Rivers and Rifting: Evolution of a Fluvial System during Rift Initiation, Central Corinth Rift (Greece)*

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Abstract

Standard models for initiation of continental rifting show normal faults nucleating and growing to form isolated hangingwall depocentres that enlarge and merge due to lateral fault propagation and linkage. Sedimentation rates are usually higher or equal to accommodation during the early, pre-linkage phase with footwall-derived consequent drainage systems supplying fluvial to lacustrine sediments. However, these models do not consider the impact of antecedent river systems on facies and thickness distribution in early rifts. Stratigraphic and sedimentological analysis of the Pliocene-Recent Corinth rift is here used to understand the architecture of early rift alluvial/fluvial systems from source to sink. In the northern Peloponnese, these are preserved in a series of uplifted E-W normal fault blocks incised by present-day north-flowing rivers. By correlation of fluvial successions across normal fault blocks, we propose a new sedimentary model for early rifting. The use of magnetostratigraphy and the determination of burial age using cosmonuclides 26Al/10Be give temporal constraints along four logs. The early rift fining-upward succession thickens and fines from west to east across normal fault blocks. A basal conglomeratic unit infilled an inherited paleotopography. Palaeocurrent and sedimentological data indicate that an antecedent drainage system provided high sediment supply since the onset of rifting. Fluvial sediments were deposited by a NE-flowing low sinuosity gravel-braided river system. Earliest normal faults are sealed by syn-rift sediments as displacement became focused on larger normal faults (15–20 km long, across-strike spacing of >4 km). Little or no consequent sediment supply has been detected and therefore significant footwall relief was not created during early rifting. Spatial variability of facies records displacement gradients along faults. For
example, coarse alluvial conglomerates tend to occur in the centre of hangingwall depocentres while finer floodplain deposits accumulated along strike. At the rift scale, however, normal fault distribution and activity do not solely control facies distribution, being overwhelmed by high sediment discharge of the antecedent river. We develop a tectono-sedimentary model of normal fault growth and potential fluvial-lacustrine reservoir distribution in early rifts with high S:A ratios that involve antecedent drainage systems and distributed normal faulting.

**References Cited**


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Tectono-sedimentary model of early rift phase

Normal fault system initiation  \rightarrow  Fault propagation and linkage

- Tectono-sedimentary models of the early rift are based on footwall-derived sediments.
- Syn-rift sedimentation is the direct response to tectonic activity.
- The role of the inherited drainage system is not considered.

(modified from Cowie et al., 2006).

(Gawthorpe & Leeder, 2000).
• Implications of a major antecedent drainage system:
  — Presence of a paleotopography;
  — High sediment supply at rift initiation.

• How do rivers respond to the development of normal fault system?

• How important is it for syn-rift facies distribution and characterization of petroleum reservoirs?
Study area: southern margin of the Corinth rift

- Inactive and uplifted fault blocks provide good exposures of the early rift deposits.
- The gulf of Corinth mostly defines the seismically active part of the rift.
- Incision by the present day rivers provides exposure of the early syn-rift deposits.
- Growth strata along the north-dipping faults: syn-sedimentary tilted block or forced folds.
Onshore stratigraphy in the central Corinth rift

- In the eastern rift, basin deepening occurs during early rift stage.
- Middle group conglomerates and fluvio-deltaic deposits.
- Middle group deposits mark the onset of basin deepening in the central rift.
- The Lower group fluvial system evolve from SW to NE, from coarse alluvial conglomerates and fluvio-deltaic deposits.
Approach and methods:

- Facies analysis and distribution in the study area;
- Correlations between fault blocks by combining lithostratigraphy and age constraints.
- Stratigraphic controls: magnetostratigraphy, palynology, rats teeth.
Magnetostratigraphic correlations

Uncertain chron
Reversed polarity
Normal polarity
No data

Uncertainty in chronology and polarity changes is indicated on the graph. Key stratigraphic markers include:

- **Nitellopsis megarensis**: Upper Pliocene (>2.6 Ma)
- **Arvicolidae teeth**: Upper Pliocene (>2.6 Ma)
- **Palynology section**: >1.8 Ma

The graph shows correlations between different stratigraphic sections, including:

- Kerpini log
- Doumena log
- Ladopotamos log
- Voutsimos log
- Valimi log

Key geological features and fault blocks are also indicated:

- Pre-rift basement
- Kalavryta fault block
- Kerpini fault block
- Doumena fault block
- Ladopotamos fault block
- Valimi fault block

The time scale at the bottom of the graph indicates various time markers:

- 1.94 Ma
- 2.13 Ma
- 2.15 Ma
- 2.58 Ma
- 3.12 Ma
- 3.33 Ma
- 2.15 Ma

These markers are used to correlate different stratigraphic units across the study area.
Chronostratigraphic model

RIFT INITIATION

Lower group

STAGE 1

3.7–4.0 Ma

Drosato fin (lacustrine)

STAGE 2

3.3 Ma

Drosato fin (lacustrine)

Klavryta, Tsivlos faults blocks

STAGE 3

2.9 Ma

Coarse alluvial conglomerates

2.5 Ma

Kerpin fault block

STAGE 4

2.1–1.8 Ma

Coarse alluvial (boulders) conglomerates

1.8 Ma

2.1 Ma

Lagoonal and coastal plain deposits

Deltaic and shallow lacustrine deposits

Gravel-to fine-grained braided river deposits

Basal conglomeratic formation

Ladopotamos formation

Valimi formation

Kalavryta formation and Mega Spiliaio formations

Fine-grained member (Mega Spiliaio formation)

Mega Spiliaio formation

Kalavryta formation and Mega Spiliaio formations

10 km

Drosato formation

Katafugion formation

Ladopotamos formation

Lithopetra formation
Paleogeographic reconstructions: STAGE 1

4.0–3.7 to 3.3 Ma

Outcrop Interpretation

- Basal conglomeratic formation (Alluvial to high energy fluvial deposits)
- Pre-rift carbonates
- Paleocurrent direction
- Not observed fault
- Main active fault
- Onlap onto pre-rift topography

Pre-rift basement

Drosato lake

3.3 Ma

STAGE 1

3.7–4.0 Ma

Drosato fm (lacustrine)

Coarse alluvial conglomerates

Prinos & Tsivlos faults blocks
Doumena fault block
Ladopotamos fault block
Valimi fault block

3.3 Ma

Present day shoreline
STAGE 1: Basal conglomerates infilling paleotopography

- Basal conglomerates (Tsivlos fm)
- Pre-rift Pindos carbonates
- Lithopetra fm
- Mega Spilaio fm

- Stolos - 1508 m
- Petroux - 1345 m
- Krathis River

No exposure in the landslide area.
Paleogeographic reconstructions: STAGE 2

3.3 to ~2.9 Ma

Outcrop Interpretation

- Ladopotamos formation (Fluvial low energy)
- Lithopetra formation (High energy fluvial environment)
- Mega Spilaio formation (Alluvial to high energy fluvial)
- Drosato formation

- Paleocurrent direction
- Main active fault
- Not observed fault
- Onlap onto pre-rift topography

0 10 km

Pre-rift basement

2.9 Ma

Kalavryta fault block

Kerini fault block

Gravel- to fine-grained braided river deposits

STAGE 2

3.3 Ma
50–80% of sand and silt preserved within the Ladopotamos formation.
Paleogeographic reconstructions: STAGE 3

2.9 to 2.5 Ma

Outcrop Interpretation

- Ladopotamos formation (Fluvial low energy envt)
- Valimi formation
- Lithopetra formation (High energy fluvial envt)
- Fine-grained member (Mega Spilaio formation)
- Mega Spilaio formation (Alluvial to high energy fluvial envt)

Pre-rift basement

10 km

Homolithic gravel deposits (braided plain)

Deltaic and coastal plain deposits

2.9 Ma
Paleogeographic reconstructions: STAGE 4

2.5 to 2.1–1.8 Ma

- Valimi formation (lagoon and coastal plain)
- Main active fault
- Not observed fault
- Lithopetra formation (High energy fluvial environment)
- Onlap onto pre-rift topography
- Kalavryta formation (Alluvial to high energy fluvial)
- Fine-grained member (Kalavryta formation)

Pre-rift basement

2.1–1.8 Ma

STAGE 4

Coarse alluvial conglomerates

Lagoonal and coastal plain deposits

2.5 Ma
Conclusions

• Sediment supply is dominated by a large-scale antecedent drainage system.

• Limited evidence of local footwall-derived sediments during rift initiation.

• The fluvial depositional system extends > 50 km across several active tilted fault blocks. There is no existing facies model at this scale.

• Grain size and facies variations do not occur at the scale of individual fault blocks (5–10 km) but at the scale of the antecedent fluvial system.

• During rift initiation times, the main axis of fluvial transport crosscuts the major faults and remains constant.

• These observations from the Corinth rift emphasize the role of antecedent drainage systems in the tectono-stratigraphic evolution of rift basins.