AUTOMATED DRILL CORE SCANNING

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Abstract – A software-hardware complex for scans of core samples, extracted from drill holes in the course of drilling, is described. A scan contains visual information about the lateral surface of a sample, decreases the risks of losing, mixing and decomposing of samples and is a convenient form of their storing, copying and mailing. The structure and design characteristics of the complex, algorithms of complex control, scanning, 3D-models, the evaluation of mineral composition of core rocks, the compression and storing of scans are described. The scan storage base copies a traditional core storage system and adds it information about the time of scanning and the evaluation of mineral composition of the core rocks. The results of the tests of the work of complex are shown using a core sample from the Kostomuksha iron deposit.

Keywords: core samples, 3D-model, scan, software-hardware complex.

I. INTRODUCTION

Software-hardware complexes are widely used for studying enviroment [1-3]. In the present paper a software-hardware complex for drill core scanning is described.

Sample of core represents retain strength monolithic cylindrical column extracted from the well during its drilling. As a carrier and source of information on the earth's geological structure, a core contains information on the composition, structure, relative position and fracturing of rocks and the presence of hydrocarbons in them. These data are used to determine the genesis of rocks and to reconstruct the conditions of depositional. Core samples provide the basis for estimating the reserves and lithological studies. The substance of core samples is studied by visual description, optical and electron microscopy, microanalysis and X-ray diffraction [4]. Pores, caverns, fragments, fractures, grains, particles, micropores, microfractures, crystal and phase boundaries, crystalline structure and point defects are studied. The goal of such core sample investigation is to identify lithologically, and the lithogenetic types of its rocks constituents.

Primary treatment of a core is the most essential stage in its analysis. At this stage the core is cleaned, reconstructed and labelled; fractures are described; gamma-spectrometry and density logging are conducted, a gas permeability profile is determined; the core is sawn, scanned in day and UV-light and described and samples are selected. The porosity, gas permeability, specific electrical resistance, water-oil saturation, carbonate content and other characteristics of the core are assessed, based on the results of primary treatment. The fracturing of the rock column is analyzed by visual observation, the characteristics of individual fractures, such as sizes, orientation, sinuousness and openness, are assessed and the degree and type of mineralization are determined. These indices are used to construct their distribution pattern split up into groups of fractures and conclusions regarding the distribution pattern and genesis of fracturing are drawn. Traces of oil and carbohydrates and plant and animal residues in a core sample are searched for using the ability of such inclusions to luminesce at UV illumination. Traces of oil are revealed at concentration of at least 0.005%. Luminescent analysis of core samples allows to estimate the percentage of oil saturation in complex collectors, to correlate oil strata, to visualize the geometry of textures and fractures, which is indistinct in daylight, and irregular carbonatization, to delineate poorly saturated units and to stratigraphically subdivide sedimentary rock units devoid of plant and animal residues [5].

Drilling is expensive. Core samples are stored for their study by modern and future generations of geologists. Core samples, which to be stored for a long time, are labelled and placed in special boxes. Some of the cores are sawn along the axis. One part is used to study the substance of core sample. The rest of the core samples are described and analyzed.

As samples of core occupy a lot of room and lose their physical condition and informative value with time, they are made smaller after some time. To diminish losses, core samples, stored in this way, are photographed. The photographs of the cores show the structure of rock columns, texture, contacts, mutual transitions, lithological varieties and plant and animal residues. It is a convincing method of lithologo-facies analysis and reconstruction of a depositional environment. If the core surface contains traces of deformations caused by extraction which obscure texture of rocks, then the core is photographed after sawing. The photograph of the polished sawing surface displays the fine features of the rocks, e.g. the boundaries of interbedded fine and medium-grained sandstone. To separate luminescing sites, the core sample is photographed from all sides at UV illumination. The core samples are commonly photographed in boxes to show its original position, so that if it is displaced in case of damage to the box, the original position can be easily restored by the photo [5].

A scan is flat photographic image of the lateral surface of a sample. Like the photos, it retains information, increases the quality and speed of analysis and reduces the risk of the loss, mixing and chemical decomposition of the sample. However, in contrast to photographs that show the sample fragmentarily, it provides a complete undistorted image of its lateral surface, and a 3D model, constructed from it, shows the sample as it commonly looks. Being a digital model of the sample, a scan can be doubled and requires no storage and mailing expenditures. For the scanning, the sample is rotated to the desired angle, and its surface facing the camera is photographed. This procedure continues until the complete revolution of the sample [6]. The camera is then moved along the sample, and the procedure is repeated until the camera reaches the final position. The scan is formed by combining the photographs in the desired order. High-quality images are obtained when both the sample and the camera are immobile. The time taken to obtain a scan of a core sample is about 30 minutes and depends on the duration of transition processes.

The goal of the study was to develop a device for rapid core samples scanning. The goal is achieved by rejecting the rotation of a sample and by parallel scanning using several video cameras. Versions of a software-hardware complex, forming a sample scan by conventional and accelerated methods, are proposed. The structure and shematic technical solutions, responsible for the operation of the complex, and data processing algorithms are described. The results of

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the operation of the complex are demonstrated on core samples from the Kostomuksha iron deposit [7].

II. STRUCTURE AND FUNCTIONS OF THE COMPLEX

The complex consists of an executive unit, control and image processing units and a scans data storage base (Fig.1). The executive unit was designed by selecting immobile and mobile parts: a rotating sample and a video camera moving in stepwise manner (a conventional version) and an immobile sample and moving video cameras (a rapid version of the device). The models of the devices are shown in Figure 2. Guides with frictional linings support and rotate the sample (a). One guide is immobile; the other is rotated by cog wheels and belt transmission by a reducer controlled by a step motor. The video camera, controlled by another step motor, moves discontinuously along the guides above the sample and takes pictures of the sites beneath.

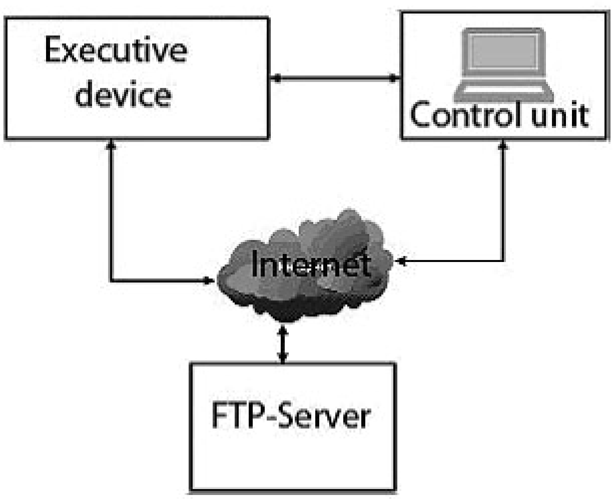
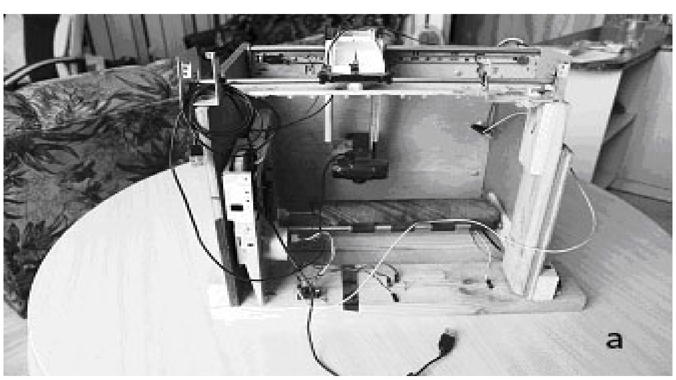


Fig.1. Structural scheme of a complex for scanning the lateral core surface.

A core sample is rigidly fixed in the model (b). A ring, coaxial with the sample, with four cameras mounted on its sides to scan the lateral surface of the sample, is a mobile element. The executive unit is controlled by a mini-computer which operates in accordance with a programme or is remotely controlled by the user in accordance with SSH protocol. In the model (a), the camera moves along the sample, scans it and, on reaching the end, returns to the original position. The sample rotates to the preset angle, and the process is repeated the sample is fully rotated. In the case of an immobile sample (b), the cameras scan simultaneously various sites on the lateral surface of the sample; the controller only maintains the movement of the ring. Upon completion of the operation, images are sent either to a FTP – server or to a computer, where they are “glued together” and processed.



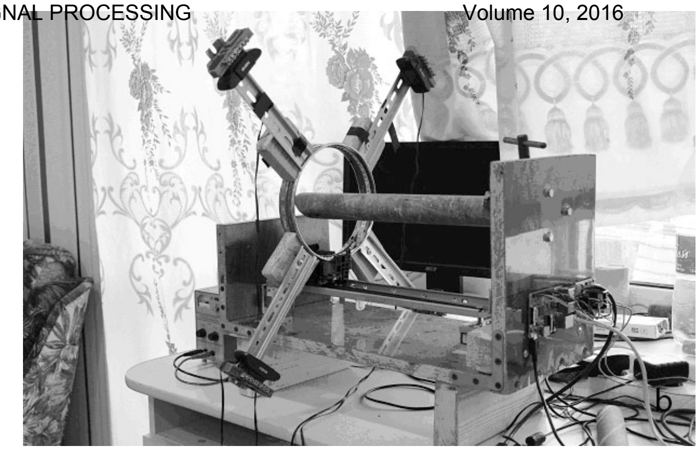


Fig.2 Models for scanning a core with a rotating “(a)” and immobile sample “(b)”.

In the course of processing the pictures taken by the video cameras were corrected, noise was removed, the pictures were compressed, a scan was formed, 3D model, showing the core sample in conventional form, was created, the mineral composition of the sample was evaluated and the scans were either stored in the computer database or were sent at the preset addresses. The images were corrected to remove distortions caused by photography of cylindrical samples and differences in illumination. A scan of the lateral surface of the core samples was obtained by glueing together the pictures of sites in the definite order. A 3D-model of the lateral surface of the sample was formed by transferring the scan onto the virtual cylindrical surface. The mineral composition of the samples was evaluated from the areas occupied by minerals on the sample scan. To store scans of core sample , we used a relational database, which copies a conventional core samples storage system and has sections corresponding to site numbers, drill hole numbers and the depths of occurrence of the samples.

III. DESIGN CHARACTERISTICS OF THE COMPLEX

The design characteristics and technical parameters of the complex were revealed by testing the models. The advantage of the device with a rotating sample is the constancy of illumination and other conditions that simplify the obtaining and processing of images. Power and time are required for the rotation of massive samples, the use of two step motors and the duration of transition processes. The power consumed by the model is 27 Wt, and the time taken to scan a 0.5 m long sample is about 20 min.

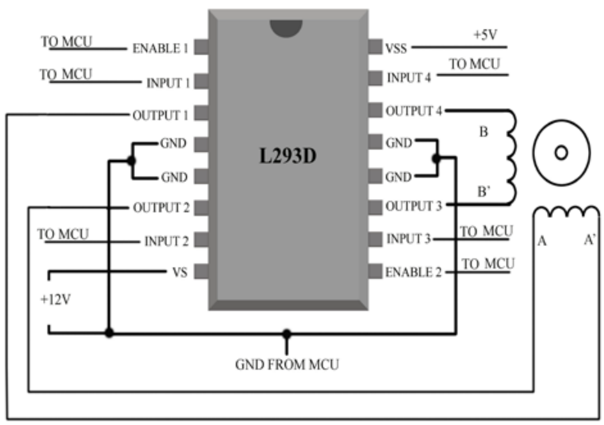
An executive device with an immobile sample and a ring with cameras is the simplest and most economical. Ring movement is controlled by one step motor. As the sample is immobile and its lateral surface sites are scanned simultaneously by the cameras, power and time consumption is considerably reduced. The consumed power of the device is 16 Wt, and the time taken for scanning a sample with a length of about 1 m is about one minute. The disadvantage of the method is manual changing of samples.

A Raspberry PI minicontroller, model B+, manufactured by Raspberry PI Foundation Company with 4 USB 2.0 connectors, an Ethernet connector, 512Mb OZU and 40 user GPIO outputs was used as a control unit controller [8]. The minicomputer was supplied with voltage from the USB – port of the computer or from the supply unit with a rating of 5B. Maximum allowable consumption current was 2.5A. The computer is connected via the GPIO ports with the drivers that control «42BYGHW208» step motor by L293D microcircuit [9]

(Fig.3). The small size of Raspberry PI controller, comparable with that of a bank card, has made it possible to make the control unit smaller than its analogues [6].

Fig.3. Connecting L293D microcircuit with the step motor coils

The units of the complex are connected via Ethernet and have access to the Internet.



IV. ALGORITHMS RESPONSIBLE FOR THE OPERATION OF THE COMPLEX.

A. MOTOR AND VIDEO CAMERA CONTROL

Step motors are used in both versions of the executive unit. In the conventional version, the executive unit has two step motors: one motor rotates the core sample, and the other moves the video camera. In the rapid scanning version, there is one engine which moves the ring with cameras. Step rotation is transformed into step translocation by belt transmission. The bipolar step motor «42BYGHW208», which have two coils designed for current consumption of up to 0.4 A, were used. Signals are supplied to the coil-connected inputs of L293D microcircuit which controls the operation of the motor (Table 1). The cycle of the engine consists of 4 steps. Signals supplied upwards in accordance with the table lines correspond to the forward rotation of the motor shaft, and signals supplied downwards correspond to the reverse rotation of the motor shaft [9]. The operation of the motor is controlled by a script written in Python language; it calls the console utility «fswebcam» of the command line bash of Linux operation system, which photograph the core sample site in front of the video camera [10].

Signals at the inputs of L293D microcircuit. **Table 1.**

Coil 1		Coil	
A	A'	B	B'
+ «1»	«0»	Not connected	
Not connected		+ «1»	«0»
«0»	+ «1»	Not connected	
Not connected		«0»	+ «1»

For the executive rapid scanning device the algorithm of the scanning of the lateral surface of the core sample consists of several steps:

1. The initial and final position of the ring with video cameras and the number p of the translocations of ring by the step motor are preset so that the next picture taken by the camera begins at the end of the preceding picture;
2. The ring is set to the initial position and the first images are obtained;
3. If the ring has not reached the final position, then:
a) the ring is translocated along the guide by p steps;
b) the images of core sites are obtained and stored;
4. Once the ring has reached the final position, the last images are registered and all the images obtained are glued together to form a scan of core sample.

B. CONSTRUCTING A 3D-MODEL OF A CORE SAMPLE

The algorithm uses transition from core sample scan with length -l and width- d to a cylindrical 3D-model which has length l and radius ρ. The element, described in the rectangular coordinate system of a scan with the coordinates x, y in the cylindrical coordinate system, has the coordinates ρ, φ, y [11]. Coordinate y, responsible for the position of the element along the scan length, remains unchanged and presets the coordinate of the element along the cylinder axis. The radius of cylinder ρ is preset by the scan width $\rho = d/2\pi$ and angle φ by the ratio $\varphi = 2\pi x/d$.

The algorithm includes several stages:
1. ρ, φ and y values are calculated for each scan pixel;
2. Scan pixels are represented graphically in cylindrical coordinates.

C. SCAN PIXEL SEGMENTATION.

Core pixel scan segmentation in coloured coordinate space was performed by data clustering using the K-mean method and MATLAB algorithm [12] with additional calculation of the percentages of pixels in the clusters:

1. The number of clusters is preset, and their centres are selected arbitrarily in the space of R-, G-, and B-coordinates. The number of clusters can be calculated using a mining clustering algorithm [12];

2. Distances to the centres of the clusters are calculated for each scan pixel, and the pixel is related to the cluster for which this distance is the shortest;

3. New centres of the clusters as the mean arithmetic values of the coordinates of the elements which constitute the clusters are sought for;

4. The previous and obtained coordinates of the centres of the clusters are compared;

5. If the new and previous centres of the clusters differ, then transition to step 2 takes place; if they do not differ, then the percentage of pixels in the clusters is calculated and the mineral composition of rocks is evaluated.

Assuming that the clusters in the coloured space correspond to minerals, the volumetric mineral content of the rock represented by the core sample is estimated by calculating the percentage of pixels in a cluster.

D. COMPRESSING SCANS

If a large number of core scans is stored, they should be compressed. The scans of core samples are compressed by Haar batch wavelets using Shannon entropy in MATLAB computer mathematics system [13].

E. DATABASE

MySQL relational database, created by Oracle Company, was used as a basis for storing scans of core samples [14].

V RESULTS

Core samples from the Kostomuksha iron deposit, the biggest deposit in the Fennoscandian Shield, were used for testing the functions of the complex. Core samples of rhyodacite and gneiss with quartz veinlets and ferruginous quartzites, their scans and 3D-models of the scans are shown in Figure 4. The scans and their 3D-models are of acceptable quality and display all the visual features of the lateral surface of the core samples. The scan of the sample of ferruginous quartzites, obtained using the traditional version of the executive unit, retains traces of being formed of many images.

To determine the mineral composition of the rock, rapakivi granite was used as an example (Fig.5). The original image of rapakivi granite (a), its decomposition into clusters (b) and images of the clusters correlated with quartz (c), potassic feldspar (d) and oligoclase (e) are shown. It is clear from the Figure that oligoclase, which crystallizes after potassic feldspar and quartz, occupies intermediate regions between their grains. The percentages of quartz, potassic feldspar and oligoclase in rapakivi grante were 26, 46 and 28 %, respectively.

Figure 6 shows a scan of sample of ferruginous quartzites (a) and its compressed image (b). The compressed image, obtained using Haar batch wavelet in MATLAB system, retains the details of the original scan, contains 95% of the power of original image, but the memory space it occupies is three times smaller.

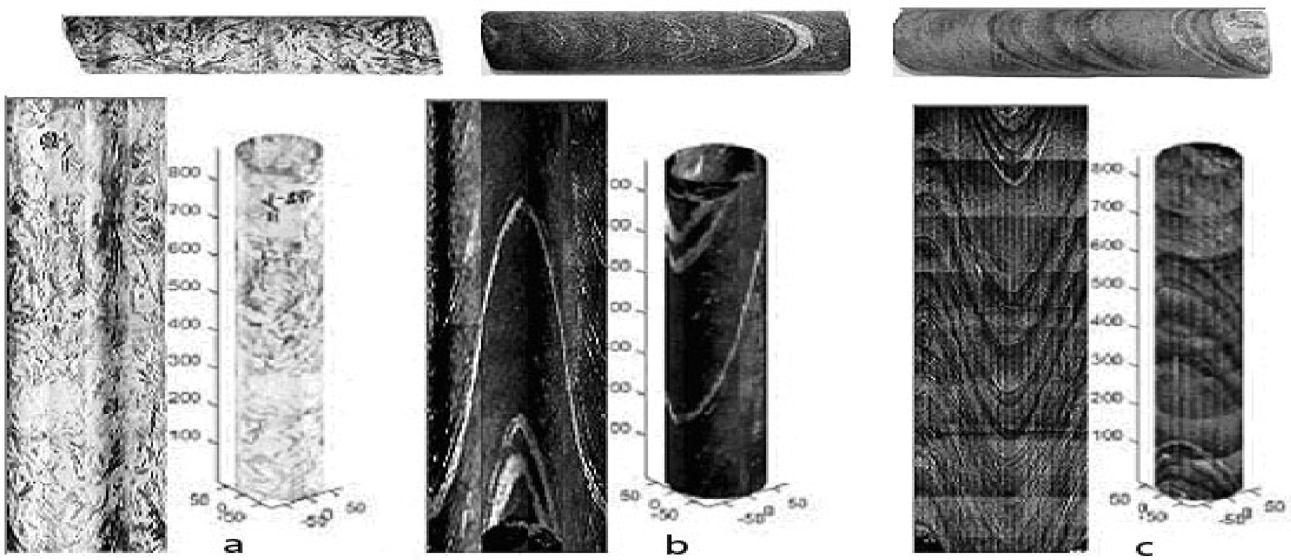


Fig.4. Core samples of rhyodacite (a), gneiss with quartz veinlets (b), iron formation (c), its scans and 3D-models of scans

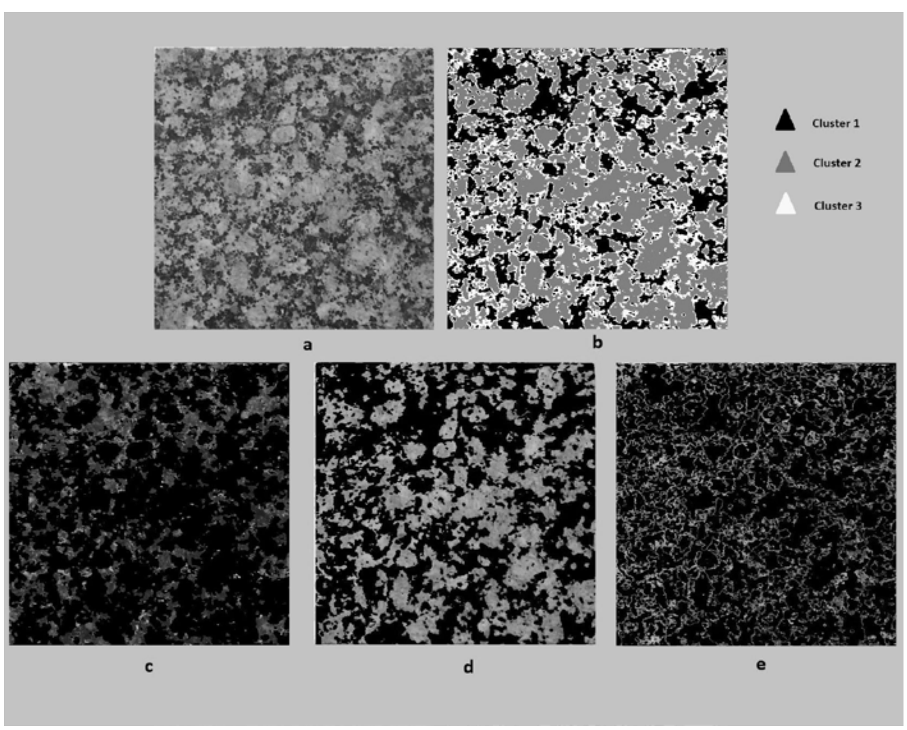
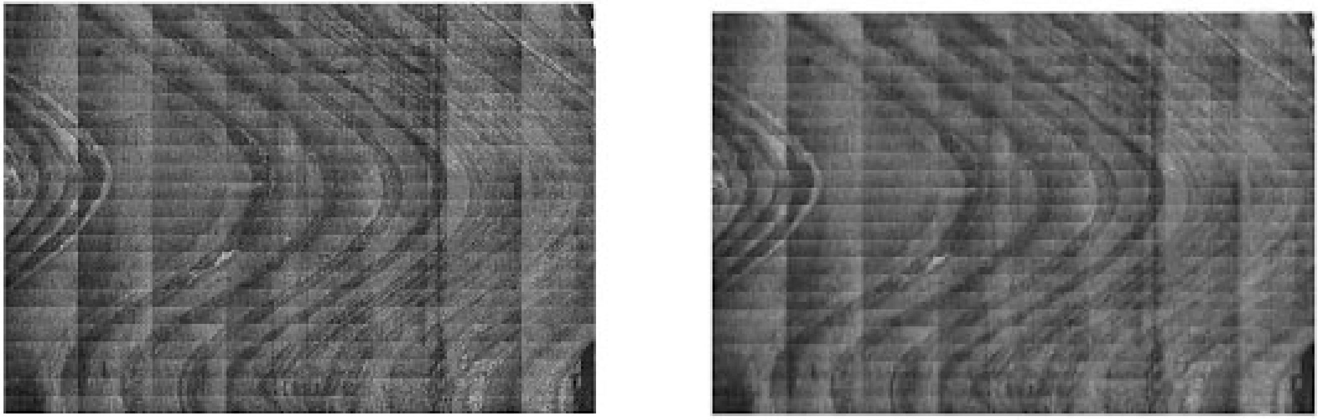


Fig. 5 Rapakivi granite image “(a)” and result of its decomposition on three clusters (b) and clusters of

quartz “(c)”, K-feldspar “(d)” and oligoclase “(d)” which make up 26, 46, and 28 %, respectively



a b

Fig. 6. Scanned image of an iron formation core sample (a) and the result of its compression (b) by a HAAR batch wavelet at level 2, Shannon entropy and a global threshold in GUI Wavelet Toolbox MATLAB package. The compression coefficient is 3.

VI CONCLUSIONS

The complex designed automates scanning of core samples at acceptable speed and provides a high-resolution of scans. The scan retains visual information on the lateral surface of the core sample and removes disadvantages connected with the storing and mailing of samples. A 3D-model of the scan was constructed to describe and analyze the scan in conventional form. The characteristics of the complex designed are high-speed scanning of core samples, low power consumption, a small size and weight and efficient control and data processing algorithms. Estimating the mineral composition of rocks from a core scan accelerates the description and analysis of the core samples and provides detailed information on drilling results.

To use the complex to UV radiation of core samples, no changes in the mechanical and algorithmical constituents of the complex are needed.

For geologists working with core samples visual information is essential but incomplete. To reliably identify the rocks or the minerals, they often have to reveal other characteristics of materials, e.g. hardness, magnetization and porosity. Therefore, for the time being the contact study and destruction of core samples cannot be rejected.

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