CURRENT RESEARCH IN MAPPING TECHNIQUES BY THE GEOLOGICAL SURVEY*

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DURING the past two decades, mapping methods have been undergoing a transition from that of the individual hand-made product to that of a complex, machine-made version, dependent largely on aerial photographs.

The Geological Survey, like all other mapping organizations, is constantly beset with problems and questions that are common to this transition period, and is earnestly striving to find reasonable answers. One question constantly in the foreground is, how can we improve our equipment and methods to produce good maps at a lower cost. In the case of photogrammetric methods, it is fairly easy to demonstrate analytically and by calculations, that certain results should be attainable from perfect photographs (theoretical pinhole photography) under a given set of conditions. We are still a long way from attaining those theoretical results in practice. It is somewhat like the gallon of gasoline that we put in to an automobile,—experts tell us that, according to the BTU's available, it should drive a car 50 miles or more, but most of us are glad to settle for 15 to 20.

If we were attaining the theoretical maximum results from our instruments and methods, perhaps we could sit back and relax. Fortunately such is not the case, for much of the zest of living would be lost if we knew all the answers in advance. It is because of the big gap between what is theoretically possible and what is practicably attainable, at the moment, that investigation and research are so essential to the problem of reducing that gap.

Research is not always a simple problem of devising a better way of doing a job, for it often happens that, in order to put a new device or method into operation, a major rearrangement of related activities is necessary. From the practical view point, research should therefore be considered under two headings; technical and operational. The research now being carried on by the Geological Survey falls in both categories.

Now that aerial photographs have become a prime necessity in mapping, it follows that many of our research problems fall in two fields, the field of photogrammetry, and a related field, that of control surveys.

Late in 1935 the Geological Survey purchased its first unit of multiplex equipment. After examination of available plotting instruments of that period, the Multiplex Aeroprojector appeared to be best adapted to our needs. Since that time, many additional instruments of that type have been obtained, each new purchase incorporating marked improvements in design. While convinced from the first that the basic Multiplex idea was sound, it had been realized that the weakest point in the process is the relatively poor quality of the stereoscopic image, particularly in the wide-angle models. Much of the loss in quality of image occurs in the diapositive-printing stage and this is to some extent the result of incorporating a factor for the correction of aberrations of the aerial camera lens into the design of the diapositive-printer lens. Repeated efforts have been made to correct the situation, but progress has been slow and results discouraging. Theoretically the combination of an aspheric correction plate with a distortion-free, high-resolution printer lens would definitely improve the quality

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of the diapositive image and the resultant projected model. We have been unable, thus far, to obtain in this country a correction plate of this type. For a year and a half, we have had on order with a Swiss manufacturer, similar plates for other use, so it is self-evident that new developments involving special optical design and manufacture cannot be accomplished in a hurry. We are still determined to have a new printer built to our specifications, that will be a definite improvement over the present type of printers. With better diapositives, the performance of the standard type Multiplex plotters will be greatly improved, and the present advantages of the standard wide-angle Multiplex for small-scale mapping greatly extended.

Another approach to improved Multiplex performance has met with most encouraging results. I refer to the recently developed Kelsh design. Mr. Kelsh at the January 1948 annual meeting presented a report on what had been accomplished to date in the design and construction of a Multiplex type plotter using full negative scale diapositives, and an instrument with normal-angle projections was also on display. Two normal-angle units have been in operation for about a year and are producing satisfactory results while operated at a "C" factor equal to more elaborate instruments of the stereo-planigraph type.

The work of developing a wide-angle design has progressed rapidly during the past year. Three instruments of this design have been built and, on the first test, one has produced exceptionally good results with a "C" factor as high as has been used with the normal-angle Kelsh type. One of the most interesting problems of the wide-angle design was providing some means of correcting for the aberrations that are present in all wide-angle camera lenses. Two methods were considered and to date one has been successfully developed, while the other is in the early experimental stage. The method presently developed, may be seen on an instrument which is in operation in room 2644, Interior Department Building. Those interested may contact Mr. Kelsh and arrange for an inspection. Most lens aberrations are assumed to be in a radial direction and thus concentric zones of radial displacement can be corrected by a slight change in the principal distance of the projector lens. This is not a new idea for this method of correction is found in some older European plotting instruments, but its adaptation to a double projection type instrument is a distinct innovation. This is possible in the Kelsh design because of its scanning light feature. The arms connecting the tracing table and the scanning light actuate a small ball cam that adjusts the principal distance of each lens to correct the section of the field that is viewed. One advantage that this method appears to offer is the ease with which the correction device can be changed to accommodate photography from different cameras. Ball cams can easily be ground to compensate for any reasonable lens distortion and are relatively inexpensive.

The other correction device that has been the subject of considerable study is a molded thin glass plate of uniform thickness. On paper, it appears to offer a solution, and experiments with molded plastic give supporting evidence. At the moment the 64 dollar question is, who will make the plate for us—we haven't found the answer.

The results obtained with the Kelsh type instruments, thus far, have been most satisfactory, but sufficient work under proper conditions has not been done to provide a basis for full evaluation. Operating with a higher "C" factor means higher flying for the proper photography and the full value of the instruments will not be achieved until we are able to readily obtain photography taken at altitudes greater than most contractors are equipped to operate. Clear and sharp stereoscopic models combined with uniform and adequate illuminations undoubtedly account for the high quality of performance. One disadvantage for small-scale mapping work is the large plotting scale required by the present models.

Another angle of attack toward improvement in Multiplex performance is at present under way and is now past the drafting board stage. Observing the benefits that have accrued from the superior image quality of the Kelsh type instrument, a radically new design of Multiplex projector is being developed based on a longer projector principal distance, but at the same time the units will be sufficiently compact to permit a long bridging operation on a single bar as with the standard instruments. Construction of a pilot model will be undertaken shortly.

For several years past, there has been considerable speculation and discussion among photogrammetrists of the Geological Survey regarding the possibility of designing an instrument that would utilize photography from a two-coupled camera.

The basic idea has a twofold purpose. The first is to provide a means of covering a much wider strip from one photographic flight with a mapping accuracy sufficient for small scale mapping. This would provide an additional method of mapping, intermediate of the Trimetrogon and Multiplex methods. The second is to provide a means of nearly doubling the air base for increased accuracy in mapping relatively flat terrain.

Paper design of this instrument has been completed and parts are on order for construction of a pilot model. Photography for a test of the idea is now under contract.

Another stereo-plotting instrument of the mechanical-optical type, more nearly comparable to the Zeiss stereoplanigraph or Wild autograph has been in the development and construction stage for about two years. Shortly after the end of the late war, we were fortunate in discovering and obtaining information about a new instrument on which the Zeiss Company had been working for several years. We were later able to obtain plans and many parts and subassemblies of the partly completed instrument. The work of completing this instrument has been very slow. New parts have had to be designed and constructed and some minor changes made in the original design. This instrument should be completed and ready for test within the next two or three months.

This instrument is expected to have performance characteristics equal, if not superior, to the Zeiss stereoplanigraph. Its potential advantages are, the use of standard gears, bearings, and other elements to simplify and cheapen construction as well as simplified adjustment, maintenance, and operation.

As has been stated earlier, aerial photography has become practically indispensable in mapping work, but alas, all too often it is found wanting. It is still the weakest link in the chain as far as predictability is concerned. All of our photography is obtained by contract performed under rigid specifications, and all work is carefully inspected before acceptance. Yet in spite of all the care taken, probably upward of 10 per cent is found wholly or partly unusable, because of imperfections detectable only after the project is controlled and plotting is in progress. To further complicate the situation, it is frequently impossible to definitely determine the cause. The list of items suspected is so extensive that it clearly indicates a vast amount of research is still needed on films, glass plates, lenses, shutters, camera mechanisms, camera mounts, airplanes, and other related items, such as the effects of low operating temperatures, air turbulence, exhaust gases, and heat within the field of the lens.

The Geological Survey is much concerned about this situation because poor photography may result in greatly increased costs through the three mapping steps that follow. Much thought has been given to the possible corrective measures that could be worked out in cooperation with other government agencies, with contractors, and equipment manufacturers. We are exploring the field of contract relations to see whether or not some better way can be found to insure delivery of as nearly as possible, the kind of photography that we want and are willing to pay a fair price for. More thorough and comprehensive tests of cameras under actual working conditions are under consideration. This may involve control surveys over a portion of each project before photography is undertaken, so that, as each roll of film is exposed, a few exposures on the ends of the roll will be made over this test area. The roll will not be accepted until the test exposures have passed a stereo-plotter test. We are also considering ways and means of recording on each negative, as it is exposed, some indication of its relation to the focal plane or, in lieu of that, some indication that the vacuum or pressure system was working effectively.

We occasionally read a head line in the press that some germ long suspected has finally been isolated and identified. Well, something akin has happened in photogrammetry in the past year. For a long time, it has been known that some photographic gremlin has been persistently putting curves into what are known to be straight lines. This was well demonstrated by Mr. John T. Pennington in a paper on tangential distortion, presented in PHOTOGRAMMETRIC ENGINEERING, March 1947. There has been much debate about this subject, particularly whether such aberration could be present in a lens system. It has been reported that Bausch & Lomb has at last perfected a method of lens tests and measurements that have isolated and identified this aberration, and the term tangential distortion is now recognized as proper and fitting. The Survey does not lay claim to the original research on this subject, nevertheless the weight of evidence that we have accumulated during the past ten years has contributed much to proper recognition of the problem. Now that it is recognized, it is hoped that, in the future, better lenses can be obtained for all steps of stereophotogrammetric work. We propose to encourage this improvement in every way possible.

One mapping step that is closely related to the quality of aerial photography, is that of control surveys. In general, it is the quality and placement of aerial photographs, combined with the performance characteristics of the plotting instruments used, that determines the density of vertical control required. It is believed that, with better photographs and plotter performance, the time will come when a moderate amount of vertical bridging will give adequate elevations for contour intervals as small as 20 or even 10 feet. At present we are not in sight of that goal, consequently any prospect of lowering control cost is most welcome.

During the past two years, much time and effort has been expended on tests and evaluation of three new instruments that have come to our attention. The first of these, the Wallace & Tiernan Altimeter, is an old idea wrapped up in a new package. The new instrument is mechanically superior to older types and therefore more precise in operation. It is these qualities that make practical a plan of operations that was discussed in an early Geological Survey report nearly 70 years ago—that is the two base method of altimeter surveying. There is yet much to be learned about local minor variations in barometric pressure, the influence of air currents and their direction as related to the topography of the region, and variations in humidity and temperature. In some regions where conditions are particularly unstable, the use of three or more bases is now under consideration. Summarizing the work of the past two years where subsequent checks have been obtained by other methods, the differences between the two determinations amounted to less than two feet on 41 per cent of the points, less than five feet on 75 per cent of the points, and less than ten feet on 95 per cent of the points observed.

An entirely new idea in the determination of elevations is embodied in two instruments developed by the Stanolind Oil & Gas Company of Tulsa, Okla., and the Sun Oil Company Physical Laboratory of Newtown Square, Pa. The fundamentals are briefly, a wheel to measure distance, a pendulum to measure the slope angle, and an integrating and computing device to calculate and record differences in elevation. The Stanolind instrument was leased by the Survey for a six month period ending in December 1948, but to date the results have not been adjusted and summarized. The approximate rate of progress was 20 miles per working day with one man driving the vehicle and recording data. The Stanolind instrument is mounted in a light truck or passenger car.

The Sun instrument, which we now have under lease, is mounted on a three wheeled trailer, with a power supply and recording instrument carried in the towing vehicle. The outstanding difference between the two instruments is that most operations in the Sun instrument are performed by electronics whereas, in the Stanolind, many of the operations are purely mechanical. The Sun instrument was thoroughly tested last summer over an area near Philadelphia, and the results were checked by spirit levels. The results were so favorable that it was decided to give the instrument a trial on a production basis. Although now operating in the south where heavy rainfall has recently hampered operations considerably, it appears from the latest report that progress is at the rate of 40 miles per day of actual operation. A three man crew is used. One is always with the instrument as recorder and the other two alternate, doing reconnaissance and noting points for elevation on one day and, the following day, guiding the instrument over the route selected.

From our first tests of these instruments, where adjusted results were compared with elevations determined by spirit levels, differences were distributed as follows. On single runs with the Sun Instrument 75 per cent were within 1 foot, 95 per cent within 2 feet, and the maximum error was 4.8 feet. On double runs with the same instrument, 85 per cent were within 1 foot, 97 per cent within 2 feet, and the maximum 2.8 feet. On double runs with the Stanolind instrument 60 per cent were within 1 foot, 85 per cent within 2 feet, and the maximum error was 3.8 feet.

The impact of instruments of this type on mapping operations is difficult to evaluate. It is already obvious that, in order to obtain full advantage of their potential productive capacity, the most economical results could be obtained on larger projects. Also careful advance planning is required to keep the instrument operating effectively.

Last summer the Survey experimented with the use of helicopters to transport triangulation parties over difficult mountainous terrain, and the results were highly satisfactory. Two areas were involved, the first trial of limited scope in Colorado was so successful that another more extended trial was carried out in Alaska. The practicability of helicopters for this purpose has been demonstrated. However, the effectiveness again depends to a large extent on careful and detailed planning of the whole operation, and close adherence to established schedules. Also, the project should be of sufficient size so that the work of several parties can be integrated to fully utilize the services of one machine and, at the same time, gain full advantage from the speed of transportation afforded.

The Geological Survey, as a part of its third order control requirements for mapping, runs several thousand miles of transit traverse lines each year. These traverse lines are maintained in accurate geodetic azimuth by frequent observations on polaris taken at any hour angle. For many years, the Survey has published the Baldwin Solar chart, primarily for use in orienting a plane table board by reference to the sun at any hour of the day. So it was natural that sooner or later an attempt would be made to design a chart that would readily give polaris azimuths for transit use. A few years ago the chart was developed and given the name "Polastrodial." The chart proved easy to use but is not sufficiently precise for our transit traverse requirements, so a design in metal was developed. This instrument is on display at the Geological Survey exhibit. Its operation from the point of both speed and accuracy has exceeded expectations.

The Survey has several other items in various stages of experiment and development, but time will not permit further discussion. Also like most other organizations, we have quite an extensive file of wishful-thinking items. I believe it is a good idea to keep such a file, either physically or mentally, and every now and then pull out an item for discussion. It is surprising how often visionary deas of yesterday are tomorrow's established standards.

COLOR FILM—SECRET LAND*

Captain R. H. Quackenbush, Jr., Chief of Naval Photography

THE motion picture, "Secret Land," which you are about to see, is the product of about six months' hard work and difficult photography of seventy-odd Marine, Army, Coast Guard, and Navy photographers under the able supervision and herculean effort of Lieutenant Charles Shirley, USN. The film shows the operations and accomplishments of Task Force 68 in the Navy's Antarctic Expedition of 1946–1947.

You may wonder why a film of a documentary nature and of entertainment value is connected with photogrammetry. I think we all know and realize that one phase of photogrammetric work is the taking of aerial photographs. The mere snapping of the shutter is not all the work connected with that.

This picture will portray the means of getting the camera to the position to take the pictures which we took on Operation Highjump.

While the picture was filmed by official military photographers, it was produced by Metro-Goldwyn-Mayer. It is being shown currently throughout the nation in theaters, and we have the privilege of showing it here through the courtesy of M-G-M.

To speak further of this motion picture, I think, would detract from its entertainment. So without further ado, and with the courtesy of M-G-M, we will now show "Secret Land."

* An introduction to the color film shown at Annual Meeting of the American Society of Photogrammetry, Washington, D. C., January 14, 1949.