AIR PHOTOGRAPHY AND ADEQUATE NATIONAL SURVEYS*

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ABSTRACT: All thinking is based on assumptions—assumptions that certain data are true and adequate. An experiment is described to test maps for the concise presentation of co-ordinated data about land and natural resources. Mapping programs of leading foreign nations indicate the necessity of adequate maps for efficient development. The United States must now develop and conserve, rather than exploit her resources—witness drought and dust storms, prolonged unemployment unrelieved by new lands. The individual no longer works by himself but finds his interests affected by a host of business executives and government officials who cannot have intimate personal knowledge of his land but must depend on adequate maps and photographs for competent, efficient administration. Modern air photographic surveying can supply adequate maps and photographs at half their former cost. The photographs give an unsurpassed record for detailed study. The maps must be made for co-ordinated, unmistakable information. The uniform experience of older nations has shown that if the surveys and maps are made haphazardly for special purposes as circumstances compel, they will not be well co-ordinated or complete. In time, so much confusion and uncertainty will arise as to force replacement of special purpose surveys by an adequate national survey. The requirements of such an adequate national survey are discussed in detail: control, cadastral-topographic maps and photographs, smaller scale topographic and base maps, nautical and aeronautical charts, provision for revision, skilled reproduction, organized distribution, and most of all a carefully planned regular annual program executed by engineers of the highest professional standards to insure authoritative and efficient surveys. The estimated cost to the United States is fully discussed.

IT IS customary for the retiring president of most scientific or engineering societies to give an address. I hope that tonight may inaugurate this custom in the American Society of Photogrammetry, for it is indeed both a duty and a privilege for every retiring president to try to reciprocate for the honor and attention given him by an expression of the thoughts which he considers most timely and useful concerning the work of the society. In so doing he may well start by pointing out that his thoughts are not necessarily those of the society but depend upon the assumptions he makes as a result of his experience. I, too, wish to make it plain that what I say here expresses merely my personal views and does not necessarily reflect the opinions or established policies of the office I have had in the Society or of the federal organization with which I am associated. What I have to say depends solely on the assumptions I have derived from my twenty odd years of experience and study in surveying and mapping.

EFFECTIVE ACTION REQUIRES ADEQUATE DATA

Note the repeated use of the word "assumptions" rather than "knowledge." Nothing so advances accomplishment in this world as habitually remembering that all our thinking must be based on assumptions that certain premises or data are true and adequate. Our thinking merely discloses correlations, implications and applications of these data. Thus the validity of our conclusions, the effectiveness of our actions depend on the precision and completeness of the data with which we start our logical processes. It is only in the last two or three centuries that we have commenced to understand this. Usually the human mind, pressed by the exigencies of life, is prone to assume as the whole truth whatever data go unchallenged at the moment, however vague and incomplete these data may be, and attend only to reasoning out the action required. Never having given the assumption of data any attention and feeling certain that the logical processes by which we reason out our conclusions are sound and true, if we get into difficulties we often argue violently or question the intelligence or good will

* Address of the Retiring President of the American Society of Photogrammetry.

of those who disagree with us. Even the most intelligent minds do this occasionally.

Of course if our data are accurate, complete, well tested, well co-ordinated and readily available, we do not get into difficulties or arguments, but can proceed with speed and precision to effective accomplishment. In some fields, as in thermodynamics and metallurgy, many careful precise measurements have been made and recorded and, as a result, motor cars and airplanes that work marvelously well can be built.

Now there is one field in which our data are not so accurate and complete, nor well co-ordinated, nor in a form readily used by those who need them. I refer, of course, to our natural resources, and to the best form of inventories of these vast resources, adequate maps of our lands.

Experiment to Test Value of Maps

Why ask for adequate maps when speaking about the land? We are rapidly accumulating data about our land without adequate maps on which to co-ordinate it. Topographic data and facts about our land are far more easily recorded graphically on maps than in any other manner, and so much easier to comprehend. In order that you may get the full weight, the full value of what I have just said, I would like each of you to make an experiment. First, get a tablet of paper—several tablets of paper— and fill your fountain pen. Maybe it would be well to have a bottle of ink handy too. Then a good map, preferably one made from air photographs. When you have more time than we have tonight, try to write down all the facts that are shown on the map. First, list all the objects and give their correct names when possible, then list the shortest distance and direction between each two of them, then the best route from one to the other on foot or by car, in detail, so that no one may need to take a a longer or more circuitous route. Describe the alternate routes so that another may make his own selection for reasons unknown to you. Then give the surroundings of each object so that a person may know when he arrives near it. Give the relative importance of all the objects on the map and how they are shown so that they can be recognized quickly in the order of their importance. Give the area of each plot or park, forest or district and the total of all similar areas. By this time you may be getting tired but you have not yet begun to discuss the advantages and disadvantages of each location, the drainage, volume of possible reservoirs, obvious geologic and physiographic forms indicative of mineral resources, the places desirable for future developments and how to foster and promote them—bits of information available on an adequate map. And so on and on for as many hours or weeks as you can afford, to do a really first class job of listing all the information available on an adequate map. Then give your reams of data to a friend and ask him to make a map of it. If he does not have you examined by a mind specialist, I'll be surprised.

Do I see some superior smiles on the map makers here? They will merely describe the objects and list them by x and y co-ordinates. Their friends will duplicate the map and not send for the alienist. All right, that illustrates the importance of co-ordinates on maps to be discussed later.

Adequate National Surveys of Other Countries

There is something else those of you who make maps, or decide when and how they shall be made, should be acquainted with. Go to a good map library or send to the Ordnance Survey of Great Britain for a copy of each of its re-

markable series of maps. Get a sample of the British twenty-five inches to the mile plans which cover all the cultivated land, and the six inches to the mile which cover the whole country. For those who think in natural scales these are approximately 1:2,500 and 1:10,000. Note that these maps show the acreage and boundaries of every field in addition to all the usual topographic data. Reflect that all objects are so accurately shown upon them that new detail is located by prolonging the range between any two objects which line up near it; that the maps are checked and revised in this way and resurveyed if they fail to meet such exacting tests. Examine carefully the latest inch to the mile series which is famous all over the world—then the half inch, the quarter inch, the eight mile and the million scale maps, all of them compiled by reduction from the large scale plans and each serving a particular set of needs most adequately.

Then reflect that Great Britain with an annual income only one-third as large as ours is spending more than $2,000,000 per annum merely to revise these maps and bring them up to date. Why? Only because they have learned the value of maps and know that they cannot afford the waste of letting them get obsolete.

One further illustration while we are talking about the English maps. About 1930 Mr. Dudley Stamp and a few other public spirited individuals decided that their country needed to know how each parcel of land was used as of 1931–32. They secured a grant of about 10,000 pounds from the University of London together with office space and staff. With this start they began enlisting the co-operation of the schools. To cut the story short, the schools bought the government six-inch maps of their districts at a shilling sixpence per copy and had volunteers among their children mark up the land use with different colors for forests, rough grass, permanent meadow, crops in rotation, gardens and orchards and agriculturally unproductive land. The children's work was carefully checked by their instructors and by voluntary university students who also assisted in compiling the data on inch to the mile maps. These maps were printed in colors according to the land use and are sold at cost to the public by the privately organized Land Utilization Survey. Some 250,000 students co-operated in the project with a marked increase in civic consciousness. The land utilization maps obtained have already corrected many false impressions obtained from bare statistics and have been of much use in planning future developments with the minimum interference to agriculture. Consider the quality of maps on which even school children can tell precisely where they are and mark each field correctly!

The Ordnance Survey maps of Great Britain could well be models for the world, although somewhat deficient in contours occasionally. The maps of Switzerland are also admirable. Switzerland is engaged in mapping on 1:25,000 scale for general maps and on beautiful 1:10,000 scale completely contoured cadastral maps for the more important localities. The 1:10,000 scale maps are to cover the whole country eventually except for certain waste areas. Italy, France, Germany and Holland are mapping their areas on 1:5,000 scales or larger for cadastral and detailed planning use as well as 1:20,000 or 1:25,000 scales for military uses and large area planning. All of them are expending several times as much in proportion to their incomes or national wealth as we are for mapping. They have found without exception that adequate maps, just as good roads, repay their cost many times. Of course, the European countries must conserve and develop their resources more carefully than we have been doing but why should we continue the wastes of slipshod development resulting from inadequate maps?

Conservation and Development of our Resources now Essential

It is true that until the turn of the century, we had so much rich, cheap land awaiting development that we did not bother about care in measuring it, nor whether we were using it to best advantage. It has taken prolonged unemployment unrelieved by new lands, it has taken droughts and dust storms to make us stop to think that there is a limit to our national resources and that we should consider how best to conserve and use them.

There are no more rich lands awaiting the individual homesteader to relieve unemployment. But if we make the necessary surveys, careful engineering studies, agricultural experiments, and marketing arrangements, the marshes of our Atlantic Coast and Mississippi Delta are as capable of supporting millions in happy security as the lands reclaimed from the Zuyder Zee by Holland. Whenever the nation needs more food, these lands can be developed, but they cannot be developed successfully without carefully worked out arrangements for which adequate surveys are the first step.

Needs for Adequate Maps

It is not merely in opening up new lands, but in the more important development and conservation of those lands now in use, that the strong instrument of collective action through efficient government is necessary. Every civilized nation maintains an agricultural department to aid its farmers in attaining a soil conserving, balanced agriculture. If the helping hand of government research and co-operation is to reach all the farms that need it in just proportion, it is imperative that those who extend it be not limited in their efforts to the lands they can walk over themselves and thus get to know by personal observation. Nor should they worry along with maps showing only dwellings, roads, streams, towns and perhaps forests. As we shall show shortly, it is now practicable for every county to have a file of good, clear air photographs showing every field in it, to have maps on the same scale on which are recorded the boundaries, the acreage, soil and slope data, and, if needed as time goes on, a file showing previous land use for many years. With such data the individual can readily explain his needs and the expert make sure he is doing a thorough job.

So much for agricultural needs. Consider the needs of those whose duty it is to plan and build roads, or flood control works, to extend electrification, to collect and equalize taxes. The nation spends about eight billion dollars annually for automobiles, gasoline, oil and repair service and highway taxes—the vehicle and gasoline tax amounting to a billion dollars of this. Of more than three million miles of highways in the United States, only six percent are hard surfaced and only about thirty-five percent have any kind of improvement. There is no question but that improved highways are a self-liquidating investment. They pay for themselves many times over in reduced transportation costs and development of the areas they serve. Before the nation lies the job of completing our trunk highways, straightening, widening and reconstructing inferior roads and building some two million miles of light traffic secondary roads. Are those who plan and build these roads to have a complete set of photographs and maps from which they can read the distances and grades, the drainage area for every culvert or bridge, the property the roads will pass through, the farmsteads and communities to be served, or are they to be forced to make inadequate preliminary route surveys and "guess-timate" the rest as formerly?

There is an old saying that "nothing is more certain than death and taxes." We might add "or that taxes will be inequitably assessed where there are no

adequate tax maps." It is impracticable to make sure that tax rolls are complete, that areas are accurate without adequate maps, showing every parcel of property, to say nothing of the aid such maps give to just evaluations. There are many thousands of assessment districts in this country without such maps. Here again neither the individual nor the official can depend on his personal knowledge for the protection and the just action so readily obtained with good maps.

One could go on indefinitely citing more needs for adequate maps. A few of them are listed in Table 1. The essential idea is that in our present civilization, the individual no longer works by himself but finds his interests depending on planning and action of a host of different business and government officials trying to co-operate with and to serve him. Because of the scope of their activities, it is impossible for the officials to have the intimate personal knowledge of all the land in their districts possessed by the owners of the many farms and other properties. Yet they must have the essential facts in accurate and comprehensive form if they are to make the just decisions and the satisfactory progress necessary for success and popular approval. The ideal and necessary condition is for each private individual, each business or government official to have access to accurate and complete maps with which to reach a common understanding and the most effective action.

Table 1.

USES OF PHOTOGRAPHS AND MAPS

PHOTOGRAPHS:

Original studies and notes in field and in office. The notes regarding interpretation taken in the field may be extended to areas of like appearance in the office.

Inventories of all identifiable conditions or objects.

Detailed studies, preferably under the stereoscope, of geological structure, soils, erosion, forestation, crops and land utilization, physiographic forms and changes, archeology, preliminary engineering studies of possibilities for water power, routes for roads, transmission lines, increased facilities for railroad and motor traffic, and all types of detailed planning.

CADASTRAL-TOPOGRAPHIC MAPS:

Boundaries and areas of all parcels of land; all structures and works of man; all natural features of the land in correct position and relief with contours; carefully verified names.

Administrative districts of every sort, as minor civil divisions, townships, parishes; parks, forests, irrigation or drainage areas, game preserves, reservations, quarantine areas, fire protection areas, etc.

Tax maps for discovery, description, and valuation of property; equitable assessments.

Land registration maps for quiet titles.

All engineering purposes preceding final location and construction surveys, such as river conservation and control for water power, navigation, and flood prevention; drainage, reclamation, and irrigation; development of roads, railroads, canals, harbors, transmission lines, mining properties, etc.

Detailed geographical, geological and ecological studies.

Military defense of positions to be strongly held.

Base for special maps, such as zoning maps, population density maps, public utilities maps, soil maps, erosion maps, land use maps.

USES OF MAPS

TOPOGRAPHIC MAPS REDUCED FROM THE PRECEDING:

1:50,000 or 1:62,500 scale. General geological, geographical, and ecological studies.

Military tactical maps.

Guidance, hunting and hiking tours.

General area planning, routes for highways, etc.

County maps, maps of parks, forests, reservations, quarantine and other administrative districts and purposes.

1:125,000 to 1:250,000 scale. Same uses as above for very sparsely settled areas of little economic importance or little topographic detail. Base for state road maps of congested areas.

1:500,000 scale. Maps of states of average size. Regional planning, geographical and geologi-

cal studies. Military strategic maps. Base for aeronautical charts for contact flying. Automobile road maps.

1:1,000,000 and smaller scales. Regional and national planning and geographical studies. Strategic maps, atlas maps, wall maps.

Outline maps from all the above series may be used as bases for graphic representation of areas and locations of soils, minerals, weather, climate, vegetation, population density, principal occupations, products, transportation systems, etc.

If made from the same basic survey, they greatly facilitate comprehension of the many interconnections of such data.

CHARTS:

1:5,000 to 1:40,000 scales. Harbor and airport charts for close navigation in crowded areas; depiction of special facilities, aids, and dangers; designation of permissible channels, anchorages, or parking spaces.

1:80,000 to 1:200,000 scales. Coasting charts for navigation by piloting.

1:500,000 scale aeronautical charts for contact flying.

1:1,000,000 and smaller scales. Sailing charts for offshore voyages.

Aeronautical charts for regional navigation, principally by radio or celestial navigation.

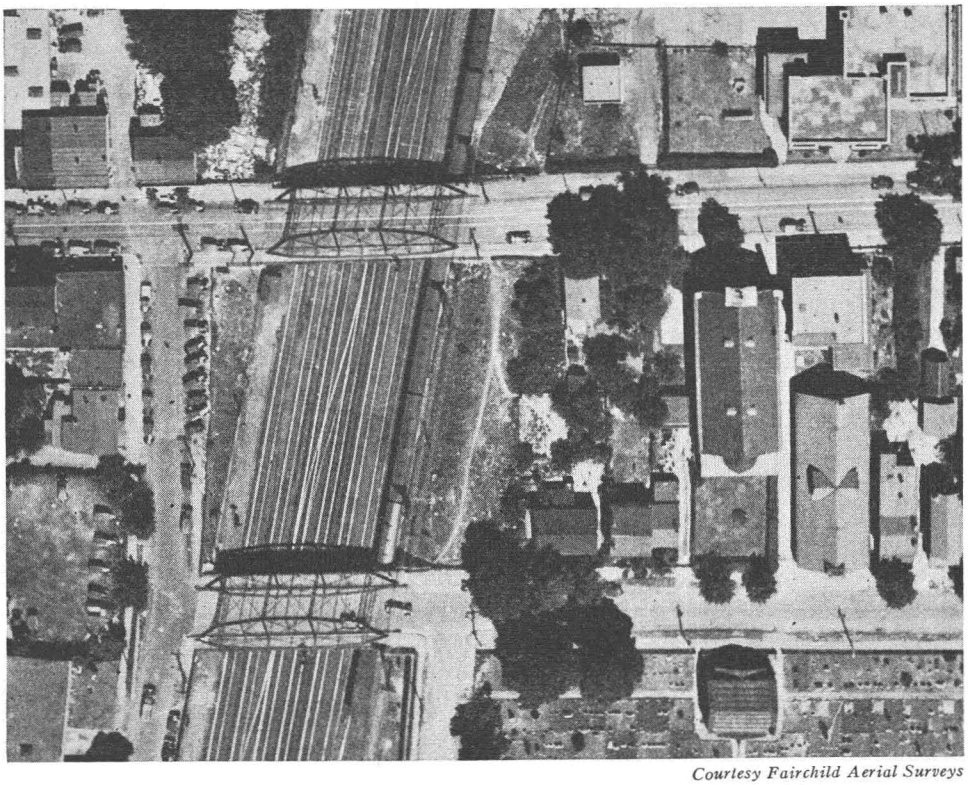
AIR PHOTOGRAPHIC SURVEYING REDUCES COST AND TIME

Now it is particularly fortunate for a country so large as the United States that a new method—air photographic surveying—has been developed which reduces to about one-half the cost and time required for adequate maps. Last summer I sat operating the nine lens camera of the Coast and Geodetic Survey as we flew along at 160 miles an hour in an Army Air Corps bomber three miles above the earth's surface. All I had to do was to watch the sight and levels while about every minute and forty seconds the shutters clicked and a fresh bit of film was automatically wound up. In an 80th of a second the light reflected from the earth below had recorded on that film every meander of coast and stream, every road, every building, every field and detail of importance in more than 120 square miles of terrain. We finished photographing the 1,400 square miles in which we were interested with every detail photographed on 1:20,000 scale with plenty of overlap in an hour and flew back to Washington. The combined ingenuity and work of more than two hundred individuals had gone into the development of that camera and no one knows how many into devising and perfecting the film and the airplane, but we do know that they first made many precise and comprehensive measurements of the materials with which they worked so effectively.

The "bird's-eye view" has always impressed the mind of man with its desirability. Today we cannot only view what the bird sees but can bring a permanent, highly detailed record home to study at leisure in our offices. Prints from the same photograph can be studied in any number of offices by any number of specialists. Whether for studies of forestation by foresters; for indications of possible mineral wealth by geologists; for crops, soils and erosion by agriculturists; or for water power, navigability of streams, routes for highways, railroads or transmission lines, city planning and zoning by engineers, or tax equalization by assessing officers, the photographs give an unsurpassed, detailed, permanent record of the terrain. Each specialist can view this complete record afresh without being handicapped by the omissions or mental slant of those who might try to make maps for him upon the ground. By using two overlapping photographs under a suitable stereoscope the third dimension can be seen, the trees and buildings stand out and every undulation of the ground is apparent, for the hills do not hide the valleys nor one hill hide behind another from the air.

TYPES OF PHOTOGRAPHS

Although one set of photographs can serve many purposes, there are advantages in using special types. Figure 1 shows a railroad passing through a



Courtesy Fairchild Aerial Surveys

Fig. 1. Built up area, scale 1 inch to 100 feet (1:1200).

built-up area on a scale of 100 feet to the inch. This was taken to aid in planning an increased right-of-way and trackage for the railroad, but this scale is also ideal for city planning and tax equalization purposes. Figure 2 is a well developed countryside on a scale of 1:10,000. Note how clearly the fields, the orchards, the roads, the buildings stand out. This is an ideal type for country in which fields average ten acres or less.

Figure 3 is an oblique taken by the Royal Canadian Air Force, showing intersecting dykes which geologists will admire and modern prospectors crave for it shows them the best places to look for valuable minerals.

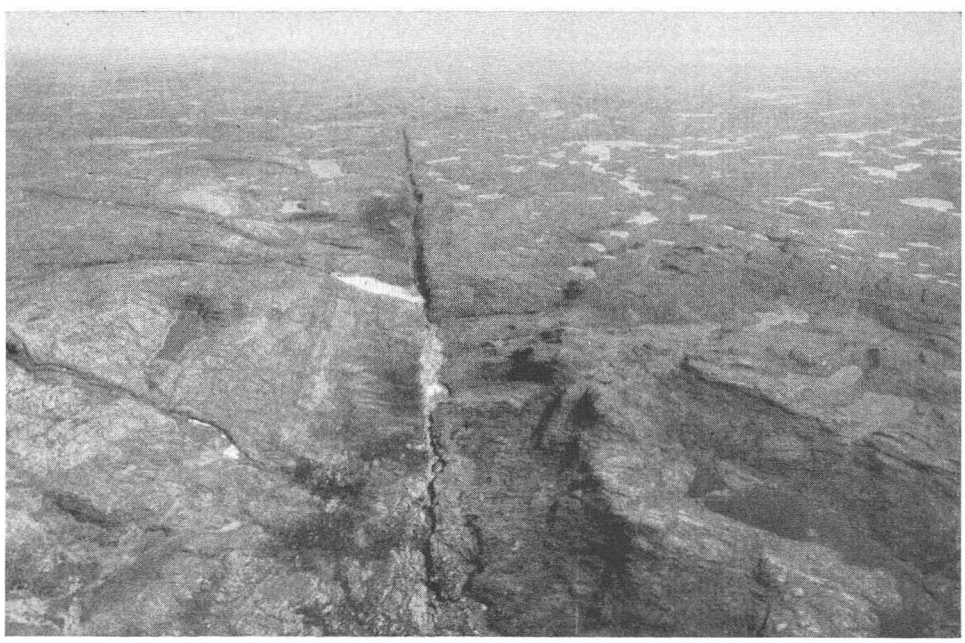
Figure 4 is another from Canada showing the famous Eldorado radium mines. Note the veins leading off to the right from the water. Canada has changed the name of such areas as these from the "Barren Grounds" to the "North Country," largely through the aid of aerial photographs which not only point out likely places to prospect for mineral wealth but can readily be compiled into maps showing how to get to it and bring it out. Incidentally, only 20,000 of the 586,000 square miles of our rich territory of Alaska have been photographed from the air.

Figure 5 shows a salt dome taken by the Edgar Tobin Aerial Surveys with headquarters at San Antonio, Texas. Such photographs explain why oil companies are some of the best customers for aerial photographs.

Figure 6 illustrates a few of the differences between a map and a photograph. You will note that the photograph must show information by variations of light and shade which almost always require local knowledge or much study

Courtesy U. S. Army Air Corps

Fig. 2. Well developed country with small fields, scale 1:10,000.

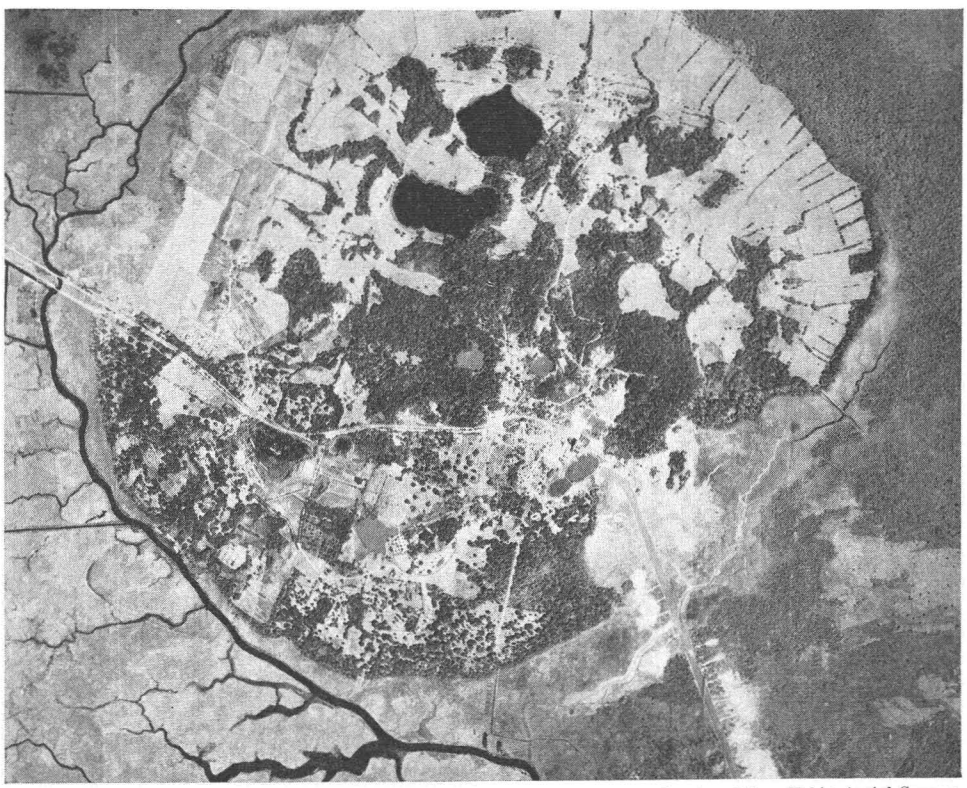


Courtesy Royal Canadian Air Force

Fig. 3. Intersecting Dykes.

Courtesy Royal Canadian Air Force

Fig. 4. Largest radium mine in the world. Note veins.



Courtesy Edgar Tobin Aerial Surveys

Fig. 5. Salt dome formation in oil country.

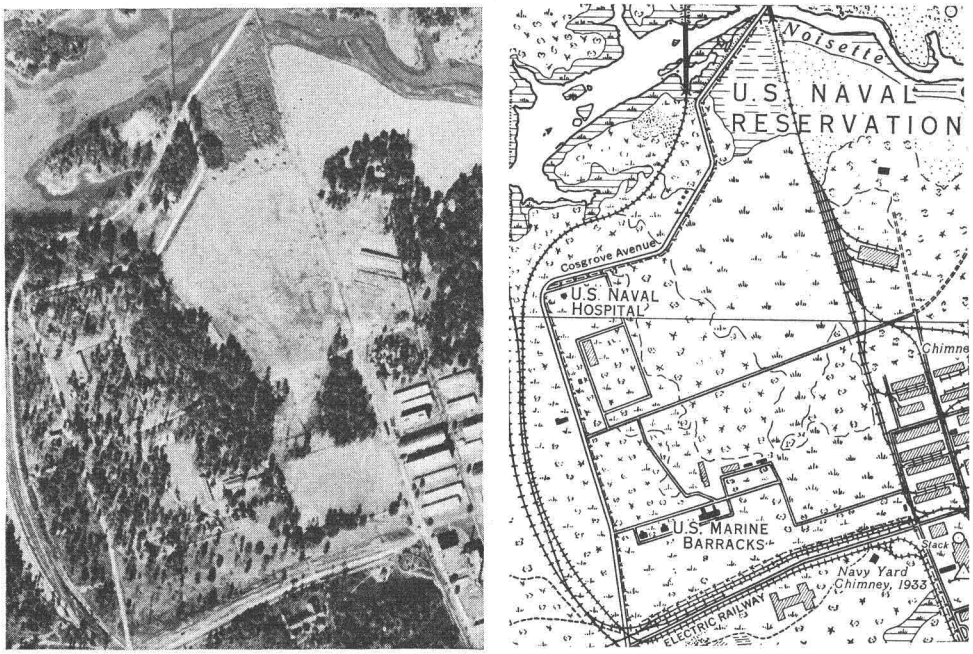


Fig. 6. Photograph vs. map. Light and shade or standard symbols.

and training to interpret precisely, whereas the map shows information by standard symbols unmistakable if one looks at the symbol sheet obtainable with the map printed or on it. Again the photograph emphasizes detail according to its light reflecting power—the map according to its importance to man. Trees often partially obscure details such as roads and buildings on the photograph—the map makes them stand out plainly. Unless you were an expert you could not tell for certain whether that streak over to the left is a road, a railroad or an electric railway, unless you had previously visited the place. Of course the map is much easier and cheaper to reproduce in large quantities than the photograph.

Figure 7 shows another difference between photograph and map. The photograph shows objects as viewed from the point in space where the shutter clicked, and the map as if every object was viewed from directly above. Objects of different heights on the outer parts of the photograph therefore have much different positions than on maps.

Figure 8 also illustrates this in plan view. Note how all the tall buildings lean away from the center of the photograph and the straight road running across the hill appears bent outward. If one did not know the hill was there and scaled the area of the squares from the photograph without correction, he would probably start an argument with the owner of the land.

Look carefully at Figure 9 for it illustrates one of the main advantages of air photographs for mapping. Both maps show the same area but the large scale detailed one was made from air photographs at less cost than the smaller one without field boundaries made on the ground.

Figure 10 shows a sheet of the Boulder Reservoir survey made from air photographs with the stereoplanigraph by the Fairchild Aerial Surveys of Los Angeles for the Soil Conservation Service. This was a remarkably efficient job

managed so excellently and described so well by Mr. Leon T. Eliel in Vol. III, No. 1 of PHOTOGRAMMETRIC ENGINEERING. There is now no doubt that for contour intervals of ten feet or more the stereophotographic method has advantages in cost as well as precision and completeness of detail over ground methods.

The illustrations given are not isolated instances, but general experience. The Tennessee Valley Authority has contracted for complete air photo-topographic surveys of several quadrangles on a scale of 1:24,000 for $36.00 per square mile, for penciled maps exclusive of control, field checking or reproduction. This compares very favorably with the cost of inch to the mile surveys made on the ground. Air photographic surveying has made the large scale detailed maps cheaper than the inch to the mile ground surveys provided that the contour interval is not decreased as the scale is enlarged.

This significant fact means that it is practicable to have complete topographic maps on scales large enough to show all enduring land boundaries at moderate cost. No national survey can be regarded as adequate which does not show the boundaries of all parcels of land when marked by fences or other features of an enduring nature. Nearly all development of the areas where such boundaries exist must take them into account before it starts. Such boundaries usually furnish the most convenient means of locating oneself on the map whenever they are accurately shown. They furnish useful guides to sketching in additional data without definite boundaries, such as sheet erosion or soil types. The areas of the parcels or their dimensions are, of course, necessary for just assessment of taxes and other administrative problems. Sooner or later the sheer awkwardness, injustice and waste of doing without cadastral maps force every civilized government to have them made.

If these are made haphazardly, as circumstances compel, along with unco-ordinated construction and other special purpose surveys, there in time arises such a babel of confused unco-ordinated data and maps that the whole has to be discarded and a well co-ordinated, adequate national survey has to be made

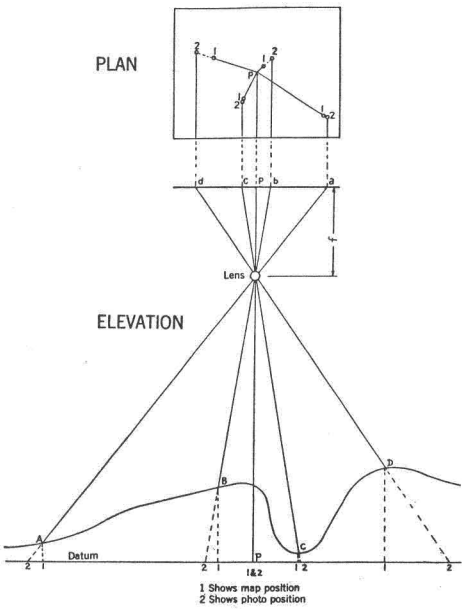


Fig. 7

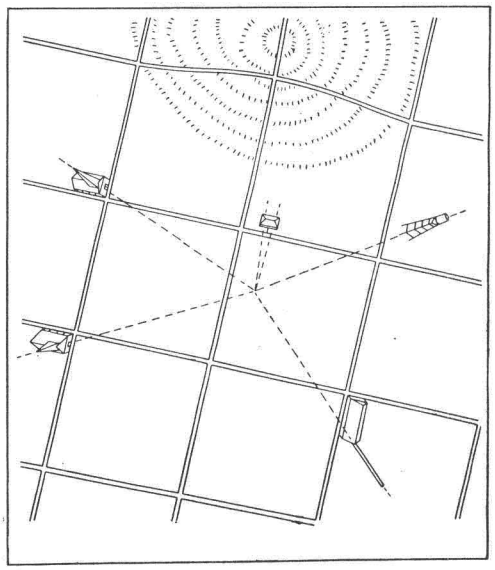


Fig. 8

Fig. 9. Both maps show the same area. 1:10,000 scale from photographs, 1:31,680 from planetable. (Much reduced in reproduction.)

Courtesy U. S. Soil Conservation Service and Fairchild Aerial Surveys

Fig. 10. Sheet of Boulder Reservoir Survey made with Stereoplanigraph (reduced to 1/3 actual size in reproduction. Original on scale of 1:12,000 with contour interval of 10 feet).

after all. This is the uniform experience of European nations. Let us profit by their experience, consider the requirements of adequate national surveys and how they are obtained so that we may reduce the waste and inefficiency of such further haphazard procedure.

Requirements of Adequate National Surveys—Control

There is a surveying method known as first-order geodetic triangulation by which it is practicable to determine relative positions on the earth so accurately that the distance between any two of them will be correct within one part in 100,000. If the object marking such a position is destroyed or lost, the position can be remarked with that accuracy. One fundamental requirement of adequate national surveys is that first-order triangulation stations shall be so distributed over the country that all boundaries can be determined from them with the accuracy warranted by their importance. Thus in cities where an inch or so is of importance, the stations should be not more than a mile and a half to three miles apart. In country where a foot more or less will not bother, they can be ten to twenty miles apart. For mapping and other purposes where such accuracy of

position is not essential, provided that the error is adjusted and not allowed to accumulate in any one place, second and third-order triangulation or traverse measurements with tapes along the ground may be used to determine the positions of important objects or additional control stations. The map detail or other less accurate surveys may then be adjusted to these control stations. In this manner, and in no other practicable way, can troublesome discrepancies be avoided in surveys and maps—discrepancies that will arise for generations, resulting in lawsuits over property and causing map users to regret that they trusted the maps.

When such control stations are made available at intervals of from two to five miles over country likely to be developed or undergoing development, every detailed survey, whether for property boundaries, highway or other construction, can be run between two of them and thus checked for accuracy. If the errors are immaterial, they can be adjusted and the co-ordinates of corners or permanent objects so determined can be used to tie in other surveys, or for re-establishment later.

The positions of the control stations are determined by geodetic surveying, taking into account the curvature of the earth, the deflection of the plumb line from the vertical and other matters which require special professional training. But the Coast and Geodetic Survey, appreciating the usefulness of easy and complete co-ordination, has devised systems of plane co-ordinates for every state which will make it practicable to do all the surveying between such control stations by plane surveying which any careful, intelligent engineer or surveyor can learn to do well. Although the complete plan has been worked out, the benefits of such co-ordination cannot be obtained until the control stations are established and the data computed and published. A million or more dollars are being spent each year in this country in unco-ordinated property and construction surveys for special purposes which could just as well be co-ordinated and added to the national net, if such control stations were available. Some day most of these surveys will have to be repeated to place their objects on co-ordinates. In fact, many of them have been repeated several times already for lack of such co-ordination.

The triangulation and traverse furnish control for co-ordination of horizontal positions only. Control for the co-ordination of heights is also important, particularly when water resources, roads, sewers, etc., are to be developed. Adequate national surveys furnish this by means of first, second, and third order leveling to determine the elevations of well distributed bench marks. The height of each bench mark above a single datum, mean sea level, is furnished to every one having need for it, including the map makers. Where such convenient bench marks do not exist, there are often found as many as ten different datums assumed by as many different surveys in a single city.

Large Scale Cadastral—Topographic Maps

A second main requirement of adequate national surveys is a series of cadastral plans or maps showing all parcels of property. This means scales of 1 inch equals 50 feet or 1 inch equals 100 feet for cities; 1:2,400 or 1:4,800 for towns; 1:7,920 (1 inch equals 660 feet) or 1:10,000 for areas in which fields average ten acres or less; scales of 1:24,000 or smaller for larger fields and less important areas.

Modern air photographic surveying has made it practicable to include complete topographic detail on such maps without greatly increasing their costs. The air photographs should be on the same scale as the maps for convenience

in transferring and interpreting information. You will remember that no hand drawn map can hope to rival the photographs in minute, unbiased detail. The photograph, therefore, is the ideal guide to take into the field for direct interpretation and study. The map made from it is just as necessary for unmistakable information clearly emphasized in the order of its importance, for the use of those without personal knowledge of the ground, or long years of experience at interpreting aerial photographs. Both are necessary for adequate national planning and development.

When the closely spaced control stations on plane co-ordinates and the large scale cadastral-topographic maps become available it will be practicable to initiate a system of voluntary land registration whenever title changes hands. A first-class system of this sort saves so much in legal and title guarantee fees that its eventual adoption is inevitable by all intelligent people.

Complete Series of Topographic Maps

A third main requirement of an adequate national survey is a series of complete topographic maps on smaller and smaller scales, each best suited to a set of similar needs. For example, a series of 1:50,000 scale or inch to the mile maps for military tactical purposes, geological studies, hunting, hiking tours, county road maps, etc.; other series on 1:125,000, 1:250,000, 1:500,000 1:1,000,000 scales for road maps, aeronautical charts, regional planning, atlases and many other uses. All of these should be compiled by reduction from the large scale cadastral-topographic maps so that there will be agreement in the detail shown.

There should also be a series of skeleton line maps available at each scale on which special information can be overprinted to make tens or even hundreds of the special purpose maps needed by the executives and legislators as well as the engineers in modern civilization. A few examples are geological maps, soil maps, crop and land use maps, erosion maps, population density and zoning maps, transportation maps, administrative boundary maps, tax maps and so on.

Let me repeat, our civilization grows so complex that it is of great importance for the clear comprehension of the many interconnections between such data that these many different maps be overprinted on the same base maps derived from the accurate comprehensive survey. If made without such common bases, which one among us will ever be able to comprehend the many correlations between these diverse data? What individual can without great difficulty trace the close interrelationships between geological structure, soil erosion, land use, tax adjustment, loan value, future development, highways and electrification needed, population density and trends if he must go to as many different unco-ordinated maps? Of course, the beautiful diagrams of the whole country in a good atlas are mildly interesting but where are we to find these data for Jones County and Smith's Ranch or the Juniper River Valley?—only on special maps based on an adequate national survey.

Consider the extraordinary gain in precision, the freedom from bias, of the reports and discussions of the best means for developing and conserving our resources when only a few minutes will suffice to check each statement against a stereoscopic pair of air photographs and an accurate map record of every significant detail.

Charts

A fourth main requirement of an adequate national survey is an accurate detailed hydrographic survey of the coast, lakes, and navigable rivers, based on

the geodetic control. These surveys should be shown on a series of large scale harbor charts, medium scale coastal charts, and small scale sailing charts for offshore navigation. The large scale cadastral—topographic surveys would furnish the topographic information needed for these surveys and charts. There should also be a series of aeronautical charts showing important airports on large scales, the general area of the country on 1:500,000 for contact flying, also on 1:1,000,000 and 1:2,000,000 for regional navigation, all compiled from the basic survey. It is essential to the safety of navigation that the lights, beacons, and other aids on these charts as well as special dangers to navigation be shown correctly as of the date the charts are issued.

Revision

This leads to the fifth main requirement, adequate provison for revising the maps and charts to keep them reasonably up-to-date as to general information and culture—revisions showing new roads and parks, the growth of towns and cities, harbor improvements and shoreline changes, changing use of the land, etc., that the maps may not lose much of their usefulness for present purposes and the planning of future developments. Here again, if the maps be thoroughly co-ordinated and accurate in the first place, air photographs can greatly facilitate the revisions and reduce their costs.

Expert Reproduction

A sixth obvious requirement is that there be adequate publishing facilities for the data collected. The compilation of first-class maps requires very high intelligence if the full usefulness of the data is to be obtained. A long apprenticeship to develop good judgment, the most painstaking care, and artistic ability to emphasize important features are required. The resulting improvement in the cartography costs relatively little, yet it greatly increases the ease with which the data can be comprehended and therefore the usefulness of the maps. The reproduction and printing, too, is an art that usually requires a life career for real excellence. Needless to say, every individual citizen has a right to the data collected at public expense to protect his interests, as well as the duty of comprehending the relations of those interests to the general welfare. The maps and photographs which so greatly facilitate the co-ordination of individual with the public interests should, therefore, be printed and sold at reasonable prices—not buried in the files of his government.

Organized Distribution

The seventh main requirement of an adequate national survey is a thoroughly organized system of distribution to make its information readily available to every citizen. All maps, charts, photographs and control data should be issued by one agency, including the special purpose maps. If the Department of Agriculture makes an outline base map for a soil overprint, if the Census makes a population density map, all should be available at a single agency regardless of the issuing agency or department. All control data including triangulation, traverse, and levels in any area should be adjusted and published in one book with supplements from time to time, no matter what federal, state, or city agency does the work. All such books should be available through the single agency.

Arrangements should be made with national, state, and local libraries for the inclusion of air photographs, maps, and survey data in their services, or special libraries for this purpose should be established at interested organizations or institutions. Each library should have a complete file of all the photo-

graphs and maps of the area it serves, with catalogs, indexes, and prepared forms by which anyone could readily determine his needs and order copies for personal use. Convenient sales agencies should be established to expedite this service.

Authoritative Standards and Planned Program

The eighth and most important requirement of adequate national surveys is that they shall be so excellently and efficiently executed as to be authoritative. The men in charge should be so thoroughly familiar with the latest, most efficient methods of surveying and mapping throughout the world, so able themselves, that the methods adopted will be the best practicable. Recognizing such excellence, their subordinates will be on the alert to help in the important work and be quick to suggest improvements in methods at every opportunity.The resulting surveys will be of such a high standard as to be unquestionably authoritative and a joy to every user. And they will be efficiently, most economically done as well. But to achieve such surveys and maps it is essential that those in charge of the work be of the highest professional standards, that the survey offer a career attractive to such men. The appropriations for this work must include money for research, first-class instruments and equipment. Most of all, the appropriations must be in accordance with a well planned program in regular annual amounts so that the employment of the junior officers and instrument men may be constant and on a career basis. They can then be trained to high efficiency and will naturally form the best material for administrative and executive positions later. The importance of thorough training and the right equipment for high quality surveying is illustrated by a bit of triangulation along the coast that I remember. It happened in this case that a hydrographic party found that the monuments marking some old control stations across a broad sound from recoverable stations had been destroyed. Now all Coast and Geodetic Survey officers are familiar with triangulation but this party was newly organized and had only equipment used in daylight on the short distances usually encountered in revision surveys along the coast. The weather proved consistently hazy during the daytime and it was finally necessary to observe two of the lines at night. This bit of triangulation cost four or five times as much as it would if done with a thoroughly trained and equipped party specializing in triangulation. Such parties because of their thorough training and organization are able to work at night with high efficiency and take advantage of the clearer atmospheric conditions usually prevailing then. In fact, first order triangulation in the United States has been so efficiently organized with portable observing towers and motor transport that our parties usually observe about two or more times as many stations a month as those in other countries.

It should not be inferred from this that the work of a national survey requires men of professional training and standards for all its work. Sixty percent of the funds needed for control surveys could be used for employment of men not specially trained in advance without material sacrifice in efficiency. Not only in control surveys but in cadastral mapping and other branches there are many jobs for which suitable men can be found from among the unemployed but the proportion of professionally trained men and continuous employment must be maintained if the cost is not to be multiplied many times and the quality of the product to suffer.

The requirements of an adequate national survey which would place the United States on a par with any other civilized nation are summarized in Table 2.

Table 2. REQUIREMENTS OF ADEQUATE NATIONAL SURVEYS

1. Geodetic control on plane co-ordinates at intervals suited to the adequate location of property boundaries. A net of precise leveling over well distributed bench marks to place all elevations on the same datum throughout the nation.

2. A series of cadastral-topographic maps on scales large enough to show the boundaries of all parcels of land, together with a set of air photographs overlapped enough for stereoscopic use on approximately the same scale as the maps, in order that either may be used in the field and the data readily transferred between them.

3. A series of smaller scale topographic maps in gradual steps from 1:62,500 to 1:1,000,000 produced by reduction from the larger scale maps. Each series should be duplicated in outline only, to serve as bases for overprinting special information such as soil maps, land use maps, population and zoning maps.

4. A series of nautical and aeronautical charts on suitable scales for harbors or airports, coasting or contact flying, and offshore or regional navigation. These charts to be compiled from detailed hydrographic and topographic surveys based on the geodetic control and to be corrected to date of issue for changes in aids and dangers to navigation.

5. Adequate provision for revising the above maps and charts to keep them generally up-to-date.

6. Provision for reproduction of the photographs, maps and charts by photographers, cartographers, engravers and lithographers of high skill.

7. Provision for national, state and local libraries to display the maps and photographs, together with well organized, convenient sales agencies.

8. A fully co-ordinated, carefully planned, regular annual program directed by engineers of the highest professional standards, in order that the national survey may be unquestionably authoritative and efficiently executed.

Costs

What will such an adequate national survey cost the United States? If made with efficient organization, thoroughly qualified professionally trained staff, and a carefully planned program as indicated, it would cost about one hundred and fifty million dollars excepting city surveys and maps, or about two hundred and fifty millions in all. This estimate, of course, assumes the full use of the latest air photographic and photogrammetric equipment.

Many topographers accustomed to planetable work will question such a low estimate considering the large scales involved. In the back of their minds are statistics that 1:12,000 scale planetable topography has cost six times as much as 1:62,500. I do not think they give full weight to the small contour interval, the exceptionally complicated topography, and the small extent of such surveys previously made on the ground. Remember the parallel of odd jobs of triangulation, as against the cost of thoroughly organized work on a continuous production basis. Aside from this small detailed job factor, modern photogrammetric methods permit of at least doubling the scale without increasing the cost, provided the contour interval is not decreased nor the additional cost of reproduction of the much larger number of maps required included. The cost of reproduction can be liquidated by the sale of the maps. As to the contour interval for the maps contemplated, it should be small enough for choosing the route of roads and the sites for other construction but not for their final placement or the computation of excavation and fills. With such a limitation the estimates stand. In regard to showing the boundaries of each parcel of land, existing marked boundaries readily recoverable on the ground are contemplated—not property lines which often involve legal questions of great complexity and are very costly to determine. Voluntary registration of land as it changes owners, with surveys tied into the co-ordinated control stations, will in time cure any objection to this restriction and save the country many times the cost of the survey. It should be remembered that much of the cadastral data can be obtained by non-professional men using air photographs, but only after they have been very thoroughly trained by professional supervisors.

The experience in the Boulder Reservoir, The Tennessee and Brazos River Valleys is the basis of the estimate. When one considers the immense areas of this country in which there are practically no field boundaries and for which an inch to the mile scale is amply large for every need, the estimate will be found to hold.

Two hundred and fifty millions of dollars—it is not so large a sum considering the tremendous wealth and resources of our country. The two new Lincoln and Queens tunnels of the City of New York plus the Golden Gate and Oakland Bridges over San Francisco Bay cost about as much. Spread over a period of ten to fifteen years, as it must be for an efficient job, it could be financed by 2 percent of the gasoline and vehicle tax. Part of the cost should be assessed against the real estate taxes, particularly in cities, but if the whole were charged to the gasoline tax we should have better roads and more of them at the end of twenty-five years than if all the 2 percent went into construction and uncoordinated special purpose surveys as at present.

Consider the wealth such maps will save in the development of our water resources, in the cost of controlling floods and excessive soil erosion, and, above all, in reducing the waste of lack of co-ordination. One of the gravest weaknesses of government in a large, rapidly developing country such as ours is lack of co-ordination among its many activities. Modern civilization requires the co-operation of citizens through the instrument of government in so many different lines that there is grave danger of losing sight of their relative importance and the many inter-connections between them.

As each agency collects its data, there accumulates a condition that resembles the lists of data on a good map or photograph that I asked you to experiment with early in this address. Just as the map automatically co-ordinated all its data in simple, understandable form, the adequate national survey described will co-ordinate the development of our nation.

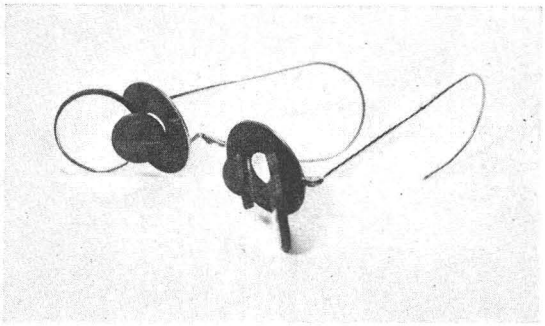
STEREOSCOPICAL EYEGLASSES

B. Scherpbier

When aerial photographs have been elaborated in the office for some purpose, e g., forestry, geology, etc., it is generally necessary to check the obtained data in the field.

For this check the photographs often have to be studied there stereoscopically.

The small pocket stereoscopes used for this purpose have the drawback that the photographs have to be put too close together, so that only part of the area of normal size pictures can be seen stereoscopically at one setting.



At our request Messrs. De Koningh, Photogrammetric Instrument-makers in Arnhem (Holland), have constructed a pair of stereoscopical eyeglasses. With this stereoscope the maximum separation of the prints is such that even prints of 30×30 cm. (11.8×11.8 in.) size can be seen stereoscopically at one setting.

Of course, the instrument is only meant for the above checking work in the field and should not be used for the elaboration proper.