PSGeologic Framework for Korolev Field, Kazakhstan - A Carboniferous Isolated Carbonate Platform*

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Abstract

Core and log data are combined into cross sections and maps to develop a geologic framework for Korolev field, a Carboniferous isolated carbonate platform located in western Kazakhstan adjacent to the giant Tengiz Field. From these results, the following observations can be made:

Platform Growth - Major changes occurred in the Korolev platform from its inception in the Devonian through the Carboniferous. In each stage, there was a change in configuration and significant decrease in size of the platform. A widespread Devonian shallow platform was much larger than the present Korolev structure. During the Tournaisian and Visean the shallow platform decreased in size in all directions. The platform edges are abrupt, showing a relatively rapid change from platform top to slope environments. Serpukhovian environments indicate the platform constricted significantly from the north and south to become relatively equidimensional and centered about the present structure. The platform thickened dramatically during the Serpukhovian, either responding to a rapid sea level rise or due to tectonic movement. The platform decreased farther in an east-west direction during the Bashkirian. Artinskian (Permian) deposits in all of the off-structure wells are interpreted as slope and basin deposits, whereas the environment in the wells over the platform is questionable.

Reservoir Quality - Facies recognized in Korolev samples are generally similar to those observed at nearby Tengiz field. Grainstones and packstones are generally widely distributed but are of very limited extent in the Bashkirian. A thick, but narrow, reef margin is confirmed for the Serpukhovian. Porosity within the Korolev samples ranges from 0% to 27%, and permeability ranges up to 1060 md. Better reservoir properties, defined for Korolev as >7.5% and/or k >2 md, are common in Bashkirian, Serpukhovian, and Tournaisian-lower Visean samples.

GEOLOGIC FRAMEWORK FOR KOROLEV FIELD, KAZAKHSTAN – A CARBONIFEROUS ISOLATED CARBONATE PLATFORM

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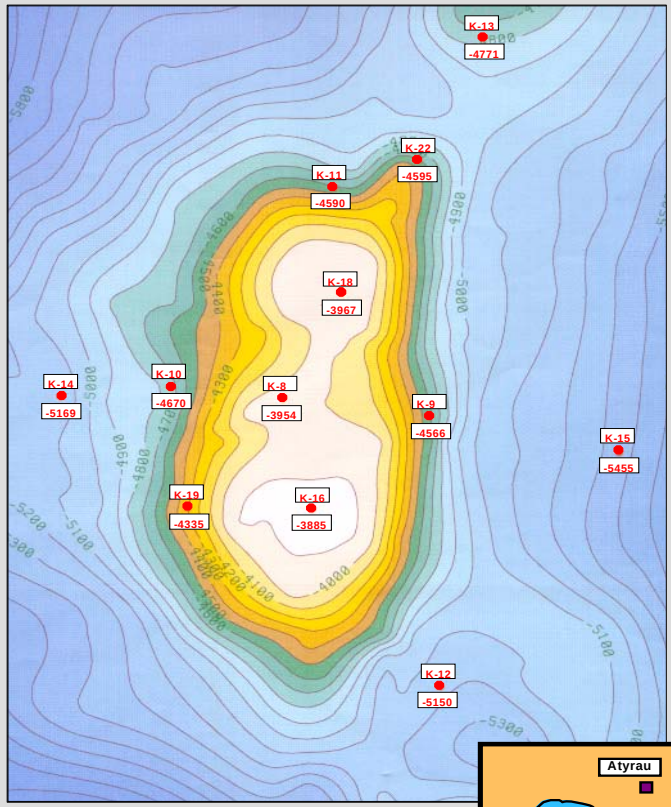
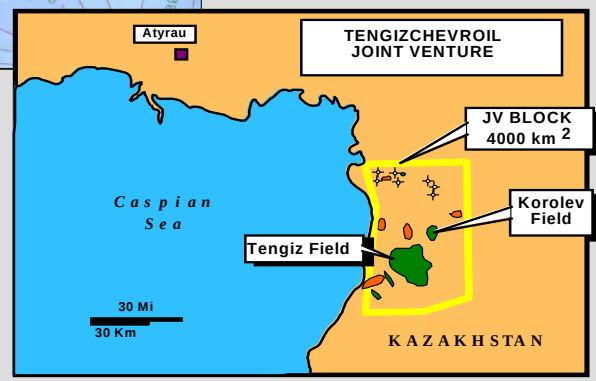
Field Map



Regional Setting



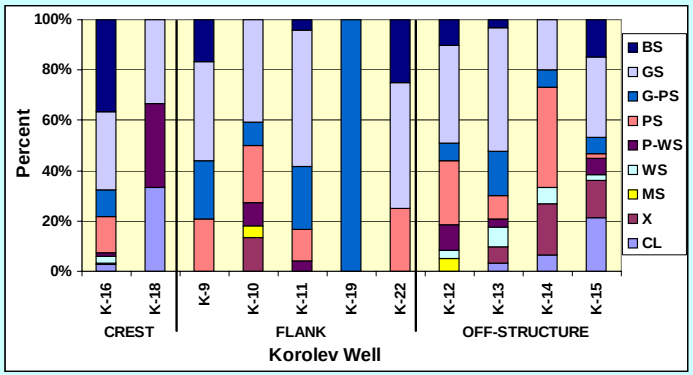
Stratigraphic Control, Facies, and Rock Types

Stratigraphic control provided by core and thin-section samples.
Number of thin-section samples is shown in parenthesis.

POSITION	CREST		FLANK					OFF-STRUCTURE			
AGE / WELL	K-16	K-18	K-9	K-10	K-11	K-19	K-22	K-12	K-13	K-14	K-15
KUNGURIAN		X (1)					X (1)				
ARTINSKIAN	X (3)	X (1)		X? (6)			X (1)	X (30)	X? (3)	X (7)	X (30)
BASHKIRIAN	X? (12)										
SERPUKHOVIAN	X (110)	X (1)	X (13)	X (7)							
OKSKY			X (1)								
TULA			X (53)	X (9)	X (23)	X (1)	X (2)		X (48)		
DEVONIAN								X (27)	X (12)	X (8)	X (10)

Depositional environment interpreted from core and thin-section samples.
(Sh = shoal, SP = shallow platform, R = reef, Sl = slope, B = basin.)

POSITION	CREST		FLANK					OFF-STRUCTURE			
AGE / WELL	K-16	K-18	K-9	K-10	K-11	K-19	K-22	K-12	K-13	K-14	K-15
KUNGURIAN		?					?				
ARTINSKIAN	?	?		?			?	B/Sl	B	Sl	Sl
BASHKIRIAN	Sh										
SERPUKHOVIAN	SP/R	SP	SP/R	SP							
OKSKY			SP								
TULA			SP	SP	SP	SP	SP		SP		
DEVONIAN								SP	SP	SP	SP/R?

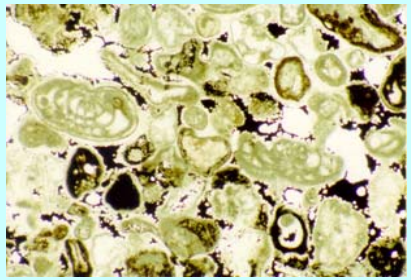


Summary of rock types recognized in wells. BS = boundstone; GS = grainstone; G-PS = grainstone to packstone; PS = packstone; P-WS = packstone to wackestone; WS = wackestone; MS = mudstone; X = crystalline carbonate; CL = siliciclastics.

Representative Rock Types

Shoal

Korolev 16
3,945.0 m Core Depth – Bashkirian



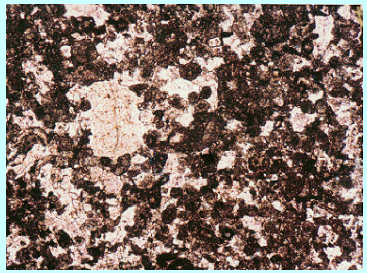
3 mm across field

Petrography: Coarse skeletal (brachiopod, crinoid, gastropod, pelecypod, foraminifer) – coated grain grainstone-packstone; thin rim cement around most grains; blocky calcite in interparticle, intraskeletal, and moldic porosity; black bitumen in microporous grains and interparticle, intraskeletal, moldic, and microfracture porosity; open interparticle and microvuggy porosity.

Core Analysis:
$Ø_{[air]}$ = 8.4 % $k_{[air]}$ = 43 md

Shallow Platform

Korolev 10
4,789.50-4789.55 m #88 Core Depth – Tula



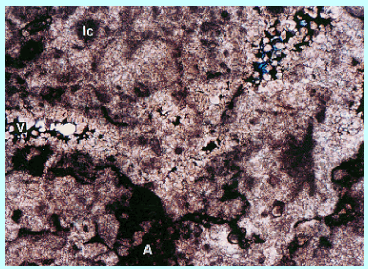
3 mm across field

Petrography: The micritic grains in this peloid-skeletal packstone have been neomorphosed and partially leached to form patches of intercrystalline micropores. Although this sample has fair porosity, the permeability will probably be low due to (1) the small size and heterogeneous distribution of the micropores, (2) compaction, (3) a micrite to microspar matrix, and (4) poorly developed syntaxial overgrowths on echinoderm fragments. Thus this sample is judged to have poor reservoir potential. Framework grains consist of peloids, intraclasts, crinoids, and forams.

Core Analysis:
$Ø_{[air]}$ = 10.1 % $k_{[air]}$ = not measured
TOC = 0.332 wt.% **Solid Bitumen** = 0.704 vol. %

Reef

Korolev 16
4,094.2 m Core Depth – Serpukhovian



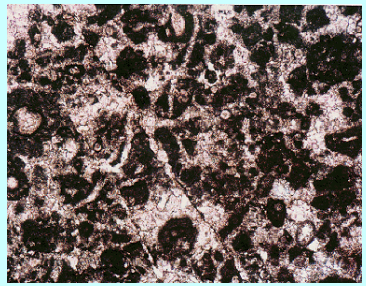
3 mm across field

Petrography: The pore system in this algal wackestone/ boundstone contains isolated vuggy pores and lesser amounts of intercrystalline micropores. Many of the vugs are partially to completely filled with equant calcite and trace amounts of an unidentified isotropic mineral. Bitumen coats the vugs and fills some of the small intercrystalline pores. Two types of algal growths are shown; dark, "tubular" algal structures and the surrounding "clotted," algal matrix. The vuggy pores appear to be solution-enhanced fractures within the algal-boundstone portion of the sample. Forams, peloids, bryozoans, and worm tubes tend to be concentrated at the edge of the sample.

Core Analysis:
$Ø_{[air]}$ = 2.6 % $k_{[air]}$ = 0.086 md
TOC = 0.28 wt.% **Solid Bitumen** = 0.6 vol. %

Slope

Korolev 15
5,415.00-5,415.12 m Core Depth – Artinskian

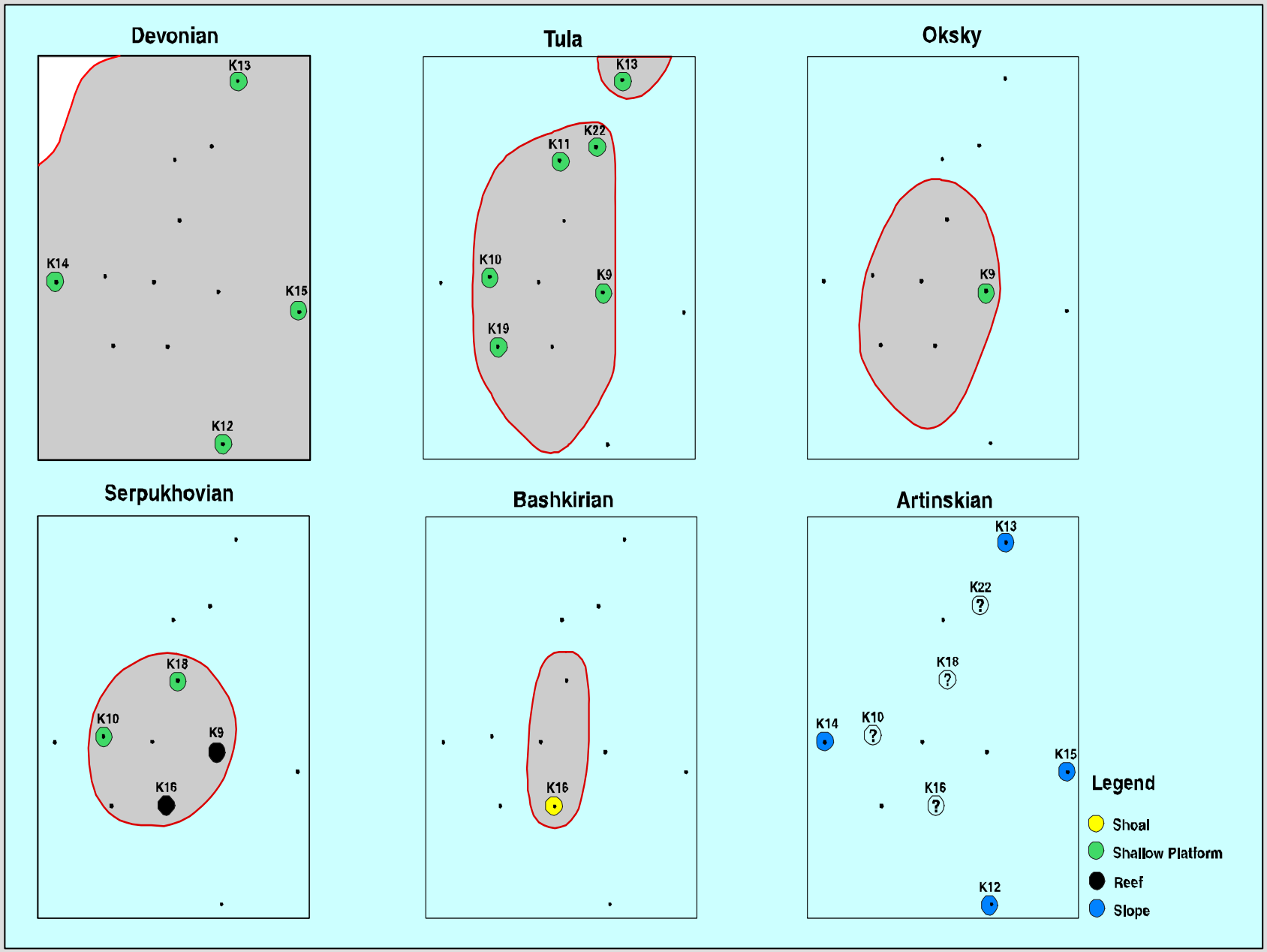


3 mm across field

Petrography: This peloid-intraclast grainstone has very narrow, bitumen-stained fractures, and slightly wider, calcite-filled and bitumen-stained fractures. There is no visible pore space due to extensive equant calcite cementation of primary and secondary pores. Framework grains are composed of peloids, intraclasts, forams, algal grains, and some larger pelecypod shells.

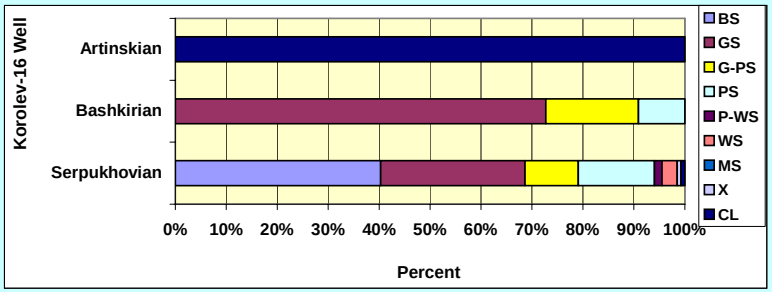
Core Analysis:
$Ø_{[air]}$ = 0.8 % $k_{[air]}$ = not measured
TOC = 0.075 wt.% **Solid Bitumen** = 0.180 vol. %

Facies Maps


Devonian
K13
K14
K15
K12
Tula
K13
K22
K11
K10
K9
K19
Oksky
K9
Serpukhovian
K18
K10
K9
K16
Bashkirian
K16
Artinskian
K13
K22
?
K18
?
K14
K10
?
K15
K16
?
K12
Legend
Shoal
Shallow Platform
Reef
Slope

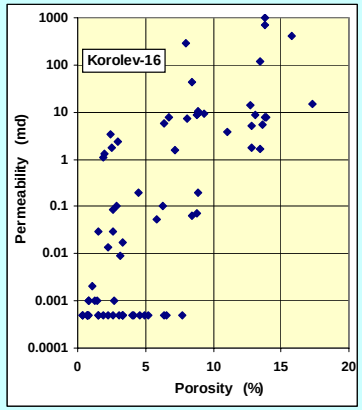
Details of A Key Well - K-16

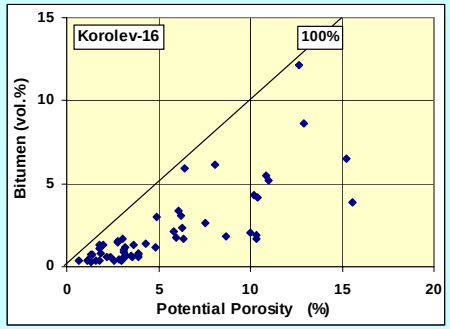
Summary of Rock Types



BS = boundstone; GS = grainstone; G-PS = grainstone to packstone; PS = packstone; P-WS = packstone to wackestone; WS = wackestone; MS = mudstone; X = crystalline carbonate; CL = siliciclastics.

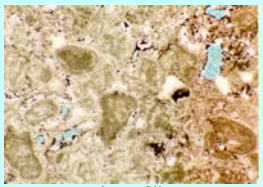
Porosity, Permeability, Bitumen





Representative Rock Types

3,947.2 m Core Depth – Bashkirian (?)

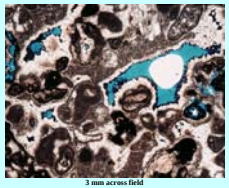


3 mm across field

Petrography: Coarse coated grain – ooid – skeletal (foraminifer, crinoid, brachiopod) grainstone; rim cement around most grains, blocky calcite in interparticle and intraparticle porosity, coarse blocky calcite in some interparticle porosity; black bitumen in microporous grains, interparticle and intraparticle porosity, microfractures in grains, and along microstylolites; open interparticle porosity, some solution-enlarged.

Core Analysis:
No core analysis data within 0.5 m of sample.

3,948.6 m Core Depth – Serpukhovian

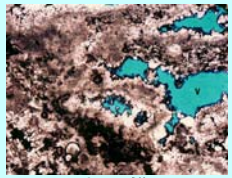


3 mm across field

Petrography: This sample has a grainstone texture in one area and a packstone texture in the remainder and shows the fairly distinct grainstone/packstone boundary. Moldic pores are common in the packstone portion, while reduced, poorly interconnected, intergranular, and moldic pores are apparent in the grainstone. An early sparry calcite cement is present on many of the allochems; bitumen (black) lines many of the pores.

Core Analysis:
$Ø_{[air]}$ = 8.6 % $k_{[air]}$ = not measured
TOC = 0.78 wt.% **Solid Bitumen** = 1.7 vol. %

4,049.0 m Core Depth – Serpukhovian

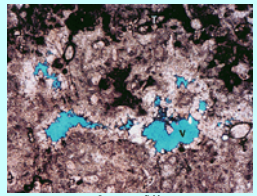


3 mm across field

Petrography: The pore system in this algal-peloid packstone consists of relatively large, apparently poorly interconnected vugs and molds. Sparry and equant calcite cement plus bitumen partially occlude the pores. Algal laminae, jointed algal plates, forams, and spines occur within the sample. The paragenetic sequence is fenestral pores form in the algal laminae, compaction, grain dissolution forms moldic pores, precipitation of sparry calcite cement, precipitation of equant calcite cement, and bitumen emplacement.

Core Analysis:
$Ø_{[air]}$ = 3.9 % $k_{[air]}$ = not measured

4,050.6 m (b) Core Depth – Serpukhovian

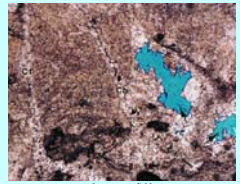


3 mm across field

Petrography: This is an algal encrustation on a pelecypod shell. Note the "tubular" structures in the algae. Vuggy and enhanced intergranular pores have a random distribution and are fairly well connected, as indicated by the high-permeability value.

Core Analysis:
$Ø_{[air]}$ = 8.0 % $k_{[air]}$ = 291 md
TOC = 0.91 wt.% **Solid Bitumen** = 2.0 vol. %

4,095.0 m Core Depth – Serpukhovian



3 mm across field

Petrography: This algal limestone is highly fractured; there are partially open, solution-enhanced fractures (arrow), calcite-filled and calcite/ bitumen-filled fractures. Algal laminae are predominant, with lesser amounts of peloids, worm tubes, forams, and fenestrate bryozoans present. Intercrystalline micropores also occur in algal grains and worm tubes.

Core Analysis:
$Ø_{[air]}$ = 2.5 % $k_{[air]}$ = 0.175 md
TOC = 0.22 wt.% **Solid Bitumen** = 0.5 vol. %

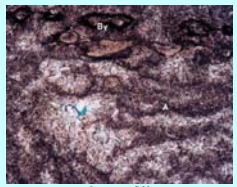
4,097.0 m Core Depth – Serpukhovian

3 mm across field

Petrography: Recrystallized skeletal (bryozoan, algae, foraminifer, crinoid, ostracod) – peloid grainstone; rim cement locally developed; blocky calcite in interparticle, intraskeletal, and moldic porosity; coarse blocky calcite in microvuggy and microfracture porosity; brown bitumen rare in microporous grains; black bitumen in microvuggy, microfracture, and intercrystalline porosity; open microvuggy and microfracture porosity.

Core Analysis:
No core analysis data within 0.5 m of sample.

4,140.5 m Core Depth – Serpukhovian

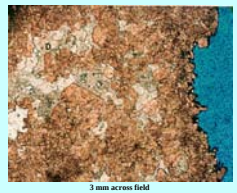


3 mm across field

Petrography: The light brown, micritic layers in the photomicrograph are algal growth laminae. Occasional fenestrate bryozoans, brachiopods, and forams are intergrown within the algal. There are traces of dolomite cement/replacement around some of the moldic pores. Calcite, dolomite, and trace amounts of euhedral quartz occlude most pore space.

Core Analysis:
$Ø_{[air]}$ = 0.8 % $k_{[air]}$ = 0.001 md
TOC = 0.19 wt.% **Solid Bitumen** = 0.5 vol. %

4,141.0 m Core Depth – Serpukhovian

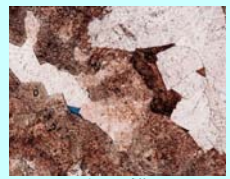


3 mm across field

Petrography: Extensive neomorphism has slightly masked the original texture of this algal boundstone(?). Euhedral dolomite and anhydrite partially replace the limestone. Heterogeneously distributed vugs (right edge) are present. The vugs are partially cemented with equant calcite cement.

Core Analysis:
$Ø_{[air]}$ = 2.2 % $k_{[air]}$ = not measured
TOC = 0.38 wt.% **Solid Bitumen** = 0.9 vol. %

4,153.1 m Core Depth – Serpukhovian

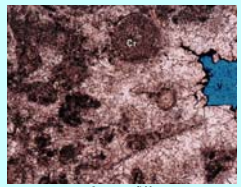


3 mm across field

Petrography: This "cuspate-laminated" algal boundstone has undergone neomorphism and partial leaching to create vuggy pores. Subsequently these vugs were partially occluded by cements, in this order: inclusion-rich sparry calcite cement; clear, equant calcite cement; dolomite cementation/replacement; quartz replacement and cementation; anhydrite replacement/cementation; and bitumen emplacement. The remnant pores are scattered and poorly connected.

Core Analysis:
$Ø_{[air]}$ = 0.6 % $k_{[air]}$ = not measured
TOC = 0.30 wt.% **Solid Bitumen** = 0.7 vol. %

4,230.2 m Core Depth – Serpukhovian



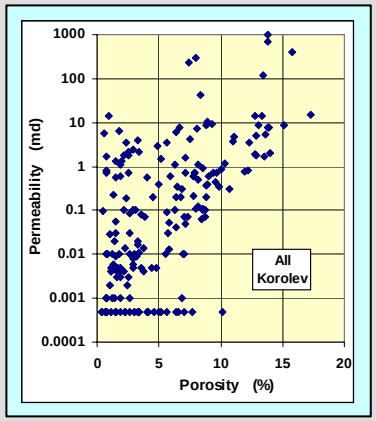
3 mm across field

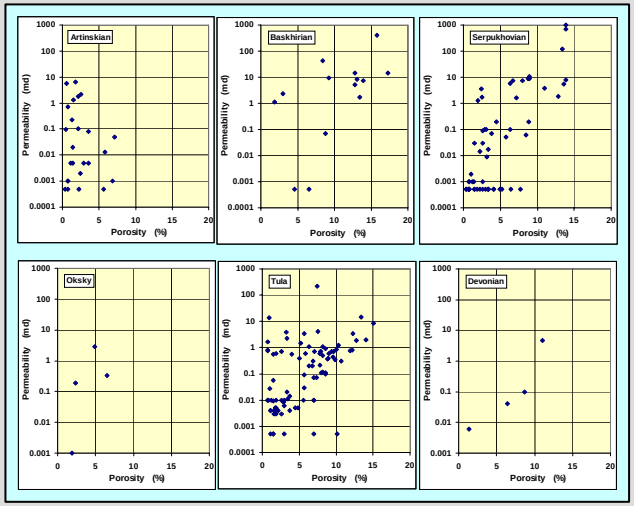
Petrography: This skeletal-peloid grainstone has a wide faunal diversity that includes forams, bryozoans, crinoids, ostracodes, and bivalves. There are widely scattered, bitumen-coated vugs, moldic pores, as well as small amounts of intercrystalline micropores in neomorphosed grains. Calcite cement occluded nearly all of the primary pore space.

Core Analysis:
$Ø_{[air]}$ = 0.4 % $k_{[air]}$ = not measured
TOC = 0.58 wt.% **Solid Bitumen** = 1.4 vol. %

Diagenesis and Reservoir Quality

Porosity - Permeability





Mineralogy

Non-calcite minerals recognized in core and thin-section samples. 1 = dolomite, 2 = silica, 3 = feldspar, 4 = pyrite, 5 = anhydrite, 6 = halite, 7 = fluorite, 8 = siderite.

POSITION	CREST		FLANK					OFF-STRUCTURE			
AGE / WELL	K-16	K-18	K-9	K-10	K-11	K-19	K-22	K-12	K-13	K-14	K-15
KUNGURIAN		5					5				
ARTINSKIAN	2,4	none		1,2,4,5			4	1,2,4,7	2,4,5	1,2,4	1,2,4
BASHKIRIAN	2										
SERPUKHOVIAN	1,2,4,5 6?	none	1,2,7	1,2,6?							
OKSKY			none								
TULA			1,2,3,7	1,3	1	none	none		1,2		
DEVONIAN								1,2,4,8	1,2	1	1

Diagenetic stages recognized in core and thin-section samples. Early diagenesis = E1 (rim cement) (dissolution), 3 (syntaxial and blocky calcite cement). Burial diagenesis = B1 (microfracturing/stylolites (dissolution), 3 (cementation/ replacement), 4 (bitumen), 5 (fracturing), 6 (coarse calcite).

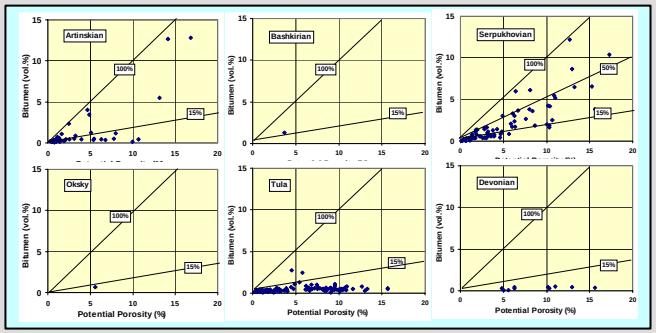
POSITION	CREST		FLANK					OFF-STRUCTURE			
AGE / WELL	K-16	K-18	K-9	K-10	K-11	K-19	K-22	K-12	K-13	K-14	K-15
BASHKIRIAN	E1,2,3 B1, 2,4										
SERPUKHOVIAN	E1, 2,3 B1,2,3 4,5,6	E3 B1,4	E1,2,3 B1,2,4	E3 B1,2,3 4							
OKSKY			E2,3 B1,2,4								
TULA			E1,2,3 B1,3,4 5,6	E1,3 B1,3,4	E1,2,3 B1,4,5 6	E3 B1,4	E1,3 B4		E1,2,3 B1,2,3 4		
DEVONIAN								E1,2,3 B1,3,4 5	E2,3 B1,3,4 6	E1,2,3 B3,4	E2,3 B1,3,4 5,6

Open porosity types recognized in core and thin-section samples. Numbers indicate porosity type: 1 = interparticle (locally solution-enhanced), 2 = intraskeletal, 3 = growth framework, 4 = intercrystalline, 5 = microporosity, 6 = moldic, 7 = microvuggy, 8 = solution-enlarged microstylolite, and 9 = microfracture.

POSITION	CREST		FLANK					OFF-STRUCTURE			
AGE / WELL	K-16	K-18	K-9	K-10	K-11	K-19	K-22	K-12	K-13	K-14	K-15
BASHKIRIAN	1,6,7,9										
SERPUKHOVIAN	1,2,3,4 6,7,9	none	1,2,5,7	1,2,4,6 7,8							
OKSKY			8								
TULA			1,2,5,7	1,5,7,8	1,2,5,7	1,7	5		1,2,5,6 7,8		
DEVONIAN								none	1,4,6,7	1,5,6,7 9	4,5,7,9

Cementation Porosity Type

Bitumen Distribution



Bitumen occurrence recognized in core and thin-section samples. Numbers indicate the porosity type that is filled by bitumen: 1 = interparticle (locally solution-enhanced), 2 = intraskeletal, 3 = growth framework, 4 = intercrystalline, 5 = microporosity, 6 = moldic, 7 = microvuggy, 8 = microstylolite, and 9 = microfracture.

POSITION	CREST		FLANK					OFF-STRUCTURE			
AGE / WELL	K-16	K-18	K-9	K-10	K-11	K-19	K-22	K-12	K-13	K-14	K-15
BASHKIRIAN	1,5,7,8 9										
SERPUKHOVIAN	1,2,3,4 5,7,8,9	1,2,7,8 9	1,2,5,8 9	1,4,8,9							
OKSKY			4								
TULA			1,4,5,6 7,8,9	5,8,9	1,5	1,5,9	1		1,5,8,9		
DEVONIAN								4,5,7,9	4,7,8,9	1,4	4,5,7,9