The Enigma of Missing Jurassic and Cretaceous Rocks - Episodic Deposition and Unroofing of the UK and Adjacent Continental Shelves during the Mesozoic and Tertiary*

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Abstract

Jurassic and Cretaceous palaeogeographic reconstructions of the UK are constrained by extensive well and field exposures that provide both lithofacies and biostratigraphic control. However, this information is limited to ‘remnant’ sections preserved after regional erosional events presenting a biased perspective of originally more extensive pre-erosion depositional systems. Stratigraphic clues remain in the preserved section which can be used to develop a more comprehensive understanding of sequence architecture including: isolated outliers of sequences more fully developed in adjacent grabens; facies characteristics of once more laterally extensive depositional systems now limited to scattered erosional remnants; and sediment recycling of pre-tectonic sediments into intra-graben lows. While missing section cannot be studied directly, its effect can be detected by palaeo-thermal indicators such as apatite fission track analyses, sonic velocities and vitrinite reflectance, allowing a much more robust reconstruction than is possible from the preserved section alone. There are several key unroofing events in the Mid-Jurassic, Late Jurassic and Early Cretaceous alternating with periods of subsidence and deposition, culminating with severe uplift and exhumation in the Late Palaeocene, followed by an Oligo-Miocene event.

Early Jurassic rocks probably once covered much of the UK region, with shale and carbonates to the south and more clastic dominated facies in the north, prior to Aalenian uplift and unroofing of the mid-North Sea Dome. As this subsided during M-eL Jurassic, it was gradually onlapped by fringing deltaic-paralic and shallow marine depositional systems. With increasing rift-generated topography in later Jurassic time, much of this earlier sedimentary cover was stripped off inter-rift platforms and recycled into adjacent grabens. The main axis of rifting jumped westwards to the North Atlantic in the Early Cretaceous when the marginal areas of western Britain, Ireland and adjacent offshore were partially exhumed. As rifting waned, the region subsided and transgressed by shallow marine sands passing up into laterally extensive chalks with marls and shales in the north during the Late Cretaceous. Intra-Tertiary unroofing removed much of the Cretaceous and earlier remnant Jurassic from the western lands and caused a pronounced easterly tilt and progressive pattern of older subcrop to the west leaving the rather ambiguous stratigraphic record of today.
ABSTRACT

Jurassic and Cretaceous palaeogeographic reconstructions of the UK are constrained by extensive well and field exposures that provide both lithofacies and biostratigraphic control. However, this information is limited to ‘remnant’ sections preserved after regional erosional events presenting a biased perspective of originally more extensive pre-erosion depositional systems. Stratigraphic clues remain in the preserved section which can be used to develop a more comprehensive understanding of sequence architecture including: isolated outliers of sequences more fully developed in adjacent grabens; facies characteristics of once more laterally extensive depositional systems now limited to scattered erosional remnants; and sediment recycling of pre-tectonic sediments into intra-graben lows. While missing section cannot be studied directly, its effect can be detected by palaeo-thermal indicators such as apatite fission track analyses, sonic velocities and vitrinite reflectance, allowing a much more robust reconstruction than is possible from the preserved section alone. There are several key unroofing events in the Mid-Jurassic, Late Jurassic and Early Cretaceous alternating with periods of subsidence and deposition, culminating with severe uplift and exhumation in the Late Palaeocene, followed by an Oligo-Miocene event. Early Jurassic rocks probably once covered much of the UK region, with shale and carbonates to the south and more clastic dominated facies in the north, prior to Aalenian uplift and unroofing of the mid-North Sea Dome. As this subsided during Middle Jurassic, it was gradually onlapped by fringing deltaic-paralic and shallow marine depositional systems. With increasing rift-generated topography in later Jurassic time much of this earlier sedimentary cover was stripped off into rift-platforms and recycled into adjacent grabens. The main axis of rifting jumped westwards to the North Atlantic in the Early Cretaceous when the marginal areas of western Britain, Ireland and adjacent offshore were partially exhumed. As rifting waned, the region subsided and transgressed by shallow marine depositional systems. With increasing rift unroofing, much of the Cretaceous and earlier remnant Jurassic from the western lands and caused a pronounced easterly tilt and progressive pattern of older subcrop to the west leaving the rather ambiguous stratigraphic record of today.

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The Mochras Farm borehole, located on the west coast of Wales, was drilled (1967-1969) through Tertiary cover and unexpectedly encountered a very thick (1305m) section of Lias. The Cambrian and older section outcrops just to the east, upthrown to the Mochras fault.

The conventional concept of Wales and much of northern and central England being an ancient highland during the Mesozoic has to be revisited. AFTA data from adjacent onshore outcrops show Early Cretaceous cooling, interpreted as due to uplift and erosion involving removal of Triassic and Jurassic cover, with remnants only preserved in downthrown faulted areas.
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**MIDDLE JURASSIC**

### Unst Basin Location and Sea Bed / Pre-Tertiary subcrop Map, plus seismic line

The Unst Basin lies in a shallow perched position. The facies similarity and subcrop geometry suggest that the Jurassic and Early Cretaceous cover extended across Scotland prior to intra Tertiary uplift and unroofing.

**INTERPRETATION**
- Previous reconstructions constrained by subcrop and well control, but lack incorporation of impact of later erosional events (Late Jurassic, Early Cretaceous and Intra Tertiary).
- Here we propose to link the preserved subcrop remnants to the submarine outcrops by extrapolate more extensive depositional systems across the UK area.
- Evidence includes the reworking of older Jurassic into the Late Jurassic (Helmsdale Boulder Beds, Magnet).
- Plus stratigraphic continuity of the Middle Jurassic deltaic facies belt.

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**LATE JURASSIC**

**CRETACEOUS**

**Cretaceous Summary**
- Deposition of onlapping Early Cretaceous units during Late Cimmerian Tectonism – Rifting of Atlantic borders and North Sea with associated burial of rifted margins by younger Cretaceous deposits.
- Early Cretaceous infill of rifted topography dominated by calcareous muds plus prominent deep marine clastic reservoirs in the Moray Firth. Coastal sediments recycled into deep marine or later eroded. Erratics of these present to north of Aberdeen.
- Late Cretaceous general subsidence dominated by chalks in south and calcareous muds in the north. Some shallow marine sands preserved on the west coast of Scotland and the Antrim area of Ireland.
- Probable near total submergence of Scotland occurred during the Senonian (Millenium Atlas).

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**Open Marine**
- Buzzard Field - Late Jurassic deep marine gravity flow sands sourced from the Grampian Spur to the SW. Buzzard sands contain recycled sediments from Permo-Trias redbeds and older Jurassic paralic sediments. Recycling of older Jurassic into the coeval deep marine Helmsdale Boulder Beds also identified indicating the proximity of coastal Jurassic sediments to the west.

**Kimmeridgian UK Palaeogeography**
- Authors' views in Brown text.
- Future revised maps are work in progress.

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The Enigma of the Missing Rocks
Where have all the missing rocks gone, deep time passing Onshore outcrops, there are none, that much we know Not a trace, the rocks have gone Eroded, recycled everyone Uplifted and unroofed in turn Enigma solving - our concern

SUMMARY

- Many Jurassic and Cretaceous palaeogeographic reconstructions of the UK and its continental shelf appear closely constrained by very extensive well and outcrop lithofacies and biostratigraphic control.
- However, this information is largely limited to ‘remnant’ sections, preserved after regional erosional unroofing events, and so offers a rather biased perspective of originally more extensive pre-erosion depositional systems.
- Any palaeogeographic interpretation attempting to account for such missing rocks must inevitably be speculative. Nevertheless stratigraphic clues remain in the preserved section which can be used to develop a more comprehensive understanding of Jurassic sequence architecture. Such clues include: isolated outliers of sequences more fully developed in adjacentgrabens; facies characteristics indicative of once more laterally extensive depositional systems now confined to grabens; or scattered erosionalremnants and sediment recycling of pre-tectonic sediments into deep water intra-graben systems. These lines of stratigraphic evidence are supported by a regionally extensive opalite fission track data base, which indicate the episodes of original deeper burial then uplift and erosion.
- Together they highlight a number of key unroofing events in the Mid-Jurassic, Late Jurassic and Early Cretaceous, culminating with severe uplift and exhumation during the Tertiary. These erosional events alternated with periods of subsidence and deposition.
- The interpretations presented in this poster are based on sound geological principles and provide a holistic approach to the late Mesozoic geological evolution of this area of North West Europe.
- Early Jurassic rocks probably once covered much of the UK region, with shall and carbonates to the south and more clastic dominated facies in the north, which was partially eroded by Aalenian uplift and unroofing of the mid-North Sea Dome.
- As this subsided in Middle to early Late Jurassic, the region was gradually onlapped by fringing deltaic-paralic and shallow marine depositional systems.
- But with increasing rift-generated topography in later Jurassic, much of this earlier cover was stripped off inter-rift platforms and recycled into adjacent grabens.
- The main axis of rifting relocated westwards to the North Atlantic margin during the Early Cretaceous and the associated uplift of western Britain, Ireland and adjacent offshore was responsible for further exhumation.
- As this waned in the later Cretaceous, the region subsided to be transgressed by shallow marine sands passing up into laterally extensive chalks with marls and shales to the north.
- A final phase of intra-Tertiary unroofing removed much of the Cretaceous and earlier remnant Jurassic from western lands to leave the rather ambiguous scattered stratigraphic records of today.

AFTA COOLING EVENTS INTERPRETATION

Scotland – Western Highlands
- Cooling below 130°C episode in Late Palaeozoic due to uplift and erosion coincident with the Caledonian Orogeny.
- Reheating due to sediment burial through to Triassic led to another cooling episode (common throughout Scandinavia, Eastern Canada and parts of NW Europe), due to uplift and erosion (removal of much of the Palaeozoic cover, recycling of Carboniferous and Devonian) possibly due to the early break up of Pangaea.
- Further sediment burial from Triassic through Jurassic to Late Cretaceous (80 to 130°C in different samples).
- Then cooling which began in the Early Cretaceous.
- No cooling through the Late Cretaceous to reach palaeotemplatures around 40°C, and subsequent Neogene uplift and erosion and recycling of former Mesozoic cover sediments, particularly into the Palaeocene and Eocene (e.g. Faroe sand in the North Sea and Viking Sand in the West of Scotland).

Scotland – Eastern Coaingore
- No early Palaeozoic cooling observed (overprinted by later events).
- Late Carboniferous cooling episode associated with uplift and erosion coincident with the Hercynian orogeny (removal of some of the Palaeozoic cover, recycling of Carboniferous and Devonian).
- Reheating due to sediment burial through to Triassic led to another cooling episode (common throughout Scandinavia, Eastern Canada and parts of NW Europe), due to uplift and erosion (removal of much of the Palaeozoic cover, recycling of Carboniferous and Devonian).
- Reheating due to sediment burial in Late Triassic followed by Jurassic cooling associated with uplift and erosion, possibly resulting in burial of western highland region.
- Slow burial of area through to Neogene with localised Palaeocene cooling due to Neogene unroofing, then uplift and erosion through to meso unconcerned cooling (recycling of basin area Palaeogene cover into North Sea).