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)

DIPARTIMENTO DI GEOSCIENZE

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Tesi triennale

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at the time of the covid-19

Supervisor: **Giulio Di Toro**

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

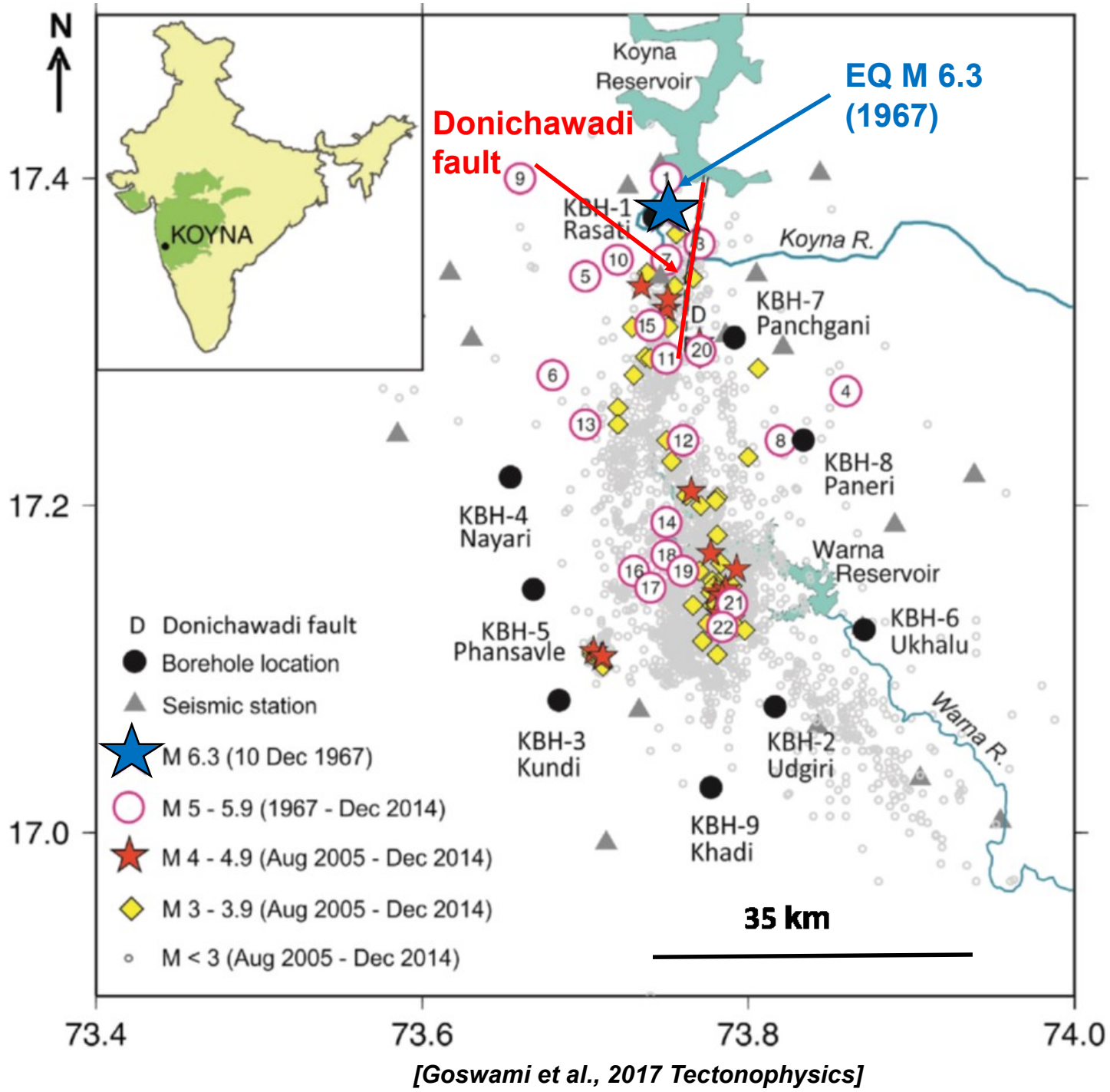
1. Motivations & goals

- 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.

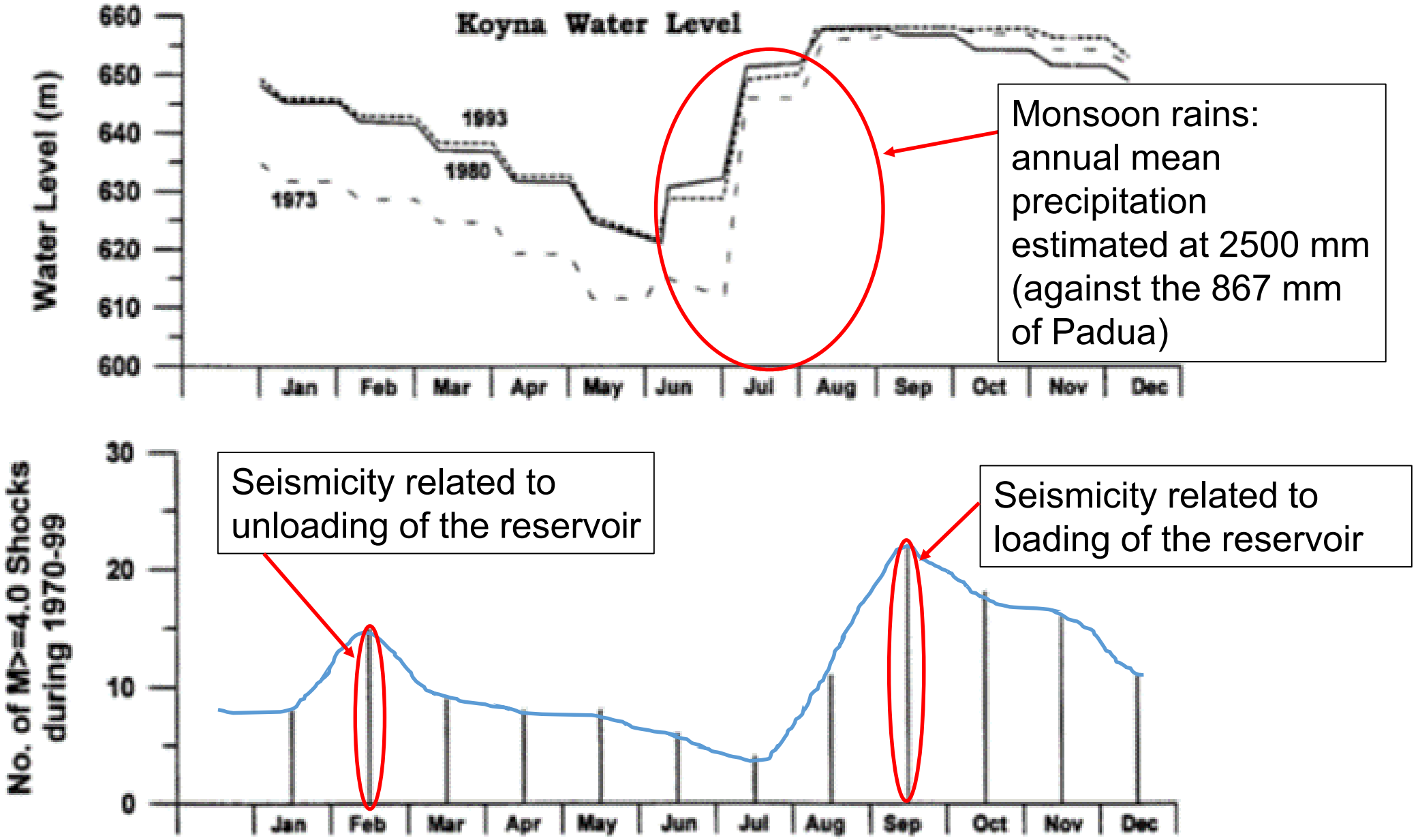
- World's largest human-induced earthquake (M 6.3, 1967).

- World's largest scientific drilling project of induced seismicity area from 2015.



[Goswami et al., 2017 Tectonophysics]

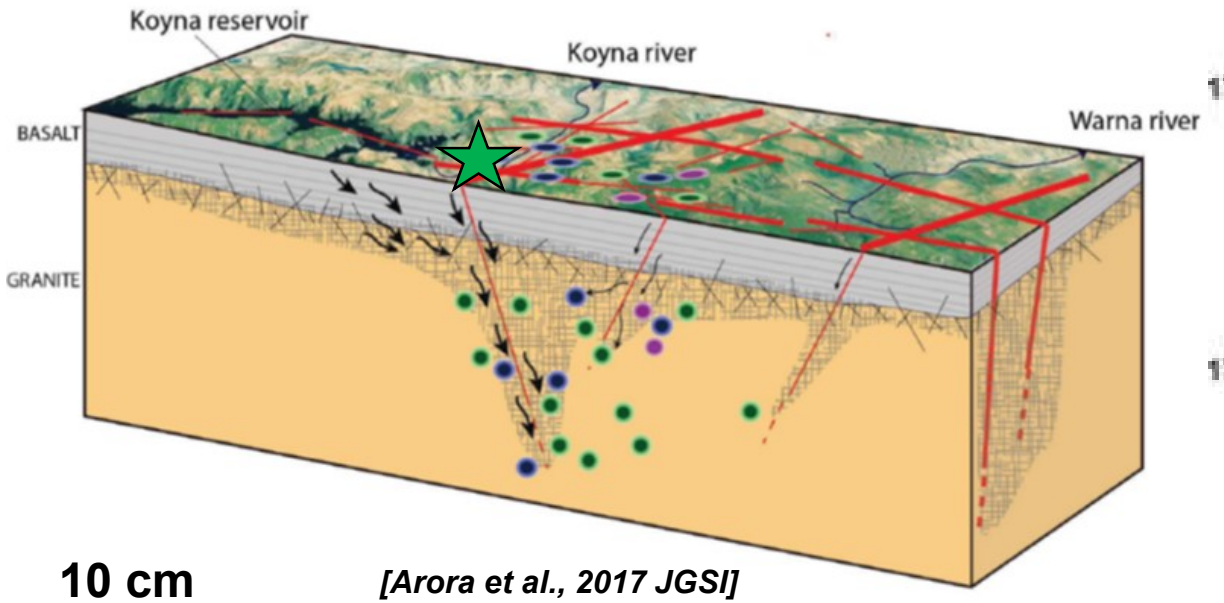
Seismicity in phase with reservoir water level variations.



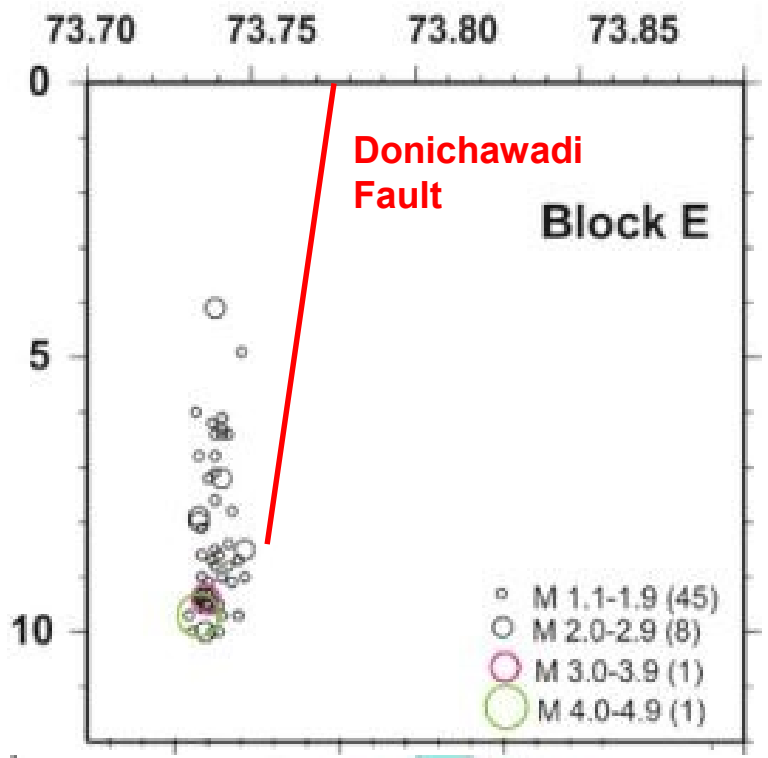
[Gupta, 2002 ESR]

- Seismic activity is restricted within in 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.

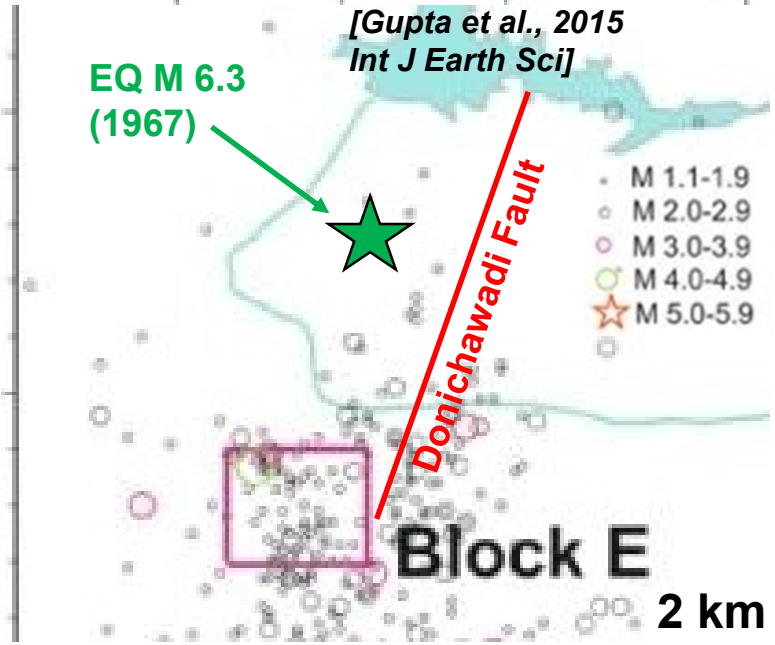
10 cm



[Arora et al., 2017 JGSI]

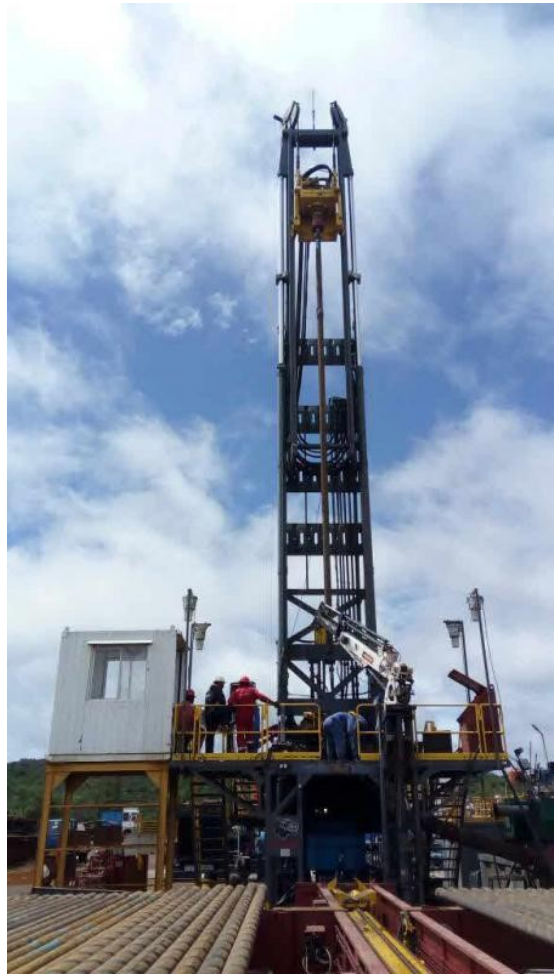


[Gupta et al., 2015 Int J Earth Sci]

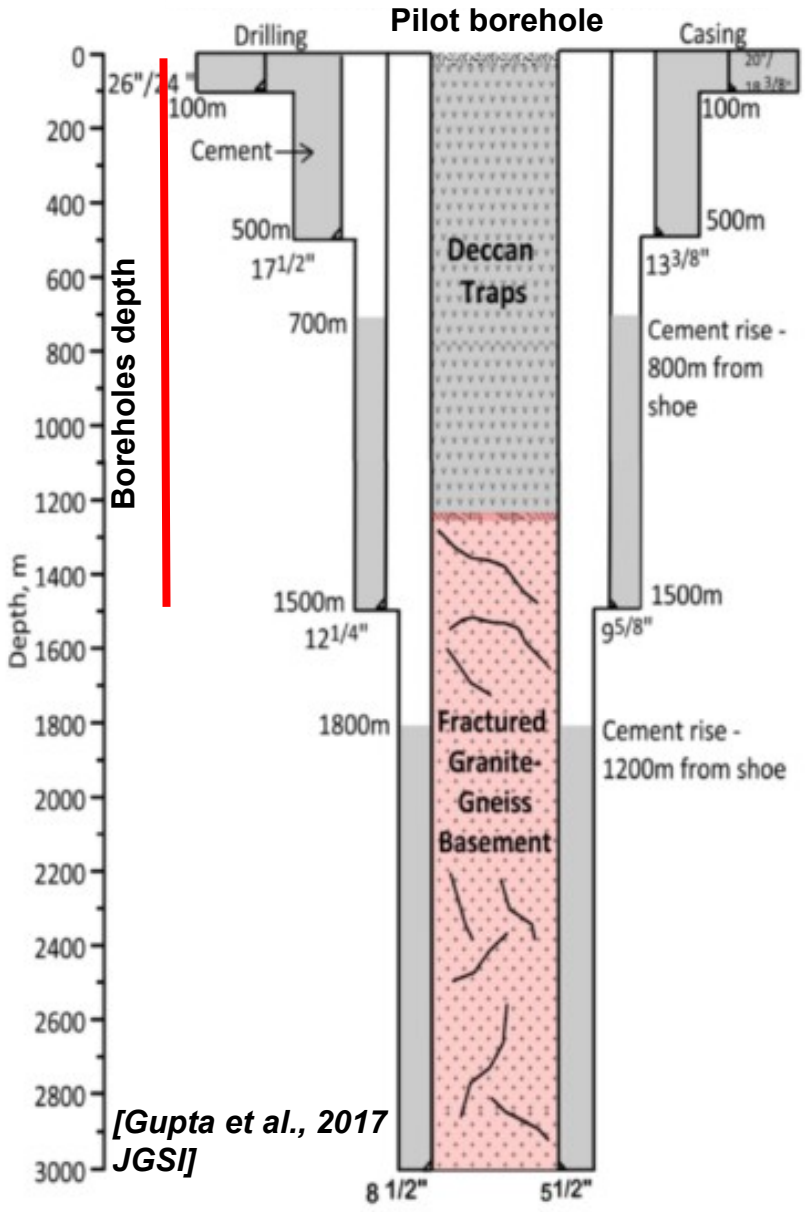


Drilling project to study the granitic basement and the fault rocks from 2015.

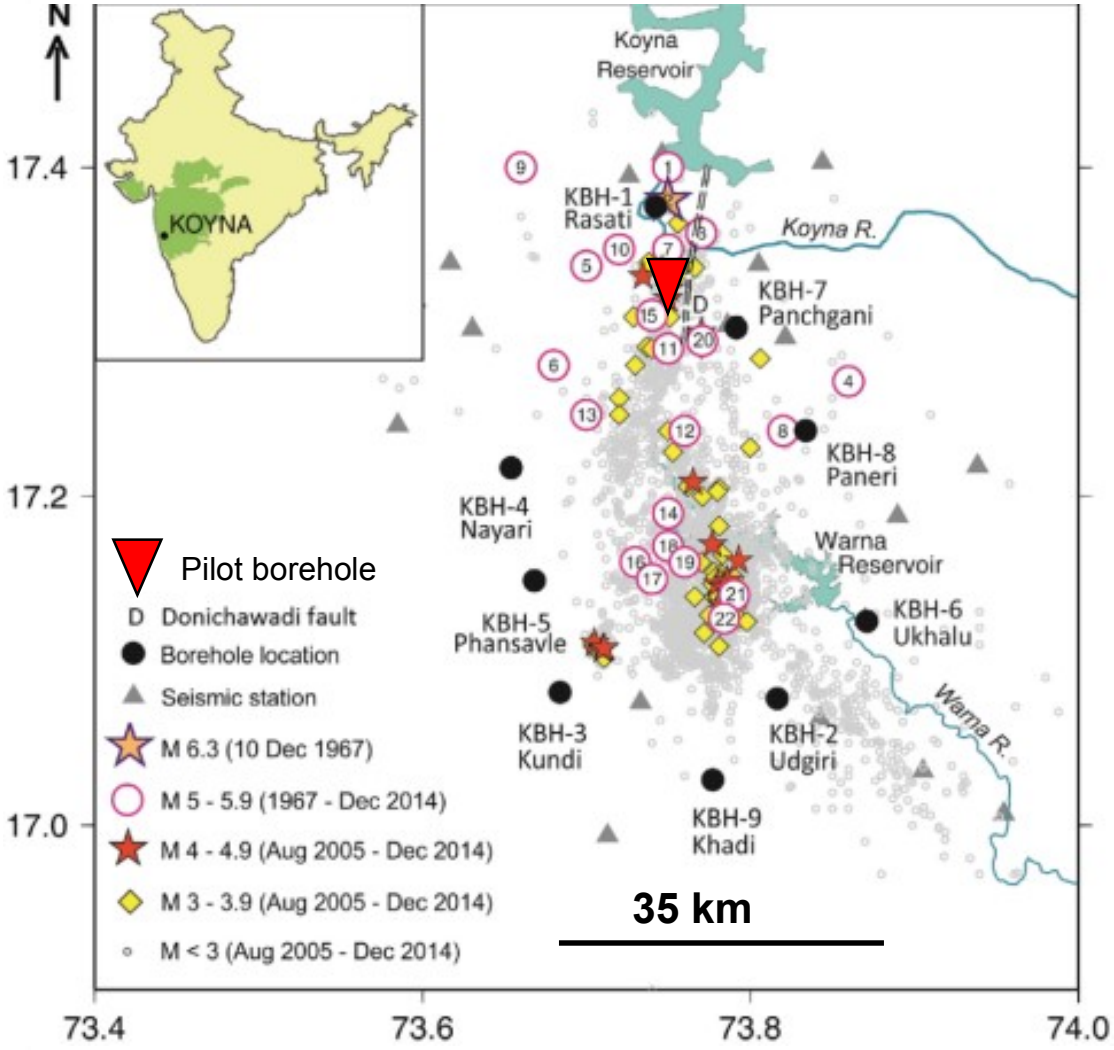
icdp
INTERNATIONAL CONTINENTAL SCIENTIFIC DRILLING PROGRAM



Deep perforation in Koyna area



[Gupta et al., 2017 JGSI]

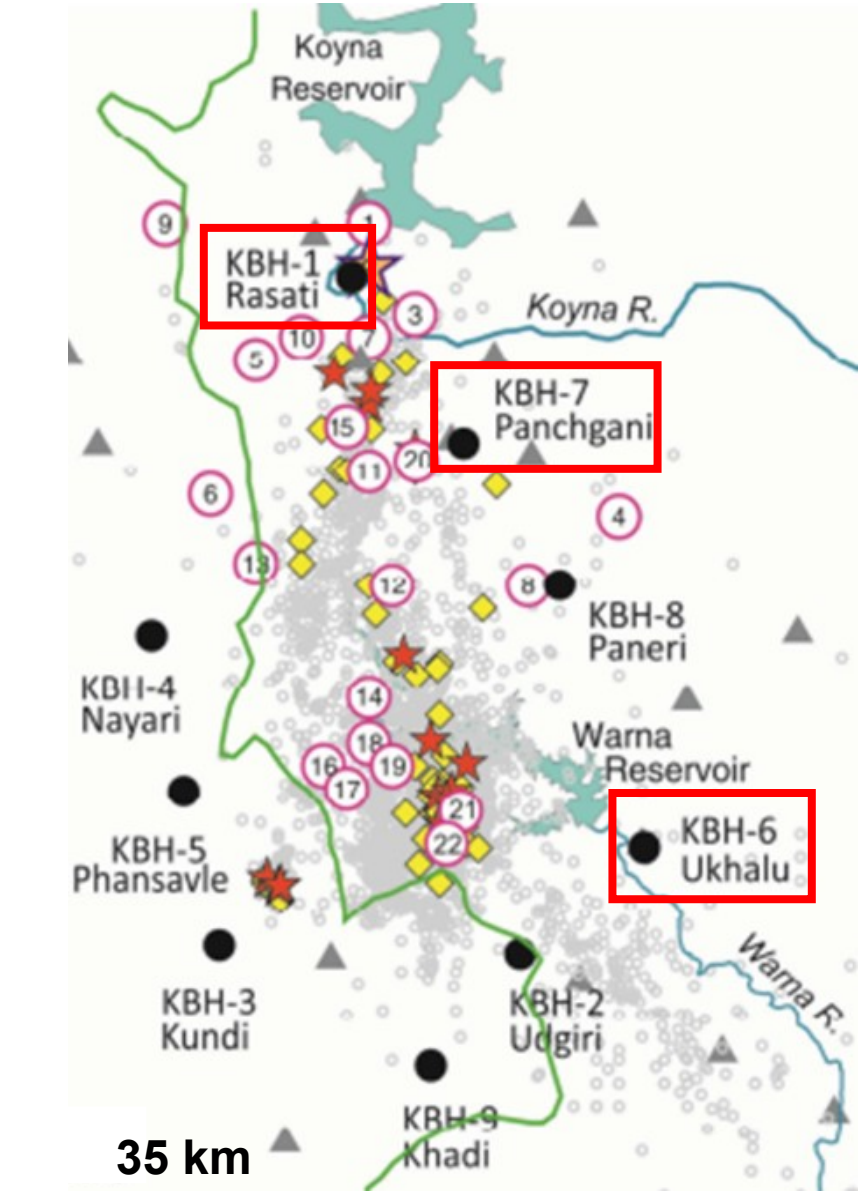


[Gooswami et al., 2017 Tectonophysics]

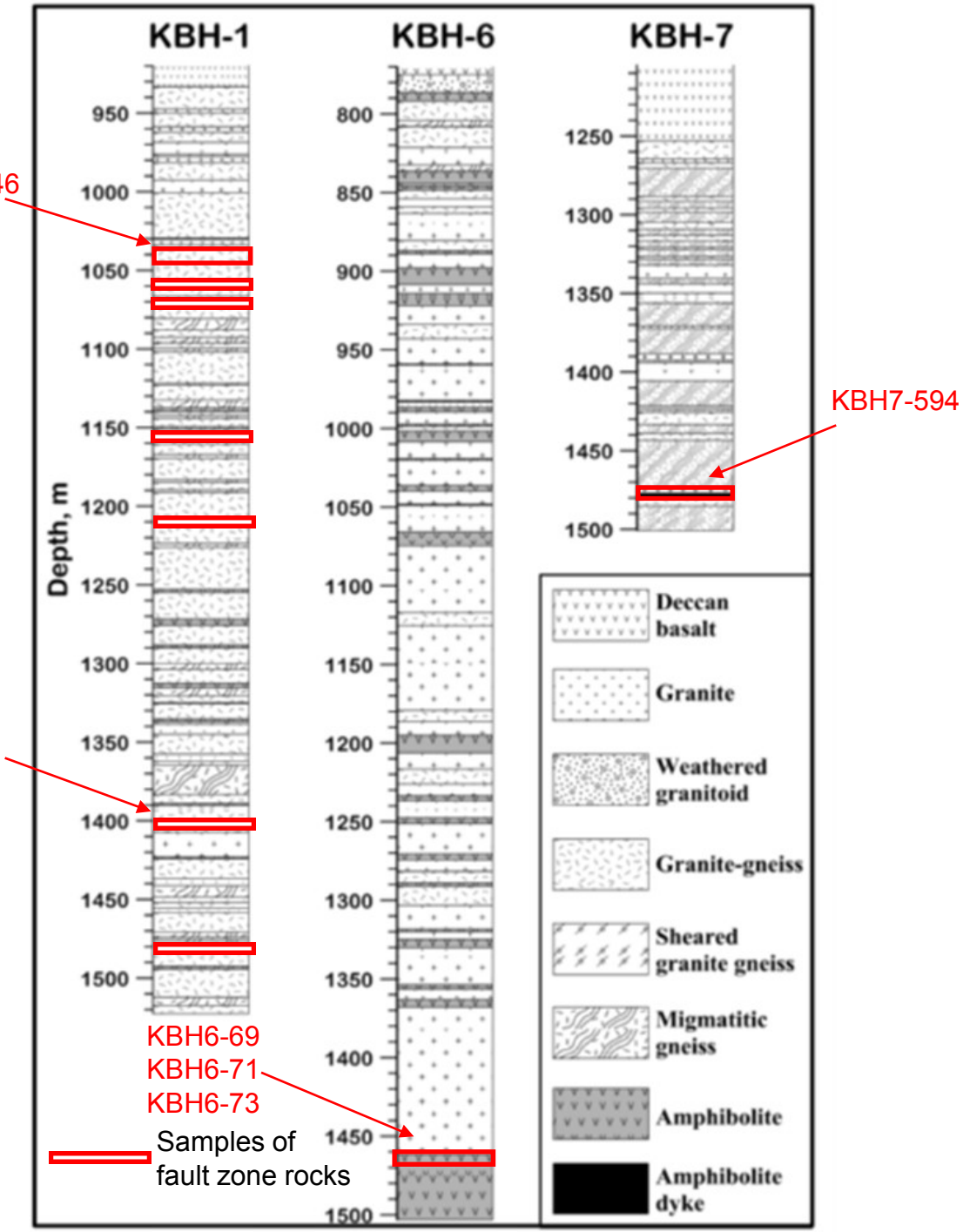
Borehole repository, in Karad

- 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]



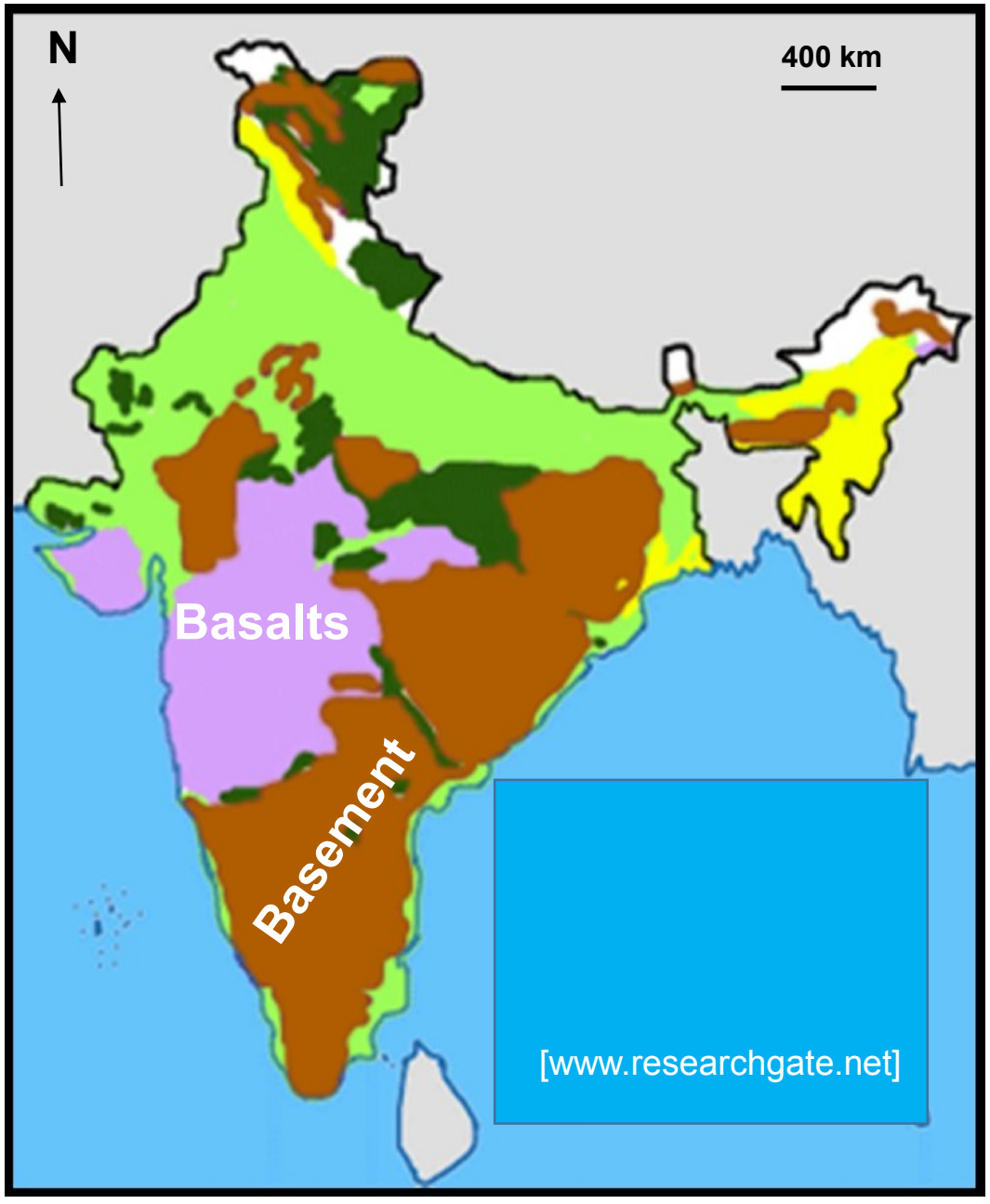
2. Geological setting of Koyna area

Koyna region:

- Deccan Traps (68-65Ma): basalts Thickness: 500-2000m

- Granitic Basement (Proterozoic): granite-gneiss, granite, migmatitic-gneiss, amphibolites.

[Misra et al., 2017 JGSI]



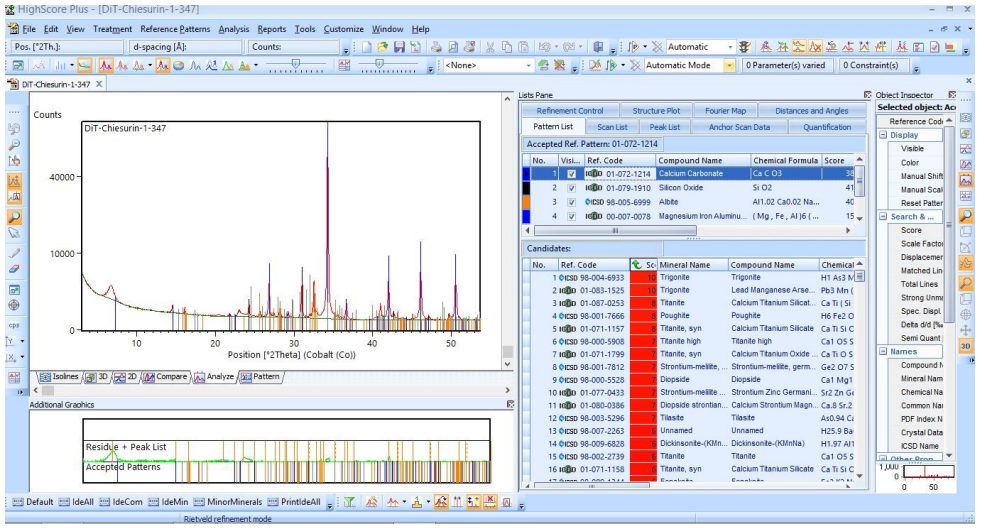
3. Methods

[Stefano Baldo's thesis, Unipd]

1. 15 samples pulverized in an agate mortar.

2. Assembly on sample holders.

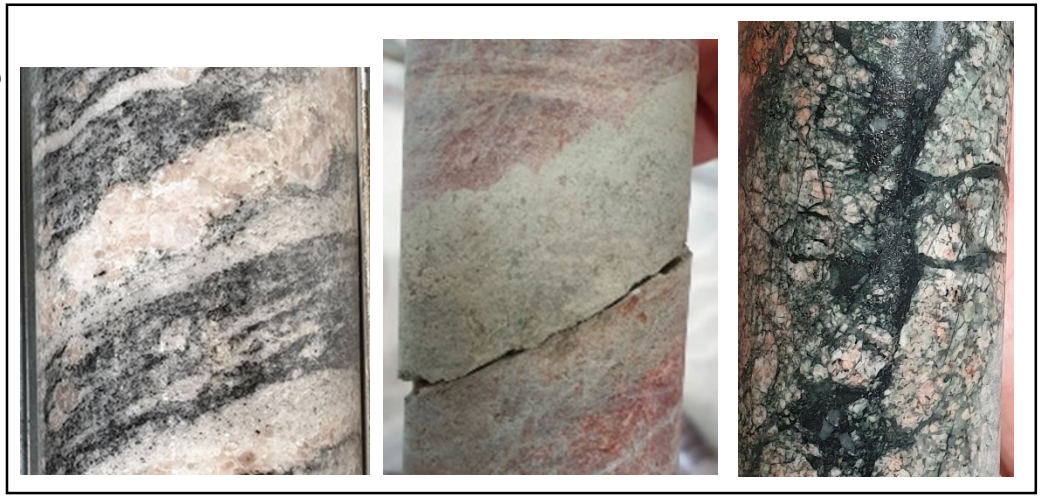
3. Semi-quantitative analysis through powder diffraction.



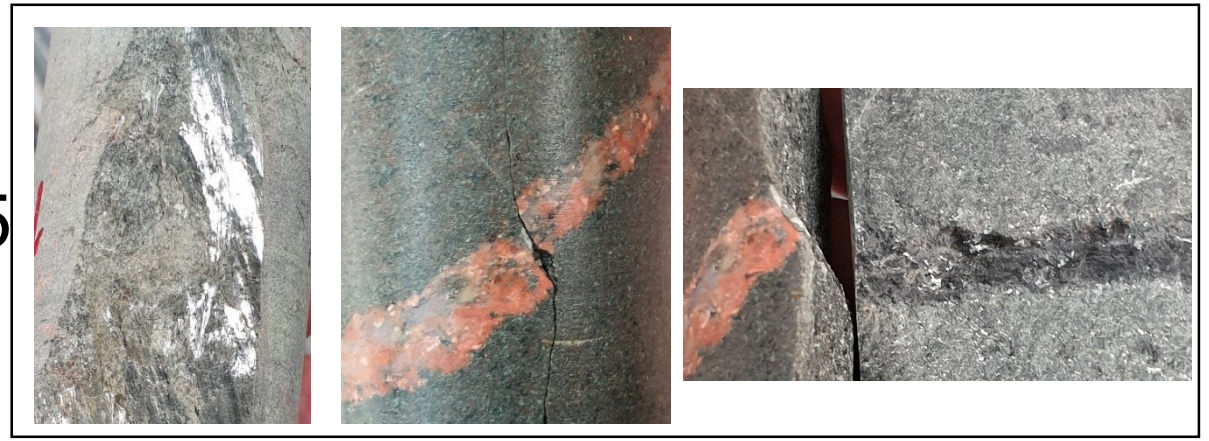
4. Interpretation of diffractograms with the HighScore Plus software®.

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.

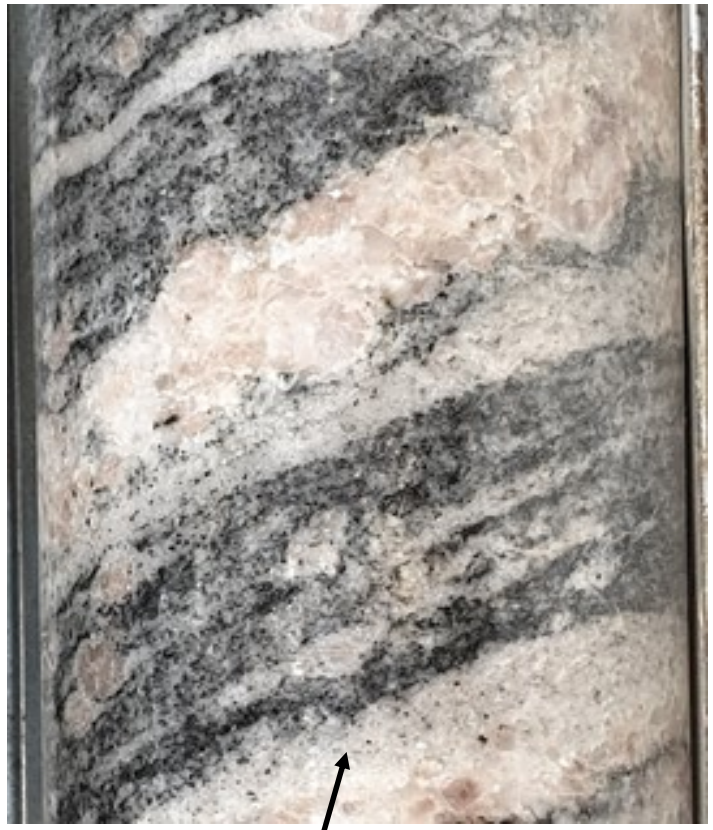


2. Cretaceous: Deccan intrusion (68-65 Ma), intense geothermal anomaly and possible chlorite filling of the joints.



3. Post-Cretaceous to today: quartz + calcite precipitation in fractures. Formation of brittle faults with gouges, breccia, cataclasite.

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



Basement

Epidote-bearing fault

Chlorite-bearing fault

Basement

2. Cretaceous: Deccan intrusion (68-65 Ma), intense geothermal anomaly and possible chlorite filling of the joints. Possible reactivated faults by human-induced earthquakes.

Chlorite filling of the joints

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

10 cm

KBH1-352
Epidote-bearing faults cutting granitic basement

10 cm

KBH6-71
Quartz + chlorite veins cutting damage zone

10 cm

KBH6-69
Chlorite rich shear zone exploited by brittle fault

10 cm

KBH7-594
Growth fibers at the basalt-basement contact

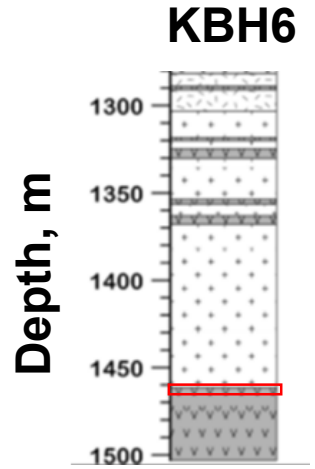
10 cm

KBH1-346
Calcite and quartz late-vein filling chlorite vein

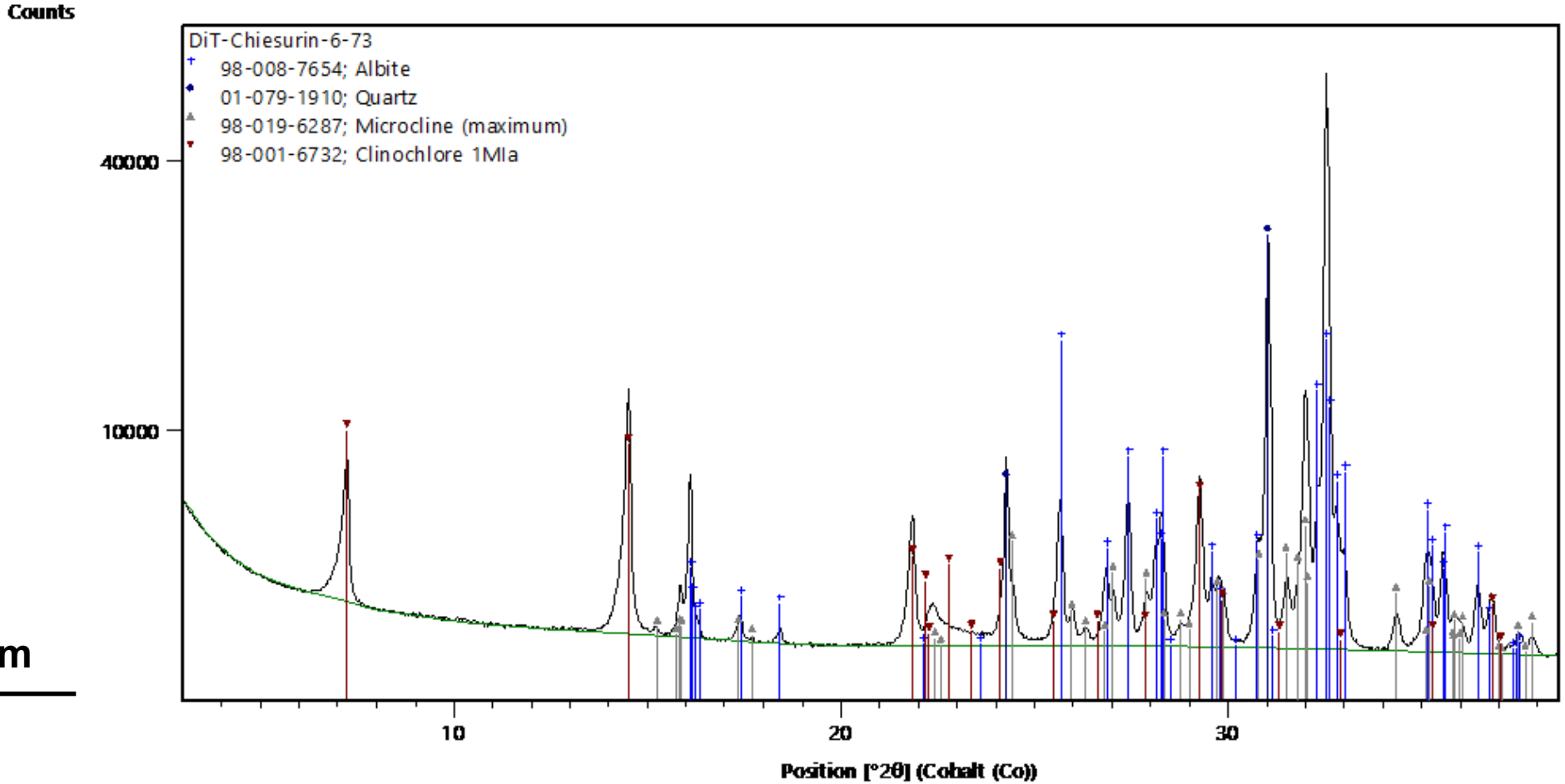
10 cm

KBH6-73	wt.%
Plagioclase	54
Quartz	19
Chlorite	15
K-feldspar (possible microcline)	12

Granitic basement



10 cm

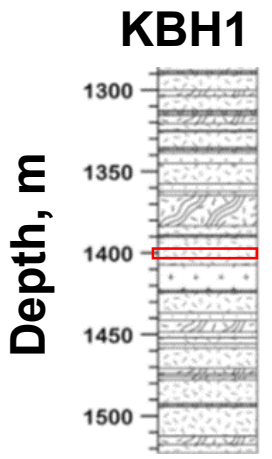


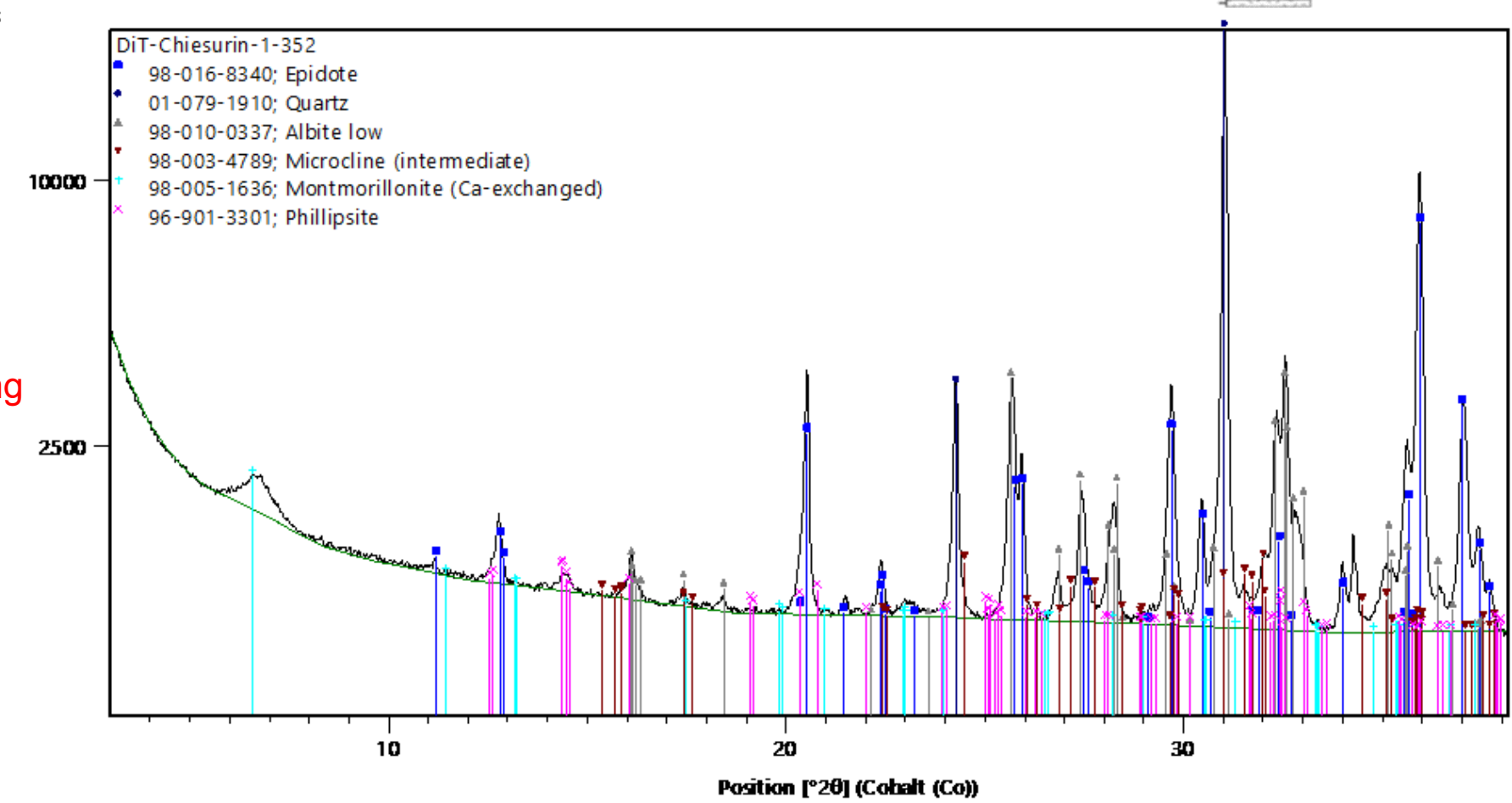
Epidote-bearing faults

KBH1-352	wt.%
Epidote	42
Albite	26
Quartz	25
K-feldspar	4
Zeolite (possible phillipsite)	3
Smectite (possible montmorillonite)	<1

Epidote-bearing faults

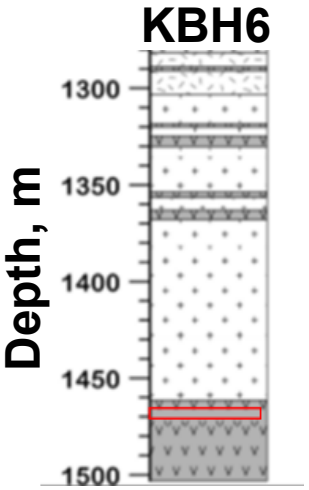
10 cm





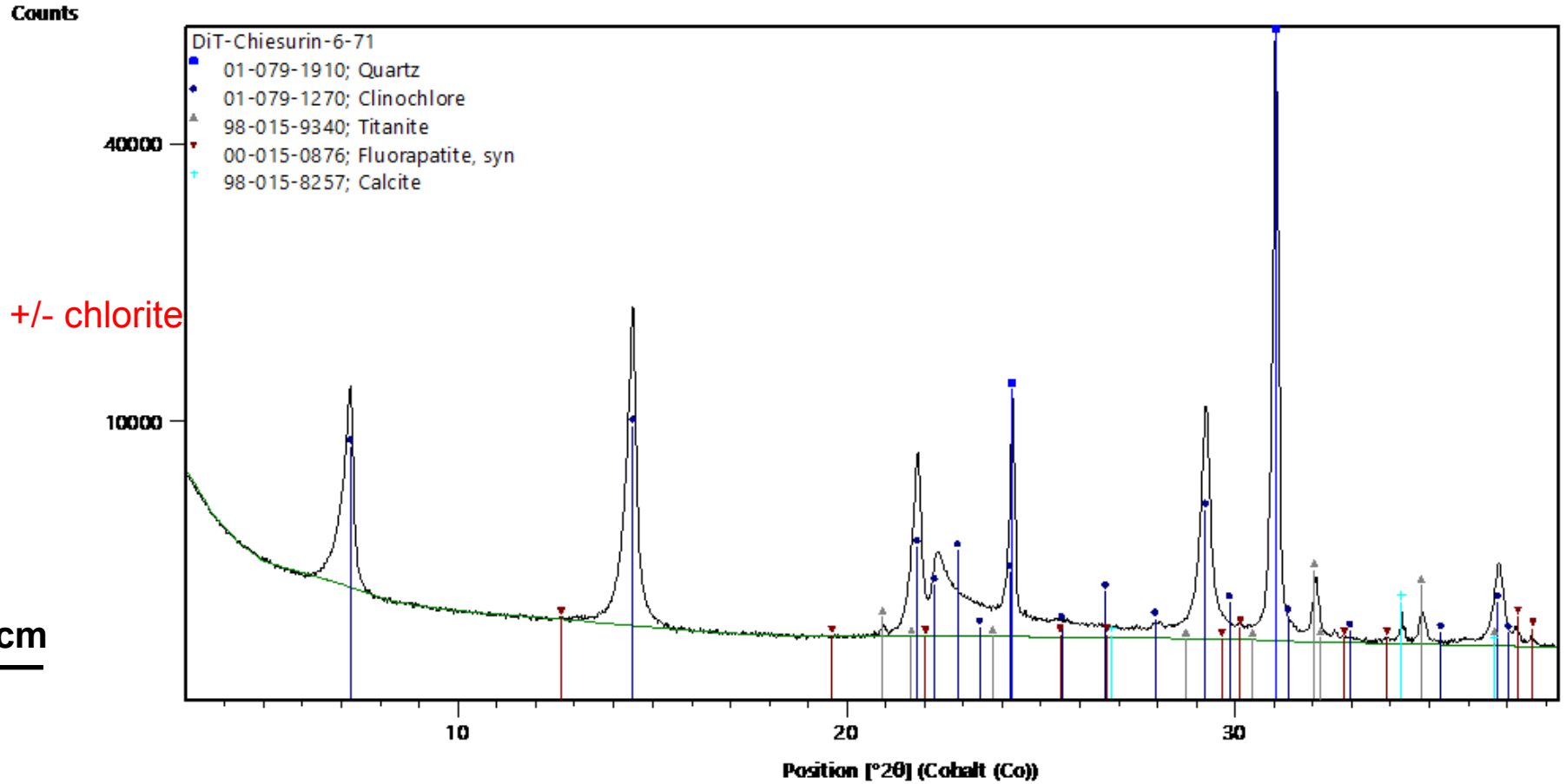
KBH6-71	wt.%
Quartz	64
Chlorite	31
Titanite	4
Calcite	1
Possible fluoroapatite	1

Quartz +/- chlorite veins cutting damage zone



Quartz +/- chlorite veins

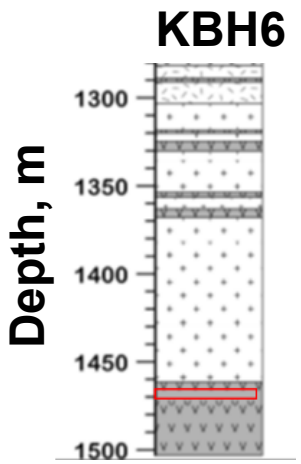
10 cm

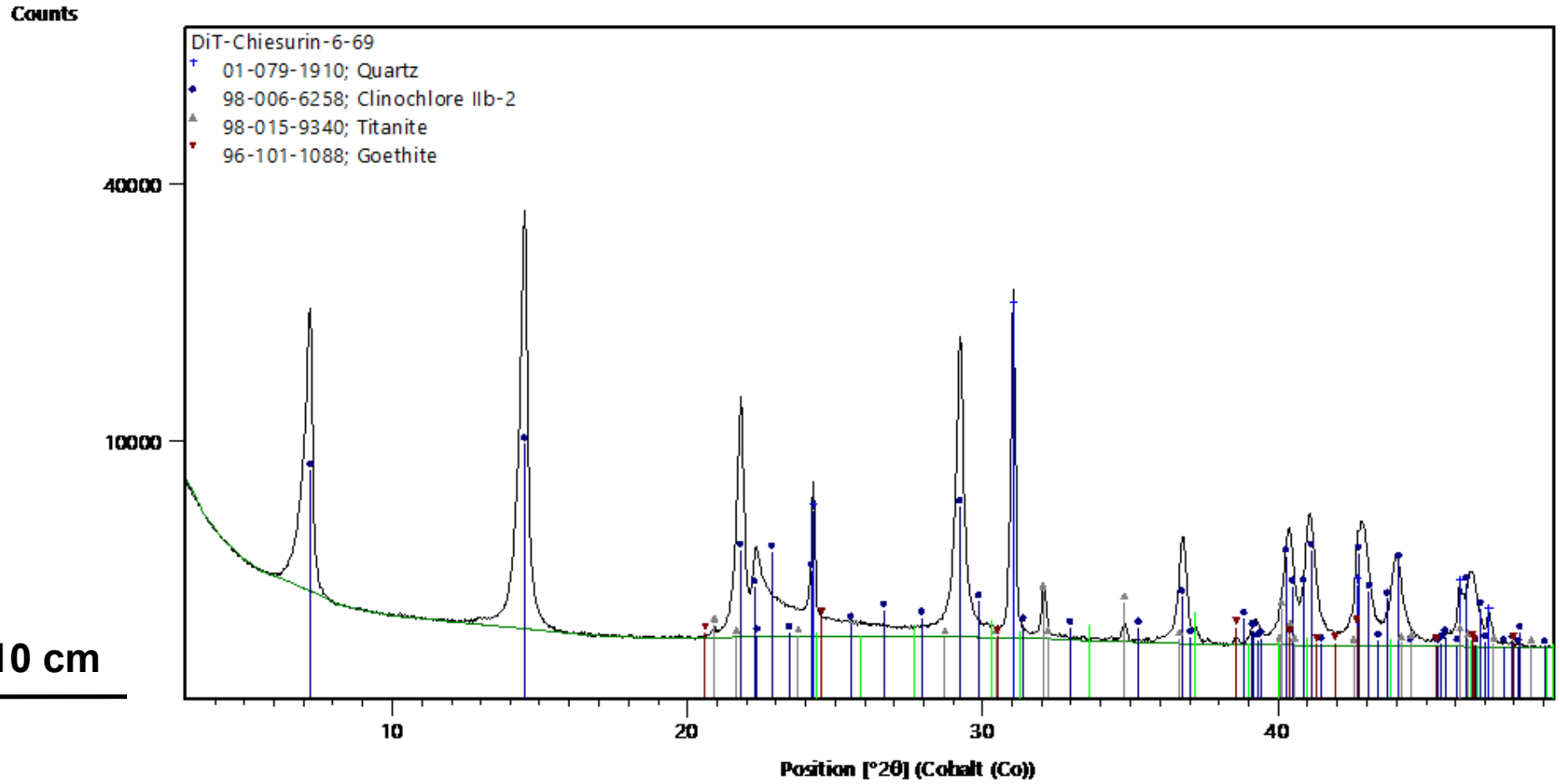


Chlorite rich shear zone

KBH6-69	wt.%
Chlorite	51
Quartz	43
Titanite	5
Goethite	1

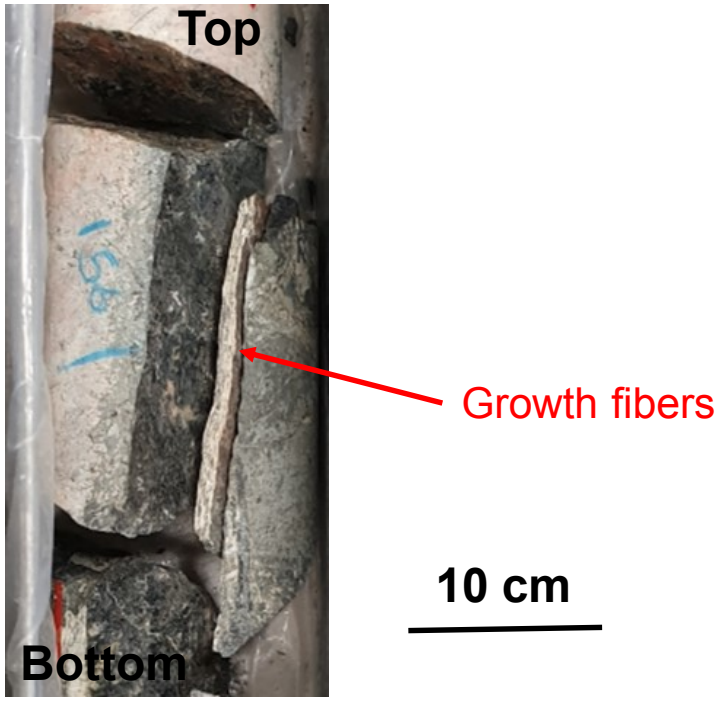
10 cm

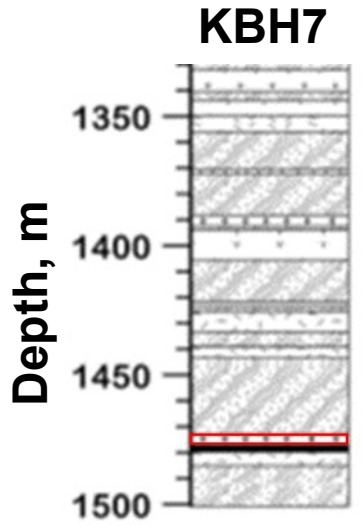


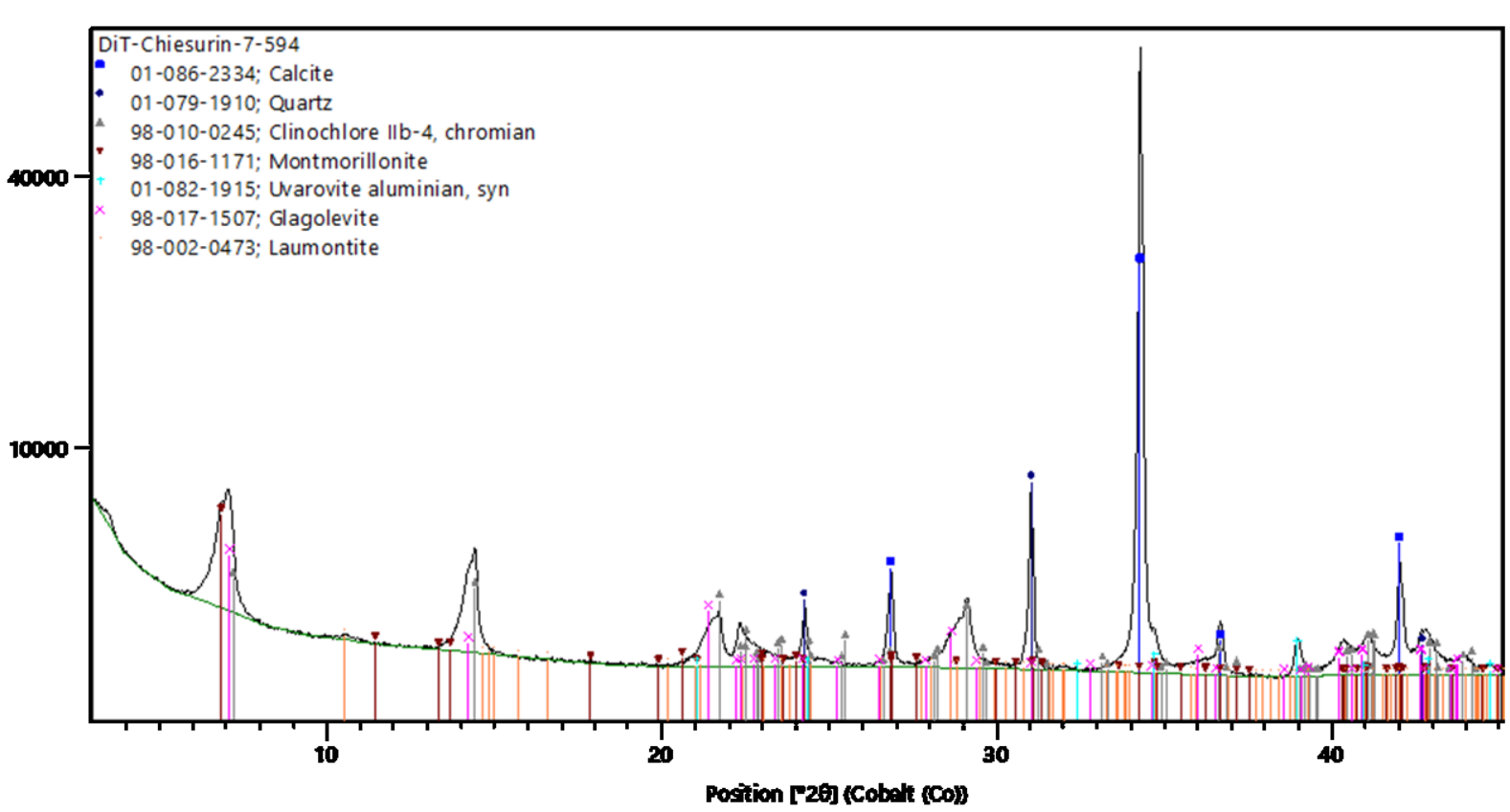


Growth fibers at the basalt-basement contact

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

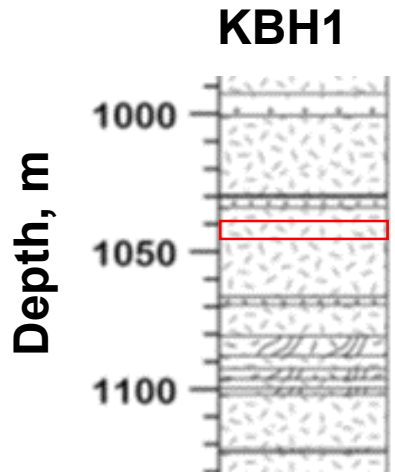






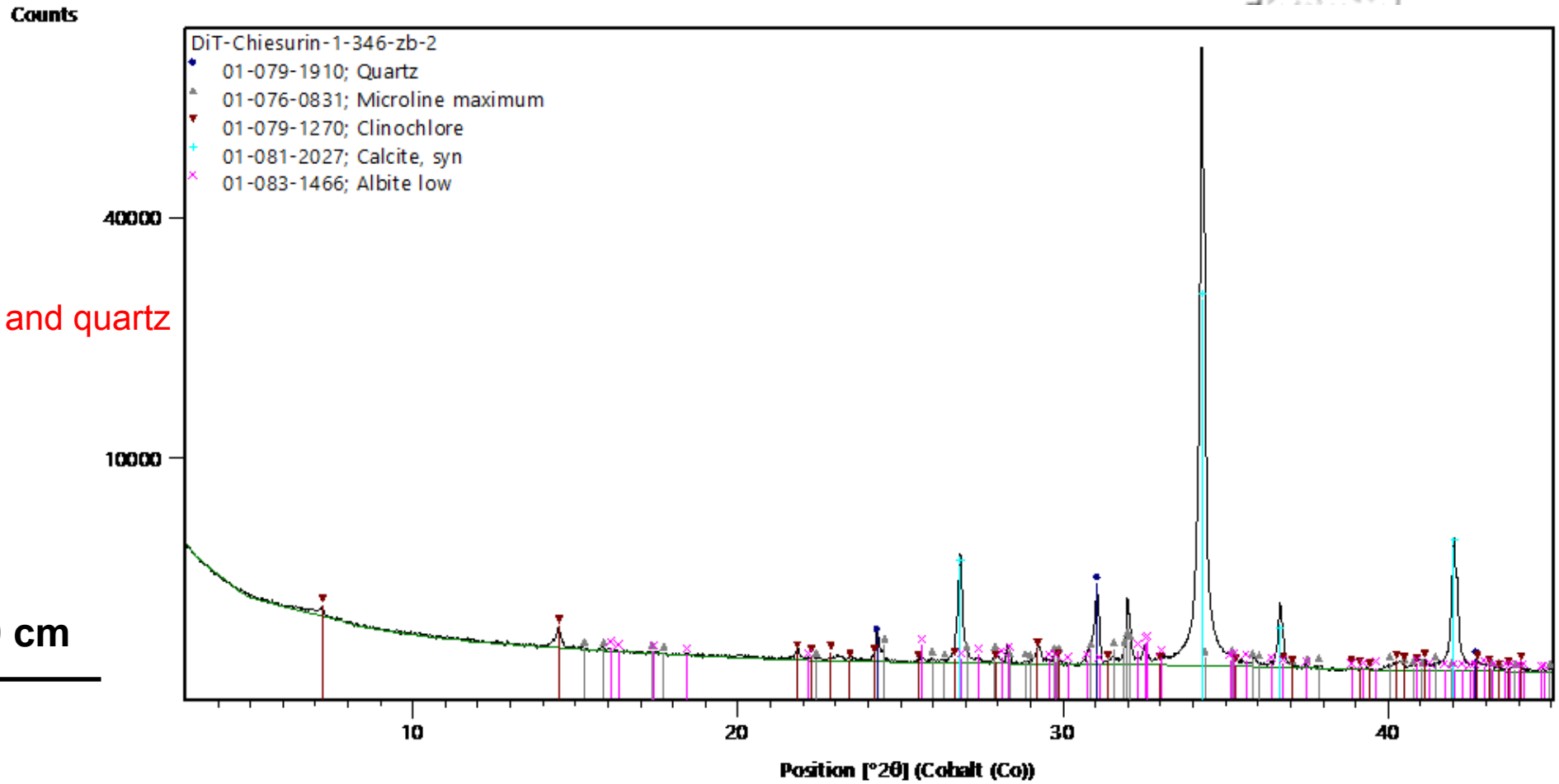
KBH1-346	wt.%
Calcite	78
K-feldspar	7
Quartz	6
Plagioclase	5
Chlorite	4

Calcite and quartz late-vein filling chlorite vein



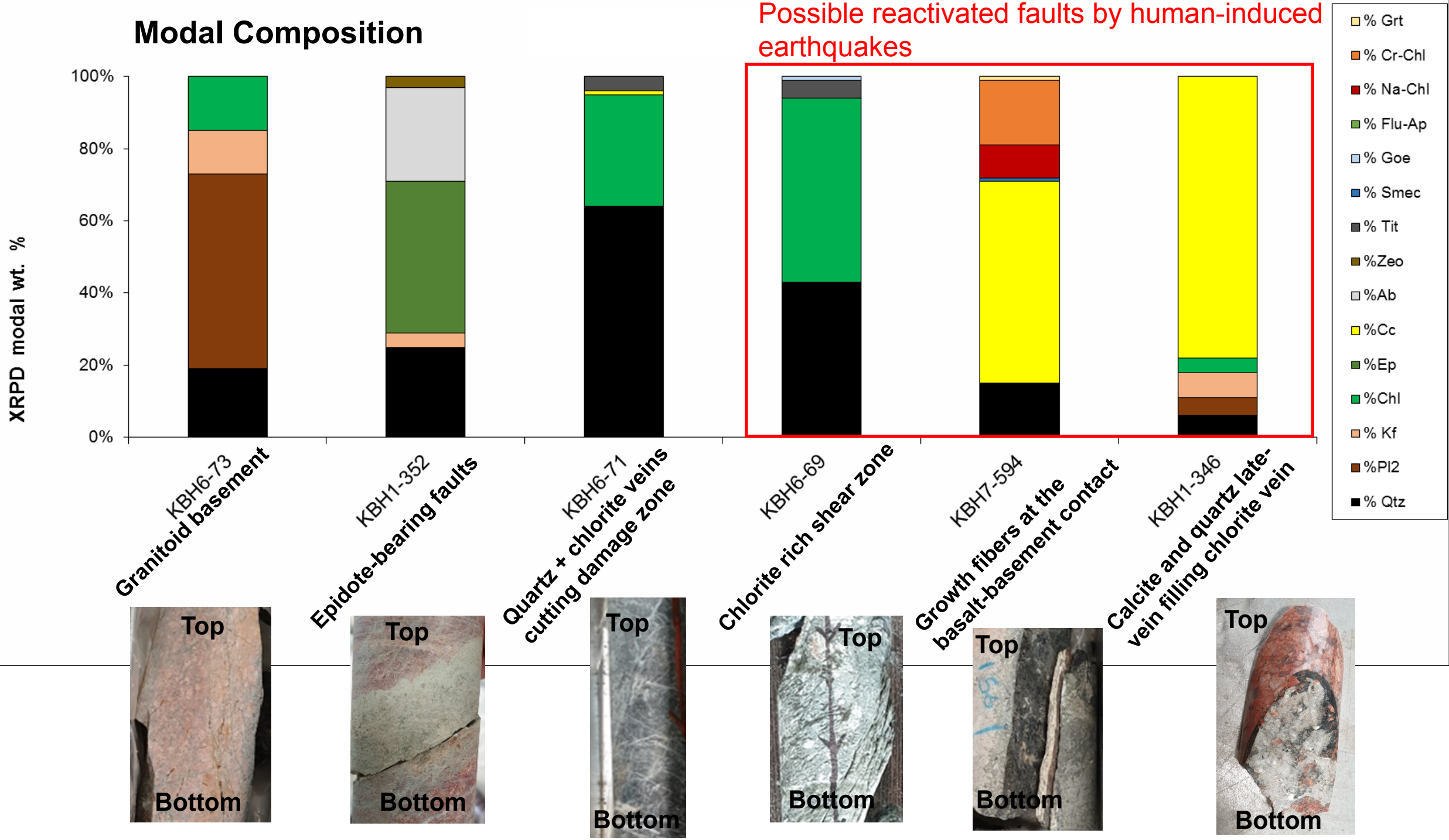
Calcite and quartz vein

10 cm



Modal Composition

Possible reactivated faults by human-induced earthquakes



5. Conclusions

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

↓

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).

Possible reactivated faults by human-induced earthquakes

- 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.
- *Goswami, D. et al. (2017), Rock strength measurements on Archaean basement granitoids recovered from scientific drilling in the active Koyna seismogenic zone, western India,* Tectonophysics Vol. 712–713, 21 August 2017, pp.182-192.
- Gupta, H.K. (2002), *A review of recent studies of triggered earthquakes by artificial water reservoirs with special emphasis on earthquakes in Koyna, India,* Earth-Science Reviews Vol. 58, (2002), pp. 279–310.
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- *Gupta, H.K. (2017), Koyna, India, an Ideal site for Near Field Earthquake Observations,* JGSI Vol.90, December 2017, pp.645-652.
- Misra, S. et al. (2017), *Granite-gneiss Basement below Deccan Traps in the Koyna Region, Western India: Outcome from Scientific Drilling,* JGSI Vol.90, December 2017, pp.776-782.