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THE CARTOGRAPHIC PROJECTIONS USED IN ALBANIAN MAPS

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SUMMARY

Map projections and coordinate transformations are the basis of achieving a common frame of reference for geographic information. The requirement of a common ellipsoid, datum, map projection, and finally plane coordinate systems make it possible to use plane geometry for all types of spatial overlay and analysis. Projection of geographic data from the ellipsoidal Earth to a plane coordinate system always results in distortion in area, shape, distance, and other properties. With appropriate selection of a projection, the user can preserve desired characteristics at the expense of others.

For the production of Albanian maps are used different cartographic projections. This is explained with the fact that most of these maps are created from foreign persons and geographic institutions, keeping safe their cartographic traditions.

The cartographic projections used as mathematical base of topographic and thematic maps of Albania are:

- Polar conic projection in the new edition of Ptolemy maps;
- Gauss-Krüger projection in Bessel ellipsoid, with origin the intersection of the Equator by the meridian of Ferro with $\lambda_{Ferros} = 17° 39' 46.5''$ in the maps, scale 1:75000 and 1:50000, published by Military Geographic Institute of Wien (1868-98, 1913-18);
- Polyconic equivalent Projection of Bonn in Clark ellipsoid with origin the intersection of the Equator by the central meridian $\Lambda_0 = 18^0\ 39'\ 09''$, in the maps of scales 1:50000, published by Military Geographic Institute of Florence (MGIF) (1922-25);
- Bonne pseudo-conic equivalent projection in Bessel ellipsoid with origin the intersection of parallel $\Phi_0 = 41° 20' 12''.809$ by the central meridian $\Lambda_0 = 19°$

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45' 45".285, in the maps of scales 1:50000, published by Military Geographic Institute of Florence (MGIF), Italy (1927-1934);

- Gauss - Boaga projection in Bessel ellipsoid with origin the intersection of the Equator by the central meridian $\Lambda_0 = 20^0$, in the maps of scales greater than 1:50000 and topographical plans of residential areas at 1:5000 scale, published by Military Geographic Institute of Florence (MGIF) (1939 - 1948);
- Gauss-Krüger projection in Krassowsky ellipsoid with origin the intersection of the Equator by the central meridian L_0=21º in the maps, scale 1:25000 and 1:10000, published by Military Geographic Institute of Albania (1950 - 1955, 1970 - 1992)[4]. During the period 1946-1996 are also created a series of cadastral maps (which covered approximately 56.27% of the Albania's territory) in scale 1: 500; 1: 1000; 1: 2000; 1: 5000; 1: 10000 and 1: 50000. Cadastral maps created during the years 1946 - 1960, are in 1: 2500 and 1: 5000 scale and based on the Bessel ellipsoid, Gauss-Kruger projection and the central meridian Lo = 20º 00'. Almost all cadastral maps created after 1960 were constructed in the state coordinate system: the Krasowsky ellipsoid, Gauss-Kruger projection and central meridian Lo = 21^0 00'.
- UTM projection in WGS 84 ellipsoid with origin the intersection of the Equator by the central meridian $\Lambda_0 = 21^0$, in the maps of scales 1:50000 and 1:25000, published by Military Geographic Institute of Albania (MGIA) (after 1994);
- Version of the pseudoconic projection, developed by prof. dr. Agim Shehu (Polytechnic University of Tirana, Albania) in the Earth sphere, was used for the first time at the "The geographical atlas of Albania" 1968, in the scales 1:2000000 and smaller ones. In the 1980 year this projection was used for the creation of the maps of Albania in the scale 1:200000, as geological, hidrogeological and fitogeographical maps, etc. also it is used for all (127) the maps of "Climatic atlas of Albania", 1986, in the scale 1:800000 and for all (256) the maps of "Agricultural geographical atlas of Tirana district" in the scales 1:100000.

Keywords: *cartography, map, mapping, map projections, mathematical cartography, Albania*

1. INTRODUCTION

New methods of acquiring spatial data and the advent of geographic information systems (GIS) for handling and manipulating data mean that we no longer must rely on paper maps from a single source, but can acquire,

[4] The central meridian, $\Lambda_0 = 21^\circ$, is located at easternmost extreme of Albania, leaving on his west over 99.7% of the territory. The area with the greatest distortions of the projection is the coastal zone. The distortions in this area reduce accuracy of topographical plans of large scales, which are necessary for development of tourist infrastructure, economic and cadastral system.

combine, and customize spatial data as needed. To ensure quality results, however, one must fully understand the diverse coordinate frameworks upon which the data are based. Datums and Map Projections provides clear, accessible explanations of the terminology, relationships, transformations, and computations involved in combining data from different sources.

The concept of cartography as science was presented for the first time under the title geography in the second century in the famous Ptolemy's work Introduction into Geography. In the middle Ages, the regional direction in geography that was built on Ptolemy's ideas, found its expression in the most important geographic works of that time, in big atlases from the 16th and 17th centuries that were collections of maps and comprehensive texts. The synonym for cartography was cosmography, and some cartographers of that time were called cosmographers.

Theory of map projections is a branch of cartography studying the ways of projecting the curved surface of the earth and other heavenly bodies into the plane, and it is often called mathematical cartography[5]. Map projections have been developing parallel with the development of map production and cartography in general.

The subject of map projections, either generally or specifically, has been discussed in thousands of papers and books dating at least from the time of the Greek astronomer Claudius Ptolemy (about A.D.150), and projections are known to have been in use some three centuries earlier.

Mapmakers have developed hundreds of map projections, over several thousand years. Three large families of map projection, plus several smaller ones, are generally acknowledged. These are based on the types of geometric shapes that are used to transfer features from a sphere or spheroid to a plane. Map projections are based on *developable surfaces*, and the three traditional families consist of cylinders, cones, and planes. They are used to classify the majority of projections, including some that are not analytically (geometrically) constructed. Which developable surface to use for a projection depends on what region is to be mapped, its geographical extent, and the geometric properties that areas, boundaries, and routes need to have, given the purpose of the map.

During last six centuries are used different cartographic projections for the production of Albanian maps. This is explained with the fact that most of these maps are created from foreign persons and geographic institutions,

[5] The object of study of the mathematical cartography it is on the one hand representation of Earth's curved surface on a flat surface (map), on the other hand how to use the maps in various scientific and practical purposes. Plan representation of a portion of the land area is done by choosing an appropriate projection system purpose and destination topographic map or plan which is to be drawn.

keeping safe their cartographic traditions. For a small country as Albania, number of the projections used must be tightly related with criteria well determined.

Albania always has profited by the wide cartographic experience of the other countries with a great economic and scientific potential. Our cartographers have followed with much attention and interest the progress in theory, technique and technology of cartography. A lot of this progress is reflected in the practice of Albanian mathematical cartography particularly in the theory of cartographic projections.

In our article, we analyzed, except some of the usual cartographic projections, some projections processed theoretically and practically by prof. Agim Shehu, which are used in the compilation of several thematic atlases in Albania.

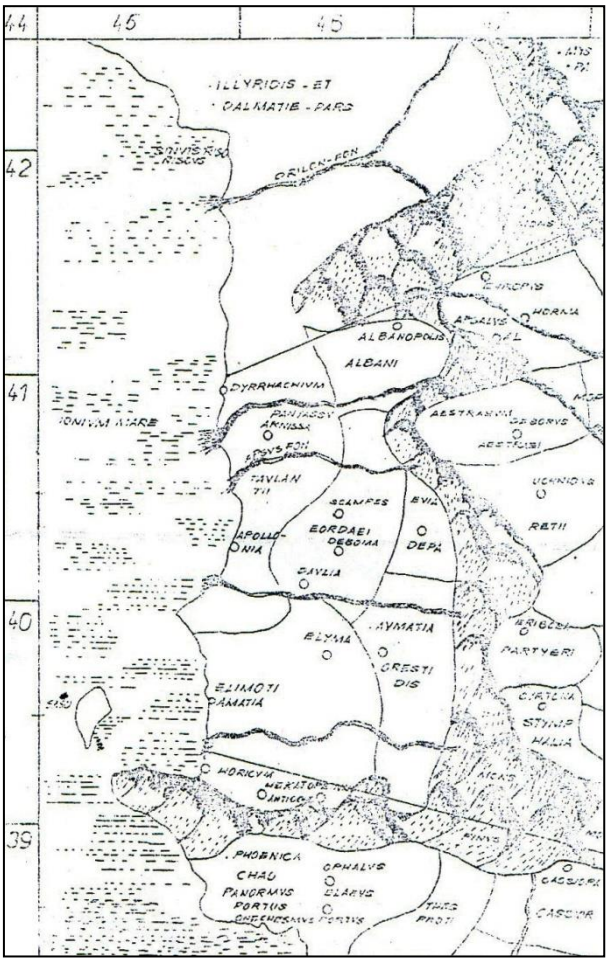
2. A BRIEF HISTORY OF ALBANIA MAPPING

Albania is one of the oldest nations in the European Continent. Some of the cities as Berat (antique name is Antipatra), Durres (Durrahcium), Apollonia (Apoloni), Lezha (Lissus), Butrint (Buthranton), etc., are founded since the fifth and fourth centuries before Christ. Some of these cities are reflected also in the small scale maps of Hecate, Eratosten, Strabon, etc.

Albania is presented detailed in the maps of Ptolemy[6] (map 1), in the Roman maps of Peutinger, in the Albanian maps and portulanes ones. In the 16-th century, after the discovery of the new continent, at the time when the world economical center has moved from Italy at Netherland, at the time when the

[6] In cartography, Ptolemy is best known for three map projections: the first projection employed straight meridians that converged at the poles and curved parallels—qualities of a simple conic projection; the second projection would be classified today as a pseudoconic projection (it has curved evenly-spaced parallels and curved meridians that converge at the poles); his third projection would be classified today as an azimuthal projection. One of the most surprising features of Ptolemy's world map (ca. 150 AD) is its excessive distortion along the east-west direction. This is because the excessive distortion of Ptolemy's maps is a natural result of the erroneous value he adopted for the Earth's circumference in combination with Ptolemy's attempt to preserve the latitudes of some locations gained through astronomical observations. Another consequence is the instability of the position of Ptolemy's Prime Meridian in the geographical coordinate system, mutual rotation of the local maps and the displacement of positions given with respect to a reference point lying approximately on the same meridian along the north-south axis. It resembled a modified perspective view of the earth, but there is little, if any, evidence that he actually used it.

flow of Europeans going towards America has began, it was seemed a great fall of cartography in many countries of Europe. The contrary has happened in Albania, where it was a great increase in the mapping of its land.



Map 1. *Ptolemy's map of Albanian territory. Claudius Ptolemy "Geographia" is a fundamental geographic and cartographic work of the 2nd century A.D. which influenced European cartography of the Renaissance. Ptolemy can be considered as one of the first who gave a "concrete" cartographic evidence to the region of central Europe a part of which is covered by today's territory of the Albania.*

We can mention through the numerous portulane maps in the 16-th century the maps of Comotio (1571), which are considered the first topographical

maps of our land; the maps of Reis (1529), Gastald (1560), Mercator (1585), etc., present rather detailed all the territory (Shehu & Dragovoja, 1984),

In the 17th century were considered valuable the maps of Canteli (1689), Coronelli (1691) and Tchelebi (1635). They have personally carried out itineraries in different areas of Albania. The maps of the above mentioned authors have served as a base for the creation of the new maps, in the 18th century.

Hartenthum (Hartenthum, 1903) has given a completed table for the maps produced in the 19th century: among them we can mention the maps of Palma, Lapie, Weis, Hahn, Kiepert, Gubernatis, Military Geographic Institute of Wien, etc.

At the beginning of the 20th century were created new accurate and rich maps for all territory of Albania from Baldacci (Baldacci, 1917) and Nopcsa (Nopcsa, 1929). These maps were based on the results of the itineraries carried out by authors.

During the First World War, the Military Geographic Institute of Wien has carries out the topographical surveying of Northern and Central Albania, in the scale 1:75000, while the Military Geodesic Services of Italy and France have surveyed a part of Southern Albania in the scale 1:50000. After the First World War, Herbert Louis (Louis, 1928) has surveyed in the scale 1:100000 the areas unfinished by the above mentioned military services and has published in 1928 the new map of Albania in the scale 1:200000.

From 1927 until 1939 the Military Geographic Institute of Firenze was involved in the creation of new topographical maps, in the scale 1:50000 for all the territory of Albania. Because of the beginning of the Second World War the works was interrupted, making impossible surveying of a small part of southern Albania.

Until this period of 20 – the century are produced a lot of thematic maps, also by Albanian authors inside and outside Albania. During centuries the Albanian administration and specialists have contributed in a decisive way to provide a complete and accurate content of the maps, continuing of the surveys, itineraries, etc. In the places where their presence has missed there are a lot of mistakes. Those who have read Armao (Armao, 1937), Ginzel (Ginzel, 1918) and Traversi (Traversi, 1965), have understood the necessity of the presence of Albanian administration and topographers.

After the Second World War were founded in the new state of Albania different topographical and cartographical services giving their precious contribution in this field (Shehu & Dragovoja, 1984).

3. THE MAIN CARTOGRAPHIC PROJECTIONS USED IN TOPOGRAPHIC AND THEMATIC MAPS AND IN GEOGRAPHICAL ATLASES

Mapmakers have a general rule that small-scale maps can be projected from a sphere, but large-scale maps always must be projected from an ellipsoidal surface such as e.g. the WGS 84 ellipsoid etc. In the above mentioned maps are used different cartographic projections:

- The new edition of Ptolemy maps are based in his polar conic projection,
- Military Geographic Institute of Wien and H. Louis have used Gauss – Kruger projection;
- Military Geographic Institute of Firenze has used Bonn pseudoconic projection;
- Most of the above mentioned authors of maps have used polar conic projections;
- Military Geographic Institute of Albania and Albanian geodesical Services have used Gauss – Kruger projection;
- The cartographic services has used polar conic, Gauss – Kruger and the versions of pseudoconic projections prepared by prof. Agim Shehu for the creation of thematic maps.
- Actually, the Military Geographic Institute of Albania is using the UTM projection for preparation of topographical maps in scale 1:50000 and 1:25000.

3.1. Polar Conic Projection of Ptolemy

Conic map projections are appropriate for mapping regions at medium and large scales with east–west extents at intermediate latitudes. Conic projections are appropriate for these cases because they show the mapped area with less distortion than other projections. In order to minimize the distortion of the mapped area, the two standard parallels of conic projections need to be selected carefully.

The new edition of Ptolemy maps are based in his polar conic projection[7]**.** Ptolemy C. ACE 130 revolutionized the depiction of the spherical earth on a map, and suggested precise methods for fixing the position of geographic features on its surface using a coordinate system with parallels of latitude and meridians of longitude. Ptolemy's eight-volume atlas Geographia

[7] The simple conical projection, from Ptolemy, Cosmographia. Ulm: Lienhart Holle, 1482

(Geography) is a prototype of modern mapping. It included an index of place-names, with the latitude and longitude of each place to guide the search, scale, conventional signs with legends, and the practice of orienting maps so that north is at the top and east to the right of the map—a universal custom today. In this work, he used information first presented by the Greeks, and was the first to come up with what are known as projections. Ptolemy approved the use of the projection for maps of smaller areas, however, with spacing of meridians to provide correct scale along the central parallel. Although Ptolemy's maps were incredible for the time, his maps were very inaccurate.

To determinate the geographical coordinates of the objects, it is necessary to know the dimensions and characteristics of the geometrical figure, which approximately coincides with the true form of earth. For that purpose, Ptolemy was based on the dimensions of the sphere, calculated by Poseidon, in which the length of the meridians and equator is 37800 km (Codazzi, 1959), i.e. about 2200 km less than the length calculated earlier by Eratosthenes. So, the radius of the Poseidon's sphere: R = 6016.057 km and the longest semi axis (a) of the Krasowsky's ellipsoid is a= 63778.245 km. Then, the difference a – R = 362.188 km.

The projection of Ptolemy is a conical, polar and equidistant, in which the length of the meridians (m) and that of standard parallel (P_0) aren't distorted. The standard parallel has the latitude $F_0 = 41^0 00'$.

3.2. The Transverse Mercator (TM) projection;

The Transverse Mercator (TM) projection in its various forms is the most widely used projected coordinate system for world topographical and offshore mapping. All *versions* (e.g. Gauss-Kruger, Gauss Boaga, and UTM) have the same basic characteristics and formulas. The differences which distinguish the different forms of the projection which are applied in different countries arise from variations in the choice of values for the coordinate conversion parameters, namely the *latitude* of the natural origin, the *longitude* of the natural origin (central meridian), the *scale factor* at the natural origin (on the central meridian), and the values of *False Easting* and *False Northing*. Additionally there are variations in the width of the longitudinal zones for the projections used in different territories.

3.2.1. Gauss-Kruger Projection, 1868-98, 1913-18, 1950 - 1951 and 1970 - 1985

Austro-Hungarian Empire for its interests in the Balkans[8], from the second half of the century 19-th and early the century 20-th through the Military Geographical Institute of Vienna (MGIW), built in the north of Albania, a reference coordinate to support mapping of this part of the territory of Albania, in scale 1:75000 and 1:50000. Geodetic co-ordinates of the points of triangulation were calculated on Bessel ellipsoid - 1841, Gauss-Krüger projection[9], with origin the intersection of the Equator by the meridian of Ferro with λ_{Ferros} = 17° 39' 46.5'', in the year 1918. False Northing origin 0.000 m and false Easting origin 0.000 m. Central meridian, each meridian go from central meridian, and the Equator are straight lines. Other meridians and parallels are complex curves, concave toward the central meridian and the nearest pole, respectively.

[8] In support of military operations during the First World War, the southern part of Albania was surveyed by Geodetic Services of the Italian Army (for Vlora's district) and the French Army (for Kortcha's district) at 1:50000 scale. These maps were used by MGIW, to produce maps at 1:75000 scale. The 1:75000 scale maps covered approximately 75% of Albania's territory.

[9] In Europe this projection is called the Gauss-Kruger, in honor of the mathematicians Carl Gauss and Johann Kruger who later worked out formulas describing its geometric distortion and equations for making it on the ellipsoid. The Gauss-Kruger projection, also known as the Gauss Conformal, is the one conformal projection of the earth ellipsoid, in which the central meridian of the projection is held to have the same length and scale as the meridian arc of the ellipsoid. The central meridian, also known as the "principal meridian", is the central axis of the projection. In its standard form, the central meridian is taken to be at longitude 0 degrees. The central scale factor set at 1.0000, coordinate units in meters, for Northing's Xn and Easting's Ye. Xn is negative for latitudes south of equator. For a conformal projection, the source image and its projection must consist of complex coordinates with isometric properties.

The conversation, of geodetic coordinates (φ, λ) into Gauss – Gruger plane grid coordinates (N, E) is accomplished in three stages:

- To convert geodetic latitude φ into isometric latitude q (a Mercator variable). The transformation of (φ, λ) into (q, λ) creates a mapping of geodetic coordinates into Mercator variables, isometric coordinates pairs (q is known as the "isometric latitude".
- To transform complex isometric latitude $\psi = q + i\,\lambda$ into the "complex intermediate latitude": $w = u + iv$, by the inverse Lambertian eGud (ψ, w).
- To evaluate the integral E_3 on w, to find the unitary coordinates: $z = x + iy$, and convert these to Gauss – Kruger metric coordinates N and E.

In the years 1950 -1955, the specialists of Military Topographic Group of Albania (MTGA) carried out the reconstruction and the densification of the MGI Net in order to grant the request for mapping in 1:25000 scales. At the same time, the first–order network was transformed from the MGI reference system (1934) into the 1942 co-ordinate system, which was based on Krassovsky ellipsoid, Gauss-Krüger projection[10] with central meridian L_0=21º.

The New Albanian Net, constituted from Triangulation and Leveling Networks, was designed, rebuilt, measured and calculated from the Military Topographic Institute of Albania (MTI) during the years 1970-1985. The triangulation was designed to fulfill the requirements of mapping till at 1:10000 scale (on account of accuracy) and for perspective maps at 1:5000 scale (on account of density).

The geodetic horizontal datum [coordinate reference of Albania (ALB86)] is based on: the ellipsoid of Krasowsky 1940; North ellipsoid origin, $\Phi_0 = 0^0$; East ellipsoid origin, $\Lambda_0 = 21^0$; Gauss-Krüger (TM) projection; *False Northing* rectangular origin, 0,000 m; *False Easting* rectangular origin, 4500000 m, and coefficient of deformation in central Meridian, $K_0 = 1$.

In this geodetic horizontal datum is based topographic map of the Albania territory at scale 1: 25000 created by former MTIA (today IGU) in the period 1959 - 1985. Figure 1 shows the number of first and second editions, by years (Shehu, 1994).

[10] The Gauss-Krüger projection is a conformal mapping of a reference ellipsoid of the earth onto a plane where the equator and central meridian remain as straight lines and the scale along the central meridian is constant; all other meridians and parallels being complex curves. The Gauss-Krüger projection is the result of a triple-mapping in two parts (Bugayevskiy & Snyder 1995).

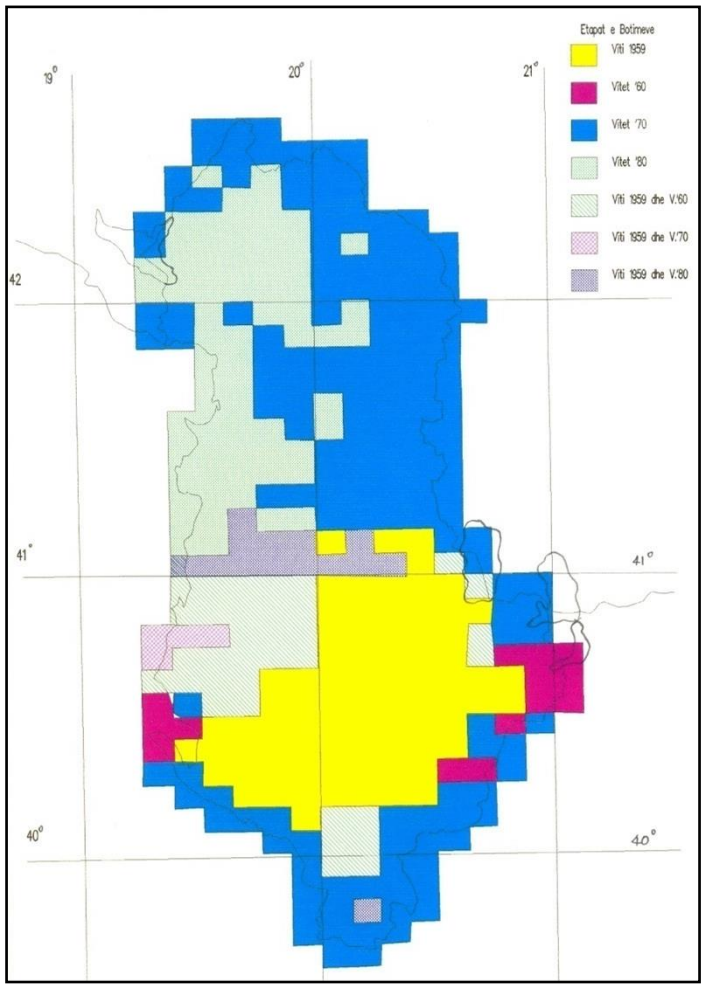


Fig. 1. The publication of the map at 1: 25000 scale by former – MTI, today MGI (1959 – 1985); (Source: Shehu, A. 1994)

Map series at scale 1: 25,000, published by the Military Cartographic Geodetic Institute of Moscow, which has MGI covers all Albanian territory, with the exception of the territory for which there are maps of this scale, published in 1959. This series of maps is published in 1962 year as a result of increasing of topographic maps in scale 1: 50000, published by the Military Cartographic Geodetic Institute of Moscow in 1952 year. The content of these maps, in most of them, corresponds to the content of the Italian maps, published in the years 1928 - 1939, scale 1: 50000, but transformed into Krasowsky ellipsoid and Gauss - Kruger projection. In the

Krasowsky ellipsoid and Gauss - Kruger projection also supported all of Albania topographic maps in scale 1: 50000 and smaller published by the former - MTI today MGI, in the period of 1976 – 1992 (fig. 2). The topographic maps of these scales are the result of works in the office, using for this purpose the source materials as: the existing topographic maps in scale 1: 25,000, published by MGI; existing topographic maps in scale 1: 50000, published by MGI and partly from foreign institutions; new aero topographic surveying and partial topographic surveys.

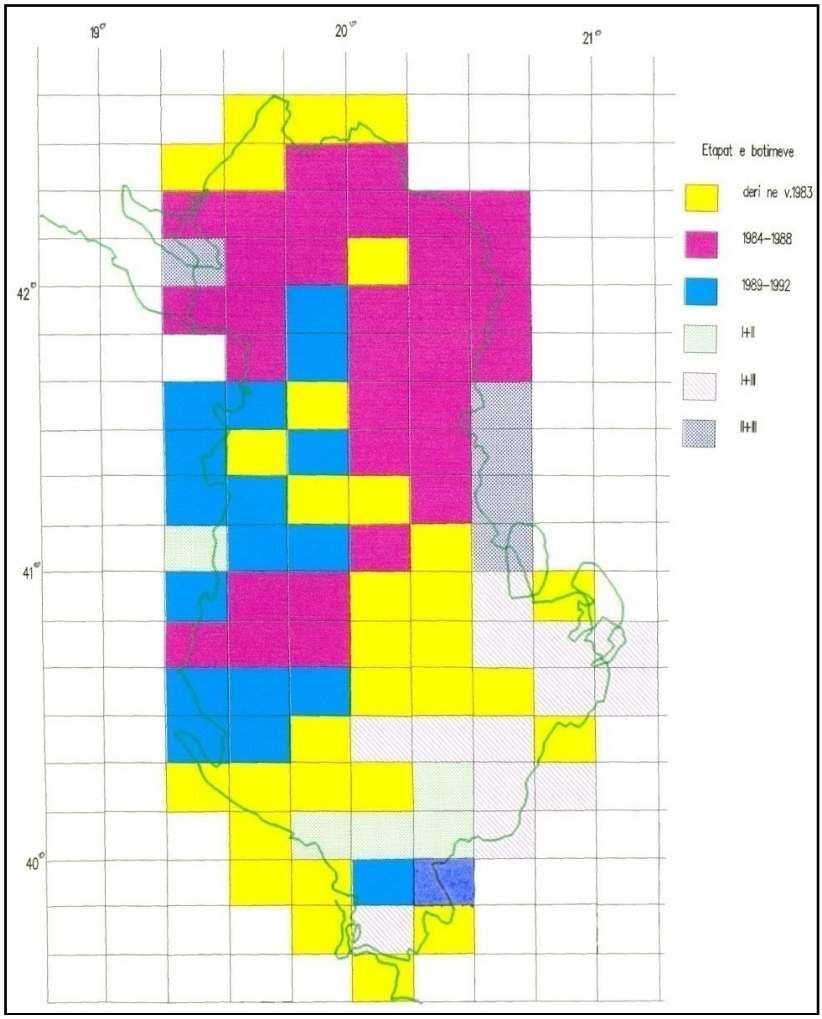


Fig. 2. The publication of the map at 1: 50000 scale by former – MTI, today MGI (1976 – 1992); (Source: Shehu, A. 1995)

During the period 1946-1996 are also created a series of cadastral maps (which covered approximately 56.27% of the Albania's territory) in scale 1: 500; 1: 1000; 1: 2000; 1: 5000; 1: 10000 and 1: 50000. Maps created during the years 1946 - 1960, are in 1: 2500 and 1: 5000 scale and based on the Bessel ellipsoid, Gauss-Kruger projection and the central meridian Lo = 20º 00'. Almost all cadastral maps created after 1960 were constructed in the state coordinate system: the Krasowsky ellipsoid, Gauss-Kruger projection and central meridian Lo = 21^0 00' (Shehu & Nikolli, 2001).
The central meridian, $\Lambda_0 = 21^{\circ}$, is located at easternmost extreme of Albania, leaving on his west over 99.7% of the territory. The area with the greatest distortions of the projection is the coastal zone. The distortions in this area reduce accuracy of topographical plans of large scales, which are necessary for development of tourist infrastructure, economic and cadastral system. Remember that Italians selected as the projection central meridian $\lambda_0 = 20^0$ for Albanian territory to support the mapping of the country at large scale (1: 5000, 1: 2000, 1: 1000).

3.2.2. Gauss Boaga projection

After 1939 year, for topographic maps of scales greater than 1:50000 and topographical plans of residential areas at 1:5000 scale, the Military Geographic Institute of Florence (MGIF) passed to another coordinate reference. The geodetic datum of this reference was: Bessel (1841) ellipsoid; the North ellipsoidal reference origin, $\Phi_0 = 0^0$; the East ellipsoidal reference origin, $\Lambda_0 = 20^0$; the Gauss- Boaga projection[11]; false Northing origin, 0.000 m; false Easting origin, 0.000 m.
At 1948, the horizontal coordinative base transformed from Moskva's CNIGA-IK Institute into Krassowsky ellipsoid (4-th zone 6°) with central meridian $\lambda_0 = 21°$ to support the territory mapping at 1:25 000 scale.

3.2.3. UTM Projection

The UTM and Gauss–Krüger coordinate systems are based on the Transverse Mercator projection. The most familiar and commonly used

[11] The Gauss–Boaga projection is a map projection used in Italy that uses a Hayford ellipsoid. The projection is named after Carl Friedrich Gauss and Giovanni Boaga. It was created by Giovanni Boaga in the 1940s who was at that time the head of the Istituto Geografico Militare. The projection method is a slight variant of the Gauss–Krüger series development for the ellipsoidal transverse Mercator projection. Like the closely related UTM, the Gauss–Boaga scales the projection down so that the central meridian has a scale factor of 0.9996 rather than 1.0.

Transverse Mercator in the topographical mapping is the *Universal Transverse Mercator* (UTM).

The Universal Transverse Mercator (UTM) projection and grid were adopted by the U.S. Army in 1947 for designating rectangular coordinates on large-scale military maps of the entire world. The UTM is the ellipsoidal Transverse Mercator to which specific parameters, such as central meridians, have been applied. The Earth, between lats. 84° N. and 80° S., is divided into 60 zones each generally 6° wide in longitude. Bounding meridians are evenly divisible by 6°, and zones are numbered from 1 to 60 proceeding east from the 180th meridian from Greenwich with minor exceptions.

Each geographic location in the UTM projection is given *x* and *y* coordinates in meters, according to the Transverse Mercator projection, using the meridian halfway between the two bounding meridians as the central meridian, and reducing its scale to 0.9996 of true scale (a 1:2,500 reduction). The lines of true scale are approximately parallel to and approximately 180 km east and west of the central meridian. Between them, the scale is too small; beyond them, it is too great. In the Northern Hemisphere, the Equator at the central meridian is considered the origin, with an *x* coordinate of 500,000 m and a *y* of 0.

The Military Geographic Institute of Albania has distributed hard-copy maps in 1:50,000 scales produced in collaboration with the USA agency NIMA (National Image and Mapping Agency – now called NGA: National Geospatial-Intelligence Agency). These products are spatially referenced in the UTM (WGS84) coordinate system.

Reference parameters of the Coordinative Reference established by Military Geographic Institute of Albania after 1994 year are: ellipsoid name - WGS 84[12]; ellipsoid origin of North - Earthy Equator ($\varphi = 0^0$); Ellipsoid origin of East - Central Meridian $\lambda_0 = 21^0$ E; map projection name - UTM zone 34 N; false northing, in grid units - 0.000 m; false easting, in grid units - 500 000.000 m, in west of meridian $\lambda_0 = 21^0$; scale factor at natural origin in central meridian ($\lambda_0 = 21^0$): k_0=0.9996; Magnitude of projection zone - 6^0 and projection Zone – 34.

[12] The WGS84 ellipsoid was established by satellite positioning techniques. It is referenced to the centre mass of the Earth (*i.e.*, geocentric) and provide a reasonable fit to the entire Earth. The WGS84 datum provides the basis of coordinates collected from the GPS, although modern receivers transform the coordinates into almost any user selected reference datum.

3.3. Polyconic equivalent Projection of Bonn, 1922-25.

During years 1922-25, the Military Geographic Institute of Florence (MGIF), constructed the triangulation network of I, II, III-orders to support the border mapping [734 km (length) x 2 km (width)] in scale 1: 50000. The geodetic datum of this reference was: Clark Ellipsoid; the North ellipsoidal reference origin, $\Phi_0 = 0^0$; the East ellipsoidal reference origin, $\Lambda_0 = 18^0$ 39' 09"; the projection, Bonn's equivalent Polyconic; false Northing origin, 0.000 m and false Easting origin, 0.000 m.

Polyconic projection is a modified form of conical projection in which cutting point of all parallels to the central meridian is true to scale. The distances between the meridians along each parallel are also true to scale. Near the central meridian both area and shape are approximately correct, but away from it both are wrong. Properties of this projection are:

- Parallels are arcs, having different centre,
- Except the central meridian, all other meridians are regular curves. The central meridian is a straight line,
- All parallels are standard parallels,
- East west distances are correctly represented along the particular parallels and north south distances are correctly shown only along the central meridians,
- The projection is neither equal area nor orthomorphic.

This projection is suitable for representing small areas. Areas with a large latitudinal and limited longitudinal extent in the middle latitudes can be represented on this projection.

3.4. Bonne pseudo-conic equivalent projection

In 1927-1934 period Military Geographic Institute of Florence (MGIF), Italy carried out the geodetic base in four orders to support the territory mapping at 1:50000 scale. The geodetic datum of this reference was: Bessel (1841) ellipsoid; the north ellipsoidal reference origin, $\Phi_0 = 41°\ 20'\ 12''.809$; the east ellipsoidal reference origin $\Lambda = 19°\ 46'\ 45".285$; the projection, Bonn's Pseudo - conic Equivalent; central meridian $\Lambda_0 = 20°$ (Shehu, 1995); false northing origin, 300 000 m; false easting origin, 100 000 m. Maps of scale 1: 50000 were published by MGIF in the years 1928-1939 (fig. 3).

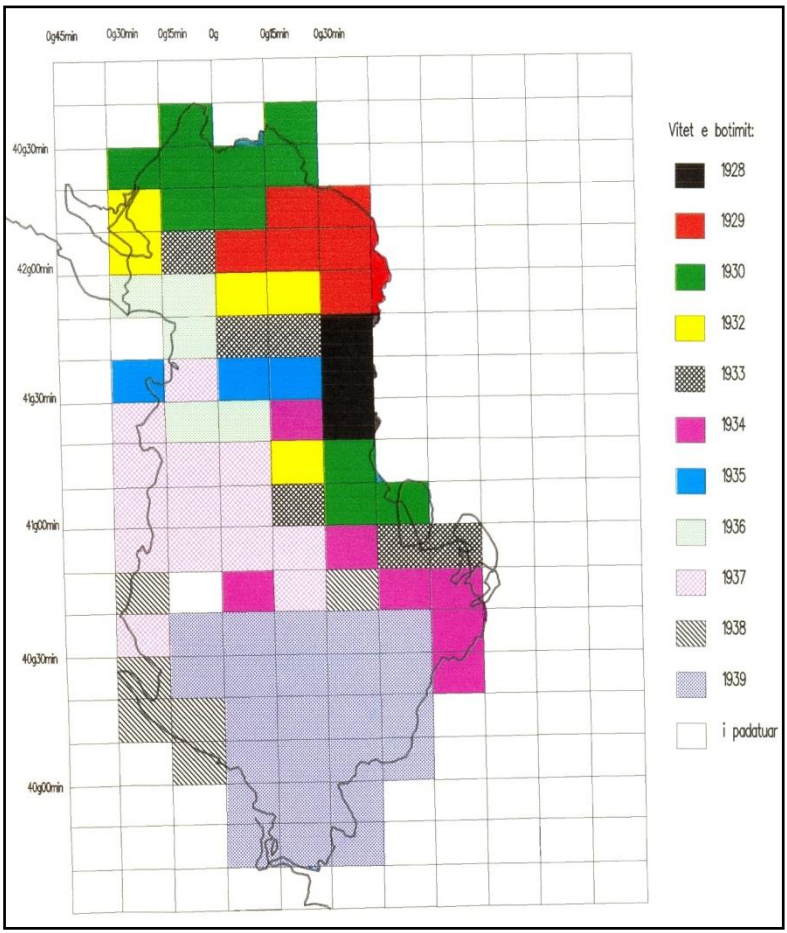


Fig. 3. The publication of the map at 1: 50000 scale, by Military Geographic Institute of Florence (MGIF) (1928– 1939) (Source: Shehu, A. 1995)

In the Bonn's Projection[13] a central meridian and a standard parallel are assumed with a cone tangent along the standard parallel. The central

[13] A Bonne projection is a pseudoconical equal-area map projection, sometimes called a dépôt de la guerre or a Sylvanus projection. Although named after Rigobert Bonne (1727–1795), the projection was in use prior to his birth, in 1511 by Sylvano, Honter in 1561, De l'Isle before 1700 and Coronelli in 1696. The Bonne projection can be seen as an intermediate projection in the unwinding of a Werner projection into a Sinusoidal projection; an alternative intermediate would be a Bottomley projection

meridian is developed along that element of the cone which is tangent to it and the cone developed on a plane.

Bonn's Projection is modified conical projection in which exaggerations of scale are removed along the parallels in the sense that all parallels are true to scale. The central meridian is straight, while the others are drawn by joining the intervals along the parallels by smooth curves. The parallels are concentric circles. It is an equal area projection. It is easy to draw with reasonable shapes around the central meridian.

Properties of this projection are:

- All the parallels are true to scale and are concentric curves,
- Central meridian is a straight line and other meridians are smooth curves,
- The scale is correct only along the central meridian; along the other meridians there is exaggeration which is increases away from the central meridian. Due to that the shape becomes increasingly distorted away from the central meridian, and
- It is an equal area projection.

3.5. Version of the pseudoconic projection, developed by prof. dr. Agim Shehu (Polytechnic University of Tirana, Albania)

The state of Albania is situated between latitude $\varphi_s = 39^0\ 38'$ and $\varphi_N = 42^0\ 39'$ ($\Delta\varphi = 3^0\ 01'$), and longitude $\lambda_w = 19^0\ 16'$ and $\lambda_E = 21^0\ 04'$ ($\Delta\lambda_{max} = 1^0\ 48'$, $\Delta\lambda_{min} = 0^0\ 49'$) and extends over an area of 28.748 km^2 (land 27.398 km^2, water 1.350 km^2). The terrain is mostly mountainous (highest point 2753 m) and hills with small plains along coast.

The proportions:

$K_1 = \Delta\varphi / \Delta\lambda_{max} = 3^0\ 01'/1^0\ 48' = 1.67$

$K_2 = \Delta\varphi / \Delta\lambda_{min} = 3^0\ 01'/0^0\ 49' = 3.75$

show the meridional extension of Albania.

Applying the well known formulas of the above mentioned projections, it is noticed that for the scale 1:1000000, $\lambda_0 = 20^0\ 00'$, $\Delta\varphi = \Delta\lambda = 0^0\ 30'$, in the most disfavorable points (λ_w, λ_E):

- the differences between coordinates (x, y) in the same points of the cartographic network and for all versions (tangential, secant) are very small ($\Delta x_{max,\ \Delta\lambda min} = 0.13$ mm);
- the differences of the abscissa values in the same parallel are also small ($\Delta x_{max,\ \Delta\lambda max} = 1.12$ mm);
- small differences are noticed in the values of deformations in the same meridian (m), parallel (p), surfaces (s) and angles (ω), where: $p_{max} = 1.001599$ and $\omega = 0^0\ 02'\ 47''$ at central perspective projections;

- in the group of polar cylindrical projections, the maximal longitude deformations reach the value 36.52% (for the tangential case) and the value 2.97% (for the secant case: $\varphi_0 = 41^0\ 00'$), while angle deformation is $\omega_{max} = 35^0\ 06'\ 34''$ (for the tangential case) and $3^0\ 11'\ 22''$ (for the secant case) (Shehu, 1977).

Based in the above mentioned observations prof. Agim Shehu (Shehu, 1977) has elaborated versions of pseudoconic projection, having these demands:

1. The meridians must be straight lines, going out from pole P;
2. The parallels must be straight lines parallel to coordinate axis E;
3. The length of the central meridian must not be deformed ($m_0 = 1$);

The studied versions are not conform ($\omega \neq 0$) and $m \neq p$, but one version can be equivalent if it is completed the condition that the length of all parallels is not deformed ($p = s = 1$). Then fixing the tangential versions ($\varphi_0 = 41^0\ 00'$), secants $p_N = p_S = 1$; $p_N \neq p_S \neq 1$ and the equivalent one, Shehu 1977 has calculated the values of coordinates (x, y) and deformations (m, p, s, ω), from which he has arrived in these conclusions:

1. For the extreme points of the cartographic network ($\Delta\lambda = \pm 1^0\ 30'$) coordinates (x, y) and the values of deformation, change very little between them and the values of the classic projections;
2. Also in the equivalent case meridians are straight lines;
3. The deformation of the meridians is smaller than the deformation of parallels;
4. Isocolls of deformation for meridians and angles correspond with the orientation of meridians, for this reason these projections are suitable for use for Albanian territory, because it has a meridional orientation;
5. The maximal deformations of the angles are $0^0\ 19'\ 44''$, $0^0\ 39'\ 24''$ and $0^0\ 59'\ 09''$, respectively for the points with a longitude from the central meridian $\Delta\lambda_1 = \pm 0^0\ 30'$, $\Delta\lambda_2 = \pm 1^0\ 00'$ and $\Delta\lambda_{3\,(max)} = \pm 1^0\ 30'$.

The tangential version of the projection above mentioned was used for the first time at the "The geographical atlas of Albania" 1968, in the scales 1:2000000 and smaller ones. In the 1980 year this projection was used for the creation of the maps of Albania in the scale 1:200000, as geological, hydro geological and fit geographical maps, etc. also it is used for all (127) the maps of "Climatic atlas of Albania", 1986, in the scale 1:800000 and for all (256) the maps of "Agricultural geographical atlas of Tirana district" in the scales 1:100000.

4. CONCLUSIONS

Map projections have a wide use. They have been widely used to solve some geometric problems of spherical geometry, astronomy, crystallography, geology, etc., in graphical form. Today, topographical and geographical maps are very important for every GIS; therefore map projections are especially important in creating geoinformation systems. Knowledge of cartographic projections of topographic and thematic maps has a great importance in creation of a geographic database suitable for studies and different geographic analyzes etc.

Map projections have their largest and most frequent application in producing maps showing a smaller or bigger part of the Earth's surface. Theory of map projections is a branch of cartography studying the ways of projecting the curved surface of the earth and other heavenly bodies into the plane, and it is often called mathematical cartography. Map projections have been developing parallel with the development of map production and cartography in general.

The cartographers working on map projections have made great achievements in both the study of theory of map projections and the exploring of new types of projections, as well as their application and development of new directions in map projections. Mapmakers have a general rule that small-scale maps can be projected from a sphere, but large-scale maps always must be projected from an ellipsoidal surface such as the WGS 84 ellipsoid.

In the Albanian maps and atlases are used different cartographic projections as:

- Polar conic projection in the new edition of Ptolemy maps;
- Gauss-Krüger projection in Bessel ellipsoid, with origin the intersection of the Equator by the meridian of Ferro with λ_{Ferros} = 17° 39’ 46.5’’ in the maps, scale 1:75000 and 1:50000, published by Military Geographic Institute of Wien (1868-98, 1913-18);
- Polyconic equivalent Projection of Bonn in Clark ellipsoid with origin the intersection of the Equator by the central meridian $\Lambda_0 = 18^0$ 39’ 09”, in the maps of scales 1:50000, published by Military Geographic Institute of Florence (MGIF) (1922-25);
- Bonne pseudo-conic equivalent projection in Bessel ellipsoid with origin the intersection of parallel Φ_0 = 41° 20’ 12’’.809 by the central meridian Λ_0 = 19° 45’ 45”.285, in the maps of scales 1:50000, published by Military Geographic Institute of Florence (MGIF), Italy (1927-1934);
- Gauss- Boaga projection in Bessel ellipsoid with origin the intersection of the Equator by the central meridian $\Lambda_0 = 20^0$, in the maps of scales greater

than 1:50000 and topographical plans of residential areas at 1:5000 scale, published by Military Geographic Institute of Florence (MGIF) (1939 - 1948);

- Gauss-Krüger projection in Krassovsky ellipsoid with origin the intersection of the Equator by the central meridian L_0=21º in the maps, scale 1:25000 and 1:10000, published by Military Topographic Institute of Albania (1950 -1955, 1970-1992)[14];
- UTM projection in WGS 84 ellipsoid with origin the intersection of the Equator by the central meridian $\Lambda_0 = 21^0$ in the maps of scales 1:50000 and 1:25000, published by Military Geographic Institute of Albania (MGIA) (after 1994);
- Version of the pseudoconic projection, developed by prof. dr. Agim Shehu (Polytechnic University of Tirana, Albania) in the Earth Sphere, was used for the first time at the "The geographical atlas of Albania" 1968, in the scales 1:2000000 and smaller ones. In the 1980 year this projection was used for the creation of the maps of Albania in the scale 1:200000, as geological, hydro geological and fit geographical maps, etc. also it is used for all (127) the maps of "Climatic atlas of Albania", 1986, in the scale 1:800000 and for all (256) the maps of "Agricultural geographical atlas of Tirana district" in the scales 1:100000.

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[14] The central meridian, Λ_0 = 21˚, is located at easternmost extreme of Albania, leaving on his west over 99.7% of the territory. The area with the greatest distortions of the projection is the coastal zone. The distortions in this area reduce accuracy of topographical plans of large scales, which are necessary for development of tourist infrastructure, economic and cadastral system.

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