COMMONWEALTH OF AUSTRALIA.

DEPARTMENT OF NATIONAL DEVELOPMENT.

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS.

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1961/45

OBSERVATIONS ON PHOTOGEOLOGY OVERSEAS

REPORT ON STUDY TOUR - JULY TO DECEMBER, 1960.

by

W.J. Perry

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SUMMARY.

From 13th July to December 5th, 1960, the writer was sent on a visit overseas to undergo training and to gain experience in the general field of interpretation of geological information from aerial photographs; associated studies were made of the methods of transferring such information to base maps, the use of stereometer-type instruments and the application of double-projection plotting instruments, such as the Kelsh plotter, to geological mapping.

Following is the itinerary and a list of organizations visited:-

depart Canberra	July 13	
arrive Denver	" 15	Geophoto Services Inc., 305 E & C Bldg., Denver 2, Colorado, U.S.A.
depart Denver	Oct. 2	
arrive Washington	" 2	U.S. Geological Survey, Dept. of Interior Bldg., Washington 25, D.C., U.S.A.
depart Washington	" 15	
arrive The Hague	" 18	Bataafse Internationale Petroleum Maatschappij, 30 Carel van Bylandtlaan, The Hague, Netherlands.
depart The Hague	Nov.19	
arrive Paris	" 19	Institut Francais du Petrole, 4 Place Bir-Hacheim, Rueil-Malmaison. S & O. France.
depart Paris	Nov.23	
arrive London	" 23	Overseas Geological Surveys, Photogeological Division, Kingston Rd., Tolworth, Surbiton, Surrey. England.
depart London	Dec. 3	
arrive Canberra	" 5	

The photogeological work of the various organizations is described in the order in which they were visited.

INTRODUCTION

Arrangements for the writer's stay with Geophoto Services Inc., Denver, were made in conjunction with the arrangements for the Company's contract for photogeological interpretation of two 4-Mile areas in Queensland for the Bureau. Visits to three companies in Denver namely, American Stratigraphic Co., Petroleum Research Corp., & Humble-Carter Oil Co. were organised by Mr. L. Brundall, Vice President of Geophoto Services.

While in Denver the writer was able by personal visits to the regional office of the U.S.G.S. to arrange for correspondence to be sent to Washington concerning his proposed visit there. Dr. Fisher also made personal mention of the visit to the Director of the U.S.G.S., Dr. Nolan, while they were attending the International Geological Congress in Copenhagen. The period of training at the BPM office at The Hague was arranged by Dr. Fisher in correspondence several months before the start of the tour, and he also visited the BPM offices while he was in Europe. A letter of introduction to BPM from the Shell Co. (Aust.) was obtained through Mr. George Sautelle, the Company's Canberra Manager.

The visit to the French Petroleum Institute was arranged by correspondence between the Secretary of Department of National Development and M. Navarre the President General Manager of the IFP., and that to the Overseas Geological Surveys London personally by Dr. Fisher while he was in Europe.

The writer confirmed all visits by letter a week or so before his arrival.

The writer wishes to express his sincere thanks to the Director and particularly to Dr. Fisher for arranging the study tour, and to those who helped with travel arrangements especially Miss Tipton of Geophoto Services, Mr. van der Bent and the Travel Department of BPM., and Mr. Frank Murray, of the Australian Embassy at The Hague.

GEOPHOTO SERVICES INC., DENVER.

Introduction

The writer's visit was mainly in connection with a project for the photo-interpretation of two 4-Mile areas in Queensland being carried out for the Bureau on a contract basis. Allowance was made in the contract for the writer to undergo a period of training at Geophoto and at the conclusion of this he assisted for five weeks with the photo-interpretation of the Queensland material.

Two training areas of contrasting geology were interpreted under supervision, one in the Loveland area 40 miles north of Denver, and the other in the Powder Wash Dome in north-west Colorado. Later the writer had the opportunity to see in the field some of the geology that had been examined in the air photos, namely the Tertiary Wasatch and Browns Park Formations. This was on the return journey from the overthrust belt of Western Wyoming, where with Mr. Robert McMillan, one of the partners in Geophoto Services, the writer attended the three day 1960 Field Conference of the Wyoming Geological Association, at the expense of the Company. A copy of the handbook on the geology of this area was sent to Canberra and is now in the Geological Branch library.

Training activities and visits to other organizations occupied five weeks, and included within this period was 1½ weeks spent in becoming familiar with the operation of the Kelsh Plotter under the guidance of Mr. Vernon Jackson, Senior Geologist in charge of Photogrammetry.

While in Denver brief visits were paid to the local office of the U.S.G.S., to a consulting firm Knox-Bergman-Shearer, Humble-Carter Oil Co., American Stratigraphic Company and the Petroleum Research Corporation.

General

The company commonly does semi-detailed work in sedimentary terrains using air photos at 1:20,000 scale to produce maps at 1:48,000 scale, each map unit usually being one 15 minute quadrangle (roughly 250 sq. miles). Air photos at other scales may be used, for example 1:50,000 and 1:60,000, depending on the photography held by the client. A small proportion of the total work done involves detailed structural interpretation, and is carried out using a Kelsh or similar plotter.

The size of a project and the time allowed for it naturally determines the number of personnel assigned to it. A supervisor, senior and junior geologists and one or more photogrammetric aides may be required for a large project.

The client's requirements as to accuracy of the final map determine whether a topographic base map - if available - should be used, or whether an uncontrolled or semi-controlled mosaic will suffice as a base on which to plot photogeological detail. In either case the base is brought photographically to the required final scale. Uncontrolled mosaics are made by stapling trimmed photos to a sheet of building board similar to "Caneite".

The assembly is photographed, printed at the required final map scale and dry-mounted on stiff cardboard. The geologists annotate directly on every second air photo, using semi-grease pencils according to a colour code (Appendix 1). There is a strong preference for the two power lens-type stereoscope, though occasional use of the mirror-type is made. A photogrammetric aide transfers the photogeological detail from the annotated airphotos to a transparent overlay of the mosaic by inspection, and adds also the cultural and hydrographic detail. The geologist then checks his interpretation on the overlay, including the tie with adjoining mosaics. If a base map is available, a draftsman transfers detail from the mosaic by reference to the geographical grid and the topographic detail common to both base map and mosaic.

Certain aspects of the general organization are now treated in more detail.

Handling of air photos

Prior to the making of mosaics the office staff trim photos on a guillotine. An automatic numbering machine (see Appendix 2.a) is used to print on the back of each photo, the run number, quadrangle number and project number. A card 9"x9" is cut from white display board for each set of photos and the disposition of runs in the quadrangle is shown on the card, to which the runs are attached by rubber bands.

Photogeologist's equipment

Each geologist's table has six drawers, one of which is a deep one designed to hold files; all drawers are lockable from a central keyhole. The light source for use with the stereoscope is a two-tube fluorescent fitting (see Appendix 2.b) fastened to the back of the table and fully adjustable as to position so that glare can be reduced to a minimum. Each room has the usual furniture such as security cabinet and bookshelf, but in addition has a large area of wall space covered with painted soft board on which maps and mosaics may be mounted. An air conditioner and heater are fitted to each room.

Compilation

An alternate method to that described above for transferring detail from the airphotos to base map involves the use of an overhead reflecting projector. The annotated photo is placed in the projector and the image projected down on to an overlay of the base map on the table below. The detail is pencilled in by the draftsman and finally inked. The type of overhead projector used (see Appendix 2.c) has automatic focussing and in one model a range of magnification of 0.25 to 4.0 and in another range of 0.33 to 3.5. Because the image is projected on to and not through the manuscript, a transparent material is not required, though for reproduction purposes a transparent overlay of an opaque map is commonly used.

Occasionally when no base map is available, a slotted templet laydown may be made, and detail from annotated photos transferred to the point plot by vertical Sketchmaster. The resulting map is at a controlled scale close to photo nominal scale.

Final maps

If the client's requirement is for geographically accurate maps, the base is prepared from a topographic sheet, and prints of the composite photogeology plus topography are mounted on linen and hand-coloured using printers' inks in pastel colours.

Less accurate maps are often satisfactory for the client's purpose, and these are made from mosaic overlay prints, hand-coloured if required.

Double-projection plotters

Kelsh Plotter

Detailed structural work such as precise dip determination in low dip areas, structure contour mapping and isopach mapping is required in certain projects, and in regions of good exposure this work is economically done using double-projection plotters such as the Kelsh plotter (Plate 1 - Fig.1).

The Kelsh plotter employs contact positive prints on glass, i.e. "diapositives", set in two projectors mounted on a frame in such a way that the images are directed downward and focussed on the platen of a tracing table that can be moved over a flat working surface. One projector has a red filter and the other a blue filter, and the operator wears glasses with lenses of red and blue; in this way the stereoscopic effect is obtained, and the overlapping images are seen as a three-dimensional model. ≠ The projectors can be oriented on the frame by reference to ground control in the area covered by the model, so that their positions are analogous to the exposure stations of the taking camera. A small hole illuminated from below in the centre of the platen is seen as a spot of light apparently "floating" in the model, and a pencil located directly beneath the floating mark is used to plot detail from the model on a manuscript. By moving the platen vertically up or down, the floating mark may be made to appear to coincide with the surface of the model, and the elevation of any point determined. When a model is correctly oriented by reference to ground control, and the scale determined, all detail can be plotted in its true map position. Furthermore the horizontal and vertical scales of the model are equal, so that profiles may be drawn conveniently and accurately.

Angles of dip may be measured by three point method or directly by the use of a tilting platen. Generally it is necessary to have a minimum of four ground control points for each model, and preferably these should be located near the corners of the model. The accuracy with which spot elevations may be determined depends upon the altitude at which the air photos were taken, the actual value being within $\pm \frac{1}{5,000}$ of the flying height. For example, with photography flown at 25,000 feet, the expected error for a spot height is ± 5 feet. The scale of the model is about five times that of the diapositives, so that for 1:50,000 scale photography the model scale is 1:10,000. The machine can be fitted with a variable ratio pantograph that gives scale ratios continuous within the range 1.5:1 to 1:7. The projectors are mechanically linked to the tracing table in such a way that the light from each projector is always directed toward the platen as the tracing table is moved over the working surface. The model is thus well illuminated throughout its entire area, and high resolution is obtained by the use of contact diapositives.

The principal requirements for a Kelsh plotter are availability of diapositives, sufficient ground control, a dark room about 12'x12' with a sturdy floor free from vibrations and with a suitable power supply, and separate projection lenses for each different focal length photography. At present there is no provision for handling 3.5" focal length photography. For geological work, particularly in structural problems, it is a drawback to be able to view only a small part of the model at a time. Rates of working vary greatly according to nature of the geological problem and the complexity of the area. At Geophoto, experienced operators obtaining precise dip measurements in well-exposed terrain using 1:60,000 photos, worked 1½ models per day i.e. about 40 sq. miles per man per day.

≠ model: the area of ground common to two consecutive air photographs seen as a three dimensional impression beneath the stereoscope.

Detailed instructions in the operation of the Kelsh plotter are given in U.S.G.S. Topographic Instructions Book 3, Part 3F, Chaper 3F5. General descriptions of the Kelsh including comparisons with Multiplex and ER-55 plotters may be found in Bulletin 1043-B of the U.S.G.S. (Pillmore, 1957), and in a paper by Geophoto geologists L. Brundall and V. Jackson (Brundall and Jackson, 1958).

Multiplex and ER - 55 Plotters

The Multiplex and ER-55 plotters were seen at the U.S.G.S. in Washington and Denver, and are thus out of place here, but they are included for the sake of continuity. They are both double-projection machines using the principle of projection of images of complementary colours on to a white surface, as in the Kelsh.

The Multiplex employs glass diapositives 55mm. square, and the model scale is approximately 2.5 times that of the original photography. Because of the reduction of the original negative in printing the diapositive, and the subsequent enlargement (about 12 times) in projection, the image is not as sharp as that in the Kelsh, with the result that accuracy of spot height determinations is less, and the model is less suitable for interpretation of geological features. It is being used however for compilation of field data on to a base map.

The term "E.R.-55 plotter" refers to a plotting instrument using E R.-55 projectors (Plate 1,Fig.2). These projectors are so called because they use ellipsoidal reflectors of 55mm. principal distance to condense the light for projecting the image, instead of a condensing lens system. The E R -55 projectors are mounted on a Multiplex bar or similar frame; they produce an image of high resolution from glass diapositives 110mm. square. The model scale is 3.4 times the original photography for a projection distance of 525mm. and 5 times the original scale for a projection distance of 760mm. Another important difference between the Kelsh plotter on the one hand and the Multiplex and E R.-55 plotters on the other is the absence of a linkage between the projectors and the tracing table in the latter. As a result there is greater freedom of movement of the projector heads, and because of this the Multiplex and E R.-55 plotters may be more suited for study of high-relief areas (Pillmore, op.cit.). Several projectors may be mounted on one frame depending on the length of the bar, and thus may be used for extending control between widely separated control points i.e. "bridging". They may also be used with low-oblique convergent photography (Hopkins, Radlinski and Thompson, 1952). Neither can be used at present with the 3.5" focal length photography, although new ellipsoidal reflectors for this purpose are being designed by the U.S.G.S.

The E R -55 plotter is well suited for geological work because of the clarity of the model and because the entire model can be viewed at one time. As in the Kelsh Plotter, the tracing table may be adapted for profiling and for direct measurement of dips.

U.S. GEOLOGICAL SURVEY, REGIONAL OFFICE, DENVER.

Several U.S. Government agencies, including the Geological Survey, have regional offices at Federal Centre, some 9 miles west of downtown Denver, in a group of buildings which housed a munitions factory during World War 11. Three days were spent at the Centre with Mr. Charles Pillmore of the former photogeology section, with whom discussions were held concerning 'paper-print' plotters, double-projection plotters, stereometer-type instruments and stereoscopes. From time to time Mr. Pillmore conducts a short course on photo-interpretation for members of the Survey, and an outline of the course was obtained. He was in the process of preparing a demonstration set of air photos at the time of the writer's visit. The photos were mounted on stiff cardboard which was loosely bound into book form. Conjugate prints were mounted in separate books and one print of each pair had an overlay which fitted over it, and the other print had opposite it a short account of the important features indicated in the overlay. Such a demonstration set of Australian air photos would be very useful to have in the Bureau, which receives many requests for photographs for teaching purposes.

KNOX-BERGMAN-SHEARER, DENVER.

This consulting firm specializes in photogeology. Techniques of annotation are very similar to those at Geophoto, i.e., directly on the airphoto with coloured pencils; however, instead of compiling the data on mosaic overlays their technicians use Kail double-reflecting projectors, which permit transfer of detail from photo to a transparent copy of a base map in just the same way as the Grant projector (Kail,1954).

HUMBLE-CARTER OIL CO., DENVER.

A brief visit was paid to the area headquarters of this company by courtesy of Mr. Hank Sharkey, of the geology department. Area headquarters has two divisions, Exploration and Production. Exploration Division is subdivided into four departments,Land, Geology, Geophysics and Scouting. The Land department is concerned with obtaining concessions over areas in which the Company is interested. The Scouting department's job is to obtain all information on an area, including the activities of other companies. Much of this work is done now by service companies to which oil companies subscribe for their information. However, for "tight" holes i.e. ones that companies try to keep secret, the scouts are still needed.

Each Area Headquarters is responsible for a number of districts. The Area Geological Department compiles several types of regional geological maps which are sent out to district offices to provide a background for local field studies. Map scales are of the order of 1:1,000,000. Examples of maps are "time isopach": a contour map in which the thickness of rocks laid down in a particular time interval is indicated; "dominant lithology": areas in which a particular lithology is dominant are indicated by colours; these may be superimposed on the time isopach contours; "sand/shale ratio": the proportion of coarse to fine clastics is indicated by colours which again may be superimposed on the time isopach contours if required.

AMERICAN STRATIGRAPHIC COMPANY, DENVER (AMSTRAT)

This company, known as Amstrat, specializes in processing sub-surface samples from oil bores, and preparing graphic logs. Samples are sent in from oil companies in the usual cloth bags: they are washed, dried, divided into the required number of splits and transferred to brown paper bags. The number of splits is determined by the number of companies that want information on the particular hole. An announcement of the availability of data from any well is made in an Amstrat newsletter which is sent to about 200 companies. Also a card index system with details of all samples held, is kept conveniently near a phone so that within a minute or two information as to the availability of particular well samples can be given to any caller.

The company gives a two-week course in the determination of carbonate sediments in well cuttings. The cost is $100 a week and is open to any interested geologist. An hour or so was spent examining carbonate sediments with Mr. Jim C. Mitchell, President of Amstrat, and in the writer's opinion, the course would be a valuable one for Bureau geologists dealing with sedimentary basins.

PETROLEUM RESEARCH CORPORATION, DENVER

This is a consulting firm that specializes in the application of the physics of fluids to oil exploration. The writer was fortunate to be able to spend a few hours with Mr. Jack W. Knight, the Executive Vice-President, who explained some of the principles which form the basis of the company's work.

In many sedimentary basins, the sub-surface fluids have differing pressures in different parts of the basin. The actual pressures within a formation are measured during drill-stem tests; these are referred to a common datum and from them a map is made in which the contours indicate lines of equal pressure. Crowding of contours means that there is some obstruction to flow such a fault or permeability barrier. Regular spacing of contours indicates even flow.

From only one well an idea of the pressure conditions can be gained. Pressure readings are taken in each sand interval encountered. A graph of pressure against depth is made. If the readings fall along a straight line, the hydrostatic line, there is no flow of fluids in the sands. Fig. 1.

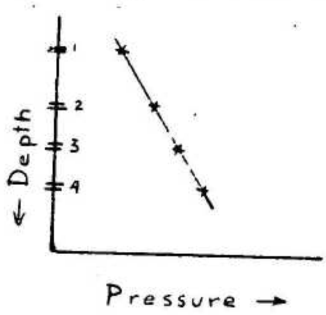

Fig. 1

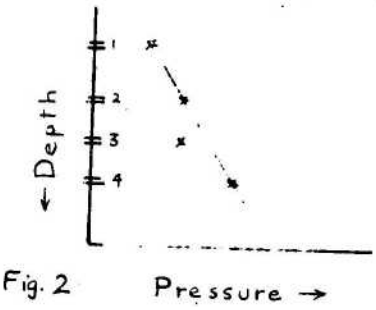

Fig. 2

If for example one reading is to the left of the hydrostatic line, the pressure in that sand is less than the expected hydrostatic head Fig.2.

Any oil in sand 3 will be trapped there because pressure in sand 2 is higher. Oil moving out of sand 4 because of the buoyant force will be trapped in sand 3.

Information on pressures from two adjacent wells can give a component of the pressure gradient, and from three wells the slope of the piezometric surface can be found. Pressures can cause oil to move down dip, perhaps out of sands with oil and gas shows into sands with lower pressures which elsewhere have no oil or gas shows. Differences in salinity of waters in adjacent sands can cause a movement of fluid from one to the other analogous to the osmotic effect, and this can be a cause of differences in pressure between sands.

U.S. GEOLOGICAL SURVEY, GEOLOGIC DIVISION, WASHINGTON, D.C.

Introduction

Here the writer's programme was ably handled by Mr. David Andrews of the Foreign Geology Branch, to whom grateful thanks are extended. The organization of the Geological Survey has undergone a change recently, and there is now no photogeology section as such (see organization chart appendix 3). However the writer was able to meet former members of the branch including Drs. W.A. Fischer, R.G. Ray, R.J. Hackman and A. Holzle. Some days were spent in becoming familiar with the use of the stereometer-type instruments, including the stereo-slope comparator and the isopachometer developed by R.J. Hackman, and with the Multiplex plotting machine. The Topographic Division at Arlington was visited for two days in connection with an evaluation of the SOM Stereoflex and K.E.K. Plotters. Half day visits were paid to the Map Reproduction Section of the Publications Division, and to the Geologic Map Editor.

General

Much work of a detailed and semi-detailed nature using air photos is done by the Survey. Most of the United States is covered by topographic or planimetric maps at 1:250,000 scale, and for some areas there is coverage at larger scales such as 1:63,360; 1:62,500; 1:48,000 and 1:24,000. Geological projects are normally authorized only if a base map is available.

Photographs commonly used are double-weight semi-matte prints of 6 inch focal length. Both mirror and pocket stereoscopes are used. For examining the whole model at once, such as is particularly desirable in structural work, a mirror stereoscope is used supported on a cantilever arm mounted on thick ply-wood about 27" square. It is thus essentially an office instrument. It is fitted with a 4-power binocular with a field diameter of 2 inches. The cantilever mounting allows for complete freedom of movement when annotating photos. The design of the instrument is such that an observer must look vertically downward to view the photos. This viewing position is not the most confortable, but it has the advantage that the observer's line of sight is in a vertical plane, and with this reference the horizontal plane is easier to visualize, and hence the estimation of dips is more reliable (Appendix 2.d).

Two types of pocket stereoscopes are commonly used, the simple 2 power lens type, and a plastic-framed lens type which has both 2 and 4 power lenses, and thus is particularly useful for the study of small-scale photography (Appendix 2.e.).

For stereometer work a prism-mirror stereoscope is used. This instrument has an inclined viewing system equipped with movable prisms, so that once the air photos are correctly oriented the complete model can be scanned by operating the prisms. The optics are good and magnifications of 1.5 and 4.5 are provided, and the field of view at 1.5 is approximately half the model (Appendix 2.f). Annotation is made directly on the face of the print, the choice of medium being left to the geologist. Coloured grease pencils may be used, but the recommended medium especially for detailed work is ink, either India or tempera, because of the finer lines that can be drawn with a pen (Ray, 1956). Tempera is water soluble, and Indian ink can be removed with ammonia except for red which is difficult to erase. Transfer of data from annotated photos to base maps is accomplished in one of several ways, such as by reflecting projector, (Appendix 2.c & g) sketchmaster, radial planimetric plotter or one of the precision plotters - the Multiplex, Kelsh or E R.-55.

The sketchmaster is a simple instrument designed for transferring detail from single vertical photographs to a base map. The image of the photo is reflected by a large inclined mirror to a half-silvered mirror through which the map id viewed simultaneously. Scale differences of photograph to map between approximately 2.5:1 and 0.5:1 may be reconciled. For comfortable viewing it is important to balance the intensity of illumination of map and photograph.

The radial planimetric plotter (Plate 2, Fig.1; Appendix 2.h) is a device consisting of mirror stereoscope set over two photo tables, from the centres of which radiate plastic arms connected by a machanical linkage to a plotting pencil between the tables. The instrument is designed to plot detail from air photographs at a desired scale having removed distortion due to relief, and it is used particularly for semi-detailed mapping. The principle of operation is the same as that of the radial line plot. The centres of two consecutive overlapping photos are used as points of occupation, and from them, lines are radiated to other points whose positions are found by the intersection of the lines. The instrument is placed over the base map and correctly oriented by reference to detail common to map and photograph. The scales that can be accommodated range from slightly greater than photo scale to 1/3 photo scale. Scribed lines on the plastic arms that radiate from the photo centres are seen under the stereoscope as a cross superimposed on the model. This so called 'plotting cross' is moved about the model following the required details which are simultaneously plotted on the base map overlay in their true map position by the pencil linked to the plastic arms. The radial planimetric plotter does not remove distortion due to tilt and cannot be used for large scale precision mapping (Ray, op cit.).

Much use of negative scribing is now being made in the Geologic Division for compilation purposes. If the geologist prefers to scribe rather than draw, he uses a print of his base map on the specially coated plastic "scribecoat", and transfers the detail in pencil using the radial planimetric plotter. The detail is later scribed using tools of appropriate size for the different line thicknesses required.

In the same way a print of the base map on scribecoat may be used when transferring detail from air photos by the reflecting projector or high-order plotting instrument.

For detailed geological work in well-exposed terrain, the geologist, having studied the available literature, may do as much interpretation as possible with the Kelsh or E R - 55 plotter before going to the field; if contacts can be seen, sections may be measured, possible correlation of lithological units indicated, possible solutions to structural problems obtained and so on, thus saving much time in the field. After field work the annotated paper prints are compared with the Kelsh models and the necessary detail added to the compilation.

When a project is completed the compilation is fair drawn and the final map is printed in colour by the Map Reproduction Branch of the Publications Division.

Of general interest is the use of polaroid cameras in the field for photographing geological features. The polaroid camera, though bulky, can produce a print in its special back about one minute after exposure of the film, and thus the results of photography are known before the geologist leaves the area of investigation. This is an advantage over conventional photography, in which because of the time necessary for processing films, poor exposures are not discovered until long after the geologist has left the particular area.

Stereometer-type instruments

A number of stereometer-type instruments have been or are being used in the U.S.G.S. for quantitative determination of dip, stratigraphic thickness, difference in relief and so on. Among these instruments are the parallax bar, the parallax ladder, the stereo-slope meter and the stereo-slope comparator ("super duper dipper"), all of which are well described and illustrated by R.G. Ray, op, cit.). The methods of using stereometer-type instruments are described in detail by Hemphill (1958), who points out that care must be taken to obtain reliable results. The formula

$$h = \frac{H}{b} p$$

where h = difference in elevation

H = height of plane above ground

b = average of photo bases of left and right photographs

p = difference in parallax

gives satisfactory values for h in terrain of low relief, but in areas of rugged topography the actual height above ground must be computed from the local photo scale determined from a base map, and a more accurate measure of the photo base should be used, which takes into account the elevations of the left and right photo centres in relation to the elevation of the lower of the two points between which the difference in elevation is required.

Parallax bars are made for use with either mirror stereoscopes or lens stereoscopes; one compact design for use with lens stereoscope clamps to the legs of the stereoscope in such a way that when the stereoscope is correctly oriented with respect to the air photos so also is the parallax bar (Appendix 2.i). This feature though very convenient, is not an essential requirement, as satisfactory orientation of a parallax bar may be made visually.

The parallax ladder is used for the direct reading of differences in relative elevation. Designs for use with both pocket and mirror stereoscopes are available (Appendix 2.j; Plate 2, Fig.2).

The stereo-slope meter is designed to measure the percentage grade of slopes. The prototype model can be used only with the lens stereoscope and the maximum measurable slope is 12% (6°51'). (Appendix 2.j; Plate 3 Fig.1).

The stereo-slope comparator (Plate 3, Fig.2) is used for determining the strike and dip of planar surfaces observed under a mirror stereoscope. Two small T-shaped targets may be fused in the model and physically tilted to parallel the observed surface; the exaggerated dip is read directly, and converted to true dip by reference to a supplementary slope model and slope conversion graph.

A new type of parallax bar, the isopachometer, has recently been developed by R.J. Hackman of the U.S. Geological Survey (Hackman, 1960). The instrument, designed for use with mirror stereoscopes, features two floating dots which can be set to a specific vertical interval and moved about within the stereoscopic model. The principal use is in geological mapping in which thickness of rock units is important. (In October, 1960 only the prototype instrument had been made).

Paper-Print Plotters

General

Three so-called "paper-print plotters" will be referred to, namely, the K.E.K. plotter, the Zeiss Stereotope, and the SOM Stereoflex. The information presented is based on published material and on discussions with officers of the various organizations visited, particularly those of the Topographic Division of the U.S. Geological Survey.

Paper-print plotters are used for the determination of quantitative data from air photos. Provision in their design is made for removal of distortion due to relief and for approximate correction for tilt. The principle advantages, considered in relation to 2nd Order plotters are

1. low cost (approx. £750-1400)
2. easy portability
3. use of contact prints (preferably on special stable paper)
4. no darkroom required

The principal disadvantages from a geological point of view are

1. low accuracy relative to 2nd order plotters; spot height accuracy approx. 1/2,000 of flight height
2. no direct-reading dip device; all dips must be calculated by the three point method
3. no direct profiling device.

The amount of horizontal and vertical control necessary to set up a model is the same as for 2nd order plotters, namely, a point at each corner of the model and for best results, also one in the middle. The time necessary for internal and absolute orientation of a model is the same, roughly 1 to 2 hours, as for a 2nd order plotter. In general 3rd order plotters are suited more for topographic mapping than for geological work, and as Pillmore points out they are more difficult to operate than the double projection plotters (Pillmore, op.cit., p.25).

K.E.K. Plotter

This plotter (Ray, op. cit., p.17) consists of four basic parts: a mirror stereoscope, a floating dot assembly and a drawing arm on which the floating dot assembly is mounted. (Plate 4, Fig.1; Appendix 2k).

The principle is that of radial line plotting plus an approximate correction for tilt. The stereoscopic model is viewed in its entirety at photo scale; the plotter is designed for 8½" focal length photography, but will accept 6" photography. Some modification by the maker is necessary before 3½" focal length can be used. The drawing arm is attached to a pantograph with a range of 2 times enlargement to 2 times reduction in practice, although nearly 3 times reduction is theoretically possible.

The instrument is fairly easy to scale to any two points on a model and therefore it is useful for map revision, the accuracy being sufficient for areas of low relief. One K.E.K. Plotter is employed on revision work by the Topographic Division of the U.S. Geological Survey.

Zeiss Stereotope

This consists of the Zeiss Oblique Viewing Stereoscope mounted on a base, the picture carriage, containing mechanical computers which make corrections for altitude and horizontal position by measuring horizontal parallaxes. (Plate 4, Fig.2; Appendix 2.1). It is necessary to have at least four control points, one at each corner of the model whose horizontal position and altitude are known. Paper prints up to 9" by 9" of any focal length may be used, but special non-shrink paper is desirable. A pantograph attached to the picture carriage has a range of 2 times enlargement to 5 times reduction of the average photo scale. The Oblique Viewing Stereoscope has only a small field of view, slightly less than half the model parallel to the flight line, and about half the model normal to the flight line. The model must be scaled to the control points in the corners and it is therefore impractical to scale locally within a model, a step which is often required in map revision.

SOM Stereoflex

The Stereoflex consists of a three-legged frame to which are attached photo-holders facing inwards towards a viewing device made up of two semi-aluminized mirrors inclined at 45 degrees to the vertical. (Plate 5; Appendix 2.m). On looking into the viewing device a virtual image from each photograph is seen, and with correct orientation these images fuse to a three dimensional model. Orientation is accomplished by certain movements of the mirrors and photo-holders for which controls are provided on the frame. A tracing table having a black circular platen with a central illuminated hole serving as a 'floating dot' is fitted with a pantograph. The model is viewed at photo scale and the scale of the drawing may be varied within the range 3 times enlargement to 10 times reduction. The platen of the tracing table can be raised or lowered so that the 'floating dot' appears to rest on the surface of the model. The altitude of any point can be read off on the altimetric disc attached to the tracing table. The Stereoflex can use paper prints up to 9" by 9", or diapositives up to 7" by 7". The vertical scale of the model is approximately equal to

$$\frac{\text{instrument principal distance P}}{\text{focal length of taking camera f}} \times \text{horizontal scale}$$

The principal distance P is an instrumental constant, 300 mm, and when the ratio $\frac{P}{f}$ becomes greater than about 2, inaccuracies are introduced in the plotting, therefore it is inadvisable to use photography with a focal length shorter than 5 inches.

Owing to the fact that there is only one reflection of the photographs by the semi-aluminized mirrors, the model is reversed on the platen, and after compilation the drawing must be turned over to bring it to its proper orientation. This would be an inconvenience for geological work. To calculate the exact vertical scale, several factors, including the eyebase of the observer, must be taken into account. A vertical exaggeration of about 2 to 2½ times may be expected with 6" focal length photography. A direct-reading dip device attached to the platen would therefore measure exaggerated dips. In the same way a direct profiling device would give a vertically exaggerated profile and the exaggeration factor would need to be applied to obtain correct results.

An evaluation of the Stereoflex from the point of view of topographic mapping has been made by an officer of the Department of Lands, Sydney (Plummer, 1959).

Colour air photography

The best application so far of colour aerial photography to geology is in detailed studies of mineral terrains, where alteration effects show up as colour differences. Colour transparencies i.e. positives, mostly are used because of the high cost of prints. For field work a special photo holder is necessary for the transparencies, with some sort of cover for protection from the glare, and a mirror system to reflect sunlight through the transparencies from below. Colour negative film has been tried also; both colour prints and black and white prints can be made from negative film. The black and white prints show a stronger tonal contrast than conventional black and white prints. The Geologic Division of the U.S. Geological Survey is engaged in continuing investigations into the geological uses of colour aerial photography (Fischer, 1958). However, at present, conventional black and white photography has better resolution than colour photography, and with special filter-film combinations is probably just as effective for detailed study of mineral terrains.

Training course in photogeology

The Foreign Geology Branch of the Geologic Division in Washington runs a seven months course in photogeology for foreign participants, with a short orientation in photogrammetric base map compilation. The first three months are taken up with a study of photogeological principles, divided into qualitative and quantitative interpretation. This phase includes the study of specific areas which are subsequently checked in the field. Then follows a brief orientation in photogrammetry and finally about three months are devoted to the study under supervision of a particular area, preferably within the country of the foreign student. There are two classes each year one starting in April and the other in September. A detailed syllabus of the course is included in Appendix 4.

Geologic Map Editor

The Geologic Map Editor is attached to the Chief Geologist's office under the Staff Geologist for Publications, as is also the Text Editor. The position of Text Editor is a two year assignment, but the G.M.E., Mr. Douglas Kinney had occupied his position for four years at the time of the writer's visit. The G.M.E. does two months field work, in one period, each year.

At the regional offices at Denver and Menlo Park, and at Washington there is a Regional Geologic Editor together with an Assistant Text Editor and an Assistant Regional Geologic Map Editor. Before field work begins the Chief of the Branch concerned in the project consults with the Regional G.M.E. about availability of base maps for the job. If no base map is available the project is not authorized.

U.S. GEOLOGICAL SURVEY, TOPOGRAPHIC DIVISION, ARLINGTON, VIRGINIA

Establishment of supplementary horizontal control by stereotemplet triangulation.

This method was developed by M.B. Scher of the U.S.Geological Survey (Scher, 1955) in order to take advantage of the special features of stereoplotting instruments.

The conventional radial templet is prepared from a single photograph. The photo centre is used as the point from which slots through each pass point are radiated. The templets mechanically correct for radial displacement due to relief, but if tip or tilt is present the radials from the centre will form triangles instead of point intersections, and the triangles of error have to be eliminated or reduced as much as possible by averaging. The scale of the compilation may be changed by changing the distance (expansion base) between principal points along the flight line. Fig. 3.

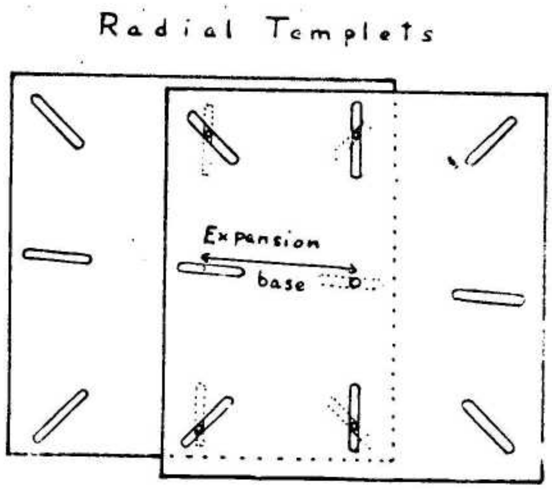

Fig. 3

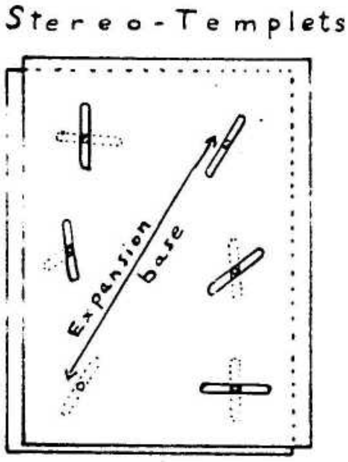

Fig. 4

Stereotemplets are prepared from an oriented model in a stereoplotting instrument. The positions of image points are thus rectified with respect to tilt and have no horizontal displacement due to relief. "The positional data furnished to the stereotemplet is therefore at a random but uniform scale. The only function of the stereotemplet is to maintain this scale relationship between any and all points plotted from a single model, while allowing for the enlargment or reduction of the over-all scale of the templet. The stereotemplets are adjusted to the desired common scale when they are assembled to satisfy horizontal control positions" (Scher, op. cit., p.655).

Each stereotemplet contains a minimum of four plotted positions, one at each corner of the neat model ≠, i.e., in the zone of overlap of adjacent flights. Fig. 4. Principal points are usually included. For each stereo model, two identical templets are prepared; in each templet radial points are chosen in diagonally opposite corners, so that the slots when cut will intersect at the greatest possible angle. The expansion base of the stereotemplet (Fig. 4) is longer than that of conventional radial templets of the same area, and because "the length of this base governs the accuracy with which the individual templets retain uniform scales while changing size "(Scher, op.cit., p.659) the stereotemplet gives more accurate results than conventional templets. Furthermore, "stereotemplets permit the achievement of scale solutions in the direction perpendicular to the line of flight as accurately and conveniently as along the line of flight" (Scher, op. cit., p. 659).

Briefly the procedure is as follows:- the air photos are marked in coloured pencil to show field control points and pass points in separate colours by letter and figure designation. In a stereo-plotter the models are oriented and field control points and pass points identified by reference to the photos. Using the pantograph the scale of the model is reduced to approximate compilation scale. On a sheet of opaque white plastic (equivalent to astralon) the position of each pass point and control point is marked and each point labelled. Using this original templet, a duplicate is made by pricking through to a second astralon sheet the positions identified in the model. Diagonally opposite points, one on each templet, are chosen as radial points, and slots $\frac{1}{4}$" wide and 1" long cut. When all templets are cut, a preliminary lay-down is made to see whether any gross errors occur. If the laydown is satisfactory the templets are taken up, and the base sheets laid down. This is done on a flat rigid surface to which the base sheets are stapled. Base sheets are prepared on a stable plastic (usually coated for scribing); on these the geographical grid at the required projection is scribed, and the positions of all horizontal control points marked. After the base sheets are attached to the table, special studs are taped over all horizontal control points. All studs are of machined brass $\frac{1}{4}$" in outside diameter, and are of two types; control studs and supplementary control studs. The latter are hollow to allow a mounted needle to pass through them, while in control studs the central hollow is filled with lucite, a clear plastic, so that marks on the base sheet can be seen through it. Centrally on the lower surface of the plastic where it rests on the base sheet, is inscribed a small black circle. This can be positioned precisely over a control point on the base sheet and the stud then taped down. When the lay-down

≠ neat model: the area between lines normal to the flight line through the principal points of adjacent photos, and including half of the side lap with adjacent flights.

is completed satisfactorily, the position of pass points is recorded on the base sheets by pricking through the hollow studs with a mounted needle which fits exactly the internal diameter of the studs. As the templets are taken up, the designation of each pass point is noted on the base sheets.

Map Reproduction Section, Publications Division

Here the main point of interest was the colour system used in printing geological maps, which has been developed within the Section. It is known as the Color-trol System, and utilizes three basic colours red, blue and yellow, in intensities of 30%, 50%, 70% and solid, in combination with 11 basic patterns each having densities of 30%, 50% or 70%.

As far as geological copy for printing is concerned, line work is mostly scribed, and lettering is type set by Fotosetter machines which produce positive type on film; this is sent to the photo laboratory where it is photographed and a positive contact print made on strip film.

The Publications Division controls the distribution of maps and keeps the Map Reproduction Section informed as to how many copies of any map are required. The aim is to keep a three year supply of each map on hand.

BATAAFSE INTERNATIONALE PETROLEUM MAATSCHAPPIJ. THE HAGUE.

Introduction

At the head office of the Royal Dutch/Shell Group of Companies the writer was attached to the Exploration and Production Department under the authority of Mr. Charles Mackay, whose responsibilities include the supervision of the Group's activities in Australia. To Mr. Mackay and to Mr. Th.van der Bent, photogeologist, the writer wishes to express his thanks for their help during his visit.

Nearly two weeks were spent in work connected with Mr. van der Bent's course in photogeology, and in a method of triangulation of points on high-angle oblique photos, and three weeks in photointerpretation of special training areas. A one day visit was made to the Group's Geological Research Laboratories at Delft where the Director, Dr.de Raaf, arranged for the writer to meet Dr. A. Kruit who is engaged in studies in sedimentation in modern deltas, and Dr. A.J. Wells who has been studying the structure of reefs. Dr. Wells' work has included an investigation of the Devonian reefs of the Fitzroy Trough. On the ground these reefs are readily mappable into fore-reef, reef, and back-reef zones, but these units could not be satisfactorily delineated on vertical air photos. Probably high-angle oblique photos would be more suitable for this purpose than the verticals.

General

The Exploration and Production Department has one photogeologist on its permanent head office staff. He is responsible for the training in photogeology of all newly appointed field geologists, and also for the production of reconnaissance scale photogeological maps as required. He has a permanent staff of two draftsman and may call on the services of additional geologists and draftsman if a large project require it. A typical project might involve the examination of 1,000 to 2,000 photos at 1:50,000 scale, and production of a photogeological map at 1:200,000 scale, the time for the job depending on the complexity of the geology, but probably 2 to 3 months. The aim is to provide the Exploration Department with a map covering a whole area of interest as a basis for planning, rather than a detailed photogeological map to assist the field geologist in his programme. There is a strong emphasis in the training course on visual estimation of data from photographs - dips, heights of features, and so thickness of stratigraphic sequences. Most maps are accompanied by estimated photogeological columns and cross sections. Much work is done in regions where base maps are inaccurate or lacking, so that in compilation use is made of principal point plots, radial line plots and semi-controlled mosaics.

Outline of procedures

Photos purchased by the Company are indexed and stored by the topographic branch and obtained as necessary by photogeology section. Annotation of photos is done directly on the surface of prints with grease pencils according to a colour code (Appendix 1). Single weight semi-glossy prints are preferred both for field and office use, while double weight fully glossy prints are used for training, because of the ease with which grease pencil marks can be removed (with a soft cloth or with cotton wool moistened with methylated spirits).

Mirror stereoscopes are used almost exclusively, a high quality mirror-prism instrument of Swiss manufacture being preferred; it has excellent optics and a wide field of view (Appendix 2.n.). A light source consisting of a single fluorescent tube is mounted on the back of the stereoscope in a position that gives minimum glare.

The method of compilation adopted depends on whether or not a base map is available, and if so also on the quality of the base map. If no map is available, either a principal point plot or radial line plot is used, and the resulting compilation tied in to any control that can be found, such as astrofixes. If a base map containing sufficient planimetric detail is available, the geology is transferred by inspection to an overlay of the map. If the base map has only little detail the following method may be used. When annotation of the photos is completed by the geologist, the draftsmen make mosaics by matching detail and taping photos to a board. An area built up in this way until the change of scale due to relief displacement of image points makes it difficult to match detail. A separate mosaic is then built up and so on until the whole area is completed. Detail from the mosaics is traced off on to separate overlays, which are at different scales. From the base map, the actual scale of each overlay is computed and each is photographically brought to final scale (usually 1:250,000 or 1:200,000). The reduced overlays, now at a common scale, are fitted together and taped down. Any points whose geographical co-ordinates are known are placed in their correct positions relative to each other and to a temporary grid which may be drawn at this stage. A contact diapositive of this assemblage is then made on the lower polished surface of sensitized astralon. All unwanted lines, for example, those originating from the tape used to stick the overlays together, are scraped off, and the final geographical grid drawn on the upper matte surface of the astralon. The necessary prints can then be made from this positive.

Training course for Company geologists

The Company gives an eight weeks course to those of its geologists who will need the knowledge. The course is modified as necessary to suit the needs of particular students, but usually includes elementary geometry of air photos, estimation of vertical exaggeration of stereoscopic models (Fichter, 1954), group tracings (principal point plot), radial line plot, and the working of special training areas. Two to three weeks may be taken up with the principles, including a week to ten days practice in estimating dips and differences of elevation from photos, and checking results against topographic maps; the remainder of the time is spent in applying the principles to actual geological problems. The training areas, which are in various climatic zones, have been selected to emphasize the necessity for three dimensional thinking rather than routine mapping of linear features. Thus stratigraphic thicknesses must be estimated in various parts of an area and kept in mind so that possible stratigraphic anomalies are recognised and hidden faults detected. At the completion of annotation the student prepares a photogeological map accompanied by photo-estimated cross-sections and stratigraphic columns. There is commonly sufficient time in the course to do three training areas.

INSTITUT FRANCAIS DU PETROLE, PARIS

Introduction

Only two working days were spent at the Institute of Petroleum. but this gave sufficient time to gain an understanding of the photo-geological procedures used, and also to pay a brief visit to the factory of the Sociéte d'Optique et de Mécanique de haute précision, makers of the Stereoflex (p.11). The writer would like to record his appreciation of the hospitality extended to him during his visit to the Institute, particularly by M. Guyonnaud, Chief of the Photogeology Department of the Bureau of Geological Studies.

General

The French Petroleum Institute is a Government sponsored professional organization with the purpose of promoting scientific and technical activity within the French petroleum industry. The Institute carries out its aims by research into the technical problems confronting the industry, by the training of engineers and technicians in new techniques, and by the publication of technical information such as the results of research studies.

Its operational expenses are paid for by a tax on petroleum products. Projects may also be carried out on behalf of outside organizations and these are arranged on a contract basis.

The IFP is divided into four Divisions

1. National Advanced School of Petroleum and Motors
2. Documentation-information (Libraries)
3. Technical divisions
4. Management

The Technical Divisions are subdivided into

1. Sedimentology
2. Bureau of geological studies
3. Drilling-production-reservoirs
4. Chemistry-refining
5. Analyses and syntheses
6. Applications (fuel and lubricant research).

The Photogeology Department is part of the Bureau of Geological Studies and is itself divided into five sections: Photo-interpretation, Photogrammetry, Drafting, Photography, and Research. The staff of the Photogeology Department consists of twelve geologists and forty technicians. Planning of projects is done by the Chief and Assistant Chief Photogeologists, the photo-interpretation of any one project being done by a team consisting of a supervising geologist in charge of several geologists, the number depending on the size of the project. A supervising technician co ordinates the operations of photo grammetry, photography and drafting, and thus while the geologists are doing the interpretation, the technicians make a slotted templet laydown and prepare the base sheet. Routine jobs such as adding centre and pass points to photographs and preparation of templets are often sent out to sub-contractors, but the actual laydown of templets is done in the IFP. Projects commonly carried out include the preparation of reconnaissance photogeological maps of both sedimentary and metamorphic-igneous terrains from air photos of 1:50,000 scale.

Outline of procedures

Air photos are supplied by client or, for the IFP's own work, by the Institut Geographique National. These are filed by the secretarial section of the Bureau of Geological Studies. Unless good base maps of a region are obtainable a slotted radial templet laydown is made. Thick transparent astrafoil is used for templets; in the preparation of a base sheet at 1:200,000 or 1:250,000 scale from 1:50,000 scale photos, the templets are made at 1:100,000 scale and the resulting laydown photographically reduced to final scale. The centre and pass points from this reduction are pricked through on to a sheet of metalmount paper (equivalent to Pegraboard) and labelled. This is the compilation sheet.

Annotation is done on transparent overlays of alternate prints. For an area in which the geology is little known, a preliminary annotation may be done on the face of photos; the prints are then laid out so that the overall picture of the geology can be studied, and subsequently the principal features are transferred to transparent overlays. Coloured 'clutch' pencils are used according to a standard code (Appendix 1). As with the Shell Company, more importance is attached to physiographic expression of lithological units than to simple dip mapping. For the annotation on the overlays, a Swiss mirror stereoscope similar to the Fairchild is used; binoculars give a magnification of 3.5, and the photos are observed looking vertically downward (Appendix 2.o). Less commonly used is a high quality French mirror-prism stereoscope with an inclined viewing system; without binoculars this has a field covering the complete width and ¾ of the height of the model at a reduction of 0.7 times full size. With the binoculars the field of view is just over 2 inches at a magnification of 3.2 (Appendix 2.p).

The legs of mirror stereoscopes are set on a wide U-shaped yoke of aluminium attached to a drawing arm. The yoke carries a light source of two 40 watt bulbs, and rests on two glass plates on the table. The outer edges of each photo are held under the glass plates on which the yoke slides easily with a parallel motion by virtue of the drawing arm.

Transfer of detail from photographs to base sheets is done in one of two ways depending on whether the scale of the final map is close to photo scale or much smaller, e.g. 1:200,000.

If the photos are at 1:50,000 scale and final map is to be at e.g. 1:60,000 or 1:100,000 then during the preparation of the photo overlays both centre points and pass points are traced off. Individual overlays are then rectified and reduced to final scale in a special rectifying camera developed by the IFP which is capable of a maximum reduction of 3 times. The slotted templet point plot is placed on the table of the rectifying camera and the image of the overlay moved until the control points of the overlay coincide with the homologous points on the slotted templet assembly. A piece of printing paper substituted ~~for~~ for the point plot and exposed then provides a rectified 'map' of the particular photo at final map scale. About sixty such prints per day can be handled by the machine. These photo overlay prints are then mounted on the compilation sheet with heat-sensitive mounting tissue in their correct positions by reference to the control points common to both. The geologist receives the compilation sheet and does the re-interpretation he considers necessary to try to determine lithological units; at this stage, known as the synthesis, he may use a 2-power pocket stereoscope (Appendix 2.q.) ; he indicates by colouring the various features how the draftsman should proceed with the fair drawing. He also indicates how many plates will be required in the printing.

If the photos are at 1:50,000 scale and the final map is to be at 1:200,000 or 1:250,000 scale, then during the preparation of the photo overlays only the centre points and transferred centres are traced off. Individual overlays are reduced in a copying camera to final map scale, and the reduced photo overlay prints mounted on the compilation sheet by reference to the centre and transferred centre points only. Then this is the geologist's compilation.

Final maps are printed with the line features indicated in several colours (up to five) plus black. Ten copies are supplied to the client, one of which is hand-coloured completely; in addition a composite ozalid transparent positive is supplied, from which further prints can be made by the client.

OVERSEAS GEOLOGICAL SURVEYS, LONDON

Photogeological Section

Introduction

Just over a week was spent at the Photogeological Section of the Overseas Geological Surveys at Tolworth. Mr. Gordon Whittle, the geologist in charge, arranged for the writer to spend a period with each of the five geologists in the section in order that he might gain an appreciation of the diversity of the work being done. Thanks are due to Dr. Shaw, Director of the Overseas Surveys, and to Mr. Whittle and his staff for a pleasant and instructive visit.

Mr. Whittle also arranged a half day tour of the map reproduction section of the Directorate of Overseas Surveys. During a brief visit to the head office in London, an excellent punch card system for recording mineral analyses was seen in the chemistry laboratory, and a short paper describing the system is now on file in the Geological Branch.

General

In 1947 a central organization, the Directorate of Colonial Geological Surveys was formed in London for British Colonial and Dependent Territories in order to facilitate the expansion of geological work considered necessary by the Committee on Colonial Geology. Because many Colonies gained their independence during the years following the war, the name of the central organization was later changed to Directorate of Overseas Geological Surveys.

The Photogeological Section was formed in 1949 with a staff of one geologist which increased to five in 1956. During 1960 there were also five geologists in the Section. The main work of the Section is photogeological interpretation of certain areas requested by the Overseas Surveys, followed usually by the necessary field investigation to complete the mapping. The work is financed by votes from the Colonial Development and Welfare Fund.

The Section is housed with the Overseas Geodetic and Topographic Surveys at Tolworth in Surrey, in order to take advantage of the drafting facilities and the air photo library available there. Liaison is also maintained between the Topographic division and the Geological division which has its office in London.

Projects carried out by the Photogeological Section include reconnaissance and detailed mapping in both sedimentary and igneous-metamorphic terrains.

Outline of procedures

A typical project required the mapping of 2,000 sq. miles of basement complex in a tropical area difficult of access in east Africa. Available photos were at 1:40,000 scale and the final map scale was 1:125,000; also available were planimetric base maps at 1:50,000 scale. Two geologists were assigned to the project, and as a first step extra detail was added to the drainage on the 1:50,000 scale planimetric sheets using a radial planimetric plotter, so that they would be more useful for compiling geology in the field. Two months were spent on photointerpretation before going into the field, then followed four months of "detailed reconnaissance" field work, including panning for minerals. After returning to the office three months were spent in compiling maps and writing a report. In compiling the geology for the final map the 1:50,000 scale planimetric sheets were photographically reduced to 1:100,00 scale and geological detail transferred by inspection from photos to overlays of the reduced sheets. Fair drawings were made at 1:100,000 scale from these compilations, and reduced to 1:125,000 scale in making plates for colour printing of the final map.

Another project involved mapping over 100,000 sq. miles in Aden Protectorate from photos at 1:80,000 nominal scale for a final map scale of 1:250,000. For this project photo-scale rectified mosaics were available from the Topographic Division of the Directorate, and geological information was transferred by inspection to mosaic overlays. The scale of these was reduced to 1:250,000 scale on a Grant projector.

Coloured grease pencils are used for annotation according to a general colour guide (Appendix 1). For general interpretation a mirror stereoscope mounted on a parallel guidance mechanism is used (Appendix 2.r.) this device allows the stereoscope to traverse across four consecutive stereo prints parallel to the flight line (x direction), and the complete models normal to the flight line (y direction). As the device supports the stereoscope on a carrying arm, legs are unnecessary, thus giving unrestricted access to the prints for annotation. Even illumination of the prints is provided by an 18" fluorescent tube mounted on the carrying arm behind the stereoscope. Adjustable friction pads control the freedom with which the stereoscope moves. The stereoscope is fitted with a 4-power binocular. A 2-power lens stereoscope is often used in conjunction with the mirror instrument.

Equipment for compilation includes a Grant projector and a radial planimetric plotter (see p.8).

Training course for Survey Geologists

A course lasting 3½ weeks is run each year for recent graduates joining the Overseas Geological Surveys. To quote from the syllabus for the 1960 course it consists "of a series of lectures together with practical work covering stereoscopic acuity, alignment of prints and transfer of points under the stereoscope, reconnaissance and detailed interpretation of topographical and geological features in various territories, use of parallax bar and the construction of maps from air photographs." The course includes photo-interpretation of a field area in North Wales, a subsequent field check and preparation of a geological map. A useful aid to instruction is a "3-D" projector by which stereoscopic models can be projected on to a screen and discussed by the lecturer with the students.

MAP REPRODUCTION SECTION, DIRECTORATE OF OVERSEAS SURVEYS

The section uses the three colour system for printing geological maps. The basic colours are red, yellow and blue, applied in three intensities approximately 50%, 75% and full, by the use of a fine line screen. For each colour non-photographic blue positives on astralon are prepared, and on the polished side all detail except that required for a particular colour is duffed out with opaque. Three such positives are needed for each colour, one with the screen used singly (50%), one cross-line (75%) and one full. The three positives are superimposed using brass studs along the edges to ensure accurate register and a negative is made; from this negative the plate for the particular colour is prepared.

PRICES OF CONTRACT PH OTOINTERPRETATION

Prices of course have a wide variation because the nature of the geology ranges from simple to complex, from poorly to well exposed and so on, and hence the time required for a project varies greatly. For example the contract price for interpretation of geology on 1:50,000 scale photos and transfer of geological and planimetric detail to overlays of photo scale mosaics provided by the client, ranged from approximately 4/- per square mile to 22/6 per square mile.

For preparation of a slotted templet laydown, annotation of 1:50,000 scale photos, and preparation of a photogeological map at or near photo scale the price ranged from 19/- to 33/- per square mile; with the same scale photos and slotted templet laydown, and preparation of a photogeological map at 1:250,000 scale the price ranged from 4/9 to 9/5 per square mile.

Recommendations

Procedures

The principal functions of the Photogeology Group are considered to be as follow:-

to prepare (a) Photogeological Maps of broad areas, for example basin-wide studies in sedimentary terrains, at 1:250,000 scale for planning purposes; (b) photo scale compilations to aid the field geologist. Other functions include photo-interpretation of igneous-metamorphic terrains and detailed interpretation of small areas as required. When the Group is firmly established another function may be to run a short course in photogeology for recent graduates joining the Geological Branch.

As shown in Table 1 much the same procedure can be used to compile maps at either photo or 4-Mile scale. For areas in which the geology is unknown, the photo interpretation should be followed by a field check by the photogeologist.

It is of prime importance for the smooth running of the mapping programme that the Bureau, since it is required to produce a standard series of maps conforming to National Mapping standards of accuracy, should be supplied with planimetric base maps several months before field work is due to start. If maps have to be compiled on substitute base maps, much time is inevitably lost in re-compilation when the proper planimetric maps become available.

It is apparent from comparison with overseas organizations, particularly private establishments, that more use should be made in the Bureau of technical assistance to geologists engaged in compilation of maps so that more of their time is available for purely geological matters. That such assistance will be available has been assumed for the procedures outlined in Tables 1 and 2.

Equipment

Each photogeologist should be equipped with a good quality mirror stereoscope mounted on a suitable scanning device, a parallax bar and a pocket stereoscope. The Wild ST3 stereoscope mounted on a Casella parallel guidance mechanism is preferred. The pocket stereoscope recommended at present is the Casella-type 2-power instrument. However, it is also recommended that an Abrams CB-1 stereoscope be purchased; this instrument is furnished with both 2 power and 4 power lenses, and should be tried with the new small scale (1:85,000) photography to see whether it will be useful to field geologists. It is highly regarded by U.S.G.S. geologists at the Denver regional office. An accessory parallax bar is available for the Abrams stereoscope which clips to the legs of the instrument and thus can be conveniently used in the field. Another accessory is a circular computer which readily solves the parallax equations used in determination of elevation differences. It is recommended that both accessories be obtained.

A simple instrument for compilation of semi-detailed maps from air photos is the radial planimetric plotter. It removes the image displacement due to relief and is very suitable for plotting geological and extra planimetric detail from air photos directly on to a base map, provided that the scale of the map is not less than 1/3 photo scale. Two horizontal positions for each stereoscopic model need to be known to provide scale and orientation. It is recommended that one radial planimetric plotter be purchased.

As far as plotters capable of contouring are concerned, in the writer's opinion there is not sufficient need at present for this type of work in the Geological Branch to warrant purchase of a machine. Any special project that requires provision of contours could be let out to contract.

Furthermore in many areas in Australia which the Bureau investigates geologically, horizontal and vertical control points are few and far between. For accurate work, all plotters require at least 4 control points, preferably located near the corners of each model. For 1:50,000 scale photos this means 4 control points in each 20 square miles or so; the problem is less acute with 1:85,000 scale photography in which 4 control points are necessary only in each 55 square miles approximately.

In the writer's opinion, probably the best stereoscopic plotter for geological use is one which employs ER-55 projectors (see p.6) because of the good resolution of the model, and the fact that the model can be viewed as a whole. Reduced scale diapositives are used, requiring the use of a special reduction printer, and at present these may be difficult to obtain. However, many mapping agencies in Australia have been using photogrammetric equipment for some years. The N.S.W. Department of Lands for example has, besides Wild Plotters, Multiplex machines and a Kelsh Plotter (Middleton, 1955, p.62). At present, as far as is known, ER-55 plotters are not used by any Australian organization, but with the expanding use of photogrammetry in Australia (Rassaby, 1960, p.150) their use is likely within the next few years.

Rather than purchase one of the 'paper-print' plotters which avoid the use of glass diapositives, but which are not particularly well suited to geological use, it would be better, in the writer's view, when the need for a plotter arises to buy a high quality second-order instrument that can accommodate both 6 inch and 3½ inch photography.

This recommendation leads to the question of space required for the Photogeology Group .

Space requirements

An essential requirement for photogeological work is sufficient space to lay out large numbers of photos, possibly several hundred prints at a time, in order to observe the photo patterns over a complete 4-Mile map for example. No room suitable for this work exists in the buildings presently being used by the Geological Branch, but provision should be made for such a room in the proposed new building now in the design stage. A suggested arrangement of furniture and equipment in such a room is shown in Plate 6.

One room 12 feet by 14 feet should be held in reserve for a stereoplotter; it is desirable that it have a concrete floor and at least two power outlets, and be suitable for modification into a darkroom when the plotter is obtained. The majority of our air photos in use at present are at 1:50,000 scale, and to lay out a complete 4-Mile sheet at this scale requires an area of approximately 14 feet by 12 feet. Such a layout is most conveniently handled on two tables each 16 feet by 7 feet so that the central part of the layout is readily accessible. The Land Research & Regional Survey Division of C.S.I.R.O. uses braced plywood sheets of this size, supported on sets of metal filing drawers in which air photos are stored when not in use. (Filing drawer dimensions are - width 22½", depth 18", height 12½"; three sets of drawers one above another are used for each table support, giving an overall height, including table thickness, of 3' 3¾"). If in the future the Bureau changes over completely to the use of 1:85,000 scale air photos, the two tables will cope with a two-fold increase in work rate, because at the smaller scale one 4-Mile area will fit readily on each table.

A possible arrangement of furniture and equipment for a staff of four geologists and four draftsmen is shown in Plate 10, though to begin with only three geologists and draftsmen will comprise the Group.

It is difficult to estimate space requirements in say, 10 or 15 years time. If it is assumed that Bureau regional mapping will be confined largely to the area of Australia north of lat. 26°S, then an estimate of the time necessary to complete, for the first time, geological mapping at 1:250,000 scale can be attempted. North of 26°S, excluding Papua-New Guinea, there are 264 4-Mile areas, of which slightly less than 15% have been published or are nearing publication. At the rate of 4 man-years per 4-Mile, approximately 10 sheets should be mapped each year, and thus the project can be expected to take 25 to 30 years, with present staff. If earlier completion of the project became desirable an increase of staff would be necessary. An increase of photointerpreters could also become necessary if for some reason extra work were required, for example if it became policy to carry out photointerpretation for outside agencies.

In this event expansion of staff to five photogeologists and five draftsmen can be handled by accommodating a draftsman in each of the 14' by 12' rooms, and moving a new geologist and draftsman into the 19' by 12' room.

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January 1,1960.

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Table 1

SCALE OF AIR PHOTOS: 1:50,000 or 1:85,000 nominal

REQUIREMENT : Photogeological compilation at 1:250,000 or Photo scale.

BASE AVAILABLE	PROCEDURES 1.	2.	3.	3a	4.	5.
A. Photo index sheets at or near photo scale	Geologist annotates directly on photos using coloured pencils. Amount of annotation depends on whether final scale is 1:250,000 or photo scale.	Technician transfers detail to overlay of photo index sheet by inspection.	Geologist checks overlays and does any re-interpretation necessary	For photo scale compilation prints are made at this stage and pencil coloured for field geologist.	Overlays photographically reduced to 1:250,000 by reference to a grid prepared by draftsman.	Transparent positive of 4-Mile area made from assembly of reductions.
B. Slotted templet point plot at or near photo scale	as above	Technician transfers detail by Map-o-Graph or Grant projector to overlay of point plot or transparent positive of point plot using coloured pencils; culture and drainage in distinctive colours so can be traced off later for final compilation after field work	as above	as above	as above	as above
C. Slotted templet planimetric sheet at or near photo scale	as above NB. For B.C&D need centre pts & pass points from templet control.	Technicians transfers detail by Map-o-Graph or Grant to overlay of planimetric sheet or transparent copy of it.	as above	as above	as above	as above
D. Base Map at 1:250,000 scale with control pts.	as above	Tech. transfers detail by Map-o-Graph or Grant direct to map overlay or positive.	as above			

TABLE 2.

SCALE OF AIR PHOTOS: 1:50,000 or 1:85,000 nominal

REQUIREMENT: Photogeological compilation at 1:250,000 or Photoscale

BASE AVAILABLE	ALTERNATIVE PROCEDURES							COMMENTS
A. Slotted point plot at or near photo scale	Geologist annotates on transparent overlay of every second photo using coloured pencils; centre and conjugate centre points traced off; drainage & culture also	For accurate photoscale final: (both centre & pass points traced off)	Overlays rectified by ref. to point plot at photo scale.	Reduced overlay prints stuck to pagra board sheet by ref. to point plot marked on it.	Geologist checks compilation	Draftsman does fair drawing from compilation.		Not practicable until BMR photographic section is equipped with a suitable camera and enlarger.
		For 1:250,000	Overlays reduced photographically to 1:250,000 scale by ref. to point plot at final scale					
		For either photo scale or 1:250,000	Geologist tapes overlays to dyeline print of point plot in position of best fit.	Draftsman traces off detail from assembly of overlays Geologist checks compilation	For photo scale compilation, prints are made at this stage and pencil coloured for field geologist.	Compilation reduced photographically to 1:250,000 by ref. to a grid.	Transparent positive of 4-Mile area made from assembly of reductions.	Method at present being used by IFP Mission in Canberra; rapid method and probably sufficiently accurate for the purpose.
			Draftsman using ratio machine transfers geology to templet sheet	Geologist checks compilation.		as above	as above	Probably the most accurate of the methods for 4-Mile scale compilation, but slower than taping photo overlays to dyeline print.
B. Planimetric sheet at or near photo scale	Geologist annotates geology only on overlay of every second print							

APPENDIX 1

Colour codes for annotation of information on airphotos

Geophoto Services Inc., Denver   Numbers refer to

'Prismacclor' pencils made by Eagle Pencil Co., N.Y., London & Toronto.

Purple 931 - stratigraphic contacts and labels.
Orange 918 - quaternary boundaries and labels.
Peacock green 907 - Key beds and synclines
Scarlet lake 923 - Anticlines
Crimson lake 925 - Structural features and labels
Black 935 - Cultural features (except roads) and labels
Topographic features and labels.
Blue 906 - Streams, lakes, playas etc and labels
Burnt amber 947 - Roads and trails.

B.P.M. The Hague

Grease pencils similar to "Chinagraph"; also new self-propelling pencil with a wax'lead' "Scripto" brand is now used;

Red - faults and anticlinal axes
Blue - scarp edges
Green - synclinal axes
Yellow - formation boundaries
Brown - morphological features viz. accumulation terraces, erosional terraces, landslides, dip of surface of plain or terrace, Karst solution hollows, crests.

I.F.P. Paris

Annotation on overlays with Staedtler clutch pencils;

Red - dips and edges of beds
Orange - boundaries
Light brown - alluvium boundaries and laterite
Yellow - sand dunes
Blue - faults
Green - dykes

Overseas Geological Surveys, London.   General colour guide ; grease pencils "Chinagraph" or similar type.

Red - anticlinal axes, faults, flexures, dykes
Purple - Geological data except axes & faults e.g. dip slopes, scarp edges, formation boundaries
Green - synclinal axes and vegetation
Blue - jointing, coral features
Brown - morphological features e.g. terraces, landslides, crests; boundaries between areas of solid rock and areas of detrital material.

APPENDIX 2

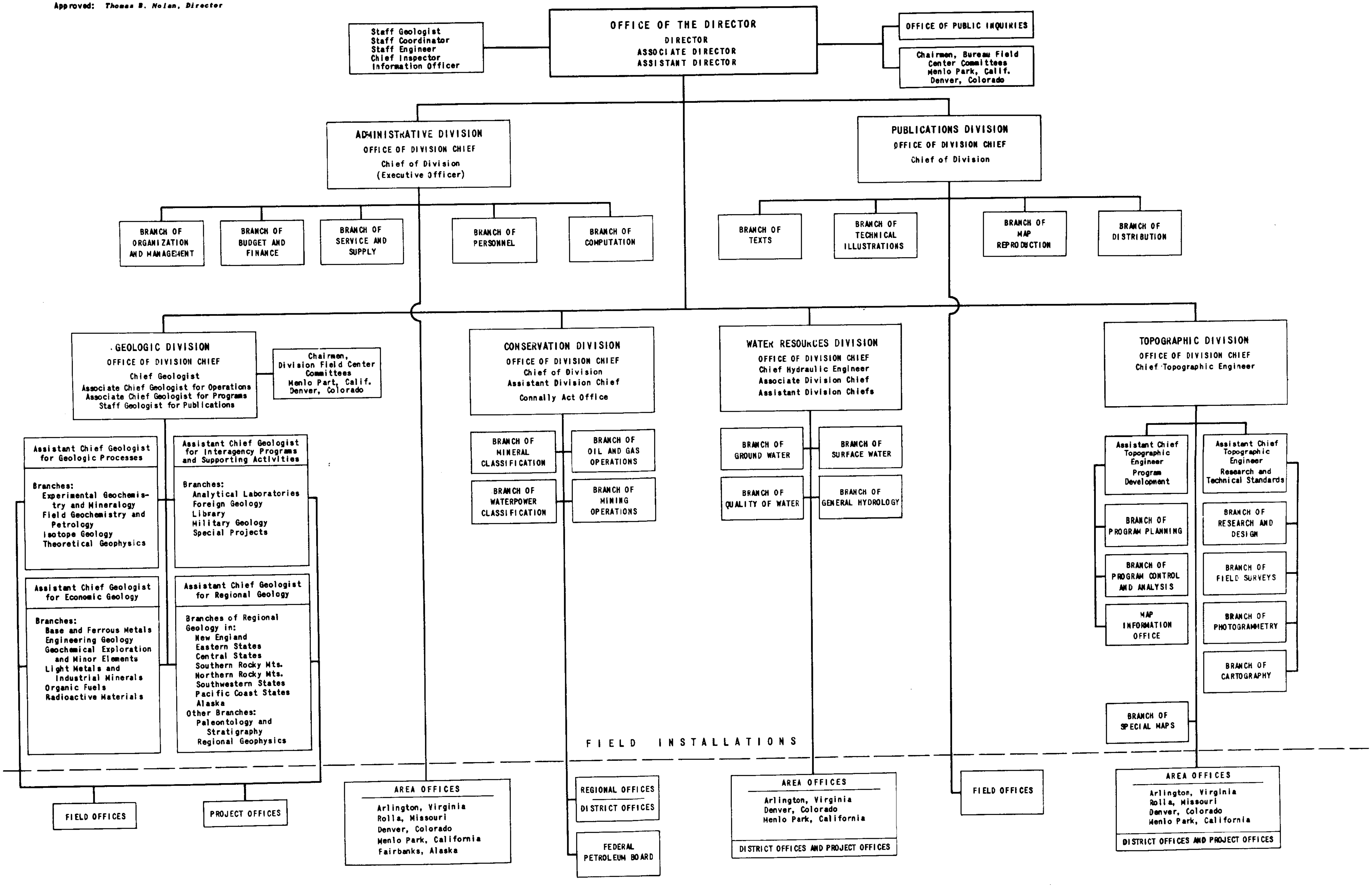
	Equipment	Manufacturer
a.	Automatic numbering machine:	- Roberts Rapidprint Time Recorders Inc., 700 Jamaica Avenue, Brooklyn, 8, New York, U.S.A.
b.	Desk mounted fluorescent light:	- Dazor Mfg. Corp., St. Louis, Missouri, U.S.A. Model UP-P-2134-16 (Similar type of lamp with a single 20 watt tube made in Australia by Planet Products, Victoria)
c.	Overhead projector: Model 70 Magnification 0.33-3.5; 70a " 0.25-4.0	- J.C. Saltzman Inc., 480 Lexington Ave., New York 17, N.Y.
d.	Ryker M-11 Mirror Stereoscope with 4 x binocular	- Harrison C. Ryker, California.
e.	Abrams Pocket stereoscope CB-1 2 and 4 power	-Abrams Instrument Corp., 606 E. Shiawassee St., Lansing, Michigan. U.S.A.
f.	Old Delft Scanning Stereoscope ODSS 111	-N.V. Optische Industrie "De oude Delft", Delft, Holland.
g.	Portable Reflecting projector "Reed Focamatic"	- Reed Instrument Co., 1048 Potomac St. NW., Washington, D.C.
h.	Radial Planimetric Plotter	- Philip B. Kail Associates 1601 Eliot Street, Denver, Colorado U.S. A£160
i.	Abrams Parallax bar for lens stereoscopes CF-8 and CB-1	- Abrams Instrument Corp. 606E. Shiawassee St., Lansing. Michigan. U.S.A.
j.	Parallax ladder & Stereo-slope meter	Photogrammetry Inc., Silver Spring, Maryland. U.S.A.
k.	K.E.K. Plotter	- Philip B. Kail Associates 1601 Eliot St., Denver, Colorado. U.S.A. Price f.o.b. Denver (July 1960) A£780 (Similar instrument made by Hilger & Watts London)
l.	Zeiss Stereotope Plotting Instrument	- Zeiss-Aerotopograph Munchen 27 Ismaninger Strasse 57 — Price C.I.F. Aust.port 1960 A£1200
m.	Som Stereoflex Plotting Instrument	- Societé d'Optique et de Mecanique de haute precision 125, boulevard Davout Paris, 20e. — Price f.o.b. French port 1960 A£1365
n.	Wild ST 3 Mirror Stereoscope	Wild Instrument Supply Co. Pty.Ltd., 137-141 Bayswater Rd., Rushcutters Bay, Sydney.
o.	Mirror stereoscope with 3.5 x binocular (similar to Fairchild)	Benz, Hirt & Jehle Reinh Benz Feinmechanik Dornacherstrasse 179 Basel Switzerland.

p.	SOM C3 Mirror-prism stereoscope with 3.2x binocular	Société d'Optique et de Mecanique de haute precision 125 Boulevard Davout Paris xx^{e}	Stereoscope Approx. £125.10.0 Stereometer A£35 ex works
q.	Pocket stereoscope 2 power	Mattey 15 rue Clavel Paris XIX^{e}	
r.	Parallel Guidance Mechanism	C.F. Casella & Co. Ltd., Regent House, Fitzroy Square London W.1.	

July 1, 1960

Approved: Thomas B. Nolan, Director

ORGANIZATION OF THE GEOLOGICAL SURVEY
DEPARTMENT OF THE INTERIOR



APPENDIX 4.

U.S. GEOLOGICAL SURVEY PHOTOGEOLOGY TRAINING
COURSE FOR FOREIGN PARTICIPANTS WITH ORIENTATION
IN PHOTOGRAMMETRIC BASE MAP COMPILATION

PHASE 1 - STUDY OF PHOTOGEOLOGIC PRINCIPLES (3 months)

QUALITATIVE INTERPRETATION

1. Factors affecting the photographic image.

2. Philosophy of interpreting aerial photographs. Need for sound geologic background in making photointerpretations.

3. Study of recognition of elements.

4. Uses of aerial photographs in general geologic mapping.

    a. Geologic information obtainable from photographs.

    b. Photographic characteristics of rock types (sedimentary, igneous, and metamorphic).

    c. Photographic characteristics of rock structures (folds, faults, joints, etc.).

5. Uses of aerial photographs in petroleum geology.

6. Uses of aerial photographs in search for mineral deposits.

    a. Structural guides, lithologic guides, physiographic guides and botanical guides.

7. Uses of aerial photographs in engineering geology.

    a. Study of elements of soil pattern in locating engineering materials (sand, gravel, etc.), determining highway locations, pipeline routes, dam and reservoir site studies, etc.

QUANTITATIVE INTERPRETATION

1. Measurement.

a. Principles of vertical measurement.

    1. Practice in determining altitudes by parallax methods from paper prints.

    2. Uses of parallax measurements in geologic interpretation, such as determining slopes of rocks, thicknesses of rocks, etc.

b. Direct determination of slopes.

    1. Methods and instruments used. Practice in making such determinations.

2. Plotting

a. Plotting geologic data - methods.

    1. Orthographic plotting using photogrammetric instruments.

    2. Plotting on orthophotographs.

    3. Uses of plotting in geologic interpretation.

QUANTITATIVE INTERPRETATION (cont)

3. Examples of measurement and plotting in geologic interpretation.

   a. Study of photographs of areas where such measurements and plotting have been accomplished (case studies).

4. Interpretation and plotting systems.

   a. Discussion of methods to use in various geologic studies, scale of photographs to use, instruments needed to meet specific geologic requirements, etc.

SPECIFIC PROBLEMS OF INTERPRETATION (Based on areas previously mapped in the field.)

1. Interpretation and annotation of 50-square-mile area in western U.S. (Uintah mountains, Utah) using 1:20,000 and 1:60,000 scale photographs.

2. Interpretation and annotation of 150-square-mile area in eastern U.S. (Anthracite region, Pennsylvania) using 1:20,000 scale photographs.

3. General mapping studies.

4. Petroleum studies.

5. Mineral deposits studies.

6. Engineering geology studies.

METHODS AND PRACTICE IN CONSTRUCTING PRELIMINARY BASE CONTROL SHEETS WHERE NO MAPS EXIST

METHODS AND PRACTICE IN TRANSFERRING GEOLOGIC INFORMATION FROM PHOTOGRAPHS TO BASE SHEETS

FIELD CHECK AND STUDY OF FIELD METHODS PERTINENT TO PHOTOGEOLOGIC INTERPRETATION (20 days, including travel)

RESEARCH IN DEVELOPMENT AND APPLICATION OF PHOTOGEOLOGIC INTERPRETATION METHODS

PHASE II - ORIENTATION IN PHOTOGRAMMETRY FOR PHOTOGEOLOGISTS (3 days)

1st Day
- Organization and functions of the Topographic Division
- Background of photogrammetry in the United States
- Control operations for mapping
- Inspection of plotting instruments
- Aerial cameras and camera calibration

2nd Day
- Diapositive preparation
- Orientation procedures
  - a. Interior orientation
  - b. Relative orientation
  - c. Absolute orientation
- Map preparation
  - a. Base sheet preparation
  - b. Aerotriangulation
  - c. Compilation procedures
- Cartographic operations

3rd Day
- Tour of Branch of Special Maps
- Orthophotoscope and orthophotograph
- Principles of radial line plotting
- Principles of stereoscopy
- Survey of paper print plotters
- Special purpose mapping

PHASE III - APPLICATION OF PHOTOGEOLOGIC PRINCIPLES (3 months)

Intensive photogeologic study of area, preferably within country of foreign trainee. All phases of photogeology - interpretation, measuring, and plotting - applied to individual study by participant under close guidance of instructor.

PLATE I

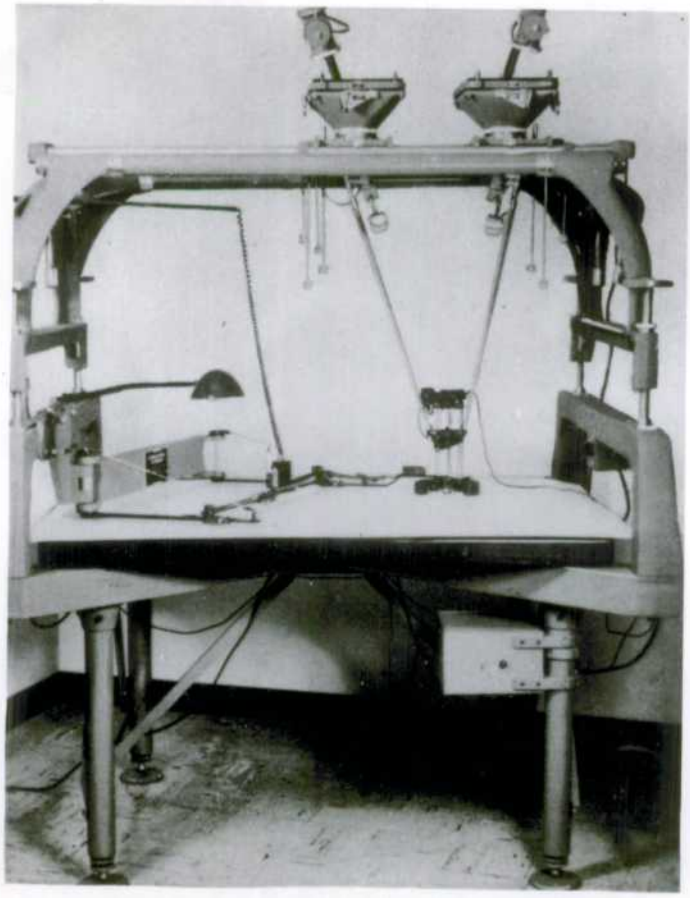


FIG. 1 KELSH PLOTTER

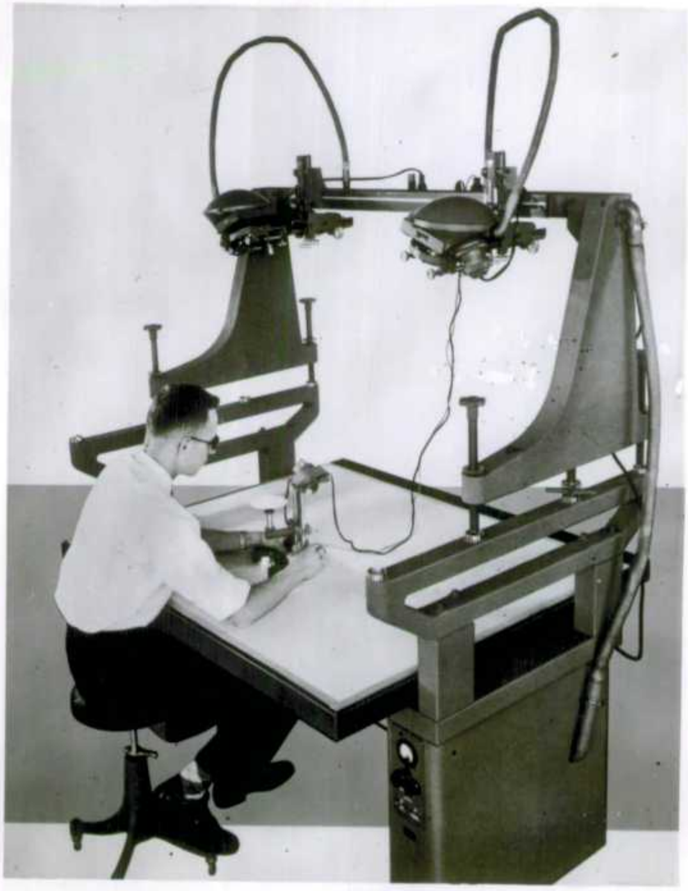


FIG. 2 ER-55 PLOTTER

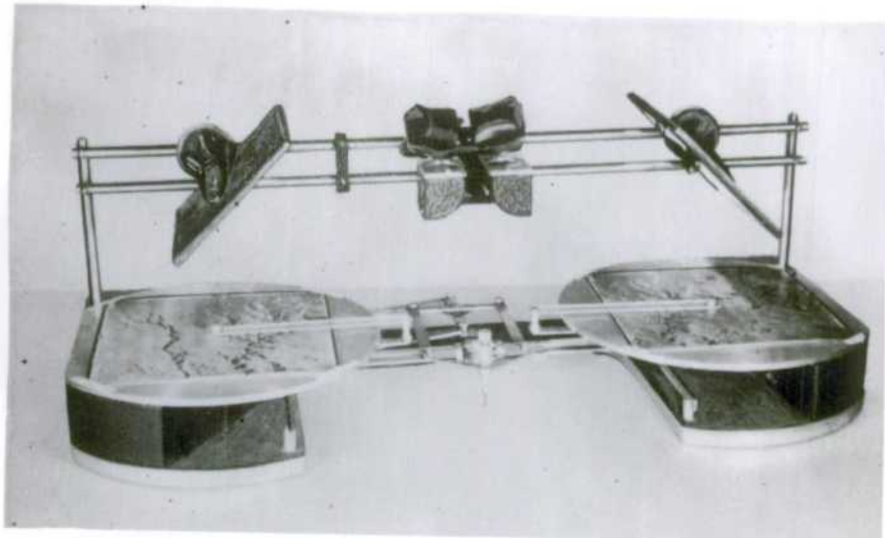


FIG. 1 RADIAL PLANIMETRIC PLOTTER

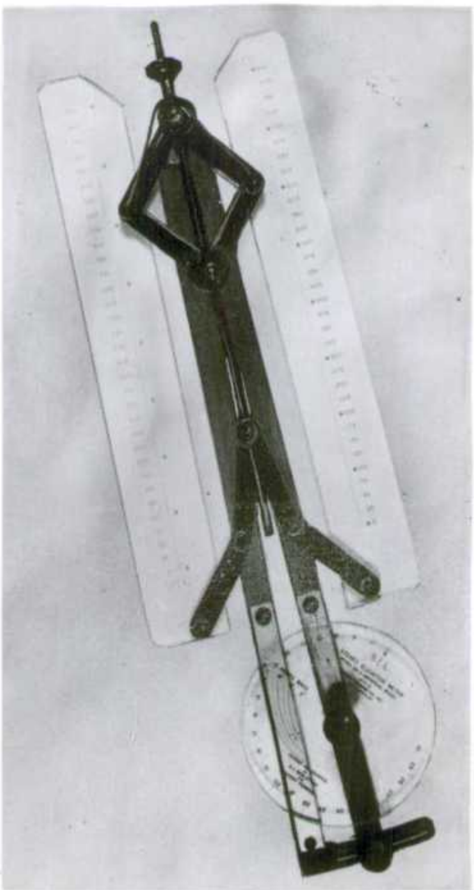


FIG. 2 PARALLAX LADDER

FIG. 2 PARALLAX LADDER

PLATE 3

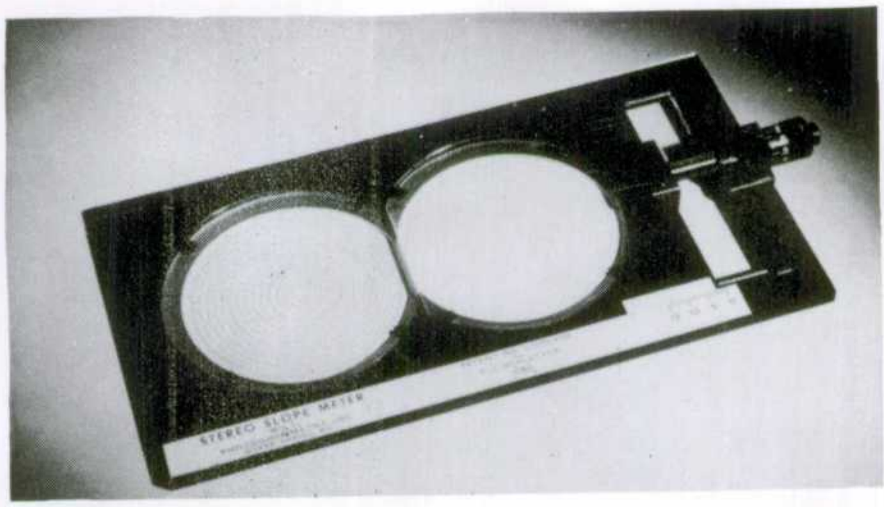


FIG. 1 STEREO-SLOPE METER.

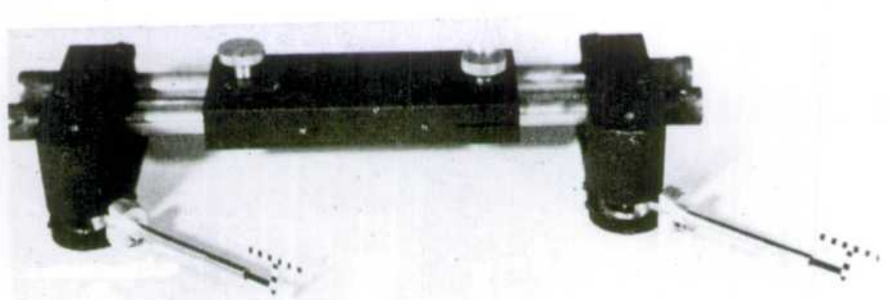


FIG. 2 STEREO-SLOPE COMPARATOR.

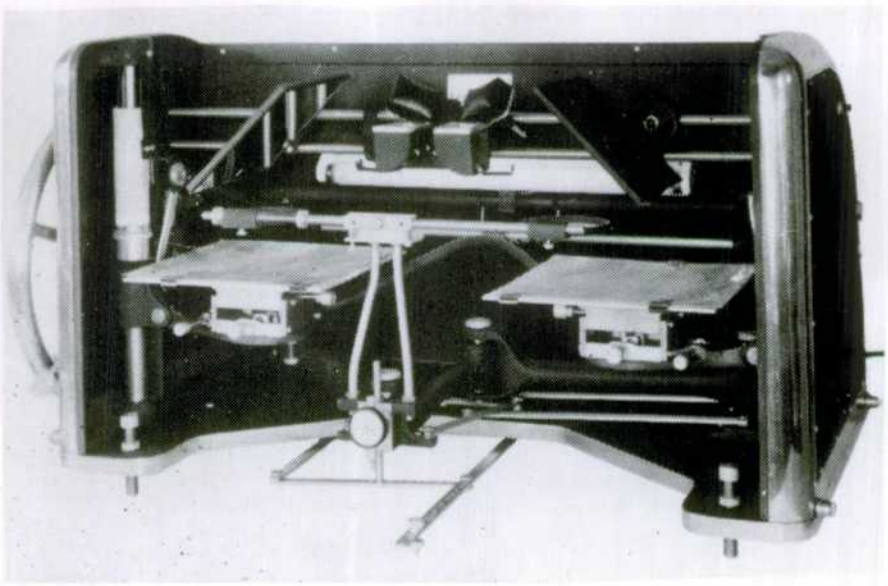


FIG. 1 K.E.K. PLOTTER

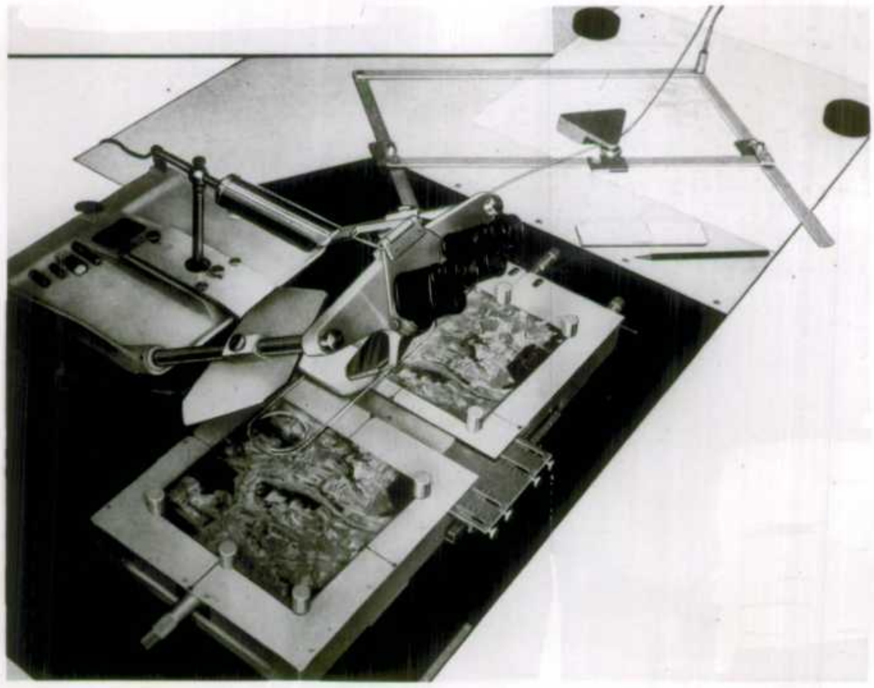
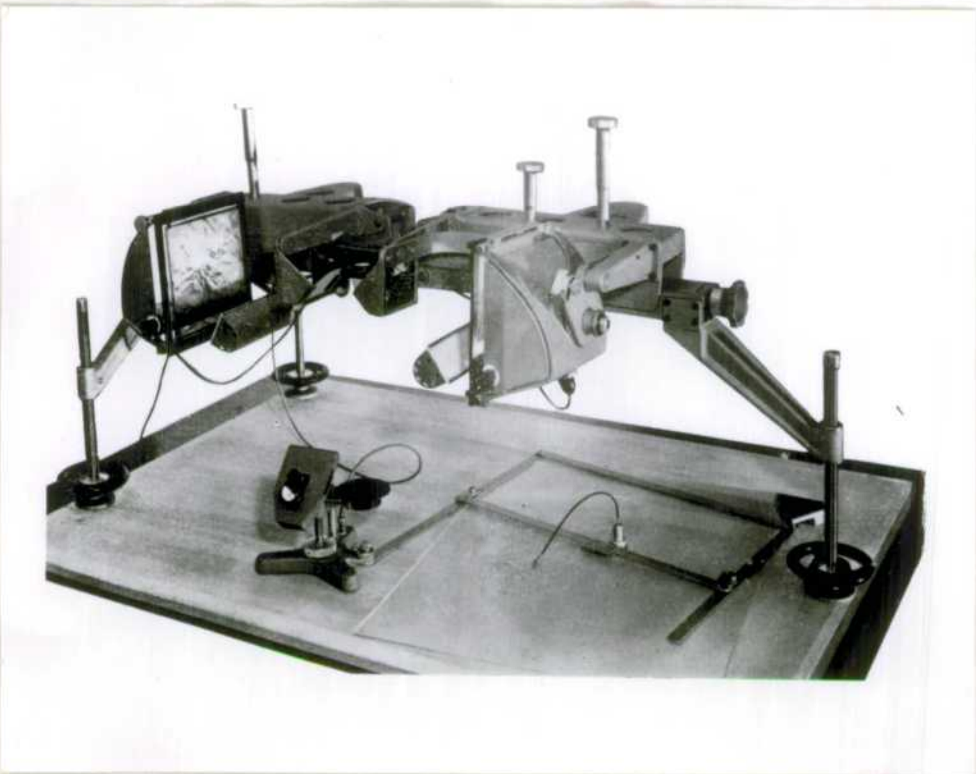


FIG. 2 ZEISS STEREOTOPE



SOM STEREOFLEX

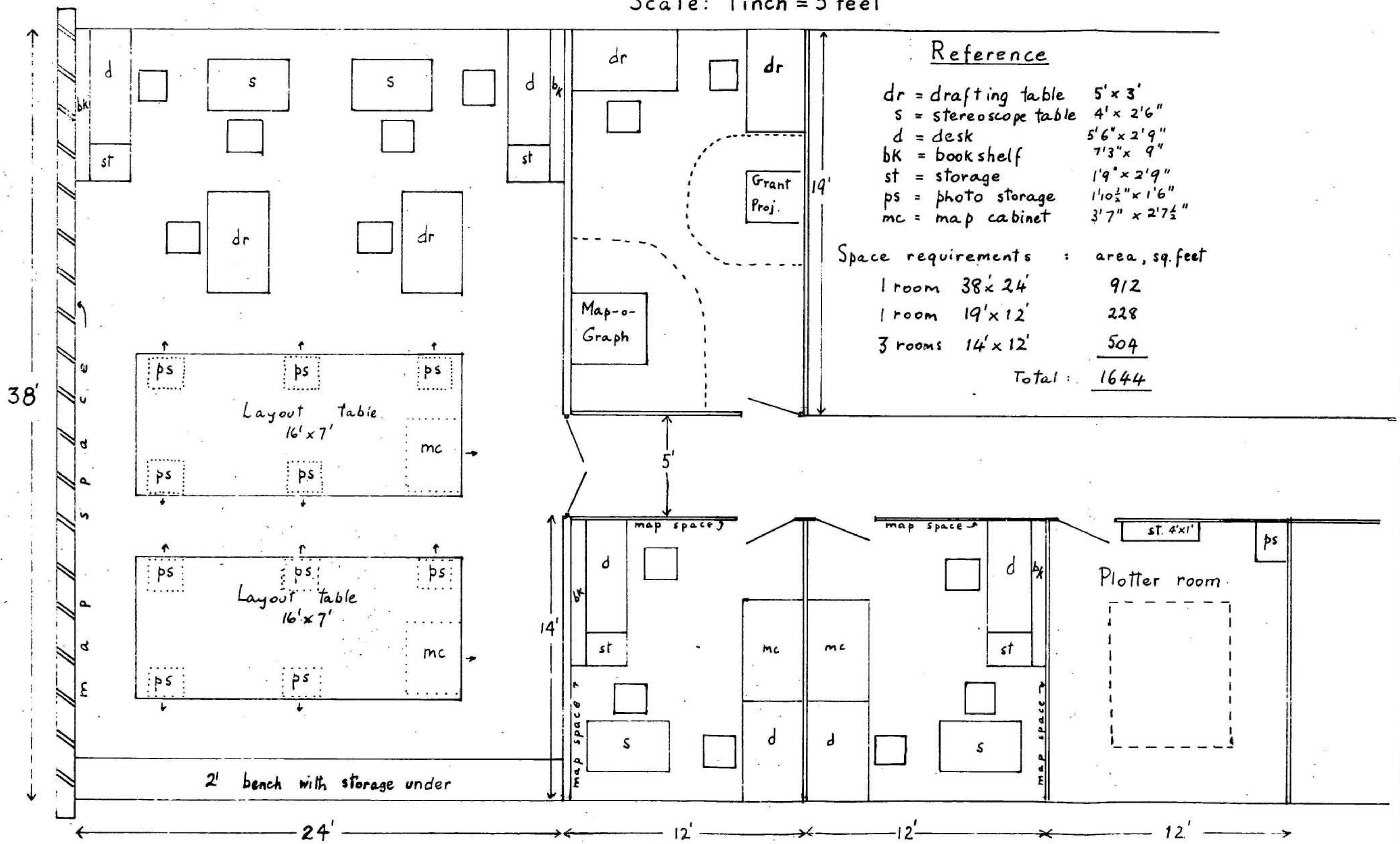
SOM STEREOFLEX

PLATE. 6.

Photogeological Group

Possible arrangement for
four geologists & four draftsmen

Scale: 1 inch = 5 feet



Reference

dr = drafting table 5' x 3'
s = stereoscope table 4' x 2'6"
d = desk 5'6" x 2'9"
bK = bookshelf 7'3" x 9"
st = storage 1'9" x 2'9"
ps = photo storage 1'10½" x 1'6"
mc = map cabinet 3'7" x 2'7½"

Space requirements		: area, sq. feet
1 room	38' x 24'	912
1 room	19' x 12'	228
3 rooms	14' x 12'	504
	Total :	1644