THE ANALYSIS OF CARTOGRAPHIC PROJECTIONS USED IN ROMANIA

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Abstract:*Basic documents that are made according to measurements and topographic surveying for the purpose of creating various projects are plans and topographic maps. Achieving these documents must accurately represent the earth's surface with its representative elements. These documents are made by using cartographic projections that must be analyzed according to the quality of the representation in order to obtain plans and maps with high accuracy and superior quality. Regarding the elements that can be deformed within a projection, these are angles, distance or acres. Between the years 1855-1857, the first map of Wallachia was made (also known as "Satmari Map") using the scale 1:57 600. This map contains the historical provinces Wallachia and Oltenia, and it is the first map under the name of Romania. After the First World War, due to economic, political and administrative reasons, the necessity arose for a large-scale map (1:20 000, 1:10 000 or even 1:5 000) by reproducing and multiplying existing land originals. The new cartographic documents, known as "drawing master plans" were drawn up in a unique projection throughout the country, namely the Lambert projection. After the Second World War, the Romanian Cartography has strongly developed. Thus, in order to obtain plans and topographic maps in the shortest time and at the lowest possible price, the Photogrammetry Center was established in 1958, which later in 1970 became the Institute of Geodesy, Photogrammetry, Cartography and Land Management (IGFCOT), where plans were drawn up to the scales 1:2 000, 1:5 000 and 1:10 000 required either by national economy, or for land records, or to urban planning. The modern topographic map was also created to the scale 1:25 000 (1972-1981) using the Gauss-Krüger transverse cylindrical projection. In Romania, over time many cartographic projections were used to create basic maps, as follows: Muffling polyhedral projection introduced in 1873 – for the Austrian map covering also Transilvania; Cassini cylindrical projection introduced in 1876 based on Bessel ellipsoid; Bonne equivalent conical projection introduced in 1873, based on Clarke 1880 and Bessel 1841 ellipsoid;Lambert- Cholesky conformal conic projection - introduced in 1917, based on Clarke ellipsoid; Gauss Kruger transverse cylindrical conformal projection introduced in 1951, based on ellipsoid Krasovski 1940; Stereographic secant conformal perspective azimuthal projection 1970 plan introduced in 1970, based on ellipsoid Krasovski 1940;UTM conformal secant transversal cylindrical projection (Universal Transverse Mercator) introduced in 1947 based on WGS 84 ellipsoid.*

Key words: *maps, cartographic projections, Muffling, Cassini, Bonne, Lambert- Cholesky, Gauss Kruger, UTM, Stereographic projection*

INTRODUCTION

Cartography is the science that studies the mathematical basis of maps, their methods of construction and multiplication. In general sense, cartography is the science that deals with the construction of maps. As an applied science, it aims at carrying out different types of mapping work required needs of the national economy and national defense. Therefore, the problems also mapped in establishing methods of preparation, preparation for editing, editing and editing maps and cartographic production organization and planning principles. Map is a document for many human activities, is used to guide the field research and design geographical, geological, agro, meteorological, ecological, etc. For military map is an essential document for the planning, organization and conduct of operations, battles and movements.

MATERIAL AND METHODS

Passing any part of the globe on a flat surface requires applying a projection system. The number of these projections is very large systems. For a better understanding of these projection systems, it is necessary to know some notions about the projections.

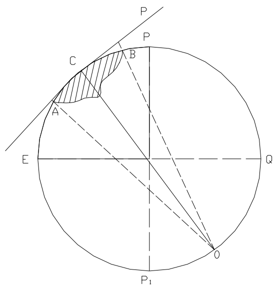

Figure 1: Elements of a projection system

- P is the projection plane surface that makes the design portion of the ellipsoid (Figure 1). Project plans are flat surfaces, tangent or secant to the area represented in the world, deployable surfaces of cylinder or cone form;
- the center of projection c is the central area which is designed to projection this area. This point can be materialized or fictional (stereographic projection center used in our country has a fictitious point in the center of the country in the mountains Persian);
- Point of view 0 is the point where the observer's eye is considered settled when the projection area;
- scale representation of a given point coordinate projection (networks) x, y in any direction α of a segment map and the segment length and the same thought in the world.

So $\alpha = \frac{s}{S}$, where s=f (x,y,α);

- geographical network is the network of meridians and parallels of the globe is projected on the map;
- mapping network is the network of straight lines or curves resulting from the projection of meridians and parallels globe;
- rectangular grid consists of parallel equidistant lines with the flat rectangular axes Ox and Oy.

RESULTS AND DISCUSSIONS

In the following it will be presented the cartographical projections used in our country.

POLYHEDRAL PROJECTION MUFFLING introduced in 1873 - Austrian paper cover and Transylvania

Müffling projection was introduced in 1873 by the German geodetic Karl von Muffling and was used to achieve large scale maps. This projection mapping was used which included Austria and Transylvania, scale 1:75 000.

In this projection the Earth's surface is regarded as divided into a large number of trapezoids spheroid, bounded by the meridian and parallel plan are represented by straight lines, resulting plan straight trapeze. If trapezoids are small spheroid then they will not be very different face shape polyhedron, so deformations are small. For each trapezoid is considered a project plan which is tangent to the central keystone respectively. Earth's surface looks similar to a polyhedron with a large number of faces. Great disadvantage of this projection is that it not allows connecting multiple sheets of paper. Papers can be connected only if they are along the same meridian.

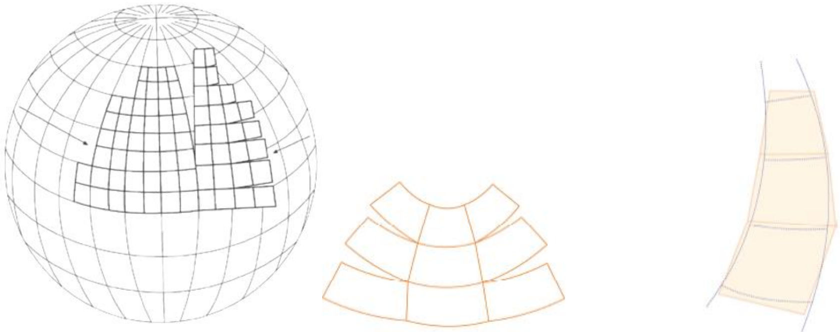

Figure 2: Ordering the sheets scale 1:1.000.000 and projecting into a plan

- EQUIDISTANT CYLINDRICAL PROJECTION CASSINI introduced in 1876 on Bessel Ellipsoid.

The Cassini Projection was developed by César-François Cassini de Thury in 1745.

Cassini projection topographic map, drawn to scale 1: 2000 by the Romanian Military Topographic Service, between 1873-1900, first used the decimal system of meter, including East Moldova and Wallachia using Bessel 1841 ellipsoid.

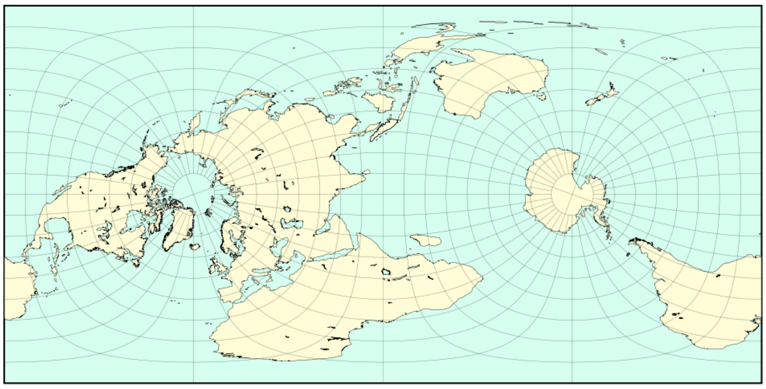

Figure 3: World map in Cassini Projection

Figure 4: Romanian Map in Cassini Projection

- PROJECTION PSEUDO-CONIC EQUIVALENT BONNE introduced in 1873, based on Bessel 1841 and Clarke 1880 ellipsoid.

Pseudo-conic Bonne projection was first used by the French Geodesic Bonne, in 1752, to build the map of France, and by the late nineteenth century in our country. In this projection parallel circles in this projection are represented by arcs of concentric circles. Central meridian is represented by a straight line and the other meridians through curves. For their construction, a side of the central meridian, the arcs representing parallel circles, note the parallel arc length between two meridian circle data. The results point to draw curves that are meridians (Figure 5). Bonne projection is a projection equivalent, so deformed surfaces. This projection shows 2 lines forming 0: central meridian and parallel Rctg φ0 = φ0. When this projection is used to build large scale map, tracing meridians will be the point which is calculated coordinates X and Z. In terms of the deformation is equivalent to a projection. Main staircase is kept only for the purposes of parallel and along the central meridian, on the other meridians; secondary stairs are larger than main staircase.

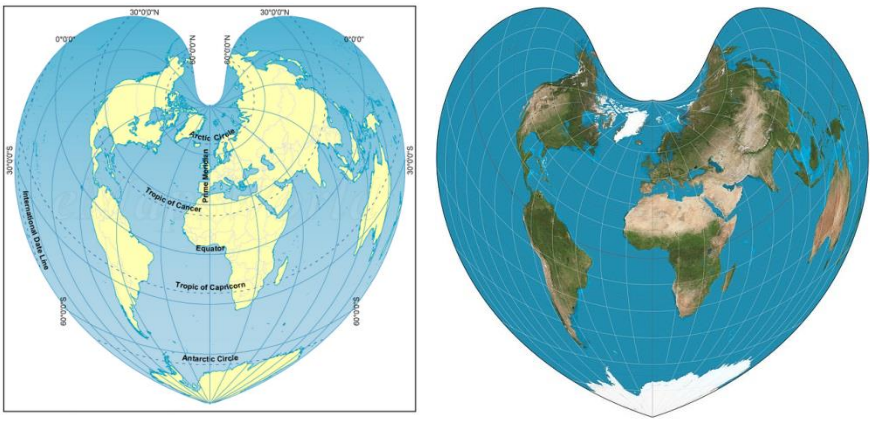

Figure 5: Cartographical network in pseudo conic Bonne projection

In Romania, Bonne projection was applied between 1873-1932 and it was used differently although the country because there were applied different reference ellipsoids and different coordinate axes systems.

For the Romanian territory located to the East from Zimnicea Meridian, Bessel 1841 ellipsoid has been used, land surveying being done between 1873-1876 and 1884-1893 for the territory of Moldavia, and between the years 1893-1902 for the region of East Muntenia. The coordinates of the central point of the projection are:

$$\lambda = 25^0 00' 00'' EParis$$

$$\varphi = 46^0 30' 00'' N$$

For the Romanian territory located to the Vest from Zimnicea Meridian, Clarke 1880 ellipsoid has been used, land surveying being done between 1902-1932 for the territory og West Muntenia and Oltenia. The coordinates of the central point of the projection are:

$$\lambda = 23^0 46' 30'' EParis$$

$$\varphi = 45^0 00' 00'' N$$

The biggest disadvantages of the Bonne projection are the high distortions of the angles and the junction of the map plans which could not be done because of using different ellipsoids.

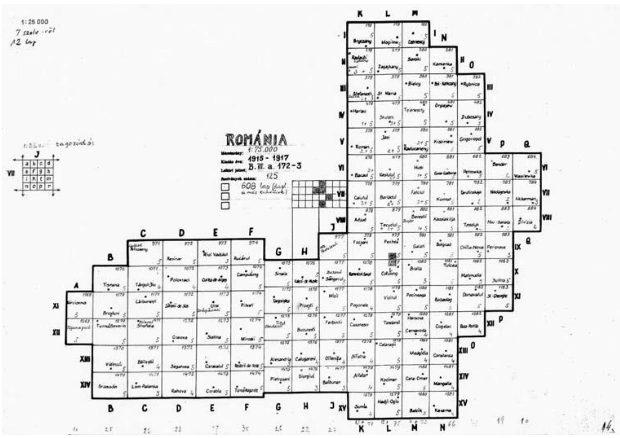

Figure 6: The index series topographic maps of 1:75000 Romanian

- CONIC CONFORMAL LAMBERT - CHOLESKY – used between the years 1917-1930, on Clarke 1880 ellipsoid.

This projection was introduced in 1917 to unify different cartographic projections used until that date. Reference surface used for projection Cholensky Lambert using Clarke 1880 ellipsoid. This projection was adapted due to military reasons, but also because the Bonne projection used until that time showed several disadvantages,

Base map of Romania called "Director Plan Drawing" was performed at scale 1:20 000 in a total of 2118 sheets covering the territory of Romania and also topographical maps on 1:100.000 scale.

The importance of maps in projection Lambert - Cholesky is that mapping is the first product that covers the whole country in a single projection system and unified legend.

Moreover, these maps are made at the highest level to date. At the same time it is also a public cartographic product, unclassified.

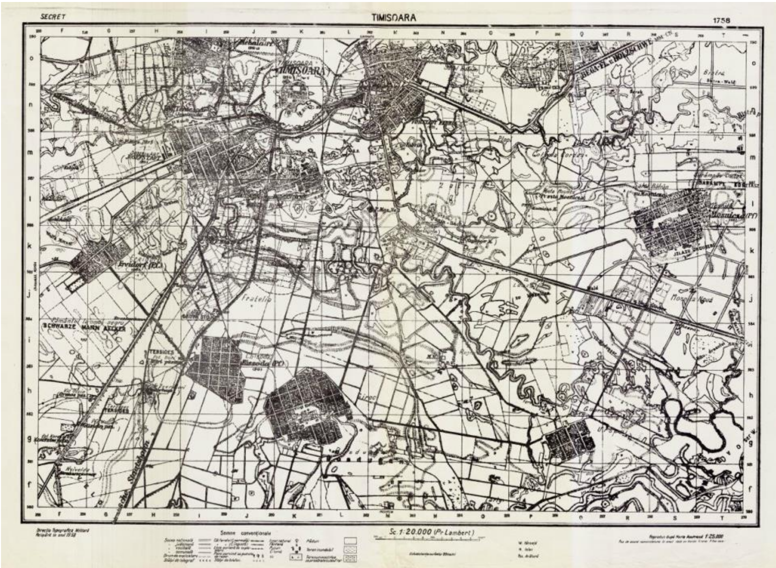

Figure 7: Timisoara – Directorial drawing Plan –Lambert Cholesky Projection

The central point of the projection is:

$$\lambda = 27^0 01^{'} 38",843 \ EGreenwich$$

$$\varphi = 50^0 00^{'} 00^{"} N$$

- PERSPECTIVE AZIMUTH PROJECTION WITH THE SECANT PLAN STEREOGRAPHIC BRAŞOV introduced in 1933, on Hayford ellipsoid

Azimuth stereographic projection has been adopted in our country in 1930, initially in version tangent plane with the center point located in the city, later (1933) adopting the plan Secant version only. In both cases we used reference elements of the Hayford ellipsoid. The central point was considered a point about 30 miles north of Brasov (near Feldioara), which has the following geographical coordinates:

$$\lambda = 28^0 21^{'} 38.51^{"} EGreenwich$$

$$\varphi = 51^0 00^{'} 00^{"} N$$

Secant plane was lowered to 4253 m vertically from the surface of the ellipsoid, resulting in zero distortion circle with a radius of 232, 378 km and is about half the distance from the focus point (center Romania) to the distant points. Deformations are negative inside the circle, touching the center - 0.332 m / km and positive outside, reaching the periphery + 0.554 m / km.

- TRANSVERSAL CYLINDRICAL CONFORMAL PROJECTION GAUSS KRUGER introduced in 1951, on the Krasovski ellipsoid 1940

This projection is characterized that a certain area of the terrestrial surface is represented on a cylinder tangent or transversal to the surface of reference which is considered a sphere (Figure 9).

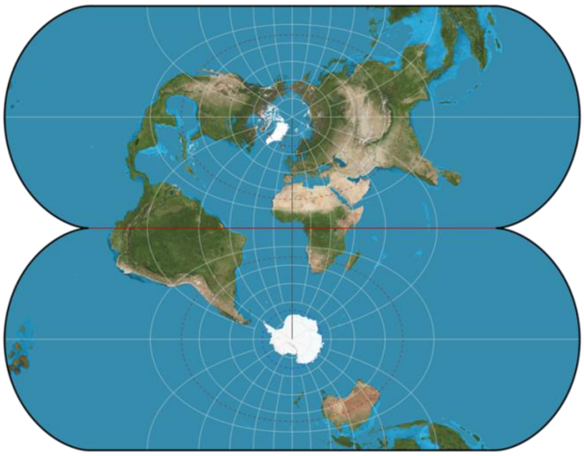

Figure 8: World Map in Gauss Kruger Projection

In a certain position of the reference surface inside the cylinder this is tangent after the median line. This line after it is developed into the plane of the cylinder remains unreformed. It is deformed any element of length situated on a side and the other side of the tangent meridian if the distance is big. By being imposed the limit of 1/2500, it results that the representing area is limited to 6o and it is named shaft of representation. By imaginary rotting of the reference surface inside the cylinder it can be obtained 60 shafts numbered from 1 to 60 over the meridian 180o. In these conditions our country belongs to the shafts 34 and 35 limited by the meridians 18o and 24o respective 24o and 30o. The reference surface is divided in bends having the width of 40 numbered for each hemisphere with letters from A to V. being situated at the latitude of 45o of the north hemisphere, our country belongs to the bend L, with small regions in bends K and M, limited by the parallels 44o and 48o.

By such deviation it results trapezes having the sizes of $4^{o}X4^{o}$ noted for our country with L-34 and L-35. We can notice from the following diagram (Fig. 3) that into the Gauss projection the linear relative deformations are positive and proportional with the distance over the axial meridian.

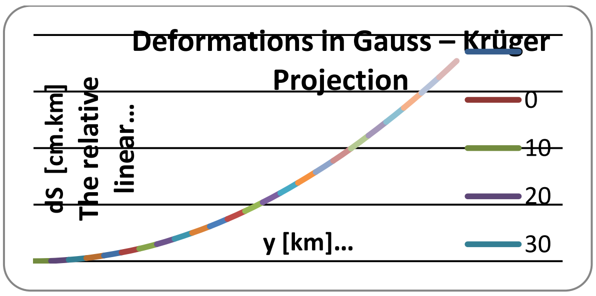

Figure 9: Diagram of deformations in Gauss-Kruger projection

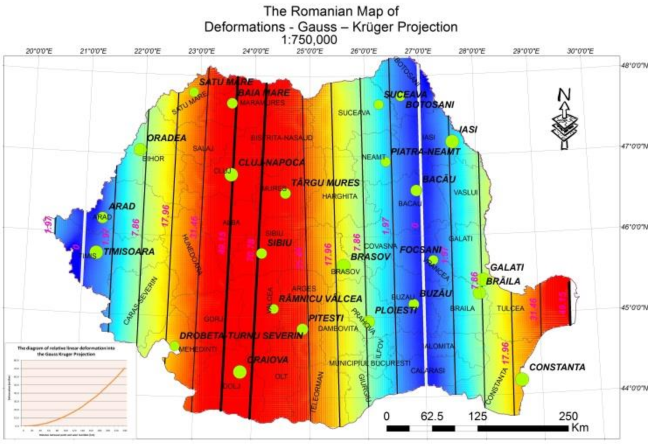

Figure 10: The Romanian Map deformations in Gauss – Kruger projection

- PERSPECTIVE PROJECTION AZIMUTH LINE WITH THE SECANT STEREOGRAPHIC 1970 introduced in 1970, on the ellipsoid Krasovski 1940

The stereographic representation (projection) is characterized that a certain part of terrestrial surface is represented on the surface of a plan tangent or secant on the reference surface (Figure 11). Geometric elements of the representation are: H – projection plan tangent or secant to the reference surface; C – projection center; O1 – point of view where start the projection rays situated on the reference surface opposed to C point; P – point which is represented; P' – projection of P point on H plan; x ax on the direction of the C point meridian; y ax on the direction of the C point parallel;

In order that all coordinates should be positive the origin of axes that are moved and becomes O (500 Km; 500 Km). The geographic coordinates of C point are:

$$\lambda_0 = 25^0 00^{'} 00^{"} EGreenwich$$

$$\varphi_0 = 46^0 00^{'} 00^{"} \mathrm{N}$$

The C point is situated near Făgăraş town.

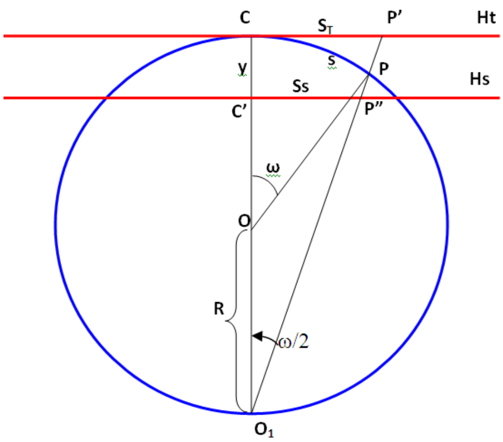

Figure 11: Stereographic projection with tangent and secant plan

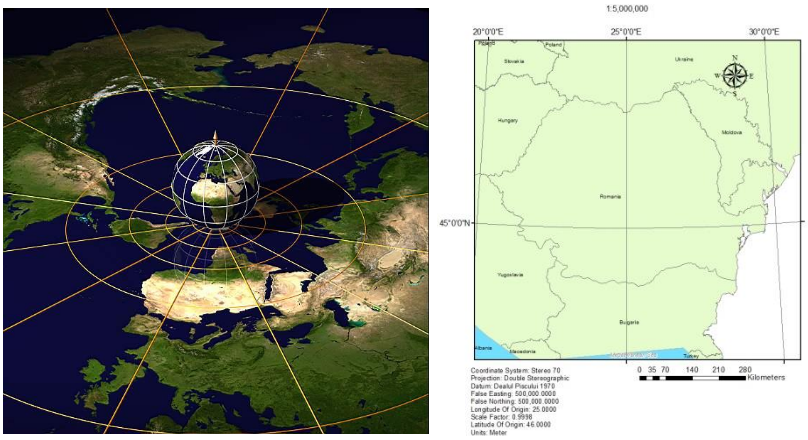

Figure 13: The World Map and the Romania Map in Stereo Projection

The linear local deformations depending on the distance over the central point of the Stereo 1970 projection are shown in the table 1 (R0=66378956,681 m)

Table 1

The distance over the central point of the Stereo 1970 projection

S [km]	Region deformation [cm/km]	Relative deformation
0	-25	1/4000
1	-25	1/4000
10	-24.94	1/4010
20	-24.75	1/4040
30	-24.45	1/4090
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200	-0.42	1/38000
201.718	0	--------
210	2.09	1/47800
220	4.74	1/21000
230	7.5	1/13000
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430	88.6	1/1100

The curve of regional (local) deformations on secant plan is shown in the following diagram (Figure 14).

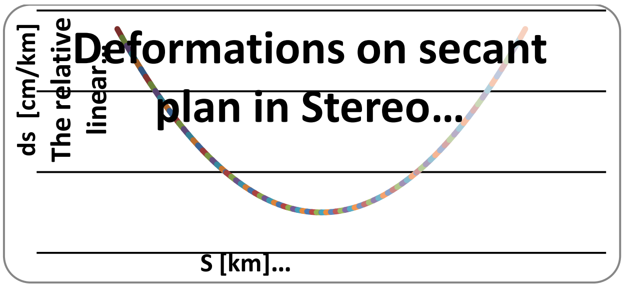

Figure 14: Diagram of deformations in Stereo70 projection

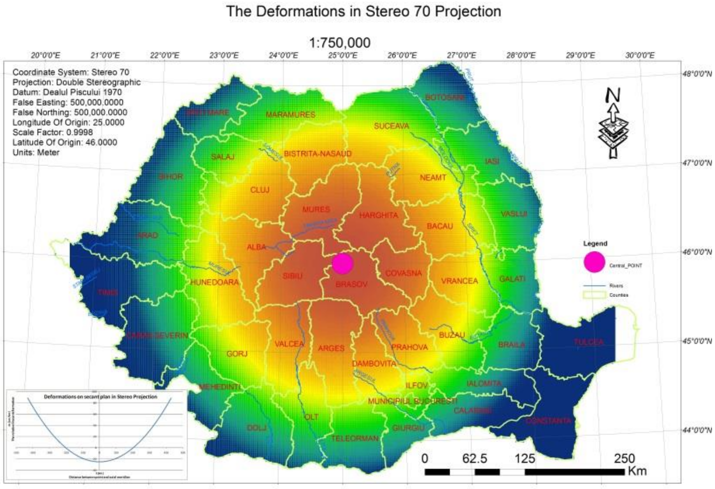

Figure 15: The Romanian Map deformations in Stereo 70 projection

CONCLUSIONS

The basic documents made after the geodesic and topographical measurements for accomplishing different projects are the topographical plans and maps. The accomplishment of these documents must represent very good of the terrestrial area with representative elements. Using the cartographic projections that must be made depending on the quality of the representation so that the plans and maps, which are obtained, should be made with high precision and high quality makes these documents. The elements that are deformed are as follows: angles, distances and areas.

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