3D source-rock modelling of the Espirito Santo Basin, Brazil

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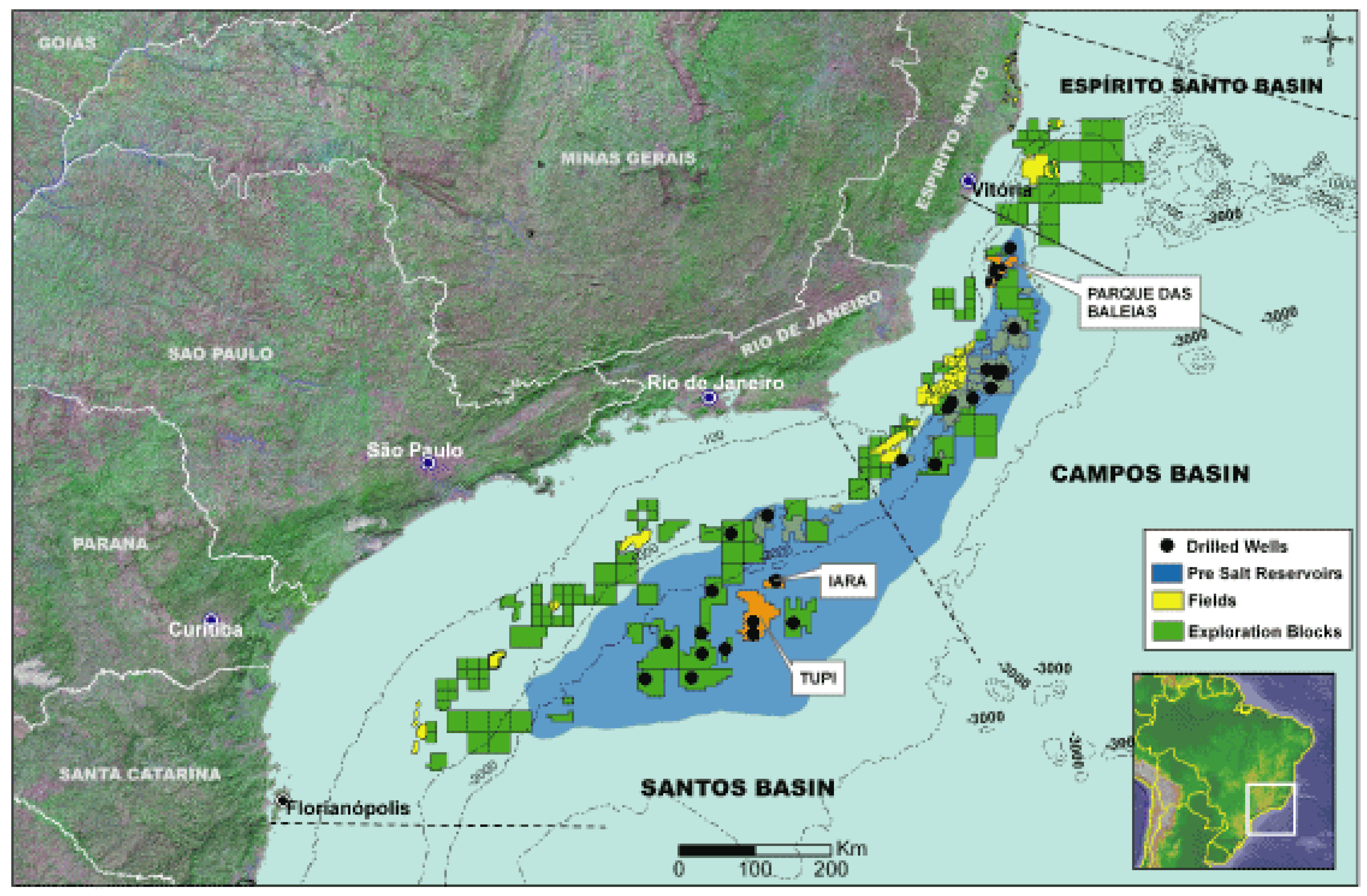
Introduction and background

Geological setting

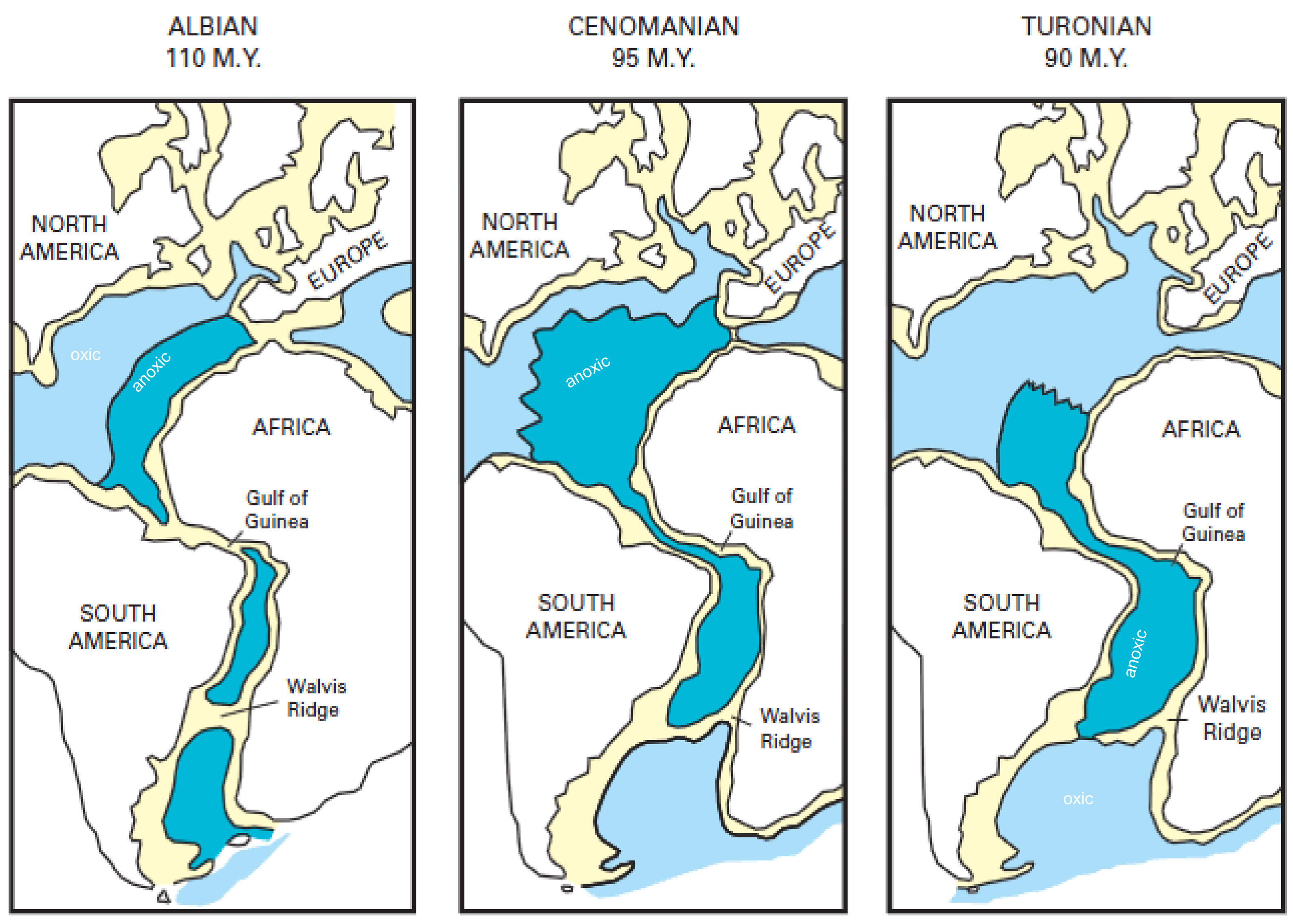
The study area covers a 110 km x 332 km offshore portion of the Espirito Santo Basin (see location map). The studied section consists of a transgressive sequence that drowned the Albian carbonate platform with deltaic and prodeltaic sediments and canyon-fill turbidite sandstones (Urucutuca Fm.).

This study examines to which extent the local canyon-fill turbidite sediments overprint the possible influence of the Cenomanian/ Turonian Anoxic Event on the source rock properties of Top Albian to Top Turonian (99.0 – 89.0 Ma) sediments.

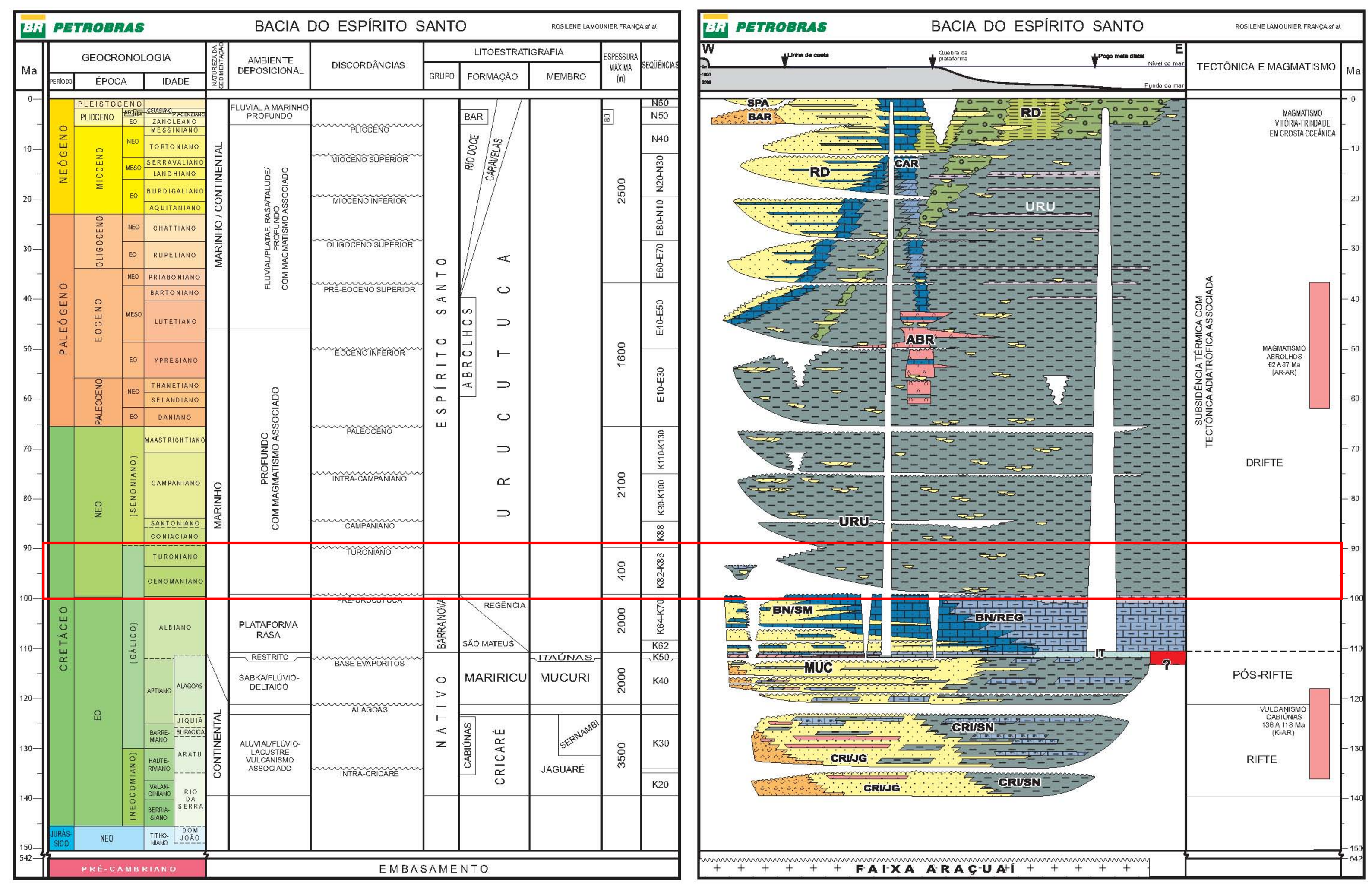
The process-based modelling software OF-Mod 3D - Organic Facies Modelling (Mann and Zweigel, 2008) was used to model Total Organic Carbon (TOC) and Hydrogen Index (HI) distribution throughout the area during the Cenomomanian -Turonian interval.



Location map of the Espirito Santo Basin.



Palaeogeographic maps of the Cretaceous breakup of South America and Africa showing the extent of anoxia in this region. From U.S.Geological Survey Bulletin 2207-C, 2006 (after Tissot et al., 1980).



Stratigraphic chart of the Espirito Santo Basin (Franca et al., 2007)

Geochemical information available from wells:

Three key wells were selected for comparison between measured and modelled results. These wells were chosen because of

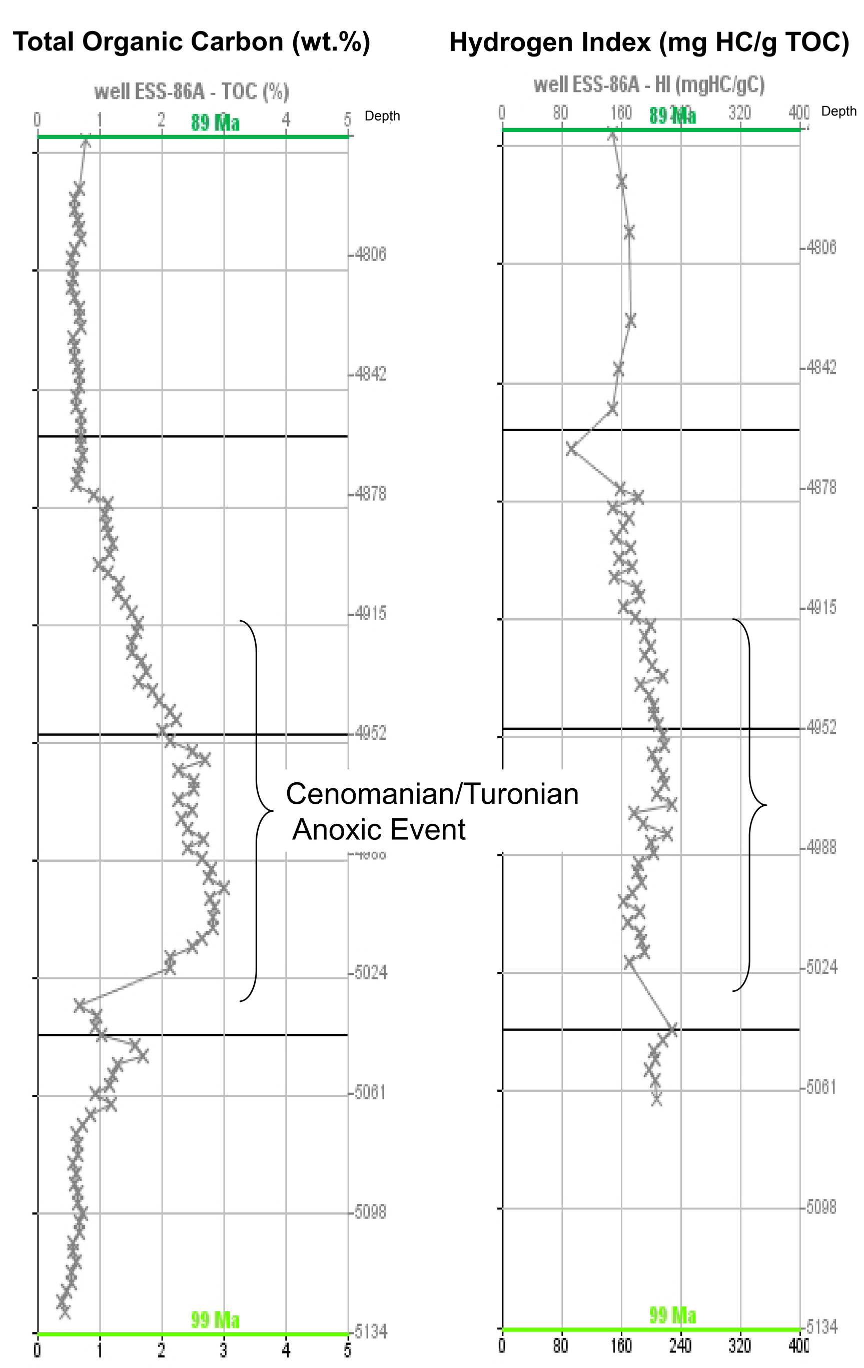
(1) their geographical position within the investigated area and

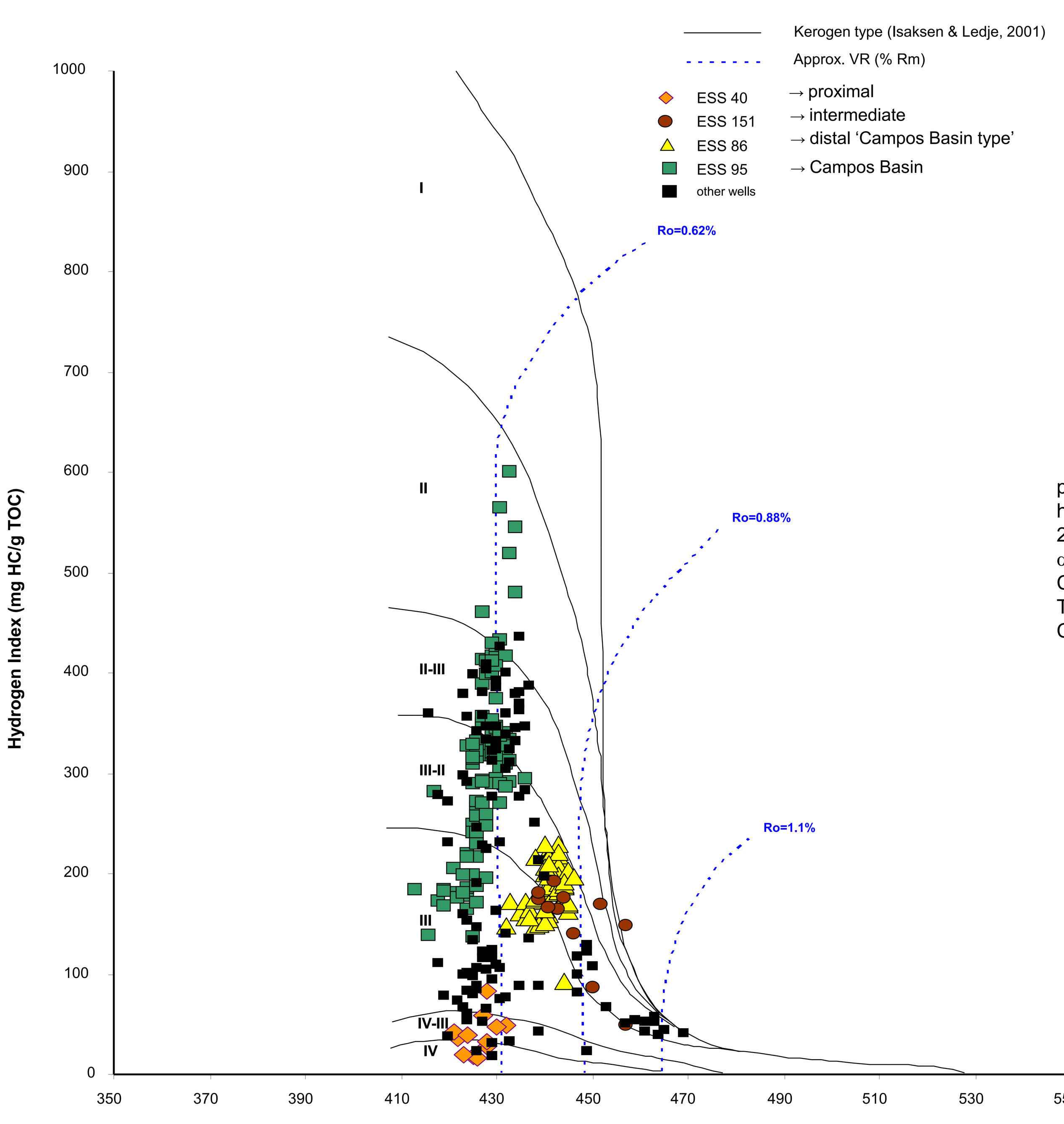
(2) data density including biomarker data.

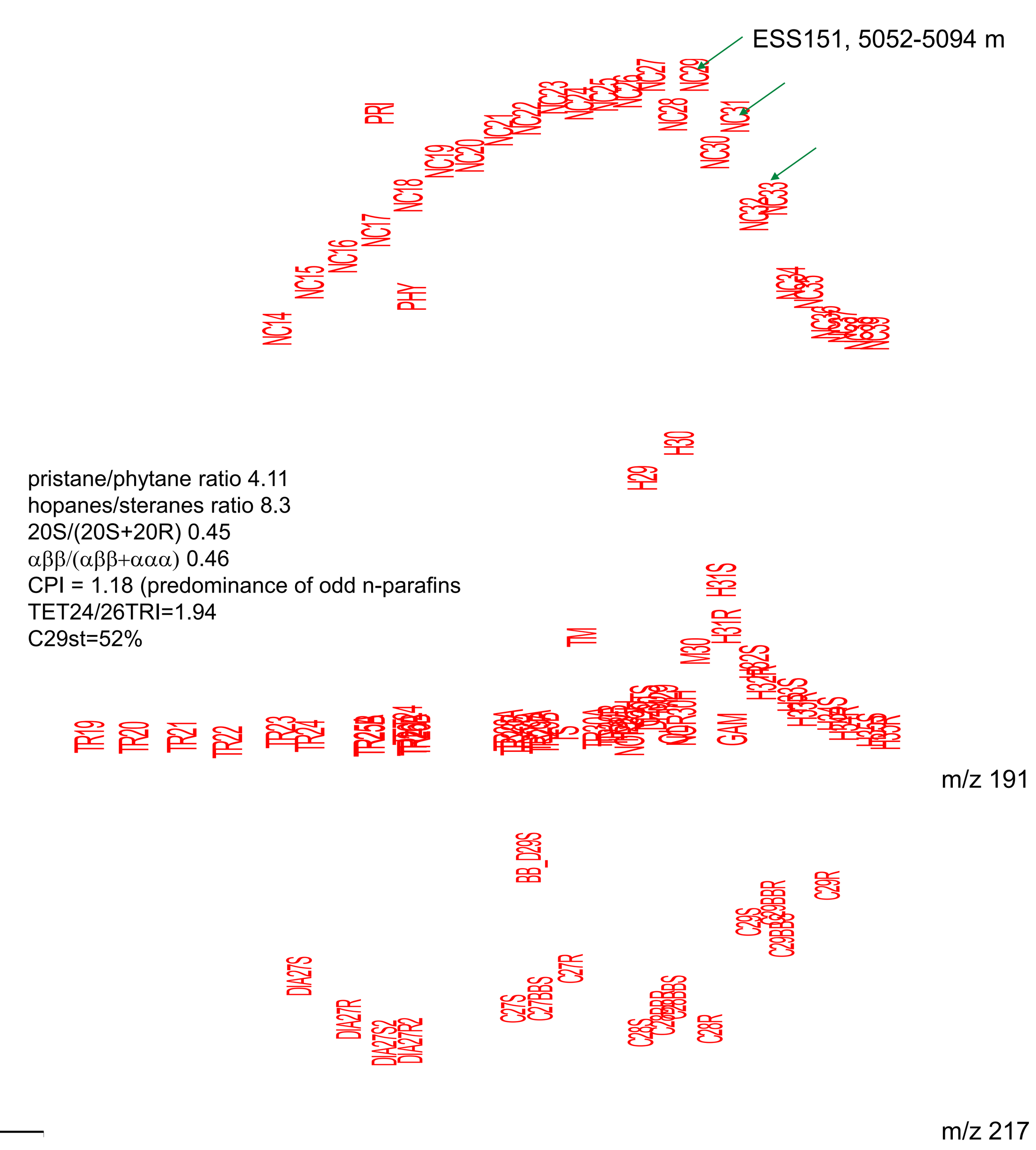
- ESS-40 - proximal, influenced by river input,
- ESS-151 - intermediate distance from shore,
- ESS-86A - distal, “Campos Basin type”.

The data show:

- Distinct terrestrial input in all wells including ESS-86A ‘Campos Basin type’
- Terrestrial organic matter confirmed by biomarkers: high hopanes/steranes ratio; high C_{29} steranes > 45 % and saturated hydrocarbons dominated by long-chain *n*-alkanes (e.g. ESS-151 well)
- ESS-86 well (distal, Campos Basin type) shows the signature of the C/T anoxic event, higher TOC but only slightly higher HI







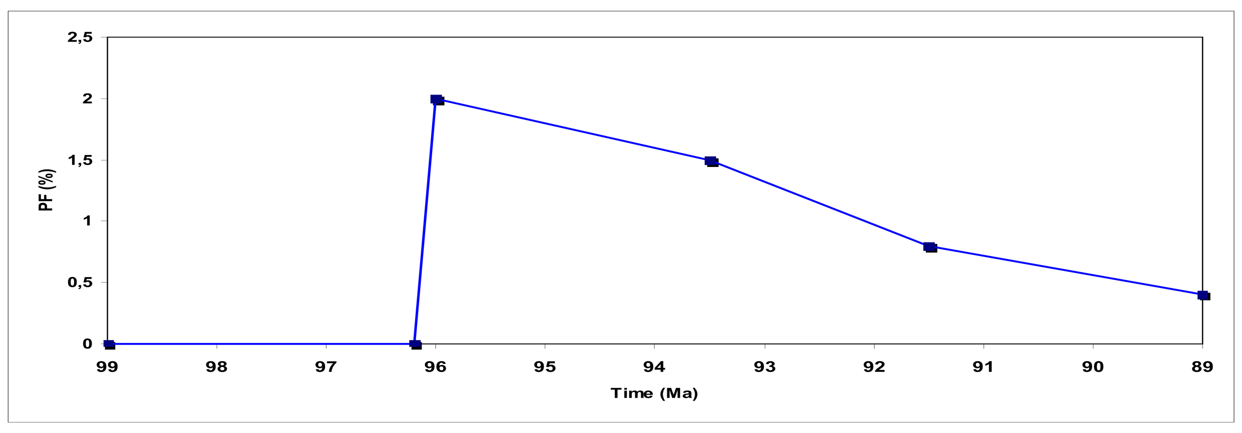
Source rock modelling

The organic input into OF-Mod:

Primary productivity – defined in OF-Mod as a function of distance from shore:

- **PP at the coast:** 10 $gC/(m^2a)$ to reflect high energy environment, low export production out of the photic/shallow water zone, and transport of deposited organic material away from shore
- **PP in the open ocean:** 60 $gC/(m^2a)$

Preservation variable with time:



- (Deep water) preservation in the model is increased during the time period of the CTAE, to reflect the reduced oxygen conditions to a max. PF of 2% (Bralower & Thierstein, 1984).

Organic Matter Properties:

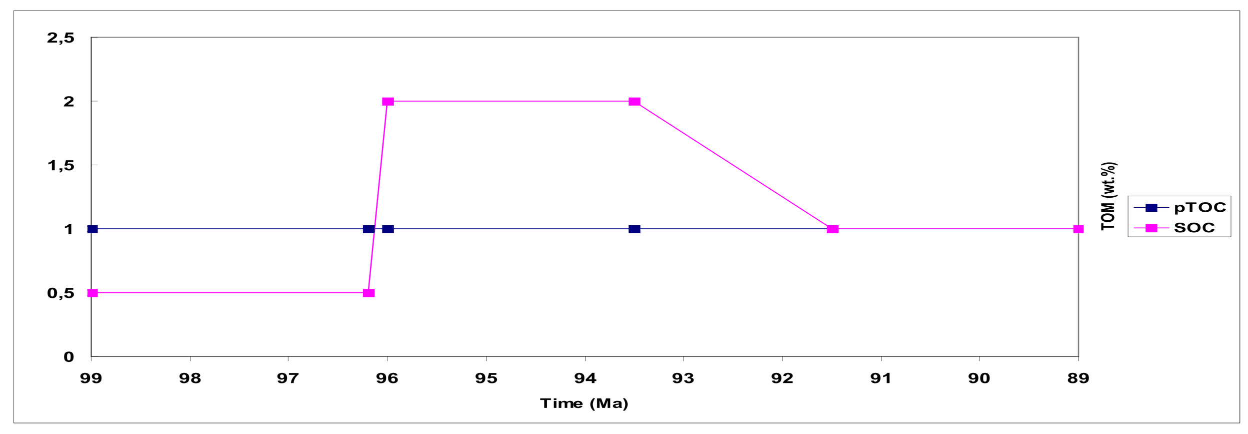
OF-Mod calculates the HI from the amount of marine, terrestrial and residual organic matter

HI MOC: 550 (mg HC/gTOC)

HI pTOM: 80 (mg HC/g TOC)

HI SOM: 20 (mg HC/g TOC)

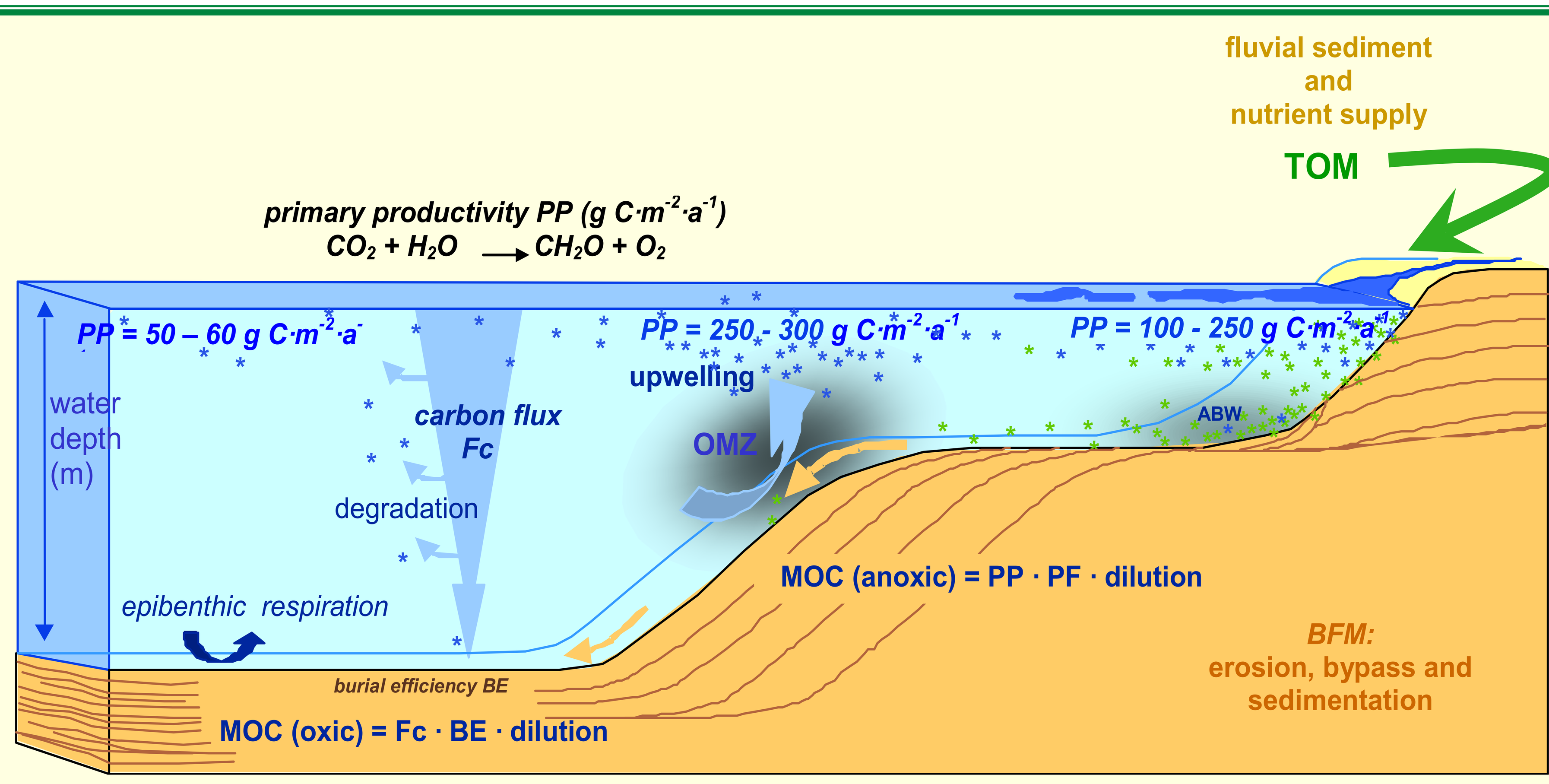
Terrestrial Organic Matter:



- pTOC constant over time
- High content of residual organic matter (SOC) - the highest value in anoxia period (93.5 – 96Ma)

OF-Mod considers

- basin-fill stratigraphy
- organic carbon source fractions: marine/autochthonous and terrestrial/allochthonous
- degradation of the organic matter in the water column and burial efficiency at sea floor
- oxic and anoxic conditions
- calibrated with analytical data from well samples



Stratigraphic input into OF-Mod

Geometry

- Seismic depth maps: Top Albian (99Ma) and Top Turonian (89Ma)
- 110 x 332 km area of the Espirito Santo Basin

Age model

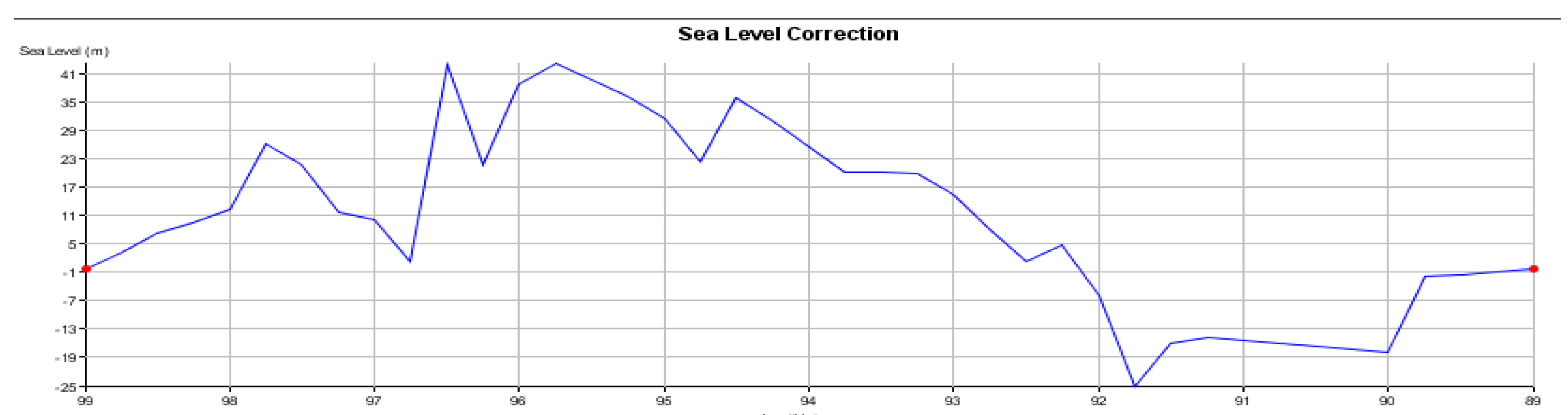
- Modelled interval: 99.0 – 89.0 Ma;
- 40 layers - i.e. 250 ky/layer on average

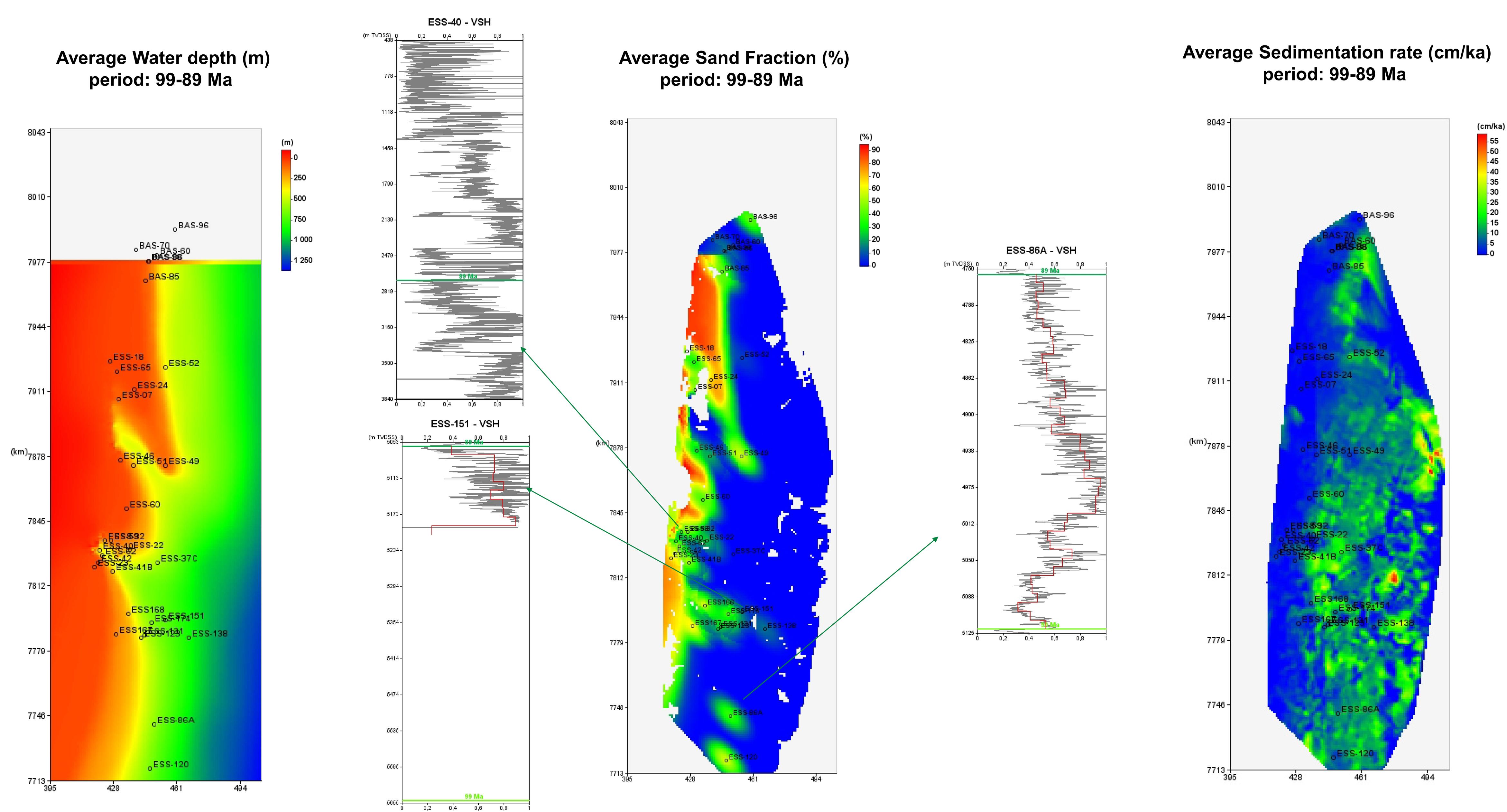
Reconstructed palaeowater depth

- top Turonian
- top Albian

Sea level:

- Eustatic sea level curve of Miller et al. (2005)





Sand fraction model created based on:

- V-shale logs data from 29 wells (V-shale calculated from gamma ray), and a background model based on the water depth
- Results in isolated sand patches, which are reminiscent of actual turbidite sands

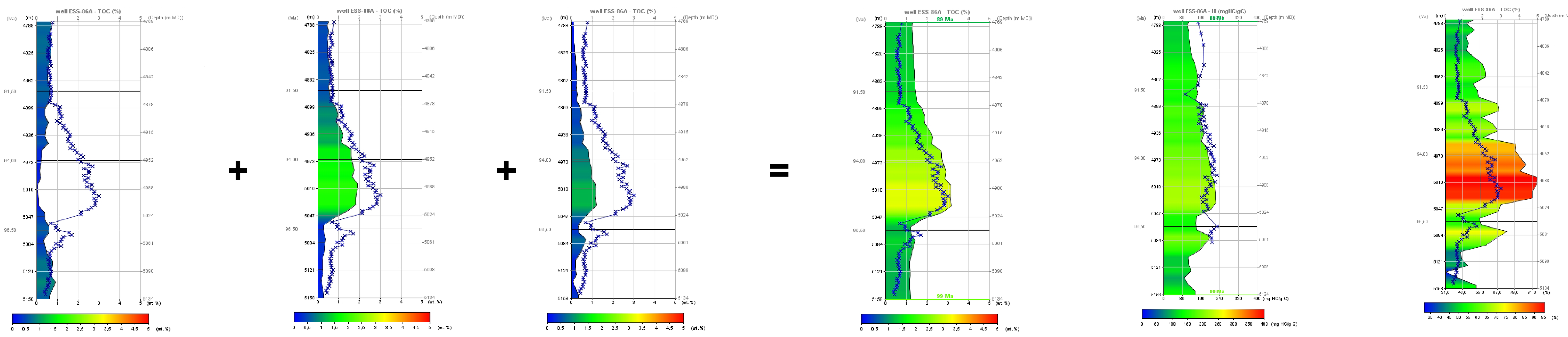
Results

Distal - Campos Basin type well:

Particulate Terrestrial Org. Carbon (wt.%) + Soil/Residual Org. Carbon (wt.%) + Marine Org. Carbon (wt.%) = Total Organic Carbon (wt.%)

Hydrogen Index (mg HC/g TOC)

Shale fraction (%)

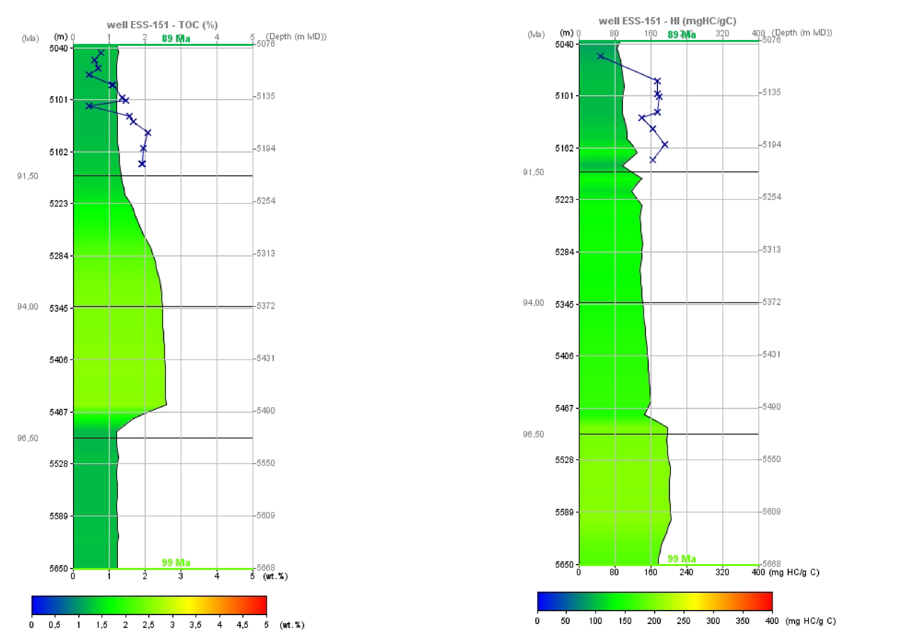


Modelled total, terrestrial, and marine organic carbon and hydrogen index for distal well (ESS-86A). The distinct increase of TOC in the depth range between 4900 and 5025 m is caused by increased preservation and higher shale content.

Intermediate distance from shore well:

Total Organic Carbon (wt.%)

Hydrogen Index (mg HC/g TOC)



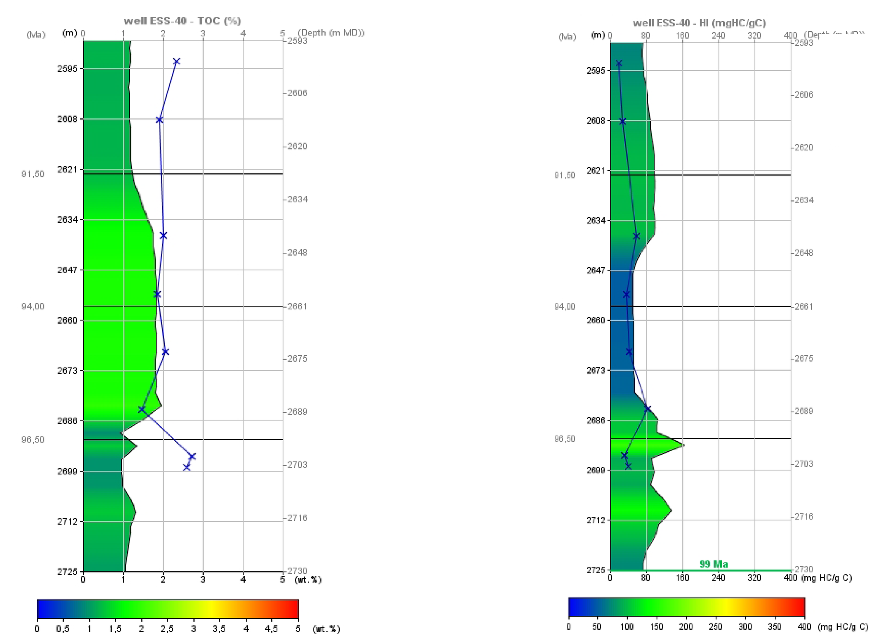
no marine organic matter, mainly SOC and pTOC

Modelled TOC and HI values (colours) compared to measured data (dark blue crosses) vs. depth for proximal (ESS-40) and intermediate (ESS-151) distance to shore wells. In both wells the data indicates a predominance of terrestrial organic matter.

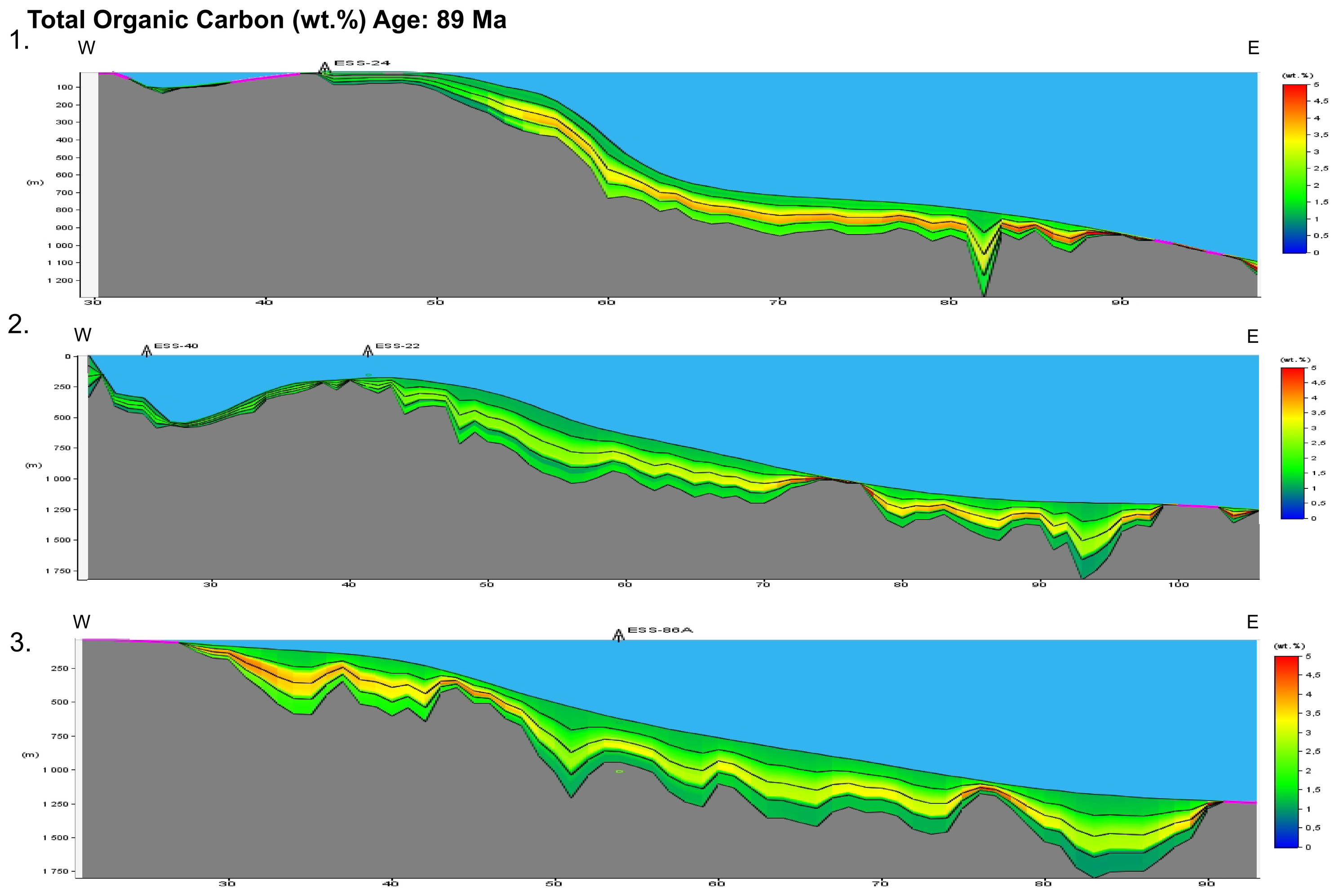
Proximal influenced by the southern river input well:

Total Organic Carbon (wt.%)

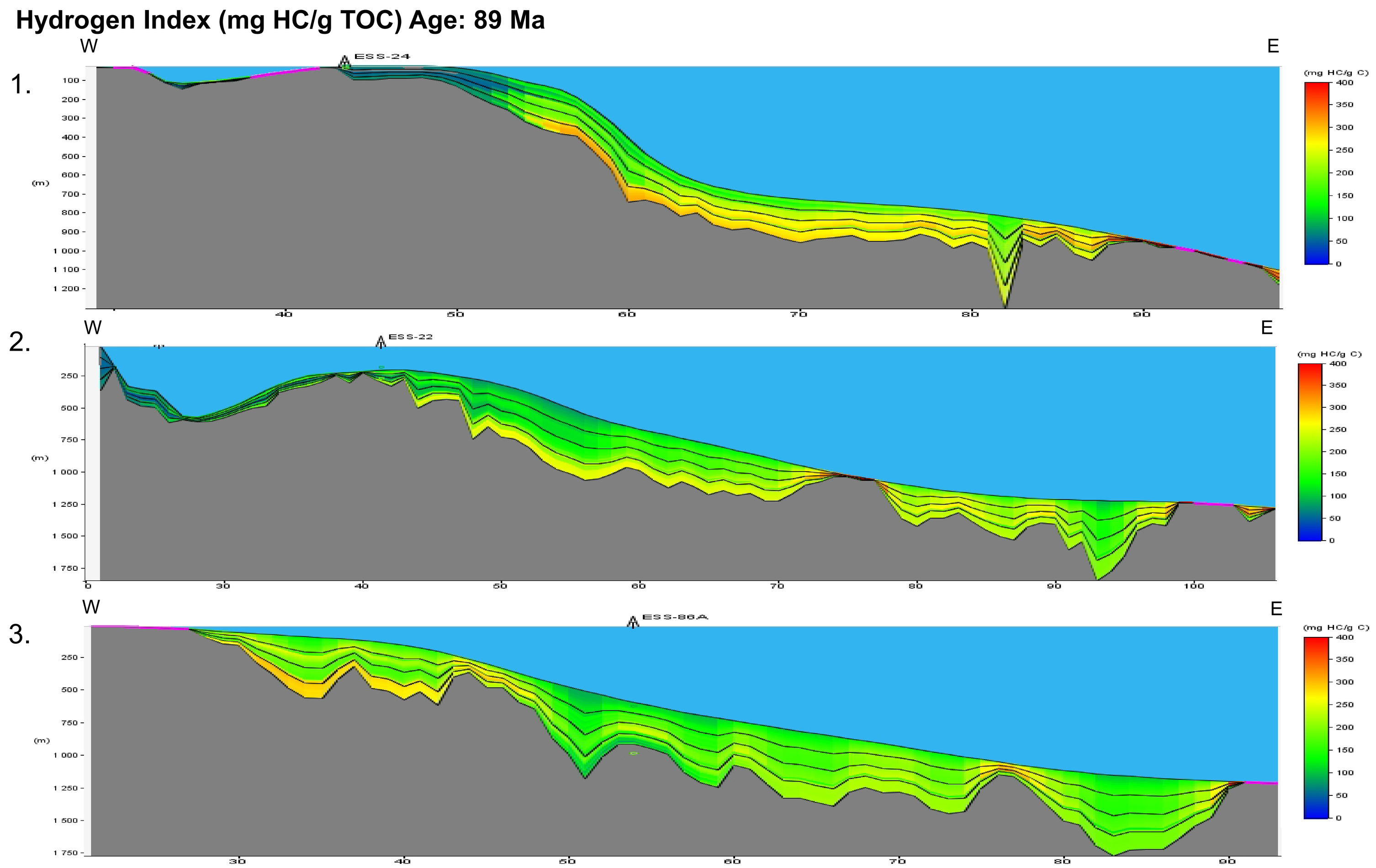
Hydrogen Index (mg HC/g TOC)



Total Organic Carbon (wt.%) Age: 89 Ma

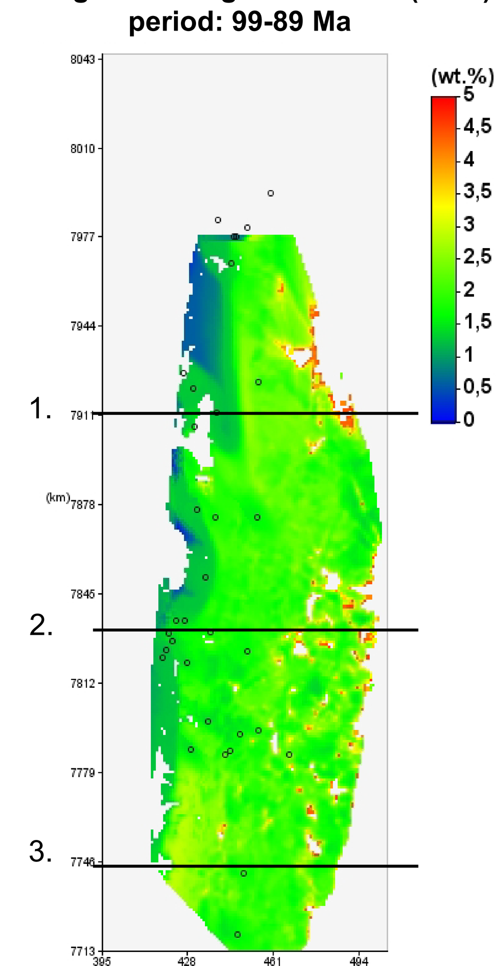


Hydrogen Index (mg HC/g TOC) Age: 89 Ma

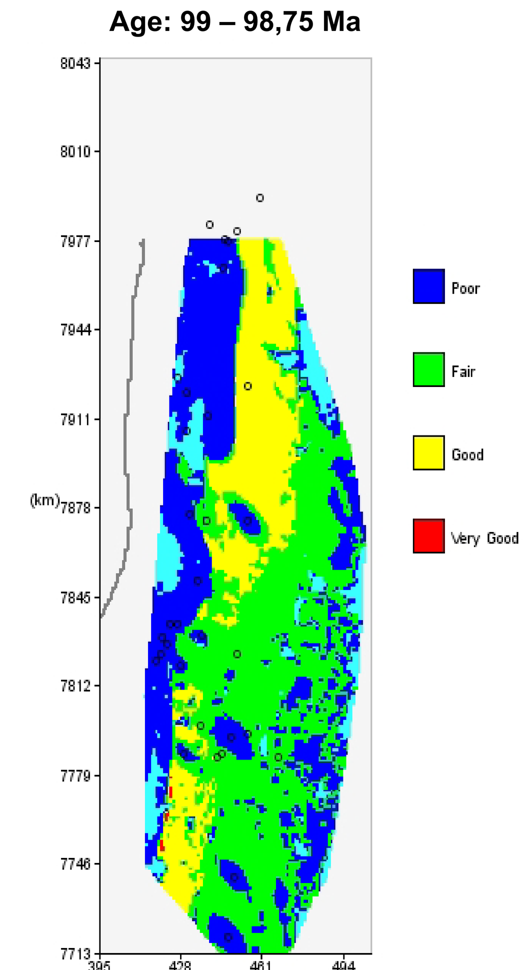


W-E cross-sections showing the influence of the anoxia: enhanced TOC values but only slightly enhanced HI values. The wells are indicated by drilling symbol.

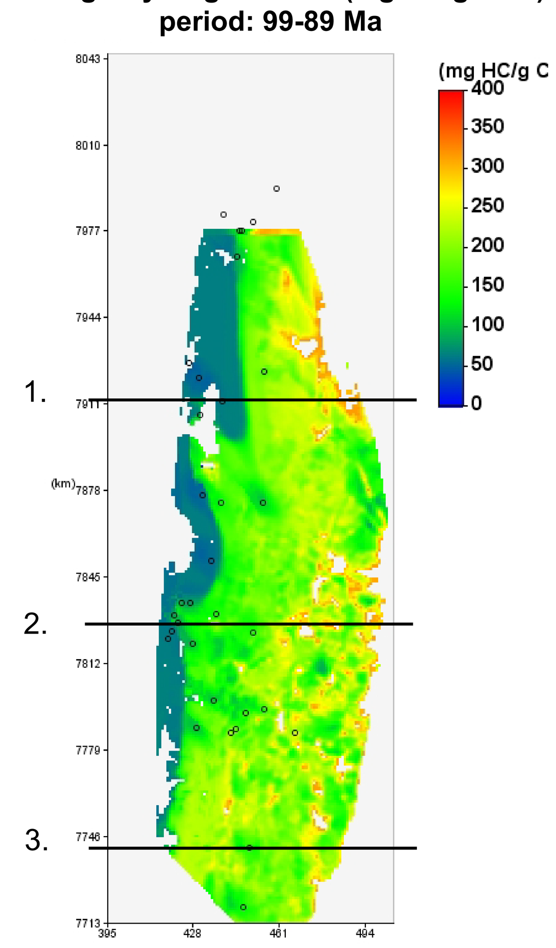
Average Total Organic Carbon (wt.%) period: 99-89 Ma



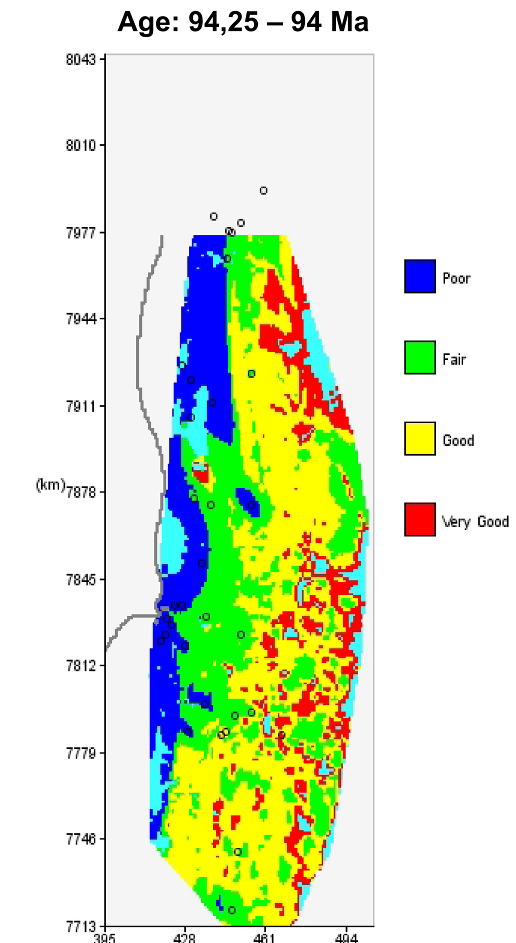
Source Rock Potential before CTAE Age: 99 – 98,75 Ma



Average Hydrogen Index (mg HC/g TOC) period: 99-89 Ma



Source Rock Potential in CTAE Age: 94,25 – 94 Ma



Maps showing trends of increasing TOC and HI distribution to the deep sea for the entire modelling interval. However, maps of source rock potential before and within the CTAE show that the general trend of increasing TOC and HI values is only due to the enhanced preservation conditions during the CTAE.

Conclusions

- ❖ The model results in a good match between modelled and measured TOC and HI values
- ❖ Increased preservation has been modelled during the CTAE to match the high TOC values in well ESS-86A and to produce a slight increase in HI
- ❖ Influence of the turbiditic infill decreases and influence of the CTAE increases from NW to SE
- ❖ CTAE event has minor impact in near shore area but more prominent in the distal area