The rich isotopic memory of illite; an example of clay dating and fluid fingerprinting from the Zimapán Basin in Central Mexico

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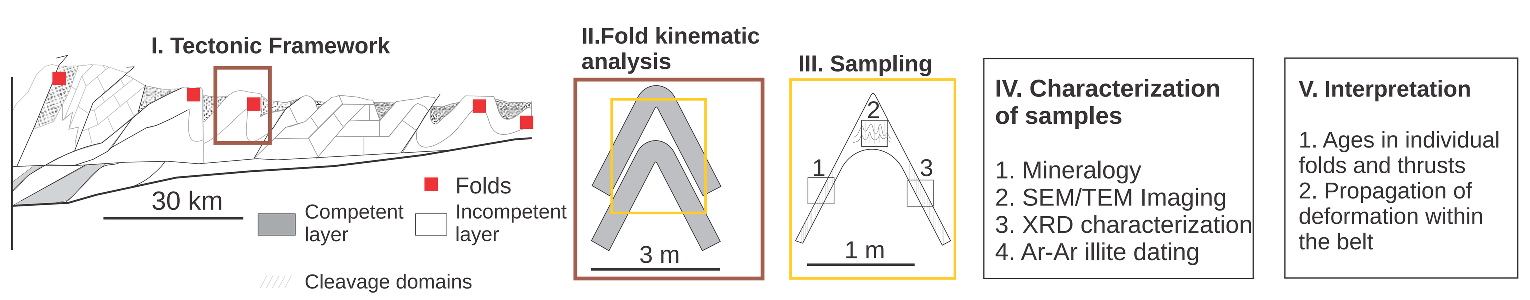
I. SUMMARY

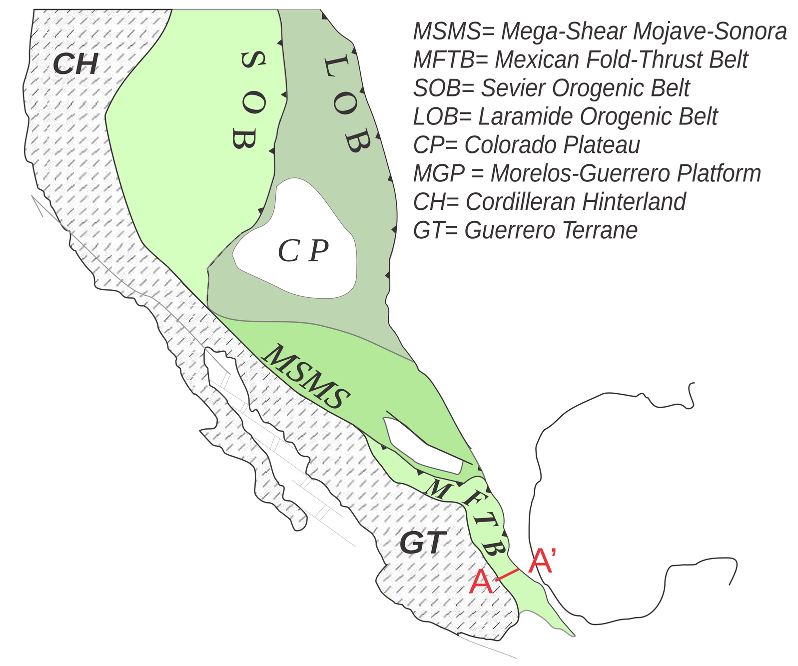
Besides vein-forming minerals such as quartz and calcite, clay minerals are one of a few species that grow during deformation in the upper crust. Among the family of clay minerals, illite contains a particularly rich isotopic memory that can be applied to a variety of geologic studies. Illite contains potassium, a radioactive element that can be used to obtain the age of deformation through Ar-Ar dating. Illite also contains structural water (OH^- ions in the octahedral layer), which, through δ^2H or $\delta^{18}O$ analyses, can provide information on the source(s) of the fluids present during deformation. Finally, illite contains boron in its structure, which provides independent information on the nature of the fluid(s) that were active during deformation and/or ambient temperature conditions.

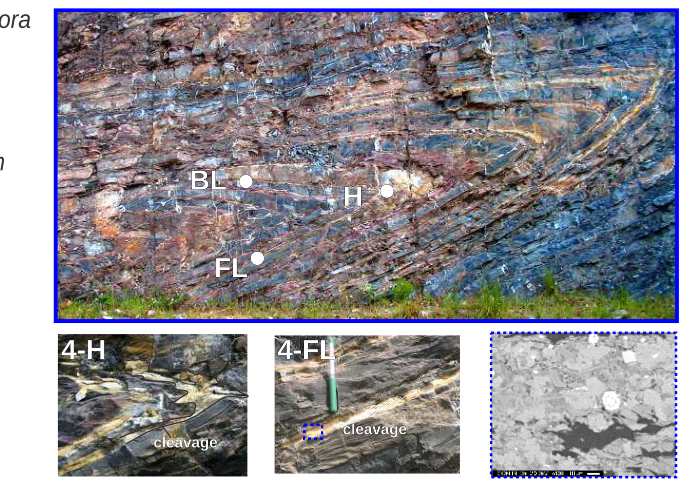
In order to understand the mechanisms and significance of illite crystallization during folding, a structural, textural and isotopic study was conducted on rocks of the well-exposed and well-preserved Zimapan Basin of Central Mexico. This now-inverted basin contains a succession of Cretaceous deep-water marine carbonates, which were strongly folded during the Late Cretaceous. Structural observations identify two shortening events in these rocks (tight folds refolded in spaced open folds and two generations of axial plane cleavage). SEM analysis of shales that were sheared parallel to bedding during flexural folding, show that illite grains grew parallel to cleavage. Based on Ar-Ar illite age analysis (IAA) of neocrystallized clays these events are constrained to have occurred at 80-84 Ma and 75-77 Ma. New in-situ U-Th/Pb ages from monazite included in calcite and quartz from syntectonic stretching veins agree within uncertainty of the Ar-Ar data, supporting the robust nature of the IAA. δ^2H analyses of both illite and fluid inclusions trapped in syntectonic veins show that they grew in isotopic equilibrium with pore water that was a mixture of marine and meteoric sources, reflecting a combination of fluid re-cycling marine water meteoric water infiltration during basin inversion and regional deformation.

II. METHODOLOGY

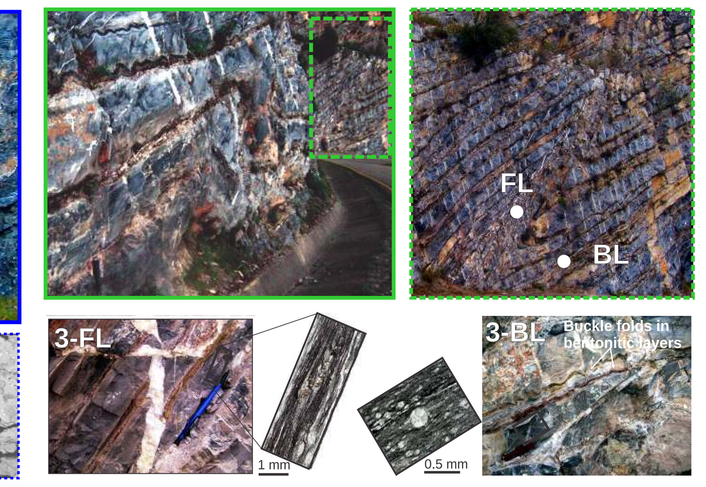


III. STUDY AREA AND FOLDS EXAMINED

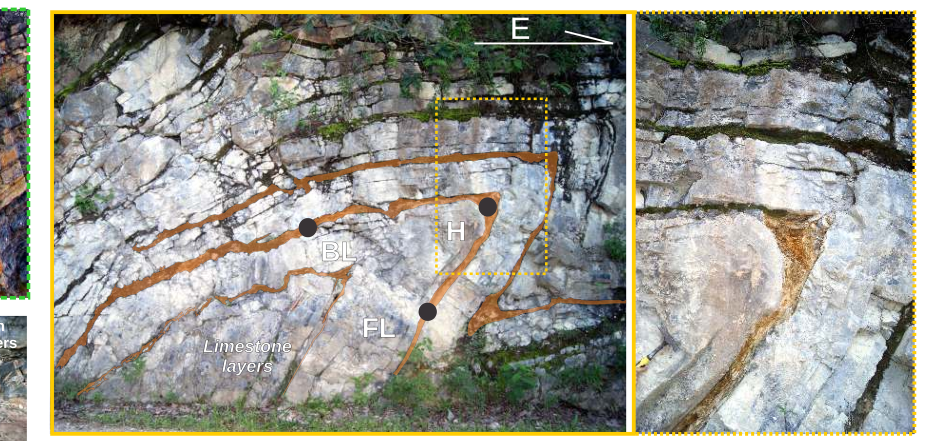




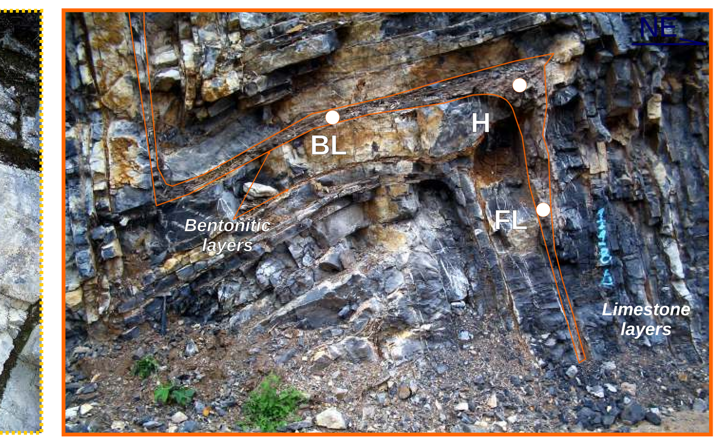
Fold 4: Tight, flattened almost recumbent quasi-symmetric chevron fold representative of D1 folding affecting rocks in the Zimapan Basin.



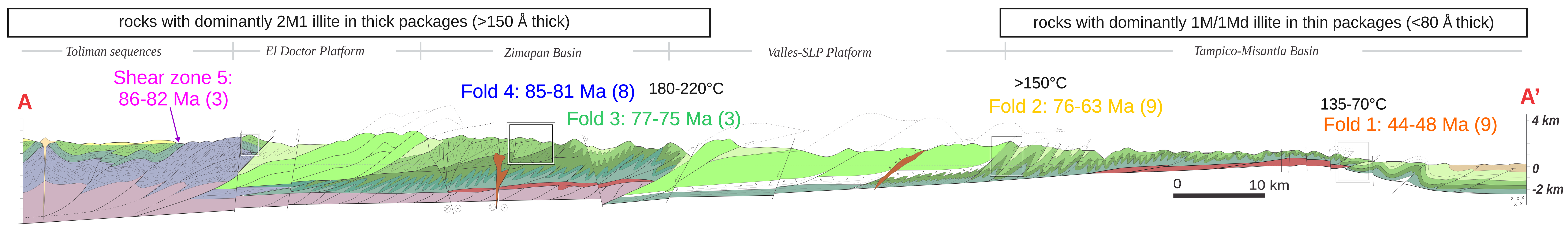
Fold 3: Asymmetrical chevron fold with an attenuated straight forelimb. Cross-cutting relationships and fold-kinematic analyses indicate that the limb was attenuated after D1 folding.



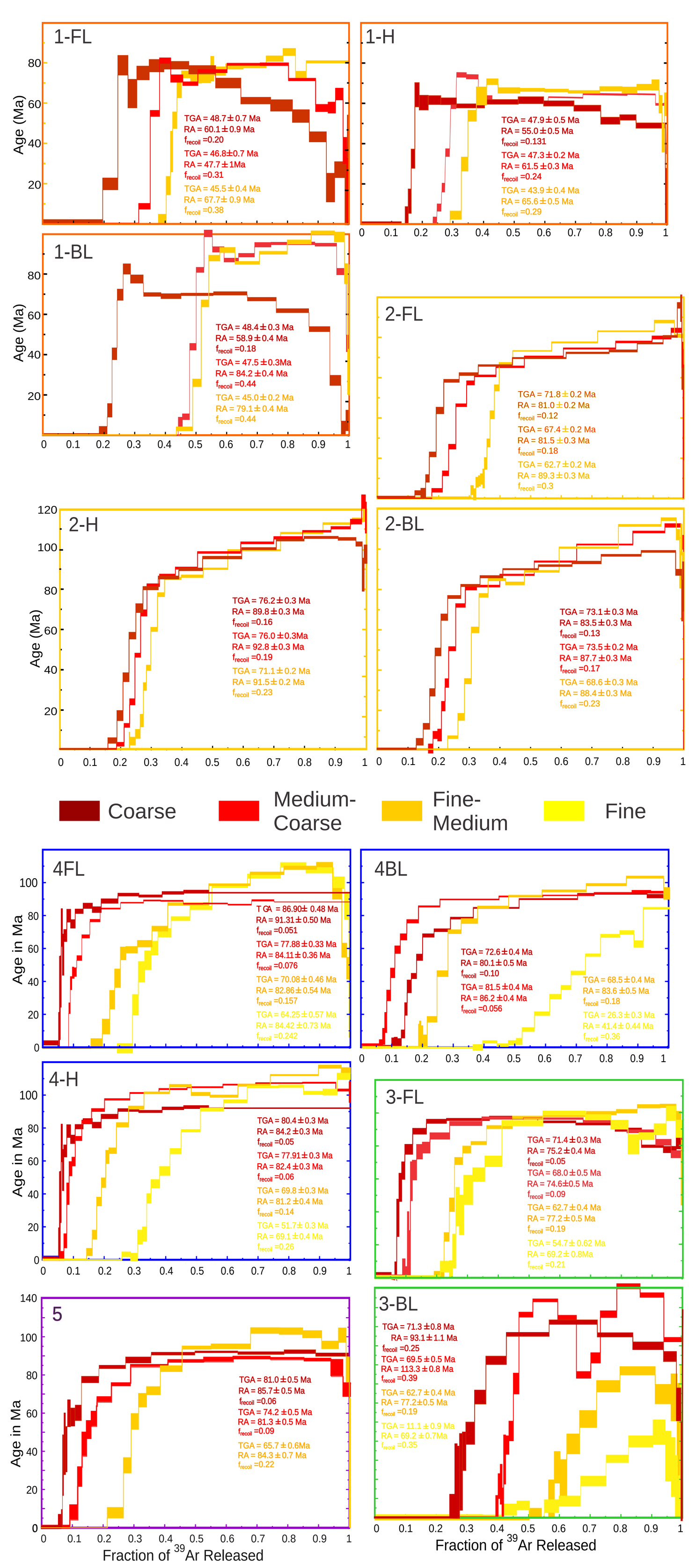
Fold 2: Closed chevron fold with small buckle folds in the back-limb and a straight forelimb. This fold was likely formed during D1, and the forelimb might straightened and the back-limb buckled later.

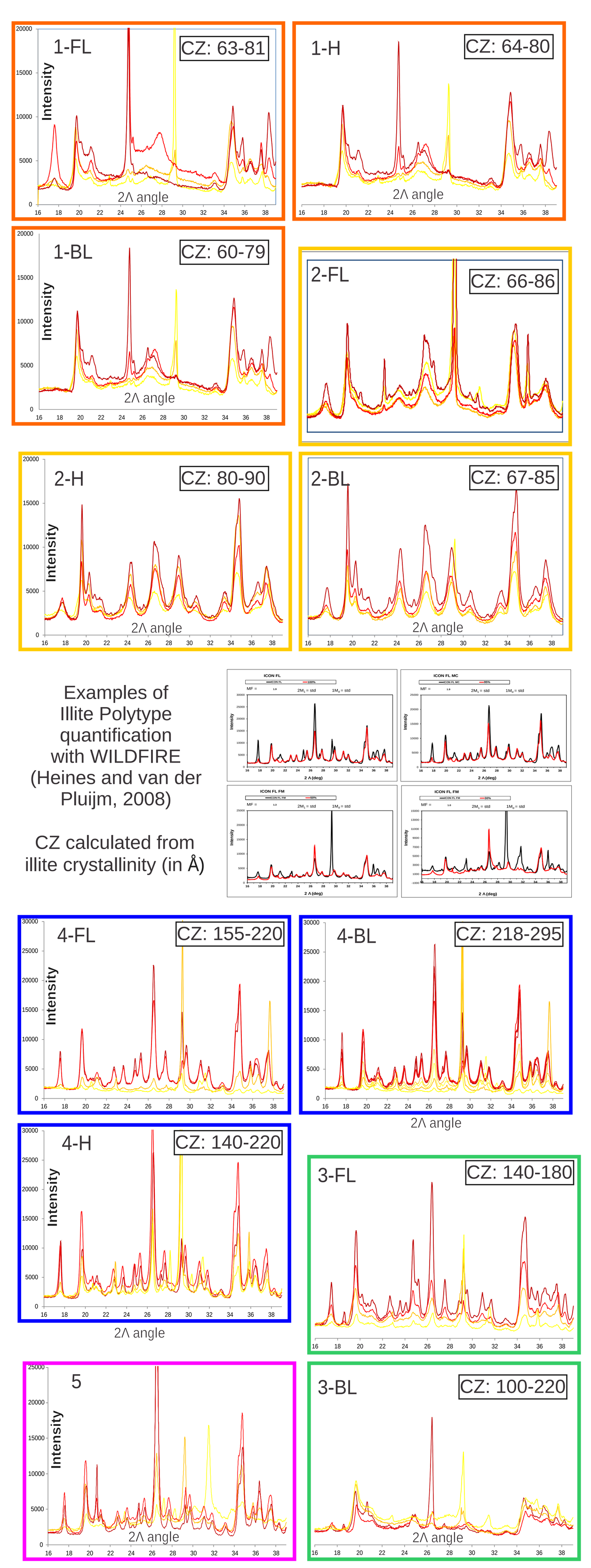


Fold 1: Open chevron fold with straight limbs. This fold was formed in one single event of folding (D2).



IV. RESULTS: ILLITE PROPERTIES AND AGES

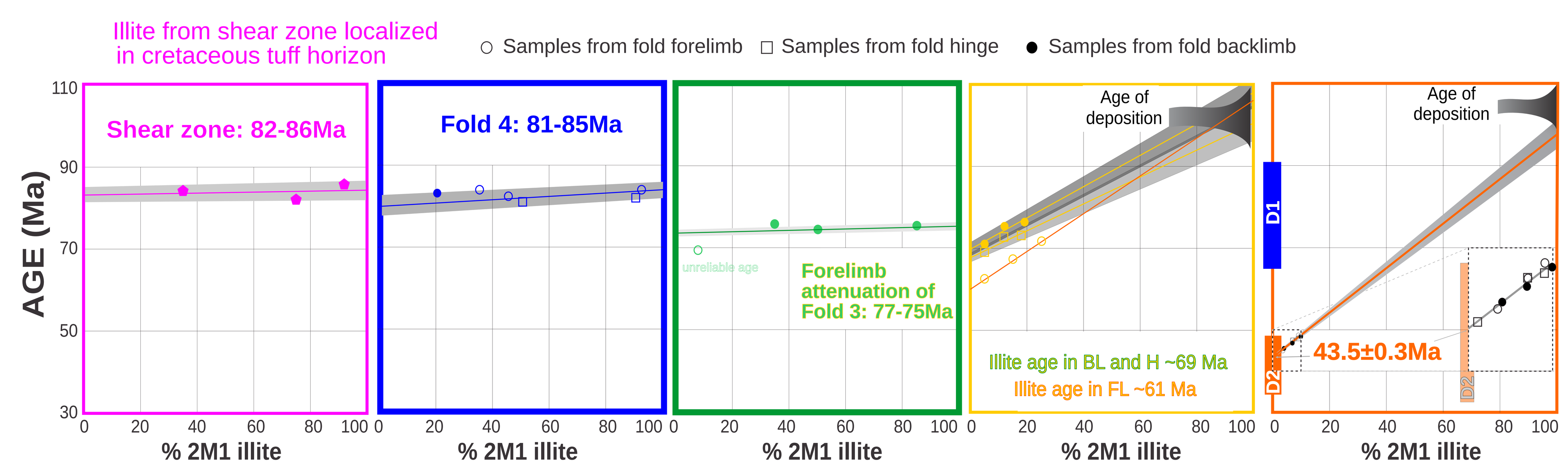




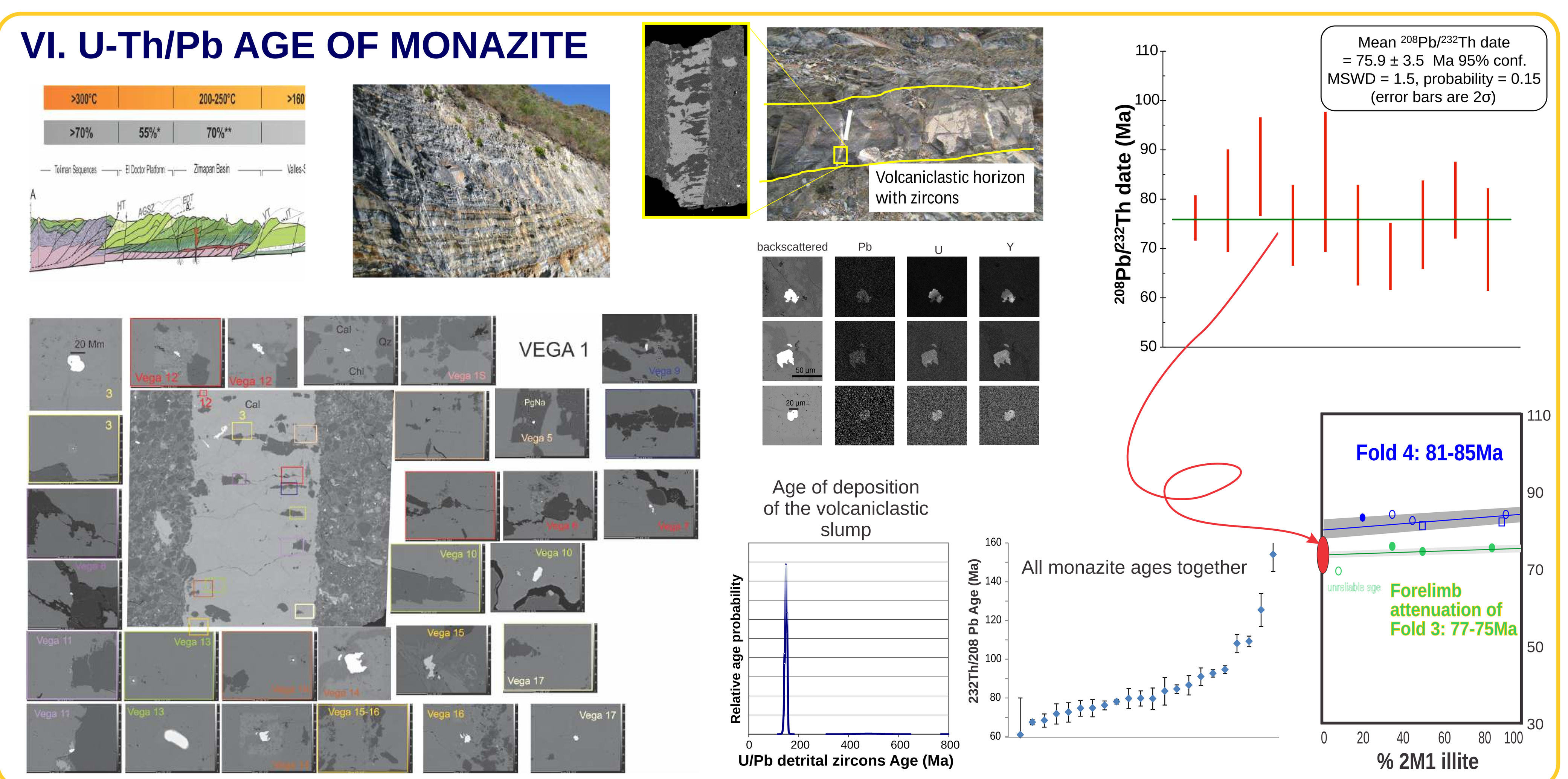
Examples of Illite Polytype quantification with WILDFIRE (Heines and van der Pluijm, 2008)

CZ calculated from illite crystallinity (in Å)

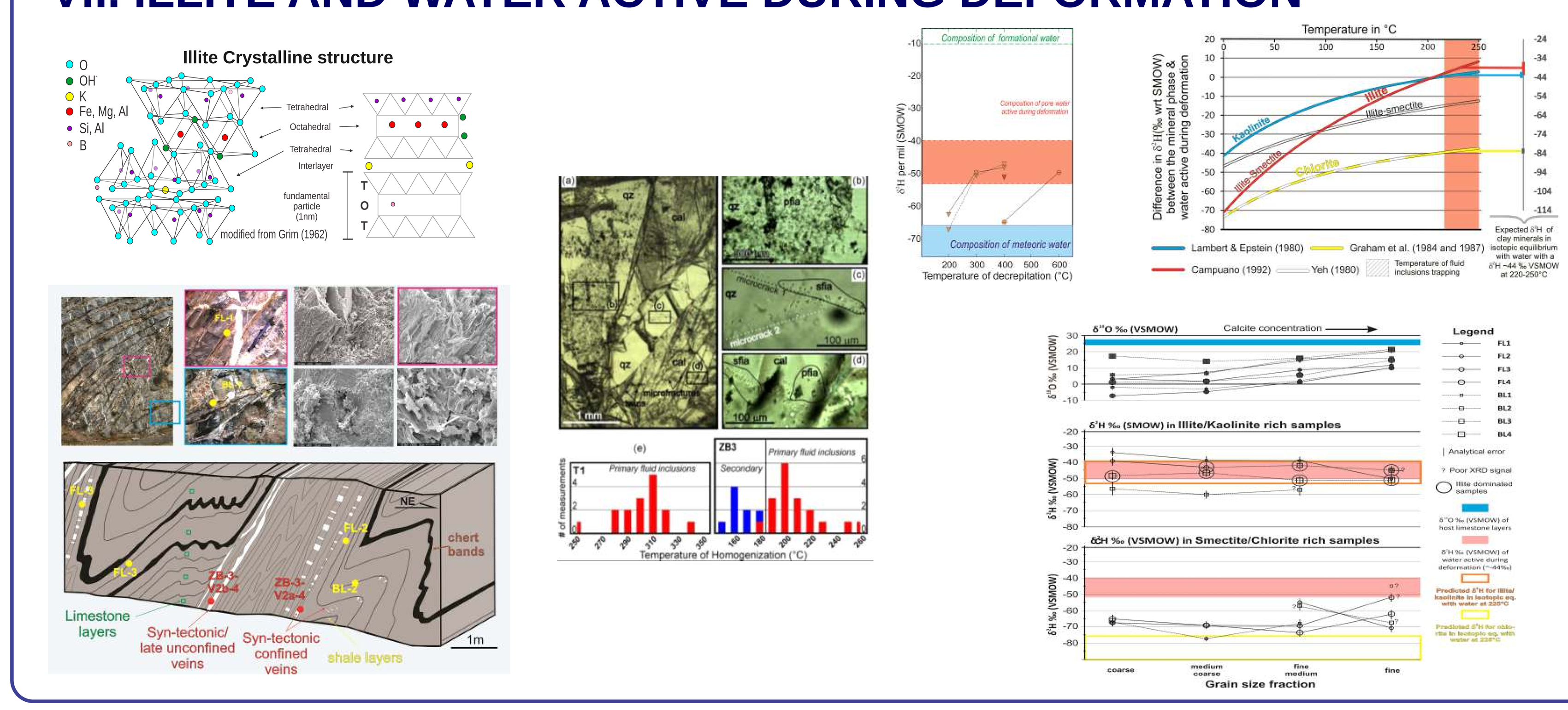
V. AGE OF DEFORMATION FROM AGE VS. % 2M1 PLOTS (YORK REGRESSION)



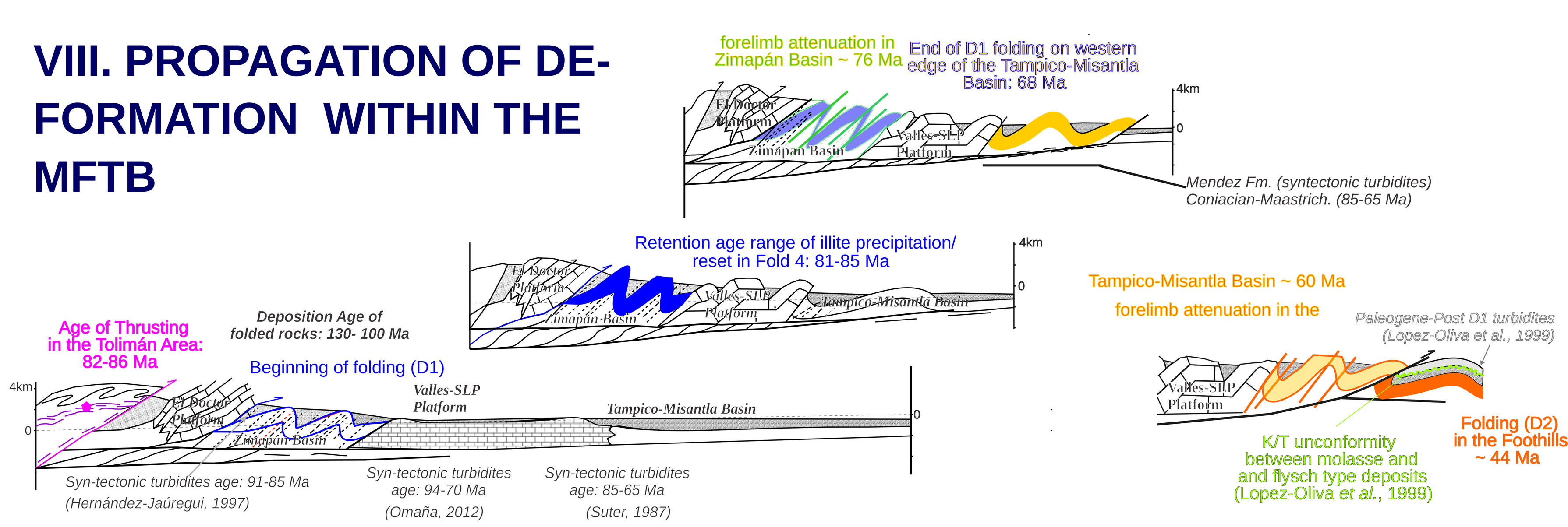
VI. U-Th/Pb AGE OF MONAZITE



VII. ILLITE AND WATER ACTIVE DURING DEFORMATION



VIII. PROPAGATION OF DEFORMATION WITHIN THE MFTB



CONCLUSIONS

Structural and geochronological data are in good agreement with the rocks of the Zimapán Basin being deformed in two episodes of shortening at 80-84 Ma and 75-77 Ma.

Hydrogen stable isotope signatures of illite and U-Th/Pb ages of monazite support the idea of illite formationduring folding.

Acknowledgements

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