Application of Geologic Modeling Technologies in Educational Process and Scientific Activity (Based on Petrel Software Package)

Tatiana Ibragimova[a], Alexandra Rozhnova[a], Natalia Yeriomina[a], Katerina Chernenko[a]

[a] *North-Caucasus Federal University, Kulakova avenue, 16, Stavropol City, 355035, Russia*

Abstract

In this article the description of the main software packages used in the teaching process at institution of higher education is given. In this research the main criteria and principles of the Petrel software package are highlighted, which is one of the innovative digital technologies for use in education and scientific researches. The scientific work is demonstrated in the field of oil-and-gas engineering based on creation of productive horizons models in Petrel software.

Keywords [1]

Professional development, information-communication technologies, hydrocarbon accumulation, digital geologic modeling, software package Petrel, cumulative production of oil, net oil pay, structural map, porosity, oil-saturation, collector, natural reservoir, productivity.

1. Introduction

Segment of NCFU majoring in the field of oil and gas - one of the biggest scientific-educational centers in the South of Russia, specialized on training and refresher training of specialists for oil-and-gas industry of the world. The graduates of the institute of oil and gas at NCFU are in demand as well as in the Russian Federation as in the USA, Norway, Germany, African countries, the Far/Near East.

Nowadays when training of specialists for the oil-and-gas complex the special attention is given to the assistance for student to realize a professional career as the pathway of personal growth, stages and phases of professional growth, criteria of achievement of career growth against a background of the professional development. This task could not be solved without forming the student's qualification potential that corresponds to the modern level of development of information and communication and digital technologies. Professional knowledge, skills and abilities must be formed, they allow using the digital integrated working processes for team work that open a way to the description of the natural reservoirs in real-time mode. Besides, these working processes must combine geophysics, geology and development of the investigated oil-and-gas field into one technological chain.

The study of geophysics, geology and development of hydrocarbon accumulations as components of the integral digital constant-updated model allows increasing the personal efficiency of young specialist. Comprehension of the processes that happened in the time of the geologic history during the accumulations forming and that have happened in the productive horizon in the process of their development allows students (and future specialists) not only to realize the estimates of volumes in-place of hydrocarbons on the different stages of exploration works but also to construct the

SLET-2020: International Scientific Conference on Innovative Approaches to the Application of Digital Technologies in Education, November 12-13, 2020, Stavropol, Russia

EMAIL: tatiana250190@mail.ru (Tatiana Ibragimova); poghsasha@yandex.ru (Alexandra Rozhnova); yeriominasai@mail.ru (Natalia Yeriomina); kabiso@rambler.ru (Katerina Chernenko)

ORCID: 0000-0002-5159-5767 (Tatiana Ibragimova); 0000-0001-5315-1185 (Alexandra Rozhnova); 0000-0001-5869-2749 (Natalia Yeriomina); 0000-0003-1884-2313 (Katerina Chernenko)

hydrodynamic accumulation model. Three-dimensional digital geologic and hydrodynamic modeling which nowadays is actively-developed allows calculating the capital and the operating expenses in the process of development of the hydrocarbon accumulations; it contributes to increase oil- and gas-recovery and to increase the efficiency of enterprises of the oil-and-gas complex.

The start of works on the three-dimensional (3-D) geologic modeling in the Russian Federation is connected with the selling of the softwares: IRAP RMS (Smedvig Technologist), Stratamodel (Landmark) and 3D-Property (Shlumberger) at the beginning of the 90's of the last century.

2. Materials and Methods

Nowadays in the process of the three-dimensional geologic modeling the most often-used are the software packages: Petrel of Shlumberger (it replaced 3D-Property), IRAP RMS of Roxar (successor of Smedvig Technologist), Gocad of Paradigm Geophysical. As advanced Russian software products the most often-used is tNavigator of Rock Flow Dynamics. This prospective high-efficiency software complex is used to create the models of the hydrocarbon accumulations on the stages from interpretation of seismic data up to systems of well-stream gathering on the daily surface.

The process of assimilation of educational programs of oil-and-gas profile at NCFU is supplied with license software packages Petrel and IRAP RMS; the contracts are concluded with Shlumberger and Roxar. The software package tNavigator of Rock Flow Dynamics is planned to be included in the educational process.

The technologies of the three-dimensional geologic modeling are applied at the realization of the educational programs of the different level. On Specialist's level the three-dimensional geologic modeling is used in the educational process on training program 21.05.02 «Applied geology» in the discipline «Modeling of natural oil-and-gas systems» and 21.05.03 «Technology of geologic exploration» in the discipline «Geologic-geophysical modeling of the developing accumulations». On Master's level the 3-D modeling of geologic objects is used on training program 21.04.01 «Oil-and-Gas Engineering» for four master's programs: «Geologic-geophysical methods of problems-solving of oil-and-gas fields development», «Modeling of natural reservoirs of oil and gas», «Design of deep oil-and-gas wells in complex geologic conditions» and «Facilities control of production, transportation and storage of hydrocarbons» in the discipline «Modeling of natural reservoirs of oil and gas». The biggest volume of the geologic modeling falls to the educational process in Master's program «Modeling of natural reservoirs of oil and gas» in such disciplines as «Modeling of hydrocarbon accumulations», «Geologic-production modeling of natural reservoirs with the aim to increase certainty of reserves estimation and resources appraisal of oil and gas», «Scientific-research internship», «Scientific-research work». Besides the three-dimensional modeling is realized by post-graduate students on training program 05.06.01 «Earth sciences» of direction (profile) «Geology, prospecting and exploration of oil-and-gas fields». In a number of disciplines including «Geo-information systems and software packages in oil-and-gas industry».

Teaching the discipline has been held by the workers of the field-oriented enterprise, they have specialized in creating the geologic-technologic models of the oil-and-gas accumulations long time. Over the last 5 years more than 700 students have been taught the work with the software packages Petrel and Roxar.

In the educational process the software package Petrel of Shlumberger was mainly applied for the aims of the three-dimensional modeling.

This software product is used to construct the geologic and hydrodynamic models and estimation of volumes in-place of hydrocarbons.

The software product Petrel is applied in the educational process to solve the next tasks:

- forming skills to gather, systemize, generalize, analyze and adapt different-type and different-scale information at constructing the three-dimensional digital models similar to natural oil-and-gas systems (reservoirs and accumulations of hydrocarbons);
- acquaintance with the modern methods of the three-dimensional modeling of natural hydrocarbon reservoirs;
- forming students' knowledge, skills and abilities to use methods and means of the digital 2-D and 3-D modeling of geologic objects on the different stages of «their live».

The software package Petrel allows describing the simulating objects in real-time mode, new data can be readily changed (at entering), to realize an analysis of the development history, to assess risks and uncertainties over all period of oil-and-gas field development.

Petrel modules have enough simple interface; from 2008 there is a context menu in Petrel module that makes easier students' work with this program.

Petrel program is integrated one. It includes the spectrum of modules; allows working as with the initial data that are necessary to create the digital models as with ready-made models. Nowadays all modules of Petrel are facilitated in the educational process.

On the practical trainings students make the acquaintance with information about possibilities of the program, its interface [1,2,3,4]. Then the teaching of load and editing of initial data is realized. The next step is the creation of structural framework; logging and correlation. Then the structural modeling is realized, models and horizons are created. The next steps are the creation of zones, separation on layers, rescaling of the logging diagrams. Then the analysis of lithological data is held. In Petrel package the newest geostatistical methods are used that allow carrying on the facies and the petrophysical modeling. The contacts between fluids are simulated to construct an accumulation model. Based on the loaded initial data and the created projects in the software package by students; the estimation of hydrocarbon reserves is realized and the preparation of model for hydrodynamics is created, and when necessary the graphical constructions (maps, cross-section and correlation patterns) can be printed out.

With the aim to solidify the formed knowledge, skills and abilities on practice in view of course paper, students of Master's degree realize construction of the three-dimensional geologic model of the hydrocarbon accumulation according to initial data. Shlumberger software package is facilitated at writing and defence of final qualification works; at writing of scientific papers by students and lecturers; for participation with proceedings on regional and all-Russian conferences.

Students are carrying on the final qualification works with the elements of scientific researches, and scientific works relating to a sphere of technological enterprise. The example of such works is the research dedicated to the analysis of degree of impact of geologic factors on a value of oil wells productivity of Velichayevsko-Kolodezny field [5,6].

3. Work Methodology

The accumulations of Velichayevsko-Kolodezny field like most oil-and-gas fields at Stavropolie have already been on the final stage of their development long time. The considerable volume of the initial, geologic-geophysical and field material is accumulated. It can allow evaluating true-to-fact the geologic structure of the accumulations, to determine the connection between geologic factors and a value of wells productivity. An attempt has been made to find out what factors (hysometric position of perforation interval, thickness of the drilled collector, values of porosity and oil-saturation) mainly influence on cumulative production on a well. The research results would allow choosing the best location for the designing well for drilling or realization geologic-field measures to increase hydrocarbon production on the operating wells. This scientific research had been realized with the assistance the software package Petrel. From an analysis below the relevancy and the value of this software package in the educational processes are clearly distinguished as the innovative instrument in education.

The investigated field opened in the middle of the last century (1956 year) and in the next year it has been already brought into development. The main object of development with the biggest oil reserves is $VIII_{1+2}$ horizon of the lower cretaceous. It is terrigenous collector (gravelstones, sandstones, aleurolites, argillites). The average value of gross pay thickness is 21.2m, net pay thickness – 3.7m. The horizon on thickness is heterogeneous on collectors' distribution (there are zones of replacing of collectors by non-collectors), from 2 to 3 impermeable interlayers are fixed with the middle thickness – 4.5m.

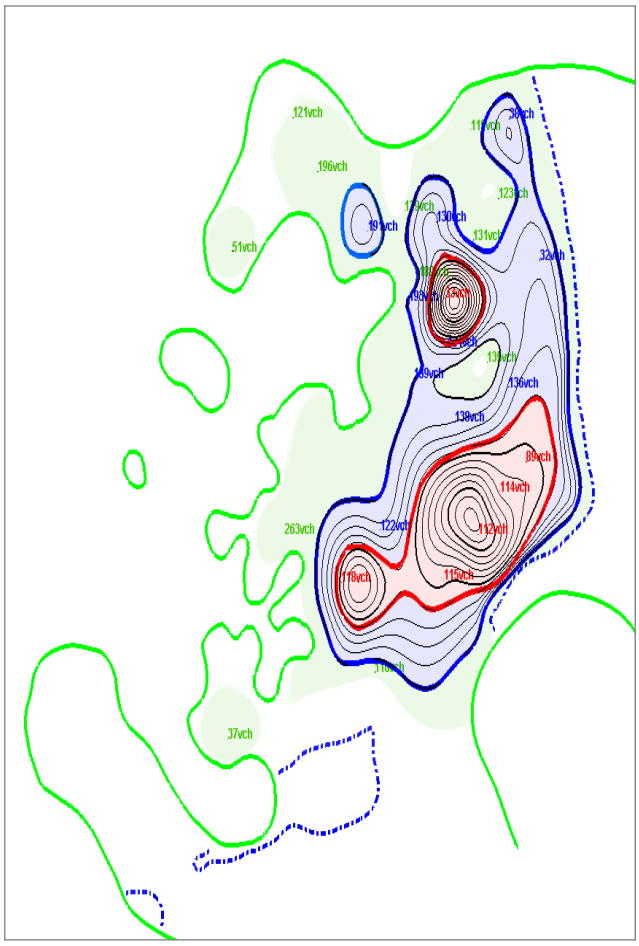
The commercial development of the accumulation started in 1968 year. The initial flow rate of oil was in average 70 c.u. a day at 50 % water cutting of well production. The maximal oil withdrawals – up to 532 c.u. - were achieved at the begging of 70s of the last century (at that time the accumulation

was developed at minimal water cutting of well production). The maximal number of the producing wells in the operating well stock is 63.

The analysis of impact of the geologic factors on the values of oil wells productivity of $VIII_1$ and $VIII_2$ horizons that separated by the impermeable interlayer between themselves and having the different marks of oil-water contact has been independently realized.

Horizon $VIII_1$. In the software package a map of cumulative production was built (figure 1).

The area of the low oil production (less 20 c.u., wavy line) is confined to non-collectors, the area of the high production (more 100 c.u., toothed-line) is marked out in the central and the south parts of the accumulation. The picked zones are confronted with the structural map of collector top and with maps of the geologic parameters of the investigated horizon (net oil pay map, porosity map and oil-saturation map).



Legend:

oil production - 1-20 c.u., -20-100 c.u., - more 100 c.u.

oil production -more 20 c.u. - more 100 c.u.

- line of non-collector, -outer oil-water contact, 5 – value of oil production in c.u.

Figure 1: Map of cumulative production of oil of horizon K_1VIII_1

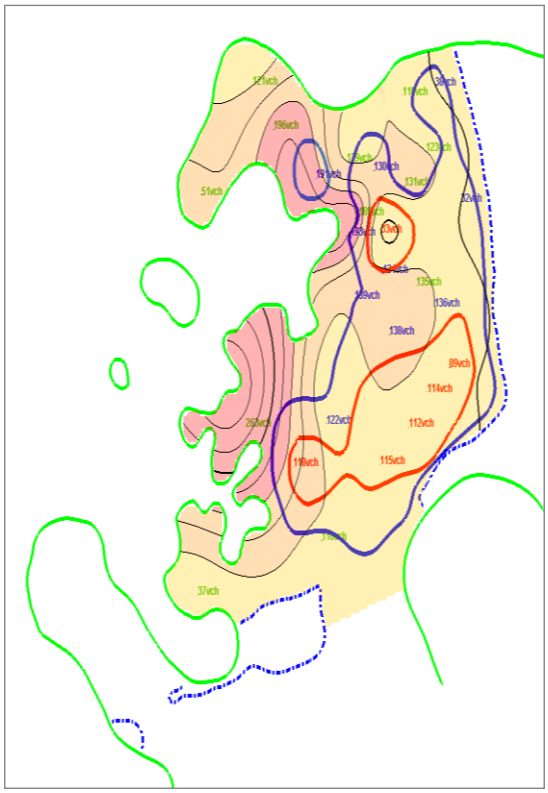
It was established that the hypsometric location of collector top does not influence on wells productivity. The influence of distance up to oil-water contact and up to the pinch-out line is established.

The high-productivity wells are gravitating towards the edging areas of zones of the high net oil pay thicknesses. The low-rate wells and wells with the average values of rate are confined to the area of the high values of net oil pay thicknesses.

The tendency of confinedness of all high-production wells to the area of the higher porosity is fixed. However, in this area there are some wells with the average and the low productivity. To the higher oil-saturation area only one high productivity well is confined and there are wells with the average and low oil production.

In the process of the academic disciplines assimilation and the further scientific-research activity student in cooperation with lecturer have made a comparison of wells productivity with map of yield factors. The last one map was built in the software package Petrel as product in the grid nodes of the digital surfaces of three geologic parameters ($h_{net\ oil\ pay}$, $k_{open\ porosity}$, $k_{oil\text{-}saturation}$). The confinedness of the biggest reserves to the area of wells with the average and not-big production is established; the average reserves' values – to the high-productivity wells; the low reserves – to wells with not-big production.

The analysis of impact of the time of wells bringing into development on wells productivity was realized. Towards this aim in the software package Petrel a map of wells bringing into development of the horizons was built (figure 2).



Legend:

oil production - more 20 c.u., - more 100 c.u.

- line of non-collector, - outer oil-water contact

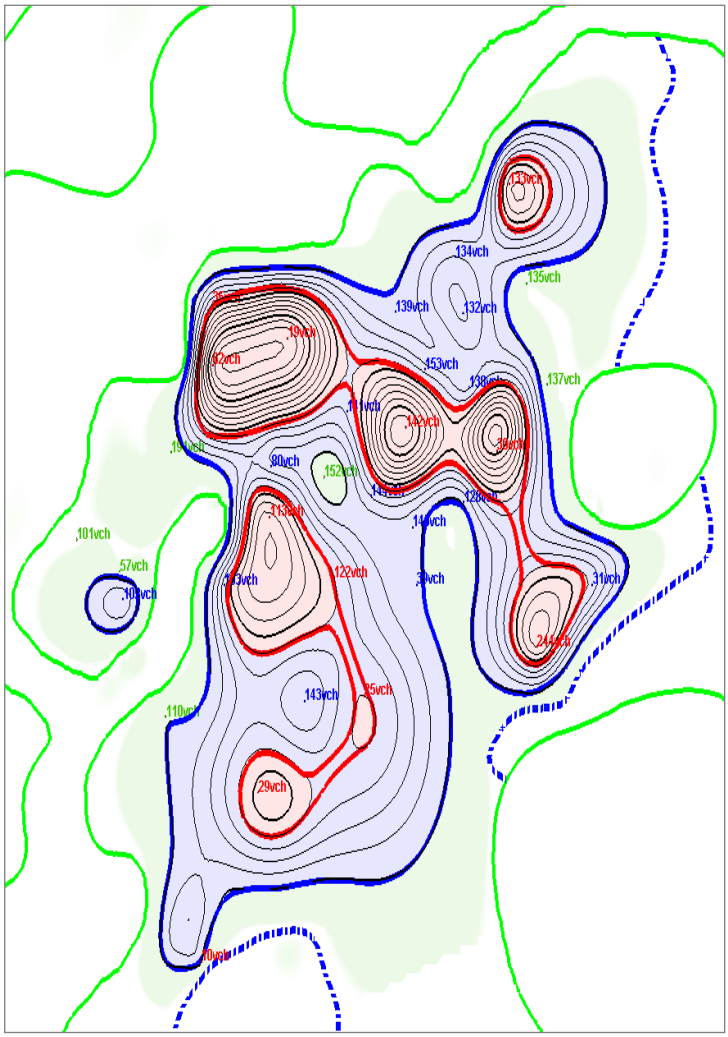
wells bringing into development: 1965-1970, 1970-1980, 1980-1997

Figure 2: Map of wells bringing into development of horizon K_1VIII_1

Wells bringing at the development process was controlled by the movement of oil-water contact. The definite impact of time of bringing on productivity was not established. So, from 1965 to 1977

not only wells with the maximal production were being brought into operation but almost all wells with the average production and some wells with the small cumulative oil production.

Horizon $VIII_2$. For this horizon in the created project the graphic constructions according to the same principles as for the horizon $VIII_1$ were realized (figure 3). Wells with the low production are gravitating towards the zones of non-collectors distribution; wells with the high rates – to the central and the south parts of the accumulation.



Legends:

oil production - 1-20c.u., -20-100c.u., - more 100 c.u.

oil production - more 20 c.u., - more 100 c.u.

-line of non-collector, - outer oil-water contact, 5 – value of oil production in c.u.

Figure 3: Map of cumulative production of oil of horizon K_1VIII_2

The comparison results of the map of cumulative oil production, the maps of geologic parameters, time of wells brining into operation for the horizon $VIII_2$ allow on the whole coming to the same conclusions as for the underlying horizon $VIII_1$. The values of cumulative rates of wells in a considerable degree are defined by farness from oil-water contact and from boundaries between

collector and non-collector. The high-productive wells are gravitating towards the edging zone of the high net oil pays and towards the areas with the higher open porosity. Nevertheless, some wells with the average and the low productivity fall into the area with higher values of $k_{open\ porosity}$.

Only one high-productive well is fixed in the area of the higher values of $k_{oil\text{-}saturation}$, three wells – with the average, one well – with low cumulative production of oil. The high-productivity wells are situated in the area of the average yield factors; one part of the low- and the average-productivity wells – in the area with the biggest yield factors.

4. Results

The realized researches allowed coming to the next practical conclusions.

1. The biggest negative impact on production is the position of wells near non-collector. This area is characterized by the low thicknesses of collector and the worst reservoir (collector) properties. The wells position near oil-water contact is also undesirably because of the quick water cut. So, the determinant factor is the structural peculiarities of horizon.
2. The second important factor can be called open porosity of horizon. Good open porosity means that there will be good permeability in the same place, this indicates high surface efficiency coefficient.
3. The third important factor is net oil pay of horizon. The analysis of set of three geologic parameters ($h_{net\ oil\ pay}$, $k_{open\ porosity}$, $k_{oil\text{-}saturation}$) that determining yield factors allowed establishing that in the area of the low yield factors will be the same low cumulative production. However, the high yield factors do not guarantee the high cumulative production of oil.
4. The considerable influence of such factor as oil-saturation of collector on a value of cumulative production of oil was not displayed.

The research results after application at writing of the final qualification work were reported on the international scientific-practical conference «Innovative technologies of oil-and-gas industry» and also published in the scientific magazine «NCFU bulletin».

5. Conclusions

So, the application of the three-dimensional modeling technologies in the educational process and the scientific activity allows successfully assimilating the educational programs of Master's degree, realizing the scientific researches and developing the skills of the public presentation of their results for the scientific community.

Besides, the software package Petrel referential to the modern high-technological scientific soft supplying is used for the purposes of the participation in the grants competitions of RSF, RFFR; for the realization of the educational programs of Specialist' degree and the post-graduate program in a part of implementation of the final qualification works with the scientific researches elements; also in the design works referring to the sphere of technological enterprise. The obtained skills of the work with geologic and geophysical information in the software package Petrel help the future specialists at the further training and job placements.

The application of the software package is seems potential to increase the training and education activity of engineering staff of exploration and oil-and-gas enterprises; and to improve the career guidance works and the pre-university training.

6. References

[1] M.V. Nelepov, N.V. Yeriomina, O.O. Lutsenko, T.V. Ibragimova, Modeling of natural oil-and-gas systems, Teaching guide, Training program 21.05.02 Applied geology, Specialty – Geology of oil and gas. NCFU, Stavropol, 2016, 143 p.

[2] T.G. Perevertailo, A.A. Zakharova, Formation of 3-D geologic models of hydrocarbons accumulations in software package Petrel (Schlumberger), Practical course, Publishing house of TPU, Tomsk, 2010, 93 p.

[3] G.V. Larin, Application of domestic software packages to construct geologic models: Proceedings of News of gas science: Issues of resource provision of gas producing regions of Russia up to 2003 year, Gasprom VNIIGAS, Moscow, 2010, pp. 156-160 http://vesti-gas.ru/sites/default/files/attachments/156-160-1001-geo-v30.pdf.

[4] E.A. Gladkov, Geologic and hydrodynamic modeling of hydrocarbon accumulations, Teaching guide, TPU, Tomsk, 2012, 84 p. .http://portal.tpu.ru/SHARED/g/GLADKOVEA/Uchebnaya/Tab4/GLADKOV_3D_MODELING.pdf

[5] T. Logvinova, M. Nelepov, A. Likhovid, Patterns of changing of productive horizons of oil-and-gas wells on Velichayevsko-Kolodezny field, NCFU bulletin: scientific magazine, 6(39), 2013, pp. 54-58.

[6] M.V. Nelepov, V.M. Harchenko, T.V. Ibragimova, Influence of tectonic factors of sedimentary cover on hydrocarbon production in wells of oil-and-gas fields of Stavropolie: Proceedings of international scientific-practical conference Innovative technologies in oil-and-gas industry, Publishing house TESERA, NCFU, Stavropol, 2015, 336 p.