Software Architecture of the Atlas of Digital Oil-Gas Formations[1]

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Abstract. The ATLAS MPhM is a collection of digital formation models of oil and gas-saturated reservoirs. It is intended for most realistic modeling that includes changes in fluid-saturated rock properties in the borehole environment, and describes the processes of the formation fluid replacement with mud filtrate, taking into account changes in the geomechanical parameters and evolution of the spatial distribution of electric resistivity. The ATLAS software organization uses a scalable "cloud" of computing agents for high-performance scientific calculations.

Keywords: digital twin; data analysis; electromagnetic logging; VIKIZ.

1 Introduction

The processes occurring in the borehole environment during and after drilling entail modification of the near-wellbore zone properties. The resulting heterogeneities are recorded on well logs, and, if the interpretation model fails to take their changes into account, then the inversion algorithm incorrectly translates nonuniformities of the invaded zone to reservoir properties, thereby leading to inaccurate prediction of the production characteristics. The improvements of accuracy and reliability of reservoir properties evaluation from results of geophysical studies and geotechnical well tests, requires building maximum realistic models, which includes variations in fluid-saturated rock properties in the near-wellbore zone, characterization of the mud filtrate invasion process and changes in geomechanical parameters and evolution of resistivity distributions.

The coupled geoelectric, hydrodynamic, and geomechanical reservoir model using practical field measurements incorporates largely inhomogeneous data [1-3], specifically: numerical values of the geoelectric, hydrophysical, and geomechanical parameters of a reservoir, formation fluids, and well operation processes; functional relationships between permeability and effective stress, effective electrical conductivity and formation water saturation and mineralization and rock structure parameters; as well as 2D / 3D spatial distributions of pressure and water saturation and mineralization, resistivity, well logs corresponding to this reservoir model (Fig. 1). Both direct and inverse problems solution and reservoir parameter evaluation from borehole measurements require providing storage, access and a specialized software services for a large amounts of heterogeneous data. These requests are implemented in the collection of multiphysical models ATLAS MFM [4-7]. ATLAS MPhM is a relational database of digital formation incorporating their geophysical and geotechnical well logging. A large series of representative oil and gas-saturated reservoirs using various available in practice well drilling technologies are presented by their models in ATLAS MPhM.

Conception of digital twin has recently become the center of attention for industry and has aroused great interest of scientists [8]. The digital twin is described as the integration of data between a physical object and its virtual analogue in either direction [9–12]. Following [9] we can describe digital formation as integrated multiphysics, multiscale simulation of real formation that uses the best available models of processes in borehole environment, well operation history, well logs, core measurements, etc., to mirror the life of its corresponding physical twin.

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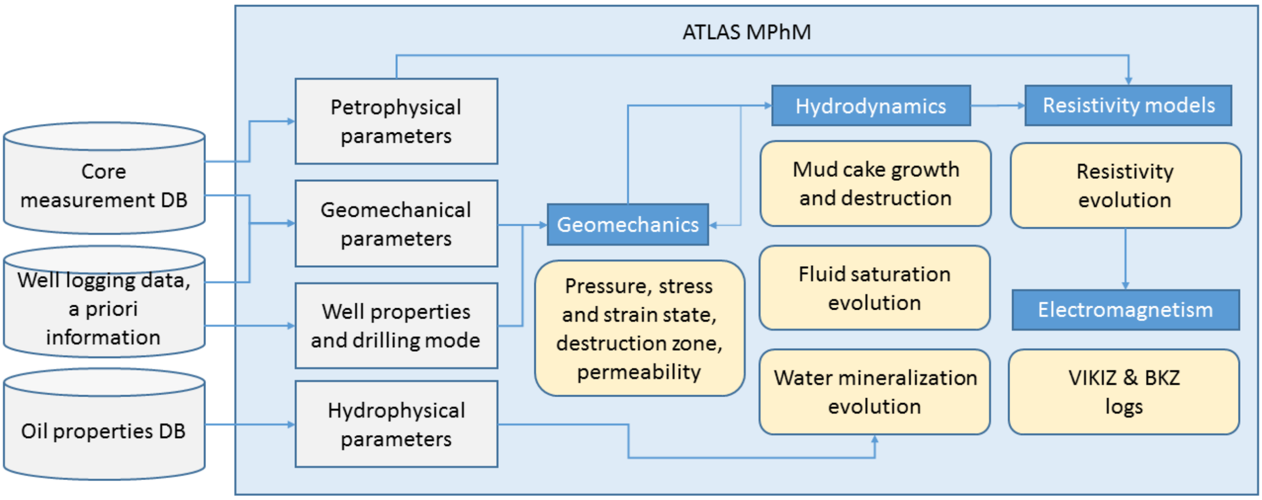

Figure 1. ATLAS MPhM structure.

2 ATLAS MPhM Architecture

One of the major distinction of software tools intended for collection of digital formations is the use of cross-platform scalable distributed computing. ATLAS MPhM is organized as a client-server application; the client part is a web application run by any modern browser, ensuring thereby its independence from the user's platform. This allows the user after authorization, to upload calculated models to the database, to search for previously uploaded constraint-based models, and to run additional computations of logging probe signals.

The server part (Fig. 2) consists of the ATLAS server itself, the PostgreSQL database [13], the RabbitMQ message broker system [14], and the computing cloud built using Docker technology [15, 16].

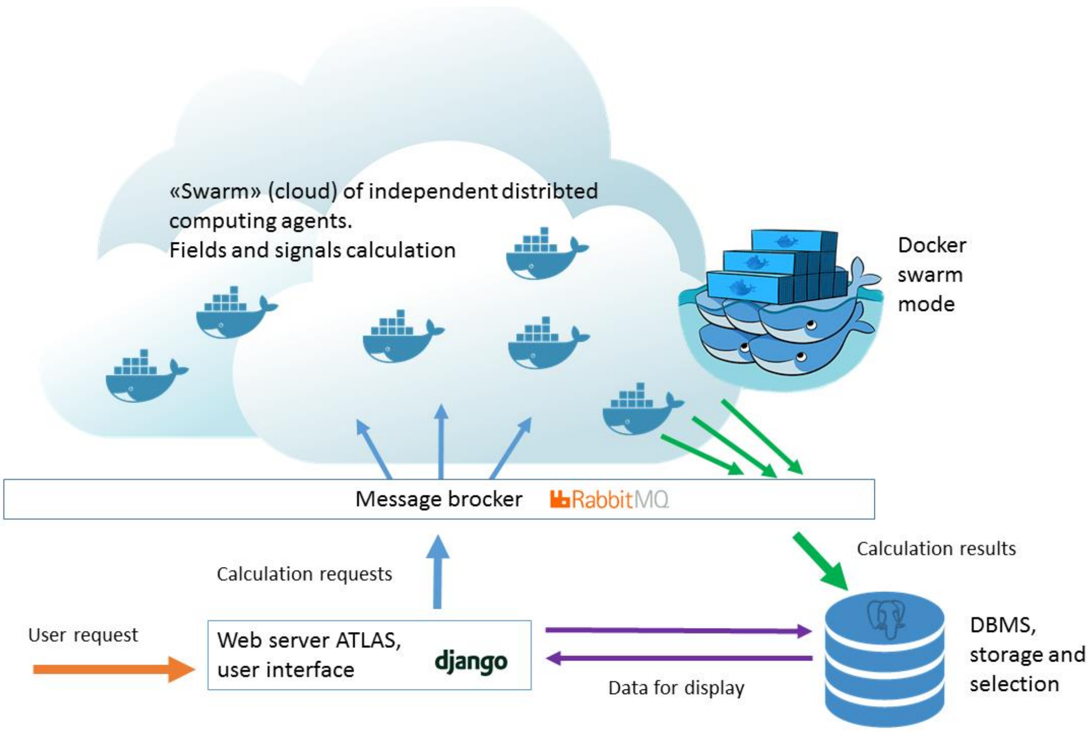

Figure 2. ATLAS back end structure.

The ATLAS server being the main point of interaction with the system, is represented by the Django application, which handles the client applications' requests, generates queries to the database subsystem, and queues computing tasks.

RabbitMQ was selected to be a message queue management system. The queue server collects requests for signals calculation and distributes them to the cloud of computing applications, and receives the results of calculations. The calculation subsystem is a cloud of independent computing agents that run on accessible computers using the Docker system (which ensures its independence from the system and scalability) and are integrated into a Docker Swarm mode cluster (Fig. 2).

Computing agents intended for different types of tasks (e.g. calculating VIKIZ (High Frequency Induction Isoparametric wireline Logging tool) or BKZ (Russian lateral log) signals in 3D media) are unified, and at startup are connected to the RabbitMQ server, to have their type queues processed accordingly. Once the task emerges, the calculations are performed, with the results sent to the result queue. The collector, a dedicated result queue handler, adds the results to the database and removes them from the queue (which is not shown in the illustration, for simplicity). The resource-intensive calculation results safety and the database integrity are thus achieved.

The ATLAS user can save the components of the multiphysical model in text or graphic form, or view them on the screen. Sample reservoir model parameters, distributions of fluid saturation, water mineralization and resistivity, and synthetic logs for timestamp 36 hour after drilling are shown on Fig. 3.

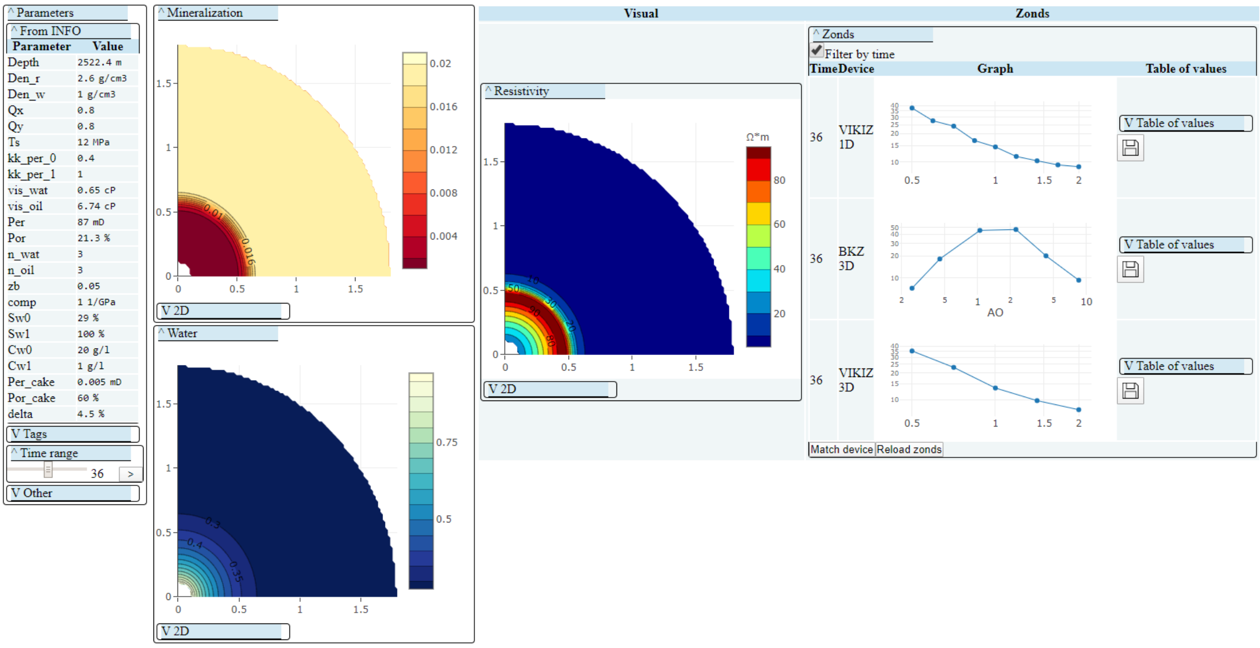

Figure 3. Reservoir model 36 hour after drilling.

3 Conclusion

A complex of geophysical, technological, engineering and other well studies can be successfully used for system analysis and the formation evaluation refinement. It was shown that for drilling into conventional terrigenous intervals it is critical to take into account geomechanical and hydrodynamic conditions of the borehole zone evolution. This however requires a multiphysics model of the processes occurring in the borehole environment, and the development of tools for processing heterogeneous data pertaining to digital reservoir modeling.

The created ATLAS MPhM is a collection of digital formation digital formation models of oil-gas saturated reservoirs that enables simulations of reservoir development scenarios and analysis of the influence of significant parameters on the borehole zone evolution and logs, as well as selection of geological formations that fit best the available logging measurements and a priori data. The ATLAS software system uses a scalable "cloud" of computing agents for high-performance scientific calculations in a heterogeneous environment, and a computational graph maintaining the integrity of interdependent calculations. A further development of the ATLAS MPhM involves application of machine learning methods for predicting missing values and selecting digital formations that are best represented by the investigated reservoir information.

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References

[1] Yeltsov, I.N., Nesterova, G.V., Sobolev, A.Y., Epov, M.I., Nazarova, L.A. and Nazarov, L.A. Geomechanics and fluid flow effects on electric well logs: multiphysics modeling. // Russian Geology and Geophysics, 2014. No 55 (5-6), pp. 775-783.

[2] Glinskikh, V.N., Nesterova, G.V. and Epov, M.I. Forward modeling and inversion of induction logs from shaly sand reservoirs using petrophysical conductivity models. // Russian Geology and Geophysics, 2014. No 55 (5-6), pp. 793-799.

[3] Nesterova, G.V., Yeltsov, I.N., Kindyuk, V.A., Nazarov, L.A. and Nazarova, L.A. Simulation of hydrodynamic processes in the borehole environment under stress-strain state and geophysical applications. // EAGE collection of articles “Petrophysics of complicated reservoirs: Problems and Perspectives 2014”, pp. 327-344.

[4] Yeltsov, I.N., Nesterova, G.V., Sobolev, A.Y., Epov, M.I., Nazarova, L.A. and Nazarov, L.A. Geomechanics and fluid flow effects on electric well logs: multiphysics modeling. // Russian Geology and Geophysics, 2014. No 55 (5-6), pp. 775-783.

[5] Yeltsov, I.N., Nazarov, L.A., Nazarova, L.A. Nesterova, G.V. and Sobolev, A.Y. ATLAS_GEHM. Certificate of state registration of database 2018620241; RU; № 2017621566/69, publ. 09.02.2018.

[6] Nazarov, L.A., Nazarova, L.A, Yeltsov, I.N. and Nesterova, G.V. GEHM2. Certificate of state registration of computer program 2018613634; RU; № 2017663592, publ. 21.03.2018.

[7] Surodina, I.V. and Nesterova, G.V. VIKIZ and BKZ log simulation using Graphics Processing Units. // EAGE collection of articles “Petrophysics of complicated reservoirs: Problems and Perspectives 2015”, pp. 85-94.

[8] Fuller A., Fan Z., Day C. Digital Twin: Enabling Technology, Challenges and Open Research // arXiv:1911.01276 [cs]. 2019.

[9] Glaessgen E., Stargel D. The digital twin paradigm for future NASA and US Air Force vehicles // 53rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference 20th AIAA/ASME/AHS Adaptive Structures Conference 14th AIAA. 2012. p. 1818.

[10] Chen Y. Integrated and Intelligent Manufacturing: Perspectives and Enablers. // Engineering, vol.3, 2017, pp. 588–595.

[11] Liu Z., Meyendorf N., Mrad N. The role of data fusion in predictive maintenance using Digital Twin //AIP Conference Proceedings. AIP Publishing, 2018. Vol. 1949. No 1. p. 020023.

[12] Zheng Y., Yang S., Cheng H. An application framework of digital twin and its case study // Journal of Ambient Intelligence and Humanized Computing. 2019. No 3 (10). pp. 1141–1153.

[13] PostgreSQL Documentation. https://www.postgresql.org/docs/current (accessed date: 20.11.2019)

[14] RabbitMQ Documentation. https://www.rabbitmq.com (accessed date: 20.11.2019)

[15] Docker Documentation. https://www.docker.com (accessed date: 20.11.2019)

[16] Docker Swarm. https://docs.docker.com/engine/swarm (accessed date: 20.11.2019)