A review of mapping fault topography since 1980s:

plane table, TS, RTK-GPS, LiDAR, and the future

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In Japan: fault mapping = fault trace locating.

Since Matsuda and Okada in 1960s by airphoto interpretation skill, as if it is a goal of fault studies. with all maps and books only with traces.

Though mapping fault topography is important:

to objectively map faults.

to quantitatively depict deformations.

to understand fault mechanics and kinematics.

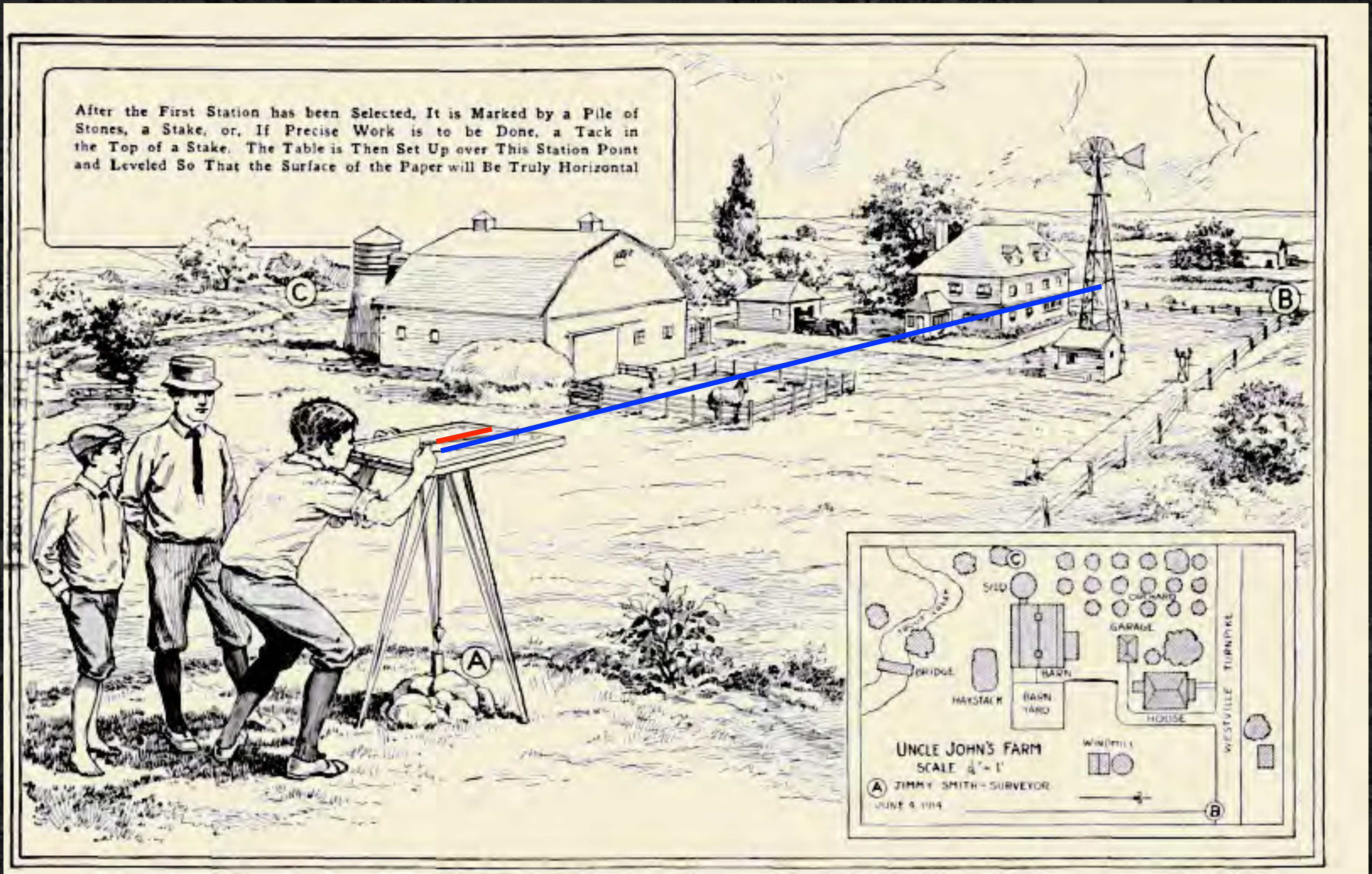
to record surface ruptures by big earthquakes

to record fault topography before destruction.

All these serve for seismic risk assessment.

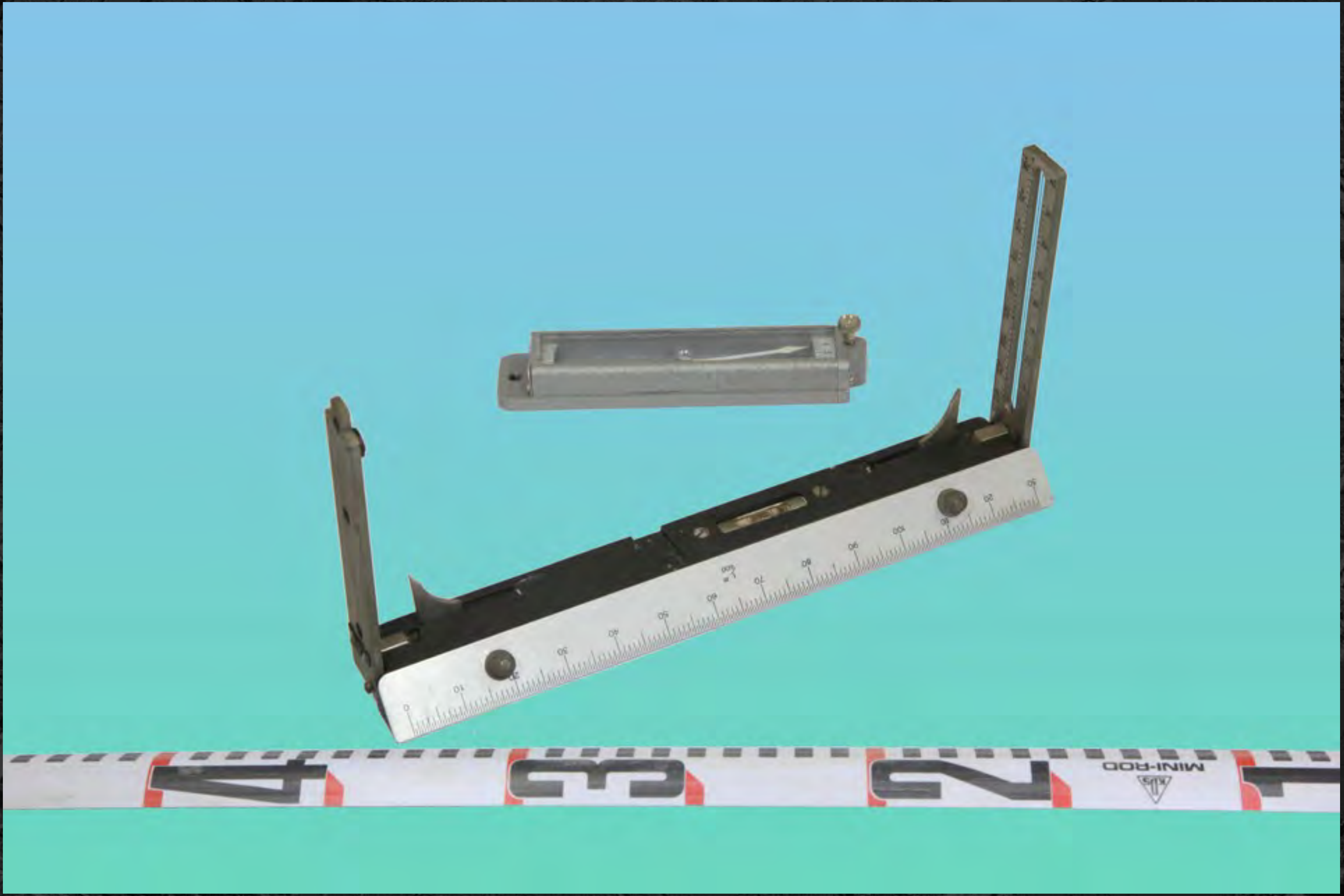
illusory and subjective
poor reproducibility
skill-dependent
essentially arbitrary
only prelimnary, not a goal

Be objective and scientific.
Be demonstrative.
Be quantitative.
Evidence is fault topography.
Just map topography!



However, it was a hard primitive age in 1980s.

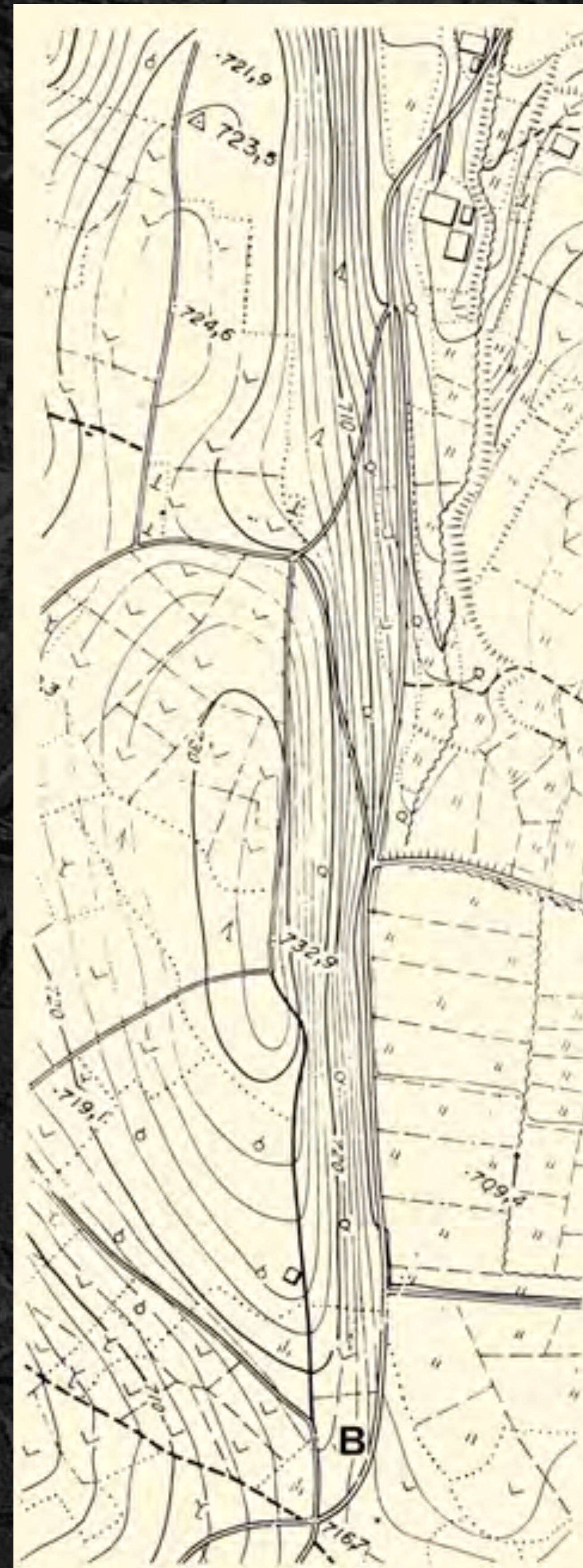
It began with tedious works on a plane table or 平板測量.

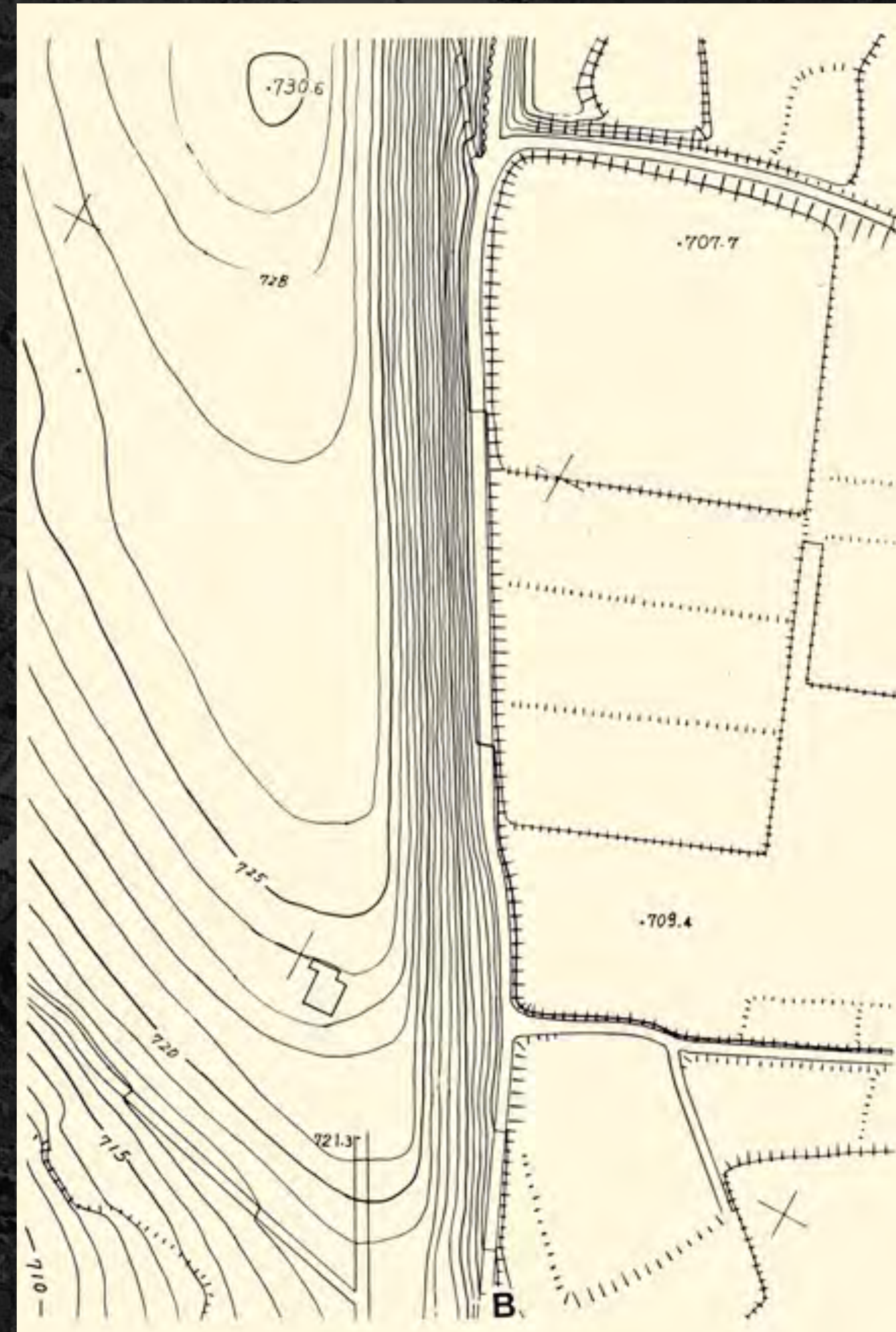


Alidade: aim and draw scaled analog map directly.

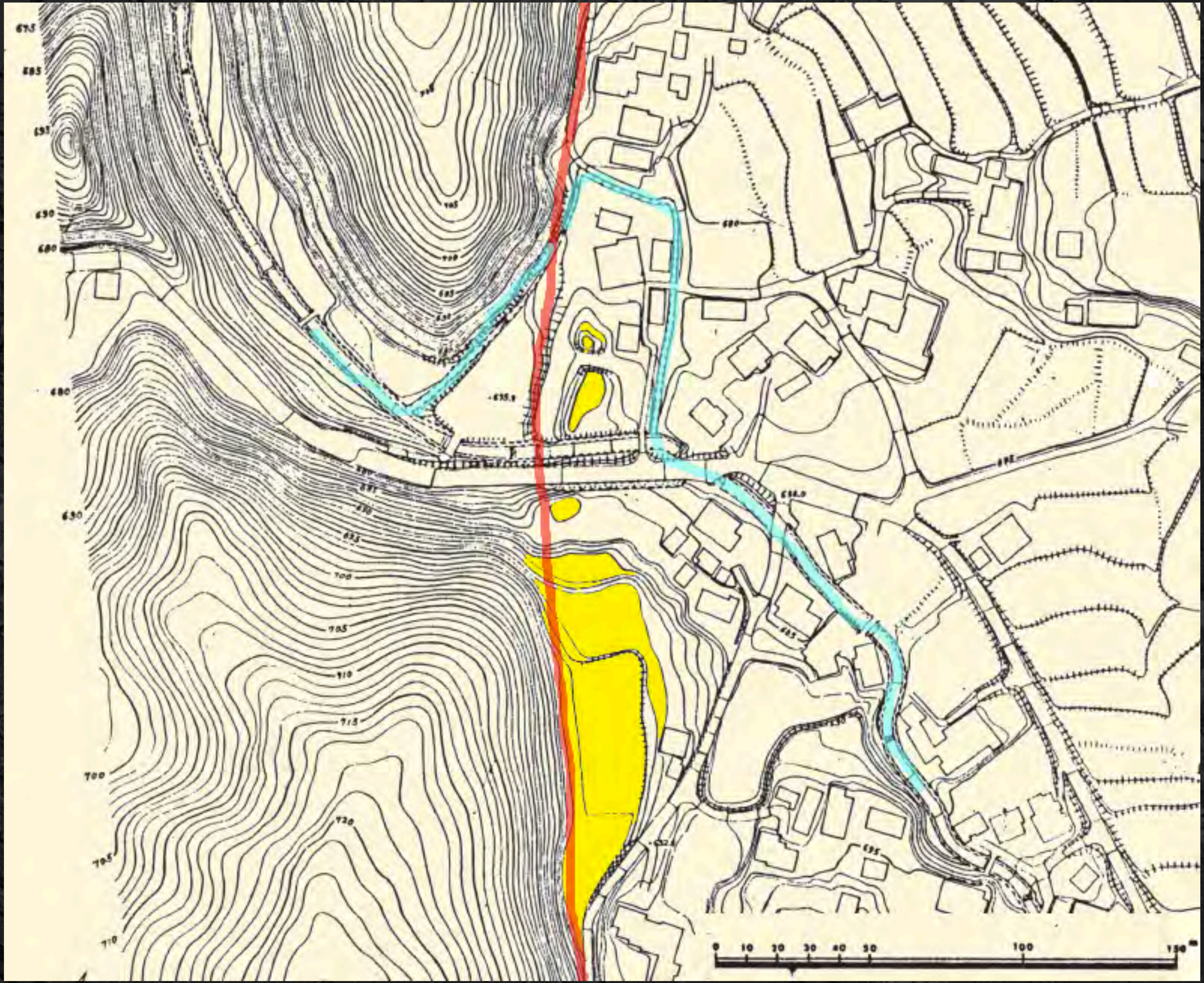
left: GSI 1/25000
center: city planning map 1/2500
right: plane table 1/500

Okumura, et al., 1987

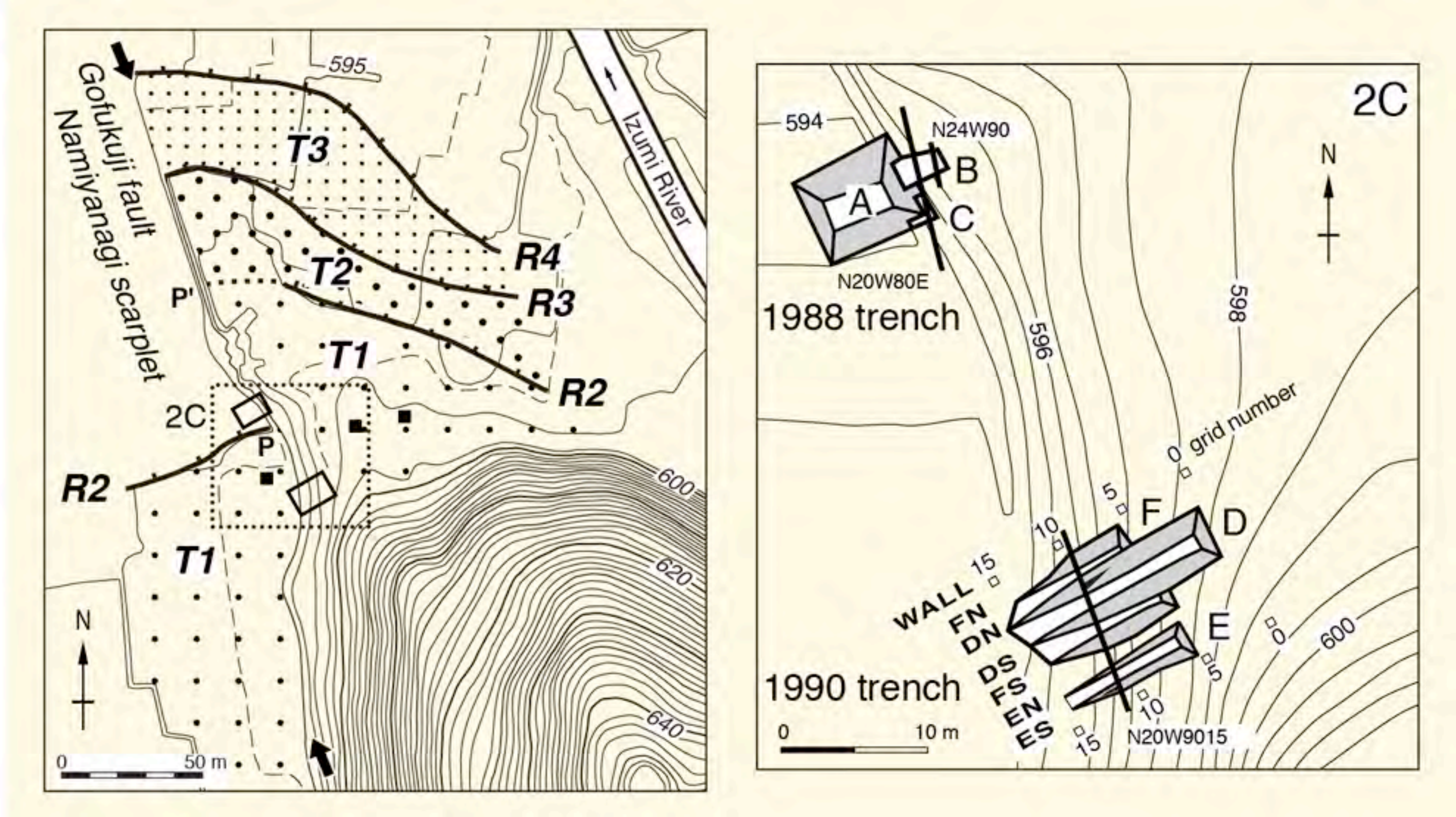




My first job at GSJ in 1987: contour lines are so cool!



GSJ surveyors did neat job on airphoto-mapping also.

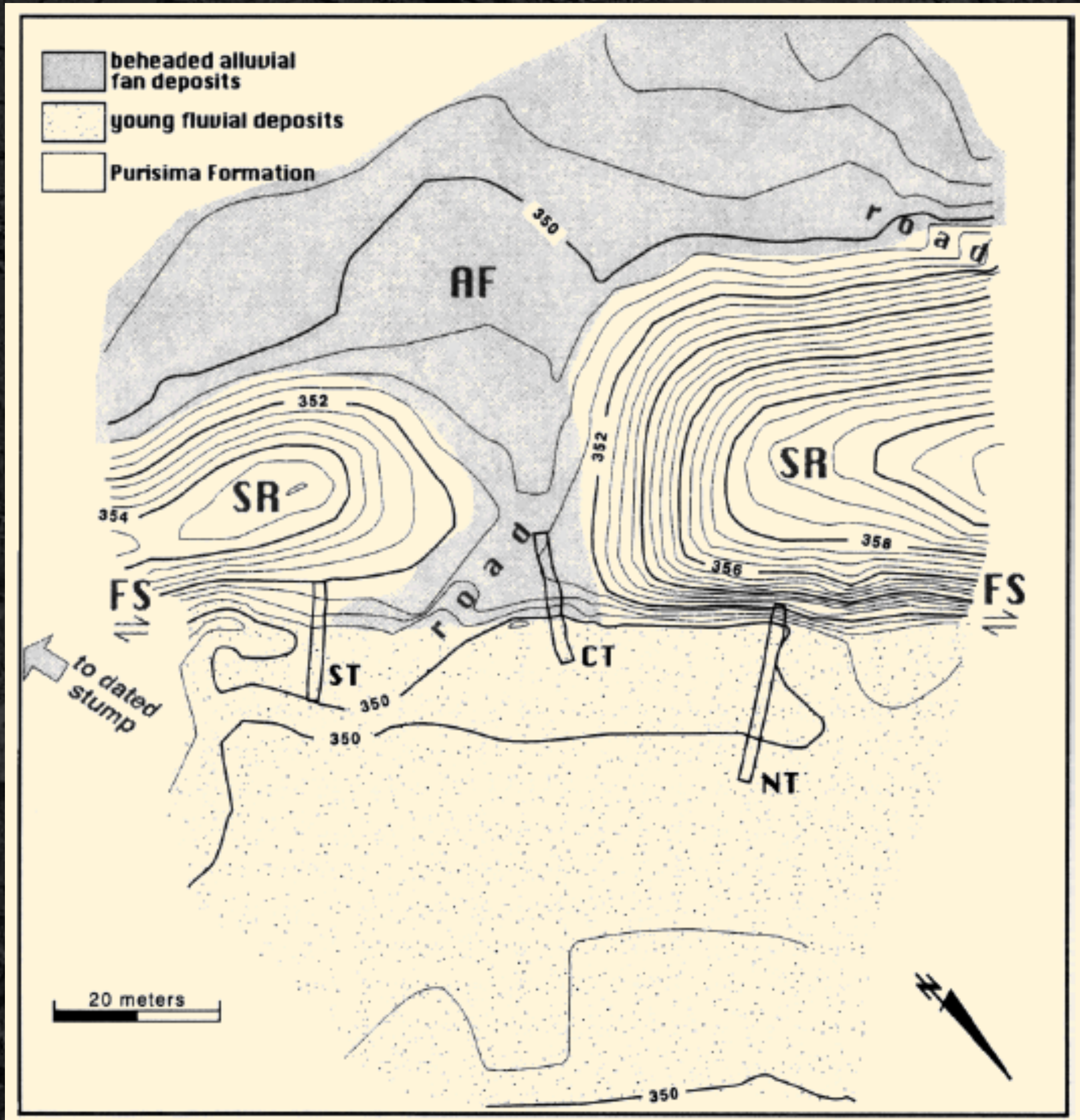


Okumura, 2001

1/500 topographic map of the ISTL at Matsumoto. For slip-rate estimation and my first trenching.

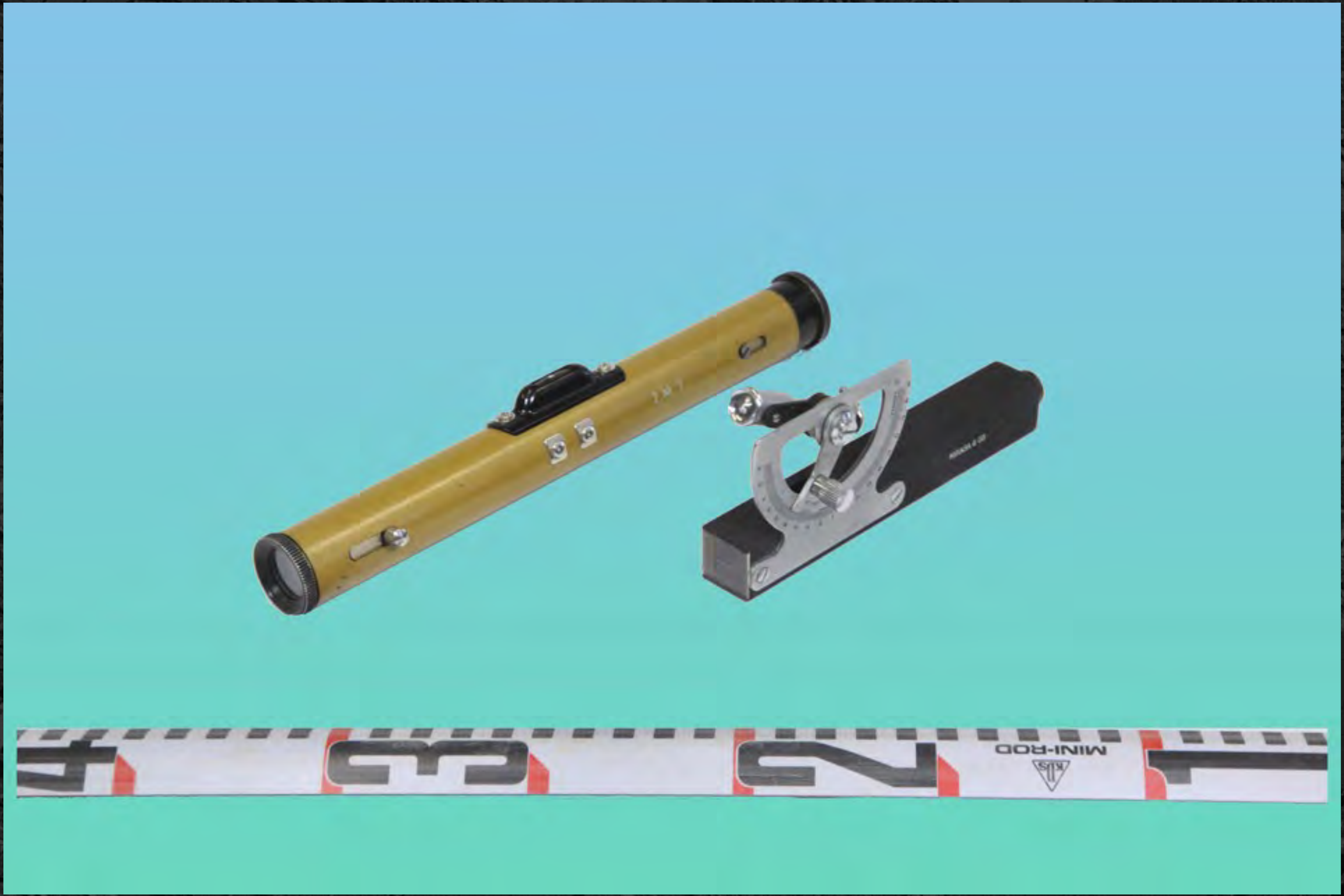
Encounter with Total Station, 1990 at USGS Menlo Park

John Hamilton, USGS: the pioneer of TS in geology.

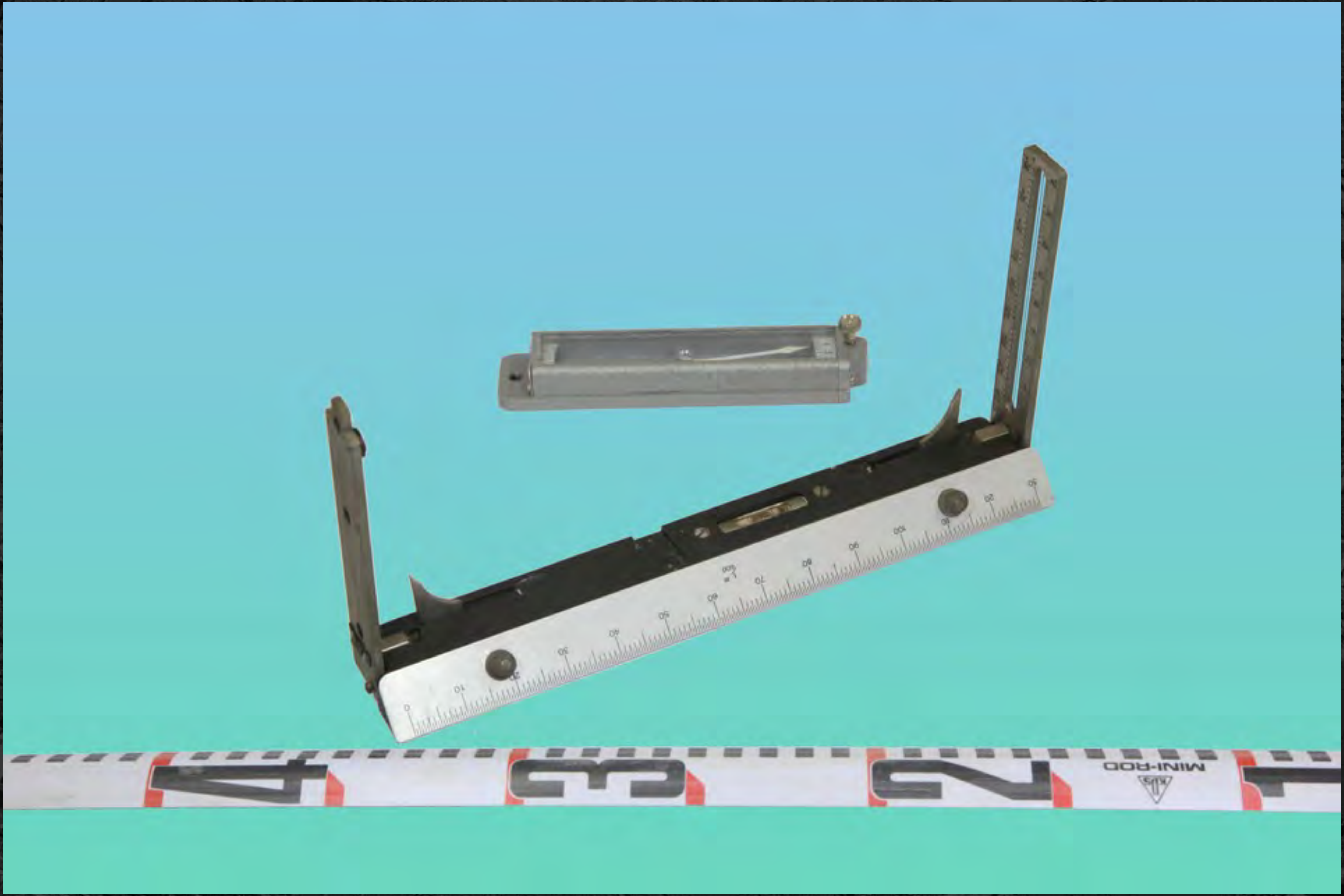


David Schwartz's Grizzly Flat trench on SAF (1990-91)
John Hamilton's TS map (Schwartz et al. 1998).

I was so happy for the encounter.

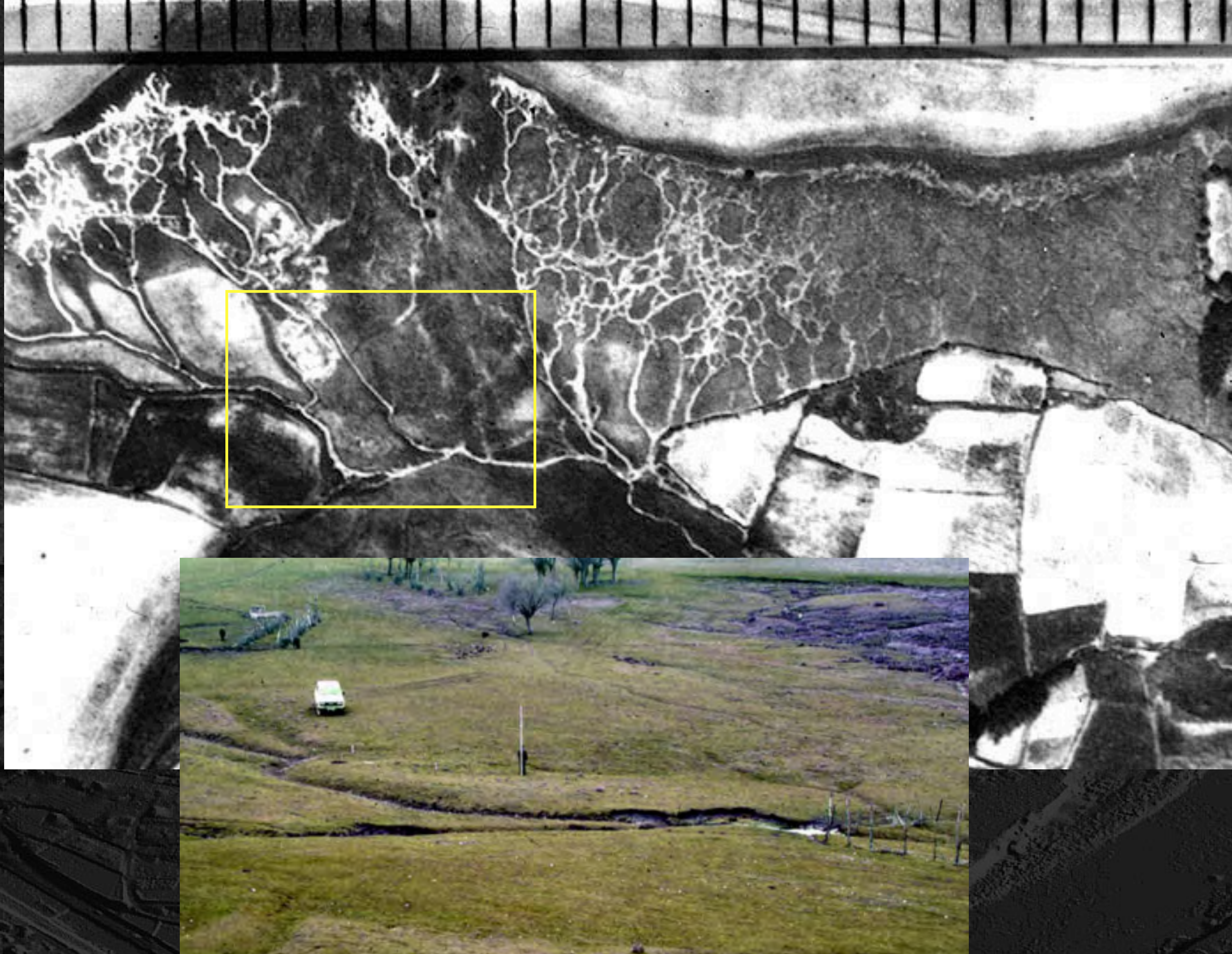


Back in Japan. In a stone-tool age... Hand Level

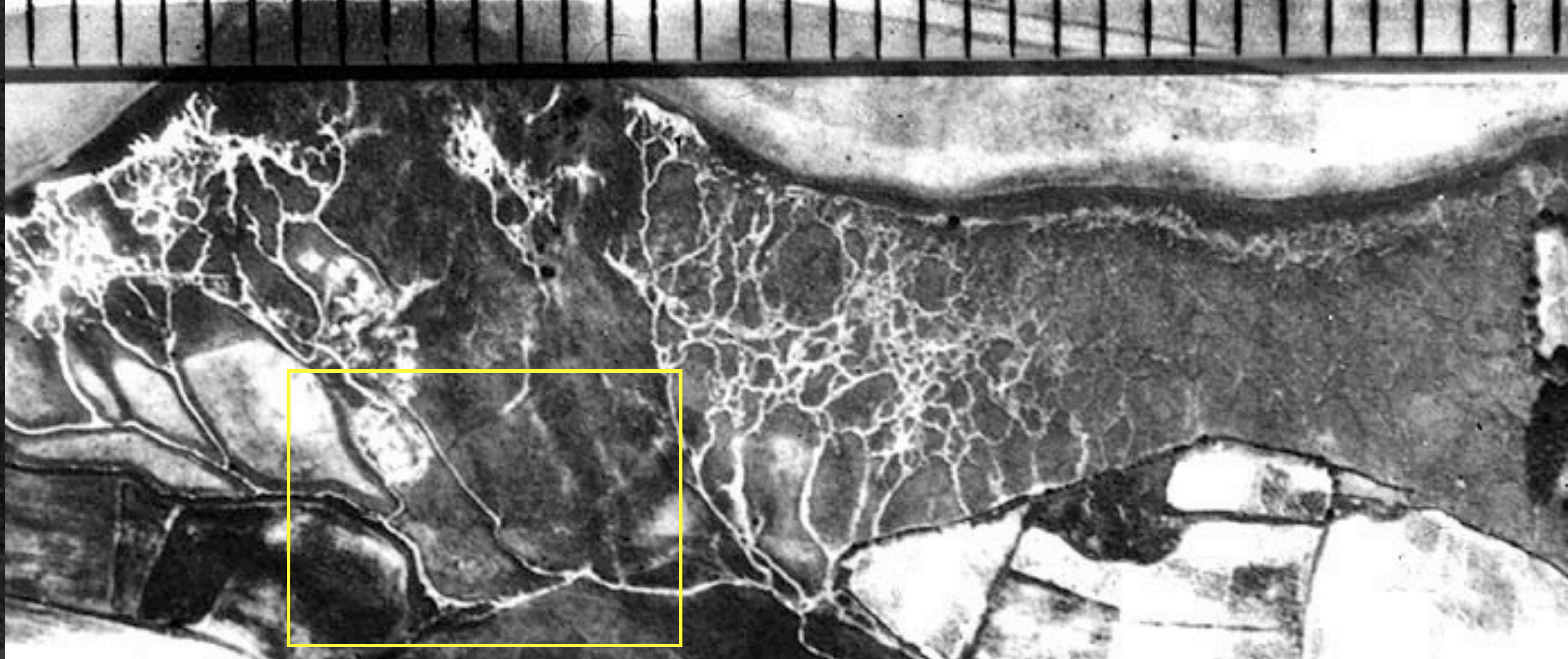


Back in Japan. In a stone-tool age... Plane Table...

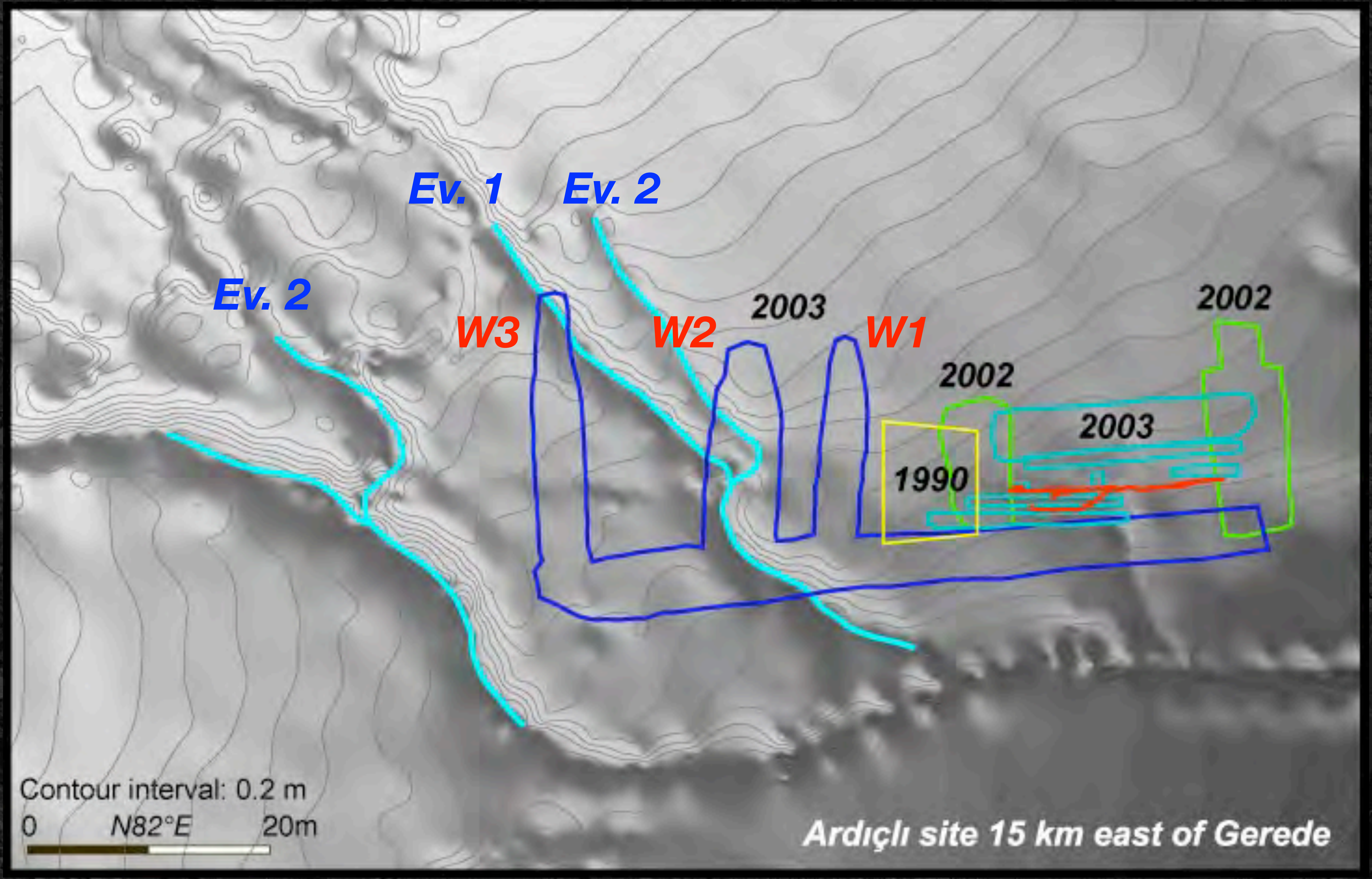
Back in Japan. In a bronze age... Automatic Level



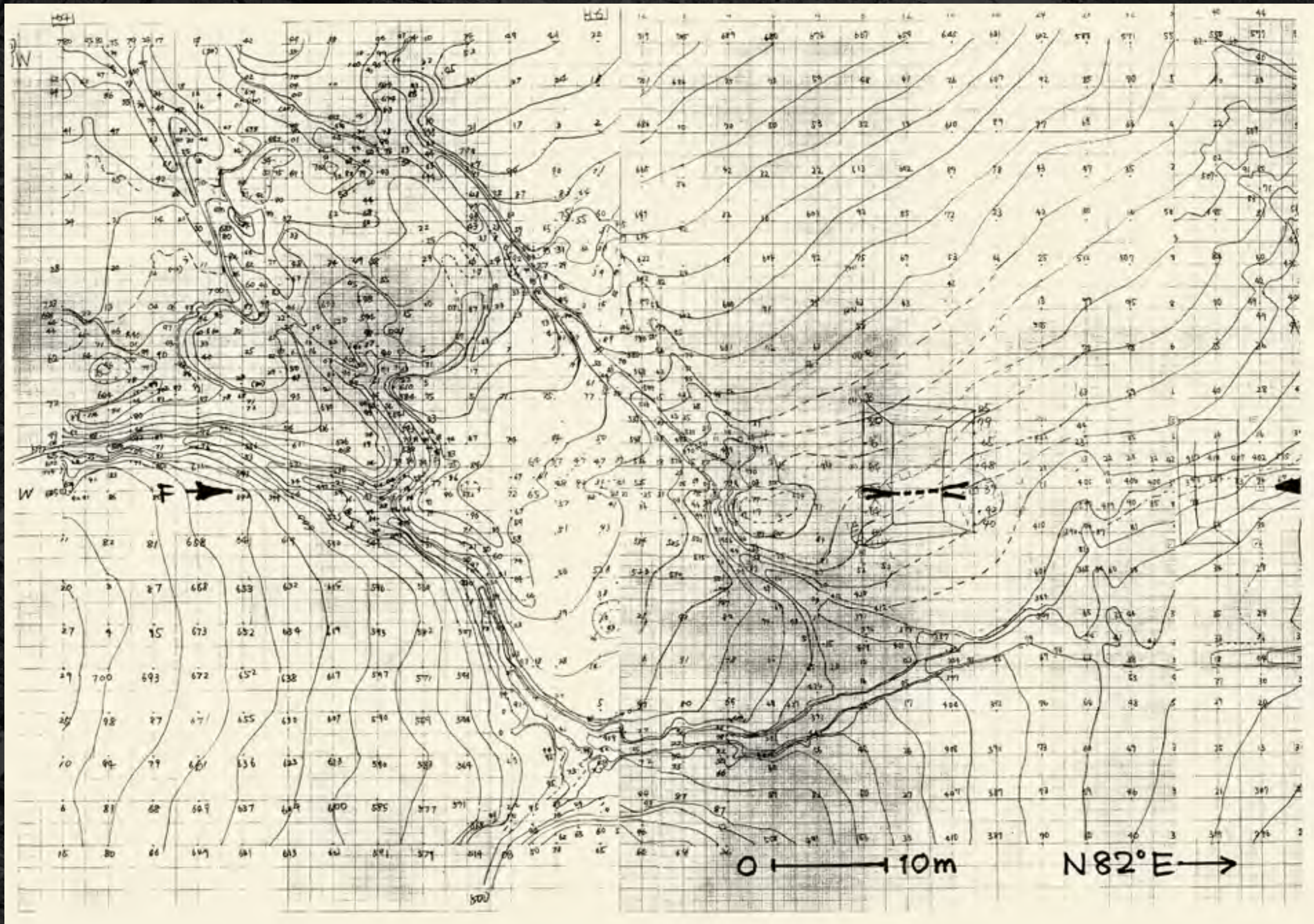
Gerede trench site on the North Anatolian fault in 1989.



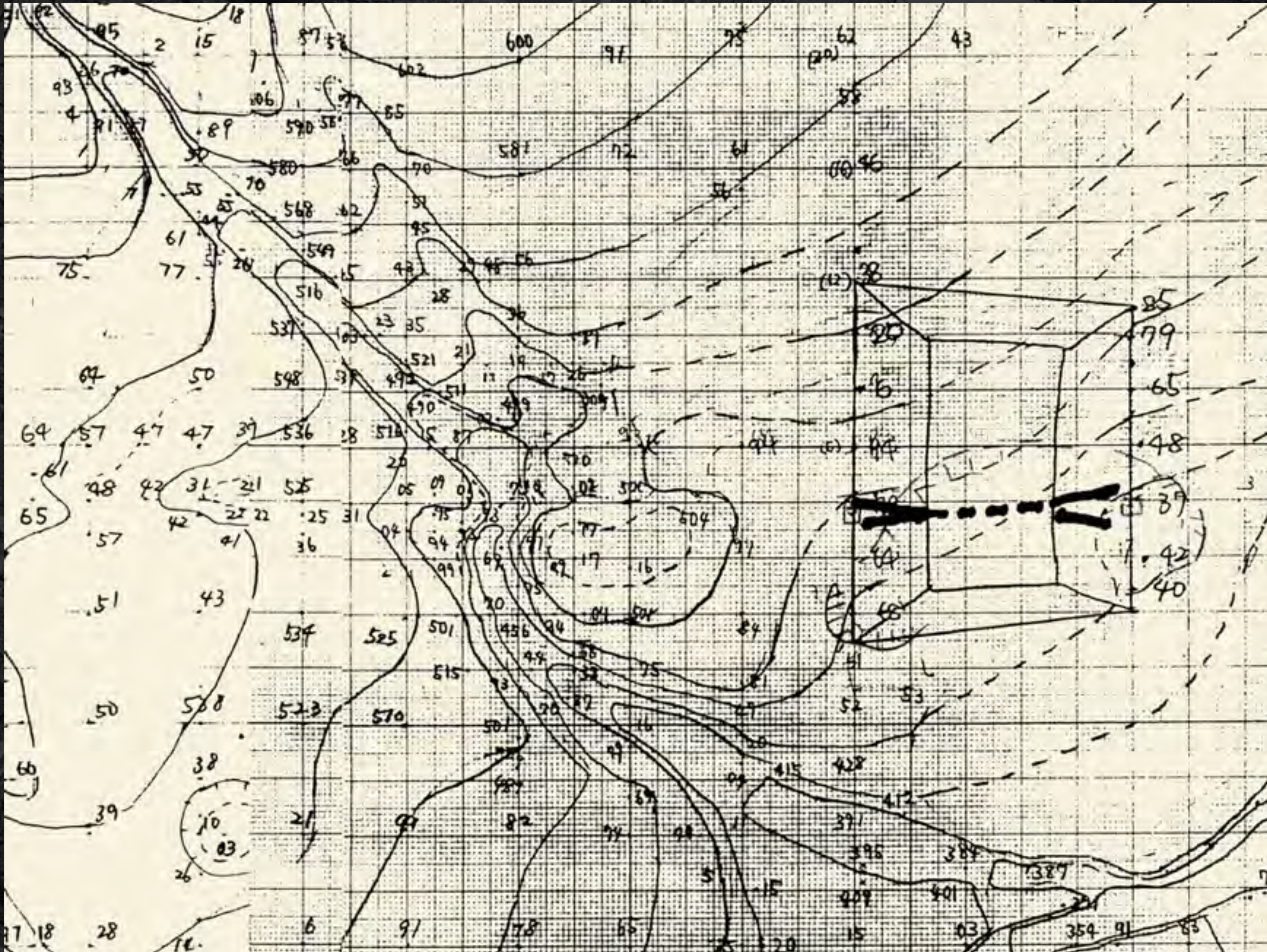
2003 Gerede trenches on the North Anatolian fault.
We should record topography before destruction.



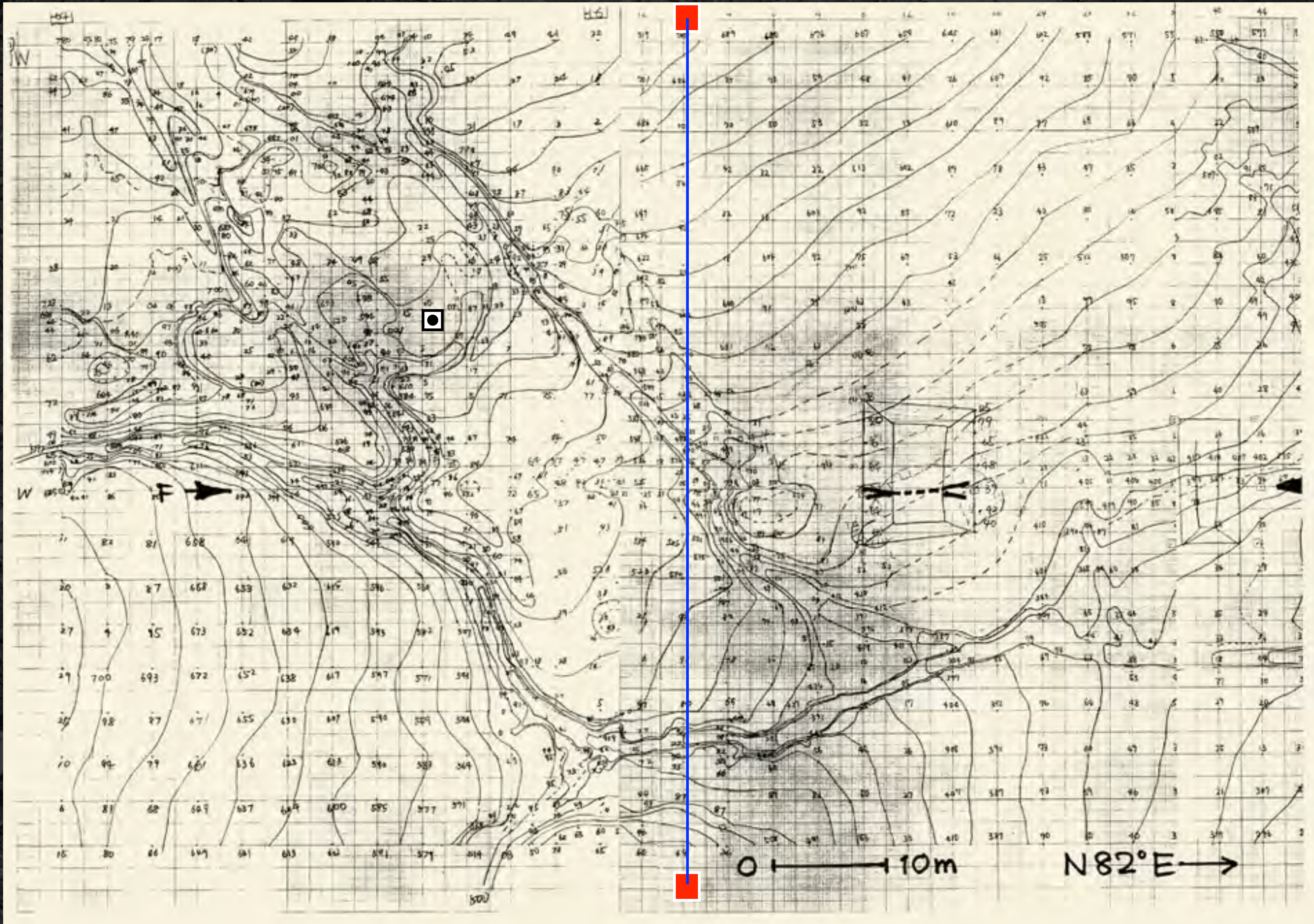
1993 automatic level map later processed with GMT.



3 days, 600 pts with level, staff, tape, and stakes.



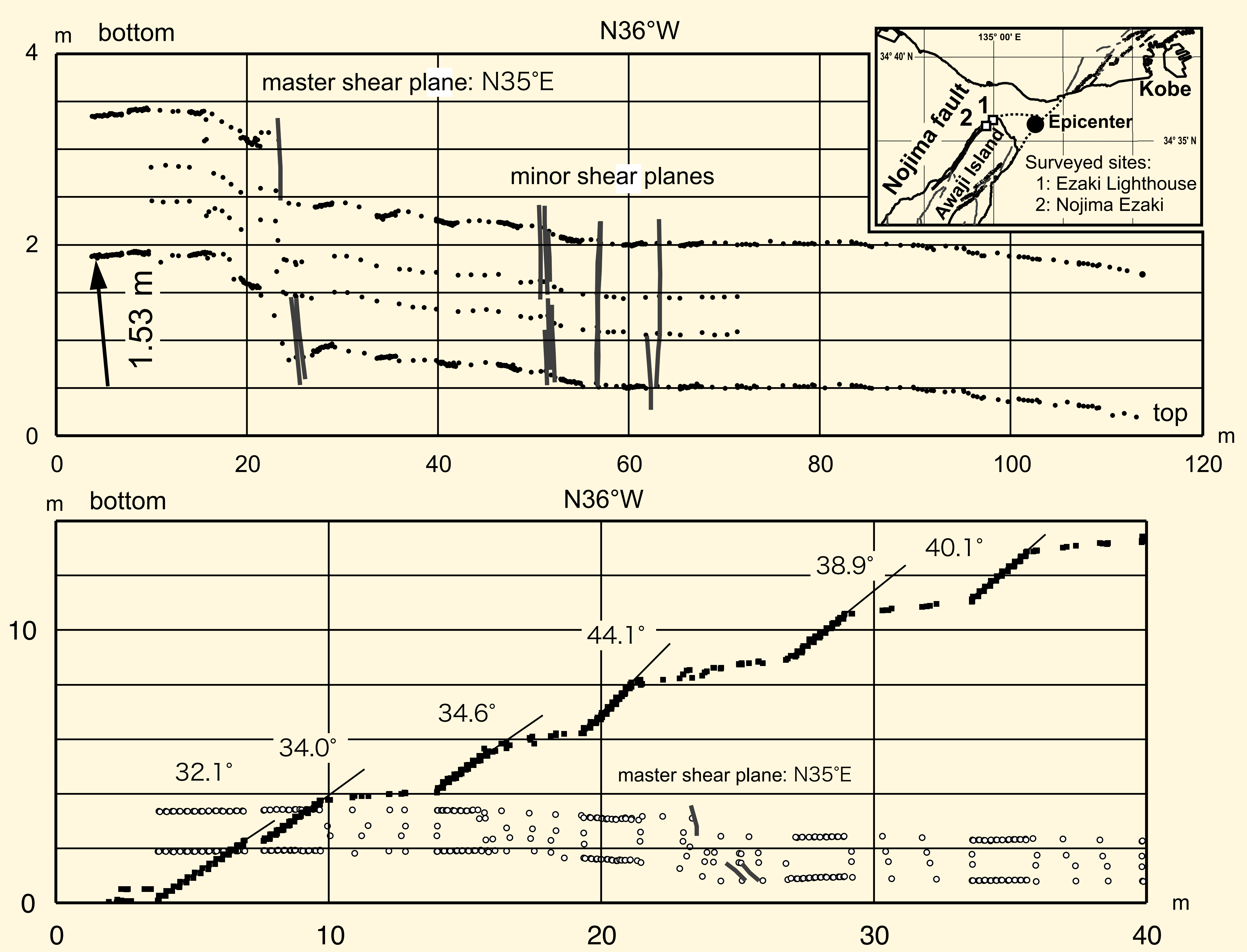
4 m mesh and details: Just as John instructed.



How level, staff, tape, and stakes worked together?

Jan. 17 1995 Kobe earthquakes urged rupture mapping.

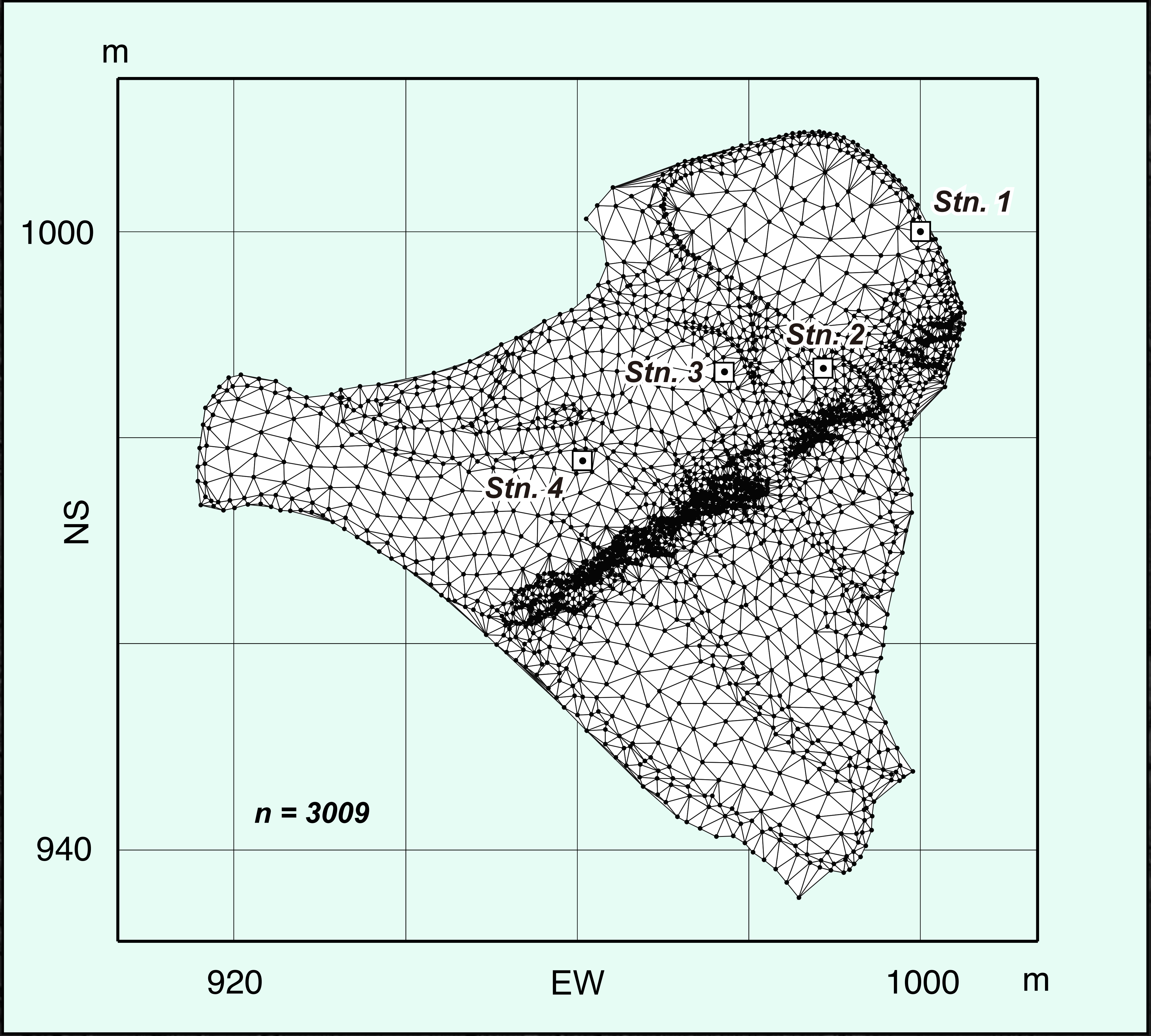
Most researchers still did plane table survey only,
but I invited John to map the rupture with Chiba Univ. TS.



Okumura, 2007

Offset stair case under Nojima Lighthouse.

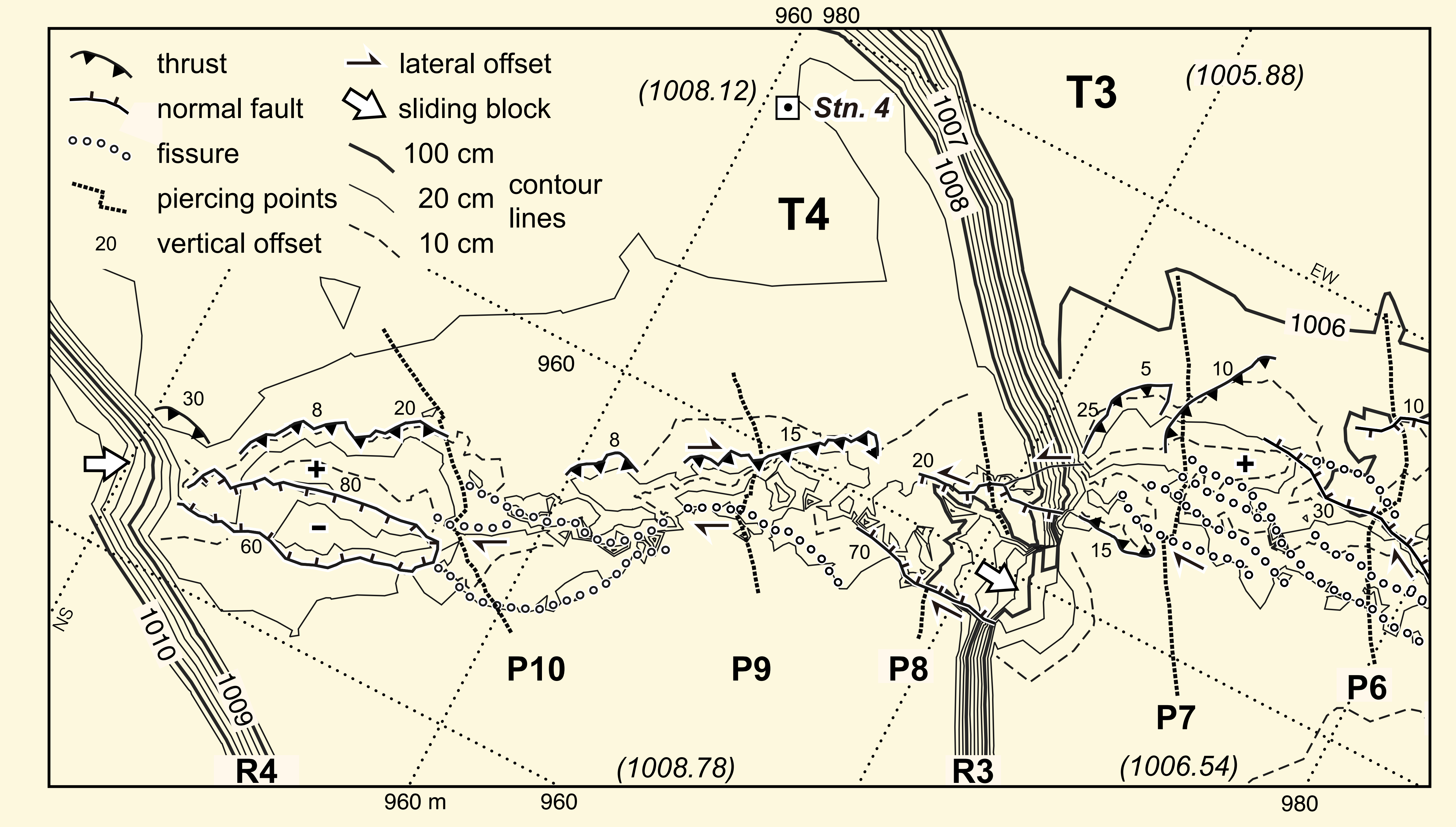
Faulted terrace paddies at Nojima Ezaki (photo by T. Nakata)



Okumura, 2007

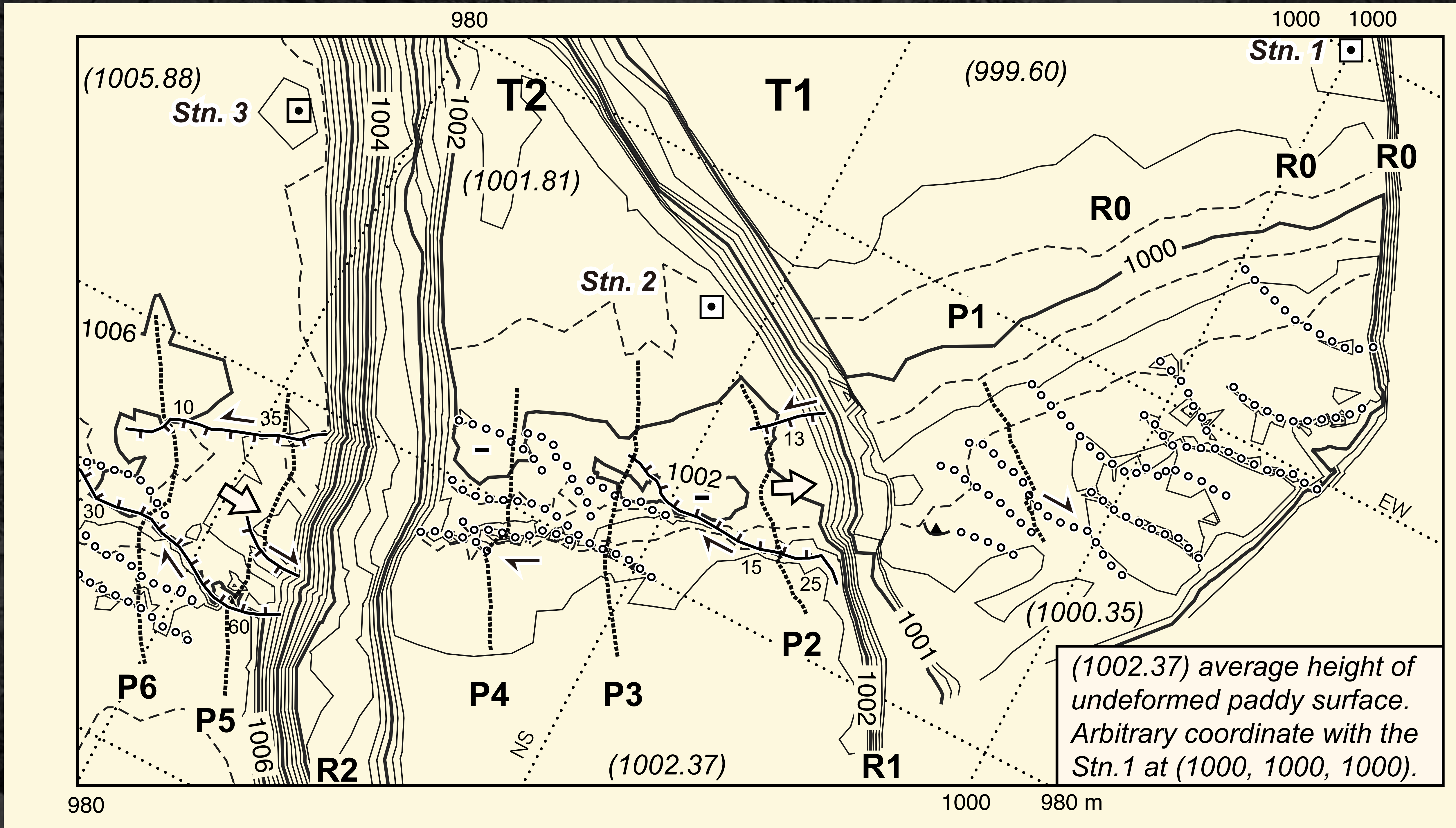
3009 points in 4 days. John's masterpiece.

1/20 mapping of all > 1 cm features.



Okumura, 2007

TIN dircet contours, all lines, and 1/20 map combined oblique RL strike-slip with E-up compression. gravitational deformation overprints tectonics.

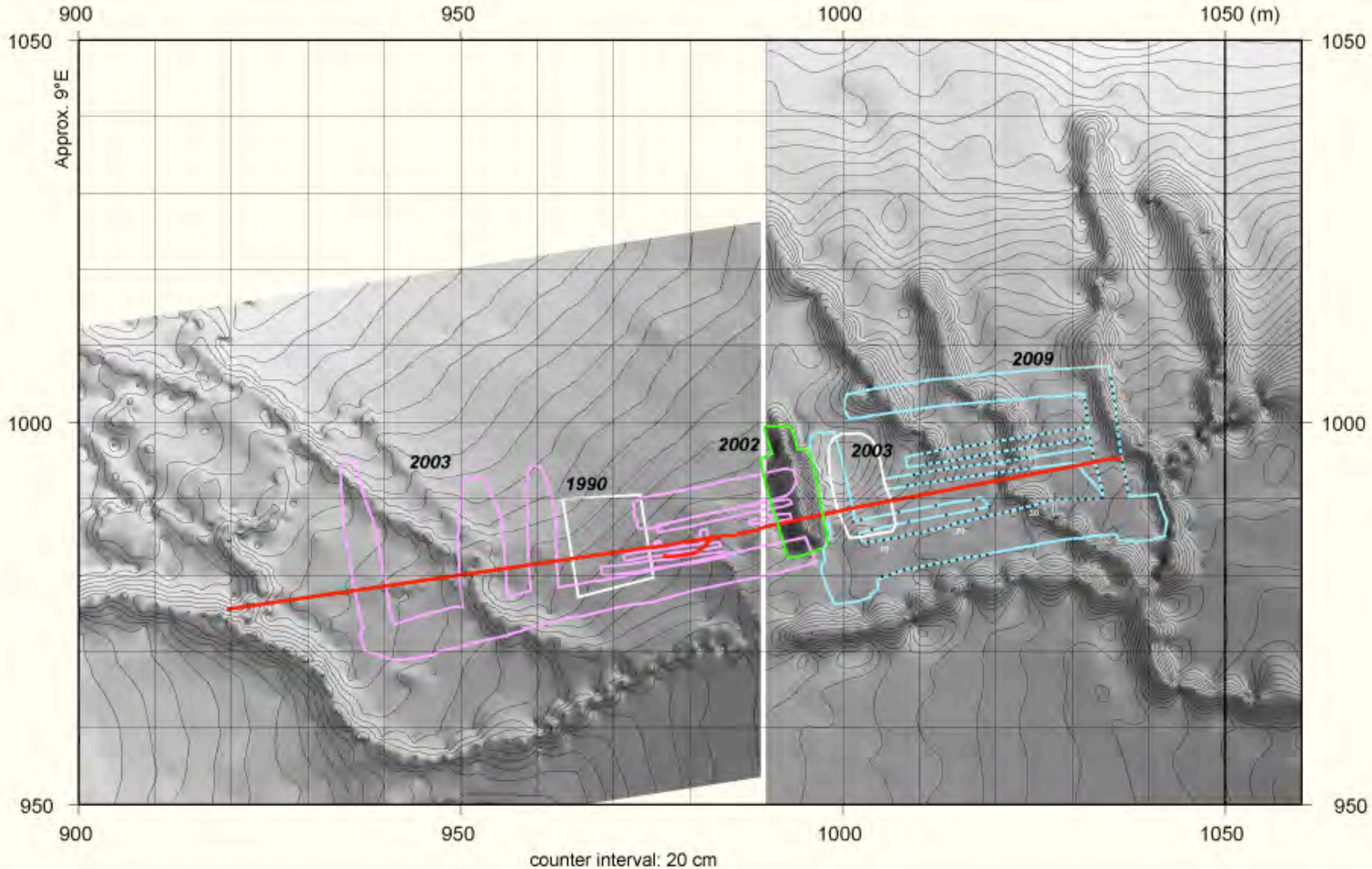


Okumura, 2007

No through-going rupture on T1, but flexured surface by a restraining bend.

Big post-Kobe funding brought me Wild TC2002, 0.5 sec.
The finest total station, my lover.

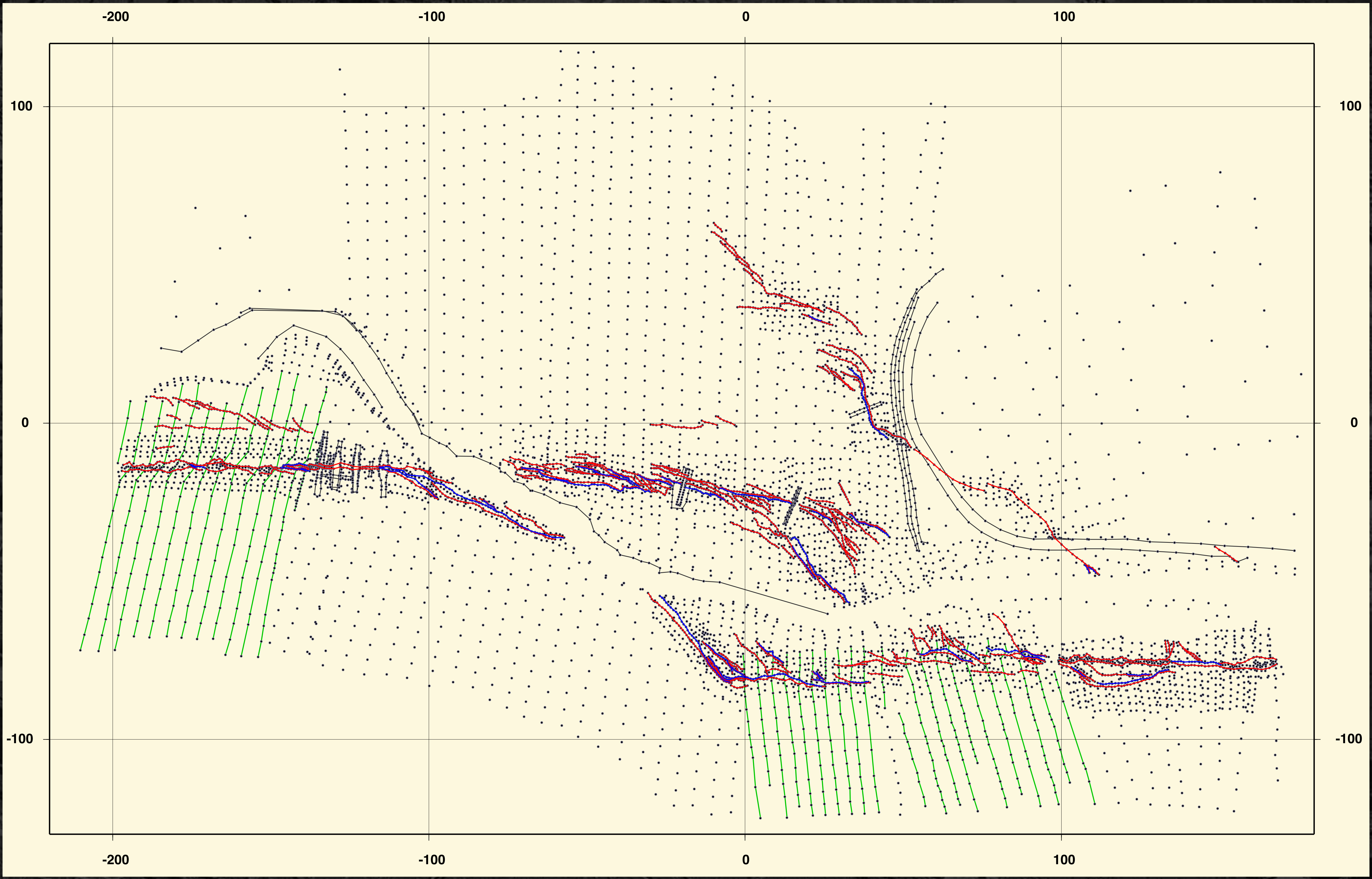
My second TS working in Gerede on North Anatolian fault.



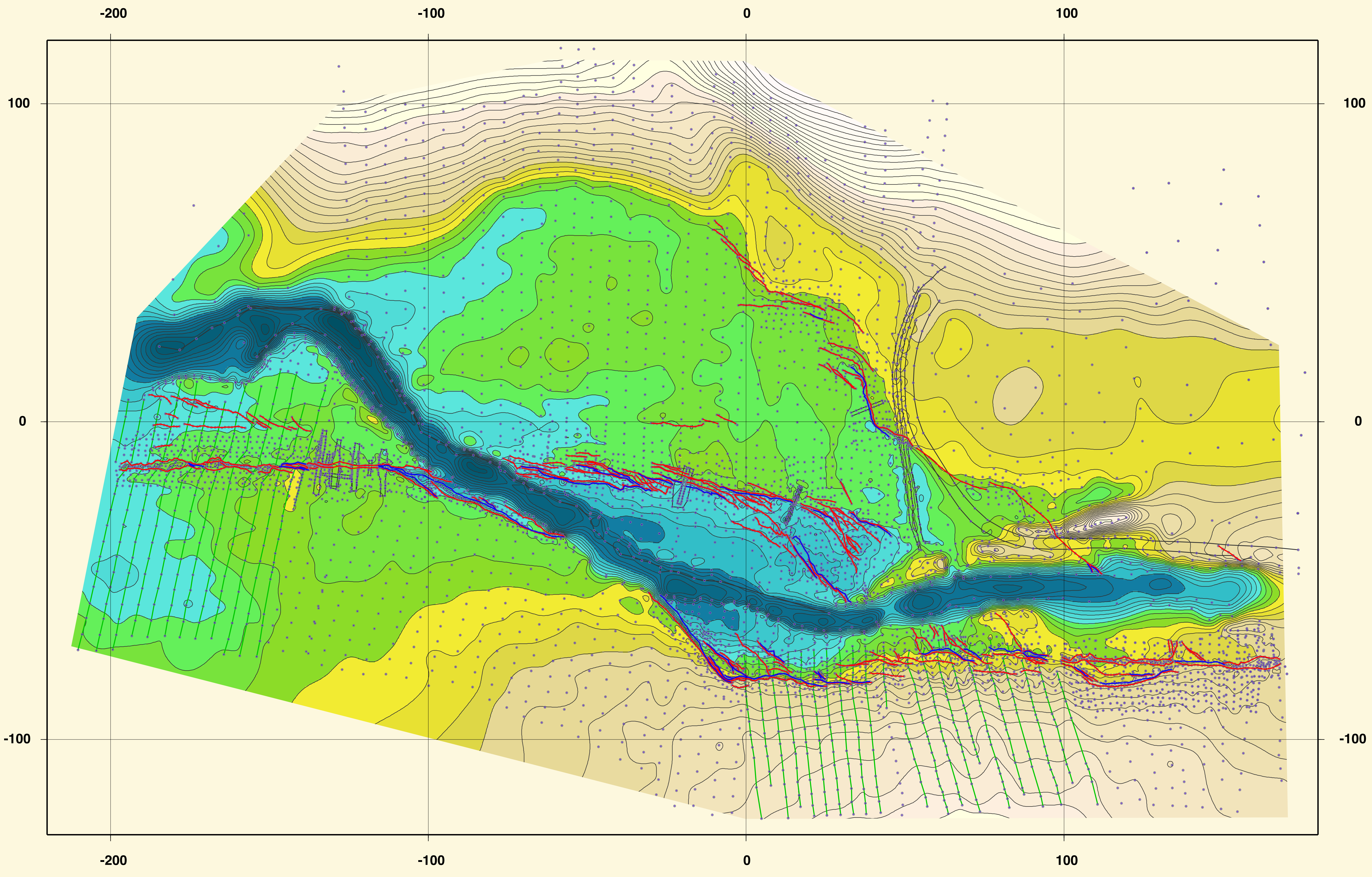
Automatic level map combined with TS map.

1999 Kocaeli earthquake on the North Anatolian fault.

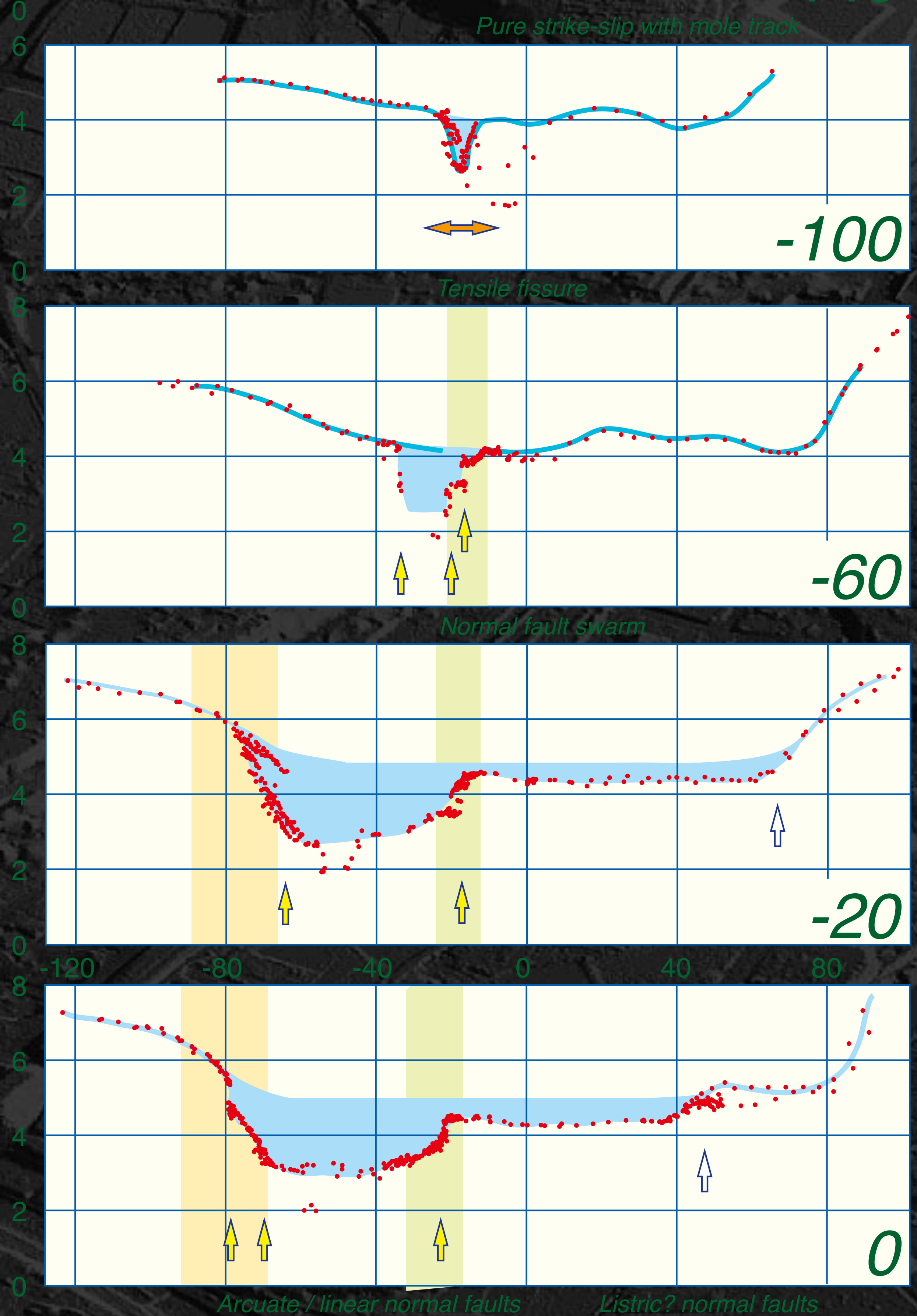
Mapping a pull-apart at Sarimese, east of Izmit.

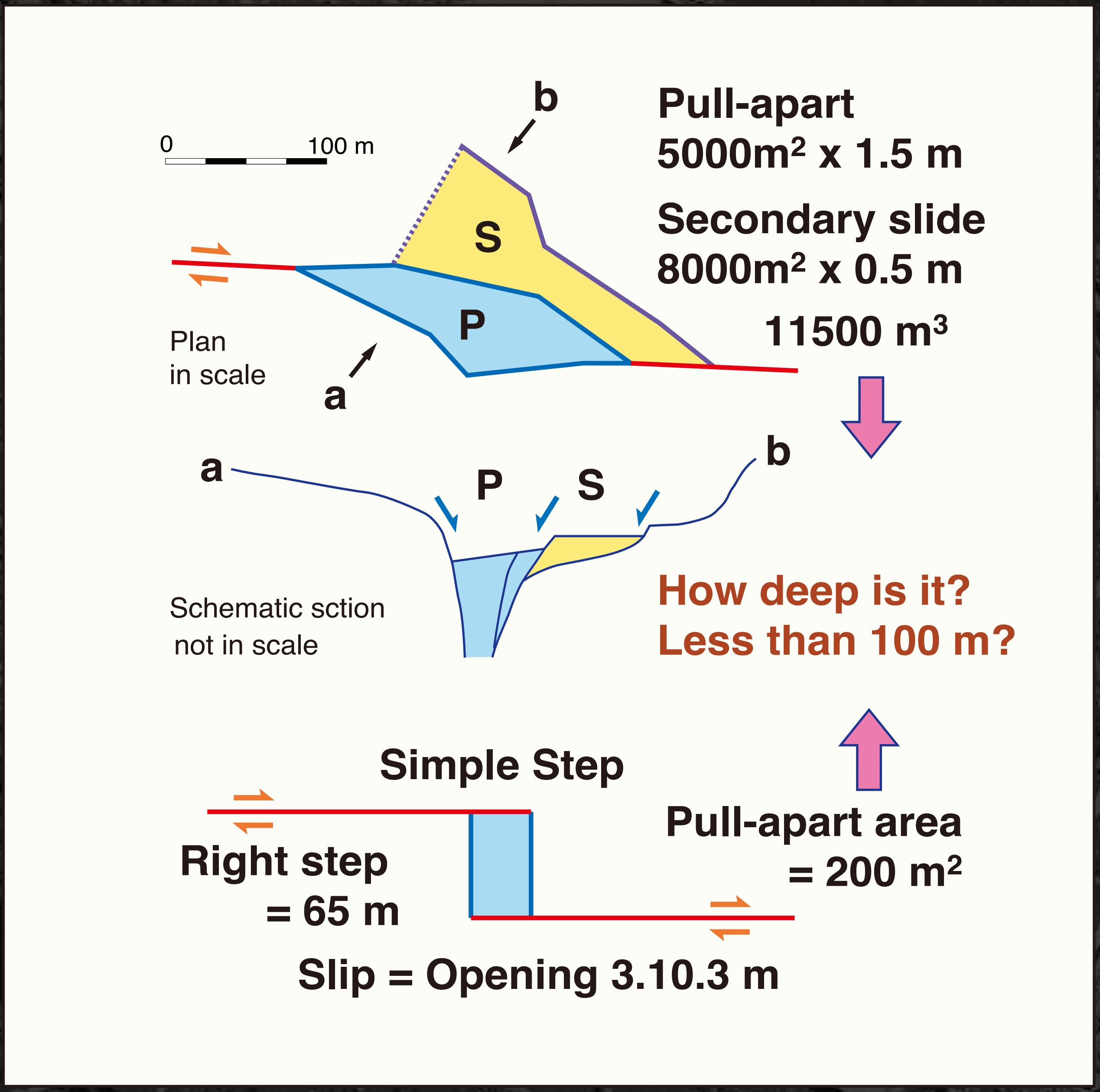


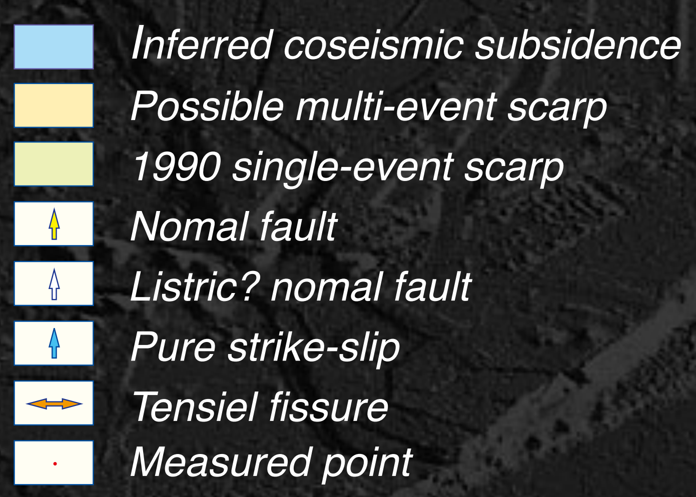
20 stations, >10000 points, 7 days. All crests and toes.



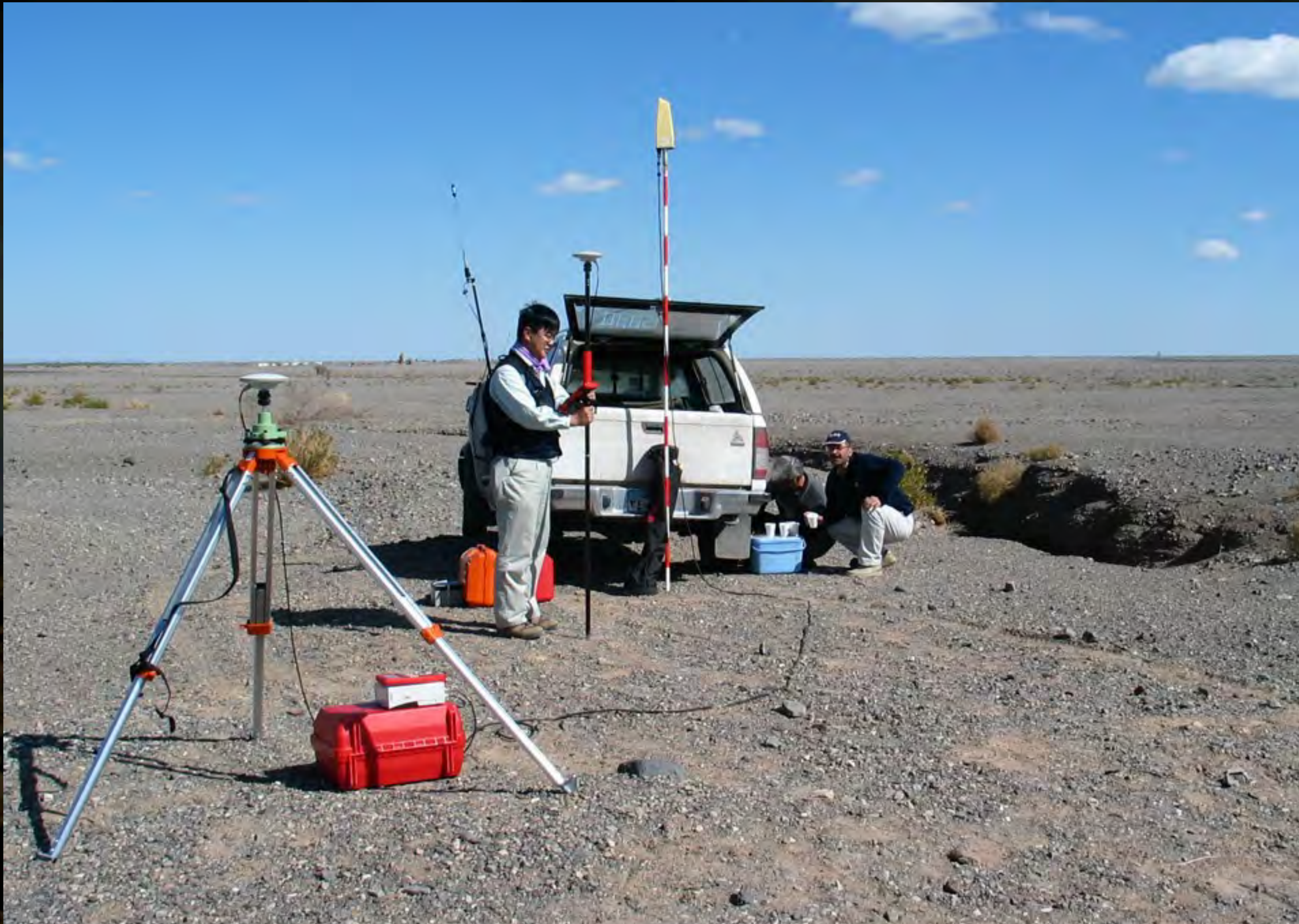
My TS masterpiece.



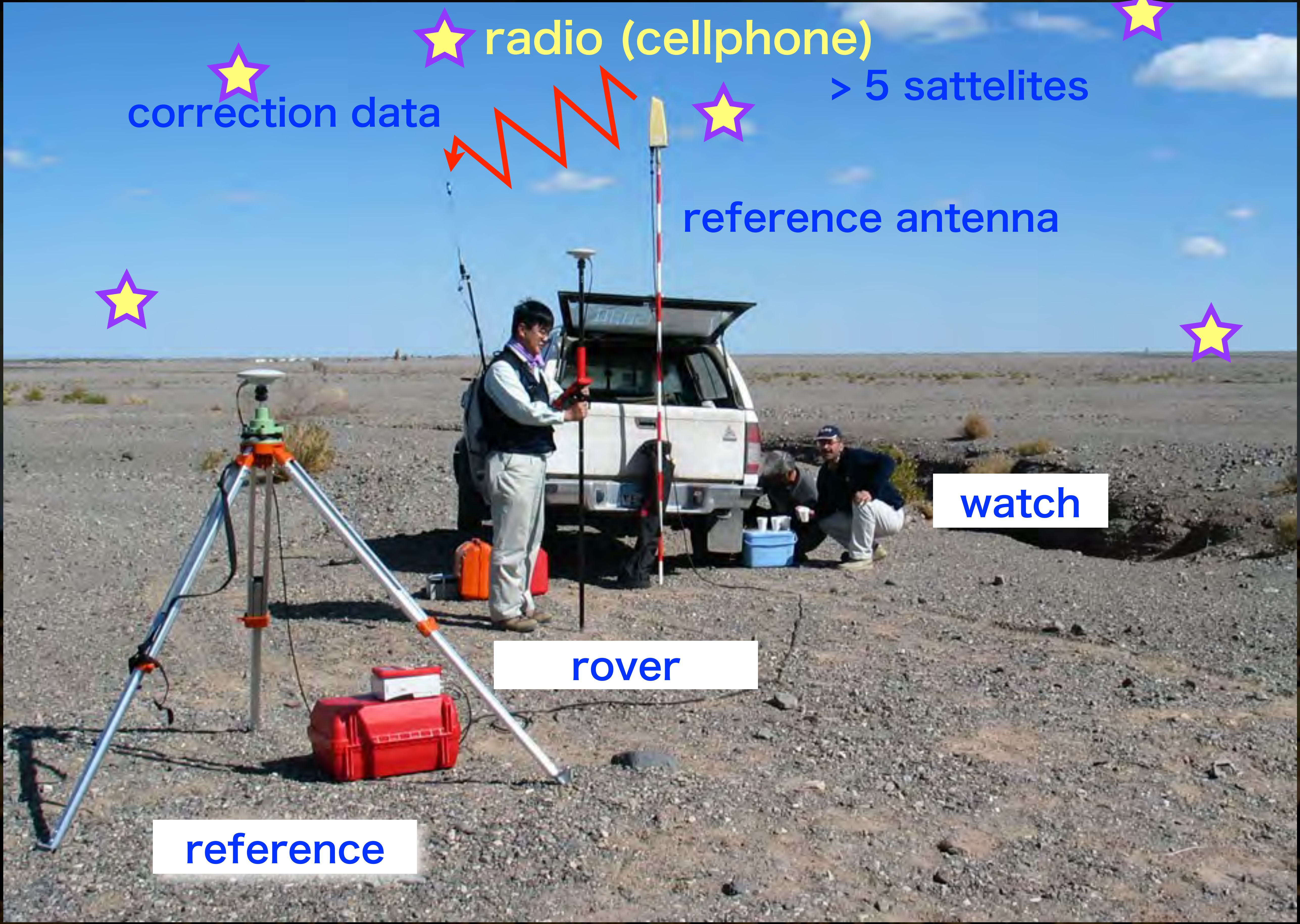




Reconstruction of subsidence and model the pull-apart.



RTK-GPS radio modem setup (Bam, Iran, 2004)



RTK radio modem setup (Bam, Iran, 2004)

	RTK-GPS	Total Station	Lidar (Airborn)	Lidar (Ground)
Error (mm)	20	1	200	1
Points/hour	36 K--300	100	360 M	36 M
Geodesy	Y / N	Y	N	N
Remote	N	Y / N	Y	Y
Processing	easy	easy	difficult	difficult
Critical issues	trees, building	slowness	precision	shadows
Cost ($1000)	25*2	10~	250	150
subcontract	N.A.	N.A.	10++ / km^2	10+? / 100 m^2

Techinical comparison. Lidar = Laser Scanner

GPS

static / kinematic: both
single frequency / dual frequency: dual frecuency
code / phase: phase
stand alone /reference & rover: reference & rover
absolute / relative positioning: relative positioning
real-time / post-processing: both

recreational	kinematic	1 freq. code	solo	> 5m error in sec.
geodetic	static	2 freq. phase	solo	< 1 cm in hours
DGPS	kinematic	2 freq. code	solo	> 30 cm in 10s min.
RTK	kinematic	2 freq. phase	pair	< 2 cm in 0.1 sec.

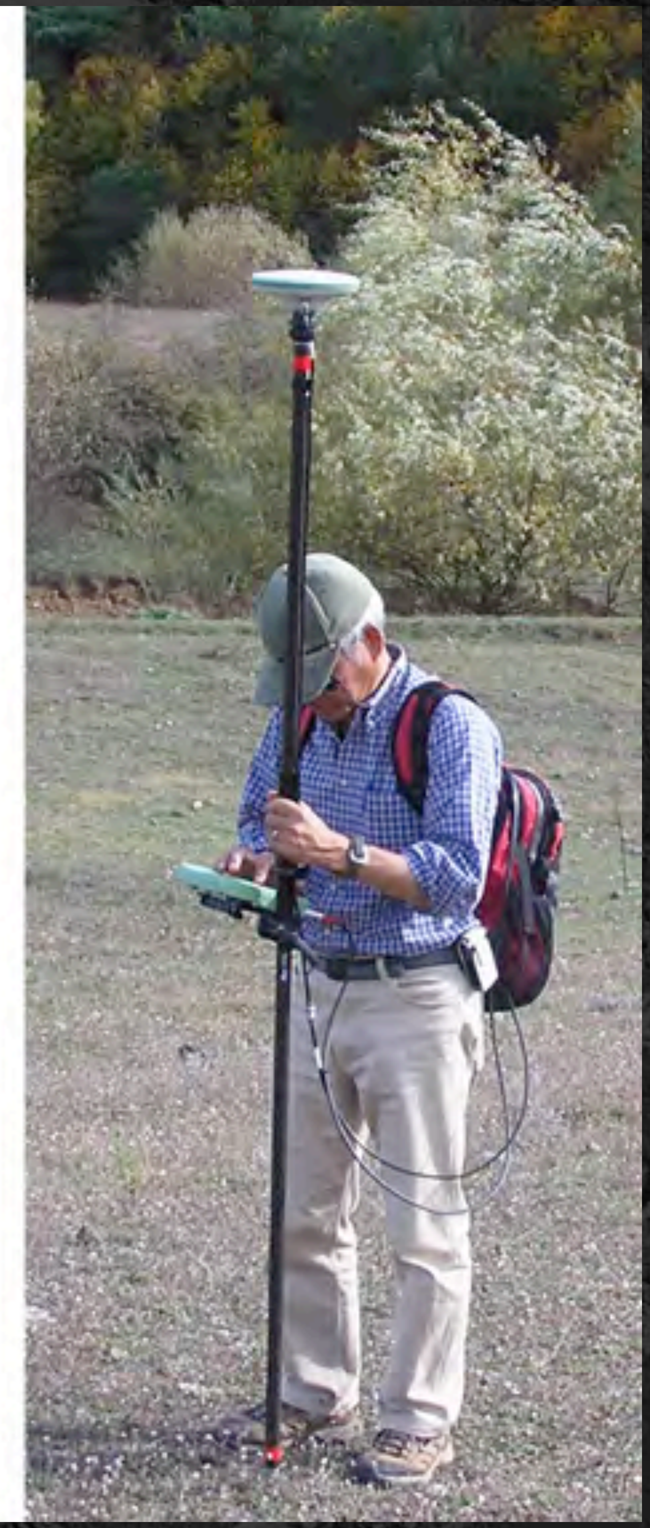
RTK = Post Processing Kinematic

Virtual Reference Station (VRS) for RTK solo < 2 cm in 0.1 sec.

Reference station

Rover: moving

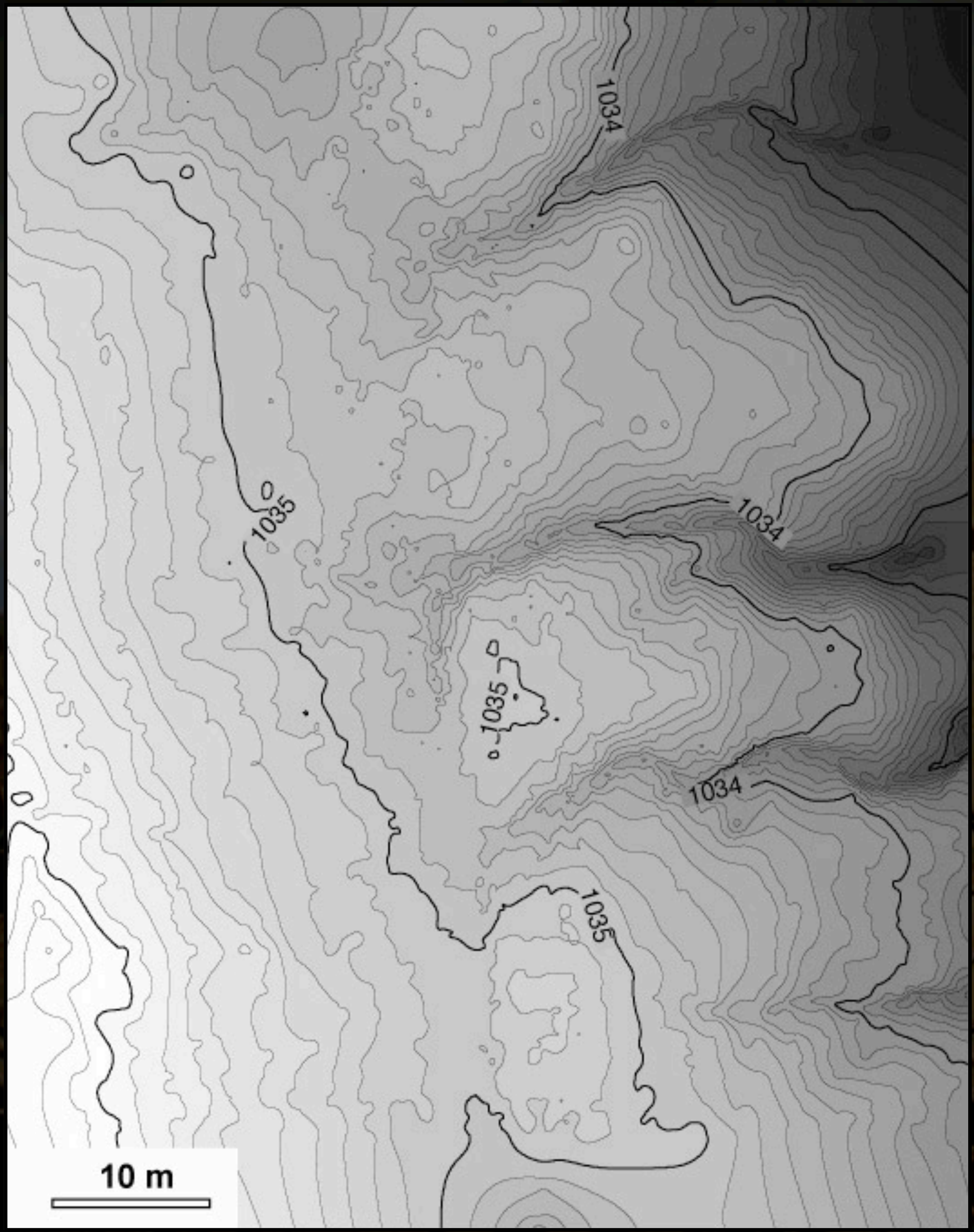
~20 Hz sampling



Rover: static

stop and go

5 sec.



10000 points
in 1.5 hours

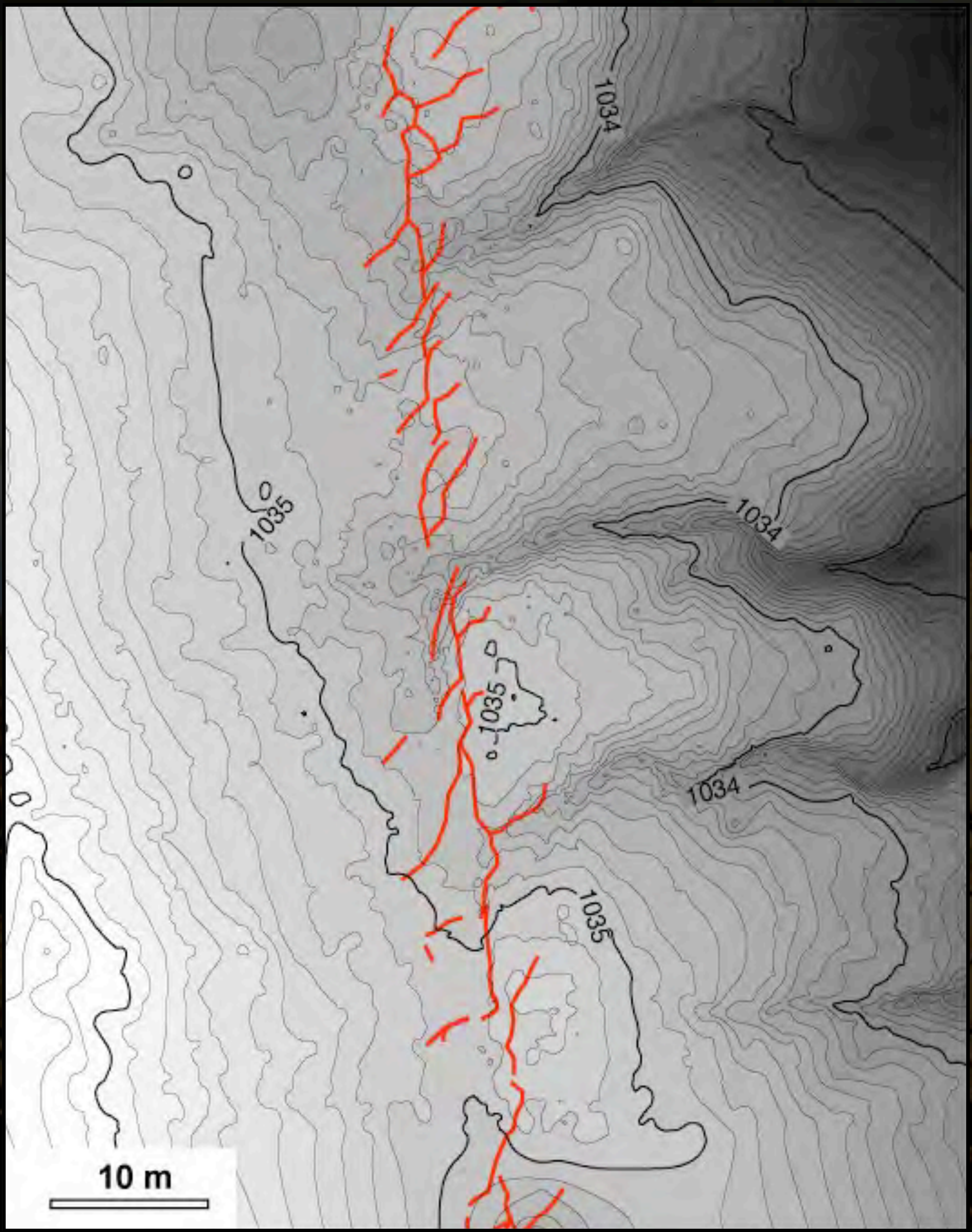
moving

post-processing
kinematic

0.25 m DEM

0.10 m contour

faulted alluvial
fan surface
along N1 fault
Bam, Iran



300 points
in 1 hour

stop-and-go

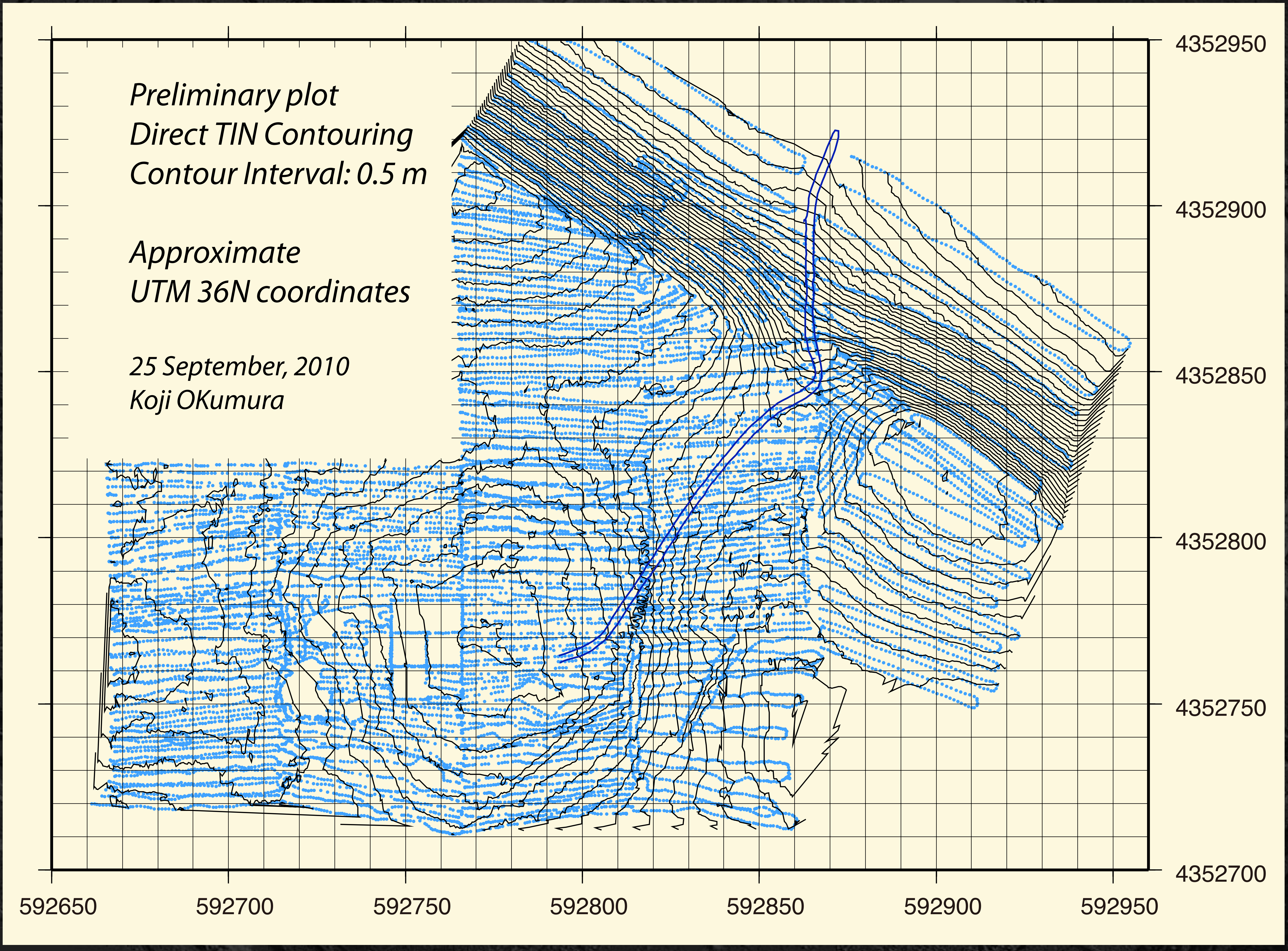
selecting each
point on fissure

comments for
line ends

post-processing
kinematic

0.25 m DEM

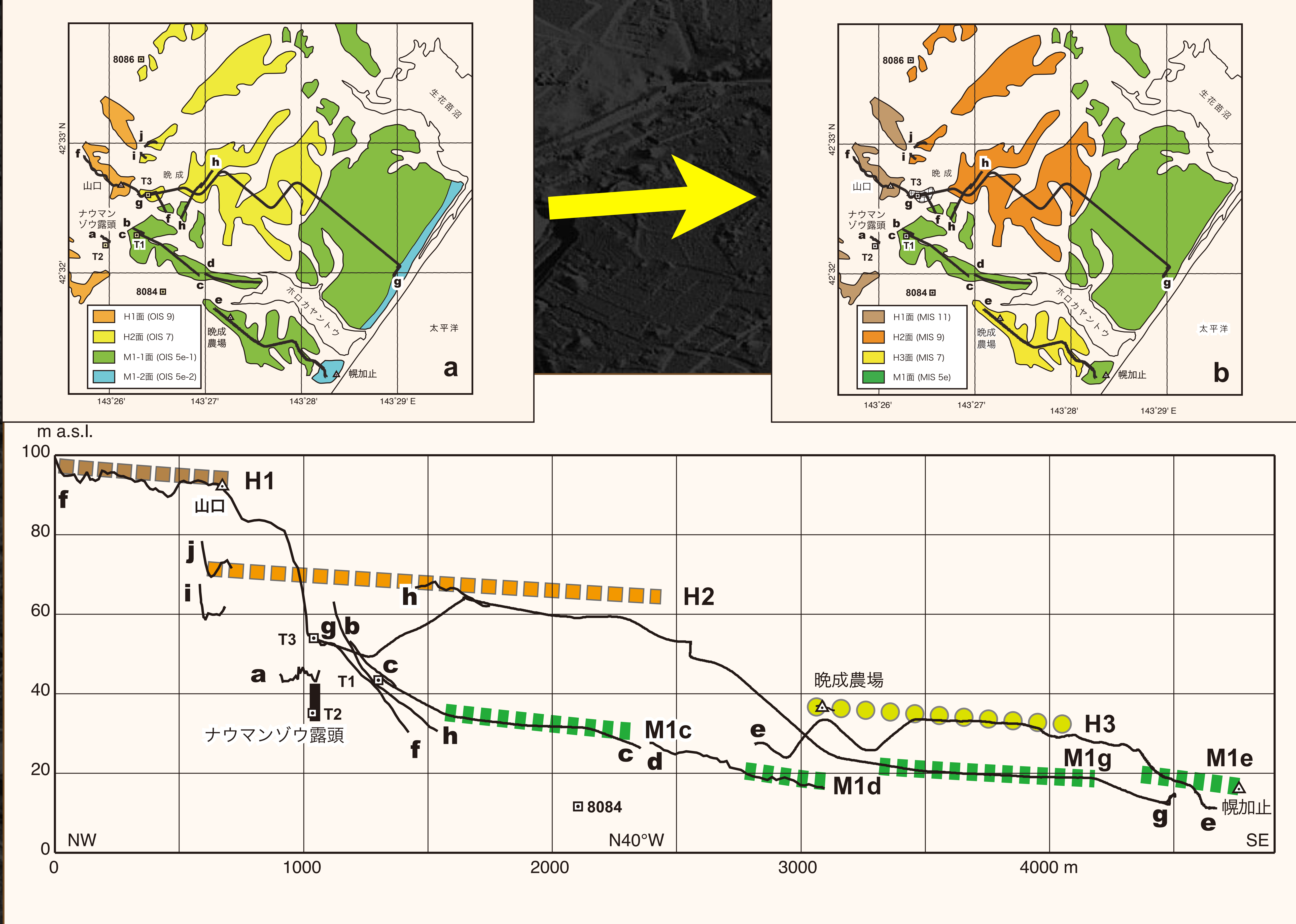
0.10 m contour


Preliminary plot
Direct TIN Contouring
Contour Interval: 0.5 m
Approximate
UTM 36N coordinates
25 September, 2010
Koji OKumura
4352950
4352900
4352850
4352800
4352750
4352700
592650
592700
592750
592800
592850
592900
592950

Lonesome scanner.

-162284.998	-66262.190	53.962	0.006
-162286.655	-66260.204	53.937	0.007
-162288.298	-66258.214	53.918	0.008
-162289.949	-66256.232	53.910	0.007
-162293.241	-66252.267	53.877	0.007
-162294.889	-66250.285	53.860	0.007
-162296.547	-66248.301	53.839	0.007
-162298.215	-66246.311	53.820	0.007
-162299.896	-66244.324	53.799	0.007
-162303.246	-66240.369	53.767	0.006
-162304.922	-66238.396	53.759	0.007
-162306.608	-66236.416	53.745	0.008
-162308.294	-66234.424	53.722	0.008

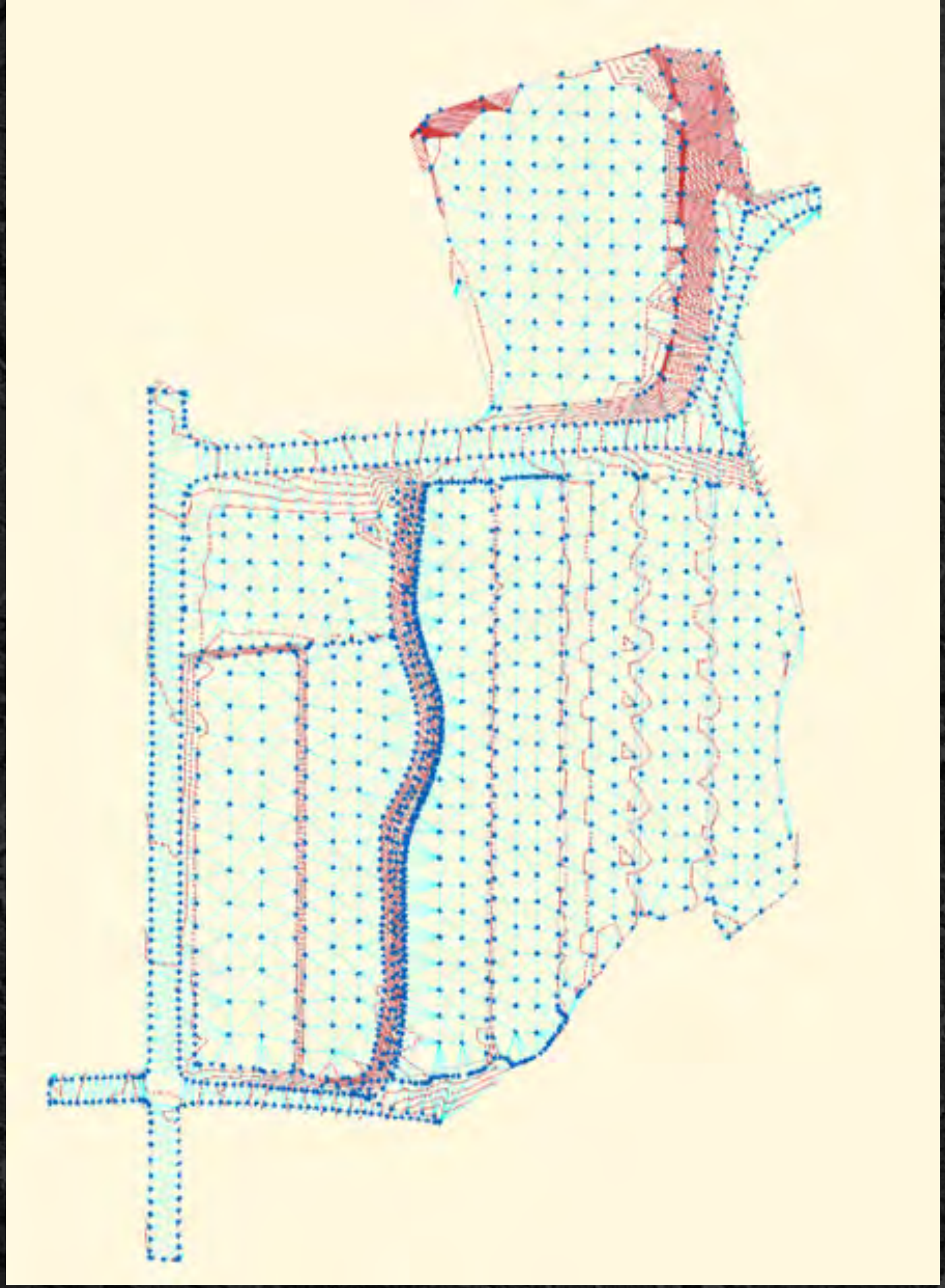
E, N, H and total error in m

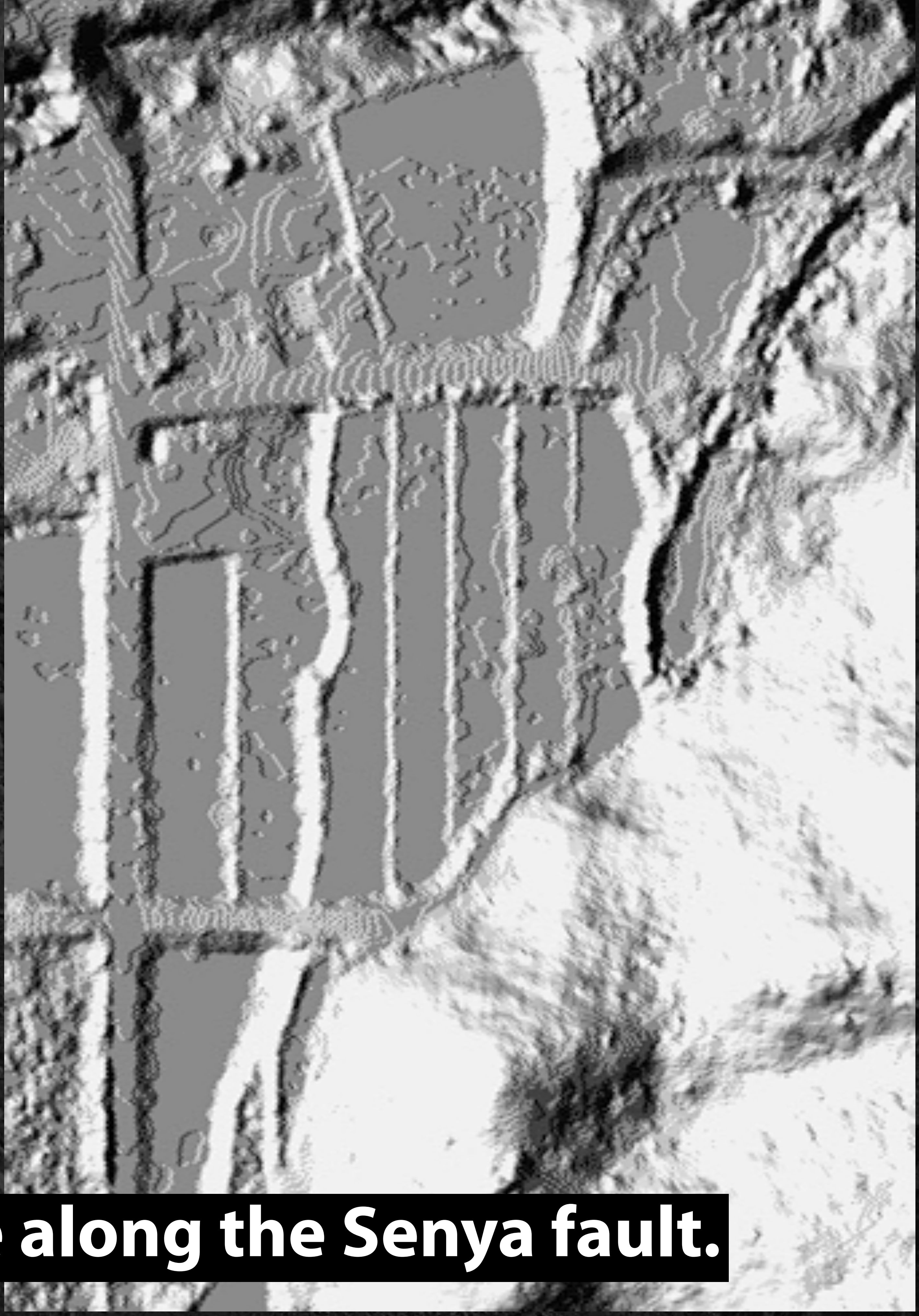


topographic survey of coastal terrace altitude.

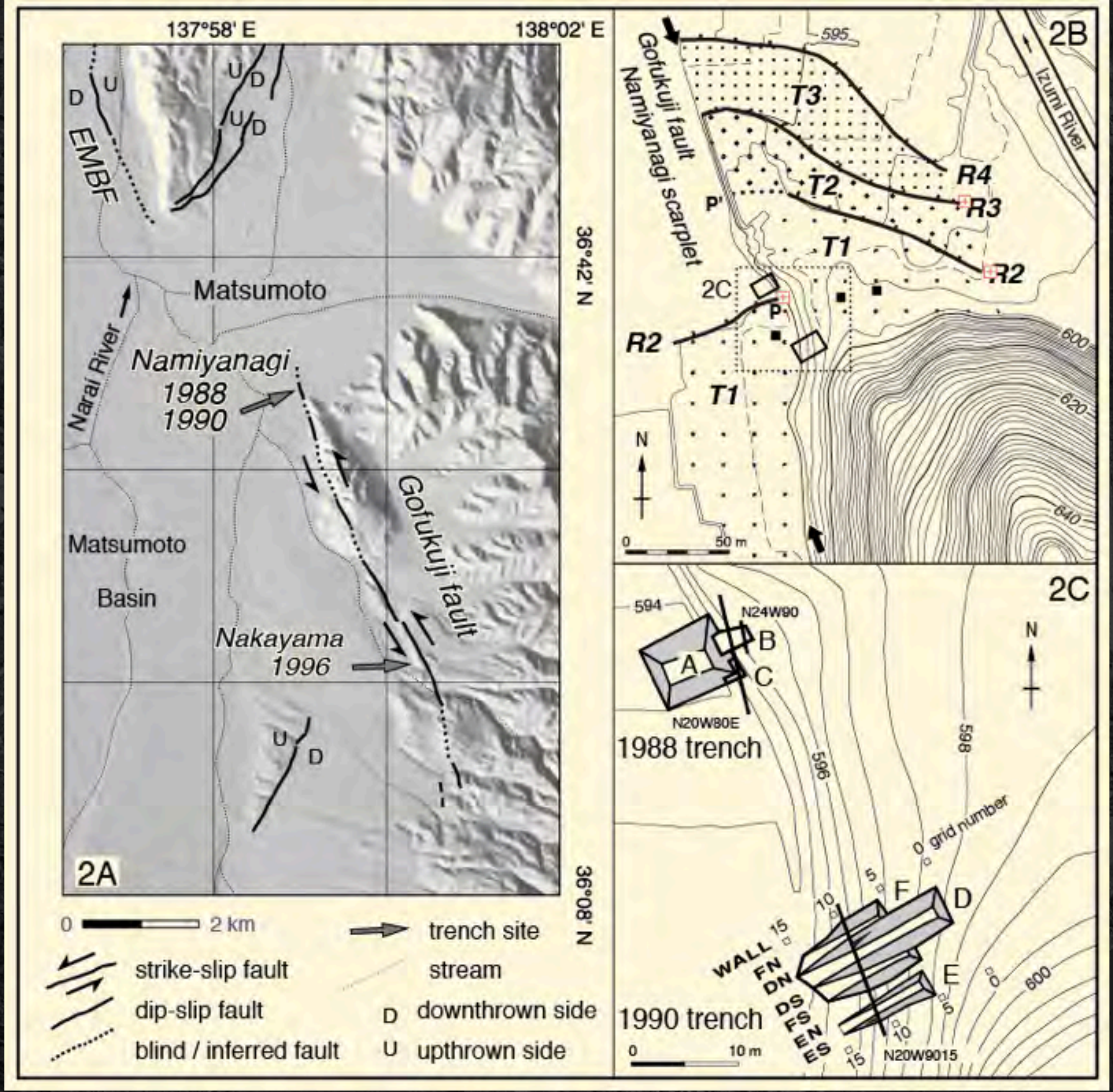

Finally, LiDAR

Sugimura & Matsuda: Atera fault at Sakashita

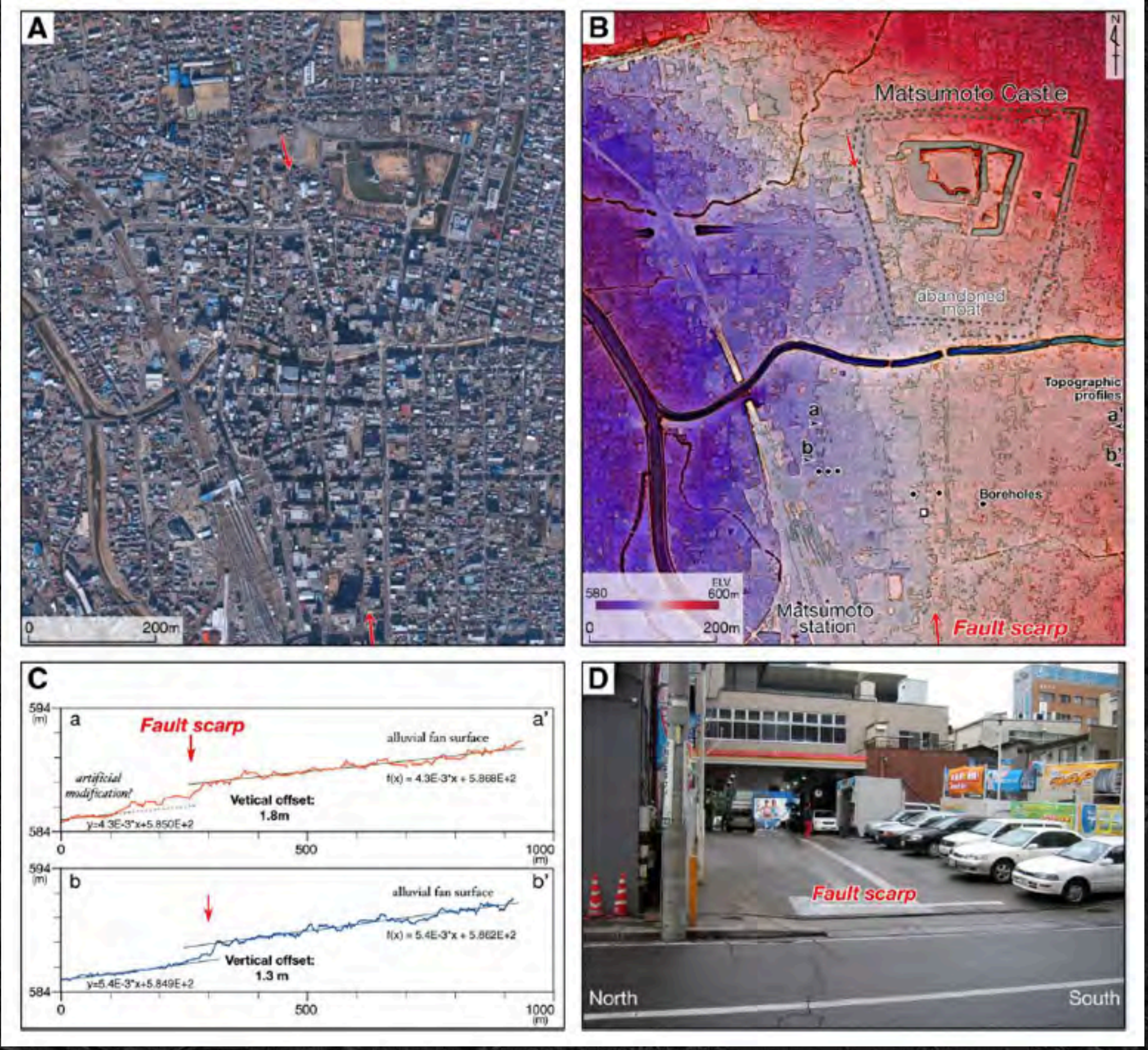




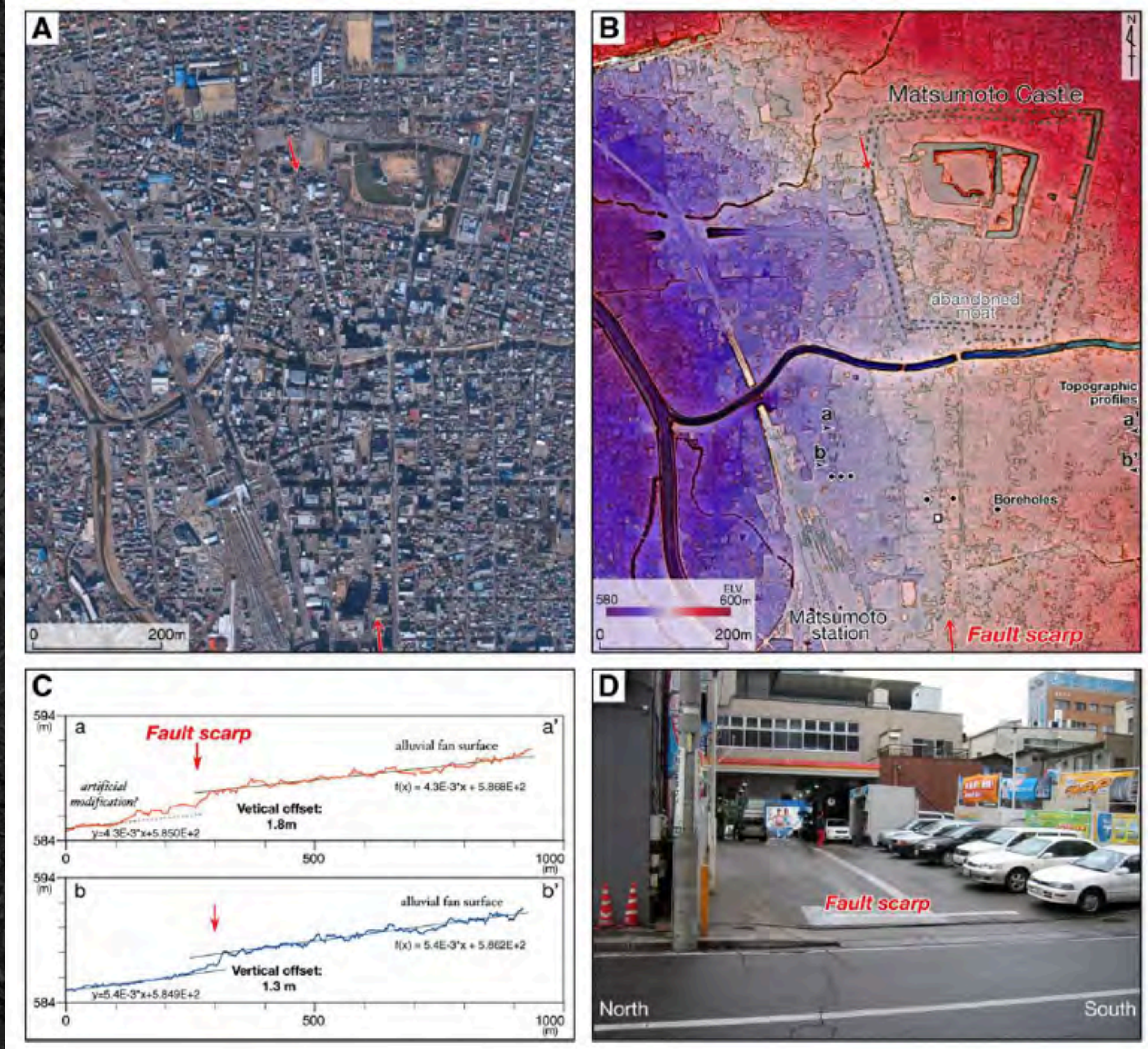
Rikuu 1897 rupture along the Senya fault.



High precision LiDAR survey along ISTL at Matsumoto



Kondo et al. (2006: Geomorphology)



Narrow and densely arranged swaths are critical.

Mapping fault topography is important:

- to objectively map faults.
- to quantitatively depict deformations.
- to understand fault mechanics and kinematics.
- to record surface ruptures by big earthquakes
- to record fault topography before destruction.

All these serve for **seismic risk assessment**.

LiDAR technology is a revolution.

- We need good ideas to utilize it.
- We need scientifically designed survey for high resolution and high precision data.