Mineral composition of fault rocks from the Koyna deep drilling project (India)

Composizione mineralogica di rocce di faglia dal progetto di perforazione profonda di Koyna (India)

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at the time of the covid-19

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Outline of the thesis

1. Motivations and goals
2. Geological setting of Koyna area
3. Methods
4. Results
   4.1 Possible deformation events
   4.2 Mineralogy of fault zone rocks
5. Conclusions
6. References
1. Motivations & goals

• Koyna area: dam for hydroelectric power & agriculture & flood hazards.

• Seismicity: started after the lake impoundment in 1962.
• Human-induced earthquakes associated with Koyna water reservoir operations in intraplate areas.


• World’s largest scientific drilling project of induced seismicity area from 2015.
Seismicity in phase with reservoir water level variations.

Monsoon rains: annual mean precipitation estimated at 2500 mm (against the 867 mm of Padua)

Seismicity related to unloading of the reservoir

Seismicity related to loading of the reservoir

[Gupta, 2002 ESR]
Seismic activity is restricted within an area of 20 x 30 km.

Seismicity is mostly in the range of 3-10 km depth. Host rock temperature 50-150°C.

Faults dip subvertically.
Drilling project to study the granitic basement and the fault rocks from 2015.

[Gupta et al., 2017 JGSI]

Deep perforation in Koyna area

[Gooswami et al., 2017 Tectonophysics]
This repository contains about 25 km length of cores.

Boreholes seismometers installed in the wells.

Geological, geochronological, geophysical and microbiological studies.
**My goal:** determination of fault zone rocks mineral assemblage.

[Misra et al., 2017 JGSI]
2. Geological setting of Koyna area

Koyna region:
• Deccan Traps (68-65Ma): basalts
  Thickness: 500-2000m
• Granitic Basement (Proterozoic): granite-gneiss, granite, migmatitic-gneiss, amphibolites.

[www.researchgate.net]
3. Methods

1. 15 samples pulverized in an agate mortar.

2. Assembly on sample holders.


4. Interpretation of diffractograms with the HighScore Plus software®.
4.1 Possible deformation events

1. Late Archean to Cretaceous: Indian crystalline (2.7 Ga) basement formation. HT shear zone and later hydrothermal epidote + chlorite precipitation.

2. Cretaceous: Deccan intrusion (68-65 Ma), intense geothermal anomaly and possible chlorite filling of the joints.

1. Archean to Cretaceous: Indian crystalline (2.7 Ga) basement formation. HT shear zone and later hydrothermal epidote + chlorite precipitation.
2. Cretaceous:
Deccan intrusion (68-65 Ma), intense geothermal anomaly and possible chlorite filling of the joints. Possible reactivated faults by human-induced earthquakes.
3. Cenozoic: quartz + calcite precipitation in fractures, formation of brittle faults with gouges, breccia, cataclasite. Possible reactivated faults by human-induced earthquakes.
4.2 Mineralogy of fault zone rocks

KBH6-73
Granitic basement

KBH1-352
Epidote-bearing faults cutting granitic basement

KBH6-71
Quartz + chlorite veins cutting damage zone

KBH6-69
Chlorite rich shear zone exploited by brittle fault

KBH7-594
Growth fibers at the basalt-basement contact

KBH1-346
Calcite and quartz late-vein filling chlorite vein
KBH6-73  wt.%
Plagioclase  54
Quartz  19
Chlorite  15
K-feldspar  12
(possible microcline)

Granitic basement

Top

Bottom

10 cm
<table>
<thead>
<tr>
<th>Component</th>
<th>wt.%</th>
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<tbody>
<tr>
<td>Epidote</td>
<td>42</td>
</tr>
<tr>
<td>Albite</td>
<td>26</td>
</tr>
<tr>
<td>Quartz</td>
<td>25</td>
</tr>
<tr>
<td>K-feldspar</td>
<td>4</td>
</tr>
<tr>
<td>Zeolite (possible phillipsite)</td>
<td>3</td>
</tr>
<tr>
<td>Smectite (possible montmorillonite)</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

Epidote-bearing faults

Top

Bottom

10 cm

KBH1-352

Epidote-bearing faults

Depth, m
<table>
<thead>
<tr>
<th>Component</th>
<th>wt.%</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>64</td>
<td>quartz +/- chlorite veins cutting damage zone</td>
</tr>
<tr>
<td>Chlorite</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Titanite</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Calcite</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Possible fluoroapatite</td>
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</tbody>
</table>

- Quartz +/- chlorite veins cutting damage zone

![Graph showing mineral composition and depth profile](image)
<table>
<thead>
<tr>
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<th>wt.%</th>
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<tbody>
<tr>
<td>Chlorite</td>
<td>51</td>
</tr>
<tr>
<td>Quartz</td>
<td>43</td>
</tr>
<tr>
<td>Titanite</td>
<td>5</td>
</tr>
<tr>
<td>Goethite</td>
<td>1</td>
</tr>
</tbody>
</table>

**Chlorite rich shear zone**

Top

Bottom

10 cm

![Graph and image](image-url)
KBH7-594 wt.%
Calcite 56
Cr-chlorite 18
Quartz 15
Na-chlorite (possible glagolevite) 9
Garnet (possible uvarovite) 1
Smectite (possible montmorillonite or corrensite) 1
Zeolite (possible laumontite) <1

Growth fibers at the basalt-basement contact

Growth fibers
10 cm
Calcite and quartz late-vein filling chlorite vein

<table>
<thead>
<tr>
<th>Mineral</th>
<th>wt.%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcite</td>
<td>78</td>
</tr>
<tr>
<td>K-feldspar</td>
<td>7</td>
</tr>
<tr>
<td>Quartz</td>
<td>6</td>
</tr>
<tr>
<td>Plagioclase</td>
<td>5</td>
</tr>
<tr>
<td>Chlorite</td>
<td>4</td>
</tr>
</tbody>
</table>

Top

Calcite and quartz vein

Bottom

10 cm
Modal Composition

Possible reactivated faults by human-induced earthquakes
5. Conclusions

- Koyna: human-induced earthquakes occurred since dam building.

![](image)

- Scientific drilling project (17 samples in Padua)

- Based on the study of borehole cores and XRPD analysis we propose the following deformation sequence:

  1. Formation of Indian crystalline basement, HT shear zones and later hydrothermal alteration including epidote + chlorite precipitation (Late Archean to Cretaceous)

  2. Deccan Traps, intense geothermal anomaly and possible chlorite filling of the joints (68-65 Ma)

  3. Quartz + calcite filling of fractures/faults (Cenozoic).

- This preliminary study of the fault rocks from the Koyna drilling project suggests that chlorite-filled and quartz+calcite-filled fractures/faults are reactivated by the human-induced EQs.
Thanks for your attention
6. References

• Arora, K. et al. (2017), Lineament Fabric from Airborne LiDAR and its Influence on Triggered Earthquakes in the Koyna-Warna Region, Western India, JGSI Vol. 90, December 2017, pp. 670-677.


