The problem of genesis and systematic of sedimentary units of hydrocarbon reservoirs

The problem of genesis and systematic of sedimentary units of hydrocarbon reservoirs

E N Zhilina [1], **O S Chernova**[2]

[1]National Research Tomsk State University, Tomsk, Russia
[2]National Research Tomsk Polytechnical University, Tomsk, Russia

E-mail: elena@ggf.tsu.ru

Abstract. The problem of identifying and ranking sedimentation, facies associations and their constituent parts - lithogenetic types of sedimentary rocks was considered. As a basis for paleo-sedimentary modelling, the author has developed a classification for terrigenous natural reservoirs,that for the first time links separate sedimentological units into a single hierarchical system. Hierarchy ranking levels are based on a compilation of global knowledge and experience in sediment geology, sedimentological study and systematization, and data from deep-well coresrepresentingJurassichydrocarbon-bearing formationsof the southeastern margin of the Western Siberian sedimentary basin.

At present, work in the field of reservoir sedimentology has increased noticeably in Russia and abroad. The modern studies of oil-bearing formationsfollow a long and well-established focus on genetic and historical-geological aspects, allowing for the determination of sedimentary conditions and the distribution patterns of sedimentary complexes capable of generating and retaining hydrocarbons. Therefore, the most important task of sedimentary oil and gas geology from an applied perspective is to examine the process of sediment generation in time and space in order to successfully predict the size and shape of the oil and gas reservoirs and which can be used in building the correct 3D geological models.

The basis for paleo-sedimentological modelling is that the morphology and filtration-capacity of productive horizons are to a large extent predetermined by the physical and geographic conditions of the ancient sedimentary environments, which are closely linked to the tectonics of the region, its geological age, and the direction and intensity of secondary processes.

The problem of identifying and ranking the sedimentary environments and their facies associations has been addressed over many years in numerous published works by many authors and groups of authors. The research hasidentifieda number of conditions that have a significant impact on the formation and placement of hydrocarbon deposits in the sedimentary space. Most authors have assigned the most important role to geomorphological, lithologic-stratigraphic and paleogeographic factors in determining all the basic characteristics of the final product of the sedimentation system. The paleo-sedimentology of the modelling in this area is based on sedimentological studies to identify and examine the various-ranked sedimentary elements of natural terrigenous systems emerging from certain natural processes.

There are several steps to successfully address the problem of developing a classification of various sedimentary units in the context of detailed elaboration of popular sedimentological models. Firstly, it is necessary, to have an identical understanding between researchers of the shared object of research, thesedimentology of natural reservoirs.Secondly, there must be consistency in the use ofspecial sedimentological nomenclature, the terms of which are often interpreted arbitrarily and thus have a mixed meaning.Thirdly, there is long overdue need to address the issues of classification ofsedimentation, facies and their component lithogenetic types, on a single methodical basis.

Abundant Russian and English geologic literature contains extensive, synthesized material on a variety of working classifications for the conditions of sedimentation, facies and types of rocks in different natural environments which were created according to the needs of authors. A singletaxonomy, which is a hierarchical structure linking separate sedimentological objects (sedimentological unit) into a strict hierarchical sequence, does not exist today. This is why there are e often significant differences and terminological difficulties in facies research into units belonging to different sedimentary levels.

The problem of defining and merging different sedimentary data into different groups arises in the early stages of the study-in the description and assigning of lithogenetic types. Subsequently, in the definition of facies associations, which in turn, compose large sedimentary cycles reflecting ancient landscape characteristics, the problem is only exacerbated.

In the analysis and prediction of the ancient conditions of sedimentation, the researcher faces the inevitable need to link multi-dimensional parts of the internal architecture of natural existing systems. The primary structures from the original sedimentation situation, recorded in the well core material are not fully visible and are significantly affected by millions of years of secondary changes of the sedimentary material, which have fundamentally changed primary character of the rocks. Therefore, the restoration of the ancient depositional environments using well core data is an inherently complex geological task. For its correct interpretation additional knowledge and understanding are required:

(1) Processes of sedimentation and the results of their formation *(what type of a deposit is formed as the result of certain sedimentary process?)*;

(2) Formation mechanisms of sedimentary processes;

3) Textural characteristics of sedimentary material;

(4) Basics ofpetrography (*composition of the units*) and geochemistry (*the conditions of the main diagenetic processes leading to the inevitable modifications of natural reservoirs at the micro and macro level*);

(5) Basic ofpaleontology and historical geology (*understanding of major groups of organisms and their living conditions).*

It is also necessary to understand the hierarchy of the main sedimentary units, to know their paragenesis in the transgressive and regressive development of the region, and to have an objective understanding of modern sedimentary processes and an understanding of the parameters controlling modern deposition environments.

When working with drill core material, it is important to understand the difference between modern and ancient paleofaciescomplexes: to know the typical facies associations, both in modern and ancient sediments; to have structural analysis skills (have experience in interpretation of textures and modern and lithified strata; and to know the identification criteria for each sedimentary environment.

In modern sedimentological and facies-cycle research on sedimentary horizons a unified conceptual approach is used for the interpretation of ancient deposition systems, based on studying and identification of genetic indications of their rocks specified on mechanisms and the conditions of their formation. It is obviously important to have the hierarchical scheme reflecting the full diversity of natural reservoirs.

Experts of petroleum engineering deal with products of ancient sedimentary systems, with the specific geological bodies representing existing systems, having certain orientation in the accommodation space, a defined stratigraphic age and certain morphological form. All existing systems (oil and gas reservoirs) have strict hierarchical association with each other. Knowing these

associations (chains) and laws of their development it is possible to predict the occurrence of those or other facies associations and to recognize ancient deposition characteristics fromdrill core wells, i.e. to solve the reverse problem of geology. For palaeo-sedimentological modeling it is also extremely important to define the main sedimentary trends which are in close geomorphological and dynamic dependence.

Thus, natural reservoirs can be considered as fossil paleo-morphostructural forms with certain dimensions, capacity, and morphology of the inner structure, and the nature of contact with the host formations. All these parameters are controlled by the depositional environment and are directly connected with geomorphological and dynamic conditions in sedimentary basin

The hierarchical structure in question is the result of a synthesis of world experience with ancient sedimentary sequences, preliminary work in the systematization of the English and Russian sedimentological nomenclature, and lithological-facies and paleogeographic studies of Jurassic terrigenous sediments of south-eastern Western Siberia.

The classification of sedimentologicalobjectsis built on a hierarchical basis, including five levels based on parameters that mutually exclude each other in different classes.Each parameter can be objectively defined, identified, and uniquely valued. The criteria for the established hierarchical structure were: the deposition of the terrigenous material and its form of accumulation (geomorphological feature) and the position of the lithified sediment in the typical sedimentation profile.

The main sedimentary characteristics, "sedimentary environment", "macrofacies", "facies association", "facies", "lithogenetic type", "hierarchical rank" are considered by various authors, both in modern and ancient sedimentary environments. The concepts adopted in the classification are defined as follows.

*Sedimentary environment:*the ancient landscape, which includes the physio-chemical conditions of the sediment formation, which are characteristic of the removal area, and accommodation space.

Facies: the final (specific) product of a particular geological process operating in a particular region with geomorphological features, or a real geological body, with three-dimensional characteristics.

*Lithogenetic type:*lithological type of rock possessing a set of genetic features, caused by the processes of its formation (in English-speaking terminology - *lithofacies*).

Hierarchical rank: the level assigned to a specific sedimentological unit is considered when building the hierarchical relationships of sedimentary objects.

According to this approach, the sedimentation, which formed the main natural reservoirs of hydrocarbons during the Jurassic age, within the province of the south-eastern part of the Western Siberian Basin, are traditionally divided into five major groups, comprising most of the other groupings.1) ***continental environments*** *(alluvial fan, fluvial, lacustrine, poludal)*; 2) ***transitional environments*** *(deltaic, estuarine)*; 3) ***nearshore environments*** *(tidal and beaches*); 4) ***shallow-marine environment*** *(sandy bars, barriers and lagoons*); 5) ***marine environment*** *(shelf sandy ridges)*. The full scheme of sedimentological units is given in the article “The Systematics and Hierarchy of Natural Reservoirs as Foundation of Palaeo-sedimentological Modelling” [1].

In order to facilitate understanding and to eliminate contradictions, the terms are presented in both Russian and English. Aeolian, glacial and volcanogenic sedimentary environments, have not been included in this scheme since these are not typical for this climatic zone during Jurassic sedimentation, but for these a separate classification can be created on a similar basis.

The sedimentological characteristics, that describe the reservoirs of humid-climate regions, display a complex hierarchy of the alternating lithogenetictypes that form the sets of facies associations of the main terrigenous environments.

Accordingly, the proposed hierarchy allows creating sedimentological reconstruction within the limits of certain sedimentary systems, represented by typical sets of reservoirs. For each described sedimentary environment are revealed diagnostic criteria, allowing determination of the genesis of ancient sedimentary complexes.

In the variation in the lowest level of systematics (lithogenetic type), the main characteristic of natural systems, its emergence is reflected. It means that there are no strict unequivocal boundaries between levels of sedimentation -facies, facies associations and sedimentation conditions. There is always a system of transitions between hierarchical levels, as defined by the work of R.C. Selly, H.-E. Reinek and I.B. Singh, H.G. Reading [2, 3, 4].

The proposed systematization of sedimentological objects may be useful for petroleum specialists studying ancient facies sequences where the morphology of the reservoirs is virtually non-preserved in pristine form. However, this systematization does not cover all kinds of natural setting, but can be a starting point for such geological discussions.

References

[1] Chernova OS 2010 The systematic and hierarchy of terrigeneous reservoirs as foundation of palaeosedimentological modeling // *Izvestiya TPUVol 317 Geology*, *investigation and exploration activities of Siberia* Tomsk pp116-122
[2] Reading HG 1996 *Sedimentary environments: processes, facies and stratigraphy* 3rd ed. Blackwell Oxford 688 p
[3] Reineck HE and Singh IB 1975 *Depositional Sedimentary Environments Springer-Verlag*Berlin Heidelberg 439 p
[4] Selley RC 1996 *Ancient Sedimentary Environments and Their Subsurface Diagnosis* 4th ed. Chapman & Hall London 30 p