

# **Structural Observations along the Salin-Pyay Pleistocene Strike-Slip Deformation Belt\***

**U Ko Ko<sup>1</sup>**

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<sup>1</sup>MPRL E&P Pte Ltd. ([koko@mprlexp.com](mailto:koko@mprlexp.com))

## **Abstract**

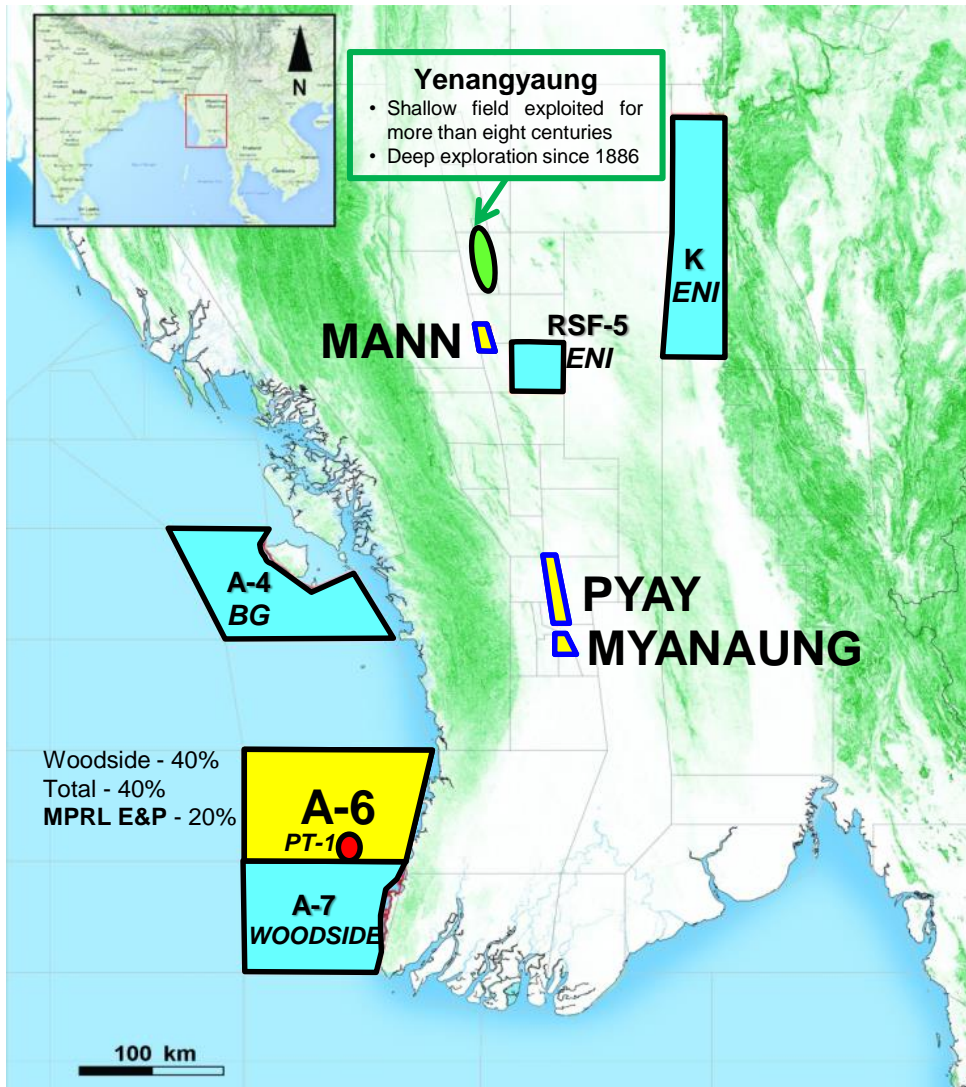
The onshore Myanmar historical petroleum producing province lies in two of the Central Myanmar Basins ("CMB"), the Salin Basin and the Pyay Embayment. These two NNW-SSE basins are separated by a complex tectonic zone known as the 20°N Uplift, active at least since Miocene, with many oil seeps and shallow oil accumulations being exploited by the local population. Much of the history of deposition of the Neogene in the region is guided by the northwards translational subduction of India below the SE Asia plates since at least the Oligocene. A major Pleistocene strike-slip deformation phase is observed over a variable 200 to 300 km wide belt of the Myanmar sedimentary basins between the Sagaing fault and the escarpment between shallow and deep waters of the Rakhine Yoma foldbelt. The major phase shows up in the Salin Basin and Pyay Embayment as en-échelon asymmetrical anticlines, partly filled with shallow oil and/or gas in with wet gas proven in tighter deeper reservoirs of a few structures (Mann, Pyay).

## **Selected Reference**

Bender, F., 1983, Geology of Burma: Berlin-Stuttgart, Gebrüder Borntraeger, 293 p.

# STRUCTURAL OBSERVATIONS ALONG THE SALIN-PYAY PLEISTOCENE STRIKE-SLIP DEFORMATION BELT

by U Ko Ko, Geoscience Manager – MPRL E&P



## ONSHORE

- MPRL E&P is a contractor to MOGE for improving the production of the Mann oil field
- MPRL E&P operates the *Pyay* and *Myanaung* oil fields as Improved Petroleum Recovery contracts

## OFFSHORE

- MPRL E&P is Woodside's and Total's partner for Block **A-6**
- Prior to farming out, MPRL E&P acquired 2D and 3D seismic and made the **first gas discovery in southern Rakhine Basin** with *Pyi Thar-1* in March 2012

## PARTNERSHIPS OF MPEP

MPEP, local subsidiary of MPRL E&P, holds a 10% share in two onshore blocks operated by ENI and two offshore blocks operated by British Gas (A-4) and Woodside (A-7)

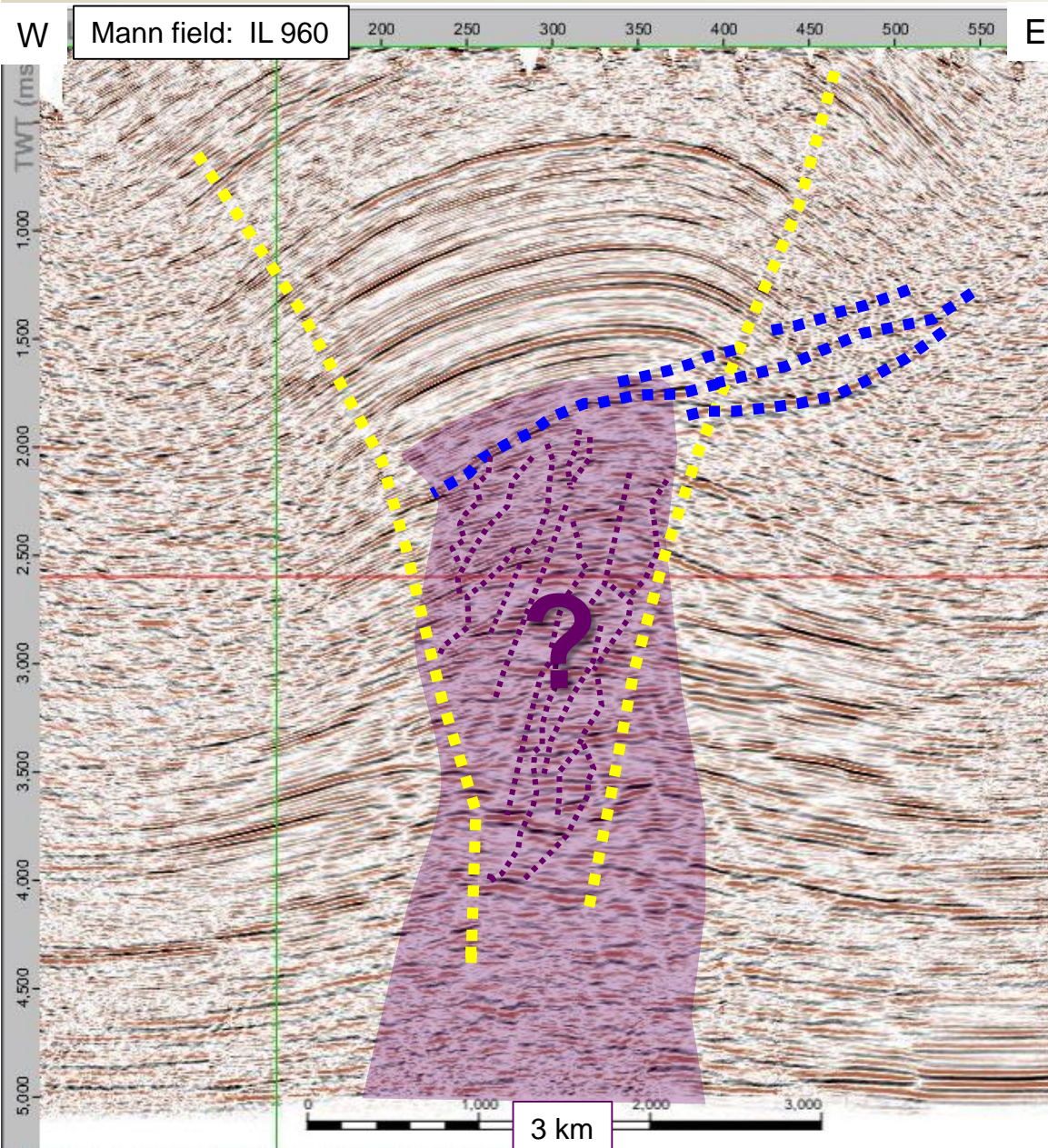
## Petroleum has a long E&P history in Myanmar

- Spanning at least eight centuries as reported by Chinese chronicles
- *Yenangyaung* is one of the oldest oil fields still in production in SE Asia

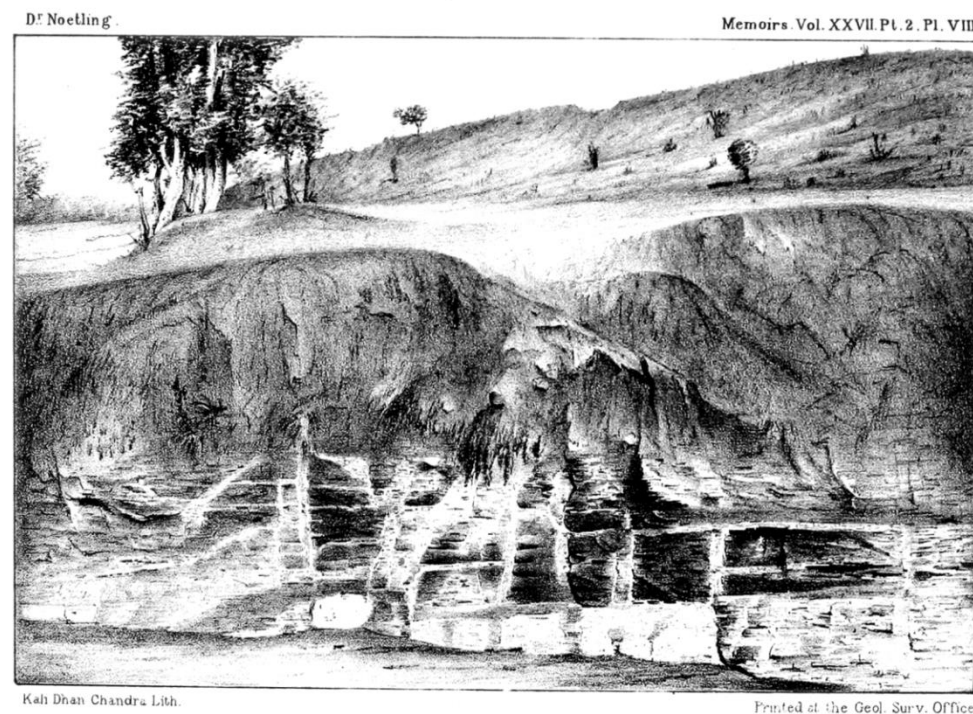
# INTRODUCTION: WHAT'S THIS GEO-BODY?



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- A **mud diapir**? But MPRL E&P is producing oil from sands within this structure
- A **flower structure**?
  - But why do these overthrust planes cross here?
- A first element of answer was published in **1897** from a drawing of shales intrusions in the nearby *Yenangyaung* field:
  - Could these shales intrusions explain what is seen on seismic? Are these veins also present in the *Mann* field?



VEINS OF INTRUSIVE MUD IN THE BEMÉ RAVINE.

# INTRODUCTION: MUD VEINS AT THE TIGHT CORE OF THE MANN STRUCTURE



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- Sure enough, **mud veins** are **present in the core of the *Mann* structure** as well, and most probably do play a role in blurring the seismic
- What we see in *Mann* and *Yenangyaung* are features related to the main deformation phase apparent in the *Central Myanmar Basins* : the **Plio-Pleistocene folding and faulting phase**, still active at the present time

- Pyay 1858 –  
Mandalay 1839 –  
Bago 1930 –  
Bagan 1975 –  
Tachileik 2011 –  
Shwebo 2012:  
building  
earthquake-proof  
skyscrapers in  
Myanmar is not  
quite a fool idea

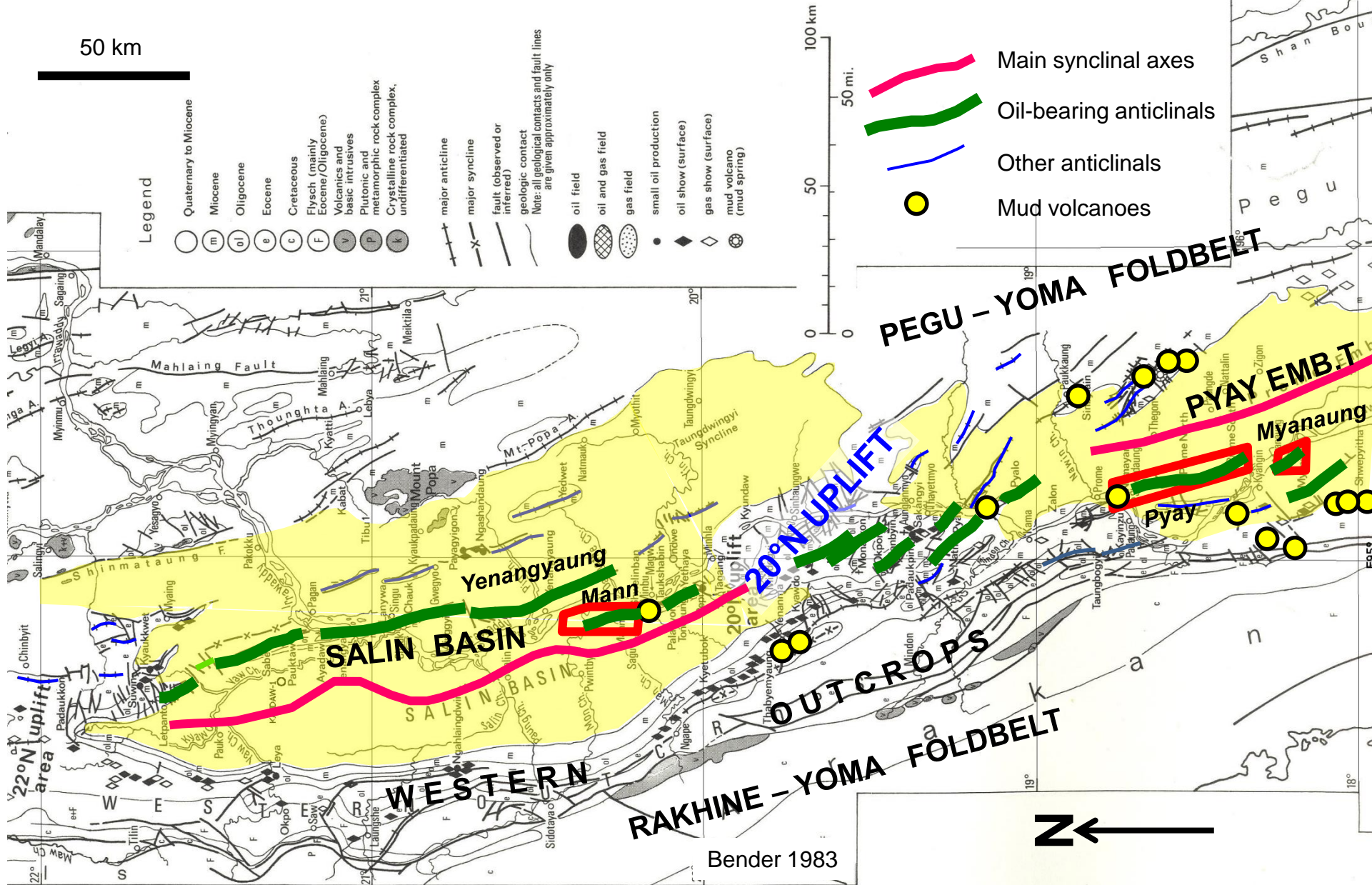


Approximate location, South of the Minbu mud volcanoes by the Sabwet Chaung: approx. N 20°09'20" E 94°52'32"

# REGIONAL STRUCTURAL MAP



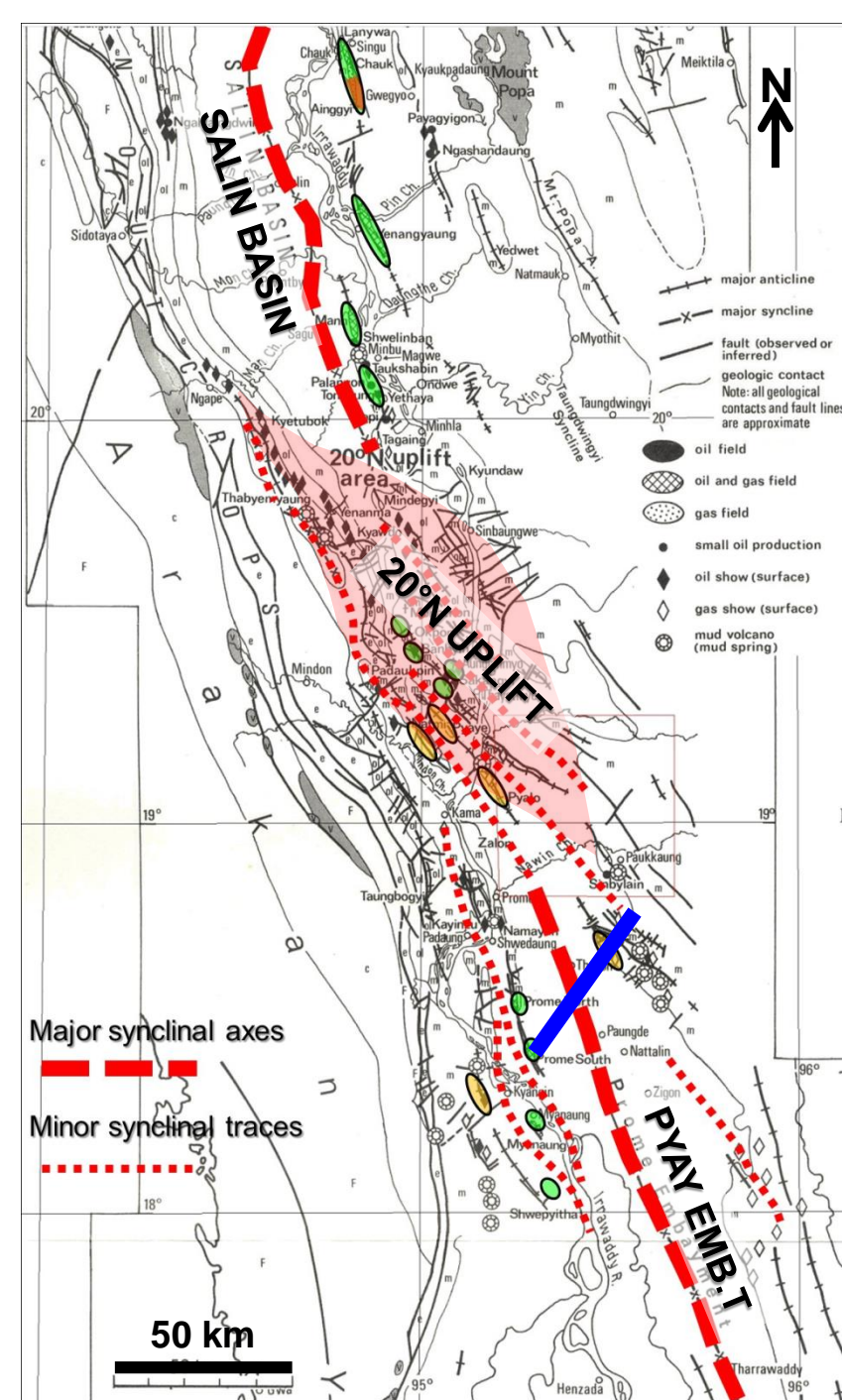
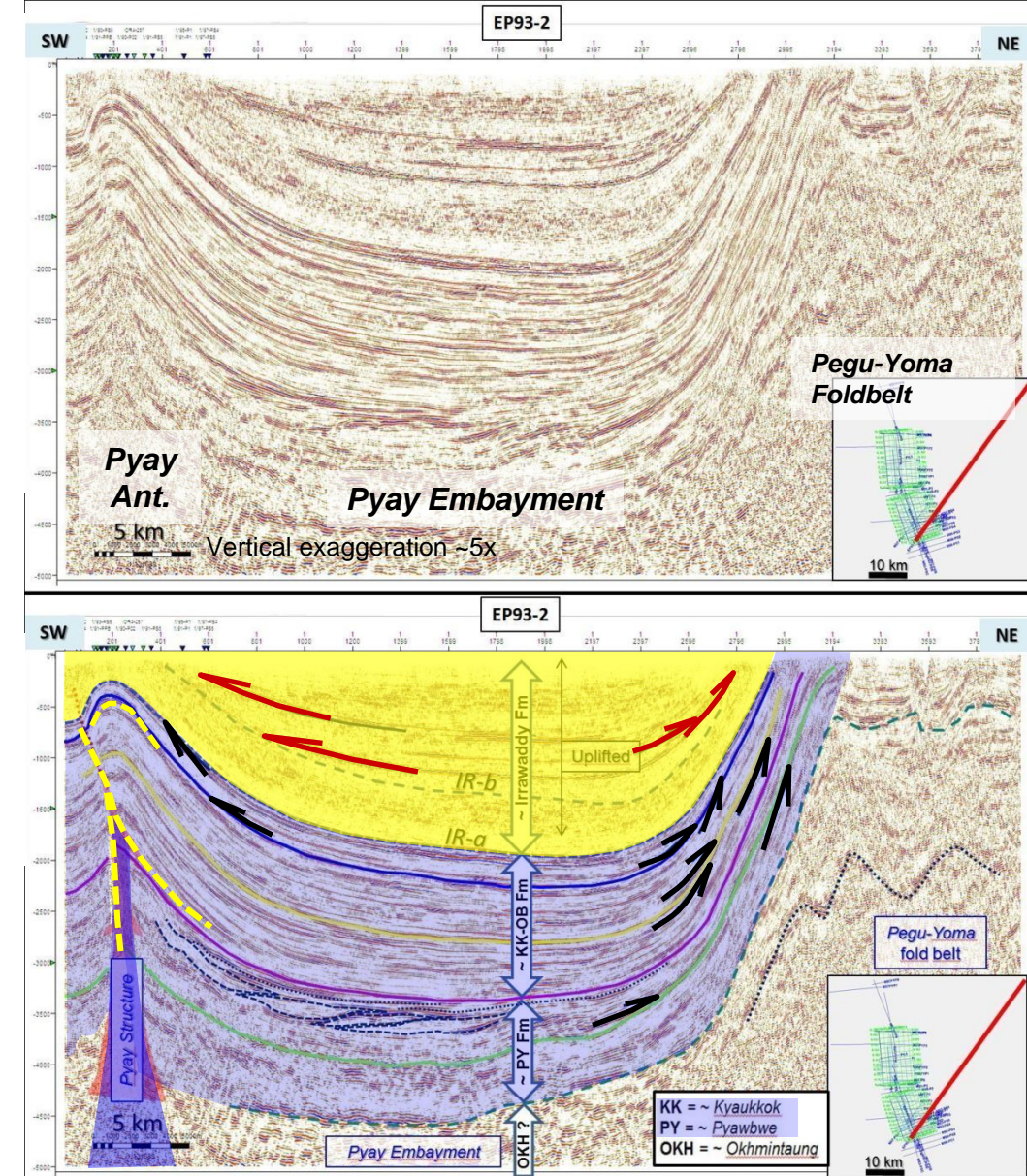
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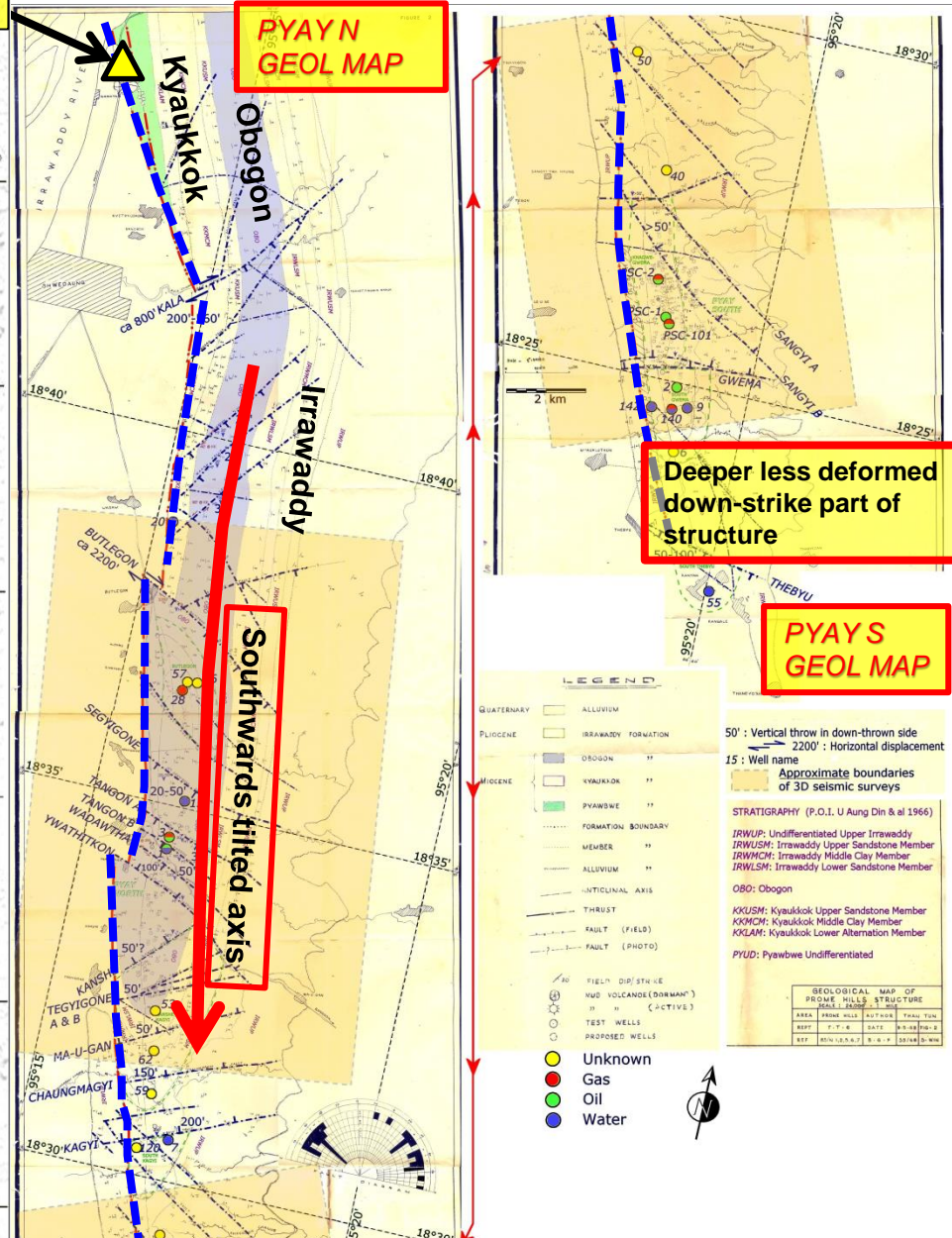
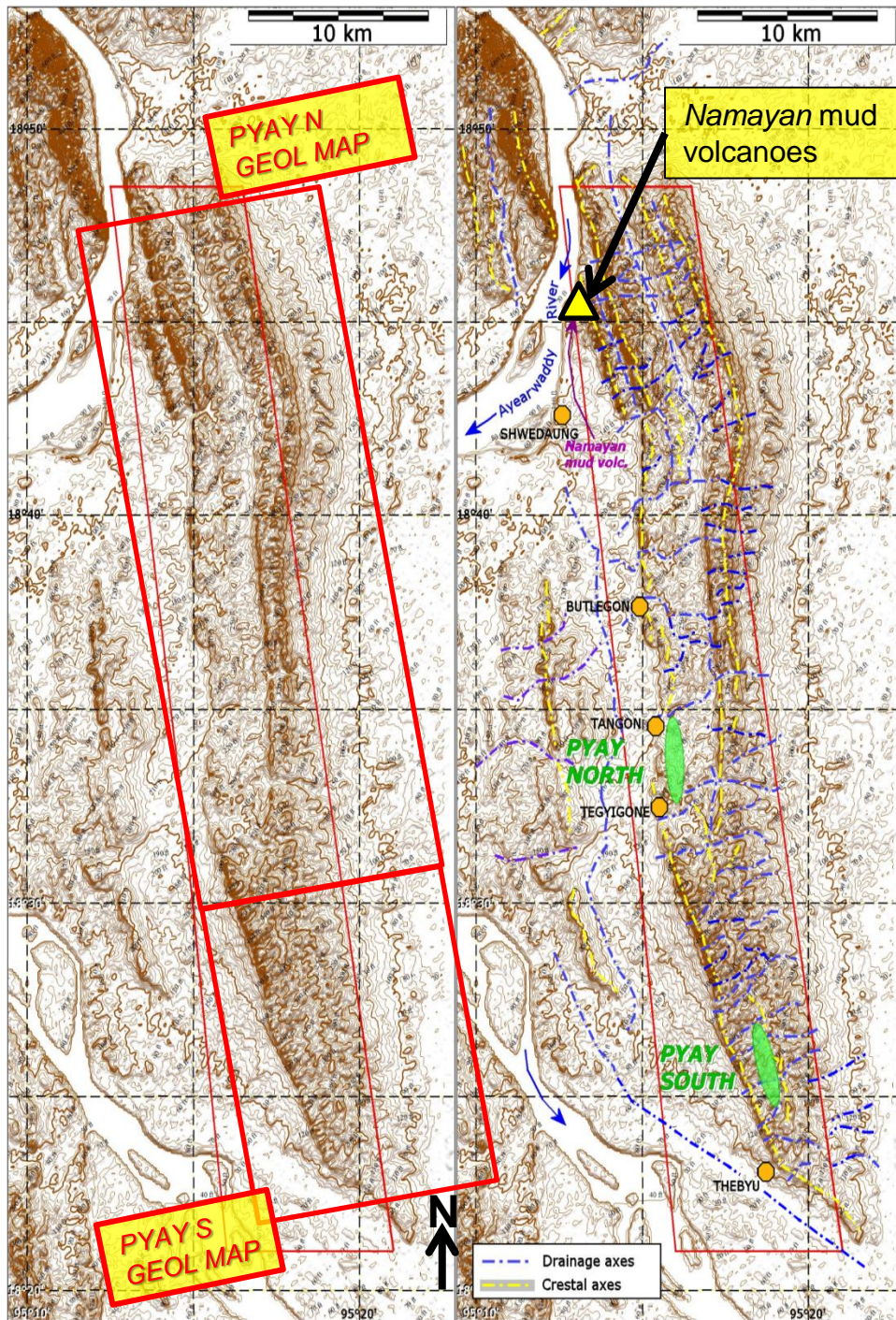
- The *Salin Basin* and the *Pyay Embayment* are separated by the Mio-Pliocene (?) *20°N Uplift*
- Note that the main petroleum bearing structural trend of en-échelon folds runs all along the *Salin Basin* southwards towards the *Pyay Embayment*: the ***Salin-Pyay trend***
- Note main kitchen of ***Salin Basin*** is to the West of oil-charged anticlines
- By contrast main synclinal axis of ***Pyay Embayment*** is to the East of main fields
- Distribution of mud volcanoes:
  - along the Ayeyarwady River &
  - to the edges of the basins

# REGIONAL STRUCTURAL STYLE (PYAY EMB.T)

- the *Pyay Embayment* is one of the Tertiary *Central Myanmar Basins*
- Regional seismic line** shows:
  - Oligo-Miocene significant multi-phase deformation active at the *Pegu-Yoma Fold Belt* to the East
  - Late Miocene, mild deformation starting along a probable **basement fault** below the *Pyay* anticline
  - Main phase of deformation** starting during early Pliocene culminating in **Pleistocene-Holocene**



# SURFACE EXPRESSION OF THE SALIN-PYAY DEFORMATION BELT

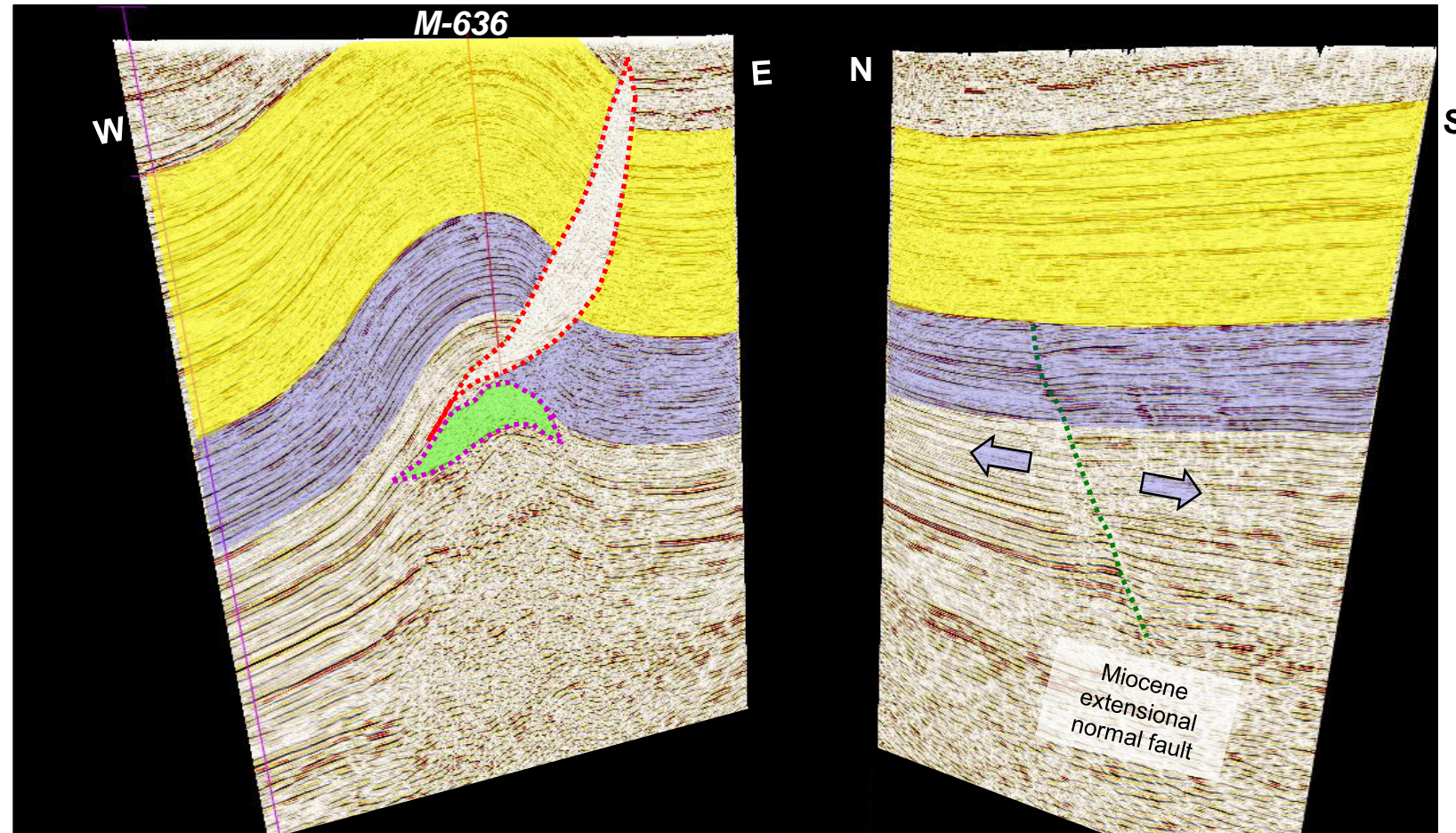
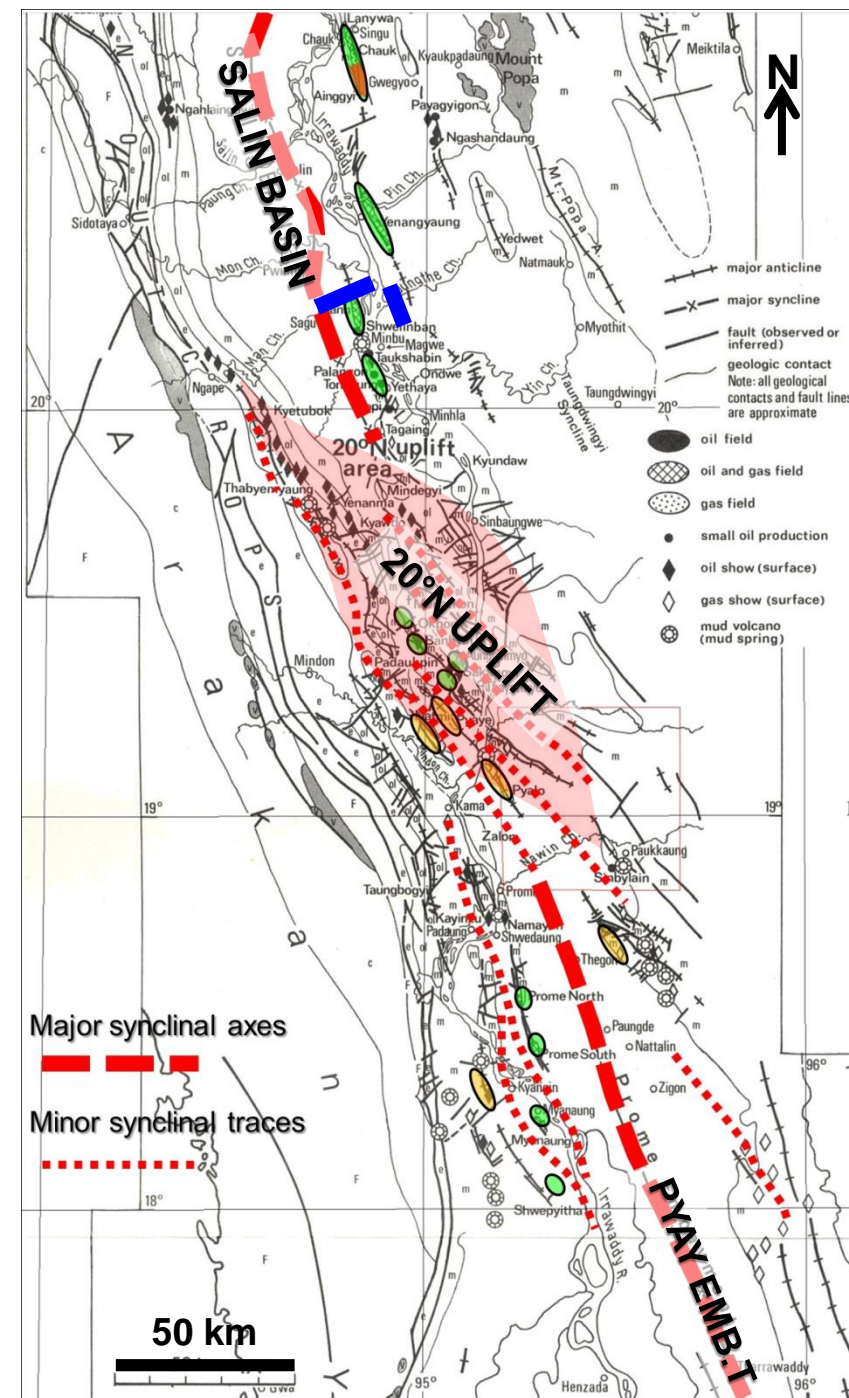


- Topographical expression: most of these very young structures mark the topography as elongated hills, such as the Pyay Hills Range
- Geological mapping by MOGE 1966 already dates main deformation as mostly **Pleisto-Holocene** as the whole Pliocene *Irrawaddy* formation is involved in the folding and faulting.
- Note general tilting of the *Pyay* structure towards South; **deformation decreases** in the **down-strike** part of the tilted structure: the structure is **not cylindrical**

# DETAIL STRUCTURAL STYLE : MANN FIELD IN SALIN BASIN



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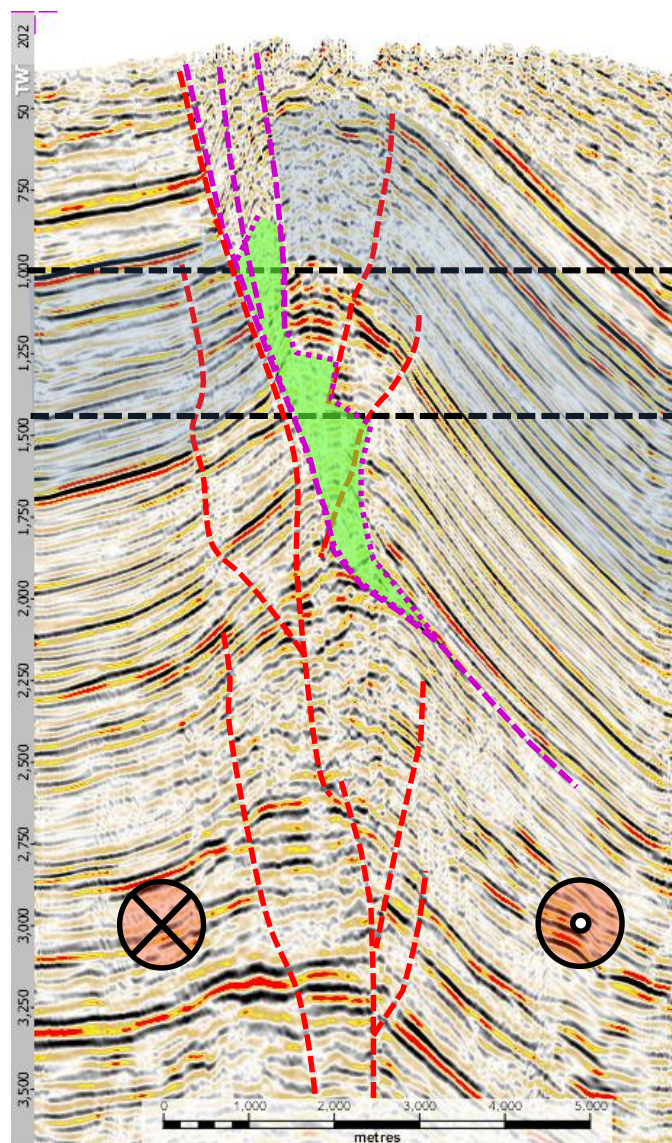
Recent 2D seismic across Mann shows:

- The structure is also showing as a **non-cylindrical tilted fault-propagated fold**,
- **Miocene normal faulting** with downthrown block to South,
- **"Overthrust" zones** rooted in shales oblique to and joining major reverse fault zone;
- Buckled zone overlying **blurred seismic**

# DETAIL STRUCTURAL STYLE : PYAY FIELD IN PYAY EMBAYMENT

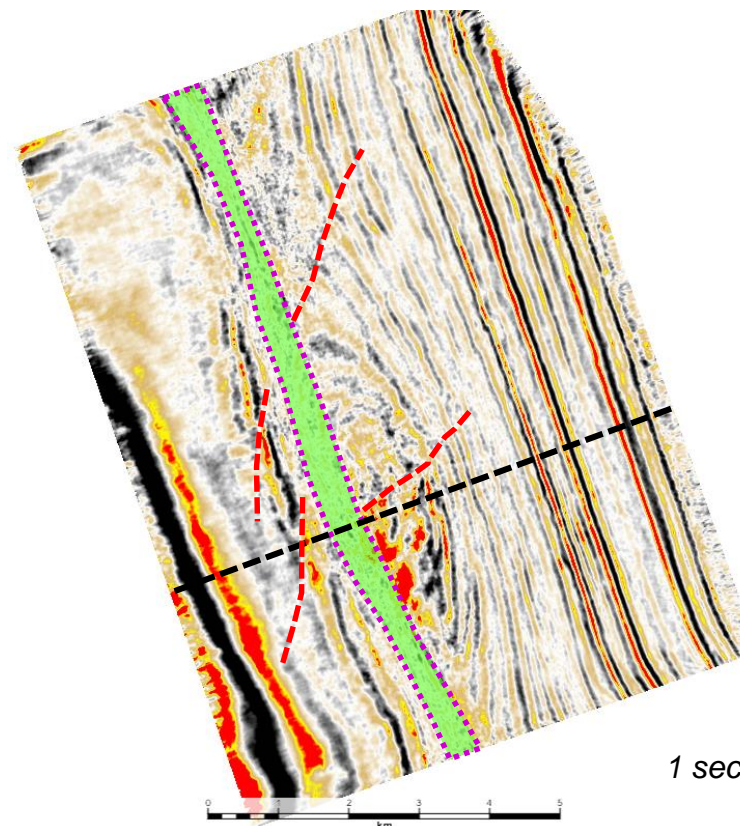


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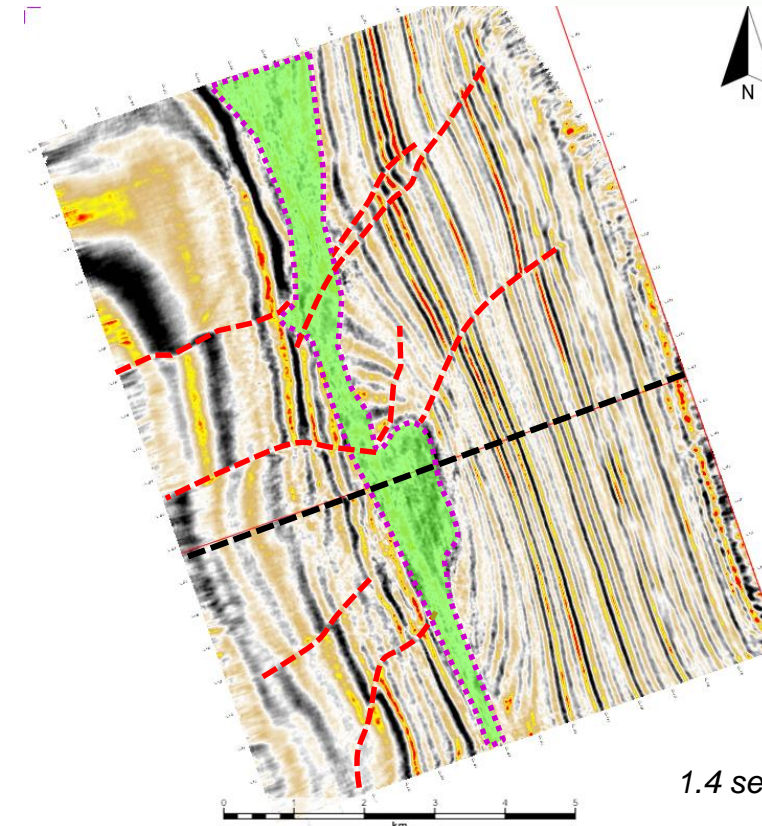


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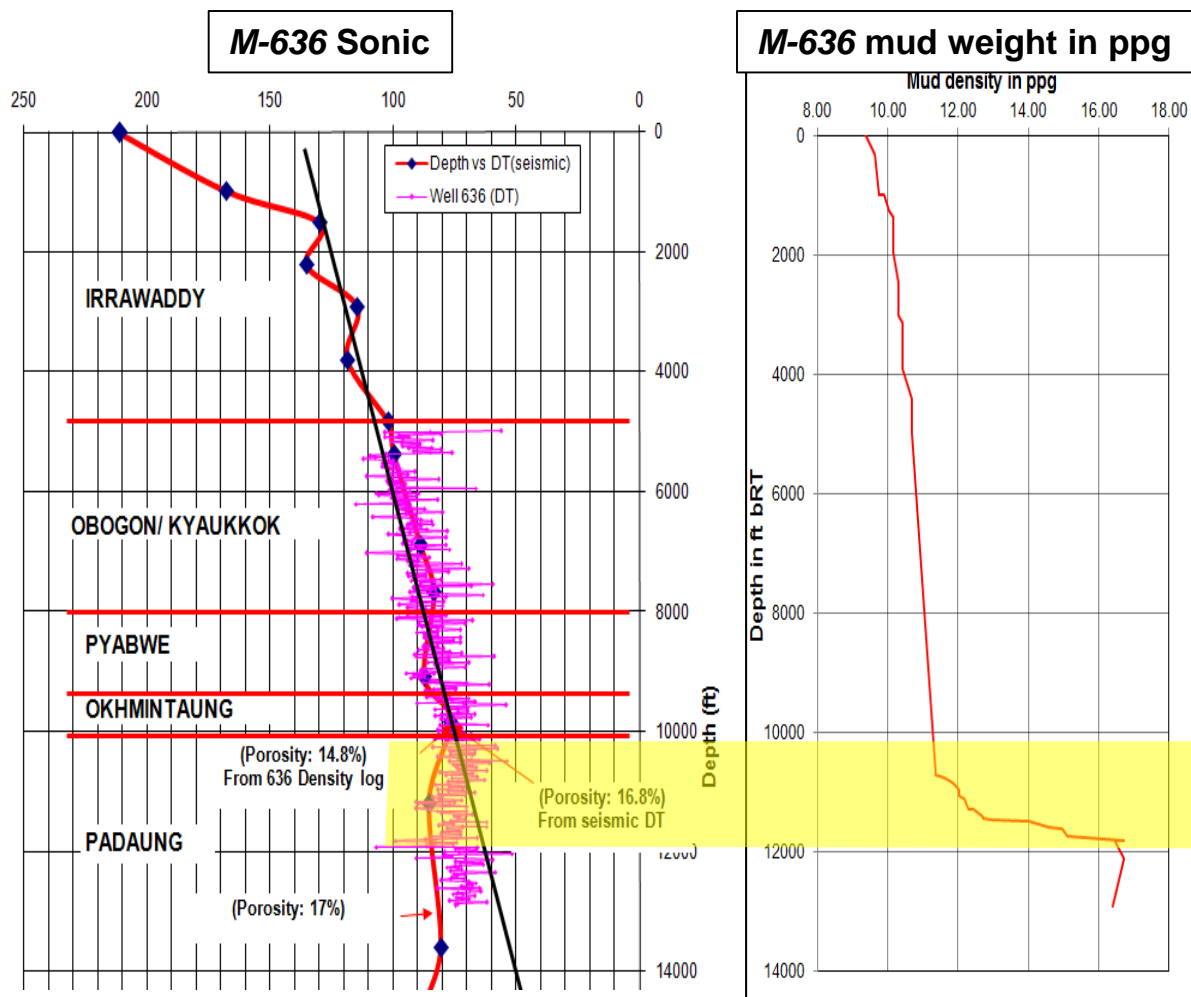
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- In the **down-strike less deformed part** of the tilted structure, seismic shows two tectonic regimes:
  - a buckled zone near surface overlying
  - blurred seismic related to a local overthrust zone
- The width of this **blurred seismic zone increases towards the up-strike part of the tilted structure** where the following is observed:
  - the buckled zone becomes eroded,
  - the deeper core of the structure outcrops and shows a **dense network of shales injections**. Mud volcanoes may occur,
  - the throw of the bounding reverse fault increases.

# OVERPRESSURES VS LOG AND SEISMIC ANSWERS IN MANN STRUCTURE

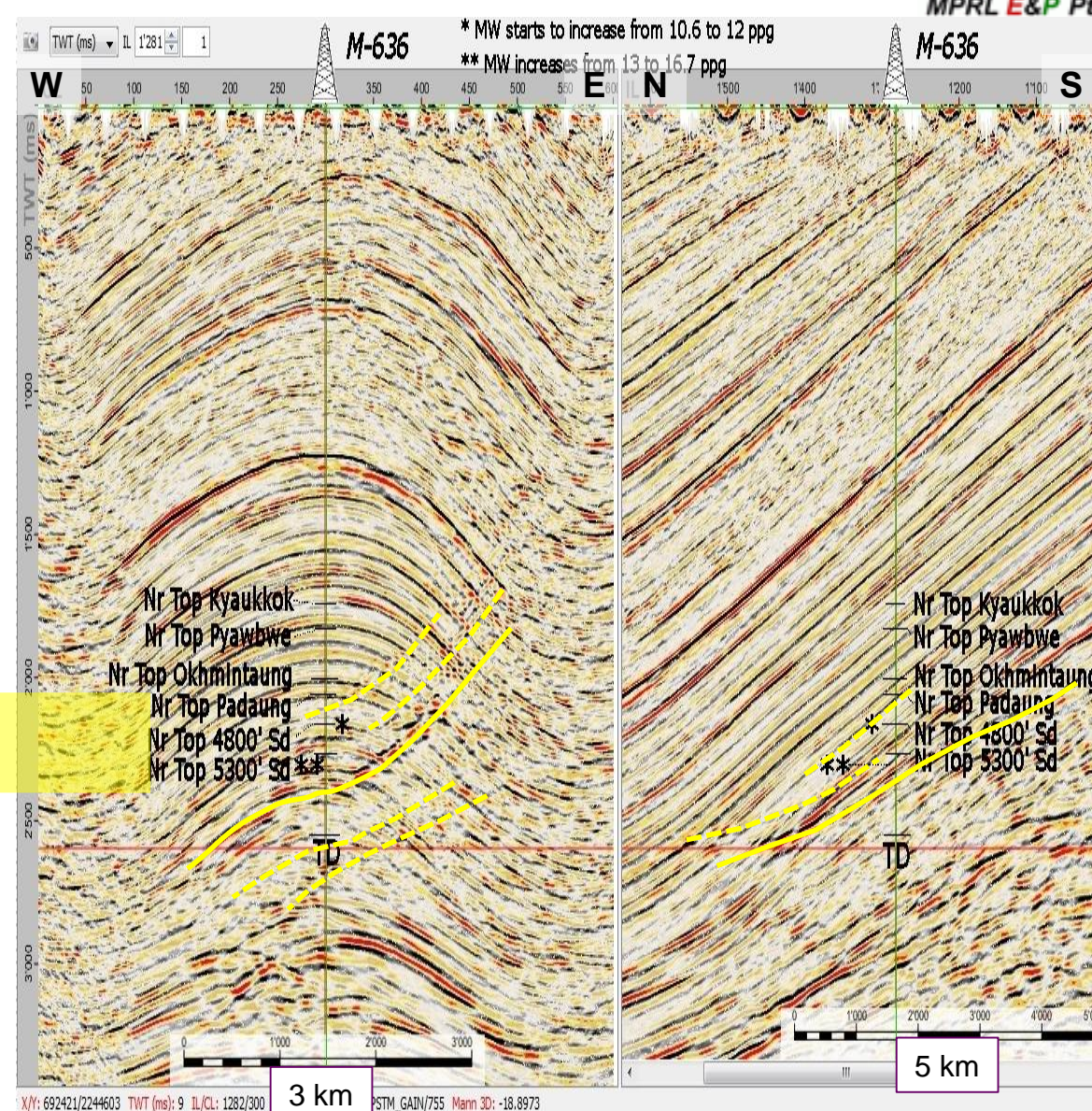


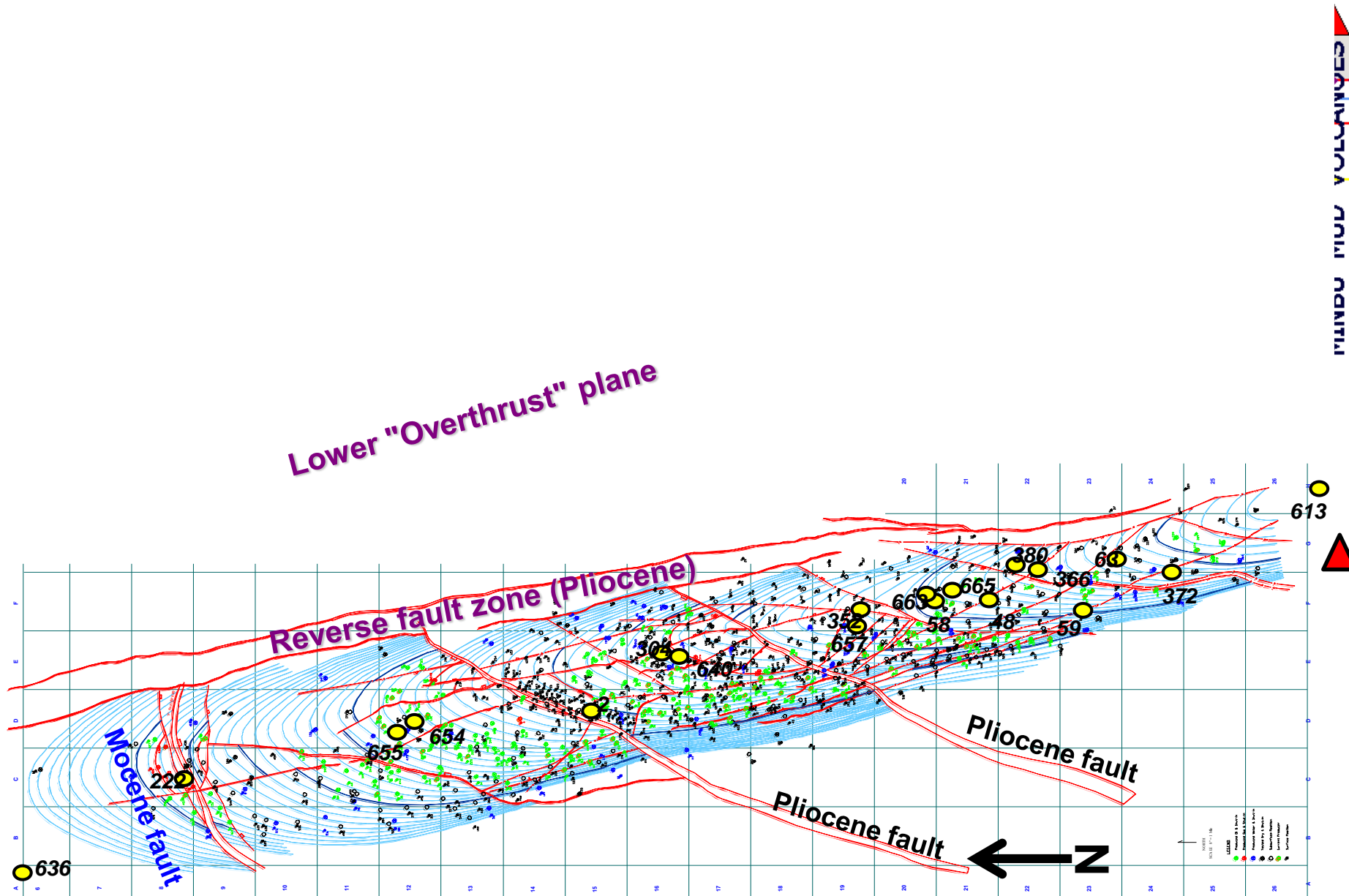
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Note good depth correlation between:

- sonic slowdown,
- mud weight increase (indirect pressure indication), forming a **pressure seal**
- network of "overthrust" planes and
- top of blurred seismic
- tectonically stressed shales (cavings)



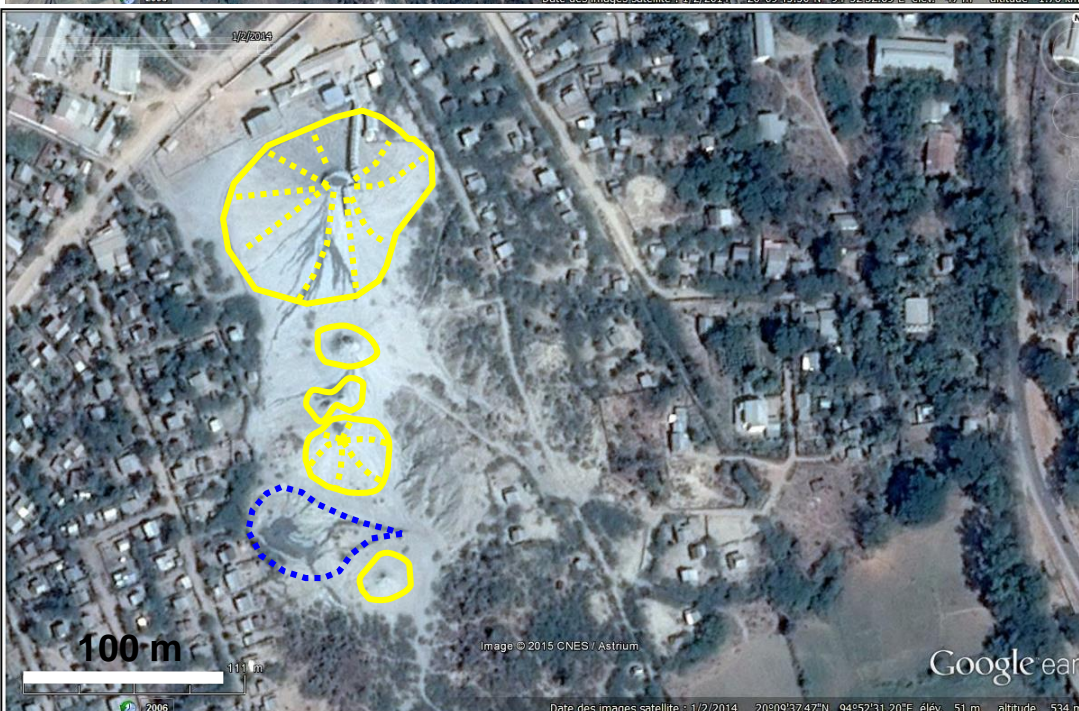


- The overthrust planes follow a stratigraphical interval in shales and mark the top of **severe overpressures** and **tectonically stressed shales**
- The pressure gradient usually increases fairly sharply from 0.5 psi/ft to some 0.85-0.95 psi/ft across a 1-3,000 ft interval forming a **pressure seal** before returning to hydrostatic gradient
- Interestingly enough, this increase in pressure and in **pressure gradient** is about the **same** in various other **structures** such as *Pyay* or *Myanaung* regardless of the intensity of deformation.
- The **mud volcanoes** in *Mann* appear to act as a **safety valve** whereby the increase of pressure with depth seems to be much slower

# MUD VOLCANOES



- Mud volcanoes: present in most deformed part of the structure in *Mann* and *Pyay*
- The most spectacular mud volcanoes of the *Central Myanmar Basins* are located South of the *Mann* field at the intersection of two fault systems;
- Another much smaller group is located N of the Pyay Hills range at Namayan village.
- **Cones** up to 60 ft high and **watery mud pools** show **gas bubbling** with **thin oil slicks** migrating through the fault systems.
- Temperature of the mud: cool, typically the average local temperature.
- Micro-fauna: the mud shows the same micro-fauna as the encasing claystone,
- Activity clearly related to the local aquifer as bubbling significantly varies with the level of the nearby Sabwet Chaung
- Absence of upwards migration of lithological material but rather interaction between nearby aquifer weakening overstress shale allowing for gas migration along faults

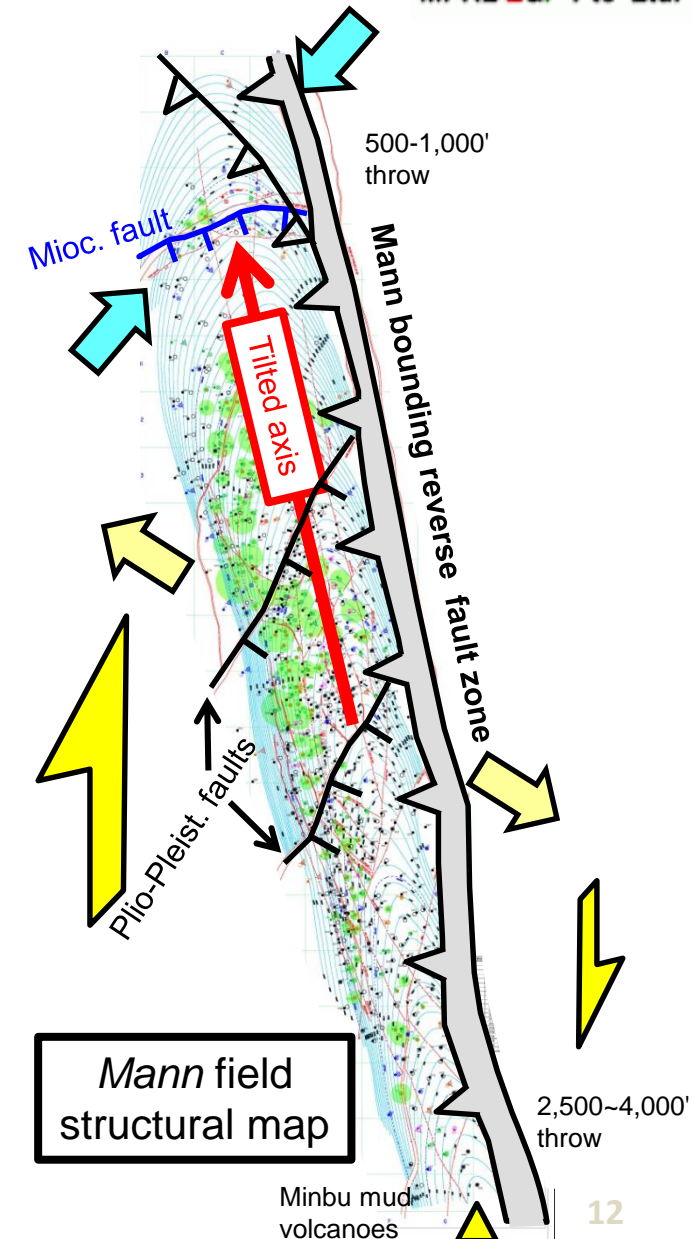
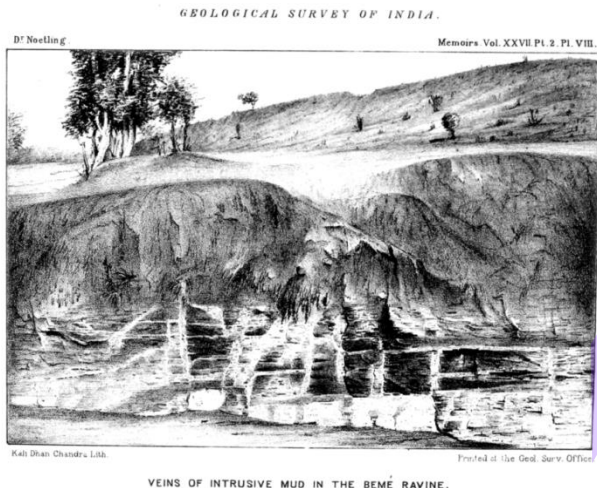
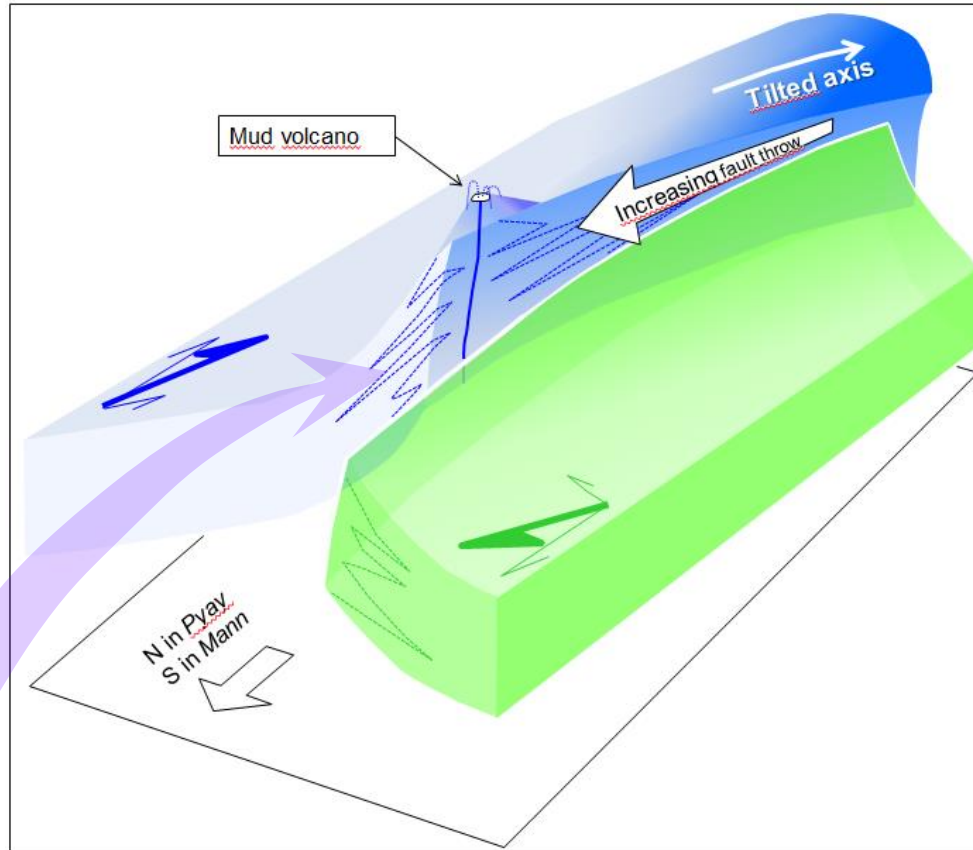


# SUMMARY OF COMMON FEATURES OF PLIO-PLEISTOCENE STRUCTURES OF THE SALIN-PYAY DEFORMATION BELT



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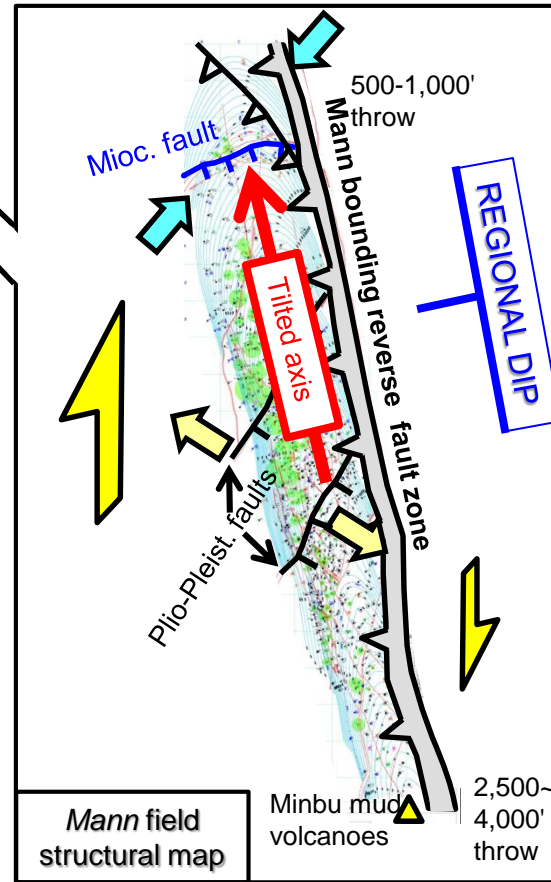
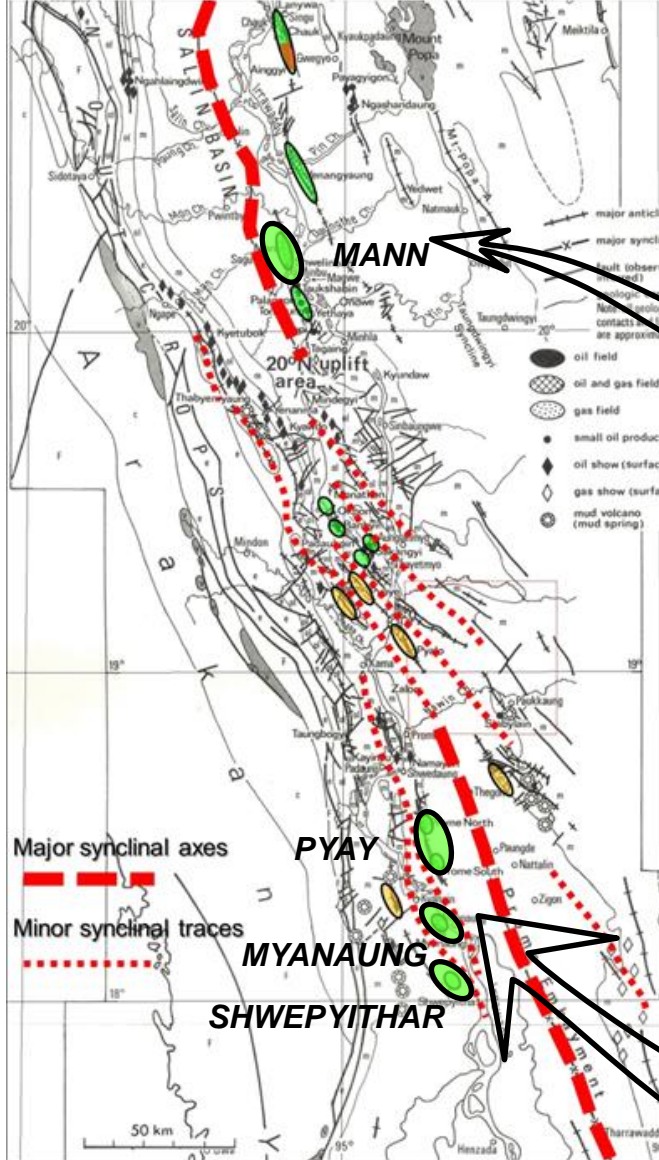
- **Non-cylindrical fault propagated folds;**
- **Topographical expression** and **geological mapping** indicate Holocene main deformation;
- **Tilted axis**, with up-strike part of the structure more tightly folded;
- **Asymmetrical folding** overlies core of structure **seismically blurred**;
- **Overpressures, tectonically stressed** shales and a **tight network of mud veins** coincide with seismic blurred zone;
- **Main reverse fault zone** bounding one side of the structure; throw increasing as deformation intensifies;
- **Local overthrust planes** rooted in shales associated to the reverse fault zone, indicating **compression**;
- **Late normal faults** across the structures indicating **extension**;
- Fault pattern fits **dextral strike-slip** with western compartment moving N'wards;
- Locally developing **mud volcanoes** and **shales intrusions** where the core of the fold outcrops at surface



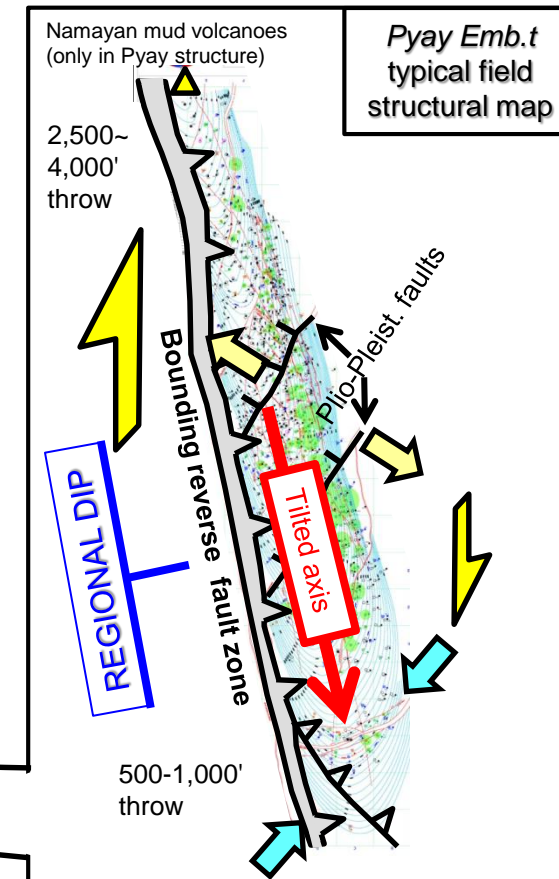
# WHAT DIFFERS FROM SALIN BASIN TO PYAY EMBAYMENT?



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- The Mann structure in the Salin Basin is **tilted northwards**, with main bounding **reverse fault dipping westwards** towards the axial syncline of the Salin Basin located West of Mann;

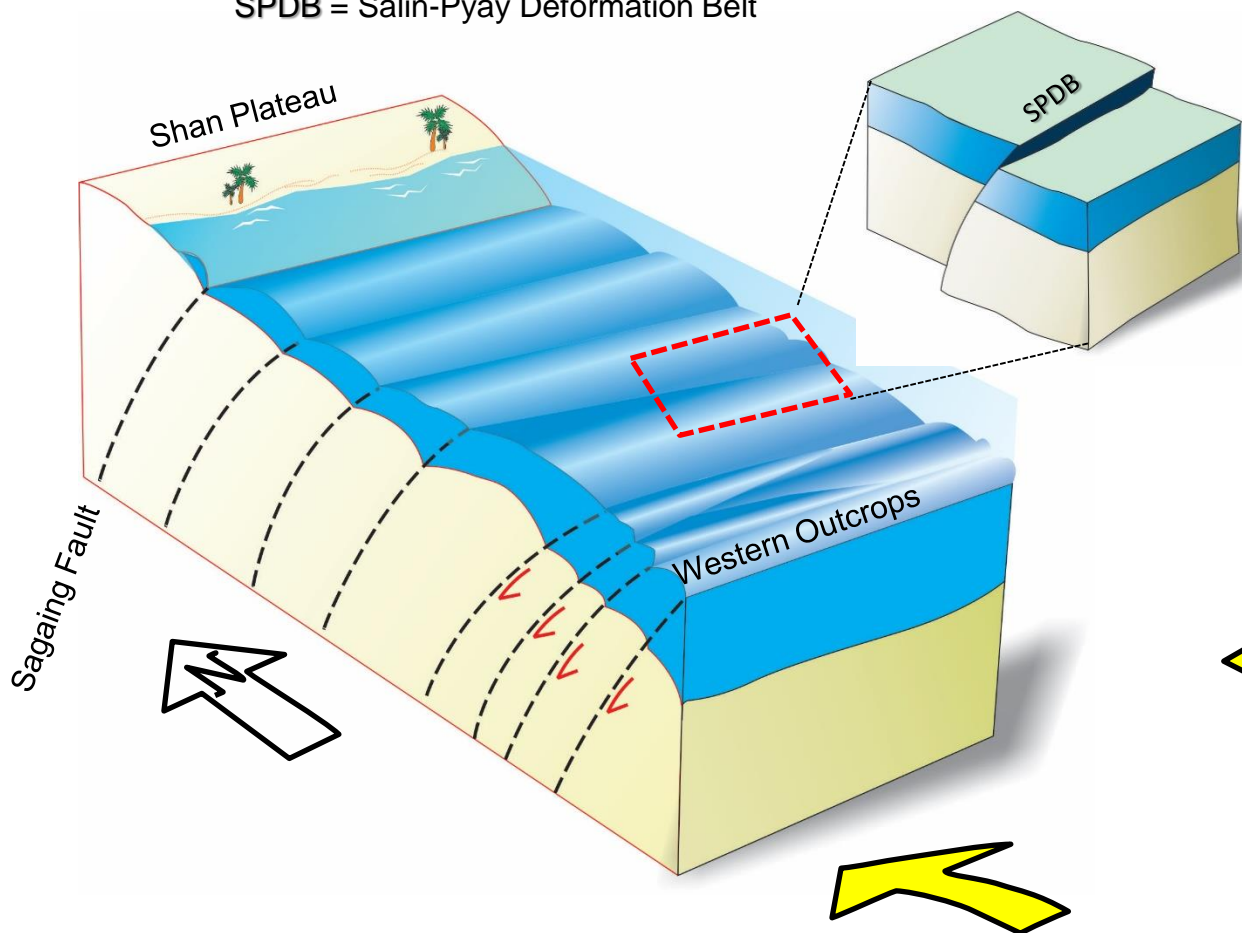


- By contrast, all three Pyay, Myanaung and Shwepyithar en-échelon structures in the Pyay Embayment are **tilted southwards**, with main bounding **reverse fault dipping eastwards** facing the axial syncline of the Pyay Embayment located East of the structures

- Whilst the strike-slip direction hardly changes from Salin Basin to Pyay Embayment, the **regional dip** seems to **dictate the direction of tilt** and the variation in intensity of deformation

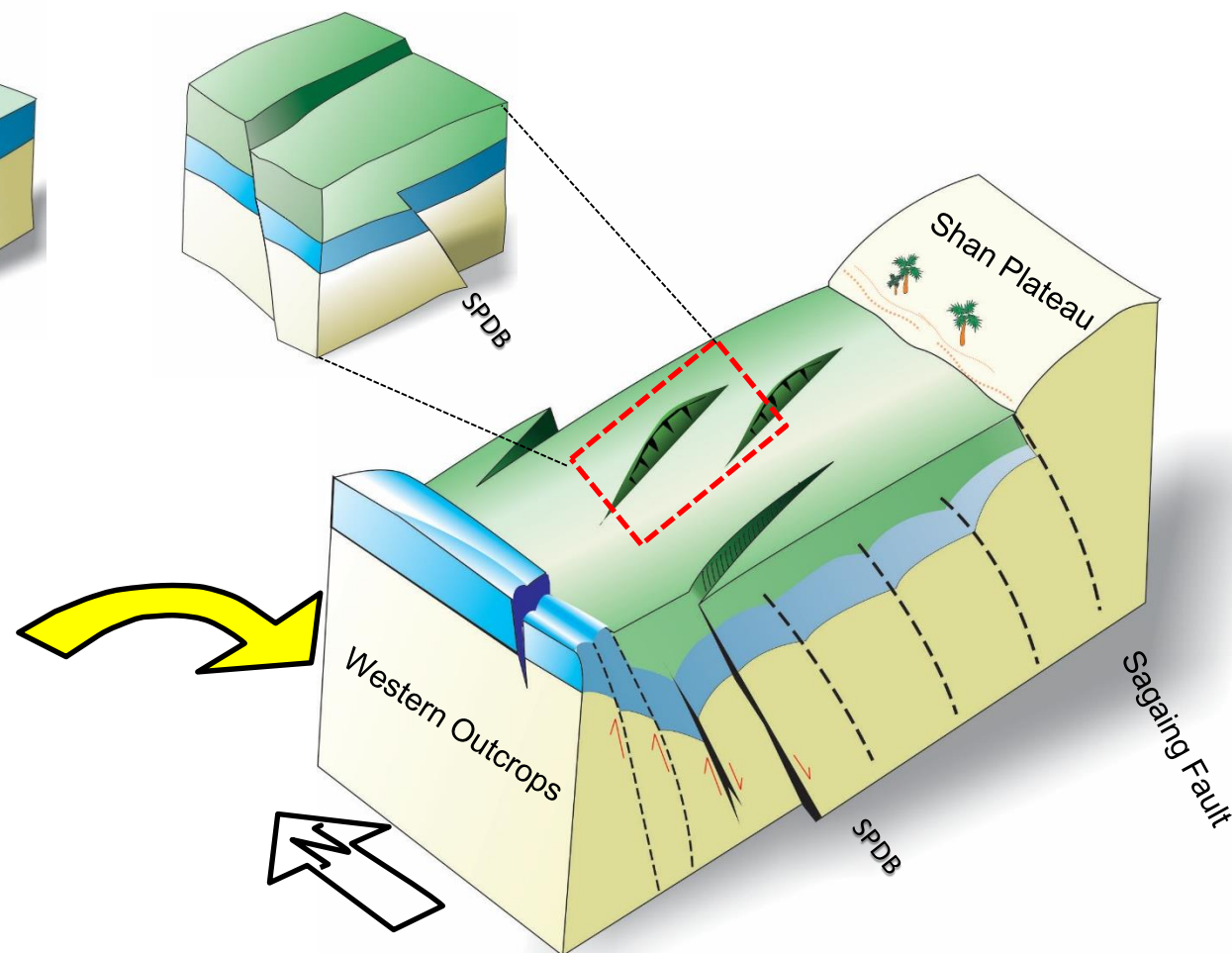
# PROPOSED MODEL : EOCENE-MIOCENE

SPDB = Salin-Pyay Deformation Belt



MAIN **EOCENE** DEFORMATION: **FRONTAL SUBDUCTION** of India Plate +/- northwards (?) beneath Burma Platelet(s),

- Main subduction zone is accretion prism of *Rakhine Onshore Foldbelt* ("Western Outcrops") inducing mostly **reverse faulting** of basement



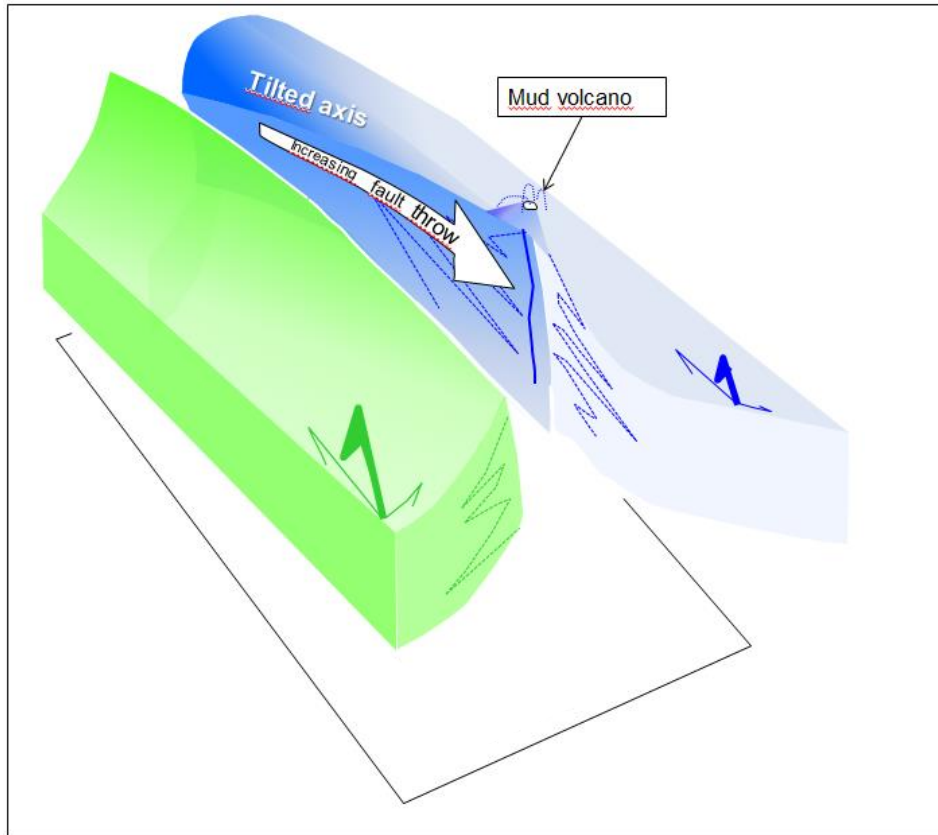
MAIN **OLIGO-MIOCENE** DEFORMATION: **CLOCKWISE ROTATION** of SE Asia, incl. Burma Platelet(s), around India Plate NE buttress:

- **Miocene extension** well documented in the field and seismic in *Salin Basin* and *Pyay Embayment*
- subduction is probably secondary (?), with minimal basement faults movements

# PROPOSED MODEL : PLIO-HOLOCENE



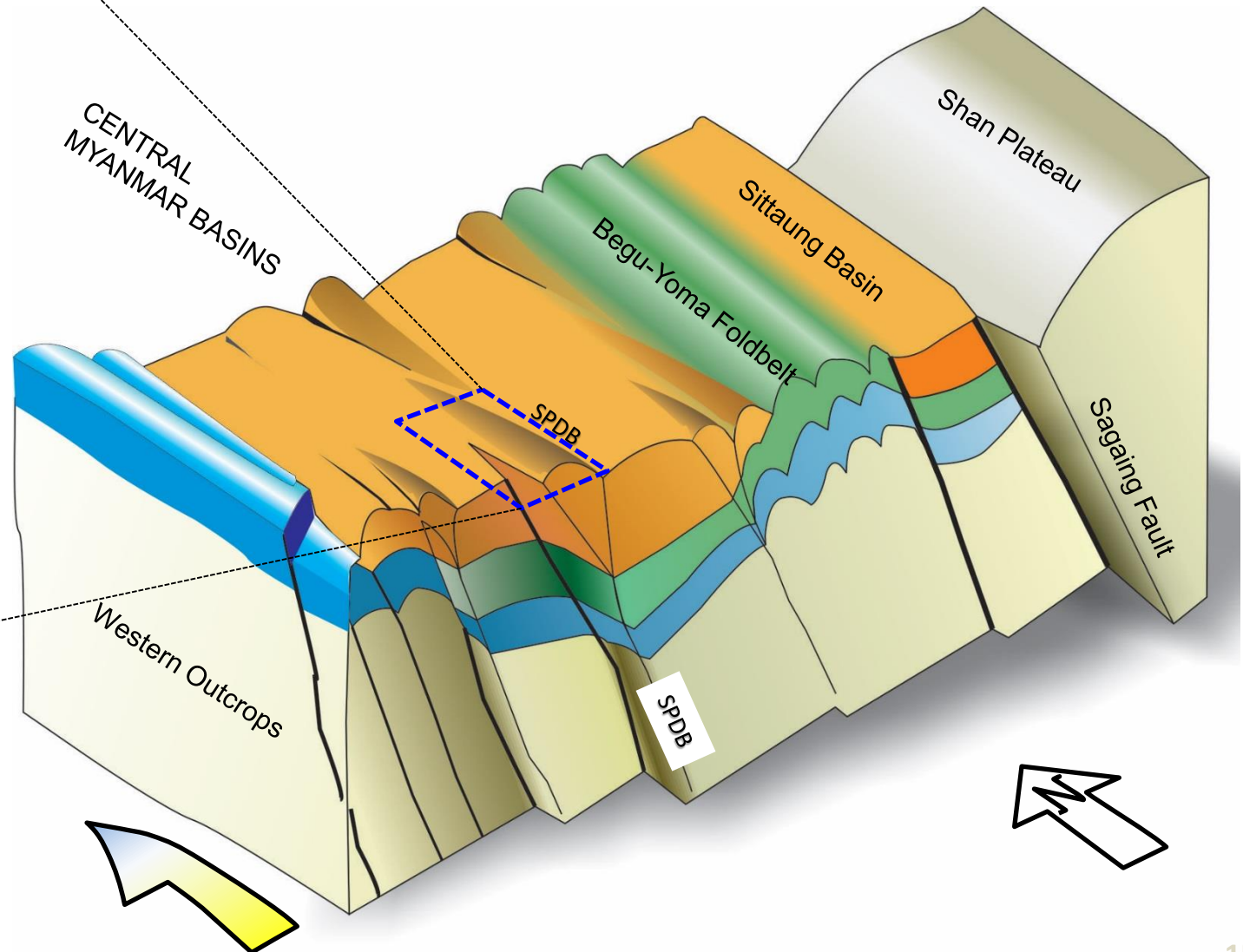
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**PLIO-HOLOCENE MAIN DEFORMATION: OBLIQUE SUBDUCTION** of India Plate NNE-NE'wards resumes beneath Burma Platelet(s):

- **Main phase of deformation in the Central Myanmar Basins (CMB)**

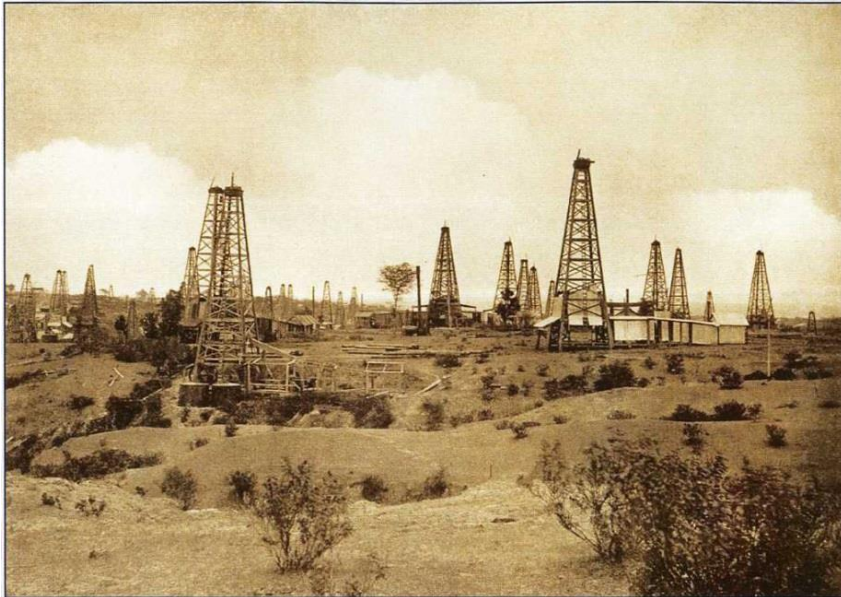
- Most probably multi-phase, continuous, with peaks of rapid deformation varying from place to place, most intense during Pleisto-Holocene
- Note **strike-slip re-activation of ancient basement faults**



# CONCLUDING REMARKS

## STRUCTURAL ASPECTS

- A **very simplified view** of the Plio-Pleistocene **main deformation phase**;
- This deformation is still **quite active** as shown by frequent deformed casings in the fields, active mud volcanoes as well as devastating earthquakes
- Holocene deformation is just the **most recent** and **most intense peak of deformation** of a **continuous collision process since Eocene**, with occasional **peaks of deformation activity** such as during Oligocene, early and late Miocene and overall **Holocene-Recent**;
- This **Plio-Holocene main deformation phase** is also well documented in **other on- & offshore areas** of the country W of & along the *Sagaing Fault*.



## PETROLEUM GEOLOGY ASPECTS

- Production; a better understanding of this ongoing main deformation may guide **geo-mechanical studies** and **other operations** to optimize production, such as hydro-fracturation;
- Exploration; contribute to better explain and predict **HC distribution** and assess **deeper exploration potential**;

## WAY FORWARD

- More field trips (detailed fault analysis, etc)
- More geomechanical data & analysis from 3D seismic and new wells
- More integrated studies with MOGE and other operators in the area

**MPRL E&P thanks MOGE for continuous support & permission to show some key data**

**I thank MPRL E&P colleagues & management for lively discussions & good ideas towards good science**