*Some Results from International Mapping Experiments**

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ABSTRACT: *At the intermediate meeting of Commission IV of the I.S.P., held in September 1954 in Rome, it was decided to organize international mapping experiments at scale 1:50,000. The French Institut Geographique National established for this purpose a test area in Southern France the size of which is 170 square km. Aerial photographs made to the specifications of various participants were used for the detailed plotting. Ten plottings were submitted by non-European countries. Plotters such as Multiplex, Kelsh, Wild A6, Wild A8, Wild A5, Wild A7, and Gamble, were used. The accuracy, completeness and efficiency of the performed plottings were analyzed. The paper contains the results of these international experiments in an abbreviated form.*

THOSE who attended the International Photogrammetric Congress in Washington in 1952 will recall the motion at the plenary session of the International Society of Photogrammetry which called for organizing international mapping experiments. After detailed discussion Commission IV set up three committees to carry out experimental work in three different fields: photogrammetric cadastral mapping, mapping of urban areas, and experimental mapping with a topographical scale 1:50,000.

I believe it is the first time in the history of photogrammetry that experimental work has been executed on an international basis. The importance and advantages of such an arrangement are quite obvious. In an applied science such as photogrammetry there are very many questions which can be answered only by actual experimentation. Because of the numerous experiments that are necessary in order to reach correct conclusions, the procedure becomes expensive. But when several organizations with a common interest in mapping jointly embark on a project of this kind, a great deal of statistical material can be gathered in a relatively short period with the minimum financial outlay by each individual participant. These results can then be analysed by experts and become available to all interested persons particularly those participating in international experiments. I believe that, in many instances, this is the only satisfactory way of assembling large quantities of unique statistical material. Without doubt the decision to carry out such experiments was one of the merits of the Washington Photogrammetric Congress.

It is generally agreed that much of the information gained from the recent international experiments is extremely interesting and valuable. In this regard I call attention to the reports submitted at the Congress in Stockholm by Dr. Harry, Dr. Dubuisson, Professor Bachmann and by myself. Being directly responsible for a part of this work I will report on some of the results as far as concerns mapping experiments with the scale of 1:50,000.

At the outset I should mention an excellent test area of about 70 square miles that was provided by the French Geographical Institute. In addition to providing all the required ground control and check data, the Institute carried out numerous photographic flights with the equipment specified by the various participants. Without this generous help by the IGN the planned experiments would not have been possible.

In all, there were 12 participants who submitted sixteen plots of the said test area, using photography taken at different scales, and employing different plotting

* Presented at Society's 23rd Annual Meeting, Hotel Shoreham, Washington, D. C., March 4, 1957.

equipment. That represents rather unique experimental material.

At this time I will report only on the results from non-European countries for which I was responsible. In all 10 plots were submitted. Four different cameras were used. The photographs with the larger scale were made with a Fairchild K-224 camera, equipped with Metrogon lens; the photographic scales were 1:42,000, and 1:50,000. The Wild RC5A camera equipped with Aviogon 6″ lens was used for photographs on a scale 1:53,000. Three other participants specified a Wild RC7 plate camera equipped with Aviogon f=100 mm. and the photographs were made with a rather small scale of 1:87,000. Finally, one of the participants requested still smaller scale photography 1:100,000, taken with a Williamson Eagle V camera, and having a focal length of about an 83 mm. The scales were decided by the participants. Their choice is very interesting. It demonstrates clearly the possibilities of photogrammetry in the field of small and intermediate scale mapping. In view of prevailing operational conditions. however, it would be more interesting if instead of plate photography, photographs were taken from the same flying height, using film cameras with a 6″ focal length.

With regard to mapping equipment, compilation from the smallest scale 1:100,000 was performed on a Bausch and Lomb Multiplex. Very rigid accuracy requirements were set for the experimental plots. For the participant using small-scale photographs and a Multiplex as a plotter, it was probably obvious from the very beginning that the results could not possibly meet the accuracy specifications. I suspect that the above combination was used in order to demonstrate the feasibility of its application to mapping under-developed countries utilizing a smaller scale than 1:50,000.

Another plotting was done with an engineering model of the Gamble Plotter and consequently the results cannot be considered conclusive. K-224 Metrogon 1:42,000 photographs were used in this plotting.

The next three participants used the Kelsh plotter. Two of them used Metrogon photographs made with 1:42,000 and 1:50,000 scales; the other used RC5A Aviogon 1:53,000 scale photographs. It is fortunate that several plottings were done on the same plotting machine as this permits drawing more valid conclusions.

As a European counterpart to the Kelsh plotter, there are two second-order plotters, the Wild A6 and Wild A8. However, the scale of photography used was much smaller than in the previous case, being 1:87,000. These photographs were made with a Wild RC7 plate camera at almost 30,000 ft. flying height. Finally, we had three participants using first-order plotting machines: Two Wild A5's and one Wild A7. The photographs from which the plottings were made are the same as in the previous group; that is RC7 plate photographs, scale 1:87,000.

As compared with this selection of photographic and plotting equipment, European participants used Italian, French and Swiss aerial cameras and the following plotters:

> Poivilliers, Type BP and D,
> Stereocartograph Santoni Model IV, and
> Wild Autograph, Type A7 and A8.

The scale of photographs ranged from 1:32,000 to 1:87,000.

As a follow-up to this preliminary information on the equipment and photographic material involved, it is necessary that I completely omit the specifications for the conduct of the test and the plotting procedure used by various participants. Instead, I shall immediately jump to the results hoping that time will permit me to indicate some very interesting conclusions.

OBJECTIVE

The objective of this experiment can be defined as follows: using large quantities of statistical material to determine the accuracy, completeness and efficiency of photogrammetric mapping when different aerial cameras and plotting equipment are used.

ACCURACY DETERMINATION

The accuracy determination is relatively simple. On Table 1 elevation errors determined from 100 ground-control points have been tabulated. The results are tabulated in chronological order as submitted to us. In column No. 2 we have listed the plotting machine used, then the aerial camera, flying height and resulting photo scale. Column No. 5 shows the mean-square elevation error and the next

TABLE 1

ELEVATION ERRORS DETERMINED FROM 100 GROUND CONTROL POINTS

Nr.	Plotting Machine	Camera	Flying Height H m	Photo Scale	Elevation Error	Elevation Error in % of H	Corresponding Horiz. Parallaxes $dp = dh \cdot \frac{b \cdot f}{h \cdot h}$	Maximum Elevation Error	No. of Ground Control Points Used
1	2	3	4	5	6	7	8	9	10
		RC7							
1	A5	f=100 mm.	8,700 m.	1:87,000	±1.5 m.	0.17%	10μ	3.4 m.	26
2	A8	f=100 mm.	8,700 m.	1:87,000	±2.4 m.	0.28%	17μ	5.2 m.	26
3	A5	f=100 mm.	8,700 m.	1:87,000	±3.2 m.	0.37%	22μ	6.4 m.	14
4	A6	f=100 mm.	8,700 m.	1:87,000	±2.6 m.	0.30%	18μ	6.5 m.	14
5	A7	f=100 mm.	8,700 m.	1:87,000	±1.9 m.	0.22%	13μ	6.4 m.	13
6	Gamble Plotter	K224 f=153	6,250 m.	1:42,000	±2.9 m.	0.46%	41μ	9.5 m.	30
7	Kelsh	f=153	7,600 m.	1:50,000	±1.7 m.	0.22%	20μ	4.2 m.	27
8	Kelsh	RC5 f=153	8,100 m.	1:53,000	±1.8 m.	0.22%	20μ	5.1 m.	37
9	Kelsh	K224 f=153	7,600 m.	1:50,000	±2.4 m.	0.32%	29μ	6.1 m.	31
10	Multiplex	Eagle V f=83	8,000 m.	1:100,000	±7.6 m.	0.95%	45μ	18.2 m.	9

column the elevation error expressed in per cent of flying height. Since various aerial cameras of different focal-lengths have been used, we thought that the efficiency of the plotting equipment would be best characterized if the scale of the photographs were taken into account. Therefore, we expressed elevation errors by corresponding horizontal parallaxes in the plane of the photographic image. Column No. 9 shows the maximum errors in elevations. Finally, in the last column is recorded the number of ground control points used for the plotting of the test area. This information is important for a proper interpretation of the accuracy obtained.

1. Examining the table in detail, it is evident that the best accuracy in elevation is shown as obtained by the first participant using A5 as the plotter and RC7 photographs. This result is surprising since a plotting from identical photographs was made on an A7, which without doubt is a more precise plotter than the A5. There are a few possible explanations for this but for the moment I draw attention to the fact that for the A7 plotting, only half the number of ground control points were used.

Surprisingly enough, for the first plotting as well as for the second, no compensating plates for the distortion of aerial cameras were used.

2. The second plotting seems to be in agreement with what can be expected from the combination of A8 and RC7 photographs. On the other hand, the difference between this plotting and plotting No. 4, made from identical photographs on an A6, is not significant, especially if the number of ground control points used in both cases is taken into account.

3. The result of the third plotting is somewhat poor in comparison with plotting No. 1, and also with Nos. 4 and 5, in which an almost identical number of ground control points were used. A comparison of the value of horizontal parallaxes, corresponding to the elevation error in this plotting—with other similar values—indicates also that this value is relatively high. Distribution of errors in particular models might give a clue in locating the cause of these errors.

4. On the other hand results of the plotting of an A6 carried out by the same organization can be regarded as better than can be expected.

5. Better results are to be expected from the plotting with an A7 than those which were obtained by the first participant using an A5 but I think we can agree that they are quite representative for this type of machine.

6. Regarding plotting No. 6, an engineering model of the newly-designed Gamble plotter was used and only a portion of the test area was plotted. Therefore, the results must be accepted with reservations.

7, 8, 9. The next three plottings were done on Kelsh plotters and the agreement between the first two is amazing. These are plottings from two organizations from different countries. In plotting No. 8, RC5A, 240 mm.×240 mm., Aviogon photographs, without compensating devices for distor-

TABLE 2

ACCURACY OF CONTOURING AND PLANIMETRIC ACCURACY

No.	Plotting Machine	Photo Scale	Average Elev. Error in Contouring (Low Relief)	Systematic Part	Planimetric Accuracy
1	Wild A5	1:87,000	±1.3 m.	1.2 m.	0.09 mm.
2	Wild A8	1:87,000	±1.4 m.	0.3 m.	0.14 mm.
3	Wild A5	1:87,000	±3.3 m.	2.8 m.	0.07 mm.
4	Wild A6	1:87,000	±3.5 m.	3.3 m.	0.08 mm.
5	Wild A7	1:87,000	±2.8 m.	2.8 m.	0.08 mm.
6	Gamble Plotter	1:42,000	—	—	—
7	Kelsh	1:50,000	±1.4 m.	1.2 m.	0.08 mm.
8	Kelsh	1.53,000	±1.0 m.	0.4 m.	0.09 mm.
9	Kelsh	1:50,000	±2.7 m.	2.4 m.	0.08 mm.
10	Multiplex	1:100,000	—	—	—

tion on the Kelsh plotter, were used. The third result is somewhat poorer for rather obscure reasons, since the aerial photographs and number of ground control points used in the plotting are very similar.

10. The last result, as can be expected, gave a much lower accuracy. We should, however, not overlook the fact that only 9 ground control points for the total area were used.

The *accuracy of contouring and the planimetric accuracy* are shown in Table 2.

Analyzing these very interesting results in more detail would require too much time. One important item is the occurrence of systematic errors. The accuracy of contouring in flat and mountainous terrain is another interesting problem. The next point of our investigation is the completeness of the various plots. The completeness of the plotting, which in my terminology also embraces correctness of the interpretation of various plotted details, would be best established by comparing the plotting results with the ground. Since this was impractical we checked the contents of various plots against very detailed plots of scale 1:20,000, from low-altitude photographs, provided again by the French Geographical Institute. As this large-scale plot has been checked on the ground, it is quite reasonable to accept it as a checking reference.

The question, however, of how to express the completeness of the maps needs very thorough study and discussion. A mechanical counting of the details not included, or incorrectly presented on the map, and expressing the results percentagewise in the total number of details which should be included, does not convey a proper picture. It is obvious that the omitted details are rather small objects. Their existence may often be expected, but plotting was omitted because of insufficient evidence for their objective identification during the mapping process.

Some details may be very important, for instance, communication lines, bridges, rivers etc. The majority of them, however, are only of limited importance and in any case do not affect the usefulness of the map to the degree which could be suggested by the percentage number of omitted details.

It is still more difficult to establish the relationship between the number of omitted points and the over-all cost of the map. To a certain degree, these omissions are caused by the equipment and procedure used in the mapping process, but in the main they are due to the basic shortcomings of the photogrammetric method. There are obviously specific details which cannot be included in the map other than by a field identification procedure. It is interesting to note how many details requiring field identification exist. Do they represent 10, 20, 50 or even a larger percentage of all details presented in a map?

The preceding are only a few of the many similar questions and remarks which have been brought to light by the international mapping experiments. To some of these questions we obtained an answer or, at least, very valuable information. Many however require further study and analysis.

Following these few remarks some general results will be shown.

TABLE 3

COMPLETENESS NUMBERS

Participant No.	Scale of Photographs	Plotting Instrument	Percentage of Correctly Plotted Details
8	1:53,000	Kelsh	60%
3	1:87,000	Wild A5	58%
4	1:87,000	Wild A6	58%
7	1:50,000	Kelsh	56%
1	1:87,000	Wild A5	52%
5	1:87,000	Wild A7	50%
2	1:50,000	Kelsh	47%
9	1:87,000	Wild A8	47%
10	1:100,000	Multiplex	37%

To assess the completeness of the various plottings we compared the same sections from each plot with identical sections from the larger scale French plot.

The type of details used in the checking procedure is shown in Table 4.

As has been stated the completeness of the figures must be regarded as comparative numbers and not their absolute value. There are some apparent contradictions which, however, are explainable, if the plotting procedure is taken into account. For example, plots Nos. 3 and 5 might be mentioned. Both are from identical photographs and the plotting machines used were Wild A5 and A7. No doubt, the A7 is a much superior plotter as compared to the A5, and in particular, its viewing system is better. Nevertheless the completeness of the plot made on the A5 is greater. The explanation lies in the fact that the plot on the A7 was made by one person only, who was a good operator, but of limited visual acuity and without an assistant at the plotting table. Consequently, there are many omissions which are not attributable to failures of photographic material or plotting equipment.

Disregarding these minor differences, the fact remains that an astonishingly high percentage of details which should be shown on the maps were omitted, and it appears that there is no other way of improving this situation except by field-checking or perhaps by a proper check from low-altitude photographs. Using the Kelsh plotter and photo interpretation as a separate step in the mapping procedure only a relatively slight improvement in the completeness of the map is achieved. The European results are only slightly better as far as the completeness is concerned. However, I must skip this point again and instead will show a time chart which has a direct bearing on the over-all cost of the plotting.

In columns 8 and 9 of Table 5, the machine time of the plotting is tabulated. The best time is for a A6 followed very closely by the plotting done on a Wild A7. Then we have a plotting on a Kelsh and another plotting on a Wild A8 and so on. For comparison purposes, it is better to express the plotting time in relative numbers accepting the best time as a unit.

On Table 6 the efficiency numbers are in the second column. The same efficiency numbers are in the last column; these were computed for a certain category or type of plotting machine used instead of the single plot. I think these results are extraordinarily interesting.

Also of interest is the time used for drawing in ink. This is often longer than the total plotting process. This phenomenon represents a striking example of a lack of proper balance in the mapping process.

TABLE 4

	1:53,000 Kelsh	1:87,000 Wild A5	1:87,000 Wild A6	1:50,000 Kelsh	1:87,000 Wild A5	1:87,000 Wild A7	1:50,000 Kelsh	1:87,000 Wild A8	Multiplex	Average
Buildings	81	81	49	76	70	67	66	63	55	68%
Roads	53	81	70	90	64	62	67	64	53	67%
Railroads	100	100	100	100	100	100	100	100	100	100%
Bridges	50	50	33	100	33	50	33	33	0	42%
Power Houses	100	100	100	100	100	100	100	100	—	100%
Churches	0	0	0	—	0	0	50	0	0	6%
Cemeteries	0	0	0	—	0	0	0	0	0	0%
Quarries	100	100	100	100	100	100	100	50	0	83%
Dams	100	100	100	100	100	100	100	100	—	100%
Rivers	89	43	100	100	64	54	54	60	59	69%
Cuttings	0	0	0	0	0	0	0	0	0	0%
Embankments	0	0	0	0	0	0	0	0	0	0%
Vineyards	0	0	0	0	0	0	0	0	0	0%
Individual trees	100	100	75	10	25	44	0	0	75	48%
Village	61	50	83	—	85	75	78	73	65	71%
Forest	100	100	100	—	100	100	50	100	75	89%
Hedgerows	94	75	69	10	50	0	0	50	70	46%
Average	60%	58%	58%	50%	52%	50%	47%	47%	37%	

TABLE 5

Nr.	Plotting machine used	Photo Scale	Operator	Draftsman at table	Time											Size of plotted surface
					Preparation	Interpretation	Relative and Absolute orientation	Plotting	Drawing	Checking	Total	Drafting in ink on plotting table	Final drawing	Other	Total	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	A5	1:87,000	1	1*	3.5		19.5	141.5	39.5	21	225	142.0				166 km.^{2}
2	A8	1:87,000	1	1*	11.0		21.0	119.7	6.3	8.3	166.3	147.0				166 km.^{2}
3	A5	1:87,000	1		6.0		13.2	170.0	47.5		236.7					166 km.^{2}
4	A6	1:87,000	1		9.5		17.0	79.0	47.0		152.5					166 km.^{2}
5	A7	1:87,000	1		2.0		10.5	86	57.5		156.0					166 km.^{2}
6	Gamble	1:42,000	1		13.5		1.3	52.5	14.0	7.0	88.3		27.0			53 km.^{2}
7	Kelsh	1:50,000	1		31.0	93.0	46.5	119.0	70.0		359.5		250.0	8.5	618	126 km.^{2}
8	Kelsh	1:53,000	1	1*	26.0	24.0	24.0	334.0		98.0	506.0	248.0	104.0	40.0	898	166 km.^{2}
9	Kelsh	1:50,000	1		9.0		17.7	172.0	26.7		225.0					166 km.^{2}
10	Multiplex	1:100,000	1		?		14.0	97.0	14.0	5.0	130.0					60 km.^{2}

* Draftsman inked the manuscript on the plotting table.

TABLE 6
EFFICIENCY NUMBERS

Plotter	Efficiency Numbers Machine Time Only	Class of Plotters	Efficiency Numbers Machine Time Only
A6 A7	1.00 1.05	II—order plotters (A6+A8)	1.2
A8 A5	1.46 1.67	I—order plotters (A5+A5+A7)	1.7
Kelsh A5 Kelsh	1.72 1.90 1.97	Kelsh (Kelsh+Kelsh+Kelsh)	2.7
Multiplex Kelsh	3.20 3.72	Multiplex (Multiplex)	3.2

Plotting of the manuscript on the instrument is, after all, the actual creative work as far as the production of a map is concerned. The rest is just a cosmetic treatment, but it appears to be more expensive than the product itself.

CLOSURE

From the detailed analysis of certain figures many other equally interesting observations can be reached. As I mentioned the complete report will be published in one of the photogrammetric journals and I hope it will be found worthy of detailed study. To attempt to report in 20 minutes the results of experimental work covering such a wide field is a difficult and sometimes discouraging task. By restricting the report to a few items only, it is very easy to create misconceptions and even wrong impressions. A few closing remarks are therefore appropriate and needed.

The international experimental work in the field of mapping is no doubt a great achievement and an outstanding example of the coordinated and collective efforts of many countries. As a result, we were able to gather extremely interesting and unbiased statistical material on an identical mapping operation. As soon as the results are published in full, not only the participant, but any person interested, will be able to study the comparative data and reach his own conclusions. The greatest advantages obviously will be obtained by the participants. Knowing from their own experiences all the details of the mapping test, they will be able to compare their own approach and efficiency with about a dozen other participants. In comparison with this unique opportunity the financial cost of the experiment to a single participant is very insignificant and can be expressed by a few hundred manhours of work. This advantage was appreciated by certain private photogrammetric outfits, which not only participated in the experiments, but also turned out some excellent results.

In planning the first international experiments in mapping, certain basic philosophy was laid down. The results, generally speaking, met the expectations. Obviously, many questions remain to be answered, some of them arising from the results of the first experiments. At the same time, we gained invaluable experience in the organization of this type of international experimental work and discovered where various improvements could be made.

Returning to more domestic matters, I should mention that two mapping agencies from the United States participated in these experiments and supplied most valuable data. However, I cannot suppress a feeling that the U.S.A. participation in this international experiment did not give a complete cross-section of the manifold character of American photogrammetry. I think this is very regrettable, not because it is important whether something can be done equally well or better in the United States than in other countries, but because I am convinced that techniques are employed in U.S.A. which could be used to advantage by others working in photogrammetry. I also recall that during the last international congress in Stockholm, I had occasion to exchange views with prominent members of your Society on the subject of U.S.A. participation in the international photogrammetric activity, and it was agreed that this participation is not in proportion to the extremely dynamic development of photogrammetry in this country. We also felt that during the next few years, prior to the next Congress, this situation ought to be changed.

In accordance with the decision of the International Society of Photogrammetry, experimental work along the lines described in my short talk will be continued. As a member of the Canadian and American Photogrammetry Societies, we should decide upon our participation in this activity now. Also it would be worthwhile to consider the use of our own test area on this continent in order to experiment with techniques which are in use here.

The Measurement of Elevation Differences by Photogrammetry Where No Elevation Data Exist

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ABSTRACT: *This paper presents a rapid and simple method for determining approximate ground elevation differences by photogrammetry. This method has been used in Creole for about four years as an aid to the geologist and engineer, but to the author's knowledge has never been published. It is not unlike other methods in principle, in that it measures parallax differences as an expression of differences of ground elevation. However it ignores the flying height; reduces the photographic scale of the spatial model to a given datum; uses a transparent templet for parallax and other photographic measurements; limits itself to the geometry of the lens-photographic plane, except for one final step; then utilizes one measured horizontal distance to determine the absolute height difference required, within a ten per cent precision range; and it requires the use of no special devices.*

THE Creole field geologist has been trained in the use of air photographs as an aid in planning, orientation and measurement. Through the medium of photogrammetry, he can measure or check the thickness of a stratum; or make a topographic profile for a geological cross-section.

He has been taught to make these measurements simply and rapidly with a few simple tools. These tools consist of a stereoscopic pair of vertical photographis, photogrammetric map, stereoscope, millimeter scale, triangle, needle, pencil, grease-pencil, scratch pad and transparent templet approximately of the size of a photograph.[1] It takes him about ten minutes to determine the height of a hill with an accuracy of within ten per cent. He does not have to know nor determine the photo scale, nor airplane height; nor does he worry about lack of good reference points, either vertical or horizontal. He does need the approximate focal length of the air camera. He makes one measurement on the map; the rest is done on the photographs with the aid of the templet.

[1] If the operator wishes, he may also use a conventional parallax bar instead of the templet.