Late Jurassic – earliest Cretaceous Boreal Shelf Anoxic Event (SAE) and its possible causes

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Black shales and oceanic anoxic events during the few last decades became among the key topic in geosciences (more than 17000 and 6000 scientific articles indexed by GoogleScholar respectively).

Black shales are clayey deposits characterized by high TOC contents which are usually deposited under euxinic / dysoxic / anoxic conditions...
Comparison of geochemical signatures of the Toarcian OAE in the marine successions of Siberia and Europe (Suan et al., 2011)
Toarcian palaeotectonic map and black shale distribution (Groecke et al., 2011)

Warming associated with Toarcian OAE as inferred from palynological data from non-marine deposits of China (Wang et al., 2005)

Early Toarcian isotope excursion in non-marine Taskomirai succession, southern Kazakhstan (Schnyder et al., 2016)
Lithostratigraphical chart for the Lower Jurassic of Arctic regions (Shurygin et al., 2011)

1. clays, mudstones; 2. silty clays and mudstones; 3. silts, siltstones; 4. sandy silts and siltstones; 5. sands, sandstones; 6. coals, coal measures; 7. pebbles (a), charred wood (b), black shales (c)
Cretaceous OAE recognized in the successions of Dagestan, Northern Caucasus (figure above) and the Middle Volga area, after Gavrilov et al., 2014.
Some common features of the OAEs

- OAEs are characterized by very wide distribution across the both oceanic and shelf basins.
- They are generally are very short-term, lasting some tens to hundreds of the thousand years (as a rule ~ equal to one ammonite zone or its part), and thickness of OAE-related black shales is usually not very big (from centimeters and tens of centimeters to meters).
- OAEs are associated with significant disturbances of carbon cycle, abrupt climate changes and strong faunal turnovers (including some famous extinction events).
- Onset of typical OAE is nearly synchronous across different basins, and through usage of either geochemical signatures or climatically-sensitive signals these events could be also traced through non-marine successions.
But this is not the case of the Late Jurassic – earliest Cretaceous Boreal black shales!
Distribution of black shales in the Upper Jurassic of Arctic (Leith et al., 1993), European Russia and Western Siberia (Braduchan et al., 1998)

**Mesozoic hydrocarbon source-rocks of the Arctic region**


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Fig. 2. Lithostratigraphic summary diagram showing age of OMM units in diverse geographical areas (after Embry, 1989b), with additional data compiled from Young et al. (1980), Worsley et al. (1988) and Gramberg et al. (1988)
Stratigraphic distribution of Upper Jurassic – lowermost Cretaceous black shales in Boreal areas

I – European part of Russia (composite, Zakharov et al., 2017); II – Dorset coast (Morgans-Bell et al., 2001); III – northern France (Proust et al., 1993); IV – Subpolar Urals (Zakharov et al., 2005); V – Norwegian sea shelf (7430/10-U-01: Mutterlose et al., 2003); VI – Barents sea shelf (6307/07-U-02: Mutterlose et al., 2003); VII – Spitsbergen (Dypvik, 1984); VIII – Western Siberia (Eder et al., 2015); IX – northern Siberia (Zkharov, Yudovny, 1974); X – Arctic Canada (Leith et al., 1993; Gentzis et al., 1996).

Black intervals indicating stratigraphic distribution of black shales; Corg contents is shown right from these columns.
Black shales of the type 1: Subboreal black shales
Distribution of the Kimmeridge Clay Fm through outcrops and subcrops (Gallois, 2004) and peculiarities of KCF in its type succession (Morgans-Bell et al., 2001)
Kimmeridge clays in the Black Head section (black shale bands indicated by the arrows)

Geochemistry of the Upper Jurassic black shales of the European part of Russia (left – Middle Volgian, Gorodischi section; right – Upper Oxfordian, Makariev section, after Gavrilov et al., 2014)
Black shales of the Middle Volgian Dorsoplanites panderi Zone and geographic distribution of such black shales
Thickness of black shale unit of the Middle Volgian *Dorsoplanites panderi* Zone attain 100 m in the Peri-Caspian region

Ammonite in the core of Uaz 21 borehole (Atyrau region, Kazakhstan)

Black shales in the Aleksandrovo-gailskaya-1 borehole
Stratigraphic and geographic distribution of black shales in the Russian Platform

Black shales embedded between Middle Volgian (left) and Ryazanian (below) sandstones
Key features of the Subboreal Black Shales (SAE shales, type 1)

- Black shale bands or units are intercalated with siliciclastic units (composed from clays, silts, sandstones etc) with low Corg contents.
- These black shale units or beds are characterized by regional stratigraphic distribution and generally cannot be traced between different paleobasins.
- Black shales are not associated with any isotope excursions and/or remarkable climate changes.
Black shales of the type 2: Boreal black shales
Black shales of the Barents sea shelf (Georgiev et al., 2017)
Black shales of the Barents sea shelf (https://www.sintef.no)
Volgian black shales of the Festningen section

Upper Jurassic black shales of Spitsbergen

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<th>Stage</th>
<th>Sampling level</th>
<th>JANUSFJELLET SECTION</th>
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<th>Foraminifera (%)</th>
<th>Life style</th>
<th>Number species</th>
<th>Relative sea level</th>
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- Dysaerobic
- Highly dysaerobic
- Anoxic

Nagy et al., 2009
Volgian black shales of Siberia
(Shurygin, Dzyuba, 2015)

Volgian palaeogeography of the Barents and Kara shelves (Basov et al., 2009)
Upper Jurassic – lovermost Cretaceous black shales of the Nordvik section, northern Siberia (after Zakharov et al., 2014)
Key features of the Boreal Black Shales (SAE shales, type 2)

- Black shale units are characterized by more or less monotonous rock type and Corg distribution across the thick successions, spanning up to 20 My.
- Both onset and offset of black shale deposition in each basin and subbasin are differ in time from each other. Peak of black shale distribution often associated with highest Corg contents is falls into the Upper Volgian.
- Black shales are not associated with any global/subglobal isotope excursions. Climate warming and aridization during the SAE deposition are possible but waiting for further confirmation.
- Biotic changes across the black shale facies are unclear; no significant turnovers or extinctions are associated with SAE.
- Nearly all these black shales were deposited in shelf environments, sometimes relatively shallow-water ones (tens of meters depth).
High-latitude black shales of the Southern Hemisphere
Tithonian-Lower Valanginian Vaca Muerta Fm (Argentine, after Kietzmann et al., 2016)
Geochemistry of the 511 DSDP hole, Falkland plateau (Deroo et al., 1983); stratigraphy after Jeletzky, 1983
Distribution of key palynomorphs across the Spiti shales, Nepal (Vijaya, Kumar, 2002)

Tithonian-Kimmeridgian black shale interval in Kachch, India (Arora et al., 2015)
Kimmeridian-Berriasian Antarctic black shales (Doyle, Whitham, 1991)
Geographic distribution of Late Jurassic to earliest Cretaceous black shales (palaeogeography after http://www2.nau.edu/rcb7/150moll.jpg)

The only mid to low latitude black shales of Texas and Mexico are marked by yellow
Possible reasons of the Late Jurassic – earliest Cretaceous
Boreal (or high-latitude?) shelf black shale event
High-latitude black shales are closely associated with warm intervals (the latter are supported by the set of palaeontological climate markers, geochemical proxies as well as by absence of rarity of glendonites and ice-rafted deposits (left, from Zakharov 2010)

Long-term Late Jurassic warming is also supported by stable isotope data from Europe (figure above, after Dera et al., 2011)
Boreal SAE is not associated with any prominent environmental changes (the latter for Phanerozoic were summarized in figure above by Trabucho-Alexandre et al., 2012; left to right: climate type, orogenic intervals; palaeomagnetic reversals; oceanic crust production and LIP occurrences; C and Sr isotope oscillations; CO2 level; global temperature oscillations; sea-level changes; continental glaciations; extinction rates in marine invertebrates; OAE; oil-and-gas-bearing rocks; passive margins)
Calcareous nannoplankton as a possible driver?

Now calcareous nannofossils are responsible for much of primary productivity – and at first they appeared in high latitudes during the Late Jurassic.


Zanin et al., 2012,
Possible reasons of the Boreal SAE are:

- Warm high-latitude climate coupled with low palaeotemperature latitudinal gradient are favored for black shale deposition.
- High-latitude black shales were deposited under influence of gradual aridisation and relatively small clastic input.
- Wide distribution and long-time deposition of high-latitude black shales during the Late Jurassic – earliest Cretaceous could be connected with rise of primary production and disturbance of plankton communities due to first high-latitude appearance of calcareous nannofossils.
Vielen Dank für Ihre Aufmerksamkeit!

Thanks for your attention!

Black shales are here!

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