AMS TRAINING AID NO. 6

MAP INTELLIGENCE

FIRST EDITION
AUGUST 1953

ARMY MAP SERVICE
CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
WASHINGTON 16, D. C.

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MAP INTELLIGENCE

Preface

College students who keep abreast of modern trends and techniques are aware of the increasing number of maps being used for a variety of purposes. Transportation agencies offer attractive maps of the areas they service. Periodicals depict many phases of current events upon simple maps and diagrams. Military and civic planners spend hours in preparing and utilizing maps. Donald Duck waddles to South America on a cartographic back-ground. In fact, no branch of modern society is untouched by maps.

To utilize this tremendous increase in visual representation of routes, statistics and tactical material, proper training in map reading and construction is imperative to modern society. Thousands of people are already employed by commercial and governmental agencies to carry on the various phases of map preparation. These agencies are increasing the scope of their operations daily but find that the number of persons with adequate background and training to prepare or use their product is limited. More systematic training of the general and selected public will increase the quality and quantity of map makers and map users.

MAP INTELLIGENCE is an outgrowth of experience acquired by the Army Map Service in sponsoring an applied cartography program since 1951 in selected colleges and universities. There has always been a full realization that the text, APPLIED CARTOGRAPHY, contained more material than could be adequately covered in one course. The author, therefore, has attempted in the new text to separate the many phases of map reading and interpretation from the actual processes of map construction which will be presented in a separate treatment and can be used as a separate course.

The primary objectives of MAP INTELLIGENCE is to give the student (1) a general understanding of the many phases involved in analyzing and interpreting different kinds of maps and (2) to provide opportunities for applying what is presented in the text.

The Commanding Officer of the Army Map Service will appreciate receiving comments and corrections directed toward improving subsequent editions. Instructors and students should regard the making of these suggestions as a cooperative endeavor to improve the quality of future training and map utilization.

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*To facilitate compilation of the text and provide an easy method for finding illustrations, each Figure has been numbered to correspond to the page on which it appears. Illustrations have been kept as near explanatory textual material as possible. If more than one illustration was used on a given page, each was assigned a letter in the order in which they were discussed. Illustrations, therefore, are not numbered consecutively and are less in total number than the final Figure numbers might suggest without the above explanation.

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CHAPTER 1

Introduction to Cartographic Representations

Setting the Scene for Map Intelligence

Prologue

"All the world's a stage" - - This and many similar analogies have been written about the earth as a stage upon which the kaleidoscopic roles of human life are enacted. Each person spends his life in close association with the earth scenes and, if he is wise and able, in harmonious adjustment to them. All known civilizations are and have been inextricably tied to some earthly base. It is true that members of these civilizations may temporarily take to the air. Eventually, however, contact must be made with the earth's surface. Scientific development, thus far, has not reached the place where any form of civilization can be suspended permanently in the atmosphere. Man and his machines must still rely upon earthly maps and instruments, food, fuel and repairs.

Even as on the theatrical stage, many different kinds of sets and props are used and abused upon the earth stage. Pilots and navigators are acutely aware of the importance of the props they use in staging scenes on the seas and in the air. They stake their lives upon the adequacy of their instruments, maps and charts. They clamor for improvements in these props and quickly adopt them when they are devised. The average man, by comparison, is often just a "ham" in the use of cartographic aids. He neglects or is only vaguely aware of the place and function of maps in the unfolding play of life. As a consequence, he spends fruitless hours and untold monetary sums searching for, waiting for, and missing cues.

The purpose of this text is to present the salient facts about, and some suggestions for, the fuller use of cartographic representations in the "play" of modern life. "Representations" is used deliberately here because emphasis will be placed throughout this text upon the fact that there is no single map, chart, or plan which is completely adequate for all phases of recreational, educational, commercial, and professional utilization. In terms of our play analogy, an assumption of an "all-purpose map" is like assuming there is a single prop to be used in any stage situation. Obviously, this assumption is ridiculous even though many current television programs seem to endorse it by the omnipresent gun!

Definition of Terms

Many discussions become confused and bog down because some simple or technical term or phrase is not clear to all concerned. Conscientious effort will be exerted, therefore, to explain new terms as they are introduced. Because of a wide difference in background of students, however, some terms may creep in, unexplained, that are new to you. Question these foreigners immediately and naturalize them into your working vocabulary of cartographic terms. Here are a few to begin on:

Cartography

Cartography is considered to be the science of preparing all

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types of maps, charts, and plans, and to include every operation from original ground surveys to final printing of map copies. It includes production in the following three classes:

Class I deals with the techniques employed in making maps, charts, and plans entirely, or principally, from original surveys and observations. Such data may be obtained from engineering surveys on the ground, aerial or ground photographs, electronic or other photogrammetric methods.

Class II uses a product of Class I, for example, a topographic map, as the base upon which to make and record additional original observations. Soil classification maps, geologic maps, aeronautical charts, etc., are typical examples. This class would also include maps that are offic-compiled from maps at scales different from the one being prepared and other intelligence.

Class III consists of office-compiled maps on which are recorded statistical data of many kinds. These maps are made entirely from existing and available data. Maps showing location, extent and character of many physical, economic, and social facts and factors are in this category.[1]

Cartographic Representations

From the above explanation, it is apparent that cartography

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[1]Adapted from Base Maps for World Needs prepared by the Committee of Experts on Cartography for the United Nations, New York:Lake Success, Sales No. 1949 I.19, 1949, p.51 This pamphlet provides a good general summary of the topic and should be scanned by everyone interested in maps.

means the actual preparation of all forms of maps, charts and plans. The term cartographic representations, therefore, will be used in this text to include all the products of cartography instead of spelling them out each time. It has been adopted by the author for the following additional reason. There are no current clear-cut definitions of or distinctions among maps, charts and plans.

Maps.- At One time the distinction between maps and charts was based upon the idea that maps portrayed land features primarily. If water bodies intervened, as in the case of continental or world depictions, they were included only to maintain the desired relationships among land masses.

Charts.- Were used primarily to show details of large water bodies. Only a limited extent of the coastal areas needed as a "setting" for the water features were included. Bathymetric details (depths), currents, and other aids or hazards to navigation usually were shown on these charts.

When man took to the air, he needed some special form of cartographic representation to aid him. Since this need was related to a branch of navigation, it was probably logical to classify the maps made for this use as charts. Actually, the aviator soars over both land and sea. In his flights, the ocean depths are of no great consequence to him since he flies well above them. His only concern is in safely traversing the water in the shortest distance and time commensurate with the capacity of his plane and the number of stops necessary for refueling and conducting military or civilian operations. As he approaches land or flies above it, however, he is concerned with terrain features, especially relief, ground indentifications, and landing fields. Special aeronautical information is superimposed upon topographic maps for these purposes. Thus the aeronautical chart is often a topographic map with navigational aids and data added to it.

Plans.- The third category, "plan", is usually applied to maps that show a large amount of detail of a small area. For example, a city plan generally shows the transportational pattern of streets, railroads, and water bodies where they exist. It also may show prominent buildings and other spots of civic pride or interest. Some plans are made especially to show property lines for ownership and taxation purposes. Once again, however, some foreign countries, notably Great Britain, use the term plan to include maps of greater areal extent than one village, town or city.

Each of the above types of cartographic representations will be elaborated in greater detail later. These first generalizations are offered to illustrate the intermingling and overlapping of terms and types. In the final analysis, each type is meant to accomplish a common objective and that is to show a part or all of the surface of the earth and any of its features selected for a specific purpose. The selection may entail: the relief of a given land area or, that below a water surface; the natural features such as drainage and vegetation; and the man-made cultural features or, it may entail a combination of two or all such details. If these selections are correlated with some organized network which establishes a locational pattern for the earth, the end product is a map. Since "map" is a simple word, it is and often will be used instead of the longer "cartographic representations" in this and other texts.

Map Intelligence

Several names were considered for this introductory course in map reading and interpretation. Map Intelligence was finally selected because of its connotation and denotation. On the one hand, it implies that someone, namely you, is to make intelligent use of maps to gain a vast amount of knowledge concerning the earth, its patterns, and their interrelationships. This can only be accomplished by using intelligence in analyzing and interpreting the material shown on and among maps.

On the other hand, you will be helped toward the acquisition of a professional definition of Map Intelligence which anticipates as well as interprets maps. By this definition Map Intelligence is taken to mean the Product resulting from the processing of all geographic, cartographic and related information that provide data necessary for the preparation or interpretation of maps, charts, and plans. In this definition, related information refers to all documents, facts or observations that may throw light on the varied aspects of map interpretation and/or preparation. The methods by which information is manufactured into intelligence are: collection, selection, evaluation, analysis, interpretation, and integration. In practice, some of these are combined into a single operation, but basically the distinction among them still exists.

A short discussion, at this point, of the many ways that maps are or can be useful in modern life should help you to understand why some map intelligence is needed by every conscientous citizen of the world.

Uses for Cartographic Representations

Location of Places

General Concept

The most universal and apparently time-honored use of maps is for locational purposes. It is trite, but none the less pertinent to remind you of the fact that wars and continuing emergencies have created unprecedented map consciousness among a tremendous public. Nearly every family or person has had some friend or relative visiting or invading an unfamiliar place. The stay-at-homes, consequently, demand a map upon which to locate the foreign spot. Too often, these folks are frustrated in their efforts because map reading is as foreign to them as the spot they seek. To lessen the consternation which ensues, newspapers and even comic books have included simple diagrams as substitutes for maps. News commentators, broadcasting through the medium of television, have set up blackboards in the studio. Sketches made on these boards during the broadcast indicate the approximate location and relationship of places in the news. (Even this crude technique overcomes some of the laymen's fear of maps and may lead ultimately to more accurate maps and capable map users.)

There are two reasons for locating a place: To find its site or precise geographic location and to determine its situation or location in relation to surrounding features. The

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average map patron is usually more concerned with the latter reason even though he may not think of his intention as "situation". Every proficient map user, nontheless, should be familiar with the two terms and their implications.

Site

Any material object from the smallest blade of grass to the tallest skyscraper or highest mountain occupies a definite site on the face of the earth. Even supposedly mobile objects occupy a specific site at any given instant of time. This instantaneous fixation is the basis for motion pictures in which a series of "stills" are turned rapidly to create the illusion of motion. In the case of either the film or the earth site, its exact position can be determined and recorded. In mapping only the positioning of fixed objects is practical.

The degree of precision with which sites can be located depends upon the adequacy of the map itself and the ability of the user to read it. Methods by which an exact location can be shown cartographically will be discussed later. At this point, let it suffice to say that some maps are so hastily or so designedly drawn that it is extremely difficult or impossible to pin-point exact locations. One commonplace example will illustrate this statement:

Literally millions of "road maps" are distributed each year by American petroleum companies. These road diagrams satisfy or confuse automobile enthusiasts and cartographic laymen. The term diagram is used here instead of map since in most cases these examples are not true maps. So long as route numbers, city, town and village names and distance approximations between them are shown, the average user is satisfied. Road-map makers have learned that precise methods for locating places will not be used, and so have devised index numbers and letters for zonal, not precise, location of a place. Anyone who has tried to transfer information from such a source to a more precisely drawn map base can vouch for the grossness of zonal locations.

Situation

In defense of road maps, it should be said that their primary function is not to pin-point sites but rather to aid motorists in selecting routes and estimating distances along them. Road maps clearly identify major roads by route numbers assigned to them. They show distances between individual populated places by means of small numbers and between selected towns by means of symbols such as red stars, and similar colored numbers representing the mileage between these symbols. Thus, the map-user really places more stress on situation than site since he is locating one place in relation to another.

Determination of situation is probably the most common objective of the general map public. They are not so much interested in pin-pointing places as they are in finding out roughly where a place, say Hiroshima, is in relation to a continent, (Asia), the rest of Japan, or to Tokyo. They are seeking a general orientation of one place in respect to something they know or have vaguely heard about.

The better-informed map reader has a similar objective in ascertaining the situation of an earth feature. The major difference between him and the novice is that he examines the feature in relation to appropriate details surrounding it, such as transportation, vegetation, drainage, or other natural and cultural features. Such utilization requires more accuracy than any road map pretends to achieve.

General Education

Classroom Illustration

You may assume that classroom wall maps are adequate media for location analyses and other forms of map reading. Unfortunately, this assumption has widespread acceptance because most students are accustomed to staring at wall maps throughout their educational career and have had little opportunity to evaluate their limitations by comparison with other types of maps.

Any canny cartographer or intelligent map user understands the purpose of wall maps and the reasons for their limitations. In the first place, most such maps are designed for clarity and good distance visibility. Since the map is to be used in fairly large rooms, colors, symbols and identifications are selected to be seen from most parts of the room by individuals with normal eyesight. Furthermore, publishers must anticipate a large volume of sales to justify the expense of producing such a map. Because highly localized maps have a limited sale at present, these publishers offer maps that are generalized enough to be sold in widely separated areas such as throughout the Continental United States. Consequently, the average wall map is designed to bring out broad generalizations and overall relationships among country, continental, and world features rather than to show detailed information about any one place.

Each student should learn to appreciate the fact that most wall map depictions are restricted by the size of the media on which they are presented in comparison to the infinitely greater size of the land mass they represent. On them a large portion of the earth's surface is squeezed into a few inches. This compression precludes any detailed visualization. Only a few of the most salient features can be shown and even these are generalized and stylized. Further elaboration of this limitation will be presented later in the discussion of scales and symbols.

Another limitation of many continental wall map series is related to the importance of continents in comparison with their size. For example, Europe is a small sub-continent of Asia. So many important countries and cities have grown on this continent, however, that they crowd each other on a map. Most wall map series, consequently, show Europe on a comparatively much larger scale than the other continents in order to maintain visibility of details. As a result, students often acquire the impression that Europe is much bigger than it actually is. Correction of this erroneous impression should be achieved by consistant referral to a good globe which is the only true proportional representation of the entire surface of the earth.

Presentation and acceptance of these and several other limitations should strengthen your realization that classroom wall maps are valuable teaching devises for showing locations of selected details. Only preliminary generalizations concerning patterns of earth distributions and their relationships should be expected from the average commercially produced wall map.

Textual Clarification

Increasing map-consciousness and the resultant demand for cartographic representations have influenced many modern publications. The tendency during the last twenty or so years has been to include more and more visual aids in text books. The expense involved in meeting such demands is one strong factor in the increased cost of textbooks. Do you get your money's worth by using these aids in clarifying the textual material presented?

A wealth of simple but clear maps in texts enables the reader to pick up details about general or specialized regional discussions. The awakening concept of including inset maps to orient small local areas to larger and more familiar masses is a decided asset and should not be ignored or neglected.

Textual maps should be used not only to clarify the material presented therein but also to provide understanding of features that cannot be shown on or gleaned from wall maps. The ability to achieve this correlation is one index of intelligent map ability.

Quite obviously no specialized purposes can be assigned to a discussion of textual maps since they can run the whole gamut of map utilization. Their only limitations depend upon the foresight of the author, the amount of money that can be expended on the project and the ultimate ability of the reader to digest their meaning.

If no maps are included to cover a special phase of textual

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development, grab an Atlas! Atlases cover a wide variety of general and interpretative cartographic representations. Once you have mastered the organization and learned the extent of mapped information in the Atlas at your disposal, use it as easily as you do a table fork. Make it the tool for conveying food for thought about earth features from book to mind.

Research in Diverse Fields

Although maps are a valuable tool of the geologist and geographer, they are not the exclusive possession of these groups. Good cartographic representations save thousands of words and help to crystalize facts and figures in diverse fields of interest. No branch of knowledge is exempted. In medicine, the distribution or localization of diseases, physical weaknesses, availability of medical care, sources of drugs and standards of medical proficiency are only a few of the factors reducable to maps. Maps showing the genesis and evolution of words, alphabets and inflections would be helpful to anyone interested in languages. Physicists and psychologists, sociologists and seismologists, economists and etymologists, theologists and thespians all have theories, principles and findings that can and should be shown cartographically. It seems to the author that the burden of students might be lightened if some advocates of special disciplines were forced to reduce their circumspect discussions to simple map terms.

Anyone doing research in specialized fields involving detailed analysis and interpretation of small areas must go beyond the preliminary generalizations made on small scale maps.

Such research demands accurate and detailed representations of the area in question. The researcher, therefore, learns to evaluate and use many different types of maps at varying scales. Many of these maps will be the product of other research for entirely different purposes.

Versatile utilization can be made of maps that reveal distribution patterns. Such patterns graphically illustrate the truism of world interrelationships. They emphasize the similarity of cultural and natural complexes in far-flung parts of the world. These conditions can be broken down into various contributing components by careful study of the distribution patterns of heterogeneous data. For example, large sections of land in Utah, Argentia and India require some form of irrigation if productive agriculture is to be carried on. Specific engineering problems and agricultrual techniques in each area are dependent upon local conditions and economic stage of development. Even among these there may be common denominators which facilitate interchange of techniques.

Although fuller understanding of an area is achieved by superimposition of maps of many types of distributions, some insight accrues from examining just the transportation and communication patterns. The unification and economic advancement of an area is reflected in the complexity of its transportation network and the possibilities for rapid exchange of ideas through communication channels. Something can even be inferred about the social stage from patterns of the sales of comic books and golf clubs!

Students correlating distribution patterns shown on maps must be cautioned constantly to check their map findings carefully with other sources. Human beings inject unsuspected ingredients into the most logical products of sensible correlation. Political, religious and provincial biases often curtail or obstruct the optimum utilization of a given area or idea. Normally such adaptations are explained in reading materials, not on maps.

Civil Planning and Research

Ownership Responsibility

Several phases of cartography are of special value to civil activities. One of the precautions to be taken by a sensible prospective property owner is to verify the boundaries of the land he intends to buy. He may run into trouble in clearing his title in many areas even within the United States. Involved inheritance, claims by adverse possession (squatters' rights) or confused disposition of large estates has created conflicting and overlapping claims. (The saying, "It takes a Philadelphia lawyer to understand it." arose from the fact that during the early settlement of eastern Pennsylvania, so many domestic and foreign dispositions were made of the same land, that many Philadelphia lawyers spent a large share of their time, and gained their reputations, in settling land disputes.)

In areas where such problems have been untangled or constitute a minor proportion of the total property settlement, careful records of property disposition are usually kept. Often maps depicting all the property lines and survey markers in a

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given place are available at the Recorders' offices.

Property owners generally seek the protection of fire and other forms of insurance. Since such insurance rates are based upon location, construction and evaluation of property, accurate records of these factors are compiled and kept up-to-date. One of the best sources for this type of information for populated places in the United States are the Sandborn Insurance Atlases. There are approximately 2000 volumes covering both incorporated and unincorporated places where growth has been sufficient to warrant formal compilation of actuarial statistics. Each volume covers a specific area and includes a wealth of detailed information about each individual piece of property, including water supply, public utilities and similar related data. Anyone doing an urban study will find these atlases invaluable.

Community Endeavors

Modern development of new areas and redevelopment of old ones take planning. Maladjustments are inevitable unless there is constant checking. Often the rapid growth of an area gives rise to inadequacies not envisioned by earlier groups. Most modern cities that have evolved from older nucleii are classic illustrations. Original city fathers could not foresee the congestion, lateral growth, and internal deterioration resulting from scientific innovations concocted by their grandchildren.

Modern society has given birth to marvels. On the other hand, it has nurtured urban monstrosities. Extensive and costly transformation must be planned to make cities socially and economically more acceptable. Transportation arteries which were adequate for the traffic flow of yester-year are now suffering from arteriosclerosis. If the blood of modern transportation is to flow, constrictions must be eased and new arteries created by engineering surgery. Older editions of maps are used as X-rays to identify the danger spots. New maps must be prepared to insure overall diagnostic improvement. Four lane arteries that do not serve the heart are poor solutions which can be avoided by proper analysis of the total transportation system.

Industrial and residential locations are planned by taking into consideration transportation, sanitation, taxation, recreation, and many other "ations". Each of these factors is developable upon maps which afford clearer visualization of their relationships than many thousands of words of text.

Regional Integration

Greater than the problems of urban planning but intimately associated with them are those arising from regional integration. Urban conglomerations are often nucleii for regional activities. The size of the urban nucleus is no index of its importance to regional integration. A very small town may be the focus for political, legislative, financial, commercial and transportational facilities and thereby exert a tremendous influence on the surrounding region. The approximate extent of such a service area constitutes one form of regional analysis which can be deduced from special maps or reduced to them.

Regional integration may, and usually does, go far beyond the confines of the service area of a particular community. Divergent interests may stymy rapid integration. Nevertheless, if enough time is permitted to elapse, many of these groups will encounter problems they cannot solve alone, and will thereby become reconciled to cooperation. Both private and public interests undertake projects which will lead ultimately toward these ends. A few examples will serve to illustrate the immediate needs and long-range planning toward regional goals that can be aided by adequate mapping and maps.

Development of iron ore deposits in new areas requires surveying of the extent of the promoters' holdings. Maps of geological structure and terrain must either be made or procured from existing sources, before actual operations can begin. Regional planning must also be done to insure workers comfort and the steady flow of the necessary supplies and products. Sources of water, construction materials, and food must be sought and insured. If the project develops into a successful, large-scale operation, it will influence the whole region around it. Research and cartographic representations will be needed in guiding this development. The steel companies, or company involved, will reach out for the assistance of other groups and government.

There are many examples of regional planning of developed and poorly developed areas in the United States. One of these is the Missouri Valley Authority. The Missouri Valley Authority regional integration is envisioned through master plans encompassing about 1/5 of the land area of the United States. Thousands of maps have been compiled and are being used in various phases of this project. Some degree of success is being achieved through acceptance of a few of the findings and recommendations of the Authority even though it has not cleared all of the political hurdles set before it. Maps are strong selling aids in showing small groups how local projects contribute to their personal and economic betterment.

National Unification

Size, shape, location, abundance or lack of natural resources, and the social, political and economic stages of development are factors that influence national unification. Maps of these pertinent factors are indispensable to students of individual and collective national scenes. In studying the problems of Brazil in striving for national unification, for example, the great size of the nation, which is larger than the United States, must be evaluated in terms of the poor to nonexistent transportation facilities over most of the interior areas. Natural resources and factors such as climate must be examined to anticipate whether they will aid or hinder national unification. Native and/or imported population must be considered as potential workers. Whether they will work together, fight among themselves or not work at all can be anticipated in part from their cultural and natural backgrounds. All these and many more tangibles and intangibles will help a student to understand what Brazil or any other country must face in working toward real national unity.

Many variables constantly present themselves which either complicate or simplify the situation. Sectional jealousies and economic fear become strongly entrenched in isolated, underdeveloped or poorly endowed areas. Many of these sectional biases grow purely on the basis of ignorance of the value of

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national unity. Development of education, transportation and communication tend to break them down. Examination of maps showing these factors may give a clue to the local condition in relation to its degree of national cooperation.

It is very helpful to have maps or a mapping system established in advance of internal national growth. Unfortunately, these aids were not ready in many of the nations of the world. Consequently, staggering sums of money and time have been wasted in conducting individual and overlapping projects. As the railroads pushed across North America, for example, they ran limited surveys and made choices of rights-of-way that were poor and would have been unnecessary if adequate topographic mapping had been available. Just the cost of fuel required to pull steep grades and to carry heavy trains along needlessly winding routes would have paid for many series of topographic maps covering the entire continent.

At a later date, maps were sought for diagnostic improvement of areas struggling toward better development. Industries often consider and eliminate these areas since no adequate maps are available to show the suitability of sites for constructing factories or warehouses and their relation to markets and materials. All of these are tied up with national unification since they strengthen the exchange of goods and the optimum utilization of manpower and other resources.

International Cooperation

Indications and actual evidence of the feasibility of international cooperation have been accumulating rapidly in the last three or four decades in spite of, or because of, world unrest and conflict. Some of these cooperative endeavors begin at the very root of international understanding which is the individual's right to live decently. The Food and Agriculture Organization, because of its obligation to work for the improvement of agriculture, forestry and fisheries, endeavors to promote the rational use of land and the renewable natural resources. Nothing is more basic to life than this. While FAO is working toward such a goal, CARE is attempting to make life more bearable in the interim.

Gigantic strides, unheralded to the common man, are being taken by many other working groups within the United Nations master organization. Educational programs are in progress which include representatives from many nations. A group of geographers has been studying the teaching techniques and tools basic to the dissemination of sound geographic information. One of the important geographic tools is maps. They serve the educators, agriculturalists, and all branches of United Nations. In recognition of their importance, a small cartographic section of United Nations is working on the availability and distribution of maps all over the world.

One type of map has been decidedly influenced by international agreement. The International Civil Aviation Organization (ICAO) was responsible for establishing the Standards and Recommended Practices for Charts for special and general purposes for air navigation. It has standardized the symbols and allocated areas of responsibility for the production of the

1:1,000,000 World Aeronautical Chart. Such an undertaking illustrates the general trend toward standardization of commercial, professional and even military procedures through international concert.

Military Strategy

Conversion from Peace to War

The interdependence among peoples and nations becomes painfully obvious when national and international maladjustments lead to war. When times of crises arrive, many nations are caught with their planning down. Valuable hours are lost in scurrying around to find out who can contribute what and how much to correct peace-time short-sightedness. Prior planning lessens the danger of such confusion and may even prove indispensable to survival. Knowledge of the distribution and requirements of vital industries is requisite to prompt conversion from peace to war. If strategists can call for and get a great variety of maps, their task is simplified. Maps of flyways and byways; barrens and forests; steel mills and grist mills, and thousands of other cultural and natural distributions contribute to and indicate rearrangement of the master strategy.

Many Maps for One War

Conflicts of global proportions are the price paid during the evolution of a unified "One World." As more and more of the parts are drawn into the whole, greater conflicts seem inevitable. Tactical operations in modern warfare take into account not only far-flung theaters, but also great numbers of men and materials. These necessitate all types of maps in astronomical quantities. During World War II the newly created Army Map Service, alone, produced 40,000 different maps and distributed a total of 500,000,000 sheets. Execution of the North African campaign within this war required 10,000,000 copies of 1,000 sheets. For the Normandy invasion 3,000 sheets were prepared and 70,000,000 copies disseminated.[1]

A single movement may require several different types of maps for its execution. If it is to be a combined land, sea and air operation, air and water navigation charts must be procured and studied for approaches and landing maneuvers. Beach heads and landing strips are studied on existing maps or plotted on new ones. Large scale maps for the foot soldier must be coordinated with tactical maps and charts for jet pilots. This in itself is no small feat when you consider the difference in distance traversed in a given time by the marching columns and the phenomenal jet plane. The pilot of the latter would hardly be able to locate the area covered by the former's map before he would be many miles away.

Raised relief models help field and headquarters officers visualize the types of topography with which they must cope. Routes for long-range movements, places for concealment can be tentatively selected and later checked with larger scale maps.

Planimetric and topographic maps, charts and plans each play a part in the detailed planning of overall and localized

[1]"Arms and the Map - Millitary Mapping by A.M.S." Print Vol-IV No. 2, 1946

strategy. These may be confiscated from the enemy, borrowed from allies or supplied by topographic units in the field and military and/or civilian mapping agencies back home. The net results of acquisitions from all sources equal huge volumes of maps. These volumes mean little, however, unless the individual maps are reliable and the personnel who accumulate them know how to use them competently.

Lengthy definitions and discussions will never make you a map expert. Acquisition of this skill can come with the analysis and use of individual maps. Analysis should come logically before any intensive use, so that you understand the prop you are using. The best way to learn about a thing is to actually or mentally take it apart or put it together. Since we are dealing with the products of cartography, we must take them apart to determine what ingredients were combined to make them.

CHAPTER 2

Map Ingredients

First Impressions

As the curtain rises on the first act of a play, the audience is pleased or dissatisfied by its initial glimpse of the scenery. If the individual parts of this scenery have been well selected and arranged, the spectators will not immediately be aware of the parts unless their attention is directed to them by a specific action. Others may consciously or subconsciously begin to analyze what makes the scene appropriate to the mood and circumstances.

Maps have the same general reception. Many will look at them, note that they are "pretty" or "ugly" and overlook the contributing details. Other more sensitive individuals will analyze what makes the map both attractive and useful.

From the largest wall map to the smallest desk edition, an earnest effort is usually exerted to make each one as attractive as possible since too often "eye appeal" is the only factor considered in the adoption or rejection of a map. Even better-informed prospective map-users will be influenced by this consideration in selecting from among several accurate maps. Any map that is pleasing to the eye encourages further inspection of it. Such appeal is achieved by application of color wherever and whenever it is feasible; by clear symbolization of the features shown; by careful placement of identifications, and by pleasing combinations of lettering.

All of the above should be combined with other aspects before a map becomes a really valuable tool. Utility is achieved by careful selection of information; by adequate aids to utilization of the information, and by some accurately determined method for locating area and details within this area both in relation to the map itself and to the portion of the earth represented.

Test your first impressions of several maps available to you. Consider why you react as you do to them. Then let us begin analyzing the many ingredients needed to make a map appealing and, above all, useful.

Geographic Coordinates

Global Bases for Geographic Coordinates

Frame of Reference

Any map is a representation of a part or all of the earth. It is tied inextricably to the earth and to be useful it should show how the tie is accomplished from earth to map details. This necessitates a frame of reference, which is a very popular term in academic literature. Connotations of this term frequently become exceedingly involved. When applied to global and map representations, obtuseness is unnecessary. The Cartographic "frame of reference" means a systematic network of lines upon which land and water positions of the world can be located. This network is referred to as a system of geographic coordinates.

To determine the origin and practicality of geographic coordinates we must first review a few simple facts about the earth.

The earth can be represented as a sphere for most practical purposes. (From the standpoint of physics, it is inevitable that a rapidly rotating mass, such as the earth, should assume an essentially spherical shape over a long period of time. Furthermore, since the earth is rotating upon an axis, centrifugal force causes it to bulge away from the center and flatten near the poles, thus creating an oblate spheroid. This bulging makes the equatorial about 27 miles longer than the polar diameter. Converted to circumference difference, it is 24,902 miles compared to 24,860 or 42 miles. Slight variations, which have been computed for these differences will be discussed later. The differential is so slight that the earth will be called a sphere for purposes of this review.)

The next plain fact is that the earth is too big to deal with as a unit. It must be divided in some manner. Geographic coordinates provide convenient reference points for the determination of location, distance and direction relationships on the surface of the earth or its representations. Many complicated trigonometric formulae are available for establishing a network of these lines on a sphere. Frequently, mathematicians and educators take delight in flaunting their knowledge before non-mathematical-minded students. The result is a fear of and confusion about the way the earth has been divided by means of geographic coordinates for convenience of its inhabitants. These coordinates are actually no more complicated to use than a simple graph having a X and a Y axis. Instead of being called X and Y, however, they are called latitude and longitude or, parallels and meridians.

Latitude - The X coordinates are latitudes or parallels. When the earth is assumed to be a sphere with a north-south axis, a line can be drawn midway between the two poles and at right angles or perpendicular to this axis. This midline is the Equator, and latitude means the angular distance north or south of this midline. Since the Equator is the line of origin from which latitude is measured, it is labelled 0 latitude. Then from the Equator to each pole is one forth of a circle (360°) or 90°. Consequently, whenever the degree method of angular measurement is used, latitudes can never be numbered more than 90. (Another method for dividing a circle will be discussed later.)

Since you are working with a round earth even though latitude measurement in terms of angles is logical determination of the origin of these angles is difficult to visualize unless you can use your imagination. To help you see how these angles can be derived graphically, you must imagine thatthe earth has been cut in half from pole to pole. In Figure 29 you now see the earths' polar circumference as a circle and the equatorial and polar axes or planes revealed in their true perpendicular alignment, intersecting at the center of the earth. Another line has been drawn to represent a plane of latitude. By drawing a radius from the axial intersection to the point where this plane cuts the circumference and extending it slightly, we can measure the angle of any latitude in question. Perhaps you remember that when two lines are drawn parallel to each other

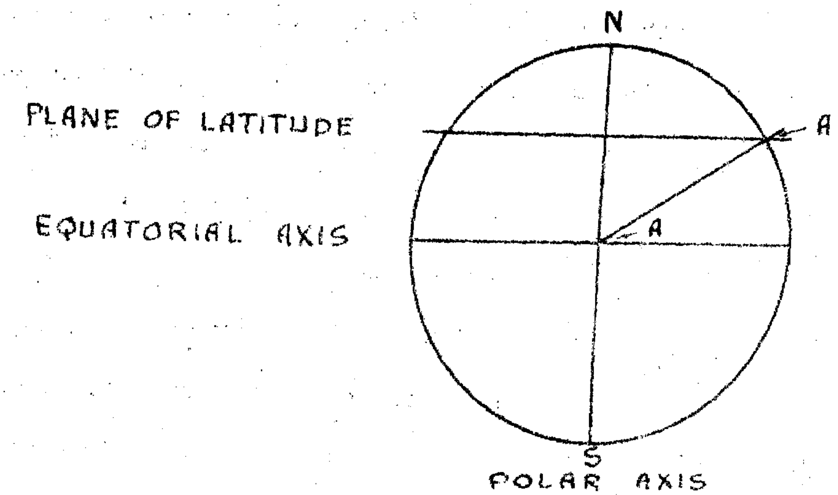

FIGURE 29

and a diagonal line is drawn between them, opposite angles are equal. Thus, the angle formed between the radius diagonal and the equatorial axis, A would be the same as that formed by the plane of the latitude with the radius A^1.

The angle in Figure 29 is approximately 30°. Therefore, the parallel of latitude is 30° N of the equator. Any number of other latitude lines could be determined in a similar fashion. They might not be even degree units, but might be minutes, seconds, or fractions of seconds of one degree apart. Multiple degree units are often used on maps and globes simply to lessen the theoretically possible maze of lines but any line that is parallel to the equator is theoretically a latitude line.

Another approach may be made to the same problem by using factors which can be seen on the surface of the earth without visualizing two axes that are buried in the exact center of the earth. This method can be applied at two dates in the calendar year and at the instant when the sun reaches its highest point (or noon) in the sky on these dates. The dates are conincident with the vernal and autumnal equinoxes, or March 21 and roughly September 22. If the sun cooperates, an observer at any given spot on the surface of the earth can calculate the angle the sun makes with a point directly overhead. Overhead is the Zenith and the angle of the sun from it, is Declination. See Figure 30.

(This declination can be proved to equal the latitude of the observer.) All observers standing the same distance from the equator record the same angle. If a line were drawn around the earth connecting their locations, it would be a complete circle of latitude.

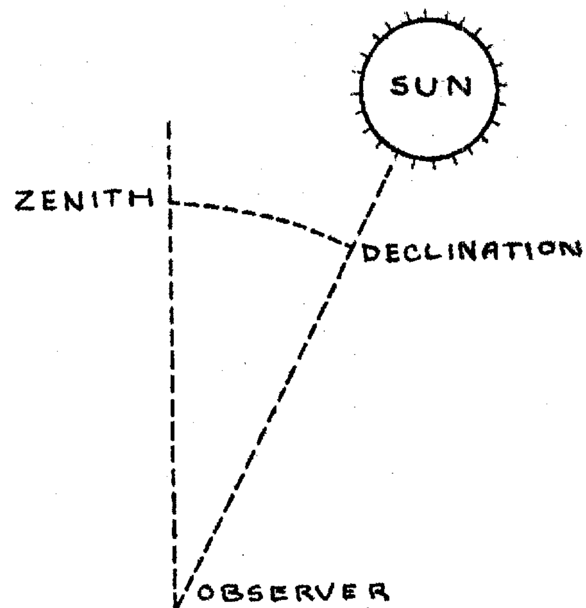

FIGURE 30

After you comprehend the derivation of latitudes, it is necessary only to remember that latitudes are lines running parallel to the equator and are used like city blocks to tell how far north or south of the equator a particular spot or long street (parallel) is located.

<u>Longitude</u> - The next consideration is where along a particular latitude, in the example, 30°N, a given spot, X, is located. Locating X could turn out to be an earth-encircling journey if no

limiting coordinates were supplied. Derivation of these coordinates is more difficult than derivation of lalitude is. There is no true E-W axis to correspond to the N-S polar axis. Dividing the globe into two hemispheres and running meridians parallel to the dividing line would mean a complete disregard of a fundamental sun-earth relationship and pole to pole orientation.

You know that the Sun is one of the stars in the planetary system of which Earth is a part. The earth moves about the sun at the rate of one revolution every 365¼ days. As a result of this revolution, earth inhabitants seem to see the sun move through one complete path in the sky each year. Furthermore, as the earth rotates on its axis, daily sun patterns are drawn. If observers could be lined up along a straight line running from N pole to S pole, they would all see the sun reach its highest point in the sky for the same day simultaneously. Other observers oriented along a N-S line to the east of the first group would have already completed a like experiment, and those to the west would be awaiting their turn. An infinite number of lines extending from pole to pole could be drawn in this fashion and each would be a meridian.

Each meridian would be one-half of the equatorial circumference or Great Circle in length. All would converge at the two poles. It is common sense to realize they could not be parallel to each other as the latitude lines are. Instead, they are equally spaced along any parallel, but the distance between meridians along succeeding parallels decreases poleward from the equator.

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When the zero meridian is established, common sense again dictates that numbering around the circle must stop somewhere or else 0 would coincide with 360 upon completion of the numbering. The meridian which together with 0 on the opposite side completes a great circle, consequently, is numbered 180°. Moving eastward from 0, under this system, numbers increase to 180° and then de-crease back to 0. All numbers eastward between 0 and 180 are la-belled E. Those progressively eastward from 180 to 0 are labelled W. It is now possible to locate an exact spot in terms of its latitude north or south of the equator and its longitude east or west of the Prime Meridian and 180°.

Determining Directions - Notice the numerical values for meridians increase in the direction, relative to the Prime Meridian, for which they are to be named. The same is true for latitudes. It is useful to remember this axiom. You may be called upon to work with a map of a small area which does not include the equator, prime meridian, or 180°. By noting the progression of

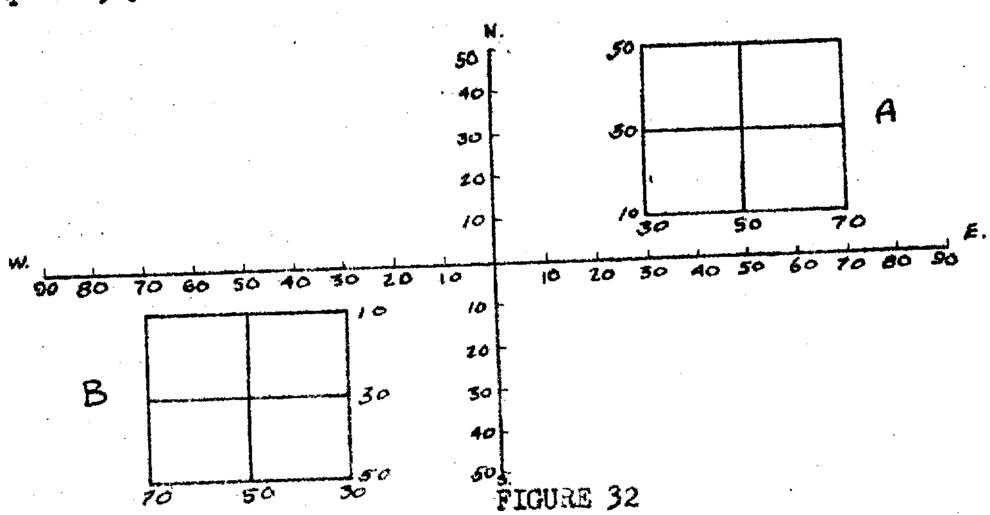

FIGURE 32

latitude and longitude numbers, you will be able to fit the particular sheet into its proper earth position. In terms of east-

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west, north-south coordinates, where are A and B on figure 32?

Do not confuse the locational east-west values assigned by the above technique with active movement in either direction. You can travel around the world always going either east or west relative to a fixed starting point by following a compass in either direction. In contrast, however, directions always change when you move across the poles. For example, from Greenland to Antarctica is south. If you proceed over the south pole and move toward Siberia, you will be going north.

Points of Origin

The Equator

The Equator so logically is a point of origin for the determination and numbering of latitudes, that no conflict has ever arisen, so far as the author knows, over using it for this purpose.

The Prime Meridian

Dissension and divergence have been common to the choosing of a point of origin for meridian numbering. Almost every country at one time used a zero meridian passing through some nationally prominent place, such as a capital or, a place where an outstanding observatory was located. Increasing contacts, occasioned by travel and economic and political associations, created navigational and cartographic confusion in trying to coordinate such a variety of prime meridians. One of the earliest attempts to settle on one prime meridian was made by an international group meeting in Paris in 1634. They decided to select a neutral meridian rather than one then in use by any country.

They chose 19° 55' 03" W of Paris. Since this was an awkward string of numbers to handle, the geographer, Delisle, shortened it to 20° W of Paris. By association it soon came to be thought of as the Paris meridian in disguise which discredited its intended neutrality and strengthened the arguments for an adoption of another point of origin such as Greenwich.

Most of the major nations of the world finally came to a common agreement at the International Conference which was held at Washington, D.C. in 1884. By this time, Greenwich had slowly gained popularity and was being used as the Prime Meridian on more than 3/4 of the maps and charts published throughout the world. Since this choice was based upon a first order observatory that also had wide influence upon time synchronization, the conference logically endorsed Greenwich as the Prime Meridian.

Even today, however, there are some 20 different prime meridians in use. Although many of these are seldom seen, some of them appear on important foreign map series and should be recognized. Many older European map series are based upon Ferro, which is the western-most of the Canary Islands. A meridian passing through this region was long thought to be the western limit of the world. As knowledge of the world increased, mapping kept pace in many respects, but Ferro Meridian has been retained into the present century.

The Pantheon in Paris which is 2° 20' 13.95" east of Greenwich is another origin of longitude used on many map series compiled or influenced by the French. Spanish maps were based on still another, through Madrid; Norwegian, on Oslo; and Italian, on Monte

Mario in Rome.[1] Most new mapping compiled in these countries is being converted to Greenwich, but some of the other origins persist or appear on sheets that are still extant. These examples are sufficient to warn users of foreign maps to beware. Check the origin of longitude! Any calculations based on Greenwich would be false and would cause incorrect interpretation or correlations if some other meridian had been used as the prime meridian.

Methods of Representing Geographic Coordinates

Sexagesimal System

Just as there are variations in the origin of longitude so are there variations in the methods for representing geographic coordinates. One variation arises from different methods used in the division of a circle. The degree system that was used above in the determination of latitude and longitude distances is the one with which you are familiar. It is a part of the sexagesimal system which is based upon divisions of sixty.

The whole sexagesimal numbering system evolved from ancient observation of and reverence for heavenly bodies. Since many ancients were shepherds, they obviously had ample opportunity to watch the sky. They noted that the moon waxed and waned every 30 days. One moon round was called a moonth. Twelve moonths (months) elapsed from spring to spring. Since this completed a cycle or circle, 30 x 12 made 360. All circles were divided accordingly. Sixty was an even multiple or divider of 12 and

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[1]See Appendix for complete list.

360, so was used to represent the number of units in 1 degree, 1 minute, etc. This sexagesimal system became the basis for the English units of measurements for many things besides a circle--of which, more later.

Centesimal System

Circles can be divided in other ways in spite of the saction of long usage given to 360 degrees; 60 minutes and 60 seconds. The centesimal system was originated in France in the 18th century. It is based on a decimal subdivision of the circle. The complete circle is divided into 400 parts called GRADES, or more commonly, Grads. Each grade is divided into 100 minutes and each minute into 100 seconds. Values may be written in grades, minutes and seconds or merely in grades and a decimal fraction. For example, 4 grades, 97 minutes, 30 and 25 hundredths seconds = $4^G\ 97^{\backprime}\ 30.25^{\backprime\backprime}$ or $4.^G973025$. Note: minute and second symbols slope in the reverse of sexigesimal symbols.

If you wish to convert from the centesimal to the sexigesimal or vice-versa, you work on the basis of a quadrant which equals 100^G or 90°. One grade, therefore, equals .9 degrees. Thus,

$$4^G\ 97^{\backprime}30.25^{\backprime\backprime} \times .9 = 4^\circ.4757225$$
$$.4757225 \times 60 \text{ minutes} = 4^\circ.28'.53335$$
$$.53335 \times 60 \text{ seconds} = 4^\circ28'32.601''$$

If a greater degree of accuracy is required, $.01^{\backprime\backprime}$ or $.000001^G$ = .003''.

Latitude and Longitude Symbols

Latitude and longitude are shown on maps in several ways. Usually, when only the geographic coordinate method is used, the latitude and longitude lines are drawn from neat line to neat line on the map sheet. (The neat line is the finishing line around the body of a map and should not be confused with the margin beyond). Each line is appropriately numbered in the margin. Ordinarily, the lines representing full degrees are completely numbered and intermediate lines are numbered by minutes or seconds, omitting the larger units. (Refer to: USGS Tennessee: Chattanooga).

In cases where full lines running across the body of a map might interfere with detail or are unnecessary to the reading thereof, a system of ticks and crosses is employed. Ticks are placed inside the neat line and true vertical-horizontal crosses are distributed throughout the sheet where latitude and logitude lines intersect. such crosses are often called INTERCEPTS. (Anderson Island, Sheet 1478 11 NW)

Some foreign maps contain only marginal notations of latitude and logitude. A long straight-edge must be used between these notations if internal intersections are desired. (Wolfstein West, Sheet 58 W)

Cartographic Frameworks

Characteristics of Projections

Historical Background

The task of the cartographer would be far less complex if the earth were flat, as the early Christian theologians insisted. Convenient discs were mandated by them as the shape of the earth in spite of many scientific hypotheses and proofs that the world was round. These clerics may have believed that they could keep track of their flock better on an earth that had definite linear extent. ("World Without End" was written many centuries latter when sphericity of the earth was a generally accepted fact.) Furthermore, religious adherents and potential converts could be kept in order by gruesome tales of horrible monsters inhabiting the border regions. Religious followers also feared entry into Hades by falling off the edges of the flat earth. Few wanted to attempt to disprove this depiction of terrestrial limits by shoving off into monster-infested seas and supernaturally inhabited lands. Such bravery was built up gradually through succeeding generations. A few men of each generation pressed outward a little farther from the familiar and well defined Mediterranean lands. When they lived to tell such tales as Marco Polo and many forgotten adventurers recited, others took heart. Columbus symbolizes many men who conquered fear to prove the earth is round.

While the adventurers were pushing the physical frontiers further and further afield, mathematicians and scientists were broadening the cartographic horizons. The historical development of maps is a fascinating tale. Many excellent books are devoted entirely to the subject. The reader is referred to these if he is interested in the background for present cartographic achievements.[1] Historical cartography had to be omitted from this present text because of time and scope factors. It is felt that you will have a full enough schedule in learning how to use and interpret maps of the present century.

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[1]One of the most scholarly but at the same time enjoyable volumes is Lloyd Brown, The Story of Maps New York: Little Brown, 1949. Others are listed in the Bibliography at the end of this text.

Global Criteria for Evaluating Projections

So many varieties of projections have been devised and have received limited or widespread acceptance that the average person is either lost or, by inertia, fails to recognize any difference among projections. As soon as he learns there is no such thing as an all-purpose map base and accepts the conclusion of a newspaper writer who titled his article "All Maps are Liars"[1], then he must learn some method for evaluating the strengths and weaknesses of individual projections. The globe itself provides the necessary tools. Let's take the time to identify these tools so we can use them. Take your turn at the classroom globe to verify and digest the following points:

(1) The equator is a line drawn mid-way between the two poles and perpendicular to the polar axis.

(2) Each line of latitude is parallel to the equator.

(3) The interval or spacing between each parallel is equal to the same number of degrees.

(4) The equator is the only great circle line of latitude.[2] All others are small circles, the

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[1] "All Maps are Liars" - New York Times, Sunday Magazine, Oct. 11 1942.

[2] A great circle is any circle whose plane passes through the center of the globe and cuts the circumference at two points 180 degrees apart.

total length or circumference of which decreases in relation to their distance away from the equator.

(5) Each meridian is $\frac{1}{2}$ a great circle in length. (Two opposite meridians make one great circle.)

(6) All meridians converge at the two polar points.

(7) Spacing between meridians is equal along any parallel, but the total space between meridians decreases poleward.

(8) Latitude and Longitude lines cross at right angles.

(9) All areas are in correct scale ratio to earth measurements.

If you will digest the meaning of these criteria, you will have a "saw" for the dissection of any projection to decide its general value for a particular job. You must, of course, know whether shape, size, or direction accuracy is most essential.

Attributes of an Ideal Projection

An ideal projection would conform exactly to the global criteria and any map developed on it would truly represent earth features. Such a map would contain four important attributes required of a perfect projection. These are:

(1) Mapped areas conform to their true earth shape.

(2) Areas retain their correct size in ratio of earth to map scale.

(3) Directions anywhere on the map are identical

to true earth directions.

(4) Stated distances anywhere on the map are in correct proportion to true earth distances.

In essence then, these four properties control conformality of shape, equality of area and correctness of directions and distances. If all were present, the much-sought perfect projection would have been achieved.

Compromises of Existing Projections

The very nature of the relationship of round earth to flat paper makes a perfect projection impossible. Any large part of a spherical surface cannot be laid out on a flat surface without shrinking, breaking or stretching it somewhere. It follows, therefore, that it is impossible to lay out a flat unbroken network of lines that will conform to all the global criteria listed above. Consequently, it is equally impossible to achieve the four properties required to make a perfect flat map. The problem has stumped the experts, but has led to many compromise projections which contain one or more of the properties or close approximations to them. These are obtained in the following ways.

Conformality - in cartography means that the shape of a map surface at any given spot is identical to the shape of the corresponding spot on the earth. This definition sometimes causes confusion when it is falsely enlarged to imply the shape of a large area such as a continent. "At any given spot" is underscored to emphasize the restriction of conformality to small areas or spots and not extension to overall shape.

On any given projection, the angle at which each parallel

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crosses each meridian governs the shape of the area adjacent to intersection. According to our global criteria, each meridian crosses each parallel at right angles. Preservation of right angles together with the same scale along the parallel and meridian at any point makes a projection CONFORMAL.

An ordinary pack of index cards can be used to illustrate conformality or the loss of it by alteration from right to acute or obtuse angles. Take the whole pack of cards and stack it vertically, taking care to maintain right angles at the corners. Draw a vertical line down the center of one side. Assume that this line and the vertical edge lines are meridians and the planes of given cards are parallels. Any earth feature correctly drawn on this assumed network, or projection, will be conformal.

Now push the individual cards in such a way as to change the edge angles but not the unity of the pack. One edge of the pack will now approximate the shape of a meridian as it varys in response to changing the angle of each card (parallel) to the edge line (meridian). The overall length of the once vertical edge will be expanded while that of the central vertical remains constant (Note: A new central vertical must be drawn for each change in card arrangement.) Call the vertical the central meridian and the outer edge the limiting or bounding meridian. On the globe each meridian is equal in length; whereas, on the card illustration, the edge line is longer than the central vertical. Any map shape drawn under these conditions will not conform to its original earth shape even though its area is preserved. Figure 43 shows this on an actual projection net on

SKETCH OF EQUAL AREA, NON-CONFORMAL PROJECTION

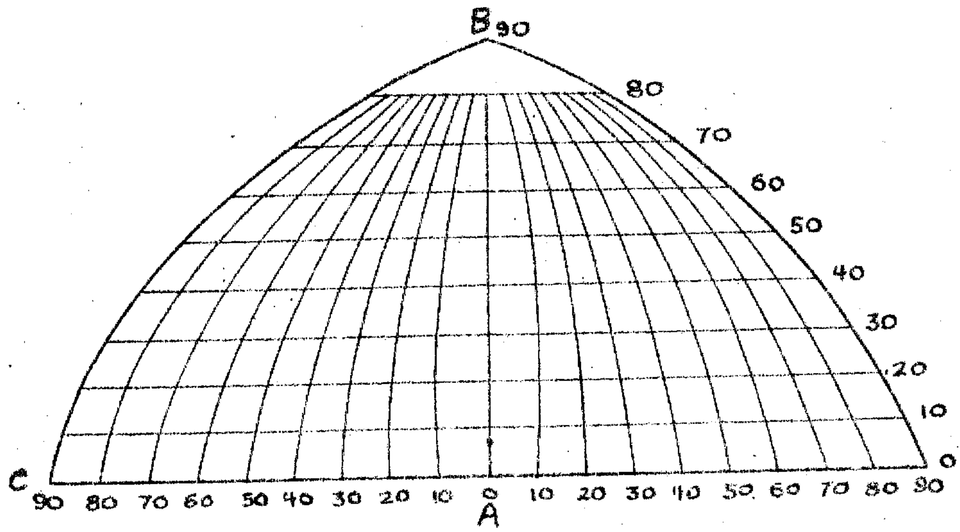

FIGURE 43

which the meridian length between A-B is shorter than between C-B.

True Directions - Quiz masters delight in stumping contestants by asking, "Which is farther north, the northern boundary of Maine or the northern boundary of Minnesota?". This question has probably been asked enough times so that many know the correct answer, Minnesota, without appreciating why it doesn't look it on many maps.

This "false" look is due to the fact that parallels have been stretched into circles which bend equatorward near the center of the projection and curve upward toward the edges. To avoid this misinterpretation of directions, the student learns that directions are true along projection lines. Relative direction must be read in relation to these lines. In other words, to see the reason for the correct answer to the quiz, the Maine and Minnesota boundaries are determined in relation to a nearby parallel, let's say 50° N. Maine's northern boundary is definitely south of this parallel (47°) while one section of Minnesota's lies north of it (51°).

When conformality is present, directions will be correct along parallels and meridians. Correctness in any direction and conformality can be achieved by uniform distortion of network intervals when the lines of this net are kept at right angles. The famous Mercator Projection was developed for the express purpose of retaining true direction, not only along projection lines, but also diagonally between them.

On the Mercator, all parallels and meridians are straight lines constructed at right angles to each other. Because meridians should converge at the two poles, there is distortion of the poleward intervals between them when they are kept parallel as on the Mercator projection. To compensate for this stretching, Mercator determined the amount of exaggeration of intervals between longitudes along each parallel north (or south) of the Equator. Then he increased the size of intervals between each successive line of latitude, which should be equal, in the same ratio as the longitude interval distortion at that latitude. Study the diagrams opposite which present graphically what Mercator did mathematically.

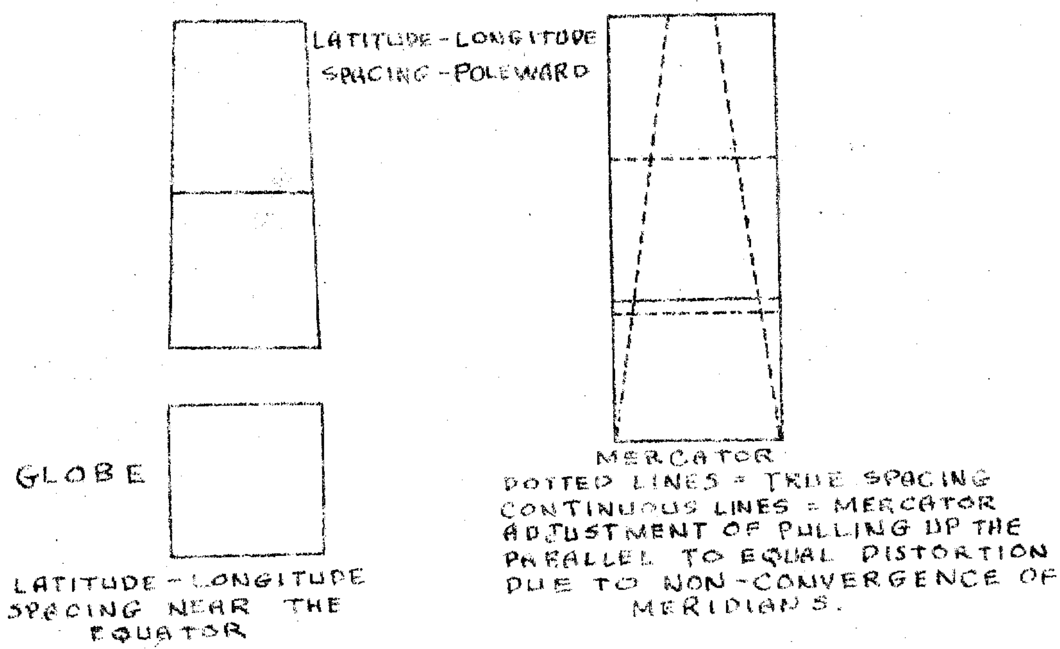

FIGURE 45A

The purpose of stretching parallel intervals in the same ratio as meridian intervals is to make <u>directions</u> constant even though map distances become increasingly distorted poleward. Observe that on the accompanying diagram enlarging the size of the square does not change the direction of the diagonal.

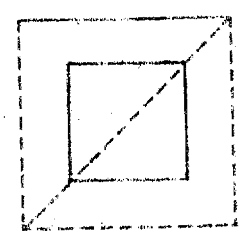

FIGURE 45B

Projections can also be constructed on a plane from one arbitrary central point to make direction true. In this type of projection, the direction of all points on the map, as taken from the central point, are the same as they are on the earth. It does not necessarily follow, however, that directions taken points are correct.

All projections which evolve from a central point on a plane are called AZIMUTHAL. Azimuth means direction. Many of the nine global criteria and one or more of the desired map properties are sacrificed to achieve correct azimuths or directions, but equal area can be retained.

Equal Area - The map-maker must choose between conformality and equal area or equivalence. These two are mutually exclusive on a map, although they are criteria derived from the globe network. An EQUAL AREA map preserves the correct ratio of mapped areas to those on the Earth. To do this on a flat surface means that shape must be sacrificed or compromised. Our card experiment substantiated this statement. During its progress, no card was added or subtracted, so the total area remained constant as shapes were changed.

Figure 43 illustrates equal area as well as non-conformality. It can be proved that if the total length of each parallel and that of the central meridian are drawn in true proportion to earth scale and if the parallel and meridian spacing is also true, then the resulting map is equal area.

Most equal area projections are the result of advanced mathematical formulae in which area has been the major consideration. The Figure just referred to shows a projection on which the meridians are sine curves and the length of each parallel is found by taking the cosine of the angle of the latitude times the length of the equator. After the length of each latitude is thus determined, each is then truly spaced along a central meridian of proportionally correct length in relation to true earth distance.

True Distances - There is no specific formula for attaining true distances. Proportional correctness of distances is determined in several ways and may vary within as well as among map sheets. Normally, distances will be fairly accurate near the central meridian if a projection is hung on one. When parallels are drawn to scale and correctly spaced, distances will be true along them. Calculation of diagonal distances may be very erroneous on small-scale maps unless they are of the equal area variety. More will be said about the determination of distances in the discussion of scales, but a preliminary word of caution is in order here. Be sure of the properties of the projection you are using, and assume generally that distances you derive from maps covering large areas are only approximations. Check these estimates against more accurate sources if distance values are critical.

Methods for Evolving Projections

The term projection is actually a misnomer when applied to all types of geographic networks. Most of them cannot be projected. Projection means literally reproducing an object by its shadow. Many so-called projections are actually derived mathematically and could never be developed from shadows. Long usage, however, has so firmly entrenched the term, projection, in reference to any geographic framework, that no attempt will be made in this text to refute it.

Generally, projections can be divided into two groups derived from the difference between true projections and other means of development. These groups are based upon developable and non-developable surfaces.

Developable Surfaces

Any surface that can be flattened and is capable of receiving lines projected or drawn directly from an assumed globe, is developable. In this category are cones, cylinders and planes. A cone may be wrapped around a globe and a source of light fixed so that it will cause shadows of the geographic network to be cast on the inside of the cone. The shadow net can be drawn and the cone cut open and laid flat to reveal the projection in a working position. Cylindrical projections can be developed in similar fashion. A third developable surface is a plane. It can be oriented to a globe at any one selected spot as this diagram shows.

DEVELOPABLE SURFACES

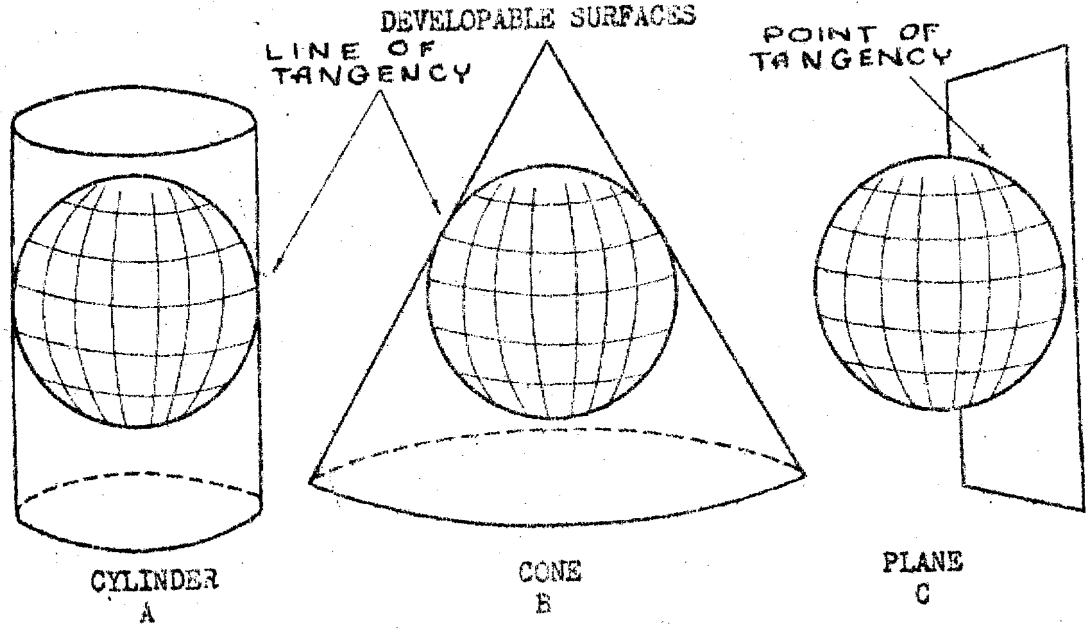

FIGURE 48

Non-developable Surfaces

Many projections have evolved as slight modifications of the basic cone, cylinder or plane to globe relationship. Any line may be curved or straightened to achieve better proportions. Such modifications that are simple enough to visualize the resulting projections, are classed with the developable group. Actually, though, they should be placed in the non-developable group. As the name implies, these projections can never be transferred by means of a source of light casting shadows on surfaces capable of being flattened. All non-developable projections are derived by mathematical computations and formulae. Fortunately, the results of much of this advanced thinking have been reduced to tabular form which requires a minimum of mathematical skill to translate into map projections.

Types of Projections

We will not be greatly concerned with all the refinements for computing and constructing projections. We will be concerned though in developing your ability to recognize and evaluate several of the most popular types. Any part of the following discussion can be amplified by studying more technical treatises. Such detailed treatment can be found in several books listed in the Bibliography.

One of the factors to be kept in mind in choosing or analyzing a projection is the amount of earth area covered by the map. Any type of projection is suitable for maps of small areal extent. Fidelity is good near the point or line of tangency and usually for short distances on either side of it in the case of developable projections. (TANGENCY is defined as the place where the basic globe touches the map surface, Figure 48) On non-developable projections, fidelity is good near the point of origin or along lines that have been constructed true to earth specifications. It is only when we deal with large parts or all of the earth that we must be critical of and careful in our choice of projections.

There is no way by which projections can be divided into mutually exclusive classes. Many texts attempt to group projections as conic, equal area, and azimuthal. Closer examination will reveal that most projections may fall into two of these classes and the attempt to make them fit one class leads to confusion. This author has attempted, therefore, to present projections in a transitional order without drawing any classification boundaries between conical, cylindrical and plane derivations leading to conformality, equivalence, or azimuthality.

Simple Conic

Although the basic conic projection is rarely used for other than small areas, it is worthy of comment since it is the basis for many conical variations.

Projection is easy to visualize and easy to construct. An assumed cone is wrapped around a globe (Fig. 48B) so that it is tangent along a given parallel located between a pole and the equator, but not at either one (A Cone made tangent to the equator becomes a cylinder, Fig. 48A; and tangent to a pole, a plane, Fig. 48C). The remaining parallels are arcs of concentric circles emanating from the apex of the cone whose height is established by the selected standard parallel. The radius of each circle is determined by the extension of truly spaced latitude intervals on the globe to the cone. This extension alters the spacing as can be seen on Fig. 51. True longitude intervals are calculated and stepped off along the standard parallel. Straight line meridians are drawn through these points to the false pole established by the apex of the cone.

BASIS OF CONIC PROJECTION

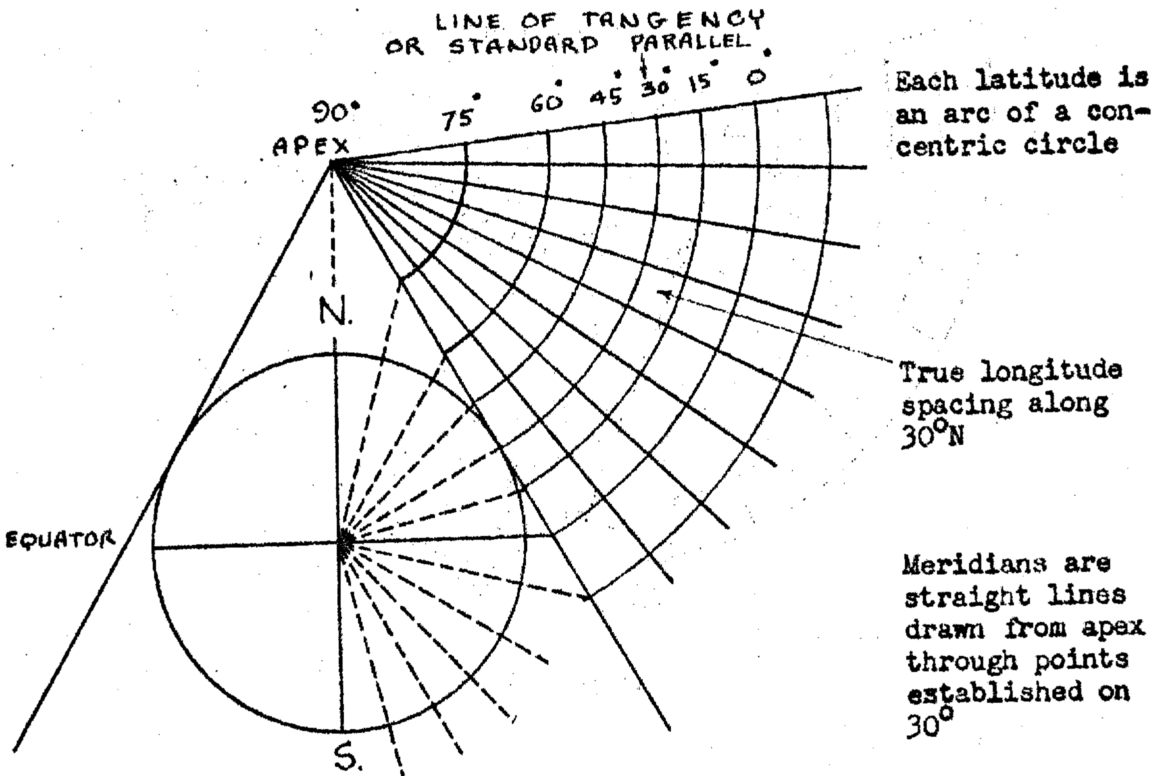

FIGURE 51

All angles are right angles, so a map developed on this fan-like network would be nearly conformal and that is about all that can be said for it. One slight change, however, will improve it. Latitudes can be spaced truly rather than according to where their shadows fall on the cone. The pole is no longer a point, but becomes a small circular parallel when this change is made. The resultant projection is a SIMPLE CONIC or just CONIC.

This projection can be recognized by its equally spaced parallels which are arcs of concentric circles and by the straight line meridians equally spaced along any parallel and converging, but not meeting at the pole. Fig. 52.

SIMPLE CONIC PROJECTION

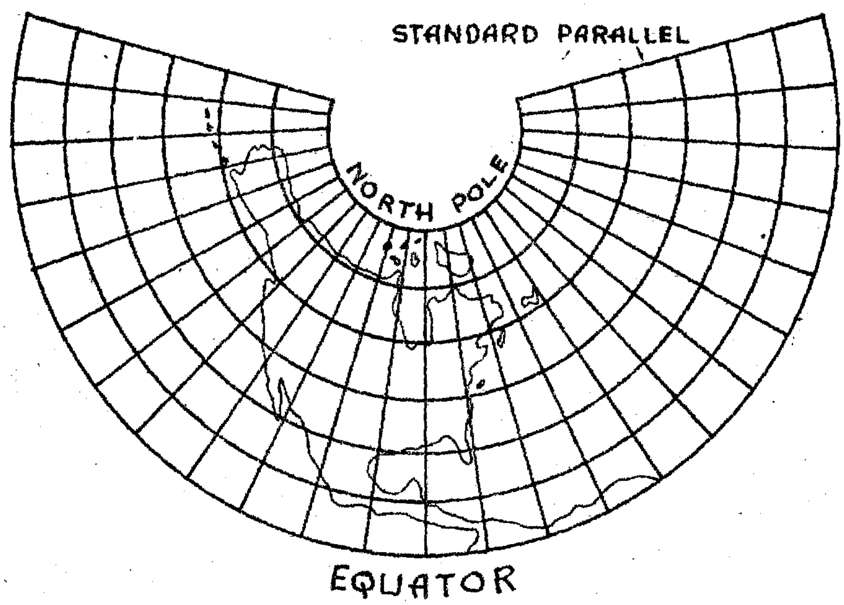

FIGURE 52

The Simple Conic Projection is most appropriate as a framework for middle latitude areas near a deliberately selected point of tangency which becomes the standard parallel. This projection is not used for world maps because of the extreme accrual of distortion in the hemisphere opposite the one in which the standard parallel is selected. The opposing pole would not be a point, but a great "hoop skirt". Even in the same hemisphere, features are distorted poleward or equatorward as can be seen on Fig.52, and by comparing the shape of North America on this figure with that shown on any good globe.

Distances are true along the standard parallel and are fairly accurate along meridians. Shapes and area are also generally good in this limited area. Great circles can be represented by nearly straight lines anywhere on the map and are straight lines along meridians. Thus, the Simple Conic Projection is easy to construct and is acceptable for mapping middle latitude areas of limited latitudinal but unlimited longitudinal extent.

<u>Lambert Conformal Conic</u>

We have seen that mapping along a standard parallel of a conic projection comes close to fulfilling the desirable properties of a flat map. This area of acceptability can be increased by selecting <u>two</u> standard parallels instead of one. Care must be exercised, however, in the selection. If parallels are too far apart, compression will make the internal distances too short and the external distances too great in relation to true distances along the standard parallels. You can see, in Fig. 53 that the surface area between the two standard parallels is cut off by the edge of the cone. This roughly illustrates why scale adjustments must be made to compensate for the loss. Notice, too, the greater divergence of the cone away from the globe when the two parallels

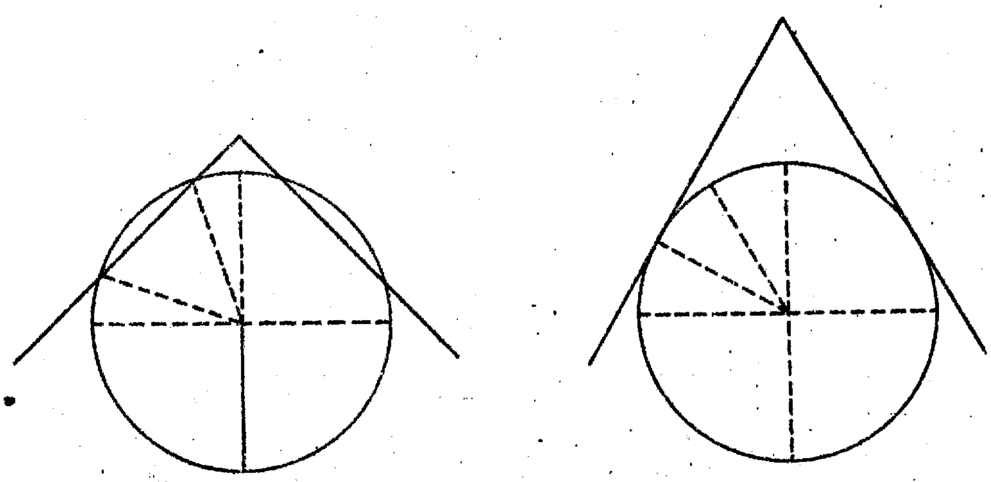

FIGURE 53

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are widely spaced.

Generally, the two standard parallels are selected to be one-sixth and five-sixths respectively of the total central <u>longitude</u> distance to be represented. For example, there will be a maximum scale error of $2\frac{1}{2}$ per cent for a map of the United States based on 33° and 45° N. By this choice, the maximum error for the economically most important area between $30\frac{1}{2}°$ and $47\frac{1}{2}°$ is only $\frac{1}{2}$ of one per cent; and the greater $2\frac{1}{2}$ per cent occurs in southern Florida. If the standards are placed at 29° and 45°, a maximum of 1 1/5 per cent is obtained, but at the expense of the central portions.[1]

These percentages mean an error in mileage equal to the percentage value in 100 miles, i.e., one half of one per cent equals $\frac{1}{2}$ mile in each 100 miles. The length is too short between the two standard parallels and too long beyond them. In other words, on a map of the United States based on 33° and 45°, the total distance from coast to coast on longitude 39° is about 13 miles too short and in the same distance along 25°, would be about 75 miles too long. This is not bad when you consider there are approximately 3000 miles over which to distribute the 13 miles, and only portion of the United States near 25° is the narrow tip of Florida which would be less than 2 miles too wide on the projection. The remaining parallels are arcs of concentric circles spaced at increasingly larger intervals north and south of the standard

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[1]Statistics concerning various projections have been adopted from: Deetz, C.H. and Adams, O.S. <u>Elements of Map Projections</u>. U.S. Dept. of Commerce, Coast and Geodetic Survey, Special Publication No. 68.

parallels in a manner similar to those shown for the basic conic in Fig. 51. Arcs of longitude are represented in their true lengths along the two standard parallels. Straight lines are drawn through these points to intersect at the point of origin for parallel arcs. The scale adjustment and right angled intersection of parallels and meridians makes this a conformal projection. The projection can be recognized by the combination of characteristics, listed above.

Conformal Conic Projections are well-adapted to mapping problems involving wide longitudinal and limited latitudinal extent. The change in scale which makes directions true and the retention of correct shapes makes the projection suitable for Aeronautical and Radio Direction Finding Charts for cross-country flying.

Albers Conical Equal-Area

Further mathematical refinement of the relation of latitude-longitude spacing was made by Albers to create and equal area projection. He calculated the radii for two standard parallels selected at one sixth of the meridianal distance from both the north and south limits of the map, so as to make the projection equal area. Next he stepped off arcs of true longitude along each standard parallel and drew straight line meridians through them to the center of origin for the parallels. This center is not the pole. A pole is represented by a circle as it is in the Simple Conic. Because equal area is maintained, the remaining parallels are spaced at decreasing intervals north and south of the two standards.

When a map of the United States is based on $29\frac{1}{2}$ and $45\frac{1}{2}^{\circ}$, the distance error is kept to $1\frac{1}{4}$ per cent. It is about 1% too large in the central areas. This error is hardly greater, as Raisz points out, than the expansion and contraction of paper with changes of humidity[1]. Areas are made equal, and directions are very close to true. Although the projection is not strictly conformal, shapes are good within the reasonable limits of the two standard parallels. Consequently, in the author's opinion, it is the best projection available for maps of any east-west and north-south extent roughly equivalent to that of the United States and should enjoy wider popularity than it does.

The recognizable traits of this projection are the straight line meridians that converge toward, but do not meet, at a pole which is represented by a circle instead of by a point and, by circular parallels that are spaced at decreasing intervals north and south of the two standard parallels.

Bonne

Another mathematically-derived variation of conic projections is the Bonne. This projection is developed upon a standard parallel selected preferably somewhere in the middle latitudes. A cone is made tangent at this point and the distance between the point of tangency and the apex is the radius for describing the arc of the selected parallel. Fig. 57

A central meridian is constructed as a vertical in the

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[1]Raisz, Erwin General Cartography New York: McGraw-Hill, 1948, p. 75

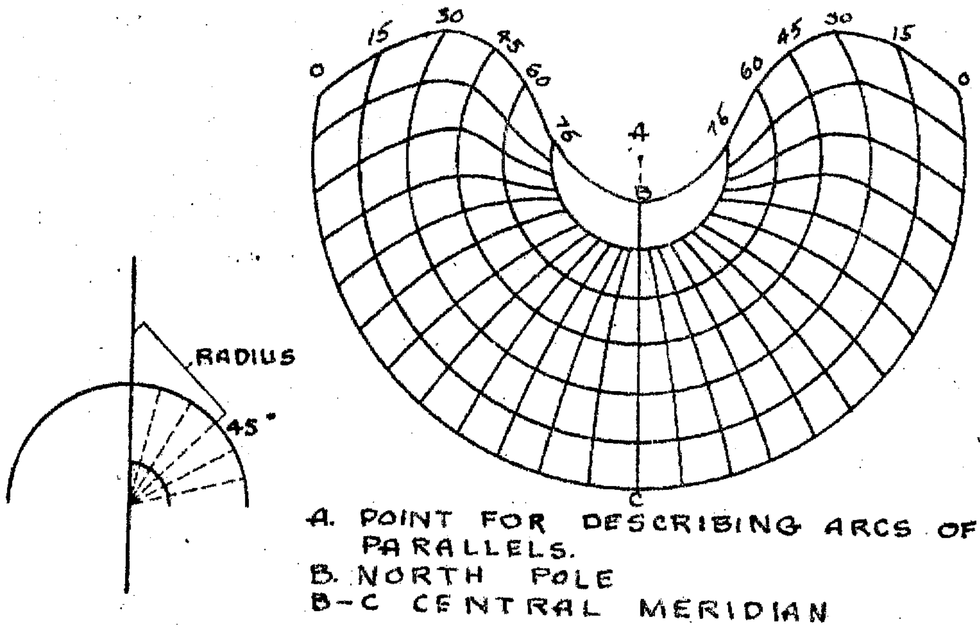

FIGURE 57

middle of the map sheet and truly proportioned latitude intervals stepped off along it. The arc of the standard parallel is described, with radius as above, to establish point (A) on extension of the central meridian. Each parallel is drawn as an arc from this point to its correct intersection with the central meridian. Longitude intersections are truly and thus equally spaced along each parallel. Meridians are drawn as curves through identically numbered longitude points on succeeding parallels. The result is a winged-shaped network base for an equal-area map. As you study Fig. 57, you will realize that the network would get entirely fantastic if it were extended to cover the world.

Obviously, on the Bonne projection, shapes are not conformal, but are reasonably correct near the central meridian. Distances are true along the central meridian and each parallel. Directions are true along projection lines but not between them.

Thus, the projection is well suited to areas of considerable latitudinal extent and can be used to include continents as wide longitudinally as Eurasia. No projection will provide complete accuracy for this large land mass, so the Bonne is often used because the curved parallels and meridians come closer to right-angled intersections than is the case on many projections. This relationship creates less distortion of shape and retains the equivalence of area sought in depicting many distributions where direction and absolute conformality are not essential.

The Bonne Projection can be identified by the following characteristics. All parallels are arcs of concentric circles emanating from a common point beyond the pole and cutting the central meridian at truly spaced intersections. All meridians are flattened curves except the central meridian which is a straight line. Intervals between longitudes decrease toward the polar point but are equally spaced along each parallel.

Polyconic

There is always good correlation of earth and map details along the line of tangency, as we have observed in previous examples. Since accuracy is the objective of mapping, why not increase the number of tangent points by utilizing many cones instead of one? The best results, in answer to this question, would be obtained by drawing an infinite number of cones tangent to a basic globe at fractions of one degree apart. Drawing such an illustration would unfold only a plethora of lines. Fig. 59 will demonstrate the principle, however, with a few cones placed 15 degrees apart.

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POLYCONIC PROJECTION

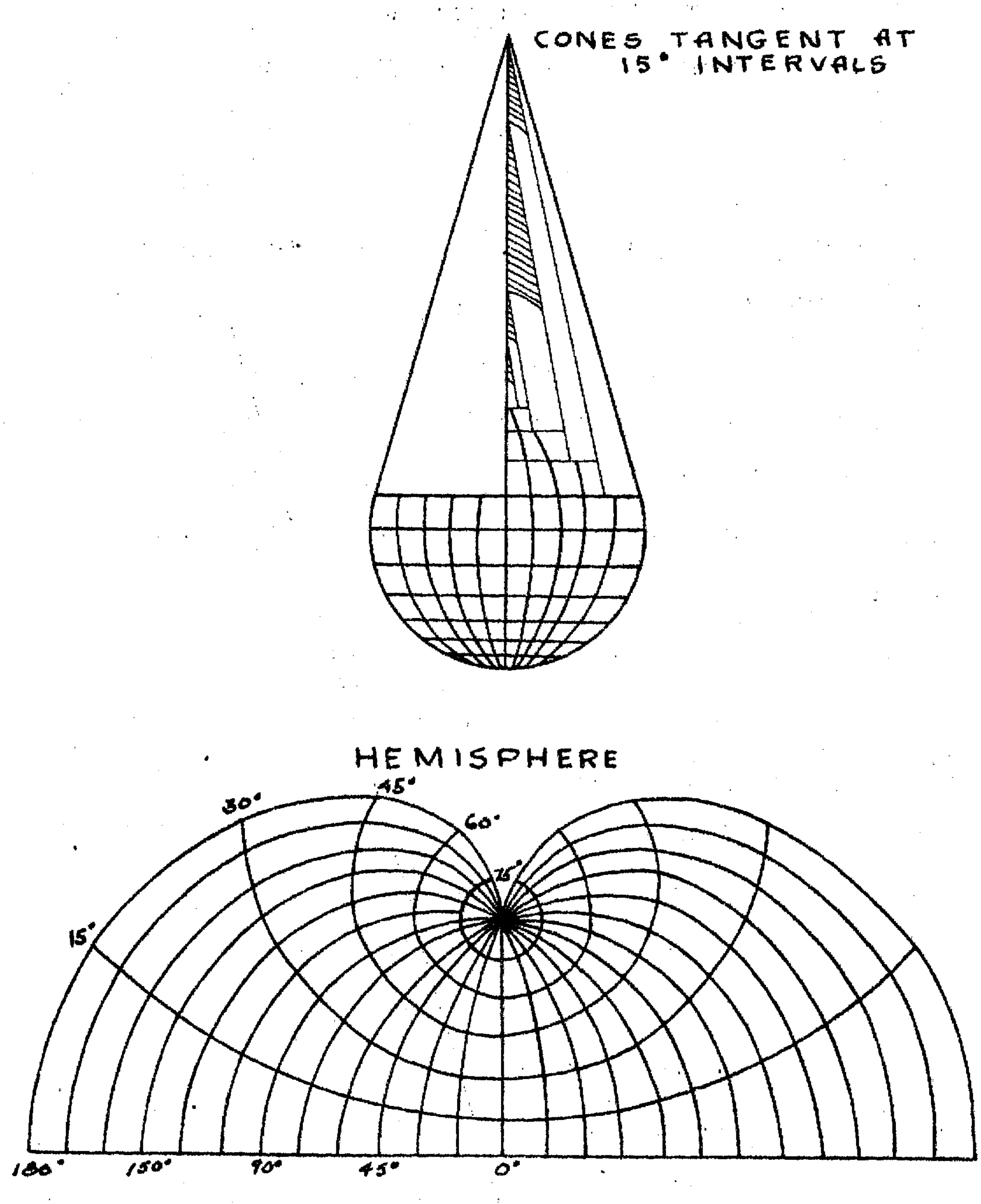

FIGURE 59

The polyconic projection is constructed from a central vertical along which latitude intersections are truly spaced. Non-concentric circles are described from these points with a radius equal to the length of the basic cone from its point of tangency to its apex. This fixes the center for each circle at successive (not common) points on the extension of the central meridian. The equator is kept as a straight line. Meridian intersections are truly spaced along each parallel and connected by flattened curves from the pole through these points.

The resulting projedtion is a compromise which approximates but does not have any of the desired characteristics of a perfect map. Increasing the number of tangent points is offset by the scale error and distorted relationship of parallels to meridians away from the central meridian. All details are badly distorted on the outer edges if the projection is developed to include a hemisphere as can be seen on Fig. 59.

The polyconic projection was devised by Ferdinand Hassler, first director of the Coast and Geodetic Survey, in 1820, to fit the mapping needs of the essentially coastal-bound United States. It was well suited to this purpose because of the largely north-south orientation of the states. Quadrangles based on this projection can be fitted together for any distance north-south, pole to pole if necessary. East-west quadrangles away from the central meridian will not fit. Possibly the only reason this projection gained such popularity was due to the fact that complete tables were worked out for the world based on polyconic computations. These tables made construction of sheets comparatively easy. Most of the quadrangles of the Geological Survey consequently have been based on the Polyconic which is as good as any conic projection for small areas, but is questionable for large area coverage.

Special characteristics are difficult to recognize on U.S.

Topographic quadrangles that are normally less than one degree in extent. In this interval, both parallels and meridians curve so slightly that they are treated as straight lines. Furthermore, lateral distortion is slight when individual sheets are developed from rather closely spaced central meridians. On maps of larger areas, the projection can be recognized by the straight-line, central meridian and equator, and by the non-concentric parallels and flattened curved meridians which intersect each other at increasing angles and distances away from the central meridian, but are equally spaced along any given latitude or longitude line.

Modified Polyconic

The modified polyconic is included in this appraisal of projections because it was adopted for the International Map of the World series discussed in the next chapter. The modification consists of making the central meridian scale a fraction smaller than it should be, causing the scale to be true on two separate meridians, 2° on either side of the central one. Scale is kept true on the bounding parallels which are constructed like those for the Polyconic. These bounding parallels are divided truly and meridians are straight lines joining the corresponding points of the top and bottom parallels.

When the conference members were debating the merits of projections for the IMW, they disapproved the Polyconic because the curved parallels and meridians would not permit a number of sheets to be fitted together. (Individual sheets are 4° x 6° to latitude 60° and may be 4 x 12° poleward from 60°. Inclusion of this larger area makes it impossible to [illegible] way U. S. Topographic quadrangles do.) Consequently, the modification was made to the Polyconic so that every sheet edge fits exactly with the corresponding edges of its four adjacent sheets. More than five sheets will not fit perfectly. Fig. 62. Obviously, the projection was not intended for and is not adaptable to a single map of the world.

Fit of Modified Polyconic Sheets of
International Map of the World

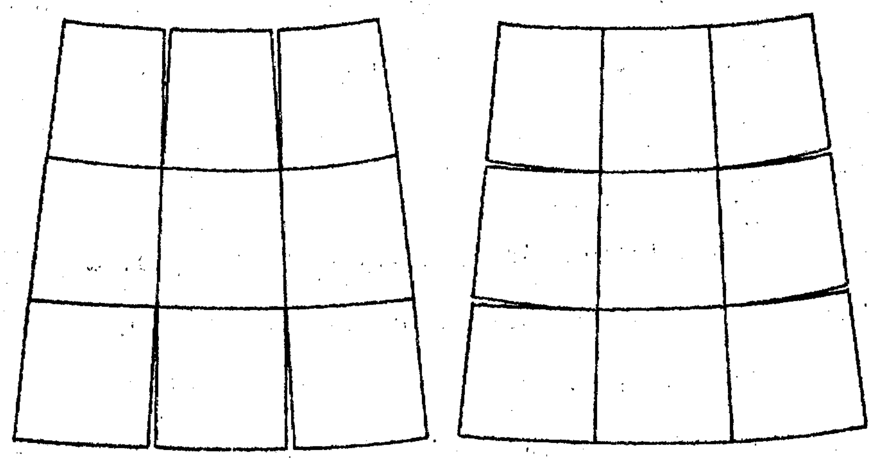

FIGURE 62

Sinusoidal

If the Bonne projection were made tangent at the equator, it would have the same characteristics as the Sinusoidal projection. This projection is easier to understand, though, if its development is explained in another way. To do this, we can elaborate on the brief explanation and diagram given on page 43 illustrating equal-area and non-conformality. The equator is laid down as a straight line drawn in correct ratio to the length of the earth equator. A central meridian of true length is erected at right angles to the equatorial line. Straight lines are drawn parallel to the equator and spaced at true latitude intervals along the central meridian. The total length of each parallel is in true proportion to its earth distance which can be obtained by taking the length of the equator line times the cosine of the angle of the latitude. For example, the cosine of 60° is 0.500 or in other words, the length of the 60th parallel north or south is $\frac{1}{2}$ the length of the equator. True longitude spaces are stepped off along each parallel. Meridians are drawn as flattened (sine) curves through the points established on each parallel to meet in a point at the poles.

By construction, the projection is equal area. Distances are true along each parallel and the central meridian. Directions are true along projection lines. Shapes are compressed in polar areas because of the rapid convergence of meridians toward the polar points and are greatly distorted toward the edges of a hemisphere or world map network in response to the elongation of meridians along the periphera. On the other hand, shapes are reasonably good in equatorial areas to 40° poleward due to the slight decrease in the lengths of parallels around the bulge of the earth in this zone. The Sinusoidal projection, therefore, is best suited for mapping near a central meridian or in lower latitudes, although it is used for world distribution maps because of its equivalence.

Distinguishing characteristics are the equally spaced straight line parallels intersected by curved meridians which are equally spaced along each parallel but converge to a point at the poles. The overall appearance of this projection somewhat resembles a top.

All of the preceding projections can be explained or illustrated by the relation of cone to globe even though historically it is known that many of them were developed purely by mathematics without recourse to the cone concept. Later attempts at simplification brought out the conic relationships. The next few projections have never been resolved beyond the mathematical stage, but can be simplified in explanation.

Homolographic

Molleweide is given credit for the homolographic projection although others produced similar results. Homolographic means a proportionality of areas on the globe with corresponding areas on the map. The main idea is to open out a sphere so as to have not only the whole earth on one map, but also to have given areas the same as their corresponding areas on the globe. To achieve this, Molleweide computed the area of a hemisphere and then of a circle encompassing the same area. Next, he added the area of ½ a hemisphere on each side of the circle to form an elipse. Fig. 65.

When we construct the Homolographic graphically, the equator is twice the length of the diameter of the constructed circle, or central meridian. The area enclosed between consecutive parallels is computed by the law of equal surfaces, and straight lines are constructed perpendicular to the central meridian to enclose a comparable area on the elipse. Parallels, therefore, are not equally spaced but occur, rather, at decreasing intervals poleward

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polar points in much more flattened curves than the rounded Homolographic meridians. Consequently, there is always a change in the curvature at 40°. Study Fig. 70 to confirm this point. All the other recognizable traits are the same as those for the two contributing projections.

Van Der Grinten

Another oval-shaped projection can be obtained by lopping off the polar areas of the circle based Van der Grinten projection that is used for some maps of the world. The basic projection is evolved from a circle whose area is equal to that of a globe of one half the diameter of this circle. The central meridian and equator are straight lines. The central meridian is

VAN DER GRINTEN PROJECTION

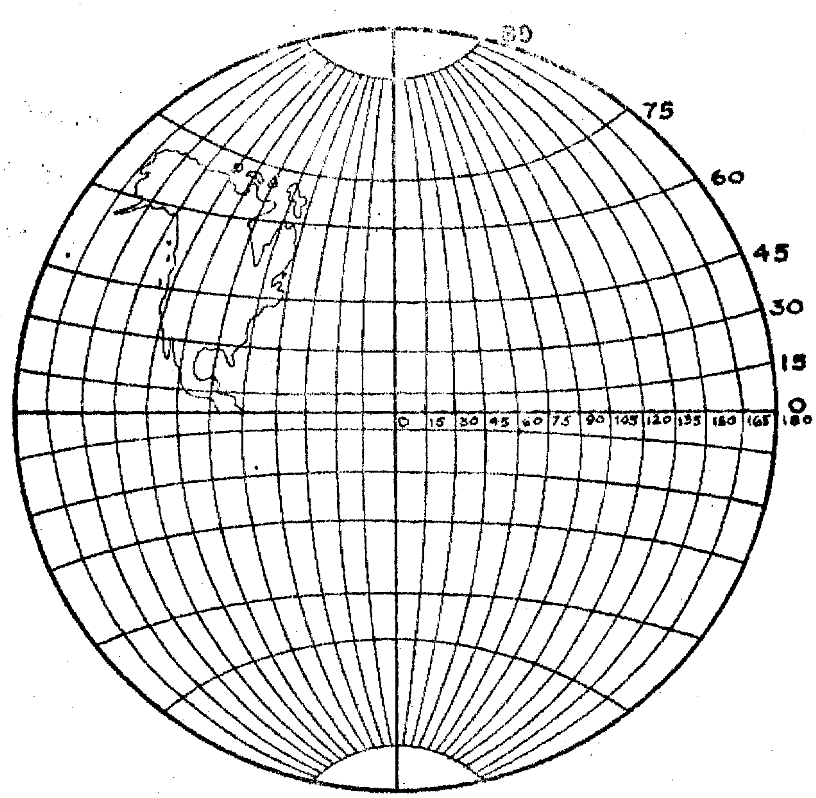


FIGURE 67

unequally divided into parts of 180° from pole to pole, while the same diameter representing the equator is equally divided into parts of 360° (Fig. 67)

This projection is neither conformal nor equal-area and has no properties of scientific value. It does present a fair uniformity of shapes and less distortion than some equal-area projections and so is adequate for imparting pictorial impressions.

Interrupted Projections

No one uninterrupted map of the world can be both conformal and equal area. Shapes, however, are found to be most nearly correct near the central meridian of equal-area world maps and to become more distorted the farther they are removed from it. A large number of interruptions can be used to correct this fault at the expense of unity and readability. Since no spherical printing presses have as yet been prefected that are commercially feasible, maps for world globes are usually printed as gores on flat paper and then fitted to a sphere. Polar areas are printed as small circular maps that cap the gore-fitted globe. Fig. 69 illustrates how the globe map looks. Extreme segmentation of the earth's surface features makes it impractical for use as a flat map. The principle can be followed however, by using a number of central meridians selected to minimize interruptions of the details to be shown. In other words, interruptions can be made to occur in ocean areas if continuity of land masses is desired or, vice versa. If both land and water distributions are to be shown at the same time, the choice of an interrupted projection is an unsatisfactory one even if it is justified on the plea of economy

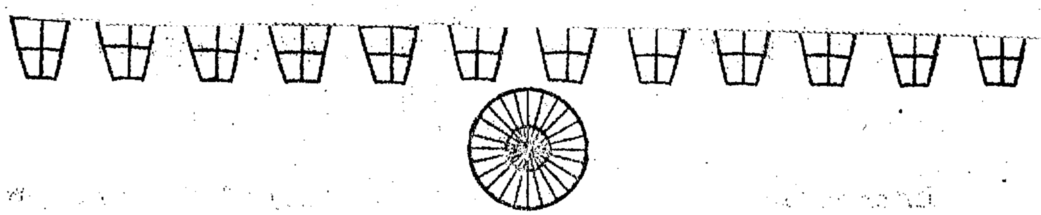
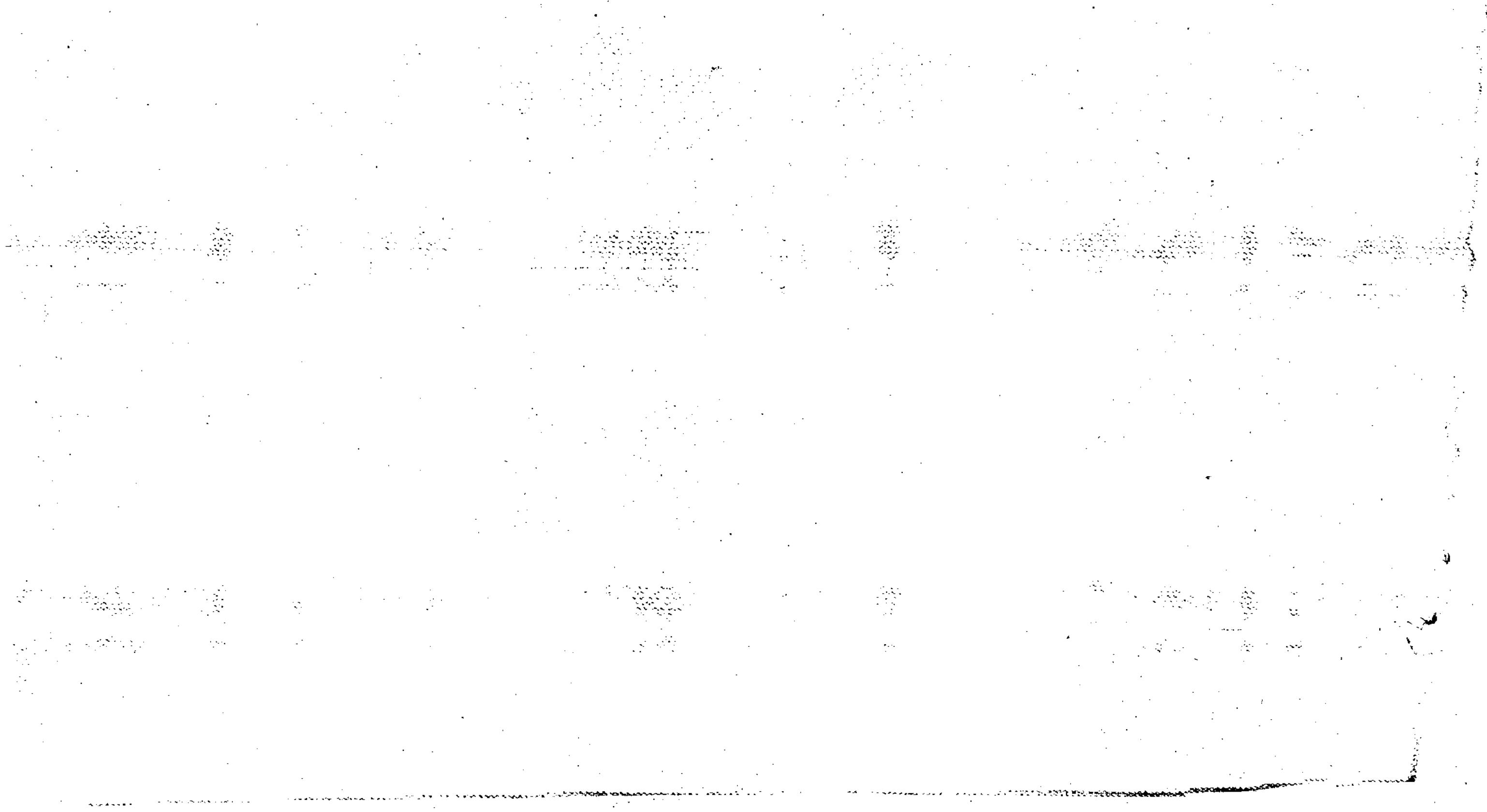


FIGURE 69

of space or interrelationship of patterns.

Usually when improvement of land shapes is desirable, longitude lines that come nearest to the middle of each continent except Eurasia are selected as central meridians. No one central meridian can lessen shape distortion on a land mass as wide, longitudinally, as Eurasia. As a result, a compromise must be reached that usually favors Europe in actuality since Europe is the smaller but more important part of the Europe-Asia complex.



NOTE DEFLECTION OF MERIDIANS AT 40th PARALLELS

FIGURE 70

Interruptions have been introduced on many of the world projections which show the equator as a straight line but those most commonly seen are Interrupted Sinusoidal, Homolographic or Homolosine.

<u>Mercator</u>

One projection for world mapping that has enjoyed long and continued popularity is neither interrupted nor equal area. Gerhard Kremer, whose latinized surname becomes Mercator, developed his famous projection for the benefit of sailors of the sixteenth century who had limited navigational equipment with which to plot and keep on their intended course. These navigators needed a map or sailing chart on which they could lay their courses with nothing more complicated than a straight edge. Mercator made possible the straight rhumb line by the method shown on page 45. A rhumb line is a line that crosses each parallel and each meridian at a constant angle. It may become complicated to plot if it develops as a spiral or curved line in response to the peculiarities of many projections.

Although the Mercator projection can never be projected, since it is mathematically computed, it was inspired by the idea of a cylinder tangent at the equator. Spacing of parallels is worked out mathematically from the basic cylinder to globe relationship. A horizontal line is drawn in correct ratio to the globe equator. Meridian intervals are stepped off truly along this Equator line and parallel meridians erected perpendicular to it. Instead of allowing the parallel spacing to fall as it would on a gnomonic[1] cylindrical projection, each is spaced in proportion to the increasing meridian spacing distortion poleward. Such proportioning makes intervals between parallels less exaggerated than the gnomonic cylindrical, but, nevertheless, makes the projection impractical for mapping poleward of approximately 75 or 80 degrees and impossible for polar areas. In the days of Mercator, this weakness was not critical since little was known of polar areas, and they were not involved in the navigational business of the times. How times have changed!

Almost every educated person has heard of the shortcomings of the Mercator projection for a world map. Overall areas,

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[1]For a definition of Gnomonic, see page 79

shapes and distances are increasingly enlarged away from the equator. Critics of the projection are always quick to point out that many false concepts of the comparative sizes of land masses are due to the widespread use of the Mercator in classrooms. Then in

MERCATOR PROJECTION

Latitudes 60° south to 78° north

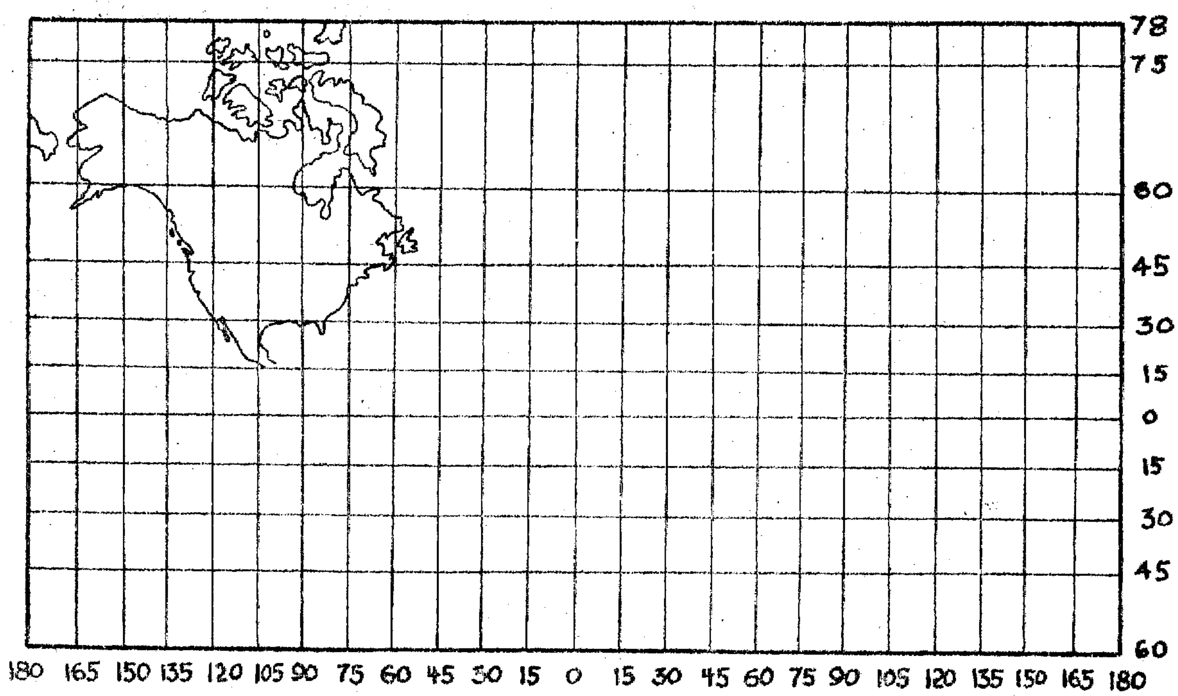


FIGURE 72

the next breath, they often suggest substituting a polar projection which you will soon see is just as false in a different way. The truth of the matter is that inadequate teaching and explanation are at fault and not the projections. True shape and, spatial and size relationships among continents can only be acquired from a globe. Even the globe medium has a limitation. Because of sphericity, the whole world cannot be viewed simultaneously. In this respect, a Mercator based map is superior. It shows the whole world on a simple network that retains directions and relative positioning of continents except in respect to the poles. Learn its limitations and appreciate its advantages before you are tempted to join the antagonists or protagonists of any projection.

Study Fig. 72 and do your own listing of the recognizable characteristics of a Mercator projection.

Transverse Mercator

Thus far, we have been examining projections that are tangent to or developed from a parallel of latitude. There is no reason, however, why a longitude or even a diagonal line might not be used. Although this is not a new idea, it has gained its greatest popularity in the present century. The English and other European map makers had used the Transverse Mercator for several military map series before its value was finally appreciated by U. S. map makers. By international agreement a slight modification of the standard Transverse Mercator projection was adopted in 1948 by many of the allied nations for military mapping of the world.

We will consider the standard transversing first, and then the adopted modification. A Transverse Mercator can be conceived upon but not developed from a cylinder tangent at any given great circle except the equator. Except in special cases, tangency is fixed along a great circle formed by two opposing meridians as shown in Fig. 74. It is not the Equator,

RELATIONSHIP OF BASIC CYLINDERS TO GLOBE

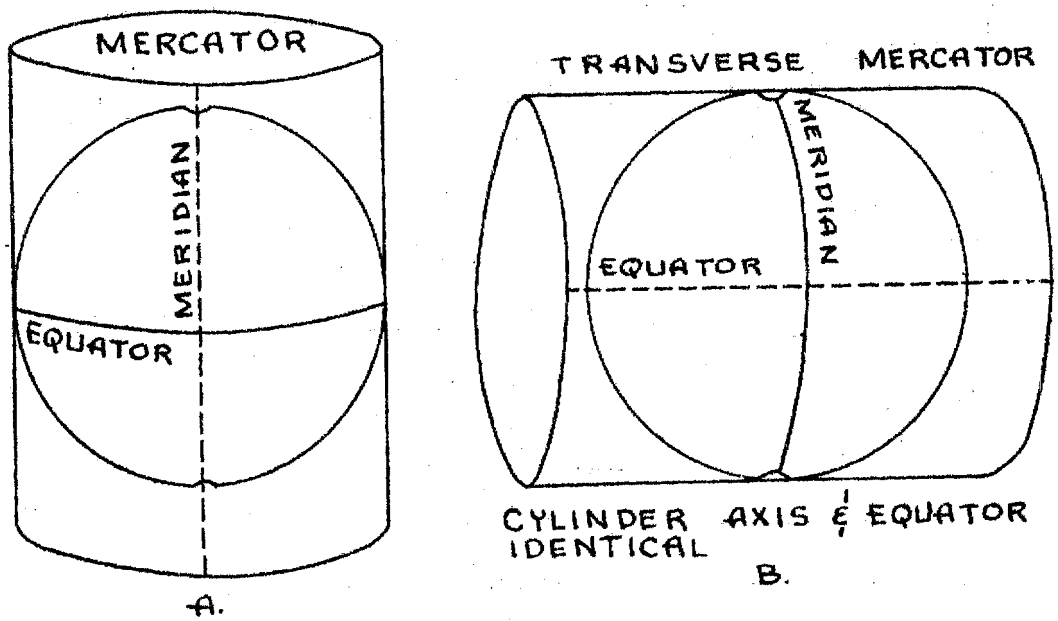
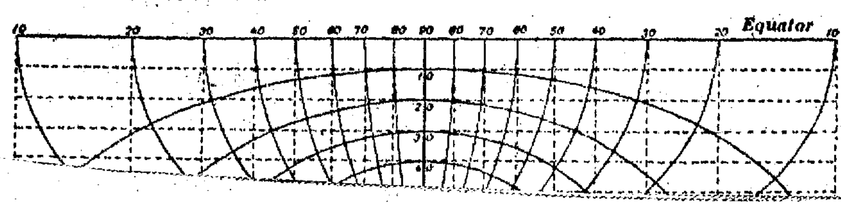


FIGURE 74

on a Transverse Mercator, therefore, which is true to scale and correctly divided, but a central meridian. Just as the Equator is the only line true to scale on the ordinary Mercator, the central meridian is the only line true to scale on the Transverse Mercator. All parallels except the equator are curved and their lengths, while not exactly true to scale, do decrease poleward. The poles, which cannot be represented on the Mercator because the polar axis is parallel to the plane of the cylinder (Fig. 74A), can be shown on a Transverse Mercator since they are in the plane of the tangent line, Fig. 75. Distances between meridians increase outward from the central meridian in either direction toward higher numbered meridians. The intervals increase in the same ratio as latitude intervals increase poleward on the Mercator. Meridians converge at the poles and are curved lines except for the straight meridian. Parallels and meridians intersect at right angles to aid conformality. Distortion of distances is relatively slight near the tangent meridian. The projection serves therefore, for mapping belts that are narrow longitudinally and wide latitudinally.

TRANSVERSE MERCATOR



imperative that maps used for these purposes be conformal and also provide accurate distances. It was found that maps approaching this ideal could be created by modifying the standard Transverse Mercator Projection. Such modification is achieved by assuming a secant rather than a tangent cylinder. When the cylinder is tangent to a globe, the radius of the cylinder is equal to that of the globe resulting in no distortion of mapping along the central meridian (tangent line). Thus, distances and shape are true along this line and are distorted eastward and westward from it. In projecting military maps, the axis of the cylinder is identical with the equatorial plane. (Fig. 74B). The Cylinder is made elliptical in cross section so that it cuts through the globe, as in Figure 76, along two lines parallel to the central meridian. Scale is true along these two meridians and the rest of the projection is manipulated mathematically to equate the stretch in longitude with that in latitude. No attempt is made to project the

MILITARY TRANSVERSE MERCATOR

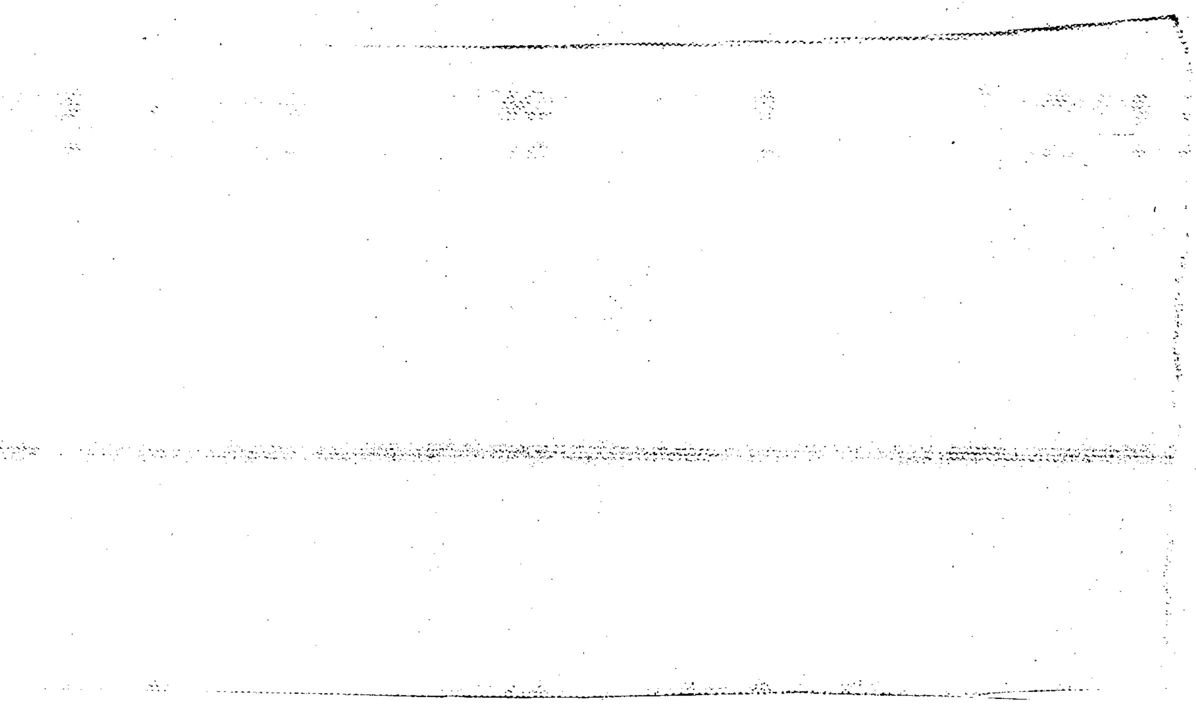


FIGURE 76

world as a whole on one sheet. Instead, the project is broken into zones, each with its own central meridian. A special military framework has been devised to facilitate the use of this zonal mapping. Refinements of the framework are discussed in the next group of map ingredients called grids.

The Transverse Mercator Projection is used for military mapping between 80° north and 80° south latitude at any longitude. Because of the special characteristics and requirements for polar maps, another projection was adopted to complete world mapping in the areas from 80° to the poles. This Polar Stereographic leads us to the third type of graphic presentation of projections, those based on planes, which we will discuss briefly before concluding with the projection in question.

Azimuthal Projections

Any network that can be presented graphically by projection from globe to plane has only one point that touches the assumed globe, (Fig. 48). Directions are true from this point at any angle. They are not necessarily true from other points. All directions measured in terms of angles from a given point are called azimuths. Hence the name AZIMUTHAL is assigned to plane projections emanating from a given point. The given point of origin may be the poles or any other selected place. Many interesting maps have been developed to show an important city as the "projection" pole or center of terrestrial activity. All directions can be measured truly from this city to any other rival or complementing city in a manner similar to using spokes from a hub.

In the simplest azimuthal projections, all meridians are straight lines radiating from the point of tangency and are equally spaced along given parallels. These parallels are spaced in relation to where rays from a source of light cast shadows of latitude lines on the plane. The light could be placed anywhere, but four basic placements will illustrate the principle. Figure 78 shows these placements and the relationship of light rays to plane. For purposes of demonstration, only one

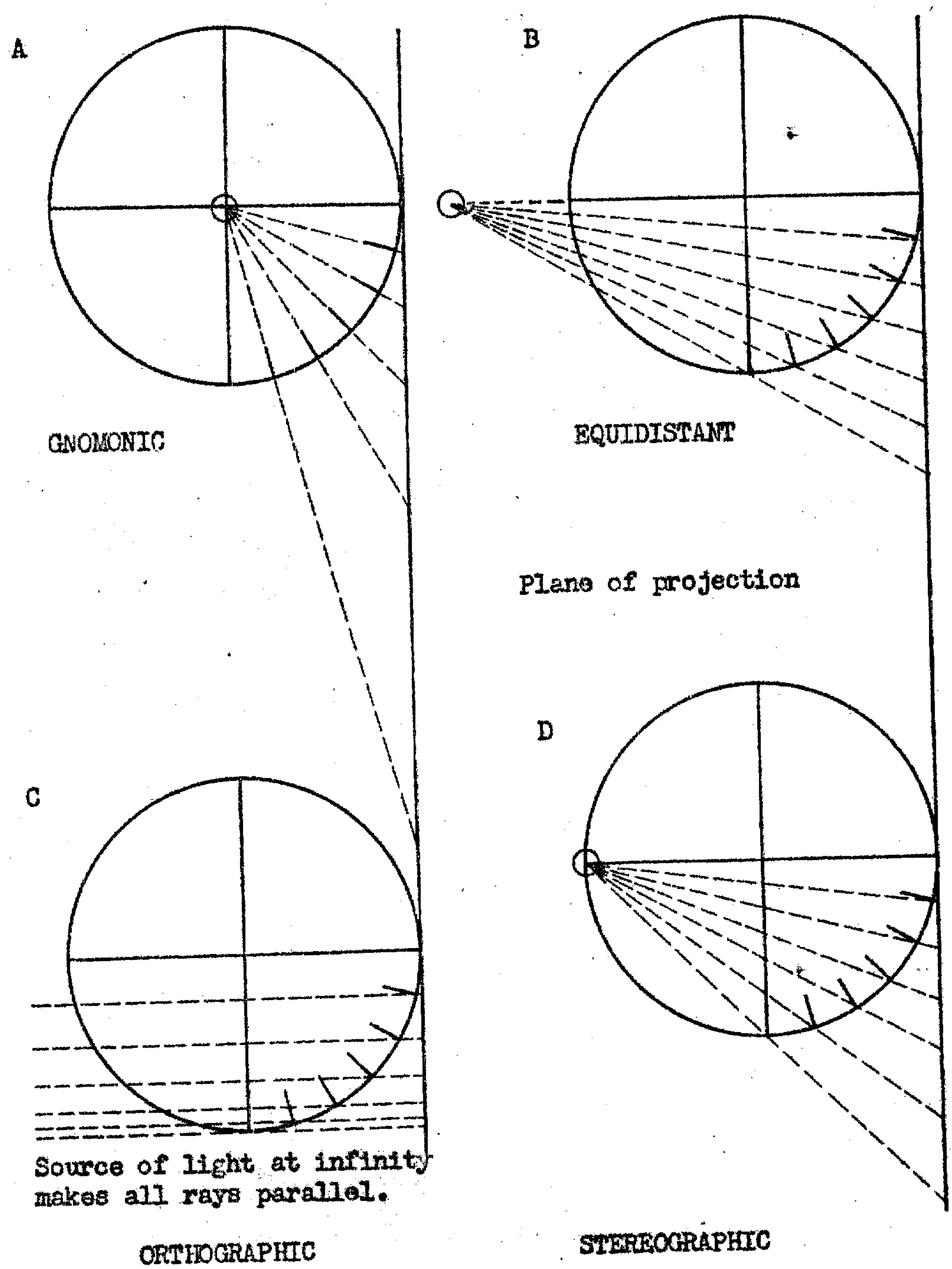


FIGURE 78

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quadrant has been developed in each of the assumed globes. The point of tangency is a pole. Ticks on each globe represent true latitude spacing along the circumference.

Gnomonic - The source of light is at the center of the globe or gnomen. This Greek name may have been derived from mythology. Something was responsible for internal disturbances that the ancients observed. Since there had to be an explanation for everything and the scientific geologic ones of volcanism and diastrophrism had not been expounded, the Greeks invented a group of people called gnomes who inhabited the center of the earth and pushed the earth's crust around!

These same gnomes push latitude projection lines far away from their true spacing as can be seen on Fig. 78A. Stretching increases so rapidly away from the point of tangency that it becomes impossible to project 90° away from the point. If extensions of light rays are constructed accurately, the 90° ray would be parallel to the plane of projection and so would never touch it.

Stereographic - Some distortion of latitude intervals can be eliminated by placing the light at the antipode or point on the circumference 180 degrees removed from the plane of projection. Spacing still increases away from the point of tangency but the distortion is not so great. Projection of 90° falls well within the limits of a plane of reasonable length and points nearly 180 degrees away can be drawn if the plane is extended an unreasonable distance. These relationships are shown on Fig. 78D.

Orthographic - Placement of light conforms to the sun-earth relationship in orthographic projections. The sun is so far removed and so much larger than the earth that its rays strike the earth perpendicular to the plane of projection. Notice in Fig. 78C that the spacing decreases away from the point of tangency which is the reverse of the previous two. It is apparent that only 90 degrees on either side of the tangent point can be projected from such a source of light.

Equidistant - Instead of having latitude spacing increase or decrease away from a point, it can be equally but not truly spaced by rigging the source of light. Figure 78B shows the light in a predetermined position by which the distance between it and the axial point on the circumference is equal to the radius of latitude 45. Graphic derivation of the distance at which to place the light for Equidistant projection is included in Fig. 78C.

It should be noted that sources of light can be applied to other than planes. This was indicated in the explanation of the equatorial aspect of the Mercator evolved from a gnomonic cylindrical concept. Furthermore, azimuthals, like other types of projections, can be devised mathematically. These are impossible to reproduce or illustrate by reference to a source of light casting shadows of a network of global lines on a developable surface.

Only two azimuthal projections are to be given as examples. Explanations for other more complicated types will be found in texts dealing primarily with projections and not heading deliberately in the direction of using projections as one ingredient in map reading.

Polar Gnomonic

The Polar Gnomonic projection is widely used for navigation

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ORIGINAL DOCUMENT MISSING PAGE(S):

81, 82, 83, 84

The choice of projection is not especially critical for map sheets covering a small area if the projection is carefully and accurately constructed in relation to this area. Even the experts will admit that it is impossible to recognize the projection used on very large scale map sheets.

When the area to be mapped extends over considerable latitude and longitude the choice of projection is critical and must be made on the basis of the properties that are most essential to good depiction of the entity to be shown and the purpose for which it is to be used. Let's take distance (scale) as one case in point. Distances can be made correct along 1) all meridians and one or two parallels, 2) along all parallels and one or two meridians; they cannot be correct along all parallels and all meridians. If a conformal projection is chosen, then if scale along a given parallel is too great, scale along its intersecting meridians will also be too great. If an equal-area projection is chosen, then if scale along given parallels is too great it will be too small along meridians. The choice among equivalence, conformality and azimuthality throws out some other property, especially on small scale maps covering a large area such as the U.S., the U.S.S.R., Africa, or the world, and so it goes, since most human activity is a compromise with perfection.

Military Grids

From Graticule to Grid

In all of the above discussion, any organized network of latitude and longitude lines, regardless of whether they can be projected or not, has been called a projection. Some cartographers, however, would object to this since they prefer to differentiate the projectable from the non-projectable varieties by calling the latter grids. Addition of the term "military grids" leads inevitably to confusion with this method of grouping projections. Personnel at the Army Map Service and many other map makers and users, consequently, have decided to call any organized framework of latitude and longitude used for maps, a **GRATICULE.** The necessity for determining the mechanics of the map network derivation is thus eliminated. Furthermore, a reference intended to mean geographic projection will <u>not</u> be construed to mean MILITARY GRID or simply GRID.

<u>Reasons for Two Frameworks</u>

Representation of large sections of the world on a rectangular graticule would violate most of the criteria for an accurate map, and would distort earth features beyond usefulness. In order to represent an area with a minimum of distortion, the graticule is therefore adopted first (earth features to be mapped will be drawn to conform to this framework). After the projection is selected, some spot on it is chosen as point of origin and some direction indicated for orienting the military grid. A GRID is a rectangular system of coordinates composed of two sets of parallel lines drawn at right angles upon a plane map surface. This grid is superimposed upon the map graticule and extended over the entire area controlled by the graticule. A definite relationship then exists between any grid intersection and any adjacent intersection of latitude and longitude. The grid system is used in scaling distances, determining directions and locating points. Although any convenient unit of linear measurement can be adopted, yards and meters are most commonly employed on military grids.

Locating Points

Accurate locations can be given in terms of geographic coordinates. Any high degree of refinement in pin-pointing an objective, however, requires a lengthy enumeration of letters and numbers. For example, the exact geographic location of the Lincoln Memorial in Washington, D.C. is 38°53'20.221"N - 77° 03'02.199"W.

Translation of this long list of numbers to or from a graticule would be complicated. It would necessitate the inclusion of more latitude and longitude lines than are normally found on a finished map. Attempting to interpolate the site of the memorial between more widely spaced lines would be inadequate on those graticules on which intervals between parallels and meridians are not uniformly correct. A map reader can locate the Memorial more quickly and accurately by using the military grid. Each grid interval is the same as any other interval on the same sheet. Interpolation between the grid lines can be done with a ruler or even the straight edge of a piece of paper.

Locating objects on a grid is accomplished by a set technique which does not vary from map to map, or hemisphere to hemisphere. This technique is always to begin in the southwest (lower left-hand) corner of a sheet and read the coordinates to the right to the desired distance and then up along this line to the point being located. In short: READ - RIGHT - UP.

The map sheet showing the Lincoln Memorial is not available to you, but one of the Hagerstown series will do just as well to illustrate how to apply the above technique. On Hagerstown Sheet 5463 II NW our objective will be Rockdale School. (To make you more appreciative of the efficiency of locating places by grid references, try to find this school by the "search" method. Then see how much simpler locating places can be when you follow the grid technique.) There are three different sets of grid numbers printed in black, blue and brown on this sheet; the fourth set of values in the margin represents geographic coordinates. Black numbers are UTM grid numbers; the blue, the overlapping UTM grid; and the brown, U.S. Polyconic. All of these will be explained later. Now we will be concerned with only the black grid numbers.

In the lower left (SW) corner find $^{2}64^{ooom}$ E. Read <u>RIGHT</u> along the lower margin until you find $^{2}67$ from which the three small zeros, ooo, have been omitted for convenience. Read on .9 of the way toward $^{2}68$. Keep your finger on this estimated spot and refer back to SW corner to read the first full grid line <u>UP</u> from the corner which is $^{43}90$ ^{ooom} N, continue to read up until you arrive at $^{44}00$. Estimate .9 of the distance beyond this number toward $^{44}01$. The Easting (reading right) is $^{2}67.9$ and the Northing (reading up) is $^{44}00.9$. In writing these grid coordinates, the elevated numbers and decimal points are omitted and all figures are written as one unit with the Easting part of the coordinate first, thus: 679009. There is Rockdale School! Note that the terms Easting and Northing arise from the fact that reading is relative to the fixed southwest origin for map sheets of

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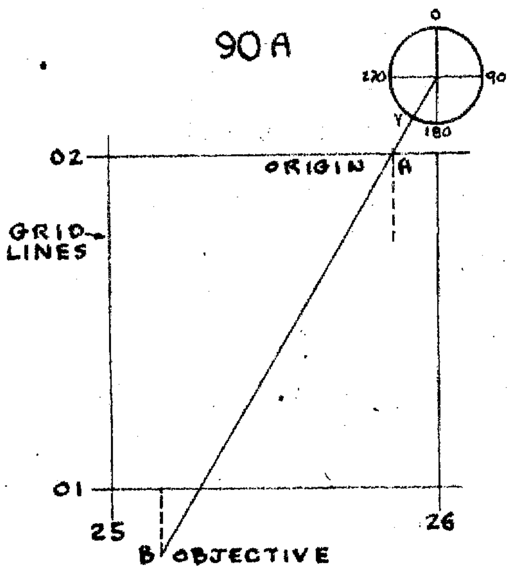
any area in the world.

Giving Directions

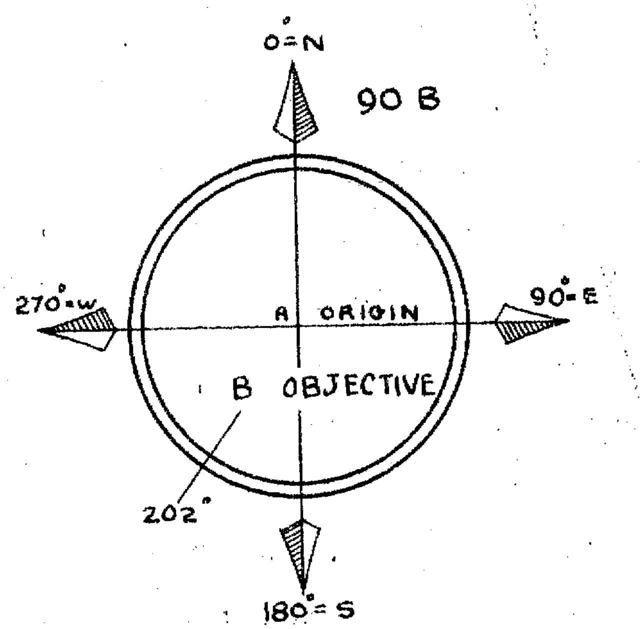
So long as two places lie on exactly the same graticule line, giving direction between them is easy since only one of the four cardinal points of the compass is involved. When map directions involve "boxing the compass", they become less definitive and tend to be confusing to the average map user. Furthermore, you recall that there are types of projections upon which diagonal directions between coordinates are not true to earth directions.

When a military grid is used as the basis for giving directions, many of these complications and inaccuracies are averted. In describing the position of one point on a gridded map with reference to some other point (origin to objective) the azimuth system is used. An AZIMUTH is the angle formed between two N-S lines passing through the center of the given origin and objective. (These lines may be magnetic, true or grid north lines, of which more later.) The azimuth determines the direction and is used instead of the compass points in giving direction.

The procedure for determining azimuth is shown graphically on Fig. 90A on which it is assumed that the parallel lines represent grid lines "lifted" from a map. To determine the direction from origin (A) to objective (B), draw a straight line (X) between the two points and extend it to the nearest grid line (26). Orient a protractor with its 0 on the grid line and it indicator on the intersection of the grid and extended lines.



A. Determining direction from a grid with a protractor.



B. Azimuth interpretation of compass readings.

FIGURE 90

Read the protractor clockwise to the point where the extended line meets the protractor (Y). The number of degrees read at this point is the azimuth (202) or direction from A to B. Figure 90B illustrates how the azimuth , in this case 202, is the key to giving directions without having to spell out that B is south by southwest by south of A.

No other manipulations are necessary in using azimuths on a map. Whenever grid azimuths are used with a compass in the **field,** they must be adjusted to magnetic north to insure proper interpretation of compass readings. Such adjustments are accomplished by use of declination data explained later in this chapter.

Giving soldiers instructions in compass directions could be disastrous. By the time a beleaguered soldier had interpreted the lengthy notation and applied it to a graticule to get his bearing, the enemy might have spotted him and made any further use of the map unnecessary. With aid of a compass and the military grid he would need less time to determine his position and head in the direction of safety as you can now readily see.

A word of caution is probably not amiss at this point. Zero azimuth is not always north. Azimuth is often taken from the south point on land and from the north point on sea. Thus, the diagram on the preceeding page might be a sea azimuth, and the land azimuth for the same problem would be 22 which is equivalent to the back azimuth in the first case. (202-180= 22)

A comparison of terms reveals that they all mean the same thing, direction. You would probably ask for direction; a soldier or astronomer would ask for azimuth, and land surveyor would ask for bearing. Bearing and azimuth mean the same thing to 90°, since azimuths are measured in terms of a whole circle and bearings in terms of a quadrant of a circle. The answer shown on Fig. 90B might look something like this.

By:	The Average Man	Southwest
	Mariners Compass	South Southwest by south-SSWS
	Surveyors Bearing	S 22°W
	Land azimuth	22
	Sea azimuth	202

Translating Distances

Unequal spacing of graticule intervals, inadequacy of one bar scale for an entire sheet and many other weakneses arising from geographic determination of distances also make the grid a useful complement of the graticule.

Grid spacing, of one thousand and ten thousand yards or meters depending upon the scale of the map, creates perfect squares of equal size over the entire map. These squares can be subdivided into smaller units by inspection or through the use of a straight edge. All distance values remain constant and so diagonals can also be drawn and distances measured along them. Short distances can be given in terms of parts of units. Such measurements are important for local operations. An added advantage of grid units over geographic units is that the latter must be converted to distances by means of tables while grid units represent distance and so require no conversion.

Military Grid and Grid Reference Systems

Universal Transverse Mercator Grid

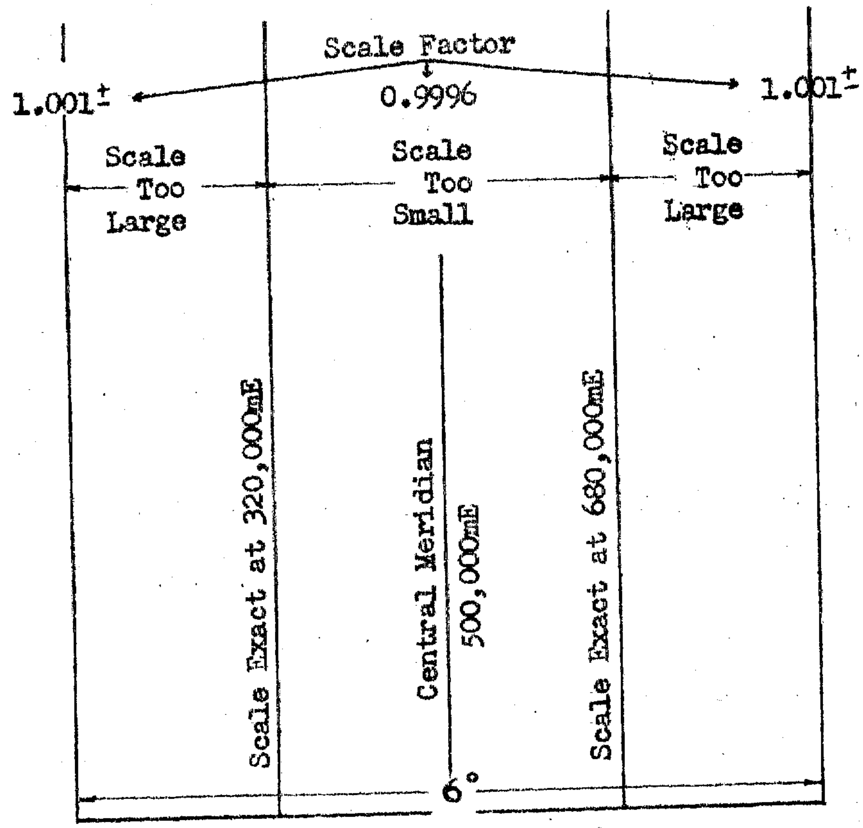
To achieve a comprehensive and uniform coverage of the world, several agencies and countries have adopted a common military grid system. For example, United States military large and medium scale map series covering the world are being constructed on or converted to the Universal Transverse Mercator Grid system (UTM). This system is based upon the Transverse Mercator Projection. Derivation of coordinates for the projection is based upon computations for a given spheroid.

The military Transverse Mercator Projection as you remember from the previous discussion of it (see page 73) is used in zones 6° wide. The longitude of origin for each zone is the central meridian which is arbitrarily numbered 500,000 and is called a FALSE EASTING (labelled E). False easting numbers are assigned to each vertical grid line with their values decreasing toward the western and increasing toward the eastern limit of each zone. Zones are numbered from east to west around the world beginning with 1 at 180 to 174° W and increasing eastward to 60 on zone 174 to 180° E. Each zone is bounded by meridians which are multiples of six degrees W or E of Greenwich. At the juncture of one zone with another an overlap of approximately 25 miles of one grid over the next is made on maps to insure accuracy of correlation.

Because of the secant character of the graticule, scale factors must be employed when longitude distances are being computed for projections or when grid distances are converted to actual East-West distances for precise control of artillery firing. The reason for these scale factors is shown in Figure 94. The ordinary map user, however, need not be concerned with scale factors in giving or using grid references.

The latitude of origin in all zones is the Equator. FALSE NORTHING (N) numbers are assigned to latitudes beginning with 0 meters at the Equator for the northern hemisphere and with 10,000,000 at the Equator for the southern hemisphere. These numbers increase in value from the origin to the latitude limits of the UTM which are 80° N and 80° S.

GRAPHIC REASONING OF NEED FOR SCALE FACTORS



Grid and Secant Projection Lines Coincide at A & B

FIGURE 94

<u>Spheroids</u> - You have just been introduced to the UTM Grid. Now you must meet its partners, the Spheroids.[1] Each spheroid controls the business of dispensing coordinates for a particular area as shown on Fig. 95. The ideal, of course, would be to have the whole world based on one spheroid. Strides are being made in this direction with the International Spheroid. At present, however, five spheroids are used because regional surveying, for

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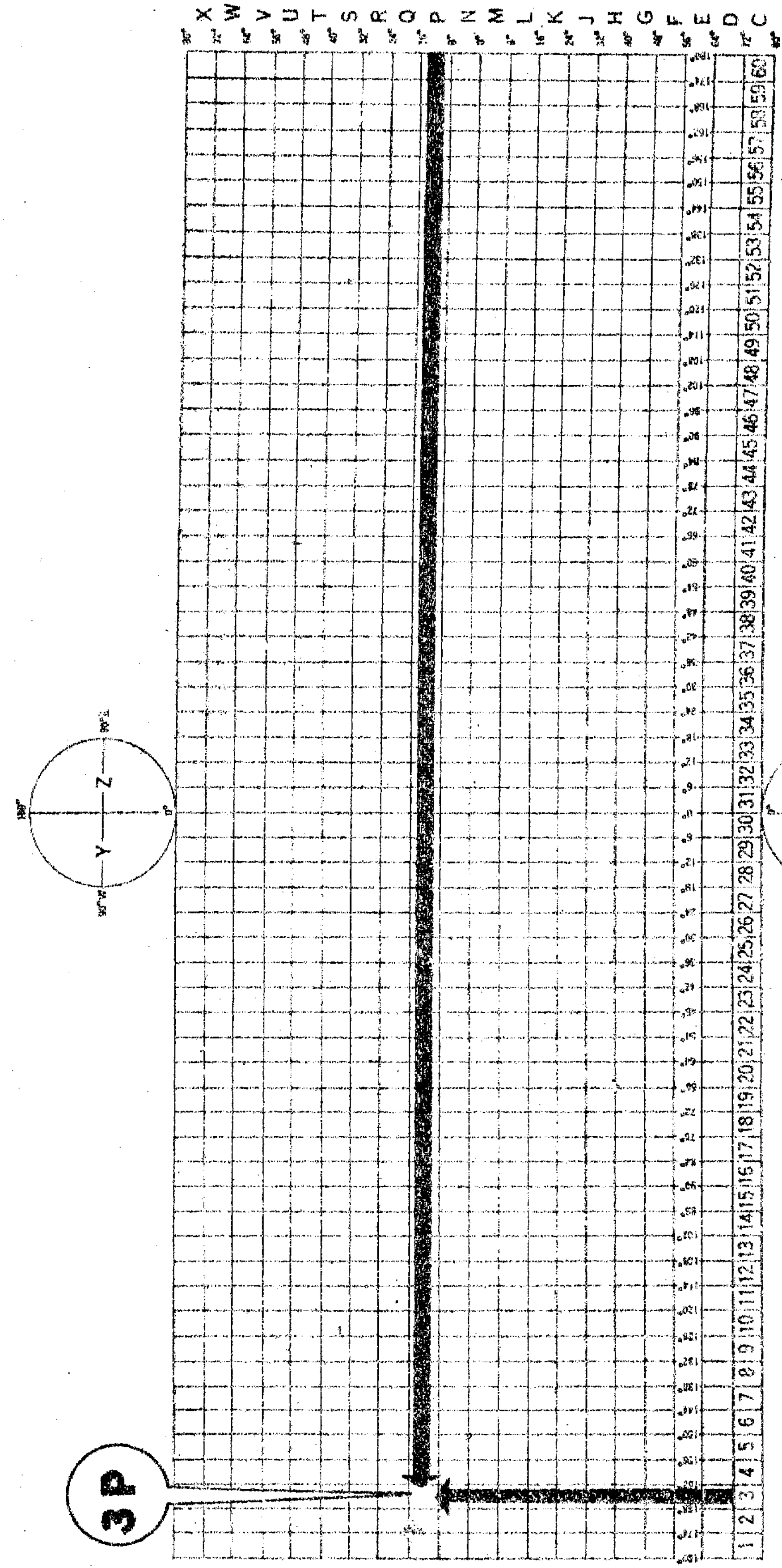
[1]A spheroid is an geometric figure describing the size and shape of the earth developed from measurements of the earth's surface. Accepted spheroid figures are used for computation of all exact projections but were not introduced in the section on projection because they would have added little then, but are now essential to the UTM grid explanation.



GRID ZONE DESIGNATIONS OF THE MILITARY GRID REFERENCE SYSTEM. THE DESIGNATIONS IDENTIFY THE POLAR AREAS AND 6°E.-W. BY 8°N.-S. DIVISIONS OF THE GLOBE BETWEEN 80°N. AND 80°S.

ex[illegible]
has been adapted to one of the spheroids. Selection of these spheroids is based on the fact that the men who did the original computations of them produced more precise results in one area than in others of the world. Subsequently volumes of tables were completed to give figures adjusted to each spheroid. Since the computation of spheriod tables is a lengthy process, existing tables are being used for the best portions of each of the five spheriods until new tables are completed for the International Spheroid. These tables are used for finding and plotting grid coordinates.

Universal Polar Stereographic Grid

Rapid convergence of meridians near the poles makes the UTM grid system impractical for polar areas. For this reason a grid based on a polar projection is preferable. The Polar Stereographic Projection is used, consequently, from 80° to the poles and is based on the International Spheroid.

The Universal Polar Stereographic Grid (UPS) adapted to this projection completes world coverage in combination with the UTM Grid. Polar areas are simply divided into two parts by the 180° and 0° meridians based on Greenwich. Scale factors are available for precise measurements, but again they are unnecessary for ordinary use.

Military Grid Reference System

The UTM or UPS Grid is all that is necessary for reading single map sheets but reference to specific sheets and areas necessitates a reference system. Numerical grid references alone might be interpreted to mean 120 places in the world as a result of similar numbers in 60 zones and 2 hemispheres in the UTM grid system. Thus, the Military Grid Reference System is designed for the UTM and UPS grids.

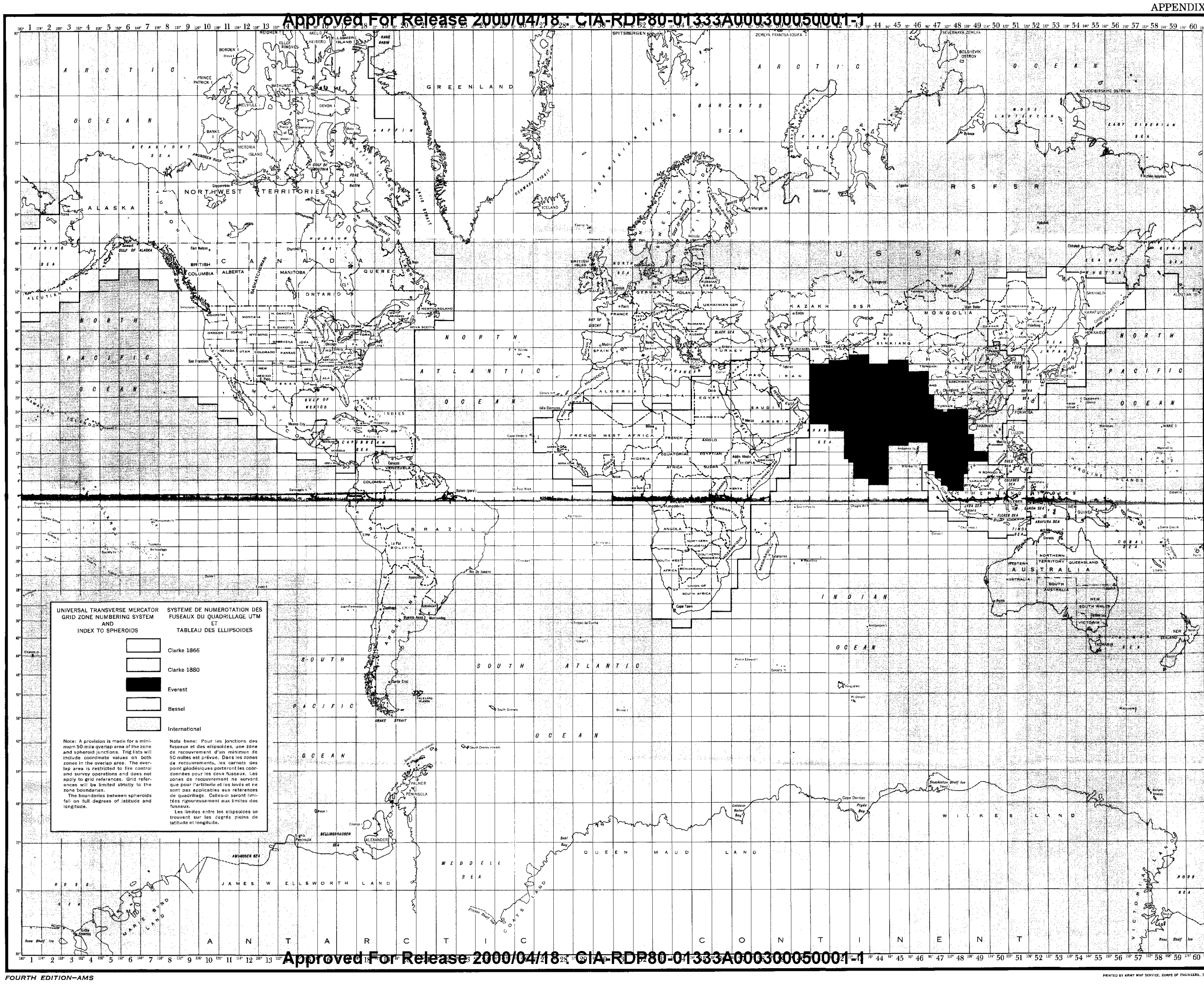
For convenience in using the Reference System, the world is divided into large, regularly-shaped, geographic areas each of which is given a unique Grid Zone Designation. Between 80° S and 80° N the world is divided into areas 6° east-west and 8° north-south. The columns, 6° wide, aligned from west to east are identified by the UTM zone numbers from 1 to 60. The rows, 8° high, aligned from south to north are identified by letters. Starting at 80° South and proceeding northward to 80° North the rows are lettered alphabetically beginning with C through X and omitting I and O. Reading RIGHT UP the combination of the column (zone) number, i.e., 3, and the row letter, i.e., P, gives the Grid Zone Designation, 3P. Fig. 98.

These areas are further subdivided into 100,000 meter squares based on the grid covering the area. Each square is identified by two letters called the 100,000 Meter Square Identification. This identification is unique only within the area covered by the Grid Zone Designation. Anyone using this Identification must, therefore, be careful to include the proper Grid Zone Designation. Numerical references within the 100,000 meter square are given to the desired accuracy in terms of easting (E) and northing (N) grid coordinates. For the sample point given on Hagerstown, Sheet 5463 II N.W., the Grid Zone Designation is 18 S. The 100,000 Meter Square Identification

UTM GRID ZONE DESIGNATIONS

FIGURE 98

(opposite)



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FOURTH EDITION—AMS

is TU and numerical reference is 688959.

For reference purposes the polar areas are divided into two zones by the 0° - 180° meridians which form a diameter of the Universal Polar Stereographic Projection extending from 80° to the poles. References are made to Y in the western half and to Z in the eastern half of the north polar grid; and to A and B in similar relationship in south polar areas. Each is further subdivided by 100,000 meter square identifications.

It is not necessary for you to digest further refinements of this system at present. A complete analysis is given in books devoted to the development and utilization of grids and grid references.[1]

Polyconic Grid System

U.S. Polyconic - The Grid System for Progressive Maps of the United States is based upon the Polyconic Grid. Older military topographic maps of the United States show this system so that even though all new mapping in this category use the UTM grid, you will find examples of the Polyconic System still in use. Furthermore, during the period of transition, both grids are shown on map sheets as you noticed on the Hagerstown map sheet used to demonstrate how to read grid numbers.

The United States is divided into 7 zones each 9° of longitude in width with a ½ degree overlap on each side. The

[1]For precise breakdown of the Reference System, see Army Map Service Technical Manual No. 36 Grids and Grid References or, Department of the Army TM5-241 to 16-1-233 The Universal Grid Systems.

overlapping area can be shown on two sets of maps, one on each grid system thus making it possible to have progressive maps for each zone. Although the System is called progressive, it is actually an interrupted system with the overlap acting as a stepping stone to the next system of coordinates. Each zone has its point of origin at a central meridian which is $4\frac{1}{2}$ degrees from either edge of the zone, but is actually a multiple of 8° from 73° W due to the 1/20 overlap of zones. (The longitude 73° W obviously is the practical eastern limit for the U.S.). Each central meridian is numbered 1,000,000 on the grid. Values increase to the east and decrease to the west from the central meridian. The latitude line of origin for all zones is 40°30' N. This line is numbered 2,000,000 on the grid. Values increase to the north and decrease to the south of the standard parallel. Grid references are identical in each zone.

For complete reference purposes the zones are lettered from east to west beginning with A for the New England area and ending with G on the west coast.

The whole system was inspired by the French Quadillage System based on the Lambert Conformal Projection and is very similar to it. Certain modifications were necessary because the French system is expressed in grades and meters and the United States system in degrees and yards. The diagram on the following page shows the grid reference system.

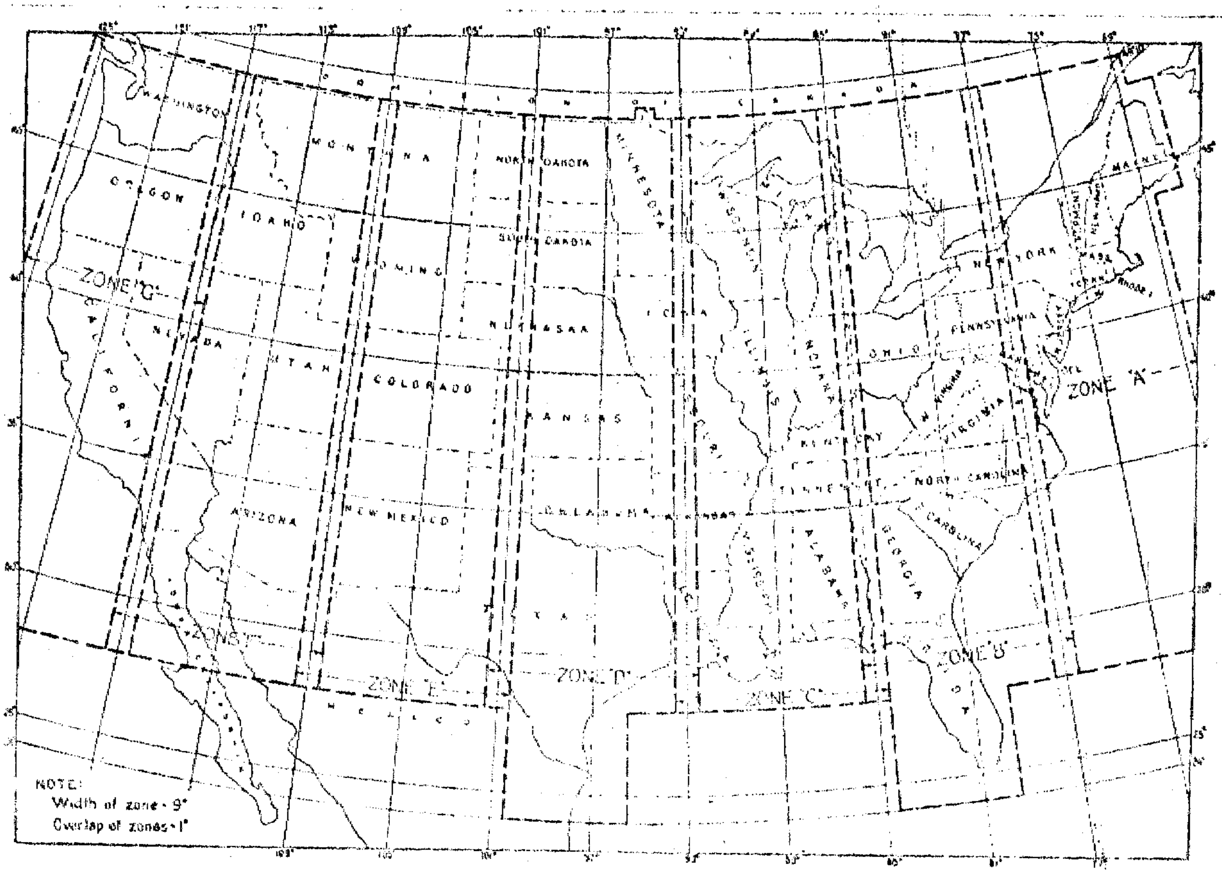

FIGURE 101

<u>World Polyconic</u> - The World Polyconic Grid system is merely an elaboration of the progressive military grid of the United States. It could have been made to cover the entire world but actually was only used in areas not covered by British grids. Adoption of this grid was an emergency solution of the world mapping problem during World War II and like its U.S. predecessor has been abandoned in favor of the UTM grid.

The world is divided into five north-south bands each 73°

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wide, overlapping 1° and extending from 80° S to 80° N. Bands are numbered from I, over the United States, westward. Each band is divided into nine zones each 9° wide, overlapping 1° like those for the United States. Zones are lettered from A to J omitting I from east to west within each band. Fig. 102.

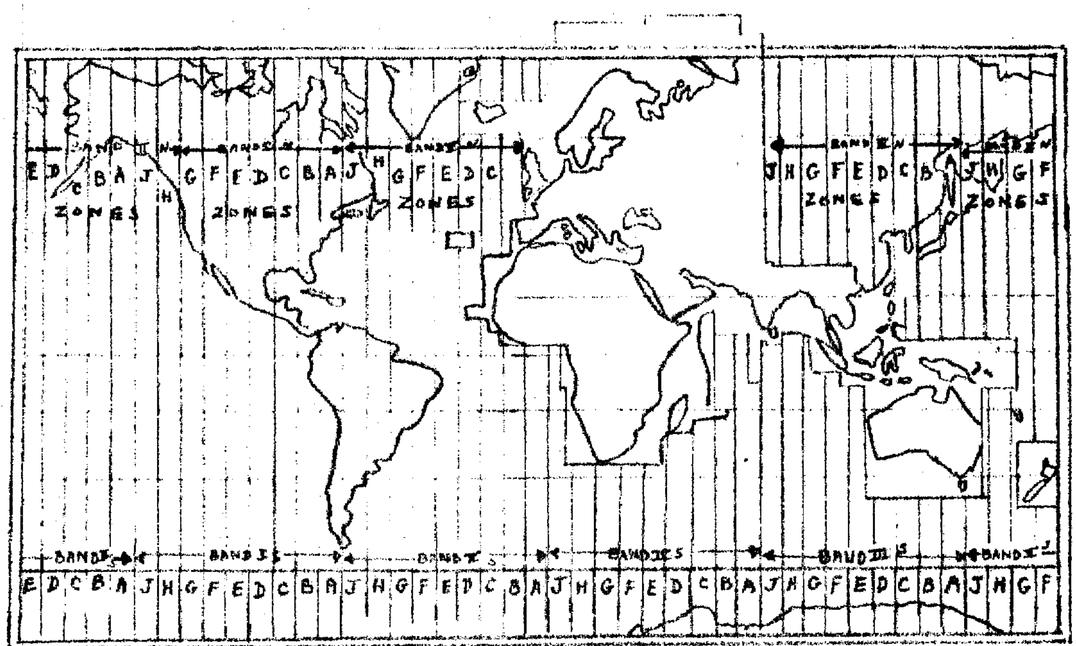

FIGURE 102

Two latitude points and one longitude point of origin can be used in each zone. For the part north of 28° the origins are at the central meridian and 40°30' N to agree with the United States system. Origins for the remainder of each zone are at the central meridian and the equator which are numbered 1,000,000 and 0 respectively.

A 1,000 yard grid is the basis for the system. Thus, all measurements are in yards.

<u>British Grid Systems</u>

Each British grid is referred to either as a grid, a zone or

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a belt. These terms are applied in relation to the types of projections used. Each grid, zone or belt has a name, see Fig. 104. Interval division is made on an alphabetical and numerical block system. Large blocks covering 500,000 meter squares are identified by a 25 letter block system beginning with A in the northwest block, omitting I, and ending with Z in the southeast block as shown in Fig. 103. Each block may be further subdivided into

A	B	C	D	E
F	G	H	J	K
L	M	N	O	P
Q	R	S	T	U
V	W	X	Y	Z

Arrangement of Lettering in 500,000 meter blocks
or 100,000 meter squares.

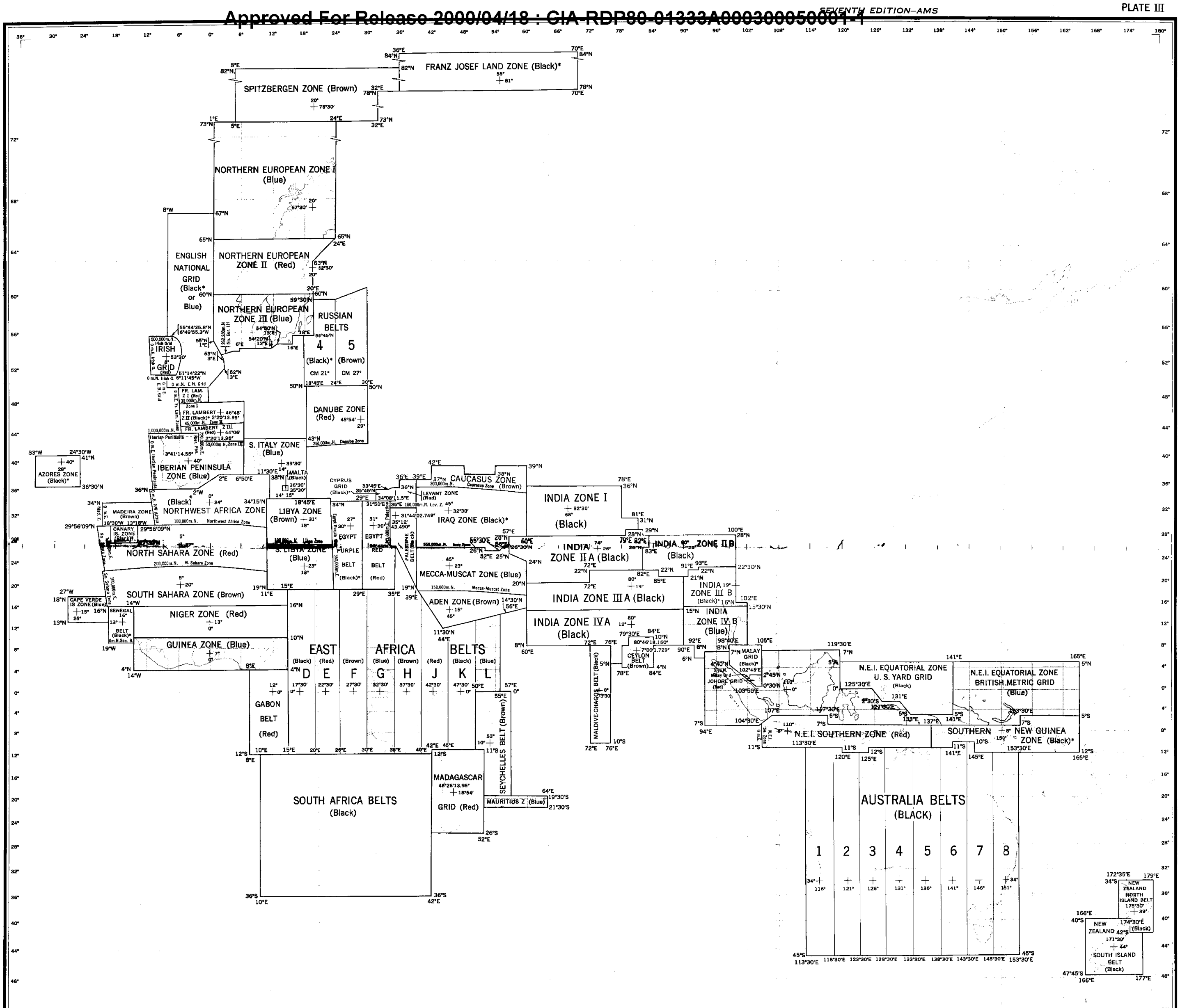
FIGURE 103

100,000 meter squares which are lettered in the same way as the blocks. Each 100,000 meter square can be broken into 10 smaller squares of 10,000 meters on each side. In this case, not the squares but the lines forming the squares are numbered from 0 to 10, beginning in the southwest corner. The false origin of the grid coincides with V at the southwest corner. If the area mapped exceeds 2,500,000 meters in either direction, the basic lettering and number plan is repeated for the additional squares needed. Identification letters are printed in the color assigned

INDEX OF BRITISH GRIDS

FIGURE 104

(opposite)



*Purple on GSGS Maps

INDEX OF BRITISH GRIDS

NOVEMBER 1952

PRINTED BY ARMY MAP SERVICE, CORPS OF ENGINEERS, 8-53, 117561

to a large division.

Because of the variety of grids which causes difficulty in making correlations and other international pressures the British are beginning to convert to the Universal Transverse Mercator Grid System.

Other Systems

The same general procedures as that are followed for the British grid and grid references systems are applied by most countries of the world. Different countries use different basic graticules, or, units of measurement, which may alter the system slightly. As you encounter miscellaneous foreign military grids, you should examine them carefully to see if they fit into any of the above classifications. If they don't, then begin a search for an explanation of the system. Chances are, however, you will not need to cope with too many of these special cases since you can probably substitute another sheet or series prepared by the Army Map Service, British, French or some agency influenced by these leaders.

Measuring Devices: Scale

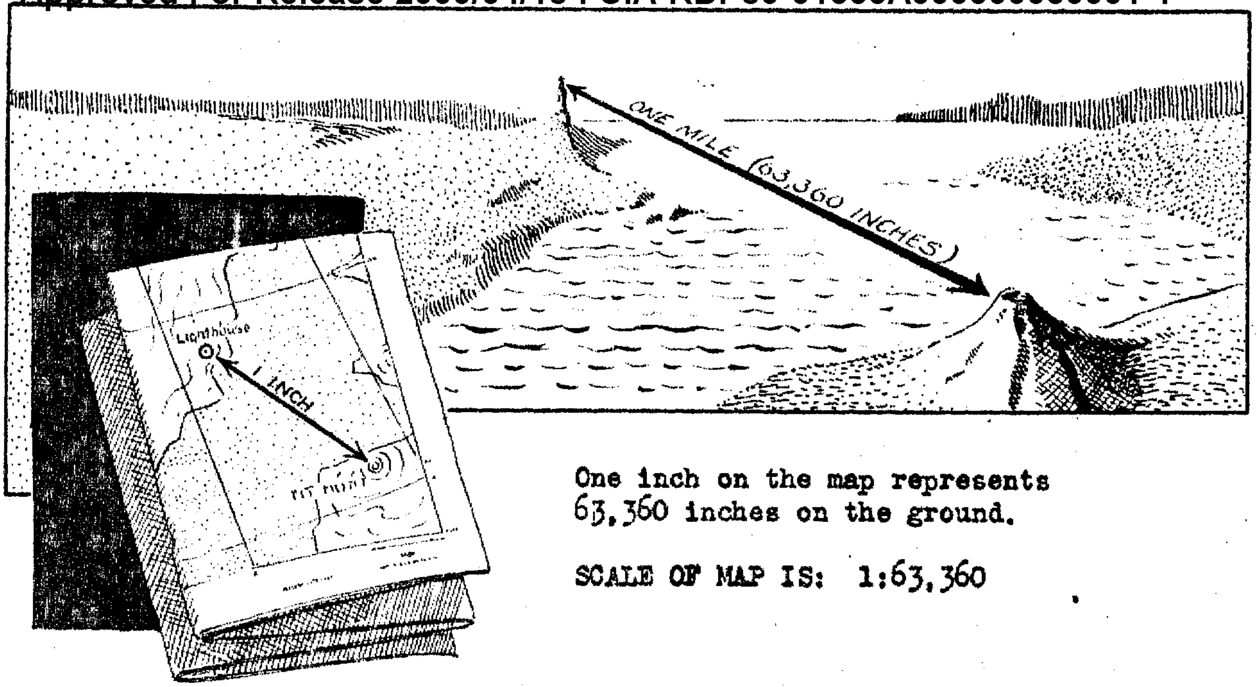
Meaning of Scale

Projections are the cartographers solutions of how to pin the round earth down on flat paper. Scales are the logical resolution of the problem of shrinking the earth down to usable map size. A general definition of scale is: the ratio of distance on a map to its corresponding distance on the earth. In a final analysis, what is distance but a linear measurement of size?

Two major factors must be considered in selecting scale and should be borne in mind in analyzing and interpreting maps. The first consideration is how large or small a part of the earth's surface is to be shown and the second is how much map space is available for this purpose. If a whole wall is to be covered by a map of the world, the scale of this map will be different from that of one showing the world on a desk-sized sheet. In other words, how much earth to how big a map sheet. These two together dictate the scale. As soon as this coverage decision is made, then scale becomes the dictator of the practical size and amount of detail that can be depicted within the limits of the map.

You will never be confused by map scales if you learn to visualize what they mean. Remember you are viewing a portion or all of the earth's surface squeezed down to a smaller size, on <u>any</u> map. You can anticipate how much distance will be represented as the result of this compression by fixing certain basic scale relationships firmly in your mind.

One way of identifying a map or map series is by a representative fraction. What does it represent? Why a fraction? Let's take the first question and visualize what it means in terms of a basic scale 1:63360. There are 63,360 inches in one mile. Therefore, one inch on a map at this scale represents 63,360 inches laid out in a straight line across the surface of the earth Fig. 107. Ups and downs on the actual surface are discounted because this is a linear or horizontal line scale. If you started from the building in which your class meets and traveled in one direction along a level line, where would you



One inch on the map represents 63,360 inches on the ground.

SCALE OF MAP IS: 1:63,360

FIGURE 107

arrive at the end of one mile, 63,360 inches?

"Mile" was used to start you off in visualizing scale, but any kind of unit can be substituted and the representation will be the same-one map unit to x earth units. The actual earth representation is controlled by the answer to the second question. "Why a fraction?" Ratios and fractions are the same thing said in a different way. Consequently, scale ratio of map to earth is representative fraction.

$$RF = \frac{\text{Distance on the map}}{\text{Distance on the earth}}$$

Representative fractions are read and interpreted just like any common fraction and produce the same proportions. When the denominator is a small number each part represents a large piece of the whole. For example, it takes only two parts to make one

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whole in the fraction ½. As the denominator is enlarged, it takes more parts or, in other words, one part represents a smaller piece of the whole. Since map scales are generally expressed in comparatively small intervals of linear measurement, they show several thousand parts to be expressed in one part or unit. At a scale of 1:20,000, twenty thousand earth units would be compressed into one map unit. The total compression, however, would only be about 1/3 as great as that necessary at 1:63,360. At the first scale it would take more than three inches on a map to represent one mile of earth surface. This means you would travel only one third as far from school to cover the territory shown in one inch at 1:20,000 as you would in one inch at 1:63,360. Visualization in this fashion is a good technique for you to practice until it becomes automatic. Try these three steps to help you form the habit:

1. Fix in your mind that at a scale of 1:63,360 it takes one inch on the map to show one mile of the earth's surface. A map that is 20 inches across then represents 20 miles linear earth distance.

2. Visualize the distance of a basic unit, one mile, on the map as a similar distance in your own locality. Learn in this way to "feel" the scale as well as to be able to compute it abstractly.

3. Compare different map scales in relation to a basic unit such as inch to one mile, Don't be hesitant about rounding off numbers for this purpose. Even the map makers use 62,500 which is easier to multiple and divide than 63,360 and yet is still very close to one mile. A few other scales and their rough equivalents will start you in your comparisons.

1:25,000	=	about	.4	miles	to	the	inch	or	2½	inches	to	the	mile
1:125,000	=	"	2	"	"	"	"	"	½	"	"	"	"
1:250,000	=	"	4	"	"	"	"	"	1/4	"	"	"	"
1:1,000,000	=	"	16	"	"	"	"	"	1/16	"	"	"	"

Every good map must have a scale to tell its reader what to expect in the way of details as well as to aid him in estimating distances. Large scale means that specific features of the landscape such as individual buildings and intricate local patterns will be shown on a map covering a small area. As more area is covered by the map, exactness of delineation decreases and less detail can be shown within the scope of each map unit. When a suggestive outline, circle or dot replaces actual urban detail, then more earth area has been covered in each map unit and the scale is either medium or small. Thus increasing the size of the denominator means either making each detail smaller or less exact.

The size of objects can decrease only so far, and then they must be eliminated because it becomes impossible for the human eye to see them. By the same line of reasoning, important details to be retained must be exaggerated. These are no longer drawn to scale but rather to achieve legibility. The following whimsical little quotation may help you to recall the significance of scale: "Big frog in a little pond" LARGE SCALE, "Little fellow in a wide, wide world" SMALL SCALE[1]. In other words, if the physical features of the frog can be seen, little space is left for showing much of the world in which he lives. If large sections or all of the world can be seen, then the little frog retires to the insignificance of a X which marks his jumping spot.

<u>Classification of Maps According to Scale</u>

How are large and small scale differentiated? Universal

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[1]Greenhood, p 44

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acceptance of any one classification of maps according to scale would be ideal but, like all human ideals, it does not exist. Instead, each specialized group of map users sets up its own categories and sometimes becomes very dogmatic about its own pet classification. College instructors and classroom teachers are accustomed to using maps which show large sections of the world. To this group all scales of 1:1,000,000 or larger are large and only scales of several millions or more are small. At the other extreme are the personnel who constantly work with detailed analyses of small areas. To them, any scale smaller than 1:50,000 is classified as small scale. The truth of the matter is that a classification which fulfills the needs of one group may be inadequate for another. If any rule exists it should be, "to each his own". Please accept the following classification with this rule in mind.

Large Scale

Mapping agencies commissioned to make special sheets of small, medium and large scale generally agree that large scale applies to mapping projects demanding up to 1:75,000 scales. On all compilations made by the Army Map Service, this is true.

Large scale mapping is done for tactical purposes and detailed study of small areas. If the scale is large enough, the resulting map closely approximates a photographic image of the area. (Compare the Photo Map on the back of Anderson Island 1478 II NW with the face of the map). Such mapping has limited patronage because of the size and quantity of maps needed for covering even a small area. Greater numbers of sheets are demanded at

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scales of "about" 1:50,000. The use of "about" implies the fact that mapping is done on scales of 1:48,000, 1:62,500 and 1:63,360 as well as 1:50,000.

Medium Scale

The Army Map Service considers all scales larger than 1:600,000 and smaller than 1:75,000 to be medium scale for mapping projects. Obviously, less detail can be shown. Much of the large scale minutiae is dropped because each square inch on the map now represents a greater earth area. Stylization of cultural and natural features is more abstract. Relative, rather than more nearly exact, relationships are maintained between map symbols. In other words, the map compiler guarantees, insofar as his information permits, that a road runs next to a stream. He does not guarantee the precise distance between them since he must use the space normally allotted between them for drawing symbols for road and river.

Small Scale

Any mapping done at a scale of 1:600,000 or smaller is Small Scale. All the restrictions given for medium scale are intensified at this scale. Only the most pertinent details can be shown.

Small scale maps can never be used effectively for intensive microgeographic studies. They are useful, rather, in laying master plans covering large areas. Overall distribution patterns can be visualized and mapped. Local features that are necessary in integrating plans of populated areas in relation to their surroundings must be shown on other maps or Back-Up Plans

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mentioned earlier.

Systems of Measurement

Crude Approximations

There are several different ways for measuring distances. Any measurement is just a convenient way of telling someone else how far a given thing is from something else. Some of the most elementary ways of designating distances arise from common knowledge. There is a saying, for example, "It is just a stone's throw away." This draws upon the common knowledge that stones are comparatively heavy or else so light that the average person cannot throw one very far, George Washington to the contrary not withstanding!

Another rough way of estimating distances is by "stepping off". In this case, it is assumed that the length of an average man's foot is about 12 inches or I foot. (The origin for calling 12 inches a foot). Consequently, if a man puts one foot in front of the other, he can make an approximate measurement in terms of how many feet one object is from another.

In early frontier days in the southwest, land was measured in this unique way: The extent of a property line was determined by the distance a man on horseback could cover while he smoked a hand-rolled cigarette. King-sized ones weren't in use then, or they would have added to a man's property!

Although any of these methods are too crude for map scales, nevertheless, they represent quaint predendents of precise systems. Even today there are several types of measurement but the English (sexigesimal) and Metric are most widely used. Either or both systems are used for scales on maps made by leading cartographic agencies throughout the world.

Metric System

The Metric system is used in many foreign countries and is increasing in popularity in the United States even though it may perhaps be unfamiliar to you. You are probably more accustomed to the English system of inches, feet, yards and miles. If you are to become a proficient map reader, however, you will have to find your way around in the metric system. Furthermore, since both systems are common, you should know how to convert from one to the other. To do this, you must understand how the metric system is developed.

Metric Conversions

The basic unit is the METER which is one ten-millionth of the meridianal distance from the Equator to a pole. Every other unit in the system is a fraction or a multiple of this unit. Prefixes attached to meters determine whether the new unit is a fraction or multiple. The prefix "milli" means thousandth, so one millimeter is $\frac{1}{1000}$ of a meter. "Centi" means hundredth. One centimeter equals $\frac{1}{100}$ meter. "Kilo" means thousand, thus one kilometer equals 1000 meters.

English conversions of metric units are accomplished by setting up a base equivalent and then moving the decimal point to the right or left in accordance with the dictates of the metric prefix under consideration, as follows:

1 METER = 39.37 inches.

To find the inch equivalent of one millimeter, move the decimal point 3 places to the left of its place in the basic equivalent to obtain 1 millimeter = .03937 inches. To find the inch equivalent of one kilometer, move the decimal point 3 places to the right to obtain 1 kilometer = 39,370.00 inches.

Multiple metric unit values are obtained by converting to the single unit equivalent and multiplying by the number of units desired. 10 centimeters = .3937 inches x 10 = 3.937 inches.

The same basic technique of shifting the decimal to the right or left to obtain a basic equivalent can be applied to conversion of any English unit or the reverse. For example, 1 yard = 91.44 centimeters = .9144 meters. One centimeter = .09144 yards.

Since you will probably need to make some kinds of conversions only occasionally, there is no point to committing each type to memory. Instead, a list of conversion values has been included in the appendix as Table II. You may wish to digest its composition now so you can use it readily whenever the need arises.

<u>Adaptations of the English System</u>

Adaptation of the English system to special occupations has led to the addition of adjectives such as Nautical, to the general term, mile. Some hydrographic charts have scale expressed in NAUTICAL MILES which are slightly longer than standard miles. Originally this unit was taken to be one minute of latitude. The actual length of one minute of latitude varies so that the length of a nautical mile was somewhat smaller at the equator than near the poles. This discrepancy became significant when sailors pushed into polar waters. To avoid confusion, the British Admiralty adopted the ADMIRALTY MILE which is the mean value of one degree of latitude, 6080 feet. The length of the official U.S. nautical mile is slightly longer or 6080.2 feet (1853.25 meters).

GEOGRAPHICAL MILE is another term based on geographic co-ordinates. It was originally defined as the length of one minute of longitude on the Equator corresponding to 1.1516 miles. It is now used interchangeably with nautical mile and sometimes even with statute mile.

A STATUTE MILE is the legal term for the standard land mile. It is 63,360 inches, 5280 feet or 1609.347 meters depending on the unit you choose. A statute mile is roughly 7/8 (0.8683) of a nautical mile.

You may also encounter a few foreign maps calibrated in unique units. Nations of essentially Slavic or Oriental origin and not greatly influenced by western civilization at an early date or dominated by it later, have developed units that have no resemblance to either the English or metric ones. Versts, Schritte, alnir and sajen or saszhen are a few of these. Four schritte equal three meters: 1000 alnir equal 625 meters (Icelandic). Equivalents for the rest and several others can be found in Table II of the appendix.

Notation of Scales

As was indicated previously, any unit or system of measurement can be used for expressing the relationship implied by map scales. These ratios can be noted on maps in any or all of the following three ways.

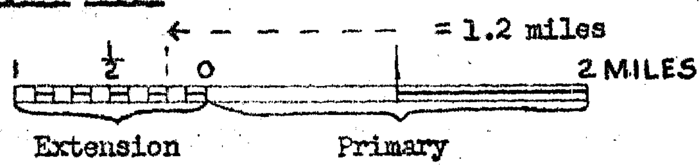
Representative Fraction (RF) 1:63360 or $\frac{1}{63,360}$

The representative fraction expresses the relationship of map to earth distances. The numerator or first part of the ratio determines the unit of map distance. The denominator determines the amount of earth distance represented by each map unit.

<u>Verbal Scale - One inch to one mile</u>

This method is self-explanatory since it simply means that the numerical values are written out. Do not confuse this with the popular English method of referring to maps. For example, what the English call the Quarter Inch map really means a scale of four inches to the mile.

<u>Graphic Scale</u>

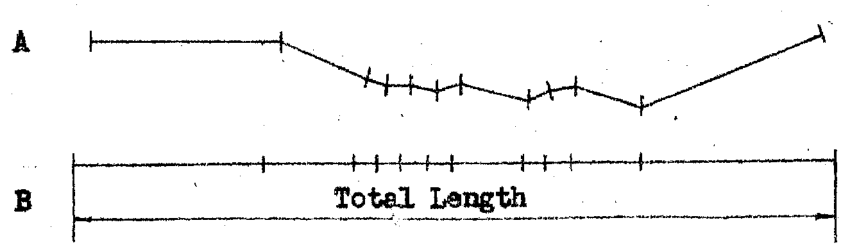


Graphic scales are calibrated to express visual equivalents of the representative fraction or, verbal scale. They can be used directly without the preliminary conversion needed for using the representative fraction. Furthermore, they are safer to use if a map sheet is to be reduced or enlarged photographically since the graphic scale notation automatically conforms to the change. Beginners often make the mistake of applying representative fractions or verbal scales to maps they assemble without anticipating such photographic changes. Scales will then be incorrect on the final map if they are computed for the original instead of the final map sheet.

<u>How to Use Graphic Scales</u>

For a graphic scale, a line or parallel lines are drawn of the appropriate length and divided into units. On the preceding illustration the two practical divisions of a graphic scale are shown. The primary portion to the right of the 0 is divided multiples of the whole unit such as 1-2-3 miles. The extension to the left of the 0 is divided into fractional parts of a whole unit, such as tenths of miles. CAUTION: If you are measuring full units begin at 0 and use the right side or primary scale. If the distance you are trying to measure does not equal even mile units, orient the line to be measured with its right end on the last full unit that is applicable and read the remaining fraction on the extension to the left of 0.

Bar scales, which is the name commonly given to graphic scales, can be useful for measuring other than straight lines. Rarely do you have to compute perfect circles on maps, but often physical and cultural features are irregular curves with expanses of nearly straight lines. Any medium with a straight edge can be used to measure distance along them. Lay the straight edge along the line to be measured and tick off short intervals to represent straight line segments of the curve thus:



A Method of ticking off distances along curved line.
B As ticks appear along straight edge.

FIGURE 117

Be certain that the last tick made is not moved away from the point from which it is derived as you rotate the medium of measurement. Measure the total length of the straight line resolved from each segment to get total mileage between two places connected by a curved line road, river, etc.

When such specific uses of a bar scale are made, the student must be sure that the scale is applicable to all parts of the map. Various types of projections invalidate use of a single scale beyond limited graticule points. For example, a single bar scale on a Mercator projection is usually constructed on true distances for a given parallel of latitude. Poleward distortion of the projection will produce highly erroneous measurements based upon this given latitude, for example equatorial, scale. In such cases, multiple scales adapted to correct proportions along succeeding parallels are necessary for correct measurement. If only one scale is provided, the student must disregard it in poleward areas. He may approximate distances here by consulting tables giving true earth distances for any latitude and longitude interval. It is worth while in this connection to remember that 1 degree of latitude anywhere and 1 degree of longitude on the equator equal about 70 miles. One degree of longitude represents decreasing distances in poleward directions. At 60 degrees north or south, one degree of longitude equals one half of what it would at the equator, or about 35 miles. Remember these are earth approximations to be used for gross estimations only, not accurate measurements.

Determination of Scale Values

Although you are not actively compiling a map in this course, you will need to know how to determine scale values. If you do any extensive work with maps, you will encounter maps on which either the Representative Fraction or the Graphic Scale has been omitted. You may even find one with no scale of any kind. You can cope with any of these emergencies by following the same technique used for deriving scales for original mapping.

<u>No scale given</u>

The exact distance between two earth features must be known or found from source material if no scale is provided. Then, measure the map distance between these two and divide earth by map distance. Each must, of course, be converted to a common unit. For example, the earth distance is 2 miles and the map distance is 2 inches. Two miles = 136,720 inches. The ratio is then 2:136,720. Dividing we obtain the unit ratio of (136720 ÷ 2) 1:63,360, or 1 inch to 1 mile.

<u>Representative Fraction Given</u>

Now, lets assume you are given a Representative Fraction only and want to use a graphic measurement. For example, Given 1:125,000 to find graphic equivalent.

Divide 125,000 by 63360 to find what earth distance each map unit will represent. This equals 1 inch: 1.81 miles. It is normal procedure to have graphic units represent even earth units. To do this, cast the known units into a ratio, thus: X:1::100:181 (100 unity taken to eliminate decimal)

$$181\,X = 100 \qquad X = \frac{100}{181} = .552$$

Therefore, .552 inches represent 1 mile on a graphic scale constructed for the RF, 1:125,000.

<u>Graphic Scale Given</u>

If the Graphic Scale is given and you want to find the Representative Fraction, begin by measuring the exact length of one unit on the graphic scale. Divide one earth unit by this figure.

Given: one earth unit of one mile = 63360 inches, Scale unit is found to equal 76/60 inches. 63,360 ÷ 76/60 = 63,360 X 60/76 = 3,801,600 ÷ 76 = 50,000 appr. Therefore, the RF for this Graphic Scale is 1:50,000.

Reduction and Enlargement of Scales

Effect of Reduction and Enlargement

As you work with maps, you may want to reduce or enlarge some of them or have this done for you. You will want to have some idea of how they will look in terms of their comparative size and the size of detail shown on them after these changes are made. Upon careful thought, you may decide, furthermore, that a given map should not be reduced because details on it would be too crowded in a smaller space. Remember that scale should control the sensible choice of detail. Large scale maps can contain much specific detail that has to be generalized and exaggerated at smaller scales.

One simple way to illustrate what happens to the size of a map sheet and all detail shown on it for a given area when it is reduced or enlarged is to fold a sheet of paper. Take a sheet of ordinary notebook paper and assume it is a map of a given scale. to show the same area reduced to 1/2 the original scale, fold the paper in half each way since any reduction is proportional in each dimension. You now have 1/4 the paper area of the original while the scale is 1/2 that of the original. Fold the paper once again in each direction to illustrate a 4 times reduction which gives a paper area 1/16 the size of the original.

Formulae for Reduction and Enlargement

The mathematical formula of which this paper folding is illustrative is: The ratio between the area of a map on one scale and its area at another scale is equal to the square of the ratio between the scales of the original and converted map.

Example: Reduce 1:10,000 to 1:50,000 scale

$10{,}000 : 50{,}000 = \frac{10{,}000}{50{,}000}$ or 1/5 the original linear scale and $(1/5)^2 = 1/25$ the area of the original

Enlarge 1:100,000 to 1:20,000

$100{,}000 : 20{,}000 = \frac{100{,}000}{20{,}000}$ or 5 times the original linear scale and $(5)^2 = 25$ times the area of the original

If you know the original scale of a map sheet and want to find the new scale of a reduced or enlarged version of it, use the principle of ratios. Place the unknown first to enlarge and second to reduce, thus:

Enlarge: Given scale 1:100,000 to be enlarged 10 times

$\frac{1}{X} : \frac{1}{100{,}000} = 10 \quad \frac{100{,}000}{X} = 10 \quad 100{,}000 = 10X \quad 10{,}000 = X$

The new enlarged scale is 1:10,000

Reduce: Given 10,000 to be reduced 5 times.

$\frac{1}{10{,}000} : \frac{1}{X} = 5 \quad \frac{X}{10{,}000} = 5 \quad X = 5X \quad 10{,}000 = 50{,}000$

The new reduced scale is 1:50,000

Any of the above problems can be solved in terms of other English units or in Metric units.

Scale Exercise

Five maps of the Hagerstown area have been provided to aid you in visualizing the effect of scale on map depictions.

(1) Hagerstown City Plan
(2) 1:25,000 Hagerstown
(3) 1:50,000 Hagerstown
(4) 1:125,000 Hagerstown
(5) 1:250,000 Baltimore

Assemble these five in the order given above and compare the differences that result from scale.

1. How much linear distance is covered by one unit of the graphic scale on each sheet? You will have to compute a graphic scale for the City Plan to complete this exercise.

2. What is the linear extent of the earth area covered by each graphic scale? Of each map sheet?

3. What is the geographic extent of each map in terms of geographic coordinates? Note: geographic coordinates for the City Plan must be determined from the corporate boundaries of Hagerstown.

4. When military grids are provided, what interval is used and how is the grid depicted?

5. What happens to symbolization of hydrographic detail on each progressively smaller scale sheet? Why?

6. How does the depiction of Hagerstown change from map to map? Why?

7. How is the transportation pattern adapted to the various scales?

8. Why is the Through Way Plan printed on the reverse of the Baltimore Sheet?

9. If the 1:25,000 Hagerstown sheet is reduced to 1:200,000 scale, how large a map sheet would be needed to cover the same

area? Why would such a direct reduction be impractical?

10. If the 1:250,000 Baltimore sheet is enlarged to 1:10,000, how large a map sheet would be needed to cover the same area? How would details "look" on this direct enlargement?

11. Which of these maps would you use to analyze the accessibility of Hagerstown to other cities within 10 miles of it? 25 miles? 75 miles?

12. Which maps would you use if you wanted to buy a piece of property in Hagerstown for a homesite? For commercial purposes? For a factory? Would you need other maps and source material to aid you in each of these selections?

Control

Cartographic Dependence on Other Fields

Correct positioning of earth features and scales for precise measurement on maps depend upon a great deal of preliminary ground work. No accurate map has ever been "dreamed up" by a cartographer alone. He must utilize the products of the combined efforts of astronomers, geodecists and surveyors. Exact positioning of geographic coordinates begins with astronomical observations. Specific distances are measured by the surveyor from points fixed by these observations. Geodecists utilize these established distances in computing the exact figure of the earth or spheroid and are also responsible for detailed studies leading to the determination of the base for topographic mapping.

When the cartographer compiles an accurate map, he uses the coordinates established on the earth and scales them to their proper place on his map sheet. The thoroughness with which each ground control was determined validates or invalidates his scaling and any aids he may provide the map user in reconstructing earth-map relationships. The most carefully calculated Representative Fraction and the most accurately constructed bar scale are useless if earth features are misplaced in respect to their true earth position. One critical example of this dependence is the use of maps for artillery fire control. Scientists have been able to perfect highly accurate guns and instruments for directing missiles. Men can be trained to compute firing distances from maps and to adjust their instruments accordingly but if the map from which range was calculated is incorrect, the missile will still miss its target. The most highly trained operator and most precise artillery piece cannot be combined to hit a mark that isn't where the map says it is, but may be several hundred yards away.

A slightly different application of control often results in civil litigation. Single surveys can be run to determine the size of a piece of property. If there are no neighbors nearby, this type of survey is adequate. As adjoining property is taken up or sold, however, legal disputes are almost inevitable if the original survey was not tied to true earth coordinates. Surveyors need something, therefore, to control and fix property measurements where they belong.

The Meaning of Control

A control point is merely a spot on the earth whose precise location has been established. It is a point of reference from which measurements are made to find the location of earth features and from which to establish other such points. In this way, it controls the location of features. Like the word "sheep", control may be used to mean either singular or plural points. It is also used as an abstract noun as in the sentence "There is little control in this area."

The greater the number of control points that are established in a given region, the better becomes the accuracy with which features can be located. Adequate control also improves the potentiality for better translation of these features into map symbols.

The Genesis of Control

Making a map by compiling information from other maps and map sources is a complicated task. It is even more complicated to make a map of an area that has never been surveyed. Imagine, for example, being sent to an uncharted island with instructions to produce an accurate map of it.

You would have to begin by looking to the heavens and making astronomical observations of the stars. This is the only way the true latitude and longitude location of an isolated place can be determined. Additional control could be surveyed from these primary points for laying a projection and fixing island features. As you remember any graticule is only a network of lines referred to some origin.

Astronomical positions are derived from the celestial sphere that encompasses the earth. Because the earth is such a tiny entity among the heavenly galaxy, notation of the position of a given star is not affected by the location of an observer on the earth. Earth latitude is the declination of a selected star from the zenith of an observer. (The point directly over the head of an observer is his ZENITH). The angle formed between the Zenith and the location of a star down toward the horizon is the DECLINATION. Such declination determination of earth latitude coordinates is not too complicated and is very accurate when careful observations are made.

The longitude of an observer corresponds to the Greenwich Hour Angle of a selected star. In nontechnical terms, this is the exact spot occupied by a star at a given instant of time. To obtain such a star reading, a good telescope[1] is leveled in a true north-south line and sighted at the declination where a selected star is known to appear. Celestial positions of selected stars can be obtained from any reliable star almanac. As the star moves into the field of vision, it is located in reference to vertical lines on the telescope lens. The instant that the star passes the meridian (central line), the observer stops a watch that has been synchronized to some accurate timing device. This time is converted to sideral (star) time to identify the meridian of the observer.

Accurate longitude determination is subject to many variables. One crucial variable in any of these observations is how the time is obtained. Rough time approximations are possible with an accurate pocket watch. More accurate calculations are

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[1]An astrolabe may be used instead of a telescope for such observations. Since this instrument is built at a fixed angle, appropriate stars must be picked up at this angle.

based on chronometers. Even chronometers, however, are subject to error, both human and mechanical. Many explorers have found themselves without accurate timing devices because somebody forgot to "wind the clock" or some accident injured its mechanism. Introduction of wireless receivers and radios have eliminated the former and lessened the latter chronometer hazard since the radio technician can usually repair a damaged set.

Sound impulses sent out by key observatories are picked up by radio to obtain the correct time. These observatories relay tone beats synchronized to Greenwich Standard Time. An observer using these beats must know the rhythmic variation in intensity to interpret the correct time from these tones. Otherwise, he will be thrown off by incorrect notation of seconds that will lead to false positioning of longitude.

The seriousness of time notation accuracy is revealed in the few following words. Remember that the earth rotates on its axis at the rate of 15 degrees each hour. Using 69 miles as the approximate distance of 1 degree of longitude on the Equator, fifteen degrees equal 1035 miles; divided by 60 is 17.2 miles a minute or about 1584 feet a second. An error of one second, therefore, would mean that a longitude point would be falsely located in the neighborhood of a third of a mile west of its true position.

With the latitude-longitude coordinates of a given point and true north established as correctly as possible, this spot becomes a point of reference from which other control points can be measured without astronomical observations.

Datum Points and Datum Plane

Datum Point

Before any definitive surveying can be done covering an extensive area, two critical factors have to be decided. One factor is the DATUM POINT which is the origin for further comprehensive linear measurements and the other is the DATUM PLANE which establishes the base level for determining elevation.

Finding a true datum point is difficult. Leveling of the instruments for stellar observations is done by means of a plumb bob. The plumb bob is supposed to point directly toward the center of the earth. In most places, it doesn't do this because the bob is influenced by earth masses such as mountains so that it actually "leans" toward the pulling force. Although this pull is known to exist, there is no known way to calculate its force and so correct the error. The only thing that can be done is to take a mean which is the station (point) that seems to be least affected by disturbing influence. Meades Ranch, Osborne County, Kansas was selected as this mean for the whole North American Continent. A bronze disk oriented over this spot on the ranch of Mr. Meade is the origin of latitude-longitude determination. This point is called North American Datum of 1927 and its coordinates are $39^{\circ}13'26.686''$N - $98^{\circ}32'30.506''$W referred to Greenwich meridian.

Mean Sea Level or Datum Plane

Equally difficult to determine is a datum plane. All datum plane research is complicated by the ever changing nature of the accepted origin. Tides vary: coast lines emerge and submerge due to internal and external forces; water levels change. Researchers disagree as to the placement of the statistical mean among these variables.

"The mean level of the sea is one of those things that art must smooth over, since science gives conflicting answers. Regional and national cartographers generally fix the mean level for their own areas and often mark it with a brass plate on a rock, but the findings are not absolute. This is because the oceans seek but do not find their own level.

A result of this is that there have been some controversies over the heights of such peaks as Mount Everest. The figure depends, on where the measurer thinks sea level would be under Mount Everest if a sea were there.

The usual solution is that geographers agree on a certain figure that they believe to be accurate within fifty feet. If somebody comes along with another figure, they generally ignore it because it would mean changing all the mountains in the neighborhood without achieving any greater accuracy.

The case of the Frenchman's map not jibing with the Englishman's caused a practical difficulty in World War II when English and German cannons dueled across the Straits of Dover. National discrepancies gave the gunners an unwanted choice of target fixes because they never reached an agreement on whose maps to use."[1]

Some of this confusion is resolved by the Coast and Geodetic

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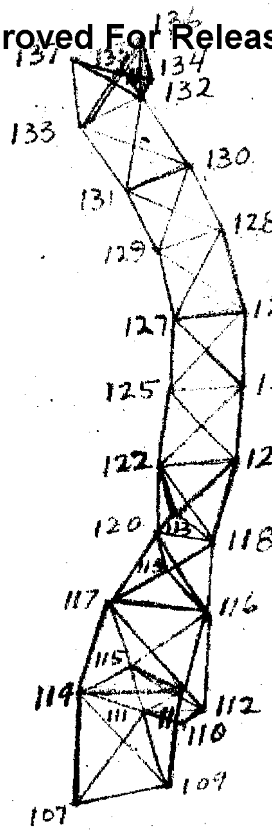
[1]Abstracted from interview of David Bickmore, Chief Cartographer of the Clarendon Press at Oxford, appearing in The New York Times, March 16, 1952

Survey in the United States. Scientists in this agency decide what mean sea level is to be and mapping or surveying agencies conform to this standard. The presently accepted base for North America is the 1929 Revision of the 1927 Datum, Mean Sea Level.

Horizontal Control

Two types of control are established from the datum point and datum plane. The first is horizontal control. HORIZONTAL CONTROL are points from which horizontal distances and azimuths are measured in linear units discounting elevations on the earth's surface. Such points are derived by TRIANGULATION which is a method of establishing control stations by means of a set of mutually connected triangles. At least one side of the first triangle in a triangulation system is measured to establish the "base line" or "base". An object is sighted from one end of this base which will produce a triangle when lines are run from each end of the base to the object. Each angle or azimuth is carefully measured several times and checked by adding the three angles of a triangle to see if their sum is 180 degrees. Another object is sighted and angle measurements are repeated for another roughly equilateral triangle whose base is the same as one leg of the previously determined triangle. The process is repeated until all triangles of a system are completed by setting up stations at each triangle point.

The lengths of remaining sides are obtained by computation of the successive triangles which are treated as plane triangles and corrected if necessary, in terms of spherical considerations. It is customary to actually measure the length of a leg of a



TRIANGULATION NETWORK

Portion of triangulation net along 30°E.

(") Identifies measured base line.

Triangulation stations established at numbered points.

FIGURE 131

triangle every hundred miles and/or at the end of the desired network. Small errors can be corrected in this way by adjusting the angles and lines between measured bases.

Measuring Horizontal Distances With Tapes

Horizontal distances are measured on the earth's surface by using a graduated chain or tape. In the United States, civil engineers use a foot as the unit of measurement and fractions of it are expressed decimally. The length of tapes is checked by the Bureau of Standards to maintain uniform Accuracy. The standard engineers' tape is 100, 200, or 300 feet or 50 meters. It is called the "Engineers Chain" to distinguish it from the 66 foot or 100 link, Gunter Chain of special value in surveying acreage. (Ten square chains = 1 acre)

The same basic technique is used for measuring one unit of length that is used for measuring property and running additional intermediate surveys for mapping and so is reviewed at this point. A base line to be chained is frequently marked out first with range poles set along it at convenient intervals for sighting. To do the chaining effectively, two persons are needed, a head and a rear chainman. One pin is set at the starting point and the head chainman walks toward the first range pole drawing out the tape until it is extended almost to its full length from the starting point where the rear chainman remains. The rear chainman then signals to him to indicate how much and in what direction the chain is out of line. Finally with such cooperation, the tape is stretched taut along the true line, and a "pin" is stuck into the ground to indicate the point 100 feet (if that length chain is being used) from the starting point. This pin becomes the next starting point and the process is repeated as many times as need be in order to cover the distance which is to be measured.

There are two methods for finding the horizontal distance between two points on a slope. Distance between them can be chained along the slope. The amount of the slope can then be measured by use of an instrument called a level, and the horizontal distance between the two points corrected to compensate for the slope. Or, the tape can be held in a horizontal position and the pin placed with the aid of a plumb "bob line" dropped from the "high" end of the tape. If the slope is steep and the second method is used, units less than 100 feet must be measured which is known as "breaking" the chain.

Triangulation Field Work

In actual triangulation field work, stations are selected at various places throughout a given area. Selection is made after careful reconnaissance of the number and distribution of stations depending upon the order of triangulation and the character of the country. In rugged terrain, stations are placed on the crests of ridges and on peaks of hills and mountains from which unobstructed views in all directions can be obtained. In flat country, it is necessary to erect tall towers to overcome the loss of visibility due to curvature of the earth or obstacles such as vegetation and buildings. These towers are really a tower within a tower. The inner one is for the instruments, and the outer one for the technicians. Double towers help to lessen vibration of the precisely-set instruments. As an added precaution most work is done at night when the atmosphere is more stable because it, too, has an effect on the instruments. Lights or flares are used for nightwork to identify the points under consideration.

Orders of Triangulation

There are four orders of triangulation. The basis for classification is the degree of accuracy with which the length and azimuths of lines are defined. First order triangulation requires that all triangles must close within 1 second of error and lengths must agree to earth measurement within 1 foot in 25000 feet or roughly 4½ miles. Second order permits 3 seconds and 1 foot in 10,000 feet. Third order permits 5 seconds and 1 foot in 5000 feet or roughly 1 mile. Fourth order allows more than 5 seconds and less than 1 foot in 5000 feet. First order exactness requires geodetic adjustments to conform to the curvature of the earth which is not necessary for 3rd and 4th order.

The bulk of control work of the first and second order is done by the United States Coast and Geodetic Survey for this country. A first order triangulation, Figure 131 has been extended over the United States, adjusted to Meades Ranch and 1929 Mean Sea Level Datum. Other orders are utilized in breaking down the longer lines of the main control system and in increasing the density of fixed points which need to be located for various purposes. To be effective, all mapping should be based upon triangulations derived from first order nets but not necessarily of that order themselves.

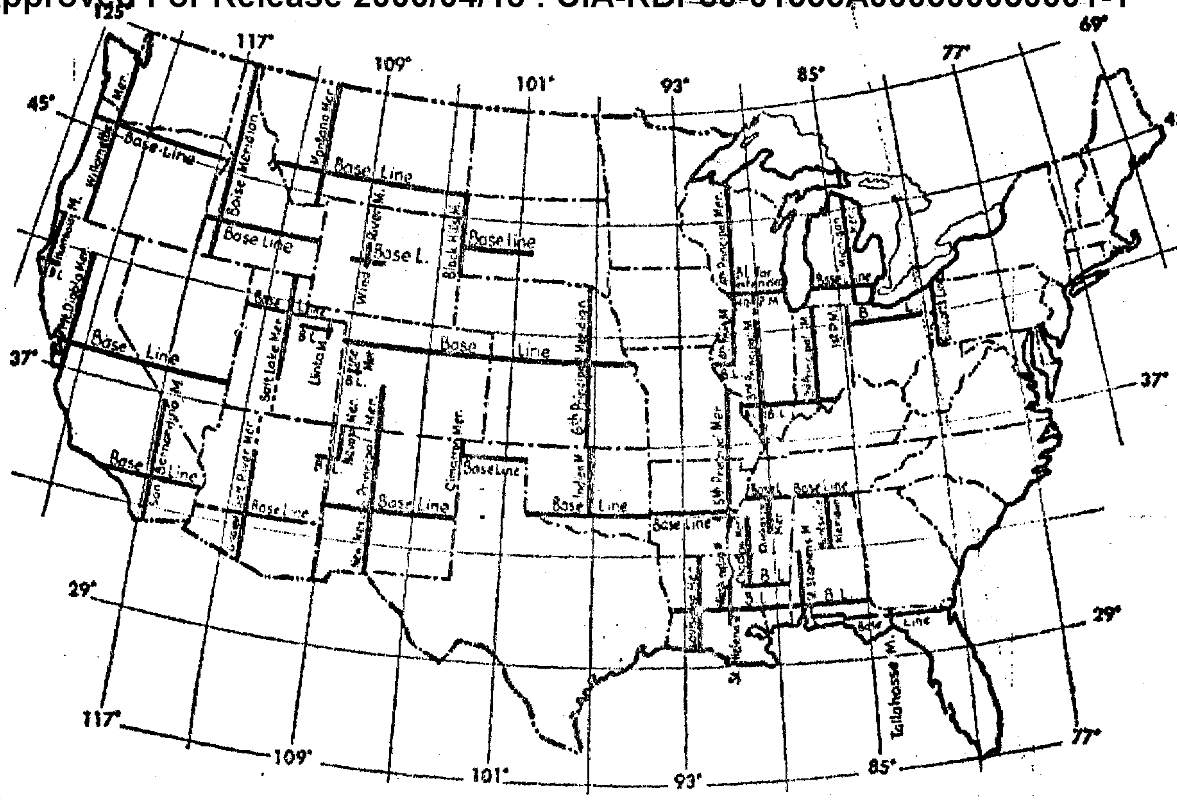
Basic techniques for determining points and surveying property were used at an early date for the Public Land System of the United States which preceded an adequate triangulation net. The discrepancies that were revealed in attempting to connect these earlier surveys have given rise in recent times to a State Coordinate System in many states. Since either or both of these systems may be found on large scale maps of the United States, you should be familiar with both of them.

Public Land Survey System

Evolution of the Systems - Public Land Survey is a rectangular surveying system by which public land is divided. This system does not apply to states falling within the area of the thirteen original states, nor does it apply to Tennessee, Kentucky and Texas. In these areas, either private appropriation of land or the method of its annexation made any useful public land survey hopeless. Fig. 135.

It should further be noted that surveys are not completed

GENERAL LAND-OFFICE MAP



Principal Meridians and Base Lines of the great public-land surveys.

FIGURE 135

in all the "public land" states and are not necessarily continuous throughout any given area.

The first law governing public land surveys was enacted in 1785 and provided for the partitioning of public land north of the Ohio River. The original intent was to establish townships exactly 6 miles square with each to be divided into 36 sections. Each section was to be exactly 1 mile square. Since no allowances were made for the curvature of the earth, numerous complexities resulted. The present day system consequently is based upon a grid of staggered control lines. It takes into account the narrowing of townships due to meridianal convergence, while at the same time providing townships as close to 6 miles square as the shape of the earth will permit. Sudden sharp turns in roads in the rectangular township pattern often identify sections where an offset is made.

Present Day System - As stated above, the unit of the system is a tract approximately 6 miles square designated as a TOWNSHIP. It is bounded on the east and west by true north-south RANGE LINES and on the north and south by east-west TOWNSHIP LINES. Each township is divided into 36 SECTIONS each of which is about 1 mile square. The limits of a section are known as SECTION LINES.

Since the east-west limits of a township are true meridians, the width of a township decreases progressively from south to north to give it a trapezoidal rather than perfectly square shape. In order to maintain townships as close to square as possible, township layouts are based on principal meridians and base lines and guide meridians and standard parallels located at fixed intervals throughout the survey area.

All surveys in a given area are referred to two primary lines: a PRINCIPAL MERIDIAN and a BASE LINE passing through an initial point. The first is a true north-south line and the other a true east-west line. These two lines constitute the axes of the system. There are 34 different systems in the U.S. and Alaska, each with a different principal meridian. Along each principal meridian, auxiliary base lines, called Standard Parallels, are drawn 24 miles apart. They are numbered with reference to the base line, such as Second Standard Parallel North or Fifth Standard Parallel South, Figure 135.

Along the base line at intervals of 24 miles east and west of the principal meridian, guide meridians are drawn due north to the next standard parallel. Thus, each guide meridian runs due north from on standard parallel to the next standard parallel, and on each of the standard parallels the next meridian is offset to correct for convergence. They are numbered with reference to the principal meridian, First Guide Meridian East or Fourth Guide Meridian West.

Map Depiction of Land Survey - Land Survey information is not specified for all maps. Such data may be useful on maps having a large enough scale to include specific detail of local features. When land survey data is included it is printed in various colors and by a variety of techniques. Marginal ticks, no matter what their color may be, can be identified by the Large T, denoting Township, followed by a number and either N or S. Those appear in the right and left margins. The top and bottom margins are used to show Ranges which are identified by R, and a number followed by either W. or E.

On the Anderson Island Sheet 1478 II NW, all Land Survey data is printed in red. In the right and left margins, you will find T 19 N and T 20 N. These denote that the areas adjacent to the numbers are the nineteenth and twentieth tiers of Townships north of the Base Line which is in the state of Oregon. East-west Range divisions are based upon the Willamette Principal Meridian. This is drawn as a solid red (reliable) line on the map. Range 1 west (RIW) and Range 1 east (RIE) are identified in the top and bottom margins. Section divisions of a township are given by red numbers and the points of origin for them by red lines (199224 is the grid location of one of these). Sections are numbered from 1 to 36 beginning at the northeast corner of each township and going across it from side to side in continuous serpentine progression, thus:

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

State Plane Coordinate System - The State Plane Coordinate System is the solution devised by Dr. Oscar Adams of U.S.G.S. to the problem of supplying control for locating and surveying property lines and other civil projects within the various states. Thousands of separate surveys and local maps have been prepared on the basis of local landmarks. Even state boundaries have been laid out in this fashion and have led to interstate conflicts. Dr. Adams organized a rectangular coordinate system to eliminate the confusion. Sufficient control points are provided in this system so that any local project can be tied into these points by plane survey methods without geodetic adjustment. Measurements are given in feet to fit the usual U.S. surveying units.

North Carolina asked for the system and was the first to adopt it in the early 1930's. Other states have followed suit so that there is now nearly nation-wide acceptance.

The choice of projection upon which the State Coordinate System is based depends upon the geographic shape of the state. States and localities whose greater dimension is from east to west, such as North Carolina, Tennessee and, Long Island, New York, are developed on the Lambert Conformal Conic Projection. Those with a greater north-south extent, such as New Jersey and California, are developed on the secant Transverse Mercator Projection. Some states, such as Michigan, that are wide in either dimension, are based on zones of the Transverse Mercator. Tables are published for both projections for the conversion of coordinates to latitude and longitude or the reverse, to facilitate adaptation of any state to the system.

References to state coordinates are found on the recent editions of many large scale maps. Dotted ticks along the neat line indicate the position of these coordinates in terms of a state 10,000 foot grid. An example of these dotted ticks appear on Porter, Indiana, U.S. Topographic Quadrangle.

Vertical Control

Relationship of Vertical to Horizontal Control

Triangulation nets and plane surveying provide the control for locating geographic coordinates and for measuring plane distances on any earth or map surface. Surveyors and topographic engineers must contribute a second type of control, however, before any real interpretation of the actual terrain is possible. This type control completes the data needed for adding the third dimension to earth forms. Horizontal control supply the "where" and "how big" and vertical control add "how high". Obviously, the "where" must be established first so that an earth feature can be pin pointed in its proper location. After the spot is located, then we want to know something about its physical form which depends in part on how high it is. VERTICAL CONTROL which does this is a point whose location is determined and exact elevation measured.

Any measuring must begin from somewhere and any relative measuring must be done from a common somewhere. Even though the ocean is far from a high mountain in Colorado, we can appreciate the height of the mountain only by comparing it with an ocean tideland flat. Abstract elevations in themselves are impossible to visualize because the human mind comprehends only by comparison. The measurement of all vertical control, therefore, should logically begin at or be on an extension from a common base, Mean Sea Level.

Points are measured progressively inland from the ocean Mean Sea Level to complete a network of vertical control that coincides with points of the horizontal triangulation net. Topographic surveying may then be carried out to increase the density of control. Such subsequent surveying is done for the purpose of determining more or less precisely the elevation of selected points within an area, given some point or points of known elevation. This is accomplished by a process called LEVELING.

Leveling - There are several methods of leveling, and as in triangulation, there are, also, orders of leveling differentiated in terms of the degree of accuracy of the results obtained.

(1) In Differential or Spirit Leveling the difference between the elevation of given points is obtained from direct readings on a graduated rod. An instrument called a "level" which consists essentially of a telescope with an attached Spirit level parallel to the telescope tube or line of sight is used in

the process. The telescope tube can be adjusted in a vertical plane, and also, when adjusted so that the bubble is in the center of the tube in the spirit level, in a horizontal plane. In the better types of levels, a tripod supports the telescope. When the level is properly set up, the telescope tube (and therefore the line of sight) can be revolved in a horizontal plane.

The level is placed at a point (to be referred to as A) which is 50 or so yards, for example, from a vertical control point visible from A. The elevation of that control point has already been established. (The control point will be referred to as C.)

With the level properly set up at A, the next step is to determine the elevation of its horizontal plane of sight. In order to do so, a graduated rod is held by a rodman on the vertical control point C so that zero on the rod is at a known elevation. Assume that the known elevation of point C is 255 feet. The levelman at A can tell, as he sights the rod at C through the telescope, when it is in line with his vertical wire and so signals the rodman what adjustments are needed to bring the rod to a vertical position. The levelman can then see through the telescope that his horizontal line of sight cuts the vertical rod at 4 feet, for example, above the control point. The elevation of his line of sight, therefore, is 255 plus 4, or 259 feet. (Figure 142)

The rodman then moves to another point of unknown elevation (to be referred to as B) which is about as far from the levelman at A as C is from A, but in the opposite direction.

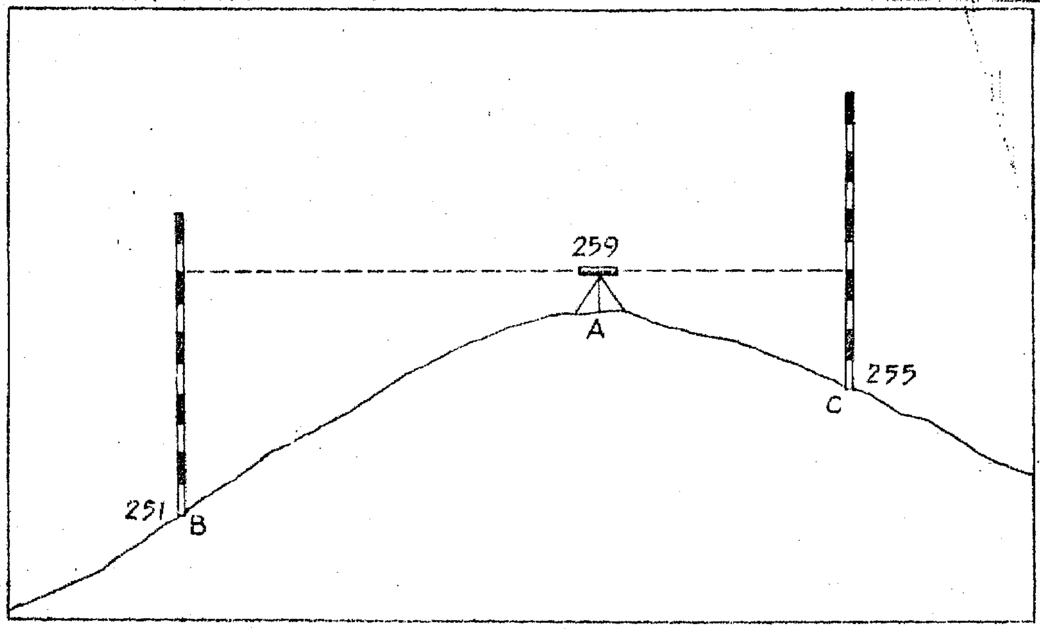


FIGURE 142

The levelman at A now sights the rod held upright over B. His line of sight (which he now knows has an elevation of 259 feet) cuts the rod held at B at the 8 foot mark. The elevation of B, therefore is 251 feet (259-8). Point B is now a point of known elevation which can be marked and used in determining the elevation of other points. Going to D, for example, the levelman would read the rod held over B to find the elevation of his new line of sight, and then would read the rod held above a point of unknown elevation E. The elevation of his line of sight plus or minus the rod reading at E would be the elevation of E, and so on.

(2) A variation of differential leveling is called "Profile Leveling". This procedure differs chiefly in that the points whose elevations are to be determined, are so selected that all elevations and depressions along a given line are measured. A profile can then be drawn showing all elevations and depressions as they would be seen from the side of a vertical cut or slice

made along that line.

(3) In "Trigonometric Leveling" a transit or theodolite is used to measure vertical angles. An object or point is sighted which is along a horizontal line from the eye of the observer. Another object or point which is in the same vertical plane but above or below the first object is sighted. The vertical angle between the horizontal line and the line to the second point is read. With the elevation and length of the horizontal line known (length can be determined by chaining or by stadia) the elevation of the second point can be computed by the use of trigonometric formulae.

(4) In "Barometric Leveling" differences in elevation are estimated from differences in barometric pressure. Atmospheric pressure changes with variations in elevation. Results achieved through barometric readings are difficult to check at a later date since local pressure readings vary rapidly in response to atmospheric changes accompanying cyclonic activity.

Orders of Leveling - The allowable errors of closure in feet for the orders of leveling may seem extremely small to anyone accustomed to measuring with a yardstick and are really amazing in view of the distance covered. First order leveling requires 0.017 times the square root of the length in miles. Second order changes the multiplier to 0.035; third order to 0.050, and fourth order to greater than 0.050 times the square root of the length in miles. Spirit leveling can be used for the first three; trigonometric is adequate for second and third order, and barometric is accurate enough for fourth order only.

Markers for Control Points

Horizontal Control

Permanent station marks of either first, second, or third order triangulation are usually marked by tablets of non-corrodible metal set firmly in posts of concrete, in large boulders, or in outcropping bedrock. Where a station is on a building, suitable markers such as a tablet set in place by means of cement, sulfur, or lead may be used. On the metal tablet is inscribed triangulation station data established by the Coast and Geodetic Survey, for example, "U.S. Coast and Geodetic Survey Triangulation Station. For information, write to the Director, Washington, D.C. $250 fine or imprisonment for disturbing this mark". The name given the station should be stamped on the tablet. At the center of each tablet is a triangle. Such markers are called Monuments.

In cultivated land the marker is normally set below the depth to which the land is plowed. In such cases, measurements of distances to readily-identifiable, nearby surface objects are recorded. Persons seeking to recover the marker at a later date are aided by these records, if no one has cut down the old pine tree, or moved the barn.

Vertical Control

Monuments marking points of vertical control are called "Bench Marks". Since a terrace is sometimes called a bench, the term "bench" was adopted to indicate a definite level, step or platform. A bench mark, then, is a mark showing the altitude or elevation of a given place above sea level. The chief difference between a bench mark and a monument set up to show the location

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of horizontal control points is the inscription on the tablet. The inscription may read, for example, "U.S. Geological Survey B.M. Elevation above sea level 1640 feet. $250 fine for disturbing this Mark". There is a triangle at the center of the tablet. Elevations determined by leveling of lower than third-order commonly are not marked by standard bench mark monuments in the field but their location is recorded in appropriate notes. Some monuments, as earlier stated, may be both bench marks and markers of horizontal control points.

The map symbol for a bench mark is a small X followed by letters B M or P B M (permanent or precise) and the elevation of the mark. The letters B M following the dot and triangle symbol for horizontal control indicates that monument serves for both horizontal and vertical control. Other bench marks marked in the field are shown on the map as an X followed by the elevation. Spot elevations, usually such prominent features as cross roads or peaks, are indicated by elevation number only.

The preceeding synopsis of methods for establishing control should reveal the contributions of other professions to cartography. When you see a Bench Mark or triangulation marker on the land or its symbol on a map, you may now better appreciate all the work it implies. The sign should, also, prompt you to seek information concerning the accuracy and adequacy of such work. Anyone can draw a bench mark symbol but, "where did you get your information" may be and embarrassing question.

Symbolization of Earth Patterns

Topographic Patterns

The foundation and framework of a map have been inspected.

The next step in analyzing components of a map is to find out how earth features are developed on the framework by symbolization.

Such cultural detail as buildings, city symbols, roads, telegraph poles, etc., are applied to a map by symbols placed in reference to horizontal control points only. Mapping done in this manner is called PLANIMETRIC. A plane is a flat surface and metric means measuring. Thus applied to mapping, planimetric means showing the horizontal relationship of symbols and does not involve elevations. If a line represents a stream without reference to how high above sea level it is or its relationship to the surrounding terrain, the river "line" is planimetric. Although such symbolization is valuable its usefulness is enhanced by the addition of topography.

The rough character of the surface of the earth is visible nearly everywhere. There are few places where this surface is perfectly level or flat. RELIEF, the difference in height between the lowest and highest spots in a given area, creates contrasts in most areas. Even where the general landform classification is level Coastal Plain, gently rolling topography provides considerable relief. A variety of landforms and differences in relief can usually be seen by taking a short field trip in any area. It is strongly recommended that you take such a trip, if possible, for the specific purpose of studying the changes in terrain and of trying to visualize how you would show such changes on a flat map sheet.

Topographic relief also affects the way the land is used. Types of such utilization range from farmers tilling their fields, through construction of passable grades on roads to the placement of structures in conformance to or definance of slopes. In hilly country the transportation and communication problems are critical in either peace and war-time planning. You have only to recall the traffic tangles created by small hills, when snow and ice or rain collects on them, to appreciate one problem of transportation adjustment to hills. Steeper hills present additional construction problems. Where slopes are steep, the number of turns and curves must be increased in roads to be used for other than donkey travel.

Defensable and assaultable positions are important in warfare. Heartbreak Hill, Iwo Jima and Vimy Ridge are names reminiscent of the relationship of rugged topography to the fortunes of war.

Visiting an area and checking specific features against their symbolization on a map would seem to substantiate the old adage "Seeing is believing". Like all generalizations, however, it has its weaknesses. One weakness lies in the fact that ground views may not reveal relationships among surface formations. Furthermore, a large amount of study and planning is done by people who cannot visit the area on which they are working. These folks must rely upon maps, photographs and other source material to reveal a mental picture of the region.

How can a flat map aid them in understanding a variety of topography? Cartographers have offered several solutions to this difficult question. One of these is the application of contour lines. A CONTOUR is an imaginary or arbitrary line drawn through points of equal elevation. Imaginary is a very unsatisfactory adjective since a contour is no more imaginary than a property line or boundary. Actually, there is more justification for its reality than for either of these. Good examples of contour lines can actually be seen in nature. A coastline is a rough contour although it may not be the 0 contour, which is MEAN SEA LEVEL, of the land. Often the edge of a flat plateau is of uniform elevation. Lake terraces formed during the recession of once greater glacial lakes are other clear-cut evidences of contours. Because water will seek its own level, it will leave successive water marks (contours) of nearly equal elevation as it recedes. These water levels are clearly visible in the Salt Lake Area, for example, and are a tourist attraction to the area.

Certainly a contour is not an imaginary line to the model maker who uses it to construct a relief model. He piles up sheets of cardboard, plyboard or plastic LAMINA. The thickness of each sheet is equal to the interval between contours that he has selected for the scale of his model. The total thickness of the pile is equivalent to the difference in relief of the area upon which he is working. Then, by cutting along the outline of each contour, he achieves a stepped model. Because shapes are normally not angular in nature, he smooths off the steps to emulate the rounded character of terrain slopes.

Three major stages in the preparation of a model will help you to visualize and understand the character of contours. A special training aid showing these steps, therefore, has been prepared for this purpose. Normally the "step-cut" stage, the middle section of this aid, is not formed in plastic. It is the product of cutting along contour lines and must be smoothed off. Fig. 149. The smoothed model is then cast in plaster to create

MODELING TECHNIQUES

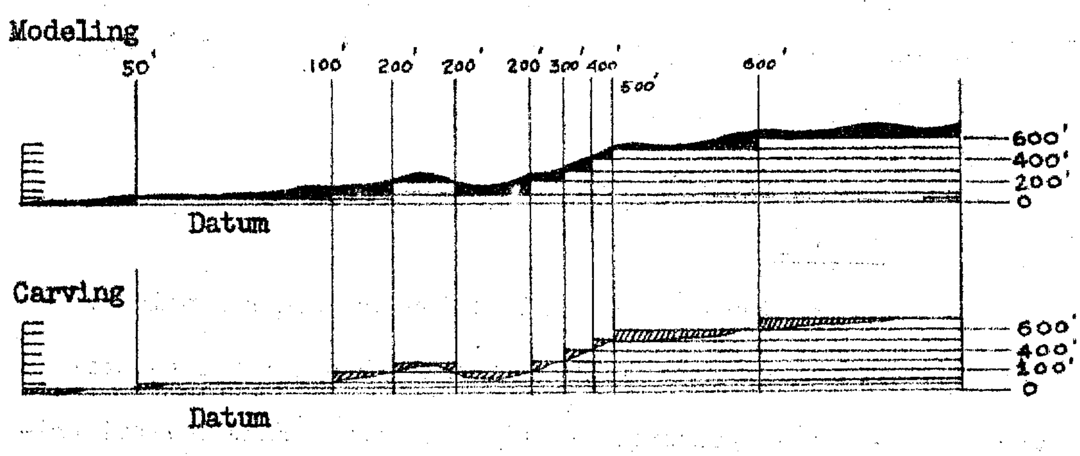

ILLUSTRATION OF THE DIFFERENCE BETWEEN BUILDING UP (MODELING) AND CUTTING DOWN (CARVING) STEP-CUT MODELS

FIGURE 149

a mold from which the final product is derived through a heated, vacuum-press process. At this point we are not concerned with the process but rather with the product as shown on the Training Model (100549) cast for the first time in this form by AMS to illustrate the above steps.

The left third of this Training Model contains a portion of an hypothetical topographic map sheet. Representation of an actual earth area was not attempted because of the difficulty in finding a single sheet covering all the different contour variations desired. Hence it will be pointless for you to try to orient the sheet to its earth counterpart in terms of geographic coordinates as you would normally do in analyzing a map. The assumed geographic coordinates of the models would place the area in the Atlantic Ocean off the coast of Connecticut where it would take a deep-sea diver to find it! You can use the military grid coordinates, however, for locating items to be discussed. Use the Read-Right-Up technique on the grid coordinates referring you to specific examples.

Contour Analyses from Training Model

Control

The origins for contour delineation are control points. These points of known elevation determine contour values drawn through them or in measured relation to them. Find several triangulation points and spot elevations on the flat map section of the Training Model. By reading these values decide where the highest elevations lie.

It is hard for the beginner to visualize the intervening terrain from these points, so turn to the middle model to build up a contour concept that will enable you to "see" the purpose of the brown contour lines on the flat model.

Topographic surveys are fun from high order triangulation points to establish the elevation of additional control needed in the placement of contour lines. If these contours were laid out on the ground a person walking along one of them would go neither uphill nor downhill but would remain on a level parallel to the DATUM PLANE. The graphic presentation of contours on the "step-cut" model reveals this fact. Each contour looks like a little terrace which you can follow easily.

Contour Interval

By viewing the middle model from the side, you can see that each "terrace" is the same interval apart above or below its neighbor. Thus each contour interval represents the same vertical amount on any given map unless a specidic statement to the contrary is made. (This sometimes happens on maps where a decided change from relatively flat to steeper terrain gradient occurs).

Any contour interval is selected on the basis of:

1. the amount and character of relief between the highest and lowest elevation in the area to be mapped and,
2. the scale of the map to be developed.

If an area is flat and the map scale is large a small interval such as 5 feet is selected to make possible the showing of slight differences in elevation. If the area is very hilly or mountainous, a large interval is chosen. Scale always affects the decision. Smaller interval values are more feasible on large scale than on small scale maps. The contour interval of the Training Models is 100 feet. On the raised models, however, a vertical exaggeration was deliberately introduced to emphasize contour relationships. VERTICAL EXAGGERATION simply means that the vertical distance used for each step is made wider than its true distance. The relief expression should be a 1:1 ratio of the map scale. On the model, exaggeration is 2:1.

Contour lines are strengthened for every fifth contour on the "litho". (Let's use the shop term "litho" to refer to any flat map sheet which has been lithographed). These are called

INDEX CONTOURS and are drawn with a heavier gauge line to serve as handy reference in determining contour values. In some cases they are too widely spaced to define the "shape" of a landform. Trace one or two of these index contours with your finger on the "step-cut" to fix their distribution and definitiveness or lack of it.

INTERMEDIATE CONTOURS equal in value to multiples of the contour interval are drawn by finer gauge lines. These fill in detail of the landform shape except in sections of the map where relief cannot adequately be shown by the selected contour interval. The river valleys on the training model are examples of how the character of the terrain would be lost in using only 100 foot intervals. In such situations AUXILIARY or SUPPLEMENTAL CONTOURS are interpolated to supply the refinement necessary to give character to what might overwise be misinterpreted as a featureless plain.

Find the 50 and 150 foot auxiliary contours on the litho. The 150 foot contour was drawn only along the area where it was necessary to indicate sloping land and not a bench or terrace. The incompleteness of this auxiliary contour should not be interpreted to mean that a contour begins or ends in the middle of an area. Such application of contours may be termed cartographic license that is permissible in only a very few cases where clarification landform configuration is necessary.

<u>Continuity of Contours</u>

Since each contour denotes a given elevation plane above MEAN SEA LEVEL, each is a continuous, closed curve. Do not be fooled by the fact that an individual sheet may not be large enough to include the entire closed curve. If enough sheets are pieced together, the curve will close. Even on an individual sheet you can often note the tendency of the curve in that direction as you can see along the north and upper east neat lines of the models. Whenever only a part of the contour curve falls on one sheet, the line representing it must begin at a neat line and continue to a neat line. It can no more stop short in midair than an aviator can skip several feet in ascending from an airfield.

For the same reason, contours never cross or compress into one line. Some may have to be drawn as a single line in the rare case of an overhanging or vertical cliff (not shown on model). This inaccuracy merely reflects the inadequacy in depicting three-dimensional situations on two-dimensional paper.

Summits and Depressions

Wherever contours close the inclosure represents either a summit or a depression. Summits can often be spotted on a map by a number which is not an exact multiple of the contour interval such as the one at 819741. Normal declivities such as the sides of valleys and ravines are revealed through the progression of contour numbers. Unusual depressions are marked by contour lines containing short ticks pointing toward the center of the depression. If more than one contour interval is involved in a depression, its total depth is obtained by subtracting the stated unit for each interval shown. Find C on the models. How deep is this depression? Sometimes even a small depression of less than one contour interval in depth is significant in the local topography. This condition is shown by a finer line ticked toward the center as at 848726.

Geologic forces often create saddles in ridges. The "horns" of the saddle are formed by small tops or summits like those at D. Find similar saddles elsewhere.

The summits of landforms are sometimes neither ridges nor tops. They are, instead, elongated and flattened into table-like plains. If this plain is small it is called a butte or mesa and is similar to the area at E. Larger versions of this condition are called plateaus.

Flat areas may also be found along slopes as well as at their summits. These "benches" or "terraces" are shown on topographic maps by a wide space between two contours on a slope and may be further defined by a cliff symbol along the contour to indicate an abrupt, not gradual, rise to the next contour. (Not shown on model. See symbol sheet for topographic maps to identify cliff symbol.)

Slope Interpretation of Contours

Each contour interval represents the same amount of difference in elevation but it does not necessarily follow that all contours are evenly spaced. Place the model vertically before you and study the unevenness of spacing thus revealed. Spacing between contours is indicative of the amount and character of the slope occuring between and among them. Wherever contours are closely spaced, the slope is steep. Such a steep slope occurs just to the south of F as you can see on the raised models. Conversely when

Illustration of Uniform Slope

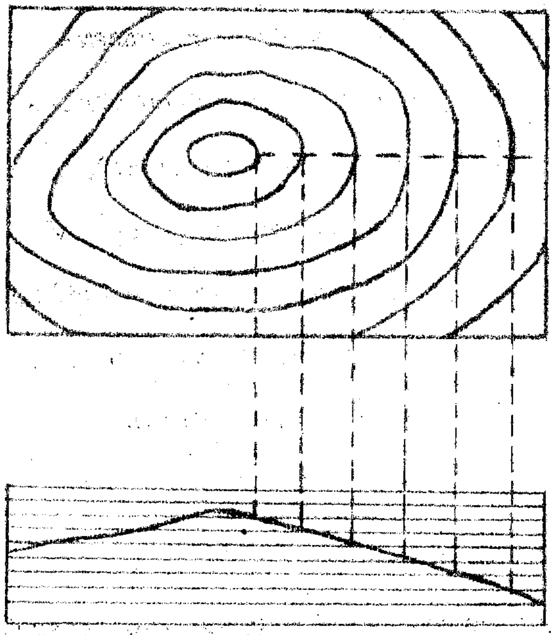

FIGURE 155A

contours are widely spaced, the slope is gentle as on the south-central portion of the model.

Not only are slopes classified as gentle or steep they are also distinguished by their surface shape. Some slopes rise or decrease at a uniform grade Contour depiction of a uniform slope and a generalized profile line are shown graphically on Fig. 155A and at O on the model.

Illustration of Convex Slope

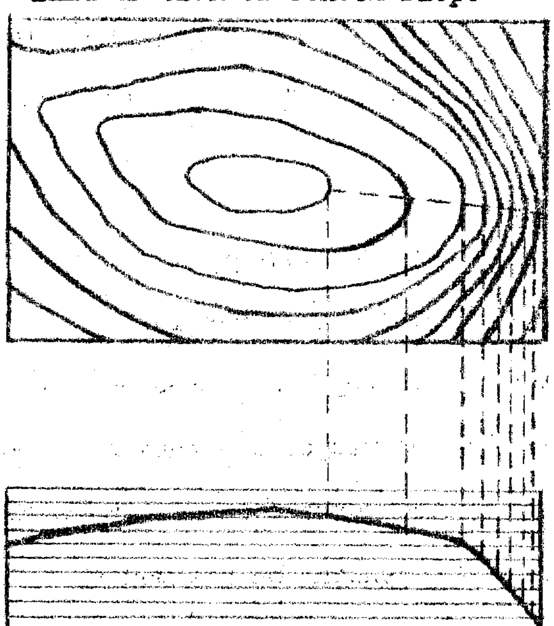

FIGURE 155B

Another type of slope is convex in appearance when viewed in profile. Convex slopes have contours widely spaced near the top and close together near the bottom of the slope, Fig. 155B. Study M and its counterpart on the raised models.

Illustration of Concave Slope

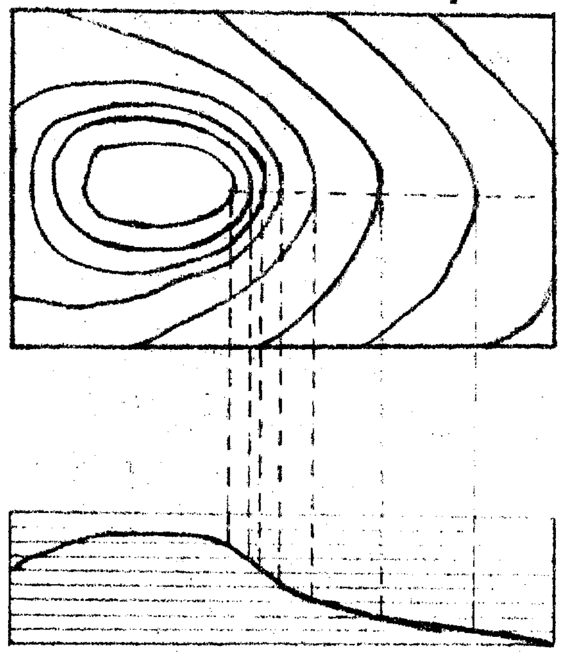

FIGURE 156

Some slopes have a "pushed-in" or concave appearance. Such slopes have contours closely spaced near the top and far apart near the bottom as shown on Fig. 156 and at N on the models.

Notice on all the illustrations and on the litho the general trend of each contour tends to resemble that of its neighbors. Each follows a roughly parallel course along similar landform slopes and bends with a fair degree of uniformity except in some highly dissected or geologically disturbed areas. Study the litho to appreciate this resemblance and see it dramatized on the step-cut.

Contour Response to Ridges and Valleys

Since contour lines are merely symbolized impressions of topographic variation it is logical that they should respond to the influences of resistant rocks forming ridges and running water forming valleys. In crossing valleys, contours form a V by running up one side, turning at the stream, and running back along the other side of the valley. Contours, therefore, reveal the direction

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of stream flow since the point of the V always points upstream, Fig. 157. The contour near the source of a stream shows the

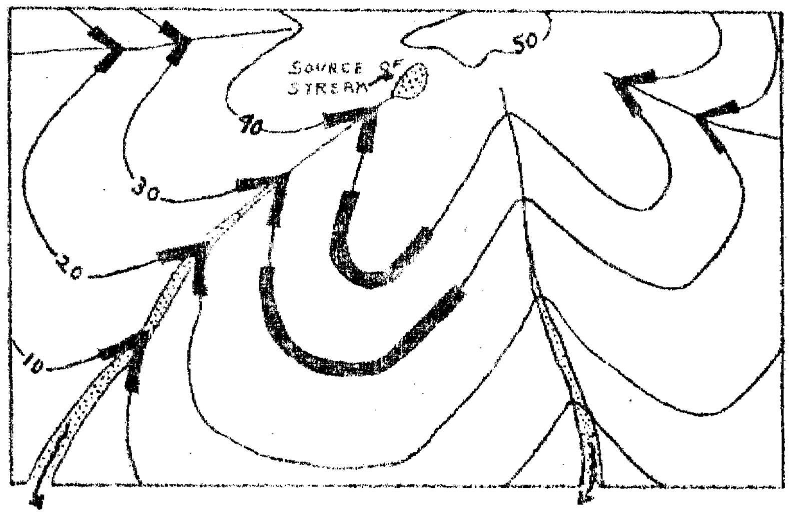

FIGURE 157

tendency of forming a V but is less clearly defined than the ones below it in elevation, as you can see at L, on the model.

The logic of such trends is apparent when you realize that streams must cut beds in which to flow. There must be some gradient, no matter how slight, along which gravity is pulling the water toward a base level. Cutting of the water into a slope causes the bed of the stream to be lower than its banks. Contours must, therefore, be bent upstream to find that lower elevation in the streambed.

The larger the stream, the flatter tends to be their slope as shown on the model. Larger streams are usually older streams approaching base level and so have wider, flatter valleys. As the valleys are broadened and covered with water-borne (fluvial) deposits less resistence is offered to the water in flood time and consequently the stream will find many channels and become braided (I) or leave remnants cut off from the master stream as crescents or oxbows (just north of F). A tired, old stream wanders through the countryside instead of heading straight for the ocean. As it meanders, it will follow a course like that shown up-and downstream from J. Because gradient is slight, contours crossing such valleys are widely spaced and more U shaped (877683) than those in their younger tributaries racing down steeper slopes in V shaped valleys (near L). Flood waters may stagnate in swampy lowlands where the soil is water retentive and gradient is insufficient to force them to run downslope (F).

Ridge or interstream patterns are shown by U shaped contours with the oval of the U pointing downhill, Fig. 157. The intensity of the oval is dependent upon the forces molding its shape. Study several different ridge patterns on the model.

Man-made Alterations Expressed in Contours

Nature doesn't always arrange ridges, valleys and slopes to suit man and his mechanical servants. Ridges may be too high, valleys too low and gradients too steep to be traversed or built upon. Man applies dynamite or dumps dirt and presto, the contours are changed! Man made alterations to contours are ordinarily easy to spot on a topographic map. The contour lines look as though they have been ruled off along a straight edge and turns are sharper angles than those generally following natural situations. Three examples of these unnatural contour formations were included on the Training Models. The slope at K was too steep for the railroad right-of-way, so the slope was graded to create a more practical roadbed. Contours here had to be bent uphill in the angular pattern shown. The hard-surfaced, two-lane highway (refer to marginal note) running from west to east on the litho follows the contours in general to take advantage of the uniformity of elevation along contours. In some cases where the slope is not too great it climbs over a contour but in two places special alterations were necessary to avoid steep grades or lengthy detours. A cut was made through the "top" at B. Find it on the step-cut and carved models. Instead of having the road dip down one side and up the other side of the river valley at A, filling was done in the valley to keep the road at the 500 foot elevation. Some provision was made for carrying the stream through this fill since you can see that it continues on downslope toward the larger stream. It is not dammed off as the river was at 881723 to form a lake. Note the chopped-off appearance of the contour and the fact that ticks along it point toward the downgrade as they do for a depression contour. Approximately how far above the river is the road on top of this fill?

Logical Contouring

Providing continuous control for the delineation of contours would be prohibitive in cost and of no great practical value. Even the largest scale map cannot show each quirk of a contour as it would be plotted on the earth. In actuality there is more often a dearth of control or just enough to make further mapping possible. Logical contouring is used to fill in the gaps between points by interpolation. Improper shaping of contours is often the result of illogical interpolation. The trick of good contouring is to make lines connect control points as logically as possible.

The theory of logical contouring is basically dependent upon the assumption that the slope between two points is constant; that is, the ground surface from one point to the other is assumed to be an inclined plane along which logically drawn contours would appear to be equally spaced. Obviously, then the first step in logical contouring is to plot or spot all fixed control points and note their position in relation to the master lines formed by ridges and drainage. Next, examine the drainage pattern carefully and measure off the total number of equally spaced contours between points of known control. Insert small V's along a stream places where contours cross it. Do the same thing for ridges but use a U instead of a V, (Fig. 157).

After you have ticked off all drainage V's and ridge U's join all points of equal elevation along index contours. INDEX CONTOURS are those even-numbered lines which are made heavier. As was stated previously they are usually every 5th line. After you have established the general shape of the landform by index contours, then interpolate the intermediate contours.

Check the ridge and drainage patterns after you complete their logical delineation by interpolation. Are the curves smooth? Do you have the correct number of contours? Does each contour either complete a closed curve or run from edge to edge of the map sheet? Have you included all points of equal elevation within the appropriate contour? If two slopes are adjacent have you shown identical contours for each in so far as their elevations are identical?

Visualization of Topographic Features by Profiling

Raised relief models are not always available for three dimensional visualization of topographic maps even though proper interpretation of contours is vital to many diverse undertakings. The highway or railroad construction engineer must know the character of the topography he is to traverse with a band of transportation. Steepness of slopes (gradient) determines the number of curves and switch-backs he must construct or the amount of blasting he must do to reduce gradients. He must also bear in mind that the cost of fuel needed for pulling vehicles up slope is directly proportional to the gradient. To the military tactician and soldier alike the bottom of hills or depressions provide concealment and the tops, observation posts. Intervening hills may obstruct the ally's or the enemy's view. Nature plays no favorites but she does give succor to people who know how to use her gifts and interpret her features.

One means of visualizing and interpreting topographic changes when no model is at hand is through constructing a profile. This technique produces an imaginary but extremely valuable cross section of an area along a line drawn across a map. An approximation of how a profile looks can be seen where a cut is made through a hill in order to construct a road-bed. This vertical cut reveals the amount and degree of slope along the surface, as well as, the sub-surface structure. Large profiles can serve the same dual purpose but for the person interested in surface features only a profile outline is all that is necessary.

Each side of the step-cut training model is a profile of the corresponding topography show along the neat line of the flat litho. Its smoothed-off version appears on the third model. You will have to realize that the profiles on the raised model are not vertical because of the way they are molded in a vacume press. Grading toward the margin provides more exact registration of detail than is possible on a sharp-angled profile-like margin and also makes it possible to fit adjacent models together smoothly. These over lapping marginal slopes on models are called Flow Lines.

Construction of a Profile

Select an area on a map. Although it is possible to profile along any surface feature such as a ridge, stream or road, drawing a straight line across a diversified area usually provides the most satisfactory base for a beginner.

Note the highest and lowest elevation, expressed in contours or control points along the line you have drawn.

Next choose a vertical scale for the profile to be constructed. Keeping in mind that the numberical value assigned a vertical scale is directly dependent upon the linear horizontal scale. In most cases when maps of large scale are used for profiling there is no need for exaggerating the vertical scale. Smaller and smaller scale implies more and more area to be covered in a single unit of linear scale which will require greater vertical exaggeration. When you remember that the highest known elevation is just under 30,000 feet; that most mountain peaks are under 20,000 and that most of the highly populated areas of the world are under 1,000 feet you can appreciate the reason for "blowing them up" enough vertically to be seen. If true scale were maintained, the highest mountain shown on the continental map of Asia at a scale of 1:64 miles would be less than 1/10 of an inch high. This is really making mole hills out of mountains.

It is good practice, however, to keep the amount of exaggeration as small as possible to avoid unnecessary distortion of earth features. Small hills can be made to take on the appearance of enormous jagged icicles. Profiling can be like caricaturing where a prominent feature is changed so much that nothing like it really exists. It is expedient, therefore, to figure out roughly the exaggeration accruing from the vertical scale you choose. To do this convert both scales to the same unit of measurement and divide the horizontal by the vertical equivalents. Thus on a linear scale of 1:125,000 with 1/10 inch allotted to every 500 feet the exaggeration will be:

METHOD:

Foot Conversion

Horizontal

1:125,000" + 12 = 1:10,416'

Vertical

1/10" : 500'

1" : 10X500' = 5,000'

Inch Conversion

Horizontal

1:125,000"

Vertical

1/10" : 500'

1" : 10X500' = 5,000'

1" : 12X5,000 = 60,000"

Vertical Exaggeration

Feet 10416 + 5,000 = 2.08

Inches 125,000 + 60,000 = 2.08

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After proper selection of vertical scale, assign a vertical scale number to each 1/10 inch line on squared paper beginning a couple of intervals below the lowest contour value and ascending to the highest. It may not be necessary to number each line but only enough to keep you straight as to their value.

ILLUSTRATION OF PROFILING

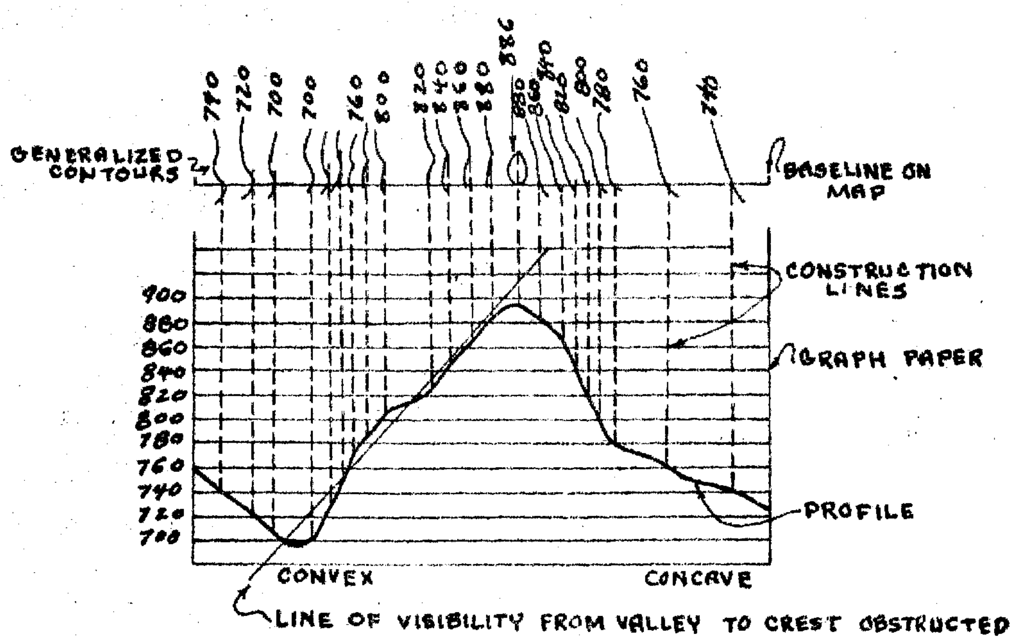

FIGURE 164

Lay this graph paper just below the profile line leaving enough room so you can read the contour values printed on the map.

Drop lines from the profile to the appropriate elevation on the graph. Be sure to keep their linear relationship correct.

After all lines are dropped to the graph, connect the points thus established by a solid line and you will have an outline of the surface profile.

Filling in the body of the profile will facilitate visualization but is not mandatory. Figure 164 illustrates this simple method for constructing a profile. The character of the slopes can be interpreted from the resulting profile. The straight diagonal line drawn along this profile shows that there are several places along the left slope which would be hidden from view at other spots. In military terminology these spots are DEFILADED.

Form Lines

Insufficient control in some parts of a map may require slightly different methods for indicating relief. The character of these spots may be shown by form lines. (Technically many contours evolved by logical interpolation are form lines but the term is normally applied to lines that have no precise elevation). The generalized shape of some prominent feature is sketched in with form lines to give an impression of what to expect in the field. Such an impression is useful because often a person, military or civilian, can identify the objective shown without having to know its exact height. It thus becomes a natural signpost rather than being an exact height for which firing range must be determined or an obstacle to be surmounted. Such form lines are shown by dashed lines on a map.

Color Interpretation of Topography

Bands of Elevation

You are familiar with hypsometric types of maps although you may never have been introduced to them by this name. How often in a classroom have you stared at a physical map of some place or other. Physical-political maps of the common classroom variety show elevation by means of color. The normal sequence of color, as you may recall if you were awake during the "staring" period, is gradation from dark blue for deep water through increasingly lighter shades of blue for shallower water. Land elevations are represented by transition through shades of green, yellow, tan and brown, to red which indicates all elevations above 10,000 feet. The same tinting with a slight variation in color values has been used on the North Borneo NB 50 sheet. Here meter equivalents are given for the altitude tints because the sheet will be used by many who are trained to measure in meters and kilometers rather than in feet and miles.

The use of different colors is intended to distinguish elevation and relief relationships among areas. Unfortunately, misinformed or poorly trained map readers are prone to erroneous interpretation of the significance of colors. To them green means vegetation or else perfectly flat land. Actually extremely rugged desert lands exist in the world which are colored green on a map because their highest elevation does not rise above the measured limits set for the green tints. By contrast, there are level plains that lie at altitudes high enough to bring them into the brown or even red tints. Land surfaces of these high plains are as nearly level as the less vigorous forces of erosion will allow. They are not covered with jagged peaks and steep canyons as some map abusers erroneously infer from the red coloring.

Shade of Color

Widespread misuse and aesthetic objection to the International Color scheme of blue through red color-banding have prompted the utilization of a variety of other color schemes. Shadings of violet through purple were long the British choice and have only recently been abandoned. Variations in green and grey tinting are used by some famous German cartographers.

The range of shading possibilities is unlimited using the air brush method. The Baltimore NJ 18-1 sheet illustrates this technique although the relief shading is partially concealed by a green vegetation overprint. A better example is the Goldfield NJ 11-8 sheet on which gray shading accentuates the western ridge pattern. Notice that all topographic shading is arbitrarily applied on the eastern and southern slopes to create the impression of ridges rising above the flat sheet. Placement of shading in this manner is dictated by optical illusion and not by shadows cast by sun position.

Air brush shading improves visualization of the shape of topographic features but, in itself, gives no key to the actual elevation and degree of relief. Sometimes just a feeling for the "look" of an area is the primary objective. At other times more precise delineation is desired. Recourse must then be made to contour lines. The two sheets cited as examples of color shading carry contours as well.

Hachure Method of Topographic Presentation

An overall impression of topography can be conveyed by a series of systematically-arranged, short lines. These short strokes, called HACHURES, create the effect of terrain slopes. Unless frequent spot heights are provided, however, it is impossible to determine elevations and relief even approximately from hachuring. For this reason, ironically, hachuring proved to be an unsatisfactory medium of topographic presentation for the very group it was designed to help. It was created for military maps to help untrained personnel visualize terrain. It is poor economy, however, to make military maps for general impressions and no further use. Artillery fire control, troop movement and strategic planning are impossible on maps that do not provide accurate means for determining the height and amount of slope in an area involved in war.

Hachuring enjoyed considerable popularity several decades ago. During the latter part of the nineteenth century the French produced a series of 1:80,000 hachured maps that were later used as the basis for other map series on different scales. The French worked out an elaborate correlation of lengths, widths and spacing of hachures to depict variations in slope gradient. Various shading and grading techniques were also used to heighten the illusion of perspective. Application of finer lines on the north and west and heavier lines on the south and east slopes created a light and shade contrast in black and white. The introduction of the contour method late in the nineteenth century and the improvement of color printing in the twentieth have now caused the abandonment of hachuring for terrain representation except on a few foreign maps. Some of the best examples of modern hachured maps have been compiled by German and Swiss cartographers. Study the 1:50,000 Wolfstein West 58 W sheet as an example.

1. Compare your ability to visualize topography on this sheet with that for a contoured sheet.
2. Find examples of: steep river embankments - a rounded hilltop - level areas (Do not misinterpret the blank area in the extreme northeast corner of the sheet as level plain or possibly sea. The International Boundary marks the <u>end</u> of German mapping. This situation will be found on many sheets where an international boundary appears.)
3. Are all hachures the same length? Are they spaced equally? Why?

4. Study the marginal notations. Apply the legend to the sheet to find as many examples as possible of legend explanations.

Color is frequently applied to modern hachured sheets to increase differentiation of terrain slopes and other physical features such as glaciers. Some series may even include contour lines as guides to elevation determination which is lacking on hachured depictions.

Hachuring is now being used less and less for several reasons. It takes a highly skilled cartographer to do a creditable job. Since it is an interpretative and impressionistic technique there is considerable variation among cartographers in applying hachuring. Finally, the finished product has limited usefulness and reliability which makes it inadequate for definitive purposes. Although there is no such thing as an all purpose map, most map users prefer contoured and shaded or tinted maps which provide greater flexibility than hachured maps for terrain interpretation.

Hydrography

In the illustrations of contour characteristics you saw that contours are affected by drainage features as well as by measured control points. In preparation for mapping, control is established for contour depiction of drainage features. In nature the process is the other way around. As water drains downslope on its way to the ocean, it erodes the landforms over, or under, which it moves. Water eats away at subsurfaces to form caves which may eventually collapse to form holes in the surface. Water scours the surface before it sinks in or finds its way to the oceans. Water wears off this surface in sheets and dumps the eroded material somewhere else as an alluvial fan, mud flat, delta or some other depositional landform. Wherever it encounters cracks and weak spots in the surface, it digs into them to gouge out gullies and canyons. Streams are formed in these depressions and their courses altered by the erosive and depositional effects of water. Lakes and swamps trap some of the water. In any of these and many other cases, terrain is affected and contours are altered. Terrain formations depicted on maps, therefore, should be evaluated in relation to hydrographic symbols and with the knowledge in mind that changes are occurring continously.

Webster says that HYDROGRAPHY is "the description and study of seas, lakes, rivers and other waters." Maps provide a visual description of water bodies and some of them chart the physical characteristics of these water features. Hydrographic symbolization, therefore, is an important ingredient of several kinds of maps. Such symbolization should not only portray the hydrographic detail, itself, but should also guide the map reader in analyzing the influence of water agents upon the earth.

Land Drainage

Streams

Intermittent - Youthful streams that are just getting started in their important work of carrying off water are not steady in their flow. If drainage is slight they will receive no water in dry periods and so will have to be shown on large scale maps as INTERMITTENT, They will not be shown at all on medium and small scale maps.

Porosity of the surface strata may cause disappearing and/or intermittent streams. When drainage is great, water will flow on the surface because its velocity is great enough to retard sinkage. As soon as velocity is decreased the water will sink into sandy or porous surfaces leaving a dry channel. In some sections of the world people flock to these dry stream beds because they can scoop out shallow wells to get the water that has sunk beneath the surface. Examine any good Atlas or larger scale map of the Sahara for WADIS symbols marking this condition.

Intermittency of streams is the product of climate as well as porosity of strata. Desert and semi-arid climatic regions are characterized by sudden downpours. During such storms the volume of water is great and there are insufficient vegetational obstacles to keep it from racing downslope. Run-off rapidly fills and erodes stream beds. The people who moved into the dry stream bed to get water are sometimes trapped and destroyed by it when a sudden storm occurs. After the storm, however, the streams soon subside from raging torrents to mere trickles or dry beds. Visualize an intermittent stream symbol in a desert area as this precarious condition and you are using "map intelligence".

In certain other types of climate, all or a large percentage of the precipitation comes in one season and in the following season or seasons there is insufficient drainage to keep the streams supplied. Melting snow in the spring in Continental climates, wet monsoons in Tropical climates and winter precipitation in Mediterranean climates make the rivers run full and sometimes overflow. When the precipitation is over, evaporation may accentuate the dearth of water. This story is told on maps by a wide stream bed with an intermittent line running through it.

Permanent - In more hunid climates, streams seldom cease to flow although there may be a variation in the amount of flow within and among streams. There are so many different names given to streams that it is cartographically impossible to classify them by name. It would take a master mind to tell which is larger: rill, creek, run, or brook. These are only a few American versions which you could probably multiply by several thousand in other languages. It is far safer to call any permanent ribbon of water a river and classify it according to width. Even this classification must be tempered by the knowledge that scale affects the width of line or lines used. Symbol sheets for the particular series and scale should be referred to for correct interpretation of the size of rivers.

Generally river symbols are graded from fine lines for small rivers to double-lines symbols for wider ones. If a river is very wide it may be shown by either a filled-in or solid symbol or by color or shading. Some very wide symbols are filled in with roughly parallel lines running lengthwise that are either indicative of depths or just impressionistic representation of water. Normally river symbols present fine-gauged lines near the source which are broadened downstream. The symbols for braided and meandering streams were included on the Training Model for contour analysis.

Lakes

Lakes reflect many of the same water conditions as rivers in their formation and character. Symbols for them should reveal these geologic and climatic influences. On large scale maps, actual shorelines should be defined or retained by contours. On small scale maps, only a generalized outline is necessary to indicate the presence of a lake. No definite shoreline should be given for a lake whose expanse varies greatly. Instead an appropriate symbol or color should indicate the limits of variation. Man-made lakes show by their regular shaped outlines or by an appropriate symbol, such as dam, how they were formed.

The symbols for large navigable lakes and rivers that have outlets to the ocean should note the head of navigation. This symbol is usually an anchor,  . Locks, canals, channels and other navigational aids are shown by appropriate symbols like those given on any standard symbol sheet.

Swamps

At places where the underground water table is close to the surface of a flat area or where the soil is impervious in humid flat areas, drainage may not be sufficient to carry water away. It will collect in shallow pools or mushy, muddy patches conducive to dank vegetation. The symbol for such areas is more definitive on large scale than on small scale maps. At larger scales a short horizontal line surmounted by five prongs  suggests reedy MARSHES. Grass symbols interspersed with tree symbols suggest SWAMPS in which trees are dominant such as in the swamps along the southeastern areas of the United States. On medium and small scale maps the marsh symbol is used for either swamps or marshes and so can only be interpreted to mean a wet area.

Swamp symbols are usually danger signs on a map. Their presence indicates a barrier to land utilization and travel. They are, also, areas to be avoided in wartime unless troops and their equipment have been adapted to swamp conditions.

This does not imply that swamps are of no value. Some of them are sources of lumber, furs and fish. They may also be critical "water catchers" stabilizing fresh water supply. If they are drained, surrounding areas such as those adjacent to the Everglades in Florida, find their fresh water supply is endangered and subjected to intrusion of salt water because the underground water balance is disturbed. Knowledge of these resources is important to the researcher.

Oases, Springs and Other Special Hydrographic Features

If swamp areas are to be avoided, oasis and spring areas are to be courted in most situations. Oases and springs are often responsible for the growth of population or a concentration of people around them. The size of an oasis symbol, for example, often gives no clue to its economic importance. The map reader must supply this by realizing that thousands of nomads may make an oasis or spring a regular stop in their wanderings. Here they find fresh water, food and other supplies for themselves and their animals. The oasis dweller, in turn, is usually glad to sell his products or exchange them for goods and skins that the nomads bring. All this behind an oasis symbol!

In cold or mountainous areas ice and snow symbols replace stream and flowing-water-made symbols. Glacier, ice field, iceberg, stream ice and frozen lake and stream symbols tell the story of the possible and impossible uses to be made of the area thus shown on a map.

These and many other hydrographic symbols appear on special map sheets. They are often explained on the legend printed in the margin if they are not common symbols to be found on standard symbol sheets.

Coastal Foreshore Features

The part of the shore between high-water and low-water marks is the foreshore. This area is used in many different ways depending upon its configuration. Along the coasts of New England and the Maritime Provinces tidal flats are widely used directly or by reclamation, for pasturing livestock. During low tide pigs, for example, are brought to the tidal flats to eat the grass and any marine life that was stranded by the last high-tide. Then the animals are driven inland as the tide comes in again.

Farther south along the east coast the sandy, tidal flats add to the area of beaches and resorts catering to the tourist trade. Interspersed between both the grazing and recreation spots are harbors and ports which must be adapted to the changes in shoreline created by the tides. At other spots rocks intrude upon the shore and extend into it. These rocks are hazards to navigation that must be carefully marked on maps. Some rocks and reefs are clearly visible at low tide but become submerged by the rising tides and may tear at the hulls of boats that venture too near them. Rocks become exceedingly dangerous at any tide when storms drive boats ashore to be pounded to pieces on them. In other areas coral replaces rock and is equally dangerous.

Sandbars may develop along coastlines or across outlets to important harbors. They must be clearly marked so that ships are not grounded on them. If sandbars or passages are navigable at stated times only, large scale maps contain a warning to that effect. For example, there are many passes between the islands along the north-west coast of North America where boats must wait for the opportune moment and then race through the passes at top speed. If the timing is wrong, the boat is gone.

In time of war, establishment of beachheads is a critical combination of accurate map symbolization of foreshore features and intelligent interpretation thereof. Anyone who followed the fortunes of war in Europe or the Pacific during World War II is well aware of the importance of choosing the right spots to land troops and the disasters that occur when the choice is poor. Thus the symbols for foreshore features are vital to belligerent as well as pacific evaluation of coastlines. Study the symbols in a legend with this in mind.

Offshore Features

Where is the continental shelf (ledge of submerged land adjacent to many coastlines)? How deep is the ocean? What is the bottom of the ocean like? What aids and dangers to navigation occur in open water? Look to map symbols for the answer or clue to these and many more questions concerned with man's relationship to open water and offshore features.

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Measurement of Depth - One clue lies in comparative water depths. Depth is measured in fathoms. One fathom equals six feet and its origin is the span of a man's extended arms. As the word applies to water depths a seaman could get a rough measure by counting the number of arm-lengths needed to cover length of the sounding line used to touch the bottom. Weighted lines can be used in comparatively shallow water to take soundings but are ineffective in deep water. The force or specific gravity of deep water will keep the weight from touching bottom. Special sonic devises have now been developed for this purpose. They send down sound waves which hit the bottom and bounce back. Depth is then determined by the time lapse between transmission and reception of the sound. Bathymetric curves are plotted on charts or maps to show the relationship among points of equal depth. These curves are like land contours in reverse since they are measured from the top down, based normally upon mean low tide. Sometimes where "water" contours are drawn in shallow water, their value is expressed in feet instead of fathoms. You must determine which measurement was used from the map legend or by exercising your good sense. For example, if you know that a particular body or section of open water is not likely to be 18 fathoms deep, you will interpret the figure given to mean feet.

Troughs - Deeps or troughs are noted on maps for several practical purposes. Fishermen want to know about them because of the general lack of usable marine life in such areas. Fish avoid troughs because there is a general lack of surface fish food (plankton) and also because they would be crushed by the weight of water if they tried to submerge too deeply in search of food. This same weight of water will trap submarines that cannot generate enough "lift" to rise to the surface. Cables for trans-oceanic communication will sag into submerged depressions and snap so cable-layers must know, too, where depressions are and avoid them.

Submerged mountain peaks; wrecks; seaweed, such as the Sargasso Sea, that traps unwary boatmen; currents, and eddys must all be symbolized on maps and charts to warn the navigator of what to expect or shun. These symbols also reveal the character of open waters to land-bound map readers.

Cultural Symbols

Map symbols for cultural features are not photographic reproductions of these features but they do bear a suggestive stylized resemblance to them. You must remember that this is a "roof top" resemblence, however, and is not the same as the one you are normally accustomed to see as you travel along the surface. If you could stand directly above a toy village you would have the proper perspective. It would require little imagination on your part to see how symbols could be derived from this miniature village and stylized into conventional patterns for the various cultural components of the actual terrain.

Population Symbols

Buildings - As you looked straight down on the roof outline of one of the tiny houses it would probably look very much like a block or square. Embellishments such as porches, carports or garages would not affect the central unit. A small, easily drawn square is a logical symbol, therefore, for a single dwelling or home. Wherever multiple units occur under one roof or in close approximation, an elongated roof outline is just as logical.

Buildings also serve other purposes than as dwellings. Specific uses can sometimes be identified by the addition of special signs to the basic square. Two common examples will illustrate such adaptations. The patriotic objectives of nearly every school are symbolized by a flag flown during school hours. Hence a square surmounted by a triangle to represent the flag stands for school on a map. Similiarly a cross suggesting religious activity is used to identify a church.

Structural types also vary with the culture of a people. One of the baffling phases of map reading is the correct interpretation to be placed upon symbols for unfamiliar structures such as temples and shrines. These symbols cannot be overlooked because they are indices of the character and number of people in a region and may also be vital to wartime strategy. The structures may be used to billet soldiers or as field headquarters and supply depots by either friend or foe, depending upon the turn of events.

Built-up Areas - Wherever many structures have been consolidated into a village, town or city pattern, symbolization of this fact depends upon the scale of the map. In a large city area such as London, Tokyo or New York it is impossible to draft symbols for each structural entity unless a very large scale is used. On many large scale maps only prominent buildings are given definite outlines. Block patterns indicate the closely built-up portions of the city and give way to individual squares only in the suburbs. On medium scale maps an outline suggestive of the shape of the town is drawn. Refer to the Hagerstown series of maps to verify this progression of symbols.

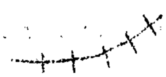
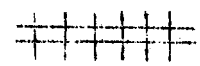
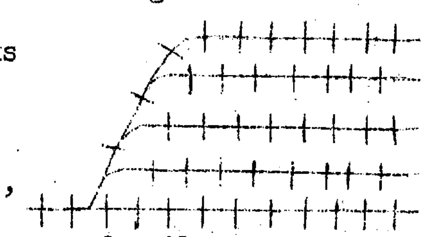
On small scale maps, a suggestive outline can be used for only the largest cities. Smaller towns and villages are reduced to a circle, square or dot. You have undoubtedly noticed that a circle is commonly used to identify the location of a city.

There is some disagreement about the origin of this usage but two plausible explanations may interest you. One is that the circle evolved from the way medieval cities were constructed. Dwellings were built inside a circular or nearly circular wall. It was logical, therefore, to establish the tradition of using a circle on a map to show that city. The other explanation arises from places where homes were grouped in a rough circle around the center of town. In depicting this arrangement on a map, the houses were shown at first and then gradually a circle was drawn to show the center of town and the individual home symbols were omitted. No matter what the origin of the circular symbol, long usage of it has made its implication common knowledge, even though visualization of the detail it replaces is lacking.

Transportation Symbols

Railways - Let's assume a position high above the earth and look down on the transportation pattern. Many branch lines of railroads fall into one pattern. Transfer of this pattern to a map requires a symbol which can be recognized as standing for railroad and drawn by anyone without special artistic ability.

Nature produces nothing that resembles a straight or smoothly curved line intersected by uniformly spaced crossticks. Since railroad rights-of-way are laid out by engineers whose job it is to keep sharp curves and steep grades to a minimum, lines symbolizing them are smooth. They are normally drawn with special pens and railroad-curve templates. Knowledge of these facts will help you differentiate both railroad and highway symbols. from river symbols.

Railroad symbols are usually drafted in black. A solid line intersected at specified intervals by crossticks represents a single track.  Double track railroad symbols are two parallel cross-ticked lines on some maps  and on others are single lines with two cross-ticks evenly spaced.  Wherever there are several tracks in juxtaposition, a number of lines approximating the number of tracks are drawn and then cross ticks alternated along them. Abandoned railroads, trolley lines, cable cars,  narrow gauge tracks and many other types of railway construction have their own special symbols. As you study any map be sure you have the correct definition of the transportation symbols so that you do not mistake abandoned and special types for standard types.

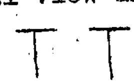
<u>Roads</u> - It is sometimes possible to confuse not-too-carefully-engineered road with river symbols. Part of this difficulty is eliminated by using conventionalized symbols for different classes of roads. Style sheets and legends

provide explanations of the different classifications used. Delineation of roads by red further facilitates differentiation among various types of roads and their distinction from other symbols. Several governmental and private agencies have adopted red and so it is found on recent editions of both foreign and domestic maps.

Trails and Routes - The irregular courses of trails and caravan routes are shown by broken, dashed, or dotted lines in either red or black. Sometimes these primitive routes are the only avenues of transportation in economically backward areas or in regions of very rugged terrain. It is vital in emergencies, therefore, to know whether a trail leads to a farmhouse or connects with a through road. Much of the strategy in Korea, for example, had to be planned on the basis of trails since no other roads exist. Maps were devised to show this condition by using large red dots to mark the through routes.

In areas inhabited by nomadic herders dashed or dotted lines show the yearly paths taken by the herders in pursuit of food and water for themselves and their livestock. These routes are not fixed trails in many cases. They represent, rather, progress from one place to another as the livestock exhaust the forage in one area and are driven to greener pastures farther along.

Communications

Communication cables are occasionally buried beneath the surface, but more often they are strung upon poles. Symbolization of these poles force us to abandon the vertical view and look at them as we would from the ground; they are,  . Their usual placement along road and railroad symbols are a clue to their identity.

Cable crossings of rivers and other bodies of navigable water are shown and explained on many large scale maps. Television, radio and signal beam symbols appear on special maps such as aeronautical charts. Study these symbols on the charts assigned to you.

Boundaries

What is a Boundary? - Boundaries range from fences enclosing individual property holdings to lines demarcating international separations. There are also civil, administrative, legal and provisional boundaries. Boundaries are sighted, surveyed and contested. One country or minor civil division may decide its boundaries are in one place and its adjoining neighbors will decide they are somewhere else. This conflict may be the result of: improper establishment of control; discovery of critical materials such as petroleum or uranium; political and military aggrandizement, or the migratory character of the people who feel that their boundaries are governed by their movements and not by a surveyors tape or by treaty.

What can the poor map maker do in cases like these? Put the boundary symbol as near as he can to the place that seems to have the most justification for it and wait for a storm of protest. All too often, however, the storm never breaks for the average map reader assumes that a boundary is a god-given line and never questions it. Farther along in this course the author hopes to quicken your boundary perception and instill an attitude of questioning its reliability until it is proven to be accurate.

Boundary Symbols - The lowly fence often becomes a dash and cross symbol for barbed wire and a dash and circle for non-barbed wire. Township, country, state, national and international boundaries or their equivalents in foreign lands, each have individual symbols. Unfortunately, there is no universal agreement on what they should look like. Many mapping agencies, however, are tending toward standardization. International boundaries, for example, are frequently drafted with a heavy weight line broken into one long and two short dashes alternately. Refer to the margin of specific map sheets or to the series explanations for precise definition of what the cartographer intended his boundary symbols to represent.

Vegetation

Strategic Importance

Rare is the child living in climates admissible of trees, who has never played hide and seek among a copse of trees, hidden behind a single tree or used it for a safety post or "Home". War and tactical maneuvers are far grimmer than these childhood pastimes, but they use vegetation cover in much the same manner. A large number of men and supplies can be concealed beneath the protective foliage of a forest. When a soldier is avoiding detection by the enemy he will hide behind the nearest tree. Snipers find that trees make excellent "home bases" or safety posts.

The natural camouflage of growing vegetation is far superior to any artificial devices. Personnel trained in

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camouflage detection can usually penetrate the cleverest subterfuge. Growing vegetative cover is much harder to penetrate. This cover is not restricted to trees but includes all kinds of vegetation from small clumps of grass just big enough to conceal or confuse the outline of a man, through bushes and tall grass that will close above the heads of men.

The scope of vegetation utilization is not limited to concealment. Sometimes it is just as important to know vegetation warning signals. Five pronged swamp symbols figuratively shout, "Don't get bogged down here! Take your boots or tanks around by what seems to be the long way". Another type of vegetation may bristle its barbs and claw at the unwary trespasser if no advance map notice is given.

Vegetation may be the provider of food and fuel for men or armies travelling under short supply. Woodfires also cook the food and take away the chill unless the enemy is so close that fires are forbidden. Shelters can be improvised from meager vegetation with the aid of a little ingenuity.

Economic Importance

Vegetal covering is just as vital to normal everyday utilization of terrain. It is pointless to dwell upon the significance of vegetation in any life. In any case you may want to know not only why a symbol is necessary but how it represents the man-nature relationships that are possible in any given area. From rice to guayule and from mesquite to sequoia each vegetation symbol indicates the potential and actual economic value of the land to man.

Any lengthy discussion of the many symbols devised to show different types of vegetation is also pointless. The best way to appreciate them is to examine a manual of symbols and find examples on maps as you work with them. As your appreciation of the value of definitive symbols grows you may perhaps join the ranks of map readers who would like to have more vegetation than just a symbol for woods or brushwood included on maps. These two broad generalizations are shown by green coloring on many sheets such as the 1:250,000 Baltimore NJ 18-1. Woods, however, are not just woods. There are all sizes, shapes and varieties of them which the map reader cannot possibly visualize from a green vegetation tint.

Marginal Data

"The first shall be last and the last shall be first" can certainly be twisted to our discussion of map ingredients. You had to analyze each of the other map ingredients before you could appreciate and evaluate the marginal data supplied on most worthwhile map sheets. When this analysis is completed you should have a general concept of what to expect of any map. Hence foreward as you tackle any new map the first thing to inspect is the marginal data for identifications and reliability of the data shown in the body of the map.

Soldiers and civilians alike use maps. Their backgrounds for interpretation run the gamut of competence. If map distribution were limited to highly specialized and trained groups, many explanatory items would be superfluous. Since this is not the case, several man hours and a large number of operations are

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devoted to compiling and presenting information to explain the use of even simple sheets. These marginal data should be studied carefully before any map work is begun.

Although the amount of data varies from sheet to sheet, careful inspection of a few sheets will facilitate the reading of any one of them. It will become apparent that there is a marked uniformity of placement of certain types of data. If the agencies bother to supply the props, it behooves us to note their position and recognize their value.

Map Identifications

Sheet Identifications

It is a human tendency to name things and to remember these titles better than a long string of numbers. Full references to maps that are a part of a series usually involves both a name for quick identification and a number to locate it in relation to a series. The principal identifications thus, which positively identify an individual map are the series name, sheet name and sheet number. While reading the following paragraphs refer to the sheets showing the Hagerstown area on 1:25,000 to 1:250,000 scales.

Series Names - Most mapping agencies group maps of similar scale covering a recognizable geographic area into a map series. These series names are generally found in the upper left margin of the map. The series names assigned to the Hagerstown area sheets and to other similar maps illustrate how these names were determined from the area covered and the scale. The 1:24,000 to 1:125,000 (which include the 1:25,000 and 1:50,000 Hagerstown

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sheets) in the United States are grouped into series which are based on individual states and hence take the state name. (Maryland). The 1:250,000 scale map of the United States encompass areas which may involve many states. A series name based on all the state names would be cumbersome. Here it is more practical to make a more general division such as Eastern United States and Western United States. Small scale maps (not included in the Hagerstown group) are identified by continental names or other accepted divisions which overlap continental boundaries. Examples from the 1:1,000,000 series carry such identifications as Africa, South America, Eastern Asia.

In all of the above appropriate representative scale fractions are appended directly to the series names. For example: Maryland 1:25,000; Eastern United States 1:250,000; South America 1:1,000,000.

Sheet Names - Individual sheet names are chosen normally from the most prominent geographical or cultural feature on the sheet. Where more than one map series covers the same area, it may be found that the name of the larger scale map is the same as that used on a smaller scale map with only a geographical designation added. For example the sheet name at 1:50,000 scale might be Washington and that at 1:25,000 scale, Washington N.W.

Sheet Numbers - Sheet numbers for large scale maps are ordinarily assigned in a logical manner following an arbitrary coordinate system based on an origin which always permits a positive number to be assigned for the area covered by the system. Also, sheet numbers covering an area are usually so designed that the number of 1:100,000,1:50,000 and 1:25,000 scale maps are inter-related. For example, the sheet number for the 1:50,000 scale Hagerstown quadrangle is 5463 II and that for the 1:25,000 Hagerstown quadrangle (actually the northwest portion of the 1:50,000 scale sheet) is 5463 II NW. Similarly the 1:100,000 scale sheet of which the 1:50,000 is a part would also carry the number 5463.

Sheet numbers on medium scale map series are commonly based on a breakdown of the numbering used on the International Map of the World (IMW) 1:1,000,000.

Geographic Index - Another item known as a Geographic Index number, although it is no longer shown on new Army publications, may still be found on many maps. These numbers, printed directly beneath the Geographic Location Name in the lower right margin, represent the geographic coordinates of the map. The first four numerals and letter indicate the number of degrees and direction from the equator to the limiting parallel closest to the equator. These notations are separated by a dash from the coordinates of the limiting meridian closest to the prime meridian (Greenwich). Numbers shown after a diagonal line give the overall dimensions of the graticule of the sheet in degrees or minutes; e.i., Baltimore, United States. This notation means the graticule
N 3900-W7600/100X200
for the 1:250,000 Baltimore sheet covers 100 by 200 minutes.

Index and Locational Diagrams

One or more boxes are to be found in the bottom or side margins of many maps. On large scale maps one box accommodates the Index to Adjoining Sheets diagram which shows the location of the sheet under consideration in relation to the immediately adjoining sheets. Thus, adjoining sheet numbers (and often names) are available if reference to extended areas is desired. On medium scale maps the relationship of adjoining sheets is shown in a Location Diagram.

A third box, not always included, gives the identification of political boundaries adjacent to or actually shown on individual sheets. This Index to Boundaries helps research personnel or map compilers in comparing miscellaneous maps that do conform to one method of locational identification but can be oriented with reference to recognizable boundaries. It also provides quick reference for persons concerned with relative political locations.

Still another box which is Grid Reference found in the lower margin explains the method by which specific objectives or place references can be located in terms of grid zone designation and the military grid method. Students can follow the step by step instructions given in the box. They will arrive at a sample objective and can then apply the same technique to other map objectives.

Separate Indexes and Catalogues

Even though we are concerned with analyzing marginal data appearing on given map sheets it will be worth your while to digress for a moment to show you how to find whether a particular map that you may desire exists.

Index sheets are available for any given series of maps. All you need to know is the scale you want. Then consult the appropriate index sheet for that scale to determine whether there is a sheet covering the area you desire. Its availability is shown by symbols such as the "filled-in corner" on the Index to Maps of World 1:1,000,000. If the sheet is available, you need only to note the series name, sheet name and series number. Several index sheets have been provided for you to study the series description, method of determining availability and the referencing system used for identifying particular sheets.

Catalogues covering single series and also all series for given areas are available from some mapping agencies. These are indexed so that you can find the area for which you want map coverage by scale and region.

Significance of Dates

Non-governmental map agencies often avoid putting dates on maps, especially the desk and wall variety. Their reasoning for this omission usually runs along the line that putting a date on maps would arouse sales resistence to any but the most recently dated one. "What the public don't know, won't hurt them" attitudes are the product of limited map intelligence among the public themselves. As soon as more people appreciate the significance of map dates publishers will be forced to include them as most government agencies do on their map sheets.

Maps issued by the latter group normally include not one, but several dates in the marginal information. It is important that you compare all of these dates in making an accurate evaluation of a single map or among several of them. There are many known instances where the most recent edition date does not mean the most recent or accurate map. A little time spent in comparing the following types of dates will keep you from jumping to erroneous conclusions based on one date alone.

Edition - You will usually find the edition date in the lower right margin of a map sheet. Each new map or series is given an edition date at the time of its first reproduction. You can figure that at least one year, and possibly longer, has elapsed in preparing the materials and compiling a sheet or series before it is printed. Since nothing is permanent but change, it can be truly said that any map is out of date before it is printed. How far out of date can better be determined by the following than by the edition date.

Date of Compilation - This date tells when the data was collected but still does not tell whether the information used was up-to-date or not. In this case, the dates of sources, such as photography, vegetation classification, road and other culture data, are helpful. These special dates are generally included in the credit notes in the lower right margin.

Date of Copy - The time when the copy was made from other sources without revision or with very slight revision is shown by this date. During war emergencies it has been the practice of such agencies as the Army Map Service to supply interim coverage of critical areas until other maps can be compiled. Direct copies of existing and captured maps are printed. The agency is responsible for the printing only and not the information contained on the copied map.

Date of Publication - This is the date when the map is made available for general use. It is not a really good clue to the recency or adequacy of map information as indicated previously.

Date of Reprint - This is the date of a re-run of existing reproduction copy and does not signify that any changes have been made to the original compilation.

Date of Revision - This is the most definite evidence of up-to-dateness if the extent of revision is known or indicated.

Date of Survey - The date when the basic surveys were run is extremely critical in accurate map evaluation. Map makers have been known to produce new maps based on old surveys that have since been superseded by newer and better surveys. Obviously these "new" maps will not be as accurate as "old" maps that are based on the newer survey data. Furthermore since landforms change slowly as we indicated in the discussion of land drainage, maps based on good surveys completed in the nineteenth century may not present a true picture of the present terrain. (Roads and culture change even more rapidly). Cartographic mistakes can be perpetuated for a long time if no one checks the accuracy and number of surveys that have been completed in a given area and selects the best one for determining control on the latest edition. Brand new cultural changes don't mean much if they are "hung" on incorrect or obsolete control expecially if the new maps are to be used in the field. Survey dates from which you can check the possible errors just mentioned are normally found in the credit notes in the lower left margin.

Date of Revision by Special Methods - Many maps are revised

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by special methods. When these special methods are used by competent personnel they contribute to the accuracy and definitiveness of map sheets. Photography of recent date can be used for sterophoto and photogrammetric revision such as multiplex (explained later).

Each date, therefore, contributes or subtracts something from the total value of a map and should be sought for among the marginal data(usually in the credit notes) in evaluating map sheets.

Sources and Types of Information Utilized

Coverage and Reliability Diagrams

Coverage diagrams are included on many sheets. This box shows the types of material and methods used in compiling the map. Previously published maps, and various kinds of photography as well as preparation methods are cited. This diagram states the techniques and suggests the accuracy. More definite proof of the accuracy may be given in another box labelled Relative Reliability. This diagram warns the user about the degree of credence to be given parts or all of the information contained on the map

Credit Notes

Greater insight into the probable reliability is achieved by further inspection of the credit notes normally found in the lower left margin. Credit is given here for the use of several types of information. Agencies responsible for surveying; extending topographic controls; compiling vegetation data; supplying photography and other important and pertinent data are acknowledged. If the map user is at all acquainted with these sources, or the men representing them, he can estimate the reliability of their findings.

Data for Utilization of the Map

Reference Data

Whether it be called Legend, Key, Reference Data, or any other title, there is nearly always some explanation of the terms and symbols found in the body of the map. Although there is a surprising uniformity among agencies and nations in depicting common objects, there is still a vital need for explanations of unusual symbols and translation of foreign terms. Reference data can make the difference between ignorant and enlightened map interpretation. Train your eyes to look for such data whenever you are in doubt about the meaning of something you find on a map. Consult standard symbol sheets or books if the legend doesn't satisfy your curiosity.

The exact marginal placement of these explanations varies widely but can be spotted by the organized array of terms and symbols

Declination Data

Anyone who is trying to orient a map in the field welcomes the addition of declination data. Declination diagrams and explanations, as was suggested earlier, are a must for the soldier, student, or traveller who has to translate compass readings and map directions into earth directions.

The most common form of graphic symbolization of declination is a three-pronged diagram like the one shown on page 196.

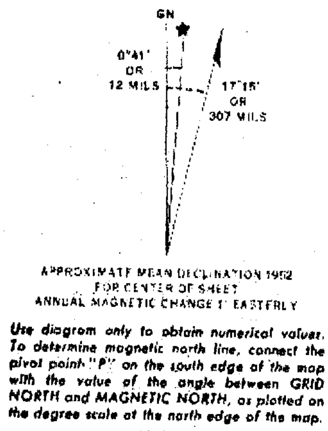

FIGURE 196

These three prongs diverge from a common point to indicate the approximate direction and angle of each component in relation to the grid. No attempt is made to plot the angles correctly. The placement of the three barbs is meant to show only the relative directional divergence.

One prong is tipped with a half arrowhead placed on the left or right side depending on the direction of its divergence with the barb placed on the outer edge. This half arrowhead points toward <u>magnetic north</u>. A compass is pulled toward the north magnetic lode which is not true north. The pull of this force is not uniform for all parts of the world at all times so the magnetic prong will indicate different angles for different places and periods of time.

The second prong capped by a star identifies <u>true north</u>. The star was adopted because the North Star appears in the sky directly above the north pole and is used in the field for locating true north.

The third prong may be labelled either G N or y. This prong is oriented parallel to the central grid meridian for the zone in which the map falls. This prong identifies <u>grid north</u>. Thus, the overall function of a declination diagram is to indicate the rel[illegible] magnetic north to grid orientation for each map sheet.

Declination diagrams printed on military maps often give angle readings in terms of mils as well as, or instead of, degrees. A MIL is the angle subtended by an arc of 1 unit on a radius of 1000 units. If instead of dividing the circle in 360 equal degree parts you divide it into 6400 you get the unit of angular measurement called a mil. The radial lines you use to mark off one of these equal parts will form an angle of 1 mil and will therefore mark off an arc of 1 mil on the circumference. The length of the chord subtending that arc will be equal to approximately 1/1000 of the radius. The word MIL comes from milli (1/1000) of the metric system. In this system 17.8 mils = 1°, approximately and 1000 mils (or a radius) = 57° 17' 44.8", approximately. On figure 196, 17°15' equals 307 mils which is the value of the angle between grid and magnetic north.

If you ever have occasion to use the declination diagram, be sure to read the accompanying directions carefully. Note any mean annual changes that might have to be added to or subtracted from the figure that was correct when the map sheet was compiled or revised. Here again, let the dates be your guide!

Magnetic Graphs - Magnetic graphs for rapid determination of magnetic declination are printed on many large scale maps. The amount of declination of a compass reading can be determined from these for any part of the map sheet. A line drawn from origin to degree scale establishes all points of equal declination along that line, see explanation last paragraph page

195 - page 196.

The 1:25,000 Hagerstown Sheet 5463 II NW can be used to illustrate how a magnetic north line is obtained. Find the point P at 730894. The vertical extending northward from this point has no magnetic declination. Lay a straight edge from this point to connect with the value between magnetic and grid north as plotted on the graphic scale in the north (upper) margin. Thus the declination diagram gives the correct value for a particular sheet and the graph provides a way for interpreting the value in terms of any changes that may have occurred since printing. In the case of the Hagerstown sheet there is no mean annual change to be considered.

Isogonic Lines - Declination diagrams and magnetic graphs cannot be used on medium and small scale maps because of the variation in magnetic declination over large areas. There are several kinds of attractions which disturb the compass needle and distract it from the magnetic north readings. The possibility of such misreading is greater in covering large areas than small ones. Consequently, isogonic lines are drawn directly on maps for use where such information is critical, such as on navigation and aeronautical charts. ISOGONIC LINES connect all points of equal declination and are usually shown as broken lines. (World Aeronautical Chart, Chesapeake Bay) If a solid line is used it can easily be differentiated from either a graticule or grid line by its faltering curve across the map and marking at either end for the east or west amount of declination in degrees or mils. Cautionary notes are appended in the margin stating

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the time limit for using the isogonic information. This note may also tell the user what source of information to use if the map is obsolete and when new information will be printed. See the margin of sheet suggested above.

Compasses Roses - Another graphic aid to compass map orientation is shown on the same chart. It is the COMPASS ROSE that is truly oriented on the map with its 0 toward magnetic north. These roses are scattered over the map sheet at strategic points for extending lines to determine azimuths. The technique of drawing a straight line from origin to destination and extending it to the nearest convenient reference line can be applied to the most convenient compass rose for obtaining azimuths, taking bearings and plotting rhumb lines.

Enough introduction to and explanation of the ingredients that go into the making of a map have been given in this chapter to enable you to analyze most map sheets or, at least, to make you aware of what to expect on them. The next question is what is available for you to work with?

CHAPTER III

MAPS, CHARTS AND PLANS

Recipes for maps are as varied as recipes for cakes. All the basic map ingredients are combined with special ones as needed. Different combinations create diverse types. Some have lots of "icing"; others are plain. Each is concocted for a special purpose but may be consumed by anyone who develops a cosmopolitan appetite. Cartographic taste is developed through exposure to and sampling of all kinds of maps rather than by the continued use of one "old favorite". This chapter is devoted to preparing you to be a cosmopolitan map user by presenting the types and adequacy of world coverage in maps available for your consumption.

Planimetric Maps

There are several kinds of planimetric maps ranging from small scale political wall maps to very large scale cadastral maps and city plans. You will recall that planimetric maps show details in reference to horizontal linear scale only. No information is provided concerning the ups and downs of the land except possibly a few spot elevations. Cultural symbols such as buildings, cities and roads dominate this type. Vegetation symbols may be given without reference to topographic features underlying them. Drainage patterns when, included, are not concerned with water level or flow.

Cadastral Information

Cadastral maps are one of the most highly specialized of the planimetric maps. Cadestral comes from the word Cadastre which means an official register of the quantity, value and ownership of real estate, used in apportioning taxes. Because of its very nature, maps compiled from information contained in these registers must always be on a large scale. As a matter of fact, they seem more like scaled diagrams of a landscape engineer's plan than the common conception of a map.

Cadastral maps are derived directly from cadastral surveys. Such surveys are run by several methods (presented in Chapter 2) but their function is always to determine the site, size and distribution of the components of individual property holdings. The information obtained from such surveys is written up in elaborate detail for the permanent records that are normally kept in the court house in each county in the United States. A similar arrangement is used in many foreign countries, although the civil division may not be called a county.

Maps showing this information are extremely detailed. They show: hedgerows and fences that may or may not coincide with property boundaries; the size and arrangement of all structures within the confines of each holding and, any other pertinent information related to the improvement of each piece of property or group of properties. Cadastral maps are probably too detailed for general public use but are invaluable for micro-geographic analyses of a small community or as a source of information for prospective property owners.

Because of the time and expense involved in original preparation and constant revision, many communities do not attempt to provide cadastral maps to supplement their official registers. Those who do make the original effort may become lax in keeping the maps up-to-date for the same reasons. They are more apt to provide City Plans. Even though City Plans are sometimes called cadastral maps, they are not necessarily the same.

City Plans

City engineers, local planning groups usually compile City Plans although some are prepared by other agencies such as AMS. Occasionally elevation information is superimposed on these maps but more often they are comparable to the sample Hagerstown City Plan assigned to you. Examine this sample to determine the types of information engineers generally show upon their plans. Ordinarily color (for example, tan) is employed to set off the area within the city limits and another color (red), the actual boundary lines. Still another color (green) highlights buildings and other property either belonging to the city or for non-commercial public use. All existing and, sometimes, planned streets and the various means of public transportation are shown on the Plan. Sites of prominent industries are indicated by the name of the company and may even include a clue to the type of industry located there. Large blocks of property are identified by the owners' names.

Our example, Hagerstown, is situated in the relatively level northern section of the Shenandoah Valley. The absence of relief symbols on its City Plan, therefore, is no serious handicap. In contrast there are cities such as Pittsburgh or San Francisco where adjustment to rolling topography is unavoidable. Steep hills and deep depresions seriously affect the mode of land utilization in such sites. The inadequacy of planimetric maps here is evident. Any interpretation or urban adaptation or planning demands the aid of maps showing relief.

Each class studying maps should be supplied with local city plans whenever they are available. Study this local plan, if possible, and compare it with the Hagerstown sample. Find in what respects they are alike and where they differ.

Highway Maps

Local communities, counties and states are primarily responsible for the maintenance of roads. Highway engineers prepare highway maps, usually on an annual basis, showing the current status and extent of roads under their jurisdiction. These maps depict the planimetric pattern of the roads. They are more accurate in detail than the gasoline company "handouts" mentioned earlier. The engineer's highway map is also on a much larger scale and contains more information about local features. This type of map is an asset to anyone carrying on field research or conducting intensive local field trips involving auto transportation.

A large quantity of any one local highway map is not available for material distribution for this text. You can probably procure one for your own use from the appropriate agency in your local county. Compare it with a "gas station" road map showing the same area and evaluate their comparative usefulness.

Through-Way Plans

Adequate presentation of the transportation pattern in urban conglomerations is impossible on medium and small scale maps. Many people using maps on these scales, especially military personnel, want to know the possible way through urban areas. In response to this need, Through-Way plans are rapidly gaining popularity. The name Back-Up Plan is sometimes used in place of Through-Way Plan because the data backs up or strengthens correct interpretation of a given area and appears on the back of some sheets. (Back-ups may also be photomaps or other types of information not immediately pertinent to this discussion. Remember, therefore, to turn smaller scale map sheets over to see if they contain supplementary information on the back.)

Find the 1:250,000 Baltimore NJ 18-1 sheet. Study the three planimetric maps on the reverse side of this sheet. What types of information can be obtained from them? Locate the York, Hagerstown and Baltimore areas on the face of the sheet. How does their representation here differ from that on the back? How does one complement the other? What are the limitations of each?

<u>Hypsometric Maps</u>

<u>Topographic Maps</u>

<u>Advantages and Limitations</u>

Large scale topographic quadrangles are probably the nearest thing to a general purpose map of a small area. Each sheet contains a wealth of information that can be utilized in many different ways. This information is revealed in its proper earth setting to anyone who can interpret topography from contours. Even this interpretation is elucidated on many recent editions by the application of shading which accentuates slopes and makes it easier to visualize elevations and relief on a flat map.

Notice that the general purpose statement was modified by large scale and small area. Topographic maps are definitely restricted by these two factors. Medium scale topographic maps have to be much less definitive. Even though generalization of detail is kept to a minimum, the total amount of such detail that can be shown on scales smaller than roughly 1:100,000 is much less than that for larger scales. Generalization of detail, consequently means generalization of interpretation.

Definitive topographic depiction becomes very questionable on scales smaller than 1:1,000,000. The term should be changed to "topographic impressions" on medium and small scale maps. Contour intervals become so gross at these scales that local niceties in terrain are lost. If one interval covers five hundred to a thousand or more feet, for example, only the vaguest impression of rough or level terrain is imparted and should be corrected and adjusted by studying larger scale sources for precise regional analyses.

The small area covered by a single large scale topographic quadrangle makes regional analysis impossible unless a whole series of such sheets are used. Trying to interpret topography from a single sheet produces a very restricted understanding of the local area covered. Such a lack of perspective brings to mind the old cliche of not being able to see the forest for the trees. In any map reading exercise, the first step is to get a general overview of the whole region, state, country or continent,

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depending upon the depth of understanding desired. The next steps are to refine the problem to what kind of "forest" is present and the final step is to study the trees in relation to the "forest" and its setting. This brings us back to large scale topographic maps but with a better overall perspective for their use.

Further limitations to the use of large scale topographic sheets are the size of individual sheets and the amount of space required for piecing them together (mosaicking) to obtain a comprehensive map of the "forest". The average size for a topographic quadrangle is somewhere in the neighborhood of 22 X 30 inches with an effective map area of approximately 17 X 22 inches. It would take about 50,000 of these sheets to cover the United States. Even the mosaic of one state the size of Maryland, would require the space of one wall in a 30 foot room. What of Texas then! Furthermore, if the region to be studied covers such a large area it would be impossible to make a mosaic, even if space were available for it. Because of convergence of meridians sheets have to be stepped and will not match perfectly continuously along the edge of adjoining sheets. This was pointed out in discussing the Modified Polyconic Projection (in the last chapter).

General Adaptability of Topographic Maps

None of the above prerequisites and limitations invalidates the original statement in this section. Topographic maps are adaptable to many kinds of cartographic interpretation. They contain both natural and cultural information vital to office and field research and to peace-and wartime planning.

Natural Features

1) Terrain. Contour symbols are the most accurate way

for showing topography on a flat map. They reveal the character of the terrain. Elevations and depressions; ridges and valleys and all types of landforms are captured by contours if the person who drew them knew what he was doing. Since terrain is basic to any use of the area, such maps are a must for any type of detailed research.

2) Drainage. Distribution of drainage features is shown on each sheet. A clue to the geology or physiography is revealed in the patterns that rivers follow in response to the resistance, or lack of it, presented by underlying and adjacent surfaces. Glaciers, lakes, swamps, etc., further reveal the background and water potential of the area. Cattlemen, farmers, wildlife enthusiasts, bridge and reservoir engineers and a host of other specialists interested in surface waters, find topo sheets invaluable.

3) Surface Cover. Unusual outcrops of sand, gravel and rocks may be indicated on quadrangles where such features are significant. Unfortunately not enough of this information is included because the average map reader doesn't know how to use it. Special maps are made for this purpose and will be treated later.

Generalized vegetation symbols are also over-printed on many sheets. Some topographic series are more definitive in this respect than others but most of them will at least differentiate woodland from other vegetation.

Land Utilization

1) Population. Houses, shown by little squares on large scale maps, shelter a statistical average of four to five people.

By counting these symbols you can get an approximate idea of the total population and by noting the arrangement of the symbols, of the distribution of population in response to transportation and similar factors and, of the possible use they are making of the land.

Density of population in built-up areas can sometimes be approximated from the size of the symbolized pattern. In small communities you can figure roughly 2,000 people to a square mile. In densely built-up cities this generalization breaks down because there may be as many as 100,000 people in a "sky-scraper" infested square mile. Here source knowledge of the regional pattern must be applied or obtained from census figures.

As in the case of individual buildings some clue to the possible functions of a built-up area can be abstracted from the relationship of the site and situation of urban areas or of its component parts. This type of interpretation is sought by sociologists, geographers, industrialists and others interested in people in relationship to their environment. A word of caution should be injected here. Just because a city or factory is beside a river is no positive indication that either is making any use of the river. They may be there because it was the only suitable site available. Or, they may have started there because of the river but have long since come to ignore it.

2) Transportation. Methods for depicting transportation patterns are constantly being improved. Classifications of roads are definitive enough on many topographic series to supply a fair idea of the width and type of road under scrutiny. Field

classification is performed on all recent large scale domestic and some foreign series. Road classifications on these maps are correct as of the credit note. The same holds true for railroad rights-of-way and navigable water-ways.

3) Industries. Special types of symbols such as those for mining quarries, round-houses and airplane landing fields, identify many specific industries. Many more industrial types can be inferred from the shape of symbols indicating factories and the distribution of these symbols as indicated above.

The character and frequency of slopes and plains give some indication of the types of industries, from grazing to manufacturing, if terrain is a major determining feature. Climate, relative location and, the economic stage of development also obviously play a part in the final definition of land utilization by different types of industries. Clues to each of these factors can usually be found on topographic quadrangles if the map reader knows the signs.

Topographic Map Interpretation Exercise

These perfunctory remarks are enough to show you that all types of civilian and military use can be made of large scale topographic maps. These remarks do not indicate exactly how to accomplish these ends. The following maps have been selected to reveal the potentialities of topographic maps and indicate the variety of information that can be applied to and derived from them. The group includes a variety of landform types as well as examples of the most commonly used scales and evidences of land utilization. Some sheets are the same as those suggested by the Map Information Office, of the United States Geological Survey as examples of different Land Forms. All are available from the U.S. Geological Survey.

The Hagerstown series provided the opportunity for seeing only one area depicted on different scale maps. You will now work with different: areas, contour intervals, methods of compilation, projections and grids, back-ups and symbols. The following instructions and questions merely suggest a few of the ideas to be gained from individual sheets. They can be used or altered to fit the time schedule and background of any particular class.

It will be to your advantage to form the habit of noting and analyzing the significance of each of the following general points before beginning a detailed inspection and interpretation of information contained in the body of any map.

1. Establish earth position from latitude and longitude coordinates.
2. Establish the areal extent from linear scale and attendant limitations on detail.
3. Judge the character of the terrain in relation to contour interval and configuration.
4. Compare the various dates to determine currency and probable reliability.
5. Note and evaluate agencies responsible for the map and map sources.
6. Note the number and kinds of marginal aids.

Apply the above suggestions to each of the following sheets before you attempt further analyis and interpretation of them.

I <u>Grassy Cove</u>, <u>Tennessee</u>, <u>117-SW</u>. <u>U.S.G.S.</u>, <u>1949 ed.</u>, <u>1:24,000</u>

Grassy Cove is an unusually large sink area. The grassy inlet was formed by underground drainage into limestone beds capped by massive sandstone which lies along an anticlinal structure formation extending across most of eastern Tennessee and the northern third of Alabama.

1. Describe your first general impression of the ...

topography shown on this sheet.

2. What and where is the highest elevation? The lowest?

3. What is the relief from Grassy Cove to the top of Brady Mountain?

4. Compare the opposite longitudinal slopes of Brady Mountain.

5. Describe the drainage pattern in Grassy Cove and explain the reason for it. Contrast it with the drainage pattern shown on the southeastern part of the sheet.

6. Why is a special contour symbol used in the Cove area?

7. Describe the character of the eastern and western slopes of Hinch Mountain. Draw a hasty profile to illustrate your answer.

8. Describe the types and distribution of transportation.

9. What generalizations can you make about the quantity and distribution of population?

10. What is the meaning of the symbol just north of Looney Hollow?

11. What different types of land use are shown by symbols.

12. What political boundaries are shown? Are they related to topography?

II <u>Quebradillas, Puerto Rico. Sheet 1222 IV NW A.M.S. 1948 ed. 1:25,000</u>

Quebradillas is another area of underground and surface limestone erosion. Numerous sinkholes are shown in the Montanas Aymamon. To the northeast, erosion has created a region of conical limestone hills called haystacks or papinos. The Rio Guajataca has incised a deep gorge in cutting through the limestone from Lago de Guajataca to the Atlantic Ocean.

1. Compare the general appearance of this sheet with the previous one.

2. Convert the contour interval to feet and compare it with the previous sheet.

3. What special caution must be taken in interpreting contour intervals on this sheet? Why was this proceedure followed?

4. Describe the character of the slopes and the relief of the valley of the Rio Guajataca.

5. Why are the lake, river and ocean the only visible means of drainage with a few minor exceptions?

6. How deep, approximately, is the lake?

7. How far is it from the lake to the ocean and what is the difference in elevation between the two?

8. What is the gradient of the river and what is the character of the river near its mouth?

9. What is the probable purpose of the Canal across the center of the eastern half of the sheet?

10. Study the different types of boundaries and the way they were laid out.

11. Study and describe the overall and localized population patterns. Describe the pattern of the largest town.

12. Use the declination information and magnetic graph to determine the present compass orientation or magnetic declination for the sheet.

13. Locate in terms of grid coordinates examples of the following:

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a. Railroad switch-yard

b. Power line

c. Triangulation point

d. School

e. Sinkhole

f. Haystack or papino

g. An area of intermittent streams

III Greenfield Massachusetts, Sheet 6469 II SE, AMS, 1947 ed., 1:25,000

The Greenfield sheet shows a variety of physiographic features such as a trap rock ridge: a river valley terrace along an old glacial valley that was downfaulted to create an irregular mountain area and several low hills along the valley edge. There are several meandering streams, crescent lakes, ponds and marshes.

1. Notice the well defined contour of the river terrace upon which Deerfield is located. The terrace is just as pronounced at Greenfield but is more difficult to differentiate because of the urban symbolization.

2. Trace the courses of both the Deerfield and Connecticut Rivers. Find examples of meanders creating two channels; where oxbow or crescent lakes remain.

3. Find examples of sinkholes in the alluvial river plains and the large depression area near the east margin of the map.

4. What is the character of Pocumtuck Range?

5. What is the relief from Deerfield River to the trail along the crest of Pocumtuck Ridge?

6. How was the area near the town of Montague formed?

7. What types of industry are found in the area near:

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a. 69987159
b. 70007195
c. 69577168
d. 69667128
e. 70317185

8. Where is the industrial section of Greenfield probably located? How did you arrive at this supposition?

9. Describe the site and situation of Greenfield in relation to nearby natural features.

10. Describe the road and railroad pattern shown on this sheet. Note any special adaptations to terrain.

IV Walled Lake Michigan. U.S.G.S. 1945 ed. 1:24,000

The Walled Lake quadrangle illustrates depressions and accumulations of water on glacial, morainic soils consisting largely of sand and gravel.

1. Describe the general relief and overall appearance of this area. What use is probably made of the area?

2. What was the general direction taken by the Continental glacier in this area as shown by the drainage pattern?

3. Compare the road pattern in this area with that on the preceding sheet.

4. How far is it along South Commerce Road from its intersection with East Lake Drive to Carroll Lake Road?

5. How were populated places laid out in this area?

6. What different coordinates can be used for locating places on this sheet?

V Minersville, Pennsylvania U.S.G.S. 1947 ed. 1:31,680

Sandstone ridges and limestone valleys are evident on this sheet. The hard sandstone is steeply inclined in the south and gives rise to a trellis drainage pattern. Several clues to strip mining are shown in the irregularity of contours, and the road and spur-railroad pattern, especially in the Cove of Broad Mountain.

1. Differentiate reservoirs and abandoned mines that have filled with water.

2. Study the drainage pattern of the large and small streams. How are contours affected by this drainage?

3. How does the population pattern contrast with the corporate limits of Minersville?

4. Locate some specific examples of strip mining.

5. What is the shortcoming of declination information given on this sheet?

6. What do the irregular shaped boundaries that are so apparent on this sheet mark?

7. Explain the irregular pattern of the hard-surfaced, heavy-duty roads.

VI <u>Bright Angel, Arizona U.S.G.S. reprint 1947 1:48,000</u>

This quadrangle covers the central portion of the Grand Canyon. Between the fairly level Coconino Plateau to the south and the sloping Kaibab Plateau to the north, the horizontal beds of eroded hard and soft sedimentary rock form a succession of ledges, cliffs and talus slopes descending to a granite gorge in the igneous and metamorphic rocks underlying them.

1. Study the reverse side of this sheet which contains a special explanation of the Grand Canyon.

2. How do the horizontal and vertical scales on this sheet compare with those on the Grassy Cove sheet? What adjustment should be made to elevations on this sheet?

3. What caused the unusual formations along the edge of the Kaibab Plateau?

4. What is the relief from Pima Point to Granite Rapids?

5. In which direction does the Colorado River flow across

this sheet? Cite your proof.

6. Study the drainage pattern. Why are there so many intermittent streams? What must be true of the volume when water does flow?

7. Follow the means of transportation by which the area can be entered from the south and from the north.

8. What must be kept in mind in interpreting any cultural patterns shown on this sheet?

9. When revision of this sheet is made what adjustments will be made to graticule lines?

VII <u>Bath, Maine Sheet 7071 IV. A.M.S., 1950 ed. 1:50,000</u>

An excellent example of the drowned-river-mouth, irregular coastline of New England. The north-south trend of the low hills indicates the direction of movement of continental glaciation.

1. What is the general elevation of the hilltops above the sounds and bays?

2. Where are the populated places located? Of what natural features have they taken advantage?

3. Which waterway shown on this sheet is navigable as indicated by what symbols?

4. Why were the political boundaries drawn through the middle of water bodies?

VIII <u>Holden, Washington. U.S.G.S. 1949 ed. 1:62,500</u>

This is a mountainous area lying along the eastern side of the Cascade Range. It contains the small remnants of a once extensive coverage of glaciers. The previous extent of these glaciers is indicated by fairly straight major stream valleys, glacial cirques, and small lakes ponded by moraines.

1. One example of a steep-walled ampitheatre, called

a cirque, that is formed in the side of a mountain by a glacier, can be found just south-west of Holden Lake at approximately 48°13'N - 120°51'W. Find other examples.

2. Study the relationship of glacier contours shown in blue to adjacent brown colored contours. What effect do glaciers have on contours?

3. Find examples of lateral and terminal moraines.

4. Study and describe the general stream pattern.

5. Evidences of what types of industry are shown on this sheet?

6. What changes have been made to the topography at Holden? What product probably comes from this town? Check your supposition with statistical sources.

7. How adequate are transportation facilities in the area of this sheet?

IX <u>Porter</u>, <u>Indiana</u> <u>U.S.G.S.</u> <u>1940</u> <u>ed</u>. <u>1:62,500</u>

The Porter quadrangle presents another aspect of continental glaciation. The Valparaiso terminal moraine appears in the southeast corner of the sheet. Rounded irregular hills and many small lakes are typical of this type of topography. To the north, lake terraces formed by the recession of a much larger glacial lake, antedating Lake Michigan, can be seen. Active dunes are shown along the lake shore by dune formations and blowouts. The dunes are the result of wind and water action at the southern end of the Lake.

1. Study the dune formation along the lake. Find examples of dunes and blowouts.

2. What use is made of this shoreline?

3. Describe the general appearance of the area between the dunes to the north and the moraine area to the southeast.

4. Why are so many transportation lines crowded into

this area?

5. What has been done to the Little Calumet River? How do you know this?

6. Describe the drainage pattern of the whole area.

7. What has been done to aid drainage in some places? How did you decide this?

8. What is the probable function of the Chesterton-Porter area?

9. Give the location of Chesterton in terms of the Public Land Survey System.

10. Would you expect to see any major changes in the cultural pattern of this area?

X <u>Cut-Off, Louisiana U.S.G.S. 1941 ed. 1:62,500</u>

This sheet is typical of the swamp and bayou country of Louisiana. Notice the natural and man-made levees along the natural waterways. Three areas were entirely reclaimed from the swamp by levees and pumping. They sank below sea level when the water was drained from them and the one marked by Dixie Delta Club House became a new lake when pumping was abandoned.

1. Notice some spots in Delta Farms and Clovelly Farms that are below sea level. This is the result of sinking when water was pumped out of the spongy swamp land.

2. What is the average elevation of the area. Where are the highest spots?

3. The elongated property patterns show the dependence of the population upon the natural waterways and levees for transportation rights-of-way and the distribution of land to get some higher ground for each piece of property.

4. In what types of occupations might the local people be engaged?

XI Florence West, South Carolina U.S.G.S. 1945 ed. 1:62,500

This coastal area is poorly drained but is not so completely swampland as the Cut-Off, La. area. It is an area that is extensively ditched. The major natural drainage is by braided streams running at base level through swamps.

1. Study the unusual contour pattern that has been created by ditching. Follow several contours to determine their elevation.

2. Except for ditches, notice how flat the area is.

3. In which direction do the braided streams within the swamps flow?

4. Note the pattern of the corporate limits of Florence and the layout of streets within it.

5. Explain the unusual road pattern in the area.

6. What major railroad serves the area?

XII Strasburg, Virginia U.S.G.S., 1950 ed. 1:62,500

Parallel ridges and wide valleys show clearly on this sheet of a part of the Shenandoah Valley. The North and South Forks of the Shennandoah River flow in entrenched meanders at base level below the general level of the valley floor in sharp contrast to the steep slopes, adjacent to them.

1. Where could you stand and see both North and South Forks of the Shenandoah River?

2. In which direction do these rivers flow? Which fork has more rapids?

3. Describe tributary drainage in the area.

4. Why is generally, east-west-trending transportation so poor in this area?

5. What is the difference in relief between Passage Creek and the mountain ridges on either side of its valley?

6. Describe the topography of the area within the Shenandoah National Park boundary in the southeast corner.

7. Describe the population pattern.

XIII Waterville, Pennsylvania U.S.G.S. 1943 ed. 1:62,500

This sheet illustrates the appearance of the nearly horizontal strata of the Alleghany Plateau. Streams have been cut down into these strata in a typical dendritic pattern. The area is in contrast to that shown on the preceding sheet where rock strata was sharply tilted during the Appalachian Revolution leaving anticlinal ridges and cynclinal valleys.

1. What is the average elevation of the top of the plateau?

2. What is the average relief from the plateau to the stream valley floors?

3. Find examples of concave, convex and uniform slopes.

4. Describe the character of Pine Creek, its valley and the direction of its flow.

5. What was used as the boundary between Lycoming and Clinton Counties as shown on this sheet?

6. Why was the small town of Waterville, for which the sheet was named, located where it is?

XIV Kilauea, Hawaii U.S.G.S., 1924 ed. 1:62,500

This is an older sheet showing the effect of volcanic activity on an area. At the time the area was mapped, Kilauea Crater consisted of a large crater with an active fire pit over 900 feet deep. (More recent eruptions have altered the area). Earthquake cracks, lava flows and volcanic ash areas extend to the southwest. Cliff areas near the ocean are due to land slippage.

1. Notice the typical wave-like character of contours found in volcanic areas. Study the change in the trend of contours when lava outflowed from Kilauea Crater and moved to the

southwest cutting over the older flows from the northwest.

2. Find several minor craters or vents.

3. What is the highest elevation in the area?

4. Why are most of the streams intermittent?

5. Notice the water tunnel in the southwest corner of the map; also the pipe line extending from it. Why these special provisions?

XV San Francisco North, 1559 IV SW, A.M.S., 1951 ed. 1:25,000

Oakland West 1559 IV SE, A.M.S., 1951 ed. 1:25,000

These two sheets are presented together to provide better coverage of the San Francisco Bay area than either alone affords. Dense cultural detail dominates the land areas on these sheets and is typical depiction of similar urban areas. Hydrographic and navigation information is well shown and should be compared with that on the sample Hydrographic Chart when you come to that section later in this chapter.

1. Describe the terrain of San Francisco from its contour depiction. What problems of urban development are the result of terrain?

2. Compare the physical characteristics of the Pacific and Bay coasts of the San Francisco area. These and what other factors contributed to the location and development of the port?

3. Study the port development on both the San Francisco and Oakland side of the bay. How are they alike? How do they differ? How many docks are shown on the San Francisco bay front? How are they serviced?

4. By what means may traffic move across the Bay? How does railroad traffic enter San Francisco?

5. How are channels maintained on the Oakland side? If an older edition of the 1:62,500 San Francisco topographic

quadrangle is available, compare it with the present Oakland Sheet to see why this is necessary. Find examples of this same condition on the newer sheet.

6. What types of anchorages are shown?

7. How deep is the water in the center of the Golden Gate?

8. Why are markers of cablé crossings so important? How are they shown on the sheets?

9. What other types of information concerning the character and utilization of the bay are shown?

10. Study the development of urban areas in relation to the bay. Explain their urban patterns in this light.

Zonal Depiction of Hypsometry

Zones of Elevation in Place of Contours

On small scale hypsometric sheets and wall maps selected zones of elevation, often differentiated by colors, replace consistant contour intervals. This is done because precise terrain depiction and interpretation of a large area of the earth's surface is difficult or impossible when this surface is squeezed into small map units. At scales of 1:500,000 or smaller it is impossible to do more than generalize terrain features. This applies equally to depiction of elevations. A small scale map can only impart a generalized overview of the topography of the area it represents. Altitude tints are added to highlight those proportions of the overall area lying within selected generalized contour intervals or zones of elevation. Such "color-band" symbolization is intended to aid intelligent generalization. It should never be used in an attempt to gain or impart any detailed local analysis.

Where zones replace more precise contouring, it is customary to vary the numerical value of the zonal intervals. Usually small intervals are used for low elevations and are made increasingly larger for higher elevations. For this reason, selected colors indicating segments of a given area according to elevation may be deceptive and sometimes confusing. For example, a large plateau with steep escarpements may be entirely lost on a small scale wall map if this plateau lies within a zone encompassing an elevational difference of several thousand feet. The same danger may apply to a gently rolling area which undulates within the elevational limits of any specified color. This condition can be found within any zone ranging from green to red in color if the International Color Scale is used.

Illustrations of Zonation

Study the following maps and compare the degree of definition or generalization shown on them.

1. Compare the 1:25,000 and 1:50,000 Hagerstown sheets with the same area shown on the 1:1,000,000 Chesapeake Bay NJ-18 sheet. Notice the difference between precise contour and zonal depiction of terrain.
2. Examine the two 1:1,000,000 sheets of Piura SB-17 and North Borneo NB-50 as examples of color-banding. Note the differences in presentation among these and Chesapeake Bay sheet.
3. Compare each of these with any small scale physical wall map or maps showing the same areas. Are there any differences in zone depiction or delimitation? If so, is it due to scale?
4. Draw several rough profiles to illustrate the differences in topographic definition between contouring and color-banding.

Perspective Maps

Many semi-pictorial and at the same time useful types of maps are developed on the principle of perspective. These follow the same general principle as that used for perspective projections and oblique photographs. They result in maps that look like simplified pictures of the earth since the major difference between them and actual aerial photographs is in the amount and type of detail shown. An aerial photograph includes all visible features in a limited area. The perspective map shows only selected detail of a large or small area.

Perspective maps have been widely used in American newspapers and periodicals such as Time, Life and Fortune. Many similar examples have been produced by European cartographers. The addition of color makes features drawn on these maps seem to rise off the flat sheet. Mountains stand out, the entire map surface seems to curve and recede from a given eye point because of the optical illusion created by clever applications of perspective.

The similarity between perspective maps and photography is revealed in the fact that such maps can be created photographically by taking pictures of globes or raised relief models. Textbooks often include maps giving general impressions of features as they are "seen" by looking at a globe. The globe may be tilted or revolved in several ways to achieve different perspective views of it.

One of the major difficulties in this type of map is scale. On most of the popular maps the inadequacy of scale is subordinate to the realistic appearance and easy visualization of terrain. By different placement of the camera or eye point, however, scale can be made smaller or larger or retained in equality of size to near objects.

The chief value of such maps, and the only reason this brief mention is made of them, lies in their attractiveness and visual presentation of topographic features. They do not require the educational sophistication needed to interpret contoured maps. Make it a class project to prove the truth of this statement by collecting several examples of these picture-like maps from newspapers and periodicals.

Specialized Types of Maps

Many types of maps can be adapted for several purposes if only generalized coverage of an area is desired. Since every map is constructed with specific purposes in mind. Their adaptability is conditioned by the fact that some are more highly specialized than others. On some, information is intended so specifically for a special purpose that they have little value for other purposes. Intelligent use of these highly specialized types of maps necessitates correlation of information shown on them with other maps or sources. "Other sources" can well be knowledge which the map-user has stored in his mind as well as that contained in books.

The modern trend in cartography has been toward making individual maps for each different type of information rather than trying to crowd everything on one sheet. This tendency facilitates visualization of one or a few patterns without having to search and pick out the information desired from among a profusion of symbols. It presupposes the understanding on the part of the user

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that he cannot use one map as an end in itself but rather, as a means to an end.

As was indicated in the introductory chapter, no field of human endeavor is, or need be, devoid of cartographic representations. The diversity of information reducable to maps, charts or plans is endless. Such mapping can be allocated to three major classes which overlap in many cases. These classes are:

1) Maps presenting statistical information in graphic form;
2) Maps revealing the distribution of cultural and/or natural patterns;
3) Maps interpreting special types of information.

Statistical Depictions

Comprehension and visualization of tables of figures is difficult for most people. When numbers increase to astronomical proportions it is probably impossible for anybody to fully comprehend them. Possibly the best approach in this case is to present the values in some comparative way by reducing them to units that can be counted or compared at the level of the average person's mathematical ability. These simplified units may either be presented as graphs, maps or map-graphs. Each of these is a form of cartographic representation and will be briefly considered at this point since each is useful in the development of map intelligence.

Essentials of Graphing

Many forms of graphs can be incorporated into a map to correlate a real location with statistical quantity. Graphs may also be used in conjunction with maps without a physical unity between them. The chief purpose of a graph in any case is to present statistical material in an easily read form. Since this is true, graphs should not be so complicated as to obscure the message they are meant to convey. Not more than one or two major groups of statistics per graph is a good rule to follow if you have ocassion to select or construct a graph or group of them. A simple graph will tend to stimulate thought concerning comparisons, trends, changes or current values whereas a complicated one may intimidate its user and stifle original thought.

The following major factors to be considered in the construction of a graph apply equally well in analyzing and evaluating the finished product.

1. Selection of a Unit of Measurement: This can best be done by considering the largest and smallest amount involved. Too widely differing amounts are not compatible to most types of graphing and should be avoided or regrouped in another way. A suitable type graph and unit must be selected which will accommodate the smallest amount and still stay within the size of the paper when units are multiplied to equal the largest entity.

2. Arrangement: Since readability is the primary objective, statistical depictions should be arranged in ascending or descending numerical order whenever this is feasible. Individual units should be separated if it is at all possible in order to aid the reader in defining and evaluating the number of units.

3. Symbols: Symbols should be selected that can be differentiated. Complicated symbols are difficult both to reproduce and to read. Symbols should also be large enough to be seen and yet not so large as to distract the reader from the main purpose of the graph.

4. Key: Symbols should either be clearly labelled or else a statement should appear in the margin explaining what each symbol represents in terms of its quality and/or quantity.

5. Numbering: Sufficient numerical guides should be included so that units or total amounts can be read. A graph has two and material on each axis should be explicitly labelled. For example, the horizontal axis might represent years and the vertical axis the number of automobiles.

6. Title: A title should contain as few words as possible and yet clearly indicate the import of the graph. It is often wise to have a major title to tell the overall story and then a subtitle to convey the idea of time, dates, amounts, etc.

7. Source of Information: Credit should always be given to the source of the information used. This enables the reader to evaluate the reliability of the information or check the accuracy of the graph maker in using that source. A credit note also relieves the maker of some of the responsibility for inaccuracies in the source. The compiler should, of course, use reasonable care in selecting his sources to lessen the possibility of such errors.

Types of Graphs:

1) Pictograph: This is the simplest type to read since conventionalized pictures are used for units. An even quantity should be used for each full unit, and should be represented by an easily recognized symbol. One of the major shortcomings of a pictograph occurs in the presentation of less than unit quantities. Small fractional parts of an ear of corn, railroad car or other pictorial unit are almost impossible to evaluate. The best that can be derived from such disjointed parts is that something less than a full unit is intended.

2) Dots, Circle or Square Units: Just as in map symbolization, actual objects can be reduced to abstract symbols such as dots, circles or squares. These are easy to count but have the same weakness as pictographs in presenting fractional parts of a whole unit.

Bar Graphs:

Single Bar Units: In place of separate units a bar can be used to present the quantity desired. This is the simplest type of abstract symbol showing a direct comparison of quantities. Amounts are represented by bars of equal width and of a total length equal to their proportionate value in terms of the selected basic unit.

When many bars comprise a single graph, a vertical arrangement of the bars tends to produce a more pleasing result than an horizontal placement. There is no arbitrary rule about this, however, and attractive arrangements can be a achieved in either plane.

Double Bar Units: This type may also be called a mirror bar graph. Two sets of related statistics are united by some characteristic they have in common. The center is the common factor and bars extending outward on either side represent amounts, value, character, etc. Such unification brings together related statistics and creates an opportunity for stimulating more relationship thinking than is possible with single bar graphing.

Multiple Bars: Several bars can be tied together by a common unit such as period of time. For example, a graph showing retail sales over a given number of months can be presented by bars representing the sales of each of several major retail groups such as grocery, bakery, hardware, etc. repeated for each month involved. In this case symbols or colors must be added to differentiate what each bar represents unless labelling is repeated on each bar. Spaces should be left between the sets of bars or their conglomeration becomes confusing to the eye and temptation to skip over the whole mass is encouraged.

One Hundred-Percent Bars: All component figures are arranged along a bar according to percentage parts and the total length of the bar represents one-hundred percent. Thus, the bar is divided into the percent each factor bears in relation to the whole.

Values must be converted into percentages before this type of graph can be constructed. It is often advisable, therefore, to show two scales along the bar, one giving percentage values and the other the numerical equivalents. If the latter is omitted the reader must resort to mathematics to determine what the actual value of a given component is on the basis of its percentage value in relation to total value.

Bar and Trend Graph: This is a combination of two forms. Each bar shows totals for a given period and is further subdivided into components of the whole. A line drawn across comparable subdivisions of the bars will show the trend of that item over the period of time covered by the graph.

Line Symbols: Lines indicate the change of one factor in relation to another. The most common variety presents change of an entity over a period of time. If the change is continuous it is customary to draw the line connecting points as a smooth curve. If the change is noncontinuous the plotted points may be joined by a series of straight lines. Care must be taken to locate and to read these points at the intersection of the two coordinates.

All lines should be related to a zero point of origin which is usually placed in the lower left corner of the graph. If it is impractical to start at zero because of the uniformly large size of the values to be graphed, some prominent signal should appear on the graph to call attention to the revised datum point. In this respect graphing is similar to contouring on topographic maps or to profiling of a given area.

Line graphs may either present the total amount of change or, the rate of change. If the former is desired scale intervals must be uniform arithmetic intervals. If the rate of change is desired, logrithmic intervals can be used.

Line graphs may also be adapted to show percentage changes by adding symbols or colors on either side of the line or between lines if more than one has been plotted on a graph. These divisions can then be labelled in terms of their percentage of the whole picture shown by the complete graphed surface. This type is analogous to the bar-trend graph mentioned above.

Circle Symbols: This type is often referred to more expressively as a "pie" graph. A whole quantity is represented by a circle and component parts are shown as pieces of the pie. Here, again, statistical values must be translated to percentages of the whole. These percentages are then computed in terms of the angle or part of the 360° they represent and radii are drawn at the appropriate intervals to thus divide the circle.

Although the circle graph enjoys widespread popularity, it is the author's belief that it should be avoided whenever possible. It is difficult to read. Most reading experience is developed along straight lines and consequently the eye has difficulty differentiating parts of a circle, especially if there are several small segments of nearly the same total value. It takes a great deal of practice to be able to see the difference between segments that may be as much as five percent smaller or larger than other segments. No such difficulty is presented by bar graphs.

There are many other types of graphs that can be constructed for statistical visualization, but they are not commonly used in combination with map bases and so are not included in this summary.

Statistical Maps

The general principles of graphing are readily converted to statistical mapping. One category of special type maps depict variations in amount, value or density of distribution of given items. These statistics are shown by dots, different types of isolines, as well as by superimposed graphs.

There are several factors that the map reader must consider as soon as he turns to any type of statistical map for information. He must determine whether the information is reliable or is a biased presentation for propaganda purposes. Just as in other types of mapping, the sources used or responsible for the map will give him a clue to reliability. He must also determine whether the data is recent or old enough to be of historical rather than current significance. The user must recognize of course, that some entities remain valid and are not affected materially by time lapses. On the other hand, there are times when such things as wars, emergencies, droughts, etc, create extenuating circumstances that alter or disrupt normal distributions. The map reader must appreciate the possibility of such factors and check for their existence rather than accepting any statistical map on the blind faith that it is the answer to his needs.

Dot Maps

Most students are familiar with the dot method for showing comparative density and distribution of given items. These facts are presented by dots usually of uniform size with each dot representing a given quantity. Careful consideration must be given to the assignment of value for each dot so that, taken together, they will not create a false impression of density. If each dot is assigned too large a quantity, the resultant pattern will seem very sparse. If each dot stands for too small a quantity, they may coalesce into a solid unreadable mass. The trick, obviously, of good dot mapping lies in the selection of a value for each dot that will create block areas where distribution is heaviest and yet will reveal any proportionately sparser distribution over the rest of the area.

Interpretation of a very dense pattern needs to be tempered with understanding as this little anecdote illustrates: A class had been studying a dot map of pig distribution in the corn areas of Iowa. Finally one little boy timidly ventured to ask, "If there are so many pigs in Iowa, where do the people live?"

Effective dot maps are usually compiled on large scale map bases, preferrably ones that include the outlines of minor civil divisions or countries. Statistics are usually compiled on the basis of such political units and, therefore, can be better distributed on a map outlining these units. The resultant compilation can then be reduced, omitting the civil boundaries. Only the dots and densities remain in their proper positioning on the final map.

Normally dot maps show the pattern of only one item unless the distribution of two related items is such that their patterns do not overlap as, for example, wheat and rice production in the United States. It is also possible to show more than one distribution in a common area by the using of contrasting colors.

Some wall maps show world distribution of commodities in this fashion. They have the disadvantage that where areas of dense distribution overlap, the colors become ineffective and the separate patterns are not clear-cut. Scattered rather than concentrated distributions are more feasible for representation by different colored dots.

Isoline Maps

The density and distribution of several different kinds of elements can be shown by lines connecting points of equal quality or quantity, such as, contour lines (isohypses).

Considerable disagreement exists as to what generic name should be given to this group as a whole. Some authorities favor the term isopleth derived from "isos" which means the same and "plethron" meaning measure. Others prefer isarithm combining isos and arithmos meaning number. Still others advocate isogram. The term "gram" refers to the whole system rather than the lines composing it. Because of this disagreement, your author has chosen the simple term ISOLINE since each line expresses an equal or same amount of something.

All forms of isolines are figured from a common datum plane or value such as Mean Sea Level or Zero and are drawn at selected intervals and numbered appropriately. Isoline type of depictions can only be used when statistical coverage is fairly ample and for items that are transitional and not variable in distribution.

Isotherms

Lines showing the distribution of equal temperature values are isotherms. It is quite common to apply graduated color tints

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between isothermal lines to clarify the interval values and highlight the transition of average temperature readings within the total area being mapped.

For general study of the variations of the temperature component of climate, average figures are preferrable for developing isotherms. Averages covering at least a twenty-five year period, whenever records have been kept that long, insure a typical rather than annual variable pattern. This holds true for figures recorded concerning any natural changeable phenomenon such as temperature, precipitation, pressure, etc.

The map reader should note the length of the averaged record if it is given. If the figures cover a long period, he must realize that the process of averaging smooths out annual fluctuations and presents only the statistical norm for an area. Even a map for one year is based upon monthly averages. For any given month, the daily temperature of a place may vary a large number of degrees between the lowest and highest recorded temperature,

Isohyets

Places recording equal amounts of precipitation are connected by isohyets. These lines are constructed and the intervals between them are often tinted in the same way as for isothermal maps. Isohyets may be reckoned in either metric or English units. Normally they are expressed in inches in the United States.

Isobars

Equivalence of barometric pressure is depicted by isobars. Previous to World War II pressure was usually expressed in inches. Normal pressure on a column of mercury at sea level was taken to equal 29.45 inches. More recently the tendency has been increasing to express pressure in millibars. The United States Weather Bureau adopted this unit in 1945 to conform to international practice in this respect. Normal sea level pressure equals 1013.2 millibars in this system.

<u>Daily Weather Map</u>

Definitive research into the weather that lies behind statistical climate of an area demands inspection of daily weather phenomena. Daily, and even hourly, information is also needed by businessmen and airmen. Such weather maps are available in many countries for this purpose. The United States Weather Bureau is responsible for the compilation and dissemination of these maps in the United States.

Weather maps are an excellent example of cartographic statistical compilations. On them, pressure is shown by <u>isobars</u> expressed in millibars. Station models provide numerical and symbolic information about pressure tendency; temperature; dew point; amount and kind of precipitation; velocity and direction of wind and, the amount and kind of cloud coverage. Each of these variables is well explained and illustrated on each map sheet. In addition, the Weather Bureau publishes items of special interest on the back of sheets from time to time. Such things as explanations of unusual types of storms; the effect of temperature on certain crops and other research in weather or climate are included on these Back-Ups.

It would be well worth class effort to spend a short time analyzing a few weather maps, obtainable for this purpose from

The Chief Forecaster, United States Weather Bureau or the Superintendent of Documents, Washington, D.C. The object of such an exercise would be to gain familiarity with the types and interpretation of the statistical presentation of weather rather than to memorize these symbols.

Isogones

Lines connecting equal amounts of magnetic declination from true north are isogones. They were mentioned previously in the discussion of magnetic declination diagrams and graphs.

Many other types of isolines have been devised but those defined above are the ones used most frequently in mapping natural phenomena.

Isopleths

Lines indicating an average number of units are defined in this text as isopleths. Isopleths are generally better adapted to cultural elements such as population density etc. Although such lines are drawn through spots having a given number of people it does not necessarily follow that there is a uniform gradation of population between any two consecutive lines, as for example, between 80 and 100.

Isopleths may also be used to define changes in the percentage distribution of an element. For example in a steel producing area isopleths could be used to indicate the percentage of the total number of plants in each band or zone devoted to some form of steel production or fabrication.

Choropleths

In this form of statistical map, information is presented in terms of fixed divisions such as minor civil divisions. Each civil division is colored or lined as a unit without attempting to differentiate distribution within the unit. In other words the statistics are presented by political blocks or shapes.

Modelled Isoline Maps

Any of the isoline variety of maps can be built up into raised models just as contours were built up by plastic laminae on the raised relief Training Model. Elevating the areas of densest distribution highlights this fact for the viewer and eases his job of differentiation. The technique is not widely used, however, probably because of cost and distribution factors.

Graphs Superimposed on Maps

Many atlases include maps that present various distributions by circle or sphere graphs superimposed on maps. Circles are oriented over the spot of densest concentration or center of gravity for a group of concentrations. Circles may be made uniform in size or varied to express changes in total quantity. These circles may be subdivided to show two or more related quantities composing a whole. For example, circles of varying size may show the total consuption or production of power for each political unit in Europe; these circles may then be divided internally to show the types of power such as carbo-hydro-and petro-electric. Subdivisions of circles can be shown by different colors. If the colors are kept light in tone some overlapping of circles is possible but not too attractive because of the "muddy" tones that result.

All the disadvantages of circle graphs are magnified in superimposing them on maps. The major advantage in using such a technique seems to accrue from the possibility of showing several items on one map where space is critical or when cost of production of several separate maps would be too great. Specific examples of this type of statistical map are to be found in Goode's School Atlas which is available in most colleges.

Bar graphs may also be used on maps. In general, they lack the individual unity of circle graphs and so can only be used in a spaced distribution. Too many or too lengthy bars would overlap neighboring graphs.

Pictorial symbols can create an interesting map. To be statistical each symbol must stand for a given quantity of the item. The major difficulty here is that it takes more space to reproduce a picture of an ear of corn or a sheep than is needed for a dot to represent the same fact. Coalescing of pictorial symbols is both unattractive and valueless.

These pictorial symbol maps are not to be confused with the pictorial map. The latter merely shows that tobacco, tomatoes or trucks are produced in a given area. They give no clue as to quantity or even degree of importance. Often pictorial maps only serve to perpetuate false impressions about the functional importance of a product in the total economy of an area. The unwary may be led to believe that oranges are the only thing produced in central Florida, or automobiles in Detroit.

<u>Special Patterns</u>

Valuable statistical information is presented in qualitative as well as quantitative cartographic representations. Often in developing an understanding of specific regions or some particular phase of human activity statistical quantities are less important than areal distributions. Specialized branches of the various earth sciences have developed and rely upon maps and diagrams showing such things as geologic formations, physiographic details and provinces; soil classification; mineral distribution; vegetation types, etc. Such qualitative analyses are needed to introduce newcomers to the particular field and to keep experienced researchers properly oriented to overall relationships within and among fields.

Geology

Geologic formations are implicated in all surface and subsurface utilization of the earth. Construction engineers must analyze the materials into which foundations are to be sunk. Mining engineers examine the strata and types of formations to estimate the probability of finding particular minerals they seek. Agricultural experts study the relationships of geology to soils and farmland utilization. Military intelligence specialists delve into the geology of strategic areas for sources of such things as construction material and the potential and actual trafficability of an area. Geographers review the geologic base as a foundation for the cultural and natural distributions occupying the terrain.

In response to these and many other needs and objectives, both large and small scale geologic maps are prepared. Private industries contract for the preparation of such maps or maintain their own staffs of cartographers. Large scale maps and geologic folios to accompany many of the topographic quadrangels have been prepared and distributed by the Geological Survey in the United States. Similar sources are available in several foreign countries. These sources give detailed explanations of surface formations and columnar sections of subsurface conditions. They are often accompanied by geologic profiles showing the arrangement of rock strata and descriptions of the geologic processes involved in their formation. Such large scale coverage is used as the basis for providing generalized information about larger areas shown on small scale maps such as the wall sized 1:2,500,000 Geolgic Map of the United States prepared by U.S.G.S.

1. Examine the Geologic Map of the United States.
2. How are different types of formations shown?
3. Compare a specific formation shown on the generalized geologic map with a topographic quadrangle covering this area.
4. Obtain the appropriate geologic folio to accompany this quadrangle if such a folio is available.
5. How does the depiction of formations compare as to symbolization and content on these two sources?
6. What construction materials and minerals are available in this area?
7. What advantages or disadvantages exist in the utilization of these materials?
8. Are any cultural or natural distributions specifically affected by the geology of the area?

<u>Physiography</u>

Information concerning physiography is most commonly shown in either of two ways on physiographic maps. One divides a country or continent in terms of Physiographic Provinces. A PHYSIOGRAPHIC PROVINCE is a region where the landforms are similar because they are all in the same stage or cycle of erosion. This similarity of landforms often leads to a similarity of occupations and land utilization. This does not imply geographic determinism but does infer that logical relationship potentials exist and may become actualities in given areas.

The other depicts landforms in physiographic symbols that strongly suggest the actual terrain condition. This type is especially valuable in visualizing an area without involving precise elevations above sea level. Natural reasons for such things as the movement and concentration of population can be appreciated by studying physiographic diagrams and landform maps. Natural avenues of transportation such as passes and valleys show up very well if these maps are not too generalized.

There are several examples of such physiographic representations with which college students should be familiar. Guy Harold Smith, Erwin Raisz and Wallace Atwood are outstanding exponents and creators of these maps in the United States. Examples of each of their works should be examined and compared to obtain an appreciation for the value of physiographic depictions.

The following three plates and glossary of terms to accompany them provide a basis for exploring and interpreting physiographic symbols. The terms are arranged alphabetically and each that is illustrated is followed by a letter A,B, or C referring to the Plate, and a number indicating their respective locations.

On all of the Plates will be found a name and number for each object illustrated. Cross reference between text and plates is thus made easy. Certain physiographic terms, referring to such processes as MARINE EROSION or such abstract concepts as ALTITUDE or CLIMATE do not lend themselves readily to illustration on the scale used for the Plates and so appear only in the text.

PHYSIOGRAPHIC TERMS

AA LAVA
A lava flow with a very rough surface.

ACIDIC
An igneous rock composed of minerals which have a high proportion of silica (SiO_2). Granite and Syenite are acidic rocks. Such rocks are usually light in color; some shade of gray, pink or red.

ADOBE
Mud which is very slippery and sticky when wet, and hard when dry. Commonly used for sun-dried brick.

ALLUVIAL CONE. C-226
Stream-carried gravels and sands piled in a steep-sided cone-shaped mound at the foot of a steep slope.

ALLUVIAL FAN. C-207
Stream-carried material piled in a gently sloping cone-shaped mound at the base of a slope. Rather coarse material; pebbles and coarse sand.

ALLUVIAL PLAIN. A-89
An essentially level surface underlain by stream-deposited material. Broad flood plains are alluvial plains.

ALLUVIUM
Stream-deposited material, usually gravel, sand, mud, or silt.

ALP
a. A high upland meadow.
b. A very high mountain.

ALTITUDE
Height above a reference point or surface; most commonly, the height above mean sea level. Same as "elevation".

ANGULAR PROFILE. B-153
A profile in which abrupt changes in slope occur in contrast to rounded slopes.

ANNULAR DRAINAGE PATTERN
Streams flowing in arcs around a central area.

ANTECEDENT STREAM. C-214
A stream which antedates the ridge it cuts through and which carved its valley as the terrain was being up-lifted.

ANT HILLS
The piles of sand and organic material built by ant.

ANTICLINAL MOUNTAIN. B-140
A mountain in which the rock layers are bent in the form of an arch.

ANTICLINAL VALLEY. B-142
A valley which has been carved in the apex of arched layers of rock.

ANTICLINE
Rock layers bent into an arch form.

AQUIFER
A water-bearing bed or layer of rock.

ARCH. A-51
An arch hollowed out of bedrock by erosion. See "natural bridge and sea arch."

ARCHIPELAGO. A-51a
A group of islands of considerable extent. Example: the West Indies, the Aegean Archipelago.

ARETE. A-9
A sharp-crested ridge between two mountain gorges.

ARID CLIMATE
A climate generally deficient in moisture. An area with such a climate usually has dry soils streams, mostly intermittent, and a sparse plant cover. Semiaridity means a lesser deficiency in moisture.

ARROYO
A small valley or gully, often dry. Also used to mean a small stream. Western U.S. usage principally.

ARTESIAN WELL
A well in which the water is underpressure so that it rises to the surface without pumping.

ASH
Fine-grained rock material blown from a volcano. Commonly called "volcanic ash".

A.T.
"Above Tide" or above sea level.

ATOLL. A-45
A more or less complete ring of coral reefs around an area of open water.

AVALANCHE
A sliding, falling mass of snow, ice and rock. See "snowslide" and "landslide."

AXIS OF A FOLD
The mid-line of a fold in rock layers.

BACKSLOPE. C-211
The less steep of the two slopes on opposite sides of a ridge when there is considerable difference in the slopes.

BADLAND TOPOGRAPHY. C-217
Highly gullied relief surfaces that develop under simi-arid conditions in weak strata-largely sandy clays characterized by many pinnacles, shelves, spurs, etc., formed from these rocks.

BANK (Submerged). .A-36
An elevation under the sea which forms a shoal or shallow area.

BAR. A-27
A bank of sand, mud, gravel, or other material, as at the mouth of a river or bay.

BARCHAN DUNE. B-122
A horseshoe-shaped pile of sand built by the wind.

BARRAGE
An artificial bar, wall, or dam in a watercoarse, constructed to raise the waterlevel up stream. Common English usage.

BARRIER BAR. A-60
A bar built along the shore but separated from it by a lagoon. Also called a "barrier beach."

BARRIER REEF. A-46
A coral reef lying offshore but parallel with it.

BASALT
A fine-grained basic rock, usually dark green or greenish-black in color.

BASE-LEVEL
The lowest level to which running water can erode the land.

BASIC ROCK.
An igneous rock which has a low proportion of silica(SiO_2) in its

minerals. Basalt and gabbro are basic rocks. Such rocks are usually dark in color, as dark gray, green, or black.

BASIN. C-189
A depression in the earth's surface varying greatly in size but usually fairly large. Of varying origin; may be eroded by a river or formed by earth movements, i.e., downfaulting.

BATHOLITH. B-154
A huge mass of igneous rocks intruded into the surface rocks and enlarging downward without a known base. Must exceed 40 square miles in area; if less, it is known as stock. See "stock".

BAY. A-34
An inlet or arm of the sea partly surrounded by land, usually smaller than a gulf.

BAYHEAD BAR. A-33
A bar near the inner end or margin of a bay but separated from the shore by a lagoon.

BAYHEAD BEACH. A-25
A strip of wave-deposited material along the shore at the inner end of a bay.

BAYSIDE BEACH. A-39
A strip of wave-deposited material along the shore at the side of a bay.

BEACH. A-66
A zone along a coast from the upper and landward limit of effective wave action out to the lowest tide level.

BEACH RIDGE
Ridge of sand or pebbles built along a beach usually parallel with the shore.

BEDROCK. A-48
The solid or hard rock of the crust of the earth. The "mantle rock" is broken up bedrock.

BETRUNKED RIVER SYSTEM. A-94
A river system, the lower course of which has been depressed below sea level and hence all the tributaries have had their lower courses drowned. Example: Chesapeake Bay, the Susquehanna River, and the Potomac, York and James Rivers.

BLIGHT. A-64
A curve in the coast forming an open bay; or, the body of water in such an open bay.

BIOTITE
Black mica, a mineral.

BIRDS-FOOT DELTA. A-70
Deposit at the mouth of a stream in the form of low radiating ridges which rise above water level.

BISCUIT-BOARD TOPOGRAPHY
A rolling upland scalloped by numerous cirques which appear like huge bites.

BLOCK BASIN. C-215
A low area lying between adjacent segments of the earth's crust which are at high levels. Such basins result from uplift of the adjacent segments of the downward movement of the block basin itself. See "bolson," "graben," and "rift valley."

BLOCK BASIN LAKE. C-209
A lake in a trough, graben, rift, or basin that was formed by faulting of the earth's crust.

BLOCK MOUNTAIN. B-108
A mountain formed by the elevation of a part of the earth's crust by faulting or earth movements.

BLOCK PLATEAU
An extensive upland formed by the elevation of part of the earth's crust by faulting. See "horst."

BLOWOUT
A depression made across a ridge of sand, such as a dune ridge, by the sand being blown away.

BLUFF. A-81
A high, steep bank of loosely consolidated material such as clay, sand, or loess.

BOG
Wet spongy ground where a heavy body is apt to sink.

BOLSON
A broad, enclosed basin with gentle slopes found in a desert or semi-arid regions. See "rock basin."

BORE
An inrushing high tide, occurring as a definite, crested wave in certain rivers. Example: Amazon, Ganges, Indus.

BOULDER
A more or less smoothed rock fragment over a foot in diameter.

BOULDER CLAY
A mixture of large and small rock fragments without assorting. See "glacial till."

BRAIDED STREAM. C-177
A stream course in which the water flows in several more or less parrallel channels.

BRECCIA
Cemented gravel in which the pebbles are angular rather than rounded.

BROOK
A stream smaller than a river; a rivulet.

BUTTE. C-156
A flat-topped and steep-sided erosional remnant, smaller than a mesa or mountain.

CALDERA. B-127
Crater or pit-like basin of great size formed where a volcanic cone has had its top blown off by eruption. Example: Crater Lake, Oregon.

CANOE-SHAPED MOUNTAIN. B-149a
A ridge shaped like the bow of a canoe. It is formed from an eroded syncline whose upturned edges form the end of an ellipse, whose axis dips below the earth's surface.

CANYON. B-113
A narrow valley with at least part of the walls vertical.

CAPE. A-57
A point or projection of land extending into the sea of a lake.

CATSTEPS
Small paths made by animals which mark steep slopes with a step-like pattern.

CAVE
A solution cavity in the ground which is usually reached through a narrow opening. Also a hollowed out chamber in the earth or in the side of a cliff.

CAVERN. C-163
An underground chamber or cave, usually large.

CENOTE
A sinkhole in Yucatan. See "sinkhole."

CENTRAL ISLAND. A-44
An island, usually a volcano, surrounded by a barrier reef.

CHALK
A fine-grained, soft, light-colored limestone.

CHERNOZEM
Rich, black soil. The name is given to a soil belt across Central

European Russia.

CIGAR-SHAPED MOUNTAIN. B-150
A long, oval-shaped mountain formed from an anticline whose axis is bowed along the length of the ridge.

CINDER
A broken fragment of porous lava.

CINDER CONE. B-123
A volcanic cone or hill made of broken fragments of lava; the product of volcanic explosion.

CIRQUE. A-22
An amphitheater-shaped hollow made in a mountainside by glacial erosion. See "corrie."

CLASTIC
Broken rock fragments of any size.

CLAY. C-229
The smallest size of fragments; too small to be seen individually by the unaided eye.

CLEAVAGE
The tendency of minerals or rocks to break more readily in certain directions.

CLIFF. A-37
A steep face of bedrock.

CLIFFED HEADLAND. A-56
A point of land jutting into the sea, which has cliffs at its outer end.

CLIMATE
The average of weather conditions over a long period of time, i.e., several years or centuries.

COARSE-GRAINED
Having particles or grain easily visible to the unaided eye.

COARSE-TEXTURED DRAINAGE
A drainage pattern with the streams far apart.

COARSE-TEXTURED TOPOGRAPHY. A-13
A land surface with long unbroken slopes.

COAST
The seashore and land near it, including islands.

COASTAL PLAIN. A-71
A plain along a coast, usually an uplifted part of the old sea floor.

COASTLINE
A line delimiting the water level of a lake, or the upper and landward limit of effective wave action along the ocean.

COL. C-220
A low place in a mountain ridge. See "gap."

COLUMN. C-231
A deposit in a cave which is in the form of a more or less cylindrical mass which reaches from floor to ceiling, made by the joining of a stalactite and a stalagmite.

COLUMNAR STRUCTURE. C-224
The form of jointing in some dark colored igneous rocks which is in long, flat-sided prisms, frequently six-sided and more or less vertical.

COMPLEX TOMBOLO. A-53
Several formet islands tied together by bars.

CONDUIT. B-143
The channel or vent through which molten rock reaches the earth's surface.

CONGLOMERATE B-143
A rock of rounded or water worn gravel which has its sand and pebble constituents cemented together.

CONSEQUENT STREAM. A-75
A stream which has its course determined by the slope of the land.

CONSTRUCTION FORMS (Features)
Topographic features which have been made by deposition, volcanic eruption, or faulting.

CONTINENTAL GLACIER. C-165
An ice sheet which covers an extensive area such as a considerable part of the continent. Example: Antarctica and Greenland.

CONTINENTAL SHELF
The area along the edge of a continent where the sea is shallow, i.e., not over 600 feet in depth.

CONTOUR INTERVAL
The difference in elevation (feet, yards, or meters) between any two adjacent contour lines.

CONTOUR LINE
A line on a map, every point of which is of the same elevation above mean sea level. See "marine contour."

CORAL REEF
The accumulation of masses of coral skeltons with other lime

deposits in tropical waters.

CORDILLERA
A mountain range or system; usually refers to the principal mountain range on a continent.

CORRIDOR
A relatively narrow section of terrain extending towards the enemy and limited laterally by ridges, rivers, lakes, or other natural features.

CORRIE
Scottish. See "cirque."

CRATER. B-120
The depression in the top of a volcanic cone.

CREEK
A stream of moderate size, not always distinguished from a "river" or "brook". Also used to refer to a small narrow inlet or extuary. (English usage).

CREVASSE
A large crack or crevice in the surface of a glacier.

CRYSTALLINE ROCK
A general term applied to most igneous and metamorphic rock; commonly hard and resistant.

CUESTA. A-98
An elevated area with a steep face on one side and a long gentle slope on the other.

CUSPATE FORELAND. A-26
A triangular patch of sand built out from a point of land which projects into the sea.

CUT-OFF. C-201
The channel which a stream cuts across the neck of a meander. (A "chute" in the lower Mississippi).

CYCLE OF EROSION
The wearing away of land surface from the beginning of the erosion, to the completion of the erosion process, a process which may take millions of years. No cycle in nature is ever complete without interruption.

DECOMPOSITION
The disintegration of rocks by chemical agents so that the mineral composition of the rocks is changed. See "weathering."

DEFILE
Any feature such as a narrow valley, ford, bridge, or swamp that

restricts the front of an advance or prevents lateral deployment.

DELTA. A-65
A deposit made by a stream at its mouth; more or less triangular in shape. Example: Mississippi and Nile deltas.

DELTA LAKE. A-69
A water area enclosed within a delta.

DELTA PLAIN
The level surface built above water by a stream at its mouth.

DENDRITIC DRAINAGE. A-74
A pattern of streams in which the tributaries tend to converge toward a central drainage line, thus roughly resembling the convergence of veins on a leaf.

DEPOSITION
The laying down of material by natural transporting agents such as water, wind or ice.

DEPOSITIONAL FORMS
Topographic features made by deposition of material usually gravel, sand, or silt.

DESERT
A more or less barren and arid area incapable of supporting much vegetation or any considerable population without an artificial water supply.

DETRITUS
Loose material that results from breaking up of the bedrock.

DIFFERENTIALLY WEATHERED SURFACE
Irregular surface produced because some rock disintegrate more easily and quickly than others.

DIKE. B-128
The tabular mass of igneous rock, in a more or less vertical plane, that fills a fissure or crack in other rocks. Erosion may cause the dike to appear above the surface as a wall, or below as a trough.

DIP
The angle in degrees that tilted rock layers form with the horizontal plane.

DISINTEGRATION
The breaking up of rocks by physical agents. See "weathering."

DISSECTED
An area with numerous valleys or gullies that have been eroded in into its surface.

DISSECTED PLAIN
A plain in which numerous valleys have been cut by streams or glaciers.

DISSECTED PLATEAU
A plateau in which valleys are so close together that most of the area is in slopes.

DISTRIBUTARIES. C-203
Streams formed, expecially on a delta or alluvial fan, when a stream subdivides.

DIVIDE
A line separating two drainage systems. See "watershed."

DOLINE. C-161
A large sinkhole or funnel with irregular outline. Essentially like the cenote of Yucatan.

DOLOMITE
A rock composed of calcium an magnesium carbonate. Sometimes included under the general term "lime."

DOME. C-193
An area in which the rocks are arched or pushed up so as to dip away from the center in all directions.

DOME MOUNTAIN
A domed area raised high enough to be a mountain.

DOWN
A grass covered tract of rolling land; especially in Great Britain.

DRAINAGE
The way in which water flows from an area through streams and rivers, or "underground."

DRAINAGE PATTERN
The arrangement of the streams which drain an area.

DRIPSTONE
Deposits made from the water which drips in caves.

DROWNED COAST
A coastal area which has been depressed so that the sea enters the lower ends of the valley. Example: The New Jersey-Delaware coast.

DROWNED VALLEY. A-67
A valley which has beendepressed so that the sea has flowed into it, Example: Chesapeake Bay.

DRUMLIN. C-191
An oval-shaped hill with rounded profile made by glacial deposition.

DRYING FLAT
A bank of mud or sand, or a ledge of rock which is uncovered at low tide.

DRY LAKE
See "playa."

DUNE
A wind-deposited pile or ridge of sand.

DUNE AREA. C-178
A surface largely covered with wind blown sand heaped up into hillocks (dunes) Example: Southern and eastern shores of lake Michigan.

DUNE RIDGE
A long pile of wind-blown sand.

DUST STORM
Winds which carry a large amount of silt and fine sand.

EARTH
a. Our planet.
b. The lithosphere as distinct from the oceans and the air.
c. The soil or regolith.

EARTHQUAKE
Shaking or jarring of the earth by natural causes as from a volcanic explosion or fracturing of the rocks (faulting).

ELEVATED BEACH
A beach which has been raised above the reach of the waves.

ELEVATION
See "altitude" and "spot elevation."

EMBAYMENT. A-73
An arm of the sea extending into the land.

ENTRENCHED STREAM
A stream which has carved its channel down into bedrock below the general level of the area through which it flows.

EPICENTER
The zone, place, or center where an earth movement, resulting in an earthquake, takes place.

ERG
A desert region of shifting sand. Example: The Grand Ergs of southern Algeria.

ERODED DOME. C-179
A dome whose upper portion has been more or less removed by erosion.

EROSION
The process of wearing away the land by streams, waves, glaciers, winds, etc.

EROSION CYCLE
See "cycle of erosion."

EROSIONAL FORMS
Surface features such as gorges, cirques, sea caves, or wind hollows produced by the destructive work of streams, glaciers, waves or wind.

ERRATIC. A-80
A rock fragment foreign to the area in which it is found. Usually restricted to glacial erratics.

ERUPTIVE ROCKS
See "igneous rock."

ESCARPMENT
An abrupt slope between two areas at different levels.

ESKER C-184
A sharp-crested, winding ridge of gravel deposited by a former stream along its channel under a glacier.

ESTUARY. A-85
The wider tidal stretches of the lower course of a river. Same as "firth" in Scotland, "aber" in Brittany, and "ria" in Spain.

EXFOLIATION
The peeling off of flakes or sucessive curved layers of rock from a surface due to temperature changes and chemical action.

EXFOLIATION DOME. B-100
A rocky mountain or hill rounded off by exfoliation. See "exfoliation."

EXIT
A defile, opening, or route leading inland from a beach.

EXTINCT VOLCANO. B-134
A volcanic vent which has ceased to have eruptions.

EXTRUSIVE FLOW
Lava which pours through an opening and spreads out on the surface of the earth.

FALL LINE. A-96
A line or zone of contact between rock formations of varying resistance. Streams crossing the line drop in falls from the more resistant to the less resistant rock. Example: The Fall Line, Atlantic Coastal Plain.

FALLS
See "waterfall."

FALSE BEACH. A-84
A bar a short distance offshore with a lagoon between it and the shore.

FATHOM
A unit of marine measurement equal to 6 feet.

FAULT. B-126
A fracture or crack in the earth's crust accompanied by a displacement of the rocks on one side or the other.

FAULT-BLOCK. C-204
A part of the earth's crust which has moved as a unit along a fault.

FAULT PLANE. C-212
The surface along which one mass of strata slide against another such mass.

FAULT SCARP. C-197
The face of a fault block which projects above the adjacent block or general surface level.

FAULT SHORELINE. A-11
A shoreline which has its shape determined by faulting. Such shorelines are usually straight and the slopes along them are steep.

FELDSPAR
Common, usually light-colored, minerals which decompose to form clay. Examples: Plagioclase, Orthoclase, Oligoclase.

FILL
The loose or unconsolidated material which lies on the bedrock in valleys or other depressions.

FINE-GRAINED
Having particles or grains which are too small to be distinguished by the unaided eye.

FINGER LAKE
A long, narrow lake in a deep glacial valley. Example: The Finger Lakes of Central New York.

FIORD. A-19
A narrow, deep, glacial-eroded valley partly filled with water. Also fjord. Examples: The Oslo and Sogne Fiords, Norway.

FIRTH
A narrow arm of the sea, as the opening of a river into the sea.

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Example: Firth of Forth, Scotland. See "estuary."

FJORD
See "fiord."

FLATIRON. C-194
The triangular face of tilted rock layers which rest against the uplifted area.

FLAT-TOPPED DIVIDE. C-206
A flat-surfaced area between two valleys.

FLINT
A dense, hard, usually dark-colored variety of quartz which chips with sharp edges, and strikes sparks against steel.

FLOOD PLAIN. C-171
The area along a stream which may be covered at times of high water and where deposition of stream-carried material takes place. Examples: the flood plain of the Mississippi or Nile Rivers.

FLUVIO-GLACIAL DEPOSITS
Deposits made by the waters which flow from a glacier.

FOLD
A wrinkle in rock layers.

FOLDED MOUNTAINS. B-137
Mountains in which the rock layers are compressed into great folds, in some cases several miles across and tens of miles long. Examples: The Allegheny Mountains, Pennsylvania; the Jura, France.

FORD
A place where a stream or other body of water may be crossed by wading.

FORESHORE
The shore nearest the water. Also the shore area between high and low water, See "stand."

FORMATION (Geological)
A rock unit which can be identified by its distinctive characteristics--color thickness, composition, etc.

FORM LINE
A line on a map showing the general outline or shape, but not the exact elevation of the relief.

FRAGMENTARY
Broken into pieces.

FRINGING REEF. A-59
A reef (usually of coral) which lies along the shore.

GABBRO
A fine-grained, basic, igneous rock; usually dark-colored--gray, green or black.

GAP
A low place through a mountain ridge. See "col."

GEOGRAPHY
The science which describes and interprets the earth's surface in relation to man's distribution and his activities.

GEOGRAPHICAL MILE
See "nautical mile," statute mile."

GEOLOGICAL STRUCTURE
The size, shape, and arrangement of the rock units which make up the crust of the earth.

GEOMORPHOLOGY
The science that describes the terrain features of the earth and interprets their origin.

GEYSER. B-132
A hot spring which spouts water at intervals.

GEYSER CONE. B-131
The mound of mineral matter which is built around the opening through which a geyser erupts.

GLACIAL DRIFT
All material-boulders, clays, sands, etc.--deposited during the melting of glacial ice.

GLACIAL LAKE. C-192
A lake due to glacial action.

GLACIAL LOBE
A rounded part of a glacier or ice sheet which was pushed ahead of the adjacent parts.

GLACIAL OUTWASH
Material deposited by streams flowing from glacial ice.

GLACIAL TILL. A-62
All the heterogeneous material--clays, boulders, gravels, sands, etc.--deposited directly by glaciers or indirectly in glacial streams, lakes or the sea.

GLACIAL TROUGH. C-202
A glacially eroded valley which has steep sides and a broad, rounded bottom, a U-shaped glacial valley.

GLACIER. . . . . A&B-21
A creeping of flowing mass of ice in high altitudes or high latitudes that is slowly moving downward or outward as a result of its own weight.

GNEISS. A-20
A banded metamorphic rock which has been greatly changed from its original character by high pressures and temperature.

GORGE
A steep-sided, narrow valley; a canyon.

GRABEN. B-104
A part of the earth's crust which has been faulted or displaced down below the areas on each side of it; a rift valley.

GRADED STREAM
A stream which is neither cutting its valley deeper nor filling it up.

GRADIENT
The degree of slope of a stream, beach, hillside, or road.

GRANITE
A common coarse-grained, lightcolored igneous rock.

GRAVEL. C-227
Water worn rock fragments, usually coarser than sand; sometimes used for a mixture of pebbles and sand.

GROUND WATER
Water that is contained below the earth's surface in the more or less porous rock or soil.

GULF. A-24
A part of the sea which extends into the land, usually larger than a bay.

GULLY. C-222
A short, steep-sided gorge or valley with a sharp gradient. Usually small.

HACHURE
The fine lines or shading used on certain types of maps to indicate elevations and relief features.

HAMMADA
A flat, bare rock floor in a desert.

HANGING VALLEY. A-23
A tributary valley which enters the main valley at a level above that of the main valley. Hanging valleys are common along glacial

troughs in mountain areas.

HARBOR. B-145
A portion of a sea, lake, or river so protected as to be a place of safety for vessels in stormy weather.

HARDPAN
A firm consolidated layer in the mantle rock--usually glacial till--that occurs a few inches for a few feet below the surface.

HEADLAND
A high point or projection of land extending into the sea.

HEATH
A tract of level or rolling land, covered with heather or other coarse vegetation, especially in Great Britain.

HELPING CONTOUR
See "intermediate contour."

HIGHLAND
An area generally above the surrounding region. See "upland."

HIGH WATER
a. The time, or the height, of high tide.
b. A flow or flood of water above the normal stage of a stream.

HILL
A more or less rounded elevation rising to moderate heights, relatively lower than a mountain.

HILLOCK
A small hill.

HOGBACK. C-180
A steep-sided, sharp-crested ridge usually along a mountain front.

HORN
A sharp peak in a rugged mountain region. See "Matterhorn." Sometimes used for a ham-shaped lake or piece of land, as Cape Horn.

HORSESHOE MORAINE. C-213
A glacial moraine which loops roughly in the shape of a horseshoe.

HORST. B-117
A block of the earth's crust which has been elevated by faulting above the level of the blocks on either side. See "block plateau."

HOT SPRING
A spring in which the water is above the ordinary ground temperature.

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HOT SPRING DEPOSIT. B-129
Mineral matter deposited from the waters of a hot spring.

HOT SPRING POOL. B-130
Basin filled with water from a hot spring or geyser and lined with silica deposits known as siliceous sinter.

HUMID CLIMATE
A climate with adequate or excessive moisture. An area with such a climate usually has moist soils, a thick plant cover and streams with water throughout the year.

HYPSOMETRY
The science that deals with the measuring of heights of points upon the earth's surface.

ICE LOBE. C-183
A part of the margin of a glacier or ice sheet which has a convex front. See "glacial lobe."

ICE TUNNEL. C-182
A long opening either under or through glacial ice, over which there is an ice roof.

ICEBERG
A block of glacial ice floating in the sea or in a lake.

ICECAP
Glacial ice lying over a plain, usually more or less circular in outline.

IGNEOUS INTRUSION
Molten rock which has been squeezed into the crust of the earth and there hardened into igneous rock.

IGNEOUS ROCK. A-49
Rock solidified from a molten condition. Sometimes called "eruptive rock." See "lava".

IMPERVIOUS FORMATION. A-49
Rock material such as clay through which water will not pass.

INCISED
Cut, as by a stream, into a rock surface.

INCISED MEANDERS
Meanders of a stream which have been cut into bed rock below the level of the flood plain on which the meanders were formed.

INLIER. A-58
Partly buried hills or areas of older rock which extend above the younger rock which partly covers them. It is an area of older rock completely surrounded by younger rock.

INNER LOWLAND
Lowland farthest from the sea where there are several lowland areas.

INTERIOR PLAIN
A plain lying away from the sea coast.

INTERMEDIATE CONTOUR
A line of definite value, usually discontinuous, that is drawn between any two of the regular contour lines.

INTERMITTENT STREAM
A stream which flows only part of the year.

INTRUDED SHEET
See "intrusive sheet."

INTRUSIVE SHEET. C-139
An igneous rock structure which was formed by a molten mass being squeezed into a crack or between two more or less horizontal layers in the surface rocks. Dikes and sills are forms of intrusive sheets.

ISLAND. A-55
A tract of land surrounded by water.

ISLET
A small island.

ISOBATH
See "marine contour."

ISTHMUS
A neck of land connecting two larger land masses. Examples: Panama and Suez

JOINT
A fracture in rock without dislocation. All rocks in the crust of the earth have joints.

JOINT PATTERN. A-12
Joints are straight lined partings due to pressure and disturbance and usually form a more or less regular arrangement called joint pattern.

JOINT SYSTEM
See "joint pattern."

KAME
A conical or rounded hill of gravel deposited by streams flowing from a glacier.

KAOLIN
A white mineral which forms the bulk of all clays and when pure is the basic material in pottery.

KARST REGION
A limestone region in which there are numerous sinkholes, abrupt slopes, and irregular rock projections formed by solution.

KETTLE HOLE. C-186
A depression resulting from the melting of a buried ice block; usually found associated with glacial moraines.

KETTLE LAKE
A lake in a kettle hole.

KNOT
A unit used to express the speed of a ship, one knot being equal to one nautical mile per hour.

LACCOLITH. C-174
An igneous intrusion which has raised the rocks over it into a dome-shaped mountain or mountains.

LACUSTRINE DEPOSITS
Gravels, sands, clays, or silts laid down in lakes.

LAG GRAVEL
The larger stones left after wind has blown away the finer material.

LAGOON. A-43
A shallow body of water close to the sea or a lake but more or less separated from the open water by a bar of sand. Same as the "haff" of the Baltic coast of Germany.

LAKE. B-110
A considerable inland body of nonflowing water, either fresh or salty.

LAKE PLAIN
a. The level area adjoining a lake.
b. The level floor of a lake that has been drained.

LANDFORM
An individual feature of the terrain.

LANDSLIDE. C-221
The slipping down of a mass of earth and rock on a mountain side or other slope.

LAND-TIED ISLAND
See "tombolo."

LATERAL MORAINE. C-216
A moraine formed along the side of a valley glacier or the margin

of an ice lobe.

LATERITE
Residual mantle rock, red in color, high in iron and alumina but low in silica. Usually found in the tropics where heavy rains cause intensive leaching.

LAVA
A form of igneous rock, in both its molten state and later when solidified; which has come to the earth's surface in a liquid condition.

LAVA FLOW. B-115
A stream of liquid lava pouring from a vent; also used for the lava after it has solidified.

LAVA PLATEAU. B-114
A plateau surface built up by one or more lava flows.

LEDGE
A mass of rock projecting in an essentially horizontal plane.

LEE SLOPE. A-92
Slope which is away from the direction of prevailing winds or of glacial movement.

LEVEE
An embankment to prevent overflow by water. See "Natural levee."

LIME
See "limestone."

LIMESTONE. A-4
A rock composed dominantly of consolidated or indurated calcium carbonate particles or fragments. Often called "lime" or "lime rock."

LITHOSPHERE
The solid part of the earth as distinct from the atmosphere (air) and hydrosphere (water) parts.

LITTORAL
a. The zone near the ocean shore in which the bottom is affected by waves and currents.
b. The strip of land near the shore.

LOAD
The rock material being carried by wind, running water, or glacial ice.

LOAM
A type of soil composed of clay, sand, and organic matter which is easily crumbled.

LOBATE DELTA
A delta which has a rounded front or with more than one lobe-shaped extension at its edge.

LOCH (Scotch)
A lake or a small, almost enclosed arm of the sea.

LOESS
Wind-blown and deposited dust, usually buff in color, which will stand in vertical bluffs.

LOOPED BAR. A-54
An arc-shaped bar attached to the shore at both ends.

LOW CONE. B-119
A volcanic cone built almost wholly of lava flows and therefore having low slopes on its sides.

LOWLAND. A-87
An area, low in altitude, consisting of hills, rolling terrain, and plains.

MAINLAND
The principal land, or the continent as distinct from island or peninsula.

MANTLE ROCK. A-1
The loose unconsolidated material over the bedrock. Also called the regolith.

MARBLE. B-111
Limestone which has been altered by great heat and pressure. A metamorphic rock.

MARGINAL LAKE. C-170
A lake dammed in by the ice along the side or margin of a glacier.

MARINE ARCH
See "sea arch."

MARINE BENCH. A-50
A platform along the shore formed by the erosion of the waves.

MARINE CONTOUR
A line on a map showing the floor of ocean or lake, every point of which is of the same distance below, mean sea level. Same as "Isobath." See "contour."

MARINE DEPOSITS
Deposits made in the ocean or sea.

MARINE EROSION
The wearing away of the land through the work of waves and currents

of the seas.

MARL
The variety of limestone which is soft and porous. Usually white or buff in color.

MARSH. A-83
A tract of soft wet ground, treeless, but covered with grass or reeds.

MASSIF
A dominant, mountainous block rising more or less sharply above surrounding lower lands. Example: The "Massif Central" of France.

MASSIVE
a. Applied to minerals lacking a definite crystalline form.
b. Geologically, a rock mass showing neither stratification nor foliation.

MATTERHORN. A-8
A type of mountain peak, like the Matterhorn in the Alps, which has several concave, steep sides made by glacial erosion. See "horn."

MATURE BLOCK MOUNTAINS. C-198
Block mountains in which streams (and glaciers) have dissected or carved up the surface of both the front and back slopes of each block.

MATURE MOUNTAINS. A-93
Mountains in which almost none of the original upland surface is left and which have great diversity of topographic form.

MATURE PLATEAU. C-159
A plateau which has been so cut by streams that only small patches of the originally uplifted plateau surface remain.

MATURE SHORELINE. A-14
A shoreline which has been eroded so that the waves are cutting everywhere at nearly the same rate.

MATURE SHORELINE PROFILE. A-95
The profile of the land surface both below and above water across a mature shoreline.

MATURE TOPOGRAPHY
An area of great diversity in relief and from which erosion has nearly everywhere removed the original surface.

MATURELY DISSECTED SURFACE. A-88
A land surface which has very little flat area in it.

MATURELY ERODED DOME. C-181
A dome from which the original top of surface has been removed by erosion.

MEANDER NECK. C-166
The area between two successive loops of a meandering stream.

MEANDER SPUR. C-200
The area within a loop of a meandering stream.

MEANDERING STREAM
A stream which flows in a winding or turning course.

MEAN SEA LEVEL
A plane that represents the average elevation of the ocean's surface extended around the glove and serving as a datum plane for measuring heights and depths.

MEDIAL MORAINE. A-31
A long mound of rock material extending lengthwise on the surface of a glacier near its axis.

MESA. C-157
A steep-sided, flat-topped prominence or mountain (larger than a butte) in an arid or semi-arid area. Usually western U.S. usage. See "butt."

METAMORPHIC ROCK. C-164
Rock which has been subjected to high pressures and temperatures in the earth and has been changed by these forces.

MICA
An elastic mineral which reflects light brilliantly and which may be cleaved into very thin sheets.

MID-BAY BAR A-40
A bar extending into a bay from its side.

MILITARY CREST
The line near the top of a ridge from which all, or nearly all, of the ground toward the enemy can be seen and reached by gunfire.

MILITARY GEOGRAPHY
That branch of geography which applies geographic knowledge and techniques to the solution of problems in tactics, strategy, and logistics.

MINERAL
A naturally occuring inorganic substance with definite chemical composition and with characteristic physical properties.

MONADNOCK. B-101
A mountain or hill of resistant rock rising above a surface which has been almost leveled by erosion. From Mt. Monadnock in southern New Hampshire.

MONADNOCK GROUP. B-106
A group of mountains or hills which rise above the general erosion level. Sometimes called Unakas.

MONOCLINAL RIDGE. B-136
A ridge formed over the edge of a resistant rock formation with a single limb of a fold.

MONOCLINAL VALLEY. B-135
A valley developed by erosion along a weaker member of a monocline and bordered by more resistant ridges, each dipping in the same direction.

MOOR
A tract of treeless land, more or less waste and usually elevated, boggy, and frequently covered with peat.

MORAINE. C-185
Deposits made by a glacier commonly as hummocks and irregular hills at the edge of the ice.

MOUNTAIN
A conspicuous elevation with small summit area, relatively higher than a hill.

MOUNTAIN GLACIER
A glacier which flows down the side of a mountain.

MOUNTAIN RANGE
A series of mountain peaks more or less in a row and considered to be one connected system.

MOUNTAIN SPUR. B-133
A projection from the side of a mountain mass.

MOUTH
a. The opening through which the water of a stream is discharged.
b. The entrance to a cave.

MUD
A mixture of clay or sand and clay with water.

MUD FLOW
A mass of wet mud which flows down a slope. See "landslide."

MUD VOLCANO. B-151
A small pit in which mud is kept disturbed by gas bubbling through it.

MUSCOVITE
The transparent potassium mica; natural isin-glass.

MUSHROOM ROCK. B-155
A projecting rock, with cap and neck resembling a mushroom, formed partly at least by wind erosion in alternating hard and soft rocks.

MUSKEG
A bog in which the principal plants are mosses. Common in arctic Canada.

NATURAL BRIDGE. C-162
An open arch of rock which has been developed by erosion.

NATURAL LEVEE. C-167
A low ridge built along a stream channel where overflowing flood waters deposit mud and silt.

NAUTICAL MILE
A unit of linear measurement equal to one sixtieth of a degree of the earth's equator. In United States equal to 6,080.27 or 1.1515 Statute Miles. In British Admiralty usage the Nautical Mile equals exactly 6,080 feet. Nautical Mile is the same as Geographical Mile. See "Statute Mile."

NEAP TIDE
The lowest tide, occurring one or two days after the first and third quarters of the moon.

NECK OF LAND
A narrow stretch of land, usually between water bodies. See "isthmus."

NECK OF MEANDER
See "meander neck."

NOSE OF SYNCLINE. B-149
The end of a syncline where it passes underground.

NUNATAK
A hill or mass of rock which projects through a glacier.

OASIS
A watered tract in a desert; green because of local vegetation.

OBSIDIAN
Volcanic glass, the form in which some lava solidifies.

OCEAN
The whole body of salt water which covers about three-quarters of the earth.

OCEAN CURRENT
A progressive horizontal motion of the water occurring throughout a large region of the ocean as a result of which all bodies floating therein are carried with the stream. Examples: The Gulf Stream of the North Atlantic; the Kuro Siwo (or Japan Current) of the North Pacific.

OLD BLOCK MOUNTAINS. C-208
Block mountains in which erosion has worn the mountain down to a rounded surface profile.

OLD PLATEAU. C-158
An eroded plateau in which only a few hills rise to near the former erosional level.

OLD VOLCANO. B-124
A volcanic cone which has been much eroded.

OLDLAND
An extensive area of old crystalline rocks which has low relief because of long erosion.

OPEN VALLEY. A-82
A valley with broad valley floor and widely flaring sides.

OUTCROP
Bed rock where it is exposed at the surface of the ground.

OUTLIER. A-97
An area of younger rock entirely surrounded by older rock.

OUTWASH PLAIN. C-195
A more or less level surface formed of deposits made by streams flowing out from a glacier. Usually of gravel, sand or silt.

OXBOW LAKE. C-172
A part of a meander bend which has been abandoned by the stream.

PAHOEHOE LAVA
A lava flow which has a smooth or ropy surface, as distinct from rough and broken surface. The opposite of AA lava.

PALISADES
Columnar lava which has the sides of the columns exposed.

PASS
A passageway through mountainous country; usually a relatively low place across a ridge.

PEAK
The top of a hill or mountain which ends in a point.

PEAT
An accumulation of more or less decomposed plant matter found in bogs.

PENEPLAIN
A land surface which has been eroded so that it is almost level.

PENINSULA. A-86
A land area jutting out into the water.

PHYSIOGRAPHIC PROVINCE
An area in which the landforms are essentially all in the same stage in the cycle of erosion and therefor similar.

PHYSIOGRAPHY
The study or science of the earth as a whole; of the land masses or lithosphere, of the oceans or hydrosphere, and of the air or atmosphere.

PIEDMONT
The area at the foot of a mountain range.

PIEDMONT GLACIER. A-32
A glacier which flows from a mountain area and spreads out at the foot of the mountain. Several valley glaciers may merge into one piedmont glacier.

PILLAR
See "column."

PITCHING ANTICLINE. B-146
An anticline (arch of rock strata) the axis of which pitches or dips to form an angle with the horizontal.

PLAIN
A broad level area which slopes gradually up from near sea level. An area of generally level land.

PLATEAU
An extensive surface standing conspicuously above the adjacent area on at least one side.

PLAYA
The flat-floored bottom of an undrained desert basin which, after a rain, may become the site of a temporary lake. Same as "dry lake."

PLAYA LAKE
A temporary lake in a playa; usually very shallow.

PLUNGE POOL. A-7
The water which fills the depression at the foot of a waterfall.

POINT
A small tapering projection of land usually extending from a larger cape or peninsula.

POLDER
A formerly marshy or swampy or submerged area which has been reclaimed from a sea, lake or river.

POND
A small body of standing water.

POTHOLE. C-176
A rounded depression formed in a streambed by the swirl of water and sediment.

PRECIPICE
A nearly vertical or overhanging cliff.

PRECIPITATION
A general term including all forms of moisture falling from the air (rain, snow, hail, sleet).

PROFILE
The up and down character of the land surface, drawn to show the relief along some particular line.

PROMONTORY
A high point of land or rock projecting beyond the general coastline.

PUMICE
Volcanic rock which is very porous, light in weight and color.

PYROCLASTIC
Adjective referring to the broken or fragmental material of volcanoes chiefly thrown out by volcanic explosions.

QUAGMIRE
Soft and wet land which shakes under foot.

QUARTZ
A mineral composed of silica (si O2) which is harder than glass, usually light in color or transparent, and with a glassy luster.

QUARTZITE. B-107
A hard and durable metamorphic rock composed of quartz sand grains with the space between the grains filled with quartz.

QUICKSAND
Fine sand suspended in water so that heavy objects sink in it. Draining will remove the "quick" property.

QUIESCENT VOLCANO
An active volcano between periods of eruption.

RADIAL STREAM PATTERN
A pattern of drainage lines which radiate from a central high area.

RADIATING DIKES. B-128
Tabular masses of igneous rocks, filling fissures in older rocks and running out more or less from a center. See "dike."

RAINFALL
The amount of water which falls as rain, usually stated as the depth to which it would cover a level surface. Also, used as equivalent to precipitation.

RAPIDS. A-29
A part of a river in which the current is fast and the water surface usually broken by rocks.

RAVINE
A stream-eroded valley which is short and steep sided; larger than a gully.

REEF
A ridge of rocks or sand lying at or near the surface of the water.

REEF RING. A-42
A circular row of coral reefs around a central island.

REGOLITH
See "mantle rock."

REJUVENATION
The renewal of erosion activity, usually by uplift of the land.

RELIEF
The irregularities of land surface. Also, the vertical distance between the tops of the hills and the lowest points in an area.

RELIEF FEATURES
The topographic features which constitute the irregularities on the surface of the earth.

RESIDUAL MANTLE ROCK. A-47
Mantle rock which is formed by weathering at the place where it is found. Contrasted with "transported mantle rock."

RESIDUAL SOIL
Soil formed on residual mantle rock.

RIA SHORELINE
An irregular shoreline with numerous long narrow embayments extending into the land.

RIDGE. C-190
A range of hills or mountains. Also, the upper part or crest of such a range.

RIFFLE
A shallow place across a stream over which the water flows rapidly.

RIFT VALLEY
See "graben."

RIFT VALLEY LAKE. C-196
A lake formed in a rift valley, or graben, or trench-like depression, due to down faulting.

RILL
A very small brook or rivulet.

RING
See "reef ring."

RIPPLE MARKS
Small wave-shaped marks made on sand or mud by wind and water.

RIVER
A natural stream of water larger than a brook or creek.

RIVER TERRACE. C-173
A level area along a river valley, elevated above the reach of high water.

ROADSTEAD. A-38
A place where anchored ships will be protected from storms.

ROCHES MOUTONNEES. A-91
A rock mass or hillock rounded off by glacial action with the gentle slope on the stoss (that receiving the impact of the ice) and the steep slope on the lee side due to ice plucking.

ROCK
The solid material of the earth. The loose fragments make up the "mantle rock." The consolidated or cemented material is the "bed rock."

ROCK BASIN
A basin surrounded by bed rock above the level of the basin floor.

ROCK GLACIER
See "rock stream."

ROCK STEPS. A-17
A series of steepfaced ledges of rock outcropping across a glaciated valley floor.

ROCK STREAM. C-233
A mass of rock fragments which moves slowly down a depression. Sometimes called "rock glacier."

ROCK STRUCTURE
The shape, arrangement, and size of the rock units that make up the crust of the earth.

ROLLING TERRAIN
An area covered with a succession of rounded hills with low to moderate slopes.

ROUTE
A natural highway leading between significant areas or cities. May or may not have roads, railroads, rivers, or canals passing through it.

RUGGED
Having a rough, uneven surface with steep slopes.

RUN-OFF
The water which flows from the land over the land surface.

SADDLE
A low point in the crestline of a ridge. See "col."

SALINA
A salt marsh, pond or lake enclosed from the sea.

SALT DOME
A dome in sedimentary rock made by a column of rock salt which has been thrust up underneath it. Sometimes used to refer to the column of salt under the dome.

SALT MARSH. A-76
A low area kept wet by sea water or water from a salt lake and possibly with some salt-tolerating grasses or reeds.

SALT PAN
A flat area in which evaporation has left salt deposited on the surface.

SAND. C-228
Particles of rock large enough to be seen by the unaided eye but less than one-eight inch in diameter. Predominantly of quartz grains, but may be "coral sand," "olivine sand," etc.

SAND DUNE. B-118
See "dune."

SANDSTONE. A-3
An accumulation of sand grains which have been cemented together.

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SCARP
See "escarpment."

SCHIST. A-15
A metamorphic rock consisting of very fine layers which can usually be split along parallel surfaces.

SEA
a. Any considerable body of oceanic water more or less enclosed by land.
b. The waves caused by local winds.

SEA ARCH
An arch hollowed out of bed rock by wave erosion. See "arch."

SEA CAVE. A-61
A shallow recess in a cliff cut out by the action of waves. If above present water level it is evidence of a change in elevation of the land.

SEA CLIFF
An abrupt slope or cliff made by waves cutting at its base.

SEA LEVEL
The datum plane for determining altitude. At any place it is the position of mean sea level if the sea were free to enter that area. See "mean sea level."

SEDIMENTARY ROCK. B-103
A rock which is composed of the consolidated products--such as sand, clay, gravel, marl, etc.--of other rock masses.

SEISMIC CENTERS
Areas in which earthquakes are more common than in neighboring areas.

SEMI-ARID CLIMATE
See "arid climate."

SERPENTINE
a. Twisting or winding, as a meandering stream or curved shoreline.
b. One of the metamorphic rocks; usually greenish in color.

SHALE. A-2
A sedimentary rock made of consolidated particles of the smallest sizes such as clay or silt, in thin layers and black, gray, red, or greenish etc. in color.

SHINGLE
Coarse, rounded stones along a beach or stream, with many pieces larger than pebbles.

SHOAL
A shallow area in a sea, lake, or river.

SHORE
The land immediately next to a body of water.

SHORE PROFILE. A-79
The profile, or cross section at an angle to the shore, which crosses the area both above and below water in which the effects of wave work are found.

SHORELINE
A line delimiting the water level of a lake, or the low tide level or seaward limit of the beach along the ocean.

SHORELINE OF EMERGENCE. A-78
A shoreline which has been formed by an elevation of the coast. It is generally characterized by few and shallow indentations.

SHORELINE OF SUBMERGENCE. A-28
An irregular shoreline with characteristics determined in part by the irregularities of the eroded surface which has been partly submerged. See "drowned coast," and "youthful coastline of submergence."

SIERRA
A ridge of mountains or craggy rocks which has a saw-tooth outline. Example: Sierra Nevadas, California.

SILL
Sheet of igneous rock lying between beds of sedimentary rock. See "intrusive sheet."

SILT
Unconsolidated material in which the particles are smaller than sand and larger than clay. Individual particles usually not visible to the unaided eye.

SINK-HOLE. C-160
A hollow in the land surface made by the solution of the underlying rock, usually limestone. See "cenote" and "doline."

SLATE. A-5
A dense, fine-grained rock which can be split in slabs. It is metamorphosed shale and may be blue-black or gray, green or red.

SLOPE
The inclination of a given land surface to the plane of the horizon. Expressed either in degrees of slope or in a percentage as, a 10, 20, or 30% slope; i.e., a 10-, 20-, or 30- foot rise per each 100 feet.

SLUMP
The slipping of a mass of mantle rock on a slope.

SNOW LINE
The lower limit at any time of snow cover. The lowest limit of perpetual snow is the permanent snow line.

SNOW FIELD. A-10
An accumulation of snow which lasts from season to season. The accumulation over a long time may result in the formation of a glacier.

SNOWSLIDE
A mass of snow sliding on a steep slope. See "avalanche."

SOIL
The surface layer which is a mixture of rock material and organic matter in which plants grow. Also sometimes used to mean mantle rock.

SOIL EROSION
Erosion which removes much or all of the soil layer.

SOUND
A long water passage connecting two larger water bodies, usually too wide to be called a strait.

SPIT. A-35
A small point of land, usually sand, extending into a body of water.

SPOT ELEVATION
A figure in feet, yards or meters, giving the exact height above mean sea level of a particular point on the map.

SPRING. C-199
A stream of water coming from the earth.

SPRING TIDE
The highest tide, occurring one or two days after the new moon, and similarly after the full moon.

STALAGTITE. C-230
An icicle-like porjection hanging from the ceiling of a cave.

STALAGMITE. C-232
A mound or column of material built up by dripping water on the floor of a cave.

STATUTE MILE
The legal mile of 5,280 feet used in the United States and British Empire. See "nautical mile."

STEPPE
A vast level or undulating area, devoid of forests, but more or less richly covered with grass. Example: In the lower Volga Basin, southern Siberia.

STOCK
A large mass of igneous rock intruded into the surface rocks and enlarging downward without a known base. Must be less than 40 square miles; if more it is known as a batholith. See "batholith."

STONE
A term usually used for small or quarried masses of rock. Sometimes used to mean "rock."

STOSS SLOPE. A-99
A slope facing the direction from which an overriding glacier approached.

STRAIT. A-63
A narrow neck of water connecting two larger water bodies. Usually smaller than a sound.

STRAND
The part of the shore between high and low water. See "foreshore."

STRATUM (Strata, plural)
A layer of rock.

STREAM
Water flowing over the surface of the earth in a channel.

STREAM MEANDER. C-168
A loop of a meandering stream. See "meandering stream."

STRIKE
The direction of a horizontal line along the surface of a dipping layer of rock, or along a fault plane.

STRUCTURAL BASIN
A low area around which the rock layers have been upturned or uplifted.

SUBMARINE CONTOUR
See "marine contour."

SUBMERGED COAST
See "shoreline of submergence."

SUBSEQUENT STREAM. A-72
A stream whose course has been determined by the position of less resistant rock into which it has eroded its valley.

SUMMIT
The top of a hill, plateau, or mountain.

SUPERIMPOSED STREAM. . . . . .B-1&2
A stream which cuts across the general trend of the strata because its course was established when the present pattern of ridges was covered with other rock.

SURF
Waves which break upon a shore.

SWALE
A slight depression.

SWAMP
A poorly drained area with numerous trees and shrubs.

SWELL
The waves which have progressed beyond the direct influence of the winds which caused them.

SYNCLINAL MOUNTAIN. B-147
A mountain in which the axis of a syncline (downward fold or inverted arch of rock layers) lies along the mountain crest.

SYNCLINAL VALLEY. B-141
A valley in which the axis of a syncline (downward fold or inverted arch of rock layers) lies along the valley floor.

SYNCLINE. B-144
A down-warped fold or an inverted arch of rock layers.

TABLELAND
An elevated flat-topped area of considerable dimensions.

TALUS. C-218
Broken rock fragments piled up at the base of a cliff from which they have broken off. Commonly "scree" in Great Britain.

TALUS CONE. C-219
A pile of talus or broken rock along the base of a cliff, roughly in the shape of a cone.

TALUS SLOPE
The surface of the loose rock piled along the base of a cliff.

TARN. A-16
A small lake in a rock basin, usually in a glacial valley.

TEMPORARY STREAM
A stream which flows only part of the year. An "intermittent stream."

TERMINAL MORAINE. C-187
A moraine piled up at the outer or lower margin of a glacier at its maximum extent.

TERRACE. A-90
A level and usually narrow plain with commonly a steep front or scarp bordering a river, a lake, or the sea.

TERRAIN
The surface of the land.

THALWEG
A line connecting the successively deepest parts of a stream.

TIDAL CREEK
A small stream in which the tide causes the flow to be reversed at intervals.

TIDAL CURRENT
A flow of water caused by tidal action, usually of short duration in one direction and reversing with the change of tide.

TIDAL DELTA. A-77
A delta built by tidal waters where these flow out through a tidal channel.

TIDAL FLAT
An area which is more or less covered with water at high tide but uncovered at low tide.

TIDAL INLET. A-68
The opening through which tidal waters may enter a lagoon or estuary.

TIDAL RACE
The meeting of two strong tidal currents.

TIDAL WAVE
An exceptional wave caused by seismic movement of heavy winds. Incorrectly attributed to tidal influence.

TIDE
The regular rise and fall of the level of the sea, under the gravitative influence of the moon and the sun. See "spring tide" and "neap tide."

TILL PLAIN
A glacial plain underlain by boulder clay.

TOMBOLO. A-52
A former island now connected to other land by a bar of sand or mud. See "land-tied island."

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TOPOGRAPHIC OLD AGE
A land surface on which the agents of erosion have largely completed their work of wearing away the land.

TOPOGRAPHY
The physical features of an area, including relief, drainage, road, cities, and other physical items of the landscape.

TORRENT
A rushing stream of water. Also, (in Europe) a mountain channel which is dry part of the time but filled with rushing water at certain seasons.

TRAP RIDGE. B-116
A ridge eroded from trap rock.

TRAP ROCK. B-122
A fine-grained, dark-colored igneous rock, commonly having columnar structure.

TREE FOSSIL. C-223
The form of a tree, or some of the wood itself, buried in rocks of former geological ages, especially in the coal strata.

TRELLIS DRAINAGE
Drainage which has one or more main trunks with a number of short branches at right angles, resembling the branches of a vine on a trellis.

TRIBUTARY GLACIER. A-30
A glacier which joins and becomes a part of another glacier.

TRIBUTARY VALLEY. A-18
A valley which unites with another usually a larger valley.

TROUGH
An elongated narrow depression. See "graben."

TRUNK GLACIER
The main glacier with which tributary glaciers unite.

TUNDRA
Treeless plains characteristic of artic regions. The soil is dark in color, thin, and mucky, and lies over permanently frozen subsoil. Mosses and lichens are the typical plant forms.

UNAKAS
See "monadanock group."

UNDERCUT SLOPE. C-205
A slope usually steep, which has been eroded at the base, usually by a stream.

UPLAND. B-109
An area with a large part of its surface elevated considerably above the surrounding region. See "highland."

U-SHAPED VALLEY
See "glacial trough."

VALE
A valley or low-lying area.

VALLEY
An elongated depression between areas of higher land. Most valleys contain streams, though some have lakes, salt pans or glaciers in them.

VALLEY GLACIER. A-21
A glacier which lies in a valley.

VALLEY TRAIN. C-188
The material deposited in a valley by a stream flowing from a glacier. See "glacial outwash."

VOLCANIC ASH. C-225
Fine rock material blown from a volcano. Sometimes called volcanic dust.

VOLCANIC CONE
The pile of lava and volcanic ash built up around the crater of a volcano.

VOLCANIC ERUPTION
The active outpouring of lava, ash, gases and steam from a volcano.

VOLCANIC NECK. B-125
See "volcanic plug."

VOLCANIC PLUG
The cone of an extinct volcano which has been eroded so that only the central part, or hardened core is left. Also called volcanic neck.

VOLCANIC SOIL
Weathered lava or volcanic ash which has become soil.

VOLCANO. B-121
A hill or mountain built up of lava, volcanic ash or both, around a vent. Also, the vent in the earth's crust from which the molten rock, steam, ash and gases issue. Examples: Mt. Vesuvius, Italy: Fuji-san, Japan: Mt. Shasta, California.

V-SHAPED VALLEY
A valley with steep sides and narrow floor. Such a valley is

called "young valley."

WADI
Arabic term for any valley; usually with a stream during the rainy season only. Similar to arroyo.

WASTELAND
Uncultivated, especially barren land.

WATERFALL. A-6
A fall or very steep descent of a stream. Cataract, where the water falls free. Cascade, where the water flows over a very steep slope. See "falls."

WATER GAP. B-139
A valley through a mountain ridge in which the stream flows that eroded the gap. Example: Delaware Water Gap, Pennsylvania.

WATERSHED
a. The area which is drained by a stream and its tributaries.
b. In English usage, a "divide." See "divide."

WAVE-CUT CLIFF. A-37
A cliff which has been formed by waves which cut into its base.

WEATHERING
The process of breaking up rock material by either chemical (decomposition) of physical (disintegration) means. See "decomposition," and "disintegration."

WEIR
An obstruction or dam built in a stream to divert the water into a spill-way into irrigation ditches or to form a fish pond: Usually smaller and of less solid construction than a barrage. Common English usage.

WET WEATHER STREAM
See "intermittent stream."

WIND GAP. B-138
A pass or low place through a mountain ridge which no longer has a stream that eroded the gap flowing through it.

WINGED HEADLAND. A-41
A headland which has bars or spits attached to its sides.

YOUNG BLOCK MOUNTAINS. C-210
Block or faulted mountains which have been little eroded since their uplift.

YOUNG PLATEAU. B-152
A plateau which has an extensive level surface, with few stream valleys cut in it.

YOUNG STREAM. B-105
A stream which flows in a narrow steep-sided valley.

YOUNG TOPOGRAPHY
Topography which has been but little affected by erosion. Slopes generally are few, but steep.

YOUNG VOLCANO. B-121a
A volcano which is still in the process of building its cone.

YOUTHFUL COASTLINE OF SUBMERGENCE. A-28
A coastline which shows deep embayments and few bars. See "shoreline of submergence."

ZIG-ZAG RIDGE. B-148
A crooked ridge eroded from folded rocks. The ridge is usually more or less continuous.

Soils

Soil maps are available from the United States Department of Agriculture, Soil Conservation Service, which has made detailed and generalized studies and maps of the soils in many parts of the United States. Goverment agencies and soil scientists have produced soil maps in many foreign countries. At present special organizations within the United Nations organization are studying soils as one basis for the economic development of several areas of the world.

Soils classifications are usually worked out on the basis of structure, texture, content and age of the soil samples. Excellent explanations of these factors and other soil information are contained in government pamphlets prepared by Curtis F. Marbut and Hugh H. Bennett of the United States Department of Agriculture. These pamphlets and maps will provide sufficient information for the average student but are too generalized for guides to specific small areas. Analysis of small areas lead to highly complex maps

Plate A

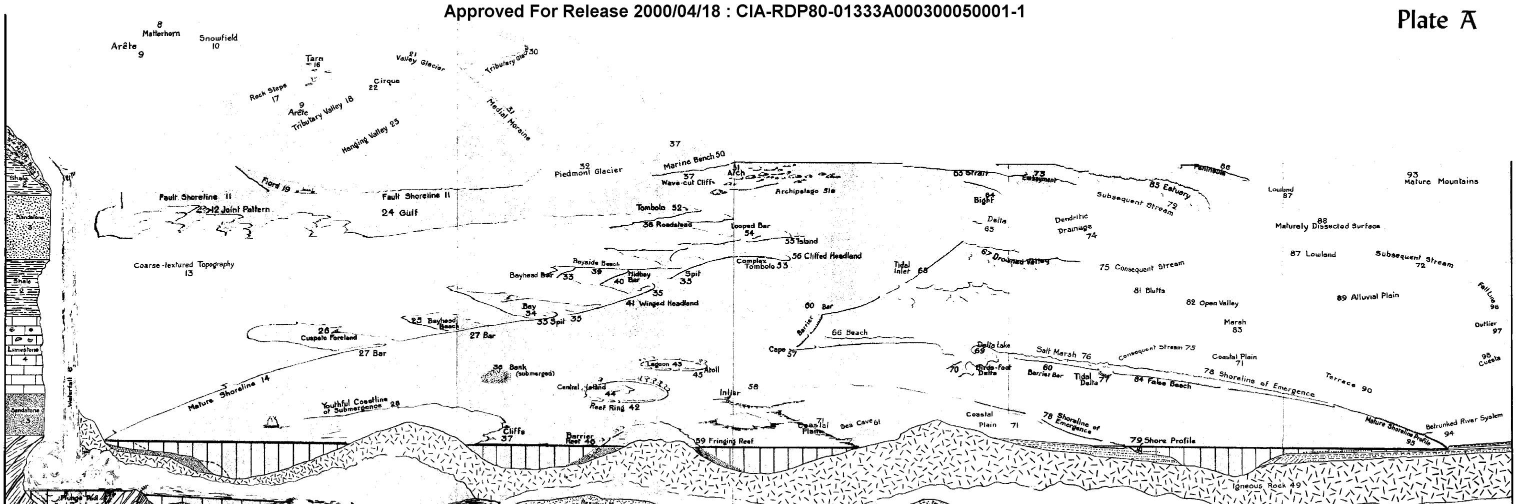

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Plate B

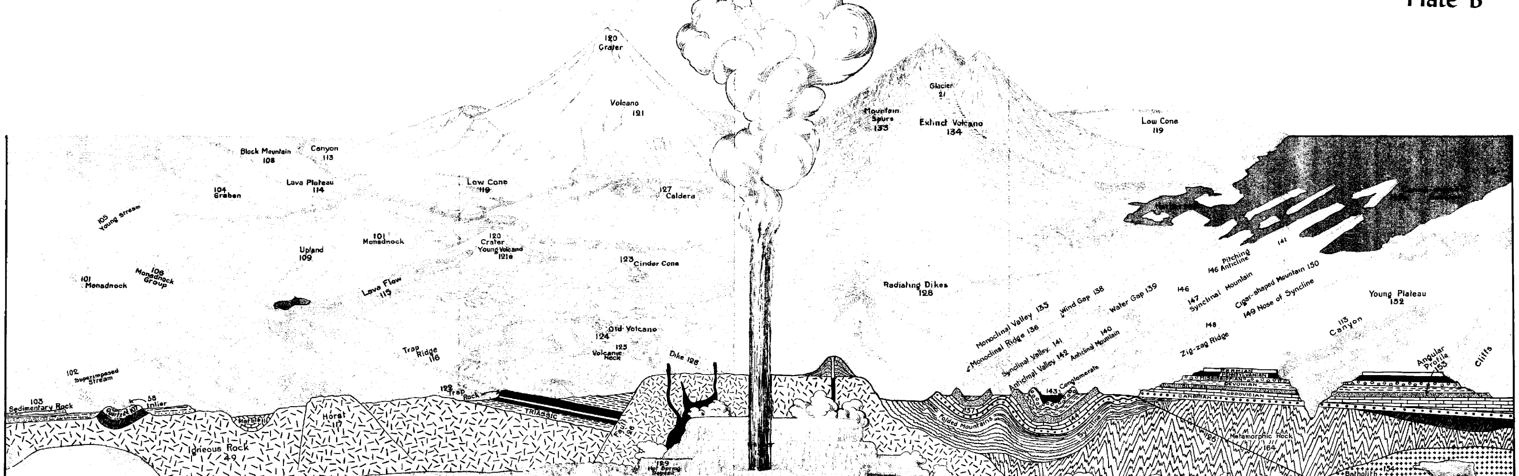

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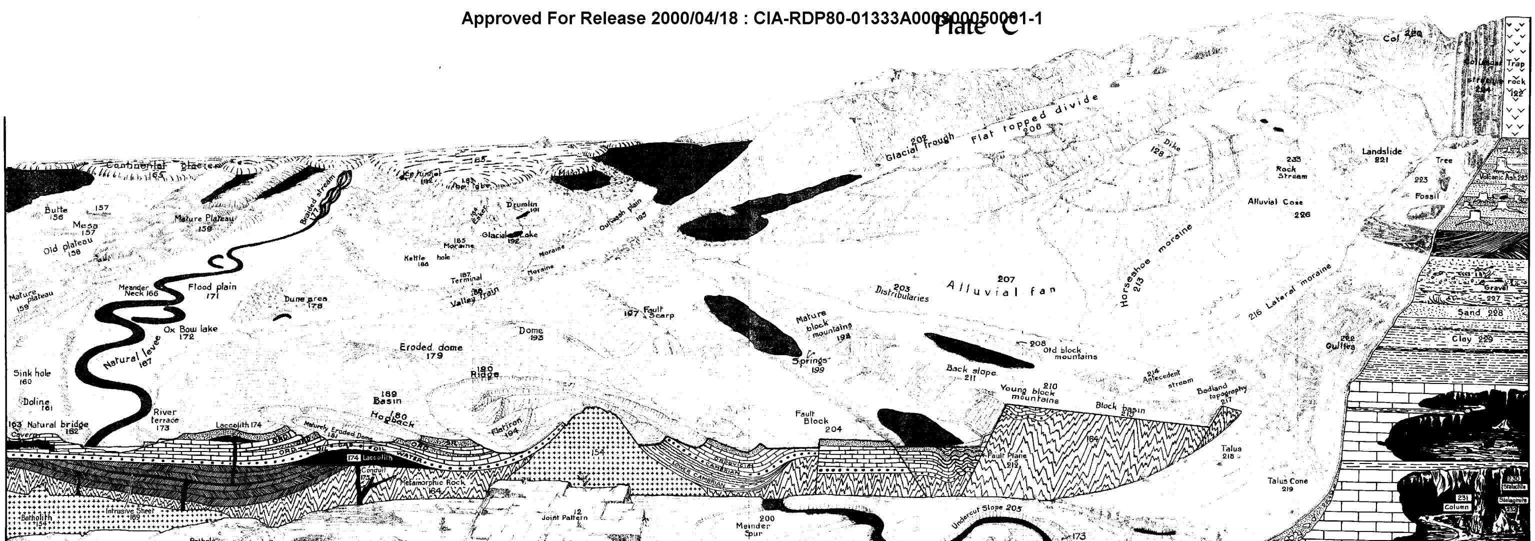
Plate C



CORPS OF ENGINEERS, U. S. ARMY MAP SERVICE

since soils vary greatly in the space of a few yards or even feet.

Minerals

Each state and the federal government have prepared mineral maps showing the location of various deposits and in some cases the estimated and actual reserves contained in these deposits. The number of different maps is especially large covering, coal, oil, and gas fields. Several small scale maps are available for the United States and the world showing the distribution of these vital power resources. In addition there are detailed maps covering small fields because of the dependence of mining operations on maps in locating diggings or drillings.

There is no mineral of economic value whose known distribution has not been mapped by some agency. Some of the data may be scanty or even inaccurate because of limited exploration, inadequate mapping techniques, or governmental restrictions on dissemination of such information. This does not deter the map maker since minerals are a source of power or wealth and most nations and people are interested in these factors. Accurately or otherwise distribution may be shown by symbols indicating the outline of local areas containing the mineral. If there are varieties, such as the types of coal, different symbols may be used for each type or, colors may be applied to differentiate among them.

Mineral distribution maps help the reader to visualize: location of minerals as being in either accessible or inaccessible spots; the relationship of sources of minerals to areas of consumption, and the vulnerability of these sources in time of

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emergencies.

Flora and Fauna

Maps showing the distribution of plants and animals are usually more valuable for areas of sparse population and limited economic development. When man enters the picture in any great numbers he so disturbs or destroys the native plant and animal patterns as to make maps of the natural condition almost worthless to anybody but botanical or zoological specialists. These specialists might then prognosticate the present condition through their knowledge of the succession of plants and animals. Even by utilizing the knowledge of ecology, however, they cannot predict what man-introduced changes may have completely obliterated the natural pattern.

Maps of flora and fauna once native to a well-populated area do have interpretative value for earth scientists and geoggraphers who know that many species reflect the character of their environment through adaptations climate, soils and topography. Even if all of the conifers have been cut down, for example, the climate of the area would still be fairly humid and the soils would probably be low in mineral content, unless they had been heavily fertilized, and podzolic in character.

Logical animal patterns of the distribution of insects are often more vital for present-day research than those for the larger animals. Man constantly has to cope with the insects in his struggle for healthful conditions and agricultural products. Several studies have been conducted in the present century to isolate and tabulate the location and distribution of mosquitoes, grasshoppers, the corn borer, and other insect pests who are far more dangerous than grizzly bears and tigers to human welfare.

Medical Research

In close association with fauna studies and their cartographic representations is the considerable amount of research that has been conducted to determine the causes and incidence of and remedies for various diseases and malformations plaguing man and his useful plant and animal servants. For example, to add or not to add fluoride to drinking water is a current problem in many areas of the United States. Background studies leading to this controversy showed that the incidence of dental cavities was in direct proportion to the fluoride content of water. Detailed maps of the distribution of the percentage of fluoride in water have been correlated with those showing the results of studies of dental health in selected areas.

Other maps show the distribution of malarial mosquitoes, elephantiasis, cholera, fungus diseases, etc. These maps and scientific explanations of the symptoms and causes of diseases aid the medical profession in making diagnoses of special cases. The same maps help military experts and geographers in analyzing and interpreting living conditions in given regions.

Land Utilization

When man infiltrates and permeates the landscape, land utilization patterns are inevitable. He may plant forests or hay over large areas; he may divide the land into fields for different kinds of crops, or he may completely clear the land for residential, commercial and industrial sites. No matter what he does, the results are reducible to land utilization maps. A land utilization map defines some major divisions of the economic use of an area. These divisions include grazing; forestry; agriculture, which may be broken down to specific types and, industrial and/or urban concentrations, and patterns.

Private and public planning groups have produced many land utilization maps. A city plan is, in actuality, a form of such mapping. More expressive, however, are the maps showing the generalized groupings of economic activities. State Planning Commissions have been especially active in producing such maps but other local, state and federal agencies have also been active. The finished maps are usually available from the producing agency.

A favorite method of symbolizing categories of land utilization is by the use of contrasting pastel colors. When the number of categories is large, abstract symbols such as horizontal and diagonal lines are combined with the colors to designate detailed divisions of major groups. Elaborate legends are then necessary to identify the symbols for these groups and subdivisions.

Interpretative Cartography

For every form of factual data there are a number of different interpretations possible according to the use to be made of the map. Relief data on a topographic map serves as an example of the possibilities of various interpretations. In reading contours the cartographer may merely interpret and classify his information as to landforms. More complex and specific interpretations can be made of topographic data using the terrain map in combination with other subject material.

If there is a critical slope or topographic form that will prevent the effective use of some motorized equipment an interpretive map can be prepared indicating slope in terms of possible alternative movement of the equipment. Such a map is obviously incomplete since soil conditions, stream depths, and vegetation also control the movement of the equipment across country. If this latter information is combined with slope analysis and interpreted in terms of movement of the vehicle, there results a trafficability or cross-country movement map. While the map presents no contour information or other factual topographic data, it is essentially an interpreted form of topographic information.

In designing an interpretive map the technical or scientific background of the map user is a factor limiting the scope and form of information shown. If a map is prepared to show the depth to groundwater in an area, let us say a county, and is designed for use by farmers it must express conditions in terms understandable to them. Such simple categories as:

> Large supplies of soft water ample for dairy farm of 100 heads from dug wells less than 10 feet deep; or
>
> Hard water in small supply ample for household use only from drilled wells over 100 feet deep in hard limestone

are understandable to the ordinary layman and would be satisfactory in the case cited. If the map is designed for a person having some knowledge of water resource analysis, the categories can be more specific and can deal with the anticipated yield in gallons per minute and the chemical content of the water. In the latter case this may appear to be factual type of data but it is actually interpretive since it is based on the interpretation of geology, soil, rainfall, topography, and observed wells in the area in relation to water supply.

The use of interpretive cartography today is more extensive than most of us realize. It has long been an excellent tool in the hand of the propagandist, both political and commercial. It is far more effective to present an interpretation of facts that fit the line of thought being projected on the public than to present the mere facts themselves.

Industry and science use interpretive cartography extensively but with different motives than those of the propagandist. The final cartographic product of most consultant reports, prepared for business executives, is not a factual one but rather one that is tailored to fit the intention of the report.

The most intensive use of interpretive cartography is probably made in military planning and operations. Rapidly moving, mechanized war has brought forth many map problems that the topographic map cannot resolve. Geology, soils, water resources, climate, and a host of other cartographic subjects are intricately intertwined in a modern military plan or operation. The specialist's role in the preparation of such data lies in the production of interpretive maps that combine heterogeneous subject material into a finished integrated form that allows the user to arrive at specific conclusions without consulting a multitude of sources.[1]

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[1]This section on Interpretative Cartography is adapted, by permission of the author, from a paper presented by William Davies at the Eleventh Annual Meeting of the American Congress on Surveying and Mapping in Washington, D.C. in 1951.

Navigation and Aeronautical Charts

The number of cartographic representations that combine qualitative, quantitative and even interpretative characteristics is large. As a matter of fact there are few varieties devoted to one function exclusively. Because the number of types of maps is so large, only navigation and aeronautical charts have been selected to illustrate combined characteristics beyond those shown on topographic maps. These charts were also singled out because each has an important function in modern life. Each is widely used for both civilian and military purposes.

Water Navigation Charts

The ancient art of navigation consumes the time and talents of many besides navigators. Engineers and cartographers are kept busy collecting, revising and improving materials for the preparation of navigation charts which aid navigators in their difficult business of negotiating inland, coastal and oceanic waters. They must be provided with accurate details about these waters and their banks or coast features.

You have been introduced to some of the details given on navigation charts under the short review of symbolization. These symbols are translated by the navigator into information about the location of channels; depth of water, aids and hazards to navigation, port facilities for accommodating cargo and passenger freight and provisions for servicing and repairing ships.

Sample Hydrographic Chart

Let's now actively shift your point of view from a topographic to a hydrographic perspective through examination of the following sample of hydrographic charts.

Chespeake Bay 1226 U.S., Coast & Geodetic Survey, 1951

1. What is the scale unit? How does this compare in distance with the scales normally found on U.S. Topographic quadrangles? Of what value are the scales along each neat line?

2. How does the datum plane differ from that for topographic quadrangles?

3. What types of control were used for land features?

4. How is declination information provided? What magnetic variations must be considered?

5. What are the average Baltimore Harbor Channel depths? What draft boats could safely use this channel?

6. What tidal differences can be expected between mean low and mean high water at Sevenfoot Knoll Light? How does this affect navigation at this point?

7. Locate and explain the importance of showing fish trap areas.

8. How are channels marked?

9. How are bathymetric details given? What do white areas in open water indicate?

10. How are the character of the bay and river bottoms indicated?

11. Locate and follow the course of the Chesapeake and Delaware Canal. What specific information is given about it?

12. What types of land features are shown by symbols as visual aids to navigation and orientation?

13. Locate railroad and highway bridges crossing open water. Where is navigation stopped by them and where can boats pass through or under them?

14. Where have channels been deepened to gain entry to docks? How are docks and quays indicated?

15. Describe the amount and character of land details shown.

River Charts

Navigable inland waterways in the United States have been charted by the Corps of Engineers. These charts are available from the District Engineer in charge of their maintenance for particular rivers. For example, the Ohio River Charts are under the supervision of the District Engineer, Louisville, Kentucky. River charts normally include more detailed information about the type of land utilization adjacent to the river banks than is shown on a hydrographic charts. Their scale is larger and is expressed in statute rather than nautical miles.

Control points of land areas are marked by two elevations which may be confusing. The dual notation arises from the use of Cap and Bolt Markers which means a concrete block sunk below the surface and a bolt imbedded in it. The exact elevation of the bolt is determined. A pipe, rising five feet above the bolt, is extended above the earth's surface and a cap is set on this pipe with the elevation of the cap indicated. Since the cap may be disturbed, it is possible by this dual system to measure through the pipe to the bolt below or to dig down to the bolt if both cap and pipe are disturbed.

Any regional study where a navigable river is involved will be aided by the use of River Charts. They reveal characteristics, normally not shown on topographic quadrangles of large rivers. River charts also provide specific details about bankside utilization that can be used to indicate the importance of the river to the surrounding area and to contribute information needed in microgeographic studies.

Pilot Charts

Hundreds of port studies have been published for oceanic and lake ports all over the world. These studies are bound

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individually or in groups of related ports. A wealth of verbal and cartographic information is included in each report. Descriptions, maps and diagrams of port facilities as well as pilot details are presented.

No special instruction is needed for analyzing and interpreting the maps included in pilot reports after you have mastered the reading of Hydrographic Charts. Your attention is merely called to the existence of Pilot Charts and Admiralty Charts because they are a valuable source of information for the study of any major port and should be available in most college libraries. They are issued by the United States Coast and Geodetic Survey and by the British Admiralty. Others are prepared by foreign governmental agencies interested in port development.

Aeronautical Charts

Navigating in space involves different types of information than navigating in water. Flights and flightways are affected by both land and air conditions. Aeronautical charts, therefore, must show the paths of flightways, radio beams, beacon lights, airport facilities and any obstacles to be surmounted or avoided. Rugged topography introduces one such obstacle which is of major importance to aviation. Inaccuracies in elevation notations on charts have been the cause of more pilots crashing into mountain sides than the authorities care to admit. Thus it is essential to have elevations of mountain peaks and chains determined and shown accurately if planes are expected to fly over them.

Aeronautical charts are produced in several different series for specific purposes. A complete listing of types available for the United States and adjacent areas is given on the back of the Sectional Aeronautical Chart described below. Examples of three series were selected for exercise material. Information is not sufficiently different on other series to warrant their inclusion. After you have examined the three, the names of the rest will give you clues as to their particular use.

Sectional Aeronautical Chart Washington T-9 1:500,000 USC & GS, 1951

1. Examine the variety and kind of information given on the reverse of this sheet. Locate examples of the information on the face of the chart.

2. What is the scale of this chart? Study the graphic scales along the bottom neat line.

3. How is magnetic declination information given? Is declination uniform over the sheet?

4. How are ground elevations shown? What contour interval is used for the generalized terrain depiction?

5. What types of cultural detail are shown? Why these?

6. Notice the paths of beams for instrument flying overprinted on the chart. Signals A and N indicate whether an airplane is approaching or flying away from the sending tower. Channel identification N, sending the dash-dot signal, is on the right approaching the tower and on the left flying away from it. A, sending the dot-dash signal, is the reverse of N. Azimuths are labelled on the beam overprint and arrows indicate whether this is a forward reading from magnetic north or a back azimuth. Verify this statement by checking the forward and back azimuths given for the Washington beam.

7. Does Hagerstown have an airport? An instrument flying beam?

8. What hydrographic details are shown. Why these?

World Aeronautical Chart. United States, Chesapeake Bay, 357, 1:1,000,000 USC & GS

This sheet is an example of the World Aeronautical Chart (WAC) coverage provided by international agreement. Each cooperating nation is responsible for the compilation and revision of a given area of the world. Because of their usefulness many nations of the world are producing 1:1,000,000 charts rather than completing their map coverage in the International Map of the World series, discussed in the next section. Aeronautical information is overprinted on standard 1:1,000,000 topographic map bases. An index of the location and index number of WAC charts is given on the reverse of the example. Notice also the explanation of topographic symbols on the reverse of this sheet.

1. Compare the Washington Aeronautical Chart with the WAC Chart of Chesapeake Bay. How are they alike? Where do they differ?

2. What is the contour interval and how is it shown?

3. Notice that the habitat of surface feeding (pelagic) fish are indicated? Why is this shown on an air chart?

4. Study the chart from the viewpoint of an earthbound person. Of what value would it be in this light?

<u>Aeronautical Planning Chart</u>. <u>United States, AP-9</u>

The larger size and smaller scale of a 1:5,000,000 Aeronautical Planning Chart makes it possible to include all of the Continental United States on one sheet for planning purposes. Only the major flightways together with general information about elevation, length and condition of runways at selected airports and location of major beams and control towers are idicated. Thus, a pilot planning a trip across the United States can plot his general course in terms of restrictions and aids to his particular type of aircraft. (Notice that an index to the Sectional Charts covering the country is included on the face of the map so the reader can pick out specific sheets needed for more detailed analyses.)

1. Examine the graphic scale in the lower margin. Why is this type scale needed? How is it used? Use it to determine linear distances between several cities or airports of your own choice.

2. Plan a flight route from an Atlantic to a Pacific airport. List the specific Sectional Charts you would need along the way.

3. Give a logical explanation for the comparative scarcity of flightways between 105° and 115° W.

4. Study and give probable reasons for the routes that connect the United States and Canada. The U.S. and Mexico.

Relief Models

All the techniques for presenting topographic features discussed thus far force the reader to use his imagination in bringing elevations up from a flat sheet. Considerable practice is needed to achieve three-dimensional visualization from flat abstractions. This is a difficult feat, for persons who have travelled far enough from home to have seen many different kinds of topography. It is hard for a resident of level coastal plains to visualize rolling hills and high mountains. Conversely, mountain inhabitants cannot conceive of lands where rivers move sluggishly and avalanches are unknown. Hence it is the problem of the map-model-maker to overcome both provincial and visual map reading weaknesses. Models of many kinds are his contribution.

Construction of Models

Raised models can be constructed in several ways. They can be built up from clay, plaster, paper maché, cardboard, wood or plastic. The cummulative thickness of these materials can be made to a selected scale ratio of the established elevations of the terrain. The surface configuration is modelled or carved on this base as shown on Fig. 149. Wire or wooden frameworks may be used in place of a built -up base and then covered with a thin shell to represent the terrain surface. Miniature models of trees, towers, houses, etc., may be superimposed on a model developed by any of the above methods. Such surface details may also be supplied by printed symbols and data like those shown on the Training Model which you used for contour analysis and interpretation.

Raised relief models are so calibrated that vertical distortion is kept to a practical minimum consistent with the amount of relief in a given area. At the Army Map Service some large scale models of military reservations are compiled without vertical exaggeration. Plastic models of 1:250,000 linear scale are kept to three times vertical exaggeration. Similar ratios are maintained for other scales because too much exaggeration distorts the shape of objects into caricatures of their actual form. Although caricatures create comic impressions they obliterate critical relief relationships needed for serious terrain research.

Babson Model

One interesting example of a relief model should be seen by anyone visiting the Boston area. It is the Giant Relief Model of the United States at Babson Institute located near Wellesley Massachusetts. A giant dome-shaped framework supports a 65 x 45 foot model of the United States. The dome is scaled to the shape of the earth spheriod. A linear scale of 1:250,000 with 6 to 12 times exaggeration in the vertical scale has been used. In areas of low relief 12 times exaggeration was selected in order to bring out details in the topography. In areas of high relief a 6 times exaggeration was preferable because it eliminated unnatural depiction of rugged mountain country. If horizontal and vertical scales had been made equal, Pikes Peak would rise less than one-quarter of an inch above the surrounding region and the Central Lowland would appear as an almost perfect plain. Greater exaggerations were necessary on this model than on the plastic relief models due to the difference in distance and perspective of the viewers. The Babson Model is viewed from a balcony around the four sides of the model and nearly one story above it. Visitors, thus, look down obliquely upon the model. Plastic sheets on the other hand, are meant for closer inspection. Details can be picked out with the aid of smaller exaggerations than those mandated by greater distance viewing.

Utilization of Models

Many models present problems similar to those posed by globes. They are difficult to store and inconvenient to transport. For example, a special room had to be constructed for the Babson Model. The Model itself is composed of 1216 rectangles, covering 1 degree of latitude and longitude, which can be moved individually for correction but would be subject to many of the following hazards if they were to be moved en mass. Plaster models are heavy but fragile and require expert treatment. Paper models crack and crush if they are stacked. Plywood and cardboard models often warp and split with atmospheric changes. Any of these media create shipping problems since careless handling can ruin them. Imagine yourself squeezing into a crowded bus with a two by four foot model tucked under your arm! Multiply your dilemma by several thousands to appreciate the difficulty of foreign shipments to soldiers in the field.

The introduction of plastic and foam rubber media to the cartographer's bag of tricks made the distribution of relief models much easier. It is now possible for field personnel to use maps showing relief in a third dimension without too much careful handling. Plastic models can be stacked with a minimum of protective packing and can be dropped without fear of shattering or crushing. Some types are so durable they can bear heavy weight upon them without permanently depressing the raised portions. They are not highly susceptible to moisture or the vagaries of climate.

Another strong advantage of relief models, such as the Baltimore example issued to you, is their attractiveness. First reactions to these models are usually favorable and stimulating. Interest is aroused and the temptation to explore map minutiae is more compelling on a model than on a flat sheet. This can be explained in part by the fact that the map reader can see what he is doing in terms of the terrain so vividly reproduced thereon.

Model Exerice

Compare the 1:250,000 Baltimore NJ 18-1 sheet with the plastic relief model molded from the same base map.

1. Compare the depiction of terrain in Baltimore County on the model. With that on the flat litho to illustrate the improved visualization possible with the model.

2. Which route between Baltimore and Hagerstown would have the easiest grades? The steepest?

3. Where are the most rugged mountainous areas?

4. Describe the valley of the Susquehanna River. Where are its escarpments most pronounced?

5. If Hagerstown were to be attacked by land forces, what

factors in its site and situation would have to be considered by the attackers and the attacked?

6. Explain the probable reasons for the finger like development of Baltimore.

7. Follow and explain the choice of the route of the Baltimore and Ohio Railroad from Silver Spring to the western edge of the model.

8. Suggest other civilian and military uses that could be made of the model.

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CHAPTER IV

Cartographic Coverage of the World

Quality and Quantity of Coverage

Adequacy of Coverage

Adequacy is a relative term. Long hours might be spent in arguing what constitutes adequacy of map coverage and for what purpose. Certainly popular, commercial, governmental and military needs differ in the amount and type of coverage they demand. Educated map readers in any of these groups would probably finally agree that adequacy depends upon the maps themselves, the areas they cover and the purposes for which they will be used.

Sketch maps that are made to illustrate certain facts should not be expected to be accurate in every detail. If only relative locational relationships are desired, high standards of control accuracy are unnecessary. Maps for this purpose should only be expected to tell their limited or timely story in clearly presented understandable symbols with some means provided for approximating their earth location.

National Standards of Map Accuracy

When maps are meant to be accurate topographic presentations they should conform to standard requirements for such mapping or tell wherein they fail. Topographic map standards vary but most of the reliable mapping agencies conform fairly closely to our National Standards of Map Accuracy for large scale mapping which require that:

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All horizontal control be referred to North America 1927 Datum.

All elevations be referred to Sea Level Datum of 1929.

All geodetic control be of third order or better.

All plotted horizontal control shall not be in error by more than .005 inch when referred to the map projection.

All plotted military grids shall not be in error by more than .005 inch when referred to the map projection. Ninety per cent of all contours shall be accurate to within one-half of the contour interval. Ninety per cent of all elevation values must be accurate within one-fourth of the contour interval.

All symbols shall meet specified requirements. If these standards are met, the map will usually carry a marginal note to this effect.

Dependence of Adequacy Upon National Economy

Adequacy of coverage of specific areas is dependent upon their economic stage of development or local strategic importance to either peace or wartime activities. As an initial endeavor a very large scale, detailed map series meeting the highest standards for map accuracy, covering, let's say, the Amazon rainforest would be silly. Its costs would be fantastic and the results would have limited practical value. Large scale series coverage of the Ruhr area, on the other hand, is so essential that the costs involved are minor in comparison with the benefits derived from such mapping.

Records also show that many nations have envisioned far too ambitious mapping programs for the resources at their disposal and the number of outlets for their maps. The long time result has been that the whole program has collapsed with no worthwhile results to show for the original enthusiasm.

Other countries have been penny wise and pound foolish. Money was not appropriated for adequate mapping that would later have saved millions of dollars in public and private money. Independent surveys, local construction mistakes and loss of industries to particular communities, could have been lessened or eliminated in many places throughout the world by a unified and comprehensive system of control and map coverage. Continental isolation or false economy have been offered as excuses for such short-sightedness. Now that there is little security provided by isolation anywhere in the world, the falseness of economizing on mapping is painfully apparent.

Still other countries and areas of the world have no mapping programs at all. Any existing maps are the results of: private interests, such as petroleum companies, doing the work; of explorers maps, or of cartographic fantasy. Numerous examples of each exist. Several large petroleum and mining companies have done yeoman service in supplying cartographic material in such places as the Near East, northern South America and several islands of the Pacific. Large sections of interior Asia have only spotty coverage of explorers maps of local areas or traverses of expeditionary routes.

Dependence of Adequacy Upon Cartographic Accuracy

There are also many potentially dangerous examples of fantasy. They are dangerous because a majority of people look at many atlas maps and even fairly large scale maps and assume these maps depict the area accurately. False concepts of featureless plains are the result of inadequate cartography and not actuality. An excellent example is the average conception of the Arabian Peninsula as being a perfectly flat monotonous expanse of sand. Aerial photography reveals that quite the reverse is true. There is considerable diversity in relief and landforms.

Partially educated map readers also make the mistake of believing that all maps produced by a given agency or government are reliable. They assume, for instance, that all German maps are good simply because they know that most German maps of western Europe are good. The truth is, that although they may "look" as good, many German maps of the Near East, for example, are entirely unreliable. They were based on scanty and poor sources. The same condition holds true for large percentages of the hasty, provisional maps made of critical areas by many map agencies to supply some sort of coverage under stress or threat of war. Although these make-shifts may look very professional and attractive, they are hardly worth the paper they are printed on. Inaccurate source materials and poor control can and do make liars of the most precise draftsmen and printers.

All this discussion boils down to the original basic assumption that adequacy depends upon the purposes for which maps are to be used. Purpose determines what scales and symbols are appropriate. Accuracy of control and source materials determine whether reliable maps can be produced at these scales. For many general purposes minimum adequacy could be provided by 1:250,000 to 1:1,000,000 coverage. Wherever heavy concentrations of population and considerable economic activity exist, nothing less than

1:25,000 to 1:62,500 coverage can be considered adequate.

Areal Coverage of the World by Topographic Maps

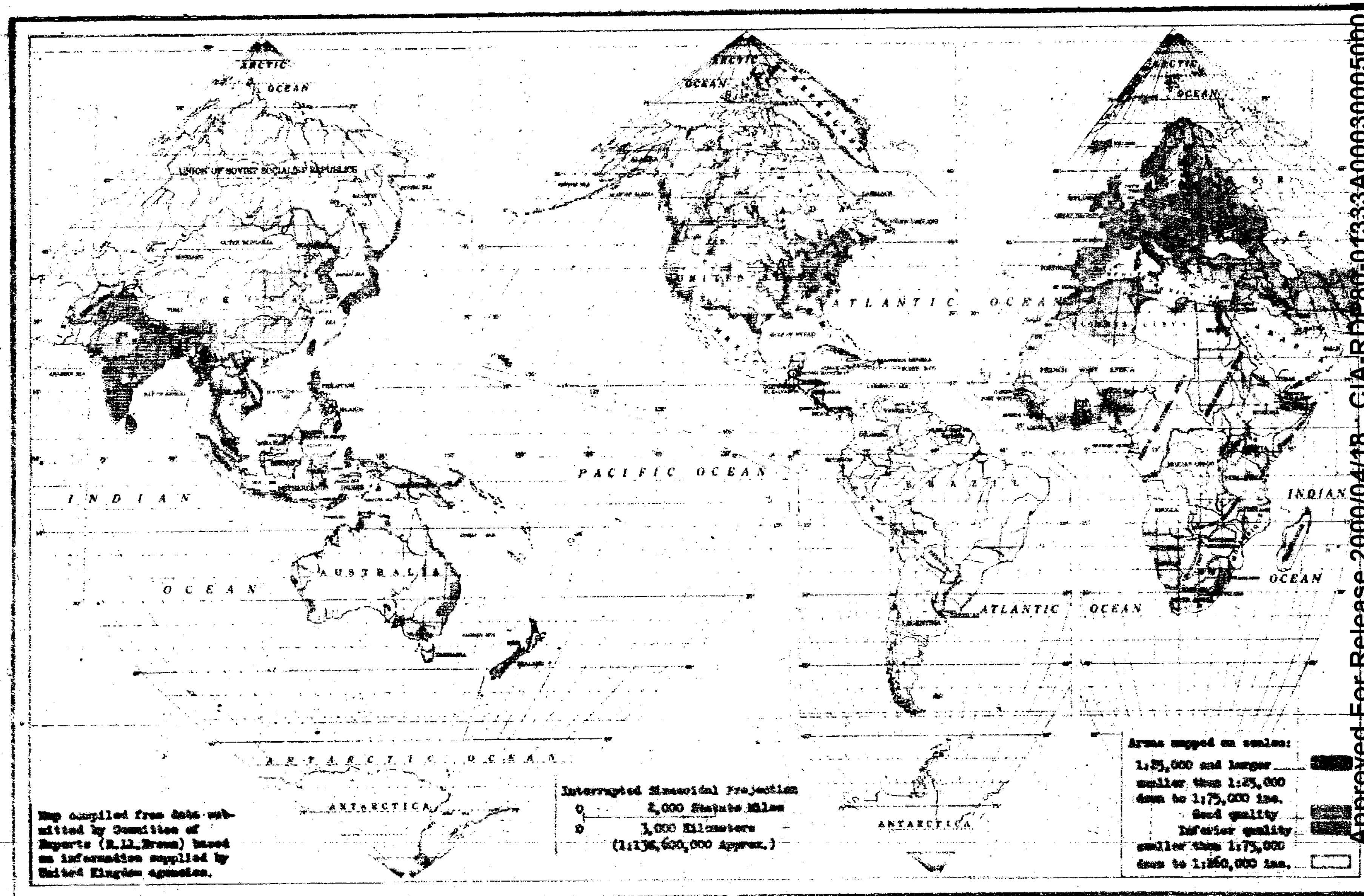
Present Status

No one person, agency or group of agencies knows about every map that has been produced within even the last decade. Intelligence groups are constantly at work buying, begging, borrowing and stealing maps and source material all over the world. These groups cannot possibly catch everything of cartographic value published in books, periodicals and other sources. They are able to collect enough of the topographic coverage, however, to formulate working files and analyses of the amount and general adequacy of world coverage.

The general results of such work show that most of the world has been very poorly mapped and in many spots has not been mapped at all. If you have never examined a map showing the status of topographic mapping of the world, you are in for a shock. Study Fig. 310 which presents a startling picture of the dearth of any medium to large scale topographic coverage for wide spread areas of the world including parts of the United States. Equally shocking is the small amount of large scale coverage where it would prove most valuable.[1] Continental Europe stands out as the major exception. The quality and quantity of coverage in Europe can be traced to the constant threat of and preparations for war

[1]Map taken from Modern Cartography. United Nations Publications No. : 1949. I. 19. Although changes have been made in some classified areas since this map was made the overall picture has not been changed materially.

STATUS OF TOPOGRAPHIC MAPPING
1 January 1949



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in most of the densely populated and intensively used lands of this sub-continent.

Some excellent mapping has been done in north Africa for the same general reasons. North Africa, in fact, has acted as a proving ground for many European theories and cartographic methods. Practical results were then used for other areas.

Exploratory Exercises

On Figure 310

1. Find other areas where large scale coverage exists.

2. What does the legend tell you about the adequacy of the existing coverage? Locate areas of each type.

Compare Figure 310 with Figure 312.

1. Find areas where topographic sheets exist based upon poor control.

2. Find areas where there is positive correlation between mapping and control.

3. Find areas where good control and little or no mapping exists.

Two large maps of the Status of Topographic Mapping in the United States are issued by the Map Information Office of the United States Geological Survey. Map A shows the area covered by maps at scales of 1 inch to 1 mile or larger. Map B shows the area covered by 1 inch to 1 mile or smaller scales. Both are available in your classroom and will provide the necessary background for evaluating the extent and adequacy of our national mapping programs.

Indexes of Map Coverage

The simplest way to determine specific coverage of an area is to examine map indexes. Each major series of maps produced by

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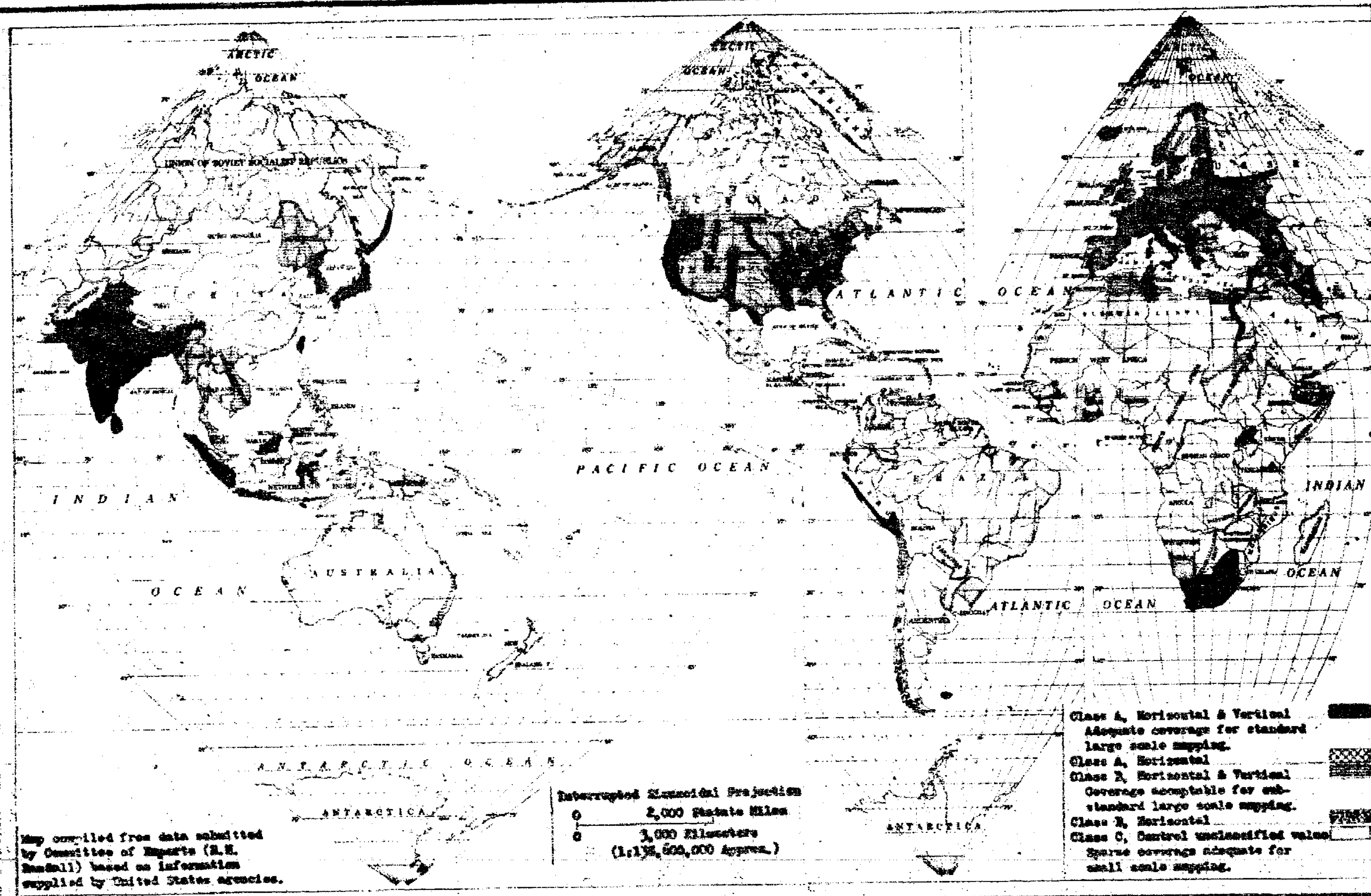
STATUS OF GEODETIC CONTROL SURVEYS
1 January 1949



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responsible mapping agencies is planned and indexed according to some organized system of classification and referencing. The Military Grid Reference Stystem and the general system of British referencing were presented in the last chapter. Each map series is set up within such master frameworks.

Major divisions of the world, often called theatres, are designated on a master map of the world in the Army Map Service System. Each theatre is then divided into smaller units to be covered by one or more series of maps at designated scales. The major divisions or theatres are assigned a letter. For example, North America is V. Series within the division are assigned a specific number such as V 895 shown as the series on the California sheets.

The location and extent of each series is plotted on an appropriate index map. It should be noted that there is no single master index showing all scales of topographic coverage in a given area. Each scale and series or combination of series at one scale, has a separate index printed on a base map that also shows the political boundaries of the area covered by the index. Normally a little box, rectangle or other regular-shaped figure, scaled to the projection of the base index map, shows the location and relative position of each sheet within a series. Various stages of completion, obsolescence and distribution of individual sheets are shown by small triangles placed in the corners of the boxes; by color or, by some other symbol overprinted within the box. A sheet reference number, such as NJ 18-1 for the Baltimore 1:250,000 sheet, and sometimes the actual name of the individual sheet are printed within its appropriate box. You have had a number of small samples of indexes on map sheets containing Index Diagrams. Several separate index sheets are also available for your class use.

College Depository Program

Many of the schools where this text will be used have cooperated with the Army Map Service in a College Depository Program. Hundreds of thousands of all types and scales of maps were distributed to colleges and universities to serve a two-fold purpose:

1. Valuable maps were made available for academic research.
2. Dispersal of copies of these maps insured against the loss of critical map material in the event of destruction of the central collection. Sets of indexes were included in this distribution to colleges to increase the usefulness of the map collections. These indexes can be used in: cataloguing map sheets in the local collection; determining the existance and extent of coverage at specific scales and identifying the name or number of sheets needed for particular purposes.

Any student interested in finding maps to cover specific places should first consult master maps showing the breakdown of the world into major theatres or countries as the case may be, then proceed to the appropriate series index. In some cases, where no college depository collection is available or where permanent retention is desired indexes can be obtained directly from the source of their publication such as those for topographic quadrangles indexed by states and issued by United States Geological Survey. When the correct index is located it will show which sheets have been published. If a sheet or series, shown to be current on the index, is not obtainable from a local library it may be possible to get it elsewhere. The producing agency may have a direct sales policy. If this is not the case, the sheet may be procured from some central agent or map collection such as the Superintendent of Documents or the Library of Congress. Foreign maps may be obtained from comparable sources established by foreign governments or private agencies.

Mapping Agencies and Their Influence

Just as in numerous other fields of endeavor, there are a few agencies in each country which dominate or strongly influence the cartographic policies and activities of that country. This applies especially to topographic mapping and special adaptations such as hydrographic and aeronautical charts. Although the major portion of such mapping is done by public agencies, some important contributions have been made by private organizations. Examples of these are the National Geographic Society and American Geographical Society in this country and the Consociazone Turistica Italiana (Italian Touring Society) in Italy. These groups produce excellent maps that have been used as sources for government compilations at the same or different scales.

It would be difficult to review all the mapping agencies of the world. Only a few of the major ones are discussed by countries to give you some idea of their special fields of endeavor and of their influence up on these fields and upon mapping in general.

United States

All government mapping in the United States is directed by the Bureau of the Budget which allocates areas of responsibility as well as funds to each government mapping agency.

The United States Geological Survey

Rapid westward expansion and national economic development within the United States after the Civil War revealed the urgency of a unified cartographic program. Too little was known about topography and mineral resources anywhere in the nation to keep abreast of this expansion and development. Lack of adequate maps had also been apparent during several compaigns of the Civil War. All of these were used as arguments in justifying the need for a national mapping program to Congress. Several un-official and semi-official groups who had already done pioneer work in mapping were consolidated into the United States Geological Survey under the Department of the Interior in 1878. The new agency was commissioned to send out field parties to establish central points, compile topographic maps and collect other source materials concerning the geologic and topographic features of the country. Appropriate results were to be published and made available for general use. USGS, thus, became the official organization for servicing civilian topographic map and geologic information needs.

The early start plus the high quality of work done by USGS have made the agency influential in developing standards and methods of topographic mapping throughout the length of its service. Each year the Survey has contributed new sheets and revised some existing domestic topographic coverage. The fact that there is still incomplete coverage of the United States is due largely to allocation of insufficient funds to underwrite a comprehensive mapping program and is not a reflection on the efficiency of the Geological Survey.

During the war periods many of the resources of the agency were diverted to special projects and consequently many domestic mapping projects were delayed or suspended. Since the cessation of hostilities of World War II there has been an increased production of new domestic sheets. Some of this increase has been due to cooperative arrangements with interested local communities. According to the terms for such agreements any community can request topographic mapping of its area if it will underwrite one half of the costs involved in such an undertaking. As a result, several 1:24,000 scale sheets have been completed and distributed.

The Survey is responsible for various other cartographic activities. A Geologic Atlas of the United States and Geologic Folios to accompany specific topographic quadrangles have been compiled but have not always been kept current. Stocks of various scale base maps of the United States as well as mineral maps, including wall-sized maps of coal, oil and gas fields of the United States; Physical, Physiographic and Relief Maps on scales of 110 miles to 1 inch are maintained by the Survey. It has also cooperated to a very limited extent in producing domestic sheets for the International Map of the World Series. Catalogues of publications, maps and indexes of topographic sheets are obtainable from the Director of the United States Geological Survey, Department of the Interior, Washington, D.C.

The United States Coast and Geodetic Survey

The Coast Survey, which was authorized on 1807, had been doing significant geodetic work for many years before it was given much notice. The smaller unit was finally recognized and expanded into the United States Coast and Geodetic Survey, Department of Commerce in 1878. Official recognition was the direct result of their completion of the transcontinental arc of triangulation along the 39th parallel, one of the most famous projects in geodetic history.

The subsequent influence of the United States Coast and Geodetic Survey upon mapping has been great because of its responsibility for determining control data. It determined Mean Sea Level and North American Datum and extended primary triangulation and leveling networks from these bases. The agency is also responsible for tidal, current and coastal surveys needed to aid navigation. Based on these and similar types of information, the agency prepares and publishes coast pilots, tide tables, hydrographic charts, aeronautical charts and other materials essential to safe navigation on the sea and in the air. It also makes magnetic observations throughout the country to establish the amount of magnetic variation or declination. Findings from these observations are essential to the use of the magnetic compass and are the basis for declination information shown on various maps and charts.

Agencies Under the Department of Defense

Navy Hydrographic Office - This office develops and distributes maps and charts based upon research into the needs of navigators and aviators. Its nautical charts cover principally foreign waters and coast lines. Its aviation charts cover only narrow strips along the coastlines of the United States, Central America, the West Indies and the Hawaiian Islands. Both types of charts thus supplement rather than duplicate similar charts prepared by the Coast and Geodetic Survey. The Hydrographic Office also issues base and outline charts of the world and, charts of compass variations, magnetic declination, communications, great circle distances and time zones. In addition, the group directs research in the various phases of oceanography. Thus the major contributions of the Hydrographic Office are of primary importance to persons involved in nautical affairs as might be expected but can be adapted to many other fields of endeavor.

Aeronautical Chart and Information Service - The Air Forces have developed a special service of their own to cope with cartographic problems related to flying. They conduct experiments on the types of maps and special symbolizations best adapted to various flying conditions and types of planes. Special aeronautical details are overprinted on standard topographic base maps. The Aeronautical Chart and Information Service has prepared both domestic and foreign coverage but has been especially active in the latter because of the critical need for foreign charts in the conduct of "hot" and "cold" wars. Domestic needs are met by United States Coast and Geodetic Survey.

Corps of Engineers

The Corps of Engineers are responsible for navigation of inland waters and keeping maps current of river and stream conditions.

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Many of these river charts are not available for sale but may be studied at District Engineer Offices. The engineers have also published several port series and, the Official Railroad Map of the United States in four sheets at a scale of 1:2,500,000. These port studies and maps are available from the Superintendent of Documents.

The Army Map Service - One of the largest cartographic agencies in the world has grown to its present size and importance in one decade. Its origin was the Engineer Reproduction Plant of the Corps of Engineers, which consisted of a handful of people. With the expanded military operations occasioned by World War II, the need for a comprehensive military mapping organization was critical. Consequently E.R.P. was vastly expanded and began operations as the Army Map Service, Corps of Engineers, in 1942. In the ensuing period it has grown to include a twelve building base-installation, and several scattered field offices employing nearly four thousand people in all.

The fundamental responsibility of the Army Map Service is to produce good topographic maps for military purposes. In fulfillment of this mission, several different branches of planning, procurement, compilation, reproduction and distribution are involved. A large group of personnel are kept at work acquiring and evaluating source materials for military and mapping intelligence. They are also responsible for amassing one of the largest library collections of maps in the world. Liaison for these purposes is maintained among civilian and military attaches and other government agencies. Policies concerning geodetic control,

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grid systems, cartographic format and various other questions of mapping policy are studied and passed upon by agreement with other agencies in the Department of Defense and the federal and foreign governments.

Several methods of compilation including stereoscopic and photogrammetric techniques are used. These compilations are carried through all the stages of reproduction necessary to complete large, medium and small scale maps.

The Map Service also conducts research upon, constructs, and reproduces raised relief models. As was mentioned before, this medium of cartographic representation is increasing in popularity among military tacticians and the Map Service is the only government agency producing rubber and plastic models.

Although AMS produces all types of maps those produced in greatest quantity are topographic maps at scales of 1:25,000; 1:50,000; 1:250,000; and 1:1,000,000. Most of these represent coverage of foreign areas, countries, continents and the world. Domestic sheets are the responsibility of U.S.G.S. except in areas containing military installations and adjacent to them. Thus the Map Service exerts influence in the preparations for an operations of mapping programs throughout the world as well as in the determination of policy for national mapping techniques and operations.

Other Federal Government Agencies

Several Departments and Bureaus of the federal government have limited cartographic responsibilities and operations. These groups follow accepted techniques generally and do not exert much influence upon the overall planning and operation of mapping programs. This does not mean that their contributions have no value or are unimportant in various fields of research.

Catalogues are obtainable from each of the following agencies and should be consulted to determine what maps have been prepared for public sale or distribution.

United States Department of Agriculture - Several bureaus and agencies in this department issue maps. The list includes the: Bureau of Agricultural Economics; Bureau of Chemistry and Soils; Soil Conservation Service; Weather Bureau; Forestry Service; Bureau of Public Roads and direct contributions of the Department as a unit.

United States Department of Commerce - The Coast and Geodetic Survey within this department was presented separately because of its special significance to mapping. Other agencies within this department who prepare maps are the: Bureau of the Census; Congress, Joint Committee on Printing and the Federal Power Commission.

The United States Department of the Interior - The General Land Office; National Park Service and Bureau of Reclamation as well as the Geological Survey issue maps through the Department of the Interior.

The State Department - Most of the maps produced by the State Department involve boundary and treaty settlements at home and abroad. They are the work of various boundary commissions or the Office of the Historical Advisor.

The Tennessee Valley Authority - The last agency to be mentioned in this brief summary of federal activities having some responsibiliy

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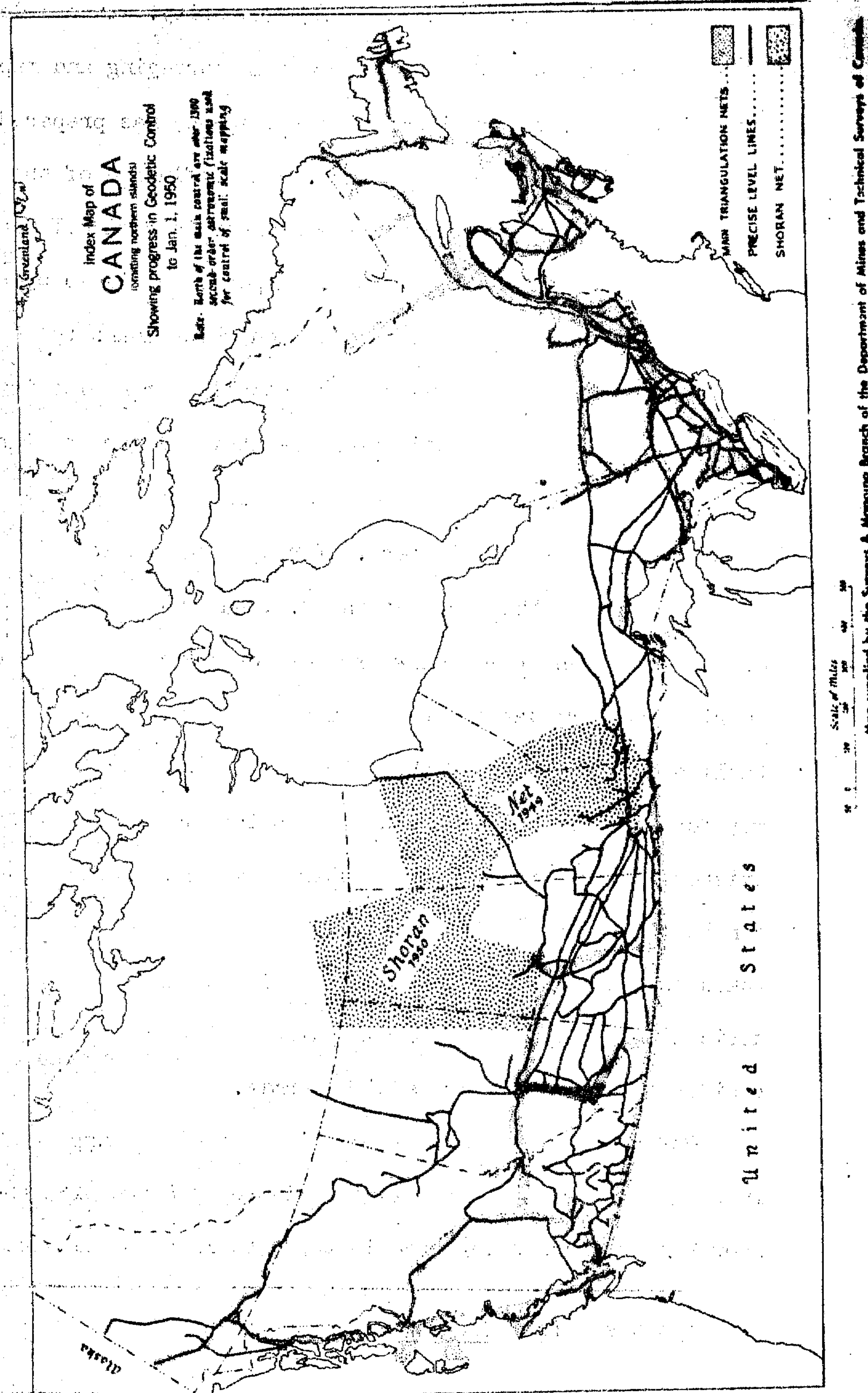
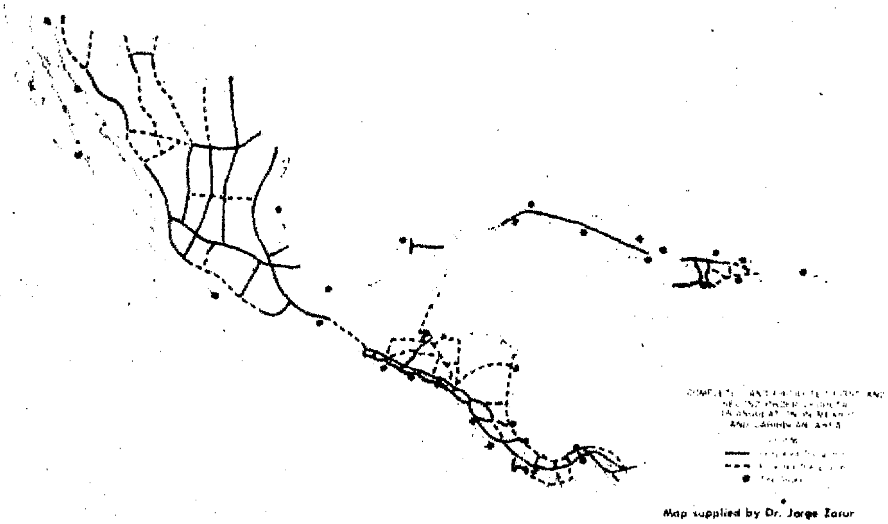
for mapping, is the Tennessee Valley Authority. It has done extensive work throughout the southeast in surveying and mapping. In addition to topographic mapping the agency has prepared several interesting isopleth and soil maps. The Influence of the TVA arises from the fact that it was a pioneer in regional planning and implementation of these plans. Reports published by the Authority have had world-wide attention which means that their cartographic endeavors have had an unusally large distribution.

Through the contributions of the above listed mapping agencies, the United States has come to dominate the mapping activities of the Western Hemisphere. Through cooperation with Canada and countries to the south of the U.S. the North American Datum of 1927 has been or is being extended over North and Central America and correlated with a South American Datum to be established. Extension of these triangulation nets will pave the way for greater and more accurate mapping programs than previously existed in most areas of the western hemisphere. Photography can be flown comparatively rapidly as compared to the time it takes to establish primary triangulation so that once the geodetic net is established topographic mapping can be done as rapidly as need and budgets will permit.

Before you read the next sections on other mapping agencies in the western hemisphere examine Figures 324 and 325A and B[1]. They show the progress being made in the establishment of geodetic control.

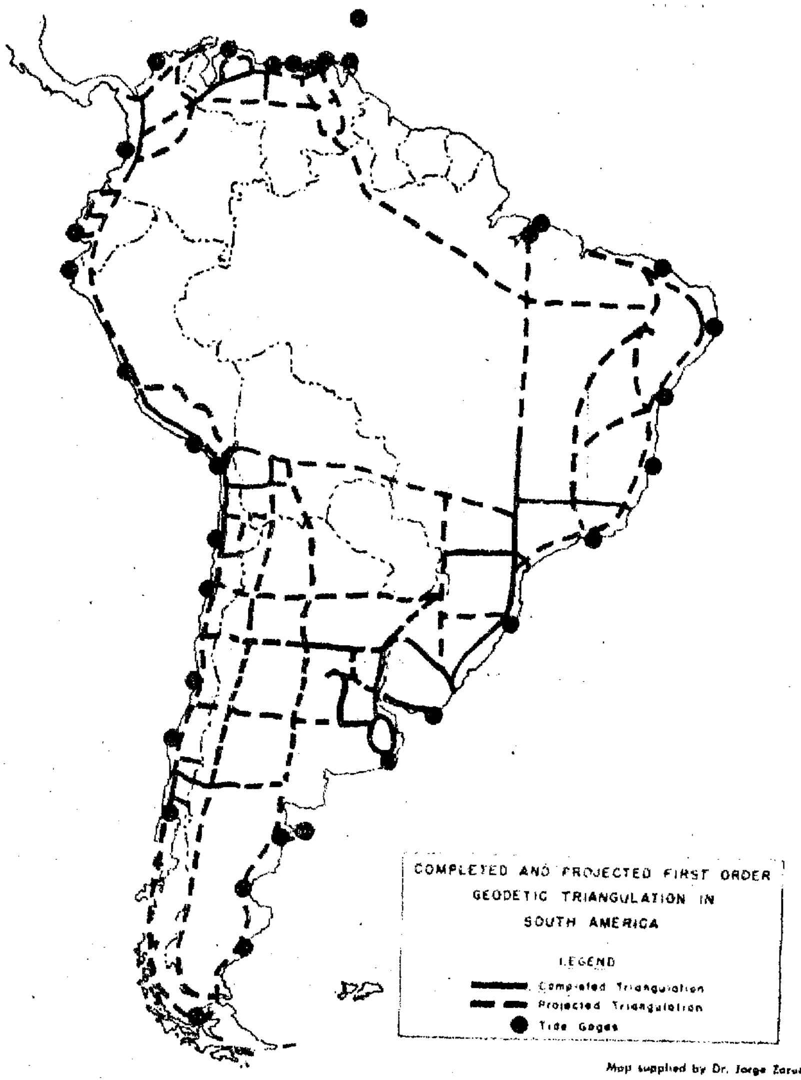
[1]Maps taken from World Cartography Volume I United Nations 1951.


Index Map of
CANADA
(omitting northern islands)
Showing progress in Geodetic Control
to Jan. 1, 1950
Greenland
MAIN TRIANGULATION NETS
PRECISE LEVEL LINES
SHORAN NET
Net 1949
Shoran 1950
United States
Alaska
Scale of Miles
Map supplied by the Surveys & Mapping Branch of the Department of Mines and Technical Surveys of Canada



A

STATUS OF GEODETIC TRIANGULATION IN THE AMERICAS
A. Central America
B. South America



B

1. What is the correlation between triangulation nets and population patterns?

2. What economic activities would affect the development of triangulation nets and resulting mapping programs in each major area?

3. Give a geographic explanation for the lack of geodetic work in the northcentral area of South America.-In northern Canada.

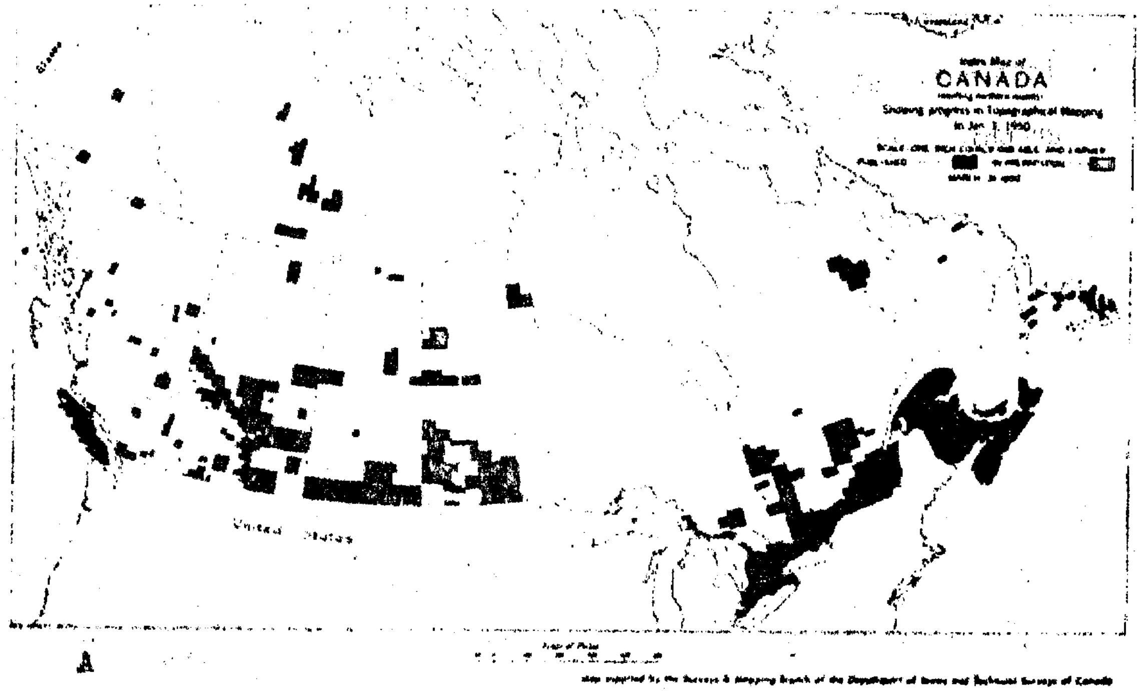
Canada

The areal extent of Canada which is greater than that of the United States and the vast expanses of sparsely to uninhabited forests, muskegs and rocky uplands make an extensive mapping program very difficult. These very handicaps, however, have brought the Canadians into prominence in one method of mapping. Canada was one of the first nations to use aerial photography and photogrammetic techniques. As a matter of fact the method of mapping from oblique photos was developed in Canada and the Canadians have been strong proponents of Trimetrogon Techniques[1]. This method can be adapted to mapping of the lake and forest contry of the northern frontiers.

Through the use of photography, much of Canada has been covered by maps at the scale of one inch to four miles. There is still very poor coverage at one inch to one mile except in the St. Lawrence Valley and scattered mining areas where large scale coverage is essential.

Your attention is called to the adequacy of coverage of Canada, at this point, to further the point that there is much still to be done in mapping North America despite the

[1] See next chapter under section on Photography if these terms are new to you.

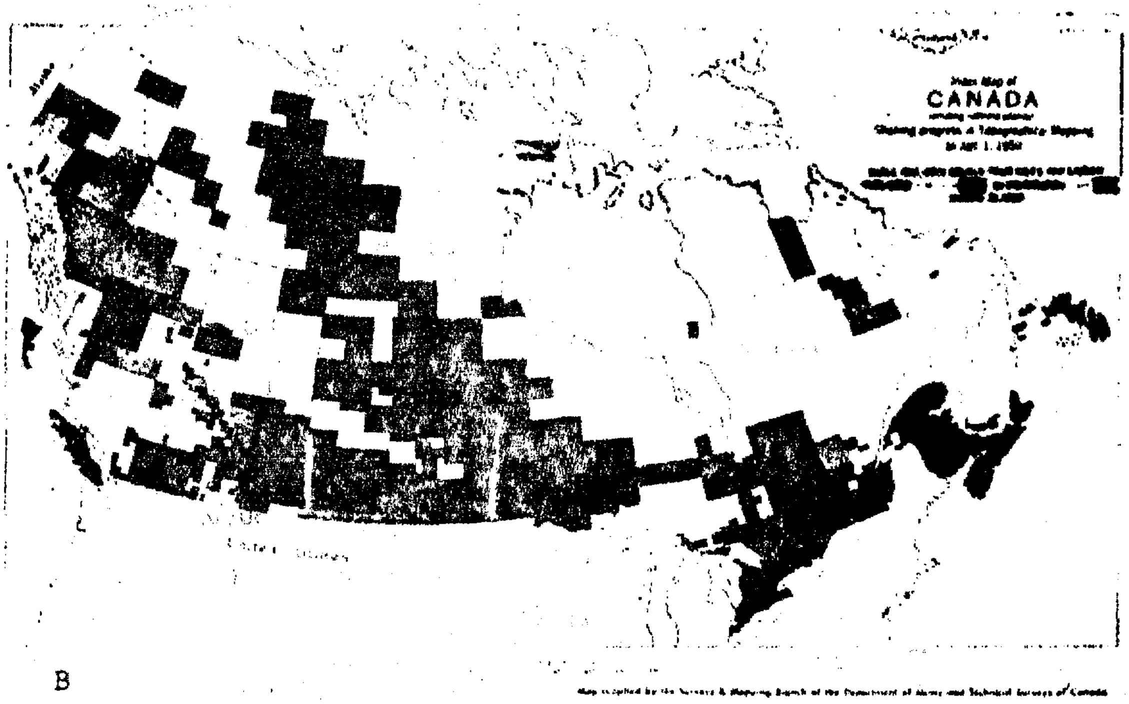


A

STATUS OF TOPOGRAPHIC MAPPING IN CANADA

A. One inch to one mile

B. One inch to four miles



B

international influence of the United States and Canada on cartographic policy and methods.

Department of Mines and Technical Surveys of Canada

Surveys and Mapping Branch - Most of the work involving geology, engineering and technical development of mineral resources is directed by the Department of Mines and Technical Surveys of Canada. There are several branches within this department, one of which is important in the fields of mapping.

The Surveys and Mapping Branch combines many functions that are spread among several agencies in our federal government. The Geodetic Survey in this Branch is responsible for the establishment and extension of primary triangulation and related geodetic research. The Hydrographic Service is comparable to the U.S. Hydrographic Office in the Type and scope of its work. It is responsible for the maintenance and charting of coastal and inland waters. Another division is responsible for aeronautical charts and map compilation and reproduction. The functions of this division are similar to those of the U.S. Aeronautical Chart and Information Service.

Topographical Survey Division - The Topographical Survey Division, one segment of the Surveys and Mapping Branch, is separated from the general discussion of the Branch because of the significance it has to mapping activities for the Dominion. Most topographic surveys and compilation of topographic maps is done by this division in much the same way that the U.S. Geological Survey carries on the work for our country.

The National Topographical Series include four scales--

1, 2, 4, and 8 miles to 1 inch. Index maps and other cartographic information are available from the Survey or the Minister of Internal Affairs and Information, Ottawa, Canada.

An important adjunct of the Topographical Survey Division is the National Air Photographic Library. Prints of all aerial photographs taken by or for the Dominion government are collected in this library. Since Canada is being covered very rapidly by blankets of aerial photography the collection is an excellent source of material for regional analyses and research. The collection is indexed and both prints and indexes are available to the public.

Army Survey Establishment of the Department of National Defense

Topographic surveying and mapping needed for Dominion defense and security are accomplished by the Army Survey Establishment of the Department of National Defense. The work of this Establishment is similar to the Army Map Service but on a much smaller scale and of far less influence in international mapping developments.

Provincial Agencies

Each Province has an agency or agencies which carry on local mapping activities. Their influence upon mapping generally is not great. They are more especially local service functions in establishing roads or for supervision of land utilization and natural resources. Catalogs of maps covering the individual provinces are available from government headquarters in each province or from the dominion government headquarters in Ottawa.

The Americas

Countries south of our border in Central and South America and the nearby islands are lumped under the general term, "The Americas" for two reasons. First, the term is generally accepted in mapping circles and so stands for the areas indicated. Second, discussion of each country would be of little value in this chapter because the mapping contributions and influence exerted by these countries are so small.

Topographic mapping of the Americas and especially South America is still so fragmentary that it will take a long time or major threats to national security to complete large scale coverage of most areas. The American Geographic Society 1:1,000,000 series is the only coverage in many places. The Society began compilation of this series in 1920 and completed it in 1945. The series consists of 107 sheets which conform to the format and areal coverage of the 1:1,000,000 International Map of the World. Each of these sheets has a reliability diagram which shows how the maps were compiled and the types of surveys used[1].

In many cases the reliability is questionable on these and many other maps produced by different agencies. The inadequacy of present coverage can be illustrated thus: Less than 60 miles from the Panama Canal there is a range of mountains about 120

[1] The Society has also published a Catalogue of the Maps of Hispanic America in which are listed not only separate maps but also those to be found in books and periodicals.

miles long and over 5200 feet in elevation that does not appear on current maps. Numerous rivers and mountains throughout The Americas are shown 30 to 40 miles off their actual positions. Some elevations are in error as much as 50%. Coastlines are inaccurate and there are even instances where the positions of ocean and mountains are reversed. In some cases the only coastline charts are compiled from surveys made one hundred or more years ago by British and Spanish mariners. There has recently been some reason to suspect that the Isle of Pines, used as a check point for approaching Havana International Airport, may be as much as 15 to 18 miles out of position on the Map[1].

During the 1940's a Western Hemisphere MAPPLAN (Mapping and Charting Plan) was proposed by the U.S. Joint Chiefs of Staff to correct these shortcomings. It was found that this 20 year plan could not be carried out because of the lack of control and photography. As a result, the Inter-American Geodetic Survey was established as a subordinate command of the U.S. Army, Caribbean and was delegated the specific mission of cooperating on surveying and mapping with any Central and South American country with which agreements had been made.

The objectives of I.A.G.S. in carrying out this mission are five-fold:

1. To establish a first order triangulation net over South America using a South American Datum based on the International Spheroid. This Datum will connect with North American Datum (based on Clarke 1866 Spheroid) which is to extend to the Panama-

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[1]Adapted from "Cartography in the Americas", World Cartography. United Nations 1951.

Colombia border and include the Caribbean Islands (line passes through Windward Passage).

2. To establish Mean Sea Level datum for all of Latin America.

3. To correlate maps of scattered areas on either side of the international boundaries and coordinate isolated systems.

4. To produce maps and charts by aerial photography and surveying.

5. To standardize mapping procedures and products.

It is apparent that the fulfillment of the IAGS objectives will have a tremendous influence upon the mapping activities and resultant maps of the Americas. Furthermore, in addition to the guidance and assistance provided by IAGS, the U.S. Air Force is helping to fly photography in several countries. For example, nearly half of Brazil has been given Trimetrogen coverage. This included most of the Amazon and São Francisco basins and Atlantic Coastal areas. Thus, the emissaries of Uncle Sam are constructively at work throughout the western hemisphere.

The overall organization and responsibility of foreign mapping agencies is not materially different from those in the United States. In most foreign countries mapping is accomplished by the government as a military or civil function. Wherever a civil government agency does military mapping, the organization may come under military control during wartime. It is not uncommon for one agency to publish both a military and a civil edition of the same map. In certain instances, just as in the United States, private agencies also produce maps of recognized quality and utility.

<u>Europe</u>

The following is an abbreviated listing of the agencies producing maps for countries in Europe.

British

Ordnance Survey of Great Britain - The beginning of the British military mapping can be traced to the Highland Rebellion of 1745 when it became obvious that coordinated planning, surveys and mapping were needed to strengthen the unification and defense of the island groups.

"The Ordnance Survey was formed in 1791 in order to make a map of Great Britain at the scale of one inch to one mile, principally for defence purposes. Almost simultaneously Parliament directed that a trigonometrical survey of England and Wales should be undertaken, and, since the task was a military one, entrusted it to the Board of Ordnance hence the title 'Ordnance Survey'." [1] This Survey ultimately became the official mapping agency of Great Britain. (In 1922 Northern Ireland and the Republic of Ireland took over the mapping of their own areas.) Since its inception and especially during the twentieth century, the Ordnance Survey has done outstanding work in establishing triangulation networks and developing large scale map series covering the British Isles. The present large scale survey and continuous revision of existing series together with Land Utilization Survey maps provide what is undoubtedly the most comprehensive map coverage of any country in the world.

Shortly after World War I thousands of English school children

[1] A Brief Description of the Ordnance Survey Large Scale Plans Published by the Director General at the Ordnance Survey Office, Chessington, Surrey 1947 p. 17

cooperated with the Land Utilization Survey by doing detailed field work of the land utilization of England. These children and their teachers made exhaustive studies and field maps that were comprehensive to the finest detail such as, for example, the exact kinds of structures and crops found in the area of their study.

Directorate of Military Survey, War Office - A section for military mapping has existed for years in the military intelligence division of the War Office. In 1940, the Geographical Section, General Staff, as it was then known, was set up as a separate directorate. In 1943, its name was changed from Geographical Section, General Staff to the Directorate of Military Survey. The director of Military Survey, however, still carries the supplementary title of chief of the Geographical Section, General Staff. Overall mapping policies for foreign coverage are established by the British Directorate of Military Survey which is also responsible for military topographic maps and, in collaboration with the Air Ministry, and Ordnance Survey for air charts for the Royal Air Force. Although it does some field and radar work, most of the maps compiled or issued by this agency are derived from existing map sources. Many maps are reprints or slight revisions of ones prepared by other British or foreign agencies. Whatever the source, the Directorate maintains map coverage of Europe, Asia, Africa, Australia, and parts of the Americas.

Directorate of Colonial Surveys - Maps for the British Commonwealth of Nations exclusive of the British Isles, are the responsibility of the Directorate of Colonial Surveys. This

Directorate has fostered the establishment of many triangulation and mapping projects in what are now former colonies, protectorates or dependencies of the British Empire in Africa, Asia and Australia. Compilation of all Colonial Survey maps, with the exception of a few small scale special maps, depend on aerial survey.

Some of the once dependent agencies such as the Survey of India will be mentioned again because of their influence not only on their own but also on surrounding areas. The present importance of the Directorate is in the coordination, unification and standardization of mapping policies and techniques of the member nations of the Commonwealth.

French

The eighteenth century Cassini maps were the first in the world to show the results of systematic surveys. These surveys were small in extent and scattered over France. For obvious military reasons, Napoleon ordered more comprehensive surveys which were later used in the preparation of the Carte de l'Etat Major upon which many later maps covering France were based. It wasn't until 1864, however, that another world's first was accomplished in France in the form of a systematic and coherent network of precise leveling. This level net is of special significance because it proved the merit and utilitarian value of such a network to civil and mapping projects and encouraged other countries to follow suit.

Institut Geographique National - The IGN or National Geographic Institute is a civilian agency attached to the Ministry of Public Works and Transportation, responsible for military maps. In

1940 IGN replaced the Service Geographique de l'Armee and took over its duty of supplying the French General Staff with maps for planning and operations including geodetic observations and ground and aerial surveys. The Institute's total operations cover France and the French Colonies and overseas territories.

German

Before World War I topographic mapping was almost exclusively the responsibility of the military. After this war it was transferred to civilian agencies, the foremost of which was the Reichsamt für Landesaufnahme under the Ministry of the Interior. Centralization of mapping responsibilities was furthered in 1938 when thirteen Regional Land Survey Offices were established under the jurisdiction of this Federal Land Office. During World War II the Generalstab des Heeres, Abteilung für Kriegeskarten und Vermessungswesen (General Staff of the Army, Division of Surveying and Mapping) was also very active. At the end of the war all operations were suspended by the downfall of the government. With the resumption of some German government functions all mapping responsibilities were vested in agencies (Landesvermussungsamt) of the respective states. At present these state agencies and the Institut für Angewandte Geodäsie (Institute for Applied Geodesy) are responsible for mapping in the Federal Republic of Germany and, the Ministry of the Interior and its five subordinate regional survey offices (Vermessungsdienst) are responsible in the German Democratic Republic (Soviet Zone of Occupation).

In addition to these government agencies there are several private organizations in Germany whose maps have enjoyed international popularity. Among these are: the Justus Perthes organization that issues Haack wall maps, Stieler's Hand Atlas, Petermann's Geographical Reports and Vogels map of Europe; Carl Beedeker, famous for travel guides and maps; George Westermann for school atlases and wall maps and, Karl Wenchow for relief maps.

Prussia was always essentially a part of the German complex and so is included under the German section. As a separate mapping authority the Central Directorate of the Prussian Survey was founded in 1870 under the Chief of the General Staff. Five years later two sections, the Topographic Division and the Bureau of Land Triangulation, were combined into the Prussian Land Survey, known after the war of 1814-18 as the Federal Land Survey Office. After 1919 plans were made to centralize all mapping, which had formerly been the responsibility of the separate German states, under a single organization--the Reichsamt für Landesaufnahme. This consolidation was not actually achieved until 1937, at which time an official decree made the Federal Land Survey Office responsible for all mapping carried on within the German Reich and for the fulfillment of the mapping requirements of the General Staff of the Army.

Italian

The major responsibility for all mapping in Italy is vested in the Istituto Geografico Militare (Military Geographic Institute). The IGM has been active in mapping continental Italy and areas which formerly belonged to Italy or were of interest to Italy. During the Italian Campaign in Africa in the 1930's, IGM completed coverage of Ethiopia and Eritrea and also Libya. Aside from these areas, the Italians have had less major influence on foreign areas than might be expected because of their former political aspirations.

Within the realm of private endeavor some excellent work has been done by the Consociazone Turistica Italiana (Italian Touring Club). Their detailed maps of Italy and nearby Alps are internationally famous. The British used these maps as the basis for their 1:250,000 coverage of the area.

Spanish

All mapping in Spain is done under the direction of the coordinating agency, Consejo Superior Geográfico (Supreme Geographic Council) which regulates plans, and organizes and directs all mapping and related geodetic work as well as research in cartography and related fields. The council is composed of representatives from the various government map producing agencies.

Institute Geografico Catastral y Estadistico - The Geographic, Cadastral and Statistics Institute was created in 1873. It is responsible for civilian geodetic and topographic work; weights and measures; geodesy; physics; astronomy; photogrammetry and cadastral surveys. It is now completing a 1:50,000 series to be the "National Topographic Map of Spain" which will be the basic map of Spain, Andorra and the Balearic Islands.

Servicio Geográfico del Ejercito - The Army Geographic Service is the military mapping agency which coordinates and produces topographic mapping and geodetic work for the military. It publishes and distributes maps and photographic materials in cooperation with the Cartographic and Photographic Service of the Air Force. The

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Service is also the official military mapping agency for Spanish colonies and protectorates.

Portuguese

The Geographic and Cadastral Institute is the oldest and most important mapping agency in Portugal. It is also responsible for printing the work of other government agencies and the unrestricted maps of the Ministry of War. In time of war IGC is administratively under the jurisdiction of the Army Cartographic Service a division of the General Staff of the Army. In peacetime there is liaison only between the two. The IGC produces the standard topographic series and maps of all military establishments in Portugal and her dependencies.

Swiss

Swiss topographic maps are produced by two agencies, the Confederate Topographic Office and the Confederate Survey Administration. The former whose native title is abbreviated to ELT is a section of the Swiss Military Department. This office is responsible for first to third order triangulation, leveling and all operations necessary to the production of military and topographic maps. The Administration supervises fourth-order triangulation and the production and maintenance of cadastral maps.

Belgium

The Institut Geographique Militaire formerly known as the Institut Cartographic Militaire is the official military mapping agency of Belgium. IGM produces topographic series of the country using the French and Flemish language for marginal information and place names. It is responsible for the triangulation, leveling and other work related to cartographic projects.

Dutch

The Dutch Topografische Dienst (Topographic Service) is the agency responsible for the various phases of work needed to produce topographic maps for the Netherlands. It is necessary for this agency to maintain an active large scale mapping program, including constant revisions, because of the lowland character of the country and the need for detailed maps to be used in reclamation and maintenance projects.

Danish

The Geodetic Institute provides the Danish General Staff with domestic topographic maps for both planning and operations. The Institute is the official agency responsible for all surveying and mapping in Denmark and the Faeroe Islands. The agency produces new mapping and makes revisions on existing planimetric and topographic maps.

Norwegian

As in so many other countries the Norwegian Geographic Survey supplies the Norwegian General Staff with topographic maps for planning and operations in Norway. In addition there is a Polar Institute which is an agency of the Norwegian Department of the Interior. It is responsible for the surveying and mapping of the Norwegian dependencies of Svalbard, Bear Island, Jan Mayen, and parts of Antarctica.

Swedish

Topographic mapping in Sweden is the responsibility of

Generalstabens Topografiska Avdelning (Topographic Section, General Staff). The surveying and mapping activities and the initial compilation processes for producing topographic and economic series and photomaps are carried out by a civilian agency, the Rikets Allmanna Kartverk--R.A.K. (National Public Map Service). The military maps of Sweden are printed and distributed by a private company, the Generalstabens Litografiska Anstalt--G.L.A. (Lithographic Institute of the General Staff). The R.A.K. and the G.L.A. are parts of Esselte, A.B. (Esselte Corporation), which is one of 67 corporations making up the gigantic A.B. Sveriges Litografiska Tryckerier (Swedish Lithographic Publishers, Incorporated.) These organizations do contract printing for the Swedish government and provide the Swedish General Staff with domestic topographic maps for planning and operations. These independent corporations also compile and publish various maps, charts, town plans, atlases, and cartographic and geographic books.

Finnish

The Geodetic Institute of Finland and the General Survey Office have pioneered in the fields of Geodesy and Photogrammetry respectively. Both have done outstanding research, followed by successful application too recently (since about 1936) for the full influence of their methods to be felt. The Geodetic Institute, headed by Dr. V.A. Heiskanen, has contributed greatly to the development of geodetic methodology which is playing a most important part in the gravimetric and geodetic work of the postwar world. The General Survey Office has developed a method of rectification of aerial photographs which makes possible their use as basic source for exceedingly accurate large scale maps.

Estonian, Latvian and Lithuanian

Before 1918, the General Staff of the Russian Army was the primary agency for surveying and mapping activities in the Russian area that later became the republics of Estonia, Latvia, and Lithuania. In the early part of the post-1918 period, each of the three new countries used the Russian survey and mapping data as the initial base for their own mapping activities. When these native cartographic agencies subsequently attempted to develop uniform national series on a common datum, the elimination of considerable discrepancies resulting from the different triangulation systems of the early Russian period became a major problem. It was for this reason that, after an early period of surveying and mapping based on the old Russian work, each of the cartographic agencies of Estonia, Latvia, and Lithuania initiated new state triangulation surveys designed to produce sound geodetic bases for modern large-scale maps.

Czechoslavakian

The principal topographic mapping agency in Czechoslavakia is the Military Geographic Institute at Prague. The topographic maps covering the area are of heterogeneous nature derived from both Czech and German maps some of which, in turn, were based on old Austrian surveys made from 1860 to 1898, and others on modern Czech and German surveys. The Institute is now working on large scale military maps using recent triangulation and leveling completed under its direction.

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Polish

The Military Geographic Institute was the direct result of the unification of two minor agencies known as the "Surveying School for Officers" and the "Topographic Section of the Ministry of War". This consolidation took place between the years of 1919-1921.

From 1921-1927 the Military Geographic Institute's primary concern was the consolidation of the diverse material they inherited from the German, Russian and Austrian agencies. This compendium was found to be inadequate for large scale mapping, and in 1927, new 1:25,000 controled ground surveys were planned, which were due to culminate in the early 1950's.

Several new map series were completed within the (1927) pre-war boundaries, however; the large scale mapping & surveying was interupted by World War II.

During and after World War II mapping activities were taken over first by the German Federal Land Survey and General Staff and then by the agencies under the Soviet Zone of Occupation.

Hungarian

The military maps of Hungary were produced by the Royal Hungarian Cartographic Institute or its successor the Royal Hungarian Military Cartographic Institute. Many Hungarian maps like those of Czechoslavakia were based on Austrian surveys of 1860 to 1898. As of 1947, however, over half of the total area mainly in the north and along the frontiers was covered by large scale maps prepared by the Institute.

Austrian

As has been noted several times previously, the old

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Austrian surveys of 1860 to 1898 extended beyond the recent Austrian boundaries into surrounding areas of the Austrian Empire. At present the official mapping agency is tho Federal Office of Gauging and Surveying. The agency is re-surveying Austria. New large-scale maps are developed from these field surveys. Both aerial and terrestrial stereophotogrammetric methods are used. In addition to its own work this Office also publishes maps prepared by other departments of the government.

Tourist maps and special large scale topographic series within the Austrian Alps are published by the private organizations of Freytag-Berndt and Artaria, and the German and Austrian Alp Society.

Rumanian

The Military Geographic Institute formerly known as the Geographic Service of the Army is the principal mapping agency of Rumania.

Bulgarian

The domestic topographic mapping agency of Bulgaria is the State Geographic Institute.

Yugoslavian

Modern topographic mapping in Yugoslavia was initiated during the nineteenth century by the Military Geographic Institute, Vienna and the Serbian Geographic Division of the General Staff. When Yugoslavia was fromed in 1918, the Serbian mapping organization was renamed the Military Geographic Institute. A few postwar mapping agencies are known to produce town plans and small scale maps for school and tourist use. These agencies include Ucila, The State

Press of Slovenia, and the Disabled Veterans Book Publishing Enterprise.

Albanian

Until the end of the World War II, Albania had no native mapping, and since that time there has been no report of the formation of a native agency for the purpose of making maps. The major contributions to the mapping of Albania have been made by agencies of other countries. Because of the accurate surveying and mapping of this area by the Italian Military Geographic Institute, this agency is considered to be the Official mapping authority of Albania.

Greek

The Geographic Service of the Army and the Ministry of Public Works are the principal mapping agencies of Greece. Maps of the Dodecanese Islands which formerly belonged to Italy and of portions of the Ionian Islands were produced by the Italian Military Geographic Institute.

Overall Coverage

Some specific references to coverage provided by a few countries for other countries in Europe have already been made. Notation of others was deliberately omitted until this point because there would have had to be a repetition for practically every entry. Outstanding in this respect are the map series produced by the British Geographical Section, General Staff and its agencies; the German Generalstab des Heeres or German General Staff and the United States, Army Map Service. These three have compiled, adapted or reprinted maps amounting to complete

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coverage of Europe. In many areas each group has used the other's work as well as that of the country involved. Because of this adaptating and reprinting, the overall coverage prepared by these agencies is not uniform in quality. The GSGS and especially AMS have been working steadily since the end of World War II to improve the quality of their sheets and series. These two organizations have, at the same time, exerted considerable influence on the overall mapping policies and standards of the NATO and other pro-Allied European countries.

Africa

The total map coverage of Africa is spotty and uncoordinated with vast intervening areas that are either poorly or completely uncontrolled and unmapped. Some excellent quality mapping projects that are far in advance of what the average person might expect have, nevertheless, been completed in northern Africa. Just as many dreams of empires were tested in this mediterranean area, so, also, were many cartographic schemes and experiments and, with more success. The French, Spanish, Italians, British and, to some extent, even the Germans, individually or in temporarily cooperative teams have completed surveys, flown photography and compiled several map series. The progress of new sheets is now slow, however, due to budget problems and the extensive amount of work involved.

The quality of coverage in central and interior Africa generally has been poor with some areas not covered at all. Only parts of the central area have been mapped by the Belgians. Improvements have been made recently due to the development of mineral areas and British agricultural experiments. The British are engaged in large scale mapping based on aerial photography, of the economically important areas throughout East, Central and West Africa. The farther south one moves in Africa, generally, the poorer becomes the quality of mapping until the Union of South Africa is reached where the situation is improved.

Union of South Africa

Intensive mining and agricultural regions in the Union of South Africa have shown the need for topographic coverage but it has not yet been completed. The Trigonometrical Survey is charged with the preparation of all maps other than geological. This Survey has completed primary and secondary orders of triangulation and much of the necessary aerial photography has been flown. Line maps at the scale of the photography are prepared by topographic field parties upon completion of aerial missions and copies of these maps are then made available until topographic sheets can be finished. It will be some time before large scale coverage of the economically advanced portions of the Union is completed.

Northern Africa

Since native mapping agencies have been or are still largely under the influence of European agencies they have not contributed many original mapping projects. It should not be inferred thereby, that they have not been at work on local cooperative projects. It is, nonetheless, questionable in many areas just how much the natives would have done without the guidance or proding of foreign interests.

Spanish Influence

Spanish Morocco - The official military mapping agency for all Spanish Colonies including Spanish Morocco is the Army Geographic Service and the agency directly responsible for gathering geodetic data and publishing maps is the Geographic and Cadastral Institute. Maps produced by these agencies covering Spanish Morocco west of 5° W are fairly reliable since they are based on a first order triangulation net. East of this meridian basic control consists of reconnaissance and stadia surveys of low geodetic accuracy.

French Influence

French Morocco - Two French agencies, the National Geographic Institute and the National Geographic Institute — Moroccan Annex are the official agencies for French Morocco. Two types of maps are published by these agencies. The Regular series is based upon a strong network of first, second, and third order triangulation while the Reconnaissance series is based on triangulation hastely established to meet military needs during the early French pacification of Morocco.

Algeria and Tunisia - The French IGN is responsible for official mapping in Algeria and Tunisia but it delegates mapping to the Topographic Service in Tunisia and the Cartographic Service in Algeria. These services perform local surveys for civil use reconnaissance work and produce cadastral maps with the assistance of the Director of Public Works.

During World War II most of the official topographic series of Tunisia and Algeria were copied by the British GSGS with the addition of British grid zones, conversion tables and road overprints. The Army Map Service copied the British sheets and the Germans copied the French with the addition of intelligence data. All, therefore, are based on the original French work.

French Somaliland - Once again the French IGN is responsible for mapping in French Somaliland. An active program is in progress whereby preliminary plots are being made from ground surveys.

Italian Influence

Libya - Libya only recently became an independent nation and has not yet been able to establish a national agency for official mapping. For this reason the work of the Italian Military Geographic Institute which performed the official mapping of Libya prior to World War II is still used. The Italians established a second and third order net of geodetic control covering all of the Libyan Coastal area except part of the Gulf of Sirte where they added a connecting link of fourth order control.

Official mapping of Tripolitania and Cyrenaica was the responsibility of the British Administration between 1943 and 1951. During this time they published special purpose maps as needed and maintained the regular map series which consisted largely of reprinting British World War II series without revision.

Ethiopia and Eritrea

Prior to World War II the Italian Military Geographic Institute was the official mapping agency for Ethiopia and Eritea. Only reconnaissance maps resulting from expeditions, travelers' notes, route sketches etc., were produced by IGM before the Italian invasion in 1935. In fact, so little mapping existed prior to 1935, that the Italians were forced to make maps of the invasion areas from aerial photography tied to existing sketches. These maps were later improved but most of them were lost during World War II.

During World War II the British East Africa Forces reproduced Italian maps mainly of the Eritrea area and compiled the East Africa 1:500,000 map which is the largest scale series covering all of Ethiopia. Since the war the British Middle East Land Forces has continued to reprint these same maps.

British Influence

British Somaliland - Topographic mapping in British Somaliland is performed by the British Directorate of Colonial Surveys and Directorate of Military Survey (GSGS). An active program is in progress by the Directorate of Colonial Surveys under which planimetric plots are being made from aerial photography.

Egypt

Although Egypt is now an independent country, the influence of the British administration is still evident in their mapping. At present the Survey of Egypt at Gisa under the supervision of the Egyptian Army is the major topographic mapping agency. Other government departments compile special purpose maps but these maps are printed and in some cases compiled by the Survey of Egypt. Maps of the Survey are based on a network of geodetic control radiating from the observatory of Helwan, toward Libya, Israel and southward along the 30th meridianal arc of triangulation.

The actual work of surveying and mapping is being continued by the Survey following the high standards set by the British Administration.

During and since World War II the British Middle East Land Forces has continued to reproduce and revise Survey of Egypt maps. During the war the German General Staff also partially revised and reproduced practically every series that the Egyptians and British had produced. Some of these were also reproduced by the U.S. Army Map Service.

Asia

Southwest Asia

Since the beginning of World War II, the Middle East Land Forces has been extremely active in the mapping of a number of the countries of southwest Asia. In Iraq and western Iran, new field work was started by Indian Field Survey Companies operating under the Middle East Land Forces. The results were published at various larger scales and were incorporated into recompilations of the Quarter Inch Series. British influence is seen in the work of the Iraqi Survey Directorate, Baghdad. The Iranian Geographical Section, General Staff has utilized some of the work of the MELF in preparing Persian-script editions of the Quarter Inch Series.

From July 1941 to the end of World War II, the Middle East Land Forces cooperated with French military organizations in the mapping of Syria and Lebanon, resulting in the revision of older maps and the extension of the coverage. Since World War II, native Syrian and Lebanese agencies have assumed the responsibility for the mapping of their respective countries.

Mapping of Israel and Jordan was begun with the British mandate of 1923 as a part of the Survey of Palestine. During World War II, and to some extent until the end of the British occupation, map publication in Palestine was carried out under the direction of the Middle East Land Forces. The field work, drafting, and reproduction were performed by a Field Survey Company, the Survey of Palestine, or by a unit at G.H.Q., Middle East Land Forces, but the ultimate responsibility was with M.E.L.F.. Since the creation of the State of Israel, the mapping for that portion of the former British mandate has been in the hands of the Survey of Israel although M.E.L.F. has published several sheets based on earlier surveys.

British mapping in Jordan was carried on throughout the years of the Mandate as an extension of the Survey of Palestine. Beginning in 1941 and continuing throughout the war, the Middle East Land Forces compiled and published maps at various scales, based in part on aerial photography. At present, the responsibility for the preparation of topographic maps of Jordan is vested in the native Department of Lands and Surveys. However MELF has retained an active interest in the mapping of Jordan.

The United States was also active in south-western Asia during World War II. Trimetrogon photography of considerable areas was flown by the U.S. Air Force. This photography was used in the compilation of USAF Pilotage and World Aeronautical Charts. These charts are of primary value for planimetric detail shown and for the depiction of terrain in the desert areas about which there had previously been so many misconceptions.

Turkey - The work of the official Turkish mapping agency, the General Map Directorate, has long been influenced by German techniques. Early Turkish maps employed the German Bonne projection and grid; later the Gauss-Kruger (Transverse Mercator) projection and grid were adopted. The Bonne sheets were cut on grid sheet lines rather than geographic and Istanbul was utilized as the prime meridian. In addition, much of the Turkish mapping equipment, especially in the photographic and photogrammetric fields, has been of German origin. On the other hand, German contributions to the actual mapping of Turkey have been negligible.

It may be significant to note at this point that, although German maps of southwest Asia generally reflect high cartographic standards, they contribute little to the basic knowledge of the area. They were compiled frequently by enlargement from other sources, many of which are now out of date.

Russian surveys were carried out in eastern Turkey at various times between 1869 and 1917 with some reconnaissance at later dates. Russian sheets were used by the British for the Turkish portions of their 1 inch to 4 mile series and by the Germans for their 1:200,000 scale series. The Turkish General Map Directorate has used some Russian sources in preparing its own maps.

Iran and Iraq - The first detailed topographic maps of Iran, which were limited to a small area in the extreme northwestern part of this country, were published by the Russians. These sheets were based on surveys of 1896 and 1909 and on the 1911-14 survey of the Turko-Persian boundary. The General Staff of the Red Army began a series about 1931 and extended it during the Russian occupation of northern Iran in 1942. The Geographical Section of the Iranian General Staff, the official mapping agency, has prepared Persian-script editions of one of the Russian series.

Generally until 1914 rough compilations constituted the total coverage of Iran. The first organized series of maps was begun during World War I by Survey of India units operating under Mesopotamia Expeditionary Force. By the end of that war most of the populated areas of Iran and Iraq had been surveyed. Maps in color were made from these and published by the Survey at Calcutta as part of the Quarter-Inch Series. In 1924 the British GSGS assumed responsibility and followed the Survey practices. Additional work was carried out during World War II by Field Survey Companies some of which were Indian in origin, but which operated under the Middle East Land Forces. It is quite logical, therefore, that the Geographical Section of the Iranian General Staff has relied heavily on British mapping of the area.

Afghanistan - During the period of strong British influence, the Survey of India was also responsible for the preparation of the necessary maps of Afghanistan. Limited areas along the Afghanistan-India (now Pakistan) boundary were mapped at 1 inch or ½ inch to a mile. The basic British mapping for much of the country, however, was of the reconnaissance type at the scale of 1 inch to 4 miles. In 1947 Afghanistan established its own Map Service under the Ministry of War. This service is charged with the preparation of all military topographic mapping, but, to date, no maps have been published.

India, Pakistan, Burma and Thailand

Much of the mapping of southwestern Asia, as has been indicated, and nearly all of the basic geodetic framework as well as map series of southern and southeastern Asia were developed by or with the help of the Survey of India. No other single agency has had more influence on the original surveying and mapping of such a widespread area of the world. In 1767 Major James Rennell was appointed Surveyor General of Bengal and this is regarded as the beginning of the Survey. The Survey gradually spread a system of primary triangulation over a large area that includes great variation in terrain ranging from the Himalayas to the Ganges and from the jungles to the desert. This foresight avoided the confusion that has developed in so many areas where scattered topographical surveys preceeded an overall triangulation network and must, therefore, be recorded as an outstanding contribution to world mapping. In addition to this triangulation net, the Survey has also been responsible for precise level nets, magnetic surveys, gravimetric computations, as well as, land analyses of agricultural and economic projects and cadastral surveys. With few exceptions, maps are based on a plane table surveys tied to the triangulation network. Aerial photography has been used only recently.

Since the partition in 1947, the Survey of India is responsible for all topographic mapping in India including the Andaman and Nicobar Islands, and the Independent countries of Nepal and Bhutan. To date it has established additional triangulation, carried out some large scale surveys in connection with development projects, and it is currently compiling, revising, and reprinting sheets of the Quarter-Inch and One-Inch series.

The mapping of Pakistan, since the partition of India, has been the responsibility of the Survey of Pakistan which plans to retain the style and format of the original Survey of India sheets. To date, Survey of Pakistan has reprinted and revised numerous sheets of the standard series. Aerial photography will be emphasized in new and revision work.

Survey of India scales and, to a certain extent, styles and format are reflected in mapping accomplished by the Directorate of Military Survey, India, the British organization responsible for the Allied mapping of Southeast Asia during World War II. The several series, the sheets of which with few exceptions are revisions or reprints of existing civil editions with added military grid, are designated by "Hind" series numbers and cover Thailand, Burma, Malaya, and parts of India, Pakistan and Indonesia. Hind maps of Malaya are revisions of original work accomplished by the Survey of Malaya (formerly the Federated Malay States and Straits Survey). These series are similar to the Hind maps covering other countries of southeast Asia.

The Mapping of Burma has been the responsibility of the Survey of Burma since 1946, but no constructive mapping program has, as yet, been developed.

The Royal Survey Department is the official mapping agency of Thailand. It has produced maps which cover the entire country and range from those based on plane table surveys tied to geodetic control to those based on reconnaissance surveys only.

Indonesia

The existing geodetic control of Indonesia, ranging from first order triangulation to astronomic observations was established by the Dutch. They also prepared the existing coverage of the islands ranging from topographic sheets to reconnaissance maps compiled from uncontrolled data.

The (Indonesian) Army Topographic Service has been responsible for the mapping of the area since June 1950. To date only broad plans for a mapping program have been developed so that the Indonesians will have to rely on the earlier work of the Dutch for some time to come.

China

Chinese mapping began between 1708 and 1718 when a group of Jesuit Fathers, commissioned by the Emperor Hsu, carried out a survey of China. The results of this early work have been in use until very recently. Early in the twentieth century planetable surveys and maps were prepared by the Central Land Survey Board in Peiping which has since gone through the following changes in name, Bureau of Land Survey (1929); Fourth Department of the Board of Military Operations of the Chinese National Council (1943); Bureau of Survey, Ministry of National Defense (1946) and after the with-drawal of Chinese Nationalist Government to Taiwan, the Survey Department, Ministry of National Defense.

In spite of all the above changes in name the Chinese government has never been very agressive in its mapping activities. Much of the interior and even parts of the coastal areas were never adequately surveyed. During World War II, U. S. reconnaissance flyers tried to control their aerial photography by beginning at the coast and flying straight inland. About 85% of this photography had to be discarded after the war because control had been so poor. The Army Map Service has been conducting an extensive program for China since World War II to improve this condition.

After the Russo-Japanese War the Japanese did some work in secret especially in Manchuria. After 1931 they openly published maps that were based on a combination of Japanese, Chinese and Russian work.

Japan

Most of the coast of Japan had been surveyed by instruments by the Japanese by 1816. The British later surveyed a part of the coast of Japan in 1861. A comparison was then made with the Japanese charts and the latter found to be so accurate that the British Admiralty gave up their survey project and decided to use the Japanese charts.

Modern topographical mapping, as we know it today, began in Japan in 1875. The Japanese Imperial Land Survey Bureau was established in 1888. This was the official cartographic agency for Japan. It operated under the direction of the Japanese General Staff and made maps for both civil and military needs. By 1925 all of the main islands of Japan proper were mapped in the 1:50,000 topographic series, with a uniform contour interval of 20 meters, based upon Tokyo datum. In the years to follow this series was extended to cover Korea, Karafuto, Kuriles, Ryukyu-retto and Taiwan. The Japanese also did original mapping in

Indonesia, New Guinea, the Philippines and various other parts of the Pacific during World War II. In 1948 the present Geographical Survey Institute was established as the official mapping agency of Japan.

Japanese map symbols which are highly pictorial, have been gradually standardized as evidenced by their symbol charts issued in 1900 and 1917. Their topographic manual of 1935, keyed to symbol charts, was also a significant contribution toward uniformity of treatment. To achieve lucidity without the aid of color the Japanese have employed more than 300 symbols on their recent 1:50,000 series. About 100 of these symbols appear on the regular map legend. Land use symbols, for example, have been generously applied (even rice fields have been broken into three groups) yet not in a fashion to obscure other detail.

Due to the accuracy and homogeneity of the Japanese maps it was possible for the Army Map Service and other mapping agencies to quickly compile a tremendous quantity of maps in a variety of scales and types on a mass production basis for the military needs of World War II in the Pacific and the Far East. Recently the Japanese Imperial Land Survey maps (JILS) have again been utilized in the preparation of maps by the Army Map Service and others in support of the United Nations effort in Korea.

U.S.S.R.

Perhaps the discussion of Russian mapping should properly be divided under the European and Asiatic sections. It was placed under the Asia section for convenience.

Mapping largely confined to European Russia was carried on originally under the old Czarist regimes. It was based on a central meridian, Pulkova at 30°19'36"E, and contours were measured in sazhens (1s. = 2.134 meters). Surveys were inadequate and the maps were inferior. Improvements came with the downfall of the Czars in the Revolution of 1917. At that time the General Staff, Red Army in conjunction with the Chief, Administration of Geodesy and Cartography and Chief Aero-Geodetic Administration and local sub-authorities were made responsible for official mapping. These agencies make maps for economic and administrative as well as military purposes. Most of Europe and south Russia have been covered by maps based on accurate surveys. Northern Siberia and part of Central Asia are poorly mapped.

Just how much mapping of the total world the Russians have accomplished is difficult to estimate. You will remember, however, that the work of the Russians has been noted on several occasions in Europe, Africa, southwestern and eastern Asia. If their dreams of conquest are as strong as present events seem to indicate it is reasonable to assume that their cartographers are hard at work on world coverage

Australia and New Zealand

Australia

The Australian Survey Corps of Australia seems to have broken away from the influence of the British except in the use of similar scales. This is rather surprising in view of the popular saying that Australians are more British than the British themselves, but this divergence may be due to the isolation and independence of the Australian people.

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The Australian Survey Corps Department of the Army is responsible for military mapping of the Commonwealth including the basic triangulation and topographic surveys and the publication of maps at the several standard scales. Localized surveys have been made by the various State Survey Departments but their areas are small compared to the total area of Australia. Standard military maps and the International Maps are the only contoured maps of the continent published by native sources.

New Zealand

Early surveys were conducted on a regional basis in connection with land tenure and the requirements of a rapidly growing population and consequently discrepancies were inevitable. First-order triangulation was finally achieved by the Lands and Survey Department. Topographic surveys have been tied to this network and are being used to complete topographic mapping in the densely populated areas. Recently aerial photography has been used to hasten completion of the 1 inch to 1 mile series.

Summary

After this abbreviated annotation it must be obvious that there are many mapping agencies in the world but only a handful that have had widespread influence on recent topographic mapping. These are the British Directorate of Survey or Geographical Section, General Staff; The German General Staff; the French National Geographic Institute; the Survey of India and the United States Army Map Service. Each has made outstanding contributions to world coverage and has had widespread influence on world mapping.

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CHAPTER V

Aids To Map Interpretation

The Role of Photography In Map Intelligence

Photographs and Maps

A map is a stylized picture of earth features which may be prepared with the aid of pictures or photographs but a photograph is not, in itself, a map. The intent of this statement is not to confuse you but rather to keep you alert to the fact that photography makes a vital contribution to cartography but does not eliminate the need for maps. Competent cartographers skillfully select details to be shown on a map. Many items that appear in the landscape are omitted, generalized or stylized to aid the map-user in obtaining certain information without having to sift through all non-pertinent details. These selected items are tied to their correct earth positions by means of control points and geographic or grid coordinates. Photographers, on the other hand, achieve a non-selective product from their cameras since these instruments reproduce all details within the scope of their lens capacity. The photograph-user has to pick out what he wants. Unless he has been especially trained, he may have difficulty in identifying what he sees or in being able to pinpoint what he wants to its specific location. In addition to these limitations numerous other photographic characteristics and aberrations make it imperative that photographs be considered as sources for map intelligence and compilation rather than as maps in themselves.

The fact that a photograph is not a map in no way lessens its informational value. The importance of pictures for conveying and clarifying ideas has been recognized for many centuries. In truth, the human desire to preserve images of objects and scenes is probably as old as man himself. Ways for satisfying this desire have been varied but the motivation for it is constant. Development of the basic ideas of photography were undoubtedly inspired by the demands of many people who wanted a graphic medium for recording the images that they lacked the artistic ability to re-create. The camera could do this. Realization of the utilitarian as well as aesthetic value of photography came rapidly on the heels of the development of the camera itself. It wasn't long before photography was linked to mapping as a valuable adjunct thereto.

Types of Photography

Terrestrial Photography

So long as man was unable to soar above the surface of the earth, the application of photography to cartography was restricted to the scope and perspective of pictures that could be taken from ground positions.

Horizontal Orientation - The bulk of all terrestrial photographs have always been taken with the camera lens oriented nearly horizontally to the surface of the earth. This produces a "head-on" exposure of the scene lying immediately in front of the camera. Thus, too, the areal extent of the resulting picture is limited by the scope or angular capacity of the lens. The actual lineal arrangement of terrain features and the visual effects of perspective create distortions of and obstructions to those features not in full view of the camera "eye". Images of nearby objects are large, sharp and clear while background and lateral features are blurred, distorted or obstructed. Some modifications of the foregoing statement are, of course, possible by changing the focal distance of the lens.

Oblique Orientation - Although horizontally oriented photographs are most common, it is obvious that cameras can be tilted at various angles to obtain oblique rather than horizontal orientation of photographs. Such tilting is employed most often in situations where the camera can either be placed on a prominent elevation above the features to be taken or else where the camera can be tilted upward from below them. Distortions introduced by tilting the camera will make features seem to lean either toward or away from the point of projection. Features will also be misshapen in response to the altered perspective introduced by the angle of the projection plane from horizontal.

Panoramas - A sequence of either horizontally or obliquely oriented exposures can be taken by rotating the camera along or around the plane of the horizon or by moving it along any given line. Negatives or prints of such exposures can then be developed or spliced together to create a continuous or panoramic view covering more terrain than is possible with a single exposure. Because of the limited scope of each exposure, composites covering any considerable distance are either cumbersome in size and shape or have been so greatly reduced that objects are difficult to distinguish with the naked eye. Furthermore, they contain all the limitations and aberrations inherent in horizontally or obliquely oriented exposures mentioned above.

Application of Terrestrial Photography to Mapping - Any one or all types of terrestrial photography are useful in checking the identification and appearance of specific features for or with their symbolization on maps. They also aid in supplying a fuller appreciation and understanding of the numerous landscape features not shown on maps. The researcher may want to know about these things in making a regional study or for the purpose of revising impressions obtained from maps or other source material. He may even find it necessary to revise the map symbols themselves on the basis of what the photographs show. Foreign scenes, specifics in the terrain and facts about cultural features can thus be reviewed with more understanding than is possible using only a map containing selected conventionalized symbols.

Horizontal photographs provide restricted but specific information about details in direct line with the camera. Since most of the feeling of third dimension is lost, horizontal photos are of limited use in trying to fix objects in the proper depth or distance relationships that are so vital to mapping.

Obliques taken from ground elevations above the scene being photographed afford a slightly better understanding of the distance relationship of foreground to background features. Foreshortening, however, still creates false impressions that cannot be overcome with either type of terrestrial photography. Obliques nevertheless reveal more about the overall shape of features if the photo-interpreter is able to compensate for perspective distortions.

Terrestrial photography is used in much the same way in compiling maps as in obtaining map information. It provides a means of identification and interpretation of topography, vegetation, transportation industry, population and other cultural or natural data. It cannot be used in other than relative positioning of earth features. More exact positioning can only be done through the medium of aerial photography.

Aerial Photography

A small camera attached to a kite and sent aloft was the genesis of a wholely new technique for obtaining terrain intelligence and making maps from photographs. These first "kite" pictures were of inferior quality because a camera had not yet been perfected for such use and the path of a kite could not be controlled beyond the restrictions imposed by the string attached to it. Even under these conditions, nevertheless, the future potentialities of aerial photographs were evident. Each exposure produced a far more comprehensive view of the terrain than could be obtained from ground photography.

Better controlled photographic conditions than were possible using a freely floating kite were obtained by taking a camera in a balloon. Even though a balloon is largely at the mercy of air movements, the balloonist can maneauver it to some extent and then await the opportune moment to aim his camera and snap exposures of selected areas below. It is interesting to note that during the Spanish-American War, Lieutenant Colonel Reder of the

United States Signal Corps took carefully directed photographs of Cuba from a balloon. From these exposures he made one of the first maps compiled from aerial photography.

Shortly after the airplane proved that it was not a mechanical curiosity but an established means of transportation, aerial photography took another step forward. Aerial photographs for reconnaissance purposes were taken from airplanes during World War I. In 1920 aerial photography was undertaken in the United States by the Corps of Engineers and the Geological Survey. A few years later in 1924, the U.S. Coast and Geodetic Survey used aerial photography in its mapping of the Mississippi delta area. About the same time the U.S. Navy Hydrographic Office used aerial photos for compiling hydrographic surveys of Cuba. Private oil companies did large sections of the southwest because government agencies were slow in adapting the technique to domestic mapping. In 1936 the Tennessee Valley Authority finally took the lead in using aerial photography for topographic maps which was a milestone in the progress of photogrammetry in the United States.

Scientists and governmental agencies conducted similar experiments in Europe. They were quicker, however, to realize the potentialities of aerial photography for various types of terrain research and cartographic representations. In consequence precise photographic and cartographic equipment far in advance of those in use in the United States were developed in many western European countries, especially Germany. Many of these instruments were captured and brought to the United States during World War II and were put in operation immediately in the mass production of maps of all parts of the world needed to carry on a global war.

The net results of all these pioneering experiments in aerial photography have mushroomed in less than half a century into one of the most important sources of cartographic information, aside from actual exhaustive field work, yet known to man. Aerial photographs are now almost indispensable in analyzing, revising and bringing up to date the details shown on existing maps. In addition, with adequate photography and a minimum of good ground control, either original planimetric or topographic maps can be and are compiled by photogrammetric techniques.

Vertical Orientation - Essentially vertical replaces horizontal photography when the camera is taken aloft by any airborne medium. Except in rare cases of low altitude flying in mountainous areas, having the camera oriented horizontally to the surface of the earth would be pointless unless exposures of cloud or storm effects were desired. Vertical orientation obviously places the camera in a better position in relation to terrain features lying below. Actually "vertical" as applied to aerial photography is a relative rather than absolute term in most cases. Reasons for this qualification will be given under Factors Affecting Aerial Photography since they are important enough to warrant separate treatment even in this abbreviated discussion.

Oblique Orientation - The designation "oblique" is applied to aerial as well as ground photography with the same implications. It is now common practice to use cameras capable of taking both vertical and oblique exposures rather than obliques exclusively.

For example tri-metrogon photography, used extensively for mapping purposes, is obtained from one vertical and two oblique cameras coordinated in one unit to expose three negatives simultaneously. Other cameras, that work on the same principle, have multiple lenses for exposing one vertical and as many as eight adjoining obliques.

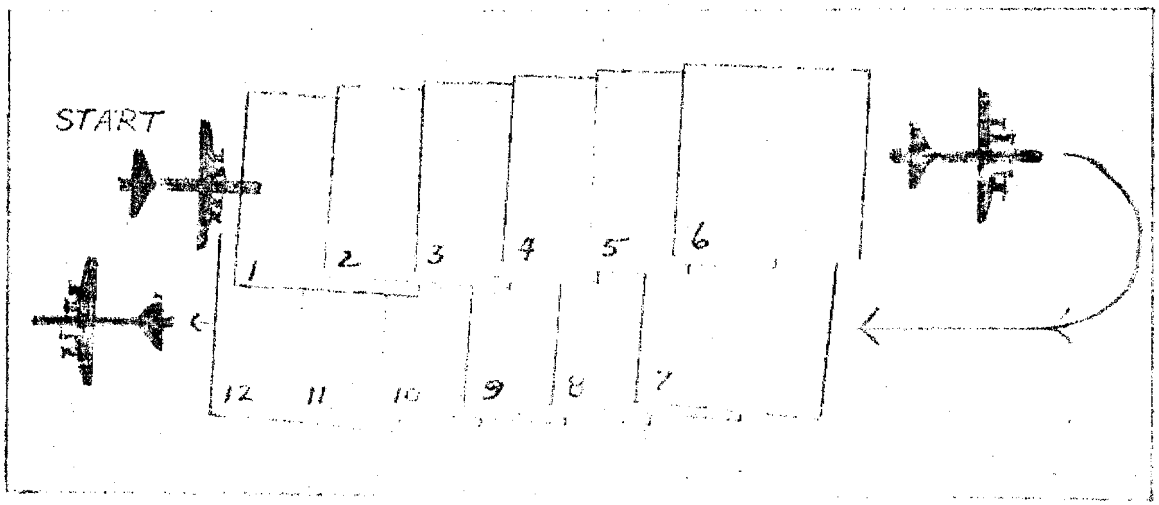
Aerial Mosaics - When comprehensive aerial coverage of an area is desired aerial mosaics normally are used instead of panoramas, typical of ground coverage. Since an airplane can traverse large areas in a comparatively short time, it is more feasible to join strips of photography to achieve more extensive coverage than is possible with a single strip panorama. Common practice is to use either verticals or obliques for mosaics. A few mosaics are prepared from photographs taken with multiple lens cameras. Mosaicking a vertical and oblique together produces a comprehensive view in all directions emanating from a central point in the vertical photo.

(1) Uncontrolled Mosaics - Sequential but not necessarily consecutive aerial photographs can be spliced together by matching features shown in common on their edges. In such mosaicking little attempt is made to rectify photographic distortions or to tie specific features to precise ground control. Consequently uncontrolled mosaics are not used for precise intelligence research or mapping. They do, nevertheless, provide comprehensive coverage of an area for purposes of preliminary overview or general orientation.

(2) Controlled Mosaics - All aerial photography for mapping purposes is taken with a forward and side overlap. Specifications

vary lightly in respect to the amount of overlap but average about 60% forward and 30% side lap. Figure 371 illustrates the method of flying in horizontal overlapping flight lines to obtain the necessary coverage.

FLIGHT LINES



Method of flying in lines to obtain 60% forward and 30% side lap of photographs

FIGURE 371

Overlapping is done for three main reasons:

1. to insure complete coverage of the terrain
2. to provide overlapping needed for stereoscopic utilization of adjoining photos
3. to lessen the necessity for having to use information reproduced distortedly along the edges of individual photos.

Only the central portion of each photo is normally used for mosaicking because there is less error in definition and representation of surface features near the center of an aerial photo. This portion together with similar portions from adjoining photos are pieced together (paneled) to form a mosaic. Such mosaics may be either semi- or carefully controlled. The degree of control is determined by the precision with which photographic images or picture points are tied to ground control points.

(3) Photo Maps - Although a photograph is not a map, controlled aerial mosaics are used as the basis for photo maps which closely approximate the format of true maps except that only selected details appear on the body of maps whereas everything visible to the camera is shown on photo maps. Particular features on the latter are differentiated by overprinting appropriate symbols and titles. Either geographic or grid coordinates or both are added to guide the user in locating objects. Most photo map sheets contain a graphic scale which should be used as an approximate not exact measuring device.

The Back-up of the 1:25,000 Anderson Island 1478 II NW sheet will help you to appreciate the values and shortcomings of most photo maps. This Photo Map of Anderson Island is oriented with North toward the top because popular demand and uniformity of format dictate that north be toward the top of most maps. Unless you have had considerable practice reading photographs, however, it will be much easier for you to interpret surface features, if you turn the sheet upside down. You will then have the shadows toward you so that elevations and depressions will be in proper perspective to reveal them as heights and holes in the same relationship as they are on the earth and not reversed due to optical illusion.

Study the Anderson Island sheet for the following:

1. Compare the map and mosaic depiction of
   a Graticule and grid notation   c Foreshore features
   b Graphic scales and their use   d Water depths

e Warves and other related data
f Types of vegetation
g Roads
h Railroads
i Houses and buildings
j Other cultural detail

2. What outstanding limitations do you find to photo maps?
3. How does the mosaic supplement the map?

Stereoscopic Coverage - Many of the questions that arise concerning analysis or interpretation of surface features can be answered if you have stereoscopic coverage of the area in question. With some practice you can then distinguish elevations or comparative heights of natural or cultural features. Any truly definitive use of aerial photography demands stereoscopic coverage together with the mastery of stereoscopic viewing either with or without the aid of various mechanical devises. These methods are discussed in Applied Cartography and many other more specialized and definitive texts on the subject of aerial photography and its applications.

Factors Affecting Aerial Photographs

Physical Conditions

What is so rare as a day in June! Then, if ever, come perfect photography days! In paraphrasing the poet in this way, there is no direct implication that June is the perfect month in all places in the world. The implication is rather that the aerial cameraman would like weather such as people of the Northern Hemisphere visualize as typically ideal.

In any climes, the ideal plysical conditions are clear air, bright sunshine, a properly functioning camera and good stable negatives. Clear air will improve the definition of objects and make sharper prints possible without the aid of camera filters.

Smoke and dirt in the air, on the other hand, act as moisture collectors (hygroscopic nucleii) which create a haze. A dust haze which materially changes or accentuates colors may appear even in very dry areas. The camera will pick these particles up as shades on black and white negative or as brilliant colors on color film.

Bright sunshine increases the shadows so necessary to photo interpretation. The ideal angle of the brightly shining sun should be away from vertical to increase the size of shadows. If the sun is directly overhead, however, there will be few tell-tale shadows on vertical photographs to aid in the identification of objects. Proper functioning of the camera obviously means that the proficient cameraman can expect to reproduce an image of high quality if the film is as good as his camera.

Political Conditions

Another ideal condition would be an unmolested cameraman. If the plane in which he is working is being shot at, the pilot may plunge, dip or lift at the exact moment when the picture is being taken. These departures from ideal position introduce the familiar aberrations of war-time photography. The resulting photos are not uniform in scale, tone, and normal distortion. As much as 85% of the wartime photography of Asia had to be discarded after World War II. After the cessation of hostilities, new missions were flown during which the crew could devote their entire attention to achieving good photographic results.

Altitude in Relation to Scale

The altitude at which the airplane is flown and the focal length of the camera determines the scale of the photograph. Specific instructions are supplied to the photographic team as to how high each mission is to be flown. The pilot ascends to this altitude and attempts to maintain the proper direction and altitude while the cameraman completes his assignment.

Distance from the ground is one determinant of the scale of the resulting photograph. Emphasis is placed upon ground because it is not the altitude above sea level but above the elevation of the local terrain that influences the scale. This relationship is expressed in the following formula in which R·F means the Representative Scale Fraction:

$$RF = \frac{\text{Focal length of the camera}}{\text{Altitude of the plane minus the average elevation of the ground.}}$$

EXAMPLE: Focal length is 12 inches
Altitude is 11,000 feet
Average elevation of ground is 1,000 feet.

Since the focal length and height must be expressed in the same unit of measurement, convert 12 inches to 1 foot.

$$\text{THEN: } RF = \frac{1}{11{,}000 - 1{,}000} \text{ or } \frac{1}{10{,}000}$$

Thus a mission flown at 11,000 feet will supply photographs of approximately $\frac{1}{10{,}000}$ scale. Roughly 1 inch (or meter) on the photograph will represent 10,000 inches (meters) of the earths surface or approximately 1 inch to 1/6 of a mile.

The above formula, logically, implies the difference in the amount of terrain covered by photos taken at different altitudes. The higher the altitude, the greater becomes the unit coverage of each photo. With constant improvements being made in camera equipment, photographic processes and aircraft, it is now possible and desirable to fly photo missions at higher altitudes. Where formerly missions were flown at altitudes up to 5,000 feet they are now more likely to be flown at from 20,000 to 40,000 feet or higher.

If a 12 inch focal length camera[1] were used to take pictures of the same area, lying approximately 1,000 feet above sea level, at each of the altitudes mentioned above, the scales of the resultant photos would be:

At 5,000 Ft. RF = $\frac{12}{5,000(12)-1,000(12)} = \frac{1}{4,000}$ or 1 inch to about 4/5 miles.

At 20,000 Ft. RF = $\frac{12}{20,000(12)-1,000(12)} = \frac{1}{19,000}$ or 1 inch to about $3\frac{1}{2}$ miles.

At 40,000 Ft. RF = $\frac{12}{40,000(12)-1,000(12)} = \frac{1}{39,000}$ or 1 inch to about $7\frac{1}{2}$ miles.

This means that approximately 12 to 56 times as much area is covered by each photo at 20,000 to 40,000 feet as at 5,000 feet. Coverage from any of three altitudes is greater than can be obtained from ground photography with any degree of definition.

Altitude-scale relationships affect the degree of definition attainable from aerial photos. Precise definition is easier to attain at low altitudes than at high. In all high altitude photography it is difficult to obtain images that are large enough to be distinguished readily. The sketches shown in Figure 377 illustrate schematically the difference in definition of information between photographs taken at 10,000 and 20,000 feet respectively.

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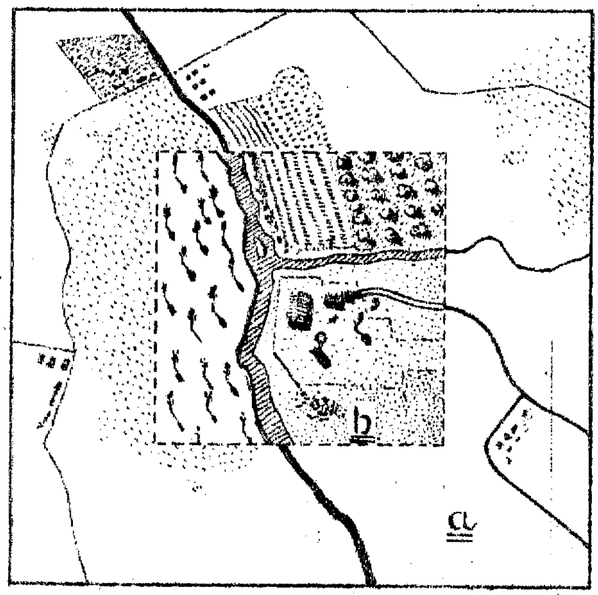
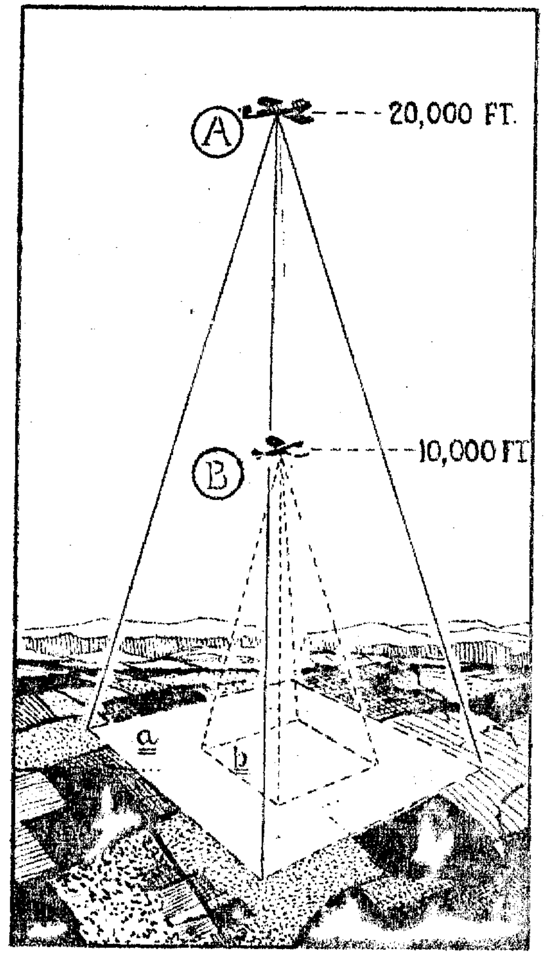
[1]Focal length is the distance in the camera between the lens and the negative.

RELATIONSHIP OF PHOTO DETAIL TO ALTITUDE



A
Schematic effect of altitude on definition shown on photo



B
Schematic visualization of difference in coverage due to altitude.

FIGURE 377

Ground Relief Distortions

A vertical photograph might be substituted for a map if the entire area included in the photograph were perfectly flat; if the focal plane were perfectly parallel to this surface and if the camera had a perfect lens that would create no lateral distortions. Quite a combination of "ifs". Fulfillment of these qualifications would produce the ideal conditions sketched in Figure 378. Images of ground objects are focused through the

IDEAL RELATIONSHIP OF PLANE TO GROUND

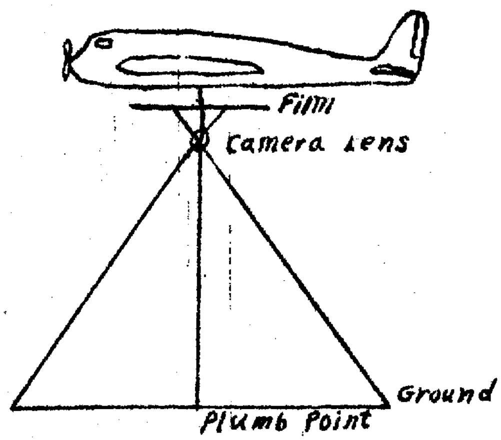


FIGURE 378

camera lens upon the film plane behind it. If a plumb line could be dropped from the airplane to the ground, it would pass directly through the center of the film and the center of the area being photographed. Any feature in this alignment would be perfectly reproduced and the scale of the photograph would be true over its entire area. Any points an equal distance from the plumb point on the ground would be an equivalent distance from the plumb point on the film.

Since no earth surface is a perfectly horizontal plane, ground relief will inject distortions on a vertical aerial photograph. The amount of distortion is proportional to the amount of relief and becomes a critical factor in photos of rolling to mountainous topography.

The distortion introduced by ground relief is more properly called PARALLACTIC DISPLACEMENT or simply DISPLACEMENT. Parallax is the apparent change in the position of one object or point with respect to another when the two are viewed at different angles. As applied to aerial photos, parallax refers to the relative displacement of two points along the same line when viewed from an exposure point that is not directly overhead. This displacement can be illustrated by holding one finger up at arms length and noting the seeming change in placement of distant objects as you move your line of sight from one side to the other of your finger. All such parallactic displacements are radial from the center. This is the explanation for the fact that peripheral objects seem to lean away from the center of an aerial photo in contradiction to their true vertical alignment.

Study Figure 379 as you read the following explanation.

DIAGRAM SHOWING PARALLACTIC DISPLACEMENT DUE TO TOPOGRAPHIC RELIEF

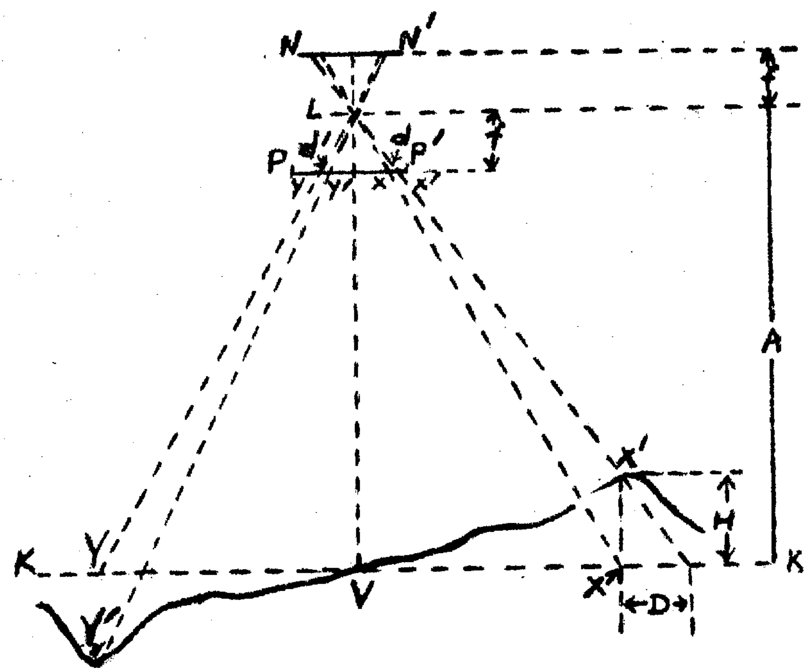


FIGURE 379

K-K' Datum plane
N-N' Negative
P-P' Positive
L Lens
H Height of X' above datum plane
X Projection of X' on datum plane
D Parallactic displacement on datum plane
Y Projection of Y' on datum plane
y-y' True and apparent positions respectively of Y
d-d' Amount of displacement

Displacements due to parallax are always along lines radiating from the plumb point (V) which in the absence of disturbance to airplane alignment coincides with the center point of the photo. Those points on the ground (Y') lying below the datum plane (K-K') are displaced inward (d') on both the negative (N-N') and the positive (P-P'); those points (X') above the datum point (K-K') are displaced outward (d). The total amount of such displacement is directly proportional to terrain relief and to the distance from the plumb point and is also inversely proportional to flight altitude.

If the highest elevation coincides with the plumb point or center of the exposure the resultant photo will show a photographic distortion similar to the "big feet" exaggeration that can be obtained in horizontal photography by having a person sit on the ground with his legs stretched out in front of him. On the photo his feet will appear to be bigger than any other part of his anatomy. The mountain-peak or hill-top will stand out in the same way on a vertical photo and necessitate scale adjustments in relation to surrounding features.

Effects of Airplane Deviations

Tip and Tilt - Modern instruments have provided possibilities for the improvement of controlled flying but neither they nor the pilot are infalliable. Sudden convective up- or down-drafts may strike the nose or tail of the plane unexpectedly and tip the plane away from a truly horizontal alignment. If the camera shutter is being clicked at this instant, the resultant photo will be distorted. Displacement will occur in the direction the plane is tipped and with results similar to displacement due to ground relief.

Tilt will occur when something happens to disturb the horizontal alignment of the wings on the plane. This tilting will produce lateral rather than forward displacement of the images on the photo. Figure 381 shows this displacement of objects

DISPLACEMENT DUE TO TIP OR TILT

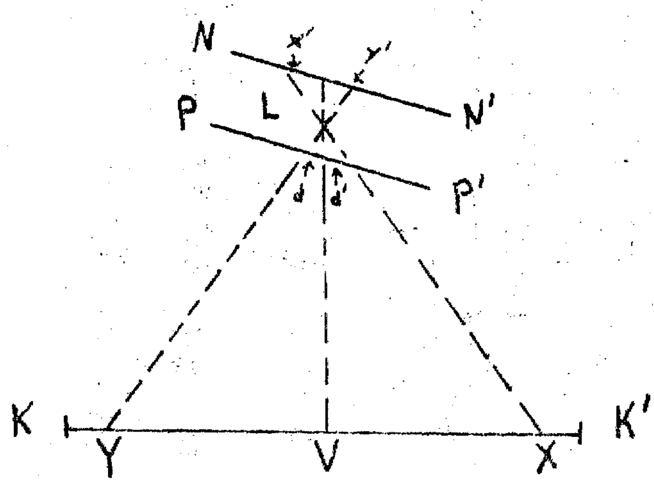


FIGURE 381

X and Y. The diagram can be adapted to either TIP or TILT conditions by orienting it for forward or lateral disturbances to the alignment of the airplane.

Ground relief, tip and tilt distortions may occur in such combinations that one may compensate for the other. Photographs taken under these combinations will have less total distortion than the reader might expect from any one set of variables. Photographs, in this respect, are much like other projects where errors tend to cancel one another.

<u>Crab</u> - The lowly crab has been the source of many analogies. His side-slipping gait is likened to one condition affecting aerial photography. Winds may nudge a plane from the course set

along a flight line. These may not be violent gusts which immediately put the aviator on his guard. They may, instead, be quiet little winds that slowly cause the plane to drift sidewise. Photographs taken under uncompensated drift conditions cannot be perfectly aligned in strips. See Figure 382. The drift may reduce

ALIGNMENT OF PHOTOS

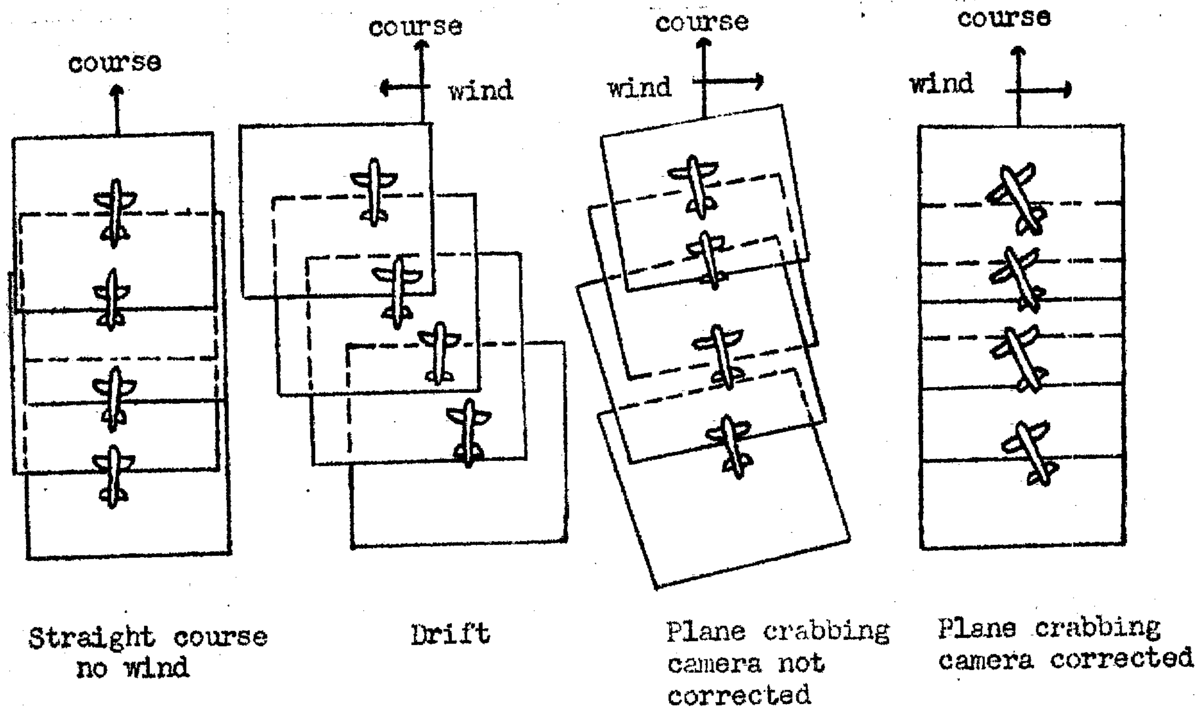


FIGURE 382

side lap or merely cause a wave in the placement of photographs for further use. Skewing of the photos, for example, impairs normal alignment needed for stereoscopic viewing. To revert to the vernacular, this "crabs the act" for multiplex compilation of maps from aerial photos.

This explanation of crabbed photos should not be confused with the pilots adjustment to drift conditions. He <u>crabs</u> his plane so that he is flying forward with the plane slanted [illegible] the wind. This crabbing compensates for the disturbing force of the wind and enables the pilot to hold to a nearly straight forward course.

Interpretation of Aerial Photographs

Effects of Clock and Calendar

Photographs have a far greater range of scenery possiblities than maps. Anything that appears on the landscape is reflected on the film. Sometimes this means too much detail or the obscuring of necessary features. Roads get lost under a canopy of foliage when leaves are thick upon the trees. Railroad tracks disappear into mountain sides. Heavy shadows mantle vegetation. These, combined with many other details, confuse the patterns made by man and nature unless the viewer is skilled in interpreting photography. Map symbols are created to clarify and standardize the patterns. Standardized map symbols, however, do not reflect the time of day or year. Photographs mirror the changing mood of each season as it alters the scenery.

Effects of the Clock - Camera equipment is available for exposing films at any time of the day or night. Beautiful patterns of lights can be caught from a plane at night. Dazzling images appear under the noonday sun. Best photographic results for mapping purposes, however, accrue from exposures taken when the sun is well above the horizon but not directly overhead. Mid-morning and mid-afternoon are the best times, all other things being equal, for vertical exposures taken in the middle latitudes. In higher latitudes where the sun never reaches an overhead position, the noon-day hours are best since the morning and afternoon sun casts exaggeratedly-long shadows. Conversely, in latitudes where the sun is nearly overhead it is difficult to secure pictures on which long enough shadows are cast to provide clues for object identification.

Effects of the Calendar - Skilled photo interpreters check the date of exposure as soon as they receive the prints. In areas of deciduous vegetation, the amount of leaf and grass coverage indicates the change of season. In areas of either permanent vegetation or sparse coverage these clues are missing. In any case it is better to check the exposure date to ascertain which adaptations of geographic patterns apply to the particular project.

The relationship understandings of the geographer are brought into use in accordance with seasonal variations he finds in the landscape; the photo interpreter must also be aware of such variables. For example, an intermittent stream shows different patterns at different seasons. During periods of heavy thaw or rains this stream may be a wide, raging torrent but when dry periods come only a narrow trickle or even just the dry-streambed remains. If a symbol is to be drawn on a map to represent this fickle stream, both conditions should be shown. The flood tide width of the bed should be retained so that anyone using the map in the field at this season will be prepared for plenty of water. The stream line symbol should be dashed to indicate that there is little or no water running in the stream during the dry season. Map readers are thus warned that they can cross the stream at this time if they remember that sudden heavy rains may temporarily swell it to overflowing even in dry seasons. Ignorance of this important fact has caused the sudden death of unsuspecting travellers in such areas.

Snow shown on photos can be erroneously interpreted as poor photography. The skilled person recognizes the true condition and appreciates the concealing effect that snow has on the landscape. Furthermore he knows that snow lies longer on protected slopes and also affects normal shadow patterns by lessening the contrast between sunny and shaded slopes. An optical illusion of reversal of these slopes may result from a highly reflecting snow cover on one side and barren slopes from which the snow has been melted on the other.

In areas of considerable seasonal vegetation change, better interpretation of the landscape can be made by using spring or late fall exposures. Underlying patterns are not so confusingly hidden at these seasons. An exception to this statement must, of course, be made for agricultural and vegetation analyses. For these purposes photos taken at the height of or late in the growing season are best. Only then can the true type and quantity of vegetation be recognized from photographs. Long practice and several presicion instruments enable photo research personnel to make detailed analyses not only of the character but even the height of homogeneous groupings of vegetation from such seasonal photos.

Any other seasonally induced changes in the landscape aside from vegetation must also be known by a competent person working with vertical photographs. If he doesn't know all of the geographic facts, he seeks other sources to help him.

<u>Utilizing shadows on the Photo</u>

<u>Shape</u> - All objects will cast shadows when the source of light is behind them. The sun is the source for the creation of aerial

photo shadows. (Optimum angle of the sun for best exposures has already been mentioned.) The shadows that result reveal characteristics of the shape of an object which is vital to accurate interpretation.

The vertical image of an object shows only the top portions of it on a photo. Vertical offsetting in the shape of the object will show but poorly and few clues will be provided for its under-lying shape. By studying the shadows of this object, though, much can be learned about its overall shape. For example, different species of trees can be identified by the characteristic shape of their shadow.

In analyzing cultural features not only the shape of structures but also the general type of construction can be read from the shape of their shadows. For example, the number of spans, cable suspensions and/or abutments are often reflected in the shadow of a bridge. Furthermore, structures built for specific purposes often conform to characteristic patterns. If the photo interpreter is familiar with the shapes of special purpose structures as they appear on the landscape, he can catalogue their probable use from their photo shadows.

Size - Relative size of objects can be estimated by an amateur and actually determined by a professional by measuring the length and width of shadows as well as from scaling the size of images on aerial photos. Tall buildings cast long shadows, small buildings, less pretentious ones. Adequate interpretation of size is impossible, however, in the case of shadows of tall buildings that do not have a chance to stretch themselves upon the ground but are cramped into the narrow cracks made by streets between them.

Mountains also throw large shadows across the land. The size of these shadows may be great enough to nearly engulf the pattern of other features such as trees beneath them. It is often necessary to sift the pattern of the trees from these shadows. Under some conditions, a knowledge of relative tone supplies the sieve.

Value of Relative Tones

Tone to Vegetation - Tonal values may aid in the discrimination of several objects. Interstices between trees and possibly their foliage produce different tones. Shadows of solid objects like mountains are more uniform in tone. Careful inspection of the mountain shadows may unfold a lighter tonal effect that offers a clue to the presence of vegetation which at first glance seemed to be lost in the shadows.

Freshly plowed fields show up, as dark patches on photos because the moisture which has been brought to the surface by plowing, darkens the ground. The surface of unseeded, plowed fields dries out rather rapidly, however, with the result that pictures taken a short time after plowing will show a lighter toned image for these than for newly plowed fields. Fields of growing crops will produce still other tones that are keys to interpreting the amount, density of growth and type of crop. No amount of explanation can help you to visualize these tonal values. Tonal preception can be developed only through practice.

Transportation Tones - Smooth curved roads, especially those constructed with concrete, show as light bands on photos. Dirt and rough-surfaced roads appear much darker in tone. The dirt between railroad ties shows in sharp tonal contrast to the metal rails on large scale photos. Airstrips, landing fields and surfaced parking areas reflect light and, consequently, are much lighter to nearly white in tone as compared to the darker ground usually surrounding them. Differences in tone facilitates differentiation between right-of-way and the equipment which travels over it as, for example, trains upon railroad tracks, boats in a river and motor vehicles on a road.

Interpretation of Water Depths - Shallow water produces a lighter tone than deep water. Sand bars, subsurface shelves and sawyers can be spotted by lighter tones in clear water bodies. Much, therefore, can be learned about foreshore, offshore and streambed features by studying the varying tonal intensity of water bodies.

Any nuances of tone are lost on muddy, under-or over-developed photos. A large part of the interpreter's success depends upon the quality of the prints he uses. All of the above discussion about tone could be in vain if the photographer has not cooperated in developing these tonal qualities.

Surroundings

"Know a man by the company he keeps" applies equally well to data shown on aerial photographs. Many objects can be identified by examining their surroundings. Common-sense helps a great deal, too. If the viewer sees a solid object sitting in the middle of a field he might be misled by its shadow to conclude it was a house. Little common sense influenced this selection because there must obviously be some means of entry into any inhabited building. Even if a house has been deserted for some time, some evidence of a path or roadway will normally show on a photo. The dark object in question is more probably a haystack.

Comparison of the various sizes of buildings in a given area in relation to their surrounding aids in determining probable usage. Commercial and industrial areas tend to contain large buildings in close proximity. Small buildings with more room around them mark the usual pattern of residential areas. In a sparsely settled area a large building may be an isolated factory but is more likely to be a consolidated school. This supposition is strengthened if a play field of one kind or another is found in the immediate vicinity.

Water tanks can be distinguished from oil tanks by surrounding structures and also by the fire protection moat that most communities require around inflammable storage facilities.

Thus time, season, shadows, size, shape, relative tone and surroundings should all be considered as you learn to interpret photographic images.

Applications of Photographs to Map Reading

Direct application of terrestrial or aerial photography for checking purposes has already been mentioned. A good photograph or, preferrably, set of them can save hours of reference reading and produce a clearer impression of many features shown on maps. They can also increase the value of a physically reliable but culturally obsolete map.

It is impossible to obtain an absolutely current rendition of cultural and even of some natural features on most printed maps because of the time and money required to prepare and reproduce a map. Changes occur in the landscape even while the map is being made. The costs of producing a good topographic map make it impractical to undertake constant revisions of one sheet or series of one area when there are other areas that have either never been covered at all or whose coverage is completely obsolete. Students should thus expect cultural changes and know why and where to expect natural changes to be revealed on photographs rather than on maps of the same area.

The rapidity of cultural changes is commensurate with the pace of daily living and the receptiveness of a given group of people to economic and cultural innovations. For example, photographs should not be expected to reveal as many cultural changes in the purely agricultural areas of China as in the bustling city of Shanghai. This generalization may not apply in areas that have been affected by war or natural disasters such as tornadoes, typhoons and earthquakes. Either the aftermath of such distructive forces or the results of a program of reconstruction, sponsored by domestic or foreign agencies, may be shown on photographs of the affected areas. Rapid cultural changes may also be introduced by the discovery of critical mineral deposits or the application of some modern techniques in a previously somnolent region. A knowledge of political and economic geography is an asset in predicting and recognizing such cultural changes.

In similar fashion, a knowledge of physiography, geomorphology and geology contributes to the understanding of natural changes. If a student knows that earthquakes are common in an area, he is not alarmed at finding changes in natural patterns there. Nor is he disturbed by finding a new channel development in a braided or meandering stream or in the delta of a silt-laden river. No published map could be kept abreast of such rapidly changing natural phenomena. Even photographs, unless they are used almost immediately after exposure, may show conditions that are slightly different from the existing situation. In general however, photos will provide more nearly accurate information than old editions of maps. Intelligent application of photographs to maps, therefore, alleviates the ill-effects of time-lag in mapping.

Reliance upon change should never be developed to the point where it is used as a "pat" explanation for all discrepancies between photographs and maps of the same area. Some skepticism should accompany the comparison of many maps and photos. A map may have been inaccurately compiled. Inadequacy of source materials, misinterpretation of sources and/or lack of cartographic integrity can be and are responsible for incorrect map representations. Photographs should be used to catch these shortcomings as well as the logical changes due to passage of time.

The exigencies and restrictions occasioned by international strifes makes it difficult to tabulate sources for the procurement of aerial photography to aid you in map intelligence. Consequently, only one suggestion is offered. The Map Information Office of the United States Geological Survey compiles and distributes an index map, which is revised periodically, of the photo coverage of the

United States. It is called, Aerial Photography of the United States[1]. A key giving the names of major agencies who have aerial coverage of given areas is included. One of the most readily accessible of these agencies is the Production and Marketing Administration of the United States Department of Agriculture. This agency sells photographs at very reasonable rates for all types of civilian use.

Textual Contributions to Map Intelligence

Even the most skillful photo specialist using the best photography and photogrammetric equipment cannot always identify everything he sees on given photos. Unique features and products of cultural peculiarities found in far-flung areas of the world and even close to home impose problems that cannot be solved by studying photographs alone. Photo, regional and map intelligence made further research and reading mandatory. Reading from diverse sources can throw light upon otherwise unexplained details. Conversely, many selections of information to be shown on maps are based upon exhaustive reading. The following are suggestive of only a few of the myriad reading sources used in map intelligence.

Field Survey Notes

As was pointed out in an earlier chapter, scientific aids to mapping have not yet been developed that eliminate all field work from mapping projects. Even the best photogrammetric equipment cannot be made to produce reliable maps without the aid of field

[1]Copies of current editions should be made available for class use since the information changes from year to year.

established control data.

Whenever it is possible field survey notes, amassed during the progress of field work are used before and while a map sheet or series is being prepared in an office. These field notes, which are the rule rather than the exception, contain more than survey computations and station coordinates. Locations of control points and markers are carefully described in terms of nearby objects and features. Notes are also kept of unusual features and unique local adaptations. Other items having no immediate bearing upon the survey but that are a part of daily living such as weather conditions and conversations with the natives are often injected by members of the survey party because they add "spice" to the daily log or diary. All of these entries aid the office-bound compiler and intelligence specialist in visualizing and analyzing the area in which the field work was done.

Before the incorporation of aerial photography into cartographic compilations and even today in many parts of the world, reliable topographic maps were developed by plane table methods and from extensive field notes. Field parties spent weeks in an area working out map details tied to established and extended control points. Distances between control points were scaled and plotted on base sheets. Selected cultural and/or topographic features were sketched on this control established framework. Although the accuracy of such delineations depended upon the ability and integrity of the topographer, some of his interpretations could be clarified by reading his field notes.

Whatever the original method of compilation, it is common

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custom to check domestic topographic maps before they are reproduced. Normally sepia prints are made of the compilation copy. These prints are either sent to responsible local agencies or are taken directly into the field by members of the producing agency. Questions about or requests for specific information are answered by the field checkers who also make necessary corrections and revisions due to errors in compilation or changes that occurred since the original work was begun. Notes taken during the checking process add to the total information available concerning the area shown on the prints.

The observational and conversational entries and sketches of former and present-day field parties would add up to large libraries of information for each country and to large files for particular regions. Since these materials can cover many details that never appear on finished maps it is well worth the map researchers time to find out where they are kept and to use them whenever they are available.

Travelers' and Explorers' Notes

An even richer source of information than field survey notes are the notes, diaries, logs, sketches and maps prepared by explorers and alert travelers. The true value of these materials depends, of course, upon the discriminative powers and ability of the traveler to describe what he has observed. Such notes may be limited to the scope of some specific objective or they may include detailed information about many facets of the region traversed and the people living therein. Seasoned explorers keep careful records of their observations and normally accompany them with detailed maps of local areas or traverse maps of the routes they follow. Such cartographic depictions may contain local cultural and some of the outstanding topographic detail. Explorers maps, at best, however, constitute only fragmentary and widely scattered coverage of large areas of the world where no other coverage exists. Furthermore, most of these maps are difficult to reconcile with any subsequent mapping. Most explorers' cartographic endeavors are based upon astronomical observations taken under conditions and with instruments that are not conductive to the establishment of accurate control and geographic coordinate points. Many hours must be spent, therefore, in attempting to fit various features into their correct locations or more accurately controlled maps. For this reason it is usually much easier to use explorers contributions as source data rather than as bases for subsequent mapping projects.

Periodicals and Newspapers

Aside from the purely fictional types, most periodicals are published to keep their readers informed about what is happening in the scientific or professional world or just, in the world. Some are openly propaganda organs; others attempt to be more subtle in their suasion of public opinion; still others report current happenings and ideas without attempting to convert their readers to anything. None of them are deliberately published for map intelligence but all of them can be useful in this field of research. Through careful reading, sorting, shifting, and considering of the source, many valuable bits of information can be gleaned from periodicals and newspapers. Isolated bits of information such as reports of new buildings, extensions of roads, new mineral discoveries, business reviews, diagrams, graphs and even maps can provide insights or clues to current developments. These may be just what is needed to explain unusual features shown on photographs or to aid in completing map patterns. Some of these bits of information may merely raise questions in the minds of the researcher. Once he is made aware of the possibility, however, he can read or ask further questions to determine whether the possibility is actually fact or fiction.

Occasionally, carefully and accurately written articles and maps appear in periodicals of learned societies and more serious minded popular magazines. Although some may be classed as popular reading, they are actually substantial contributors to map intelligence. Such sources should be kept in mind and consulted regularly. Some suggestions of these sources would include: geographical societies and publications of the various nation's geological, engineering, sociological, anthropological, and trade journals.

Information derived from reading the various sources may not always be needed immediately. Items of possible value, then, are filed for later use. Many libraries also maintain vertical files of clippings from periodicals and newspapers. It is well worth the college student's time to find out if the college library has such files and if so what they contain to help him in map intelligence or other fields of study.

A bulging file does not necessarily mean a good file. It may simply reveal a "pact-rat" at work. Good files are built up by selective clipping or notetaking and intelligent indexing. A part of map intelligence is to learn what to save and what to discard as useless from among the popular offerings.

Pamphlets and Guides

Guide books, street guides, chamber's of commerce literature, hotel and motel brochures, civic and historical society booklets, industrial and advertising and resumes of various industrial operations are but a few of the many free or inexpensive sources of local information and maps that seldom appear in standard texts or more scholarly works. Such information must be digested with a large grain of salt, to offset local pride and prejudice, but not disregarded.

Most popular maps included in these sources are rather hastily drawn sketches or diagrams intended to clarify some specific details or to present the approximate site or situation of a given place or event. For example, railroad and other forms of transportation companies insert maps in their timetables and advertising literature to show the relative positioning of places (and incidentally help keep the traveler occupied by identifying passing places.) A right-of-way or route that had not been previously identified by a given research group may be shown on these maps. After the existence of such items is revealed, it then is possible to request more details.

The sum and substance of the above discussion is to look for information to aid map intelligence in all types of printed material. Then read it, analyze it, interpret it, and apply it intelligently.

The Importance of Names

Problems of Toponymy

What is the correct name for a place? This sixty-four dollar question stumps map-makers and map readers alike. TOPONYMY or place names are one of the most confused and confusing factors in mapping. Much of this confusion arises from conflicts in origin and linguistic interpretation of names. Further complications are injected by differences among alphabets, syllables, and diacritical markings used to express spoken language in written form. Still another complication is introduced by a general lack of "linguistic sophistication" among a large proportion of the general public. This is especially true of the English speaking peoples. Most Americans, for example, seem to feel that everybody should know English and that all foreign names should be reduced to an English version. Smug, aren't we?

Conflicting Origins

Explorers, pioneers and invaders have a habit of naming outstanding terrain features in the area of their infiltration without checking to find out if those features already have native names. Quite often the new names have no relationship to the local complex. Instead, they are given to satisfy a common human desire to perpeturate family names or to memorialize some outstanding figure or event in the newcomers national heritage.

Where there are few natives living in the area, this practice creates no conflicts. Even in areas of denser population composed of isolated groups of illiterate natives, the practice is not too objectionable. Names bestowed on local features by the more widely known and literate groups will be printed in the literature and subsequently will be accepted. This has been true, for example, of such Dutch names as Transvaal and Johannesburg in South Africa, that were not materially altered after the British assumed control and continue to be used today. In areas like these, however, it would be difficult to predict what might happen to place names if the aborigines were to gain absolute control.

Effects upon toponymy are often quite different when attempts are made either wittingly or unwittingly to change names in well established communities or countries. Once a name becomes familiar there will be either internal or external resistence or both to substitutions. Native groups may exhibit remarkable obstinacy as has been the case, for example, in the shifting back and forth between Siam and Thailand. External resistence may appear as in the case of Constantinople to Istanbul.

The problem of changing and conflicting names has been aggravated by recent political upheavals, native independence movements and general international conflicts. During the present century the names of several well known cities in Russia have been changed more than once in response to changes in politics and political figures. There can, of course, be no outspoken internal conflict resulting from such changes but no fear can squelch external confusion occasioned by such changes as St. Petersburg to Petrograd to Leningrad. In other areas natives may feel that by the process of renaming or reverting to original native names, they achieve recognition of their new world status. One example is the very recent change from

Batavia to Djakarata. At other times colonizing nations may concede to native demands to either placate them or give them a greater sense of participation in local affairs as reflected in the change from Dutch Guiana to Surinam. If the natives are not placated and receive their independence name changes are logical and almost inevitable. This is the case in the change from the Netherlands East Indies to Indonesia.

No matter what happens to be the source of conflicting names and no matter what name finally is generally accepted, two or more names will be found for the same place during the period of transition. Ill-informed map users will have trouble in associating more than one name to the same place. References can even be found in the literature giving the distance of one place name from the other when in reality they refer to the same place. Map-makers often attempt to eliminate such confusion by showing two names for the same spot. Since most maps are not up-to-the minute, however, there will still be a period when the general public is confused and the map intelligence expert will have to be on guard for dual references to common places.

Problems Arising From Linguistic Variations

Many of the problems of toponymy arise from linguistic variations in spelling or pronounciation. Different sounds are assigned to identical letters by different European languages. In German, for example, W is pronounced like an English V which leads to Wein-Vien-Vienna. The rules for sounding and eliding letters lead to confusion in how a name should be pronounced and then spelled in written form.

For a period, a conventionalized form was promoted among map makers and names' specialists which lead to such forms as Copenhagen, Moscow and Venice. Attempts are now being made to revert to something that more nearly approximates the native interpretation such as Cobnhaven, Muscova and Venicia. Even these, however, are not truly native because the English tongue has difficulty with the foreign inflections and nuances. For this reason pronounciation glossaries are sometimes inadequate because they cannot show the proper stress or intonation.

Translation vs Transliteration

Translation implies giving the equivalent from one language to another. If a word is properly translated it can be converted back to its original language form. Transliteration on the other hand is a letter for letter conversion from non-Roman to Roman alphabet characters which permits little freedom for recognition of specific language peculiarities. Transliteration is not a reversible process because of the fact that the Roman alphabet is less rich in expressive characters than others. Many special signs or characters cannot be reproduced and thus it is impossible to reconvert from the Roman transliteration to the original.

This difficulty is compounded in the Japanese and Chinese languages. In Chinese, for example, twenty or thirty different ideographs may be represented by one syllable in transcription. This transcription gives no clue to the spoken equivalent. Its English equivalent is really not an equivalent at all, but an approximation that cannot be recaptured in Chinese.

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Importance of Linguistic Sophistication

Lest the reader may be tempted to give up and think map intelligence requires a thorough knowledge of every language, which is impossible, let's inject an encouraging note. Map intelligence requires what one expert at AMS terms a "linguistic sophistication". This means that the person using foreign maps and map sources should know at least one foreign language to make him aware of the differences between languages. From this point he should be able to appreciate the variations that exist among written and spoken languages. Such open-mindedness fosters the ability to adjust to sounds and characters not found in the English language. He will not then demand a "pat" English translation of every foreign term or name. When the occasion arises he will even be able to acquire enough insight into a particular language to enable him to interpret map toponymy without having a full knowledge of the language in question.

The phases and problems involved in a full treatment of toponymy are far greater in number and more complex in detail than is indicated in the above resume. It can only be hoped that the student is made aware of the scope of the simple sounding factor of "place names". Such awareness should make it apparent that names provide important clues to the backgound and heritage of an area as well as means of identification of specific spots. Thus toponymy is vital to the interpretation of specific maps and map series involved in any military or civilian research.

APPENDIX

Table I

Prime meridians used on foreign maps with longitudinal distances from Greenwich.

Amsterdam	4°35' 05" E.
Athens	23°42' 59" E.
Batavia	106°48' 28" E.
Brussels	4°22' 13" E.
Copenhagen	12°34' 40" E.
Ferro	17°39' 46" W.[1] 17°40' W.[2]
Istanbul	28°59' 20" E.
Lisbon	99°11' 10" W.
Madrid	3°41' 15" W.
Moscow	37°34' 15" E.
Oslo	10°43' 23" E.
Padang	100°22' 01" E.
Paris	2°20' 14" E.
Peking	116°28' 10" E.
Pulkovo	30°19' 38" E.
Rome	12°27' 07" E.
Singkawang	108°59' 41" E.
Stockholm	18°18' 30" E.
Tokyo	139°44' 41" E.

[1]French value.
[2]German value.

Table II

A. Table of equivalent units of length.

	Mile	Yd	Ft	In	Km	M	Cm
Mile	1.0000	1760.0000	5280.0000	63,360.0000	1.6093	1609.3490	
Yd		1.0000	3.0000	36.0000		.9144	91.44
Ft		.3333	1.0000	12.0000		.3048	30.48
In		.0277	.0833	1.0000		.0254	2.54
Km	.6214	1093.6112	3280.8336	39,370.0032	1.0000	1000.0000	100,000.00
M		1.0936	3.0828	39.3700	.0010	1.0000	100.00
Cm		.0109	.0328	.3937		.0100	1.00

B. Metric system of linear measure (with equivalents in English system).

1 millimeter	0.1 centimeter	0.0393	inch.
10 millimeters	1.0 centimeter	0.3937	inch.
10 centimeters	1.0 decimeter	3.937	inches.
10 decimeters	1.0 meter	39.37	inches.
10 meters	1.0 dekameter	32.81	feet.
10 dekameters	1.0 hectometer	328.1	feet.
10 hectometers	1.0 kilometer	0.62	mile.
10 kilometers	1.0 myriameter	6.21	miles.

C. Japanese system of linear measure (with equivalents in metric and English systems).

	1 rin	0.303	millimeter	0.012	inch.
10 rin	1 bu	3.03	millimeters	0.12	inch.
10 bu	1 sun	3.03	centimeters	1.2	inches.
10 sun	1 shaku	30.3	centimeters	0.994	foot.
6 shaku	1 ken	1.82	meters	1.99	yards.
10 shaku	1 jo	3.03	meters	3.31	yards.
60 ken	1 cho	109.0	meters	119.0	yards.
36 cho	1 ri	3.93	kilometers	2.44	miles.

D. Chinese system of linear measure (with equivalents in metric and English systems).

	1 hou	0.032	millimeter	0.0012	inch.
10 hou	1 li	0.32	millimeter	0.0125	inch.
10 li	1 feng	3.2	millimeters	0.1259	inch.
10 feng	1 chun	3.2	centimeters	1.259	inches.
10 chun	1 chi	32.0	centimeters	12.59	inches.
10 chi	1 chang	3.2	meters	10.49	feet.
180 chang	1 shi li	576.0	meters	1889.28	feet.

Note: When length of shi li differs from that shown above, all other units change correspondingly.

(As used on Chinese general staff maps).

	1 chang	3.333	meters	10.935	feet.
150 chang	1 shi li	500.0	meters	1640.5	feet.

E. Russian system of linear measure (with equivalents in metric and English system).

	1 duim	2.54	centimeters	1.0	inch.
12 duims	1 foute	30.48	centimeters	12.0	inches.
7 foutes	1 saszhen	2.1336	meters	7.0	feet.
500 saszhen	1 verst	1.066	kilometers	0.663	miles.
7 versts	1 milya	7.467	kilometers	4.64	miles.

F. Equivalent units of angular measure.

1 mil	1/6400 circle		0.0166	degree	0.0185	grade.
1 grade	1/400	circle	16.0	mils	9/10	degree.
1 degree	1/360	circle	17.8	mils	10/9	grades.

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