Proceedings of the International Symposium
Trebinje / Bosnia and Herzegovina / 6-9 June 2018

KARST 2018

"Expect the Unexpected"

Editors:

Saša Milanović and Zoran Stevanović

Centre for Karst Hydrogeology
Hydro-Energy Power Plant "Dabar"

Belgrade, 2018

Publishers:
University of Belgrade
The Faculty of Mining & Geology
Department for Hydrogeology
Centre for Karst Hydrogeology
Belgrade, Serbia

Hydro-Energy Power Plant "Dabar"
Trebinje, Bosnia and Herzegovina

For the publishers:
Dr Dušan Polomčić, Dean of the Faculty of Min. & Geol., University of Belgrade
Željko Zubac, Director of the Hydro-Energy Power Plant "Dabar"

Editors:
Saša Milanović
Zoran Stevanović

Technical preparation:
Branislav Petrović
Veljko Marinović

Circulation:
300 copies

Front page:
Arslanagića most bridge across the Trebišnjica river, Bosnia & Herzegovina
(photo S. Milanović)

The authors of contributions in these proceedings are responsible for the content and copyrights of their respective contributions. Neither publishers nor any person acting on its behalf is responsible for the possible use of information contained in this publication.

Printed by:
FineGraf d.o.o. Beograd

ISBN 978-86-735-325-5

ESTIMATIVE KARST INTERPRETATION OF SATELLITE IMAGES OF THE SOUTH – SOUTH-EASTERN DISTRICTS OF PERM REGION

Evgeny Erofeev[1], Valery Kataev[2]

[1]Perm State University (PSU), Russia, e-mail: erofeev-ea@yandex.ru
[2]Perm State University (PSU), Russia, e-mail: kataev@psu.ru

Abstract: This publication is dedicated to the methodology of karst areas interpretation in the Southern and South-Eastern districts of Perm Region by using large-scale high resolution satellite images. This paper describes methodical approaches for identification of karst forms on the day surface by various terrain conditions: forest coverage, illumination, building density and seasons. Approaches for determination of karst diameters depending on their geometry and on the density of vegetation are recommended. Maps of karst landforms have been created.

Key words: karst forms, funnels, diameter, cosmic images, interpretation

Introduction

Estimative karst interpretation is performed within the frame of solving applied research tasks, such as: identification of on the day surface visually detectable karst forms, including karst hole genesis, local ground depression and their concentration, in karstological literature called «karst fields». In addition to the location of surface deformations, their geometrization is preformed and the following data are defined: area, perimeter, diameter, karst forms concentration. The interpretation was accompanied by the standard procedure of factual data gathering and systematization, the building of karst areas database and the preparation of geological information for following analysis. As a result of the interpretation and analytical actions, influence patterns of various geological and hydrogeological factors on the positional relation, the intensity of formation and parameters of fixed karst forms were determined.

Research area

Studies have been conducted on the karst developing areas, which in the scheme of karst zonation of the Perm region [1] conform structural-tectonically to the Eastern edge of the East European Plain and the adjacent part of the Ural Foredeep, such as: Nizhnesilvenskiy, Ilinskiy, Kishertskiy areas of gypsum and carbonate-gypsum karst developing, Osintsevskiy area of the closed salt and gypsum karst and the area of carbonate karst of Ufimskiy swell. On the specified areas sulfate (gypsum, anhydrite) deposits of the Irene horizon of the

Kungurian stage are mainly karsting and carbonate (limestone, dolomite) rocks of the Filippovsky horizon of the Kungurian and Artinskian stages of the Cisuralian Epoch of the Perm System are karsting in a lesser extent. Geological-structural conditions - platform, karsting - conform to the bald, covered with turf, on large areas to under-eluvial, in the river valleys to under-alluvial and to the under non-karst rocks closed type of the Solikamsk Horizon of the Ufa Stage of the Cisuralian Epoch of the Permian System. Karst forms are very diverse: funnel, sinkholes, swallow holes, caves, karst ravine, sinks, etc. On the earth's surface the most common karst forms are funnels including dolines. The total area of interpretation is 9558.2 km^2.

Expert method

This study is technically based on the high resolution satellite images (CFS) provided by Google Maps, Bing Maps, Geo Hab, ESRI, Yandex. The view and justification of using images from the public package of satellite images concerning their quality and resolution, as well as analysis of present karsting areas to identify surface karst forms, were carried out using the program SAS Planet.

Viewing, analysis, and vectorization of the CFS, which meet the requirements of the tasks according to their content, quality and resolution, were carried out in the Next GIS (nextgis.com). The analyzed KFS were used as the background without downloading. Settings of the working draft are following: WGS 1984 UTM Zone 40N projection Mercatora / WGS84. As karst interpretation was based on the large-scale CFS, the resolution of images has become the determining choice factor of the suitable images for karst forms diameter calculating with a required accuracy. The parameters and scale of KFS were estimated in the program SAS Planet. Based on the resolution of the images, the working scale (level) of the images and the calculated theoretical error of the cross-section of the karst forms were determined. The parameters for displaying CFS in SAS Planet and Next Gis in the raster format with JPG extension are shown in the table. 1.

Table 1. Parameters of CFS in the raster format with JPG extension

Level CFS	Scale	Resolution m/Pix	Size jpg in pixels	Jpg size in inches	Mp jpg	DPI jpg
z19	1:1000-	0,32 м/pixel	256*256	(3,56*3,56//)	0,1	72
z18	1:1870-	0,64 м/ pixel	256*256	(3,56*3,56//)	0,1	72
z17	1:3750-	1,29 м/ pixel	256*256	(3,56*3,56//)	0,1	72

The digitization of karst forms was carried out on the operational scale 1:500 - 1:1000-1:2000 (z18-z19), by increasing the scale to more than 1:500, the

boundaries of forms were blurred and lost their clarity, so the evaluation of the cross bars of karst forms became meaningless.
The main interpreting features on the CFS are the karst phenomena themselves (the number and the pattern of their spread over the area), easily recognizable geometric parameters (usually a rounded, symmetrical form), which are visually easy to determine in large-scale images (Fig. 1).

Color CFS of high resolution Google, Bing Maps, Yandex, etc.are well-read photographs, on which the elements of the terrain, hydrographic networks, vegetation, buildings and structures are clearly and definite reflected. Deciphering features are usually well expressed, and the shape and the color of the objects allow to identify karst forms (mainly funnels) in the open area with a sufficient degree of reliability.

All the above has determined the choice of the research area. The Southern and South-Eastern parts of the Perm region are of unique landscape – Kungur forest-steppe, which is characterized by a predominance of steppe areas with alternating small forest areas. Favorable natural and geological environments – a significant intensively developed karst areas, free from forests, have provided optimal conditions for the interpretation and for the receiving of standard source material [2].

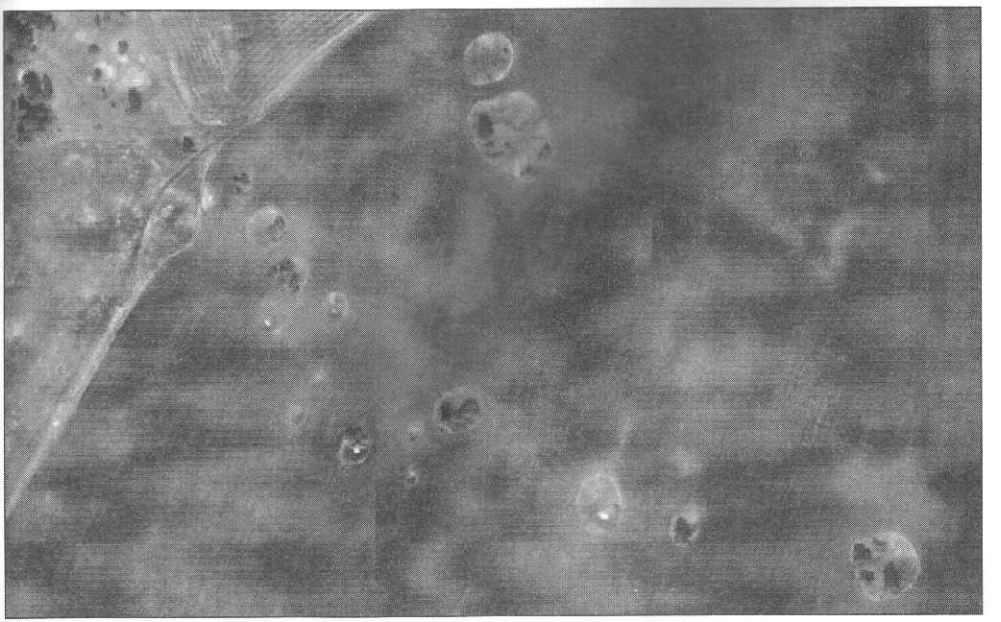

Fig. 1 Karst field in 2.3 km from the village Upper Kungur.

The undoubted advantage of the methodological approach is the unified method to identify karst forms on the terrain and to evaluate their parameters

with the specified accuracy (error) by the actual resolution of the FSC. Karst forms are a characteristic feature of the landscape of Kungur, Orda, Kishert, Suksun and other districts. Funnels are easily recognizable and stand out in the pictures because of their shape (round, oval, elongated), as well as of the nature of their location in large or small groups (fields), usually chaotically and randomly. However, there are a few funnels or an ordered set in the form of a chain along splits or groups of linear grikes. In time, the shapes of funnels on the Earth surface do not change, but the shapes of their transverse profiles change because of gentling their boards. The craters are overgrowing with thick grass, shrubs and trees. Vegetation is also an important indicator of surface karst forms deciphering.

The funnels are the point elements of collection of melt and rainwater and thus create conditions for active development of grassy and woody vegetation within their limits. On some areas there are funnels with varying degrees of grass, shrub, trees, which indirectly indicates the order of collapse and allows to estimate the size of the forms depending on their relative age [2].

For the present CFS (72 DPI) by the maximum allowable scales of 1:500 – 1:1000 decryption, when 1 mm on the map corresponds to a distance of 0.5-1.0 m, areal visualization of forms up to 1 m is meaningless, because the error of 1 mm may exceed the actual size of a karst funnel. The geometrization of forms up 1 m by scale 1:500 is more balanced, so 4 mm on the map will correspond to a funnel with the diameter of 2 m. For this reason, all forms smaller than 1 m weren`t geometrized.

The transverse dimensions of karst forms identified by the classification were compared with their dimensions during the field verification work in Orda and Kungur districts. The control check was selective, there were measured more than 30 craters with lateral sizes from 5 to 40 m. The results of the research have estimated the following: the dimensions of the forms (from 5 to 30 m), calculated remotely, on average, were smaller than the actual dimensions (measured by tape) for 1-1,5 m. The remote calculated diameters of 30 m and more - for 1.0-2.0 m exceeded the actual dimensions. In this case, the measurement error could be made during both measurements: during tape measurement - because of the rugged relief, and during the karst forms visualization.

During the identification and the subsequent vectorization karst forms were divided into two groups (SHP-files): areal and pointlike. In the first group are those karst forms which diameters were established easily. As the "nominal diameter" of a karst form the biggest or the external, visually discernible diameter (the circle) of a funnel was taken; at the same time, the actual material

obtained from karst fields verification surveys showed that in most cases, for bushy or treed funnels, it is possible to determine the diameter accurately enough, as the edge of vegetation is usually limited by shape, or slightly goes beyond it. For Kungur and Orda districts, fields verification surveys have confirmed this assumption. In some areas the process of karst forms overgrowing was observed; at the same time there were funnels (identical by the form in the picture and the size) completely open, partly overgrown and completely closed by vegetation; that allowed for overgrown forms to substantiate the diameter dimension by analogy with open funnels (Fig. 2).

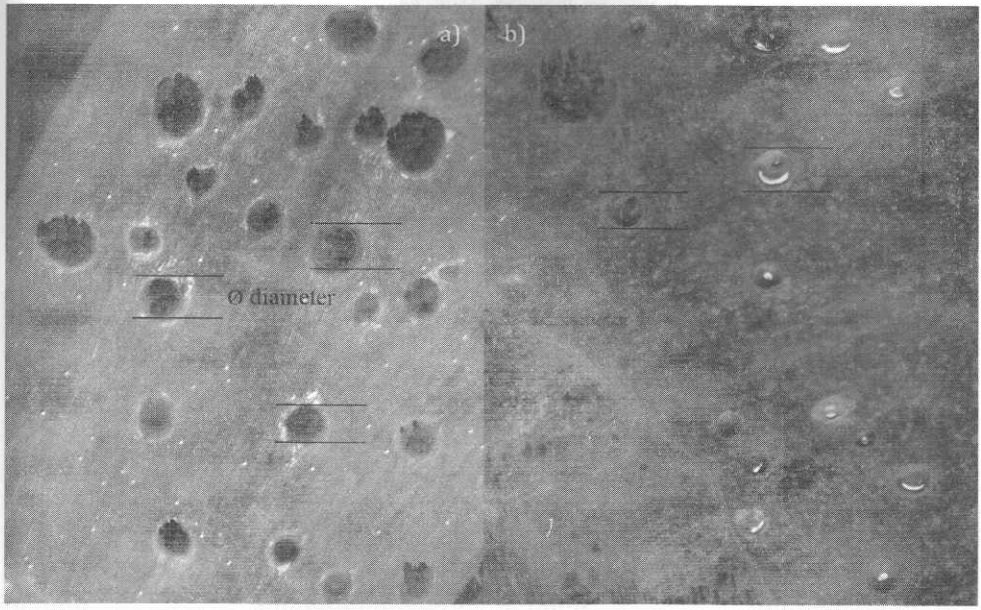

Fig 2. Methodical approach to the geometrization of karst forms: a) The district is 1.5 km from the village Klyuchi b) The district is 0.6 km from the village Kiselevo

To the same group was subsumed the part of the forms, which etiology was doubtful because of the strong population, the layout of the relief, the location in the forest or in a shade of another object, etc. [2].

Large clusters of sinkholes in areas, where the karsting rock comes up to the day surface, were detailed analysed and visualized as point objects; on the karst density map such areas are specified as the areas with the highest karst density, up to 600 pieces/km^2.

Research results

The volume actual material characterizing the karst landscape of Southern and South-Eastern districts of Perm region was obtained as a result of conducted

research. The verification field work has confirmed the objectivity of the work performed. Statistical parameters of karst interpretation are presented in the table 2. The empirical distribution of the diameters of the polygonal karst forms corresponds to the lognormal law (Fig. 3), the average diameter reaches 18.5 m. The character of the development of karst forms on the daily surface is illustrated on the density map (Fig. 4).

Table 2. General statistical indicators of interpretation of the territory

Karst area	The number of forms, pieces	Point feature, pieces	Polygon features, pieces	The area of the region, km²	The area forms, km²	Karst, %	Conditional density, pieces / km²
Kishertsky	1954	648	1306	306,33	0,81	0,26	6,38
Irene	39016	21973	17043	3380,71	6,38	0,19	11,54
Nizhnesaldinsk	22704	7830	14874	2132,7	5,37	0,25	10,65
The Ufa	4484	3232	1252	2703,63	0,27	0,01	1,66
Osintsevsky	297	150	147	861,04	0,058	0,01	0,34
Total:	68455	33833	34622				

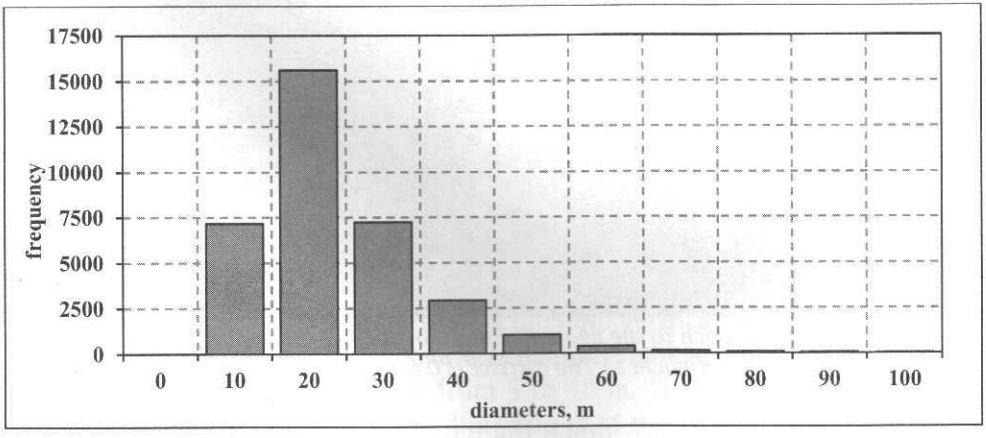

Fig 3. A graph of the diameter distribution of karst forms

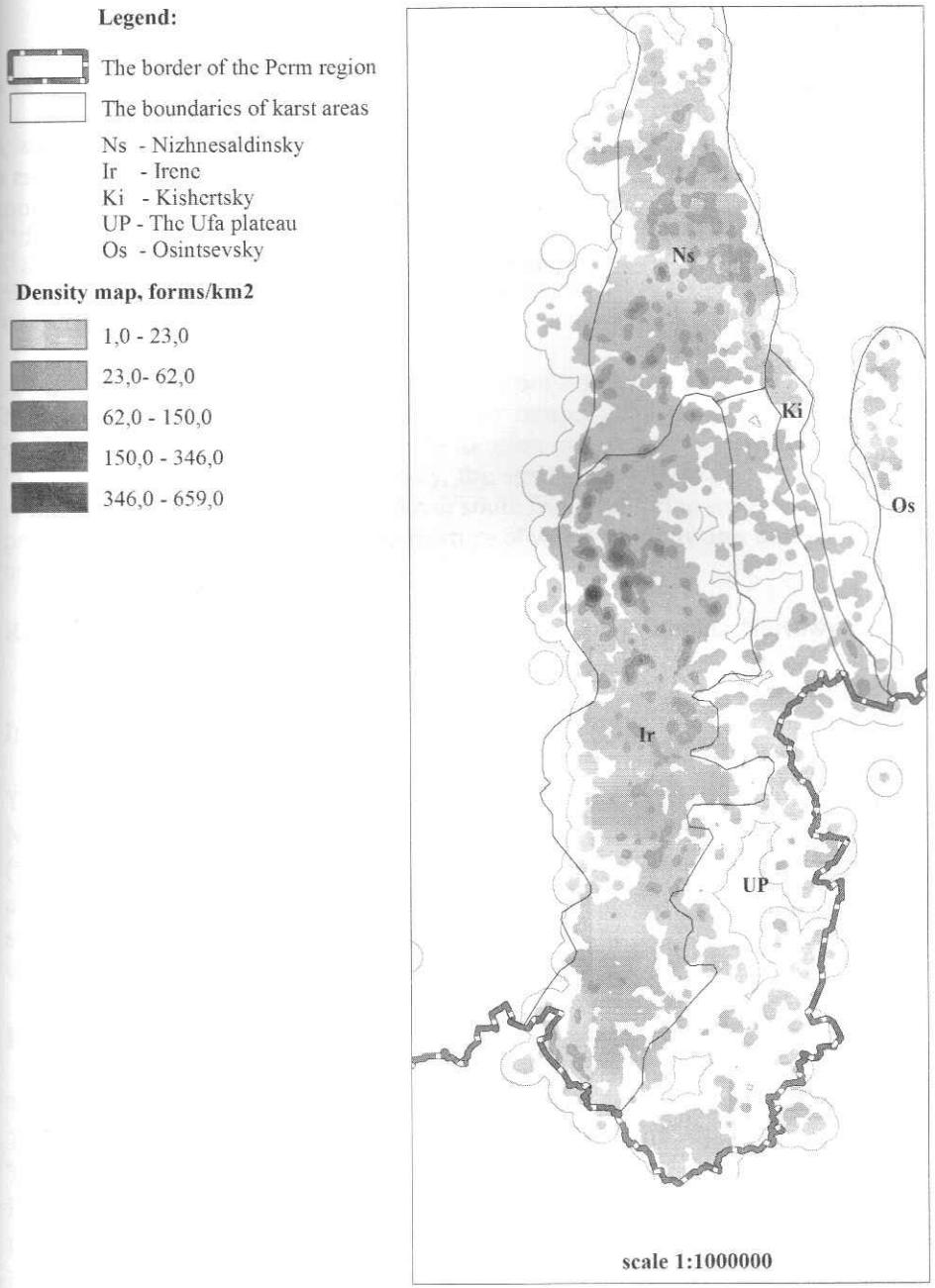

Fig 4. Map of the density of surface karst forms

References

Gorbunova KA., Andreychuk VN., Kostarev VP., Maksimovich NG. *Karst and caves of Perm region.* – Perm. Publishing: Perm State University, 1992, 200 p.

Erofeev EA., Kataev VN. *Identification of surface karst forms on satellite images* // Geology and mineral resources of the Western Urals: collection of articles of the 37-th all-Russian scientific-practical conference with international participation (May 23-24 2017, Perm) / under General edition of R. G. Iblaminow, Perm State University. Perm, 2017. pp. 193-197.