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Analysis of the Deformations Recorded in the Extreme Geographical Administrative – Territorial Units of Romania Using the National 1970 Stereographic Projection System

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ABSTRACT: *The national registration of all real estates in the integrated cadastre and land registration system is performed, according to the Law of cadaster and land registration no. 7/1996, respecting the cadastral sectors of the administrative territorial units and includes both the execution of accurate field measurements and the knowledge of regional deformations in the national projection system. In this context, the aim of this study is to determine the values of these deformation in the following four geographical extreme points of the Romanian border: Horodiştea village, Păltiniş commune, Botoşani County at North; Zimnicea city, Teleorman County at South; Sulina city, Tulcea County at East; Beba Veche commune, Timiş County at West. The basic cadastral plan for the administrative – territorial units is drawn using the national 1970-Stereographic projection coordinates system. The digital and analog representation of the basic cadastral plan is drawn using the 1:5000, 1:2000, 1:1000 and 1:500 scales, depending on the topographic details' density. Given the feature of the representation, the 1970 – Stereographic Projection is a conformal perspective projection that preserves the angles undeformed while it deforms the lengths and surfaces. The regional deformations determined for the four extreme points, differed from one another depending of their position in relation to the projection central point. The obtained relative linear deformations were: 19 cm/km (Zimnicea), 24 cm/km (Horodiştea), 58 cm/km (Beba Veche) and 63 cm/km (Sulina), respectively. The total areolar deformations were first established based on the cartographic framing trapeziums at 1:5000 scale. At the same time, the total areolar deformations have been evaluated for the four administrative units with the following surfaces: 7553 ha (Păltiniş); 13647 ha (Zimnicea); 32834 ha (Sulina) and 9415 ha (Beba Veche). Based on the high values of the areolar deformations obtained for these administrative units, we have concluded that for impleminting the cadastral works at administrative-territorial units level, is esential to take into consideration the deformations caused by the cartographical projection system.*

KEYWORDS: *cartographic projection, linear relative deformation, areolar deformation, cadastre and land registration*

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I. INTRODUCTION

The systematic registration of real estates in the integrated cadastre and land registration system is performed respecting the cadastral sectors of the administrative territorial units. The implementation of the integrated cadastre and land registation system covers, at national level, 3181 administrative-territorial units, more precisely: 103 municipalities, 217 cities and 2861 communes with 12957 villages [1]. „The National Programme for Cadastre and Land Registration 2015-2023" is conducted based on the annual financing fund that is assigned according to the stages of the works performed. These works are financed by The National Agency for Cadastre and Land Registration (NACLR), as well as from European funds as The Regional Operational Fund [1]. The European funds are, mainly, assigned to the rural administrative-territorial units of Romania.

The legal frame for conducting the specialized technical works is regulated by the Law on Cadastre and Real Estate no. 7/1996 with the subsequent modifications and completions. The basic cadastral plan is drawn on administrative-territorial units using the 1970 Stereographic Projection System, at standard scales, considering the density of the topographic details [2].

Given its cartographic representation, the 1970-Stereographic Projection is an azimuthal, perspective, oblique, conformal projection that preserves the angles undeformed while deforming lengths and surfaces, depending of the position of the territory with respect to the projection's central point. The maximum regional deformations for the 1970-Stereographic Projection are registered in the extreme geographic areas of Romanian border.

The aim of this study was to determine the linear and areolar deformations in the extreme points of Romanian border and also for the geodetic trapeziums at 1:5000 and 1:25000 scales, corresponding to the administrative-territorial units located in the extreme geographical points of Romania: Păltiniș, Zimnicea, Sulina and Beba Veche.

II. ROMANIA GEOGRAPHICAL POSITION

Romania's central point, also known as the pole of the 1970-Stereographic projection is situated at the intersection of the 46° north latitude paralel with the 25° east longitude meridian.

Romania's geographical position from north to south is characterized by 4°37′59″ latitude difference, and 9°25′40″ longitude difference from west to east. Romania's territory is situated both inside and outside the Carpathian's Mountains arch, on the lower part of the Danube river with opening to the Black Sea. Officially, Romania's geographical position is delimited by the following extreme points (localities): Horodiștea – Botoșani County, in the north; Zimnicea – Teleorman County, in the south; Sulina – Tulcea County, in the east; Beba Veche – Timiș County, in the west (Table 1).

Table 1. The coordinates for Romania's extreme geographical points

Cardinal point	*Extreme point (locality)*	*Geographical coordinates*		*Stereographical coordinates*	
		Latitude	*Longitude*	*X < 70 >*	*Y < 70 >*
		φ (° ′ ″)	*λ(° ′ ″)*	*(m)*	*(m)*
North	Horodiștea	48 15 06	26 42 05	751,674. 291	626,361. 492
South	Zimnicea	43 37 07	25 23 32	235,460. 937	531,665. 642
East	Sulina	45 09 36	29 41 24	417,440. 673	868,585. 768
West	Beba Veche	46 07 27	20 15 44	524,700. 549	134,018. 612

Starting with the 2016 edition of the Statistical Yearbook, the total area of Romania was updated by the National Agency for Cadastre and Land Registration (NACLR) according to the Law of cadastre and land registration no. 7/1996, with subsequent amendments.

The present surface of 238397 km^2 of Romania's territory is delimited from the neighbouring countries by a border with the total length of 3149.9 km, of which: terrestrial (1085.6 km); rivers (1816.9 km) and maritime (247.4 km).

Romania's borders with its neighbouring countries: Ukraina, The Republic of Moldova, Bulgaria, Serbia and Ungaria are taken over in the works of cadastral delimitation for those extreme administrative – territorial units.

III. CREATING THE INTEGRATED CADASTRE AND LAND REGISTATION SYSTEM

Cadastre and land registry creates a unitary and compulsory system for keeping technical, economic and legal records of all real estates in the country. In order to do this, general and systematic cadastral works are conducted in all administrative units [3].

The present property management, according to the data published on October 22th, 2019 by the National Agency for Cadastre and Real Estate, included 13817.520 real estates, that represent 34.54% of approximately 40000.000 real estates estimated nationally. At the same time, it is noticed that 1938.165 real estates are the result of the systematic real estate registration activity [4].

According to the ongoing process of the systematic real estate registration program at national level, the works are conducted in 2245 administrative-territorial units, that is 72% of the total basic units [5].

The geographic point of Horodiștea is cartographically positioned in the administrative-territorial unit of Păltiniș. The administrative organization of the territory of Botosani County includes, for its 4987 km^2, 78 administrative - territorial units. The present stage of the systematic cadastral works indicates the process is in progress in 55 administrative units, Păltinis unit, included (Figure 1).

The geographic point of Zimnicea is cartographically positioned in the administrative-territorial unit of Zimnicea. The administrative organization of the territory of Teleorman County includes, for its 5788 km^2, 97 administrative – territorial units. The present stage of the systematic cadastral works indicates their completion in 7 administrative – territorial units and the ongoing process in the other 90 units (Figure 2).

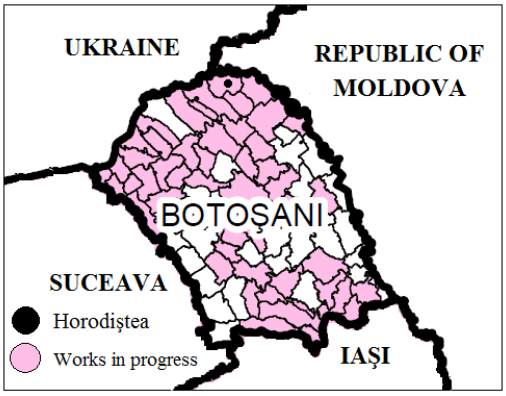


Fig. 1. The stage of the cadastral works conducted in Botoşani County (according to NACLR, 2019)

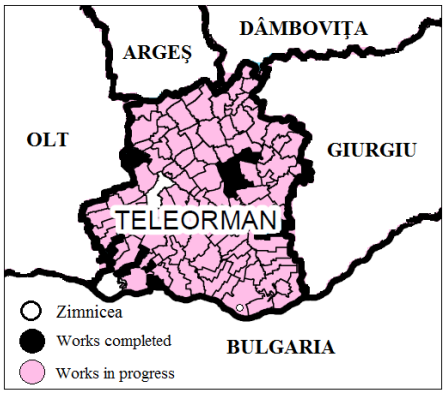


Fig. 2. The stage of the cadastral works conducted in Teleorman County (according to NACLR, 2019)

The geographic point of Sulina is cartographically positioned in the administrative-territorial unit of Sulina. The administrative organization of the territory of Tulcea County includes, for its 8484 km^2, 51 administrative – territorial units. For this County, there is only one administrative territorial unit where the systematic registration of the real estates has been completed, while the process is in progress in the other 46 units (Figure 3).

The geographic point of Beba Veche is cartographically positioned in the administrative-territorial unit of Beba Veche. The administrative organization of the territory of Timiş county includes, for its total surface of 8692 km^2, 99 administrative – territorial units. For this county, the systematic cadastral works have been completed in 6 administrative units, while the process is in progress in the other 52 basic units (Figure 4).

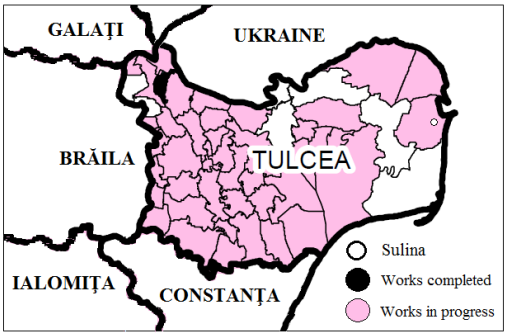


Fig. 3. The stage of the cadastral works conducted in Tulcea county (according to NACLR, 2019)

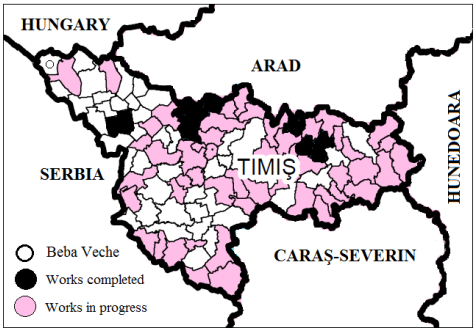


Fig. 4. The stage of the cadastral works conducted in Timiş County (according to NACLR, 2019)

IV. THE CARTOGRAPHIC FRAMING OF ROMANIA'S EXTREME GEOGRAPHICAL ADMINISTRATIVE - TERRITORIAL UNITS

After completing the cadastral activity for the entire territory of an administrative-territorial unit, the technical documentation is drawn up. It includes graphical representations and tables. The graphical representation consists in the basic cadastral plan at 1:500 or 1:1000 scale for the interior areas and 1:2000 or 1:5000 scale for the exterior areas. The accuracy of the cadastral plan must correspond to the graphical accuracy of the representation scale used , within the limits of ± 0.2 mm graphical error.

The general cadastral map is drawn up when completing all general cadastral works or when completing the systematic cadastral works for a certain administrative-territorial unit. It is drawn up at the

following scales: 1:10000, 1:25000 or 1:50000. For making the plan sheets and the cadastral map on geodetic trapeziums, it is first necessary to complete the cartographic framing of the borders of the administrative territorial units [6].

The administrative territorial unit of Păltiniş commune which includes Romania's northest point covers a total surface of 7552.6707 hectares, its perimeter being 52461 m long [7]. The Horodiştea point is part of the geodetic trapezium with nomenclature M-35-138-A-b-4-III at 1:5000 scale. The distribution and the connection of both map and plan sheets are presented in Figure 5.

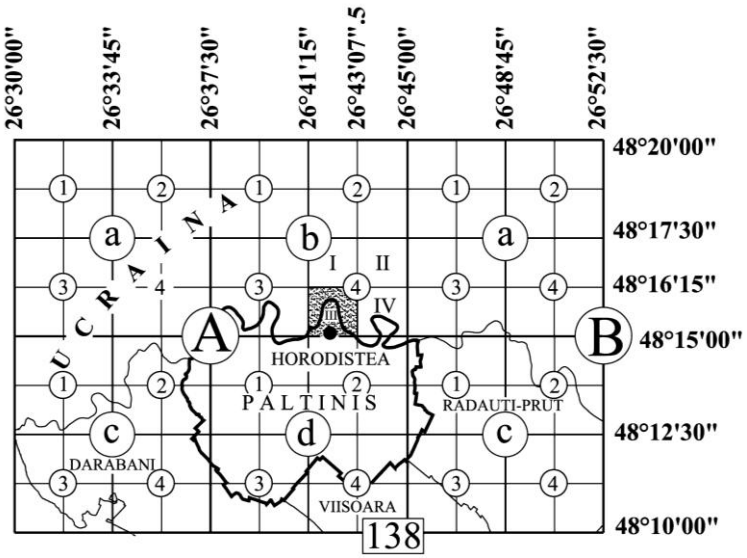


Fig. 5. The cartographic framing of the administrative – territorial unit of Păltiniş commune

The admistrative territorial unit of Beba Veche, which includes the westernmost point of Romania, covers a total surface of 9414.6346 hectars, its perimeter being 48506 m long [7]. The Beba Veche point is part of the trapezium with nomenclature L-34-65-D-a-3-I at 1:5000 scale (Figure 6).

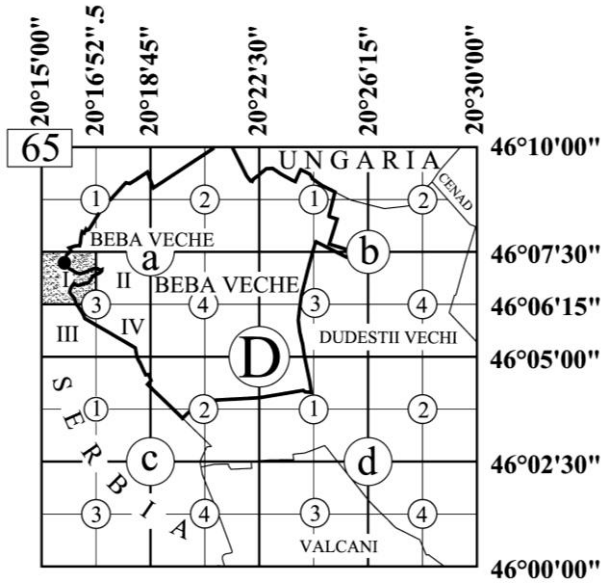


Fig. 6. The cartographic framing of the administrative–territorial unit of Beba Veche commune

The administrative territorial unit of Zimnicea city which includes Romania's southernmost point covers a total surface of 13647.2270 hectares, its perimeter being 62909 m long [7]. The Zimnicea point is part of the geodetic trapezium with K-35-15-B-b-3-I nomenclature at 1:5000 scale. The scheme of the trapeziums used for the cartographic framing of the borders of Zimnicea administrative-territorial unit is presented in Figure 7.

The administrative territorial unit of Sulina, which includes the easternmost point of Romania, covers a total surface of 32833.7452 hectares, its perimeter being 89500 m long [7]. The Sulina point is part of the trapezium with L-35-108-C-b-2-I nomenclature at 1:5000 scale (Figure 8).

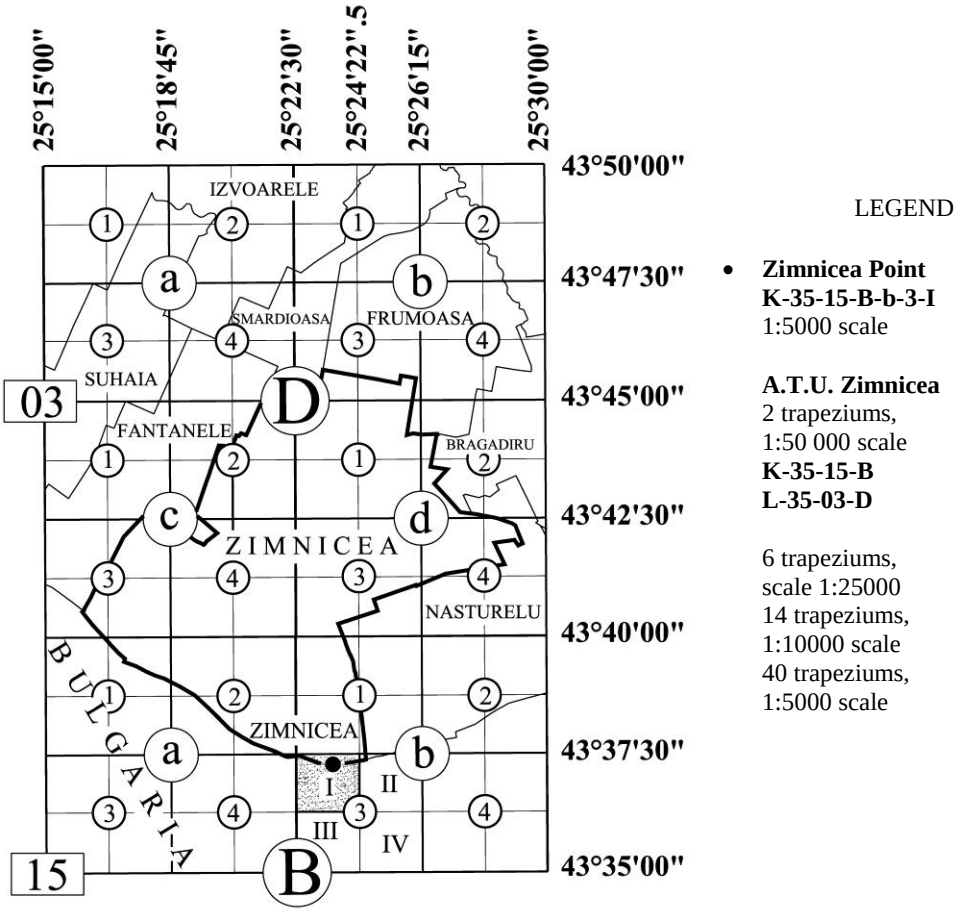
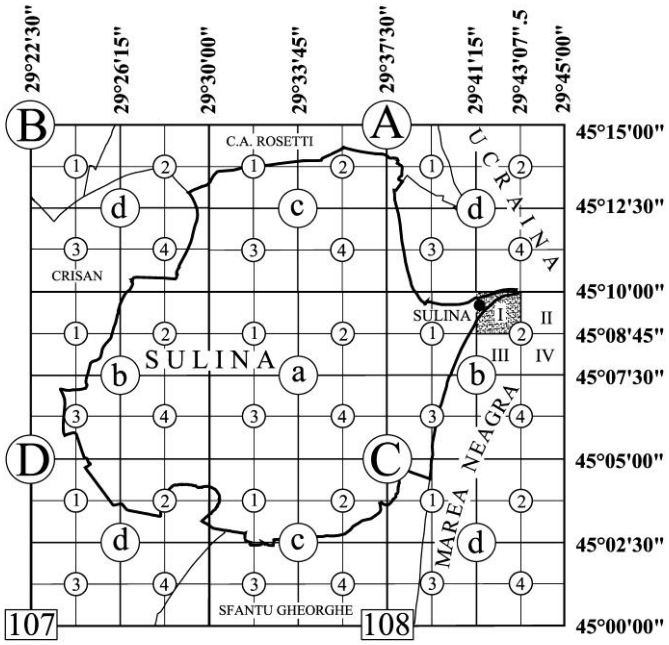


Fig. 7. The cartographic framing of the administrative – territorial unit of Zimnicea



LEGEND

- **Sulina Point**
  L-35-108-C-b-2-I
  1:5000 scale

A.T.U. Sulina
4 trapeziums,
1:50 000 scale
L-35-107-B
L-35-107-D
L-35-108-A
L-35-108-C

9 trapeziums,
1:25000 scale
25 trapeziums,
1:10000 scale
78 trapeziums,
1:5000 scale

Fig. 8. The cartographic framing of the administrative – territorial unit of Sulina city

V. THE CARTOGRAPHIC BASE FOR THE MAP AND PLAN SHEETS REPRESENTED ON TRAPEZIUMS

The geographic area of the geodetic trapeziums is delimited on the reference elipsoid surface by arches of meridians and parallels which in the projection plan represent the lengths for the sides of both map and plan sheets, drawn on trapeziums. The conversion of the geographical coordinates from the 1940 Krasovski ellipsoid into the 1970 Stereografical coordinates is done by using mathematical relations with constant coefficients.

The coordinates from the "tangent plan" (X_{tg}, Y_{tg}), paralel to the "secant plan" are calculated based on the difference in latitude (f) and in longitude (l) between the projection pole $Q_0(\varphi_0, \lambda_0)$ and the given point $P_i(\varphi_i, \lambda_i)$, using the following relations:

$$X_{tg} = (a_{00} + a_{10}f + a_{20}f^2 + a_{30}f^3 + a_{40}f^4 + a_{50}f^5 + a_{60}f^6)\ 1{,}000 + + (a_{02} + a_{12}f + a_{22}f^2 + a_{32}f^3 + a_{42}f^4)\ l^2 + (a_{04} + a_{14}f + a_{24}f^2)\ l^4 + (a_{06} + \dots)\ l^6 \quad [m]$$

$$Y_{tg} = (b_{01} + b_{11}f + b_{21}f^2 + b_{31}f^3 + b_{41}f^4 + b_{51}f^5)\ l + +(b_{03} + b_{13}f + b_{23}f^2 + b_{33}f^3)\ l^3 + (b_{05} + b_{15}f + \dots)\ l^5 \quad [m]$$

The coordinates from the "tangent plan" are transformed into the "secant plan" using the scale reduction coefficient C = 0.999 750 000, based on the relations with the following general formula: $X_{sec} = X_{tg}\ C$ and $Y_{sec} = Y_{tg}\ C$.

The coordinates from the "secant plan" are expressed in the official system axes with the translated origin: $X < 70 > = X_{sec} + 500,000.000$ m; $Y < 70 > = Y_{sec} + 500,000.000$ m.

Both, the geographical and stereographic coordinates of the corners of the four trapeziums at 1:5000 scale framing the four extreme points (localities) from the territory of Romania (Figures 5, 6, 7 and 8) are presented in Table 2.

Table 2. The coordinates of the corners of the geodetic trapeziums at 1:5000 scale

ATU name and point number*	*Geographic coordinates*		*Stereographical coordinates (m)*	
	φ (° ′ ″)	*λ(° ′ ″)*	*X < 70 >*	*Y < 70 >*
Păltiniş	M-35-138-A-b-4-III			
1 – North West	48 16 15	26 41 15	753,783. 230	625,284. 038
2 - North East	48 16 15	26 43 07.5	751,466. 607	625,334. 063
3 - South West	48 15 00	26 41 15	753,833.790	627,603. 902
4 - South East	48 15 00	26 43 07.5	751,517.182	627,654.853
Zimnicea	K-35-15-B-b-3-I			
1 – North West	43 37 30	25 22 30	236 164, 358	530 271, 954
2 - North East	43 37 30	25 24 22.5	236,176.482	532,794.607
3 - South West	48 36 15	25 22 30	233,849.228	530,282.634
4 - South East	48 36 15	25 24 22.5	233,861.354	532,806.177
Sulina	L-35-108-C-b-2-I			
1 – North West	45 10 00	29 41 15	418,169.295	868,346.097
2 - North East	45 10 00	29 43 07.5	418,313.395	870,800.270
3 - South West	45 08 45	29 41 15	415,856.452	868,481.434
4 - South East	45 08 45	29 43 07.5	416,000.579	870,936.511
Beba Veche	L-34-65-D-a-3-I			
1 – North West	46 07 30	20 15 00	524,849.404	133,080.612
2 - North East	46 07 30	20 16 52.5	524,705.650	135,493.034
3 - South West	46 06 15	20 15 00	522,536.449	132,942.341
4 - South East	46 06 15	20 16 52.5	522,392.666	135,355.674

ATU – administrative – territorial unit

In a similar manner, the Stereographic coordinates for the corners of the trapeziums have been calculated using 1:25000 scale for the administrative territorial units of Păltiniş, Zimnicea, Beba Veche and using 1:50000 scale for the administrative territorial unit of Sulina (Table 3).

Table 3. The coordinates for the corners of the trapeziums for the 1:25000 and 1:50000 scales

ATU name and point number*	*Geographic coordinates*		*Stereographic coordinates (m)*	
	φ (° ′ ″)	*λ(° ′ ″)*	*X < 70 >*	*Y < 70 >*
Păltiniş	M-35-138-A-d			
1 - North West	48 15 00	26 37 30	751,368.234	620,692.448
2 - North East	48 15 00	26 45 00	751,568.677	629,975.632
3 - South West	48 10 00	26 37 30	742,101.900	620,885.048
4 - South East	48 10 00	26 45 00	742,302.524	630,183.049
Zimnicea	K-35-03-D-d			
1 - North West	43 45 00	25 22 30	250,054.949	530,207.830
2 - North East	43 45 00	25 30 00	250,109.208	540,277.052
3 - South West	43 40 00	25 22 30	240,794.582	530,250.587
4 - South East	43 40 00	25 30 00	240,848.879	540,334.061
Sulina	L-35-108-C			
1 - North West	45 10 00	29 30 00	417,324.819	853,620.454
2 - North East	45 10 00	29 45 00	418,458.448	873,254.418
3 - South West	45 00 00	29 30 00	398,820.780	854,659.154
4 - South East	45 00 00	29 45 00	399,956.133	894,350.886
Beba Veche	L-34-65-D-a			
1 - North West	46 10 00	20 15 00	529,475.337	133,357.223
2 - North East	46 10 00	20 22 30	528,906.249	142,999.807
3 - South West	46 05 00	20 15 00	520,223.502	132,804.090
4 - South East	46 05 00	20 22 30	519,653.954	142,461.244

ATU – administrative-territorial unit

The area of the trapezium (T) from the surface of the Krasovski-40 reference ellipsoid, delimited by two paralels of φ_j and φ_i latitudes and by two meridians of λ_m and λ_n longitude is calculated considering the geographical coordinates using the formula:

$$T = [\Delta T\,(\varphi_j)_{\Delta\lambda=1'} - \Delta T\,(\varphi_i)_{\Delta\lambda=1'}]\,(\lambda_n - \lambda_m)' \quad [km^2]$$

where: $\Delta T\,(\varphi_i)_{\Delta\lambda=1'} = A\sin\varphi_i - B\sin 3\varphi_i + C\sin 5\varphi_i - D\sin 7\varphi_i$ $[km^2]$

$\Delta T\,(\varphi_j)_{\Delta\lambda=1'} = A\sin\varphi_j - B\sin 3\varphi_j + C\sin 5\varphi_j - D\sin 7\varphi_j$ $[km^2]$

$(\lambda_n - \lambda_m)'$, *longitude difference*, expressed in minutes and parts of minutes.

The numerical values of the A, B, C and D constant coefficients used to calculate the elements of the ellipsoidal $\Delta T\,(\varphi_j)_{\Delta\lambda=1'}$ and $\Delta T\,(\varphi_i)_{\Delta\lambda=1'}$ areas, were determined based on the geometrical parameters of the Krasovski – 40 reference ellipsoid.

The elements of the ellipsoid $\Delta T\,(\varphi_j)_{\Delta\lambda=1'}$ and $\Delta T\,(\varphi_i)_{\Delta\lambda=1'}$ areas between the Ecuador and the paralels of (φ_j) and (φ_i) latitude respectively, were calculated considering the geographic coordinates of the corners of the trapeziums and the numerical value of the constant coefficients for a longitude difference of $\Delta\lambda = 1'$.

In order to analyze the total areolar deformations of the trapeziums used for the cartographic framing of the extreme points and for the above mentioned administrative-territorial units (ATU), the analytical calculation of the plane surfaces of the trapeziums was also performed.

The area of the trapezium (S) from the secant plan of the 1970 - Stereografical projection was calculated using the rectangular coordinates (X<70>, Y<70>) of the corners of the trapeziums previously presented in tables 2 and 3 with the following relations:

$$\pm 2S = \sum_{i=1}^{n} x_i\,(y_{i+1} - y_{i-1}) = \sum_{i=1}^{n} y_i\,(x_{i+1} - x_{i-1}) \quad [ha]$$

The areas of ellipsoidal (T) and plane (S) cartographic framing trapeziums of the four geographic points and of the four administrative-territorial units, respectively, situated on Romania's borders are presented in tables 4 and 5.

Table 4. The areas of the cartographic framing trapeziums for Romania's extreme points

Point name	*Trapezium nomenclature*	*Trapezium scale*	*Surface of the geodetic trapeziums (ha)*	
			KA-40 elipsoid	*STEREO-70*
Horodiştea	M-35-138-A-b-4-III	1:5000	537.5278	537.7862
Zimnicea	K-35-15-B-b-3-I	1:5000	583.9244	584.1435
Sulina	L-35-108-C-b-2-I	1:5000	568.9506	569.6701
Beba Veche	L-34-65-D-a-3-I	1:5000	559.4287	560.0728

Table 5. The areas of the cartographic framing trapeziums for the administrative units situated in the extreme geographical areas of Romania

ATU name*	*Trapezium nomenclature*	*Trapezium scale*	*Surface of the geodetic trapeziums (ha)*	
			KA-40 elipsoid	*STEREO-70*
Păltiniş	M-35-138-A-d	1:25000	8609.0977	8612.9001
Zimnicea	K-35-03-D-d	1:25000	9328.4116	9331.3197
Sulina	L-35-108-C	1:50000	36458.7475	36503.6321
Beba Veche	L-34-65-D-a	1:25000	8949.1844	8959.1976

ATU – administrative-territorial unit

VI. ANALYSIS OF THE REGIONAL DEFORMATIONS FROM THE 1970-STEREOGRAPHIC PROJECTION PLAN FOR ROMANIA'S EXTREME GEOGRAPHICAL AREAS

The 1970-Stereographic projection system preserves the angles undeformed but generates a radial deformation of lengths and surfaces as the distance between the central point of the projection $Q_0\,(\varphi_0, \lambda_0)$ and the extreme points of Romania's territory increases.

The basic parameters for the 1970-Stereographic projection were established considering the geometrical elements of the 1940 – Krasovski reference ellipsoid, the position of the central point $Q_0\,(\varphi_0, \lambda_0)$ and the depth of the unique secan plan that was lowered in relation to the tangent plan by 3189.478 m.

The regional deformation per length unit (1 km) in the unique secant plan – 1970, from the projection pole $Q_0\,(\varphi_0, \lambda_0)$ is of – 0.25 m/km. As the distance from the projection pole increases length deformations decrease up to 0 m/km on the nul deformation circle with the radius of 201.718 km. Outside the nul deformation circle ($d > r_0$), the relative linear deformation of lengths increases up to the positive value of + 0.25 m/km, for a distance of 285 km in relation to the projection pole and up to + 0.637 m/km at 385 km.

The 1970 - Stereographic projection system complies with the accuracy of the representations, for the topographic plans at 1:2000, 1:5000 and 1:10000 scales everywhere where the linear deformation of lengths does not exceed ± 0.15 m/km [8].

a. The deformation of distances in Romania's extreme geographical areas

The implementation and the use of cartographic projections which, in time, have been used for drawing topographic plans and maps considered the hypothesis of making deformations for distances, surfaces and/or angles as small as possible.

In this context, within the 100 years that passed from the Great Union (1918-2018), the following cartographic representations are mentioned as used: the modified Lambert-Cholesky conformal conic projection (1918-1933); the 1930 - Stereographic projection (1933-1950); the Gauss cylindrical projection (1951-1973) and the 1970 - Stereographic projection, starting with 1973 [9].

In a previous study we analysed the regional deformations of the distances and surfaces corresponding to the four extreme points (localities) of Romania when represented cartographically with the following projections systems: the 1970-Stereographic projection, the Gauss-Krüger and the Universal Transversal Mercator projection plan [10].

The national registration of all real estates in the integrated cadastre and land registration system includes both the execution of accurate on field measurements and the knowledge of regional deformations in the 1970 - Stereographic projection system. In this context the study on regional deformations was expanded to the entire territory of the administrative-territorial units from the four extreme geographic areas of Romania: Păltiniș, Zimnicea, Sulina and Beba Veche.

The relative linear deformation (D_{sec}) per length unit (1 km) from a random point of the unique secant plan – 1970, was obtained with the formula:

$$D_{sec} = D_0 + \frac{L^2}{4R_0^2} = -0.000\,250\,\text{km/km} + \frac{L^2}{4R_0^2} \quad [\text{km/km}]$$

where:

- D_0 is the deformation value calculated in the central point $Q_0(\varphi_0, \lambda_0)$;
- $L^2 = (X^2 + Y^2)$, the distance between the central point Q_0 (X_0=0.000 m; Y_0=0.000 m) and the given point (P_i) of not-translated Stereographic coordinates (X_i < 70 > - 500,000 m; Y_i < 70 > - 500,000 m) from the projection's secant plan [km];
- R_0 = 6378. 956 681 km, the medium radius of curvature of the reference ellipsoid for the geographic latitude $\varphi_0 = 46^o\ 00'\ 00''$ N.

The linear deformation module (μ) was established considering the relative linear deformation (D_{sec}) from a random point of the unique secant plan, using the formula:

$$\mu = 1 + D_{sec}$$

The relative linear deformation (D_{sec}) and the linear deformation module (μ) were established based on the above mentioned algorithm, both for the four extreme points (localities) as well as for the central point of the geodetic trapeziums used for the cartographic framing of the extreme administrative – territorial units.

The distances between the central point (Q_0) and the extreme points $P_i(X_i, Y_i)$ considered in the study exceeded the length of 201.718 km of the nul deformation circle' radius. The spatial distribution of the regional deformations of distances was characterized by the well known shape of concentric circles with the centre in the origin of the coordinate system (XOY). It represents the plane image of the central point of the 1970-Stereographic projection. The length of the distances between the projection pole (Q_0) and the extreme geographical points and the central points of the geodetic trapeziums considered in the study, respectively, ranged between a maximum of 363 km and 379 km and a minimum of 257 km and 283 km (Figure 9).

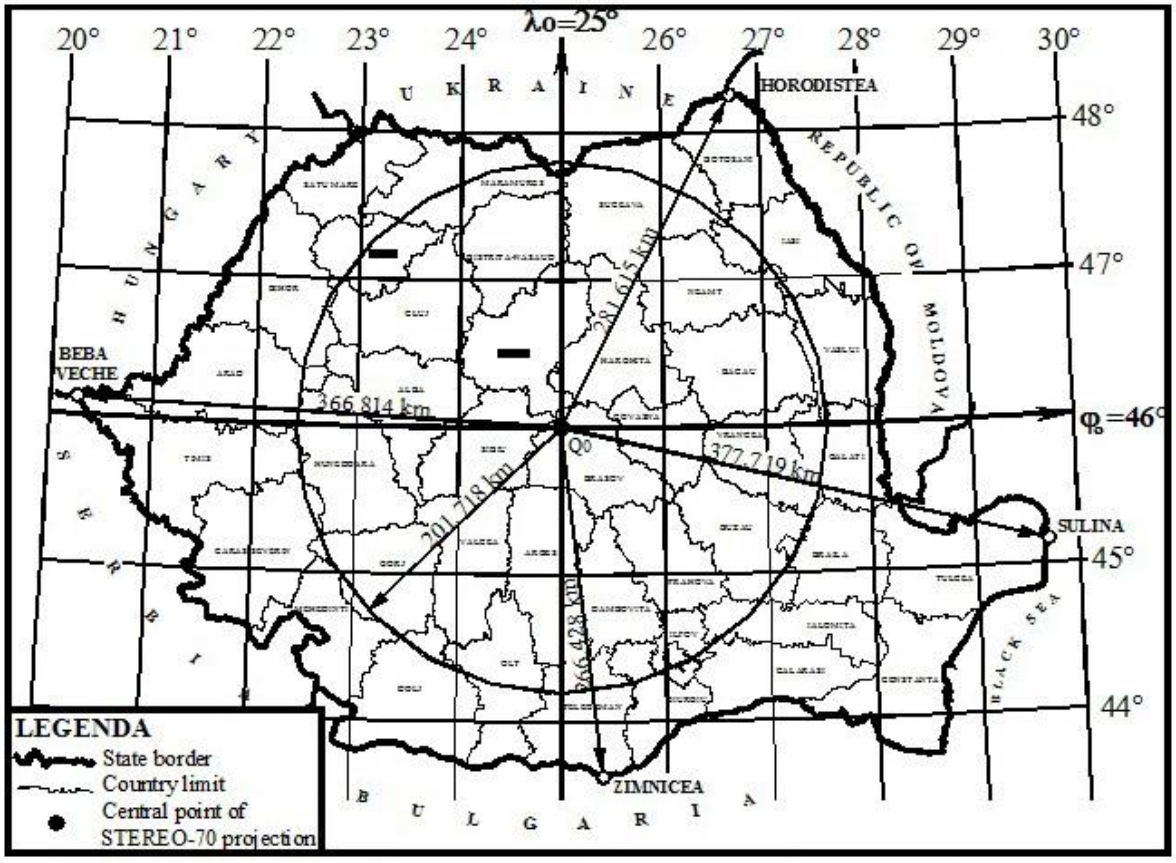


Fig. 9. The extreme administrative-territorial units' position in relation to the central point of the 1970 – Stereographic projection

The value of the relative linear deformations from the secant plan (D_{sec}) varied depending of the distance (L) between the projection pole and the analysed points, ranging between +18.6 cm/km in the southermost point and +23.7cm/km in the northermost point. For the westernmost and easternmost points the regional deformation of lengths ranged between +57.7 cm/km and +62.7 cm/km, respectively (Table 6).

Table 6. The distances deformation corresponding to the Romania's extreme points

Name of the extreme point	*Stereographic coordinates*		*Distance to pole (L)*	*Relative linear deformation (D_{sec})*	*Linear deformation module (μ)*
	X <70> - 500,000	*Y <70> - 500,000*			
	m	*m*	*km*	*cm/km*	
Horodiştea	251,674.291	126,361.492	281.615	+23.7	1.000237251
Zimnicea	-264,539.063	31,665.642	266.428	+18.6	1.000186113
Sulina	-82,559.327	368,585.768	377.719	+62.7	1.000626553
Beba Veche	24,700.549	-365,981.388	366.814	+57.7	1.000576671

For the geodetic trapeziums at 1:5000 scale, which cartographically framed the geographical position of the extreme points, the deformations of the distances from the central point of these trapeziums were also calculated. The stereographic coordinates of the central point were presented as the arithmetic mean of the not-translated coordinates from the corners of the trapezium.

The distance (D) between the projection pole (Q_0) and the central points (P_i) of the trapeziums ranged between 267 km and 379 km. The relative linear deformations from the secant plan (D_{sec}) ranged between +18.8 cm/km and +63.2cm/km (Table 7).

Table 7. The deformations of the distances from the central point of the trapeziums at 1:5000 scale

Trapezium nomenclature	*Stereographic coordinates*		*Distance to the pole (L)*	*Relative linear deformation (D_{sec})*	*Linear deformation module (μ)*
	X <70> - 500,000	*Y <70> - 500,000*			
	m	*m*	*km*	*cm/km*	
M-35-138-A-b-4-III	252,650.202	126,469.214	282.536	+24.0	1.000240443
K-35-15-B-b-3-I	-264,987.144	31,538.843	266.857	+18.8	1.000187521
L-35-108-C-b-2-I	-82,915.070	369,641.078	378.826	+63.2	1.000631755
L-34-65-D-a-3-I	23,621.042	-365,782.082	369.262	+57.5	1.000575454

In a similar manner there were calculated and analysed the deformations of the distances from the central point of the trapeziums at scale 1:25000 and 1:50000. They frame the geographic position of Romania's extreme administrative-territorial units.

The relative linear deformations from the secant plan (D_{sec}) also indicated the distance between the trapeziums'central points and the projection pole. They ranged between + 15.5 cm/km - Zimnicea ATU and + 61.5 cm/km - Sulina ATU (Table 8).

Table 8. The deformations of the distances from the central point of the trapeziums at 1:25000 and 1:50000 scales

Trapezium nomenclature	*Stereographic coordinates*		*Distance to the pole (L)*	*Relative linear deformation (D_{sec})*	*Linear deformation module (μ)*
	X <70> - 500,000	*Y <70> - 500,000*			
	m	*m*	*km*	*cm/km*	
M-35-138-A-d	246,835.334	125,434.046	276.878	+22.1	1.000221114
K-35-03-D-d	-254,548.095	35,267.382	256.979	+15.5	1.000155832
L-35-108-C	-91,359.955	363,971.228	375.262	+61.5	1.000615403
L-34-65-D-a	24,564.760	-362,094.409	362.927	+55.9	1.000559444

b. The deformation of surfaces in Romania's extreme areas

For analysing the areolar deformations it was used the linear deformation module (μ), which was identified in the central point of the trapeziums of cartographic framing for the administrative territorial units (Tables 7, 8). The following calculation formulas were used:

- Areolar deformation module: $p = \mu^2$;
- Relative areolar deformation: $P = (p-1)$;
- Total areolar deformation: $\Delta T = P \cdot T_{elipsoid}$ [ha];
- Total areolar deformation: $\Delta T_S = (S - T_{elipsoid})$ [ha].

The verification of the calculation for the total areolar deformation (ΔT) was conducted considering the difference between the two surfaces of the trapezium taken into consideration. They were established in the 1970-Stereographic projection plan (S) and on the Krasovski – 40 reference ellipsoid (T).

In principle, the total areolar deformations, assessed for the plan sheets at scale 1:5000 and for the map sheets at 1:25000 and 1:50000 scales, in relation to the undeformed surface of the geodetic trapezium from the terrestrial ellipsoid confirmed the variation of distance deformation.

The numerical values for the total areolar deformation identified for the trapeziums at 1:5000 scale ranged between +0.2191 ha (Zimnicea) and + 0.7195 ha (Sulina), depending of the distance between the central point of the trapezium taken into consideration and the projection pole. The equal values of the two formulas (ΔT and ΔT_S) pointed out the accuracy of the calculation method within a ± 1 m^2 and ± 4 m^2 difference limit (Table 9).

Table 9. The areolar deformations on geodetic trapeziums at 1:5000 scale

ATU name*	*Nomenclature of the geodetic trapezium*	*Areolar deformation module (p)*	*Relative areolar deformation (P)*	*Total areolar deformation on geodetic trapeziums*	
				$\Delta T = P \cdot T$	$\Delta T_S = (S - T)$
				ha	*ha*
Păltiniş	M-35-138-A-b-4-III	1.000480944	0.000480944	+0.2585	+0.2584
Zimnicea	K-35-15-B-b-3-I	1.000375078	0.000375078	+0.2190	+0.2191
Sulina	L-35-108-C-b-2-I	1.001263909	0.001263909	+0.7191	+0.7195
Beba Veche	L-34-65-D-a-3-I	1.001151239	0.001151239	+0.6440	+0.6441

ATU – administrative-territorial unit

For assessing the total areolar deformation of the surfaces corresponding to the extreme administrative-territorial units there were first analysed the areolar deformations of the geodetic trapeziums, scales 1:25000 and 1:50000. Depending of the position of the central point of the trapeziums in relation to the 1970-Stereographic projection pole, the total areolar deformations (ΔT_S) also recorded positive values.

The numerical values of the total areolar deformation (ΔT_S) obtained for the trapeziums at 1:25000 and 1:50000 scales, in relation with the undeformed surface of the terrestrial ellipsoid ranged between +2.9081 ha (Zimnicea) and +44.8846 ha (Sulina). In a similar manner it was verified the calculation method for the two formulas (ΔT and ΔT_S) which placed the results within a deviation limit ranging between ±9 m^2 and ±31 m^2.

The relative areolar deformation (P) expressed per surface unit (1 hectar) was of +3 m^2/ha and +4 m^2/ha in the southernmost and northernmost points and of +11 m^2/ha and +12 m^2/ha in the easternmost and westernmost posints of Romania (Table 10).

Table 10. The areolar deformation for the trapeziums used at the cartographic framing of Romania's extreme administrative-territorial units

ATU name*	*Nomenclature of the geodetic trapezium*	*Areolar deformation module (p)*	*Relative areolar deformation (P)*	*Total areolar deformation on geodetic trapeziums*	
				$\Delta T = P \cdot T$	$\Delta T_S = (S - T)$
				ha	*ha*
Păltiniş	M-35-138-A-d	1.000442041	0.000442041	+3.8055	+3.8024
Zimnicea	K-35-03-D-d	1.000311486	0.000311486	+2.9057	+2.9081
Sulina	L-35-108-C	1.001231187	0.001231187	+44.8875	+44.8846
Beba Veche	L-34-65-D-a	1.001118797	0.001118797	+10.0123	+10.0132

ATU – administrative-territorial unit

The regional deformations determined for the four extreme geographical administrative-territorial units of Romania differentiated from one another based on their position in relation to the 1970-Stereographic projection pole.

The surfaces recorded in the technical cadastral documents are to be verified and outlined on the total surface of the administrative-territorial unit that is analytically calculated using the coordinates of the border points, considering, as well, the regional areolar deformation.

VII. CONCLUSION

There are many benefits of installing a monitoring system – some of which strongly interrelate with each other. A properly designed and installed monitoring system offers a deeper understanding of the operational parameters of the system. A close appraisal of the data generated by a monitoring system can reveal a variety of overt and subtle opportunities, including:

Romania's geographical position is marked on the cardinal directions by the four extreme points (localities) included in the administrative – territorial units, which, in the data base, cover the following surfaces: 7552.6707 ha, Păltiniş commune; 13647.2670 ha, Zimnicea city; 32833.7452 ha, Sulina city; 9416.6346 ha, commune Beba Veche.

The relative linear deformations from the secant plan of the 1970-Stereographic projection calculated both in the four extreme points (localities) and in the central point of the geodetic trapeziums, at 1:5000, 1:25000, 1:50000 scales, outlined their belonging to the administrative-territorial units in the following limits: +22 and 24 cm/km (Păltiniş); +16 and 19 cm/km (Zimnicea); +62 and 63 cm/km (Sulina); +56 and 58 cm/km (Beba Veche).

The total areolar deformations established on the geodetic trapeziums that were used for drawing the plan sheets at 1:5000 scale, ranged between +0.2191 ha (Zimnicea) and +0.7195 ha (Sulina), while for the

cadastral map sheets, at 1:25000 and 1:50000 scales, the values ranged between +2.9081 ha (Zimnicea) and +44.8846 ha (Sulina), depending on the distance between the central point of the trapezium taken into consideration and the pole of the 1970-Stereographic projection, concluding that for cadastral works at administrative territorial units level, is esential to take into consideration the deformations caused by the cartographical projection system.

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