Controls on Drainage and Facies Distributions in Continental Rift Basins*

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Abstract

Studies of modern and ancient continental rift systems are used to develop and refine models of drainage development and facies distributions, and to provide a more robust predictive model for the stratigraphic architecture of continental rift basins. Although facies models for rift basins are well established and have been widely tested, they are largely applicable to individual sub-basins within a rift province and rarely take into account the interaction between adjacent sub-basins. All these models assume that the rift province subsides at relatively constant rates and that sediment is preserved equally across all the sub-basins within the province. In reality this is rarely the case, with the majority of sub-basins in a rift province being developed at different elevations. The implications of this are that only a relatively small area of the rift province (10-20%) is actually accumulating sediment at any one time. Studies of modern rift provinces such as the Basin and Range and East African Rift indicate that net aggradation and therefore likely preservation in the rock record occurs in two types of basin, here termed: terminal and isolated.

Terminal basins occur at the lowest point(s) within a rift province and represent the terminus of the principal fluvial system(s) fed by an integrated drainage network developed across different half-grabens. Axial fluvial systems form erosional tributary drainage networks that link sub-basins and are therefore unlikely to be preserved. Isolated basins display endorheic drainage and are not integrated into the regional drainage network. Both basin types are dominated by transverse and/or longitudinal distributive fluvial systems and playa/lake deposits. The implications for the rock record are: 1) the detailed stratigraphic architecture of sub-basins in the same rift province will be significantly different, 2) correlation between adjacent rift sub-basins will be inherently difficult as it is unlikely that they will have been connected, 3) axial fluvial systems have little or no preservation potential and 4) the alluvial part of rift basin fill will be dominated by distributive fluvial systems.

References

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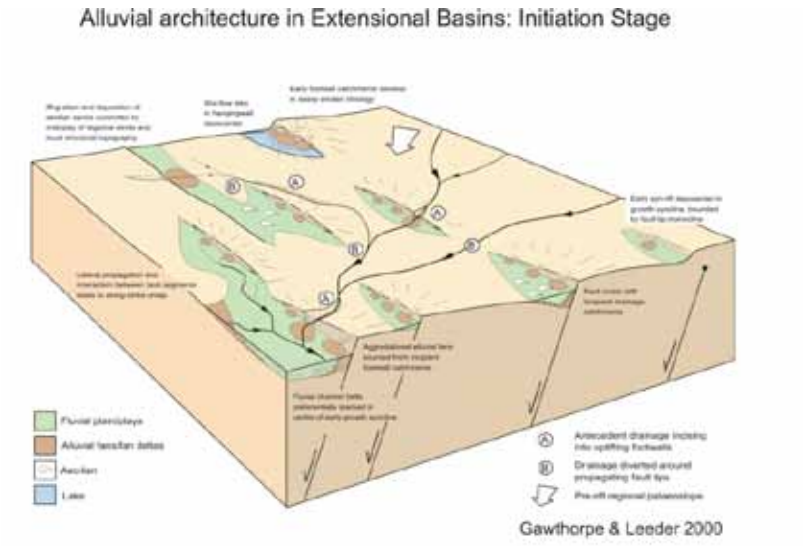
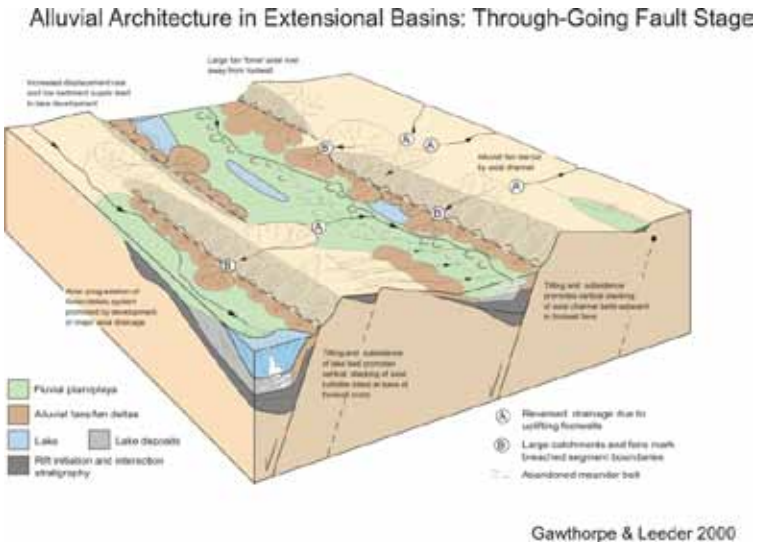
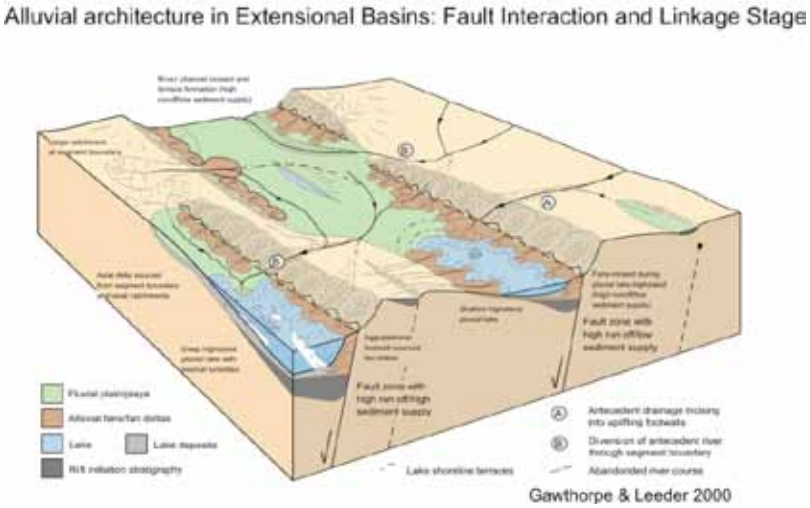
Outline

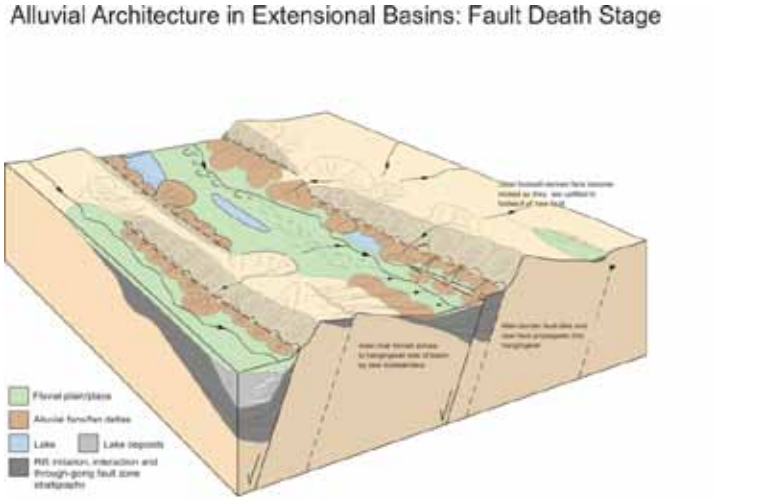
- Brief review of existing facies models in continental rift basins
- Examine facies distributions in modern continental rifts
  - Great Basin
  - East African Rift
- Discuss implications for rock record and predictive facies models

Existing facies models





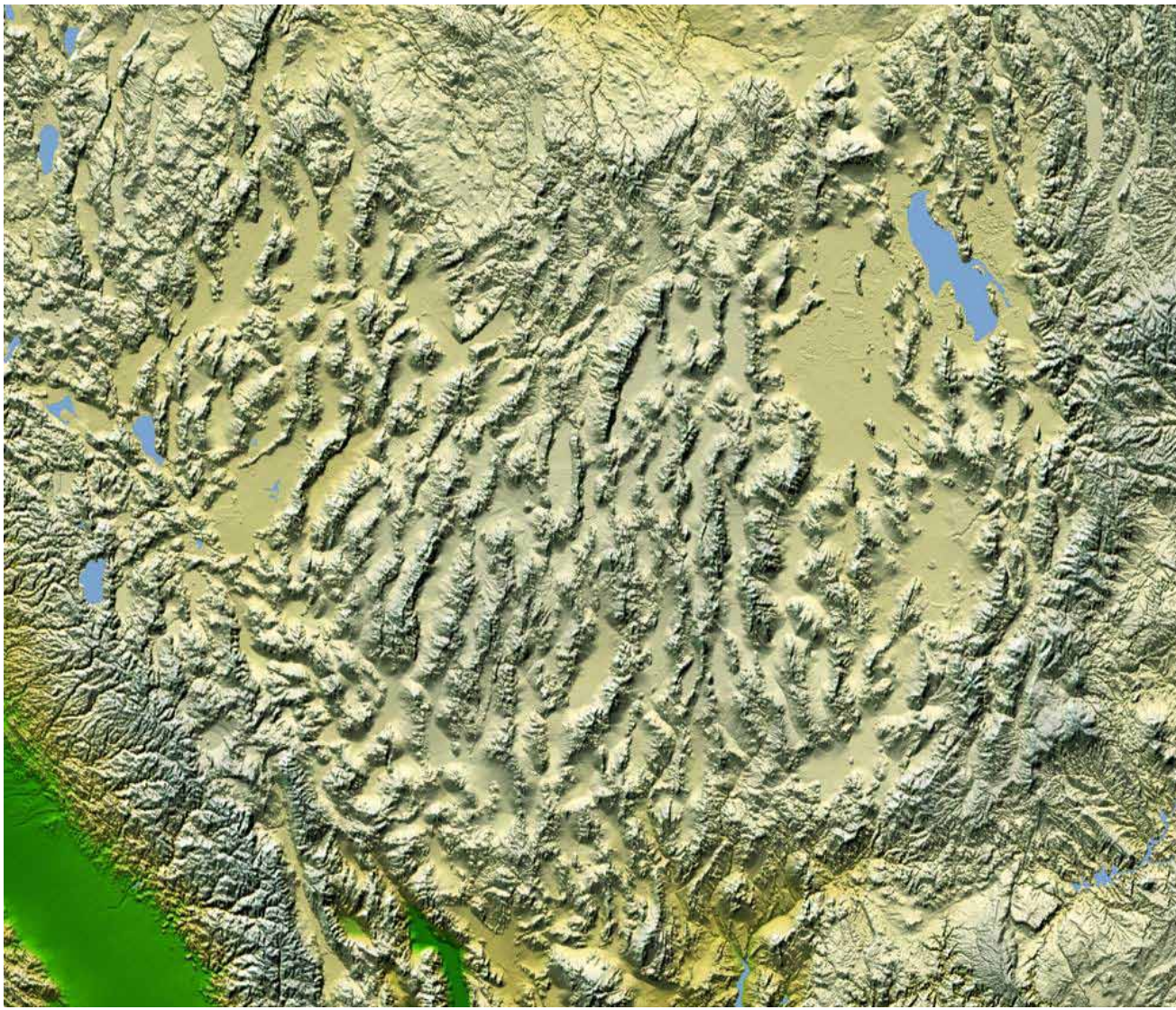




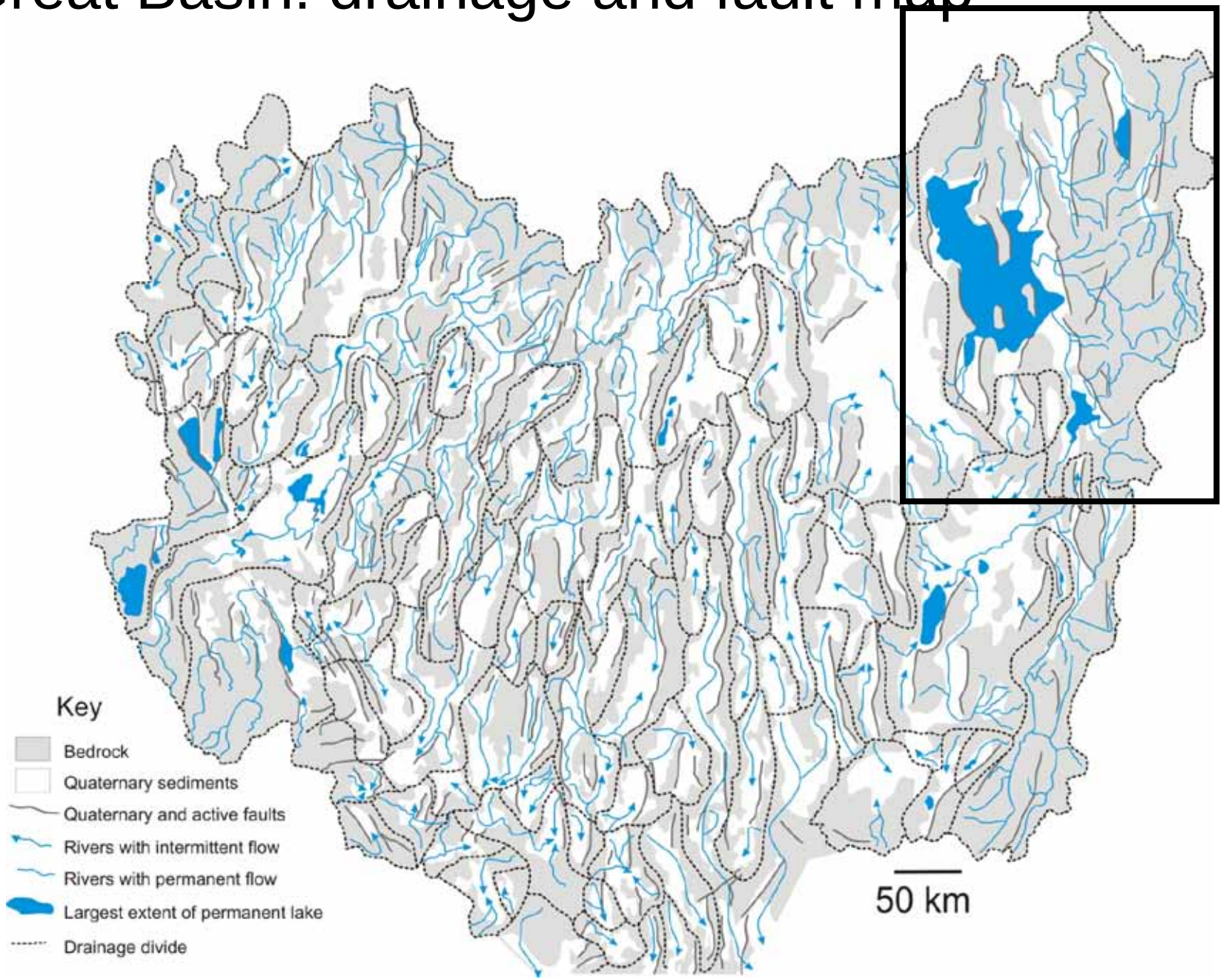
Note dominance of axial drainage

Drainage in Modern Rifts: Great Basin

- Numerous fault-bounded basins
- Highest elevation in centre
  - Largest basins on flanks
  - Smallest in centre

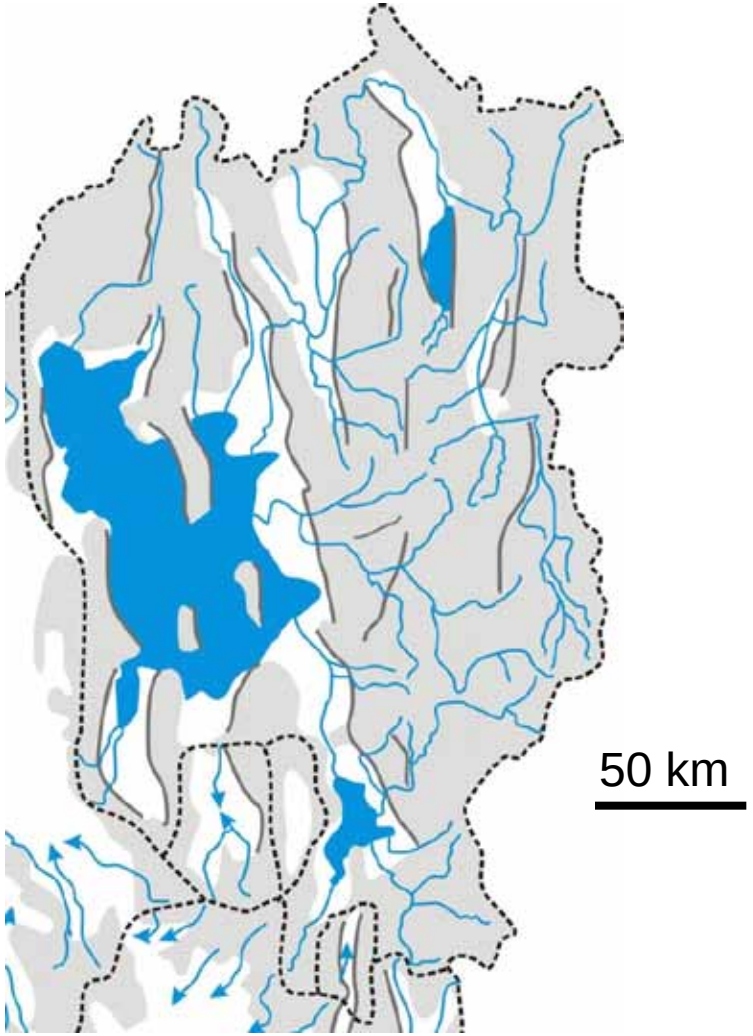


Great Basin: drainage and fault map

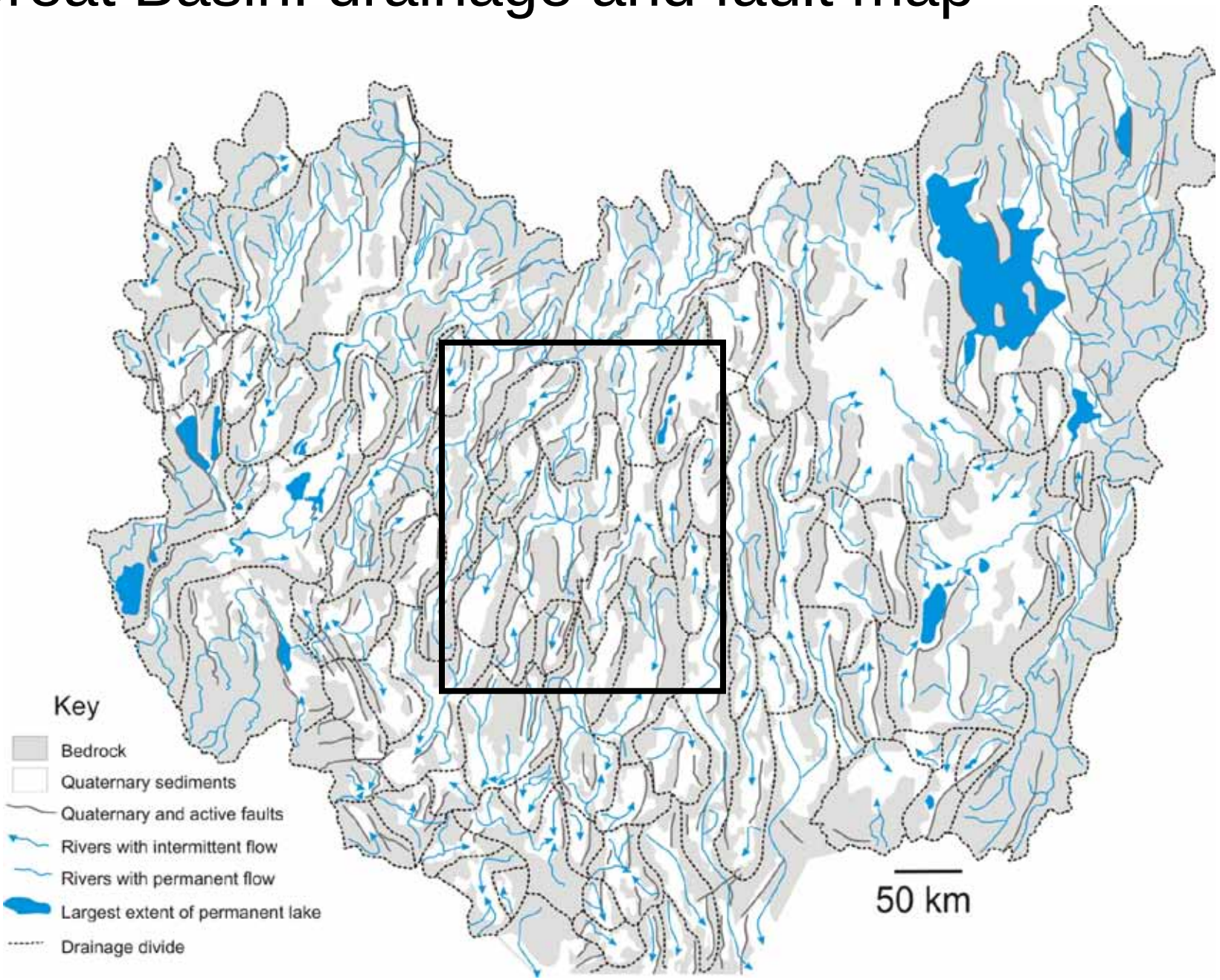


Edge of Great Basin: Salt Lake drainage

- Drainage from 12 fault-bounded basins (now subject to erosion)
- Integrated drainage systems due to capture
- Axial fluvial systems common but contributory and have no preservation potential

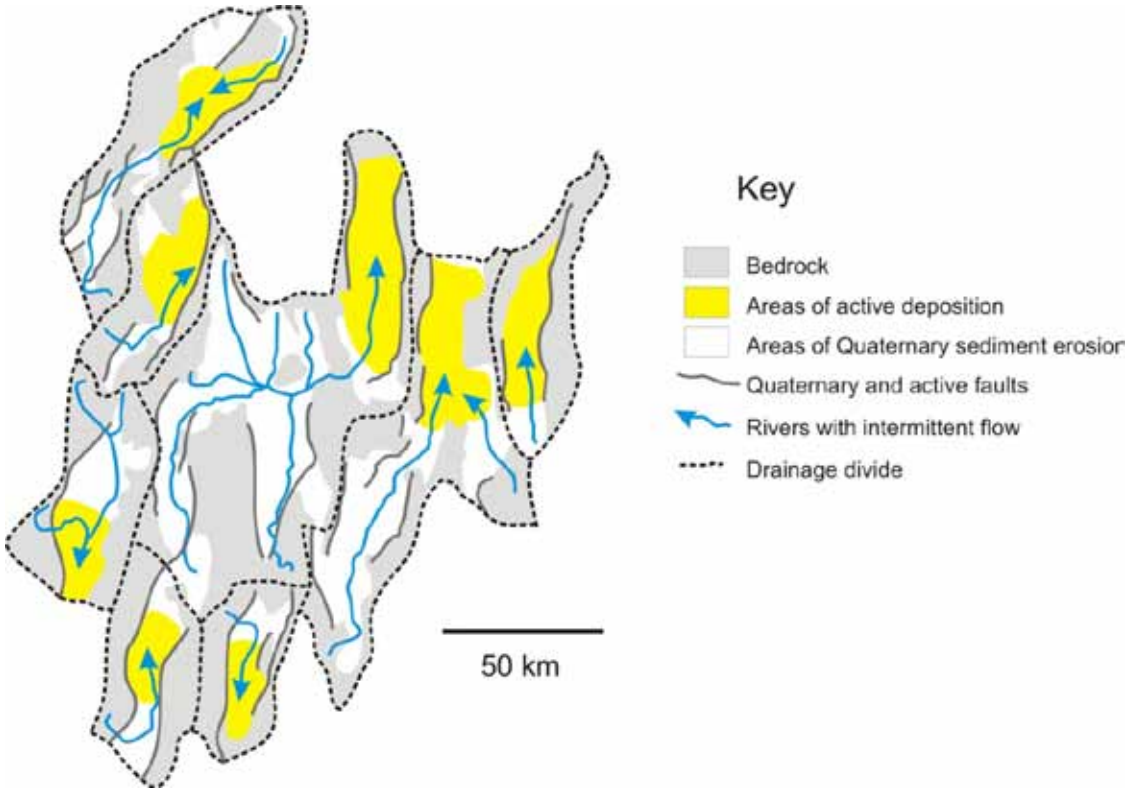


Great Basin: drainage and fault map



Centre of Great Basin

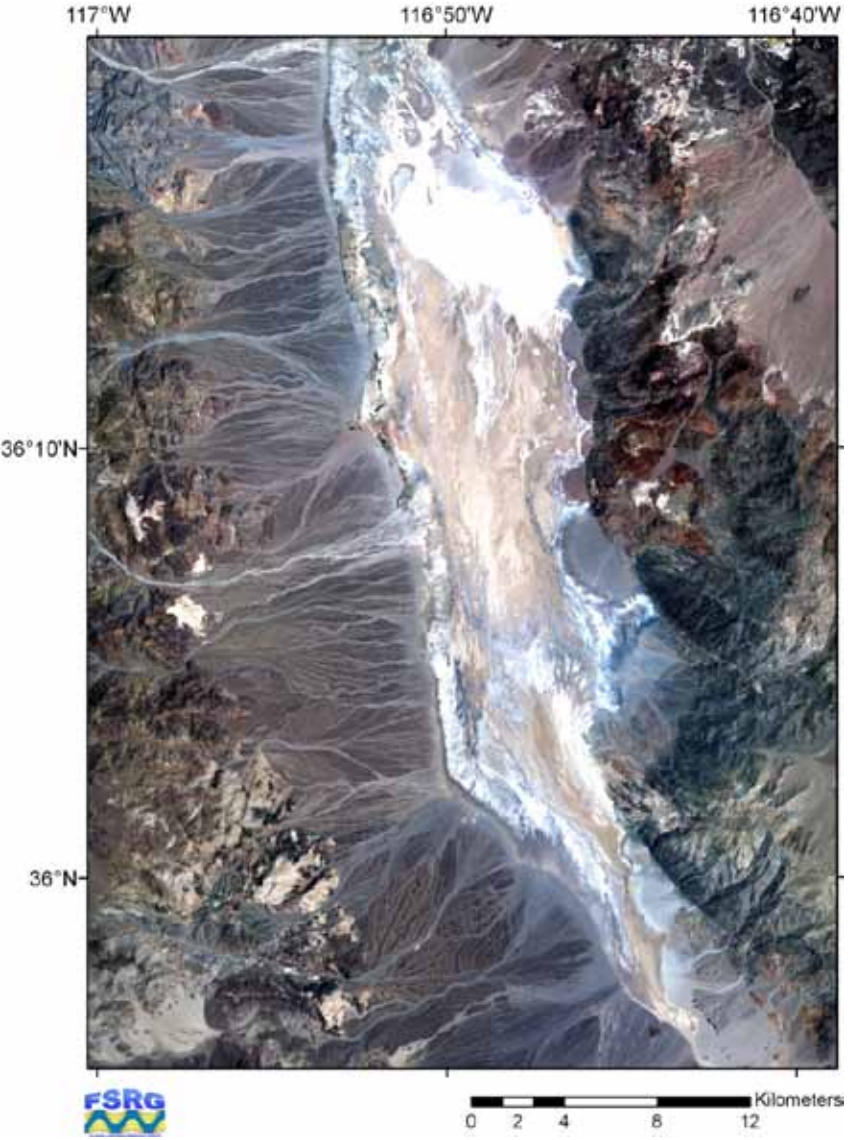
- Discrete, small, fault-bounded basins, two types: integrated and isolated
  - Integrated due to capture of drainage from adjacent (higher) basins
  - Isolated basins occur where drainage is derived from immediately adjacent ranges
- Axial fluvial systems common but have no preservation potential
- Area of active aggradation forms only 50% of basinal area



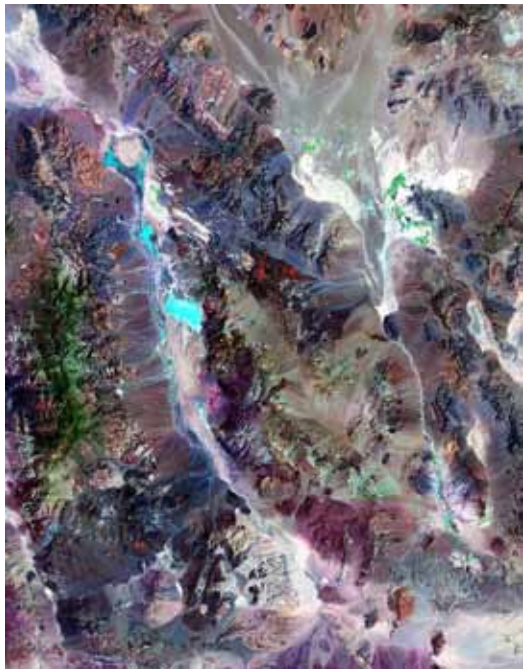
Great Basin: Facies types in isolated basins

- **Isolated basins are dominated by lateral systems (alluvial fans) , axial is minor**
- **Playas form minor component when sediment supply (relief) is high**

Great Basin: Facies types in integrated basins: Death Valley



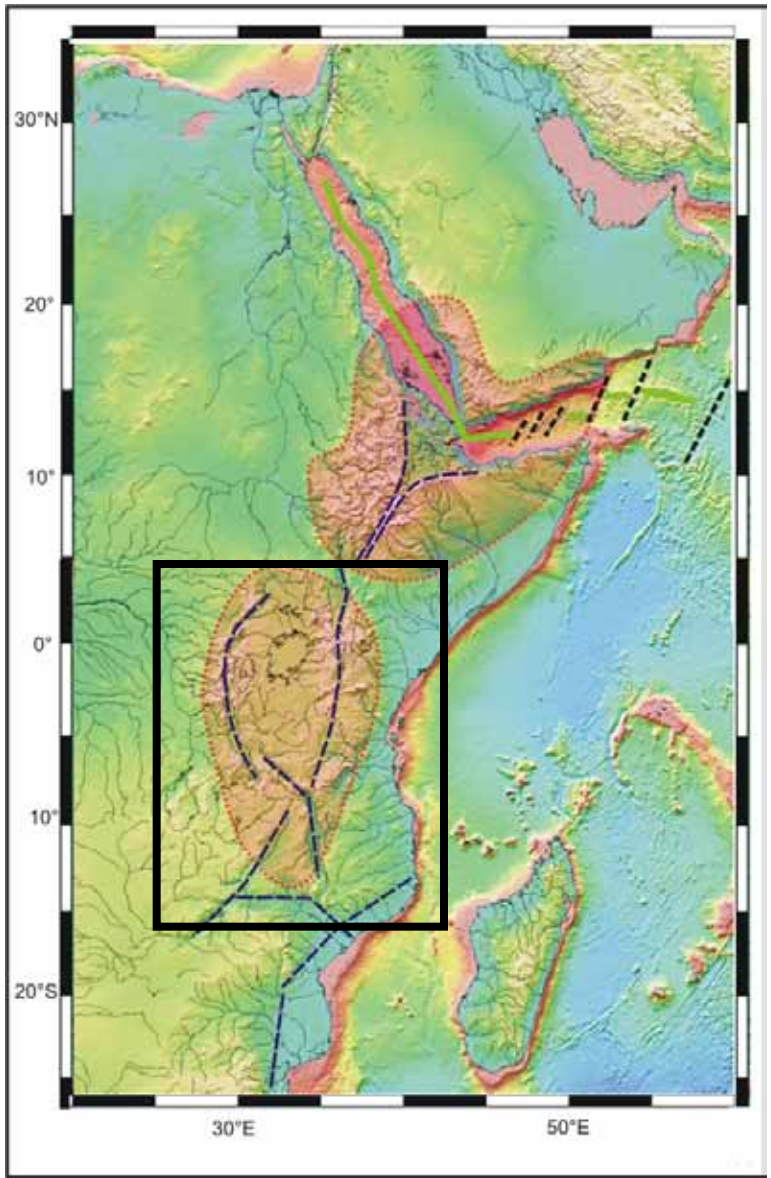
- Axial input forming a distributary fluvial system
- Lateral input important but forms only approx 50% of aggradational area

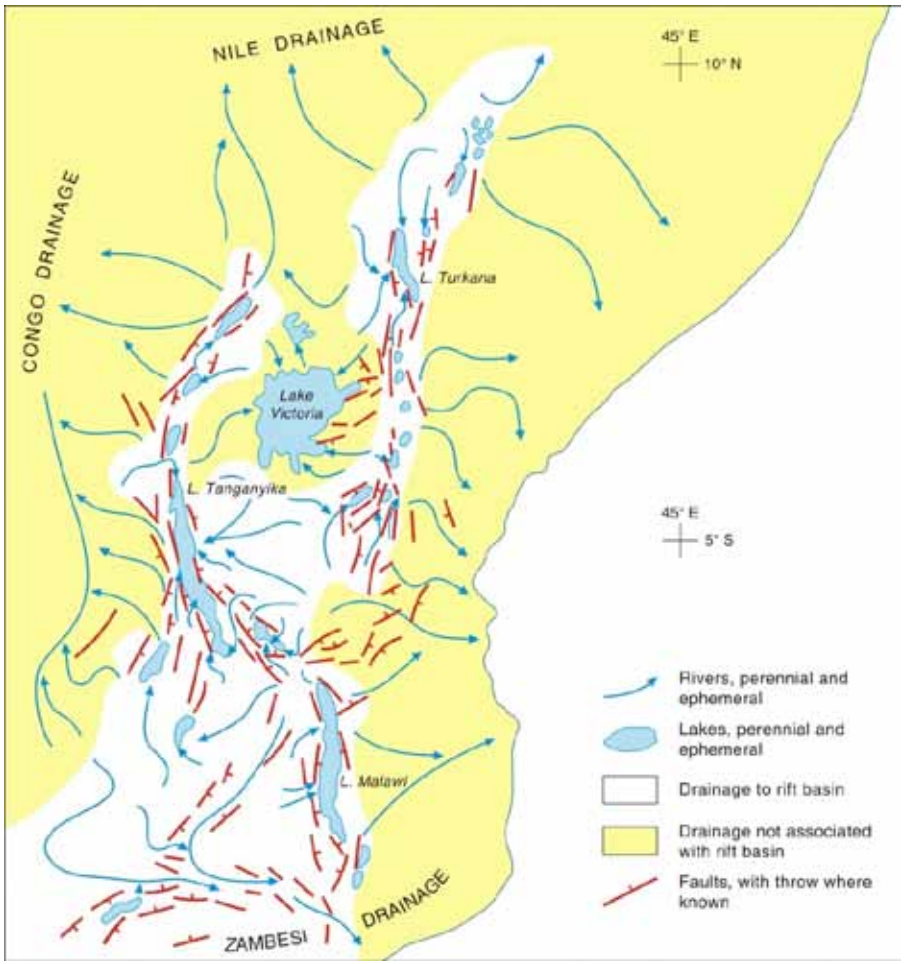


Key Points from Great Basin

- Two basin types based on drainage:
  - Integrated
  - Isolated
- Only small part of basinal area is actively aggrading and will therefore be preserved
- Axial fluvial systems comprise minor part of basin-fill as they are part of contributory drainage networks

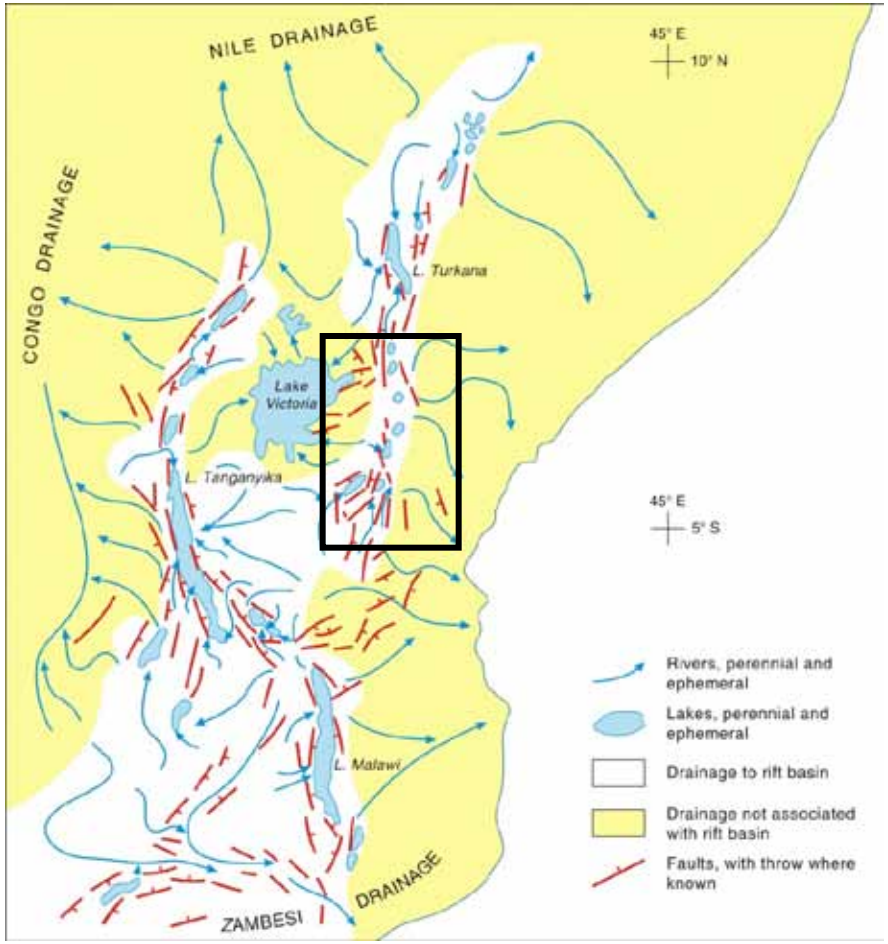
East African Rift: drainage

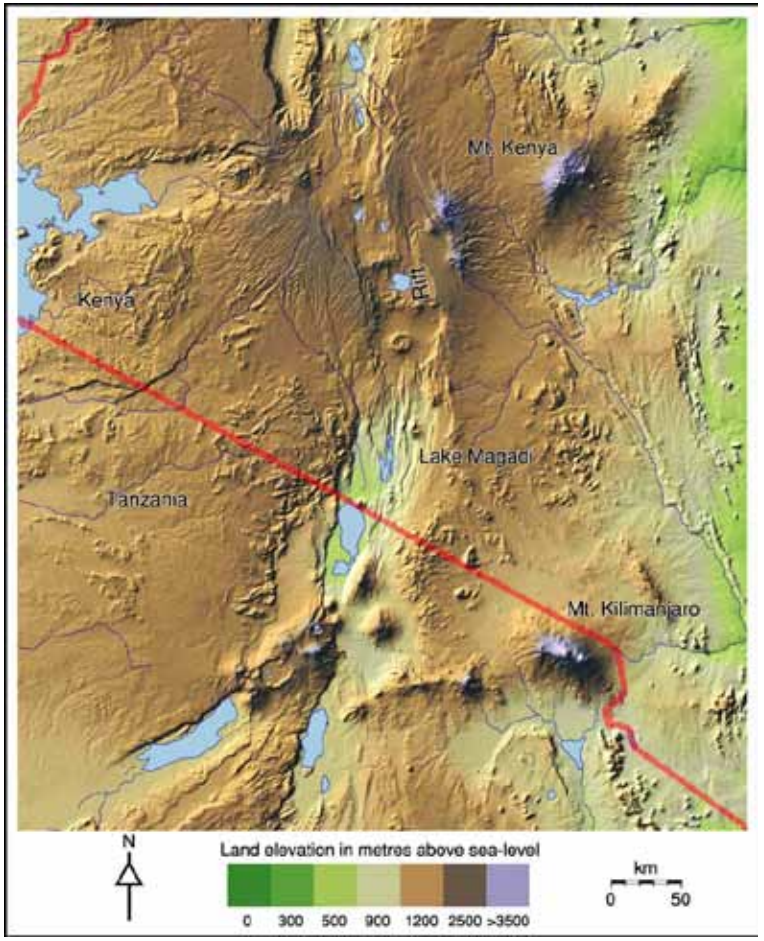




Modified from Frostick & Reid 1989

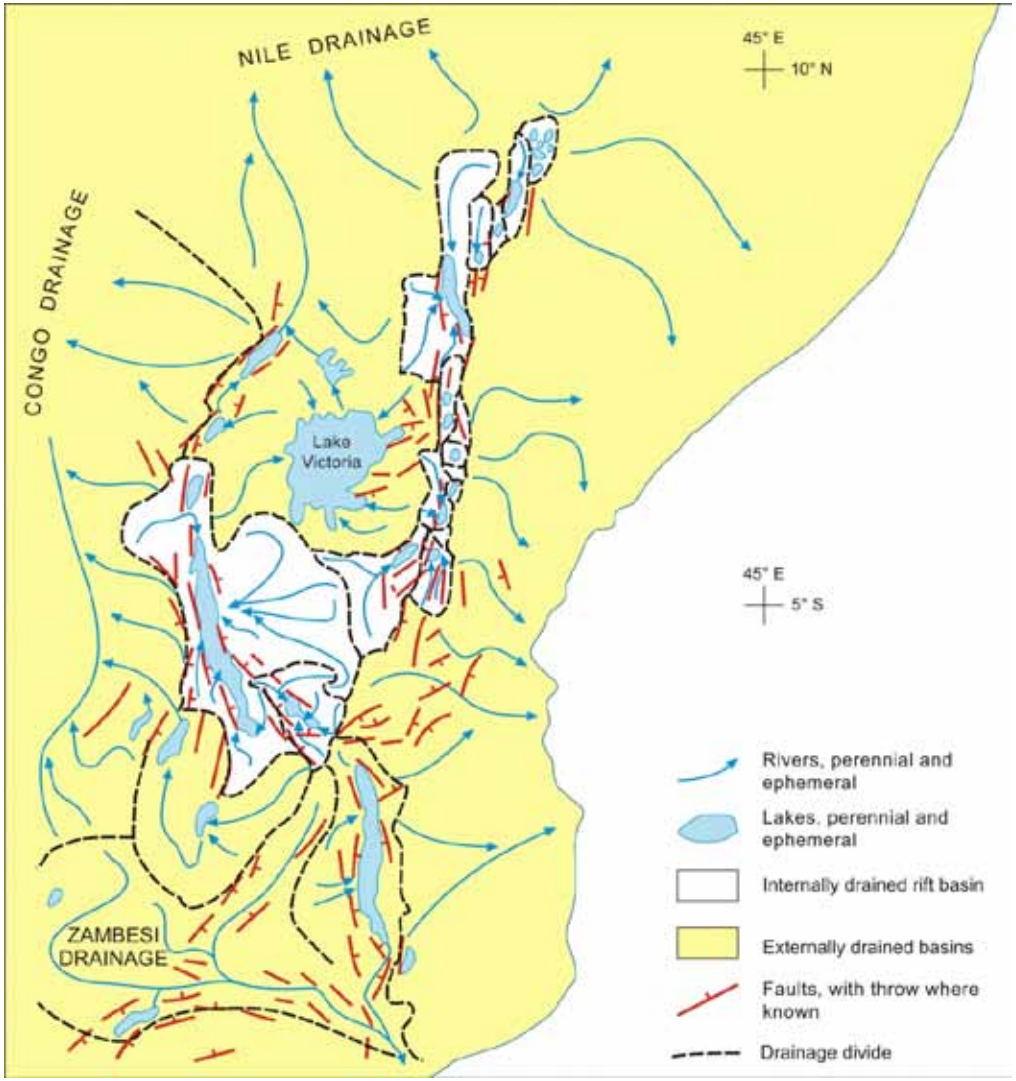
Impact of volcanism





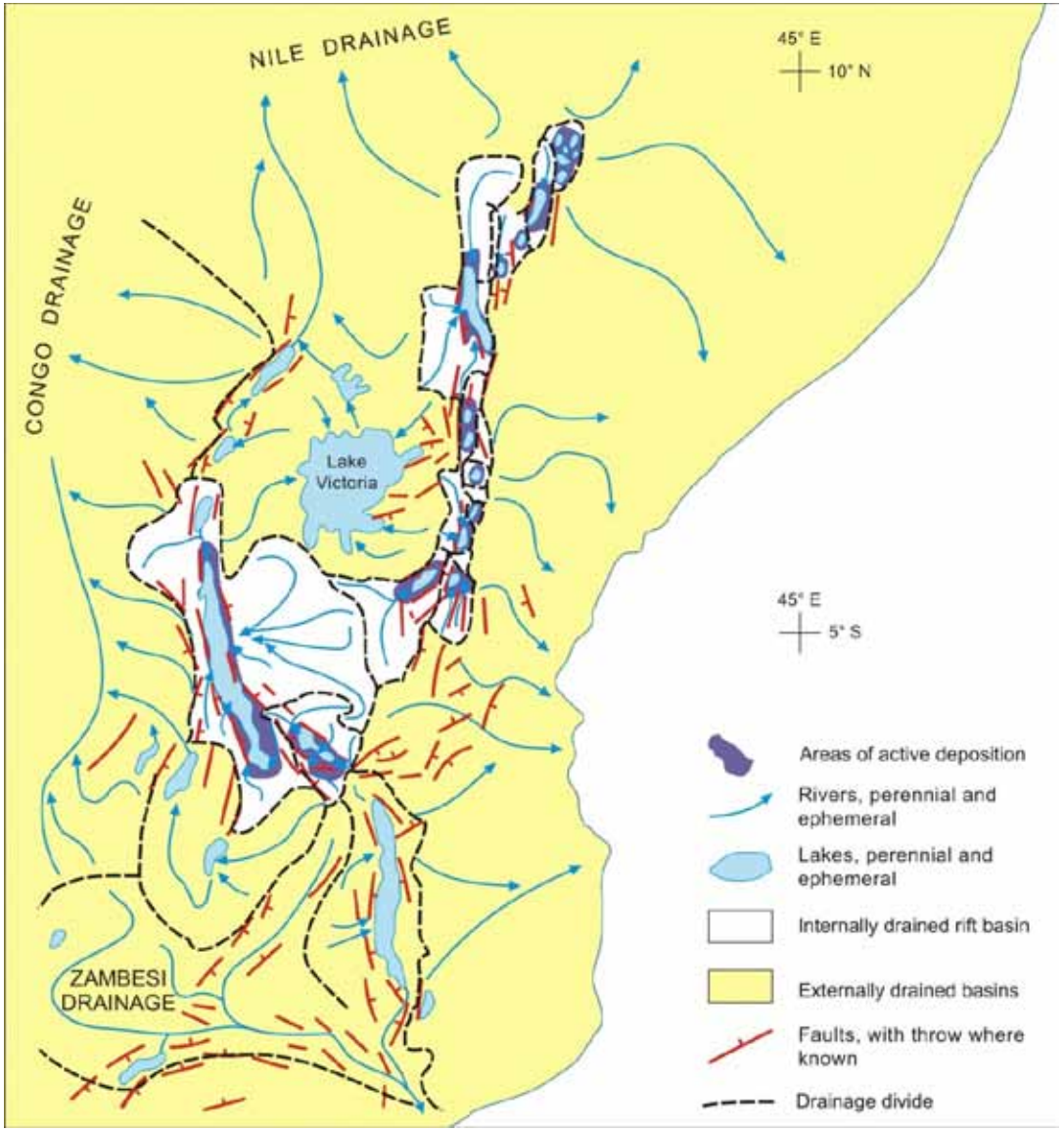
- Many of the smaller isolated basins form due to barriers related to volcanic activity

East African Rift: drainage into rift basins



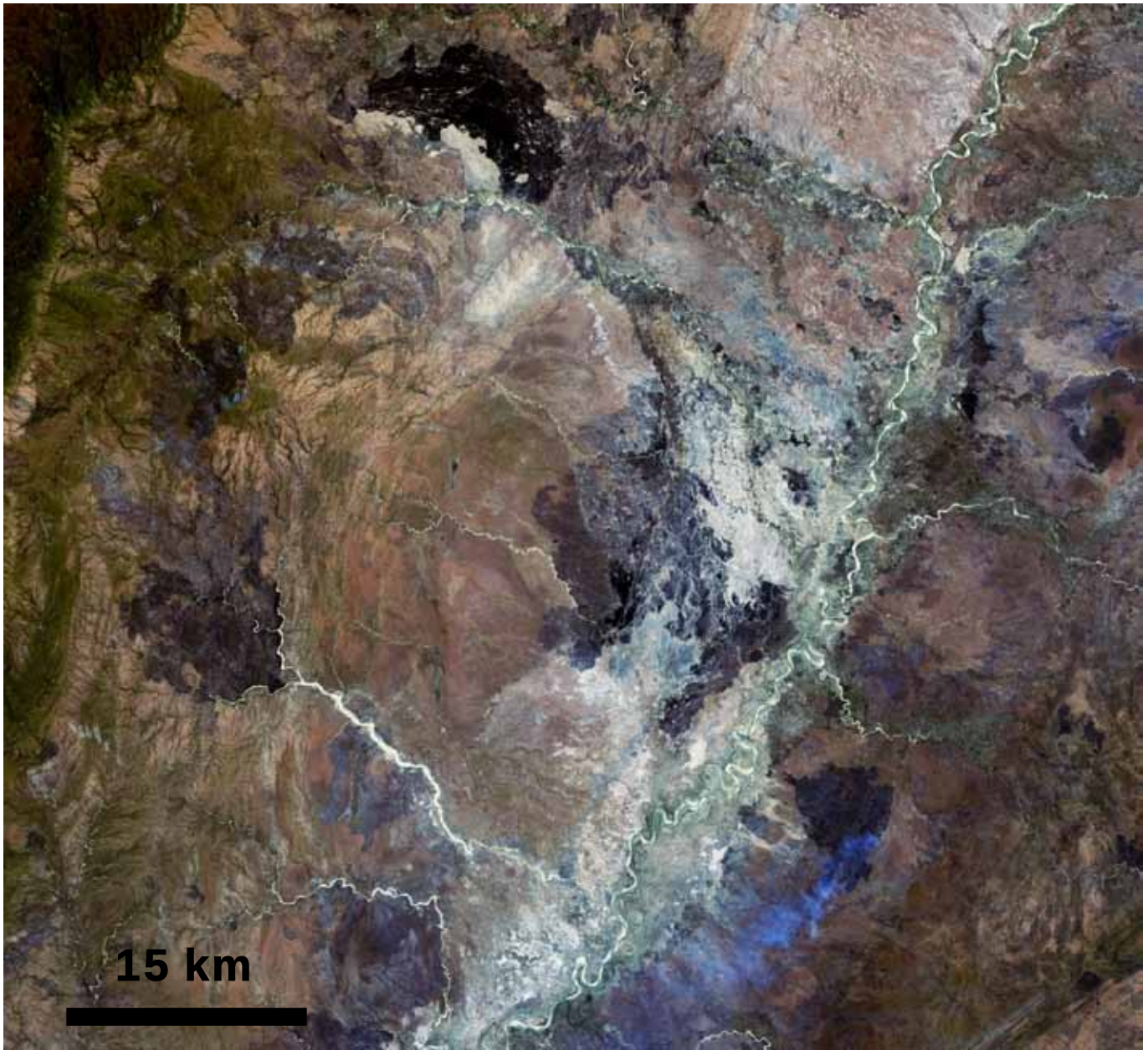
- Only a small area of entire rift is draining into rift basins due to capture by large, external river systems
- Two basin types: integrated and isolated

East African Rift: active depositional area



- Area of present day sediment accumulation is restricted to a small number of basins
- Axial fluvial systems are minor component of basin-fill

East African Rift: facies types in isolated basins



East Africa: facies types in connected basins

- Lake Manyara, Tanzania

Key Points from East Africa

- Two basin types based on drainage:
  - Integrated
    - Tend to be deeper with lake and minor axial DFS
  - Isolated
    - Tend to be dominated by lateral fluvial with lake deposits
- Only small part of basinal area is actively aggrading and will therefore be preserved
- Axial fluvial systems comprise minor part of basin-fill
  - form contributory drainage networks

Summary of East Africa and Great Basin

- Two basin types:
  - Small isolated basins supplied locally by adjacent ranges, dominated by lateral systems with minor axial component
  - Larger integrated drainages have lateral component but tend to be dominated by axial distributary fluvial system and basin centre facies in the form of permanent lake or playa depending on climate

Implications

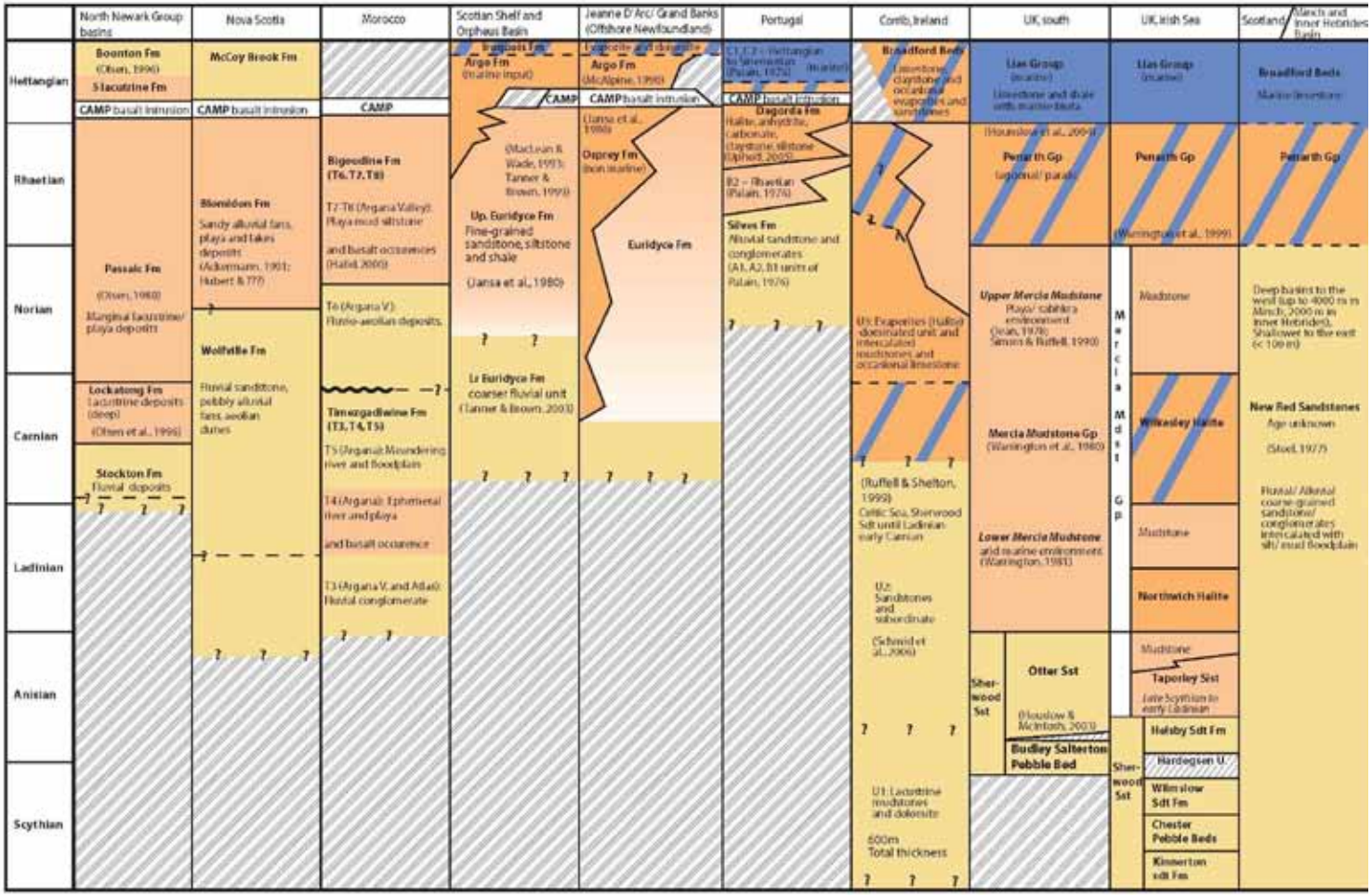
- The vast majority of rift basins will start as small, isolated, endorheic basins dominated by lateral input and minor basin centre facies
- These basins will either be:
  - Captured and eroded as drainage develops resulting in an unconformity or
  - Form the early fill of a larger integrated rift basin that is then overlain by basin centre and axial DFS deposits

Predictive Model

- Early stage of rift fill will be dominated by lateral systems with minor basin centre facies
- Late stage will be dominated by basin centre facies and axial DFS

Application to rock record

- Triassic stratigraphy of North Atlantic



Leleu & Hartley 2010 JGSL

Conclusions

- A predictive model for drainage development and fill of rift basins is developed from modern day observations
- Model applied successfully to ancient rift basins with significant differences to existing facies models in terms of predicting reservoir development and distribution
- Only the basins at the terminus of the drainage system are preserved
- Axial fluvial systems form a minor component of rift basins
  - because they link basins at different elevations they have low preservation potential