Structural Style in the Zagros: Implications for Hydrocarbon Systems

Richard Jones
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)

c.a. 1m

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

Landsat (23 x 34km)

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

• Oblique closure of Tethys
Contrasting mechanical strengths of carbonates vs. mudrocks & evaporites
Mechanical Stratigraphy

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

Softek, SE Turkey

Shaikan, Kurdistan

Iraq-Turkey border zone

Iraq-Turkey border zone
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)
Thick carbonate units are highly fractured – but often not breached by large-offset thrusts

Sarvak (Izeh, Iran)

Aqra-Behkme (Amedi, Kurdistan)

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

Sherkati & Letouzey 2004
Multiple Detachment Zones

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

Mateen anticline, NE Iraq
Multiple Detachment Zones

Kurdistan Region (GRL)

Along-strike vergence changes

Landsat (27 x 50km)  Mateen-Amedi anticline, Kurdistan

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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

Gachsaran

Recent

Safari et al. 2010
Upper & Lower Detachments

Kurdistan Region (GRL)

Dahlstrom 1969, Sherkati et al 2005

Taza block, downloaded from www.oilsearch.com
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
Transpressional reactivation of faults of the Nabitah system

Aqrawi et al. 2010
Inversion of Tethyan Rifts

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

Proprietary cross-section based on interpretation of GRL mapping in SE Turkey and northern Kurdistan Region of Iraq, showing Lower Palaeozoic in the hangingwall, thrust steeply on to Paleogene in the footwall.

Late Carb. subcrop map (Aqrawi et al 2010)

Tavakoli-Shirazi et al 2013
Oblique Closure of Tethys

Transcurrent + Compression = Transpressions

Harland 1971

Jones & Tanner 1995
Jones et al 2005
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
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
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 1\textsuperscript{st} 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.
Regional Study of Zagros Structure in Relation to Petroleum Systems

Richard Jones, Jonathan Long, David Orliade, Sebastien Gilmeat, Caitlin Woods, Susie Daniels

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

Proprietary GRL maps & cross-sections
# Table of Contents

Summary & Conclusions........................................................................................................3

Table of Contents..................................................................................................................5

1. Introduction.................................................................................................................................6
   1.1. Project Aims..........................................................................................................................6
   1.2. Area of Interest.......................................................................................................................7
   1.3. Summary of Project Deliverables.........................................................................................8
   1.4. Source Data...........................................................................................................................9

2. Zagros Geological Mapping......................................................................................................10
   2.1. Overview: Aims of Surface Mapping..................................................................................10
   2.2. Overall Mapping Strategy...................................................................................................10
   2.3. Spatial Resolution & Spatial Precision..............................................................................11
   2.4. Mapping Methodology..........................................................................................................12

3. Stratigraphy & Stratigraphic Correlation..................................................................................13

4. Structural Style........................................................................................................................15
   4.1. Observed Styles of Folds & Thrusts ...................................................................................15
   4.2. Inferences on Sub-Surface Structures................................................................................26
   4.3. Cross-sections......................................................................................................................28

5. Regional Structure and Tectonics............................................................................................31
   5.1. Tectonic Framework............................................................................................................31
   5.2. Structural Elements.............................................................................................................31
   5.3. Large-scale Tectonic Elements...........................................................................................33
   5.4. Zonation of the Zagros Orogen.........................................................................................36
   5.5. Timing of Deformation.........................................................................................................39
   5.6. Transpressional Model for Zagros Collision.................................................................41
   5.7. Transpression Model: Implications for Hydrocarbon Systems..........................................44

6. Recommendations for Future Work.........................................................................................46

7. References................................................................................................................................47