Structural Style in the Zagros: Implications for Hydrocarbon Systems

Richard Jones



THE ZAGROS 'FOLD & THRUST' BELT!



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)

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THE ZAGROS 'FOLD & THRUST' BELT



Fold axes

(GRL Zagros Regional Mapping 2015)

Thrust traces



THE ZAGROS 'FOLD & THRUST' BELT





Asmari anticline, Iran

Longhurst 1959







Behr Bahr anticline, KRI

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ZAGROS: MAIN STRUCTURAL CONTROLS

Mechanical Stratigraphy



Structural Inheritance

- Basement fault systems
- Inversion of Tethyan rift structures











Google Earth



MECHANICAL STRATIGRAPHY



Lurestan, Iran (Casciello et al 2009) 0kt Quatern. Bakhtyari Pliocene Agha Jari U Miocene M Gachsaran L Asmari/ Shahbazang Oligocene Kashkan Eocene Talch Zang 5 Paleocene Amiran Gurni Cretaceous Ilam U Bangestan Sarvak Group Dariyan Gadyan Fahliyan L Gotnia, Najmah SargeluAlan Jurassic Mus Adaiyah Neyriz Dashtak Triassic Sea 0 Kangan Re Dalan Permian Faraghan 10 Zard Kuh Ordovician Ilbevk Mila 11 Cambrian Lalun 12 Hormuz VVV VVVVV Pre-Crystalline Cambrian 13 Basement Conglomerates Evaporites Sandstones Marls Dolomites Shales +++++ lgneous and Limestones metamorphic rocks



Contrasting mechanical strengths of carbonates vs. mudrocks & evaporites



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neritic pelagic

MECHANICAL STRATIGRAPHY

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









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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)





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Amedi anticline, Kurdistan

UNBREACHED FRACTURED RESERVOIRS

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





Sherkati & Letouzey 2004



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



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







Maastrichtia Campanian

Ceno - Sant Albian Aptian Barremian Hauterivian Valanginian Berriasian







Along-strike vergence changes



Landsat (27 x 50km)

Mateen-Amedi anticline, Kurdistan





Parasitic fold closures



Mokhtar anticline, Khuzestan, Iran







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Parasitic fold closures





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







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



seeps, Kor Mor thrust, SE Kurdistan



Dunnington 1958

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Iran (Casciello et al 2009)





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

UPPER & LOWER DETACHMENTS





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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

Majnoon-3



Aqrawi et al 2010





bit shutsed on the same -N-5 tend as the Nate Unit field to the exoth. Majoon-1 was spudied of Matrix (Constraint), Nate Unit (Abban), Shuthed (Applan) and Zuban) choology.com; ages from van Bellen et al 1959; Estimates of manyes are as high as 25 billion Ually units are from Majooon-3, drilled in 1978 (Appwall et al. 2010). The width of the Majooon parrying the results of the 2011 are particular the field and the same distribution of the Same distribution of the Same distribution of the 2011 are particular the field and the same distribution of the 2011 are particular the field and the same distribution of the 2011 are particular the field and the same distribution of the 2011 are particular the field and the same distribution of the 2011 are particular the same distribution of the same are particular the same distribution of the 2011 are particular the same distribution of the same	
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	L.Fars (Miccene)
	Ghar (Miccene?)
	Dammam (Eccene) Rus (Eccene)
Umm er F	tadhuma (Paleocene-Eocene)
Shitemish - T	fayarat - Guma (late Cretaceous)
Khaab - Tanur	na - Sadi - Hartha (late Cretaceous)
Atmad - R	tumelle - Mishrif (Cenomanian)
Nah	r Umr - Maudud (Albian)

	Zubeir - Shu'aiba (Hauterivian-Aptian)
	Ratavi (Valanghrian) Yamama - Sulaiy (early Cretaceous)
T	Gotria Najmah Bargetu Atan Mus Adatyah Butmah
	Bakd Kurra Chine Titassic Geli Khans [7]
$\langle \rangle$	Permian (CNe Zhairt)
λ	L.Patseozoic
-r }	Hormuz?
	Baservarit.

GRL regional xs60

INVERSION OF TETHYAN RIFTS

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

Kani Masi valley



Late Carb. subcrop map (Aqrawi et al 2010)

Tavakoli-Shirazi et al 2013

n Geospatial Research Ltd.

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.

Dra-Oukarca anticlines

Odi+Condes valles





OBLIQUE CLOSURE OF TETHYS

Transcurrent + Compression = Transpression





STRAIN PARTITIONING

Transcurrent + Compression = Transpression





STRAIN PARTITIONING





dip-slip

strike-slip

-

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)





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













ZAGROS WORKSHOPS





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



GRL ZAGROS REGIONAL MAPPING



Add - Trathese

Patrick - Keeling

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ZRM (PHASE1): MAIN REPORT



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 hes on an inferred deep structural lineament (basement fault?) that can be traced between the ends of the Maqlub, Simrit, Alqosh, Skaikan, and West Swara Tika anticlines, and bayond. The outprop comprises northereby dipping Pila Spi Insertones, in which hydrocarbons are emanting from both the fracture network and from the ungry matrix.

Table of Contents

Summary & (Conclusions
Table of Cont	tents
1. Introduc	tion6
1.1. Proj	ect Aims6
1.2. Area	a of Interest7
1.3. Sum	mary of Project Deliverables8
1.4. Sour	rce Data9
2. Zagros C	Jeological Mapping10
2.1. Over	rview: Aims of Surface Mapping10
2.2. Over	rall Mapping Strategy10
2.3. Spat	ial Resolution & Spatial Precision11
2.4. Map	ping Methodology12
3. Stratigra	phy & Stratigraphic Correlation13
4. Structura	al Style
4.1. Obs	erved Styles of Folds & Thrusts
4.2. Infer	rences on Sub-Surface Structures
4.3. Cros	ss-sections
5. Regional	1 Structure and Tectonics
5.1. Tect	onic Framework
5.2. Stru	ctural Elements
5.3. Larg	e-scale Tectonic Elements
5.4. Zona	ation of the Zagros Orogen
5.5. Tim	ing of Deformation
5.6. Tran	spressional Model for Zagros Collision
5.7. Tran	spression Model: Implications for Hydrocarbon Systems44
6. Recomm	nendations for Future Work46
7. Reference	

