Introduction

Photosurvey for obtaining scientific information is used from the moment of invention of the camera. Scientific photography has found its application in various fields of natural sciences.

In geology photography is used both in field studies to fix objects of interest, and laboratory experiments. Remote photographic sources for geological interpretation are widely used.

The presence of photosensors with different sensitivity characteristics to certain spectral ranges and a wide choice of lenses with different focal length makes the scientific photography in geology a universal means of obtaining different-scale data. Statistical analysis of color information can assist geologists in detecting lithological irregularities or in determining the boundary values of porosity, fracturing and permeability (Axelrod, 2011).

The technology of reconstruction of geometry from photography is called photogrammetry (Wrobel, 1991) and is used in various fields of science and at production site. The methods of integrated processing of photosurvey data using a close-range photogrammetry allowed expanding the range of tasks for the application of technology, to simplify the procedure of obtaining images and the requirements for photosurveying equipment.

Currently close-range photogrammetry along with traditional topo-geodesic tasks has found its use in architecture for photogrammetric scaling of constructions and buildings, archeology for the purpose of fixing excavations and their objects (Starovoytov and Saifutdinova, 2015), geology for obtaining orthoslice of rock outcrop for the subsequent description (Corbí et al., 2017).

Method for conducting the photogrammetry of the core samples

The non-systematic photosurveying of objects for the purpose of three-dimensional reconstruction has no chance of obtaining a qualitative result in photogrammetric processing. It is recommended to use certain techniques and rules, given, for example, in work (Agisoft LLC, 2016) for minimizing the possible adjustment errors, preventing the appearance of «shadowed areas» with no reconstruction by software developers in the field of close-range photogrammetry.

- The photosurveying should take place from different points;
- The overlapping area of adjacent images should be more than 60 percent of the frame;
- It is necessary to use the frame efficiently;
- It is necessary to orientate to the center of the object when photographing;
- Excess of photos is preferable to their insufficient number.

Obviously, when survey a core, it is necessary to use the technique of the central axis (Starovoytov and Chernova, 2015), to fix information around the core. 60% overlapping of pictures, in the case of using this approach (Krasnopevtsev, 2008), provides a photographing cycle with a step of 5-10º. It is approximately 40 frames, taking into account the efficiency of the use of the frame.

A camera with macro lens was used to obtain raster images of the core surface. Experimentally, there were determined the optimal lens settings and the distance between the camera and core samples of various diameters.

Observance of the selected parameters for the equipment made it is possible to effectively use the frame, exclude errors in the mutual orientation of the images and correctly determine the elements of the internal orientation. It also made it possible to achieve high quality output data with spatial resolution of the results of photogrammetric processing from 20 to 40 μm (depending on the scale of the survey).

Reducing the distance between the camera and the core sample undoubtedly raises the spatial resolution but along with this creates certain difficulties in processing photographs in connection with the need to increase the focal length on the lens, which leads to errors in determining the distortion when the scene is aligned.

It should also be taken into account that in order to achieve 60% imposition of images with a significant coming of camera to the core, an increase in the number of images from 40 frames to about 50 per rotation around the axis is required. This leads to a significant increase in the number of images in the scene, which affects both the time of survey and the speed of data processing.

Each scene is formed due to a minimum of 2 photosurvey cycles with a shift along the core sample axis. Requirements for overlapping of pictures of neighboring scenes also make up 60 %. Thus, for the reconstruction of a core with a small length, 80 photographs are required, which is the minimum number of frames in the scene.

In view of the labour intensity of manual photosurvey a robotic core survey system was created. By automating the process of core rotation and photographing, the system allows for cyclic surveying around the core in the visible light spectrum under condition of white light with a configurable number of photographs per rotation around the axis (Figure 1).

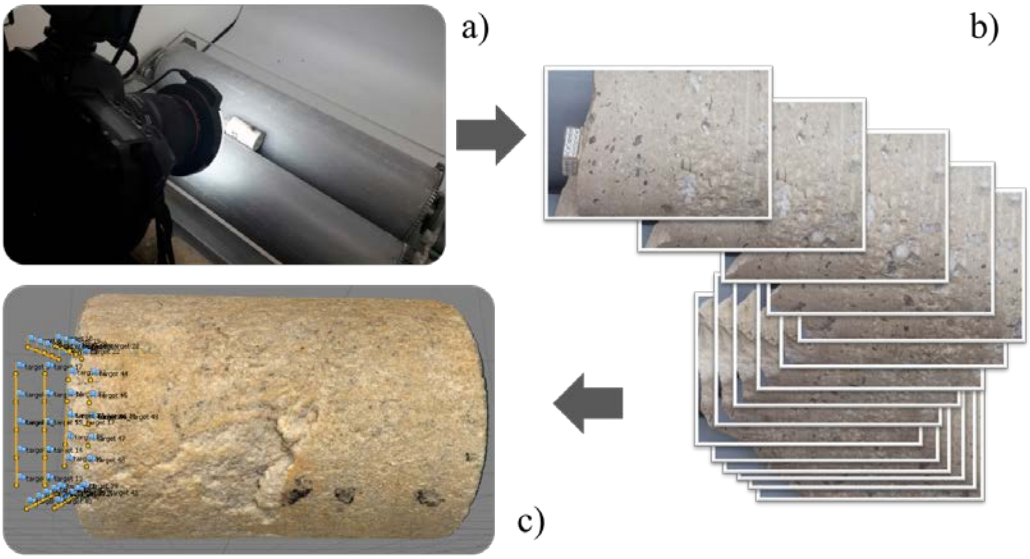

Figure 1 *The algorithm for obtaining three-dimensional data and surface scans of the core from the model: a) Photosurveying of a core sample using an automated complex, b) Pre-processing and colour correction of an image series of core samples, c) Photogrammetric reconstruction of the three-dimensional surface of the core sample*

For the processing of photogrammetry data, the software complex Agisoft Photoscan (Agisoft LLC, 2016) was used. Its functionality was supplemented with own tools to speed up the procedure for scaling and aligning the processed 3D data.

To scale the model, there was used specialized elements of external orientation, markers, applied on the core surface. With the help of the author's program modules, scale bars were created and the scene was aligned according to the geometry of the location of the survey points. It should be noted that if there is information about the position of the survey frame relative to the axis of rotation of the core, the need for using external orientation elements is lost.

The initial result of photogrammetric processing of the core is a polygonal solid-state model of the sample with the texture. A projection onto a cylinder of diameter equal to the nominal core diameter was carried out to obtain two-dimensional scan. Along with the texture, distances to the "ideal cylinder" were recorded. This made it possible to obtain a displacement map, which can be used for further computer analysis (Figure 2).

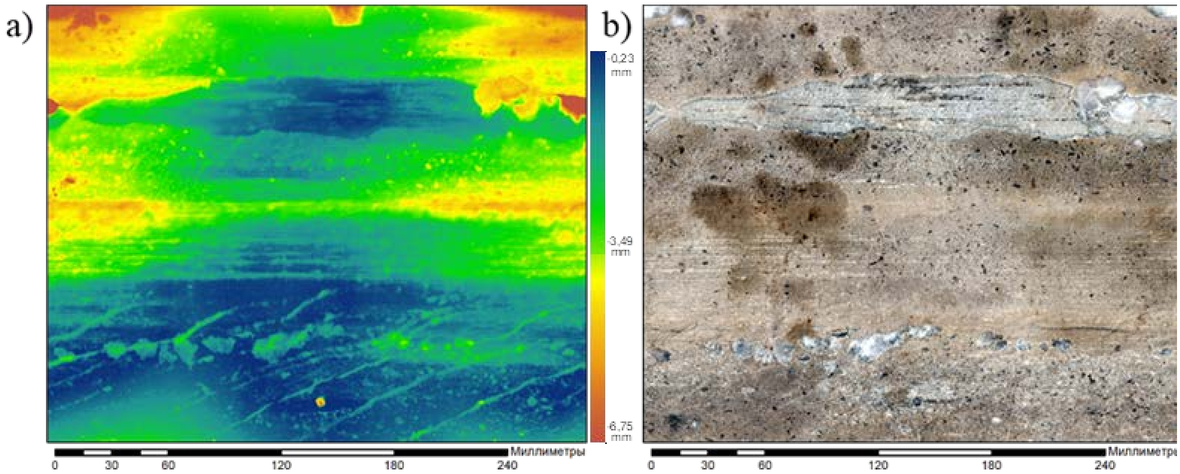

***Figure 2** The displacement map (a) and the surface texture (b) of the core with a spatial resolution of 20 μm*

The texture map is saved with a specified number of lines in JPEG format with 8-bit RGB channels and minimum compression values. The displacement map has the same number of rows and columns, but the output raster is single-channel with 32 bit signed depth. Using the author's software modules for ArcMap, the images obtained were scaled and acquired spatial resolution, the presence of which allows for various measurements.

Conclusions

The possibility of obtaining information on the surface relief of the core makes it possible to carry out further studies that allow to determine the various filtration-volumetric characteristics of the rock. Unlike methods using a goniometer, the photosurveying of the core with subsequent photogrammetric processing provides output data describing the relief of the entire surface of the sample.

Thus, it becomes possible to use existing methods of image analysis and machine vision to identify various characteristics of the rock: optical porosity and permeability, the type of the fracturing. There is also possible to determine the change in one of these parameters along the samples using this technology. This allows to compare the processing results with the log data, X-Ray computed tomography, nuclear magnetic resonance data.

In addition, the presence the texture of the core as the output data of this technology makes it possible to apply classical methods of core analysis used in lithology. In particular, there was carry out the stratigraphic description of the core using computer technologies for decoding images.

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