CSCanada
Advances in Petroleum Exploration and Development
Vol. 20, No.1, 2020, pp. 47-53
DOI:10.3968/12102

ISSN 1925-542X [Print]
ISSN 1925-5438 [Online]
www.cscanada.net
www.cscanada.org

Research on One Novel Logging Interpretation Method of CBM Reservoir

FENG Qing[a],*; LI Shengsheng[a]; SUN Yanni[a]; ZENG Ming[a]; LI Xiaonan[a]; WANG Xuxing[a]

[a] Oilfield production optimization institution •China Oilfield Services Limited, Tanggu, China.
*Corresponding author.

Supported by the Natural Science Foundation of China (Grant No. U2762212).

Received 30 November 2020; accepted 19 December 2020
Published online 26 December 2020

Abstract

Coalbed methane (CBM) is a kind of natural gas which is stored in the micropores and fractures of the "coal seam" and has not been transported out of the source rock. Conventional logging technology plays an important role in coalbed methane exploration and development. By analyzing the response characteristics of conventional logging of coalbed methane, coal bearing strata are accurately determined. Two methods of statistical model and volume model are established to analyze and calculate industrial components. Based on the study of adsorption isotherm and correlation between logging parameters and coal core gas content, the calculation method of coal seam gas content is determined In practices, the calculation accuracy of industrial components and gas content of coal seam has been significantly improved. Abstract: coalbed methane (CBM) is a kind of natural gas which is stored in the micropores and fractures of "coal seam" and has not been transported out of the source rock. Conventional logging technology plays an important role in coalbed methane exploration and development. By analyzing the response characteristics of conventional logging of coalbed methane, coal bearing strata are accurately determined. Two methods of statistical model and volume model are established to analyze and calculate industrial components. Based on the study of adsorption isotherm and correlation between logging parameters and coal core gas content, the calculation method of coal seam gas content is determined In practice, the calculation accuracy of industrial components and gas content of coal seam has been significantly improved.

Key words: CBM conventional logging interpretation method; Industrial component gas content

Feng, Q., Li, S. S., Sun, Y, N., Zeng, M., Li, X. N., & Wang, X. X. (2020). Research on One Novel Logging Interpretation Method of CBM Reservoir. *Advances in Petroleum Exploration and Development*, *20*(1), 47-53. Available from: http://www.cscanada.net/index.php/aped/article/view/12102
DOI: http://dx.doi.org/10.3968/12102

INTRODUCTION

With the increasing demand for new energy, people pay more and more attention to the development of coalbed methane resources. Coalbed methane is mainly hydrocarbon gas generated by humic organic matter in coal bearing strata during coalification. Its composition is methane, which is one of the important components of natural gas. Coalbed methane is a kind of natural gas, which is stored in the micropores and fractures of "coal seam" and basically does not migrate the source rock. It is a typical spontaneous and self-storage unconventional gas reservoir. In the exploration and development of coalbed methane, logging data is accurate, continuous and reliable, which plays an important role

 Copyright © Canadian Research & Development Center of Sciences and Cultures

in CBM reservoir evaluation. However, up to now, there is no logging detection method specially designed for coalbed methane reservoir. At the same time, due to the complex composition of coal rock, the content of each component changes greatly, and the dual pore system of matrix pore fracture, the coal seam has strong heterogeneity, which brings greater multi solution and uncertainty to logging interpretation. Therefore, using conventional logging data to evaluate coalbed methane and obtain accurate coal seam industrial evaluation information is an important direction of coalbed methane logging research. In the process of the company's intervention in coalbed methane operation, the comprehensive evaluation technology of coal seam physical properties, industrial components (fixed carbon, ash, volatile matter, moisture) and mechanical characteristics of rock was studied by conventional logging data, which achieved good results in practical application.

1. LOGGING RESPONSE CHARACTERISTICS

Coal reservoir is a kind of special sedimentary rock, which is composed of inorganic matter and organic matter. Inorganic matter includes mineral impurities (clay minerals, quartz, feldspar, etc.) and water; organic matter is a complex high polymer organic compound, mainly composed of C, H, O, S, P and other elements. The coal reservoir has a dual porosity medium structure, including matrix pores and fracture pores, and has a unique cleat system. Therefore, the coal particle size is fine and the surface area is large, and the coal seam is above $0.929 \times 10^8 m^3$ per ton, which endows the coal seam with strong adsorption capacity, so the methane gas content and hydrogen index of coal reservoir are very high.

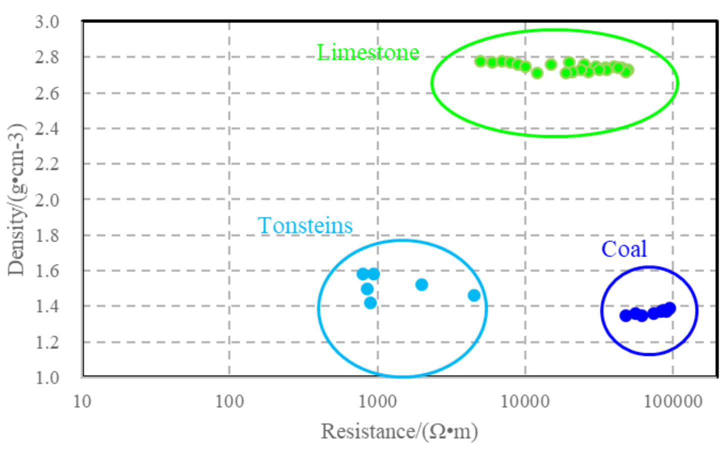
1.1 Logging Response Analysis of Coal Reservoir

Based on the above characteristics of coal seam, the characteristics reflected in the logging curve are "three high and three low", that is, the three logging values of resistivity, acoustic time difference and compensated neutron are high, while those of natural gamma, bulk density and photoelectric effective cross section are low.

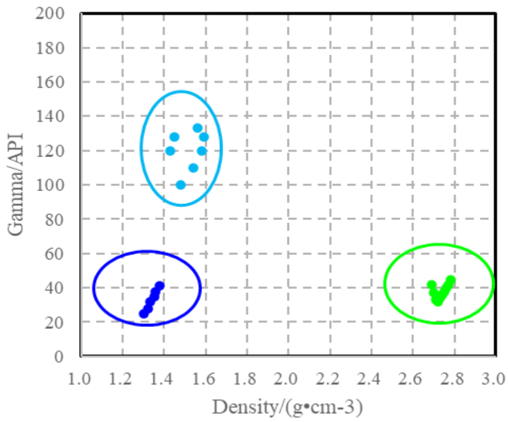
There are many factors affecting the resistivity of coal, mainly affected by coal metamorphic grade, mineral composition, water content and other factors. The electrical response of different types of coal also has great changes.

The natural gamma curve can reflect the existence of radioactive minerals in the formation, but in the pure coal seam, the content of radioactive minerals is low, and the coal seam shows low radioactivity. When the coal gangue usually contains more radioactive minerals, the natural gamma curve is more obvious to identify the coal seam gangue. The coal seam and the surrounding solution (formation water, well fluid, etc.) will have oxidation-reduction effect. When the coal is in the oxidation state, the coal has positive charge on the contact surface of the coal and surrounding rock, and the surrounding rock has negative charge, forming a positive abnormal spontaneous potential. When the coal is in the reduction state, the coal has negative charge on the contact surface between the coal and surrounding rock, and the surrounding rock has positive charge, forming a negative abnormal spontaneous potential. Therefore, the spontaneous potential (SP) in the coal seam can not reflect the permeability obviously, but more reflects the oxidation and reduction environment. Generally, when the spontaneous potential is negative, it indicates that the coal seam is in a strong reduction state.

By summarizing the logging response characteristics of coalbed methane, the coal bearing strata can be clearly distinguished by using various crossplots, as shown in Figure 1.



(a) Resistance and density cross plot



(b) Resistance and density cross plot

Figure 1
Crossplot of typical coal seams

1.2 Distinguishing Coal Rank

Coal rank refers to the extent to which the physical and chemical characteristics of coal composition and structure change in the process of Coalification. Vitrinite reflectance (RO) obtained from experimental analysis is the most commonly used method to divide coal rank. According to the coal rank classification standard formulated by the coal system, the vitrinite reflectance corresponding to each coal rank is: Lignite less than 0.5%; long flame coal 0.5% - 0.65%; gas coal 0.65% - 0.90%. Due to the different physical and chemical properties of coal seams with different coal ranks, there must be differences in conventional logging. The cross plot of porosity logging can better identify coal rank, as shown in Figure 2. The density acoustic crossplot can clearly distinguish different coal ranks.

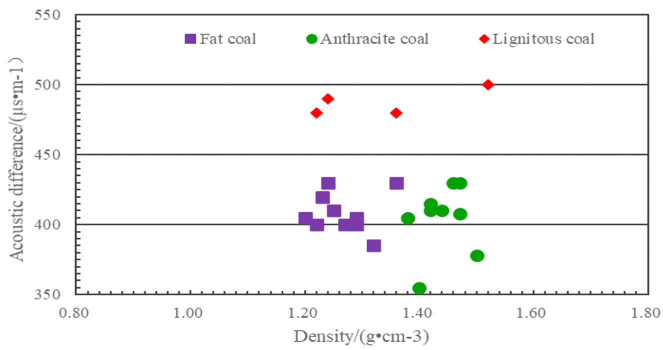


Figure 2
Cross plot of density and acoustic qualitative discrimination of coal seam for different coal ranks

2. LOGGING EVALUATION OF INDUSTRIAL CBM COMPONENTS

The industrial components of coal are composed of moisture, ash, volatile and fixed carbon. The moisture of coal refers to the moisture adsorbed or condensed in the capillary between coal particles under air drying condition. The larger the internal surface area of coal is, the higher the moisture content is. The ash content refers to the residue left by all combustibles in coal. Therefore, the higher the ash content, the lower the thermal efficiency of coal combustion. Coal insulated from air heating under high temperature conditions, the percentage of coal mass reduce after cooling minus the moisture content of the coal sample, which is the volatile matter. Fixed carbon is the percentage of coal minus moisture, ash and volatile matter. The industrial analysis index of coal is an important factor affecting coal quality, coal rank, calorific value and coal seam gas content.

There are two kinds of calculation and analysis of industrial components in this study, namely, coal core calibration statistical method and volume model method.

2.1 Cross Plot of Industrial Components

The basic idea of statistical model method is to take all kinds of geological parameters and logging physical quantities of coal as random variables, and use coal core calibration to establish the relationship between block logging response

 Copyright © Canadian Research & Development Center of Sciences and Cultures

and industrial components.

Ash content is one of the most important indexes in coal quality analysis, which varies with different areas and coal seams. Even in the same coal seam in the same area, ash content still has horizontal and vertical changes. Through statistics, it is found that the ash content of coal core analysis has good correlation with logging density or natural gamma logging value, as shown in Figure 3. Fixed carbon, moisture, ash and volatile matter had a good relationship with each other. With the increase of ash, fixed carbon decreased sharply (Figure 4).

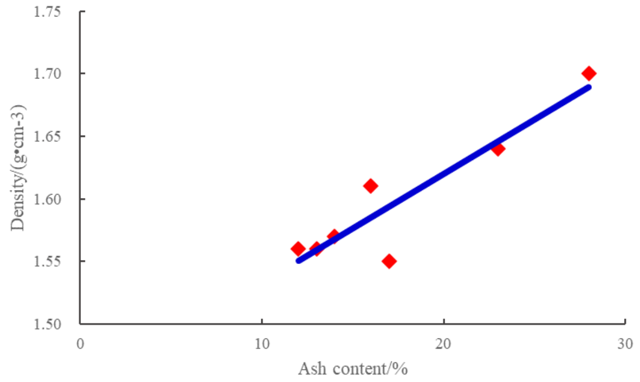


Figure 3
Cross plot of ash content and density of coal core in a certain area

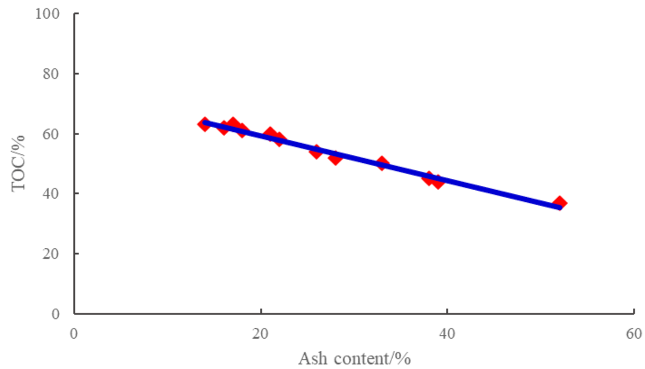


Figure 4
Cross plot of ash and organic carbon of coal core in a certain area

2.2 Logging Curve Model

The composition of coal seam is relatively complex. Many literatures regard coal seam as composed of carbon, ash and water. Carbon includes fixed carbon and volatile matter, ash includes argillaceous and mineral impurities, and moisture includes all free water and bound water. Through the establishment of volume model, as shown in Eq.(1), the equation is solved by logging curve, and the industrial component value is obtained.

$$\begin{aligned} DEN &= a_{11}Mad + a_{12}Aad + a_{13}Vm + a_{13}F_c + b_1 \\ GR &= a_{21}Mad + a_{22}Aad + a_{23}Vm + a_{24}F_c + b_2 \\ CNL &= a_{31}Mad + a_{32}Aad + a_{33}Vm + a_{34}F_c + b_3 \\ AC &= a_{41}Mad + a_{42}Aad + a_{43}Vm + a_{44}F_c + b_4 \end{aligned} \quad (1)$$

3. LOGGING EVALUATION OF CBM CONTENT

Coal seam gas content refers to the volume of methane gas contained in coal per unit mass under standard temperature and pressure conditions, which is usually expressed in terms of gas content per ton of coal (m3 / t). Strictly speaking, coal seam gas content includes three parts: adsorbed gas, free gas and dissolved gas. Most of them are adsorption gas, accounting for more than 85% - 90%. Therefore, free gas and dissolved gas are usually ignored when predicting coal seam gas content.

The distribution of coal seam gas content is mainly controlled by gas generation conditions and gas storage

Copyright © Canadian Research & Development Center of Sciences and Cultures

conditions, including geological structure, lithology of coal seam roof and floor, coal metamorphism degree (coal rank), coal quality, buried depth and thickness of coal seam, temperature, pressure and hydrogeological conditions. The current coal seam gas content is the result of the above factors, and the dominant factors in different regions may be different.

There are many methods to calculate coal seam gas content based on logging data. Empirical formula based on adsorption isotherm and correlation between logging parameters and measured gas content is used in practical research.

3.1 Kim Equation

Kim et al. put forward a method to calculate the gas content of coal seam through industrial component analysis and isothermal adsorption theory, which is called Kim equation, which assumes that the pressure and temperature of coal seam are linear functions of buried depth. In practical application, the related parameters in the equation can be replaced according to the empirical relationship of reservoir pressure and temperature changes with depth in the study area. Its form is shown in Eq. (2):

$$gc = (1 - w - a)\frac{V_w}{V_d}(k_0 \cdot p^{n_0} - b \cdot T) \qquad (2)$$

In Eq.(2), gc - coal seam adsorbed gas volume, cm^3 / g; w- moisture content, decimal; a - ash content, decimal; V_w - moisture content, cm3 / g; V_d - ash content, cm3 / g; V_w/V_d - equilibrium correction amount, about 0.75; B - constant, about 0.14 cm3 / g; ko, no - correction coefficient; P- coal seam pressure, ATM; t - temperature, ℃.

Nomenclature:
gc - coal seam adsorbed gas volume, cm^3 / g;
w- moisture content, decimal;
a - ash content, decimal;
V_w - moisture content, cm3 / g;
V_d - ash content, cm3 / g;
V_w/V_d - equilibrium correction amount, about 0.75;
B - constant, about 0.14 cm3 / g;
K_0, n_0 - correction coefficient;
P- coal seam pressure, ATM;
t - temperature, ℃.

3.2 Probability Statistics

The statistical model between the measured gas content of coal seam and the logging parameters such as coal seam buried depth, density, natural gamma ray, acoustic time difference, ash content, temperature and pressure, and coal quality component parameters is established by statistical analysis method, so as to realize the prediction and evaluation of coal seam gas content. Statistics show that ash content and gas content have a good correlation, showing a significant negative correlation (Figure 5).

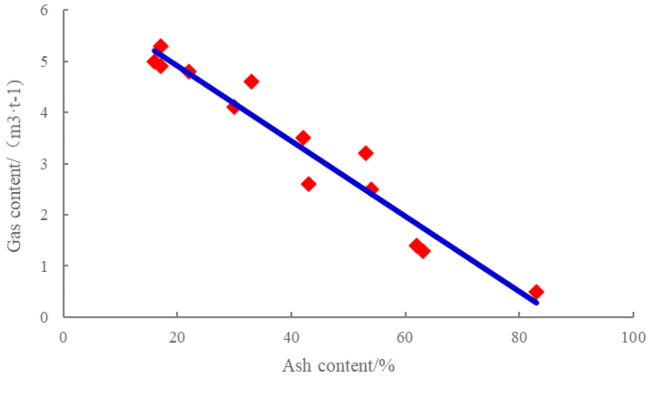


Figure 5
Relationship between gas content analysis of coal core and ash content in a certain area of Qinshui Basin

When this method is used to calculate gas content, the relationship between ash content and gas content changes rapidly as the ash content of coal seam is more than 80%. Different response equations should be established to calculate gas content.

 Copyright © Canadian Research & Development Center of Sciences and Cultures

4. RESULTS ANALYSIS

Fig.6 shows the evaluation result of gas content in No.3 coal seam of a well. It can be seen that the basic trend of gas content calculation results of Kim equation method and statistical model method is consistent, and they are consistent with the measured gas content, and achieve good application effect in actual production.

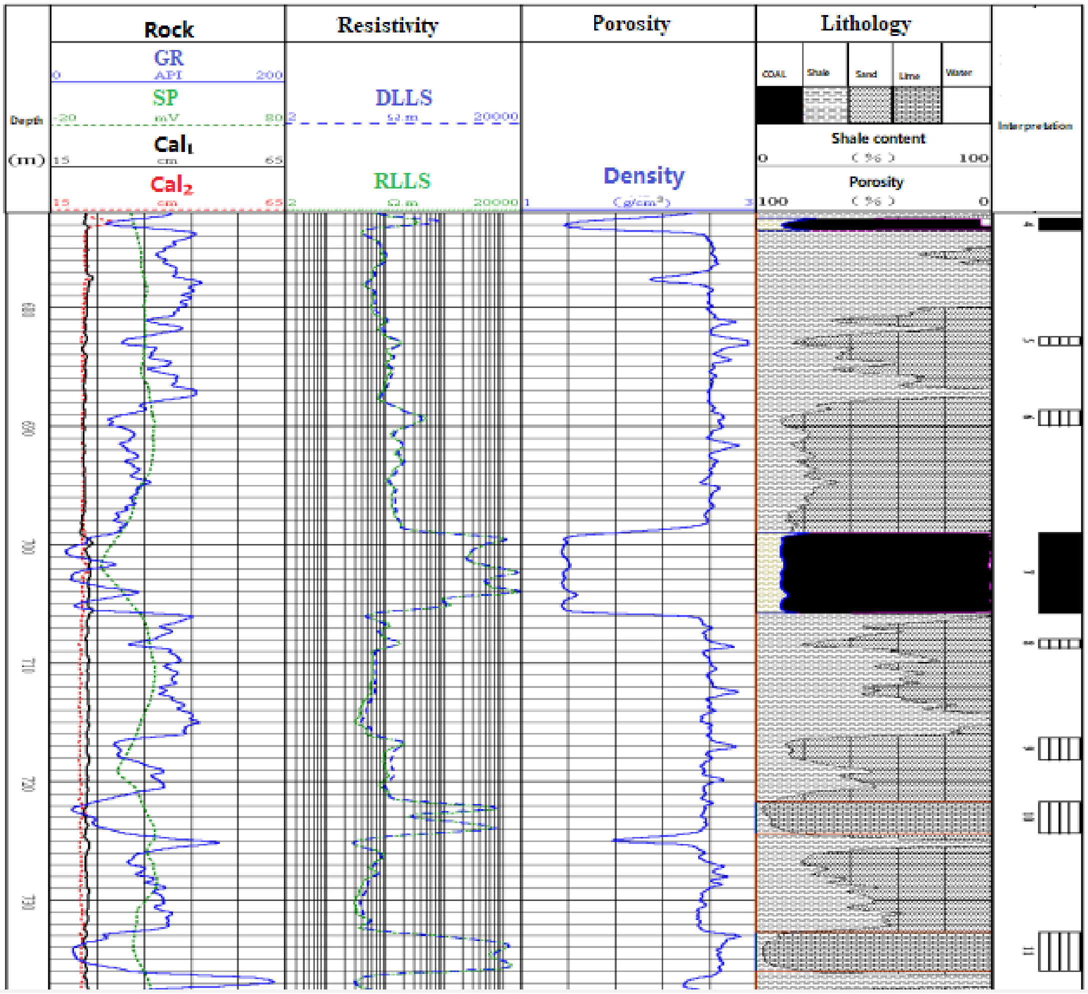


Figure 7
Results' evaluation of gas content in No.3 coal seam of a well

5. CONCLUSIONS

Research on the calculation model of CBM logging interpretation is ongoing, with valuable conclusions as follows:

(1) By analyzing the conventional logging response characteristics of coalbed methane, the coal bearing strata are accurately determined;

(2) Statistical model and volume model of coal core are established to analyze the industrial components;

(3) This paper studies the isotherm adsorption method of calculating gas content by using the empirical formula The basic trend of gas content calculated by Kim equation method and statistical model method is consistent.

REFERENCES

[1] Vinson David S., Blair Neal E., Ritter Daniel J., Martini Anna M., & McIntosh Jennifer C.. (2019). Carbon mass balance, isotopic tracers of biogenic methane, and therole of acetate in coal beds: Powder River Basin (USA). *Chemical Geology, 530*(C).

[2] Yuan, Y., Shan, Y. S., Tang, Y., & Cao, D. Y. (2020). Coalbed methane enrichment regularity and major control factors in the Xishanyao formation in the western part of the Southern Junggar Basin. *Acta Geologica Sinica (English ed.)*, *94*(2).

[3] Lu, G. Q., & Ma, S. X. (2020). Experimental study on static characteristics of turbocharged internal combustion engine with low CBM components. *Journal of Physics*: *Conference Series, 1578*(1).

[4] Zhu, S. J., Zhou, F. B., Kang, J. H., Wang, Y. P., Li, H. J., & Li, G. H. (2020). Laboratory characterization of coal P-wave velocity variation during adsorption of methane under tri-axial stress condition. *Fuel,* 272.

[5] Zhu, H. Y., Qi, Y. G., ,Zhang, F. N., Song, Y. F., Liang, L., & Zhang, J. (2020). Calculation method of production pressure drop based on BP neural network velocity pipe string production in CBM wells. *IOP Conference Series: Earth and Environmental Science, 619*(1).

[6] Yuan, Y., Shan Y. S., Tang, Y., & Cao, D. Y. (2020). Coalbed methane enrichment regularity and major control factors in the Xishanyao formation in the western part of the Southern Junggar Basin. *Acta Geologica Sinica (English Edition), 94*(2).

[7] Peter, W. (2020). The quantification and interpretation of Ceramic Building Material (CBM) assemblages in Britain. *Britannia, 51*(19).

[8] Liu, L. L., Cui, Z. H., Wang, J. J., Xia, Z. H., & Peng, X. Q. (2020). Study and application of a new method for predicting the production of low rank CBM wells. *Journal of Physics, Conference series, 1592*(1).

[9] Yu, Y. J., & Wang, Y. H. (2020). Characteristics of low-rank coal reservoir and exploration potential in Junggar Basin: new frontier of low-rank CBM exploration in China. *Journal of Petroleum Exploration and Production Technology, 10*(prepublish).

[10] Singhal, V., Chattopadhyay, S., & Friese, V. (2020). Investigation of heterogeneous computing platforms for real-time data analysis in the CBM experiment. *Computer Physics Communications, 253*.

[11] Li, Q. X., Xu, J., Peng, S. J., Yan, F. Z., Zhang, C. L., & Han, E. D. (2020). Different adsorbed gas effects on the reservoir parameters and production in coalbed methane extraction by multibranch horizontal wells. *Energy Science & Engineering, 8*(4).

[12] Lu, G. Q., & Ma, S. X. (2020). Experimental study on static characteristics of turbocharged internal combustion engine with low CBM components. *Journal of Physics: Conference Series*, *1578*(1).

[13] Zhu, S. J., Zhou, F. B., Kang, J. H., Wang, Y. P., Li, H. J., & Li, G. H. (2020). Laboratory characterization of coal P-wave velocity variation during adsorption of methane under tri-axial stress condition. *Fuel, 272*.

 Copyright © Canadian Research & Development Center of Sciences and Cultures