earth demand an explanation and the emergence of the new plate tectonic theory of continental drift has precipitated a major scientific revolution. Canadian geologist J. Tuzo Wilson (1971) states that:

> The acceptance of continental drift has transformed the earth sciences from a group of rather unimaginative studies based on pedestrian interpretations of natural phenomena into a unified science that is exciting and dynamic and that holds out the promise of great practical advances for the future.

The processes of the earth are so important to us that it is easy for us to forget that the earth is the third planet orbiting a mediocre star in an average galaxy. Space science is still awaiting a single coherent theory, and recent discoveries emphasize this need. Nevertheless a study of the observations that have been made by astronomers can give students a sense of perspective and show them the earth in its place in the universe. One valuable sense astronomy has given us, for example, is the sense of distance.

Secondary students are becoming adults in a world where terms such as energy crisis, non-renewable resources, fossil fuel and quasar are commonplace. For any student presently under the age of seventeen the space age has always existed and man has always been intensely concerned with the nature of the earth's processes and materials because of the necessity of maintaining a highly complex civilization.

Earth Science 11 is intended to provide secondary school students with the background and the desire to investigate their earth, its materials and its processes. (Thus the course should provide young people with the ability to understand and make decisions in a rapidly changing world).

References Cited:

1. Coney, Peter J., 1970, *The Geotectonic Cycle and the New Global Tectonics:* Geological Society of America Bulletin, Vo. 81, pp. 739-747.

2. Kuhn, T.S., 1970, *The Structure of Scientific Revolutions,* (Second ed., enlarged), University of Chicago Press.

PART II — LOCAL FEATURES

In all aspects of earth science there is a need for definite stress on features of the earth in the locale where they are being taught. Reality and relevance are often bandied about by students as the criteria for the "value" of a particular course. Few subjects lend themselves so readily to justification by these criteria as do the earth sciences. Evening sky watches, trips to the ocean or a mine, power station, field work at local rock outcrops of glacial sediments or simply a tour of the school's surrounding area are but a few examples of the activities which must be a part of this course if the maximum benefit is to be derived by all. **Plan ahead to make field work an integral part of the course.**

PART III — TEXTBOOKS; EQUIPMENT AND SUPPLIES

1. Textbooks

One result of a major scientific discovery is the subsequent publication or revision of textbooks on the subject. There are therefore many new and revised earth and space science textbooks. A choice must be made as to which texts, if any, will be used. The titles and scale of issue of texts may be found in the current Prescribed Textbooks List and also in the Appendix.

A subject with a scope as broad as the earth and space sciences cannot be adequately covered in a single textbook, so teachers have been presented with a choice of text and reference material. It is recommended that teachers select texts from the lists provided in such a manner as to best supplement each of the major areas of study.

2. Equipment and Supplies

A comprehensive list of equipment and supplies has been provided in order to allow for variations from school to school. The list contains all the materials necessary for completion of the investigations in each phase of the courses; however many supply items such as beakers or certain chemicals may already be present in a school in sufficient quantity. From the list provided, teachers must decide what equipment will be needed to complete the particular scope which has been selected.

PART IV — MAJOR GOALS FOR EARTH SCIENCE 11

1. To investigate the principles of many fields of earth science in order to form an up-do-date, broad understanding of the story of the earth and its environment in space.
2. To encourage the study of a selection from some of the following fields in the earth sciences:
   a. astronomy, including star systems and the earth as a planet.
   b. geology, including the study, the processes and the materials that make the earth crust — with particular emphasis on plate tectonics and the continental drift theories, the gradation forces which change the earth's surface.
   c. geologic time and earth's history.
   d. oceanography and atmospheric sciences.
   e. the resources of the earth.

LEARNING OUTCOMES and SUGGESTED ACTIVITIES

Section A

Astronomical Sciences

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Teacher Resource Material is indicated by number in the parentheses following most Learning Outcomes. Details regarding references, activities and investigations follow the respective sections of the Earth Science 11 course. (These are suggested activities only and may be used at the discretion of the teacher.)

Section A Astronomy

INTRODUCTION

Real, apparent and relative motions of the stars are all key points in the understanding of the principles of astronomy. The units in this section deal with the motion and immense energy and distance involved in stellar and solar systems. Students may also be provided with opportunities to contrast the **science** of astronomy with the **pseudo-science** of astrology.

Two stimulating ways to begin this section are:

1. The Activity: Lost on the Moon p. 249. Investigating the Earth (p. 223, Teacher's Guide).
2. Reading from Science Fiction.
   a. A Slight Case of Sunstroke by A.C. Clarke from his book, Tales of Ten Worlds, Harcourt Brace.
   b. Squ-ush by A.C. Clarke, from his book, From Earth to Heaven.
   c. Summer Time in Icarus by A.C. Clarke, from Tales of Ten Worlds.

SCOPE AND SEQUENCE

Unit 1 — Stellar Systems

a. optical and radio windows
b. electromagnetic spectrum
c. Doppler effect.
d. distances and how they are determined
e. types of stars
f. galaxies
g. the expanding Universe
h. black holes and other unusual phenomenon

Unit 2 — Solar Systems

1. The Sun
   a. its size and distance and comparison with other stars
   b. its spectrum
   c. its energy, source and output
   d. sunspots
   e. solar wind
   f. its position in the life cycle of stars
2. The Solar System
   a. retrograde motion
   b. orbits
   c. elements of solar system

d. the ecliptic.
e. views of the Universe
f. origins of the solar system
g. planetary exploration in the seventies
h. changing images of the planets

Unit 3 — The Third Planet

1. The Third Planet (Earth)
   a. composition of the earth
   b. mass of the earth
   c. movements of the earth
   d. magnetic field
2. The Moon

Section A Astronomy

UNIT 1

STELLAR SYSTEMS

Most of our information about stars comes through the optical and radio windows in forms of electromagnetic radiation, which is studied with spectroscopes and radio telescopes. Recently the analysis of X-rays and infrared and ultraviolet radiations has contributed further information. The results of these studies can be used by students to facilitate their own investigations of stellar systems. During the study of this section teachers may place stress on the indirect nature of stellar observations and measurements as well as the variety of inference and hypothesis to which this has led. Examples such as the super puzzling quasars and black holes may be used.

LEARNING OUTCOMES

The student should be able to:

1. *Discuss methods of measuring astronomical distances using triangulation, parallax and relative brightness of stars and doppler shift and solve related problems.*

   (Activity #1)

2. *Interpret a Hertzsprung-Russel diagram using luminosity and temperature to place stars on the diagram.*

   (Activity #1, 3)

3. *Describe the life cycles of stars including possible origins of pulsars, neutron stars, black holes and quasars.*

   (Activity #3, 4)

4. *Interpret the doppler effect and describe its use in the calculation of astronomical distances.*

   (Activity #6)

5. *Use discussion substantiated with evidence to compare at least two theories on the origin of the Universe.*

References:

1. Ordway, *Earth Science*, (Van Nostrand).

2. American Geological Institute, *Investigating the Earth.*

3. American Geological Institute, *Teachers' Guide to Investigating the Earth.*

4. American Geological Institute, *Geology and Earth Science Sourcebook.*

5. Jackson/Evans, *Spaceship Earth.* Earth Science (Houghton-Mifflin).

6. Nuffield Secondary Science 8, *The Earth and Its Place in The Universe,* (Longman).

7. Bishop, *Focus on Earth Science,* (Merrill).

8. Goldthwait, *Earth Science,* (Ginn).

9. Life Nature Library, *The Earth,* (Time Inc., Book Division).

10. Time Space and Matter, *Investigating the Physical World Series,* (McGraw-Hill).
    - — Encountering the Physical World
    - — Exploring a Slice of the Earth
    - — From Microcosm to Macrocosm
    - — Levels of Approximation
    - — Dimensions and Motions of the Earth
    - — The Surface of the Earth
    - — The Grand Canyon of the Colorado
    - — The Surface of the Moon
    - — Worlds in Space

11. Wolfe et al., *Earth and Space Science,* (Heath).

Activities and Investigations

1. Optical and Radio Windows and the Electromagnetic Spectrum.
   a. Use of spectroscopes (see activities listed under Sun).
   b. Doppler effect see **Earth Science,** Ordway, pp. 508-510.

2. Distances
   a. **Investigating the Earth,** has an exercise on parallax, pp. 458-459. The Teacher's Guide is excellent.
   b. Measurement of distances is discussed in the **Geology and Earth Science Sourcebook.**

3. Types of Stars
   a. Plot a Hertzsprung-Russel diagram, **I.T.E.,** p. 467, and **Spaceship Earth,** pp. 22-24, from this lead into stellar evolution. In connection with stellar evolution it is interesting to consider pulsars, neutron stars and black holes.

4. Galaxies
   a. **I.T.E.,** Investigate stars in the Milky Way, pp. 482-483.

5. Discuss neutron stars and black holes. See Film List: The Black Holes of Gravity.

6. Discuss Hubble's Law and the Expanding Universe. See Film List Galaxies and the Universe.

Section A Astronomy

UNIT 2

SOLAR SYSTEMS

Once students have been introduced to the magnitude of stellar energies and distances, attention can be focussed on our local star, Sol, and the rest of our "family", the solar system. Some teachers may prefer to move from the known to the unknown and teach the units in this section in a reverse order to their presentation here; again it is a matter of individual style.

The energies and distances which are part of stellar astronomy may be related to the evolution and functioning of the solar system by including topics such as the origin of the elements and the relative measurements of the sun and its planets.

The earth is a member of the solar system. Other planets exhibit retrograde motion along the ecliptic against the background of the stars. Along the ecliptic plane are the constellations of the zodiac.

The planets all revolve in the same direction around the sun and in nearly the same plane. Their orbits were first accurately described by Copernicus and Kepler. They are caused to move in circles, or more accurately, ellipses, by the gravitational attraction of the Sun. They are at immense distances from each other and from the Sun.

Their peculiar motions and their changes of brightness probably started the study of astrology, which led to the study of astronomy.

LEARNING OUTCOMES

The student should be able to:

1. *Discuss the study and origin of astrology as opposed to that of astronomy.*
2. *Determine the diameter of the Sun.*

   (Activity #1)

3. *Use a spectroscope to determine the nature of various types of light emission.*

   (Activity #2)

4. *Construct a sundial.*

   (Activity #5)

5. *Describe and explain the variation in day-length over a year for several widely separated positions on the globe.*

6. *Describe retrograde motion using models to explain the phenomenon.*

(Activity #6)

7. *Describe the positions of various planets and their possible origins.*

(Activity #8, 9)

8. *Define the ecliptic plane and the constellations of the zodiac. Emphasize the immense distances between the planets.*

(Activity #10)

9. *Compare and contrast geocentric with heliocentric descriptions of the solar system.*

10. *Compare at least two opposing theories on the origin of the solar system.*

(Activity #10)

Activities and Investigations

The Sun

The Sun is a star whose energy is colossal. It derives its energy through the conversion of mass (the fusion of hydrogen to form helium).

Much information about the Sun and Stars is obtained from the use of spectroscopes to analyze electromagnetic radiations.

Sunspots and other solar disturbances cause disruptions in the earth's magnetosphere and in our communications.

1. Its Size and Distance:
   a. Measuring the diameter of the Sun. Investigation 18, Investigations in Earth Science (Goldthwait).
   b. Nuffield Secondary Science (8.25-ii, p. 75).
   c. Lab Manual to Earth and Space Science, Wolfe et al., p. 123.
2. Spectra
   a. Examine light with a spectroscope. Investigation 20, Investigating Earth Science, (Goldthwait).
   b. Spectra and Spectroscopes, Developing Science Concepts in the Laboratory, Expt. V-14, Rasmussen and Schmid.

c. Temperature and Colour Demonstration, p 77, Nuffield Secondary Science (8.25-iii).

3. The Sun's Energy

   a. How Much Power is the Sun Emitting, (Nuffield), Secondary Science, (8.25-iv).

4. Sunspots

   a. Plot sunspot activity, Investigating the Earth, Teacher's Guide, p. 47.
   b. Observing sunspots, p. 73, Nuffield Secondary Science, (8.25-i), or Geology and Earth Science Sourcebook, p. 278.

5. a. Construct a sun dial. Focus on Earth Science, p. 125.
   b. Plot a graph of Times of Sunrise versus Times of Sunset for one day per month over a period of a year. This is interesting because it shows the tremendous variation in hours of daylight. Skywatch, I.T.E.

The Solar System

The earth is a member of the solar system. Other planets exhibit retrograde motion along the ecliptic against the background of the stars. Along the ecliptic plane are the constellations of the zodiac.

The planets all revolve in the same direction around the Sun and in nearly the same plane. Their orbits were first accurately described by Copernicus and Kepler. They are caused to move in circles, or more accurately, ellipses, by the gravitational attraction of the Sun.

They are at immense distances from each other and from the Sun.

Their peculiar motions and their changes of brightness probably started the study of astrology, which led to the development of astronomy.

6. Retrograde Motion

   a. Activity, p. 438, I.T.E.
   b. Retrograde Motion, p. 11, Lab Investigations in Earth Sciences, Brown, Kemper, Lewis, and p. 263, Geology and Earth Sciences Sourcebook.

7. The Orbits of Planets

   a. The Orbit of Mars, p. 95, Nuffield Secondary Science (8.12-iv, p. 19).
   b. Phases of Planet X, p. 440, I.T.E.
   c. See Appendix, Films, p. 77

8. Elements of the Solar System

   a. Make models of the solar system. Constructing a model of the solar system, (Goldthwait), p. 23, Investigating Earth Science.
   b. Investigating Interplanetary Distances, p. 436, I.T.E., p. 229.
   c. How Big is Space?, p. 40, Nuffield, Secondary Science, (8.28-i).
   d. See Appendix, Films, p. 77

9. Views of the Universe

   a. Geometric — Ptolemy and Almagest.
   b. Heliocentric — Copernicus, Galileo, Kepler, Newton.

10. Origins of Solar Systems.

Any theory must account for the facts that:

a. The planets' orbits are nearly circular and are in the same plane.
b. They revolve in the same direction about the Sun.
c. Their spacings obey Bode's rule.
d. The outer planets are light, the inner ones are heavy.
e. The sun rotates in the same direction as the planets revolve, and its axis is slightly inclined.
f. The orbits of comets are highly eccentric and are inclined at any angle to the ecliptic.
g. There are some indications that the earth was molten in its early history.
h. The periods of rotation of all planets, except Mercury, are in the same order of magnitude, which is remarkable considering the differences of their masses.

A full reference to this is made on p. 252, Geology and Earth Sciences Sourcebook; also in Ordway: Earth Science.

Section A Astronomy

UNIT 3

THE THIRD PLANET

Seemingly large measurements of the earth's dimensions can be shown in perspective when compared to the vast distances introduced in the other units of this section. The remarkable coincidence of our planet's circumstances become apparent as the distances, composition and movements of the earth are examined in this unit. This unit examines the gross physical attributes of the earth as a planet.

LEARNING OUTCOMES

The student should be able to:

1. *Calculate the volume, density and circumference of the earth.*

   (Activity #1)

2. *Demonstrate that the earth rotates on its axis, using at least two methods.*

   (Activity #2, 3)

3. *Give evidence to support a description of the earth's magnetic field.*

(Activity #4)

4. *Suggest possible mechanisms whereby a planet could produce a magnetic field which is characterized by wandering poles and frequent field reversals.*

(Activity #4)

5. *Use models to explain the causes of solar and lunar eclipses.*

(Activity #6)

6. *Describe what the Moon is like.*

(Activity #8)

7. *Describe the motion of the Moon as part of the solar system.*

(Activity #7)

References (Correspond by number to the Activities and Investigations which follow.)

1. American Geological Institute: *Investigating the Earth*, Chapter 1. Wolfe et al: *Exploration of the Universe*, p. 78. Ordway: *Earth Science*, p. 38.

2. American Geological Institute, *Investigating the Earth*, pp. 14-23 and p. 428. Ordway: *Earth Science*, p. 476.

3. Life Nature Library: *The Earth*, Time Inc., Book Division, pp. 9-18. Abell: *Earth and Space Science*, Chapters 6 and 7, (teacher reference). Ordway: *The Earth Science*, p. 20. Wolfe et al: *Earth and Space Science*, p. 237. The University of Illinois Astronomy Program, *The Universe in Motion*, Chapter 5.

4. American Geological Institute, *Investigating the Earth*, p. 68. Ordway: *Earth Science*, p. 298. Life Nature Library, *The Earth*, Time Inc., Book Division, p. 20. Teaching Aids, B.C.T.F., *Continental Drift*, D. Williams. Schmid et al., *Extending Science Concepts in the Laboratory*, p. 142.

5. Abell: *Exploration of the Universe*, Holt, Rinehart and Winston, p. 79. Ordway: *Earth Science*, p. 38.

6. Wolfe et al: *Earth and Space Science*. American Geological Institute: *Investigating the Earth*.

7. Teaching Aids, B.C.T.F.: *Continental Drift*, D. Williams. Ordway: *Earth Science*, p. 38 and p. 312. Life Nature Library: *The Earth*, Time Inc., Book Division, p. 66.

8. Investigating Lunar Surfaces #8 Time, Space and Matter, (special mats needed), (Accounting

for crater types). *Investigating Lunar Landscapes on the Moon*, p. 442, I.T.E., (special mats needed). Eclipses, p. 274. *Geology and Earth Sciences Sourcebook*.

Activities and Investigations

1. The Volume of the Earth

   Use Eratosthenes' method or some variation of his method. The following is an example:

   Take the difference in solar times between two cities on or near the equator, such as Macapa, Brazil, at approximately 50°E, and Quito, Ecuador at approximately 78°E. Their solar times differ by approximately 1 hour and 48 minutes. They are 1480 km apart. What is the volume of the Earth?

2. Motion and Apparent Motion

   a. Take time exposures of stars. Open lens wide, expose for several minutes. Use fast film. Colour slides (high speed Ektachrome) will even show star colour. For detail. **Geology and Earth Sciences Sourcebook**, p. 299.

   b. Foucault pendulum. **Geology and Earth Sciences Sourcebook**, p. 271.

   c. Encountering the Physical World #1. Time Space and Matter. Contains excellent multi-exposure photographs which could be used on an opaque projector, or by groups of students.

   d. **Geology and Earth Science Sourcebook** contains a number of activities relating to motion in the heavens, pp. 264-281.

3. Movements of the Earth

   a. The earth moves with several motions: rotation, revolution, precession, revolution about the common centre of gravity of the Earth and the Moon, rotational motion with the solar system around the galaxy and motion with the galaxy. As well as these motions, there is a relative motion between the crust and the mantle. Because of the conservation of rotational momentum, the axis of the earth is always directed to the North Star, inclinded at 23 1/2° to its plane of revolution about the sun. This fact combined with the revolution of the earth about the sun causes the seasons.

   b. The combinations of many of these motions can be shown by designating certain students as the Sun, certain planets and distant stars and chalking out their orbits on the laboratory or the gym floor. When each student performs his motion the resultant motion can be illustrated.

   c. If one student carries a chalk globe inclined at 23 1/2° while another rotates a projector representing the sun, the significance of the Arctic Circle, Tropic of Cancer, etc., becomes very evident.

   d. See Appendix, Films, p. 77

4. The Magnetic Field

   a. Show properties of magnets and magnetic fields about magnets. The magnetosphere of the earth is a doughnut-shaped tubular layer around the earth from about 970 km to 65 000 km out into space. The nature and significance of this belt can be discussed.

   b. The position of the earth's magnetic pole, its relation to the geographic pole and its apparent wanderings over the globe, together with the reversals of the earth's magnetic field can be discussed.

   c. The earth's magnetic field results from electric currents in the liquid-like core. A reversal in these currents will cause a reversal in direction of the earth's magnetic field.

d. See Appendix, Films, p. 77

5. The Mass of the Earth

The mass of the earth can be calculated by multiplying the average density of the Earth by its volume. Find the average density of about a dozen rock samples of various kinds and calculate an approximate value for the mass of the earth. The accepted values are an average density of 5.5 g/cm^3 and a mass of 5.98×10^{24} kg. What does this suggest about the structure of the earth?

6. Satellites of the Earth

The study of the Moon as a satellite can be approached in several ways. From the surface of the earth we can study the characteristics of the Moon and think about its origin or we can study the photographs and reports of the astronauts.

Eclipses of the Moon and of the Sun give us evidence about the earth and information about the great distances that separate the Moon from the Earth. The nature of the flights of artificial satellites can also be studied.

7. Structure of the Earth

This section will be dealt with in detail under the headings The Crust of the Earth and A Dynamic Planet. If the earth is to be compared to other planets certain general features (its atmosphere, hydrosphere, lithosphere and internal structure) should be presented in sufficient detail for comparison to be made.

Use a mercury manometer to make a mercury barometer. Discuss balance between the mercury column and a balancing column of air in the atmosphere. Assuming that the mercury column drops 1 cm for an increase in altitude of 108 m, starting at sea level, find the apparent height of the atmosphere. The actual height is many times this value. Discuss the implications.

Investigation of the details of the atmosphere, the hydrosphere, and the lith[illegible]here can be assigned to the pupils as an exercise. The results of their research can be disc[illegible]sed in class. The origin of the atmosphere and hydrosphere could also be discussed.

8. The Moon

The Moon is a barren place. Its orbit around the earth is small compared to the radius of the earth's orbit around the Sun. The astronauts on the Moon, the experiments they performed and the purpose of these experiments.

a. Make a scale model of the earth-moon-sun system. Have 12 pairs of students draw the orbit of the earth around the sun, each for 30 days (one month). On this superimpose the moon's orbit. Use this scale: Earth's orbit: 4.0 m. Moon's orbit 1.0 cm (Investigation 33-2, **Lab Investigations in Earth Science,** Brown Kemper and Lewis, contains detail and a slightly different method).

b. If possible, study the Moon with binoculars or a telescope during the class period.

c. The Moon as Part of the Solar System, Nuffield Secondary Science, (8.23-III).

d. What is the Moon like? Nuffield Secondary Science (8.23-i).

LEARNING OUTCOMES and SUGGESTED ACTIVITIES

Section B

Geological Sciences

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Teacher Resource Material is indicated by number in the parentheses following most Learning Outcomes. Details regarding references, activities and investigations follow the respective sections of the Earth Science 11 course. (These are suggested activities only and may be used at the discretion of the teacher.)

Section B Geological Sciences

INTRODUCTION

Geology is the science of the earth. It is the study of our planet, its external and internal structures, its materials, its processes, and its history.

SCOPE AND SEQUENCE

Unit 1 — The Dynamic Crust

1. Earth Materials
2. Igneous Activity
3. Rocks Flow Bend and Break
4. Continental Drift — Plate Tectonics

Unit 2 — A Changing Planet

1. The Earth Below
   a. the local surface
   b. soil formation
   c. land profiles
2. The Time Scale
3. Gradational Forces
   a. ice
   b. water
   c. wind

Unit 3 — The Earth's Biography/Geologic Time

1. Geologic Time
   a. relative and absolute
   b. measuring absolute time
   c. geologic time chart
2. Fossils and Earth History
   a. formation
   b. fossils and maps
   c. superposition and uniformitarianism
   d. significance of fossils

UNIT 1 — SCOPE AND SEQUENCE

1. **Earth Materials**
   a. The Crust of the Earth
   b. A First Look at Rocks
   c. Minerals
   d. Rocks, a Detailed Study

2. **Igneous Activity**
   a. Distribution of Volcanoes
   b. Magma and Lava
   c. Prediction of Eruptions
   d. Igneous Activity in British Columbia
   e. Geysers, Hot Springs and Fumaroles

3. **Rocks Flow, Bend and Break**
   a. Rocks Bend and Flow
   b. Rocks Break
   c. Earthquakes
   d. Earthquakes and the Interior of the Earth

4. **Continental Drift/Plate Tectonics**
   a. Development of the Theory
   b. Evidence for Continental Drift
   c. Current Plate Tectonic Theory

Section B Geological Sciences

UNIT 1

THE DYNAMIC CRUST

This unit deals with earth materials progressing from a close inspection of rocks and minerals to the formation and composition of rock units. The dynamic crust concludes with a study of the formation of oceans and mountains integrated in terms of theories of global plate tectonics. The four parts of this unit are:

1. **Earth Materials**

   Rocks and minerals are discussed in the context of the nature and organization of matter in the lithosphere, atmosphere, and hydrosphere. This introductory topic is basic to the understanding of many geological processes. Field activities are an essential component of this section.

2. **Igneous Activity**

   Evidence of igneous activity is common in most areas of British Columbia. Extensive volcanic activity is indicated by both landforms and extrusive materials. The Coast Range batholith is a major intrusive feature of relatively recent origin in North America. Local igneous features will determine the degree of emphasis on this section of study.

3. **Rocks Flow, Bend and Break**

   Deformation features are evident throughout the Earth's crust. The nature of the deformation is dependent on factors such as pressure, temperature, time, and composition of the rock. Slow deformation allows some varieties of rock to respond as plastic by thinning, twisting, tilting, rising or folding. Different conditions may produce fractures in rock, i.e., joints or faults. Sufficiently large and rapid faulting causes earthquakes and produces seismic waves. The study of these waves has revealed the structure of the interior of the earth.

4. **Continental Drift/Plate Tectonics**

   As emphasized in the introduction to this course, plate tectonics and continental drift are among the most important topics.

Part 1 — Earth Materials

LEARNING OUTCOMES

The student should be able to:

1. *Contrast and compare the basic similarities and differences between the atmosphere, hydrosphere and lithosphere.*

(Reference #1, 2)

2. *Recognize the importance and abundance of various elements in the earth's crust.*

(Reference #1, 2)

3. *Differentiate between rocks and minerals.*

(Activity #1)

4. *Describe the formation of igneous, sedimentary and metamorphic rocks; classify rocks as igneous, sedimentary and metamorphic.*

(Activity #3; Reference #3, 4, 5, 6)

5. *Describe the relationship between crystal size and cooling rates in igneous rocks; classify igneous rocks as volcanic (extrusive), or plutonic (intrustive).*

(Activity #2)

6. *Describe selected physical and chemical properties of rocks and minerals.*

(Activity #4)

7. *With references, identify selected rocks and minerals.*

(Reference #10, 11, 12; Special note #1)

8. *Explain the relationship between the characteristics of selected minerals and atomic structure.*

(Reference #7, 8, 9)

9. *Integrate the study of rocks and minerals with local geology and industries.*

Part 2 — Igneous Activity

LEARNING OUTCOMES

The student should be able to:

10. *Describe the world distribution of volcanic activity.*

    (Activity #5; Reference #13, 14, 15)

11. *Compare magma and lava.*

    (Activity #6; Reference #17)

12. *Critically discuss theories of magma formation.*

    (Reference #17, 19)

13. *Recognize local intrusive and extrusive forms.*

    (Activity #7, 8; Reference #18, 19, 20)

14. *Relate local evidence of igneous activity to other parts of British Columbia and North America.*

    (Reference #21, 22)

15. *Specify limitations and assumptions in the prediction of volcanic activity.*

    (Activity #9)

16. *Describe the occurrence and nature of geysers, fumaroles and hot springs.*

    (Activity #10; Reference #18, 19, 23)

Part 3 — Rocks Bend, Break and Flow

LEARNING OUTCOMES

The student should be able to:

17. *Describe and classify deformations such as folds, joints and faults.*

    (Activity #11, 12; Reference #24, 25)

18. *Describe the world distribution of earthquake epicentres.*

(Activity #13, 17)

19. *Compare the world distribution of earthquakes and volcanoes.*

(Activity #13, 17)

20. *Illustrate the elastic rebound theory.*

(Activity #14; Reference #26, 27)

21. *Compare the properties of P and S waves; demonstrate P and S waves with a "slinky".*

(Reference #28, 29)

22. *Locate the epicentres of an earthquake given appropriate seismographic data and wave-speed information.*

(Activity #15)

23. *Illustrate the principle of a seismograph.*

(Activity #16)

24. *Distinguish earthquake magnitude and earthquake intensity.*

(Reference #30)

25. *Relate the study of earthquakes and our understanding of the interior of the earth.*

(Reference #31, 32, 33)

Part 4 — Continental Drift — Plate Tectonics

LEARNING OUTCOMES

The student should be able to:

26. *Recognize and cite evidence for continental drift/plate tectonic theory.*

(Reference #34, 35, 36; Special Note #2)

27. *Correctly distinguish between constructive, destructive, and conservative plate margins.*

28. *Compare and contrast the convection theory, the expanding earth theory, and the shrinking earth theory.*

29. *Describe and/or demonstrate the principle of isostacy.*

30. *Illustrate the formation of geosynclines and geosynclinal mountains (deposition, uplift and deformation).*

31. *Describe the meaning of a gravity anomaly; discuss gravity anomalies in relation to mountain ranges.*

References

1. American Geological Institute, *Geology and Earth Sciences Sourcebook*, 1970, pp. 1-4.
2. American Geological Institute, *Investigating the Earth* (revised edition), Sec. 2-1, 2-10.
3. American Geological Institute, *Geology and Earth Sciences Sourcebook*, p. 28.
4. American Geological Institute, *Investigating the Earth* (revised edition), Sec. 2-2, 2-3.
5. *Crusty Problems*, (General Learning Corporation), Chapter 2 — Resource 5, 7, 8, 9, 10, 12.
6. Jackson/Evans, *Spaceship Earth/Earth Science* (Houghton-Mifflin), Chapter 9.
7. American Geological Institute, *Geology and Earth Sciences Sourcebook*, 1970, pp. 4-27.
8. American Geological Institute, *Investigating the Earth* (revised edition), Sec. 2-9, pp. 506-7.
9. *Crusty Problems* (General Learning Co[illegible]ration), Resource 11.
10. American Geological Institute, *Geology and Earth Sciences Sourcebook*, 1970, pp. 28-56.
11. American Geological Institute, *Investigating the Earth* (revised edition), Chapter 12 (note the overhead master in the teacher's guide).
12. Jackson/Evans, *Spaceship Earth/Earth Science* (Houghton-Mifflin), Chapter 9.
13. McKee, B., *Cascadia, The Geological Evolution of the Pacific Northwest*, (McGraw-Hill), pp. 121-195.
14. American Geological Institute, *Geology and Earth Sciences Sourcebook*, 1970, p. 65.
15. American Geological Institute, *Investigating the Earth* (revised edition), Sec. 11.6.
16. Goldthwait, L. *Earth Science* (Ginn), pp. 260-266, 272-273.
17. Atlas of Volcanic Phenomena (U.S. Geological Survey), Sheets 1 and 2.
18. American Geological Institute, *Geology and Earth Sciences Sourcebook*, 1970, pp. 59-77.
19. Heller, et al., *Challenges to Science/Earth Science* (McGraw-Hill), pp. 101-113.

20. Atlas of Volcanic Phenomena, (U.S. Geological Survey), Sheets 4, 5, 6, 7, 8, 9.

21. Goldwait, L., *Earth Science* (Ginn), p. 265.

22. Woodrow, et al., *Readings about Science III* (Holt, Rinehart and Winston), pp. 27-34, 41, 44-48.

23. Atlas of Volcanic Phenomena, (U.S. Geological Survey), Sheet 15.

24. Goldthwait, L., *Earth Science* (Ginn), pp. 276-287.

25. Ordway, R.J., *Earth Science* (Van Nostrand), pp. 140-149.

26. American Geological Institute, *Geology and Earth Sciences Sourcebook*, 1970, p. 81.

27. Heller, et al., *Challenges to Science/Earth Science* (McGraw-Hill), p. 116.

28. Jackson/Evans, *Spaceship Earth/Earth Science* (Houghton-Mifflin), Sec. 11.11, 11.12.

29. American Geological Institute, *Investigating the Earth* (revised edition), Sec. 13.1-13.6.

30. American Geological Institute, *Investigating the Earth* (revised edition), Sec. 13.6.

31. Jackson/Evans, *Spaceship Earth/Earth Science* (Houghton-Mifflin), Sec. 15.10, 15.11, 15.12, 15.13.

32. Ordway, R.J., *Earth Science* (Van Nostrand), pp. 159-165.

33. American Geological Institute, *Investigating the Earth* (revised edition), Sec. 13.2.

34. Jackson/Evans, *Spaceship Earth/Earth Science* (Houghton-Mifflin), Chapter 15.

35. *Crusty Problems* (General Learning Corporation), Chapter 1.

36. American Geological Institute, *Investigating the Earth* (revised edition), Chapter 2.

Activities and Investigations

1. Differentiation between rocks and minerals — have students take a close look at a "typical" rock, e.g., a piece of coarse granite. Binocular microscopes and crushed granite would enhance this activity.

2. Volcanic and plutonic rocks and the important concept of crystal size and rate of cooling can be illustrated with a study of the crystallization of a low melting point organic compound such as salol, thymol, or naphthalene. Examples of procedures can be found in a variety of references including: **Spaceship Earth/Earth Science**, Sec. 9.4. **Crusty Problems**, demonstrate only, resource 6.

3. Discuss characteristics and classifications of igneous, sedimentary and metamorphic rocks. Prepare a selection of 10-12 typical rocks and have groups of 3-4 students sort these samples into their respective classes (including igneous, plutonic and volcanic).

4. Minerals — deal with the following properties:
   a. colour
   b. colour of powdered mineral, i.e., STREAK
   c. lustre — ordinary descriptive terms

d. hardness or "scratchability" — Mohr's scale — ordinary objects (fingernail, penny, etc.)

e. breaking:
   — cleavage
   — fracture — ordinary descriptive terms

f. heft (density, specific gravity)

g. form e.g., massive, crystalline, etc.

h. special properties:
   — reaction to 1M HCl (calcite)
   — magnetic
   — attracted by a magnet
   — fluorescence
   — radioactive

5. Have students plot the location of a variety of volcanoes on a world map and attempt to discern a pattern. Jackson/Evans, **Spaceship Earth/Earth Science** (Houghton-Mifflin), Sec. 10.

6. Activities in: Jackson/Evans, **Spaceship Earth/Earth Science** (Houghton-Mifflin), Sec. 10.1, 10.2.

7. Intrusive and extrusive forms in: **Crusty Problems** (General Learning Corporation), pp. 74-78.

8. Construct a cinder cone model: American Geological Institute, **Geology and Earth Sciences Sourcebook,** 1970, pp. 62, 71.

9. Volcano prediction activity in: Jackson/Evans, **Spaceship Earth/Earth Science** (Houghton-Mifflin), Sec. 10.

10. Construct a model geyser: American Geological Institute, **Geology and Earth Sciences Sourcebook,** 1970, pp. 71-76.

11. Deformation activities in: **Crusty Problems** (General Learning Corporation), pp. 79-86.

12. a. Laboratory Investigation #31 in: Goldthwait, **Investigations in Earth Science** (Ginn).
    b. Activities 7.1, and 7.2 in: Heller, et al., **Challenges to Science/Earth Science** (McGraw-Hill).

13. Earthquake epicentre exercises in: **Crusty Problems** (General Learning Corporation), p. 4. Jackson/Evans, **Spaceship Earth/Earth Science** (Houghton-Mifflin), 11.1, 11.2.

14. Elastic rebound theory: Jackson/Evans, **Spaceship Earth/Earth Science** (Houghton-Mifflin), Activities in Sec. 11.7, 11.8, 11.9, 11.10.

15. Locate the epicentre of an earthquake: Jackson/Evans, **Spaceship Earth/Earth Science** (Houghton Mifflin), Sec. 11.13 **or**
American Geological Institute, **Investigating the Earth** (revised edition), Sec. 13. 4 **or**
Goldthwait, **Investigations in Earth Science** (Ginn), Laboratory Investigation #25.

16. The Principle of a seismograph: Heller, et al., **Challenges to Science/Earth Science** (McGraw-Hill), Activity 6.1 (p. 118). American Geological Institute, **Geology and Earth Sciences Sourcebook,** 1970, p. 92. Jackson/Evans, **Spaceship Earth/Earth Science** (Houghton-Mifflin), p. 313.

17. Earthquake watch-see **Investigating the Earth,** Teacher's Guide, p. xi, PLANNING AHEAD (Note: action is required at the start of the year for this activity).

18. Interior of the earth: Jackson/Evans, **Spaceship Earth/Earth Science** (Houghton-Mifflin), p. 449.

SPECIAL NOTES:

ROCKS AND MINERALS

The Geological Survey of Canada has inexpensive, good quality sets of rocks and minerals (Prospectors' Set of Mineral Chips and Prospectors' Set of Rock Chips) with 36 samples in each set. Only a selection of samples should be studied in detail at this stage of earth science studies.

1. **Mineral Chips**
   a. The sets are deficient in the copper ores. If the opportunity arises add samples of bornite, azurite, malachite, and native copper. Other useful additions would include cinnibar, halite (cleavage quality), corundum and olivine.
   b. Stress GROUP properties, e.g., feldspars micas. Hornblende is a member of the amphibole group. Pyroxenes are a group of which augite is a common example.
   c. Labels can be secured using fiberglassing resin.
   d. Egg cartons may be used for the organization of samples.

2. **Rock Chips**
   a. Stress field identification. Use a few broad categories to identify the rocks.
   b. Sedimentary rocks are by far the most common exposed rocks on the crust. Shale, sandstone and limestone form the majority of these rocks.
   c. Useful additions would include pumice and obsidian.
   d. See (c) and (d) under Mineral Chips.

CONTINENTAL DRIFT/PLATE TECTONICS

The following publications are excellent general references for this important topic:

1. Mathews, S.W., *This Changing Earth*, National Geographic, January, 1973.
2. *Continents Adrift*, readings from Scientific American, W.H. Freeman and Company.

This topic might best be dealt with in three parts, i.e.: (1) briefly introduce descriptive and historical aspects early in the course. (2) integrate relevant aspects with appropriate topics, e.g., volcanoes, earthquakes, oceanography. (3) summarize the overall theory (present the "big picture").

3. **Development of The Theory**
   a. Topographical fit between continental margins: the idea of continental drift.
   b. Wegener's theory.

4. **Evidence for Continental Drift**
   a. Distribution of:
      — volcanoes
      — earthquakes and depth of foci
      — deep ocean trenches
   b. Orogenic belts:
      — match from continent to continent
      — do not extend across ocean-floors
   c. Paleoclimates match, i.e., glaciation.
   d. Fossil correlation.
   e. Polar wandering.

f. Ocean-floor:
— mid-oceanic ridge
— rocks are geologically young
— age of rock increases towards continental margin
— thickness of sedimentary rock is greater towards the continental margin
— the pattern of magnetic anomaly is remarkably symmetrical; one side is the mirror image of the other with respect to the oceanic ridge

g. Distribution of mountain ridges.

5. **Current Plate-Tectonic Theory**

a. Description of plates.

b. Plate margins:
— constructive margins: (a) rifting (b) down-dropping (c) thinning and volcanoes
— destructive margins (ocean-ocean/ocean-continent/continent-continent) (a) trenching: earthquake foci, gravtiy anomaly, geosyncline formation (b) folding and mountain building (c) thrusting and mountain building
— conservative margins, e.g., San Andreas fault

c. Cause of plate motion:
— convection current, mantle extensively involved
— modified convection current theory, long flat convection cells
— contracting earth
— expanding earth

Section B Geological Sciences

UNIT 2

A CHANGING PLANET

INTRODUCTION

Change is the key word to this unit. Students can be challenged to produce examples of any landscape which is not changing. This type of introduction leads directly to a study of the changes presently occurring and the forces which cause them. The unit then turns to the effect of such changes over geologic time and thus leads to Unit 3.

SCOPE AND SEQUENCE

1. The Earth Below

a. the local surface

b. soil formation

c. land profiles

2. The Time Scale

3. Gradational Forces

   a. ice

   b. water

   c. wind

Part 1 — The Earth Below

LEARNING OUTCOMES

The students should be able to:

1. *Describe at least four types of changes in evidence at a local gravel pit or road cut relating the changes to causal factors.*

   (Activity #1; Reference #3)

2. *Identify soil horizons and indicate their origins and composition.*

   (Activity #2; Reference #1, 2)

3. *Correlate common local sedimentary deposits with possible origins, methods of transport and environments of deposition.*

   (Activity #1, 2, 5; Reference #3)

4. *Construct a model of a soil profile.*

   (Activity #2, 4)

5. *Analyse the products of weathering such as crushed granite, sub-soil and top soil. Account for differences in the samples.*

   (Activity #2; Reference #1)

6. *Recognize the significance of porosity and permeability in soil production processes.*

   (Activity #3)

References

1. Goldthwait, Lawrence, *Earth Science*, 1972, Formation of Soil, pp. 41-42.

2. American Geological Institute, *Investigating the Earth*, 1973, investigating products of weathering, soil — a basic earth material, factors that influence soil formation, kinds of soils, pp. 194-200.

3. American Geological Institute, *Investigating the Earth*, 1973, water, ice, and wind erode the land, the magnitude of erosion, pp. 203-208.

Activities and Investigations

1. American Geological Institute, **Investigating the Earth,** Teacher's Guide, 1973, pp. 188-189, field trip: investigating earth history in the field.

2. American Geological Institute, **Geology and Earth Science Sourcebook,** 1970, pp. 160-161.

   This activity includes comparing soils with parent material, a variety of tests on the soil horizons, and a diagrammatic reconstruction of the soil profile. A diagram of the stages of maturation of soil is also given.

3. Goldthwait, Lawrence, **Investigations in Earth Science,** 1972, p. 107, activities in porosity and permeability.

4. Goldthwait, Lawrence, **Investigations in Earth Science,** 1972, pp. 98-106, Construction of a Model is Outlined in Investigation 30 and 31.

5. Williams, David, **Getting Your Hands into the Till,** B.C.T.F. Lesson Aids, Vancouver, British Columbia.

Part 2 — The Time Scale

Geological time is vast — much longer than historic time. This concept can be presented quite naturally in the sequence here, or else in a later section. (See Section B, Unit 3)

LEARNING OUTCOMES

The student should be able to:

1. *Determine age by direct observations, such as the counting of tree growth rings and of varves.*

   (Activity #1; Reference #1, 2)

2. *Understand absolute dating by means of radioactive elements.*

   (Activity #2, 3; Reference #3)

3. *Construct a Geological Time Scale of your own.*

(Activity #4; Reference #4)

References

1. Bisque, Pratt and Thompson, *Earth Science: Patterns in our Environment,* 1975, pp. 12-15.

2. American Geological Institute, *Investigating the Earth,* Teacher's Guide, 1973, pp. 168-171.

3. American Geological Institute, *Investigating the Earth,* 1973, pp. 333-337.

4. Goldthwait, Lawrence, *Earth Science,* 1972, pp. 109-125.

Activities and Investigations

1. Ask students to bring stump-ends from logs (known as lily-pads in the saw-mills of British Columbia) to determine age by counting growth rings. Note how ring growth patterns enable us to link up with trees of pre-historic times.

2. American Geological Institute, **Investigating the Earth,** Teacher's Guide, 1973, pp. 171-172, radioactive elements and atomic clocks, using atomic clocks to measure geologic time.

3. American Geological Institute, **Investigating the Earth,** 1973, pp. 328-329, an exercise to illustrate probability rate in radioactive decay is presented.

4. American Geological Institute, **Investigating the Earth,** 1973, pp. 333-339. The Geologic Time Scale is presented together with problems in calibration for the same.

Part 3 — Gradational Forces

The action of running water, of ice, and of wind not only reshaped the mountains but also has had a great impact on much of the continental North American land mass.

LEARNING OUTCOMES

The student should be able to:

The Action of Ice

1. *Account for the features produced through valley glaciers and through continental ice sheets.*

   (Activity #1; Reference #1, 3, 5)

2. *Prepare tables which indicate contrasting as well as common features present in areas influenced by valley and continental glaciers.*

   (Activity #2; Reference #1, 3, 5)

3. *Apply concepts of super-position and uniformitarianism in order to analyse cross-sections of glacial tills and outwash plains.*

(Activity #3)

4. *Reconstruct conditions during the retreat of the ice sheets using paleontological evidence and a geological map of the Ice Age.*

(Activity #4)

The Action of Water

1. *Set up a stream table to determine the effect of stream slope, of water volume and of soil particle size in stream erosion.*

(Activity #5, 7; Reference #2, 4)

2. *Determine the effect of erosion upon various portions of a valley.*

(Activity #5, 6, 7; Reference #2, 4)

3. *Recognize the effect of dissolved or suspended particles in water upon erosion of the stream bed.*

(Activity #6; Reference #2, 4)

4. *Recognize the effects and characteristics of shoreline erosion and deposition.*

(Activity #8, 9; Reference #7)

5. *Indicate the significance of the effect of water as an erosional agent in oxidation, hydration, frost action, and in mineral solution.*

(Activity #10, 11; Reference #2, 4)

The Action of Wind

1. *Demonstrate how winds move sediments and modify the earth's surface.*

(Activity #13, 14; Reference #6)

2. *Recognize the major features characteristic of a desert landscape.*

(Activity #14; Reference #6)

3. *Differentiate between wind blown and water eroded sand.*

(Activity #12)

References

1. Goldthwait, Lawrence, *Earth Science,* 1972, Chapter 17, Formation and Movement of Glaciers, Erosion by Glaciers, Deposition by Glaciers, pp. 358-379.

2. Goldthwait, Lawrence, *Earth Science,* 1972, Chapter 16, Action of Running Water, Erosion by Running Water, Stream and Valley Development, pp. 335-357.

3. American Geological Institute, *Investigating the Earth,* 1973, The Great Ice Age, pp. 406-410.

4. Ordway, Richard J., *Earth Science,* 1972, Chapter 7, Weathering, Mass-Wasting, and Stream Erosion, pp. 171-208.

5. Ordway, Richard J., *Earth Science,* 1972, Chapter 9, Glaciation, pp. 235-259.

6. Ordway, Richard J., *Earth Science,* 1972, Chapter 10, Winds and Dry Lands, pp. 261-276.

7. American Geological Institute, *Investigating the Earth,* 1973, The Continental Margins, pp. 226-230.

Activities and Investigations

1. American Geological Institute, **Geology and Earth Science Sourcebook,** 1970, pp. 213-216, an analysis of the Glacial Map of North America is presented. Adaptation of the principles as they apply in Canada is suggested for students in British Columbia.

2. American Geological Institute, **Geology and Earth Science Sourcebook,** 1970, pp. 212-213, characteristic features of valley and continental glaciation with locations for some are tabled here.

3. American Geological Institute, **Investigating the Earth,** 1973, pp. 410-411, an ice-age puzzle is presented with research data plotted on a map. Students determine time lapse between layers of deposition as well as conditions prompting the particular deposit.

4. Using the **Geologic Map of Wisconsin and Recent Ice in North America,** Geological Survey of Canada, 57A and 1253A, in conjunction with the National Geographic chart, Animals of the Ice Age, National Geographic Magazine, March, 1972, study the evidence of animal migration to the American Continent.

   An interesting poster to augment the above can be obtained by writing for:

   Deposits Near Medicine Hat, Alberta
   Publications Distribution Office
   Geological Survey of Canada
   601 Booth Street
   Ottawa.

5. American Geological Institute, **Investigating the Earth,** Teacher's Guide, 1973, p. 108, the

relationship between stream slope and volume of water is investigated.

6. Goldthwait, Lawrence, **Investigations in Earth Science,** 1972, Investigation 34, p. 115, and Investigation 37, pp. 125-128, present the following exercises, Effects on various stream beds, and The effect of dissolved and suspended particles, respectively.

7. American Geological Institute, **Geology and Earth Sciences Sourcebook,** 1970, pp. 168-169, using either a stream-table or a small gully out of doors study and identify areas of erosion and of deposition.

8. Hoyt, John H., **Field Guide to Beaches,** E.S.C.P. Pamphlet Series, p. 7, presents a number of activities for shoreline studies.

9. American Geological Institute, **Investigating the Earth,** Teacher's Guide, 1973, pp. 113-114, shows how to construct a model of depositional processes.

10. American Geological Institute, **Geology and Earth Sciences Sourcebook,** 1970, pp. 160-161, frost action, rock and soil oxidation, hydration and solution process exercises.

11. American Geological Institute, **Investigating the Earth,** Teacher's Guide, 1973, pp. 105-106, hydration and oxidation activities.

12. Obtain samples of beach sand and of wind deposited sand. Compare the two in as many ways as possible through a microscope. Check average grain size, possible facets, break down of original crystalline formation, transparency, texture, etc.

13. Wolfe, et al., **Earth and Space Science, Lab Manual,** 2nd ed., Exercise 18, p. 65, movement of sand particles by wind.

14. American Geological Institute, **Geology and Earth Sciences Sourcebook,** 1970, pp. 164, 167, exercises in sand dune development and in particle sorting using an electric fan.

Section B Geological Sciences

UNIT 3

EARTH'S BIOGRAPHY/GEOLOGIC TIME

INTRODUCTION

This unit has two basic themes:

1. **TIME**

   History as viewed by an historian is a very different concept from history as viewed by a geologist. The immensity of the geologic time scale is of such vastness it is difficult to comprehend its impact on science and philosophy. This unit will attempt to put time, its measurement and duration into a more concrete perspective.

2. **CHANGE**

   As rocks and minerals have changed with time, so have living organisms changed or evolved. An understanding of this process is gained through a study of the fossil record.

SCOPE AND SEQUENCE

1. Geologic Time
   a. relative and absolute time
   b. the determination of absolute time
      — radioactivity: carbon-14, uranium-lead, potassium-argon
      — other procedures
   c. the geologic time chart

2. Fossils and Earth History
   a. the formation of fossils
   b. examine fossils and geologic maps (local site if possible)
   c. principles of superposition and uniformitarianism
   d. the significance of fossils
      — dating and correlation of rock formations
      — index fossils
      — prehistoric climates and environments
      — fossils and evolution

UNIT 3 — EARTH'S BIOGRAPHY/GEOLOGIC TIME

LEARNING OUTCOMES

The student should be able to:

1. *Distinguish between relative and absolute time.*

   (Activity #4, 5, 6, 7, 8, 9, 10, 12, 19, 20, 21, 22, 23)

2. *Construct a geologic time scale: use this scale to compare the ages and lengths of various segments of geologic time.*

   (Activity #1, 2, 3, 11, 14, 15, 17, 18, 27, 31, 32, 33)

3. *Describe radioactive dating.*

   (Activity #8, 9, 10, 21, 29, 30, 35)

4. *Solve simple problems related to a variety of dating procedures, e.g., carbon-14, uranium-lead, potassium-argon, tree-rings, varves, etc.*

(Activity #5, 6, 8, 9, 10, 19, 20, 21, 27, 28, 30)

5. *Use geologic maps to determine absolute dates of local rocks.*

(Activity #33, 34)

6. *Interpret geologic maps.*

(Activity #33, 34)

7. *Upon examination, suggest hypotheses for the formation of a fossil.*

(Activity #24, 31, 32, 36)

8. *Describe how fossils form the key to past geologic events.*

(Activity #10, 11, 24, 25, 27, 32, 33, 36)

9. *Discuss critically the principles of* **Superposition and Uniformitarianism.**

(Activity #5, 11, 15, 20, 22, 23, 24, 25, 31, 33, 34, 36)

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7. Gilluly, James, Waters, A.C., and Woodford A.O., 1974, *Principles of Geology*, (4th Edition). W.H. Freeman and Company, Chapter 7 — Fossils, Strata and Time.

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10. *Continents Adrift*, Readings from Scientific American, 1970, Paper 12 — Continental Drift and Evolution, (pp. 114-123).

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11. Eicher, D.L., 1968, *Geologic Time*, Prentice-Hall. Inc.: 150 p.

12. Eisbacher, Gerhard, 1973, *Vancouver Geology*, Geological Association of Canada, 56 p.

Activities and Investigations

1. Have you ever seen a million of anything? Count sand grains and see how big a pile 1 000 000 grains would be. Do this by sampling rather than actual counting. Count the grains in one ml and extrapolate. (ref. 1. p. 461.)

2. How many life[illegible]es are there in 1 000 000 years? (ref. 1. p. 461.)

3. How many copies of a ditto sheet (use a master ditto sheet and run off part of the required number) filled with asterisks would you need to have 1 000 000 asterisks? (ref. 1. p. 461.)

4. How could a burglar tell that the owner of a house has been away for almost a week? (ref. 1. p. 462.) This illustrates an indirect method of measuring time, a common practise in geology.

5. Illustrate a method of measuring time indirectly by studying varves. (ref. 1. p. 463.)

6. Illustrate a method by which trees can be used to place events in time. (ref. 1. p. 464-467.)

7. If you were locked in a room with no windows (but plenty of air, food and water), how could you measure the passage of time so that you would know the day of the week when you would finally be let out? (ref. 1. p. 468.)

8. Two kinds of carbon can be found in wood. The main [illegible]pe is called carbon-12, and the other kind is called carbon-14. Discuss the difference be[illegible]een these two kinds of carbon and illustrate how the ratio of the two types of carbon can be used to determine the absolute date of organic mate[illegible]al. (ref. 1. p. 468-471.)

9. Uranium can be used for dating. Demonstrate a Geiger counter on a rock that contains radioactive minerals such as uranium, which decays in steps. Geologists can tell the difference between lead that came from uranium and lead that was there all the time, because the weights are different. List some radioactive materials and indicate how the decay of one of these substances can be used to determine the age of a rock. (ref. 1. pp. 472-474.)

10. What methods could be used to date a series of objects such as (a) a wooden mummy case

from Egypt, (b) a fossil fern found in shale, (c) a mammoth found frozen in a glacier, (d) coal found in Antarctica, (e) a very old sequoia tree, (f) a spear point from a prehistoric campfire, (g) a "fire arrow" oldest known Chinese gun and (h) moon rock? (ref. 1, p. 475.)

11. Both fossils and mountain building can be put on a kind of geologic calendar called a geologic time scale or geologic column. To make a calendar of your own, you will need a metrestick and a strip of adding machine tape 5 metres long. If you have coloured pencils use them for marking. (ref. 1, pp. 474-478.)

12. If you found an old newspaper nailed between the walls of a house, could you tell when the house was built? (ref. 1, pp. 478-479.)

13. Once you have completed your calendar you can use it as a ruler for measuring time. Suppose you found a rock layer with a fossil dinosaur in it. During which era was the rock layer probably laid down? (ref. 1, pp. 478-479.)

14. Write an article for the school newspaper using the names of all 12 of the different time periods. (ref. 1, p. 479.)

15. If you could spend any amount of money or use any amount and kind of equipment, how could you better determine the age of the earth? (ref. 1, p. 479.)

16. Use your calendar to figure out what is wrong with some of the cartoons in your local newspaper (such as the one entitled "B.C."). (ref. 1, p. 483.)

17. If you tape your calendar to the wall so that you can see all of it at once, you will notice that even if the very first man to walk the earth could read, write and measure time he could tell us very little of the earth's history. Why not? (ref. 1, p. 483.)

18. Your school may have a stairway. If so, count the number of steps from the bottom to the top and determine how much time you would pass through by walking up the stairs if each step represented an equal percentage of the total age of the earth (about 5 billion years). Mark the appearance of man with a piece of masking tape on the appropriate step.

19. Given a cross-section of a tree, can you determine when the tree was cut down? (ref. 1, p. 484.)

20. If you were given a varve sequence in which the oldest varve had been dated, would you be able to date a fragment of bone found somewhere in the middle of the section? Students could be given such a drawing and asked to determine the age of the bone. (ref. 1, pp. 484-485.)

21. A flood washed an old log out of a river bank. It should contain 0.28 grams of carbon-14 if the log were still alive. Geiger counter readings showed that the log contained 0.035 grams of carbon-14. How old was the log? (ref. 1, p. 484.)

22. An introduction to a unit on the measurement of time might include the following exercise. Use any method you can think of, except your watch, to determine the duration of a five-minute period. Cover all clocks and watches in the room. Choose one student to be a timekeeper. The timekeeper will place a mark on the blackboard when you are to start to measure a five-minute period of time. When you think five minutes have passed, signal the timekeeper. The timekeeper will make a mark each time someone signals and the teacher will record the actual time each student stands (if possible). (ref. 6, p. 324.)

23. You can mark the passage of time by relating it to a series of events. This is termed relative time. List four events of your past life. Put the most recent event at the top of your list. Now add to your list the events that one or two of your classmates listed. Try to place all of these events in the order they happened. (ref. 6, p. 324.)

24. Show students illustrations such as are depicted on p. 326 of **Investigating the Earth** (Revised

Edition). See if you can find signs of changes that have happened in the recent past. (ref. 6, pp. 326-327.)

25. In a time-ordered sequence of events, event A happened before event B, which in turn happened before event C. Event D, however, happened before event B, but after event A. Can you represent these events in their proper order? (ref. 6, p. 327.) Answers for investigations numbers 25 to 28 are given in reference 8.

26. Can you think of any events that do not involve change? (ref. 6, p. 327.)

27. Why is it important that earth scientists be able to determine relative and measured geologic time? (ref. 6, p. 327.)

28. How would you define time? (ref. 6, p. 327.)

29. Obtain a small amount of uranium ore or a specimen of uranium-bearing mineral from your teacher and place it in a cloud chamber. A cloud chamber can be obtained from Arbor Scientific Ltd., Box 113, Port Credit. Ontario. The chamber consists of a clear plastic dish about the size of a cottage cheese container and lined at the top with a felt strip. The covered chamber is set on dry ice until the alcohol saturated felt strip produces a vapor. In the dark using the beam of a flashlight the students can see the track of beta particles emitted from a piece of radioactive ore. (ref. 6, p. 59.)

30. All the nuclei of radioactive elements do not decay at the same time. The decay process involves chance. Although atoms cannot avoid decay, it is impossible to tell when it will happen for any particular nucleus. Since even a small sample of a radioactive element contains billions of atoms. the average rate of decay can be determined. To illustrate the concept of half-life you can develop a simple model illustrating probability in radioactive decay. (ref. 6, pp. 328-329.)

31. Were the earliest methods of classifying geologic time relative or measured? Why were such methods used? (ref. 6, p. 339.)

32. How does the correlation of fossil species relate to the development of a Geolgic Time Scale? (ref. 6, p. 339.)

33. How could you develop a Geologic Time Scale for your local area if one were not available? (ref. 6, p. 339.)

34. Study an outcrop near your school and determine the sequence of sediments present there. Determine the relative age of the different beds and discuss the problems of measuring the exact age of each bed in years.

35. The magnetized bodies in the ocean-floor have provided an amazingly complete history of magnetic-field reversals that now extends back about 76 million years, into the Cretaceous period. The classic paper on this subject is one entitled REVERSALS OF THE EARTH'S MAGNETIC FIELD by Allan Cox, G. Brent Dalrymple and Richard R. Doell (**Scientific American**, February 1967). By comparing the ages they assigned to specific reversals of the geomagnetic field with the distance of the corresponding anomalies from the ridge axis it is possible to determine the rate at which the sea-floor has spread in the various oceans. Study the pattern of sea-floor spreading shown on pp. 72-73 of an article entitled SEA-FLOOR SPREADING by J.R. Heirtzler in **Continents Adrift** (ref. 10, pp. 68-78). Using the time scale given on p. 75 (ref. 10) determine the age of the following events (a) birth of Iceland. (b) opening of the Gulf of Aden, (c) separation of Australia from Antarctica. (d) separation of New Zealand from Antarctica, (e) separation of South America from Africa and (f) separation of North America from Eurasia. (ref. 10. pp. 68-78.)

36. The initial development of the Geologic Time Scale was based on the fossil record. It clearly showed that there were periods of time characterized by the abrupt multiplication and diversification of certain animal and plant groups. It is now thought that continental drift played an important role in explaining this phenomenon. The age of reptiles, for example, lasted 200 million years and gave rise to only 20 reptilian orders, or major groups of reptiles. On the other hand the age of mammals, which followed the age of reptiles, lasted for only 65 million years but gave rise to more than 30 mammalian orders. The difference between the number of reptilian orders and the number of mammalian ones may partially be explained by the fact that for most of the age of reptiles the continents were collected in two supercontinents, whereas early in the age of mammals the two supercontinents broke up into the continents of today. Write an essay on the effect of these events on the evolution of living organisms and how this has influenced the development of the geologic time scale. (ref. 10, pp. 114-123.)

Learning Outcomes and Suggested Activities

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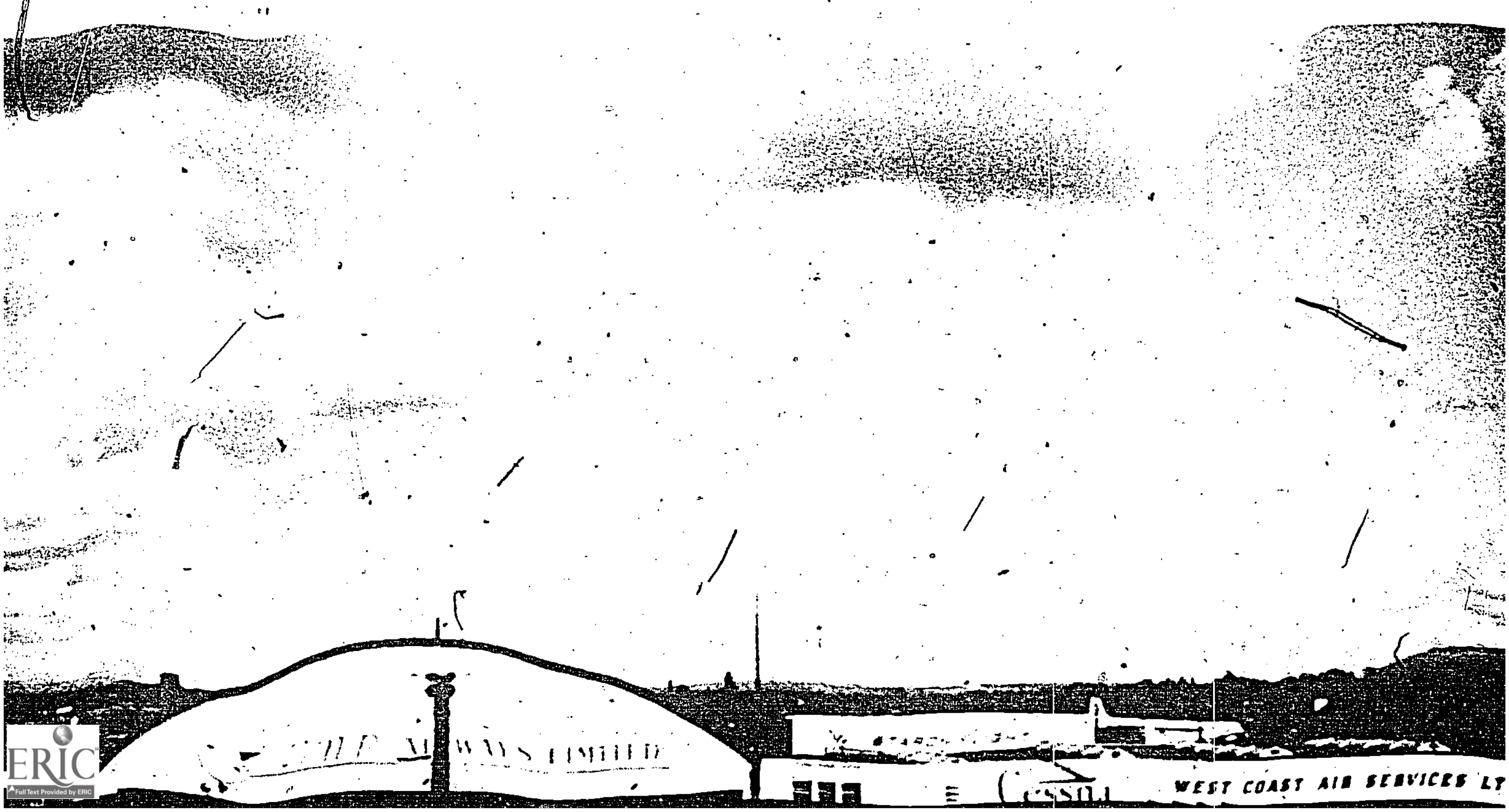
Teacher resource material is indicated by number in the parenthesis following most Learning Outcomes. Details regarding references, activities and investigations follow their respective sections. (These are suggested activities only and may be used at the discretion of the teacher.)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Section C

Oceanographic & Atmospheric Sciences

INTRODUCTION

The oceans and the atmosphere are composed of fluid bodies which move in response to differences in density. The circulations of ocean waters and atmospheric gases then, are similar processes. This section also examines the ocean basins; the sources of discoveries which have confirmed theories of continental drift and led to the new plate tectonics.

SCOPE AND SEQUENCE

Unit 1 — Oceans and Ocean Basins

1. Ocean Waters
   - a. characteristics of seawater
   - b. energy water and motion
   - c. oceans and man
2. Ocean Basins
   - a. a cross-section of features and processes
   - b. the mid-ocean rise
   - c. deep ocean trenches
   - d. the life cycle of an ocean basin

Unit 2 — The Atmosphere

1. The Study of Weather and Climate
   - a. the nature of air
   - b. the structure of the atmosphere
   - c. solar radiation in the atmosphere
   - d. the effects of changing the current of air
2. The Air in Motion
   - a. the general circulation of air
   - b. planetary winds
   - c. local winds and seasonal wind systems
   - d. wind erosion and deposition
3. Moisture in the Atmosphere
   - a. water vapour
   - b. fog and cloud formation
   - c. cloud types
   - d. precipitation

4. Air Masses, Fronts and Storms
   a. air masses
   b. air masses affecting Canada
   c. weather fronts
   d. cyclones and anticyclones
   e. storms

5. Weather and Climate
   a. weather prediction
   b. determination of climate

Section C Oceanographic & Atmospheric Sciences

UNIT 1

OCEANS AND OCEAN BASINS

This section of the course (Oceans) presents students with opportunities to investigate the structural and energetic interrelationships which characterize the oceans and ocean basins of the earth. Teaching strategies should be designed so as to direct student inquiry toward an awareness of the following principles:

1. **Oceans**
   a. The major feature of any ocean are its movements. The dynamic qualities of oceans should be stressed in all investigations.
   b. Motions require energy. Several methods of energy transfer occur in the production of movements in the ocean.
   c. Water movements circulate minerals and gases which in turn influence biological productivity. All men are either directly or indirectly dependent on this productivity.
   d. Water movements influence and participate in the production of climates and weather.
2. **Ocean Basins** (May be covered in Dynamic Crust)
   a. The major features of the ocean basin are the mid-oceanic rise (M.O.R.) and the deep ocean trenches.
   b. Oceanic crust is compositionally and structurally different from continental crust.
   c. Ocean basins are dynamic structures which may "grow" or "shrink" over geologic time as new oceanic crust is created at the M.O.R. and eventually destroyed at deep ocean trenches.

LEARNING OUTCOMES

The student should be able to:

1. *Describe and diagram the major currents in a hypothetical earth ocean.*

   (Activity #1, 2, 3, 4, 5, 6, 7, 16, 17)

2. *Give examples and demonstrate the production of surface currents.*

   (Activity #11, 12, 13, 14, 15, 16)

3. *Give reasons for the production of the Eckman effect.*

(Activity #9, 11, 13, 14, 15)

4. *Demonstrate at least two methods of producing deep ocean currents.*

(Activity #1, 2, 3, 4, 5, 6, 7)

5. *Correlate oceanic currents with world climates.*

(Activity #13, 14, 15, 17, 18, 20)

6. *Discuss and describe the origin and extent of the mid-ocean rise.*

(Activity #21, 22, 23, 24)

7. *Compare oceanic crust with continental crust and hypothesize regarding the consequence of the differences.*

(Activity #23, 24, 26, 27, 28)

8. *Describe the probable life cycle of an ocean basin.*

(Activity #23, 24, 26, 27, 28, 29)

9. *Diagram a cross-section of a typical ocean.*

(Activity #21, 22)

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1. A.G.I.: (1973). *Geology and Earth Sciences Sourcebook*. Holt, Rinehart and Winston.
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4. Goldthwait. (1975). *Investigations in Earth Science*. Ginn & Co.
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7. I.S.C.S., (1972), *Winds and Weather*, Silver-Burdett Co. (G.L.C.).

8. Jackson, Evans, (1975), *Spaceship Earth, Earth Science*, Houghton Mifflin.

9. Nuffield Secondary Science 8: *The Earth and its Place in the Universe*, Longman.

10. Pickard, G.L., *Descriptive Physical Oceanography*, Pergamon Press, Elmsford, N.Y., 1963.

Activities and Investigations

1. Density Currents: **Geology and Earth Sciences Sourcebook,** p. 185.
2. Salinity: **Investigating the Earth** (revised ed.), Investigation 4-7 (p. 51 Teacher's Guide).
3. To investigate the effects of varying salinity, temperature and suspended solids on the density of seawater, fill an aquarium or a plastic garbage pail with an "artificial seawater" and do not change it during the experiment. Then fill balloons with seawater modified in various ways (by solutes, suspensions or temperature) and place them in the pail. Make sure that there are **no** air bubbles. You can compare the densities of the contents of each balloon with the density of the seawater in the pail by observing the buoyancy of the balloon.
4. Fill a styrofoam cup with crushed ice and food colouring. Punch holes in the bottom of the cup and tape the cup securely in the corner of an aquarium. Fill the aquarium with room temperature (or warmer) water to a level just above the base of the cup. Observations will indicate the method of movement of some deep ocean water bodies. (See investigation 4-7, p. 49, **Investigating the Earth.**)
5. Goldthwait, **Investigations in Earth Science,** Investigation 26, "The Solubility of Substances in Water", p. 85.
6. Goldthwait, **Investigations in Earth Science,** Investigation 33, "The Density Changes in Water", p. 110.
7. Goldthwait, **Investigations in Earth Science,** Investigation 37, "How to Produce and Measure Density Currents", p. 125.
8. Goldthwait, **Investigations in Earth Science,** Investigation 38, "Salts in Seawater", p. 129.
9. Waves can be defined and investigated through the use of a "ripple tank" of the type used in P.S.S.C. physics. A stream table equipped with a wave generating device can be used to demonstrate or investigate the effect of waves on shorelines.
10. **Investigations in Earth Science,** Investigation 39, Development of Shorelines, p. 133.
11. **Investigating the Earth** (T.G.), Section 4-4, Waves Carry Energy, p. 48.
12. **Investigations in Earth Science,** Investigation 40, Surface Ocean Currents, p. 137.
13. **Investigations in Earth Science,** Investigation 13, The Coriolis Effect, p. 42.
14. **Investigating the Earth** (T.G.) Section 4-6, Investigating the Coriolis Effect, p. 48.
15. **Earth Science** (Heller), Activity 11-1, The Coriolis Effect, p. 237.

16. Have students trace and map concentrations of O_2, CO_2 and important nutrients in the Atlantic or the Pacific (**Descriptive Physical Oceanography** is a good reference.)

17. Convergences, Divergences and Upwelling make good essay, discussion or modelling topic (e.g., How do the above phenomena relate to whaling and fishing?).

18. Some investigations involving the water cycle are found in **Spaceship Earth,** pp. 200-203, (7-6 and 7-7).

19. Audio-visual aids are best used to describe tidal influences on the earth. (See the list at the end of this guide.)

20. Societal aspects of the earth's oceans are best discussed and investigated as essay and debate topics. Many recent books and articles on the subject are available, some of which are listed at the end of this guide.

21. One of the best coverages of topics related to ocean basins is found in **Earth Science**, (Heller et al.,) Chapter 10. The chapter discusses oceanographic techniques, continental shelves, slopes and rises, trenches, valleys and mid-ocean ridges. A good exposition of sea-floor spreading is also found in this text.

22. Most profiles of the continental margins which appear in reference books are shown with an exaggerated vertical scale. The construction of a 10 metre long "scale" cross-section gives students a better appreciation of true relationships. Such a cross-section will come in handy for the demonstration of sea-floor spreading later in the unit.

23. A Seismic Map of the earth accurately pinpoints the mid-ocean rises and indicates that they are activity centers of the earth's crust. Chapter 11 of **Investigating the Earth,** details much information regarding the location and mechanics of the mid-ocean rise.

24. **Investigating the Earth,** Investigation 11-5: Investigating Earthquakes, p. 242, Teacher's Guide, p. 126.

25. Activity 10-1: Determining Shape by "Depth Soundings"; **Earth Science,** (Heller et al.,) p. 214.

26. Trenches are the areas where the earth's crust is destroyed. To conserve the earth's crust, new crust is produced at mid-ocean ridges. **The Earthquake Watch,** investigation (11-5) indicates the presence and position of diving crustal plates at subduction zones or trenches.

27. Students should be encouraged to attempt models of plate boundaries to show what happens when plates collide or separate.

28. Trenches may also be investigated from an earth resource viewpoint as potential "garbage dumps" for nuclear wastes and other materials.

29. Using maps of ocean basins and surface features of the earth students should be able to give substantiated examples of oceans or former oceans which are at a particular phase in their lifecycle.

Section C Oceanographic & Atmospheric Sciences

UNIT 2

THE ATMOSPHERE

The study of weather and climate is a growing science. The atmosphere is an integral part of our planet. Through climate the atmosphere effects the erosion of the earth' surface by water, ice and wind. The study of the atmosphere and the physical and chemical laws that apply are also an integral part of earth science. Physical processes such as convection, exchange of energy, changes of pressure, changes of phase and other mechanical processes are often more obvious in the atmosphere. They are therefore easier to teach using as examples their occurrence in the atmosphere rather than in the lithosphere where they also take place. An understanding of these physical processes requires continuing scientific investigation and there are practical experiments in meteorology and climatology that secondary students can perform to aid in the growth of this understanding.

LEARNING OUTCOMES

The student should be able to recognize:

1. *The importance and abundance of various substances in the earth's atmosphere and the structure of the atmosphere and the effects of the sun's radiation on the structure and substances of the atmosphere.*

   (Activity #1, 10, 16, 17, 19, 20)

2. *The natural cycles such as the carbon, nitrogen, hydrologic and ozone cycles by which the atmosphere maintains its balance as a life-supporting gas system.*

   (Activity #1, 3, 4, 5)

3. *The effect of changing the content of the air — the function of each component.*

   (Activity #1, 4, 5, 15, 16)

4. *The complex wind circulation patterns over the earth.*

   (Activity #6, 7, 8, 26)

5. *The local conditions that determine the patterns of local and seasonal winds.*

(Activity #6, 8, 9)

6. *The elements responsible for the circulation of the earth's atmosphere:*
   a. the heat from the sun.
   b. the rotation of the earth.
   c. the friction between the earth's surface and the air.

(Activity #4, 6, 7, 8, 20)

7. *The hydrologic cycle, including phase changes of water in the atmosphere, relative humidity related to temperature and pressure.*

(Activity #1, 3, 4, 10)

8. *The three basic types of clouds — cumulus, stratus and cirrus.*

(Activity #9, 10, 12, 13)

9. *The forms of precipitation — rain, hail, snow, sleet, and dew.*

(Activity #2, 14, 15)

10. *The relation of the volume and density of air to pressure and temperature.*

(Activity #10, 11, 16)

11. *The four conditions of the atmosphere that give rise to weather — heat, wind, moisture, and air pressure.*

(Activity #15, 16, 17)

12. *The movement of air masses across the earth in low-pressure and high-pressure systems.*

(Activity #9, 11, 20, 22, 23)

13. *The formation of fronts between air masses.*

(Activity #9, 11, 20, 22, 23)

5. Have a student research the ozone layer and its possible destruction by fluorocarbons (spray cans).

6. View and discuss the investigations depicted in the film **What makes the Wind Blow?**

7. Discuss the relationships between the theoretical and actual circulation patterns as depicted in figs. 5-2 and 5-3, pp. 118 and 119 of **Geology and Earth Sciences Sourcebook.**

8. Use climatic data, (see fig. 6-8, p. 129 of **Investigating the Earth** or use an encyclopaedia or reference such as **Climate Canada**) to prepare Northern Hemisphere maps of atmospheric pressure in January and July. Such maps can be used to investigate wind and weather patterns as described in **Geology and Earth Sciences Sourcebook,** pp. 121-122.

9. Have students undertake a weather watch as a project: (a) Investigation 3-2, p. 51 of **Investigating the Earth,** (also see Appendix B, p. 501 of the same book). (b) Weather watch pp. 15-19 of **Winds and Weather.**

10. Investigate the cooling of air on expansion and cloud formation as described on p. 123 of **Geology and Earth Sciences Sourcebook.**

11. Have students relate density currents in water to movement of air masses and weather systems: see Activities #3, 4, and 7 of Unit 1; p. 129 of **Geology and Earth Sciences Sourcebook** and Investigations 3-5, 4-7 and 4-8 of **Investigating the Earth,** pp. 56 and 93-96.

12. Students can collect, photograph or sketch and classify various cloud types and formations as described in section 5-8 and 5-9 of **Investigating the Earth,** pp. 108-111.

13. Assign excursion 2-2 "Billboards of the Sky" as a project, p. 107 of **Winds and Weather.**

14. Compare and discuss forms, sizes and modes of formation for the various types of precipitation as in **Investigating the Earth,** pp. 116-118.

15. Use some of the many investigations available to demonstrate and investigate the dew-point and relative humidity: e.g., (a) Making Visible the Invisible, pp. 37-49, of **Winds and Weather.** (b) Air Pressure and Vapour Pressure, section 5-6 of **Investigating the Earth,** pp. 105-107.

16. Condensation and evaporation may be investigated in many ways but should always be related to the suns energy as the driving force: e.g., (a) Section 5-7 of **Investigating the Earth,** p. 107. (b) Section IV (Moisture in the Atmosphere), pp. 110-111 of **The Earth and its Place in the Universe.**

17. Have students attempt to demonstrate as many causes for the movement of air masses as possible. A good starting point is the first chapter of **Winds and Weather,** (pp. 1-14).

18. Use data from a source such as **Climate Canada** to describe the differences between the weather and the climate of a specific area.

19. Have students investigate factors which give rise to climate, using a hypothetical continent (see problem break 6-2, pp. 78-79 of **Winds and Weather,** or investigation 7-10, pp. 158-159 of **Investigating the Earth.**

20. Use a film such as Storms, the **Restless Atmosphere,** to introduce the topic of weather systems and their movements.

21. Have groups of students set up weather stations at various locations on the school grounds or throughout the community (i.e., at home) to compare and contrast "mini-climates" and their causes.

22. Obtain weather maps from the nearest office of the Atmospheric Environment Service and have students make three dimensional models based on each map. (Modelling clay, wire mesh, styrofoam and clear plastic are all suitable materials.)

23. Adapt Chapter 7 (Moving Weather) of **Winds and Weather** (pp. 81-96 to local weather conditions with the help of maps and materials from the **Atmospheric Environment Service.**

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OUTCOMES
and
SUGGESTED
ACTIVITIES

Section D

Resource Sciences

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Teacher Resource Material is indicated by number in the parentheses following most Learning Outcomes. Details regarding references, activities and investigations follow the respective sections of the Earth Science 11 course. (These are suggested activities only and may be used at the discretion of the teacher.)

Section D Earth Resources

INTRODUCTION

Earth resources includes the study of the origin and development of mineral resources including fossil fuels, metals, soil and water. Mineral resources have become essential ingredients for life — building blocks of society. But are they sufficient for a healthy future, and are they sufficiently accessible to allow easy exploitation? Mineral resources such as coal, oil, copper, iron and fertilizers are not renewed each season although resources derived from living matter such as food, clothing and wood may be. Students should be concerned not only with the understanding of the distribution and availability of these vital resources but also with the problems associated with their development.

Use should be made of the knowledge and skills gained from other sections of this course. Discussions and other activities should be designed to suit the locality, the students and the teacher. It is hoped that these discussions will lead to a prudent, conservative and economical attitude towards the use of our resources. Printed materials are readily available from government sources and private industry and most of this material is free and available in classroom quantities. Texts selected for Earth Science 11 do not treat this subject adequately so that it is essential that outside sources be consulted. The following framework is intended to provide a general basis upon which the learning outcomes for the section can be developed.

Non-renewable Resources: The minerals of the earth take hundreds of millions of years to form and some were formed by geological processes that may not be repeated. For either reason they are non-renewable. Beyond these facts most of these minerals are present in the crust in limited amounts. Extreme concentrations of minerals occur in relatively small deposits. Most desirable minerals occur in very diffused quantities throughout the rest of the crust. In any deposit a point is reached where it is not economical to move the ore for the amount of mineral available. How large are our mineral resources and can exploration add to these resources? What processes are used to answer these questions? What thought is given to conservation?

The processes needed to change minerals into useful metals or alloys and the amount of energy necessary to make the processes work are also topics that need to be considered.

Renewable Resources: British Columbia has an abundant supply of fresh water and a large potential of hydroelectric power. There are many valuable renewable resources that are being developed in British Columbia by British Columbia Hydro and some large privately owned corporations. At the same time the effect that the development of these resources have on the environment is often adverse. While the maintenance of hydroelectric power resources and fresh water supplies must be accomplished in the most efficient manner, consideration of the environment must be taken into account.

Section D — Earth Resources

Non-renewable Resources

LEARNING OUTCOMES

The student should be able to:

1. *Discuss the origin of deposits of coal, petroleum and minerals of economic value.*

   (Activity #1, 2, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, 16)

2. *Study geological and geophysical methods of exploration for coal, petroleum and economic minerals.*

   (Activity #7, 8, 11, 12, 13, 15, 17)

3. *Explain the methods of extraction employed by man in the development of coal, petroleum and ore minerals.*

   (Activity #4, 5, 7, 8, 12, 13, 16, 24)

4. *Describe the methods of concentrating and refining ore minerals and fossil fuels.*

   (Activity #7, 13, 14, 16, 24)

5. *Discuss the uses of ore minerals and fossil fuels.*

   (Activity #7, 13, 14, 16)

6. *Define energy.*

   (Activity #18, 19, 20, 21, 22, 23)

7. *Describe the forms and sources of energy.*

   (Activity #18, 19, 20, 21, 22, 23)

8. *Explain how energy is transformed and used by man.*

   (Activity #18, 19, 20, 21, 22, 23)

9. *Explain methods that might be employed to conserve energy.*

(Activity #23)

10. *Discuss the methods used to transmit energy from one place to another.*

(Activity #13)

Renewable Resources

LEARNING OUTCOMES

The student should be able to:

11. *Discuss the various resources that are classified as being renewable.*

(Activity #20, 21, 22, 23)

12. *Describe problems which may be encountered by man in his attempt to renew such resources as food, clothing and wood, all obtained from living matter.*

(Activity #20)

Environmental and Economic Problems

LEARNING OUTCOMES

The student should be able to:

13. *Discuss the problems related to development of one of the natural resources listed above, such as coal, oil and gas or any metallic or non-metallic mineral of economic value.*

(Activity#2, 3, 7, 13)

References

1. American Geological Institute, 1973, *Investigating the Earth* (revised edition), Houghton Mifflin Company. Chapter 17 — Life: Present, Past, and Future, (pp. 389-391), Chapter 8 — Waters of the Land, (pp. 180-183).

2. Jackson, J.H., and Evans, E.D., 1973, *Spaceship Earth/Earth Science*, Houghton Mifflin Company. Chapter 19 — Man in His Environment, (pp. 543-572).

3. Ordway, R.J., 1973, *Earth Science*, Van Nostrand Reinhold Co. Chapter 4 — Weathering, Mass-Wasting, and Stream Erosion (Floods and Flood Control). Chapter 5 — Subsurface Water (Water Conservation).

4. Intermediate Science Curriculum Study, 1972, *Crusty Problems/Probing the Natural World*, Silver Burdett. Chapter 3 — The Midlands, A Pathway to the Sea (The Force of Waves, pp. 154-155).

Additional References

1. Rau, J.L., 1977, *Sources of Free Materials for Canadian Earth Science Teachers and Students*, GAC Publications, 111 Peter Street, Toronto, Ontario — $4.

2. Mining Association of Canada, 1975, *What Mining Means to Canada*. Free. The Mining Association of Canada, 20 Toronto Street, Toronto, Ontario M5C 2C2.

3. Department of Energy, Mines, and Resources. 1975, *Minerals for the Use of Man*. 48 p. Excellent introduction to the importance of minerals in Canada. Free. Department of Energy, Mines and Resources, Ottawa, Ontario K1A 0E4.

4. Department of Energy, Mines, and Resources, 1974. *100 Ways to Save Energy and Money in the Home*, 160 p. Free. An excellent pocket book on tips that can stretch Canada's energy resources and put money in your pocket. Department of Energy, Mines and Resources. Ottawa, Ontario K1A 0E4.

5. Department of Energy, Mines and Resources, 1974. *Introduction to Energy in Canada*. Discusses original energy sources, the changing pattern of energy sources in Canada, water, coal, current uses, outlook, petroleum and natural gas, uranium, electric power development, pros and cons of hydroelectricity, thermal power, and consumption of electricity by sector. Available in classroom quantities. Free. Department of Energy, Mines and Resources, Ottawa, Ontario K1A 0E4.

6. Department of Energy, Mines and Resources, 1974, *Exploring for Minerals*. An illustrated guide to the stages of mineral exploration including the structure of the earth, geological changes, drilling, exploring the ocean depths, etc. Available in classroom quantities. Department of Energy, Mines and Resources, Ottawa, Ontario K1A 0E4. Free.

7. Shell Canada Limited. The following booklets are available free of charge. *Story of Petroleum, Wonderful World of Oil, How to Save on Energy, Conserving the Environment* and *Let's Collect Shells and Rocks*. Shell Canada Limited, Public Relations Department, Box 400, Terminal A, Toronto, Ontario M5W 1E1.

Activities and Investigations

1. Ore deposits in Western Canada are located in the Canadian Cordillera. The Western Cordillera was Canada's Leading source of metal until the Canadian Shield took the lead early in the present century. The Cordillera is still a large producer and has great potential. Large deposits of lead, zinc, and silver are mined in southeastern British Columbia. Massive and porphyry-copper types of copper deposits are or have been mined in several areas. A large molybdenum deposit recently began to produce in central British Columbia. Many placer and lode deposits were mined for gold, and some are still operated. The coastal region contains many metasomatic magnetite deposits, some of which yield copper as well as iron. Asbestos deposits are mined in Northern British Columbia and in the Yukon. Deposits of other industrial minerals are worked in various parts of British Columbia. (**Geology and Canada,** 1970. Department of

Energy, Mines and Resources, Ottawa, Ontario, K1A 0E4. Free). Study the geology of the Western Cordillera and try to explain the distribution of an important metal deposit.

2. Copper is one of Canada's principal mineral products. Copper is used in great quantities by industry, and in recent years the price of copper has dropped considerably. If this trend continues the future of several of British Columbia's copper mines is in jeopardy. The economic future of British Columbia is heavily dependent upon the development of its mineral resources. Consider the effect of a continuing drop in the price of copper and explain how the "cut-off" point for a copper mine could influence the people and economy of certain regions of British Columbia.

3. Iron and steel plants are usually located near the markets for iron and steel products. The principal plants in Canada are at Sydney, Nova Scotia, and Hamilton and Sault Ste. Marie, Ontario. Ores that contain 50 per cent or more or iron are usually shipped direct or after washing; ores of lower iron content are usually treated at the mine by some method such as gravity concentration, magnetic separation, or sintering, to bring them up to shipping grade. Because iron ore has a relatively low unit value, compared to other ores, only large deposits of high iron content can be worked profitably. Discuss the location of iron ore deposits in British Columbia and determine where the ore is shipped and whether or not these deposits are likely to remain profitable.

4. The Sullivan mine at Kimberley in Southern British Columbia is the largest source of lead and zinc in Canada. The huge Sullivan deposit is a replacement body along a zone in beds of early Precambrian argillite. The whole zone is up to 92 m thick. It occurs on a limb of a broad anticline, the ore zone dipping about 30 degress northeast. The ore is banded and contorted. Galena, sphalerite, pyrrhotite, and pyrite are the principal sulphide minerals. Because of the importance of the deposit, its geology and origin have been studied intensively. Write to Cominco for more information about the Sullivan mine and display a collection of ore minerals obtained from the ore body. Cominco Ltd., 200 Granville Square, Vancouver, British Columbia V6C 2R2.

5. Canada produces over 70 per cent of the world's nickel. Canada's nickel comes chiefly from numerous mines of the INTERNATIONAL NICKEL COMPANY OF CANADA LIMITED and FALCONBRIDGE NICKEL MINES LIMITED in the Sudbury district of Ontario. In 1883 a blacksmith named Flanagan, working on the construction of the Canadian Pacific Railway near the village of Sudbury, found copper sulphides along the right-of-way. He did not record a claim and others staked the ground a few months later. The typical orebodies of the Sudbury district are large irregularly shaped masses containing massive and disseminated sulphide minerals, mainly pyrrhotite and chalcopyrite. The nickel is contained in the mineral pentlandite and the platinum in 'sperrylite', an arsenide of platinum. The orebodies occur at and near a body of basic intrusive rock called a micropegmatite. Detailed studies have shown that the orebodies are generally localized where fault and breccia zones cross the intrusive rocks. It appears that the ore may be hydrothermal in origin but the exact sequence of events and the geological processes responsible for the emplacement of the ore minerals is still hotly debated. Discuss the hydrothermal theory of ore deposition and include one or two other newer ideas on the origin of the Sudbury deposit. International Nickel Company of Canada Ltd., P.O. Box 44, Toronto-Dominion Centre, Toronto, Ontario, M5K 1E3.

6. Canada is one of the world's largest producers of uranium, the 'fuel' from which atomic energy is derived. In the mid-fifties the Eldorado mine at Great Bear Lake became the principal source on this continent, and as a security measure the Canadian Government bought the Eldorado company, prohibited private staking and mining for uranium and prospected successfully for other deposits such as the one in the Beaverlodge region of Saskatchewan. Many minerals contain uranium, but most of them are comparatively rare and difficult to identify by field methods. The uranium-bearing minerals fall into three main classes: (1) primary minerals found in veins and other hydrothermal deposits; (2) primary minerals found usually in pegmatites and related types of deposits, and (3) secondary minerals formed by near-surface alteration of primary minerals. The most important mineral is uraninite and its variety pitchblende. Write to Uranium Canada Limited, Ottawa for additional information. Free samples of uranium bearing ore may be obtained by writing Rio Tinto Canadian Exploration Ltd., Suite 2400, 120 Adelaide Street W., Toronto, Ontario.

7. The full appraisal of mineral deposits and mining properties is a technical matter that may involve the expenditure of much time and money. Discuss as completely as possible the various factors that must be taken into account in appraising a discovery. Write to Placer Development Limited, 700 Burrard Building, 1030 West Georgia Street, Vancouver, British Columbia for their excellent booklet entitled **The Mine Development Process.**

8. Few deposits consist of a single mineral. They usually contain one or more minerals that may be of value, in a worthless matrix of rock or of concentrations of valueless minerals. The valuable or possibly valuable minerals may be dispersed so finely that they can be seen only under a microscope, or they may be in grains visible to the unaided eye, or they may be in pure masses several centimetres or even a metre in size. These are sometimes called ore minerals even if they do not occur in commercial quantities in the particular deposit being discussed. The worthless non-metalliferous rock or minerals accompanying the ore minerals is called gangue and the minerals comprising it are called gangue minerals. The most common gangue minerals are quartz and calcite. List at least ten ore minerals and be able to identify them in either a slide or hand specimens.

9. The principal kinds of deposits directly related to igneous intrusions are magmatic segregation deposits, contact metasomatic deposits, pegmatites and some veins, and replacement deposits. Describe one of these types of ore deposits and show by a diagram how a mineral deposit may be related to igneous intrusion. **Prospecting in Canada,** Department of Energy, Mines and Resources, Ottawa, Ontario or Geological Survey of Canada. $2.50 (3rd edition), $10.00 (4th edition).

10. Sediments precipitated from sea water or formed from the erosion of rocks exposed at the earth's surface lead to the formation of unconsolidated sediments that in turn become hard sedimentary rocks. Such sediments and sedimentary rocks may in their entirety be useful commercially, particularly as deposits of industrial minerals; or they may contain concentrations of heavy minerals and thus form 'detrital' deposits. Detrital mineral deposits are of two main kinds: (1) those that are still unconsolidated and are called 'placer deposits' or 'placers'; and (2) consolidated detrital deposits, which are placers that have been changed into metal-bearing conglomerate, sandstone, or other sedimentary rock, and which, therefore, form one of the classes of consolidated sedimentary deposits. Discuss one of the following types of placer deposits; gold, platinum, cassiterite, ilmentite, diamonds, and rubies. Precambrian sedimentary beds composed of iron minerals and silica are very important in Labrador. Write to Noranda Mines Limited, P.O. Box 45, Commerce Court Postal Station, Toronto, Ontario M5L 1B6 for a free bag of ore samples and an interesting booklet entitled **Noranda Is.**

11. Almost all metalliferous minerals lying at or near the surface are altered by the effects of surface water that attacks them and causes the formation of new ones, generally oxides or hydroxides (compounds composed of a metal plus hydrogen and oxygen). These new minerals are called supergene or secondary minerals, and deposits composed of them are called supergene or secondary deposits. Some minerals containing metals, such as copper, iron, and uranium are readily attacked by surface waters, others are less susceptible, and a few like gold and platinum are so resistant that they do not form compounds in this way. Deposits containing secondary iron minerals have a characteristic rusty appearance and are called gossans. Alteration may also cause removal of valuable metals from the upper part of a deposit, so that sampling of this part yields misleadingly low assays or fails to detect a particular metal at all. The metal so removed may be dispersed, or it may be concentrated in a lower part of the deposit to form what are called 'zones of secondary enrichment' or bonanzas. In most Canadian deposits the secondary effects have only a minor influence on the value of the deposit but they often lead the way to the primary deposit. Study examples of secondary minerals and be able to identify at least the following: limonite, hematite, malachite, azurite, and gypsum.

12. The principal fuels are wood, coal, petroleum and natural gas. All but wood are classed as mineral fuels because they are produced from rock formations. There is a great demand for these materials in the present energy short world. Discuss the origin of coal and be able to differentiate the following types of coal; lignite, bituminous, anthracite. Write for the following free booklet entitled **Coal in Canada.** Department of Energy, Mines and Resources, Ottawa.

13. Petroleum is more familiarly known as 'crude oil' or simply 'oil'. It is customary to distinguish 'natural gas' from the other gases, but for the purposes of this discussion it can be assumed that the word 'gas' refers to naturally occurring combustible gas. Canada is fortunate in having large supplies of crude oil in the subsurface of the Prairie Provinces, Foothills Belt of Alberta and in the Mackenzie Valley region. Petroleum and natural gas are allied substances of organic origin accumulated under special conditions in porous beds in the earth's crust. The organic materials were deposited in past geological ages in bodies of water, together with the sand, silt, and mud of normal sediments such as are brought down the rivers of today to be deposited in the sea.

Organic materials long exposed to air or water decompose, but salt water retards the decomposition and, if sedimentation is sufficiently rapid, organic matter is trapped in the sediments. Some limestones may also have a high content of organic substances, especially those formed in fairly warm seas. The organic substances trapped in shales and limestones are slowly subjected to heat and pressure and changed into gas and small globules of oil, which are at first widely scattered and must migrate into suitable concentrations and be trapped to form commercial deposits. Nearly all rocks contain some open spaces between the grains. When oil and gas get into rocks that are sufficiently porous, or are fractured or faulted, they migrate slowly upward, until the surface is reached or until relatively impervious rock prevents further movement. There are many kinds of structural and other traps. The simplest traps are anticlines and domes. Other types of traps are provided by faulting of a porous stratum in impervious beds, by the pinch-out of a porous bed within a shale or other impermeable unit or by large coral reefs such as are found in the Foothills Belt of Alberta. Diagram one of these oil structures, and be prepared to explain the process by which oil can migrate and be trapped in such a structure. The following booklets are available free of charge from the Department of Energy, Mines and Resources, Ottawa, Ontario K1A 0E4.

Finding Out About Fuels

100 Ways to Save Energy and Money in the Home

Introduction to Energy in Canada

Energy and Out Way of Life

Resources Under the Sea

Coal in Canada

The following booklets are available from Shell Canada Limited, Public Relations Department, Box 400 Terminal A, Toronto, Ontario M5W 1E1.

Story of Petroleum

Wonderful World of Oil

How to Save on Energy

Conserving the Environment

Let's Collect Shells and Rocks

14. Canada is one of the world's leading producers of asbestos. Asbestos, of the variety called chrysotile, is the principal industrial mineral mined in Canada. Chrysotile asbestos is a fibrous variety of serpentine formed by alteration of ultrabasic rocks. The Cassiar asbestos mine on McDame Mountain in the northern part of British Columbia began production in 1953. The deposit contains chrysotile in a basic rock, probably Jurassic in age, which is so altered to serpentine that its original nature is doubtful. After a large body of chrysotile-bearing rock was outlined by the company optioning the claims from the prospector, and tests had shown that the mineral was of such high quality that the deposit would pay to work despite the distance from markets, a branch road was built to join a road leading to the Alaska Highway. Write to the Cassiar Asbestos Corporation Limited, Suite 2000, Guinness Tower, 1055 West Hastings Street, Vancouver, British Columbia V6E 3V3 for their booklets entitled:

Cassiar

The Geology of the Cassiar Asbestos Deposit

Samples of the ore minerals of the Cassiar deposit can be obtained by writing the Cassiar Asbestos Corporation Limited, Cassiar, British Columbia V0C 1E0.

15. Gold is one of Canada's chief mineral products, the annual production in recent years being about 54 million grams. Canada's Precambrian Shield has produced approximately 4 394 million grams of gold, about 80 per cent of Canada's total. Most has come from quartz veins in volcanic rocks intruded by granites and porphyritic rocks. Some has been by-product from base-metal deposits in volcanic rocks. In spite of the present price of gold, Canadian gold mining is in a sad state of decline because of no large new ore discoveries, labour shortages, rapidly diminishing reserves, and steadily increasing costs. Although one or two small mines have been brought into production in the past several years, and one or two others are planned, they by no means make up for the great number of formerly big producers which have closed down or are closing down. It is likely that Canada's annual production will soon be less than 42 million grams. Assuming a $5 per gram price, Canada's total lode reserves probably do not exceed 283 million grams valued at about 1.4 billion dollars.

Most of the lode gold deposits in the Cordillera of Western Canada have been worked out and were discovered as a result of the impetus given by the building of the Canadian Pacific Railway. Most important were the replacement veins containing gold and copper in the Rossland camp, where production began in 1894 and a large output was obtained from 1897 to 1916. Another important producer, the Nickel Plate mine at Hedley, began production in 1903 and is now shut down. For a time it was the largest gold mine in Canada. The Nickel Plate ores are gold-bearing contact metasomatic deposits in limestone, containing much arsenopyrite. These mines, together with several smaller ones, made British Columbia the leading province in the production of lode gold during the early years of the present century.

A somewhat later major producer was the Premier mine at Stewart. In the 1930's the price of gold increased and the value of production soared; new discoveries were made and old mines were revived. The principal gold camps, in order of output of gold, have been Bridge River, Rossland, Portland Canal, Hedley, Wells, and Sheep Creek. In 1971 the Bralorne mine in Bridge River closed; it was the last major gold mine in the Province to operate. To date the gold mines have paid a total of about $82 million in dividends. Some useful references on gold include the following:

Cooke, H.C., 1946, Lode Gold Areas, Summary Account. Geol. Survey., Canada, Econ. Geol. Ser. No. 15.

Robinson, A.H.A., 1935, Gold in Canada. Mines Branch, Dept. Mines and Tech. Surveys, No. 769.

Structural Geology of Canadian Ore Deposits. Canadian Institute of Mining and Metallurgy, Montreal, 1948. (A symposium containing descriptions of many Canadian mining camps and mines, including the principal gold mines.)

Gold in Canada, Dept. of Energy, Mines and Resources, Annual Review.

16. Copper is British Columbia's most important base metal and provides the heart of the Province's mining industry. Copper concentrates are shipped to Japanese and American smelters because no copper smelter has operated in British Columbia since 1935. One is now under construction near Kamloops. Small amounts of gold and silver are commonly present and add value to the ore, but some ores contain important amounts of gold (as at Rossland), silver (Silver King mine), lead and zinc (Tulsequah) or zinc (Britannia mine). Most of the smelting in British Columbia in early years was done on ore shipped direct from the mines without concentration, but the modern practice is to concentrate the ore first.

Ore was smelted in British Columbia first in 1896 at Nelson (from Silver King mine) and at Trail (from Rossland mines), and four and five years later at Grand Forks (from Phoenix mine) and

Greenwood (from Mother Lode mine). Later, small smelters were built in the Boundary district and on Vancouver and Texada Islands, and in 1914 the Anyox smelter was blown in. Copper smelting ceased in the Boundary district in 1919, at Trail in 1929 and at Anyox in 1935. British Columbia copper concentrates were then smelted mainly in Tacoma, and since 1961 have gone chiefly to Japan.

Most of the production has come from southern British Columbia — from Britannia, Copper Mountain, Greenwood, Highland Valley, Merritt, Nelson, Rossland, Texada Island, and Vancouver Island, although a sizeable amount came from Anyox and some from Tulsequah. During recent years exploration for copper has been intense (until 1972) interest being especially directed toward finding very large, low-grade deposits suitable for open-pit mining. This activity has resulted in the establishment of operating mines at Merritt (Craigmont) in 1961, in Highland Valley (Bethlehem) in 1962, on Babine Lake (Granisle) in 1966, near Peachland (Brenda) in 1970, and Stewart (Granduc) in 1971. Large mines near Port Hardy (Island Copper), Babine Lake (Bell), McLeese Lake (Gibraltar), Highland Valley (Lornex) and Princeton (Ingerbelle) came into production in the early 1970's.

After a lapse of many years, copper has been produced comparatively recently on Vancouver Island at Jordan River, Courtenay, Benson Lake, Quatsino, and also at Buttle Lake together with zinc and silver. Copper is now the most valuable single commodity of the industry. Production in 1970 was 455 million kg. Write to the following mining companies for additional information and describe the occurrence and mining methods used at one of these copper mines.

Bethlehem Copper Corp.
1055 West Hastings, Vancouver.

Craigmont Mines Ltd.
1030 West Georgia, Vancouver.

Granisle Copper Ltd.
1050 West Pender, Vancouver.

Brenda Mines Ltd.
P.O. Box 420, Peachland, B.C. V0H 1X0

Granduc Operating Company
890 West Pender Street, Vancouver.

Lornex Mining Corp. Ltd.
Suite 202, Imperial Bank Bldg.
580 Granville, Vancouver.

17. Ultraviolet rays, also known as "black light", have found a very definite place in the mineral sciences during the past 30 years. Ultraviolet rays cause certain minerals to glow or release their own light — a phenomenon called fluorescence. The emission of "cold light" has proven of decided value in the detection and identification of many minerals and ores. Its greatest usefulness is in the identification of scheelite, zircon, willemite, mercury and petroleum. Hide a sample of scheelite or willemite in an open field or beach and then have an exploration "team" systematically search for the minerals at night using a "black light".

18. A healthy, hard-working person can only produce enough energy to keep a 100-watt light bulb burning. Our ancestors found it necessary to develop supplementary sources of energy. First animals, then sails, water wheels, wind mills, steam and internal combustion engines, and eventually motors. Supplementary energy now exceeds muscle power and comes from coal, oil, and uranium. Reverting to muscle power alone would bring chaos. Discuss one alternative to the present sources of energy and discuss when this alternative might become an important source of energy to the world.

19. Study the costs of the energy used to heat and light your school during the period of one year. Do the same for your home. Then compare the cost of fuel per capita in the two situations. List the types of data that one needs to know in order to save fuel and lighting costs.

20. Despite the green revolution and great advances in farming methods the population is increasing faster than food production. Even with great efforts to expand production from all sources, including the oceans, it is inevitable that the population will cease growing. The earth's theorectical carrying capacity is about 33 billion people according to the U.S. National Academy of Sciences. What is the present world population and by what date will it reach 33 billion if present growth rates continue? Is the growth rate the same for every country? In what country is it lowest? Highest?

21. The supplementary energy used by man, from all sources, is now about 3×10^{20} joules per year. Although this number is enormous, it is small by comparison with the solar energy received by the Earth each day: 1.5×10^{22} joules. What recent developments have occurred to focus man's attention on the sun as a source of energy and how can the sun's energy be harnessed?

22. Nuclear energy is becoming more important as a source of power in eastern Canada but so far has met with intense resistance in British Columbia. What factors about nuclear reactors and their spent fuel pose threats to life and property throughout the world? If you were faced with the choice of building a dam on the main stem of the Fraser River or constructing a nuclear power plant somewhere in British Columbia which would you choose and why? What are the advantages and disadvantages of these two types of power generation?

23. Read the booklet entitled **100 Ways to Save Energy and Money in the Home.** Keep a record of any energy saving devices you have employed and compute the value of the savings after the end of a given period. The booklet is available free of charge from the Department of Energy, Mines and Resources, Ottawa or any local office of the Department such as 100 West Pender Street, Vancouver (Geological Survey of Canada).

24. Play a simulation mining game such as GET THE ZINC OUT, a game developed by VEEP at the University of British Columbia and for sale as a lesson aid by the B.C. Teachers' Federation.

SPECIAL NOTES:

Non-renewable Resources

1. **Formation of Coal:** During the Late Devonian, the Mississippian, and the Permian Periods a great variety of fern-like plants grew in great swampy areas. The fossil remains of the these plants are sedimentary rock called coal. Pressure from overburdens of sediment changed the plants from peat with 80% moisture to lignite with 40% moisture to bituminous coal with 5% moisture. Further pressure changed the bituminous carbon to anthracite with about 95% carbon. The lack of the proper conditions and the millions of years involved in the process makes the renewal of this resource impossible.

2. **Formation of Oil:** Ranging from the Ordovician through the Tertiary Period the remains of marine plants and animals have contributed to the formation of petroleum and natural gas which are mixtures of hydrocarbons in the gaseous, liquid and solid phases. These products are dispersed in the pores of the rock formations that result from the sediment that has covered the original remains. Many of these products have escaped to the surface of the earth but some of them have become trapped between an impermeable caprock and the permeable reservoir rock in which they formed. The petroleum is often found floating on salt water within the rock formation. It is also in a carbonaceous shale called oil shale which will become economically important in the future. The lack of the proper conditions and the millions of years involved in the process make the renewal of these resources impossible.

3. **Formation of Ore Deposits:** Metallic minerals sometimes exist in ore deposits thousands of times more concentrated than they would be in the average igneous rocks of the earth's crust. An ore containing platinum that is two per cent of the mass of the rock in which it occurs is a

billion times more concentrated than it would be in an average piece of igneous rock. When molten rock flows up from the magma and starts to cool metallic minerals may crystallize and settle against the solid country rock. Great bodies of ore-bearing minerals such as the Sudbury nickel deposits of Ontario were formed in this way.

Hot aqueous solutions of lead, copper, silver and zinc compounds deposit metallic ores by contact metamorphism with the country rocks. These deposits are located along joints and faults. Large deposits of lead, copper, silver and gold have originated from hydrothermal solutions.

Ore deposits formed in sedimentary rock in a variety of ways. Halite, gypsum and potash deposits remained when restricted bodies of water that contained these salts evaporated. Large deposits of such minerals exist in Ontario and Saskatchewan. Weathering and leaching enrich low-grade ore deposits. This has happened in the formation of some of the copper deposits near Merritt. Heavy minerals such as gold are often concentrated in stream beds. Many common minerals such as clay sand, gravel, and stone aggregate are more abundant than are metallic minerals. However, these materials are used in greater quantities. They are generally quarried rather than mined.

Exploration to discover hidden deposits of minerals is an important branch of most mining and petroleum companies. Area surveys of Canada done by the Department of Mines have indicated many places where minerals are likely to be concentrated. The text, **Earth Science,** by Ordway, discusses some of the methods used. The Catalogue of Shell Films lists several films about the search for new sources of oil. The pamphlet Mining, produced by the Mining Association of Canada discusses the methods used to discover and mine ore deposits.

Renewable Resources

Water power and water are two renewable resources that are important to the study of earth science in British Columbia. There are at least a half dozen river systems that have great hydroelectric potentials and which contain great water storage potentials. The water stored can be used in this province for mining and for agriculture or it can be exported. A study of the hydrologic cycle will give an understanding of how the average water flow in a river can be calculated and how the water use can be proportioned for everyone's use as the water flows down the water system.

The environment is affected by hydroelectric dams and by the controlled flow of water down a water system. A study of possible effects on the environment before the dams are built will help to reduce some of the adverse effects on the environment. Some of these are obviously the loss of land used for agriculture and recreations, the interference with fishing resources, the silting of the storage lakes behind the dams, the lack of normal silting below the dams and the change in the normal flooding patterns of a river which will affect the downstream flora and fauna. Studies of these effects on any area of the river systems can be done as a scientific study. Available reports on water resources and hydroelectric potentials are listed.

The concentration and refining of useful elements and compounds and crude petroleum and coal should be discussed. Films and field trips to departments of mines could provide useful material for discussion.

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EARTH SCIENCE 11

GENERAL SUPPLIES AND EQUIPMENT LIST

The following list is provided as an aid in setting up new laboratories. It will also function as a convenient checklist for schools where some of the equipment listed will already be available. In deciding on quantities listed, a maximum class of twenty-four (24) students and an organization of two pupils per working station has been used.

Quantities are allotted on the following plan:

1. **Per Station:** A station is two students working as a team. If the laboratory seats 24 students and the amount required is one per station, twelve units will be required.
2. **Per Class:** Required for each class using the laboratory, e.g., if two Earth Science 11 classes use one laboratory, then requirement will be two times the unit issue.
3. **Per Laboratory:** Required per laboratory classroom.

Items that are marked + are desirable for the most effective presentation of the course but may not be essential.

EARTH SCIENCE II

GENERAL SUPPLIES AND EQUIPMENT LIST

	Item	Amount Required	Unit of Supply
	Aluminum foil	1 per lab	roll
	Aquarium, approx. 75 l	1 per lab	each
	Bags, plastic or baggies (local supply)	as needed	
	Balance, Centigram type,	8 per lab	each
	single pan		
	triple beam, 311 type		
	Beakers, pyrex, 50 ml	3 per station	case of 48
	Beakers, pyrex, 100 ml	6 per station	pgk. of 12
	Beakers, pyrex, 250 ml	3 per station	each
	Beakers, pyrex, 1 litre	2 per lab	each
+	Binoculars, 7 × 50	6 per lab	each
+	Blacklight (short wave)	1 per lab	each
	Bottles, dropping, 50 ml polyethylene	4 per station	dozen
	Bulbs, show case type, clear, 60 watt	2 per lab	each
	Bunsen burner	1 per station	each
+	Camera, 35 mm	1 per lab	each
	Clamp, burette, universal	1 per station	each
	C-clamp, 8 cm	2 per station	each
	Clay, (local supply)	10 per lab	1/2 kg
	Clock, sweep second hand, 24 hr.	1 per lab	each
+	Cloud chamber, dry ice type, students diffusion, radioactive source included (Welch type)	1 per school	each
	Compasses, blackboard style	6 per lab	each
	Connectors, 50 cm length	12 per lab	each
	Connector tips, slotted	24 per lab	dozen
	Corks, miscellaneous sizes	3 per lab	bag of 100
	Cork boring set, 9 pieces	1 per lab	each
	Cover glasses, microscope slide, size #2	2 per lab	box
	Crayons, wax (local supply)	30 per class	
	Cups, paper; unwaxed	30 per class	
	Cylinder, graduated, 100 ml	1 per station	each
	Cylinder, graduated, 250 ml	1 per station	each

	Item	Amount Required	Unit of Supply
+	Discharge tubes, Helium, Mercury, Hydrogen, Neon	1 of each per lab	each
	Elastic bands, miscellaneous sizes (local supply)	1 per lab	box
+	Fan, electric	1 per lab	each
+	Film, ektrachrome high speed	as needed	
+	Film, kodachrome 2	as needed	
	Filter paper, 15 cm. diameter	2 per class	pkg. of 100
	Food colouring (local supply)	as needed	
	Gas lighter, spark renewal type	1 per station	each
	Glass cutter for glass tubing	1 per lab	each
	Globe, blackboard, 50 cm	1 per lab	each
	Globe, hydrographic relief, 50 cm	1 per lab	each
	Goggles, safety	1 per student	each
	Hot plates, electric, single control	4 per lab	each
+	Induction coil, spark type	4 per lab	each
	Iron filings, fine	3 per lab	1/2 pkg
	Knife (pocket style, large) (local supply)	as needed	
	Labels, gummed, 40 × 60 mm, (local supply)	2 per lab	box
+	Light meter	1 per school	each
	Magnet, bar-Alnico 15 cm × 1.9 cm × 0.6 cm (approx.), set of 2 in a box	1 per station	set
	Magnetic compass, approx. diameter 16 mm	1 per station	each
+	Magnetic compass (Silva type)	1 per station	each
	Magnifiers, 3 lenses in one, hand lens	1 per station	each
	Metrestick	1 per station	each
+	Microscope, stereoscopic, powers of 20X and 40X	1 per station	each
	Nails, 6 cm (local supply)	1 per lab	1/2 kg
	Overhead projector (Apollo 6 type)	1 per lab	each
	Paper, white cardboard, (local supply)	as needed	
	Paper, white, 1 m width roll	1 per lab	roll
	Paper, graph, log-log type	1 per lab	pkg
	Paper, graph, cm squared	as needed	
	Parawax (local supply)	1 per lab	pkg. of 4 each
+	Pencils, coloured	1 set per station	set of 10
	Petri dishes, 150 mm × 20 mm tops and bottoms, clear plastic	1 per lab	case of 24
	Plaster of Paris	10 kg per lab	
	Plasticine (local supply) 3 colours	10 kg per lab	

	Item	Amount Required	Unit of Supply
	Plastic tubes, 5 cm × 100 cm	1 per station	each
	Plates, streak, small white porcelain (unglazed bathroom tiles)	1 per pupil	each
	Pneumatic trough, non-magnetic (plastic, large)	1 per lab	each
+	Power pack, 6 volts	4 per lab	each
	Prism, high dispersion	2 per lab	each
	Projector, slide, with remote control and extension cord	1 per Science Dept.	each
+	Prospector's pan, 35 cm diameter	6 per lab	each
	Protractor, blackboard style	6 per lab	each
	Pump, hand air	1 per lab	each
	Radioactive material set	1 per school	set
	Radioactive demonstrator with accessories	1 per school	each
	Razor blades, single edge (local supply)	3 per lab	pkg of 10
	Ripple tank and accessories (Welch type)	1 per lab	each
+	Rock polishing unit	1 per school	each
+	Rock saw, 25 or 30 cm diameter, combination trim and slab saw	1 per school	each
+	Rock tumbler	1 per school	each
	Ruler, flexible, metric	1 per lab	each
	Sand, coarse (local supply)	as needed	
	Sand, fine (local supply)	as needed	
	Scissors, fine point, student laboratory grade	1 per station	each
	Screen, projection	1 per lab	each
	Scoopulas, dispensing, stainless steel	1 per lab	dozen
+	Screen sieves (set of 6)	2 sets per lab	set
	Sea water salt (local supply)	as needed	
+	Sechii disc	1 per lab	each
	Seismograph		
	(Tripod-base ringstand	1 per lab	each
	Ringstand rod, 50 cm	1 per lab	each
	Machine screws to go through rod	2 per lab	each
	Copper wire #22 or #24, 60 cm	1 per lab	each
	Dowel, 50 cm long 1.25 cm diameter	1 per lab	each
	Brad to insert in end of dowel	1 per lab	each
	Strip of sheet lead, (450 g) 5 cm wide	1 per lab	each
	Sheet plastic, transparent (local supply)	as needed	
	Silly Putty (local supply)	100 g per lab	
	Slides, microscope, standard	1 per lab	box of 72
	Soil testing kits (local supply)	4 per class	
	Spectroscopes, hand type	1 per pupil	each
	Spoons, plastic (local supply)	3 per lab	dozen
	Spring, "slinky", 7.5 cm diameter	1 per lab	each

	Item	Amount Required	Unit of Supply
	Stirring rods, glass, 15 cm	6 per lab	pkg of 10
	Stoppers, hard rubber, 1-holed, (assorted)	1.5 kg per lab	kg
	Stream table (Demonstration type)	1 per school	each
	Stream table (Student Models)	1 per 4 students	each
	String, heavy (local supply)	1 per lab	roll
	String, nylon (local supply)	1 per lab	roll
	String, light (local supply)	1 per lab	roll
	Styrofoam cups	1 per lab	gross
	Suction cup, 1.25 cm	12 per lab	each
+	Stereoscopic viewers	1 per station	each
	Tape, cellulose, transparent (Scotch) 1.25 cm width	as needed	
	Tape, masking 1.25 cm width	3 per lab	roll
	Tape, ticker	1 per lab	package
	Test tube 18 × 150 mm, pyrex	2 per lab	pkg of 72
	Test tube brush, medium	3 per lab	each
	Test tube supports	1 per station	each
	Thermometers, Celsius scale −20 to 110°C, student grade	1 per station	each
	Thumbtacks (local supply)	3 per lab	box
	Tin shears, straight 25 cm	1 per lab	each
	Tissue for cleaning microscope lenses	1 dozen per lab	booklet
	Tongs, beaker	1 per lab	each
	Tools,		
	— file, triangular, 15 cm	per lab	each
	— hammer, claw	1 per lab	each
	— hammer, geologist's	1 per station	each
	— hammer, sledge	6 per lab	each
	— pliers, long nose cutting edge	1 per lab	each
	— pliers, combination	1 per lab	each
	— screwdrivers (combination)	1 per lab	set
	— screwdriver, jewellers	1 per lab	each
	— spade, folding type	6 per lab	each
	Tubing, soft glass, 4 mm and 6 mm	1 of each per lab	450 g
+	Vacuum pump, motor driven with plate	1 per school	each
+	Vacuum wax	1 per school	tube
+	Variac	1 per lab	each
+	Video Tape Recorder (Cassette and colour see PEMC)	1 per Science Dept.	each
	Wire gauze, asbestos enmeshed centre, 12.5 cm × 12.5 cm	1 per station	each

CHEMICALS

Item	Amount Required	Unit of Supply
Alum	2 kg per lab	kg
Ammonium dichromate	1/2 kg per lab	kg
Ammonium oxalate	1/2 kg per lab	kg
Copper II sulphate (Tech)	2 kg per lab	kg
Hydrochloric Acid	4 kg per lab	kg
Nickel II sulphate hexahydrate	2 kg per lab	kg
Salol	1/2 kg per lab	kg
Sodium chloride	3 kg per lab	kg

GEOLOGICAL SPECIMENS

Item	Amount Required	Unit of Supply
Prospector's set of Mineral Chips	1 set per station	set
Prospector's set of Rock Chips	1 set per station	set
Raw materials of Canada: Mineral Industry, 120 specimens	1 per class	set

(The above are available from the Geological Survey of Canada)

Azurite	1 per station	each
Bornite	1 per station	each
Copper (native)	1 per station	each
Corundum	1 per station	each
Halite	1 per station	each
Obsidian	1 per station	each
Olivine	1 per station	each
Pumice	1 per station	each

AUDIO-VISUAL MATERIALS

MAPS AND WALL CHARTS

Item	Amount Required	Unit of Supply
Maps:		
Geologic Map (local area)	1 per station	each
Surficial Geology Map (local area)	1 per station	each
Geologic Map of Retreat of Wisconsin and Recent Ice in North America	1 per station	each

(The above are available from the Geological Survey of Canada.)

Item	Amount Required	Unit of Supply
Wall Charts:		
Chart showing physical features of ocean basins (Available from: Geological Society of America, 419 West 117th Street, New York)	1 per class	each
Charts showing physical features of ocean basins (Available from: Time, Incorporated, Time-Life Building, New York)	1 per class	each
Deposits Near Medicine Hat, Alberta (Available from: Publications Distribution Office, Geological Survey of Canada, 601 Booth Street, Ottawa)	1 per class	each

FILMS

Films listed below are recommended as support material for Earth Science 11. Films marked (★) are available as free loans from the Provincial Educational Media Centre, 4455 Juneau Street, Burnaby, British Columbia V5C 4C4.

Films marked (T) are available for purchase, in video tape format, from PEMC through each district's PEMC liaison.

Arrangements for obtaining other films may be made through local district resource centres. (Films with TYPE not indicated are not presently available from PEMC.)

The sections where the films are pertinent to learning outcomes are indicated. Films recommended as highly desirable for successful implementation of the course are marked (●).

	Type		Title	Source	Date	Time	Section
	T		At the Speed of Light	PEMC	1976	30 min.	A-1
		★	Cosmic Zoom	NFB		8 min.	A-1
		★	Doppler Effect (b&w)	MGH	1952	11 min.	A-1
	T		The Invisible Messengers	PEMC	1976	30 min.	A-1
●	T		The Life Story of a Star	PEMC	1976	30 min.	A-1
	T		Horizon: The Black Holes of Gravity	BBC	1975	54 min.	A-1
			Van Allen Radiation Belt	EBE		13 min.	A-1
	T		Horizon: The Planets	BBC	1975	54 min.	A-2
●	T	★	Mars: The Search Begins	NASA	1973	25 min.	A-2
	T	★	Satellites of the Sun	NFB	1975	12 min.	A-2
	T	★	Space Science: The Planets	COR	1969	13 min.	A-2
●	T	★	Jupiter Odyssey	NASA	1974	28 min.	A-2
		★	Earth: Its Movements	COR	1967	11 min.	A-3
	T	★	Earth: An Interplanetary Perspective	MOC			A-3
	T		Earth Resources Technology Satellite	NASA	1973	27 min.	A-3
	T	★	The Face of the Earth	NFB	1975	15 min.	A-3
	T	★	The Moon: An Emerging Planet	NASA	1973	13 min.	A-3
	T	★	The Moon: Old and New	NASA	1970	25 min.	A-3
		★	The Earth: Its Magnetic Field	COR	1969	14 min.	A-3
●			The Moon: A Giant Step in Geology	EBE	1976	24 min.	A
	T	★	Continental Drift	NFB	1968	10 min.	B-1
		★	Continents Adrift	AEF	1968	17 min.	B-1
	T		Horizon: Drifting of Continents	BBC	1975	50 min.	B-1
		★	How Solid is Rock?	EBE	1968	22 min.	B-1
	T		Italy: The Udine Earthquake	UPIT	1976	10 min.	B-1
		★	Rocks that Form on the Earth's Surface	EBE	1965	16 min.	B-1
		★	Rocks that Originate Underground	EBE	1965	23 min.	B-1
	T		Castleguard Caves	NFB	1975	50 min.	B-2

Type	Title	Source	Date	Time	Section
★	Erosion: Levelling the Land	EBE	1965	14 min.	B-2
● ★	Evidence for the Ice Age	EBE	1965	22 min.	B-2
● ★	Glacier on the Move	EBE	1973	11 min.	B-2
★	Heartbeat of a Volcano	EBE	1970	20 min.	B-2
● ★	The Rise and Fall of the Great Lakes	NFB	1968	17 min.	B-2
● T ★	Volcanic Landscapes Part 1	MOY	1974	45 min.	B-2
● T ★	Volcanic Landscapes Part 2	MOY	1974	45 min.	B-2
★	Why do we still have Mountains?	EBE	1964	20 min.	B-2
● ★	San Andreas Fault	EBE	1974	21 min.	B-2
	The Continuing Past	NFB		21 min.	B-2
★	The Face of the High Arctic	EBE	1959	14 min.	B-2
● ★	Volcanoes: Exploring the Restless Earth	EBE	1973	18 min.	B-2
	The Great Lakes: How they were Formed	EBE		11 min.	B-2
★	Atmosphere in Motion	EBE		20 min.	C-1
★	The Beach, a River of Sand	EBE		20 min.	C-1
● ★	Storms: The Restless Atmosphere	EBE		22 min.	C-1
★	What Makes Clouds?	EBE		19 min.	C-1
● ★	What Makes the Wind Blow?	EBE		16 min.	C-1
●	Challenge of the Oceans	MGH		27 min.	C
	How Level is Sea Level?	EBE		13 min.	C
	Ocean Basins Series, Lamont Laboratory, Columbia University	Marine Science		16 min.	C
T ★	Origins of Weather	EBE NFB	1963	13 min.	C
	Restless Sea	BC Tel		54 min.	C
	Science of the Sea	International Film Bureau		19 min.	C
	Tides and Current, Washington Science Centre, Rockville Md. 20855 #P-1056-24	ESSA		15 min.	C
★	Waves on Water	EBE	1965	16 min.	C
	Weather Satellites	EBE		15 min.	C
	World without Sun, Trans-Surface Produced; directed by Jacques-Yves Cousteau			93 min.	C
● T ★	Energy Series				
	a. The Dilemma	GWF	1975	20 min.	D
	b. The Nuclear Alternative	GWF	1975	20 min.	D
	c. New Sources	GWF	1975	20 min.	D
	d. Less is More	GWF	1975	20 min.	D
	Miner	NFB		16 min.	D
★	Riches of the Earth	NFB	1954	19 min.	D

THE PLANET OF MAN (SERIES)

The series hinges on the theory of global plate tectonics. It also reconstructs, in model form, how vast forces of water, wind, ice and the shifting crust have shaped the earth we walk on today, and show how we may be able to predict future consequences.

	Name	Source	Time	Section
T	Voices of Time (Grand Canyon of Arizona)	OECA	30 min.	B-3
T	The Jigsaw Fit (Plate Tectonics)	OECA	30 min.	B-1
T	The Fire Within (Types of Volcanic Activity)	OECA	30 min.	B-2
T	Trail of Ice Age Blues (Effects of Glaciation on the Features of North America)	OECA	30 min.	B-2
T	Mountain Heritage — The Appalachians (Plate Tectonics, Volcanism, Mountain building)	OECA	30 min.	B-2
T	Shield of Plenty (Precambian Earth)	OECA	30 min.	B-2
T	Challenge of the Deep (Minerals on the Ocean Floors	OECA	30 min.	B-1
T	The Inner Limit (A Cross-Section of the Earth)	OECA	30 min.	B-2
T	The Cosmic Connection (Meteorite Bombardment)	OECA	30 min.	A-3
T	Beyond A Doubt: A Revolution (Concept of Continental Drift)	OECA	30 min.	B-1
T	The Uneventful Day (Weathering and Erosion)	OECA	30 min.	B-2

This series is available by purchase through your district PEMC liaison.

NASA Films may be obtained from:
National Science Film Library
1762 Carling Street
Ottawa, Ontario

or

NASA Ames Research Centre
Public Affairs Office
Moffet Field
California, U.S.A. 94035

Hubbard Super 8 Filmloops may be obtained from:
Visual Education Centre
115 Berkeley Street
Toronto, Ontario

FILMSTRIPS AND SLIDES

FILMSTRIPS

SECTION A

McIntyre Educational Media Ltd.

4005	Radioastronomy
681	Solar Radiations
4033	The Earth's Gravity Field
637	Universal Gravitation

SECTION B

Arbor Scientific Ltd. (Ward's Natural Science)

71W2300	An Introduction to Fossils
79W0040	Continental Drift 11: Sea-Floor
79W0080	Fossils: Clues to the Past
79W0100	The Record in the Rocks

Scholar's Choice Ltd. (1150 Homer Street. Vancouver, British Columbia)

Anatomy of a Volcano	EB
Basic Principles of Radioactivity	
Investigating a Glacier	NFB
Reconstructing the Ice Age	NFB
The Earth — Part 1	

McIntyre Educational Media Ltd.

4007	Dating Geologic Events
654	Diastrophism
589	New Discoveries about Planet Earth
672	Probing the Interior of the Earth

Visual Education Centre (Encyclopaedia Britannica)

6412K	Glaciers and the Ice Age
6415K	Investigating Rocks

SECTION C

Arbor Scientific Ltd. (Ward's Natural Science)

79W0040	Continental Drift 11: Sea-Floor
79W0050	Resources of the Ocean

Scholar's Choice Ltd:

Avid FS Exploring the Sea Tides

Landscapes of the Sea (Life)

Mighty Currents of the Sea (Life)

Oceanography: Understanding our Deep Frontier EB

McIntyre Educational Media Ltd.

4001 Oceanography — A Developing Science

Visual Education Centre (Encyclopaedia Britannica)

A Career in Oceanography

Air-Sea Interaction

Biological Oceanography

Chemical Oceanography

Geological Oceanography

Marine Resource

Ocean Engineering

Physical Oceanography

SECTION D

Scholar's Choice Ltd.

Coal Petroleum and Methane

McIntyre Educational Medial Ltd.

4504 Minerals of Economic Importance

SLIDES

B.C.T.F. Lesson Aids, Reference Number LA No. M1

— Earth Science Slides . . . Set of 120 slides

— Exploration of Planets: Mariner, Pioneer and Viking Missions . . . Set of 50 slides

PEMC Produced Filmstrip Series

The Provincial Educational Media Centre has produced a filmstrip, audio-cassette kit specifically as support material for the Earth Science 11 course

Dr. W R. Danner, Department of Geology, University of British Columbia was the specialist advisor to the PEMC.

Working titles for the filmstrips are:

1. Plate Tectonics Theory

2. Island Arcs and Mountain Ranges

3. Intermontaine Region

4. Vancouver Island and the Completion of Western North America

All of these slides (or filmstrips) refer to the geology of British Columbia.

These kits are available on a free loan basis from the Provincial Educational Media Centre, 4455 Juneau Street, Burnaby, British Columbia V5C 4C4.

SUPPLEMENTARY REFERENCE TEXTS

1. Jastrow/Thompson. *Astronomy: Fundamentals and Frontiers* (Wiley).
2. University of Illinois. *Astronomy Program.*
3. McKee. *Cascadia: The Geological Evolution Of The Pacific Northwest* McGraw-Hill).
4. Hare/Thomas. *Climate Canada* (Wiley).
5. Williams. *Continental Drift* (B.C.T.F. Lesson Aids).
6. Schmid et al., *Developing Science Concepts* (Prentice-Hall).
7. Obourn et al., *Earth Space Science* (Van Nostrand Reinhold).
8. Trowbridge. *Experiments In Meteorology* (Doubleday).
9. Abell. *Exploration of the Universe* (Holt, Rinehart and Winston).
10. Schmid et al. *Extending Science Concepts* (Prentice-Hall).
11. Allison et al., *Geology* (McGraw-Hill).
12. Geological Survey of Canada. *Geology and Economic Minerals of Canada.*
13. Schmid et al. *Introducing Science Concepts* (Prentice-Hall).
14. Navarra/Strahler. *Investiguide. Our Planet In Space* (Harper and Row).
15. *I.S.C.S Pamphlet Series.* PS 1-10 (Houghton-Mifflin Science Program).
16. Brown Kemper & Lewis. *Laboratory Investigations In Earth Science* (Silver Burdett — GLC).
17. Life Nature Library Series:
    - i) *The Earth* (General Learning Corporation)
    - ii) *The Planet* (GLC)
    - iii) *The Sea* (GLC)
    - iv) *The Universe* (GLC)
    - v) *Weather* (GLC)
18. Pratt/Thompson. *Patterns In The Environment* (Prentice-Hall).
19. Dutton. *Space Encyclopaedia* (Clarke Irwin).
20. Russel et al., *Sourcebook For Earth Science And Astronomy,* (Collier-Macmillan).
21. American Geological Society, *The Dictonary of Geological Terms,* Dolphin (Doubleday).
22. Hibbs/Eiss. *The Earth Space Sciences,* Laidlaw (Doubleday).
23. Alberta Society of Petroleum Geologists, *The Face Of Time,* (A Geological History of Western Canada). 612 Lougheed Building, Calgary, Alberta.

24. *Time, Space and Matter,* Investigatir The Physical Worl Series. Modules (McGraw-Hill).

i) Encountering The Physical World

ii) Exploring A Slice Of The Earth

iii) From Microcosm To Macrocosm

iv) Levels Of Approximation

v) Dimensions And Motions Of The Earth

vi) The Surface Of The Earth

vii) The Grand Canyon Of Colorada

viii) The Surface Of The Moon

ix) Worlds In Space

25. *Unesco Sourcebook For Science Teaching* (Unesco).

PRESCRIBED TEXTBOOK LIST

The textbooks authorized for the Earth Science 11 course are listed below. The scale of issue of authorized texts is indicated in the **Prescribed Textbook List.** The Prescribed Textbook List is published annually by the Curriculum Development Branch and is available from the Publication Services Branch.

EARTH SCIENCE 11

1. Krynowsky et al.: *Foundations of Space Science,* (Holt, Rinehart and Winston).
2. Wolfe et al.: *Earth and Space Science,* 2nd edition (D.C. Heath).
3. (a) American Geological Institute: *Investigating the Earth,* revised edition (Houghton-Mifflin).
   (b) Goldthwait: *Earth Science* (Ginn)
   (c) Jackson/Evans: *Spaceship Earth/Earth Science* (Houghton Mifflin)
4. (a) Heller et al.: *Challenges to Science, Earth Science* (McGraw-Hill)
   (b) Bishop et al.: *Focus on Earth Science,* 2nd edition (Merrill)

Reference Package

1. Ordway: *Earth Science,* 2nd edition (Van Nostrand Reinhold).
2. Intermediate Science Curriculum Study: *Crusty Problems,* (plus Record Book) Silver Burdett (GLC Educational Materials and Services Ltd.).
3. I.S.C.S.: *Winds and Weather* (plus Record Book) Silver Burdett (GLC).
4. Readings from Scientific American: *Oceanography* (W.G. Freeman & Company).
5. Readings from Scientific American: *Continents Adrift and Continents Aground* (W.H. Freeman & Company).
6. Nuffield Secondary Science 8: *The Earth and Its Place in the Universe* (Longman).
7. U.S. Geological Survey: *Atlas of Volcanic Phenomenon* (Washington. D.C. 20402).