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A digital study on the Generalkarte relief representation

Keywords: Generalkarte; late 19th and early 20th century cartography; cartographic heritage; cartographic relief; relief shading; digital relief comparison.

Summary

Generalkarte is the famous map series in scale 1:200.000 produced by the military geographical service of Austro-Hungarian Empire in the late 19th and the early 20th century, which covers an extended area of central and southeast Europe. Some of the map-sheets of this monumental cartographic work, with the visually impressive shaded relief representation, cover the north part of the actual territory of Greece, at that time under the Ottoman Empire. The *Generalkarte*, apart of its original use in the frame of the overall Austro-Hungarian geopolitical strategy in SE Europe and the Balkans, was extensively implemented, using more or less modified copies, not only by the nations in that area, involved in national antagonisms during the turbulent early 20th century, but also by the great powers which played a decisive role in the area during the Great War. Greece has extensively used the relevant *Generalkarte* sheets, covering the north part of the country, during almost the whole of the first half of 20th century. In the Greek *Generalkarte* versions, planimetry was kept almost unaltered updating mainly toponyms and redrawing the relief. The relief in the Greek series is mainly represented by contours supported by surface colouring (a sort of choropleths) without insisting in the dominant shading of the originals. In this work, digital techniques were used in order to study the differences in the relief representation between the original *Generalkarte* sheets and the Greek version counterparts. The sheets put under comparison were transformed in digital form and relevant 3-d models were produced. The comparison scheme is also associated to modern relief models, derived from the actual Greek map series, in order to test the fitting of the *Generalkarte* models to the actual relief representation, generating residual 3-d maps of the relief. The study is extended to a digital analysis of the *Generalkarte* shading by virtually simulating the optimally fitted illumination of the relief in the modern 3-d model.

Introduction

The result of the “third” state (military) mapping of the Austro-Hungarian Empire, the famous *Franzisco-Josephinische Landesaufnahme* (Witt 1979: 423), at the late 19th and early 20th centuries, was the production of 282 map-sheets in 1:200.000 scale, covering a 1° by 1° unit-area on the Bessel’s ellipsoid of reference. The map-sheets covered a large part of central Europe and the entire Balkan Peninsula, and was prepared not only for the generalization, revision and the update of the previous “second” *Franzisco-Josephinische* mapping¹ but also for the support of the Empire’s wider geostrategic interests in Southeast Europe (Stefanidis 2003: 11; Vogli 2003: 15). In this great value map (Fig. 1), under the name *Generalkarte* which was started issuing from 1889 (see Haardt von Hartenthurn 1902 for the state of the art in 1901 and Livieratos 2003 (Ed.) for an extensive study), 18 sheets represent the north regions of the actual territory of Greece (Boutoura and Papadopoulou 2003: 56-57) which a part of it, at that time, was under the ottoman rule. These map-sheets survived, in fact, for the whole first part of 20th century, much longer after the end of the Great War, because were the origin and the basis for a number of revised and

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¹ This second mapping (1869-1887) concerned the production of 752 map-sheets of the *Spezialkarte* in 1:75.000 scale which replaced the first historic mapping known as the *Josephinische Landesaufnahme* (1764-1787) ordered by Maria Teresa.

updated reproductions, in a number of languages of the forces involved in conflicts at that region for almost half century period, e.g. French, English, Greek, Bulgarian, Italian (Ploutoglou 2003: 65). A number of the 18 *Generalkarte*'s sheets (Fig. 2), mainly those originally entitled 'Monastir', 'Vodena', 'Saloniki', 'Janina', 'Larisa', were the first used by Greek forces in the struggle for the liberation of the northern lands of the actual territory of Greece, at the beginning of 20th century and were extensively used by the troops during the Balkan Wars (1912-1913) and few years later during the allied operations at the 'Front of Thessaloniki'. The maps -especially those at the top north strip- transliterated into Greek with revisions and updates concerning not only toponyms but also some geometry and thematics, were used extensively not only by the military and the state authorities for planning infrastructures and implementing the Greek administration at the 'new lands' but also by the domestic map market since publishing houses printed the 'Hellenized' *Generalkarte* sheets for the general public which was looking at the liberated territories with great interest. In this sense, these 18 map-sheets both in their original *Generalkarte* form and in their 'Hellenized' versions are considered as important and worth to study, parts of our recent cartographic heritage. An important feature of this legendary map series was, among others, the impressive representation of the land relief and its shading (for the geodetic and projective properties and characteristics and for the impact to modern Greek cartographic history, see Livieratos 2003: 21; for the historic and archaeological information given on maps, see Pazarli 2003: 121). The representation of the land relief, with line-shading, enjoys great tradition in Austrian cartography since the *first* Landesaufnahme in the second half of 18th century. The Austrian map-sheets, thanks to its shading, appeared 'superior' to the French map-sheets of the time, even if lacking trigonometric control which, on the contrary, was the strong point of the French maps. This tradition is evident in the *third* Landesaufnahme, especially in the sheets issued by the end of 19th century, where the combination of Lehmann's technique (vertical illumination) for relief representation with the support of fume-shading, which adds a sense of relief continuity, gave highly aesthetic visual results (Boutoura 2003: 64). In the map-sheets after 1902, mainly when stereophotogrammetry was applied in the relief representation, line contouring was dominating the depiction of third dimension (Fig. 3).

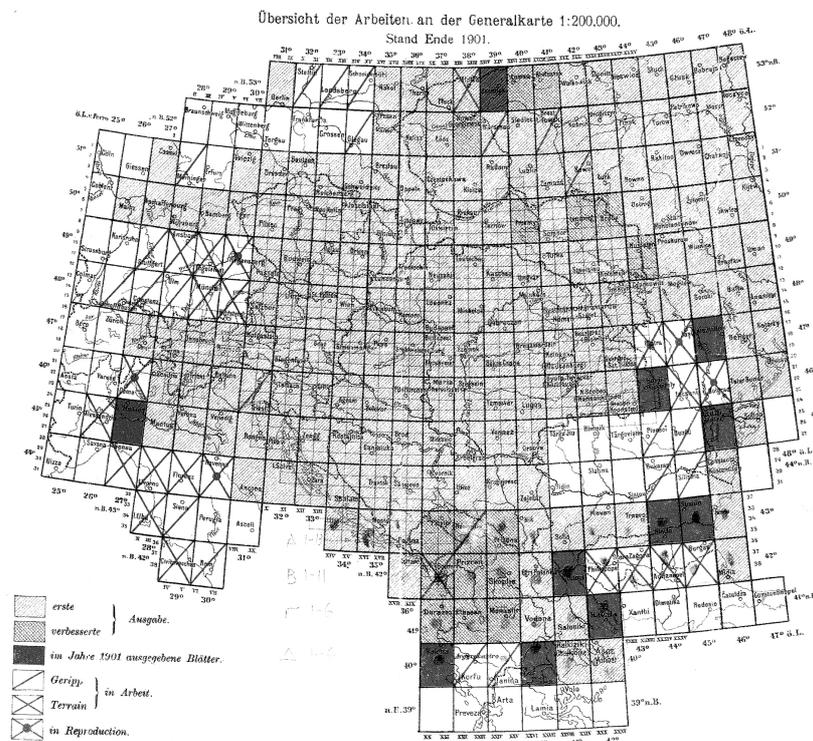


Figure 1. The 282 map-sheets of the 1:200.000 *Generalkarte*, product of the *Franzisco-Josephinische Landesaufnahme* (here, the progress of the work in 1901)

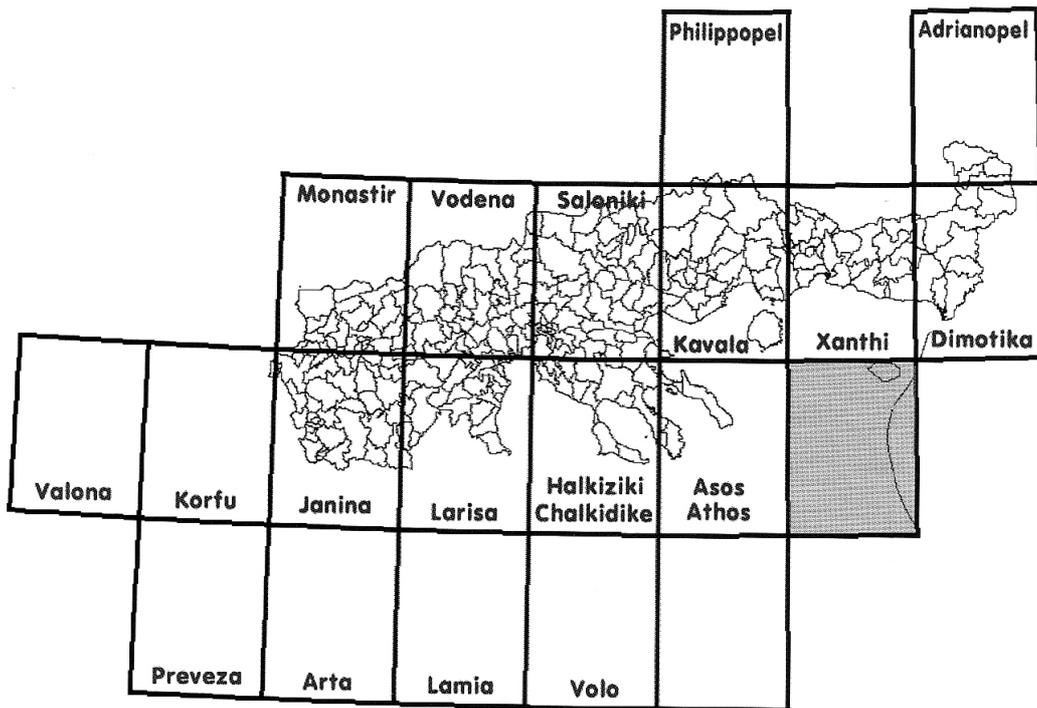


Figure 2. The *Generalkarte* 18 map-sheets covering parts of the actual territory of Greece. Here, only the three Regions of Macedonia and Thrace are depicted.

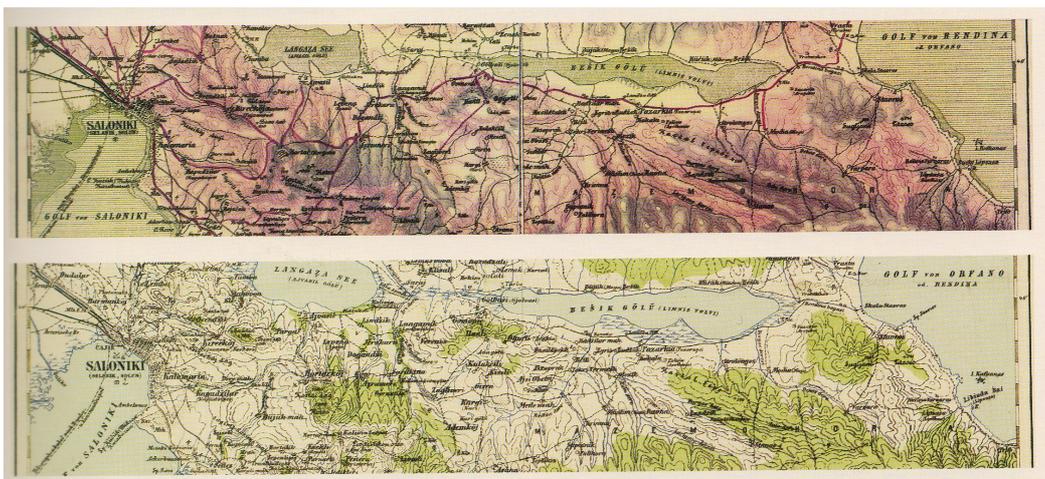


Figure 3. Relief representation in two editions (up: 1900, bottom: 1904) of the same *Generalkarte* map-sheet, 'Saloniki'.

The Greek versions of *Generalkarte* apparently followed the simplified contouring method without shading, obviously for practical reasons. Instead, in some cases, simple areal colouring, corresponding to the relief-shading of the original, simulates the shading effect (Fig. 4).

In this paper, with the assistance of actual digital technologies, as applied to modern cartography and image processing for the relief representation by shading due to simulation of solar illumination (Boutoura 2002: 255), a key comparison of the relief representation and shading in a *Generalkarte* map-sheet 'Saloniki' is carried out, with respect to the map-sheet counterpart 'Θεσσαλονίκη' ('Thessaloniki') of a *Generalkarte's* Greek edition.

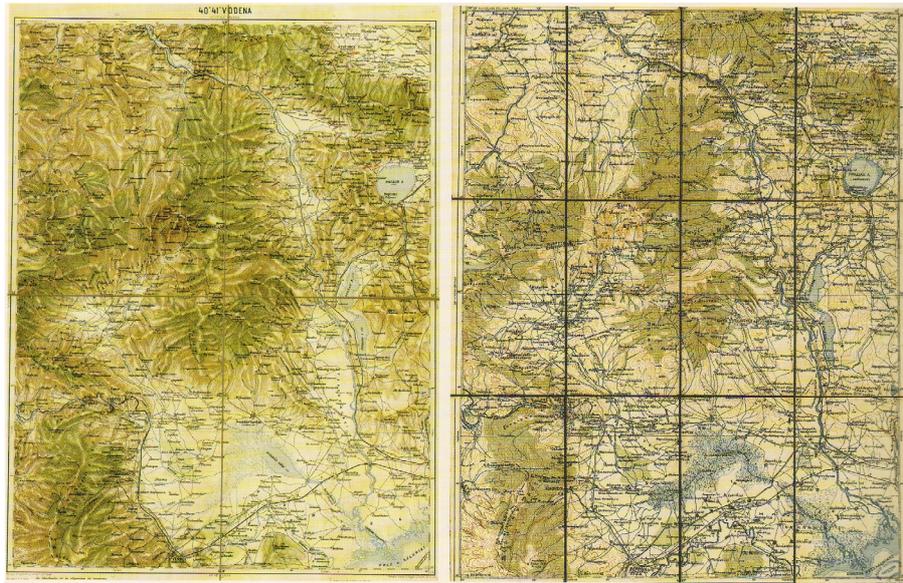


Figure 4. Left: The map-sheet ‘Vodena’ of the *Generalkarte* edition (1900-1902) with relief shading according to Lehmann vertical illumination. Right: The map-sheet ‘Εδεσσα’ (‘Edessa’) of the Greek version (1909) with relief contouring and areal colouring simulating shading.

The adopted process

The process followed in this study, is illustrated in Fig. 5 and Fig. 6. Two old map-sheets are used, one from the *Generalkarte* series dated 1903 and one from its Greek version series dated 1927, both in 1:200.000 scale. The $1^{\circ} \times 1^{\circ}$ map-sheet is respectively entitled ‘Saloniki’ and ‘Θεσσαλονίκη’ (Thessaloniki) with coordinates at the map centre 41° for longitude (east from the Ferro Island) and 41° for latitude. The projection frame of the map-sheet is a trapezium with actual length of central meridian, computed on Bessel’s ellipsoid (Livieratos 2003: 34) 111.041,829 m and the top and bottom actual lengths of parallels, respectively, 83.486,116 m (at $41^{\circ} 30'$ latitude) and 84.757,572 m (at $40^{\circ} 30'$ latitude). These values correspond to 55,5 cm for the sheet’s central meridian length and to 41,7 cm and 42,4 cm for the top and bottom parallels for the 1:200.000 scale reduction, giving thus the order of the sheet’s dimensions for this specific area².

The *Generalkarte* map series, as it is known in bibliography, obey the projective properties of the family of the *polyhedral* or *trapezomorphic* projections, as a slight variation of the *Prussian* version, called thus, as the *Austrian* variant (Reignier 1957: 276). According to this projection system, each map-sheet constitutes a proper projection reference system which is independent of the neighbouring sheets.

In order to apply the adopted work-flow shown in Fig. 5, the old sheets should be georeferenced. For this purpose, a ‘working’ projection has to be selected, preferably in an operational computational environment available in the software used in the applications. Since the *Austrian* variant of the *Prussian polyhedral* projection is not included in the available software menu, a test was made (Dalas 2006: 31) comparing the lengths of central meridian ($\lambda = 41^{\circ}$) and the top and bottom parallels ($\varphi = 41^{\circ} 30'$ and $\varphi = 40^{\circ} 30'$ respectively) given by the geodetic computation on the ellipsoid, with the relevant results given by a number of map projections listed in the software menu. The closest results are given by the *sinusoidal* projection as shown in Tab. 1, and this projection was used in order to perform the georeference processing of the old map-sheets.

² Due to the projection adopted in this mapping, the dimensions of the map-sheets vary, depending on the latitude of the region, especially concerning the lengths of parallels, where the variation on the map-sheets is large, reaching 10 cm from the north to the south end.

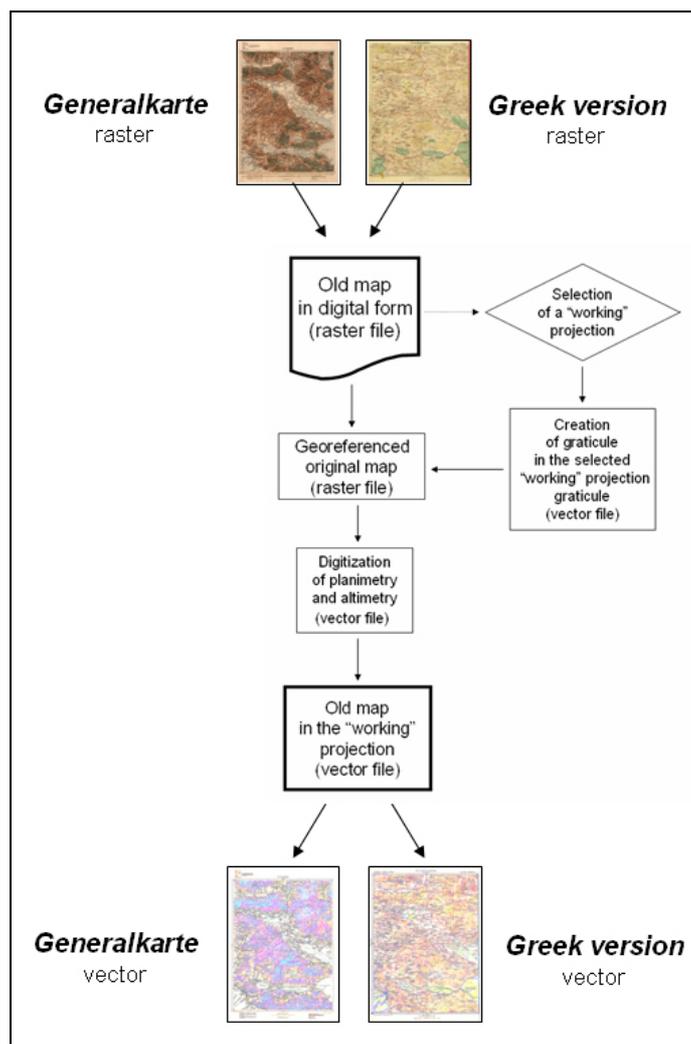


Figure 5. The transformation of the two old map-sheets (raster files) in georeferenced vector form.

Projection	Central meridian (41°)	Top parallel (41° 30')	Bottom parallel (40° 30')
<i>Austrian polyhedral</i> (computed)	111.041,829 m	83.486,116 m	84.757,572 m
<i>Sinusoidal</i> (market software)	111.041,827 m	83.486,114 m	84.757,572 m
<i>Azimuthal equidistant</i> (market software)	111.041,827 m	83.486,714 m	84.758,188 m
<i>Laborde</i> (market software)	111.041,827 m	83.486,246 m	84.757,742 m
<i>Transverse Mercator</i> (market software)	111.041,828 m	83.486,246 m	84.757,742 m

Table 1. The selection of a 'working' projection for the georeference process according to the vicinity in the values of the length of central meridian and of the top and bottom parallels.

After the georeferencing of the old maps in raster form, their planimetric and altimetric contents were digitized transforming thus, the maps in vector form. In this way we obtain the vector *Generalkarte* map-sheet and its Greek version in a common ‘working’ projection, the closest to the nominal original one. These two vector files can now be compared in order to study their planimetric and altimetric similarities and differences.

Another class of analysis is the digital comparison of the old map-sheets with a modern map, of the same area, available in vector form (Fig. 6).

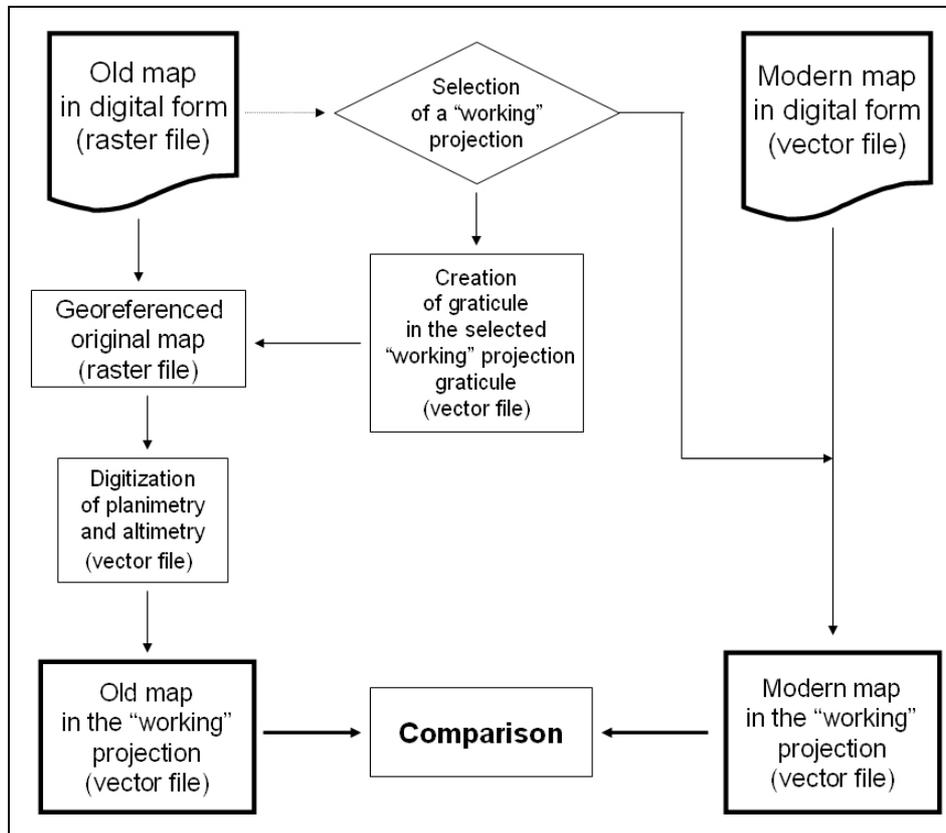


Figure 6. The comparison of the old map-sheets with modern counterpart.

The modern digital map is also easily transformed in the adopted operational ‘working’ projection allowing a further step of comparison in maps’ planimetry and altimetry (Fig. 7).

In this paper, we present results mainly from the altimetric comparison option, without avoiding some hints on the planimetry as well, since in some extend these two options are closely interrelated. The study, both quantitative and qualitative (Fig. 8), focuses on the contouring, on the reliability of heights and on the shading relief representation. Of special interest is also the study of the depiction of the international borders and of the shading as simulation of the relief illumination.

It is worth to stress here, that the whole study was carried out using the digital copies of maps entirely in vector form. This allows flexibility and a major number of processing possibilities associated with high degree of precision in elaborating the overall comparison processes.

In both the *Generalkarte* and the Greek version sheets, altimetry is represented by contours in 100 m height intervals, but relief shading is drawn only in the first. Thanks to the transformation of the two sheets in vector form with all altimetric information digitized, it is then easy to compute the 3-d models of the two sheets. The 3-d models are then put into a comparison process, concerning both the plain contours and the relief, which is digitally shaded in all files, using the same illumination parameters and optionally colouring according to the altitude levels (Fig. 9). The modern map-sheet is also treated in the same way in order to be used in the comparison too.

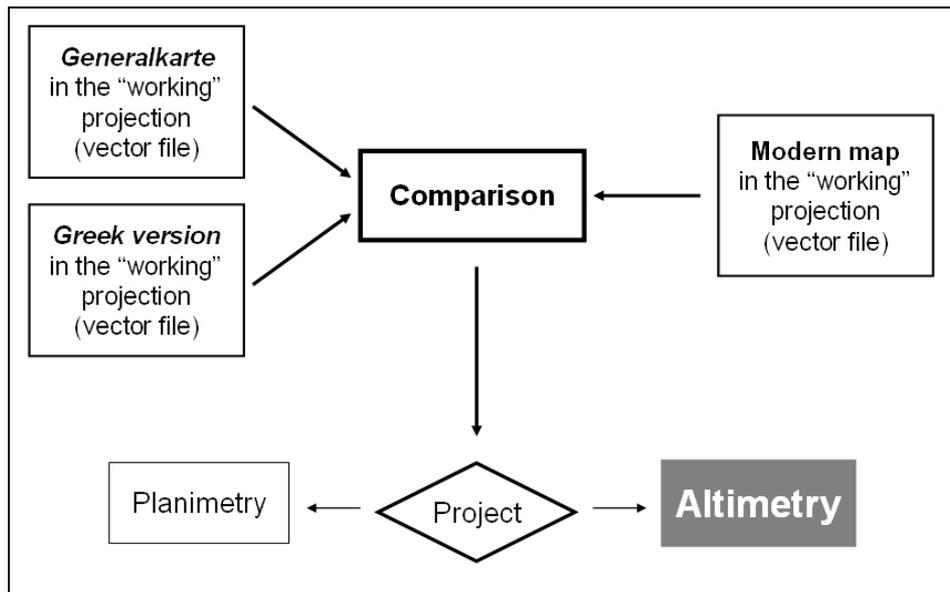


Figure 7. Alternatives in the comparison process. In this study the focus is on the analysis of altimetry.

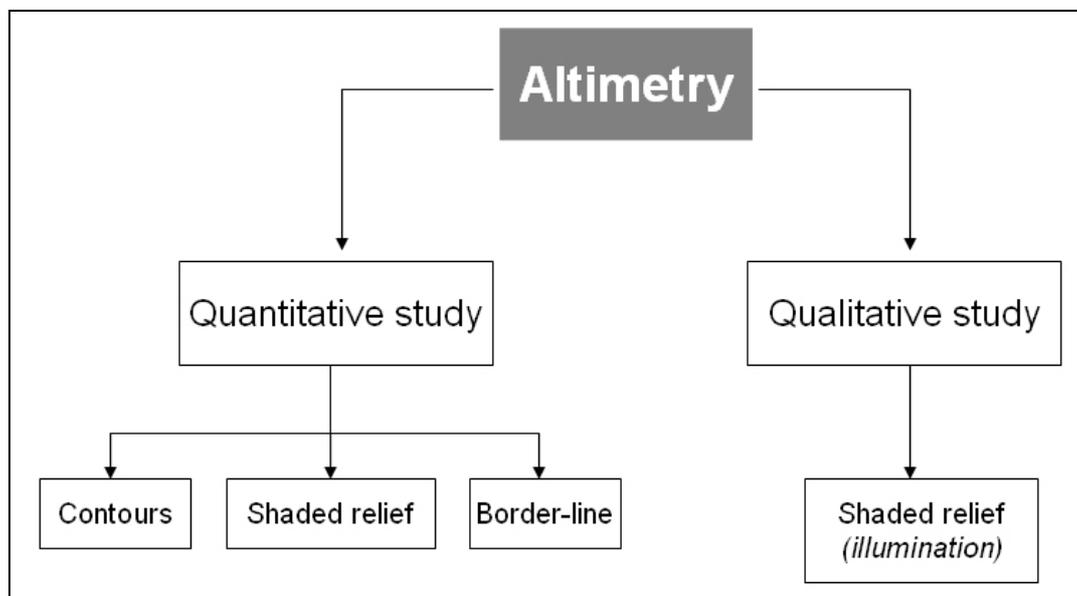


Figure 8. The quantitative and qualitative study of the altimetric relief.

The comparison then follows both as a quantitative and as a qualitative analysis. The first concerns the comparison of the contouring and the shaded relief representation as derived from the digital process and the second the simulation study of the shading due to illumination. A special focus is on the configuration of the international border-line directly associated to the mountain ridge at the area.

Constructing and comparing digital altimetry and 3-d models

Comparison of contours

From the comparison of the contours in the two old map-sheets (Fig. 10) it is evident the changes applied in the Greek version, at least in three areas, where obviously new surveys were done. Some coast-line differences are also shown especially in the Gulf of Thessaloniki and the areas of the lakes in the

southern part of the sheet. The remaining major part of the map-sheet area is almost identical in both maps.

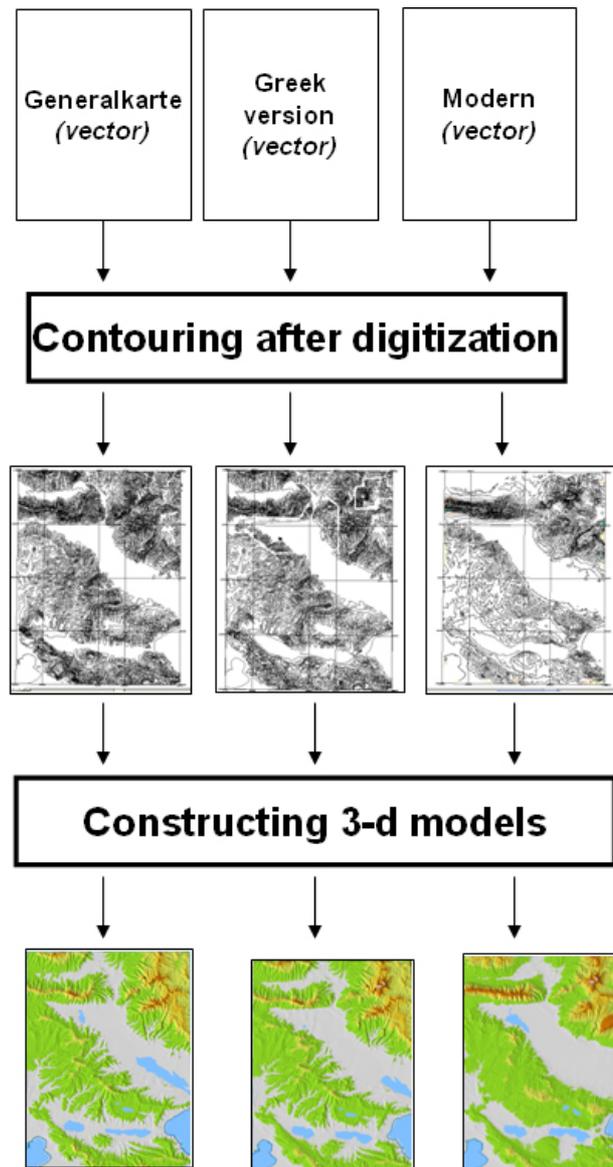


Figure 9. Digital contouring and 3-d modelling

The contours derived from the 3-d models of the two old maps and the modern map, are put under comparison. In Fig. 11 and Fig. 12 are respectively shown the height differences between the *Generalkarte* model and the modern counterpart and between the Greek version model and the modern counterpart. It should be noted that the gross differences are also due to planimetric errors which influence the height positioning.

Combining the maps in Fig. 11 and in Fig. 12, the gross height differences due to positioning are cancelled and the derived residual height differences are those between the *Generalkarte* and the Greek version maps (Fig.13). The remaining height differences are localized at the resurveyed areas A, B and C, for the update of the Greek version sheet, as shown in Fig. 10.

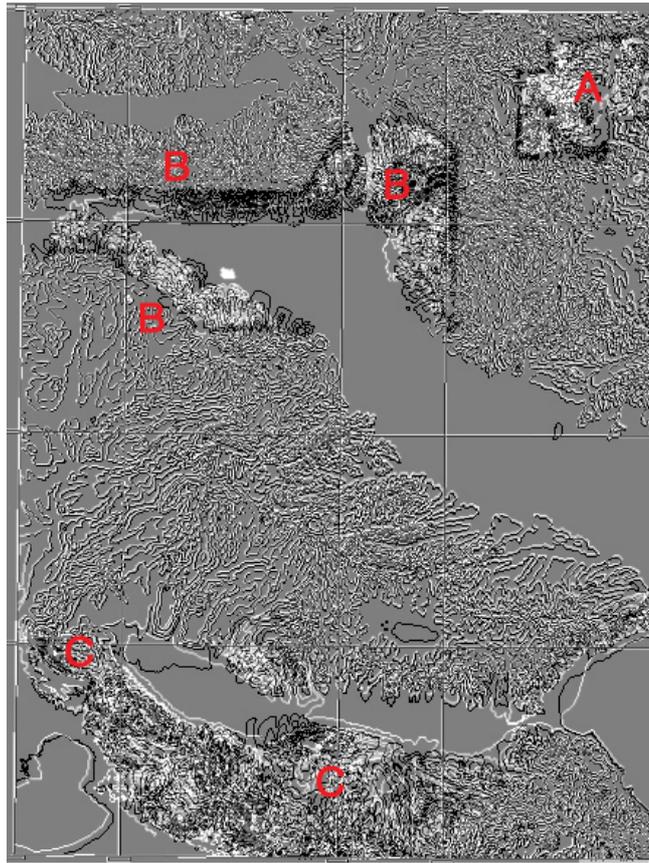


Figure 10. The comparison of contours in the two old map-sheets by exact transparent superposition. It is evident that in the areas A, B and C some later surveys were performed.

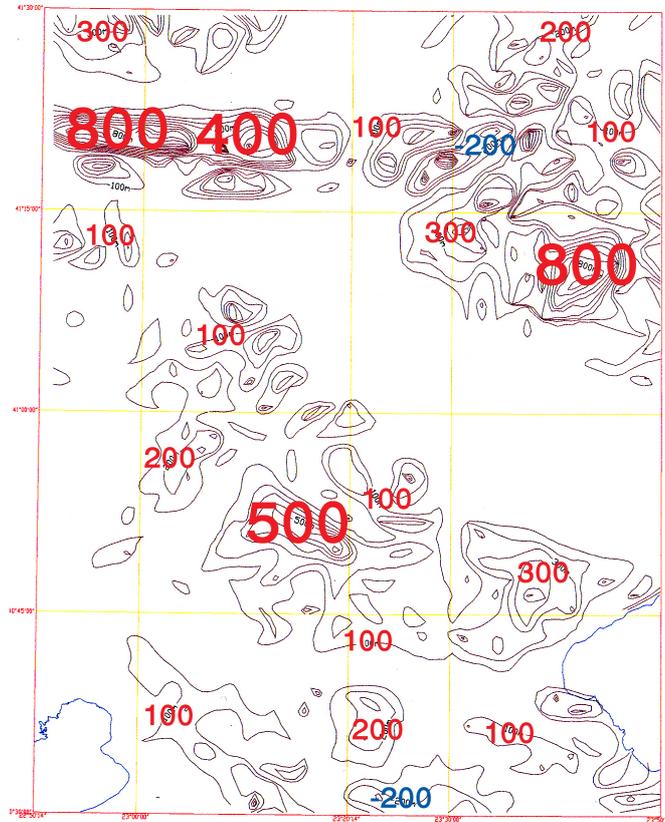


Figure 11. Height differences (m): *G-k* vs Modern map. The gross differences are due to positional errors.

Comparison of the shaded relief

From the digitization of the altimetric features (contours) of the map-sheets the 3-d digital terrain model is derived and the relevant shaded relief properly illuminated with solar position parameters (solar height = 55° and azimuth = 255°) which correspond to the solar position of June 21, 2003 at 15:00 hrs local time (for the illumination discussion, see the next paragraph). The shaded relief are coloured using six distinct levels of elevation intervals.

In Fig. 14, the digital reconstruction of the shaded relief of the Generalkarte map-sheet is shown with colouring up to five height level intervals. In Fig. 15, the same is applied for the Greek version map-sheet, where one more elevation level is appeared at the NE part of the map-sheet. In Fig. 16, the shaded relief of the modern map-sheet counterpart is shown in six height level intervals. Obviously the updated relief in the Greek version is in some areas higher than in the *G-k* original. The differences in the orography and the alterations in the hydrography of the area are clearly shown. The course of the semantic linear symbol of the border line is also interesting to study on relief representations, especially in cases when the border line follows a mountainous course and was subject of changes during the ages. In Fig. 17 the border line course is shown on the digital shaded relief representation of the three map-sheets and in Fig. 18 in relation to the altitudes and to the planimetry.



Figure 14. The digital reconstruction of the shaded relief in the *G-k* sheet with colouring in five height levels.



Figure 15. The digital reconstruction of the shaded relief in the Greek version sheet with colouring in six height levels.

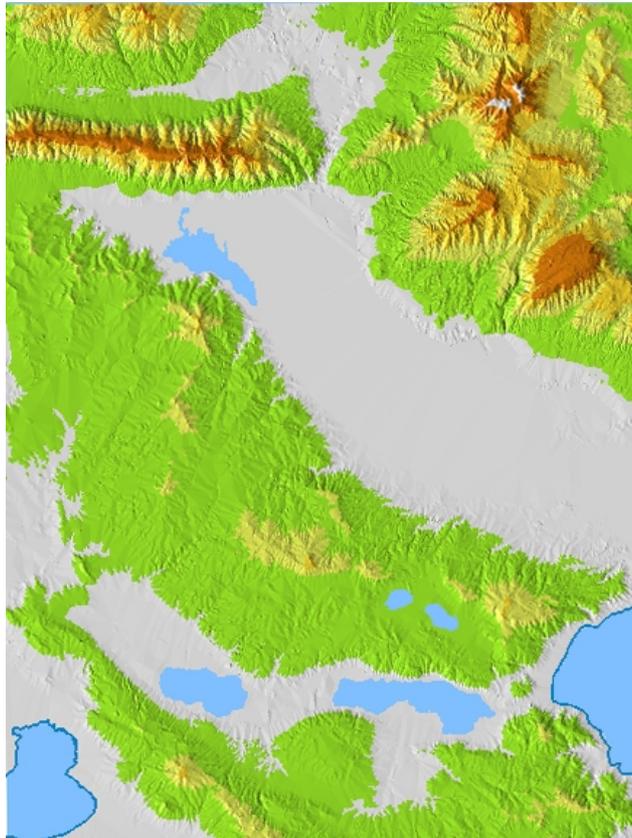


Figure 16. The digital reconstruction of the shaded relief in the modern sheet with colouring in six height levels.

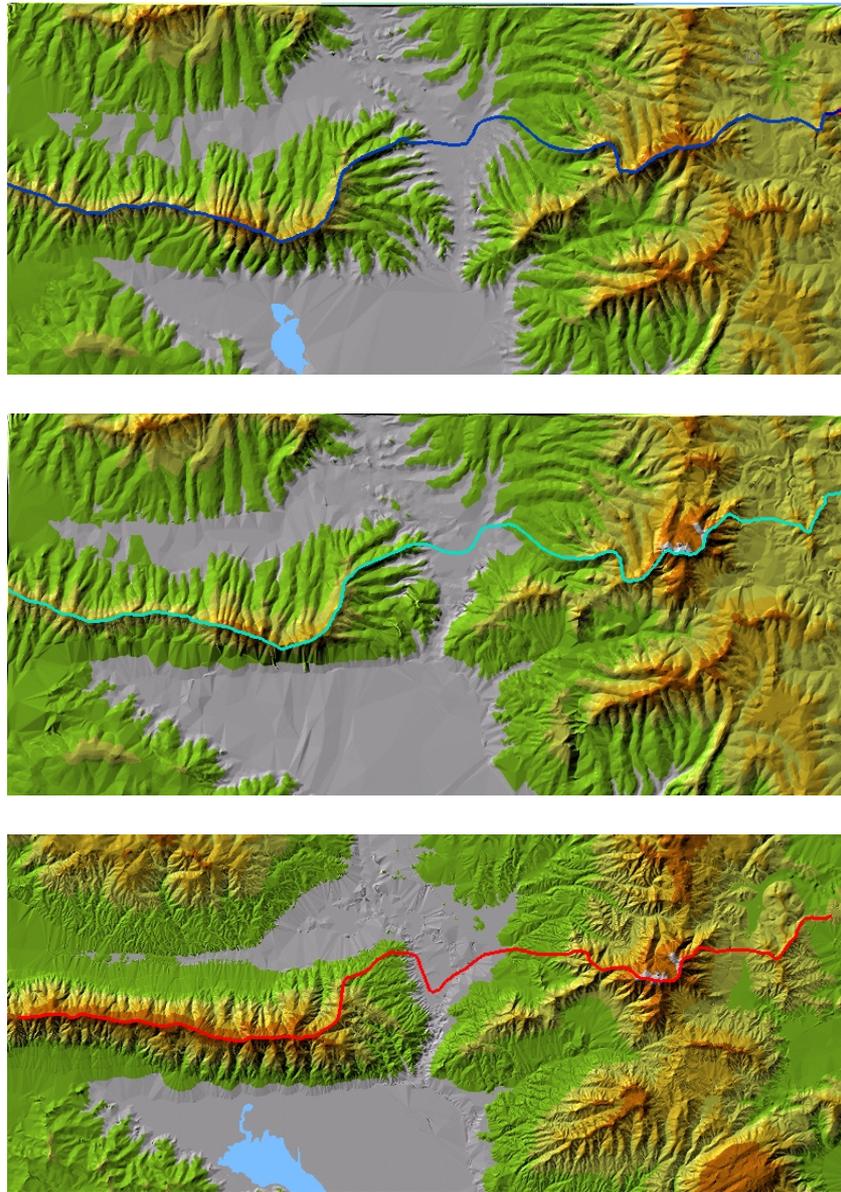


Figure 17. The border line course on the digital reconstruction of the shaded relief. Top: In the *G-k* sheet (1903). Middle: In the Greek version sheet (1927). Bottom: In the modern sheet.

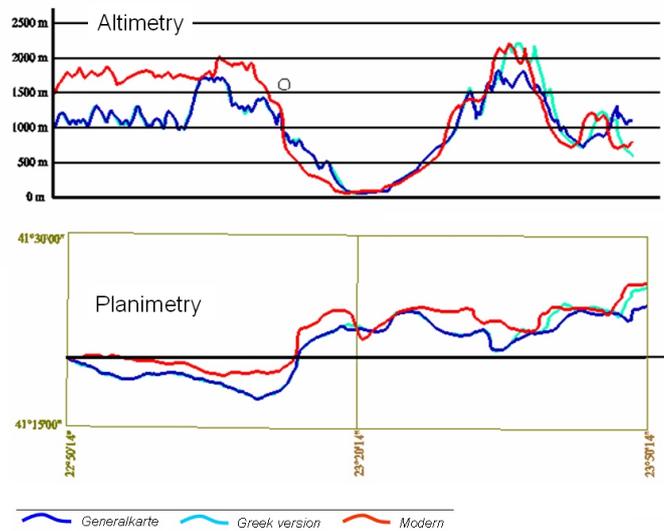


Figure 18. The altimetric (top) and the planimetric (bottom) border line course on the digital reconstruction of the shaded relief.

Qualitative study of altimetry

The discussion on how to treat illumination for shading mountainous relief, simulating the position of the lighting source, is not new in cartographic literature (for discussions on shading see, e.g., Horn 1982; Imhof 1982; Brandes 1983; Stefanovič and Sijmons 1984; Judd 1986; Keates 1989; Jenny 2001; Collier, Forest and Pearson 2003 and the relevant literature given).

A first approach to relief shading, in use almost up to the early 1920s, followed the Lehmann technique, is based on the acceptance of a vertical lighting source. Later on cartographers tried to put this technique under arbitrary mathematic formulation. The technique was focused on a gradual representation of shading, proportional to the slope-gradient, since the main axiom was that *slight slopes* go with *light colouring* and *heavy slopes* with *dark colouring*. In many cases, this principle does not lead to satisfactory perceptual results, especially in the case of complex relief patterns. After all, vertical lighting could never be 'real' due to the solar position which is never in vertical position over a place and because light diffusion is always there.

Later on, and up today, oblique lighting sources are used due to good visual results in representing third dimension on maps. Digital processing and visualisation of shaded relief depends on the use of the mathematical shading model and especially on the properties of light-reflectance governed by the adopted model (Horn 1982).

For the qualitative testing of Generalkarte shaded relief, depicted in the 1903 map-sheet, a digital DTM was derived from its contours. Two approaches are then tested on Generalkarte's digital 3-d reconstruction:

- a) To verify the validity of the map-sheet's vertical lighting, and
- b) To simulate this vertical illumination (if true) with the "real" solar illumination which gives similar relief shading.

Verifying vertical illumination

Since in market software environment, vertical illumination for relief shading is not an option, the only way to check the validity of vertical lighting on the old map, is to find out its relation with the distribution of the terrain slope gradient. For this reason, a map of slope-vectors was created from the DTM and was overlaid on the raster copy of the original old map-sheet. The result is impressive! A strong correlation appeared between the magnitude of the slope gradient and the degree of darkness representing the steepness of the slopes (Fig. 19).

This confirms the hypothesis that the relief shading of Generalkarte map-sheet was designed with the vertical lighting technique.

Simulating illumination

In recent times, modern digital technologies, embedded in the relevant market software applications, gave a wide spectrum of possibilities in testing shading by simulating the position of the lighting source e.g. the solar position given by its topocentric angular coordinates of height and azimuth. Usually, market software offer default illumination parameters (default height and azimuth) satisfying, mainly, perception findings related to the visual optimal representation of the shaded relief. But these default parameters are not at all relevant to the 'real' solar illumination, mainly as far as the azimuth is concerned (which actually forms the shading), and the nice visual 'by default' shaded relief effect is in fact 'unrealistic'. Boutoura (2000: 401; 2002: 255) has simulated 'real' solar illumination by respecting the solar

position along the Sun's diurnal spatial path for given epochs³. This approach is used in this study in order to test qualitative, in this stage, the shaded relief of the Generalkarte map-sheet.

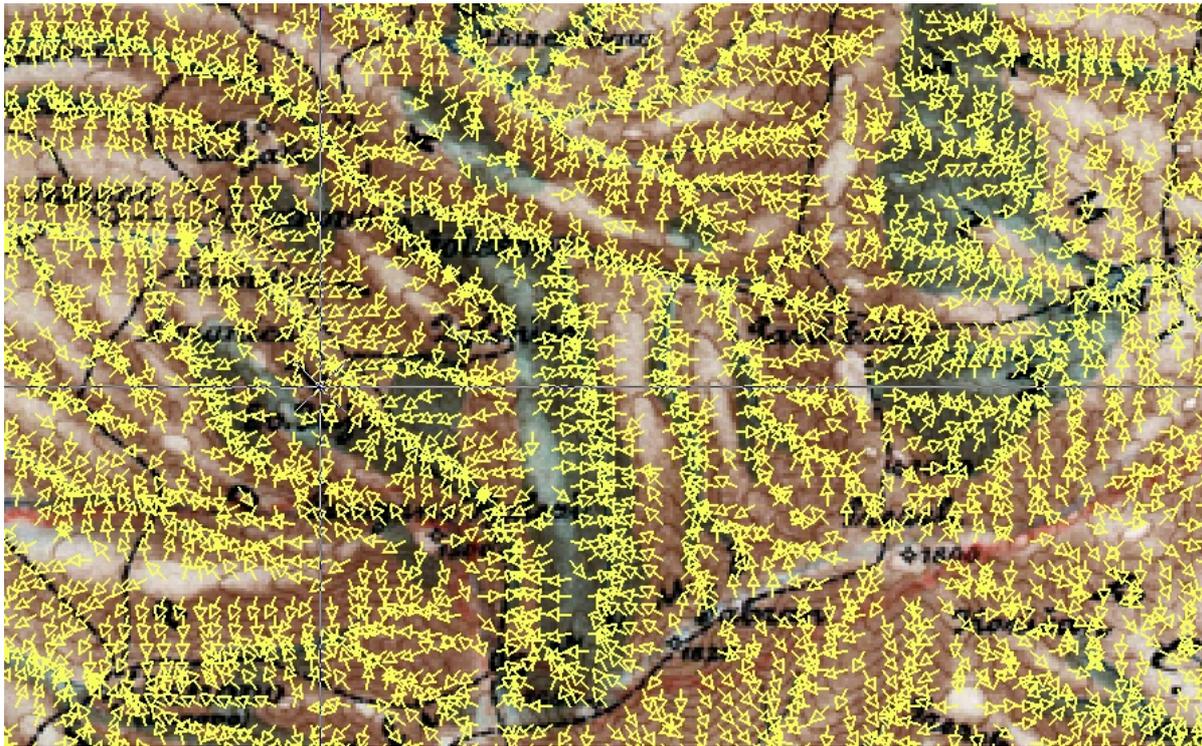


Figure 19. In dark areas of the old map there is a densification of slope vectors since luminous areas seem to be where terrain is not very bluff or the inclination changes in reverse.

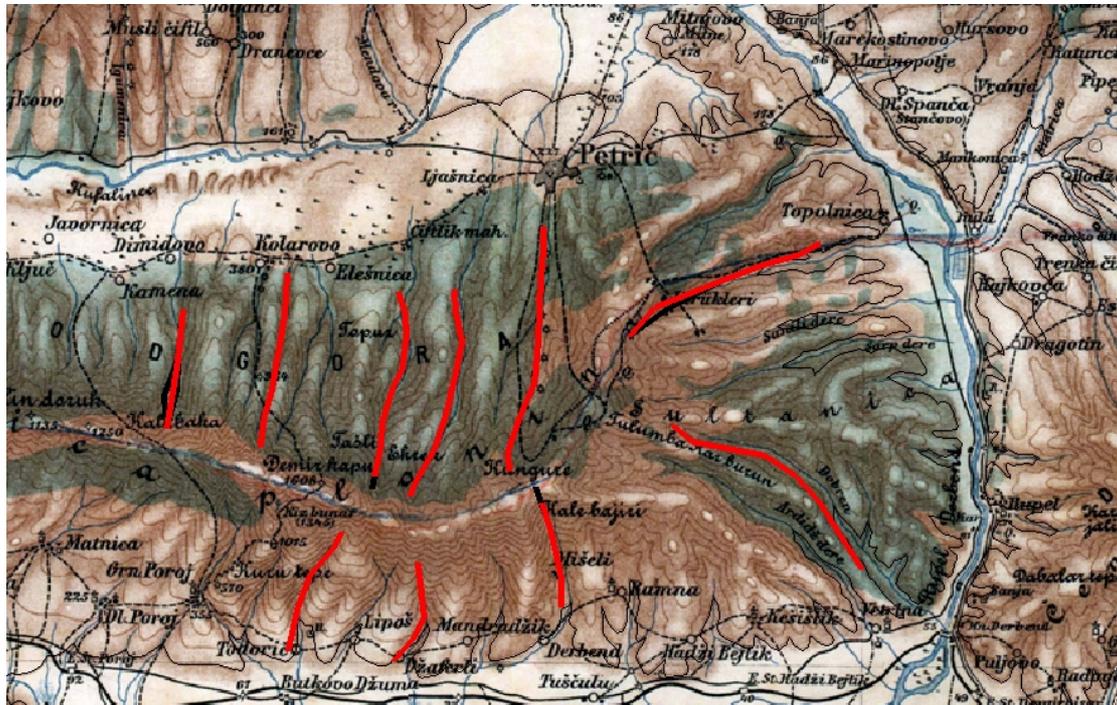


Figure 20. Detail of the shaded relief in G-k map sheet. The added red lines indicate the course of the gullies, the water-worn ravines in the mountainous terrain.

³ The approach is followed, since then, by the Hellenic National Centre for Maps and Cartographic Heritage in its map production projects.

For the study, applied to a part of the map-sheet (Fig. 20), the course of the gullies, the water-worn ravines in the mountainous terrain, are identified and signed by visible red lines. These lines are used as linear reference in order to evaluate the similarity of the original hand-made relief with the digitally constructed and shaded relief simulations.

Five and one distinct examples are tested, for its shading, on a digital reconstruction of the terrain relief in a part of the Generalkarte map-sheet used here. For the production of the five first reliefs, five different “real” solar positions were selected for the day duration of 21 June 2003, from 6:00 to 18:00 hours, and the angular solar coordinates of height and azimuth are taken. Additionally, the use of relevant default software parameters gave one more shaded relief. The resulted digital shaded reliefs can now be compared with the analogical counterpart on the old map.

In the first three cases (Fig. 21), where the solar lighting comes from the East (azimuths varying from ca 60° NE to ca 160° SE) the shading images are far from the Generalkarte shaded relief model which is drawn relevant to the course of the gullies alignment related to vertical lighting. In the last three cases, the first two (Fig. 22, Top and Middle) are illuminated from West (azimuths varying from ca 255 SW to 285 NW) and the third (Fig. 22, Bottom) is illuminated by default parameters (azimuth 315 NW) which are unrealistic as far as the solar position is concerned. In any case, all three lightings in Fig. 22, are close to the Generalkarte depiction of shading.

Shading unshaded maps

The advantage of disposing digital terrain models of old cartographies, is that shading relief can be added a-posteriori, for better evaluation of the altimetric quality and trend and for terrain relief comparisons with other relevant cartographies old and modern.

In the test old map-sheets used here, the Greek version sheet of Generalkarte’s is missing a shaded relief, the altimetry represented by contours and some poor areal colouring of the altimetric levels. Having available the 3-d digital altimetric representation of this map-sheet the shaded relief can be easily added as a digital transparency. A ‘new’ old map is thus obtained with ‘added value’ as far as the continuous altimetry spatial pattern is concerned. In Fig. 23, the part of the Greek version of *G-k* map-sheet (left) is enhanced by the merging of shaded relief constructed digitally from its own altimetry.

In Fig. 24, the Greek version map-sheet is reproduced with the exact overlay of the digital shaded relief as derived from the digitization of its own contours. In this way the old map is regenerated offering a new enriched image concerning the continuous form of the terrain depiction. This enriched image is of main importance for the enforcement of the study of the historic content of the old map and for its comparison with other old (Fig. 25) and modern altitude and relief representations.

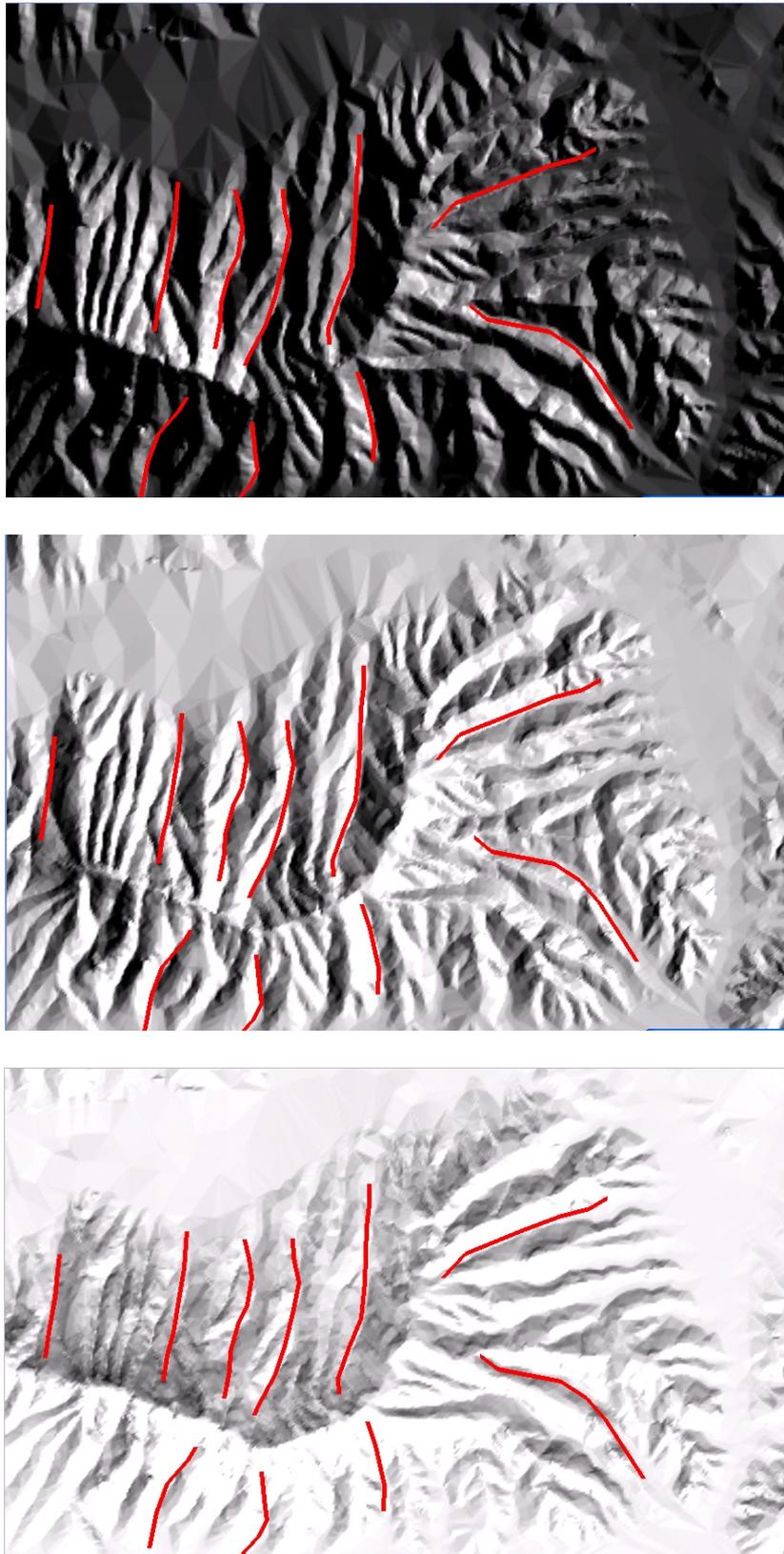


Figure 21. Shaded relief of the digitally reconstructed terrain of the *G-k* sheet with red lines, indicating the course of the gullies, the water-worn ravines (as in Fig.20). The Solar illumination simulation parameters are: (Top) height = 10.3° , azimuth 67.9° at local time 06:00; (Middle) height = 43.9° , azimuth 95° at local time 09:00; (Bottom) height = 72.6° , azimuth 159.9° at local time 12:00.

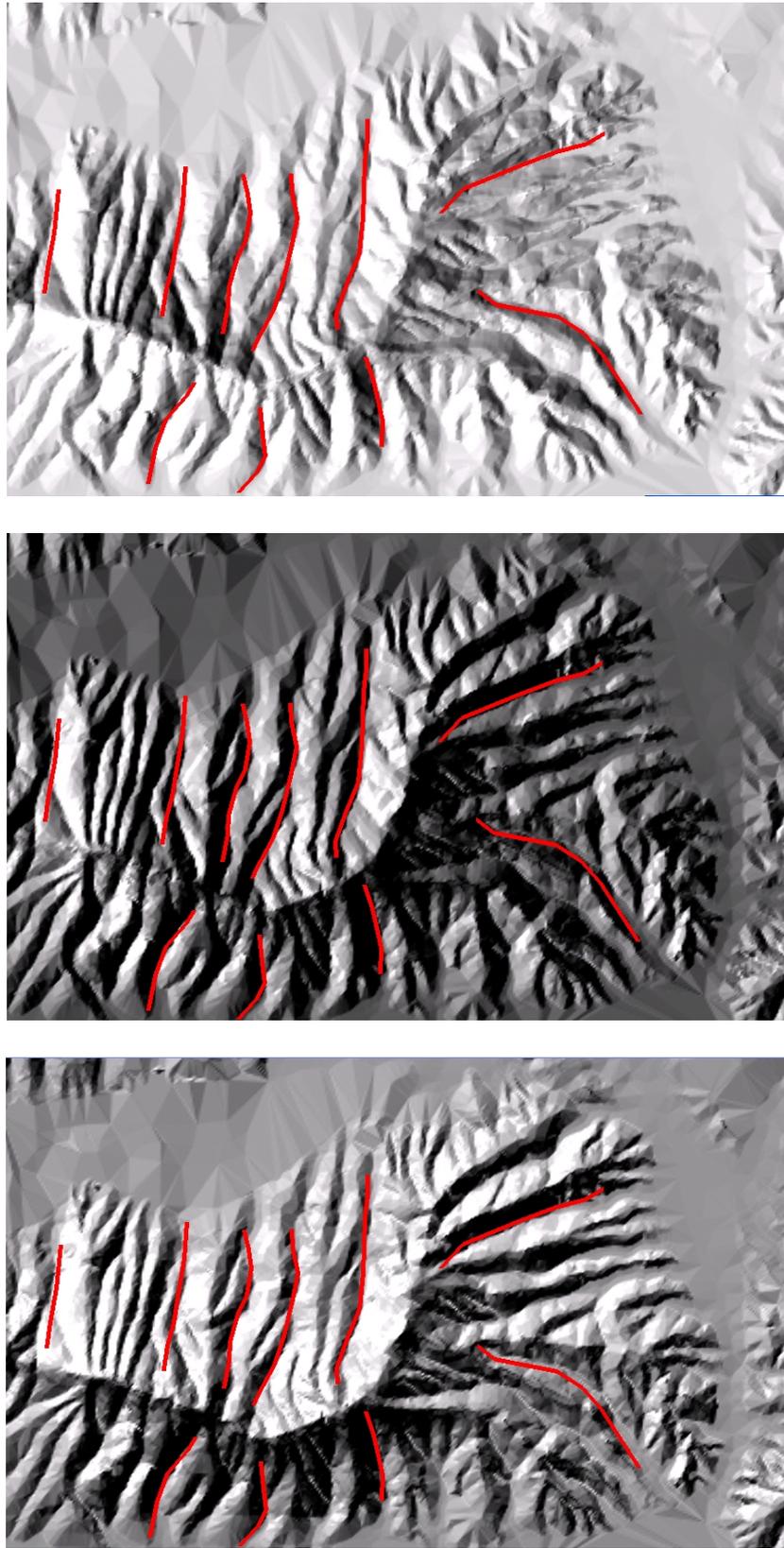


Figure 22. Shaded relief of the digitally reconstructed terrain of the *G-k* sheet, with red lines, indicating the course of the gullies, the water-worn ravines (as in Fig.20). The illumination simulation parameters are: (Top) Solar height = 55°, azimuth 255 at local Time 15:00; (Middle) Solar height = 19.6°, azimuth 284.6° at local Time 18:00 (Bottom) Software default height = 35°, azimuth 315°.

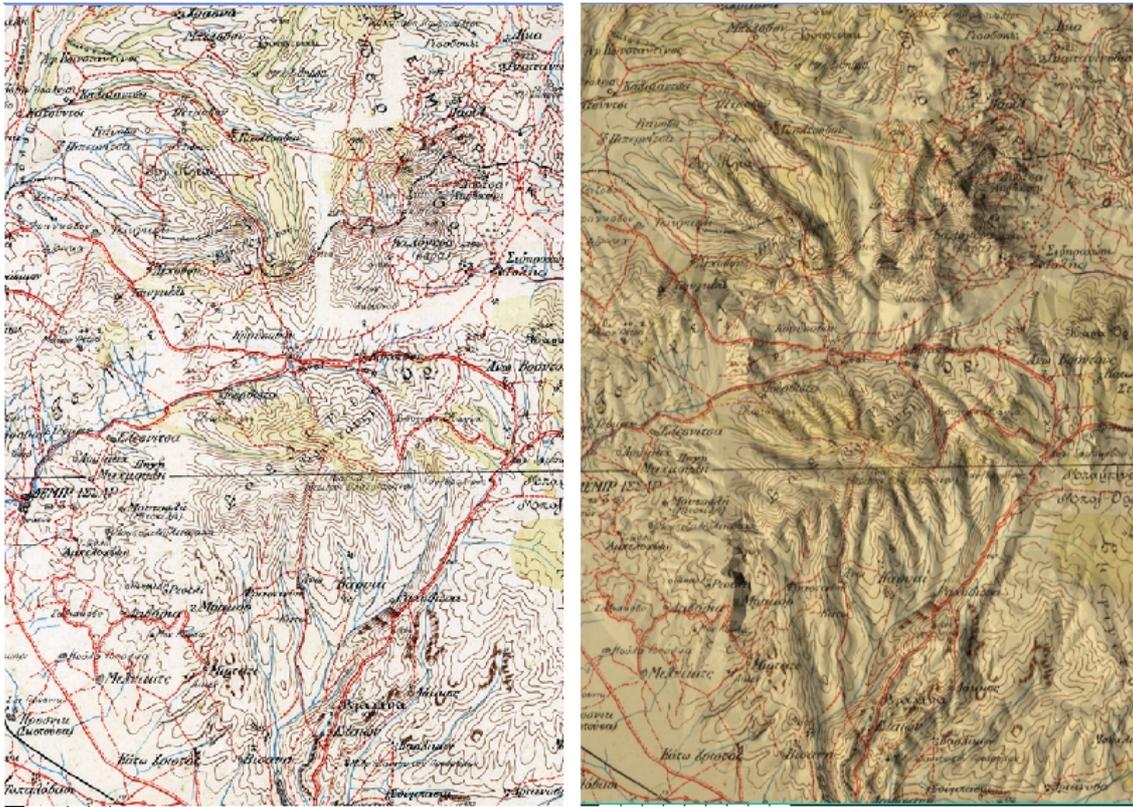


Figure 23. Left: A part of the Greek version map-sheet without shaded relief. Altimetry is represented by contours. Right: The same part of the Greek version map-sheet with the merging of shaded relief constructed digitally from its altimetry.

Concluding remarks

This study, which is part of a wider research on the issue, shows the impact that digital cartographic technologies can have on the comparative altimetric study and the relief evaluation of old maps with respect to older or newer counterparts. The key here is the digitalisation of the old map and its transformation to vector form, which makes all relevant analyses easier and multimode. The digitization and the transformation of old map in vector form permits, in principle, the adjustment and the elimination of a part of errors inherent in the map's analogical printed form and in its digital form as well. More specifically the relatively recent maps of medium scale, like the ones used in this study, are proper test materials suitable for such analyses because they are produced on the basis of specific norms as far as the map geometric content is concerned.

A basic step which allows the comparative analysis of digital maps is the homogenization of their geometric elements. In this way a uniform system of geometric reference of the map content is established, enforcing the possibilities of comparison. The geometric accuracy of the map content both in planimetry and in altimetry its improvement and corrections applied, from map to map, in the course of time, are detected and analyzed together with the derivation of important conclusions relevant to the reliability of the measuring methodologies and instrumentations of the time the maps were made. More specifically in altimetry, the representation of the third dimension in old maps -with all altimetry related elements- usually in a second level of interest in the paper map, it becomes very important in its digital form, concerning map geometry and readability. The digital terrain models which are constructed from a single map's altimetry on a common reference system offer the possibility not only for a comparative analysis of the methods and accuracy of altimetric surveys but also for qualitative and quantitative evaluation of the methods used for shading the relief, which in the paper case remained on the level of hypotheses.

The methodology followed in this study is very relevant for this type of maps, which represent a historically interesting territory and were compiled in periods of great changes. Due to their medium scale,

these maps contain a great amount of geometric and thematic information with a small amount of generalization, which after proper analyses could be used in a variety of historical studies. Finally, it should be pointed out that digital transformation of old maps allow not only the extraction of information mentioned above but also the redrawing of the map-content and its enrichment by adding new elements, as it the shaded relief we treated in this paper.

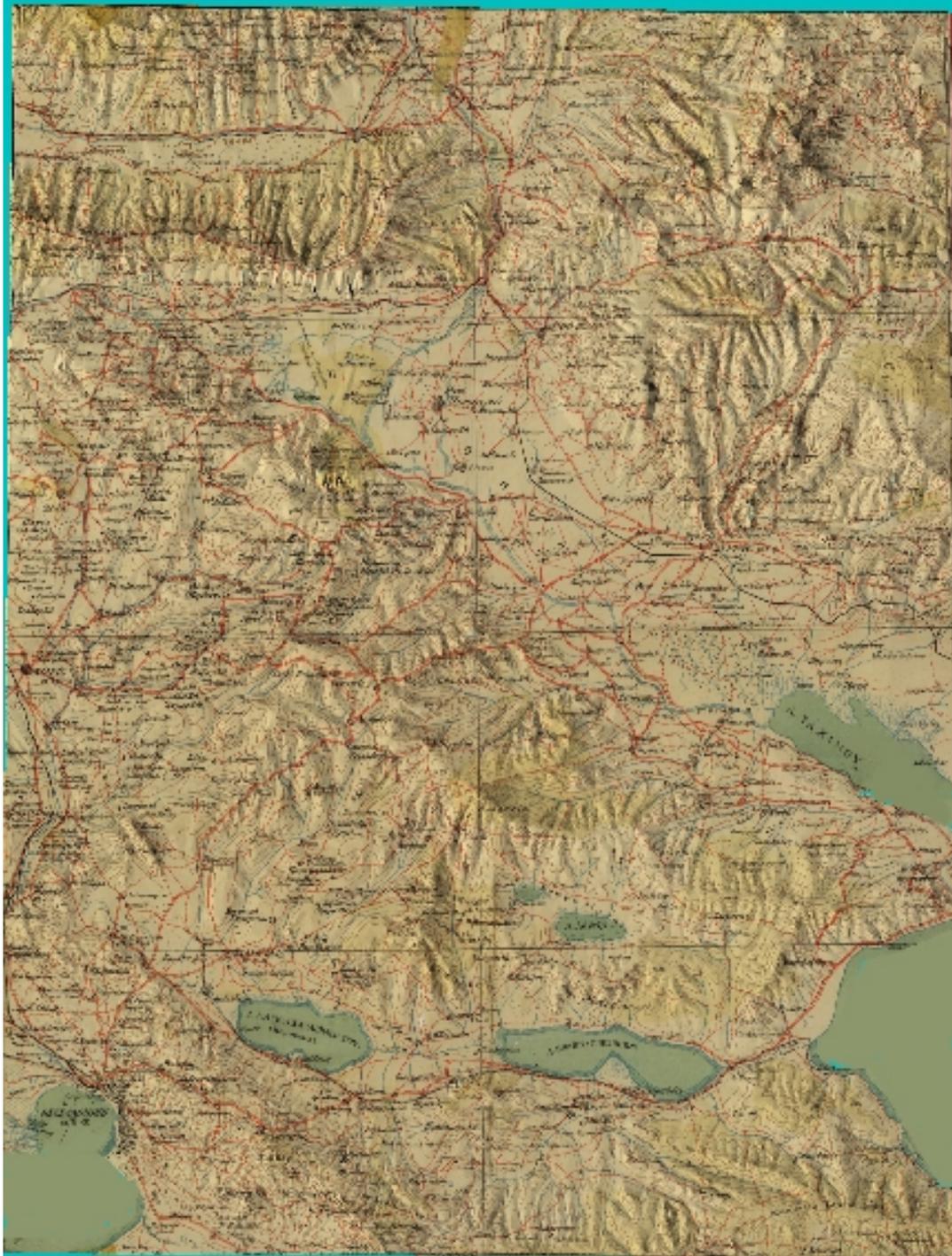


Figure 23. The reproduction of the Greek version map-sheet with the merging of the digital shaded relief as derived from its 3-d model.

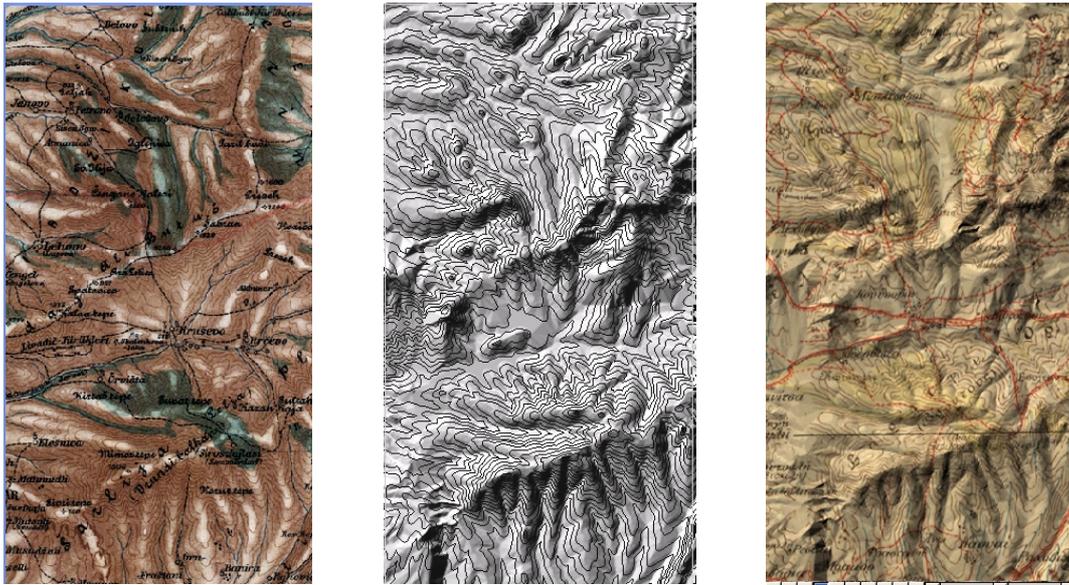


Figure 24. Comparison of the relief representation (detail). The course of the gullies, the water-worn ravines, are traced in yellow, in both maps by one-to-one correspondence. Left: The Greek version map-sheet enriched with the shaded relief constructed digitally from its own altimetry. Right: The shaded relief in *G-k* map-sheet

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