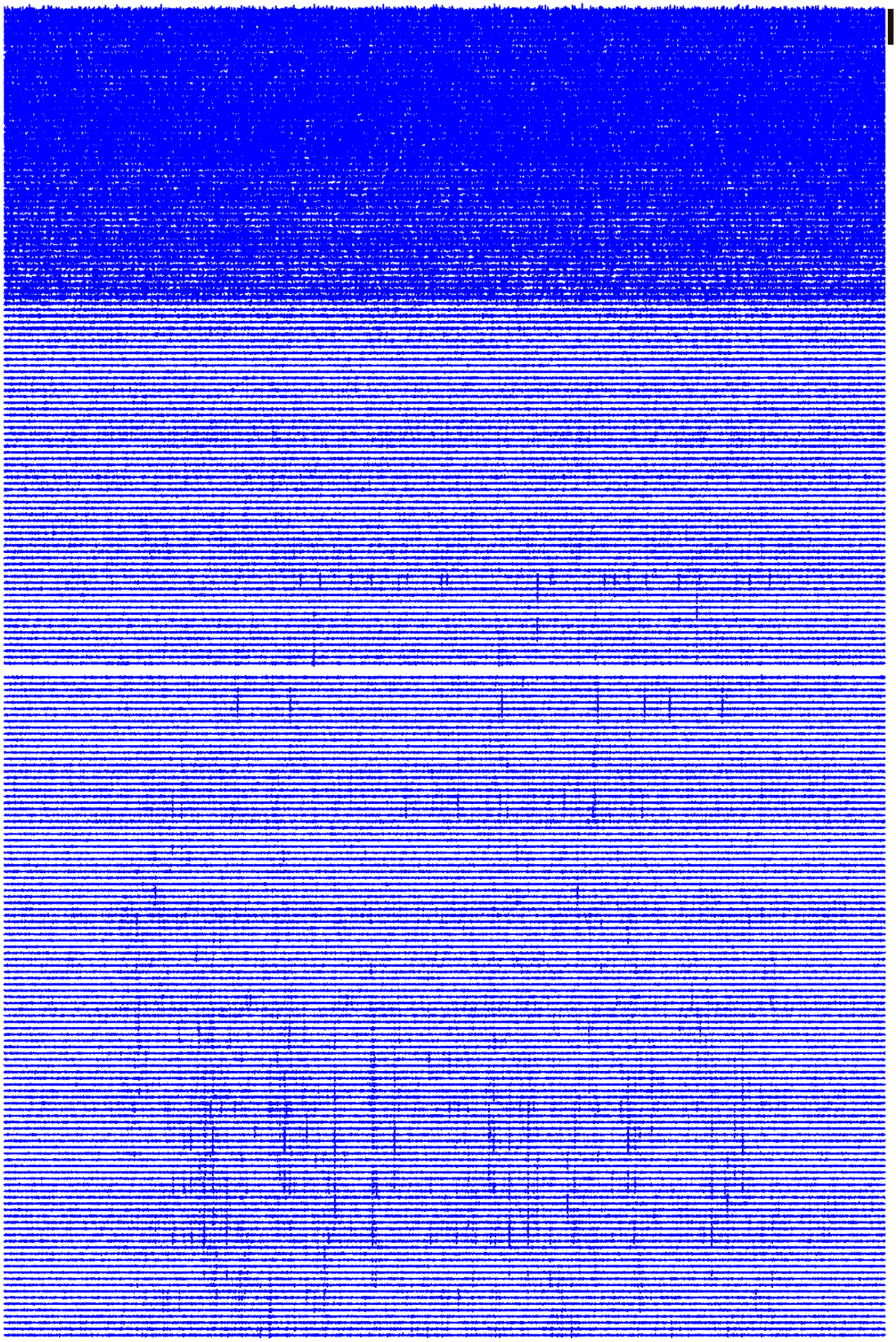
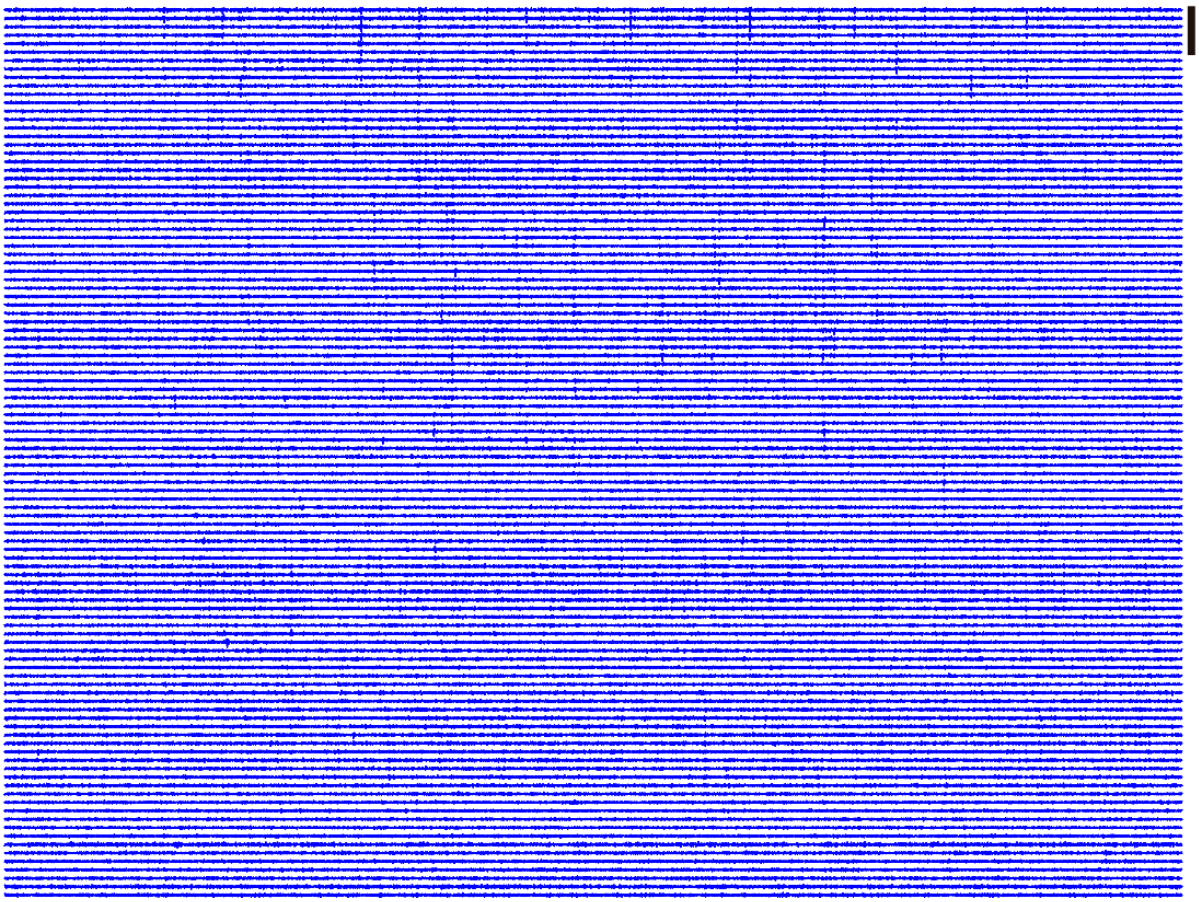
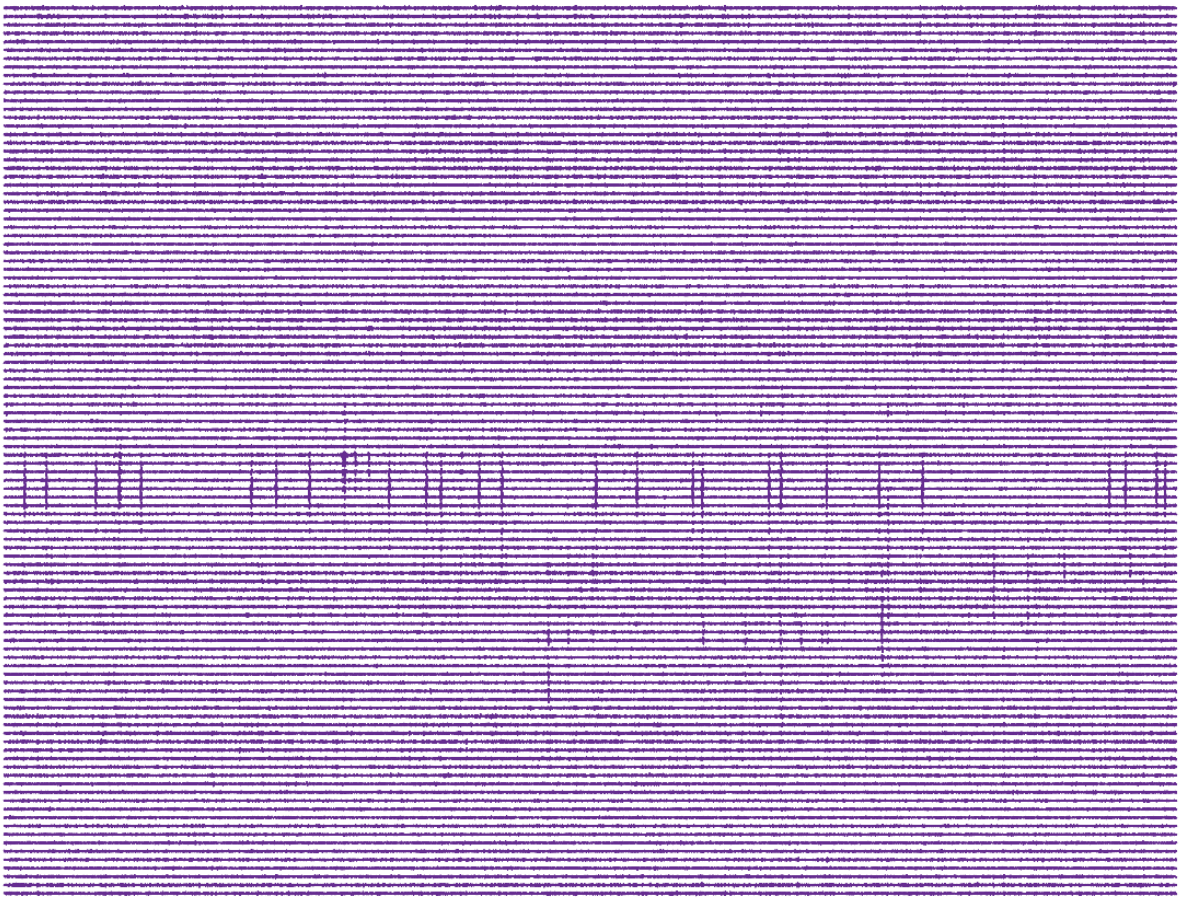
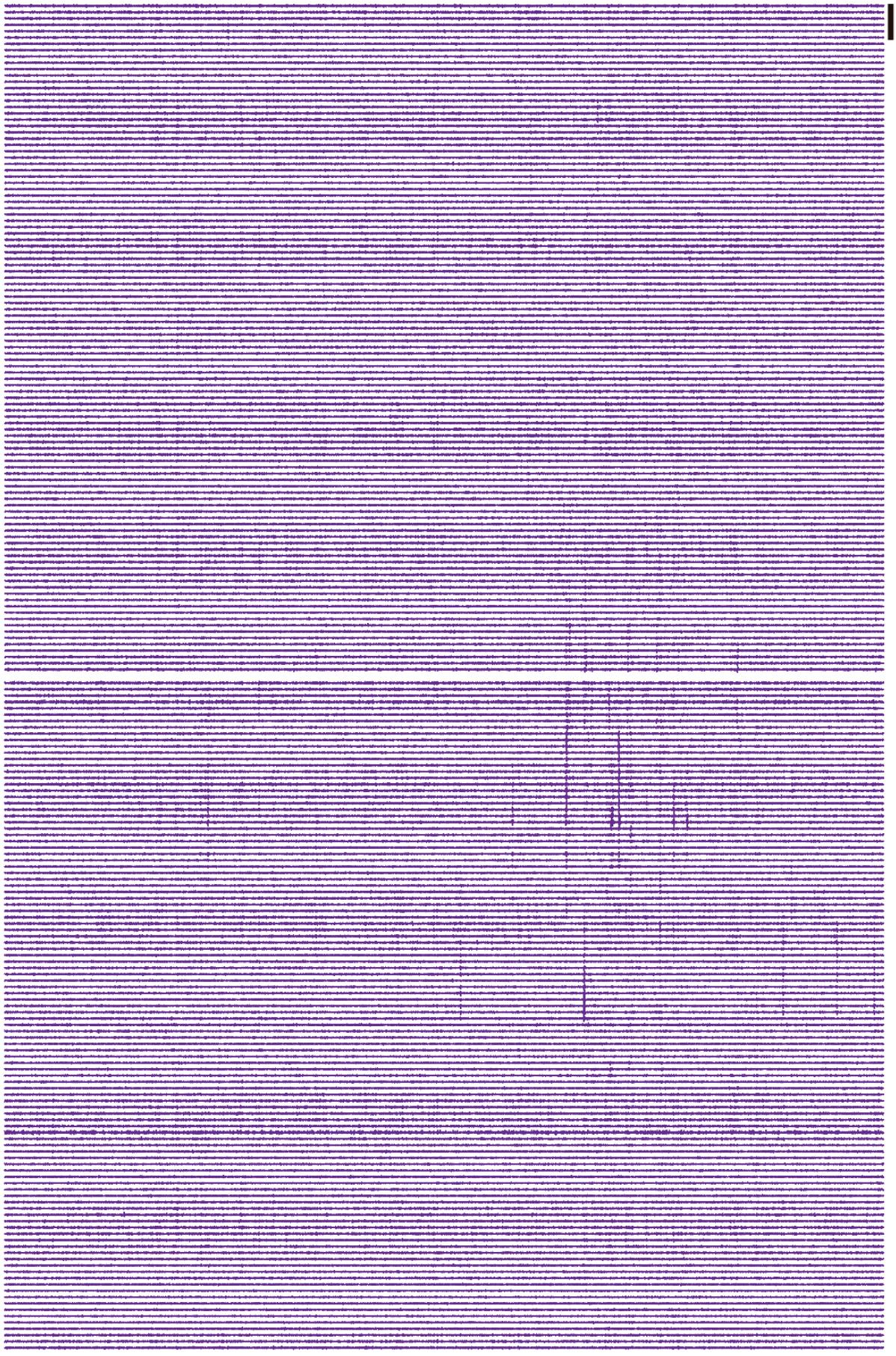
Why not record from *every* channel with a CMOS scanning probe?

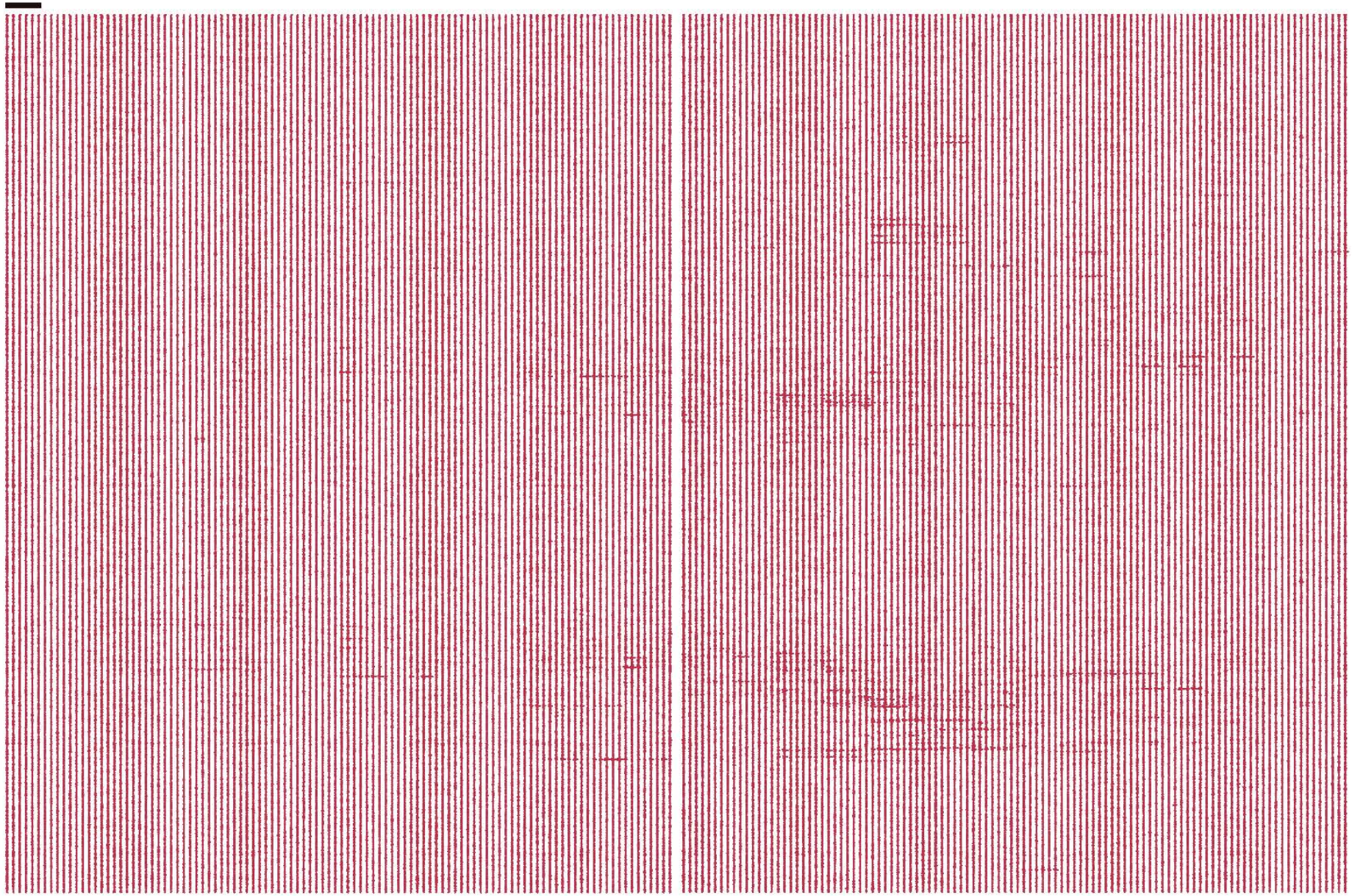
Supplementary Information











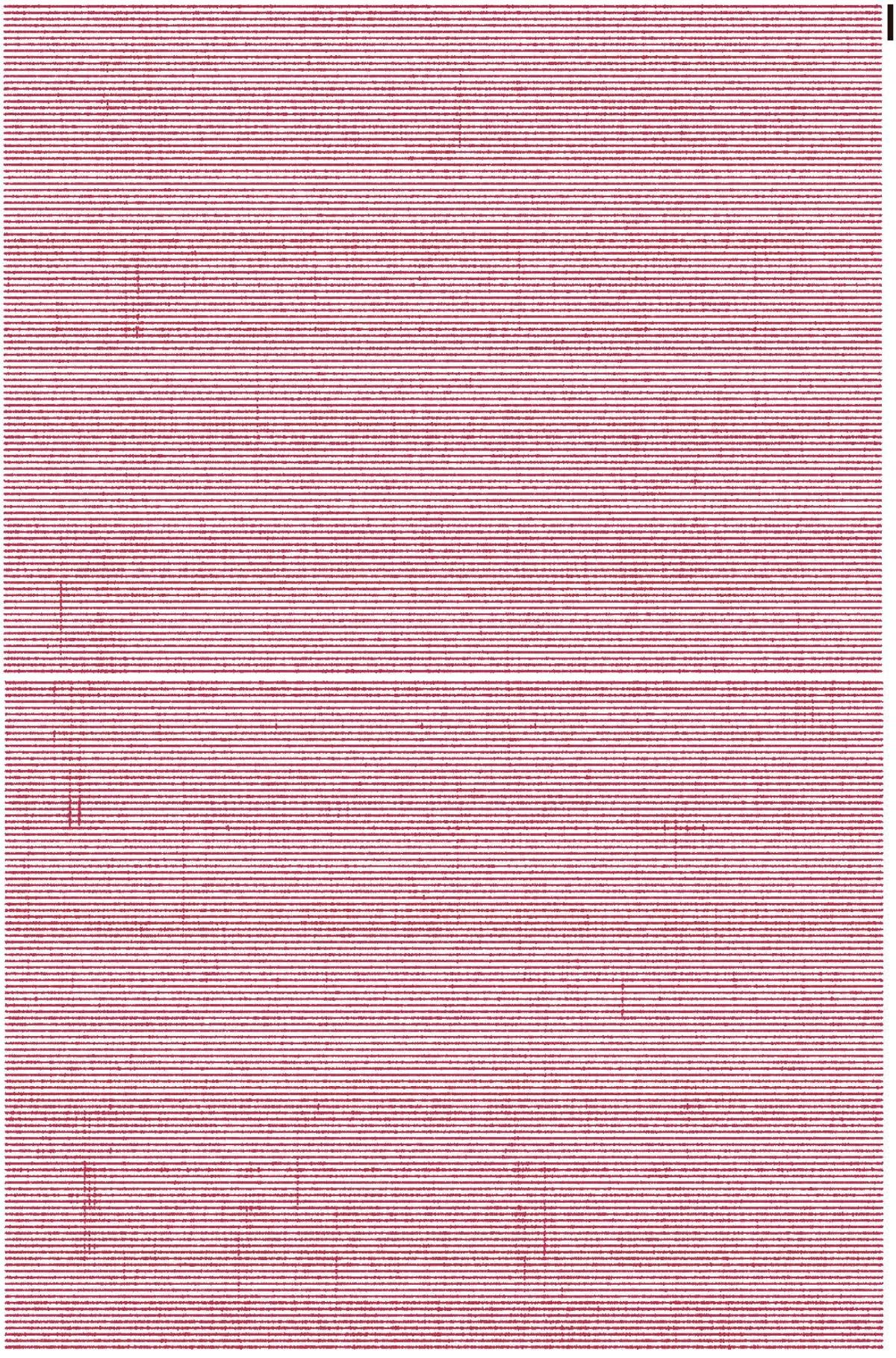
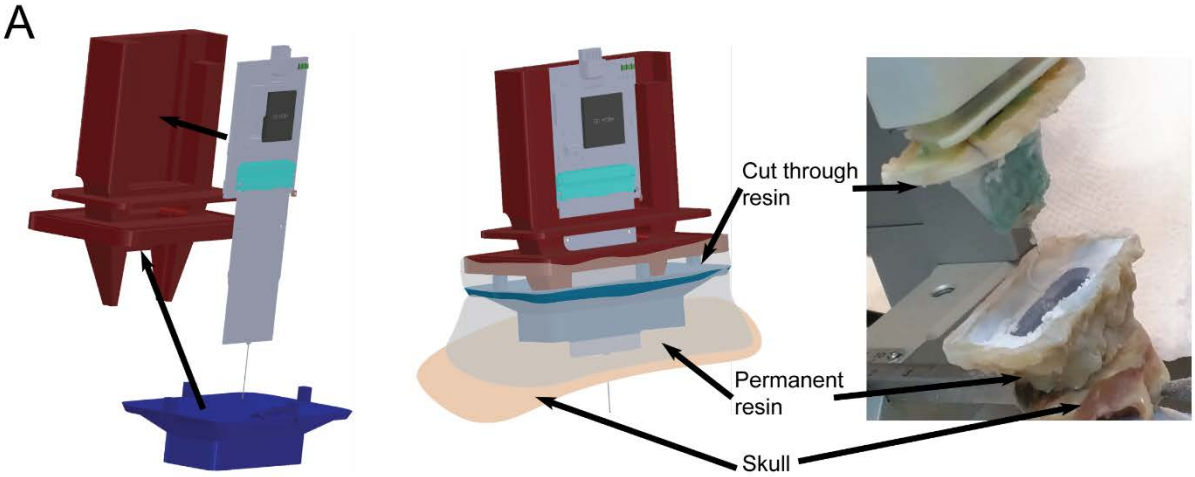


Figure 1. Example of a recording (*18_26_30.bin*) segment performed by a CMOS scanning neural probe with 1060 electrodes set to AP mode. 500-ms-long AP traces from a probe spanning multiple brain regions (cortex shown in blue, hippocampus shown in purple and thalamus shown in red). In each page, two groups from the probe are represented; scale bar= 600 µV.


A
Cut through resin
Permanent resin
Skull

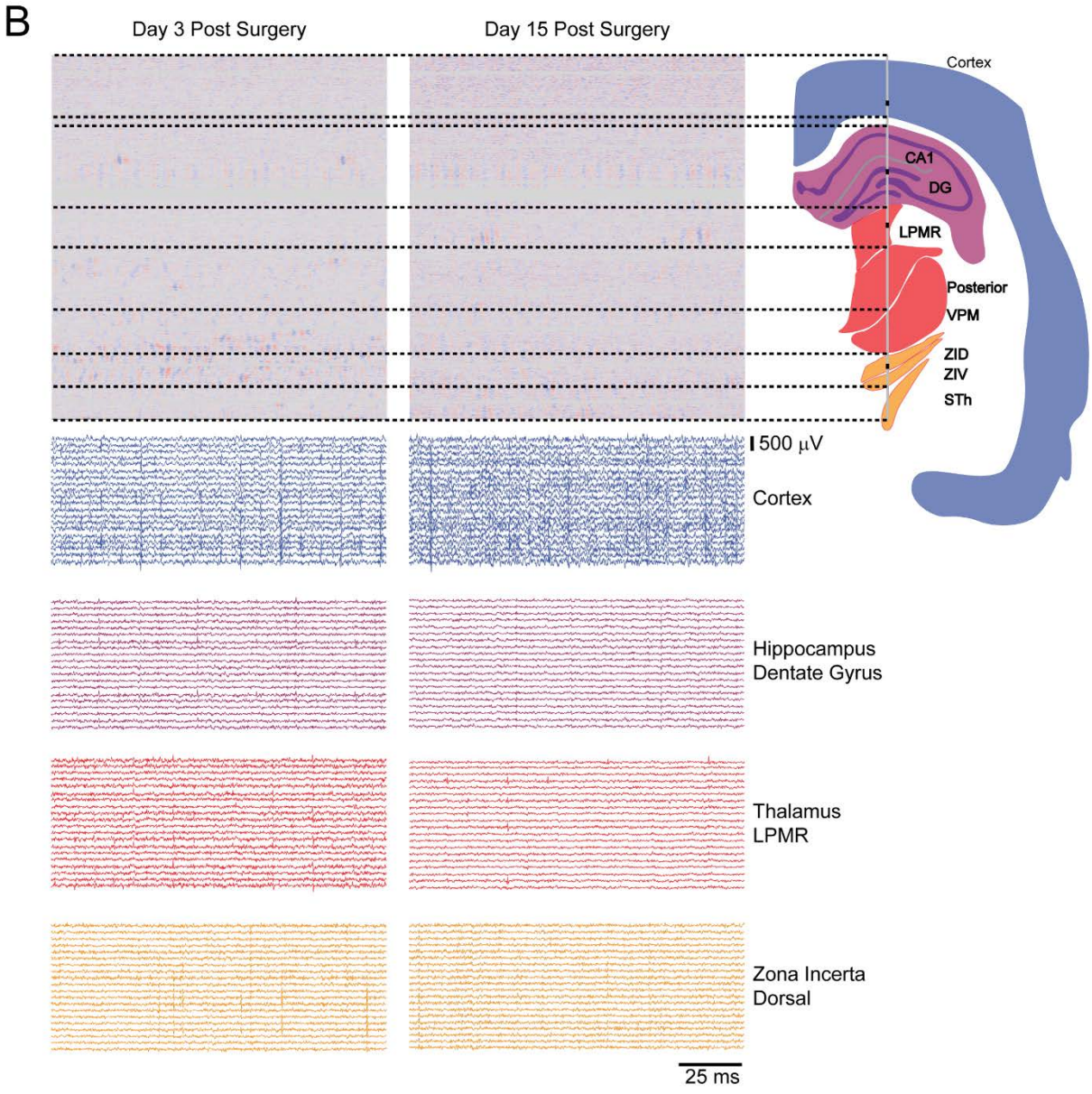

B
Day 3 Post Surgery
Day 15 Post Surgery
Cortex
CA1
DG
LPMR
Posterior
VPM
ZID
ZIV
STh
500 μV
Cortex
Hippocampus
Dentate Gyrus
Thalamus
LPMR
Zona Incerta
Dorsal
25 ms

Figure 2. Chronic recordings and probe removal process. A) The processes of inserting the probe in the probe holder before surgery (left), implanting and gluing the probe in place during surgery using Flowable Composite dentistry resin (Henry Schein, UK) (middle) and removing the probe by cutting the cut through resin layer after the end of the chronic recordings (right). This cut is achieved with a diamond circular saw that fits in the large empty space between the holder and the probe PCB without risk of damaging the probe. The cut and removal of the probe are done after the brain is dissolved by inserting the head (with the probe still attached) in tripsin for several days. This prevents any misalignment between the head and the probe's removal axis to break the shaft due to the brain pushing against it. Of course it also prevents any post mortem anatomical analysis. B) The NeuroSeeker probe was implanted in the regions depicted in the schematic. The red and blue pictures show a 250 ms snippet of data from the full probe using the GPU visualization method described in the document. The blocks of voltage vs time traces each shows the traces of 20 neighboring electrodes (whose positions are defined by the black dots on the probe shaft schematic). The recording done 15 days post-surgery was of the same quality as the one just after surgery. We quantified the noise in all the channels recording from a specific brain region over the two recording days shown here. Cortical electrodes had a mean noise of 27.2 ± 4 μV and 26.4 ± 4 μV for the first and last day respectively. For electrodes in hippocampus the noise values were 18.2 ± 2 μV and 16.9 ± 2 μV, while for electrodes in the thalamic and sub-thalamic regions they were 16.1 ± 3 μV and 13.3 ± 2 μV.

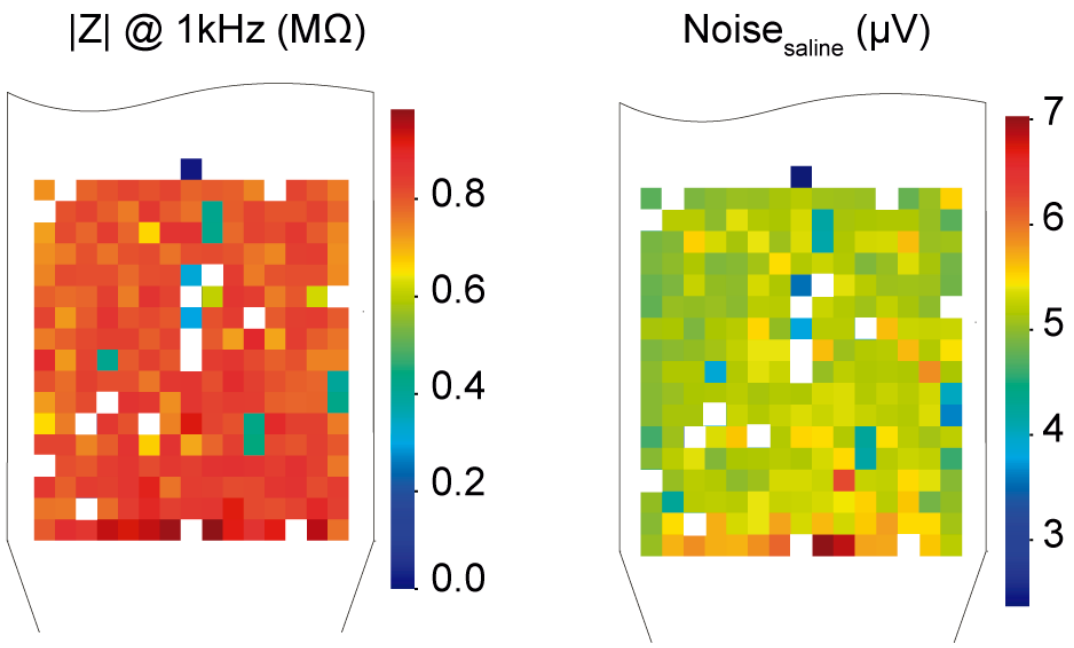


Figure 3. The 256-channel probe: impedance and noise. Electrical properties of 5 x 5 µm electrodes. Left: the majority of electrodes report an impedance magnitude at 1 kHz lower than 1 MOhm, but 16 of the 255 sites are non-functional because the impedance is higher than 2 MOhm (electrodes represented by white squares). Right: noise magnitude in saline solution. The noise measurements were performed with the probe in a dish with saline solution and a reference electrode, Ag-AgCl wire (Science Products GmbH, E-255). The white squares denote the non-functional electrodes.

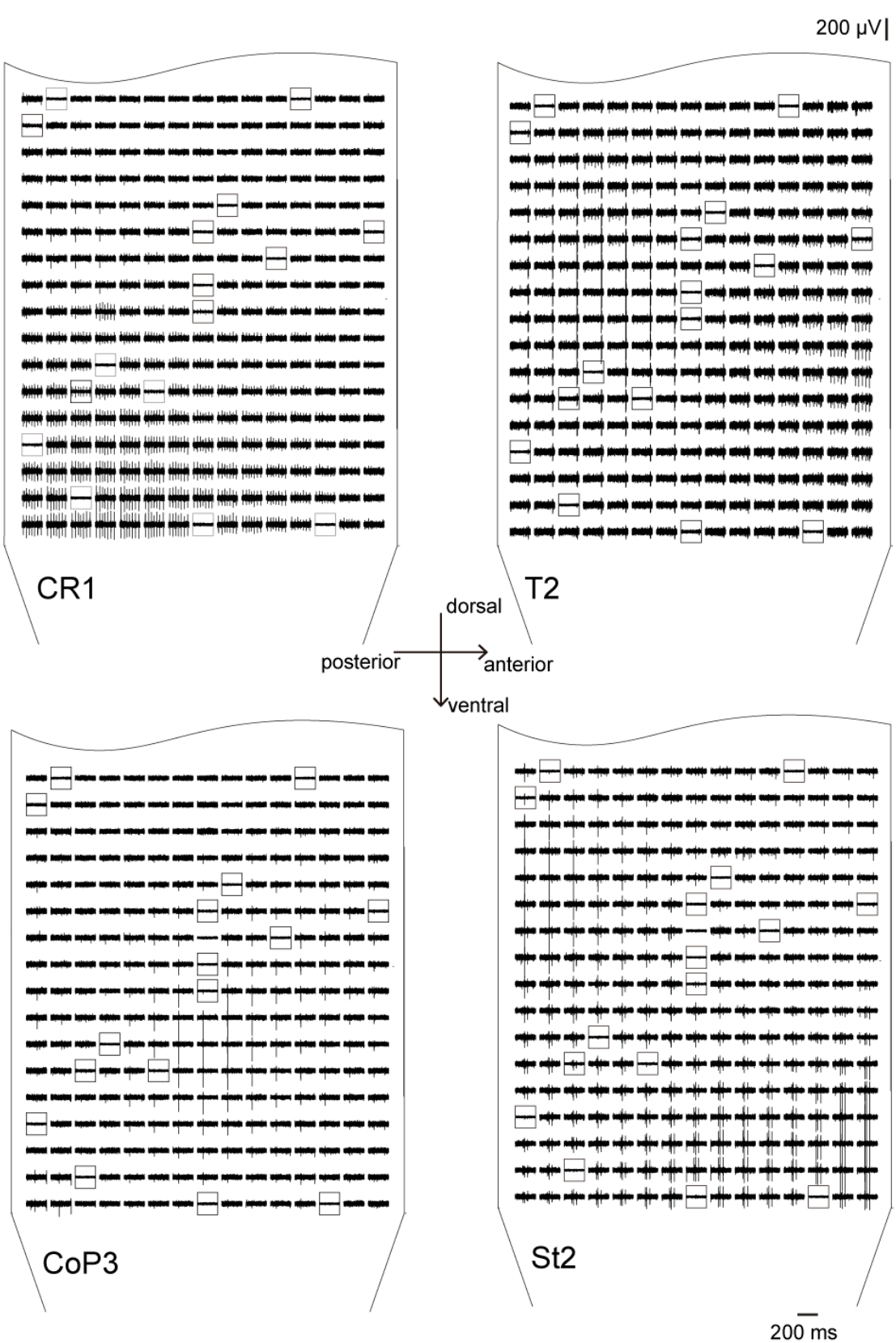

200 µV
CR1
T2
dorsal
posterior
anterior
ventral
CoP3
St2
200 ms

Figure 4. Different patterns of voltage deflection within the electrodes array introduced by neuronal activity across different brain regions (CR1, T2, CoP3 and St2 as recording labels). The black rectangles denote the non-functional electrodes.

Table 1. Summary of the dataset used to validate CMOS-based probes. Acute recordings performed with different number of active groups, reference type configuration and recording depths. We targeted the brain regions under the stereotaxic coordinates, anterior-posterior -3.4 mm and medial-lateral 1.3 mm. The high-pass cut-off frequency for the AP mode was set to 500 Hz and the low-pass cut-off frequency for the LFP mode was set to 500 Hz. The bias voltage is a parameter that was adjusted for each recording depending mostly on the number of active groups.

Filename	Depth tip (mm)	Number of Active groups	Reference type	Time (min)	Bias voltage (V)
17_50_36.bin	6.7	2	Internal	1	2.25
17_52_36.bin	6.7	4	Internal	1	2.34
17_54_35.bin	6.7	6	Internal	1	2.37
17_56_25.bin	6.7	8	Internal	1	2.39
17_58_26.bin	6.7	10	Internal	15	2.425
18_15_12.bin	6.7	12	Internal	1	2.44
18_18_41.bin	6.7	2	External	1	2.3
18_20_31.bin	6.7	4	External	1	2.38
18_22_40.bin	6.7	6	External	1	2.4
18_24_20.bin	6.7	8	External	1	2.42
18_26_30.bin	6.7	10	External	15	2.43
18_40_36.bin	6.7	12	External	1	2.45
19_13_16.bin	7.6	12	Internal	15	2.43

Table 2. Summary of the dataset gathered with the 256-channel probe. Acute recordings (30 minutes long) from anesthetized rats. The recording label specifies the brain region and more specifically the recording position (i.e., anterior-posterior and medial-lateral stereotaxic coordinates and the distance between the brain surface to the tip of the probe).

Filename	Label	Depth tip (mm)	AP (mm)	ML (mm)
amplifier2017-02-08T14_34_33.bin	Co1	0.6	-3.15	1.94
amplifier2017-02-08T15_34_04.bin	Co2	0.7	-3.15	1.94
amplifier2017-02-08T16_03_06.bin	Co3	0.8	-3.15	1.94
amplifier2017-02-08T18_06_19.bin	H1	2.5	-3.15	1.94
amplifier2017-02-08T18_38_09.bin	H2	3.3	-3.15	1.94
amplifier2017-02-08T20_04_54.bin	H3	3.5	-3.15	1.94
amplifier2017-02-08T20_54_26.bin	T1	4.6	-3.15	1.94
amplifier2017-02-08T21_38_55.bin	T2	6.4	-3.15	1.94
amplifier2017-02-16T15_37_59.bin	CR1	1.5	-10.60	0.65
amplifier2017-02-16T16_14_15.bin	CR2	1.7	-10.60	0.65
amplifier2017-02-16T16_58_01.bin	CR3	2.1	-10.60	0.65
amplifier2017-02-23T14_38_33.bin	Co4	1.4	+1.91	1.79
amplifier2017-02-23T15_48_36.bin	St1	3.8	+1.91	1.79
amplifier2017-02-23T17_29_48.bin	St2	5.5	+1.91	1.79
amplifier2017-02-23T16_55_00.bin	St3	5.6	+1.91	1.79
amplifier2017-02-23T18_25_19.bin	CoP1	2.8	+2.02	4.11
amplifier2017-02-23T19_00_56.bin	CoP2	3.2	+2.02	4.11
amplifier2017-02-23T19_36_39.bin	CoP3	3.6	+2.02	4.11