THE APPLICATION OF PHOTOGRAMMETRY TO THE SURVEY IN GEOPHYSICAL AND GEOCHEMICAL EXPLORATION IN CHINA

Chi Ming
Technicist
The Surveying and Mapping Battalion of
Southwest China Mettalurgical Geological
Prospecting Co.
East People's Road
Kunming, Yunnan Province
People's Republic of China

ABSTRACT

For a long period, the surveying work was backward in the field of geophysical and geochemical exploration (GPCE). In traditional method, the coordinates of the GPCE network were determined by using theodolite, and the heights of the points of the network were determined by level survey. This traditional surveying method, of course, is unable to meet the need of the rapid development of the new GPCE technology...... The application of photogrammetry to this field, instead of the traditional method, has a good and efficient result. This paper is to describe such development in China. And the different methods, results and their accuracy will be given below.

INTRODUCTION

In geological exploration for mineral deposits, the GPCE is one of the important means. And the surveying work on the GPCE network is its basic work. The purpose of the survey in GPCE is to lay out the network in the field and to determine the coordinate and the height of every observing point in the network before the beginning of the GPCE. All GPCE methods have no requirement for height except the method of gravity, electrical sounding and cross-section. The layout of the network is to locate observing points with certain distances at straight lines. The GPCE network is formed by many such orthogonal lines and the shape of the network is gene rally square or rectangle. These crossings are called observing points and the GPCE work will be carried on at these points. The GPCE work includes observing, sampling, indoor analysis and deducing,ect.

Generally, the surveying work in GPCE includes the two-level extension control under the state's Fourth-order and Fifth-order triangulation control network as well as the location of GPCE network.

In recent years, with the rapid development of science and technology, the GPCE methodology and technology are also improved rapidly. Compared to this improvement, the survey methodology in GPCE was developed slowly. It had been using traditional theodolite tacheometric and level survey to determine the coordinates and heights of the points and to locate the network. This method is just waste of manpower, materials and is lower-efficient and uneconomical. It did not meet the rapid development of exploration for mineral deposite. The situation appeared, in professional GPCE teams, that the surveying technicians were much more than GPCE technicians.

In these years, new surveying theory, technology and method have been used in the survey field of GPCE by technicians within different GPCE departments in various industrial ministries, such as geology, metallurgy, coal, as well as the department of surveying and mapping. In accordance with actual condition in our country, they have developed and applied photogrammetry to locate GPCE network. The first thing is to design the GPCE network, including its specification, direction, scale and the surveying method it will take, on the topographic map available according to the GPCE work scope, work method, work scale and terrain slope circumstances.

In our country, most of the land have now been covered by aerial photographs. So, it is possible to use these available materials to locate GPCE network with the method of photogrammetry instead of the traditional one. And it is unnecessary for specialized aerial photography. The practice has proved that, by using the photogrammetric method, it is economical and efficient, and the accuracy of the GPCE network is also higher than the old one. It has made a new way for the survey in GPCE.

METHODCLOGY

1. The Locate of GPCE Network on Photographic Plan

It is well-known that, in photogrammetry, the map-plotting on level and hilly terrain is completed by the method of planimetric air survey. Now, when the GPCE network is to be located on these two terrain types, it can use the corresponding method of photogrammetry. Firstly, try to get the surveying results concerned, including triangulation control and topographic maps and photographs in which the GPCE network is covered If these photographs have the result of control points on them, we can apply the control points directly to rectify the photographs on rectifier. Then put the GPCE network designed on the map onto the rectified photographic plan. After the photographic plan of GPCE network is completed, we can lay it out in the field according tothe corresponding points on both the photographic plan and ground. So far, the location of the GPCE network is fulfilled. If the terrain type is hilly land, we can rectify the photo in multiple-stage.

1.1 Planimetric Accuracy

In the normal case, error evaluation is as follows:

$$M = \pm \sqrt{Mc^2 + Mp^2 + Mi^2 + Md^2 + Me^2}$$

$$= \pm \sqrt{0.4^2 + 0.2^2 + 0.2^2 + 0.2^2 + 0.5^2}$$

$$= \pm \quad 0.73^{mm} \quad (\text{ on plan })$$

Where

M: mean square error of a point;

Mc: centring error on rectifier;

Mp: error of plotting points from layout plan of GPCE network to rectified photographic plan;

Mi: error of field interpretation;

Md: error of photo distortion;

Me: error of photogrammetric office control extension.

This shows, the accuracy of the location of GPCE network with this method has shut or is up to the accuracy requirement in GPCE. Actually, in the root above, the accuracy of office control extension is higher than that mentioned.

If the orthophoto is to be used, it is possible to be applied to any terrain type and the accuracy is certainly higher than that operated at normal rectifier. But at present, the orthographic device is too expensive and it can not be in use at every GPCE survey party. Therefore, the full use of the new available devices and surveying achievements to meet the needs of GPCE, if the expected accuracy can be reached, is, after all, a good way in doing this.

But, the method, described above, is merely possible to that which has no demand for height accuracy. If you plan to locate a GPCE network which demands for height, you can utilize another method described as follows.

2. Optical-mechanical method

In this method, the basic work of the location for GPCE network is accomplished on stereoplotter. Its foundation is the principle of geometric reversion of the photographic bundle of rays. That is to build a optical-geometric stereomodel indoor to restore the circumstances of aerial photography. This is, according to a pre-designed orthoprojected GPCE network points, to conversely seek their corresponding position and height on the central-projected aerial photographs. the steps are described heres:

After the comletion of office control extension, the horizontal and vertical control point on the photo covering the whole GPCE area can be obtained. Then, put all thess control points and designed GPCE network on polyster grid drawing film. After the relative and absolute orientation of stereoplotter is accomplished, centre the plotting head which is linked with stereoplotter to the crossing points of GPCE network and conversėly seek its designed points on the corresponding position of the central-projected photos and determine their planimetric coordinates and heights. Now, we have the orthoprojected GPCE network moved to the aerial photos. We have clearly seen that the program is just opposite to that of stereo map-plotiing on stereoplotter in photgrammetry. When this method is used, we are able to lay out hte GPCE network for any purpose at any terrain type and the height of the network can also be determined at the same time..

2.1 Planimetric Accuracy

The error by using this method mainly comes from the following:

- Mo: error of photo orientation on stereoplotter;
- Mt: point transfering error from normal photo to enlarged one which is convenient in field interpretation;
- Min: field interpretation error;
- Mp: error of plotting GPCE network on polyester grid drawing film.

So, the mean square error of a point;

$$M = \pm \sqrt{Mo^2 + Mp^2 + Mt^2 + Min^2}$$

$$M = \pm \sqrt{0.4^2 + 0.2^2 + 0.2^2 + 0.2^2}$$

$$= \pm \quad 0.53^{mm} \quad (\text{ on plan })$$

2.2 Height Accuracy

Considering field interpretation error, the height accuracy of a point is

$$MH = \pm \sqrt{MI^2 + (Mi \cdot tg\alpha \cdot M)^2}$$

Where

- α : terrain slope;
- M : denominator of the photo scale;
- MI: instrument accuracy.

This method is suitable for the location of the GPCE network on large and medium scales. If the small-scaled network is to be located, use the following method.

3. The Method of Analytical Aerial Triangulation

With the development of computer and computation technology, the analytical aerial triangulation is ripening and it has showed great advantage. When this method is applied to the survey in GPCE, it is most suitable to locate the small-scaled network in large area and to the location of gravity exploration, as well as to the network with an unregular form. The steps are as follows:

1) Find out observing GPCE points at aerial photos from corresponding designed plan on map, in field.

2) In the GPCE area, position the necessary field control points for office control extension on the photos.

3) Measure all these points on stereocomparator then obtain their planimetric coordinates and heights from computer. Finally, supply these known points to GPCE.

3.1 Planimetric Accuracy Estimate

If the GPCE network computation uses the program of the single flying strip, the planimetric accuracy is

$$ML = 0.28 \cdot k \cdot Mq \sqrt{n^3 + 2n + 46}$$

Where

ML: mean sqare error of the weakest part between the two neighbouring flying strips;

Mq: mean square error of weight unit of the measured vertical parallax (reducing it to photo scale);

n: base line number between control points;

k: ratio of the denominators of the photo scale and the map scale.

3.2 Height Accuracy Estimate

$$Mh = 0.088 \frac{H}{b} Mq \sqrt{n^3 + 23n + 100}$$

Where

Mh: mean square error of the weakest points between the two neighbouring flying strips;

H: mean absolute flying height;

b: mean base line of the photos.

When calculating with this formula, we generally make Mq=0.02.

3. 3 ~~Accuracy of Independent Model Triangulation~~

3. 3. 1 Planimetric Accuracy Estimate

When the area is in a square shape with four control points, we use this formula:

$$ML = (0.47 + 0.25n_s) \sigma oL$$

Where

n_s: number of flying strip covering the GPCE area;

σoL: mean square error of weight unit.

3.3.2. Height Accuracy Estimate

$$Mz = (0.34 + 0.22 iH) \sigma oH$$

Where

iH: length of the chain formed by height control points.

4. The Method of Space Resection

The large-scaled GPCE network location can also be laid out with the method of analytical aerial triangulation. But, the method here differs from that just mentioned above. That is, obtain GPCE points' coordinate values on central-projected photos from the corresponding points on a designed plan which is ortho-projected, through the collinearity equation. The equation is

$$X = -f \frac{a1 (Xt - Xs) + b1 (Yt - Ys) + c1 (Zt - Zs)}{a3 (Xt - Xs) + b3 (Yt - Ys) + c3 (Zt - Zs)}$$

$$Y = -f \frac{a2 (Xt - Xs) + b2 (Yt - Ys) + c2 (Zt - Zs)}{a3 (Xt - Xs) + b3 (Yt - Ys) + c3 (Zt - Zs)}$$

We have obviously seen that the planimetric coordinate of a designed GPCE network is a known factor. Therefore, if knowing the elements of exterior orientation of every photo, by using this equation, we are able to get to the destination (here, Zs is an unknown factor, we will explain how to obtain it hereafter.) After this , orientating the photo or enlarged photo on a coordinatograph, we can plot the points according to the calculated values of the coordinates on the photo. What should be noticed here is that the photo papers used for enlargement must be regular distortion. So, the calculated coefficient of magnification is only reliable. Then we interprete the position of point from the photos to the corresponding position in the field. The condition of using this method is that there should be aerial photos covering the whole GPCE area, result of office control extension and maps which scales are equal or bigger than that of the working scale of GPCE, because in collinearity equation, it is necessary to know the elements of exterior orientation as well as the heights of crossing points on GPCE network. The elements of exterior orientation can be obtained from the result of office control extension and the heights can be obtained from the map . This method is suited to the GPCE networks which have no requirement for height (in GPCE, all exploring methods have no demand for height except a few, such as the method of gravity and electric sounding.) But, it can be used to determine the planimetric position for all GPCE method.

4.1 Planimetric Accuracy

Generally, the difference between the values of photographic spatial coordinates calculated through the collinearity equation and the values of the coordinates of corresponding points measure on stereocomparator before the computation are usually small than $\pm$ 0.25mm. This has been stipulated by the computer program. Now , the designed GPCE network which the computation relies on has no height except planimetric coordinate. But the height required in the collinearity equation, as just metioned, is obtained from the corresponding map of GPCE area. The error of getting height from the map is smaller. Now, let's have an analysis about it.

If we find the height of the point of GPCE network on the similar-scaled map, e.g. the scale at 1:10000, by putting it on the map precisely, the maxium of height error is $\pm$10m; Now , if the focal length of the camera is:

$$f = 154mm;$$

$$Zt - Zs = -2500m \pm 10m$$

then, the error of the planimetric position of a point:

$$Emax \leq \pm 0.40mm$$

It can be seen that the planimetric error affected by getting height from map is as small as we can expect.

According to the whole procedure of obtaining points' value of this method, the accuracy of point position is as follows:

$$Mp = \pm\sqrt{Mc^2 + Me^2 + Mo^2 + Mco^2 + Mt^2 + Mi^2}$$

$$= \pm\sqrt{0.25^2 + 0.5^2 + 0.1^2 + 0.1^2 + 0.2^2 + 0.2^2}$$

$$= \pm\ 0.64^{mm} \text{ (on plan)}$$

Where

Mp: mean square error of the point;

Mc: error of calculation by using the collinearity equation;

Me: point planimetric error of office control extension (usually, the accuracy of control extension is higher than that appeared in the root.);

Mo: error of photo orientation on coordinatograph;

Mco: error of coordinatograph;

Mt: error of point transferring;

Mi: error of field interpretation.

The advantage of this method is that it is unnecessary to measure the photographic spatial point's coordinates on any comparator, and it makes the full use of the known survey results and only a pocket programmable calculator is available. It has showed a great advantage to the department which has no photogrammetric device and instrument, especially those in developing nations.

5. Relative Accuracy of Base Line and Surveying Line* of GPCE Network

Now, considering that the distance error between two arbitrary neighbouring terrain points is equal approximately, we find that on the maps at various scales, the distance error between two arbitrary points is as in the following list:

terrain type \ metre \ scale	1:10000	1:25000	1:50000
level & hilly	5.0	12.5	25.0
mountainous district	7.5	18.8	37.5

From above, the relative accuracies of base line and surveying are listed below:

* Base line is a framework line, and surveying line is lines which form grid pattern in GPCE network.

scale	Base line L(km)	Base line relative Error	Surveying Line L(km)	Surveying Line Relative error
1:1000	1	1/1333	0.3	1/4000
1:2000	2	1/1333	0.6	1/4000
1:5000	4	1/1066	1.2	1/1320
1:10000	7.2	1/1388	2.5	1/1333
1:25000	15.0	1/1666	4.5	1/240
1:50000	30.0	1/1666	9.0	1/240

The mean square error of terrain point obtained by control extension is smaller than 10mm, and the mean square error of terrain point obtained through the collinearity equation is at 0.4-0.5mm. Therefore the accuracy of base line and surveying line got by the two methods can be raised by 1-4 times.

6. <u>The Layout of GPCE Network in Field</u>

All the methods described in this paper have showed a great advantage at the area with an open terrain as well as rich surface features on ground. At mountainous or high mountainous areas with a little surface features on the ground, they may meet some difficulties. But, if some measures are taken, they are still available and, at this time, the instrumental and semi-instrumental methods can be used. (such as compass and surveying rope.)

CONCLUSION

It is a success of applying photogrammetry to GPCE in geological exploration engineering even if it has got no experience at the area covered with thick grass and forests. And, the old and traditional method surffers by comparision. The new methods save not only a great manpower and the working amount in field but also can make the work more efficient by 4 times, especially, 2-3 times at mountainous areas, and it reduces the production costs by 60 to 70 percent. Its merit is that it has no errors accumulation and the accuracy of GPCE network is higher. What should be noticed here is that the accuracy will be mainly affected by using old or newly taken aerial photos; as well as the photo scale. The systematic error mainly comes from the error of control points, but this can be corrected by using statistical method .

REFFERENCES

1. Wang Zhizho, 1979, The Principle of Photogrammetry.
2. Qian Zengbo, 1980, The Fundamentals of Analytical Aerial Triangulation.
3. The Department of Photogrammetry of China Wuhan College of Geodesy, Photogrammetry and Cartography, 1979. Analytical Aerial Triangulation.
4. Li Quan, Dong Wenbi, 1981, The Discussion of the layout of GPCE Network by Using Aerial Photos, Yunnan Survey.
5. Cai Shijun, Lu Zhaowen, 1982, The Application of photogrammetric Technology in GPCE, Surveying and Mapping in HeiLongjiang Province.
6. Chi Ming, Zhuang Baofan, 1983. The Application of Analytical Triangulation to the Layout of GPCE Network, No.7, Surveying and Mapping in Metallurgy and Geology of China.