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Reservoir Architecture and Log Motifs of Slump/Intrusion Masses (a Comparison of Arkansas Outcrops to Neocomian (K1) Sediments of West Siberia Basin)

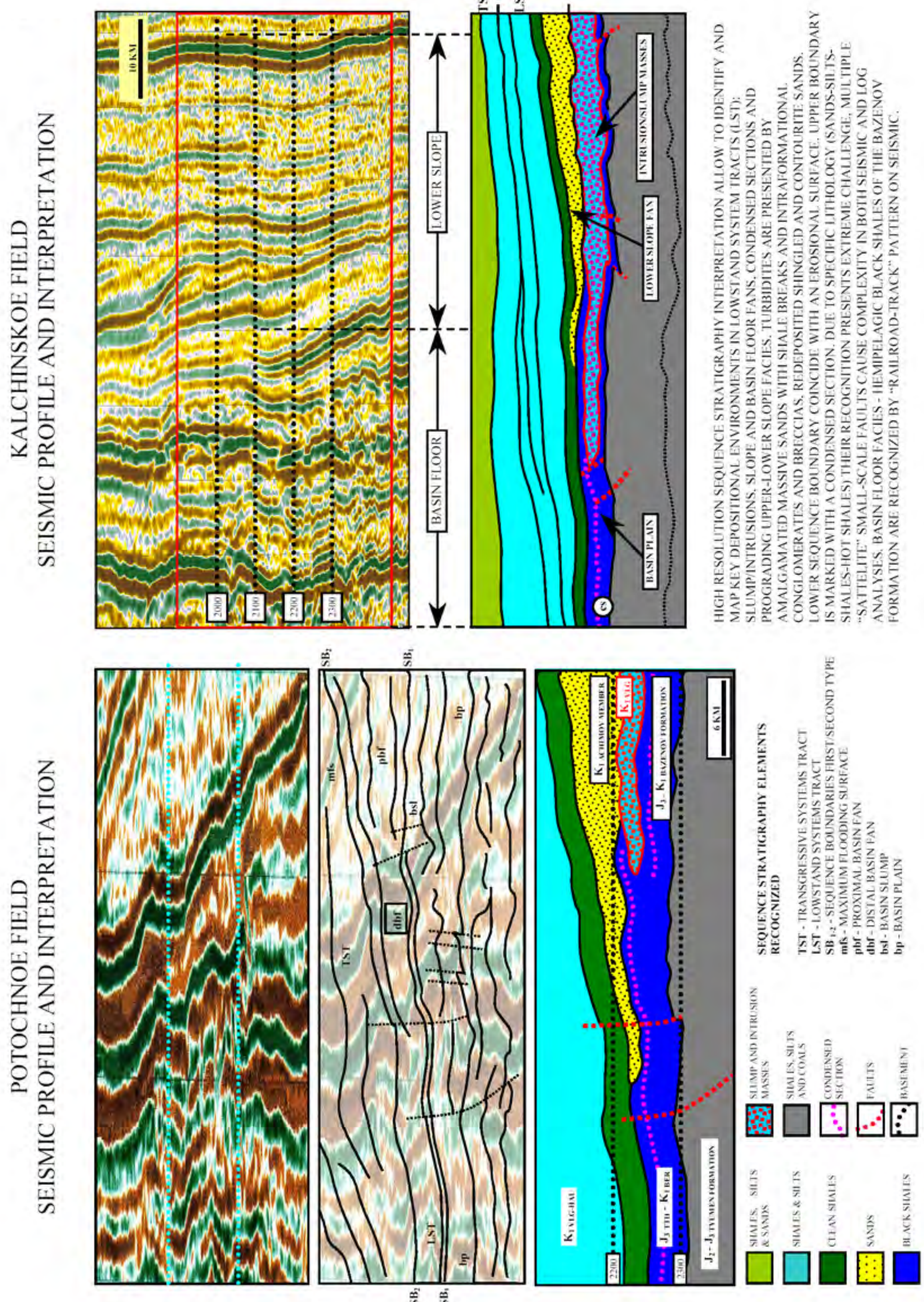
Reservoirs in the slope slump deposits pose multiple challenges to geologists, geophysicists and reservoir engineers. Complex architecture and variations in rock properties make it hard to find good quality facies and optimize their development. In West Siberia basin such problems are enhanced by lack of outcrop analogs and extreme variability in depositional environments of the K1 sequences. Prolific data set (2520 core samples, 380 exploration and 280 production wells, multiple notes and field photos, and 8 seismic surveys) was included into this two-year study. Incorporation of examples from Arkansas (Jackfork Formation) and selected sections from West Texas allows several questions of reservoir geology to be answered with confidence.

The striking characteristic of the Lower Cretaceous section is its well-developed clinoforms (fig. 1). Stacking of the various scales of genetic sequences develops a complex hierarchy of sandstone bodies and various types of sandstone - mudstone contacts. The relative abundance of mudstones separates amalgamated fine and very-fine grained sandstone bodies into a complex, multi-layered, clinoform geometry hydrocarbon reservoir. An integrated sequence stratigraphic analysis of the area indicates that eight distinctive environments could be recognized. These environments correspond to the shelf, upper and lower slope, reworked lower slope (suprafan), distal fan, proximal fan, slump/intrusion masses and basin floor. Interpreted accumulation water depths extend from 50 to 550 meters. In this study we review information and results related to active slump/lower slope sliding facies that traditionally cause multiple interpretation confusions.

During progradational periods the shelf area receives abundant sediments from landward sources, but it's accommodation is limited. Processes of erosion and re-deposition transfer sediments to the shelf-slope break and more seaward where there is a rapid increase in the amount of space, and sands mostly are deposited within the upper slope. Farther seaward, muds rapidly replace deposition of sand-rich sediment. During periods of rapid or enhanced progradation, a shelf-slope break develops in the outermost shelf area. This enhanced progradation is a result of an increased amount of accommodation as sediments continue to be deposited into deeper areas of the basin. If enough sand was transported to the upper slope, they could slide/slump down during subsequent regression or local seismic activities, eroding or partially destroying the underlying formations. During subsequent transgression, the shelf area receives progressively less sediment due to trapping of sands and muds in valley complexes in more landward positions. Eventually, during periods of maximum transgression there is no deposition of sediment in the shelf, shelf-slope break, and deep water environments; at this point the condensed section forms.

In Volgian time (J_{3tth}), the basin was subsiding, placing the majority of West Siberia Plain in a paleo-geographic setting that was in the deep (>500 m.) axial portion of the paleo-basin which was sediment starved. The result was accumulation of an organic-rich shale interval as a remote distal facies of the initially regressive sequence. Simultaneous burring of biomass, highly-dispersed clayey and some vulcanoclastic particles resulted in forming of specific Black Shales with OM transformation under anoxic conditions, low catagenetic processes and low diffusion rates. High amount of carbonaceous and silicia materials aids to fast sediment consolidation. The key character of Bazhenov Formation is a high content (12-17%) of organic matter predominantly of algal and microzoon origin. During

Figure 1


POTOCHNOE FIELD
SEISMIC PROFILE AND INTERPRETATION
TST
mfs
pbf
dbf
bsl
LST
bp
SB₂
SB₁
K₁ VLG-HAU
K₁ ACHIMOV MEMBER
K₁ VLG
J₃ TTH - K₁ BER
J₃ - K₁ BAZENOV FORMATION
J₂ - J₃ TYUMEN FORMATION
2200
2300
6 KM
SHALES, SILTS & SANDS
SHALES & SILTS
CLEAN SHALES
SANDS
BLACK SHALES
SLUMP AND INTRUSION MASSES
SHALES, SILTS AND COALS
CONDENSED SECTION
FAULTS
BASEMENT
SEQUENCE STRATIGRAPHY ELEMENTS RECOGNIZED
TST - TRANSGRESSIVE SYSTEMS TRACT
LST - LOWSTAND SYSTEMS TRACT
SB 1-2 - SEQUENCE BOUNDARIES FIRST/SECOND TYPE
mfs - MAXIMUM FLOODING SURFACE
pbf - PROXIMAL BASIN FAN
dbf - DISTAL BASIN FAN
bsl - BASIN SLUMP
bp - BASIN PLAIN
KALCHINSKOE FIELD
SEISMIC PROFILE AND INTERPRETATION
10 KM
2000
2100
2200
2300
BASIN FLOOR
LOWER SLOPE
TST
LST
cs
BASIN PLAIN
LOWER SLOPE FAN
INTRUSION/SLUMP MASSES
HIGH RESOLUTION SEQUENCE STRATIGRAPHY INTERPRETATION ALLOW TO IDENTIFY AND MAP KEY DEPOSITIONAL ENVIRONMENTS IN LOWSTAND SYSTEM TRACTS (LST): SLUMP/INTRUSIONS, SLOPE AND BASIN FLOOR FANS, CONDENSED SECTIONS AND PROGRADING UPPER-LOWER SLOPE FACIES. TURBIDITES ARE PRESENTED BY AMALGAMATED MASSIVE SANDS WITH SHALE BREAKS AND INTRAFORMATIONAL CONGLOMERATES AND BRECCIAS, REDEPOSITED SHINGLED AND CONTOURITE SANDS. LOWER SEQUENCE BOUNDARY COINCIDE WITH AN EROSIONAL SURFACE. UPPER BOUNDARY IS MARKED WITH A CONDENSED SECTION. DUE TO SPECIFIC LITHOLOGY (SANDS-SILTS-SHALES-HOT SHALES) THEIR RECOGNITION PRESENTS EXTREME CHALLENGE, MULTIPLE "SATTELITE" SMALL-SCALE FAULTS CAUSE COMPLEXITY IN BOTH SEISMIC AND LOG ANALYSES. BASIN FLOOR FACIES - HEMIPELAGIC BLACK SHALES OF THE BAZENOV FORMATION ARE RECOGNIZED BY "RAILROAD-TRACK" PATTERN ON SEISMIC.

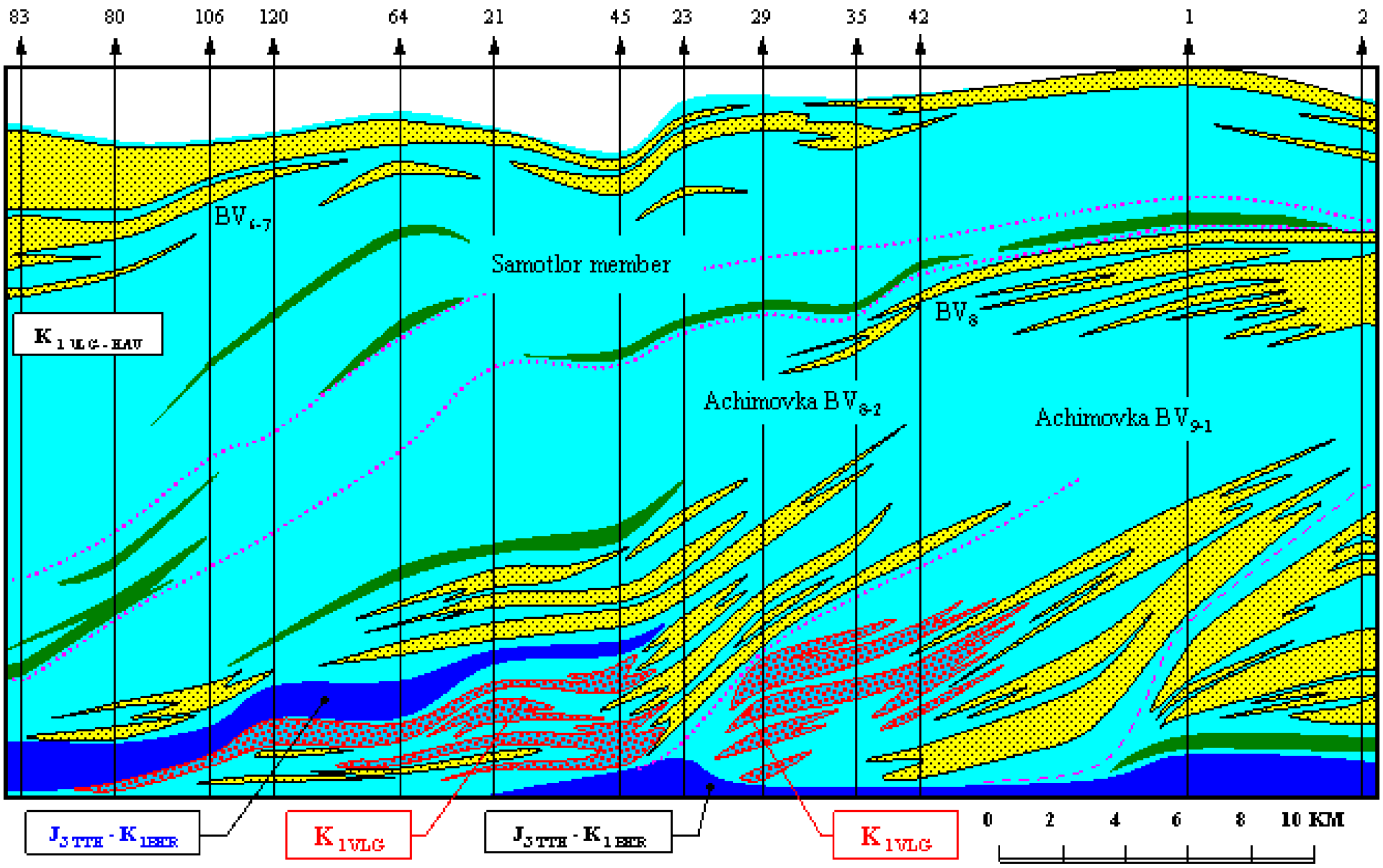


Figure 2
Geological cross-section through Potochnoe area, with two avalanche deposited slump masses one over another (K_{1vlg}). Second sequence forms an intrusion or lateral diapir uplifting Black Shales (J_{3tth} - K_{1ber}) over a significant distance.

Table 1
Paleo data from slump and intrusion sequences, suggesting younger (K_1) age of intrusion or older (J_3) age of uplifted Black Shales.

Intrusion	Interval	Paleodata	Age	Field & author
2681-2825	2728-2734	Ammonites: *Dorsoplanites sp.indet., Pavlovia cf. iatrensis Ilon emend. Michl.; Dorsoplanites sp(cf.D.antiquus Spath); Dorsoplanites sp.indet.; Pavlovia cf. iatrensis Ilon emend. Michl*	$J_3v_2^1$.	Tagrinskoe 55. Vyachkileva N.P.
2673-2824	2732-2737 2737-2740	Ammonites: *Dorsoplanites sp.cf. flavus Spath*; abundance *Laugeites and Dorsoplanites*;	$J_3v_2^3$	Tagrinskoe 70, Vyachkileva N.P.
2977-3077	3047-3067	Spore and pollen	$K_{1\ Ber-Vlg}$	V-Perevalnoe 42, Bezrykova T.S.
		Spore and pollen: abundant *Conifers* lack of *Classopolis*	K_1 (Neocomian)	Tevlinsko-Russkinskoe 118

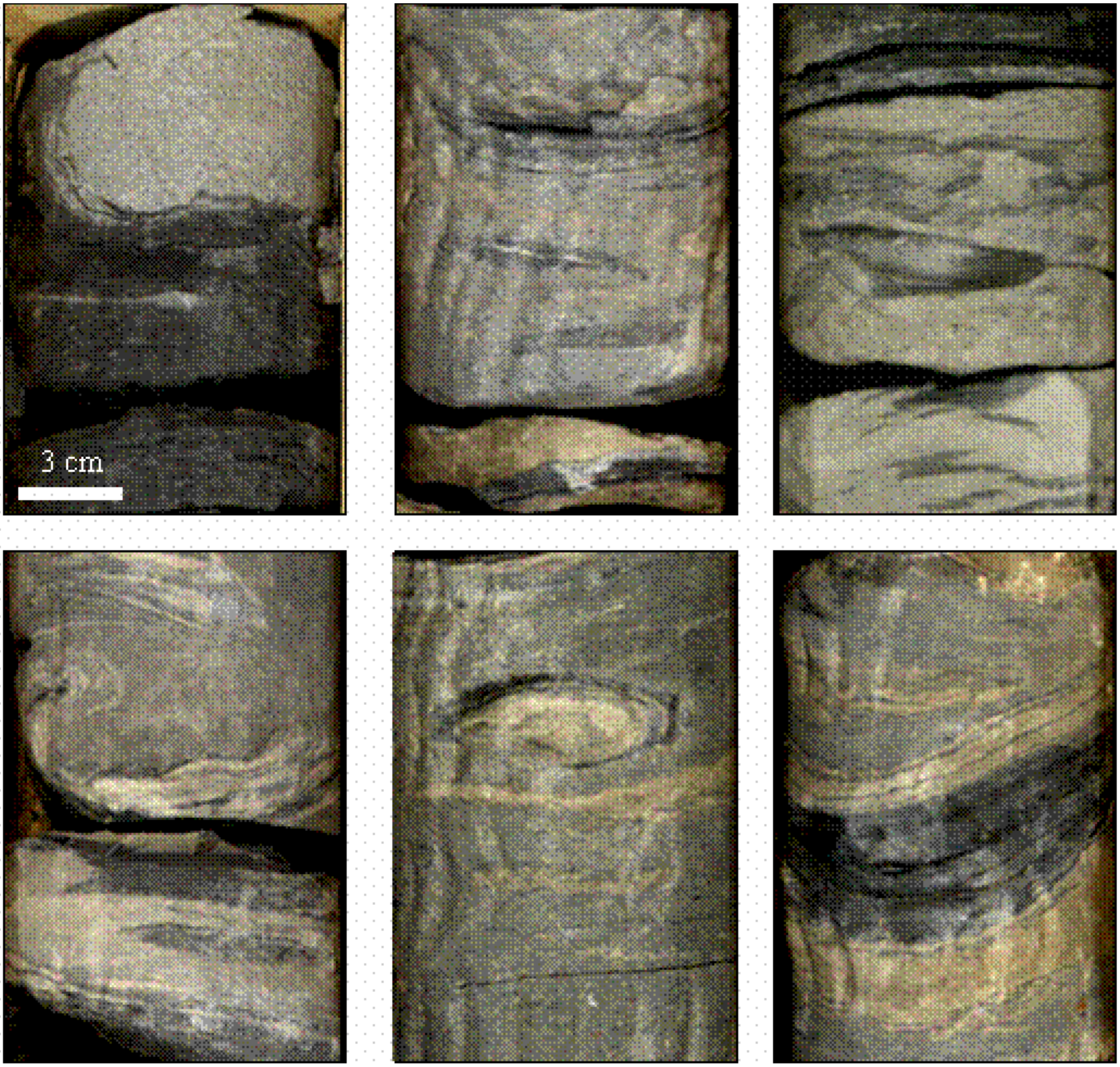


Figure 3.

early Berriasian time the central part of basin began to experience the onset of a prolonged period of regional transgressions and regressions against the background of a major regression superimposed on a local tectonic settings (paleorelief). Clinoforms which are isochronic packages elongated to the paleo-axis of the basin, began infilling the area from the east-southeast, and gradually filled the basin; sometimes resulting in catastrophic avalanche-type events.

These slump bodies have a very distinct shape: in west directions they are progressively joining and forming a single unit; in east directions they are separated by sands and sand-shale masses; and then abruptly disappear. In Ur'evsko-

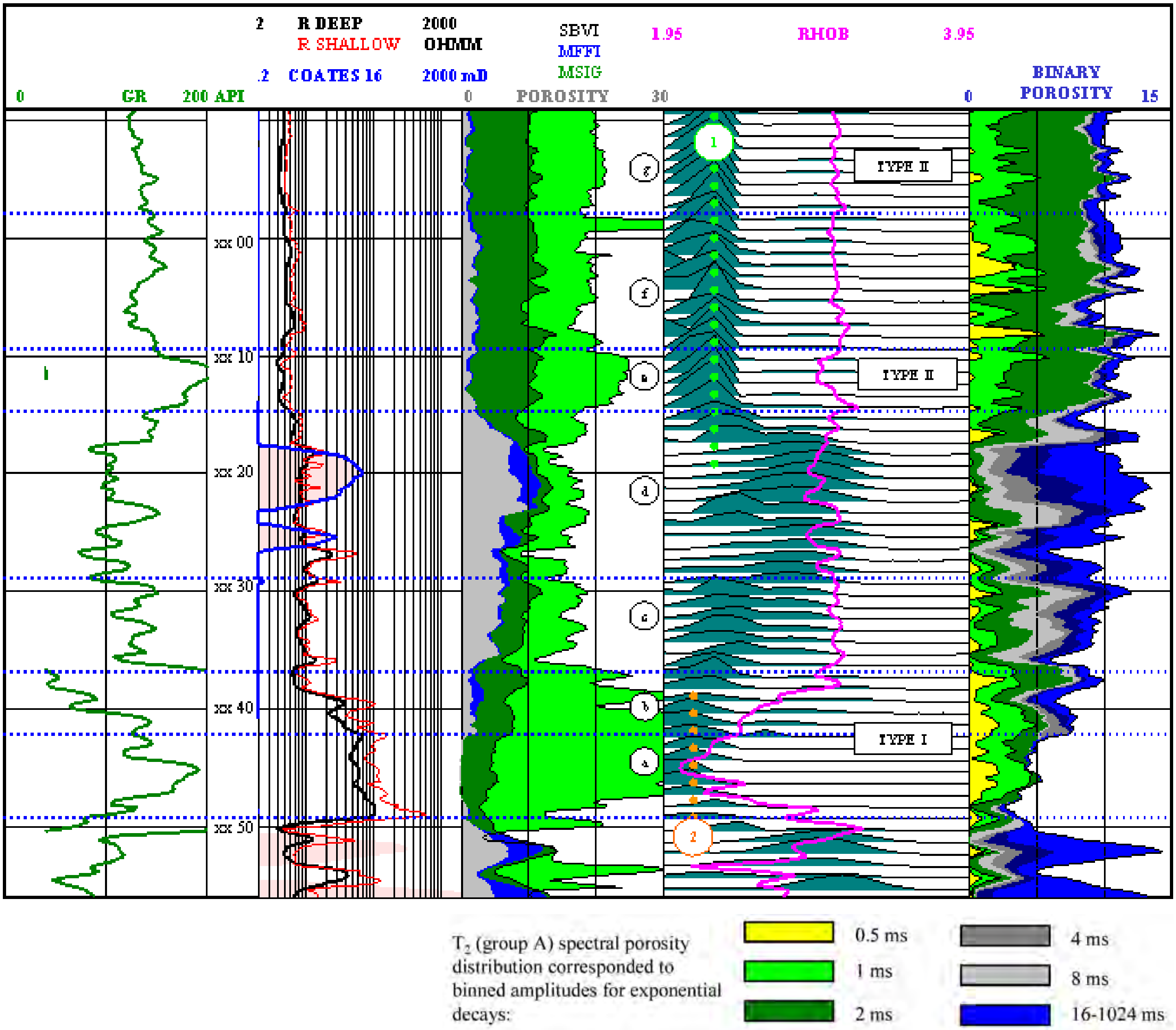


Figure 4.
Two successions of slump deposits and Bazenov Black Shale Formation are recognized on NMR materials in well 51348, Ust-Vakh (Samotlor) field.

Potochnaya area such slumps occurs as a separated "tongues" up to 15 km long and 3-6 km wide. Similar events have been described from ancient deep-sea clastic sequences, some with volumes of the order of 10 km^3, and may be interpreted as an indicator of paleo-seismology. Multiple slump deposits and associated intrusion masses are observed at the boundary between K_1 (Neocomian) and J_3 (Valanginian) sequences in Uvatskoe, Zimnee, Endurskoe, Kalchinskoe, Severo-Demyanskoe, and Tor-Eganskoe fields. This specific geological phenomenon occurs at the lower slope and at the basin floor, and forms an excellent target for oil prospecting. High-resolution sequence stratigraphy analyses show that they were formed during cycles of sea level falling when abundant sand masses were discharged in a deep-water zone. An abnormal sections (stratigraphic anomaly) with younger (K_{1vlg}) sediment intrusions or lateral diapirs into older Bazenov Black Shales (J_{3tth}- K_{1ber}) were formed when high density avalanche masses strikes into local paleohighs close to basin floor-lower slope boundary (table 1). These deposits could be recognized on seismic profiles were they are represented by chaotic low amplitude reflections. Towards basin floor slump facies progressively form a "shingled" type of seismic reflections with very good amplitudes and low continuity. In cores they are characterized by sliding and flowing structures, presence of elongated clasts of underlying formations in sandy masses, multiple gliding planes and slick-an-sliding.

Paleofacies recognized on log diagrams and in outcrops are often serve as a key to optimal exploitation of a hydrocarbon accumulation and an advanced understanding of the reservoir's geometry. The characteristic of single curve (SP or GR for example) is inconclusive as its deflection may or may not indicate the changes in various parameters. Complex mixture of various lithologies (carbonates, silica shales and various sandstones) in slump sediments suppresses density, sonic and neutron response making them non-diagnostic in reservoir quality prediction. In attempt to resolve these problems an NMR log has been runned using tool pusher (fig. 4), providing information on the specifics of pore structure and identifying facies of slump system in xx00 - xx70 m. interval, as well as qualitatively assess some changes in clay mineralogy.

A spectacular variety of depositional structures in Neocomian slumps/intrusion facies: balls, folds, thrusts, overfolds rotational slump scars etc. Sedimentological study was based on the core analysis from the fields: Kalchinskoe, Tor-Eganskoe, Vyemskoe, Suvero (North) Tumskoe, Zimnee, Em-Egovskoe and Probskoe. The field descriptions were made with note of lithology, thickness, contacts, grain size, color, bedding, and trace fossils. However final interpretation become possible only after outcrop materials (Atoka, Bloyd and Jackfork Formations) and some of modern (Middle to Late Eocene) Yegua - Cook Mountain Formations in the Texas and Louisiana Gulf Coast Basins were reviewed.

Two types of shales Type I - Black Shales (J_3) with partial recovery, and Type - II Neocomian (K_1) with full recovery were recognized; some additional fast components appear at "f" due to intermixture and subsequent re-deposition. Noticed that maximum of fast T_2 components associated with microporosity is shifted from "normal" position (1-green) in Achimov shales, to faster position, and even part of spectrum is missing (2-orange). "Hot shale" signature typical for Black Shales @xx36.7-xx50.4 m. (a,b) and @xx09.2-xx15.5 (e), NMR undercalling porosity due to significant presence of iron (pyrite), tar in vugs and unknown matrix lithology. Cavernous part of Black Shale Formation with FFI signal at the upper part (xx38.6 m.) marked as "b".