Fold-related deformation bands in a weakly buried sandstone reservoir analogue: A multi-disciplinary case study from the Numidian (Miocene) of Sicily (Italy)


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Outline

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  - Deformation bands (DBs)
  - Purpose of this study

- Geological setting

- Methodology

- Observations
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  - Microstructures (DB in micro-scale)
  - Physical properties of DBs

- Discussion & Conclusions

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Introduction

Purpose of this study
- How DBs develop during folding?
- How DBs impact rock petrophysical properties (porosity)?
Geological setting

- **Location**: Sperlinga (Enna province, Sicily)
- **Focus**: DBs form tight syncline
- **Lithology**: Numidian turbidites sandstone >99 vol% quartz, grain-size: 0.3-0.5 mm, cementation: quartz and iron deposits
- **Turbidites**: are sea-bottom deposits formed by massive slope failures.
- **Sandstone**: deposited above a growing thrust-wedge, then buckled during continued deformation.
Methodology

**Determine DBs**
- **Microscope**
- **EPMA (Electron Probe Micro Analyzer) 4 samples:**

**DBs Physical properties**
- **Mercury porosimetry 2 samples:**
  - Determine effective porosity value, pore size based on properties of non-wetting liquids

- **X-ray microtomography 2 samples:**
  - Determine total porosity value based on creating 3D model.
Observations

Field observation – DBs (macro-scale)

DBs appear sub-vertical to steeply overturned southern limb of syncline, developed under low burial conditions.

Site 1 (6 sets)

- Main set (set 1-red color): sub-parallel to bedding, length >5m, dipping NW 55°, spacing > 1 m.
- Smaller network of DBs: lengths 0.5-1 m, small spacing. DBs evolve towards joints and fractures, termination on the main set.
Observations

Field observation – DBs (macro-scale)

Site 4

- Cluster zone: (orientation: N30W/75NE) length > 5m, 50 cm-thick, offset (34 cm on left)
- Prominent DB: (orientation: N57W/60NW) cutting Cluster zone
DBs in micro-scale

- **Microstructure** → Compaction bands
  - Shear bands

- **Compaction bands** (CBs) characterized by compaction, iron deposit, coarser grain-size than shear band, 1-5 mm thickness.
• **Shear bands** (slip band) (SBs): grain-rotation, cataclastic, 0.5–1 mm thick, in some instances, formation of a discrete slip surface
## Observations

### Physical properties

Porosity (vol. %) inferred by means of high-resolution SR micro-CT.

<table>
<thead>
<tr>
<th>Sample/VOI</th>
<th>Size (mm$^3$)</th>
<th>Pores (vol. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPR1b Host rock</td>
<td>0.94</td>
<td>17.90</td>
</tr>
<tr>
<td>SPR1b comp. band</td>
<td>0.94</td>
<td>6.75</td>
</tr>
<tr>
<td>SPR2 Slipped DB</td>
<td>0.91</td>
<td>0.86</td>
</tr>
<tr>
<td>SPR2a comp. band</td>
<td>0.91</td>
<td>3.90</td>
</tr>
</tbody>
</table>

![X-ray micro-tomography](image)

**Table 2**

**Table 3**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Total intruded volume (mm$^3$/g)</th>
<th>Accessible porosity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host rock</td>
<td>101.68</td>
<td>26.75</td>
</tr>
<tr>
<td>Deformation Band</td>
<td>38.65</td>
<td>15.95</td>
</tr>
</tbody>
</table>

Porosity (red) and iron-deposit (green)
Discussion & Conclusions

- Built-up 3D model show distribution, orientation and cross-cutting relations of DBs within the overturned southern limb of syncline

Why they are only use data form southern limb to talk about fold-related DBs? Northern limb doesn’t have DBs or inaccessible?
Discussion & Conclusions

• Explanations of structures kinematics
  ✓ Prominent set represents incipient bed-parallel thrusting before amplification of syncline
  ✓ DBs formed by accommodated flexural flow during folding.

**Deformation stages** (How DBs develop during folding)

1\textsuperscript{st} stage might have created prominent set of DBs, which were overprinted and partially obliterated during next stages.

2\textsuperscript{nd} stage incipient bed-parallel thrusting before amplification of the syncline has formed DBs cluster zone visible on top of the fold.

Continued deformation formed broadly main set (set 1) and network of smaller
Discussion & Conclusions

- Compaction bands and shear bands decrease porosity of host rock 26%. Porosity is reduced within the compaction bands (3.90–6.75%) and further reduced (0.86%) within the shear deformation bands.

- Shear bands are preferential pathways for fluids especially when they coalesce and evolve to fractures.

- 3D model shows distribution, orientation of DBs can be apply for DBs develop during folding in inaccessible reservoir.
My Future work

- Filed observation
- Research questions
- Answers & applications
- Laboratory experiments
- Theoretical approach
Anticline in Zhoshui river, ChiChi dam, central Taiwan
Field observation: structural discontinuities
How can we know it is DBs or filling fractures?

How DBs influence on fluid flow?

How DBs development during tectonic setting? Folding? Thrusting? Or both?

What factors control DBs' development?
Examine DBs or other SD

Microscope

SEM (Scanning Electron Microscope)

DBs Physical properties tests

porosity and permeability