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Arbeitsbericht NAB 22-02

TBO Stadel-2-1: Data Report

Dossier II
Core Photography

September 2022

National Cooperative
for the Disposal of
Radioactive Waste

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Dossier II Core Photography

September 2022

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[1] Maya & Daniele
[2] Nagra

Keywords:
STA2-1, Nördlich Lägern, TBO, deep drilling campaign, drill cores, cuttings, photos, composites, CoreScan[3]

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Nagra Arbeitsberichte NAB ("Working Reports") present the results of work in progress that have not necessarily been subject to a comprehensive review. They are intended to provide rapid dissemination of current information.

This NAB aims at reporting drilling results at an early stage. Additional borehole-specific data will be published elsewhere.

In the event of inconsistencies between dossiers of this NAB, the dossier addressing the specific topic takes priority. In the event of discrepancies between Nagra reports, the chronologically later report is generally considered to be correct. Data sets and interpretations laid out in this NAB may be revised in subsequent reports. The reasoning leading to these revisions will be detailed there.

This report was finalised in June 2023.

This Dossier was prepared by:
D. Kaehr (photography post-processing and core photograph composite design and compilation)
M. Gysi (project management, conceptualisation, QC and writing)

Editorial work: Geomecon and M. Unger

The Dossier has greatly benefitted from technical discussions with, and reviews by, external and internal experts. Their input and work are very much appreciated!

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Note: The appendix is only included it the digital version of this report and can be found under the paper clip symbol.

1 Introduction

1.1 Context

To provide input for site selection and the safety case for deep geological repositories for radioactive waste, Nagra has drilled a series of deep boreholes ("Tiefbohrungen", TBO) in Northern Switzerland. The aim of the drilling campaign is to characterise the deep underground of the three remaining siting regions located at the edge of the Northern Alpine Molasse Basin (Fig. 1-1).

In this report, we present the results from the Stadel-2-1 borehole.

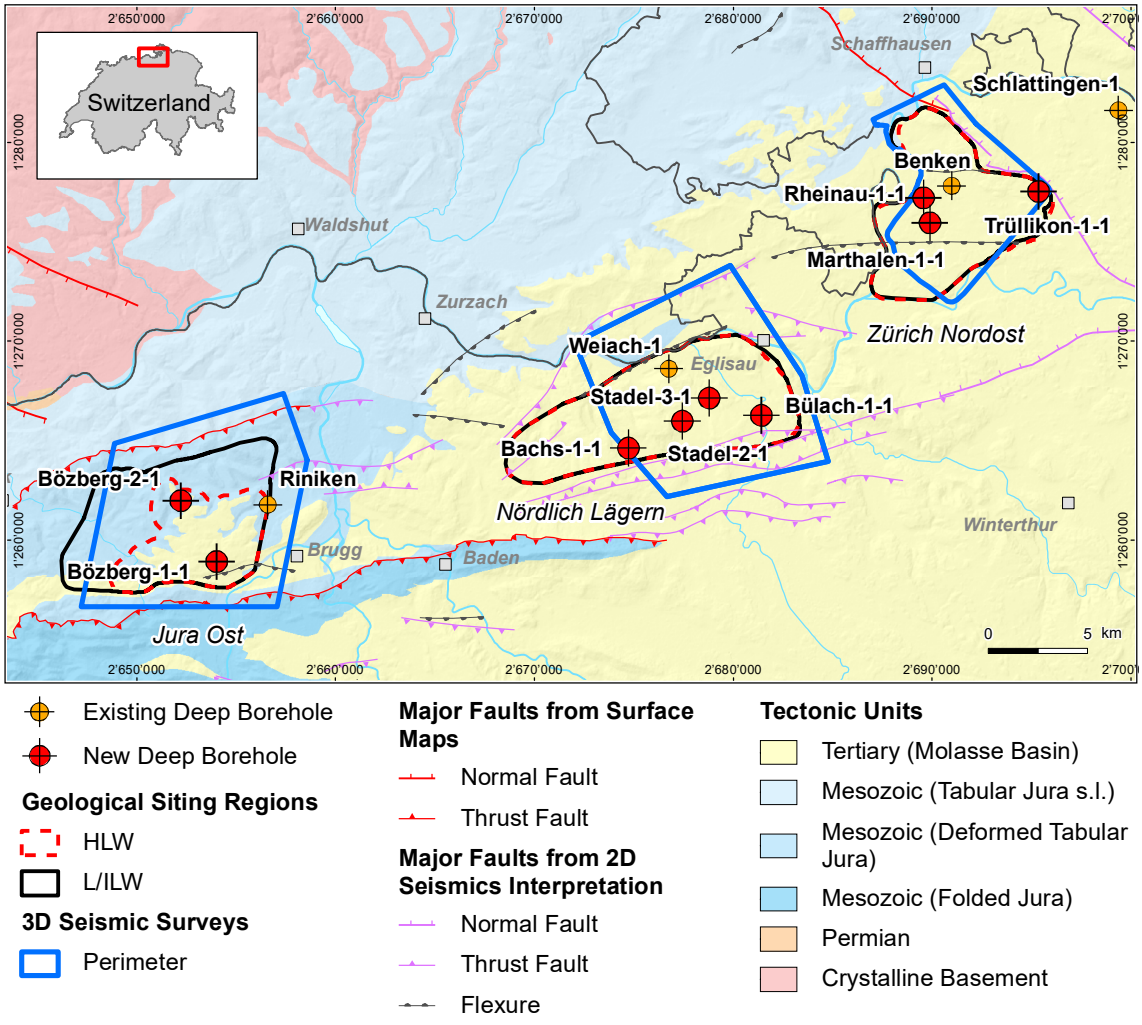


Fig. 1-1: Tectonic overview map with the three siting regions under investigation

1.2 Location and specifications of the borehole

The Stadel-2-1 (STA2-1) exploratory borehole is the third borehole drilled within the framework of the TBO project. The drill site is located in the western part of the Nördlich Lägern siting region (Fig. 1-2). The vertical borehole reached a final depth of 1'288.12 m (MD)[1]. The borehole specifications are provided in Tab. 1-1.

Tab. 1-1: General information about the STA2-1 borehole

Siting region	Nördlich Lägern
Municipality	Stadel (Canton Zürich / ZH), Switzerland
Drill site	Stadel-2 (STA2)
Borehole	Stadel-2-1 (STA2-1)
Coordinates	LV95: 2'677'447.617 / 1'265'987.019
Elevation	Ground level = top of rig cellar: 417.977 m above sea level (asl)
Borehole depth	1'288.12 m measured depth (MD) below ground level (bgl)
Drilling period	25th January – 8th July 2021 (spud date to end of rig release)
Drilling company	Daldrup & Söhne AG
Drilling rig	Wirth B 152t
Drilling fluid	Water-based mud with various amounts of different components such as:[2] 0 – 670 m: Bentonite & polymers 670 – 1'051 m: Potassium silicate & polymers 1'051 – 1'117 m: Bentonite & polymer 1'117 – 1'288.12 m: Sodium chloride brine & polymers

The lithostratigraphic profile and the casing scheme are shown in Fig. 1-3. The comparison of the core versus log depth[3] of the main lithostratigraphic boundaries in the STA2-1 borehole is shown in Tab. 1-2.

[1] Measured depth (MD) refers to the position along the borehole trajectory, starting at ground level, which for this borehole is the top of the rig cellar. For a perfectly vertical borehole, MD below ground level (bgl) and true vertical depth (TVD) are the same. In all Dossiers depth refers to MD unless stated otherwise.

[2] For detailed information see Dossier I.

[3] Core depth refers to the depth marked on the drill cores. Log depth results from the depth observed during geophysical wireline logging. Note that the petrophysical logs have not been shifted to core depth, hence log depth differs from core depth.

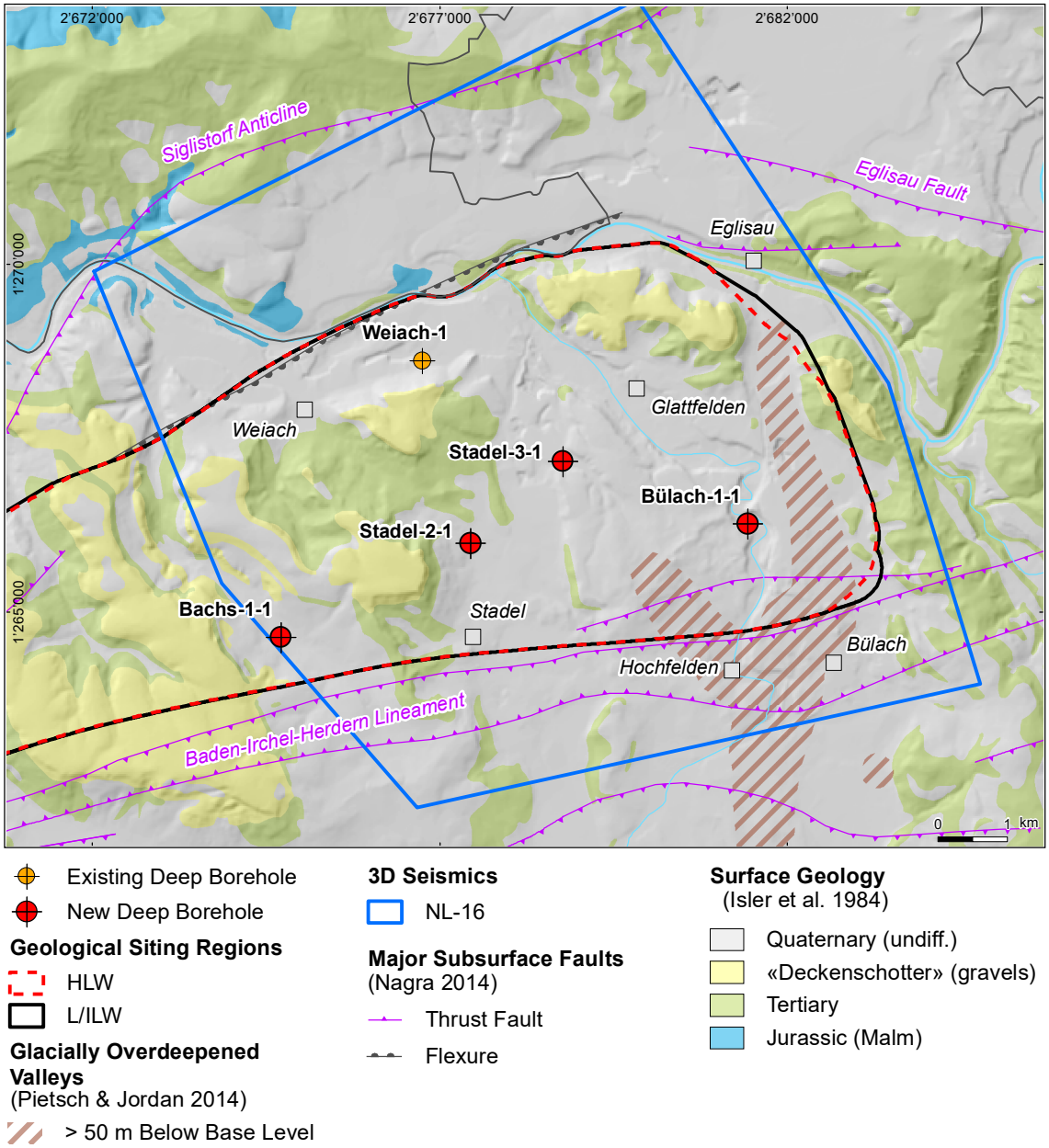


Fig. 1-2: Overview map of the investigation area in the Nördlich Lägern siting region with the location of the STA2-1 borehole in relation to the boreholes Weiach-1, BUL1-1, STA3-1 and BAC1-1

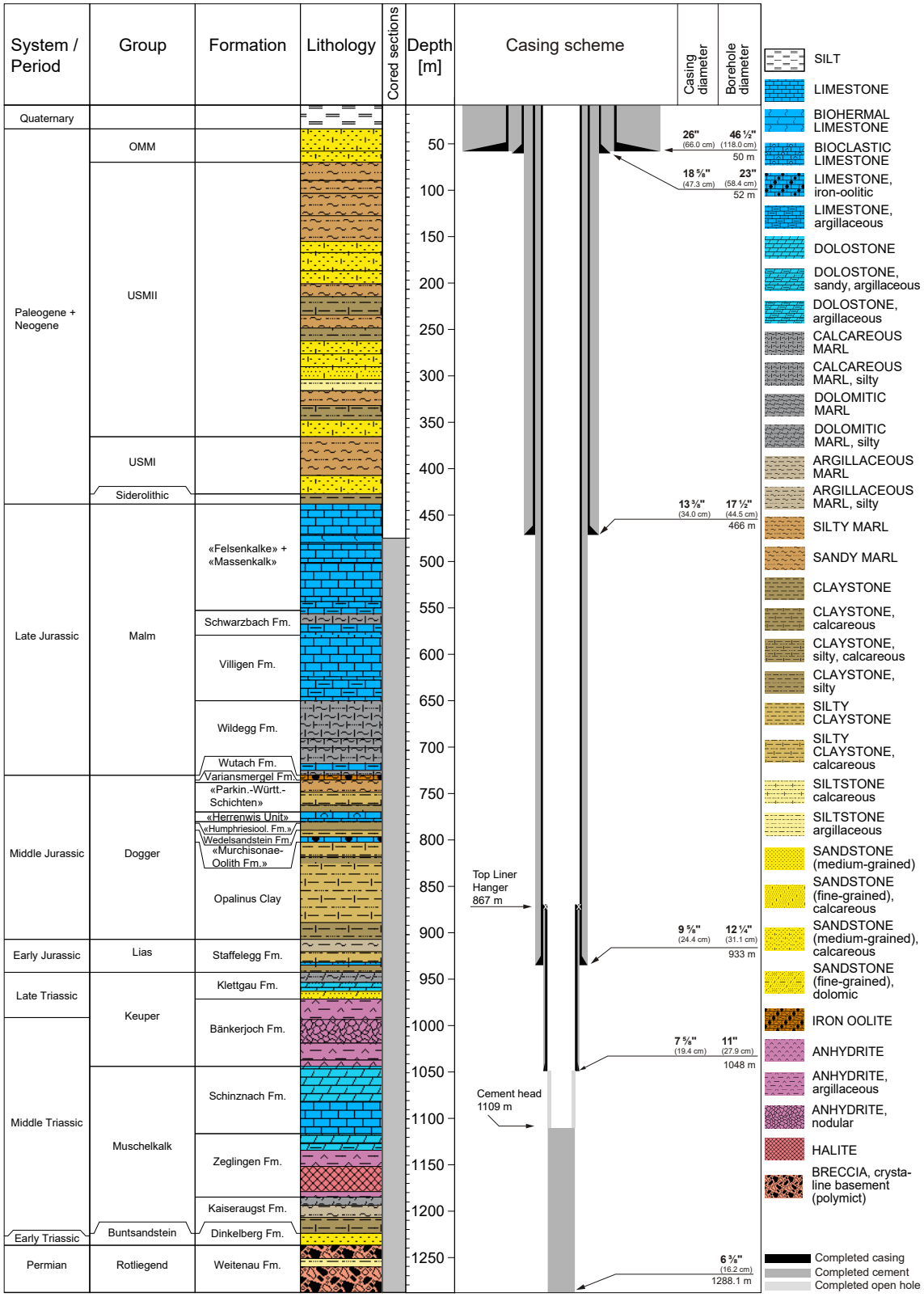


Fig. 1-3: Lithostratigraphic profile and casing scheme for the STA2-1 borehole[4]

[4] For detailed information see Dossier I and III.

Tab. 1-2: Core and log depth for the main lithostratigraphic boundaries in the STA2-1 borehole[5]

System / Period	Group	Formation		Core depth in m	Log depth in m (MD)	
Quaternary				**26.0**		—
Paleogene + Neogene	OMM			62.0		—
	USM			422.0		—
	Siderolithic			**433.0**		—
Jurassic	Malm	«Felsenkalke» + «Massenkalk»		548.35	548.62	—
		Schwarzbach Formation		575.08	575.45	—
		Villigen Formation		646.23	646.63	—
		Wildegg Formation		727.18	728.20	—
	Dogger	Wutach Formation		732.16	733.25	—
		Variansmergel Formation		734.92	735.95	—
		«Parkinsoni-Württembergica-Schichten»		767.02	768.05	—
		«Herrenwis Unit»		777.54	778.47	—
		«Humphriesioolith Formation»		779.34	780.27	—
		Wedelsandstein Formation		786.85	787.79	—
		«Murchisonae-Oolith Formation»		799.67	800.67	—
		Opalinus Clay		905.20	906.87	—
	Lias	Staffelegg Formation		**940.89**	**941.42**	—
Triassic	Keuper	Klettgau Formation		969.87	970.52	—
		Bänkerjoch Formation		1043.07	1043.62	—
	Muschelkalk	Schinznach Formation		1116.01	1116.69	—
		Zeglingen Formation		1184.72	1185.42	—
		Kaiseraugst Formation		1224.20	1225.07	—
	Buntsandstein	Dinkelberg Formation		**1237.01**	**1237.94**	—
Permian	Rotliegend	Weitenau Formation	final depth	1288.12	1288.87	

[5] For details regarding lithostratigraphic boundaries see Dossier III and IV; for details about depth shifts (core goniometry) see Dossier V.

1.3 Documentation structure for the STA2-1 borehole

NAB 22-02 documents the majority of the investigations carried out in the STA2-1 borehole, including laboratory investigations on core material. The NAB comprises a series of stand-alone dossiers addressing individual topics and a final dossier with a summary composite plot (Tab. 1-3).

This documentation aims at early publication of the data collected in the STA2-1 borehole. It includes most of the data available approximately one year after completion of the borehole. Some analyses are still ongoing (e.g. diffusion experiments, analysis of veins, hydrochemical interpretation of water samples) and results will be published in separate reports.

The current borehole report will provide an important basis for the integration of datasets from different boreholes. The integration and interpretation of the results in the wider geological context will be documented later in separate geoscientific reports.

Tab. 1-3: List of dossiers included in NAB 22-02

Black marks the dossier at hand.

Dossier	Title	Authors
I	TBO Stadel-2-1: Drilling	P. Hinterholzer-Reisegger
II	**TBO Stadel-2-1: Core Photography**	**D. Kaehr & M. Gysi**
III	TBO Stadel-2-1: Lithostratigraphy	P. Jordan, P. Schürch, H. Naef, M. Schwarz, R. Felber, T. Ibele & H.P. Weber
IV	TBO Stadel-2-1: Microfacies, Bio- and Chemostratigraphic Analysis	S. Wohlwend, H.R. Bläsi, S. Feist-Burkhardt, B. Hostettler, U. Menkveld-Gfeller, V. Dietze & G. Deplazes
V	TBO Stadel-2-1: Structural Geology	A. Ebert, S. Cioldi, E. Hägerstedt & H.P. Weber
VI	TBO Stadel-2-1: Wireline Logging, Micro-hydraulic Fracturing and Pressure-meter Testing	J. Gonus, E. Bailey, J. Desroches & R. Garrard
VII	TBO Stadel-2-1: Hydraulic Packer Testing	R. Schwarz, R. Beauheim, S.M.L. Hardie & A. Pechstein
VIII	TBO Stadel-2-1: Rock Properties, Porewater Characterisation and Natural Tracer Profiles	C. Zwahlen, L. Aschwanden, E. Gaucher, T. Gimmi, A. Jenni, M. Kiczka, U. Mäder, M. Mazurek, D. Roos, D. Rufer, H.N. Waber, P. Wersin & D. Traber
IX	TBO Stadel-2-1: Rock-mechanical and Geomechanical Laboratory Testing	E. Crisci, L. Laloui & S. Giger
X	TBO Stadel-2-1: Petrophysical Log Analysis	S. Marnat & J.K. Becker
	TBO Stadel-2-1: Summary Plot	Nagra

1.4 Scope and objectives of this dossier

The dossier at hand (Dossier II) documents core photography. The objectives are the following:

- summary of core handling and core photography of this drilling campaign
- visual documentation of the cuttings samples and cores of STA2-1 from 2 m to 1'288.12 m MD core depth

2 Executed working procedures

2.1 On-site core handling

The cores were drilled with a 6 m long inner core barrel containing an inner plastic tube. To avoid core jamming and to obtain a better core quality the length of a core run was 3 m, only. After cutting the core, the drilling crew pulled the inner core barrel up with a winch (wireline coring) and placed it on the pipe rack (Fig. 2-1). The core catcher was detached and the inner plastic tube was removed and laid down on trestles. The section containing the core was separated from the empty plastic tube by cutting the tube to a length of approximately 3.5 m. The core was then carried to the core processing area (Fig. 2-2) and pushed out of the tube using an appropriate rod. If the core was jammed inside the tube, the plastic liner was cut laterally using an electric cutting machine.



Fig. 2-1: The inner core barrel is placed on the pipe rack

Showcase picture of rig 16 (Marriott); workflow comparable at the Daldrup rig (picture credits: © Maya & Daniele)



Fig. 2-2: The 3 m core in the plastic liner is carried to the core processing area

Showcase picture of rig 16 (Marriott); workflow comparable at the Daldrup rig (picture credits: © Maya & Daniele)

Once laid out, the core was washed with water to remove the drilling fluid (Figs. 2-3 and 2-4). Afterwards, the top of the newly cut core was aligned with the bottom of the previous core section. If the two core pieces did not fit properly, they were marked with a red cross and a new set of orientation lines was started. If a fit was established, the orientation lines were correctly copied onto the newly cored section. These orientation lines consist of two parallel lines drawn along the core axis with additional arrows indicating the downhole direction. The line on the right-hand side when looking towards the core top is red (Figs. 2-5 and 2-6). The colour of the line on the left-hand side can be white, yellow or black depending on the colour of the cored rock. The core depth was marked on the core with a line perpendicular to the core axis and corresponding depth labels at 0.5 m intervals.

To facilitate proper core handling, transportation and further analyses, the core sections were cut into pieces approximately one metre long using a diamond-impregnated rock saw before being stored in one metre core boxes.



Fig. 2-3: A core covered in drilling fluid on the core processing table

Picture credits: © Maya & Daniele



Fig. 2-4: A core is washed with water on the core processing table to remove the drilling fluid

Picture credits: © Maya & Daniele



Fig. 2-5: A core is marked with orientation lines

Picture credits: © Maya & Daniele

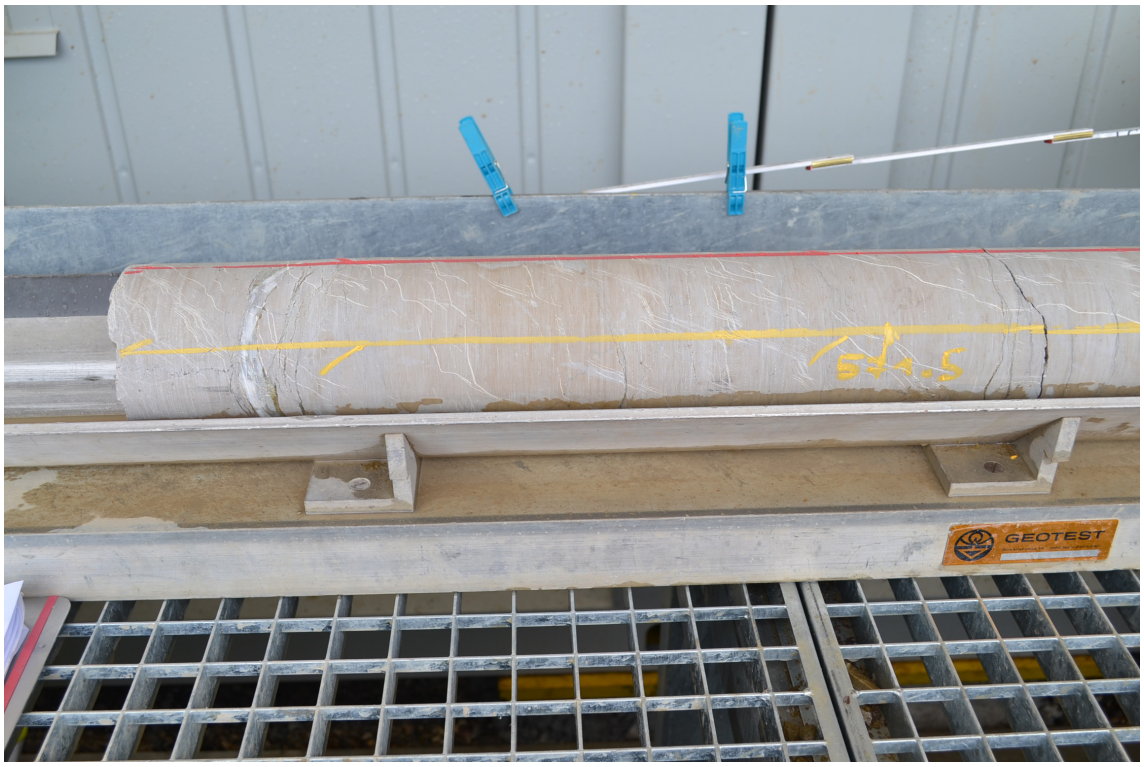


Fig. 2-6: Cleaned, measured and marked core

2.2 Core photography

All core pieces were photographed (planar pictures) using a modified version of the DMT CoreScan^3 system (Fig. 2-7) specifically designed to take high-resolution core photographs (10 px/mm). If the core geometry and condition allowed it, 360° photographs of the core surface were also taken (not documented in this dossier). For both planar and 360° photographs, the core was placed on two rubber rollers and a digital line scan camera recorded the picture via an inclined mirror in the top section of the CoreScan^3 system. During 360° photography, the core was rotated around its longitudinal axis and the picture was taken at the upper section of the core. In addition, all 360° photographs were digitally rotated to set the red orientation line to 0°. Both planar and 360° photographs were saved on the CoreScan^3 computer, which automatically synchronised the data with the Nagra network-attached storage (NAS) located at the core storage facility in Würenlingen.

2.2.1 Specifications

Camera:

- manufacturer: avaluar GmbH
- camera model: CCD-Colour camera CSc3b1.26
- resolution y: 6'400 (10 px/mm)
- resolution x: 10'680 (10 px/mm)
- spectral response: 400 nm to 700 nm
- sharpening: 0
- gamma: 1.4
- lens maker: Schneider Kreuznach
- lens model: APO COMPONON f4.0/60mm
- aperture: f/8
- focal length: 35 mm
- exposure time: program very dark (custom calibrated for Nagra's LED panels)

LED panels:

- 4x Aladdin BI-FLEX 4 (200 W Bi-Colour Panel): two at the back and two at the front of the CoreScan^3 system, protected in aluminium boxes with a diffusor plate as front cover
- 2x Aladdin BI-FLEX 2 (70 W Bi-Colour Panel): one on the left-hand side and one on the right-hand side of the CoreScan^3 system, protected in an aluminium box with a diffusor plate as front cover
- all six panels are calibrated to 5'000 K with a Sekonic C-800 SpectroMaster

Reference cards:

- X-Rite ColorChecker White Balance: used for camera calibration (shading)
- X-Rite ColorChecker Classic Mini colour chart: colour reference on every core photo
- BST14 greyscale chart: greyscale reference on every core photo
- Datacolor SpyderCHECKR 48 colour chart: colour reference chart for reference photographs

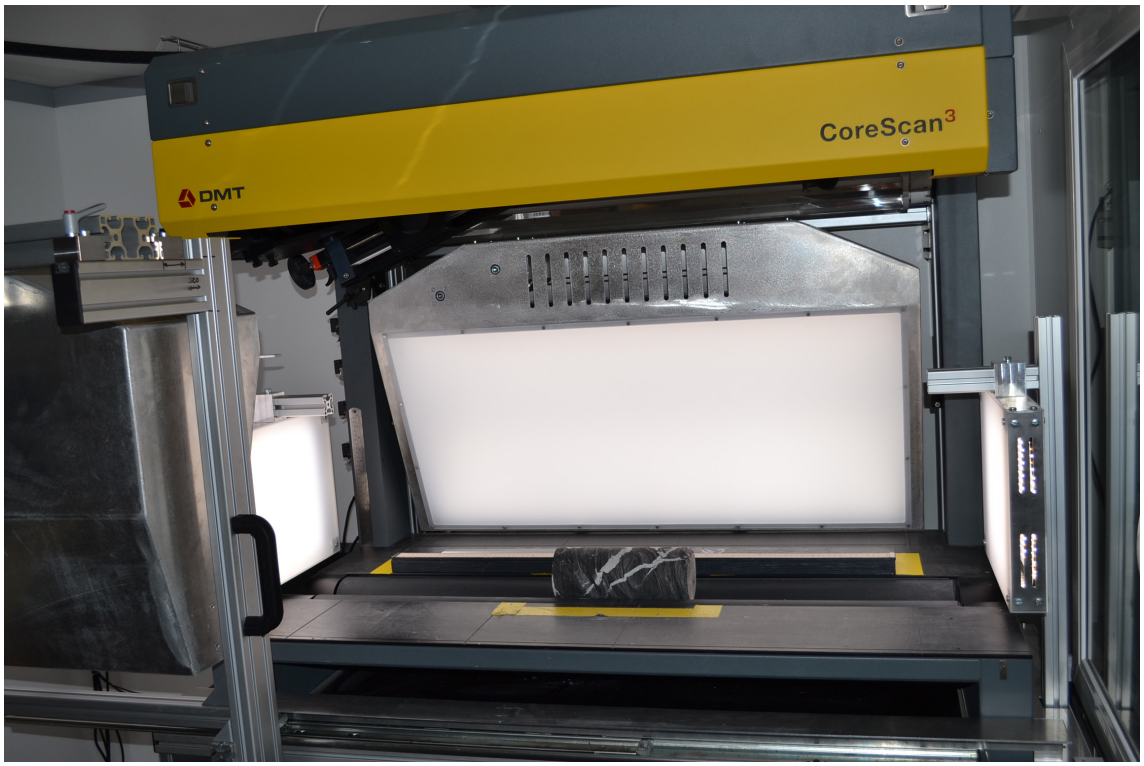


Fig. 2-7: Modified DMT CoreScan^3 system at the drill site

2.2.2 Colour drift monitoring

During coring operations, a reference photograph of the Datacolor SpyderCHECKR 48 colour chart was taken with the CoreScan^3 system at least twice per 24 h (Fig. 2-8). These reference photographs enabled to monitor the proper functioning of the CoreScan^3 system during operations. Issues regarding colour correctness and contrast could be detected early and necessary adjustments to the CoreScan^3 system or environment conditions (especially room temperature) could be made. The reference photographs could further be used to create an ICC profile (International Color Consortium): a data set characterising the colour input / output for the most accurate colour matching.

Each core photograph taken included a metre scale, a BST14 greyscale chart and an X-Rite ColorChecker Classic Mini colour chart (Fig. 2-9). The metre scale is essential to have a depth indicator on the core photograph, whereas the colour and greyscale charts allow manual colour management during post-processing of the core photograph if required.



Fig. 2-8: Reference photograph setup of the CoreScan³ system with a Datacolor Spyder-CHECKR 48 colour chart, a metre scale, a BST14 greyscale chart and an X-Rite ColorChecker Classic Mini colour chart

Picture credits: © Maya & Daniele



Fig. 2-9: CoreScan³ system setup during core photography with a metre scale, a BST14 grey-scale chart and an X-Rite ColorChecker Classic Mini colour chart

Picture credits: © Maya & Daniele

2.3 Post-processing of core photographs

All core photographs taken on the drill site were post-processed by a professional photographer. The colour management of the post-processing workflow provided colour-matched, high-resolution core photograph reproductions with enhanced quality and fidelity. The following post-processing steps were applied to a batch of core photographs with comparable camera settings and environmental conditions:

1. noise reduction of the reference photographs of the Datacolor SpyderCHECKR 48 colour chart, shot with the CoreScan³ system
2. ICC profiling of the noise-reduced reference photographs, shot with the CoreScan³ system
3. evaluation of the ICC profiles and selection of the best ICC profile for the post-processing of the core photographs
4. ICC profile application to the core photographs in batch mode
5. correction of contrast and brightness of the core photographs in batch mode
6. conversion of the photographs to eciRGB_v2 standard colour space in batch mode
7. noise reduction and pre-sharpening of every single core photograph
8. correction of colour, exposure and contrast of the core photographs in batch mode

9. comparison between the best ICC profile of the Datacolor SpyderCHECKR 48 colour chart reference photograph, shot with the CoreScan^3 system and the ICC profile of the Datacolor SpyderCHECKR 48 colour chart reference photograph, shot with a Canon 5DmkIV camera
10. visual adjustment of the best ICC profile of the Datacolor SpyderCHECKR 48 colour chart reference photograph, shot with the CoreScan^3 system to the ICC profile of the Datacolor SpyderCHECKR 48 colour reference photograph, shot with a Canon 5DmkIV camera
11. application of the colour adjustement defined in the previous step to the core photographs in batch mode
12. if required, manual colour neutralisation of every single core photograph based on the BST14 greyscale chart and the X-Rite ColorChecker Classic Mini colour chart
13. cropping of the core photographs to the core outlines
14. export of the core photographs as .jpg and .tiff in pre-defined resolutions and corresponding sharpening parameters

2.4 Signatures

The following signature was used in the composite displays of the complete cores:

- white hachures: missing core due to formation integrity test (FIT) pilot hole or drilling-related technical issues (Fig. 2-10)

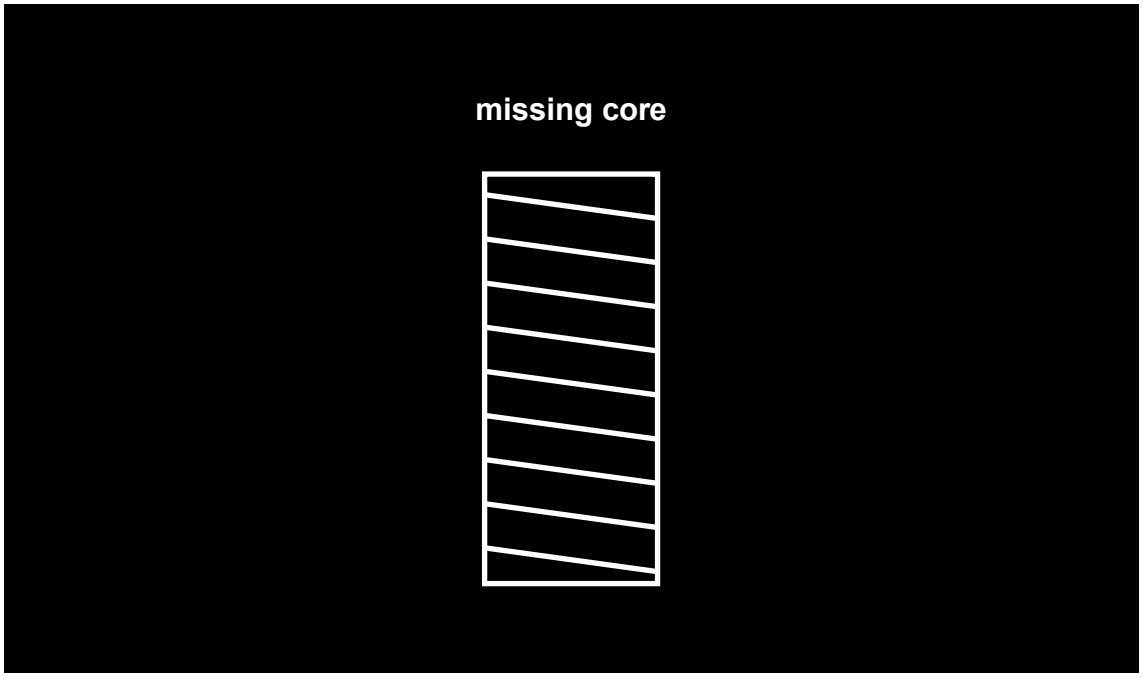


Fig. 2-10: White hachures signature used for missing core due to FIT pilot hole or drilling related technical issues in the composite displays

3 Stadel-2-1 core- and cuttings composites

2.00m 18.00m 34.00m



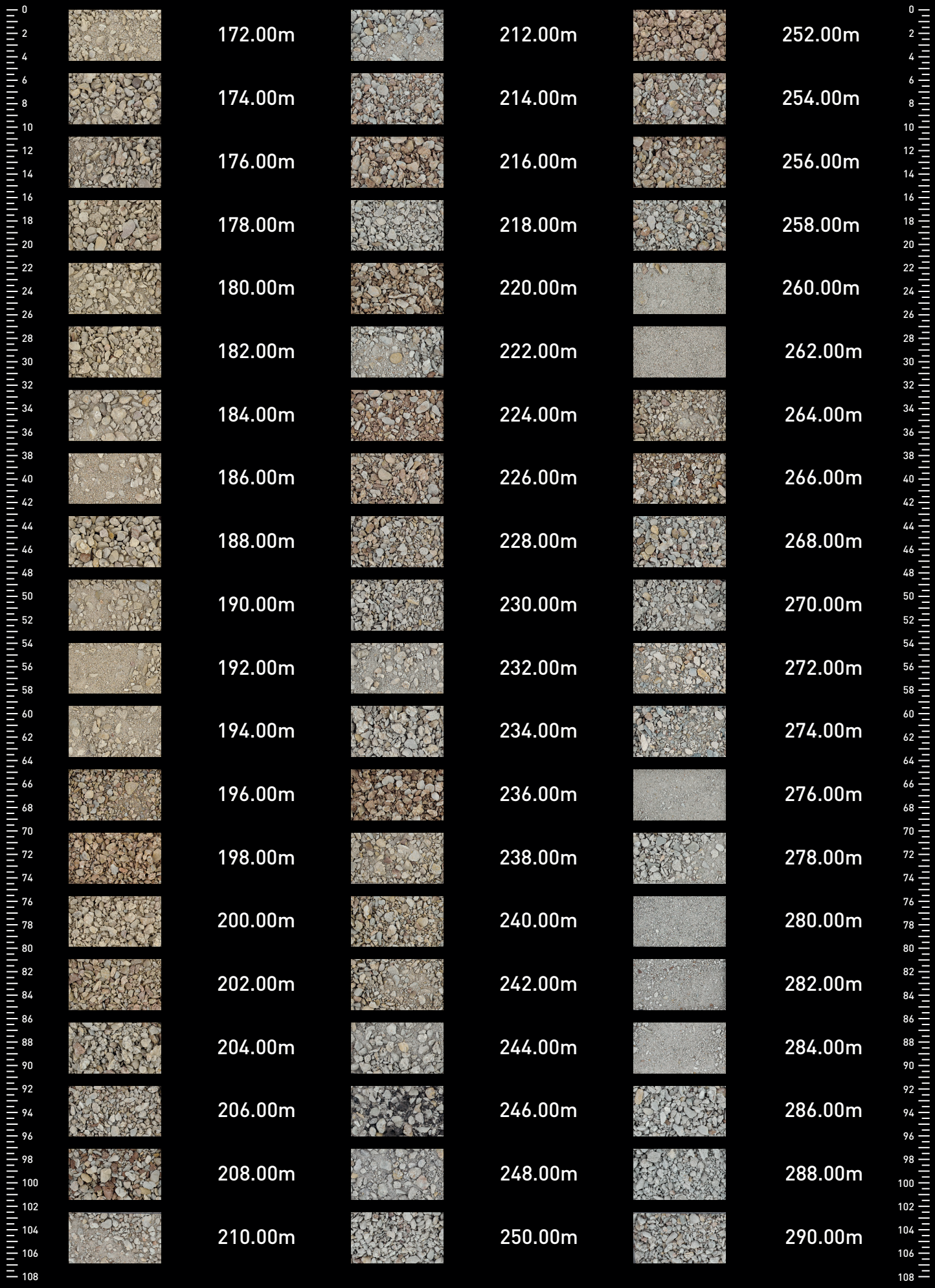
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52.00m 92.00m 132.00m



90.00m 130.00m 170.00m

172.00m 212.00m 252.00m



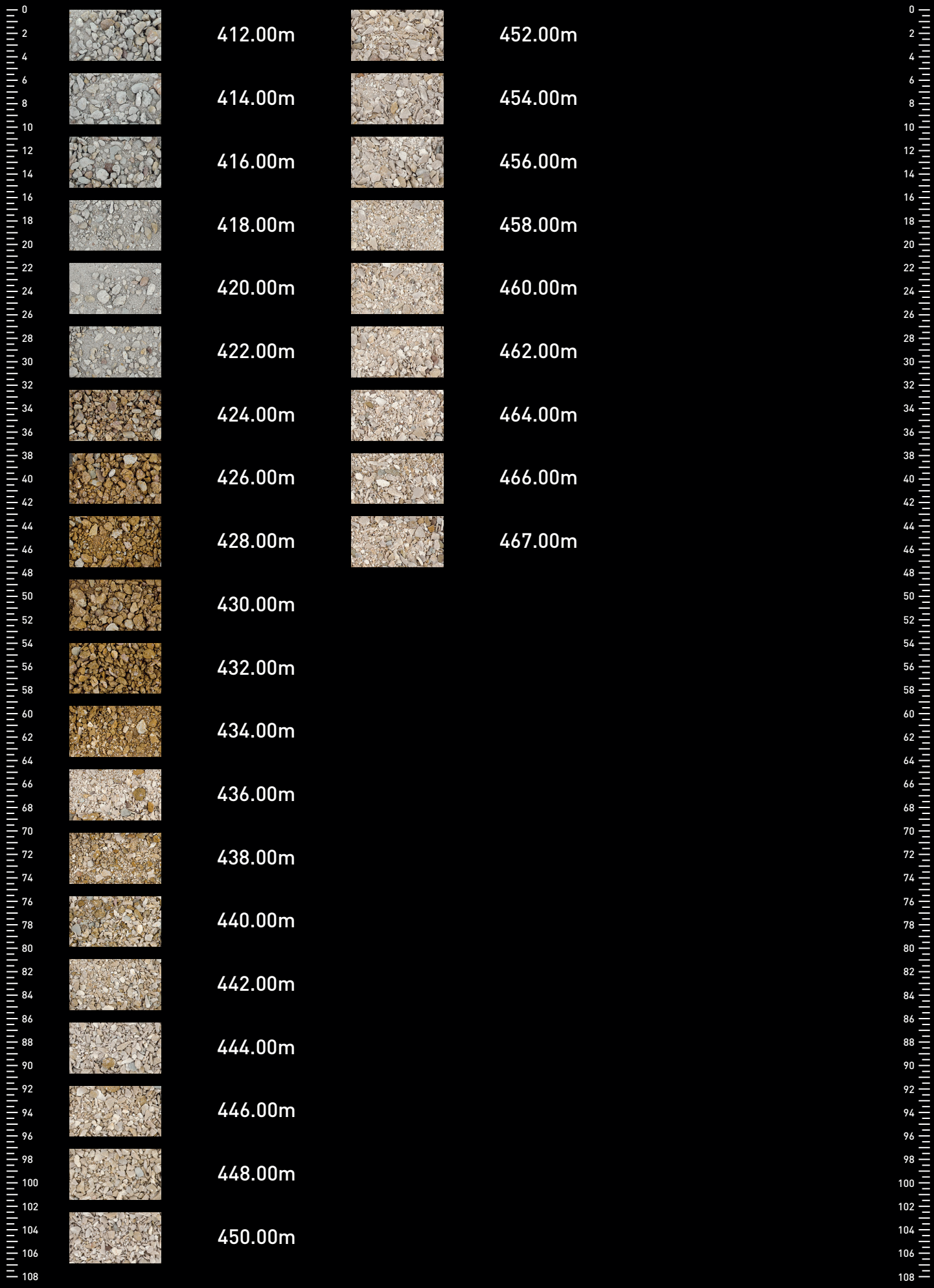
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292.00m 332.00m 372.00m

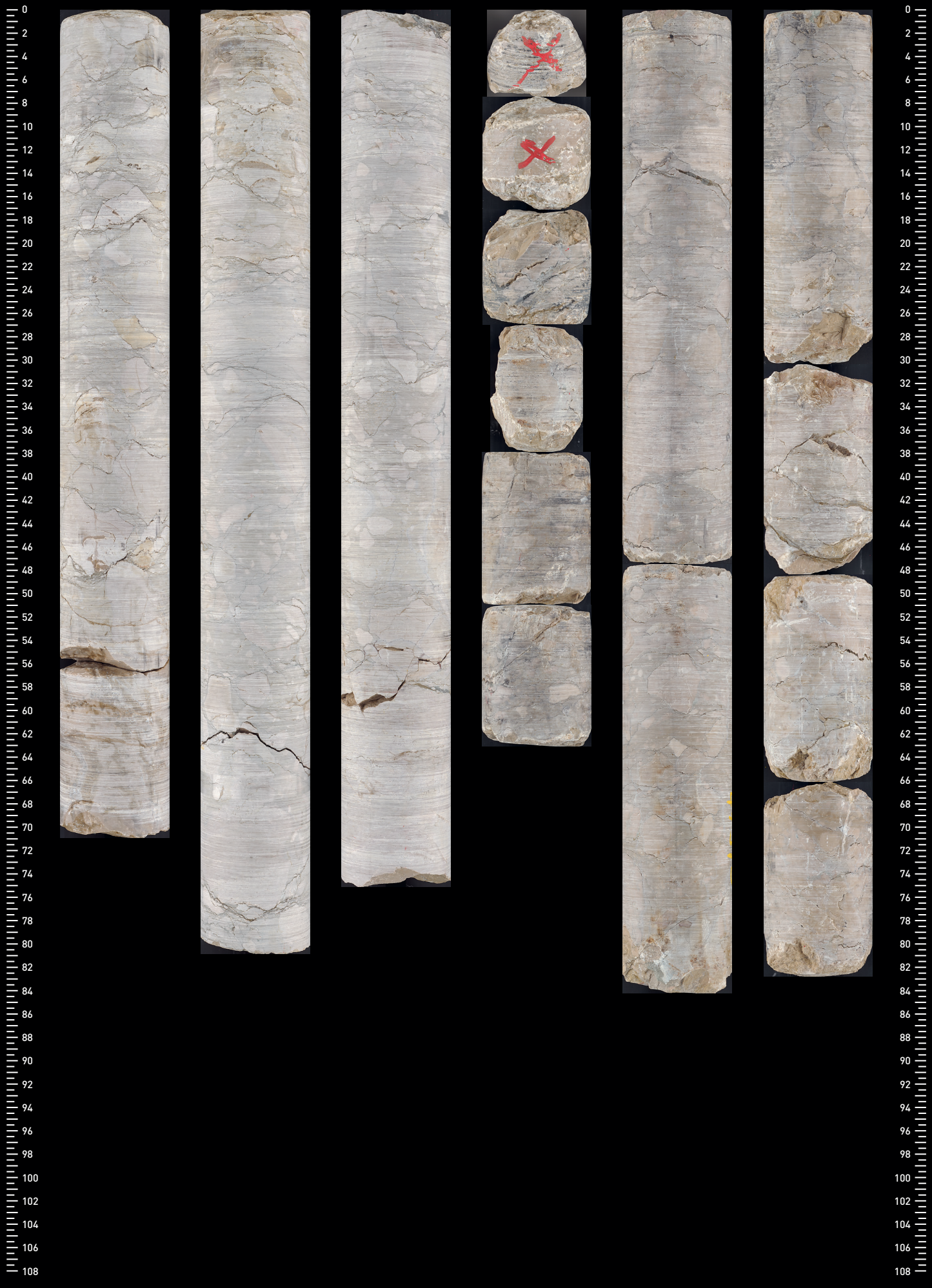


330.00m 370.00m 410.00m

412.00m 452.00m



450.00m 467.00m


470.00m
470.69m
471.48m
472.21m
472.82m
473.65m
470.69m
471.48m
472.21m
472.82m
473.65m
474.45m

474.45m 475.50m 475.84m 476.59m 477.17m 478.01m



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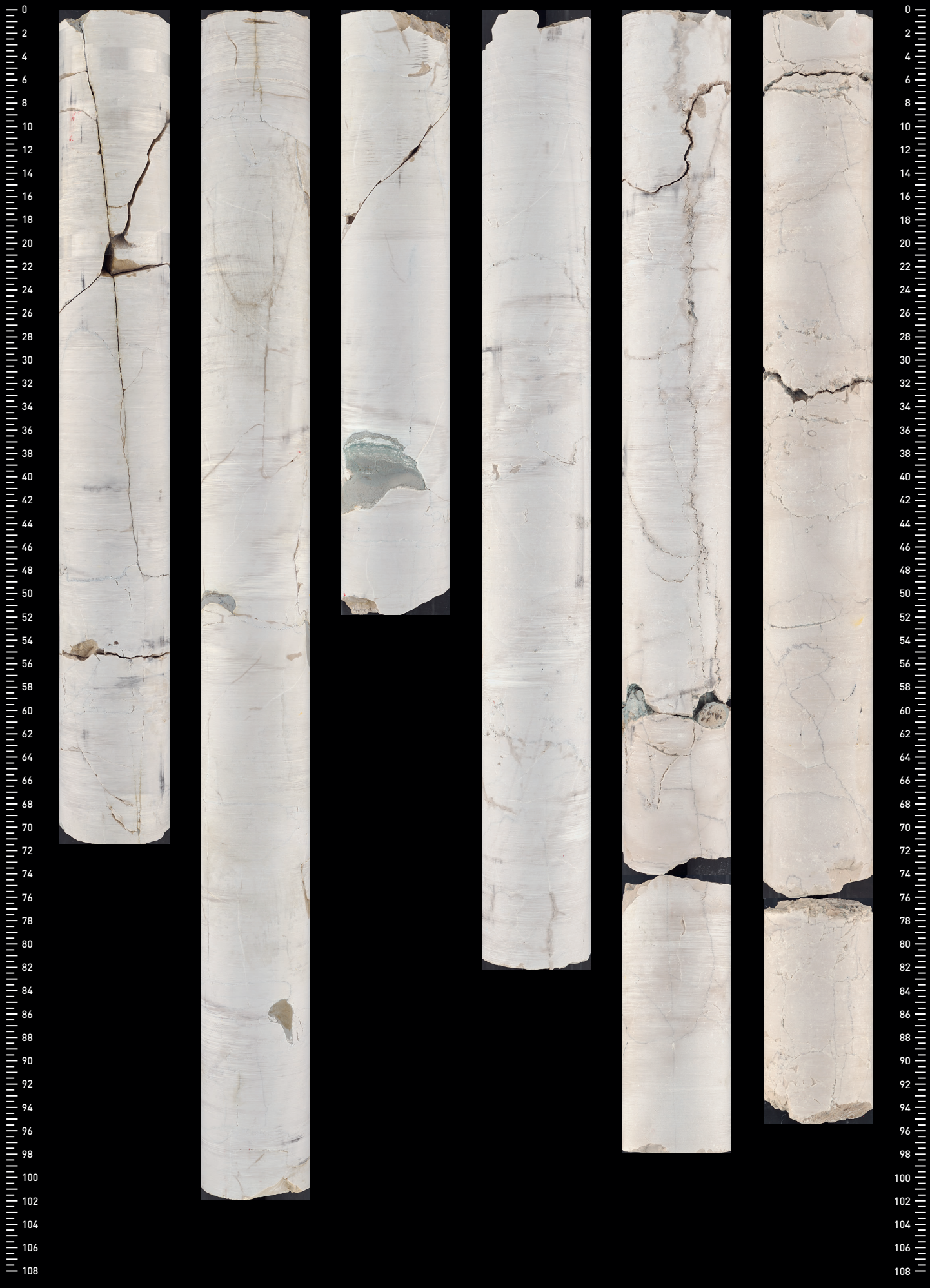
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483.00m
483.96m
484.56m
485.32m
486.12m
487.00m
483.96m
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485.32m
486.12m
487.00m
487.86m

487.86m 488.66m 489.39m 489.90m 490.77m 491.61m



488.66m 489.39m 489.90m 490.77m 491.61m 492.32m


492.32m
493.00m
494.00m
494.50m
495.30m
496.23m
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495.30m
496.23m
497.17m

497.17m 497.87m 498.87m 499.67m 500.35m 501.04m



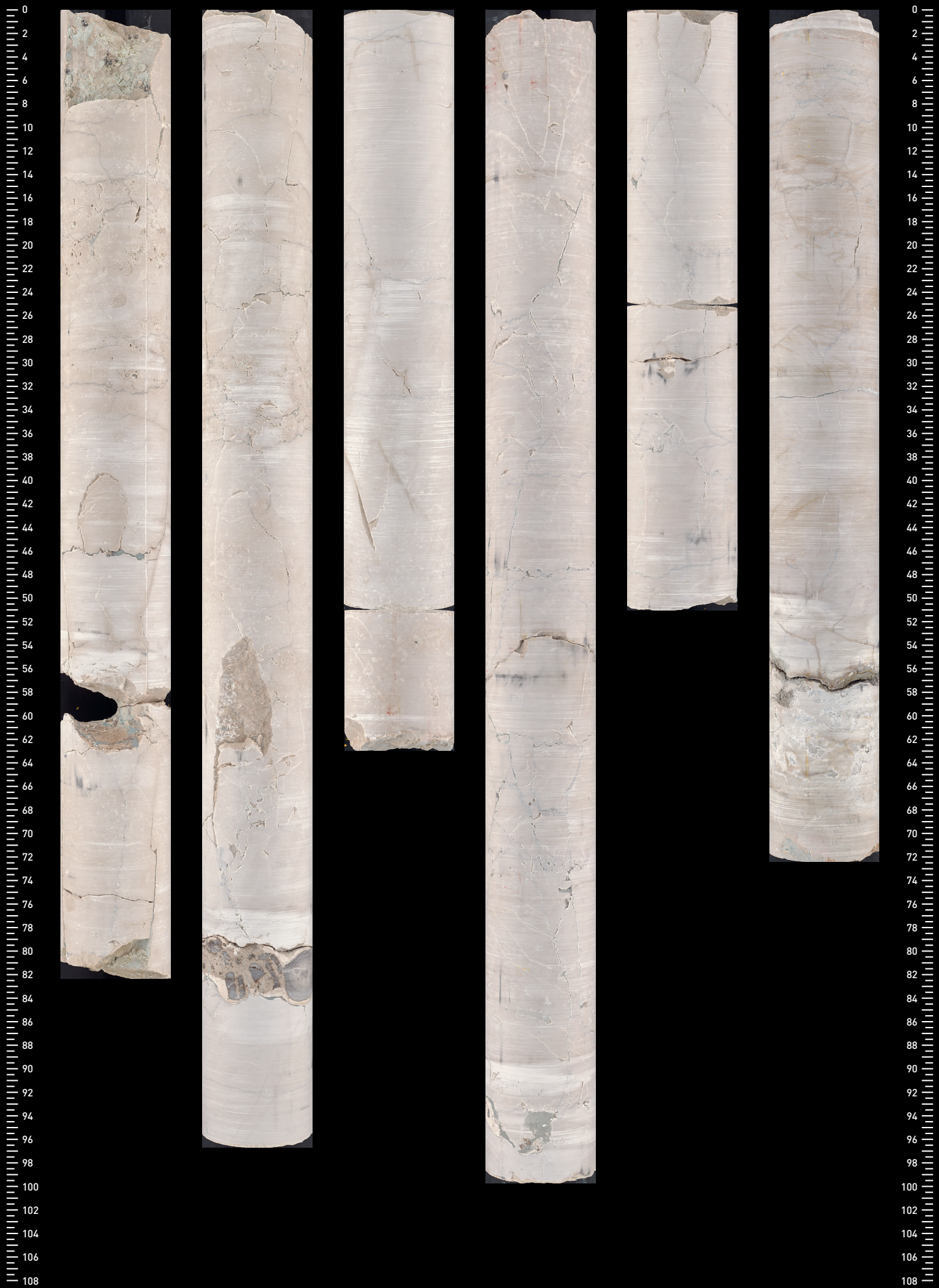
497.87m 498.87m 499.67m 500.35m 501.04m 501.95m

501.95m 502.87m 503.80m 504.77m 505.53m 506.40m



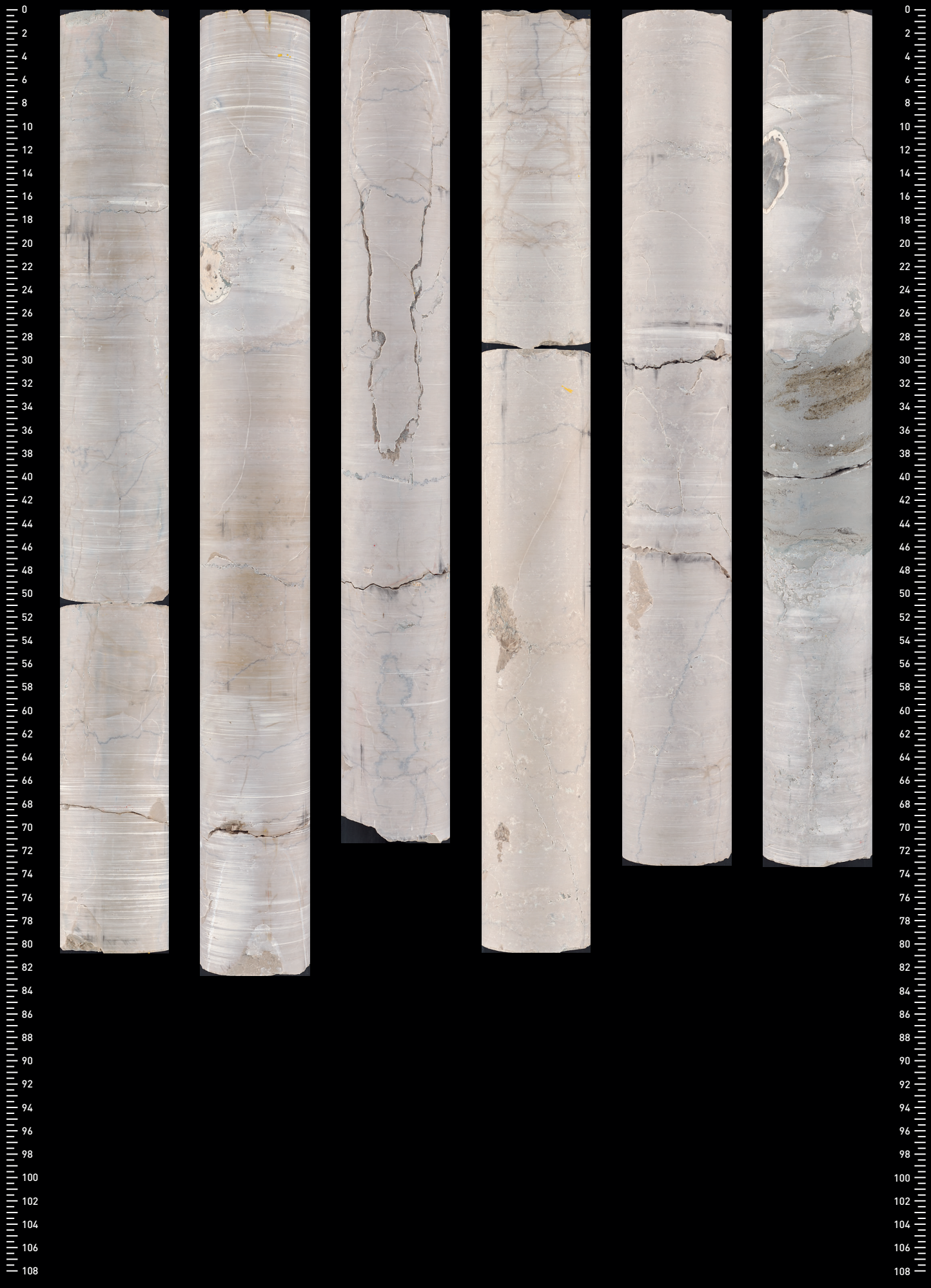
502.87m 503.80m 504.77m 505.53m 506.40m 507.14m

507.14m 507.96m 508.90m 509.51m 510.47m 510.97m



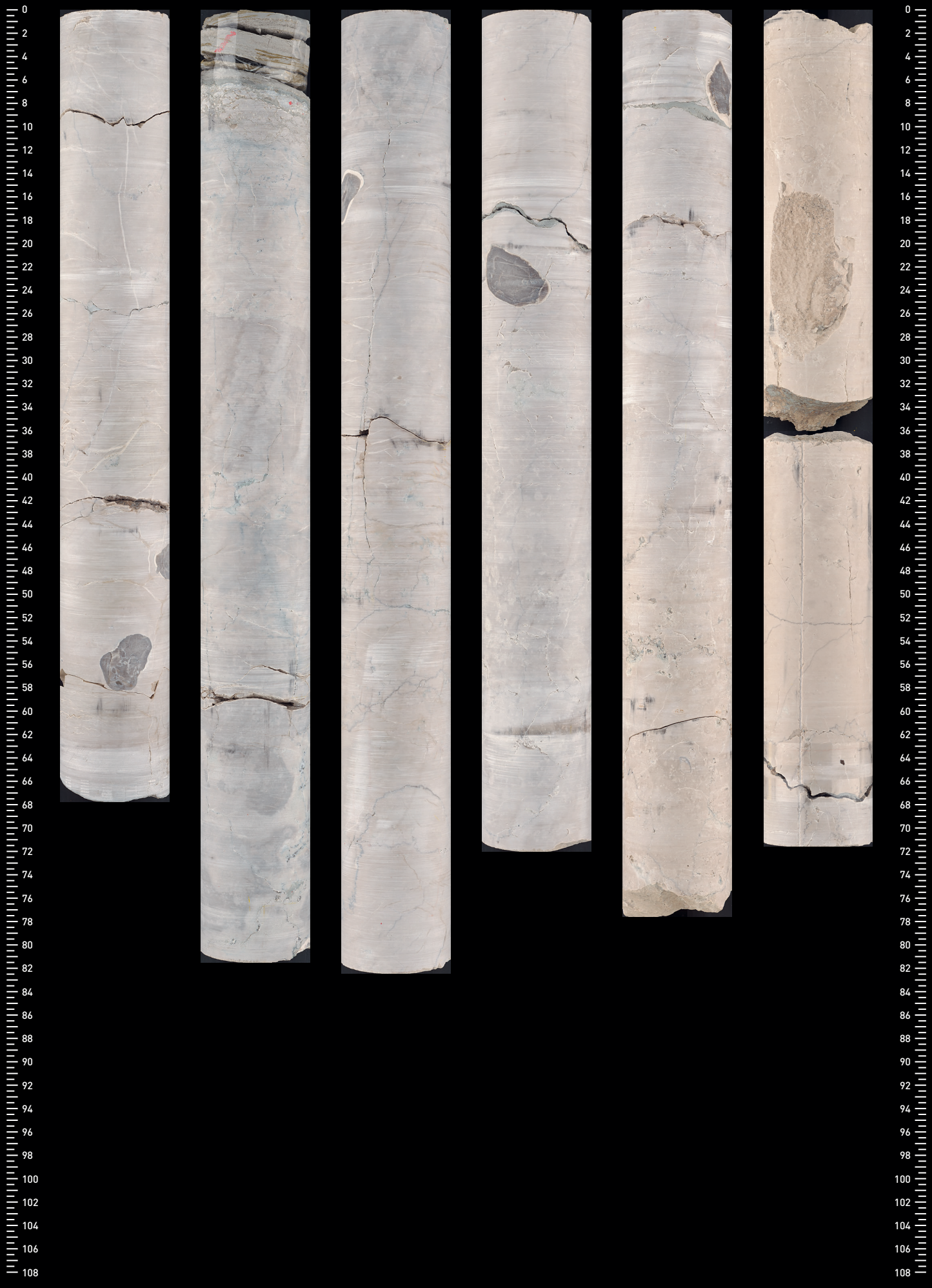
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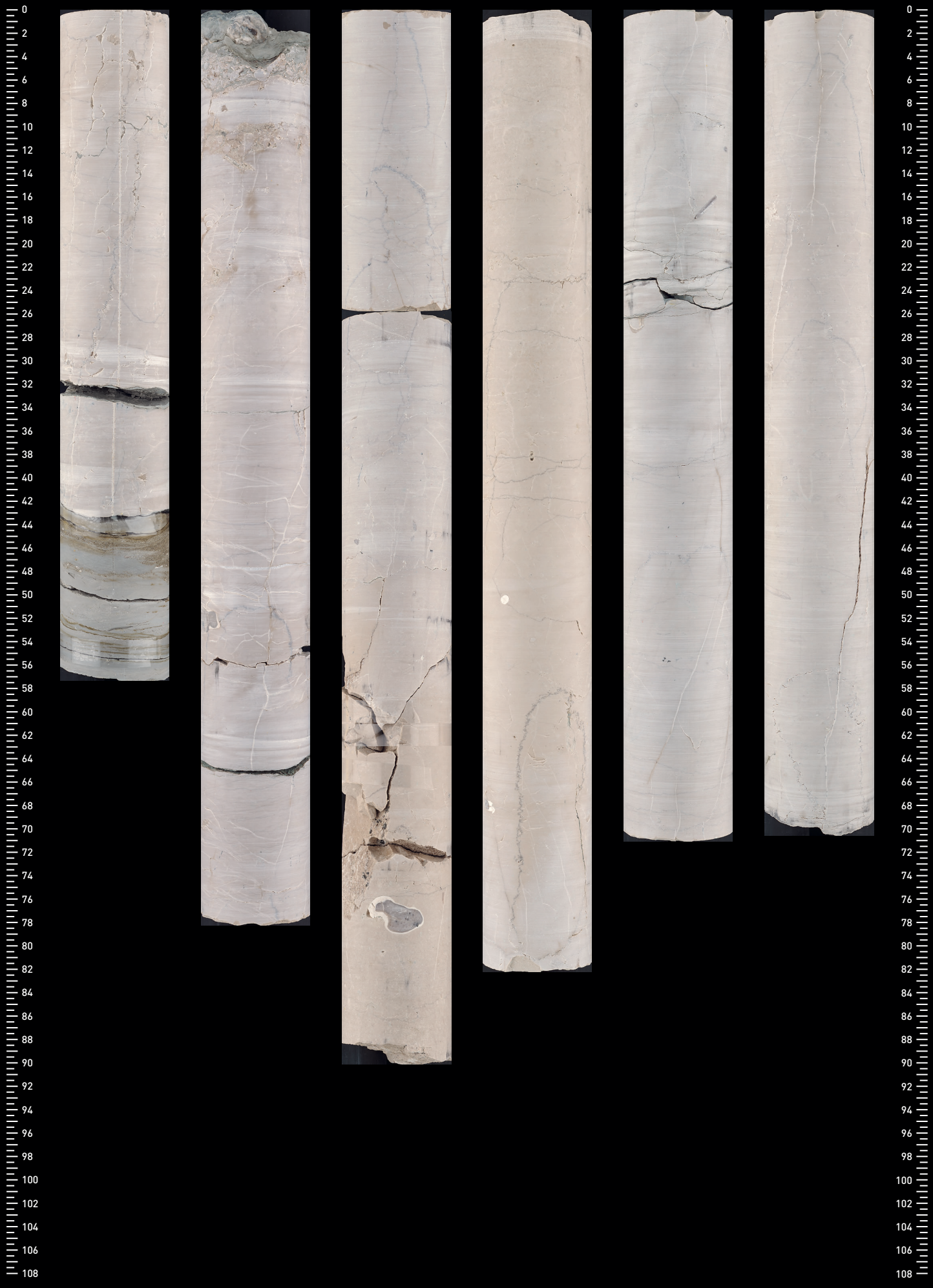
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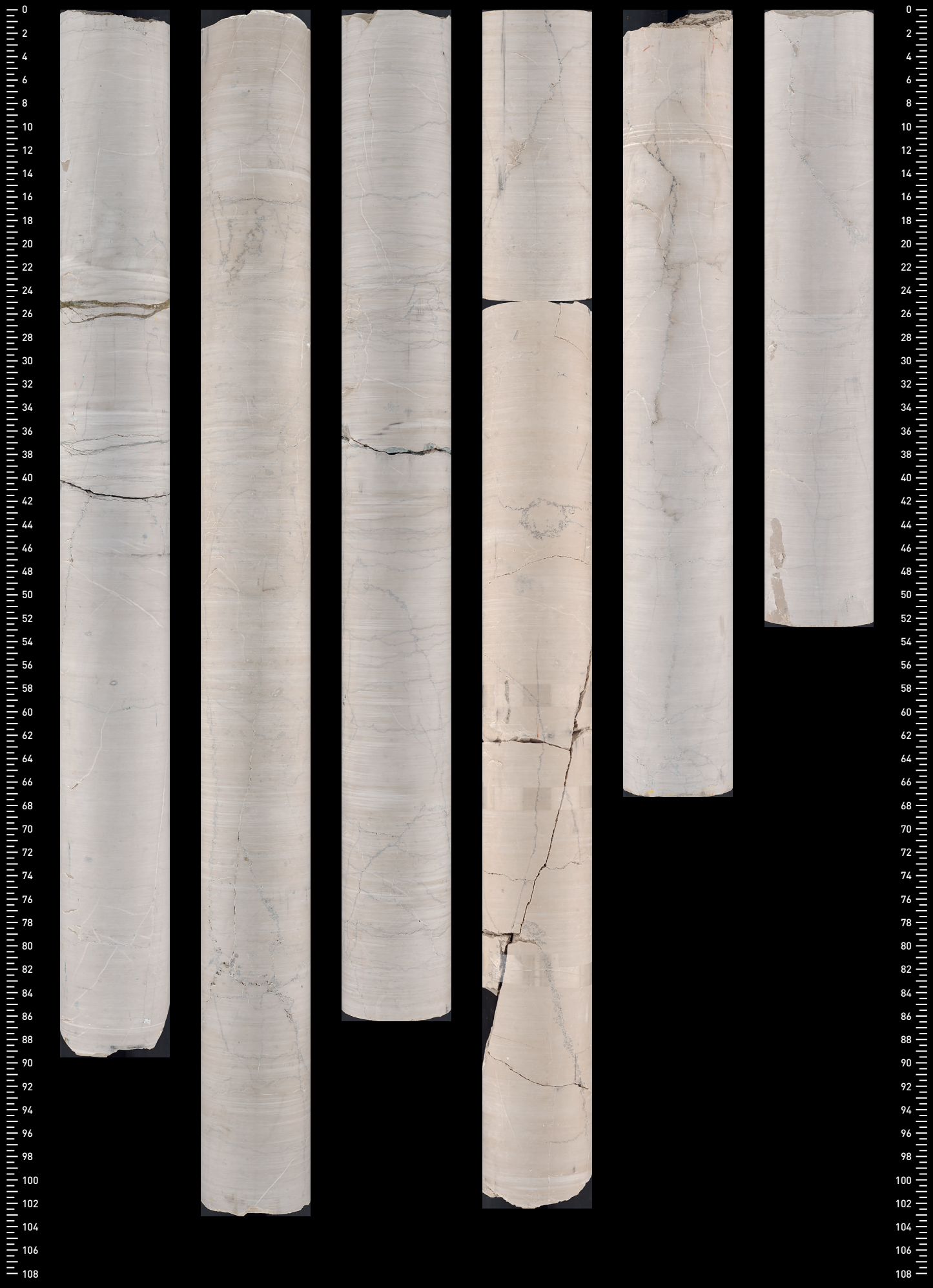
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520.69m 521.25m 522.10m 523.00m 523.80m 524.50m



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525.17m 526.00m 527.00m 527.85m 528.84m 529.50m



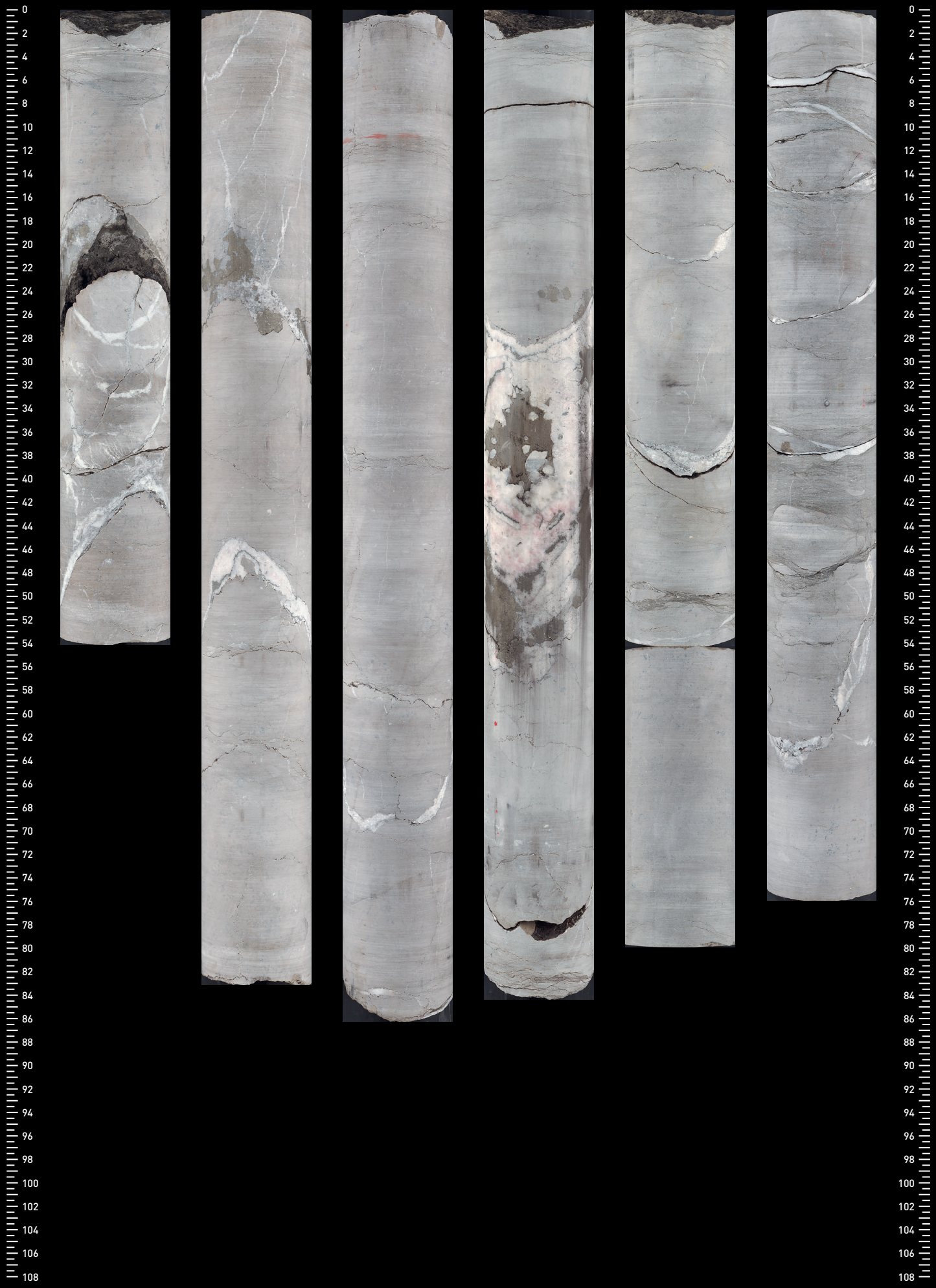
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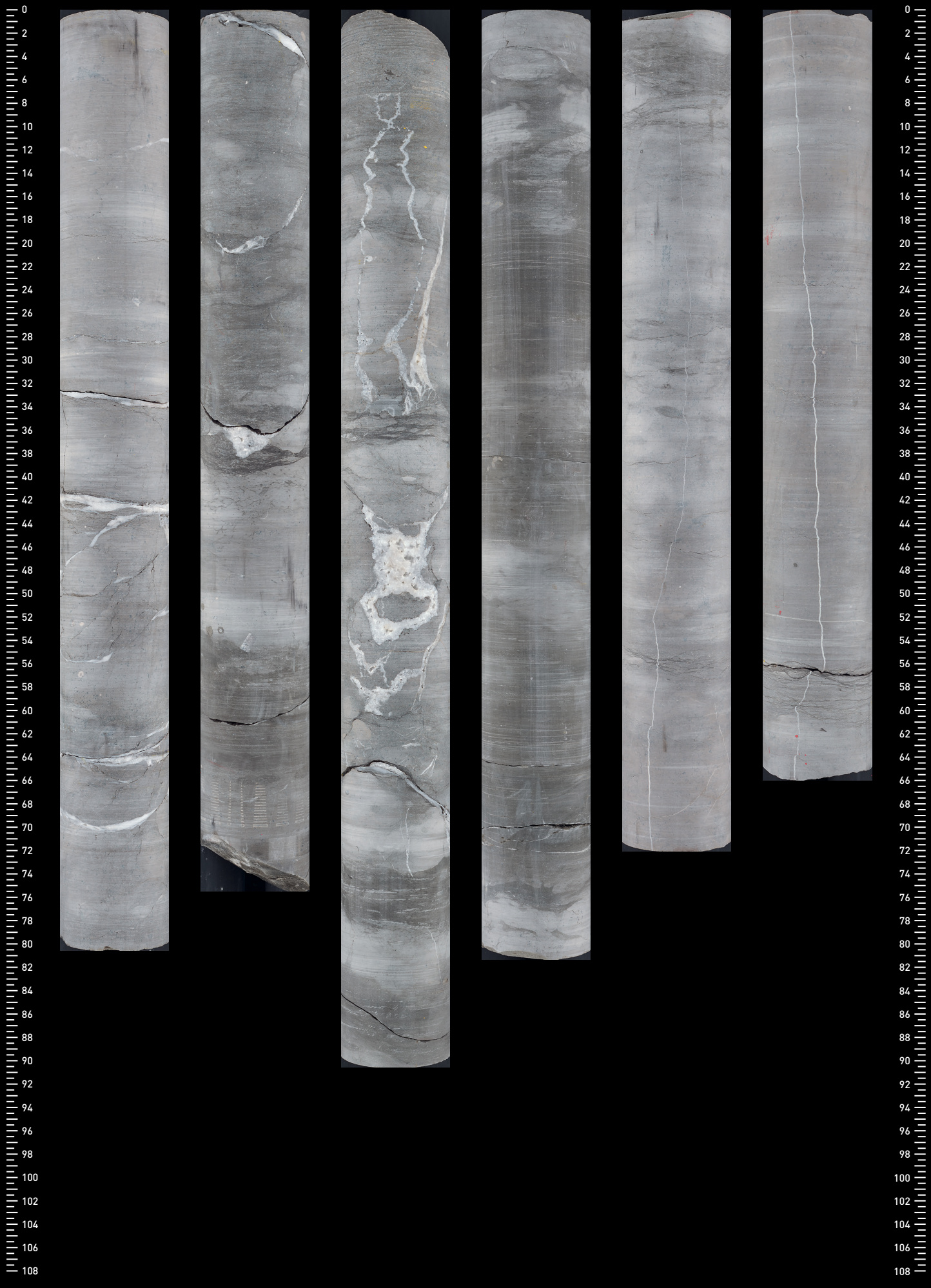
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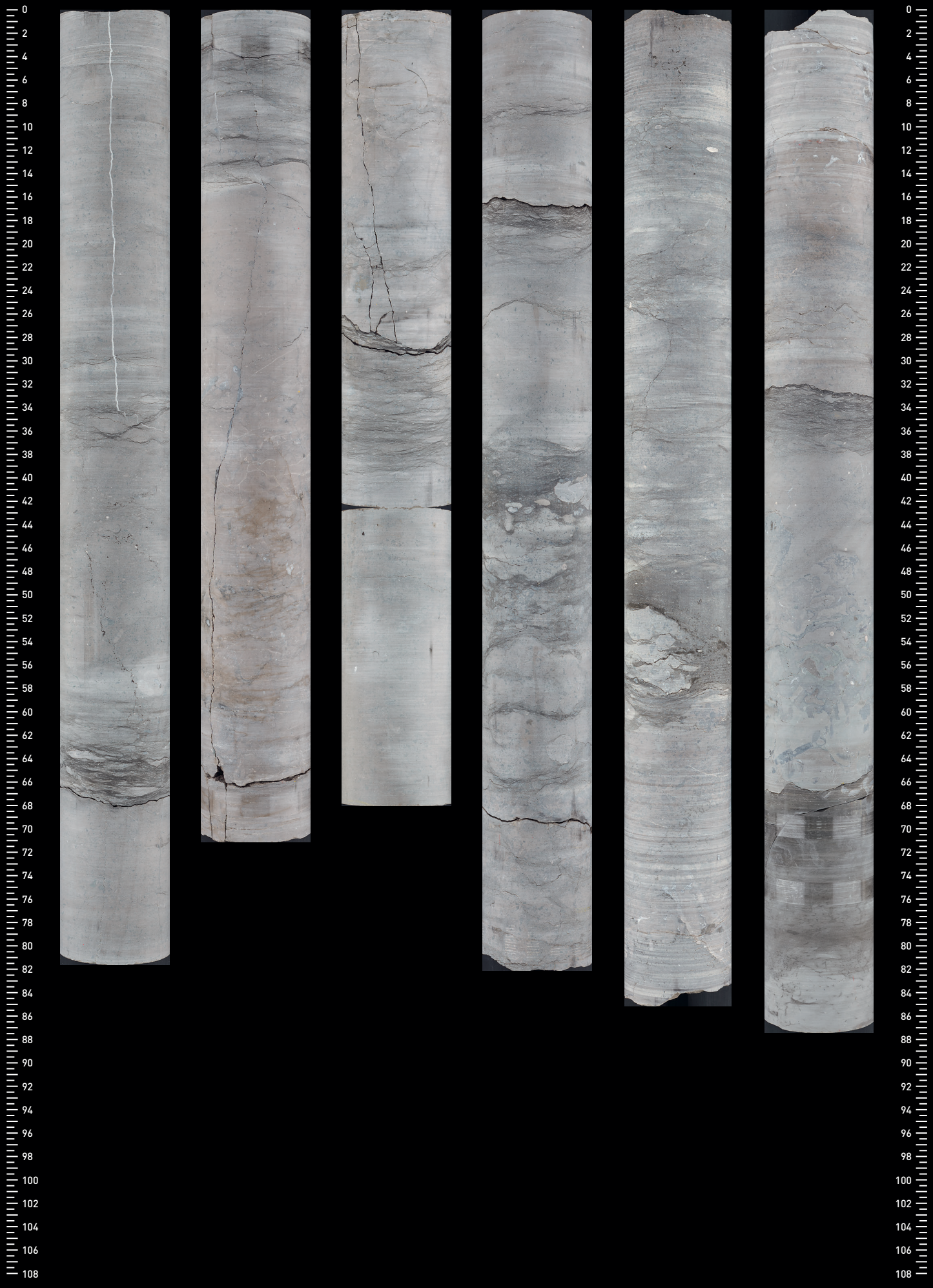
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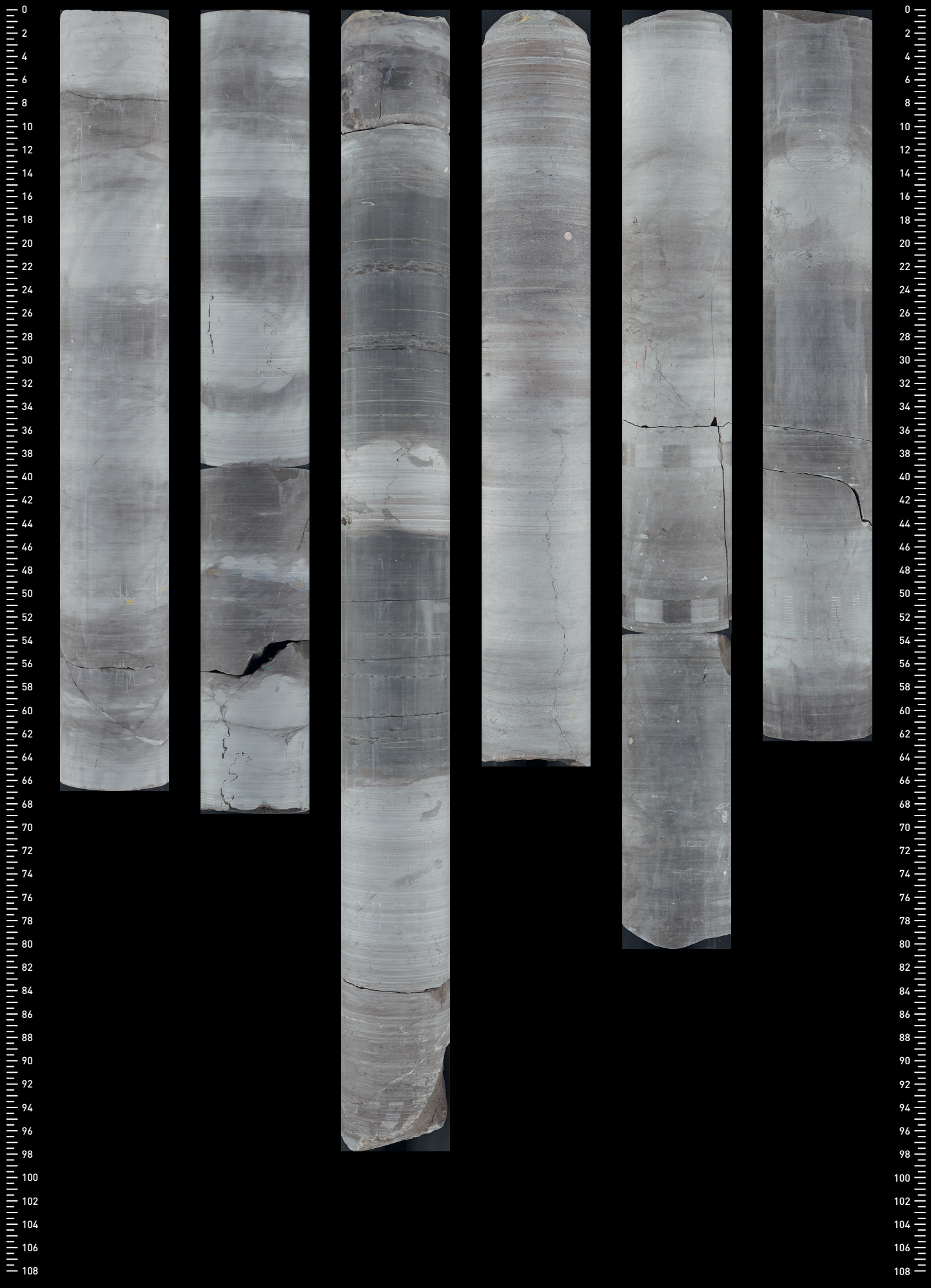
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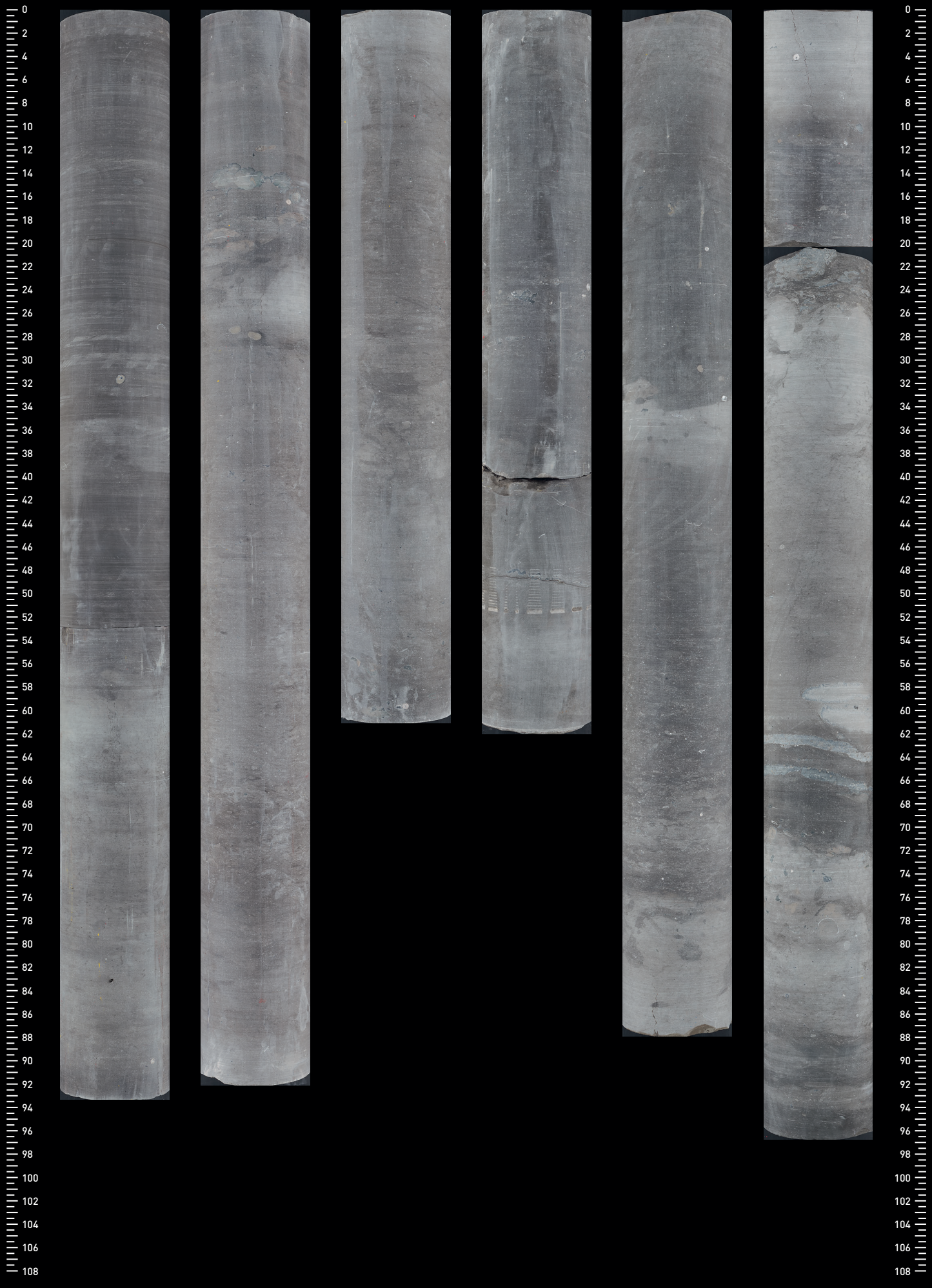
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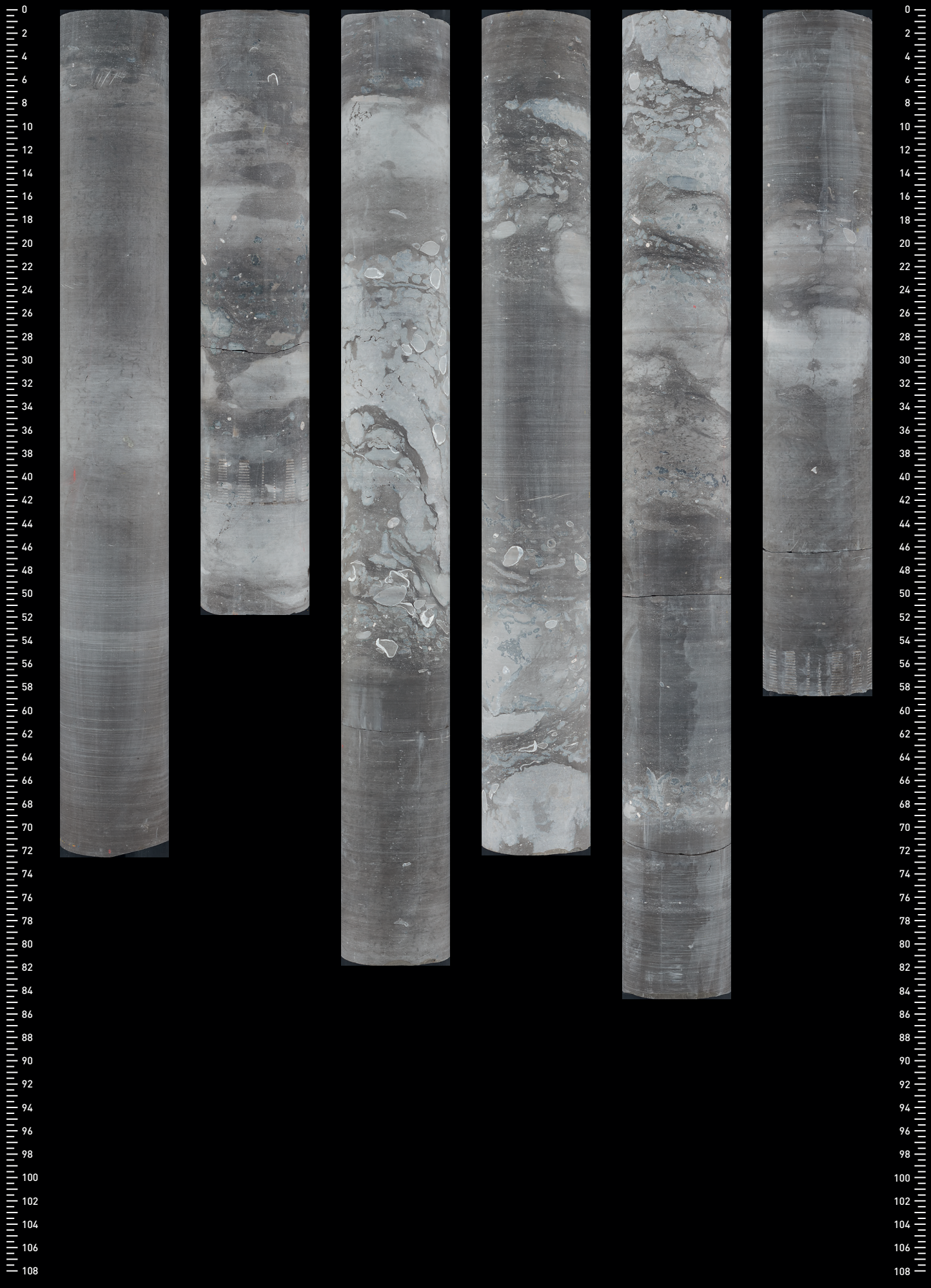
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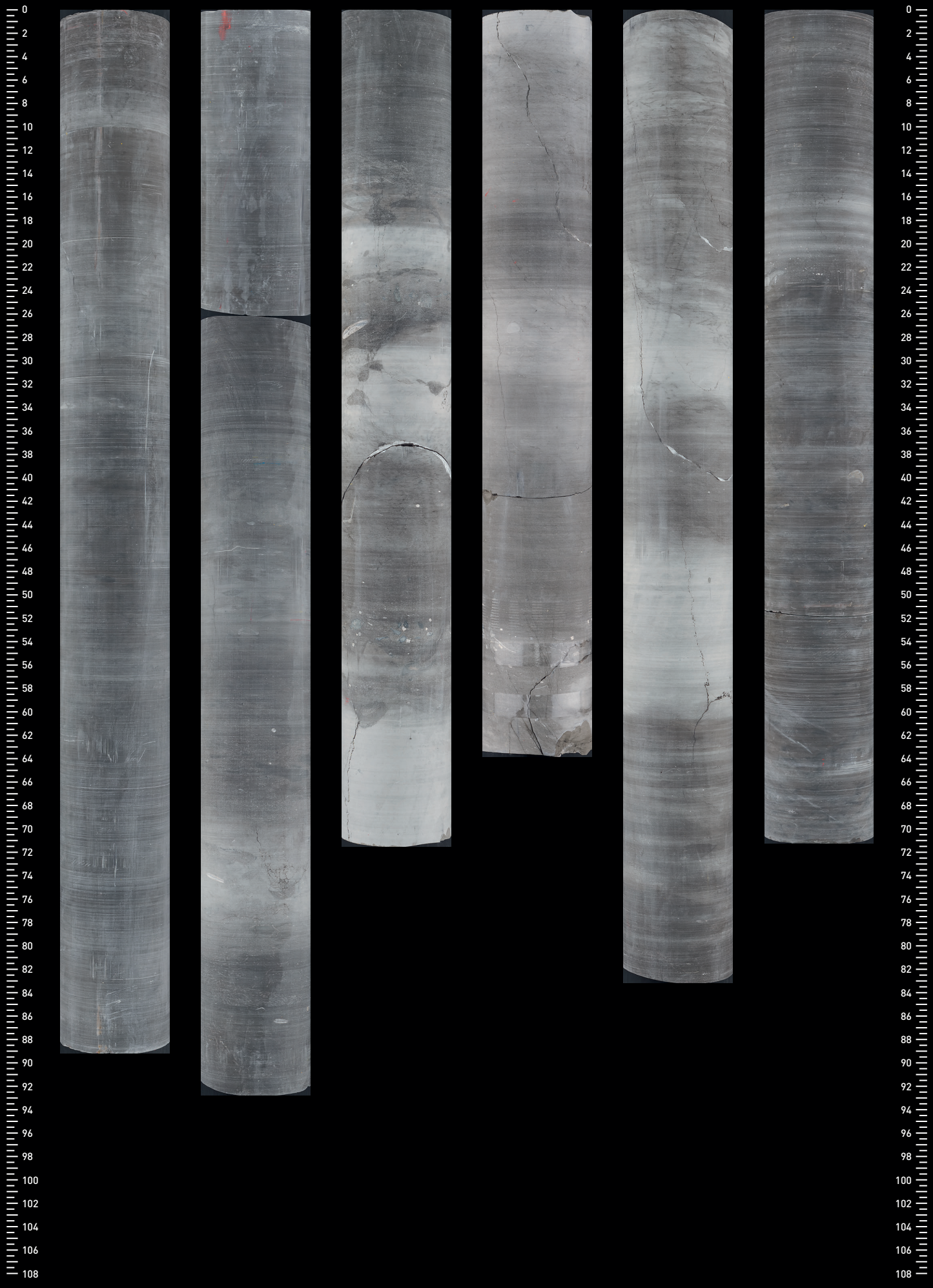
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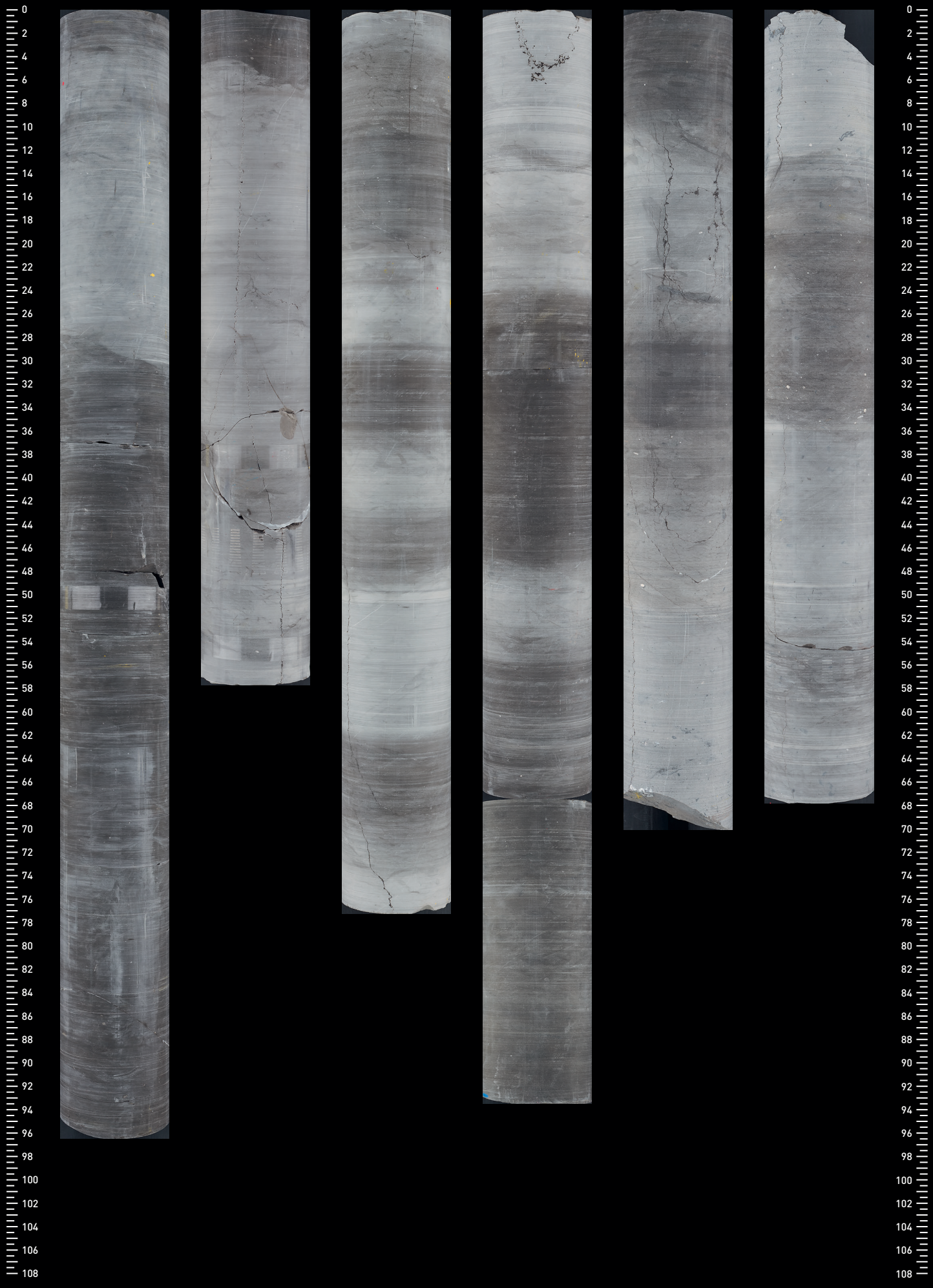
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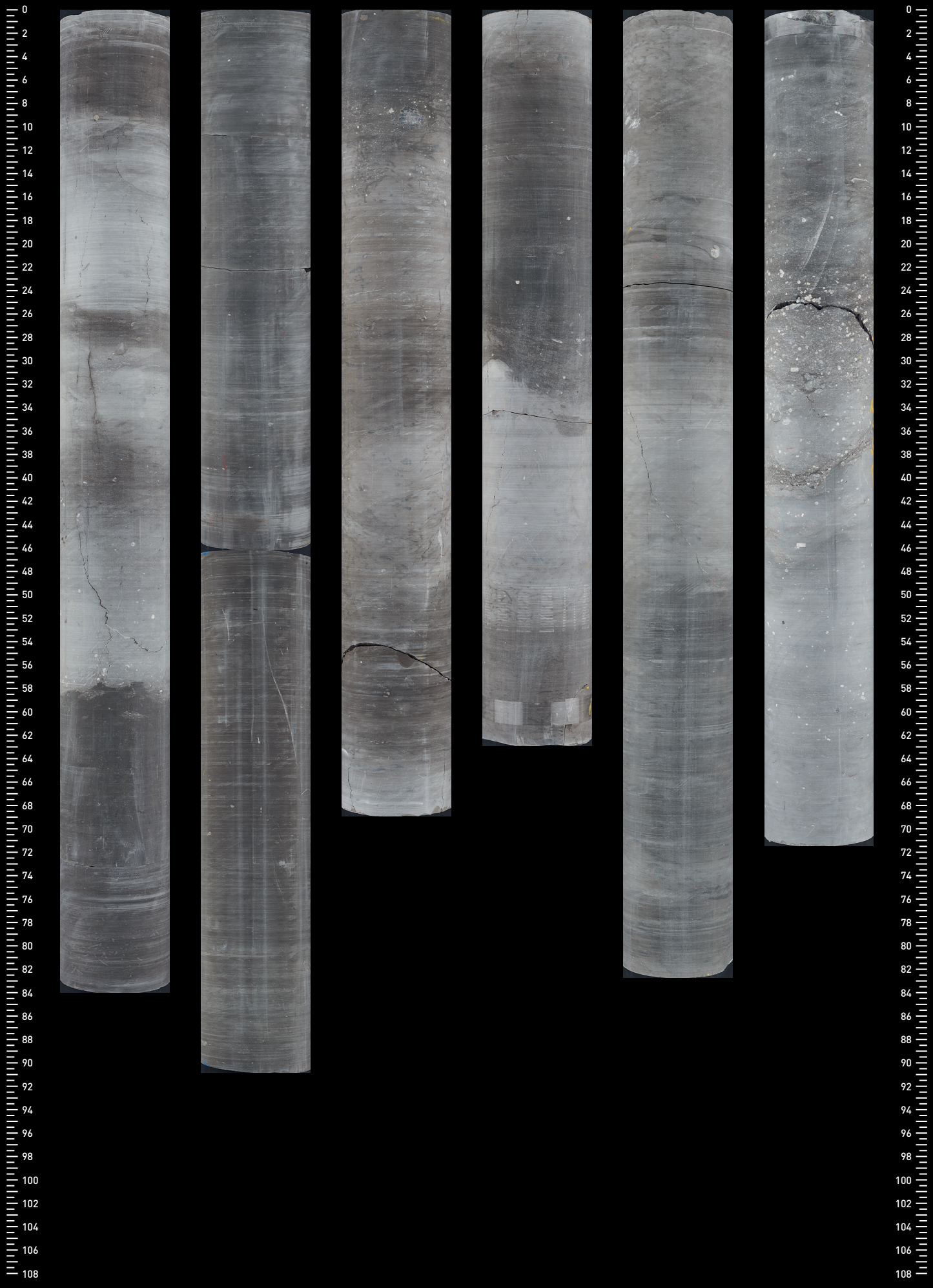
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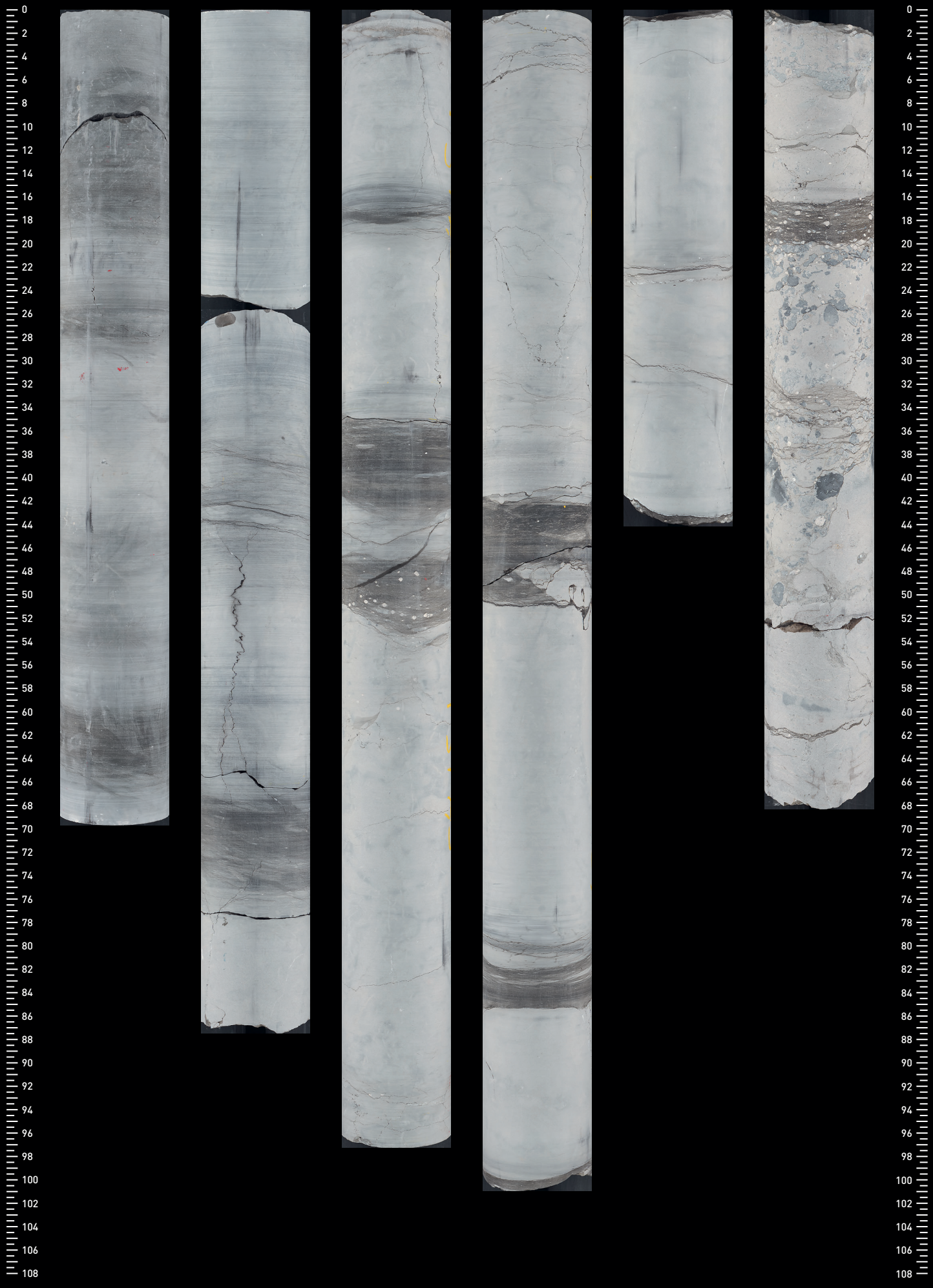
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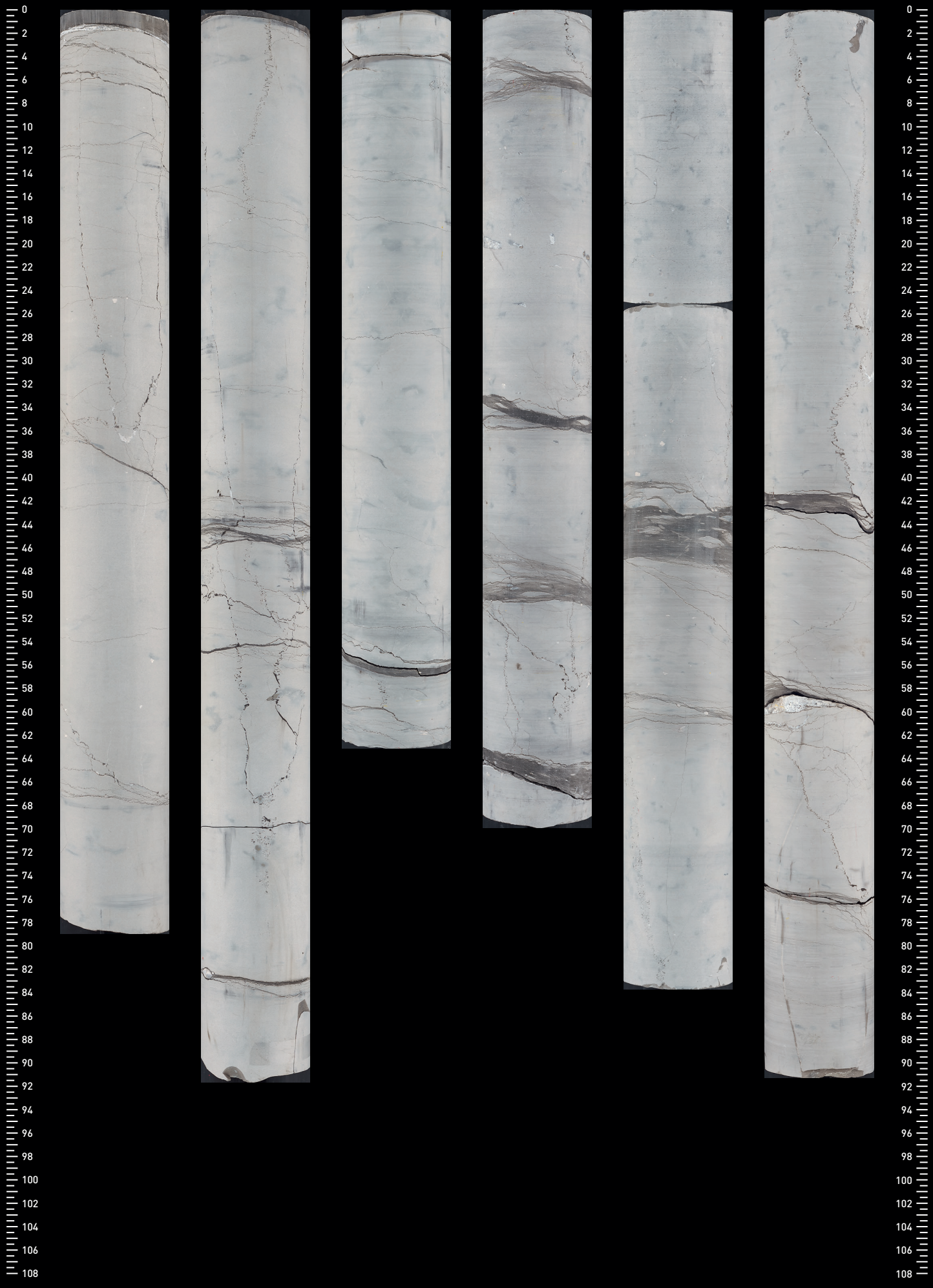
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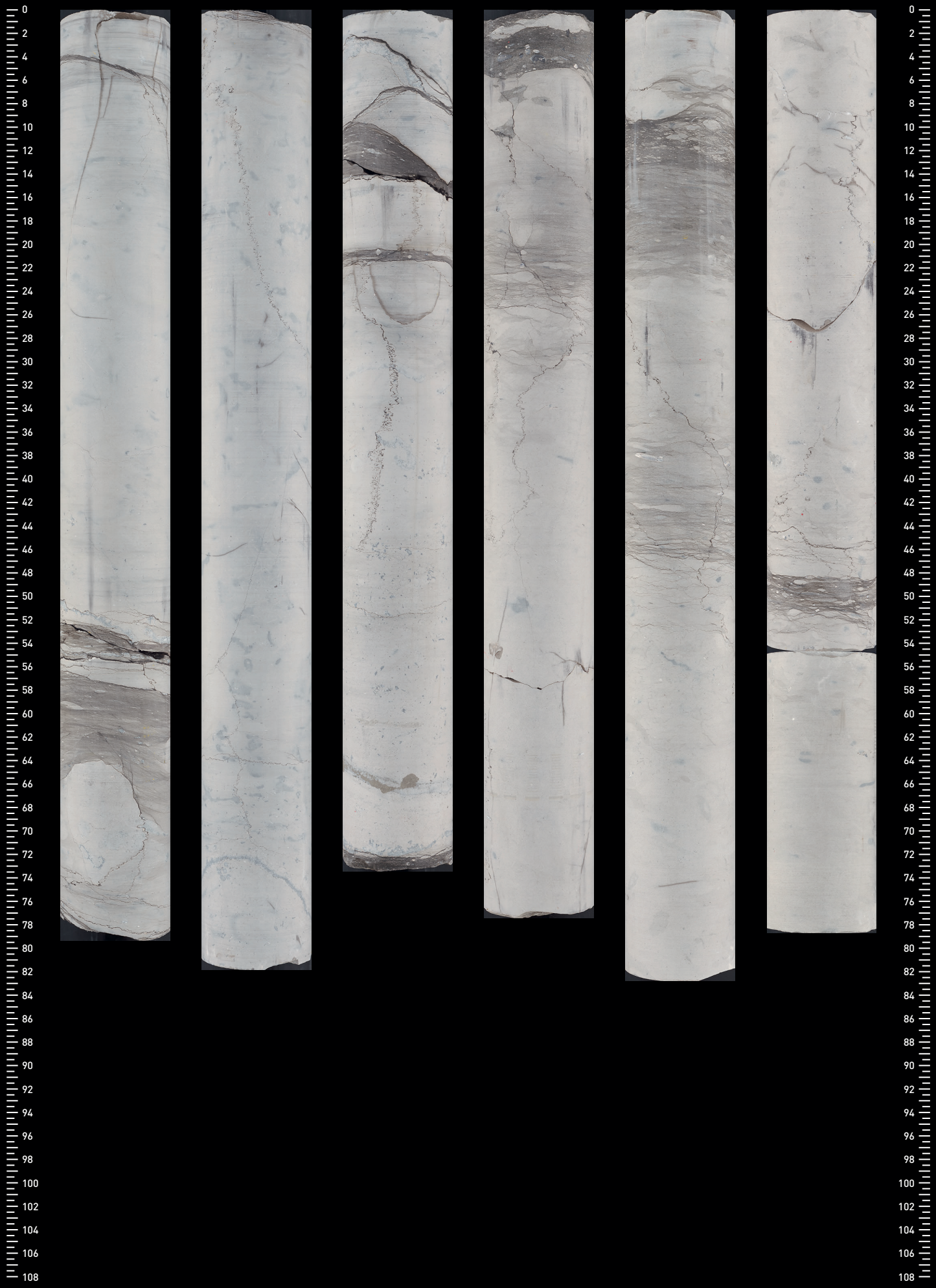
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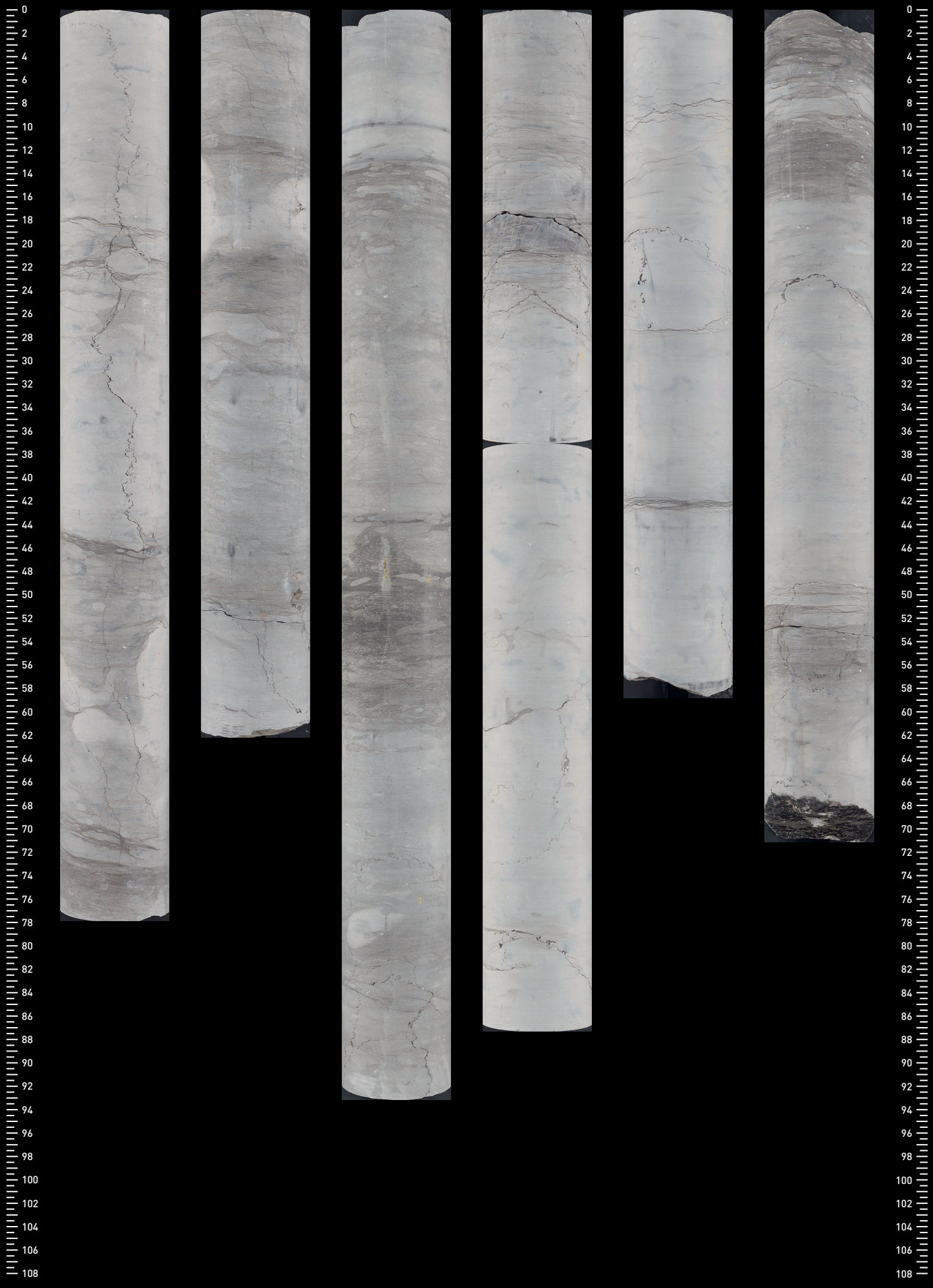
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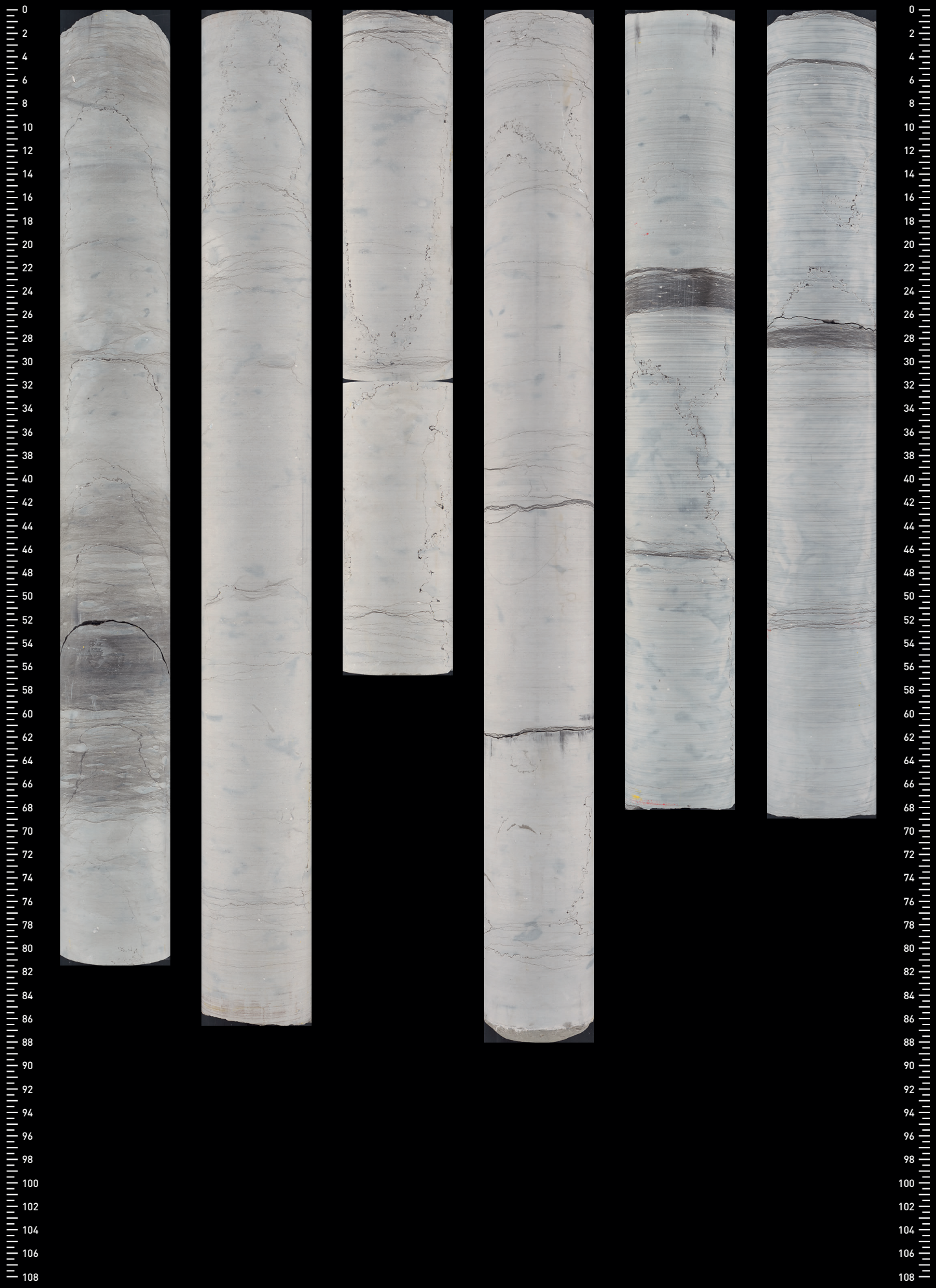
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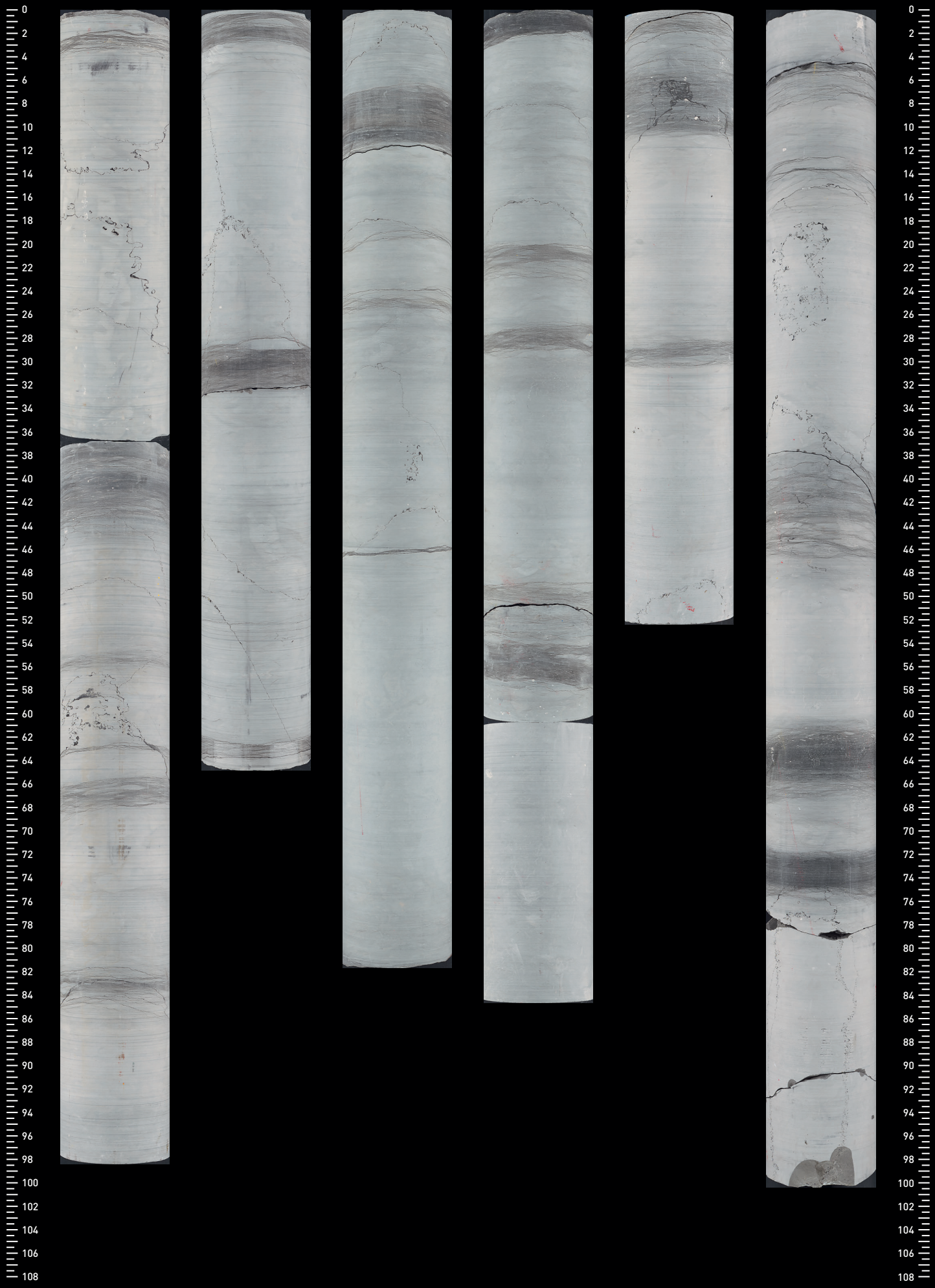
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598.66m 599.52m 600.07m 600.92m 601.60m 602.27m

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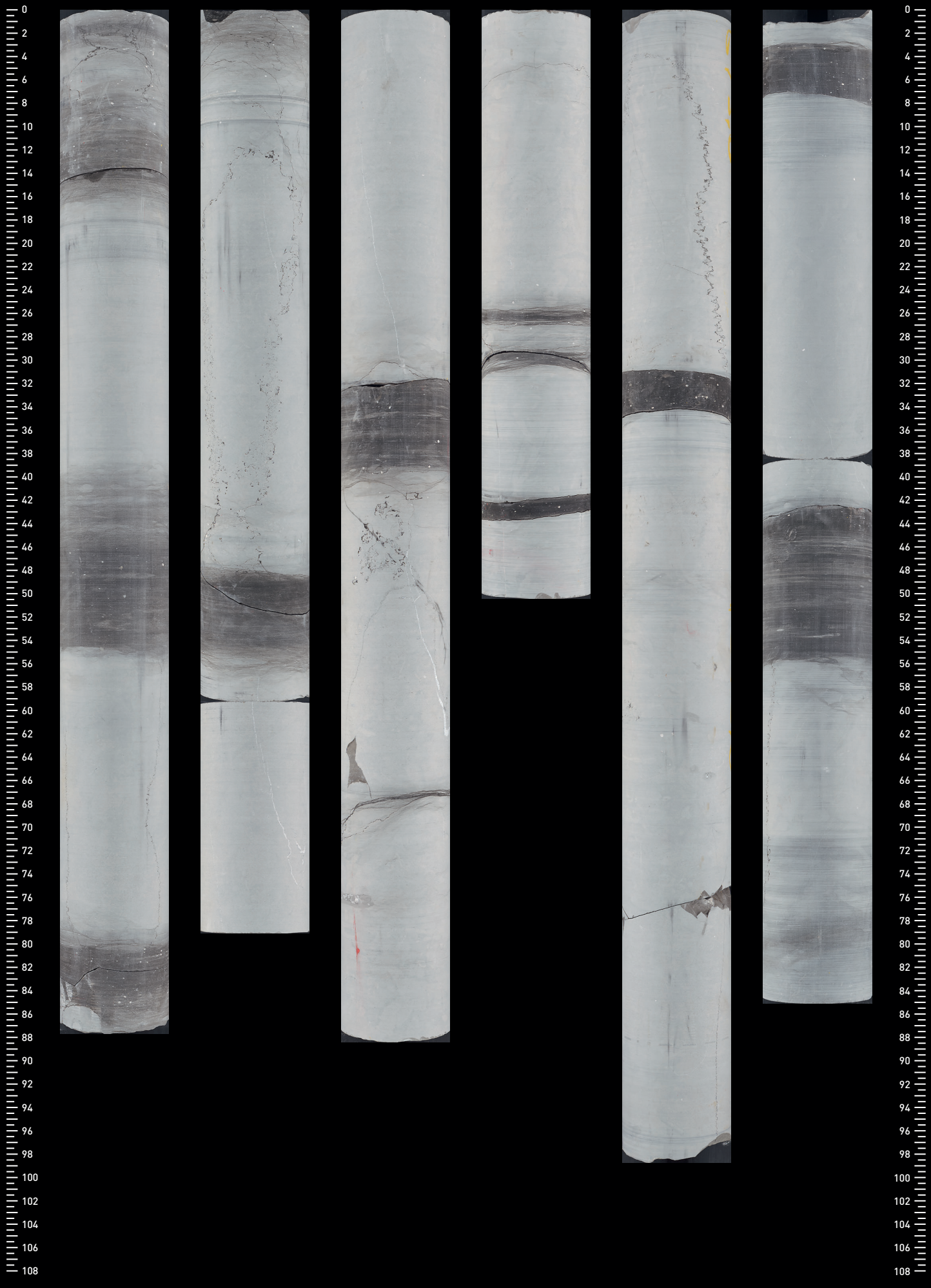
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607.90m 608.85m 609.77m 610.60m 611.50m 612.00m

612.00m 612.85m 613.64m 614.50m 615.00m 615.95m



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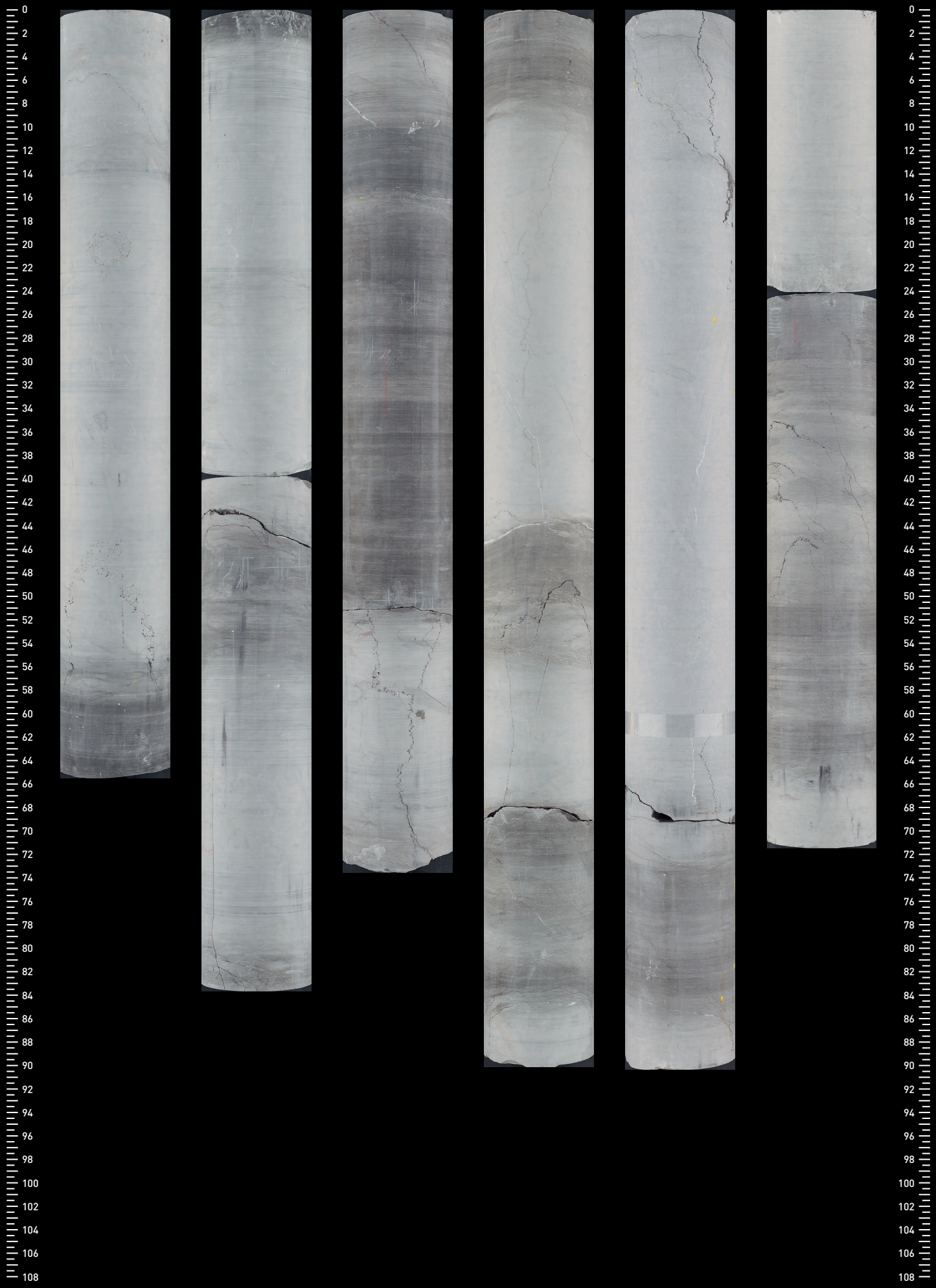
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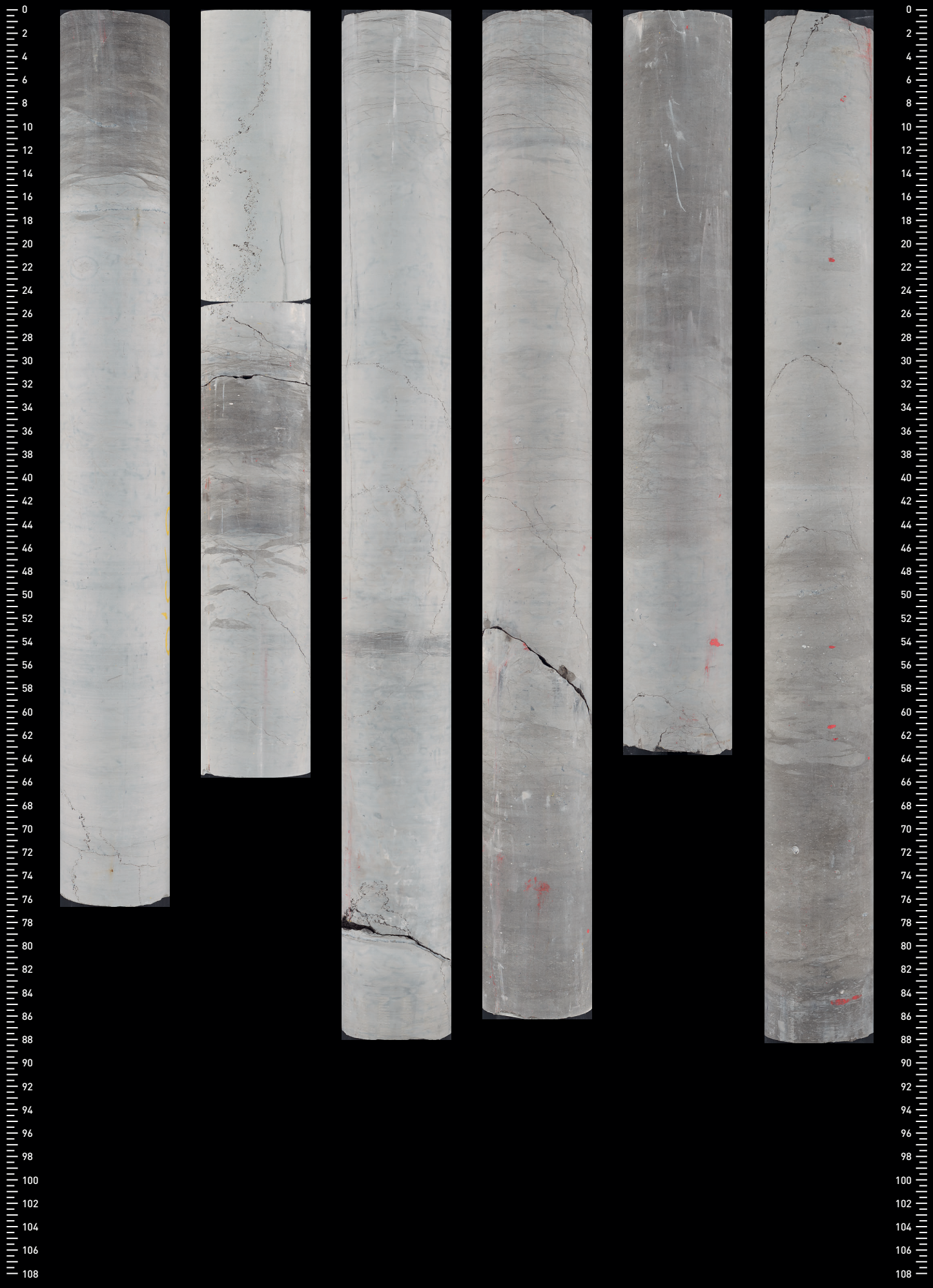
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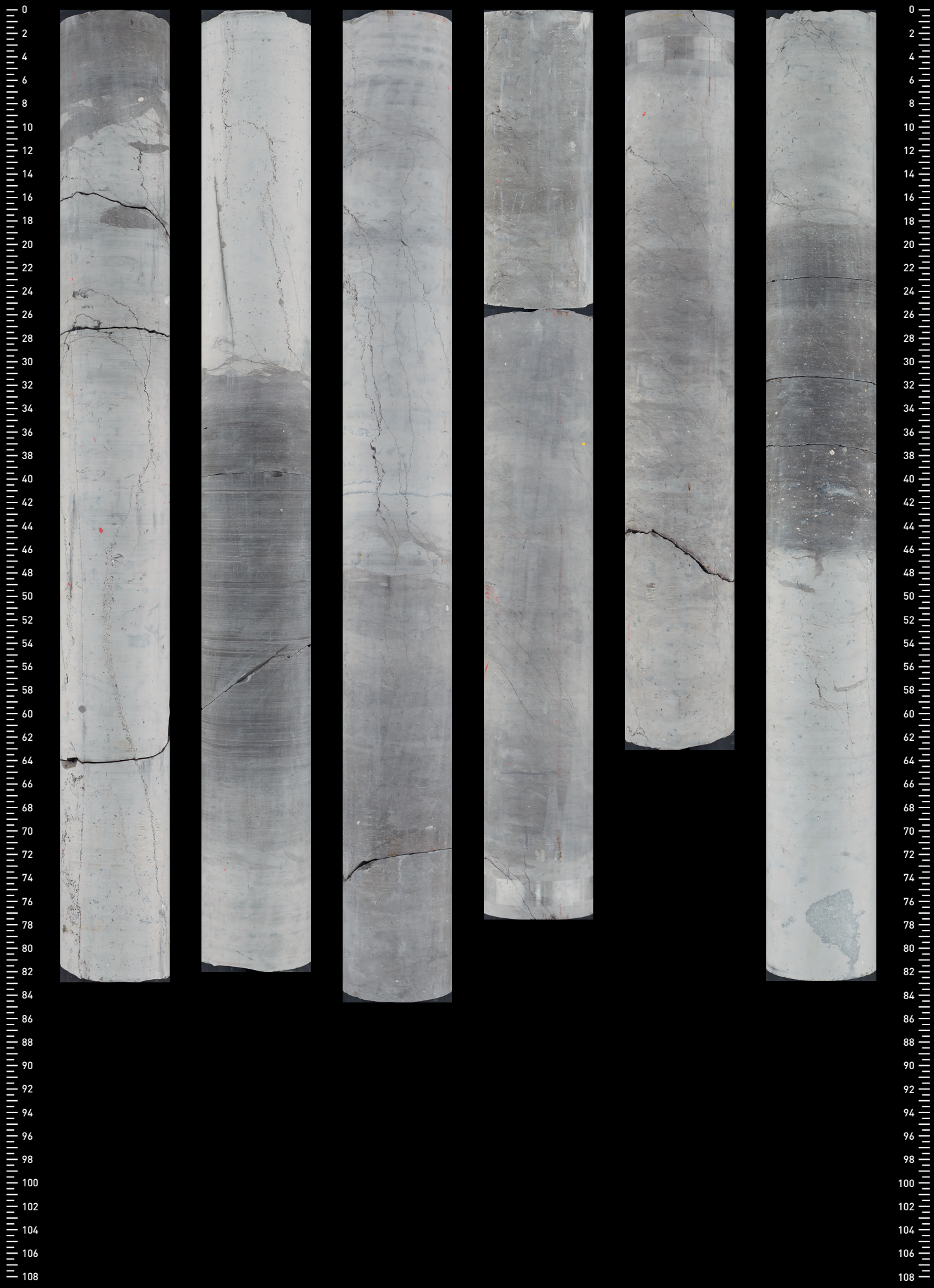
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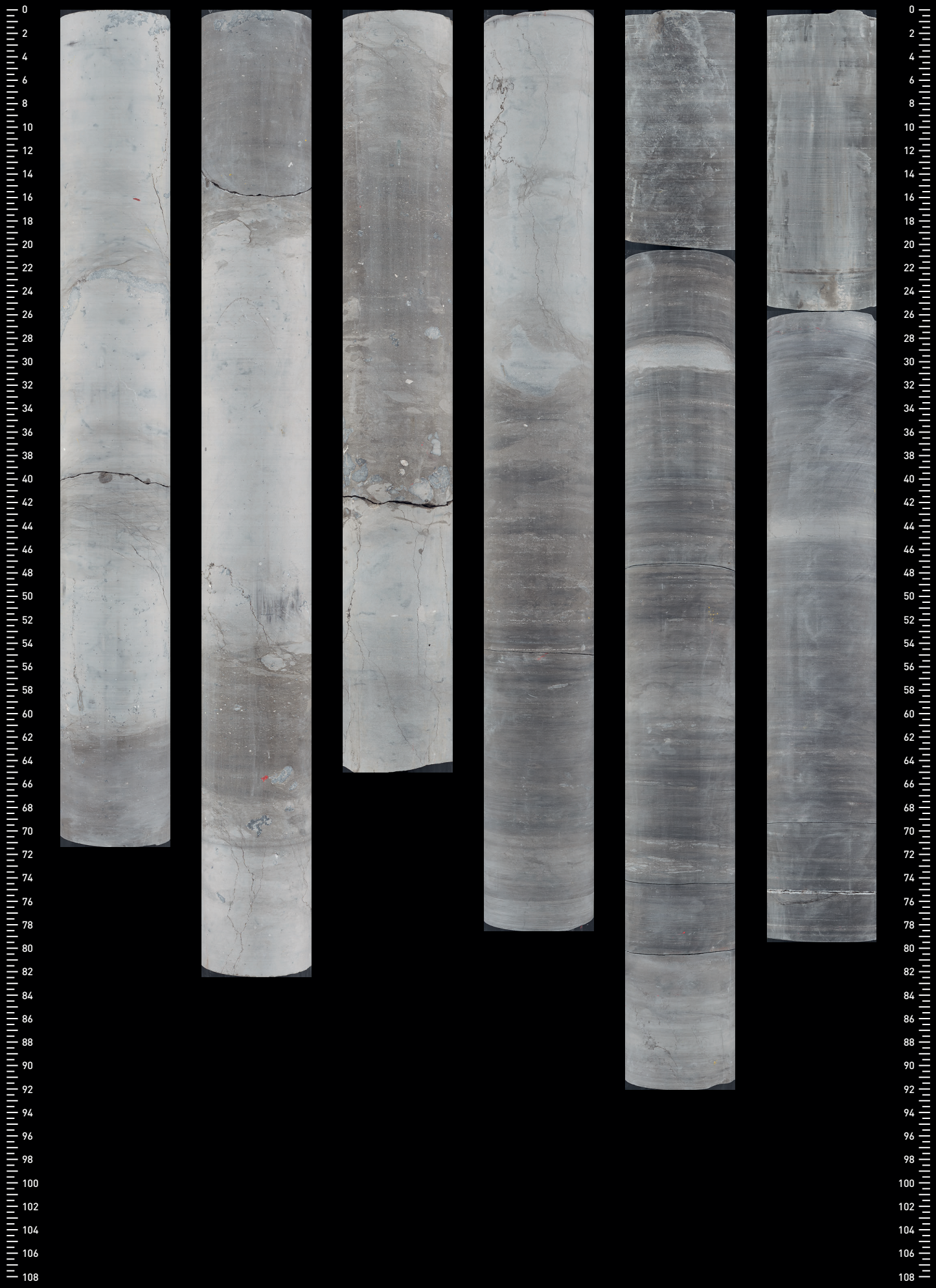
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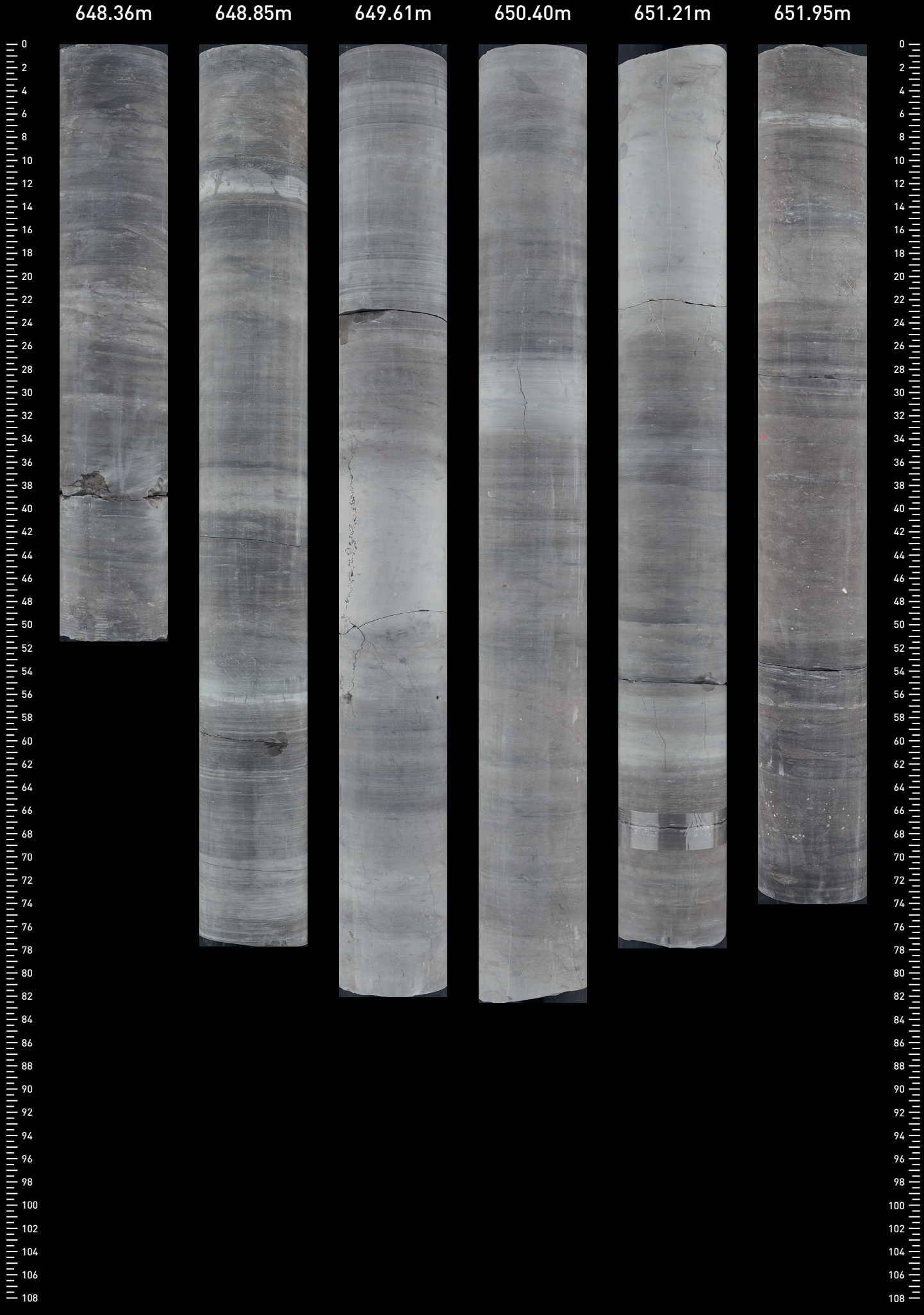


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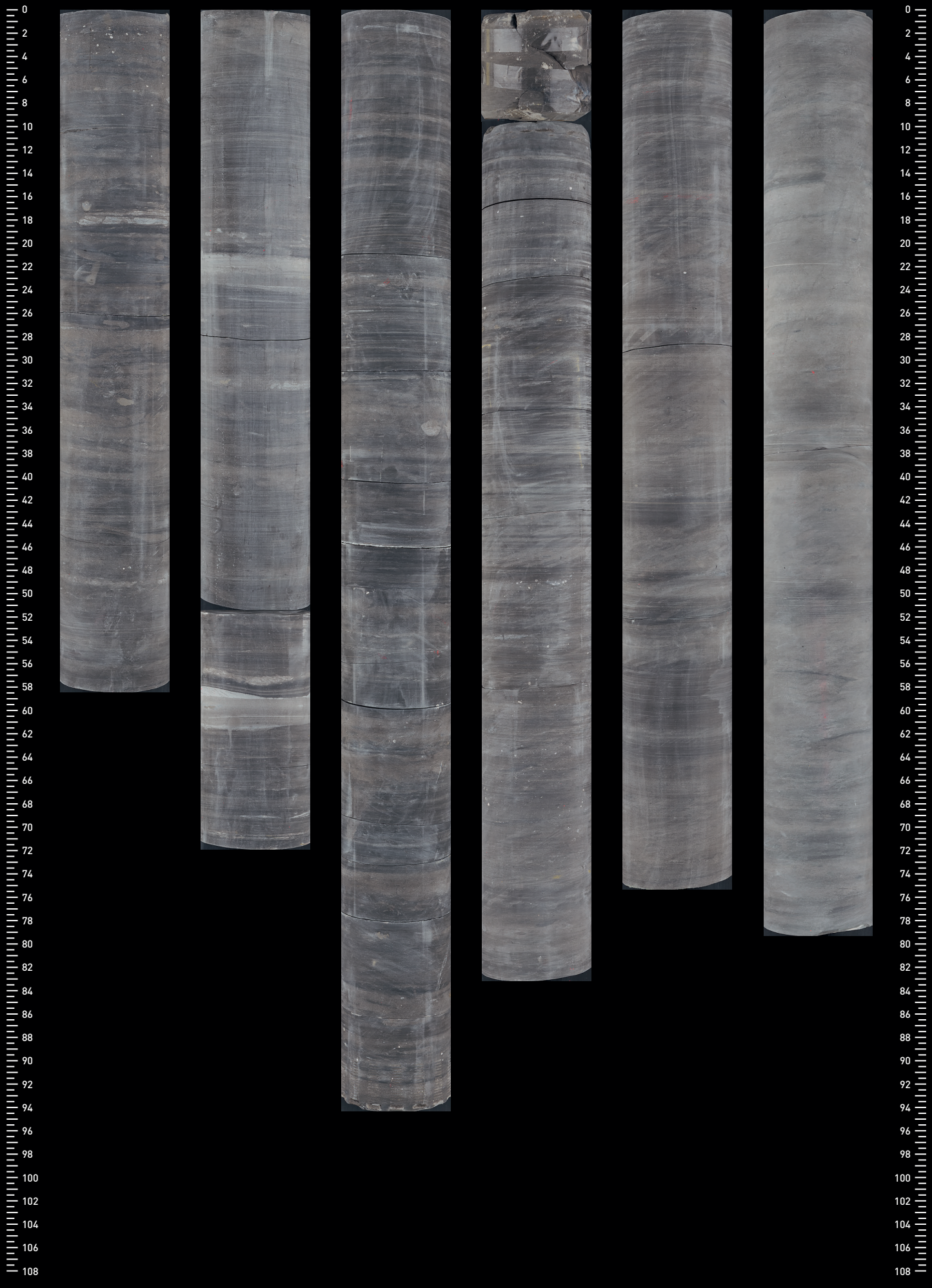
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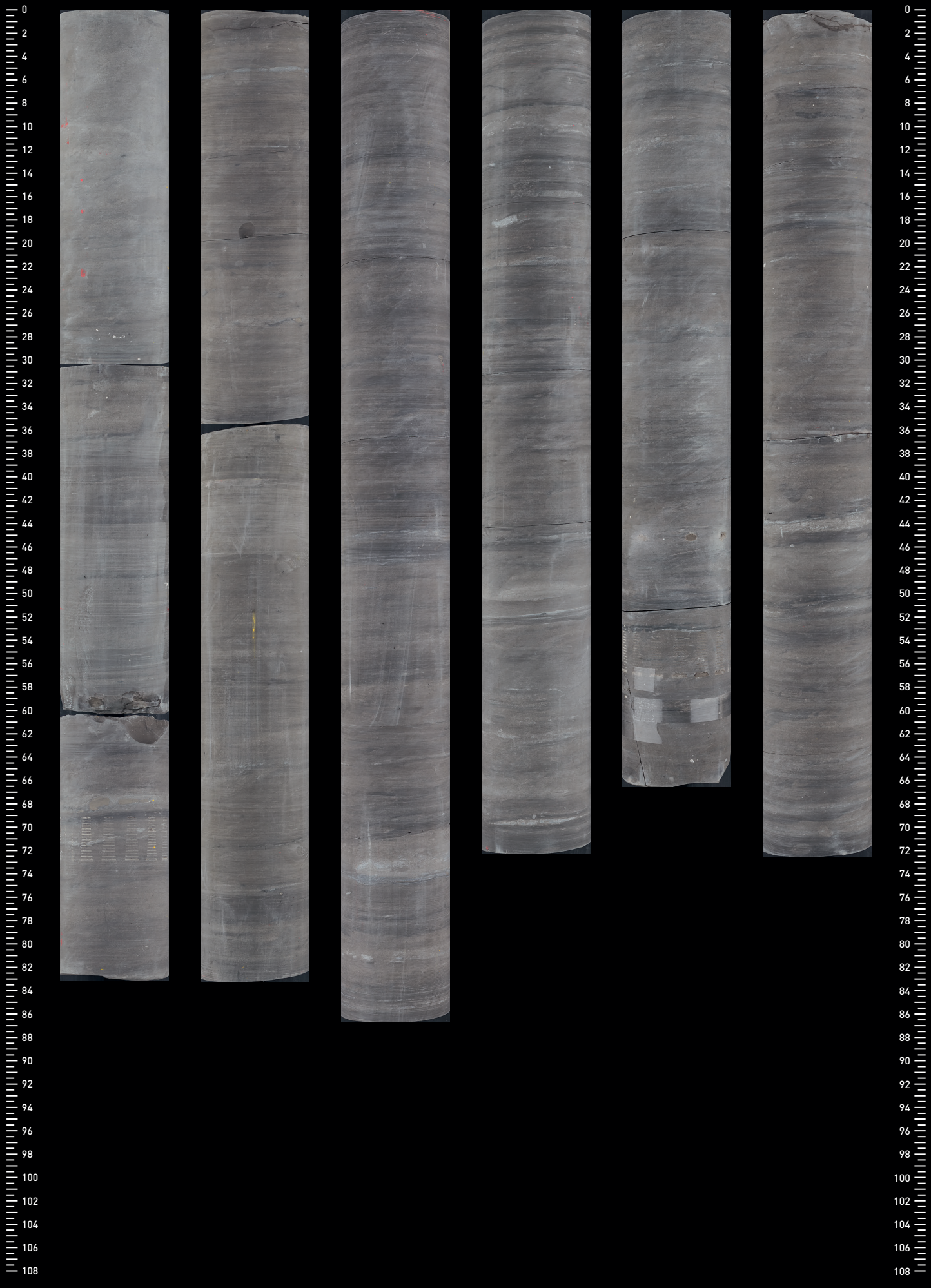

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648.85m
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652.66m 653.23m 653.92m 654.84m 655.65m 656.38m



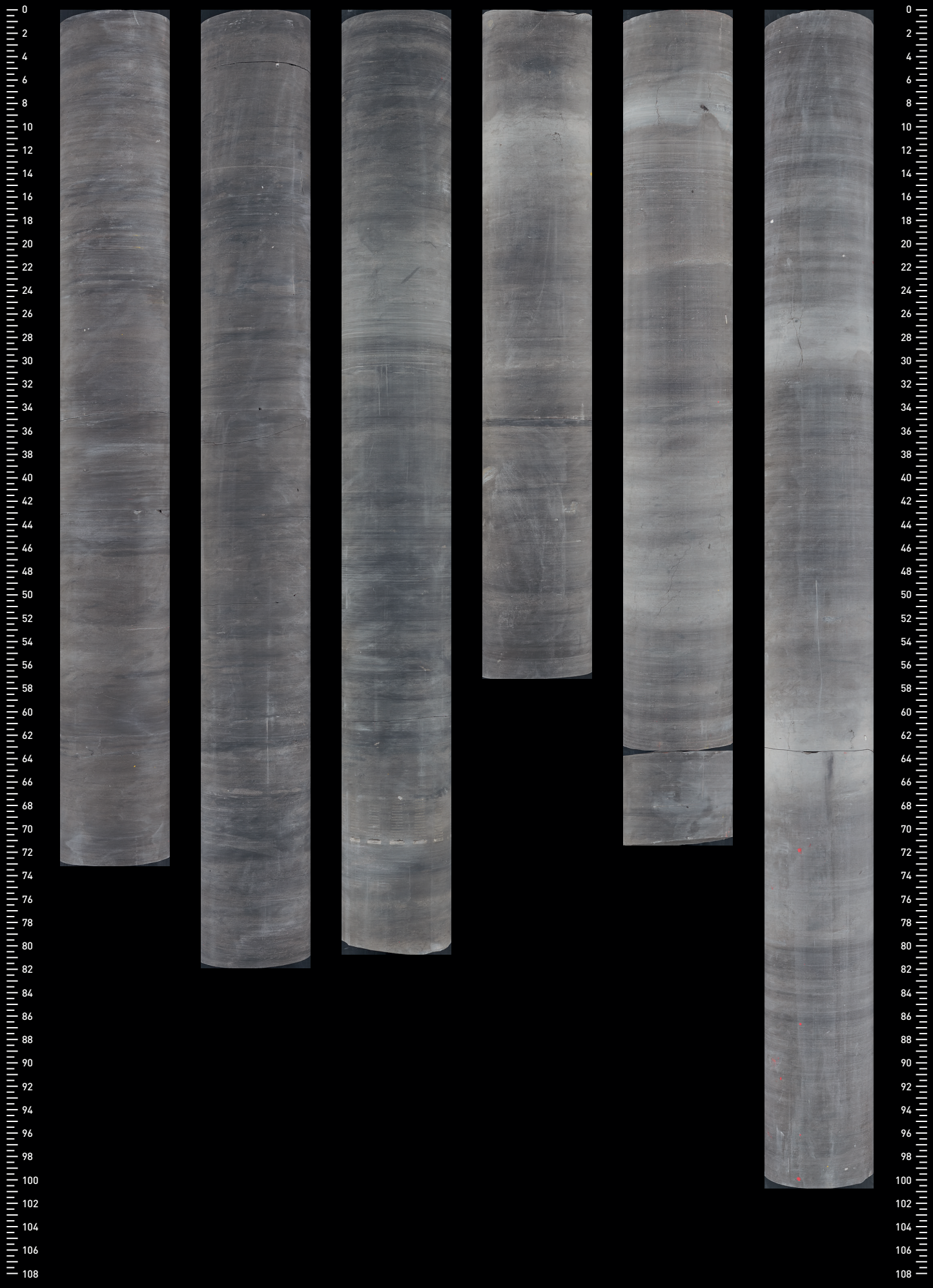
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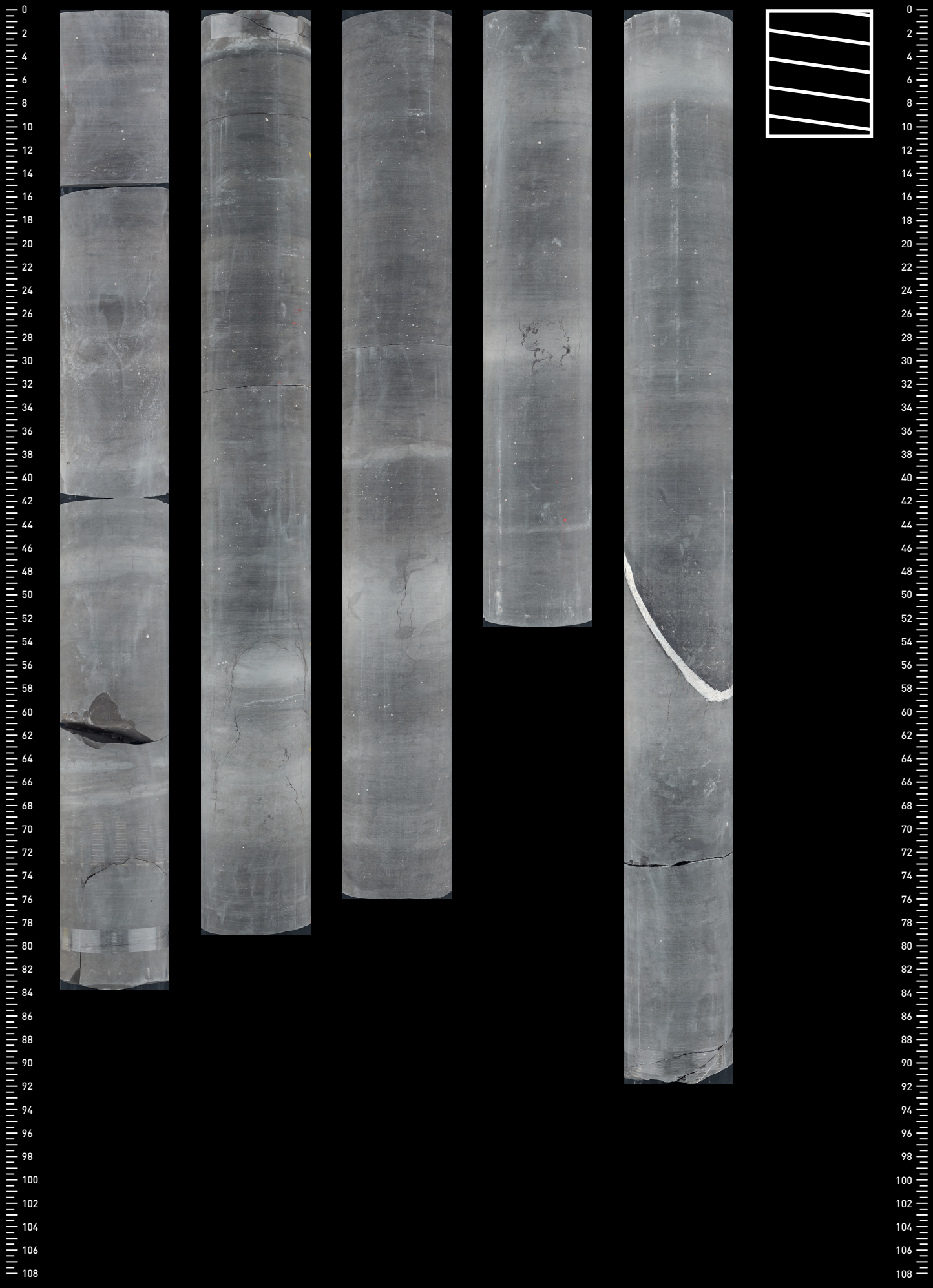
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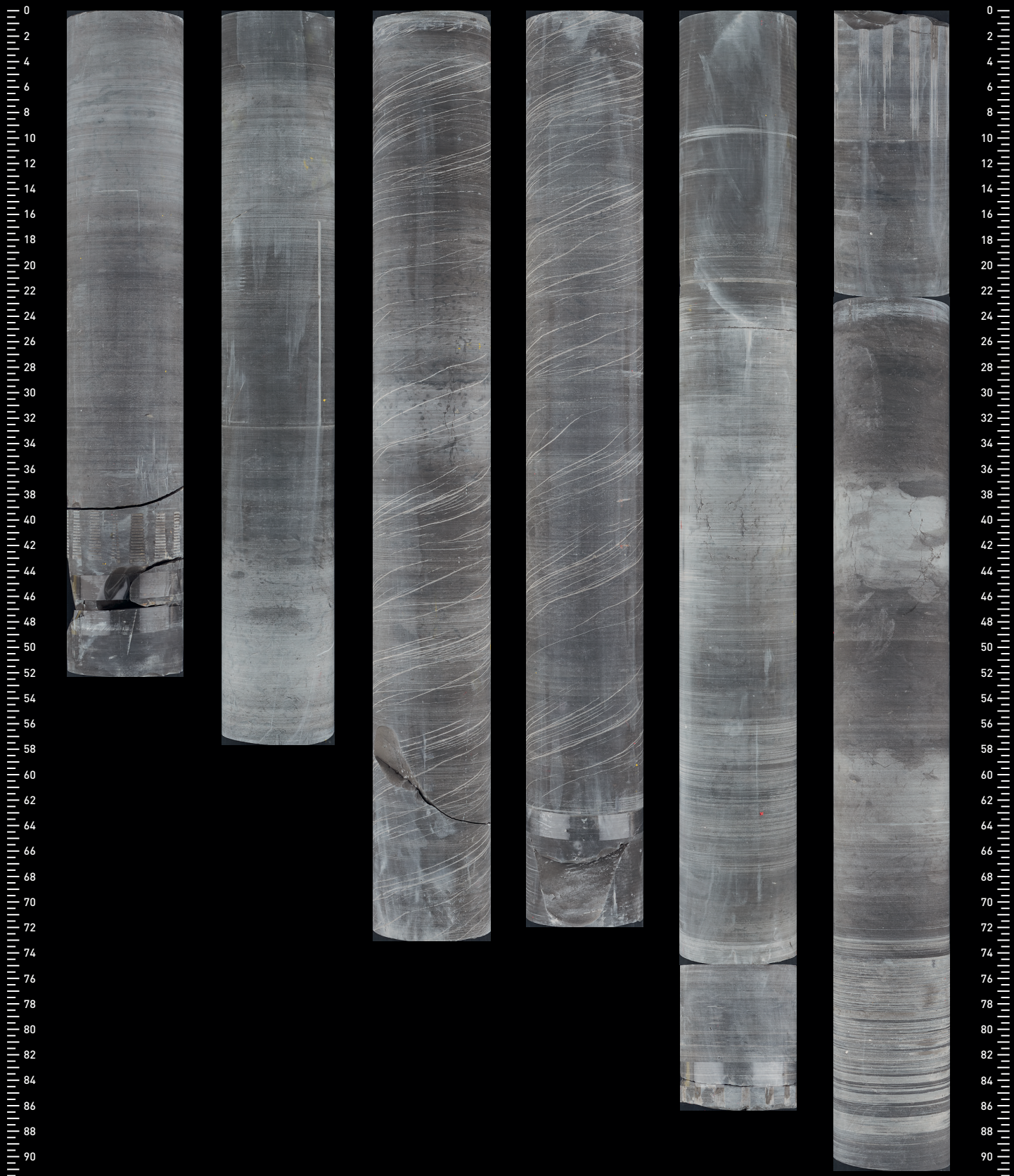
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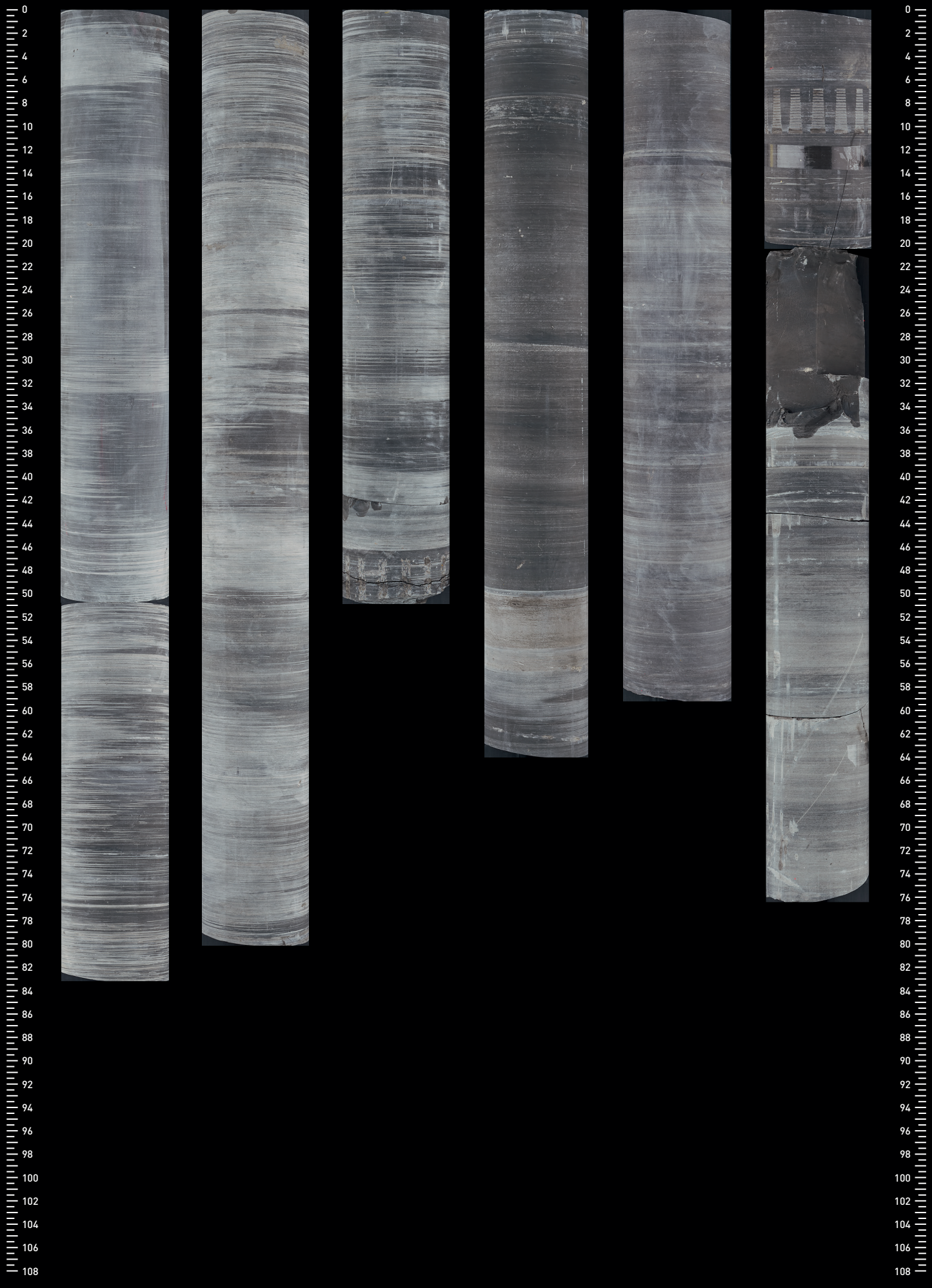

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671.65m
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673.32m
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671.02m
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675.00m

675.00m 675.52m 676.08m 676.80m 677.50m 678.36m



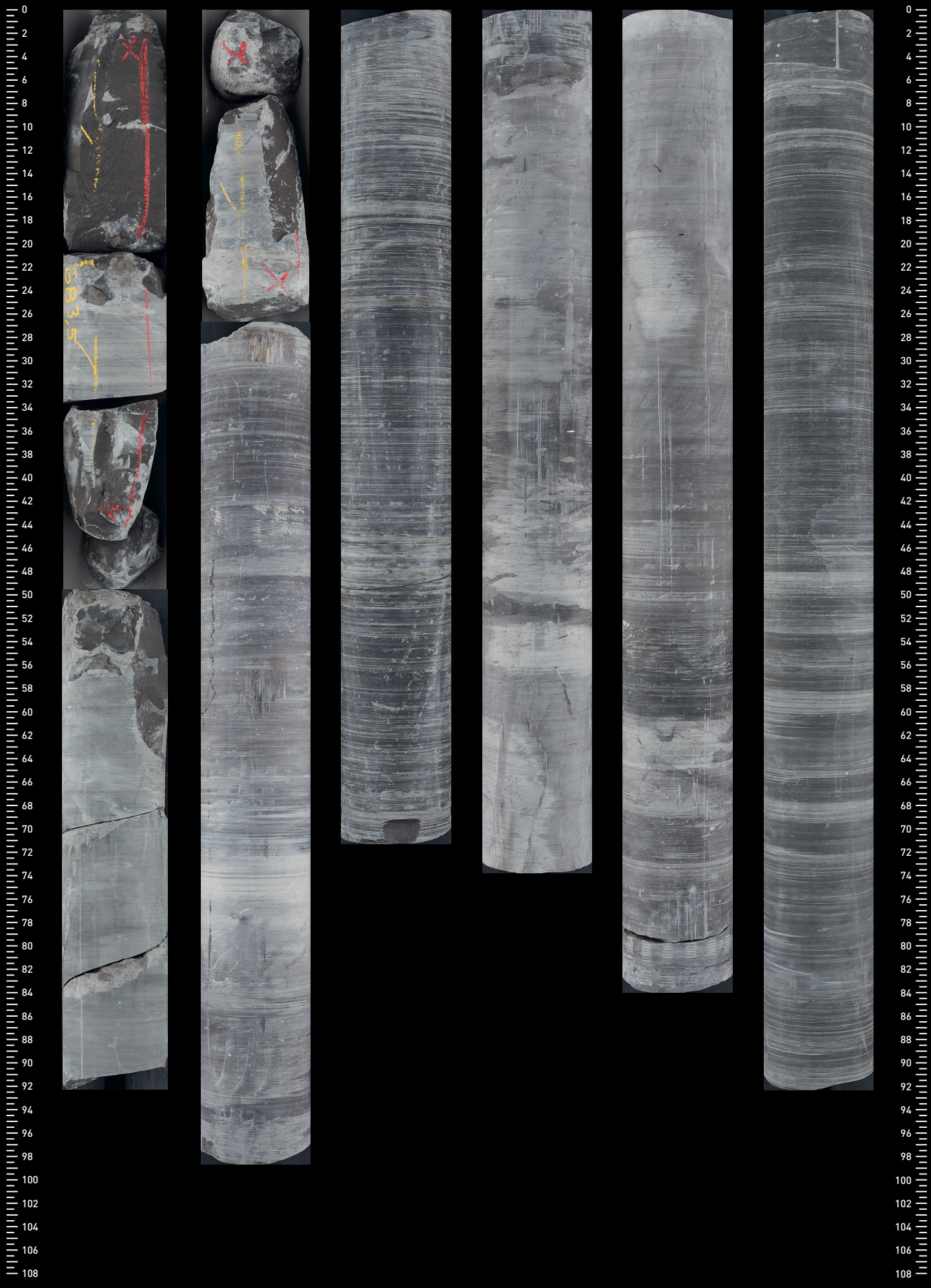
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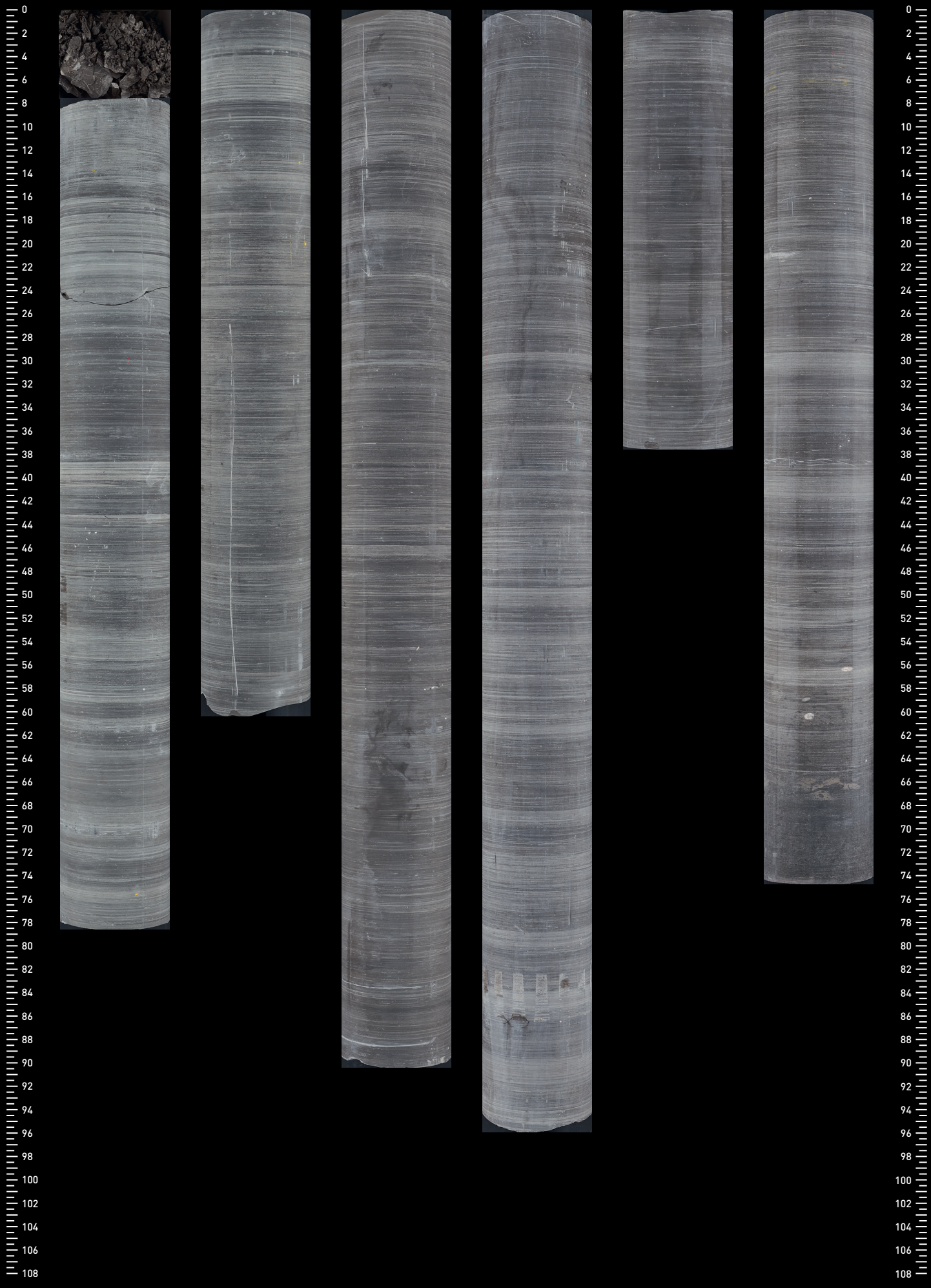
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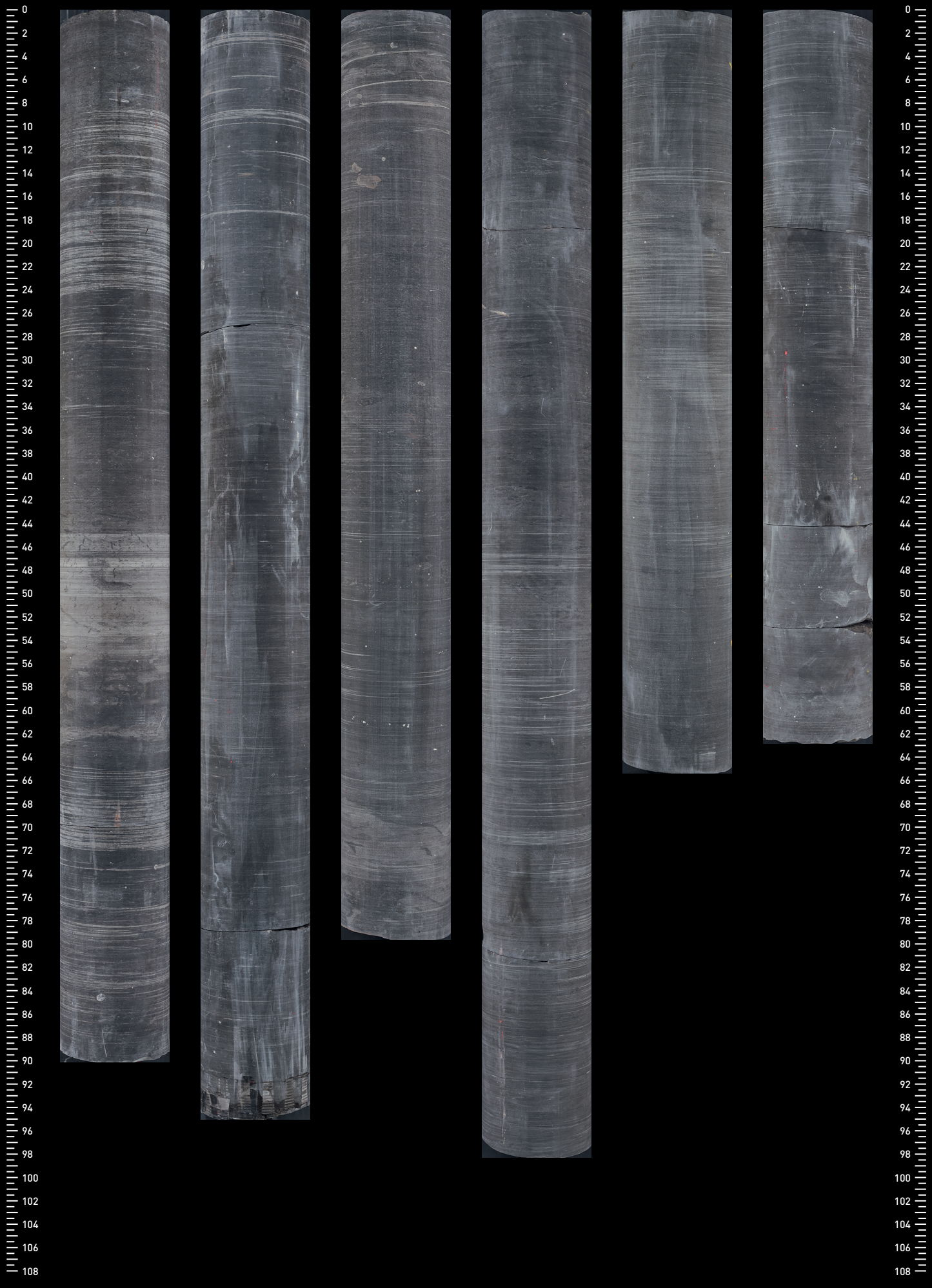
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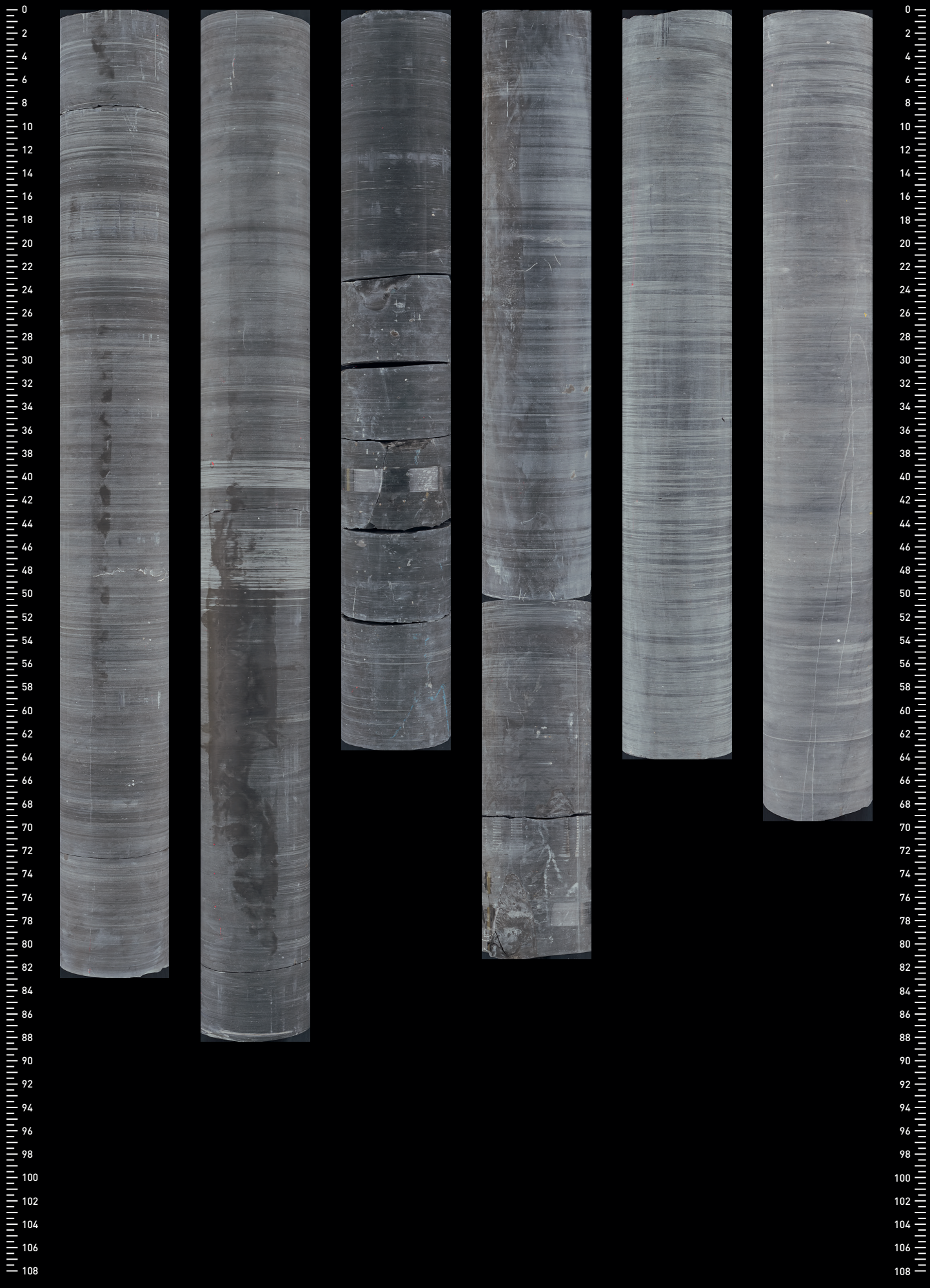


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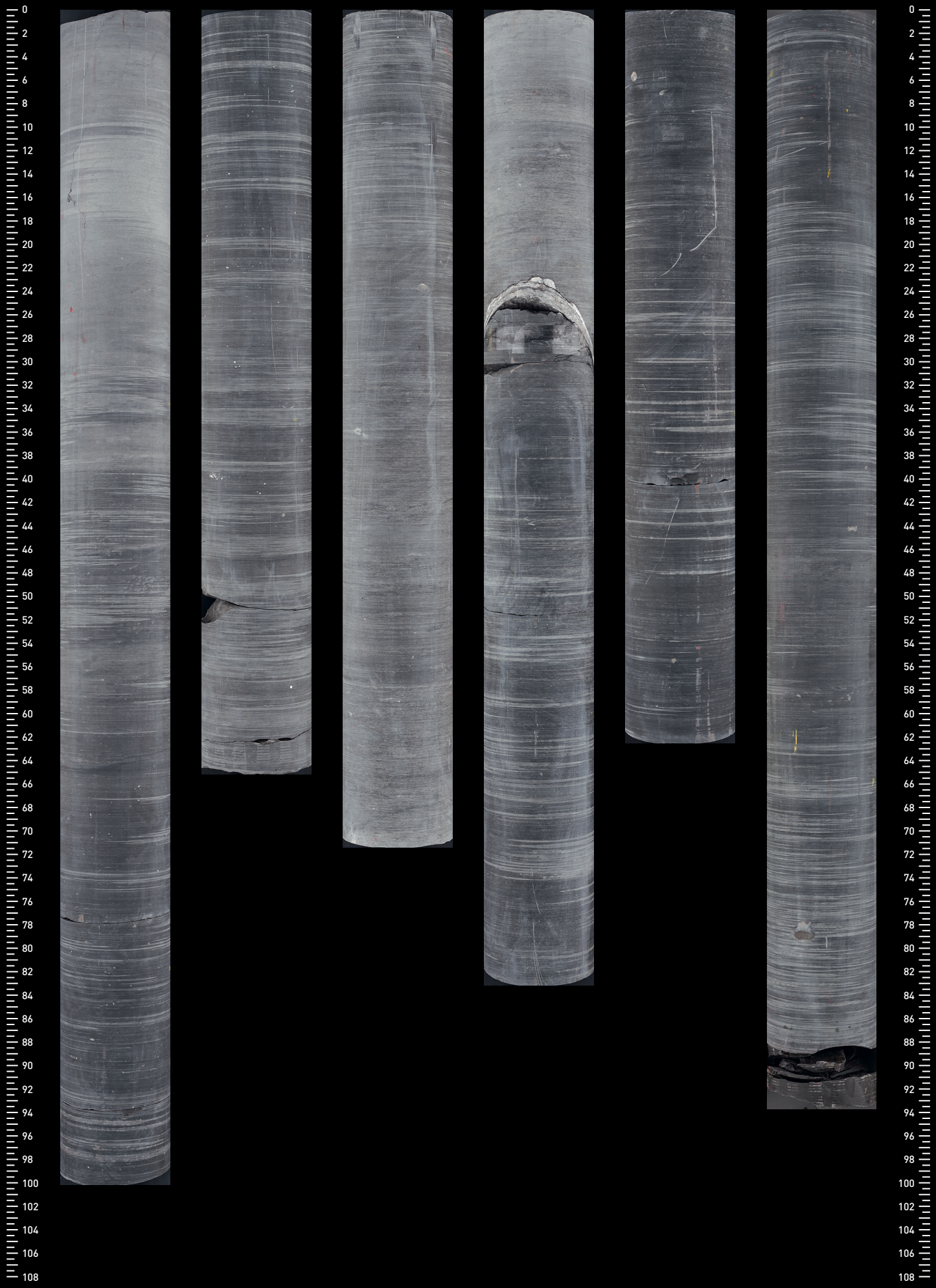
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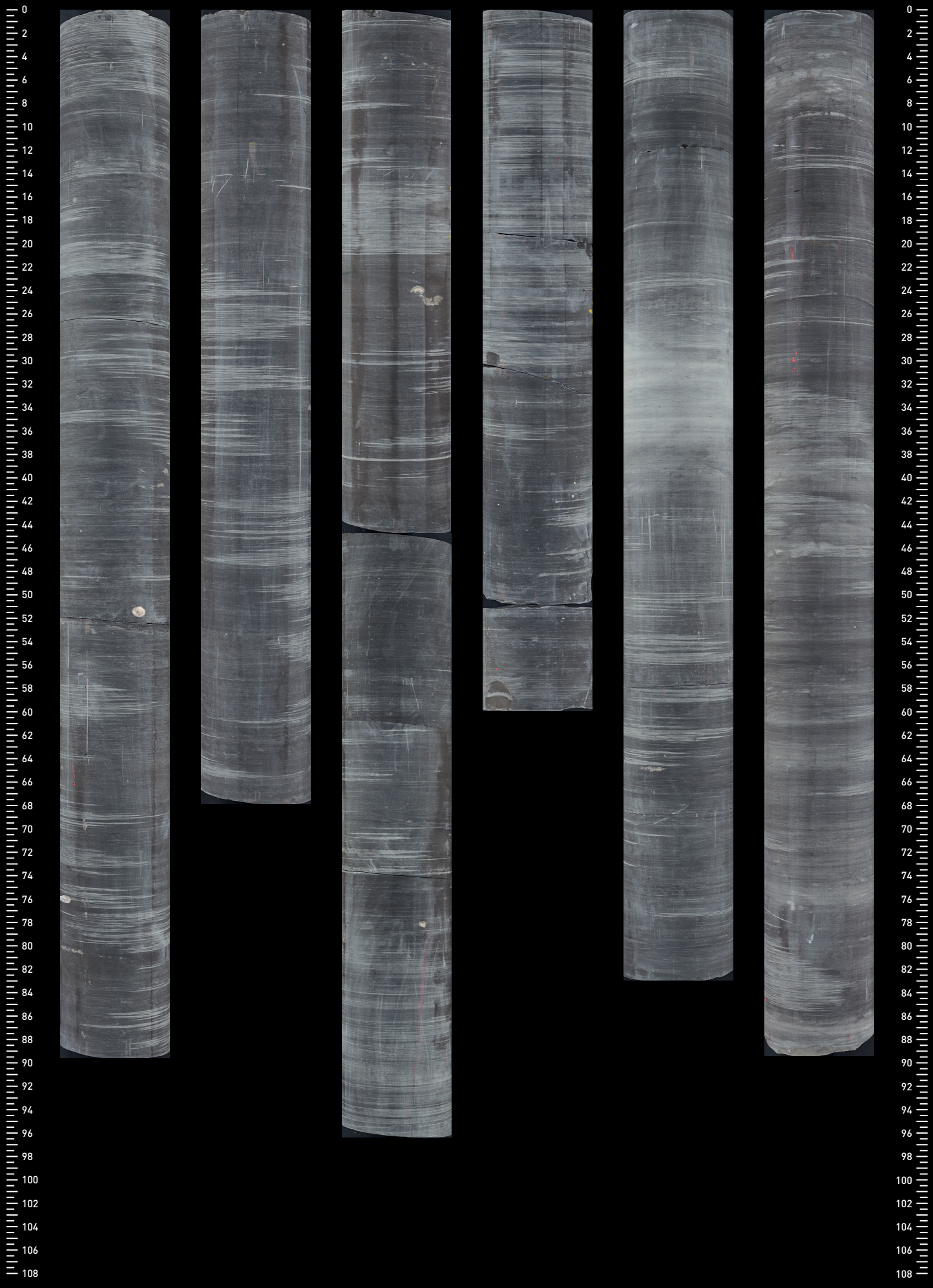

702.29m
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706.67m 707.65m 708.30m 709.00m 709.80m 710.41m



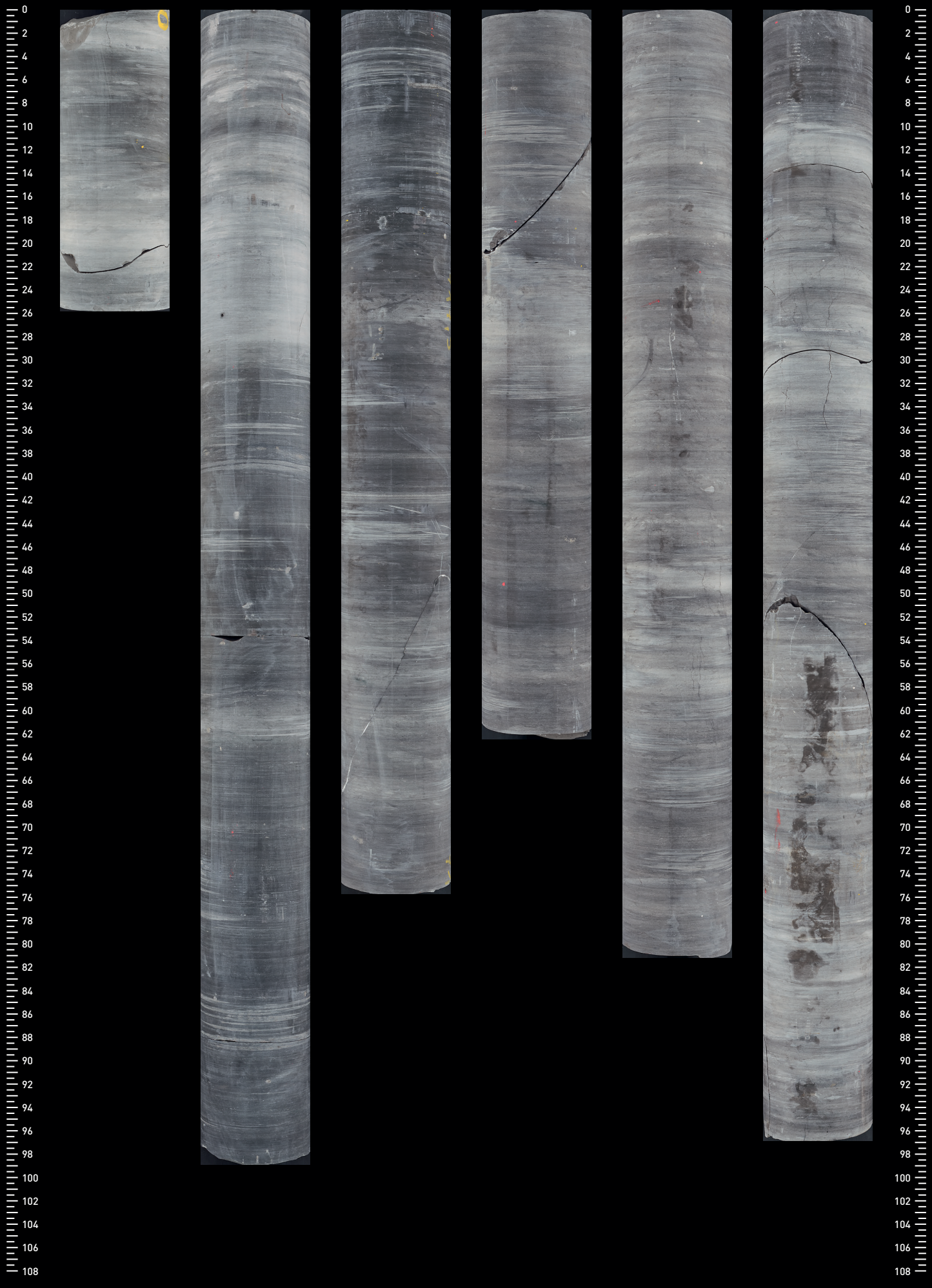
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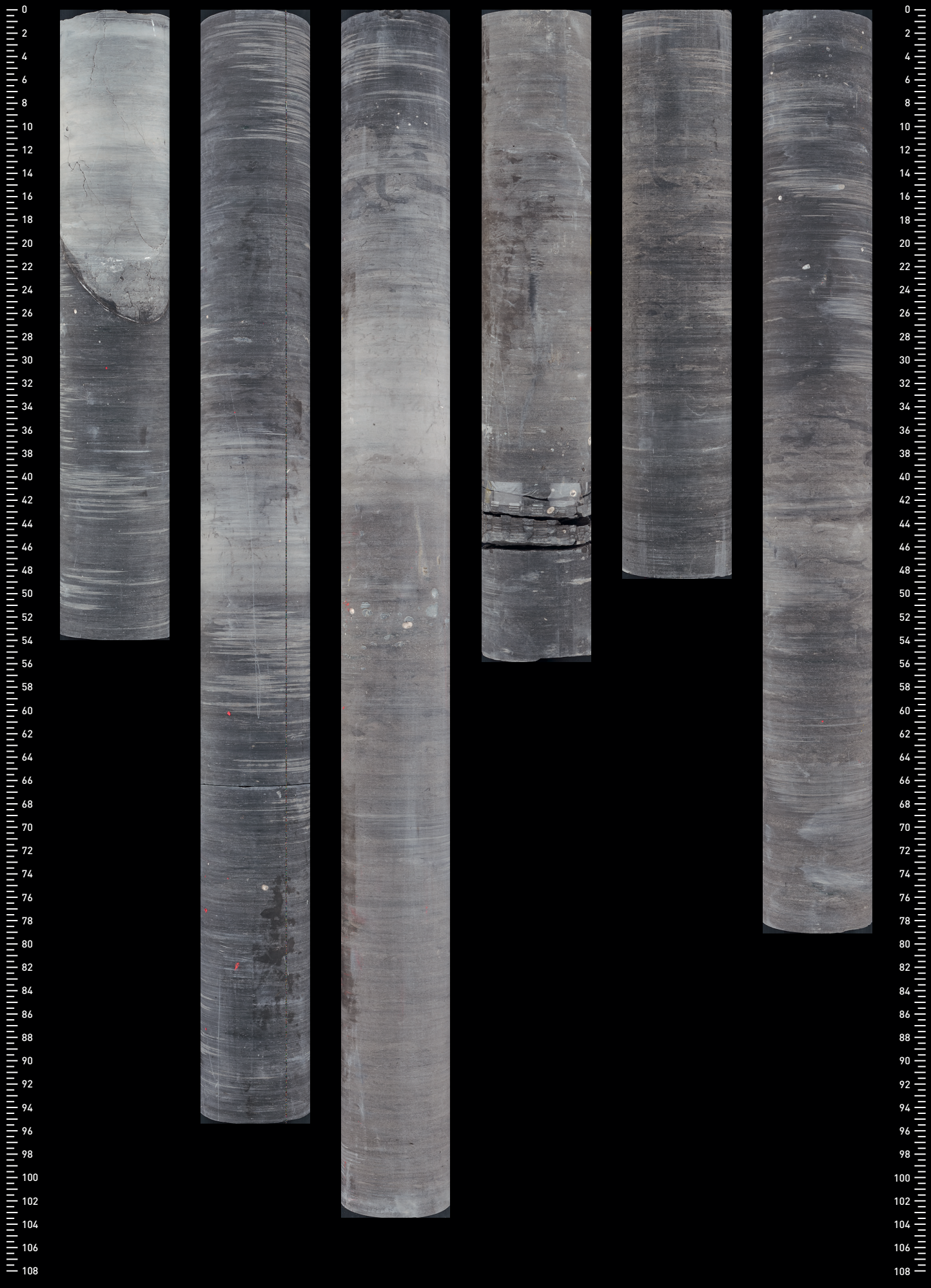
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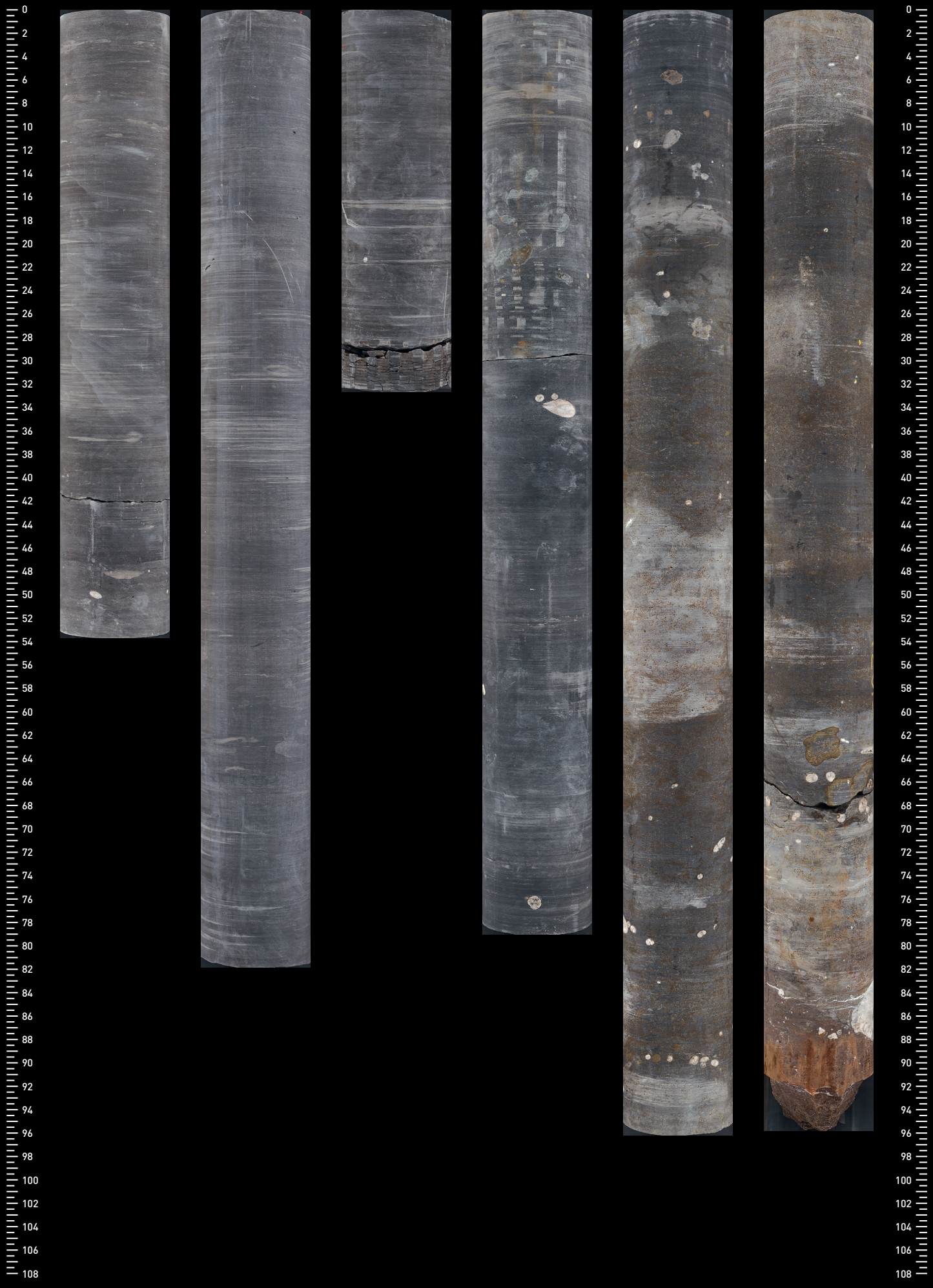
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724.60m 725.13m 725.94m 726.24m 727.01m 727.95m



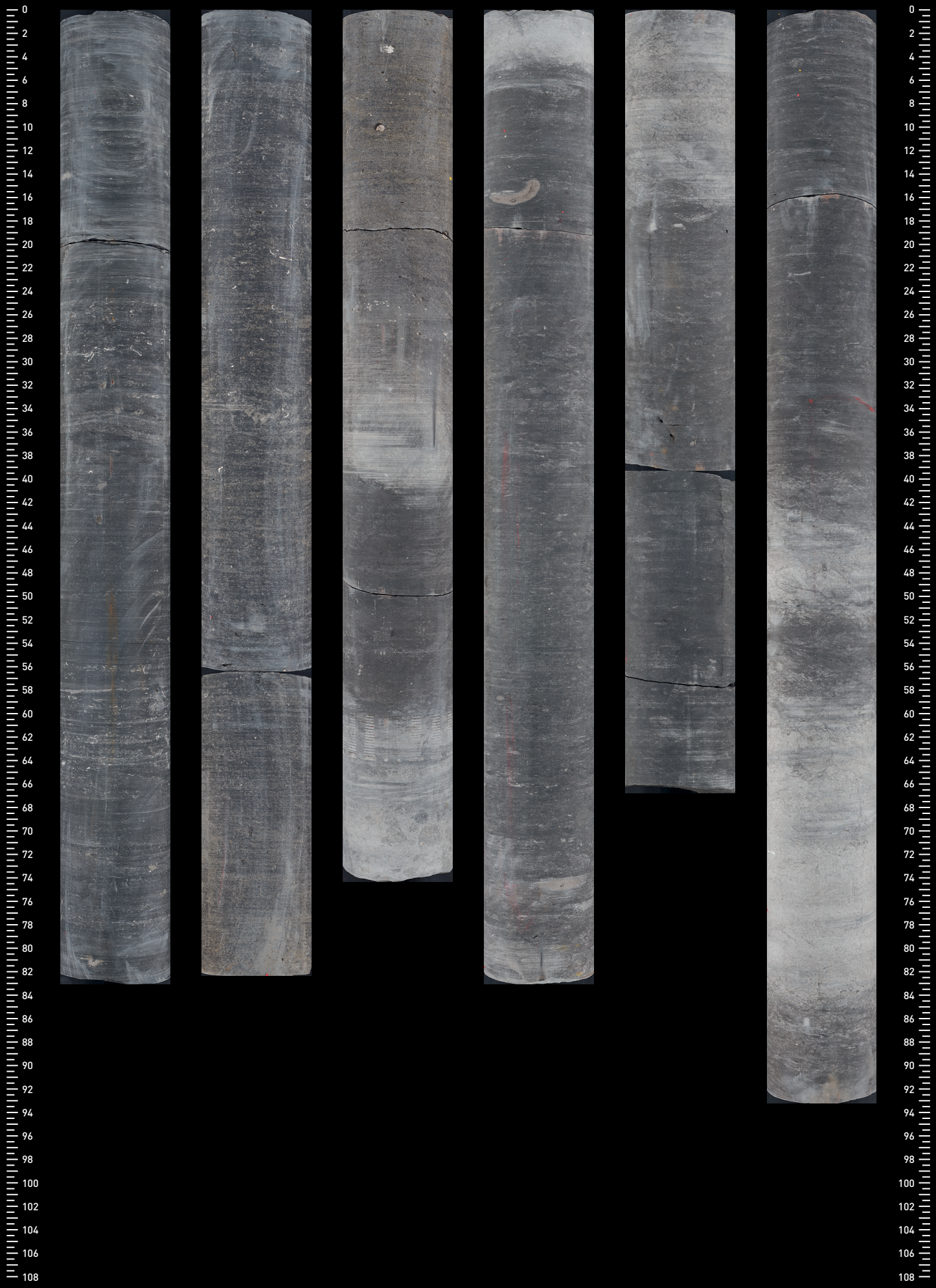
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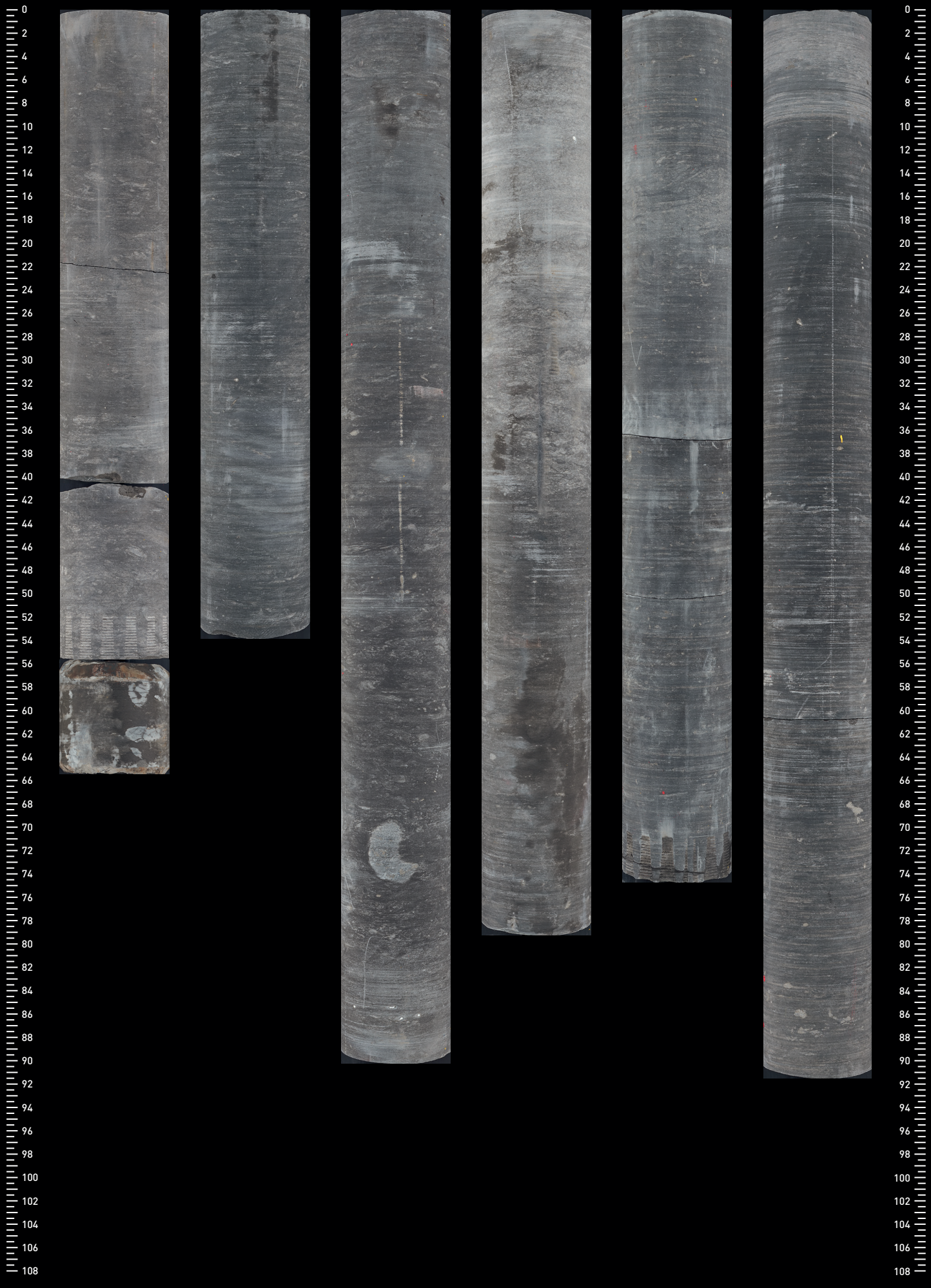
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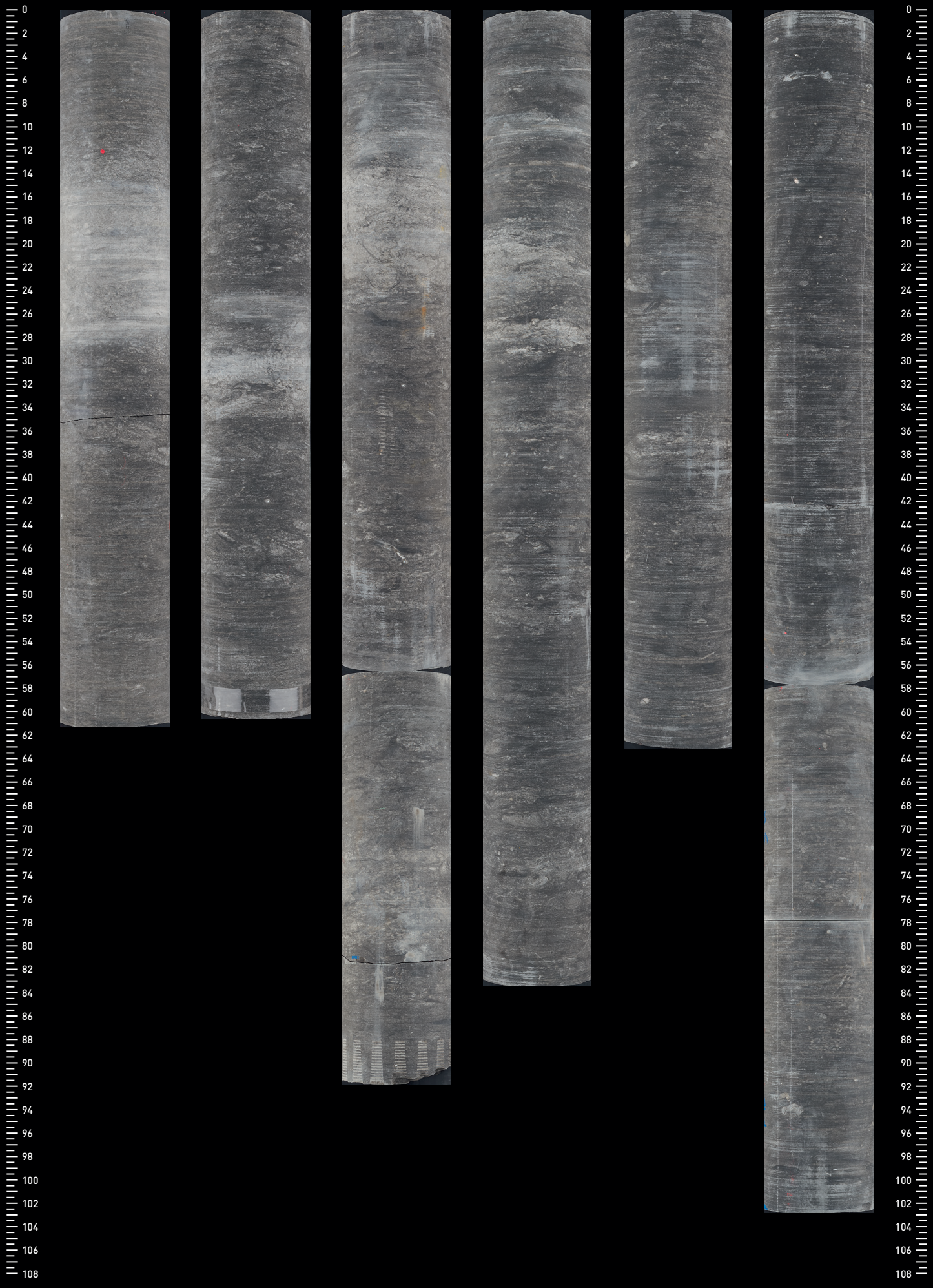
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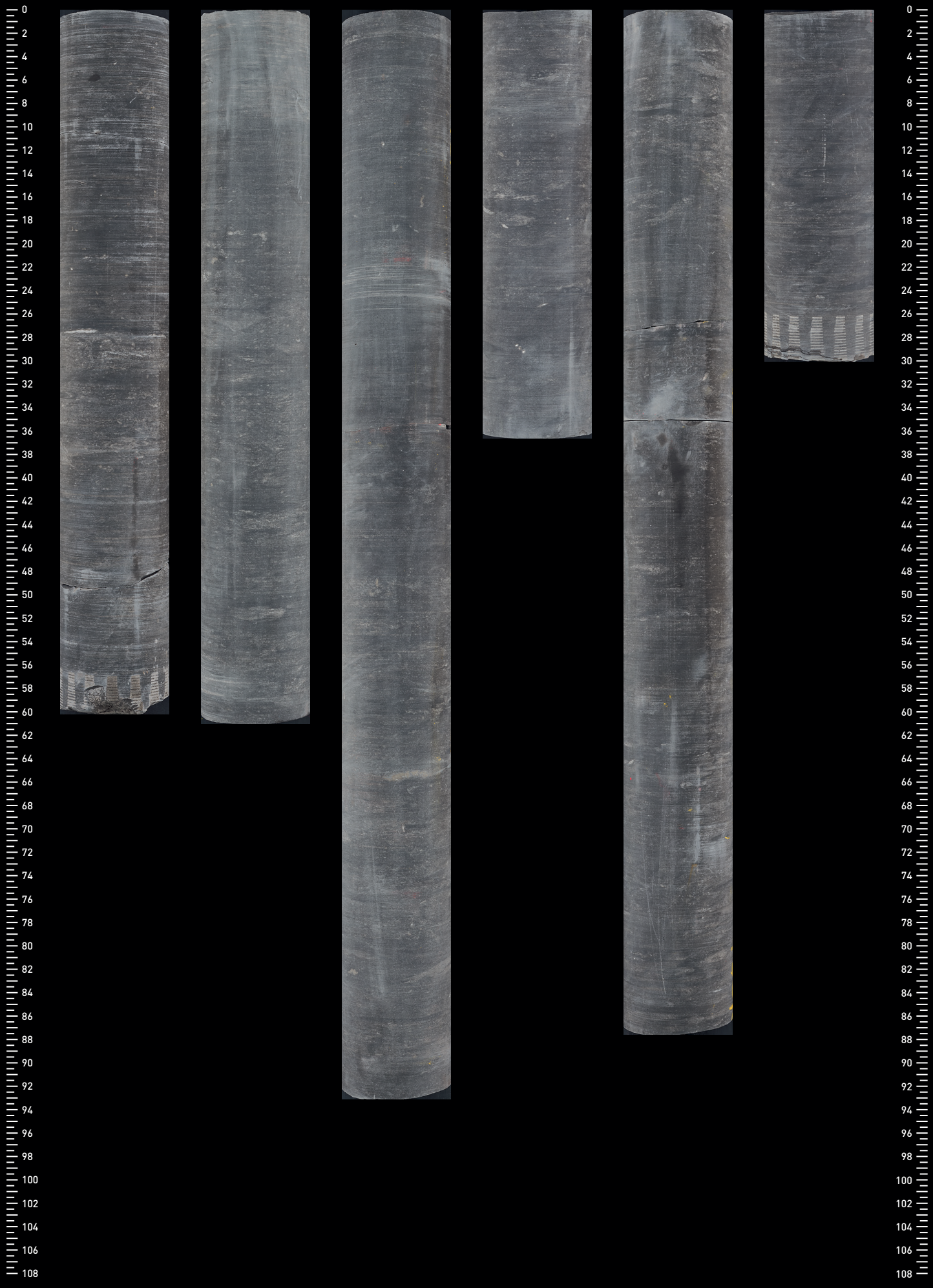
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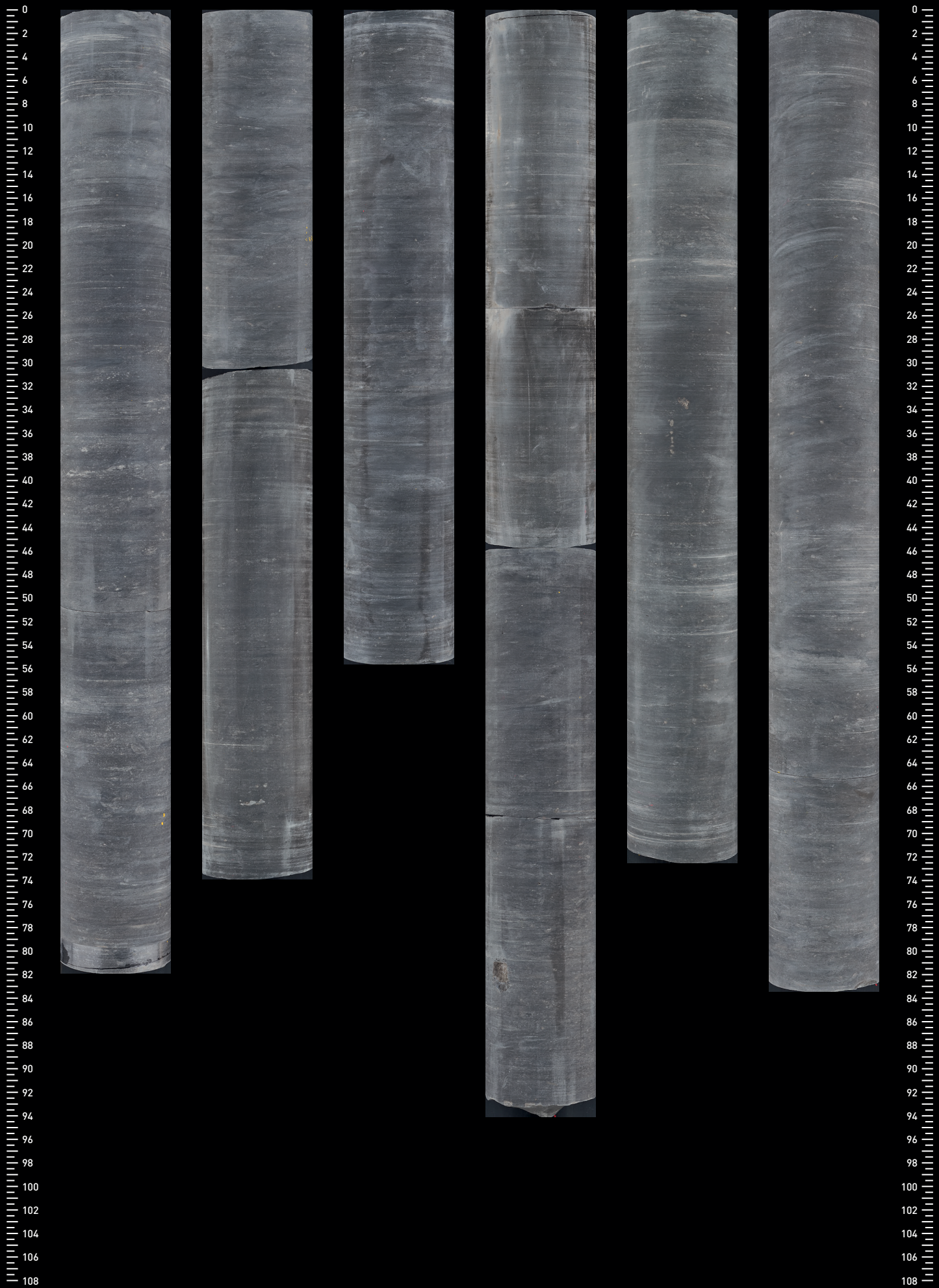
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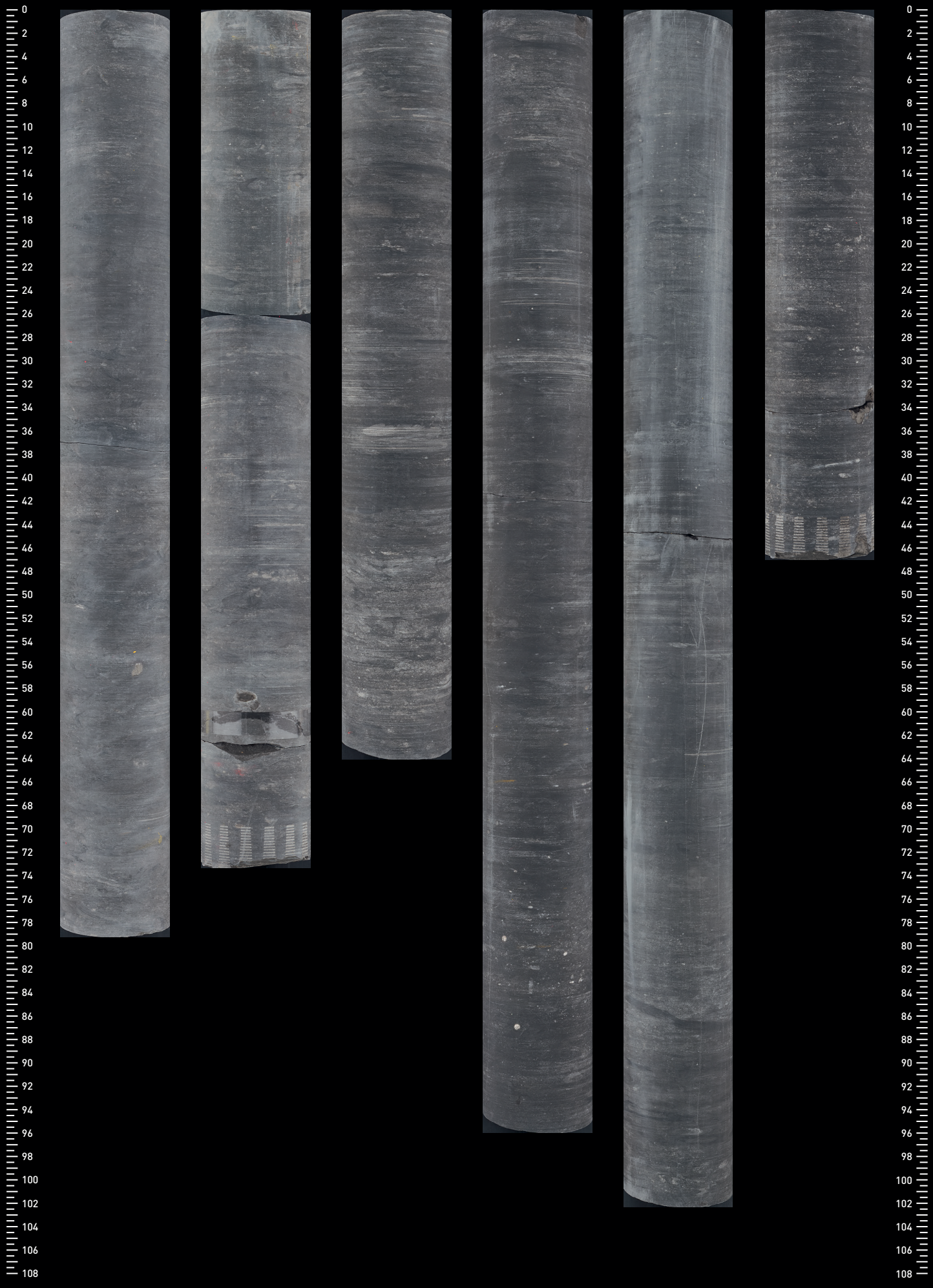
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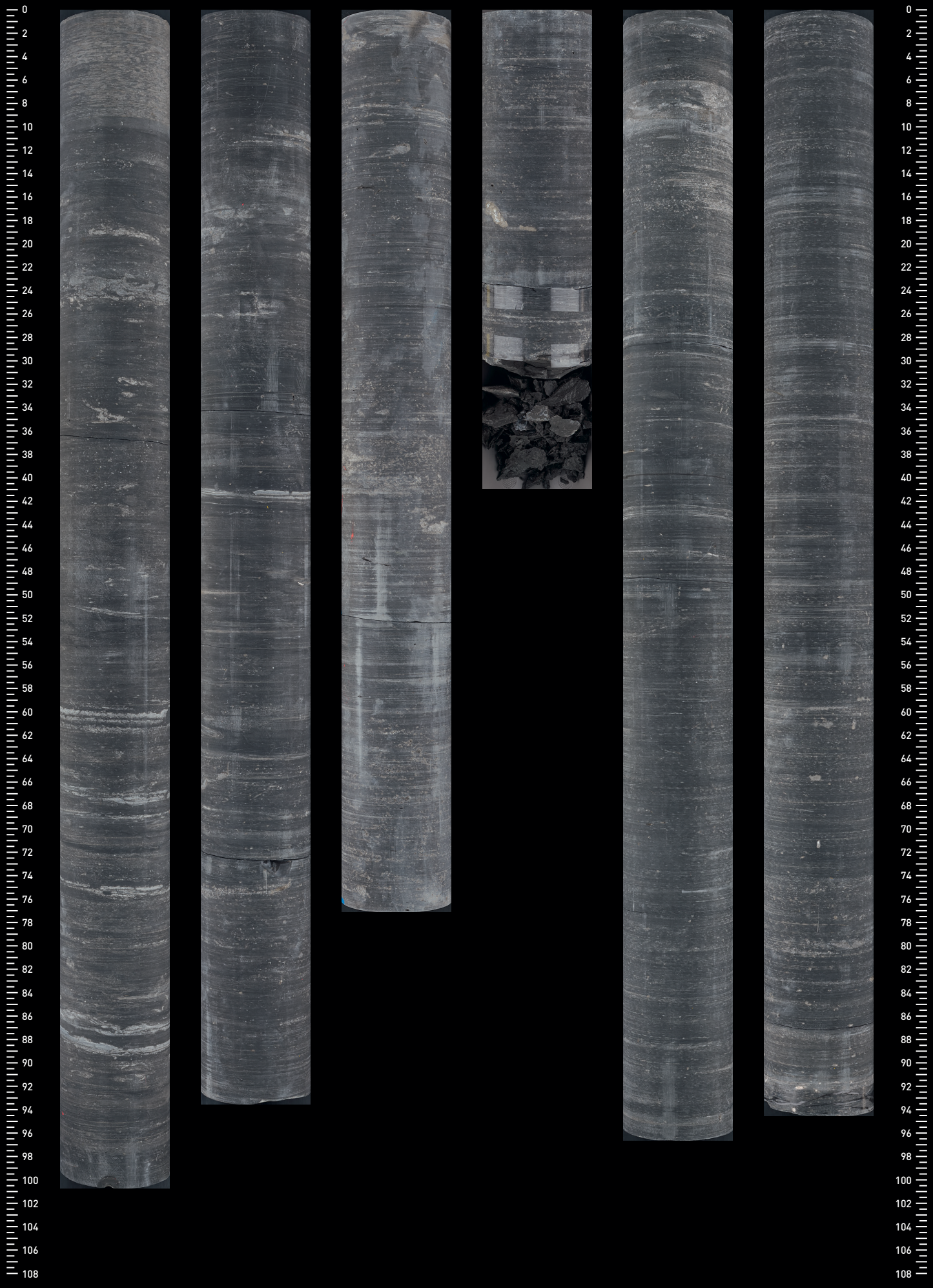
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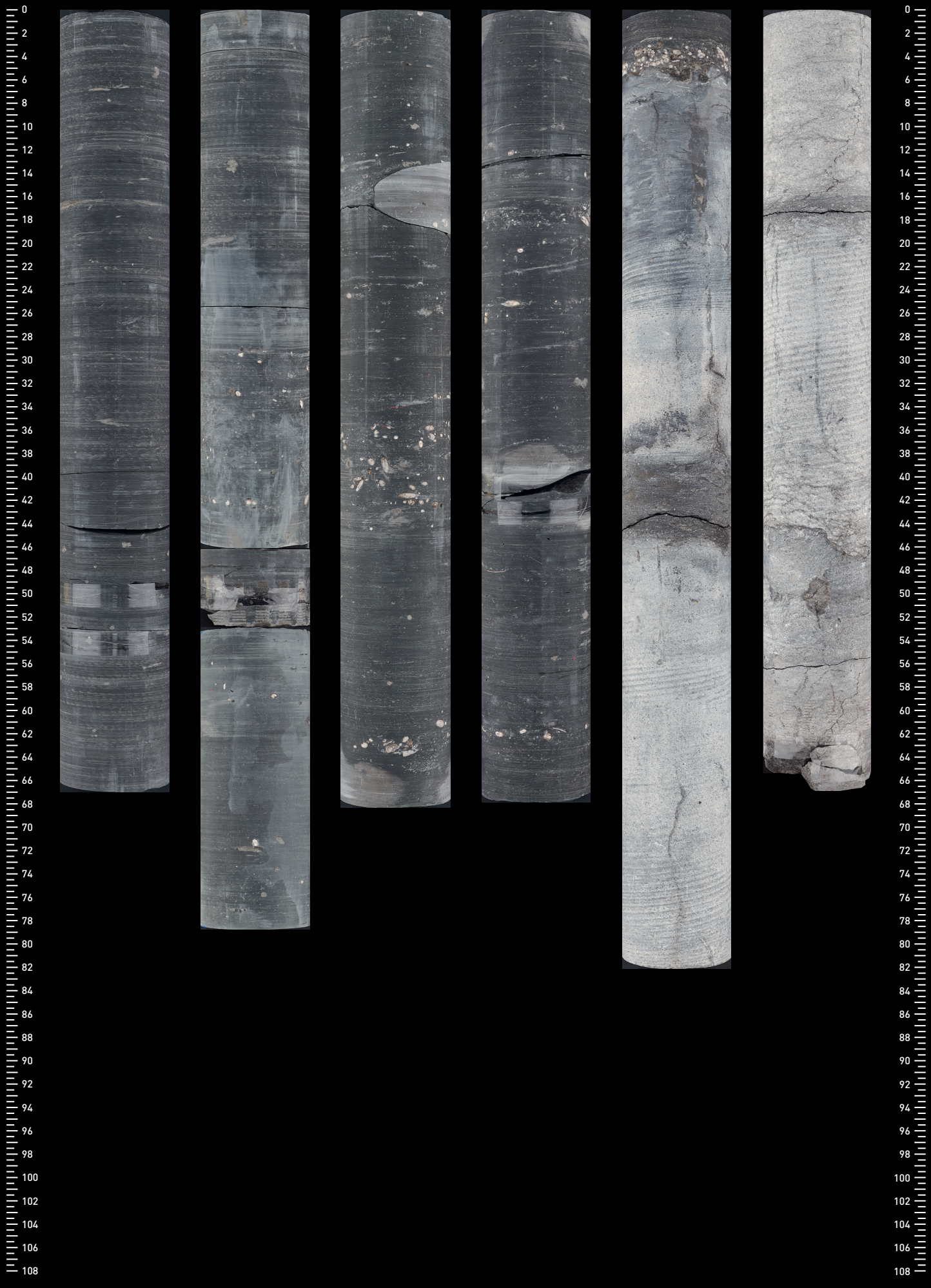
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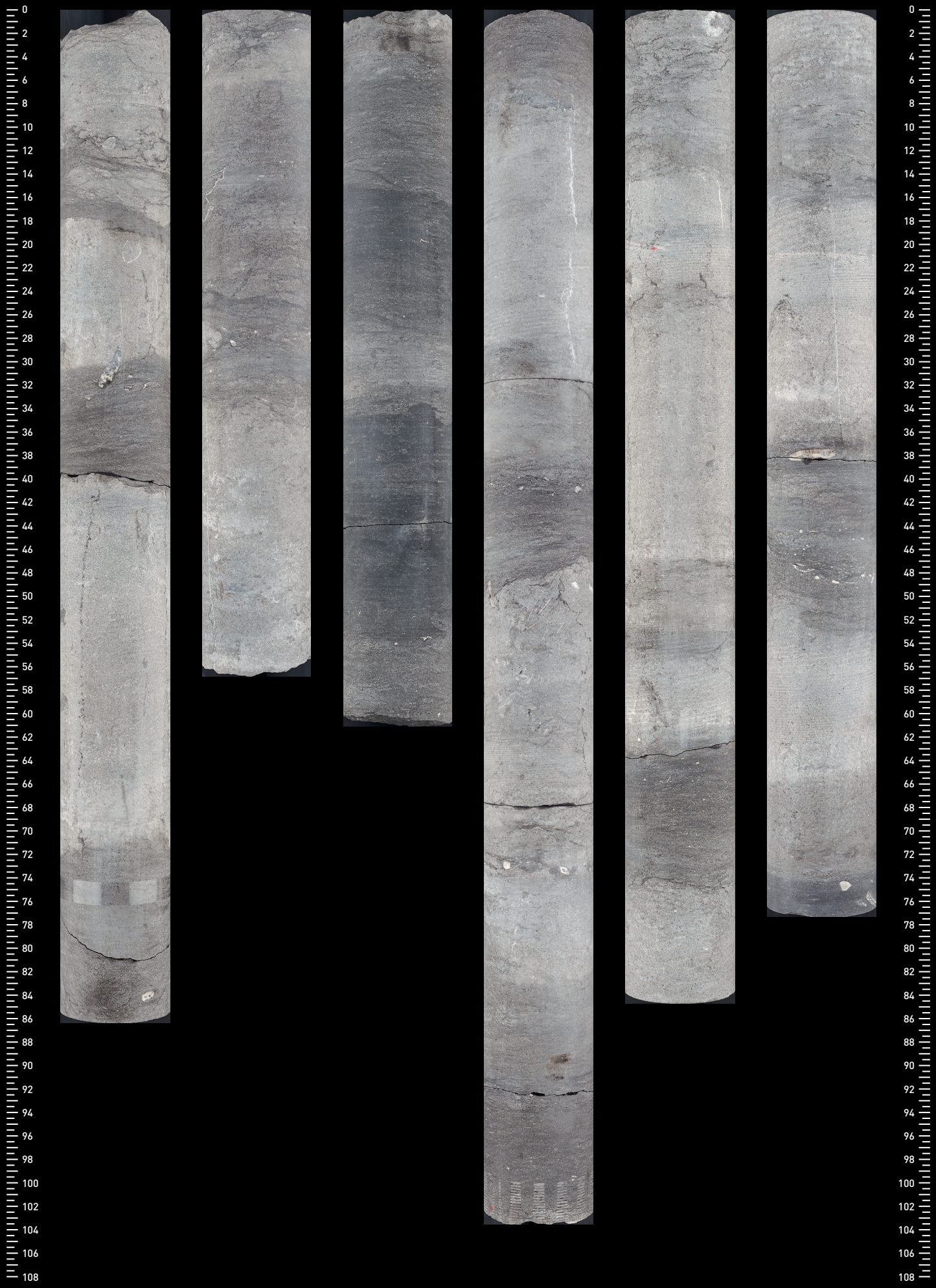
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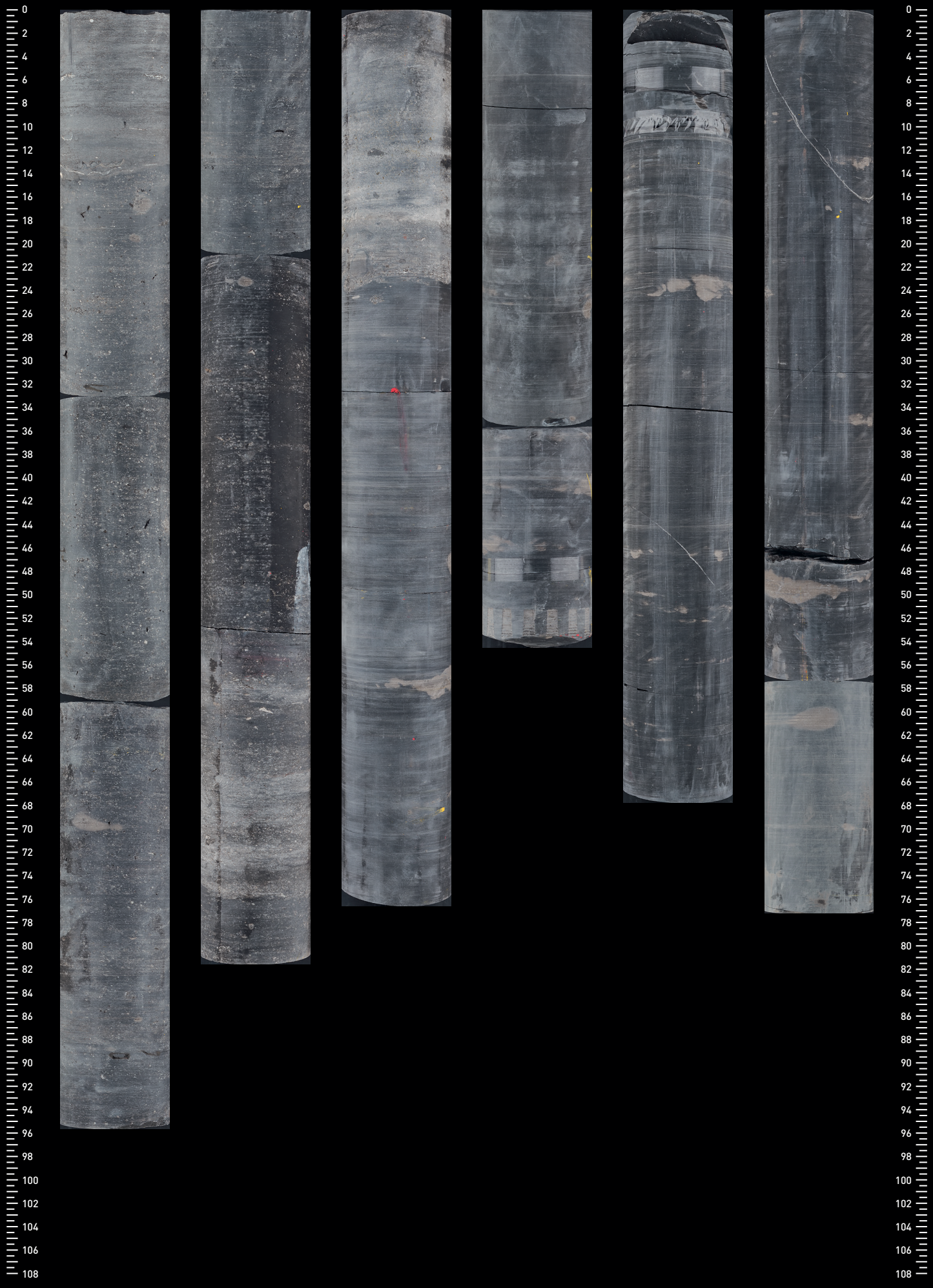
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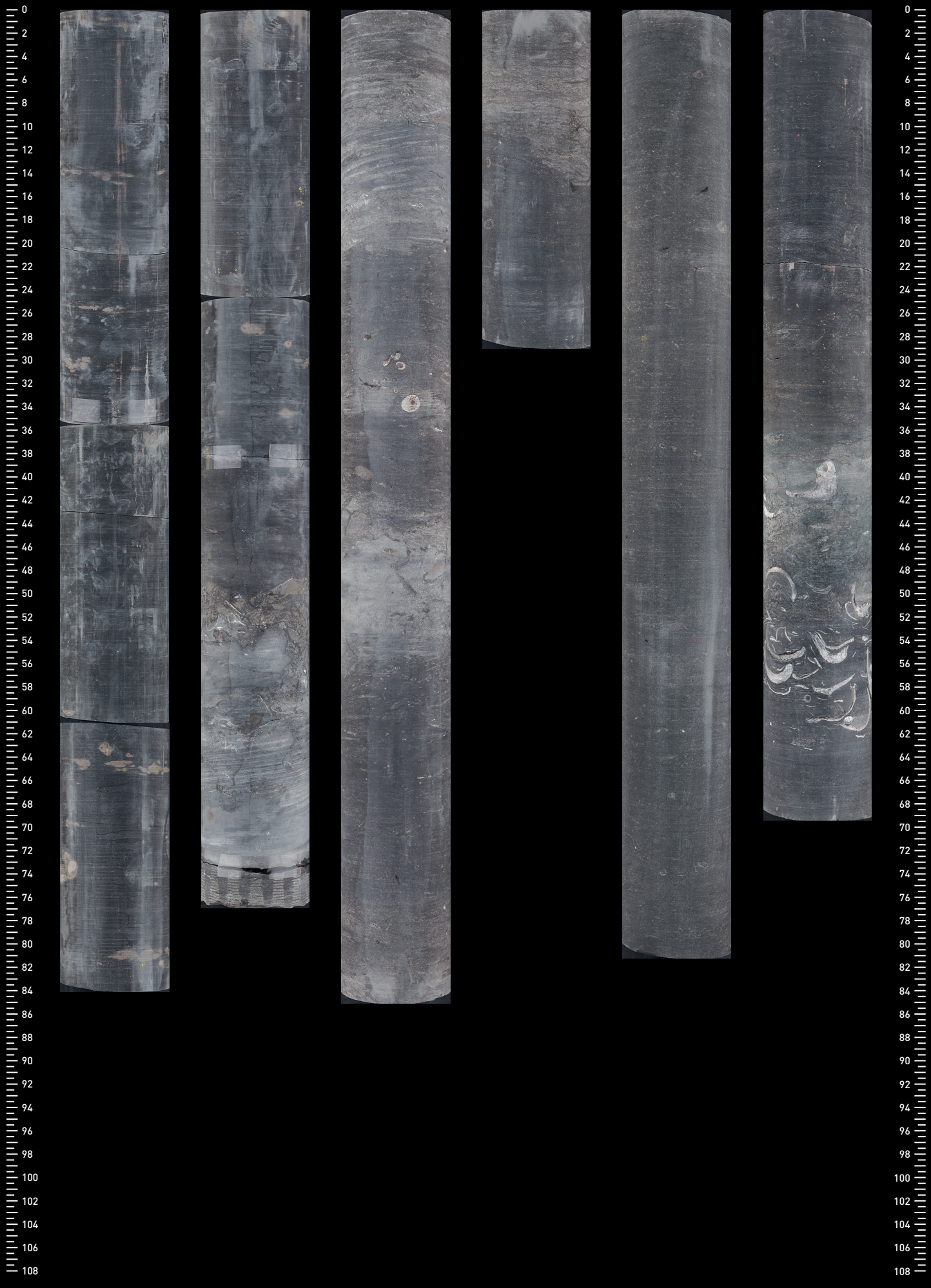
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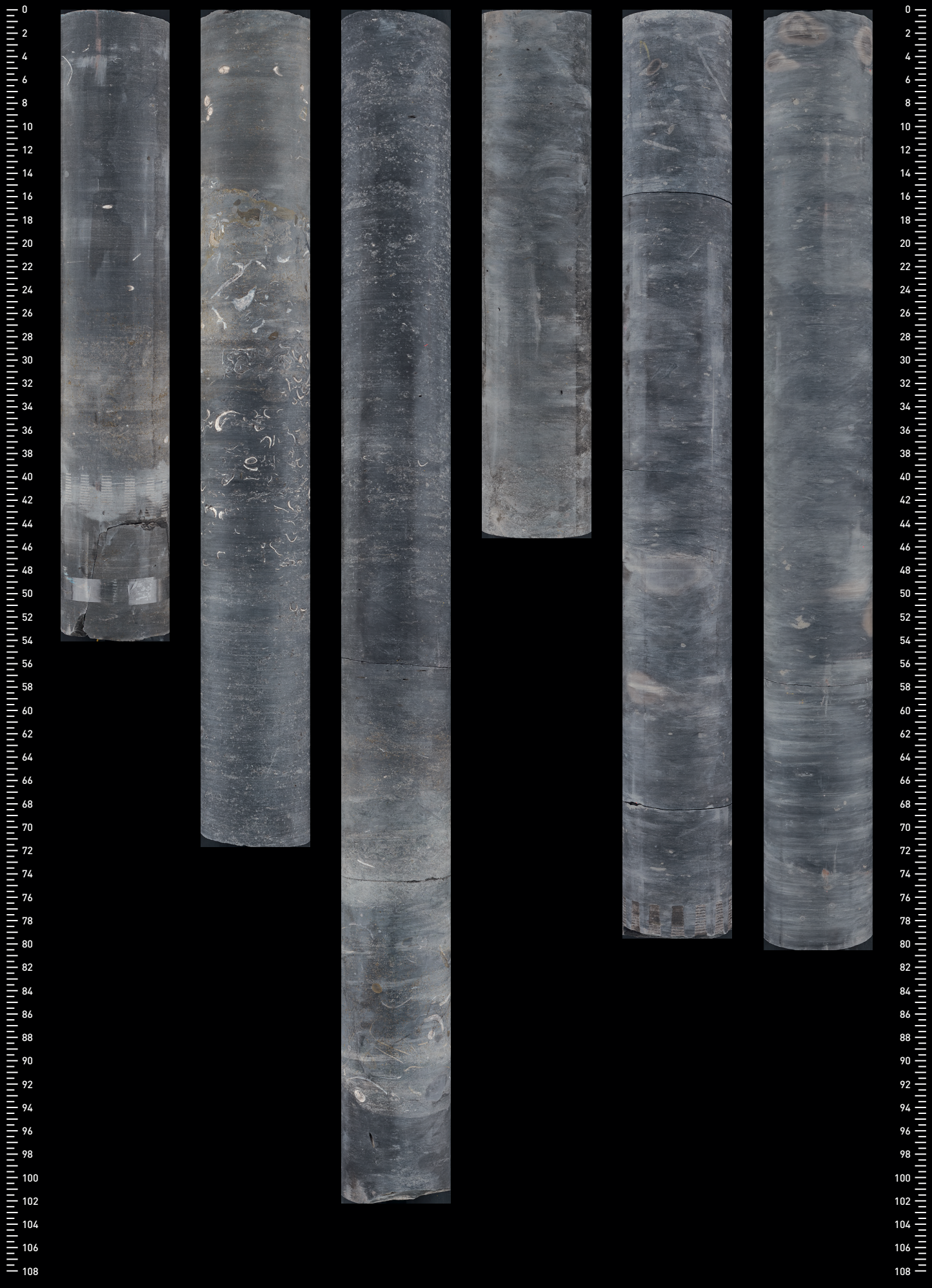
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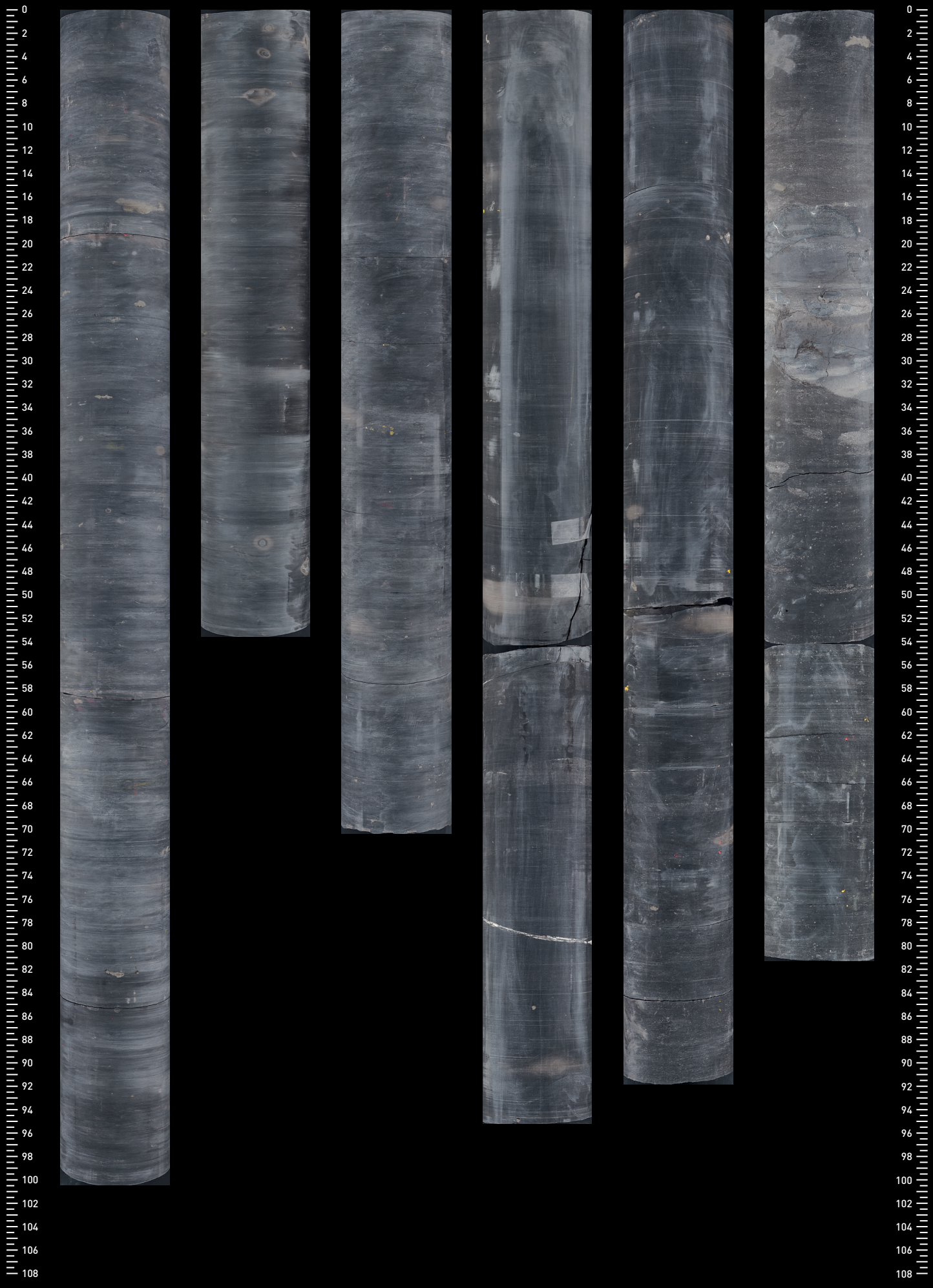
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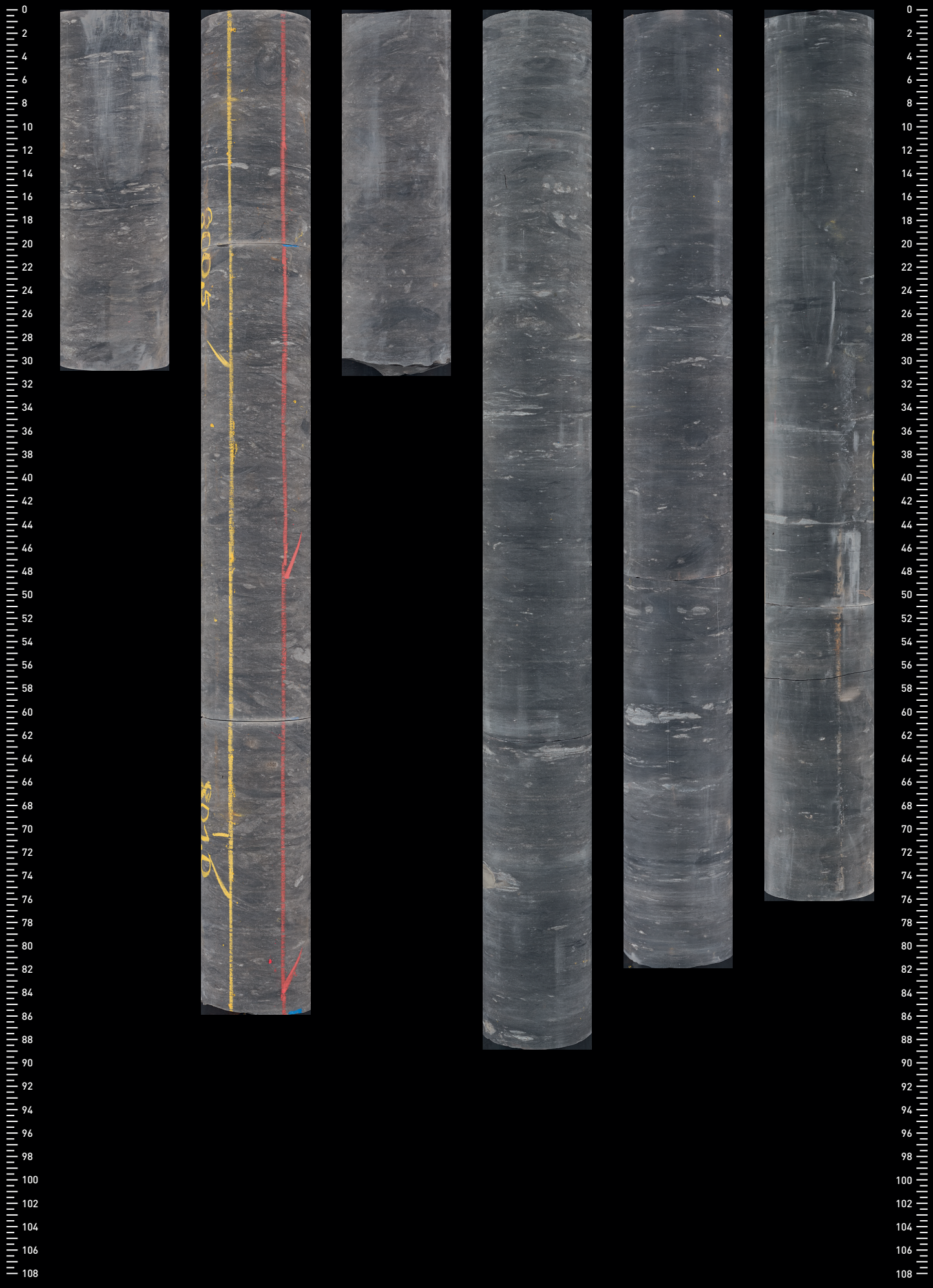
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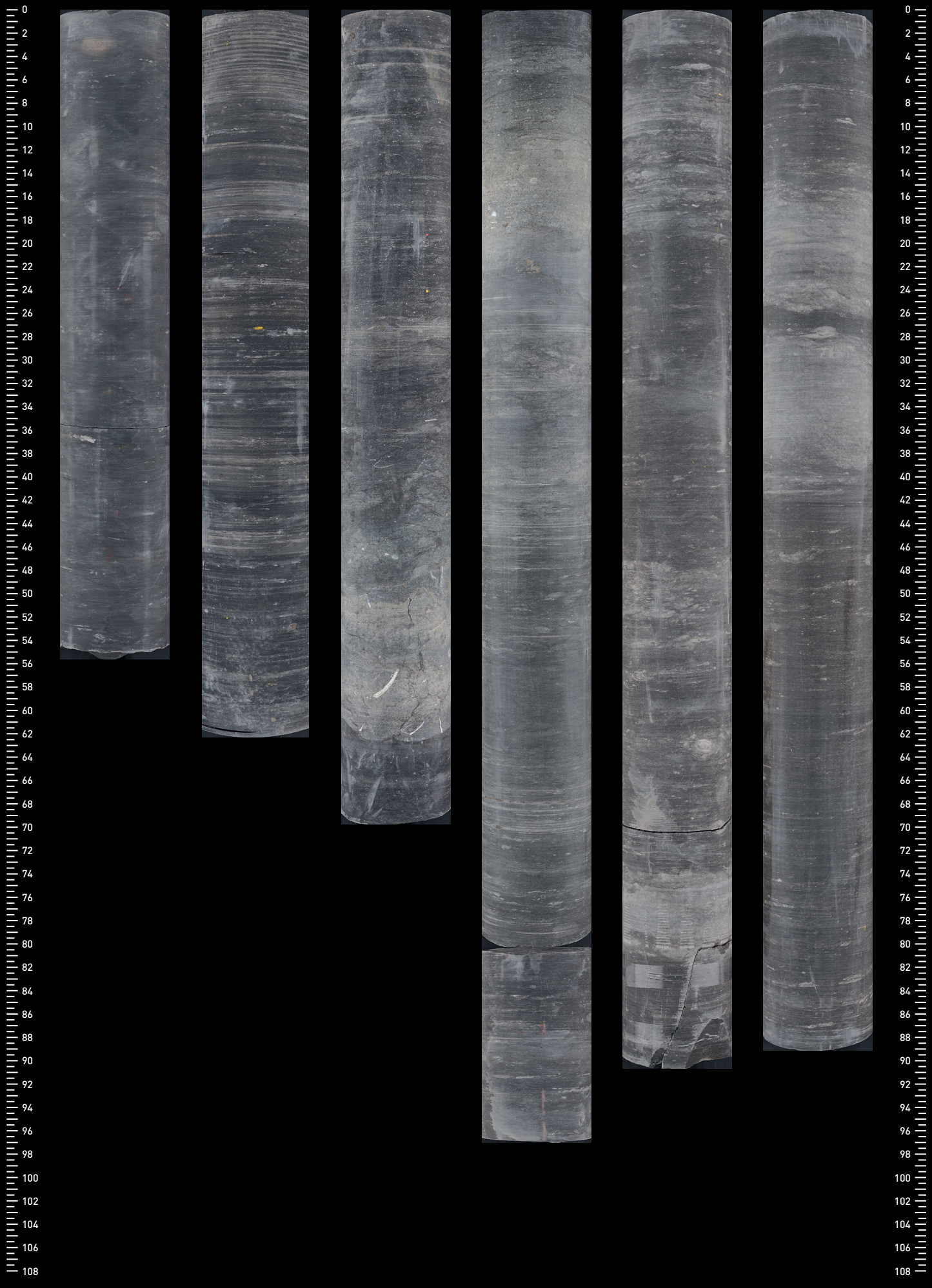
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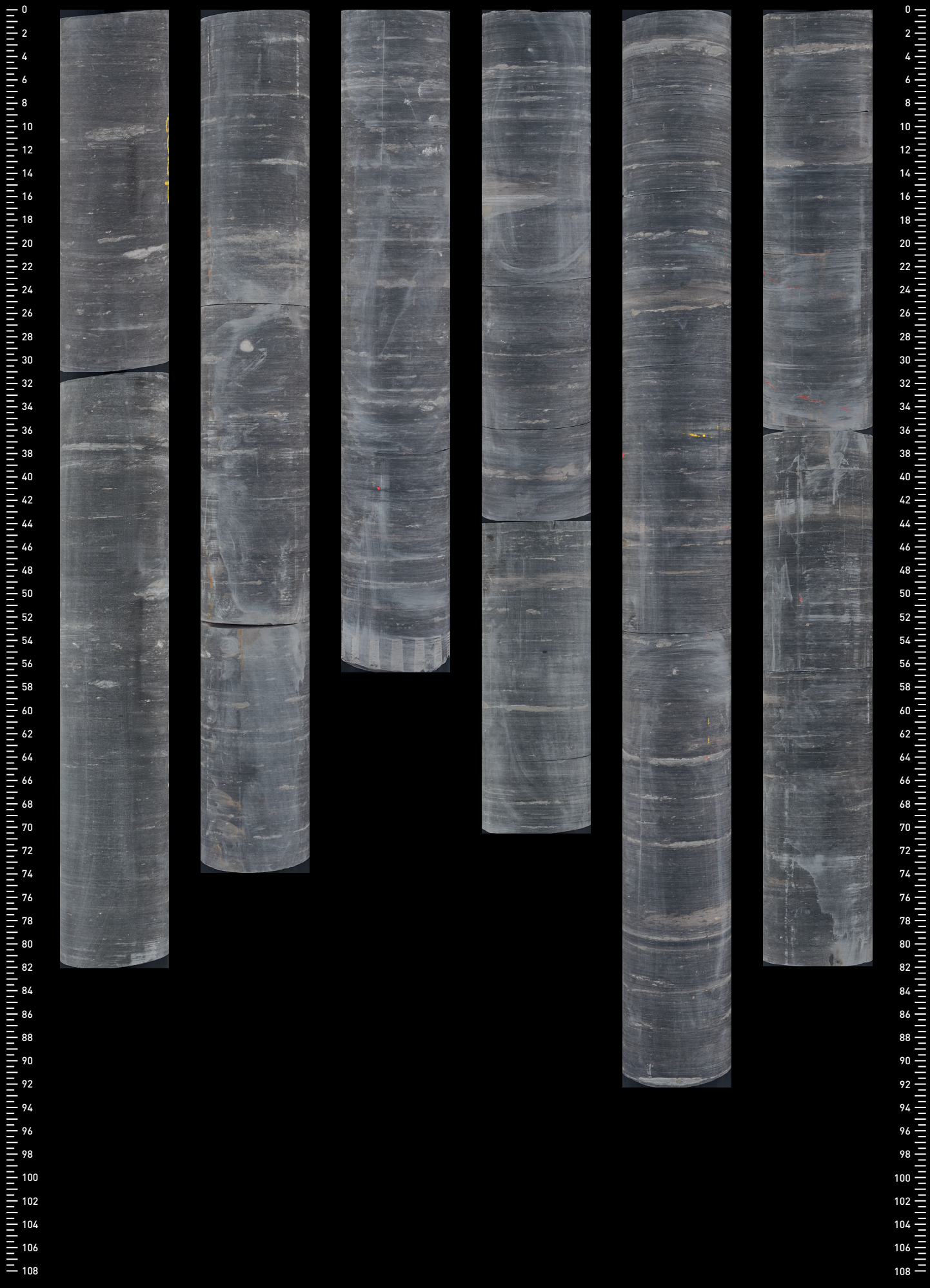


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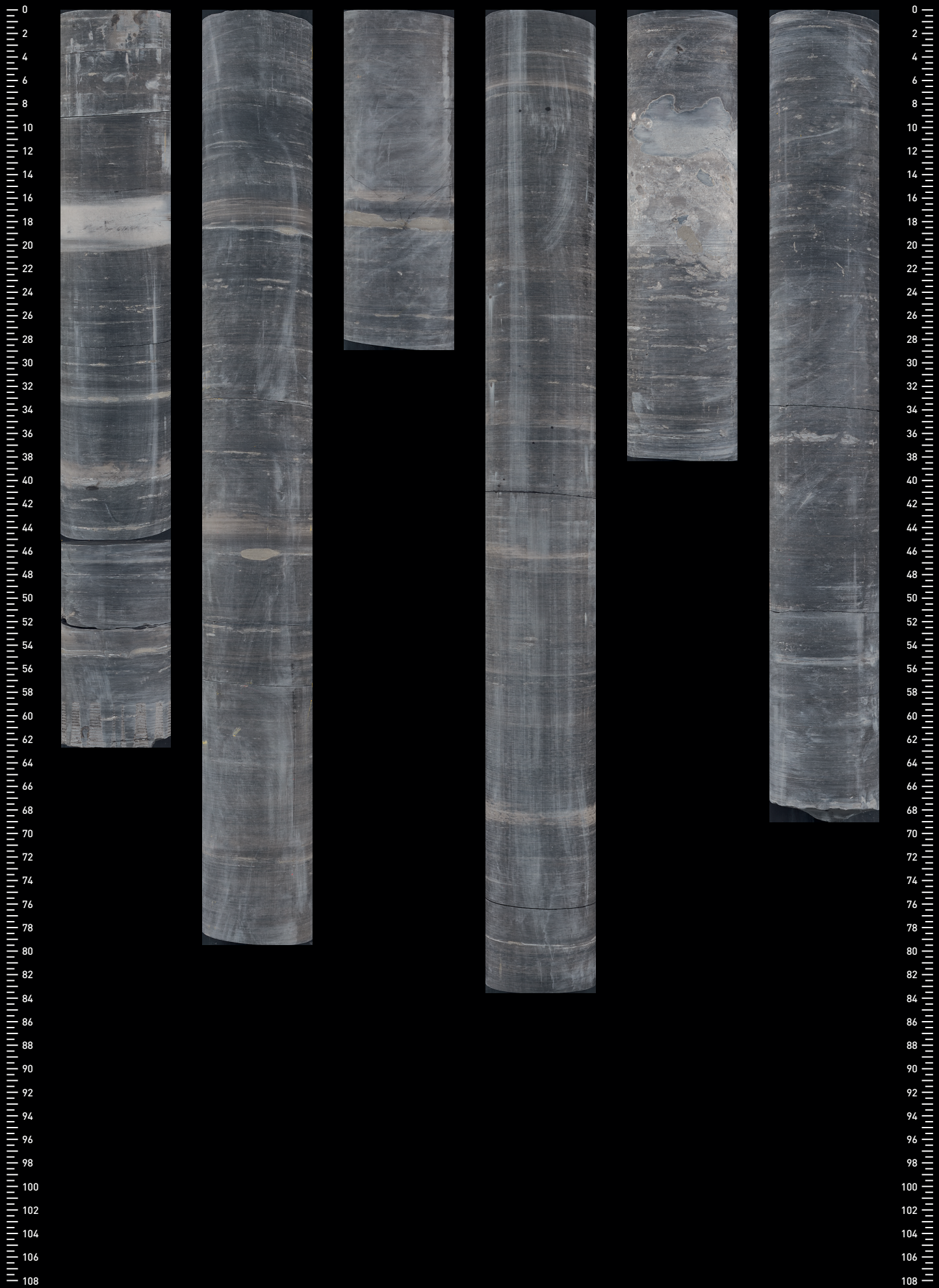
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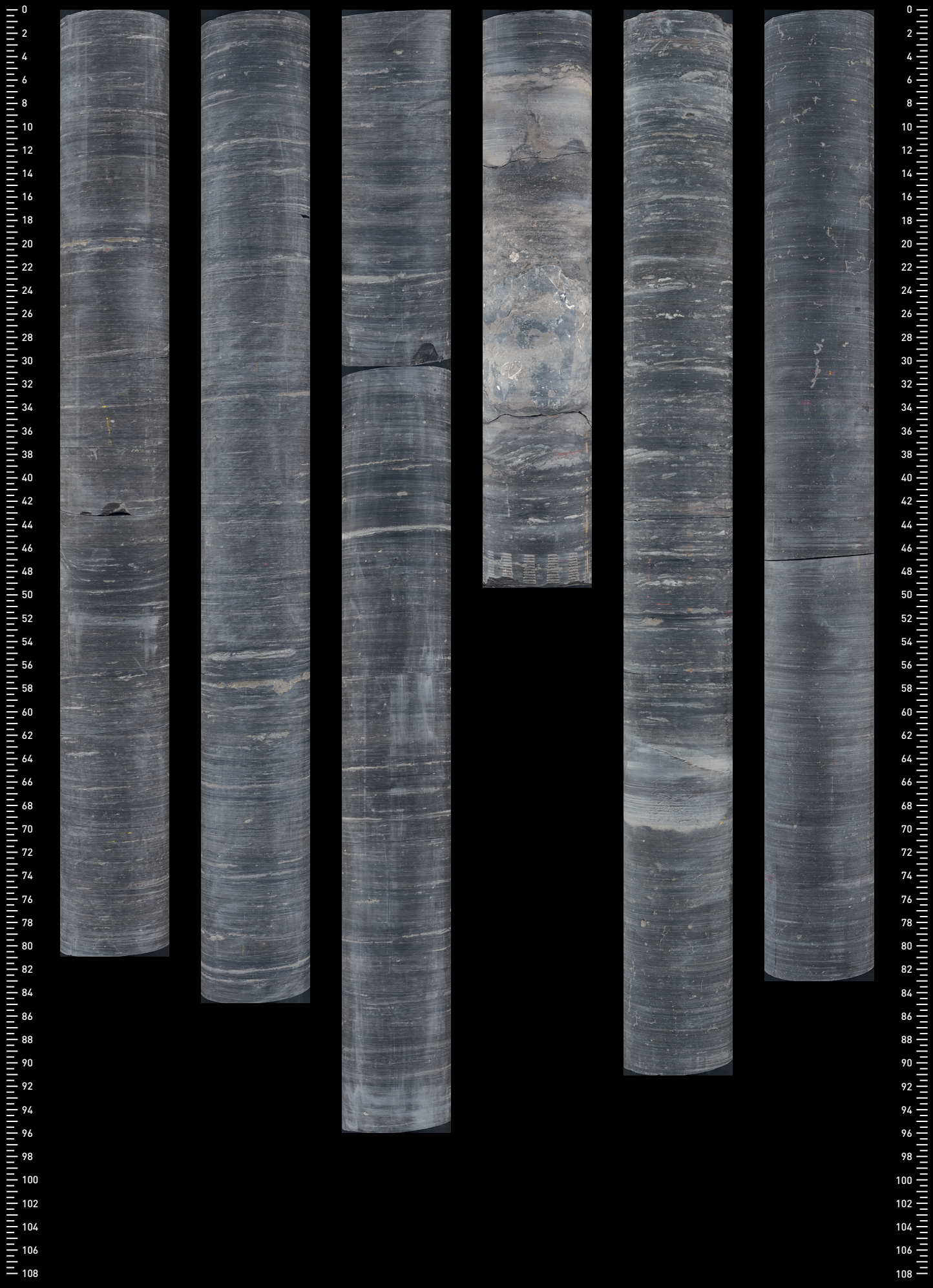

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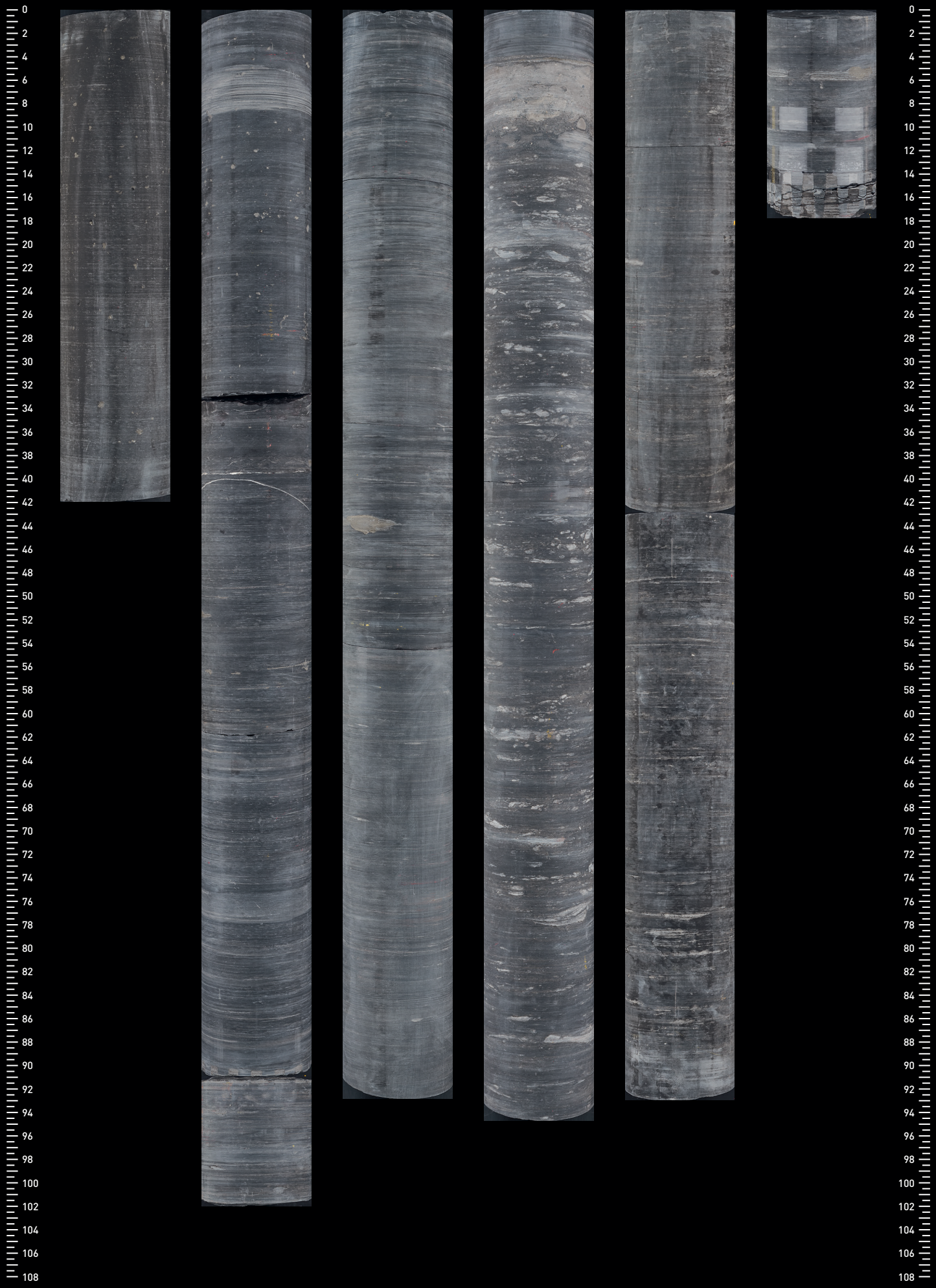
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817.18m 818.00m 818.94m 819.43m 820.31m 821.12m

821.12m 821.53m 822.56m 823.47m 824.38m 825.28m



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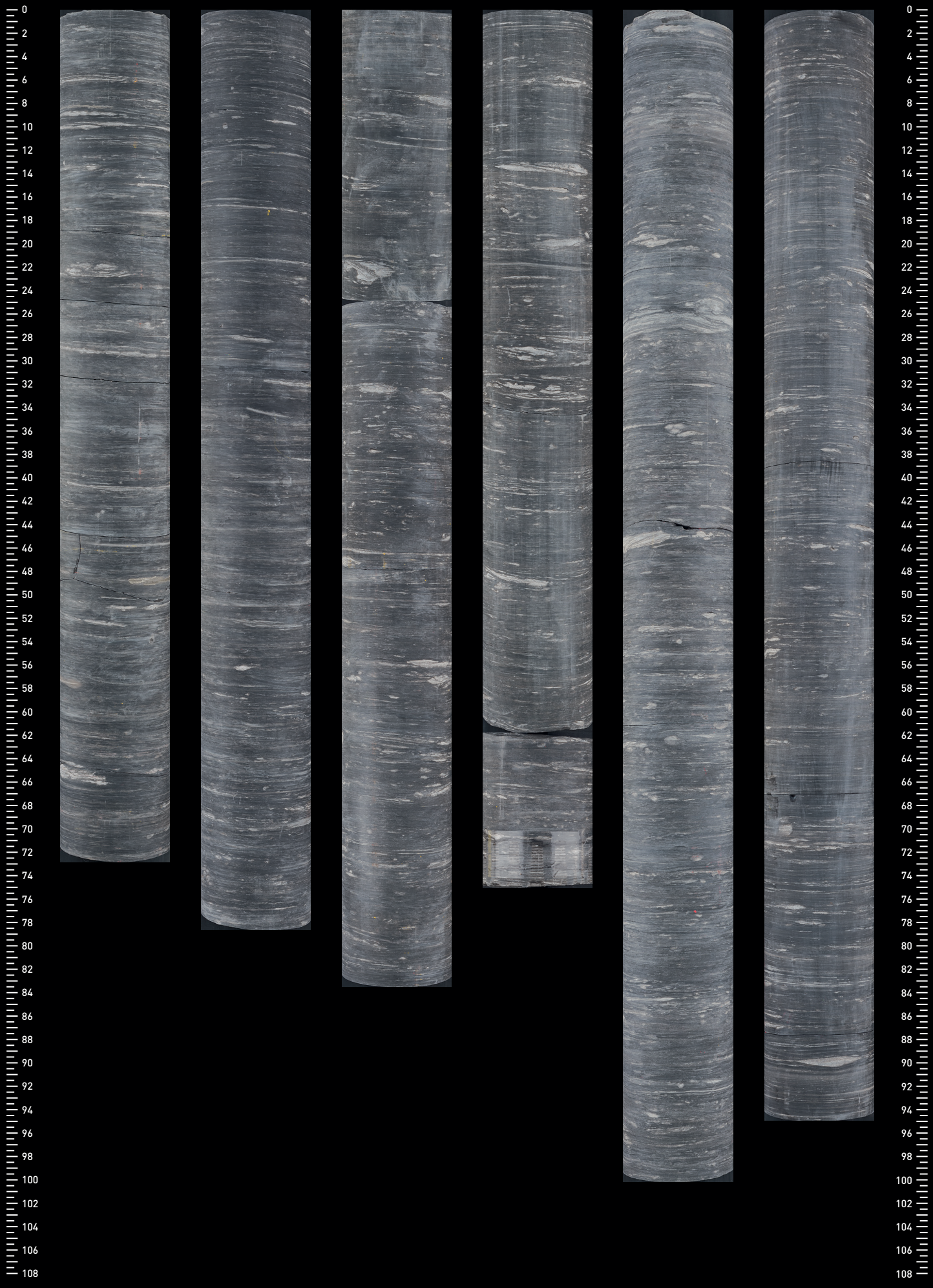
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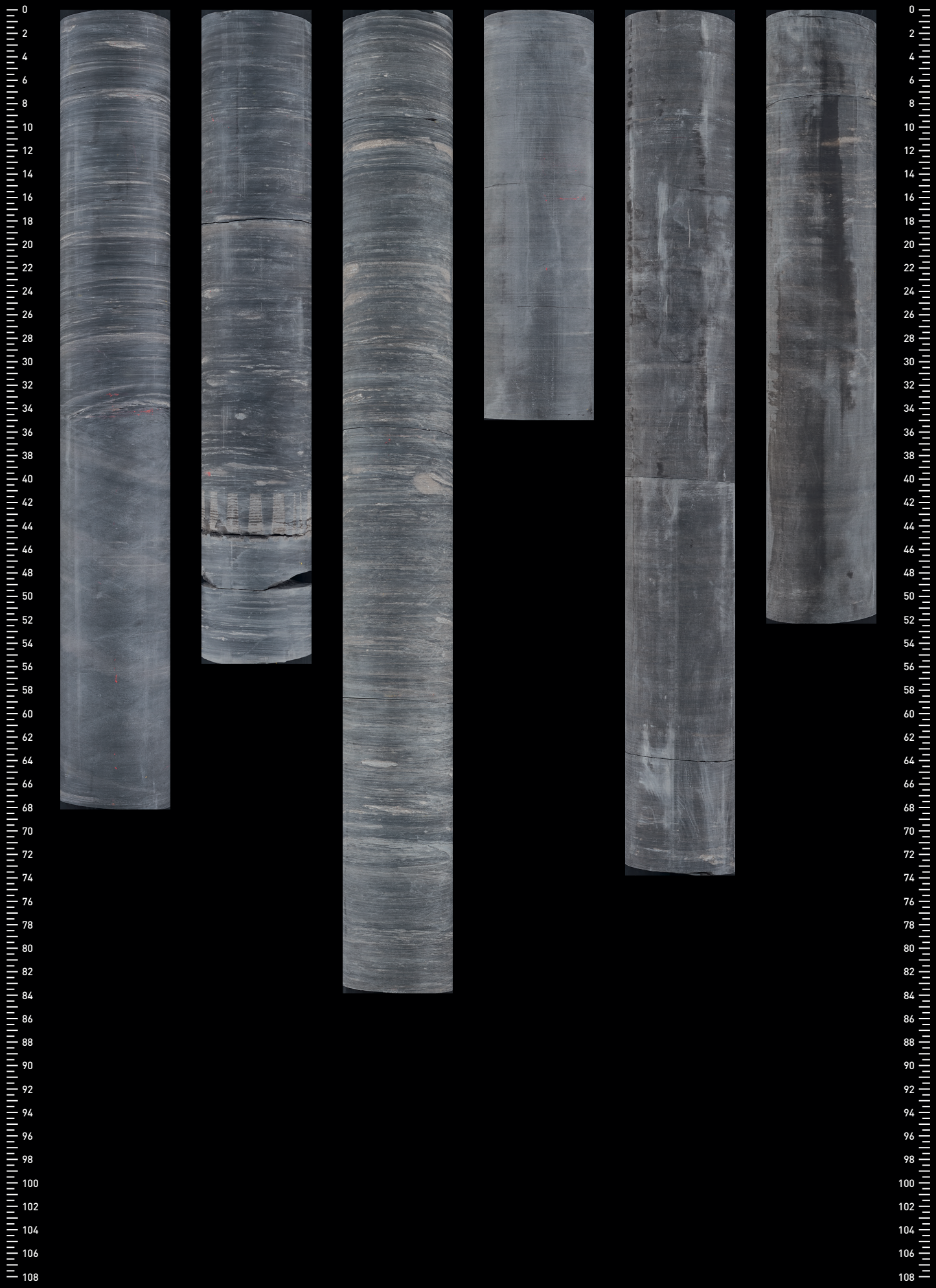
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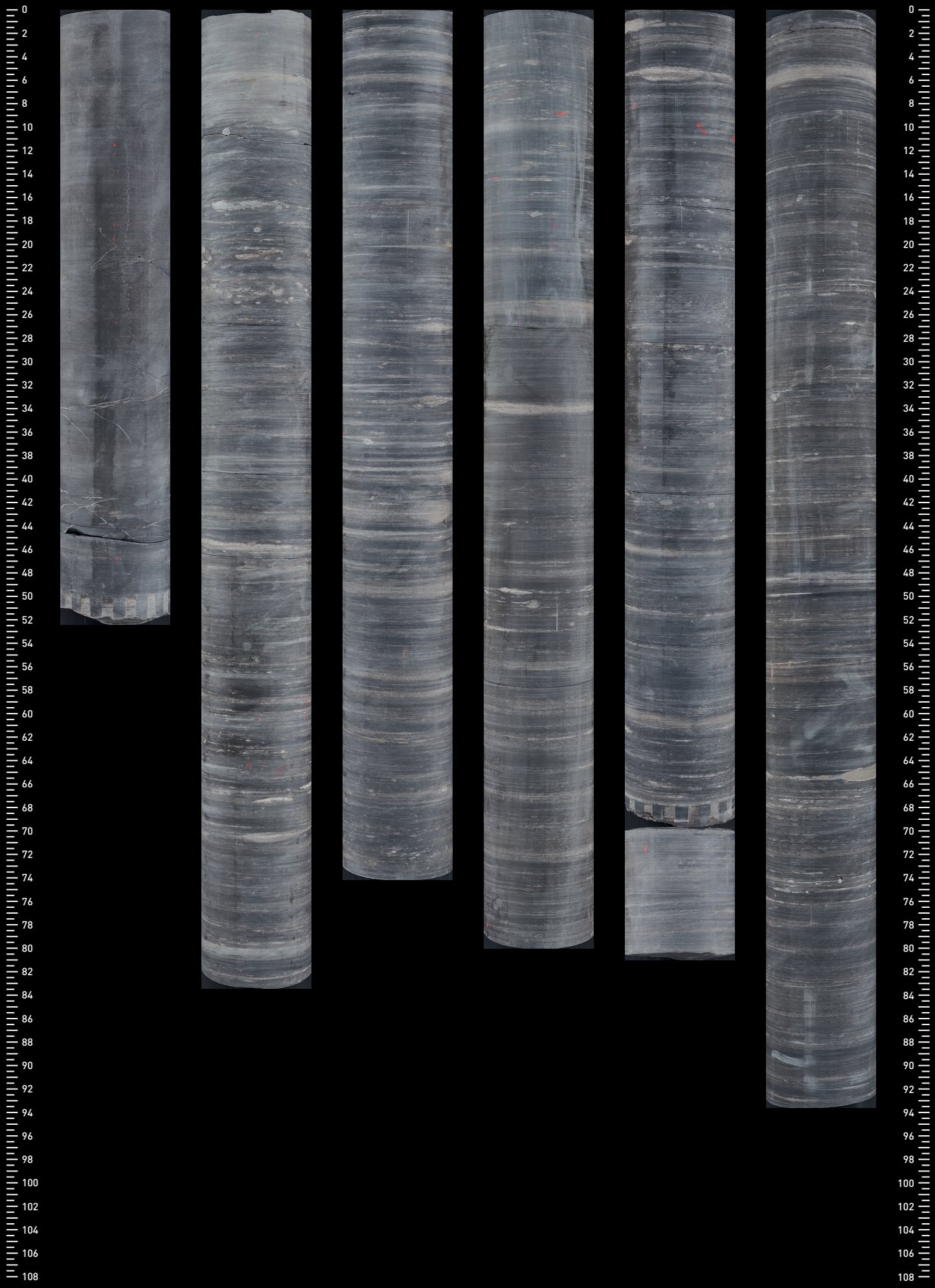
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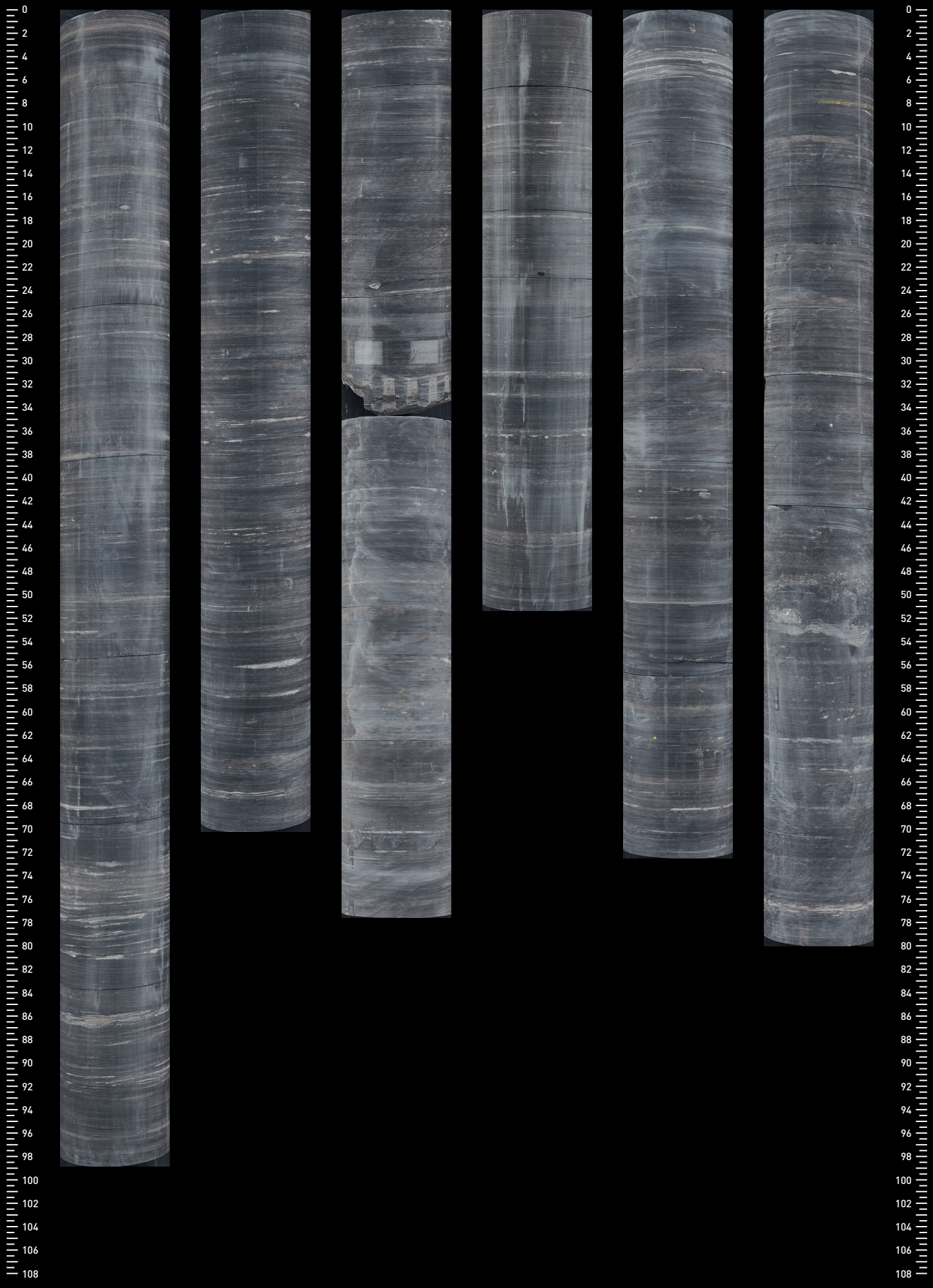
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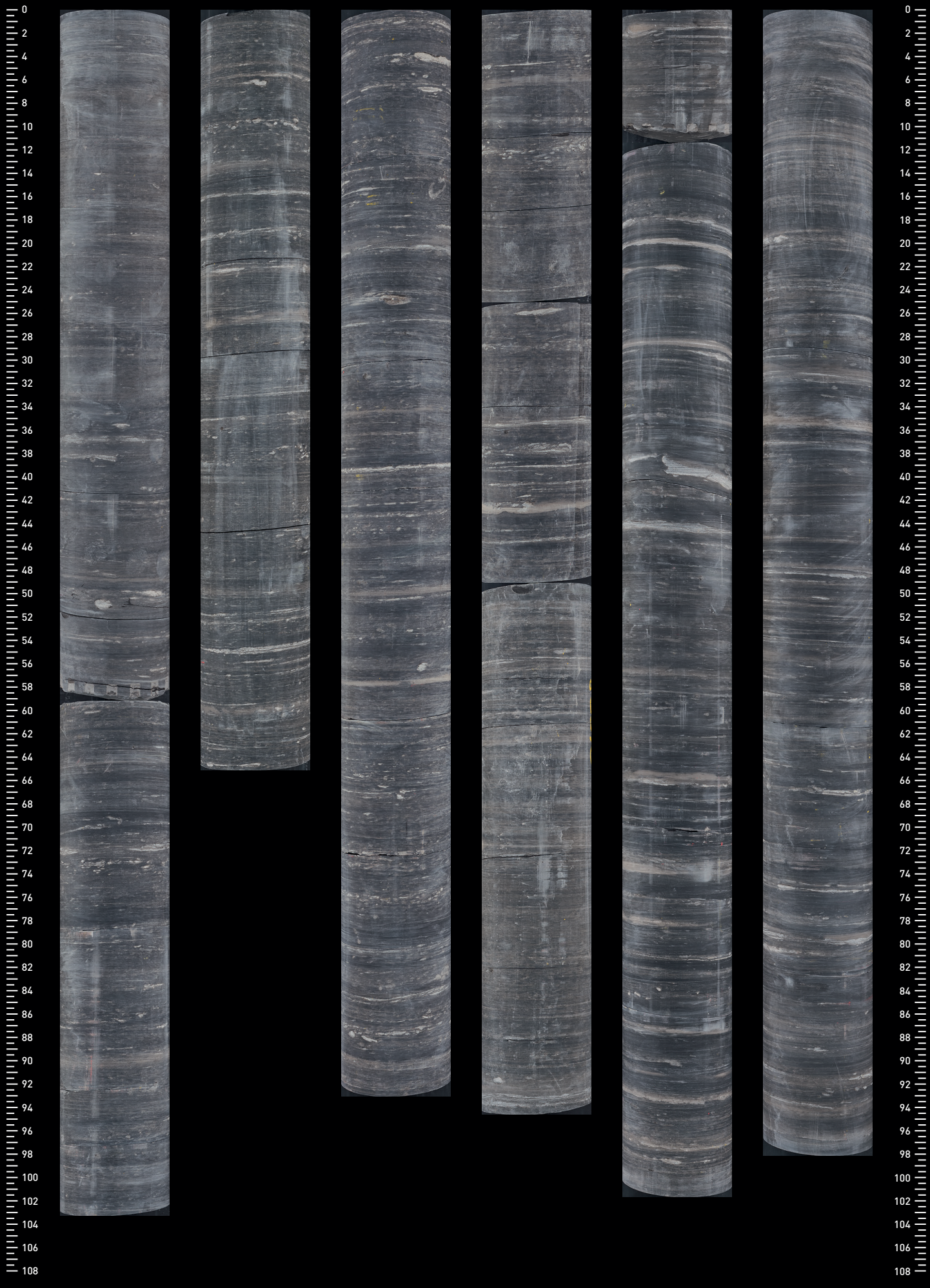


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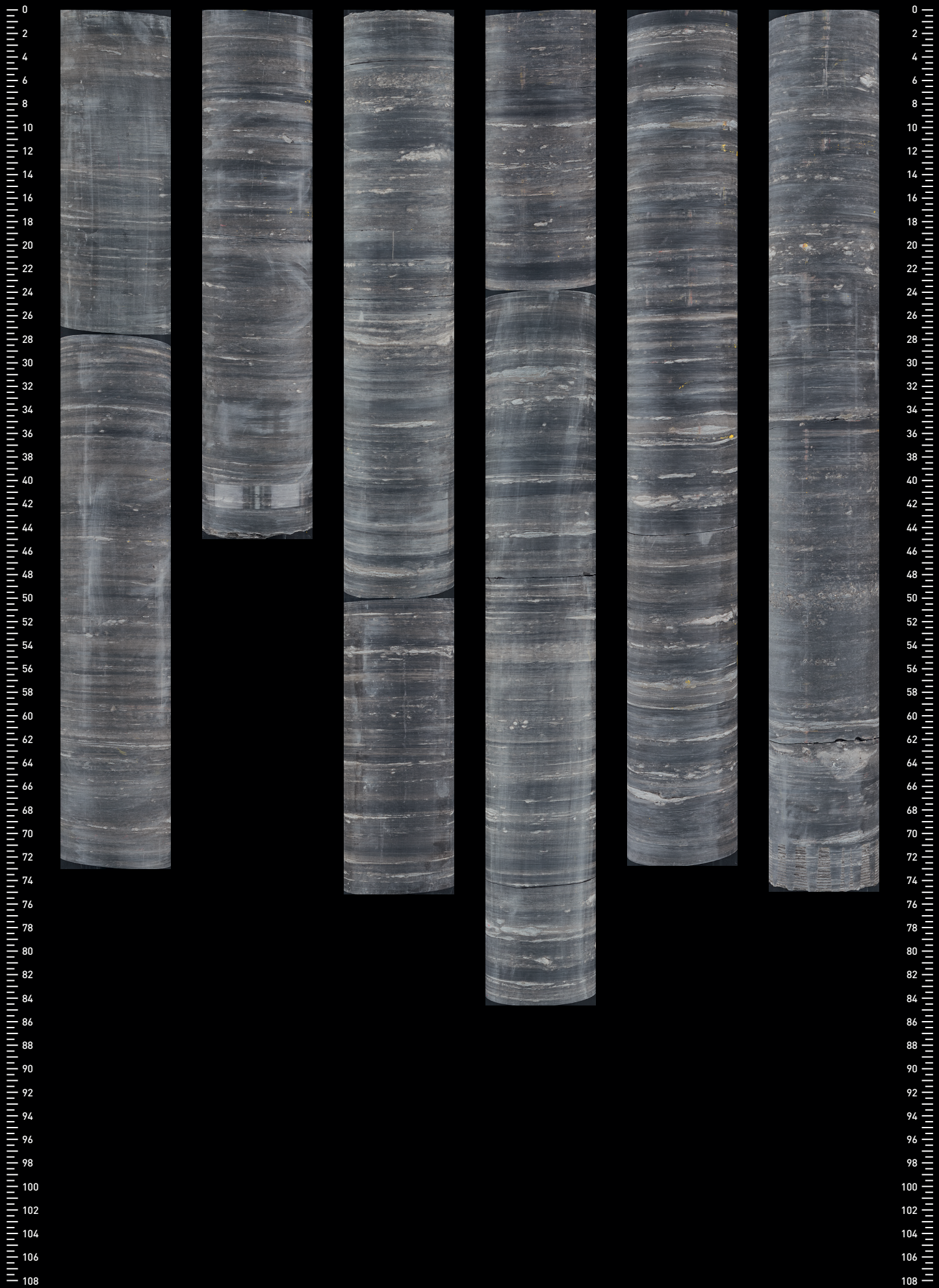
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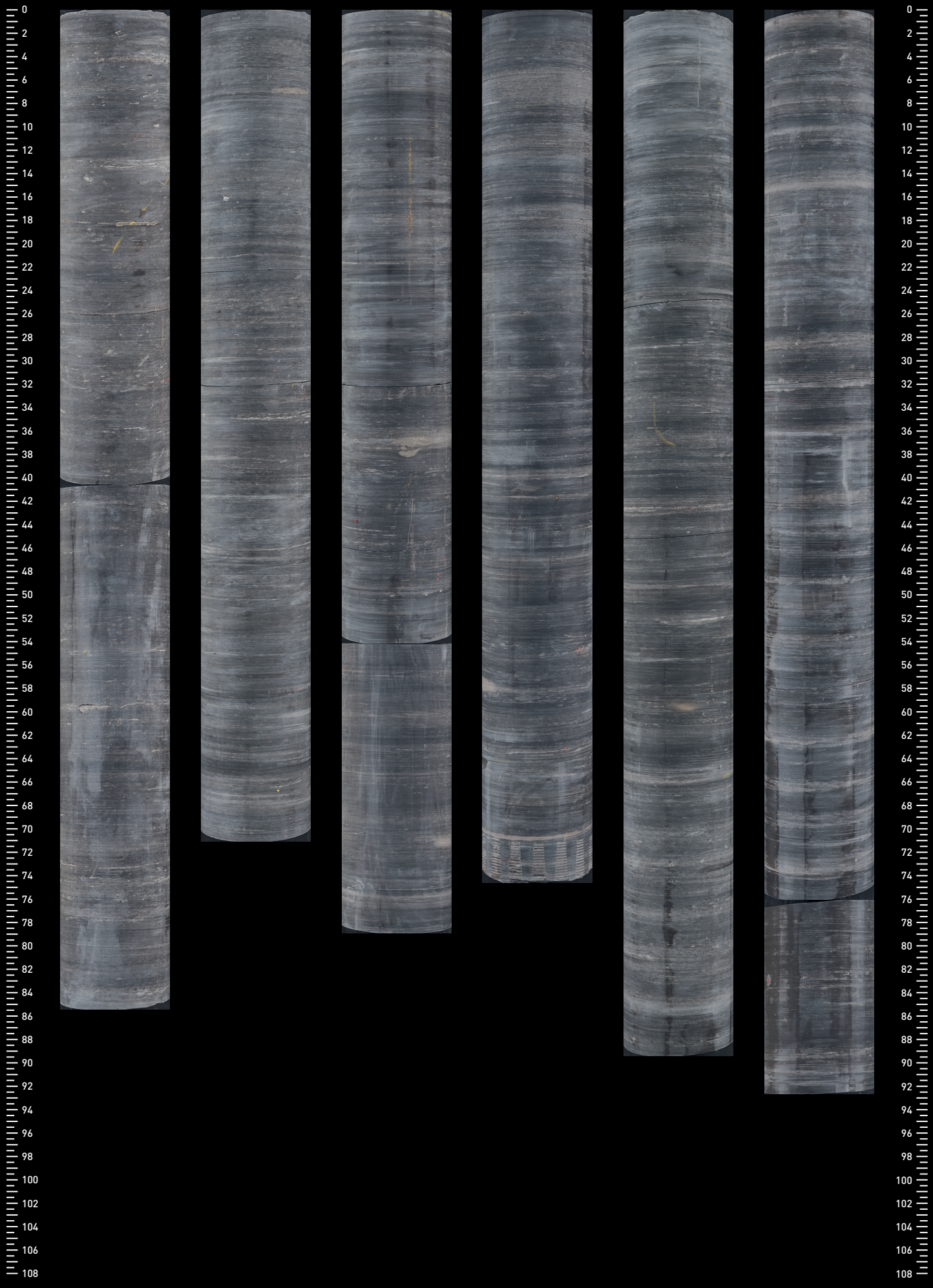

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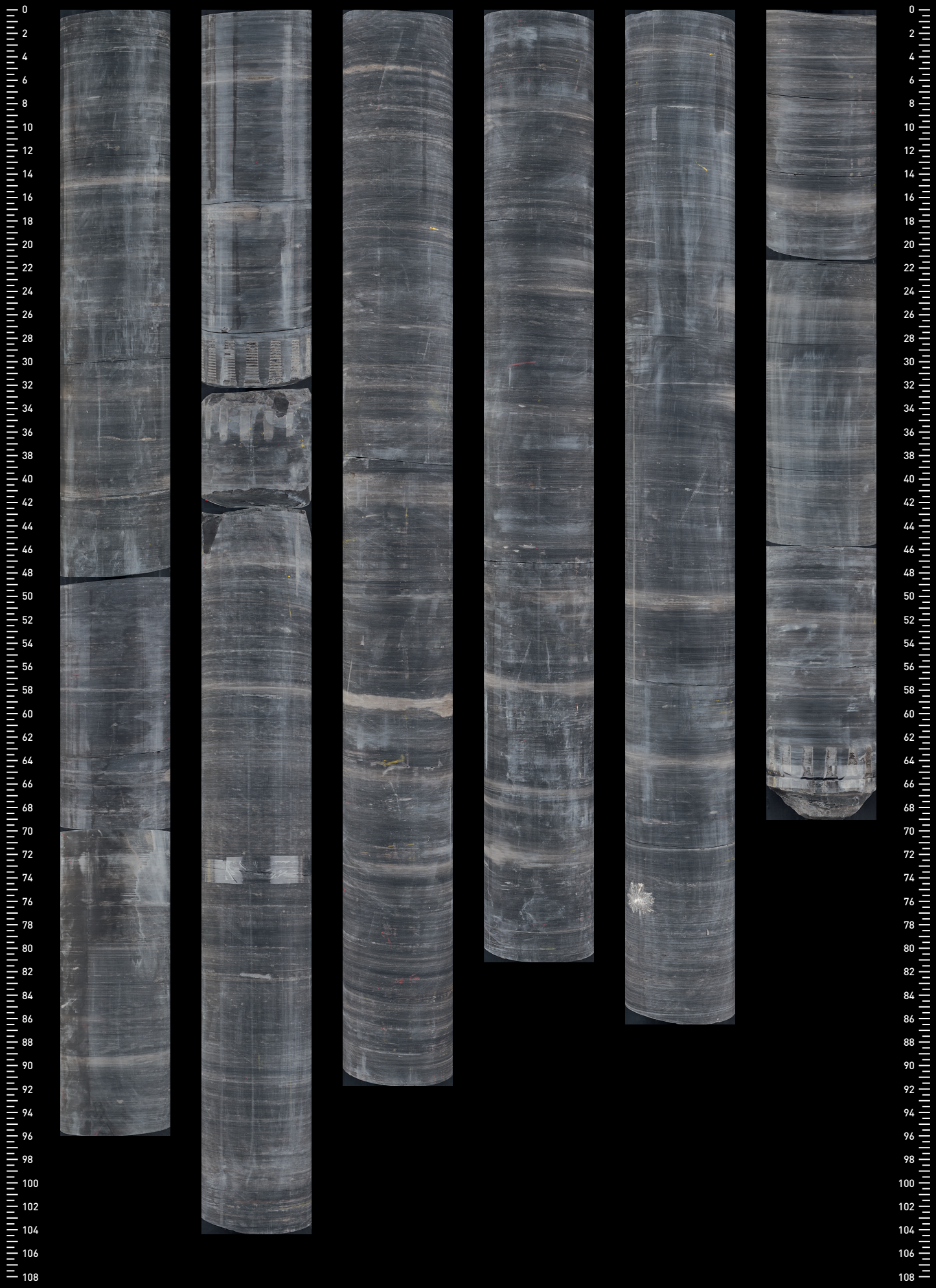
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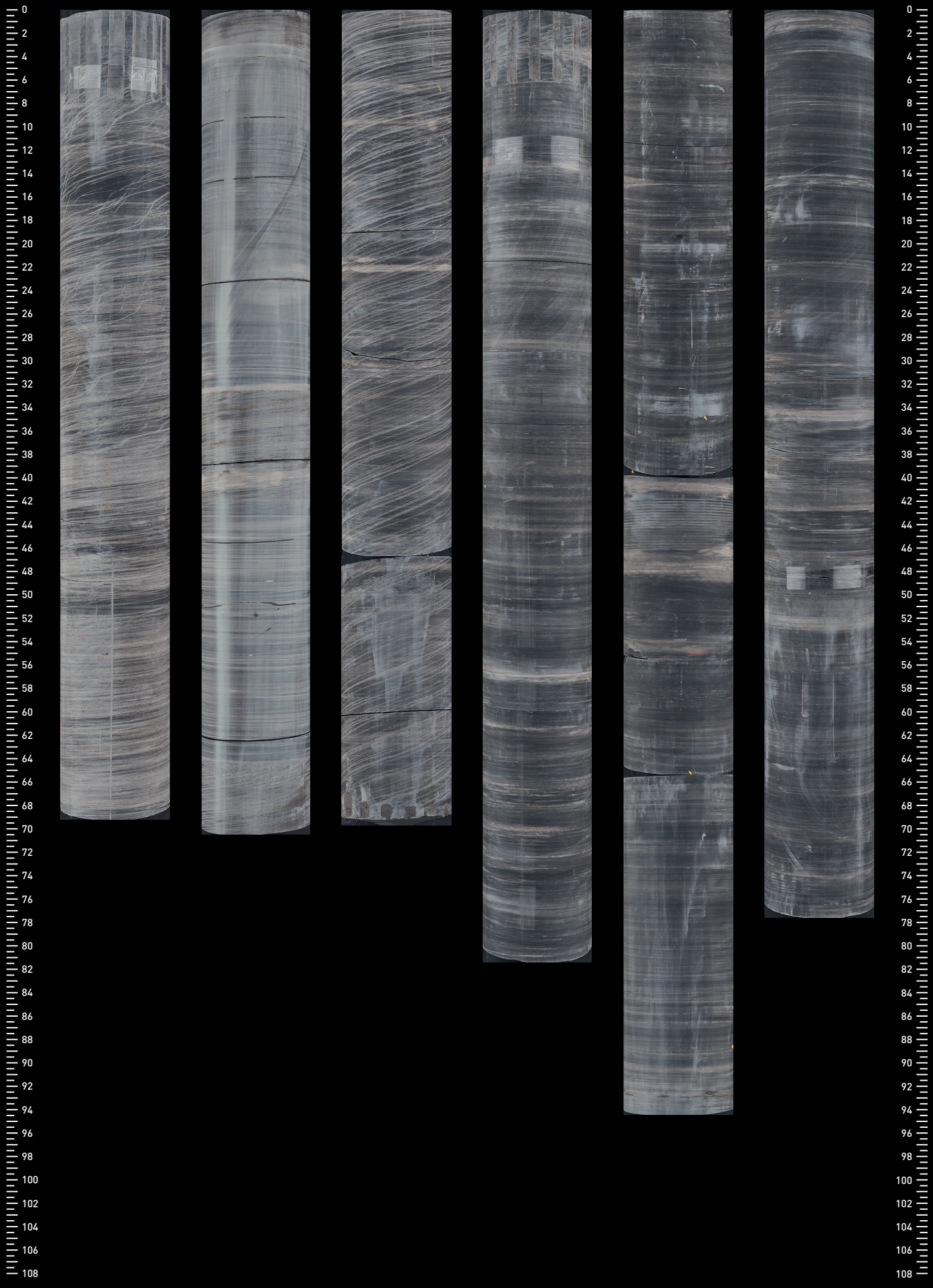
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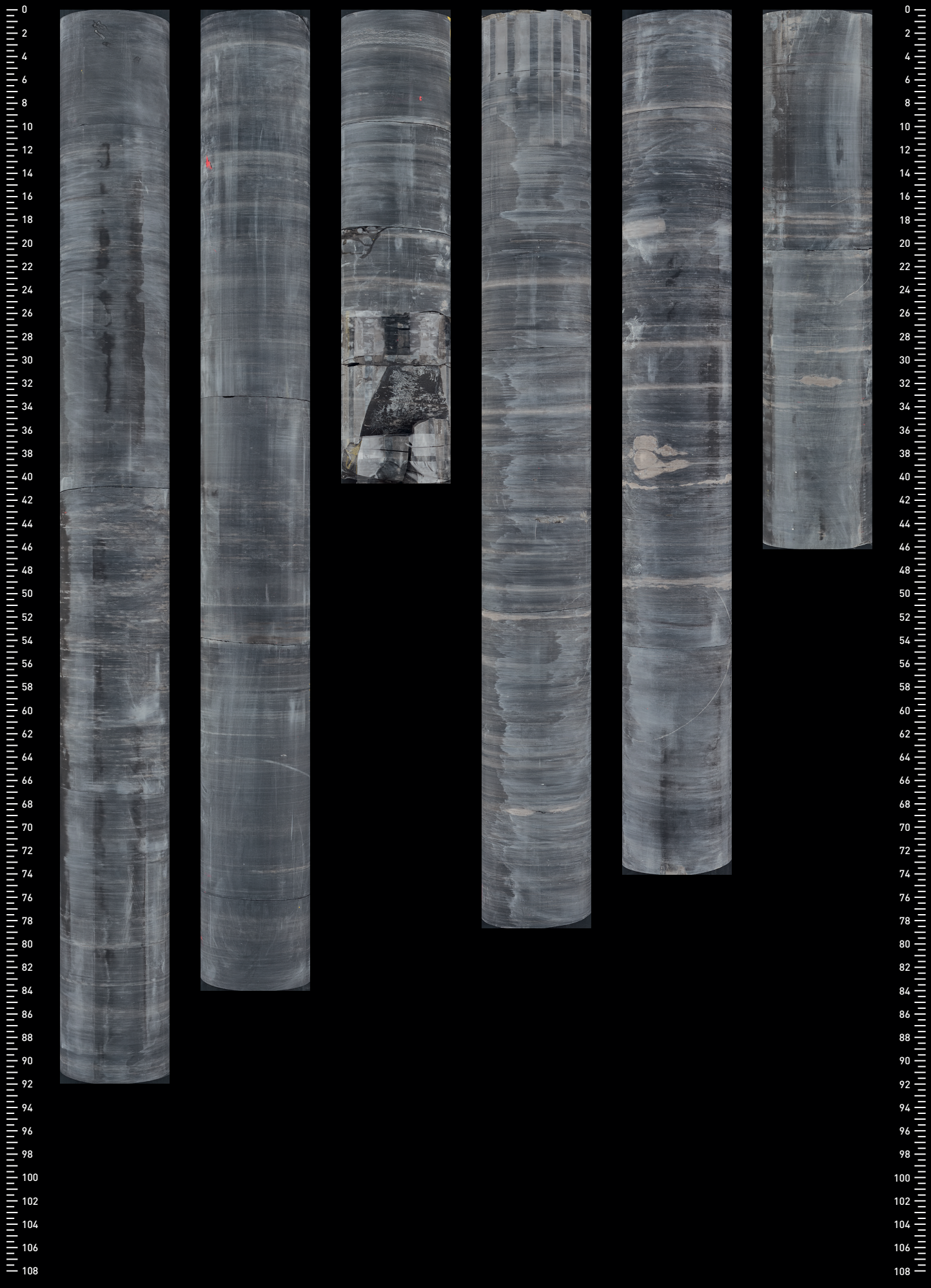
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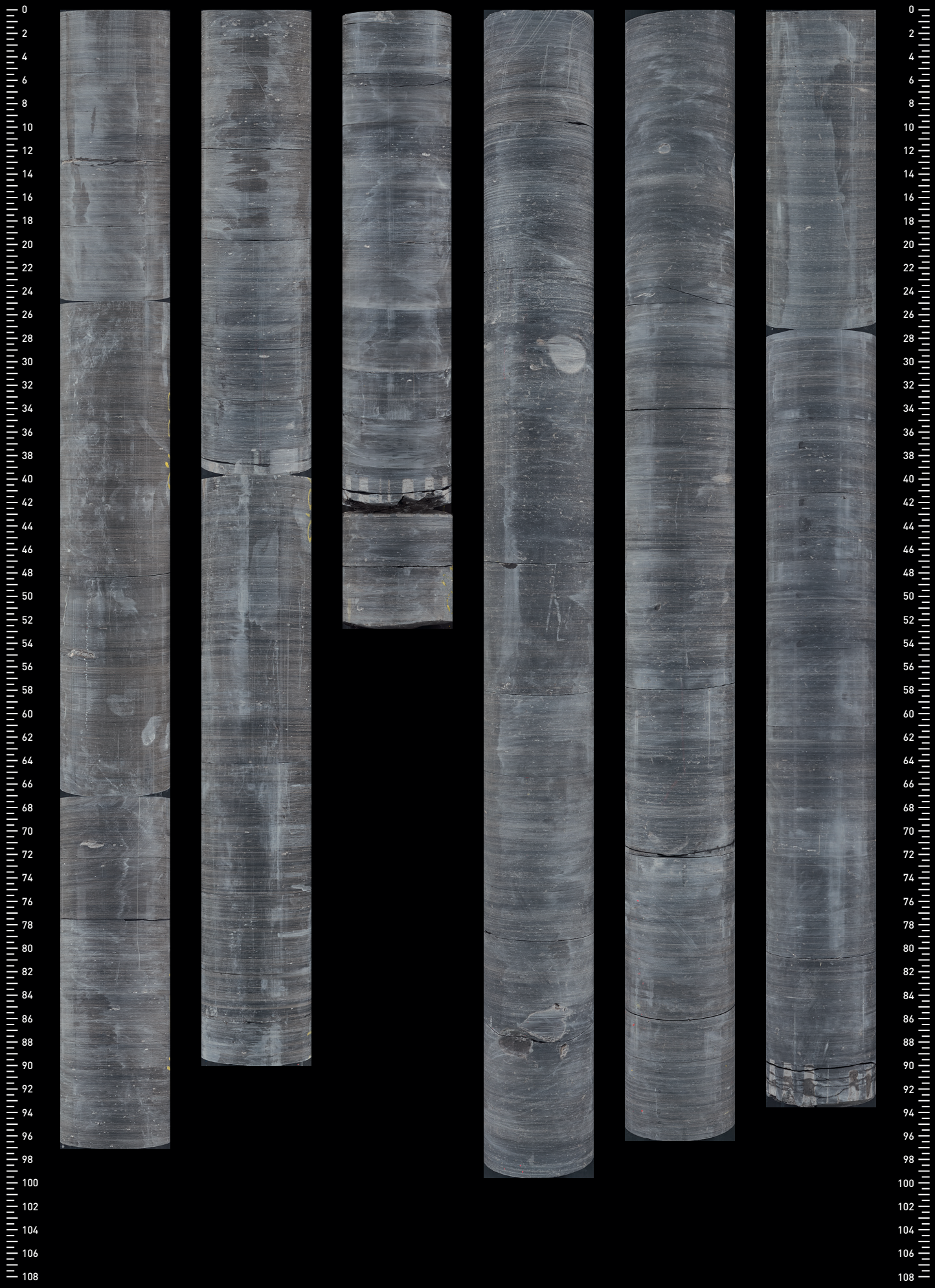
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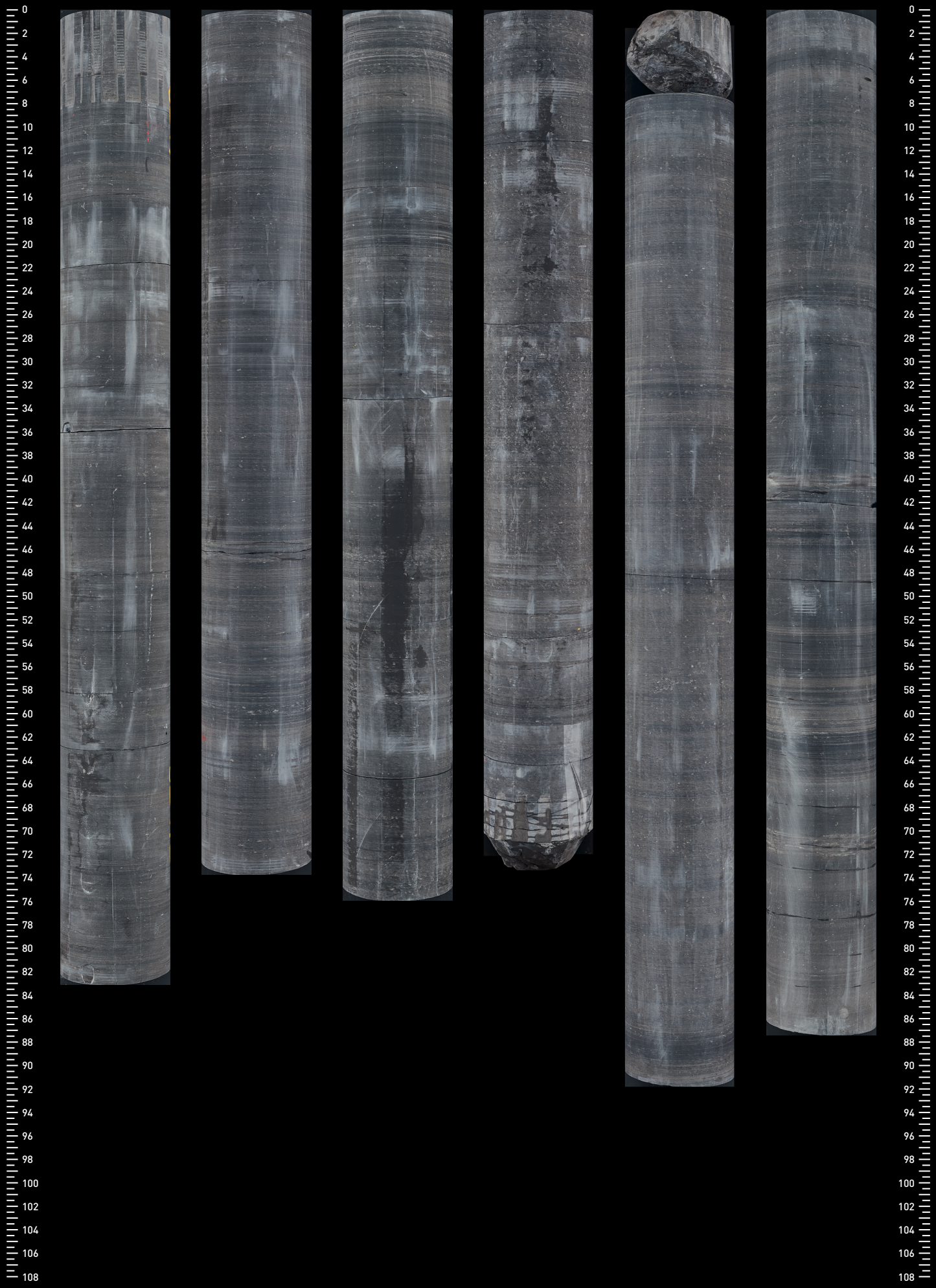
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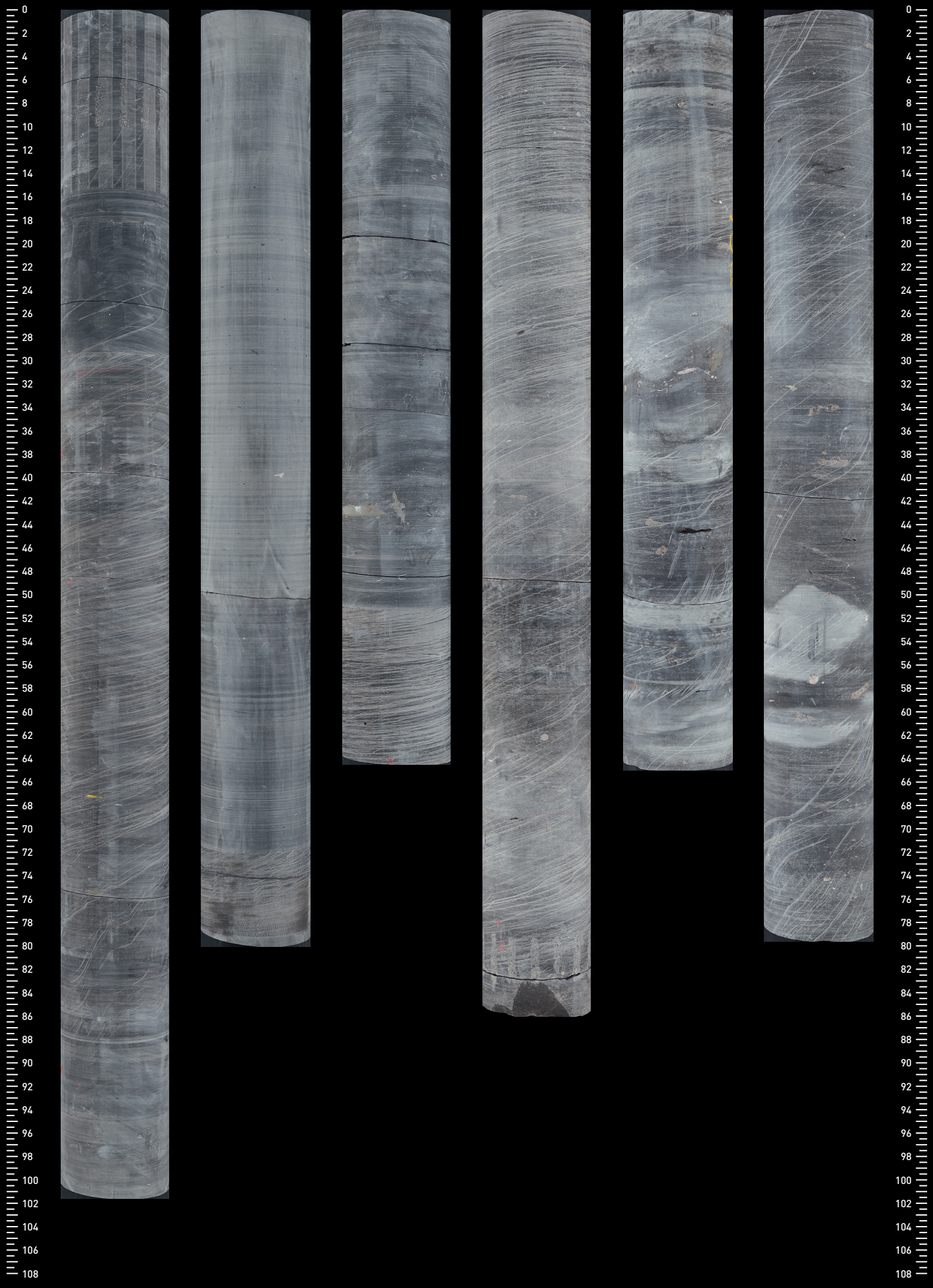
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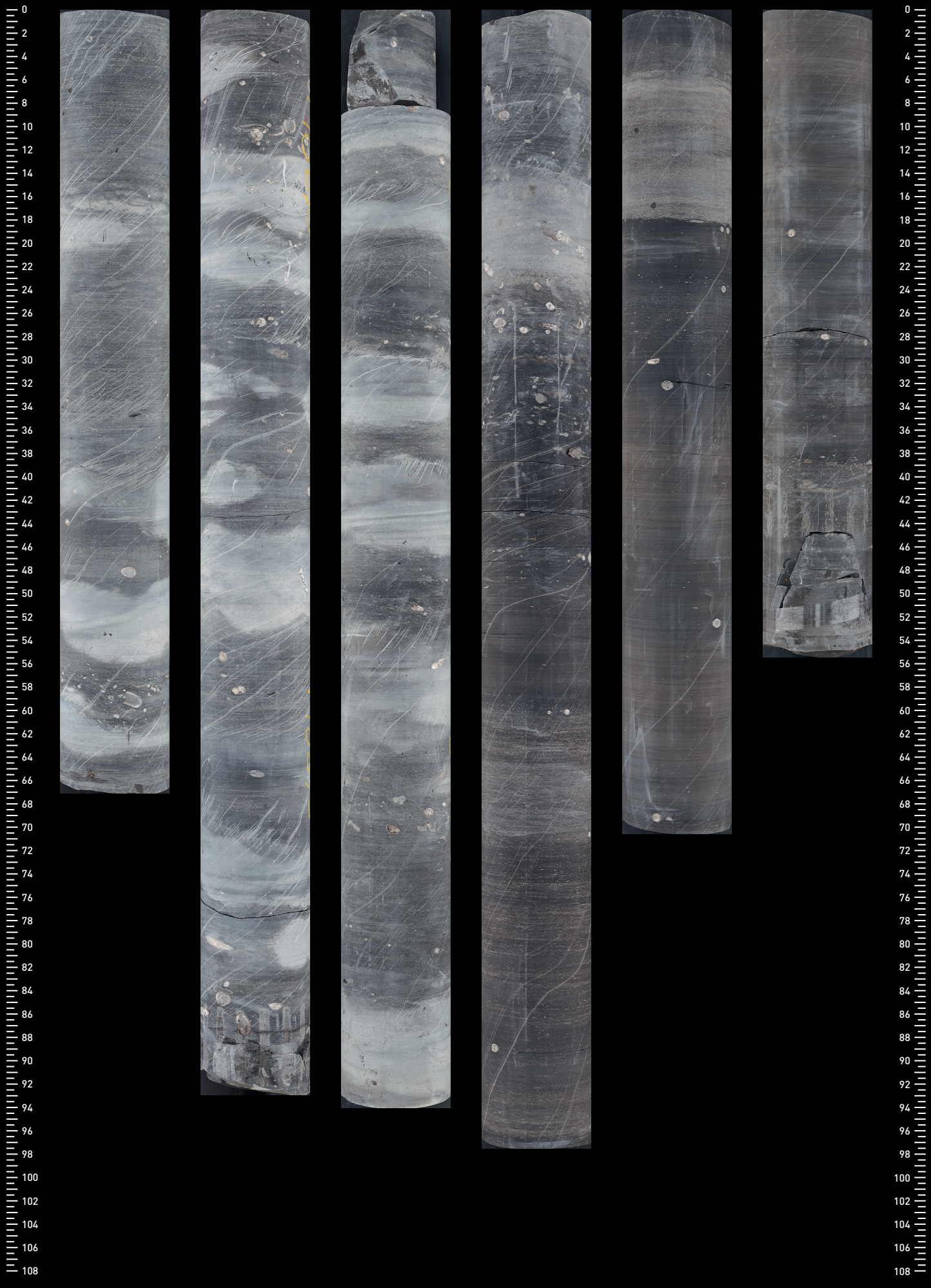
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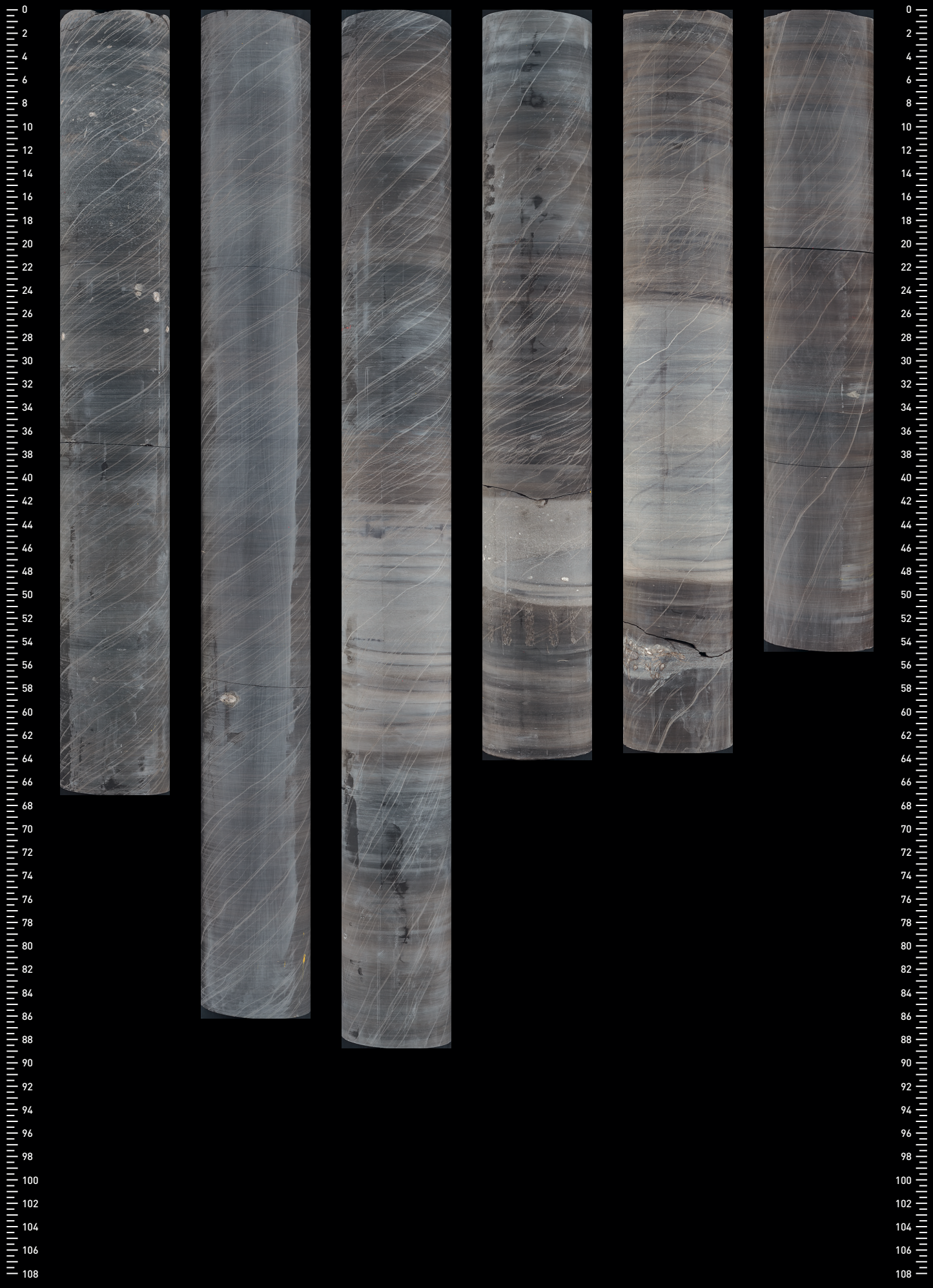
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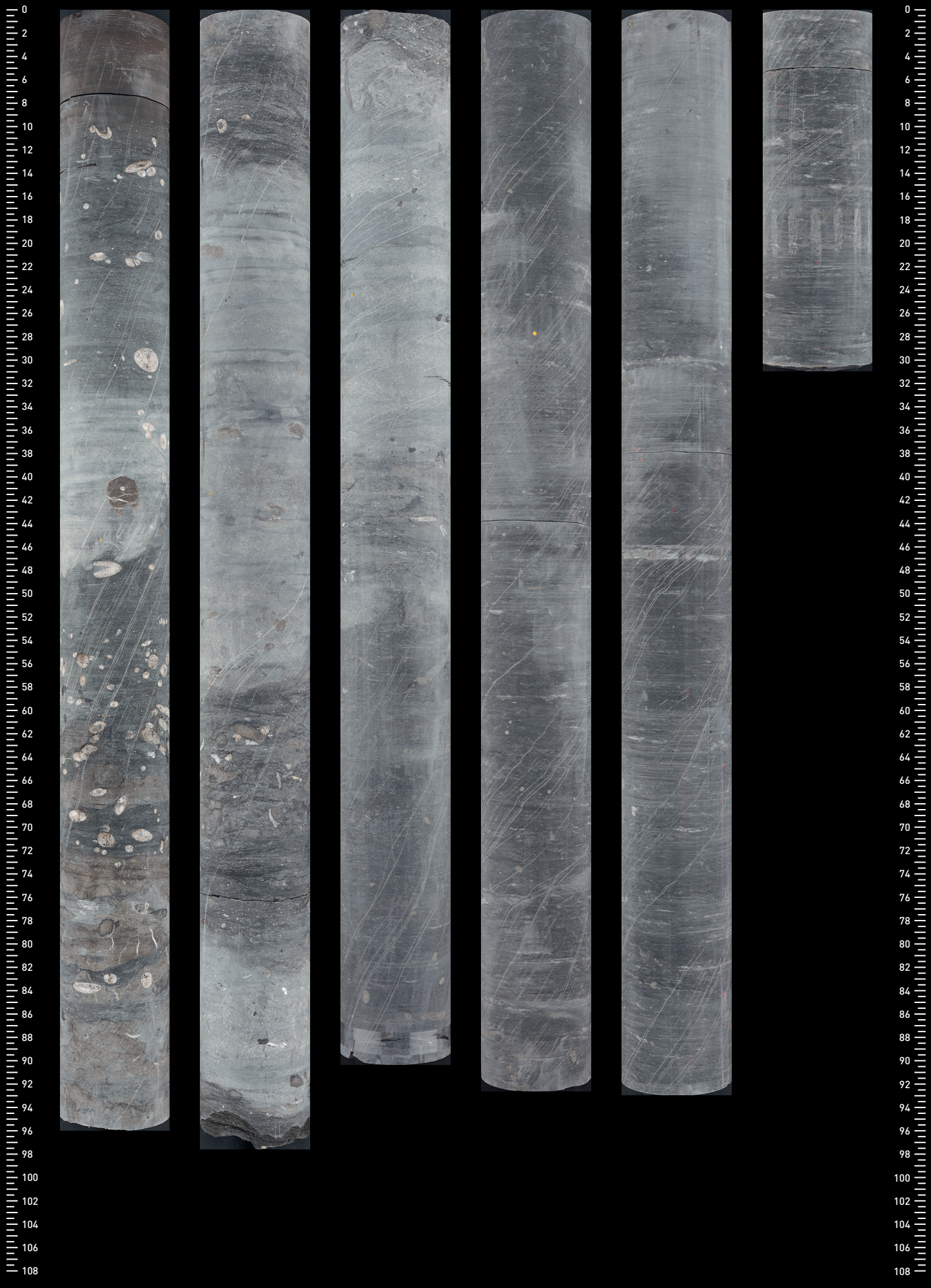
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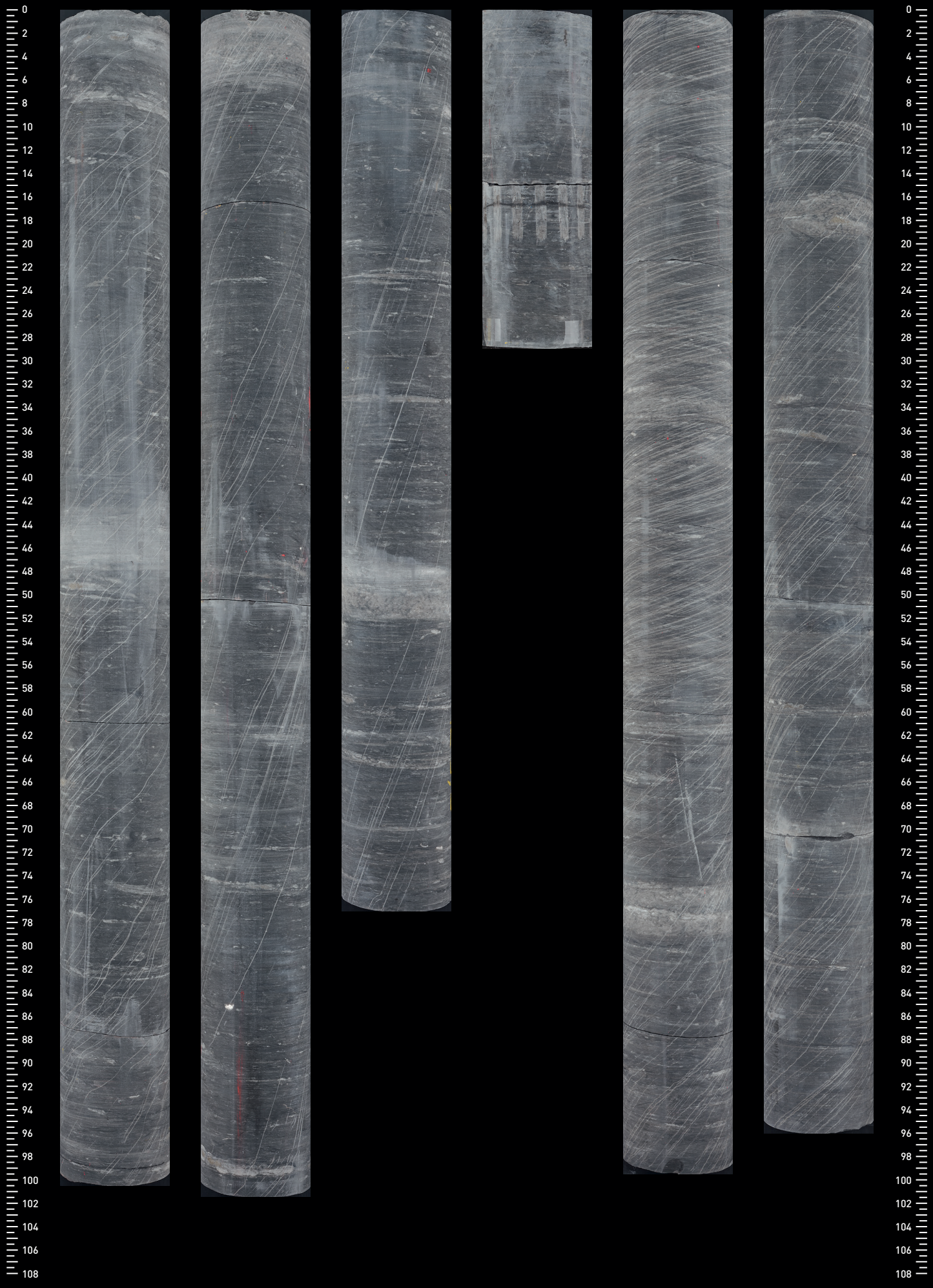
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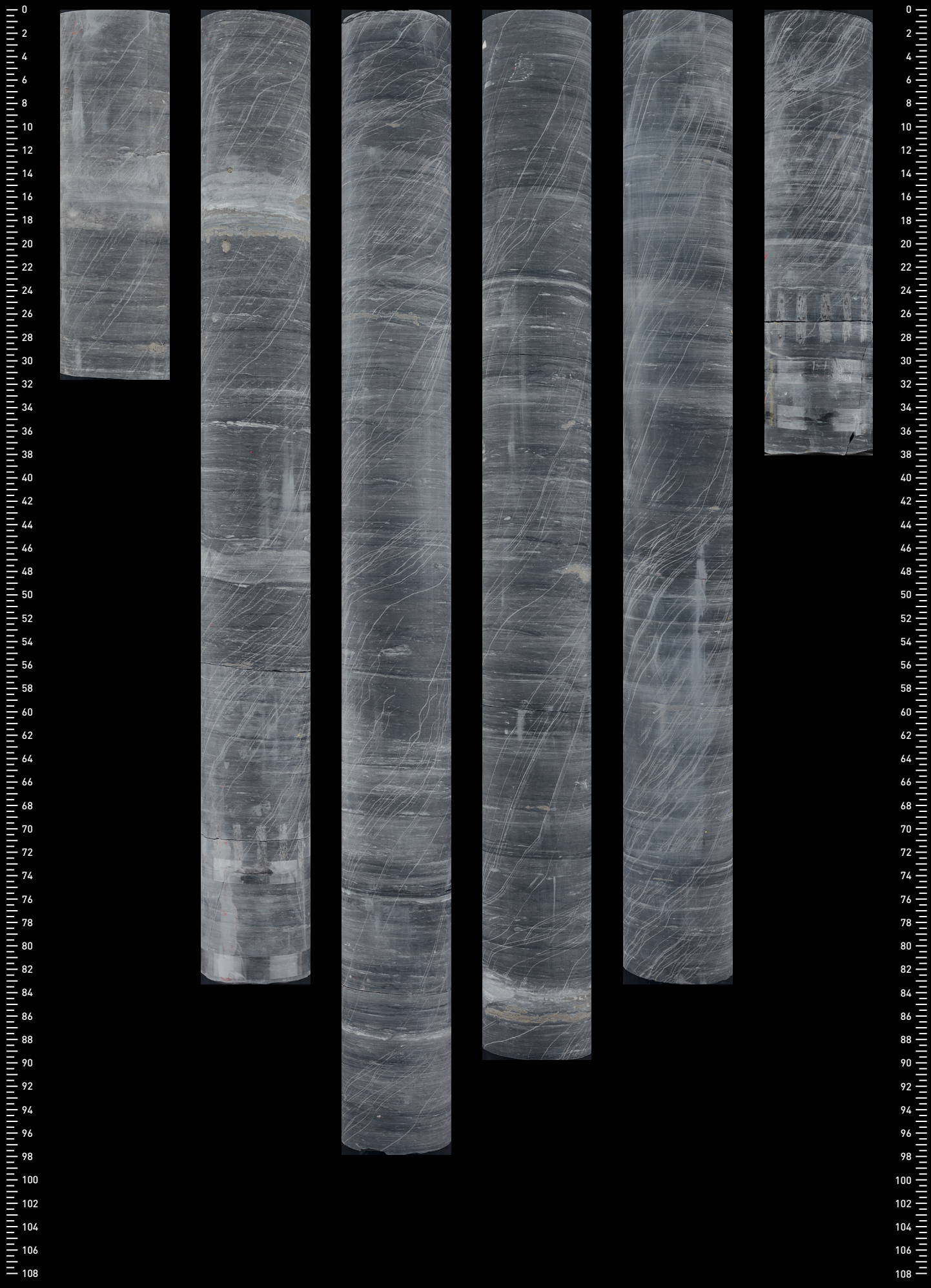
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921.93m 922.92m 923.67m 923.95m 924.92m 925.86m

925.86m 926.17m 926.98m 927.93m 928.81m 929.62m



926.17m 926.98m 927.93m 928.81m 929.62m 929.99m

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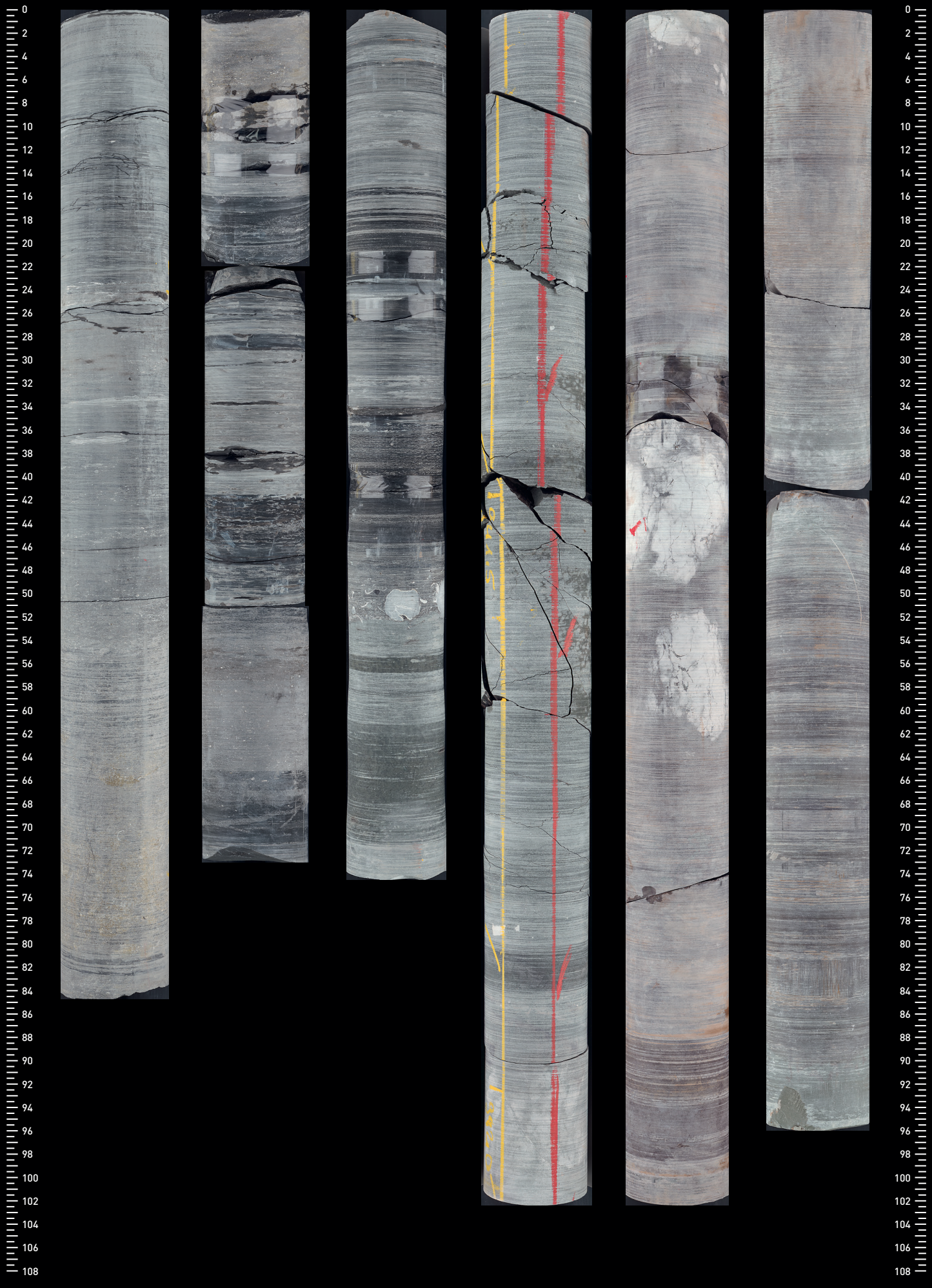
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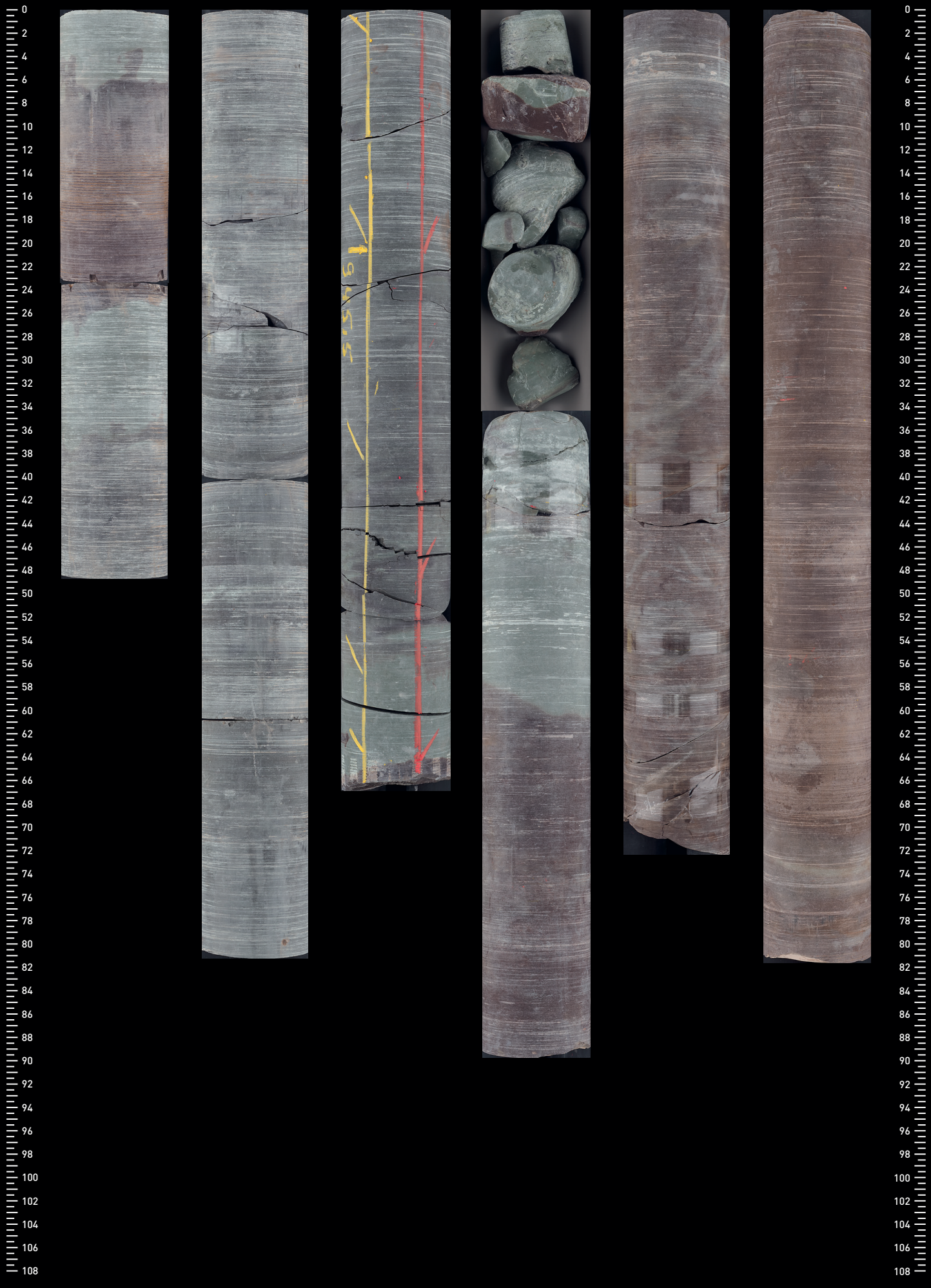


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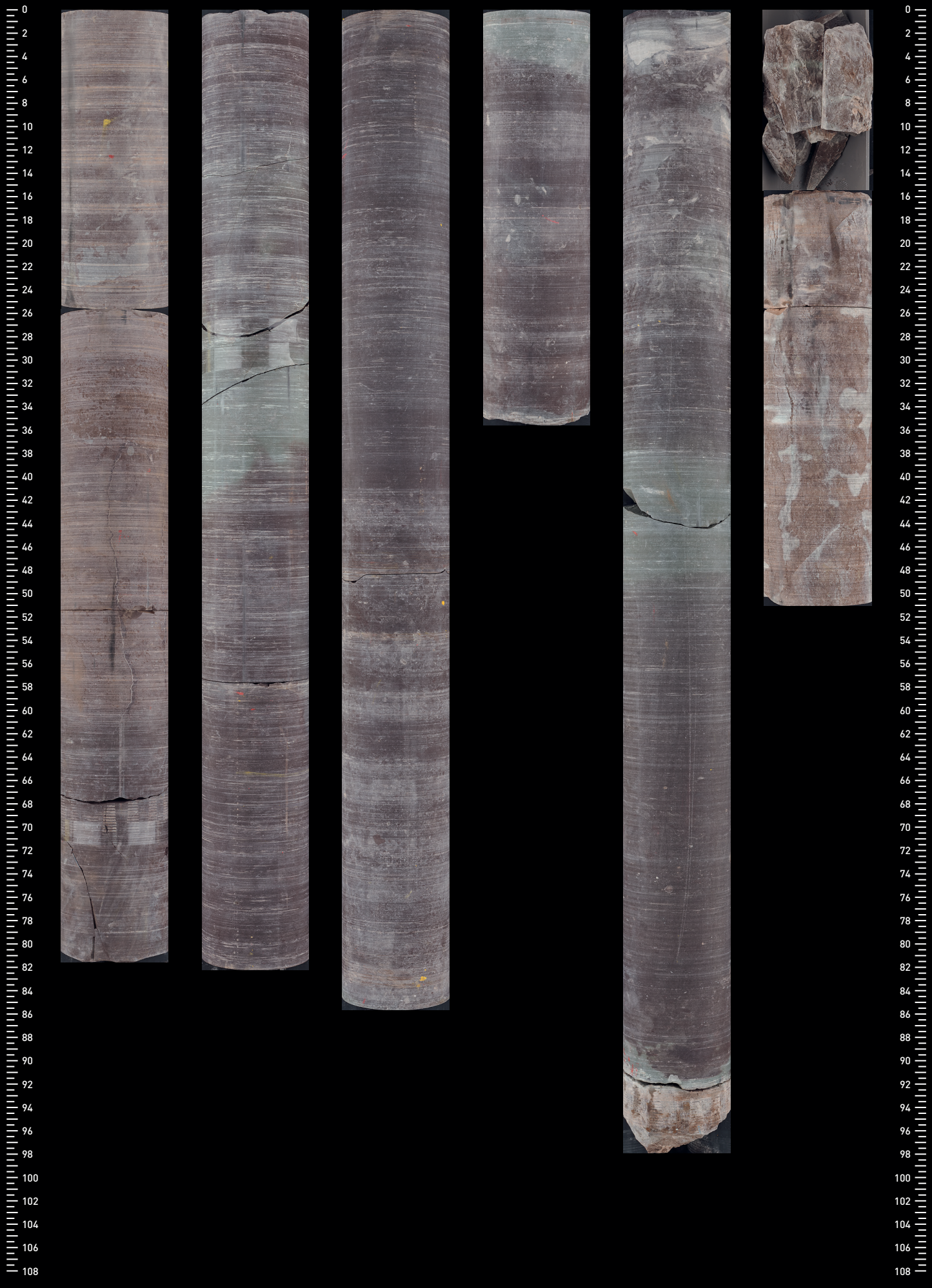
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948.20m

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949.00m 949.79m 950.63m 950.98m 951.95m 952.35m

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953.32m 954.30m 955.00m 955.75m 956.70m 957.40m

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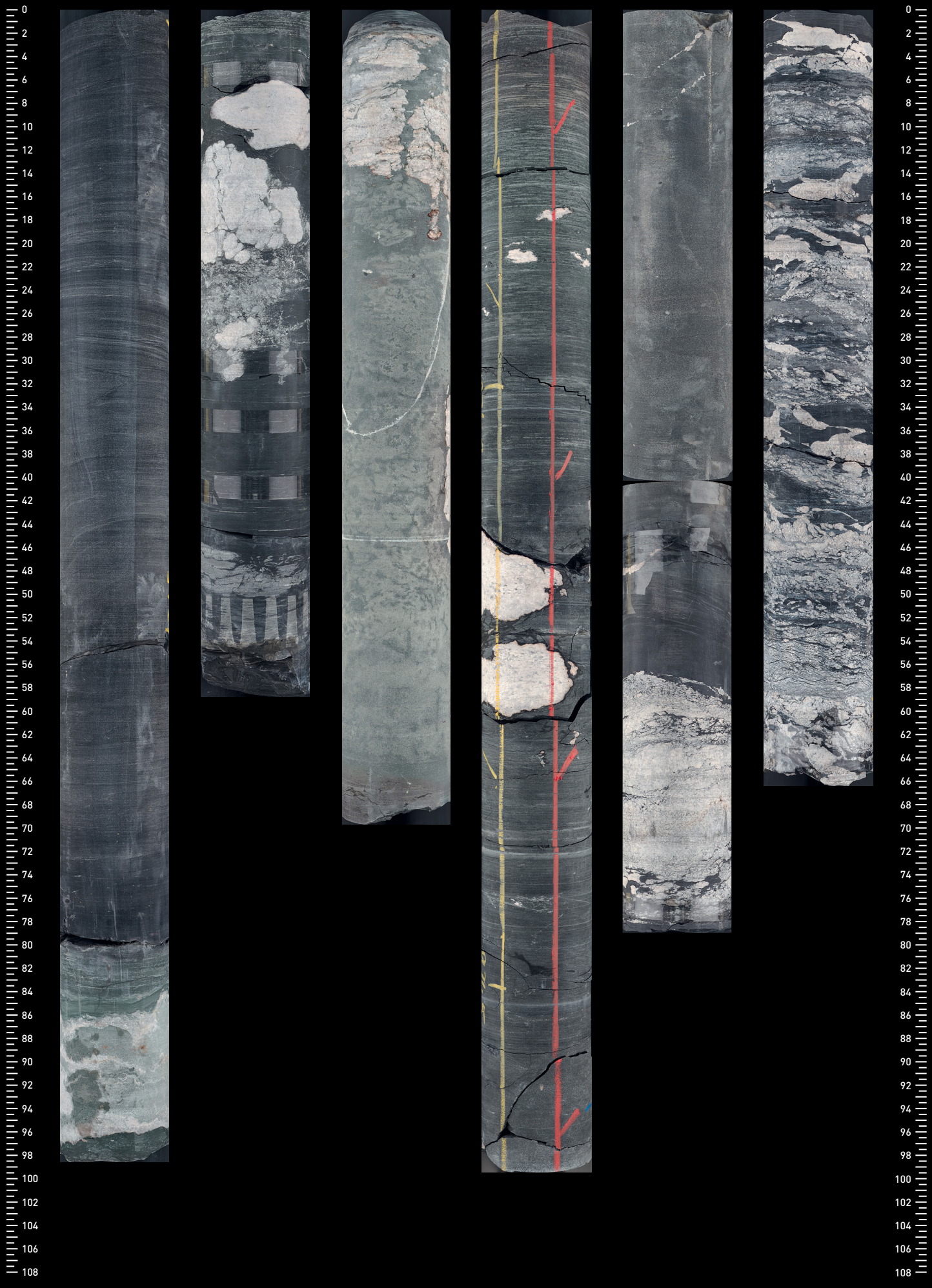
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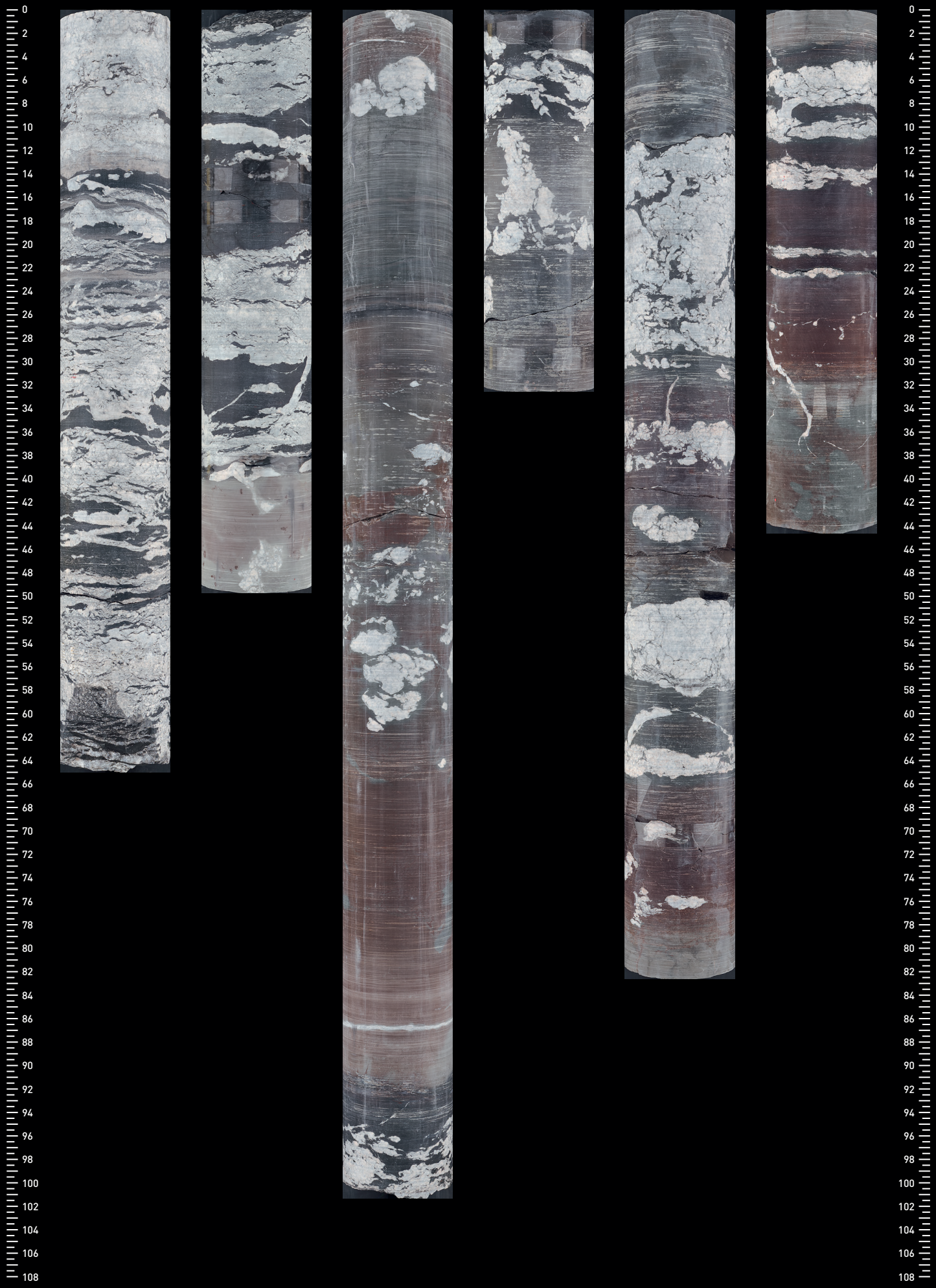
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981.24m 982.03m 982.84m 983.14m 983.99m 984.40m

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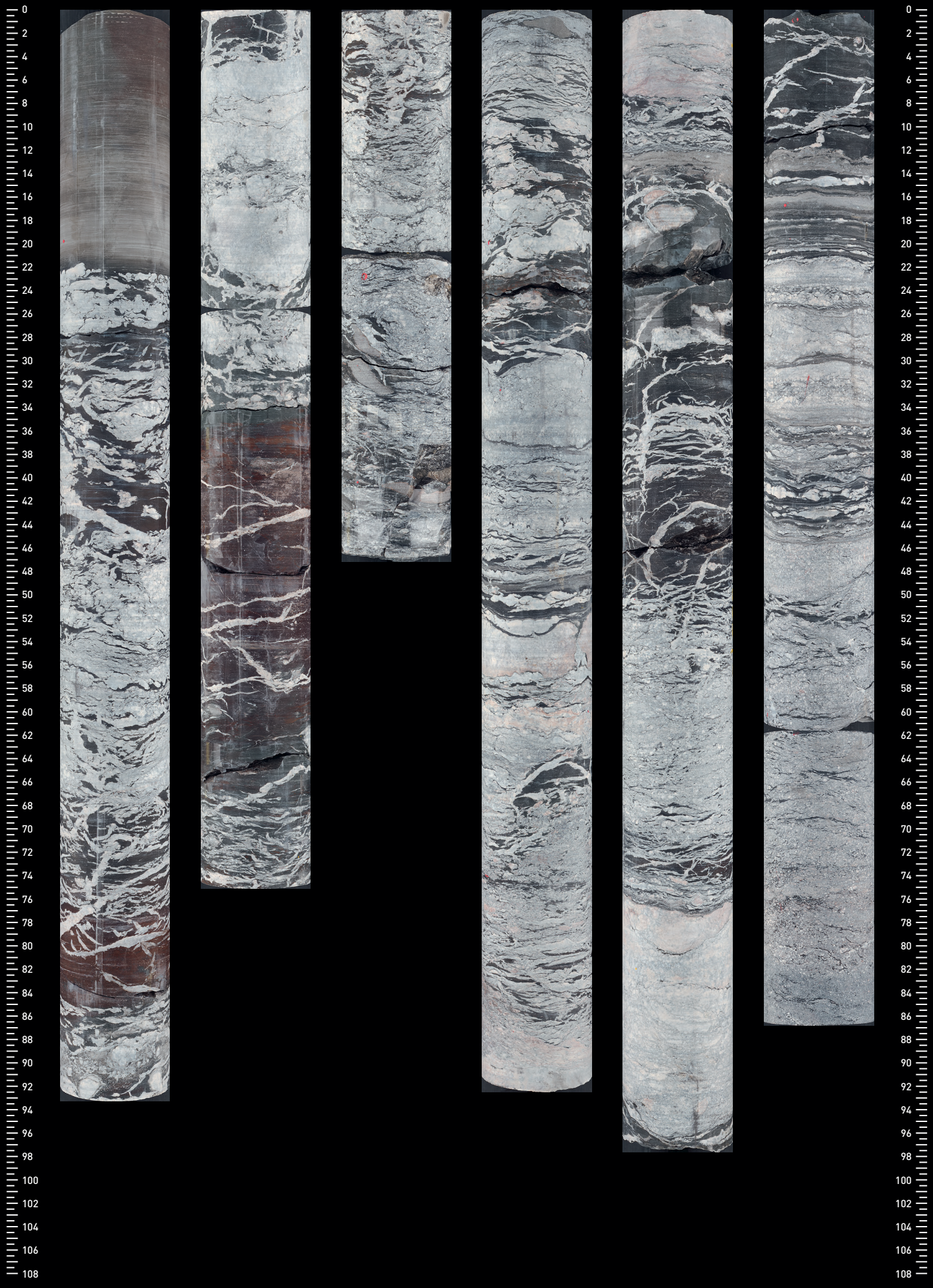
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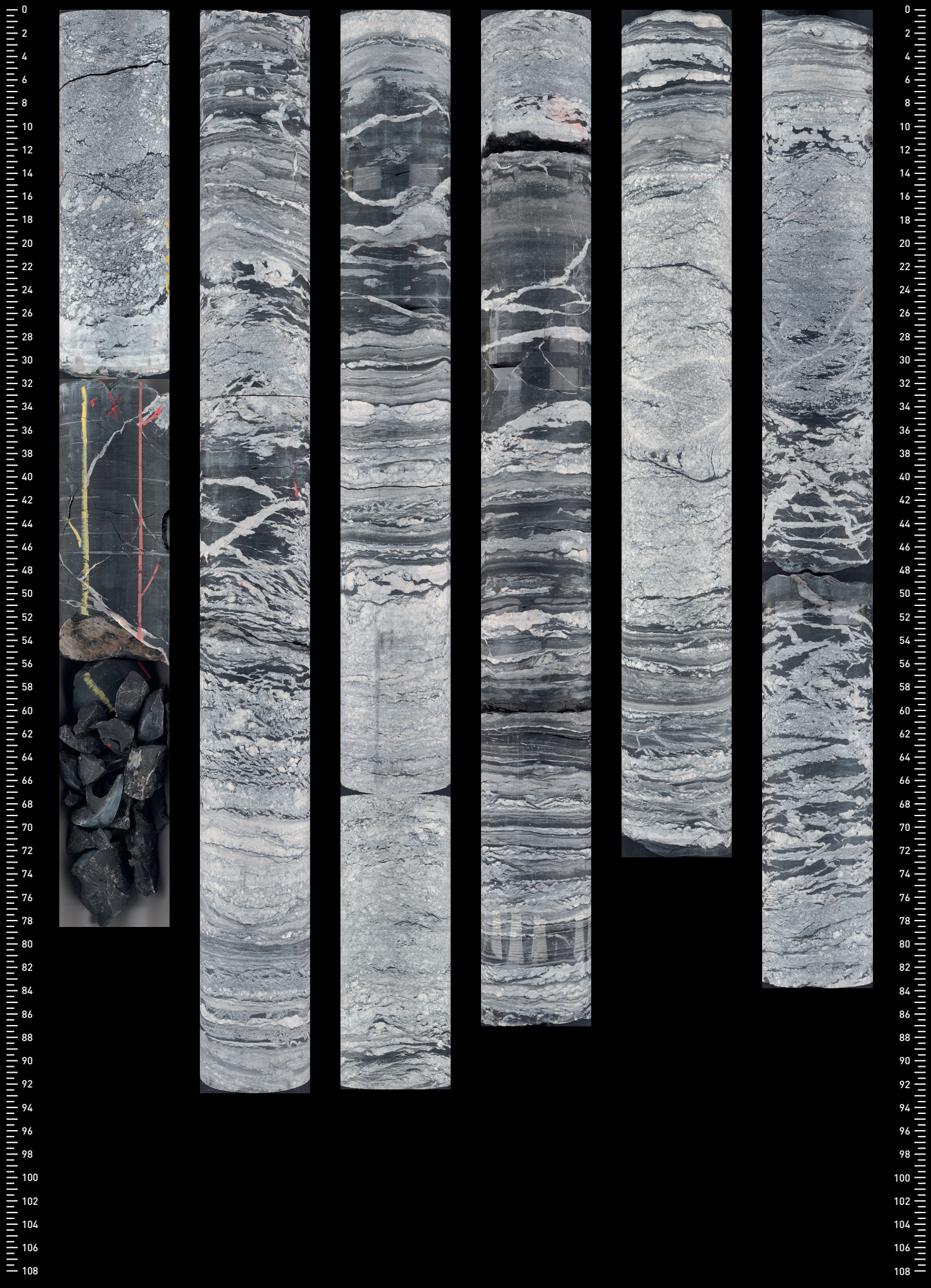


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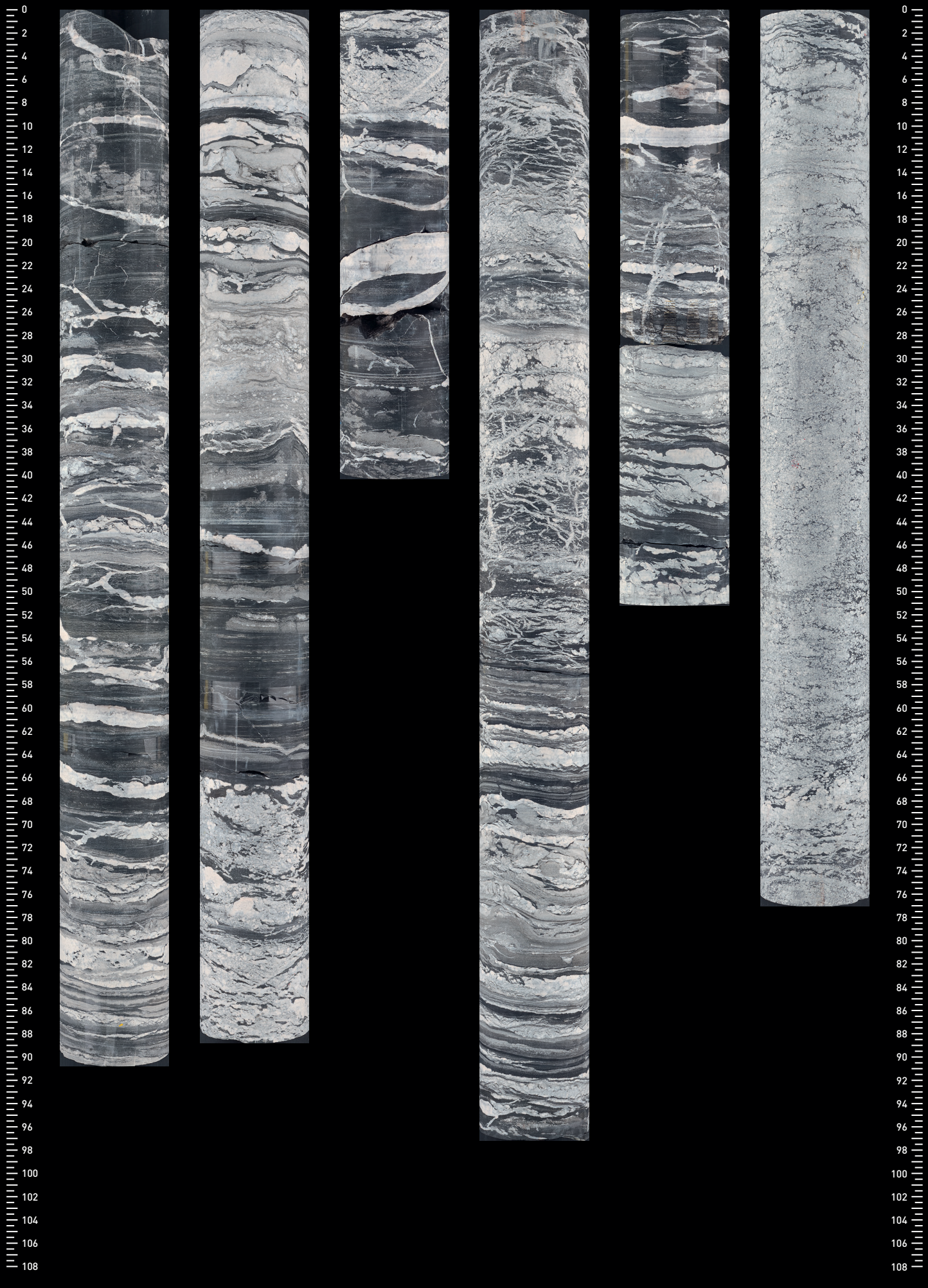
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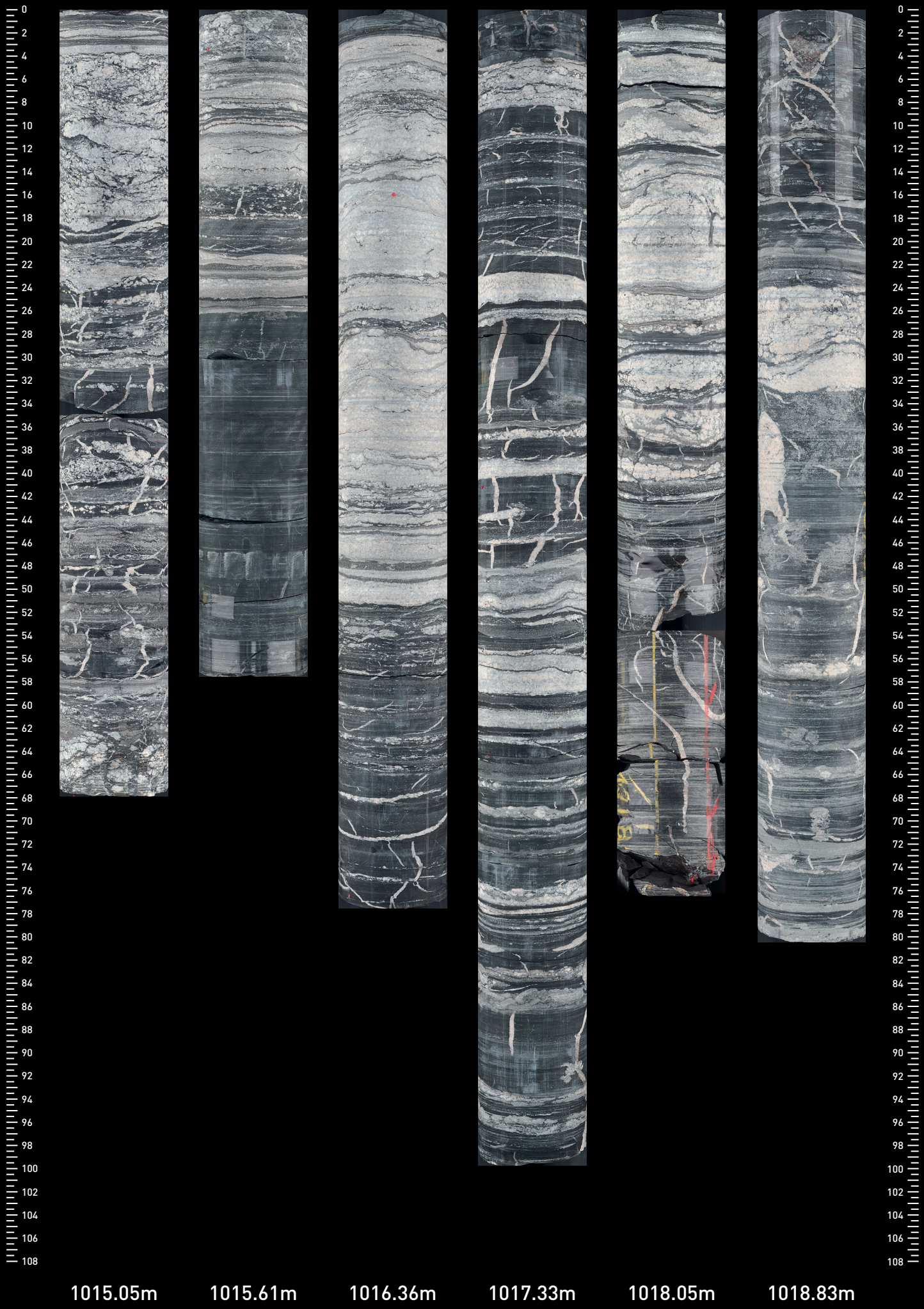
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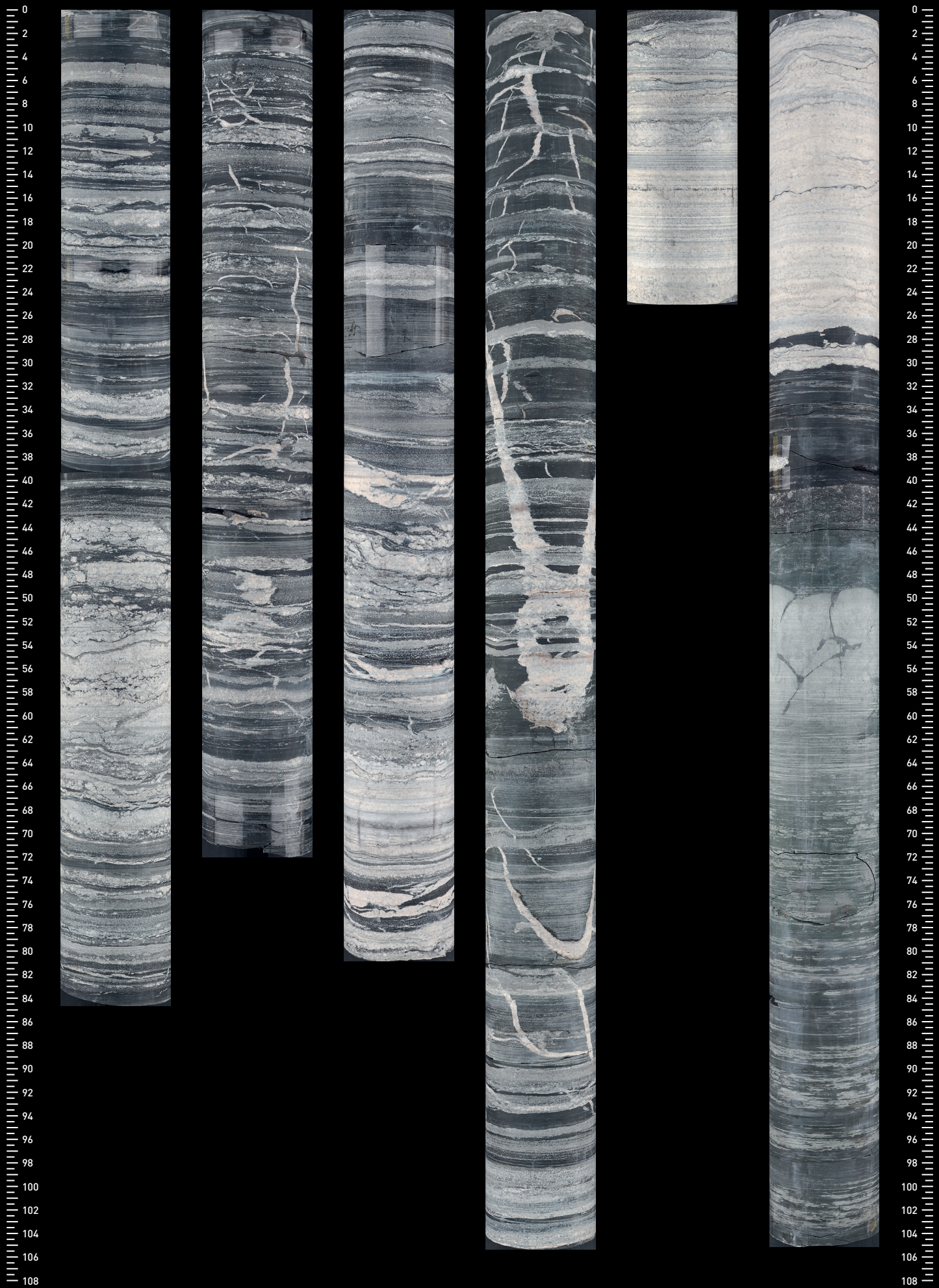
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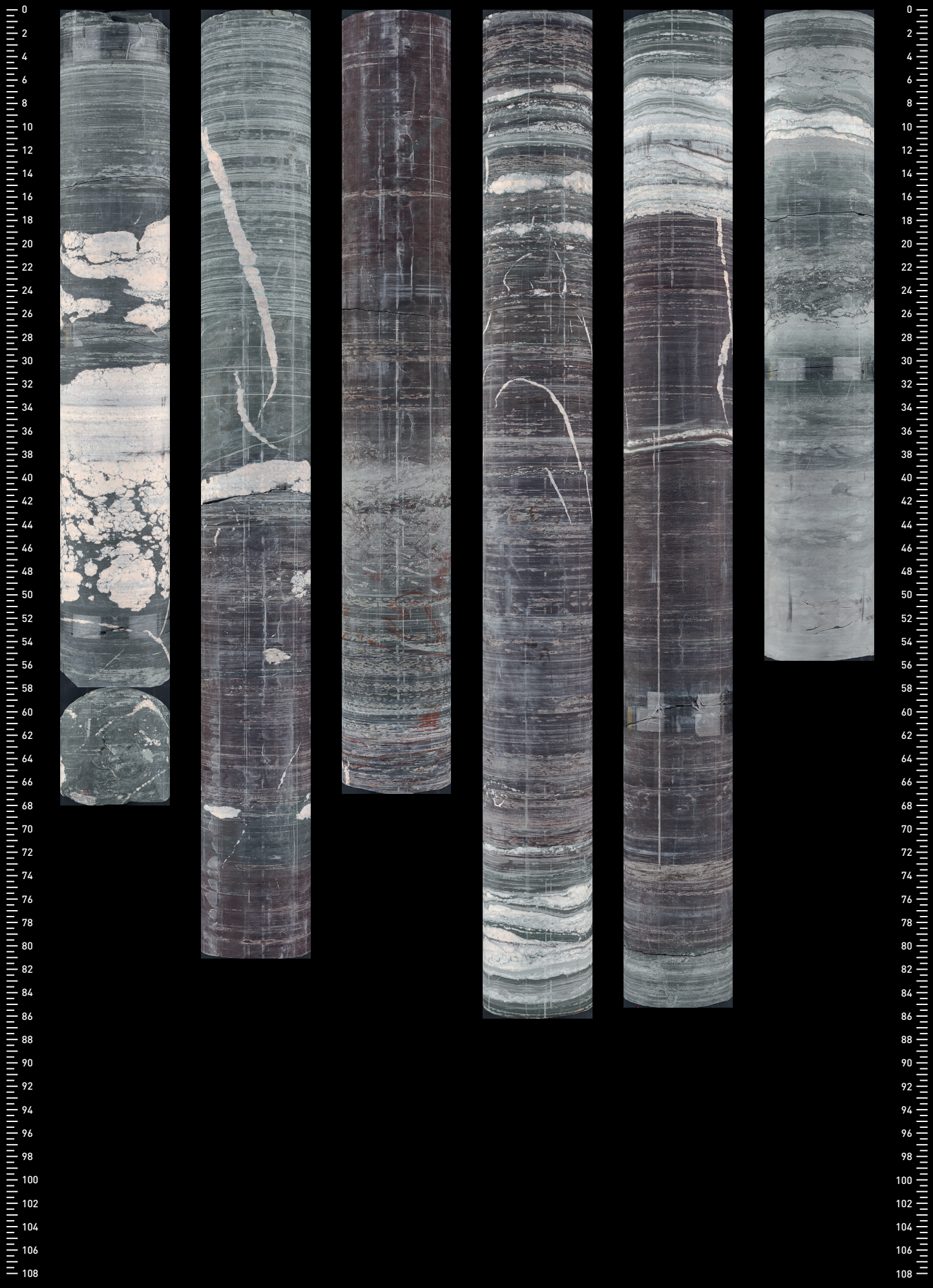

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1018.83m 1019.64m 1020.35m 1021.14m 1022.15m 1022.40m



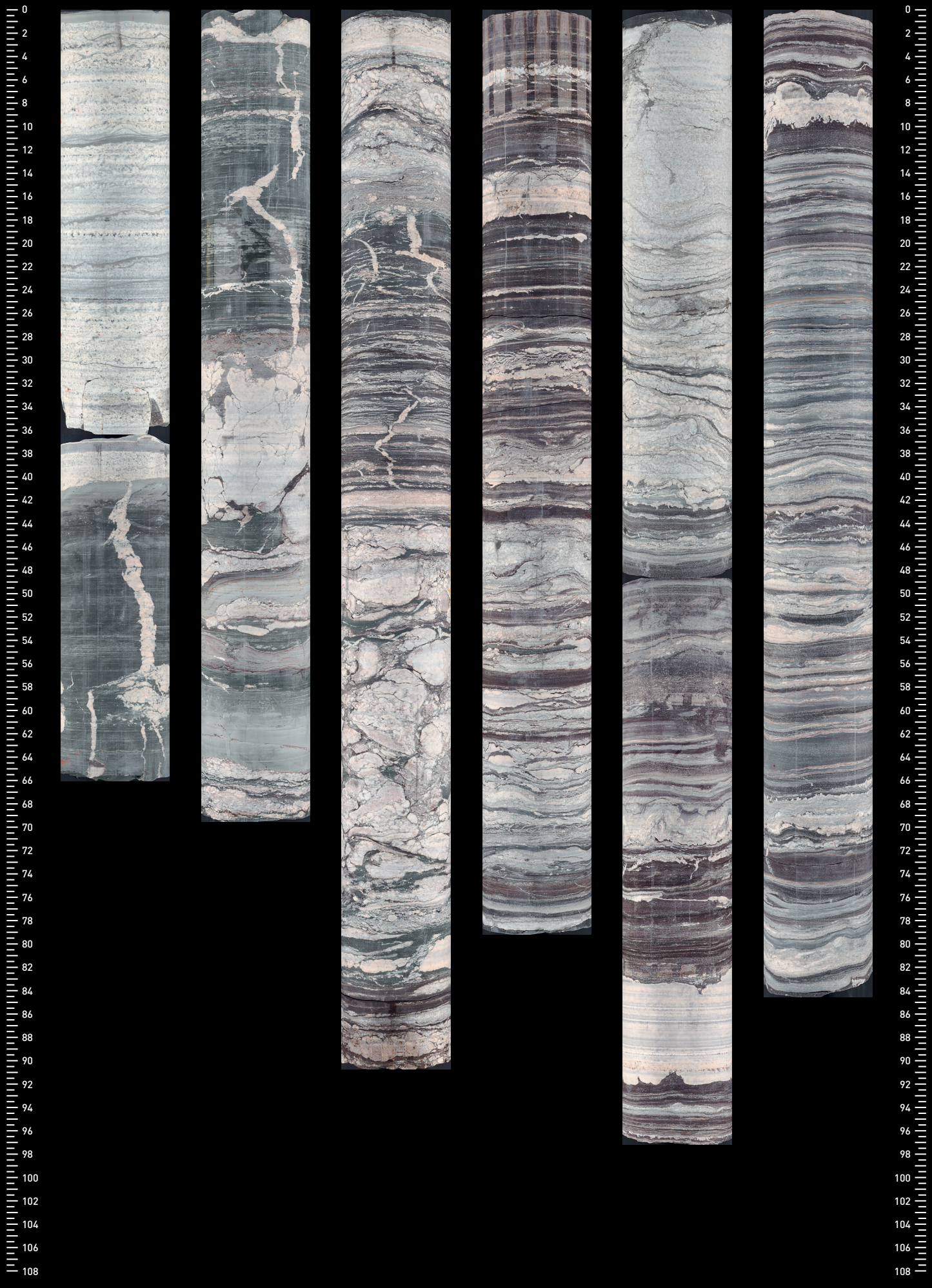
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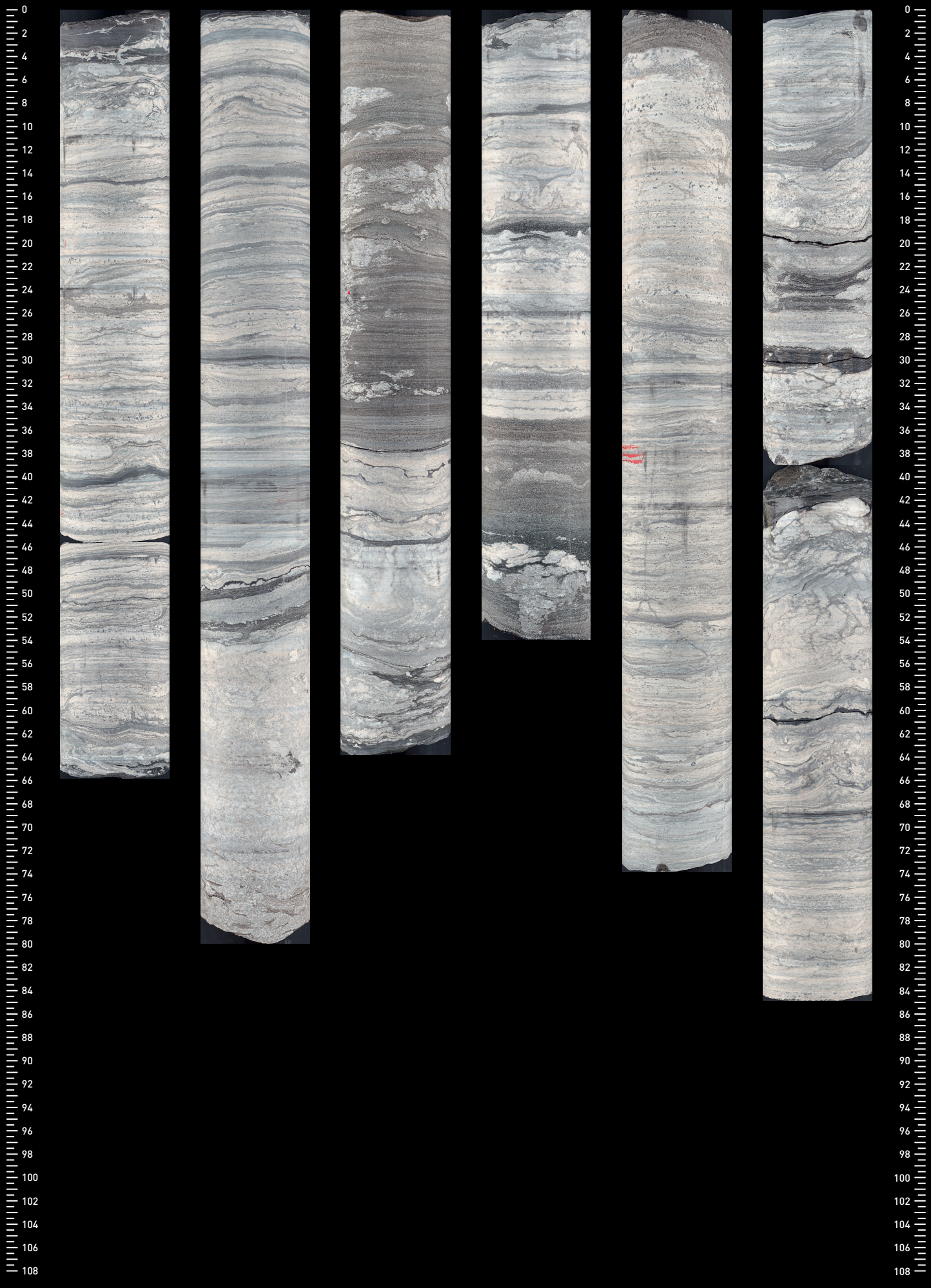
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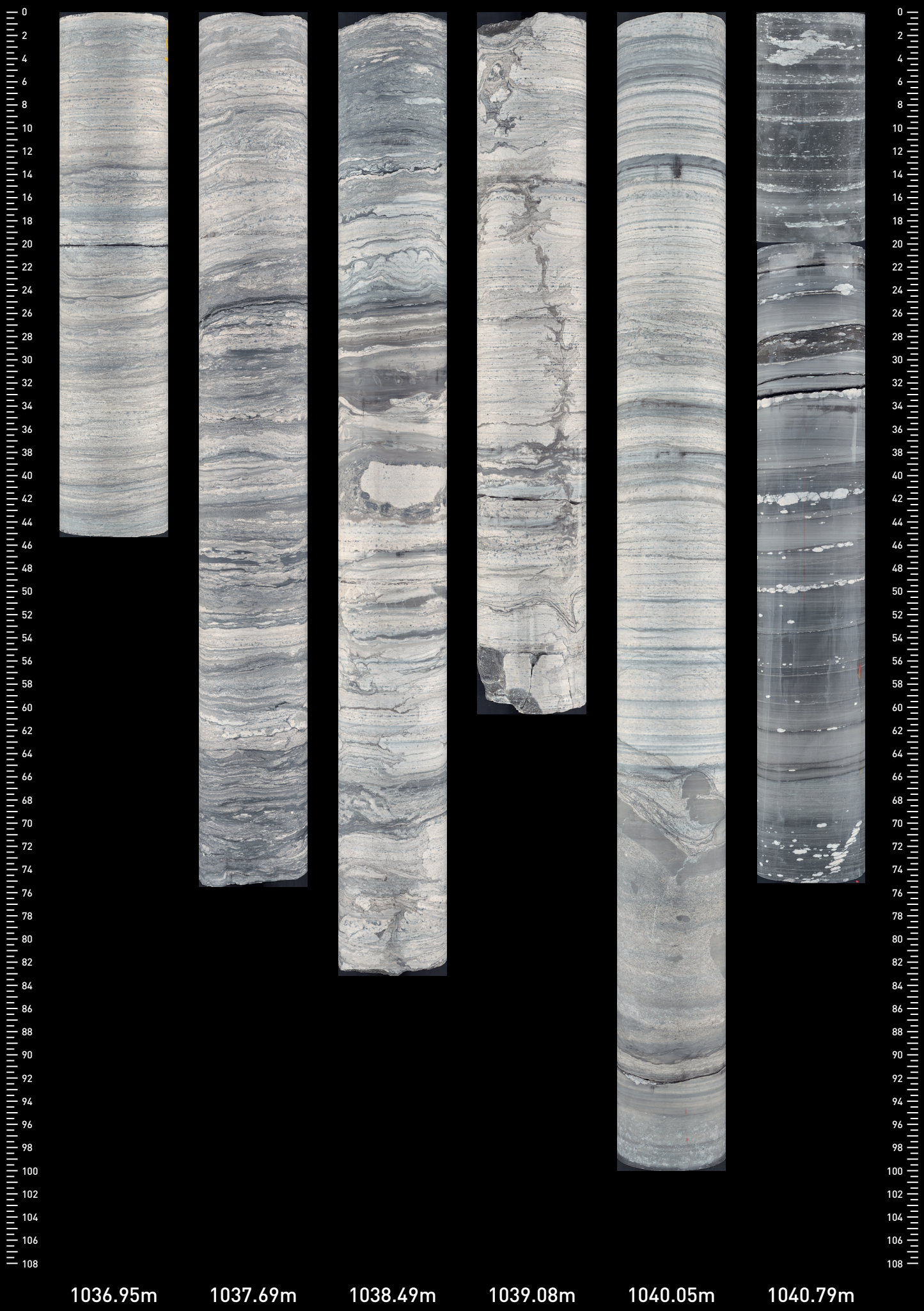


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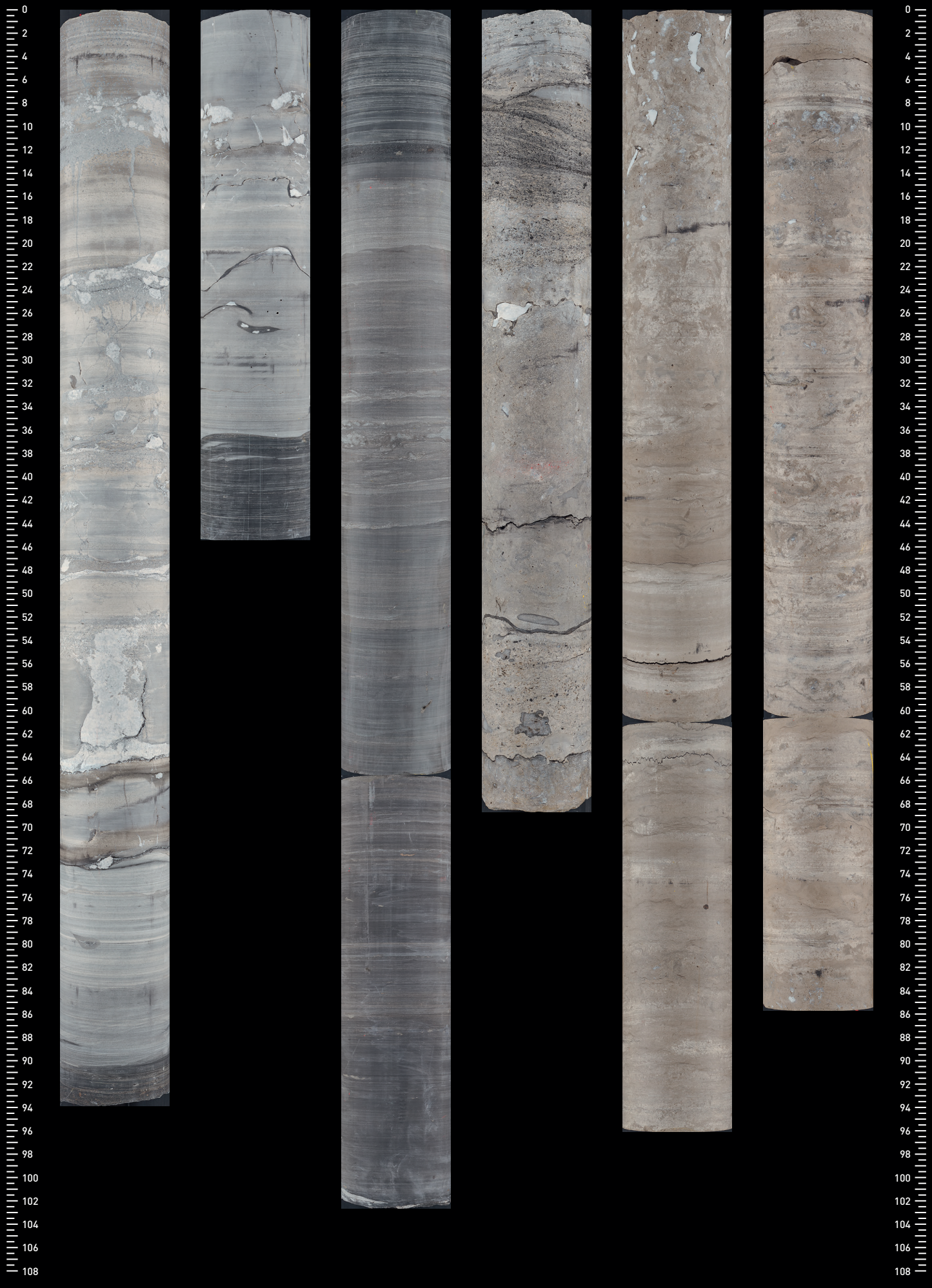


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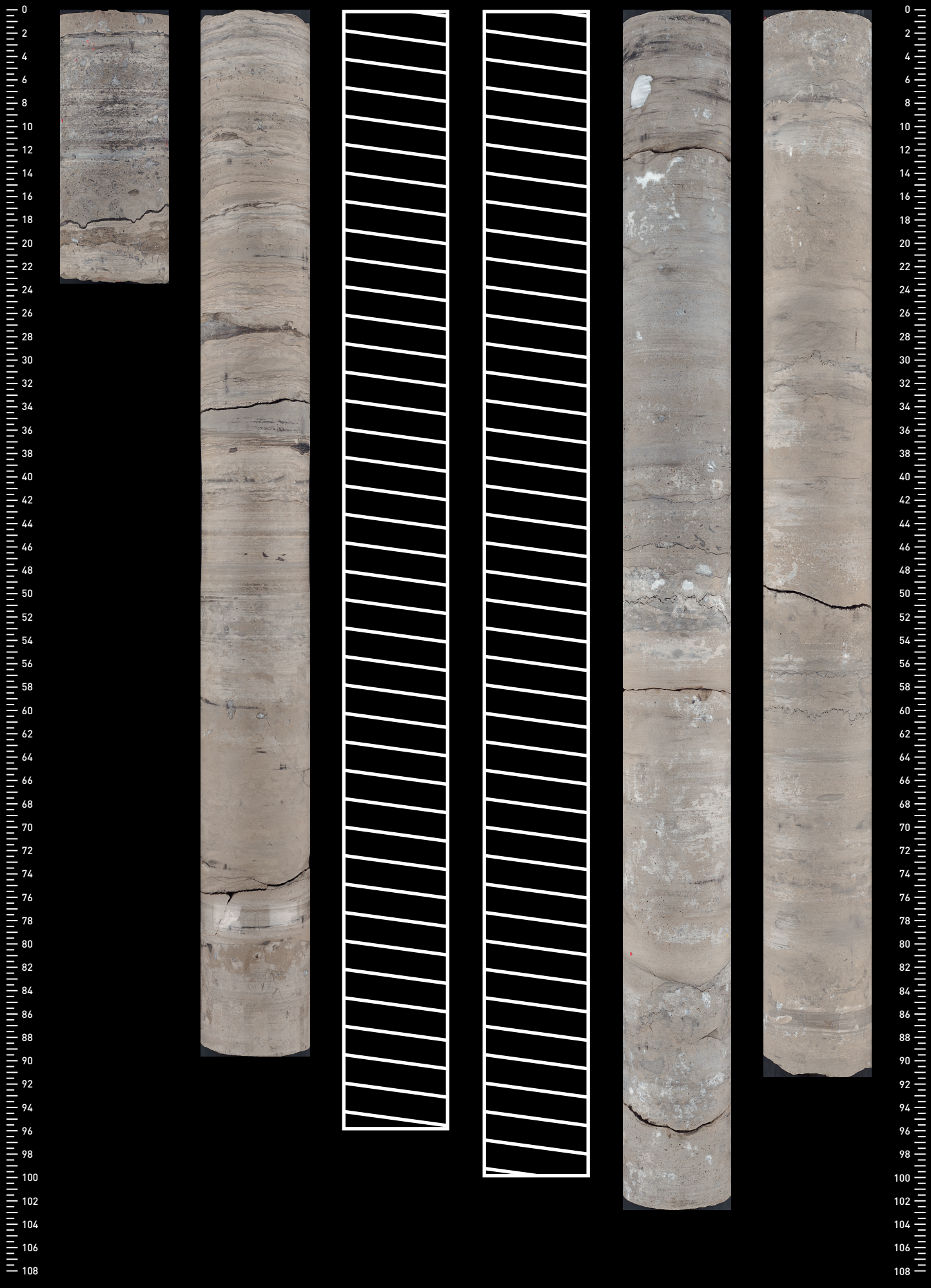

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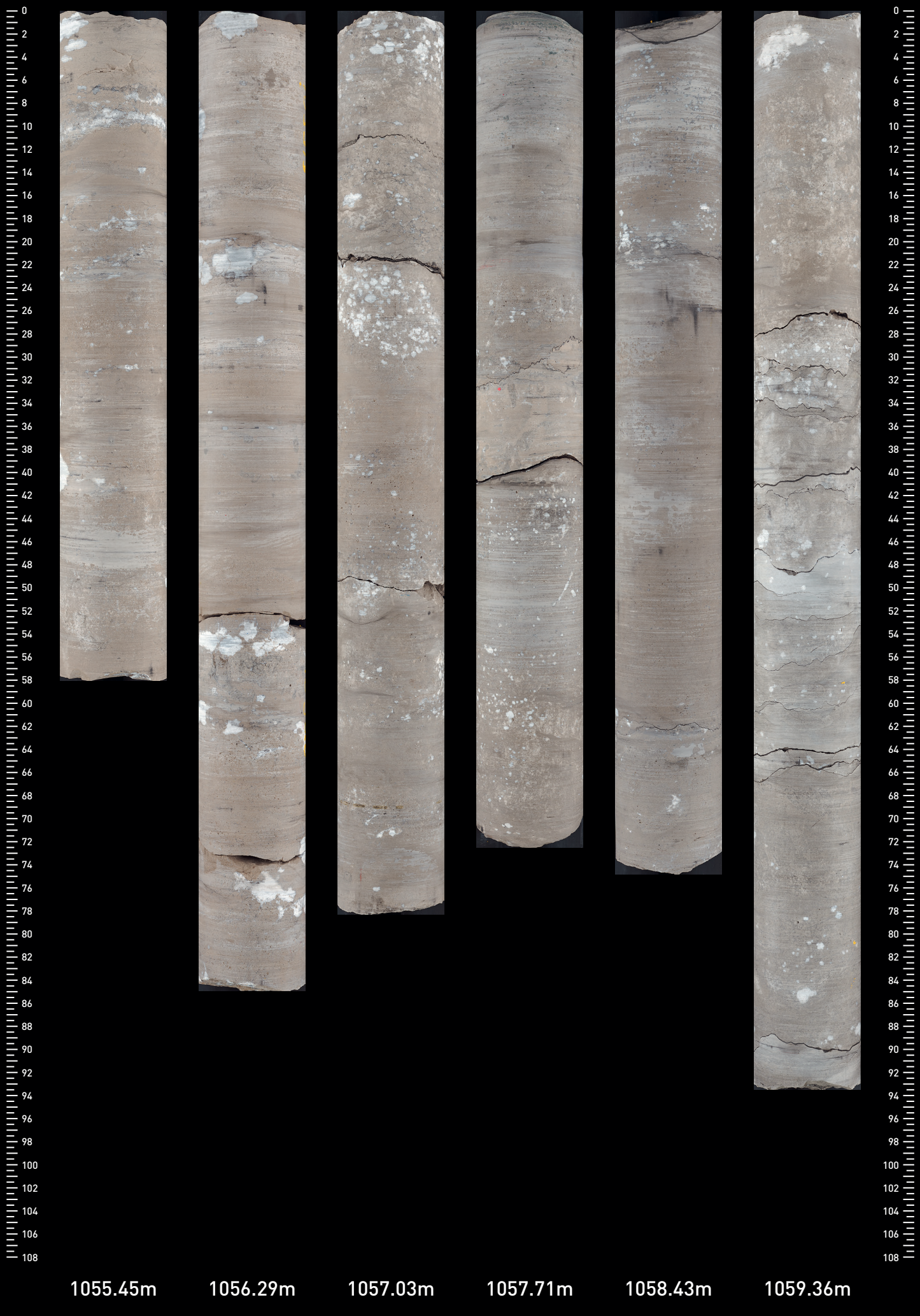

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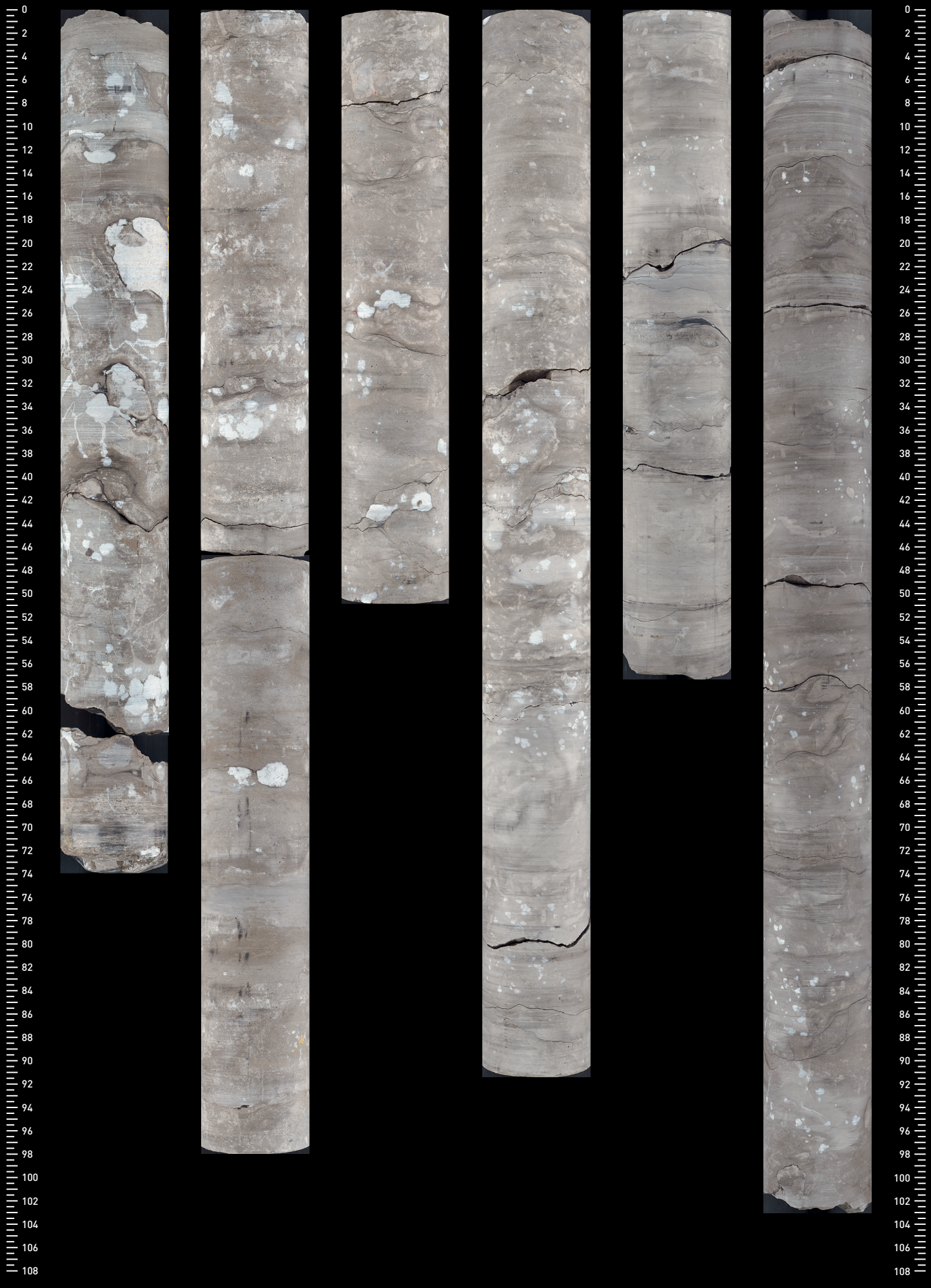
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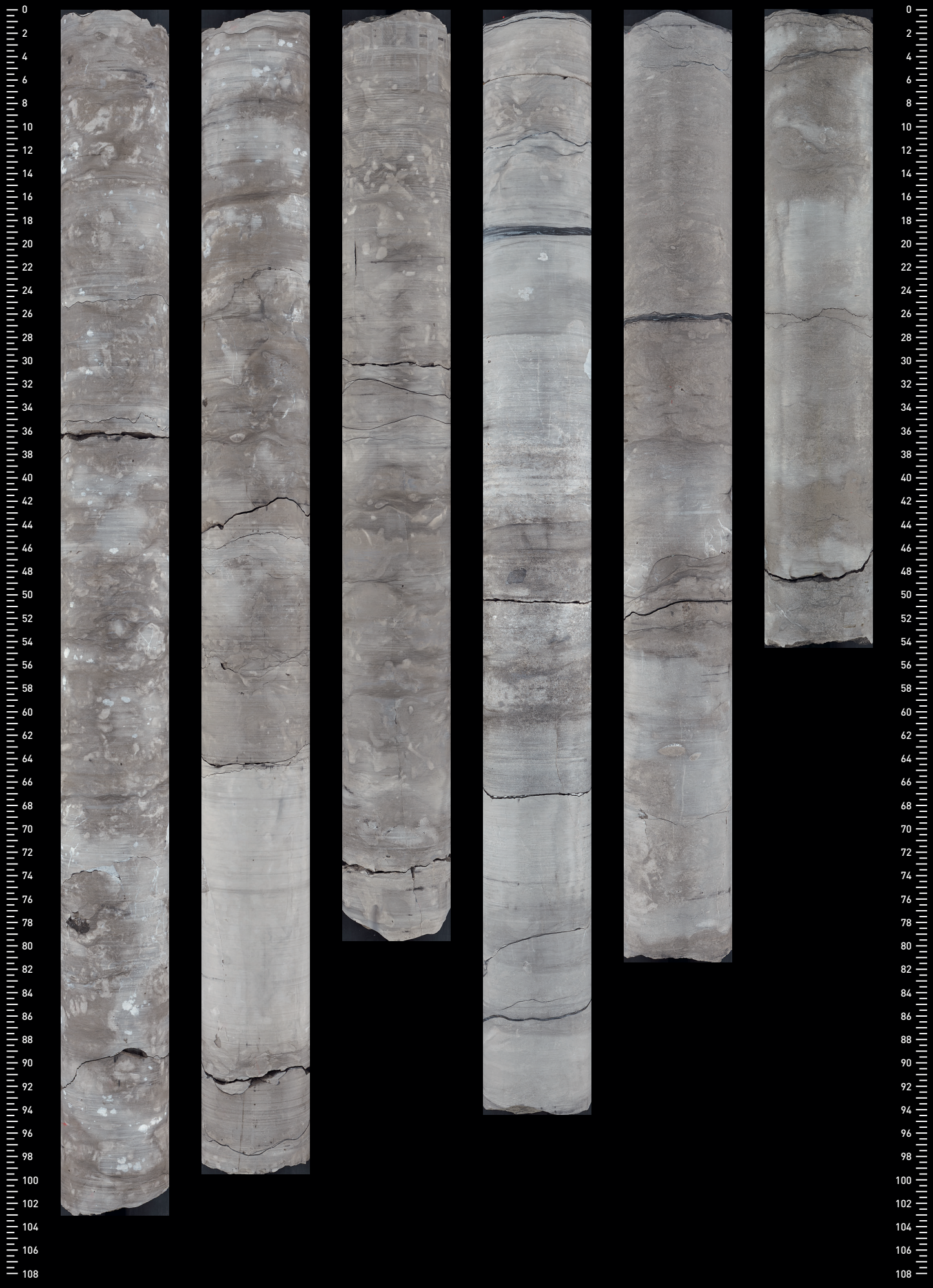
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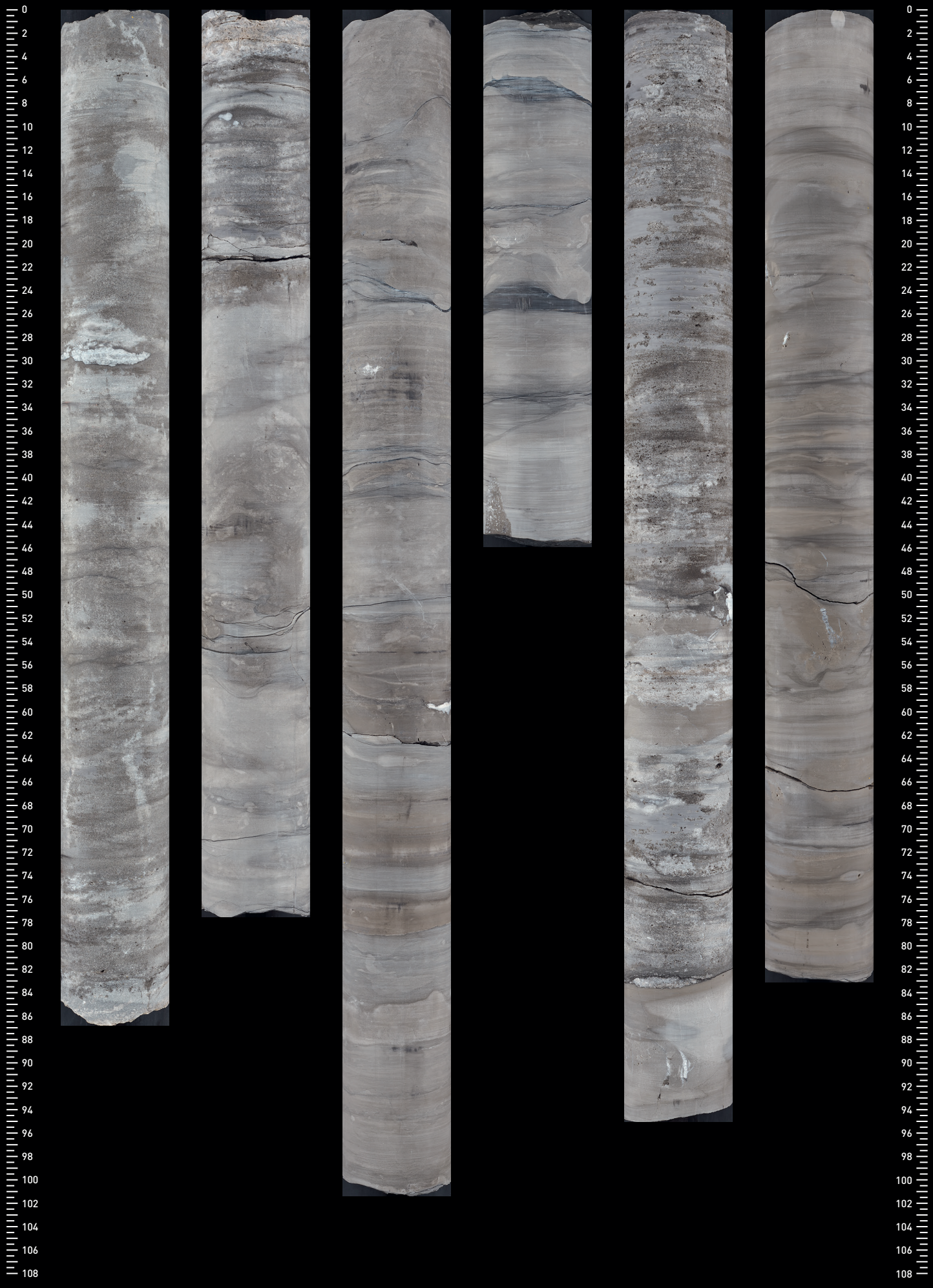

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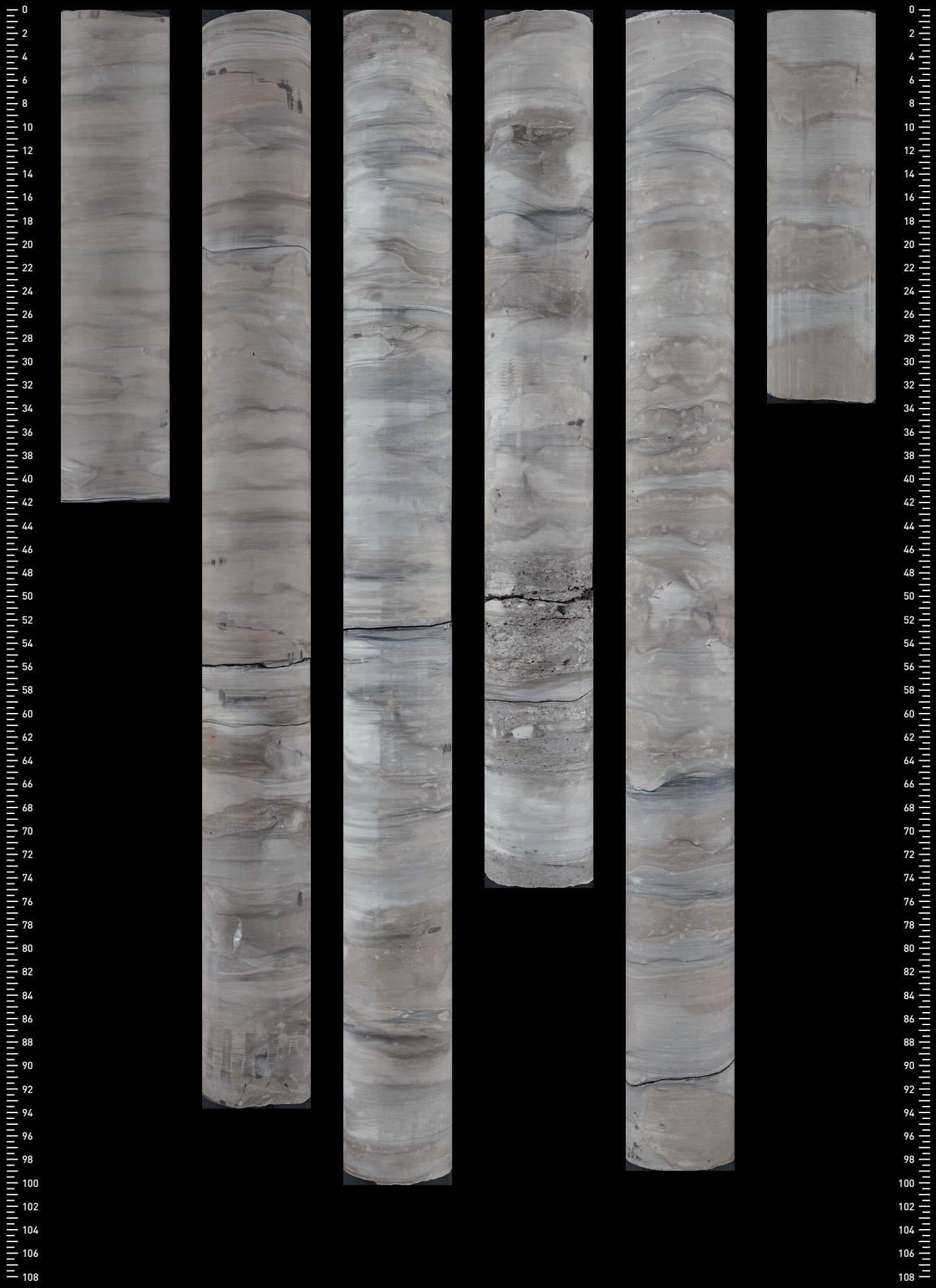
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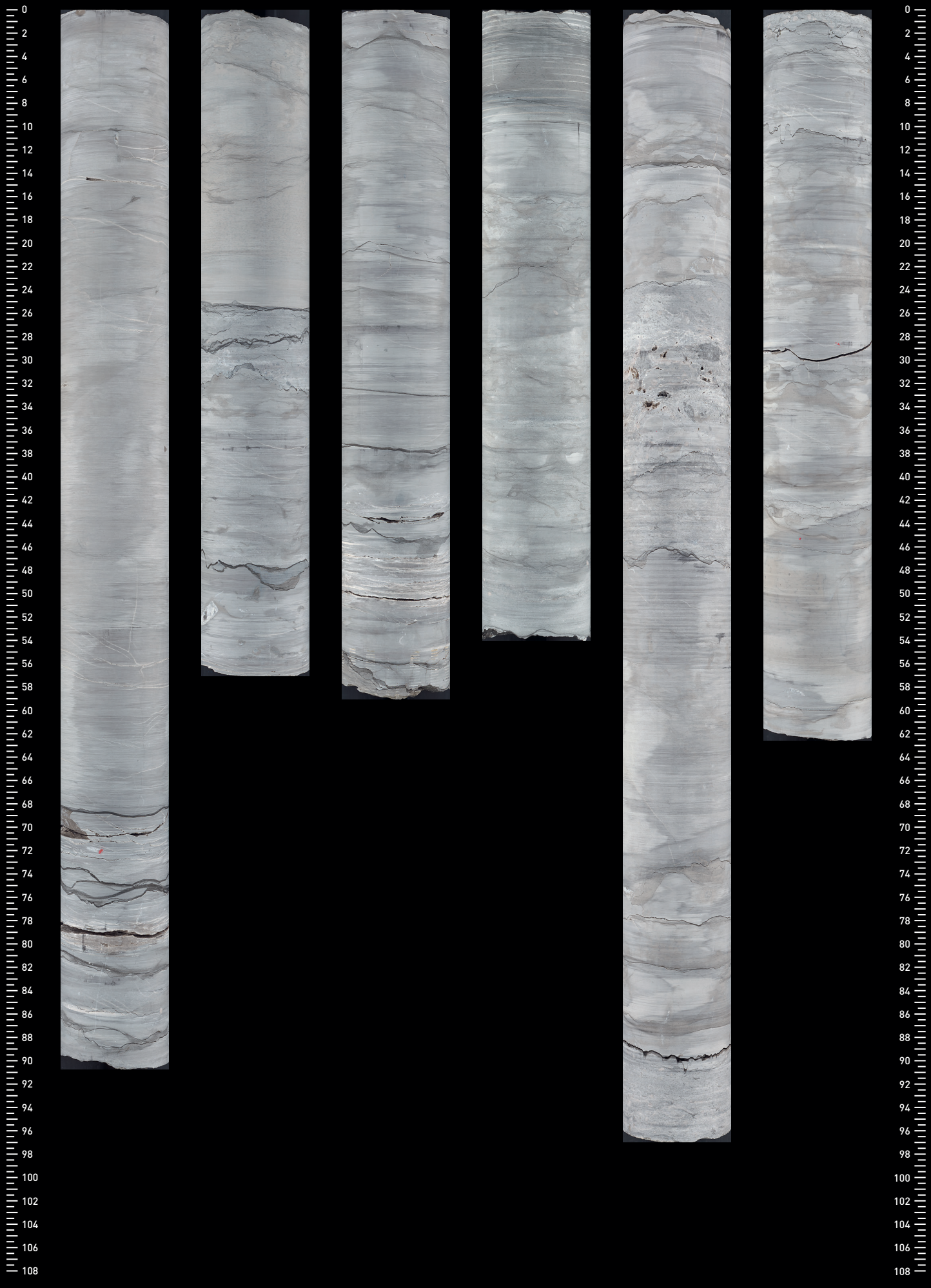
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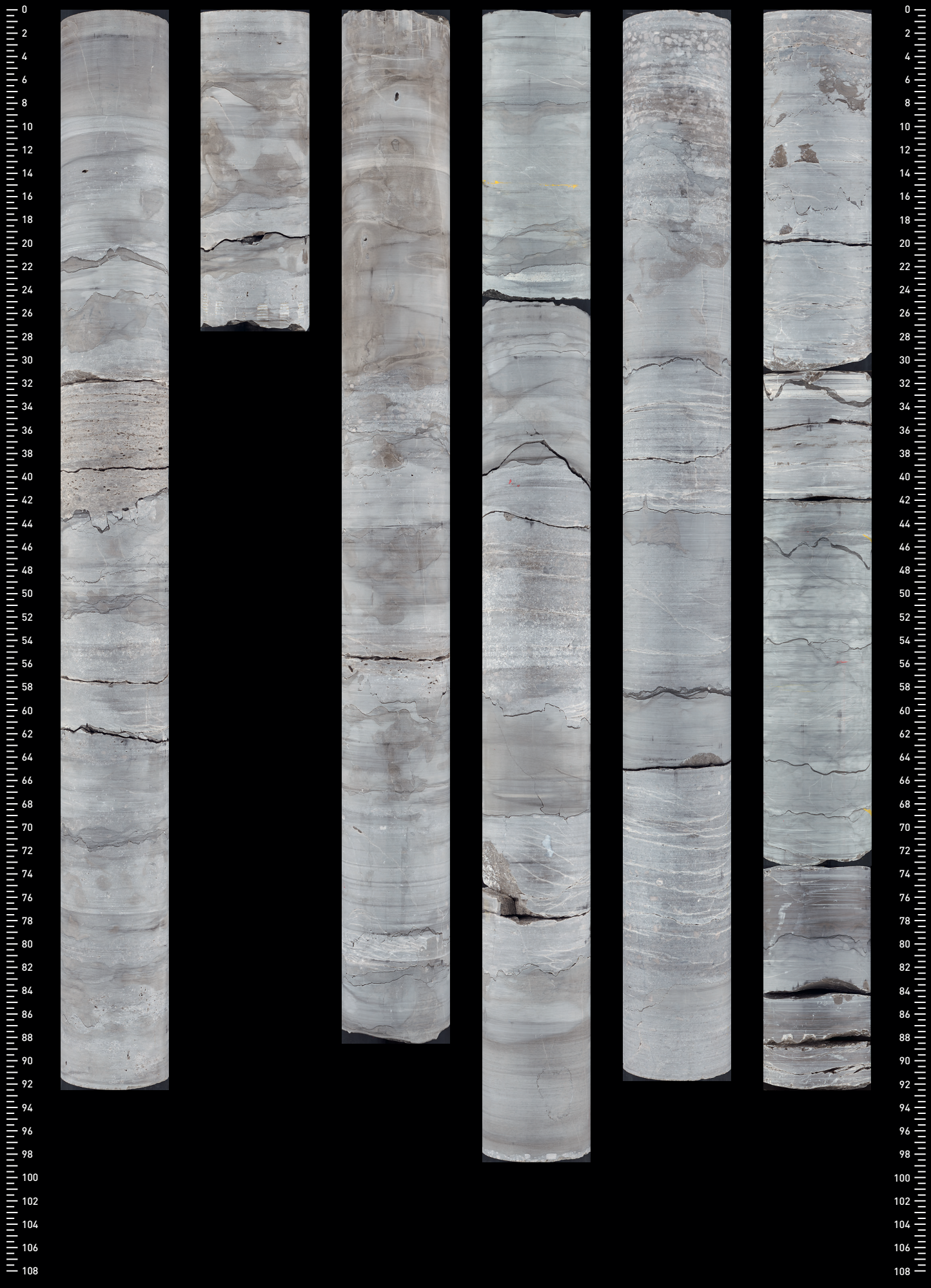

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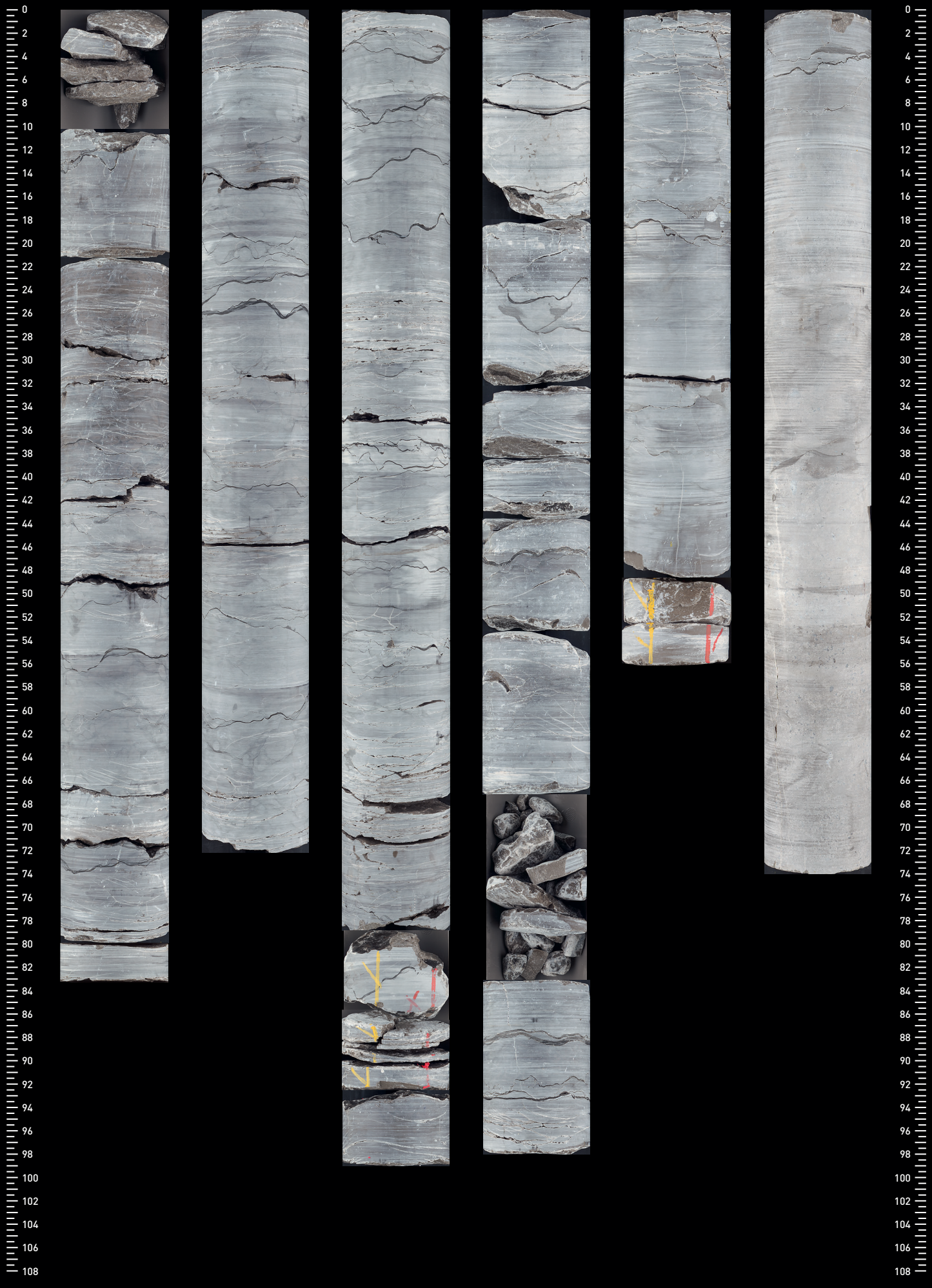
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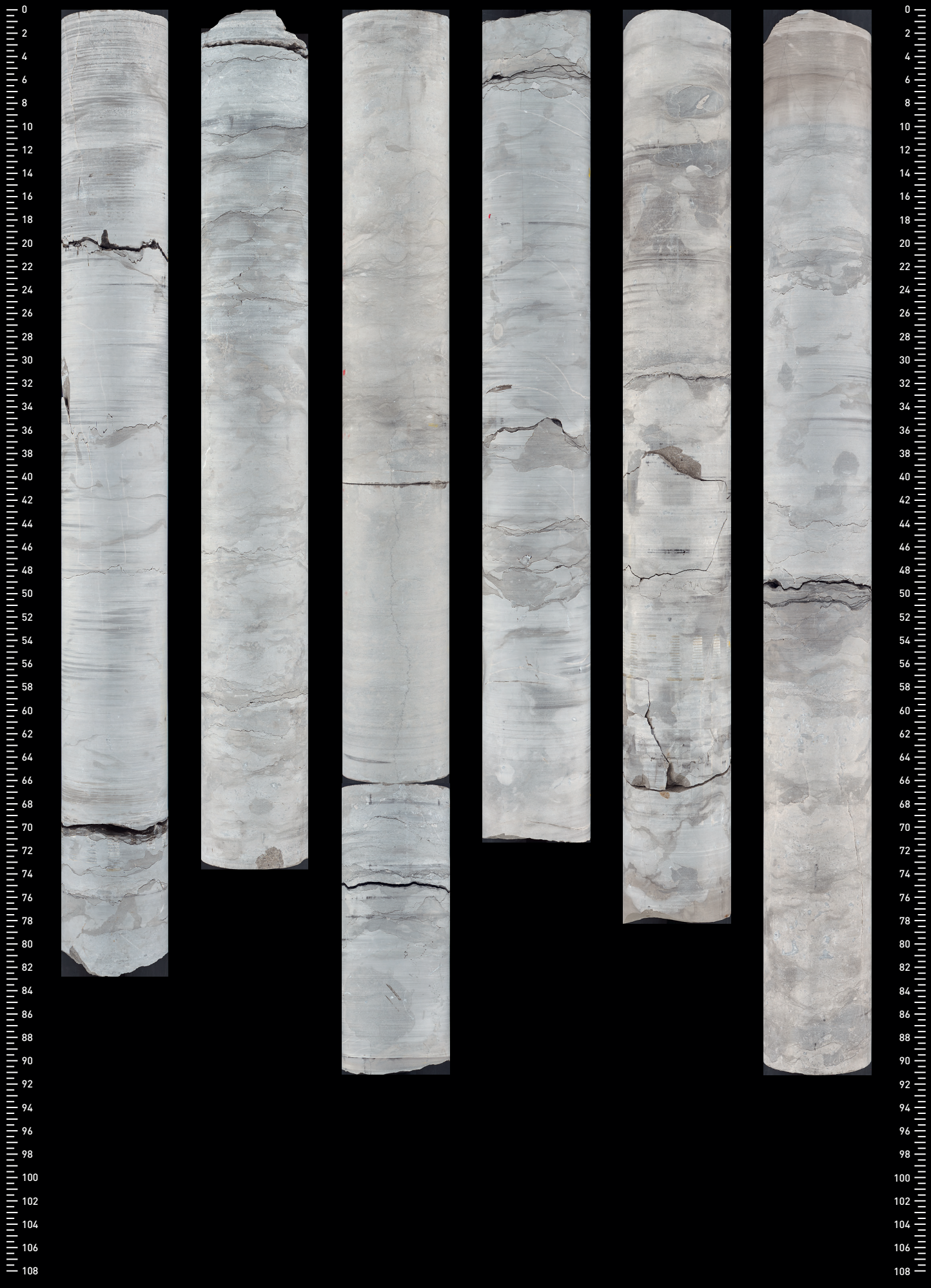
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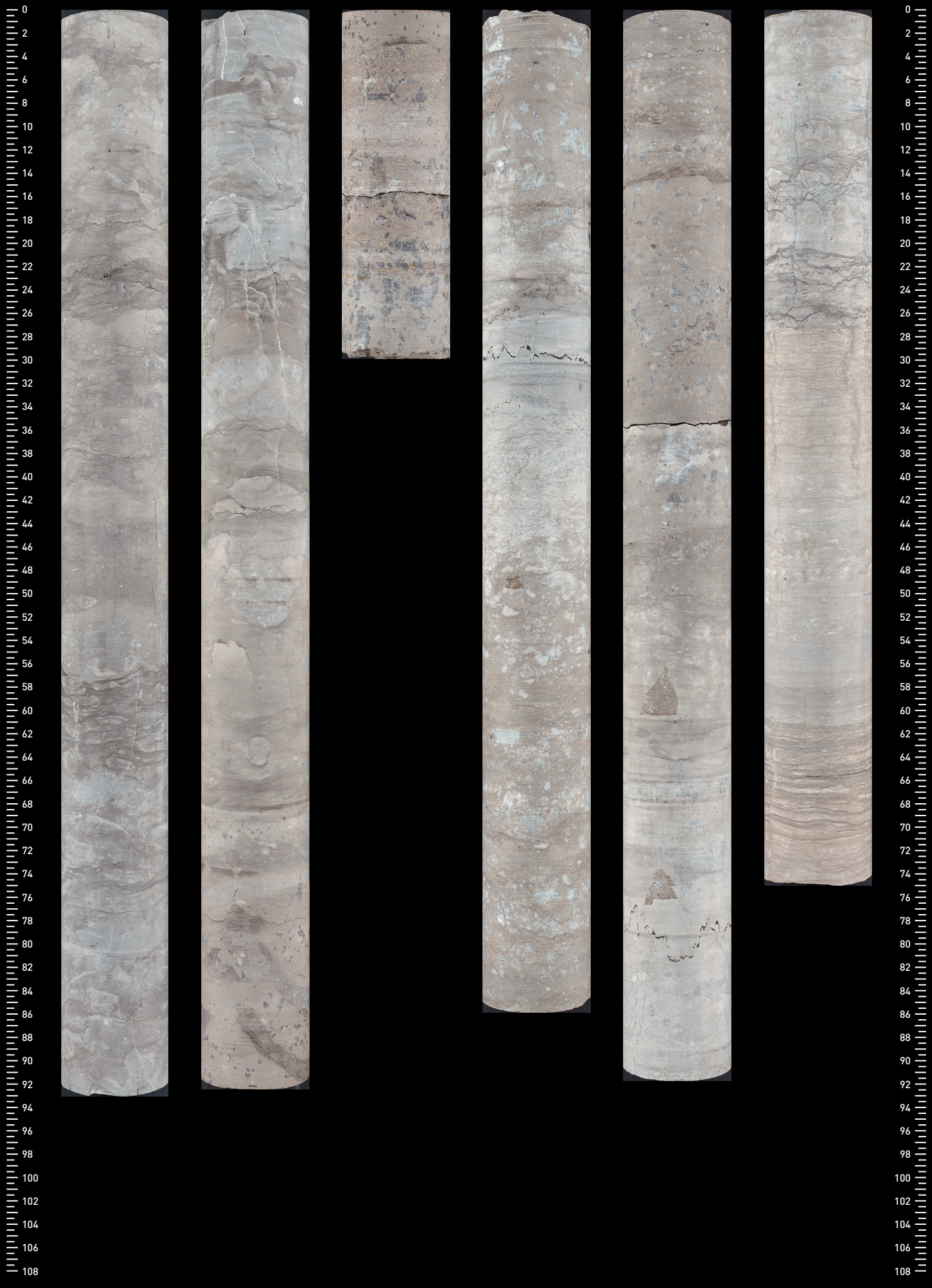
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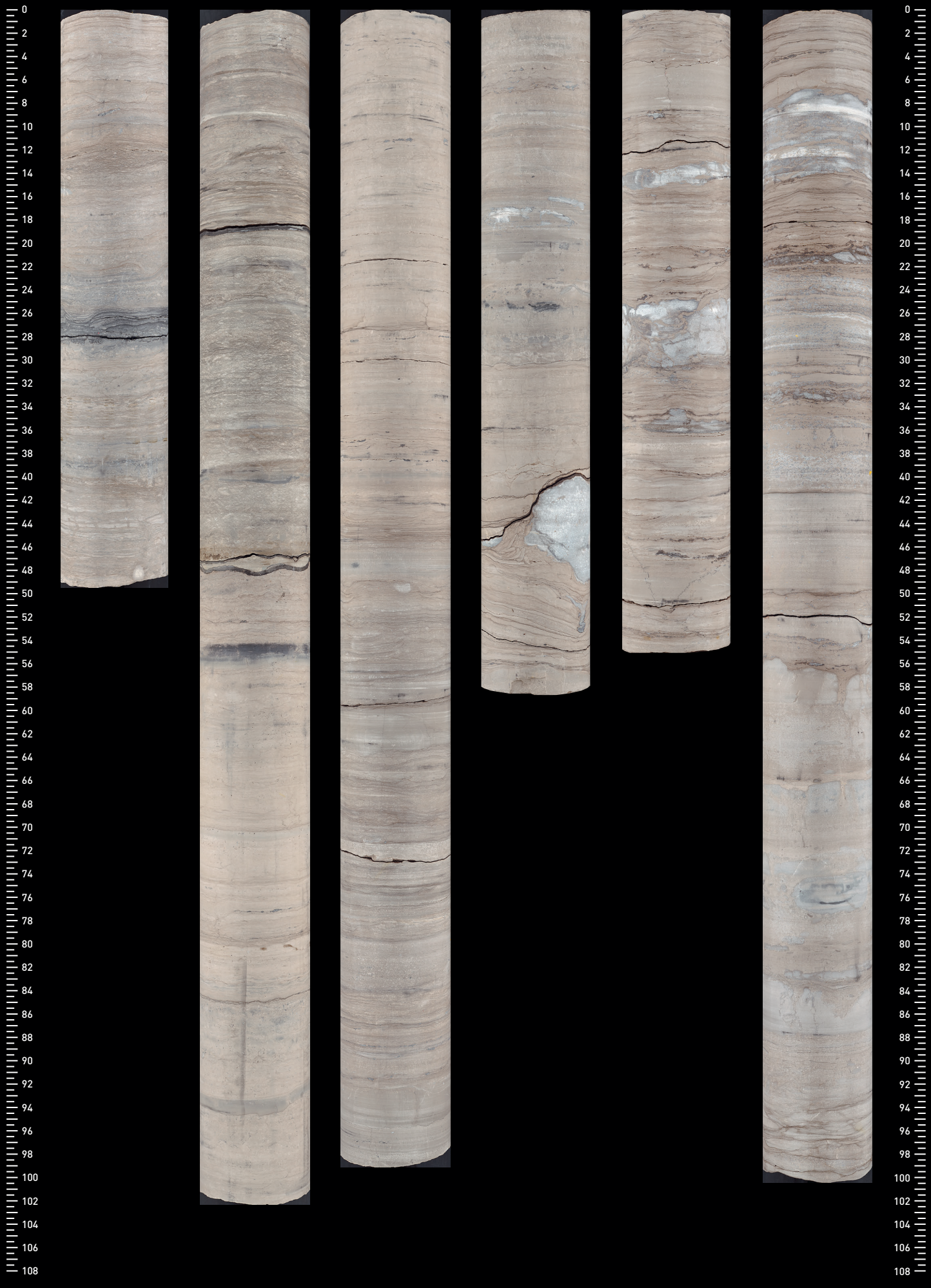
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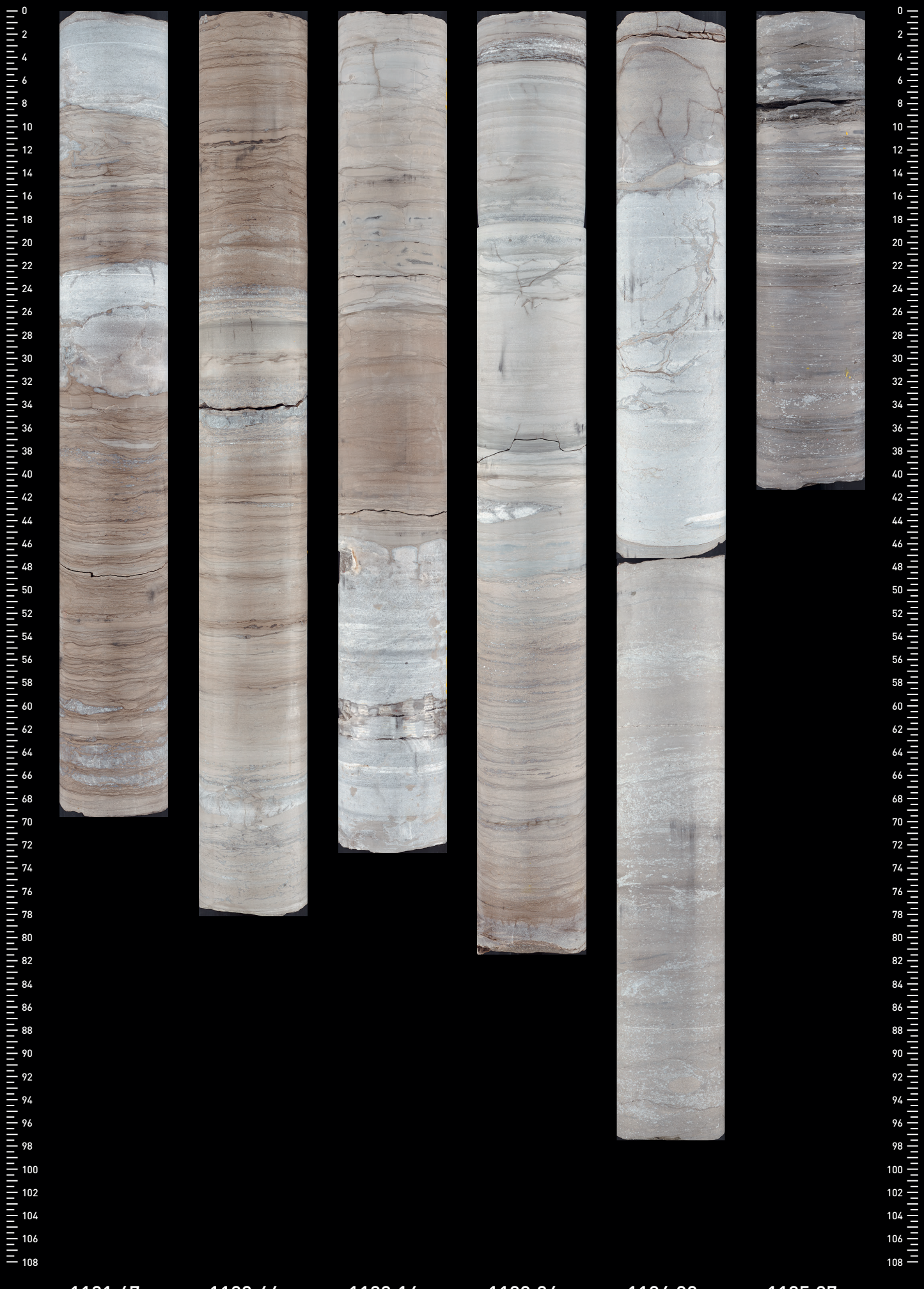

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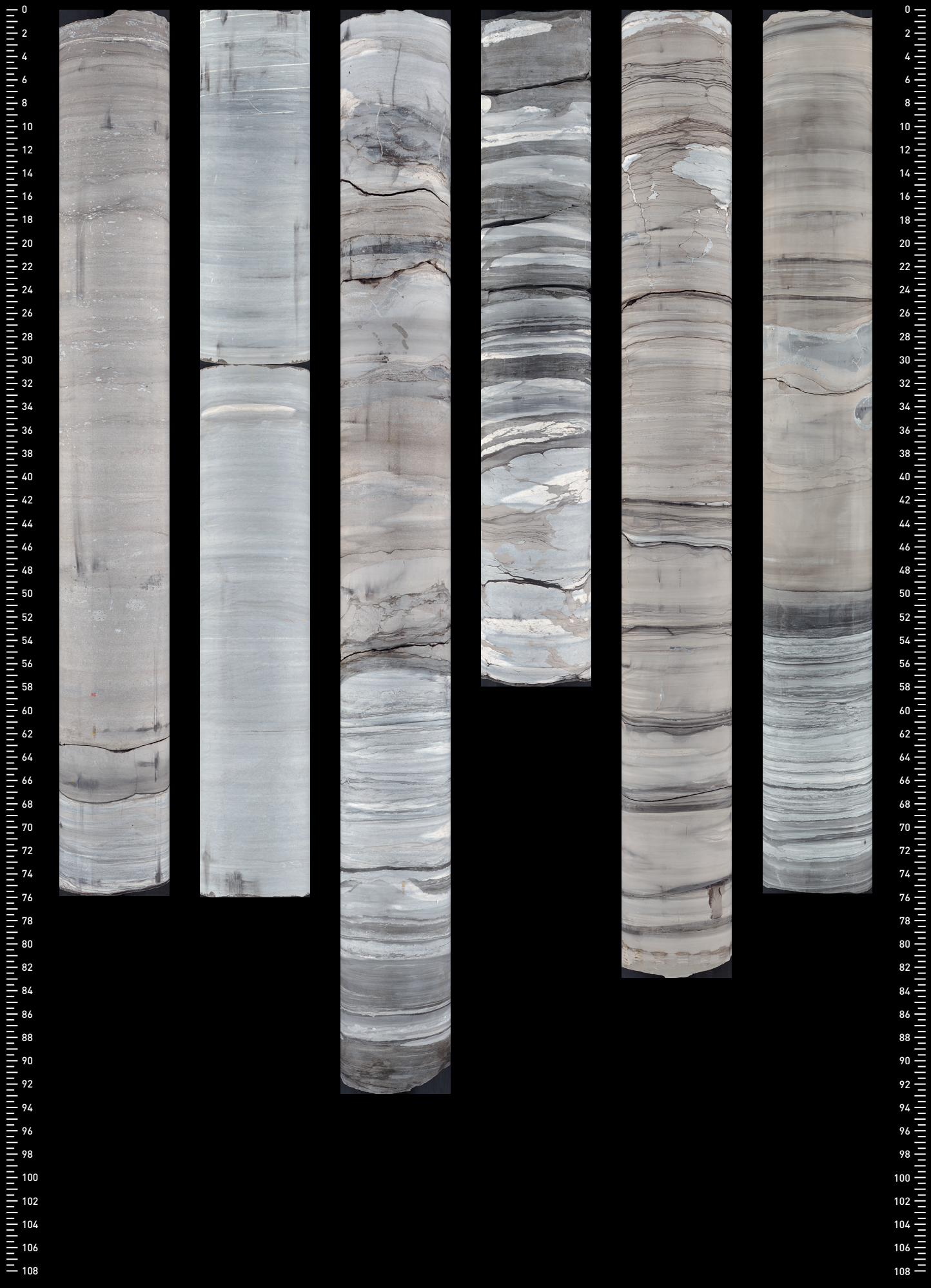
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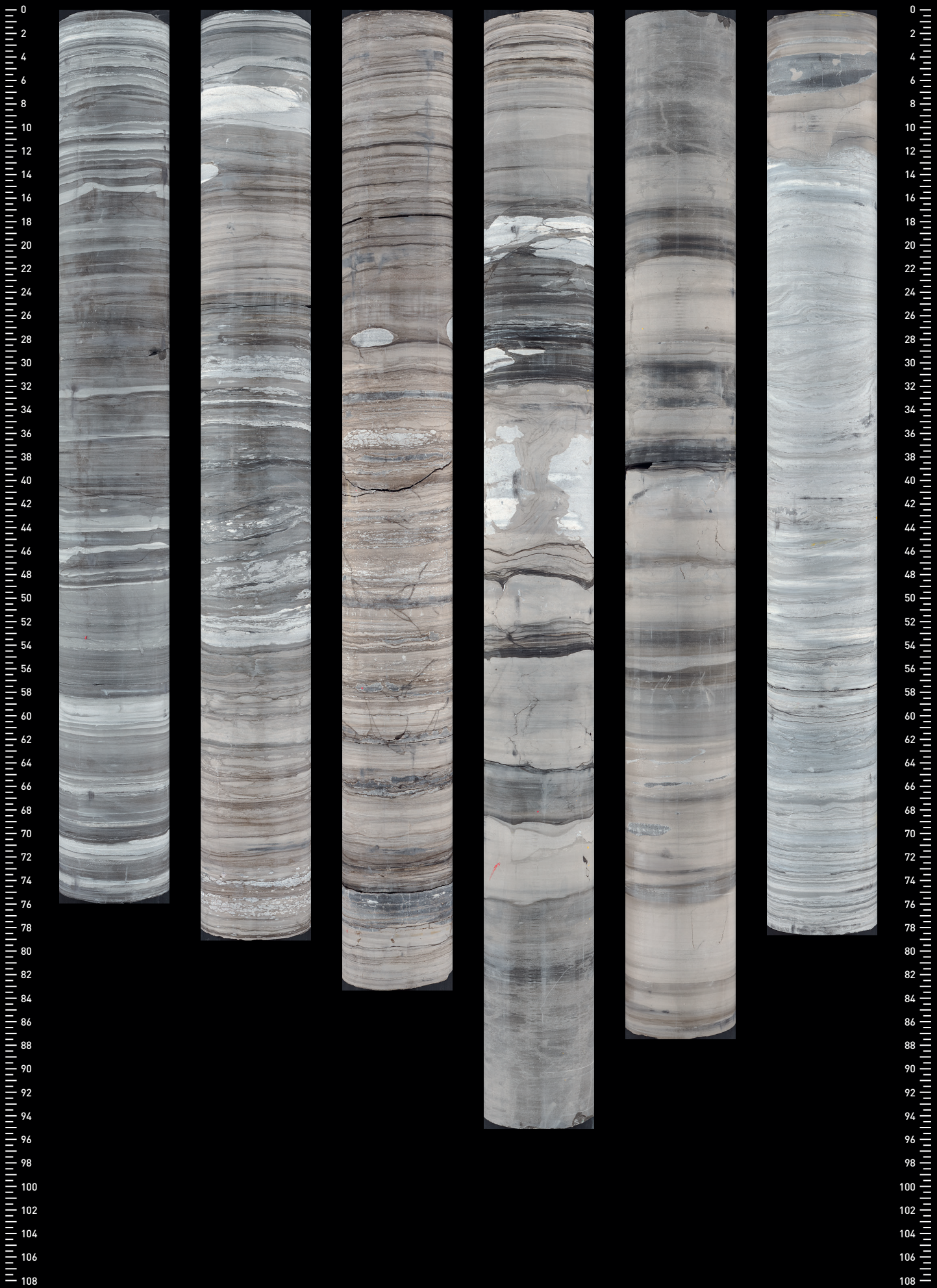
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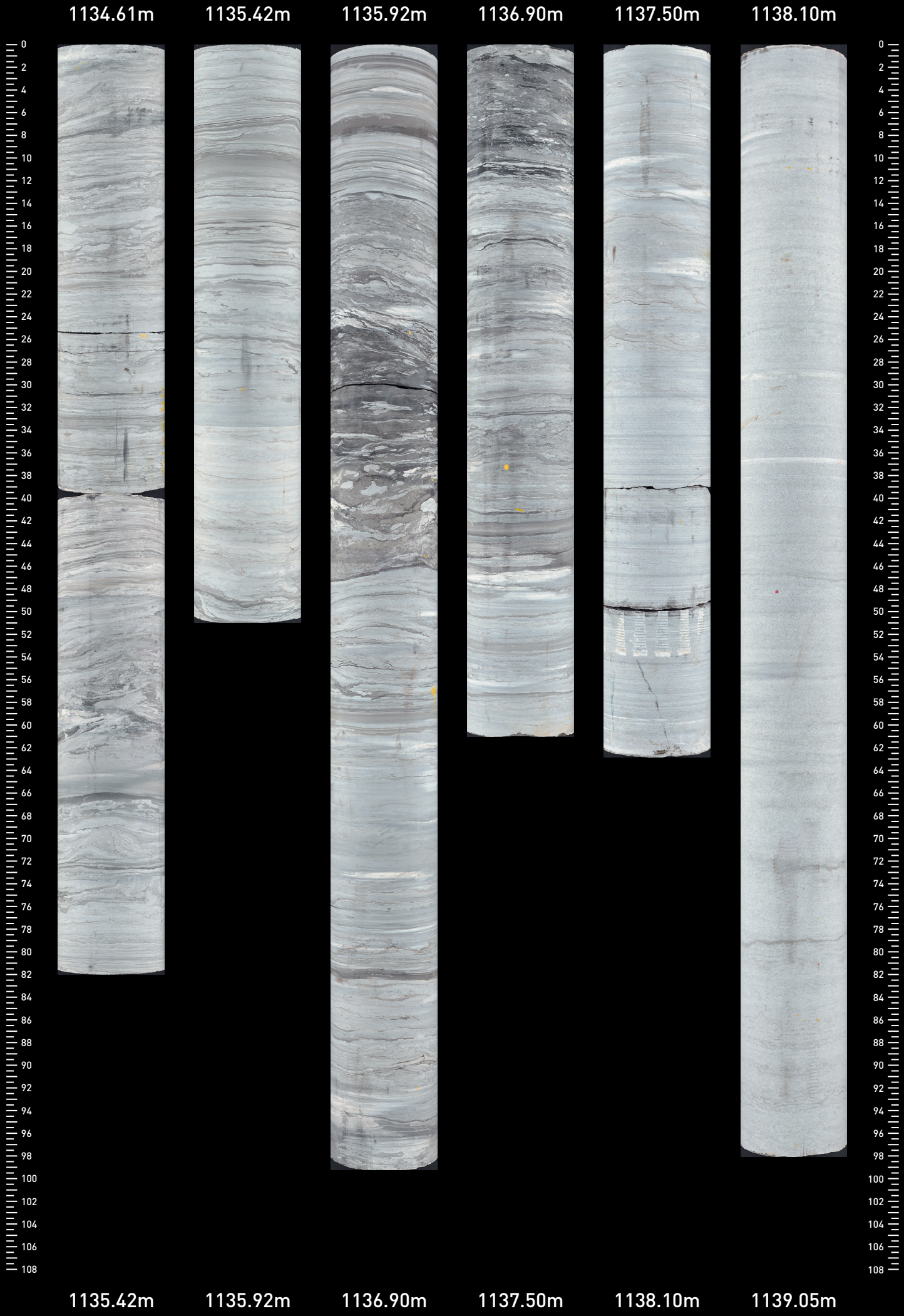

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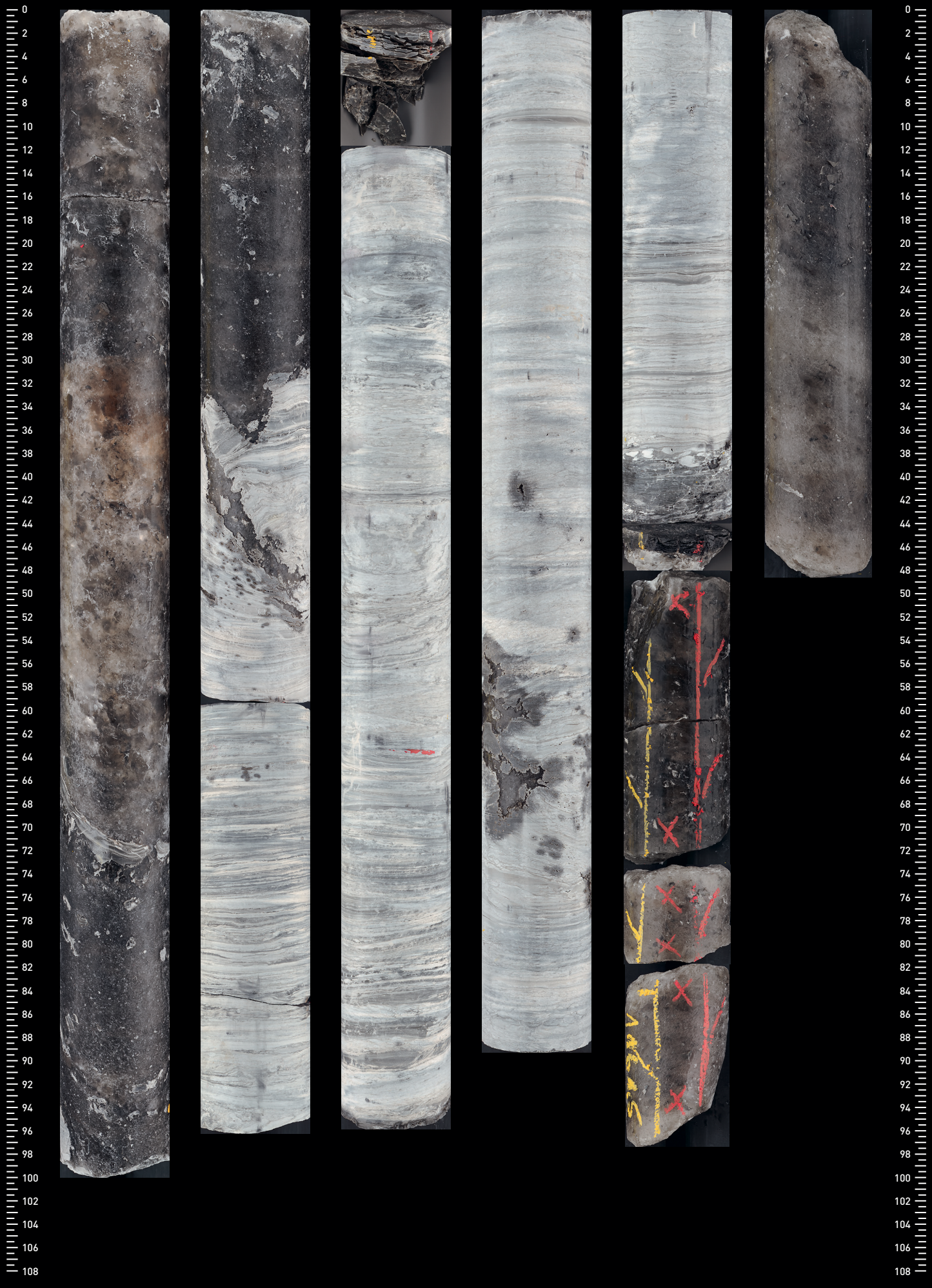
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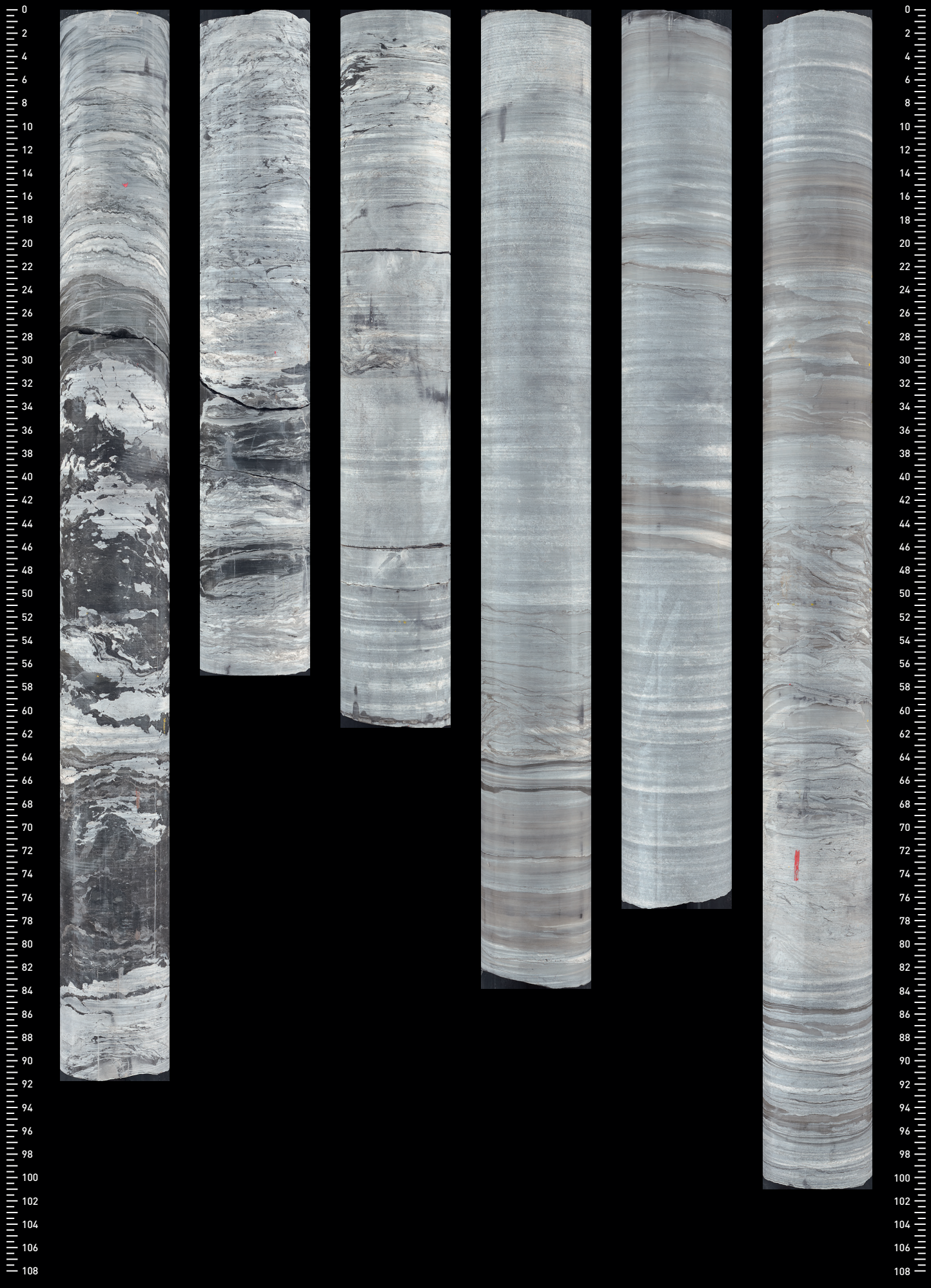
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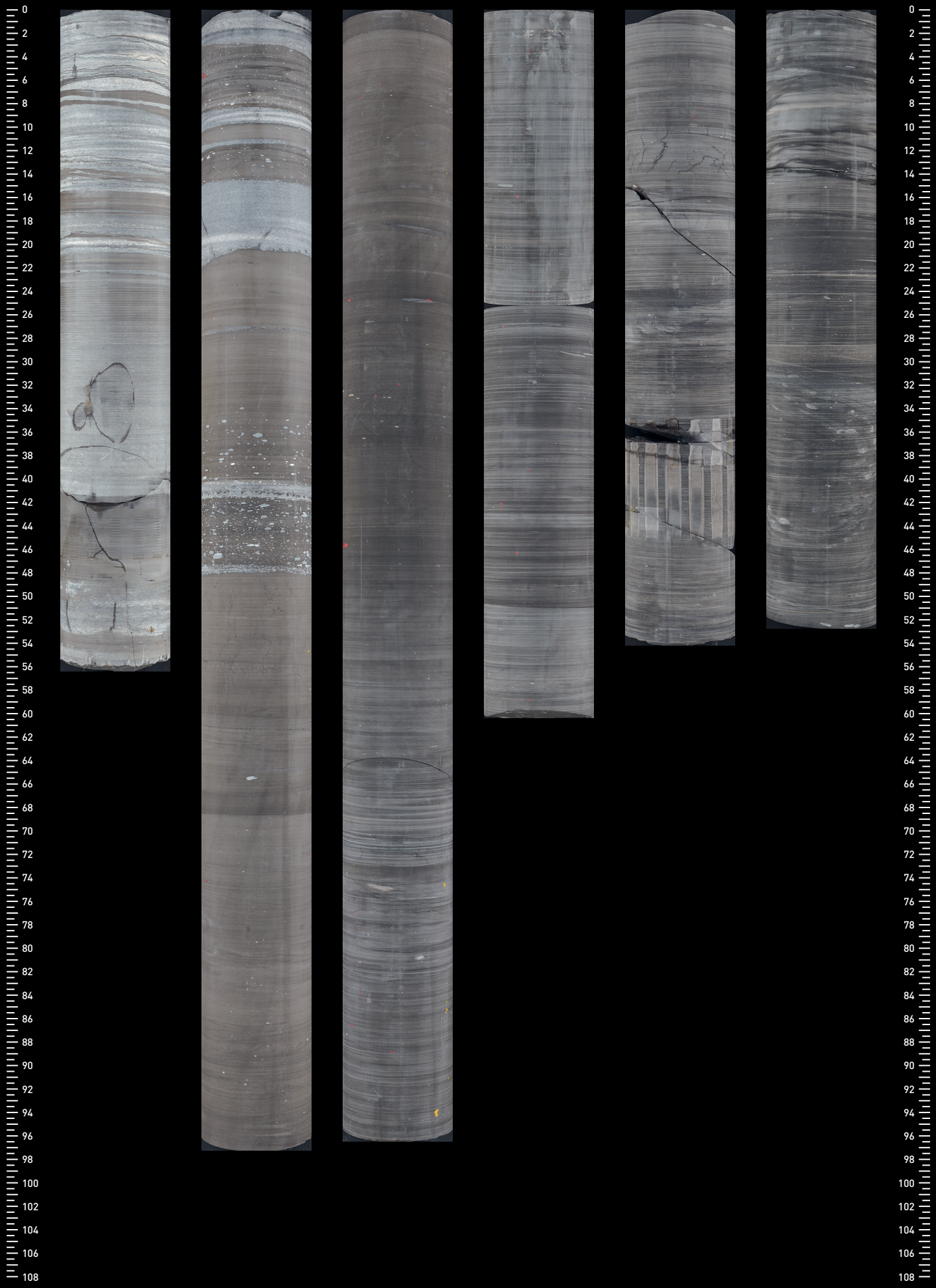
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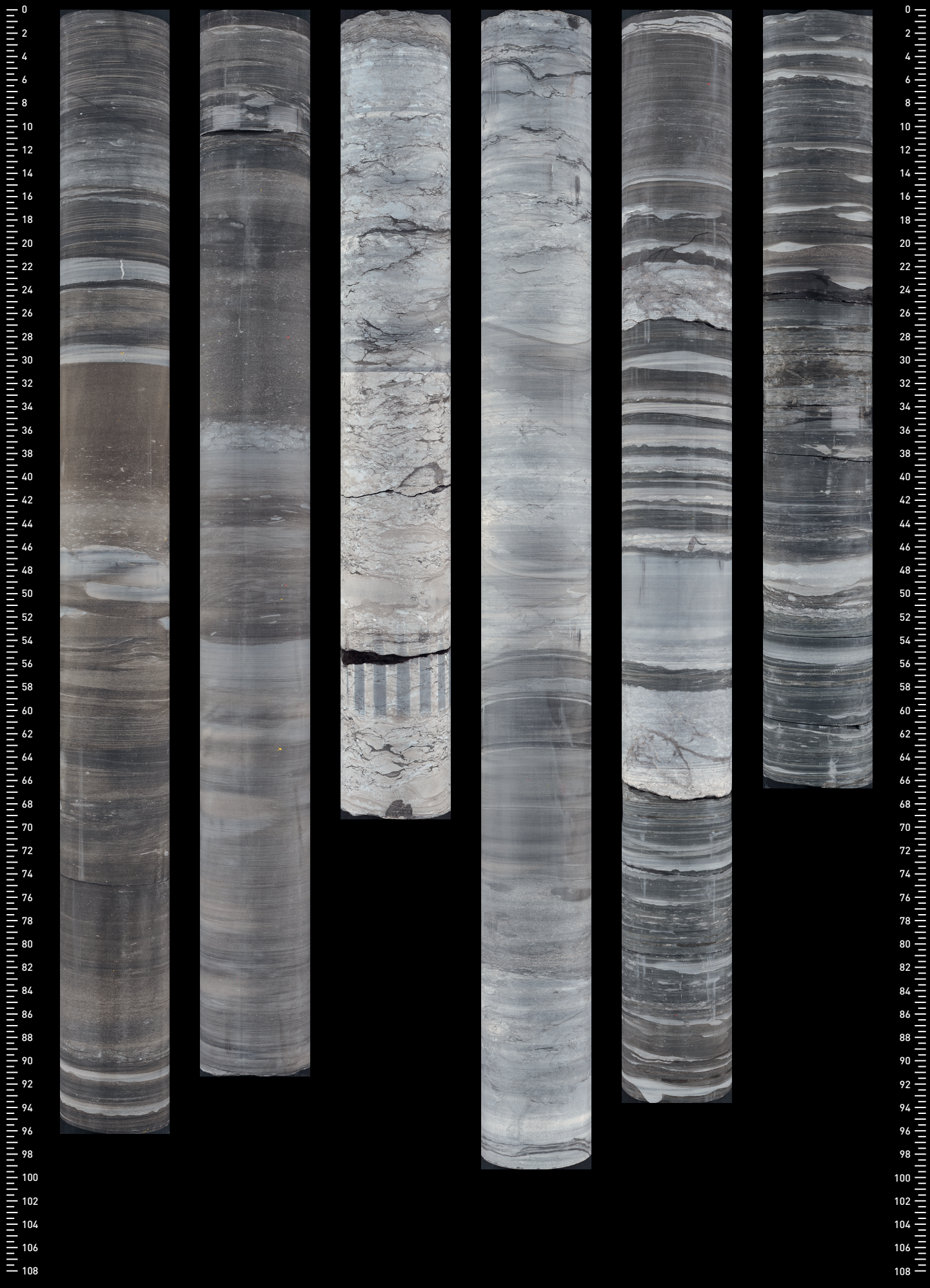

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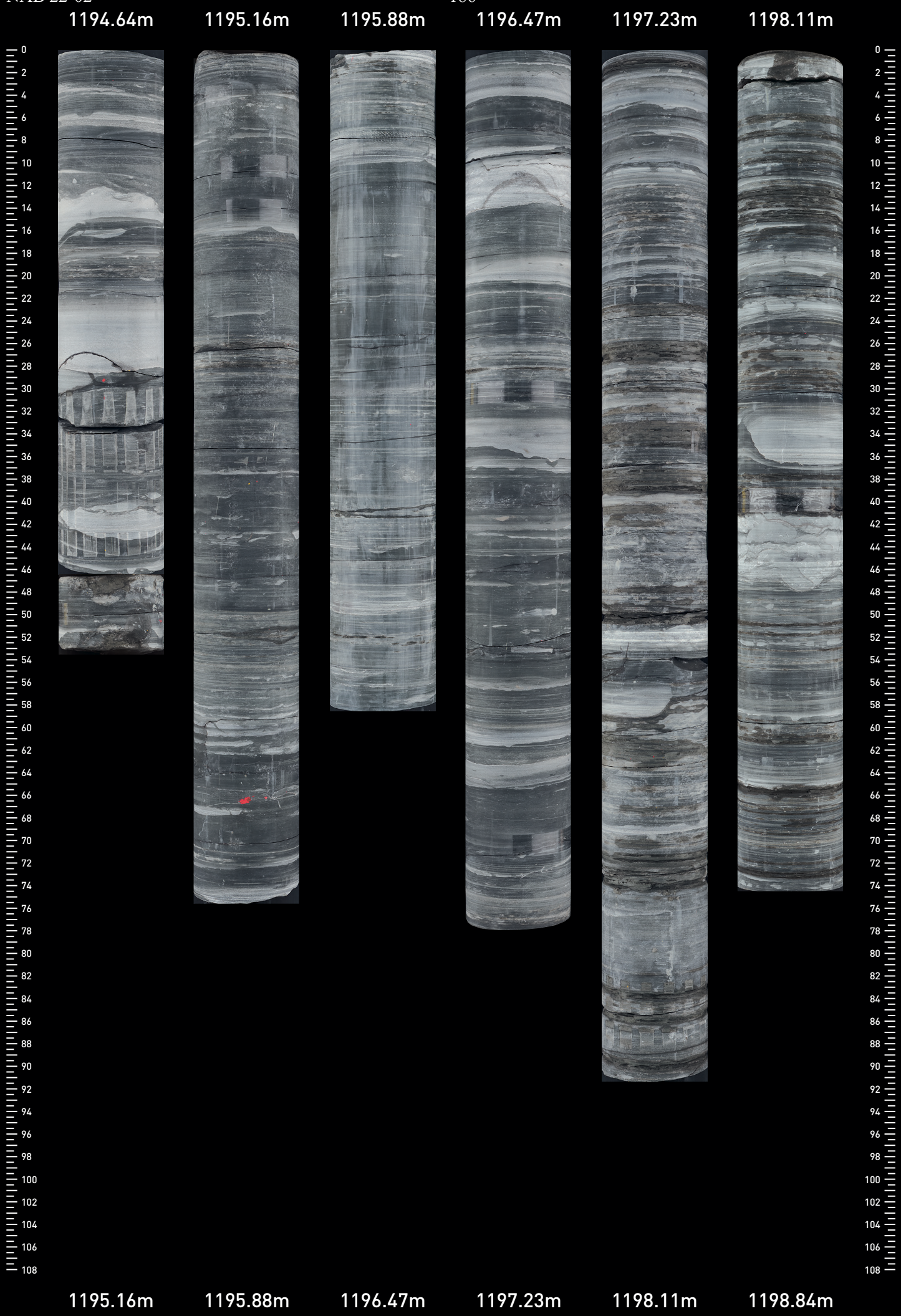

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1185.58m

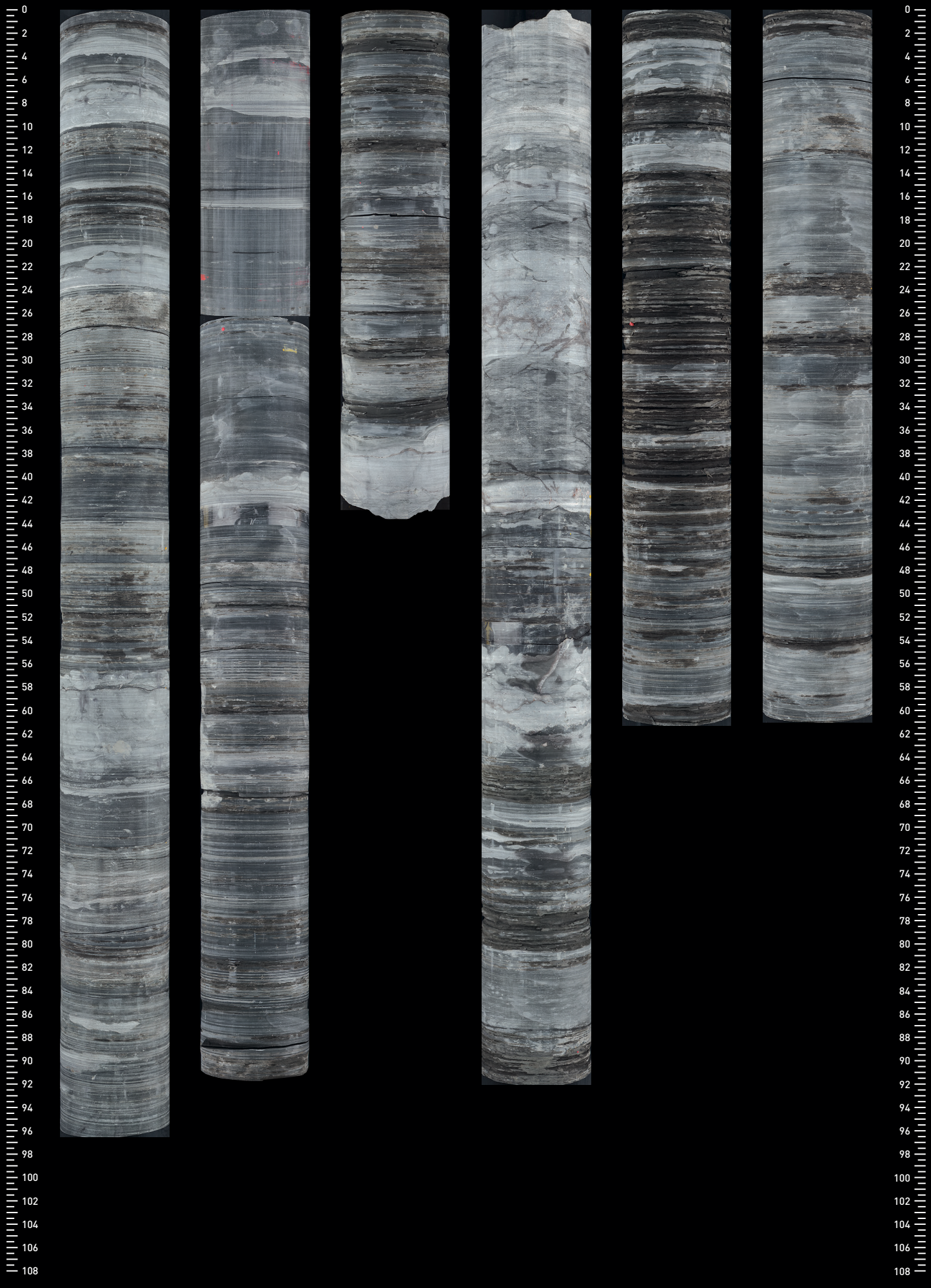
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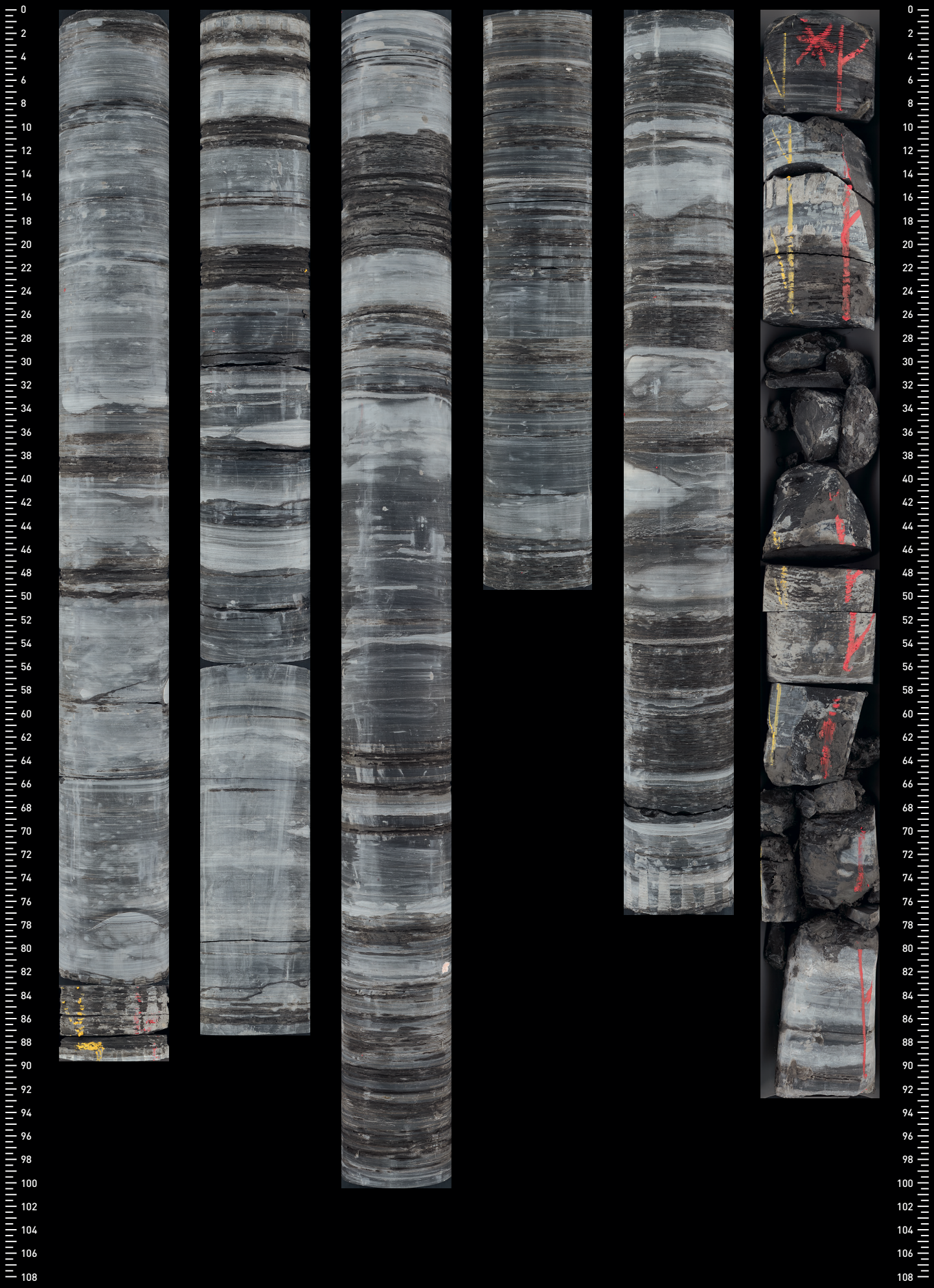
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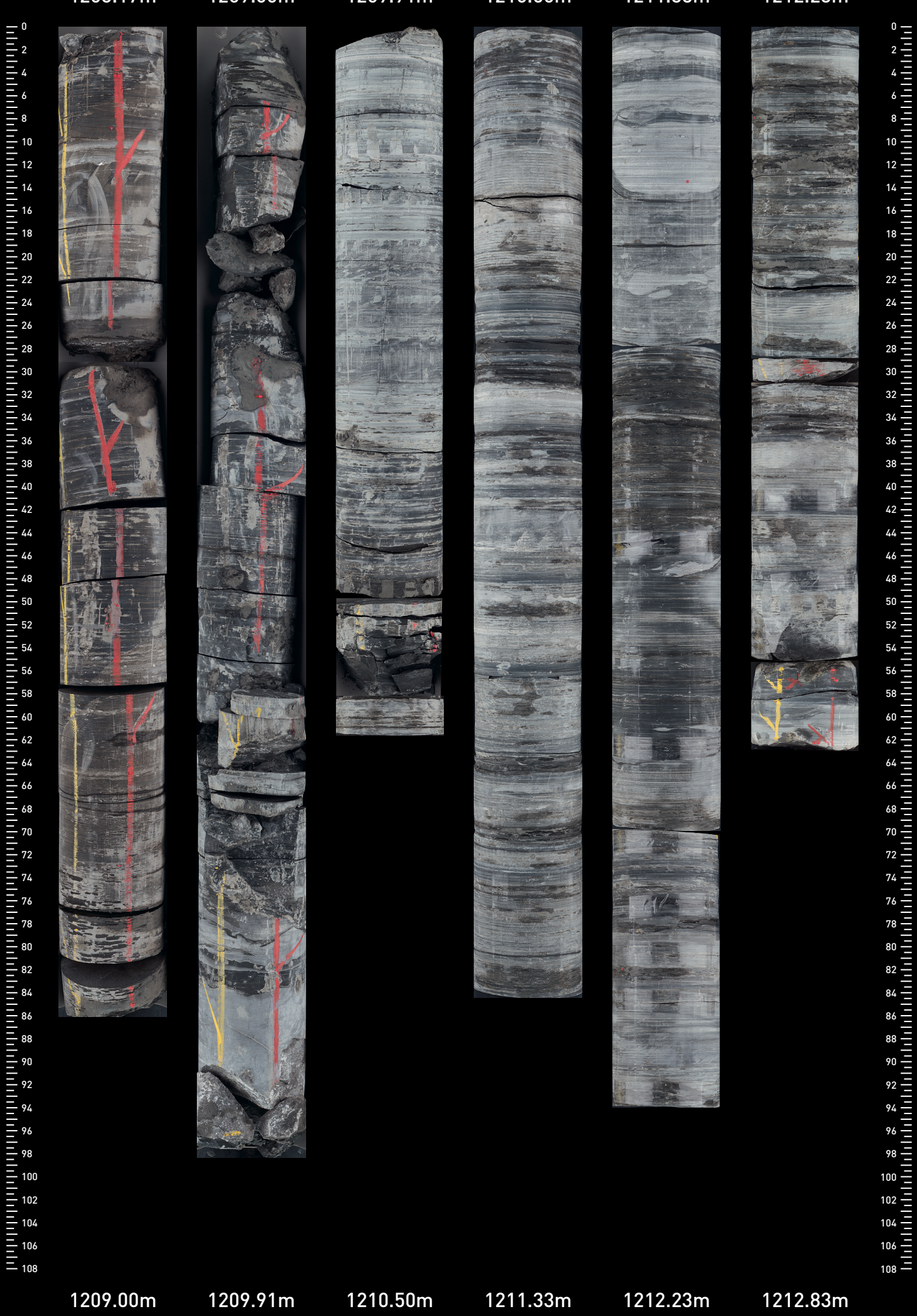

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1198.84m
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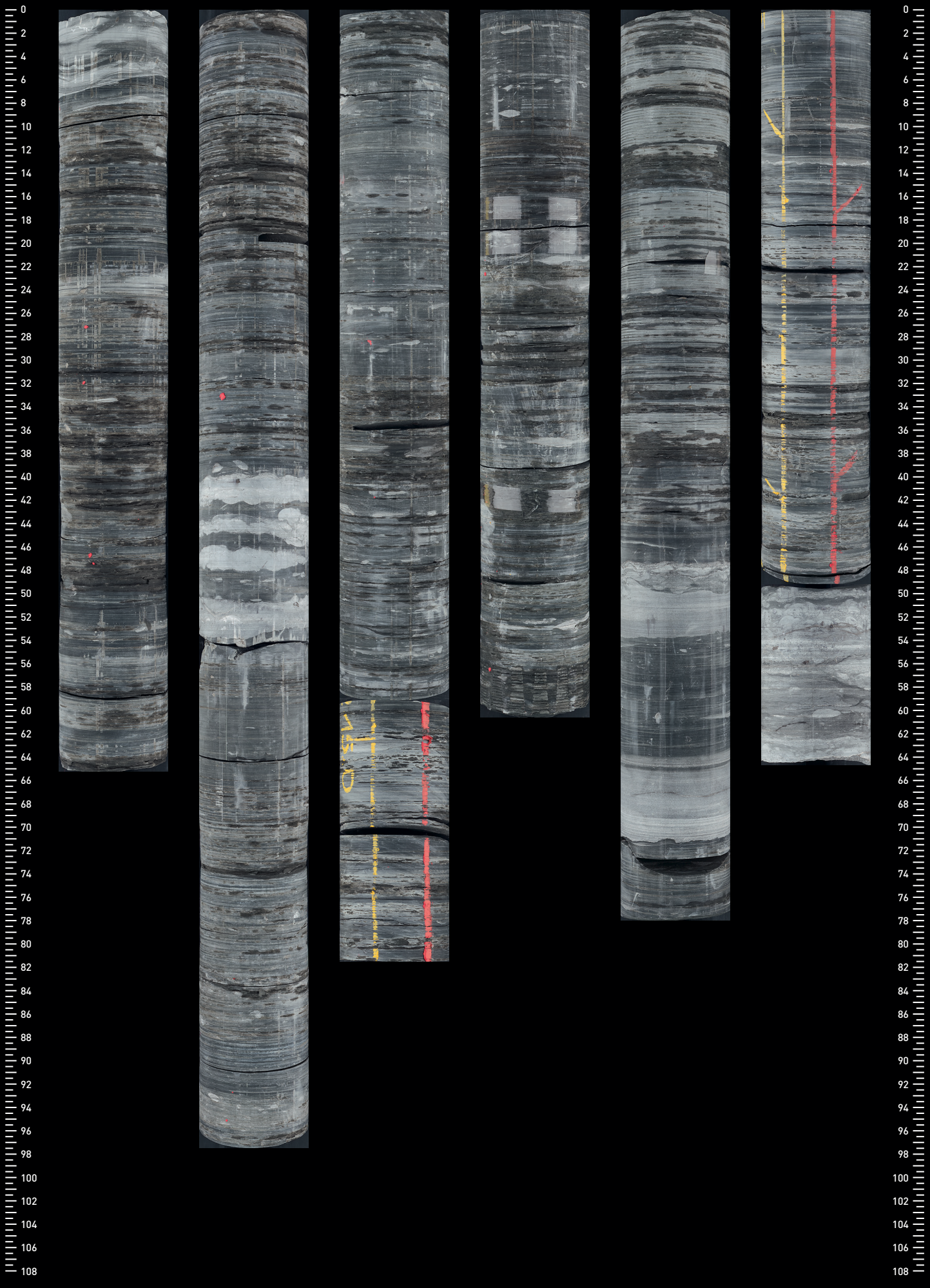
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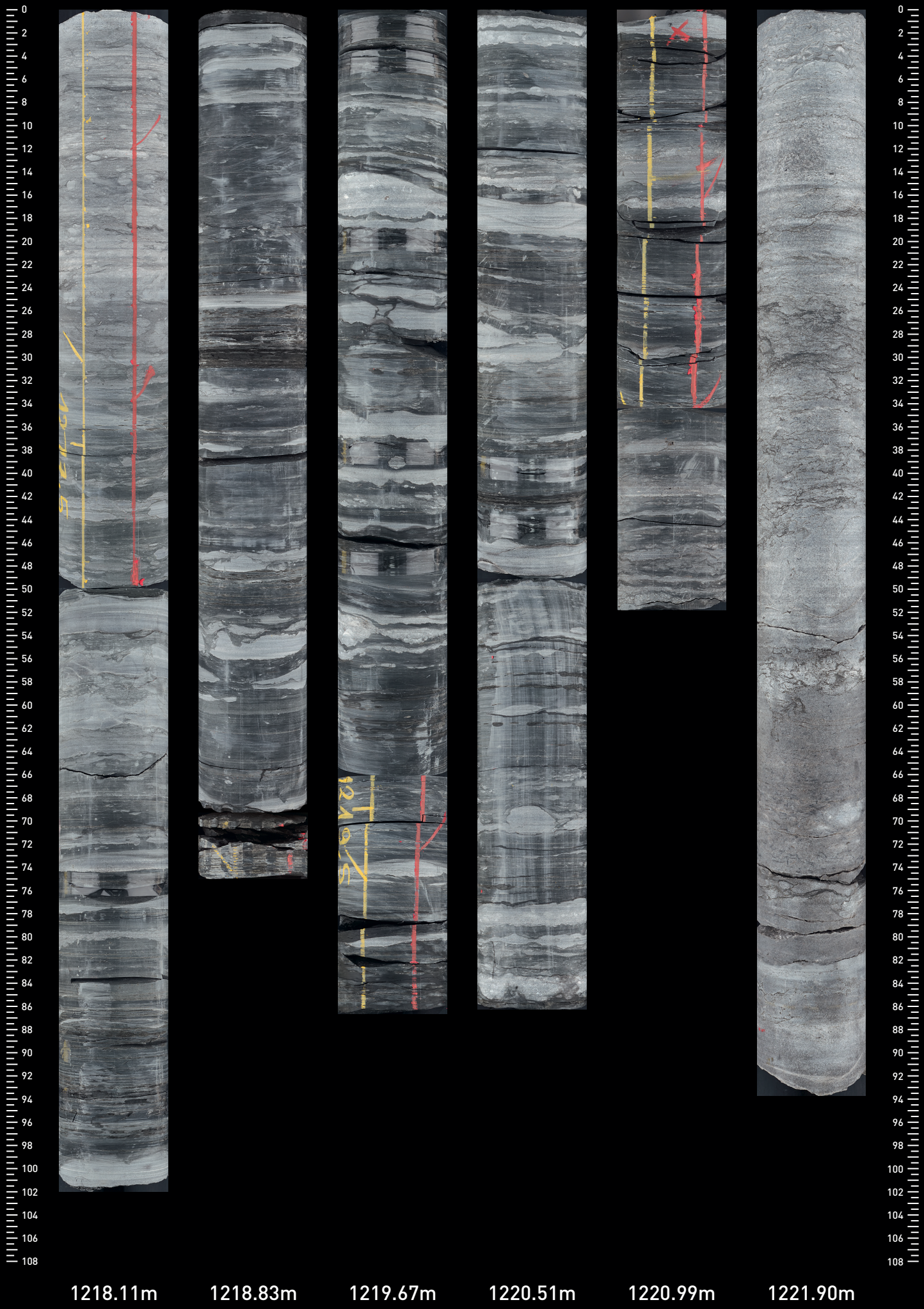
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202

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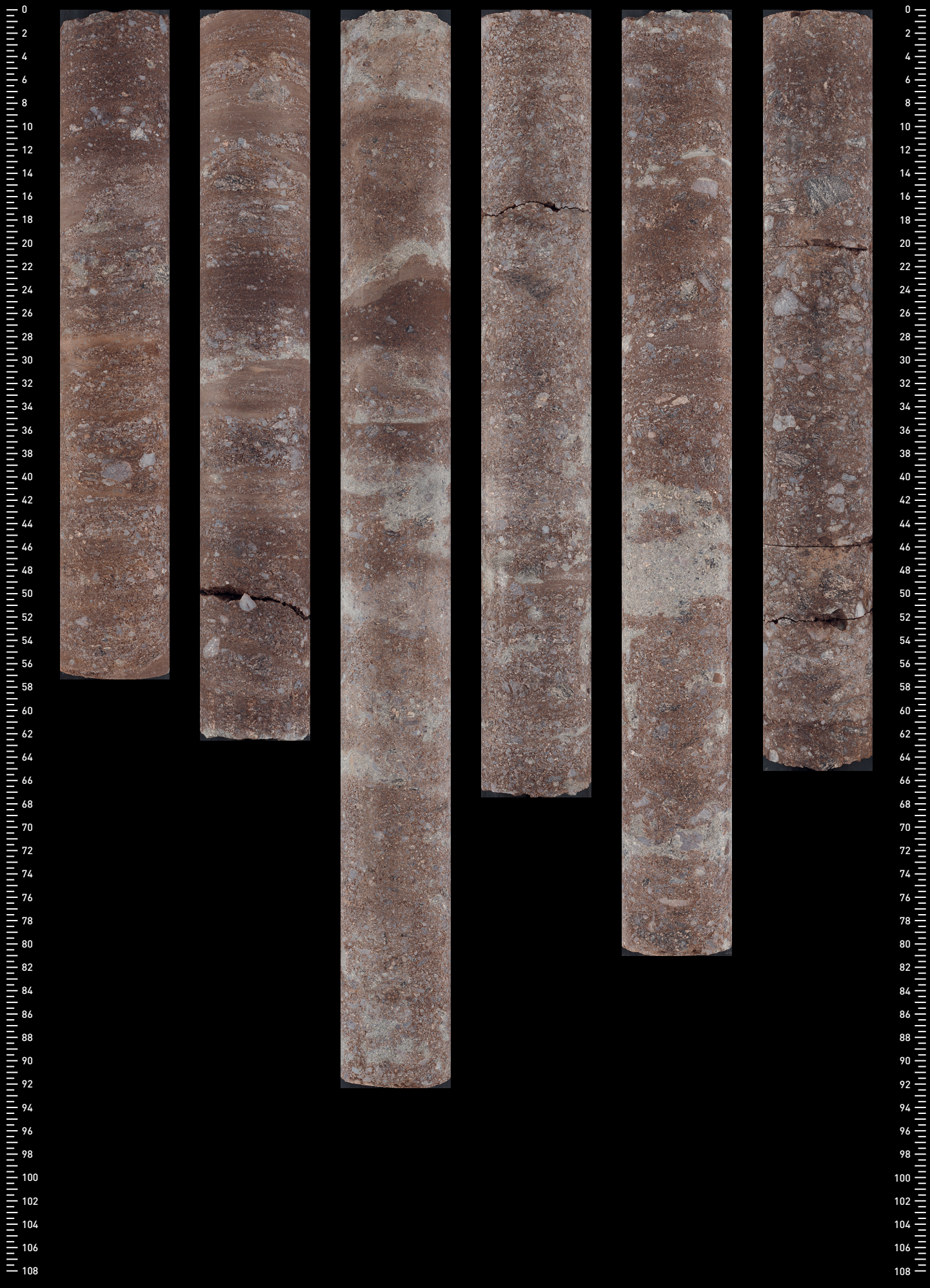
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1286.04m 1286.87m 1287.50m 1288.12m

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