Cross-Strike Structures and Hydrocarbon Migration and Accumulation: Examples in Three Alpine Thrust Belts*

Raffaele di Cuia[1], Raffaele Bitonte[1], and Paolo Pace[1]

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[1]G.E.Plan Consulting, Ferrara, Italy (raffaele.dicuia@geplan.it)

Abstract

Cross-strike structures or transverse zones are discontinuities trending remarkably oblique to the thrust belt structures causing sharp along-strike variations and lateral changes (Leslie et al., 2010). Among the possible causes controlling the location of cross-strike structures and transverse zones are (1) preexisting sub-décollement basement faults, (2) cover strata deformed above basement faults, and (3) along-strike variations in mechanical stratigraphy and lateral thickness/facies changes. Commonly, these cross-strike structures are constituted by regionally important faults or array of faults mostly represented by lateral/oblique thrust ramps, oblique faults, strike-slip, or transfer faults. The study focused on the comparison between three case studies related to three different carbonate-dominated Alpine-type fold-and-thrust belts: the Zagros in the Kurdistan region of NE Iraq, the outer Albanides in Albania, and the Central Apennines in southern Italy. Selected thrust-related structures are investigated by means of remote sensing (LANDSAT ETM+ and QUICKBIRD satellite images) analysis allowing large-scale structural reconstructions integrated also with some field observations. The considered thrust belts have in common a similar genesis as they formed at the expenses of formerly passive margins, which were developed over the Mesozoic Neo-Tethys Ocean. In that sense, they present similar structural characteristics allowing straightforward comparisons among structures. The cross-like transverse structures have a critical impact on controlling different modes of fluid pathways. Furthermore, they can affect the development and distribution of fracture patterns within thrust-related anticlines. By comparing selected practical cases coming from similar thrust belts, the results of this study suggest that cross-strike structures have a dramatic impact on hydrocarbon migration and accumulation. They mostly act as structural barriers to lateral fluid migration being crucial in compartmentalizing the reservoirs and contributing in localizing hydrocarbon accumulation. Generally, the fracture intensity is variable and it increases up drastically approaching closer fault zones. Considering the lithological units, structures and stresses, the characterization of fractures network along cross-strike faults is fundamental and contribute to understand fluid migration behaviors within carbonate reservoirs having potentially a positive impact for hydrocarbon exploration.

Selected References

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CROSS-STRIKE STRUCTURES AND HYDROCARBON MIGRATION AND ACCUMULATION: EXAMPLES IN THREE ALPINE THRUST BELTS

RAFFAELE DI CUIA, RAFFAELE BITONTE, PAOLO PACE

GEPlan Consulting (Italy)

AAPG ACE Calgary (Canada) – 21st June 2016

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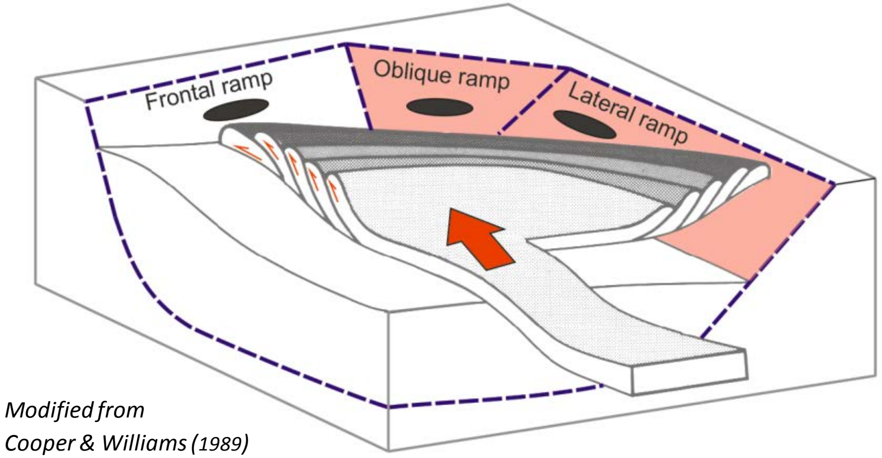
AAPG Annual Convention & Exhibition 2016

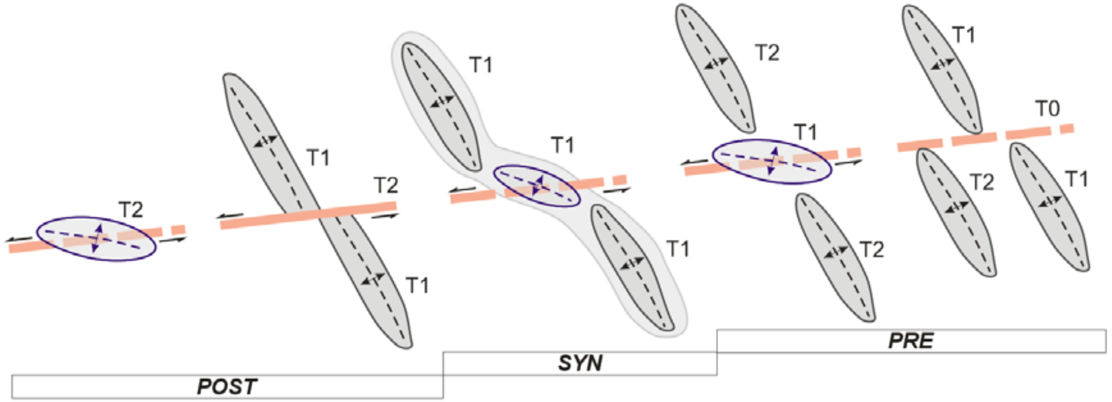
CROSS-STRIKE STRUCTURES

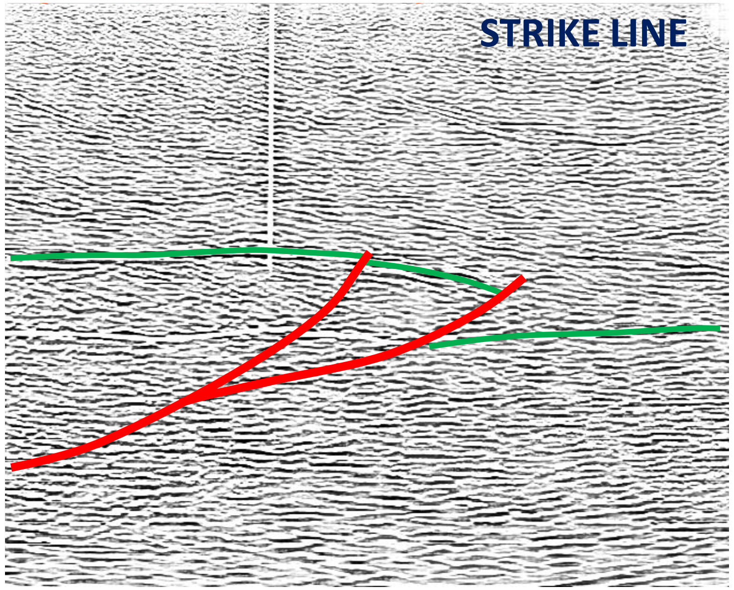
LATERAL/OBLIQUE THRUST RAMPS



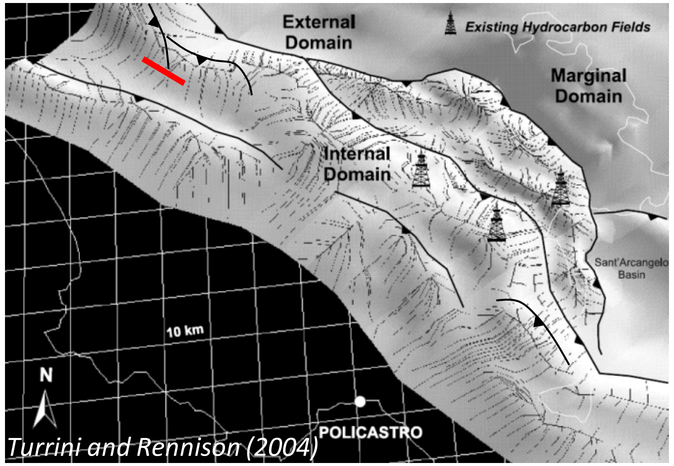
Modified from
Cooper & Williams (1989)

STRIKE-SLIP FAULTS

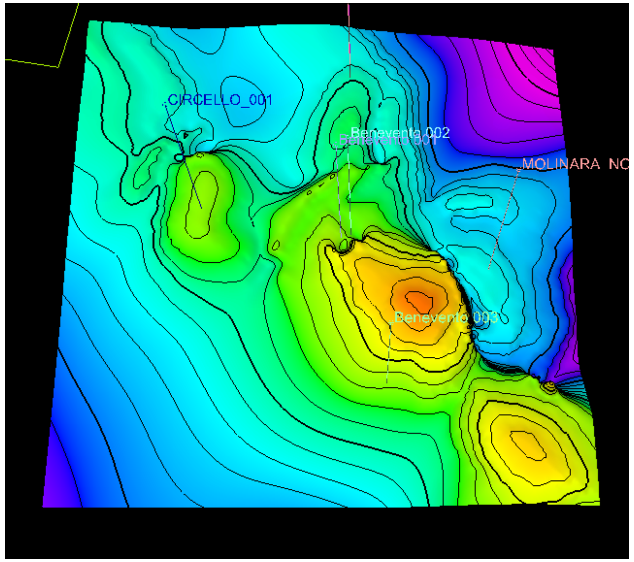




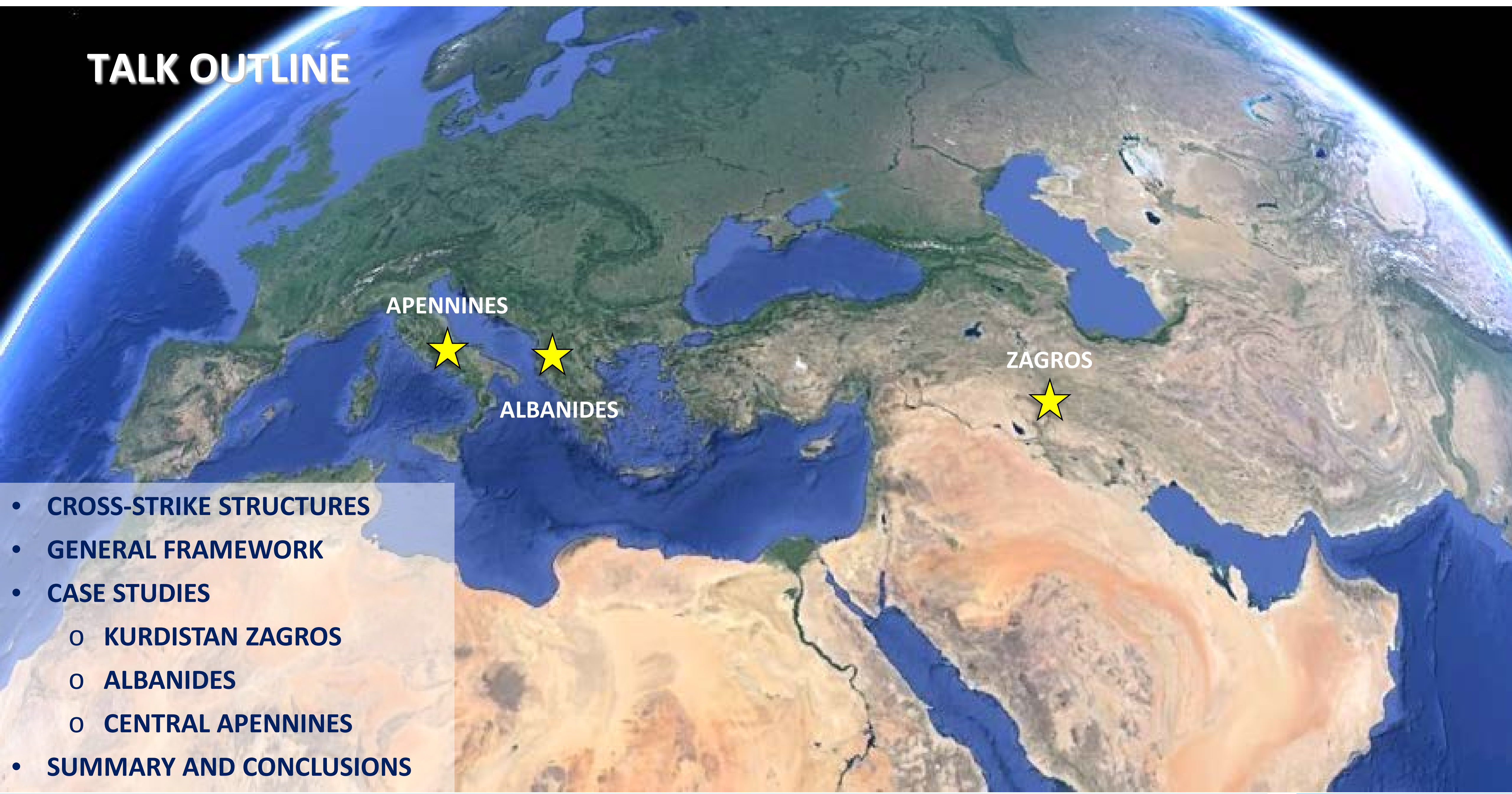
TOP APULIAN CARBONATES



Turrini and Rennison (2004)

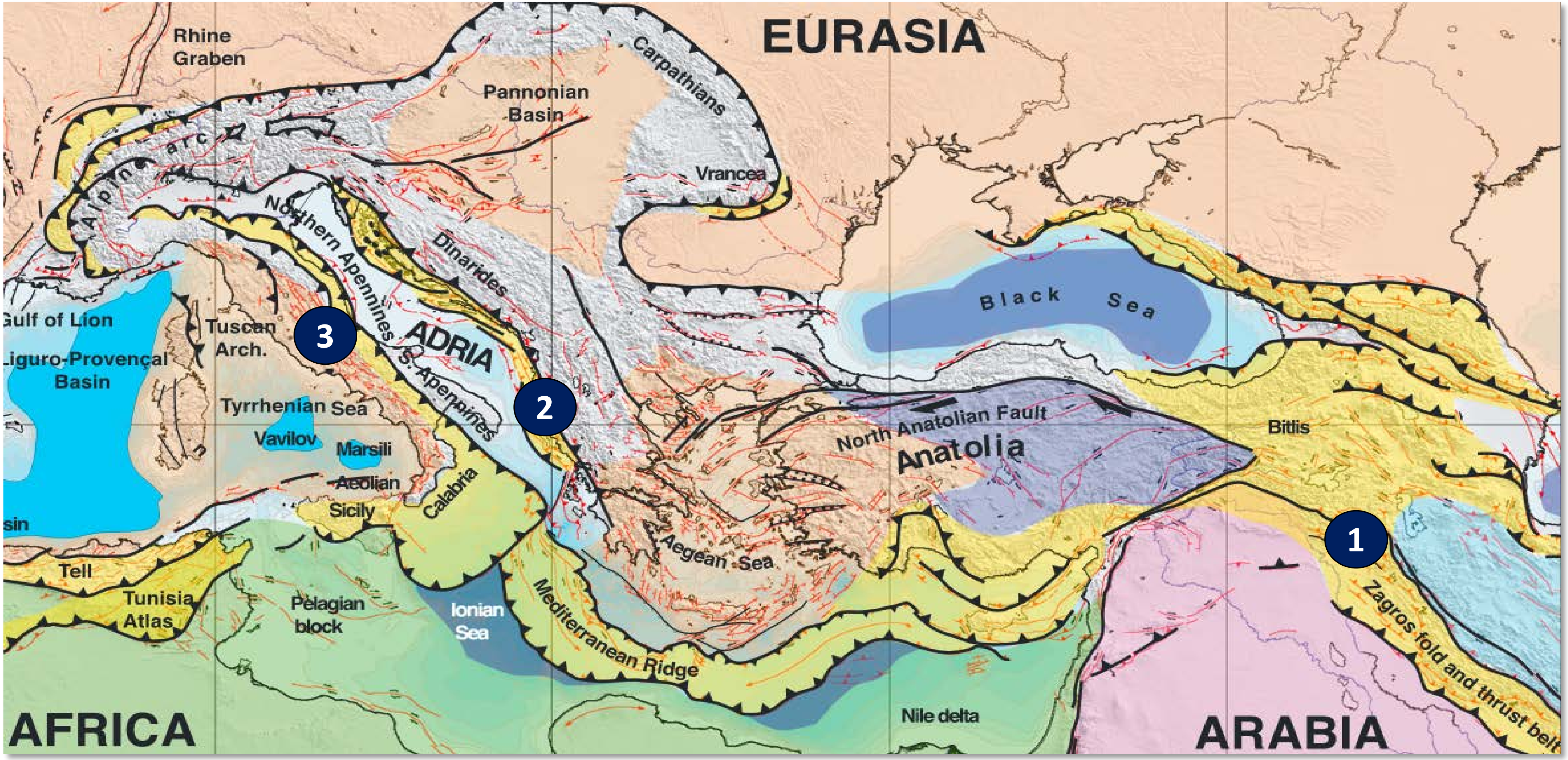


TALK OUTLINE



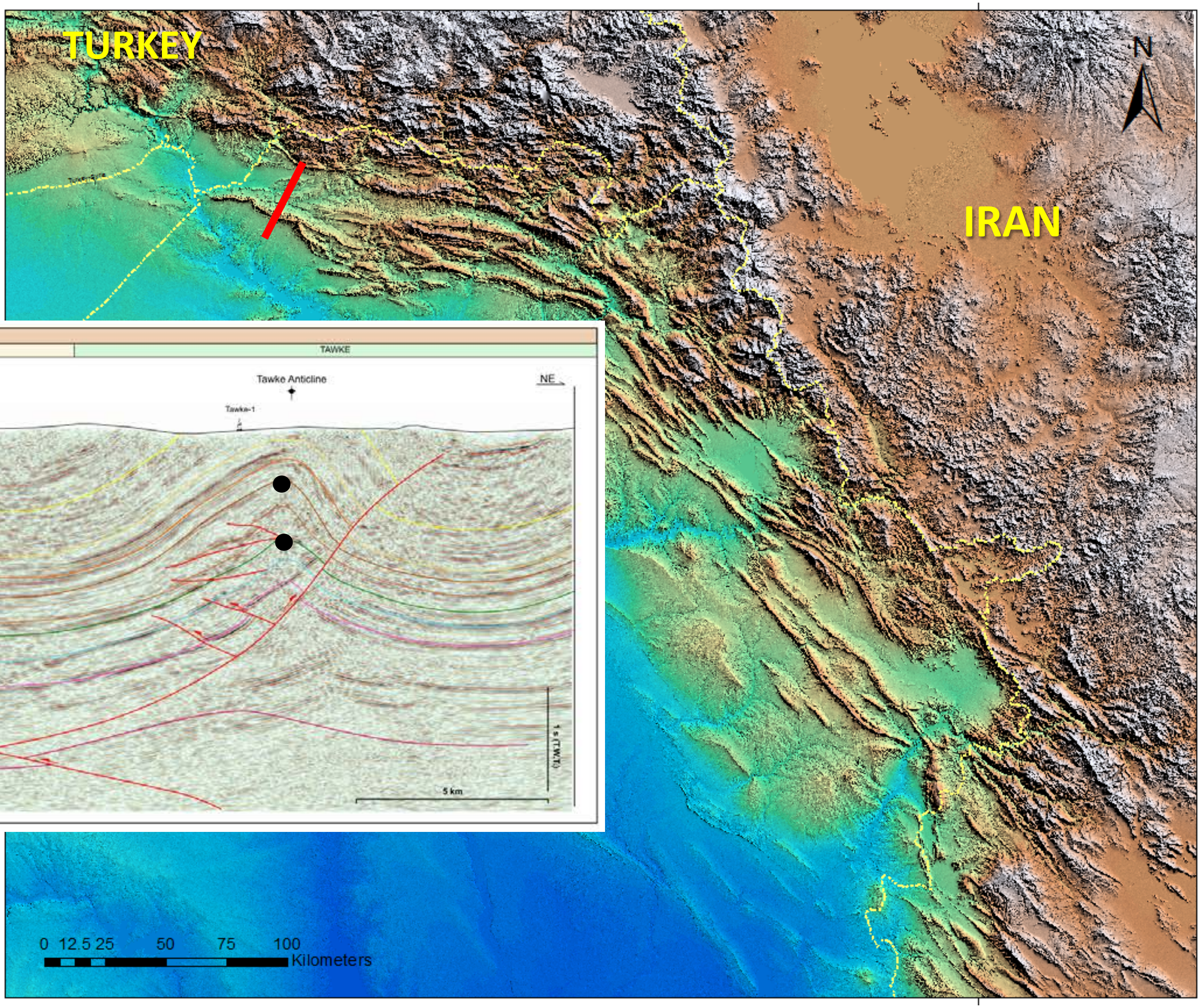
- **CROSS-STRIKE STRUCTURES**
- **GENERAL FRAMEWORK**
- **CASE STUDIES**
  - **KURDISTAN ZAGROS**
  - **ALBANIDES**
  - **CENTRAL APENNINES**
- **SUMMARY AND CONCLUSIONS**

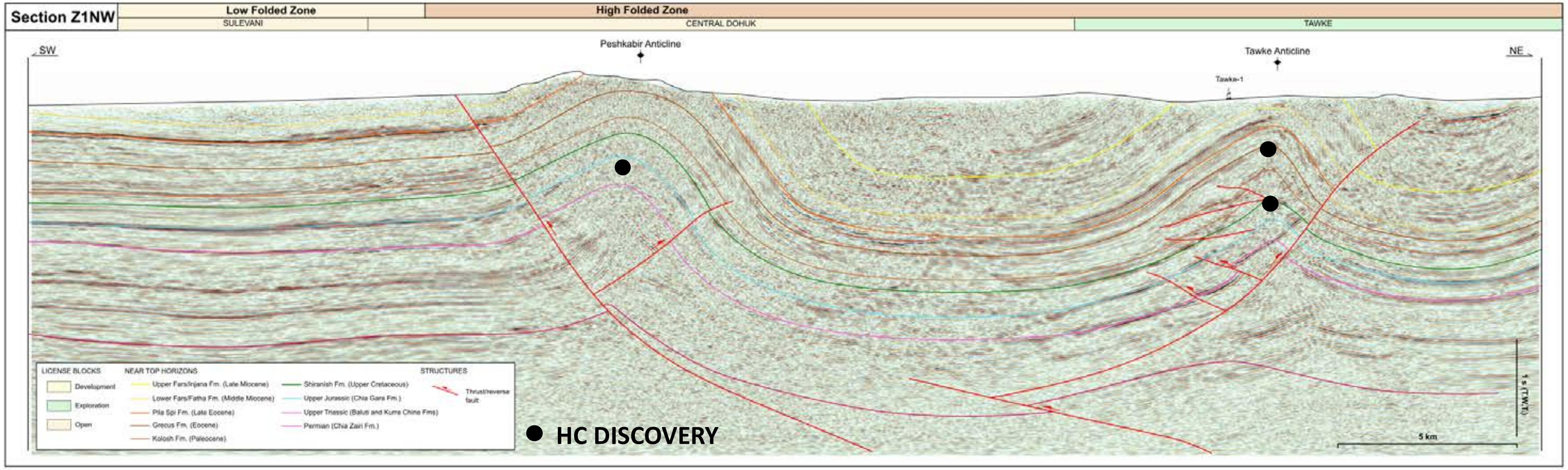
PLATE TECTONIC SETTING



Faccenna et al. (2014)

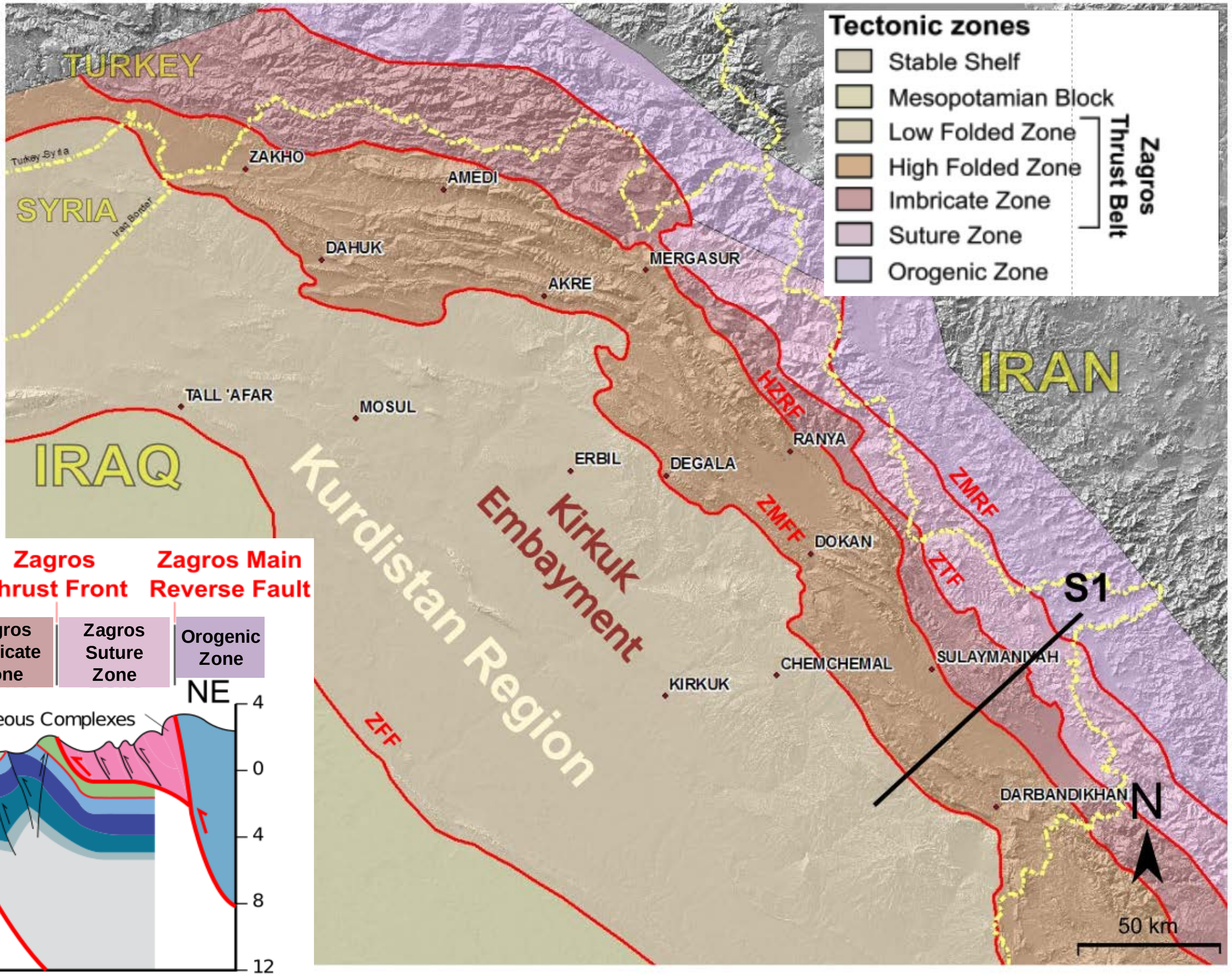
CASE 1: NORTHERN ZAGROS THRUST BELT



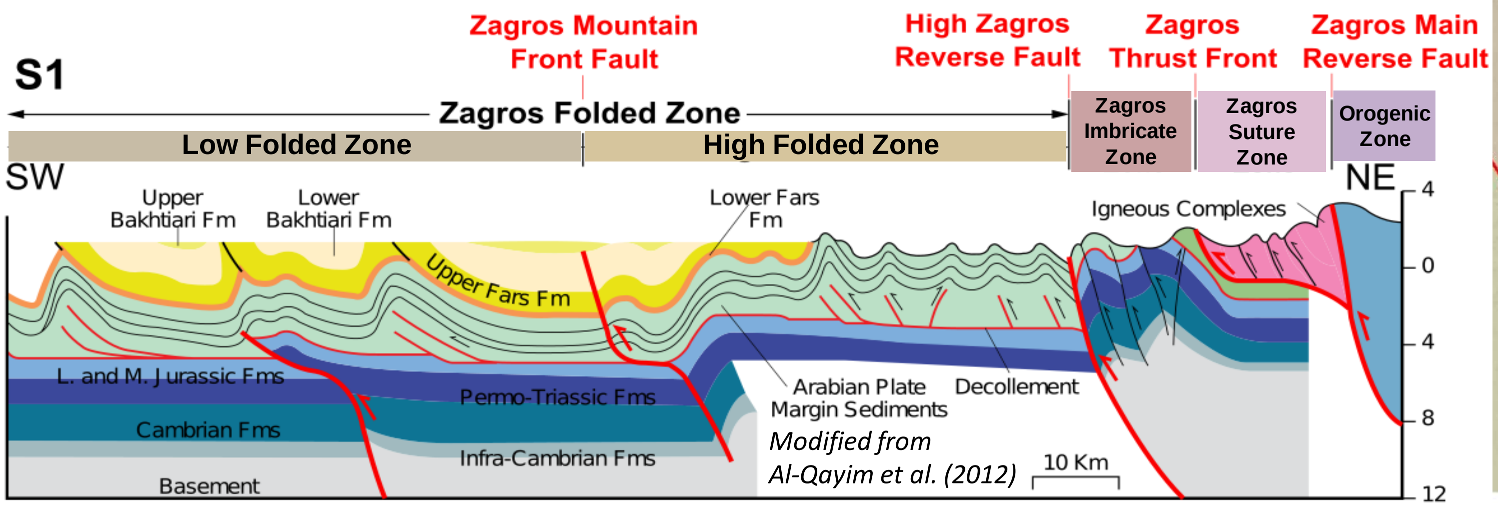


KURDISTAN ZAGROS

- MOST OF THE PRESENT-DAY STRUCTURAL GEOMETRIES AND ANTICLINES RESULT FROM THE LAST ZAGROS TECTONIC PHASE (MIOCENE-PLIOCENE)
- NW-SE TREND IN THE SOUTHERN SECTOR DEVIATING TO WNW-ESE AND E-W NORTHWARD
- HYDROCARBONS WITHIN TRIASSIC TO TERTIARY FRACTURED CARBONATE RESERVOIRS HOSTED IN THRUST-RELATED ANTICLINES

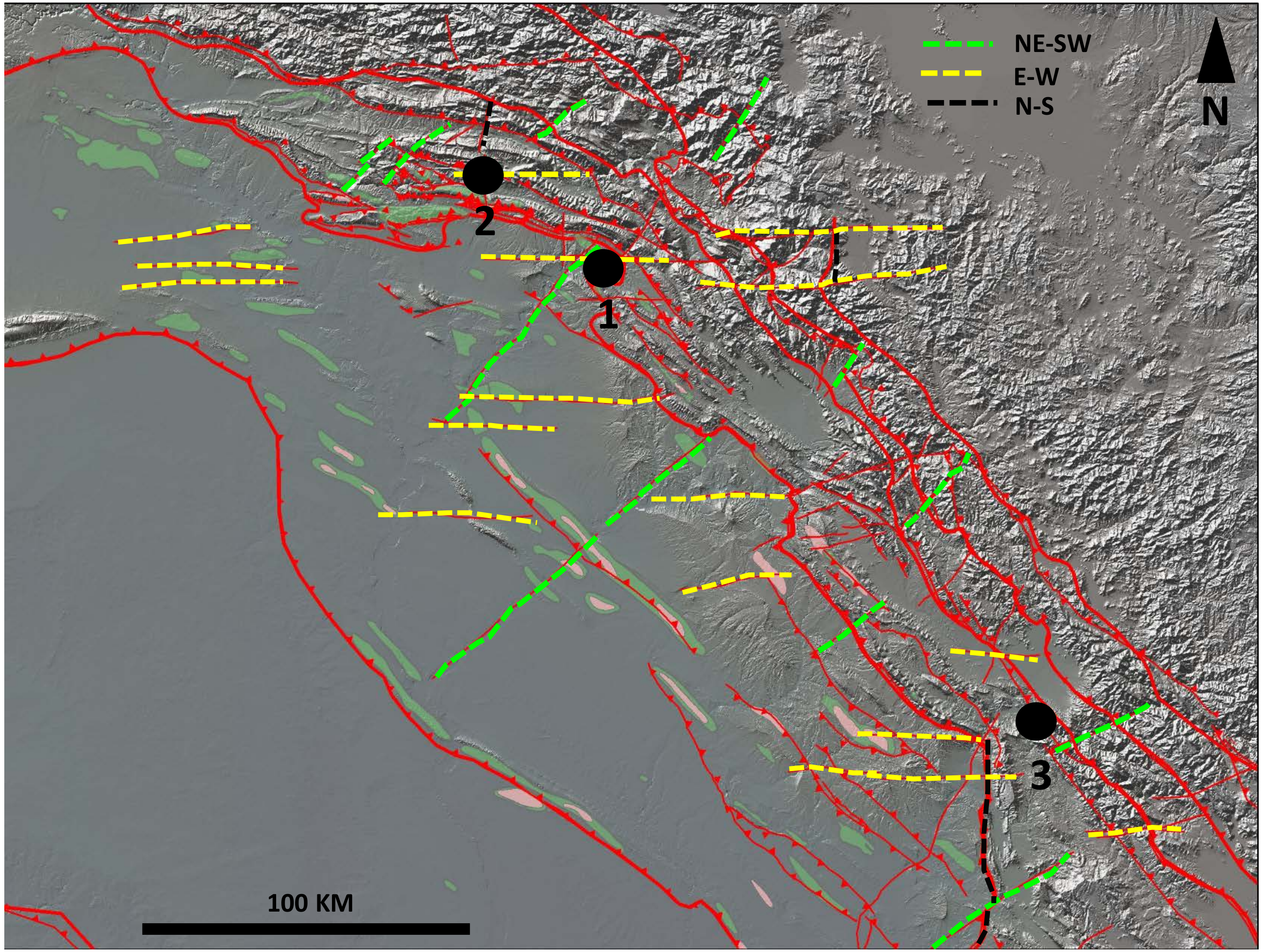


HYDROCARBON OCCURRENCE

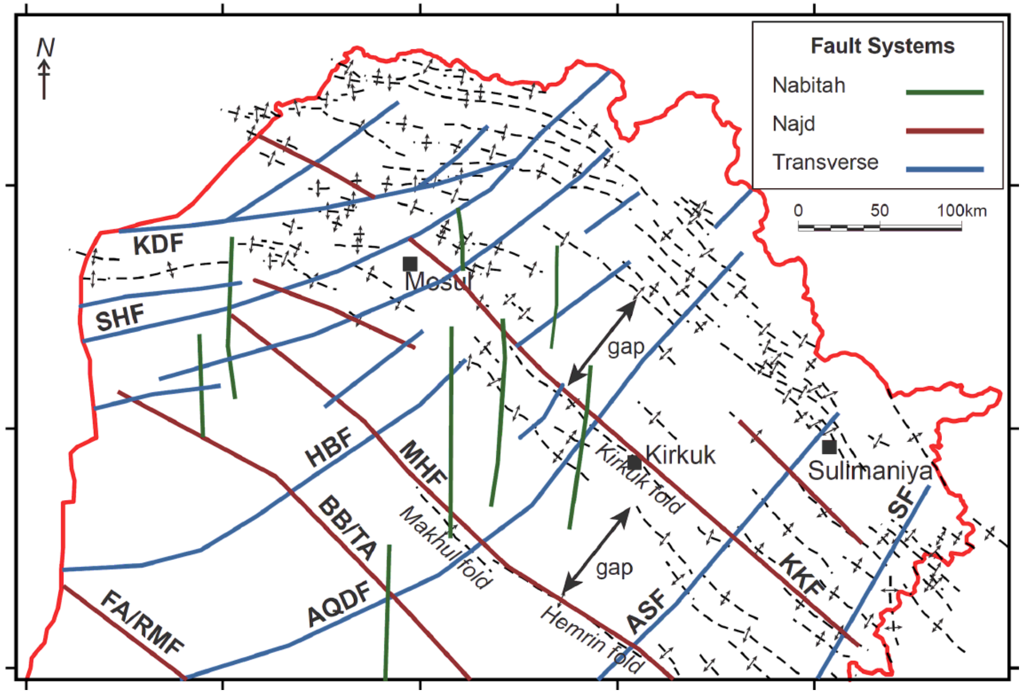


Modified from Al-Qayim et al. (2012)

CROSS-STRIKE FAULTS AT REGIONAL SCALE

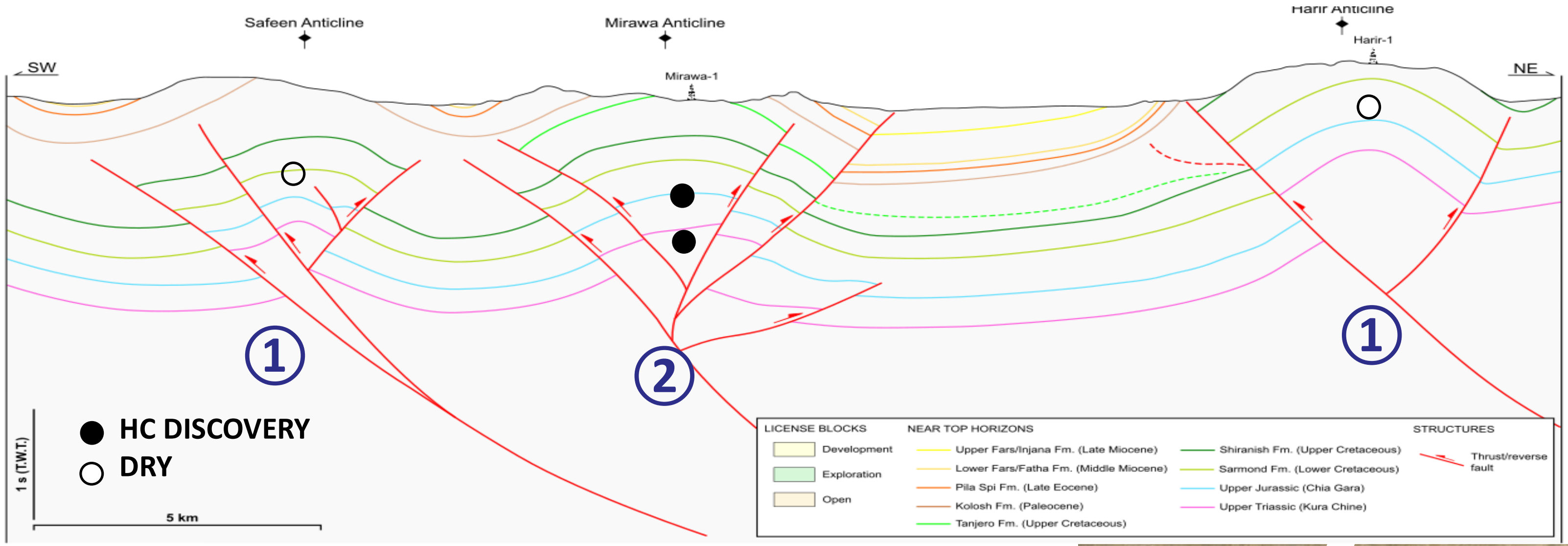


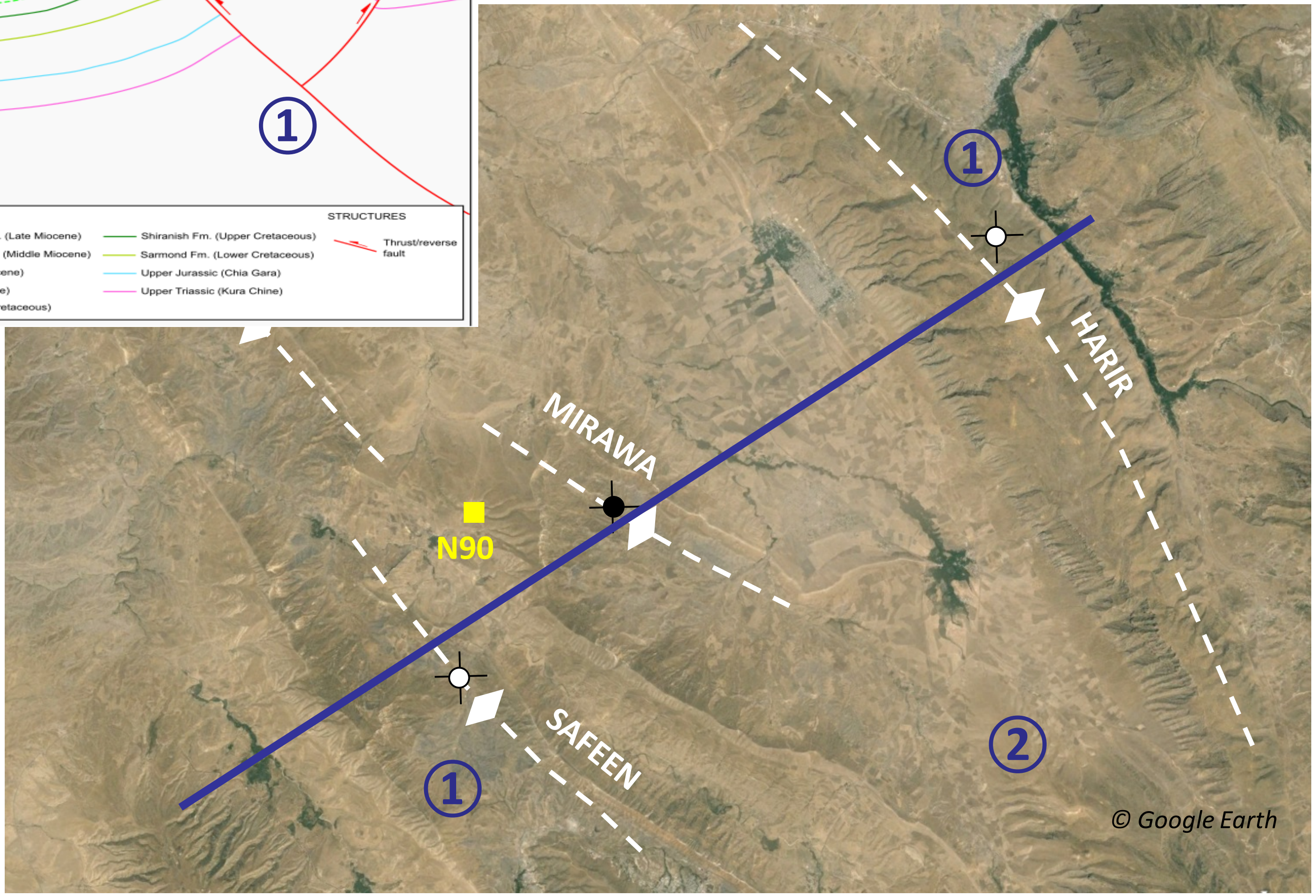
- N-S, E-W AND NE-SE-TRENDING TRANSVERSE FAULTS AT BOTH SURFACE AND BASEMENT LEVELS
- SEGMENTATION OF THE THRUST BELT



Burberry (2015)

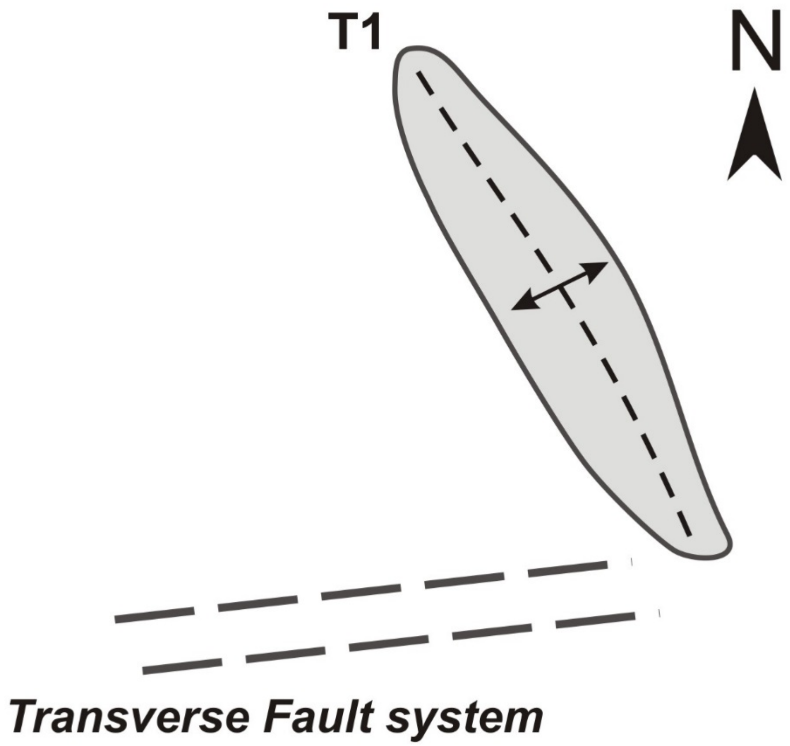
MIRAWA STRUCTURE





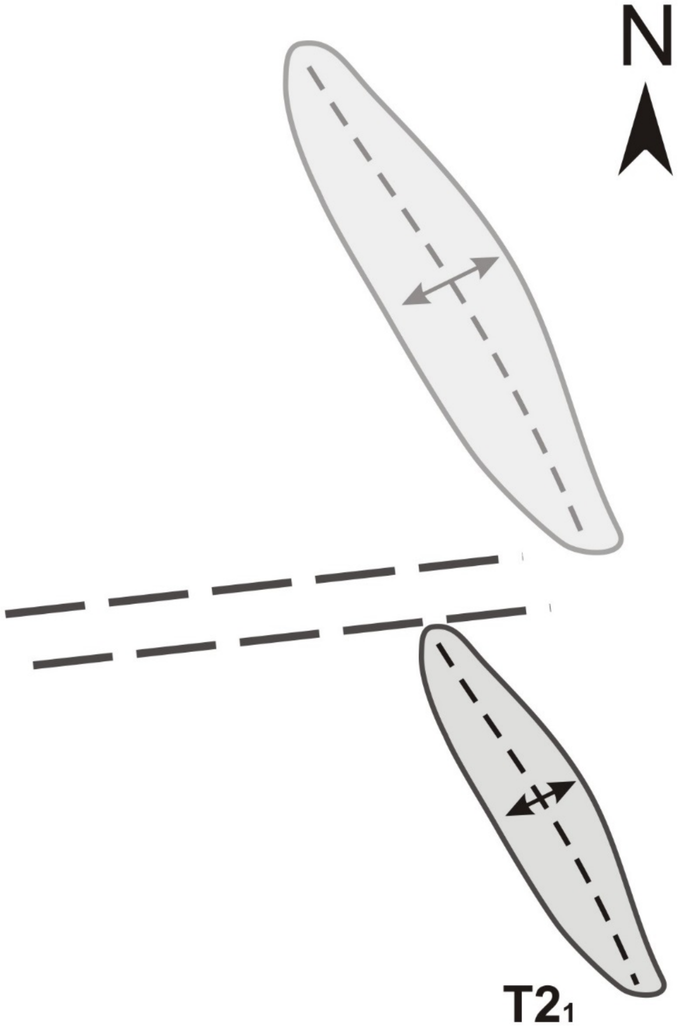
1. ZAGROS-TYPE (HIGH-FOLDED ZONE) NW-SE-TRENDING ANTICLINE STRUCTURE AND ASSOCIATED FAULT & FRACTURE SETS (SAFEEN AND HARIR ANTICLINES)
2. IN BETWEEN WNW-ESE TRANSPRESSIONAL PUSH-UP (MIRAWA STRUCTURE) RELATED TO AN E-W TRENDING REGIONAL TRANSFER ZONE

STRUCTURE-1: MIRAWA



T1 - INNER NW-SE THRUST-RELATED ANTICLINE DEVELOPMENT

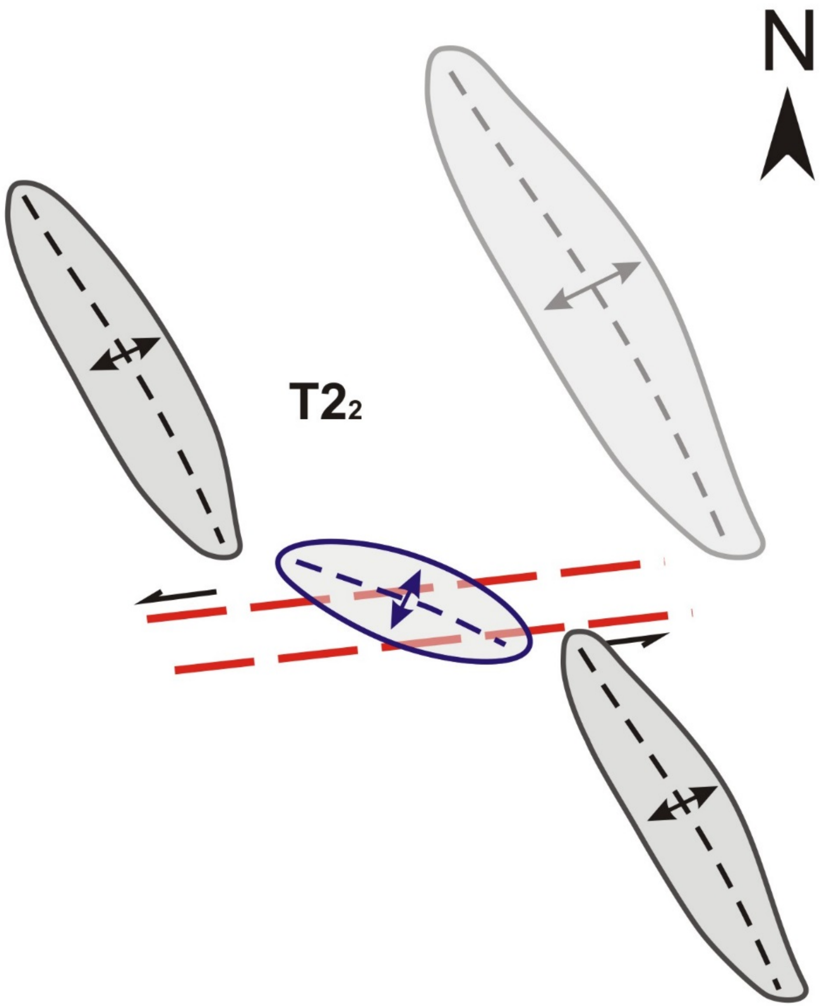
STRUCTURE-1: MIRAWA



T1 - INNER NW-SE THRUST-RELATED ANTICLINE DEVELOPMENT

T2₁ - NW-SE THRUST-RELATED ANTICLINE DEVELOPMENT

STRUCTURE-1: MIRAWA

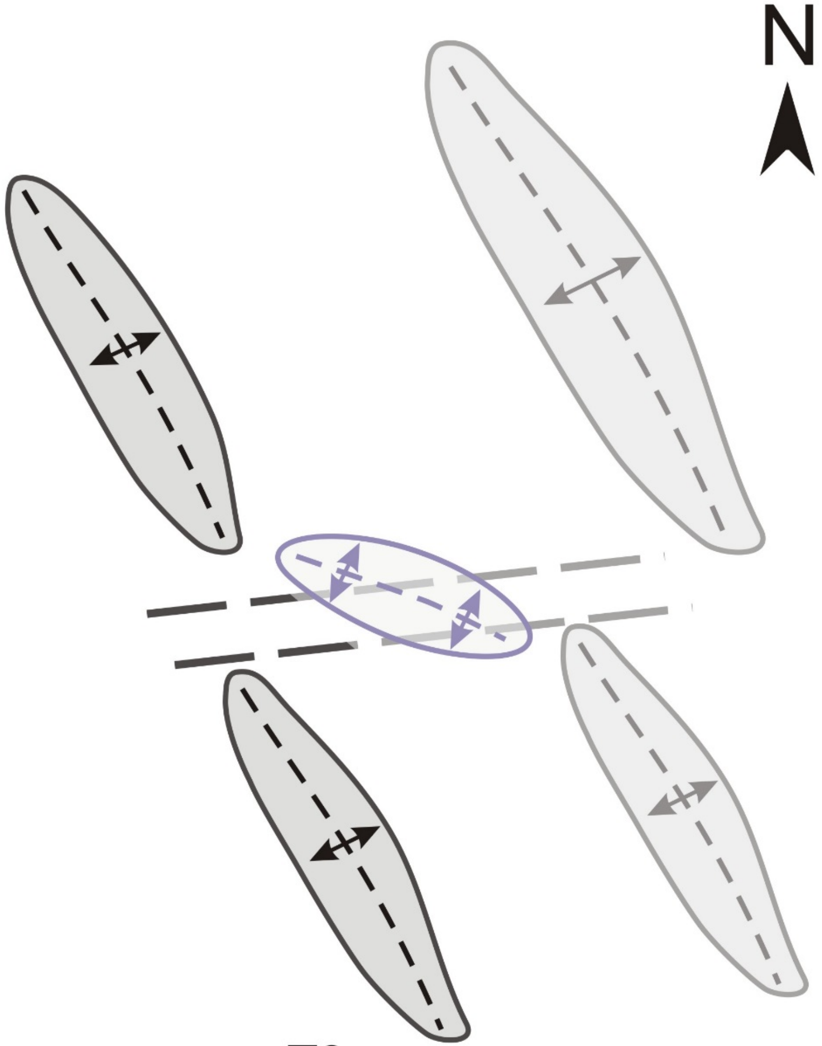


T1 - INNER NW-SE THRUST-RELATED ANTICLINE DEVELOPMENT

$T2_1$ - NW-SE THRUST-RELATED ANTICLINE DEVELOPMENT

$T2_2$ - NW-SE THRUST-RELATED ANTICLINE DEVELOPMENT ACCOMPAINED BY MOVEMENT ALONG THE TRANSFER ZONE WITH LOCAL REORIENTATION OF THE STRUCTURAL TREND, DEVELOPMENT OF A WNW-ESE-TRENDING STRUCTURE

STRUCTURE-1: MIRAWA



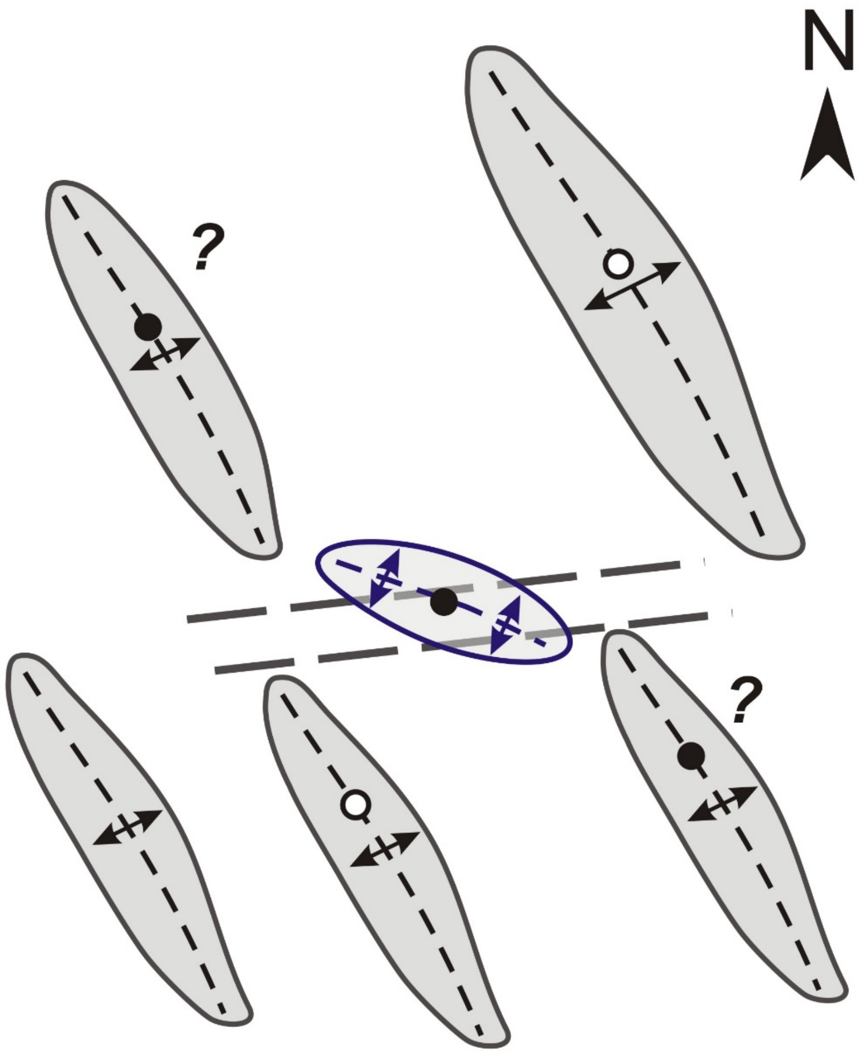
T1 - INNER NW-SE THRUST-RELATED ANTICLINE DEVELOPMENT

$T2_1$ - NW-SE THRUST-RELATED ANTICLINE DEVELOPMENT

$T2_2$ - NW-SE THRUST-RELATED ANTICLINE DEVELOPMENT ACCOMPAINED BY MOVEMENT ALONG THE TRANSFER ZONE WITH LOCAL REORIENTATION OF THE STRUCTURAL TREND, DEVELOPMENT OF A WNW-ESE-TRENDING STRUCTURE

T3 - NW-SE THRUST-RELATED ANTICLINE DEVELOPMENT

STRUCTURE-1: MIRAWA



T1 - INNER NW-SE THRUST-RELATED ANTICLINE DEVELOPMENT

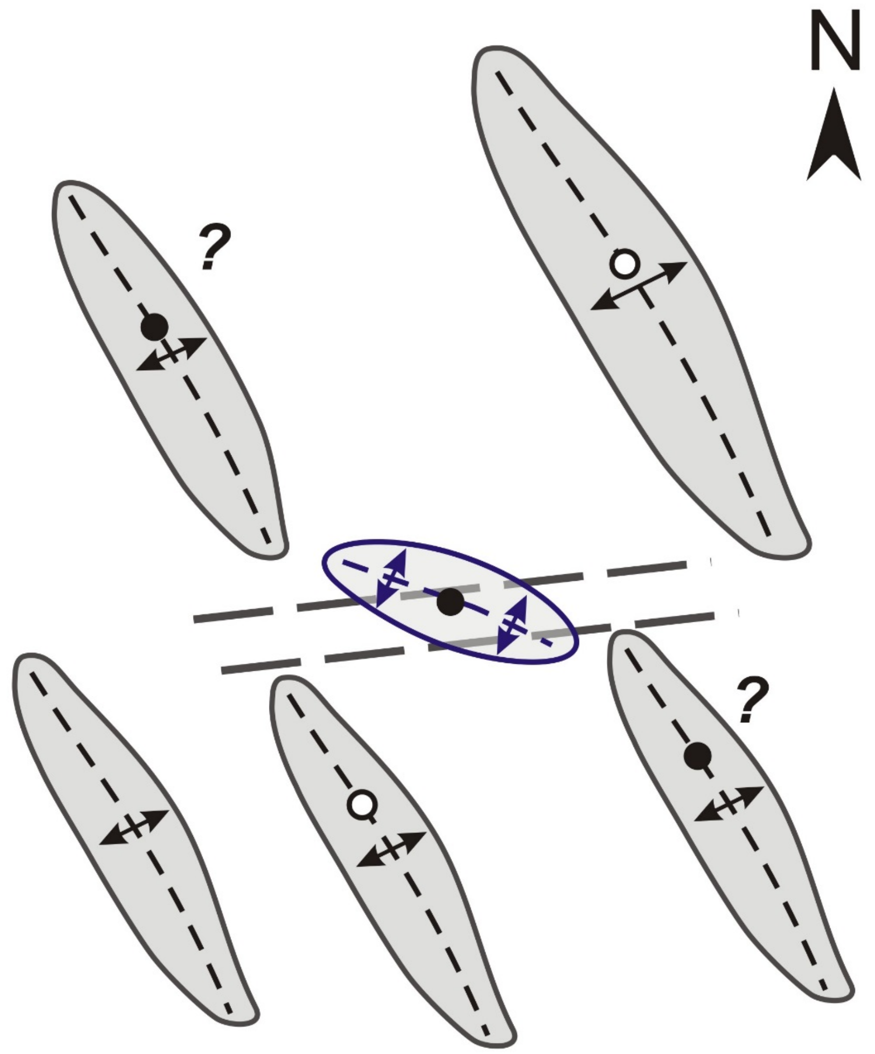
$T2_1$ - NW-SE THRUST-RELATED ANTICLINE DEVELOPMENT

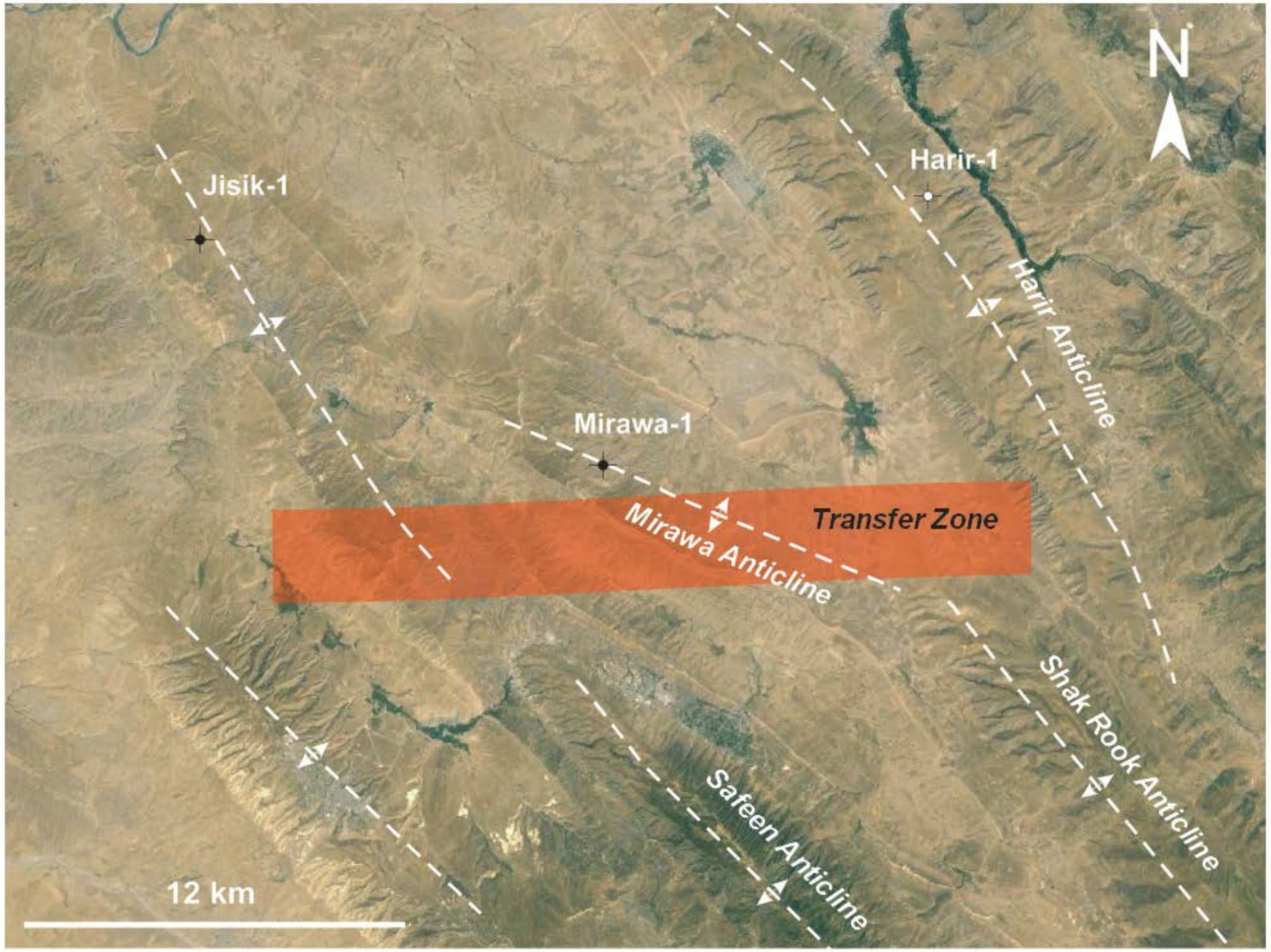
$T2_2$ - NW-SE THRUST-RELATED ANTICLINE DEVELOPMENT ACCOMPAINED BY MOVEMENT ALONG THE TRANSFER ZONE WITH LOCAL REORIENTATION OF THE STRUCTURAL TREND, DEVELOPMENT OF A WNW-ESE-TRENDING STRUCTURE

T3 - NW-SE THRUST-RELATED ANTICLINE DEVELOPMENT

T4- OUTER NW-SE THRUST-RELATED ANTICLINE DEVELOPMENT

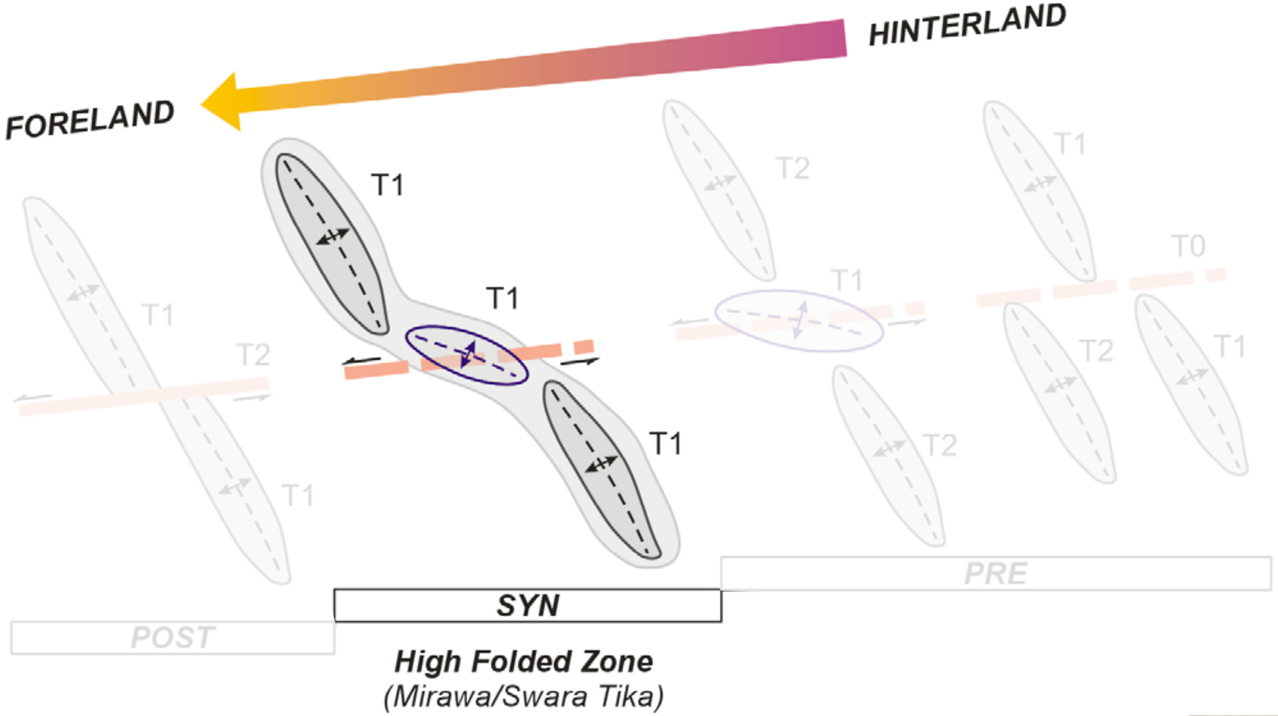
STRUCTURE-1: MIRAWA

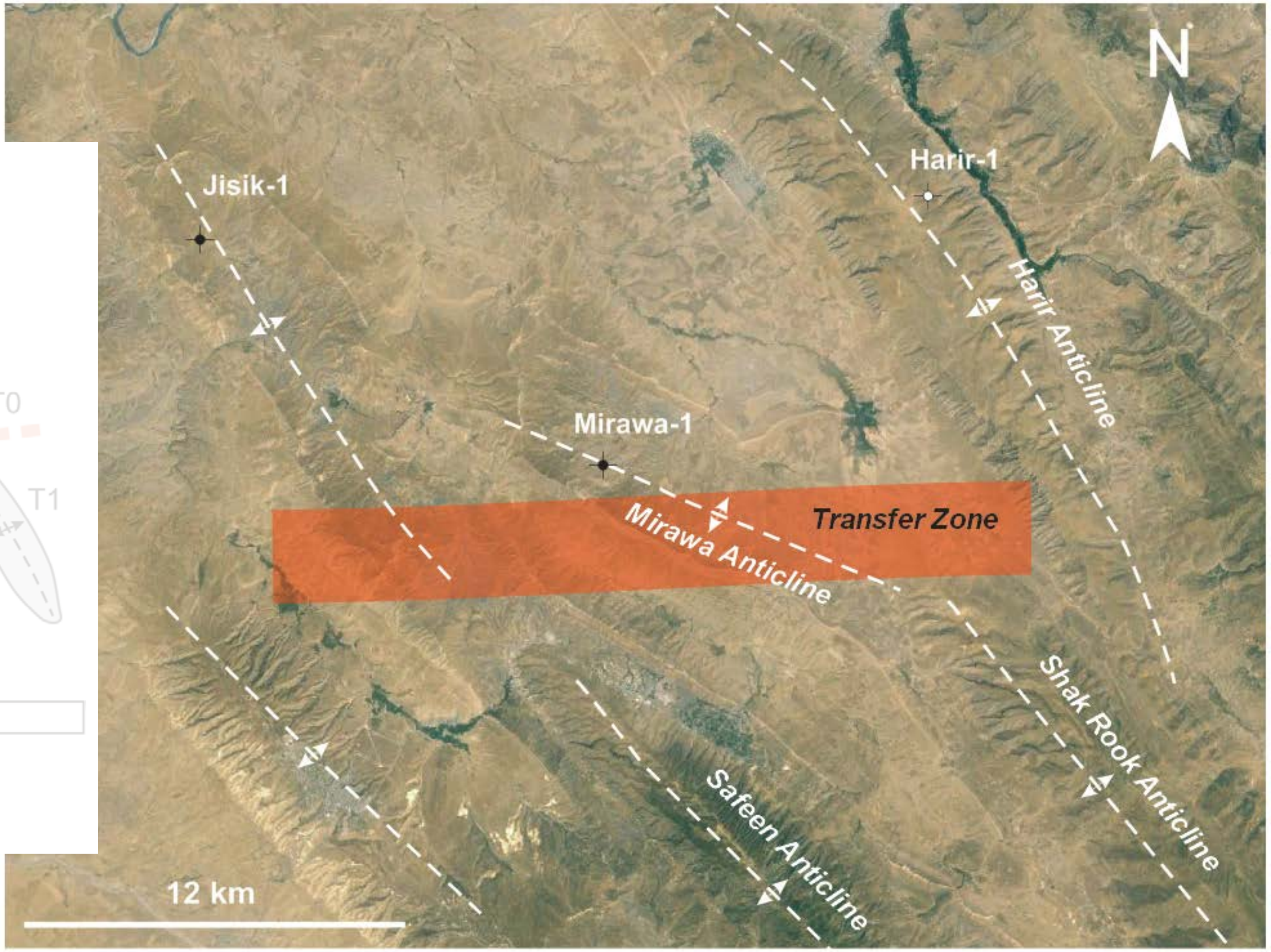




HYDROCARBON OCCURRENCE: HIGH EXPLORATION POTENTIAL IN THE OBLIQUE STRUCTURE CONTROLLED BY TRANSVERSE FAULTS (MIRAWA)

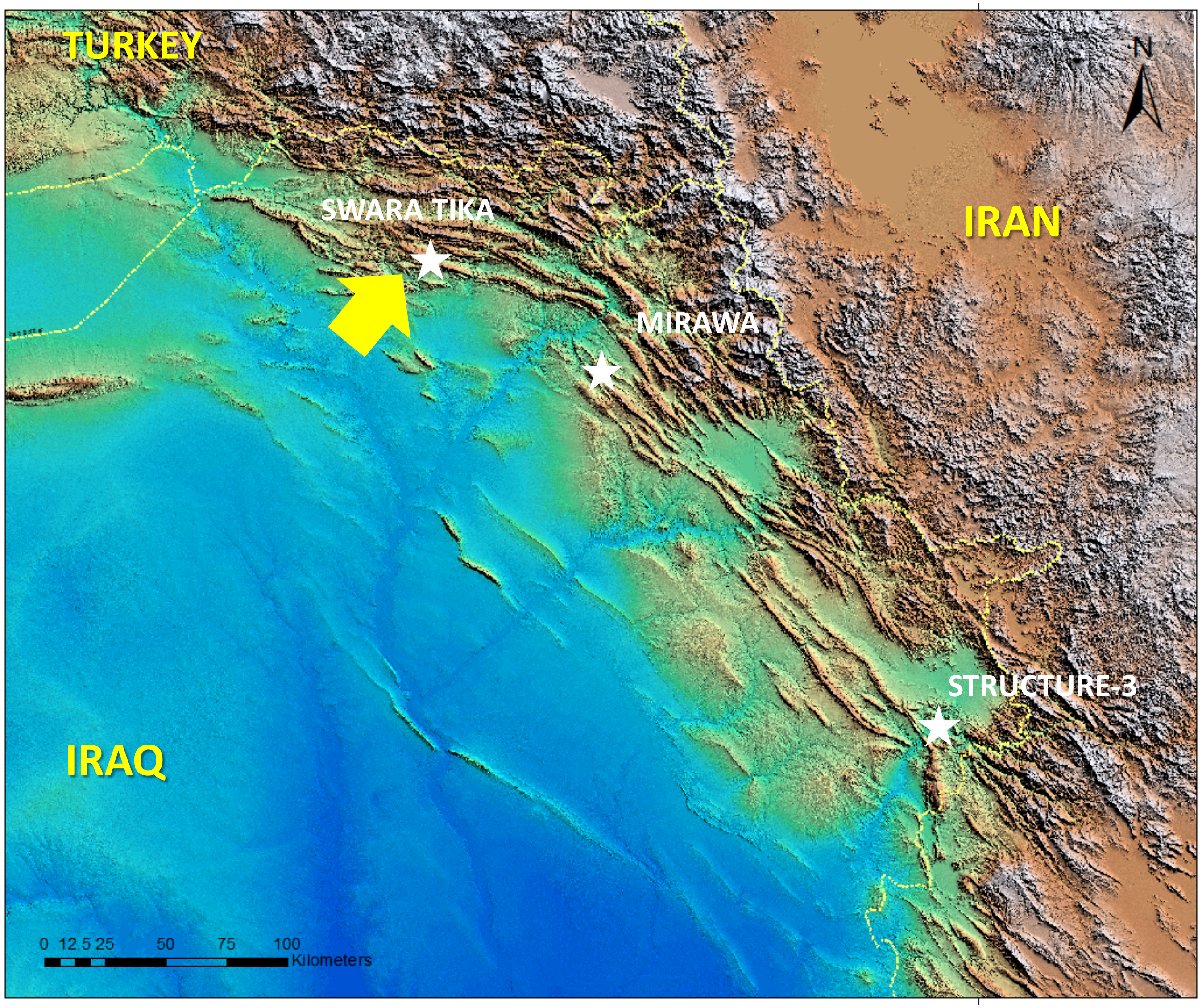
STRUCTURE-1: MIRAWA



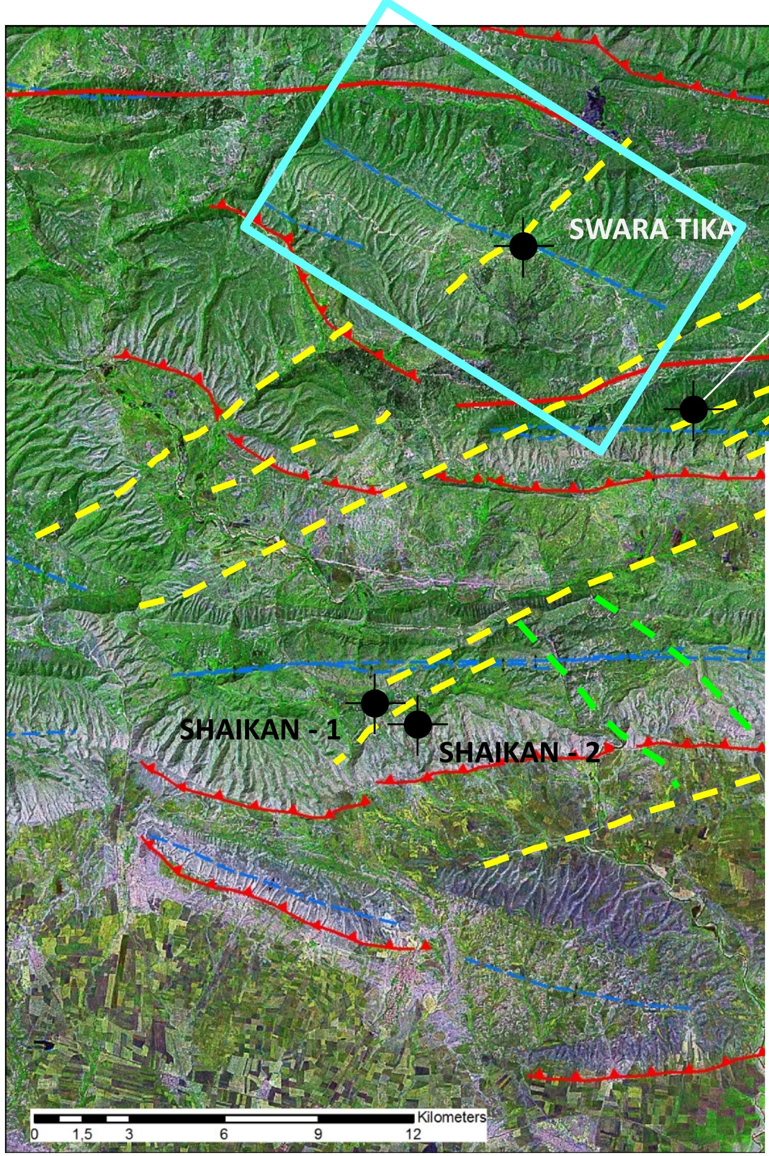


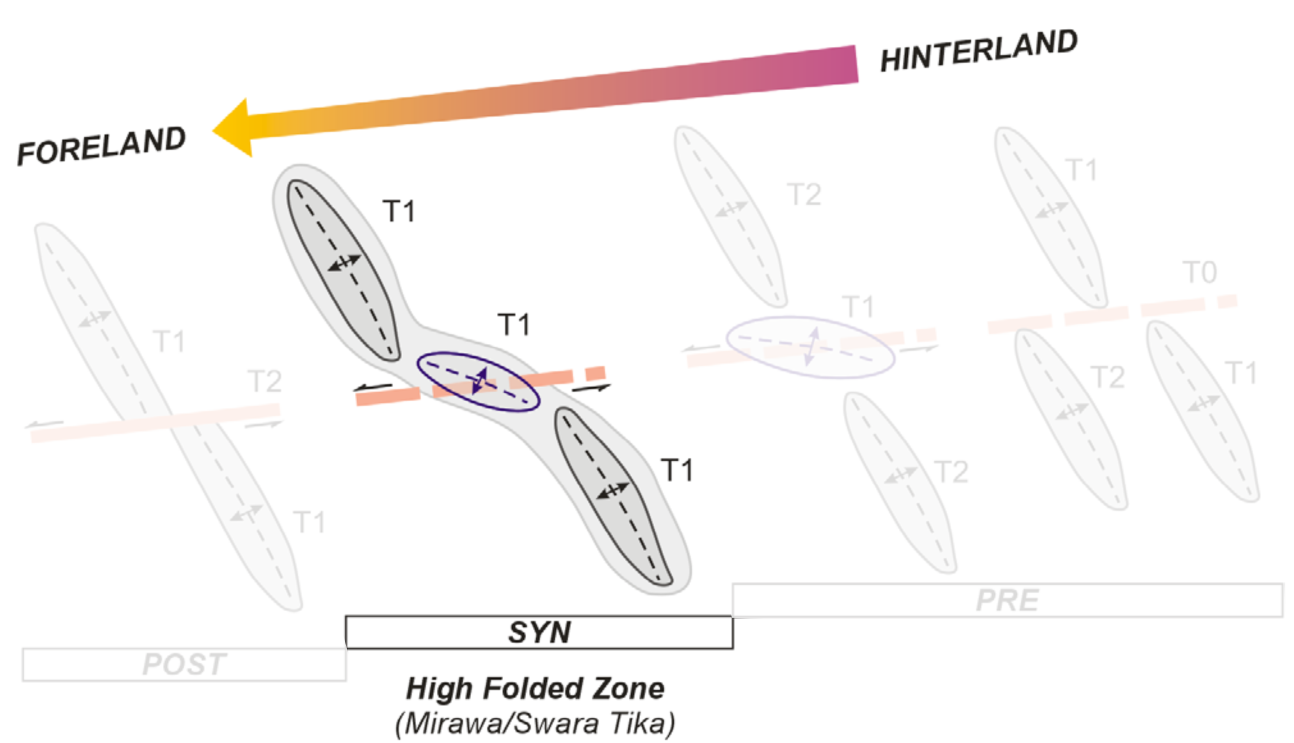
HYDROCARBON OCCURRENCE: HIGH EXPLORATION POTENTIAL IN THE OBLIQUE STRUCTURE CONTROLLED BY TRANSVERSE FAULTS (MIRAWA)

SWARA TIKA STRUCTURE

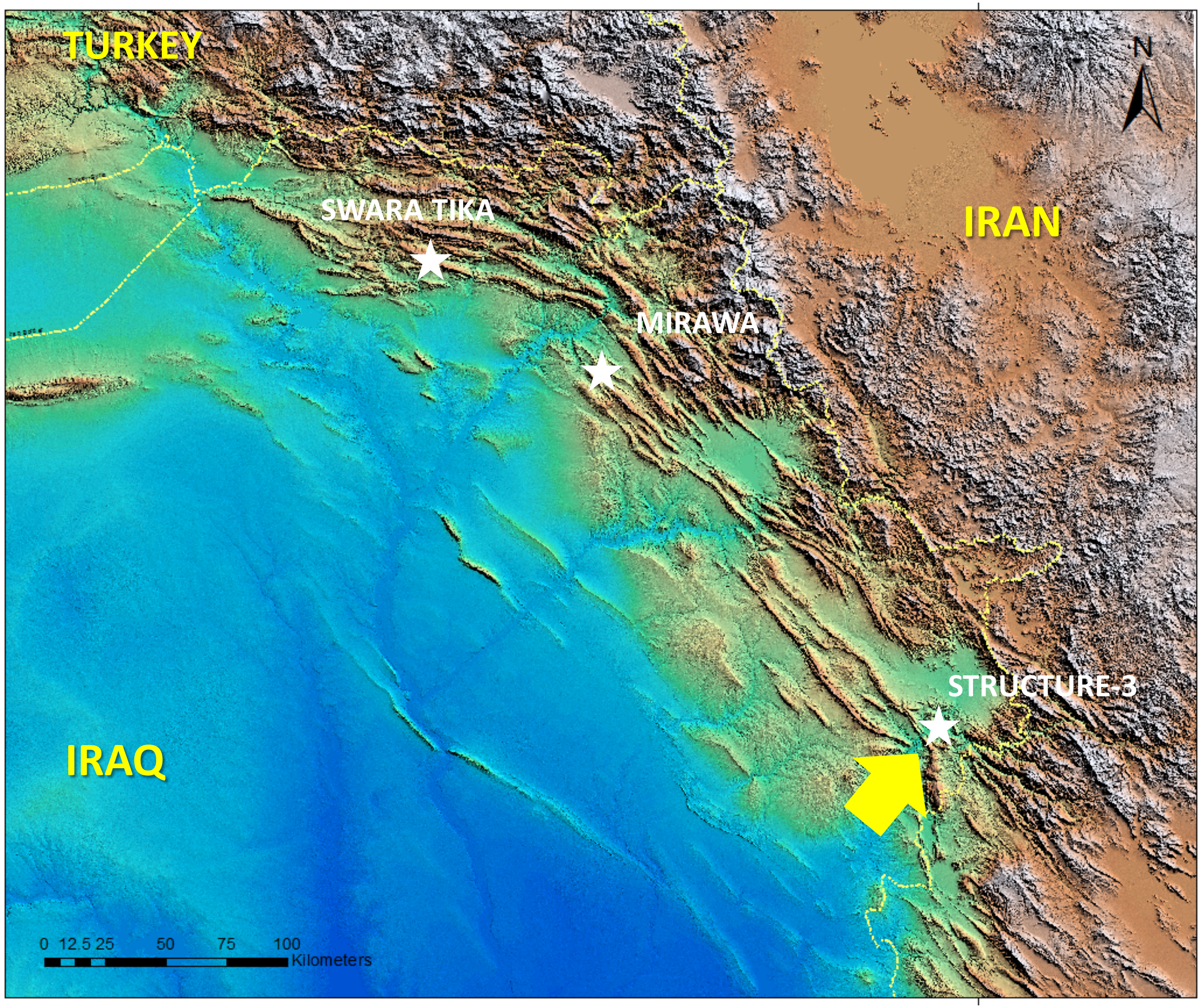


STRUCTURE-2: ATRUSH





SOUTHERN STRUCTURE



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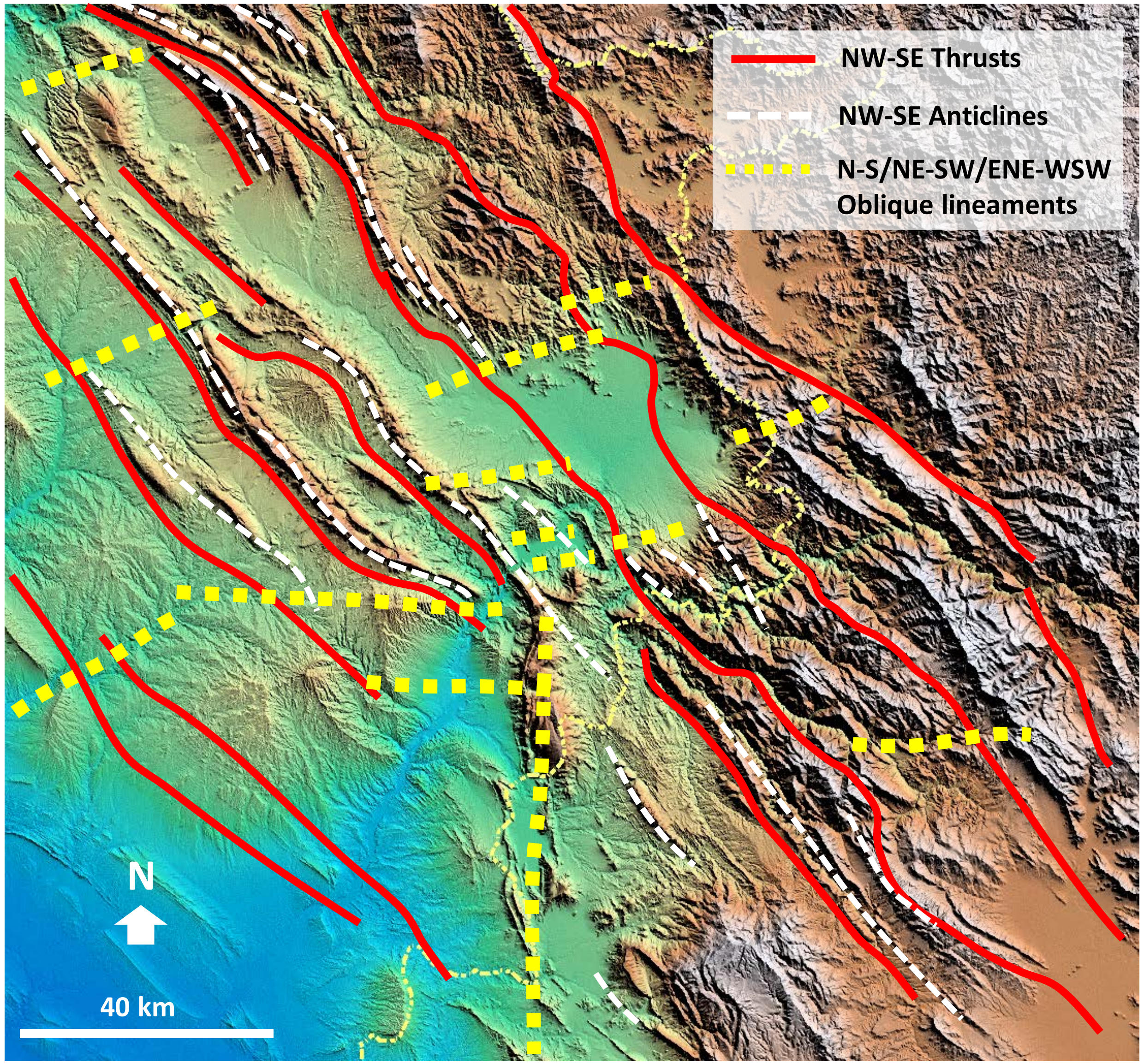
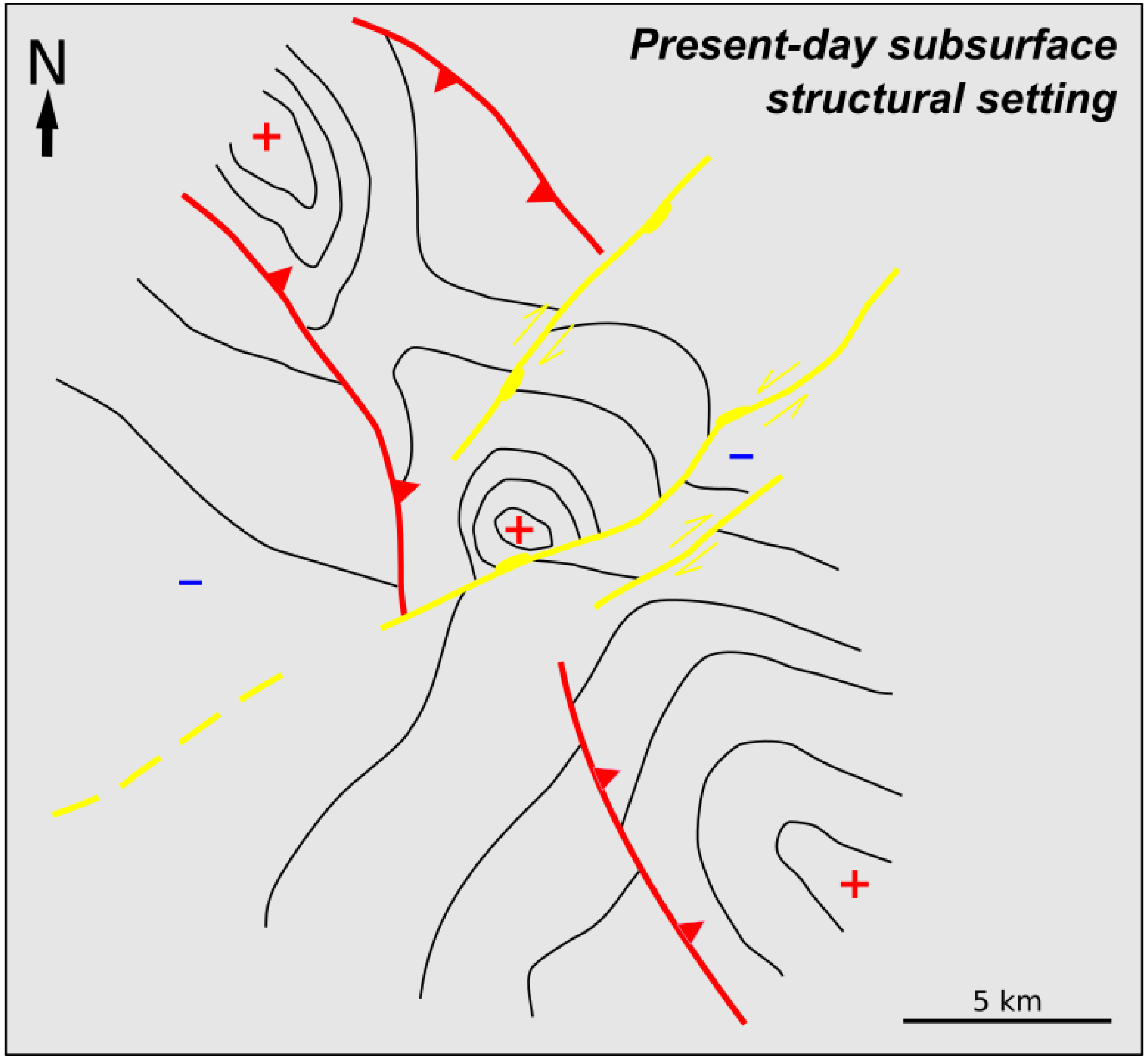
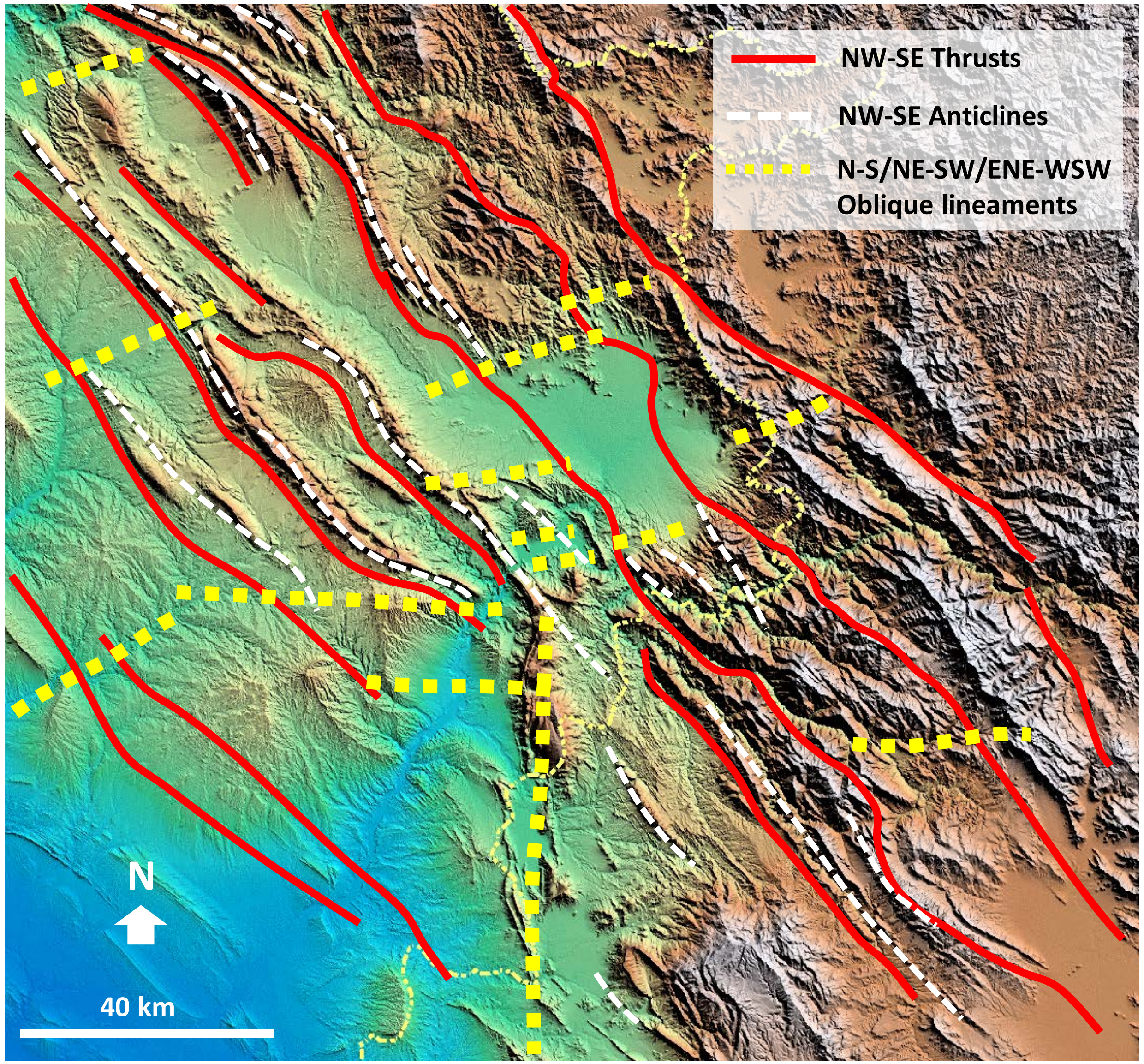
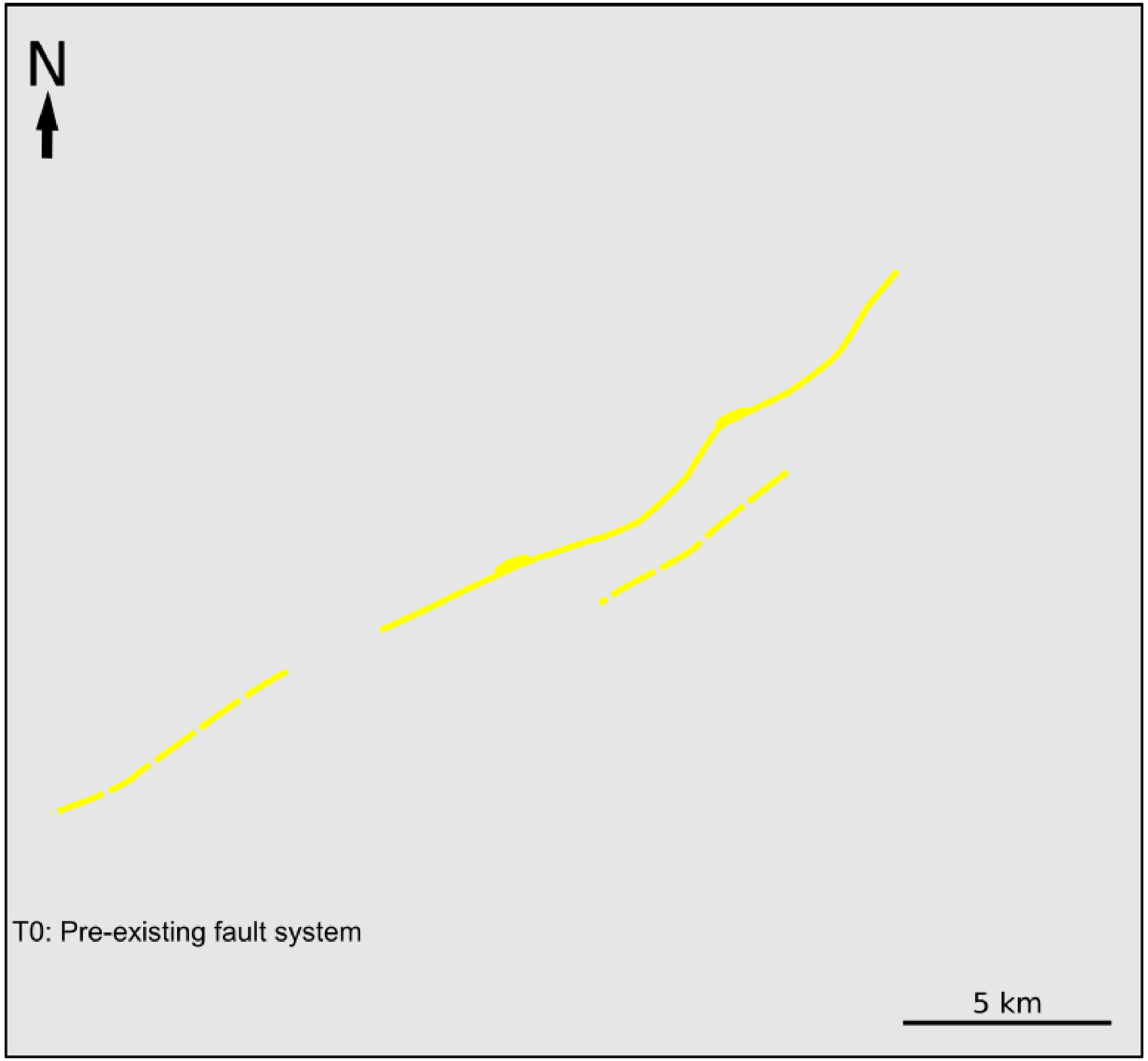
STRUCTURE-3


NW-SE Thrusts
NW-SE Anticlines
N-S/NE-SW/ENE-WSW Oblique lineaments
N
40 km

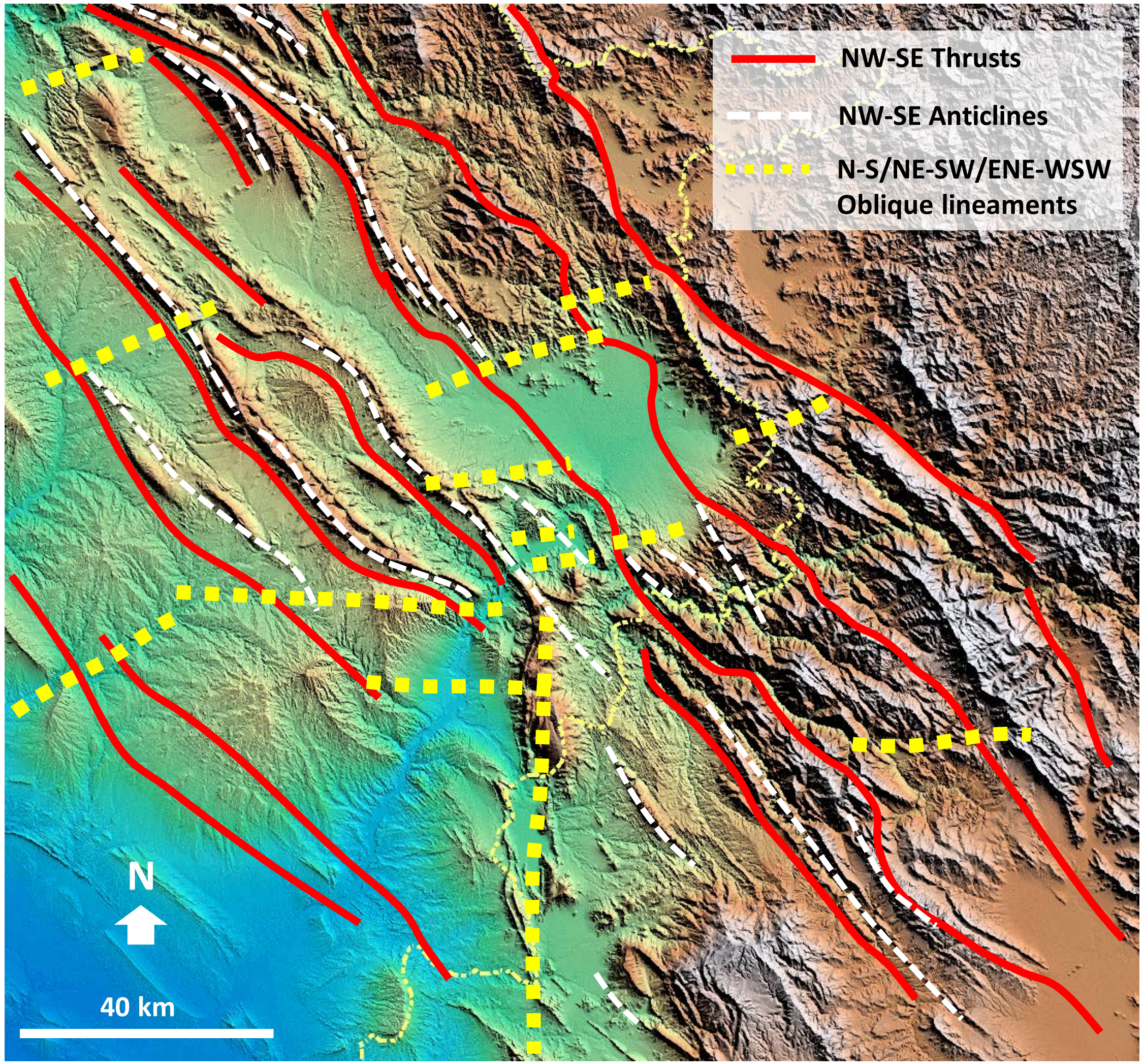

Present-day subsurface structural setting
N
+
–
5 km

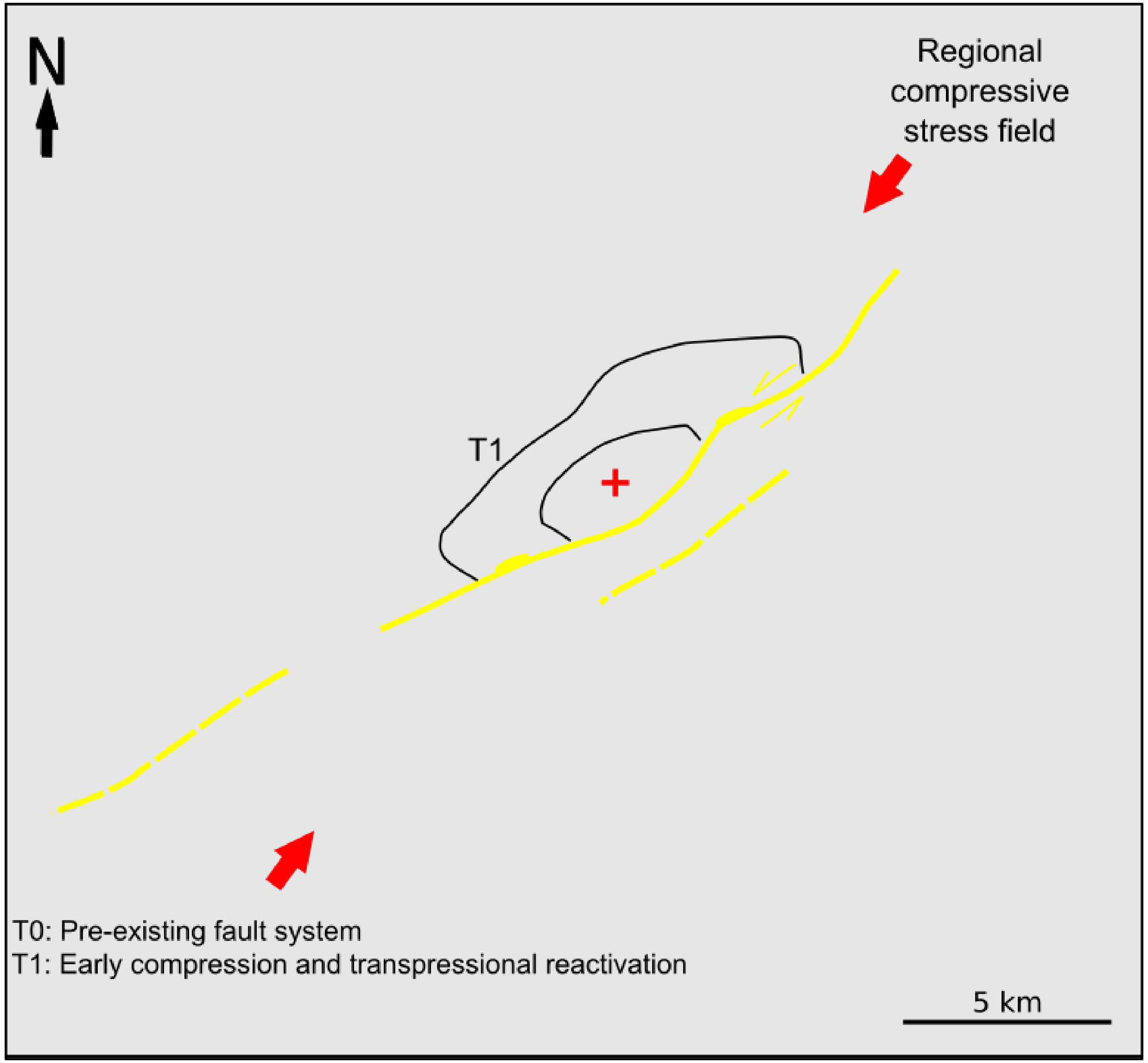
STRUCTURE-3


NW-SE Thrusts
NW-SE Anticlines
N-S/NE-SW/ENE-WSW
Oblique lineaments
N
40 km

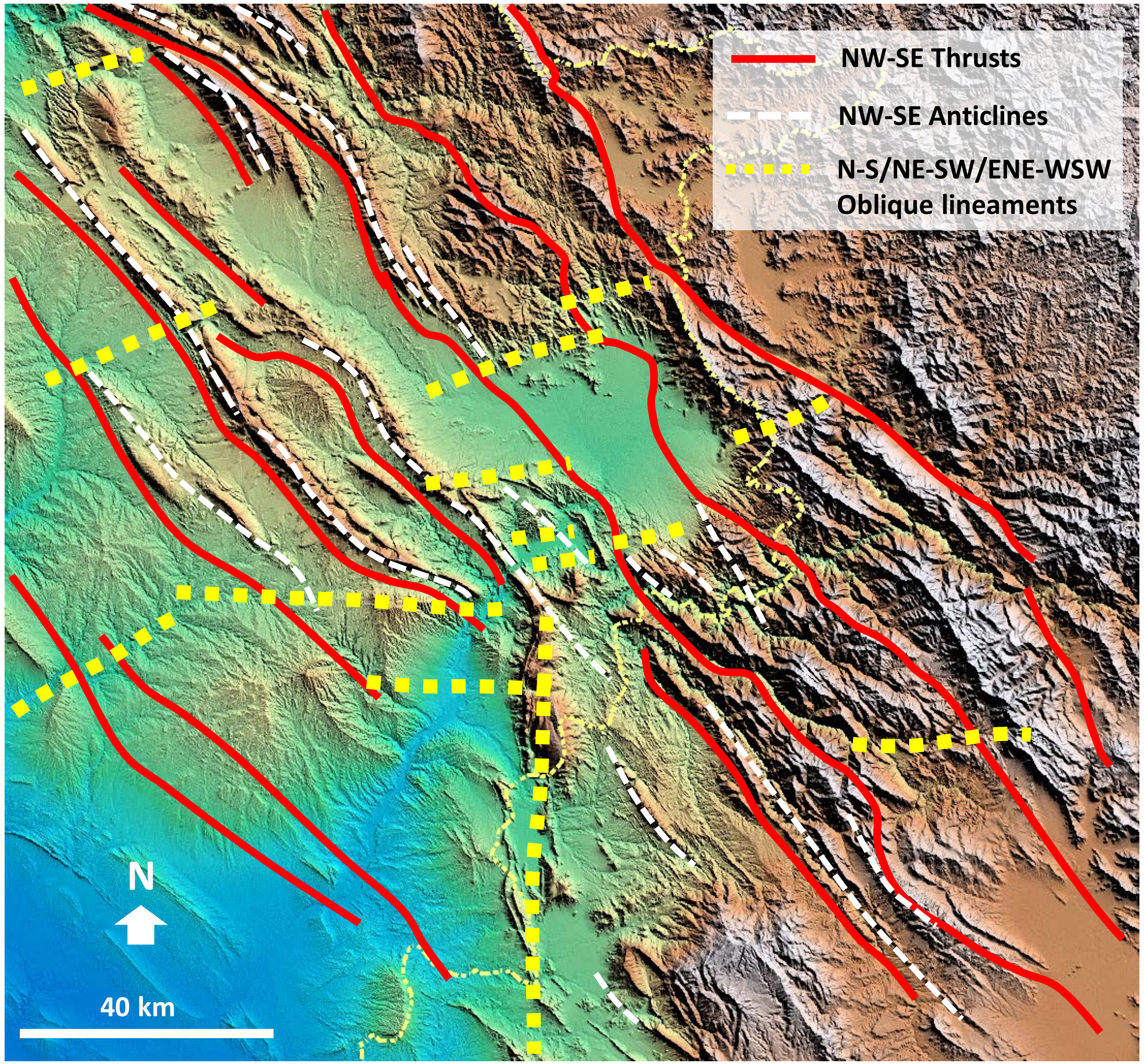

N
T0: Pre-existing fault system
5 km

STRUCTURE-3

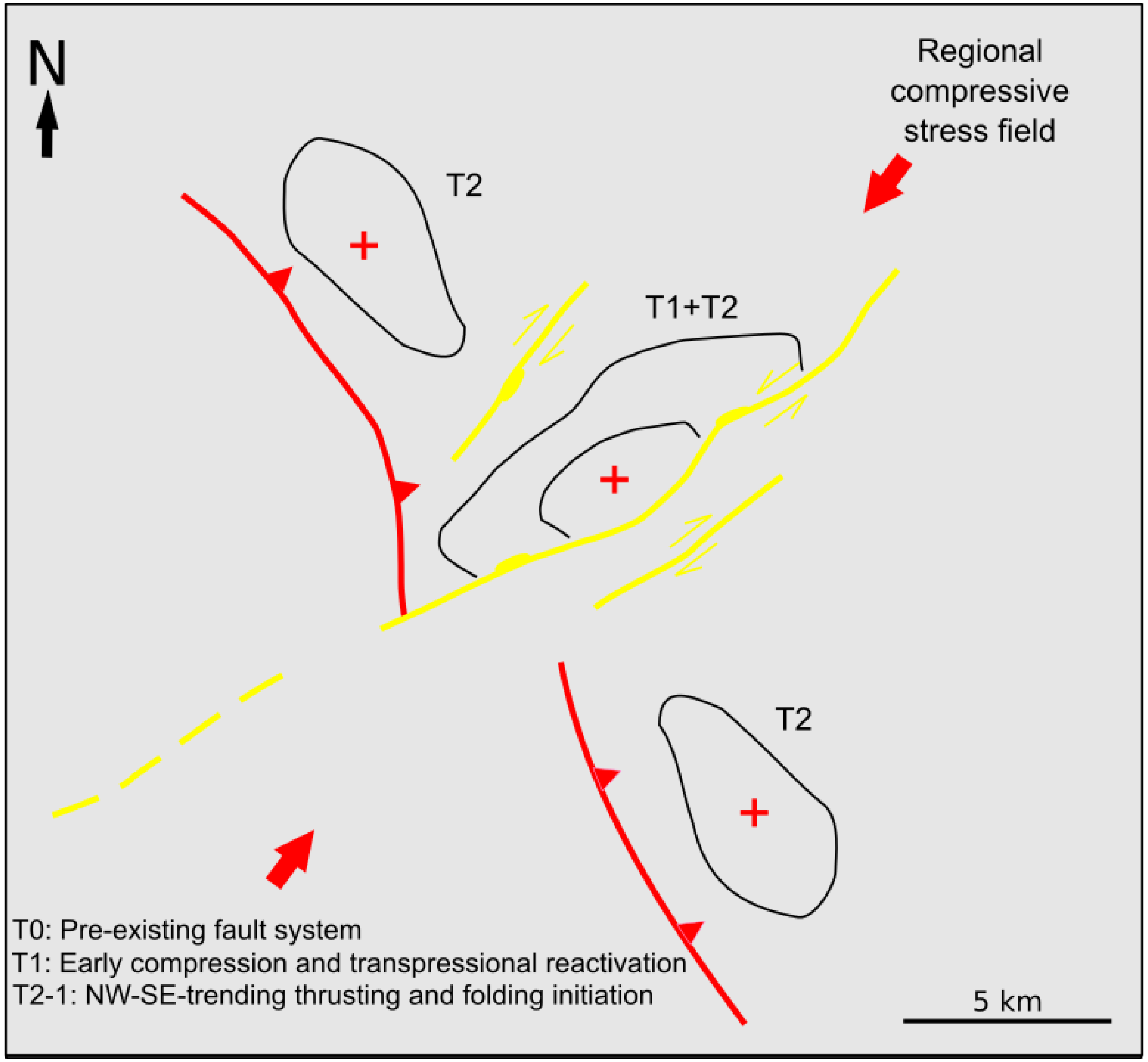

NW-SE Thrusts
NW-SE Anticlines
N-S/NE-SW/ENE-WSW
Oblique lineaments
N
40 km


N
Regional
compressive
stress field
T1
T0: Pre-existing fault system
T1: Early compression and transpressional reactivation
5 km

STRUCTURE-3

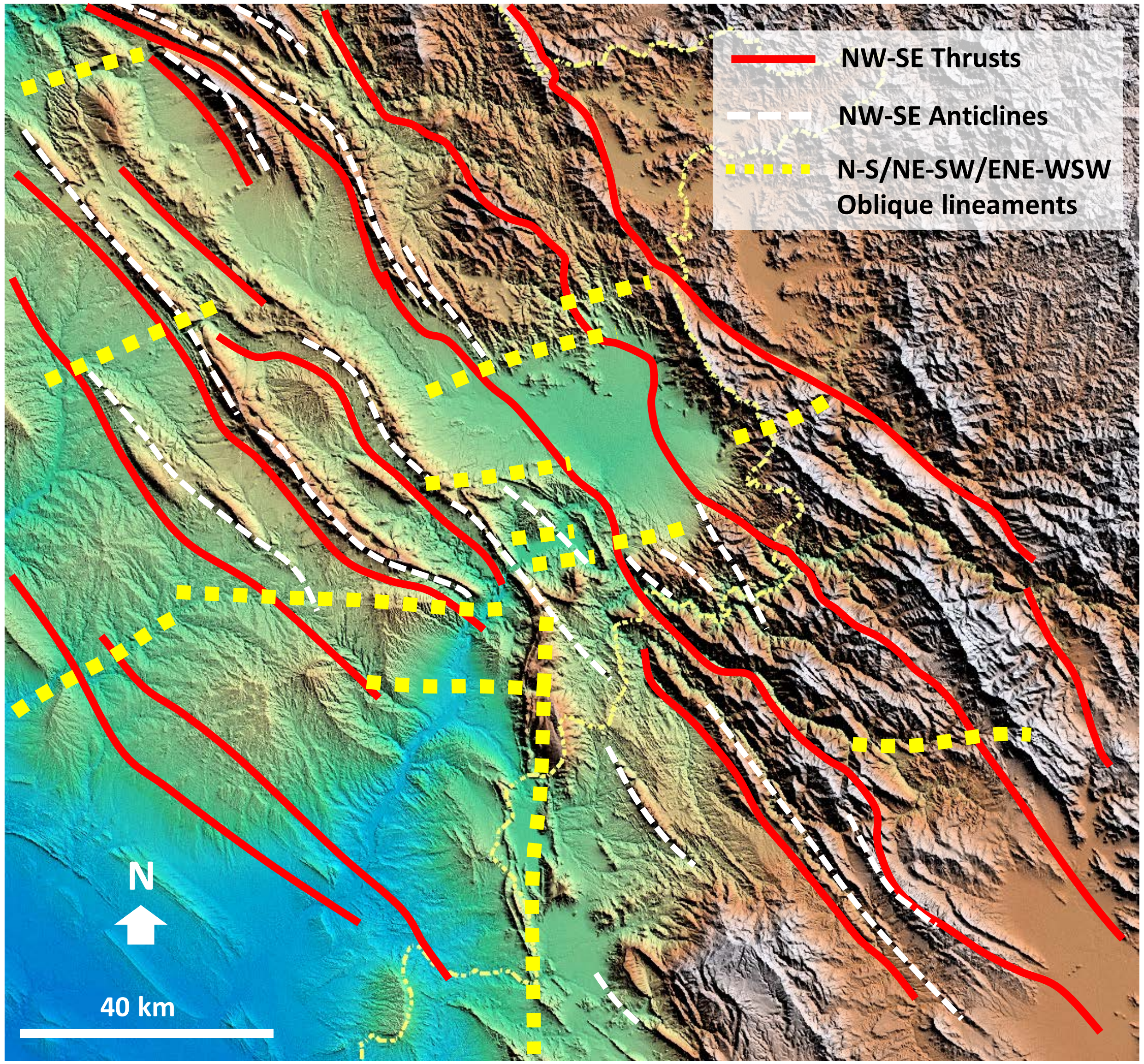


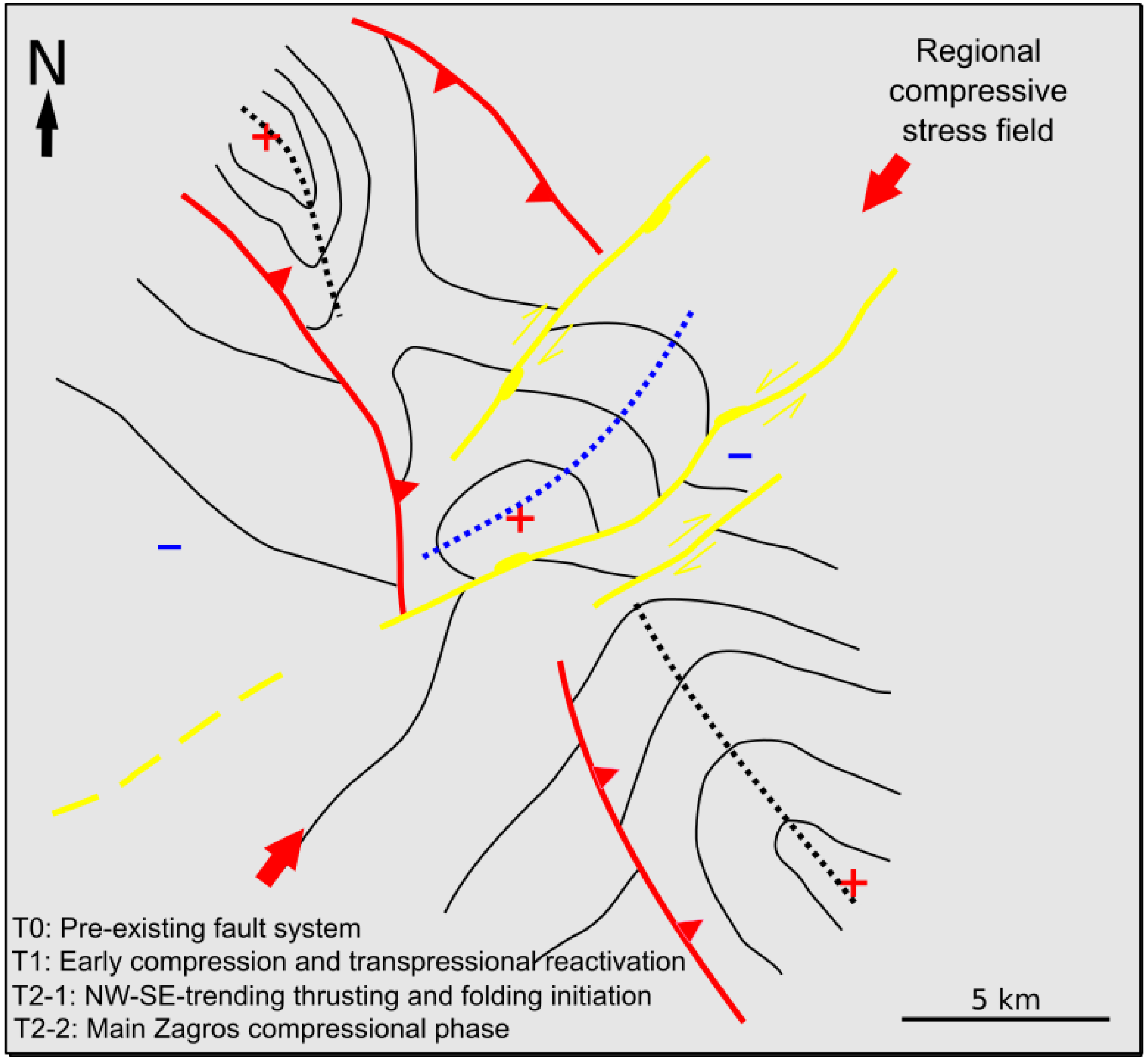
NW-SE Thrusts
NW-SE Anticlines
N-S/NE-SW/ENE-WSW
Oblique lineaments
N
40 km



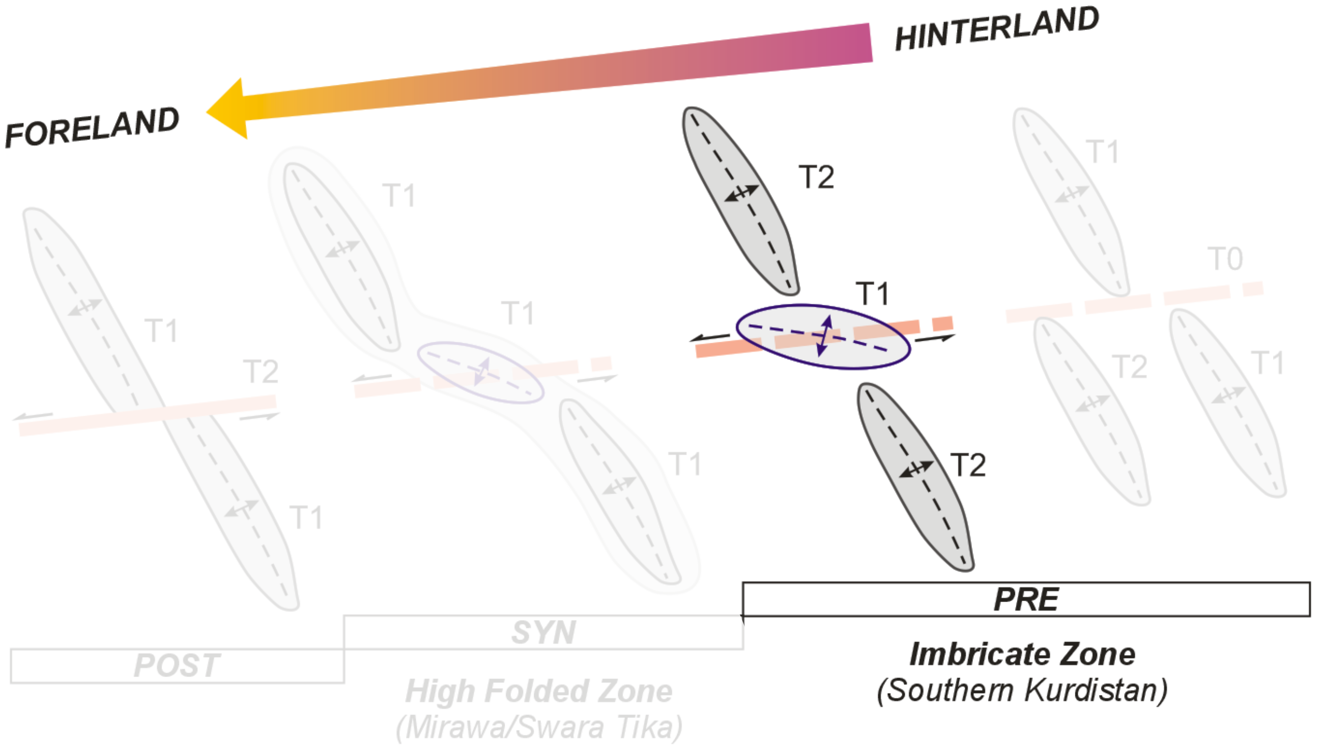
N
Regional
compressive
stress field
T2
T1+T2
T2
T0: Pre-existing fault system
T1: Early compression and transpressional reactivation
T2-1: NW-SE-trending thrusting and folding initiation
5 km

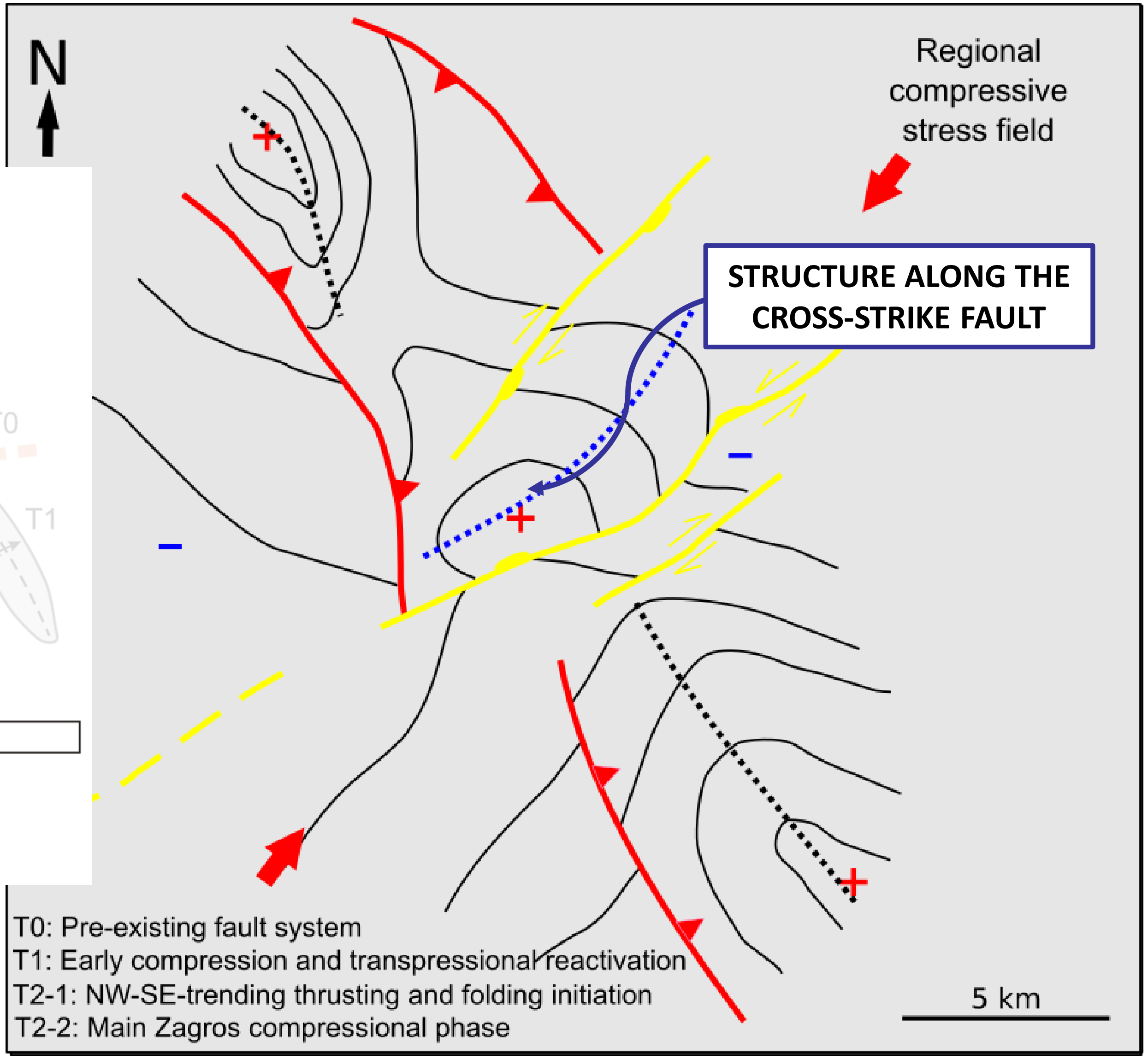
STRUCTURE-3


NW-SE Thrusts
NW-SE Anticlines
N-S/NE-SW/ENE-WSW
Oblique lineaments
N
40 km


N
Regional
compressive
stress field
+
–
+
–
+
5 km
T0: Pre-existing fault system
T1: Early compression and transpressional reactivation
T2-1: NW-SE-trending thrusting and folding initiation
T2-2: Main Zagros compressional phase

STRUCTURE-3

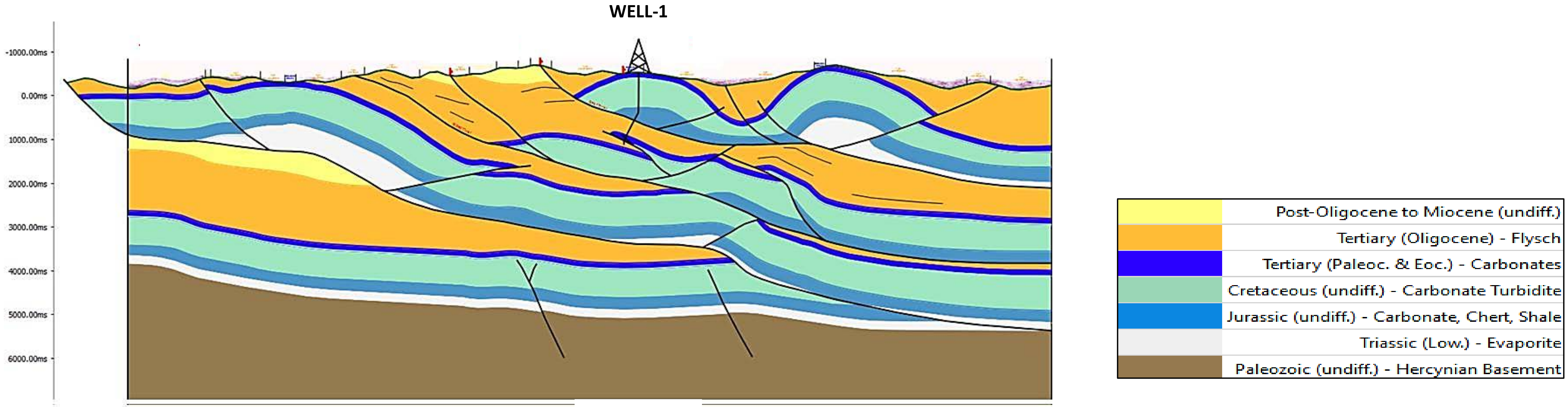

HINTERLAND
FORELAND
T2
T1
T2
T1
T0
T1
T2
T1
T1
T2
T1
T1
T1
PRE
SYN
POST
Imbricate Zone
(Southern Kurdistan)
High Folded Zone
(Mirawa/Swara Tika)

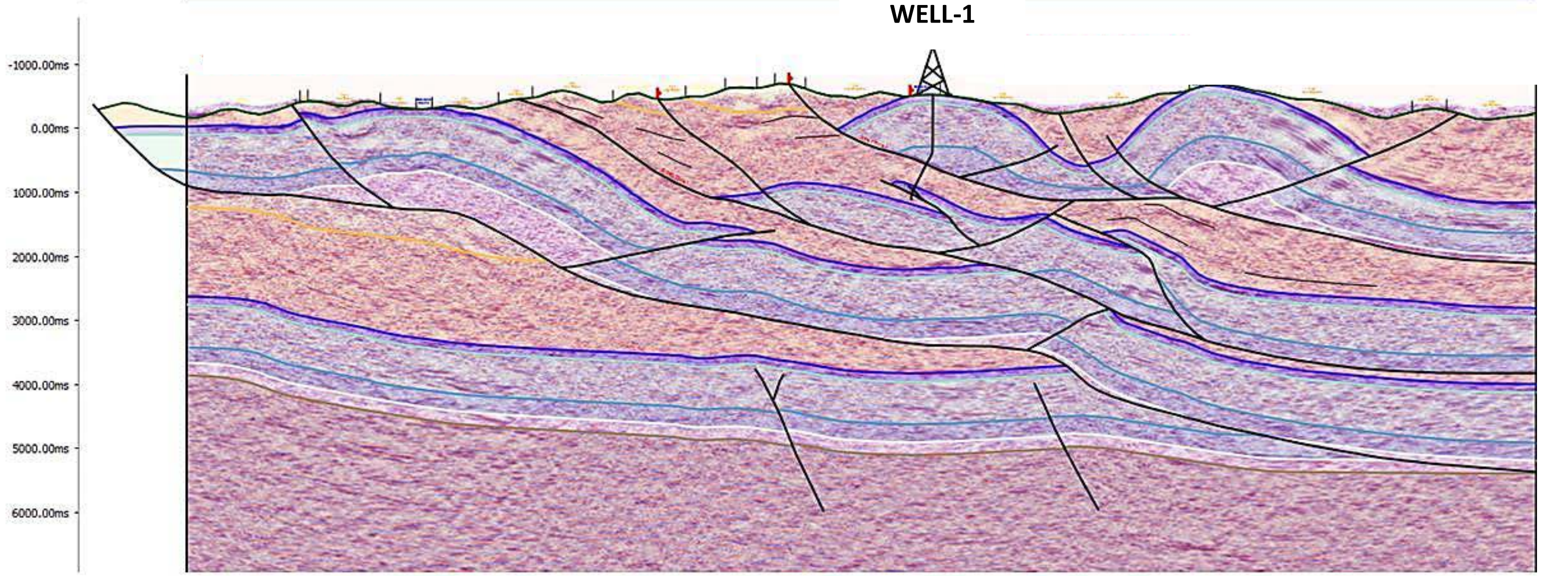

N
Regional compressive stress field
STRUCTURE ALONG THE CROSS-STRIKE FAULT
5 km
T0: Pre-existing fault system
T1: Early compression and transpressional reactivation
T2-1: NW-SE-trending thrusting and folding initiation
T2-2: Main Zagros compressional phase

CASE 2: ALBANIA

CASE 2: ALBANIA

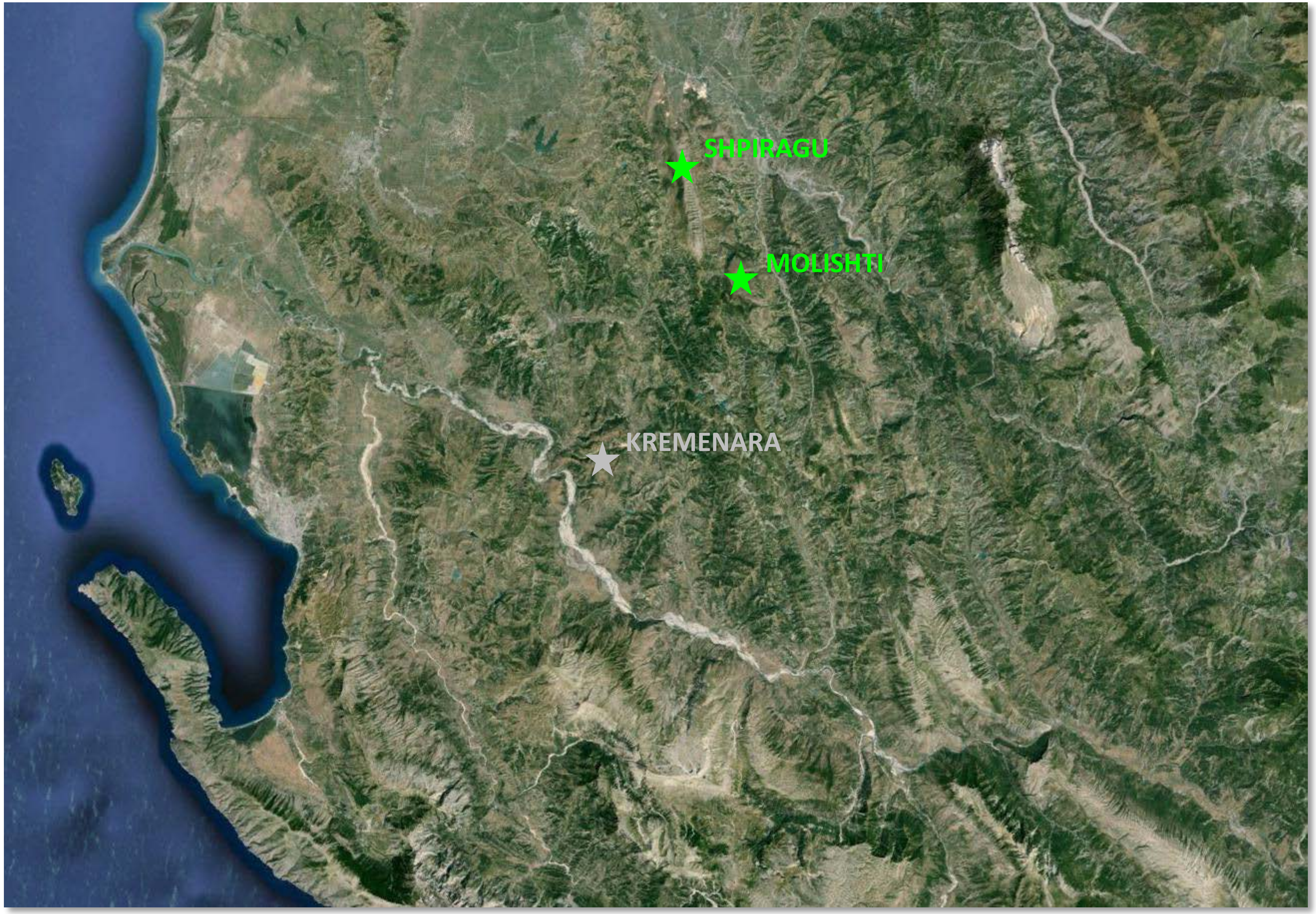
ALBANIDES STRUCTURAL SETTING



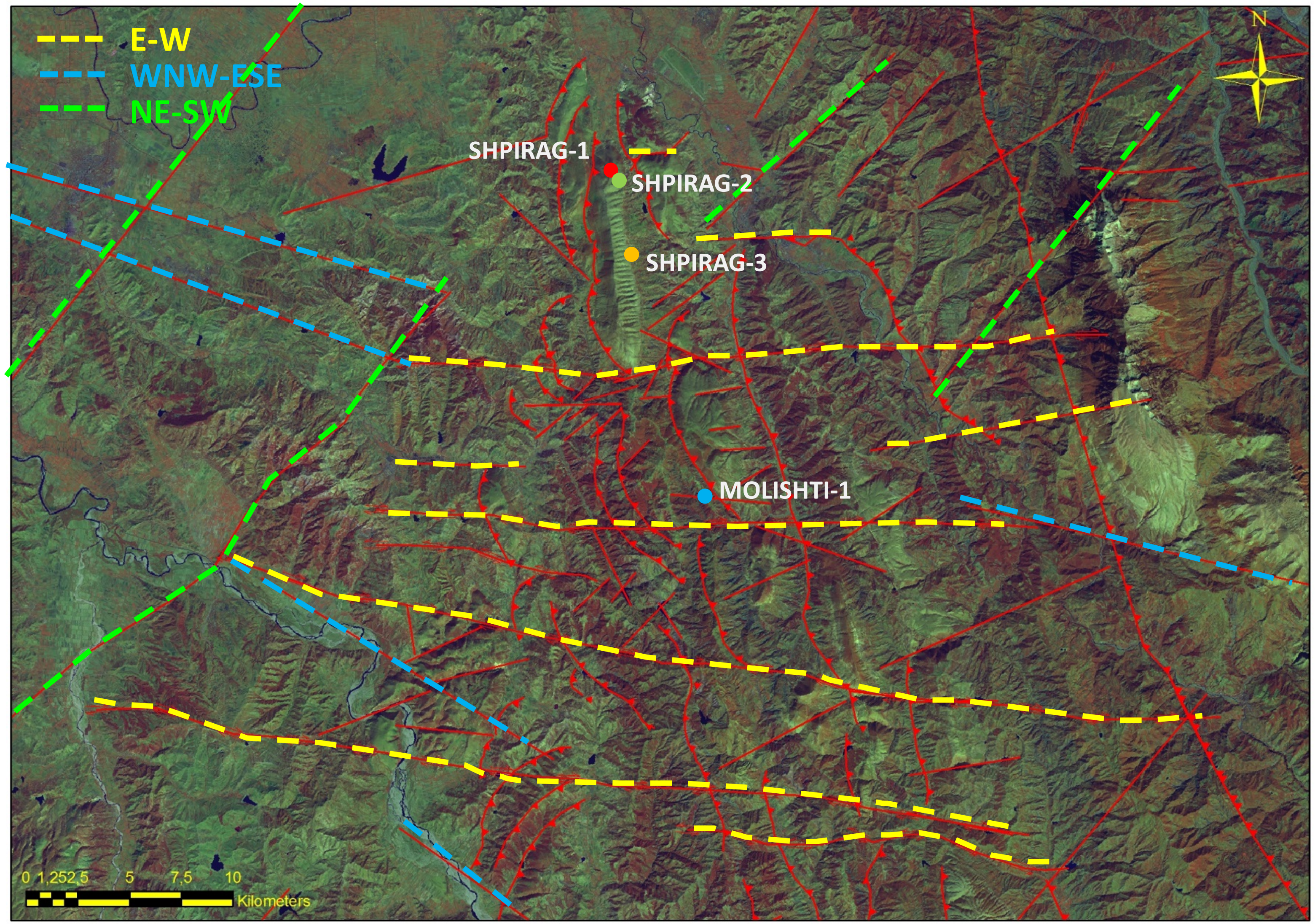


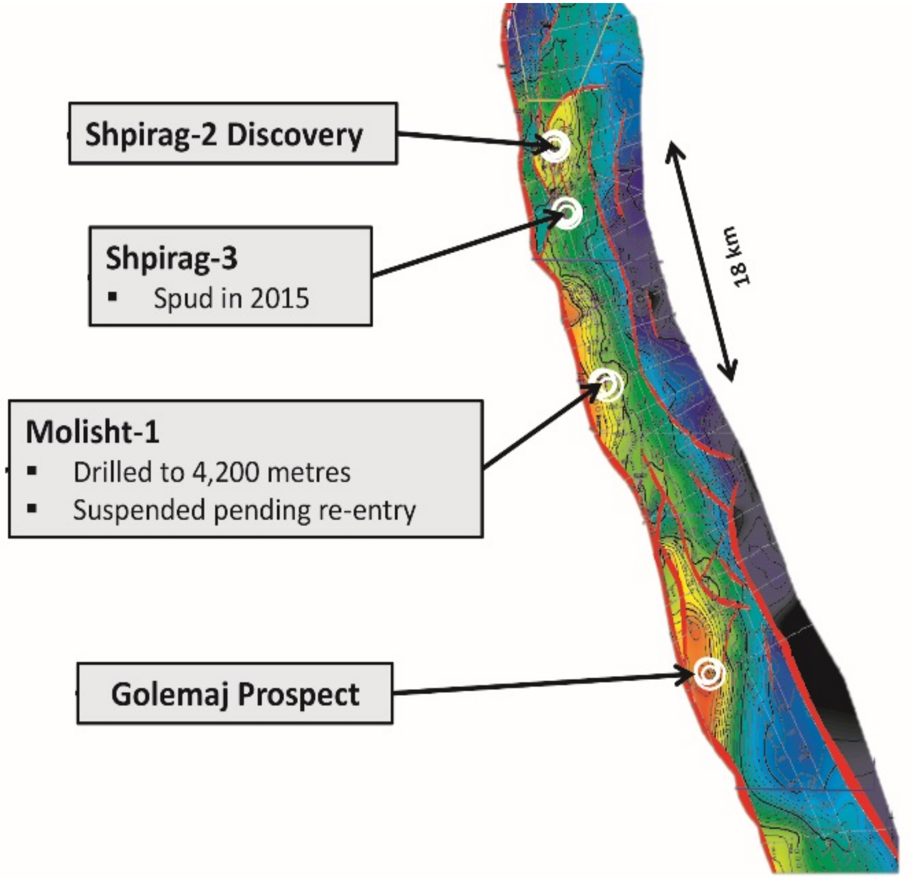
(Di Cuia et al., 2015)

SHPIRAGU AND MOLISHTI STRUCTURES



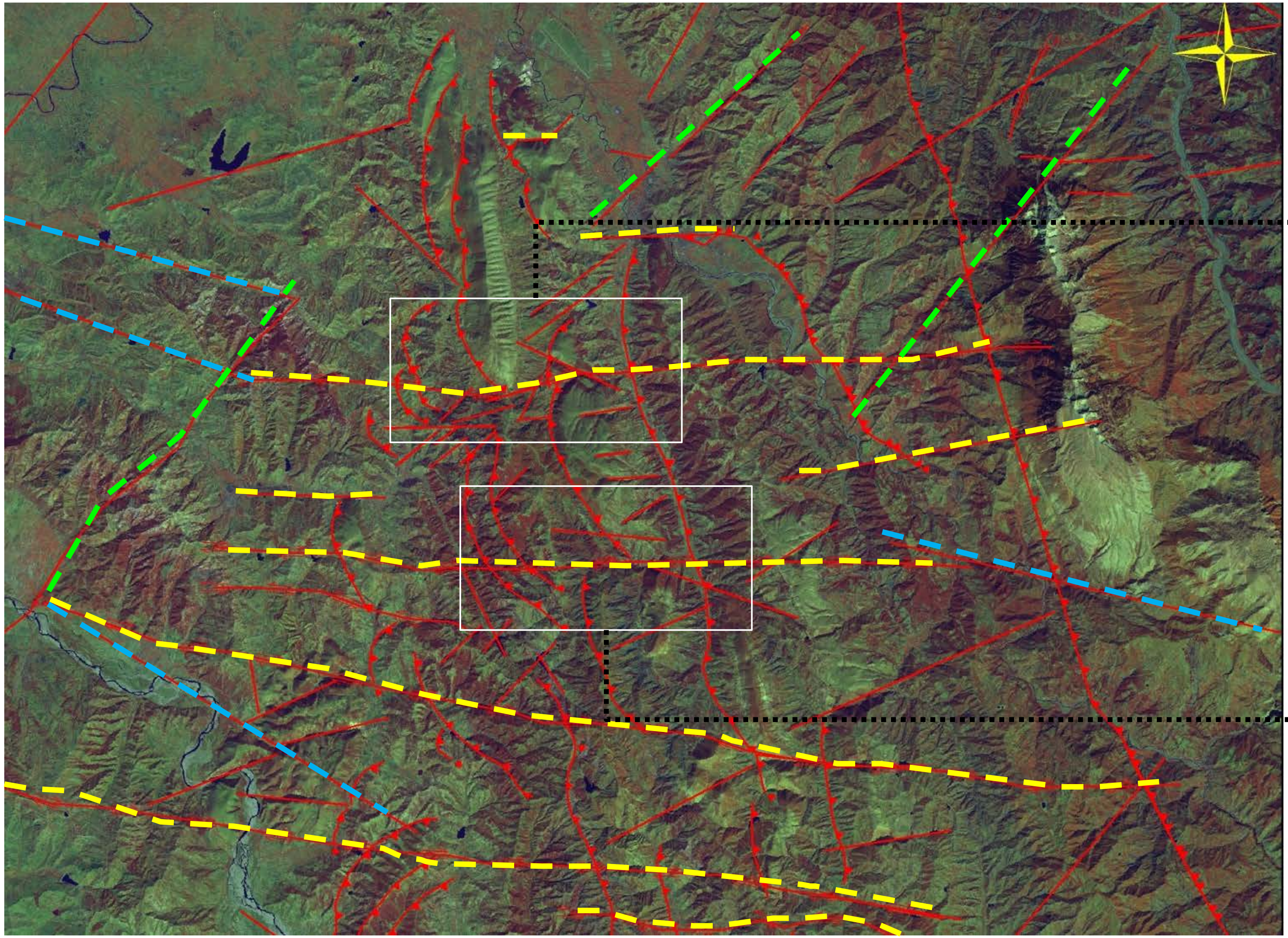
SHPIRAGU AND MOLISHTI STRUCTURES

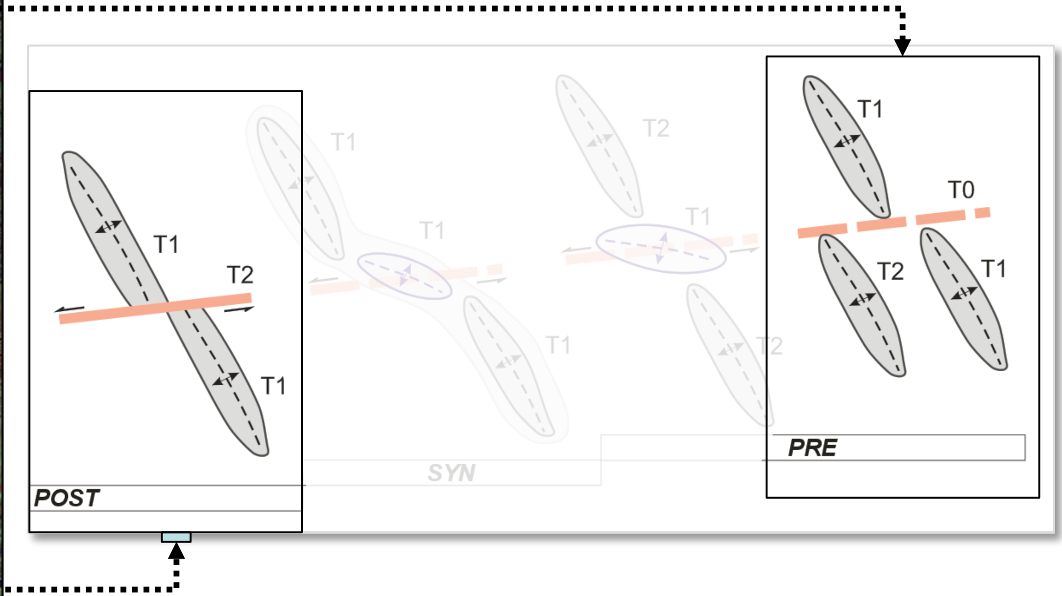




Petromanas, 2014

SHPIRAGU AND MOLISHTI STRUCTURES





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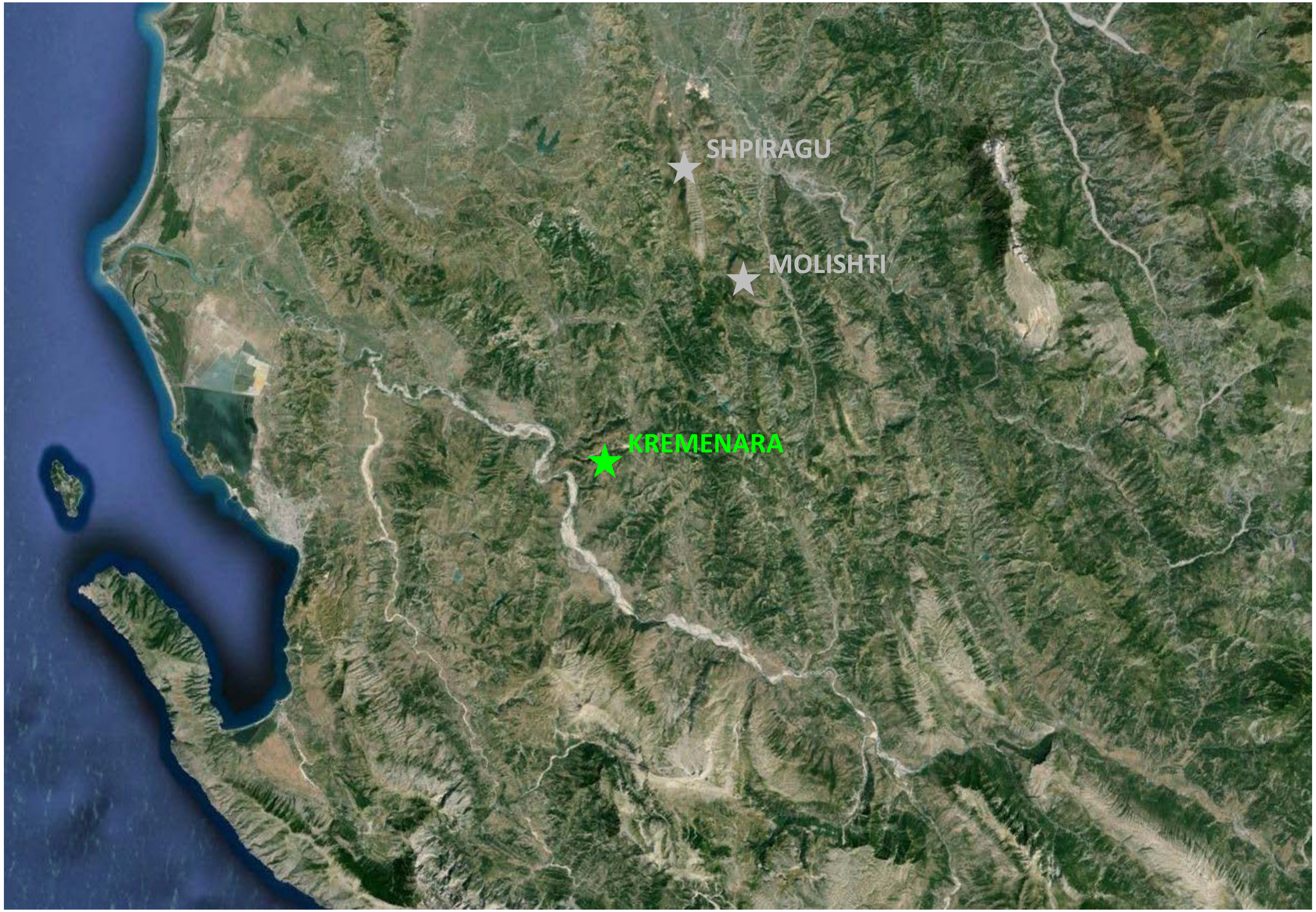

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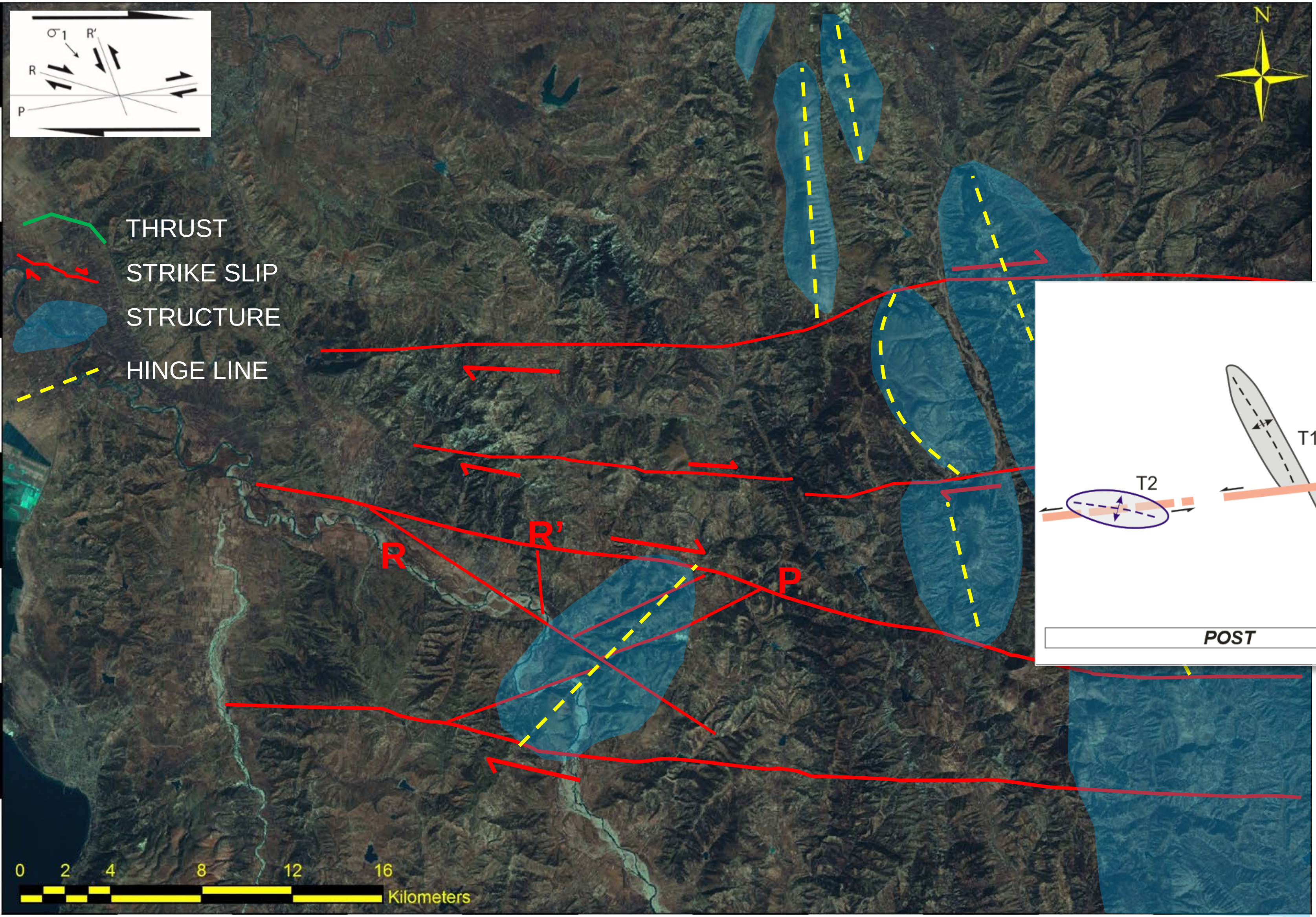
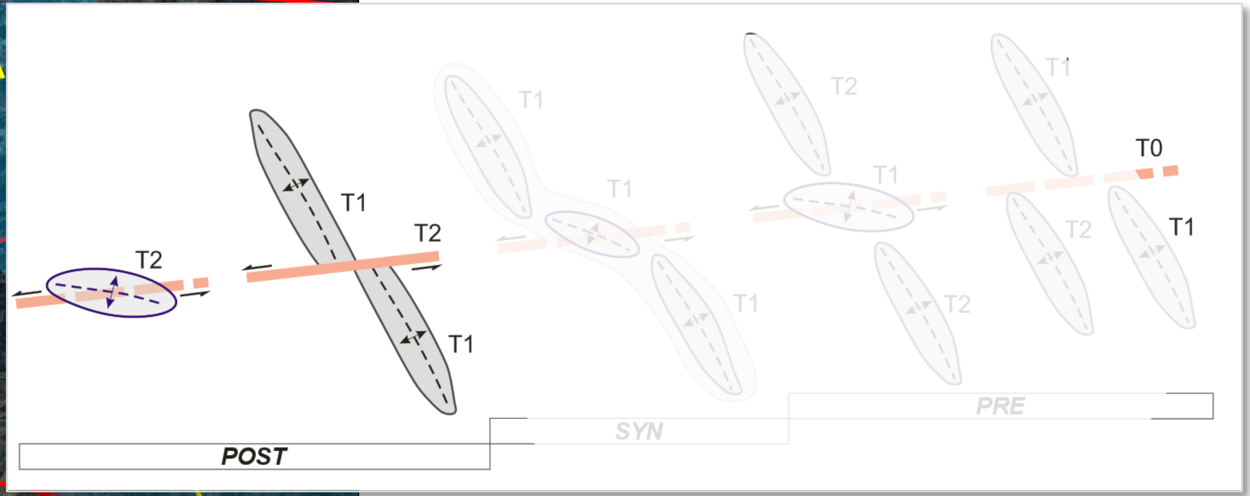
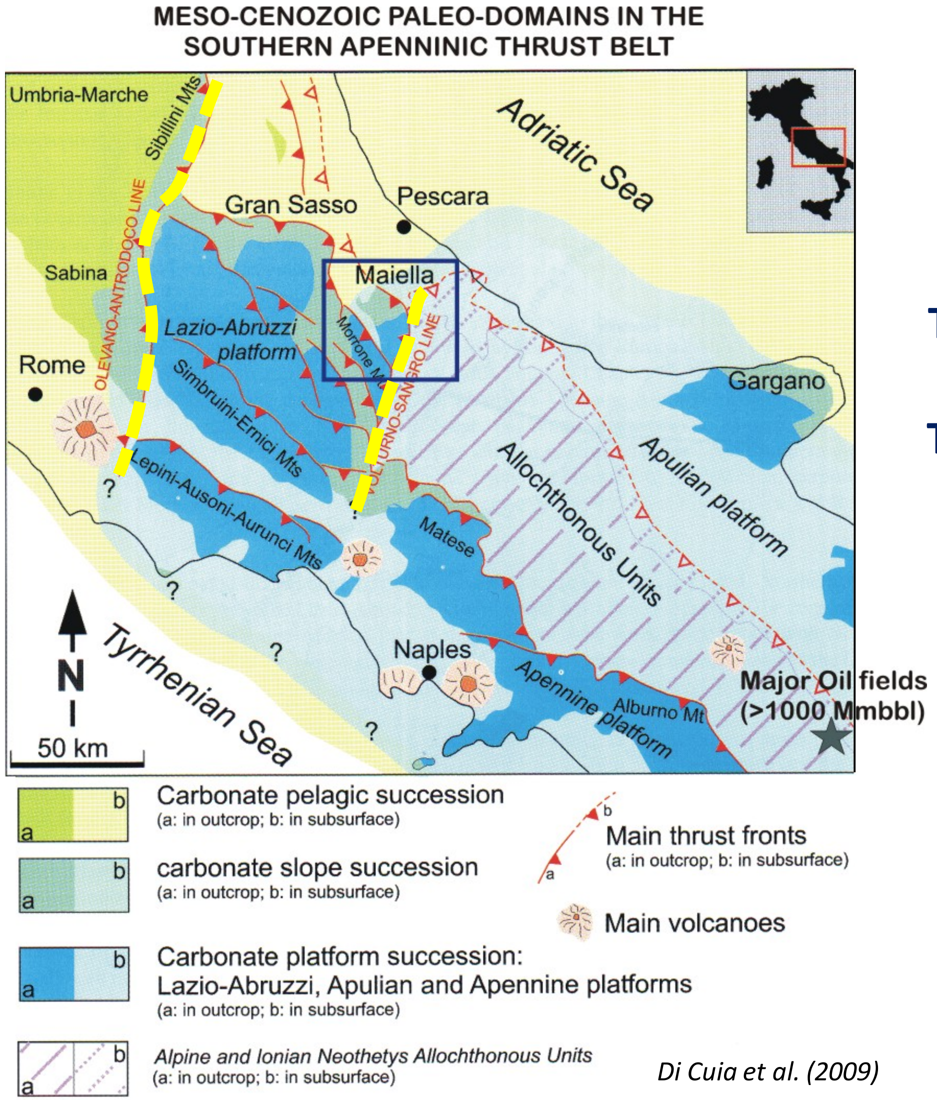




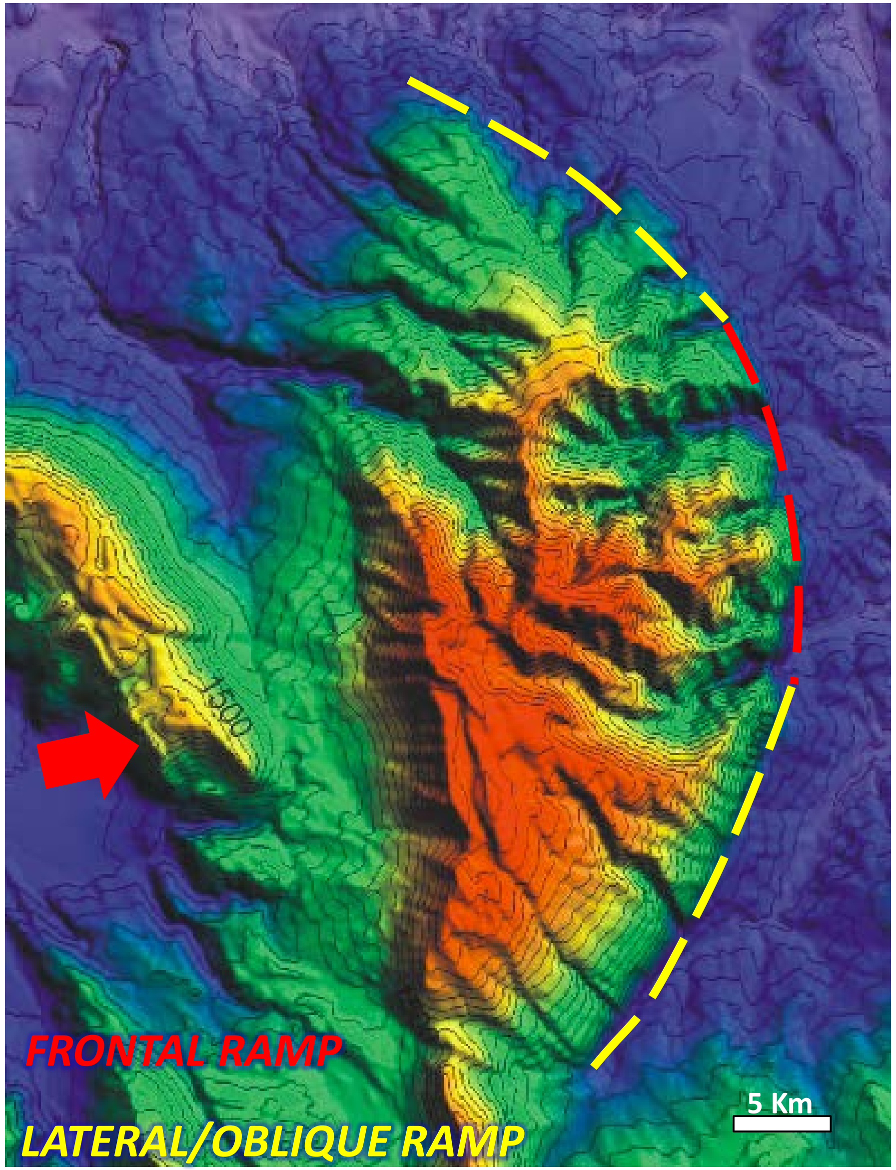
CASE 3: CENTRAL-SOUTHERN APENNINES

CENTRAL-SOUTHERN APENNINES – GEOLOGICAL SETTING

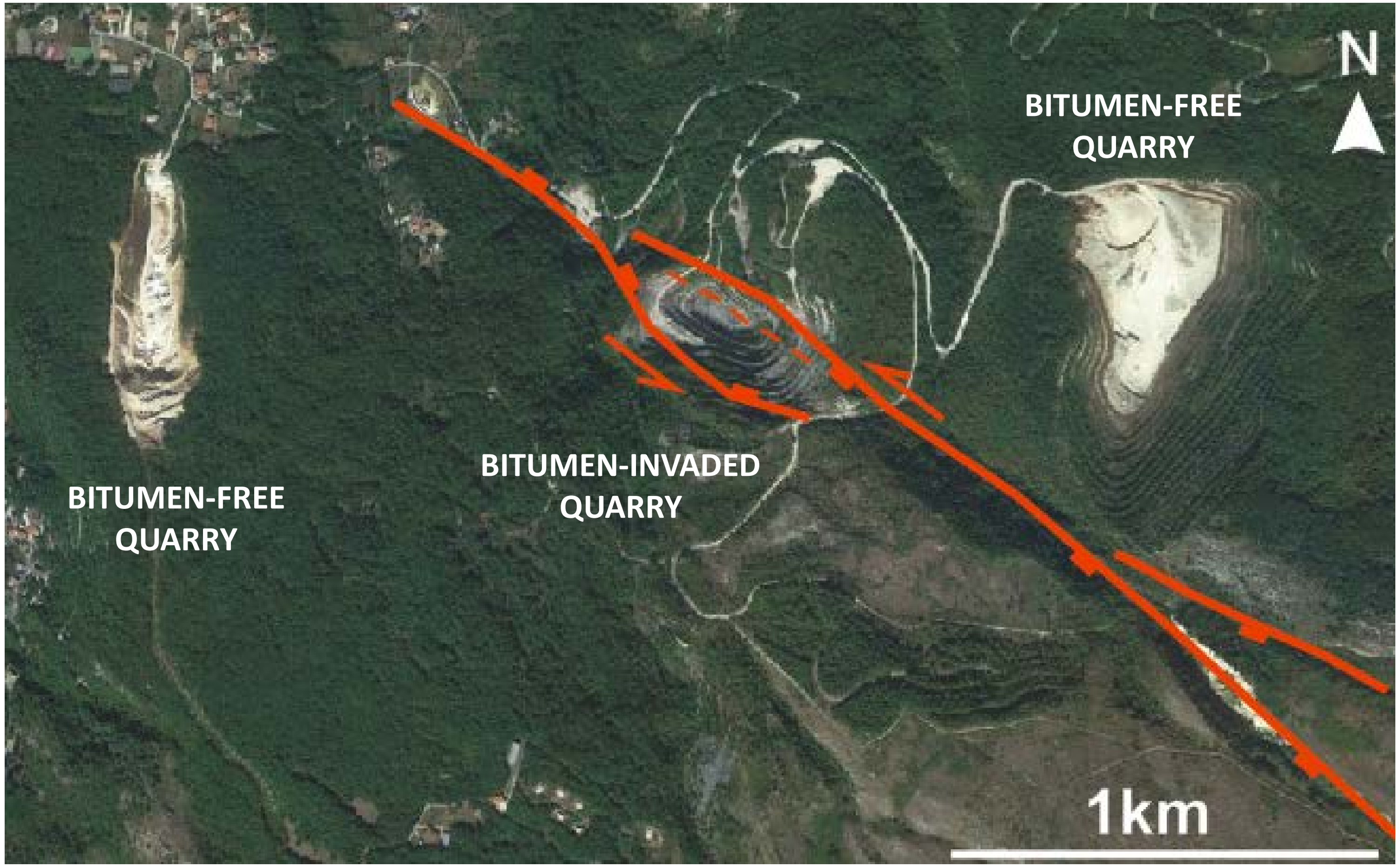


Di Cuia et al. (2009)

REGIONAL NNE-SSW-TRENDING OBLIQUE THRUST RAMPS CONTROLLING THE TRHUST BELT ARCHITECTURE AND MESO-CENOZOIC PALEO-DOMANS

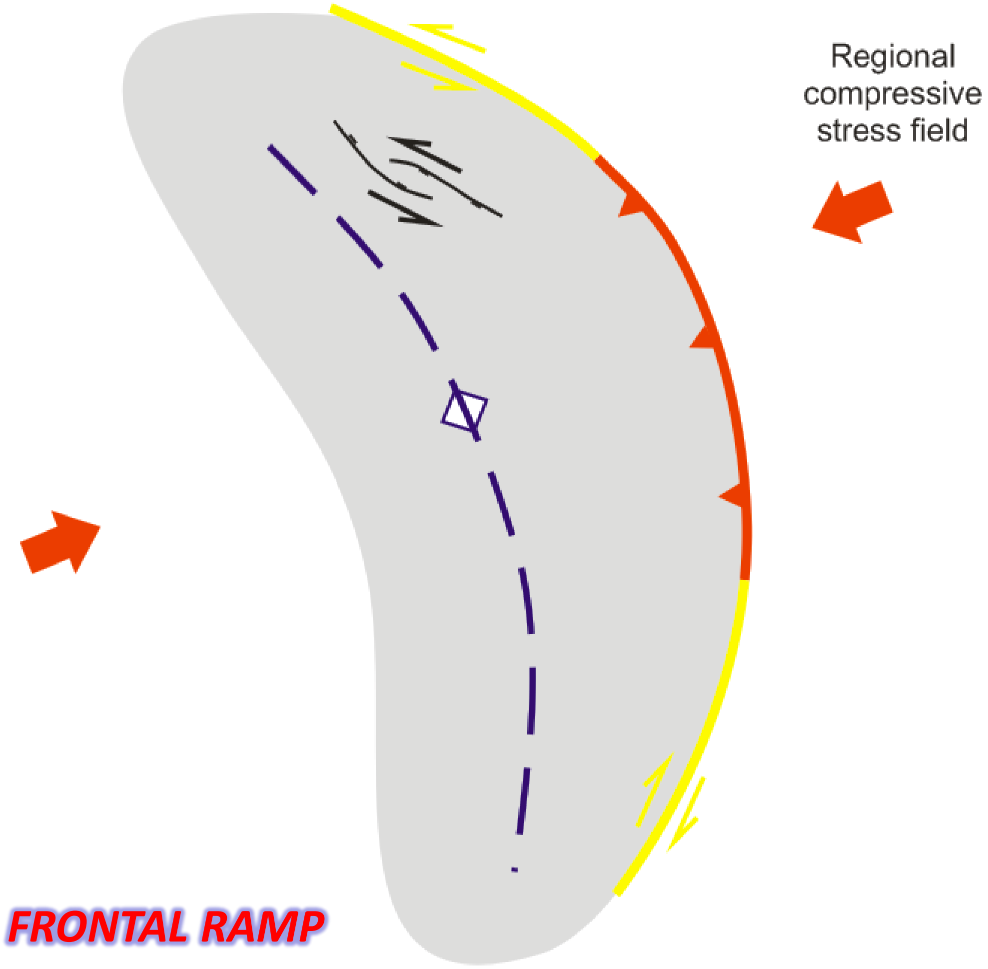


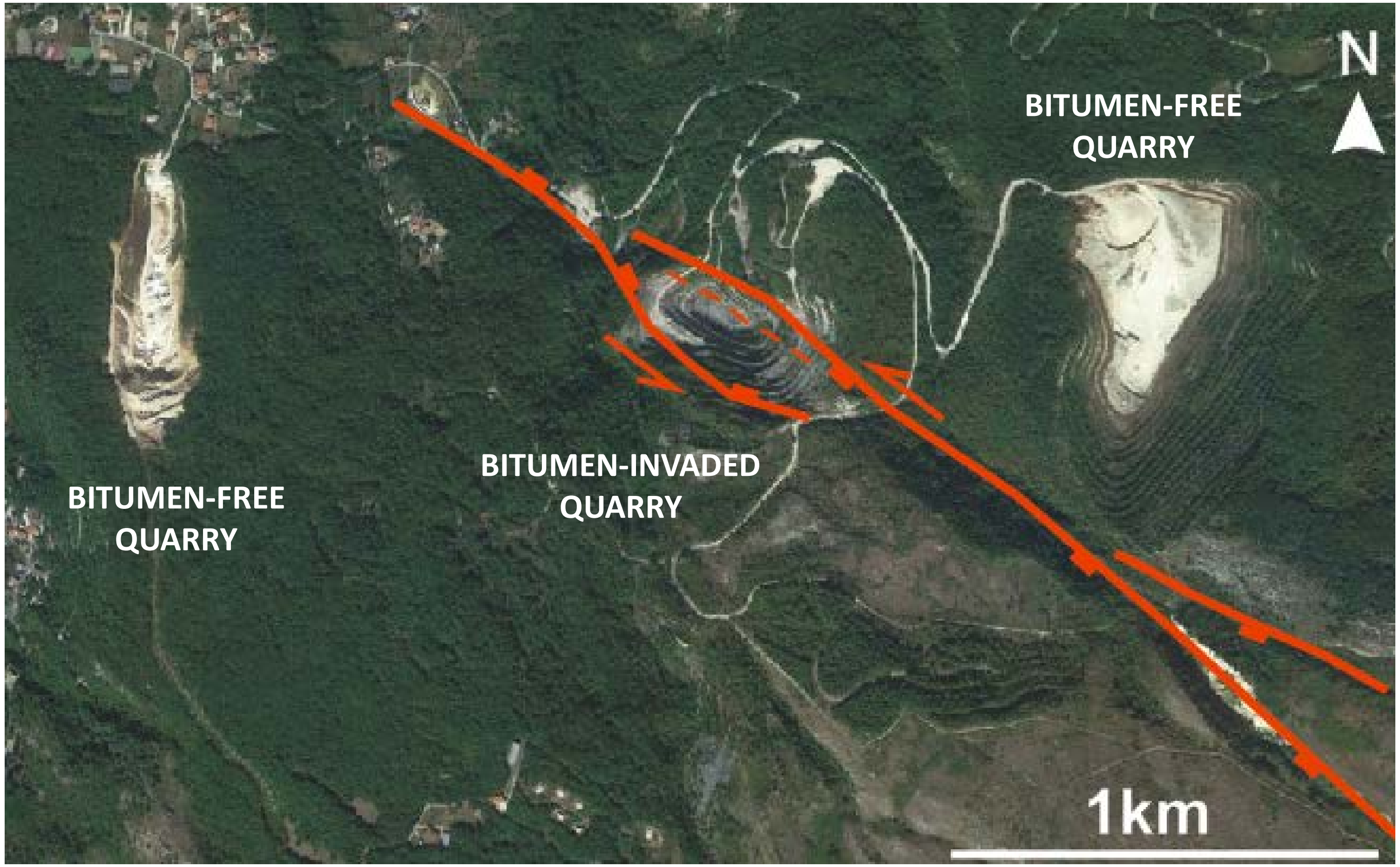
MAIELLA STRUCTURE



SEVERAL OIL SEEPS OCCUR IN THE NORTHERN PERICLINAL TERMINATION OF THE MAIELLA ANTICLINE WHERE A NW-SE-TRENDING SYN-OROGENIC OBLIQUE FAULT NETWORK IS WELL DEVELOPED

MAIELLA STRUCTURE





FRONTAL RAMP

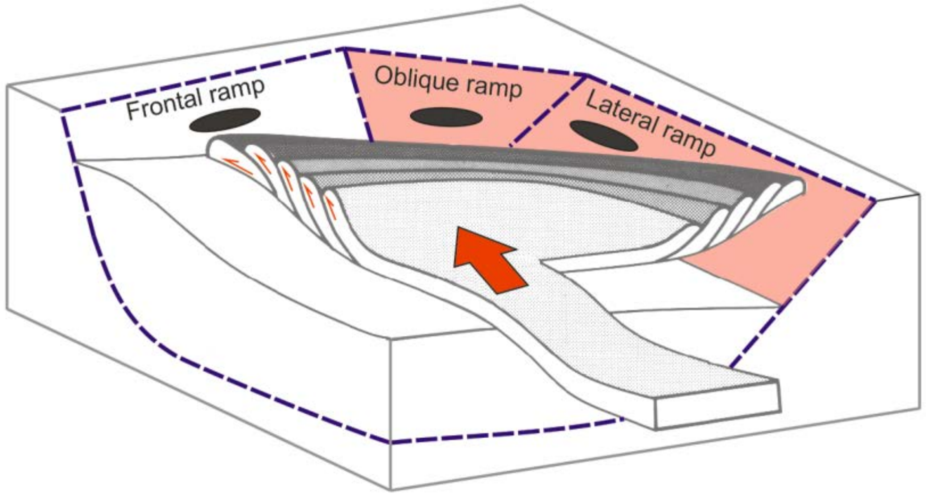
LATERAL/OBLIQUE RAMP

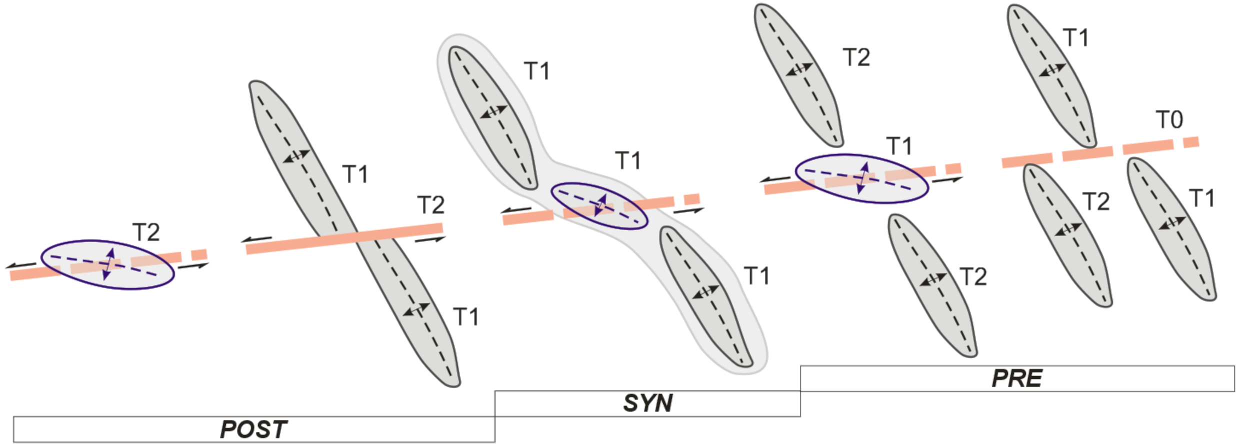
SEVERAL OIL SEEPS OCCUR IN THE NORTHERN PERICLINAL TERMINATION OF THE MAIELLA ANTICLINE WHERE A NW-SE-TRENDING SYN-OROGENIC OBLIQUE FAULT NETWORK IS WELL DEVELOPED

CONCLUSIONS

LATERAL/OBLIQUE THRUST RAMPS

- RE-ORIENTATION OF THE FAULT & FRACTURE NETWORK
- SHEARING AND REACTIVATION OF PRE-EXISTING FAULT SYSTEMS
- PREFERENTIAL HC ACCUMMULATION WITH SYN-CONTRACTIONAL MIGRATION





STRIKE-SLIP FAULTS

- DEVELOPMENT OF 'OUT-OF-TREND' STRUCTURES
- DIFFERENT SCENARIOS OF HC ACCUMULATION WITH SYN-CONTRACTIONAL MIGRATION DEPENDING ON EITHER THE PRE-, SYN-, OR POST-CONTRACTIONAL ACTIVITY OF THE STRIKE-SLIP FAULTS

THANK YOU!