An integrated approach to evaluating the Second White Specks Formation in Alberta using elemental chemostratigraphy, programmed pyrolysis, and advanced mud-gas compositional data

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Summary

The Second White Speckled Shale Formation ("Second White Specks") of Alberta, Canada is a Cretaceous mudstone that was deposited during a period of overall high sea level, spanning the Cenomanian-Turonian boundary, and including Oceanic Anoxic Event 2 (OAE2) (Fig. 1). The formation name is descriptive in that it reflects the abundance of light colored, sand-sized fecal pellets that can characterize the interval. This light-oil bearing mudstone / marlstone sequence is a fairly recent addition to the global list of shale resource plays, and an active target of drilling programs.

Core and cuttings from two wells penetrating the Second White Specks were analyzed by XRF spectroscopy for elemental composition, and by programmed pyrolysis for TOC and thermal maturity. Detailed mud gas composition (C_1-C_8) obtained while drilling was compared with the rock-based results. The aim of this integrated data set was to provide improved formation evaluation by : 1) refining stratigraphic correlation with elemental chemostratigraphy; 2) assessing paleodepositional environments using redox-sensitive trace-element proxies; 3) establishing, if possible, quantitative relationships between proxy elements and TOC; 4) determining if fluid composition (gas and inferred liquids) could be correlated with elemental composition, TOC, and thermal maturity. The ultimate goal of the study was to develop relationships that could be used to rapidly characterize lateral wells as the drilling program progresses.

Theory and/or Method

Continuous cuttings samples were available at a five-meter spacing in Well 1, while 39 meters of core were sampled in Well 2.

Data for 31 elements was obtained from powdered and pelleted samples using a tabletop energy-dispersive X-ray fluorescence (ED-XRF) instrument with multiple secondary X-ray targets and a silicon-drift detector. The data comprises an extended set of 12 major elements as well as 19 trace elements, the latter including redox-sensitive transition metals, Th, and U.

Rigorous quality control was maintained using a set of well-characterized international geochemical reference materials (GRMs).

Programmed pyrolysis was performed on powdered rock samples using an automated source-rock analysis instrument, which employs a flame ionization detector (FID) and helium carrier gas. After a static temperature of 300°C was attained for each sample, temperature was slowly increased to 600°C, followed by oxidized heating of the sample. The standard organic parameters S_1, S_2, S_3, T_{max}, and TOC were obtained from the analysis.

The formation gas data was obtained using a system which extracts and characterizes gas samples directly from drilling fluid using a semipermeable membrane and a helium carrier gas. The extracted gas is analyzed by chromatograph employing a thermal conductivity detector (TCD). Values of C_1 through C_8, CO_2, N_2, benzene, and toluene were quantified by the analysis.

An increase in GC-TRACER THC% or total hydrocarbon content indicates possible pay zones, while C2-C3 and C4-C5 crossover sections infer good relative permeability zones or possible fractures along with a high C1/ROP. Low THC% values reveal tight formations or low permeability zones. Higher methane percentage and lower wetness would imply lower fluid density, such as gas condensate, as seen in the Blackstone. (Table 1)

Geochemical Analysis of the Second White Specks Interval

Significant elemental changes in the two study wells allow a clear chemostratigraphic zonation and correlation to be constructed. Al_2O_3-normalized major and trace elements are used to determine this correlation and to develop a model of the paleodepositional environment. Ratios such as SiO_2/Al_2O_3, Na_2O/Al_2O_3, and K_2O/Al_2O_3 identify areas with greater terrigenous input (Fig. 2), while ratios such as V/Al_2O_3, Ni/Al_2O_3, and Mo/Al_2O_3 identify zones where relatively anoxic conditions are inferred to have existed on the sea bottom during deposition (Fig. 3). The latter zones correlate with higher TOC values, and carbonate content reaches its maximum as well. The redox-sensitive trace metals can be used as effective proxies for TOC estimation.

Conclusions

A clear chemostratigraphic zonation is present in the studied sections of the Second White Specks Formation, and reflects changes in detrital mineralogy and provenance, with a strong overprint due to redox conditions in the paleodepositional environment. The overprint, as expressed in elevated values of redox-sensitive trace metals such as V, Ni, Zn, Mo, and U, can be tied to the measured organic parameters, particularly TOC. Finally, the composition of the formation gas obtained during drilling can be positively correlated with the rock data, particularly the amount of total hydrocarbons.

Areas determined by GC-TRACER to be enhanced in total hydrocarbons also coincide with an increase in paleoredox proxies. Gas composition data suggests that the “Zone Y” interval would produce very light oil, while the “Zone Z” would indicate a light oil zone (Fig. 4) (Table 1).

Figure 1. Regional stratigraphic setting of the Second White Specks Formation. From www.fortitudeenergy.ca/uploads/Summary_Document_Second_White_Specks_Resource_Potential.pdf.

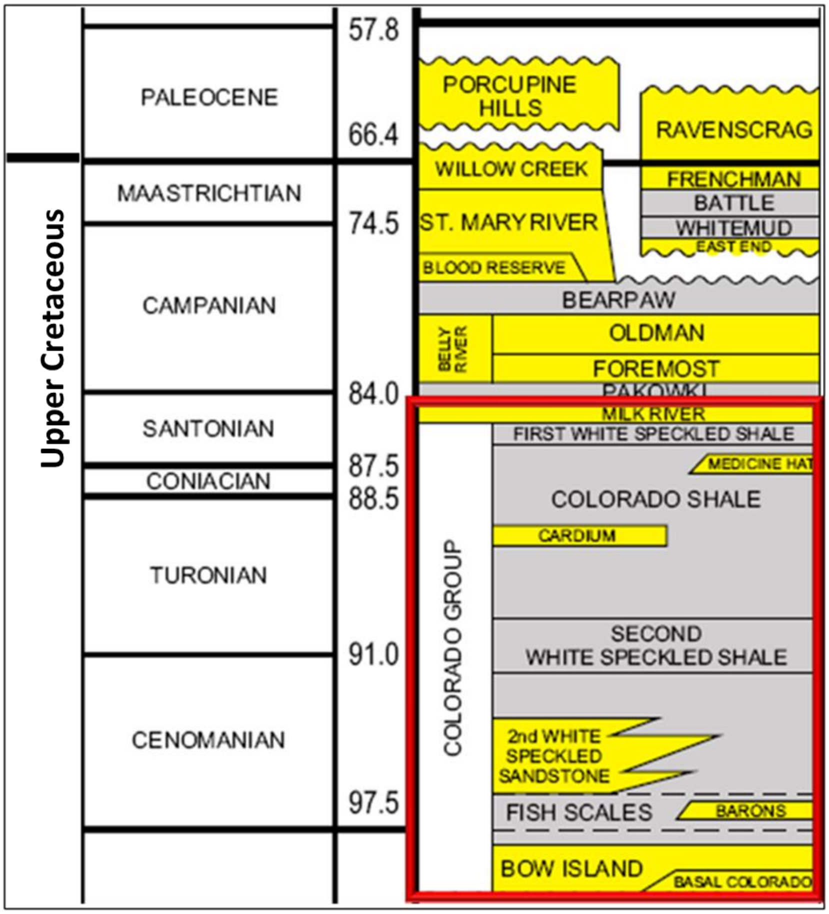

Figure 2. Depth plot of major elements normalized to Al_2O_3, from ED-XRF data obtained from cuttings in Well 1. Chemostratgraphic zonation of Second White Specks section based on all elemental data is shown at right.

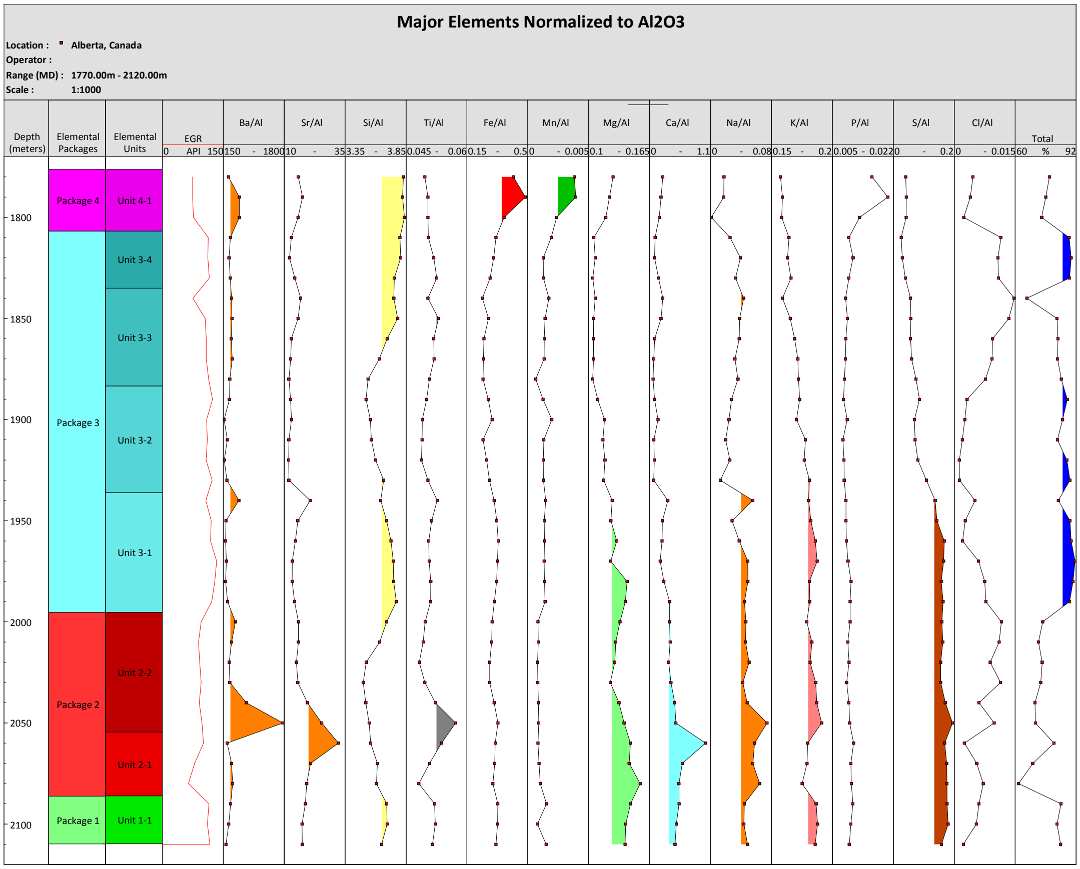

Figure 3. Depth plot of redox-sensitive trace elements normalized to Al_2O_3, from ED-XRF data obtained from cuttings in Well 1. Chemostratgraphic zonation of Second White Specks section based on all elemental data is shown at right.

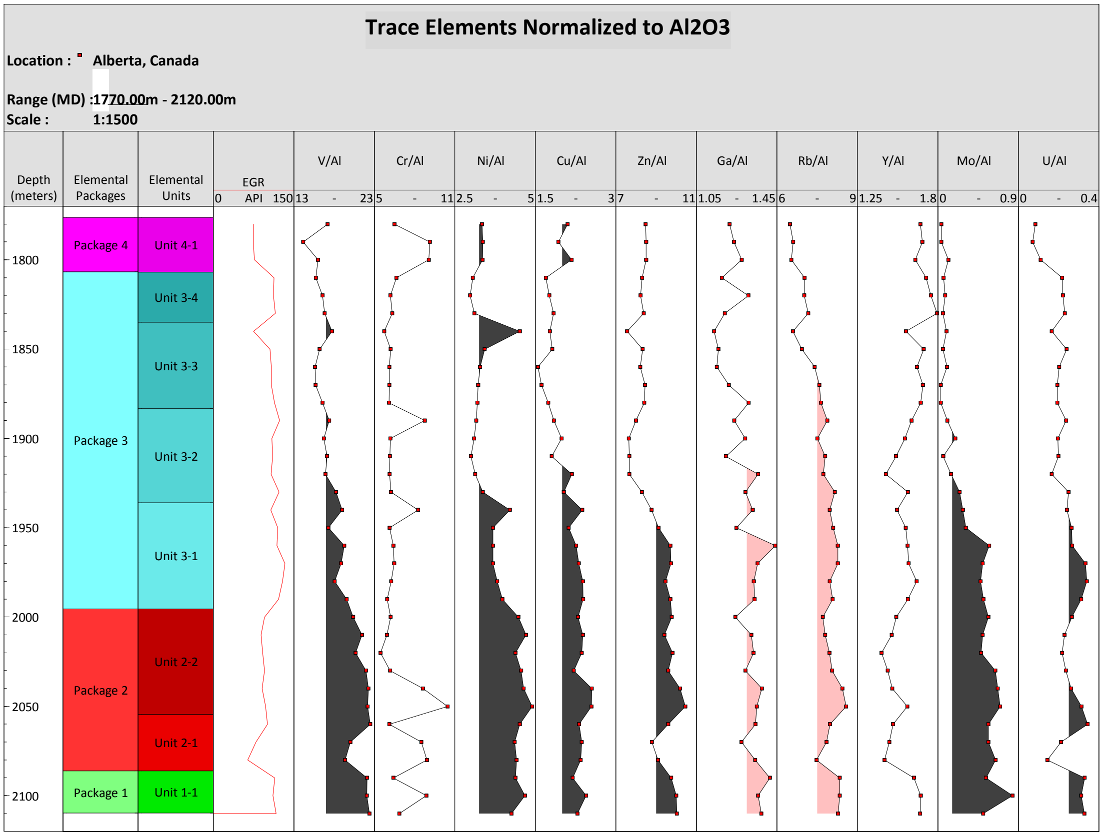

Figure 4. Gas ratio log for Second White Specks section in Well 1.

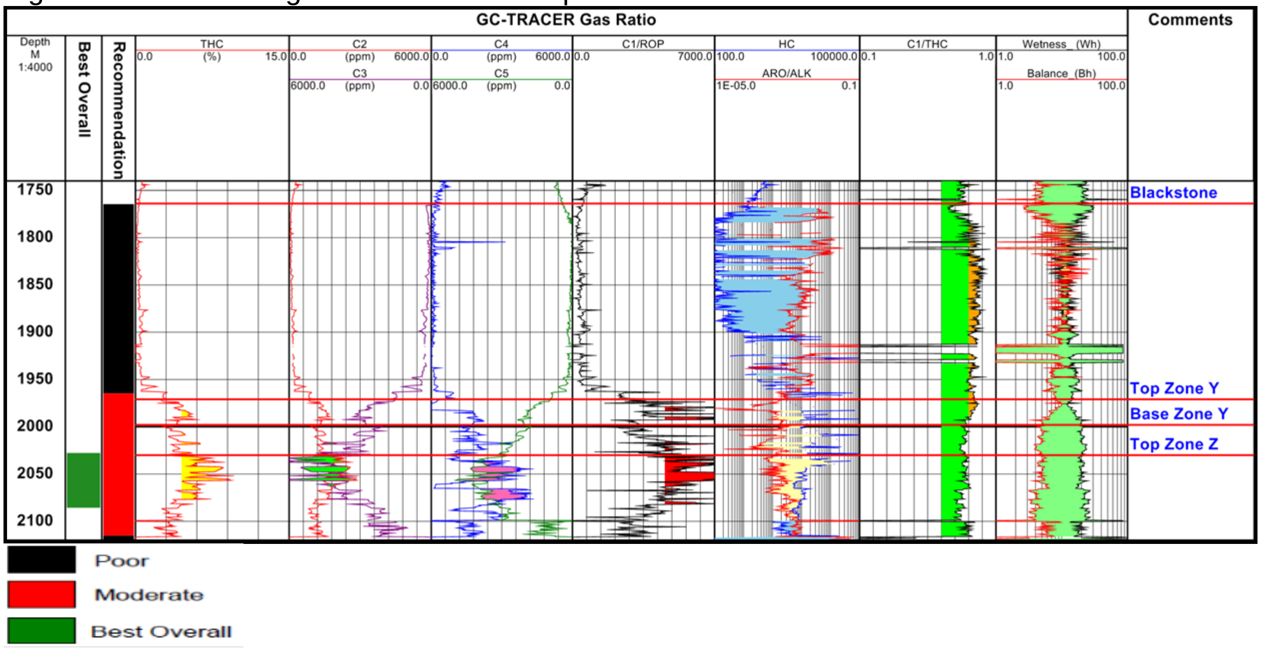

Table 1. Gas composition and interpretation for Second White Specks section in Well 1.

Sample/Formation	**Blackstone**	**Top Zone Y**	**Top Zone Z**
GCT_THC %	**0.4%**	**4.5%**	**6.5%**
GCT_Methane % _(C1)	**88.8**	**84.4**	**79.5**
GCT_Ethane % _(C2)	**2.9**	**3.2**	**3.2**
GCT_Propane % _(C3)	**4.0**	**6.2**	**7.3**
GCT_Iso-Butane %_(iC4)	**2.2**	**0.0**	**0.3**
GCT_N-Butane %_(nC4)	**0.2**	**2.1**	**3.5**
GCT_Iso-Pentane %_(iC5)	**1.4**	**2.1**	**3.0**
GCT_N-Pentane %_(nC5)	**0.0**	**1.9**	**3.1**
Wetness (Wh)	**10.7**	**15.5**	**20.3**
Balance (Bh)	**12.6**	**7.5**	**4.9**
C1/C2	**31.1**	**26.7**	**25.3**
Fluid Mobility	**29.0**	**16.7**	**8.7**
Fluid Density	**0.681**	**0.737**	**0.813**
API	**55.6**	**50.0**	**46.9**
Fluid Type	**Gas Condensate Window**	**Very Light Oil Window**	**Light Oil Window**

Acknowledgements

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Reference Cited

Regional Setting of the Second White Specks Formation - A Case for a Resource Style Play; www.fortitudeenergy.ca/uploads/Summary_Document_Second_White_Specks_Resource_Potential.pdf.