Schweizerische Eidgenossenschaft
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Swiss Geological Survey (swisstopo)

wissen wohin
savoir où
sapere dove
knowing where

swisstopo

Shallow Modelling: squeezing more out of imperfect borehole and outcrop data

7th European meeting on 3D geological modelling, April 2025, Poland

Państwowy Instytut Geologiczny
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Aims

Why are we modelling?

- Assist the map making process:
  - Fieldwork planning: by providing **potential field outcrop locations**
  - Map content: by providing an **estimate of the map outcrop lines**
- Contribute to the map «explanatory guide»:
  - Figures: by providing basic **input for the geological profiles**
  - Text: section/chapter on «Modelling»
- Input for other products:
  - Update of 3D models e.g. **GeoMol** (Swiss Molasse Basin), Jura3D, Alps3D
  - **Geocover** (electronic map data set).

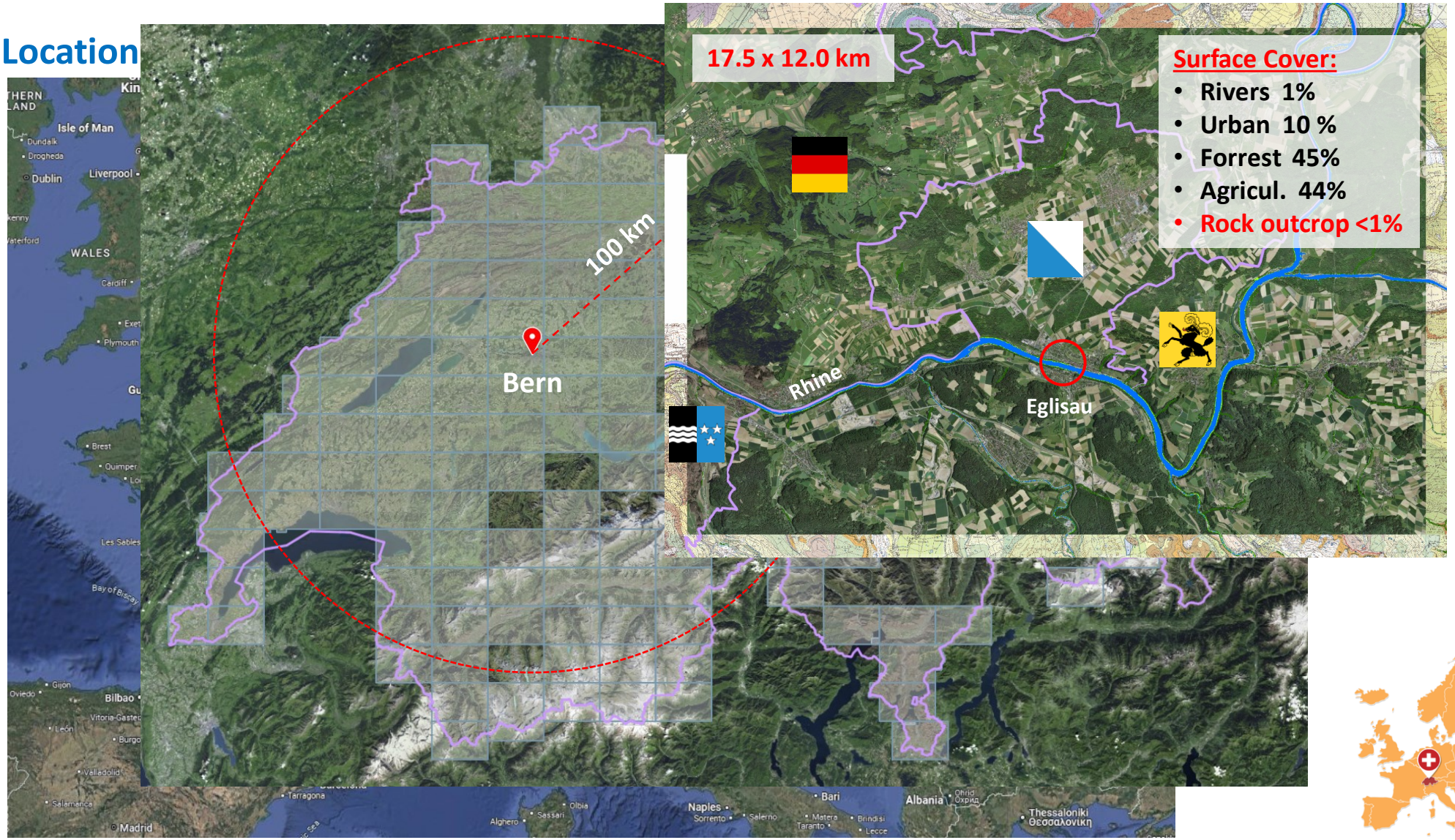
Main Benefits:

- more productive time in the field
- improved quality:
  - map outcrop lines
  - more coherent profiles
- improved efficiency across processes
- the basis for multiple products.

Example: the GA25 map sheet «Eglisau»

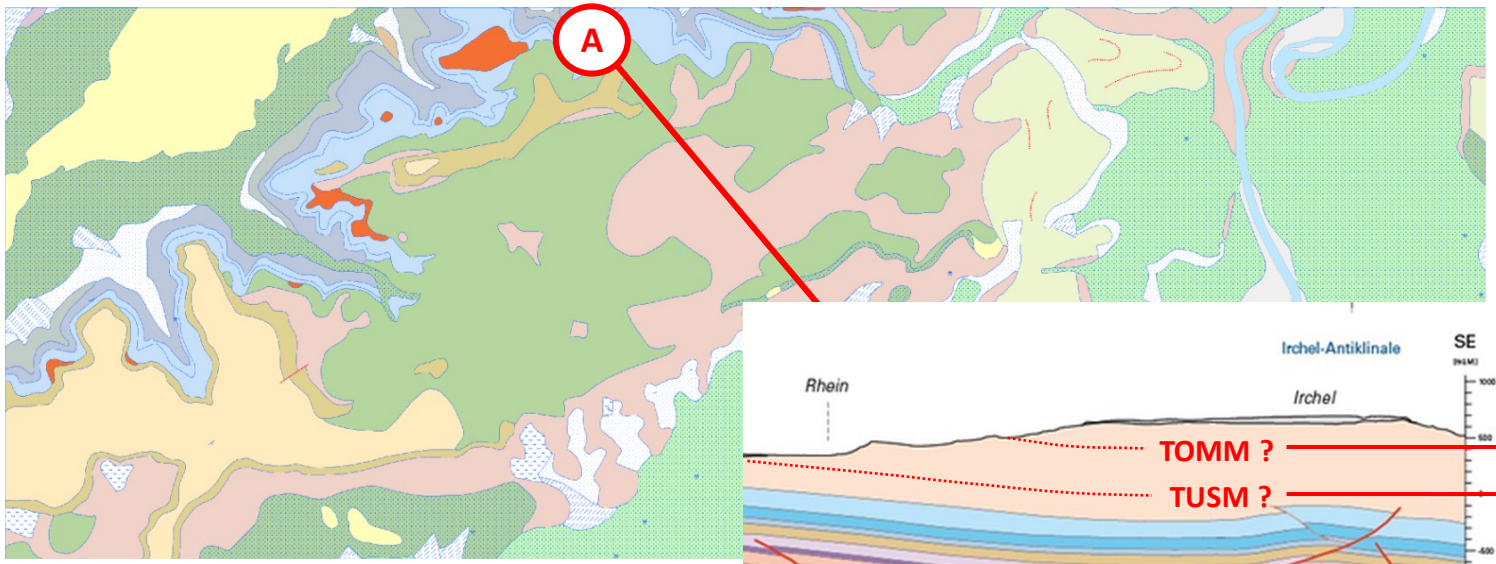
Location

Location



Geology

Stratigraphy of GA25 map sheet «Eglisau»

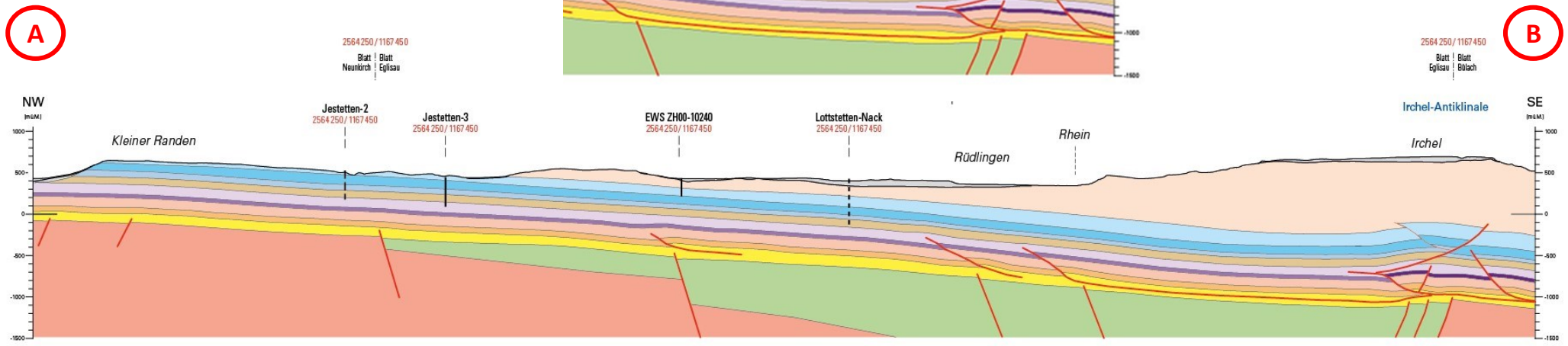


Quaternary

- Alluvium (Ho)
- Talus, stream sediments, landslips (Ho)
- Moraine (lP)
- Slope and alluvial clays (P)
- Glaciofluvial gravels (e-lP)
- Moraine (mP)

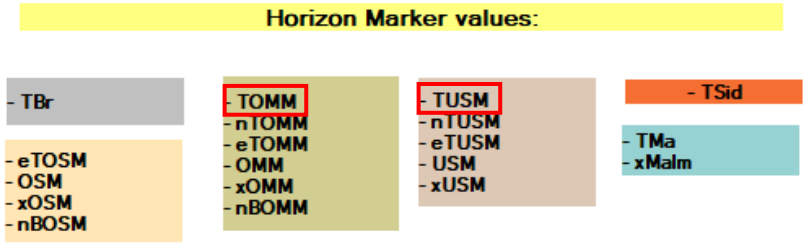
Neogene

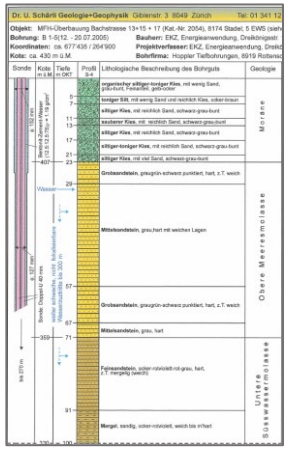
- Upper Freshwater Molasse (OSM) (Bu-Se)
- Lower Marine Molasse (OMM) (Bu)
- Lower Freshwater Molasse (USM) (Aq)



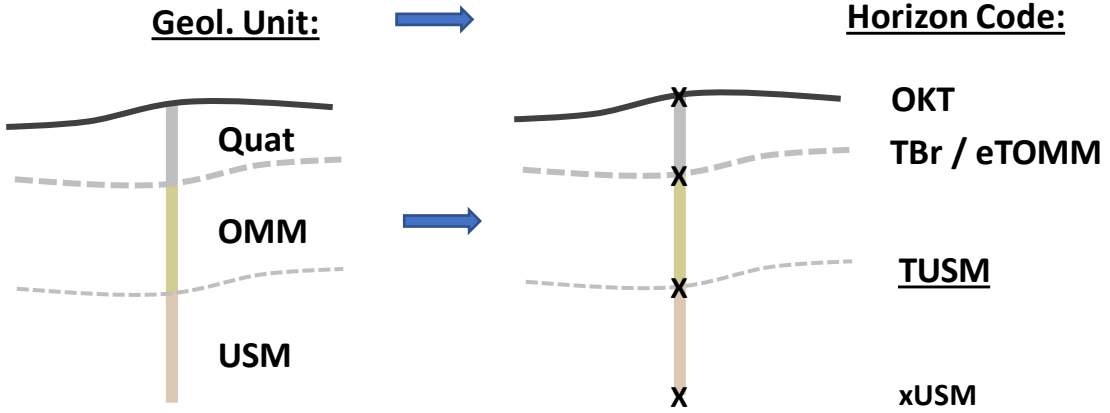
Modelling Data

Geol. Unit/Horizon Codes

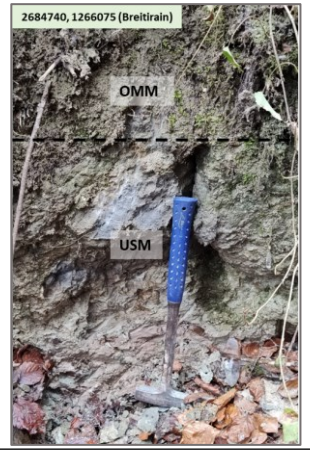




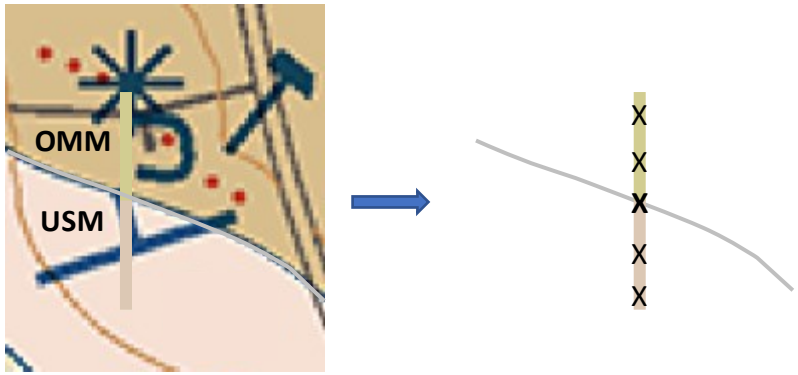
Well Data (Profile View)



Notes: 1) the above logic applies to eTOSM/TOMM as well, 2) eTUSM also possible



Outcrop Data (Map View)



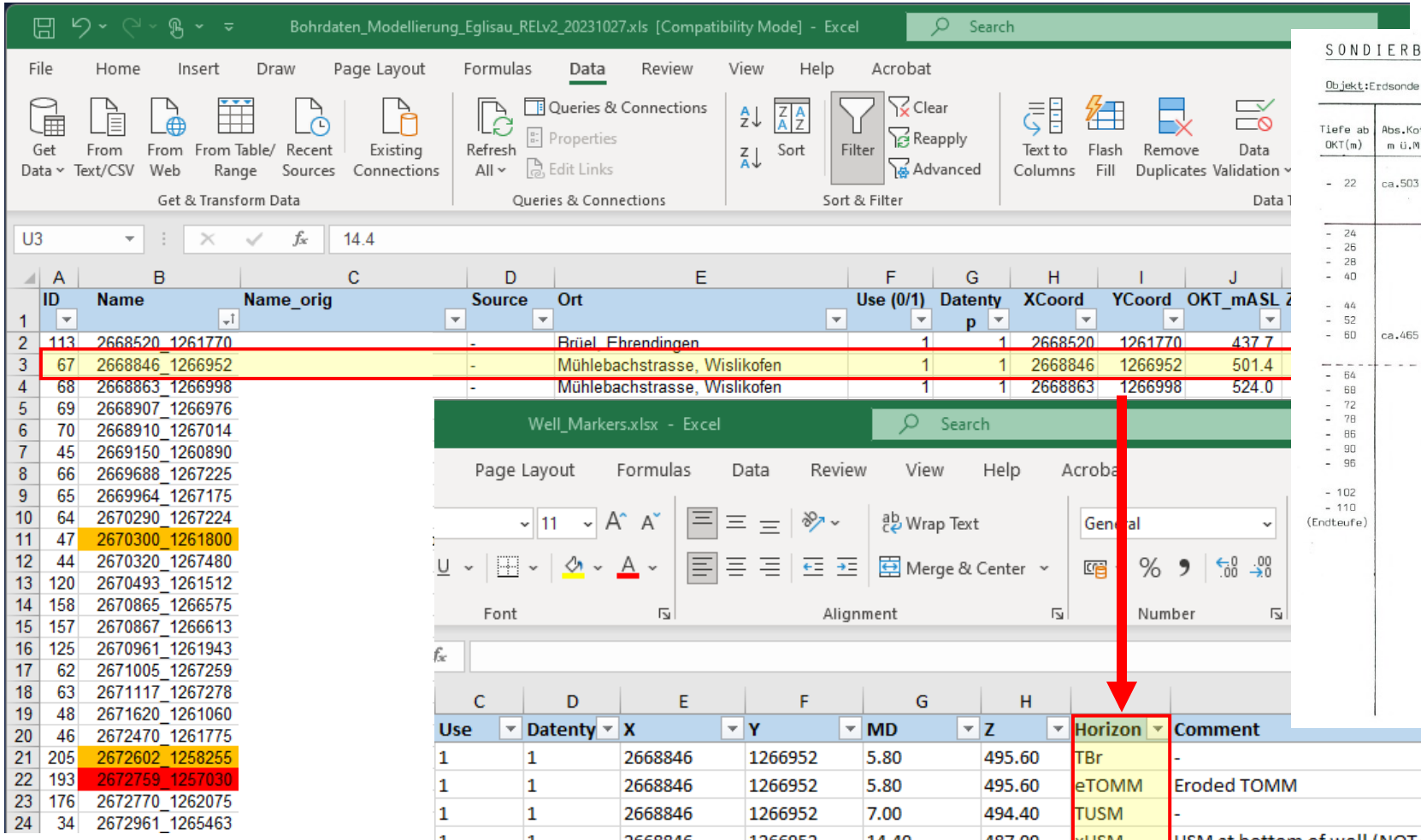
Constraint Points:
cpTOMM and cpTUSM were also derived from near base or near top points.

Modelling Data

Borehole data

Borehole Data Challenges:

- Poor data quality (few verifiable sources e.g. PDFs)
- Various sources (n=8) with different table layouts.

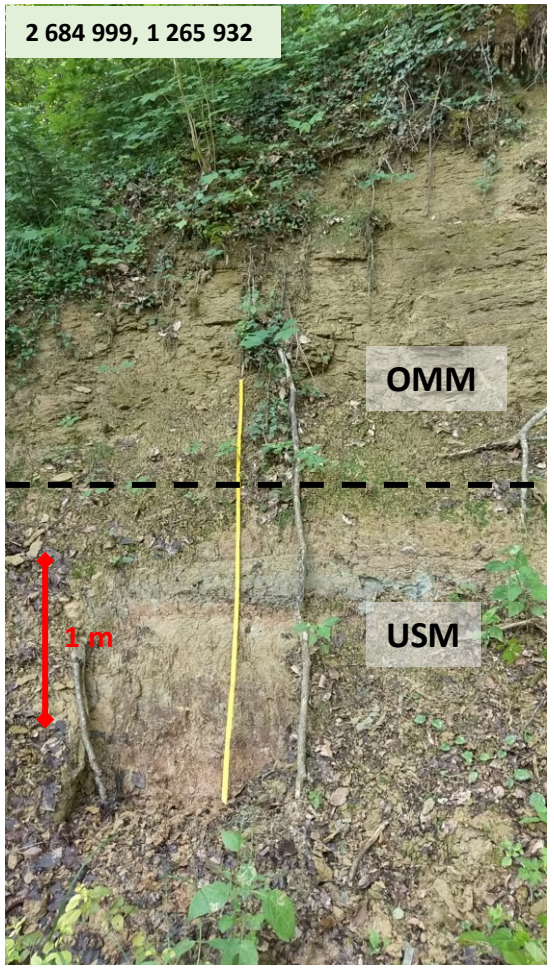


Modelling Data

Outcrop data 1/2

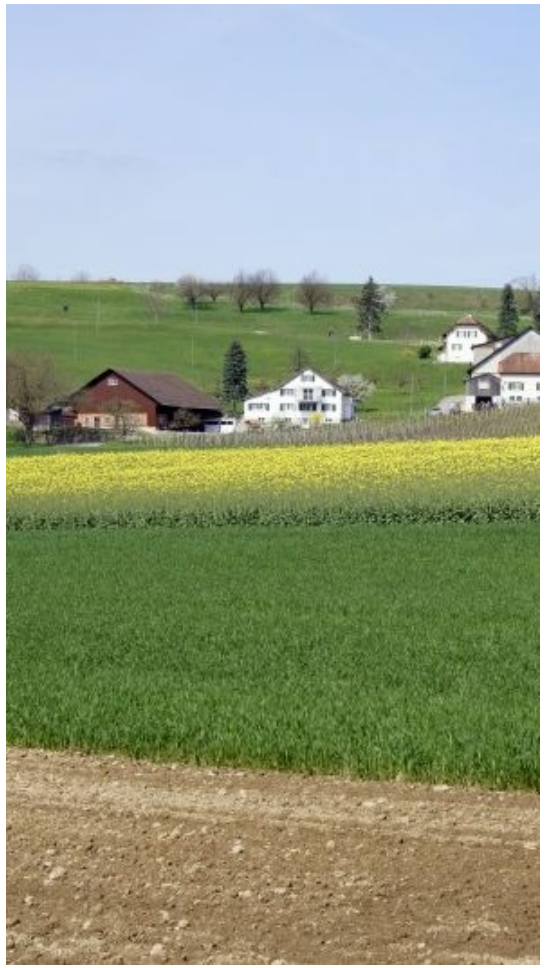
Outcrop Data Challenges:
- Low number of good outcrops
- Almost no horizon tops!

First prize ...



Last prize ...

No prize ...

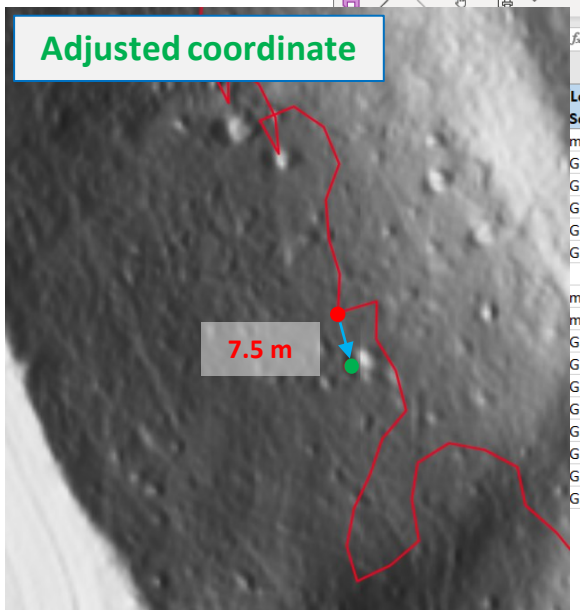


Modelling Data

Outcrop data 2/2

Field Trips:

- 20230418
- 20230426
- 20230524
- 20230530
- 20230606
- 20230706
- 20230717
- 20231219
- 20240206
- 20240326
- 20240716 → Coords, Maps, Pics → 207_09h52, 209_10h15, 211_10h48, 212_11h57, 213_14h38
- 20241003
- 20241023

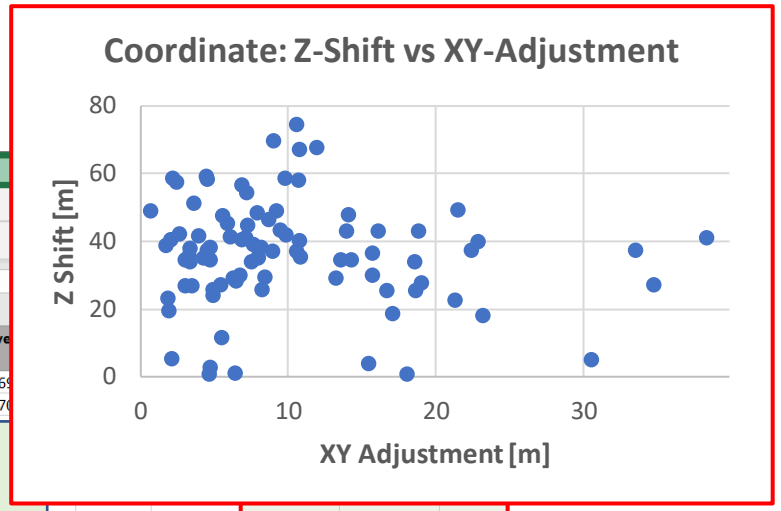


Transformed and corrected coordinates ...

Lon, LV95)											
Source1	Waypoint File	Date	Time		X2	Y2					
map.geo.admin			-		2674790.4	1266					
Garmin GPSmap 62sc			11h22		2674843.143	1267					
Garmin GPSmap 62sc											
Garmin GPSmap 62sc											
Garmin GPSmap 62sc											
Garmin GPSmap 62sc											
map.geo.admin							491.6		2683662.1	1275229.5	491.6
map.geo.admin							485.6		2683586.9	1275277.4	485.6
Garmin GPSmap 62sc	Waypoints_06-JUN-23.gpx		09h55		2683491.002	1275381.425	471.4801	REFRAME	2683491.0	1275381.4	528.8
Garmin GPSmap 62sc											
Garmin GPSmap 62sc											
Garmin GPSmap 62sc											
Garmin GPSmap 62sc											
Garmin GPSmap 62sc											
Garmin GPSmap 62sc											

Tools:

- REFRAME
- mag.geo.admin + Hillshade



Horizon markers ...

Aufschluesse.xlsx - Excel

	Name	Use	Datentyp	X	Y	Z	GPS_Nr	Date	Time	Location	Pic	Horizon
21	2674424_1267334	1	2.1	2674423.6	1267334.2	458.9	188	20240206	15h40	"	IMG_20240206_152554_1.jpg IMG_20240206_154319_1.jpg	TUSM
	2674430_1267430	1	2.1	2674430	1267430	459.4	186	20240206	15h12	"	IMG_20240206_150709_1.jpg > IMG_20240206_152105_1.jpg	nTUSM
	5_1267429	1	2.1	2674435	1267429	456.3	185	20240206	15h06	"	IMG_20240206_150654_1.jpg > IMG_20240206_152105_1.jpg	USM
	8_1266794	1	2.1	2674488	1266794	452.9	130	20230530	11h21		IMAG4085.jpg > IMAG4200.jpg	nTOMM
	4_1273569	1	2.1	2674724	1273569	523.6	212	20240716	11h57	Kalter Wangen (DE)	IMG_20240716_115716_1.jpg > IMG_20240716_120140_1.jpg	nBOMM
25												

Waypoints_16-JUL-24.csv ... **WGS84**

```
207;8.47062;47.60838;543.4
208;8.47061;47.608352;545
209;8.469832;47.609472;529.3
210;8.469798;47.609514;529.3
211;8.47196;47.60859;538
212;8.432412;47.608583;533.3
213;8.613836;47.547257;510.5
```

Modelling Data

Overview - all available data

Boreholes Markers (nBH=352, nBHm=902)

- TOMM (n=57) **16%, 6%**
- TUSM (n= 79) **22%, 9%**

Outcrops (nOC=166)

- TOMM (n=1) **<1%**
- TUSM (n=6) **4%**
- nTUSM, nTOMM…

Manual Constraint Points (CPs):

- TOMM (n=10)
- TUSM (n=20)

GA25 Map Sheets

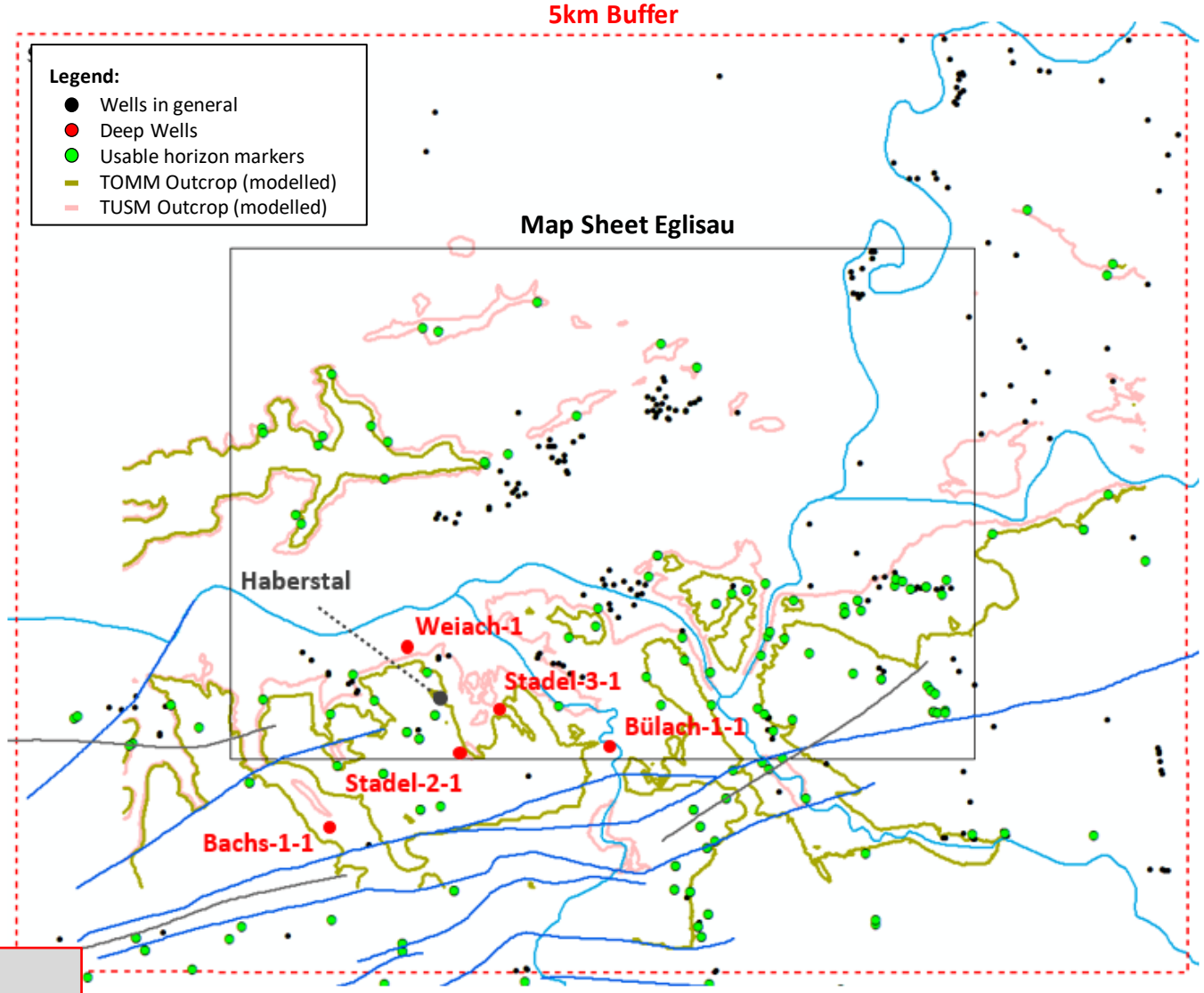
- Neunkirch (N), Diessenhofen (NE)
- Andelfingen (E), Winterthur (SE)
- Bülach (S), Baden (SW)
- Zurzach (W)

TK500

- Anticlines/Synclines
- Fault zones

GeoMol

- Faults (proj.) [Nagra, Etappe 2]



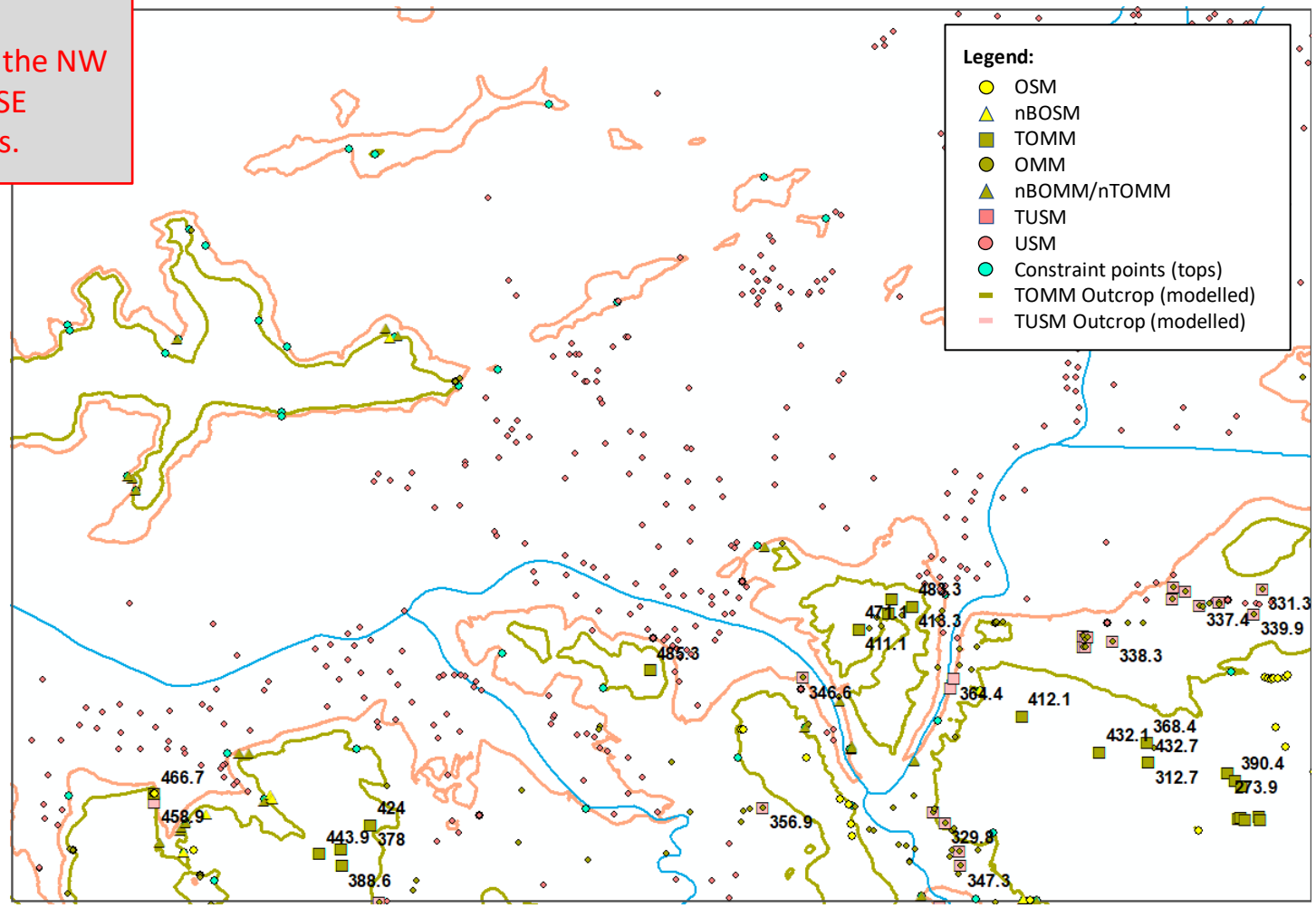
Main Challenge:

- <14% of all geol. horizon codes are actual tops

Modelling Data

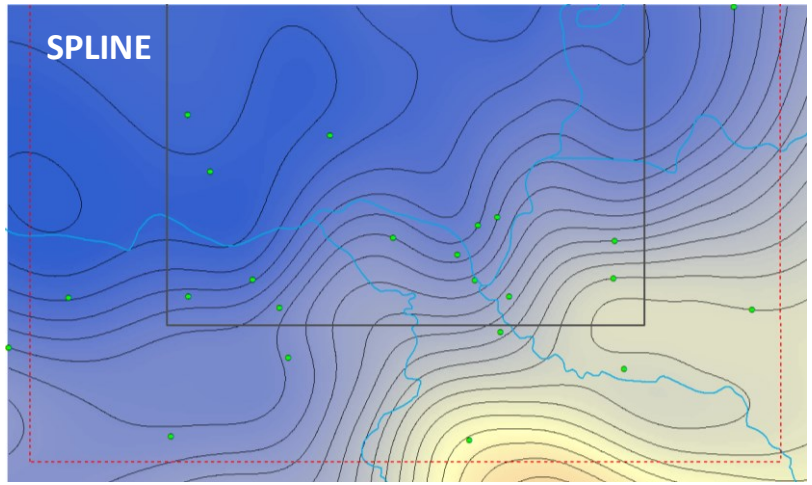
Distribution of horizon tops

Main Challenges:
- Insufficient number of tops, especially in the NW
- Predominantly USM in NW and OMM in SE
- Very few primary TOMM-TUSM data pairs.

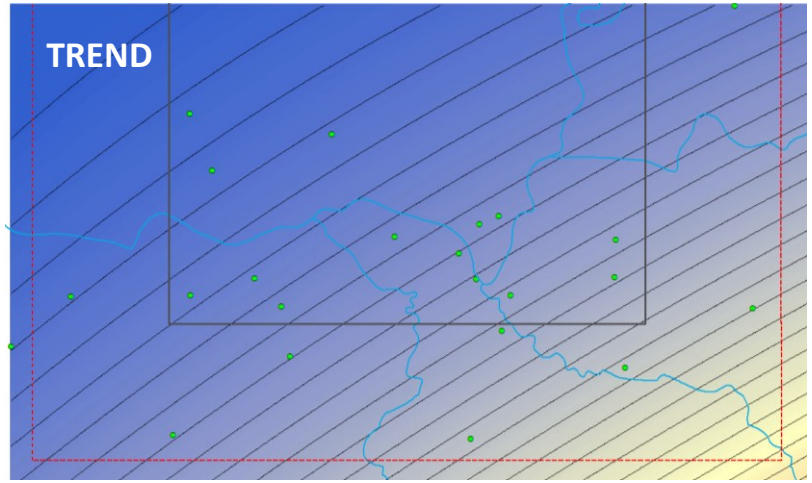


Modelling Data

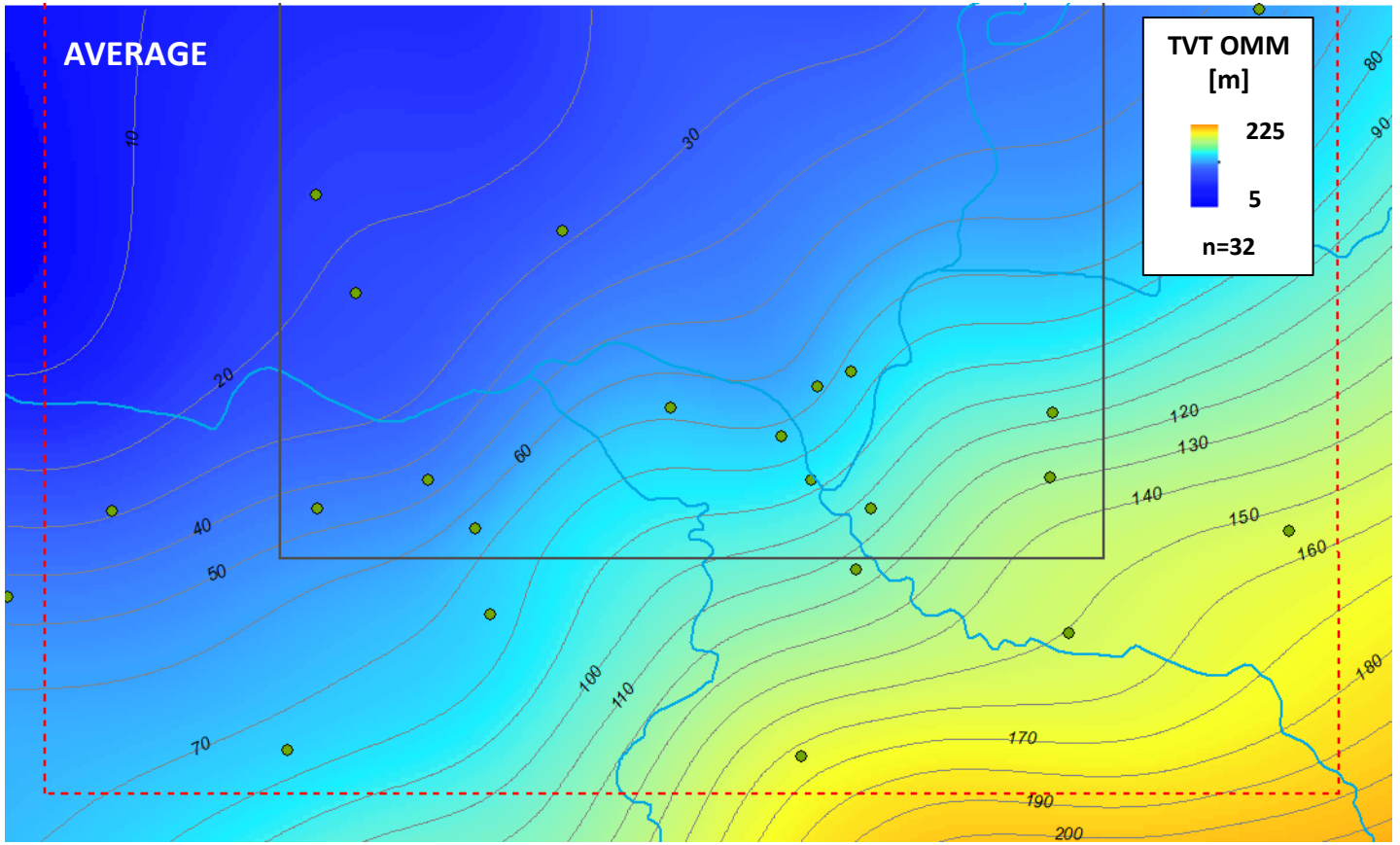
OMM “average” thickness grid used to generate missing tops in TOMM-TUSM pairs



Average

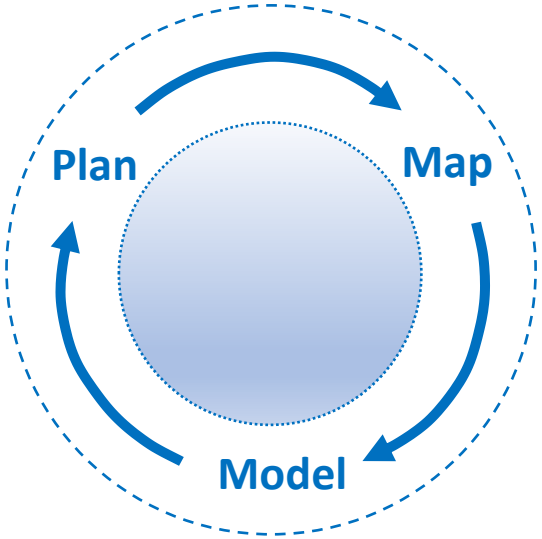


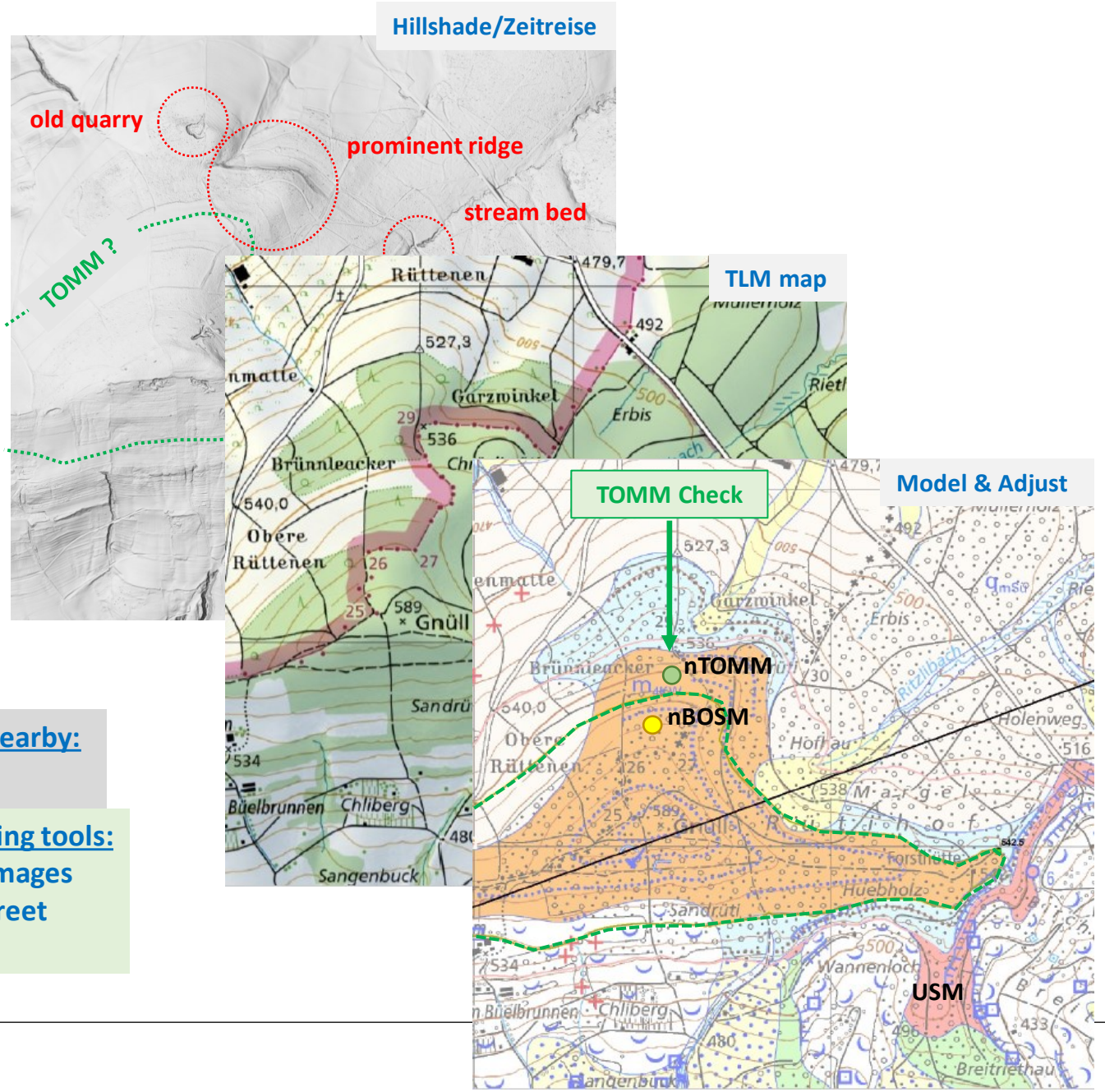
This method more than doubled the number of usable TOMM-TUSM pairs!



Modelling Data

Outcrop mapping cycle





Identify potential mapping locations based on nearby:

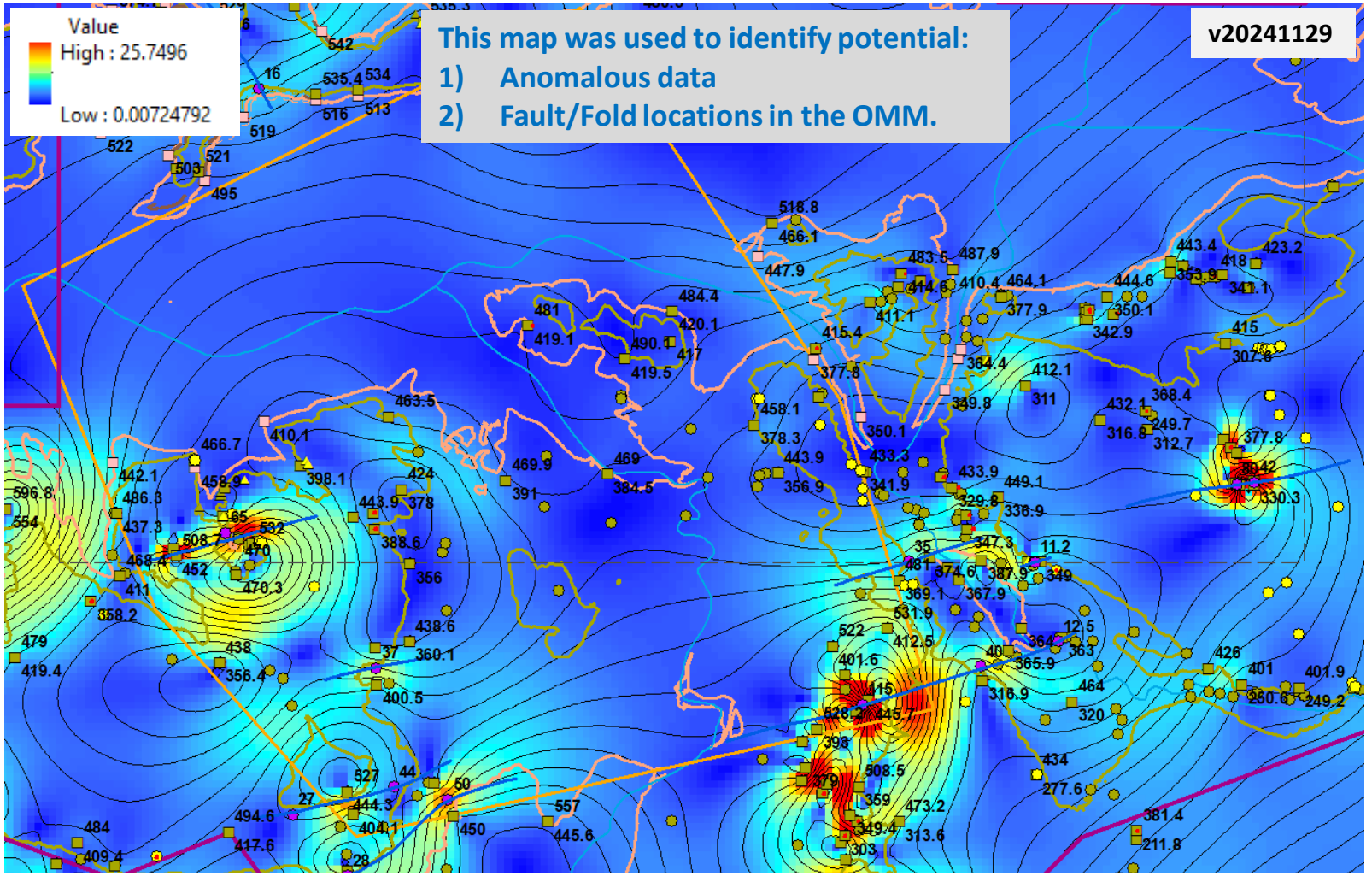
- stream/river beds
- (old) quarries
- road/track/path cuttings
- ridges/cliffs
- bedrock

Other planning tools:

- Satellite images
- Google Street View

Model Analysis and QC

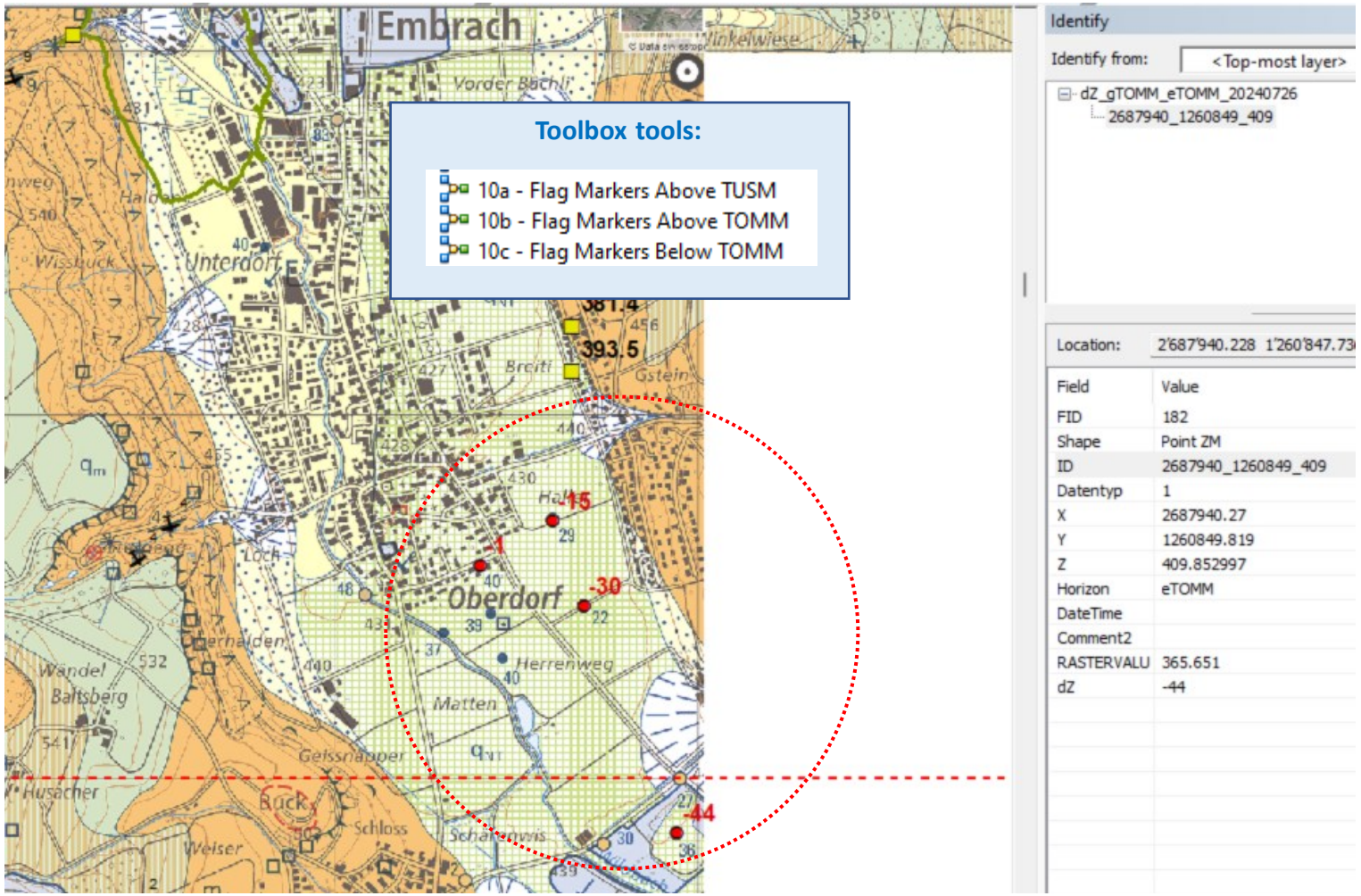
TOMM horizon surface gridded WITHOUT faults highlights Dip anomalies



Model Analysis and QC

QC of borehole data

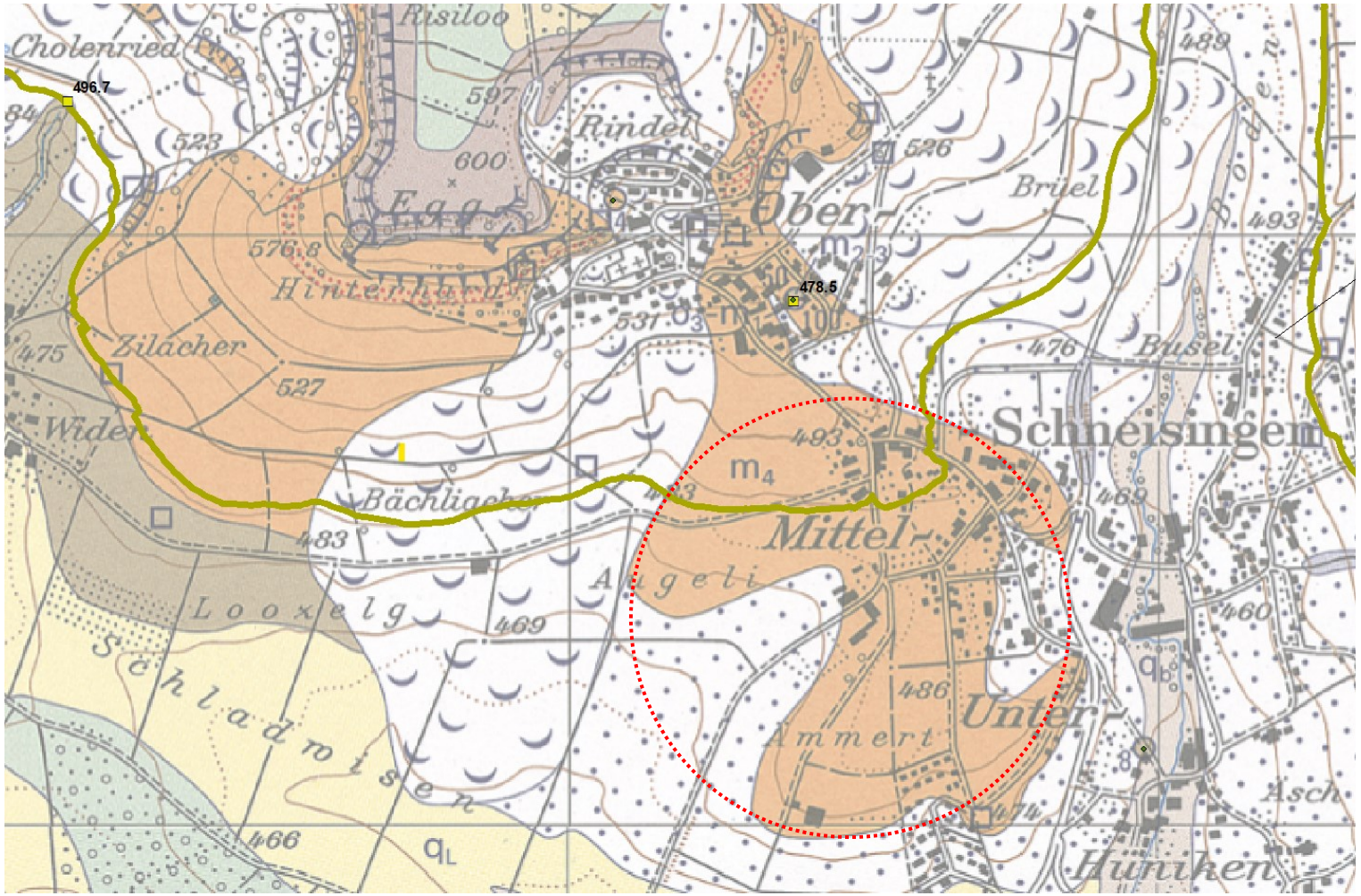
eTOMM errors - Embrach (2669539, 1263414) , GA25 sheet «Bülach»



Model Analysis and QC

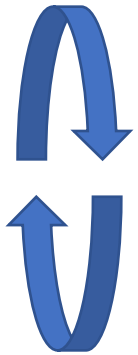
QC of existing map sheets

Error OSM - Schneisingen (2669539, 1263414), GA25 sheet «Baden»



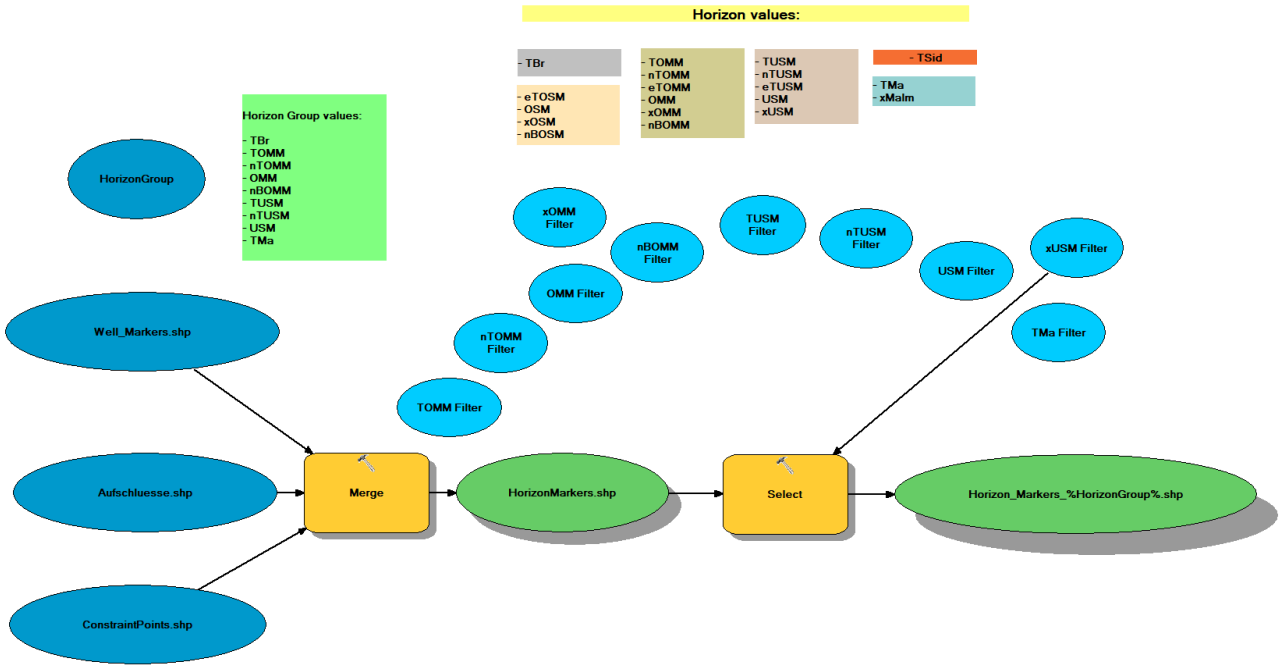
Modelling Workflow

(Semi)automated ... as far as possible ...



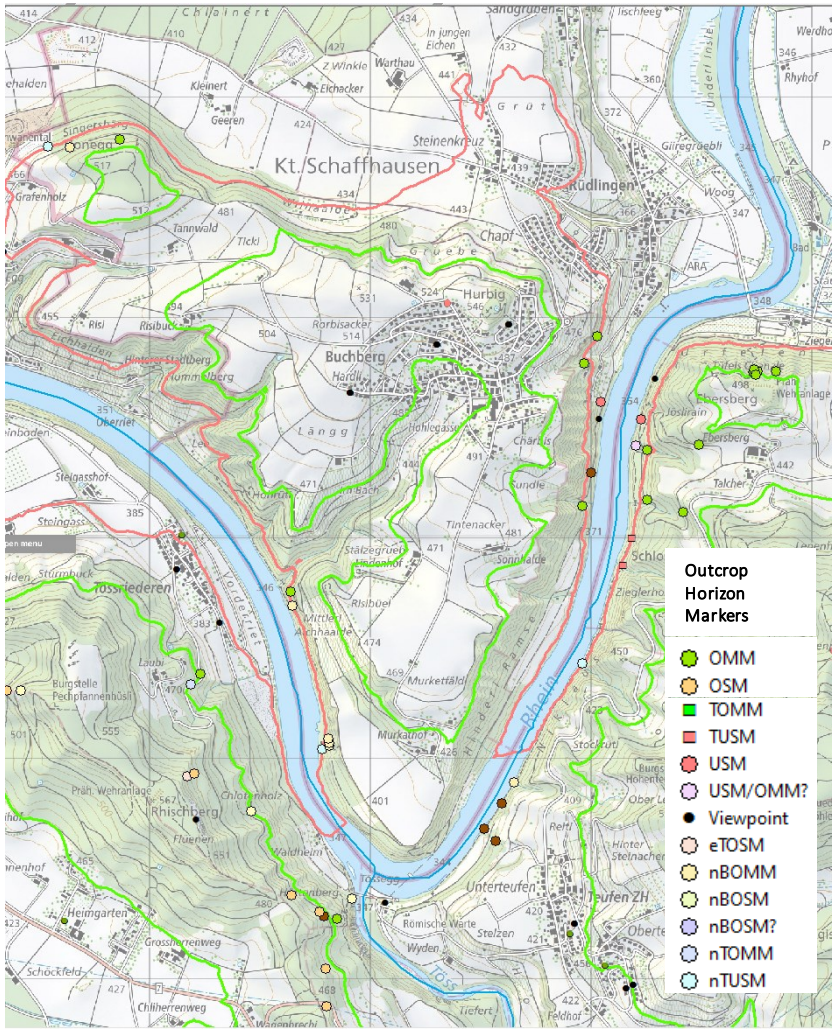
- Eglisau_20240924.tbx
  - 00 - Delete_TempFiles
  - 01 - Eglisau Buffer 5km - BROKEN
  - 01 - Raster to GDB
  - 02a - Select InfoGeolPoints - Blatt Eglisau +5km
  - 02b - Select InfoGeolPoints - Buffer Zone Only
  - 02c - Select InfoGeolPoints - Not Lockergestein
  - 03a - Select Hillshade raster - Blatt Eglisau + 5km
  - 03b - Select ALTI3DRegio - ModelData Limit
  - 04a - Merge Geocover Well Points
  - 04b - Generate GCWPt Horizon Markers
  - 06a - XLS to DB
  - 07a - Generate TVT_OMM Data - BHs - ONCE ONLY
  - 07b - Generate TVT_OMM Data - OCs - ONCE ONLY
  - 07c - Merge TVT_OMMs - ONCE ONLY
  - 07d - Interpolate TVT - Spline and Trend
  - 07e - Gen Ave TVT Grid
  - 08a - Generate BH CPs from TVT - TOMM
  - 08b - Generate BH CPs from TVT - TUSM
  - 08c - Generate CP CPs from TVT - TOMM
  - 08d - Generate CP CPs from TVT - TUSM
  - 08e - Merge and Filter - Horizon Markers
  - 08f - Generate Use 0 Buffers - ONCE ONLY
  - 09a - Flag Horizon Markers - Use 0
  - 09b - Interpolate Horizon - RBF - AnomDect - TEST
  - 09c - Interpolate Horizon - TTR - AnomDect - TEST
  - 09d - Interpolate Horizon - Spline - without Faults
  - 09e - Interpolate Horizon - SWB - with Faults
  - 09f - Generate Horizon Contours

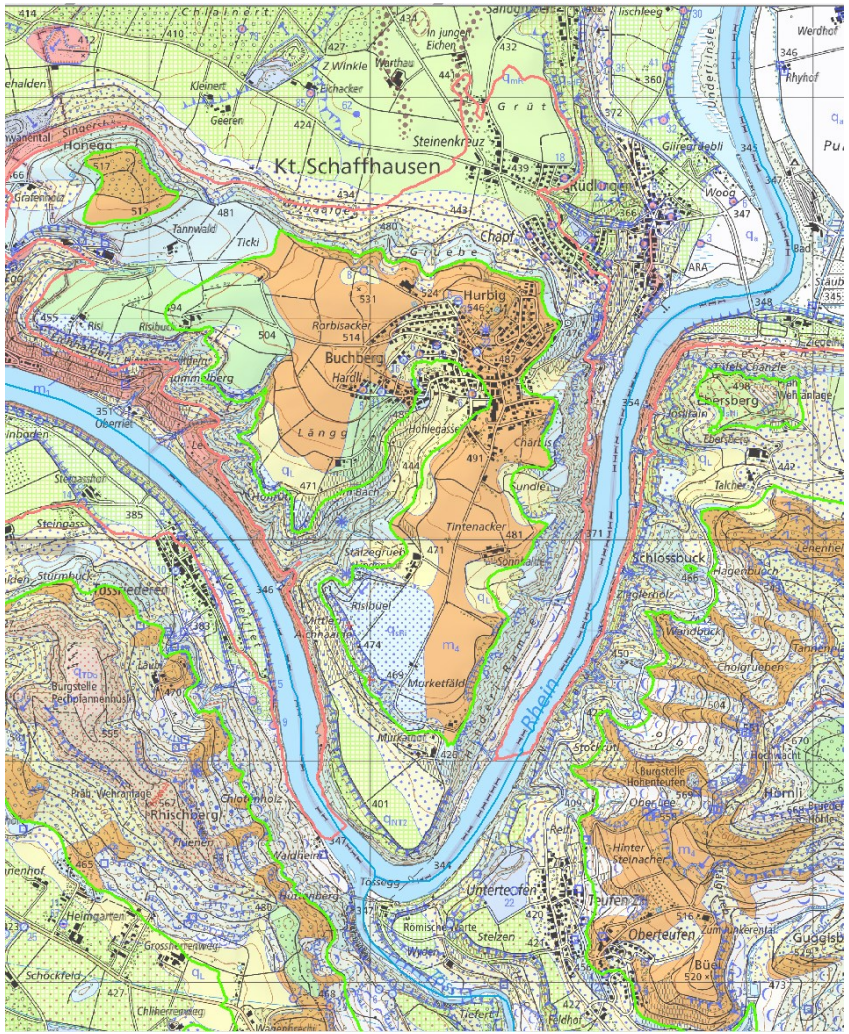
ArcGIS Toolbox: Semi-automated modelling workflow enables faster turnaround and more model iterations.



Modelling Output

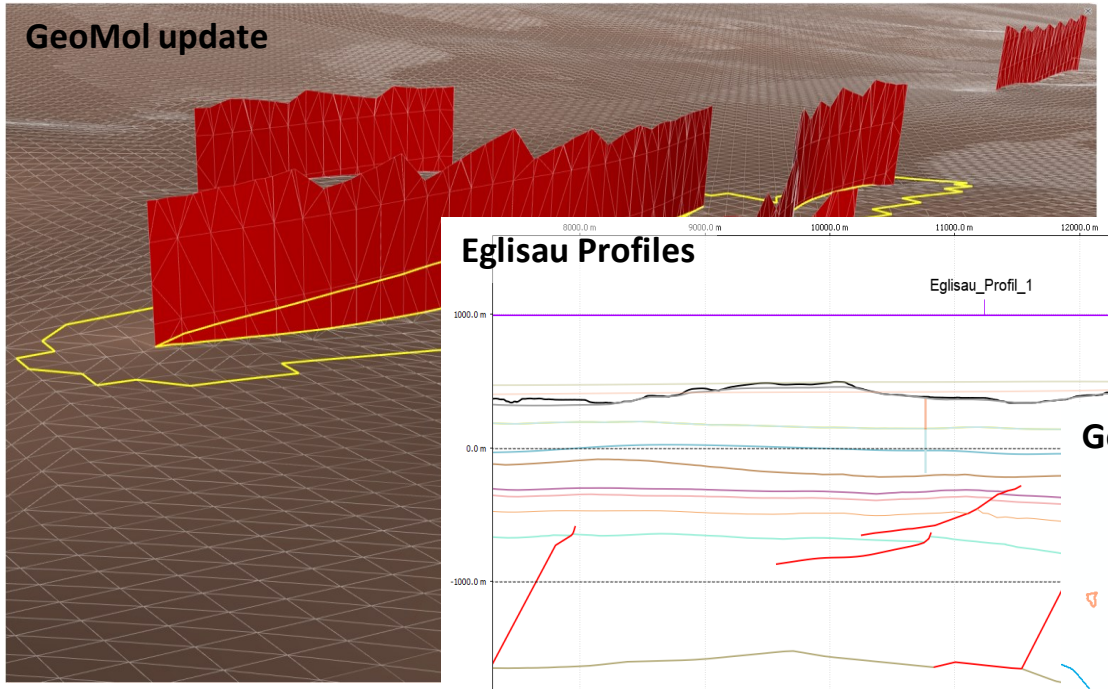
Modelled Outcrop Lines > Input for GA25 map sheet Eglisau

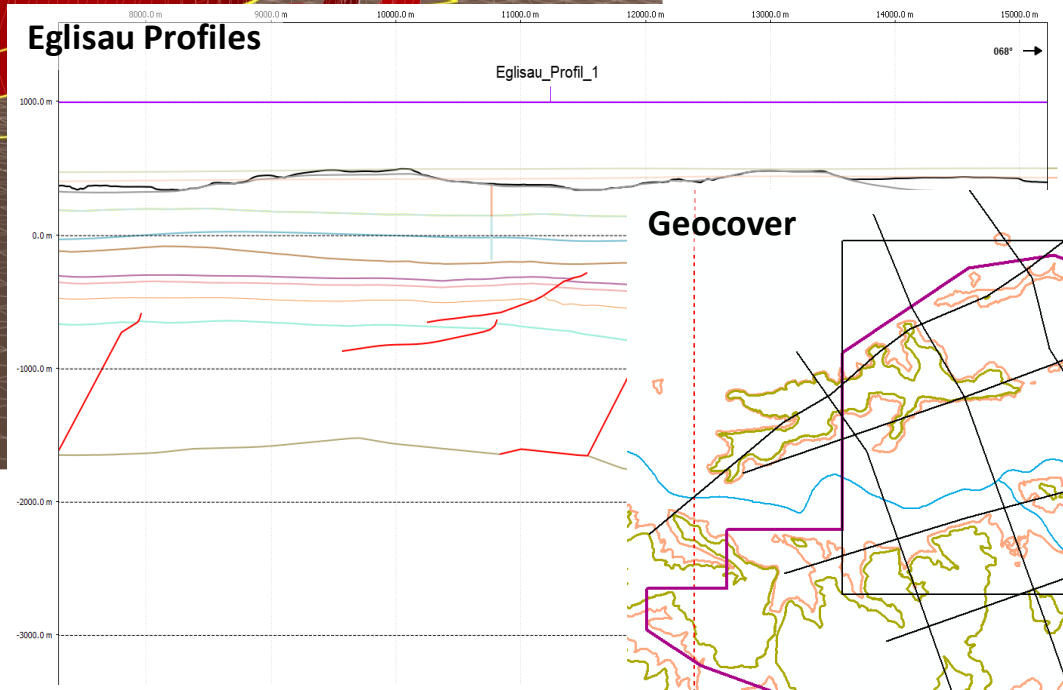


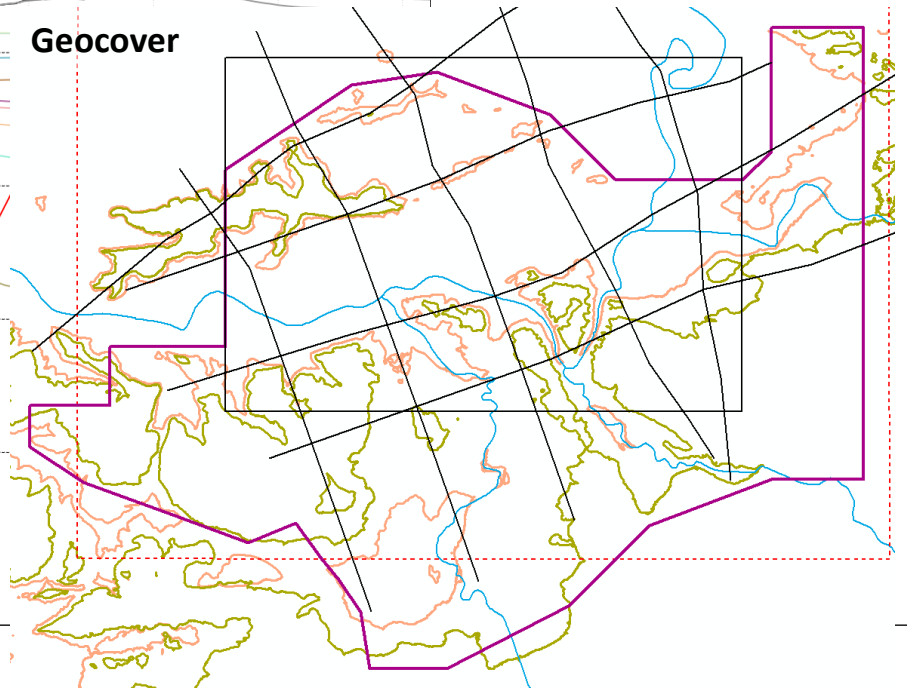


Modelling Output

Horizon surfaces and outcrop lines for GeoMol update, Eglisau profiles and GeoCover ...







Questions?

Thank you ...