# Estimation of the Pleiades Imagery Potential for the Creation of Digital Topographic Maps

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**KEYWORDS**: contour lines, digital topographic map, estimation, image interpretation, Pleiades, satellite imagery, WorldView-2.

**ABSTRACT**: The present research was a stages of the complex project on testing of space images Pleiades which included also an imagery orientation accuracy assessment and 3D modeling of urban area. Research is spent in the Racurs and Technology2000, Russia. In the article results of an estimation of the Pleiades imagery potential for creation and updating of digital topographic maps are resulted, the accent is made on topomaps 1:2000-1:5000-scales. The attention is given to the interpretation and metric properties images.

## 1. INTRODUCTION

The creation of digital topographic maps provided by the two major factors:
1) completeness of the feature contents and attributive information;
2) accuracy of the feature metrics description.

Feature contents completeness means both representation (or omission) and detalization (or a level of generalization) of some features in accordance with the normative documents and standards. For example, a one-storey building will be represented on a 1:2000-scale map as two areal features (a residential fireproof building and a porch), on a 1:5000 map – as one areal feature (a residential fireproof building), and on a 1:10 000 map – as one point feature (a residential fireproof building) or will not be shown at all.

Therefore the estimation of space imagery potential for the creation of digital topographic maps includes following procedures:
- estimation of the image interpretation properties, i.e. a degree of recognition of the features which need to be represented on a topographic map of a particular scale;
- estimation of the metrics accuracy of the represented features, using permanent structures as an example;
- sketching of contour lines using the space imagery.

Questions of imagery orientation accuracy and creation orthophoto are not considered in the article.

## 2. SOURCE DATA

The main source data were Tristereo Pleiades images, covering a greater part of Yekaterinburg city and its vicinity, Russia (table 1 and figure 1). There are three images and three stereopairs (table 2).

The orientation of images Pleiades was executed in PHOTOMOD using RPC and 1 GCP. GCP and 45 check points were defined in field and had the accuracy of 0.2 m (XYZ). The orientation accuracy of dX = 0.3 m, dY = 0.3 m, dZ = 1.0 m (mean error of check points) was achieved.


Figure 1 – Area of interest.

Table 1 - Tristereo Pleiades images.

| **Parameters** | **L** (left) | **N** (nadir) | **R** (right) |
|---|---|---|---|
| Time | 2013-06-01 07:19:53.3 | 2013-06-01 07:20:16.7 | 2013-06-01 07:20:27.3 |
| Azimuth angle | 180.02 | 180.03 | 180.03 |
| Incidence angle | 11.18 | 3.99 | 10.02 |
| Viewing angle across/ along track | 1.22 / -11.11 | -3.10 / 2.50 | -5.07 / 8.69 |

Table 2 – Stereopairs Pleiades.

| **Stereopair** | **Stereo angle** |
|---|---|
| L+N | 15.17 |
| N+R | 14.01 |
| R+P | 21.20 |

Orthophoto scale 1:2000 was created from nadir image. DEM for the orthophoto had the vertical accuracy 0.5 m.

As additional data were used :

- 1:2000-scale orthophotos WorldView-2, the pixel size of 0.5 m, viewing angle of 13 degrees, RGB, 8 bits, acquired in 2010;
- 1:2000-scale orthophotos created on the A3 (Vision Map) aerial photos, the pixel size of 0.1m, RGB, acquired in 2012;
- 1:500-scale topographic maps on urban area;
- 1:10 000-scale map with a contour line interval of 2.0 m on all territory.

## 3. EXPERIMENT OUTLINE

### 3.1. Estimation of the image interpretation properties

Research technique: the visual estimation of the Pleiades imagery interpretation possibilities and their comparison with the WorldView-2 images and aerial photography were performed. The aim research isn’t so much comparison with aerial data, it is so much to define volume of office interpretation / field inspection for mapping.

We analyzed the objects of district which should be shown on map scale 1:2000 (inhabited/uninhabited buildings, fire-resistant/not fire-resistant buildings, industrial objects, highway and field roads, communications and so on). The same objects should be shown on map scale 1:5000, 1:10 000, but with selection and generalization.

The recognition reliability resulted in four levels:

- A – easy interpretation with no additional data being used;
- B – interpretation is possible using the office data analysis and additional materials;
- C – interpretation is possible only with the field identification data being used;
- D – interpretation is impossible.

Research results

236 types of features are analyzed. The general statistics is presented in Table 3 and Figure 2.

The very high resolution image allows a confident interpretation of slightly less than half of the features (level “A”), about 10% are impossible to be detected (level “D”), and approximately 50%

can be recognized using additional data and field identification data. As for the aerial image, the results are 55, 5 and 40% respectively.

Interpretation properties of the Pleiades and WorldView-2 images are similar. However, the operators admit that the WorldView-2 features are better extracted.

Table 3 - Summary results of the feature interpretation possibilities

| **Type of the source data** | **Number of the features** | | | |
|---|---|---|---|---|
| | **A** | **B** | **C** | **D** |
| Pleiades | 103 | 92 | 21 | 20 |
| WorldView-2 | 106 | 90 | 19 | 19 |
| Arial_data | 126 | 78 | 15 | 14 |

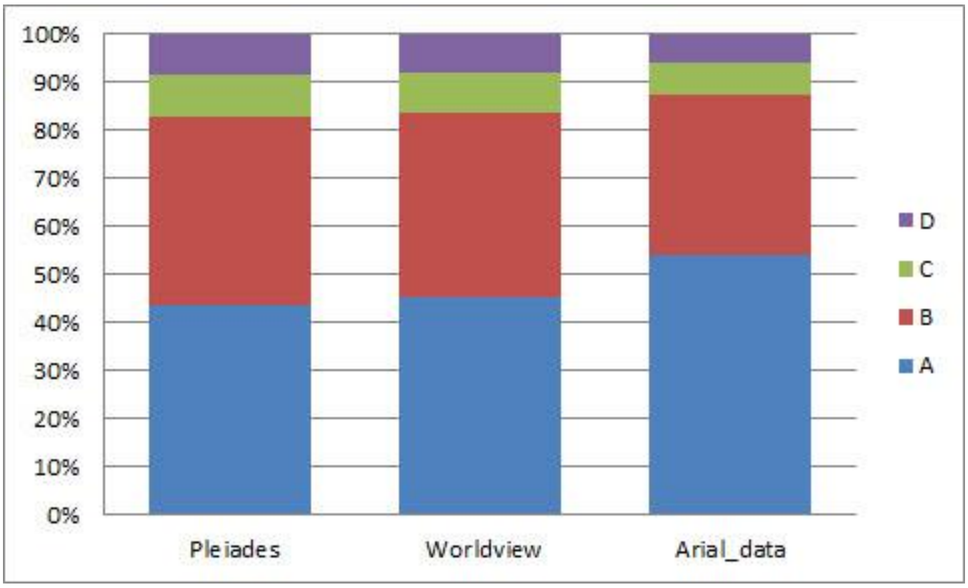


Figure 2- The feature interpretation potential in percentage terms.

The characteristics of interpretation properties for various types of features are given below.

*Settlements.* The resolution of the analyzed images allows to detect even individual constructions of small size, so all types of settlements can be confidently interpreted, as well as settlements' blocks and garden plots. Some difficulties appear in the identification of fireproof buildings and constructions: it's hard to identify the fireproof building materials even on off-nadir images.

*Cultural and industrial features.* This layer contains nonresidential buildings and structures (industrial and agricultural enterprises, socio-cultural and religious facilities), as well as towers, poles and posts, power and communication lines, pipelines, fences and enclosures. Most of these features are of a considerable size as compared to the resolution of the imagery acquired and can be rather easily interpreted.

Poles and posts have a small size (horizontally), that's why there are some difficulties with interpretation of their footing even by sharp shadow. The main problem is to place a feature into a particular group or level: without additional data, it is difficult to identify the material and shape of a pole or enclosure, the working voltage of power lines, the purpose of an industrial enterprise, etc.

*The road network and road constructions*. This layer includes features of the transport infrastructure (highways and railways; some facilities associated with them: border levees, bridges and tunnels,

railroad poles, etc.), above-ground facilities of the underground railroad and pedestrian paths.
The linear features of big length from this layer are interpreted best as compared to the features of other layers – more than 2/3 of them belong to level "A".
There are some difficulties with interpretation of the point and small-length linear features such as pipes, going under the roads, and some sidewalks (often hidden by plants), even if additional data are available. Detection of these features becomes easier with stereo imagery and additional data.

*Land relief*. This feature group – besides the basic relief elements such as contour lines and elevation marks – also includes various relief deformations both of natural (ravines, washouts, precipices) or of man-made origin (holes, slopes). On the single scene the relief deformations can be interpreted mainly due to shadows. With the stereo pair, a degree of recognition highly increases – in effect, almost all the features (present on the analyzed image) get to level “A”.

*Hydrography*. As a rule, the features of natural and man-made origin, belonging to this layer, can be confidently interpreted by direct indicators on any images, because usually the size of hydrographic features surpass by far the resolution of analyzed imagery. Only the features hidden by vegetation get to levels B, C, D.
Difficulties mainly occur in interpretation of man-made constructions: different types of wells and standpipes have small sizes and can hardly be recognized. All point features of this layer need some additional data to specify their location and purpose.

*Vegetation and soils*. This layer embraces all types of vegetation, both of natural or man-made origin.
Most areas, covered with vegetation, are easily interpreted by colour and/or photo-shade. As a rule, it’s hard to classify its type (for example, it is difficult to distinguish grassland vegetation from the steppe one).

When creating the 1:2000- and 1:5000-scale maps, main problems appear in representation of the following features:

- parts of buildings (prominent parts of intricately-shaped buildings represented on 1:2000-scale maps);
- point features (only using additional data or stereo images);
- posts and poles of the power lines;
- some parts of hydrographic features (because of vegetation);
- hydraulic (engineering) structures (only using additional data);
- bridges – metric is ok, attributes (height over water, load-carrying capacity) are difficult; overpass bridges, ferries (only using additional data);
- land relief;
- vegetation (its classification);
- microforms of the land surface.

In summary, with the additional information and field data being used, the Pleiades interpretation potential allows to update and create 1:5000- and 1:2000-scale maps for small, sparsely built settlements; for semi-rural territories mainly with linear and areal features. With the field data available, it’s possible to interpret all point features.
Pleiades imagery can be confidently used for updating and creating the 1:10000-scale maps.

### 2.2. Estimation of the features representation accuracy

Research technique: Rendering of the permanent structures (buildings) is performed using orthophotos and stereo pairs and using orthogonal models, with oblique distortions being considered and with a very detailed representation of architectural elements. Two types of buildings are chosen: multi-storey buildings in urban areas and one- or two-storey private houses. Their location, dimensions and shapes are compared.

The research results were analyzed in accordance with the normative documents and standards:

- maximum error of point positioning for adjacent objects is 0.8 m for 1:2000-scale maps and 2.0 m for 1:5000-scale maps;
- figured elements and prominent parts of the buildings architecture should be represented if their size is 1.0 m for 1:2000-scale maps or 2.5 m for 1:5000-scale map.

Same buildings were rendered on Pleiades stereo images (N+R), orthophoto_Pleiades, orthophoto_WorldView-2. The control data was the 1:2000-scale ortophotos_aerial.

Research results

Represented are 40 buildings from the urban area (of different shapes, types and built in different years) and 43 private houses (finely extracted from the image; not hidden by vegetation).

Results obtained:

1. Average error for the building corner extraction is 1.3 – 1.5 m for both Pleiades and WorldView-2 single images (orthophotos). The average error for Pleiades stereo images is twice better, than for single images and is 0.9 m.
2. Maximum error is 4.0 - 5.4 m for single images and 3.5 m for stereo images.
3. Shapes and dimensions of the permanent structures (buildings) of a simple form are correctly represented using satellite imagery.
4. Figured details of building architecture can be represented both correctly and incorrectly depending on contrast effects and sometimes can be omitted.
5. The difficulties with the private house sector are about distinguishing between residential and nonresidential facilities when they are attached; and some errors in representation of shapes and dimensions (up to 2m).

The results are given in Table 4 and Figures 3-6 (left – a Pleiades orthophoto, right – a arial orthophoto; blue – the outline of a building from the Pleiades orthophoto, pink – the outline of a building from the arial orthophoto; the bias shift in image orientation is considered).

### 3.3. Analisis of the contour line sketching

Research technique: Manual contour line sketching for the test site using the Pleiades stereo pair and its comparison with control data. The test site is an open hilly area with private houses (Fig. 7). On one hand, it presents no difficulties for relief representation, as it's not forested and has no high-rise buildings, on the other hand– it's common for creating 1:2000-1:5000-scale maps. Elevation difference is 60 m (absolute elevations are from 220 to 280). The area of the site is 1.5 sq. km.

Source data:

- Pleiades stereo images (N+R with a stereo angle of 14 degrees and L+R with a stereo angle of 21 degree), the pixel size of 0.5 m (0.7 m GSD);
- Control data: a 1:10 000-scale map with a contour line interval of 2.0 m.

Research results are given below and illustrated by Figures 8-9.

1) General relief forms are represented correctly.
2) Relief is too generalized, some hills of 3-4 m high are omitted, ravines are smoothed and not represented.

3) Relief forms are better detected on the L+R stereo pair, than on the N+R image, because the stereo angle is bigger. In this case the "triplet" mode is more helpful than the stereo one.

This result is preliminary, because it is only one small site of one concrete stereopair and the statistics is not enough for the complete analysis.

## 3. CONCLUSIONS

In our research we have tried to define limiting possibilities of space images for mapping. Which objects and characteristics are read? With what accuracy objects can be put? The conclusions are according to Russian standards for the creation topo maps.

For the purposes of creating digital topographic maps, intended for different applications, Pleiades imagery can be surely used for the creation of 1:10 000-scale maps with a contour line interval of 2m.

Creation (updating) of 1:2000-scale maps for built-up areas using Pleiades images is impossible.

Creation (updating) of 1:5000-scale maps for the built-up areas using Pleiades images should be performed on a stereo imagery. The use of single images does not meet standard requirements.

These conclusions are true for WorldView-2 images as well.

Very high resolution satellite imagery can be used for creating special-purpose maps of large scales with the incomplete feature content and low accuracy in comparison with standard topo map.

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Table 4 - Accuracy estimation of the features representation on the digital topographic maps.

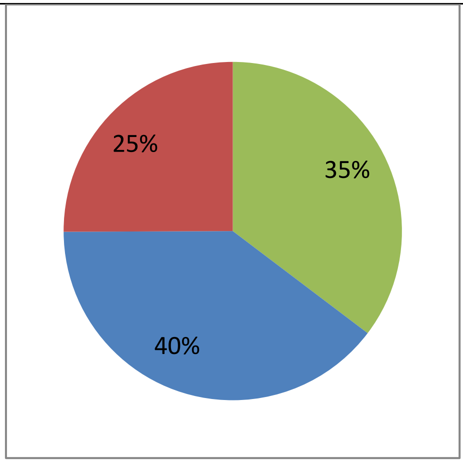
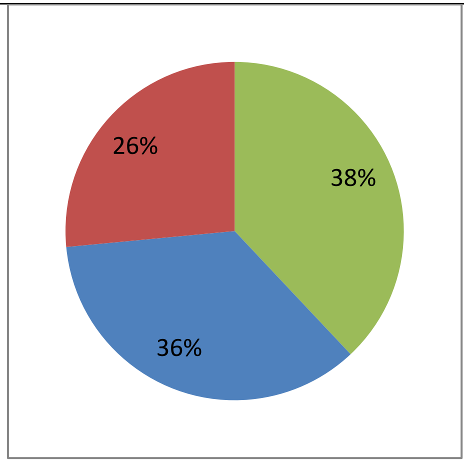
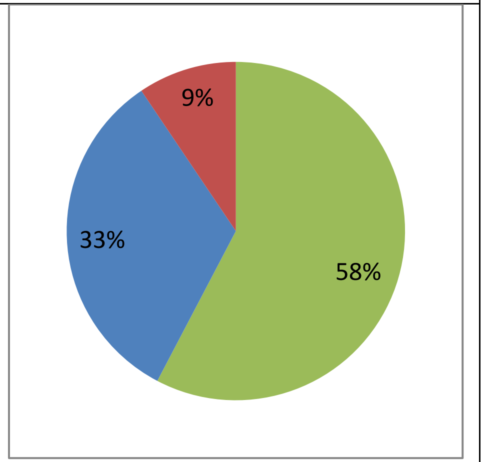
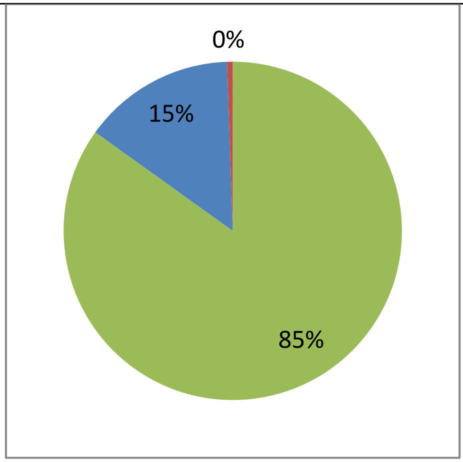
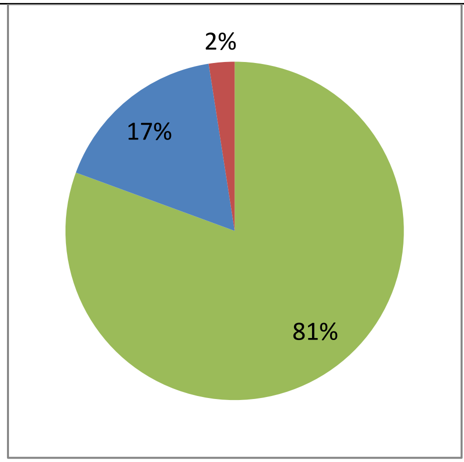
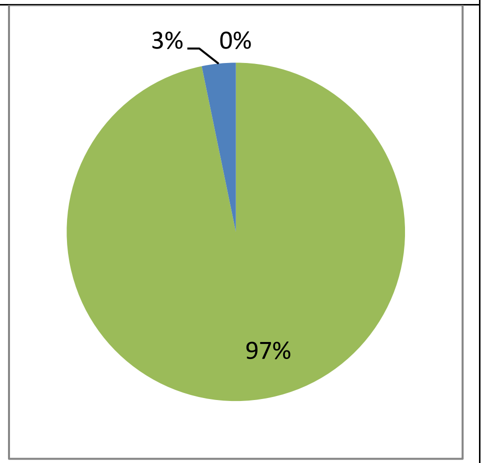
| Parameter | Orthophoto WV2 | Orthophoto Pleiades | Stereo Pleiades |
|---|---|---|---|
| Number of measurements | 371 | 366 | 371 |
| Mean error, m | 1.3 | 1.5 | 0.9 |
| Maximum error, m | 4.0 | 5.4 | 3.5 |
| Distribution of errors for digital topographic maps, scale **1:2000**<br>0-0.4 mm (OK)<br>0.4-0.8 mm (normally < 10%)<br>more 0.8 mm (badly) |  |  |  |
| Distribution of errors for digital topographic maps, scale **1:5000**<br>0-0.4 mm (OK)<br>0.4-0.8 mm (normally < 10%)<br>more 0.8 mm (badly) |  |  |  |

Figure 3 - The dimensions of the building are incorrect (its width is 9 m on the A3 aerial photography and is 10 m on the Pleiades image) (1); on Pleiades it is impossible to distinguish residential and nonresidential constructions (2).

Figure 4 - The prominent part  of 1.5 m wide(1) is not represented, the form (shape) and size of the building are represented with an accuracy error of 2 m (2).

Figure 5 - The shape and size (dimensions) of the permanent multi-storey buildings of a simple form are correctly represented.

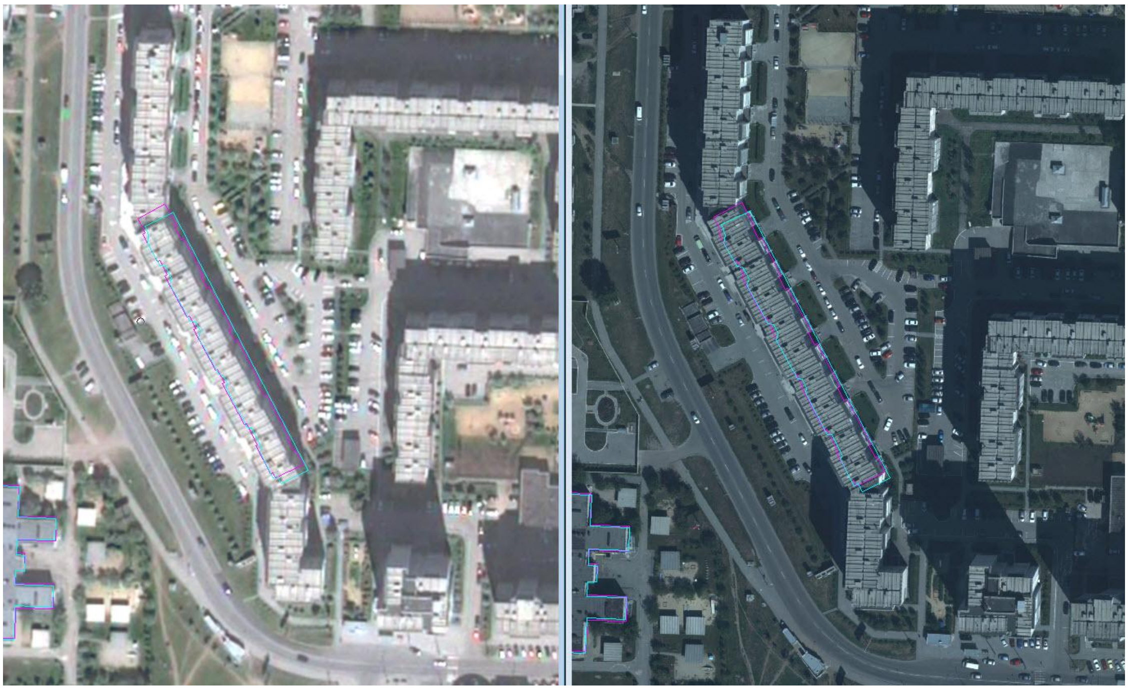


Figure 6 - Architectural figured details can be omitted (the prominent parts on the left-hand side of the building are shown, those on the right-hand side are omitted).

Figure 7 - A test site for the contour line sketching.

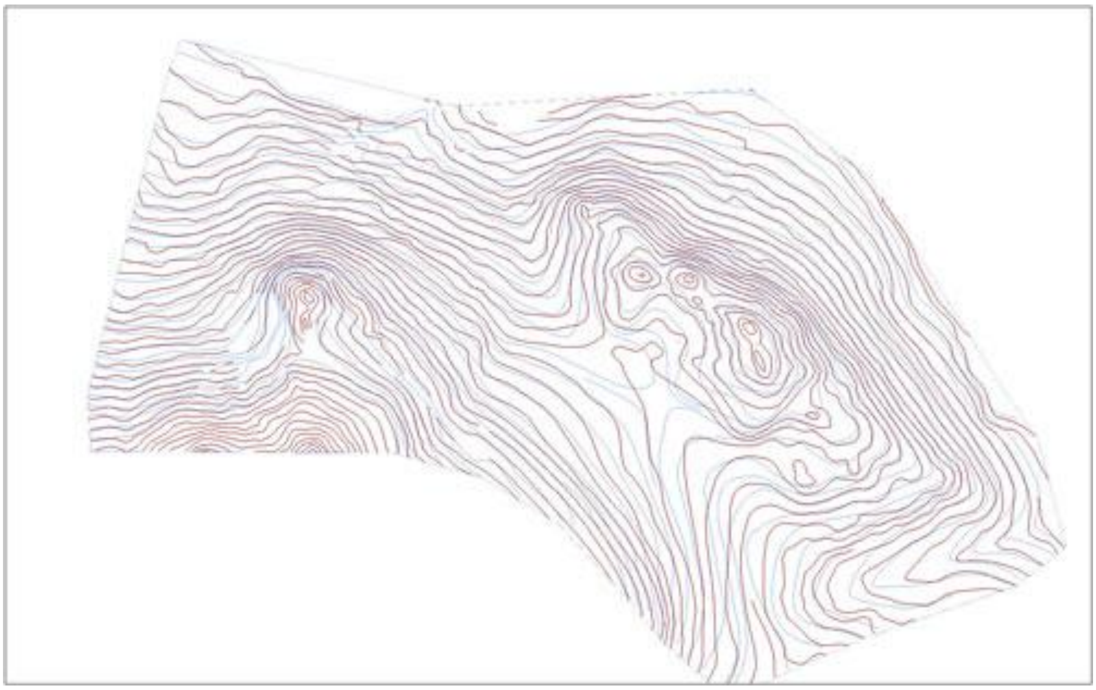


Figure 8 - General comparison of the contour lines: brown - based on the aerial photographs, blue - based on the Pleiades image. The general relief forms are truly represented.


Figure 9 - Comparison of the contour lines: brown — based on the aerial photographs, blue — based on the Pleiades image. Hills ( up to 3-4 m high) (1), (2), (3) are omitted, the ravine (4), (5) is not represented.