Curriculum RP-47

ISSUED BY AUTHORITY OF
THE MINISTER OF EDUCATION

ONTARIO
DEPARTMENT OF EDUCATION

GEOLOGY

AN OPTIONAL COURSE FOR GRADE 11
OR GRADE 12 OF THE FOUR-YEAR
PROGRAMME

*These courses are experimental in that they will be subject to review.
Suggestions for their improvement will be welcomed.*

G E O L O G Y

CONTENTS

INTRODUCTION

"The earth is a nearly spherical body that travels through space at high speeds. It is tied to the sun by the invisible but unyielding bonds of gravity as are the other planets of the solar system.

Man is a product of the earth and he depends upon it for his physical being.....With his mind he studies the earth, and within the limits of experimental science he knows its size, its shape, its weight, its composition and its architecture. He knows that it had a beginning and that it will have an end.

Above all man has found that the earth has no preferred position in time or space, and that it is the centre of nothing.

The earth is but a sample of cosmic matter and a great laboratory in which man can investigate his environment."

Text which introduces the Bickell Globe
in the Royal Ontario Museum,
University of Toronto.

This course introduces the student to the study of the physical world around him, its history and the development of life upon this earth. The course also emphasizes the practical aspects of geologic study such as the analysis of topographic and geologic maps and air photographs, the examination of rock, crystal and fossil specimens, rock tests in the laboratory and in the field and the practice of making geologic observations and of collecting samples.

The teaching of geology should involve, wherever possible, the local area. Furthermore, students learn best about Nature when they see her processes exemplified in the surroundings with which they are most familiar. The study of local geology, therefore, cannot be over-emphasized. The course is divided into units and in a sequence that begins with a student's natural question, "What is a geologist?" The programme then explores the work of the geologist and the methods he uses in the field, in the laboratory and in the office. Thereafter, the student, as from a vantage point in space, views the earth as a whole and, as the course develops, studies its details at closer range. Finally he learns how the earth provides his food and shelter and how its many materials make his life more comfortable, interesting and enjoyable.

AIMS

The aims of this course are:

(1) to promote an understanding and an appreciation of the earth - man's physical environment, the processes that shape it, its position in space, its three-dimensional structure, and its composition;

(2) to introduce students to the fascinating study of the physical history of the earth and to the development of life upon it;

(3) to promote the powers of observation, and deduction based on observation in the field and in the laboratory;

(4) to aid students to develop a concept of the geological history of Ontario and its surrounding areas and to aid them to become familiar with the more important geological features of their districts;

(5) to gain a knowledge of the basic principles which have enabled man to explore and to develop the resources of the earth's crust with special reference to Ontario.

In conclusion, this course should stimulate interest in and promote curiosity about "the world around us". It should create an awareness of the geological structure and history of our country, of its many landscape features, and of its rich and varied natural resources. The course should also encourage the development of worthwhile hobbies such as mineral and fossil collecting and the research of the local region, and the new knowledge gained should add greater interest and pleasure to travel and to camping excursions.

The study of this course may, in some cases, provide for a future livelihood in the many fields demanding a background in geology.

UNIT A. THE GEOLOGIST AND HIS METHODS

The purpose of this unit is to introduce the student to the science of geology by describing briefly the nature of the science, its practical applications, and the work of the geological scientist. Map study is included in this unit because maps are both a'tool'and a product of geological work. Perhaps the most important part of the unit from the standpoint of motivation is the field trip; it should be organized carefully and with purpose.

1. What geology is and why it is studied:

   (a) The interest and romance of geology: examples, such as the earth, the home and the laboratory of man; the fossil evidence of changing life; gems; the antiquity of the earth; the youth of man

   (b) Geology as a pure and applied science: examples, such as measurement of geologic time; the atomic structure of crystalline substances, prospecting for ore and oil; winning diamonds and metals from the earth

   (c) Relationship of geology to other sciences: examples, such as geophysics, the physics of the earth; geochemistry, the chemistry of the earth; paleontology, the biology of fossil organisms

   (d) Geology and its influence on geography.

2. How geology is studied:

   (a) In the field: measurement of distance by pacing and by chaining; measurement of direction using the compass; measurement of attitude using the clinometer; recording location and nature of rock outcrops on maps, air photographs and in notebooks. Field or laboratory exercises in these techniques are recommended.

   (b) In the laboratory: identification of rocks and minerals by chemical and physical properties including the use of the microscope; fossil identification (Brief demonstrations should be made.)

   (c) In the office: compilation of field and laboratory data on maps and graphs and the interpretation of data (Displays should be used.)

3. Field trip

   Where possible, appropriate topographic and geologic maps and air photographs should be used by the students on the field excursion.

3. (Cont'd)

The half day field trip should be carefully planned and carried out to permit students to examine local geologic features and to give them practice in making geologic observations and in collecting samples.

A photographic record of the trip should, if possible, be made for use in subsequent lessons. A 35 mm camera is recommended.

4. Maps

The construction and interpretation of topographic and geologic maps, and the use of air photographs

(a) Topographic maps: the portrayal of distance, land relief, natural and human cultural information by scales, contours and/or hachures, latitude, longitude and symbols; practice in these aspects of map interpretation, stressing contour patterns

(b) Geologic maps: the portrayal of different rock masses by colour and patterns, of rock structure by symbols and of sequence of formations by ages; examination of simple geologic maps

(c) Air photographs: the appearance of relief features, rock outcrops and rock structures in air photographs; the use of the stereoscope.

UNIT B. THE EARTH TO THE GEOLOGIST

The first purpose of this unit is to study the relief of the earth's surface by considering such matters as the average height of land, the average depth of the oceans and the hypsometric curve in order to bring out the differences between continents and the ocean basins. This is followed by a study of the atmosphere because it is familiar to the student and he is aware that it is layered. Thirdly, a study of the layered earth and its internal order follows. The unit closes with a brief look at the earth as a planet, including its geometry.

1. The Earth around us

(a) Relief of the earth's surface: definition of relief; the contrast indicated by the highest elevation of the land (Mt. Everest) and the greatest depth of the ocean floor (Challenger Deep); the average height of land and the average depth of the ocean floors; the hypsometric curve; definition of continental shelf. The use of a coloured world physical map is advised.

1. (b) The materials of the earth's surface: the concepts and definitions of regolith, bedrock and outcrop, stressing variability in their physical properties and compositions; density determinations on, and display of, these materials gleaned from the field trip and elsewhere are urged; the hydrosphere definition - its lateral and vertical extent; its geological importance.

2. The Earth above us

(a) The atmosphere: the near surface composition of the atmosphere; changes in the nature of the atmosphere with elevation; brief reference to the importance of the atmosphere as a geologic agent and as a shield for the earth's populations.

3. The Earth beneath us

(a) The dimensions of the earth: its geometry; polar and equatorial diameters of the solid earth with suggested reasons for the difference; the equatorial circumference of the earth; the shape of the earth

(b) The layering of the earth: the disparity between the average density of the earth and that of the near surface rocks of the earth's crust; evidences of layering of the earth; the earth's crust - its thickness and composition; the layered nature of the crust; lithologic distinctions between continents and ocean basins; the mantle - its thickness and probable nature; the core - its thickness and probable nature.

4. The Earth in space

(a) Materials from space: meteorites - types, composition, relationship to meteors, origin and inferences with regard to the earth's interior composition; examples of meteorite craters

(b) Place in space: the moon as related to planet Earth; the place of planet Earth in the solar system; galaxies and possible other solar systems.

UNIT C. MATERIALS OF THE EARTH'S CRUST

Having introduced the students to some of the interesting topics within the subject, the work of the geologist and illustrated viewpoints which geologists hold regarding our earth, a more intimate acquaintance with the materials of the earth follows. The student now studies the composition of the earth's crust and some of its important rocks and minerals.

1. Physical properties of minerals:

   (a) Specific gravity: illustrated by comparing the heft of calcite, barite, galena, and pyrite

   (b) Hardness: determined experimentally for several minerals with reference to the thumb nail, copper coin, piece of window glass, and a knife blade; by such procedure, compare the hardness of talc, gypsum, calcite, pyrite, chalcopyrite, and quartz

   (c) Colour: its use and limitations as a determinative property of minerals, illustrated by the examination of calcite, magnetite, chalcopyrite, and galena to show minerals which differ in colour; also by the examination of mineral pairs such as calcite and gypsum, magnetite and specular hematite, and of varieties of minerals such as quartz, sphalerite, apatite and hematite to bring out the limitation of colour as a distinguishing characteristic of minerals

   (d) Streak: the meaning of the term; how streak is determined; the comparison of colours and streaks of the following mineral pairs to illustrate the greater reliability of streak over colour for the purposes of mineral identification: hematite and specular hematite, and brown and black sphalerite; the comparison of the streaks of calcite and barite, of calcite and gypsum and of pyrite and chalcopyrite to illustrate the insufficiency of the use of streak alone as a distinguishing property of minerals

   (e) Lustre: the meaning of the term; illustrations of lustre using minerals (1) having non-metallic and (2) minerals having metallic lustre (Dark coloured varieties should be used where possible to avoid giving the impression that minerals with non-metallic lustre are light coloured.)

   (f) Cleavage: the meaning of the term; examination of minerals with cleavage such as mica, halite and calcite, and of some without cleavage such as quartz and magnetite (No attempt should be made to classify cleavage types geometrically or crystallographically.)

   (g) Magnetism and florescence: the meaning of the term; a display of minerals that have these properties well developed; a demonstration of these properties with one or more minerals

1. (h) Crystal form and growth: the definition of a crystal; emphasis on the fact that the external form of a mineral crystal is one outward expression of the systematic internal arrangement of its constituent atoms; demonstration that crystalline material need not possess regular outward form; experiments to illustrate the formation of crystals from vapour, from solution and by freezing; examination and description of cleavage pieces of minerals such as feldspar and calcite and of crystals such as quartz to show that the angles between corresponding crystal faces are constant for a particular mineral, are characteristic of it and are independent of the sizes of the faces.

2. Chemical properties of minerals

Demonstration and/or class experimentation by the use of at least three of the following to establish that minerals possess chemical properties:

(a) the reduction of powdered galena to metallic lead on charcoal with the use of blowpipe

(b) the conversion of pyrite to a magnetic residue

(c) flame tests to show the flame colours of sodium, potassium, calcium, barium and copper

(d) the borax bead test for cobalt

(e) the closed tube test for sulphur using pyrite

(f) the wet test for sulphur in pyrrhotite, galena or sphalerite

The classification of minerals into: native elements, sulphides, oxides, halides, carbonates, phosphates and silicates, is made possible by the above and other concepts of chemical composition. (The illustration of these groups by several specimens of each should, as far as possible, be accomplished.)

3. The study of minerals

The examination and identification of the following minerals. Minerals of local interest may be added to the list at the teachers' discretion:

silver	amphibole	calcite	talc
copper	hematite	apatite	asbestos
graphite	magnetite	gypsum	mica
pyrite	bauxite	quartz	chalcopyrite
galena	halite	feldspar	

4. Rocks

<u>Note</u>: Rocks may be studied in this unit or their study may be integrated with the consideration of geologic processes in Units D and E. If the rock study is made here it will not be repeated in Units D and E.

In this section, where 'rock study' is indicated, as many hand specimens as possible should be provided for each class. In addition, a simple biological or preferably a polarizing microscope should be available and used so that students may examine thin sections of these same rocks.

(a) <u>General</u>: definition of rock; grouping of rocks on a genetic basis into igneous, sedimentary, and metamorphic classes; brief consideration of the origin of each class and its relation to the rock cycle; texture and structure as the principal distinguishing characteristics for these classes

(b) <u>Igneous rocks</u>: short consideration of the origin of igneous rocks (genesis, movement, and environments of consolidation of magma); definition of igneous rocks - especially to distinguish them from the other classes; bases of classifications for igneous rocks; a simple working classification into two families or clans, namely, granite and gabbro, and three textural groups, - granitoid, porphyritic, and felsitic, but stressing the gradational principle; definition and exemplification of diabase and pegmatite and their places in the group; the significance of mineralogical composition; the origin of igneous rock texture; rock study to involve the examination and discussion of physical properties of granite, granite porphyry rhyolite, gabbro, basalt, basalt porphyry diabase and pegmatite

(c) <u>Sedimentary rocks:</u> brief summary of the origin of sediments and the formation of sedimentary rocks involving notions on the origin of clastic particles and solutes, the movements of both, their deposition in certain environments, and their consolidation or lithification; definitions of, and distinction between sediment and a sedimentary rock; notable properties of sedimentary rocks which distinguish them from the other two classes; bases of classification; a simple division into clastic and non clastic with the further division of each as organic and inorganic; the significance of composition and texture; gradational principle applied to sedimentary rocks; rock study to include conglomerate, sandstone, shale, rock salt, limestone, gypsum, and coal

(d) <u>Metamorphic rocks</u>: summary of the origin of metamorphic rocks emphasizing the conditions involved in metamorphism and the environments in which these can be realized; distinguishing characteristics of metamorphic rocks; the concept of foliation;

(d) (Cont'd)
practical classification into two classes, - the foliates and the non-foliates: rock study to include slate schist, gneiss, marble, quartzite.

UNIT D. INTERNAL GEOLOGICAL PROCESSES AND THEIR CONSEQUENCES

Familiarity with Earth's surficial materials invites investigation into their origin and architecture. The purpose of this unit therefore, is to investigate the processes which originated, shaped and gave textures to igneous and metamorphic rocks. The study should also result in some understanding of the existence of a store of energy within the earth and the sources and modes of expenditure of this energy.

Note: A film on volcanism should introduce this unit. Maximum use should also be made of models, maps, and photographs to develop and convey the various concepts.

1. Internal energy at work

   (a) Magma, genesis, movement and consolidation: the meaning of magma and its relation to lava; the two principal magma types compositionally - granitic and basaltic; ideas on their origin; explanation of how and why magmas move; the conditions for the freezing of subsurface and surface magmas and lavas and the resulting textural variations; shapes of igneous rock bodies including batholiths, sills, dikes, volcanic plugs, cones and lava fields (or flows)

   (b) Deformation:
      (i) Earthquakes: their intensities, earthquake belts, depth of foci; causes of earthquakes; effects of earthquakes on rock structures and scenery
      (ii) Simple deformational structures: anticlines, synclines, faults and joints; the mechanisms of their formations; varieties in each of these structures and their significance
      (iii) Alteration in rock fabric and composition or metamorphism: metamorphism and how it affects rock fabric and mineralogy.

2. Sources of energy for the Earth's internal processes

   Heat, radioactivity, chemical reactions, gravity.

UNIT E. EXTERNAL GEOLOGICAL PROCESSES AND THE CHANGING FACE OF THE LAND

From an examination of the Earth's internal processes and energies which build its crust and synthesize its minerals a look is taken of the outside. A study of the external processes is also made and of those energies which keep them in operation. The effects of these surface-shaping phenomena upon man is also observed.

1. The Earth's external energy at work

   (a) Weathering: definition; processes and agents of chemical and mechanical weathering; the factors influencing the rate and depth of weathering; brief reference to residual soils, e.g., laterites

   (b) Erosion, transportation, and deposition:
      (i) Definitions; relationship to weathering agents of erosion, transportation and deposition
      (ii) Mass movement: definition; examples to be studied, - talus, land and submarine slides; importance of mass movements; man's struggle against, and conservation measures to overcome, mass movements; examples from topographic maps and air photographs
      (iii) Running water: from rain drops to rivers; carrying power of water; erosional effects of stream flow; profile and gradient; velocity and discharge; resulting land forms; examples; erosional land forms such as river valleys; depositional landforms such as flood plains and deltas; lakes and marshes associated with erosion by running water; examples from maps and photographs
      (iv) Ground water: the ground water profile and factors determining its configuration; movements of ground water; erosional effects and resulting landforms, e.g., karst topography, caves, stalactites and stalagmites; the economic importance of ground water; its increasing use and the questions of reserves; the importance of maintenance of ground water level; the examination of water profiles and well data
      (v) Waves and shore line effects: the formation of waves and currents; erosion of shorelines and resulting features, e.g., headlands, shoreline cliffs; depositional features, e.g., spits, bars, hooks; types of shorelines, e.g., emergent and submergent

(b) (Cont'd)

(vi) Ice in motion: formation and movement of glaciers; glacier types, e.g. valley, continental sheets; glacial erosion, e.g., striae, U-shaped mountain valleys, rounded hills and lakes in ice sheet areas; glacial transport; erratics; depositional features of glaciers and their meltwaters, e.g., till and stratified drift; landscape forms, e.g., groundmoraine, drumlins, endmoraines, eskers, outwash, glacial lake plains and their strandlines; examples from field trips and as seen in topographic maps and photographs

(vii) Air in motion: mechanics of erosion by air and subsequent deposition; resulting land forms, e.g., dunes; loess; erosion control and conservation; examples from photographs and topographic maps

(c) The Formation of Sedimentary Rocks:

(i) Compaction of sediments by water and ice

(ii) Cementation of sediments (See UNIT C, 2(c) for detailed treatment).

2. Sources of energy for Earth's external processes

(a) Gravitational energy

(b) Kinetic energy of the agents of erosion

(c) Radiant energy (heat, light, etc.) from the sun

(d) Chemical energy of minerals of igneous and metamorphic origin.

UNIT F. TIME AND GEOLOGY

When time is added as a dimension to the study of earth's processes, geologic history unfolds. That history is for man's interpretation from the succession of rocks, whose formation, destruction and modifications have been studied in the preceding units. In any one area, no matter how large or small, the record is usually incomplete and the gaps remain to be filled by research and deduction.

The advent and development of life through time have left their imprint in the rocks. This has helped man to interpret past environments and, above all, to give him an understanding of his place in earth history.

1. The physical record

(a) Sequence of events from field observations: intrusive relations (i.e., a dike is younger than the rock it intrudes); sequence in structural deformation (e.g., faults and folds are younger than the disturbed rocks); laws of superposition; conformities and unconformities

(b) Rock types and their significance: the concept of environment on formation based on specimen study, e.g., granite, obsidian, vescicular lava, and greenstone; conglomerate, sandstone and shale; cross-bedding and ripple marks; salt and gypsum; till and tillite; fossiliferous limestone or shale.

2. The biological record

(a) Fossils and fossilization:
(1) definition and formation of fossils; examples of fossils from the following phyla of the animal kingdom:

PHYLUM	LIVING FORM	FOSSIL FORMS
Protozoa	Amoeba	Fusulinid
		Foraminifera
Porifera	Sponge	Sponge
Coelenterata	Hexacorals	Tetracorals
Annelida	Worm	Tracks
Bryozoa	Moss animal	Bryozoa
Brachiopoda	Lamp shell	Butterfly shells
Mollusca	Clam	Byssonychia
	Snail	Maclurites
	Octopus	Ammonite
Arthropoda	Crayfish	Trilobite
	Insect	Insect in amber
Chordata	Fish	Ostracoderms
	Reptile	Dinosaur
	Placental mammal	Sabre tooth tiger
		Woolly mammoth
		Mastodon
		Man

(ii) Fossil plants (Lepidodendron; Calamites; Equisetum)

(iii) The variety of marine life of today illustrated by film

(b) The fossil record and the geological time-scale: sequence of deposition (law of superposition) in relation to the occurrence of fossils to give the evidence for changing life; the division of rocks, with correlations, into younger and older rock units; the evidence for organic evolution and the basis for the geological time-scale from immediate previous items; the geological time-scale - displayed as a wall chart

(c) The measurement of geological time: all time measured by processes taking place, and known to have taken place in the past, e.g.,

(i) The growth of tree-rings
(ii) Rates of erosion - the retreat of Niagara Falls
(iii) Rates of sedimentation - Atlantic Ocean
(iv) Radio-active time clocks

(d) The eras of earth history: discussion of the principal physical features, biological characteristics, the relative duration in time for each of the eras listed below, and in the order given; reference to economically important products associated with each era

(i) Cenozoic
(ii) Mesozoic
(iii) Paleozoic
(iv) Precambrian

(e) The origin of the earth:

(i) Some theories of earth genesis as a basis for discussion
(ii) Emphasis on the approach that any theory is based on the facts of the time in which it was prepared; new facts and concepts require the discard of old theories and the development of new ones.

UNIT G. THE ONTARIO RECORD

To be familiar with world wide natural processes and phenomena, and yet fail to see earth history in phenomena near home is to miss a great deal of interest and experience. In this section of the course the students should be exposed to the geology of their own Province. They should also understand the history of this environment and interpret for themselves their local geological scenes.

1. The bedrock pattern and structure of Ontario

(a) The relationships of the rocks of Ontario to the adjacent areas by a study of the geological maps of Ontario, Canada, and North America; discussion of the age, type, and distribution of the rocks with respect to the Standard Geological Time Scale; note the gaps in the complete record - some are unconformities, others are shown by outliers which result from erosion; use of outline maps

(b) An outline, using similar geological maps stated in (a) of the structural features of Ontario and surrounding areas to include: the Precambrian Shield and its divisions into the Grenville and Superior Provinces (this term province to be defined); the Grenville Front; the continuation of the Shield into the Michigan Basin and under Southern Ontario and the Hudson Bay Lowlands; the Frontenac Axis and its connection with the Adirondacks; the Algonquin Arch; the Ottawa-Bonnechere Graben.

2. Major subdivisions of the bedrock

Note: Using the nomenclature and interpretation of each of the general subdivisions listed below ((a) to (g) inclusive) of the rocks of Ontario, discuss their geographic distribution and their economic products. Thus a general concept of the geological history of the Province is developed. On this framework, the details of any local school area may be amplified.

(a) Keewatin - Timiskaming and "Algoman" or "Early Precambrian Intrusives": the oldest rocks of the Shield; the Keewatin-Timiskaming consists of volcanic rocks and sedimentary rocks now greatly altered and structurally deformed; intrusions numerous and varied; many of the details of the "Algoman" unknown

(b) Huronian and Animikian: sedimentary rocks of marine and floodplain origin; evidence of glaciation; evidence for early life (algal concretions); iron formations

(c) Keweenawan: sedimentary rocks and injections of dikes, sills, and other intrusives

(d) The Grenville Province: metamorphic terrain representing the roots of an old mountain range; reason for the varied mineralogy in certain areas, e.g., Bancroft

(e) The Paleozoic Terrains: the Niagara Escarpment and the Silurian Deltas; sub-surface distribution of formations; the origin of the Niagara Escarpment (post Paleozoic erosion)

(f) The Pleistocene: evidences for continental glaciation; glacial features of Ontario, stressing local scene where possible

(g) The Present: general discussion of present-day geological processes operating within Ontario or the local area; man's struggle with these processes and with their effects

Note: It is suggested that basically one period be allotted for each of (a) through (d), two periods for (e), three periods for (f), and one period for (g). If a school is located on the Canadian Shield, an additional two periods should be allotted for elaboration on the best-developed subdivisions of the area. For example, Port Arthur-Fort William schools would elaborate on the Keweenawan, Tri-town schools (Cobalt-Haileybury-New Liskeard) on the Huronian, Keweenawan, Paleozoic, or Pleistocene, Sudbury schools on the Sudbury basin, Elliot Lake-Bruce Mines schools on the Huronian, Bancroft schools on the Grenville, and Kirkland Lake and Timmins on the Keewatin-Timiskaming. Schools in the Paleozoic terrain of Southern Ontario would allocate two extra periods for an elaboration of their area, stressing either the bedrock or glacial geology.

3. The local scene

This section proposes to make the student aware that much of the total concept of the whole foregoing course may be applied by first-hand observation within his own environment and to make him aware that he, indeed, lives with such.

A carefully planned one-day field trip is imperative in order that these principles shall be brought to the student's thinking and awareness of geological environment.

UNIT H. MINERAL RESOURCES AND APPLIED GEOLOGY

So dependent is man upon the earth's metallic and other products, that geology, in addition to being a study of pleasure and interest, is a necessity for our existence. In this unit the students directly observe rock and mineral substances and study them as useful economic products.

Two aspects of the study are therefore presented: the occurrence and genetics of earth materials, and man's methods of extracting them for his use. The latter part involves the study of exploration techniques and of the development of mines, oil wells, quarries and other deposits.

1. Canada's world position in mineral products and the Ontario share

   (a) Products and statistics to be selected from tables in the Canada Year Book - the following are possible suggestions: copper, gold, iron, nickel, silver, tin, uranium, asbestos, petroleum and natural gas, sand and gravel

   Note: Tin is inserted here to show the effects on Canada of the very small production of such an important mineral.

(b) The ore concept: the distinction between ore, mineral, and mineral product, e.g., pyrrhotite-nickel; galena-lead; chalcopyrite-copper; limestone-cement
Specimens of the above materials to be presented as illustrative examples

(c) The importance of water as an economic (and vital) product

Note: It is suggested that three sample studies be carried out; a study of a metal mine, an oil field, and an industrial mineral deposit. The sample studies should be studied under the headings presented in 2, i.e., (a) to (g) inclusive.

2. The search for mineral deposits and the development of a mine

The Marmora Iron Mine is presented here as an example of the location of a deposit by the aeromagnetic geophysical method. Other similarly found deposits may be used as examples if so desired (e.g. Thompson Lake nickel, Manitoba).

(a) Early Prospecting. The location of small magnetite deposits had for many years been known in the Grenville-type rocks of the Marmora area. Some were mined on a small scale in the early 1900's. The present deposit lay undiscovered because it was beneath 100 feet of Paleozoic limestone.

(b) Recent Scientific Methods. The discovery of the deposit resulted from the study of aeromagnetic data produced by the Ontario government in flying over the area.

(c) Optioning of the Deposit. The actual financing of a mine now begins when private steel companies deal with the farmer-owner of the deposit.

(d) Detailed ground program.
   (i) Diamond drilling
   (ii) Examination of core
   (iii) Concentration tests - estimation of valuable ore content and limitation of deposit

(e) Development of the mine.
   (i) Stripping of the unwanted rock cover
   (ii) Pilot plant tests for a proper mill process

(f) Production. Samples of ore pellets for examination

(g) Social effect on community

3. Other suggested examples which could be studied under the same headings include, salt, oil, or gas in southwestern Ontario, sand and gravel in the Toronto area or others.

4. Conclusions regarding the three sample studies

   (a) Similarities between the types of deposits - all show concentrations of some type, mostly carried out by nature; because they are concentrations, they are rare and thus finite

   (b) Conservation of resources because they are non-renewable by:
      (i) Improving mining methods
      (ii) Mining all possible ore.

5. Geology in the service of man

   (a) <u>Practical applications</u>
      (i) Impact of geological services
         e.g., nickel (coins, stainless steel)
         uranium (cancer research, atomic energy)
         asbestos (building products, insulation, fire-proofing)
         gold (its importance in the country's economy)
         natural gas and fossil fuels (energy, automobile)
      (ii) The use of geology in construction
         e.g., faults, testing of "danger areas"
      (iii) The development of countries and regions due to geological exploration
         e.g., South Africa - gold in the Rand
         Australia - gold at Kalgoorlie
         Canada - the opening up of Yellowknife, Northwest Territories

   (b) <u>Philosophical applications</u>
      (i) The development of the theory of evolution from geological data.

APPENDIX A

BIBLIOGRAPHY

Astronomy

Baker, Robert H., Astronomy, Van Nostrand, 1959

Bergamini, D. and the Editors of Life, Life Nature Library, The Universe Time Inc., New York, 1962

Dictionaries and Directories

Fay, H. A., A Glossary of the Mining and Mineral Industry, U. S. Government Printing Office, Washington, 1947

*Himus, G. W., A Dictionary of Geology, (Penguin Reference Books) Longmans Canada

*Howell, J. V., (co-ordinator), Dictionary of Geological Terms, a Dolphin Reference Book No. C-360, (Doubleday and Company Inc., Garden City, New York) Doubleday

Howell, J. V., (co-ordinator), Glossary of Geology and Related Sciences, American Geological Institute

Howell, J. V. and Levorsen, A.I., Directory of Geological Material in North America, 2nd ed., American Geological Institute

*Moore, W. G., Dictionary of Geography, (Penguin Reference Books) Longmans Canada

Economic Geology and Mineral Deposits

Bateman, Alan M., Economic Mineral Deposits, (John Wiley and Sons, Inc., New York) General Publishing, 1950

Langford, G. B., Out of the Earth, University of Toronto Press, 1954

Levorsen, A. I., Geology of Petroleum, W. H. Freeman and Co., San Francisco, 1954

General and Physical Geology

Gilluly, J., Waters, A.C., and Woodford, A.O., Principles of Geology, 2nd ed., W. H. Freeman and Co., San Francisco, 1959

*Heller, Robert L., Geology and Earth Science Sourcebook for Elementary and Secondary Schools, (Prepared under the guidance of the American Geological Institute), Holt, Rinehart and Winston, 1962

*Hurley, Patrick M., How Old is the Earth?, Doubleday Anchor Books, Science Study Series, Doubleday, 1959

*Leet, L. Don and Florence J., (Editors), The World of Geology, McGraw-Hill, 1961

Leet, L. Don and Judson, S., Physical Geology, Prentice-Hall, 1954

Moore, Ruth, The Earth We Live On: the Story of Geological Discovery, (Knopf, New York) McClelland and Stewart, 1956

Rapport, S. and Wright, H., The Crust of the Earth, An Introduction to Geology, Signet Science Library, The New American Library of World Literature, New York, 1955

Shrock, Robert R., Sequence in Layered Rocks, McGraw-Hill, 1948

Spencer, E. W., Basic Concepts of Physical Geology, (Thomas Y. Crowell Co., New York) Ambassador, 1962

*White, J. F., Study of the Earth: Readings, Prentice-Hall, 1962

Zumberge, J. H., Elements of Geology, 2nd ed., (John Wiley and Sons, New York) General Publishing, 1963

Glacial Geology

Flint, R.F., Glacial and Pleistocene Geology, (John Wiley and Sons, New York) General Publishing, 1963

Thwaites, F.T., Outline of Glacial Geology, Edwards Bros., 2500 South State Street, Ann Arbor, Michigan, 1946

Historical Geology

Dunbar, Carl O., Historical Geology, (John Wiley and Sons, New York) General Publishing, 1960

Moore, R. C., Introduction to Historical Geology, 2nd ed., McGraw-Hill 1958

Moore, Ruth, Man, Time and Fossils, revised ed., (Knopf, New York) McClelland and Stewart, 1961

Spencer, E. W., Basic Concepts of Historical Geology, (Thomas Y. Crowell Co., New York) Ambassador, 1962

Stokes, W. L., Essentials of Earth History; an Introduction to Historical Geology, Prentice-Hall, 1960

Indices to Publications

General Index to Ontario Department of Mines, vol. 1-6, 1891-1960

Index of publications of the Geological Survey of Canada, 1845-1958, by A. G. Johnston, (1961), Ottawa, Department of Mines and Technical Surveys, Canada. Also Supplement for 1961, 1962, and revised price list for 1963.

Maps

Geological Association of Canada:
- (1) Glacial Map of Canada
- (2) Tectonic Map of Canada

Geological Society of America:
- (1) Geological Map of North America
- (2) Glacial Map of Eastern North America
- (3) Tectonic Map of North America (to be published)

Geological Survey of Canada:

(1) Geological Map of Canada	1" to 60 mi.
(2) Geological Map of Canada	1" to 120 mi.
(3) Mineral Map of Canada	1" to 120 mi. (latest edition)

Ontario Department of Mines:

(1) Geological Map of Ontario	1" to 20 mi.
(2) Mining Districts of Ontario	1" to 20 mi.

Map of the Ocean Floors - Life Magazine.

U. S. Navy Hydrographic Office - Mercator projection. Scale 1:12,233,000 at equator. 12 sheets. ($12.00 U.S.)

Mineralogy

Berry, L. G., and Mason, B, Concepts, Descriptions, Determinations, W. H. Freeman and Co., San Francisco, 1959

Dana, E. S., Dana's Manual of Mineralogy, revised by Cornelius S. Hurlbut, Jr., 17th ed., (John Wiley and Sons, New York) General Publishing, 1959

Dana, E. S., and Hurlbut, C. S., Minerals and How to Study Them, 3rd. ed., (John Wiley and Sons, New York) General Publishing, 1949

English, G. L., and Jensen, D. E., Getting Acquainted with Minerals, revised ed., McGraw-Hill, 1958

*Holden, A., and Singer, P., Crystals and Crystal Growing, Doubleday Anchor Books, Science Study Series, Doubleday, 1960

Palache, C., Berman, H., and Frondel, C., The System of Mineralogy of James Dwight Dana and Edward Salisbury Dana, 7th ed., vol. 1, 1944; vol. 2, 1951; vol. 3, 1962, (John Wiley and Sons, Inc., New York) General Publishing, 1944-62

Pough, F. H., A Field Guide to Rocks and Minerals, Peterson Field Guide Series, (Houghton-Mifflin Co., New York) Nelson, 1953

Miscellaneous

The following items may be ordered from:

American Geological Institute,
1444 N Street, Northwest,
Washington, D. C. 20005.

Pangborn, Mark, Jr., Earth for the Layman, ($1.00 U. S.). (An annotated list of more than 1400 popular books on geology and related subjects suitable for the layman)

S1. Sources of Geological Information, 1961
S2. Selected References for Earth Science Courses, 1961
S3. Films for Earth Science Courses, 1961

Price 10 cents each, but 5 cents when ordered in quantities of ten or more.

Wakefield, Dort, Jr., Directory of Geoscience Films, prepared for the A.G.I. Visual Education Committee, ($1.00 U. S.)

Paleontology

Beerbower, J., Search for the Past, (Prentice-Hall Inc., Englewood Cliffs, N. J.) Prentice-Hall, 1960

Colbert, E. H., Dinosaurs: Their Discovery and Their World, 1st ed., (E. P. Dutton and Co., Inc., New York) Clarke, Irwin, 1961

Easton, W. H., Invertebrate Paleontology, (Harper and Row, N. Y.) Copp Clark, 1960

Fenton, C. L., and Fenton, M. A., The Fossil Book, Doubleday, 1958

Howells, W. W., Mankind in the Making, Doubleday, 1959

*Romer, A., Man and the Vertebrates, vol. 1 and 2, (Peilcan Books) Longmans Canada

Romer, A., Vertebrate Palaeontology, 2nd ed., (University of Chicago Press, Chicago) University of Toronto Press, 1945

Simpson, George Gaylord, Horses; the story of the horse family in the modern world and through sixty million years of history, (Oxford University Press, New York) Oxford

*Simpson, George Gaylord, The Meaning of Evolution, (Mentor Books, 501 Madison Ave., New York 22) New American Library of Canada, Toronto

Petrography

Moorhouse, W. W., The Study of Rocks in Thin Section, (Harper Brothers, New York) Musson, 1959

Pettijohn, F. J., Sedimentary Rocks, (Harper Brothers, New York) Musson, 1957

Pleistocene Geology

Chapman, L. J., and Putnam, D. F., Physiography of Southern Ontario, University of Toronto Press (Revision to be available early 1964)

Hough, J. L., Geology of the Great Lakes, University of Illinois, Urbana Ill., 1959

Regional Geology

Clark, T., and Stearn, C., The Geological Evolution of North America: A Regional Approach to Historical Geology, (Ronald Press Co., New York) General Publishing, 1960

Eardley, A., <u>Structural Geology of North America</u>, 2nd ed., (Harper and Row, New York) Copp Clark, 1962

King, P., <u>Evolution of North America</u>, Princeton University Press, Princeton, N. J.) S. J. Reginald Saunders, 1959

<u>Statistics for Mineral Products</u>

<u>The Canada Year Book</u> (latest edition)

* Denotes paperback edition.

APPENDIX B

Sources of Geological Materials, Teaching Supplies

and Laboratory Equipment

BY CATEGORIES

Addresses of suppliers on pages 25 and 26

BLOWPIPES (For mineral determination)

Canadian Laboratory Supplies

Cave and Company Ltd.

Central Scientific Company

Eckert Mineral Research

Stratex

Ward's Natural Science Establishment

CRYSTAL MODELS

Cutrock Engineering Co. Ltd.

Dynacast Corporation

Eckert Mineral Research

Ward's Natural Science Establishment

FIELD EQUIPMENT (Geological hammers, lenses, compasses, tapes, etc.)

Gregory Bottley

P. K. Dutt and Co.

Hughes Owens Co.

Keuffel and Esser Co.

Langridge Limited

Thos. Murby and Co.

Silva Limited

Stratex

Ward's Natural Science Establishment

FOSSILS

Gregory Bottley

Eckert Mineral Research

Fossil Supply Co.

Geological Enterprises

Thos. Murby and Co.

Ward's Natural Science Establishment

GLOBES, MAPS AND MODELS

Canadian Aero Service

Denoyer-Geppert

Eckert Mineral Research

C. S. Hammond and Co.

G. M. Hendry and Co.

Thos. Murby and Co.

MINERALS AND ROCKS

Gregory Bottley

Burnham Mineral Co.

The L. I. Cowan Mineral Company

Eckert Mineral Research

Geological Survey of Canada

Minerals Unlimited

Thos. Murby and Co.

Ontario Department of Mines

Scott-Williams Mineral Co.

Ward's Natural Science Establishment

MODELS

Plastic Models of Dinosaurs to be assembled by purchaser:

Write Eaton's of Canada

Also for small models:

Write Louis Marx and Co.

STREAK PLATES

Canadian Laboratory Supplies

Cave and Company Ltd.

Central Scientific Company

Eckert Mineral Research

Griffin and George Sales Ltd.

ULTRA VIOLET SOURCES

Central Scientific Company

P. K. Dutt and Co.

Eckert Mineral Research

Stratex

Ultra Violet Products

Ward's Natural Science Establishment

ADDRESSES

Gregory Bottley,
30 Old Church Street,
London S.W.3, England.

Burnham Mineral Co.,
128 South Encinitas,
Monrovia, California.

Canadian Aero Service,
348 Queen Street,
Ottawa, Ontario.

Canadian Laboratory Supplies,
80 Jutland Road,
Toronto 18, Ontario.

Cave and Company Ltd.,
16 Rivalda Road,
Downsview, Ontario.

Central Scientific Company,
146 Kendal Avenue,
Toronto 4, Ontario.

The L. I. Cowan Mineral Co.,
Cheltenham, Ontario.

Cutrock Engineering Co. Ltd.,
35 Ballards Lane,
London N3, England.

Denoyer-Geppert,
5235-5259 Ravenswood Avenue,
Chicago, Illinois.

P.K. Dutt and Co.,
1 and 2 Alfred Place,
London W.C.1, England.

Dynacast Corporation,
509 Vandalia Road,
St. Paul, Minnesota.

Eaton's of Canada,
Toronto, Ontario.

Eckert Mineral Research,
Florence, Colorado.

Fisher Scientific Co.,
245 Carlaw Avenue,
Toronto 8, Ontario.

Fossil Supply Co.,
6507 Sondra Drive,
Dallas 14, Texas.

Geological Enterprises,
Box 926,
Ardmore, Oklahoma.

Geological Survey of Canada,
601 Booth Street,
Ottawa, Ontario.

Griffin and George Sales Ltd.,
Ealing Road,
Wembly,
Middlesex, England.

C. S. Hammond and Co.,
515 Valley Street,
Maplewood, New Jersey.

G. M. Hendry and Co.,
146 Kendall Avenue,
Toronto 4, Ontario.

Hughes Owens Co.,
470 Yonge Street,
Toronto, Ontario.

Keuffel and Esser Co.,
15 Civic Road,
Scarborough, Ontario.

Langridge Limited,
106 Richmond Street,
West Toronto, Ontario.

Arthur S. LaPine and Company,
6001 South Knox Avenue,
Chicago 29, Illinois.

Louis Marx and Co.,
21 Dundas Square,
Toronto, Ontario.

Minerals Unlimited,
Ralph E. Merrill,
1724 University Avenue,
Berkeley, California.

Thos. Murby and Co.,
40 Museum Street,
London W.C.1, England.

Ontario Department of Mines,
Parliament Buildings,
Toronto 2, Ontario.

Scott-Williams Mineral Co.,
319 E. Indian Plaza,
Scottsdale, Arizona.

Silva Limited,
77 York Street,
Toronto, Ontario.

Stratex,
3515 Sunset Blvd.,
Los Angeles, California.

Ultra Violet Products,
5205 Santa Monica Blvd.,
Los Angeles, California.

Ward's Natural Science Establishment,
P.O. Box 1712,
Rochester 3, New York.