The Volcanism of the Circum-Arctic: Implications for the Evolution of the Amerasia Basin*

C.J. Cooper[1] and E. Bjerkebæk[1]

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[1]Statoil ASA, Stavanger, Norway (CHCOO@statoil.com)

Abstract

Here we propose that the ~ 200 to 180 Ma volcanics of the landmasses surrounding the Amerasia Basin relate to the initiation of rifting within the region, an interpretation supported by Hettangian sediments which lie uncomformably within the onshore Banks Basin. Over the past 30 years the academic community has undertaken numerous studies of the magmatic bodies of the circum-Arctic and it is these datasets which we have analysed here. Embry and Osadetz (1987) were the first to note that the circum-Arctic volcanism falls into discrete cycles, reporting four age ranges of Valanginian to early Barremian, late Barremian to Aptian, late Aptian to early Cenomanian and late Cenomanian to Maastrichtian. They accounted for these episodes through invoking two periods of rifting, followed by breakup and sea-floor spreading until the Maastrichtian. Here we propose five cycles of volcanism, based on the present-day dataset, which we relate to the tectono-stratigraphic evolution of the Amerasia Basin. Following the Lower Jurassic rift-related magmatism, which existed on Amund Ringes (Sverdrup), Axel Heiberg Island (Sverdrup) and Franz Josef Land, no circum-Arctic volcanism occurred until ~ 140 Ma. Buchan and Ernst (2006) propose three successive cycles, following this re-initiation of melting, aged Hauterivian to early Barremian, late Barremian to Aptian and Albian to Cenomanian. We support these ages, noting their agreement with the sea-floor spreading duration presented in Embry and Dixon (1992). The youngest volcanism of the region, which is alkali in composition, is observed at the De Long Islands, the Alpha and Mendeleev ridges, Northern Ellesmere Island and Northern Greenland. We propose that this alkali volcanism resulted from a plume. Numerous studies have suggested that the high-standing Alpha and Mendeleev ridges of the Amerasia Basin also resulted from a plume, a hypotheisis supported by seismic 1-D velocity depth profiles from the ridges. The alkali volcanism of the De Long Islands is aged ~ 125 to 105 Ma, whilst samples from the Mendeleev and Alpha ridges are aged 89 and 82 Ma, respectively; finally that of Northern Ellesmere Island and Northern Greenland is aged between 86 and 57 Ma. This plume could at present reside under Iceland. Alkali volcanism aged between 55 and 33 Ma is observed in Southern Greenland, whilst the oldest exposed volcanics of Iceland are aged ~ 16 Ma.

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The volcanism of the circum-Arctic: implications for the evolution of the Amerasia Basin

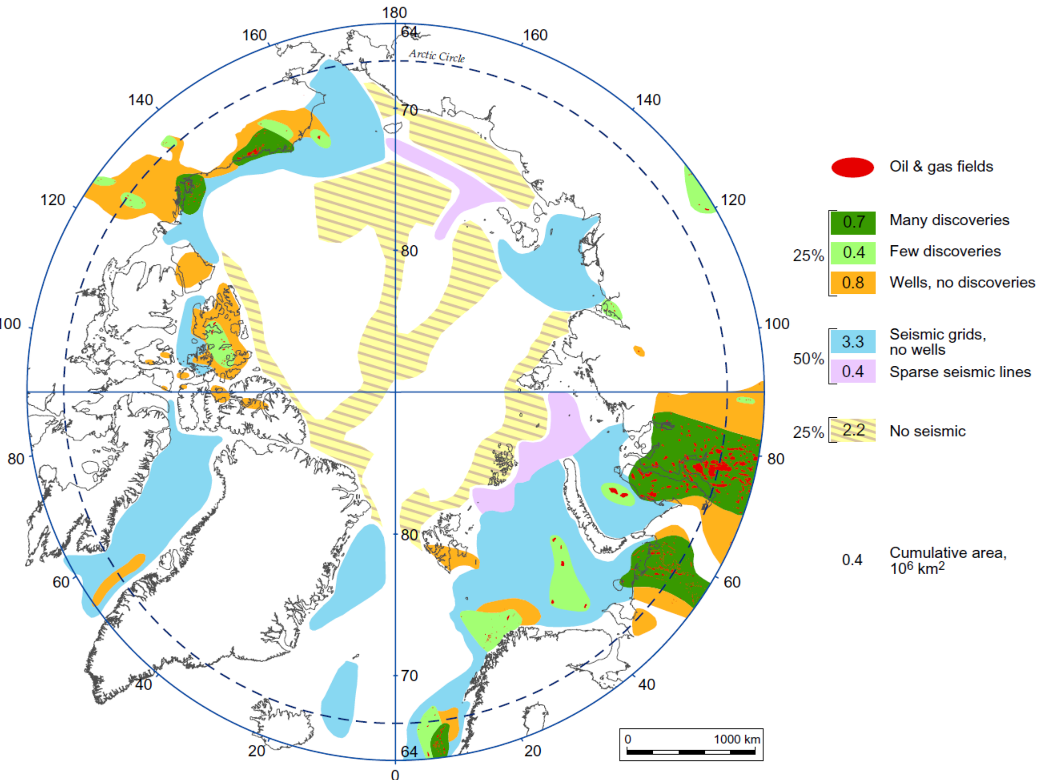
C.J. Cooper and E. Bjerkebæk

Talk overview

1) Introducing the Amerasia Basin.

2) Circum-Acrtic volcanism.

3) Our model.



Spencer et al., (2011)

Arctic Petroleum Geology, Geological Society, London, Memoir 35

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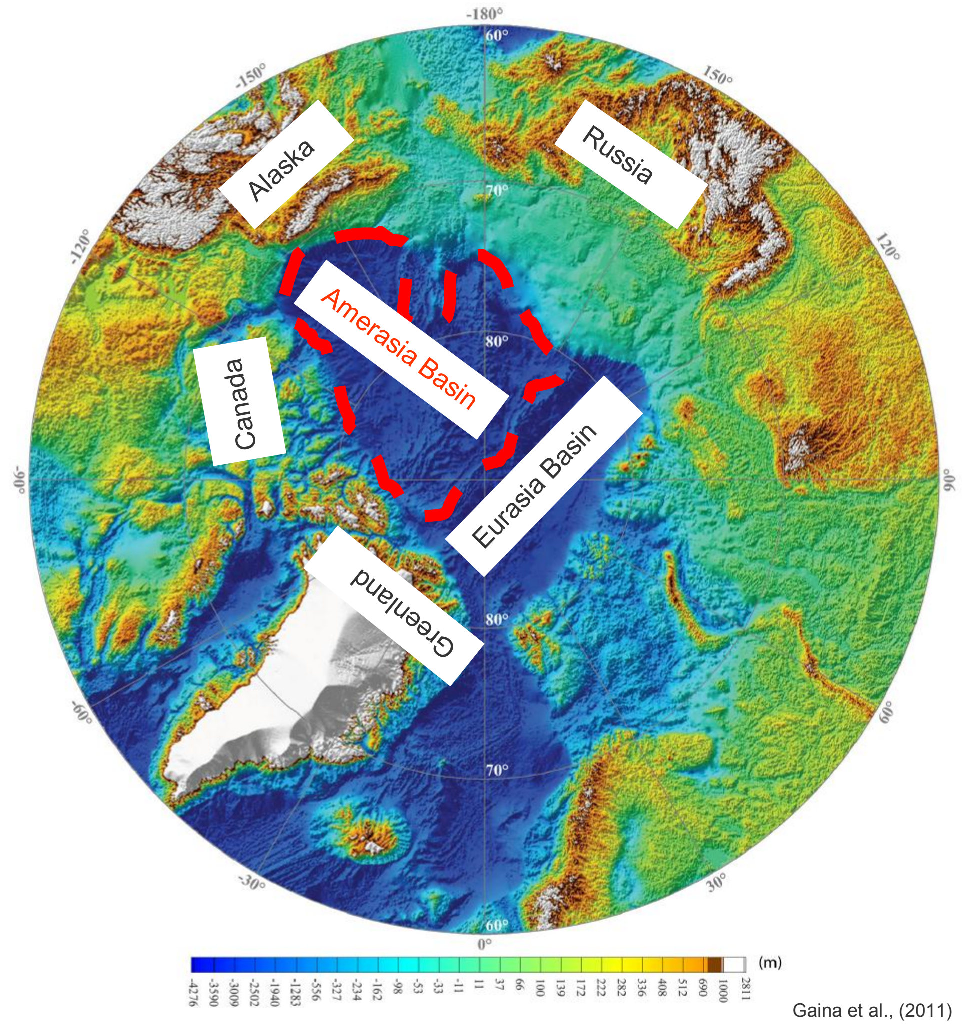
1. Introducing the Amerasia Basin - location

- Neighbouring landmasses: Russia, Alaska, Canada, Greenland.
- Neighbouring oceanic basin: Eurasia.



Gaina et al., (2011)

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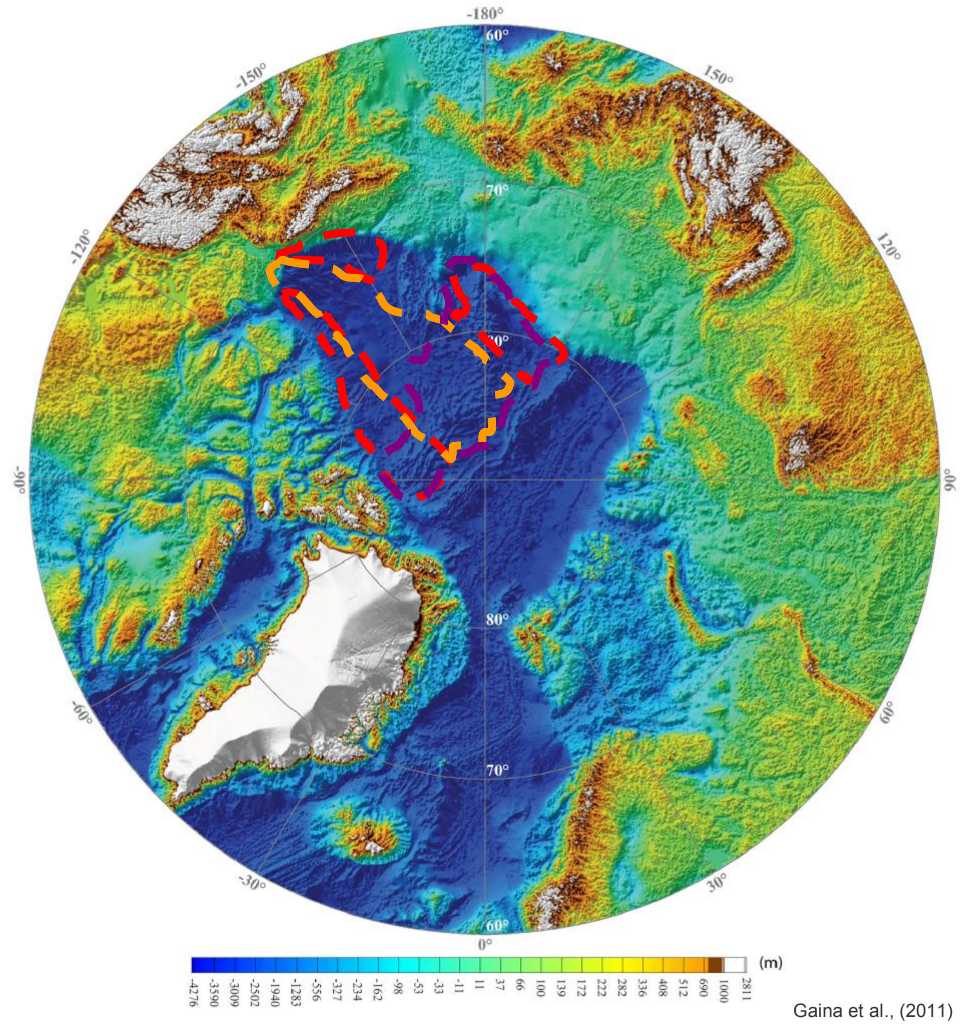
Statoil

1. Introducing the Amerasia Basin - nature

- Oceanic crust (e.g., Alvey et al., 2008).

- Large igneous province (e.g. Lane, 1992)??

- Exhumed mantle (Grantz, 2010)??



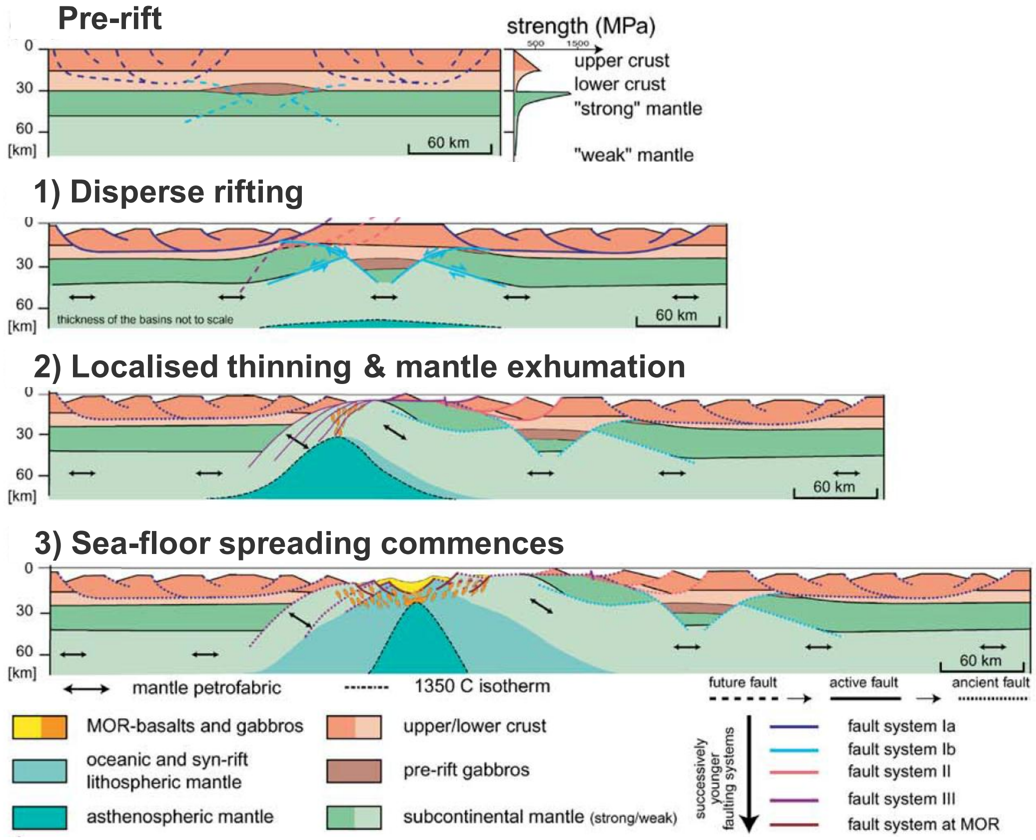
Gaina et al., (2011)

1. Introducing the Amerasia Basin – tectonic evolution

5 stages:

1. Start of rifting.
2. Crustal rupture & mantle exhumation.
3. Continental breakup & start of seafloor spreading.
4. End of sea-floor spreading.
5. Emplacement of the large igneous province (LIP).

The formation of magma-poor rifted margins



Manatschal (2004)

1. Introducion to the Amerasia Basin – timing

- Reviewed tectonic models literature since 1987.

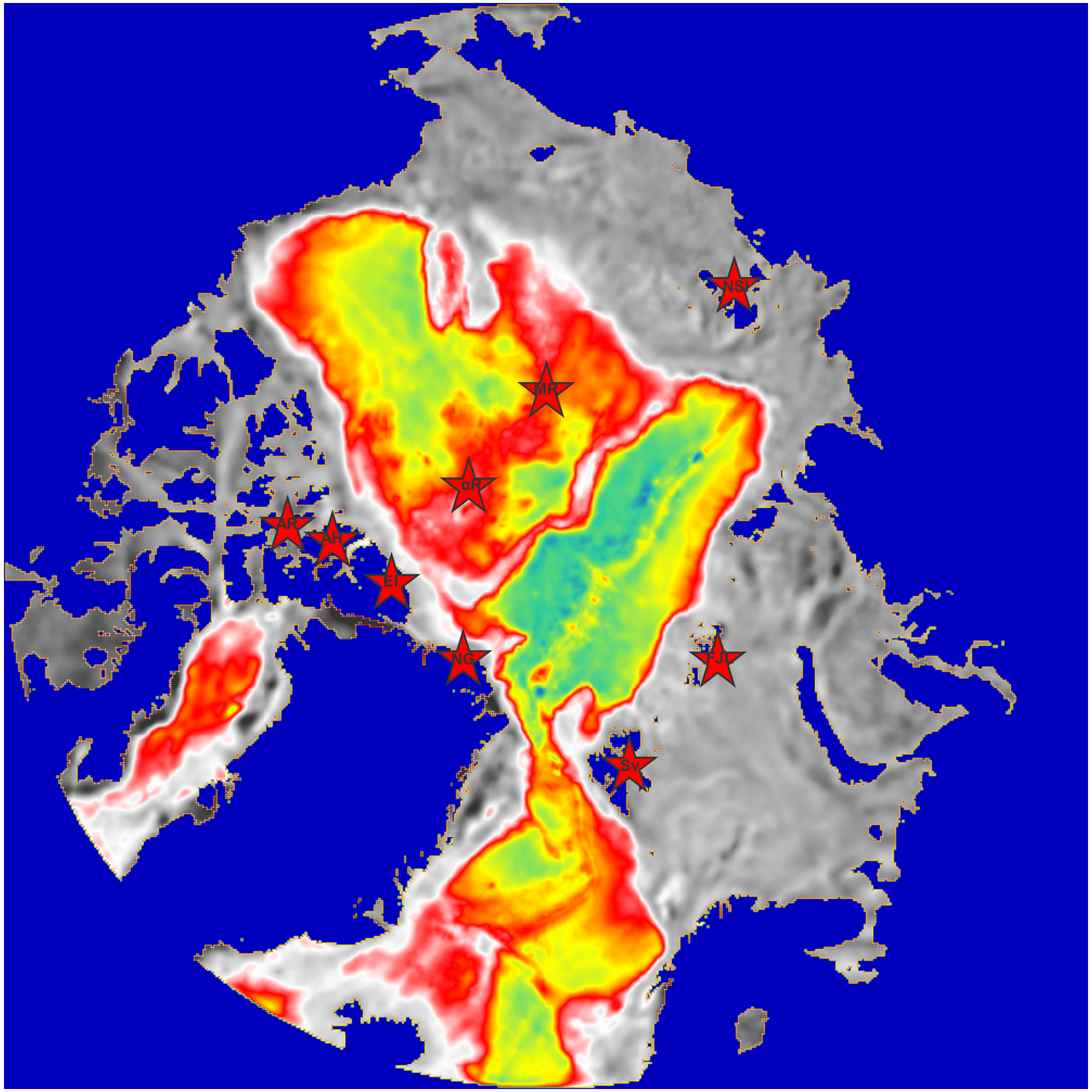
- Start of rifting – Early Jurassic.
- Mantle exhumation – mid- to Late Jurassic.
- Sea-floor spreading starts – Early Cretaceous.
- Sea-floor spreading ends – mid-Cretaceous.
- LIP emplacement – Late Cretaceous.

2. Circum-Arctic volcanism

Literature review - Jurassic and Cretaceous volcanism.

Locations:

- Amund Ringes (AR).
- Axel Heiberg Island (AH).
- Ellesemere Island (EI).
- Northern Greenland (NG).
- Svalbard (Sv).
- Franz Josef Land (FJL).
- New Siberian Islands (NSI).
- Mendeleev ridge (MR).
- Alpha ridge (αR).



(Base map: gravity-inverted crustal thickness – Kusznir et al., 2007)

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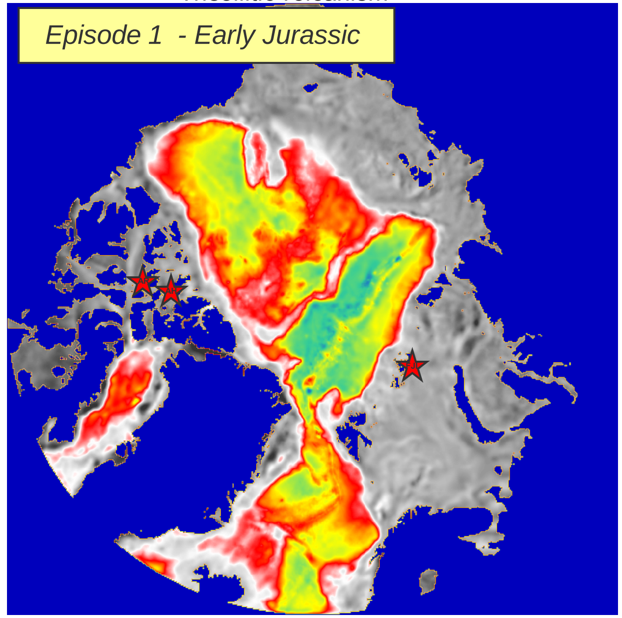
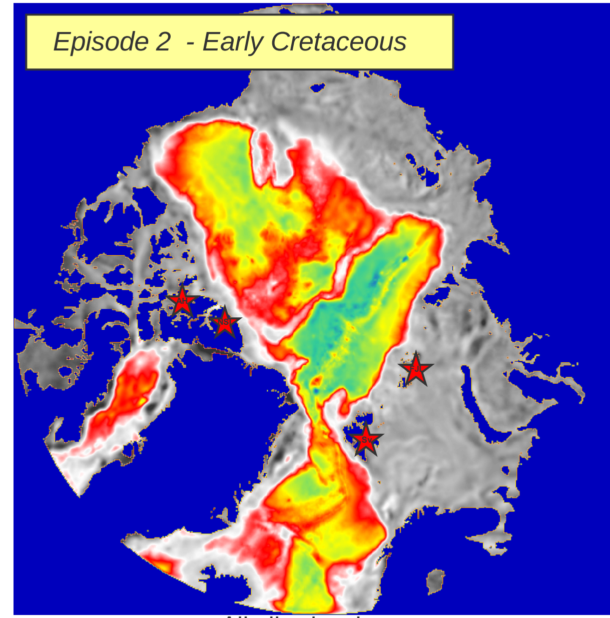
2. Circum-Arctic volcanism

5 discrete volcanic episodes are observed in the Jurassic and Cretaceous.

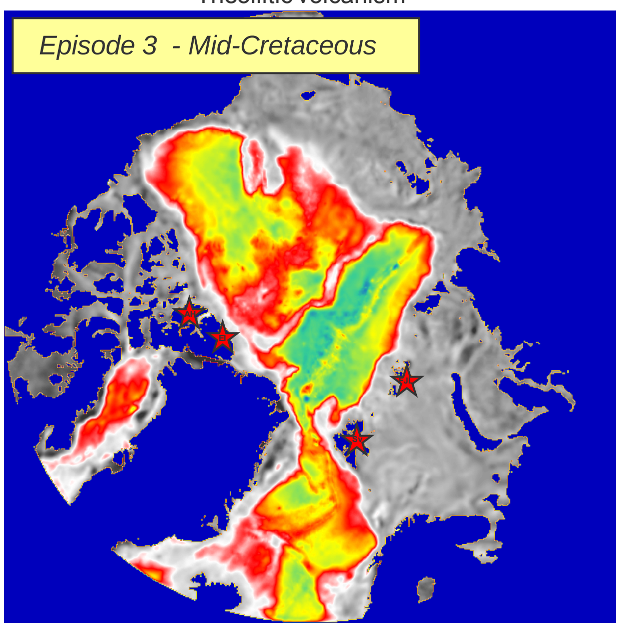
Theollitic volcanism



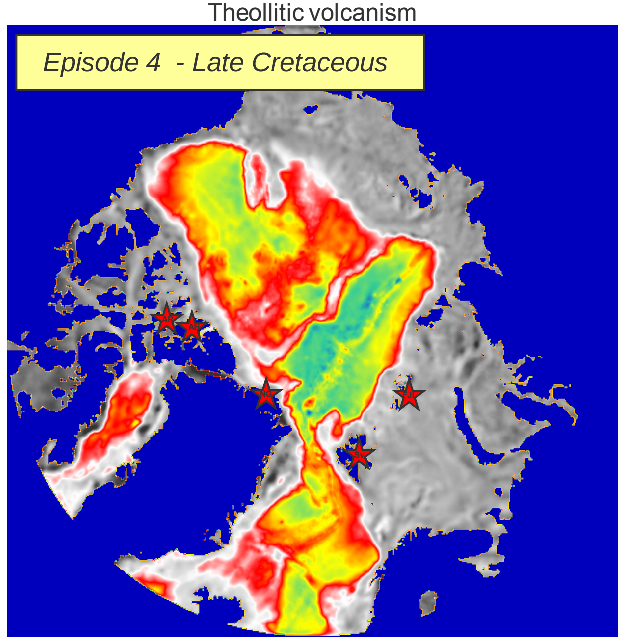
Theollitic volcanism



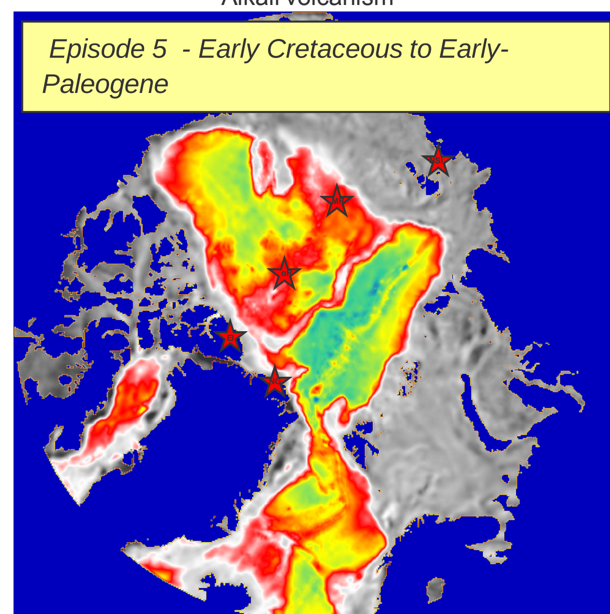
Theollitic volcanism



Theollitic volcanism



Alkali volcanism



(Base maps: gravity-inverted crustal thickness – Kusznir et al., 2007)

2. Circum-Arctic volcanism – episode 1

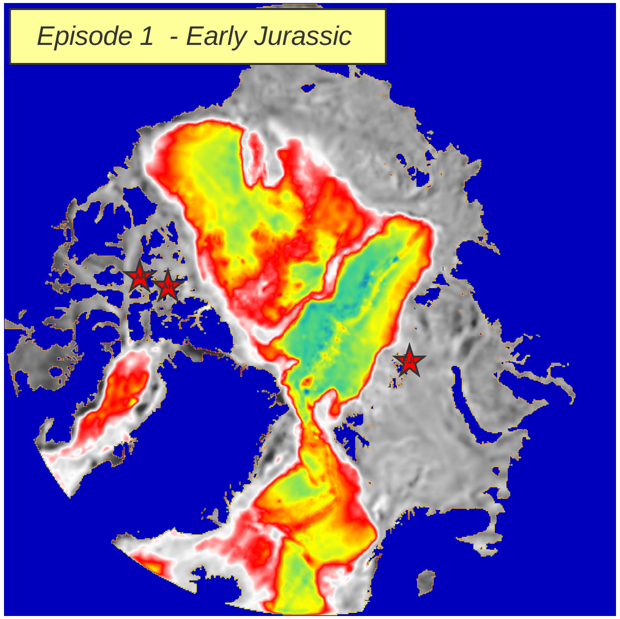
Early Jurassic

Theoliitic volcanism observed in 3 locations:

Amund Ringes: Gould & Miller (1964).

Axel Heiberg Island: Balkwill (1978).

Franz Josef Land: Maher (2001); Burov et al. (1976).



(Base maps: gravity-inverted crustal thickness – Kusznir et al., 2007)

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1. Introducion to the Amerasia Basin – timing

- Reviewed tectonic models literature since 1987.

- Start of rifting – Early Jurassic.
- Mantle exhumation – mid- to Late Jurassic.
- Sea-floor spreading starts – Early Cretaceous.
- Sea-floor spreading ends – mid-Cretaceous.
- LIP emplacement – Late Cretaceous.

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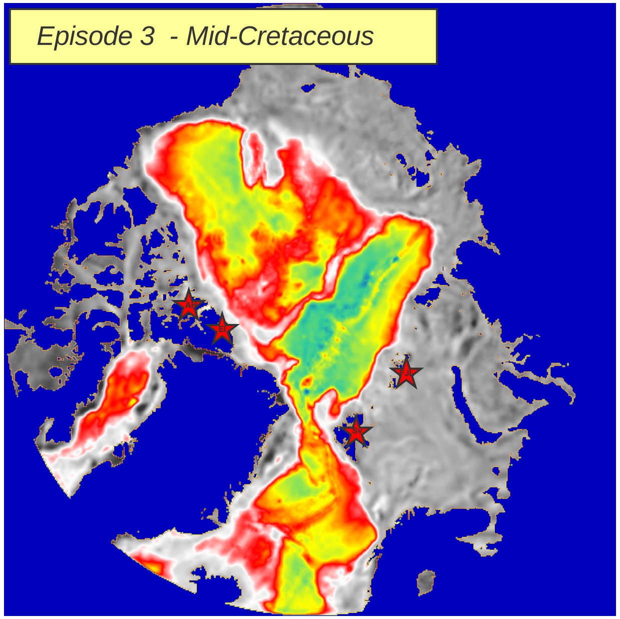
2. Circum-Arctic volcanism – episode 3



(Base maps: gravity-inverted crustal thickness – Kusznir et al., 2007)

Mid-Cretaceous

Theoliitic volcanism observed in 4 locations:

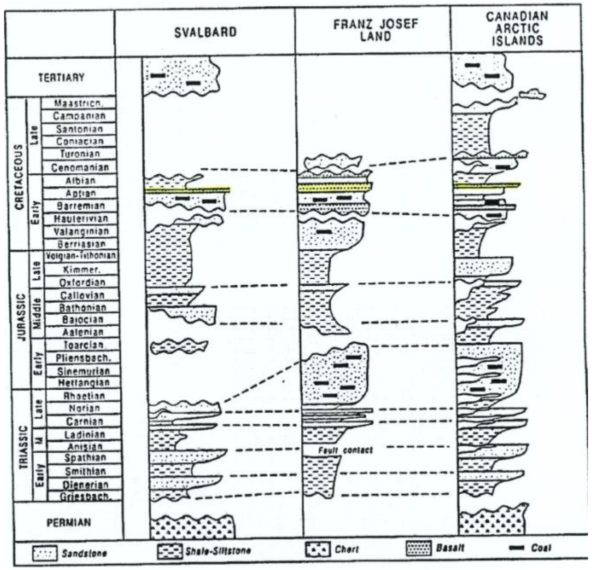
Axel Heiberg Island: Muecke et al. (1990).

Balkwill (1978)

Northern Ellesemere Island: Embry & Osadetz (2006).

Svalbard: Pumhösl (1998).

Franz Josef Land: Dibner (1998).



Embry (1992)

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Statoil

2. Circum-Arctic volcanism – episode 4

Late Cretaceous

Theoliitic volcanism observed in 5 locations:

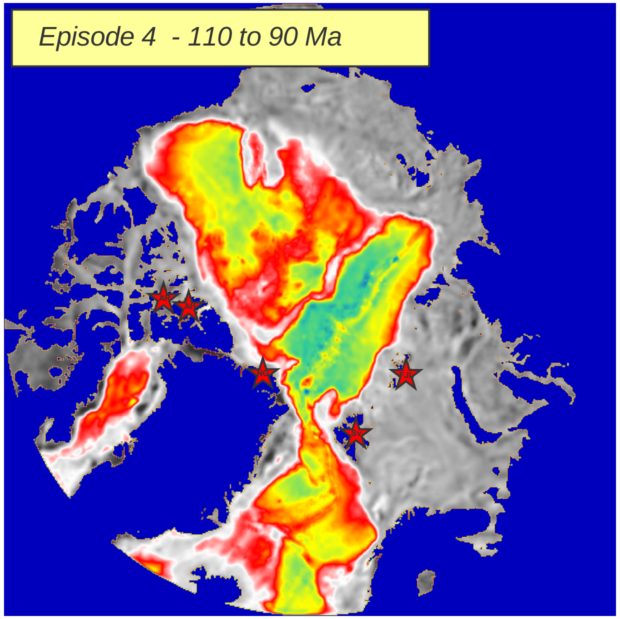
Amund Ringes: Embry & Osadetz (2006).

Axel Heiberg Island: Balkwill (1978).

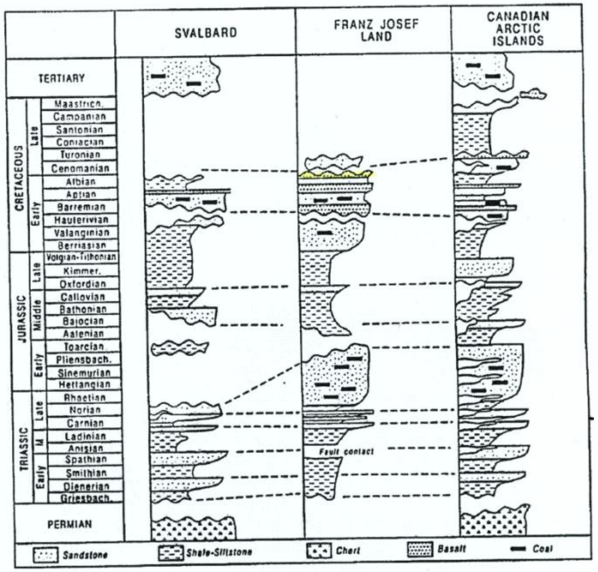
Northern Greenland: Lyberis & Manby (2001).

Franz Josef Land: Maher (2001); Burov et al. (1976).

Svalbard: Maher (2001); Burov et al. (1976).



(Base maps: gravity-inverted crustal thickness – Kusznir et al., 2007)



Embry (1992)

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2. Circum-Arctic volcanism – episode 5

Early Cretaceous to Early Paleogene

Alakali volcanism observed in 5 locations:

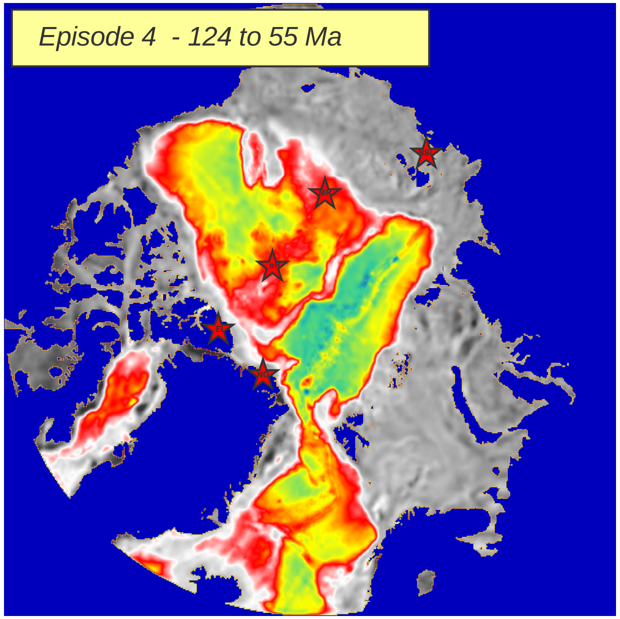
Northern Ellesemere Island: Muecke et al. (1990); Estrada & Henjes-Kaunst (2004).

Northern Greenland: Larsen (1982); Kontak et al. (2001); Abrahamsen et al. (1997).

New Siberian Islands: Gramberg et al., (2004); Drachev (1989); Fedorov et al. (2005).

Mendeleev Ridge: Grantz (2011).

Alpha Ridge: Grantz (2011).



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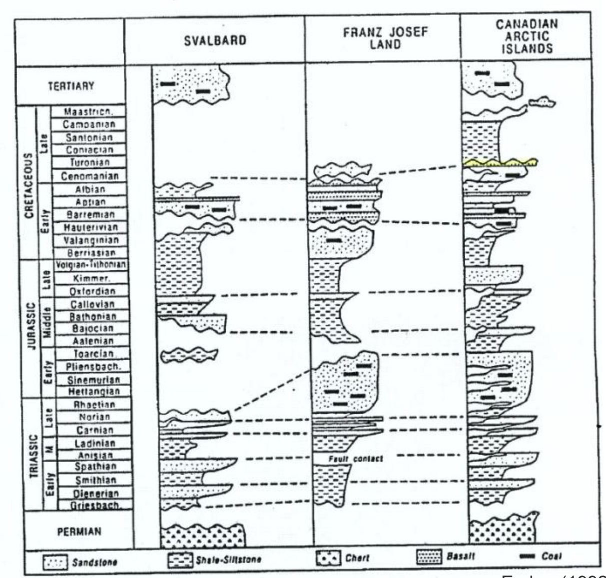

Embry (1992)

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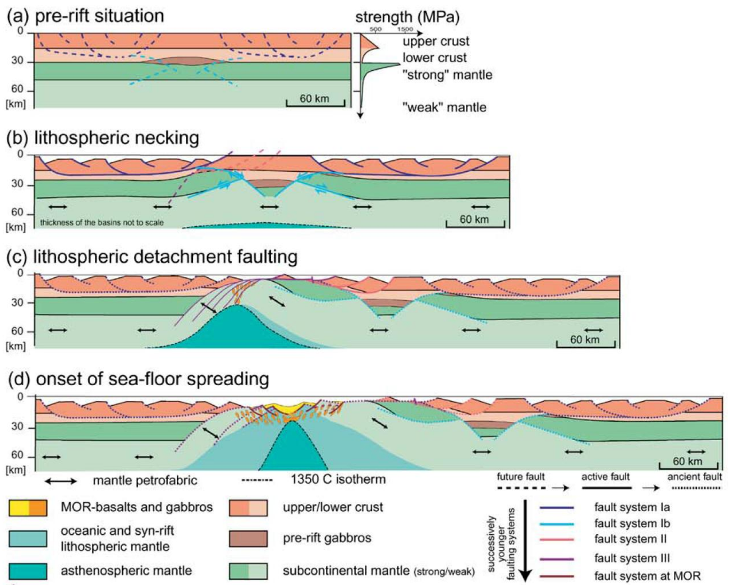
3. Our model – episode 1

Early Jurassic

Theollitic volcanism.

Start of rifting??

(Previous mean estimate Early Jurassic)



Manatschal (2004)

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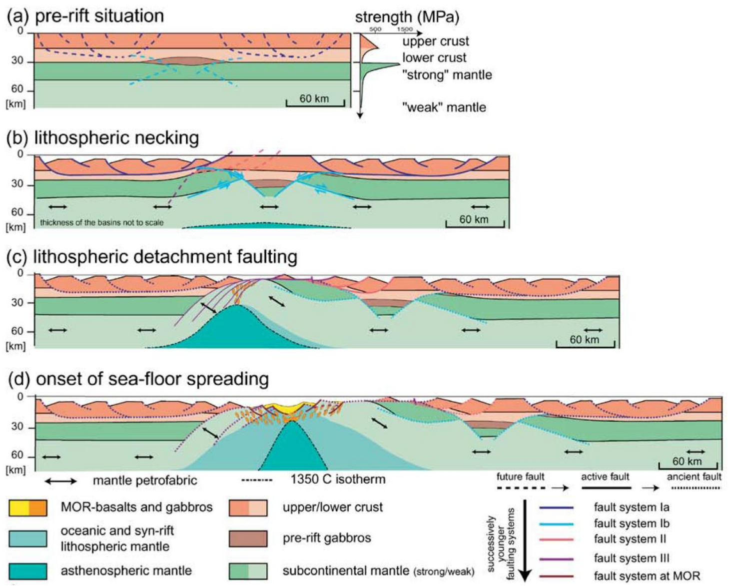
3. Our model – episode 2

Early Cretaceous

Theollitic volcanism.



Manatschal (2004)

End of mantle exhumation &

(Previous mean estimate Late Jurassic)

start of sea-floor spreading??

(Previous mean estimate Early Cretaceous)

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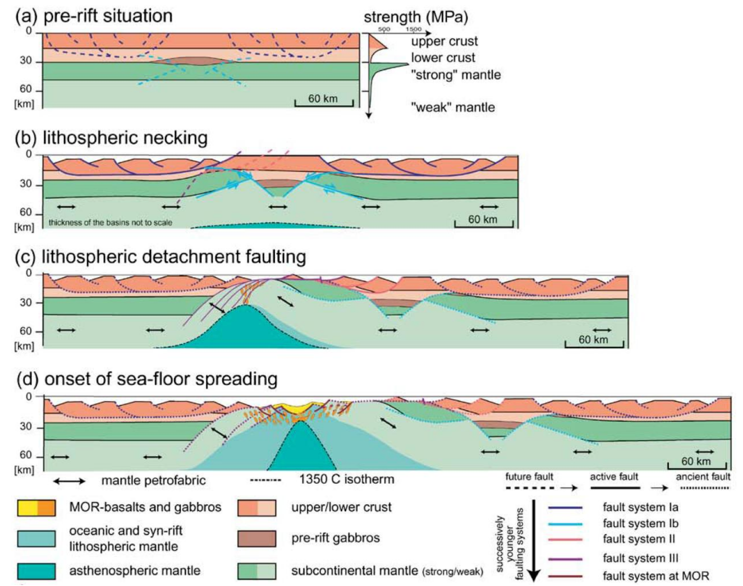
3. Our model – episode 3

Mid-Cretaceous.

Theollitic volcanism.



Manatschal (2004)

End of sea-floor spreading??

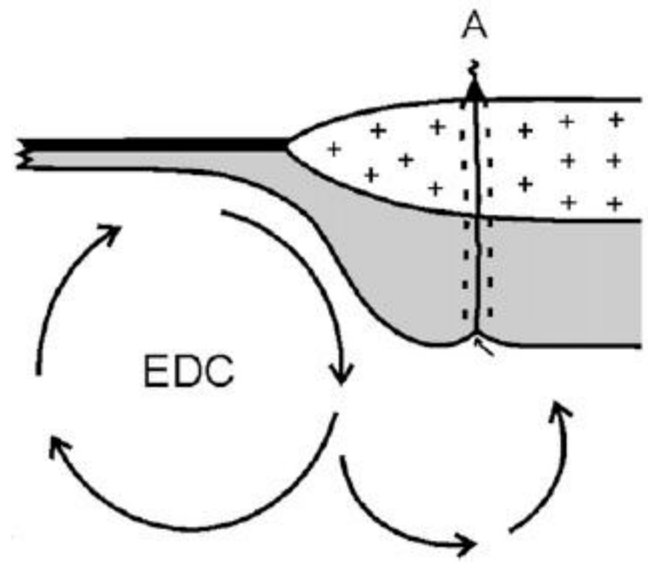
(Previous mean estimate mid-Cretaceous)

3. Our model – episode 4

Late Cretaceous.

Theollitic volcanism.

Edge driven convection??



Matton & Jebrak, 2009

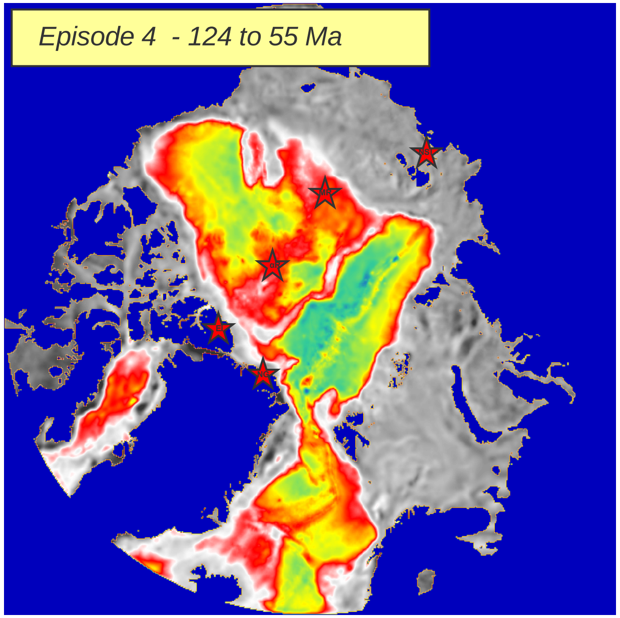
3. Our model – episode 5

Early-Cretaceous to Early Paleogene

Alkali volcanism.

Large igneous province emplacement ??

(Previous mean estimate mid- to Late Cretaceous)



(Base maps: gravity-inverted crustal thickness – Kusznir et al., 2007)

Oceanic Island Rock Suites	
Island or Group	Rock Types
Ascension	Oliv. Tholeiite (dominant) + Hawaiite + Mugearite + Trachyte + Peralk. Rhyolite
Azores	Alk. basalt + Hawaiite + Trachyte
Fernando de Noronha	Alk. Basalt + Nephelinite + Trachyte + Alkali Basalt + Trachyte + Phonolite
St. Helena	Alk. Basalt + Mugearite + Hawaiite + Trachyte + Phonolite
Trinadade	Nephelinite + Phonolite (dominant)
Tristan de Cunha	Alk. Basalt + Trachybasalt (dominant) + Trachyte
Gough	Alk. Basalt + Ol Tholeiite + Hawaiite + Trachyte
Réunion	Ol Tholeiite (dominant) + Mugearite
Mauritius	Alk. Basalt (dominant) + Mugearite + Phonolitic Trachyte
Hawaii	Tholeiite (dominant) + Alkali Basalt + Hawaiite + Mugearite + Trachyte
Tahiti	Alk. Basalt + Mugearite + Hawaiite + Trachyte
Galapagos	Tholeiite + Alk. Basalt + Icelandite (minor) + Qtz Trachyte (minor)
Jan Mayen	Alk. Basalt (dominant) + Trachyte

Nelson (2003)

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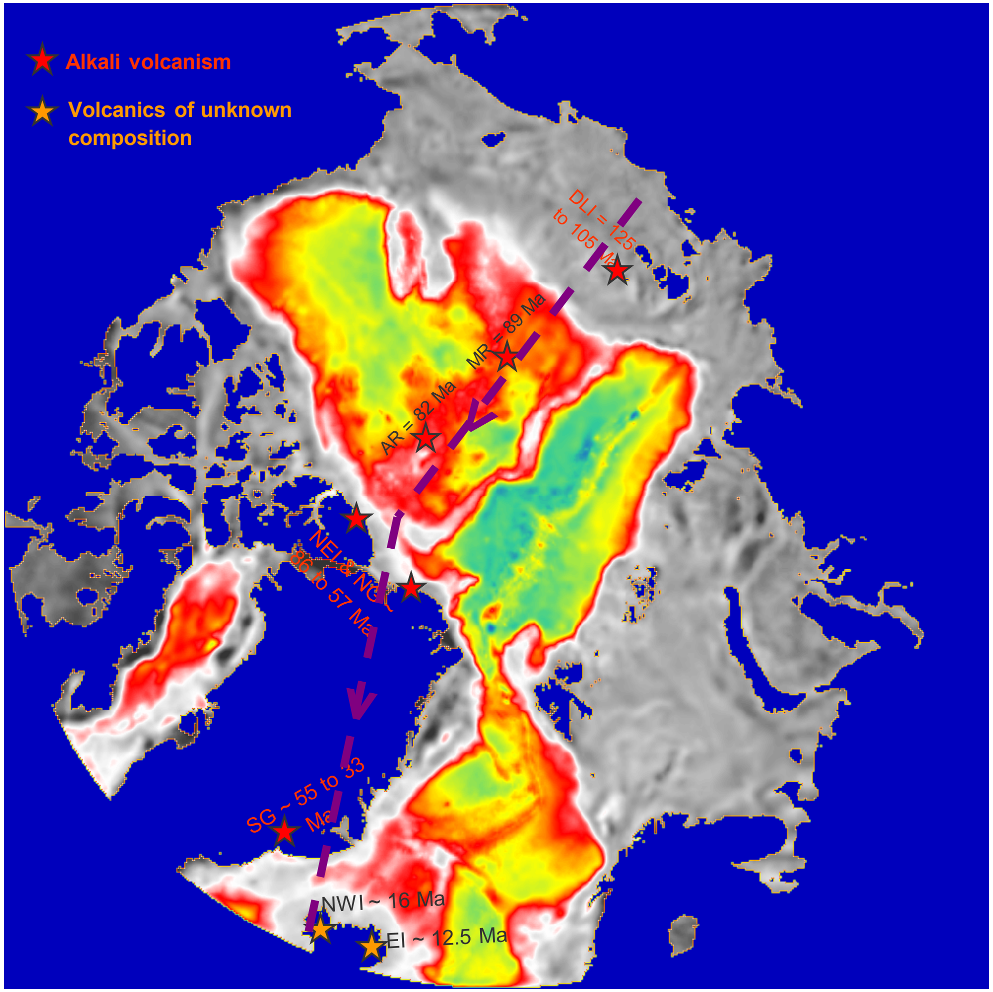
3. Our model – episode 5 continued

- Alkali volcanism of southeast Greenland: Paleogene (Heister et al., 2001).
- Oldest exposed northwest Iceland volcanism – Early Neogene (Moorbath et al., 1968).
- Oldest exposed east Iceland volcanism – Late Neogene (Moorbath et al., 1968).

Track appears to continue to Iceland



(Base maps: gravity-inverted crustal thickness – Kusznir et al., 2007)

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Summary

• Literature review into the volcanism of the circum-Arctic.

• 5 episodes of volcanism appear to have occurred.

• We tentatively explain each episode:

- Early Jurassic (start of rifting).
- Early Cretaceous (start of sea-floor spreading).
- Mid-Cretaceous (end of sea-floor spreading).
- Late Cretaceous(small-scale convection).
- Early Cretaceous to Early Paleogene (the plume which currently resides under Iceland).

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