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UTILIZING PETROGRAPHIC DATA TO EXPLOIT MIDALE BED RESERVOIRS IN THE ALAMEDA WEST STEELMAN AREA OF THE WILLISTON BASIN IN SOUTHEAST SASKATCHEWAN

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The uniqueness of the Midale Beds in the Alameda West Steelman prospect area is conducive to detailed petrographic work to assist in the resource exploitation of this underestimated and overlooked reservoir. Three potential reservoir horizons are discussed from this low permeability, low stand carbonate to evaporitic sequence that was deposited within inner shelf to supratidal flat environments.

Introduction

The Alameda West Steelman pool study included over seventy Midale cores and numerous thin sections. Based on the interpretation of reservoir quality and depositional environments, the study identified previously unexploited reservoir. The pool produces oil from the Mississippian Midale Beds of the Charles Formation. Regionally, the Midale Beds were deposited in tidally-influenced tidal flat to restricted inner shelf environments in the Williston Basin of southeast Saskatchewan. The Midale Beds are traditionally subdivided into the Midale Marly and Midale Vuggy based on localized stratigraphy initiated at the Weyburn Unit. In order to incorporate all of the lithofacies encountered, the Midale has here been subdivided into thinner Upper Midale and thicker Lower Midale. The Midale Beds are sandwiched between the underlying Frobisher Evaporite and the overlying Midale Evaporite. The underlying Frobisher Evaporite is comprised of nodular, chevron and bedded grey to white anhydrite and represents a hypersaline lagoonal environment. The overlying Midale Evaporite is composed of stacked laminated dolomitic mudstone that possesses rootlets, burrows and mottled textures with white massive anhydrite and represents the initial barrier facies for hypersaline lagoonal evaporite deposition. The upper Frobisher Evaporite contact appears erosional, while the upper contact of the Upper Midale is a hardground surface with exposure and hardground surfaces identified within the Lower Midale.

The Upper Midale is comprised of one or two limey dolomitic mudstone sequences that possess excellent sucrosic texture. The Lower Midale is a dominant lime mud to wackestone sequence with a localized thin sucrosic dolomitic mudstone reservoir occurring near the middle of the unit. Generally, the Upper Midale sucrosic dolomitic mudstone has been exploited to date, while the petrography and core evaluation suggests that the thinner sucrosic dolomites of the Lower Midale will also prove to be a very prolific producer.

The limestone portion of the Lower Midale has several thin dense white to grey lime mudstone units/cycles that overly the higher energy reservoir horizons. These thin dense mudstones were deposited as each bed reached sea level, and were no longer influenced by tidal currents; plus act as flow barriers between reservoir units. The middle or 'second' unit/cycle possesses the best reservoir development. Porosity in the lowermost reservoir unit/cycle is extensively infilled with late metasomatic dark grey anhydrite and has limited potential in isolated areas.

The four cores (Figure 1) on display represent the distinctiveness and variability of reservoir quality within the Midale Beds in the Alameda West Steelman area. The study shows the upside potential of old Mississippian oil pools in southeast Saskatchewan and the importance of a comprehensive geological understanding of the entire reservoir package.

Theory and/or Method

Athena Resources Limited recently reviewed seventy-five wells with Midale core. This included the correlation of core gamma ray logs to open hole wire line log suites to ensure everything was on depth. This aided in the geologic interpretation of open hole log responses to depositional environments, lithofacies, textural and structural components, geologic contacts, plus exposure and any other diastemic surfaces. Reservoir parameters such as porosity, permeability, oil stain and fluorescence were also subjectively evaluated during the core logging process. The nature and degree of fracture networks, as well as the expression of salt collapse from features indicative of karsting were documented (Figures 2, 3 and 9).

Core Laboratories Canada Ltd. performed full conventional core analyses on core where previous operators had only run sparse preliminary plug analyses over this conventional reservoir. Because of the thin interbedded nature and low permeability reservoir aspects of the Midale Beds, pressure decay profile permeameter (PDPK) analysis was also completed by Core Laboratories. Core Laboratories also prepared forty-five thin sections using potassium ferricyanide and Alizarin red-S staining for dolomite identification from six key wells.

Calgary Rock and Material Services Ltd. ran X-Ray Diffraction Analysis (XRD) for Athena Resources at Alameda West Steelman. This included clay and bulk powder analyses from cuttings taken from four vertical wells at selected depths and six horizontal wells along critical measured depth intervals in order to distinguish lithology and reservoir changes.

Examples/Discussion

The Midale Beds in the Alameda West Steelman prospect area are very unique and special in regards to geologic deposition and reservoir parameters that influence the economic potential of this old oil field. This presentation illustrates how comprehensive reservoir description leads to further economic exploitation of an underestimated and underdeveloped region and geologic interval. Previous activity had focused primarily on the stratigraphically higher Midale Marly beds of oilfield terminology in the region because of the excellent reservoir development within the sucrosic dolomitic mudstone units plus the excellent oil shows and production histories. Subsequent evaluations by Athena showed that porous lime wacke to packstone sequences and locally developed sucrosic dolomitic mudstone within the Lower Midale to be excellent reservoir horizons to develop.

The Alameda West Steelman area is unique in that the upper Frobisher and Midale Bed sequences were deposited on a paleotopographical high region which led to the subsequent development of a thinner sedimentary accommodation package for both units. This paleotopographical high region was assembled between two northerly-trending Precambrian basement facture network systems that set up a north-northwest trending basement hinge zone that allowed Winnipegosis reef complexes to develop. Later Prairie Evaporite Formation salt dissolution on the down dip side of these reefal platform prepared regions for thicker sedimentary accommodation packages to develop and thus thicker reservoir packages to be preserved (Figure 4).

Detailed core work revealed much of the differing character in the Alameda West Steelman area in that the Upper Midale or Midale Marly is not always a thick sucrosic dolomitic mudstone, but could be either very thin or a very limey dolomitic mudstone with varying degrees of anhydritization (Figure 5). The Lower Midale or Midale Vuggy is a dominant lime wacke to mudstone sequence with higher energy units comprised of white anhydrite-plugged lime pack to grainstone sequences at the top of each cycle. Where there was a thickening of the sedimentary accommodation package and lack of erosion, the quieter energy restricted lagoonal mudstone units that possess excellent sucrosic textures were preserved. Examples of this are illustrated with core taken from the Midale Beds at 121/08-16-004-03W2M (Figure 6) and 121/10-16-004-03W2M (Figure 7) vertical locations. Where the sedimentary accommodation package is thinner; the more carbonate-rich reservoir that is occasionally plugged with to white to pale brown anhydrite is illustrated with the core taken from the stratigraphic test location at 121/12-17-004-03W2M (Figure 8). Evidence of the influence of salt collapse is illustrated in the core taken from the vertical test at 121/01-17-004-03W2M (Figure 9).

Critical features recognized in core and documented by Christopher G. St. C. Kendall (2005) as indicative of restricted inner shelf parasequences deposited in semi-arid environments includes: basal coarsening-up units capped by erosive cycles prior to dominant shoaling-up cycles that end in evaporitic packages in arid settings; widespread carbonate muds with higher energy units capped with alternating muds and argillaceous units; restricted faunal assemblages that are sometimes very high in number with varying degrees of disarticulation and abrasion; aeolian silts comprised of very fine quartz grains in capping muds, cyanobacterial mats and rooted muds near the top; mud cracks and gypsum microrosettes near the top; several hardground, erosional and glossifungites surfaces internally developed as well as bounding exposure and hardground surfaces. Kendall (2005) notes that these settings are typified in shallow epeiric seas and inner backreef lagoons where local storm driven higher-energy deposits are confined in channel or tidal creek environments.

Thin section work identified common trace floating subangular quartz grains in the Upper Midale along with common anhydrite and occasional gypsum-infilling the central voids and rimmed with anhydrite (Figure 10). Where the Upper Midale is thicker, there are several interbedded units of varying sized and developed micritic textures. The higher energy carbonates of the Lower Midale have several early stages of intensive carbonate cementation and plugging. Thin sections from core taken in 120/10 16 and 121/08-16-004-03W2M; illustrate excellent uniform sucrosic textures with excellent reservoir parameters within the Lower Midale (Figure 11). The Basal Midale in places show good porosity on logs and core, but is generally well cemented with limited reservoir potential because of very low permeability (Figure 12).

X-Ray diffraction data (XRD) was completed on well cuttings from six horizontal and four vertical wells. The Lower Midale which was the reservoir target in the horizontals wells and the XRD results showed variations in the amount of calcite and dolomite present along the trajectories which could be related to those observed by well site geologists. From the vertical wells, higher amounts of silica, plagioclase and potassium feldspar were noted in the Upper Midale. Within the Lower Midale, there was lower silica, but trace and varying amounts of pyrite and illite were identified. These features corroborated well cuttings and core descriptions which also recognized a more dolomitic package spatially to the north as the Midale subcrop edge was approached within the Alameda West Steelman prospect.

Conclusions

Detailed reservoir characterization has revived an old oilfield at Alameda West Steelman and outlined numerous potential drill targets which will significantly increase the recovery of oil.

Acknowledgements

Thanks to Athena Resources Ltd. for their permission to release this study. Thanks to Core Laboratories Canada Ltd. for completion of full conventional core analyses and pressure decay profile permeameter (PDPK) analysis, as well as thin section preparation and evaluation. Calgary Rock and Material Services Ltd. is acknowledged for their X-Ray diffraction analyses from cuttings taken from both vertical and horizontal wells. Special thanks must also be given to the staff at the Saskatchewan Ministry of the Economy, Energy and Resources, Subsurface Geological Laboratory for their help with the core handling. Tyler Music and Megan Love from Energy and Resources should be recognized for their contributions in completing the figures and posters.

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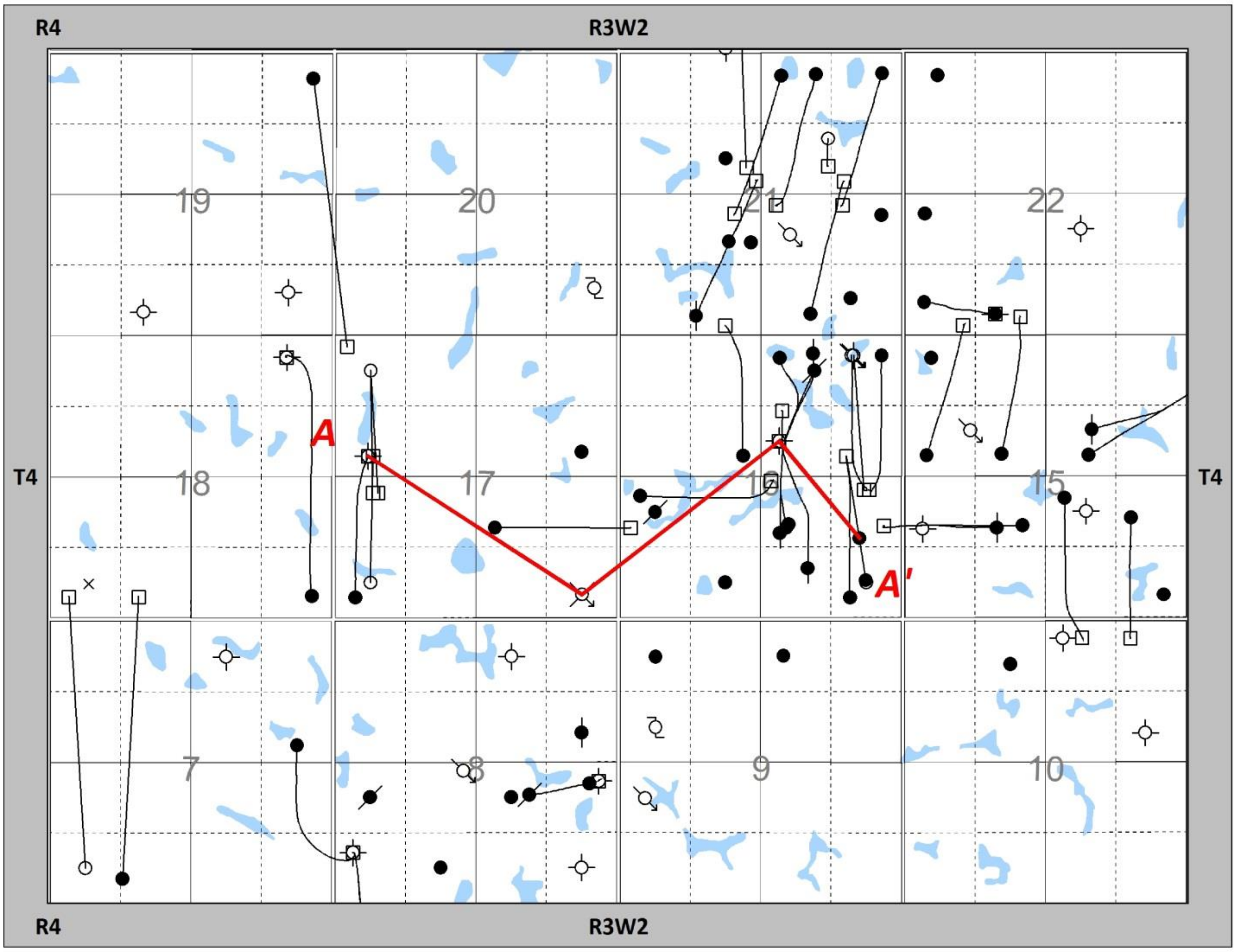

Figure 1 Core and cross section location map where the cross section includes only the wells which are used in this presentation with core described by John Lake. Locations from west to east include 121/12-17-004-03W2M, 120/01-17-004-03W2M, 121/10-16-004-03W2M and 121/08-16-004-03W2M. Source of map is from geoSCOUT.

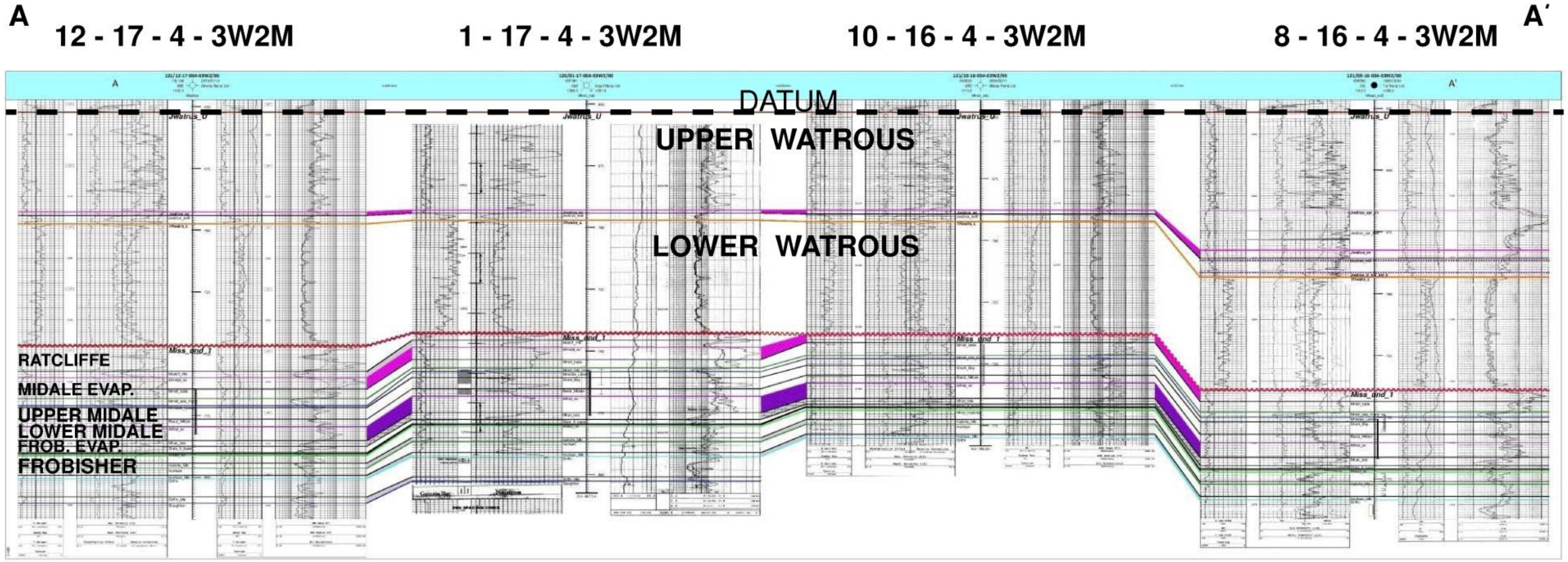

Figure 2 Stratigraphic cross section using the key four cored well logs in the Alameda West Steelman project area with the top of the Upper Watrous chosen as the stratigraphic datum. Key geologic stratigraphic units are the Upper Watrous (brown), Lower Watrous (orange), Mississippian erosional surface (wavy red), Ratcliffe (light grey), Midale Evaporite (light purple infill), Upper Midale (dark green), Lower Midale (medium blue), Frobisher Evaporite (dark purple infill) and Frobisher Beds or State ‘A’ (hachured medium grey infill). Note the increase in Upper Watrous thickening over one of the proposed salt solution features as identified from regional geologic mapping.

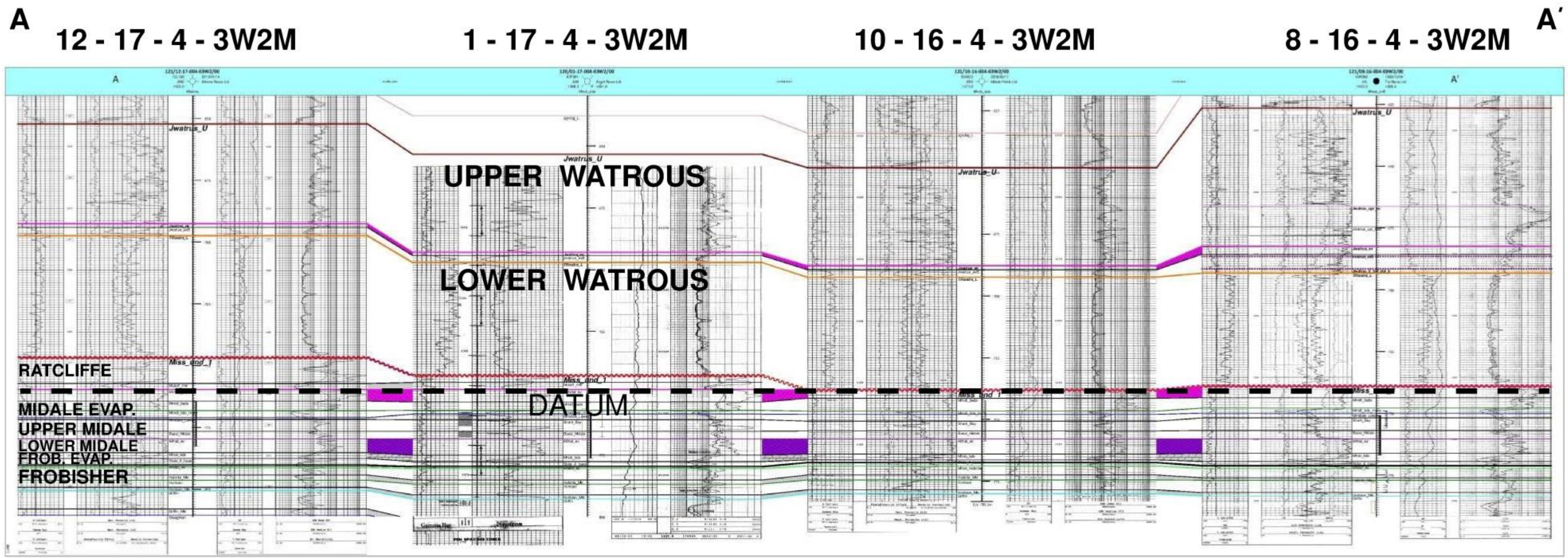

Figure 3 Stratigraphic cross section using the key four cored well logs in the Alameda West Steelman project area with the top of the Frobisher Evaporite as the stratigraphic datum. Key geologic stratigraphic units are the Upper Watrous (brown), Lower Watrous (orange), Mississippian erosional surface (wavy red), Ratcliffe (light grey), Midale Evaporite (light purple infill), Upper Midale (dark green), Lower Midale (medium blue), Frobisher Evaporite (dark purple infill), Frobisher Beds or State 'A' (hachured medium grey infill), Halbrite (light green), Huntoon (medium green) and Griffin (light Blue). Note the almost perfect uniform thickness in the upper Frobisher and Midale Beds.

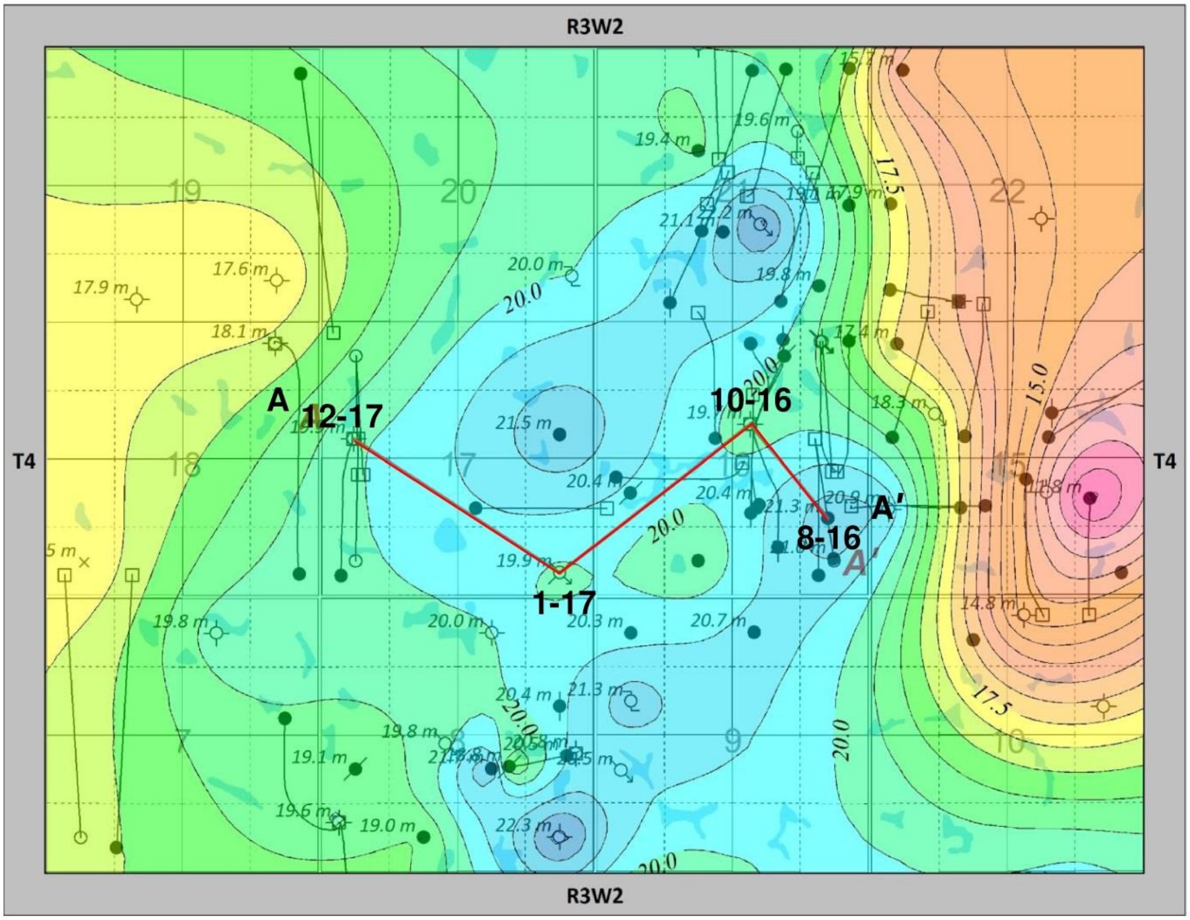

Figure 4 Isopach map of the interval between the two evaporitic units in the Alameda West Steelman project area; the overlying Midale Evaporite and the underlying Frobisher Evaporite. This interval highlights the variation in the sedimentary accommodation package within the Midale Beds sequence that is influenced by the underlying basement structure, depositional paleotopography, and salt collapse; plus which in turn affects the reservoir package that is deposited, that which escapes erosion and is locally preserved.

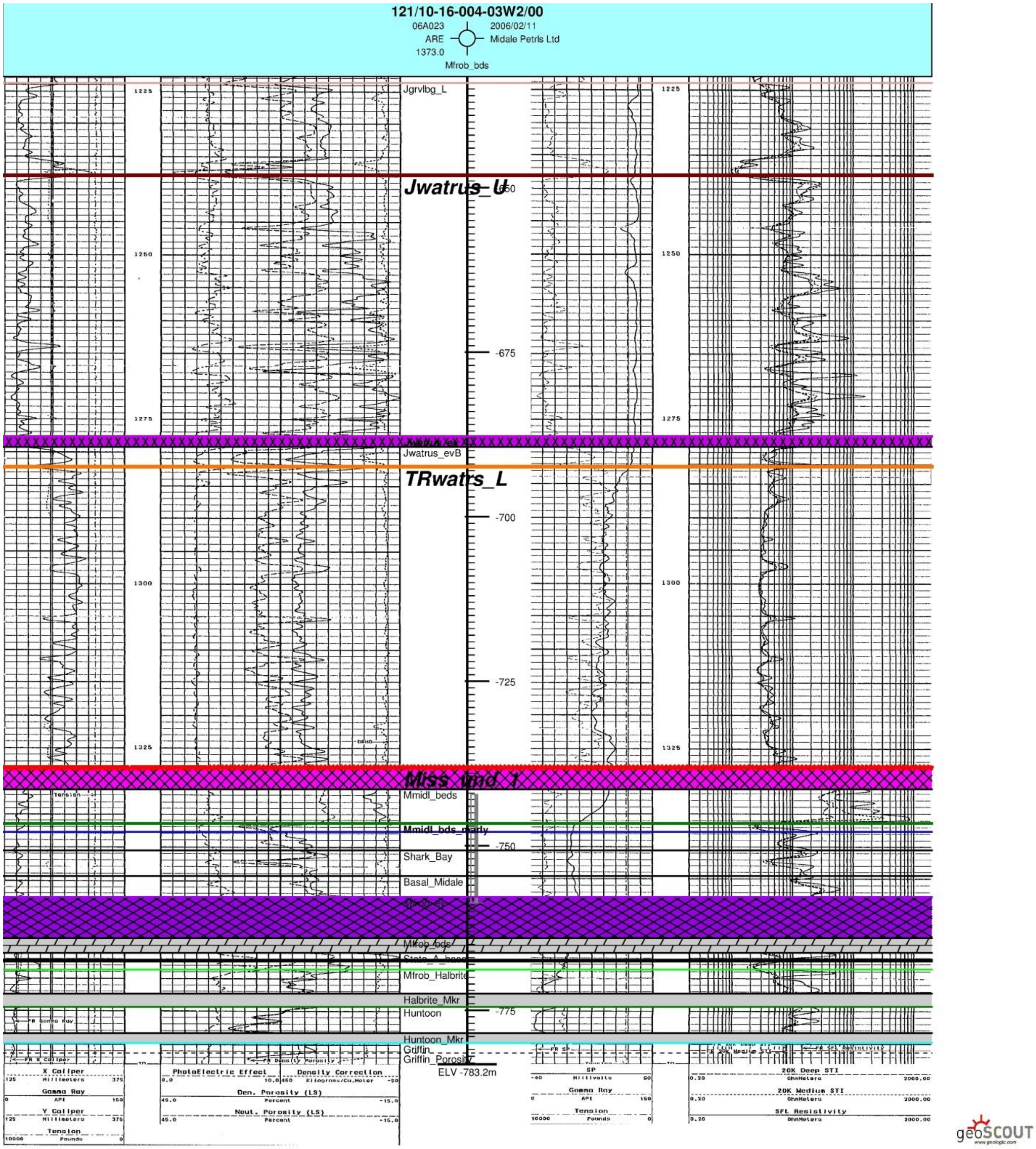

Figure 5 Type log from Midale et al Alameda 121/10-16-004-03W2M where the medium purple is the Midale Evaporite and the darker purple is the Frobisher Evaporite. The top of the Upper Midale is shown in dark green with the core interval number one from 1332.0 to 1348.5mKB is shown in the central track.

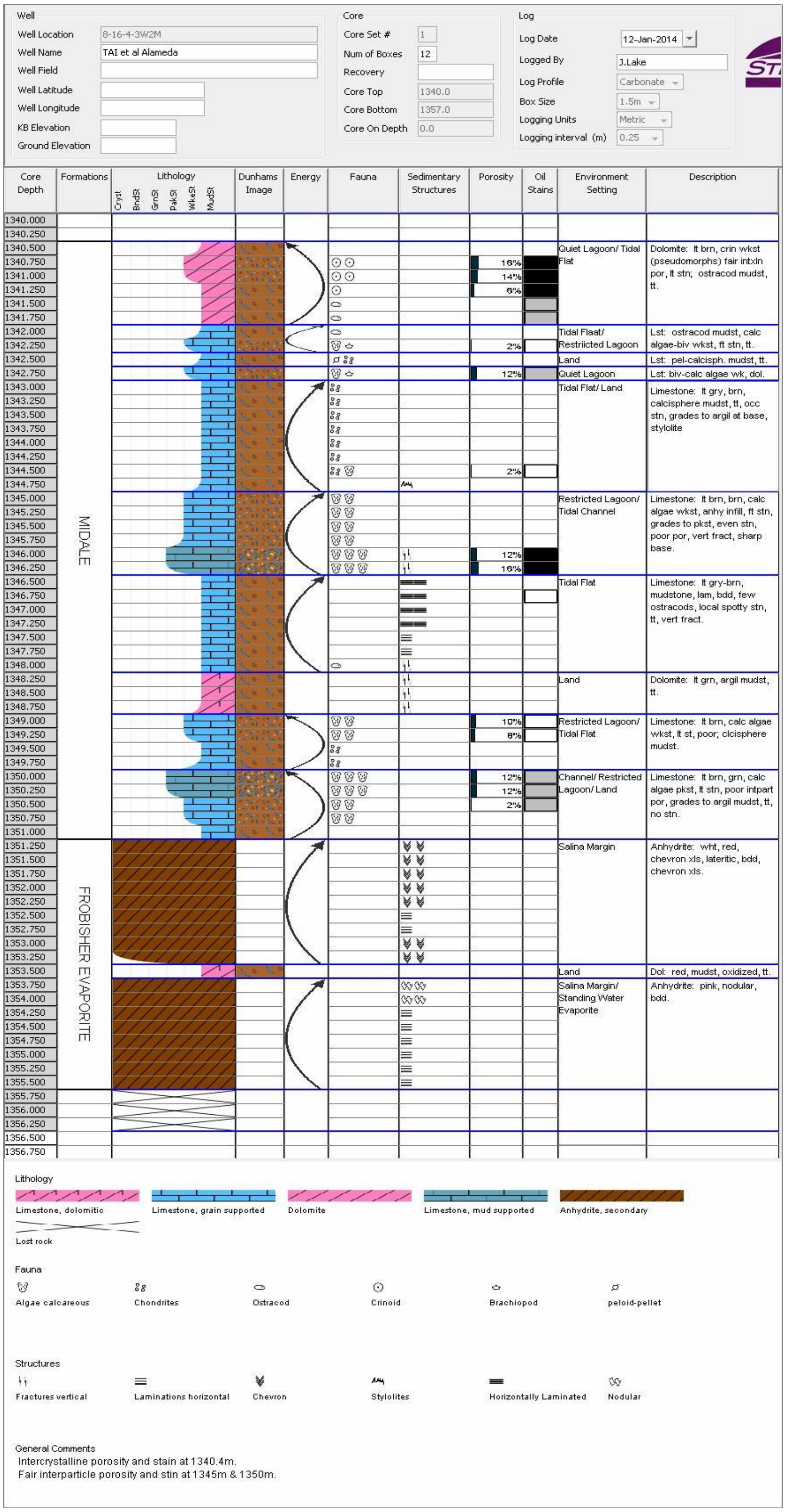

Figure 6 Core description for Tai et al Alameda West 121/08-16-004-03W2M showing excellent sucrosic dolomitic mudstone reservoir within the Lower Midale. Note the dense argillaceous dolomitic mudstone above the Basal Midale (Core Number One, 1340.4-1356.4mKB).

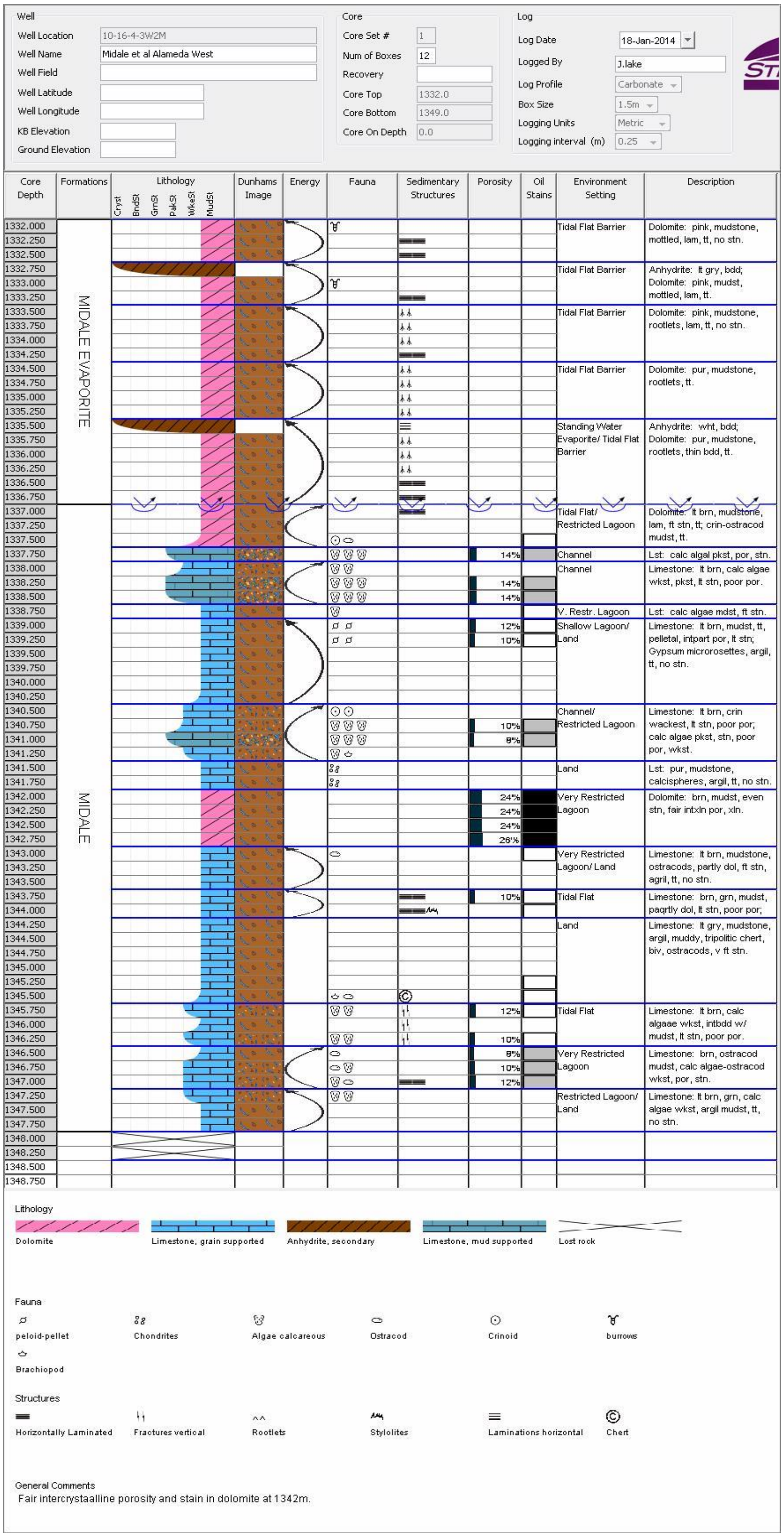

Figure 7 Core description for Midale et al Alameda West 121/10-16-004-03W2M documenting even oil stain and excellent reservoir development within the sucrosic dolomitic mudstone in the Lower Midale (Core Number One, 1332.0-1348.5mKB).

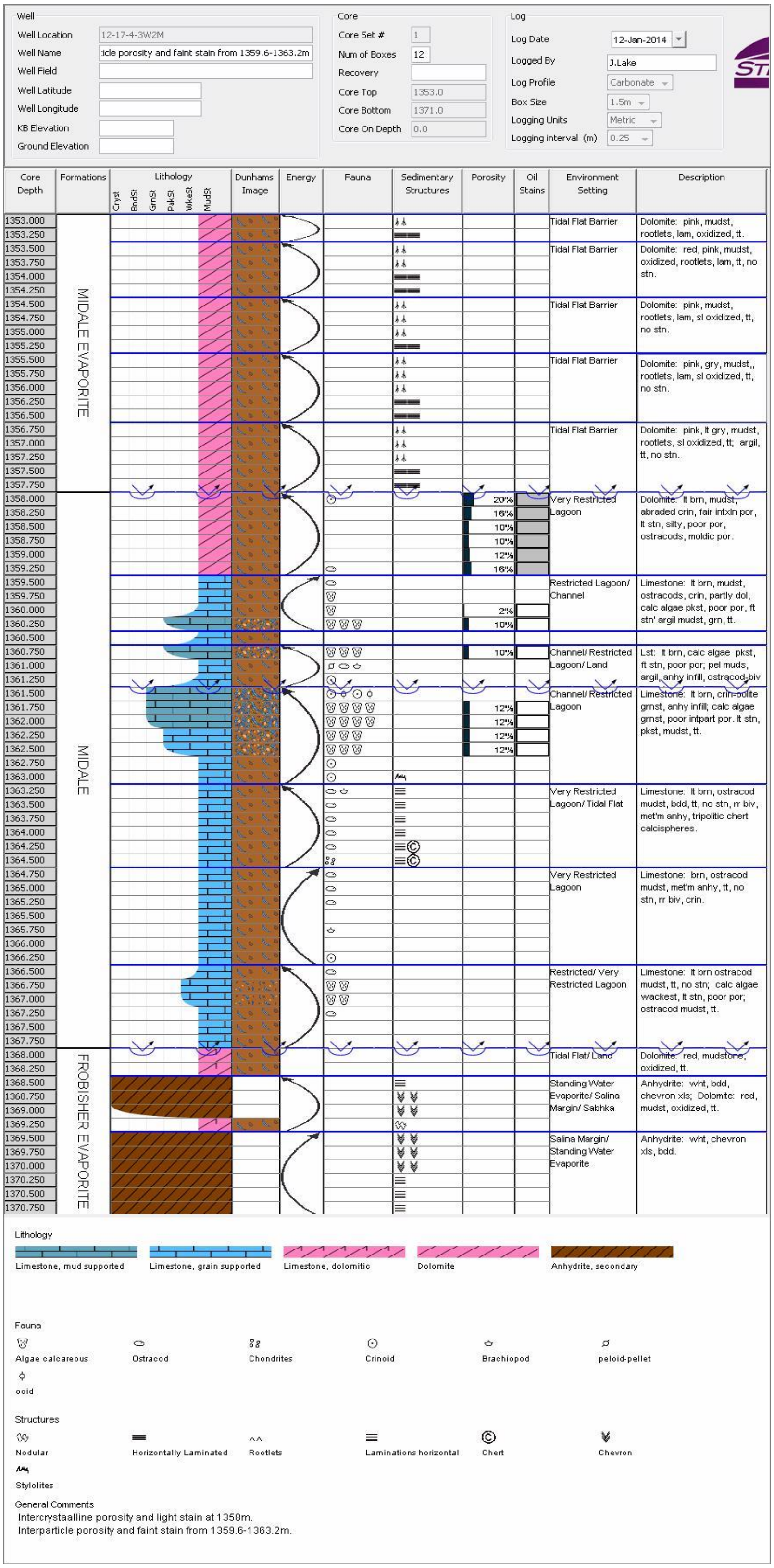

Figure 8 Core description for Athena Alameda West 121/12-17-004-03W2M illustrating a thinner Midale Beds sequence which is a more carbonate-rich reservoir that possesses good intraparticle porosity that is commonly anhydrite-infilled (Core Number One, 1353.0-1371.2mKB).

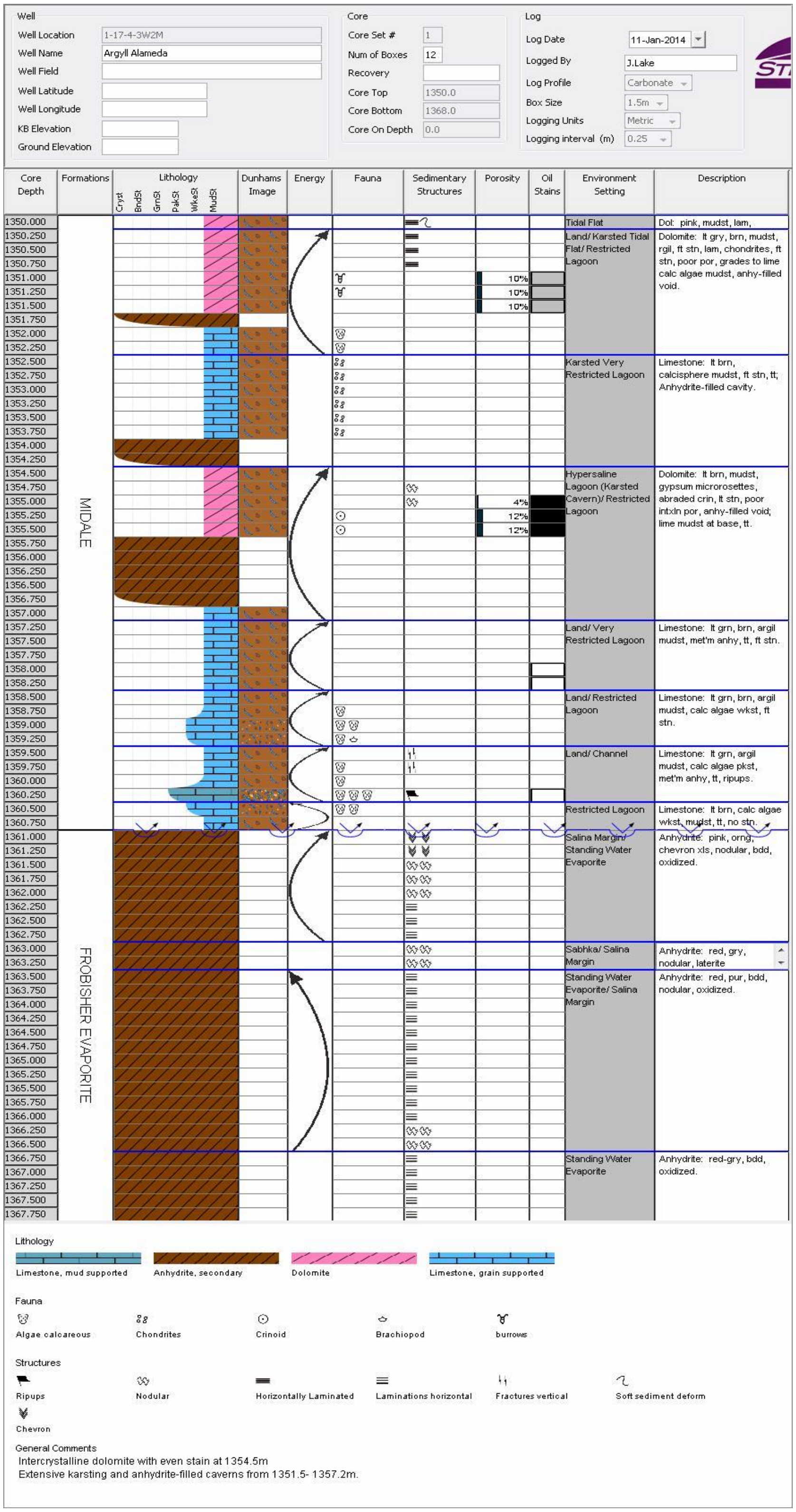

Figure 9 Core description for Argyll Alameda 120/01-17-004-03W2M which displays extensive karst and anhydrite-infilled caverns that bound a thick intercrystalline dolomitic mudstone with gypsum microrosettes and heavy dark oil staining within the Lower Midale (Core Number One, 1350.0-1367.9mKB).

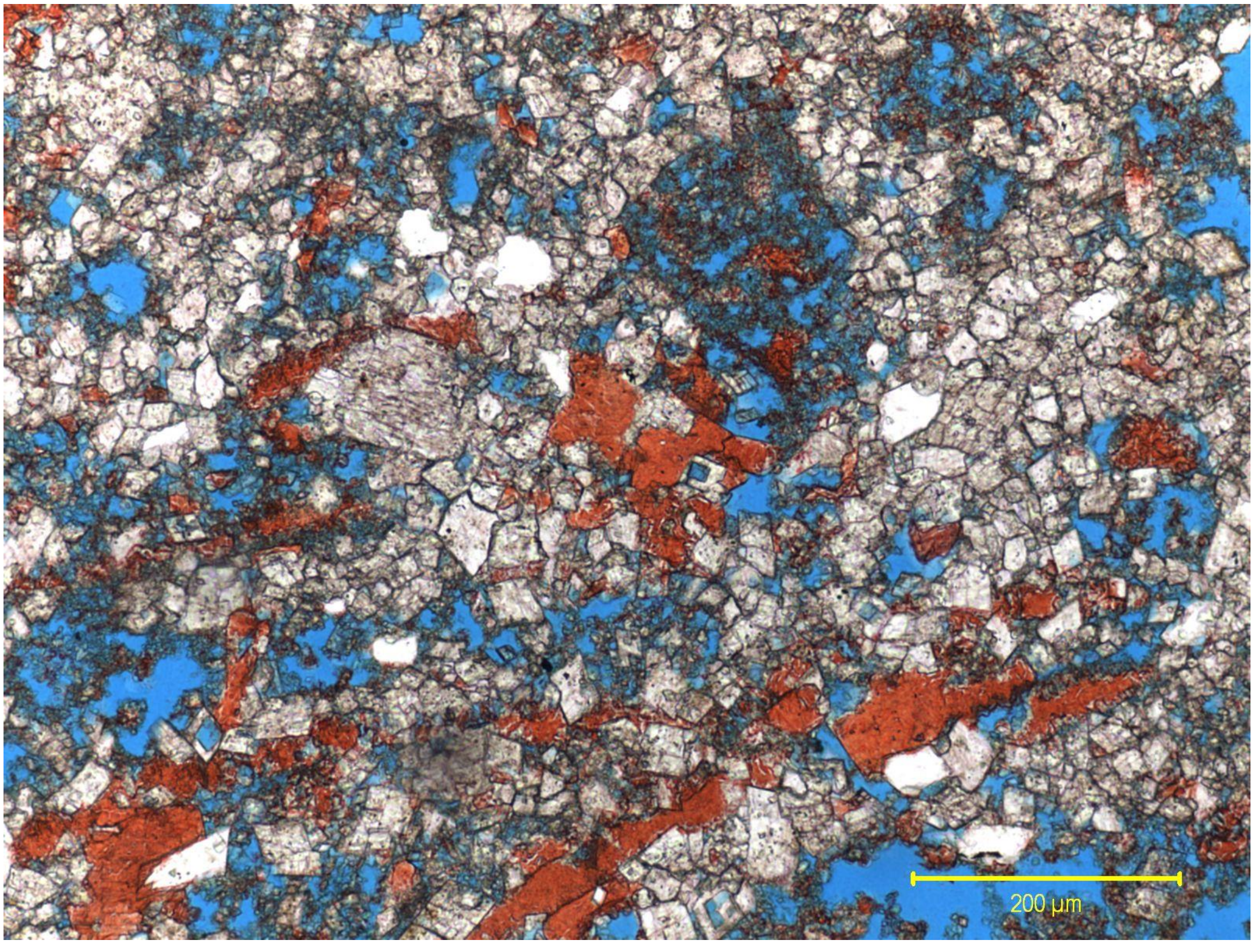

Figure 10 Thin section number one taken from the well Midale et al Alameda 121/10-16-004-03W2M using full diameter sample three over the interval of 1338.16 to 1338.88mKB. Magnification is 125 times with a white light source. Note the amount of calcite crystals in the Upper Midale, as well as the variable size and nature of the dolomite crystals in the sucrosic dolomitic mudstone matrix. Common trace amounts of angular to subangular floating quartz grains. Core analyses documents reservoir parameters of 16.6 per cent porosity, 2.88md maximum permeability, 0.39md vertical permeability and grain density of 2820 kilograms per cubic metre.

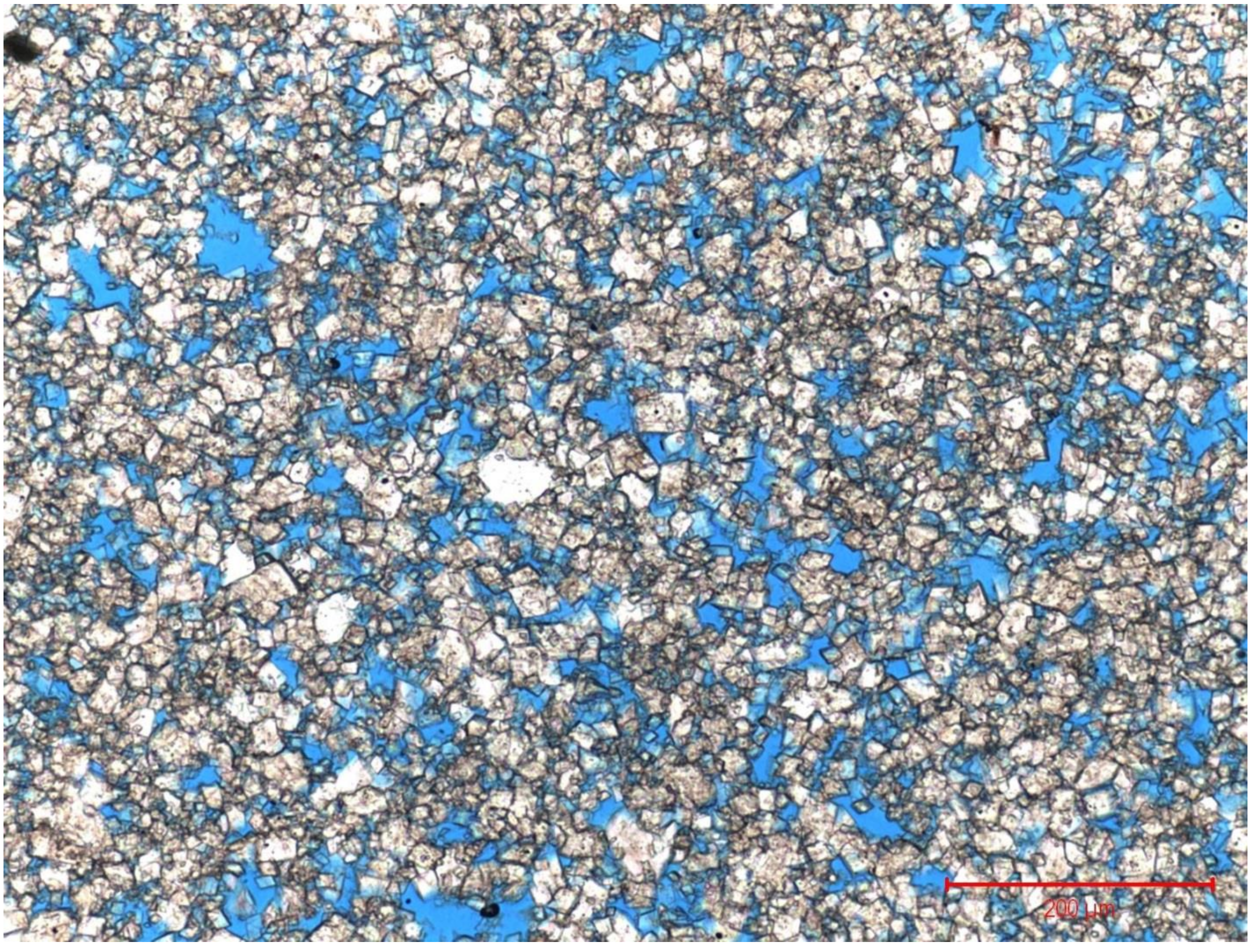

Figure 11 Thin section number two from the well Midale et al Alameda 121/10-16-004-03W2M using full diameter sample nine from the interval 1342.76 to 1343.03mKB. Magnification is 125 times with a white light source. Note the more uniform size of the dolomite crystals and the excellent reservoir development in the sucrosic dolomitic mudstone of the Lower Midale. Very minor amounts of very fine floating quartz grains are still observed. Core analyses documents 29.1 per cent porosity, 64.4md maximum permeability, 41.5md vertical permeability and a grain density of 2830 kilograms per cubic metre.

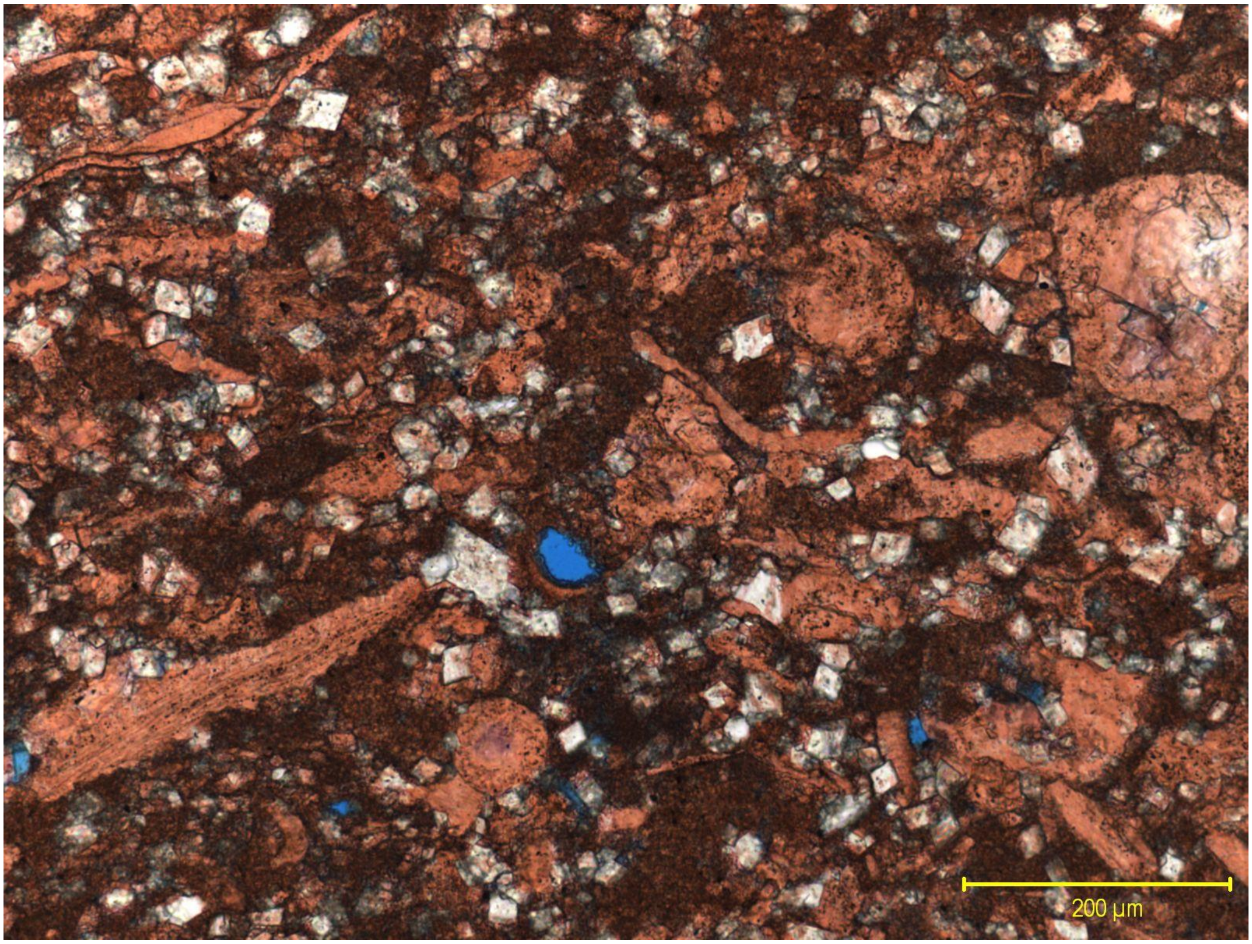

Figure 12 Thin section number three from the well Midale at al Alameda 121/10-16-004-03W2M using full diameter sample ten b from the interval 1343.96 to 1344.13mKB. Magnification is 125 times with a white light source. Note the high cementation nature of the Basal Midale with the moderate amounts of slightly abraded bivalves, crinoidal and bryozoan faunal remains. The very exact but very small size of early dolomite crystals in the well cemented limey micritic mudstone matrix. Occasional intrafragmental and intergranular porosity. Core analysis documents 9.4 per cent porosity, 0.21md maximum permeability, 0.02md vertical permeability and a grain density of 2710 kilograms per cubic metre.