Geologic Framework for the Tengiz and Korolev Fields, Kazakhstan – Carboniferous Isolated Carbonate Platforms*

By
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Abstract

The supergiant Tengiz field exhibits depositional features typically observed in isolated carbonate platforms but rare for the Carboniferous: extensive inner and outer platform deposits, a raised rim feature, steep platform margins, and thick flank deposits. Many of the same platform and slope features observed in Tengiz are inferred from much less well data for Korolev.

Platform Growth and Stratigraphic Framework

The Tengiz and Korolev platforms formed during the Carboniferous on the Primorskian Arch, one of several structural highs in the southeast portion of the PriCaspian Basin in western Kazakhstan. The platform edges are abrupt, showing a relatively rapid change from the platform top (platform, shoal, or platform margin) to slope environment. Platform deposition includes cycles shoaling upward from open marine packstones to shoal grainstones. A reef (microbial boundstone with scattered megafossils) is localized to a very narrow belt along the platform margin. Boundstones give way downslope to breccias and finally argillaceous lime mudstone beds. A variety of open porosity types are present; karst zones are best developed in the rim, and fractures characterize both the rim and flanks.

A hierarchy of cycles, sequences, and composite sequences is developed by integrating core and well logs with newly acquired 3D seismic data. The stratigraphic framework, although not finalized, explains many aspects of the reservoir quality. The buildup (actual thickening) of the platforms was seemingly initiated in the Devonian and accentuated greatly during Visean time. The position of the platform margins is controlled, in part, by deep-seated faults. The areal extent of both platforms generally diminished during the Carboniferous as evidenced by backstepping of the younger margins.

Key Platform Well

Tengiz well T-220, because of the great amount of continuous core taken in the well, is invaluable from the perspective of understanding the nature of deposition, stratigraphy, diagenesis, reservoir quality, and log response for the interior portion of the platform.

The upper contact of the Bashkirian is significant as it represents the demise of the shallow water platform. Three sequences of similar grainstone-dominated deposits form a composite sequence that comprises most of the Bashkirian. Four sequences recognized within the Serpukhovian form another composite sequence. The boundary between the Bashkirian and Serpukhovian is significant as it represents a major change in the style of deposition on the top of the Tengiz platform and equates with a time gap. Serpukhovian facies reflect slightly deeper water and more skeletal-rich environments. Three composite sequences are tentatively identified within the Visean (Oksky) interval; each contains three sequences consisting of grainstone-packstone cycles that are similar to those of the Serpukhovian. A portion of one sequence recognized within the upper part of the Visean (Tula) contains packstone-grainstone cycles. The difference in the character of the cycles between the Visean (Oksky)-Serpukhovian and the Bashkirian reflects changes in the nature of sea-level variations that occurred between Early and Late Carboniferous.

Porosity loss in T-220, and other Tengiz platform wells, is by calcite cementation and minor compaction. The variety of open primary and secondary pore types is a principal reason for the permeability variation that is observed within the well. Core samples are dominantly limestone with local partial dolomitization and silicification associated with tuffs or subaerial exposure.

T-220 displays more-or-less constant 15% porosity with 1-10 md permeability, separated by thin tighter intervals at sequence and cycle boundaries. Where bitumen occurs, it displays an inverse correlation with porosity (that is, bitumen is more abundant in rocks with low porosity). Samples with bitumen occur in short intervals, almost always at sequence or cycle boundaries, with long intervals in between with zero bitumen. The downhole porosity logs show an excellent match to core porosities; gamma-ray response increases where tuffs and shales are present.

Key Flank Well

Tengiz well T-47 is a flank well located off the southeast edge of the platform; it is an important well from the perspective of understanding the nature of deposition, diagenesis, reservoir quality, and log response in the flanks of the platform.

The Bashkirian through Visean (Oksky) consists of two general rock types: (1) coarse-grained (rudstones and grainstones rich in boundstone intraclasts), and (2) finer-grained (grainstones, packstones, and wackestones). Both rock types represent debris that was shed down the slope from the platform margin. The Visean (Tula) is predominantly fine-grained slope packstones. The Devonian (Famennian) consists of shallow platform grainstones and packstones.

T-47 penetrated a generally limestone stratigraphy, with three important exceptions: (1) dolomite-rich intervals with 50% to 70% dolomite in the basal Serpukhovian, and lower Visean (Tula) through top Devonian; (2) a silica-rich interval in the Visean (Tula); and (3) a barite-rich interval with 0% to 26 wt.% (17 vol.%) barite near the top Devonian. Bitumen fills 10% to 15% of the potential porosity (defined as core measured porosity plus bitumen) in most samples.

The Bashkirian through Visean (Oksky) slope deposits have open porosity of three types: isolated vugs, pores between clasts, and microfractures. The Visean (Tula) packstones are varyingly silicified, and a few small, open vugs are the only visible porosity.

Wireline logs indicate a porosity distribution that is generally consistent with the limited core data. Small, isolated, bitumen-stained vugs, fenestral pores, and microfractures remain open in a few Devonian grainstone and packstone samples.

Wireline logs indicate a porosity distribution that is generally consistent with the limited core data. Porosity from 0% and 9% typifies the section above the Devonian; porosity generally <4% is representative for the Devonian. The Visean (Oksky) slope deposits appear on an FMI log as irregular layers dipping up to 30° that are rarely continuous across the image, and thin continuous layers gently dipping way from the platform characterize the Visean (Tula) slope deposits. Irregular continuous layers with dips <5° typify the Devonian platform deposits.

Acknowledgements

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GEOLOGIC FRAMEWORK FOR TENGIZ AND KOROLEV FIELDS, KAZAKHSTAN

CARBONIFEROUS ISOLATED CARBONATE PLATFORMS

AAPG International Distinguished Lecture Tour

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OUTLINE OF TALK

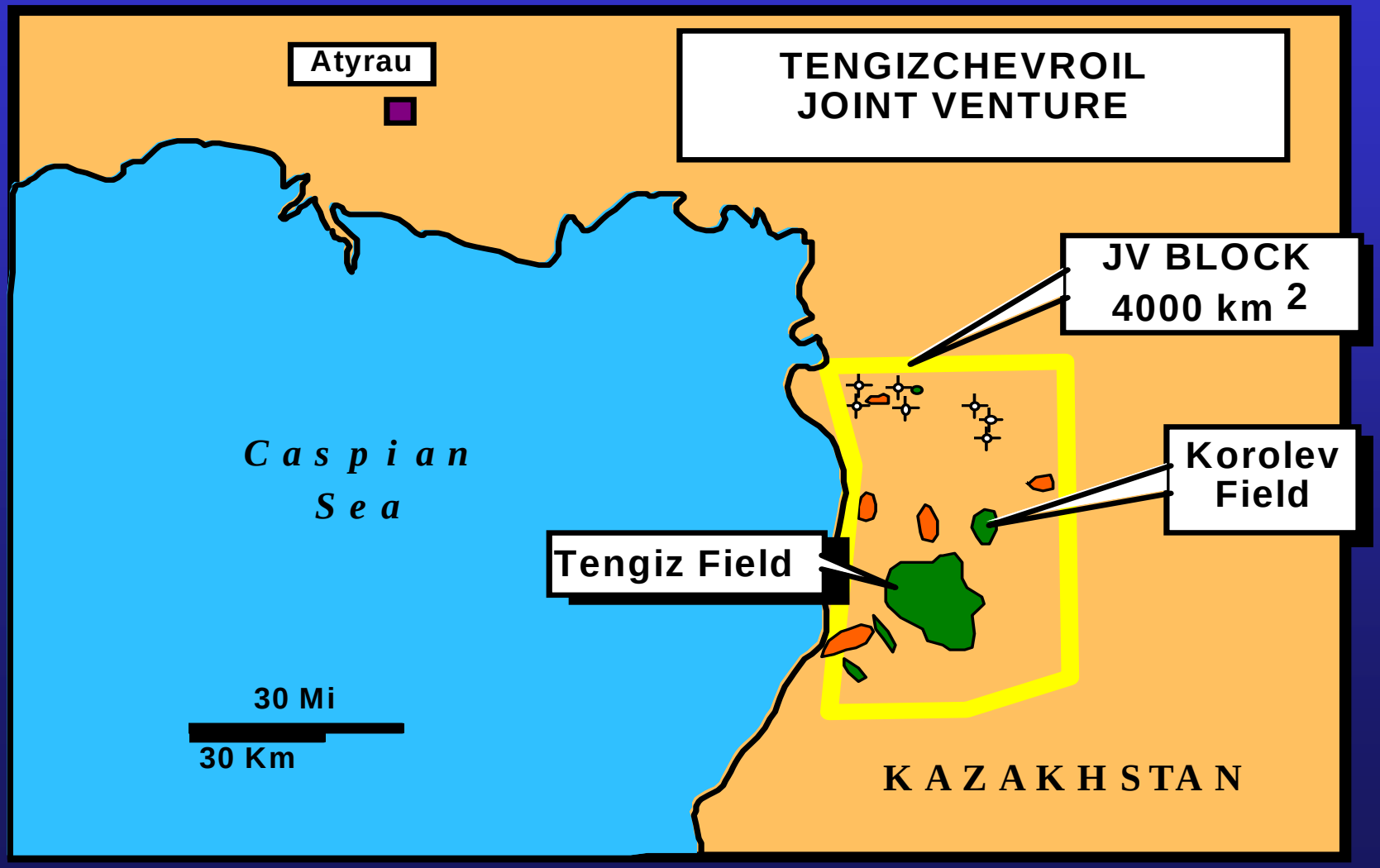
Geological Setting

Key Platform Well

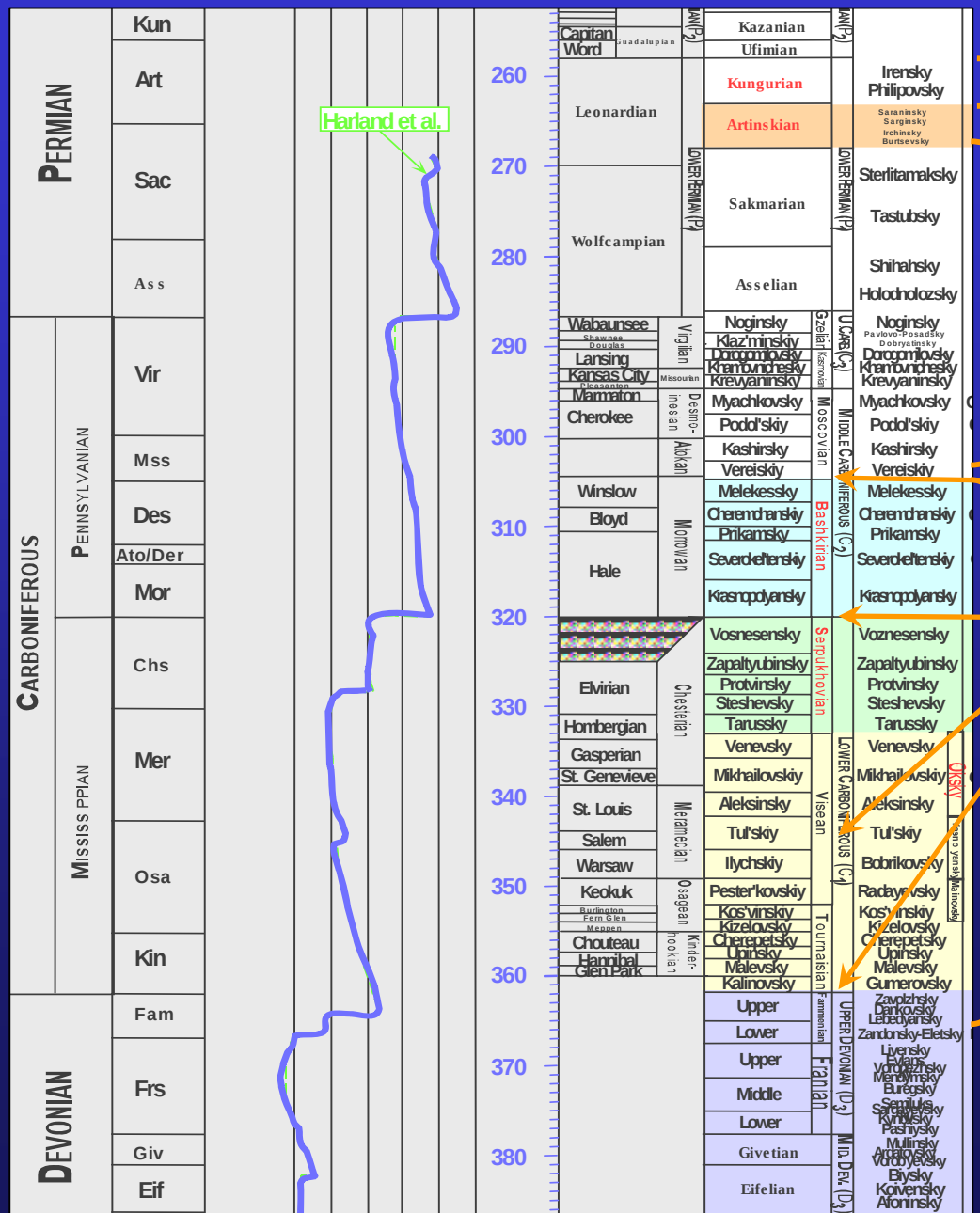
Key Flank Well

Summary

LOCATION MAP

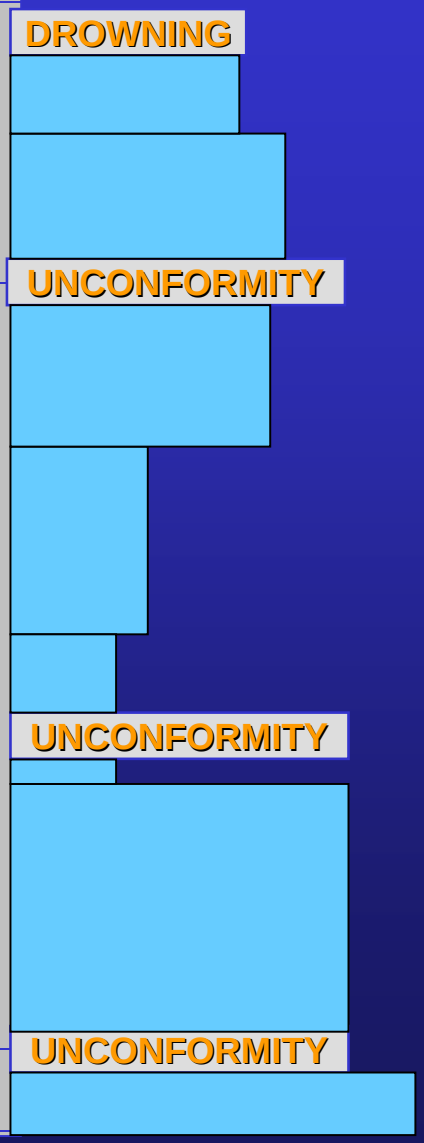


TIMING OF IMPORTANT EVENTS

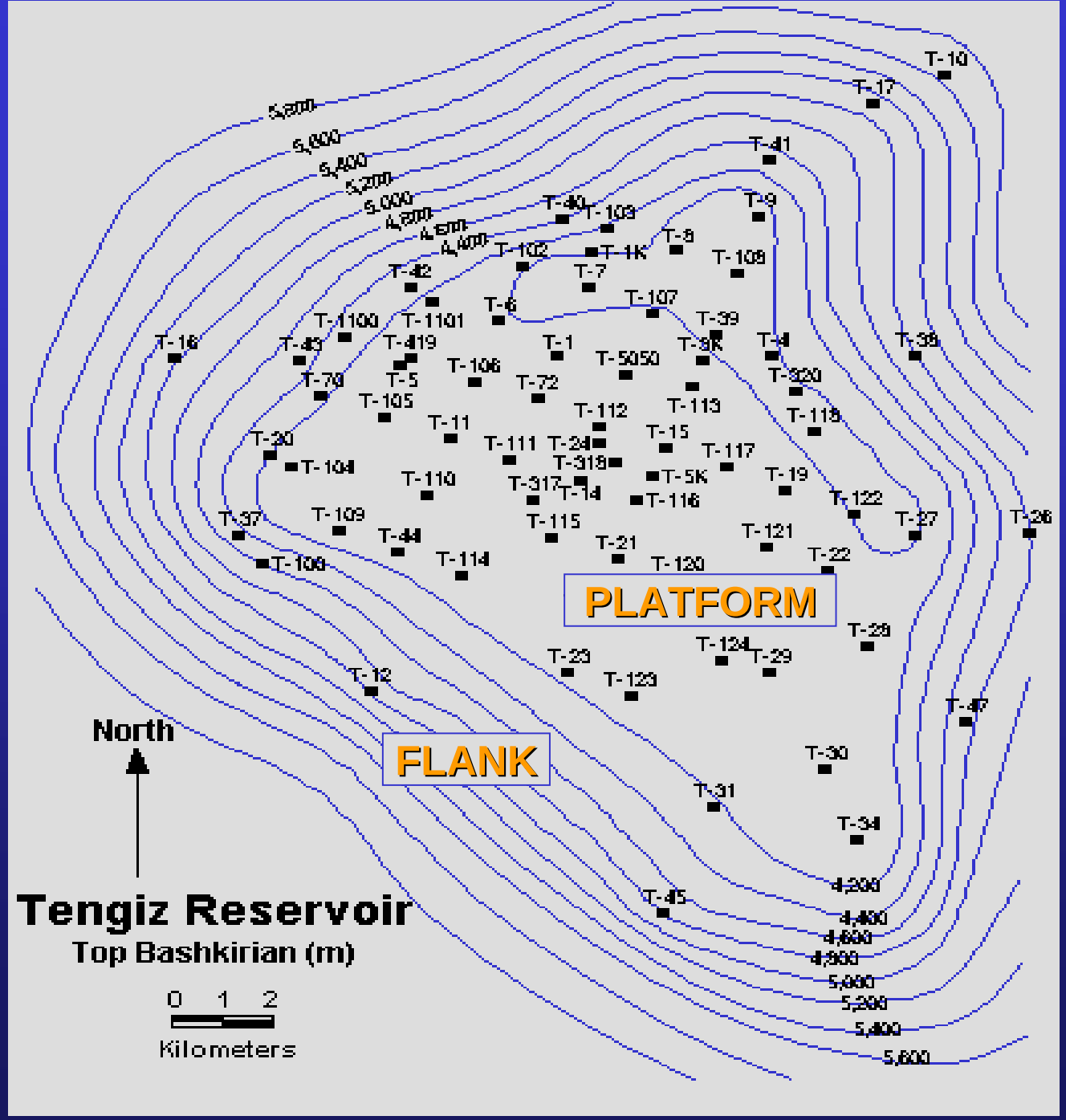


PLATFORM EVOLUTION

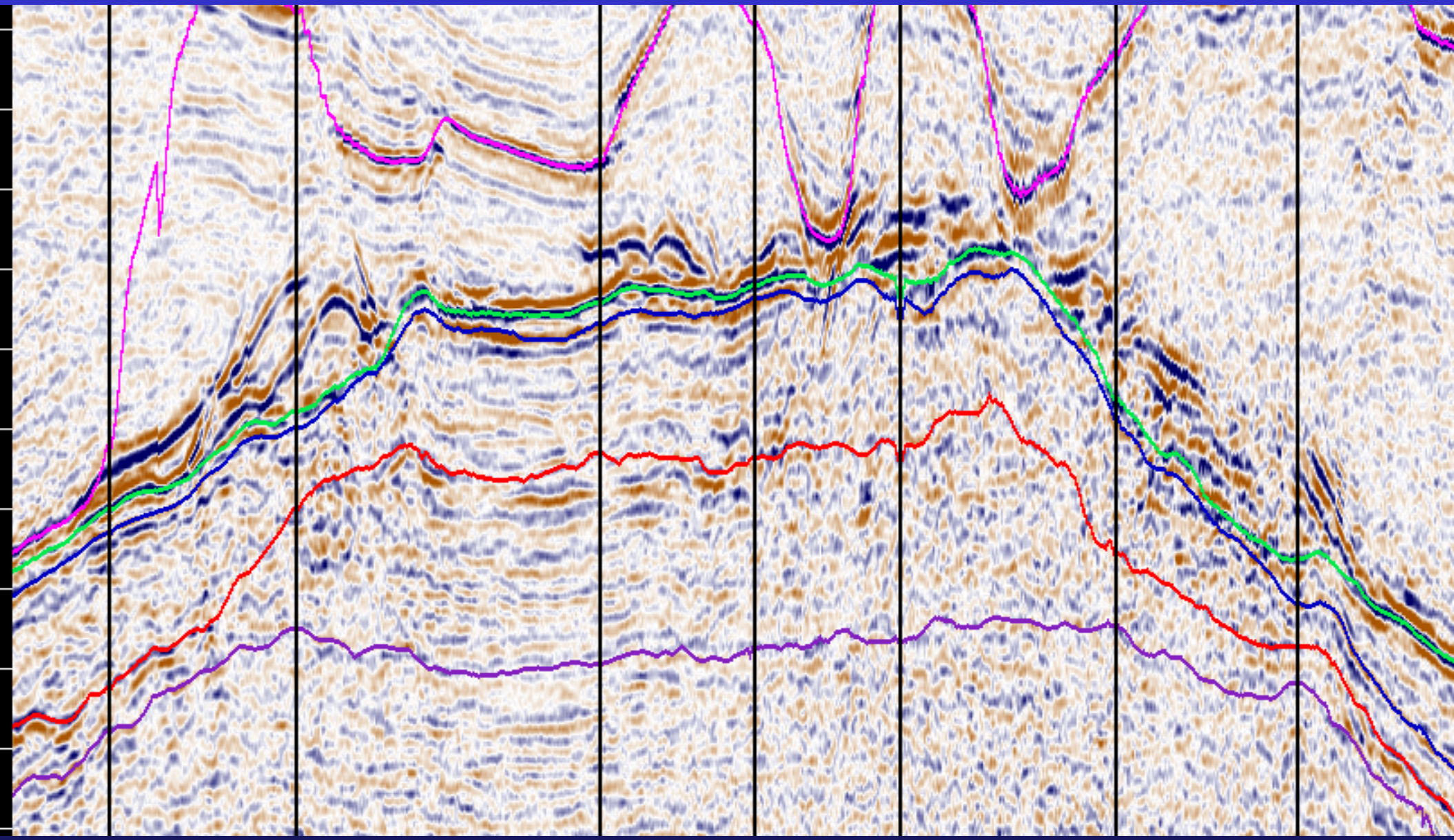
Ma (BASE)	HORIZONS		RUSSIAN STAGES		RUSSIAN SERIES
311.5 (top)- 312.0 312.5	Asatausky (Asa) Tashastinsky (Tas)		LATE	BASHKIRIAN	EARLY MIDDLE CARBONIFEROUS
312.8 313.2 313.6 314.0	Askynbashsky (Ask) Akavassky (Ak) Syuransky (Syu) Bogdanovsky (Bog)		EARLY		
316.75 319.5	Zapaltyubinsky (Zap) Protvinsky (Pr)		LATE	SERPUKHOVIAN	LOWER CARBONIFEROUS
322.25 325.0	Steshevsky (St) Tarussky (Tar)		EARLY		
328.5	Venevsky (Ven)	Oksky Super-horiz.	LATE	VISEAN	
330.5	Mikhailovsky (Mik)				
332.75	Aleksinsky (Al)				
335.0	Tulsky (Tul)				
341.5 343.0	Bobrikovsky (Bob) Radaevsky (Rad)		EARLY		
345.5 348.0	Kosvinsky (Kos) Kizelovsky (Kiz)		LATE	TOURNAISIAN	
349.5 351.0 352.5 354.0	Cherepetsky (Ch) Upinsky (Up) Malevsky (Mal) Gumerovsky (Gum)		EARLY		
364.5			FAMENNIAN		LATE DEVONIAN
369.0			FRASNIAN		



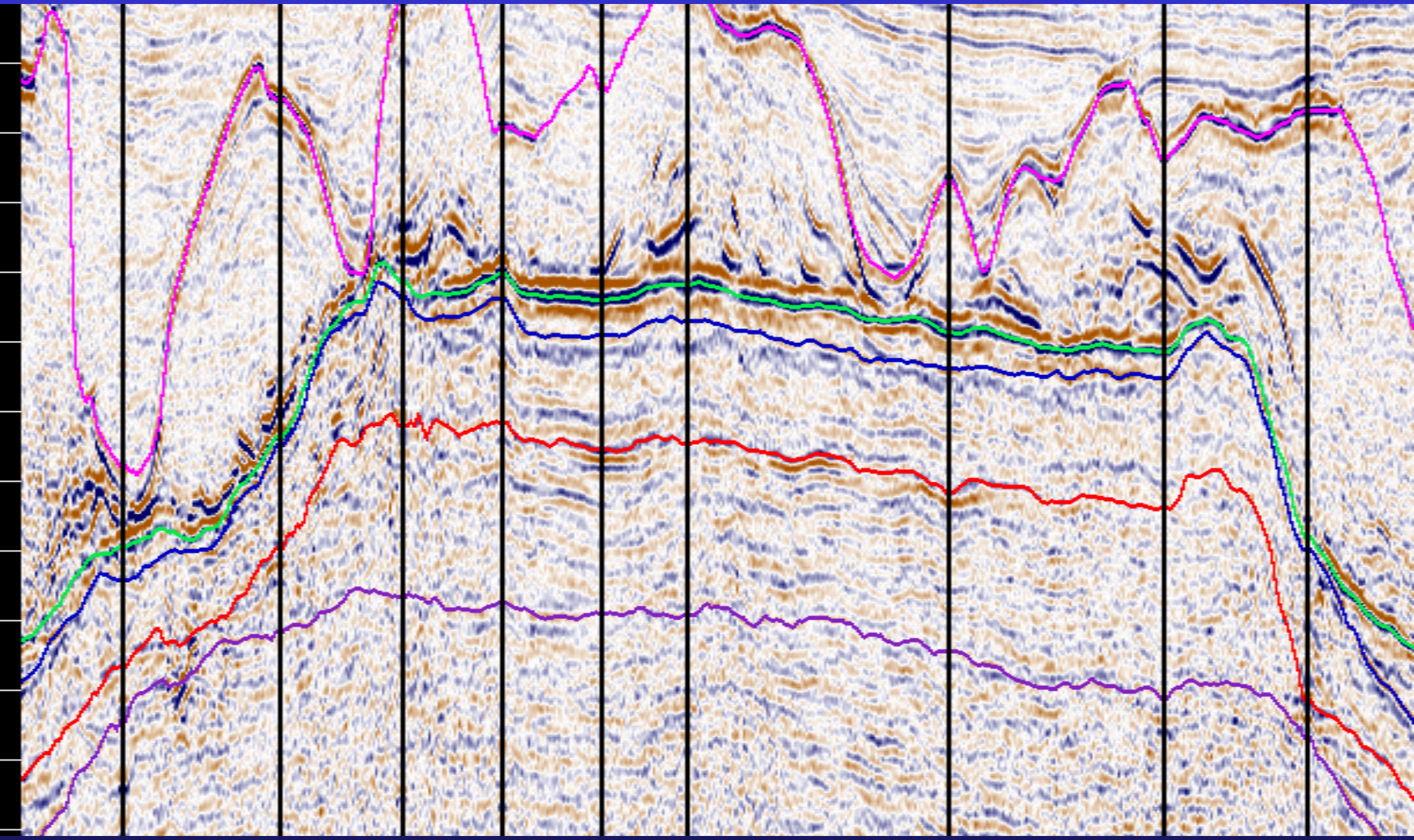
TENGIZ WELL LOCATIONS



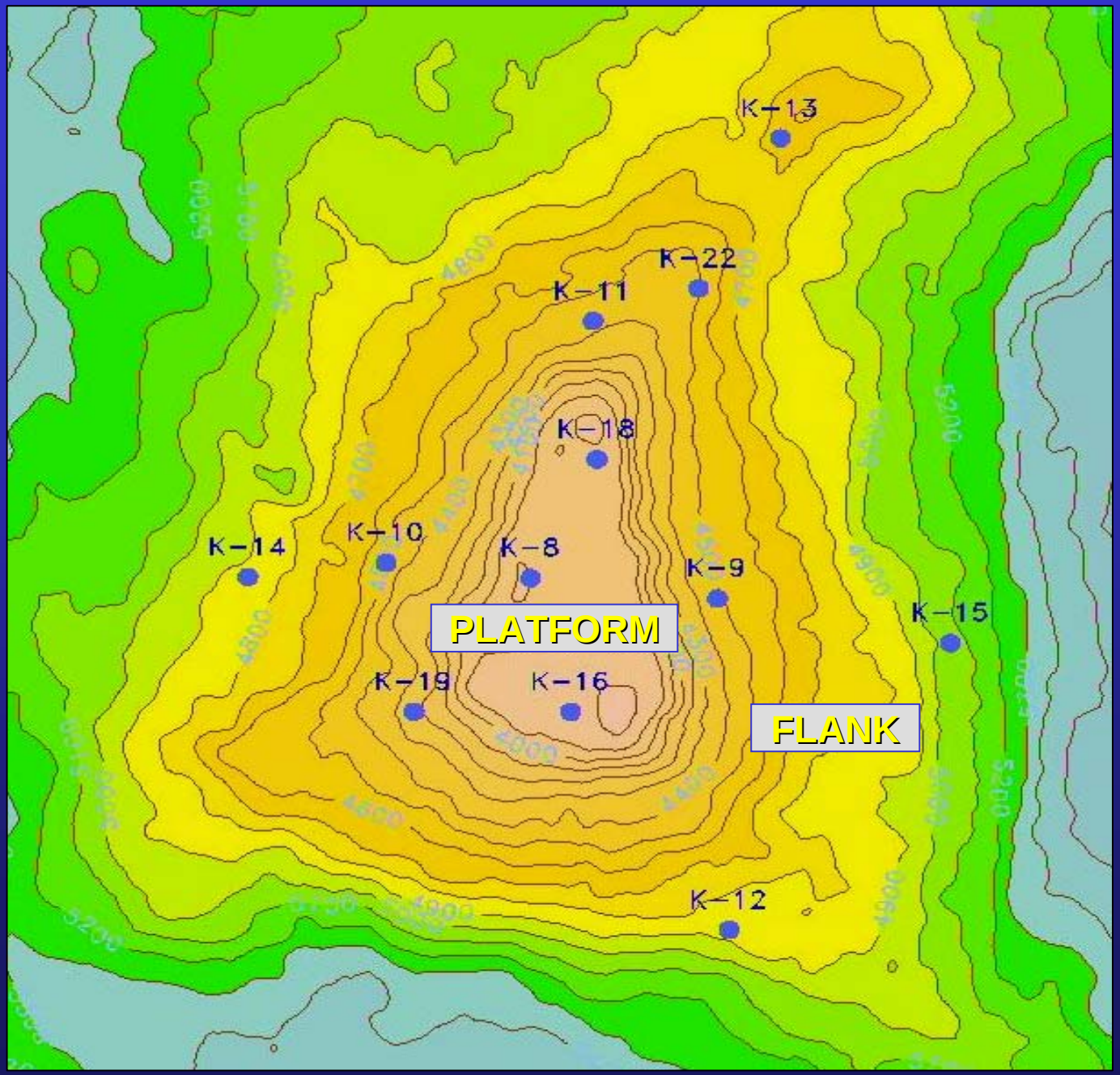
TENGIZ 3-D SEISMIC



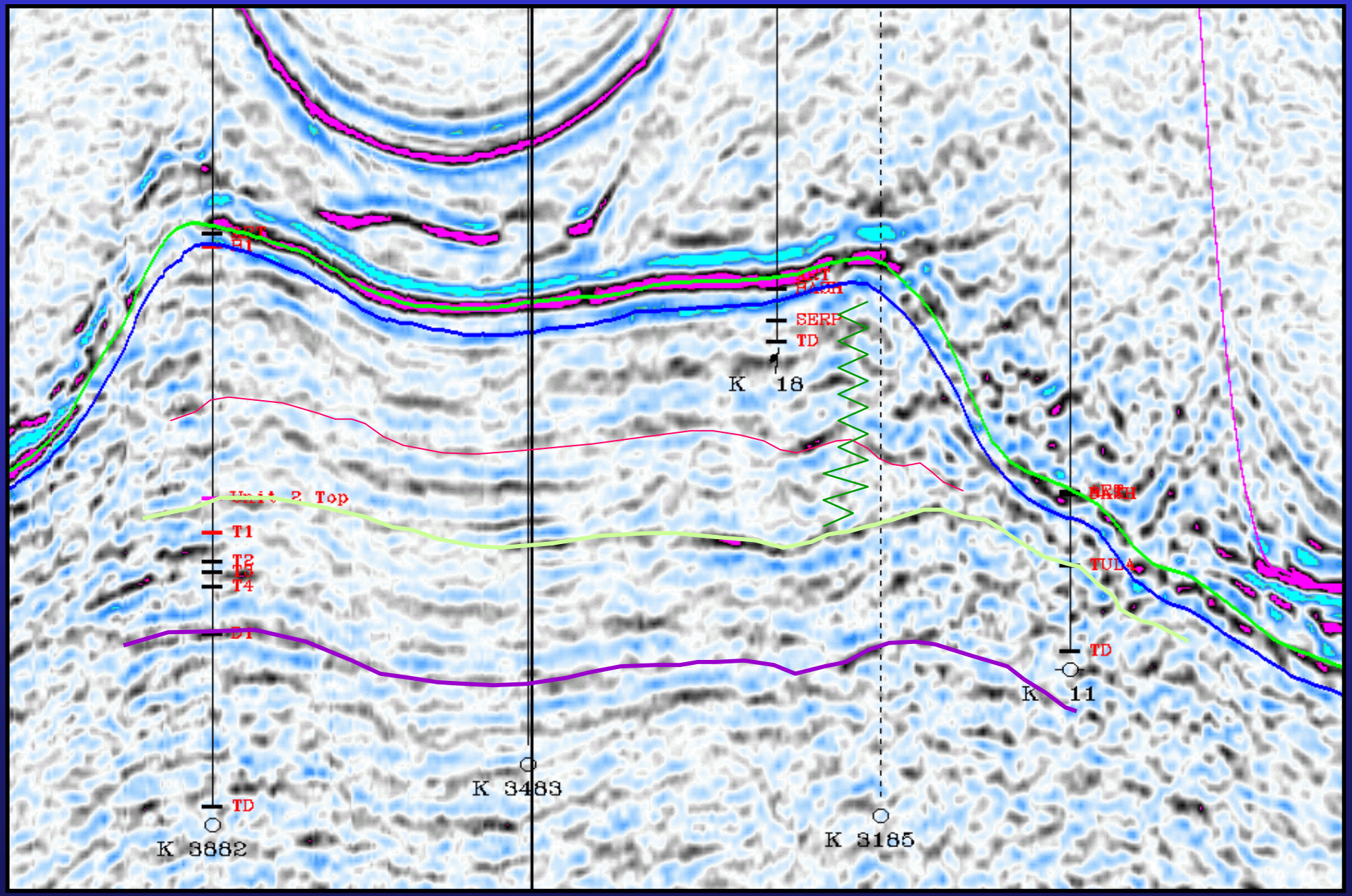
TENGIZ 3-D SEISMIC



KOROLEV FIELD MAP



KOROLEV 3-D SEISMIC



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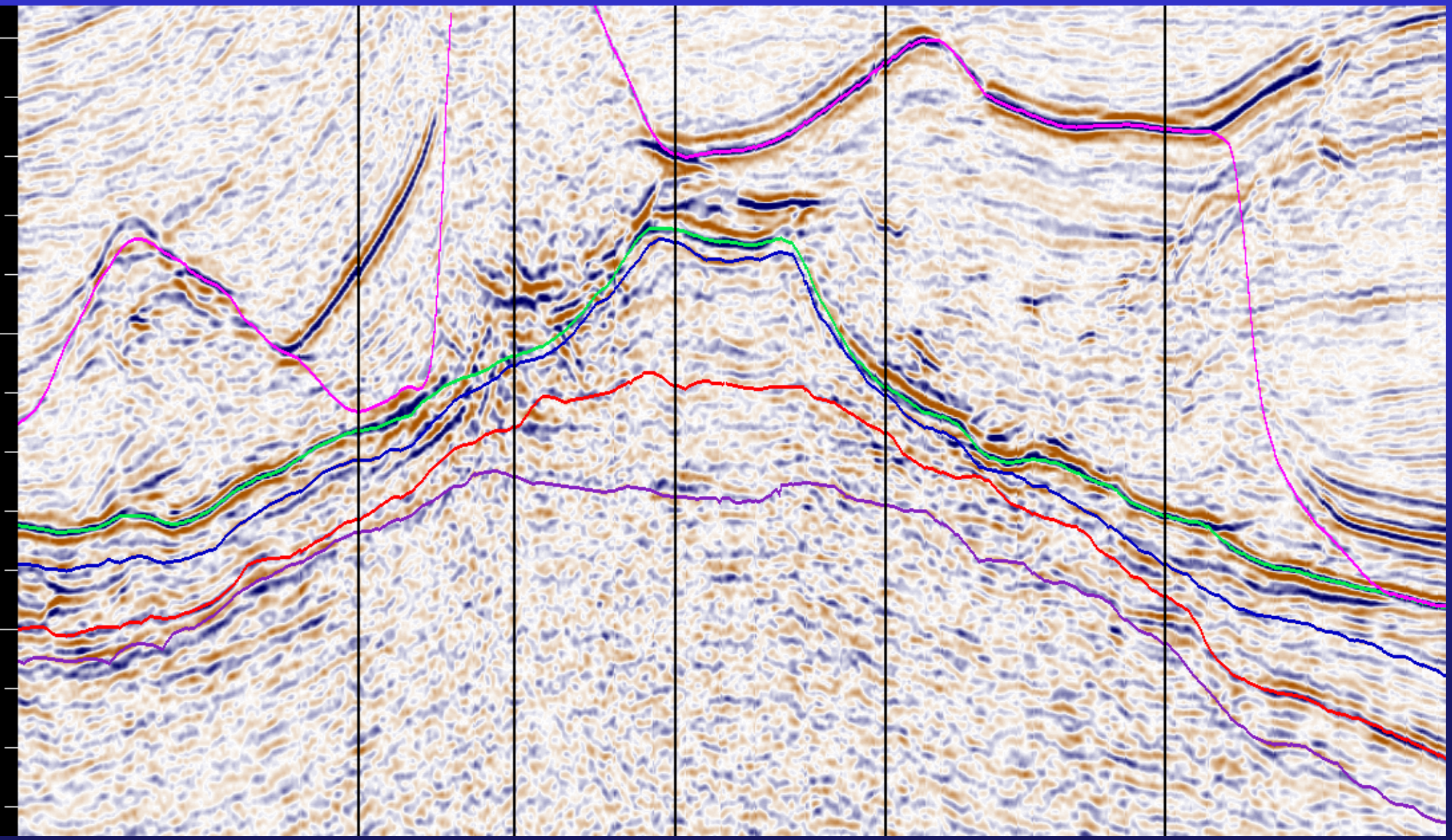
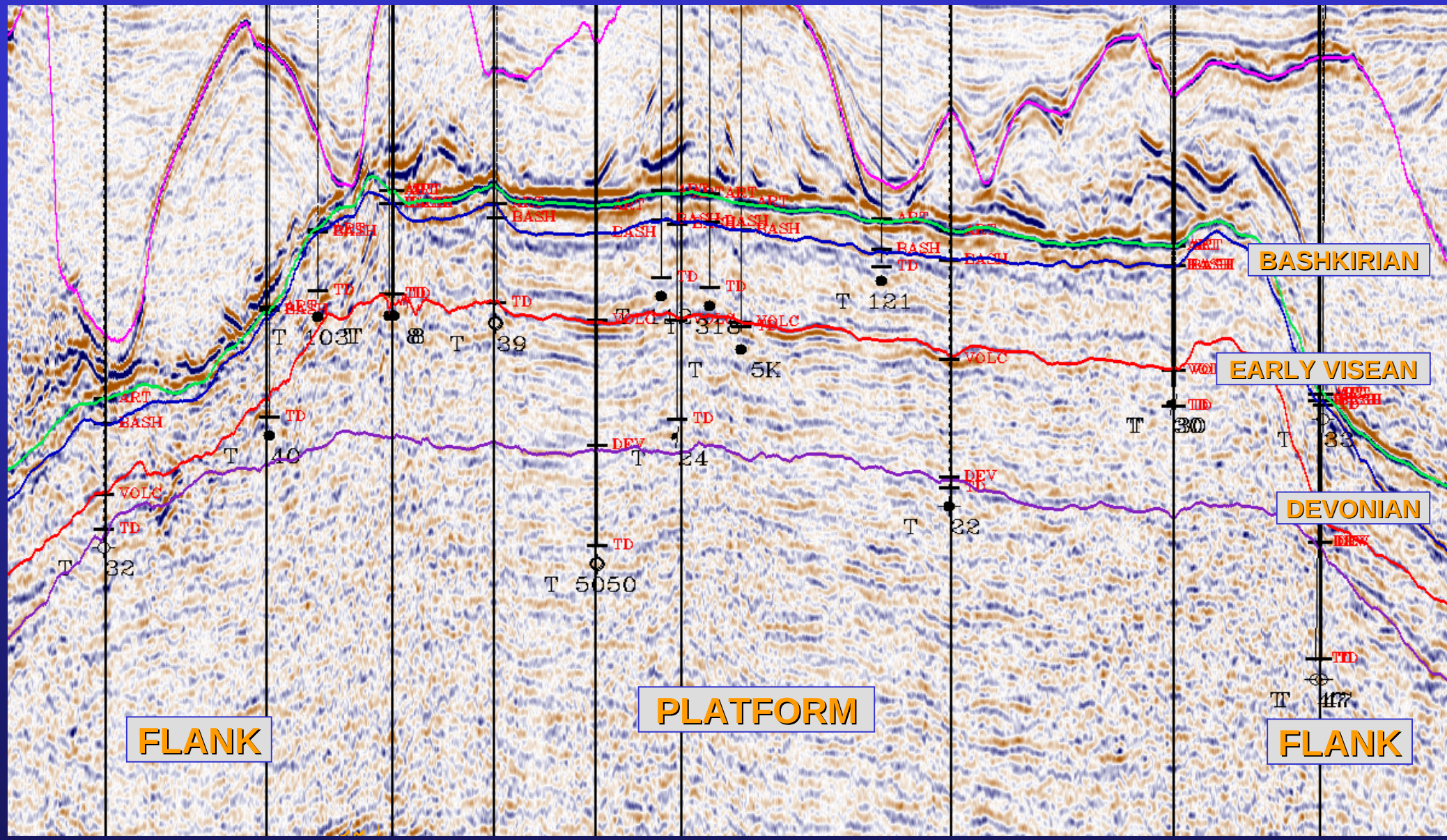


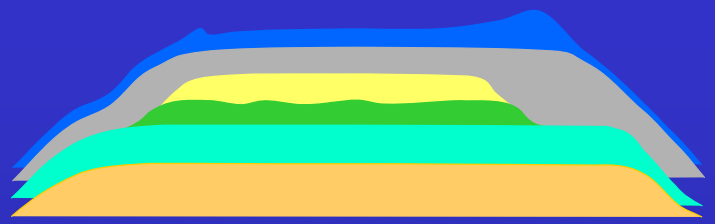
TENGIZ 3-D SEISMIC



TENGIZ STRATIGRAPHIC MODEL

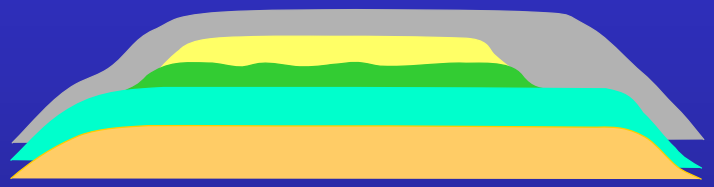
PLATFORM STYLE

BASHKIRIAN



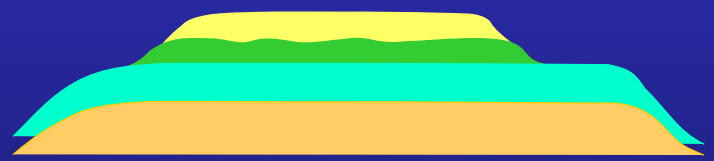
DROWNING
RETROGRADING

SERPHUKHOVIAN



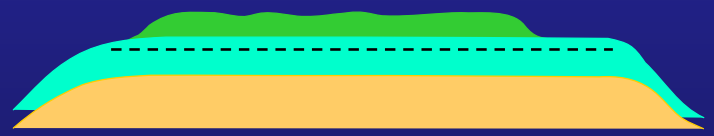
MAJOR SB
FLANK DEPOSITION
PROGRADING
AGGRADING

LATE VISEAN



AGGRADING
FILL-IN RELIEF

EARLY VISEAN



RELIEF ON MAJOR SB
AGGRADING
BACKSTEP

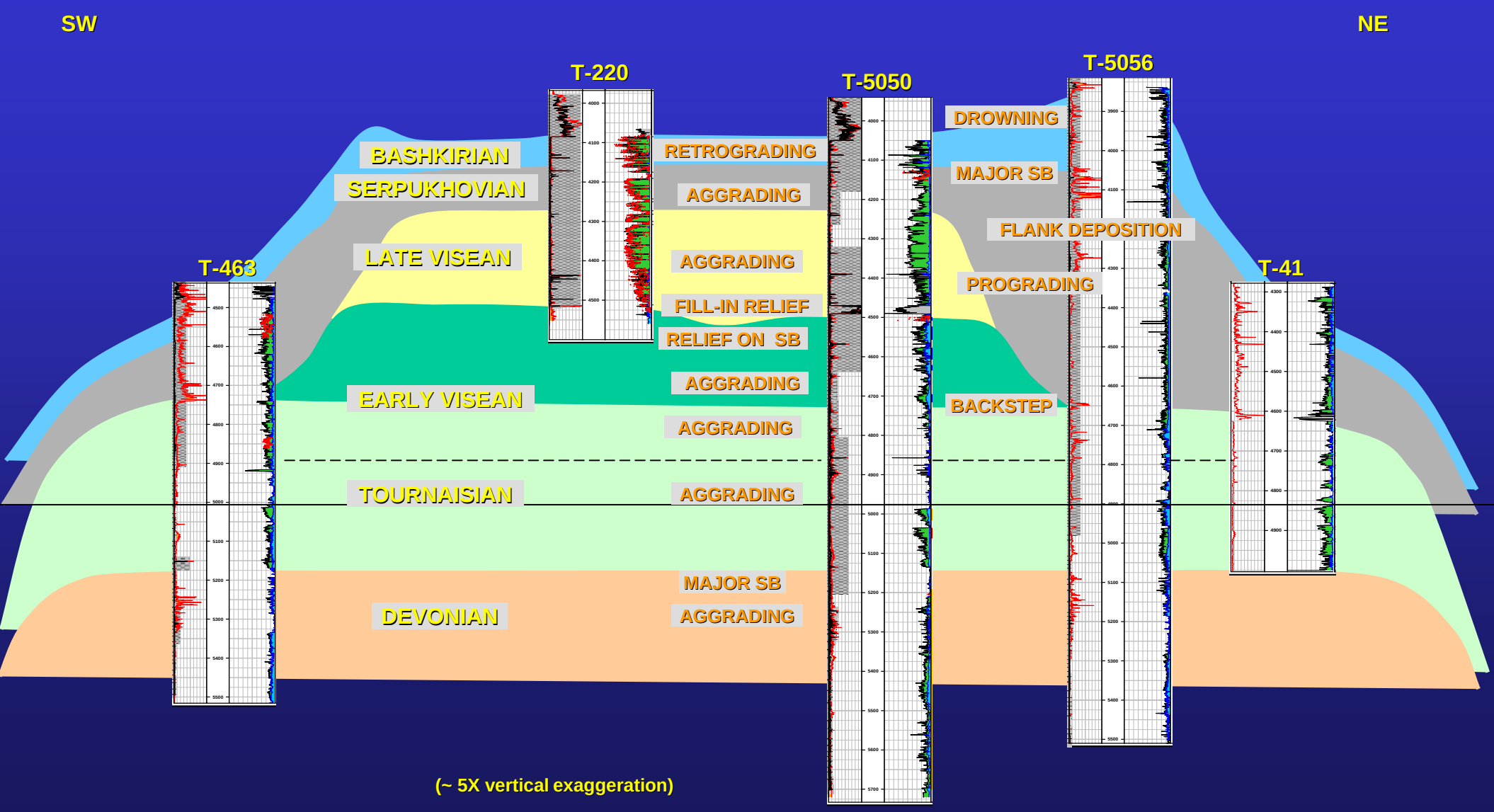
TOURNAISIAN

AGGRADING

DEVONIAN

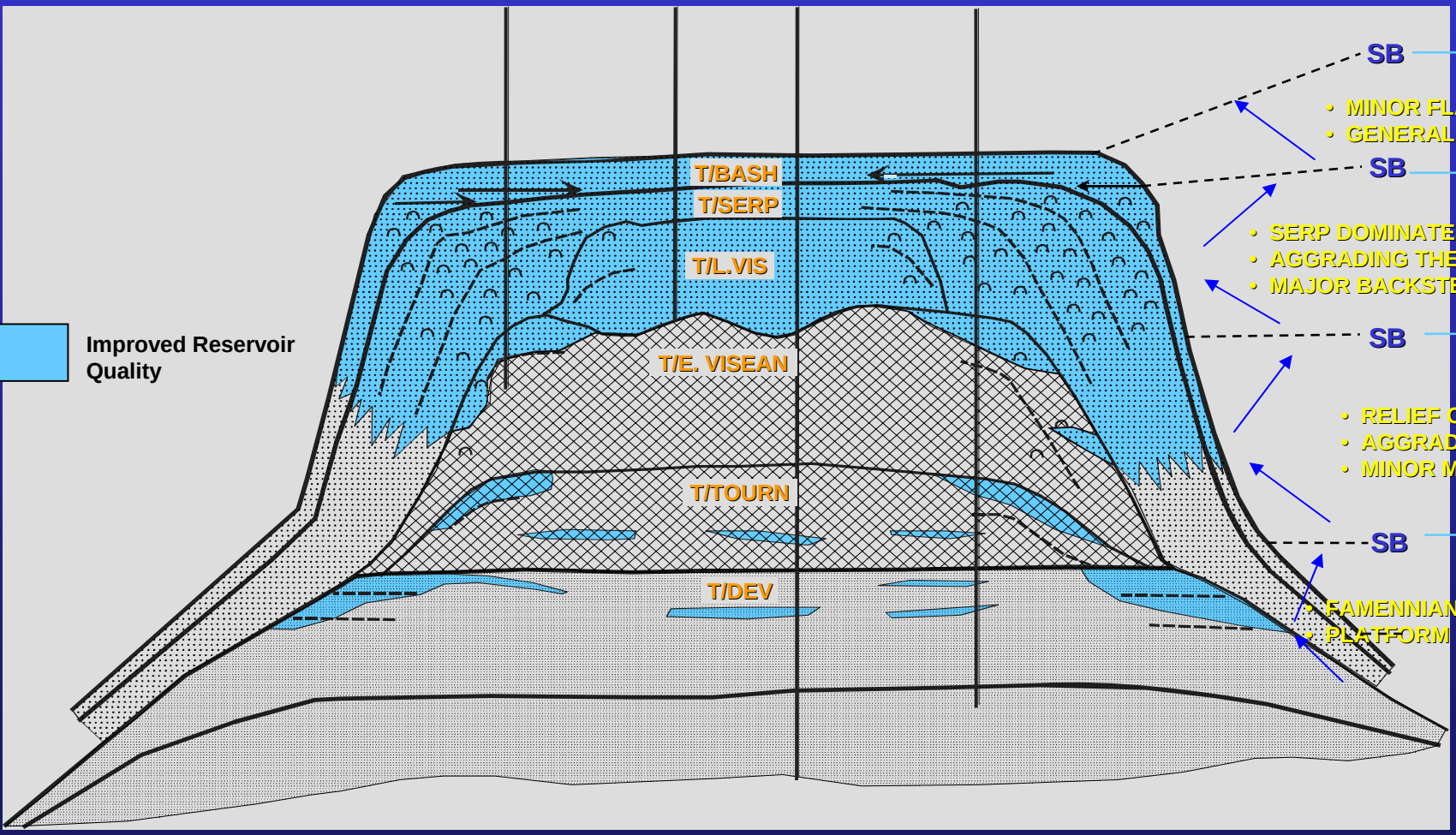
MAJOR SB
AGGRADING

TENGIZ STRATIGRAPHIC MODEL



TENGIZ GEOLOGIC MODEL

August 2000 - Structural Datum



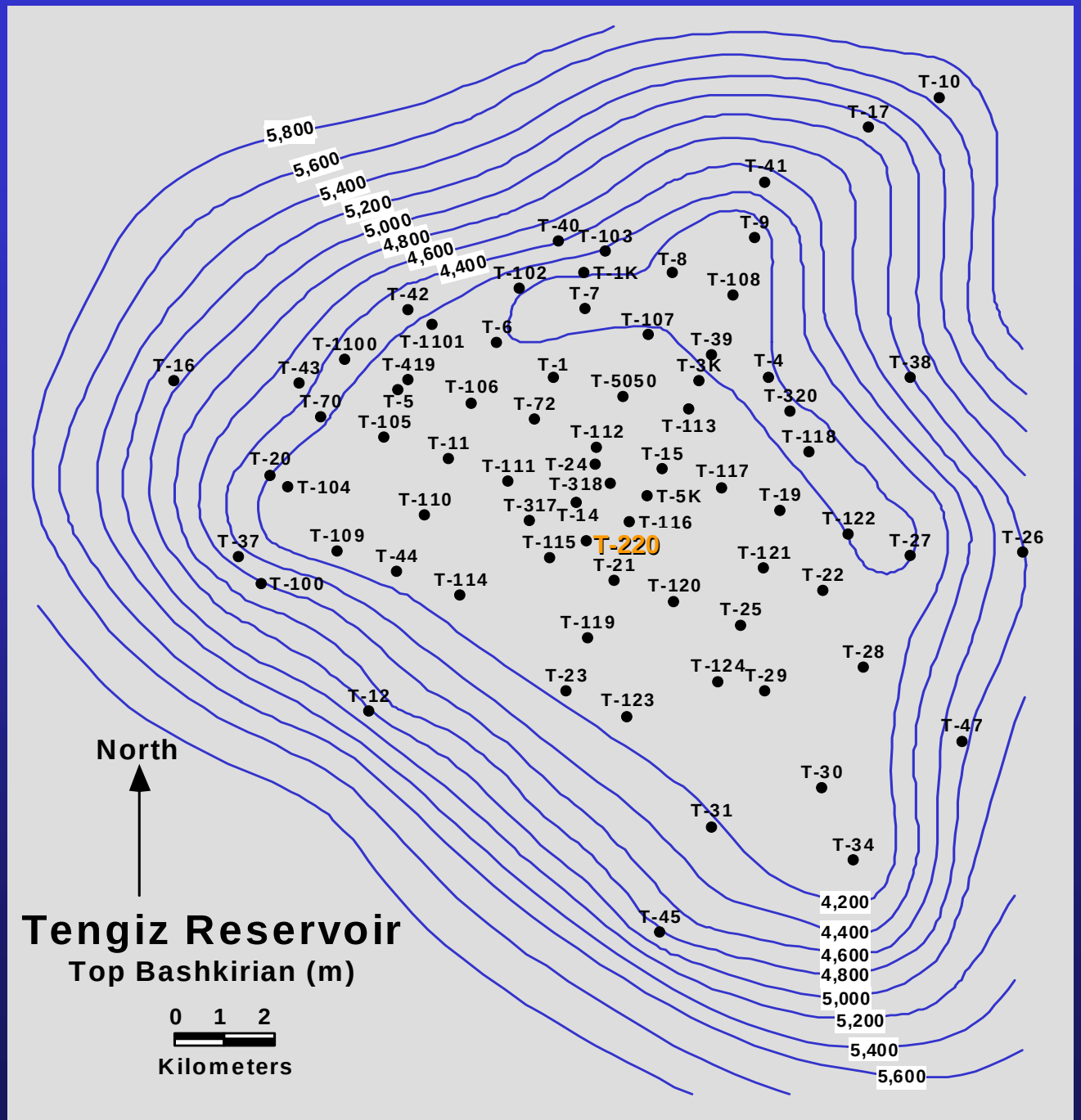
SB ~312 MA
T/BASH
- MINOR FLANK
- GENERALLY RETROGRADATIONAL

SB ~314 MA
T/SERP
- SERP DOMINATES FLANK
- AGGRADING THEN PROGRADING MARGIN
- MAJOR BACKSTEP

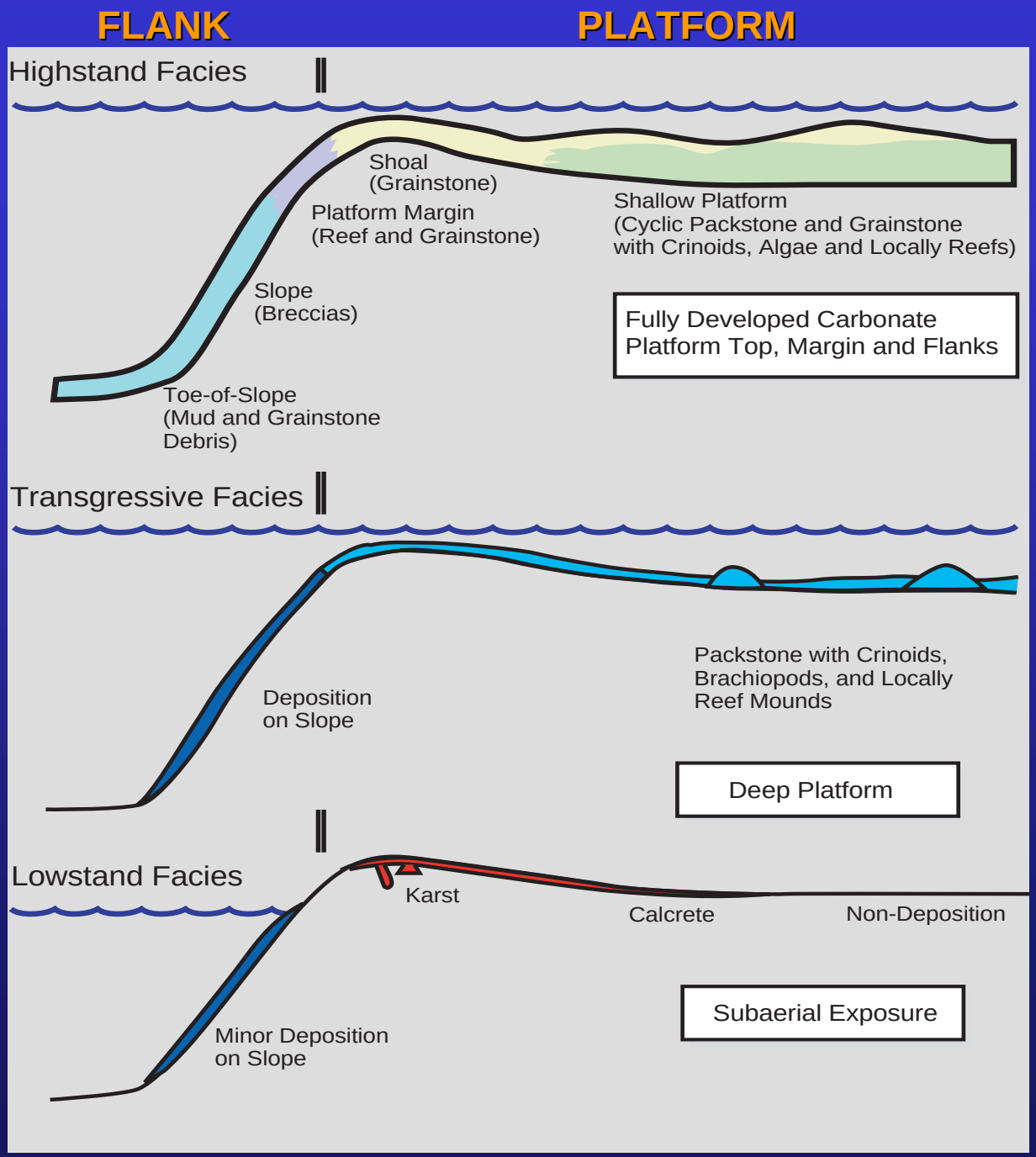
SB ~337 MA
T/E. VISEAN
- RELIEF ON SEQUENCE BOUNDARY
- AGGRADING PLATFORM
- MINOR MARGIN/SLOPE

SB ~354 MA
T/DEVONIAN
- FAMENNIAN PLATFORM SMALLER
- PLATFORM MARGIN/SLOPE POSSIBLE

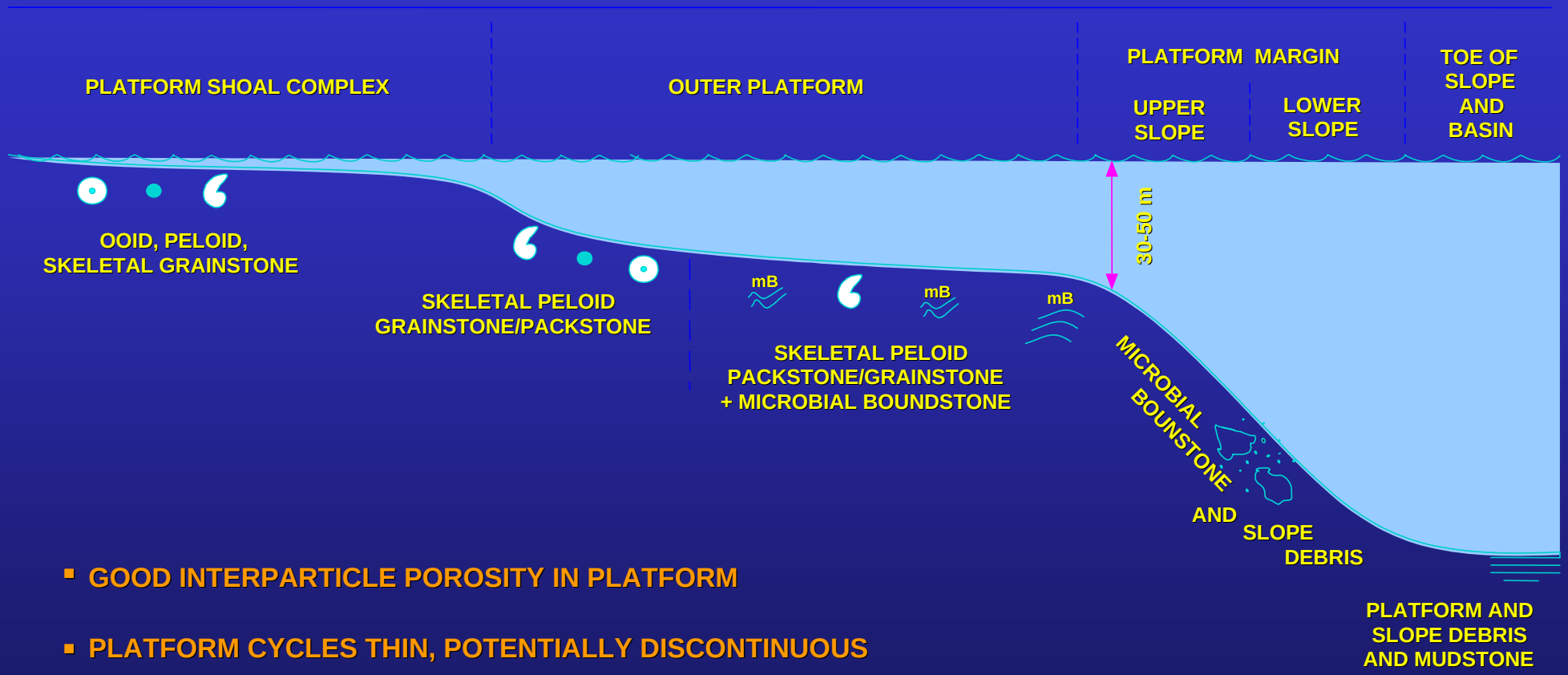
KEY PLATFORM WELL



DEPOSITIONAL MODEL

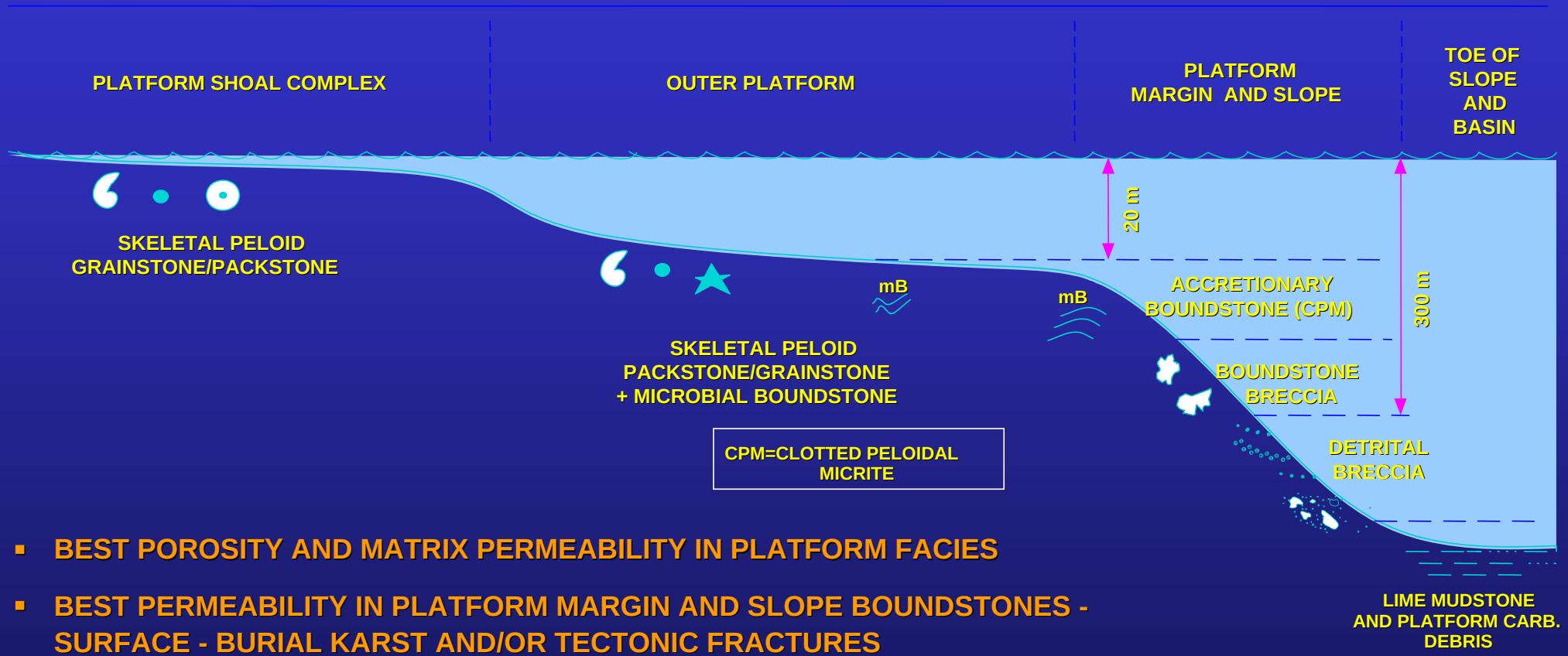


BASHKIRIAN MODEL



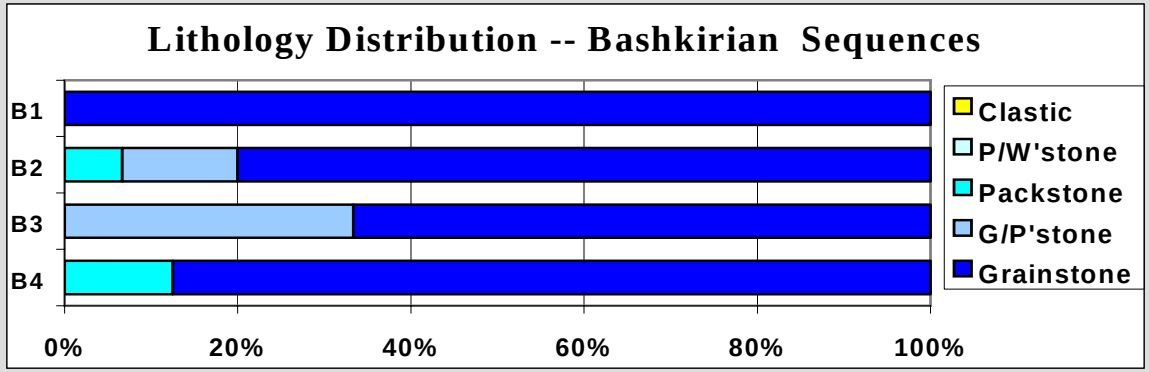
- GOOD INTERPARTICLE POROSITY IN PLATFORM
- PLATFORM CYCLES THIN, POTENTIALLY DISCONTINUOUS
- MINOR EQUANT CALCITE FILLING INTERPARTICLE POROSITY

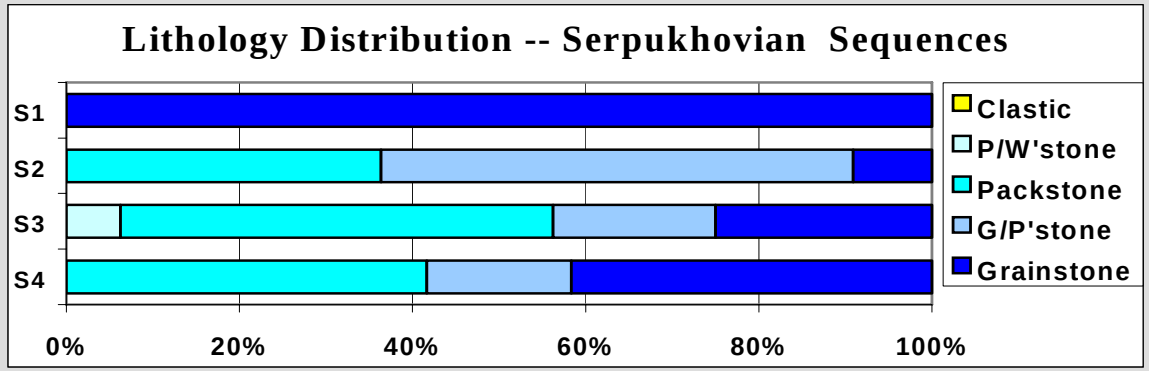
SERPUKHOVIAN - LATE VISEAN MODEL

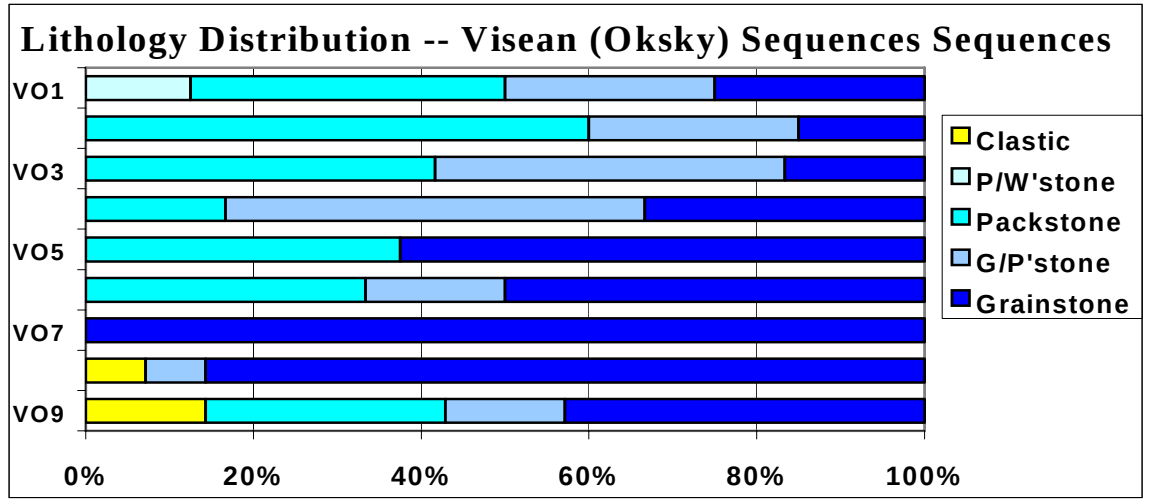


- BEST POROSITY AND MATRIX PERMEABILITY IN PLATFORM FACIES
- BEST PERMEABILITY IN PLATFORM MARGIN AND SLOPE BOUNDSTONES - SURFACE - BURIAL KARST AND/OR TECTONIC FRACTURES
- BITUMEN FILLED POROSITY INCR. TOWARD PLATFORM MARGIN AND SLOPE

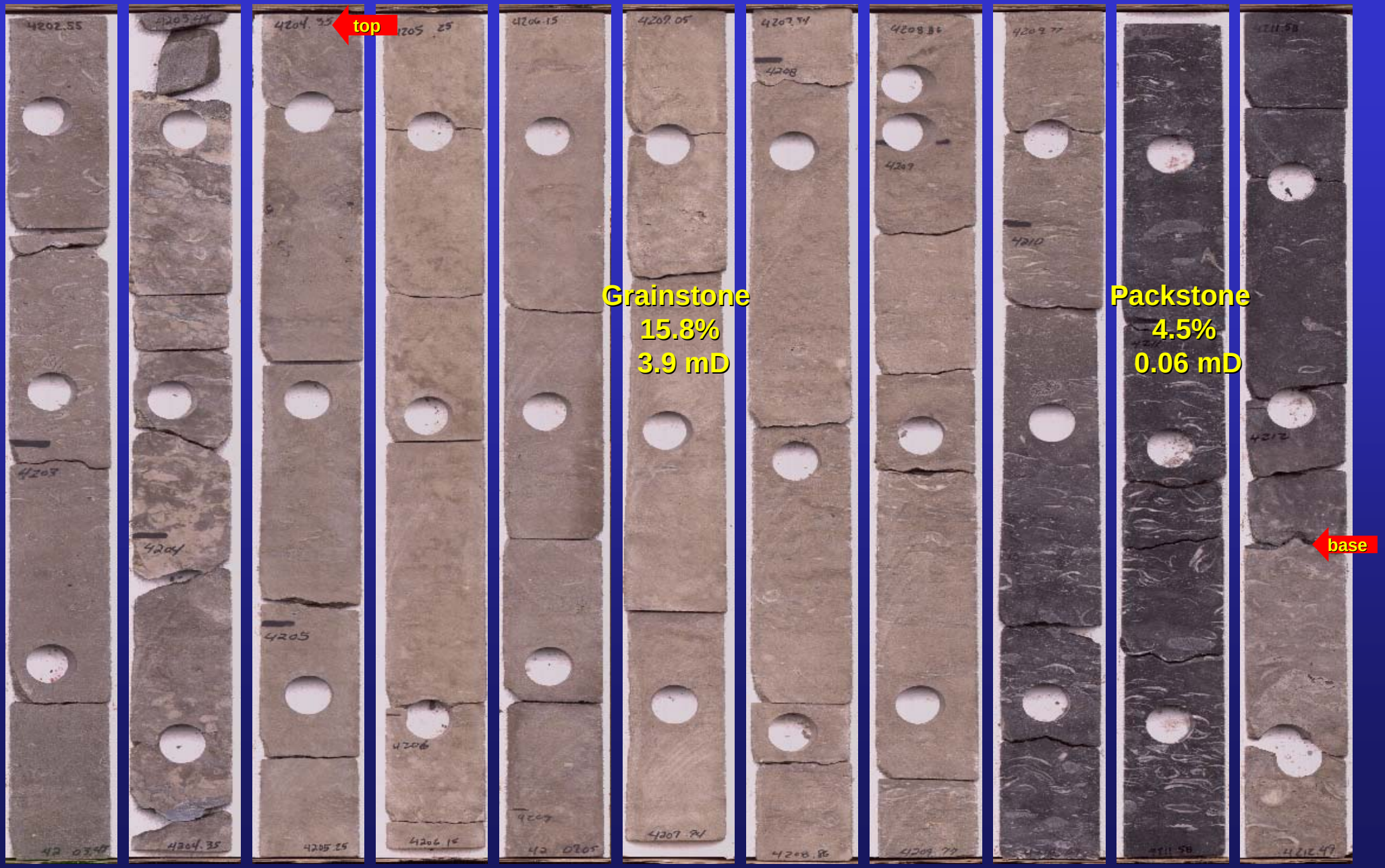
STRATIGRAPHY AND ROCK TYPE





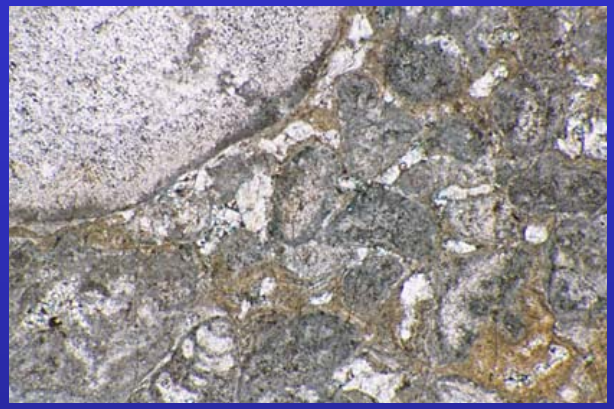


PLATFORM CYCLE

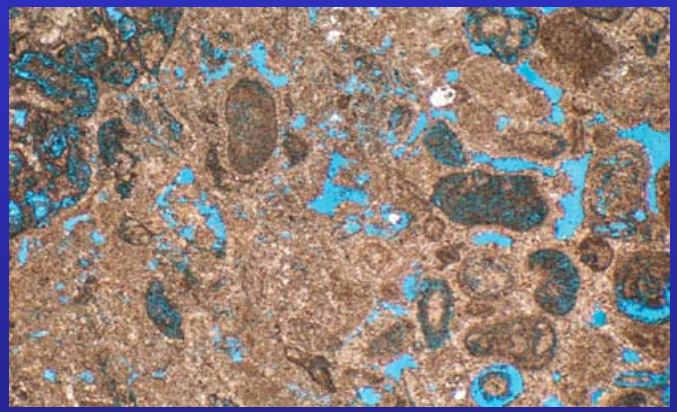


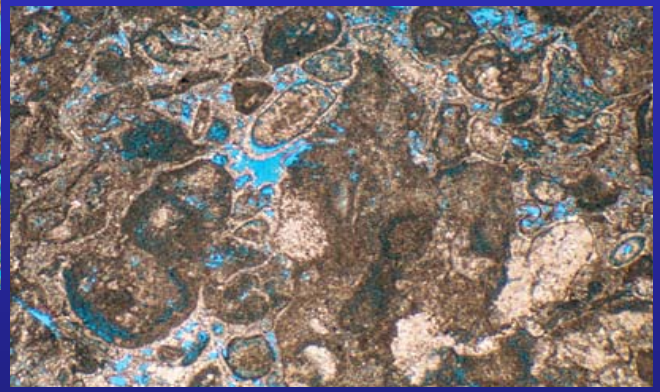
BASHKIRIAN CYCLE

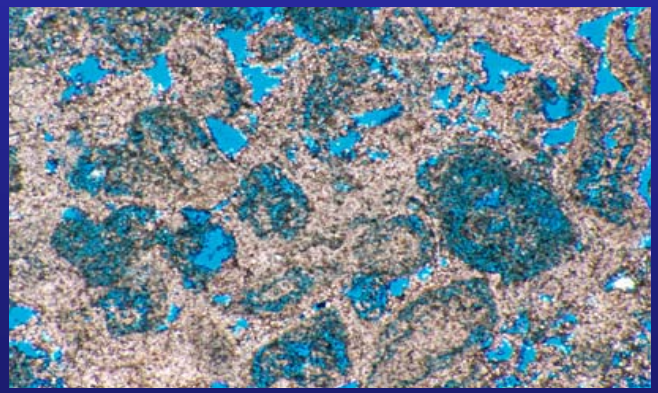
TOP



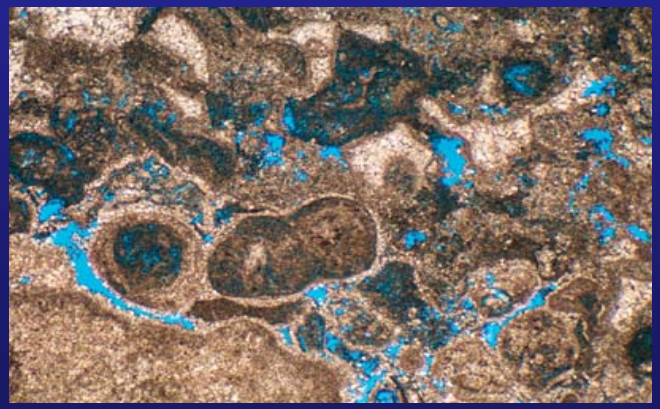
SKELETAL - COATED GRAIN GRAINSTONE

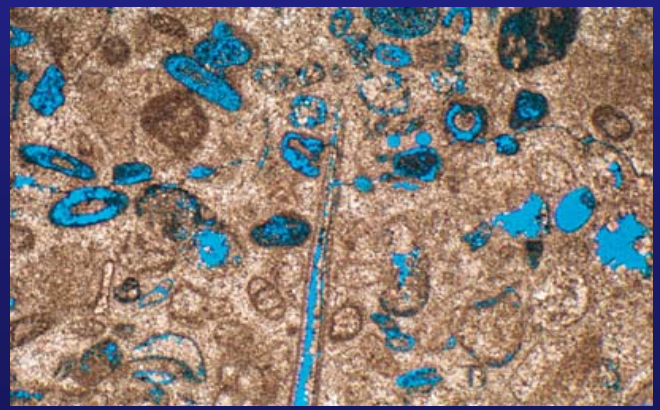






4 MM ACROSS FIELD



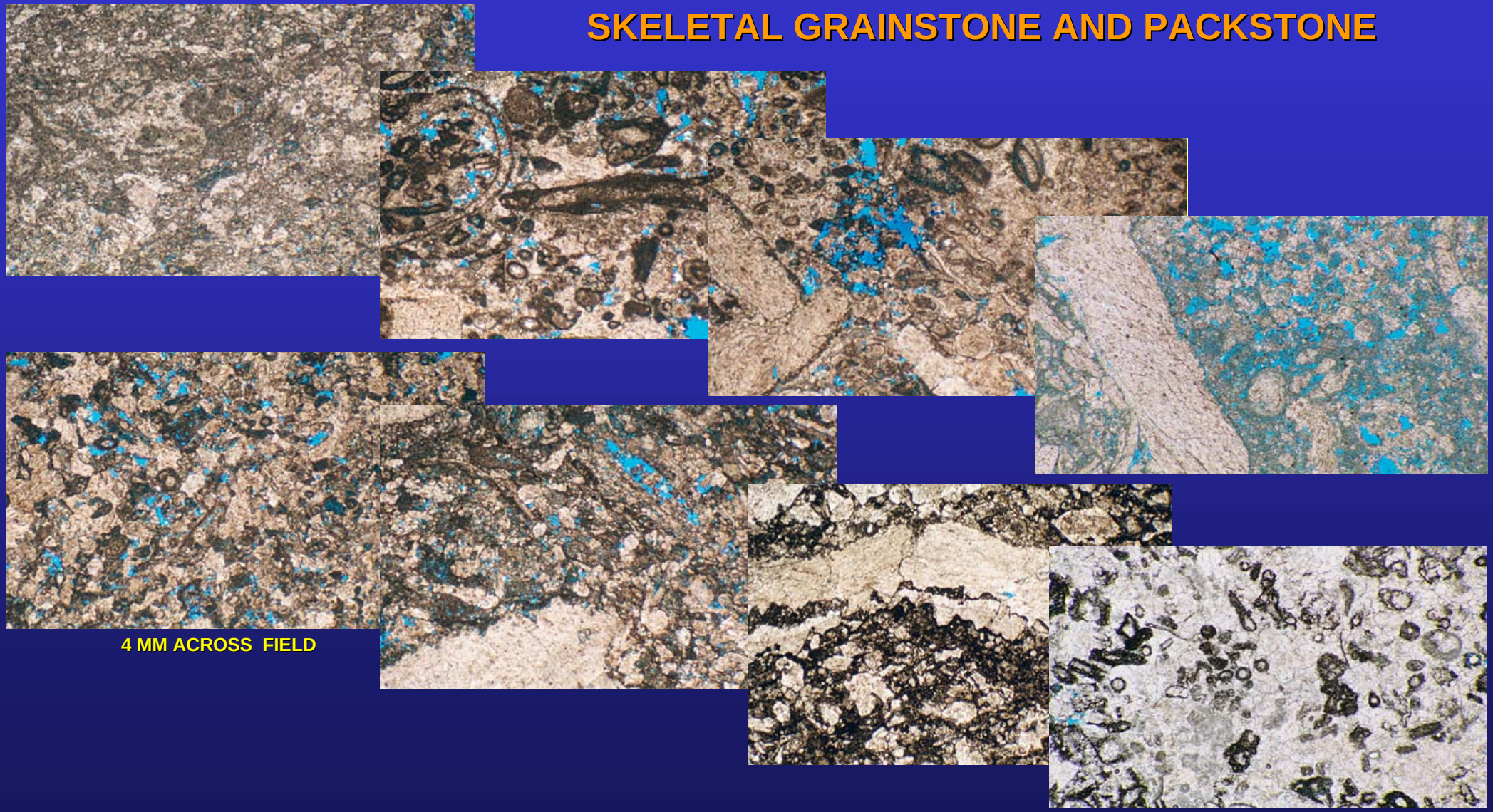


BOTTOM

SERPUKHOVIAN CYCLE

TOP

SKELETAL GRAINSTONE AND PACKSTONE



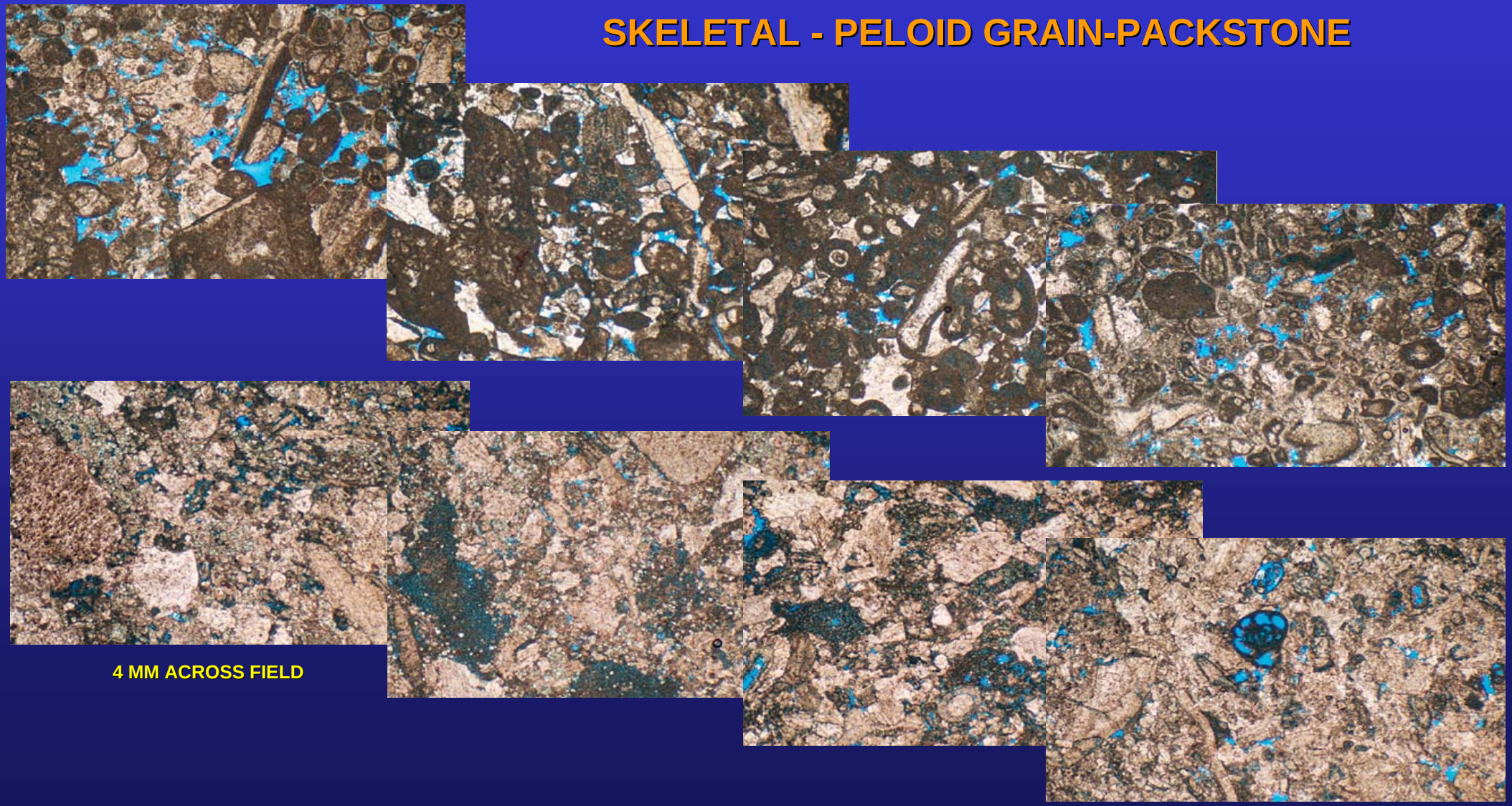
4 MM ACROSS FIELD

BOTTOM

UPPER VISEAN CYCLE

TOP

SKELETAL - PELOID GRAIN-PACKSTONE



4 MM ACROSS FIELD

BOTTOM

SUMMARY OF PLATFORM DIAGENESIS

EARLY DIAGENESIS

RIM AND SYNTAXIAL CEMENTS
MOLDIC POROSITY AND MICROPOROSITY
EQUANT CALCITE CEMENTS
KARST - VUGS, BRECCIA, AND MICROFRACTURES

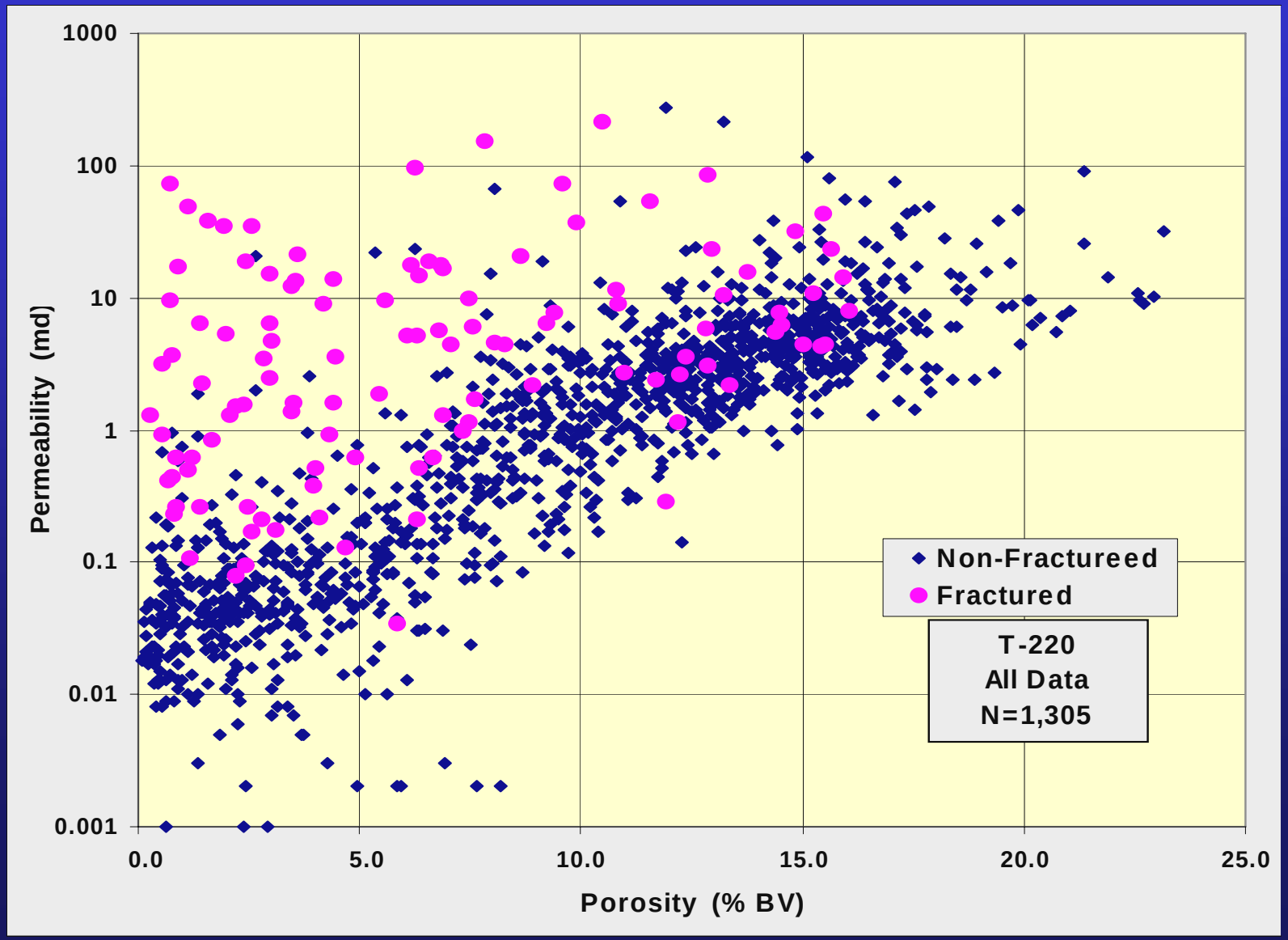
BURIAL DIAGENESIS

MICROFRACTURES AND MICROSTYLOLITES
MICROVUGGY POROSITY AND MICROPOROSITY
CALCITE, DOLOMITE, SILICA, OR ANHYDRITE CEMENTS
BITUMEN EMPLACEMENT
AUTHIGENIC PYRITE
CROSS-CUTTING FRACTURES
COARSE CALCITE IN VUGS, VEINS, AND FRACTURES

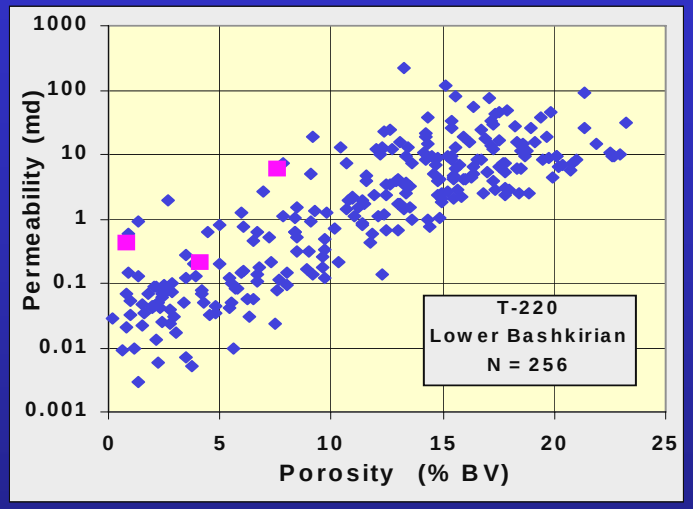
STRATIGRAPHY AND POROSITY TYPE

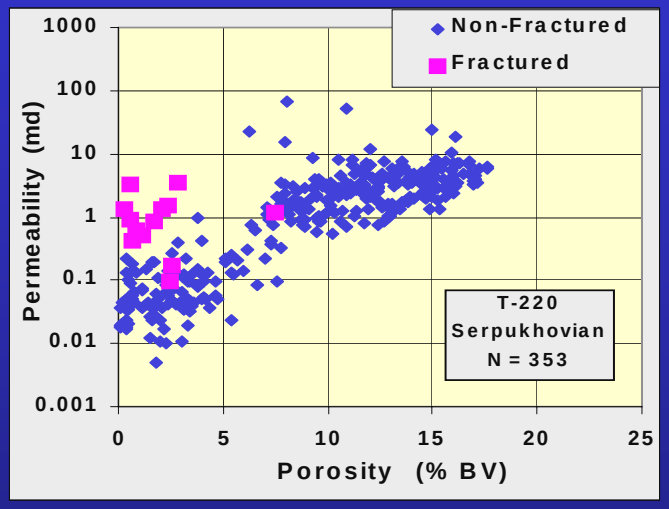
MOSCOVIAN (?) SEQUENCE
Microporosity in grains and matrix, minor interparticle porosity, and an open microfracture.
UPPER BASHKIRIAN SEQUENCE
B1 - Solution-enlarged interparticle and intraskeletal porosity, microfractures, microporosity in grains and between cement crystals.
LOWER BASHKIRIAN COMPOSITE SEQUENCE
B2 - Solution-enhanced interparticle and intraskeletal porosity, moldic porosity, microporosity in grains, local microvuggy and microfracture porosity.
B3 - Cement-reduced interparticle, moldic, microfracture, and microvuggy porosity; microporosity in grains
B4 - Solution-enlarged interparticle, intraskeletal, vuggy, moldic, and microfracture porosity; microporosity in grains.
SERPUKHOVIAN COMPOSITE SEQUENCE
S1 - Solution-enhanced interparticle, microvuggy, moldic, and microporosity in grains.
S2 - Solution-enhanced interparticle, intraskeletal, moldic, microvuggy and microfracture porosity; microporosity in grains and matrix.
S3 - Interparticle, intraskeletal, moldic, microfracture, and microvuggy porosity; microporosity in grains and matrix.
S4 - Solution enhanced interparticle, intraskeletal, moldic microfracture, and microvuggy porosity; microporosity in matrix and grains.
UPPER VISEAN (OKSKY) COMPOSITE SEQUENCE
VO1 - Locally solution-enhanced interparticle and intraskeletal porosity; moldic, microfracture, and microvuggy porosity. Microporosity in grains and matrix.
VO2 - Interparticle and intraskeletal porosity, locally solution enhanced; moldic and microvuggy porosity; microporosity in matrix and peloids.
VO3 - Interparticle, moldic, and intraskeletal porosity; microporosity in grains and matrix; microvuggy and microfracture porosity.
MIDDLE VISEAN (OKSKY) COMPOSITE SEQUENCE
VO4 - Solution-enhanced interparticle, intraskeletal, microvuggy, and microfracture porosity; microporosity in grains.
VO5 - Solution-enhanced interparticle, intraskeletal, local microvuggy porosity; microporosity in grains and matrix.
VO6 - Interparticle, intraskeletal, and moldic porosity; microporosity in grains and matrix.
LOWER VISEAN (OKSKY) COMPOSITE SEQUENCE
VO7 - Solution-enhanced interparticle to microvuggy porosity.
VO8 - Interparticle, intraskeletal, moldic and microfracture porosity; microporosity in grains.
VO9 - Intraskeletal, moldic, and interparticle porosity.
UPPER VISEAN (TULA) COMPOSITE SEQUENCE
VT1 – Intraskeletal, moldic, and microfracture porosity; also microporosity in grains.

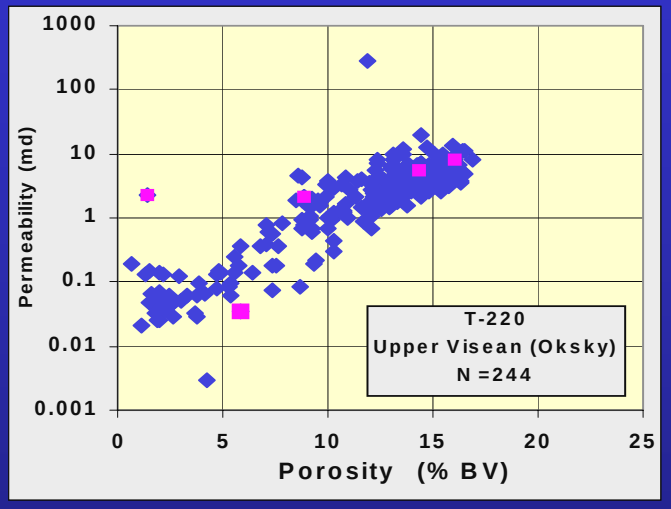
PLATFORM RESERVOIR QUALITY

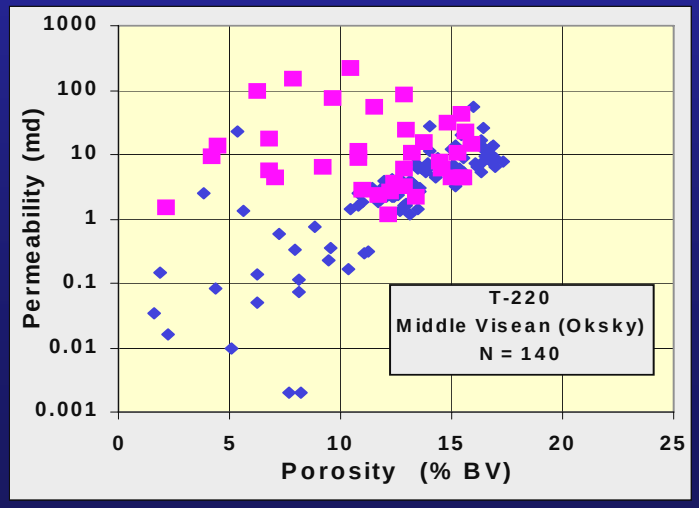


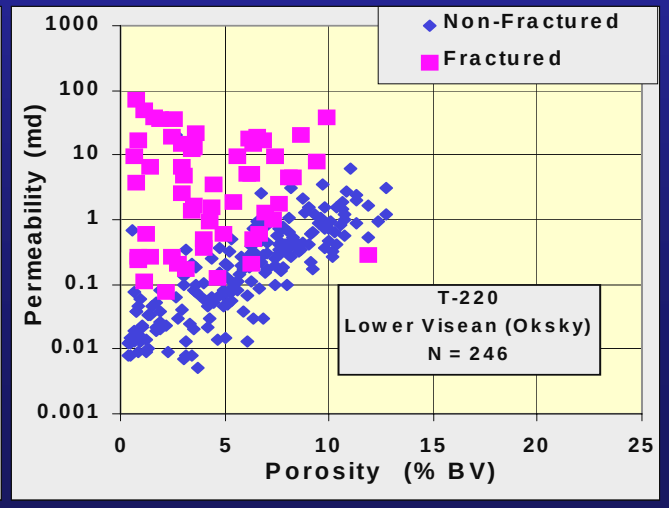
STRATIGRAPHY AND RESERVOIR QUALITY

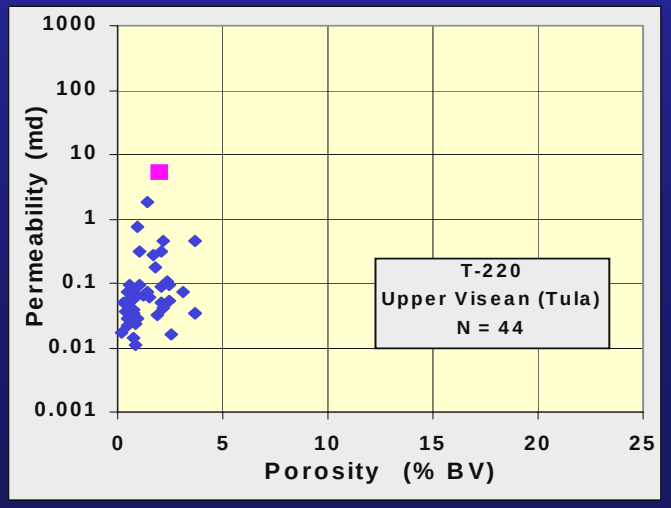




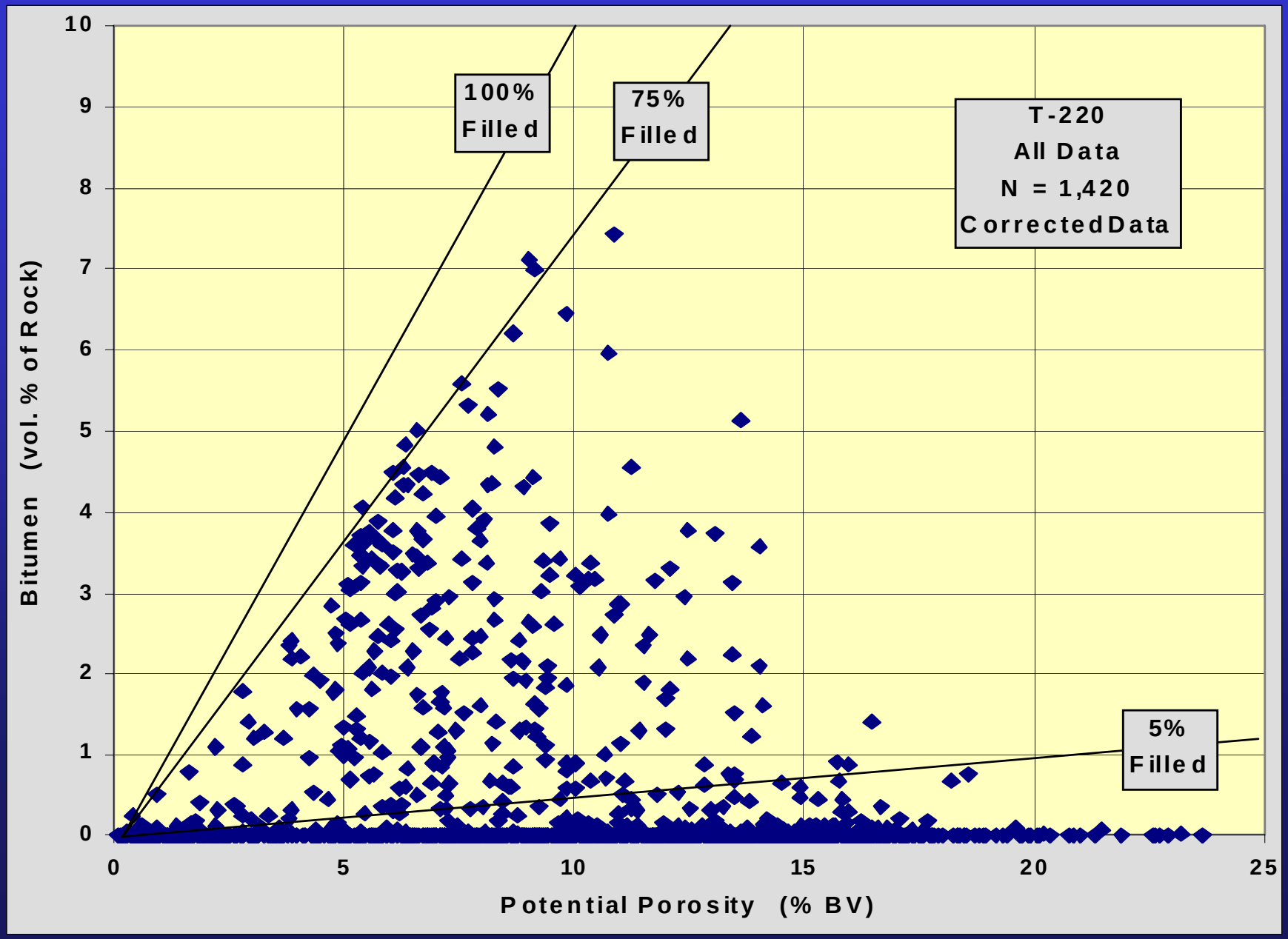




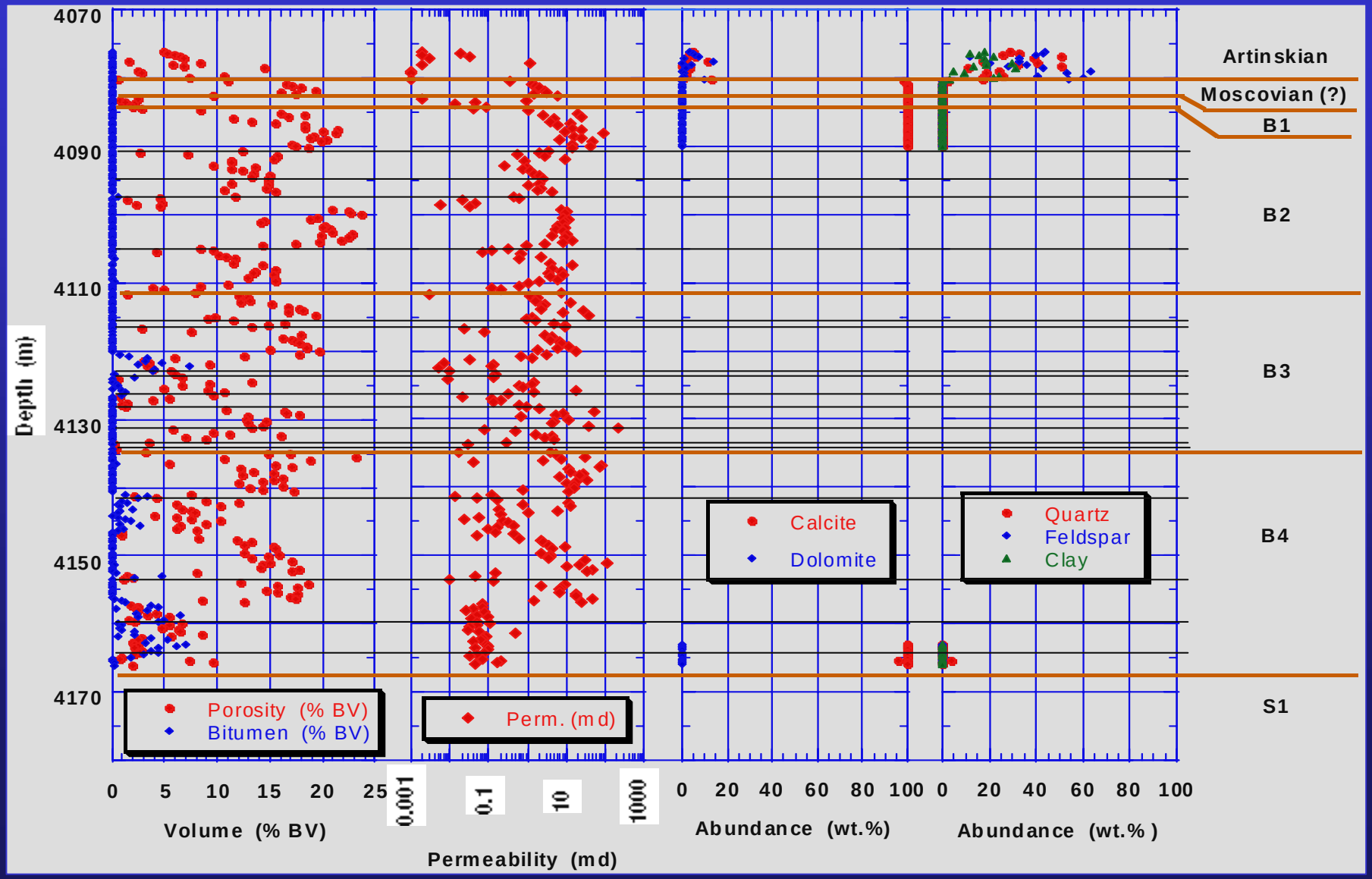




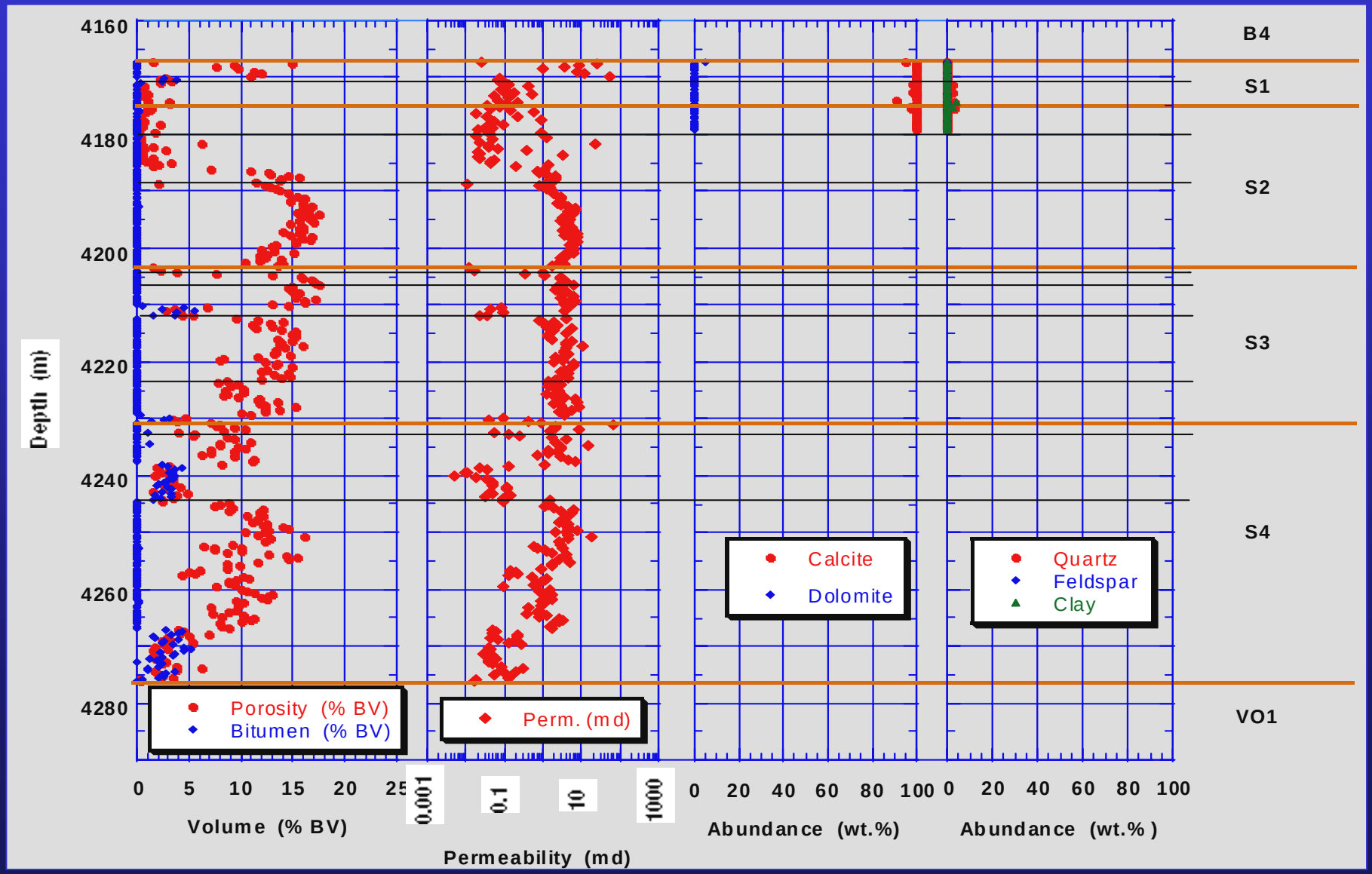
BITUMEN AND POROSITY



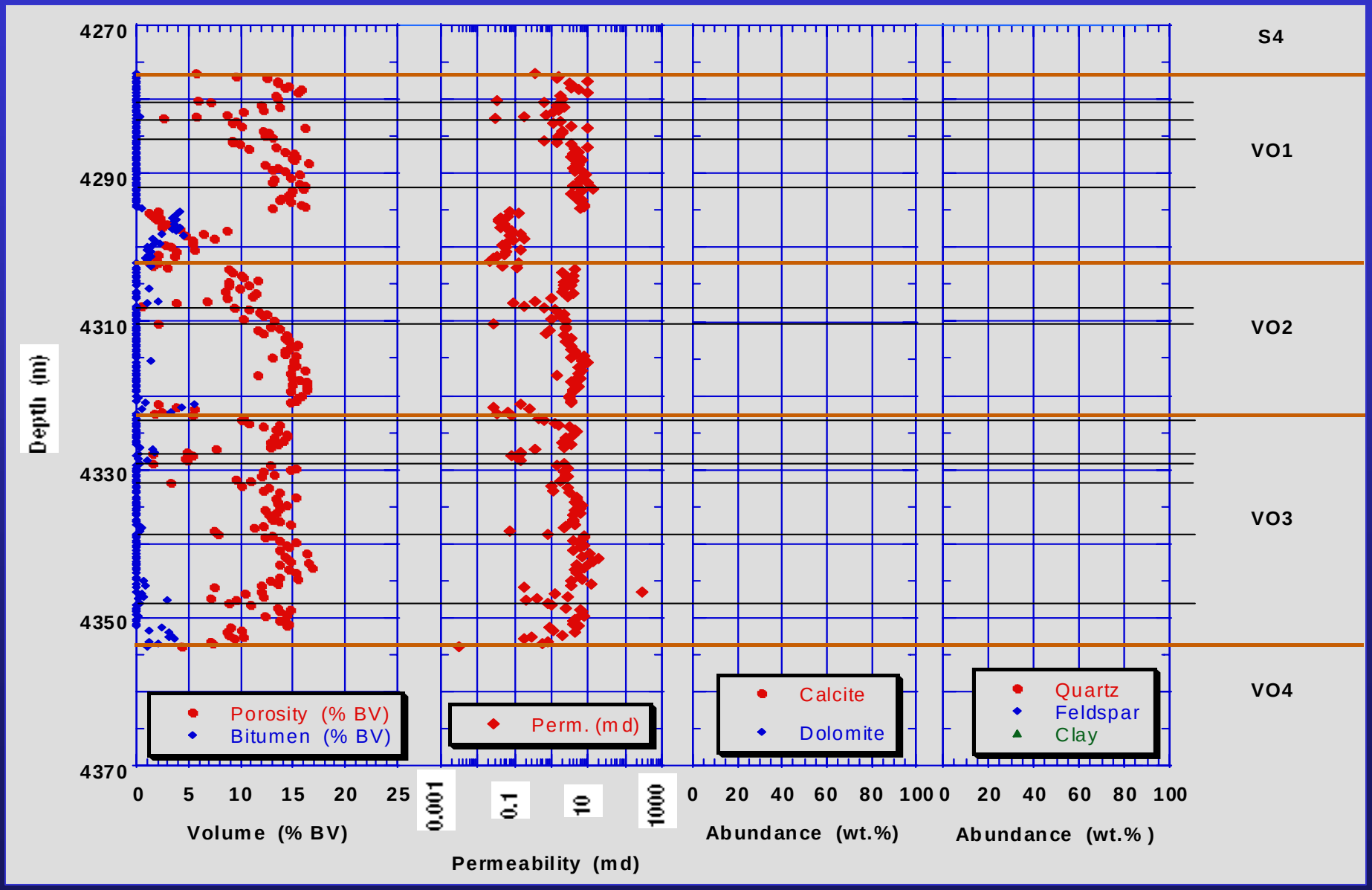
BASHKRIAN RESERVOIR QUALITY AND MINERALOGY



SERPUKHOVIAN RESERVOIR QUALITY AND MINERALOGY



UPPER VISEAN RESERVOIR QUALITY AND MINERALOGY



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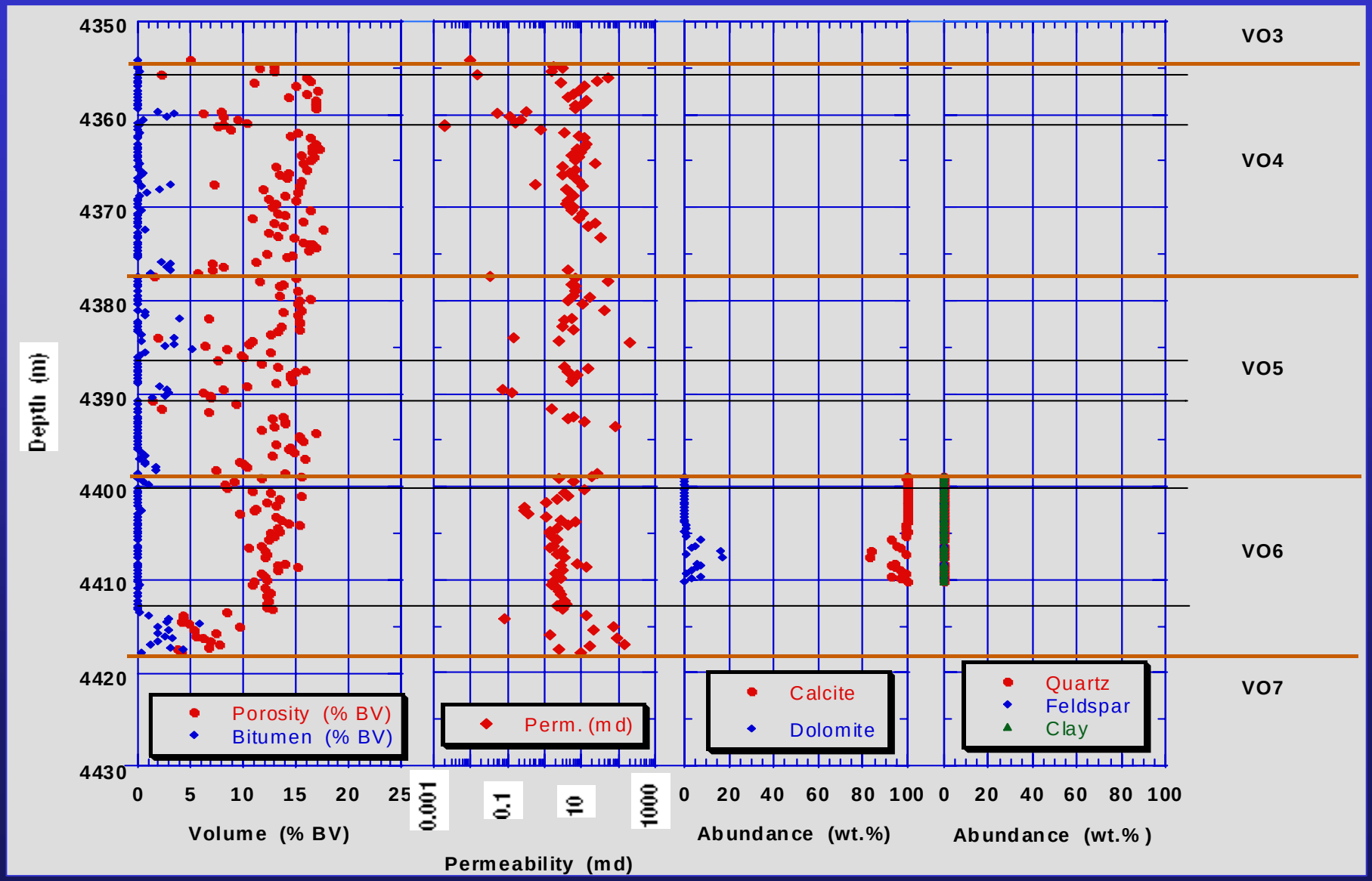

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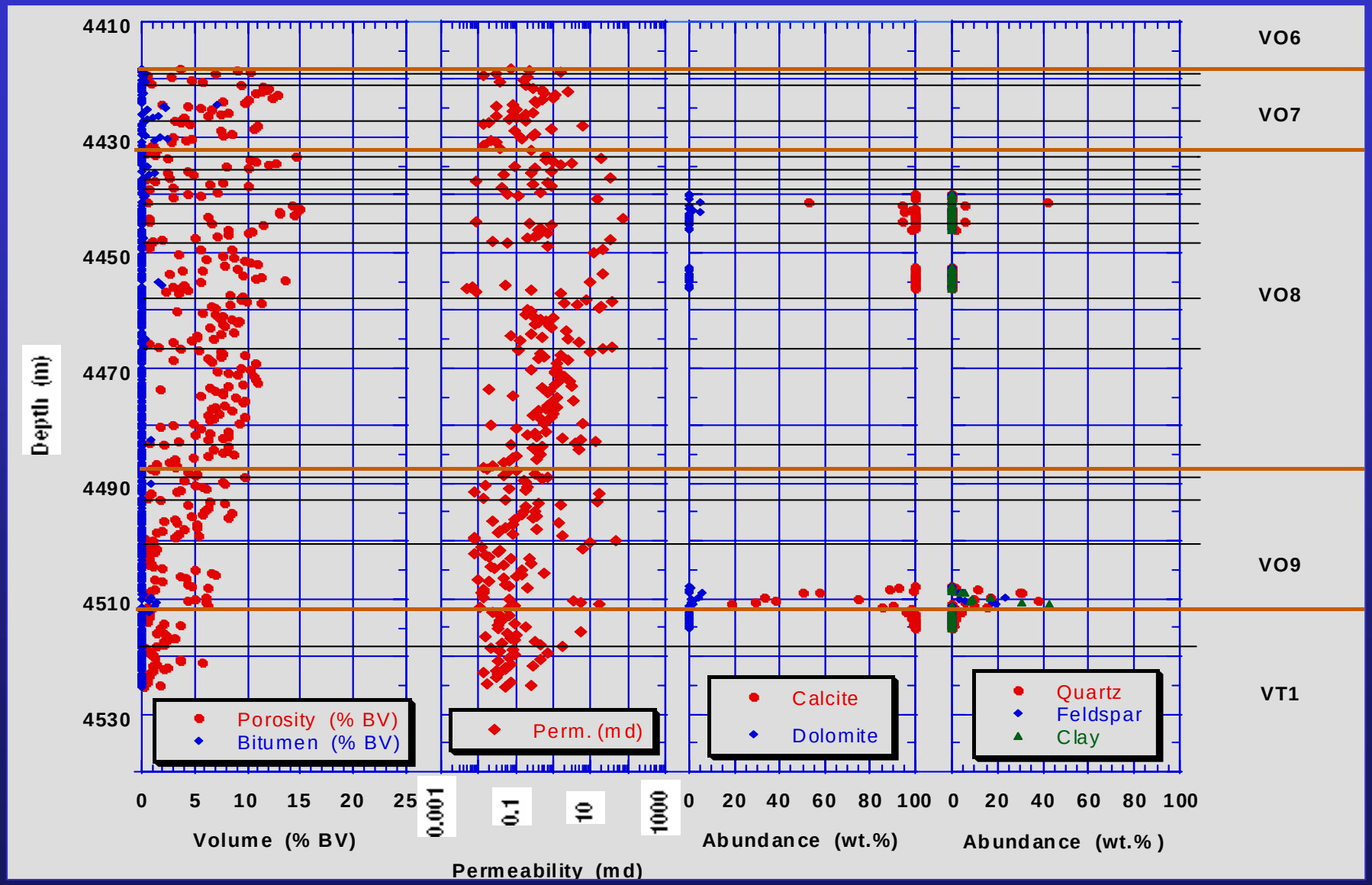
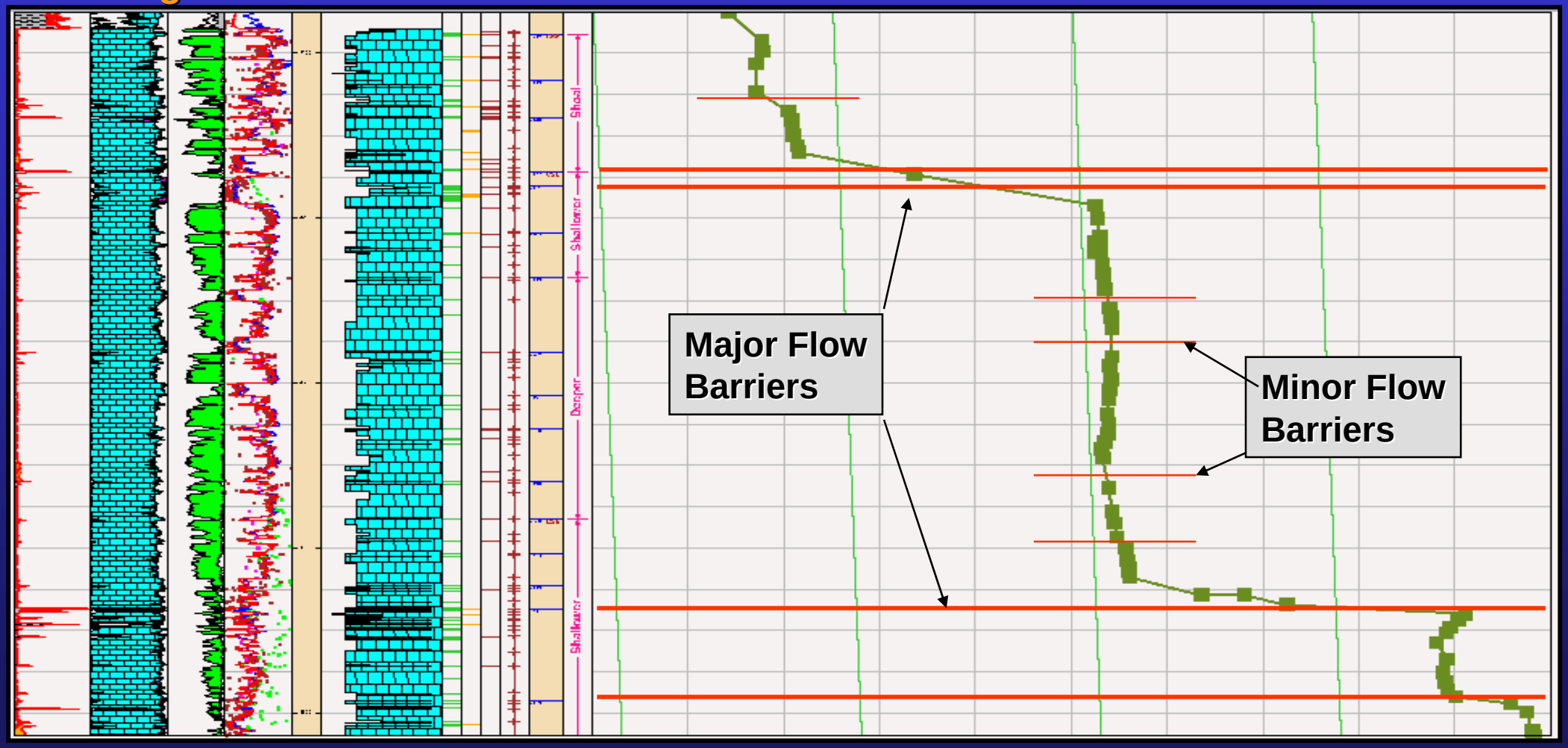
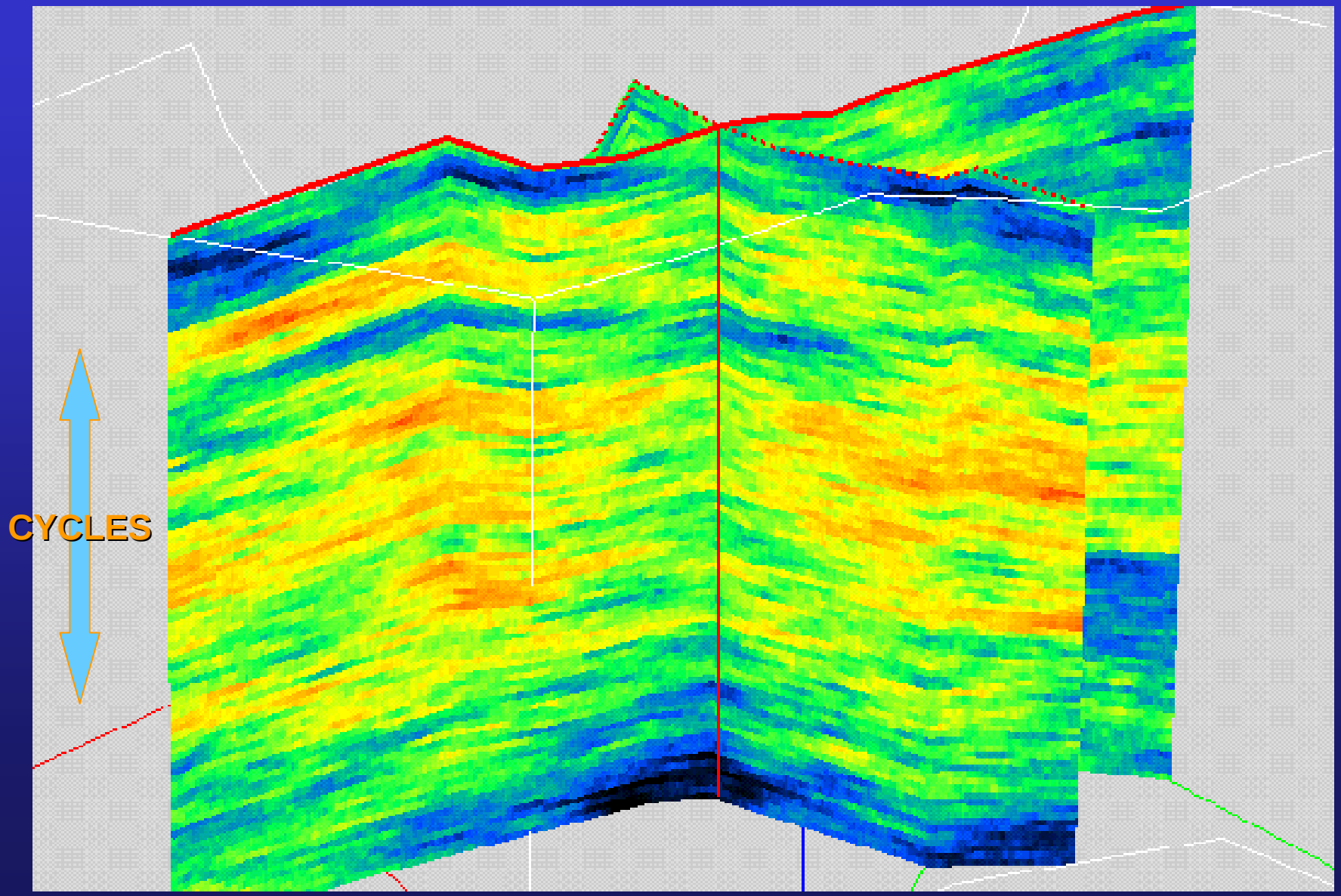


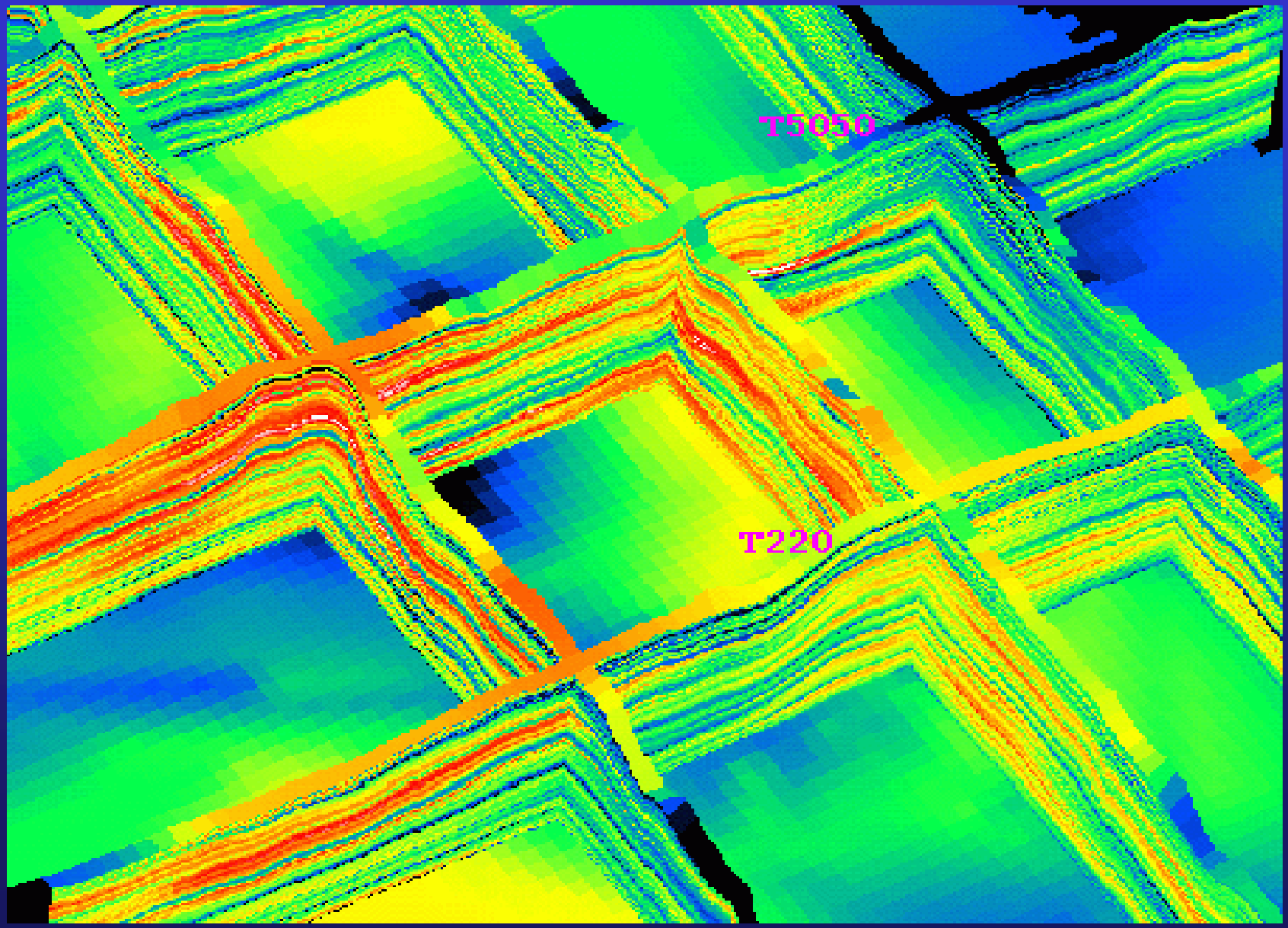
STRATIGRAPHY AND WIRELINE PRESSURES



PLATFORM POROSITY DISTRIBUTION

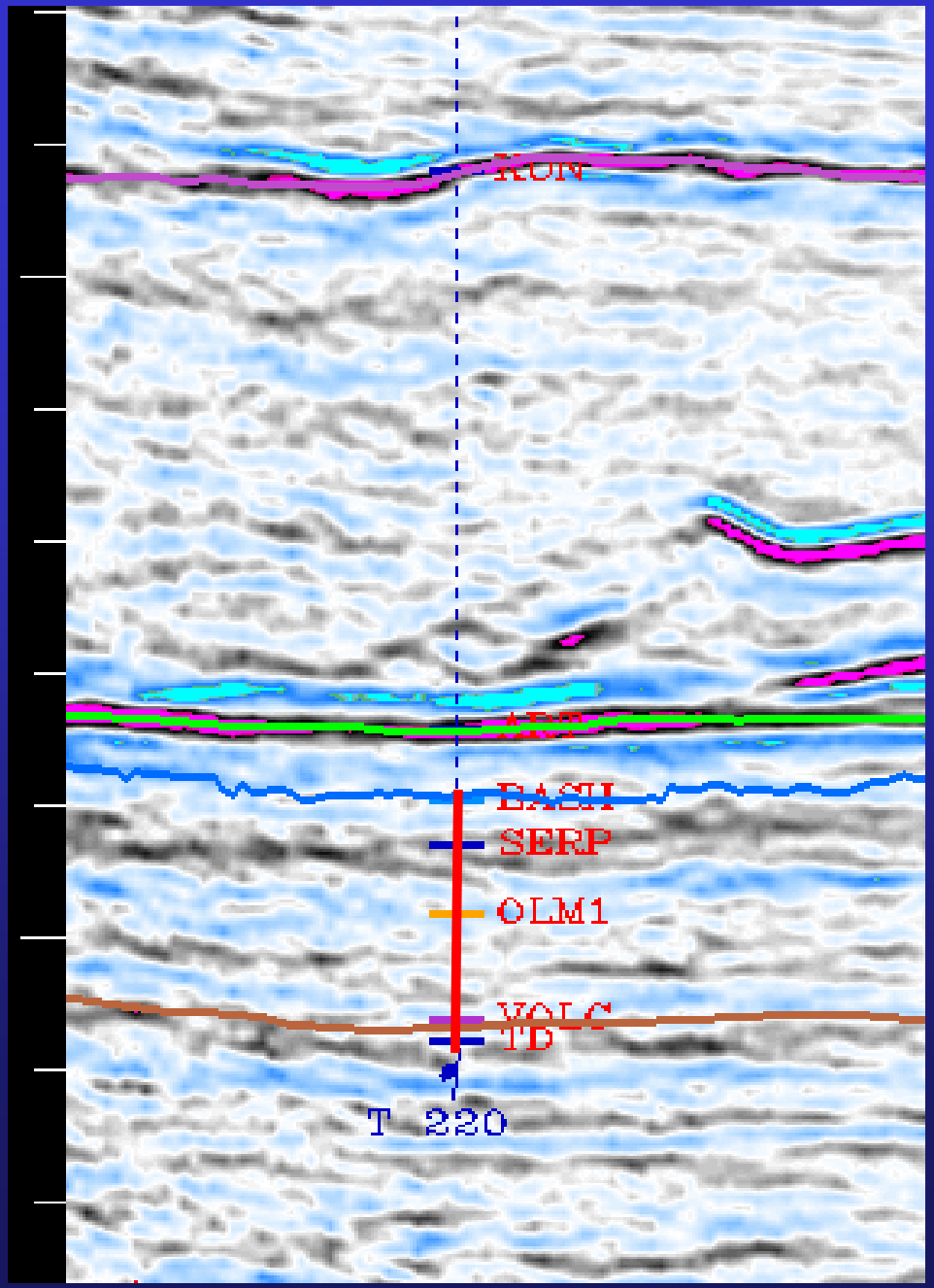


PLATFORM POROSITY DISTRIBUTION

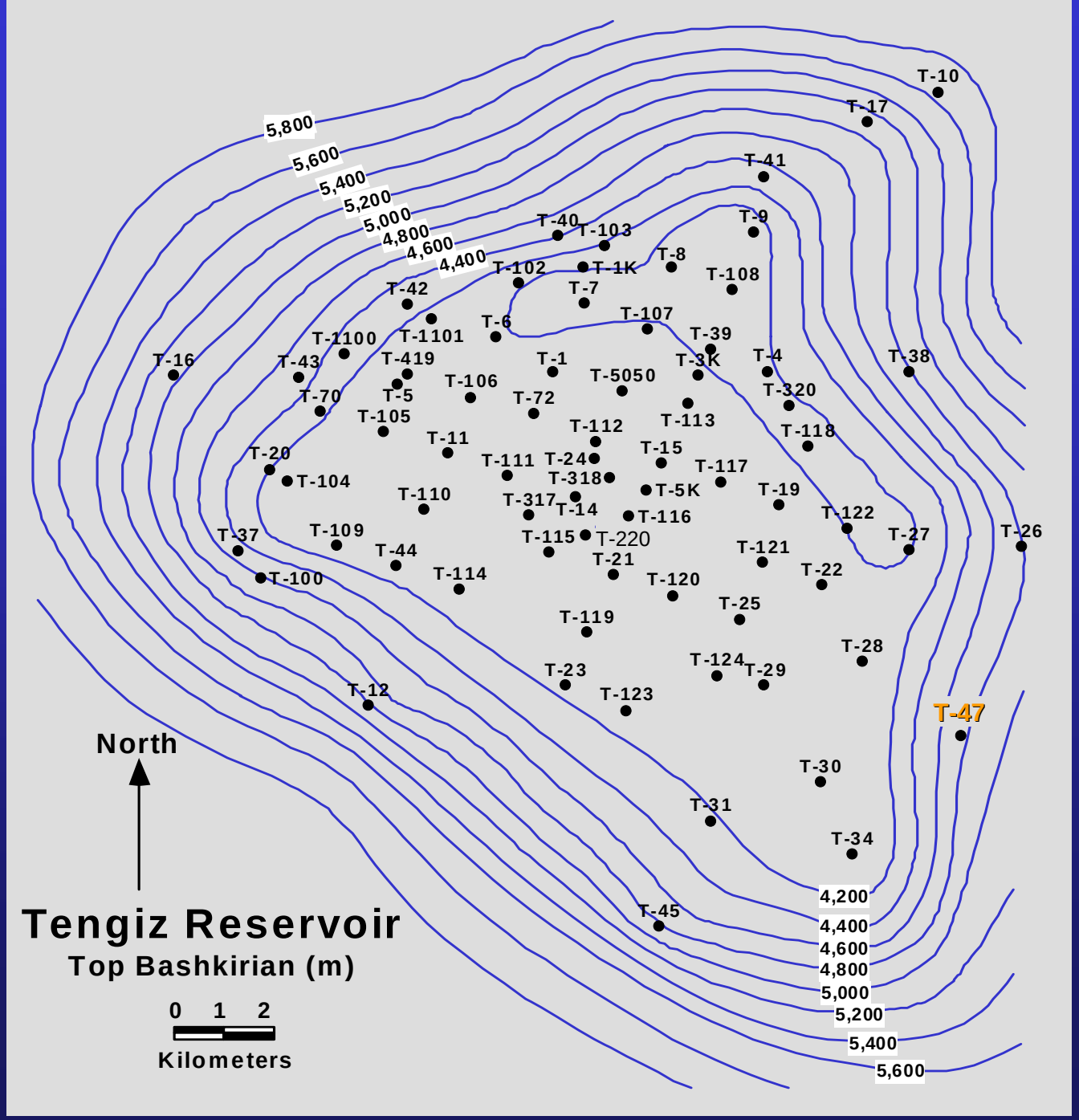


CYCLES

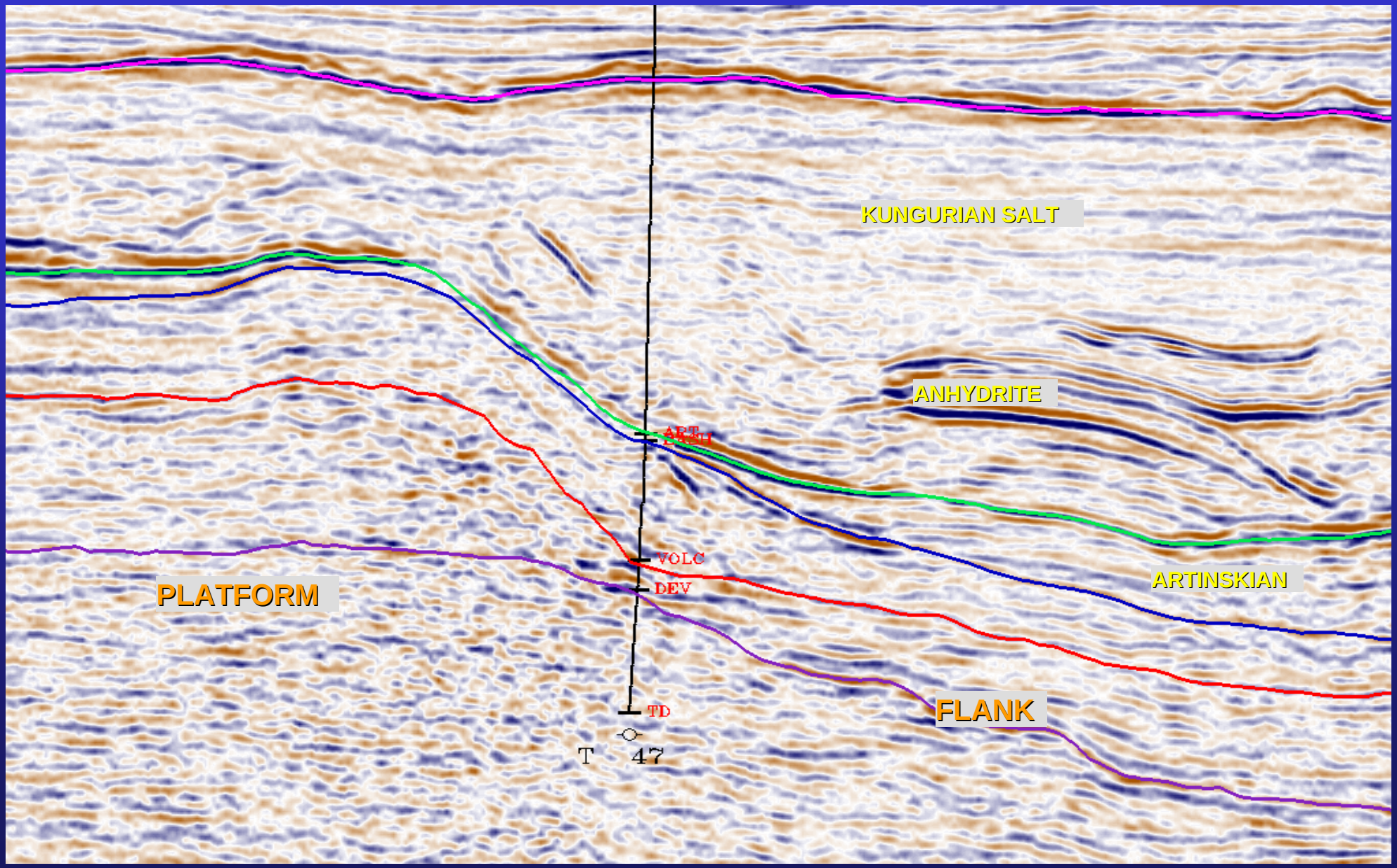
WELL TIE TO 3D SEISMIC



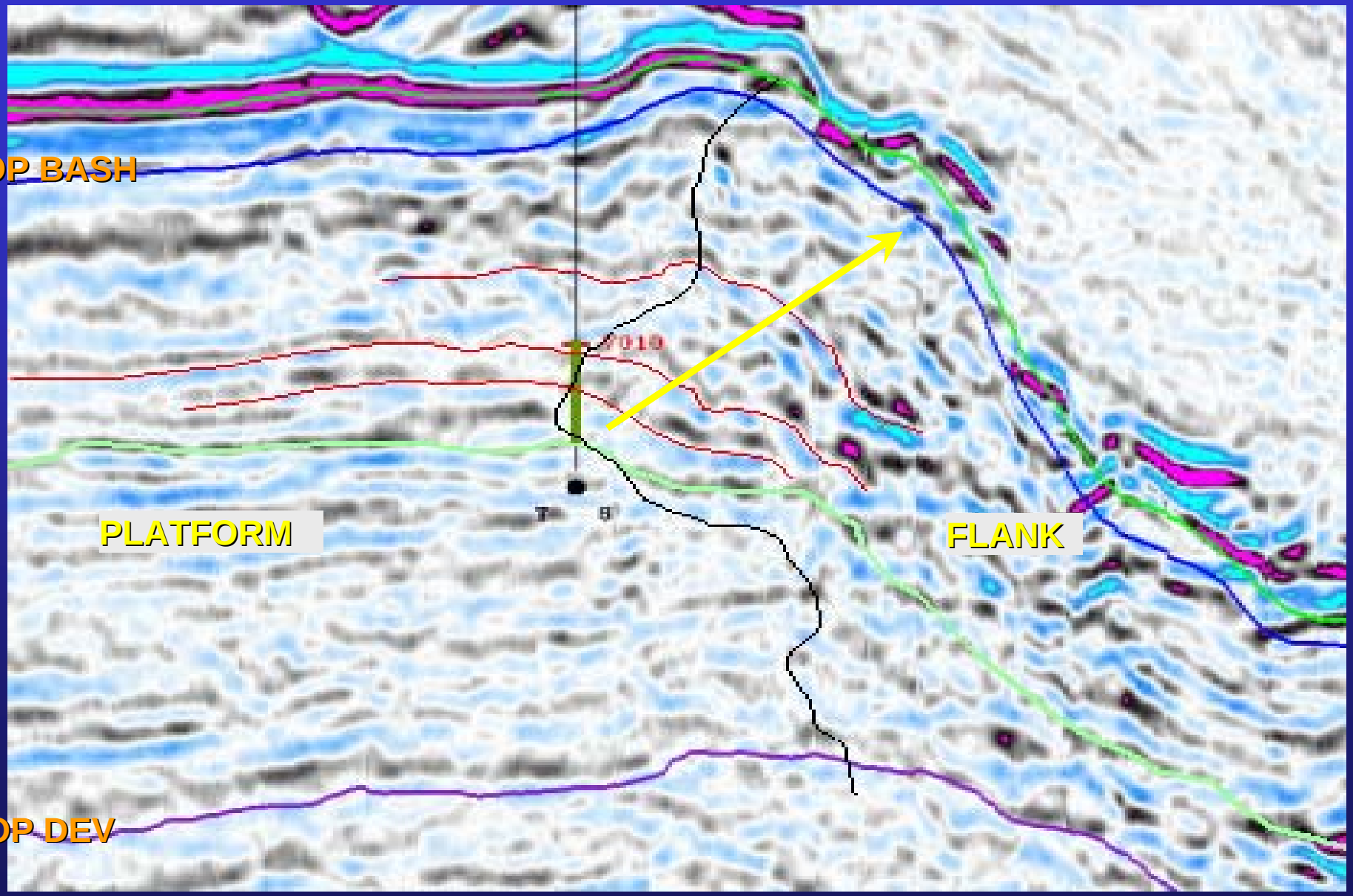
KEY FLANK WELL



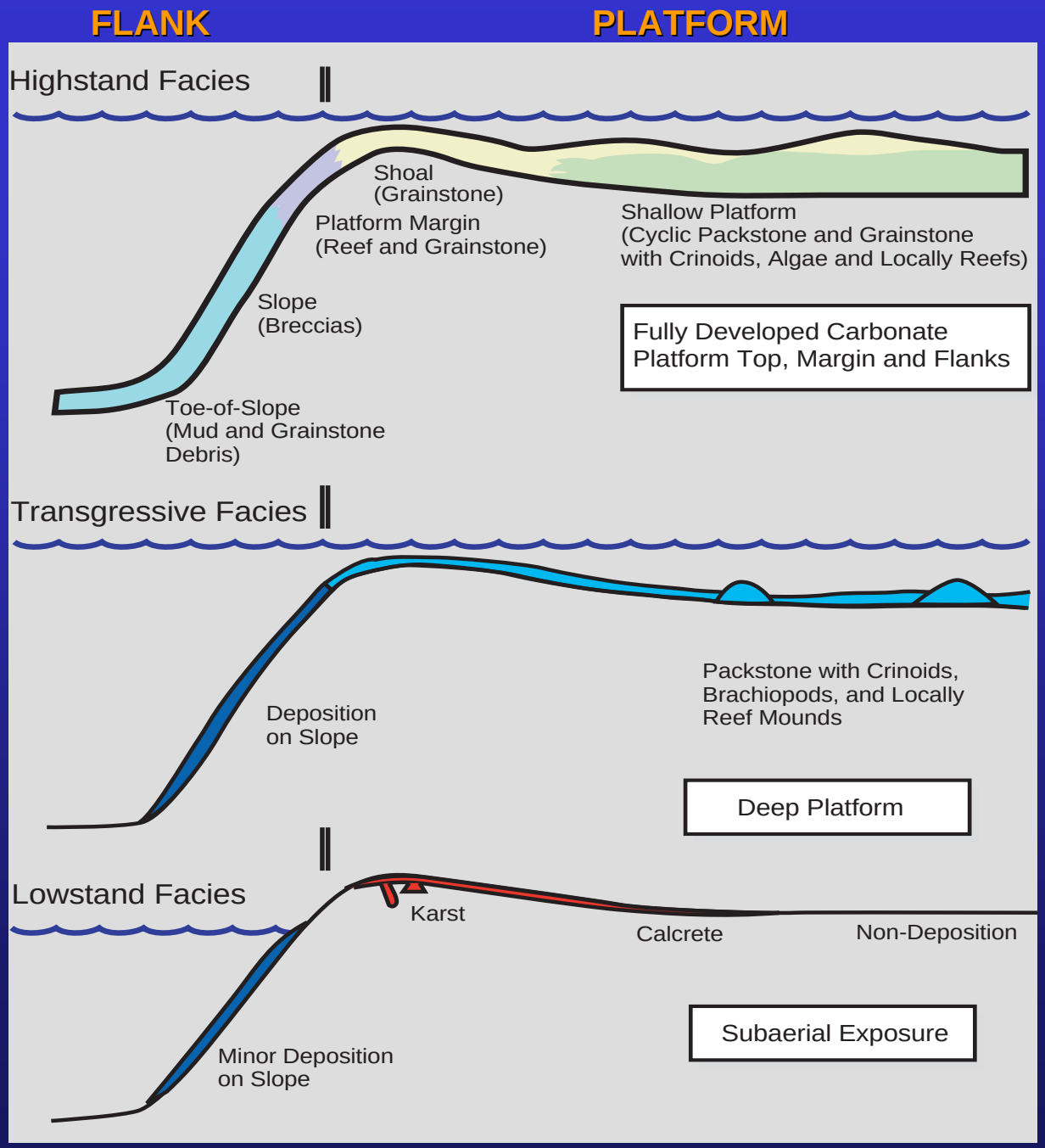
KEY FLANK WELL



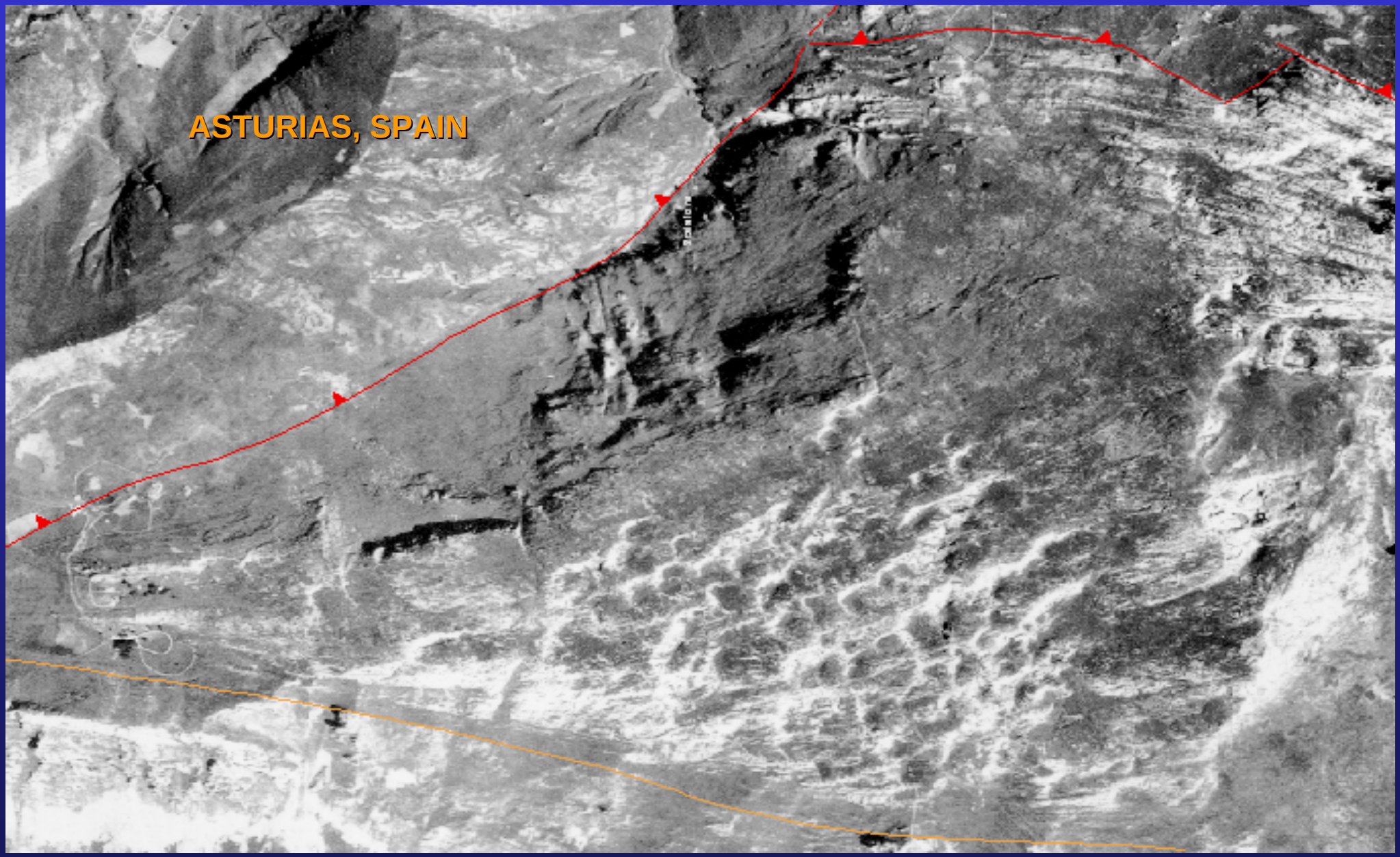
FLANK DEVELOPMENT



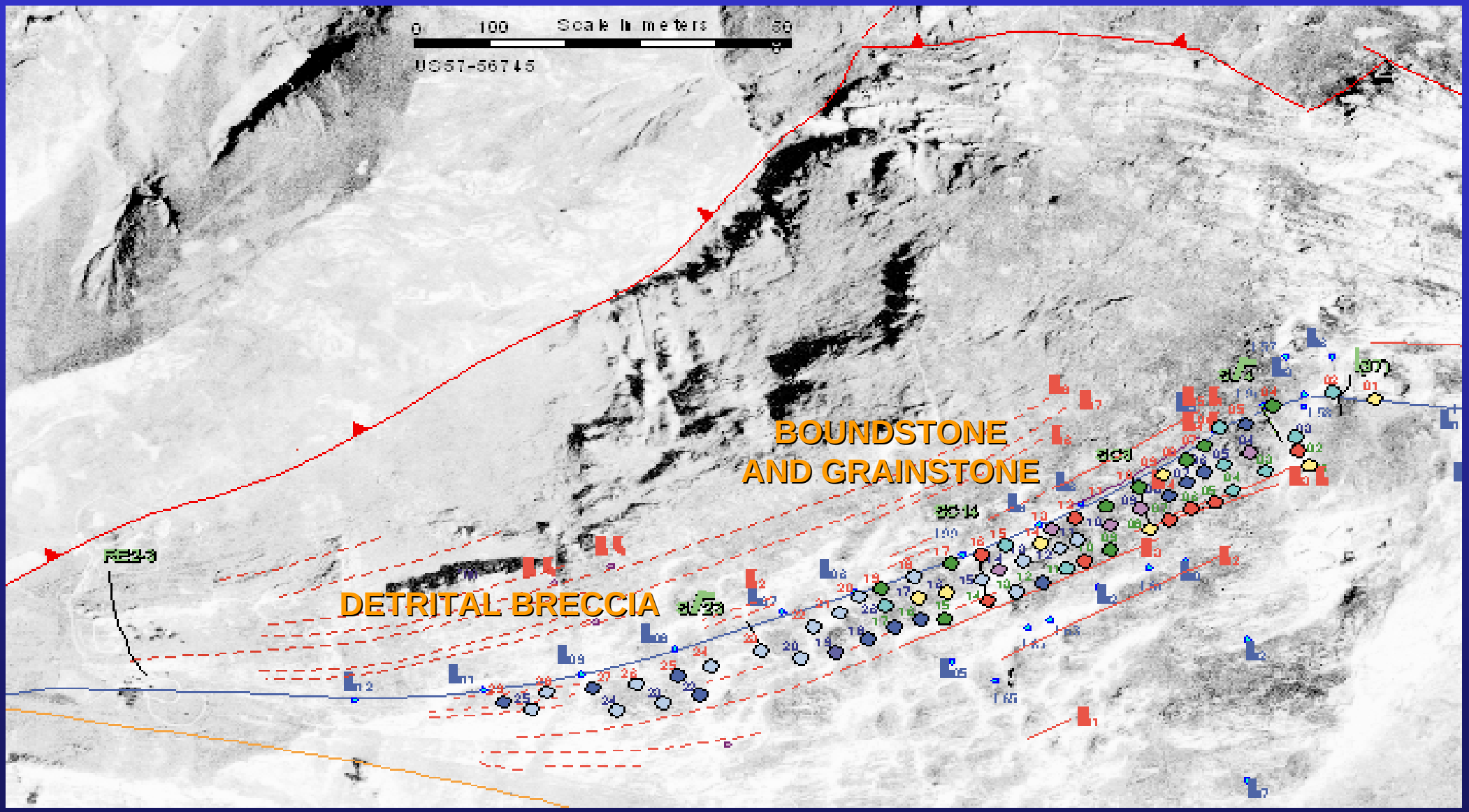
DEPOSITIONAL MODEL



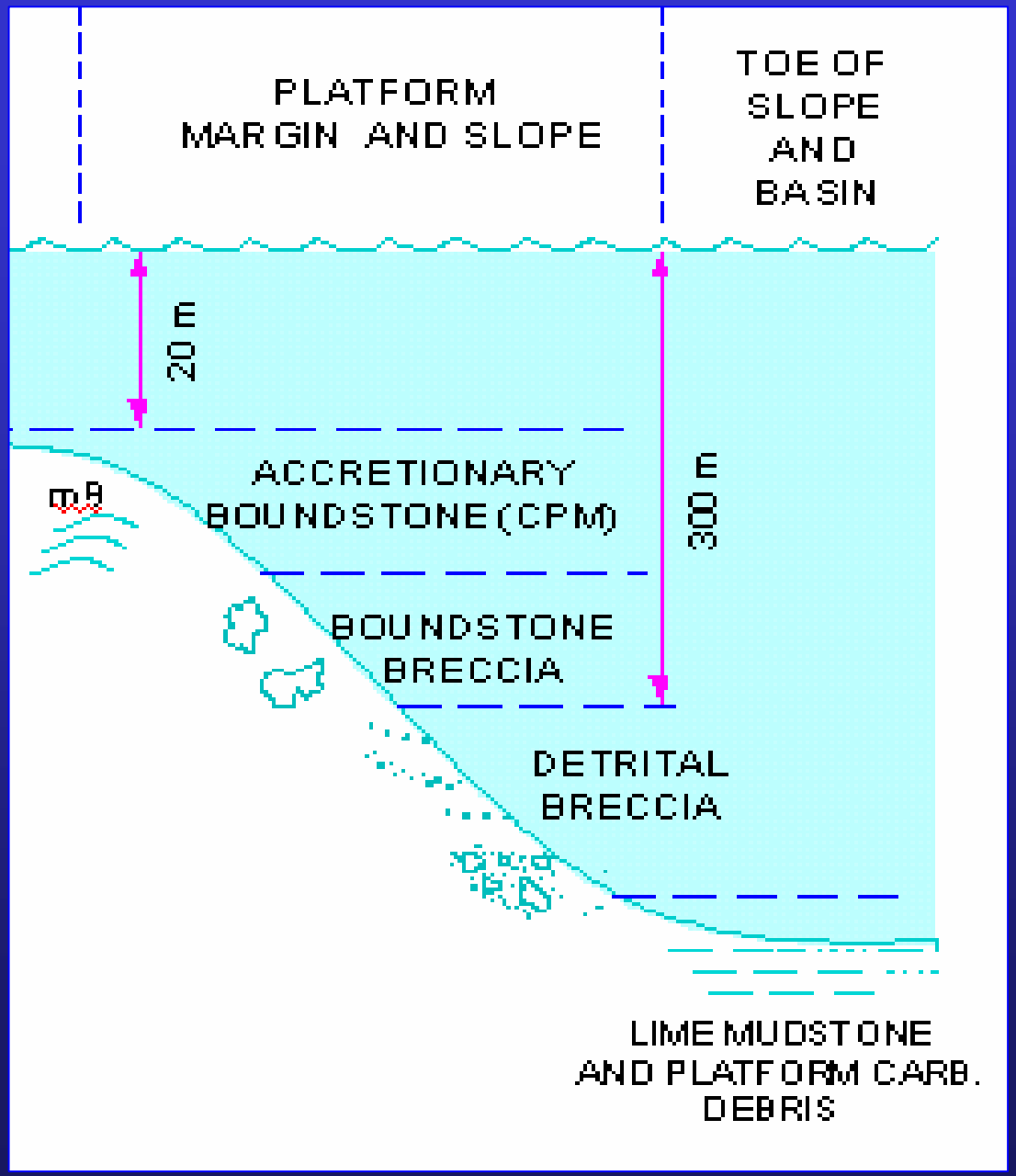
OUTCROP OF PLATFORM FLANK



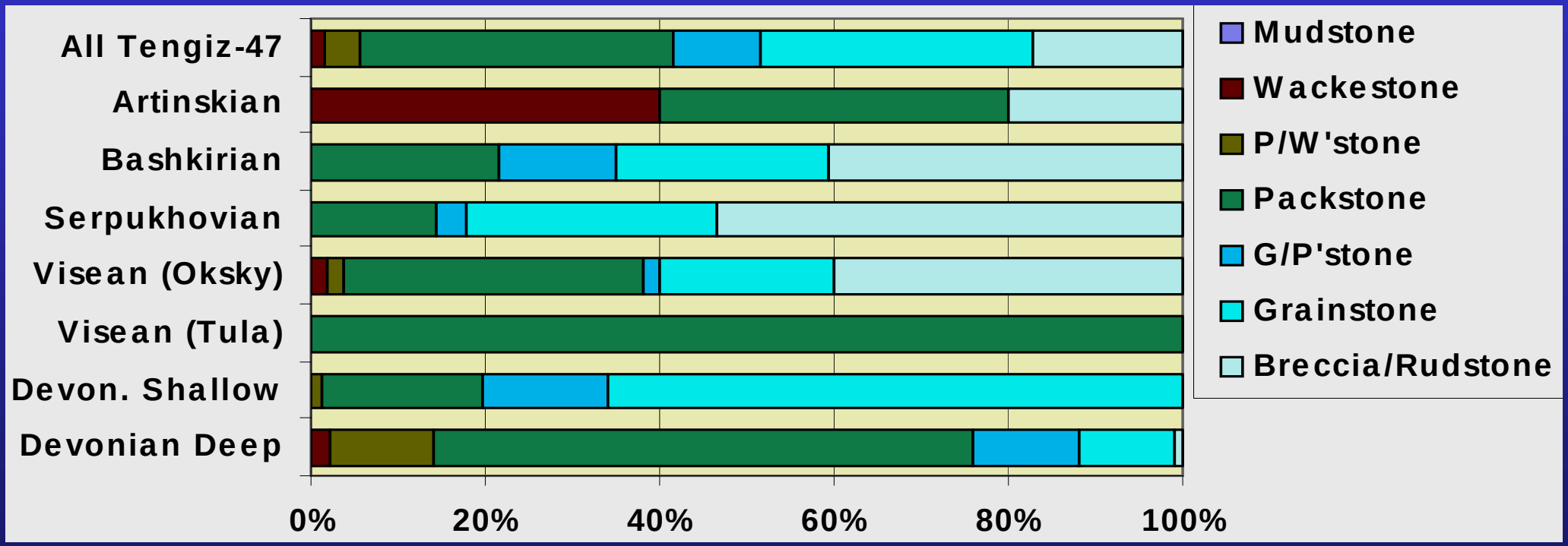
FLANK FACIES DISTRIBUTION



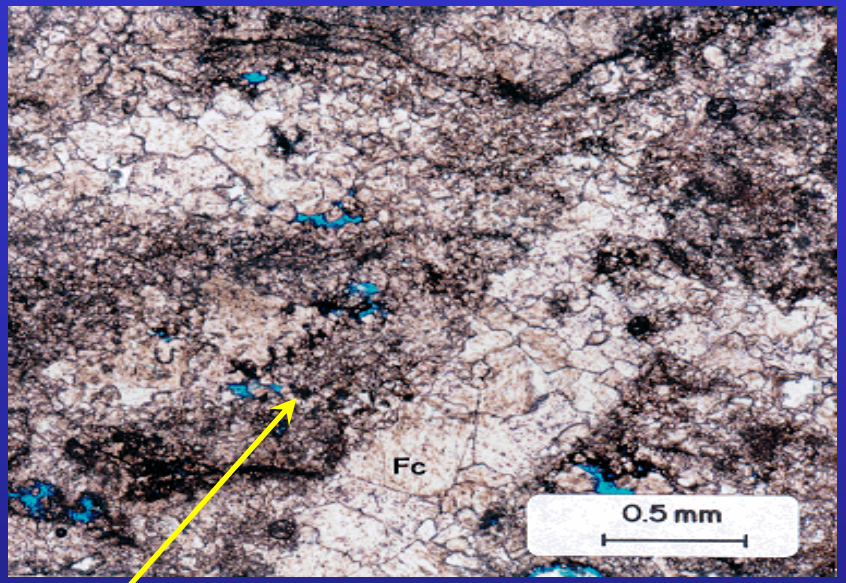
DEPOSITIONAL MODEL FOR SLOPE



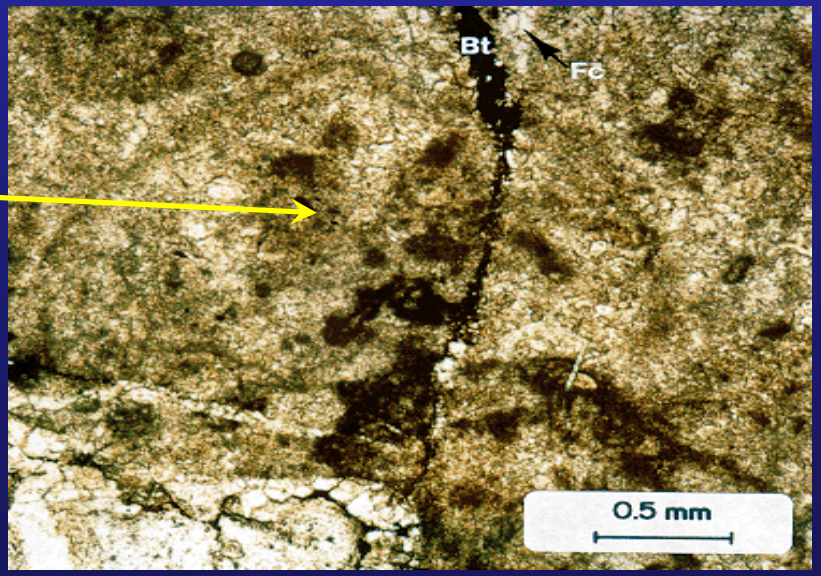
STRATIGRAPHY AND ROCK TYPE



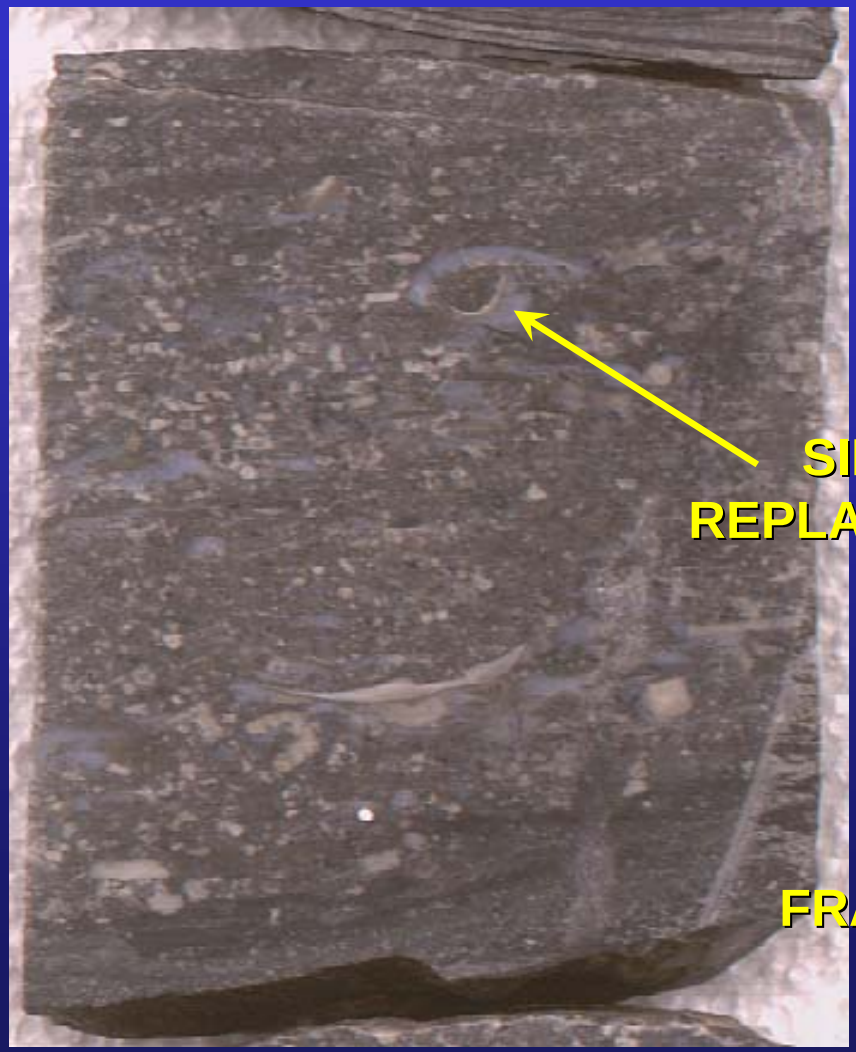
SLOPE BOUNDSTONE AND CLASTS

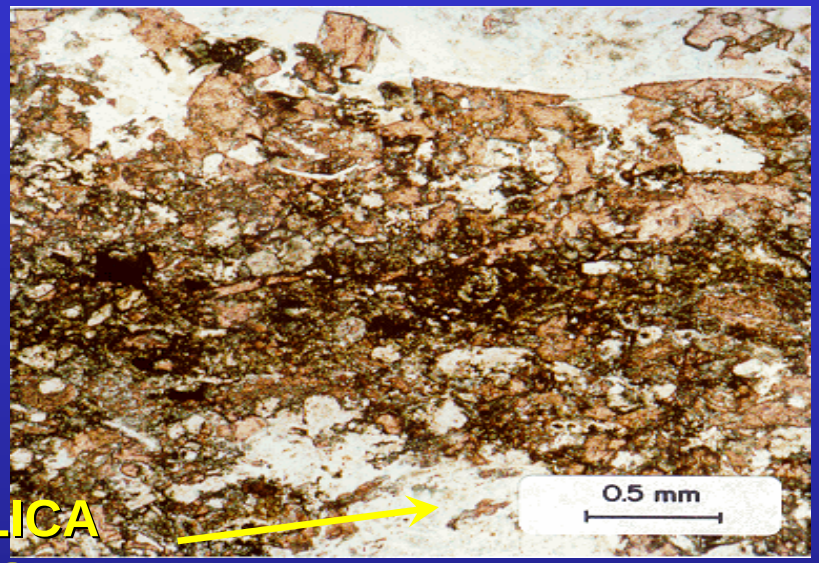


BOUNDSTONE

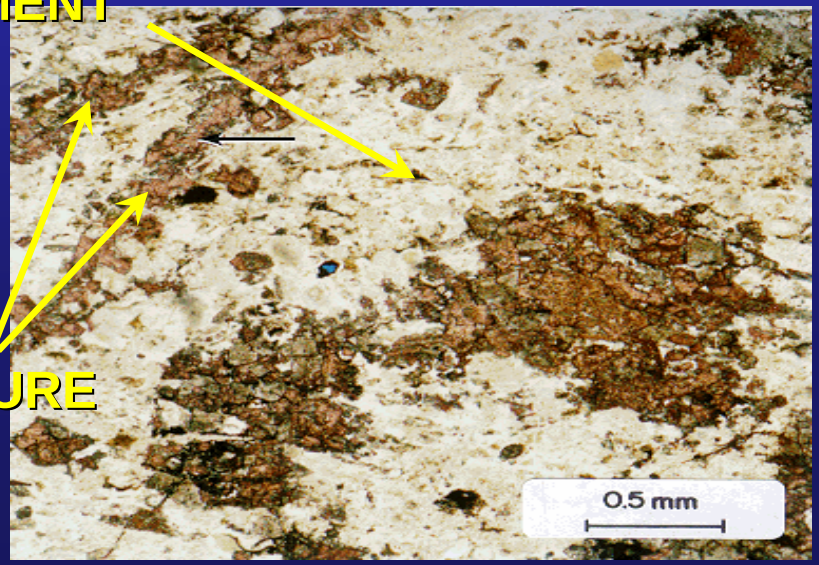


LOWER SLOPE PACKSTONES



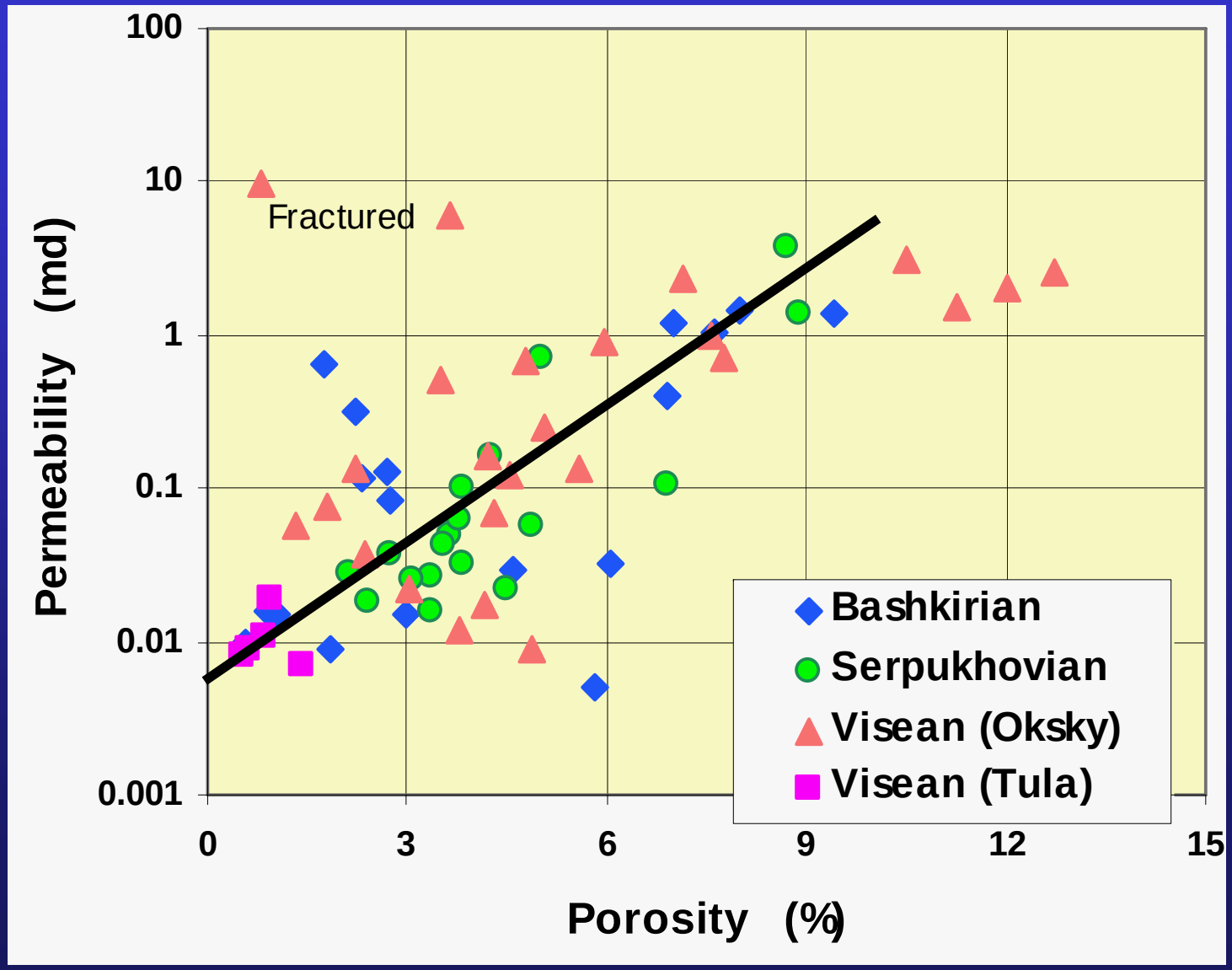


SILICA
REPLACEMENT

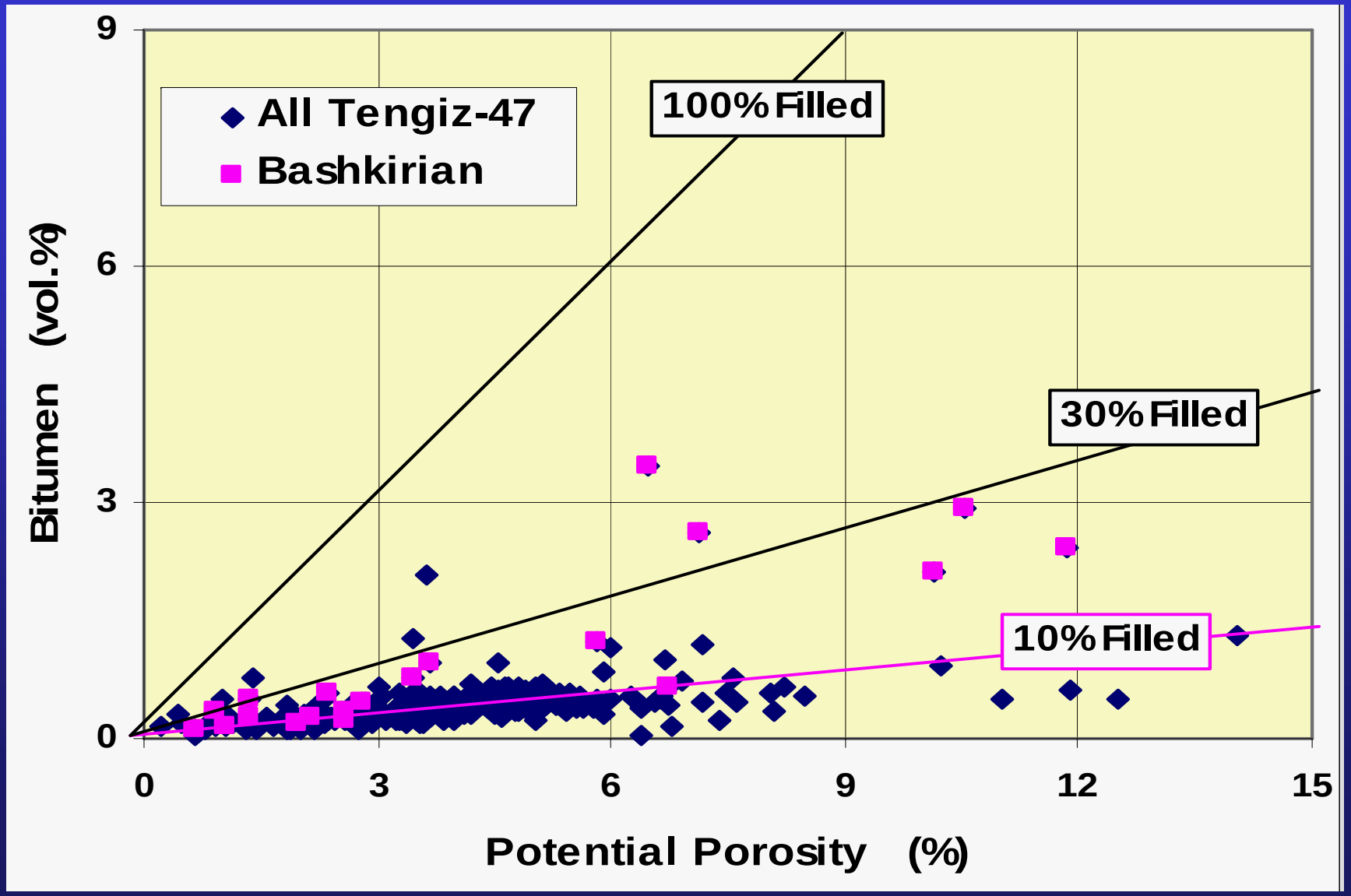


FRACTURE

SLOPE RESERVOIR QUALITY



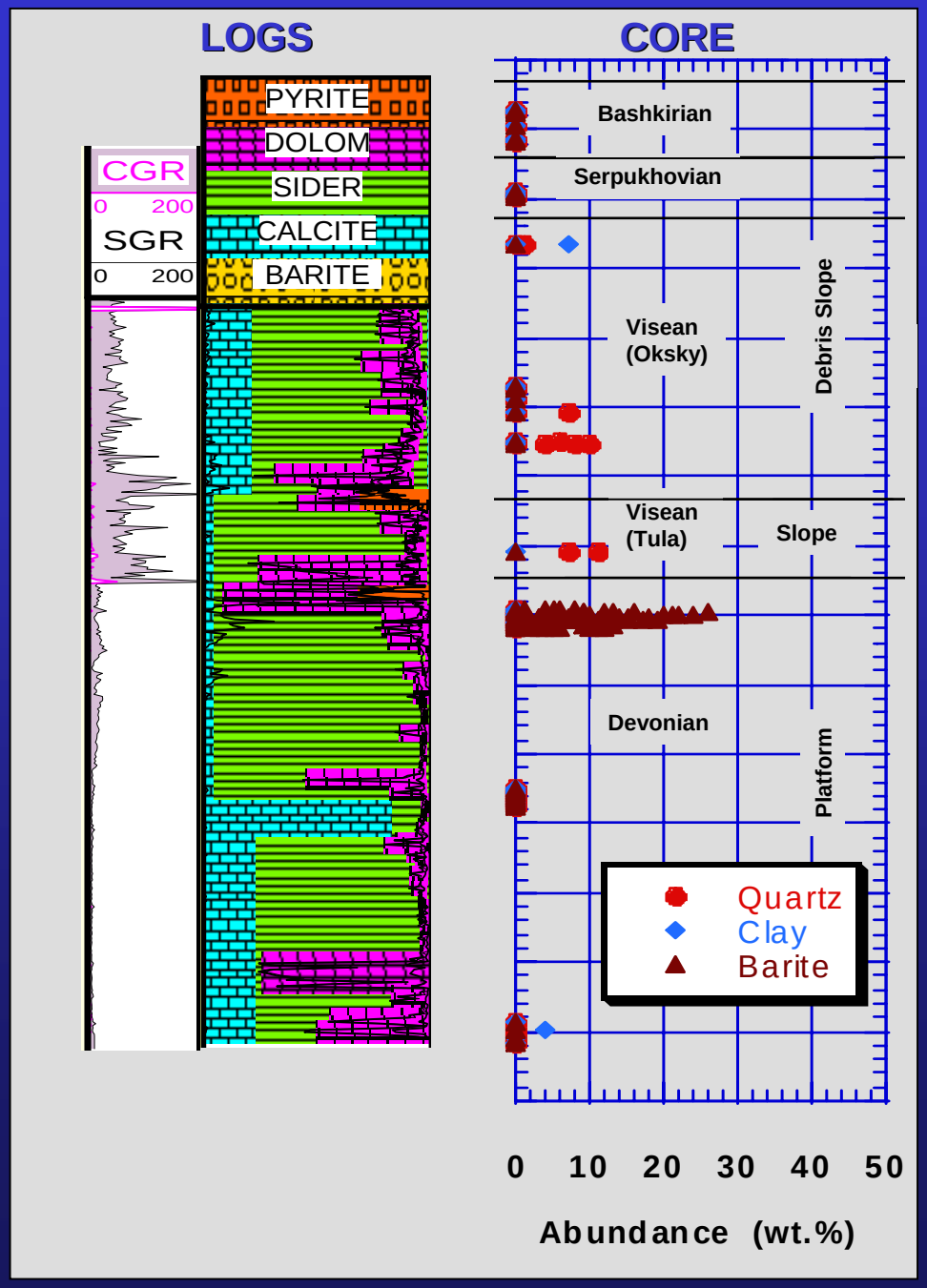
BITUMEN AND POROSITY



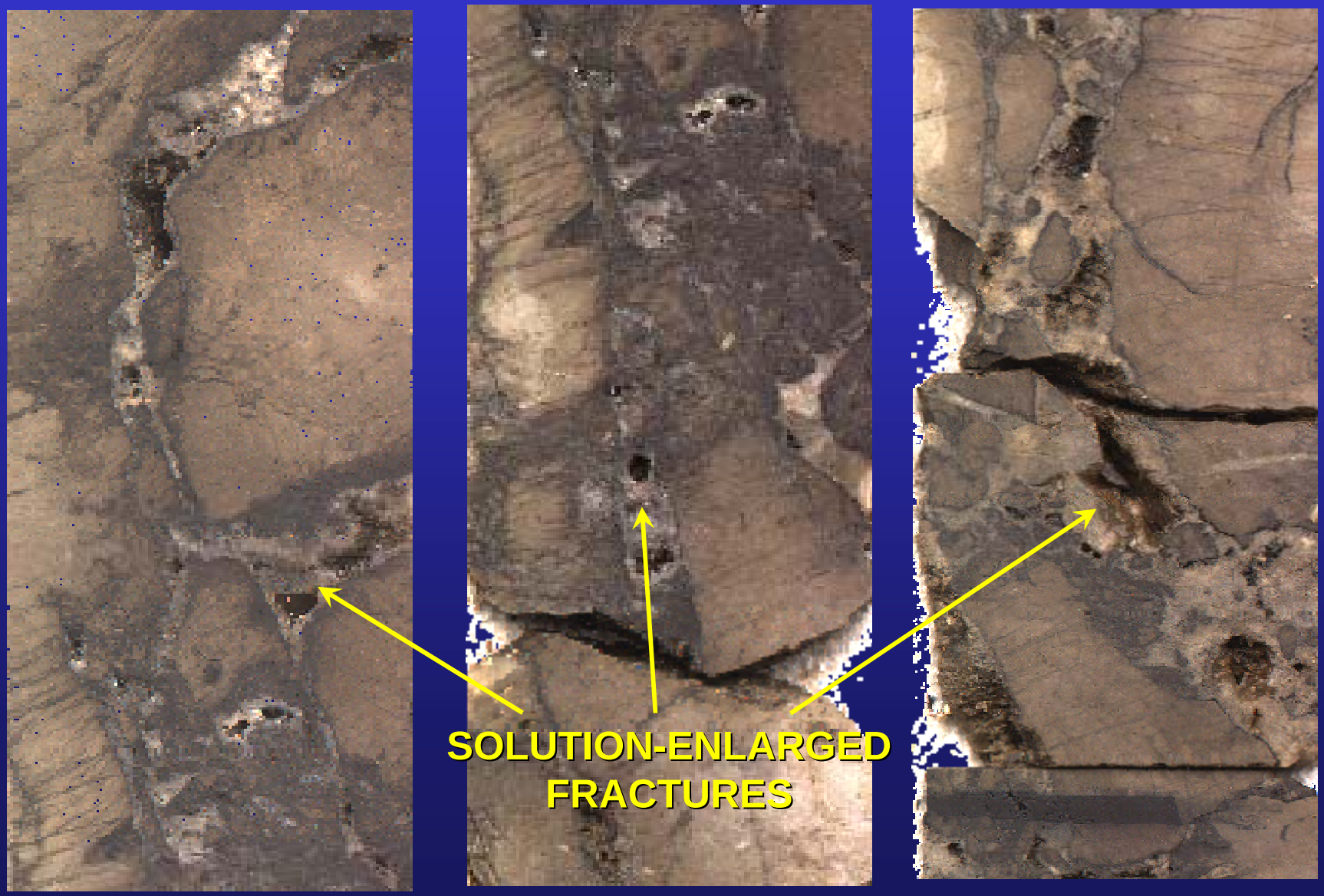
SLOPE DIAGENESIS

BURIAL
(HYDROTHERMAL?)

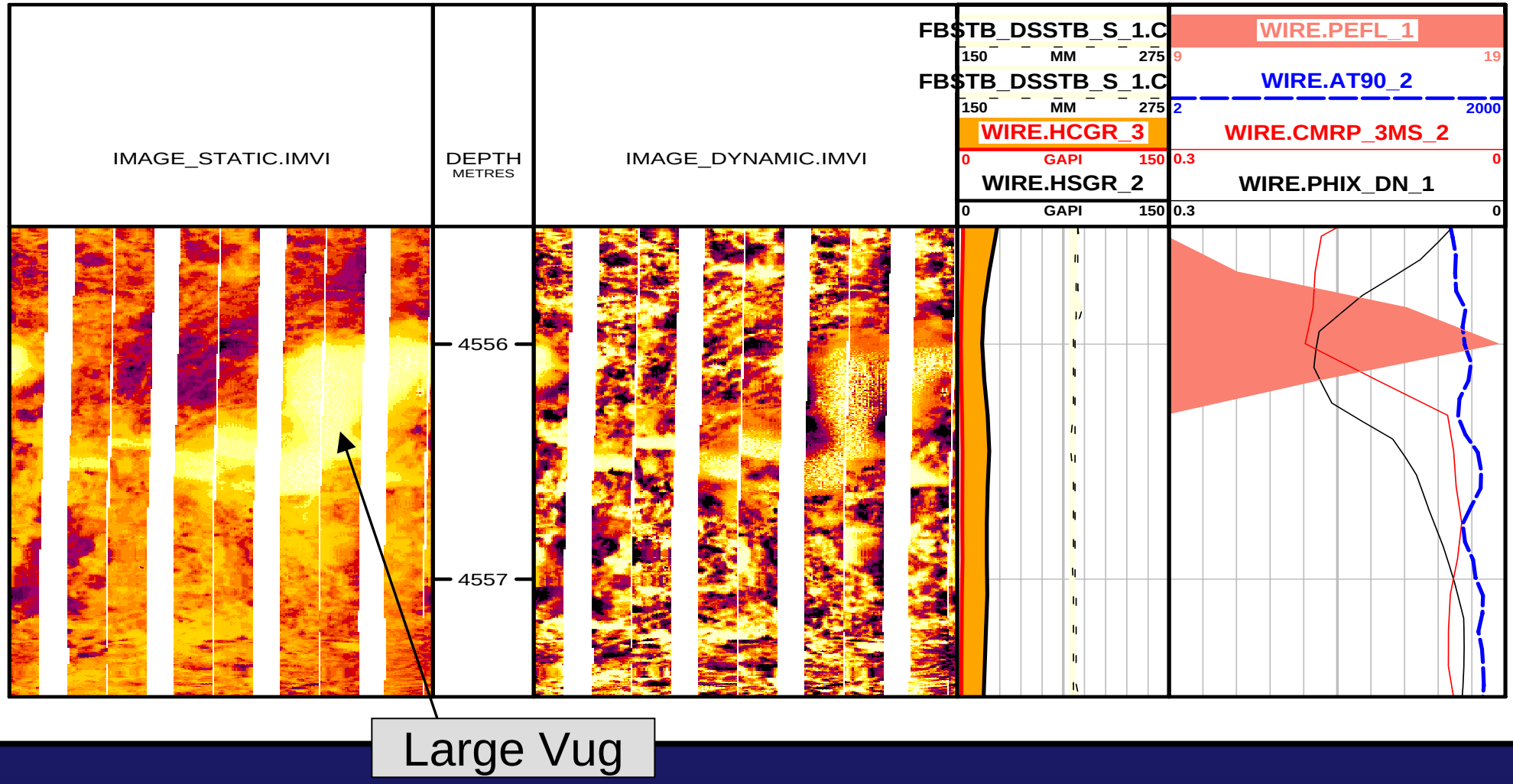
DOLOMITE
SILICA
BARITE
URANIUM



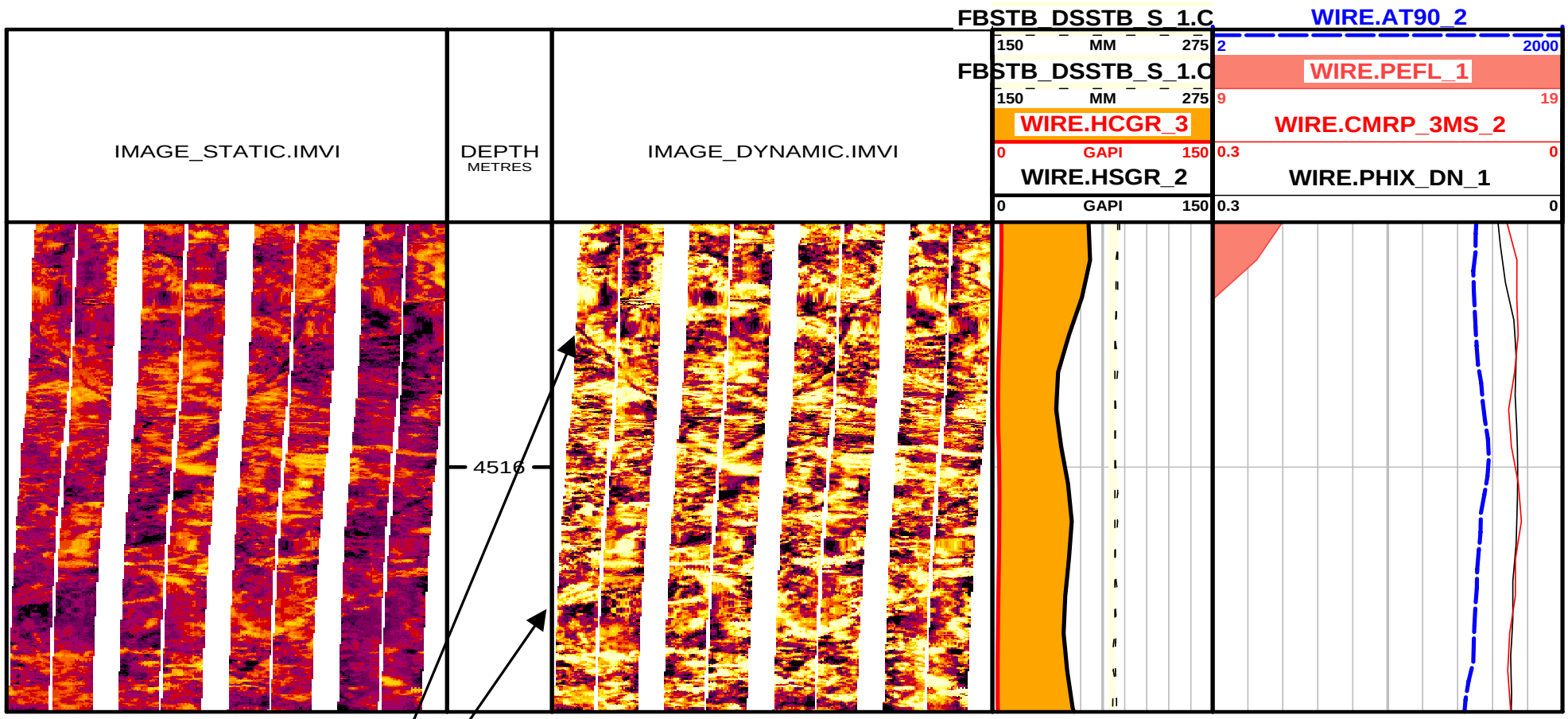
FRACTURES AND VUGS



VUGS IN FLANK WELLS

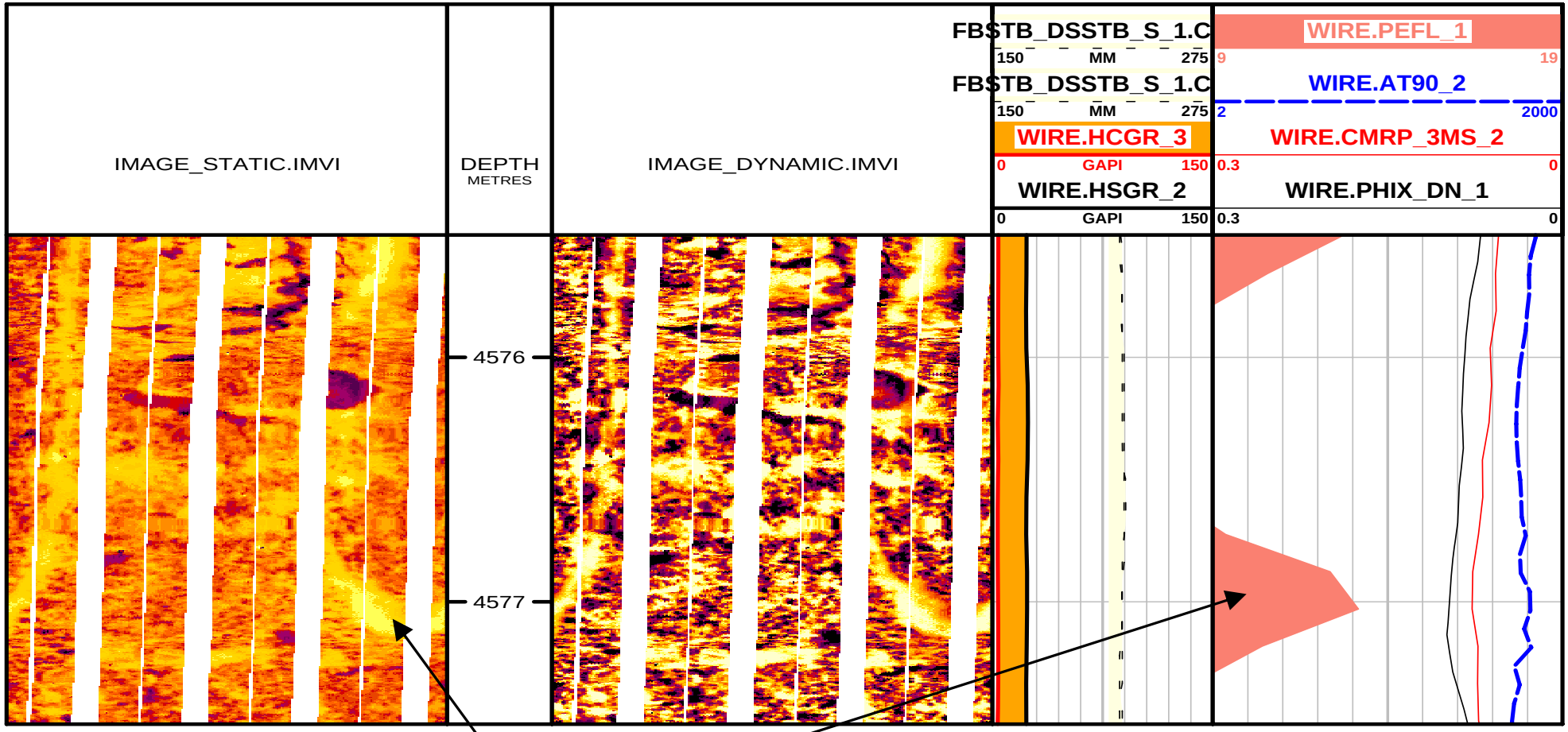


FRACTURES IN FLANK WELLS



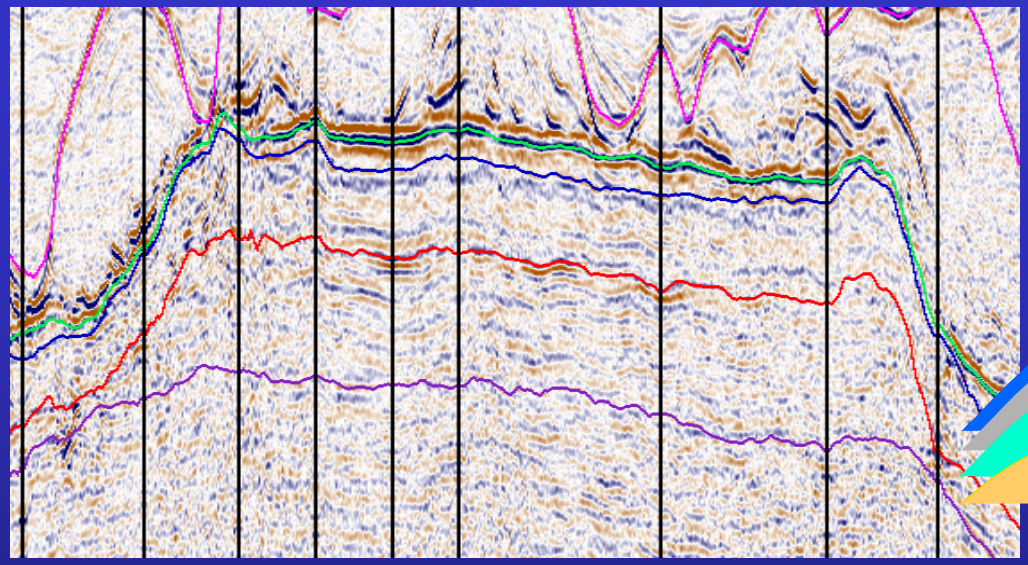
Fractures

FRACTURES IN FLANK WELLS

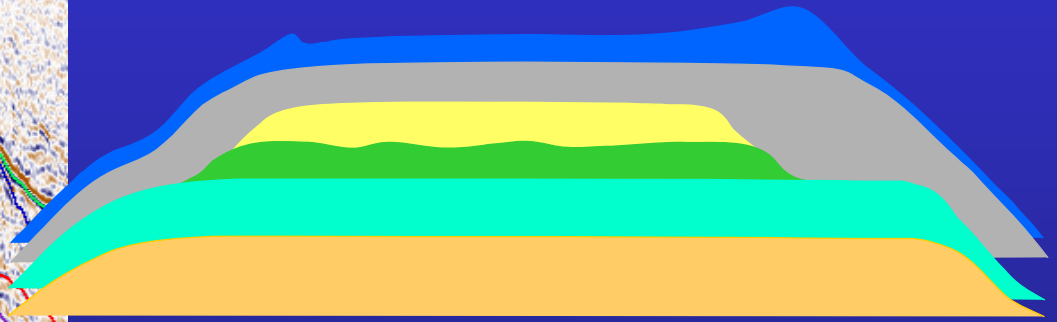


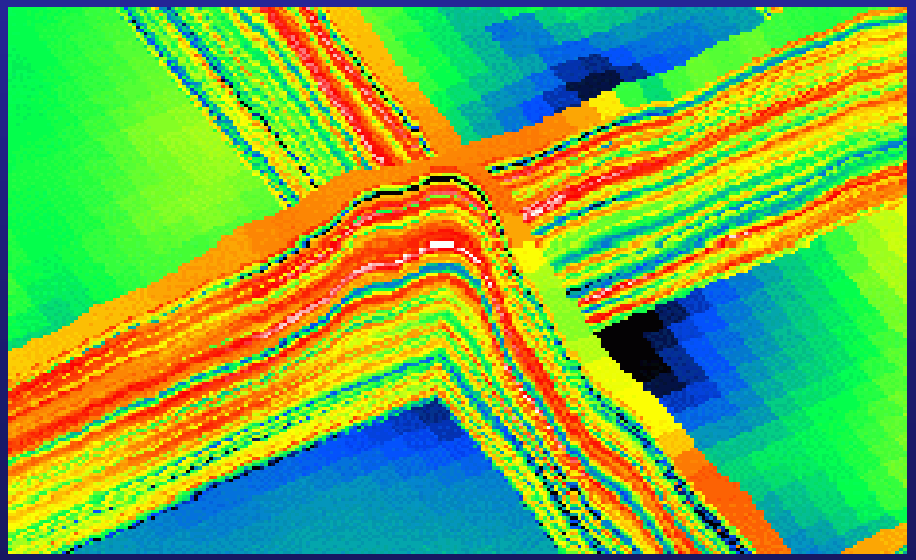
Fracture with whole mud invasion

TENGIZ AND KOROLEV

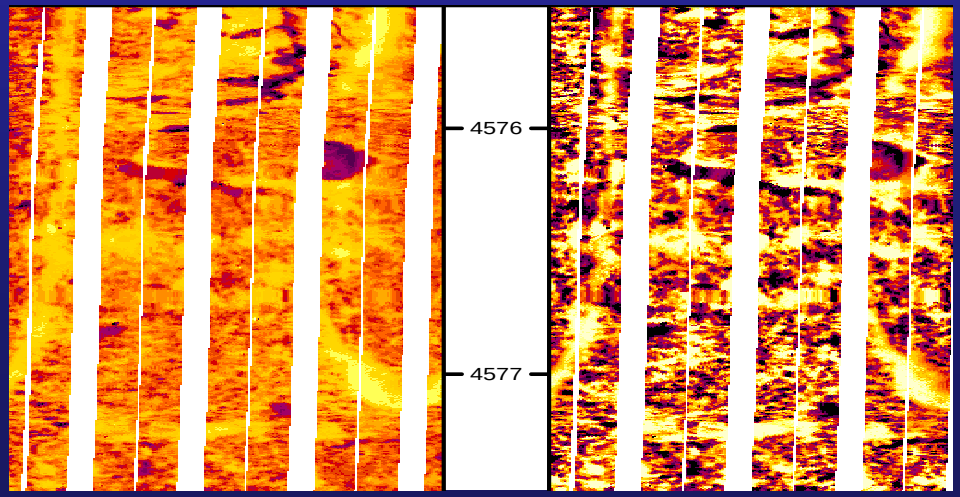


STRATIGRAPHIC FRAMEWORK





RESERVOIR QUALITY



SUMMARY POINTS

- Carboniferous Isolated Carbonate Platforms with Steep Flanks
- Platform Growth Viewed in Sequence Stratigraphic Context
- Reservoir Quality in Platform Controlled by Stratigraphy and Limited Diagenesis
- Reservoir in Flanks Related to Fracturing and Diagenesis