Geological and Geochemical Data from the Canadian Arctic Islands.

Part II: Rock Eval/TOC data

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Abstract

A total of 4716 Rock Eval analyses are given for samples from 109 oil and gas wells (or deviated legs) and 1655 outcrop samples from the Arctic Islands. Each sample is assigned to a stratigraphic unit.

Introduction

The Arctic Archipelago includes a land area of 780,000 km^2 covering much of the Northwest Territories and Nunavut. It contains three of the 10 largest islands in the world (Baffin, Victoria and Ellesmere) plus twenty-two others of appreciable size. There was an oil and gas exploration boom in the Arctic Islands between 1960 and 1985 that resulted in 191 exploration boreholes and the discovery of 20 major petroleum fields. Estimates of the hydrocarbon resource made by the Geological Survey of Canada predict 45 to 50 Tcf of in-place natural gas in the Sverdrup Basin, whereas the National Energy Board (NEB) predicts 45 Tcf of marketable gas in the whole Arctic Islands area.

The Geological Survey of Canada is undertaking an update of the geological and geochemical datasets for the Arctic Islands. This includes Rock Eval data (herein) and the depth to the top of each stratigraphic unit in the Arctic Islands hydrocarbon exploration boreholes (Dewing and Embry, 2007).

The stratigraphic nomenclature is presented in Figure 1. Formation descriptions are available from the Lexicon of Canadian Geological Names (http://gdr.nrcan.gc.ca/index_e.php). These include age and lithological information, as well as the location of the type section and references. Excellent summaries of the geology of the Canadian Arctic are found in Trettin (1991).

Experimental

Rock-Eval/TOC analysis provides fast and reliable characterization of the quantity and quality of sedimentary organic matter, as well as its thermal maturity. Pyrolysis experiments were conducted using Delsi Rock-Eval II and Rock-Eval VI units equipped with a Total Organic Carbon analysis module.

A typical Rock-Eval II experiment was initiated with heating of a pulverized rock sample at 300ºC for 3 min in helium atmosphere, when naturally occurring hydrocarbons (free and adsorbed) are volatilized. During the next stage, the oven temperature is steadily increased to 600ºC at a rate of 25ºC/min and decomposition of kerogen occurs. The final stage involves oxidation and combustion of the residual organic matter at 600ºC. The amount of hydrocarbons volatilized at 300ºC and evolved from kerogen at 300ºC to 600ºC is quantitatively determined by a flame ionization detector, and recorded as the S1 and S2 peaks, respectively. The temperature measured at the maximum of the S2 peak is referred to as Tmax. The quantity of organic CO_2 generated from 300ºC to 390ºC, determined by a thermal conductivity detector, comprises the S3 peak. The percentage of carbon in CO_2 formed during oxidation at 600ºC and in the hydrocarbon peaks S1 and S2 is used to define the total organic carbon content (TOC), expressed as a weight percentage. The determination of the quality of organic matter is based upon the calculation of Hydrogen (HI) and Oxygen (OI) indices (HI=S2/TOCx100, OI=S3/TOCx100) which are related to the atomic H/C and O/C ratios (Espitalie et al., 1977).

The OI versus HI cross plots ("pseudo van Krevelen diagrams") can be used as an organic matter type indicator at low and moderate maturities. The Tmax is an indicator of relative thermal maturity. According to Espitalie et al. (1985) the oil window is defined by the following Tmax ranges: 440º-448ºC (Type I), 430º-455ºC (Type II) and 430º-470ºC (Type III). A cross plot of Tmax versus HI is used to constrain estimations of organic matter type and its thermal maturity, while the Production Index (PI=S1/[S1+S2]) is used to indicate staining of a sample or as an additional maturity parameter.

Guidelines for Interpretation

Rock-Eval results correlate to other techniques (Espitalie et al., 1985; Tissot and Welte, 1978, Peters, 1986). Source rock potential is sensitive to lithology, TOC and S2 values. It is common practice to rate carbonate rocks with lower TOC comparable with richer clastic rocks. Extractable HC yields from leaner carbonate rocks are comparable to richer clastic rocks (Tissot and Welte, 1978, p. 430; Gehman, 1962). The organic matter associated with carbonate rocks is often more hydrogen-rich and thermally labile than that in fine-grained clastic rocks. As a result, more TOC in carbonate rocks may be transformed into bitumen compared with average clastic source rocks of comparable maturity.

Rock-Eval/TOC parameters have significance only above threshold TOC, S1 and S2 values. If TOC is less than less than or equal to 0.3% then all parameters have questionable significance and the experiment suggests no potential. Oxygen Index (OI), S3/TOC, has questionable significance if TOC is less than or equal to 0.5%. Both Tmax and Production Index (PI = S1/(S1+S2)), have questionable significance if S1 and S2 values are less than or equal to about 0.35 mg HC/g rock. Results can be affected by mineral matrix effects. These either retain generated compounds, generally lowering the S1 or S2 peaks, while increasing Tmax, or by liberating inorganic CO2 and increasing S3 and OI. These effects are important if TOC, S1 and S2 are low, an effect not significant where sources have TOC values greater than 5%. OI values greater than 150 mg/g TOC suggest either low TOC or a mineral matrix CO2 contribution during pyrolysis. Note that TOC and Hydrogen Index decrease with increasing thermal maturity due to hydrocarbon generation.

Arctic Islands borehole dataset

This report contains files (*.xls format) with Rock Eval data for samples from the Arctic Island boreholes and outcrop. These data are archived at GSC-Calgary and include data collected by Panarctic Oils Ltd and stored in the library collections at GSC-Calgary (Leythaeuser and Stewart, 1986), data collected by the GSC as part of an economic assessment of Bathurst Island (Stewart, 1999), Thomas Gentzis' PhD thesis (Gentzis, 1991), as well as samples run by the GSC as part of published (e.g., Brooks et al., 1992; Fowler, 1991; Goodarzi et al., 1987; Stasiuk and Fowler, 1994) and unpublished regional or stratigraphic studies. About 700 samples were run in 2005-06 to augment the previous datasets. An additional 1060 samples of the Kanguk Formation, previously released as GSC Open File 2727 (Nunez-Betelu, 1993), are included.

Figure 2 shows the TOC distribution and an HI vs OI plot (pseudo-van Krevelen diagram) for each of the main sedimentary successions.

The *.xls files include the following data fields:

1. SAMP_ID – either the UWI or a GSC-Calgary curation C-number
2. LOC_ID – Location ID/Unique Well Identifier
3. LOC_NAME – Section name/Well name
4. SAMP_LAT – Surface Latitude
5. SAMP_LONG – Surface Longitude (negative is west)
6. DEPTH_FROM – Depth (m) of sample top from Kelly Bushing. May sometimes be sample midpoint.
7. DEPTH_TO – Depth (m) of sample base
8. OFROM – Depth of sample top in units submitted to lab
9. OTO – Depth of sample base in units submitted to lab
10. DEPTH_UNIT – Feet or Metres
11. EQUIP_TYPE – Rockeval II or Rockeval 6

Rockeval Parameters:

12. TOC - Total Organic Carbon (weight percent)
13. TMAX - maximum temperature at S2 peak (ºC)
14. S1 - hydrocarbons volatilized at 300ºC (mg HC/g rock)
15. S2 - hydrocarbons evolved from kerogen at 300ºC to 600ºC (mg HC/g rock)
16. S3 - organic CO_2 generated from 300ºC to 390ºC (mg/g rock)
17. RC – residual carbon
18. PC – pyrolysable carbon
19. MINC – mineral carbon
20. HI - Hydrogen Index (mg hydrocarbons/g organic carbon)
21. OICO - Oxygen Index CO (mg CO/g organic carbon)
22. OI - Oxygen Index CO_2 (mg CO_2/g organic carbon)
23. TPKS2 – maximum temperature of surface S2
24. S3CO – CO from organic and mineral sources
25. PI - Production Index (S1/[S1+S2])
26. QUANTITY – Quantity of material analysed
27. REFERENCE – Source of data (if other than GSC lab or if previously published).
28. UNIT – Stratigraphic Unit, based on GSC Open File 5542

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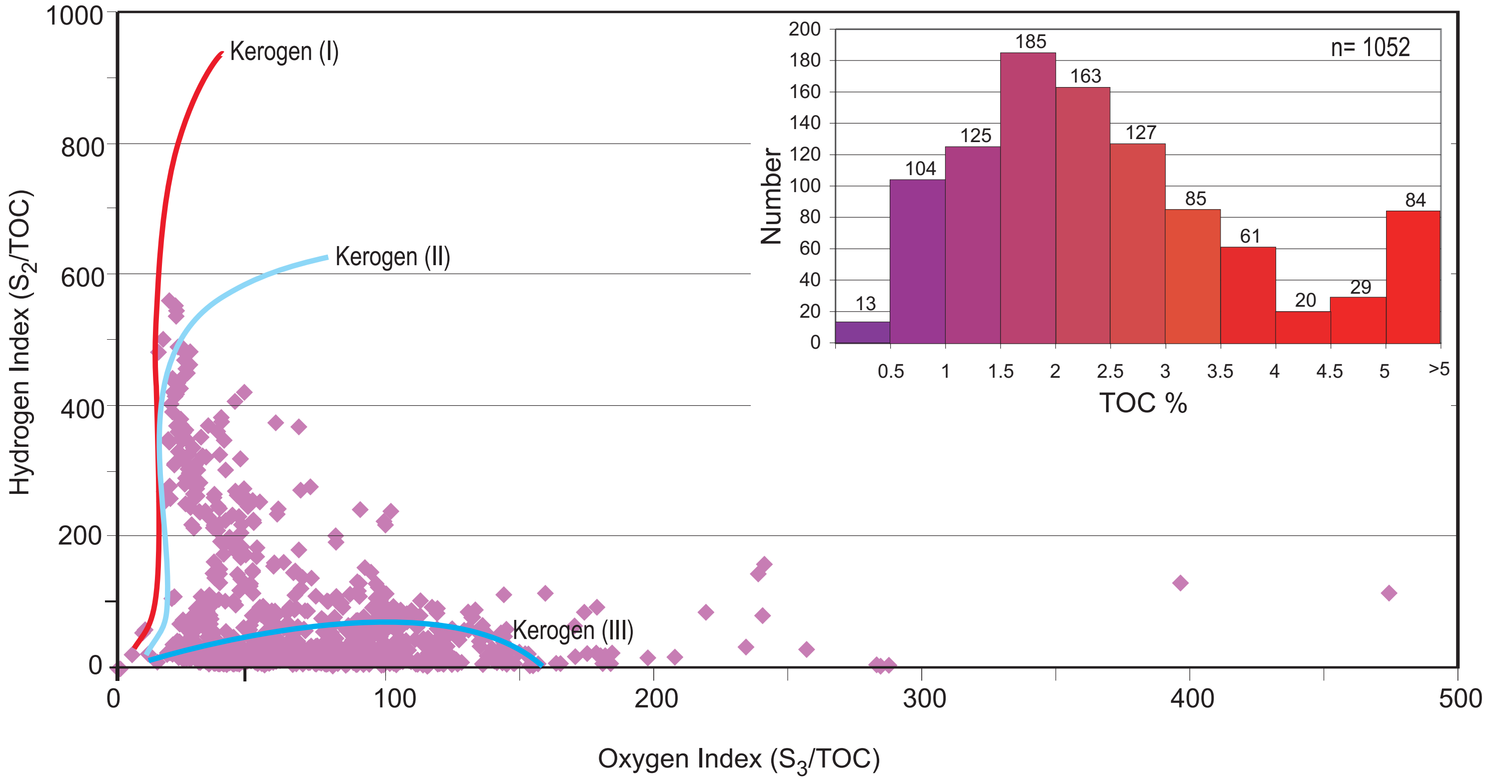
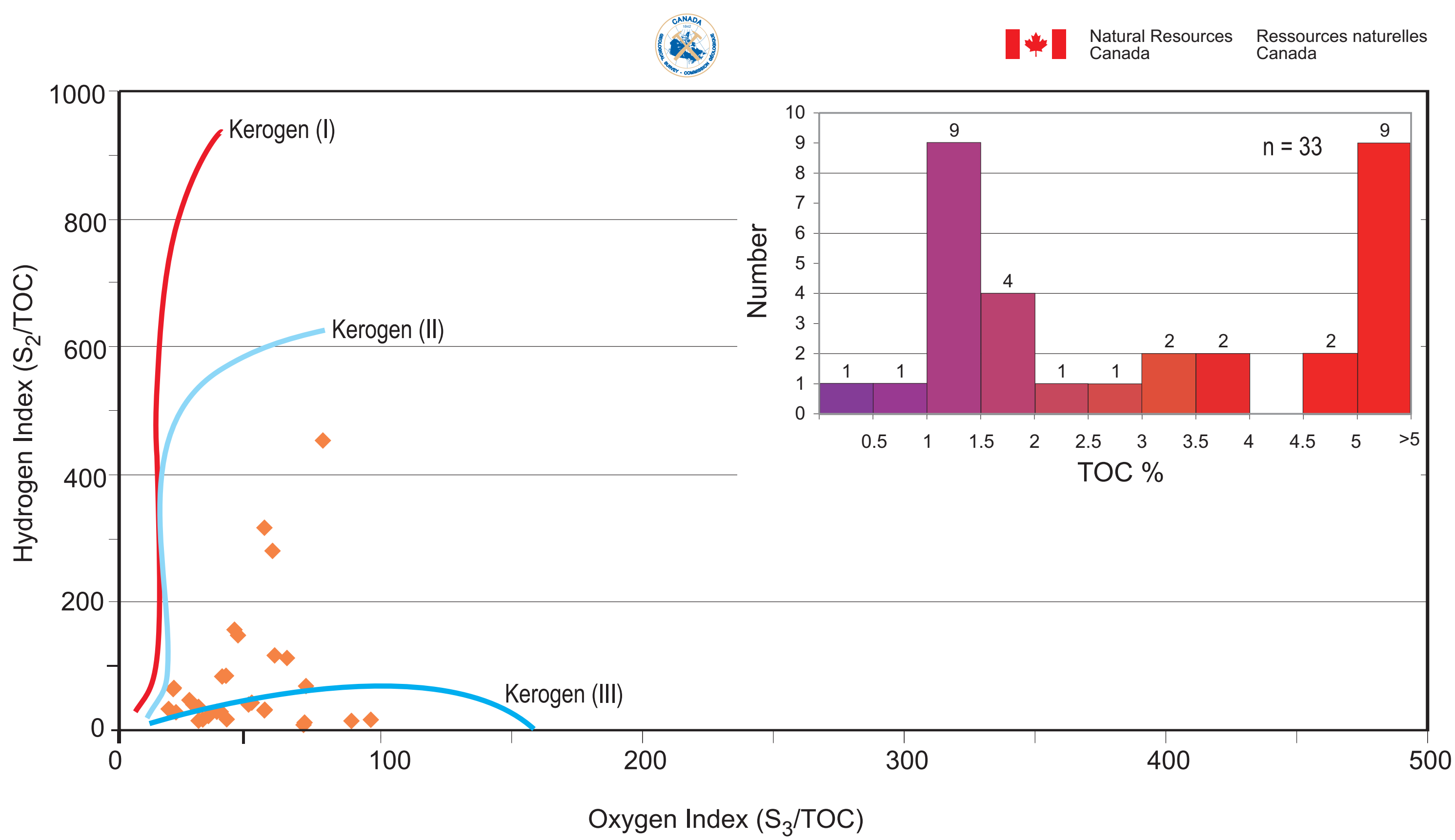


Late Cretaceous Kanguk succession



Early-Late Cretaceous Hassel succession

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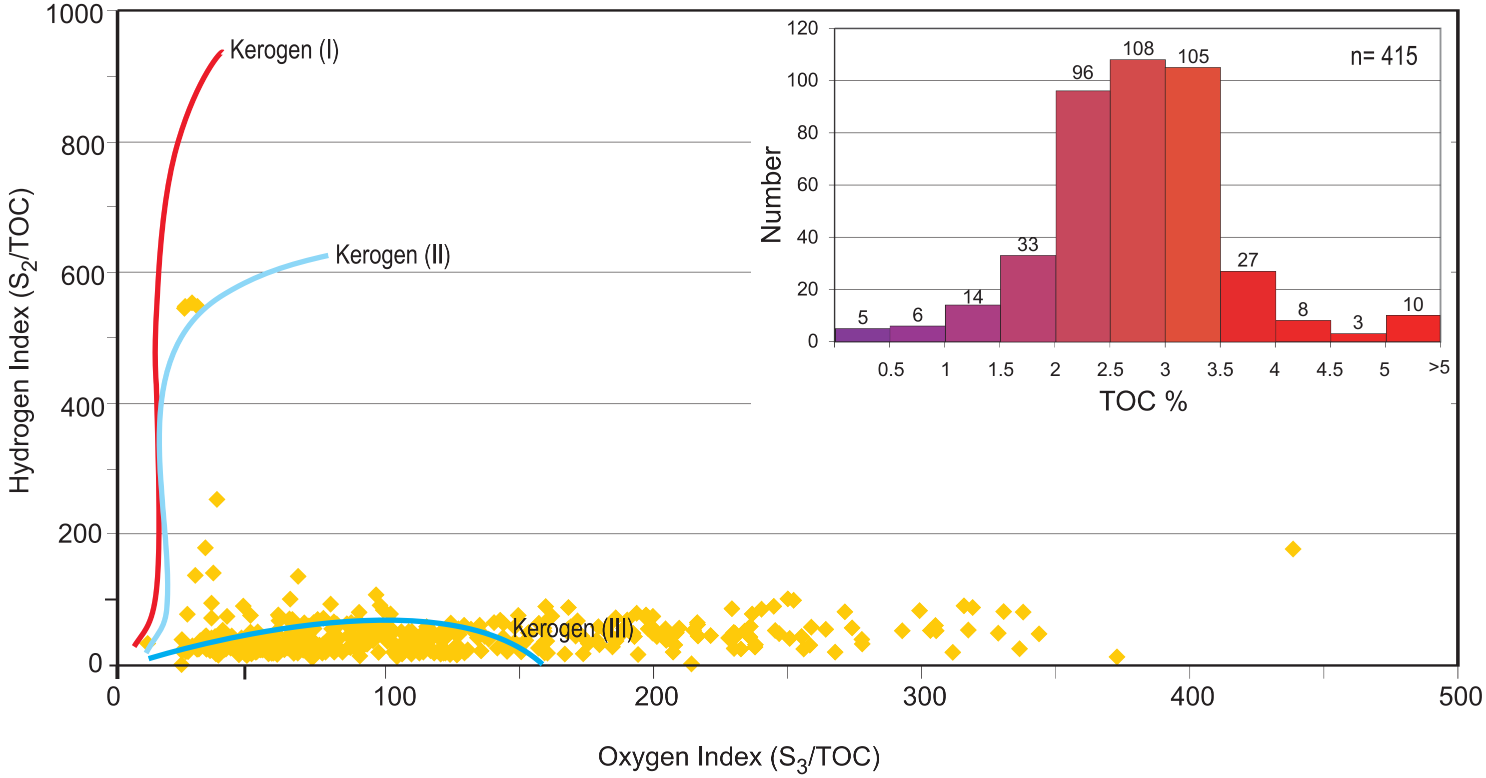
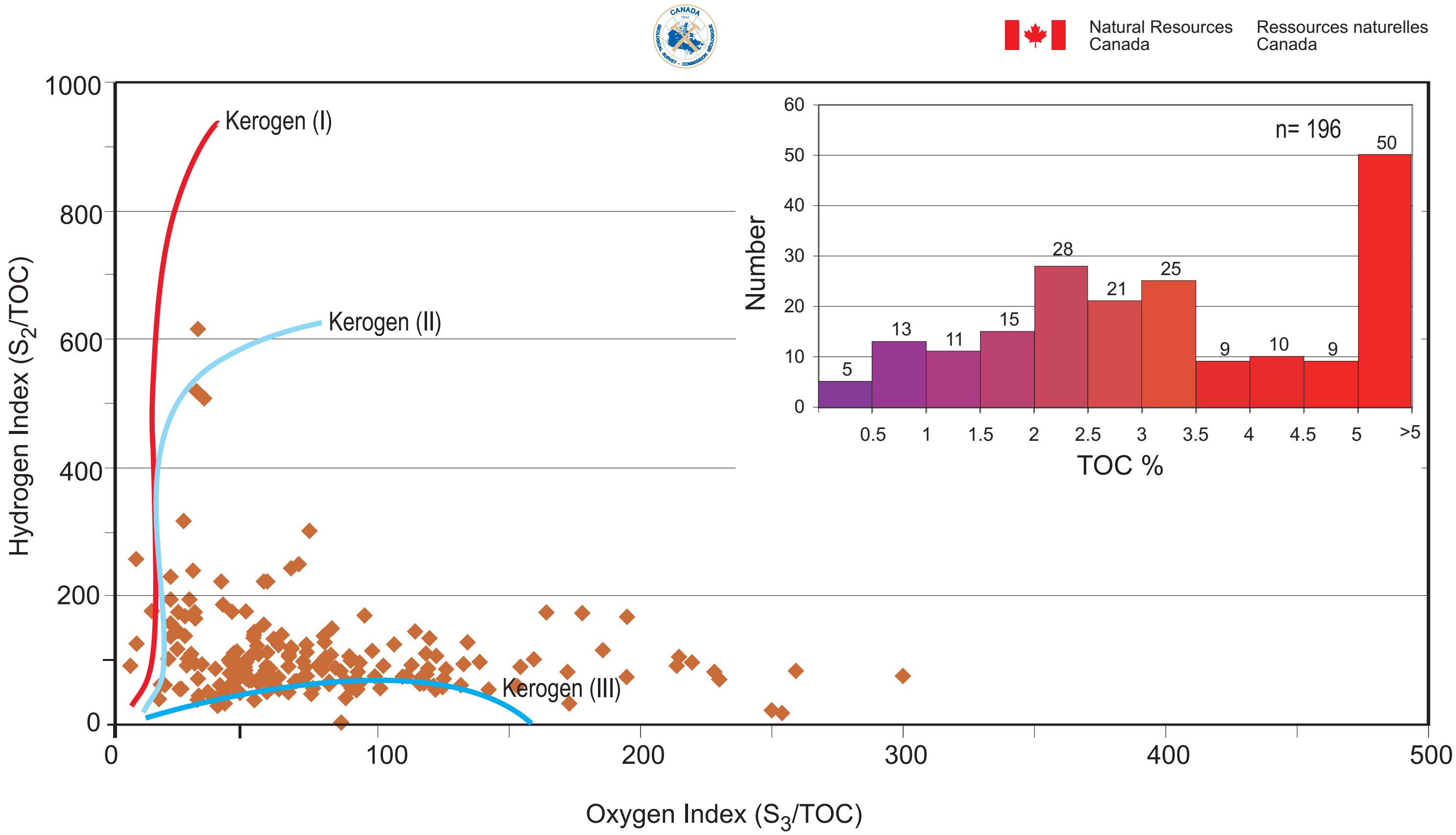
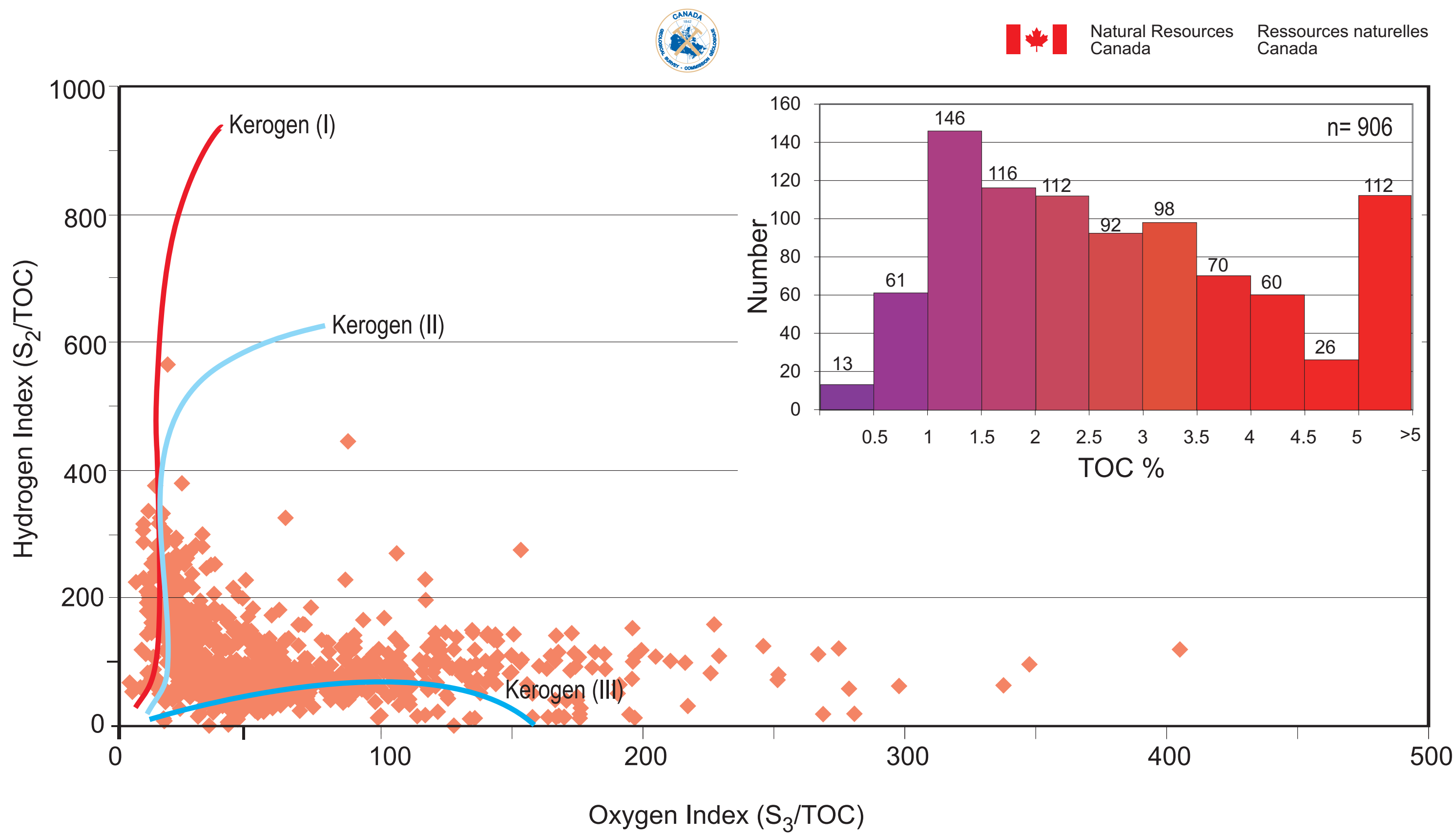


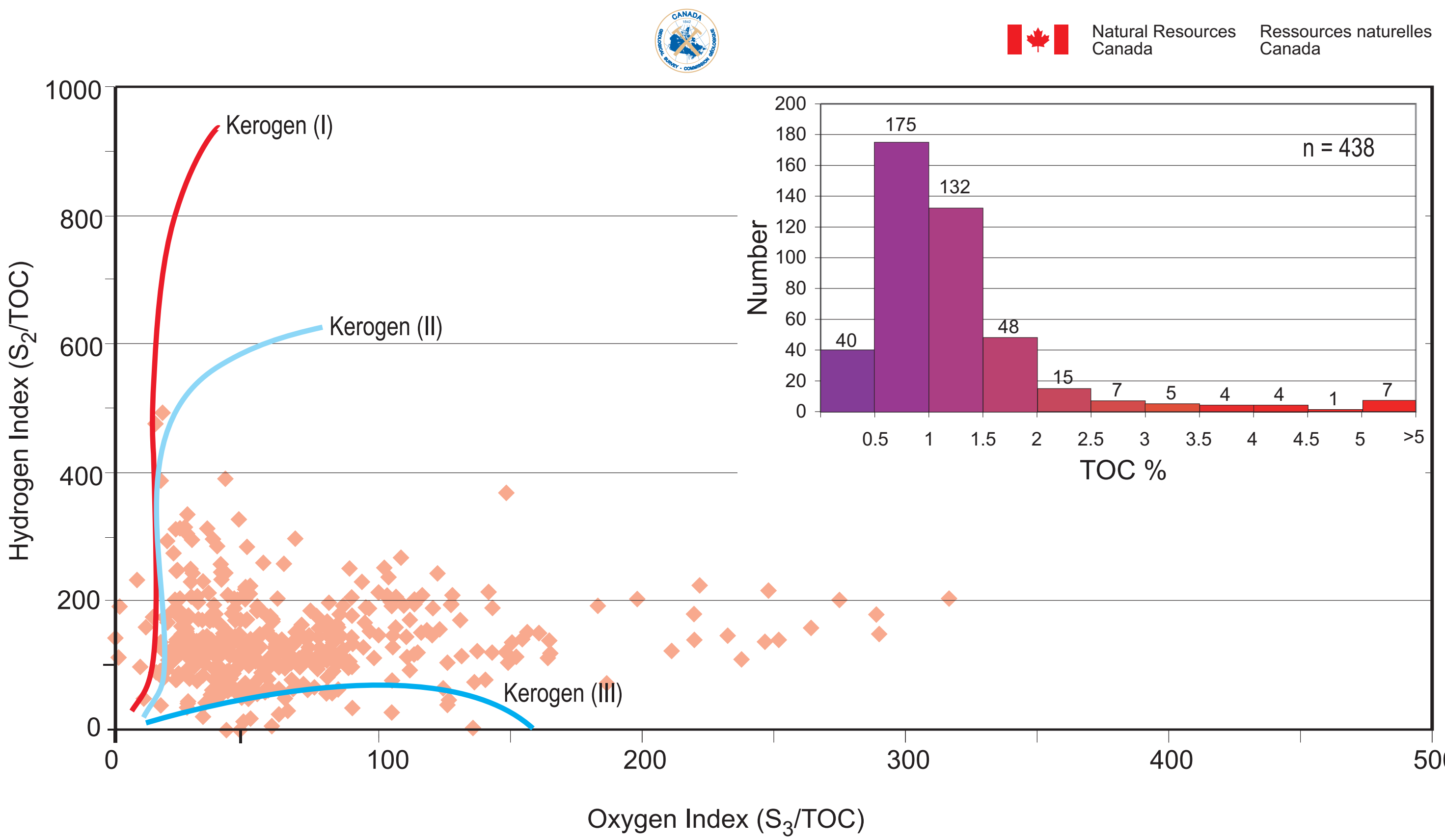
Early Cretaceous Christopher succession



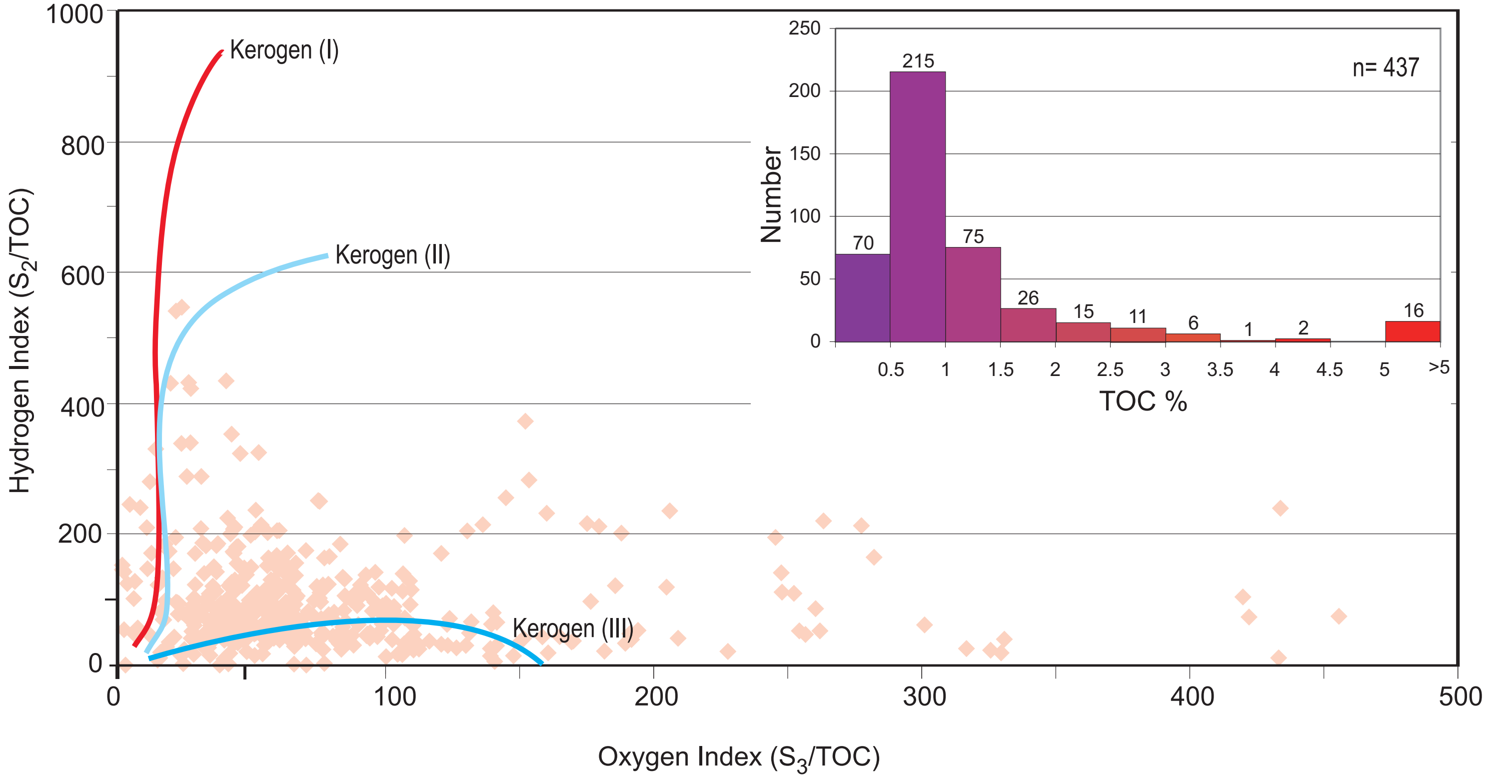
Early Cretaceous Isachsen succession



Mid-Late Jurassic McConnell Island-Rignes-Deer Bay succession



Early-Mid Jurassic Jameson Bay succession



Late Triassic-Early Jurassic Barrow-Heiberg succession

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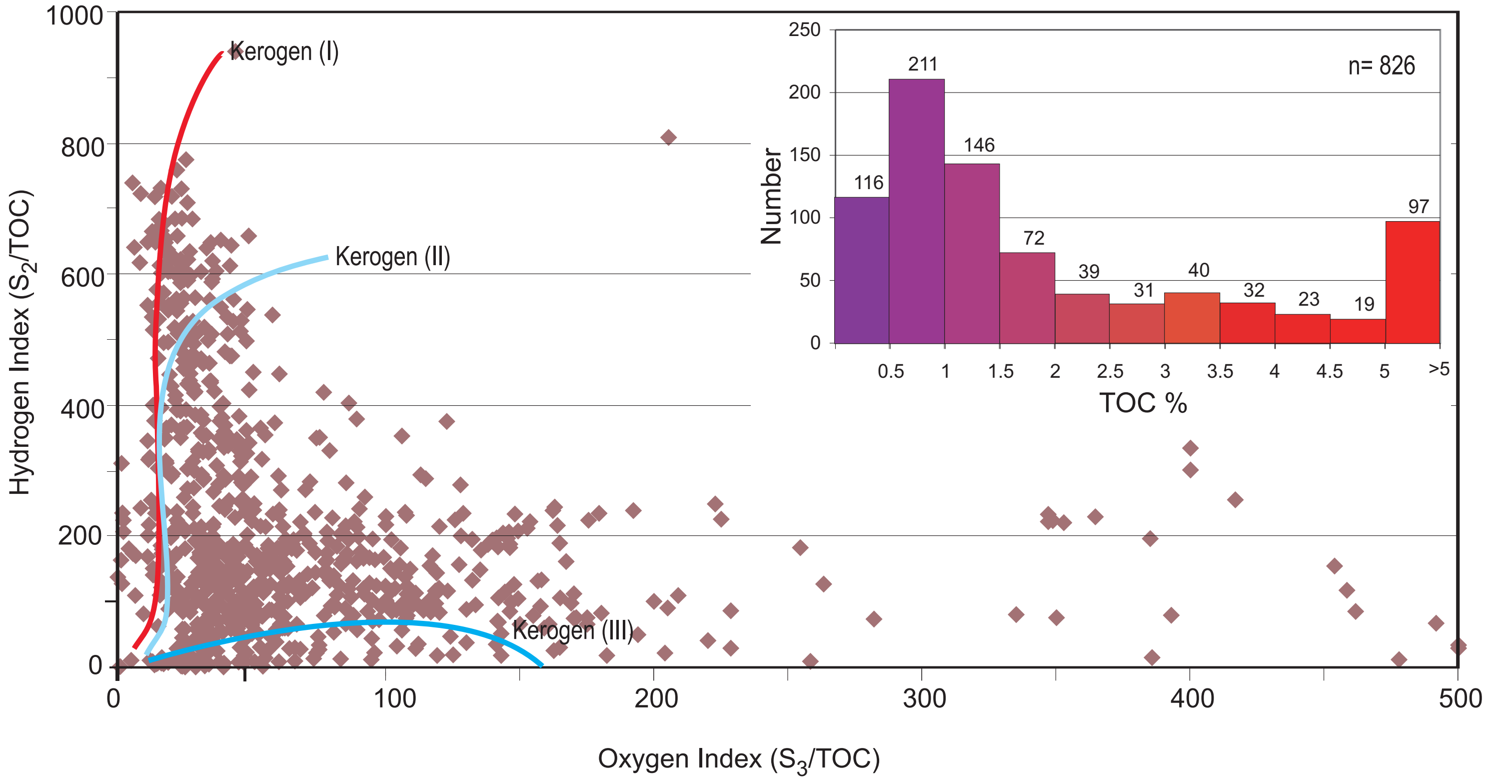

Mid to Late Triassic Schei Point Group

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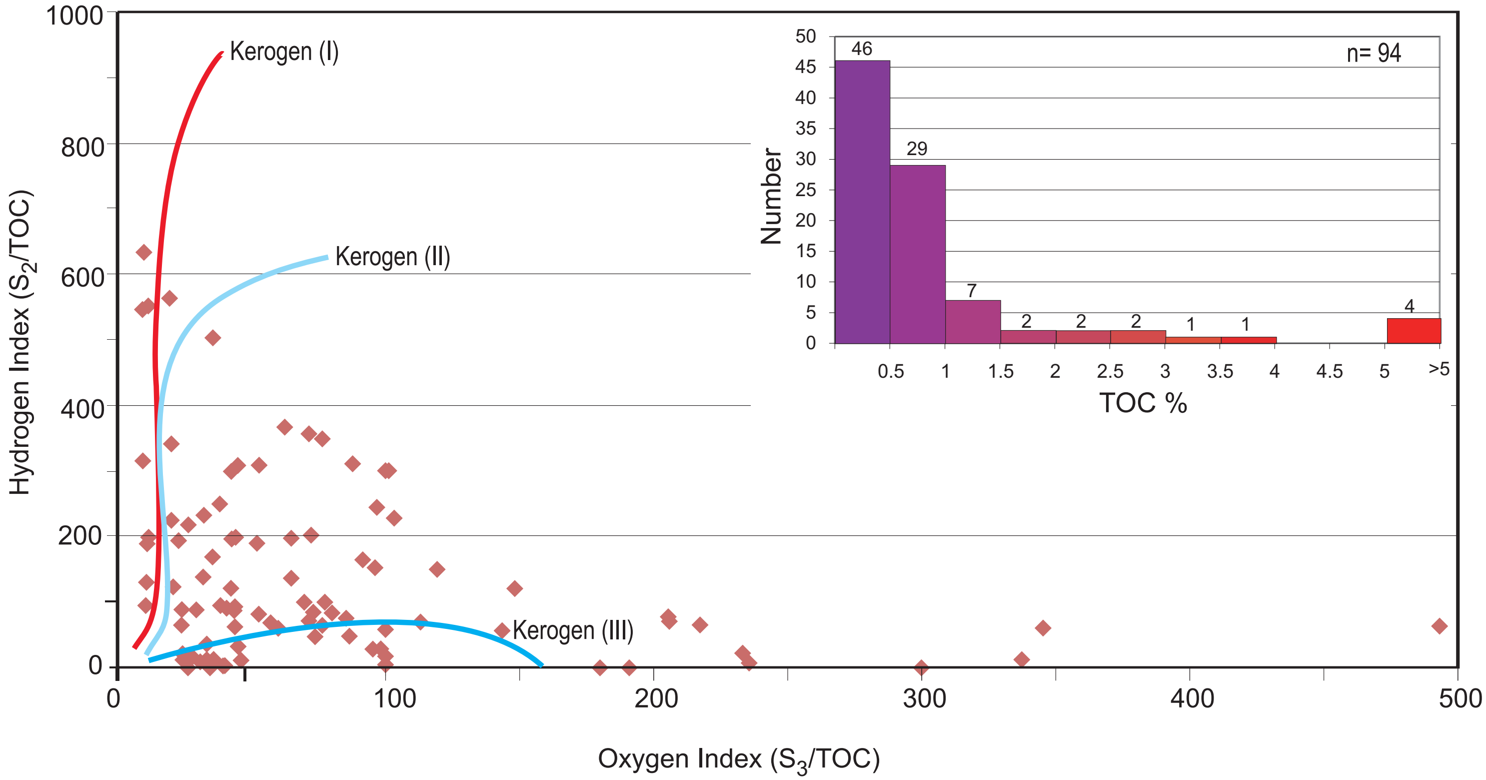
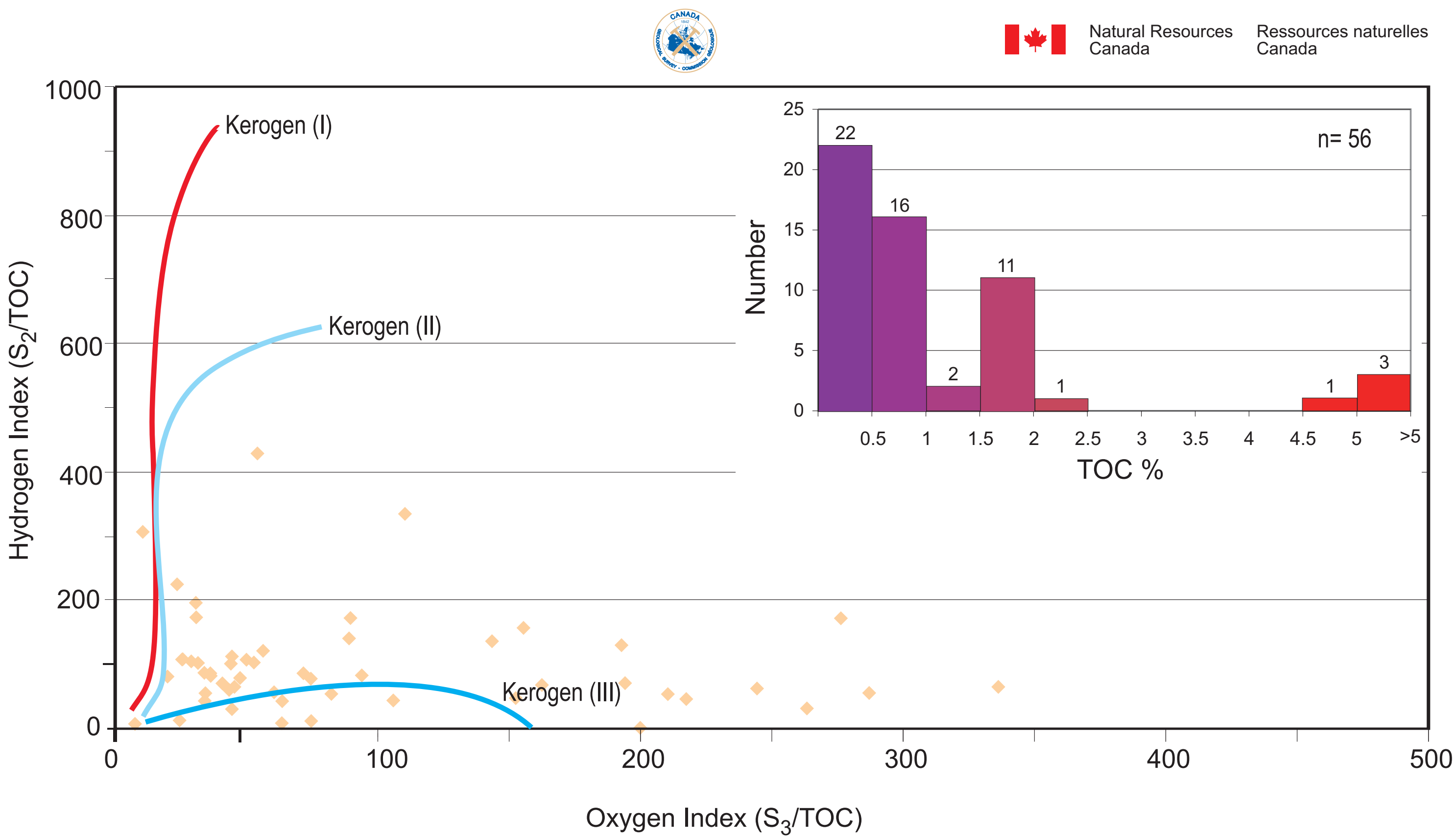
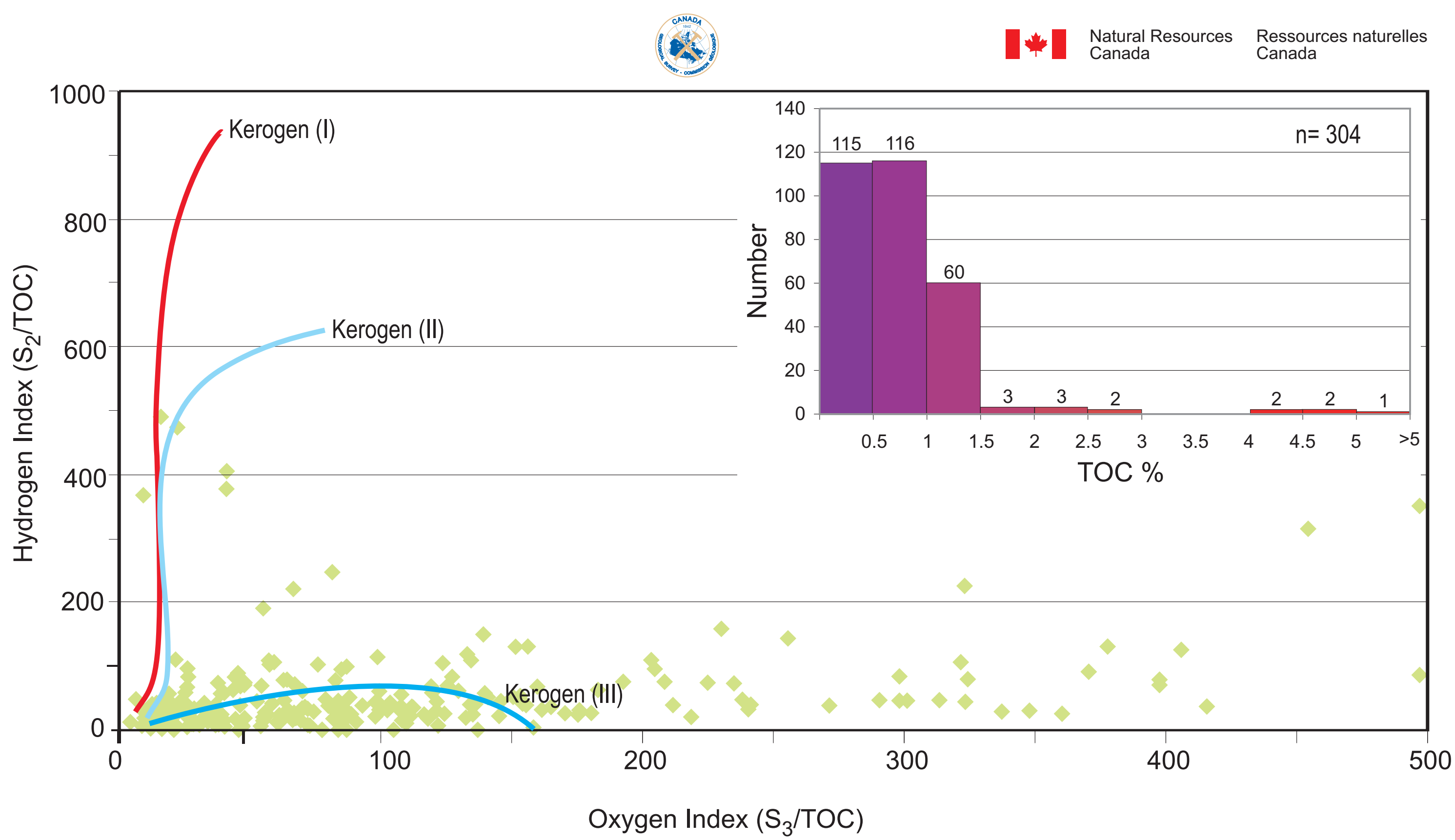


Early Triassic Blind Fiord-Bjorne succession



Carboniferous-Permian clastic succession



Carboniferous-Permian basinal carbonate succession

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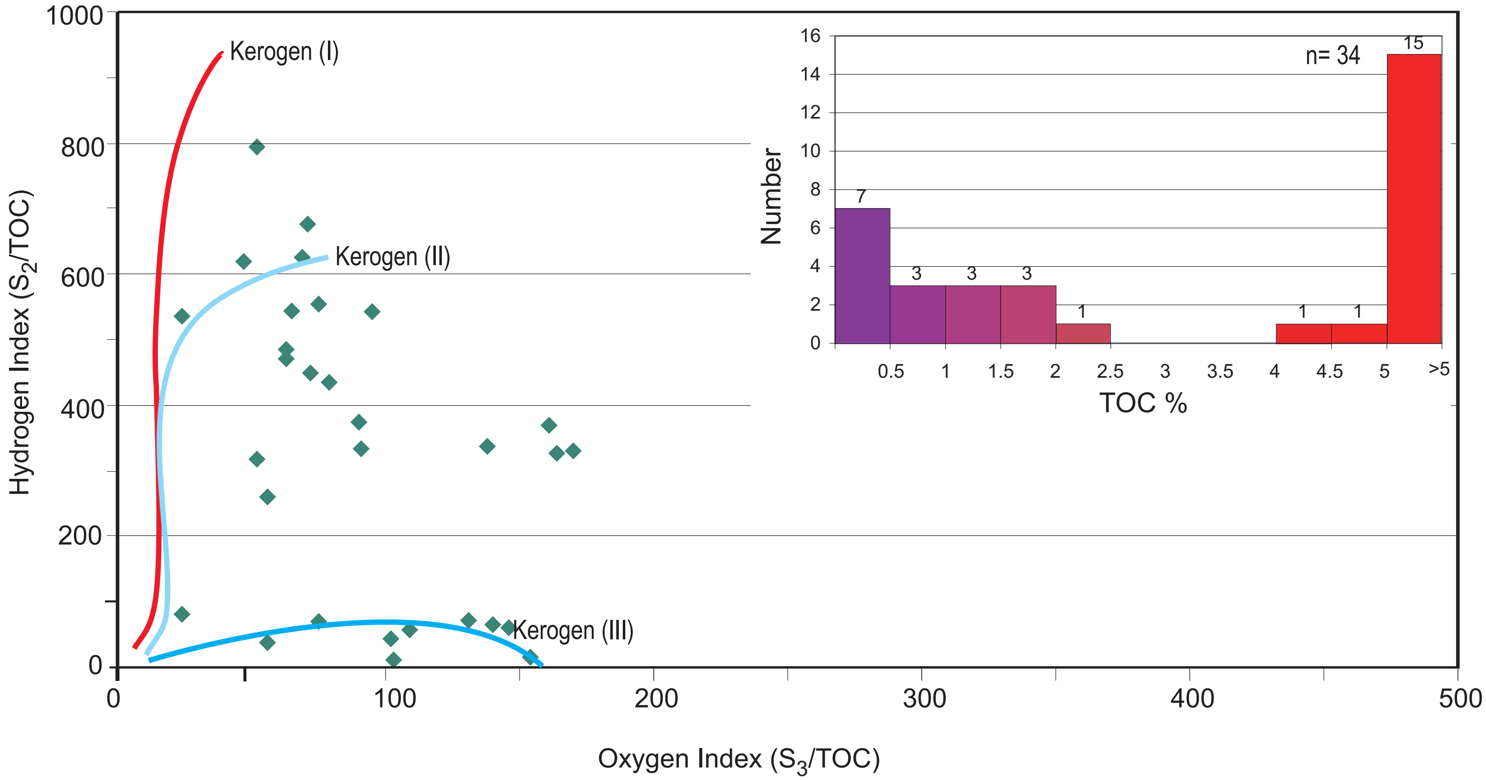
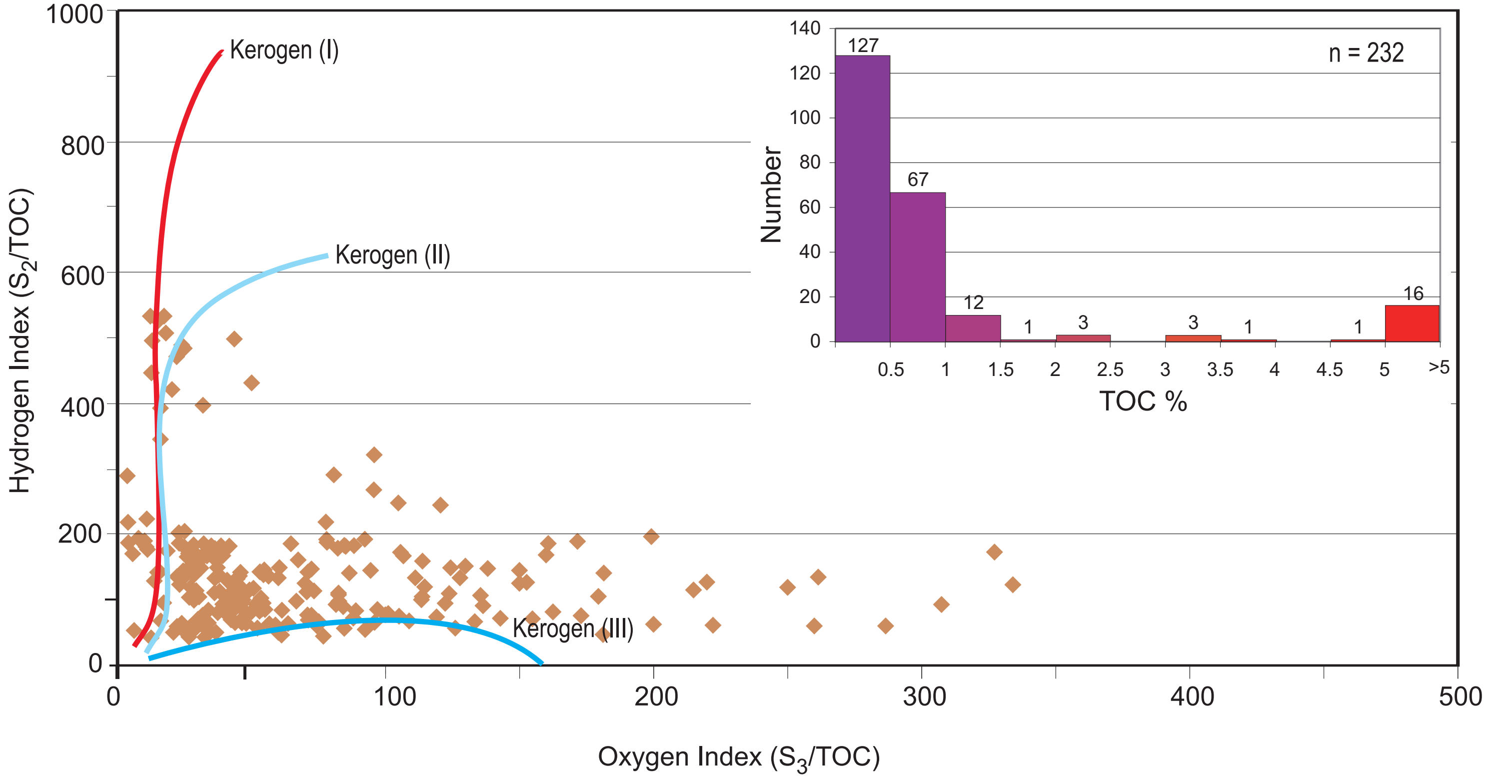
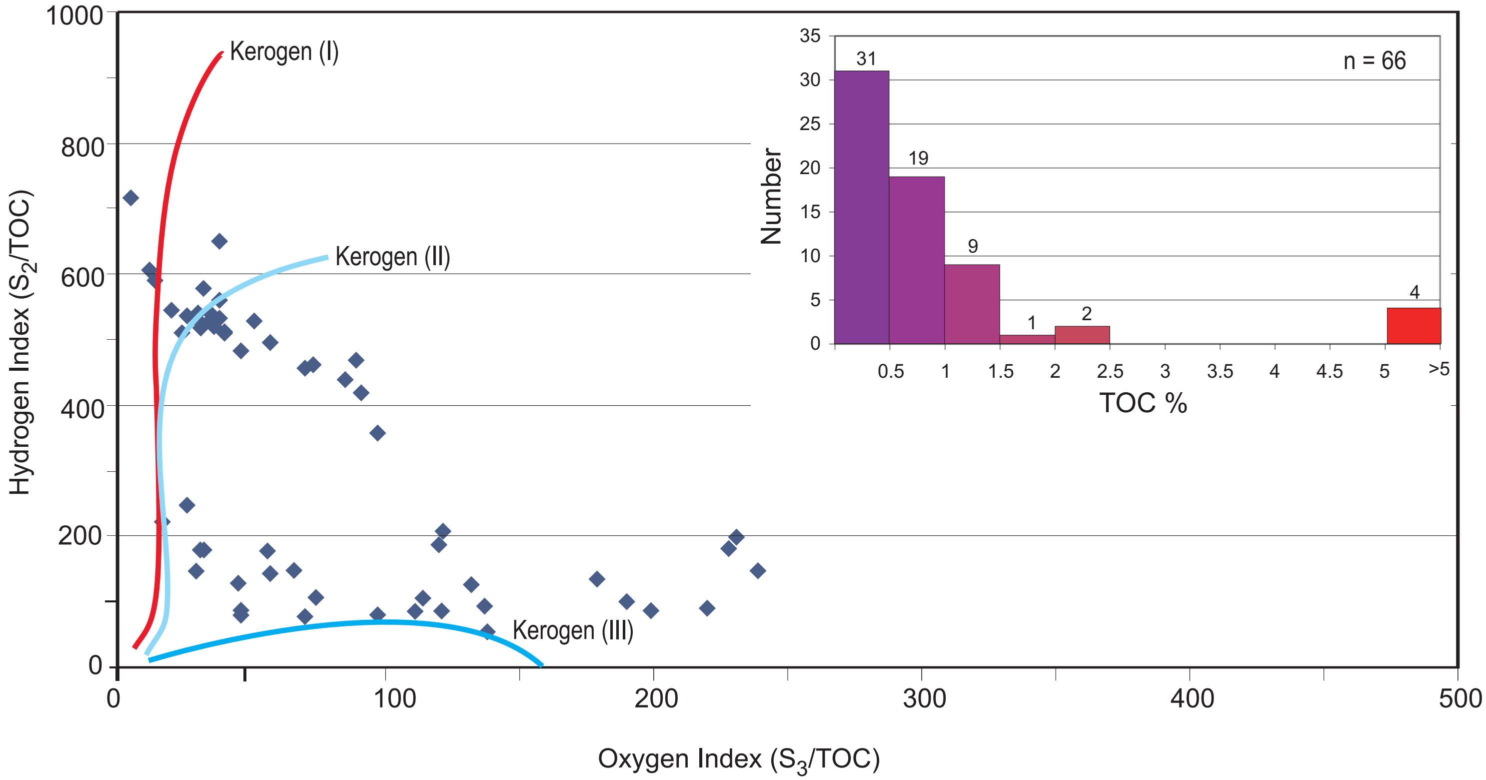


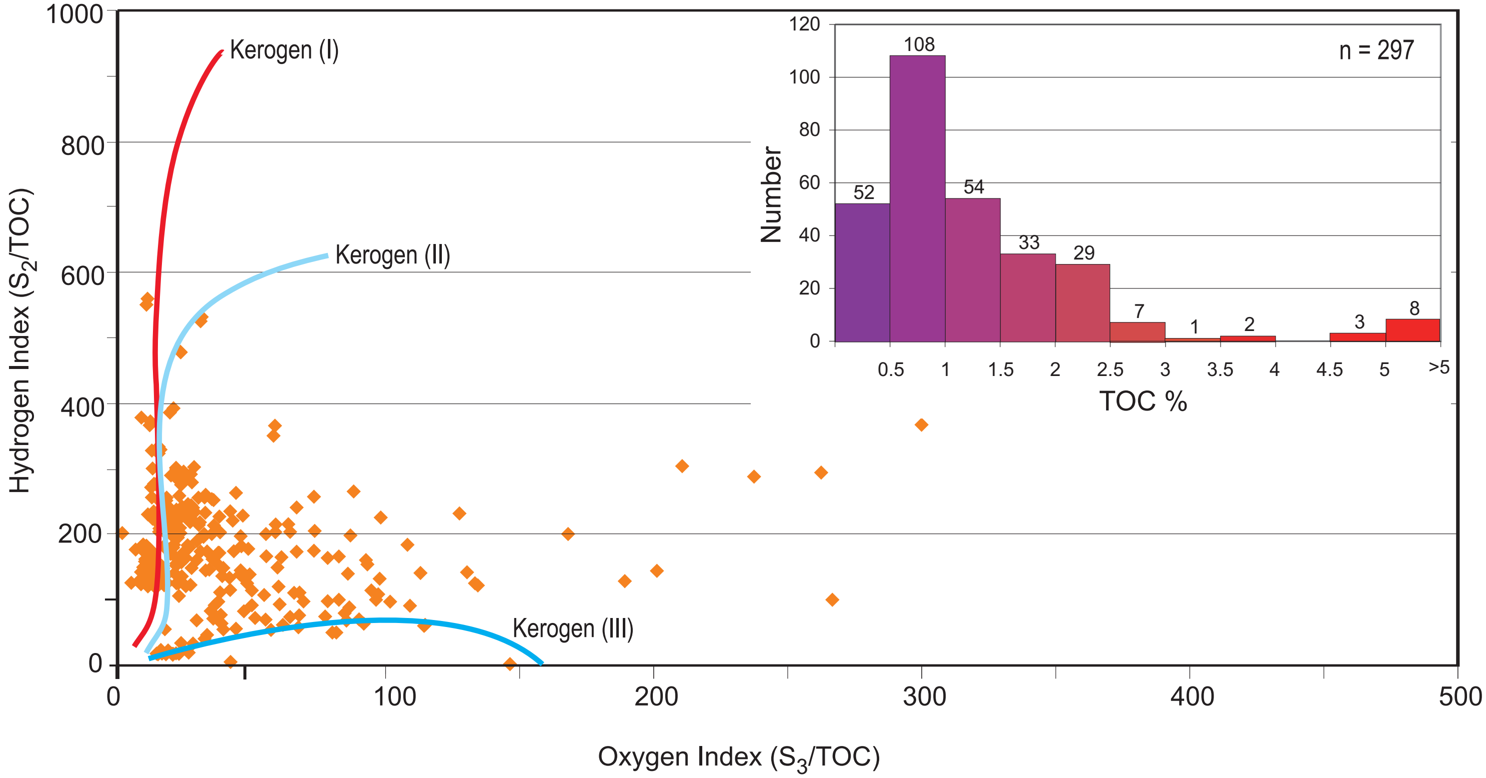
Carboniferous lacustrine succession



Devonian clastic wedge



Devonian carbonate succession



Devonian Boothia-related succession

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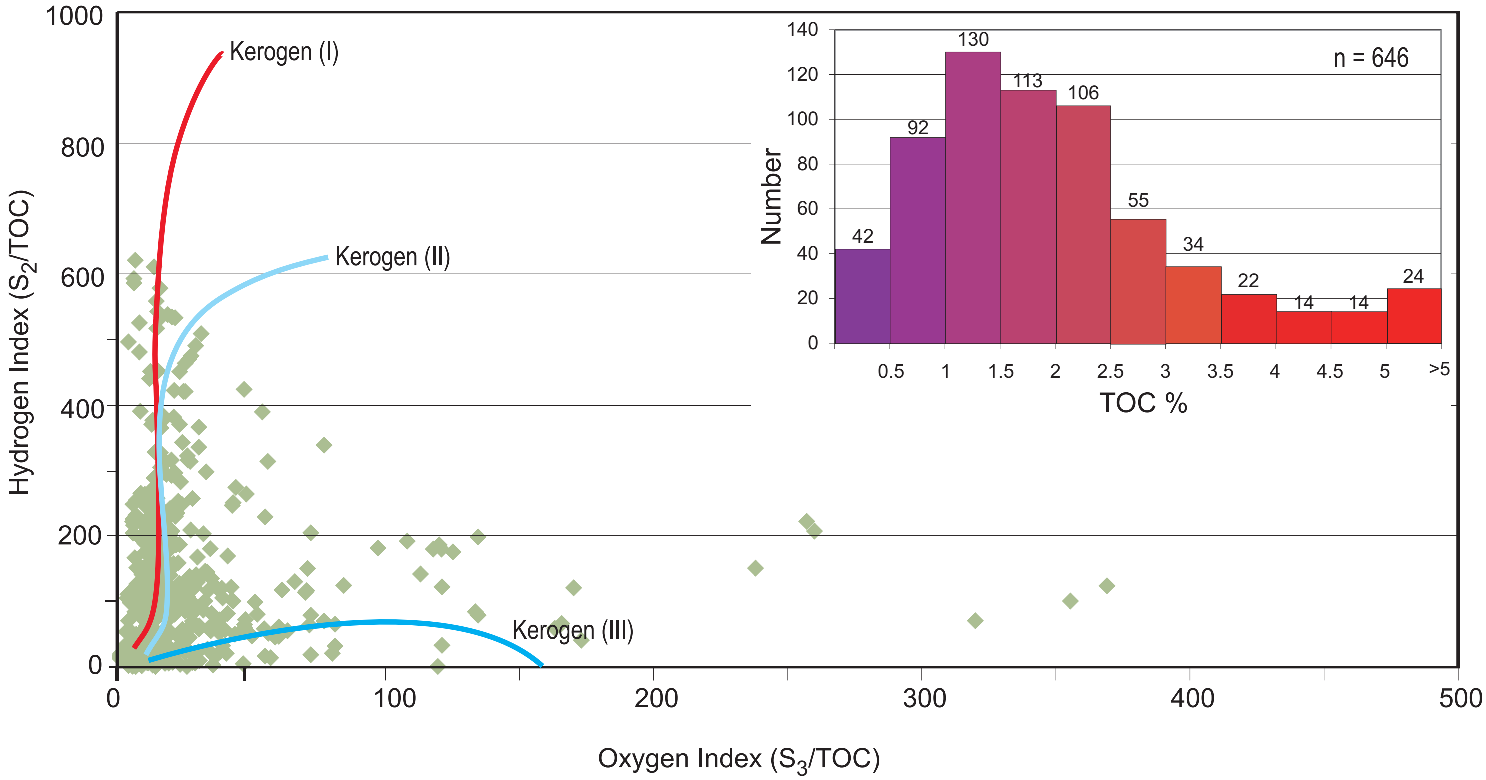

Silurian basinal succession

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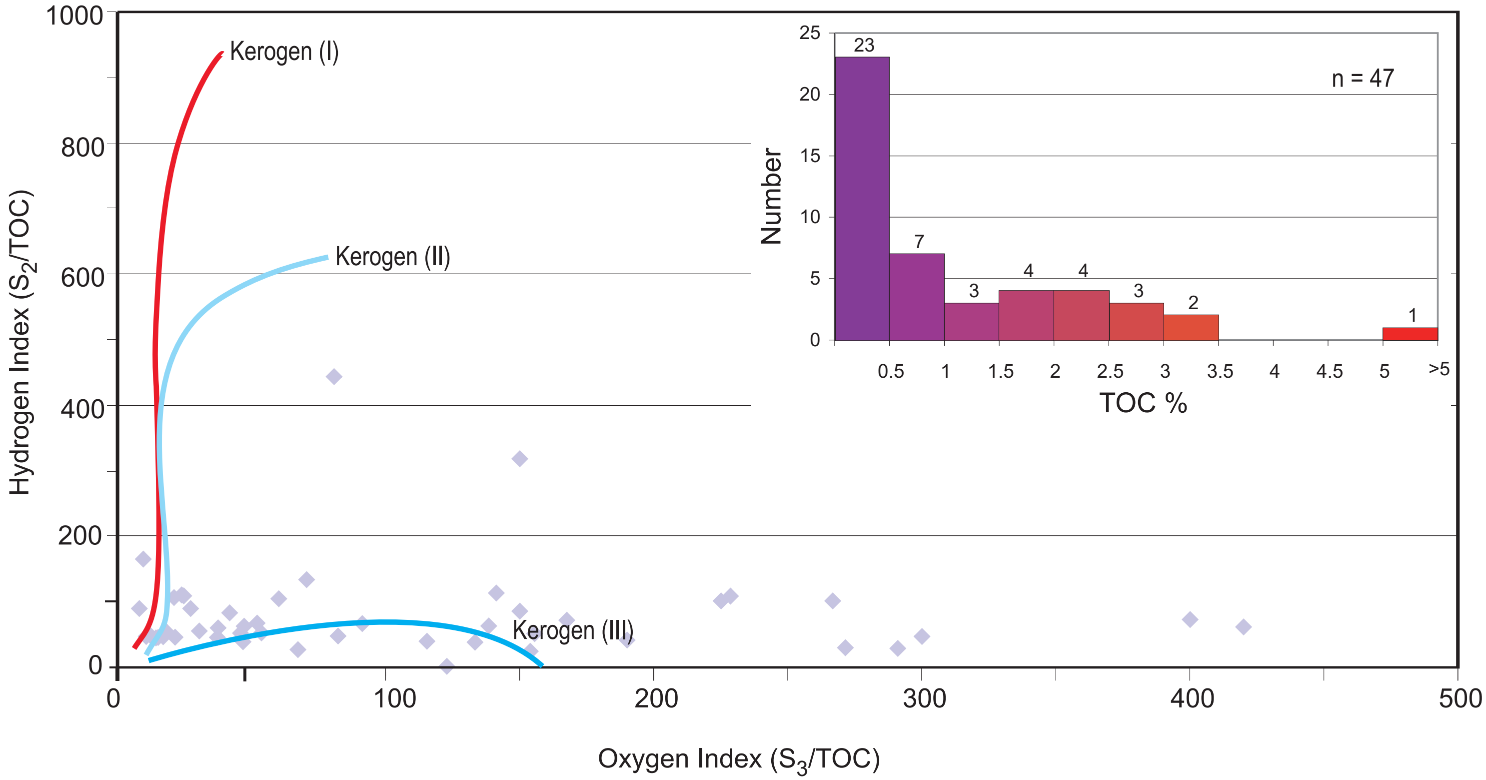

Silurian carbonate succession

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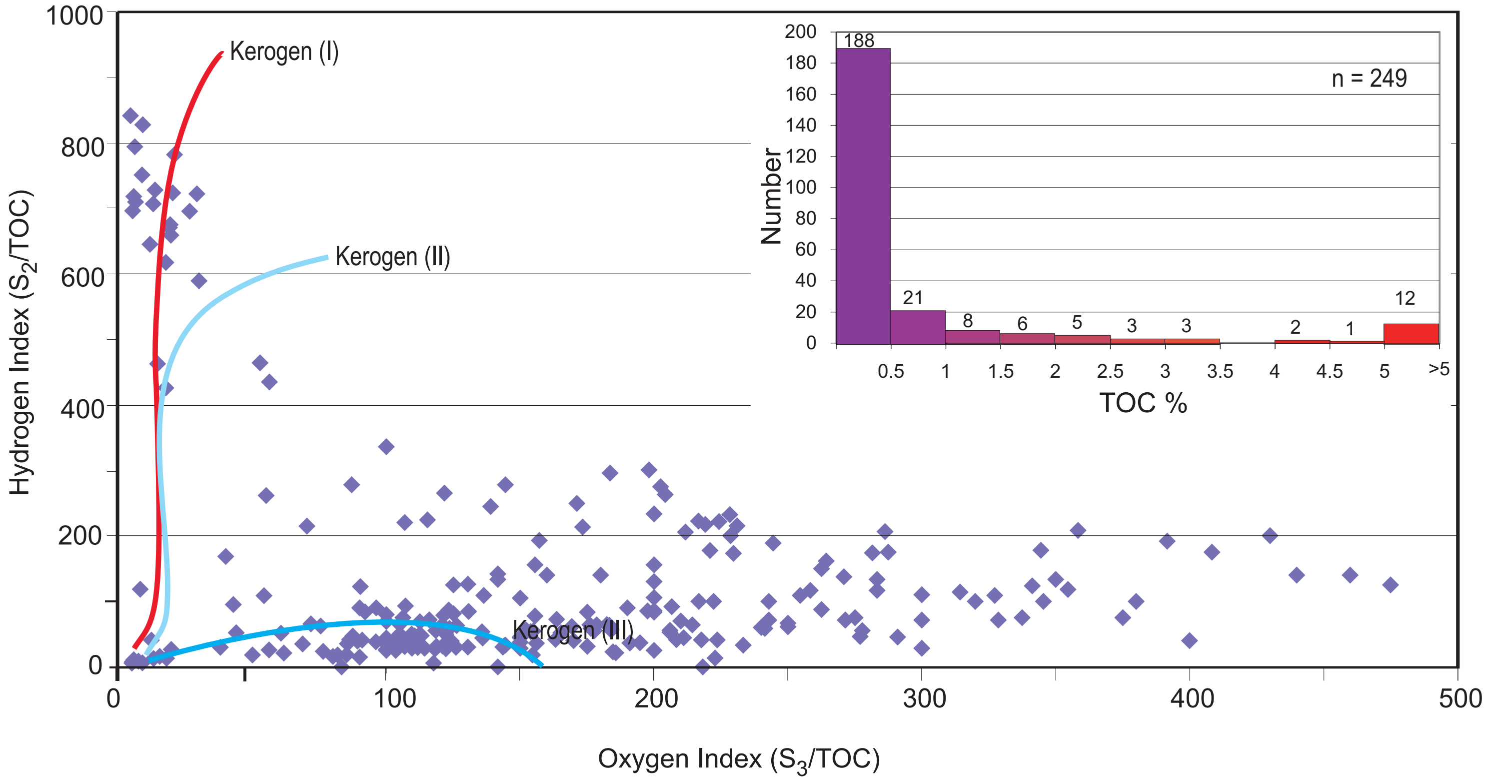

Cambrian-Ordovican carbonate succession