Strain analysis of the Xuefengshan Belt, South China

From internal strain variation to formation of the orogenic curvature

Introduction: the concept

- Structures at multiple scales may reflect different information for quantification.
  - Balanced cross-sections provide shortening estimation based on km-scale
  - Strain measurements closely depend on micro-scale to hand size samples
- Due to heterogeneity, differential deformation give rise to various structural modes of fold-and-thrust belts.
- Quantitative strain data reveal the strain variation of the Xuefengshan Belt, and then allow the geometry and evolution of this intracontinental belt.

The problem and what they seek to further understand

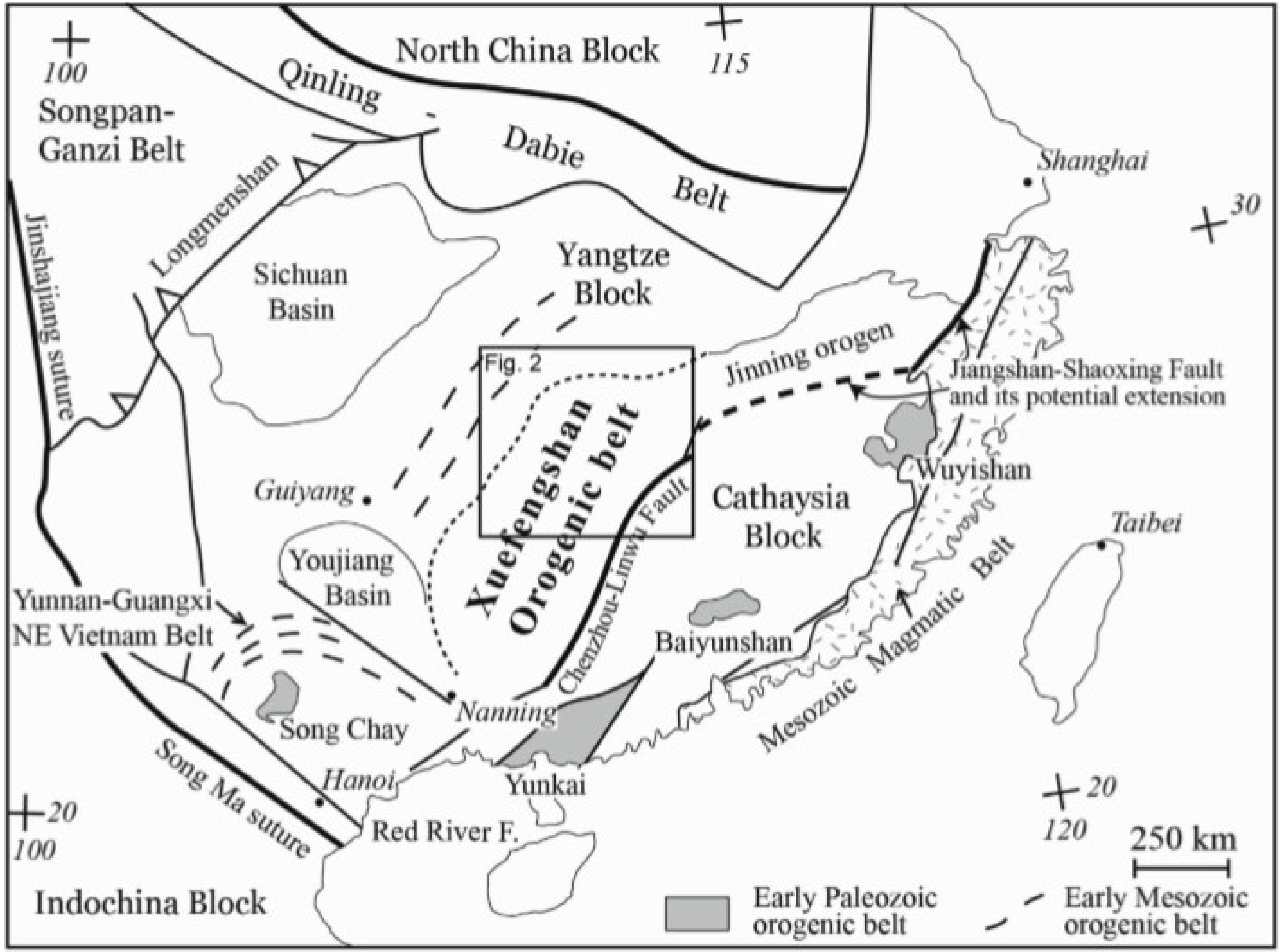
- Although the architecture of this belt has been well documented information on the internal strain patterns and how they evolved in the intracontinental setting remain less understood.

Geological setting: the tectonics

South China block occurred following the Collision between the Yangtze Block and the Cathaysia Block

SCB was confined and intensely modified by periphal orogenic belts: Qinling-Dabie, Longmenshan belt Indosinian orogen

The Xuefengshan Belt formed a tremendous intracontinental belt characterized by NE-SSW trending folds and faults with an overall northwest vergence



Stratigraphy & deformation

Deepest layer is the Mesoproterozoic-Neoprotozoic series, further subdivided

- Lengjiaxigroup
- Banxi group
- Sinian group

Xuefengshan Belt

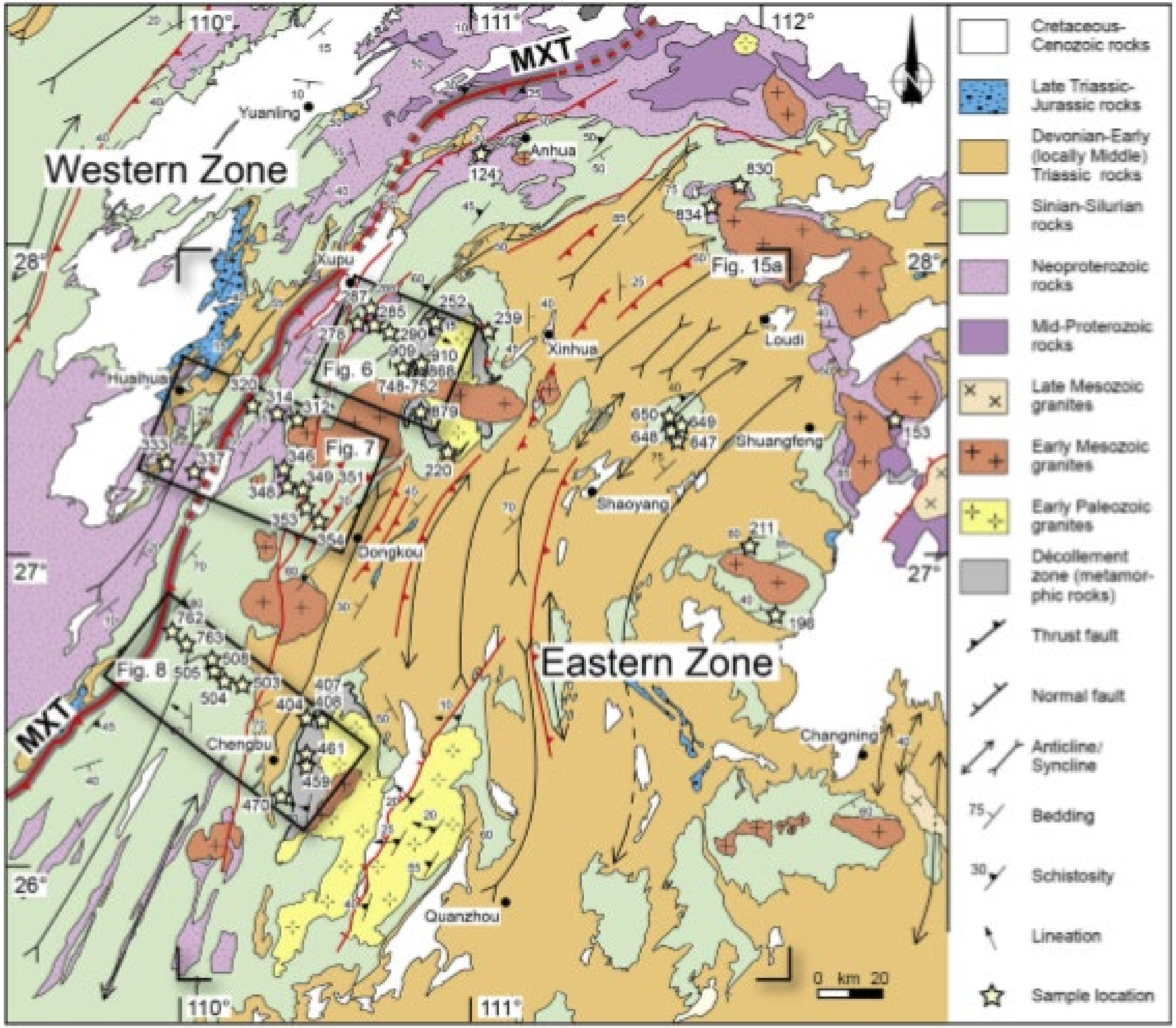
- Has a western and eastern zone
- Main Xuefengshan thrust(MXT)
  - Metamorphosed rocks on east zone
  - Non-metamorphosed on west zone

Western zone

- Box folds

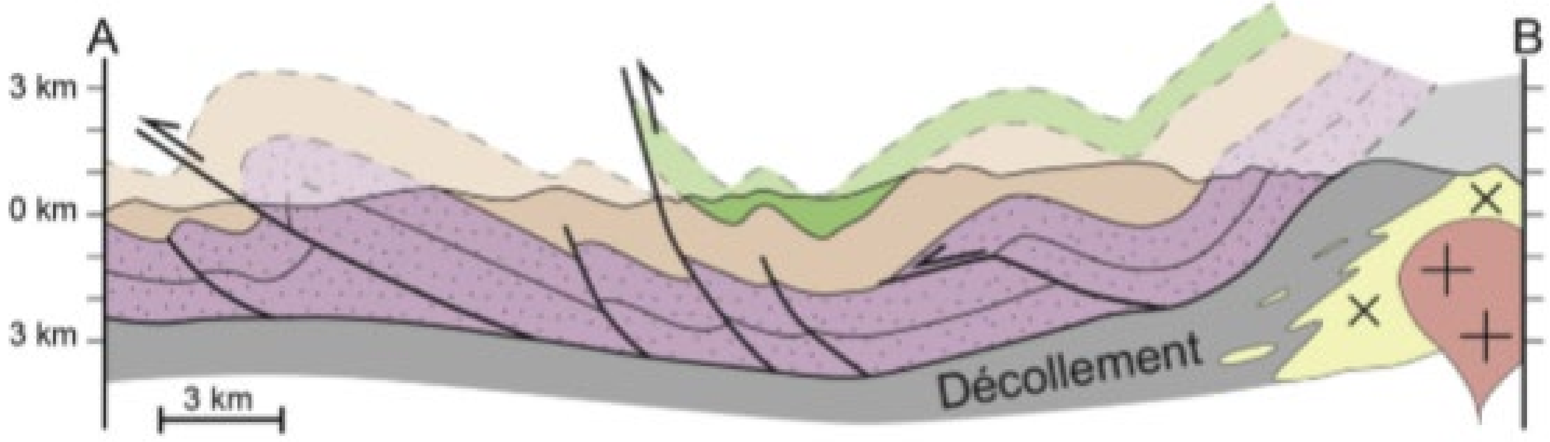
Eastern zone

- Polyphase deformation but can be regarded as continuous and cumulative



Ductile deformation of the Decollement

- High strain zone
- Uplifted by the emplacement of late Triassic granites, subsequently was exposed to the surface by erosion
- There was a single NW-SE contraction event in the decollement zone. A study suggest that the deformation in the decollement main occurred during the middle Triassic that coeval with the timing of deformation in the sedimentary cover.



Neoproterozoic conglomerate

Lowest stratigraphic unit

Contains penetrative, closely-spaced schistosity. Structural elements include bedding and lineation and show similar geometric and kinematic features as those in the whole belt

Upper tectonics levels

- random orientation, low deformity 4a,5a
- High deformity sparsely spaced cleavage but pebbles still remain undeformed and unrated 4b
- When approaching the decolement, is strongly sheared with penetrative schistosity and elongated pebbles, shearing structures 5c, 4 c-e

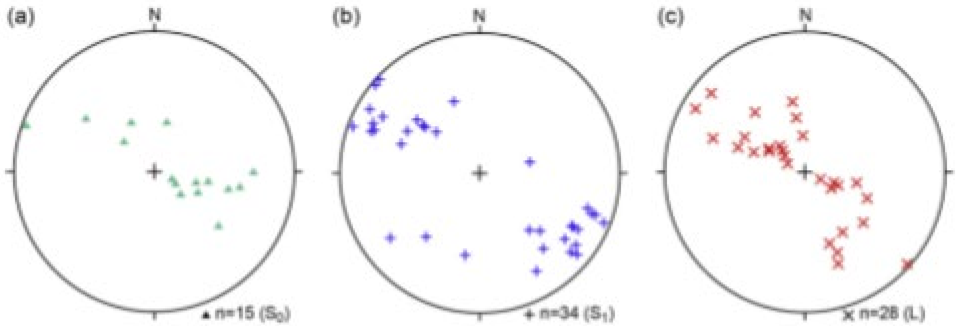
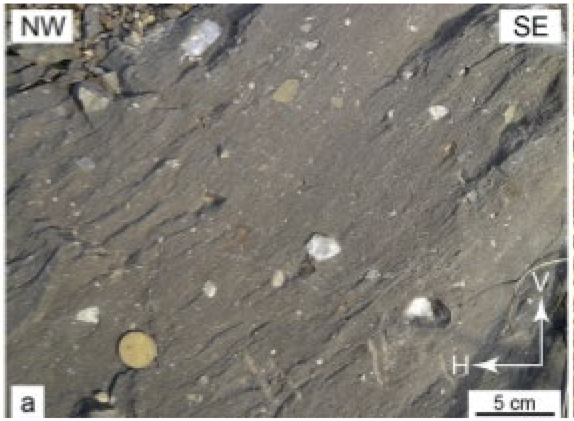
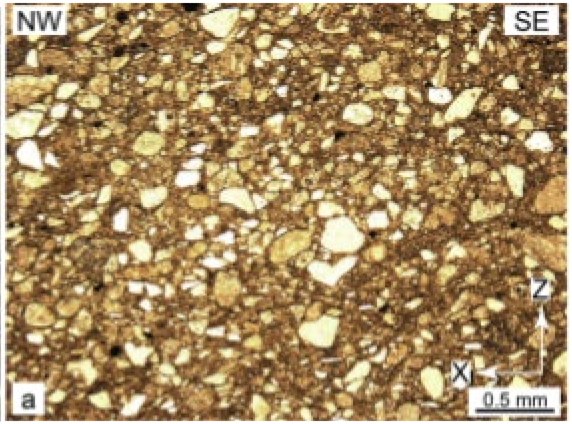
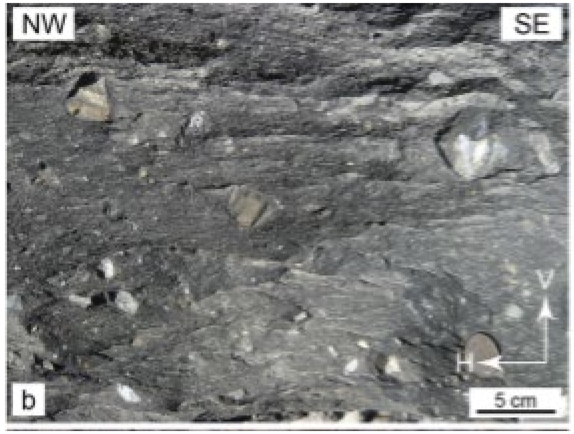


Fig. 3. Stereographic plots (Schmidt lower hemisphere projection) of structural elements from the Neoproterozoic conglomerates in the Xuefengshan Belt. (a): Poles to bedding. (b): Poles to schistosity. (c): Lineation.

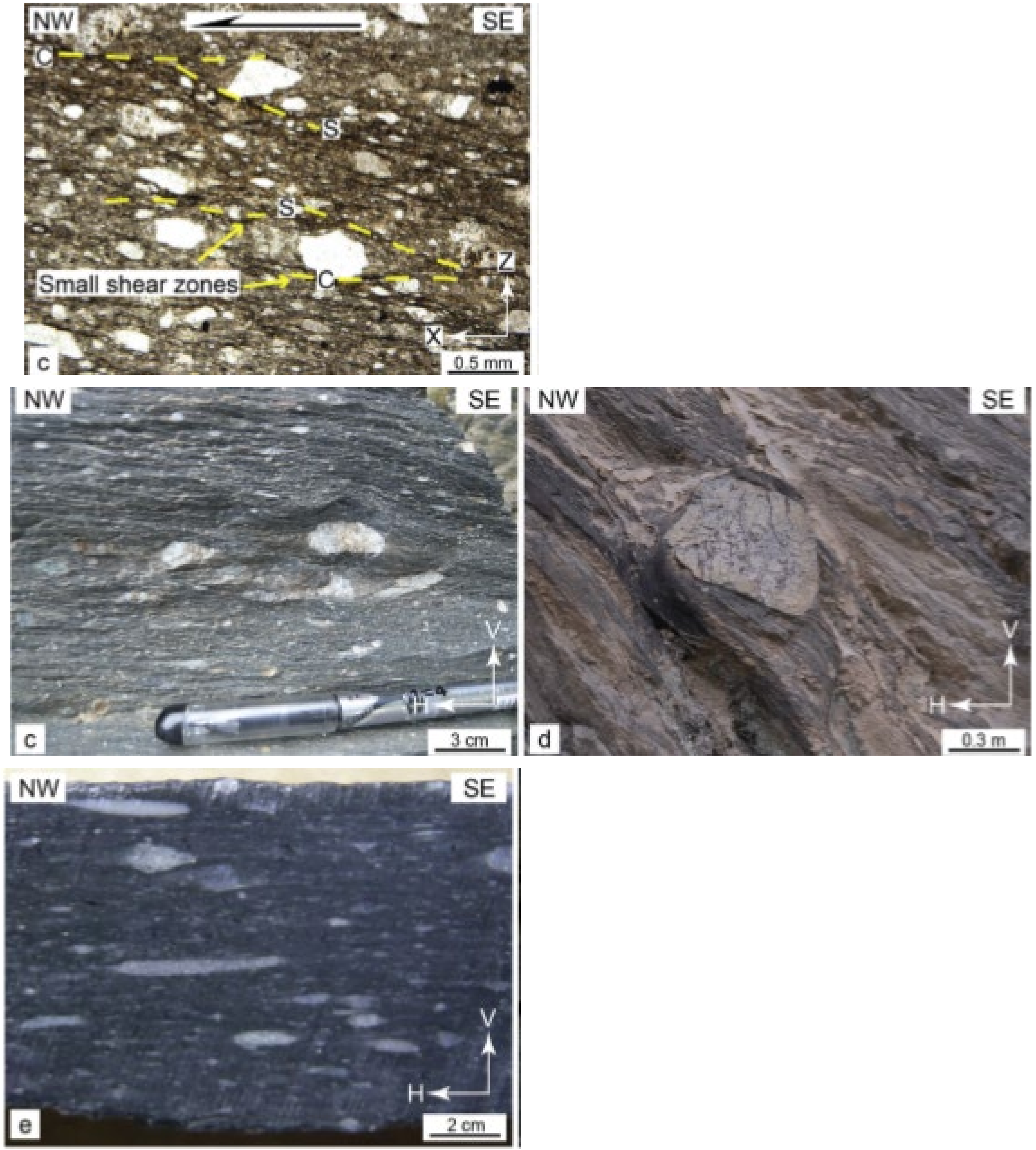






Methods for Strain estimation

- 48 samples were taken
- In the study area, despite the polyphase deformation, consistent kinematics during the Triassic orogeny has been observed in the Xuefengshan Belt, They assumed theses phases as one continuous deformation, and thus 2D strain analysis in XZ and YZ planes can reflect the strain ellipsoid in selected samples

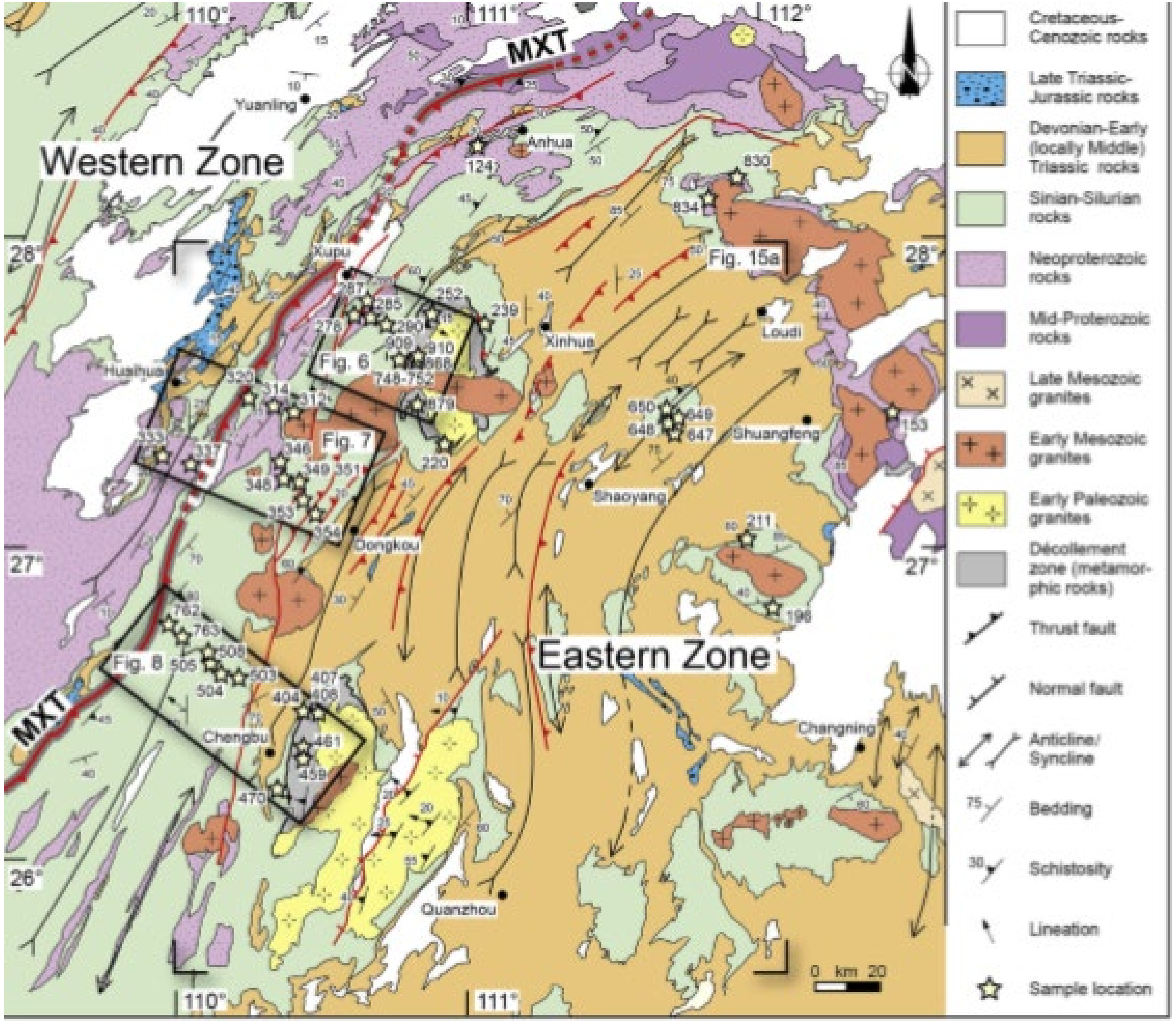


Methods of experiment

- Measured clasts in thin sections, and then obtained strain ratios for all samples
- Two oriented thin sections were cut from rock samples in the XZ and YZ planes of finite strain (XZ: perpendicular to the foliation and parallel to the lineation; YZ: parallel to the foliation and perpendicular to the lineation.
- To estimate finite strain, the Rf/ψ method was adopted
- Rf/ψ measured the strain accumulated within the matrix as better of the bulk strain
- Rf represents aspect ratios of the final shapes of clasts, and ψ is the angle between the long axis of clasts in the deformed rock and the reference line

Strain analysis results

- Separated the samples of the Banxi group into two subgroups (1) Banxi group-M, metamorphosed under greenschist facies (2) Banxi group, free of metamorphism,
- Three orogen- perpendicular sections are chosen to evaluate in detail the deformation mode and variation in the belt.



North section

- 12 samples of which 10 have the longest R_s parallel to mineral stretching lineation in NW-SE orientation
- Samples plot in the flattening field of Flinn diagram

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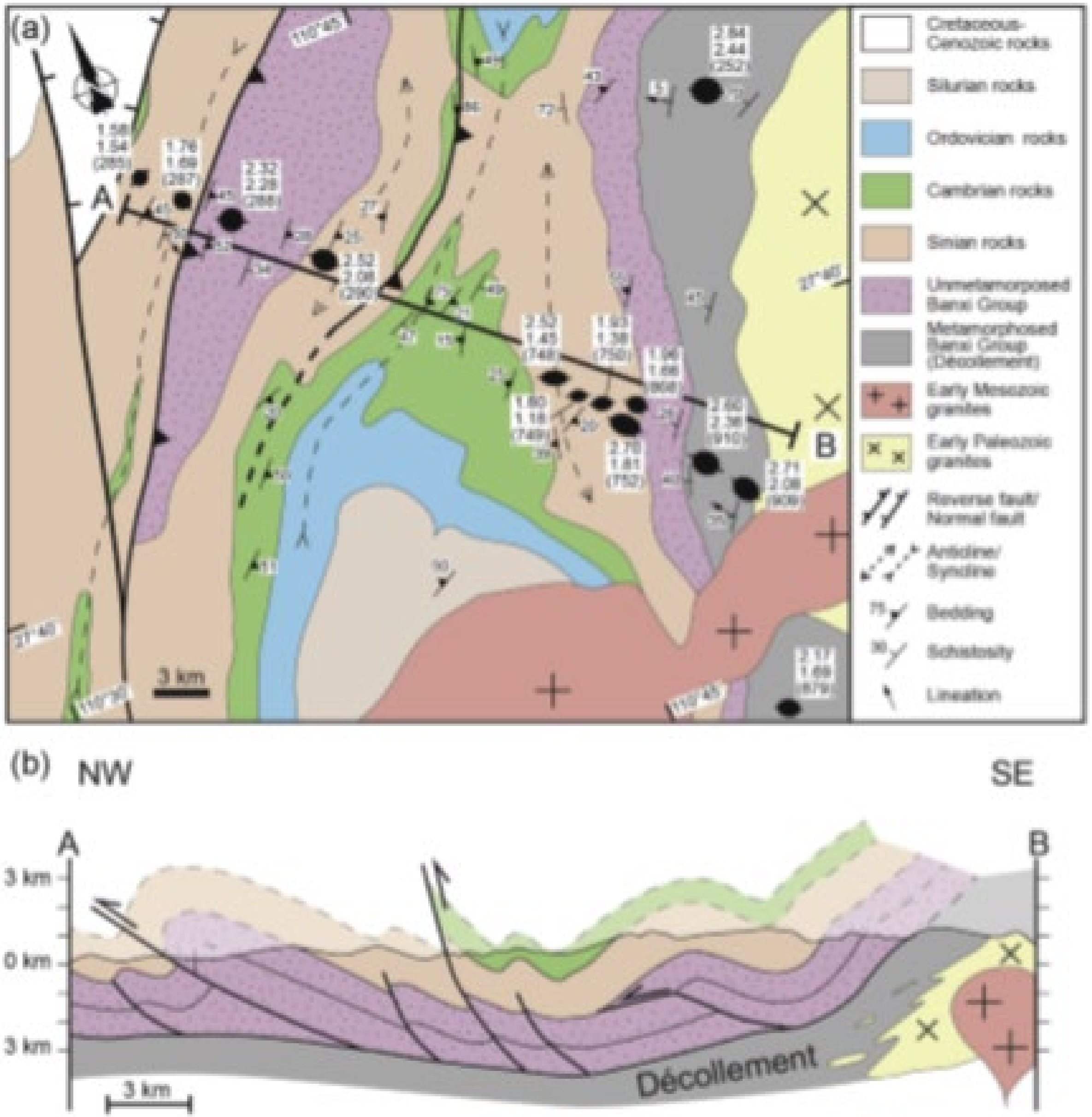
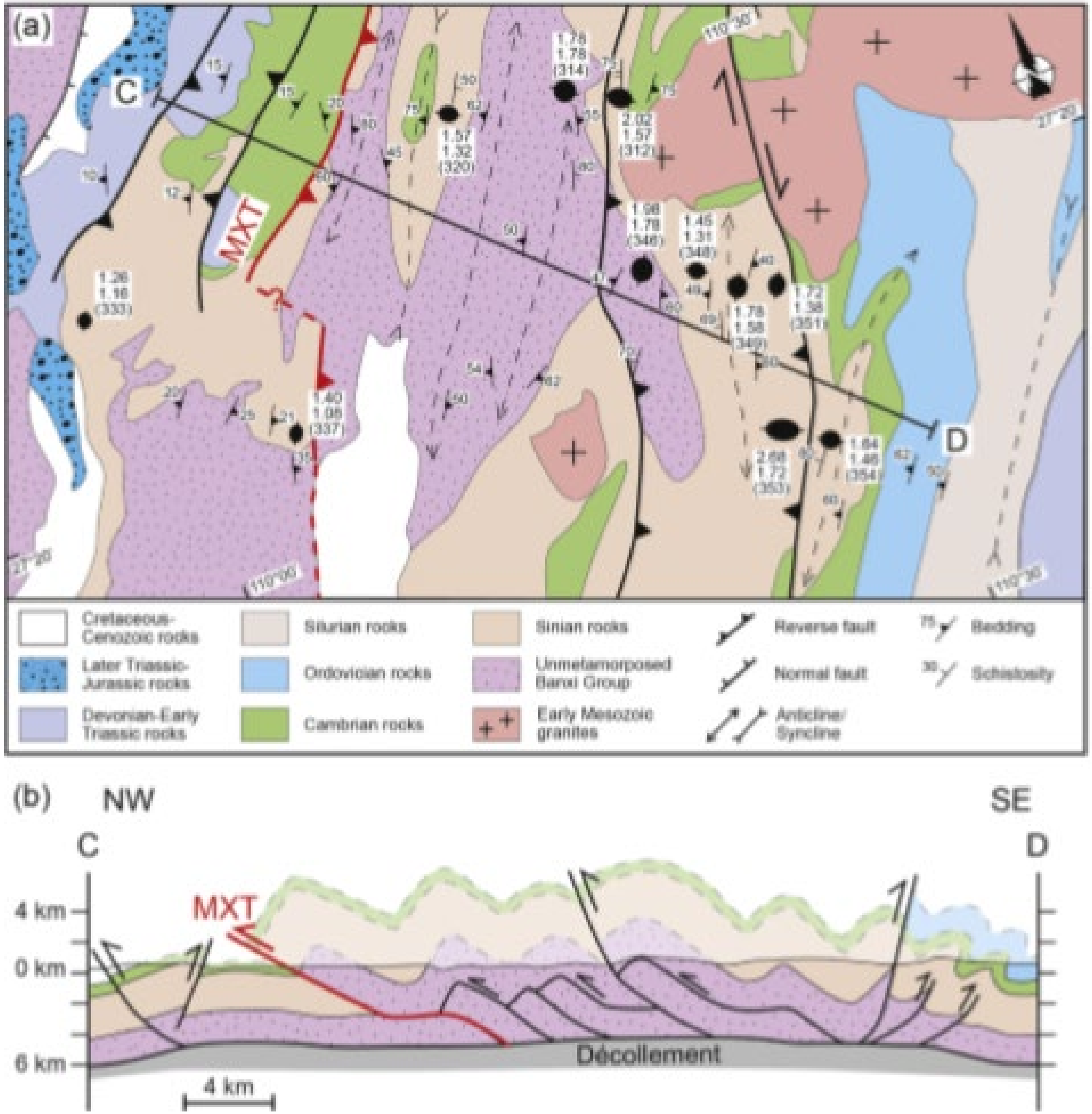


Fig. 6. (a): Regional geological map of the North Section (Modified after BGMRHN, 1988). Location is marked on Fig. 2. Strain ratios on XZ and YZ planes, ar sample numbers are labelled on the map. (b): Cross-section of the study region that provides a detailed geometry and thrust structures. The regional décollement located beneath the sedimentary cover but the eastern part has been uplifted during tectonic imbrication and Triassic granite emplacement.

Middle section

- This region is characterized by a fold and thrust system upon the buried decollement at depth, resulting in duplexing and significant upper crustal shortening.
- The longest R_S parallel to mineral stretching lineation in NW-SE
- On the Flinn diagram, all 11 samples plot in the flattening field



South Section

- D2 back thrusting and back folding dominates to the southeast of the MXT
- Most samples plot in the flattening field of the Flinn diagram similar to the results from the North and Middle section.

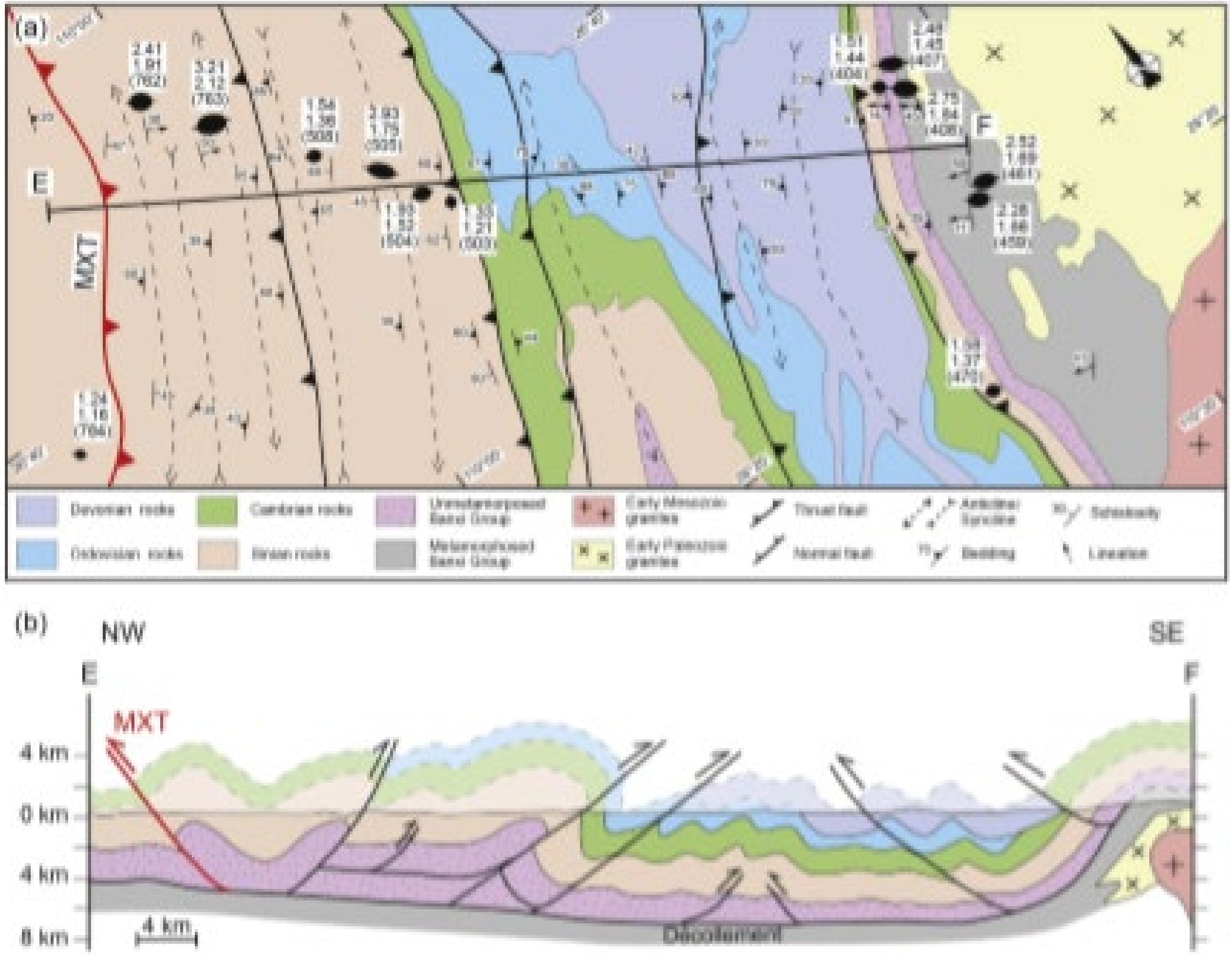


Fig. 8. (a): Regional geological map of the South Section (Modified after BGMRHN, 1988). See location on Fig. 2. Strain ratios on XZ and YZ planes, and sample numbers are indicated on the map. (b): Cross-section of the study region showing a detailed geometry and kinematics. Top-to-the SE shearing is more developed in this region. The exhumed décollement zone yields high strain ratios.

discussion

- Almost all samples are plotted in the flattening field, indicating that thrust-normal flattening mechanism dominates the strain propagation
- Differences
    - Middle & south section many of data plot near plane strain suggesting that a higher thrust-parallel shearing component
    - North section includes mostly thrust-normal flattening with some minor thrust parallel shearing
- Low magnitude orogen-parallel stretching may develop firstly in the outer part of the Xuefengshan Belt and strain ellipsoids are modified by subsequent shortening, but some initial feature is preserved due to the heterogeneity of deformation intensity.

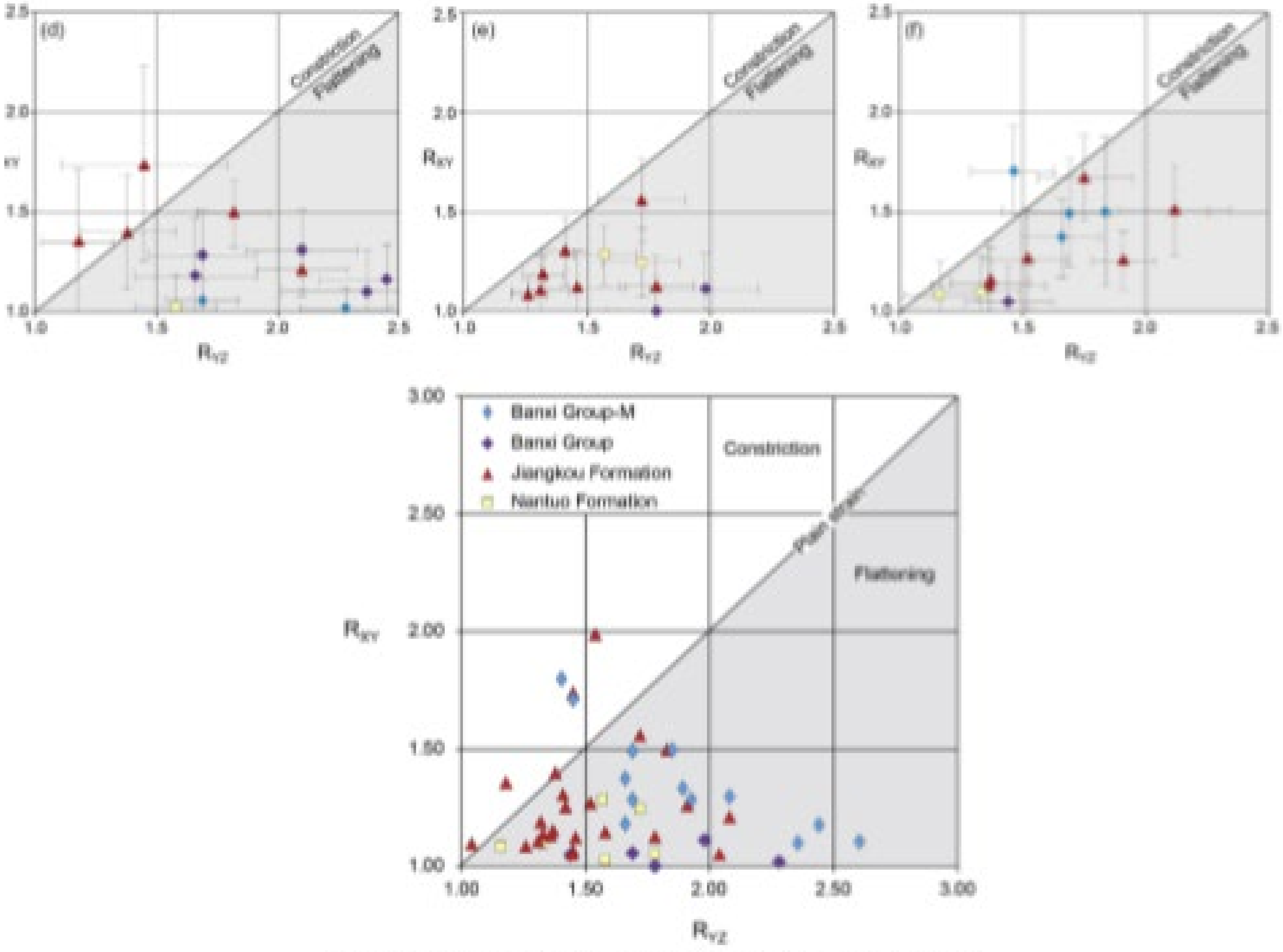


Fig. 11. Flinn diagram of all the samples analyzed in this study. Note that almost all samples are plotted in the flattening field.

Discussion

- A systematical variation dependent on structural positions
- As a whole, bulk strain of analyzed samples gradually intensifies from the upper unit (Nantuo and Jiangkou formations) to the lower unit(metamorphic Banxi Group)

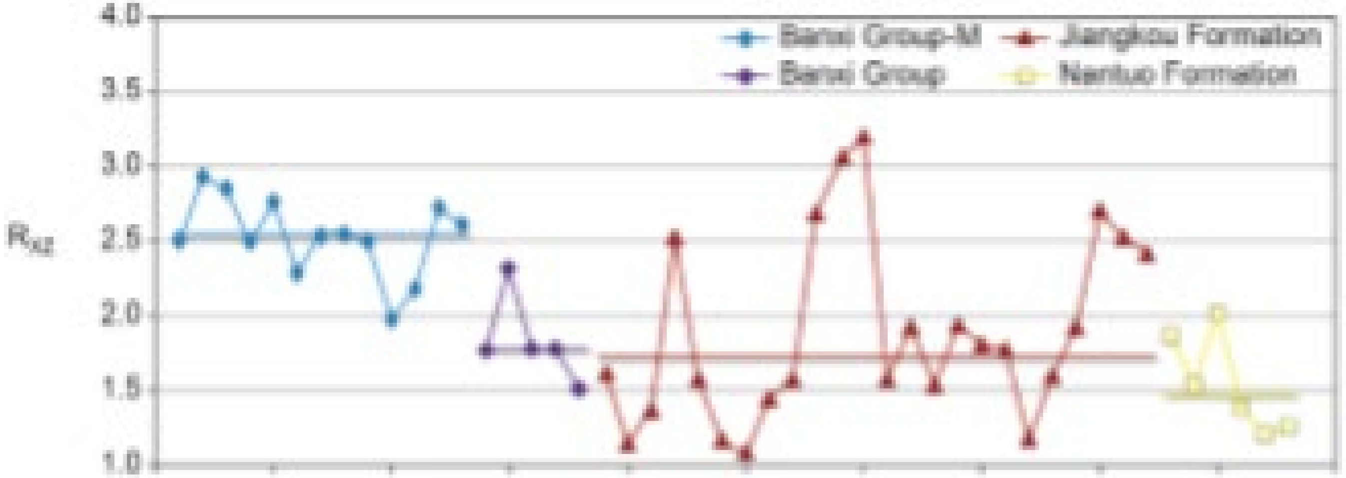


Fig. 13. Comparisons of strain ratios in R_{xz} planes for all analyzed samples. The Metamorphic Banxi Group has the highest values, while the Nantuo Formation yields the lowest value, and the Banxi Group and Jiangkou Formation have intermediate values. Lines in the middle of each group of samples are median values of Rxz ratios of the four groups, respectively.

Strain variation

- Deformation intensity and strain decrease from the east to the west, and drop significantly to the west of the Main Xuefengshan Belt, which marks the major boundary between the western Zone and Eastern Zone of higher and lower tectonic levels.
- Inhomogeneous deformation during the propagation of the belt occurred.
  - Strain ratios in the middle show low R values
  - Strain ratios in the northern and southern show high R values

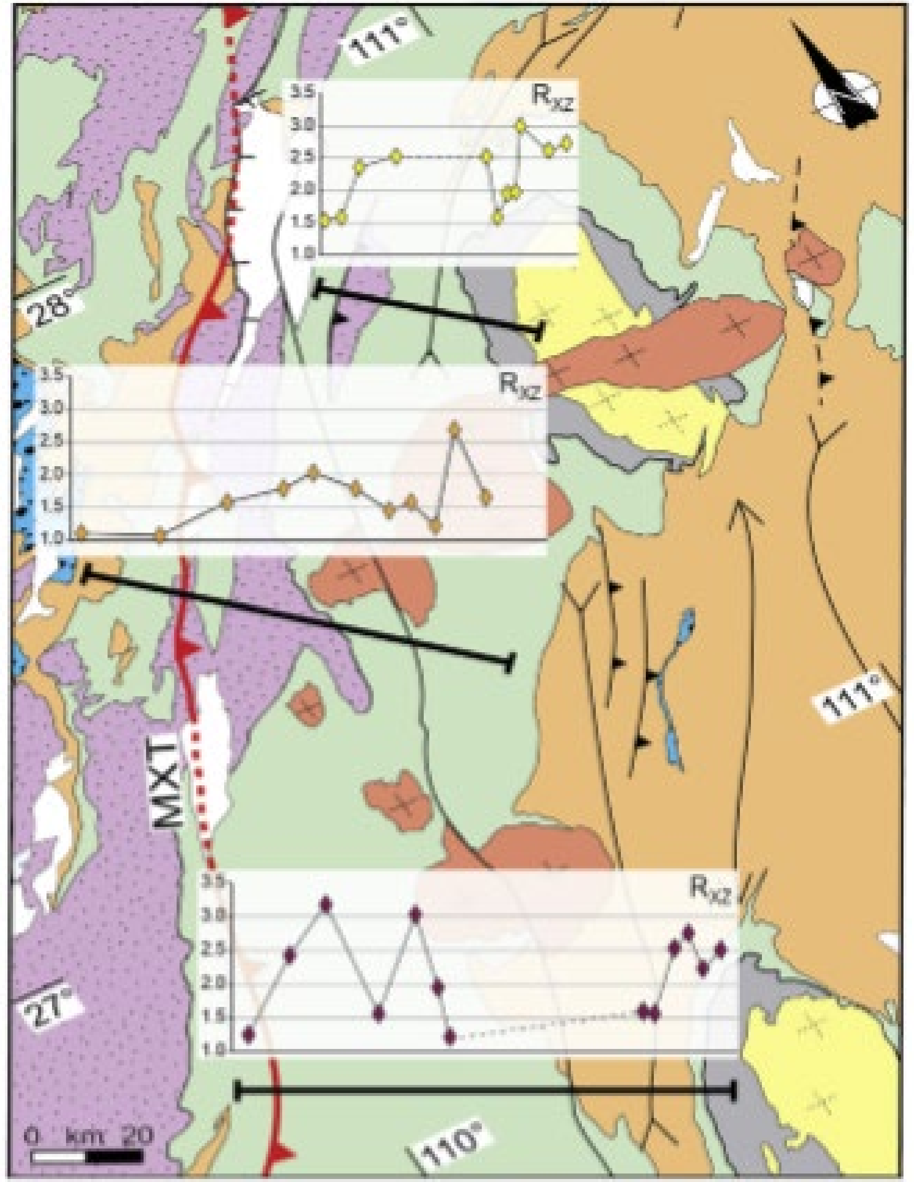


Fig. 14. Strain variation of three selected sections in the Xuefengshan Belt. An obvious decrease from the Eastern Zone to the Western Zone can be observed in the Middle and South Sections. It is noteworthy that strain ratios of the Middle section are significantly lower than those of the other two sections.

conclusions

- Accompanying the incremental deformation the linear belt propagate toward the west, but encountered the Early Paleozoic batholiths that acted as rigid blocks. Consequently strain was transferred to the west o the batholiths and resulted in high strain ratios in the north and south sections.
- Such structural patterns reflect an interacting process between the thrust wedge and batholith barriers that created the curvature of the Xuefengshan Belt

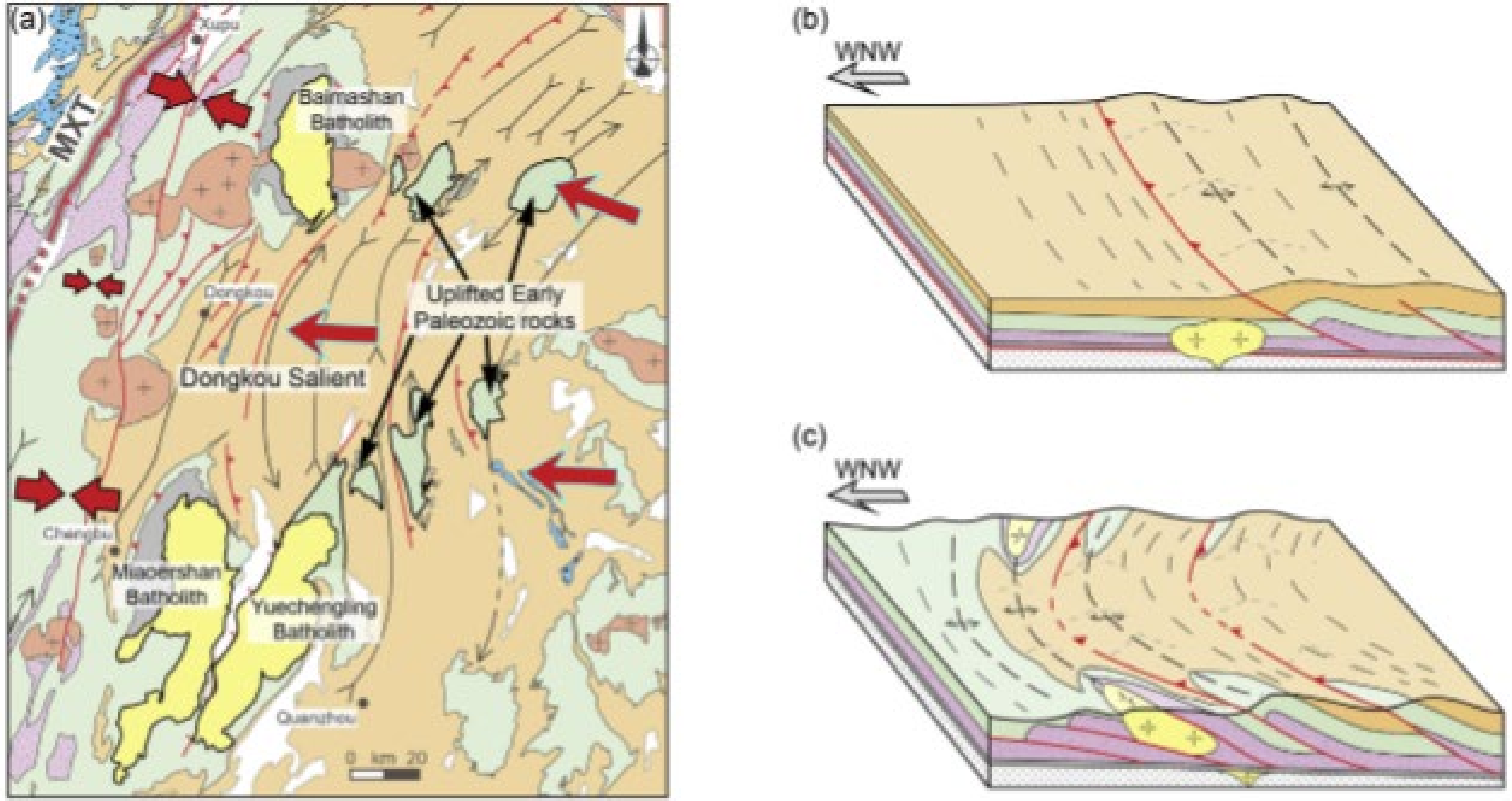


Fig. 15. (a): Detailed structural map shows the deformation pattern of the orogenic curvature. Paired red arrows represent the strain intensity as indicated b results. Single arrows represent the direction of thrust propagation. Granitic batholiths and uplifted Early Paleozoic rocks are highlighted. A tentative tectonic n illustrating the formation of the orogenic curvature (b–c). (b): The initial compression created firstly a linear belt with a top-to-the WNW shearing sense, temporaneous with pervasive SE-dipping schistosity, NW-directed thrust faults and asymmetrical folds above the décollement. (c): As the linear belt propa toward the west, the Early Paleozoic batholiths acted as rigid blocks, and strain was thus transferred to the west of these batholiths and resulted in high strain rat the north and south sections. To the east of the batholiths, back-thrusting and folding provoked by batholith obstruction may be responsible for the tectonic upl of the Early Paleozoic rocks. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)