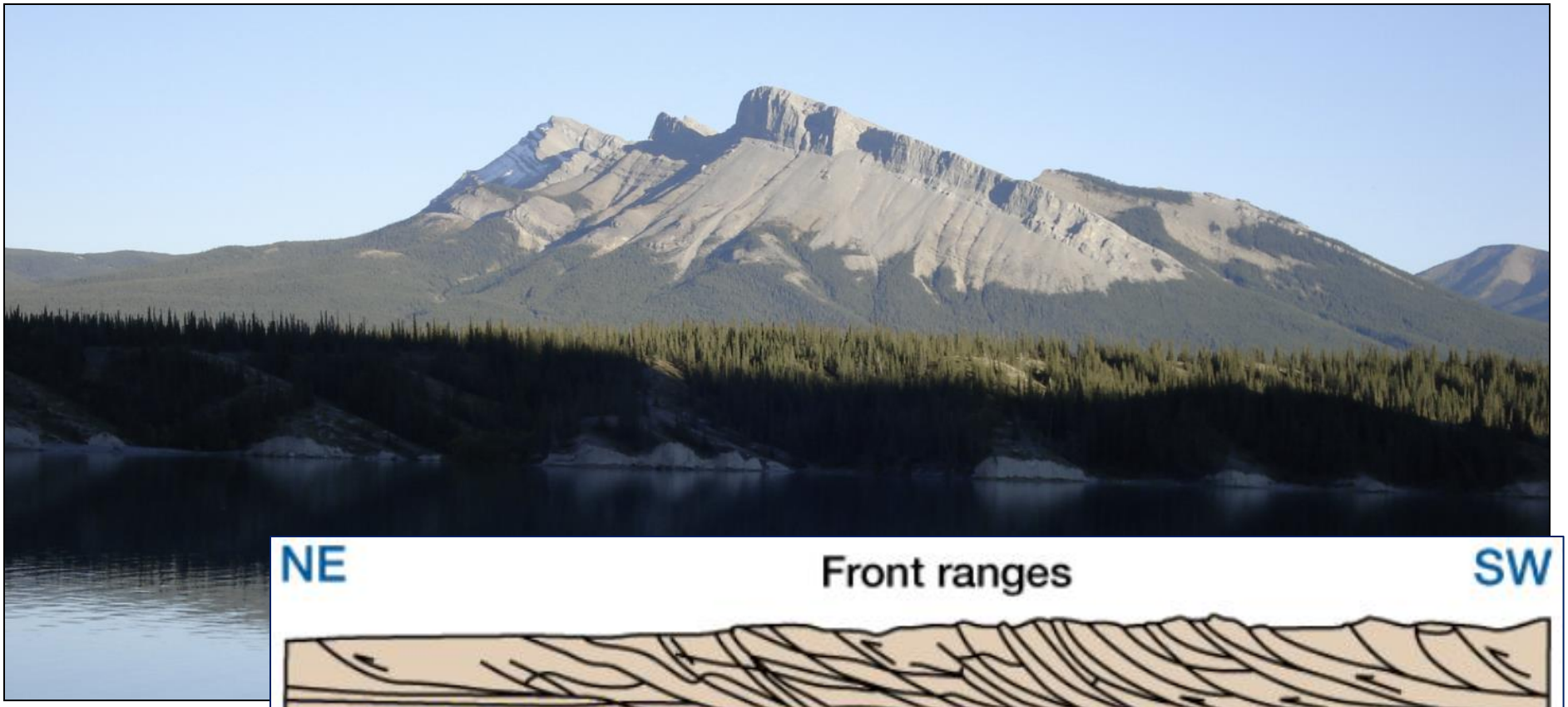
Structural Style in the Zagros: Implications for Hydrocarbon Systems

Richard Jones

Geospatial Research Ltd.

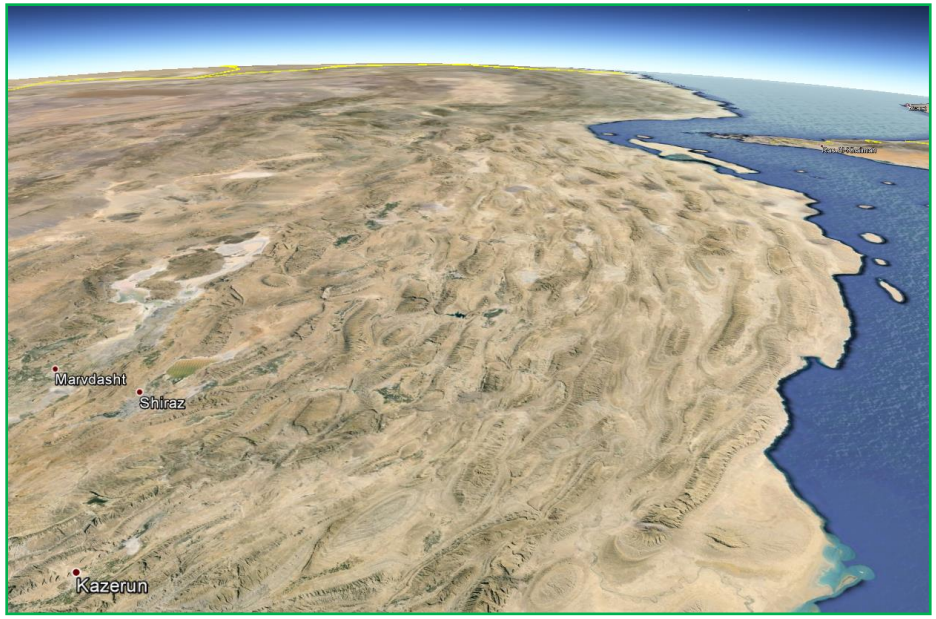
The Zagros 'Fold & Thrust' Belt!



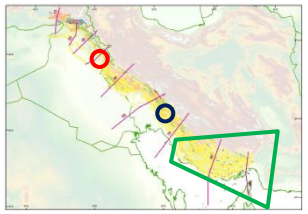
Canadian Rockies

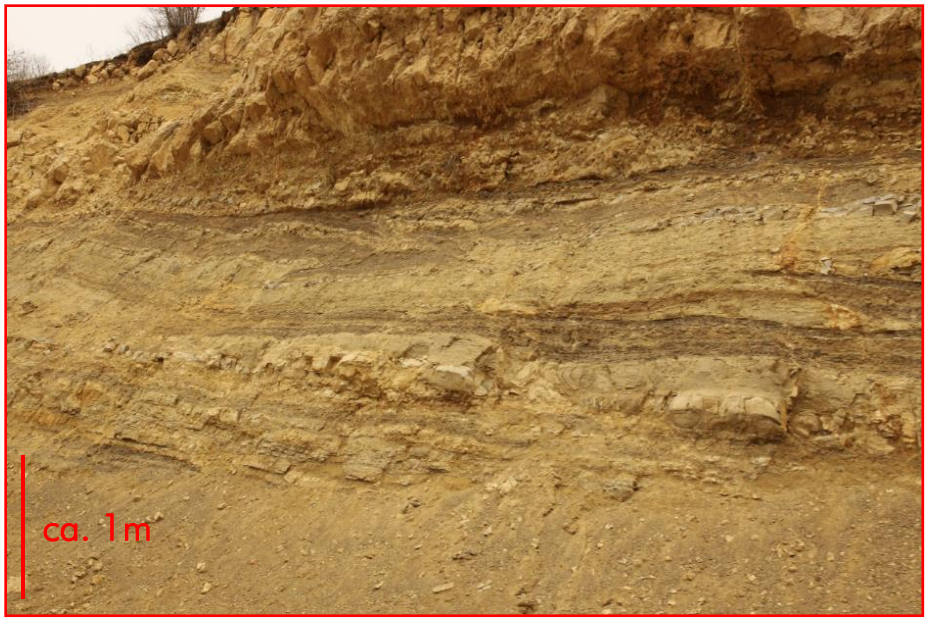
after Price & Mountjoy 1970 (AAPG)

The Zagros 'Fold & Thrust' Belt

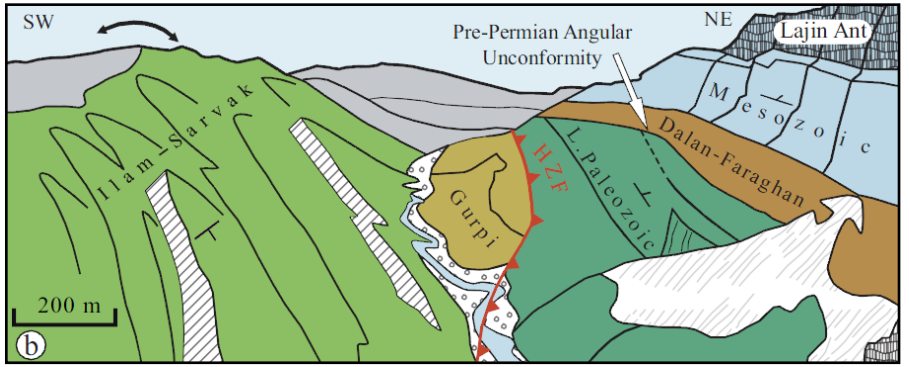


GoogleEarth, Fars (Iran), looking east



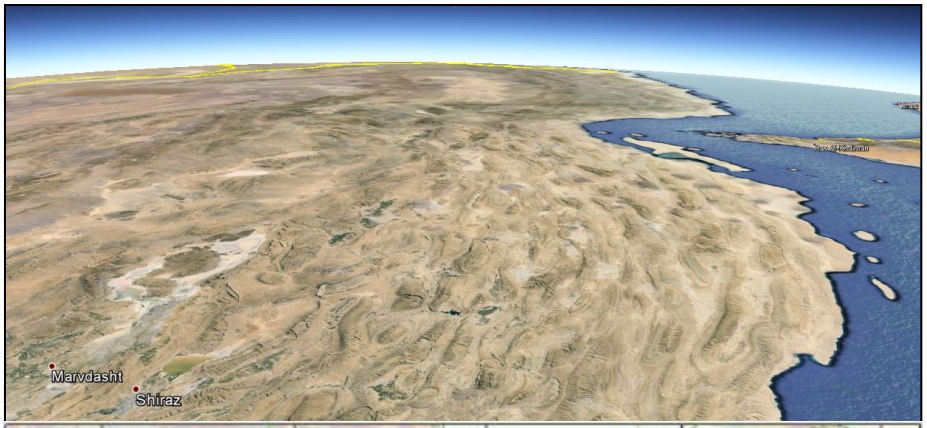


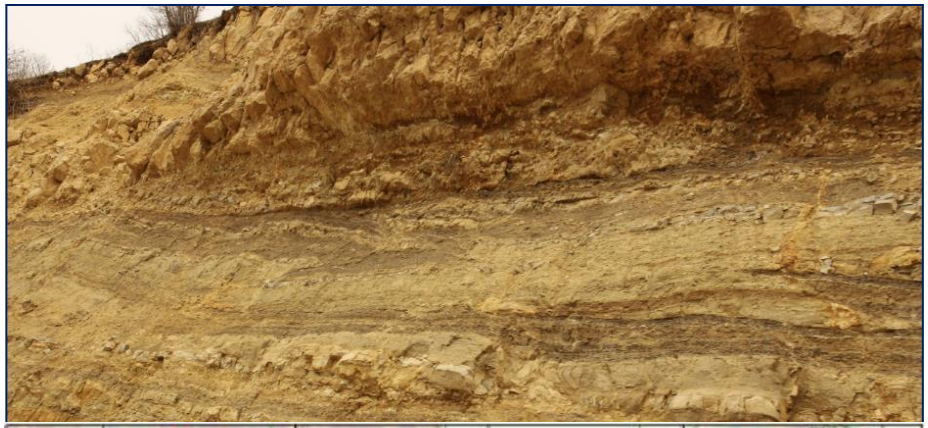
Thrust, Qara Dagh
(Kurdistan Region of Iraq)

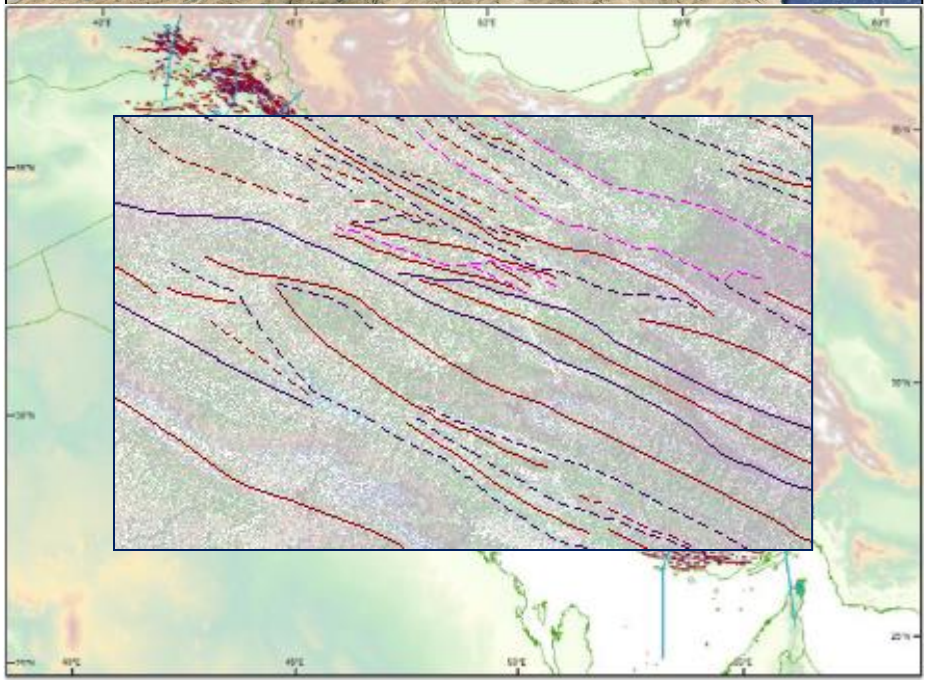


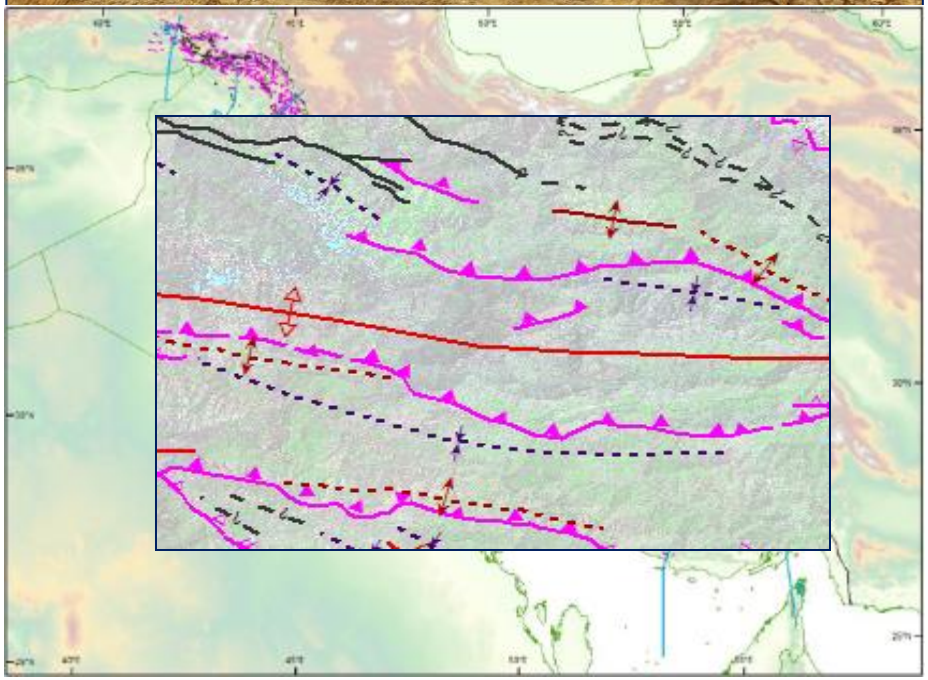
HZF, Lajin anticline (Tavakoli-Shirazi et al 2013)

The Zagros 'Fold & Thrust' Belt



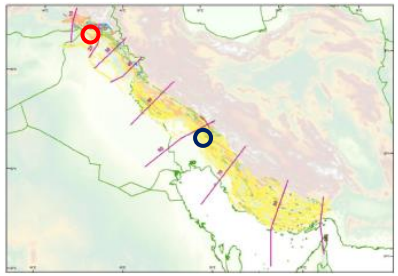


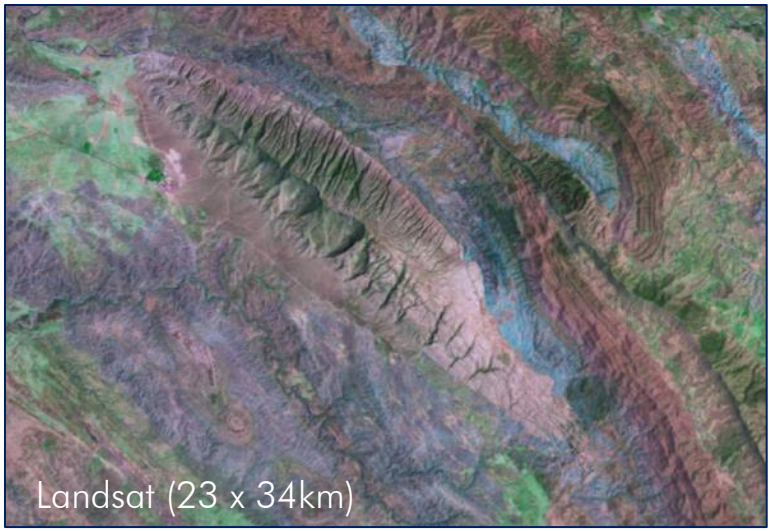


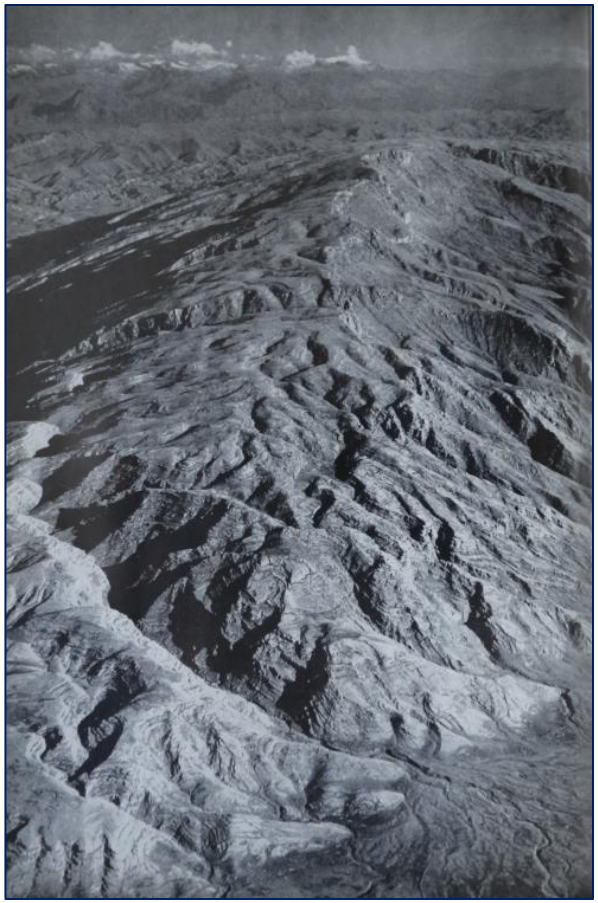


Fold axes (GRL Zagros Regional Mapping 2015) Thrust traces

The Zagros 'Fold & Thrust' Belt



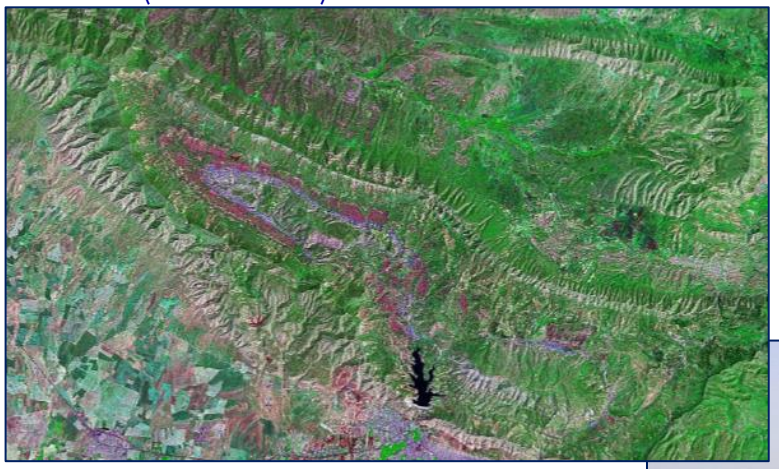




Asmari anticline, Iran

Longhurst 1959

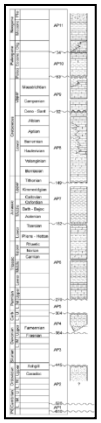
Landsat (20 x 34km)



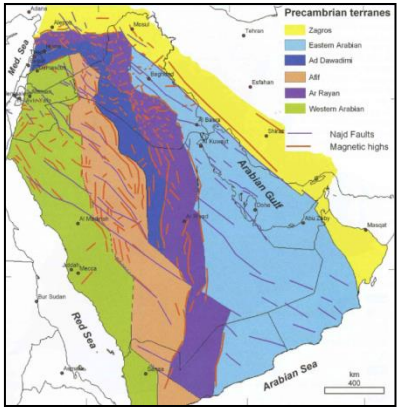
Behr Bahr anticline, KRI

Zagros: Main Structural Controls

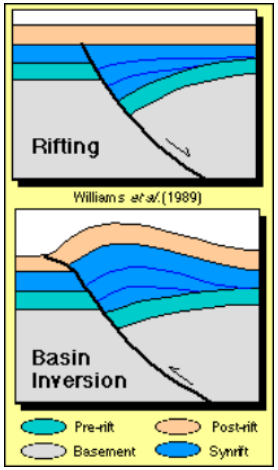
- Mechanical Stratigraphy



- Structural Inheritance
  - Basement fault systems
  - Inversion of Tethyan rift structures



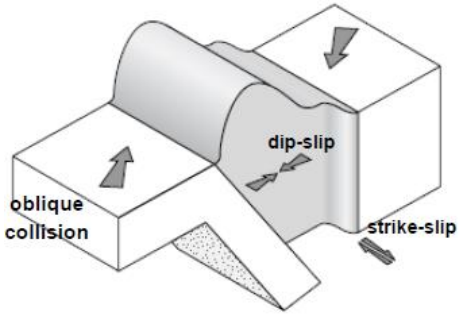
Jassim & Goff 2006



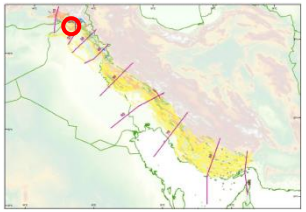
www.rci.rutgers.edu

- Oblique closure of Tethys

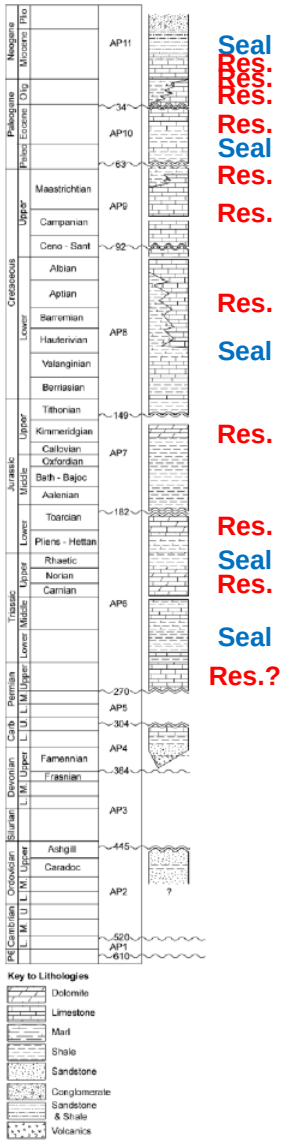
Google Earth



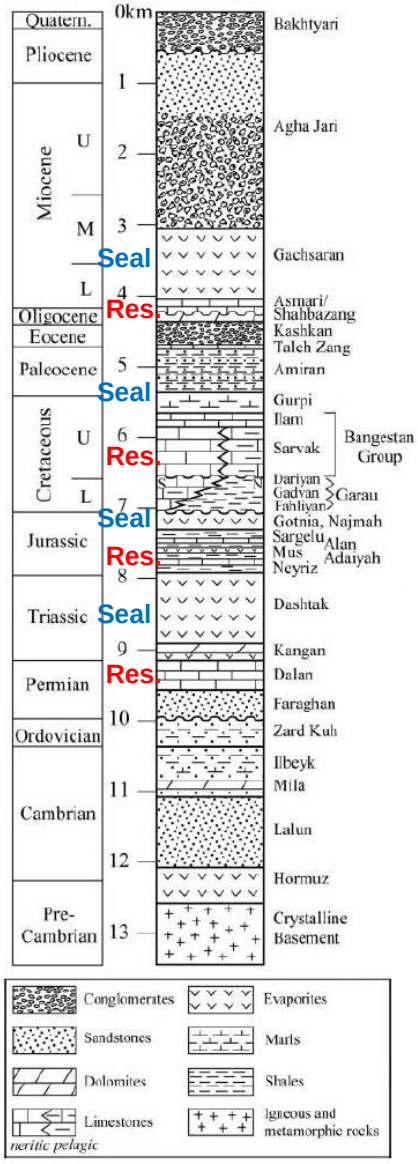
Mechanical Stratigraphy



Kurdistan Region (GRL)

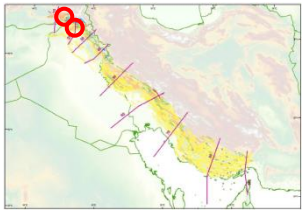


Lurestan, Iran (Casciello et al 2009)



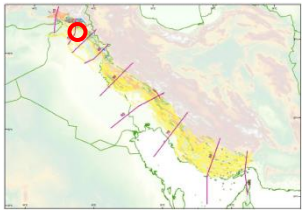
Contrasting mechanical strengths of carbonates vs. mudrocks & evaporites

Mechanical Stratigraphy

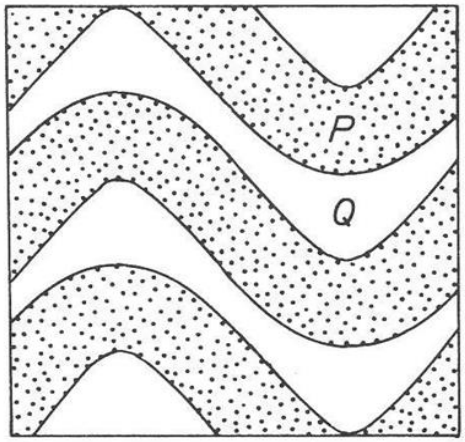


Contrasting mechanical properties of strong carbonates vs. weak mudrocks & evaporites

High Amplitude vs Wavelength

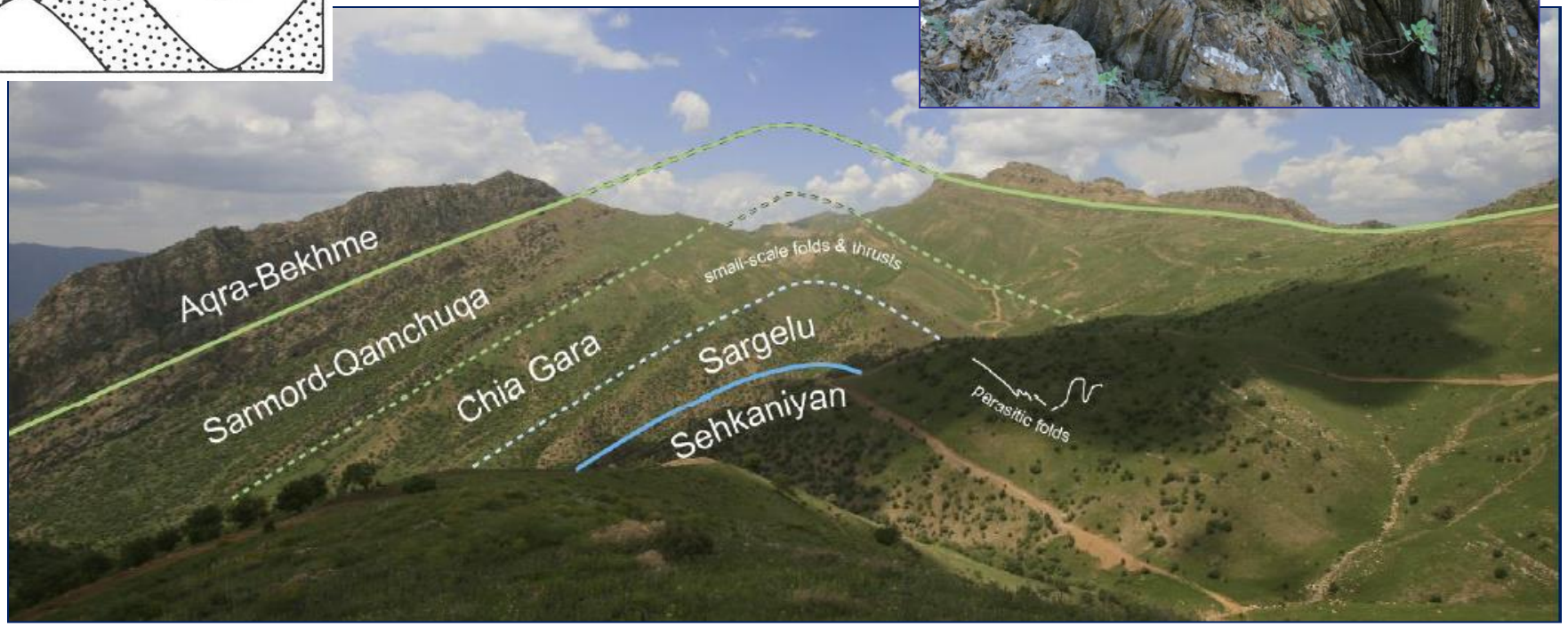


Mechanical contrast can allow anticlines with high amplitude to wavelength ratio to develop … excellent stacked 4-way traps



Ramsay & Huber 1987

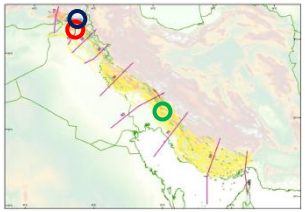
Sargelu (Gara anticline, Kurdistan)



Amedi anticline, Kurdistan

Unbreached Fractured Reservoirs

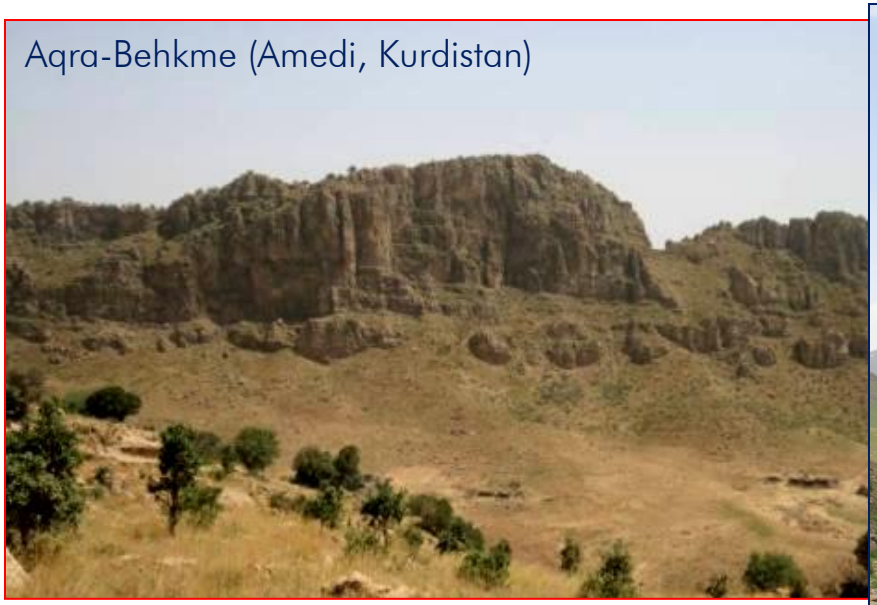
Thick carbonate units are highly fractured – but often not breached by large-offset thrusts



Sarvak (Izeh, Iran)

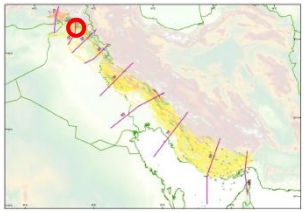
Sherkati & Letouzey 2004

Aqra-Behkme (Amedi, Kurdistan)

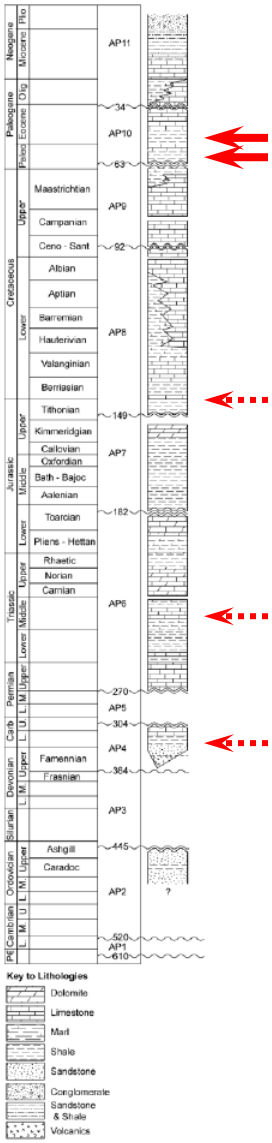


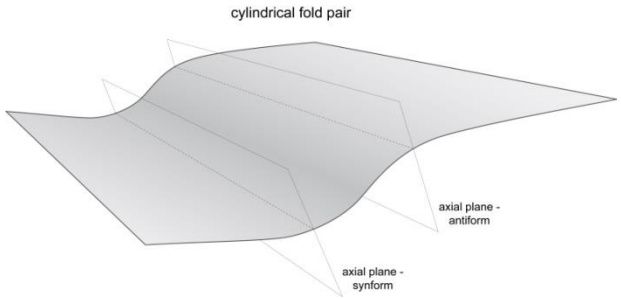
Chia Zairi & Kurra Chine (type localities near the Geli Khana, Iraq-Turkey border)

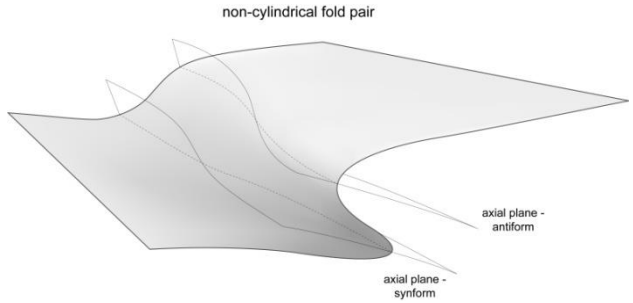
Multiple Detachment Zones

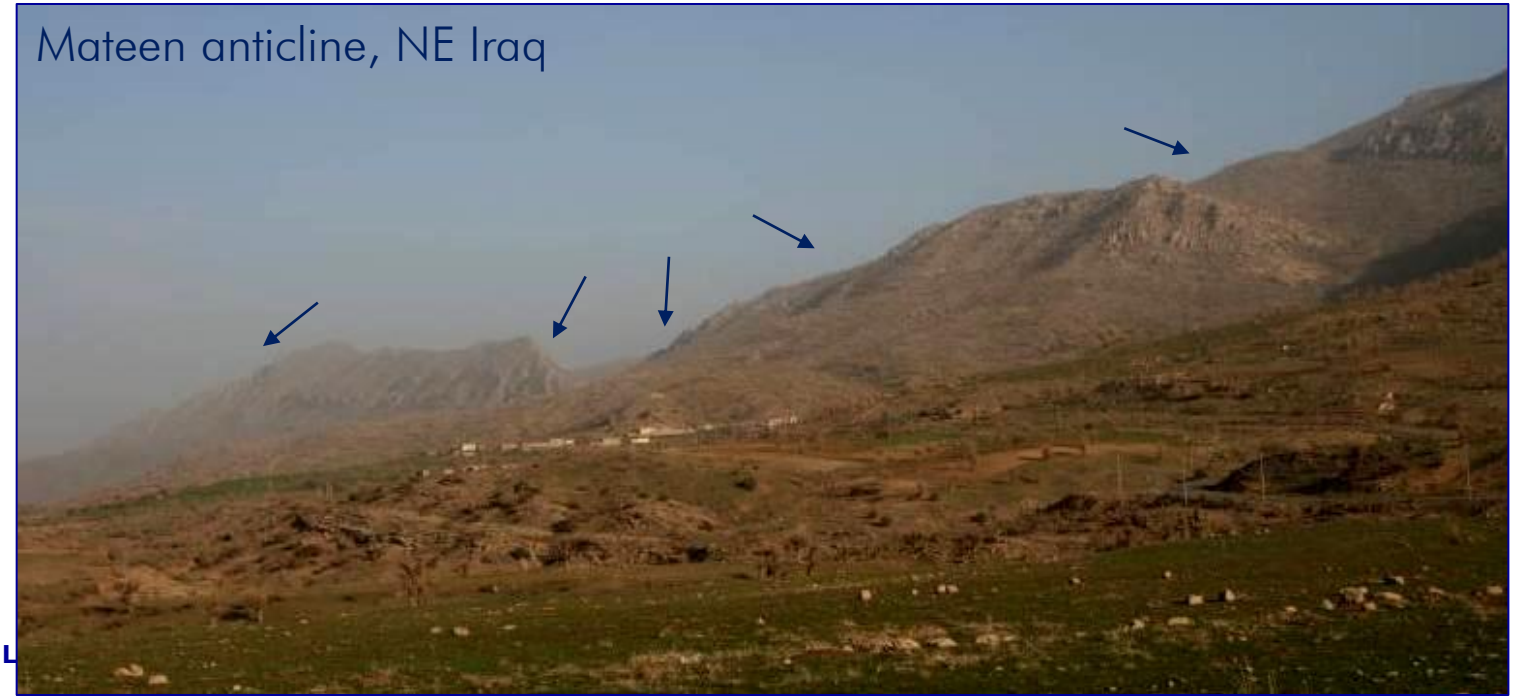


… increased structural complexity, lateral and vertical heterogeneity, and uncertainty of sub-surface interpretation



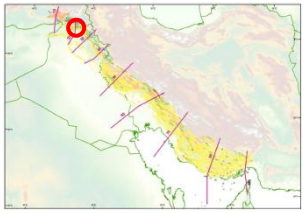




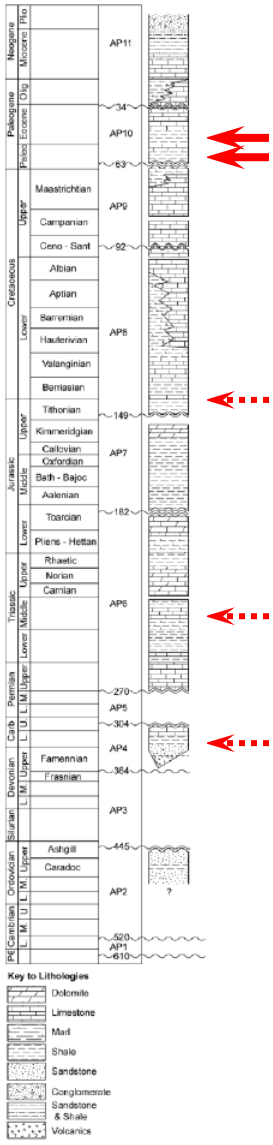


Geospatial

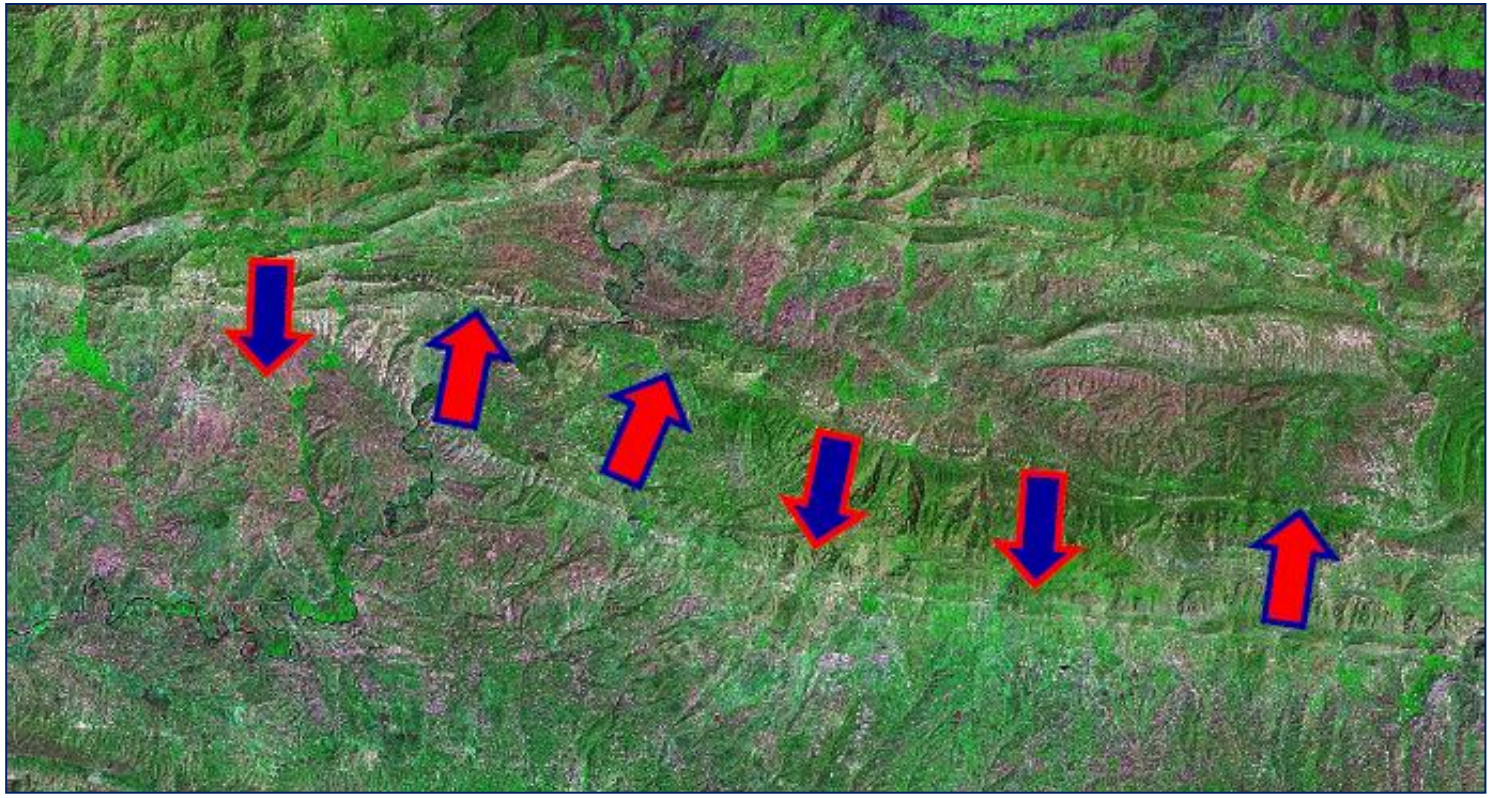
Multiple Detachment Zones



Kurdistan Region (GRL)



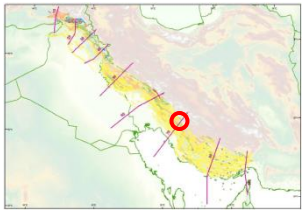
Along-strike vergence changes



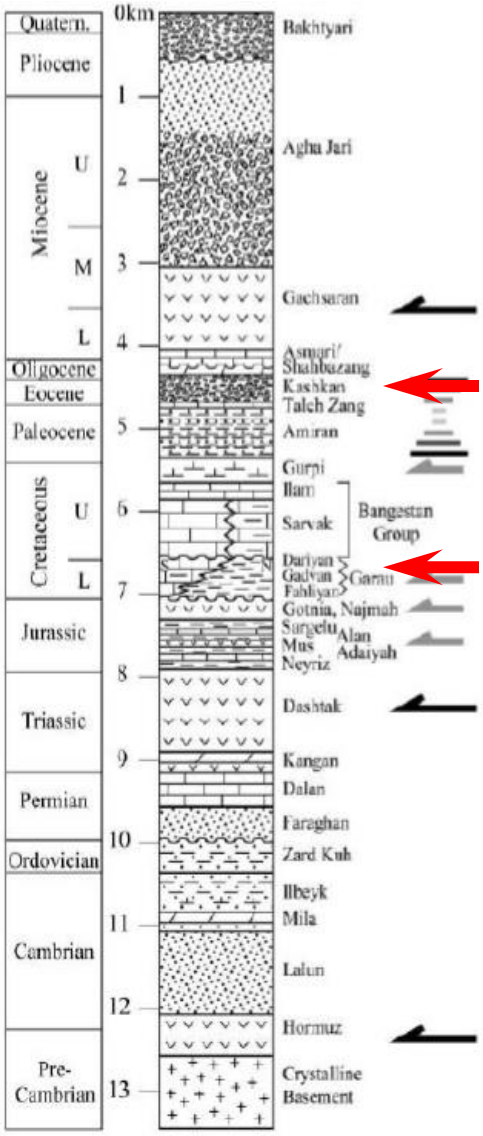
Landsat (27 x 50km)

Mateen-Amedi anticline, Kurdistan

Multiple Detachment Zones

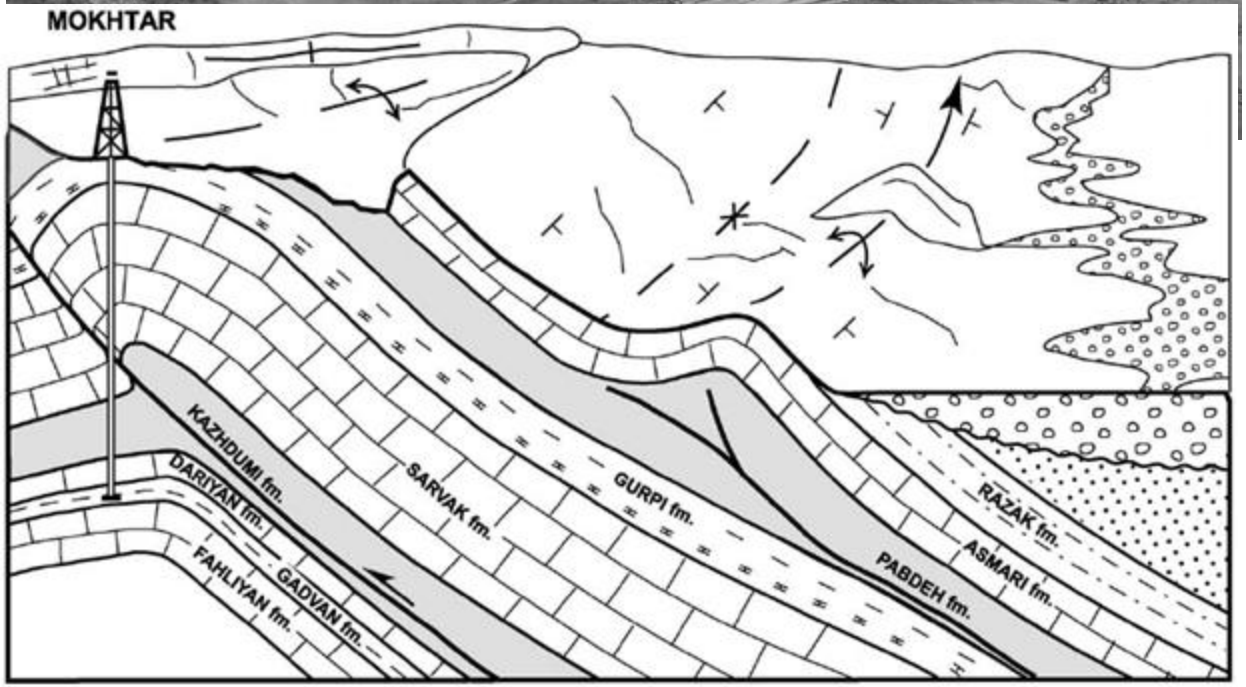


Lurestan, Iran (Casciello et al 2009)



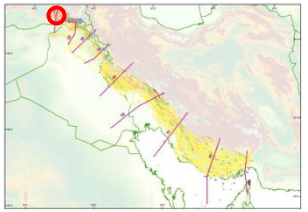
Parasitic fold closures

Mokhtar anticline, Khuzestan, Iran



Sherkati & Letouzey 2004

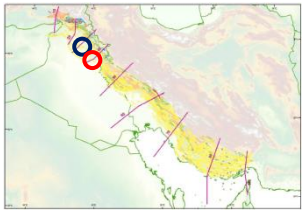
Multiple Detachment Zones



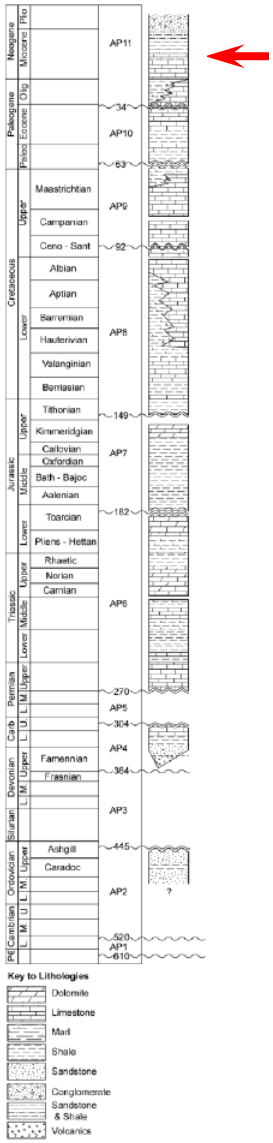
Parasitic fold closures

Kedil anticline (parasitic on N side of Softek), near Raman, SE Turkey

Multiple Detachment Zones

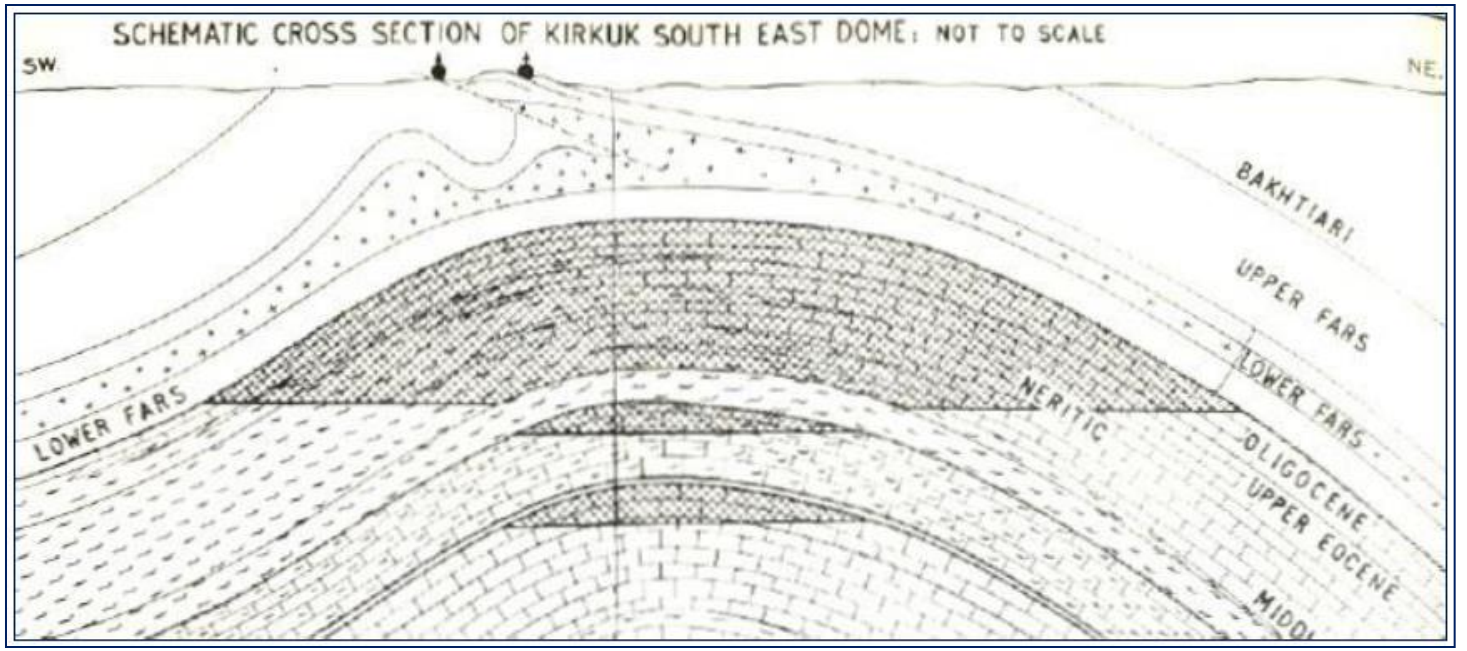


Kurdistan Region (GRL)



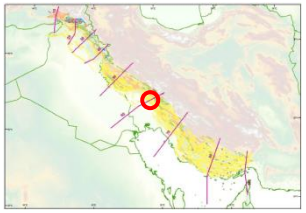
Back-limb, crestal & out-of-syncline thrusts

seeps, Kor Mor thrust, SE Kurdistan



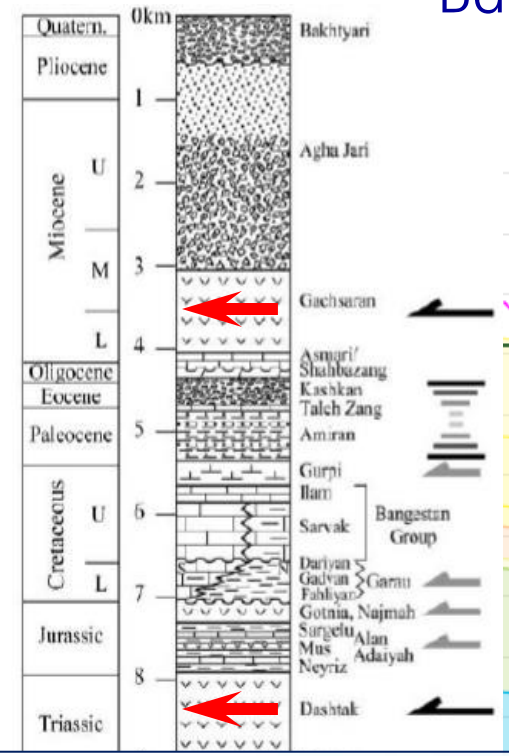
Dunnington 1958

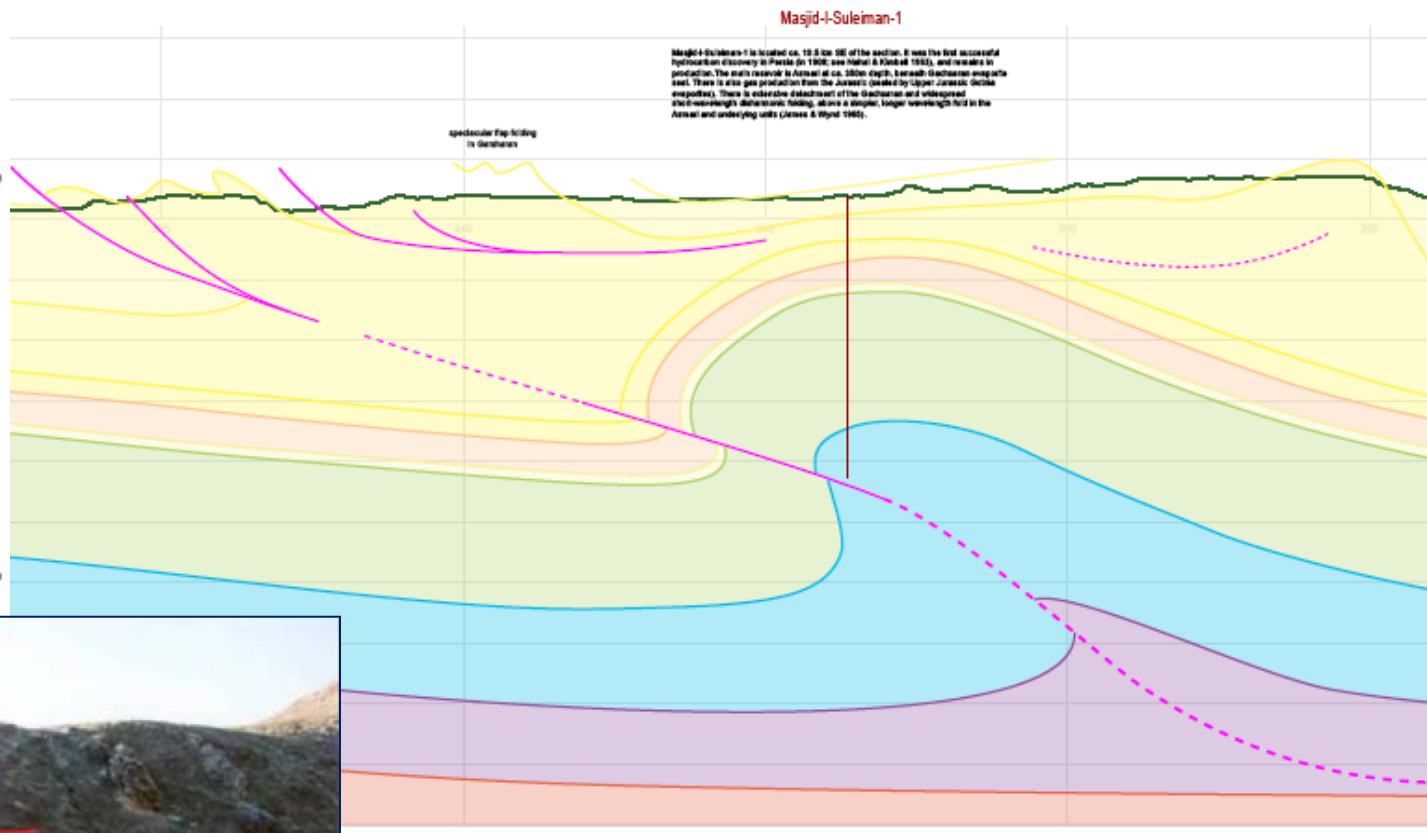
Multiple Detachment Zones



Iran (Casciello et al 2009)

Back-limb, crestal & out-of-syncline thrusts

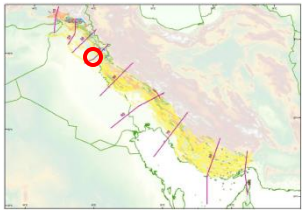




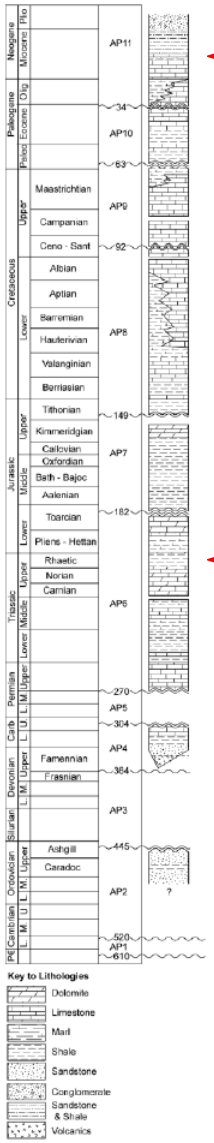
GRL regional xs60

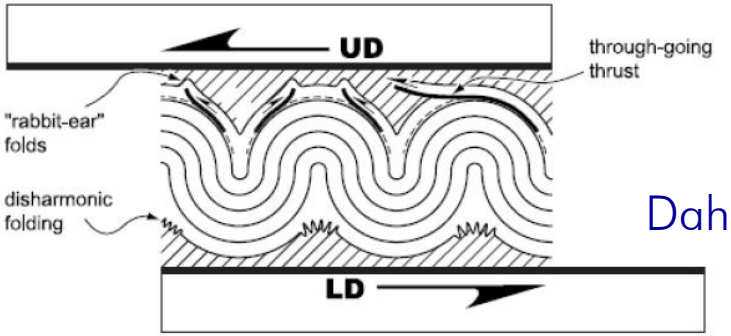
Safari et al 2010

Upper & Lower Detachments

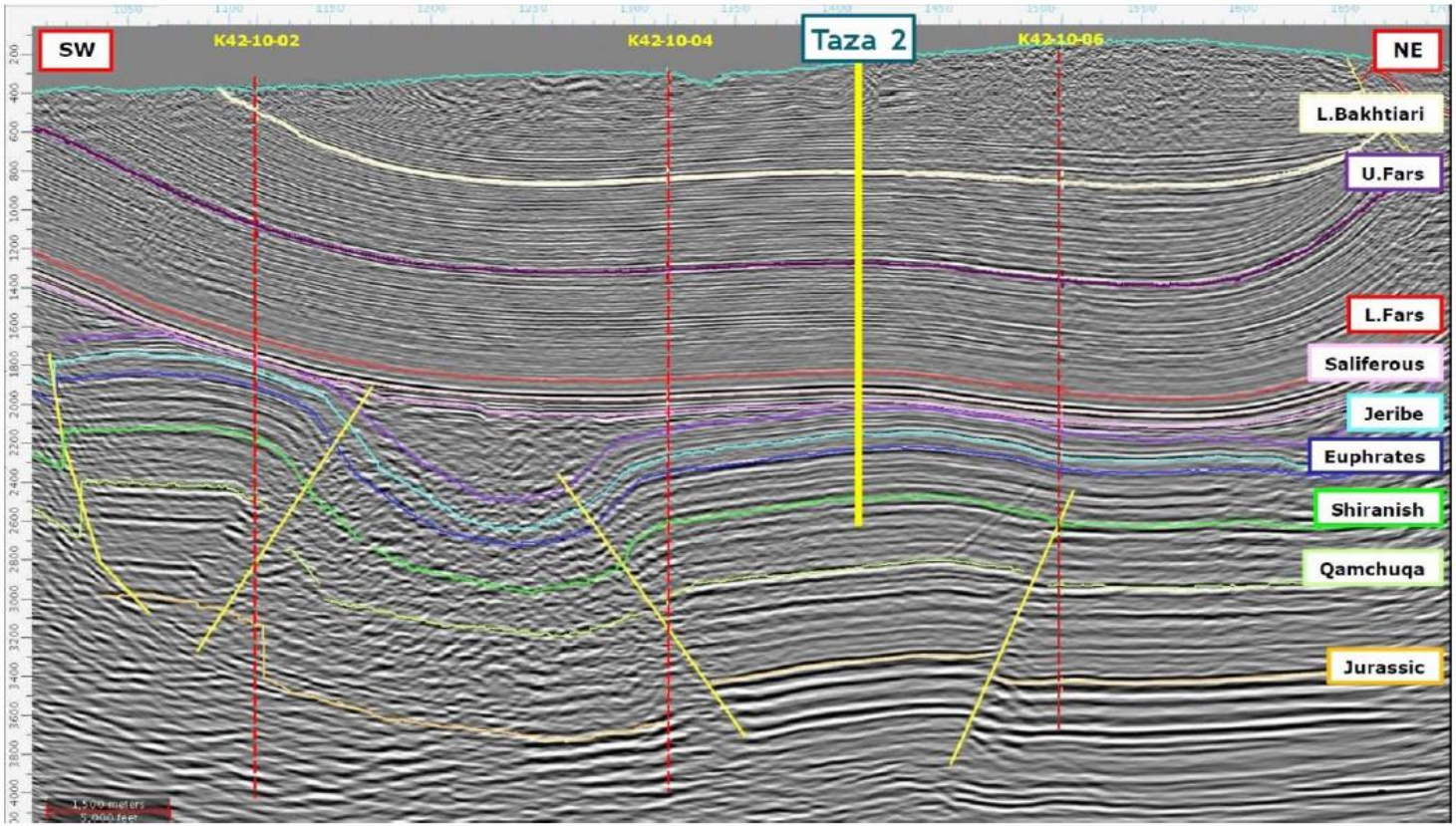


Kurdistan Region (GRL)





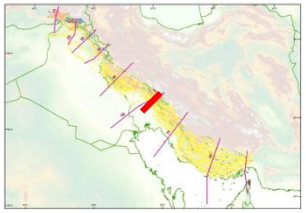
Dahlstrom 1969, Sherkati et al 2005



Geospatial Research Ltd.

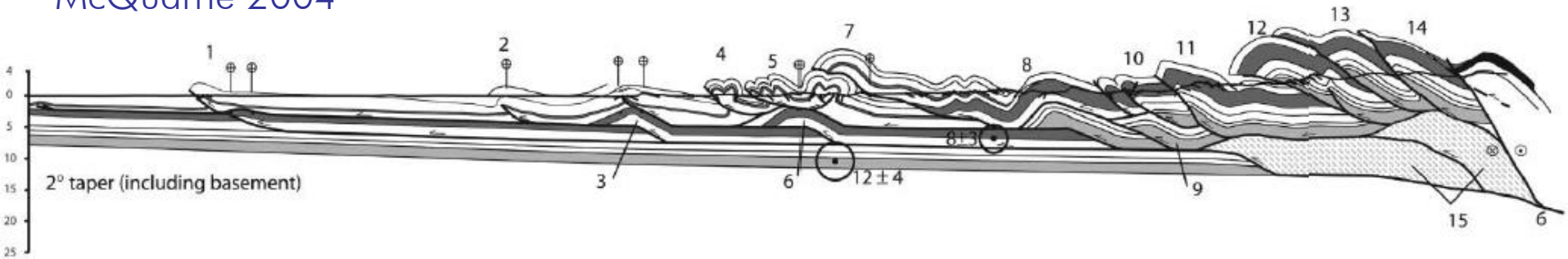
Taza block, downloaded from www.oilsearch.com

Cross Section (Balancing)

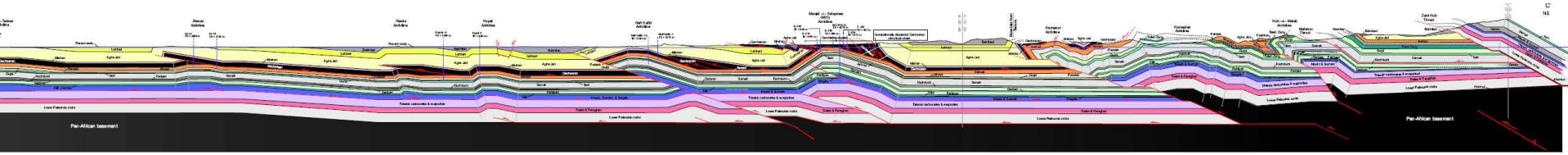


Construction algorithms need to allow for different mechanisms (and geometries) for the strong carbonates vs. weak mudrocks

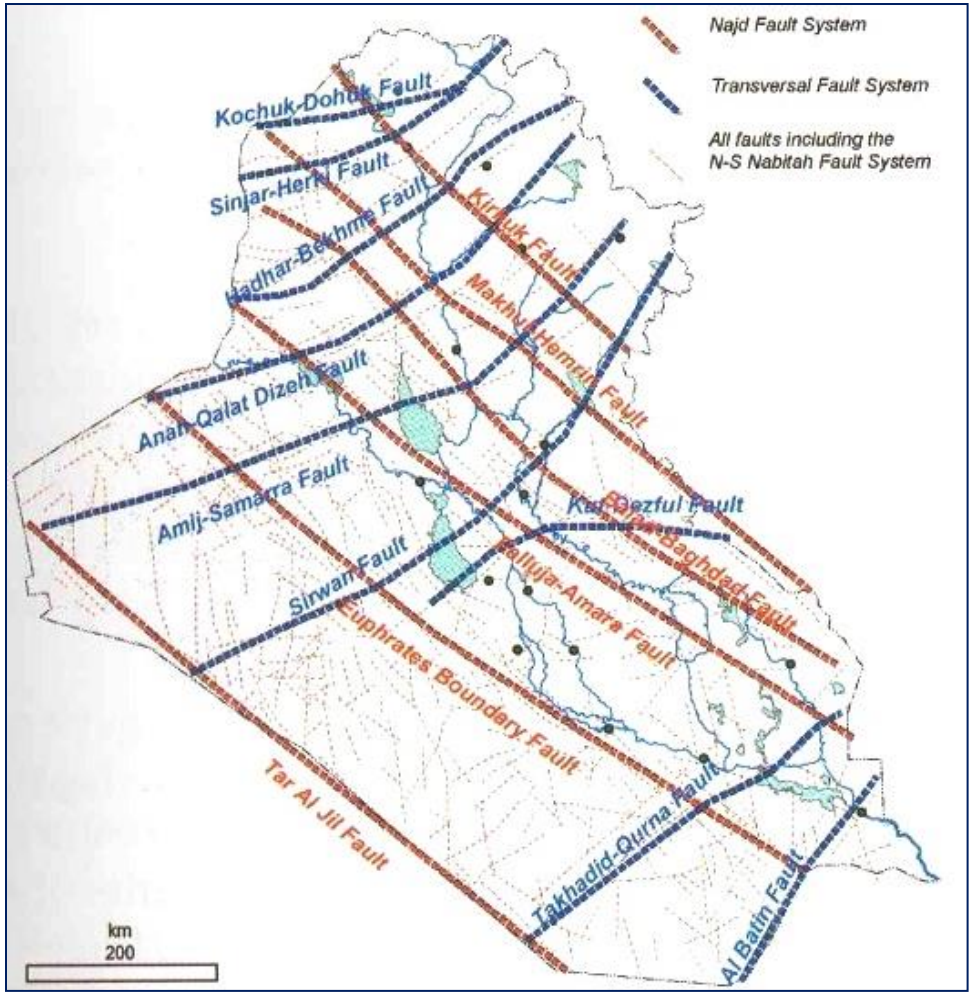
McQuarrie 2004



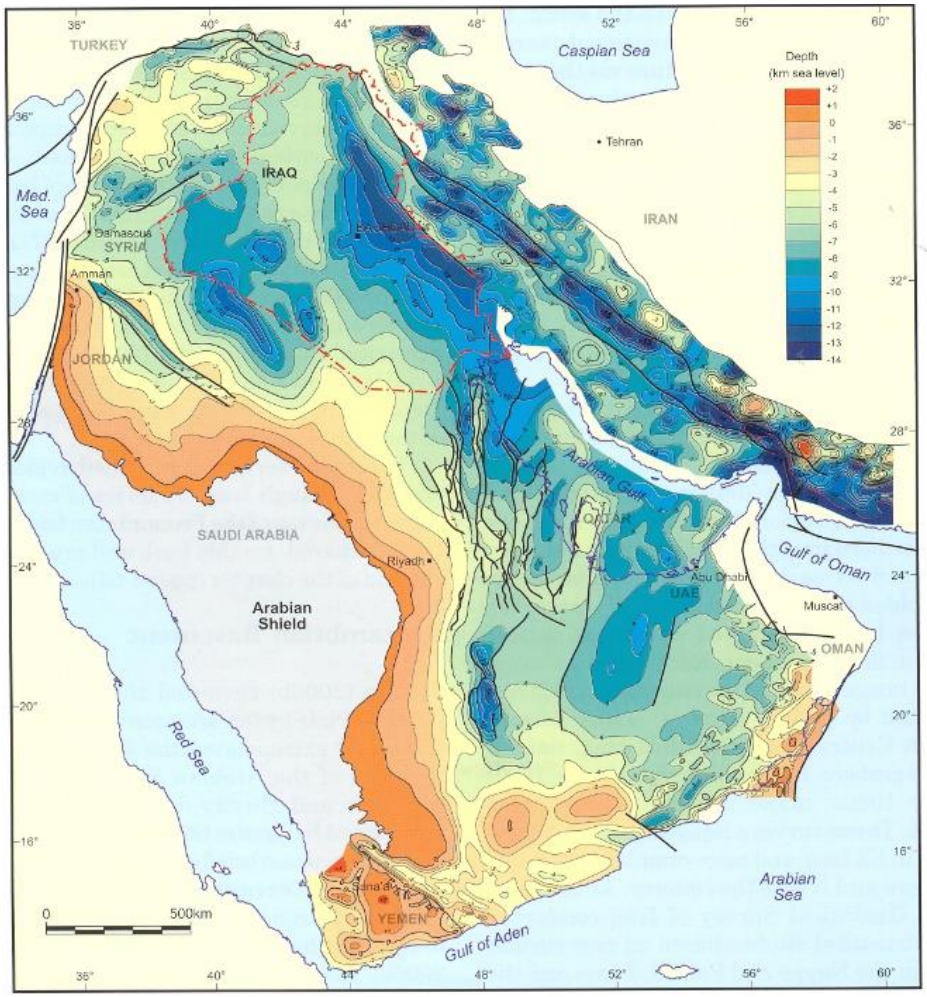
Alavi 2007



Basement Inheritance

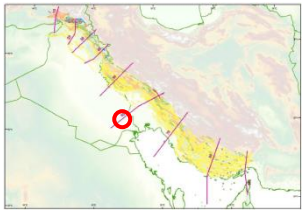


Jassim & Goff 2006

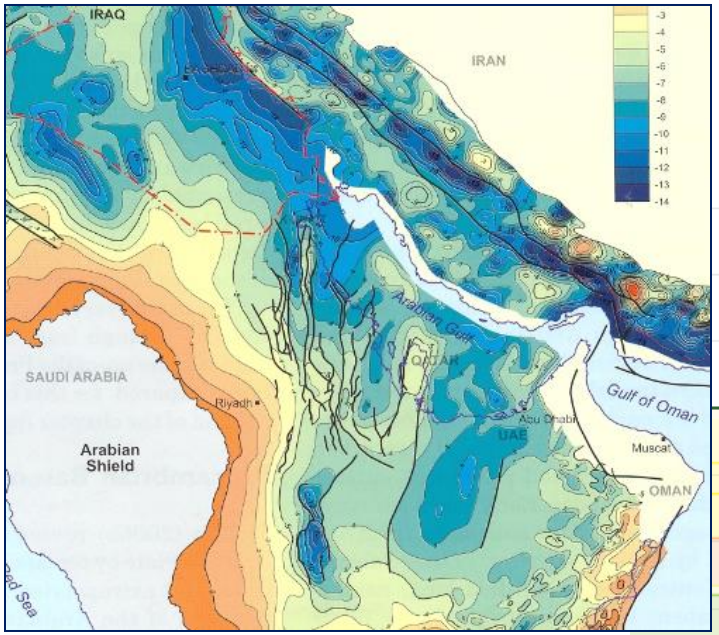


Aqrawi et al 2010

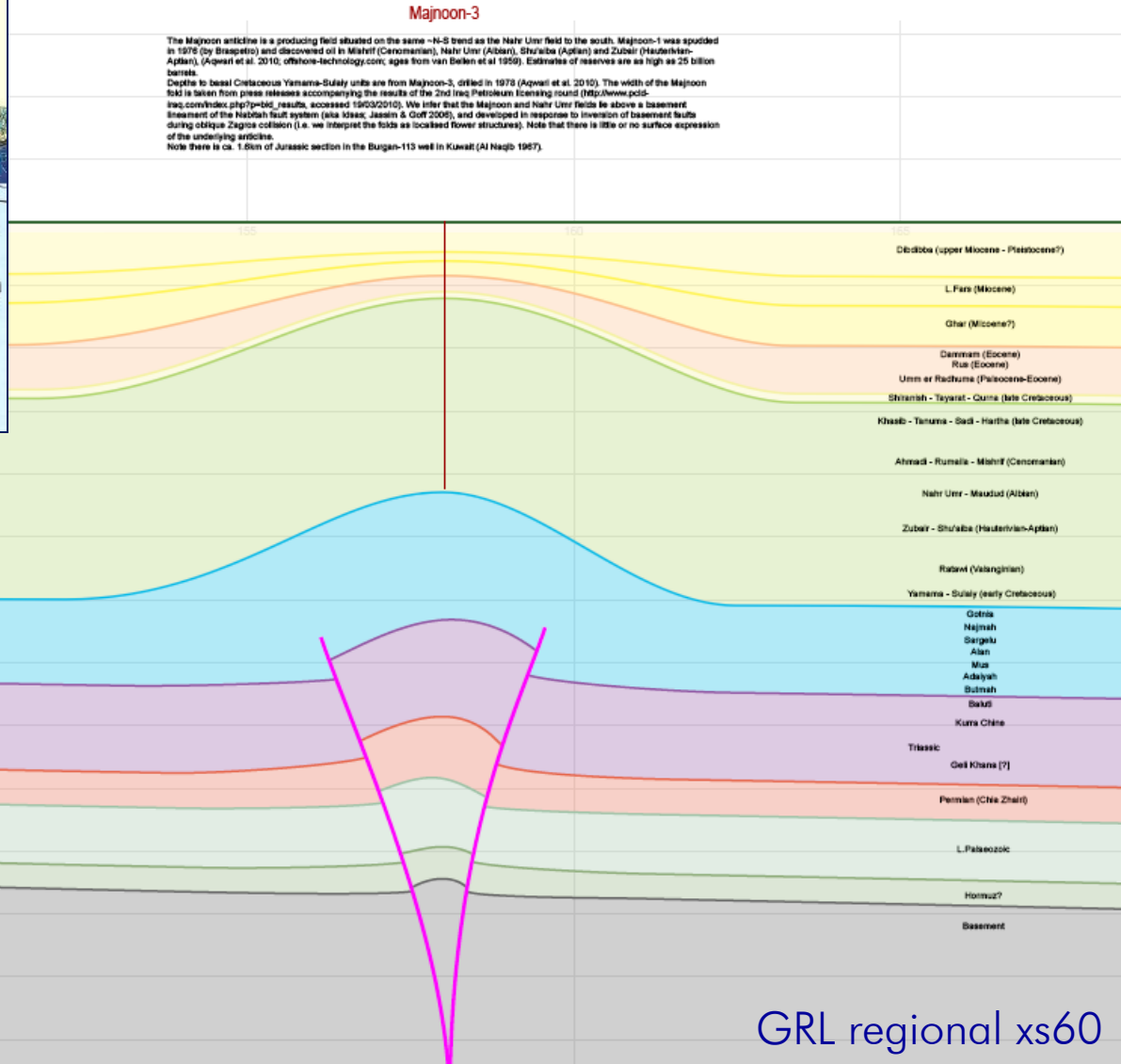
Basement Inheritance



Transpressional reactivation of faults of the Nabitah system

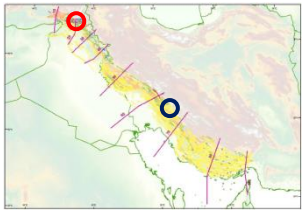


Aqrawi et al 2010

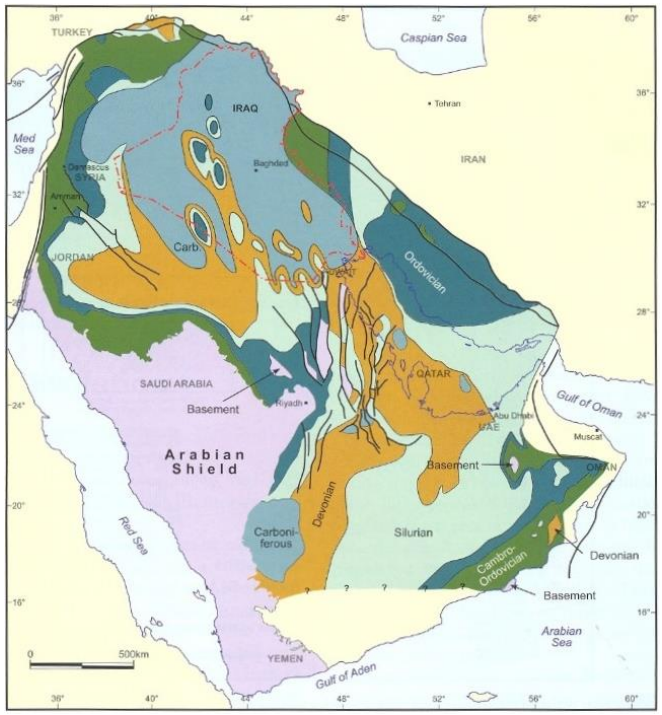


GRL regional xs60

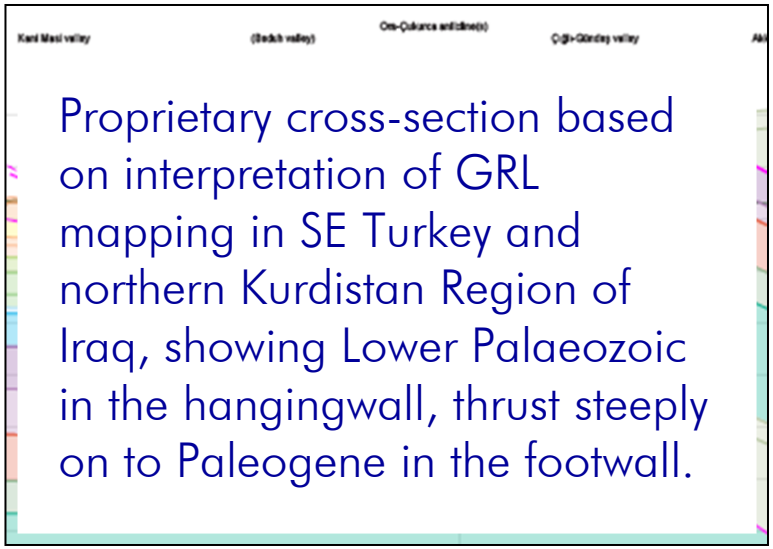
Inversion of Tethyan Rifts

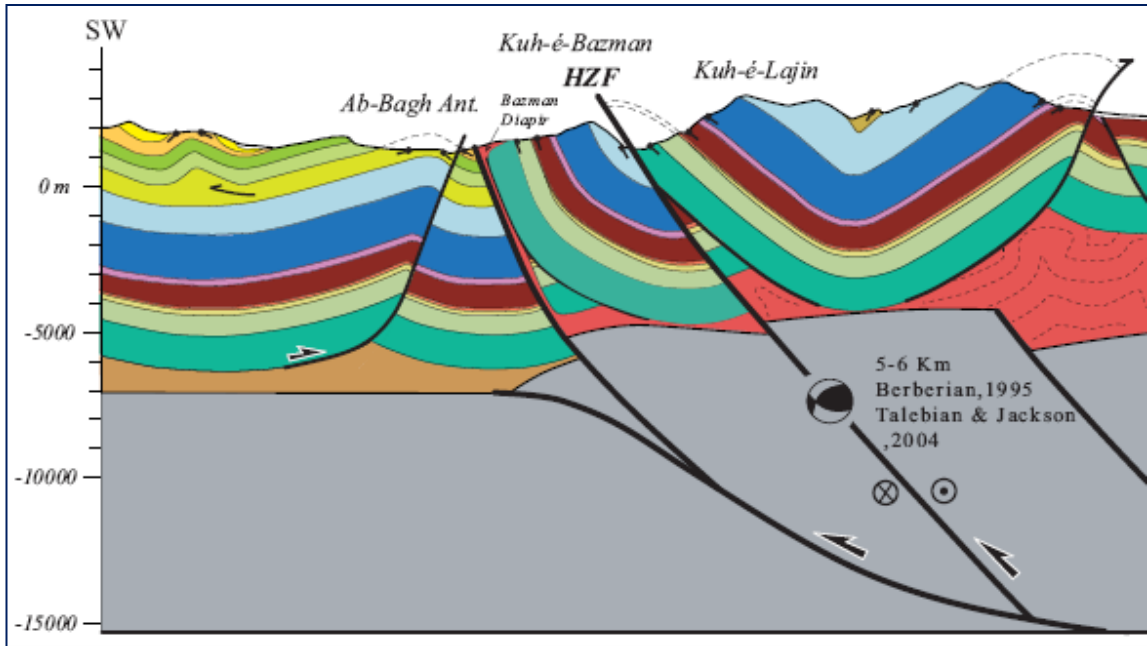


Where are they (there's a lack of really clear data)



Late Carb. subcrop map (Aqrawi et al 2010)

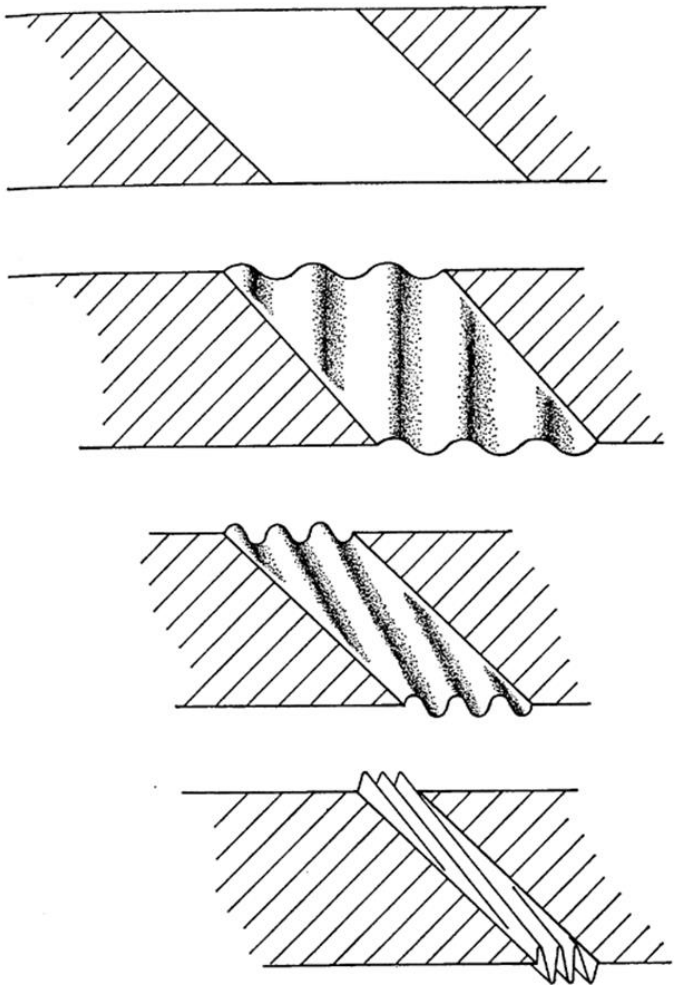




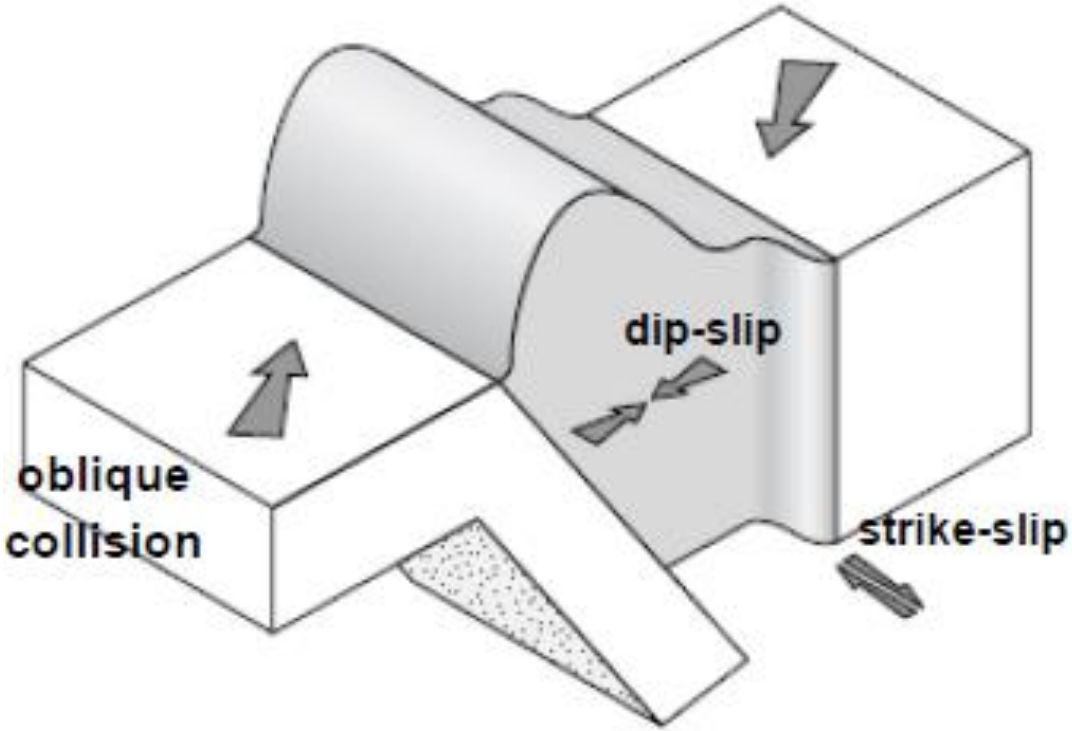
Tavakoli-Shirazi et al 2013

Oblique Closure of Tethys

Transcurrent + Compression = Transpression



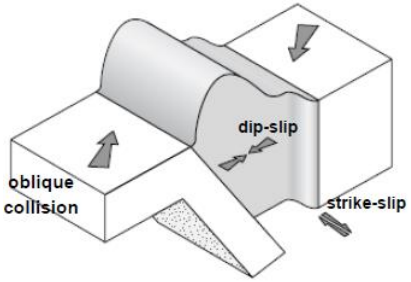
Harland 1971



Jones & Tanner 1995
Jones et al 2005

Strain Partitioning

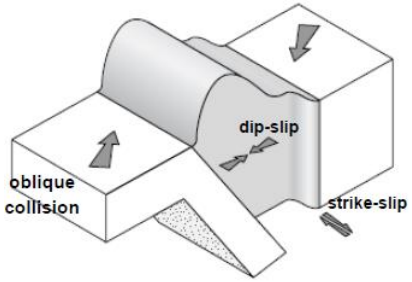
Transcurrent + Compression = Transpression

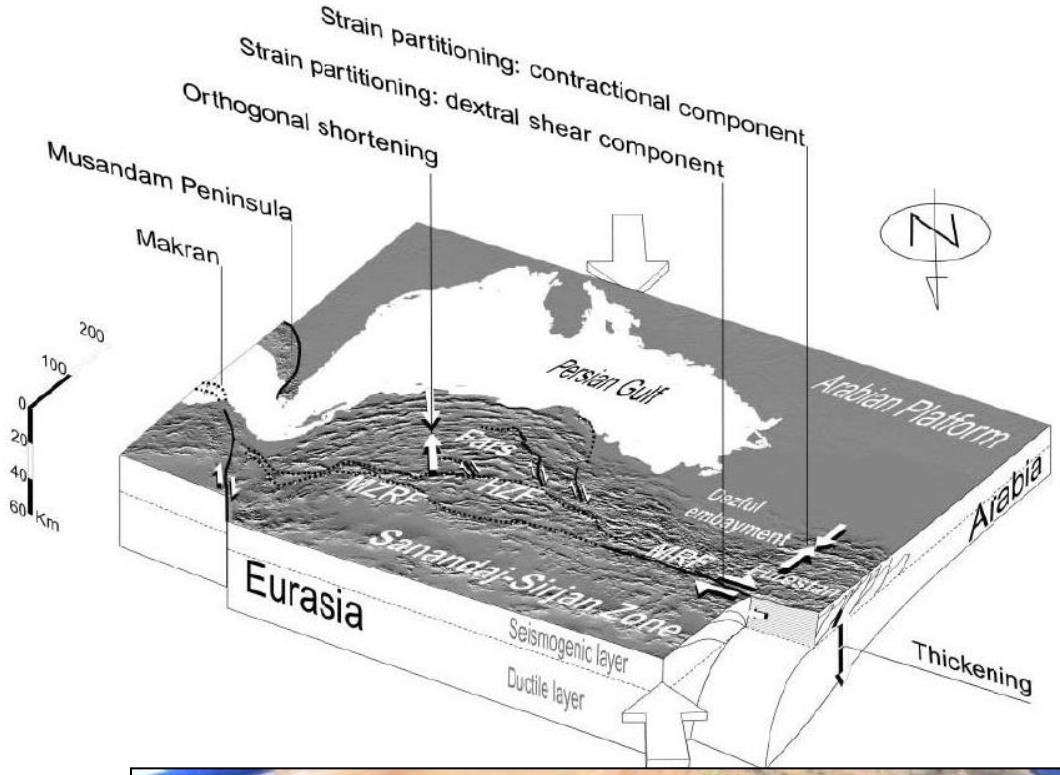


GRL Zagros Regional Mapping 2015

Proprietary GRL map showing interpretation of the main regional tectonic elements of the Zagros, including newly mapped faults that allow us to extend recent geodynamic interpretations from Iran, northwestwards into Iraq & SE Turkey

Strain Partitioning





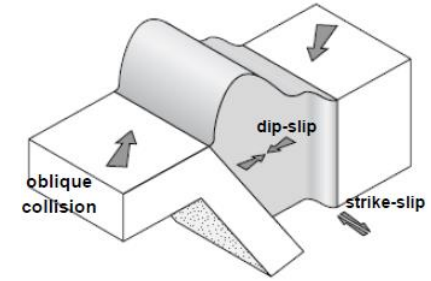
Blanc et al 2003

GoogleEarth looking S

Geospatial

Strain Partitioning: Implications

Compression-dominated zone: very long anticlines



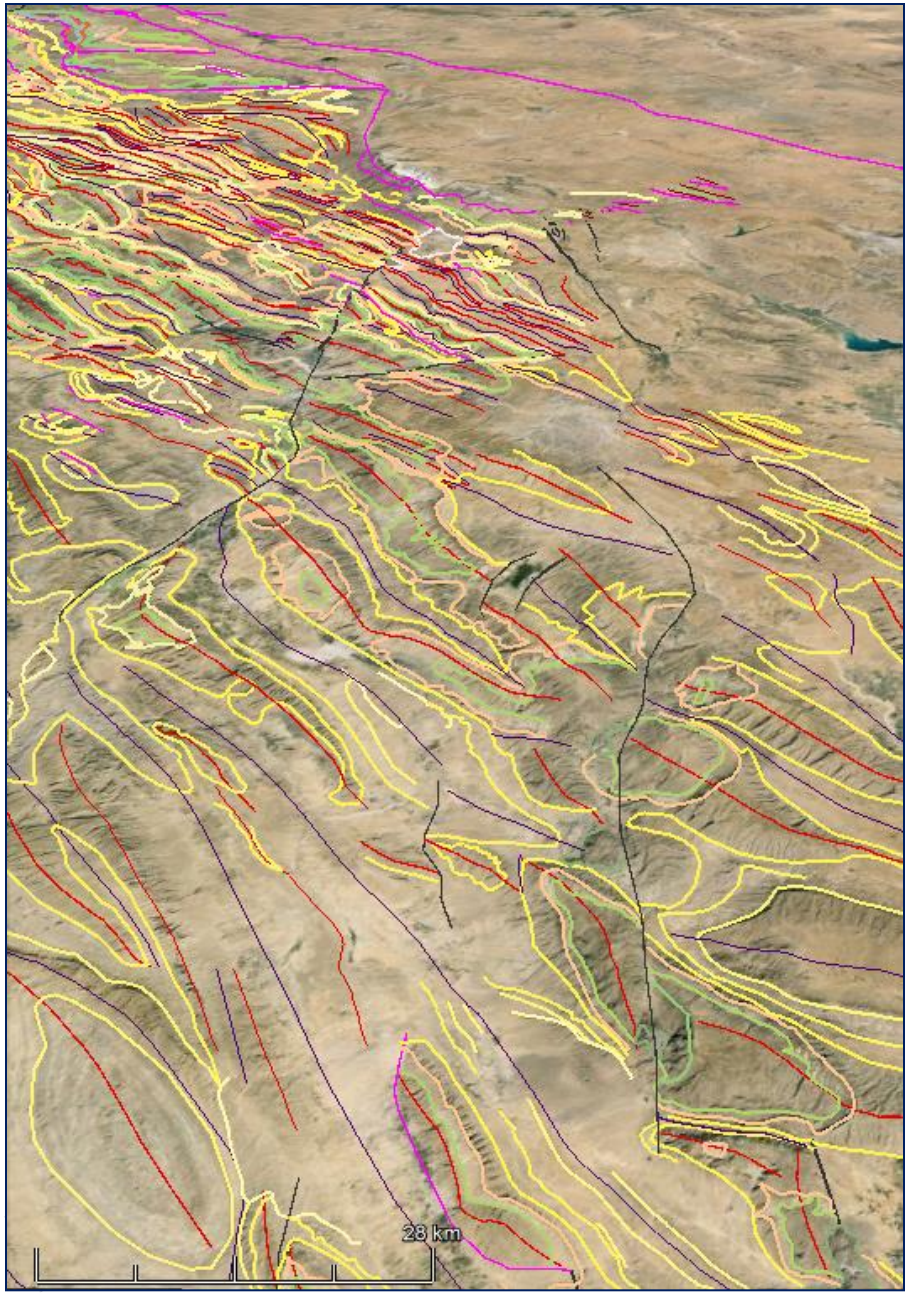
Fracture systems are often slightly asymmetrical to anticlinal hinges (i.e. partitioning is incomplete)

Strike-slip dominated:

- very large earthquakes (MRF)
- very important synthetic regional faults (Khanaqin-Izeh-Kazerun-Sarvestan)

Bergbauer & Pollard 2004, after Stearns 1968

Strain Partitioning: Implications



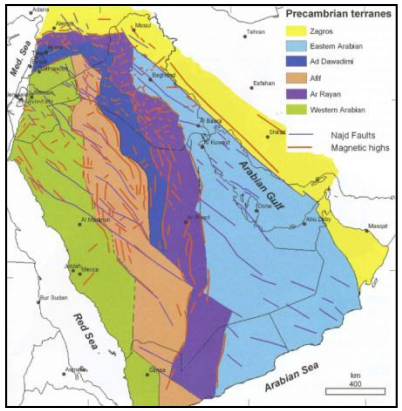
Regional synthetic strike-slip faults:

- difficult to measure large offset
- … but they control the location & termination of anticlines
- likely to be long-lived, still active
- segmented, anastomosing
- high risk to trap integrity

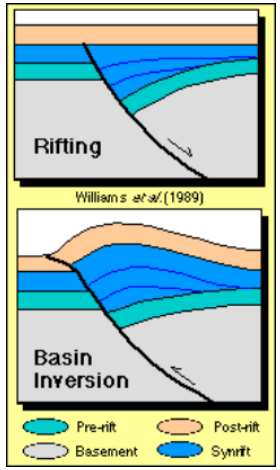
Kazerun – Kareh Bas (GRL mapping on Google Earth)

Summary: Main Structural Controls

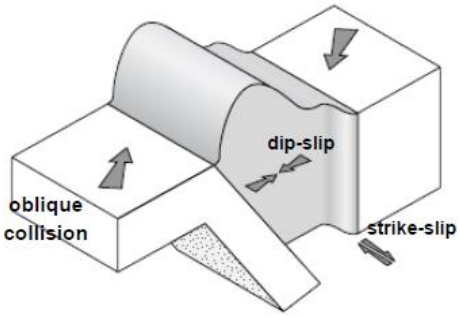
- Mechanical Stratigraphy
  - High amplitude folds, often unbreached
  - Highly fractured, contiguous, stacked reservoirs
  - Increased complexity (surface & sub-surface)
  - … carry out fieldwork – as early as possible!
  - Multiple detachments
- Structural Inheritance
  - Basement fault systems
  - Inversion of Tethyan rift structures (?)
- Oblique closure of Tethys
  - Very long anticlines (in compression dominated zone)
  - Fracture systems asymmetric to anticlines
  - Major 1st order strike-slip zones: very complex, increased likelihood of breached traps



Jassim & Goff 2006



www.rci.rutgers.edu



Zagros Workshops

GRL and Mark Allen (Durham University) are planning to run Zagros workshops in November - December

GRL Zagros Regional Mapping

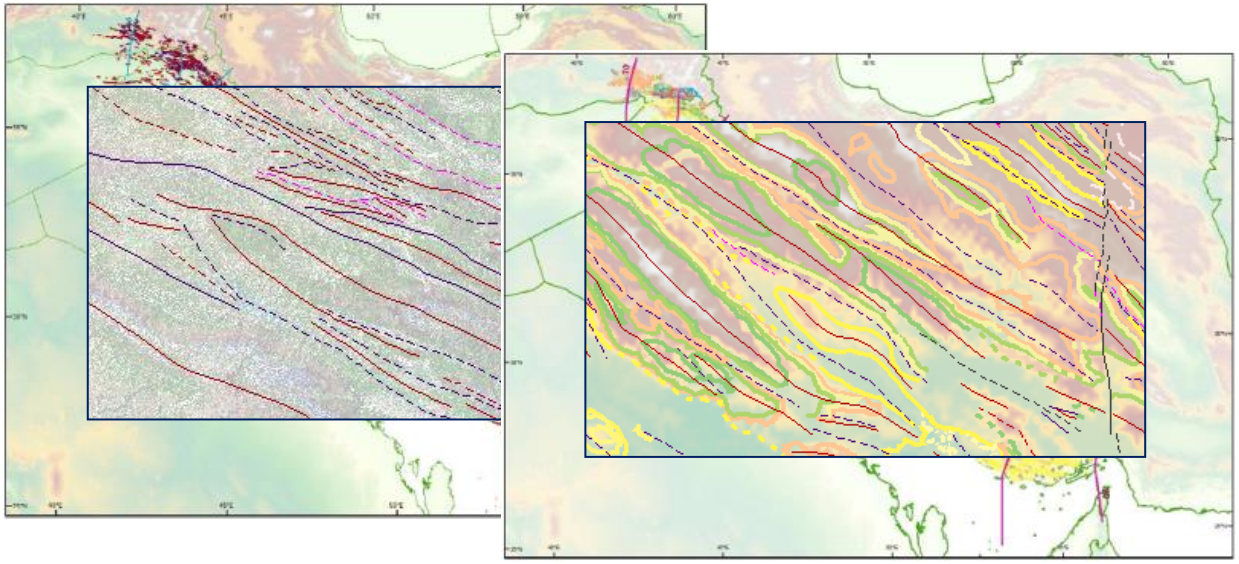
GEOSPATIAL RESEARCH LTD.
Acquisition Visualisation Analysis of Geoscientific Data

Regional Study of Zagros Structure in Relation to Petroleum Systems

Richard Jones, Jonathan Long, David Oxlade, Sébastien Gilment, Caitlin Woods, Susie Daniels

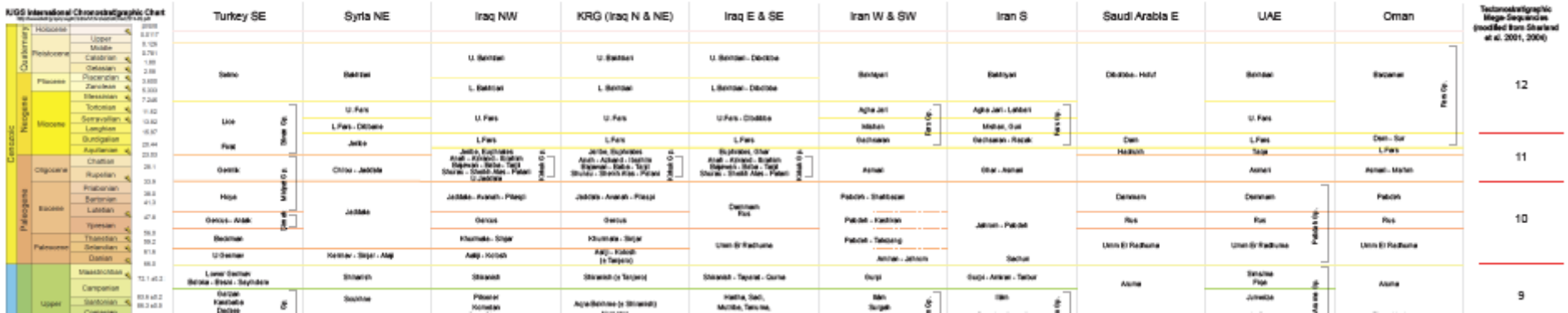
Geospatial Research Ltd., Dept. of Earth Sciences, University of Durham, DH1 3LE, UK

Frontispiece: Hydrocarbon seep at Geli Keer on the northern flank of the Shaikan anticline (Kurdistan Region of Iraq). This locality lies on an inferred deep structural lineament (basement fault?) that can be traced between the ends of the Maqlub, Simrit, Alqosh, Shaikan, and West Swara Tika anticlines, and beyond. The outcrop comprises northerly dipping Pila Spi limestones, in which hydrocarbons are emanating from both the fracture network and from the vuggy matrix.



Proprietary GRL maps & cross-sections

Zagros Stratigraphic Correlation Chart



ZRM (Phase 1): Main Report

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