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THE DEVELOPEMENT OF PROJECTION SYSTEMS IN ROMANIA

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Abstract:

This study puts forward two and a half centuries of development and changing projection systems used in Romania. It will be chronologically exposed a brief history of those, from Cassini's cylindrical projection (1873) to the system currently used (stereographic projection 1970). The purpose of this paper is to perform a comparative analysis to understand how they work, but also to see whether the current system used in the country is one ideal or can be improved. In this respect, there are considering factors such as the reference ellipsoid, axes, preservation / deflection of angles / distances or point of origin of the system.

Key words: *projection systems, comparative analysis, Romania.*

INTRODUCTION

People have always wanted to explore, to experience new territories, to let their life experience behind to their survivors so that they began to draw maps, at the beginning there had been maps of several cities, then of the countries, then of the continents and finally maps of the whole world. As time passes, maps have been improved and the people needed to enter the stairs, nomenclatures, projection systems, etc. In the last two decades, satellites have been sent into space, and now digital maps guide the everyday life of all mankind.

In Romania, the first cadastral surveys were performed in Transylvania, dating back to the nineteenth century under Emperor Franz Jozsef, based on Austro-Hungarian system of measurements. These measurements were using "Viennese fathom" as the unit of length (1 fathom Viennese = 1,896m).

Over time, several projection systems have been used in Romania. Of these, the most common are:

- Cassini cylindrical projection;
- Bonne equivalent conic projection;
- Azimuthal conformal stereographic perspective projection Targu Mures with tangent plane;
- Conic projection Lambert-Cholesky;
- Azimuthal projection stereographic perspective Brasov with Secant plan;
- Transverse cylindrical projection Gauss-Kruger;
- Stereographic azimuthal projection perspective 1970 with Secant plan.

MATERIALS AND METHODS

I. Cassini equidistant cylindrical projection:

In 1872, the measurements of Romanian territory had begun and the terrain map had been drawn up to 1: 20,000 in the Cassini-Soldner projection (Cassini-Soldner projection is Cassini ellipsoidal projection version). This is the first Romanian map which was used metric system for. Cassini equidistant cylindrical projection had been provided a basis for achieving the maps at scale 1: 50,000, 1: 100,000 and 1: 200,000 by the Romanian Military Topographic Service between 1873 and 1900. The cylindrical projections are obtained by projecting the reference ellipsoid on the lateral surface of a cylinder that then is cut after one of its generators and proceeds along the plan.

Technical Features:

- Type of projection: cylinder equidistant;
- Reference ellipsoid: Krasovski;

- Keep undistorted lengths;
- Distorts angles.

Cassini cylindrical projection has an important contribution to Romanian topography being the basis of the first map of Romania in metric system. While retaining lengths undistorted, it has some drawbacks that make the system imprecise as large deformation of angles and surfaces.

II. Bonne equivalent pseudoconic projection: Cassini projection for the territory in the western of Zimnicea meridian was no longer used (Paris 23 ° E, 25 ° 20'14.025 "E Greenwich) since 1895 until 1917, but Bonne equivalent pseudoconic projection. For this area, starting from the map at 1: 20,000, it will be produced maps at 1: 100,000 in this new projection (first Romanian maps which method was used for to contour), maps at 1: 50,000 and 1: 200000. It was the first projection in Romania which was used for drawing maps for cadastral purposes and was set for maintaining accurate projection surfaces in the plane (Fodorean, 2007).

Tehnical features:
- type of projection: equivalent pseudoconical;
- reference ellipsoid: Clarke;
- parallels are presented as concentric circles with a common center located on the central meridian which is a straight line (to which other meridians are shown as symmetrical curves);
- Projecting is made onto the side surface of a cone;
- Keep undistorted areas;
- Distorts angles.

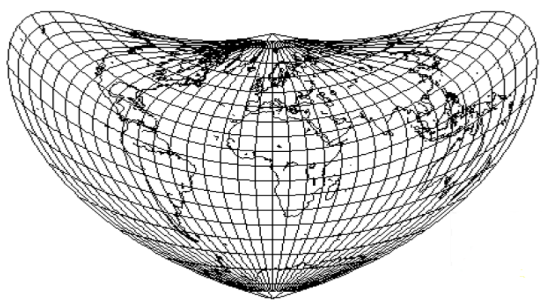

Figure 1.Carthographic network in Bonne pseudoconical projection

Bonne pseudoconical projection (Figure 1) has a special place in the history of the topography since it was the first projection which was used for cadastral purpose (not just for cartographic purposes as its predecessor's). While retaining undistorted surfaces and angles are deformed less than in Cassini projection, this one has been used regionally (Oltenia and Muntenia) because deformations for other regions of the country would have been very high.

III. Azimuthal conformal stereographic perspective projection Targu Mures with tangent plane:
It has been used between 1890 – 1916 in Transilvania.

Tehnical features:
- Type of projection: conformal perspective azimuthal line;
- Reference ellipsoid: Bassel 1841;
- The vantage point is on the sphere in the farthest position from the plane of projection;
- Projecting is made onto a plane;
- the point of origin has as geographical coordinates: φ = 46 ° 33` 8,85`` $\lambda$ = 24 ° 23` 34,935``
- azimuths are kept undistorted, projection being done per the laws of linear perspective;
- it is a projection line, but the lengths greatly distort the network edge;

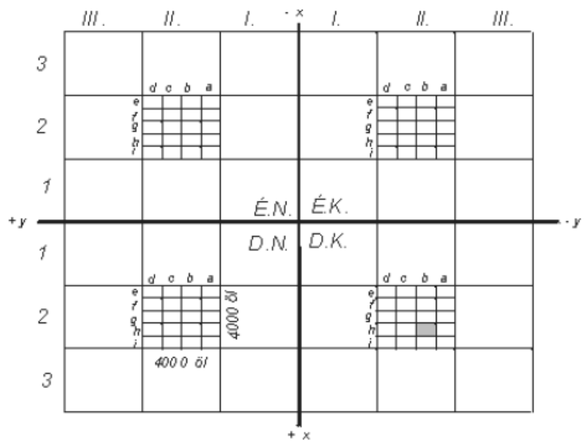

Figure 2. A map sheet in Targu Mures stereographic system (in Viennese fathoms)

As previously shown systems, **Targu Mures azimuthal projection** (Figure 2) was used regionally in Transylvania. Compared with projection systems mentioned above, it can be said that the Targu Mures azimuthal system is the most accurate, being a projection line, the azimuths are undistorted and the projection is being made in the plan (per the laws of linear perspective).

IV. Lambert-Cholesky conic projection:

During the First World War, the maps of Moldova, Dobrogea and eastern Wallachia were made in Cassini projection, the maps of West Muntenia and Oltenia were in Bonne projection, the maps of Basarabia were in Muffling polyhedral projection and the maps of Banat, Transylvania and Bukovina were in stereographic projections (Budapest or Targu Mures). The situation being very unpleasant for the Romanian army, it was necessary to adopt a uniform projection for all Romanian territories. It has been introduced a new base area, a new projection system and a new nomenclature using the Lambert projection system modified by the surveyer, mathematician and French officer Andre Louis Cholesky between 1916-1917.

The maps in Lambert-Cholesky projection (especially those made in the first period) were not the result of new measurements, but came from previous sources (Romanian, Austrian, Russian), which were transposed graphically. This system was maintained in Romania until 1930, when it had been adopted Brasov stereographic projection.

The central point of projection is located on the Olt Valley, close to the village Stolniceni belonging to Valcea county. Cartesian coordinates of the central point of projection are x = 500000m and y = 504599, 11m (Rădulescu, 2006).

Tehnical features:

-type of projection: conformal conical;

-reference ellipsoid: Clarke; -

the projection is made on the side surface of a cone; -

normal projection (pole axis is the same with the axis of the cone);

- conformal projection;
- distorts lengths and surfaces;

Lambert-Cholesky projection was the first unitary projection, which was adopted in all regions of Romania, the triggering factor of this measure being the outbreak of the First World War. Having the central point in Valcea County, this projection was used less for creating maps resulting from new measurements but was used mainly to create maps with measurements from previous sources that have been translated about graphics, being of real help for the Romanian army recently entered the war.

V. Azimuthal projection stereographic line perspective Brasov (1933) with secant plane:

Stereographic azimuthal projection was introduced in Romania in the third decade of the twentieth century and was used for drawing maps and topographical plans, drawn at different scales, until 1951. Initially, it was adopted in variant with tangent plane (1930), later passing to the version with unique secant plan (1933).

It had as a fictitious central point (not embodied in the field), located at approximately 30 km north-west of Brasov.

Indication " Brasov single secant plan" is necessary because, as mentioned above, prior to the introduction of the projections in some areas of the country (especially Transylvania) it had been working on the Budapest tangent plan or in Targu Mures stereographic projection.

This stereographic projection relied on a network of new triangulation, which is why we used reference elements of Hayford ellipsoid (a = 6378388 m, b = 6356912 m; α = 1: 297) oriented on Military Astronomical Observatory from Bucharest (Rad, 2007). It had been chosen the stereographic system of plane axes so that its origin to represent the plane image of pole Q0 (λ0, φ0), so Ox-axis was on the east-west direction with positive direction towards east and the Oy-axis was on the north -sud, in a positive direction to the north.

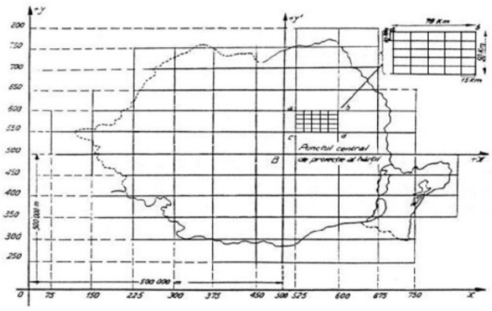

Figure 3. The system of axes in Brasov stereographic projection and the splitting system per sheets

Tehnical features:

- type of projection: stereographic oblique;
- Reference ellipsoid: Hayford;
- Conformal Projection;

- Measurements made can be processed directly in the projection plan after corrections are applied to reduce the plan;
- distorts lengths and areas;
- the point of origin has as geographical coordinates: φ = 51G 00c 00cc, 000 (45054'00 ', 0000) λ = 28G 21c 00cc, 510 (25023'32', 8722);

Stereographic projection Braşov, (Figure 3) like its predecessor, was a unitary projection, which preserves angles, but distorts lengths and areas. The advantage to system Lambert-Cholesky projection is that Brasov projection is a stereographic projection that preserves untainted the shapes angles on the field and distorts the lengths on the tangent plane, thus satisfying most representations to plan for scales smaller than 1: 2000.

VI. Transversal cylindrical projection Gauss-Kruger line:

This projection system was designed between 1825-1830 by the famous German mathematician Karl Gauss (which probably started from the conic projection Lambert, shown above, by changing the reference ellipsoid), and later, in 1912, Johannes Kruger has developed formulas required for transferring the coordinates of the rotating ellipsoid points on the projection plan.

Gauss projection was introduced in Romania in 1951, being used until 1973 for drawing the basic topographical plan of a scale of 1: 10,000, for basic topographic maps at a scale of 1: 25,000 and for unitary maps at various scales.

The introduction of this new projection system was a political decision, because the systems used in Romania (Lambert-Cholesky and Braşov) were not compatible with Gauss-Kruger projection used in the USSR, so Romania was forced to introduce a new projection system that was agreed by Russia. This projection has as a general principle the fact that a terrestrial surface is represented on the surface of a tangent cylinder and transverse to the reference spherical surface. The axis is inverted, so the Ox axis is considered parallel to the projection of the axial meridian and Oy-axis is considered the equator projection.

For unitary representation of the terrestrial ellipsoid, the Earth's surface is divided into 60 spherical cones of 6 ° longitude (starting from the Greenwich origin meridian) not to exceed the limit of length deformations (1/2500). For projection of the 60-resulted cones, the ellipsoid is considered wrapped in 60 successive cylinders (horizontally), where each cylinder is tangential to the axial meridian corresponding to each cone (Popescu, 2006).

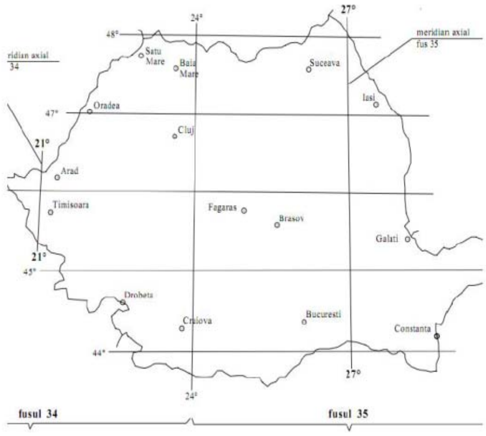

Figure 4. Romanian territory covered by 34 and 35 cone.

Tehnical features:
- Type of projection: cylindrical transversal;
- Reference ellipsoid: Krasovski 1940
- The surface projection of ground ellipsoid directly on the plan, without intermediary switching on sphere;
- Conformal Projection;
- distorts surfaces and lengths (to a small extent)

Gauss Kruger projection (Figure 4) is a universal projection, which allows any surface of any size to be represented, at any scale, providing an international feature. The main advantage of this projection is that the ellipsoid surface projection is done directly on a plan, which facilitates the work of cartographers as the intermediary transition is no longer made on sphere. It is also a conformal projection, and relative linear deformations are positive and directly proportional to the distance to the axial meridian. In Romania, the maximum deformations are along the meridian 24 ° (in Danube Delta), and these having variations from 7,1cm / km (φ = 44 °) to 6,15cm / km (φ = 48 °) (Rus and Buz, 2003).

VII. Stereographic azimuthal projection line perspective 1970 with secant plan:

To better respond to practical requirements in Romania, in 1973, it was adopted the stereographic system 1970 on unique secant plan, which followed a series of principles that satisfy accuracy terms and some specific aspects of the Romanian territory, of which reads:
- The country has an almost round shape, which can be placed in a circle with a radius of about 300 km;
- Land area is projected by the laws of linear perspective;
- Romania's territory can be represented on a single projection plan, thereby achieving a unique rectangular plan coordinates with origin in the midpoint of the projection;

The projection was used and is still used for drawing of basic topographic plans at 1: 2000; 1: 5000 and 1: 10000, as well as of cadastral maps at 1: 50000, being an alternative to Gauss-Kruger projection to remove the inconvenience created by that. The central point of the projection is a fictional, not embodied in the field, which is located approximately at the geometric center of the country, at northern side of the city of Făgăraș (25 ° east longitude, 46 ° north latitude).

The axis is inverted, so the Ox axis lies along the north-south and the axis Oy is considered on the east-west direction.

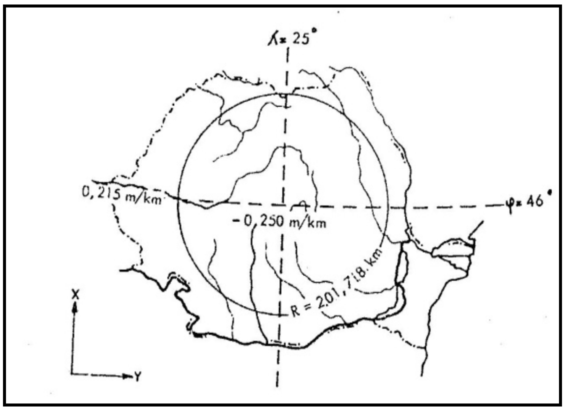

Figure 5. Stereographic projection 1970

Tehnical features:
- Type of projection: stereographic azimuthal;
- Reference ellipsoid: Krasovski 1940 oriented at Pulkov;
- Conformal Projection;
- Keeps undistorted angles and due to the use of secant plan the lengths deformations are more reduced to other projection systems;
- The reference plan for elevations is the Black Sea;
- The coordinates of the central point are φ = 25 ° and φ = 46 °

Stereographic projection 1970 (Figure 5) is a projection line, it keeps undistorted angles and due to the use of the secant plan, the lengths deformations are more reduced to other projection systems. Deformations are negative inside the circle, reaching on the center of projection - 25 cm / km and positive outside the circle, reaching on the periphery + 65 cm / km (counties Constanta, Timis). While giving a wide range of benefits, the system stereographic 70 is far to be called an ideal system because it is a local system (used only in Romania) and deformations (greater than deformations of the Gauss-Kruger system) are both positive and negative, which makes more difficult their compensation (Rădulescu, 2012).

RESULTS AND DISCUTIONS

Because of the above, it can be said that the projection system used today in Romania is not ideal because the Krasovski 42 geodetic datum has the following drawbacks:
- it is a local datum because of its position and different orientation of the reference ellipsoid in relation to geoid;
- Specific position of the ellipsoid in relation to geoid reduces angles and distances to ellipsoid, which is dependent on this position;
- Calculating the point's coordinates that refer to geodetic datum will have differences from those performed by another geodetic datum;
- Distance and azimuth between two different reference systems and coordinates can not be calculated precisely, regardless of the accuracy of individual datums.

Considering all the issues that our country has, an ideal system should have the following features:
- Romania can be represented on a single projection plan, thereby achieving a unique rectangular coordinates plan with origin on the midpoint of the projection;
- distortions should be minimal;
- to be appropriately to positioning needs from the European area;

- to ensure compatibility and interoperability of national spatial data with European and international standards;
- to ensure achievement of pan-European cartographic products in reference systems and European coordinates;
- to provide high accuracy of points coordinate, determined on GNSS technologies and thus improve the quality of national geodetic network.

Such a system, which meets all these conditions is ETRS89, it was developed in the 80's as a system applicable in all European countries. For applications at the continental level, EUREF defined ETRS89 system (European Terrestrial Reference System 1989), which is realized through a set of reference points with knowing and accepted coordinates at the time. It also had been introduced the hypothesis that all points placed on Eurasian tectonic plate do not admit relative speeds (move jointly with this tectonics plate). ETRS89 (Table 1) was put into practice after 1990, through campaigns of measurements and determining the coordinates of the points materialized in the land from each country of the European Union (Dragomir et al., 2010).

Currently, in Romania, it is used stereographic 70 system, which is based on the ellipsoid Krasovski 1940 and stereographic projection plan 1970. This reference system can be considered as one local as it is not completely geocentric, ellipsoidal elevations being known to have a poor accuracy (because it was not determined a precise geoid model) and the plane coordinates are determined in a specific projection plan (for Romania) - stereographic plan 1970.

Table 1. ETRS89`s datum

Entity	Value
Country	Romania (RO)
Reference System Identifier	ETRS89-GRS80
Alternative name of SR	European Terrestrial Reference System ETRS89
Valid area of SR	Romania
The purpose of SR	Geodesy, Cartography, GIS
Datum Identifier	ETRS89
Alternative name of datum	European Terrestrial Reference System 1989
Type of datum	Geodetic
Achievement year of datum	1989
Valid area of datum	Europa/EUREF
The datum purpose	European datum is identical to ITRS and is attached to the stable continental plate of the Eurasian.
First meridian identifier	Greenwich
Longitude of the first Greenwich meridian	0°
Ellipsoid Identifier	GRS80
Small semi-axis of the ellipsoid	6 356 752 m
large semi-axis of the ellipsoid	6 378 137 m
The reverse of flattened ellipsoid	298.257222101
Coordinate System	Ellipsoidal coordinate system
Type of the coordinate system	Geodetic
The size of the coordinate system	3
Geodetic latitude	The angle formed by the normal with the ellipsoid in a point with the equatorial plane of the reference ellipsoid
Measurement direction	To north
Unit of measurement	sexagesimal degrees
Geodetic longitude	The dihedral angle formed between the geodetic Greenwich meridian and the geodetic meridian of the considered point
Measurement direction	To east
Ellipsoid altitude	Normal segment between the position of a point on the physical surface of the Earth and its projection on the reference ellipsoid
Measurement direction	From ellipsoid to point
Unit of measurement	Meter

CONCLUSIONS

This study presents the evolution of projection systems used over time in Romania. Thus, Romanian projection systems were introduced in the country by the Austro-Hungarian Empire (XIX century), then it started to be introduced systems that advantage a specific region

(Cassini, Bonne, Targu Mures) and then, because of the outbreak of WWI it was introduced the first unified system from Romania, Lambert-Cholesky, with the successor systems Brasov, Gausss- Kruger and most recently, the stereographic system 70. Among the arguments, it can be said that none of the systems mentioned above do not constitute an ideal projection system, but one that fits best both the characteristics of Romania and those of Europe is ETR89 system.

Proposal for adopting the system ETRS89 in Romania was analyzed and discussed in the working meetings and conferences at ANCPI and national level (2005, 2006, 2007), all specialists in the field ruling favorable to implement a modern system based on global positioning systems using satellites.

In future, the need for cooperation at European and global level in the field of geodesy and cartography, the current disadvantages of the stereographic 70 system and perspectives opened by position determinations using artificial satellites, will lead to the adoption by European countries (including Romania) of the Reference and Coordinates System (SRC) ETRS89 for a wide range of works from different fields.

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