or a prograde shore, and the presence of inland swamps or sand dunes, aid in the interpretation of the type of beach, but they do not always give us the true trafficability story. It is hoped that by the study of enough different types of beaches we can present a much more accurate picture of the actual conditions.

Experiments in recent technical developments such as radar and the airborne magnetometer may help in beach and coastal interpretation. For instance, to what extent will the radar image detect the difference between a granite hill and a similar hill composed of shale or limestone? If there is a difference in the image, is it only relative and therefore only reliable for nearby areas, or could it also be used for widely separated points of interest?

As the Navy is interested in coastal conditions extending from the Arctic to the Antarctic, climatic conditions and their effects on weathering must be taken into account in the interpretation of land forms and vegetation.

In obtaining answers to these and many other questions, as well as in keeping up to date with the advancement of photogeology and photobotany, the Photographic Interpretation Center maintains contact with other branches of the Navy, other government agencies, universities, and private industries. Thus it is hoped that we can do our share in preparing photographic interpreters to fulfill their missions more rapidly and accurately.

PRESENT STATE OF THE APPLICATION OF PHOTOGRAMMETRY TO CARTOGRAPHY IN SPAIN

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TRANSLATED BY BERNARD J. COLNER

1. Since Laussedat announced the principles of what he termed *Metrographia* in 1859, the Spaniards have been interested in this new procedure of surveying. This topic was the theme for a meeting of the *Real Academia de Ciencias de Madrid* in 1861. Gen. D. Antonio Terrero published a notable work in 1862 in which he solved the problem of determining the location of an object by means of its images on two photographs. This was twenty years before Hauck, a German, presented a solution of the same problem in his "Theorem."

Since that date, many studies have been undertaken by various technicians and practical experiments were completed by several governmental agencies. The works of Lt. Col. D. Alejandro Mas y Zaldua are deserving of mention. In 1901, he completed a topographic survey using photogrammetric methods in the Pyrenees which extended more than 10,000 hectares (38.6 sq. miles). At the same time, Maj. D. Jose Galbis, a highway and cartographic engineer, completed some tests of the new methods on the municipal boundary survey of Otero de Herreros, which included an area comprising some 4,300 hectares (16.6 sq. miles) at 1:25,900, the same scale as the *Mapa Nacional.* The *Brigada Topografica de Ingenieros* tested in Calaluna y Baleares the idea of photogrammetric tachymetry derived by *Coronel de Ingenieros* D. Rafael Peralta, Chief of the *Servicio de Aerostacion.*

2. The encouragement that photogrammetry received in 1900 on substituting stereo-photogrammetric methods for conventional practices, resulted in a rapid development of its cartographic applications by utilizing the stereocomparator (Pulfrich—Zeiss, 1902); and especially the Stereoautograph (Orel—

Zeiss, 1910), the first automatic plotting instrument that permits the drawing of planimetric detail and contours in a continuous manner.

The leaders of stereo-photogrammetry in Spain were the previously mentioned Lt. Col. Mas y Zaldua, author of various works dealing with photogrammetric technique and a photo-theodolite that was still competently used with later equipment; and *Ingeniero de Caminos* and *Ingeniero Geografo* D. Jose M. Torroja Miret, famous mathematician and geodesist, who aided the birth of stereo-photogrammetry in Germany and Austria, published numerous technical works on this subject and labored ceaselessly in order to convince the scientific centers and technicians of the advantages of this new method of surveying.

3. The practical application of terrestrial photogrammetry in Spain can be said to date from 1914, when the *Instituto Geografico* completed surveys of this class utilizing Sr. Torroja's photo-theodolite. These surveys were mapped at a scale of 1:25,000 to be eventually used in the *Mapa Topografico Nacional.* Sr. Torroja worked in the capacity of Chief Engineer of the *Brigada Fotogrametrica* of the *Instituto Geografico.*

El Deposito Geografico del Ejercito made use of a photo-theodolite (*Mas y Zaldua*) for field projects and later added three pieces of Zeiss photogrammetric equipment. In 1921, a Stereocomparator (Pulfrich) and in 1923 Orel's Stereoautograph were procured to be used for work in this office. The following photogrammetric surveys were completed by 1936:

(a) At the scale of 1:20,000 and a contour interval of 10 m. (made for *Mapa Nacional*): 266,000 hectares (1027 sq. miles) in the Pyrenees and Canary Island area.

(b) At the scale of 1:20,000 and a contour interval of 10 m. destined for the *Cartografia Militar:* 854,000 hectares (3,297 sq. miles) in the *Marruecos y Sierra de Guadarrama* area.

(c) At the scale of 1:10,000 and a contour interval of 10 m. (destined for different *Cartografia Militares:* 85,000 hectares (328 sq. miles).

La Sociedad Estereografica Espanola, founded in 1916 by Sr. Torroja, employed a Stereoautograph (Orel-Zeiss) to make numerous photogrammetric maps at the scales of 1:100 to 1:1,000. An outstanding example was the plan of the *Puente de Toledo* (Madrid), at the scale of 1:100 with details at 1:20. Aerial photography was used, rather than terrestrial, to accomplish this plan.

La Compania Espanola de Trabajos Fotogrametricos Aereos was organized in 1927. This company completed many photographic flights and photogrammetric surveys which included photo mosaics for governmental and private purposes.

4. In 1930, the use of aerial photogrammetry for normal photogrammetric surveys was instituted. The full development of photogrammetry was prevented by the war years of 1936 to 1939. Since 1940 to the present, the following centers have applied photogrammetry to their cartographic endeavors:

4.1 *Instituto Geografico y Cadastral*

(a) The accomplishments of the "*Mapa Nacional.*"—Maps at a scale of 1:25,000 were drawn with the aid of terrestrial and aerial photogrammetry. These maps are made for the *Mapa Topografica Nacional* which is at a scale 1:50,000. The field work for terrestrial photogrammetry was completed with two Zeiss and one Wild photogrammetric instruments. The office work was done with a Cartograph (Ordovas) constructed by Kern and a Stereoplanigraph (C-3, Zeiss) acquired in 1928. The Army Air Force or private concerns obtain the aerial photography with a normal Zeiss $8\frac{1}{4}$-inch camera giving a 7 by 7-inch

negative. The average scale of the aerial photography is 1:18,000 with a forward overlap of 60% and a side lap of 30% which are the requirements necessary for normal coverage. The stereoplotting instruments used are a Nistri Multiplex, a Zeiss Stereoplanigraph and a Multiplex Aeroprojector. The *Instituto Geografico* also makes use of a Zeiss Radial Triangulator, and a laboratory for sensitometry and optics where are found a Zeiss Sensitometer, a Zeiss optical bench, a densitometer, a spectrometer and other accessories. The plotting done by the *Mapa Nacional* covers an area of 800,000 hectares (3089 sq. miles) on 16 sheets.

(b) *Catastro Topografico Parcelario.*—They use a photograph 19.7×23.6 inches at a scale of 1:5,000 that is obtained by rectification. Control points are established in the field for conveniently selected photographs, and with the aid of some optical linkages in the rectifier, the necessary auxiliary control points can be obtained for eventual rectification of the photographs. This rapid and economical procedure gives sufficiently precise results. One Wild and two Zeiss rectifiers have been used to survey some 220,000 hectares (849.4 square miles) by this method.

Servicio Geografico del Ejercito

(a) Maps destined for *Mapa Nacional.*—In collaboration with the *Instituto Geografico,* sheets more suitable for photogrammetric surveying are completed by means of aerial photogrammetry. The *Seccion de Fotogrametric* does not do all the work exclusively, but cooperates with the *Comisiones Geograficas* which has work recommended to it by the *Mapa Nacional* for normal topographic surveying, for example:

Determining municipality boundaries that do not follow a characteristic line of terrain;

Trigonometric leveling of roads of intercommunication, in order to fix a vertical control station on each boundary;

Checking and revising photographic interpretation in the field, completing details that aren't identifiable on photographs, e.g., transmission lines, culverts, wells, water springs, etc., and establishing place names.

Subsequent surveying is based on an intensification of the network of horizontal control as observed by the *Instituto Geografico,* and the vertical control as obtained from trigonometric leveling of roads. These sources are utilized for scaling and plotting stereoscopic pairs of photographs. In cases where the number of points obtained is insufficient, a small photogrammetric field party is organized, solely to obtain the necessary additional control.

The photogrammetric maps obtained from the aerial photography, similar to that used by the *Instituto Geografico,* are completed by the Spanish Air Forces or are contracted out to be done by private concerns. The plotting is performed utilizing one Zeiss Stereoplanigraph (C-4 acquired in 1936), two Zeiss Multiplex, and two Zeiss rectifiers (for population plans).

The photographs have an average scale of 1:20,000, and the plotting is done at a scale of 1:10,000 which is reduced to 1:20,000. This reduction is done by means of a Coradi pantograph in the Multiplex, and by means of gears in the Stereoplanigraph.

From 1941 to early 1949, 787,000 hectares (3,039 square miles) were plotted on 22 sheets of the *Mapa Nacional.* Some 240 photographs were used for each sheet, and the average hourly rate of production in square miles is:

	Mountainous Country	*Rolling Country*	*Flat Area*
Stereoplanigraph	.23	.30	.51
Multiplex	.13	.35	—

Multiplex was so much slower in mountainous areas because identification of planimetric detail was very much more difficult. The altitude at which the photography was flown precludes the use of Multiplex for mapping flat areas because of extreme difficulty in contouring and insufficient accuracy obtainable with the instrument.

(b) Revisions done by the *Mapa Nacional.*—In order to make a new edition of exhausted or nearly-exhausted maps of the *Mapa Nacional*, it is necessary to start to bring up to date and to revise the corresponding manuscripts. This process is done at a scale of 1:25,000 in cooperation with the *Instituto Geografico*, the *Servicio Geografico del Ejercito* and the Spanish Air Force.

If the photographs to be used are not the correct size or focal length for the plotting equipment available at the *Servicio Geografico*, they are examined stereoscopically and compared with the original manuscript. Changes due to revision and because of the need of bringing these manuscripts up to date, are pointed out to the *Comisiones Geograficas* so that they can make the changes by ordinary surveying methods. In flat areas, some detail can be plotted by the Zeiss stereoscopes equipped with a stereometer. Until the date of this paper (Feb. 1949), 78 editions were revised by this method.

(c) *Cartografia Militar.*—The photogrammetric originals at a scale of 1:20,000 prepared for the *Mapa Nacional*, are also used for fire control maps at the scale of 1:25,000 and a great deal at 1:10,000. The *Seccion de Fotogrametria* cooperates with the *Comisiones Geograficas* by surveying the areas that would present great difficulties to ordinary surveying methods. Aerial and terrestrial photogrammetry are used for such surveys, besides the work that was initially done for the *Mapa Nacional.* Since 1940, some 50,000 hectares (193 square miles) at the scale of 1:10,000 and a contour interval of 5 meters, were plotted for this agency.

Catastro Parcelarie (Land taxation).—In expectation of the *Instituto Geografico* forming the *Catastro Topografico parcelario*, the Minister of Finance organized the *Avance Catastral.* Rectified prints and enlargements are used as an aid in determining land taxes. The average scale of the photography was 1:7,000 and the photography was rectified to eliminate all tilt by the Zeiss and Wild Rectifiers. The focal length of the photography was 25 cm. The central part of each photograph was enlarged to a scale of 1:2,000 to 1:3,000, to be used as photomaps. An error of 5% in area is considered admissible considering the purpose of the measurements is for land taxation. Photomaps covering an area of 5,176,000 hectares (about 20,000 square miles) were completed.

Ejercito del Aire (Army Air Force).—As already mentioned the Army Air Force has played a great part in flying the photography for the two cartographic centers that do the plotting, i.e., the *Instituto Geografico y Catastral* and the *Servicio Geografico del Ejercito.* This organization does some plotting for making mosaics and photomaps. For these purposes, use is made of a Zeiss Radial Triangulator, two Zeiss multiplex, a Nistri multiplex, and several Zeiss stereoscopes with stereometers.

Compania Espanola de Trabajos Fotogrametricos Aeroes (C.E.T.F.A.) (A Spanish private company dealing in aerial photogrammetric work).—The methods employed in handling photogrammetric work are similar to those of the Air Forces. This company flies the photography for the *Instituto Geografico* and the *Servicio Geografico.* For making mosaics and producing photomaps, a Hugershoff Aerocartograph and a Zeiss Rectifier are used.

5. From the foregoing, one can visualize the intensity with which Spain has applied and developed photogrammetry. In spite of all the efforts undertaken,

many different types of difficulties were encountered, such as acquiring photographic sensitized material, especially film, and replacing the present antiquated aerial cameras. There is a strong need for cameras equipped with statoscopes, horizon or other type cameras that are useful in aerial triangulation, and those that can be used with our stereoplotting instruments. Almost all of our equipment has been German, which has given and is giving excellent results.

From February 1949 to December 1949, 16 sheets of the fire control maps (sheets which can be used for the *Mapa Nacional*) were prepared, which brings to about 790,000 hectares (3,050 square miles) the total area mapped by the *Servicio Geografico del Ejercito* since 1941 at the scale of 1:20,000 using photogrammetric methods.

A DISCUSSION OF DR. SARALEGUI'S PAPER*

O. S. Reading, U. S. Coast and Geodetic Survey

"O wad some power the giftie gie us
To see oursel's as others see us!
It wad frae monie a blunder free us
And foolish notion."

ROBERT BURNS

DIRECTOR SARALEGUI has done the members of the American Society a great service by his frank paper published in March 1950 PHOTOGRAMMETRIC ENGINEERING. Such friendly critical comments will cause many of us to re-examine carefully the premises on which our photogrammetric efforts are based. Perhaps a few of us will redirect our efforts to better advantage because of his letter.

I suppose it is both a strength and a weakness of every human mind that it tends to seek that which builds up its previously held ideas and to overlook that which tends to contravert them. A strength in that this assures the maximum reinforcement of efforts to carry out the ideas; a weakness in that one sometimes overlooks important information that can be more economically used near the start than by revising procedures later; or that would enable one to accomplish much more with the time and money available to him.

After much travel and many discussions, it seems to me that there is little difference in intelligence between the leaders in photogrammetry in the different countries. The rather marked differences in instruments and procedures used are rather due to:

(1) The different needs or problems met and comprehended.
(2) The different assumptions made as to what is most important among the needs and methods, some of which must be compromised.
(3) The "building blocks" of skills, materials and machines available.
(4) National security, national pride, tariffs and trade restrictions.

If the differences were due to differences in basic intelligence, little could be done about it. There would be little use for technical societies, meetings and publications, national or international. But fortunately much can be done about correcting assumptions, exchanging techniques and skills, and in calling attention to successful answers already worked out to meet common problems and needs.

The first step in such profitable exchanges is a frank critique of the differ-

* PHOTOGRAMMETRIC ENGINEERING, Vol. 16, No. 1, March 1950, pp. 128–131.

NOTE: Comments on this paper are invited. To ensure consideration for publication in the December Issue, receipt before October 15 is necessary.