[PS]Depositional Facies, Depositional Processes, and Reservoir Quality of the Miocene Sandstones of the Midway-Sunset Oil Field, San Joaquin Basin, CA, USA*

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Abstract

The 125-year old Midway-Sunset Oil Field has produced over 2.5 billion barrels of oil with an estimated 500 million barrels remaining in place as of 2009. A re-assessment of a prolific Miocene reservoir in the field was initiated in 2017. Over 433 feet of whole core and 168 side wall cores were taken from a recently drilled well, in a well-developed area of the field, targeting the Miocene X and Y sandstones. These cores were examined to determine depositional facies, depositional processes, and reservoir quality. The X reservoir consists of three depositional facies: (1) Disorganized, conglomeratic, coarse-grained sands, (2) Fine to very coarse-grained sandstones with no clasts, and (3) Sands with few floating or non-floating clasts. The Y reservoir consists of four depositional facies: (1) Massive, structureless sandstones (no clasts present), (2) Very thin beds between 0.1 to 5 inches (laminated sand and diatomite), (3) Conglomeratic and coarse sands, (4) Silty/Diatomaceous and bioturbated mudstones. Interpreted depositional processes are Sandy Debris (conglomerates, sands with floating clasts), Turbidites (massive, fine grained, normal grading sands), Slump (diatomites with associated sand injections), Bottom-Current-Reworked (rhythmic occurrence of thin bedded sands with sharp contacts), pelagic and hemipelagic (silty/diatomaceous, bioturbated mudstones). The sandy debrites and turbidites have the best reservoir qualities; oil saturation is over 60%, effective porosity is as high as 43%, and permeability over 10D. This is possibly caused by grain-size distribution and sorting directly influenced by depositional processes. Clasts present in sand matrix are majorly granitic, diatomitic, and carbonaceous; they act as baffles and directly influence pore volume. Some of the clasts are fractured and have been healed by carbonate cement. In other cases, carbonate cement has been dissolved and hydrocarbon has filled fractures. Visual estimation of clast percentages shows that clast percentage in the X reservoir forms over 70% of the total reservoir and less than 20% in the Y sands. In general, these sandstones are unconsolidated and are held together by heavy oil except in cemented zones. The X and Y sandstones are interpreted to be deposited in a deep-water, submarine fan complex. A thorough understanding of depositional environment is important when managing a reservoir because the internal architecture (barriers, baffles, flow units), vertical, and lateral continuity of sand packages determine the efficiency of steam cycling and/or steam flooding (EOR techniques) in heavy oil reservoirs. As a rule of thumb, the depositional environment should be considered as very important for successful subsurface heat management in heavy oil reservoirs.

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Depositional Facies, Depositional Processes, and Reservoir Quality of the Miocene Sandstones of the Midway-Sunset Oil Field, San Joaquin Basin, CA, USA

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INTRODUCTION

The 125-year old Midway-Sunset Oil Field (MWSS) has produced over 2.5 billion barrels of oil with an estimated 500 million barrels remaining in place as of 2009. A re-assessment of a prolific Miocene reservoir in the field was initiated in 2017. Over 433' of whole core and 168 side wall cores were taken from a recently drilled well, in a well-developed area of the field, targeting the Miocene X and Y sandstones. The cores were taken to determine the depositional facies, depositional processes, and reservoir quality of these sandstones. Ultimately, this allowed us to construct a depositional environment model for the Miocene X and Y sandstones. A thorough understanding of the environment of deposition is very important for a successful subsurface heat management program because the internal architecture (barriers, baffles, flow units), vertical, and lateral continuity of sand packages determine the efficiency of steam cycling and/or steam flooding (EOR techniques) in heavy oil reservoirs.

LOCATION

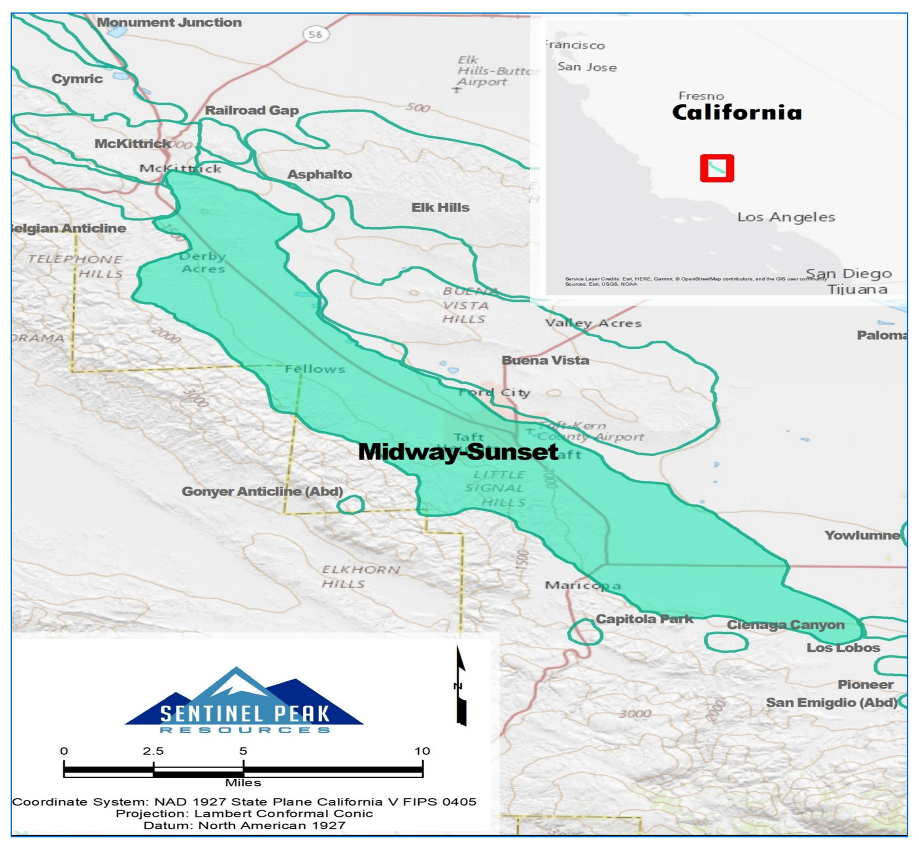


Figure 1. Map showing the Midway-Sunset Oil Field

CORED INTERVAL

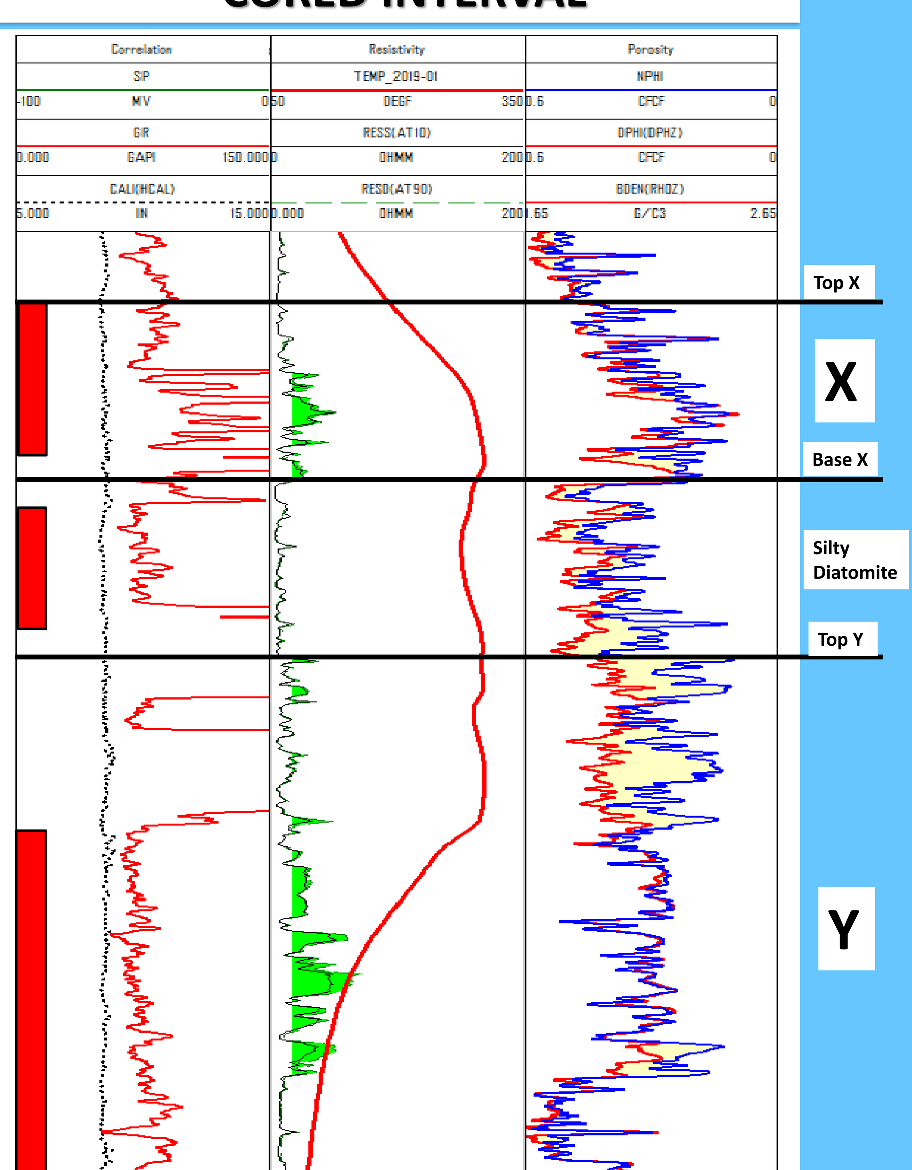


Figure 2. Type Log showing cored interval (red polygon) in the X and Y reservoirs. The neutron-density cross over is shaded yellow and an indication of depletion caused by steam injection. Maximum reservoir temperature exceeds 300 degrees.

IMPORTANCE OF DETAILED CORE DESCRIPTION

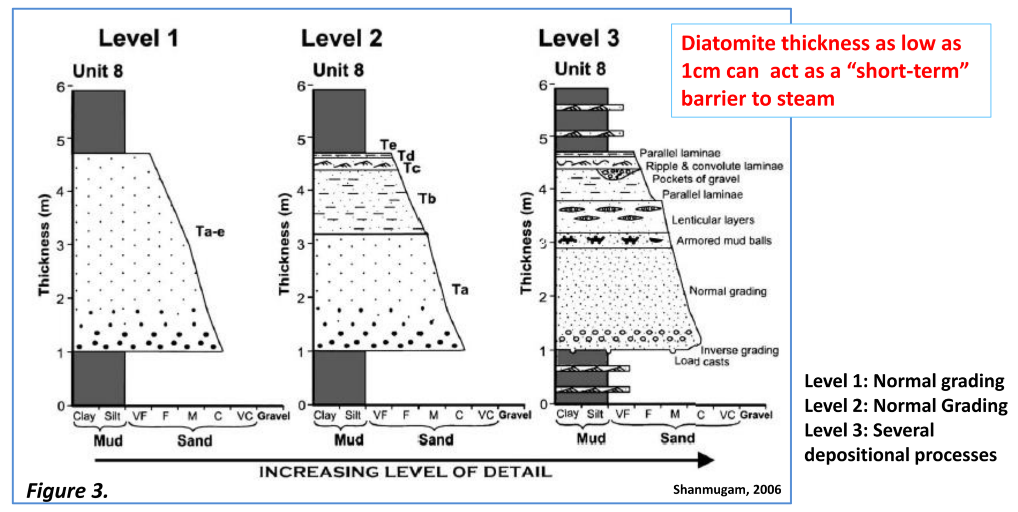


Figure 3.

- All sands are heterogenous. Capture every details and clarifies degree of heterogeneity.
- Tells us if one or multiple depositional environment.
- More accurate observational depositional facies; Internal features of the rocks as they respond to steam soaking

QUANTIFICATION OF DEPOSITIONAL FACIES AND RESERVOIR QUALITY IN THE RECOVERED CORE (X AND Y SAND)

Facies	Depositional Facies	Depositional Process	Porosity Range (%)	So Range (%)	Ka Range (mD)
1	Sands with floating or non floating clasts; conglomerates if clasts >30%	Sandy Debris	0 – 42	0 - 46	Up to 8000
2	Massive (structureless), fine-grained sands, normal grading (no clasts)	Turbidites	20 - 43	0 – 67.9	Up to 11716
3	Diatomites with associated sand injections	Slump	46 - 60	0 - 30	100 - 296
4	Rhythmic occurrence of thin bedded sands & diatomites with sharp contacts	Bottom- Current-Reworked	26 – 60	0 – 76.1	0 - 1835
5	Silty/diatomaceous, bioturbated mudstones; planar, angular and cross laminated	Pelagic & Hemipelagic	47 – 65	4 -28	0 - 112

RESERVOIR X CORE DESCRIPTION

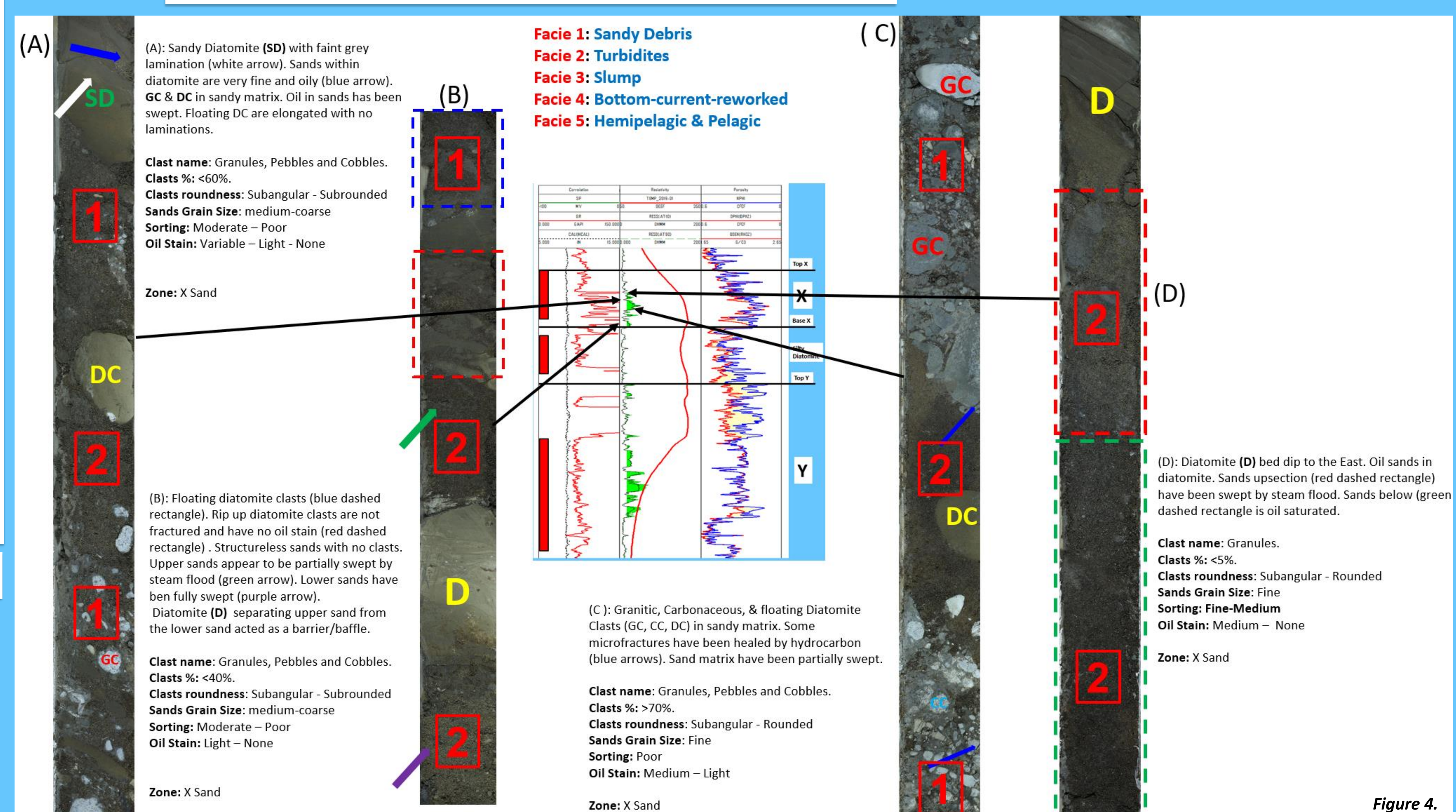


Figure 4.

RESERVOIR Y CORE DESCRIPTION

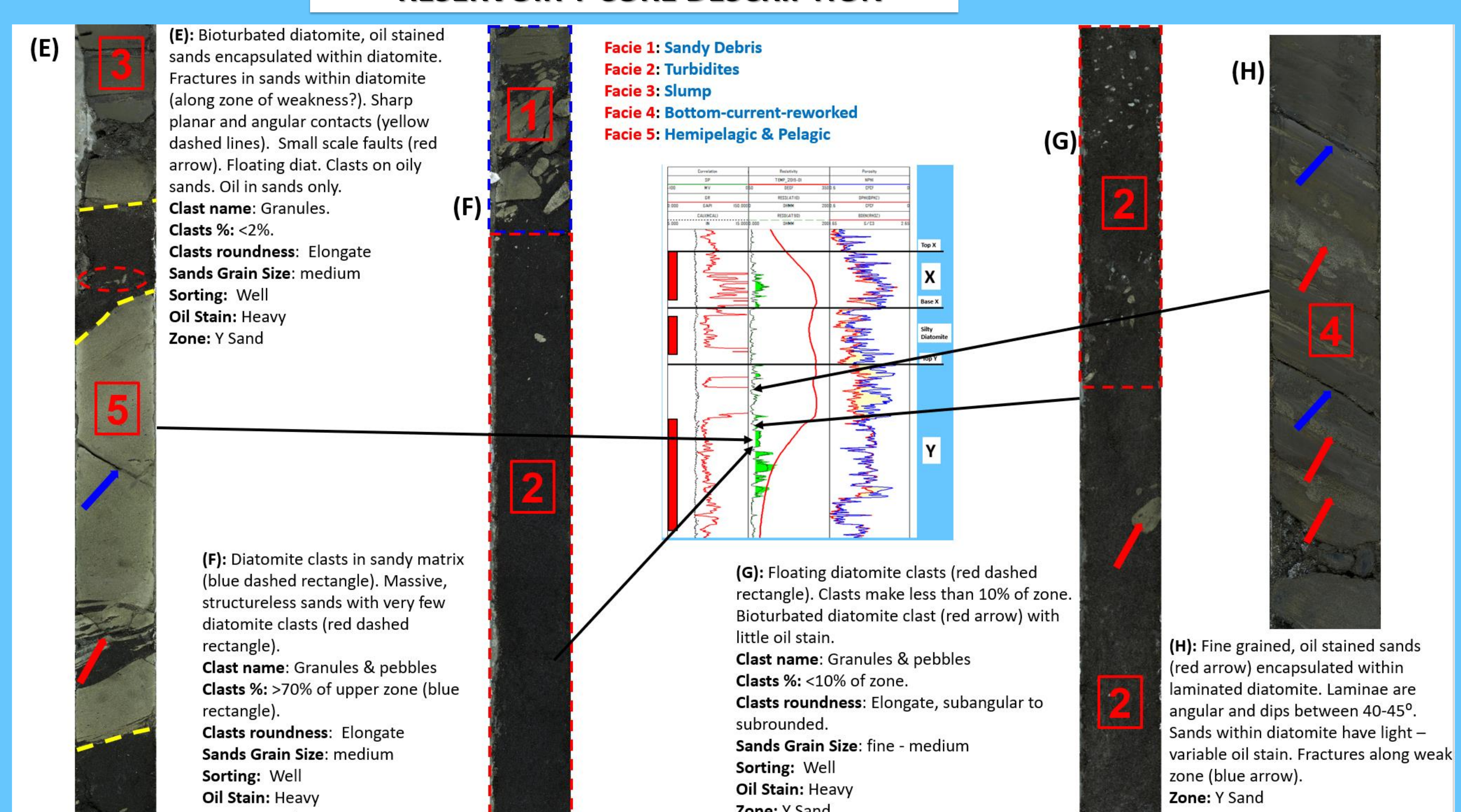


Figure 5.

DEPOSITIONAL MODEL

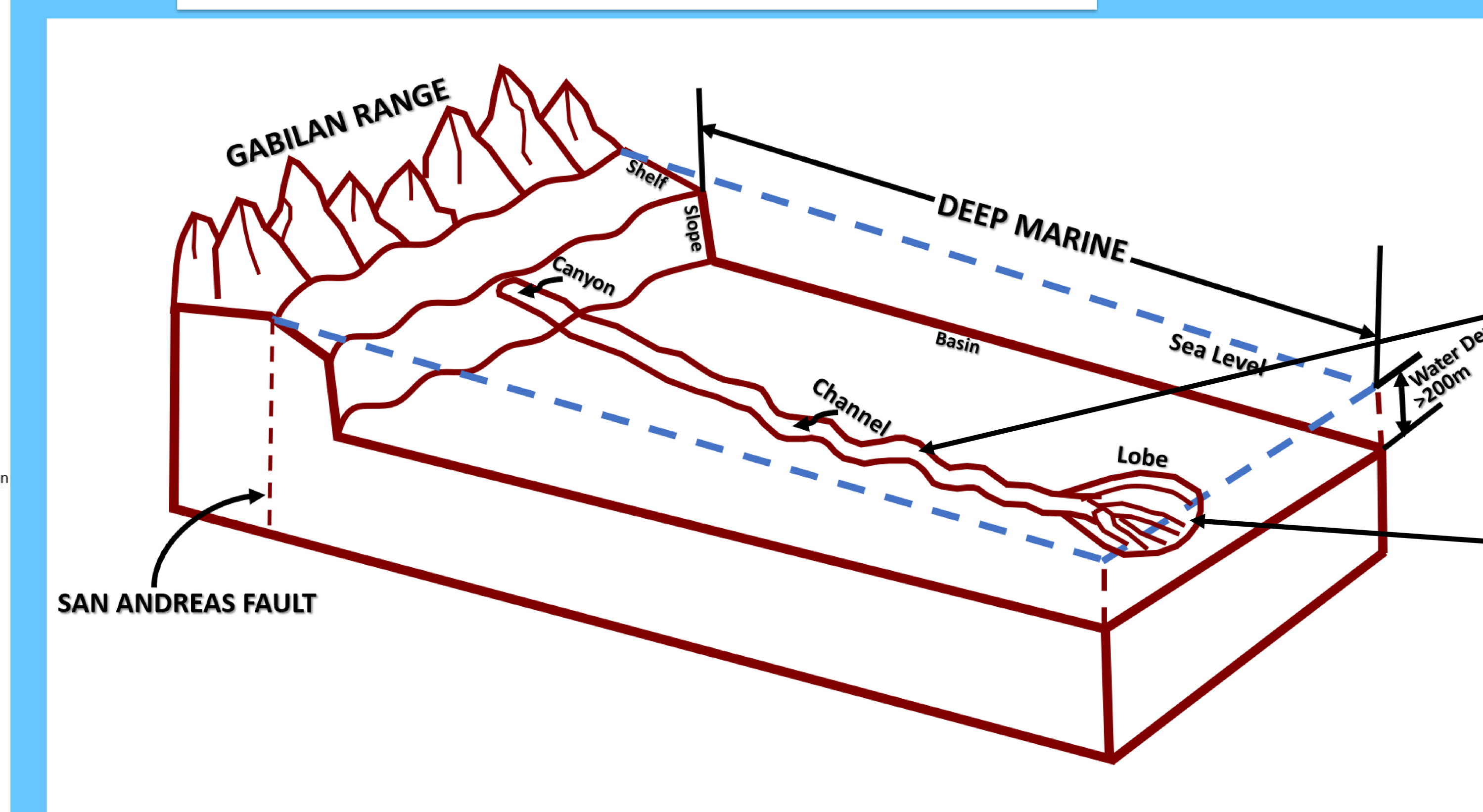
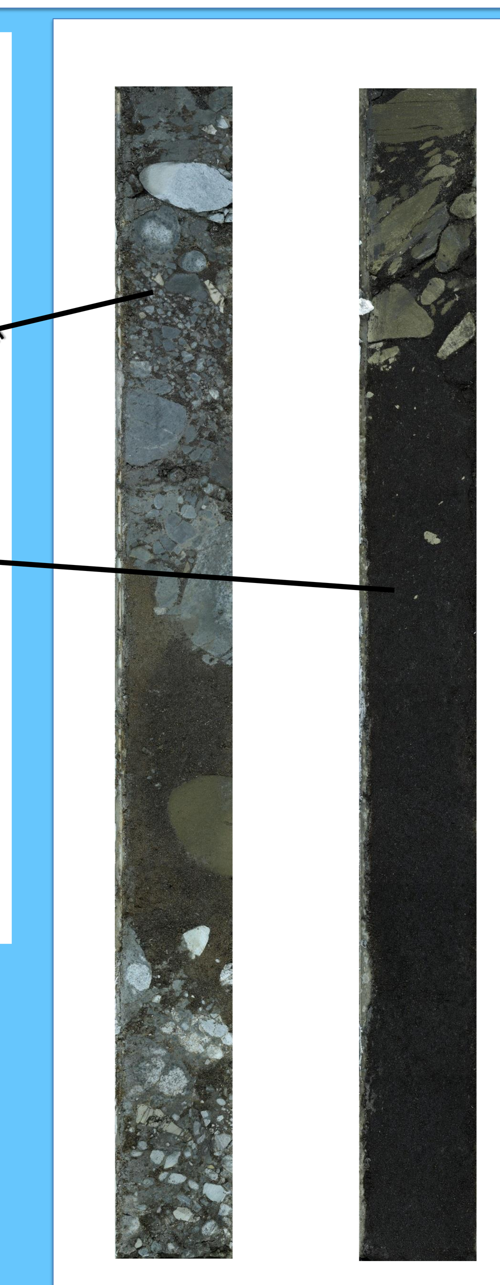


Figure 6. Schematic diagram showing deep-marine sedimentary depositional environment of the X&Y sands of the Miocene Series, Monterey Formation, MWSS Oil Field.



CONCLUSION

Clasts are majorly granitic, diatomitic, and carbonaceous.

- Clasts act as baffles
- Diatomite clast mask log resistivity
- X sand has more carbonaceous clasts

Fracture in clasts – Secondary Porosity and Hydrocarbon Migration

- Fracture is healed by carbonate cement thereby reducing porosity.
- In some cases, carbonate cement has dissolved and hydrocarbon has filled fractures.

Carbonate cements and disorganized conglomerates have reduced reservoir quality in the X sands

X & Y sands are unconsolidated & held together by heavy oil except in carbonate cemented zones.

Clasts % (visual estimation from core description): NTG

- Clast % in X reservoir: Up to 80%; has reduced pore volume.
- Clast % in Y reservoir: Less than 30%.

Reservoir quality is directly influenced by depositional processes in the Miocene sands. The sandy debrites and turbidites have the best reservoir qualities probably caused by grain size distribution; grain size and sorting control porosity and permeability.

A better understanding of different sand distribution helps to better define facies distribution in petrel facies modeling.

Dimensions & Geometries – barriers, baffles, & flow units relationships helps to determine the efficiency of steam cycling and/or steam flooding in the reservoirs.

CORE OBSERVATIONAL FEATURES

- Presence of conglomerates.
- Clasts are majorly granitic, diatomitic, and carbonaceous.
- Clasts are mostly granules, pebbles, and few cobbles.
- Presence of floating granules and pebbles.
- Clasts are mostly subangular to rounded.
- Presence of normal graded, massive, structureless sands with no clasts.
- Presence of bioturbated, diatomaceous shales and mudstones.
- Presence of planar and cross laminations.
- Laminations have grey color and are sometimes folded or faulted.
- Presence of carbonate and siliceous cements.
- Presence of carbonate, siliceous cement and, oil-filled fractures.
- Presence of sharp planar and angular contacts.
- Presence of small scale faults.
- Sands are fine to coarse grained.
- Sands are oil saturated except in depleted zone caused by steam injection.
- Some diatomite beds dip between 40 – 45 degrees.
- Presence of sand injectites

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