Salt Tectonics in the Sivas Basin (Turkey): Outstanding Seismic Analogues.

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The Sivas Basin in Anatolia is likely the world’s finest open-air museum of salt tectonic structures. It is an elongated Oligo-Miocene sag basin that developed in an orogenic context above the complex Taurus-Pontides suture. From Late Eocene to Late Miocene salt deposition, salt tectonics and salt reworking occur in a north-verging foreland fold-and-thrust belt setting north of the Taurus. The result is an intricate system of salt ridges, minibasins, salt sheets and successive canopies. The orogenic continental setting is markedly different from the deep marine-passive margin environment of the petroleum rich salt basins such as Angola or the Gulf of Mexico, but close to the Pricaspian basin setting.

Despite huge difference in content and evolution the Sivas basin provides outstanding outcrops of the classic geometries associated to the development of diapirs, i.e. halokinetic sequences along diapir walls, and associated stratal deformations. The Sivas Basin also presents more exotic structures such as 4-ways closed minibasins, megaflaps (thinned sedimentary sequences pinching out on top of diapirs and overturned during glaciers later development) and evaporites allochtonous sheets. Such structures are only observed in thick and highly deformed salt basins, and are rarely seen at outcrop: only in the Axel Heiberg area (Northern Territories, Canada - hardly accessible) and the Flinders Ranges (Australia).

Striking geometric analogies between these outcrops and seismic images from the classic petroleum province controlled by salt tectonics will illustrate the extraordinary quality of the Sivas basin as field analogue for the Gulf of Mexico, the Brazilian, Angolan and Congo Margins. Some comparisons with analog models under scanner will also be shown.
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MARGIN’S GRAVITY TECTONICS SETTINGS

Gliding dominated (Angola)

Spreading dominated (GOM)

Two major petroleum provinces
Deep marine settings
WIDE AZIMUTH SEISMIC IS VERY GOOD BUT…

NEED FIELD ANALOGS AND MODELS

Important uncertainties

- Geometries against the salt walls
- Facies near the salt walls
- Sealing against/near the walls
- Diagenesis
- Fractures network…
A GEOLOGICAL FAIRY TALE

Pre-drill

2008

Subsalt GOM on Conventional 3D

IFP for COBALT, Callot et al., 2016

Analogue modeling

2010

Sivas Field Analogue

2009

Megaflaps: Ligurian, Heidelberg...

2011

TOTAL-UPPA
Structural Geology
Chair
Prof. JP Callot &

4 PhD students since 2012:
C. Ribes, C. Kergaravat
E. Legeay, A. Pichat

WATS 3D
THE NOW FAMOUS EMIRHAN AND KARAYÜN MINIBASINS

Kergaravat, 2016
HALOKINETIC SEQUENCES: WEDGES

Giles and Rowan, 2012
HALOKINETIC SEQUENCES: HOOKS

Giles and Rowan, 2012
THE NOW FAMOUS EMIRHAN AND KARAYÜN MINIBASINS
COMPOSITE HALOKINETIC SEQUENCES AND FAULTS

Two scales of faults and fractures

From seismic to reservoir scale
Small faults and fractures

Tapered CHS
Mega Hook HS
Tapered CHS
Tapered CHS

Salt Diapir

West Karayün MB
Karayün wall
Mid. Karayün Fm.
Low. Karayün Fm.

Two scales of faults and fractures

? Isopaque

Tapered CHS
THE NOW FAMOUS EMIRHAN AND KARAYÜN MINIBASINS

Explanation:
- Black lines represent evaporite.
- Orange lines represent Miocene sediments.
- Yellow lines represent Upper Cretaceous sediments.
- Blue lines represent Lower Cretaceous sediments.
- Red lines represent Late Cretaceous sediments.
- Green lines represent Paleogene sediments.

GOM
MEGAHOOK AND UNCONFORMITY

[Diagram showing geological features, including a pseudo-weld trajectory and various geologic units such as marine, lacustrine, and fluviatile formations.]

[Images of landscapes and geologic cross-sections.]
THE NOW FAMOUS EMIRHAN AND KARAYÜN MINIBASINS
MEGAFLAP EVOLUTION

Complex tip geometries
Visible only on the field and FMI

Without salt extrusion

With salt extrusion
Below canopy

Limb rotation

Rowan et al., 2016
SALT SHEETS AT VARIOUS SCALES

SSW
Çaygören wall
Karacaören Fm.
Çaygören MB

Eğribuçak
MB

SSW
Salt Sheet
Ramp
Flat

SSW
Salt Sheet
Ramp
Flat

Ramp
Evaporite
Benlikaya Fm.

1
Flat
Flat Contact
20cm

1
Flat

2
Flat

Continental Sabkha
Benlikaya Fm.

Ramp
Evaporite

Ramp Contact
20cm

~500 m

1 cm
THE SIVAS SALT MACHINE

Thrust wedge
Salt basin in a foreland

Triangle zone
Secondary MBs on canopy

Strong shortening in WABS

Kergaravat et al., 2016
Similarities with DO provinces:
- Geometries and evolutions

Differences with DO provinces:
- Orogenic context vs passive margin context
- Fluvial to very shallow marine sediments vs shelf to bathyal
- Makes it difficult to compare facies distributions and diagenesis

Large stock of evaporite is a strong driver whatever the tectonic system.
Canopies act as a decoupling layer vs basement déformation
Influence of tectonics context increases with salt withdrawal. Toward a typical Foreland FTB
A MOVIE: « salt tectonics + Sivas » in YouTube
COMING SOON: 3D Drone acquisition of the best outcrops

SALT TECTONICS IN THE SIVAS BASIN, TURKEY:
OUTSTANDING SEISMIC ANALOGUES FROM OUTCROPS
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