The Münsterdorf sinkhole cluster: Void origin and mechanical failure

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Location

- North of **Hamburg**.
- Village of **Münsterdorf** (grey dot).
- **Sports field** (blue dots).
- **Sinkholes** (blue dots).
- Chalk in 20 m depth (red contour lines).
- Large **open-pit mines** (white areas).

Data: SRTM; Chalk depth: R. Kirsch (from: Kaufmann et al., 2018, Fig. 2).
Sinkholes

- **Sinkhole cluster**
- Roughly **one every year**.
- **Size** around 2-3 m in diameter and 2-5 m deep.
- Expose **unconsolidated material**:
  - **Peri-glacial sand**
  - **Glacial till**
- Chalk in 20 m depth.

Photo: G. Kaufmann
(from: Kaufmann et al., 2018, Fig. 3).
Geophysical field work

Methods

- Gravity
- Electrical resistivity tomography
- Georadar
- Direct-push measurements

Reveals change in sub-surface structure:

- North: Shallow glacial till
- South: Deeper glacial till

Data: Areal photo LLUR; borehole logs: R. Kirsch; ERT data color-coded.
(from: Kaufmann et al., 2018, Fig. 7).
Failure model

- **Yade** discrete-element model.
- Layers with **different** mechanical properties.
- Mechanical properties derived from **direct-push measurements**.
- Model indicates sinkhole collapse, when . . .
  - . . . Void has formed in around 20 m depth.
  - . . . Buoyant support in void (partially) reduced.
Hypothetical model

- Chalk in 20 m depth karstified.
- Meter-size voids in phreatic zone.
- Groundwater level originally in 2-3 m depth.
- Glacial till and peri-glacial sands (semi-)stable above voids.
- Groundwater drop due to pumping in large open-pit mines nearby triggers sinkholes!
Conclusions

▶ Sinkholes on sports field start with abrupt onset around 2004.
▶ Sinkholes occur roughly once per year.
▶ Sinkholes are 2-3 m in diameter and 2-5 m deep.
▶ Initial void likely in chalk in around 20 m depth.
▶ Fall in groundwater level due to open-pit mining.
▶ Loss of buoyant support can induce instability of strong layers.

References: