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THE COMPARATIVE ANALYSIS OF MAP PROJECTIONS FOR THE REPUBLIC OF MOLDOVA TERRITORY

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Key words: reference system, map projection, central meridian, relative linear deformations**.**

Introduction

Starting from 2001 a new reference system MOLDREF99 based on European Terrestrial Reference System (ETRS89) and Transversal Mercator for Moldova (TMM) map projection was established to provide large scale mapping from 1:500 to 1:10 000.

However, the deformations on the margins of the 3,5 degree zone are not fitting requirements for 1:500 mapping. In this case for marginal zones a new scale coefficient has to be used in order to reduce deformations. This circumstance complicates many geodetic applications: geodetic works, cadastral surveying, GIS, mapping, etc.

The aim of this work was to find suitable map projection for large scale mapping of territory of our country in order to reduce deformations on the margin of the zone and to establish a unique map projection for entire territory of Republic of Moldova.

The objective of the work was comparative analyze of existing map projection TMM with proposed Oblique Mercator for Moldova (OMM) projection and Azimuthal conformal projection Srereo70 (Stereographic 1970) with origin in the geometrical centre of Romania.

1. Transversal Mercator map projection for Moldova

In order to provide a unique map projection for large scale mapping, including 1:500 scale, for all territory of Republic of Moldova. The Transverse Mercator projection for territory of Moldova was adopted in 2001 using longitude of centre line of the projection λ_c = 28°24´, scale factor at the central line of the projection k_c = 0,99994. In order to avoid negative value of ordinates false Easting at central meridian $E(y)_0$ =200 000 m and false Northing $N(x)_0$ = –5 000 000 m from the equator were applied.

Relative linear deformations D were calculated using the following formulas:

$$\mu = [1 - \cos^2\phi \sin^2(\lambda - \lambda_0)]^{-1/2};$$

$$D = (\mu - 1)10^5 \ cm/km,$$

where ϕ, λ are geodetic (ellipsoidal) latitude and longitude respectively.

From Fig. 1 results that there are two lines with zero deformations situated on both sides of the central line. Between these two lines the values of deformations are negative form 0 to –6 cm/km. Outside of these lines values of deformations are positive from 0 to +16 cm/km. The zero deformation lines are about 35 km distance from the central line and the isolines are parallel.

2. Oblique Mercator map projection for Moldova

Taking in account that the territory of Republic of Moldova is extended from South-East to North-West it was proposed to use as initial line central to the map area of given geodetic azimuth α_c = 339°57'27″, passing through a defined centre of the projection with latitude ϕ_{c0} = 47°10' and longitude λ_{c0} = 28°30'.

The scale factor at the centre of projection was calculate k_c = 0,99998.

To ensure that ordinates on the map area have positive grid values false easting $E(y)_0$ = 2 200 000 m was applied. In order to avoid big numbers of false northing $N(x)_0$ = –4 800 000 m was applied from the origin of Hotine Oblique Mercator map projection.

Relative linear deformations were calculated using following formulae:

$$k = \frac{A\cos(Bu_c / A)\left(1 - e^2 \sin^2 \varphi\right)^{1/2}}{a \cos\varphi \cos[B(\lambda - \lambda_{c0})]},$$

$$D = (k - 1)10^5 \ cm/km,$$

where ϕ, λ are geodetic (ellipsoidal) latitude and longitude respectively; λ_{c0} is the latitude of centre of projection; A, B are calculated constants for the Oblique Mercator projection: A = 6384183,617 m, B = 1,000719681; a, e are GRS80 ellipsoid defined parameters; u_c is the distance from natural origin of the projection to the projection centre.

From Fig. 2 results that there are two lines with zero deformations situated on both sides of the central line. Between these two lines the values of deformations are negative form 0 to –2 cm/km. Outside of these lines values of deformations are positive from 0 to +8 cm/km. The zero deformation lines are about 40 km distance from the central line and the isolines are parallel.

3. Stereographic projection 1970

Stereographic 1970 is an azimuthal conformal projection with origin in the geometrical centre of Romania φ = 46°N; λ =25°E. The whole territory of Romania is represented on a single secant projection plane, which has a zero relative distortion circle, with the radius ρ = 201 718 m, the relative linear distortion in the center of the circle being –25 cm/km and +15…+65 cm/km distortions for the territory of Republic of Moldova. The rectangular axis system has the origin in the central point of map projection; the X axis has the positive direction towards the North and the Y axis towards the East.

In order to reduce relative linear deformations for territory of our country a secant projection plane with zero deformations was defined in the middle of our country with the depth of the secant projection plane h = 7654,618 m.

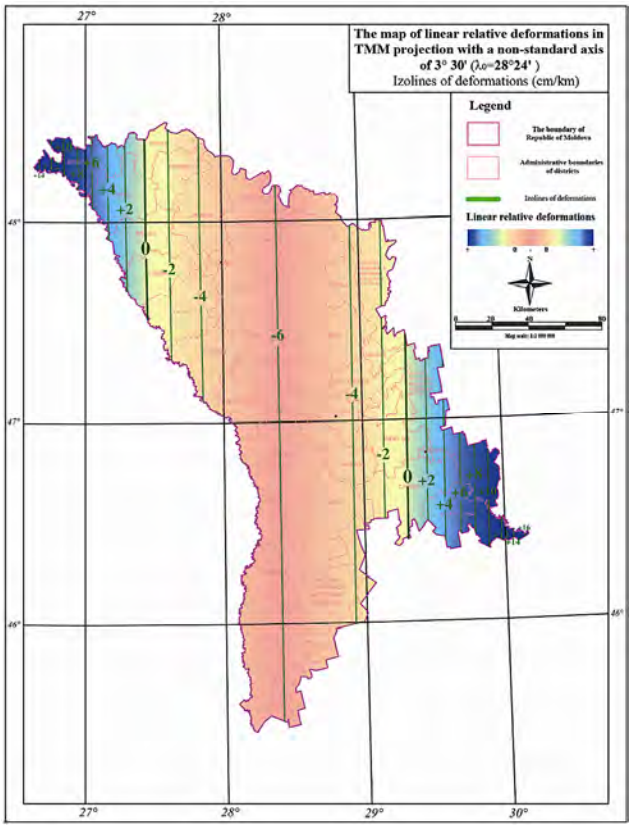

Fig. 1. Isolines of relative linear deformations for TMM map projection

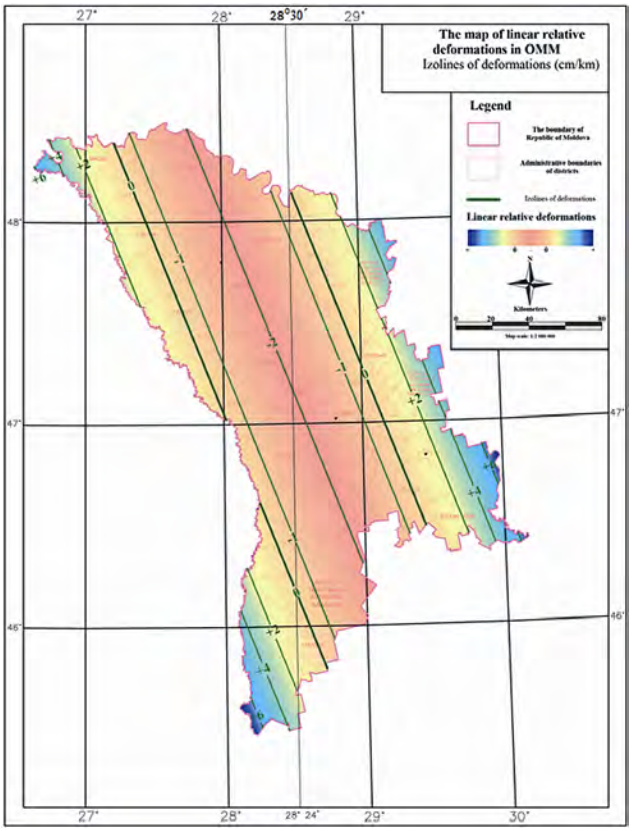

Fig. 2. Isolines of relative linear deformations f or OMM map projection

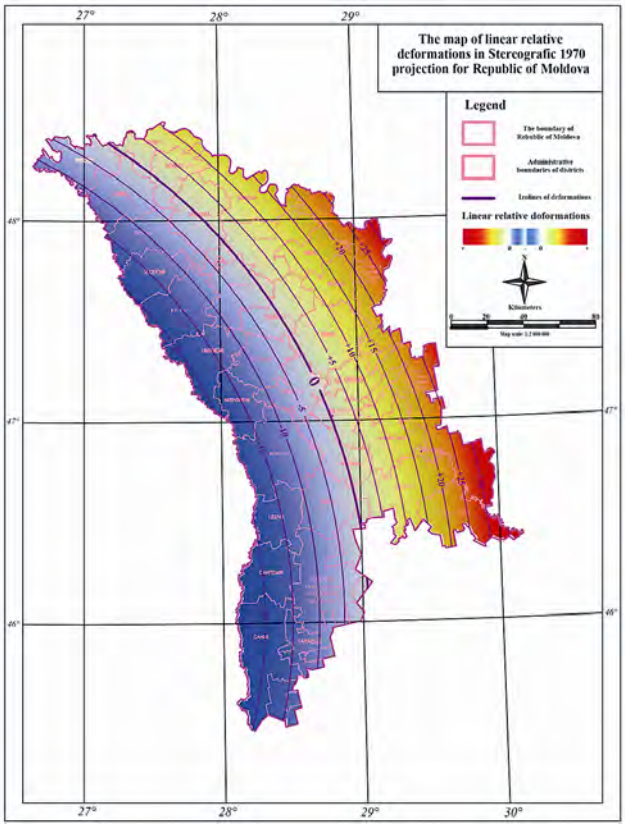

Fig. 3. Isolines of relative linear deformations for stereo 70 map projection

Relative linear deformations were calculated using following formula:

$$D = (k_0 - 1) + \frac{\rho^2}{4k_0 R_0^2} \, cm/km,$$

where mean radius of curvature on the centre of projection is R_0 = 6 378 848,680 m and calculated scale factor is k_0 = 0,9994; ρ is the distance from the projection centre.

From Fig. 3 results that there is one line with zero deformations situated in the middle of the country territory. To the West of this line the values of relative linear deformations are negative form 0 to –25 cm/km and to the East deformations are positive form 0 to +35 cm/km. The zero deformation line is a arc of the circle with radius 312 405 m and the isolines are arcs of the circles from the projection centre.

4. Comparative analysis of map projections

One of the fundamental criteria for adopting a countrywide map projection, in order that our country should be represented in large scales mapping, is the deformations character, both by the calculated values and their territorial distribution.

For this purpose it was carried out a comparative analysis of the deformations for territory of Moldova between the three map projections (Fig. 4–6).

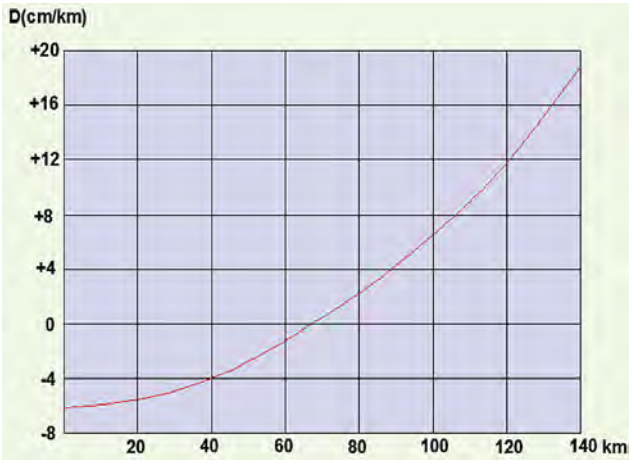

Fig. 4. Diagram of relative linear deformations for Transversal Mercator map projection

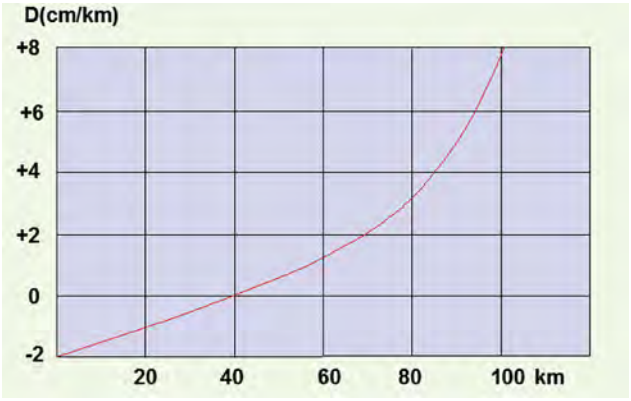

Fig. 5. Diagram of relative linear deformations for Oblique Mercator map projection

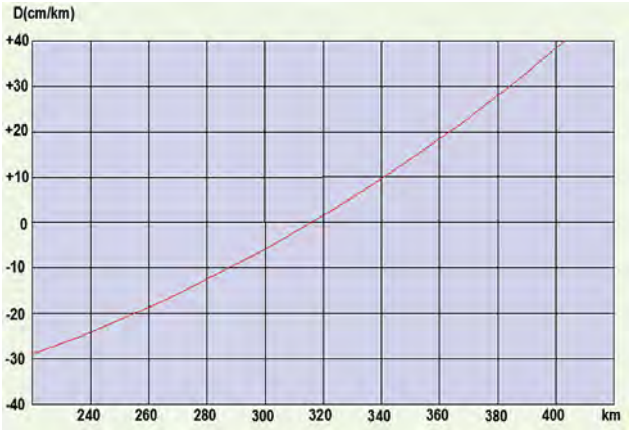

Fig. 6. Diagram of relative linear deformations for Stereo 70 map projection

Analyzing the results from the case studies of existing map projection TMM and proposed OMM projection we can see on Fig. 4–5 that the relative linear distortions on the central line were reduced from –6 cm/km to –2 cm/km and on the margins of the zone from +16 to +8 cm/km.

The comparative analyses of existing map projection TMM and Stereo 70 projection we can see on Fig. 4–6 that the relative linear distortions on the central line are reduced from –6 cm/km to 0 cm/km, but on the margins of zone distortions are increased from +16 to +35 cm/km.

The comparative analysis of the distribution of the relative linear deformations of three map projections for different intervals pointed out a percentage of 84 % of the Moldavian territory where the deformations of the OMM projection are within the ±2 cm/km while for the TMM projection this percent is only 8 % and for Stereo 70 projection less than 5 % (Fig. 7).

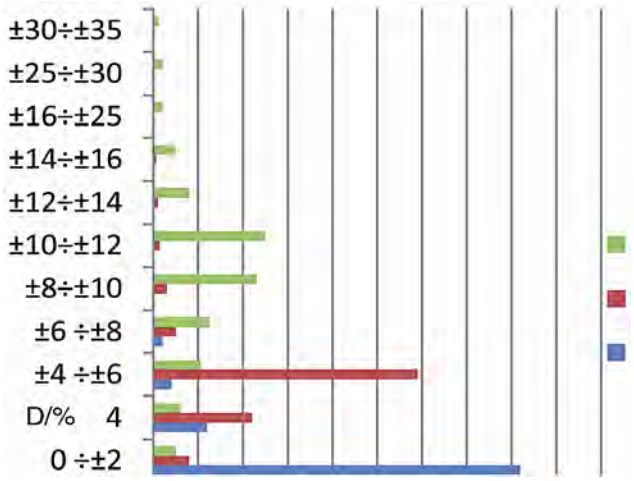

Fig. 7. Diagram of comparative analysis of the distribution of the relative linear deformations

Taking in account the admissible limit for the 1:500 scale mapping TMM map projection could be used for all territory of the country only for cadastral works and large scale mapping 1:1000–1:10000.

The analyses of Stereo 70 map projection in comparison with both studied map projection showed the compatibility with Universal Transversal Mercator (UTM) where relative linear distortions on the margins of 6-degree zone are about ±40 cm/km and could be used for small scale mapping.

Conclusions

Comparative analysis of TMM (Transverse Mercator for Moldova) map projection, currently used for large scale mapping, and Oblique Mercator map projection showed the reduction of deformations on the centre from –6 to –2 cm/km and on the margins of the zone from +16 to +8 cm/km.

The analyses of Stereo 70 map projection in comparison with both studied map projection shows than relative linear distortions from ±15 cm/km to ±40 cm/km of more than 8 % of country territory and cannot be used as a unique map projection for large scale mapping for all territory of the country. The results of this study could be used for argumentation of new Oblique Mercator map projection for large scale mapping to be adopted by Land Relation and Cadastre Agency.

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Порівняльний аналіз картографічних проекцій для території Республіки Молдова

В. Кіріяк, А. Власенко

Наведено результати дослідження картографічної проекції Меркатора для великомасштабного картування території Молдови з метою зменшення деформацій на краях зон.

Сравнительный анализ картографических проекций для территории Республики Молдова

В. Кирияк, А. Власенко

Представлены результаты исследования картографической проекции Меркатора для крупномасштабного картирования территории Молдовы с целью уменьшения деформации на краях зон.

The comparative analysis of map projections for the Republic of Moldova territory

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Starting from 2001 a new reference system MOLDREF99 based on European Terrestrial Reference System (ETRS89) and Transversal Mercator for Moldova (TMM) map projection was established to provide large scale mapping from 1:500 to 1:10 000.

However, the deformations on the margins of the 3,5 degree zone are not fitting requirements for 1:500 mapping. In this case for marginal zones a new scale coefficient has to be used in order to reduce deformations. This circumstance complicates many geodetic applications: geodetic works, cadastral surveying, GIS, mapping, etc.

This paper presents the results of study of Oblique Mercator map projection for large scale mapping of territory of our country in order to reduce deformations on the margin of the zone. Comparative study of TMM (Transverse Mercator for Moldova) map projection, currently used for large scale mapping, and Oblique Mercator map projection showed the reduction of deformations on the center from 6 to 2 cm/km and on the margins of the zone from 16 to 8 cm/km.

The analyses of Stereo 70 map projection in comparison with both studied map projection showed than relative linear distortions from ±15 cm/km to ±35 cm/km of more than 8 % of country territory and cannot be used as a unique map projection for large scale mapping for all territory of the country.

The results of this study could be used for argumentation of new Oblique Mercator map projection for large scale mapping to be adopted by Land Relation and Cadastre Agency.