Compilation of widespread, Cretaceous OAE2 black shale horizons documented in wells from the Gulf of Mexico, Caribbean, and Atlantic passive margins

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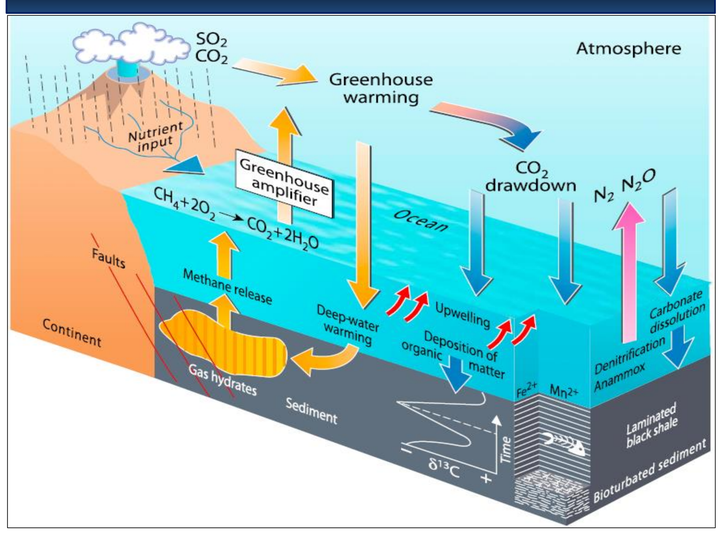
1. Abstract

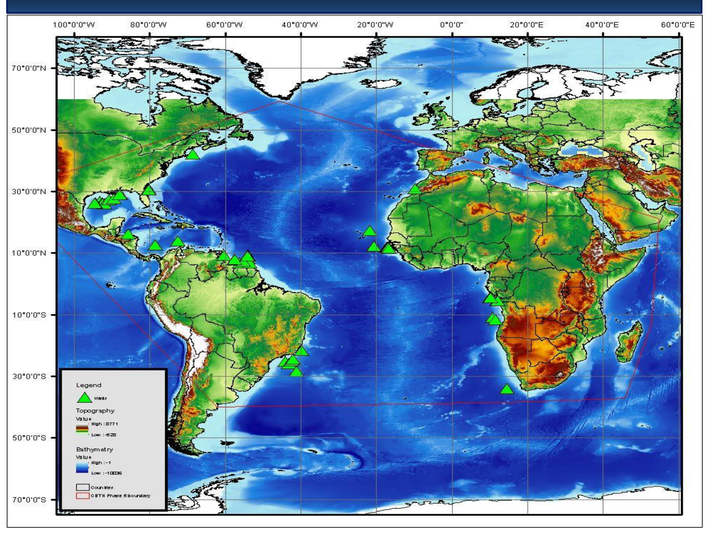
Oceanic anoxic events (OAEs) are periods in Earth's history when oceans were depleted in dissolved oxygen and characterized by deposition of organic-rich, finely laminated, black, fine-grained sediments accompanied by a spike in the δ13C ratio. Variations in δ13C are known to correlate with the presence of anomalous quantities of trace metals related to emplacement of large igneous provinces (LIPs). The Cenomanian-Turonian OAE coincided with a maximum sea level highstand. This was probably response to volcano-tectonic event, and it was the common link and ultimately the driving force for organic carbon deposition in distributed basins within Atlantic ocean under different ocean circulation regimes. Warm climates increased terrestrial weathering and input of fluvial nutrient fluxes, and decreased the levels of oxygen in the atmosphere and oceans. I have compiled the extent and thickness of OAE2 black shales on the Gulf of Mexico, Caribbean and Atlantic passive margins using published well data. Gulf of Mexico OAE2 black shale horizons can vary in thickness from 45 m to 150 m for wells KC596, KC919-2, GC653, AC557, VK826, KC102 and GC639 with undocumented TOC values for the wells but overall TOC values for Gulf of Mexico were in range from 1% to 4.6%. Caribbean margins OAE2 black shale horizons can vary in thickness from 37 m to 550 m with very low TOC value of 0.07%. South American margins OAE2 black shale horizons vary in thickness from 11 m to 610 m with TOC values ranging from 1% to 36% based on wells from Santos basin, Campos basin, Espirito Santo basin and Demerara rise. African Atlantic margins OAE2 black shale horizons vary in thickness from 100 m to 700 m with TOC values ranging from 10% to 30% based on PGO-3, GBO-1, DRO-1 and SHO-1 wells from Guinea-Bissau basin as well as DSDP 361 well from Cape basin in South Africa, DSDP 364, 365 wells from Angola basin, DSDP 367, 368 wells from Cape Verde basin and DSDP 370 from Morocco basin.

2. Conditions for OAE environments



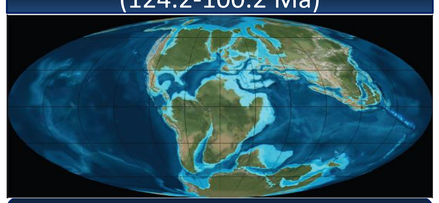
Summary from Jenkyns (2010) showing the conditions for OAE environments including: methane release from gas hydrates, greenhouse warming, CO2 drawdown, deep-water warming , upwelling and a positive δ13C excursion caused by a global increase in carbon burial.

3. OAE2 study area

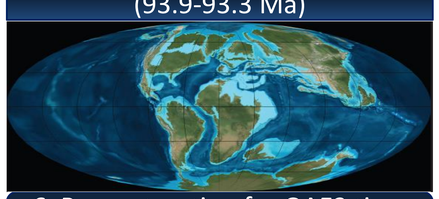


Map showing 45 wells with documented OAE2 black shale horizons and total organic carbon percentage (TOC) that were compiled for this study. Study areas include of Gulf of Mexico, Caribbean Atlantic margins, South American and African Atlantic margins.

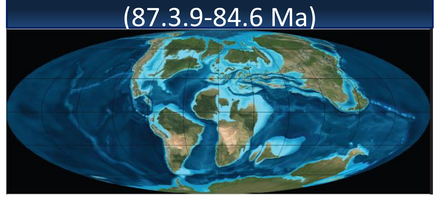
4.Reconstruction for OAE1 time (124.2-100.2 Ma)



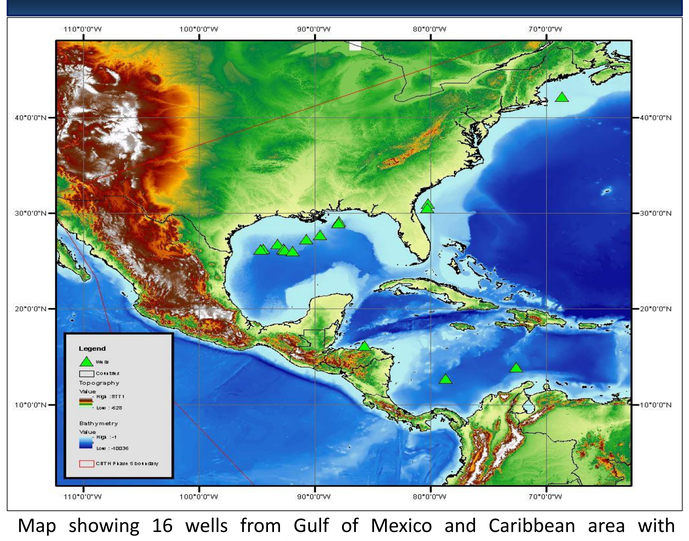
5.Reconstruction for OAE2 time (93.9-93.3 Ma)



6. Reconstruction for OAE3 time (87.3.9-84.6 Ma)

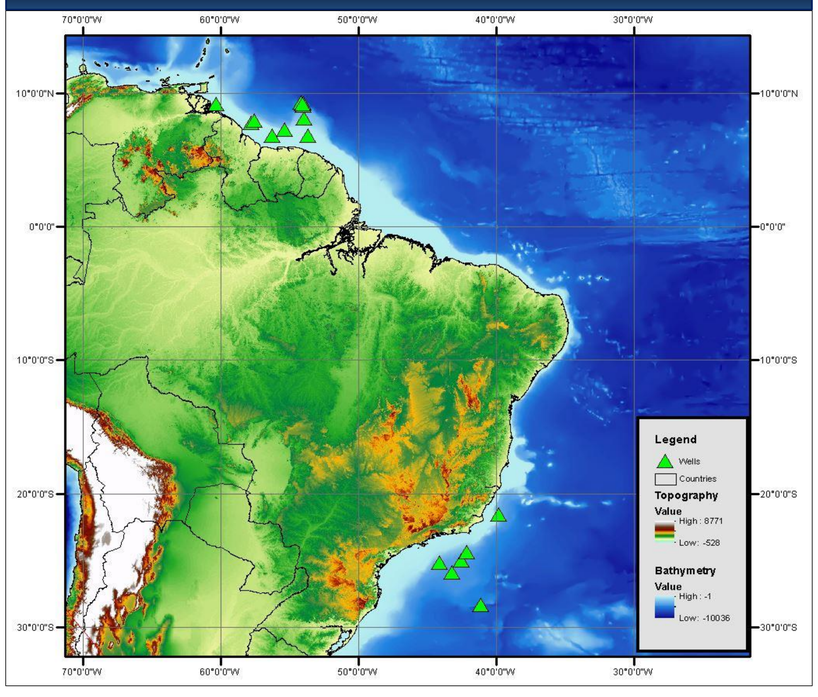


7. OAE2 localities in Gulf of Mexico and Caribbean



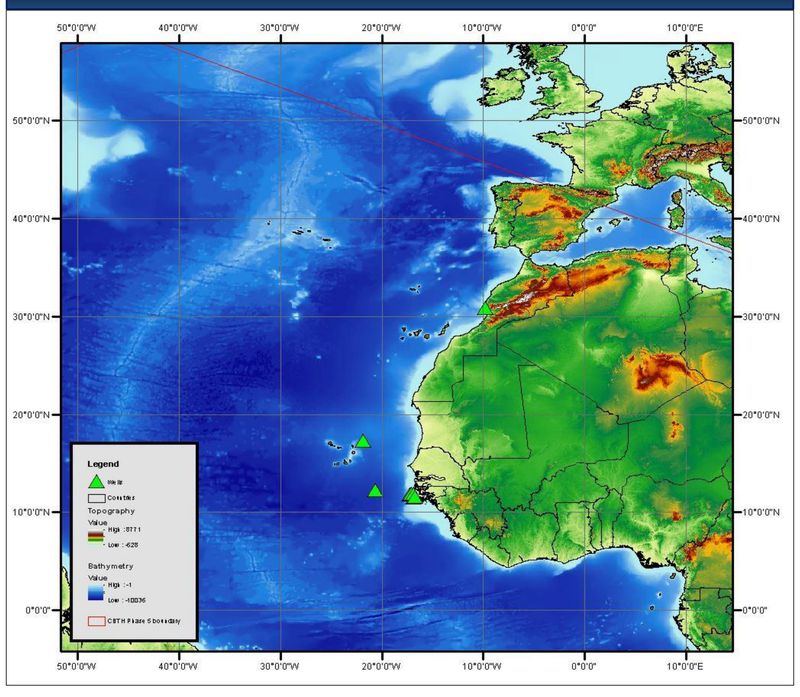
Map showing 16 wells from Gulf of Mexico and Caribbean area with documented OAE2 black shale horizons. For Gulf of Mexico, KC 596, KC 919-2, GC 653, AC 557, VK 826, KC 102, GC 639 wells contain OAE2 horizons ranging in thickness from 45 m to 150 m. TOC values ranging from 1% to 4.6%. For the Caribbean, Caribe -1, Castilla-1 and ODP 999 wells contain OAE2 horizons ranging in thickness from 37 m to 550 m - but TOC values have not been determined.

8. OAE2 localities for South American margin



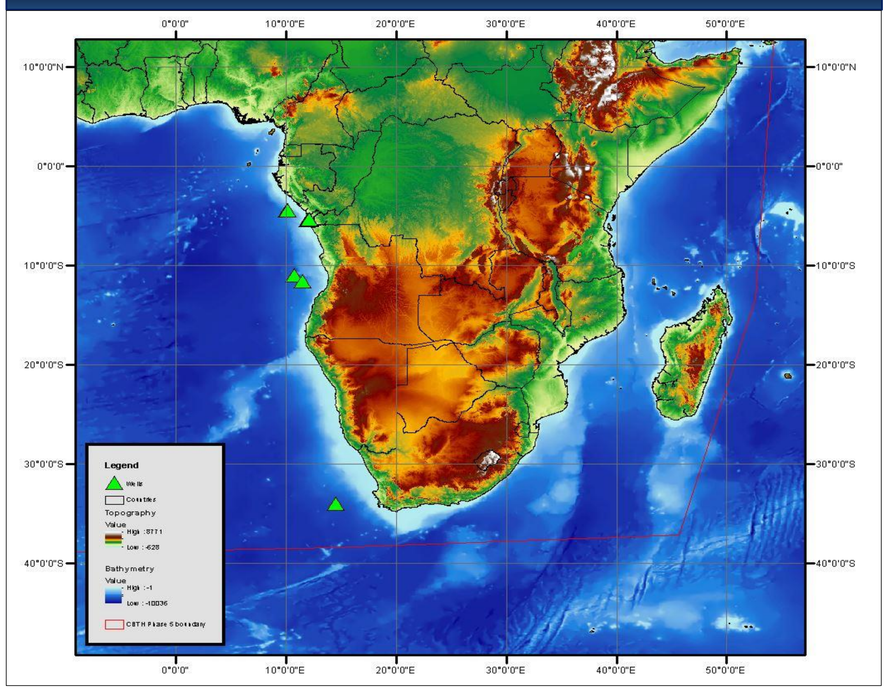
Map showing 17 wells from Demerara rise, Santos basin, Campos basin and Espirito Santo basin with OAE2 black shale horizons. For Demerara rise, wells A, Arapiama, CO-1, NCO-1, Esseq-2, CRC-1, A2-1, i23-1x, GLO-1, ODP 1258, 1259, 1260 and 1261 all contain OAE2 horizons ranging in thickness from 60 m to 550 m with TOC values ranging from 1% to 36%. For Brazilian basins wells ESS-86A, ESS-151, ESS-40, 1-SPS-19, 1-SCS-1, 1-SCS-5, 1-SCS-6, H, G, F, E, B and DSDP 356 all contain OAE2 horizons ranging in thickness from 11 m to 610 m with TOC values ranging from 0.5% to 15.86%. Wells located close to the coastline were characterized by higher sedimentation rate (over 32 m per myr) therefore their TOC values are low due to dilution of organic matter. Wells located further from the coastline - such as ODP sites in Demerara rise and DSDP site 356 offshore Brazil - are associated with lower sedimentation rates (around 20 m per myr) and higher TOC values .

9. OAE2 localities for northwestern African margin



Map showing 7 wells from Morocco basin, Guinea-Bissau basin and Cape Verde basin with documented OAE2 black shale horizons. For Guinea-Bissau basin, wells PGO-3, GBO-1, DRO-1 and SHO-1 contain documented OAE2 horizons ranging in thickness from 420 m to 700 m with unknown TOC values. For the Cape Verde basin DSDP 367 and 368 wells contain OAE2 horizons ranging in thickness from 134 m to 330 m with TOC values ranging from 10% to 11.7%. For Morocco DSDP 370 well contain OAE2 thickness ranging from 100 m to 500 m with TOC values ranging from 1% to 20%.

10. OAE2 localities for southwestern African margin



Map showing 5 wells from Cape basin, Angola basin and Congo basin with OAE2 black shale horizons. For Cape basin, DSDP 361 well contains documented OAE2 horizons ranging in thickness from 200 m to 1200 m with TOC value of 15%. For Angola and Congo basin, wells DSDP 364, 365 and SLF contain OAE2 horizons ranging in thickness from 133 m to 180 m with very high TOC values ranging from 29% to 30%.

11. Conclusion

Volcanic activity of the Caribbean large igneous province during the Cenomanian caused the rapid concentration of CO2, global warming, and formation of the OAE2 organic horizons. Volcanism released large volumes of sulfur and iron into the atmosphere which triggered huge phytoplankton blooms, which in turn deprived the oceans of oxygen and triggered extensive marine extinctions. The input of sulfate and iron facilitated increased carbon remineralization, which enhanced nutrient recycling and increased global primary productivity, eventually resulting in widespread ocean anoxia.