Mudstone Lithofacies Evaluation for Play Fairway Analysis: Characterization of the Paleozoic Shales of Poland*

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Abstract

A comprehensive sedimentological analysis of the mudstone-rich Silurian and Ordovician intervals in the Baltic Basin, Podlasie Depression and Lublin Trough of Poland comprises a key stratigraphic component of Play Fairway Analysis. This study provides the basis for regional mapping and prediction of presence, thickness, and richness of three mudstone intervals across the play. The evaluation incorporates cores from legacy wells and recently drilled wells and includes macro core and computed tomography (CT) scan descriptions of conventional cores, thin section petrographic analysis and associated X-ray diffraction and geochemical data, and evaluation of wireline logs. The goals were to analyze the rock data to determine lithofacies assemblages within mudstone-dominated stratigraphic intervals; to capture the vertical and lateral heterogeneity of the assemblages; and, to model TOC-enriched preferred environments. The Poland Play Fairway Analysis focuses on three target intervals: Late Ordovician Upper Caradoc, Silurian lower Llandovery and the Silurian lower Wenlock. Paleogeographic setting, biostratigraphy and sequence stratigraphy are related to variations in rock composition and texture in order to identify lithofacies assemblages and interpret environments of deposition. Lithofacies assemblages are recognized based on multiple data sets at multiple scales of observation from thin section to core to wireline data, and capture the vertical and lateral heterogeneity of the assemblages. Key factors driving lithofacies distributions include water energy (position relative to fair weather wave base and storm wave base), accommodation space and intrabasinal seafloor topography. Depositional models, interpreted from the lithofacies assemblages, are used for fairway risking. Elevated TOC is found mainly in mudstones associated with transgressive systems tracts. Organic richness is highest where the section onlaps submarine highs and is condensed into thin intervals. The Upper Caradoc onlaps pre-existing submarine highs and consists of organic-rich, radiolaria-rich mudstone lithofacies that

commonly occur in the Baltic Basin depression. Regionally, the lower Llandovery Formation, potential Baltic and Lublin basin targets, is highly variable in thickness as well as organic-richness. Faulting and folding associated with the Caledonian Orogeny (~450–420 Ma) affected the thickness, richness and facies distributions in the southern Baltic and Podlasie Basins.

Selected References

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Theme 2: Unconventional Resources: International Plays (EMD/AAPG)

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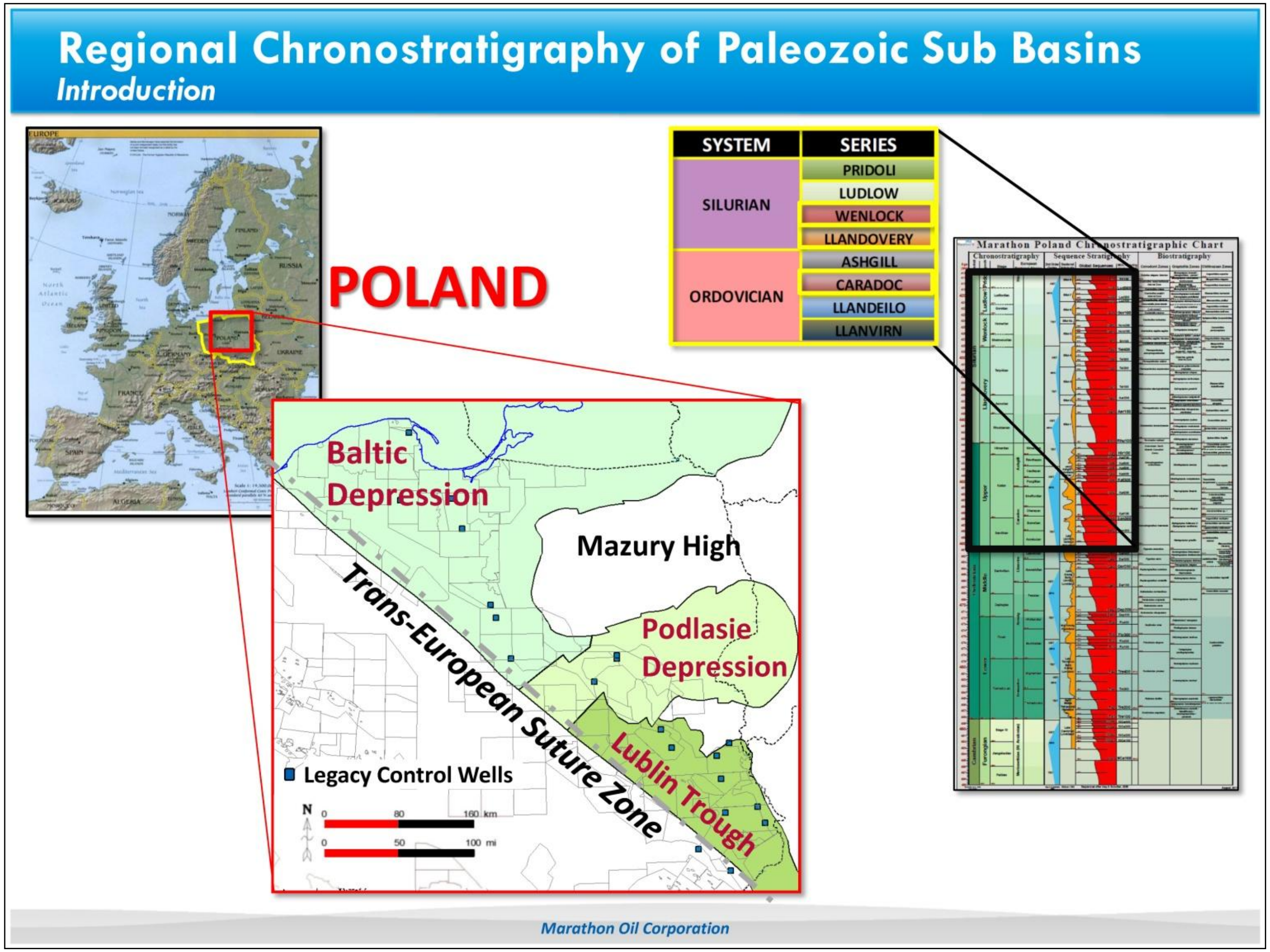


Regional Chronostratigraphy of Paleozoic Sub Basins

Introduction

POLAND

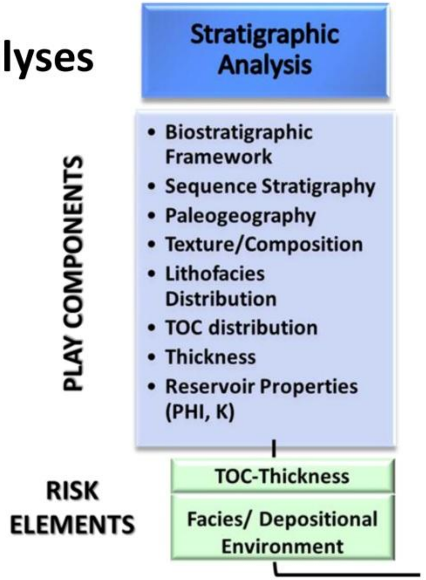
SYSTEM	SERIES
SILURIAN	PRIDOLI
	LUDLOW
	WENLOCK
	LLANDOVERY
ORDOVICIAN	ASHGILL
	CARADOC
	LLANDEILO
	LLANVIRN

Presenter's notes: With more than 2 million concession acres, extending nearly 644 kilometers across Poland, Marathon Oil, with partners Nexen and Mitsui, took on the challenge of exploring for Ordovician, Upper Caradoc and Silurian Llandovery and Wenlock shales for unconventional resources. The shales occur in three Paleozoic Sub-basins, the Baltic Depression, the Podlasie Depression and the Lublin Trough, with each basin exhibiting differing burial histories, structural complexity and a spectrum of mudstone types exhibiting both lateral and vertical heterogeneity. Which would be the most prospective mudstones and how are they distributed?

Play Fairway Analysis: Stratigraphic Elements

Introduction

- **Play Fairway Analysis (PFA) Workflow**
  - **4 Step Work Flow**
  - **Data, Structural & Stratigraphic Framework**
- **Methodology for Mudstone Lithofacies Analyses**
  - **Techniques & data integration**
- **PFA Results:**
  Lithofacies Identification & Distributions
  - **Interpretation & facies temporal distribution**



Stratigraphic Analysis

PLAY COMPONENTS

- Biostratigraphic Framework
- Sequence Stratigraphy
- Paleogeography
- Texture/Composition
- Lithofacies Distribution
- TOC distribution
- Thickness
- Reservoir Properties (PHI, K)

RISK ELEMENTS

- TOC-Thickness
- Facies/ Depositional Environment

Presenter's notes: We are here to discuss Mudstone Lithofacies Evaluation for Play Fairway Analysis: Characterization of the Paleozoic Shales of Poland. There are three important components to accomplishing this evaluation that we will examine:

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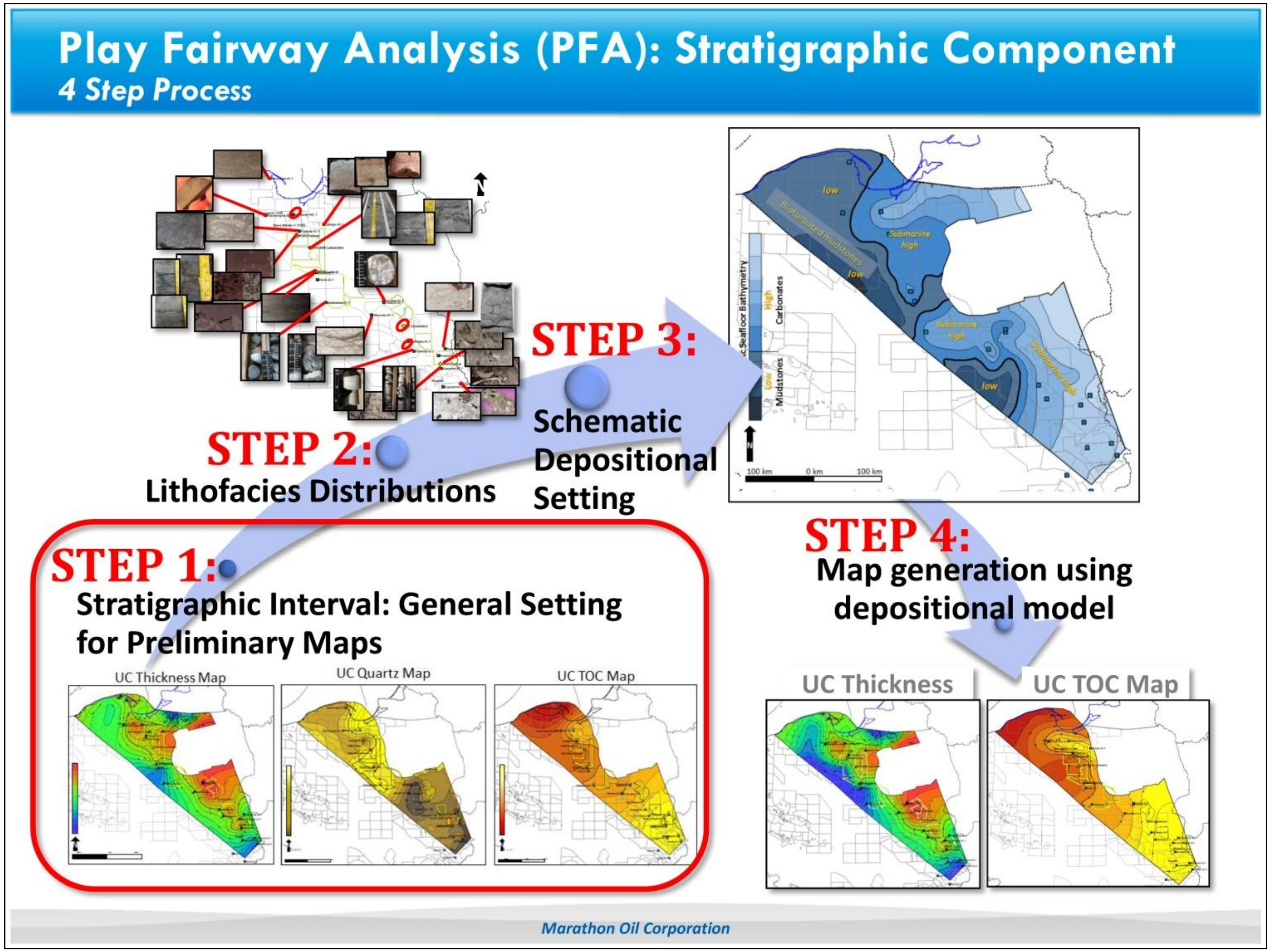
- First, Play Fairway Analysis Workflow: Data, Structural and Stratigraphic Framework: we provide an overview of the Play Fairway Analysis, or PFA, project workflow, focusing on the Stratigraphic portion of the project and the tools that can be applied to mudstones. We will show the data set that was analyzed, and the structural and stratigraphic frameworks that were applied across the sub-basins.
- Second, Methodology for Mudstone Lithofacies Analysis: we present the techniques we used to accomplish a comprehensive sedimentologic analysis of the Silurian and Ordovician intervals.
- PFA Results: Lithofacies Identification and Distributions: we illustrate how the analysis of rock data enabled us to capture the heterogeneity of the lithofacies assemblages and model TOC-enriched preferred environments.

By the end of our presentation, you will see how the application of sedimentologic analysis to these Silurian and Ordovician mudstones provides the basis for regional mapping and prediction of presence, thickness, and richness of mudstone intervals of interest across the Paleozoic shale play in Poland.



Play Fairway Analysis (PFA): Stratigraphic Component

4 Step Process

STEP 1: Stratigraphic Interval: General Setting for Preliminary Maps

STEP 2: Lithofacies Distributions

STEP 3: Schematic Depositional Setting

STEP 4: Map generation using depositional model

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Presenter's notes: Let's begin the first component: PFA Workflow: Data Set, and the Structural and Stratigraphic Frameworks. The stratigraphic component of the PFA project for evaluating the Polish Paleozoic Shale Play related paleogeographic setting, biostratigraphy and sequence stratigraphy to variations in rock composition and texture. Our goal was to identify lithofacies assemblages and interpret environments of deposition. In Step 1: We established stratigraphic intervals in each well and characterized

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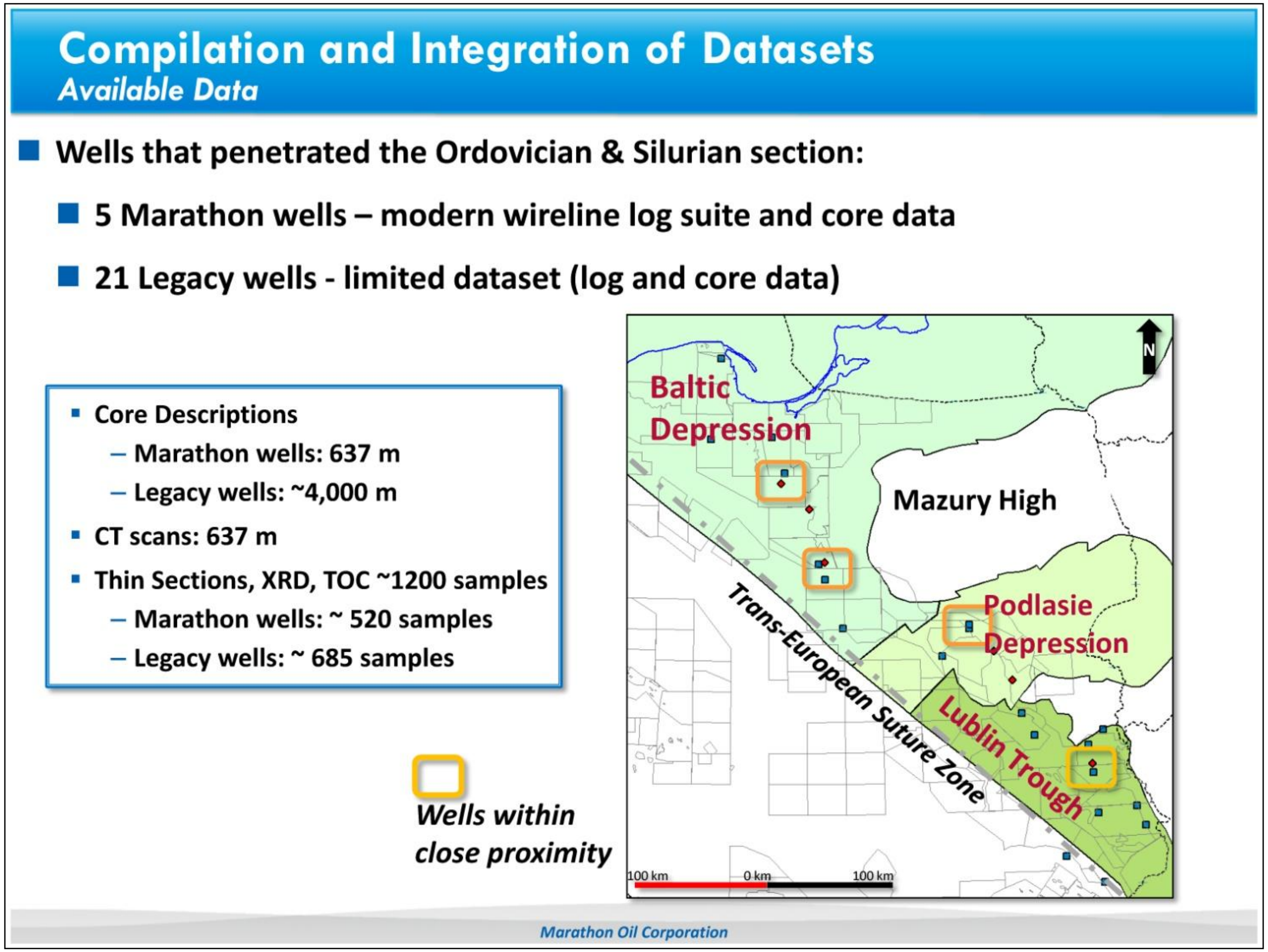
each interval with composition and thickness maps that we derived from wireline and rock-based X-Ray diffraction and TOC data. We also integrated our seismic mapping, and data from the literature. In Step 2: Lithofacies were identified from our rock data. 3D computed tomography, or CT-scans were used upscale results of our microfacies analysis, which integrated XRD and TOC data with thin section petrography. In Step 3: We developed schematic depositional setting maps incorporated the results of our lithofacies interpretations. In Step 4: For each zone of interest (ZOI), the team created TOC and thickness maps based on the integrated lithofacies and depositional setting maps. These maps illustrate the lithofacies assemblages, their lateral heterogeneity, and their interpreted depositional settings.



Compilation and Integration of Datasets

Available Data

- **Wells that penetrated the Ordovician & Silurian section:**
  - **5 Marathon wells – modern wireline log suite and core data**
  - **21 Legacy wells - limited dataset (log and core data)**

- **Core Descriptions**
  - **Marathon wells: 637 m**
  - **Legacy wells: ~4,000 m**
- **CT scans: 637 m**
- **Thin Sections, XRD, TOC ~1200 samples**
  - **Marathon wells: ~ 520 samples**
  - **Legacy wells: ~ 685 samples**

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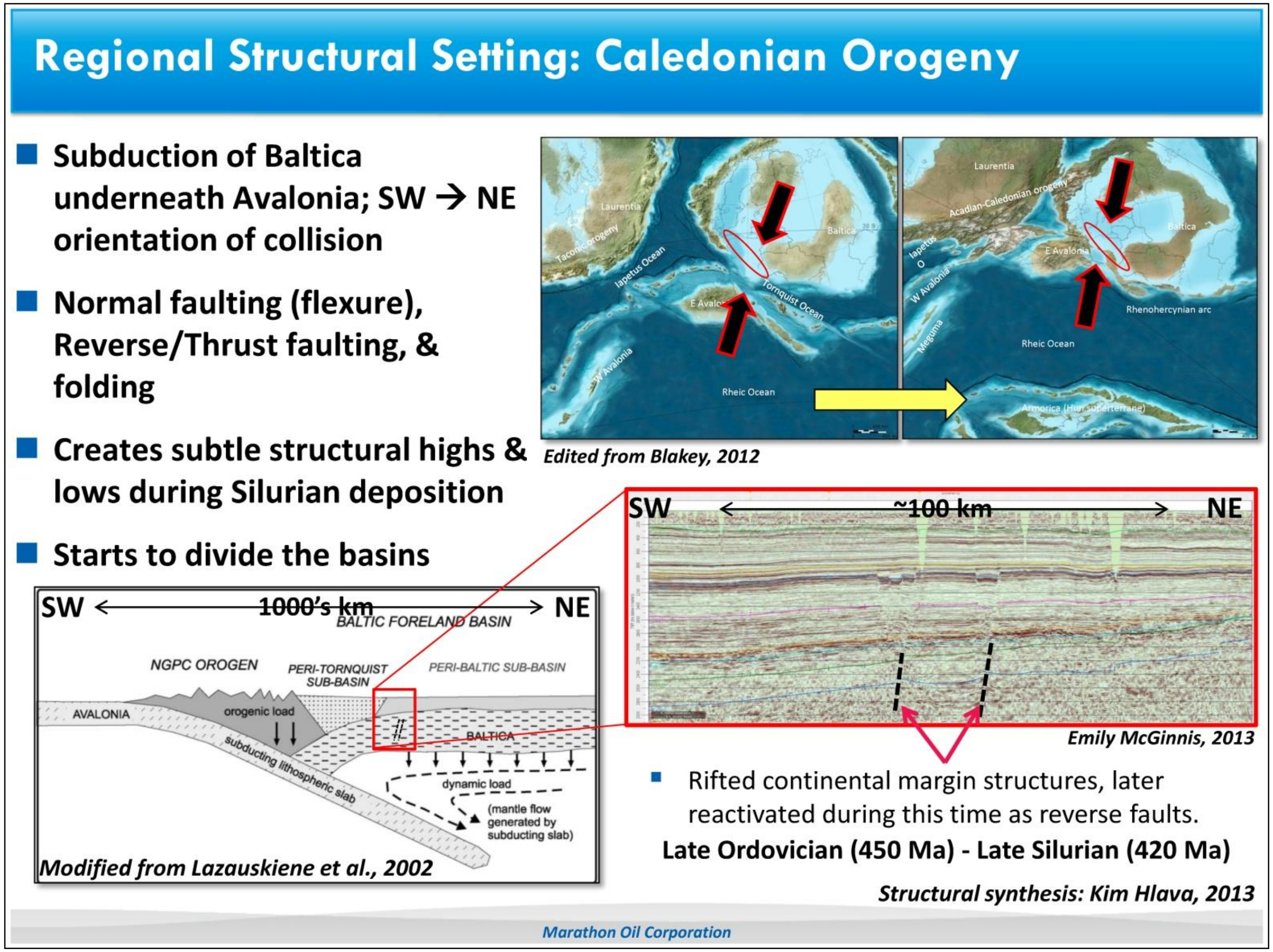
Presenter's notes: In order to characterize an area spanning nearly 644 km, the evaluation incorporates cores of 21 legacy wells, and five wells with modern wireline log suites distributed across the region. This evaluation integrated: about 6,400 meters (~13,100 ft) of macro core descriptions; nearly 640 m of (~1900 ft) 3D CT (computed tomography) scan descriptions of conventional core; and thin section petrographic analysis of over 1,200 samples with associated X-ray diffraction (XRD) and geochemical data from over 3,400 samples. Porosity-permeability was determined using GRI or crushed rock protocol, and the evaluation of wireline logs.



Regional Structural Setting: Caledonian Orogeny

- **Subduction of Baltica underneath Avalonia; SW → NE orientation of collision**
- **Normal faulting (flexure), Reverse/Thrust faulting, & folding**
- **Creates subtle structural highs & lows during Silurian deposition**
- **Starts to divide the basins**

Edited from Blakey, 2012

Emily McGinnis, 2013

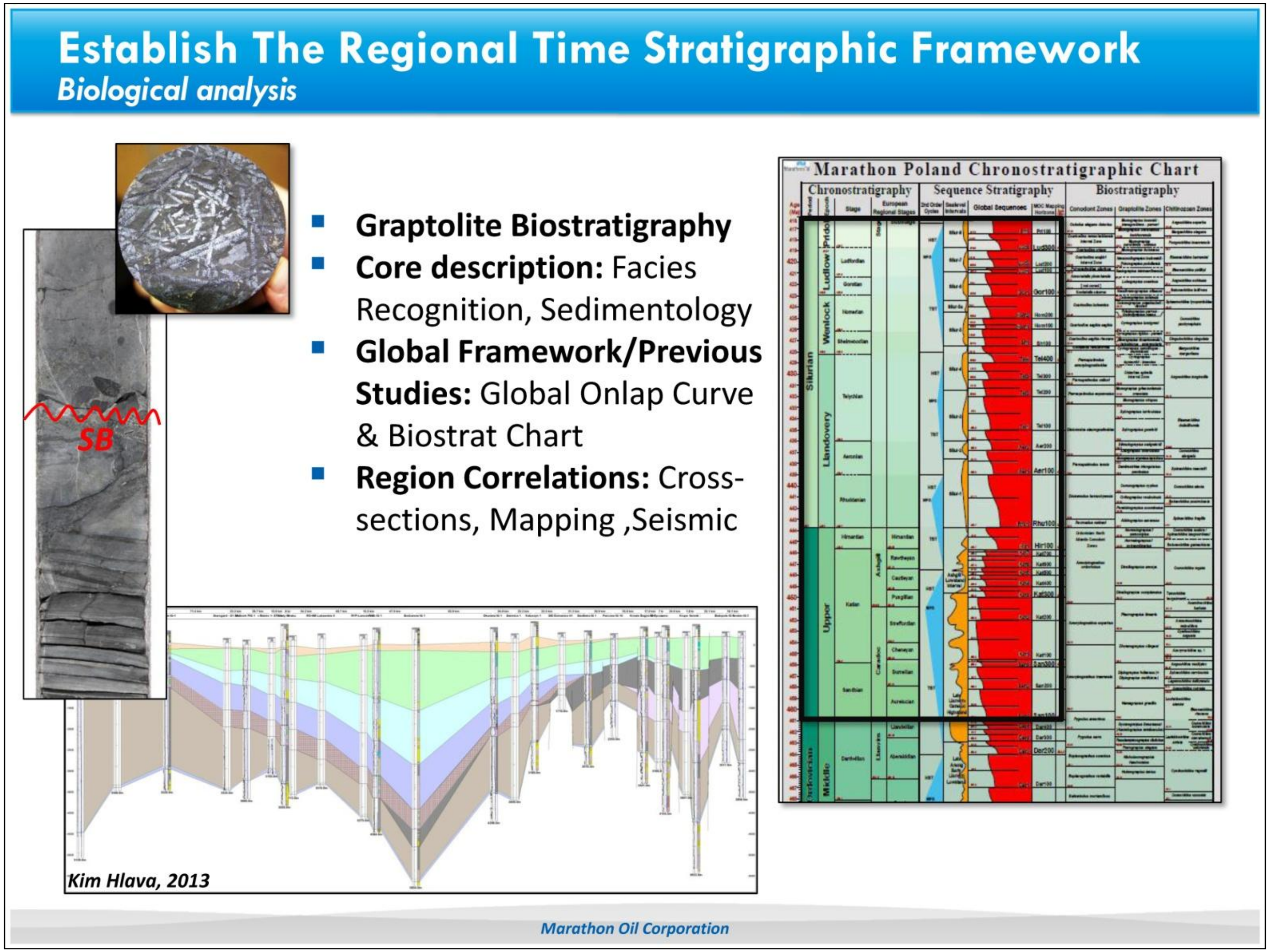
Modified from Lazauskiene et al., 2002

- Rifted continental margin structures, later reactivated during this time as reverse faults.

Late Ordovician (450 Ma) - Late Silurian (420 Ma)

Structural synthesis: Kim Hlava, 2013

Presenter's notes: The structural framework of this region is strongly impacted by the Caledonian Orogeny, which occurred due to the collision and subduction of Avalonia beneath Baltica from ~450 to 420 Ma. It mainly affects the Baltic Basin, and especially due south toward the Podlasie Depression. Throughout Caledonian time, the basins start to become separated by uplift in the central portion of the play fairway. The faulting and folding associated with the Caledonian Orogeny affected the thickness, richness and facies distributions in the southern Baltic and Podlasie Basins.



Establish The Regional Time Stratigraphic Framework

Biological analysis

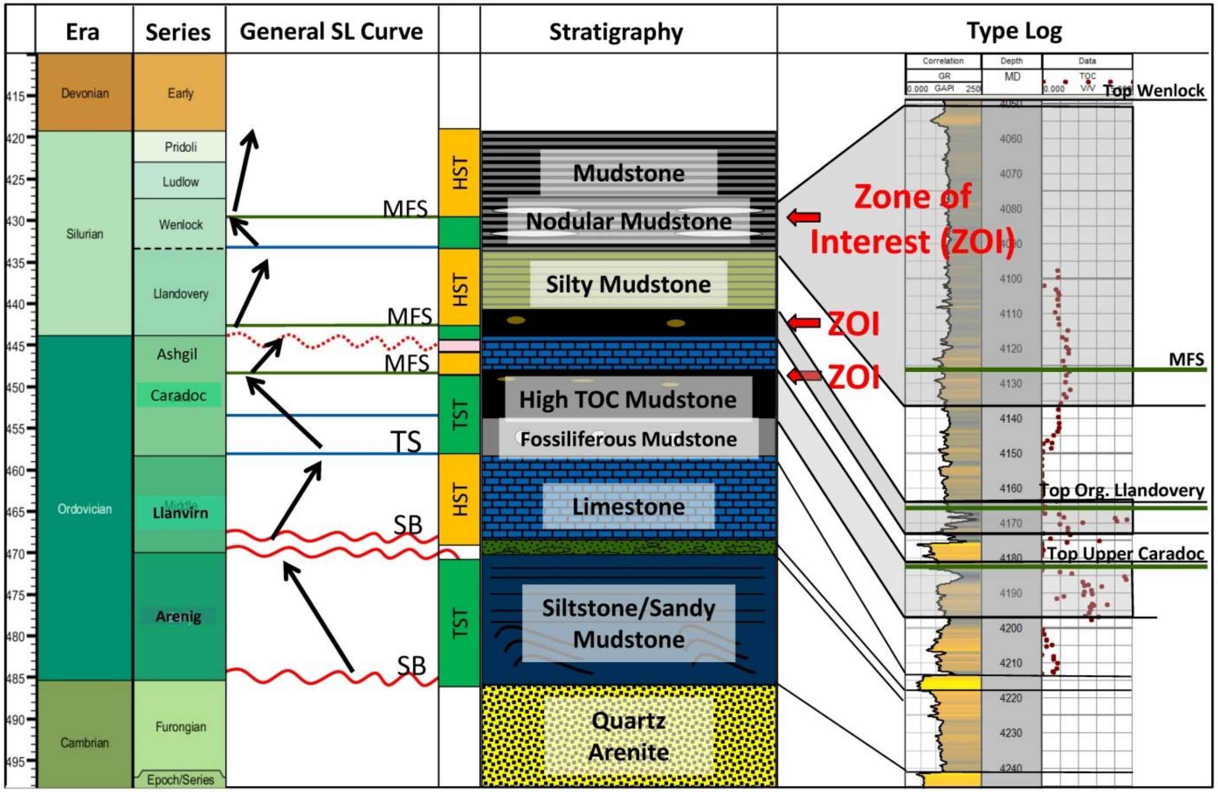
- **Graptolite Biostratigraphy**
- **Core description:** Facies Recognition, Sedimentology
- **Global Framework/Previous Studies:** Global Onlap Curve & Biostrat Chart
- **Region Correlations:** Cross-sections, Mapping ,Seismic

Kim Hlava, 2013

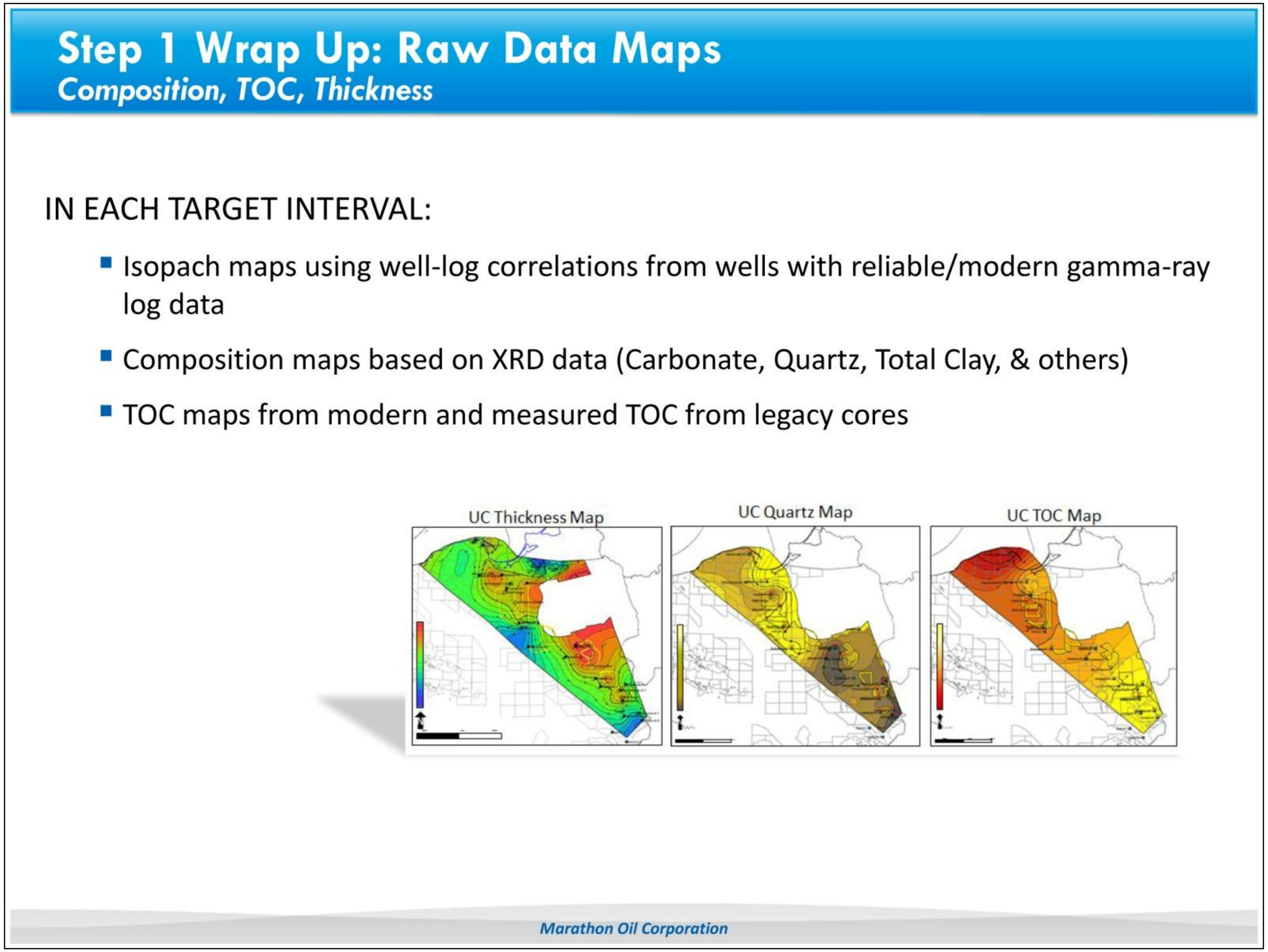
Presenter's notes: To establish the regional time stratigraphic framework, we used graptolites and included interpretations by the Polish Geologic Institute (PIGNI) as well as new data from our cores. A consistent stratigraphic framework was developed using regional correlations that were made based on modern GR log data that was calibrated to our core data. The core data gave us insights into the lithofacies variability, the presence of disconformities, as well as thickness changes and changes in depositional settings.

Establish a Comparative Stratigraphic Framework

Lithologies and Sequence Stratigraphy



Presenter's notes: Zones of interest with high total organic carbon or TOC were identified based on our geochem data and wireline data. When placed within a sequence stratigraphic framework, the elevated TOC is found mainly in mudstones associated with transgressive systems tracts. These zones occur in the Ordovician Upper Caradoc, and Silurian in the Lower Llandovery, and Lower Wenlock. This evaluation enabled us to tie the geochem to specific lithofacies identified petrographically by microfacies analysis.



Step 1 Wrap Up: Raw Data Maps

Composition, TOC, Thickness

IN EACH TARGET INTERVAL:

- Isopach maps using well-log correlations from wells with reliable/modern gamma-ray log data
- Composition maps based on XRD data (Carbonate, Quartz, Total Clay, & others)
- TOC maps from modern and measured TOC from legacy cores

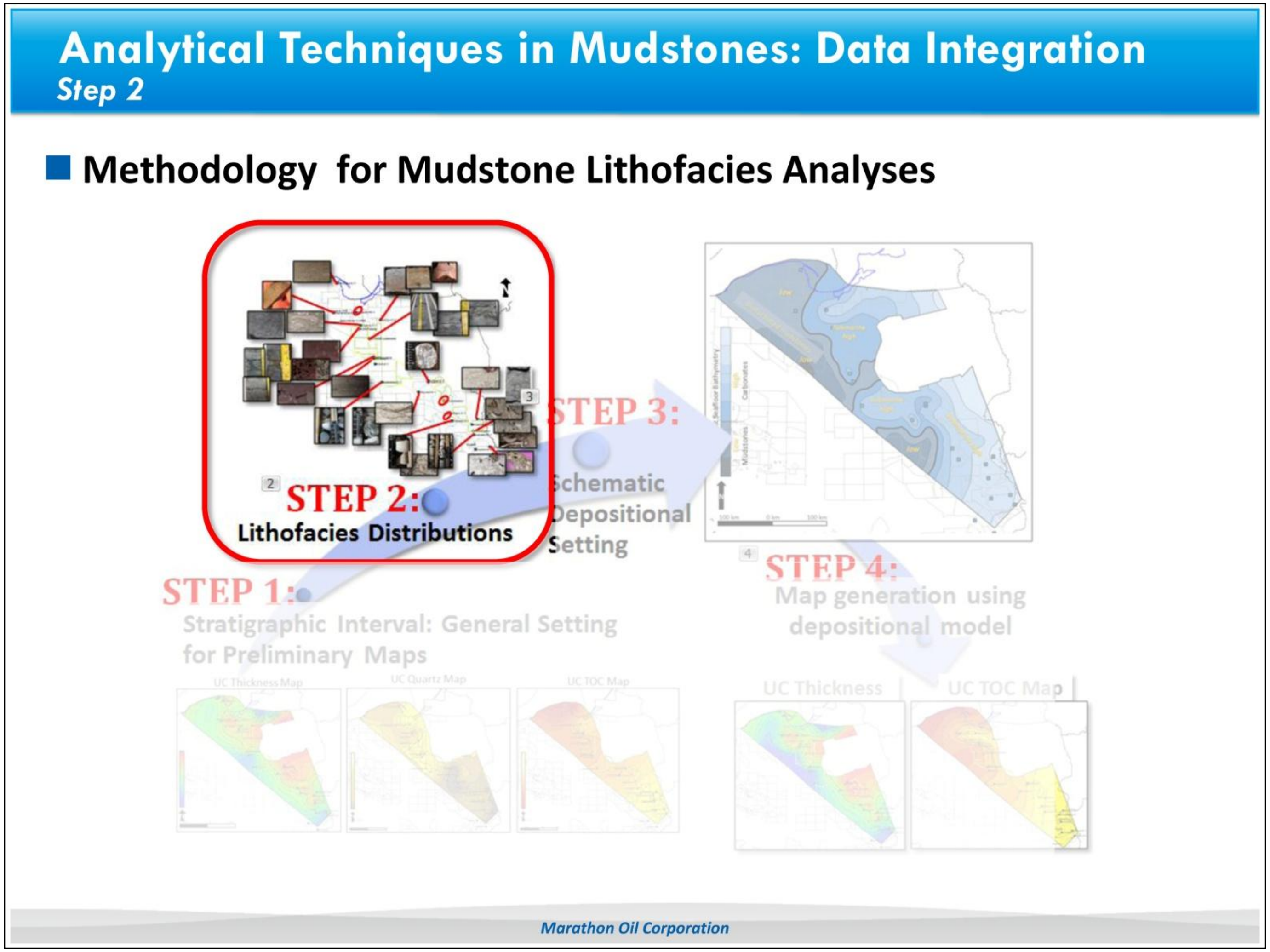
UC Thickness Map

UC Quartz Map

UC TOC Map

Presenter's notes: At the end of the first phase of our stratigraphic analysis, we are able to create map sets for each ZOI that include:

- Isopach maps of interval thickness based on our wireline log correlations
- Multiple composition maps, including carbonate content, quartz, total clay
- As well as TOC maps from new well data and from measured TOC from the Legacy cores



Analytical Techniques in Mudstones: Data Integration

Step 2

- **Methodology for Mudstone Lithofacies Analyses**

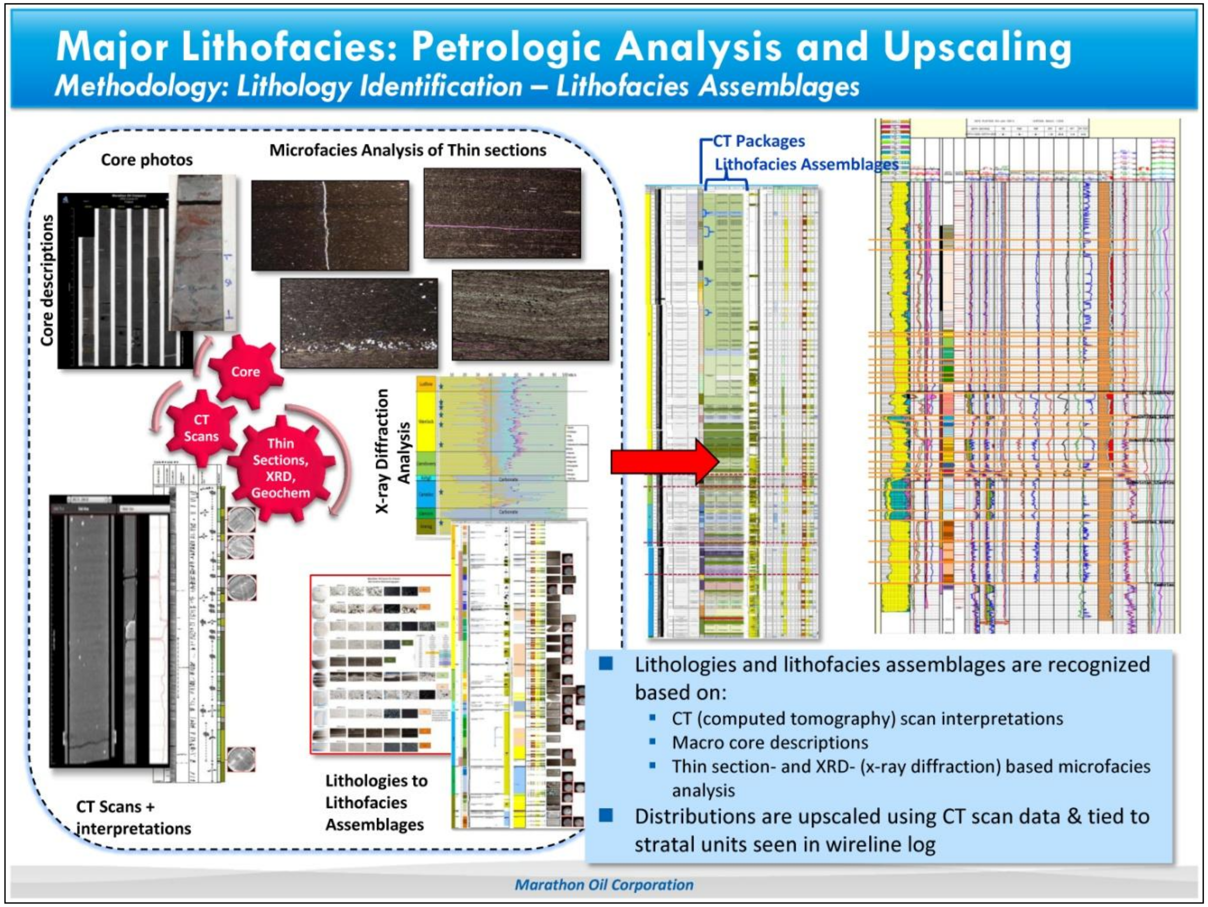
STEP 2:
Lithofacies Distributions

STEP 3:
Schematic Depositional Setting

STEP 1:
Stratigraphic Interval: General Setting for Preliminary Maps

STEP 4:
Map generation using depositional model

Presenter's notes: Let's move to the next component, our Methodology for Mudstone Lithofacies Analyses and we illustrate the techniques we used to accomplish a comprehensive sedimentologic analysis of the Silurian and Ordovician mudstone-rich intervals. Major lithofacies assemblages are recognized based on texture, composition, biogenic components, and were characterized by integrating of multiple scales of observation.



Major Lithofacies: Petrologic Analysis and Upscaling

Methodology: Lithology Identification – Lithofacies Assemblages

- Lithologies and lithofacies assemblages are recognized based on:
  - CT (computed tomography) scan interpretations
  - Macro core descriptions
  - Thin section- and XRD- (x-ray diffraction) based microfacies analysis
- Distributions are upscaled using CT scan data & tied to stratal units seen in wireline log

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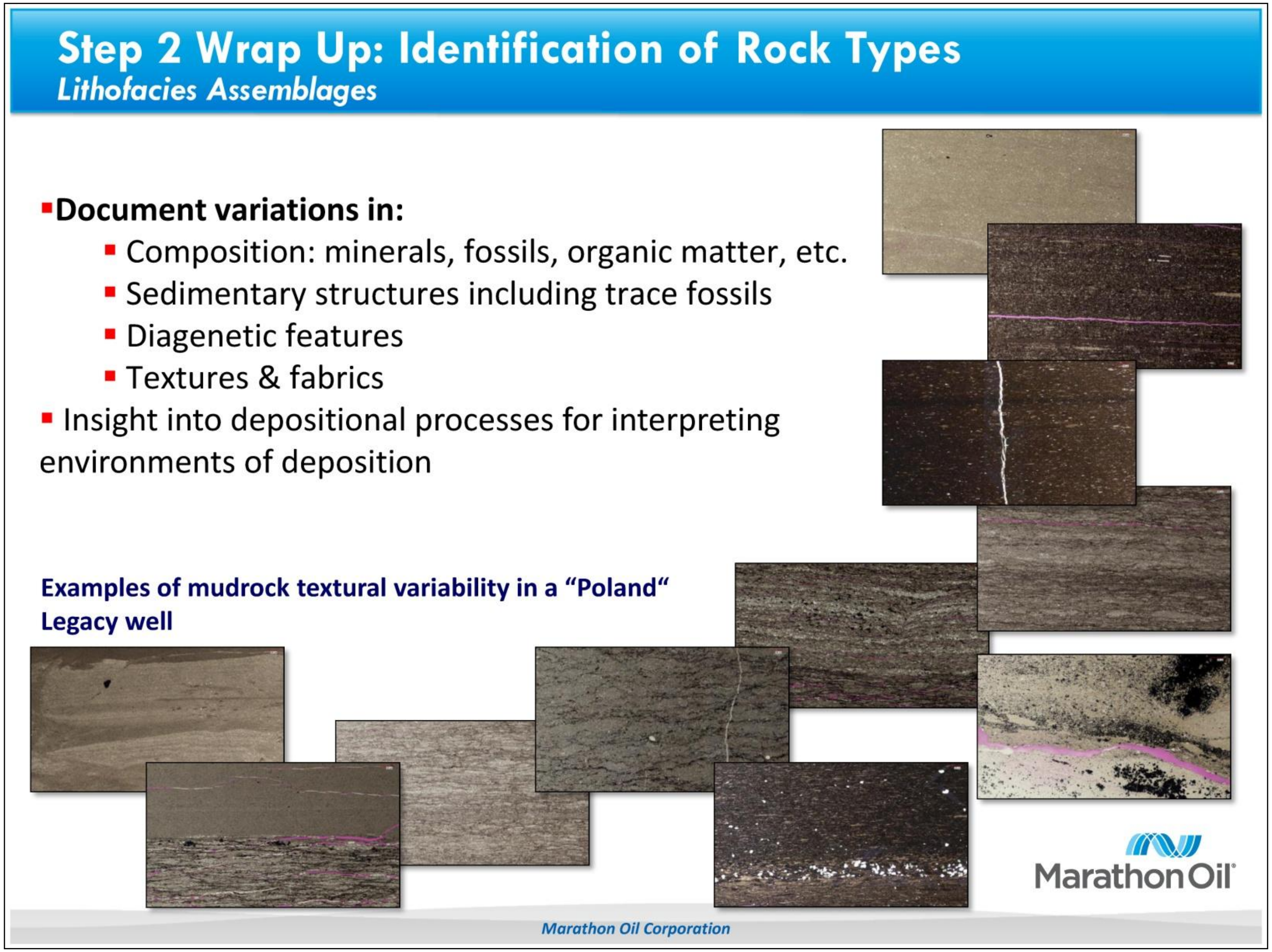
Presenter's notes: To accomplish the lithofacies analysis, our approach consists of an integrated petrologic analysis of conventional cores. For our newly acquired cores, as soon as the core arrives from the well site, it is scanned using 3D computed tomography. The resulting CT scans are interpreted in order to recognize CT scan packages of similar density values, architecture or bedding types and ichnofacies. These packages are assigned color codes as shown on track on right side of slide. When compared to the wireline logs, these CT scan packages correspond very well to stratal units recognized in the GR response (correlation lines appear on click). Using the CT interpretation and wireline log attributes, the cores were sampled ~ 1 meter or less intervals, and across selected intervals. For each sample, we conducted thin section microfacies analysis as well as XRD and geochem analyses. We documented the types of rocks are present at each location, noting the rock fabric and compositional variation.



Step 2 Wrap Up: Identification of Rock Types

Lithofacies Assemblages

- **Document variations in:**
  - Composition: minerals, fossils, organic matter, etc.
  - Sedimentary structures including trace fossils
  - Diagenetic features
  - Textures & fabrics
- Insight into depositional processes for interpreting environments of deposition

Examples of mudrock textural variability in a "Poland" Legacy well

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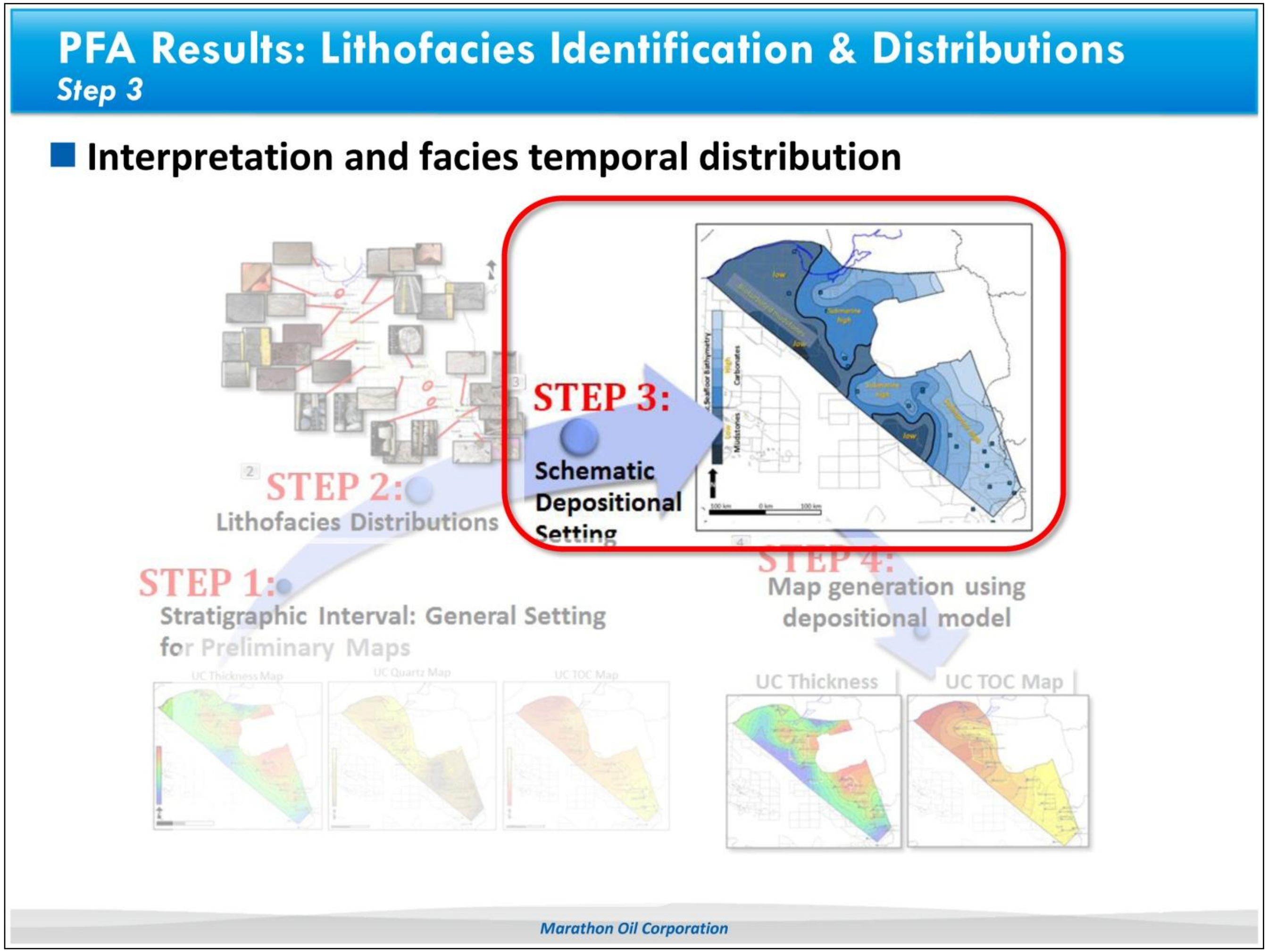
Presenter's notes: What rock types are we looking for? How are they distributed in the basins? These thin section photomicrographs of mudstone are from the intervals of interest in a single well and show the variability of shale types in this well. Which are the most prospective? To accomplish this evaluation, we use microfacies analysis, which is a technique derived from an approach employed by carbonate geologists (Flügel, 1984; 2009; Wilson, 1975) and promoted by *(Presenter's notes continued on next slide)*

(Presenter’s notes continued from previous slide)

Juergen Schieber (1987) for mudstone characterization. Microfacies analysis documents sedimentary features (such as laminae, erosion surfaces, and burrows), textures (particle relationships, diagenetic features), and the presence and condition of skeletal and other grain types. When these observations are integrated with XRD and geochemical data, microfacies analysis allows for the definition of mudrock lithofacies and captures the mudrock compositional and textural variability as well as facies associations. The results of microfacies analysis provide textural and compositional characterization and insight into depositional processes for interpreting environments of deposition.



PFA Results: Lithofacies Identification & Distributions

Step 3

- **Interpretation and facies temporal distribution**

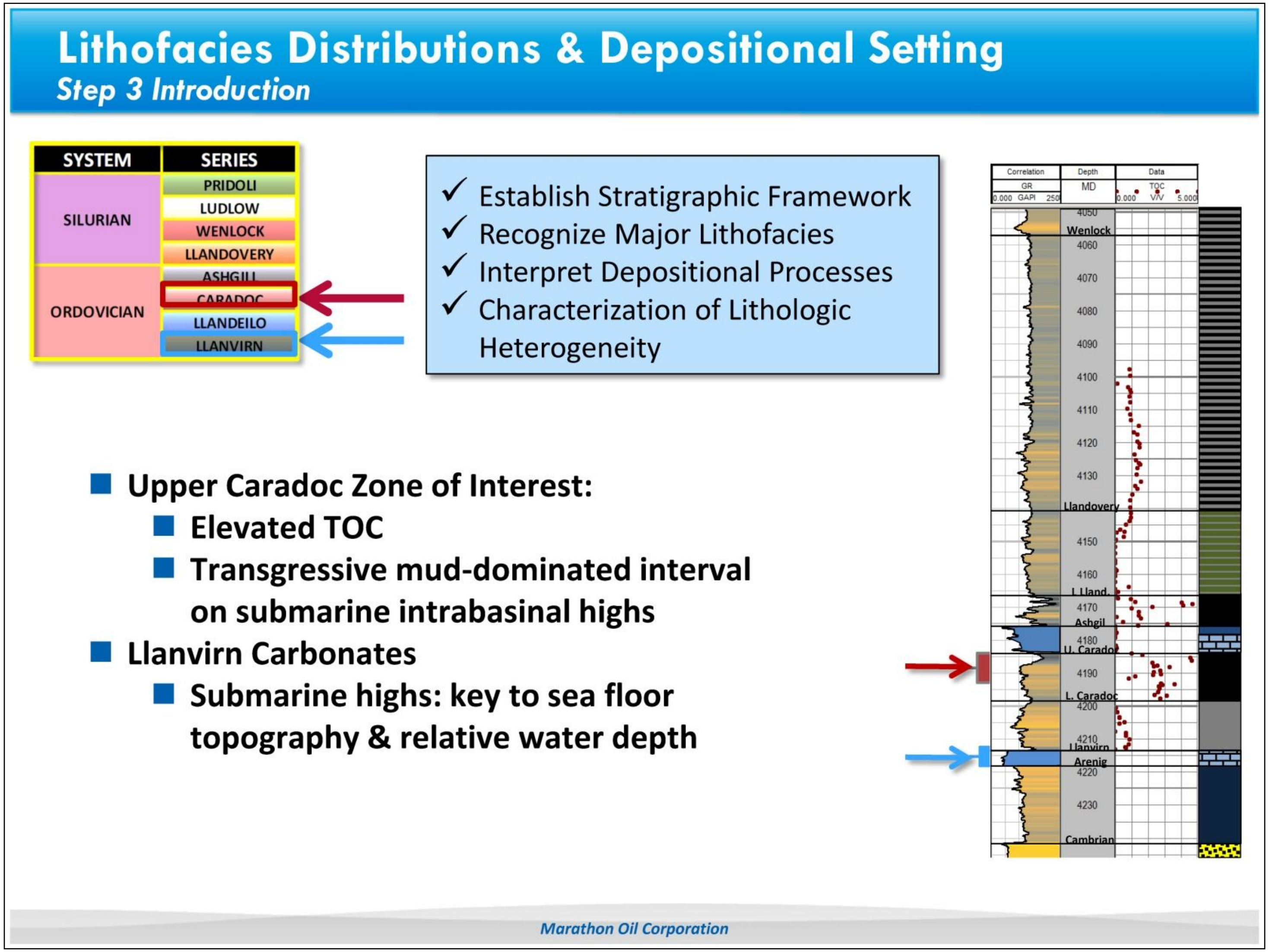
STEP 3:
Schematic Depositional Setting

STEP 2:
Lithofacies Distributions

STEP 1:
Stratigraphic Interval: General Setting for Preliminary Maps

STEP 4:
Map generation using depositional model

Presenter’s notes: The final component of PFA analysis of this mudstone is Lithofacies Identification and Distributions. We illustrate how the analysis of rock data enabled us to capture the lateral heterogeneity of the lithofacies assemblages and model TOC-enriched preferred environments. We use the lithofacies distributions with the basic compositional and thickness maps for each stratigraphic interval to develop schematic depositional setting maps. These lithofacies distributions give us insight into the key factors that drive the facies distributions.



Lithofacies Distributions & Depositional Setting

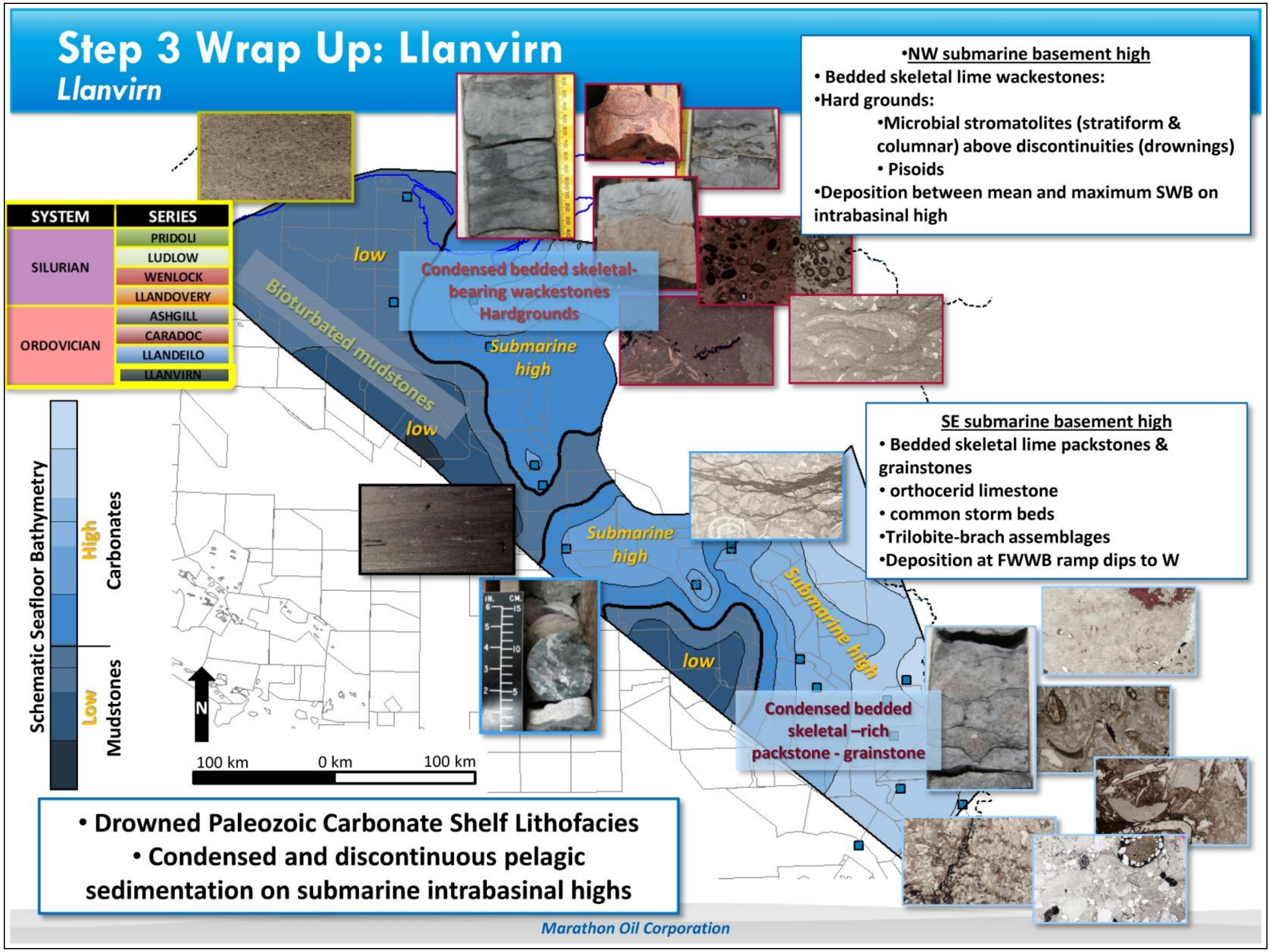
Step 3 Introduction

SYSTEM	SERIES
SILURIAN	PRIDOLI
	LUDLOW
	WENLOCK
	LLANDOVERY
ORDOVICIAN	ASHGILL
	CARADOC
	LLANDEILO
	LLANVIRN

- ✓ Establish Stratigraphic Framework
- ✓ Recognize Major Lithofacies
- ✓ Interpret Depositional Processes
- ✓ Characterization of Lithologic Heterogeneity

- **Upper Caradoc Zone of Interest:**
  - **Elevated TOC**
  - **Transgressive mud-dominated interval on submarine intrabasinal highs**
- **Llanvirn Carbonates**
  - **Submarine highs: key to sea floor topography & relative water depth**

Presenter's notes: Before we look at the mudstones with elevated TOC in the Ordovician Upper Caradoc, and the Silurian Lower Llandovery and Lower Wenlock, we begin with the underlying Ordovician Llanvirn Carbonates. These carbonate rocks provide an important key to deciphering the depositional setting of the overlying mudstone.



Step 3 Wrap Up: Llanvirn

Llanvirn

•NW submarine basement high

- Bedded skeletal lime wackestones:
- Hard grounds:
  - Microbial stromatolites (stratiform & columnar) above discontinuities (drownings)
  - Pisoids
- Deposition between mean and maximum SWB on intrabasinal high

SE submarine basement high

- Bedded skeletal lime packstones & grainstones
- orthocerid limestone
- common storm beds
- Trilobite-brach assemblages
- Deposition at FWWB ramp dips to W

SYSTEM	SERIES
SILURIAN	PRIDOLI
	LUDLOW
	WENLOCK
	LLANDOVERY
ORDOVICIAN	ASHGILL
	CARADOC
	LLANDEILO
	LLANVIRN

- Drowned Paleozoic Carbonate Shelf Lithofacies
- Condensed and discontinuous pelagic sedimentation on submarine intrabasinal highs

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Presenter's notes: The Llanvirn carbonates reflect regional distributions with important localized effects related to inherited topographic features including submarine intrabasinal highs on sea floor as well as areas of topographic lows. This predominantly carbonate system consists of condensed and discontinuous pelagic sediments. *(Presenter's notes continued on next slide)*

(Presenter's notes continued from previous slide)

The SE intrabasinal high is characterized by:

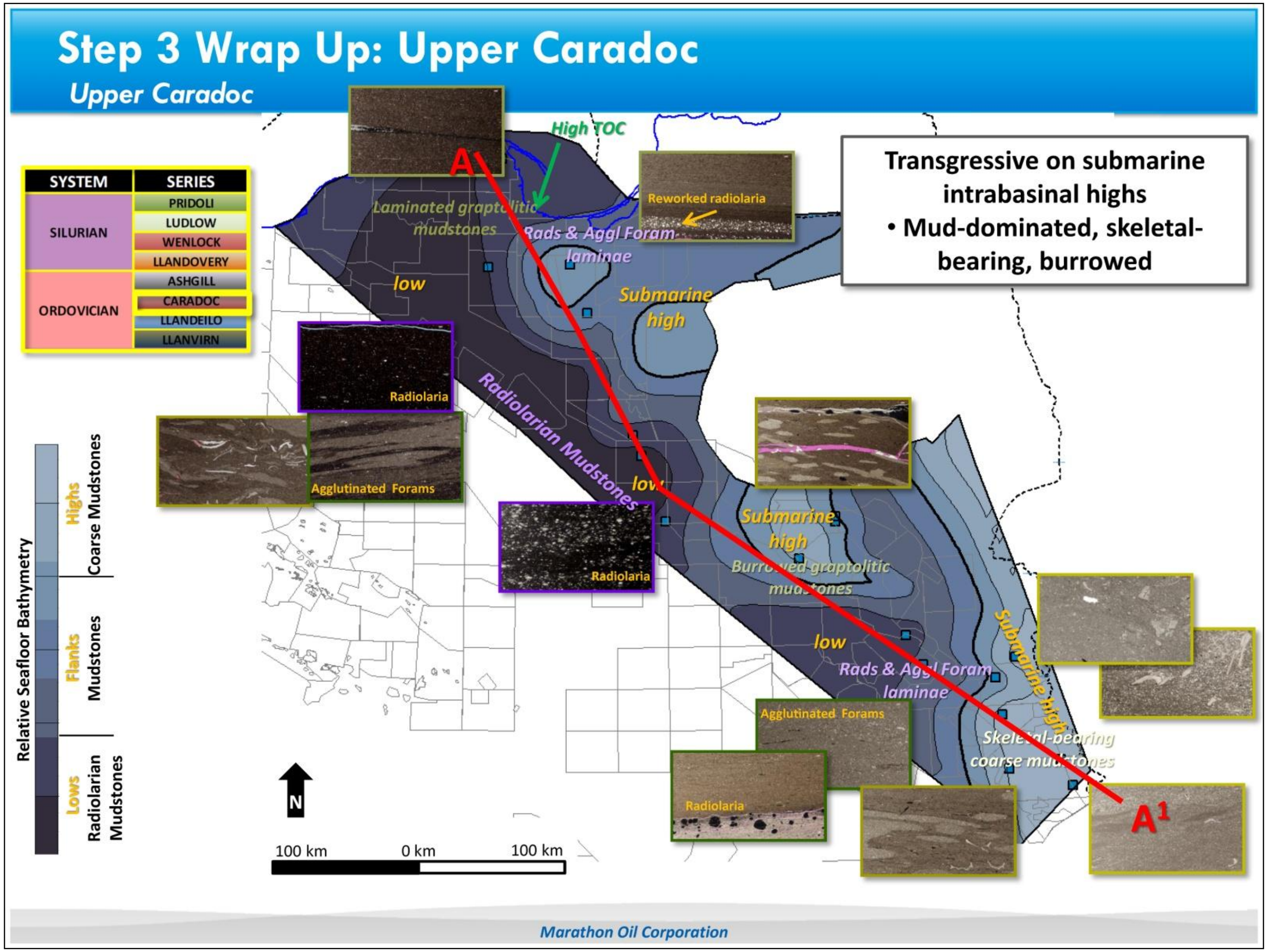
- –bedded skeletal packstones and grainstone
    - "Inner shelf" brachiopod-trilobite assemblage and Orthocerid limestone
    - Common storm deposits with pressure solution contacts, red staining
    - Worn skeletal lags with Fe-filled borings
- –Deposition most likely occurred between FWWB (fair weather wave base) and mean SWB (storm wave base)

The NW intrabasinal high has:

- –Bedded skeletal lime wackestones
    - Less diverse faunal assemblage with unabraded fossils (bivalves, crinoids, brachs)
    - uncommon storm beds
    - Hard grounds with microbial stromatolites (stratiform and columnar) above discontinuities (drownings); Pisoids and resedimented ooids with Fe crusts (transported by marine currents prior to crust fm); Red staining pressure solution contacts
- Deposition between mean and maximum SWB

In the topographic lows:

- Carbonate are absent
- Burrowed, skeletal-bearing mudstones with compacted burrows
- Deposition occurred between SWB to Max SWB



Step 3 Wrap Up: Upper Caradoc

Upper Caradoc

Transgressive on submarine intrabasinal highs

- **Mud-dominated, skeletal-bearing, burrowed**

SYSTEM	SERIES
SILURIAN	PRIDOLI LUDLOW WENLOCK LLANDOVERY
ORDOVICIAN	ASHGILL CARADOC LLANDEILO LLANVIRN

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Presenter's notes: With the paleo-topography in place, we can now look at the Upper Caradoc, a zone with elevated TOC that was identified from log and geochem data. Here in the Upper Caradoc, mud-dominated sediments occur on the submarine intrabasinal highs.

(Presenter's notes continued on next slide)

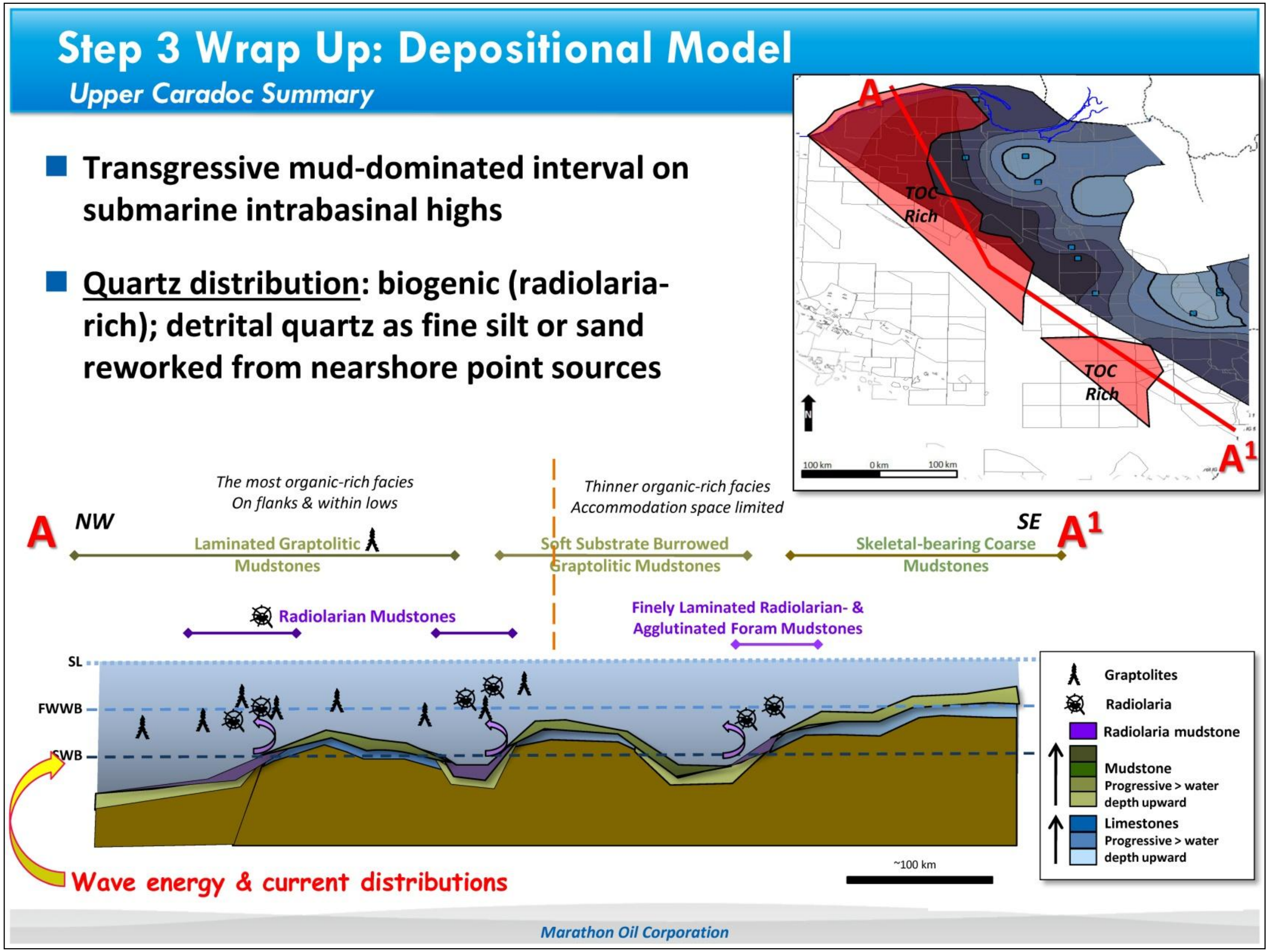
(Presenter's notes continued from previous slide)

This is a mud-dominated system:

- SE: shelly fauna-bearing mudstones (brachs, crinoids) with wide compacted burrows; soft muddy substrates
- NW: outer shelf to upper slope (steep changes in slope) laminated graptolite-bearing mudstones; semi-firm to firm muddy substrates
- Lows and flanks of submarine highs: radiolaria-rich mudstones; semi-firm to firm muddy substrates
-

Important features include:

- Radiolaria- and agglutinated foram-rich laminae associated with high productivity.
- Burrows indicate greater oxygenation at sediment-water interface to southeast could affect preservation of organic matter.
- Quartz distribution: biogenic (radiolaria-rich); and differentiate these quartz-rich mudstones from those with extrabasinal, or detrital quartz as fine silt or sand reworked from nearshore point sources.



Step 3 Wrap Up: Depositional Model

Upper Caradoc Summary

- **Transgressive mud-dominated interval on submarine intrabasinal highs**
- **<u>Quartz distribution</u>: biogenic (radiolaria-rich); detrital quartz as fine silt or sand reworked from nearshore point sources**

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Presenter's notes: A quick look at the Upper Caradoc reveals that the key factors driving the lithofacies distributions include:

(Presenter's notes continued on next slide)

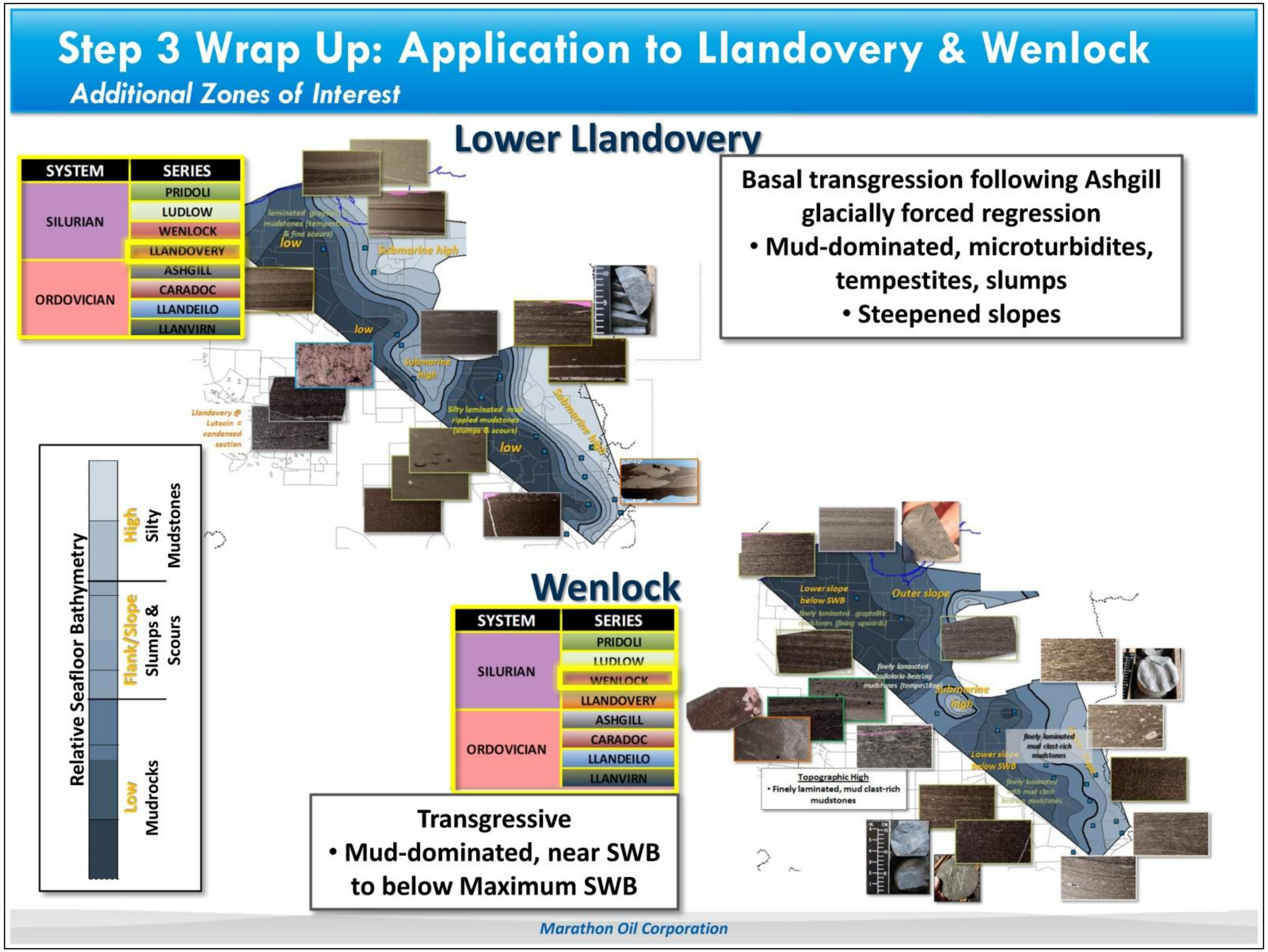
(Presenter's notes continued from previous slide)

- Water energy (position relative to FWWB and SWB)
- Accommodation space
- Intrabasinal seafloor topography (which was strongly influenced by those underlying carbonates.

In this cross-sectional view, we see the inherited topographic features, submarine intrabasinal highs on sea floor and the topographic lows from the underlying Llanvirn , influence sediment distributions and organic richness is highest where the section onlaps submarine highs and is condensed into thin intervals on submarine highs.

In Upper Caradoc:

- •SE: shelly fauna-bearing mudstones with wide compacted burrows; thin bedded, onlapping radiolaria- and agglutinated foram-bearing mudstones – high productivity
- •NW: outer shelf to upper slope (steep changes in slope) laminated graptolite-bearing mudstones thin vertical burrows or *Chondrites* (reduced oxygenation on sea floor)
- •Most importantly, Lows and flanks of submarine highs: radiolaria-rich mudstones - high productivity



Step 3 Wrap Up: Application to Llandovery & Wenlock

Additional Zones of Interest

Lower Llandovery

SYSTEM	SERIES
SILURIAN	PRIDOLI
	LUDLOW
	WENLOCK
	LLANDOVERY
ORDOVICIAN	ASHGILL
	CARADOC
	LLANDEILO
	LLANVIRN

Basal transgression following Ashgill glacially forced regression

- **Mud-dominated, microturbidites, tempestites, slumps**
- **Steepened slopes**

Wenlock

SYSTEM	SERIES
SILURIAN	PRIDOLI
	LUDLOW
	WENLOCK
	LLANDOVERY
ORDOVICIAN	ASHGILL
	CARADOC
	LLANDEILO
	LLANVIRN

Transgressive

- **Mud-dominated, near SWB to below Maximum SWB**

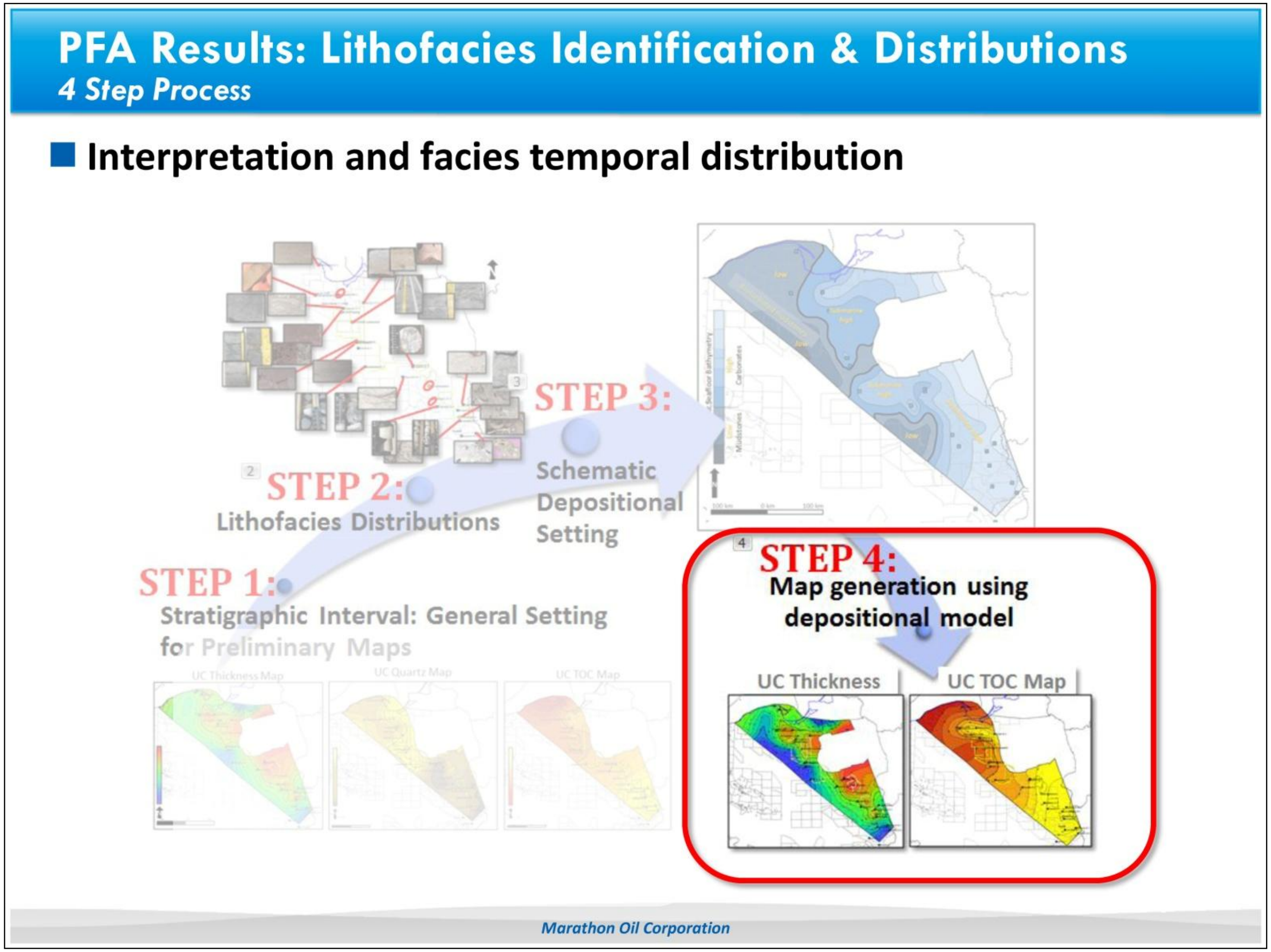
Topographic High

- Finely laminated, mud clast-rich mudstones

Presenter's notes: A similar workflow was applied to the Ashgill carbonates, another predominantly carbonate system of condensed and discontinuous pelagic sedimentation on submarine intrabasinal highs (though greater water depths than Llanvirn carbonates). This was followed by an overall regressive interval following basal transgression after the Ashgill glacially forced regression. The Lower Llandovery was a mud-dominated system with tempestite distribution *(Presenter's notes continued on next slide)*

(Presenter’s notes continued from previous slide)

influenced by relict topographic features. Regionally, the lower Llandovery Formation, potential Baltic and Lublin basin targets, is highly variable in thickness as well as organic-richness. In the rapid post-glacial sea-level rise, these deposits include organic-rich mud-dominated, very finely laminated, microturbidites, tempestites, slumps on steepened slopes. We envision trade winds induced upwelling along the paleo highs that resulted in increased primary productivity. Similar workflow was applied to the Wenlock and maps generated for both intervals.



PFA Results: Lithofacies Identification & Distributions

4 Step Process

- **Interpretation and facies temporal distribution**

STEP 1: Stratigraphic Interval: General Setting for Preliminary Maps

STEP 2: Lithofacies Distributions

STEP 3: Schematic Depositional Setting

STEP 4: Map generation using depositional model

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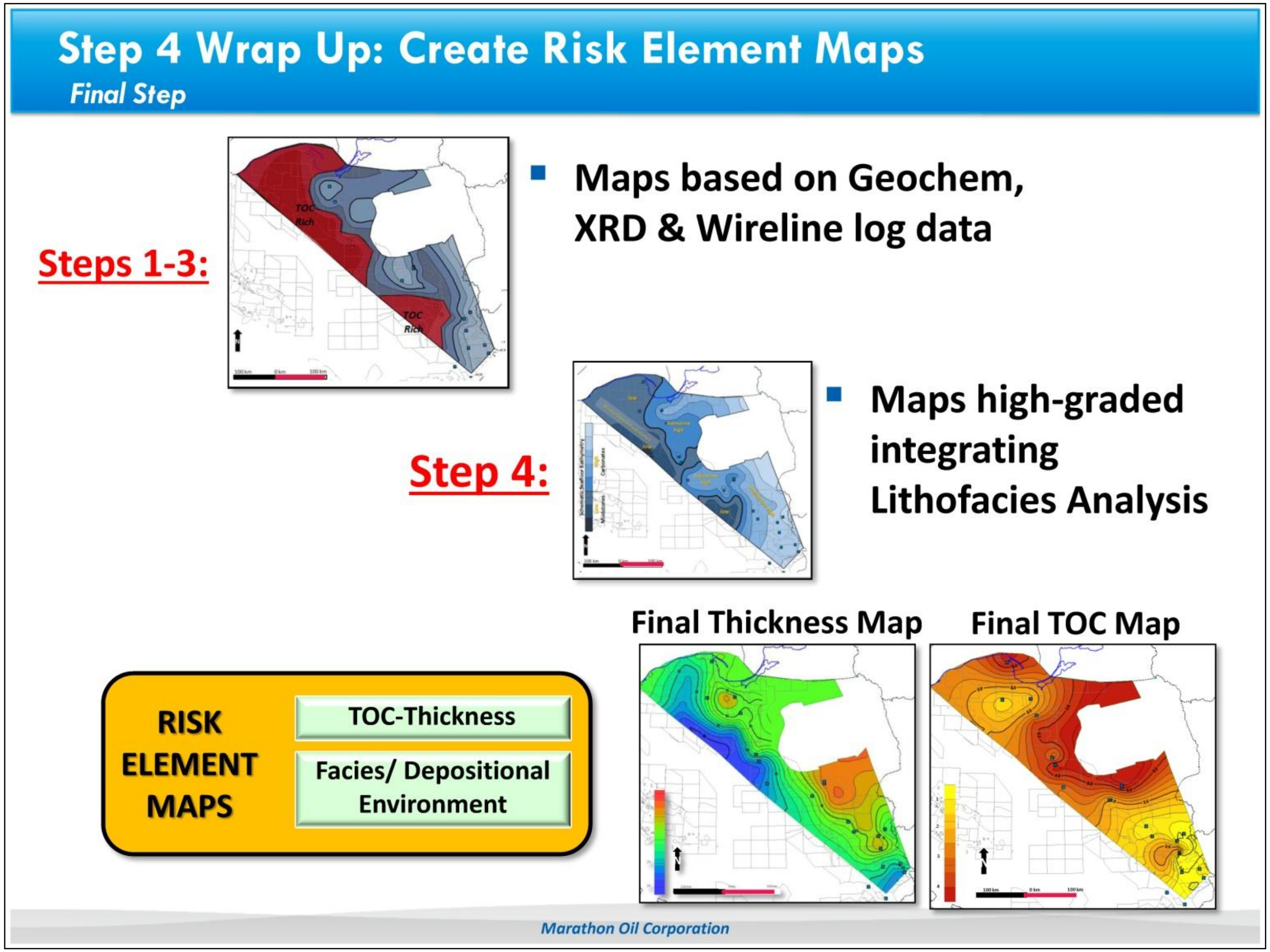
Presenter's notes: Once these lithofacies distributions were completed, we moved to the final step of our PFA workflow. For each zone of interest (ZOI), the team created TOC and thickness maps based on the integrated lithofacies and depositional setting maps. These maps illustrate the lithofacies assemblages, their lateral heterogeneity, and their interpreted depositional settings and, model TOC-enriched preferred environments.



Step 4 Wrap Up: Create Risk Element Maps

Final Step

Steps 1-3:

- Maps based on Geochem, XRD & Wireline log data

Step 4:

- Maps high-graded integrating Lithofacies Analysis

Final Thickness Map

Final TOC Map

RISK ELEMENT MAPS

TOC-Thickness

Facies/ Depositional Environment

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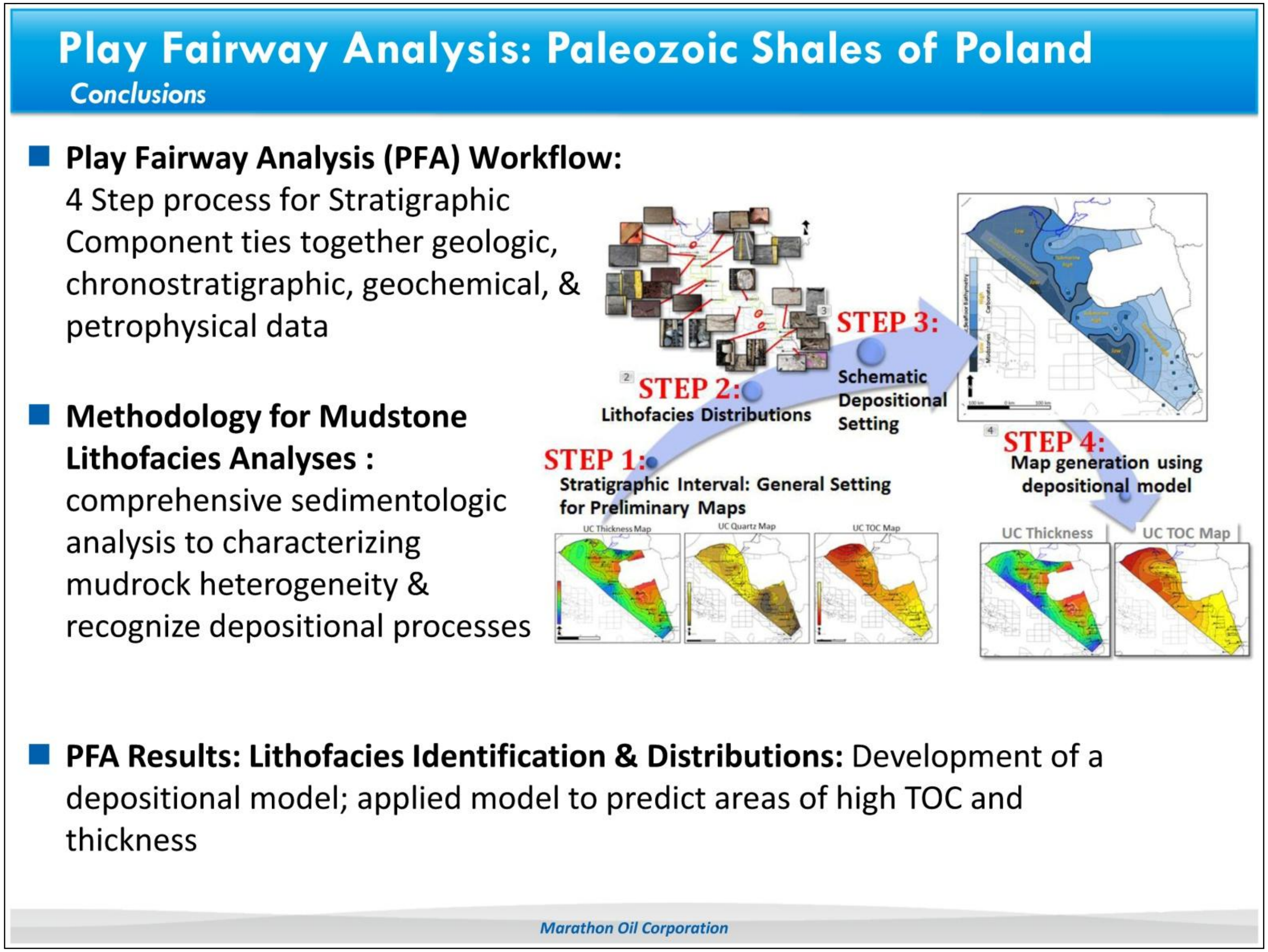
Presenter's notes: This workflow allowed us to tie together geologic, chronostratigraphic, geochemical, and petrophysical data for predictive modeling for the zones of elevated TOC, which is found mainly in mudstones associated with transgressive systems tracts (Upper Caradoc, Lower Llandovery, Lower Wenlock). This went into the Common Risk Elements of the PFA map. The resulting risk element maps would later be combined with the results of the hydrocarbon systems analysis and structural analysis to produce common risk segment maps of the comprehensive Play Fairway Analysis project.



Play Fairway Analysis: Paleozoic Shales of Poland

Conclusions

- **Play Fairway Analysis (PFA) Workflow:** 4 Step process for Stratigraphic Component ties together geologic, chronostratigraphic, geochemical, & petrophysical data

- **Methodology for Mudstone Lithofacies Analyses :** comprehensive sedimentologic analysis to characterizing mudrock heterogeneity & recognize depositional processes

- **PFA Results: Lithofacies Identification & Distributions:** Development of a depositional model; applied model to predict areas of high TOC and thickness

STEP 1: Stratigraphic Interval: General Setting for Preliminary Maps

STEP 2: Lithofacies Distributions

STEP 3: Schematic Depositional Setting

STEP 4: Map generation using depositional model

Presenter's notes: We have discussed Mudstone Lithofacies Evaluation for Play Fairway Analysis: Characterization of the Paleozoic Shales of Poland. First, we outlined a comprehensive 4-step workflow to analyze mudstones in the Polish Shale Play. This workflow ties together geologic, chronostratigraphic, geochemical, and petrophysical data for predictive modeling and Play Fairway

(Presenter's notes continued on next slide)

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Analysis. Although this type of analysis is usually applied to conventional plays, we have been able to recognize major lithofacies assemblages based on: texture, composition, and biogenic components, and have integrated multiple scales of observation. Next, we reviewed our approach to mudstone lithofacies analysis that uses Microfacies analysis by employing thin section petrography coupled with X-ray diffraction (XRD) analysis, and implemented in conjunction with 3D CT scans. This provides a methodology for characterizing mudrock heterogeneity and recognizing depositional processes. Finally, we illustrated how, facilitated by our multi-scale approach, our integrated model captures the lithologic heterogeneity in this basin and, enables us to model TOC-enriched preferred environments. This led to the development of depositional models that were used model to predict areas of high TOC and thickness. We found that elevated TOC is found mainly in mudstones associated with transgressive systems tracts in the Upper Caradoc, Lower Llandovery, and Lower Wenlock.

We were able to recognize key factors driving the lithofacies distributions including:

- Water energy (position relative to FWWB and SWB)
- Accommodation space
- Intrabasinal seafloor topography

These components went into the Common Risk Elements of the PFA map.

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Thank You