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AERIAL SURVEY AND OIL EXPLORATION

A STUDY IN ORGANIZATION

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ABSTRACT

The author presents his experience in organizing and conducting an aerial survey and oil exploration in Peru by means of aerial photo-interpretation and field study. He describes a method of preliminary organization and air reconnaissance procedure in order to obtain full advantage of aerial photogeological interpretation prior to final field mapping. The various necessary steps, such as a review of existing trimetrogon photography, preliminary aerial reconnaissance, final air coverage of selected areas, photogeologic interpretation, plotting, etc. are described. The author used specially trained photogeologists to do the interpreting, with field geologists using this information as a base for final mapping. His experience showed that three photogeologists could interpret approximately 15,000 square miles, on a scale of 1:40,000 in about one and a half years. The photogeologic interpretation was reproduced on photo scale tracings for use by the field parties which permitted the planning of field studies, but did not eliminate the need for the surveying of detail sections. The finished compilation of field and photogeologic interpretation and geophysical data were photographically reduced from the photo scale to either a 1/100,000 or 1/200,000 map for use as a base map for the geologic reports. The final step was the reproduction of regional structural maps at a scale of 1:500,000 or 1:1,000,000.

PAGE TRUESDELL

THE application of aerial mapping to oil exploration is so widely adopted and its techniques are so well known that little can be added in that respect. However, in the author's opinion the organizational aspect of the problem has not received the attention which it deserves.

This paper therefore describes how an aerial survey can be integrated into an exploratory organization so that all of its branches will derive the greatest benefit from it.

An aerial survey, if properly planned and applied, can be a very efficient tool for directing an exploration campaign. In many exploration ventures of the past, aerial surveys were decided upon and initiated considerably later than the start of the geologic field work. Accordingly the results of the photo-interpretation became available only after they were no longer required in the field.

In an unmapped or inadequately mapped area, an aerial survey has two aims: firstly to supply the topographic base for geologic mapping and geophysical surveys; secondly to supply a coherent structural picture to serve as a guide for the movements of geologic field parties engaged in stratigraphic studies and structural mapping.

In areas which are well known topographically, the problem of course is simpler in so far as ample ground control is available for locating geologic and geophysical observations. But even so, a geologic interpretation of the photographs available through Government agencies or private sources, prior to the start of field work, is of great advantage.

The author was in the fortunate position of being called upon to set up such an organization in Peru (1945–47) in behalf of the Royal Dutch/Shell Group. (He gratefully acknowledges his indebtedness to its Directors for their permission to publish this paper.) The aim of the assignment was to collect the maximum of geologic information in the shortest time possible. The means by which this aim was attained will be briefly described (see Table 1).

TABLE 1

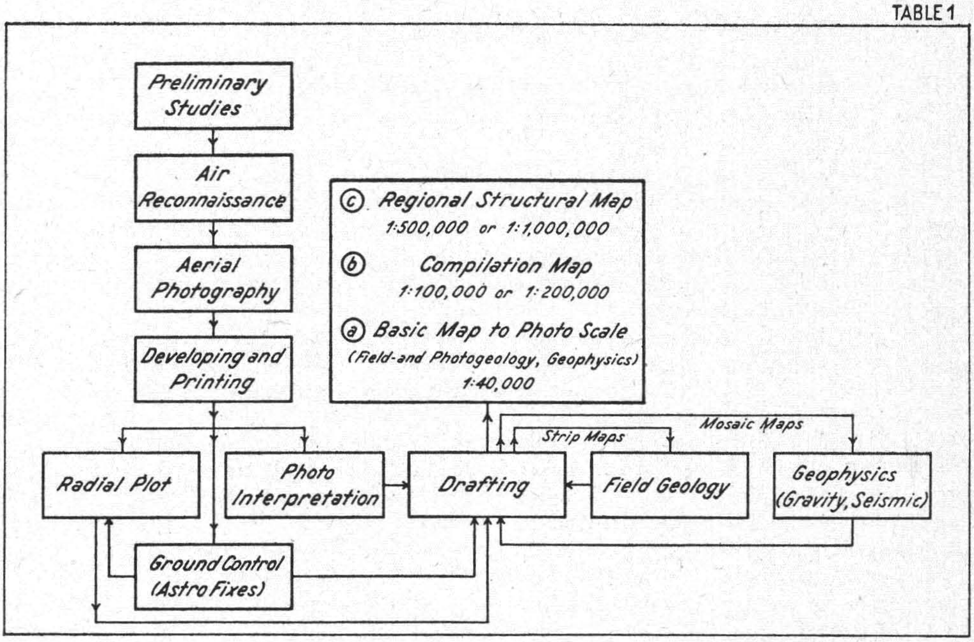

TABLE 1. OPERATIONAL SCHEME.

1. PRELIMINARY STUDIES

To make an aerial survey a success considerable attention should be paid to details. These should be studied well ahead of the date of commencing the survey. If a contracting firm is engaged on the project, its officers will either have knowledge of local conditions or will assist in working out details.

The items of prime imporance are:

a. *Airbases*

The situation and spread of existing airfields within the area of interest, their suitability and conditions (all-weather or dry-weather), the availability of service facilities, including fuel and lubricants, should be investigated. If the last two items are not available locally, the quickest and most economical means of transporting them to the operational bases should be ascertained. In the case of the Peruvian Montaña, fuel and lubricants had to be shipped from the northwest coast of Peru via the Panama Canal and Belem (Brazil) up the Amazon River. As this trip required several months, long-range planning was essential.

Likewise the local situation regarding housing facilities for the air crew, storage facilities for spares and material and radio communications with headquarters should be carefully investigated. It is an advantage if use can be made of existing housing as this eliminates the building of a camp.

b. *Meteorologic Data*

These are essential for timing the project, especially in the tropics where only the dry seasons are suitable for air mapping. In Peru it was found that at all landing fields in the Montaña region, weather records had been kept over several years. After a preliminary study of these, the data on cloud cover were selected for a closer analysis, because cloud conditions considerably influence carrying out an aerial program. A number of airfields representing the three physiographic provinces: Andean foothills, plains adjacent to the foothills and Amazonean lowlands were selected. Each had a slightly different seasonal cycle.

The figures for the three daily observations (8 A.M., noon, and 4 P.M.) on cloudiness on a zero-to-ten scale, were plotted graphically as sum-totals for each day of the year, in the manner shown in Figure 1. By overlying the plots on transparent graph paper, daily averages over 4 years were obtained.

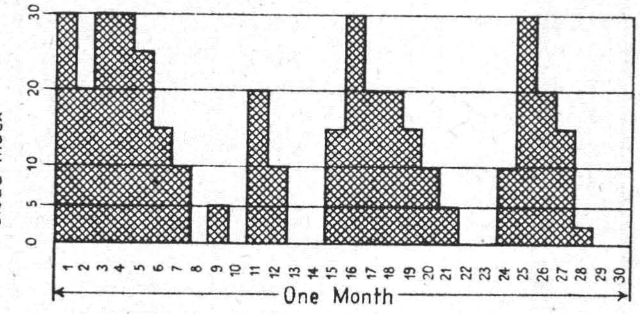

FIG. 1. Cloud Index Graph.

The graphs showed clearly the ceasing of the rains and the incoming and distribution of cloudless days within the succeeding months. They permitted timing the aerial survey, i.e. the date when preparations had to be finished and the aircraft on the spot in order to take advantage of the very first days of favorable weather. It was borne out by subsequent experience that the periods of favorable weather largely coincided with the predicted periods of low cloud index, and that days with a cloud index below 5 were suitable for photographic operations. As these meteorologic studies were made about seven months prior to beginning the air mapping, ample time was available for preparations and not a single favorable day was lost.

c. *Trimetrogons*

Trimetrogon photographs are not in favor with geologists, largely because the information derived from obliques is doubtful and in some cases misleading, especially when taken perpendicular to the strike. Nevertheless they are a great help for a preliminary reconnaissance. It is therefore recommended that a study of existing trimetrogons be included in the preparations for an exploration campaign. The following method is recommended: After the interpretation of the verticals, pairs of obliques should be studied under the mirror stereoscope and the interpretation sketched on a Kodatrace overlay. The tracing should then be placed in the oblique sketchmaster and viewed under the same angle

(60°) as the photograph was taken. The outlines should be drawn with the help of the Canadian grid. This eliminates the use of slotted templets for the obliques and is sufficiently accurate for a sketch map.

2. AIR RECONNAISSANCE

There are two ways of approaching the selection of an area to be photographed. One is outlining such an area on scanty information and/or theoretical considerations. The other is the direct approach favored by the author—by means of preliminary air reconnaissance. This requires a definite air-mindedness, but it saves time and money by eliminating large tracts of country unsuitable for photographic interpretation, and tends to concentrate efforts on photogeologically favorable areas. It is a selective method and especially suitable in highly competitive areas, where by necessity the aim is to obtain the greatest amount of information on critical or contested areas within the shortest possible time.

Several reconnaissance flights have to be undertaken when structures are not well expressed morphologically. The time of the day—by preference early morning or late afternoon—has to be chosen properly. Two-level reconnaissance—high-level (3,000–5,000′) for general orientation and low-level (1,000–2,000′) for checking of details—is recommended. The geologist in the co-pilot seat takes notes on bearing and locates by timing conspicuous ground features and structural indications. The resulting sketch map incorporates the data noted during the flights as well as trimetrogon interpretations. It is checked against existing topographic maps and serves as a base for outlining the flight areas.

For the geologist-in-charge who, as soon as operations are in full swing, is largely tied down to administrative matters and reviewing incoming data, air reconnaissance is the most time-economizing means to familiarize himself with local conditions, topography and structural pattern of the area of interest.

3. AERIAL PHOTOGRAPHY

After the area to be photographed has been selected and an order of priority for the various flight areas has been established, wherein practical considerations to the technical execution of the program should be given proper weight, the operations are in the hands of the technical personnel of the contracting firm. Due consideration, however, should be given to the conditions regarding scale, overlap, marginal coverage, flight lines, control strips, crabbing, tilt and allowable percentage of cloud cover, as stipulated in the contract. A scale of 1:40,000 is the most suitable one and is widely used.

4. DEVELOPING AND PRINTING

Facilities for these operations are supplied by the contractors. In Peru, the aerial survey was in the hands of Fairchild Aerial Surveys, Inc., while the developing and printing was done under supervision of the technical officers at the laboratories of Servício Aerofotográfico Nacionál in Las Palmas near Lima. Exposed films were forwarded directly by regular plane from operational bases in the Montaña to Las Palmas.

5. PHOTOGEOLOGIC INTERPRETATION

There are two schools of thought in connection with the geologic interpretation of aerial photographs; one favors the field geologist doing the interpretation of the area he is going to map; the other prefers assigning the interpretation to specially trained photogeologists. From the standpoint of efficiency the latter course is favored by the author. Photo-interpretation is a specialist's job, and provided he has the necessary interest and qualifications the more a geologist is allowed to acquire experience in this line, the greater is the benefit for the organization.

Various methods of photo-interpretation are in current use. If the method is the mirror stereoscope, as it was in Peru, interpretation is best done on the group tracing system. That is, principal points are transferred stereoscopically from photograph to photograph, and are then traced on 40 inch long strips of Kodatrace, the so-called group tracings. The interpretation is done on the Kodatrace overlay covering the right hand photograph of a stereoscopic pair. The use of color pencils to distinguish between geologic, morphologic and purely topographic features is recommended. After the interpretation of a unit area is finished, the group tracings are either laid out in mosaic fashion and a tracing is made, or they are photostated individually. Prints of the tracings and/or photostats are airmailed to the field parties to be used as base maps.

It is apparent that such maps to photo scale, although they are uncontrolled, are a great help to field parties, not only for their actual mapping, but also for the planning of their movements. They of course do not eliminate the necessity of surveying detail sections, but if proper care is taken to tie in such sections to recognizable features of the photo strip maps, they will be properly adjusted after control is established by radial plot. For geophysical parties working in flat country, where river courses are the only recognizable topographic features, the use of mosaic maps is more convenient.

If in any way possible, aerial photographs should be distributed for interpretation among the photogeologists according to structural unit areas, so they can specialize on certain types of outcrop patterns. However, priority of areas which might become highly competitive, should have first consideration.

Experience in Peru has shown that in about one and a half year's time, three photogeologists, whereof one is a senior man, can cope with the interpretation of an area of approximately 15,000 square miles, photographed on a scale of 1:40,000.

6. GROUND CONTROL

The selection of easily identifiable ground features for astro fixes requires special care. Otherwise difficulties will arise through faulty identification while making a radial plot. Even spacing of the astro fixes over the flight area should be the aim. No rigid rule can be laid down as this depends largely on the topography, but 75 miles should be the maximum and 25 miles a good average. The ideal case would be a distribution of ground control points in equilateral triangles, about 25 miles apart, but this can hardly be attained in tropical jungle country.

The surveyor in charge of astro work is supplied with sets of photographs covering the selected sites and their surroundings. A stereoscopic check usually makes possible a decision on whether the localities selected are suitable for astro stations (clear of high and dense jungle, above high water level, easy to identify). Simultaneously with the astronomic observations, a situation plan of the station and its surroundings, including sufficient reference points, is prepared. The location of the permanent monument is then pin-pointed and marked on the photograph, which with the calculations and other pertinent information is kept in an individual astro station file for easy reference.

7. RADIAL PLOT

The method of choice is the slotted templet plot. Preparations for this can be begun quite early, and consist of transferring and marking of principal and wing points, and the slotting of the templets. When the astro fixes become available for a certain flight area, the layout can be started immediately. It is convenient to have a special room fitted with a raised platform of masonite for this operation.

The locations of astro fixes, principal and wing points are traced on nonshrinking master tracings which in addition show the adopted grid and/or geographic coordinates. They are given to the Drafting Section.

8. DRAFTING

The Drafting Section should be well equipped and staffed, and no effort should be spared to bring it up to the highest level of efficiency. Drafting is the bottle neck in many exploration ventures, but this need not be. Experience has shown that in very short time a first-class chief draftsman is able to build up his section from scratch, by training a local staff with some experience in drafting, not necessarily geologic. A rectifier and a contact printing machine should be included in the standard equipment.

The initial task of the Drafting Section is the issuance of mosaic and strip maps on photo scale for the field parties. Likewise all maps to accompany monthly or other interim reports are uncontrolled maps to photo scale. Reductions if required are either done on the reduction light table or by pantograph.

As soon as the first master tracings become available from the Radial Plot Section, compilation of field and photogeologic as well as geophysical data is started. Finished master tracing sheets are photographically reduced from photo scale to either 1:100,000 or 1:200,000, depending on the size of the area to be covered. Standard tracings are then made. These compilation maps, from which all irrelevant data of the original photo scale maps are omitted, serve as base maps for geologic reports. They are the only maps issued for circulation during the exploratory stage of the venture. However, if this stage should be followed by detailed mapping of selected areas and subsequent drilling, then the 1:40,000 maps would be the topographic base for further field mapping and engineering work. The last step is the production of a regional structural map on either 1:500,000 or 1:1,000,000 scale.

9. THE RESULTS OF THE OPERATIONS

These are summarized as follows:

a. The *Base Map* is a map to photo scale (1:40,000), controlled by a set of evenly spaced astro fixes and a radial plot (slotted templets). It incorporates field and photogeologic and geophysical data. If desired that only one type of information be shown, say either field geology or gravity, the respective data are traced and, if necessary, interpretations are added. This map will also be the base for subsequent detail work in selected areas. It is colored according to a local color scheme with the stratigraphic member of a formation as a unit, but with distinct colors for morphologically easily identifiable key horizons.

b. The *Compilation Map* is a reduction of the base map to either 1:100,000 or 1:200,000, depending on the amount of details to be shown, and to some degree also on the size of the total area covered. Field dips are shown in symbols, each having a certain limited range. Figures for degrees of dip can be dispensed with. Coloring is done according to a locally adopted scheme. The unit to be distinguished is the stratigraphic member of a formation.

c. The *Regional Structural Map*, to either 1:500,000 or 1:1,000,000 scale, shows the main structural features such as anticlinal and synclinal axes, steep zones, faults and thrusts and structural provinces. It is colored according to the international color scheme, the unit being the system, with a color segregation within the system. If possible it should be a one sheet map. It serves as an easy reference for a final report and subsequent discussions of the prospects of the area.

The following are the pertinent data on area covered and time involved in the exploration campaign in Peru:

Total area covered by aerial survey approximately	15,000 sq. miles
Total time spent on project (including time for preparation and winding up)	26 months
Time from beginning of aerial survey to date of issue of maps b and c	19 months
Time from end of aerial survey to date of issue of maps b and c	4 months

These data clearly demonstrate the great advantage which a properly integrated aerial survey can have for an exploration venture.

THE GIFT OF ENGINEERING*

By L. E. Grinter, Vice President of the ASEE

IN THE Beginning only Divine Force could have guided creation of the Universe and the evolution of life on Earth. All creatures endured the forces of nature until the mind of man matured. Then man's desires sought satisfaction by invention of tools to strengthen his hand. But tool making brought civilization with collective cares outreaching the ability of arms even when aided by the lever and wheel. Slowly our forebears began to discover natural laws that explained the drawing of power from falling water, wind and steam. It was only in our fathers' time that electricity on wires, and then on wireless waves encircled the earth, yet *we* have cradled atomic change and released the latent energy that lights the stars, thereby threatening the existence of our enemies and of our own children. It is the engineer's destiny to control and direct power in order to "provide for the common defense, promote the general welfare," and so to help "secure the blessings of liberty to ourselves and our posterity."

As an engineer you are given a favored part in this great design; without you the plan would be less perfect. When you build a bridge, design a dam, perfect a process or link power lines together you play a role in the achievement of human destiny. You therefore owe everything that you have to give in honest and sincere effort toward engineering progress. Dishonesty is inconceivable in even the smallest detail of a professional mission. Carelessness and sloth are but little less reproachable. Integrity and energy deepen the luster placed upon the profession of engineer by the master builders of the past. Disclosure of advances must be given freely to aid in educating the engineers of the future. Thus with each generation rising above the teaching of its forerunner, progress by employment of science is the gift of engineering to mankind. With this gift must go the engineer's unending effort that ethics may mark its use and morality remain its master.

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* From an address to Engineering Students. Publication permitted by Mr. Grinter.

NEWS NOTE—FLORIDA CONFERENCE

The steering committees for the Sixth Annual Highway Conference and the Fifth Annual Surveying and Mapping Conference have decided to hold a combined Highway and Surveying Conference on October 23 and 24. This will be held in Gainesville under the sponsorship of the Civil Engineering Department, as a function of the Engineering and Industrial Experiment Station, University of Florida. There will be general sessions of interest to both groups covering a comprehensive study recently made of Florida's highway system, highway location, and the application of photogrammetry to highway location.