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ScienceDirect

Russian Geology and Geophysics 58 (2017) 963–972

RUSSIAN GEOLOGY AND GEOPHYSICS

www.elsevier.com/locate/rgg

Problems of selection and correlation of stratotype sections of the Neocomian in West Siberia in the context of clinoform structure

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Received 13 April 2016; accepted 1 September 2016

Abstract

This paper discusses the problems of selection of stratotype sections and correlation of marker beds in the Neocomian productive complex of West Siberia in the context of its clinoform structure. In this paper we present a conceptual sequence stratigraphic model and a correlation chart for beds from different lithofacies regions of the Berriasian–Lower Aptian deposits of West Siberia.

Keywords: Neocomian; stratotype; clinoform; sequence; correlation; bed indexing; West Siberia

Introduction

Correlation of reservoir units is an important element for field-scale reservoir and basin modeling studies. A wide variety of tools used by geologists for subdivision and correlation of geological sections include paleontological, lithostratigraphic, seismic stratigraphic correlation methods, as well as well log correlations. In addition, there are a number of supplementary methods such as geochemical, cyclostratigraphic, magnetostratigraphic, climatostratigraphic, tectonostratigraphic, etc.

Each of these methods has its own set of advantages and limitations, and none of them is perfect. While a combination of different methods is able to produce the most accurate results. One important limitation is the availability of factual data and the significance of each method may vary depending on the degree of detail that needs to be attained in the section subdivision, the distance between the correlated sections, the facies type of the correlated rock units, etc. The latter plays a significant role in both well log correlations and paleontological studies. The sections may differ from one another in their faunal content, the presence and lateral persistence of marker beds that can be easily recognized by their log curve shapes. Choice of a geological model is critical since it will significantly influence the selection of the correlation option that makes most geological sense and supplementary methods used to estimate the accuracy of correlation. Despite more than half a century of successful oil and gas exploration in the West Siberian petroleum province, the selection of a geological model for the Neocomian play still remains an open problem.

Geological model of the Neocomian

The clinoform geometries of the Neocomian sediments of West Siberia were first recognized by Naumov (1977) in the 1970s. A considerable amount of factual data on the structure of the Lower Cretaceous complex in this region has been accumulated over the last decades. Although the idea about the oblique geometry of Lower Cretaceous strata became widely accepted by geologists, it remains a matter of hot debate. Some researchers, including Nesterov (1992), Onishchenko (1994), Dankov (1995, 1996), Fomichev (1998) and others argue for a horizontally bedded structure of Neocomian sediments and explain an oblique seismic reflection pattern by wave interference, unconformities, and stress conditions associated with the formation of fracture zones or faults, etc. In the past decades, many researchers, namely V.N. Borodkin, V.F. Grishkevich, V.P. Igoshkin, Yu.N. Karogodin, N.Kh. Kulakhmetov, A.R. Kurchikov, O.M. Mkrtchyan, A.L. Naumov, A.A. Nezhdanov, L.Ya. Trushkova, G.D. Ukhlova, F.Z. Khafizov and others have published a series of papers, which discuss different aspects of clinoform structure and genesis. Many ideas that were only recently perceived as novel become

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1068-7971/$ - see front matter
http://dx.doi.org/10.1016/j.rgg.2017.07.007

ordinary and the scientific debate was shifted to other areas. Some scientists believe that the Neocomian complex was formed primarily by deltaic processes, while the others argue for marine basinal processes. There is a vigorous ongoing debate as to the roles of eustatic, tectonic, climatic and other factors in governing sedimentary cyclicity of the Neocomian section, or as to whether sand horizons or shale members dominate clinoform bases and tops, or as to whether deep-water fan deposits of the Achimov Formation have their correlative shallow-water topsets, etc. The answers to these questions are of both fundamental and applied importance for identifying new exploration plays, locating good quality reservoirs and traps.

According to our current understanding, clinoforms are sedimentary bodies showing transgressive–regressive cycle geometries. They were formed in response to eustatic sea-level changes during the Neocomian regression in a relatively deep-water, uncompensated basin that experienced subsidence. It should be noted that the other widely accepted approach to interpreting the cyclicity of the Neocomian section of West Siberia is based on the assertion on the pulsed character of terrigenous sediment supply. It is also widely believed that cyclic sedimentation is caused by climate changes and tectonic activity. In any case, repeated transgressions and regressions, for whatever reason, led to the deposition of rhythmic sedimentary sections.

Up to 20 large-scale regional clinoforms were mapped by different researchers in the Neocomian section. The formation time of Berriasian–Hauterivian clinoforms is estimated from 0.4 to 1.3 Myr. Based on the hierarchical sequence order proposed by Vail et al. (1991), these clinoforms are third-order sequences. The Barreman clinoform unites two sequents of the same order, the total duration of formation of which was 4.5 Myr. There are three sequence models in present-day sequence stratigraphy: Depositional Sequence II, Depositional Sequence III, and Depositional Sequence IV, aside from genetic and transgressive-regressive sequences (Catuneanu, 2006). In the context of the clinoform complex, such models are not alternative and reflect different geological situations. The main difference between the Neocomian sequences of West Siberia and those described in the literature lies in the fact that the Achimov beds representing deep-sea fans were deposited during the progradation together with shallow-water topset beds, i.e., they form part of the highstand systems tract (HST) (Fig. 1). In clinoforms of West Siberia, lowstand systems tracts (LST) are recognizable only in a small part of the section. At the very beginning of the rise in the relative sea level, sedimentation was still regressive. However, the rate of progradation decreased over time, and the aggradational component increased. This part of the section previously interpreted as a shelf-margin systems tract (SMST) is now considered to be part of the LST. This situation can be described by the Depositional Sequence III model.

However, there is some difference between the terms "sequence" and "clinoform", regarding the context of the clinoform complex of West Siberia. If the term "sequence" is a conventional notion, which is used to designate genetically related sedimentary successions produced by eustatic changes in sea level and bounded by unconformities or their correlative surfaces, then the term "clinoform" is used in a broader way. It is used to designate a wedge-shaped body with distinct primary inclination of bedding, which was formed by lateral infilling of an uncompensated basin.

Sequence boundaries of the Neocomian clinoforms are defined based on different principles. In most cases, sequence boundaries often correspond to the bases of regional shale members or strong seismic reflectors. In the latter case, sequence boundaries are marked by transgressive shale members, and clinoforms are selected between the maximum flooding surfaces. In this study, clinoforms are recognized in the volume of a depositional sequence and their boundaries do not always correspond to the bases of regional shale members. In some cases, sandstone beds are selected within the transgressive part of depositional sequences. These sand beds become increasingly shalier in a basinward direction where they merge into the overlying shale member and progressively sandier in a shoreward direction where they may merge into sand beds of the underlying sequence. The selection of an appropriate approach for defining clinoforms should be decided on the study objectives, methods used, and a specific geological situation.

Although the idea of an oblique geometry of Neocomian deposits of West Siberia was first formulated by A.L. Naumov in 1977, the term "clinoform" became widely applied to this complex in the 1980s (Kunin, 1983). It should be noted that when Rich (1951) introduced the term "clinoform" he denoted not the geological body but the sloping surface of a continental slope or delta front foresets. However, in 2000, this term was introduced in the Stratigraphic Code of Russia in the section concerning sequence-stratigraphic units and was used in a broad way for designating wedge-shaped sedimentary bodies (Supplements.., 2000). Later, this term was transferred to the rank of an auxiliary morpholithostratigraphic unit (Stratigraphic Code…, 2006).

According to a sequence stratigraphic model, the base of the clinoforms is marked by regional transgressive shale members with more or less developed basal layers. This concept is widely accepted by the proponents of the oblique model of Neocomian deposits. These members may be traced over the vast area of West Siberia, indicating a significant role of the eustatic factor. An insignificant rise in sea level during continued subsidence of the West Siberian plate resulted in the large-scale flooding of the platform and the onsets of shale deposition. Tectonic regimes in the source areas and within the West Siberian basin were complicating factors, which led to the fact that the same shale members are not equally manifested in different regions of the West Siberian basin. Almost all regional shale members typically have their own names (Pim, Sarman, Samotlor, etc.) and were included in the stratigraphic scheme for the Berriasian–Aptian of West Siberia adopted in 2005. Sand and silt horizons were deposited during regressive phases of clinoform deposition. Some part of clastic material was transported by submarine channels across a shallow-water shelf and was deposited from sediment gravity