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# AN OUTLINE FOR PHYSICAL GEOGRAPHY IN THE SECONDARY SCHOOL

by

David S. Mellander

A Thesis submitted to the
Faculty of the School of Graduate
Studies in partial fulfillment
of the
Degree of Master of Arts

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David S. Mellander

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# CHAPTER I

## THE NEED AND THE PURPOSE

### Introduction

As the earth has become more densely populated, an understanding of the space relationships between man and his environment has become essential. In particular, man needs to understand the complex interrelationship between places, and the distinctive character of places.

Major functions of geographic instruction are to guide students into discovering the distribution of physical conditions, and the interrelationships which characterize such places, as well as those between man and his environment. No other discipline attempts to discover the wholeness, order and reason in the complex totality of the landscape. It has been said:

> In this aerospace age, geographic understandings are more important than ever before. It is essential to know about people and their countries throughout the world. Time and space relationships are of increasing significance. Climate and weather information has become more important to a mobile population. More needs to be known about the earth, its shape, its polar areas, the depths of its oceans, the nature of its glaciers,

and the sun and outer space.[1]

It thus becomes a matter of grave concern when one reads:

> Ignorance of geography in the United States may be a deficiency in American education second only to the more prominently publicized lag in mathematics and physics teaching. Almost any test of geographic literacy would separate American students from students trained abroad, and the same may be said of a vast majority of American faculty members.[2]

## Status of Physical Geography in Southwest Michigan

To determine the degree to which these conditions prevailed in southwestern lower Michigan and to determine the status of secondary school geography in particular, the author conducted a survey of public high schools within the Western Michigan University service area. (See Map I). Questionnaires directed to both principals and teachers were sent to each of 130 public secondary schools in the service area. Eighty-one questionnaires were returned by principals and fifty were returned by geography teachers. The survey revealed that physical geography as an independent course

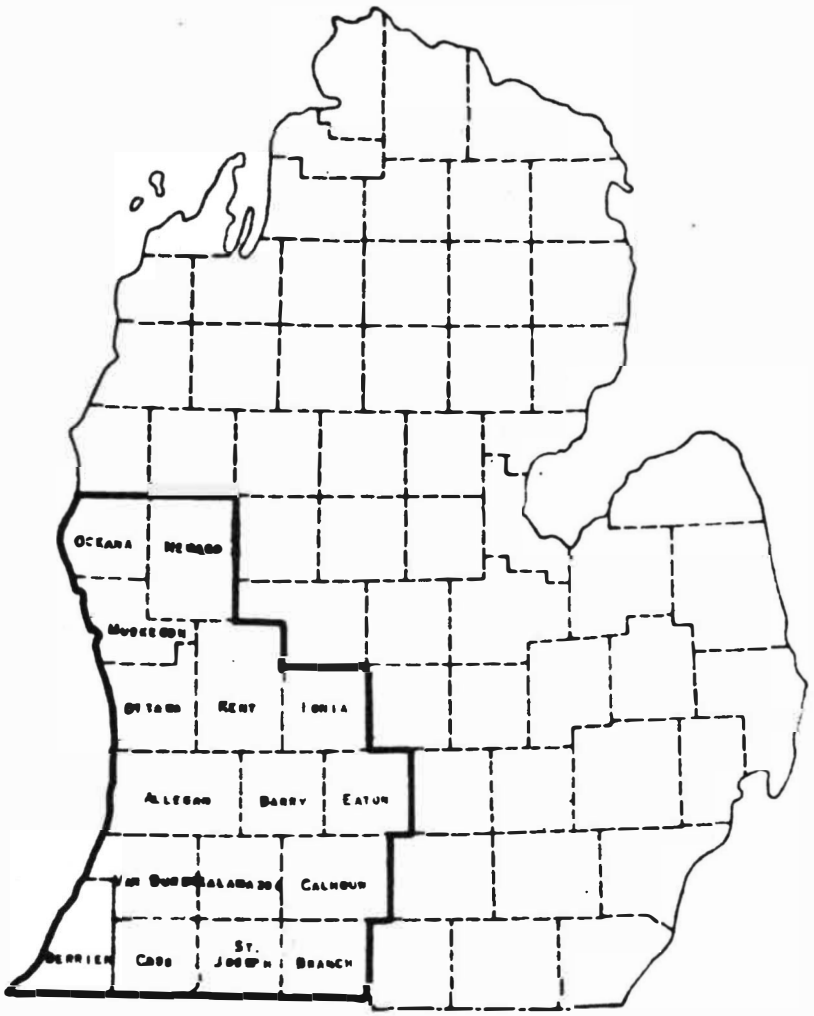
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[1] Woodson W. Fishback, "The Importance of Geography in the Curriculum," The Journal of Geography, LX (October, 1961), 329.

[2] Marian J. Levy, Jr., Statement to the New York Times, November 12, 1961.

Map 1.

# WESTERN MICHIGAN UNIVERSITY SERVICE AREA




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was not taught in over 90 per cent of the responding secondary schools. (See Appendix I.) A personal follow-up interview of 26 per cent of the non-responding schools revealed that geography was not included in their secondary curriculum. It would seem therefore that the majority of schools in this category do not teach geography.

Nevertheless, administrators and teachers alike recognized the need for physical geography in the curriculum. But they brought out many problems which posed serious obstacles to meeting this need. These problems were specified as:

(1) A basic lack of understanding by administrators and teachers as to what is, and what should be, included in a course of physical geography;

(2) a lack of appreciation of its potential in today's society and its role as part of the secondary curriculum;

(3) a lack of available instructional materials;

(4) and a lack of teachers and administrators competent in knowledge of physical geography as well as geography in general.

It is not within the author's ability to assess the validity of the second and fourth reasons stated; he has, however, had personal experiences attesting to the other two, particularly to lack of adequate materials. When appointed to the St. Joseph High School

staff to initiate a physical geography program in 1964, he discovered to his dismay that no satisfactory textbook, or even course outline, was available for a secondary-school course in physical geography. As a result he was forced to gather material from introductory college textbooks and to circulate reading material on ditto sheets. Although a textbook in earth science was used the second year, considerable deviation from the book was necessary in order to present the desired concepts of physical geography.

More recently the author made a survey of eighteen texts in human, social and economic geography presently used in high schools. Although these contain introductory units in physical geography, none treated the topic to a thorough degree.

## Purpose of This Study

To aid in remedying this lack of instructional material, and in the hope of increasing the geographic understanding of administrators and teachers, the author presents this organization of a course in physical geography. This is based upon his three years of organizing and teaching secondary-school physical geography as well as on his geographic training. He hopes that this outline may:

(1) Encourage secondary school administrators to offer a course in physical geography;

(2) give secondary-school geography teachers a basis upon which to help students better understand the significance of physical geography in our modern society;

(3) and prepare secondary-school students for geography courses at the college level.

It is fortunate that there has recently been a wealth of material published concerning the status of geography in the secondary school curriculum. In addition, the author has obtained information, opinions, and guidance by interviewing individuals in the following categories: high school teachers of physical geography in southwestern Michigan and Cook County, Illinois; administrators (including the Assistant Superintendent of Schools in Cook County); and faculty members at Western Michigan University, Michigan State University, the University of Chicago, and Roosevelt University. He is most grateful to all who have assisted him; nonetheless the conclusions are his own and the outline a culmination of his experience as a student in colleges in Europe and the United States, and as a teacher in the high schools of Colorado and Michigan.

# Recommendations For Further Study

## Books:

Ackerman, Edward A. Geography as a Fundamental Research Discipline. (University of Chicago; Department of Geography, Research Paper No. 53). Chicago: 1958. Pp. 37.

Association of American Geographers. Geography in Undergraduate Liberal Education. (Report of the Geography in Liberal Education Project.) Washington: Association of American Geographers, 1965. Pp. 66.

Bowman, Isaiah. Geography in Relation to the Social Sciences. New York: Scribner, Inc., 1934. Pp. 392.

Incorporated Association of Assistant Masters In Secondary Schools. The Teaching of Geography in Secondary Schools. 4th ed. revised. London: G. Philip, Ltd., 1956. Pp. 512.

James, Preston. New Viewpoints in Geography. (29th Yearbook of the National Council for the Social Studies.) Washington: National Council for the Social Studies, 1959. Pp. 260.

Mayo, William L. The Development and Status of Secondary School Geography in the United States and Canada. Ann Arbor: University Publishers, 1965. Pp. 223.

## Periodicals:

Anderson, R. C. "High School Geography: Retrospect and Prospect," Journal of Geography, LXV (March, 1966), 103-108.

Earth Science Committee of the National Council for Geographic Education. "The Role of Geography in the Earth Sciences," Journal of Geography, LXIII (March, 1964), 101-107.

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Franzen, Carl. "Why Geography," National Association of Secondary School Principals Bulletin, XLV (February, 1961), 130.

Frick, Mary. "The Status of Geography in the High School Today," Journal of Geography, LXIV (October, 1965), 317-321.

Harper, Robert. "Geography's Role in General Education," Journal of Geography, LXV (April, 1966), 177-185.

High, James. "Geography: Coordinating Element in the Secondary Social Studies," Journal of Geography, LIX (September, 1960), 273.

James, Preston. "Geography in an Age of Revolution," Journal of Geography, LXII (March, 1963), 97-103.

Meyer, Alfred. "The Status of Geography: Stake and Status," The Journal of Geography, LX (October, 1961), 301-309.

Smith, Villa. "Geography for the Secondary Schools," Education, LXIX (September, 1948), 47-50.

# CHAPTER II

# INSTRUCTIONS TO THE TEACHER

## The Purpose of Teaching Physical Geography

The purpose of physical geography is to broaden the student's understanding of his physical environment. All men need to know more about the earth on which they live and which they call their home. This will not only provide our country with an informed citizenry, but will greatly add to individual appreciation of the basic workings of nature.

In the broadest sense, physical geography should include much material from each of the natural sciences. It strives for conceptual understanding of the principal phenomena and features of the lithosphere, atmosphere, and hydrosphere.

An essential prerequisite of successful teaching is a high degree of comprehension of the nature of the subject. Thus it is imperative that the geography instructor be familiar with the nature of geography.

Geography includes both empirical and theoretical approaches to an understanding of the spatial relations and processes of physical and cultural phenomena,

separately or in various combinations, and on any scale, as well as spatial relations and processes in the abstract. An understanding of these relations and processes as well as of their significance to human activities encourages analysis of why things are where they are.

What then is physical geography? Strahler[1] describes it as a "study of a number of earth sciences which gives us an insight into the nature of man's environment," or "a body of basic principles of earth science selected with a view to including primarily the environmental influences that vary from place to place over the earth's surface."

Implicit in these definitions is the necessity for understanding both the physical environment and its interaction with man and his works.

Both man's physical and cultural worlds are constantly changing, reproducing additional complexities. In addition, geography teachers, understanding the relationships between elements within the world of nature and the world of man, have the essential task of developing an understanding of the relationship

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[1]Arthur N. Strahler, Physical Geography, (New York: John Wiley and Sons, Inc., 1951), 1.

between society and the physical environment. This interaction between man and land is the core of geography.[2]

Thus, as Hartshorne[3] states, there is no such thing as a "physical geography or a human geography, and the attempt to obtain a division between physical and human geography obscures rather than illuminates the true nature of geography." Therefore, in addition to human geography, physical geography demands a position of importance within the geography curriculum.

## The Aims of the Course

### Principal objectives:

The principal objective of the course in physical geography is to impart knowledge about the earth and its relationship to man. Teachers should stimulate students to probe for explanations and relationships and not to be concerned merely with the memorization

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[2]Neville V. Scarfe, "Geography as an Autonomous Discipline in the School Curriculum," The Journal of Geography, LXIII (October, 1964), 300.

[3]Richard Hartshorne, Perspective on the Nature of Geography, (Chicago: Rand McNally and Co., Inc., 1959), 65-71.

of descriptive phenomena. Thereby they come to appreciate physical cause-and-effect relationships in nature.

Since the course is a part of the general field of geography, it should include an introduction to the latest basic facts and elementary concepts of geology, pedology, climatology and meteorology.

Secondary objectives:

Another important aim of the course is to introduce the student to the scientific method. To accomplish this, the student should be encouraged to work individually on a problem, such as predicting a weather change, identifying an unknown rock, or observing reasons for a wind shift. The fundamental steps of the scientific method can be used. These include stating the problem; gathering data through observation; postulating different possible solutions; and devising tests or checks to arrive at a correct solution. As a result of scientific processes, it then follows that science is not a static body of knowledge, but is constantly changing as new facts are discovered. Too often the student accepts as "gospel" that which he reads in a book or learns from the teacher.

The course should make the student aware of the potential of science. The belief that most of the major discoveries have been made is false; every time something new is discovered, a whole world of unanswered questions opens up. Problems such as the origin of mountains, the cause of glaciation, the mechanics of the atmosphere, and many others, need considerable investigation. Still more questions are yet beyond the scope of science to answer. Thus, it is hoped that the student will recognize the challenge of these unanswered questions about the earth and will himself engage in individual investigation.

Because of greater emphasis on physics, chemistry and biology in many schools, students are not introduced to the multitude of unsolved problems in geology, meteorology, climatology, pedology and oceanography, nor are they generally made aware of the demand for scientists in these fields.

## The Conceptual Approach

Although the ultimate approach to teaching the subject will depend upon the degree of teaching skill and geographic understanding of the instructor, the author believes that the conceptual approach offers the best method of presenting a course in physical

geography.

Until recently, much of teaching was expository or deductive. Geography teachers assigned readings in text and reference books and required the students to learn facts and generalizations from their readings and classroom work. As in many other disciplines, the geography teacher of the present has adopted the inductive approach for the purpose of understanding the basic concepts of the course.

The students learn facts from their text and reference books. It is the teacher's responsibility to stimulate, encourage, and lead students to discover concepts and generalizations for themselves. By discovering concepts and building one conclusion upon another, students can more readily develop an understanding of the structure of the discipline of physical geography. By shifting the emphasis away from the accumulation of factual material for its own sake, to learning facts significant to the thinking process of physical geography, a new emphasis is given to the critical thinking characteristic of scientific learning.

A high state of human understanding is achieved when the student begins to discover for himself the similarities and differences in his environment, both

physical and cultural. The student who is involved in this approach is presented with the opportunity of exploring the unknown world; he also learns the value of formulating plausible hypotheses concerning the interaction between physical and cultural phenomena as well as that between man and land.

A conceptual approach to teaching a physical geography lesson might be applied in the following steps:

1. Introduction and presentation of material.

   Introductory activities are used that lead to generalizations; these in turn lead to concepts. Mental activity is motivated by objects and events. Questions are raised that stimulate thought and these are followed by discussions of experiences that relate to the concepts.

2. Demonstrations and laboratory work.

   Flexible inquiry is characteristic; there is no prescribed method. This work may range from studying a topographic map to studying fulley erosion near the school building. The methods of reporting are kept distinct from the methods of investigation.

3. Reading assignment.

   Reading is motivated by questions raised by objects and events observed in the classroom. A wide variety of materials is available and recommended. Emphasis is placed on reading to satisfy the students' need to know.

4. Use of audio-visual materials.

   Films are used to introduce topics for discussion or as a summary to relate things to

concepts developed. Slides and other pictures can be used in any of the above steps, or to act as a catalyst for discussion.

5. Discussion.

   Discussions relate principles developed in the investigations of other areas; these should guide the students from observation through generalizations to concepts.

6. Evaluation.

   Tests measure the ability of the students to state concepts in the topic area and related areas, and to apply them to new but similar conditions. Evaluation is also made of achievement of behavior goals; i.e. the students' ability to identify problems, form hypotheses, manipulate data, and make precise observations.

As a note of caution, teaching by the conceptual approach necessitates very careful planning on the part of the teacher. The objectives must be carefully stated in terms of behavioral goals.

## Instructional Devices

General:

Nowhere else in the world does a teacher have so great a supply of resources and equipment as in the United States. Because the teaching of geography permits a wide scope in method of presentation, it becomes the teacher's responsibility to vary the media of instruction.

Although space does not permit examples in which the different media of instruction can be applied, the survey of southwestern Michigan indicated strongly that teachers of secondary geography lack basic understanding of the uses and purposes of maps. This is a grave problem, for, as James[4] writes:

> The map is the fundamental instrument of geographic research. It reduces the patterns of area differences on the earth to a size permitting close analysis and comparison. The map is an eloquent form of presentation for those trained to read its symbols, a form of presentation much more concise than can be achieved by the use of word symbols alone. It provides the geographer with a method for reaching a degree of precision in measurement comparable to that achieved by statistical method, but it is a geometric rather than an arithmetic precision.

To help the prospective teacher realize globe and map qualities, the author hopes the following suggestions may be helpful.

Globes:

Since the earth is round, only a globe can truly represent the earth's surface in all four characteristics attempted on flat maps. These characteristics are: true shape; true relative distance; true

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[4]Preston E. James and Clarence F. Jones, American Geography Inventory and Prospects, (Syracuse: Syracuse University Press, 1954), 9-10.

direction; and equal area. No flat surface representing the earth's surface is able to portray these four characteristics simultaneously.

Use of the globe helps the student understand the earth's movements and relationships as well as their significance for the people on the earth. Only when reproduced and represented by a globe, can the earth's rotation, alternating daylight and darkness over different portions of the earth, earth-sun relationships, time, great circle routes, and many more concepts be fully comprehended. In particular, the globe and its properties must be understood by the teacher and the students before maps and projections are introduced and used in the classroom.

Maps:

Problems arising from the size of globes, their inconvenience in handling, their cost, small scale and other factors, make it desirable that the earth--entirely or in part--be transferred to a flat surface. As a prime communicative tool, the understanding and correct use of maps is indispensable for both teacher and student.

While many instructional media are designed to be presented for a particular use, maps can aid a better

understanding continually in countless ways. They may become tools to show: location; patterns of movement; distribution of natural and cultural features; differences in elevation and degree of slope; distances and much more. Therefore, the teacher should make a wide selection of maps available for classroom use as well as individual investigation.

## Use of the Outline

Each unit in the outline (with the exception of the first) has five parts. The first part, Teacher Aims, lists the basic underlying principles upon which the chapter is based. It is hoped that after studying the chapter the student will understand these concepts. The second part, Student Aims, suggests what may be expected of the student (depending on the depth to which the material was studied); it might also offer guidelines for examination questions. The third part, Content, is the subject matter specifically. The fourth part, Suggestions to the Teacher, comprises a set of ideas and devices to aid in presentation of the material as well as to suggest stimulating variations and complementary study topics. The last part, Recommendations for Further Study, lists sources to explain and supplement the subject matter; it also suggests

audio-visual aids.

Since the course outline is of a comprehensive and advanced nature, it contains some material from which only the more advanced student will profit. Under any circumstances, the course should be tailored to fit different interests; therefore, the author thinks is is easier for the teacher to abbreviate or delete material in this outline than it would be for him to upgrade a more general outline. It is hoped that a portion of each unit, and even of each chapter not indicated as optional, will be presented to the class.

The order in which the units are presented is, of course, not mandatory. Although the sequence presented herein is not common to most high school textbooks in earth science, it is generally accepted for a physical geography course at the college level.

The length of time to be spent on each unit will vary according to the number of available class hours, the ability of the students, and the purpose for which the course is planned. However, it is hoped that the teacher will plan carefully, so that important items in the unit will not be slighted due to lack of time.

The grade placement of the physical geography course need not be regarded as fixed, although in the

author's experience junior and senior students have usually proved more receptive to it than sophomores. This course may be used in preparation for later specialized work in geography (or other disciplines), or it may be presented as a terminal science course for general educational purposes.

Several of the following chapters as well as some sub-headings within other chapters are listed as optional. The optional material extends beyond that which is commonly taught as physical geography. It is included, however, to permit possible adaptation of the outline to supplement the needs of a one-year earth science course.

In Chapter III, the course outline is divided into 21 units. These units may be combined into three broad classifications consisting of: an introduction to the earth (units I through IX); the forces in the air (units X through XVI); and the face of the land (units XVII through XXI).

Suggestions to the teacher:

Review with the students several accepted definitions of geography and discuss whether they would be compatible with the concepts listed.

Briefly survey the textbook in order to call attention to the breadth of material indicated by the term "physical geography."

Introduce the students to available source materials: those in the classroom (such as globes and maps); and those facilities containing geographic materials that will be available to them (libraries, special programs on television, prospective field trips).

Inform the students what projects or materials will be required of them during the semester. It is especially necessary to call attention early to time-consuming requirements (such as term papers) or continuing projects (such as daily weather charts, astronomical observations).

The teacher may wish to highlight certain material located in the "Introduction for the Teacher" with the class so as to help the student understand what is expected of him.

## Recommendations for Further Study

Books:

Broek, Jan O. M. Geography: Its Scope and Spirit. Columbus: Charles E. Merrill Books, Inc., 1965. Pp. 116.

Freeman, T. W. A Hundred Years of Geography. Chicago: Aldine Publishing Co., Ldt., 1958. Pp. 334.

Gopsill, G. H. The Teaching of Geography. London: MacMillan and Co., Ltd., 1958. Pp. 316.

Hartshorne, Richard. Perspective on the Nature of Geography. Chicago: Rand McNally and Co., 1959. Pp. 201.

James, Preston. American Geography: Inventory and Prospect. Syracuse: Syracuse University Press, 1954. Pp. 590.

Periodicals:

Anderzohn, M. L. "Geographic Concepts in the Space Age," Journal of Geography, LX (March, 1961), 32-34.

Conroy, William. "The Misuse of Geography," Journal of Geography, LXV (March, 1961), 109-113.

Dahlem, Glenn. "Systematic and Regional Approaches," Journal of Geography, LIX (November, 1960), 410-411.

Hartshorne, Richard. "Why Study Geography," Journal of Geography, LXV (March, 1966), 100-102.

Scarfe, Neville V. "What is Geography?" Journal of Geography, LXI (February, 1962), 84-85.

# CHAPTER III

## THE OUTLINE

### Unit I: Introduction to Physical Geography

Teacher aims:

I. To teach that although this course will include study of the earth, the atmosphere, and space, they are not to be studied as unrelated subjects, but instead as closely-related parts of man's total physical environment.

II. To teach that there are specified concepts present at all levels of geographic instruction. They provide the bonds of continuity for not only physical geography but also geography as a whole and are thus necessary for an understanding of physical geography.

Student aims:

I. To reach a richer and fuller understanding of the earth as the home of man.

II. To recognize the importance of geographic study in understanding the problems facing modern society and in applying possible solutions.

III. To appreciate the applicability of geographic concepts in aiding the understanding of other fields of knowledge, such as history, world literature, and the systematic sciences.

IV. To comprehend geography as an integrated discipline.

Content:

I. Geographic concepts:

All disciplines require concepts that provide bonds of continuity. The following 14 geographic concepts by Warman[1] are intertwined and present at all levels of geographic instruction. They provide the geographic bonds of unity and continuity.

A. Regional Concept

The concept of the region is the heart of geography. A region is an area of varying size that has homogeneity of its determining features within its core. The character of the core provides the internal unity. A region is separated by zones of transition from neighboring areas from which it differs in significant respects. It entails comprehension of the meaningful factors of the natural and cultural environment. It is the ensemble or totality of the relevant features that produces the "character" of the region.

In that the earth is so large, most regions are not visible. Furthermore, certain physical features--length of growing season, soil types, climatic zones--are relatively intangible and are not easily observed. To illumine the phenomena of the landscape, geographers make use of maps. Most of the landscape can be shown on maps, either individually or in combinations.

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[1]Henry J. Warman, Geography: Backgrounds, Techniques and Prospects, (Worcester: Clark University Press, 1955), 23-28.

B. Life Layer Concept

Most of mankind live and work within a small zone on the earth's surface. Human activities seldom require man to extend far into the earth's surface or into the earth's atmosphere. It is the horizontal extent of the life layer where man engages in agriculture, industry, and transportation that is of great significance.

C. Man-Ecological Dominant Concept

Man has the opportunity to choose among the many opportunities offered by his environment, but always within limitations provided by that environment. It must be understood that it is man that is the most important factor within our environment. It is he that chooses. It is nature that is generally permissive in that man has more often been restrained by his own abilities than by nature.

D. Globalism Concept

The earth as a sphere is a basic concept of geography--physical geography in particular. Day and night, distance and time, solar insolation and climatic zones, and the circulations of air and water are only a few of the big ideas resulting from globalism.

E. Spatial Interaction Concept

Cyclic changes are always in process. The hydrolgic cycle or evaporation, water vapor, winds, condensation, clouds, precipitation, soak-in and run-off, the oceans, and the cycle of erosion represent classic topics for study.

F. Areal Relationships Concept

Geography is concerned with the close associations between various cultural and physical phenomena distributed over the earth; it is especially concerned when some cause and effect relationship exists between such

phenomena and specific environmental conditions.

G. Areal Likenesses Concept

Geographers are also concerned with a comparison of places. This concept is the basis of the entire array of patterns. Patterns of climate, vegetation, and soils are familiar ones; these patterns occur because of the similarities of these phenomena in various places on the face of the earth.

H. Areal Differences Concept

Basic to the study of geography is the recognition that physical environments differ from place to place, that people differ from place to place, and that the cultural environments differ from place to place. A major task of the geographer is to show, some degree of succession, some conceivable form, to all these differences while recognizing such features and associations as being different.

I. Areal Uniqueness Concept

This concept is sometimes called "areal distinctions." As was stated before, the essential basis of geography is the observation that places are not alike. Places differ in different ways.

Despite the numerous different physical and cultural features of the landscape and the numerous combinations of different complexes of both features, which at first present a nearly endless list of possibilities, the geographer can single out those features or combination of features that gives distinction to an area, that distinguishes that area from other areas. The arrangement and the association of features are uniquely characteristic to only certain areas.

J. Areal Distribution Concept

All kinds of phenomena are distributed unequally and unevenly over the earth. Some

places have much of one thing, others have a moderate amount, and still others have none. Where things are and in how large an amount become basic questions. Maps showing the distribution of individual physical and cultural phenomena, both tangible and intangible, are essential tools for the study of relationships and interrelationships. The nature of the pattern of distribution of things is of great concern to all.

K. Relative Location Concept

The significance of a place is due to its location in respect to other places. The core of a region may be concisely stated as 40 degrees north latitude and 89 degrees west longitude. However, this is not nearly as meaningful as to state that the location is in the heart of the corn belt, near the center of the continent, or on the margin of the glaciated area. Students need to develop "mental maps" in which they can picture these various regions, patterns, and features.

L. Comparative Advantage Concept

With his freedom of choice, man has tended to select the courses that seem to offer the greatest advantage at a particular time. From the long view of history, however, man and society have not always chosen well, nor do man and society everywhere at the present choose well. Physical, cultural, social, economic, and political factors are all involved with varying emphases.

M. Perpetual Transformation Concept

The most permanent thing in the world is change. Even the mountains are gradually being uplifted or eroded as part of the alteration of the surface of the earth. Atmospheric conditions change incessantly. Man changes the surface of earth and the physical environment changes man. Technological advances bring changes, and in recent decades, rapid changes.

N. Round Earth on Flat Paper Concept

Such topics as projections, scale, symbols, etc., can be developed under this concept. Skills in map reading, map making, and map interpreting can be used effectively in geographic studies.

II. Definition of geography

The teacher of a subject should have a clear image of the course, which affords guidelines. The following list represents the thinking and philosophy of several of the great geographers in the past 100 years.[2]

A. Geography seeks to interpret the significance of likenesses and differences among places in terms of causes and consequences.--Preston James.

B. Geography is that discipline that seeks to describe and interpret the variable character from place to place of the earth as the world of man.--Richard Hartshorne.

C. Geography deals with the observing, describing, and interpreting of landscape phenomena--more especially the ensemble of cultureal and natural features in their regional and interregional aspects.--Earl Lackey.

D. Geography is the science of places.--Paul Vidal de la Blache.

E. Geography is the science of distribution.--Freidrich Marthe.

F. Geography is the correlative science.--Griffith Taylor.

G. Geography tells us what is where, why, and what of it.--Isaiah Bowman.

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[2]Alfred H. Meyer and John H. Streitelmeirer, Geography in World Society, (Philadelphia: Lippincott, Inc., 1963), pp. 846.

III. General Survey of the Course

IV. Recommended approaches to study

## CHAPTER III

## OUTLINE (CONTINUED)

### Unit II: The Origin of the Universe (Optional)

Teacher aims:

I. To teach that there are several theories of the origin of our universe. (These should be tested both in terms of the data available at the time and with the data available today.)

II. To teach how man is constantly increasing his ability to penetrate space, both physically, and with modern technology, such as optical and radio telescopes.

III. To teach how space and time are intimately related, as proposed by the theory of relativity.

Student aims:

I. To show why there is little possibility within the forseeable future for man to determine the origin, structure, and workings of the universe.

II. To specify examples where man has reached out beyond our earth into the realm of the galaxies.

III. To appreciate the role of mathematics, physics, and mathematical description as a means of reasoning about space and time.

Content:

I. The origin of the universe

A. Explosion Theory

Many scientists believe that the universe began with a great explosion (sometimes called a "big bang") which is still proceeding as seen in the continuing expansion and the increasing distance between objects.

B. Pulsating Theory

Other scientists hold that such explosions are constantly recurring as older stars burn out.

II. Galaxies

A. Probable number of galaxies

Scientists are able to see over one billion galaxies other than our own. There is good reason to believe that there are many millions more.

B. Metagalaxies

These are groups of galaxies that are mutually attracted to each other, and thus they move through space as a unit.

C. Our Metagalaxy

Scientists believe that this consists of our Milky Way, our visible sister galaxy in Adromeda, and probably seventeen more.

III. Methods of exploring the universe

A. Visual telescopes

These have their basis in time photography, revealing objects not visible to the naked eye.

B. Radio telescopes

These explore other invisible electromagnetic radiation from space. Many objects have been discovered by their radio signals

that are visually obscured for one reason or another.

C. Spectroscopic analysis

This is used to examine consistency of celestial objects or their speed with respect to the earth.

D. Time lapse

Scientists view celestial objects as they appeared in the past, e.g., the Andromeda Galaxy is seen not as it exists today, but as it was two million years ago. This is because of the time it takes light to reach the earth. The further one looks out into space, the further back one looks in time.

Suggestions to the teacher:

It would be of considerable value to order the Bell Telephone Company film, About Time. It is free of charge and is distributed throughout the area. It would be well to reserve the film weeks in advance.

This chapter will show the student the smallness of man in the universe. Much of the discussion will involve philosophical problems; this should be encouraged. There is little likelihood that a religious connotation will be introduced in the discussion. The author has been able to evade any religious conflicts by teaching this as scientific theory rather than a personal belief. If necessary, it might be emphasized that while science seeks to explain processes, the

ultimate questions remain within the realm of personal belief.

A field trip to the Chicago Planetarium would stimulate interest at this time. If this is not possible, a four-inch telescope would provide the students with a view of members of the universe and of the solar system.

## Recommendations For Further Study

Books:

Abell, George. Exploration of the Universe. New York: Holt, Rinehart, and Winston Co., Inc., 1964. Pp. 646.

Bernhard, Hubert J., et al. New Handbook of the Heavens. New York: New American Library, 1956. Pp. 360.

Doig, Peter. A Concise History of Astronomy. New York: Philosophical Library, 1950. Pp. 320.

Eddington, Arthur S. The Expanding Universe. New York: Cambridge University Press, 1933. Pp. 182.

Kahn, Fritz. Design of the Universe. New York: Crown Publishers, Inc., 1954. Pp. 373.

McLaughlin, Dean B. Introduction to Astronomy. Boston: Houghton Mifflin Co., Inc., 1961. Pp. 463.

Films:[1]

Exploring Space. 9 minutes. b/w. Teaching Film Custodians.[2]

Exploring the Universe. 11 minutes. b/w. Encyclopedia Britannica.

In the Beginning. 17 minutes. color. Socony Vacuum Oil Co.

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[1]All films are 16 millimeter and have sound tracks. The filmstrips are without sound tracks.

[2]Check Appendix II for the address of film source.

Trip Through Space. 8 minutes. b/w. Institutional Cinema Service.

The Universe. 28 minutes. b/w. National Film Board of Canada.

## CHAPTER III

## OUTLINE (CONTINUED)

### Unit III: The Origin and Character of Our Solar System (Optional)

Teacher aims:

I. To teach that various hypotheses concerning the origin of the solar system have been proposed, and they must conform to present-day knowledge if they are to be accepted.

II. To teach that vast emptiness exists in space.

III. To teach how, although the solar system may be considered to be a whole, the various members of our solar system have different physical characteristics.

IV. To teach that some planets contain an atmosphere; this is governed by their respective masses.

V. To teach how planetary motion is governed by the laws of gravity (mutual attraction).

Student aims:

I. To describe the different theories of the origin of the solar system. The student should be able to separate the valid hypotheses from the older theories on the basis of the known properties of the solar system.

II. To know various physical characteristics of different planets, and why they are different from earth.

III. To describe the planetary motions and how they are related to the forces of gravity.

Content:

I. Theories of the origin of the solar system

A. Nebular Hypothesis

This theory presumes that the sun and its atmosphere were formed by condensation of diffused material.

B. Tidal Theory

This theory states that the planets were formed from the sun as a result of a near-collision with another star, resulting in tidal uplift on the sun and consequent ejection.

C. Planetesimal Theory

This theory hypothesizes that small particles of revolving matter became attracted to each other to form larger bodies.

II. The planets and their characteristics

A. Planets

Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto.

B. Their classification

1. Inferior--those planets nearer to the sun than the earth; and superior--those further from the sun than earth.

2. Inner planets--those within the Asteroid Belt; and outer planets--those outside the Asteroid Belt.

3. Major (giant)--Jupiter, Saturn, Uranus, Neptune; and Minor (terrestrial)--Mercury, Venus, Earth, Mars, and Pluto.

C. Orbit size

The great distances encountered when comparing distances between the sun and the planets is too great to be functional. Thus, the average distance from the earth to the sun (93,000,000 miles) is used and is called the Astronomical Unit or A.U.

D. Planet size

The earth is most commonly used as the standard reference. Thus, Venus is about the same size as the Earth and Jupiter is about 11 times the diameter, or 1300 times its volume.

E. Periods of revolutions

The earth's year is used as a standard unit.

F. Periods of rotation

The earth's period is considered the standard measuring device. The rotation periods of several of the planets are not known.

G. Surface gravity

The force of gravity at the surface is dependent upon the planet's mass--a function of its volume and the specific gravity of its component materials. The earth is used as the standard measuring device.

H. Velocity

The escape velocity and the resultant consequences is the speed required by a body to escape the gravitational pull of the attracting body, and is directly related to surface gravity. Because of molecular motion of gases, planets with low surface escape velocity are unable to hold an atmosphere and have relinquished them to space. Escape velocity has assumed additional importance in the program of launchings into space.

I. Atmospheric and temperature conditions

These conditions on other planets are contrasted with conditions as they exist on the earth.

III. Other members of our solar system

A. Planet satellites

B. Planetoids and asteroids

C. Comets and meteor showers

D. Meteors and meteorites

Suggestions to the teacher:

It would be best to follow an historical approach when explaining the origins of the solar system. This would aid the students in evaluating the different hypotheses and why they were accepted or why they are now rejected. The solar system should be treated as a whole, thus the teacher should emphasize that there was some orderly process that formed the solar system. This order is best explained by the properties observed in the solar system.

Classifications of planets usually place the bodies into groups, the most common grouping being the inner or terrestrial and the major or outer planets. It would be helpful to contrast planets first within their own group and then to contrast the groups. The earth would be the common denominator. This would

help to impress the student that, although the earth provides him with his home, it is a minor planet when considering the solar system.

It is helpful to have scale models, one to show relative sizes and the other to show relative distances. If scale models are not available, accurate diagrams may be drawn to scale on the blackboard.

It is suggested that the more advanced students do individual studies on the "other members of the solar system." This will satisfy their curiosity while not taking class time.

Either the teacher or a student could bring a meteorite specimen to class for examination.

# Recommendations For Further Study

## Books:

Baker, R. H. Astronomy. Princeton, New Jersey: Van Nostrand, 1959. Pp. 547.

Gallant, R. Exploring Mars. New York: Doubleday and Co., Inc., 1956. Pp. 62.

Moore, P. A Guide to the Planets. revised edition. New York: W. W. Norton and Co., Inc., 1960. Pp. 254.

Skilling, W. T. and Richardson, R. S. A Brief Text in Astronomy. New York: Henry Holt and Co., Inc., 1959. Pp. 353.

Watson, Fletcher. Between the Planets. Cambridge: Harvard University Press, 1956. Pp. 188.

## Films:

The Solar Family. 11 minutes. color. Encyclopedia Britannica.

The Sun's Family. 10 minutes. b/w. Young America Films.

## Filmstrips:

"Planets and Comets." Scanning the Universe series. Britannica.

## CHAPTER III

## OUTLINE (CONTINUED)

### Unit IV: The Moon (Optional)

Teacher aims:

I. To teach that the earth and the moon form a dynamic relationship.

II. To teach that the earth and the moon interact to produce ocean tides.

III. To teach the effect of the motions of the moon on man.

Student aims:

I. To describe the moon's motions.

II. To relate the different moon phases and the respective positions of earth, sun, and moon to each phase.

III. To give the causes and resulting effects of solar and lunar eclipses.

IV. To account for the different tidal effects caused by the gravitational attraction of the moon and the sun on the earth from various relative positions.

Content:

I. Theories of origin

A. Condensation Theory

The moon may have been formed from a condensation of the same material that formed the earth.

B. Theory of Terrestrial Origin

The moon may have been formed from the earth itself.

II. Phases

The size and visible area of the moon varies as it revolves about the earth. This is the basis of the Synodic Month of about 29-1/2 days.

III. Revolution

The moon revolves about the earth each 27-1/3 days. This is referred to as a Sidereal Month. The additional two days to make a Synodic Month is caused by the earth's revolution about the sun.

IV. Rotation

The moon rotates on its axis every 27-1/3 days, resulting in the same portion of the moon always facing the earth.

V. Eclipses

A. Solar Eclipses

When the moon moves between the sun and the earth and casts its shadow upon the earth.

1. Total--when the moon totally obscures the sun from view. This is seen in the umbra.

2. Partial--when the moon only partially obscures the sun. This is seen in the penumbra.

B. Lunar Eclipses

When the moon enters into the earth's shadow. The moon is still visible, however, because

of the refraction of sunlight by the earth's atmosphere.

VI. Tides

These are produced by the attraction of both sun and moon on the ocean waters.

A. Spring tides

The highest tide caused when the sun and the moon are in direct line with the earth.

B. Neap tides

A lower tide resulting when the angle between the moon and the sun with respect to the earth is 90°.

C. Tropic tides

Tides of diurnal inequality most pronounced twice monthly when the moon is directly over either of the Tropics.

D. Equatorial tides

The elimination of diurnal inequality of tides when the moon is directly above the equator.

E. Perigean tides

High tides caused when the moon is at perigee in its orbit (closest to the earth).

F. Apogean tides

Low tides caused when the moon is at apogee (furthest from the earth).

G. Tidal bores

A wall of water (perhaps several feet in height) produced by a strong flow tide against a strong river current in a narrow estuary.

Suggestions to the teacher:

It would be very helpful to have classroom demonstrations. Models are a great help, but accurate blackboard drawings could suffice.

Most of the student's previous knowledge about the moon will probably be of the descriptive variety. One should stress not just known facts but also the processes and techniques used to gather the information. This is especially pertinent in that man is preparing to travel to the moon.

The author has not included such topics of study as physical characteristics, the barycenter, or the lunar surface. If the teacher feels that it is important in light of modern developments, the recommendations for further study will supply all the needed information.

## Recommendations For Further Study

Books:

Defant, A. Ebb and Flow. Ann Arbor: University of Michigan Press, 1958. Pp. 121.

Fisher, George. Story of the Moon. New York: Doubleday, Inc., 1943. Pp. 301.

Kopal, Z. The Moon: Our Nearest Celestial Neighbor. New York: Academic Press, 1961. Pp. 131.

Russell, Robert C. H. Waves and Tides. New York; Hutchinson University Library, 1952. Pp. 348.

Skilling, W. T. and Richardson, R. S. Sun, Moon, and Stars. New York: McGraw-Hill Book Co., Inc., 1946. Pp. 274.

Wilkins, H. P. Our Moon. London: Mueller Ltd., 1954. Pp. 180.

Wyatt, S. P. Principles of Astronomy. Boston: Allyn and Bacon, 1964. Pp. 561.

Films:

The Moon. 11 minutes. b/w. Young America Films.

This Is the Moon. 10 minutes. b/w. Young America Films.

Tides. 10 minutes. b/w. Almanac Film.

Trip to the Moon. 16 minutes. color. Britannica.

## CHAPTER III

## OUTLINE (CONTINUED)

### Unit V: Physical Properties of the Earth

Teacher aims:

I. To teach that the properties of the earth were discovered and measured by careful observation. Many of these processes are not possible without technological instruments.

II. To teach how variations in gravitation and degrees of longitude and latitude result from the fact that the earth is an oblate spheroid rather than a perfect sphere.

III. To teach that the earth, including the atmosphere, is not uniform in composition, but contains solids, liquids, and gases, resulting in a constant state of change.

IV. To teach that the earth has a concentric layering of materials. The densest layer is at the center, and each successive layer is lighter as it moves outward from the center, resulting in diastropic change.

V. To teach that the topographic relief on the earth's surface is minute when compared to the earth's diameter.

VI. To teach how weight results from gravitational attraction and how it varies with the distance from the earth's core and because of centrifugal force set up by the earth's rotation.

Student aims:

I. To differentiate between the major concentric zones of the earth.

II. To describe the major properties of the earth, e.g., size, shape, and density, and give supporting examples.

III. To contrast the functions of the more important elements in the atmosphere, the hydrosphere, and the lithosphere.

IV. To approach problems by direct observation and systematic collection of data rather than by casual observation.

Content:

I. Proofs of the world's shape

The shape of the earth can be proved in a variety of ways:

A. Circumnavigation of the earth.

B. Circular shadow of the earth on the moon during lunar eclipse.

C. Observations of ships at sea.

D. Earth curvature appearing in high altitude and space photography.

E. Surveying observations.

F. Improving television reception by raising TV antennae to greater heights.

II. The dimensions of the earth

The earth can be measured in various ways. Two of the most important dimensions are:

A. Circumference

This distance is 24,840 miles at the equator.

B. Diameter

At the equator this distance is 7,918 miles. (Note: the equatorial diameter is slightly greater than the polar, thus the earth is not truly spherical, but an oblate spheroid with the bulge south of the equator.)

III. The lithosphere (the solid sphere)

The lithosphere comprises the following concentric zones:

A. The core or innermost zone

This zone has an approximate radius of 2,150 miles.

B. Mantle or intermediate zone

This zone rests on the core and has an approximate depth of 1,800 miles.

C. Crust or outermost zone

This zone rests on the mantle and has an average depth of 20 to 30 miles.

IV. The hydrosphere (the liquid sphere)

The oceans contain many of the same materials that are found within the lithosphere, e.g., oxygen, nitrates, salts, animal and vegetable life. The discontinuous nature of the hydrosphere differs from that of the other spheres.

V. The atmosphere (the gaseous sphere)

The atmosphere is composed of several gases. Water vapor, carbon dioxide and oxygen are of special importance to the geographer. There is vertical zonation that is reflected due to changes in temperature, density, composition, and physical activity of the atmosphere.

Suggestions to the teacher:

How little the students know about the size and shape of the earth might surprise many teachers. All students know that it is round, but few are able to prove it other than by circumnavigation and space photography examples. This round-earth concept is not easy to grasp fully in that the dimensions involved are too large to develop a feeling for them.

It might be well to enter into the discussion with questions as to why knowledge of the earth's size, shape and mass is important today, especially when studying physical geography. There would be a good opportunity to impress the students with facts that might be irrelevant except when they awaken interest.

For example, when referring to topographic relief, the greatest depths of the oceans (almost seven miles) and the highest mountain peaks (a little over five miles) could be compared to the size of the earth in several manners. Two of the most popular are:

1. The relief represented by the shell of the egg in respect to the entire egg is relatively greater than the topographic aberrations of the earth's surface.

2. The width of the chalk line would be greater than the extent of relief if a scale model of the earth were drawn on the classroom blackboard.

This would also be a good time to emphasize the role of oxygen in our world. Too often students associate oxygen only with the air we breathe and sometimes with water. One might point out to the students that rocks and soil also contain great amounts of oxygen (as will be demonstrated later in the course).

# Recommendations For Further Study

## Books:

Bomford, G. Geodesy. 2nd ed. revised. Oxford: Oxford University Press, 1962. Pp. 561.

Heiskanen, W. A. and Vening-Meinesz, F. A. The Earth and Its Gravity Field. New York: McGraw-Hill Book Co., Inc., 1958. Pp. 470.

Strahler, Arthur. The Earth Sciences. New York: Harper and Row, 1963. Pp. 681.

Any of the earth science books listed under "Physical Geography" in the Selected Bibliography.

## Periodicals:

Van Burkalow, Anastasia. "What Shall We Teach About the Earth's Shape?" Journal of Geography, LIX No. 5 (May, 1960), 229-234.

## Films:

How We Know the Earth's Shape. 10 minutes. color. Film Associates.

Planet Earth: Shape of the Earth. 28 minutes. color. McGraw-Hill.

CHAPTER III

OUTLINE (CONTINUED)

Unit VI: The Earth in Motion

Teacher aims:

I. To teach that the manner in which the sun's rays strike the earth's surface is a function of the earth's tilt and its revolutionary position with respect to the sun, rotation, and revolution about the sun are among the most important earth movements.

Student aims:

I. To realize that the earth's oblateness results from differences in the velocity of rotation and from the large water surface in the southern hemisphere.

II. To understand that were the earth's axis perpendicular to the ecliptic there would be no seasonal change.

III. To be able to locate the sun's meridianal altitude under certain specified conditions.

IV. To understand the reason for the apparent westward motion of the celestial bodies.

V. To understand the reason for slightly different views of the celestial bodies at the same time on different nights during the year.

VI. To understand why the hours of daylight increase during the spring months and decrease during the fall months.

VII. To recognize the difference between the terms rotation and revolution.

Contents:

I. Rotation of the earth

The earth rotates on its polar axis, thus causing night and day. The velocity of rotation is obtained by dividing the diameter of the earth in a true east-west direction from a given position by the length of the day, or 24 hours. The equatorial velocity is about 1,050 miles per hour while at the 60th parallel, which is half the diameter of the equator, the velocity is 525 miles per hour. At the poles, the velocity is zero.

II. Revolution of the earth about the sun

The earth's motion in its orbit around the sun is called revolution. This period of time takes 365-1/4 days and is called a calendar or sidereal year. The earth's orbit is an ellipse, with an average distance of 93 million miles from the sun. The distance is least (the earth is at perihelion) on about January 3 (91-1/2 million miles). The distance is greatest (the earth is at aphelion) on about July 4 (94-1/2 million miles away). These phenomena determine the length of the seasons.

III. Inclination of the earth's axis

The earth's axis is not perpendicular to the plane of the ecliptic. Rather it is inclined at an angle of 23-1/2 degrees from the perpendicular, or 66-1/2 degrees from the plane. This inclination is constant and maintains a fixed orientation with respect to the celestial bodies. It is commonly referred to as "parallelism of the earth's axis." Parallelism of the earth's axis and the earth's revolution about the sun are largely responsible for the following:

A. The seasons

Man on earth naturally associates climatic changes with the apparent path of the sun through space. We know that it is the earth moving about the revolutionary orbit maintaining a constant angle of inclination that produces the apparent movement of the sun.

1. The vernal equinox

This marks the first day of spring in the northern hemisphere and of fall in the southern hemisphere. The earth's axis is at a 90-degree angle with a line drawn to the sun. Neither the north pole or the south pole have any inclination towards the sun. This usually occurs on March 20 or 21.

2. The autumnal equinox

On the first day of fall in the northern hemisphere and of spring in the southern hemisphere, conditions are equivalent to that of the vernal equinox as far as earth-sun relationships are concerned. The earth's revolutionary path has placed the earth opposite to where it was during the vernal equinox. This usually occurs on September 20 or 21.

3. The summer solstice (northern hemisphere)

The north polar axis is inclined at its maximum angle 23-1/2 degrees towards the sun. The southern polar axis is inclined 23-1/2 degrees away from the sun. This usually occurs on June 20 or 21, and is the northern hemisphere's first day of summer.

4. The winter solstice (northern hemisphere)

This is the first day of winter in the northern hemisphere. Conditions are exactly opposite those of the summer solstice.

The earth's axis is again at its maximum inclination with respect to a line drawn to the sun, but now the south polar axis inclines 23-1/2 degrees toward the sun and the north polar axis inclines 23-1/2 degrees away from the sun. This usually occurs on December 20 or 21.

B. Circle of illumination

This is the great circle which divides the earth into day and night. The position of the circle is a function of the inclination of the earth's axis with respect to the sun.

C. The tropics and circles

1. Tropic of Cancer

This is the parallel 23-1/2 degrees N and is the farthest north reached by the sun's vertical rays at the time of the summer solstice (June 20 or 21).

2. Tropic of Capricorn

This is the parallel 23-1/2 degrees S and is the farthest south reached by the sun's vertical rays at the time of the winter solstice (December 20 or 21).

3. Arctic Circle

This is the parallel 66-1/2 degrees N where the sun's noon rays are tangential to the earth's surface at the time of the summer solstice (June 20 or 21).

4. Antarctic Circle

This is the parallel 66-1/2 degrees S where the sun's noon rays are tangential to the earth's surface at the time of the winter solstice (December 20 or 21).

Suggestions to the teacher:

Students should differentiate between revolution and rotation. The term occurs often and is used in connection with different principles, thus sometimes confusing the student.

It is very difficult for the student to visualize in his mind the idea that the polar axis remains constant in orientation. It would be wise to take a globe, and while maintaining a constant orientation of the axis, walk around the class to show that although the axis does not change its orientation, the direction of the axis will change with respect to him. The student can not understand the principles of changes in solar insolation without first understanding this principle.

# Recommendations For Further Study

Periodicals:

McKinney, William M. "Experimental Proofs of the Earth's Rotation," Journal of Geography, LXI No. 4 (April, 1962), Pp. 171-174.

Films:

Day and Night. 9 minutes. b/w. United World Films.

Earth in Motion. 11 minutes. b/w. Western Michigan.

What Causes the Seasons? 10 minutes. b/w. Young America Films.

What Makes Day and Night? 10 minutes. b/w. Young America Films.

## CHAPTER III

## OUTLINE (CONTINUED)

### Unit VII: The Map Grid

Teacher aims:

I. To teach that an invisible co-ordinate grid pattern has been superimposed upon the earth to enable man to locate places on the earth's surface.

II. To teach how circles are the basis of the grid with parallel connecting points of equal distance from the poles, and with meridians intersecting at the poles.

Student aims:

I. To be able to locate on a map any point on the earth's surface, given longitude and latitude.

II. To give distances in miles on specific parallels, given the earth's circumference at that parallel.

III. To give the distance in miles between any two points on a given meridian insomuch as each meridian is half of a great circle, and thus each degree is approximately 69 statute miles on a great circle.

IV. To see a relationship between the grid system and time.

Content:

I. Great circle

This is any circle on the surface of the earth having its plane pass through the center of the earth. Some of its characteristics are as follows:

A. It is the largest circle that can be drawn on the earth.

B. For each pair of points on the earth's surface, there is one great circle joining them.

C. The shortest distance between two points is along an arc of the great circle on which the points lie.

D. Intersecting great circles bisect each other.

II. Small circle

This is any circle on the surface of the earth, the plane of which does not pass through the center of the earth (i.e., any circle not a great circle). Some of its characteristics are as follows:

A. There is no small circle joining points on opposite sides of the earth, but every other pair of locations has a common small circle.

B. The path of a small circle is not the shortest distance between two points.

III. Equator

This is the imaginary line around the earth that is everywhere equidistant from the north and south poles. It is a great circle.

IV. Meridians

All the meridians are halves of great circles whose ends are at the north and south poles. They have the following characteristics:

A. All meridians are lines of true north and south direction.

B. All meridians converge at the poles and have their greatest spacing at the equator.

C. There are an infinite number of meridians that may be drawn on the globe; thus every point in the world lies on a meridian.

V. Parallels

Parallels are small circles whose planes pass through the earth parallel to the plane of the equator. They have the following characteristics:

A. Parallels are always parallel to each other and to the equator.

B. Each pair of parallels is equally spaced at every meridian.

C. Parallels are lines of true east-west direction.

D. Parallels always intersect meridians at right angles.

E. Parallels are small circles except the equator which is the only parallel that is a great circle.

F. There are an infinite number of parallels that can be drawn on the globe. Thus every point in the world lies on a parallel except the north and south poles.

VI. Degree

This is the basic unit of angular measurement on the earth grid. It is 1/360 of the circumference of a sphere. The actual length in miles will depend upon where it is measured. Because each parallel is a circle, regardless of its circumference it is still divided into 360 degrees. Thus, the length of each degree decreases toward the poles. Each degree is subdivided into 60 minutes and each minute is

divided into 60 seconds.

VII. Longitude

Longitude is the measurement of angular distance east or west of a given meridian (usually the Greenwich meridian).

VIII. Latitude

Latitude is the measurement of angular distance north or south of the equator.

IX. Prime Meridian

This is the meridian which passes through the old Royal Observatory of Greenwich from which the longitude east and west is measured. It is zero degrees longitude. This is an arbitrary location. Other countries have used different prime meridians in the past (e.g., French use of the Paris meridian as prime).

X. International Date Line

This is an imaginary line that runs at or near the meridian of 180 degrees. It is an arbitrary division of days on the earth, and calendar correction is made at the meridian.

XI. Nautical miles

On any great-circle, one degree is 60 nautical miles. It is used for its relative simplicity in place of statute miles, since on any great circle, one degree is 69.172 statute miles.

Suggestions to the teacher:

All the students are familiar with the standard wall maps and book maps. They are accustomed to seeing the round earth on a plane. Thus, they have difficulty in understanding the great circle concept relating to

distances. If a student is asked the shortest distance between San Francisco and Tokyo, he will most likely draw a line across the Pacific Ocean. To demonstrate that going across the polar area is shorter, take a large globe, and stretch a string from San Francisco to Tokyo and it will draw tight and pass over the Arctic Ocean. Then have the students locate other great circle routes and plot them on the wall map. It will not be long before they notice that the shortest distance between the United States and the USSR is directly across Canada and not through Alaska.

Students should get into the habit of locating major world areas by longitude and latitude. They should know the approximate longitude and latitude of their town. They should also select critical world areas and learn their approximate longitude and latitude in order to have some general idea as to where places are. It will come as a surprise to learn that Chicago is on approximately the same latitude as is Rome, and thus most of Europe is more northerly than Chicago.

It would make for interesting discussion to determine when it is feasible to travel by the great circle route and when it is not feasible to do so.

Do all planes travel by this route? Do all ships? Are road and rail transportation arranged to travel by the great circle routes? Have the students plan a trip from Chicago to New York or Los Angeles and determine by the great circle which would be the shortest distance and what cities they would encounter.

# Recommendations For Further Study

## Books:

Greenhood, David. Mapping. Chicago: University of Chicago Press, 1951. Pp. 289.

## Periodicals:

Anderzohn, M. L. "Distance and Direction Via Great Circle Routes," Journal of Geography, LXIV No. 8 (November, 1965), 358-362.

Ives, Ronald. "Longitude Degree Length at Various Latitudes," Journal of Geography, LXIII No. 5 (May, 1964), 205-210.

Kennamer, Lorrin. "Visualization of Latitude and Longitude," Journal of Geography, LXI No. 1 (January, 1962), 9-11.

McCarthy, A. J. P. and Randall, Murice. "A Teaching Unit on the Rectangular Land Survey," Journal of Geography, LIX No. 8 (November, 1960), 360-363.

Switzer, Wilbur. "The Map Exercise As A Basis for Critical Thinking in High School Geography," Journal of Geography, LIX No. 7 (October, 1960), 314-317.

## Films:

Latitude and Longitude. 9 minutes. color. United World Films.

Using Maps: Measuring Distance. 11 minutes. color. Britannica.

CHAPTER III

OUTLINE (CONTINUED)

Unit VIII: Time and Its Keeping

Teacher aims:

I. To teach how there are several ways in which time is measured.

II. To teach that the measurement of time is dependent upon the motion of the earth with respect to the sun and celestial bodies.

Student aims:

I. To determine the time of a particular area, given the time of another area. This is done by computing the relationships between longitude and hour periods or 15 degrees of longitude.

II. To determine the calendar day when moving across the International Date Line.

III. To recognize the need for adding a full day every fourth year.

IV. To see a relationship between time and longitudinal position on the earth's surface.

Content:

I. Solar day

This is the time period from one sunrise to the

next at a specific meridian. Thus, the solar day will vary in length due to the inclination of the earth's axis.

II. Sidereal day

This is the exact time period it takes the earth to rotate on its axis; 23 hours, 56 minutes, 4.09 seconds. This day is about four minutes shorter than the solar day and is not used in ordinary life.

III. Mean solar day

Insomuch as the true solar days vary in length, an imaginary "mean" sun is used to calculate a day of average length. This mean solar day is 24 hours and is also referred to as civil time.

IV. Standard time

At any given instant, the noon sun is only on one meridian. Thus, when it is solar noon (noon is determined when the sun reaches its zenith at a given meridian) at any given place, it is a different time at any other given place. For convenience, the world is divided into 24 standard time zones, each one being divided into approximate halves by a major meridian of longitude called the central meridian. These central meridians (or standard time meridians) are 15 degrees apart (360 degrees divided by 24 hours) on the earth's surface. The time of the central meridian is by agreement the time of the entire time zone. (It is also apparent then that one hour corresponds to 15 degrees of longitude; also the sun appears to travel across 15 degrees of longitude every hour.)

V. Daylight saving time

To utilize more hours of daylight in summer, the standard time at many places is set ahead at certain times of year by one hour. Thus, each day begins and ends an hour earlier than normal.

VI. Month

A period of 28, 29, 30, or 31 mean solar days constitutes a month, depending on the specific month. The original basis for months is the 29-1/2 day cycle of the phases of the moon.

VII. Sidereal year

The time interval between two successive passages of the sun with respect to the celestial bodies characterizes the sidereal year.

VIII. Calendar year

Normally a calendar year consists simple of 365 days. But, because the sidereal year is 365-1/4 days long, every four years an extra day is inserted (February 29) in order to correlate the calendar and the stars. This adjustment also seems to correlate the calendar and the seasons.

Suggestions to the teacher:

The unit on time may be one of the hardest to convey to the students. It is very difficult for the students to grasp the concept of calendar differences as they cross the International Date Line. Thus, the author strongly suggests that the change of calendar be arbitrarily stated rather than attempting detailed explanation.

It is important that the students realize that a difference of one hour corresponds to a difference of 15 degrees of longitude. This is the basis of establishing location east and west on the earth's

surface, when the time at a known location is given.

The use of maps divided into standard time zones should be especially helpful when discussing this unit. It may also be helpful to have a globe to demonstrate how time appears to circumnavigate the earth.

It should be of considerable value to use the two films suggested in Recommendations For Further Study.

# Recommendations For Further Study

## Books:

Harrison, Lucia C. Sun, Earth, Time and Man. Chicago: Rand McNally and Co., 1960. Pp. 287.

Any of the earth science books listed under "Physical Geography" in the Selected Bibliography.

## Periodicals:

Flierl, Howard H. "A Movable Date Line Chart," Journal of Geography, LXII No. 4 (April, 1963), 175-177.

Henzl, Sister Joseph Marie. "Global Time Out," Journal of Geography, LXI No. 9 (December, 1962), 415-416.

## Films:

About Time. 55 minutes. color. Bell Telephone Company.

Latitude and Longitude and Time Zone. 13 minutes. b/w. Coronet.

## CHAPTER III

## OUTLINE (CONTINUED)

### Unit IX: Maps and Projections

Teacher aims:

I. To teach the map and globe characteristics mentioned in Chapter II, pages 17 and 18.

II. To teach that projections are means of representing the earth's spherical surface onto a flat or developable surface.

Student aims:

I. To understand how different projections serve different purposes.

II. To be able to use a contour map if contour maps will be used throughout the course.

Content:

I. Characteristics

In order to accurately represent the earth's surface, all maps should have the following characteristics:

A. Conformality

A map is conformal when a portion of the earth's surface has the same shape on the projection as it does on a globe.

B. Equal-area

A map is "equal-area" or equivalent when a portion of the earth's surface has the same area on the projection as it does on the globe when drawn to the same scale.

C. True direction

A map has true direction when a line of direction drawn on the projection will coincide with a similar line drawn on a globe.

Unfortunately, no map projection displays all three characteristics. Some projections show modifications of these characteristics, while other projections may possess one and possibly two of the desired characteristics while sacrificing the third characteristic.

II. Projections (optional)

A. The cylindrical projections

These projections are formed by projecting the geographic grid onto a cylinder wrapped around the globe and then unrolling the cylinder to a flat or developable surface. They have the following characteristics:

1. They are simple to construct.

2. The map is always rectangular and the entire globe's circumference can be shown.

3. Meridians are equidistant lines at right angles to the equator.

4. Parallels are spaced according to the projection desired.

5. A straight line will be a line of true direction.

B. The conical projections

These projections are formed by transfer from the globe to a cone. The cone is then made into a flat map. They have the following characteristics:

1. All meridians are straight lines converging to a common point at either the north or south pole, but not both.

2. Parallels are arcs of concentric circles.

3. They usually show only portions of hemisphere. They cannot show the entire globe.

C. Azimuthal or zenithal projections

These projections are formed by direct transfer from a globe to a flat surface. They have the following characteristics:

1. Any line drawn from the center point is a line of true direction.

2. All points equidistant from the center lie on a circle known as the horizon circle.

3. All straight lines drawn through the center line are true great circles.

4. Distortion is uniform concentrically from the center.

III. Methods of representing topographic relief (optional)

A. Contour lines

B. Hachures

C. Shading

D. Hypsometric or color layers

E. Raised surfaces

Suggestions to the teacher:

The best way the students can learn the use of maps is to use maps themselves. The more they are exposed to maps and their purposes, the more they will come to realize their importance in geography.

The teacher should display various projections, indicating the best uses of each, and their individual shortcomings. For example, in a given area, the stereographic projections might show shape; the mercator, directions; the gnomonic, the direction of shortest distance between any two of its points; and the sinusoidal, the area relative to its neighbors.

It would be well worth the time to read several of the articles listed in the Recommendations For Further Study. They would not only aid the teacher in better understanding the nature of projections and maps, but also would allow the teacher to give a better presentation of the material.

Many excellent films that are listed should be used.

## Recommendations For Further Study

Books:

Lobeck, Armin K. Things Maps Don't Tell Us. New York: Macmillan Co., 1957. Pp. 159.

Raisz, Erwin T. Principles of Cartography. New York: McGraw-Hill Book Co., Inc., 1962. Pp. 315.

Robinson, Arthur H. Elements of Cartography. 2nd ed. revised. New York: John Wiley and Sons, 1963. Pp. 343.

Periodicals:

Arnsdorf, Val E. "Teaching Map Reading and Geographic Understandings with Projections," Journal of Geography, LXIII No. 2 (February, 1964), 75-81.

Dahlberg, Richard E. "Maps Without Projections," Journal of Geography, LX No. 5 (May, 1961), 213-218.

Delaney, Arthur A. "Making a Contour Map Model, Journal of Geography, LXI No. 7 (October, 1962), 310-312.

Espenshade, Edward B., Jr. "Verbalization from Maps," Journal of Geography, LXV No. 1 (January, 1966), 12-18.

Hazel, Joseph A. "Most 'Good' Maps Do Not Have a Directional Symbol," Journal of Geography, LXIV No. 2 (February, 1964), 81-83.

Hirt, Howard. "Reducing Distortion: A Useful Approach in Augmenting the Understanding of Map Projections," Journal of Geography, LIX No. 7 (October, 1960), 308-314.

Kingsbury, Robert. "The World of Little Maps," Journal of Geography, LXIII No. 8 (November, 1964) 355-366.

Films:

Finding Directions with a Map. 11 minutes. color. Cenco Films.

Global Concepts in Maps. 10 minutes. b/w. Western Michigan.

Globes: An Introduction. 12 minutes. color. Audio-Visual Dept.: University of Indiana, Bloomington, Indiana.

How Far? 10 minutes. color. University of Indiana.

Introduction to Map Projections. 20 minutes. b/w. United World Films.

Maps: An Introduction. 12 minutes. color. University of Indiana.

Using Maps: Measuring Distance. 11 minutes. color. Britannica.

CHAPTER III

OUTLINE (CONTINUED)

## Unit X: Introduction To Weather And Climate[1]

Teacher aims:

I. To teach how a relationship exists between the several weather elements. Each may be interpreted separately in terms of cause and effect but all should be considered together in describing the weather at any moment and in making predictions.

II. To teach how weather elements are interrelated with climatic controls.

Student aims:

I. To have an overview of weather and climate as a study of integrated phenomena.

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[1]To enable students better to understand the characteristics of the atmosphere directly, it is suggested that the following items be acquired: maximum-minimum thermometer; sling psychrometer; barometer; rain gauge; and meteorologic slide rule.

In addition to the above instruments, copies of the daily U. S. Weather Map can be ordered from the ESSA, Washington 25, D. C. These maps will be an important part of the course.

It may also prove worthwhile to subscribe to the monthly periodical, Weatherwise, 3 Joy Street, Boston, Massachusetts.

Content:

I. Definition of weather

Weather is the expression of atmospheric conditions for a short period of time at a particular place. It is a momentary state. The weather finds expression in a sphere of air called the atmosphere.

II. Weather elements

A. Atmospheric temperature

The atmosphere is a great heat machine supplied with energy from the sun.

B. Atmospheric pressure

The pressure of air is a measure of its weight per unit area. It is controlled through density differences largely created by effects of temperature.

C. Atmospheric moisture

The ability of the air to provide moisture is a function of circulation patterns, water vapor, and temperature.

D. Storms

Storms provide the earth's surface with needed moisture. The energy needed for storm development is a complex relationship of many factors.

Suggestions to the teacher:

Ask the students why the weather is the most talked about subject in the world. Find out what the idea of weather and climate means to them.

Introduce the students to supplementary devices that will be used in this unit, especially the weather instruments and weather maps. Impress the utility of each device on the students. They should be permitted to make individual use of them.

The class should start keeping daily records of the weather. This brings the lesson home to the student in a way that nothing else does. If instruments are not available, there are several available sources of information, such as the newspaper, local television and radio, or local weather stations located in such places as airports and coast guard stations. Also, most heating oil companies keep records of the high and low temperatures recorded each 24-hour period, and sometimes each hour.

The amount of information required will depend upon the teacher and the availability of the information. If information has to be gathered from a source such as the U. S. Coast Guard, it would be wise to assign only one person each day to call for this information and have him post it on the board, rather than having the students individually responsible.

The student should start to watch at least one TV (the more comprehensive the better) weather broadcast a day. It would not be long before such terms as

high and low pressure, moving or stationary fronts will be meaningful to him.

Have each student record local weather phenomena, such as wind movement, type of clouds, amount of rain. The more information the student observes by himself, the more pertinent later discussions on weather elements will seem.

# Recommendations For Further Study

## Books:

Blair, Thomas and Fite, T. A. Weather Elements: A Text in Elementary Meteorology. 5th ed. revised. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1965. Pp. 364.

Byers, Horace R. General Meteorology. New York: McGraw-Hill Book Co., 1959. Pp. 540.

Critchfield, Howard J. General Climatology. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1960. Pp. 465.

Lehr, P. W. et al. Weather: A Guide to Phenomena and Forecasts. New York: Simon and Shuster, 1957. Pp. 160.

Trewartha, Glenn T. An Introduction to Climate. New York: McGraw-Hill Book Co., Inc., 1954. Pp. 402.

## Periodicals:

Lokke, Donald. "Meteorological History in the Teaching of Weather," Journal of Geography, LX No. 4 (April, 1961), 180-182.

## Films:

How Weather is Forecast. 11 minutes. color. Coronet.

Our Weather. 11 minutes. b/w. Coronet.

Unchained Goddess. 60 minutes. color. Bell Telephone Company.

Weather. 10 minutes. b/w. Britannica.

Weather: Why It Changes. 11 minutes. color. Coronet.

Why Is the Weather? 10 minutes. color. Barr Productions.

CHAPTER III

OUTLINE (CONTINUED)

Unit XI: The Atmosphere

Teacher aims:

I. To teach how man lives at the bottom of a vast sea of air which surrounds the earth and provides his most essential elements.

II. To teach how the earth's atmosphere is a thin shell of gases enclosing the solid and liquid earth, and how it gradually becomes less dense with increasing distance from the earth, until it disappears.

III. To teach how changes in the composition of the air can affect man profoundly.

Student aims:

I. To describe some of the significant physical properties of the atmosphere.

II. To be able to draw the vertical structure of the atmosphere and discuss the differences and significant factors of each layer.

III. To recognize that of all the elements man needs for survival, it is air that he can do without for the shortest period of time.

IV. To understand that man is discovering new evidences of upper air weather controls as he penetrates higher and higher into the atmosphere with his recording instruments.

Content:

I. Definition of atmosphere

The atmosphere is the mixture of gases surrounding the earth. The mixture varies with elevation.

II. Composition of the atmosphere

A. Dry air

The air consists of a mixture of gases that are, for the most part, invisible, colorless, odorless, and tasteless. (Nitrogen, oxygen, and carbon dioxide are the three main gases.) The percentages vary in respects to constituents at different elevations. At higher altitudes certain other gases are more abundant (e.g., hydrogen and ozone).

B. Water vapor

Water vapor is a minor constituent by volume varying from less than one per cent to almost five per cent on hot humid days. It varies greatly from place to place and from time to time. It is responsible for most of the phenomena that are commonly referred to as weather.

C. Impurities

These consist of dust, smoke, fumes, monoxides, and other gaseous industrial wastes. Although they are usually considered harmful, in minute quantities some types may serve a purpose (i.e., dust particles serve as nuclei upon which water vapor may condense to form raindrops).

III. Zones (layers) of the atmosphere (optional)

A. The troposphere

This is the layer within which most of the

weather occurs, and about which most is known. It is:

1. found from the surface to about 8-10 miles,

2. composed of nitrogen, oxygen, and water vapor, gases in proportions of 78, 18, 1 to 4 respectively,

3. a zone of decreasing temperature with increasing altitude (at about 3.5°/ 1000'),

4. a zone of cumulus clouds and most stratiform clouds.

B. The stratosphere

In this zone there is a degree of control of surface weather due to such phenomena as the jet stream. It is:

1. at an elevation of from 8 to 30 miles,

2. a zone of greatest ozone ($O_3$) concentration,

3. a zone of slightly increasing temperatures with increasing altitude (to 50°F),

4. a zone of cirrus and nacreous clouds.

C. The mesophere

This is the region in which the temperature generally decreases with heigth. It is:

1. at an altitude from 40-55 miles,

2. a zone of weak ionized gases,

3. a zone of decreasing temperatures with altitude (to 105°F),

4. a zone of noctilucent clouds and the Aurora Borealis.

D. The thermosphere

This is the zone of increasing temperatures. It is:

1. at an altitude 55-400 miles,
2. a zone of ionized oxygen and nitrogen
3. where temperature may reach 2,500°F,
4. a zone of Aurora Borealis and meteors.

E. The exosphere

Very little is known about this layer. It merges with outer space. Hence, no description is given here.

Suggestions to the teacher:

The students should already have some knowledge of the atmosphere. Study of the composition of the atmosphere will be important for later parts dealing with weather and climate. Therefore, students should master it thoroughly now. Water vapor, in particular, should be thoroughly understood. The optional section on zones is more in the realm of meteorology.

# Recommendations For Further Study

## Books:

Blumenstock, D. I. The Ocean of Air. New Brunswick, New Jersey: Rutgers University Press, 1959. Pp. 457.

Cook, James G. Our Astonishing Atmosphere. New York: Dial Press, 1957. Pp. 200.

Hare, F. Kenneth. The Restless Atmosphere. London: Hutchinson and Co., 1961. or New York: Harper and Row Publishers, 1963. Pp. 192.

Ratcliffe, John A. (ed.) Physics of the Upper Atmosphere. New York: Academic Press, 1960. Pp. 586.

Reiter, Elmar. Jet Stream Meteorology. Chicago: University of Chicago Press, 1961. Pp. 515.

Sutton, Oliver G. The Challenge of the Atmosphere. New York: Harper and Row, Inc., 1961. Pp. 227.

## Periodicals:

Hare, F. Kenneth. "The Westerlies," Geographical Review, L (July, 1960), 345-367.

Hare, F. Kenneth. "The Stratosphere" Geographical Review, LII (October, 1962), 525-547.

## CHAPTER III

## OUTLINE (CONTINUED)

### Unit XII: Atmospheric Temperature

Teacher aims:

I. To teach how the sun provides the main source of heat and of practically all energy for the earth.

II. To teach that the sun's energy is received by the earth in the form of short electromagnetic waves.

III. To teach that solar insolation is balanced by radiation of heat to outer space, in the form of longer waves.

IV. To teach how temperature is a measure of molecular action.

V. To teach that air movement often results in a change of compression and expansion and subsequent convergence and divergence.

VI. To teach that the density of cold air is greater than that of warm air, thus cold air will generally subside while warmer air will generally rise.

VII. To teach that the land surface heats and cools much more rapidly than a water body.

Student aims:

I. To identify some of the forces that produce movement within the atmosphere.

II. To understand the relationship between changes in temperatures and resultant pressure differences.

III. To understand the relationship between a warm earth surface and warm air above it, and a cool surface and cool air above it.

IV. To realize the effect of earth heating on the atmosphere, seen in the decrease of air temperature as distance from the earth's surface increases.

V. To recognize that the stratosphere must be heated from sources other than the earth's surface if it is to increase in temperature as the altitude increases.

VI. To distinguish between the adiabatic rate and lapse rate.

VII. To know why seasonal changes are greatest at the middle latitudes and least at the low and high latitudes.

Content:

I. Solar insolation

The earth's atmosphere and surface are heated mainly by radiant energy received from the sun. The amount of solar radiation is dependent upon two fundamental factors:

A. Angle of sun's rays

The greatest intensity of insolation exists when the sun's rays strike vertically. With diminishing angles of incidence, the same amount of solar energy is spread over

a greater ground surface. As a result of the inclination of the earth's axis, there is a great seasonal difference in solar radiation.

B. Length of time

Length of time varies with season; further, it varies with cloud cover.

II. Warming of the atmosphere

There are four major ways in which the atmosphere is warmed:

A. Radiation

The earth's atmosphere acts as a gigantic greenhouse. Large quantities of solar radiation are transmitted to the earth's surface in the form of short electromagnetic waves. The earth in turn re-radiates energy in the form of long heat waves. The atmosphere is transparent to the short waves, but it absorbs the radiant heat energy.

B. Compression

When a quantity of air descends from higher to lower altitudes, it is subjected to greater pressures caused by the ever-increasing weight of the atmosphere above it; and is thus compressed. As a result of compression, the temperature of the air is increased.

C. Importation of warm air masses

The importation of warm air masses from outside results in temperature increases.

D. Conduction

Conduction warming occurs when cooler air comes in contact with a warmer substance such as cool air off a water body passing over a warmer land mass.

III. Cooling of the atmosphere

This is achieved by the following several processes:

A. Radiation

Cooling by radiation occurs in three different ways, as follows:

1. Radiation outward

This is especially pronounced during nights when there is little cloud cover to absorb or reflect the heat radiating back toward the earth's surface.

2. Radiation earthward

This occurs on cool or cold nights when the ground surface cools more rapidly than the air above it; the air then radiates into the ground to warm it.

3. Radiation via water bodies

This occurs when the water is cooler than the air above, so that the air radiates heat into the water; this action may be increased by circulation of the water which constantly brings colder water to the surface.

B. Evaporation

This occurs when water droplets in the air or water surfaces on the ground evaporate and heat is removed from the atmosphere.

C. Expansion

This occurs when a quantity of air rises from lower to higher altitudes and the atmospheric pressure decreases, allowing the air to expand; this expansion results in a cooling process.

D. Importation of cold air masses

This occurs when the importation of cold air from outside causes temperature decreases.

IV. Vertical temperature changes

Vertical temperature changes occur in the following ways:

A. Adiabatic cooling and heating

Adiabatic heating or cooling resulting from pressure change is a physical law of behavior. There are two rates which must be considered:

1. Dry adiabatic rate

As air rises, it expands and decreases in density, thus decreasing the intensity of molecular action. Rising dry air normally cools at the average rate of 5-1/2 degrees per thousand feet. This is called the dry adiabatic rate of cooling. The reverse occurs when air descends. The air is then warmed at the rate of 5-1/2 degrees per thousand feet. This is called the dry adiabatic rate of warming. (Note: an adiabatic change in temperature occurs without external heat actually being added or subtracted.

2. Wet adiabatic rate

Often as the air rises it cools to the point where condensation occurs. This produces latent heat of condensation; thus the adiabatic rate is no longer 5-1/2 degrees per thousand feet. The new rate of cooling is called the wet adiabatic rate, and it depends upon several factors. But in no case can it be as great or greater than the dry adiabatic rate.

B. Lapse rates

Temperature normally decreases because of expansion as the altitude increases. The amount of decrease varies from place to place and season to season. On the average, the decrease in air temperature is about 3-1/2 degrees per thousand feet. This is called the normal lapse rate. The air will also increase in temperature because of compression as one descends at the normal lapse rate. Notice: This is a change in temperature actually indicated by a thermometer carried upward or downward through the air. The lapse rate is a state of being, not a law. This normal lapse rate continues to between 35,000 and 40,000 feet. Above this, the temperature remains constant or rises with increasing altitude.

C. Temperature inversion

This is a condition of the lapse rate which occurs when the surface air is cooler than the air above it. Conditions conducive to this phenomenon are:

1. clear nights
2. cold air
3. still air
4. snow-covered ground

V. Horizontal temperature distributions

A study of temperature distributions throughout the world reveals the following general features:

A. Temperature extremes

The highest average annual temperatures are located in the low latitudes. The lowest average annual temperatures are in the high latitudes. This is a function of solar insolation.

B. Isotherms

Isotherms are lines of equal temperature. The following characteristics apply to them:

1. They are straighter and more widely spaced in the southern hemisphere, reflecting the greater percentage of water surface there.

2. They generally have an east-west orientation indicating that latitude is the primary factor in temperature distribution.

3. The greatest variation of the isotherms from an east-west orientation are the discontinuities caused by land-water surfaces. Land-water contrast ranks directly behind altitude as a climatic control.

VI. Seasonal temperature changes

Throughout most of the world, January and July are the months of greatest seasonal temperature extremes. Isotherm maps of mean temperature distributions reveal the following general features:

A. The isotherms follow the sun's vertical rays. A northern-hemisphere isotherm tends to have a more northerly location in July than in January because of the greater amount of solar radiation during the summer.

B. The isotherms shift more over land surfaces than water surfaces, indicating that land heats and cools more rapidly, and to a greater degree, than water.

C. The areas of highest and lowest temperatures are land areas.

D. There is less land-water temperature contrast in the southern hemisphere due to the relative absence of large land masses, and the presence of large water bodies.

E. Sub-tropical and mid-latitude land areas display higher average temperatures in summer than equatorial areas. This results from the longer daylight periods; days are always about 12 hours in length near the equator.

Suggestions to the teacher:

The student should be made to understand that the atmosphere is a great heat machine having important physical and fluid properties. It may be difficult for all students to understand that this transfer of energy is accomplished in several different ways. There are a variety of methods to help explain these principles.

Solar insolation could be explained by relating it to everyday experiences. Many students realize that the best sun tans are usually achieved during the mid-day hours and not late in the afternoon, even though the temperature may then be quite warm. An easy experiment to explain this would be to darken the classroom and shine a flashlight directly at the board, and then mark off the area illuminated. Next, move the flashlight to an angle without changing its distance to the board; again mark off the bright spot. It will, of course, be larger. There is still the same amount of light emanating from the flashlight, but it is distributed over a greater area; thus the light at any point

is less intense. A further discussion question could be to explain why, if the angle of the sun's rays is all-important, one would receive a sun tan in the winter if he could receive the rays of the sun at nearly a vertical angle. Many other examples of this principle exist, such as wide overhangs which block the sun's rays in summer, but are not low enough to block the low angle sun's rays in winter; different clothing colors, etc. All this could be presented in discussion to show how we should try to take full advantage of solar insolation, and to attempt to prevent it from providing excess warmth.

Have the students work out some mathematical problems involving lapse rates and adiabatic rates. Here is just one example: if air approaches the western slopes of the Rockies with an air temperature of 50 degrees at an elevation of 8,000 feet and is forced up the slopes of the mountains to a height of 15,000 feet, and then descends to 5,000 feet on the eastern slopes--what is the temperature at the eastern foot of the Rockies? (Answer: 66-1/2 degrees F.) Thus, the air on the eastern slopes is warmer than it was on the western slopes. As there was no heat added, it must have been warmed by compression. The problem could be increased in difficulty by introducing

condensation--i.e., if the same air mass cools to saturation at 11,000 feet, and the wet adiabatic rate is four degrees per 1000 feet, then what is the air temperature at the eastern foot? In this case the descending air (from 15,000 feet) warms at a rate of 5-1/2 degrees per thousand feet (the dry adiabatic rate) to a temperature of 72-1/2 degrees at 5,000 feet. Make sure the student realizes the difference between the normal lapse rate and the adiabatic rate.

The students should become aware of temperature contrasts at similar latitudes. There is a reason for each deviation of an isotherm from the norm. It should be obvious that isotherms bend in proximity to water bodies and continental locations. Have the students select an isotherm and follow it across the maps, determining what causes it to fluctuate from an east-west trend. Then select a particular latitude and follow that latitude across the map, noting the temperature differences. Cold and warm ocean currents should soon become readily recognizable.

It is likely that most students have been near Lake Michigan or some other large body of water. Discuss with them what temperature changes are likely to result from shore and inland locations in both winter

and summer. Have them then try to deduce why the east side of Lake Michigan, but not the west, is a large fruit-producing area.

Temperature inversions are difficult to understand fully. However, they are very significant. The author would suggest time be spent on description and personal experiences rather than intensive study. The killer fogs of London, the smog of Los Angeles, and radiation fogs around Michigan should capture the imagination of most students. Economic repercussions of such fogs are staggering. Topics such as these make physical geography a living subject; use them whenever possible.

# Recommendations For Further Study

Books:

Budyko, M. I. The Heat Balance of the Earth's Surface. Washington: U. S. Weather Bureau, 1958. Pp. 259.

Periodicals:

Glowacki, Walter. "Visualizing the Sun Angle at Various Latitudes," Journal of Geography, LXIV No. 9 (December, 1965), 396-397.

Films:

Our Mr. Sun. 68 minutes. color. Bell Telephone Company.

Our Nearest Star. 27 minutes. color. Western Michigan.

Solar Radiation: Sun and Earth. 20 minutes. color. American Meteorological Society.

Strange Case of the Cosmic Ray. 60 minutes. color. Bell Telephone Company.

## CHAPTER III

## OUTLINE (CONTINUED)

### Unit XIII: Atmospheric Pressure and Winds

Teacher aims:

I. To teach that major weather systems and global wind patterns are interrelated.

II. To teach that air movement near the earth's surface is greatly affected by the rotation of the earth.

III. To teach that the most important function of air movement is to transport water vapor from the oceans to the land.

Student aims:

I. To identify the main forces that cause atmospheric movement.

II. To relate some properties of circulation patterns to his own environment.

III. To understand the relationship between the main pressure belts and their relation to the planetary winds.

IV. To realize that not only does the Coriolis force cause winds to deflect, but also other objects such as speeding bullets, airplanes, guided missiles, wood floating in streams, tossed baseballs, and many more are subject to its effect.

Content:

I. Air pressure and air motions

A. The primary force

The sun is the basic source of all air movement. It provides heat and creates temperature inequalities over the earth's surface. These temperature contrasts result in air density differences which in turn produce air motion resulting from the pressure differences. Vertical air movement is called an air current.

1. Low pressure

Air that is rising and converging exerts less pressure on the earth's surface and is called low pressure.

2. High pressure

Air that is subsiding and divergent exerts greater pressure on the earth's surface and is called high pressure.

3. Wind and the pressure gradient

Air normally moves from a high pressure into a low pressure horizontally over the earth's surface. This horizontal movement of air is called wind. The greater the pressure differences between high and low pressure centers, the greater the wind force. The degree of contrast and direction of pressure difference is called the pressure gradient. The pressure gradient is indicated on weather maps by the spacing of isobars, lines joining points of equal pressure.

B. The Coriolis force (the turning force)

The Coriolis force results from the earth's rotation; moving air is deflected to the

right in the northern hemisphere and to the left in the southern hemisphere. Observation of a daily weather map will show that air does not flow directly from high pressure to low pressure at right angles to the isobars, but rather at an oblique angle to the isobars. As a result, within a high-pressure cell, internal air circulation tends to move clockwise in the northern hemisphere and counter-clockwise in the southern hemisphere. Within a low-pressure cell air circulation will tend to move counter-clockwise in the northern hemisphere and clockwise in the southern hemisphere.

C. The frictional force

Wind continues to increase in force once it has been started by the pressure gradient. Surface friction retards this acceleration until a balance is achieved and the wind is steady. Friction also prevents the wind from blowing parallel to the isobars as would normally be expected from the Coriolis force. (Above 3,000 feet the movement of the wind parallel to the isobars is the prevalent condition.)

II. Wind systems

On a global scale heat differences, the Coriolis deflection, and centrifugal force have created a large-scale system of essentially parallel pressure centers and associated large-scale wind systems. Local temperature and pressure differences create air movements that are affected by the same forces. Thus, migrating pressure systems have internal circulatory details comparable with the planetary system.

A. Planetary winds

The large-scale winds of the lower atmosphere are determined by temperature differences and set up by a rotating planet. They include the following winds:

1. the Doldrums or Equatorial Belt Variable Winds and Calms,

2. the South-East and North-East Trade Winds,

3. the Subtropical Belt of Variable Winds and Calms or Horse Latitude,

4. the Westerlies (or storms),

5. and the Polar Easterlies.

Note: There exists considerable disagreement among meteorologists and climatologists as to the causes of the general atmospheric circulation patterns. There appears to be mounting evidence that the simple heat exchange theory is complicated by dynamic processes in the upper atmosphere. There also exists doubt as to whether a belt of Polar easterlies truly exists at the surface level.

B. Modified terrestrial winds

Temperature and pressure differences, physican barriers, and land-water contrasts are the main contributors to "special winds." Some of the more important are:

1. Cyclonic storms

2. Monsoon - seasonal and daily

3. Local - topographic and Foehn

4. Land-sea breezes

5. Mountain-valley breezes

III. Wind direction and velocity

Wind direction generally foretells approaching weather over most of the United States. The prevailing direction of the winds over short periods of time generally indicates conditions of temperature and amount of water vapor. Velocity will vary greatly with distance above

the surface, and it changes rapidly at the surface because of friction and physical obstacles. Windward refers to the direction from which the wind blows and leeward the direction to which it blows. A prevailing wind is a wind which blows from one direction more than any other direction over a specified period of time.

Suggestions to the teacher:

The daily weather maps should be of interest to most students. Especially emphasize the map of the 500 mb. level to show how these air flow patterns do not correspond to the surface patterns, but are largely responsible for the major surface weather. (This circulation map shows the jet stream.)

The students should analyze a low and high pressure system on the weather map and notice the characteristics of weather surrounding the pressure center.

Students could construct a wind indicator as follows:

1) Bore a hole through a cork from top to bottom large enough to accept a glass tube which will be used as a bearing;

2) drill another small hole at right angles to the previous just large enough to insert the end of a chicken or pigeon feather;

3) pound a finishing nail into a block of wood, clip off the head of the nail and insert the glass tube with the closed end up, over which the cork and feather assembly has been placed.

This weather vane would be sensitive enough to point in the direction of a stream of cold air that spills out of a refrigerator door when opened.

Ensure that the students understand that a monsoon is a seasonal wind and is not the precipitation that usually accompanies it.

It is essential that the students understand the general planetary wind circulation. Although the latitudes vary somewhat depending upon the season, a general rule to learn would be: zero to 30 degrees are the easterlies, 30 to 60 degrees are the westerlies, and 60 to 90 degrees are the polar easterlies. Thus, in the United States, the windward side of the Rockies is the west side, but in Mexico, the windward side of the Sierra Madre is the east side. It is impossible to understand climatic patterns without knowledge of prevailing wind directions.

For an additional discussion topic, ask why the polar regions do not get progressively colder and the tropical regions do not get progressively warmer if these are regions of net heat loss and net heat gain respectively.

# Recommendations For Further Study

## Books:

Any of the books listed under "Physical Geography" dealing with "weather and climate."

## Periodicals:

James, Preston. "A New Concept in Atmospheric Circulation," Journal of Geography, LXIII No. 6 (September, 1964), 245.

## Films:

Air and What It Does. 11 minutes. color. Britannica.

The Atmosphere and Its Circulation. (Ocean of Air - Part 1). 11 minutes. b/w. Britannica.

Blow Wind Blow. 11 minutes. b/w. Coronet.

Great Winds (Distribution of Pressure and Winds). 10 minutes. color. United World Films.

Great Winds (General Circulation). 10 minutes. color. United World Films.

Unchained Goddess. 60 minutes. color. Bell Telephone Company.

Winds and Their Causes. 10 minutes. b/w. Coronet.

CHAPTER III

OUTLINE (CONTINUED)

## Unit XIV: Atmospheric Moisture, Clouds, and Precipitation

Teacher aims:

I. To teach how solar radiation is absorbed and transformed to molecular energy, which is transferred from the interface by conduction, radiation and convection, and stored by evaporation.

II. To teach that energy and matter may move in either direction across the surface-atmosphere interface at different periods of time.

III. To teach that the motion systems of the atmosphere, both vertical and horizontal, are important for transporting, condensing, and precipitating moisture.

IV. To teach how the amount of water vapor in the air is directly related to condensation and precipitation possibilities, regulation of earth temperature, energy for storm production, and sensible temperature.

Student aims:

I. To apply concepts previously learned to the general case of the earth's surface-atmosphere interface.

II. To relate information on movement and storage of water to the concept of worldwide flow of water vapor into which additional vapor is fed

from the surface and from which it is subtracted as precipitation.

III. To understand that the ability to hold water vapor varies with the temperature; therefore, high relative humidity does not always mean high water vapor content, nor vice versa.

IV. To understand that the higher the dew point reading, the greater the quantity of water vapor present in the air. (This is all-important in the potential for precipitation and in the physiological effects upon humans.)

V. To understand that the effect of rainfall is directly related to temperature; ten inches of rainfall in the Arctic is certainly more effective than ten inches of rainfall in the Sahara Desert.

VI. To distinguish between relative and specific humidity.

VII. To identify a variety of visible forms of moisture in the air and the process that produces them.

VIII. To recognize on a weather map the causes of large areas of precipitation.

IX. To identify cloud types as seen in the skies and to predict what weather patterns might be expected.

Content:

I. Atmospheric moisture

A. Source

The basic source of all water vapor is the oceans. Once moisture has been distributed over the surface, secondary sources of moisture such as vegetation, lakes and rivers, and moist land surfaces contribute to atmospheric moisture.

B. Amount

The capacity of the air to hold moisture varies with the air temperature. Warm air has a greater storage capacity than does cold air. The amount of water vapor in the air is called humidity. When the atmosphere is holding all the water vapor possible at that particular temperature, the air is then said to be saturated. There are several different methods of measuring humidity:

1. absolute humidity--the actual amount of water vapor in the air measured in grains per cubic foot,

2. relative humidity--this is a percentage of water vapor between the absolute humidity and the potential capacity at the same temperature,

3. and specific humidity--the weight of water vapor per unit volume of air.

II. Condensation

Condensation results when the air becomes saturated. This may be accomplished by adding water or by cooling the air. Air may be cooled: by radiation (especially at night); by rising to higher levels; or by mixing of two unlike air masses. The water vapor then forms around microscopic nuclei of dust such as salt from the oceans, soot from chimneys, or carbon from exhausts. There are several types of condensation; the most prominent are:

A. Fog

Most fogs result from a cooling process that does not involve a rising of air, but rather arises from radiation, conduction, and mixing of warm and cold air masses. Usually it is the result of air being cooled below the dew point (temperature at which condensation will occur), but occasionally fog is caused by the addition of water vapor until the saturation point is achieved. The most

common types of fogs are:

1. Radiation fogs

2. high-inversion fogs

3. advection-radiation fogs

4. frontal fogs

B. Dew

Dew results when water vapor condenses on the surface and the temperature is above freezing. The water vapor is provided by the vegetative cover, and the cooling effect is provided by loss of heat radiating from the vegetative cover.

C. Frost

The conditions for frost are similar to those for dew, only in this case the temperature falls below freezing.

D. Clouds

Clouds result from the formation of millions of microscopic water drops or ice crystals in the atmosphere, usually considerably above the ground. There are two ways of classifying clouds:

1. Structure

    a) cumuliform (clouds of vertical structure)

    b) stratiform (clouds of horizontal structure)

2. Elevation

    a) low clouds, below 8,000 feet--stratocumulus, nimbostratus, and stratus

b) medium clouds, 8,000 to 15,000 feet--altocumulus, altostratus, cumulus, and cumulonimbus

c) high clouds, 15,000 feet and above--cirrus, cirrostratus, cirrocumulus, and cumulonimbus

III. Precipitation forms

Precipitation follows condensation. After water vapor condenses on microscopic nuclei of dust, the droplets then formed may begin to coalesce. They thereby become too heavy to remain afloat, i.e., the cloud becomes unstable, and precipitation occurs. There are several forms of precipitation:

A. Rain

Separate water drops that fall from clouds are called rain.

B. Snow

Snow is formed directly from condensation of water vapor at temperatures below the freezing point. It takes the form of individual crystals or an amalgamation of a number of crystals. Often precipitation begins as snow but warms on the way to the surface and becomes rain. Note: Snow is <u>not</u> frozen rain.

C. Hail

Hail consists of concentric layers of ice and/or snow. It results from vigorous convectional currents that throw raindrops high into a layer of air below freezing, then keep returning it to this layer, allowing the hailstones to grow until their weight can no longer be supported. They then fall to the surface.

D. Sleet

Sleet is frozen or partly frozen rain. It results when raindrops from a warmer air

mass aloft fall through a layer of air below freezing.

E. Glaze

Glaze is not a true form of precipitation. It is the result of near-freezing rain striking objects that are below freezing, producing a surface of ice. It may also be caused by super-cooled raindrops striking a solid surface and immediately freezing.

IV. Precipitation types

There are three essential ingredients needed for precipitation: water vapor, cloud dust, and a cooling effect. The cooling effect is usually produced by mass uplifting of the air lowering the temperature until dew point is achieved. There are three primary ways in which air is cooled to its dew point:

A. Convectional precipitation

Surface heating causes the surface air to expand and thus rise. Since the adiabatic lapse rate is nearly double that of the normal lapse rate, the air will normally rise a few thousand feet before it achieves temperature equilibrium with the surrounding air. However, during this rise the temperature may have been lowered to dew point and precipitation will occur. It is usually associated with the warm seasons and the rain falls as showers or thundershowers.

B. Orographic precipitation

Air is forced to rise because of some physical barrier such as mountain ranges, plateaus, escarpments, or hills. Orographic rainfall may produce very heavy rainfall where the air already contains abundant quantities of water vapor.

C. Cyclonic precipitation

Cyclonic precipitation is associated with the movements of low pressure centers (troughs);

the cooling effect is produced by warm moist air being forced aloft over colder air of greater density. Cyclonic rainfall is usually associated with the middle latitutdes and is the predominate form of precipitation in the cool season.

V. Precipitation characteristics

There are several factors that should always be considered when analyzing a rainfall regime (or characteristic precipitation pattern). They are:

A. The total amount for the year,

B. its seasonal distribution,

C. its dependability; seasonally and annually,

D. and its efficiency coefficient.

Suggestions to the teacher:

Again emphasis should be placed upon student participation. They should already be keeping a climatological weather chart. Now they could add cloud types, and the type of precipitation that occurs (convectional, orographic, or cyclonic) to their record.

The student should view the earth's surface as an interface. Have him attempt to visualize the earth's surface as if he were seeing it from a space platform. It will make it easier for him to explain the transfers of energy and matter.

Considerable time might be spent discussing relative humidity. Be sure that the students realize that

(for constant water-vapor) when temperature goes up, relative humidity goes down. Also, relative humidity is lowered when the temperature is raised, and the warmer air is able to evaporate much more water; thus absolute himidity might increase.

On the daily weather map there are a number of weather symbols that identify the water vapor content. Study the dew point readings. These should be compared with the air temperature readings to establish the relative humidity; also they should be translated into water vapor content as a measurement of potential. Both of these measurements could be applied to an analysis of the characteristics of the several types of air masses. Study of changes in dew point readings at a particular station during successive days could then be interpreted.

The weather map should also be studied for cloud cover and types to compare with the observations that are kept in class.

## Recommendations For Further Study

Books:

Ludlam, F. H. and Scorer, R. S. Cloud Study. New York: The Macmillan Co., Inc., 1957. Pp. 80.

Any of the Physical Geography or Weather and Climate books listed under "Physical Geography" in the Selected Bibliography.

Periodicals:

Holzman, B. "Sources of Moisture for Precipitation in the United States," Technical Bulletin 589, 1937.

Lokke, Donald. "Teaching Clouds and Weather by Using a Shadow Box," Journal of Geography, LXI No. 4 (April, 1962), 169-170.

Films:

Clouds. 10 minutes. b/w. U. S. Department of Agriculture.

Clouds and Weather. 6 minutes. b/w. U. S. Department of Agriculture.

Convective Clouds. 20 minutes. color. American Meteorological Society.

The Formation of Raindrops. 20 minutes. color. American Meteorological Society.

Ocean-Air Surface Interactions. 20 minutes. b/w. American Meteorological Society.

Unchained Goddess. 60 minutes. color. Bell Telephone Company.

Water in the Air. 14 minutes. color. Cenco Educational Films.

Weather: Understanding Precipitation. 11 minutes. color. Coronet.

What Makes Rain. 11 minutes. b/w. Young America.

CHAPTER III

OUTLINE (CONTINUED)

Unit XV: Air Mass Analysis and Cyclonic Storms

Teacher aims:

I. To teach that storms are the principal producers of precipitation in the middle latitudes.

II. To teach how particular storm types are associated with latitudinal belts.

III. To teach how cyclonic weather disturbances move from west to east.

IV. To teach that some types of storms contain great energy and are potential sources of destruction and loss of life.

V. To teach how a knowledge of synoptic meteorology is necessary for the weather forecaster to accurately predict the weather.

Student aims:

I. To realize that it takes more than air blowing moisture-laden winds off the ocean to produce precipitation.

II. To predict the change in weather characteristics when a cyclone and anticyclone are known to pass through the region.

III. To understand why the presence of cyclones does not always mean that precipitation is going to occur.

IV. To recognize that most of the precipitation in the Midwest in the spring is of the cyclonic type, while the anticyclonic type usually occurs in the fall.

V. To recognize the relationship between the movement of air masses and the planetary winds.

VI. To know what conditions are likely to produce a warm, hot or moist summer and what are necessary to produce a cool, dry summer.

VII. To understand why it is necessary to determine the origin of air masses in order to predict local weather.

VIII. To realize that the passing phase of a cyclone with its cool northwesterly winds coincides with the cool northwesterly winds at the front of an anticyclone.

IX. To recall why the circulation patterns of the southern hemisphere are just opposite those of the northern hemisphere.

X. To know and recognize under what conditions a tornado would be likely to occur.

Content:

I. Air masses

These are considered to be a large mass of air that have been over a uniform surface long enough to acquire definite identifiable characteristics of temperature, water vapor content, and pressure. The movement of air masses and the interaction between different air masses produce weather variations.

A. Classification of air masses

The areas where air masses originate are called source regions. There are three major source regions, with their associated air mass types, and the proper identification symbols:

1. Geographical sources

   a) Equatorial latitudes--(E) equatorial

   b) Tropical latitudes--(T) tropical

   c) Polar latitudes--(P) polar, and (A) arctic or antarctic

2. Land and water sources

   The air masses are further qualified as to source regions by being subdivided into:

   a) Land surfaces (C) continental

   b) Water surfaces (M) marine

3. High air sources

   The air masses can be yet further refined by qualifying as:

   a) Cold air aloft (k) cold

   b) Warm air aloft (w) warm

B. The meeting of air masses along fronts

A front is a surface of separation between unlike air masses extending to the earth's surface. It is generally produced by the horizontal meeting of two air masses from different source regions, e.g., polar and tropical. A surface of relative discontinuity is formed where they meet; the warm air, being lighter than the cold air, usually ascends this frontal surface.

II. Cyclones and anticyclones

Cyclones and anticyclones are pressure areas that tend to move in an easterly direction across the earth's surface.

A. Cyclones

A cyclone is, by definition, a low-pressure center. It should NOT be regarded as synonymous with a tornado. A cyclone is a low-pressure area, possibly encompassing thousands of square miles, with the lowest pressure at its center.

The counter-clockwise winds in the Northern Hemisphere tend to converge and blow toward the center of the vortex with the warmer air being forced aloft. The rising air may then cool to its dew point and condense into clouds and result in precipitation. The counter-clockwise rotation results in easterly winds to the east (or front) of the center. Southeast and south winds will blow in the southeast quadrant of the cyclone and northwest winds tend to blow in the northwest quadrant of the cyclone. In the United States, south and southeasterly winds are usually warm and moist coming from the Gulf of Mexico, whereas north and northwesterly winds are usually cool and dry. Thus, a cyclone passes through an area and a wind-shift (with an accompanying drop in temperature) is likely to occur.

B. Anticyclones

An anticyclone is, by definition, a high-pressure area with the highest pressures at the center of the vortex. The clockwise winds (in the Northern Hemisphere) tend to diverge and blow out from the center. The subsiding air is thus heated by compression and therefore limits precipitation possibilities.

The clockwise rotation results in westerly winds east of the anticyclone's center and easterly winds to the west. Thus, as an anticyclone passes through an area, a wind-shift is likely to occur, with an accompanying temperature change.

C. Cyclonic storm paths and effects

The following descriptions characterize cyclonic movements and their consequences:

1. Cyclones move from west to east across the United States.

2. Cyclones tend to follow specific storm paths at certain seasons.

3. Cyclones usually cross the United States in three to five days in winter, and in seven to nine days in summer.

4. Cyclones are usually more energetic in winter than in summer.

5. Violent atmospheric disturbances are likely to occur along the cold front or wind-shift line of a cyclone as it changes from east to west.

6. As the cyclone center passes through an area the temperature will drop in relation to the temperature differences with the anticyclone that is to the west.

7. The change in temperature is usually greater when the storm center passes north of the observer.

III. Storms of great intensity

The origins and causes of violent storms are not yet fully understood. They usually occur between spring and autumn in the Northern Hemisphere. There are three types of common violent storms:

A. Tornadoes

A tornado has the distinction of being the most violent and destructive of all cyclonic storms. In the Northern Hemisphere, it is a violent counter-clockwise circulation within the cyclone and generally moves from the southwest to the northeast.

There is a funnel cloud consisting of dust and debris attached to the cumulonimbus source cloud. The funnel varies in diameter from 300 to 1500 feet and may contain winds with velocities in excess of 600 miles per hour. Note: When a tornado occurs over water it is called a waterspout.

B. Tropical cyclonic storms (hurricanes or typhoons)

A hurricane (so called in the Atlantic) is called a typhoon in the Pacific, and is an extreme low-pressure storm with accompanying winds of great velocities exceeding 150 miles per hour. The hurricane usually originates in subtropical latitudes. Its diameter is much larger than that of a tornado, ranging from 200 to 600 miles. Very heavy rainfall usually accompanies the winds. A characteristic of a hurricane is the eye--or center of the low pressure--which is devoid of wind and precipitation, and is clear of clouds. Also characteristic is the wind-reversal effect which is a complete change of wind direction occurring when the eye of the storm passes through an area.

C. Thunderstorms

These are violent storms, not always of cyclonic origin, usually occurring in summer and resulting from rapid uplift of air. Such storms are characterized by heavy rainfall, lightning, and thunder, produced in tall, thick cumuloform clouds called thunderheads. Types of thunderstorms include:

1. Local or heat storms

These are produced by intense heating of surface air, causing it to become extremely light and unstable. At a certain point it rises rapidly, thus setting off the storm.

2. Orographic storms

These are set off by unstable air being forced aloft initially by some elevated land obstacle.

3. Frontal type storms

These are classified as cold-front, or warm-front, depending on which front over-rides the other.

a) warm-front storms

These prevail in the springtime and are GENERALLY characterized by:

i) light and steady precipitation lasting up to several days,

ii) winds becoming gentle with the wind-shift, and temperature changes occurring gradually,

iii) and skies tending to be overcast, with stratiform clouds lasting for days.

b) cold-front storms

These prevail in the autumn and are GENERALLY characterized by:

i) precipitation usually occurring in shower form and being of shorter duration than in warm-front storms,

ii) winds tending to be strong and gusty as the anticyclone approaches; the temperature changes may be abrupt and severe,

iii) and the skies tending to clear after the showers and to remain relatively clear until the approach of another cyclone.

Suggestions to the teacher:

This might be an excellent time to have someone with meteorological experience and knowledge visit the class. Some student's father may have had experience with this field in the military service.

This might also be a good time to assign individual research on a particular topic, such as a storm type or an air mass. The students should work on some project requiring some individual interpretation and projection.

It could be recalled that Michigan has had some unusual weather the past two summers and winters. The warm winter of 1965-66, and following very cool and damaging spring, are just two examples that might be used to arouse student interest. Remind them thus that very few things affect them as directly as does the weather.

Although the author has not included a study of specific air masses in his outline, it would be a good idea, if time permits, to make a blackboard chart determining the origin of the various air masses found on the weather chart during all seasons of the year. The author feels that time spent learning all the symbols and their characteristics would be beyond the

scope of this course. However, a general understanding of the relation between the source region and the local weather is a concept easily learned and long remembered.

Although the students may not realize it, they have all experienced the passing of a front. All of us have felt the wind switch accompanied by a rapid drop in temperature. Personal experiences would be willingly vocalized once an interesting discussion has begun.

The author has not included much material on fronts, especially occluded fronts. It is presently a matter of conjecture as to just how much emphasis should be placed upon frontolysis as a generator of precipitation. This is very difficult for the student to understand. Further understanding on this subject may be safely left to individual research and/or subsequent study in an advanced course.

# Recommendations For Further Study

Books:

Fisher, Robert. How To Know and Predict Weather. New York: Harper and Brothers, Inc., 1951. Pp. 167.

Flora, Snowden D. Tornadoes of the United States. Norman: University of Oklahoma Press, 1953. Pp. 221.

Stewart, George R. Storm. New York: Modern Library, 1947. Pp. 349.

Films:

Air Masses and Fronts. 20 minutes. color. U. S. Navy.

Great Winds. 10 minutes. color. U. S. Navy.

Operation Hurricane. 15 minutes. ?? U. S. Weather Bureau.

Storm Called Maria. 48 minutes. b/w. Western Michigan.

Story of a Storm. 10 minutes. color. Coronet.

Thunderstorm. 39 minutes. b/w. U. S. Navy.

Tornado. 15 minutes. b/w. U. S. Weather Bureau.

When Air Masses Meet. 13 minutes. color. Cenco Educational Films.

CHAPTER III

OUTLINE (CONTINUED)

Unit XVI: Climatic Regions

Teacher aims:

I. To teach that climate is the most important element of the natural environment controlling man's use of the earth.

II. To teach that climatic elements are the same as weather elements, but that climate is a characterization of the occurrences of all the weather types in an area.

III. To teach that no two areas will have exactly the same climatic conditions. Thus it has been necessary to generalize climates into classes and types.

IV. To teach that there are several means of classifying climatic regions, each of which serves a specific purpose.

Student aims:

I. To take meteorological data, either from weather maps or from personal observations, and relate them meaningfully to world climatic patterns.

II. To interpret a climatic chart and to discuss anomalies intelligently.

III. To discuss the relative merits and weaknesses of the various climatic classifications. (Students might try their hand at improving on some of the classifications.)

IV. To understand how man has adapted his environment to best suit his needs and purposes.

Context:

I. Definition of climate

Climate is a composite of the general weather conditions of a region or area over a period of time. It requires study of the characteristics and distribution of weather events.

II. Climatic controls

The climatic controls, acting with various intensities and in different combinations, produce the changes in temperature and precipitation which in turn produce varieties of weather and climate.

A. The sun and latitude

As the latitude increases, solar insolation decreases; cooler temperatures result.

B. Land and water contrasts

Land surfaces heat and cool much more rapidly than water surfaces; greater temperature contrasts over land than over water surfaces result.

C. Pressure cells, permanent and semi-permanent

Large scale pressure cells act as controls of temperature and precipitation.

D. Winds and air masses

Along with pressure cells, the prevailing air mass in a region helps determine the weather on a particular day.

E. Altitude and relief

Temperatures generally decrease with increasing altitude and relief.

F. Ocean currents, warm and cold.

The greater ability of the oceans, as compared to land areas, to store heat is mainly responsible for the great contrast between continental and oceanic climates.

G. Storms

Storms result in rapid uplift of air and are thus the principal generators of the earth's precipitation.

III. Climatic Classifications

The natural environment does not adapt itself to simple categorical schemes. Therefore, there are different climatic classifications. Most classifications are based on one or more of the following criteria:

A. Temperature

Using the general parallelism of isotherms with latitude was one of the earliest climatic schemes. The earth was divided into the torrid zone (tropical latitudes), the temperate zone (the middle latitudes), and the frigid zone (the polar latitudes). Most climatic classifications use some aspect of temperature, but a temperature classification alone is unsatisfactory because it makes no distinction between humid and dry regions.

B. Precipitation

Natural vegetation, drainage systems, and ground water all reflect the effect of precipitation on nature. A classification commonly used by geographers based on this element is as follows:

| Climatic Type | Annual Rainfall |
|---|---|
| Arid | less than 10 inches |
| Semi-arid | 10-20 inches |
| Sub-humid | 20-40 inches |
| Humid | 40-80 inches |
| Very wet | 80 or more inches |

The weakness of this system lies in that no distinction is made between polar lands and hot dry deserts of the low latitudes, where precipitation amounts may be the same.

C. Vegetation

Since similar associations of vegetation reflect similar patterns of temperature and precipitation, several climatic classifications are based on one commonly used by geographers which divides climatic regions according to characteristic vegetation types, as follows:

1. Tropical rainforest

   This is found where there is abundant rain and it is warm in all seasons.

2. Jungle

   This is found where it is warm at all seasons with slightly less rain than the tropical rainforest, but with a slight dry season.

3. Scrub forest

   This is found where it is warm at all seasons with two distinct precipitation seasons--very wet and very dry.

4. Mediterranean scrub forest

   This is found when there are mild moist winters and very dry summers.

5. Broadleaf deciduous forest

   This is found where there are considerable seasonal temperature variations and plentiful rainfall evenly distributed seasonally.

6. Coniferous forest (taiga)

   This is found where there is extreme temperature range and a short, relatively

cool summer, with a long cold winter, and adequate moisture all seasons.

7. Savanna (tall grass and scattered trees)

   This is found where there is a very long, hot dry season, and a short, warm wet season.

8. Prairie (tall grass)

   This is found where there are great seasonal temperature variations, with slight moisture deficiency.

9. Steppe (short grass)

   This is found where there is a high annual temperature range and dry summers.

10. Desert (drought-resistant plants)

    This is found where annual temperatures range from moderate to extreme and potential evaporation greatly exceeds precipitation.

11. Tundra (lichens and mosses)

    This is found where there are long cold winters and short cool summers and adequate precipitation in relation to temperature.

12. Ice caps (no vegetation)

    This is found where temperatures are usually below freezing all seasons, and there is little precipitation.

The weakness of this system lies in the fact that some of these vegetation zones may reflect great variations in climate, and the same type of climate may support more than one class of vegetation under certain circumstances. But the strengths of this system greatly outweigh its weaknesses.

IV. Local climates

Certain facts are important in determining the local climate; these might be supplied by the local weather bureau.

A. Month of highest and of lowest average temperature.

B. Average temperature of the warmest and of the coldest month.

C. Annual range of temperature.

D. Daily range of temperature.[1]

E. Highest and lowest temperatures recorded during the year.

F. Average annual rainfall.

G. Season of greatest rain and of least rain.[2]

Suggestions to the teacher:

Although meteorology is largely a new subject, most students are familiar with climatic variations. They should find it interesting to see how different

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[1]This is an important supplement to average temperature, since an area might have an average July temperature of 75 degrees, but the daily range might be as great as 90 degrees in a desert, or as little as 20 degrees on an ocean island.

[2]For example, Mediterranean climates may receive as much as 35 inches of rain, as much as southern Michigan, but most of this falls in the winter; the summers are usually rainless, making irrigation or dry-farming necessary, which is not the case in Michigan.

climates have affected man's distribution on the earth and means of livelihood.

It is important that the students realize that similar climates may not produce similar occupations and cultures. Comparing culture of southern California with those of North Africa, Greece, and the Crimea--areas of similar climate--should spark a lively discussion. After the discussion has been activated, the question of the importance of these climates in understanding the regions and their cultures might be raised.

Discussion of the detailed differences of various climatic classifications by the average class may not be worth the additional time. However, they are useful to further geographic studies, especially those dealing with vegetation and soils. The following general classification of climates might well be useful:

I. The tropical climates

  A. Tropical rainforest

    1. equatorial
    2. monsoon
    3. windward coast

  B. Tropical savanna

  C. Low latitude dry climate

    1. desert
    2. steppe

II. The middle latitude climates

A. Middle latitude dry

1. desert
2. steppe

B. Warm humid climates

1. Mediterranean
2. marine west coast

C. Cold humid climates

1. humid continental long summer
2. humid continental short summer

III. High latitude climates

A. Tundra

B. Ice cap

C. Polar marine

The author sees no purpose in having the student memorize the different climatic symbols used in different classifications. It would be worthwhile for the student to characterize these climate types by their name. The author feels, from past experience, that the student can and should be able to identify the different climates by the criteria selected in classifying them. As most classifications used today depend upon variations in temperature and precipitation, the student should be able to distinguish between a marine west coast and a humid subtropical climate.

It would be a good exercise for the teacher to designate different areas and ask the students to characterize the general climate. This is a reasoning and deductive process that, once learned, is easily retained. (It is assumed that the students would already understand the effect of the climatic controls and their distribution.)

It is important that the students be well-versed in the controls and distribution of climate because of the important relationship between climate, vegetation, and soils.

# Recommendations For Further Study

## Books:

Brooks, C. E. P. Climate in Everyday Life. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1952. Pp. 314.

Brooks, C. E. P. Climate Through the Ages. New York: McGraw-Hill Book Co., Inc., 1949. Pp. 395.

Blair, Thomas A. Climatology. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1942. Pp. 484.

Geiger, R. The Climate Near the Ground. Cambridge: Harvard University Press, 1957. Pp. 494.

Gentilli, Joseph. A Geography of Climate. 2nd ed. revised. Perth: Western Australia Press, 1958. Pp. 172.

Gourou, Pierre. The Tropical World. New York: Longmans, Green and Co., Inc., 1952. Pp. 159.

Haurwitz, Bernhard, and Austin, James M. Climate, Vegetation and Man. New York: Philosophical Library, Inc., 1944. Pp. 387.

Schwartzbach, Martin. Climates of the Past: An Introduction to Paleoclimatology. Translated and edited by Richard Muir. (University Series in Geology) Princeton: Van Nostrand, 1963. Pp. 328.

Trewartha, Glenn T. Earth's Problem Climates. Madison: University of Wisconsin Press, 1961. Pp. 334.

## Periodicals:

Dorf, E. "Climatic Changes of the Past and Present," American Scientist, (June, 1958), 341-364.

Hidore, John. "An Introduction to the Classification of Climate," Journal of Geography, LXV No. 2 (February,1966). 52-57.

Opik, E. J. "Climate and the Changing Sun," Scientific American, (June, 1958).

Films:

Several film listed in chapter on "Soils and Vegetation" may be applicable for this unit.

CHAPTER III

OUTLINE (CONTINUED)

## Unit XVII: Soil Moisture[1]

Teacher aims:

I. To teach that the circulation of moisture takes place in the media of atmosphere, ocean, and land, in all of which the same operations concerning water are involved: income, outgo, and storage of moisture.

II. To teach that when precipitation exceeds infiltration, evapotranspiration, and movement to the subsurface water reservoir, precipitation is dispersed by surface runoff.

III. To teach that the rate of ground water seepage into streams and rivers corresponds to the rate of ground water discharge.

IV. To teach that evapotranspiration disperses almost twice as much precipitation as does surface stream flow.

Student aims:

I. To identify the processes by which moisture is transported and relocated in the hydrologic cycle.

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[1]The material in this unit, and the next unit as well, is presented in much more detail than in other parts, due to the positive nature and scarcity of expository available to the teacher on this subject.

II. To evaluate the relative importance of these mechanisms.

III. To relate the availability of moisture in the runoff cycle to observed phenomena.

IV. To explain the consequences that result from changes in the income, outgo, and storage values.

V. To define the important disposition processes of precipitation.

VI. To relate the infiltration mechanisms to capillary capacities.

VII. To identify areas that have surplus and deficit water balances.

Content:

I. The hydrologic cycle

This cycle is the flow of moisture from the oceans to the land, and back to the oceans. The water is evaporated from the oceans into the atmosphere. The water vapor is carried over the land surface by winds, and condensed into clouds and/or precipitation. The precipitated moisture then begins a retreat back to the oceans. This retreat may be in any of several ways:

A. Infiltration

1. The soil contains small pore spaces arranged into a network of capillaries and ducts. When precipitation strikes the soil, the water spreads over the surface in all directions. When the entire surface is moistened, surface water is drawn into the drier soil below (ground water), allowing other molecules of water to enter the surface. This action ceases when either the water can infiltrate no further downward or the entrance of surface water ceases.

2. The rate of infiltration is dependent upon the site of the capillaries. When the supply of surface moisture exceeds the rate of infiltration, the excess moisture becomes surface runoff.

B. Ground Water

Ground water is water that is in the spaces of porous rocks and joints and other crevices of all rocks. The erosive effect of ground water in motion is usually not recognized until after the water has disappeared. The water table, or upper surface of the zone of saturation, generally follows the slope of the land, but it is nearer the surface in valleys than on hilltops. The following are related to the flow of ground water:

1. Spring

This is a natural flow of water from the ground. It is formed when the water table meets the surface of the land, whether above or below water.

2. Well

Wells are holes that penetrate below the ground water table, from which water is pumped to the surface.

3. Surface well

This is a well of which the water level is less than 30 feet below the earth's surface.

4. Artesian well

This is a well of which the water level is 30 feet or more below the earth's surface.

5. Flowing artesian well

This is water which moves above the local water table, being forced upwards by

hydrostatic pressure.

C. Surface runoff

Runoff is that portion of precipitation which ultimately reaches a stream; it is water which flows off the surface rather than into the ground. The rate of surface runoff is entirely dependent on the rate of infiltration and amount of precipitation. Surface runoff is greater when the following conditions are present:

1. more rainfall in a shorter time,
2. smaller soil capillaries,
3. frozen soils,
4. and little vegetative cover to slow surface movement of water.

D. Evapotranspiration

Evapotranspiration is the combined loss of moisture from direct evaporation and transpiration by the vegetative cover. Movement of soil moisture can be likened to kerosene moving up the wick of a lamp; the upward movement of kerosene is in direct proportion to the loss caused by burning. However, the high evaporation rate that usually occurs outdoors in the summer exceeds the movement of water to the surface through the capillaries. Thus, the surface layers dry more readily than the subsurface layers. As the water is removed, that which remains moves towards the soil surface more and more slowly.

Although evapotranspiration may disperse all the water that enters the soil, there may be times when the soil is at capillary capacity. At this time, soil water continues to infiltrate downward until the water table is reached (that is, the surface of the ground water, or the surface below which rock pores are saturated with water).

II. The water balance

According to climatologist C. W. Thornthwaite,[2] water balance is based on the theory that the amount of moisture that is sufficient for a place depends upon how much could evaporate and be transpired (the potential evapotranspiration), rather than how much actually does evaporate and is transpired. Potential evapotranspiration (PE) is referred to as the water need. If the PE is less than required, there is a moisture deficit; if supplies are greater than needed, there is a moisture surplus. The soil can hold moisture to be utilized during a dry season, but this moisture will have to be restored during the wet season in order to meet the overall need. Thus, the water balance is an expression of how a runoff cycle works at a given place. It provides the information to determine whether moisture is abundant, adequate, or inadequate for any month or season. Moisture deficits may be determined by quantitative methods, and surplus moisture can be put into terms that account for streamflow.

Suggestions to the teacher:

The continuous transport and transformation of meteoric water is the major theme of this unit. After considering the hydrologic cycle, most students should realize its importance to the earth, but its importance to the oceans may be less clear. The proportion of salt in the ocean has been increasing; so the question might be asked: "Whence does this salt come?"

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[2] C. W. Thornthwaite, "An Approach toward a Rational Classification of Climate," The Geographical Review, XXXVIII No. 1 (January, 1948), 55-94.

Time should be spent explaining "porosity" and "permeability," both quantitatively and by personal observation and experiment. Perhaps many of the students have been to the beach; they should recall what happened when holes were dug near the shore.

The teacher could locate a glass container (for example, a fish tank or fruit jar) and have the students fill it with different type soils. By pouring water into the container they could observe it passing through at different rates. (Some plastic material might be used to form an impermeable layer in some part of the container.)

An excellent discussion topic could be what might happen if we exceed our mean water supply.

An aid to understanding the water balance would be to compare it to the family budget as follows:

Let potential evapotranspiration be represented by the monthly bills to be paid, precipitation or moisture by the income, and soil moisture storage by the bank savings account. Actual PE could be compared to the amount that is actually spent and they could see if the income meets the demands. If the demand is not met, students might discuss what "bills" should best be left unpaid until a later date, and what "bills" are top priority.

# Recommendations For Further Study

Books:

Kuenen, P. H. Realms of Water: Some Aspects of Its Cycle in Nature. New York: John Wiley and Sons, Inc., 1955. Pp. 327.

Thornthwaite, C. W., et al. Three Water Balance Maps of Eastern North America. Resources for the Future, 1958. Pp. 57.

United States Department of Agriculture. Soil. (USDA Yearbook, 1957). Washington: U. S. Government Printing Office, 1957. Pp. 784.

United States Department of Agriculture. Water. (USDA Yearbook, 1955). Washington: U. S. Government Printing Office, 1955. Pp. 751.

Periodicals and Pamphlets:

Thornthwaite, C. W. "An Approach toward a Rational Classification of Climate," The Geographic Review, XXXVIII No. 1 (January, 1948), 55-94.

Thornthwaite, C. W. "The Hydrologic Cycle Re-examined," Soil Conservation, 1938.

United States Department of Agriculture. Water Facts. (Soil Conservation Service PA 337). Washington: U. S. Government Printing Office, 1964.

United States Department of Interior. Water Management: Agriculture, and Ground Water Supplies. (U. S. Geological Circular 415). Washington: U. S. Government Printing Office.

Films:

Man's Problem. 19 minutes. color. Britannica.

Mountain Water. 17 minutes. color. U.S.D.A. Forest Service.

Nature's Plan. 14 minutes. color. Britannica.

Snow Harvest. 25 minutes. color. U. S. Soil Conservation Service.

CHAPTER III

OUTLINE (CONTINUED)

## Unit XVIII: Soils and Vegetation

Teacher aims:

I. To teach that soils are one of the greatest natural resources; they are essential to man's existence.

II. To teach that soils are constantly being formed by the continuous mechanical and chemical decomposition of the outermost rocks of the earth's crust.

III. To teach that soil types vary greatly in different regions.

IV. To teach that erosion is a natural process, but it can be greatly accelerated by man without proper soil management.

V. To teach that soils adjust themselves to conditions of climate, topography, and vegetation.

VI. To teach that vegetation varies greatly in kind and density from one region to another, thus constituting one of the most striking features of the land surfaces.

VII. To teach that natural vegetation is an expression of the whole physical environment and that it reflects the integration of all environmental conditions.

VIII. To teach that preservation of the usefulness of soil and of forests should be the aim of all who use them.

Student aims:

I. To understand the relationship between soil and climate.

II. To understand how soil is developed over a period of time.

III. To recognize the reciprocal relationship between soil and vegetation.

IV. To understand the different soil horizons and their cause.

V. To differentiate between sand, clay, and silt soils in the area by feel or touch, and understand the effects of texture upon soil use.

VI. To understand interrelationships of soil, climate and vegetation.

VII. To appreciate the utility of soil and vegetation to man and to realize the unfavorable results of exploitation without due consideration of the future.

VIII. To understand the importance of protection of all lands of our nation and its future, and realize what must be done to insure the continuous usability of the land.

Content:

I. Controls of soil formation

Soil consists of the loose layer of fine materials at the surface of the lithosphere. it is constantly in a process of change as a result of the interaction of many controls; these vary in their effects and importance from region to region. The major controls that combine to produce the soil are:

A. Parent material

The disintegrated rock and mineral particles, making up the largest part by weight of most of the soil, are called the parent material. The degree to which water and air can circulate in the soil layer, and the chemical character of the soil are determined in part by the parent material.

B. Climatic factors

Climate affects the rate at which rocks are decomposed into soil, and the amount of water that percolates through the soils. Warm temperatures promote rapid weathering and other chemical changes, while cold weather retards most weathering and chemical action. Overabundant water may remove soil nutrients such as lime and other soluble salts from the soil, decreasing its fertility. Climate also affects the bacterial action within the soil, limiting or accelerating their action by extremes of temperature and moisture content.

C. Plants and animals

The death of various organisms helps build up the soil by becoming part of the soil complex. Bacteria affect the amount and rate of decomposition of plant and animal remains. Some micro-organisms change atmospheric nitrogen into usable forms; some penetrate the soil, increasing the soil's porosity; and some organisms and plant roots help circulate the soil minerals by returning them to the surface.

D. Land forms

Slope characteristics are very important because they affect the moisture and air conditions within the soil, and, more important, by the rate of surface erosion. Maximum soil building occurs on undulating, well-drained lands with good subsurface drainage. These conditions allow the soil to develop a well-defined profile. Soils on poorly drained

lands develop differently because the air is unable to penetrate them. Soils on steeply sloping land never develop completely because their upper layers are rapidly eroded.

E. Time

The factors developing soils work continually towards a state of equilibrium, wherein further changes in the nature of the soil are imperceptible; a soil in this state is said to be mature. In order to mature, soils need time, otherwise various categories of immature soils are found.

II. Soil character and its components

Soils vary considerably from region to region. In order to better understand the pattern of soil regions, it is necessary to define and describe the essential characteristics that separate one soil from another. The most important of these are:

A. Fertility

All plants and animals obtain their sustenance from the soil either directly or indirectly. The soil must contain chemical elements in order to provide sustenance for other plant growth. Some of these elements are supplied by the air while others are supplied by water and inorganic soil matter. The degree to which the soil contains these elements is referred to as soil fertility. If absent or insufficiently present, some of these elements may be added as fertilizer. These elements are categorized as follows:

1. Elements needed in relatively large amounts. These are oxygen, nitrogen, carbon, sodium, calcium, potassium, phosphorus, sulphur, magnesium and iron.

2. Elements needed in minute quantities. These are copper, zinc, iodine, boron, manganese and many other trace elements.

B. Texture and structure

Inorganic soils are combinations of sands, silts, and clays, in various proportions, and are called loams. Soils are classified as follows:

1. Texture

This refers to the size of the soil particles, which may be divided into three main classes:[1]

a) sand particles - 2.0 to 0.05 mm. diameter

b) silt particles - 0.05 to 0.002 mm. diameter

c) clay particles - less than 0.002 mm. diameter

2. Structure

This refers to the ways in which the soil particles are grouped together; it largely determines the porosity and permeability of the soil. Classification of structure is subjective and descriptive.

C. Organic components

Decomposed and partly decomposed organic matter in the soil is called humus. The role of organic components in the soil are as follows:

1. Decomposition

Organic material decomposes into useful plant food such as nitrates and mineral

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[1]Arthur N. Strahler, Introduction to Physical Geography, (New York: John Wiley and Sons, Inc., 1965), 167.

elements. This decomposition yields organic acids that aid in the weathering and the oxidation of mineral matter.

2. Microorganisms

Organic material is a major source of food for living microorganisms, which support the higher forms of organic life supported by the soil.

3. Soil moisture

Humus has a high water-holding capacity and reduces leaching and makes the soil more fertile.

D. Water-air relationships

Most plants absorb the soil nutrients in solution provided by the capillary water. The soil air provides a source of oxygen, nitrogen, and carbon dioxide used in the work of soil formation.

E. Soil color

Soils vary in color from almost white to black. Red, rust, brown, and yellow soils usually result from the presence of various iron oxides. Black soils usually indicate a high content of organic matter or of lime. Dark soils absorb solar insolation better and are thus warmer than lighter-colored soils. Dark-colored soils are generally more productive than light-colored soils, although there are exceptions to this.

F. Soil profile

As noted above, soils are identifiable by their internal structure. Most soils have an arrangement of layers, or horizons, each with different chemical and physical properties. This profile is usually divided into A, B, and C horizons, with several possible subdivisions of each horizon.

1. "A" horizon

   This is the layer of most organic life and debris. Depth is usually controlled by the amount of leaching and soil erosion. It includes a zone of eluviation (zone of greatest leaching).

2. "B" horizon

   This is the zone of accumulation of leached colloids and layer of illuviation. It may be rich in nutrients deposited from the A horizon

3. "C" horizon

   This is the layer most characteristic of the parent material; it is the zone of transition from parent material to soil.

III. Soil classification

A. By origin

Some soils have formed directly above the parent material while other soils have been transported and deposited at a given location. They are classified as:

1. Residual soils

   These are soils whose parent material is the rock directly below them.

2. Alluvial soils

   These are soils deposited by water.

3. Glacial soils

   These are soils deposited by glaciers.

4. Aeolian soils

   These are soils deposited by wind.

B. Soil series

Soils have been divided in soil series. Each series includes soils with similar profiles developed from similar parent material. Basic categories of soil groups within the United States are:

1. Soils of the humid lands

a) podzol and tundra soils

These soils are found in cool or cold climates; very little humus and high acid content.

b) podzolic soils

These soils are found in regions of broadleaf deciduous forests, equatorward of podzols; little more humus in A horizon than podzols; are fertile when lime is supplied to offset the high acidity.

c) podzolic-latosolic soils

These soils are in areas of agricultural importance such as southeastern United States and China; small amounts of organic matter in both A and B horizons; can be tilled with great care that upper horizons do not erode away.

d) latosolic soils

These soils are found in regions of high temperature and heavy precipitation; unusually deep horizons, highly leached and usually infertile unless much fertilizer is used.

2. Soils of the sub-humid lands

a) chernozem

These soils are in areas which can support luxuriant grass cover; very

high in calcium, magnesium and other alkaline earth minerals; A horizon usually very dark color; considered to be very fertile if adequately moist.

b) chernozemic-desert soils

These soils have developed under less luxuriant grass cover than the chernozem; precipitation followed by rapid evaporation results in a horizon of accumulated lime; can be fertile with irrigation.

c) desertic soils

These soils are low in organic content; usually not very mature in profile development; may be chemically rich because of unleached parent material.

3. Mountain soils

Little characterization can be made of mountain soils because of the great complexities resulting from a range of slopes and climates. Most of these mountain soils are not cultivable.

IV. Relations of vegetation to soil and climate

As all the factors of the environment act collectively and simultaneously upon plants, vegetation is the best single indicator of the nature of the environment.

A. Relations to climate

Heat and water are the two most important elements affecting plant growth and its characteristics.

1. Temperature

Critically high and low temperatures as well as temperature regime are important factors affecting vegetation.

2. Moisture

Plants adapt themselves to available moisture. The following are categories of plants that are adapted to moisture extremes:

a) hygrophytes

These are plants that adapt to wet or swampy conditions by having shallow roots, roots near the surface, and large and very thin leaves.

b) xerophytes

These are plants adapted to drought conditions by having deep roots to reach subsurface moisture, long horizontal roots to find all moisture near the surface, very small leaves or thorns to avoid transpiration, a thick corky bark to avoid transpiration, short life cycles, and hibernation.

c) tropophytes

These are plants adapted to seasonal cycles of abundance of moisture and physiological drought by shedding leaves, becoming dormant, actively growing during the rainy season.

B. Relations to soils

Vegetation is highly dependent upon the soil in which it grows as the soil provided physical support and plant nutrients.

V. Vegetation classifications

There is no single accepted geographical classification of the earth's vegetation; any classification is tentative in nature, and limited in application. The classification below reflects prevailing plant associations over considerable areas, occupying characteristic physical environments.

A. Forest associations

1. Tropical forests

a) Tropical rainforest

(1) great variety of tree species
(2) strong vertical stratification
(3) large number of lianas and other climbers
(4) species drop leaves at different periods so forest is never bare of leaf cover
(5) branch development near top of the tree (crown)
(6) very little underbrush because of the deep shadows cast by heavy crown foliage

b) Less dense tropical forest

(1) contains varieties of semi-deciduous, deciduous, scrub, and thorn
(2) smaller trees, more widely spaced
(3) generally thinner foliage during dry season.

2. Middle-latitude forests

a) Mediterranean broadleaf evergreen woodland and shrub

(1) located in subtropical locations with mild, rainy winters and long, dry, usually hot summers
(2) trees adjust to dry conditions (see xerophytes)
(3) trees separated by bush and grass

b) Temperate broadleaf forest

(1) consists of broadleaf trees and needleleaf trees (or conifers)
(2) coniferous forests usually occupy the colder locations on porous, sandy soils, and where

soils are thin or rocky
(3) varies widely in composition, the dominant species from one region differing to another region
(4) largely deciduous
(5) much of the original forest has not been cleared for farming

c) Needleleaf forest

(1) consists of coniferous trees, primarily evergreen
(2) needles fall continuously rather than during a particular season or period
(3) trees are xerophytic in character
(4) little surface vegetation and bacterial action supported; thus, usually found on acidic soils
(5) found in three main regions:
(a) subarctic or taiga
(b) lower middle latitudes
(c) Atlantic and Gulf Coastal Plain

B. Grasslands

1. Tropical grassland (wooded savanna and savanna)

a) usually associated with poor subsurface drainage resulting from mild relief and impermeable subsoil

b) vary in height from one to 15 feet

c) may be found in tufts with open and bare earth spaces in between

d) merges indistinguishably with brush and scrub woodlands

2. Middle latitude grasslands

   a) not interspersed with trees

   b) generally vary in height from three to eight feet

   c) North American grasslands divided into:

      (1) short grasses of the semiarid Great Plains
      (2) tall grass prairie located west of the eastern forests
      (3) transitional grassland located between the short and long grass regions

C. Harsh climate associations

   1. Desert

      a) consists of xerophytic vegetation

      b) perennial shrubs widely separated by bare earth, due to extensive underground root systems of individual plants

      c) annual plants are not xerophytic in nature but rather have a short life cycle

   2. Tundra

      a) consists largely of mosses, lichens, and sedges

      b) permafrost (constantly frozen subsoil) retards water infiltration

      c) short frost-free periods (about two months) necessitate very rapid vegetative cycles

Suggestions to the teacher:

This will be one of the hardest units to teach effectively. Most students have little or no interest in the conservation of soil or vegetation. Therefore, the teacher will have to prepare very carefully.

The best way to show the relationships between climate, soils, vegetation, and fertility is to compare them on maps found in any good atlas.

It is probably not necessary that the student spend considerable time studying soil horizons, but it is important that he understand the distinction between soil texture and structure.

The teacher might build this unit around the local environment. A recent excavation should reveal the local soil profile.

Students could be shown that trees can be considered a crop and that wise tree farmers practice proper farm management similar to that of any other crop farmer.

# Recommendations For Further Study

Books:

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Films:

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The Deciduous Forest. 28 minutes. color. McGraw-Hill.

The Desert. 22 minutes. color. Britannica.

The Grasslands. 17 minutes. color. Britannica.

The Grassland Biome. 16 minutes. color. Western Michigan.

The Grasslands and the Desert. 28 minutes. color. McGraw-Hill.

High Arctic Biome. 22 minutes. color. Western Michigan.

Life in the Deciduous Forest. 17 minutes. color. International Films.

The Prairie. 14 minutes. color. Barr Productions.

Raindrops and Soil Erosion. 21 minutes. b/w. Soil Conservation Service.

Save the Soil. 11 minutes. b/w. Castle Films.

The Temperate Deciduous Forest. 16 minutes. color. Western Michigan.

Tropical Rain Forest. 16 minutes. color. Western Michigan.

Tundra Ecology. 28 minutes. color. McGraw-Hill.

CHAPTER III

OUTLINE (CONTINUED)

Unit XIX: The Earth's Crust

Teacher aims:

I. To teach that all matter in the earth's crust is made up of the chemical elements and combinations of them.

II. To teach that fewer than ten of the thousands of minerals comprise more than 99 per cent of the rocks in the lithosphere.

III. To teach that rocks are combinations of minerals. The structure, texture and composition change in response to the environment of the formation of rocks, providing evidences of their origin.

IV. To teach that younger rocks usually overlay older rocks in a stratified sequence.

V. To teach that reconstruction of the earth's history from study of rocks depends upon accurate correlation of rock units from one area to another area.

Student aims:

I. To see a relationship between mineral characteristics and their chemical structure.

II. To understand the origin of the bedrock.

III. To relate changes in mineral content of rocks to changes in environment.

IV. To recognize several common minerals and their importance.

V. To describe some of the obvious textural, structural, and compositional features of rock specimens, and to make some reasonable interpretation of the origin of the rock.

VI. To relate a logical sequence of geologic events on information supplied by simple cross sections or diagrams of rocks.

Content:

I. Chemical Elements

The earth's crust consists of single chemical elements or combinations thereof. An element is a substance which cannot be decomposed into a simpler substance by chemical means. Of the 103 elements known to man, about 90 are known to occur naturally. The eight most common elements composing the earth's crust are, in decreasing order of occurrence: oxygen, silicon, aluminum, iron, calcium, magnesium, potassium, and sodium.

II. Minerals

Minerals are naturally occurring substances with a characteristic internal structure and chemical composition. The essential characteristic that distinguish minerals are called its properties. These are physical and chemical.

A. Chemical properties

1. Composition

2. Acid reaction

3. Taste

B. Physical properties

1. Crystal form

2. Cleavage

3. Fracture

4. Hardness

5. Specific gravity

6. Color, streak, and luster

7. Fluorescense

8. Radioactivity

III. Rocks

Most rocks are aggregates of mineral crystals. Since there are hundreds of minerals that can be united in many different combinations, there are countless types of rocks. Rocks are divided into three main classes:

A. Igneous rocks

Igneous rocks have formed from molten material within the earth and may form extrusive or intrusive rocks.

1. Common igneous rocks

a) granite
b) feldspar
c) basalt
d) obsidian
e) pumice stone
f) scoria
g) gabbro

2. Important uses of igneous rocks

a) Most valuable metals such as gold, silver, and copper are found in igneous rocks.

b) Many, such as granite, are used as building materials.

B. Sedimentary rocks

Sedimentary rocks are those that have been formed from materials deposited on the surface of the earth and cemented or solidified by the compression under the weight of water or overlying materials.

1. Common sedimentary rocks

a) Those formed by cementation of rock fragments or particles:

(1) conglomerate

This consists of rounded pebbles cemented together.

(2) sandstone

This consists of sand particles cemented together.

(3) shale

This consists of clay and mud particles cemented together.

b) Those formed from precipitates of sea water and other surface solution:

(1) gypsum

This forms from precipitated calcium salts.

(2) rock salt

This forms from evaporated sea water.

c) Those formed by compression of organic materials:

(1) limestone

This is compacted of limey deposits and shells of small marine animals (or it may be precipitated

from sea water).

(2) coal

This is formed from accumulated vegetation.

(3) fossils

These are remains or imprints of organisms preserved in rocks.

2. Characteristics

At the time of deposition of sediments, certain features were formed that help man differentiate sedimentary from igneous rocks.

a) Bedding

This refers to layers of sedimentary rock roughly parallel to each other. They are generally separated by surfaces of discontinuity.

b) Crossbedding

This refers to oblique layering of sedimentary deposits diagonally across the individual strata beds.

c) Ripple marks

These are parallel ridges on the rocks resulting from currents moving the sediment along the bottom of a body of water.

d) Mud cracks

These result from surface shrinking of drying mud. Later, sands and silts cover and fill the cracks with sediment of a different texture from the original material.

3. Important uses of sedimentary rock

   a) They often provide fertile soil for agriculture.

   b) They provide building materials, fertilizers, fuels--oil, gas,and coal--and chemicals--salt and sulphur.

C. Metamorphic rocks

Metamorphic rocks were originally igneous or sedimentary rocks that have been changed in character and appearance by intense heat, pressure or recementation. The change in state (recrystallization) of these rocks is probably due to heat, pressure, and chemically active solutions.

1. Characteristics

   Metamorphic rocks are generally harder and more compact than the original except when the former rock was igneous initially.

2. Examples of metamorphic rock

   Igneous and sedimentary rocks have corresponding metamorphic counterparts. Some of the more familiar are:

   a) slate (derived from shale)
   b) quartzite (derived from sandstone)
   c) marble (derived from limestone)
   d) gneiss (derived from granite)
   e) anthracite (derived from coal)

3. Important used of metamorphic rocks

   a) Slate is used for blackboards and as the backing for pool tables.

   b) Marble is used as a decorative stone.

   c) Anthracite is used as a smokeless fuel.

IV. Rocks as historical documents

Just as the historian determines man's history by examining documents and articles, so the geologists, by studying the rocks, provide the earth's record.

Suggestions to the teacher:

Students should be taught that sedimentary rocks and their features are primarily the result of conditions under which the original sediments were deposited.

If there are outcrops in the teacher area, he might ask his students to locate and observe them. Here they may be able to see the thickness of the strata and distinguish one strata from another.

Teachers could have the students observe examples of different rocks as to composition, texture, and structure. If unable to find enough different rocks in your area, sets might be purchased very reasonably from department and hobby stores. Students could begin a collection of local specimens and identify them. Students are rare who can memorize this from a book; it requires actual gathering, observation, and deduction to implant this firmly in their memories.

If at all possible, teachers could schedule a field trip to observe the phenomena in the actual setting. (Students who seem the least interested often

become enthusiasts in the field.)

Comparing metamorphic rocks with their unaltered originals (slate-shale, anthracite-coal, gneiss-granite, marble-limestone) could effectively indicate the tremendous changes that heat pressure and recementation have wrought. One should ensure that the students realize that such rocks as marble and granite do not naturally occur in a polished form; this is a very common misconception.

## Recommendations For Further Study

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Shrock, Robert R. Sequence in Layered Rocks. New York: McGraw-Hill Book Co., Inc., 1948. Pp. 507.

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Walton, Matt. "Granite Problems," Science, CXXXI, 635-645.

Films:

Demonstrating Changes in Earth's Surface. 28 frames (filmstrip). color. Scribner Educational Department.

Diastrophism. 55 frames (filmstrip). color. Life Filmstrips.

The Earth: Changes in Its Surface. 11 minutes. color. Coronet.

The Earth: Its Structure. 11 minutes. color. Coronet.

The Earth's Changing Surface. 11 minutes. color. McGraw-Hill.

Earth's Rocky Crust. 11 minutes. b/w. Western Michigan.

Face of the Earth. 10 minutes. b/w. Britannica.

The Fossil Story. 19 minutes. color. Western Michigan.

Our Changing Earth: An Introduction to Paleography. 13 minutes. color. Film Associates.

The Story of the Earth We Find In Rocks. 72 frames (filmstrip). b/w. Jam Handy Corp.

CHAPTER III

OUTLINE (CONTINUED)

Unit XX: The Building Up of the Land

Teacher aims:

I. To teach that the earth's surface is constantly changing in shape and elevation.

II. To teach that crustal movement probably results from movement within the mantle.

III. To teach that the earth responds to deforming forces as a material that is brittle, plastic, or elastic, depending upon the nature of the forces.

IV. To teach that vulcanism results from the internal energy of the earth.

V. To teach that volcanic belts are scattered over the earth's surface, reflecting the structure of the earth's crust, and that there are narrow zones of seismic and volcanic activity near the continental and oceanic boundary.

VI. To teach that there are many areas of varieties of volcanic type, eruptions and products, but that all fall into similar patterns.

VII. To teach that, although mountain systems are highly diverse, they have generally similar histories.

VIII. To teach that the development of mountain systems requires millions of years.

Student aims:

I. To realize that the earth's surface is a dynamic body.

II. To recognize evidences of some of the major earth changes going on about them.

III. To appreciate the development of man's understanding of these processes.

IV. To describe and classify types of volcanic eruptions and their patterns of diversity, and to locate the major volcanoes and volcanic regions of the earth.

V. To know some proofs and evidences of earth movements.

VI. To relate the principles of uniformity to present features of mountains.

VII. To distinguish between areas where the land is rising and where it is sinking.

VIII. To analyze some mountain systems in terms of size, shape, composition, structure, location, and the forces which built them.

IX. To relate ways in which the rock cycle and a major part of the hydrologic cycle have been involved in mountain building. (This may be restricted to the advanced students.)

Content:

I. Crustal movement

There are several theories presented to explain the causes and origins of earth movement.

A. The contraction theory

This theory proposes that the earth is

constantly shrinking. Folded and faulted mountain systems are wrinkles on the crust of a shrinking spheroid.

B. The continental drift

This theory proposes that all the continents were at one time a solid land mass. Centrifugal forces and tidal attraction of both the sun and the moon have pulled the continents apart and crustal mountains have since resulted.

C. The convection theory

This theory proposes that mountain chains are formed by the action resultant from the drag of subcrustal convection currents against the continents.

D. The phase change theory

This theory proposes that sharp changes in velocity of earthquake waves within the earth's mantle and core result from changes in the way that the materials are packed together, resulting in crustal mountain building.

II. Earth building forces

A. Tectonic (forces within the earth)

These forces derive their energy from heat, and pressures within the earth; they are expressed by expansion (the expulsion of molten lava from the earth's interior to the surface), and the circulation of magma. They comprise:

1. diastrophism (warping, folding, or faulting of the earth's crust),

2. and vulcanism.

B. Gradational

These are forces operating through agents such as wind, water or ice. The are:

1. degradational forces wearing down the surface to grade level,

2. and aggradational processes that fill the sea margins and depressions, thus building up the earth's surface.

III. Volcanoes and vulcanism

Volcanoes build up the land by the ejection of molten matter from the earth's interior.

A. Types of eruptions

There are two main means of emitting lava:

1. Explosive

The violent expulsion of rock, ash, and matter composed of acid magmas in a viscous state.

2. Quiet

A relatively quiet flow of lava composed of basic magmas.

B. Classification of volcanoes

Volcanoes are classified according to cone shape. The cone is related to the type of eruption which in turn is related to the composition of the magma.

1. Shield

These are basalt lava cones with gently rising, smooth slopes, flattening near the top to produce broad-topped domes formed by repeated flows of magma. They may contain a steep-sided central depression called a cauldron. The Hawaiian Islands contain examples of shield domes.

2. Cinder cones

These are small volcanoes formed entirely from pieces of solidified lava ejected from a central vent. They resemble ash taken from a coal furnace and range in size from several tons (volcanic bombs) to pieces only fractions of an inch in size (cinders). Cinder cones have large central craters; one rim is usually higher than the other as a result of the blowing of fine ash and cinders to one side by the prevailing winds. Paricutin is an example.

3. Composite

These are cones formed by combinations of cinder layers and lava layers. The steep sides result from the angle at which the cinder and ash stands, while lava layers provide the needed stability. Fujiyama, Mt. Hood, and Vesuvius are examples.

C. Fissure eruption and lava plateaus

Great sheets of lava, sometimes covering thousands of square miles, have been extruded through fissures in the earth's surface; these are not directly associated with volcanic cones. Examples are the Columbia Plateau in Washington, Oregon, and Idaho, and the Deccan Plateau of peninsular India.

D. Intrusions of magma into the earth's crust

Igneous intrusions are the result of magma solidifying before reaching the earth's surface. This forms intrusive or plutonic rocks. Some of the more common igneous intrusions are:

1. Sills

These are formed by magma forcing its way between two layers of sedimentary rock; these may range from inches to

several hundred feet thick. It must have greater horizontal extent than vertical.

2. Dikes

These are formed by magma forcing its way toward the earth's surface through an opening or cleft, or melting a passage for itself and then solidifying. Thicknesses may vary from inches to hundreds of feet. When erosion exposes them at the surface, these are commonly called hogbacks, due to their shape.

3. Laccoliths

These are similar to sills only much larger, and may cause the earth's surface to arch over the intrusion.

4. Batholiths

These are formed by enormous intrusions of magma often covering hundreds of square miles and sometimes forming the substructure for mountain ranges.

E. Volcanic distribution

Most active volcanoes today are located in belts of crustal instability, the most famous being the circum-Pacific belt referred to as the "ring of fire." This is a zone of earthquakes, also.

F. Volcanic dissolution

Recent volcanic activity is usually associated with geysers, hot springs, and fumaroles (holes in the earth's surface emitting steam and gases, especially carbon dioxide). Excellent examples of these phenomena are found in Yellowstone National Park and Iceland.

## IV. Earthquakes

Earthquakes are relatively minor wavelike movements of the earth's crust. Although the earth is constantly vibrating, there are occasionally tremors of extreme violence that may spread over large areas and even travel around the earth. When earthquakes are on or near the ocean floor, huge sea waves may be created which build in size as they approach more shallow waters. These waves, called tsunamis, can cause considerable damage. They are often erroneously referred to as "tidal waves."

### A. Cause of earthquakes

The ultimate cause of many earthquakes still remains a mystery. The immediate cause is some movement of rock masses. These movements are usually the result of:

1. Faulting

   A fault is a break in the rocks at the earth's surface resulting from stress inequalities and causing slippage or displacement along the fault plane.

2. Elastic rebound

   This results from distorted rocks along a previous fault straightening out with a motion similar to the springing of a trap.

### B. Earthquake location and sensing

Earthquakes, like volcanoes, are most commonly located along zones of subsurface instability. The instruments used to register the motions and force of the earthquake waves or tremors are called seismographs. The data taken from these sensors accurately locate the tremors; they also show that the earth consists of a network of concentric zones of varying composition.

# V. Mountains

A mountain is an elevated portion of land with little or no level summit.

## A. Origin of mountains

No one is positive how mountains are formed. There are two important theories:

### 1. Trough line

Some scientists believe that the process begins with the formation of trough lines along the edges of continents and the filling of these troughs with sediments. These sediments are later uplifted, folded, and faulted.

### 2. Isostacy

This is a hypothesized condition of balance within the earth's crust, whereby the continents are believed to float on basaltic subsurfaces. Like icebergs in the sea, the larger blocks of the earth's crust extend deeper and rise higher in response to Archimedes' principle. Changes in the balance or in the weight of a block cause sinking or rising of the block to form new mountain ranges.

## B. Mountain building processes

Mountain chains may consist of linear belts usually formed by some form of combination of the following:

### 1. Folding

This is the bending in rock strata caused by compression and tension movements of the earth's crust. The crustal movement of the strata forms a series of arches and troughs (anticlines and synclines).

2. Faulting

This is the linear breakage of the earth's crust by opposed lateral or vertical pressures.

3. Uplifting

This is the large-scale raising of a mass of rock. It may be accompanied by faulting along the margins of the mass.

4. Vulcanism

This has already been discussed.

D. Mountain types

There are four main types of mountains:

1. Folded mountains

These are formed by a massive folding movement. The Appalachians, Pyrenees, and Apennines are examples.

2. Faulted or fault block mountains

These are formed in regions where normal faulting is on an immense scale, with displacements of thousands of feet. Faulted mountains are usually tilted or lifted; the tilted mountains have one steep face and one gently sloping side. Lifted mountains have steep slopes on both sides. The Sierra Nevadas and the Grand Tetons are examples.

3. Dome mountains

Dome mountains are formed by the intrusion of magma in between layers of sedimentary rock causing a vertical uplift that arches the rocks into a general dome form. The Henry Mountains of Utah and the Black Hills of South Dakota are examples.

4. Volcanic mountains

The most observable mountain building process is the accumulation of lava and other extruded volcanic products into deposits of mountainous size. Aconcagua in the Andes,and Kilimanjaro in Africa, are examples.

E. Mountain features

There are many of these. Some of the more important are:

1. Peak

This is the highest point of a mountain.

2. Range

This is a semi-continuous arrangement of peaks, ridges and valleys.

3. System

This is a group of mountain ranges.

4. Cordillera

This is a regional linear grouping of mountain systems.

Suggestions to the teacher:

This is a unit that could easily stir the imagination of the students. It would be easy to let description override the understanding of processes; guard against this.

The idea that some parts of the earth's crust are not stable, but move both horizontally and vertically, is important. Referrence could well be made to the

1964 Alaskan earthquake and other recent eruptions.

It would probably be wise to study crustal movement by studying confirmed evidence for it rather than only in theory. Sedimentary rocks are deposited horizontally; as they are found tilted, contorted, and fractured, this is ample evidence that there are great internal forces disrupting the earth's crust. It would be an excellent idea for the students to see examples of this in their own area, but if this is not possible, one could show slides, pictures, or films. It is almost impossible to explain folding, faulting, and other earth movements adequately without some visual reinforcement.

Some of the students might make models of different types of mountains and volcanoes. Models showing faulting and folding would be especially valuable.

The film, Eruption of Kilauea, is a very fine instructional film. It will most certainly arouse considerable interest among students. It could be obtained from the Audio-Visual Center of Western Michigan University.

Students could study the close coincidence of world-wide zones of crustal weaknesses and volcanic activity.

Some advanced student might wish to make a class report on the seismograph, which has many other uses than recording earthquake shocks.

When discussing mountains, one might point out how difficult it is to determine how mountains have originated. Their generally narrow linear shape and continental position, the lighter density of their rocks, and the nature of faults and folds, are all important facts. Show these to be consistent with various theories of mountain origin, and where contradictions arise.

It might interest the students to discuss some of the older, discredited theories on volcanoes and mountains. These could show how we may be in error today about understanding these processes. Ask why we are probably better able to judge today than before. If the discussion leads towards scientific instruments, ensure that the students understand the theory behind each instrument, and not just its function.

Students usually think of volcanoes as very destructive; one might point out that they may provide excellent soils. Most of the coffee soils of South America are volcanic soils, as are the soils of Hawaii.

# Recommendations For Further Study

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Matthews, S. W. "The Night the Mountain Moved," National Geographic, (March, 1960).

Witkind, I. J., et al. The Hebgen Lake, Montana, Earthquake of August 17, 1959. U. S. Geological Survey Professional Paper No. 435, 1964.

## Films:

Birth and Death of Mountains. 12 minues. color. Film Associates.

Birth of a Volcano. 10 minutes. b/w. Ideal Pictures.

Earthquakes. 20 minutes. b/w. Association Films.

Eruption of Kilauea. 27 minutes. color. Western Michigan.

Mountain Building. 11 minutes. b/w. Western Michigan.

Paricutin. 15 minutes. b/w. Department of the Air Force.

Rocks That Form the Earth's Surface. ? color. Britannica.

Volcanoes in Action. 10 minutes. b/w. Britannica.

Wearing Away the Land. 11 minutes. b/w. Western Michigan.

What's Under the Ocean. 14 minutes. color. Film Associates.

Work of Rivers. 11 minutes. b/w. Western Michigan.

Work of Running Water. 10 minutes. b/w. Britannica.

CHAPTER III

OUTLINE (CONTINUED)

## Unit XXI: The Wearing Away and Building Up of the Land

Teacher aims:

I. To teach that the earth's surface is constantly undergoing changes in shape and elevation, and that degradational and depositional forces, working in opposition, are always striving towards equilibrium; also that landscape-shaping processes have been working intermittently and at varying rates (although usually slowly), throughout all the earth's history.

II. To teach that the forces on the surface working at wearing away and building up the land are those of weathering, erosion, transportation, and deposition.

III. To teach that landforms are not accidentally placed, but are arranged in distinctive patterns determined by underlying structures and the active processes of surface forces.

IV. To teach that the earth has had time to have been leveled to sea level millions of years ago, but tectonic forces have uplifted land masses.

V. To teach how many of the earth's gradational processes are easily detectable.

Student aims:

I. To understand how the earth is constantly changing.

II. To recognize the more important erosional and depositional changes occurring around us.

III. To be able to define and describe gradation, and to relate these principles to those mentioned in the chapter on the rock cycle.

IV. To identify the weathering process and understand some of its major results.

V. To understand and differentiate the factors involved in landscape evolution.

VI. To be able to support the theory that continents have been at different elevations above sea level.

VII. To understand how chemical and physical weathering originate and work together in some areas, and separately in others.

VIII. To be able to relate weathering to climatic controls as well as to the different environments in which it takes place.

IX. To be able to relate the process of stream erosion and deposition and the hydrologic cycle, and recognize end products found in the area.

X. To differentiate between the effects and processes of wind erosion and stream erosion.

XI. To relate the local landscape to the period of continental glaciation, and to realize that glaciers might again cover the landscapes previously glaciated.

Content:

I. Gradational agents

"Every valley shall be exalted, and every mountain and hill made low; and the crooked places

shall be made straight and the rough places plain."[1]

The process of leveling the land is called gradation. It is a complex process including weathering, erosion, transportation, deposition, and lithification. Some gradational agents, called static, work without removal of the debris; other gradational agents move and transport weathered matter, called mobile.

II. The static processes or weathering

Weathering is a term applied to the processes that cause rocks at the earth's surface to crumble and disintegrate.

A. Chemical weathering

This causes rock to decompose by undergoing chemical change. Various types of weathering are as follows:

1. Oxidation

This results from the chemical union of oxygen with another element to form an oxide. Oxidation of iron, to form iron oxide, is the most common.

2. Hydration

This results from the chemical union of water with other molecules. Limonite and gypsum are products of hydration.

3. Carbonation

This is the result of the reaction of substances with carbonic acid. Limestone is particularly subject to such weathering. Many caves are the result

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[1] The Bible: (King James Version): Isaiah. Chapter 40, Verse 4.

of dissolution of underground limestone formation by carbonation.

4. Solution

This is the dissolving of elements and combination of elements by water. Leaching of soil minerals is an important result of solution.

B. Mechanical (physical) weathering

This causes rock to disintegrate by being cracked and broken into smaller units. Examples include the following:

1. Freezing water

Water enters cracks in the rock. It expands approximately 10 per cent when it freezes. In so doing, it cracks the rock further. Frozen water pipes and cracked engine blocks illustrate the force of this action; it is the most active physical weathering process where freezing is common.

2. Tree roots

These enter into small crevices and as they grow, the roots exert a tremendous force, thus prying rock masses apart. Uplifted sidewalks are examples of root weathering.

3. Animals

Worms, moles and other animals break up the soil by burrowing.

4. Heating and cooling

As the result of phenomena such as forest fires, or diurnal temperature changes, the further expansion and contraction of rocks results in cracking and breaking.

C. Special weathering effects

Some of the more important of these are as follows:

1. Exfoliation

This consists of the peeling of thin layers from the surface of rocks, especially in climates where there is a considerable diurnal range of temperatures. This results in surfaces with rounded forms.

2. Differential weathering

This results when rocks of different composition weather at varying rates. For example, most silicon rocks weather more slowly than calcareous rocks in humid climates.

D. Results of weathering

These are very important to mankind. Some are:

1. The formation of soil.

2. The concentration of valuable minerals.

III. The mobile processes or erosion

Erosion is defined as the removal of rock materials by one or more of a number of processes. These removal processes continue the work of weathering, and include:

A. Mass wasting

This is the falling and sliding of bedrock, soil, and mantle materials down slopes as the result of a combination of gravitational pull, water, temperature changes, earthquakes, and the works of man. It may occur slowly or rapidly.

1. Slow movement

Soil creep or earth flow usually occurs in humid regions where saturated soils and mantle may move downward over a period of several hours. Telephone poles and fence rails that are slightly tilted downhill are evidences of soil creep.

2. Fast movement

a) Mudflows

These are outpourings of great masses of mud, usually down a canyon or a ravine. They may occur in desert regions where, due to a lack of vegetation, a very heavy rainfall may cause the exposed soil to become mud. They may also occur on the slopes of erupting volcanoes, where the freshly fallen ash and dust is especially susceptible to this form of erosion. Recent violent and destructive mudflows have occurred in the southern California coastal areas, where considerable rain has followed brush and forest fires that eliminated the vegetative cover.

b) Landslides

These are violent cascades of rock and soil. Natural erosive forces may weaken earth structures, or man-made excavations may undermine rock masses. Fortunately, most landslides occur in sparsely populated mountainous regions.

B. Running water

Stream action is responsible for sculpturing over 90 per cent of all landforms. (A stream is flowing water seeking a lower elevation along a channel.)

1. Stream functions

a) Erosion

The following are factors in the erosive power of a stream:

(1) volume,

(2) gradient (the degree of slope from the source to the mouth),

(3) velocity, and

(4) tools (rock materials carried in the stream).

b) Transportation

This is achieved by one of four means:

(1) suspension - the carrying of small particles in the water

(2) saltation - the moving of larger particles causing them to jump or hop along the stream bed

(3) rolling - the pushing of the largest particles (stone or boulders) along the bottom

(4) solution - the moving of a material by dissolving it

c) Deposition by streams occurs when they become overloaded, containing more sediment than they can carry. Material thus deposited is called alluvium. Streams become overloaded as a result of:

(1) decreasing velocity (the potential load of a stream decreases approximately as the square of decrease in velocity)

(2) Tributaries contributing more sediment than the main stream can transport.

(3) decreasing volume, because of evaporation or ground water infiltration.

2. Stream stages

If no outside forces affect it, a stream will follow a pattern in its development towards equilibrium. This pattern comprises three periods, each associated with a characteristic activity.

a) Youth

Once a stream has formed, initial deepening of the channel is the principal activity. Such streams are characterized by:

(1) not being navigable.
(2) cutting more vigorously downward than laterally,
(3) maintaining a valley wider at the top than at the bottom by slopewash,
(4) having characteristically "V"-shaped valleys,
(5) often having waterfalls and rapids, especially in the early stage of development,
(6) occupying all of the valley floor,
(7) and often being susceptible to rockslides and rockfalls.

b) Maturity

Once the stream has completed its initial rapid downcutting or reached base level, and is essentially free of rapids and waterfalls, it is mature. Such streams are characterized by:

(1) losing great velocity,
(2) curving more easily,
(3) beginning to undercut the valley walls, widening the valley (lateral action more vigorous),
(4) later developing broad loops--or meanders--across the widened valley floor,
(5) establishing maximum relief between the interstream area and floor of the valley,
(6) and their valleys assuming a "U" shape.

c) Full maturity and old age

When the floodplain becomes wide enough to accommodate meanders without necessitating further lateral erosion of the valley walls, the stream enters old age. It is difficult to separate late maturity and old age, since the processes of this stage are continuations of those of the mature stage. Streams in these stages are characterized by:

(1) larger streams (and the smaller tributaries thereafter) attaining equalibrium,
(2) developing the entire region into a series of low divides.

3. Stream features

Stream features result from different methods of stream erosion; each feature depending upon the nature of the channel materials and resultant cutting power.

a) Drainage basin

The drainage basin of a stream is the area from which the streams obtain water. The line separating drainage basins is called a divide.

b) Stream valleys

These are long, relatively narrow depressions carved by streams in the earth's surface (the width of the valley depends upon the stage of stream development and volume of water carried).

c) A flood plain

The flat land at the bottom of the stream valley deposited by the stream. Each time the river overflows its banks a layer of fertile sediment is deposited over the floodplain. (Much of the world's population lives on fertile flood plains.)

d) Natural levees

These are stream banks formed by the deposition of silt from floods; they are higher than the floodplain behind them.

e) Ox-bow lakes

These are formed when a meandering stream cuts across the narrow neck in the meander, making a cutoff, and leaving a backwater; deposition then accumulating at the edges of the new stream course eventually separates the meander from the river. If the water in the ox-bow lake disappears, it is then called an ox-bow, or a meander, scar.

f) Alluvial fans

These are deposits left by a swift-flowing stream as it enters a plain or open valley and loses its velocity. Several interconnecting fans form an alluvial piedmont.

g) Deltas

These are alluvial deposits at the mouth of streams laid down because of the slowing consequent on the stream riching its base level. Because material is deposited in the stream course, the stream seeks new channels; thus a delta is usually characterized by numerous distributaries (mouths) with intervening alluvial deposits.

C. Ground water

Most of the erosive action of ground water (see Unit XVII, I-B) results from its particular chemical characteristics--usually carbonic acid with the water. Thus, tending to be slightly acidic, ground water dissolves rocks such as limestone with relative ease.

1. Karst landscape

When underground erosion affects the surface directly, such a surface is called a Karst landscape. Characteristic features are:

a) Sinkholes (depressions in the ground)

b) Sinking streams (streams whose water seeps into underground channels)

c) Blind valleys (stream valleys that end without a visible outlet for water)

2. Subsurface features

Beneath the surface, erosion of soluble rock forms caves; deposition of carbonates by precipitation of residues in dripping moisture within caves forms characteristic features:

a) stalactites
b) stalagmites
c) helictites
d) columns
e) ribbons
f) curtains

D. Wind

Wind blows everywhere, but it is most effective in deserts, along shorelines, and wherever there is inadequate vegetation to secure the soil.

1. Wind action processes

These include the following:

a) deflation

The process of surface degradation by the transportation of fine surface particles by the wind. It is least effective in humid regions.

b) abrasion

The process in which wind-blown particles strike against objects, polishing them, scratching them, and wearing them away.

2. Loess

This is very fine silt or dust which has been transported by the wind. Some of its important characteristics are:

a) It tends to compact with a vertical structure, especially along stream banks. (Vertical heights of loess banks may exceed one hundred feet.)

b) It is extremely fertile when provided with water.

c) It is very porous and dries quickly.

d) Large caves can be cut into the vertical cliffs (these are used as residences along the Hwang Ho River of China).

3. Products of wind action

These are particularly noticeable in arid regions where the result is both erosional and depositional in form. These landforms include the following:

a) desert pavements

These are very hard and comparatively smooth surfaces composed of small rocks in arid regions; they result from the removal of the lighter and finer overlying particles by the wind.

b) deflations, hollows, or blow-outs

These are shallow depressions in the surface of an arid landscape ranging in diameter from a few yards to over a mile. When small depressions in the rock or soil are filled by the infrequent precipitation, the puddle turns to mud which, when dried, is removed by the wind. Each time this sequence occurs, the hollow becomes a little larger.

c) sand dunes

These vary in size with the quantity of sand, wind velocity and wind direction. Several of the more familiar of the sand dune types are:

(1) crescent or barchan dune - resembling a crescent; their points indicate the destination of the prevailing winds.

(2) transverse dunes - found in areas where there is enough sand to completely cover the ground area; they are wave-like ridges separated by furrows, oriented at right angles to the prevailing wind.

(3) longitudinal dunes - created by the accumulation of sand behind some obstacle to the wind; they form long thin lines downwind.

E. Glaciers

Glaciers are large accumulations of ice formed by the recrystalization of compacted snow when and where snow-fall exceeds snow-melt. It is estimated that approximately ten per cent of the earth is covered by glacial ice.

1. Glacial classification

Glaciers may be classified as follows:

a) Continental glaciers

These are great sheets of ice covering large areas of continental extent and having a relatively flat shape.[2]

---

[2]Theories for the origin of periods of continental glaciation must account for differences in the amount of snow or in the rate of melting between the formative period and this present period of glacial recession. Some theories say the glacial sheets originated when the rate of snowfall exceeded melting due to lower temperatures caused by decreases in solar radiation, decreases in carbon dioxide in the atmosphere, and higher continental elevations. Other theories state that the case was increased snowfall resulting from melting of Arctic Ocean ice.

Although continental ice sheets have covered thousands of square miles in northern North America, Europe, and Russia, the only two significant remaining ice sheets are Greenland and Antarctica.

b) Alpine glaciers

These are ice accumulations occupying high mountain valleys; they assume a long and narrow shape.

2. Glacial movement

Glaciers move outward from the center towards a base level (usually the oceans for continental glaciers and the valley floors for Alpine glaciers) due to the pressure of the overlying snow near their source areas. The lower levels usually flow with a consistency similar to thick molasses; the upper levels of the glacier are more brittle and may contain crevasses on the surface. The rate of glacial movement is usually measured in inches a day, but it may attain 50 feet per day.

3. Glacial erosion

Glacial erosion is much greater when concentrated in valleys and lake beds; it is less on broad, flat plains. The moving ice erodes rock by pushing, plucking, and plowing the loose earth. These rock and soil materials become tools for further erosive action, and they themselves become scoured, scraped, and reduced in size. Evidence of rock scraping upon rock within a glacier is found in the parallel scratch marks, called striations, on large rocks and bedrock.

4. Glacial deposition

The glacier carries with it rocks and earth intermixed without regard to size, weight, or shape. Most of this debris,

due to its greater specific gravity reaches the bottom of the ice sheet eventually. Forms of glacial deposition include the following:

a) Boulder clay or till, which is the rock waste remaining as the glacier begins to melt. This till can range in thickness from inches to scores of feet. Mixed with till are large rocks and boulders called erratics.

b) Outwash, which is the glacial material that was light enough to be carried beyond the melting glacier by melt water and laid down in broad deposits of sediment.

5. Glacial landforms

Glaciers produce many spectacular landforms differing from those produced by the other erosive agents.

a) Erosional landforms

These include the following:

(1) a cirque - a deep rounded hollow with steep sides, formed by the intense pressures of snow and ice at the head of an alpine glacier.

(2) an arete - a mountain ridge formed by the erosive work of two adjoining glaciers; it is usually the divide between adjoining cirques.

(3) a horn - a sharp peak formed by the erosive work of three or more adjoining mountain glaciers.

(4) a "U" shaped valley - the characteristic valley formed by alpine glaciation. (They are differentiated from the "U" shaped valleys of streams in late maturity by the steepness and height of the valley walls.)

(5) a hanging valley - a valley of a tributary which enters a main valley above the bed of the latter; waterfalls and rapids may result. (This results from the deeper cutting action of the glacier in the main valley than that of the tributary valley.)

(6) ice-scoured plains - formed from old valleys and hills by the great force of moving ice removing angular features, changing them to smooth and rounded forms. (Usually most of the topsoil has been scoured from the hills, and a thin layer of till has been deposited in the valleys; as a result, there is very little agriculture on these plains.)

(7) fjords or firths - glacial valleys, the bottoms of which are below sea level.

b) Depositional landforms

These include the following:

(1) moraines - formed from the debris carried along by the moving glacier.

(a) rock debris broken off by frost and other gradational agents fall onto the ice to form <u>lateral moraines</u> on each side of the glacier.

(b) The intersection of two valley glaciers is likely to result in the formation of a medial moraine.

(c) ground moraines are formed from the debris that is carried along at the bottom of the glacier.

(d) terminal moraines are formed at the end of the glacier where the material is pushed.

(2) Drumlins- elongated, usually oval shaped, hills or ridges formed beneath the glacial ice and aligned parallel to each other and in the direction of ice movement.

(3) Esker - long and narrow ridge of sand and gravel deposited in the bed of a stream flowing beneath or within the glacial ice, and left behind after it melted.

(4) Kettle - depression in an outwash plain, probably formed when a mass of ice covered by level outwash melted, thus permitting debris to settle into the cavity.

(5) Drift plain or till plain - a large area of relatively low relief, the surface of which is till, occupying the greater part of the region of glacial deposition.

(6) Outwash plain - an area of outwash deposition. The materials are usually sorted; coarser material is deposited closer to the margin of the melting lacier, and the finer materials are carried farther.

(7) Lake plain - an area often covering thousands of square miles that were covered by glacial lake.

(8) Glacial spillway - produced by the runoff of glacieal meltwater, creating large valleys, many of which are presently occupied by smaller rivers.

F. Waves and currents

Waves and currents are motions created in large water bodies by external forces. They are effective agents of erosion.

1. Waves

Waves are oscillations of a substance; waves of water primarily result from wind action. In times of relative calm the waves tend to build beaches and otherwise deposit materials. In times of storm shorelines erode rapidly or slowly, depending upon the resistance of the shoreline material. Erosion also depends on the two following factors:

a) Wave motion

Waves move vertically, horizontally, and in a circular pattern. There are two resultant types of waves:

(1) Waves of oscillation - waves in which the water droplets do not change their mean position, but move in a circular pattern; the moving wave is the result of the combined motion of the water particles.

(2) Waves of translation - when the waves approach the shoreline, the decrease in depth distorts the wave patterns, resulting in the building of the wave until it crests and topples forward, forming a breaker. In these waves, the water itself is actually changing its average location.

b) Wave height

This is determined by:

(1) wind velocity,

(2) fetch (or water distance over which the wind has blown),

(3) and wind duration.

2. Currents

Ocean currents are the movement of surface waters of the oceans.

a) Cause of currents

The four main causes of ocean currents are:

(1) prevailing winds,

(2) density variations due to differences in temperature and salinity,

(3) deflection of currents caused by the Coriolis Force,

(4) and unequal atmospheric pressure.

b) Categories of currents

Ocean currents can further be divided into cold and warm currents relative to the overlying atmospheric temperatures. They can also be classified as follows:

(1) longshore currents,

(2) currents running parallel to the shoreline, or striking it obliquely; these result from the piling up of water on the shore and an oblique wind, (they may deposit materials forming a barrier beach)

(3) tidal currents, fast movements of tidal water through a narrow inlet,

(4) and rip currents, which are strong, narrow currents moving outward from the shore, resulting in excessive quantities of water on the shore being piled up by breakers.

3. Landforms produced by current and wave action

a) Depositional landforms

These include the following:

(1) beach - that portion of land between the high and low water marks formed by the action of the sea; protected beaches usually consist of sand and exposed coasts usually have beaches consisting of rocks and pebbles,

(2) bars - ridges of sand and rock fragments deposited due to a reduction of current velocity,

(3) spits - narrow bars of sand and gravel formed by longshore drift, projecting into the sea from the land,

(4) hooks - spits caused by wave action and curved at the sea end,

(5) tombolos - bars joining an island to the mainland or joining two islands.

b) Erosional landforms

These include the following:

(1) sea cliffs - cliffs resulting from the action of waves on land sloping into the sea; the waves tend to level the land on which they work, thus cutting a step into the slope. The cliffs develop as the waves cut back the material; the rise of the land slope causes the height of the cliff to increase.

(2) sea caves - formed by waves acting differentially on weaker rocks in the cliffs along the shoreline.

(3) stacks - sea cliffs cut off from the mainland by being more resistant than the surrounding rocks.

(4) sea arches - created when a cap layer of resistant rock connects a stack to shore or connects two stacks.

Suggestions to the teacher:

This is the final unit in the course. The students should now be able to look upon the landscape and see it as the result of many natural processes, e. g., a gully could be seen as relating to soil types, vegetation, soil moisture, running water, the precipitation regime, and man's interference. The key word in this unit, and all subsequent study, is synthesis.

The physical features and the cultural aspects can now be understood better as an integral whole. It is not that they must be studied as a whole, but a much greater degree of latitude in geographic interpretation should be available for the student.

Weathering is best taught by example. There are many tests to show how rocks react to different processes of physical and chemical weathering. One would be to heat the different rocks under a flame, and then to immerse them in cold water, and observe the results. Subject some to acid tests, preferably with hydrochloric acid. Remind students that dissolving of soluble rocks takes place much more slowly in nature than the test indicates.

A field trip to observe natural examples of weathering would be most effective. If this is impossible, different students could explain weathering processes they have seen, or present slides and photos in class. Students could collect materials demonstrating the effects of weathering.

One could point out that weathering can be very damaging and expensive to man, even though he accepts it as an ordinary process. Students should give examples such as buckled streets in the springtime, or outdoor plumbing twisted by moving earth.

When discussing earth movements, point out that these processes are common in all regions. Students should be aware of violent landslides, but urge them to be alert to minor local examples, e.g., slumping telephone poles and fences, or slump along streams.

Effects of erosion and deposition by streams are features easily observed and described. If possible, have a stream box built, filled with sand, and allow water to flow through the inclined box for several days, varying the flow of water. Try to have at least one of the sides made of glass. Place objects of different hardness and structure in the sand box and observe differences of erosion and deposition. Daily observation is important.

Field trips to local streams could show some of the more simple landforms produced by stream action. Make sure the students understand the theories of the different processes involved in stream erosion before taking the trip.

Go outside your school and observe some small gully wash. Try to do this on subsequent days, if you find one deep enough to continue downcutting. Observe the distribution of materials carried away by the runoff.

Wind erosion is best approached by emphasizing what conditions favor this process. It should be easy to obtain slides, films, or pictures of dry land conditions. Students should soon observe that many stream-made features occur in deserts; in fact, water is the most important agent of erosion in deserts. The students would probably disagree with this at first, but bring out the relationship between vegetation, nature of precipitation (intense, if sparse) and erosion, as applied to deserts in particular.

Few of your students may realize the effect of average temperature changes; continental glaciation brings this out. Point out that long-term temperature changes constantly occur. Explain that if the

mean temperature dropped only ten degrees, it would probably bring back the glaciers. If the atmosphere were to warm ten degrees, most of the arctic and antarctic ice would melt and the sea level would rise by more than 200 feet.

Make sure the students understand what conditions are necessary to convert snow into glacial ice, and that this ice is a substance capable of downhill movement. The best way to explain glacial landforms, or any of the erosive and depositional landforms, is by slide demonstration or personal contact.

Wave movement could easily be demonstrated by snapping a rope with one end attached to a fixed object. Although there is an apparent forward motion, the rope does not change its location; it only vibrates up and down.

In conclusion, remind the students that the world is theirs to enjoy and understand. Discuss how knowledge gained in this course could be applied to other aspects of their experience, both educational and otherwise.

# Recommendations For Further Study

## Books:

Bascom, Willard. Waves and Beaches. New York: Anchor Books, 1964. Pp. 267.

Cooper, Gordon. Along the Great Rivers. New York: Philosophical Library, Inc., 1953. Pp. 159.

Dyson, J. L. The World Of Ice. New York: Alfred A. Knopf, 1962. Pp. 292.

Fenneman, N. M. Physiography of Western United States. New York: McGraw-Hill Book Co., Inc., 1931. Pp. 534.

Fenneman, N. M. Physiography of Eastern United States. New York: McGraw-Hill Book Co., Inc., 1938. Pp. 714.

Heller, R. L. Geology and Earth Sciences Sourcebook. New York: Holt, Rinehart, and Winston, Inc., 1962. Pp. 496.

King, C. A. An Introduction of Oceanography. New York: McGraw-Hill Book Co., Inc., 1963. Pp. 337.

Sharp, Robert P. Glaciers. Eugene, Oregon: University of Oregon Press, 1960. Pp. 78.

Shepard, F. P. The Earth Beneath the Sea. Baltimore: John Hopkins, 1959. Pp. 275.

## Periodicals:

Ives, Ronald L. "Interior Erosion of Desert Mountains," Journal of Geography, LXIV No. 1 (January, 1964), 3-14.

Films:

Birthplaces of Icebergs. 11 minutes. b/w. Britannica.

The Earth: The Oceans. 12 minutes. color. Coronet.

Erosion. 11 minutes. b/w. Department of Agriculture Soil Conservation Service.

Geologic Work of Ice. 11 minutes. b/w. Britannica.

Glacier National Park. 9 minutes. b/w. Ford Motor Company.

Grand Canyon of Northern Arizona. 17 minutes. b/w. Santa Fe.

Ocean Currents. 17 minutes. color. McGraw-Hill.

Rocky Mountains: A Geographic Region. 11 minutes. color. Coronet.

# APPENDIX I

# THE QUESTIONNAIRE AND ITS RESULTS

PRINCIPAL

1. Yes No Is geography taught at your high school? If the answer is "yes", please answer questions 2-6.

2. Names of the courses. Underline those required.

   A. _____

   B. _____

   C. _____

3. Please indicate by letters "A", "B" and "C" (corresponding to courses "A", "B" and "C" in question 2) if credit is received for the geography courses in the following departments:

   _____ Social Studies

   _____ History

   _____ Economics

   _____ Science

   _____ Business Administration

   _____ Other

4. Geography is taught in the department of:

   _____ Social Studies

   _____ History

   _____ Economics

   _____ Science

   _____ Business Administration

   _____ Other

5. The majority of the students taking geography are in the:

   _____ College Preparatory Curriculum

   _____ General Curriculum

   _____ Vocational Curriculum

   _____ Business Curriculum

   _____ Other (please state)

6. Students may take geography in lieu of:

   _____ Earth Science _____ Chemistry

   _____ Biology _____ World History

   _____ Physics _____ Sociology

   _____ Other (please state)

7. _____ Is geography offered in the junior high school? Please place an asterisk before the answer if it is required.

8. _____ Is earth science offered in the high school? Please place an asterisk before the answer if it is required.

9. Do you plan on adding any of the following geography courses in the near future?

_____ Physical Geography

_____ Economic Geography

_____ Human and Social Geography

_____ Regional Geography

_____ Other (please state name)

10. If a physical geography is or could be added to your curriculum, which of the following items would you consider for purchase or require the students to purchase (textbooks and the atlas)? Please encircle the sum you would be willing to spend.

| | | | | | |
|---|---|---|---|---|---|
| Textbooks (each) | 4.00 | 5.00 | 6.00 | 7.00 | 8.00 |
| Student Atlas | 1.00 | 2.00 | 4.00 | 6.00 | 8.00 |
| Topographic Maps | 10.00 | 20.00 | 50.00 | 100.00 | 200.00 |
| Wall Maps | 100.00 | 200.00 | 300.00 | 500.00 | 1,000.00 |
| Globes & Models | 50.00 | 70.00 | 100.00 | 200.00 | 500.00 |
| Slides & Visual Aids | 100.00 | 200.00 | 300.00 | 500.00 | 1,000.00 |

11. _____ Would it be possible for all geography courses to be taught in the same room?

12. _____ Would assistance from Western be helpful in developing additional geography courses?

13. _____ Approximately what percentage of your students go on to college?

## SUMMATION OF THE PRINCIPAL'S QUESTIONNAIRE[1]

1. The number of schools teaching geography

| | |
|---|---|
| Responses | 81 |
| Yes | 43 |
| No | 38 |
| Required | 0 |

2. Type of geography course offered by number of schools

| | |
|---|---|
| World geography | 32 |
| High School grography | 4 |
| Physical geography | 3 |
| World and economic geography | 3 |
| Geography and history combined | 1 |
| | 43 |

3. Departments that accept geography for credit (even if taught in another department)

| | |
|---|---|
| Social studies | 42 |
| Economics | 2 |
| Business administration | 2 |
| Science | 1 |

[1]The numbering of the summation corresponds to that of the questionnaire. Slight rewording is necessary for clarification of the summation.

4. Departments that actually teach geography

| | |
|---|---|
| Social studies | 39 |
| Business administration | 2 |
| Economics | 1 |
| Science | 1 |

5. Curriculum of the majority of students taking geography by number of schools

| | |
|---|---|
| General | 43 |
| College preparatory | 15 |
| Business | 1 |

6. Subjects allowed in lieu of geography by schools

| | |
|---|---|
| Elective | 23 |
| World history | 6 |
| Sociology | 4 |
| Biology | 2 |
| Physics | 2 |
| Chemistry | 2 |

7. School systems offering geography in the junior high school

| | |
|---|---|
| Responses | 68 |
| Yes | 58 |
| No | 10 |
| Required | 46 |

8. School systems offering earth science

| | |
|---|---|
| Responses | 65 |
| Yes | 17 |
| No | 48 |
| Required | 2 |

School systems offering earth science but not geography

11

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9. Geography courses to be added by responding schools

| | |
|---|---|
| Physical | 5 |
| Regional | 3 |
| Human and social | 2 |
| Economic | 3 |

---

10. Responses inconclusive (money available for equipment)

---

11. Number of schools that would provide a separate room for geography courses

| | |
|---|---|
| Separate room | 54 |
| Multiple rooms | 12 |
| Undecided | 3 |

---

12. Schools that would use assistance from Western Michigan University in developing new geography courses

| | |
|---|---|
| Yes | 42 |
| No | 11 |
| Undecided | 3 |

---

13. The questionnaire revealed no valid correlation between percentage of students that go on to college and the schools offering geography courses.

---

TEACHER

1. Geography is taught by:

   A. _____

   B. _____

2. Also teach courses in:

| Teacher A. | Teacher B. | |
|---|---|---|
| _____ | _____ | Social Studies |
| _____ | _____ | History |
| _____ | _____ | Economics |
| _____ | _____ | Science |
| _____ | _____ | Business Administration |
| _____ | _____ | Physical Education |
| _____ | _____ | Other |

3. What is your undergraduate major? Undergraduate minor?

   Teacher A. _____

   Teacher B. _____ _____

4. What is your graduate major? Your graduate minor?

   Teacher A. _____ _____

   Teacher B. _____ _____

5. How many semester hours do you have in college geography?

   Teacher A. _____ Teacher B. _____

6. If you have less than nine semester hours in geography, would you please list the college geography courses you have taken?

| Teacher A. | Teacher B. |
|---|---|
| _____ | _____ |
| _____ | _____ |
| _____ | _____ |

7. Please check the following items as to the condition and published date:

| | very adequate | adequate | not adequate | not available |
|---|---|---|---|---|
| Maps | _____ | _____ | _____ | _____ |
| Globes | _____ | _____ | _____ | _____ |
| Atlas | _____ | _____ | _____ | _____ |
| Charts | _____ | _____ | _____ | _____ |
| Slides | _____ | _____ | _____ | _____ |
| Diagrams | _____ | _____ | _____ | _____ |
| Models | _____ | _____ | _____ | _____ |

8. What textbooks are you using in geography?

A. _____

B. _____

C. _____

9. _____ Is your present textbook satisfactory?

10. Comments concerning materials:

11. Please underscore appropriate word:

Teacher A: I would, would not be interested in taking a physical geography course if it could be offered in my area.

Teacher B: I would, would not be interested in taking a physical geography course if it could be offered in my area.

Teacher Questionnaire

---

1. Not applicable (Teacher's name)

---

2. Other courses taught by geography teachers

| | |
|---|---|
| History | 18 |
| Social studies | 12 |
| Physical education | 8 |
| English | 5 |
| Economics | 3 |
| Government | 2 |
| Sociology | 1 |
| Mathematics | 1 |
| Counselor | 1 |

---

3. The undergraduate major of geography teachers by number of teachers

| | |
|---|---|
| History | 21 |
| Social studies | 10 |
| Geography | 5 |
| Physical education | 4 |
| Biology | 2 |
| Guidance | 1 |
| No response | 7 |
| | |
| Geography minors | 7 |

---

4. The graduate major of geography teachers by number of teachers

| | |
|---|---|
| Education | 15 |
| History | 3 |
| Geography | 3 |
| Miscellaneous | 6 |

---

5. Number of semester hours in college geography by geography teachers

| | |
|---|---|
| 0 | 11 |
| 1- 6 | 6 |
| 7-12 | 13 |
| 13-18 | 6 |
| 19-24 | 3 |
| 25- | 6 |

---

6. Not applicable (geography courses taken by teachers of geography with less than 9 semester hours of college geography)

---

7. Responses inconclusive (condition of equipment)

---

8. Not applicable (title of textbook)

---

9. Responses inconclusive (is textbook satisfactory)

---

10. Not applicable (comments concerning materials)

---

11. Number of geography teachers interested in taking a college-level physical geography extension course

| | |
|---|---|
| Yes | 38 |
| No | 13 |

---

PRINCIPAL AND TEACHERS

1. _____ Should geography be taught at the high school level?

2. _____ Should it be required?

3. Geography should be taught as part of the:
   _____ Social Science Curriculum
   _____ Science Curriculum
   _____ Business Curriculum
   _____ Core Curriculum
   _____ Separate Discipline

4. _____ Should physical geography be prerequisite to other geography courses?

5. Please check the degree of student competence in each of the following subjects without a prior course or understanding of physical geography:

| | Good | Fair | Little | None |
|---|---|---|---|---|
| Economic Geography | ____ | ____ | _____ | ____ |
| Social Geography | ____ | ____ | _____ | ____ |
| U. S. History | ____ | ____ | _____ | ____ |
| Sociology | ____ | ____ | _____ | ____ |
| Civics | ____ | ____ | _____ | ____ |
| Democracy | ____ | ____ | _____ | ____ |
| World History | ____ | ____ | _____ | ____ |
| Literature | ____ | ____ | _____ | ____ |
| Earth Science | ____ | ____ | _____ | ____ |
| Biology | ____ | ____ | _____ | ____ |
| Physics | ____ | ____ | _____ | ____ |
| Chemistry | ____ | ____ | _____ | ____ |
| Business | ____ | ____ | _____ | ____ |
| Languages | ____ | ____ | _____ | ____ |

There are 42 NDEA Geography Institutes in the summer of 1966.

Thirteen of the institutes are in Michigan or bordering states.

6. _____ Are you or any other staff member planning on attending one of these institutes?

7. _____ Have any staff members attended a previous institute?

8. _____ Are you aware of "The High School Geography Project"?

9. _____ Do you receive their Newsletter?

Principal and Teacher Questionnaire

---

1. Should geography be taught at the secondary level?

| | Prin. | Teach. |
|---|---|---|
| Yes | 69 | 69 |
| No | 0 | 0 |

2. Required — Prin. 20, Teach. 18

---

3. The department principals and teachers believe geography should be taught in:

| | Prin. | Teach. |
|---|---|---|
| Social studies | 67 | 34 |
| Science | 5 | 1 |
| Separate discipline | 1 | 1 |
| Core | 1 | 0 |
| Business | 0 | 0 |

---

4. Should physical geography be prerequisite to other geography courses?

| | Prin. | Teach. |
|---|---|---|
| Yes | 19 | 14 |
| No | 32 | 18 |
| Unanswered | 30 | 18 |

---

5. Responses inconclusive (subject competence)

---

6. How many staff members are planning on attending one of the 42 NDEA Geography Institutes this summer?

| Prin. | Teach. |
|---|---|
| 0 | 8 |

---

7. How many staff members have attended previous geography institutes?

| Prin. | Teach. |
|---|---|
| 0 | 9 |

---

8. How many staff members are aware of the "High School Geography Project?"

| Prin. | Teach. |
|---|---|
| 15 | 8 |

---

9. How many staff members receive the Geography Project's Newsletter?

| Prin. | Teach. |
|---|---|
| 3 | 1 |

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# APPENDIX II

# SOURCES OF TEACHING AIDS

## SOURCES OF TEACHING AIDS

### Films and Filmstrips

1. Almanac Film
   516 Fifth Avenue
   New York 19, New York

2. American Council on Education
   744 Jackson Place
   New York, New York

3. American Meteorological Society
   45 Beacon Street
   Boston, Massachusetts 02108

4. American Museum of Natural History
   West 79th Street
   New York 24, New York

5. American Petroleum Institute
   50 West 50th Street
   New York 20, New York

6. Association Films, Inc.
   Broad at Elm
   Ridgefield, New Jersey

7. Barr Productions
   6211 Arroyo Glen
   Los Angeles, California

8. H. E. Budek Company, Inc.
   P. O. Box 307
   Santa Barbara, California

9. Castle Films
   1445 Park Avenue
   New York, New York 10029

10. Cenco Educational Films
    1700 Irving Park Road
    Chicago 13, Illinois

11. Contemporary Films
13 East 37th Street
New York, New York 10016

12. Coronet Films
Coronet Building
Chicago, Illinois 60601

13. Curriculum Films, Inc.
10 East 40th Street
New York 16, New York

14. Department of the Air Force
Public Information Officer
Middletown, Pennsylvania

15. Encyclopedia Britannica Films, Inc.
1150 Wilmette Avenue
Wilmette, Illinois

16. Eye-Gate House
2716 41st Street
Long Island, New York 11101

17. Fideler Company
Information Classroom Pictures
31 Ottawa Avenue, N.W.
Grand Rapids, Michigan 49502

18. Film Associates of California
11014 Santa Monica Blvd.
Los Angeles, California

19. Filmette Company
635 Riverside Drive
New York, New York 10031

20. Films of the Nations Distributors
62 West 45th Street
New York, New York 10036

21. Geography Filmstrip Series
P. O. Box 7600
Chicago, Illinois 60680

22. Haeseler Pictures
Amity Road, Woodbridge
New Haven 15, Connecticut

23. The Jam Handy Company
2821 East Grand Avenue
Detroit, Michigan

24. Hoefler Productions
7934 Santa Monica Blvd.
Los Angeles 46, California

25. Ideal Pictures
1558 Main Street
Buffalo 8, New York

26. Institutional Cinema Service
1560 Broadway
New York 19, New York

27. International Film Bureau, Inc.
332 Michigan Blvd.
Chicago 4, Illinois

28. Life Magazine: Film Strip Division
Time and Life Building
9 Rockerfeller Plaza
New York, New York 10020

29. McGraw-Hill Text Films
330 West 42nd Street
New York, New York 10036

30. Modern Talking Picture Service
3 East 54th Street
New York, New York 10022

31. National Film Board of Canada
680 Fifth Avenue
New York 17, New York

32. Santa Fe Railroad
Film Bureau
80 East Jackson Blvd.
Chicago 4, Illinois

33. Scribner
Educational Department
597 Fifth Avenue
New York 17, New York

34. Shell Oil Company
RCA Bldg., 50 W. 50th Street
New York 20, New York

35. Silver Burdett Company
45 East 17th Street
New York, New York 10020

36. Society for Visual Education
100 East Ohio Street
Chicago, Illinois 60611

37. Socony Vacuum Oil Company
Film Library:
Industrial Relations Dept.
26 Broadway
New York 4, New York

38. Soil Conservation Service
Upper Darby, Pennsylvania

39. Stanley Bowmar
513 West 166th Street
New York 32, New York

40. Stillfilm, Inc.
8443 Melrose Avenue
Hollywood, California 95046

41. Teaching Film Custodians
25 West 43rd Street
New York, New York 10063

42. Tennessee Valley Authority
Film Services
Knoxville, Tennessee

43. Union Pacific Railroad
Department of Traffic
Suite 350
625 Fifth Avenue
New York 20, New York

44. United Air Lines
80 East 42nd Street
New York 17, New York

45. United Nations, Film and Visual Information Division
New York, New York 10017

46. U. S. Department of Agriculture
Office of Information
Washington 25, D. C.

47. U. S. Navy Department
Office of Public Relations
Washington 25, D. C.

48. United World Films
1445 Park Avenue
New York, New York 10029

49. Audio-Visual Department
Western Michigan University
Kalamazoo, Michigan 49001

50. Young American Filmstrips, Inc.
18 East 41st Street
New York, New York 10017

A listing of free films may be obtained from:

Educators Guide to Free Films. Randolph, Wisconsin: Educators Progress Service, annual publication.

A listing of free science materials may be obtained from:

Educators Guide to Free Science Materials. Randolph, Wisconsin: Educators Progress Service, annual publication.

A listing of free filmstrips may be obtained from:

Horkheimer, Mary, and Diffor, John W. (eds.) Educators Guide to Free Filmstrips. Randolph, Wisconsin: Educators Progress Service, annual publication.

A further listing of films may be obtained by obtaining the audio-visual catalogs of institutions of high learning that operate a film lending service.

## Atlases

1. George F. Cram Company, Inc.
   730 East Washington Street
   Indianapolis, Indiana 46207

2. Doubleday and Company, Inc.
   501 Franklin Avenue
   Garden City, New York 11531

3. Encyclopedia Britannica, Inc.
   425 N. Michigan Avenue
   Chicago, Illinois 60611

4. Field Enterprises Educational Corporation
   Merchandise Mart Plaza
   Chicago, Illinois 60654

5. Ginn and Company
   Statler Building
   Back Bay P. O. 191
   Boston, Massachusetts 02117

6. C. S. Hammond and Company
   Hammond Building
   Maplewood, New Jersey 07040

7. Houghton Mifflin Company
   2 Park Street
   Boston, Massachusetts 02107

8. McGraw-Hill Book Company, Inc.
   330 West 42nd Street
   New York, New York 10036

9. National Geographic Society
   16th & M Streets, N.W.
   Washington, D. C.

10. A. J. Nystrom and Company
    333 Elston Avenue
    Chicago, Illinois 60618

11. Ottenheimer Publishers, Inc.
    99 Painters Mill Road
    New York, New York 10016

12. Oxford University Press, Inc.
417 Fifth Avenue
New York, New York 10016

13. Prentice-Hall, Inc.
Englewood Cliffs, New Jersey 07631

14. Reader's Digest Association
Pleasantville, New York 10570

15. Time, Inc.
Time and Life Building
Rockerfeller Center
New York, New York 10019

16. Frederick Warne and Company
101 Fifth Avenue
New York, New York 10003

## Encyclopedias

1. Americana Corporation
575 Lexington Avenue
New York, New York 10022

2. Encyclopedia Britannica, Inc.
425 N. Michigan Avenue
Chicago, Illinois 60611

3. F. E. Compton
1000 North Dearborn St.
Chicago, Illinois

4. Field Enterprises Educational Corporation
Merchandise Mart Plaza
Chicago, Illinois 60654

5. Macmillan Company
60 Fifth Avenue
New York, New York 10011

## Gazeteers

1. Columbia University Press
   2960 Broadway
   New York, New York 10027

2. Harper and Row, Publishers, Inc.
   49 East 33rd Street
   New York, New York 10016

3. Macmillan Company
   60 Fifth Avenue
   New York, New York 10011

4. Meredith Press
   1716 Locust Street
   Des Moines, Iowa 50303

5. G. and C. Merriam Company
   47 Federal Street
   Springfield, Massachusetts 01102

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No. 2. How To Use a Textbook by William Cartwright. 1960.
No. 4. How to Use a Bulletin Board by Marion Grubola. 1960.
No. 8. How to Use Recordings by Richard Siggelkow. 1960
No. 11. How to Locate Useful Government Publications by Stanley Wronski. 1961.
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Association of American Geographers, Annals (Quarterly)
1146 Sixteenth Street N. W.
Washington, D. C. 20036

University of Chicago, Department of Geography Research Papers (Irregular)
Department of Geography
Chicago, Illinois 60637

Economic Geography (Quarterly)
Clark University
950 Main Street
Worcester, Massachusetts 01610

Focus (monthly except July and August)
American Geographical Society
Broadway at 156th Street
New York, New York 10032

Geographical Review (Quarterly)
American Geographical Society
Broadway at 156th Street
New York, New York 10032.

The Journal of Geography (Monthly except June, July and August)
A. J. Nystrom and Co.
3333 Elston Avenue
Chicago, Illinois 60618

National Geographic Magazine
National Geographic Society
16th and M. Streets N. W.
Washington, D. C.

Professional Geographer (Bi-monthly)
American Geographical Society
Broadway at 156th Street
New York, New York 10032

Weatherwise (Bi-monthly)
American Meteorological Society
45 Beacon Street
Boston, Massachusetts 02108

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