საქართველოს მეცნიერებათა ეროვნული აკადემიის მოამბე, ტ. 12, №1, 2018
BULLETIN OF THE GEORGIAN NATIONAL ACADEMY OF SCIENCES, vol. 12, no. 1, 2018

Geology

Shale Gas Prospectivity for the Lower- and Middle Jurassic Terrigenous Shale Deposits of the Kazbegi-Omalo Region

Nodar Poporadze*, Irakli Shekriladze*, Olga Seskuria*

** Faculty of Mining and Geology, Georgian Technical University, Tbilisi, Georgia*

(Presented by Academy Member Irakli Gamkrelidze)

ABSTRACT. Far-reaching changes in global energy market, triggered by the so-called "shale revolution" and related worldwide activities push into the forefront the problem of investigation of shale resources of Georgia. At the stage of preliminary analysis, it was suggested to focus on the possible full geological study of promising regions by non-drilling methods, postponing a full cycle of geological exploration and mining operations to a significant improvement in technology in terms of reducing the cost of mining and the full solution of the sensitive for Georgia problem of potential pollution of natural waters. The Kazbegi-Omalo Region with record concentration of shale-bearing rocks and advantageous geographical location was chosen as an area for primary research. *© 2018 Bull. Georg. Natl. Acad. Sci.*

Key words: shale gas, catagenesis, thermal maturity, total organic carbon, sandstone

A preliminary analysis of the problem of development of shale gas resources in Georgia revealed the need to focus on the possible full geological study of promising areas by non-drilling methods, postponing a full cycle of geological exploration and mining operations to a significant improvement in technology in terms of reducing the cost of mining and the full solution of the sensitive for Georgia problem of potential pollution of natural waters.

According to geological structure and composition of rocks the territory of Georgia is rich in rocks that can be recognized as shale gas reservoirs. Considering the type of development, lithological composition, tectonic peculiarities (microporosity, fracture spacing and orientation) and natural gas content factors the authors regard the shales of terrigenous formation of the Foldsystem of the Greater Caucasus as prospective area for shale gas. Based on the great experience, gained within the sphere of shale gas in North America and the results of our studies Georgia is thought to become a country produ-cing a significant amount of shale gas.

The deposited formations of various ages and composition, considered [1,2] as prospective in terms of shale gas content, are highly developed in various tectonic units [3,4] of Georgia and comprise quite a vast area. Taking into account a number of significant data (maximal vertical thickness of shales, comparatively high proportion of rocks with the acceptable level of metamorphism and total organic component, thermal maturity, vitrinite reflectance) at this stage of researches we gave priority to formations of the Kazbegi-Omalo Region of the Foldsystem of the Greater Caucasus.

Fig. 1. Typical outcrop of shale showing a slope deposit.

In Kazbegi-Lagodekhi and Chkhalta-Laila zones the deposits of the Lower and Middle Jurassic formations with dissimilar jointing and microporosity are generally represented (Fig.1.**)** by shales (70-80%); aleuolites and sandstones (plagioclase-quartz-bearing and arkosic) occur in smaller quantity and they are characterized by similar lithological-petrographic and geochemical properties within the boundaries of the Foldsystem of the Greater Caucasus. Variable amounts of organic carbon content in the Lower and Middle Jurassic terrigenous formations define their dark to blackish colors.

Materials and Methods. We have carried out field-geological works in the Kazbegi-Omalo Region in the Main Range and Kazbegi-Lagodekhi zones of the Foldsystem of the Greater Caucasus. The samples were collected from natural exposures throughout the area from the Tergi River gorge (the Kazbegi Region, gorges of the rivers Arguni, Pirikita Alazani, Tushetis Alazani, Story) the Pirikita Alazani River gorge including. There have been taken more than 1000 samples of shale, aleuolite and sandstone stone material; then they undergone the laboratory tests (polarization, chemical, X-ray diffraction, X-ray fluorescent, thermal researches); fracturing and microporosity of the rocks was studied in a number of districts. Petrographic study has been carried out according to standard manual applying polarizing microscope AmScope PZ600-8M. Due to high dispersity of the basic mass of the studied samples their mineral composition and ratio of mineral phases had to be confirmed and specified therefore in parallel with the petrographic descriptions X-ray diffraction analysis was conducted to define the essence and quantity of the rocks; X-ray diffraction analysis was carried out using DRON-3M. The X-ray diffraction pattern distinctly shows certain phases of minerals composing the appropriate rock.

Dozens of samples of rocks, grouped by means of microscopic analyses, were subjected to chemical analysis. The chemical composition of the rocks was defined by X-ray fluorescent method (XRF analyzer EDX3600B). The rocks were ground into powder of 0,1 microns. Then they were averaged and put into a container and their chemical composition was defined on 30 elements according to the standard ORE program. Standard sample is analyzed simultaneously with the studied sample in order to prove the received data truthfulness – the accuracy of definition of separate element content in the analyzed sample.

Results and Discussion. According to granulometric composition and petrographic studies shales and slates are divided into the following groups: pelitic – without admixture of aleuric material; aleuric and sandstone-aleuric. The aleuric part of shales consists of quartz and acid plagioclase grains (Fig.2), muscovite and sericitic flakes, chlorite-muscovite packages, carbon or graphite matter. The coarse grains of carbon matter are distributed in parallel with stratification; their content in the rock ranges within 0.5 – 2%.; authigenic minerals are represented by quartz, albite, hydromica, pyrite, ferric carbonate, calcite, tourmaline, etc.

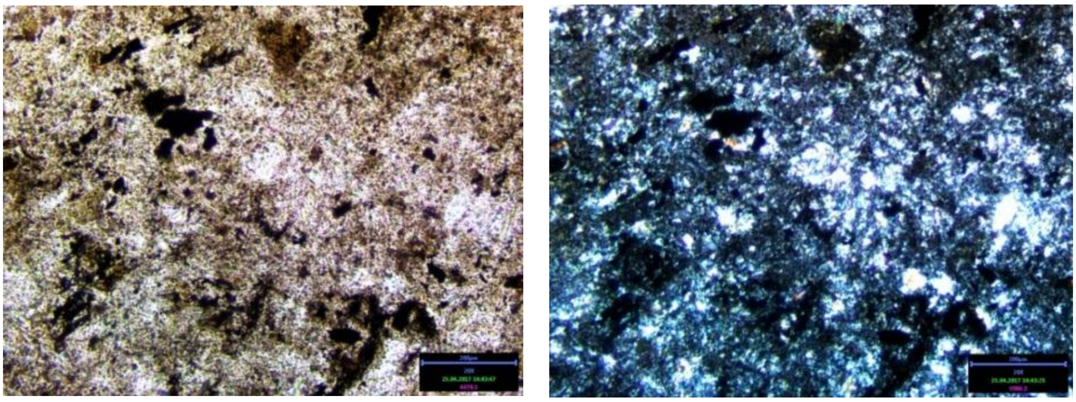


Fig. 2. Photomicrograph showing the sizes and texture of the shale composing minerals; plane-polarized light; cross-polarized light (example X-15).

Albite is fine-grained; it generally occurs in pelitic hydromica-bearing mass; it is characterized by fine polysynthetic twins or prismatic crystals distributed obliquely towards the stratification plane. Quartz occurs in the lower part of the section in the form of certain segregations and brushes parallel to stratification. The aforementioned shales are rich in herbal detritus that is formless or of elongated form; it is characterized by brownish-blackish coloring (in reflected light it is faded brownish-reddish).

The comparison of X-ray data of the Lower- and Middle Jurassic shales of the Southern and Northern Slopes of the Caucasus showed their similar – chlorite-mica composition and the occurrence of hydromica in the Aaalenian shales of the Northern Slope. At the dislocated districts of the Caucasian geosyncline zone, (in the Aalenian shales of the Kazbegi Region among them) hydromica is transformed into muscovite (in secricite) while in synchronic deposits of the Northern Slope not only hydromica but kaolinite and other clay minerals are preserved. The X-ray diffraction analysis of shale sample №229 distinctly showed the following composition: Fe-Mg chlorite (14.14 Å, 7.08 Å, 3.54 Å); quartz (4.25Å, 3.34 Å, 2.45 Å, 1.81 Å); micas (9.96 Å, 4.96 Å); Ca-Na feldspars (4.02 Å, 3.19 Å, 2.995 Å).

Study of layered silicates polytypes and, especially of illite crystallinity index is good characteristic for establishing the indicator of the metamorphism stage.

The chemical compositions of shales are quite similar: Al_2O_3 is not more than 25.84%; Al_2O_3: SiO_2=0.33 and TiO_2:Al_2O_3=0.038; generally K_2O prevails over Na_2O and MgO and the latter is more than Na_2O. Such ratio of components regularly develops in shales of the Foldsystem of the Greater Caucasus. Some differences in the compositions of shales is caused by variable composition of admixture of terrigenous aleuric matter, the existence of volcanogenic material and the superimposed process.

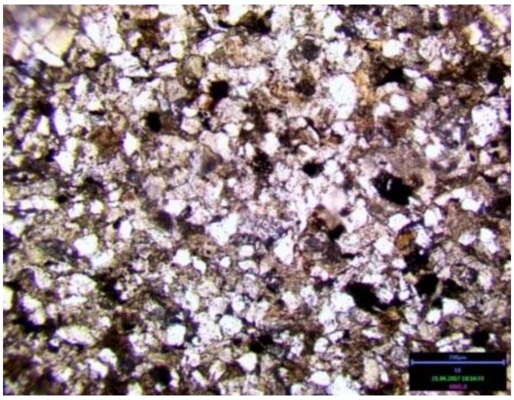
The compositions of shales and their pellitic fraction show decrease of SiO_2, CaO and Na_2O quantity and increase of Al_2O_3, K_2O and FeO. The parallel increase of Al_2O_3 and K_2O content with simultaneous decrease of SiO_2 is explained by K_2O relation with hydromica and not with potash feldspar.

Sandstones in the Lower and Middle Jurassic deposits of the Foldsystem of the Greater Caucasus area developed unequally. They occur in both transgressive and regressive parts of the section.

Among the Lower and Middle Jurassic deposits of the Kazbegi-Lagodekhi zone there occur quartz, arkosic, plagioclase-quartz sandstones and quartzites.

Quartz sandstones consist of cataclastic quartz grains (Fig. 3); black or dark grey aphanitic hornfelse grains (sandstones of Dariali site), albite relicts and aleuric quart-zite grains (the river Stori gorge) are in negligible quantity.

The X-ray diffraction analysis of sandstone sample №X-285 distinctly showed the following composition: quartz (4.25Å, 3.34 Å, 1.817 Å); Fe-Mg chlorite (14.14 Å, 7.08 Å, 3.54Å); Ca-Na feldspars (4.02 Å, 3.19 Å); calcite (3.03 Å); micas (9.96 Å, 4.96 Å).



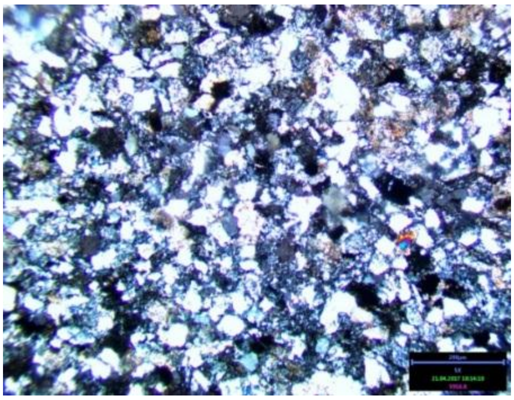


Fig. 3. Photomicrograph showing size and texture of sandstone in the plane-polarized light. Cross-polarized light (example X -236).

Upper Toarcian sandstones are quartz-mica or clay-chlorite bearing sometimes with carbonate cement; some of the layers contain unrounded shale matter.

Aalenian sandstones are composed of quartz grains; there occur colorless mica flakes and zircon grains; the cement is clayey chlorite, sometimes calcite-bearing; it makes an impression that Upper Liassic sandstone of the Tusheti Region like the synchronous ones of the Southern Slope are plagioclase-quartz bearing.

Arkosic sandstones are weakly transformed due to the weathering. Al_2O_3:SiO_2= 0.172; plagioclase-quartz bearing sandstones are almost similarly weakly transformed Al_2O_3:SiO_2=0.20.

Aleurolites are less developed than sandstones and shales though they are found in the Upper Liassic part of the section but in Upper Liassic and Dogger they occur more frequently. The aleourolites are of the analogous mineral composition to the sandstones, alternating with them in the sections but with different ratio of components. Basal cement is represented by pelitic chlorite-sericite mass where the pelitic weakly aggregated part prevails over that of fine-grained. In the cement of such type there is often scattered carbon matter giving the aleurolites dark-grey color; in aleurolites and sandstones of the same mineral composition plagioclase-quartz varieties are most highly developed; in comparison with the aforementioned sandstones in aleurolites mica content prevails over that of quartz; mica is generally colorless - rarely greenish or brownish; in the cement there often occur pyrite segregations. Aleurolites contain 10-30% of the pelitic chlorite-sericitic cement; besides, they are rich in aleurite flaky hydromica and chlorite; thus the increase of SiO_2 and decrease of Al_2O_3, MgO and H_2O contents in comparison with the sandstones seems quite natural.

In the Middle and Upper Liassic sandstones Na_2O:K_2O>1. In aleurolites and shales K_2O is almost three times more than Na_2O. SiO_2 and Na_2O content decreases from sandstones to shales but K_2O content increases. Such ratio of oxides in rocks of various granulometric compositions is explained by the diversity of mineral composition of the latter ones.

So, the quantity of SiO_2, Na_2O and K_2O in sandstones, aleurolites and shales depends upon the mineral composition of the rocks. It is mostly conditioned by the mechanical differentiation of the deposited mass that results in accumulation of hydromicas of various geneses in pelitic part; accordingly in shales (slates) K_2O content is high while Na_2O is represented in a negligible amount.

Total organic carbon (TOC) in the deposits of terrigenous formation is represented by microinclusions of various compositions scattered in different amounts. Carbon content in the rocks is conditioned by their lithologic-granulometric content and degree of metamorphism (thermal maturity). Pelitic rocks – shales are the richest in carbon content; aleurolites and sandstones are considerably poorer. It's clear that the best way to establish the accumulation and distribution regularity of organic matter in the terrigenous sedimentation basin is to study the substantial composition of clay rocks.

Our studies and literary data indicate that the Low and Middle Jurassic rocks (shales, aleurolites, sandstones) of the Kazbegi-Omalo region are characterized by quite high content (up to 2%) of organic carbon. The Tergi River gorge (Kazbegi municipality) – 0.25-1.03%; The Arguni River gorge – 0.42-1.65%; The river Pirikita Alazani gorge – 0.39-1.45%. Accordingly, the area characterized by more than 0.90% (shales) organic carbon content and the post-diagenetic transformation of rocks corresponding to the apokatagenesis stage, can be considered promising in terms of natural gas content.

The highest TOC is fixed at the Upper Pliensbachian and Toarcian stages of the Low and Middle Jurassic rocks (1.02% on average); sometimes it attains 1.7%.

According to the data [5] on the territory of Georgia and Dagestan in the Low and Middle Jurassic rocks there has been established the vitrinite reflectance (R_a measured out-of-doors); the data distinctly show that at the top of the section, in the shales of the Upper Toarcian and Aalenian Bajocian terrigenous formation thermal maturity is based on the vitrinite reflectance with index R_a =10.8-12.0%. In the Lower Toarcian flyschoids the vitrinite reflectance of half-antracites equals R_a =11.0-13.0%; in the Upper Pliensbachian monotonous shales R_a=11.4-14.6%; in the lower part of the Sinemurian-Lower Pleinsbachian phyllitized shales the vitrinite reflectance equals R_a= 10.3-14.6%.

Together with the aforementioned quite optimistic data noteworthy are the risk-factors associated with the commercial development of shale gas resources. One of the most principle problems is ecology (environmental security, underground waters protection). In the course of the research, these issues were of particular importance. Many researchers abroad argue about the environmental problems, arisen as a result of drilling and fracking activities and shale gas production, and try to settle controversial issues. Therefore, it is necessary to regulate the issues related to environmental security in the process of prospecting shale gas in our country as well.

Noteworthy is that the acquired experience of shale gas production indicates the availability of solving the most principal environmental security problems. Study of hydrogeological and environmental aspects (considering the priority of the reliable protection of natural water resources), in order to obtain shale gas in the study area, contributes the distinguishing of low-risk (drilling-fracking) districts.

Conclusions. A preliminary analysis of the problem of the development of shale gas resources in Georgia revealed the need to focus on the possible full geological study of promising areas by non-drilling methods, postponing a full cycle of geological exploration and mining operations to a significant improvement in technology in terms of reducing the cost of mining and the full solution of the sensitive for Georgia problem of potential pollution of natural waters. The article presents the results of relevant studies conducted in the Kazbegi-Omalo Region.

The researches of the rocks by microscopic, X-ray fluorescent, chemical and X-ray diffraction methods show that rocks of the shale terrigenous formation have undergone the process of catagenesis. With increasing depth, their conversion intensity increases and sometimes the level of catagenesis takes on elements of metagenesis; accordingly the degree of recrystallization of clay minerals in the section increases from the top to the bottom. In Bajocian and Upper Liassic shales clay material is fine aggregate, pelitomorphic, feebly reacts on polarization of light. In the Lower Aalenian-Sinemurian shales it is recrystallized into fine-flaked mass; it is oriented perpendicularly towards the pressure stress and behaves like a monocrystal; in certain striae hydromica and chlorite are in segregation with organic material. More profound catagenetic conversions are revealed in formation of fine-flaked sericite (converting into muscovite), light color chlorite generation and aggregate quartz segregation; as a result of the aforementioned processes there form phyllites.

The results of the study clearly show that the information is large although much still needs to be clarified and thoroughly studied. There is actual material, there are real data and quite real prospects therefore in view of a number of parameters and characteristics we consider the Lower and Middle Jurassic depositional formations to be one of the most prospective gas-bearing conventional units though for preliminary assessment of hydrocarbon resource potential in the afore-distinguished prospective local districts further large-scale geological field-works and additional laboratory researches have to be conducted.

Acknowledgement. This work was supported by Shota Rustaveli National Science Foundation (SRNSF) [№ 217754, “Detailed Geological Research of the Shale Gas Prospective Local Districts in the Kazbegi-Omalo Region”].

გეოლოგია

ყაზბეგ-ომალოს რეგიონის ქვედა- და შუაიურული ფიქლებრივი ტერიგენული ნალექების ფიქლის გაზის პერსპექტიულობა

ნ. ფოფორაძე*, ი. შეყრილაძე*, ო. სესკურია*

** საქართველოს ტექნიკური უნივერსიტეტი, თბილისი, საქართველო*

(წარმოდგენილია აკადემიის წევრის ე. გამყრელიძის მიერ)

მსოფლიო ენერგობაზარზე, ე.წ. „ფიქლის გაზის რევოლუციით“ გამოწვეული გლობალური ცვლილებები და მათთან დაკავშირებული ქმედებები, რომლებიც მსოფლიო მასშტაბით ხორციელდება, ქმნის აუცილებლობას სათანადო ყურადღება მიექცეს საქართველოში ფიქლის გაზის რესურსების შესწავლასთან დაკავშირებულ პრობლემას. წინასწარ ანალიზებზე დაყრდნობით შემოთავაზებულია მოხდეს პერსპექტიული უბნების სრული გეოლოგიური შესწავლა ბურღვის გარეშე მეთოდებით, გადაიდოს გეოლოგიური

ძიებისა და მოპოვების სრული ციკლი ვიდრე მნიშვნელოვნად არ დაიხვეწება ფრეკინგის ტექნოლოგიები, არ შემცირდება გაზის მოპოვების ღირებულება და სრულად არ იქნება გადაჭრილი საქართველოსთვის მნიშვნელოვანი ბუნებრივი წყლების რესურსების პოტენციური გაჭუჭყიანების პრობლემა. პირველადი კვლევისთვის შერჩეულია ყაზბეგ-ომალოს რეგიონი, როგორც ფიქლის გაზის მნიშვნელოვანი კონცენტრაციის მატარებელი და ხელსაყრელი გეოგრაფიული მდებარეობის მქონე ტერიტორია.

REFERENCES

1. Chikhradze G.A. (1981) Litologiya iurskikh i melovykh otlozhenii iuzhnogo sklona Bol’shogo Kavkaza. Tbilisi, p.41 (in Russian).
2. Gavrilov J.O. (2004) Dinamika formirovaniya iurskogo terrigennogo kompleksa Bol’shogo Kavkaza. p.310 (in Russian).
3. Gamkrelidze I.P. (2000) O tektonicheskom raschlenenii territorii Gruzii. *Trudy GIN AN Gruzii; Novaia seriya,* 115: 204-208 (in Russian).
4. Gamkrelidze I.P., Shengelia D.M. (2005) Dokembriisko-paleozoiskii regional’nyi metamorfizm, granitoidnyi magmatizm I geodinamika Kavkaza. p. 458 M. (in Russian).
5. Chichua B.K., Dyakonov A.N., Sidorenko S.F. (1982) O principakh sostavleniya kart katageneza i metageneza (regional’nogo metamorfizma) organicheskogo veshchestva pri kompleksnykh geokhimicheskikh issledovaniyakh. *Materialy VII mezhdunarodnogo kongressa po organicheskoy geokhimii sovremennykh iskopaemykh osadkov*, 223-227 (in Russian).

Received January, 2018