Arbeitsbericht NAB 22-04

TBO Bachs-1-1: Data Report

Dossier II Core Photography

August 2023

National Cooperative
for the Disposal of
Radioactive Waste

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Switzerland
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Dossier II Core Photography

August 2023

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[1] Maya & Daniele
[2] Nagra

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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 Dossier was prepared by:
D. Kaehr (photography post-processing and core photograph composite design and compilation)
H.P. Weber (project management, conceptualisation, QC and writing)
M. Stockhecke (QC sanner and pictures)

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 Bachs-1-1 borehole.

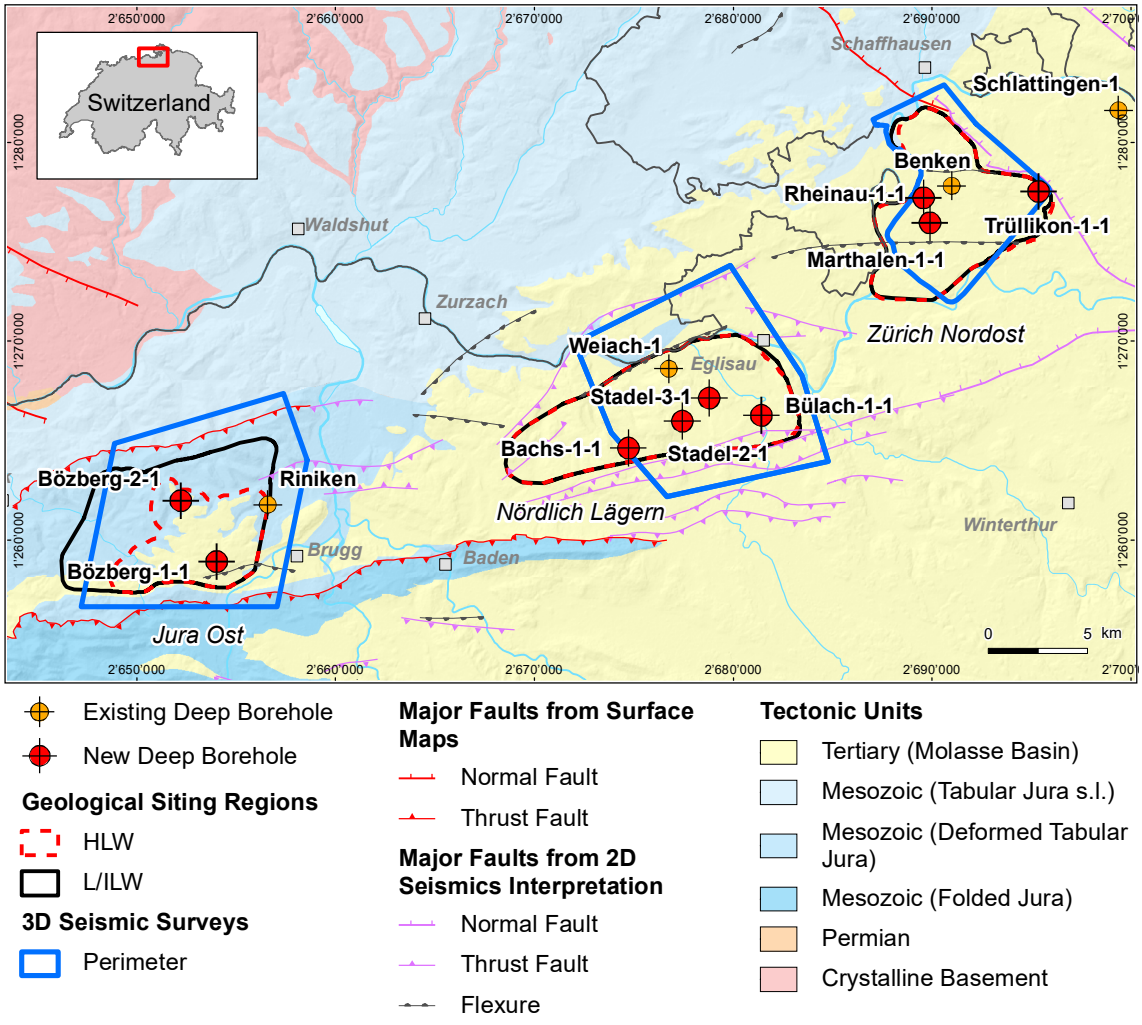


Fig. 1-1: Tectonic overview map with the three siting regions under investigation

1.2 Location and specifications of the borehole

The Bachs-1-1 (BAC1-1) exploratory borehole is the ninth (and last) 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 1'306.26 m (MD)[1]. The borehole specifications are provided in Tab. 1-1.

Due to a loss of a measurement tool (dilatometer), the borehole was cemented up to 500 m MD and a sidetrack was initiated with a kickoff point (KOP) at about 600 m MD . This sidetrack was labelled Bachs-1-1B (BAC1-1B). BAC1-1B reached a final depth of 952 m MD but was abandoned during borehole reaming operations due to entering the original borehole BAC1-1. Therefore, the vertical borehole BAC1-1 was used again for the remaining investigations. For easier communication and labelling, the name BAC1-1 is generally used for this borehole, including the sidetrack, unless stated otherwise. A detailed description of all technical details about the drilling process can be found in Dossier I.

Tab. 1-1: General information about the BAC1-1 borehole

Siting region	Nördlich Lägern
Municipality	Bachs (Canton Zürich / ZH), Switzerland
Drill site	Bachs-1 (BAC1)
Borehole	Bachs-1-1 (BAC1-1)
Coordinates	LV95: 2'674'769.089 / 1'264'600.698
Elevation	Ground level = top of rig cellar: 450.35 m above sea level (asl)
Borehole depth	1'306.26 m measured depth (MD) below ground level (bgl)
Drilling period	10th September 2021 – 23rd April 2022 (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 – 700 m: Bentonite & polymers 700 – 1'057 m: Potassium silicate & polymers[3] 1'057 – 1'129 m: Water & polymers 1'129 – 1'306.26 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[4] of the main lithostratigraphic boundaries in the BAC1-1 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] Including sidetrack.

[4] 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.

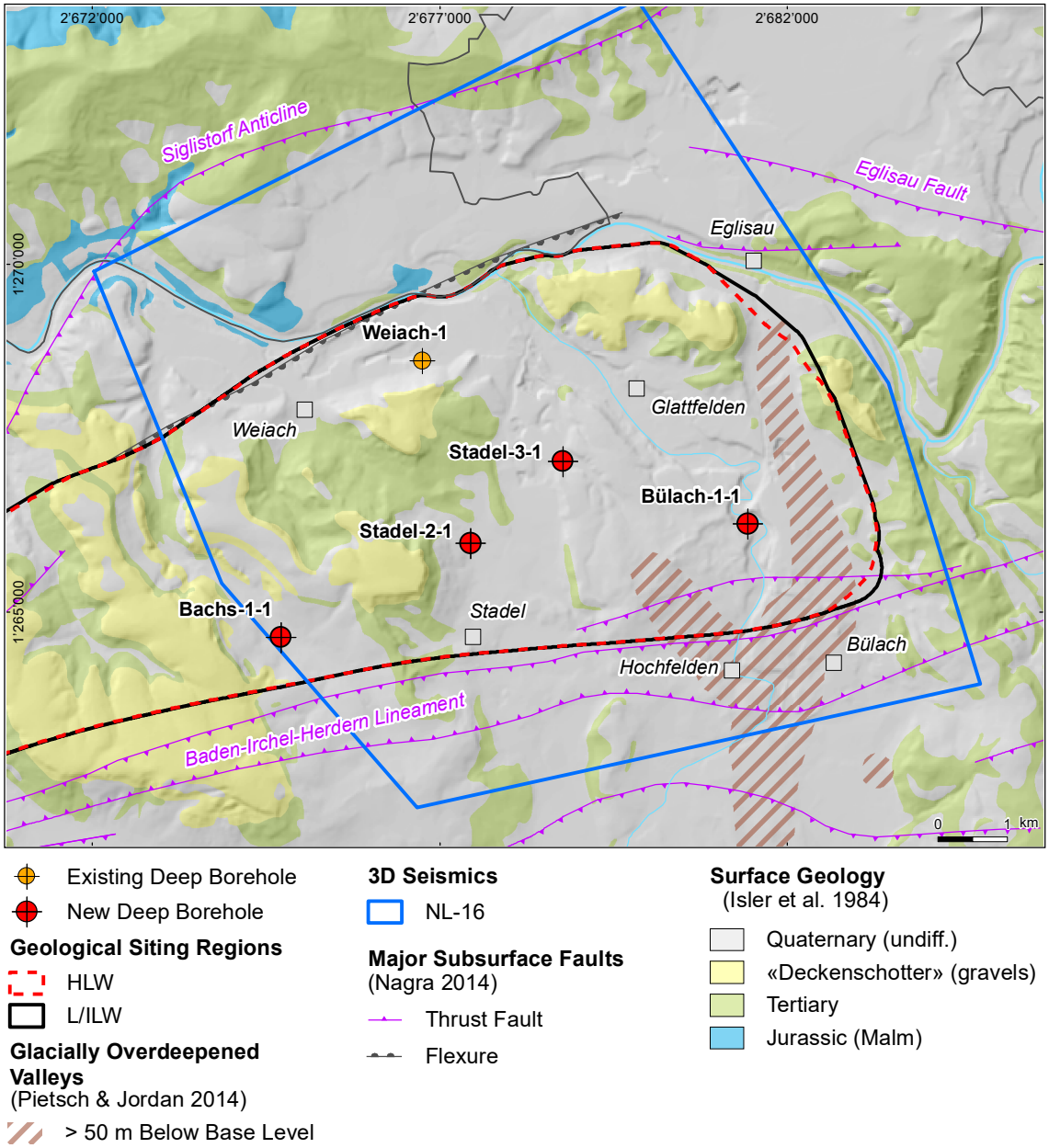


Fig. 1-2: Overview map of the investigation area in the Nördlich Lägern siting region with the location of the BAC1-1 borehole in relation to the boreholes Weiach-1, BUL1-1, STA3-1 and STA2-1

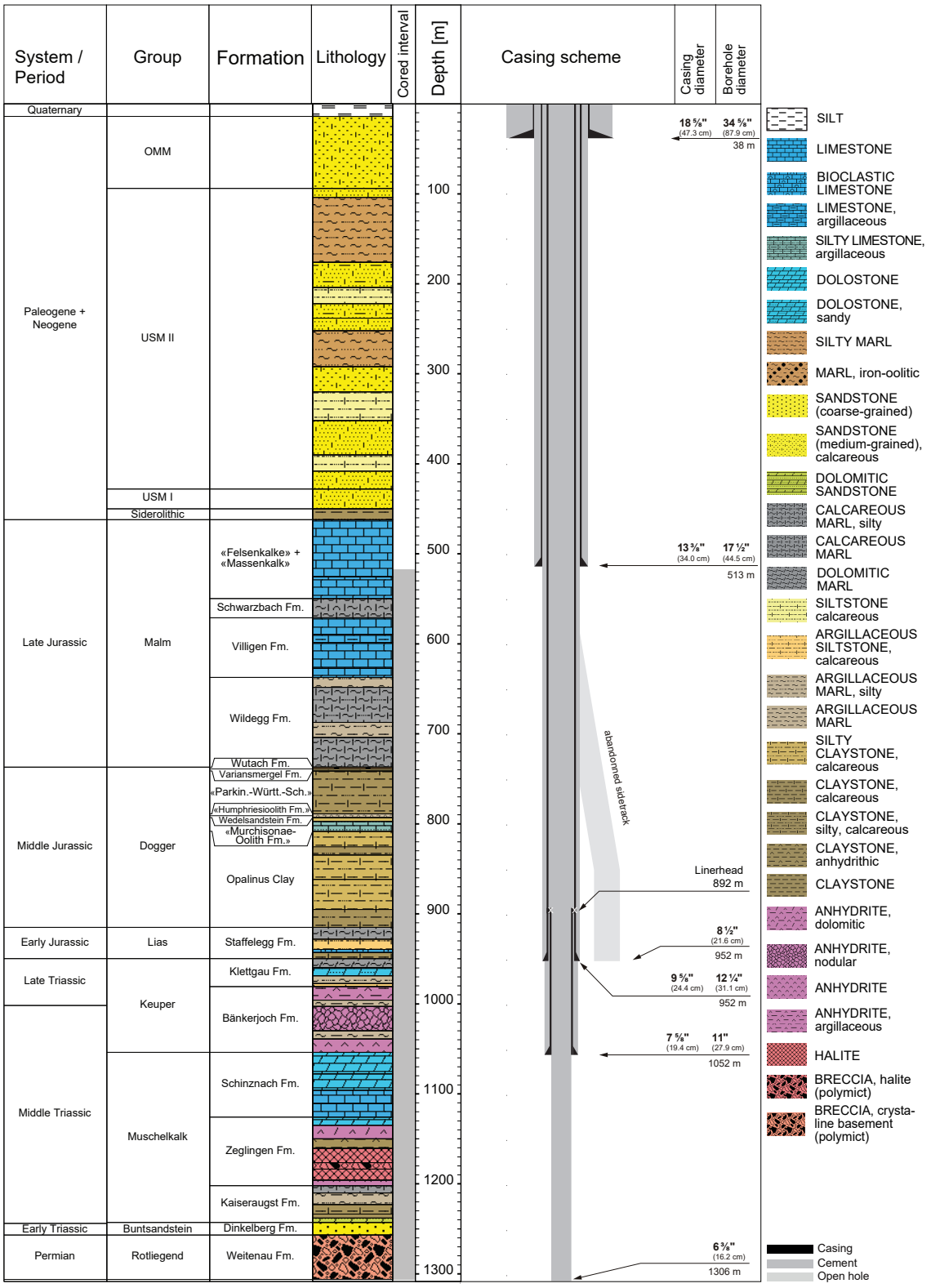


Fig. 1-3: Lithostratigraphic profile and casing scheme for the BAC1-1 borehole[5]

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

Tab. 1-2: Core and log depth for the main lithostratigraphic boundaries in the BAC1-1 borehole[6]

System / Period	Group	Formation		Core top depth in m (MD)	Log top depth in m (MD)	
Quaternary				**14**		—
Paleogene + Neogene	OMM			94		—
	USM			450		—
	Siderolithic			**462**		—
Jurassic	Malm	«Felsenkalke» + «Massenkalk»		549.69	550.03	—
		Schwarzbach Formation		570.98	571.29	—
		Villigen Formation		637.31	637.55	—
		Wildegg Formation		737.05	737.32	—
	Dogger	Wutach Formation		738.81	739.08	—
		Variansmergel Formation		741.22	741.47	—
		«Parkinsoni-Württembergica-Schichten»		788.92	789.12	—
		«Humphriesioolith Formation»		791.05	791.25	—
		Wedelsandstein Formation		793.11	793.31	—
		«Murchisonae-Oolith Formation»		808.34	808.57	—
		Opalinus Clay		914.91	915.30	—
	Lias	Staffelegg Formation		**949.73**	**950.07**	—
Triassic	Keuper	Klettgau Formation		980.93	981.27	—
		Bänkerjoch Formation		1053.90	1054.30	—
	Muschelkalk	Schinznach Formation		1125.75	1126.20	—
		Zeglingen Formation		1202.03	1202.43	—
		Kaiseraugst Formation		1242.82	1243.12	—
	Buntsandstein	Dinkelberg Formation		**1256.86**	**1257.26**	—
Permian	Rotliegend	Weitenau Formation	final depth	1306.26	1306.77	

[6] 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 BAC1-1 borehole

NAB 22-04 documents the majority of the investigations carried out in the BAC1-1 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 BAC1-1 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 22-04

Black marks the dossier at hand.

Dossier	Title	Authors
I	TBO Bachs-1-1: Drilling	P. Hinterholzer-Reisegger
II	**TBO Bachs-1-1: Core Photography**	**D. Kaehr, M. Stockhecke & H.P. Weber**
III	TBO Bachs-1-1: Lithostratigraphy	P. Jordan, P. Schürch, M. Schwarz, R. Felber, H. Naef, T. Ibele & F. Casanova
IV	TBO Bachs-1-1: Microfacies, Bio- and Chemostratigraphic Analysis	S. Wohlwend, H.R. Bläsi, S. Feist-Burkhardt, B. Hostettler, U. Menkveld-Gfeller, V. Dietze & G. Deplazes
V	TBO Bachs-1-1: Structural Geology	A. Ebert, E. Hägerstedt, S. Cioldi, L. Gregorczyk & F. Casanova
VI	TBO Bachs-1-1: Wireline Logging, Micro-hydraulic Fracturing and Pressure-meter Testing	J. Gonus, E. Bailey, J. Desroches & R. Garrard
VII	TBO Bachs-1-1: Hydraulic Packer Testing	R. Schwarz, R. Beauheim, L. Schlickenrieder, E. Manukyan & A. Pechstein
VIII	TBO Bachs-1-1: Rock Properties, Porewater Characterisation and Natural Tracer Profiles	E. Gaucher, L. Aschwanden, T. Gimmi, A. Jenni, M. Kiczka, M. Mazurek, P. Wersin, C. Zwahlen, U. Mäder & D. Traber
IX	*The geomechanical campaign in BAC-1-1 was limited to two oedometric tests. Hence, no dedicated Dossier IX was produced for NAB 22-04. The hydraulic conductivity values derived from the oedometric tests are documented in the Summary Plot.*	
X	TBO Bachs-1-1: Petrophysical Log Analysis	S. Marnat & J.K. Becker
	TBO Bachs-1-1: 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 BAC1-1 from 0 m to 1'306.26 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

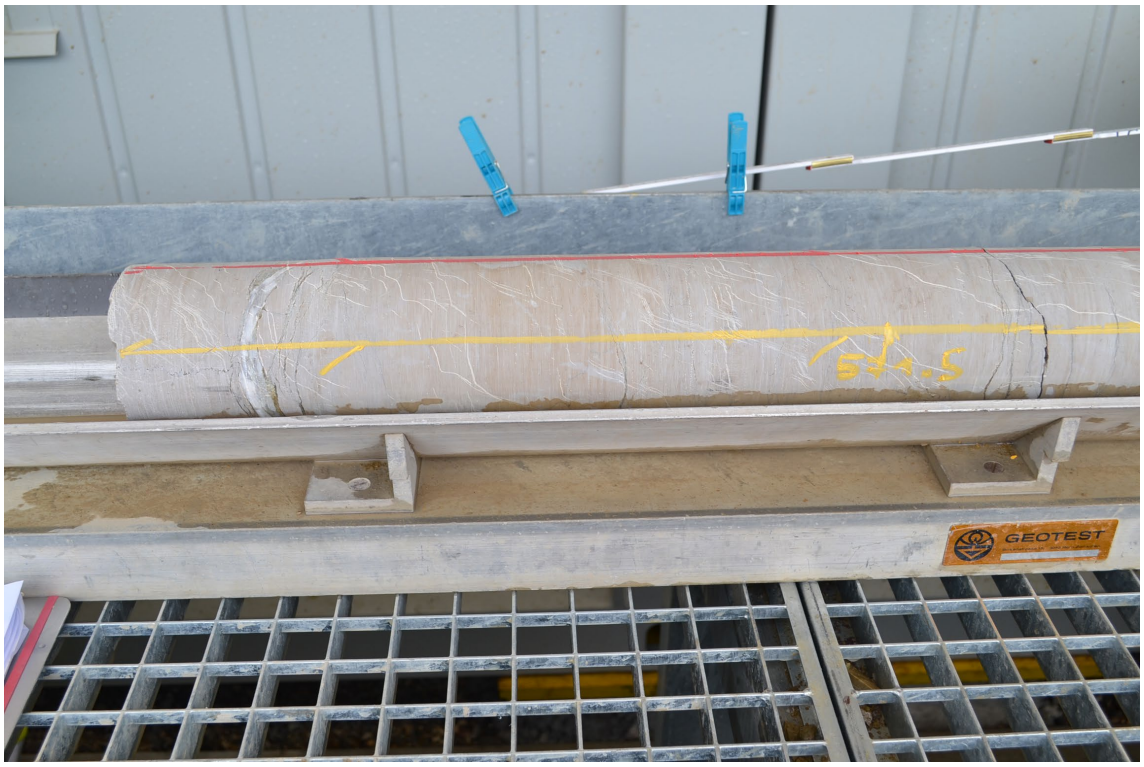


Fig. 2-6: Cleaned, measured and marked core

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

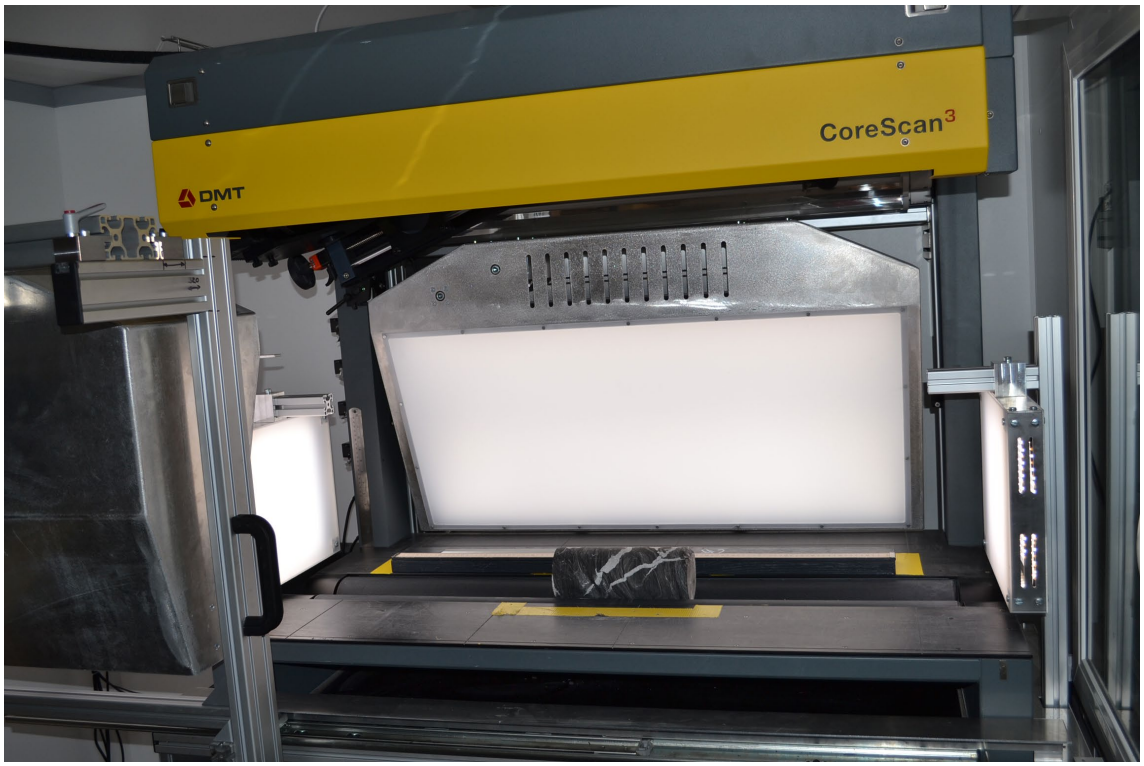


Fig. 2-7: Modified DMT CoreScan^3 system at the drill site

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.

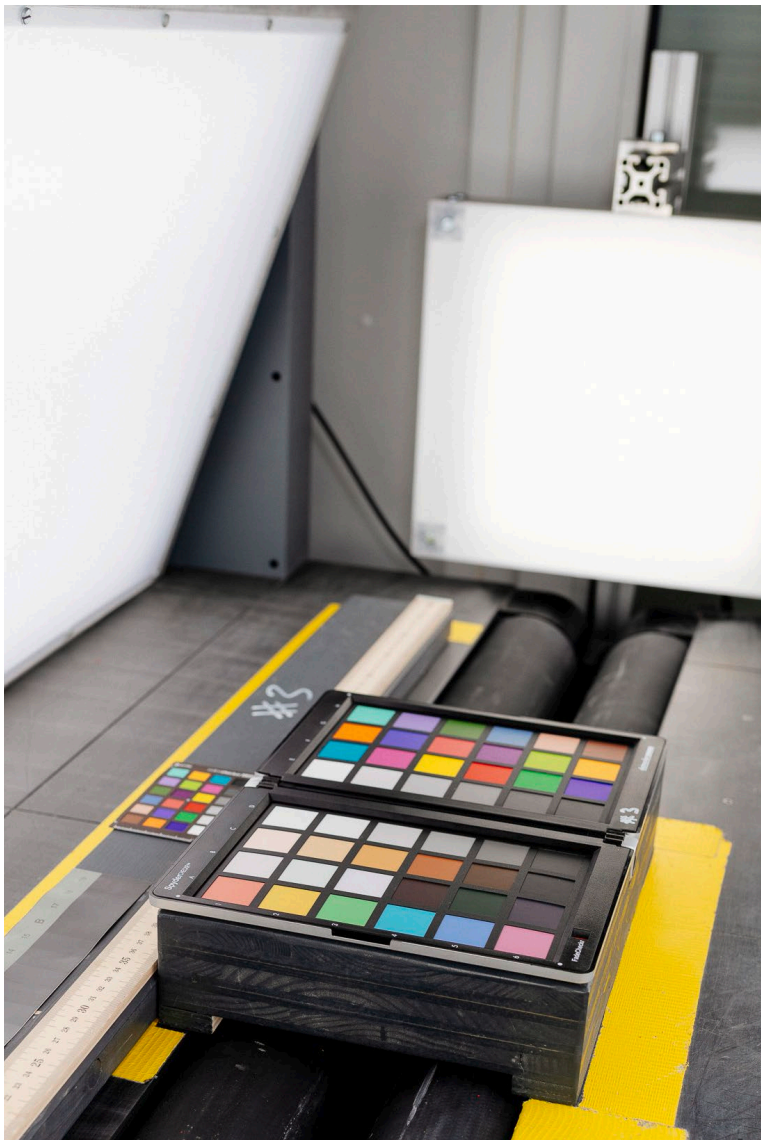


Fig. 2-8: Reference photograph setup of the CoreScan[3] system with a Datacolor Spyder-CHECKR 48 colour chart, a metre scale, a BST14 greyscale chart and an X-Rite ColorChecker Classic Mini colour chart

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)

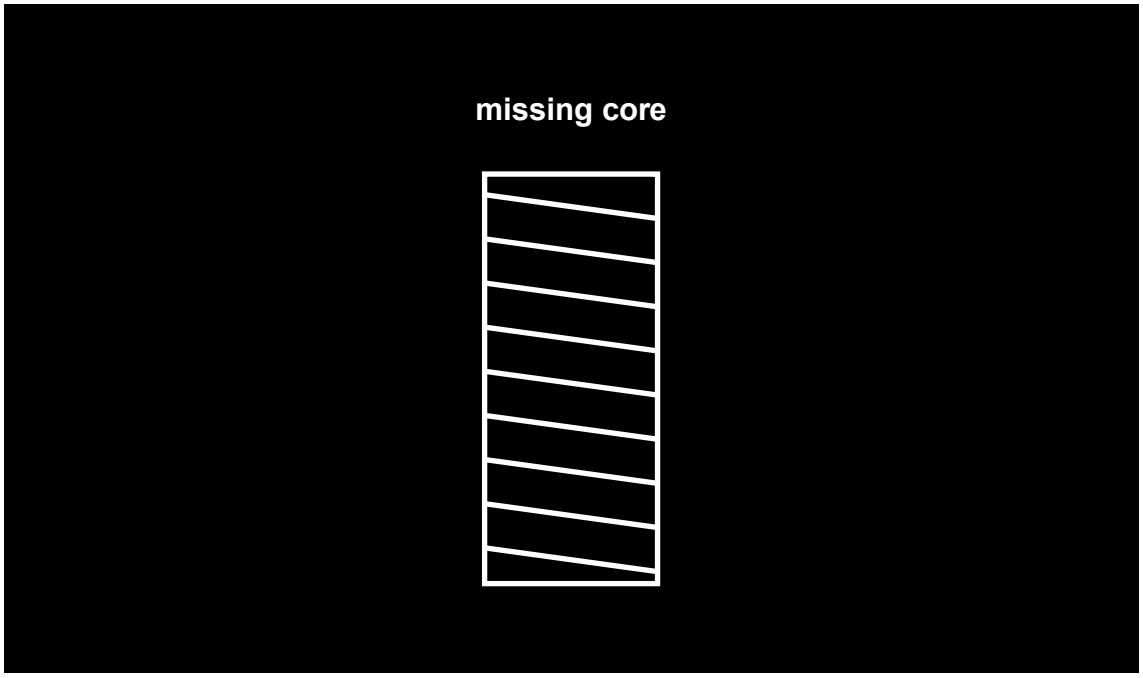


Fig. 2-10: White hachures signature used for missing core due to FIT pilot hole or drilling related technical issues in the composite displays

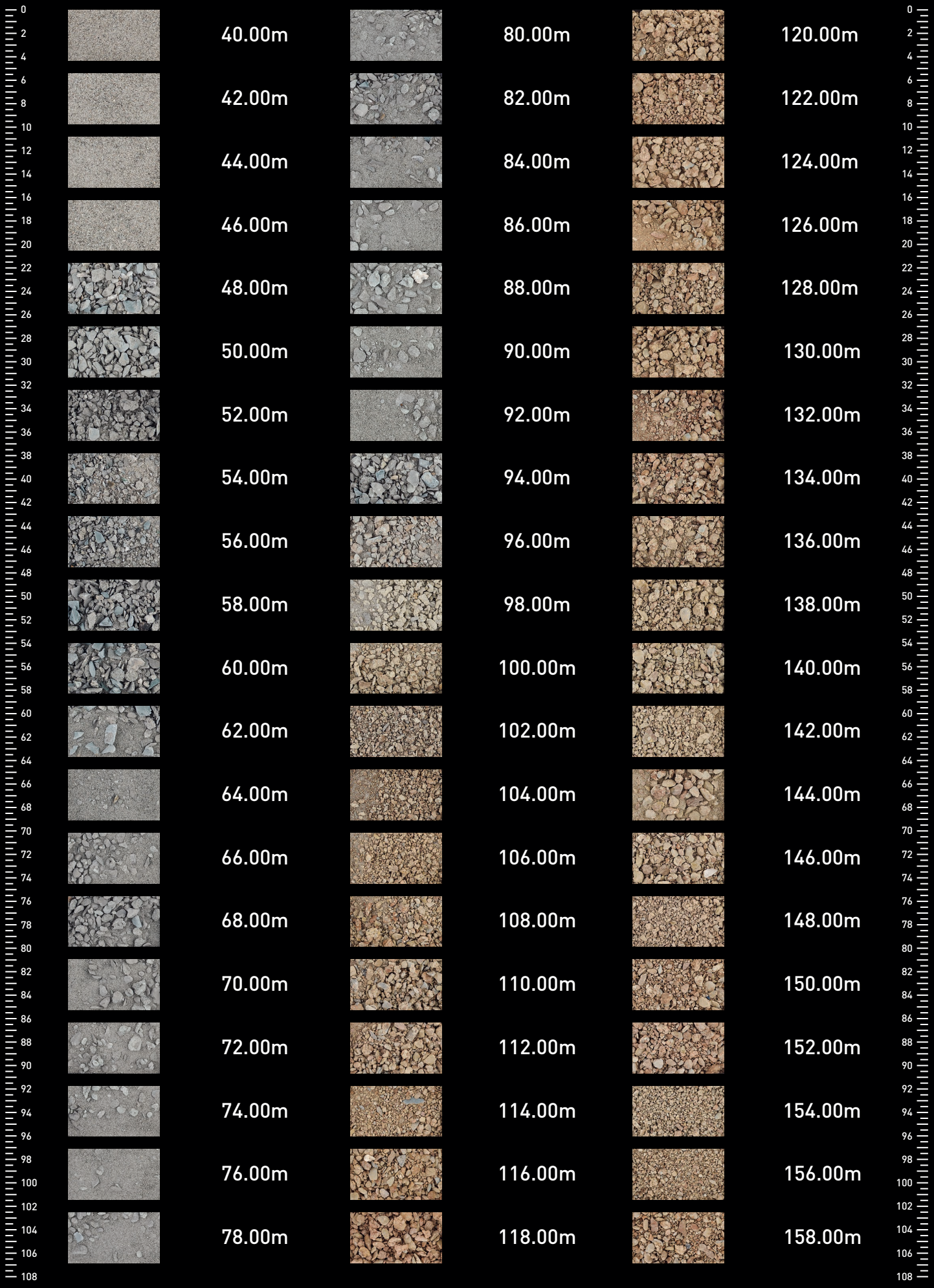
3 Bachs-1-1 core- and cuttings composites

2.00m 20.00m 38.00m



18.00m 36.00m 38.30m

40.00m 80.00m 120.00m



78.00m 118.00m 158.00m

160.00m 200.00m 240.00m



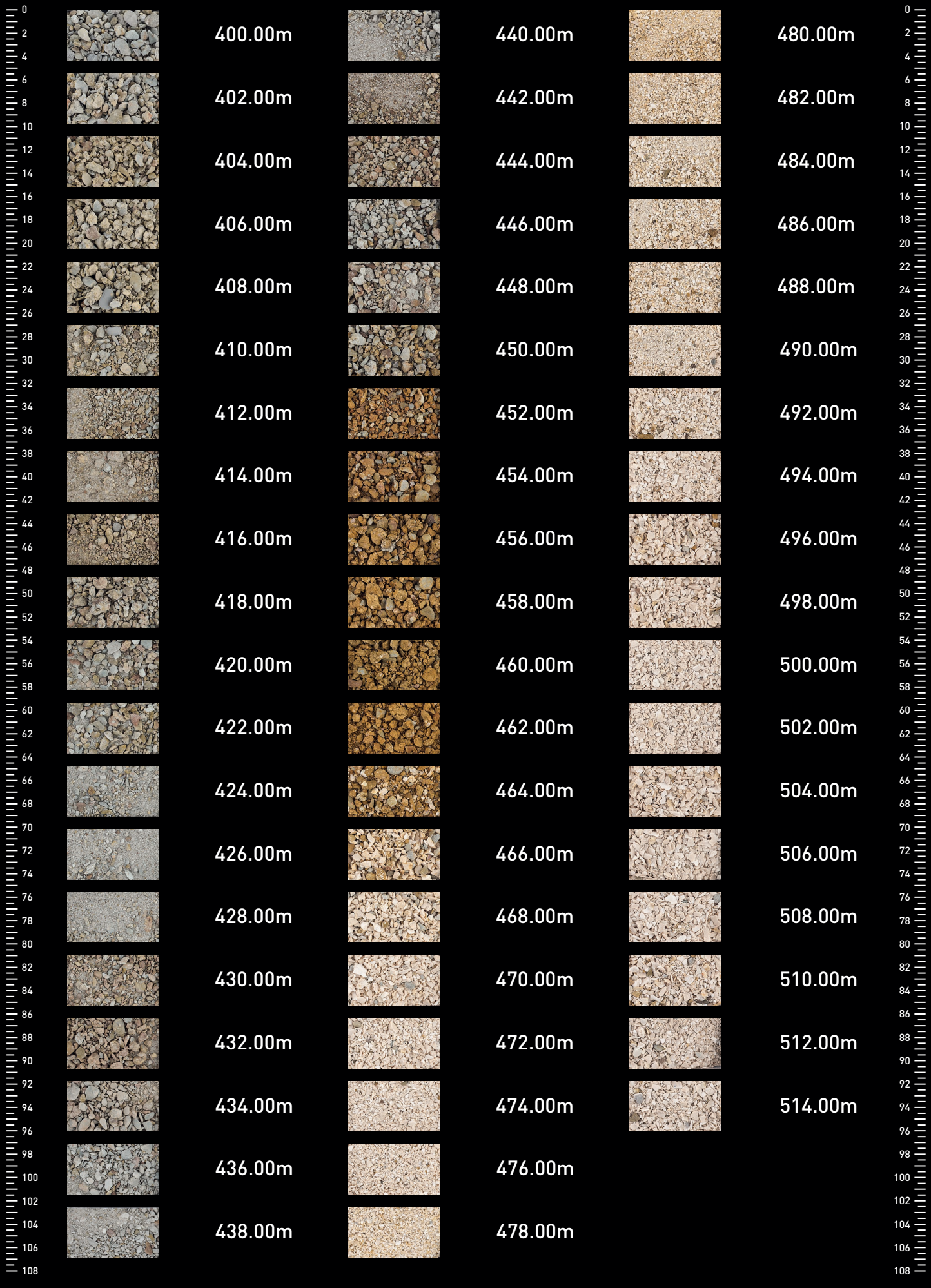
198.00m 238.00m 278.00m

280.00m 320.00m 360.00m



318.00m 358.00m 398.00m

400.00m 440.00m 480.00m



438.00m 478.00m 514.00m

517.16m 518.00m 518.90m 519.73m 520.10m 520.85m



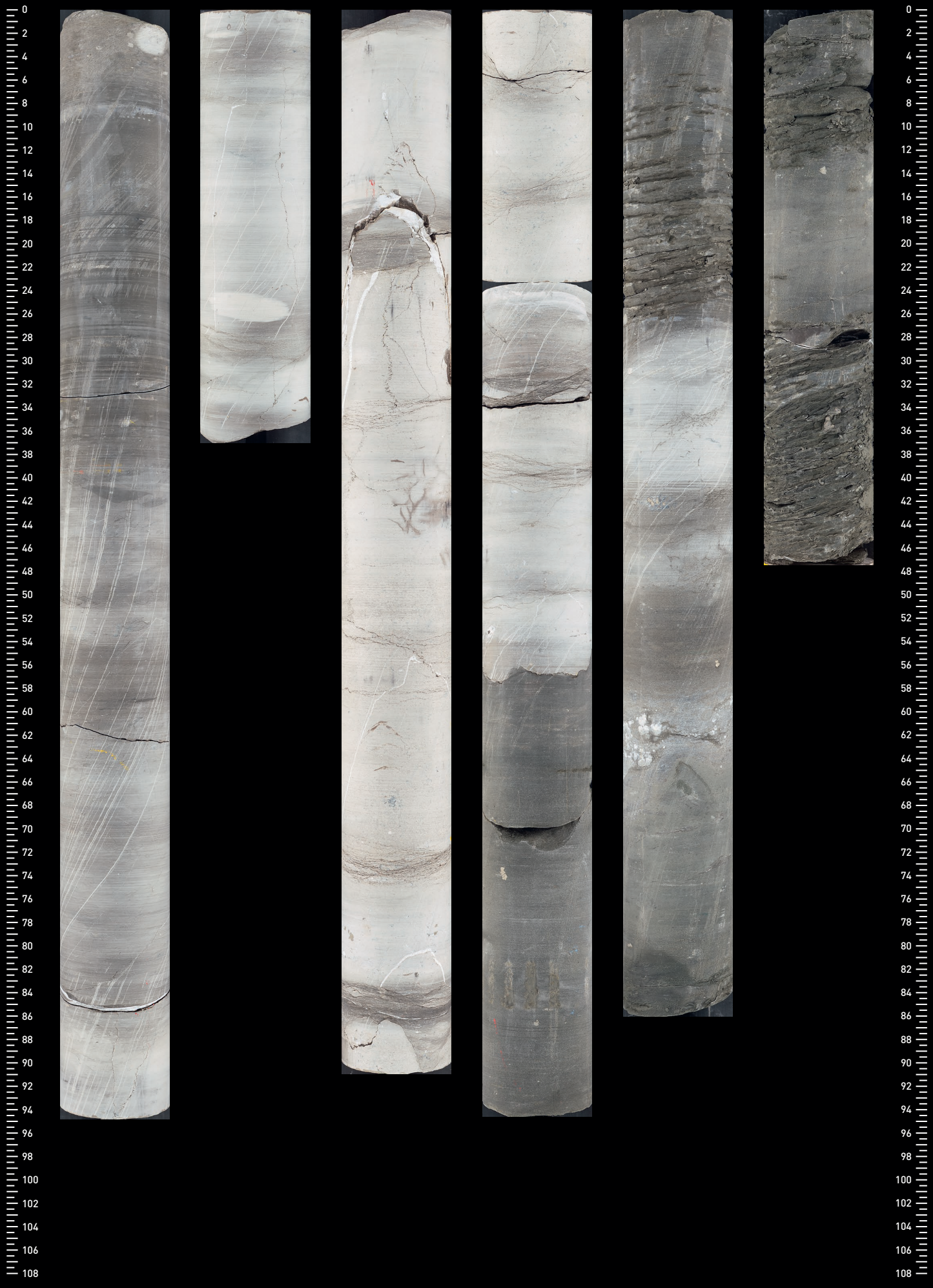
518.00m 518.90m 519.73m 520.10m 520.85m 521.50m

521.50m 522.00m 522.90m 523.85m 524.50m 525.35m



522.00m 522.90m 523.85m 524.50m 525.35m 525.98m

525.98m 526.88m 527.23m 528.12m 529.03m 529.87m



526.88m 527.23m 528.12m 529.03m 529.87m 530.31m

530.31m 531.10m 531.99m 532.72m 533.63m 534.49m



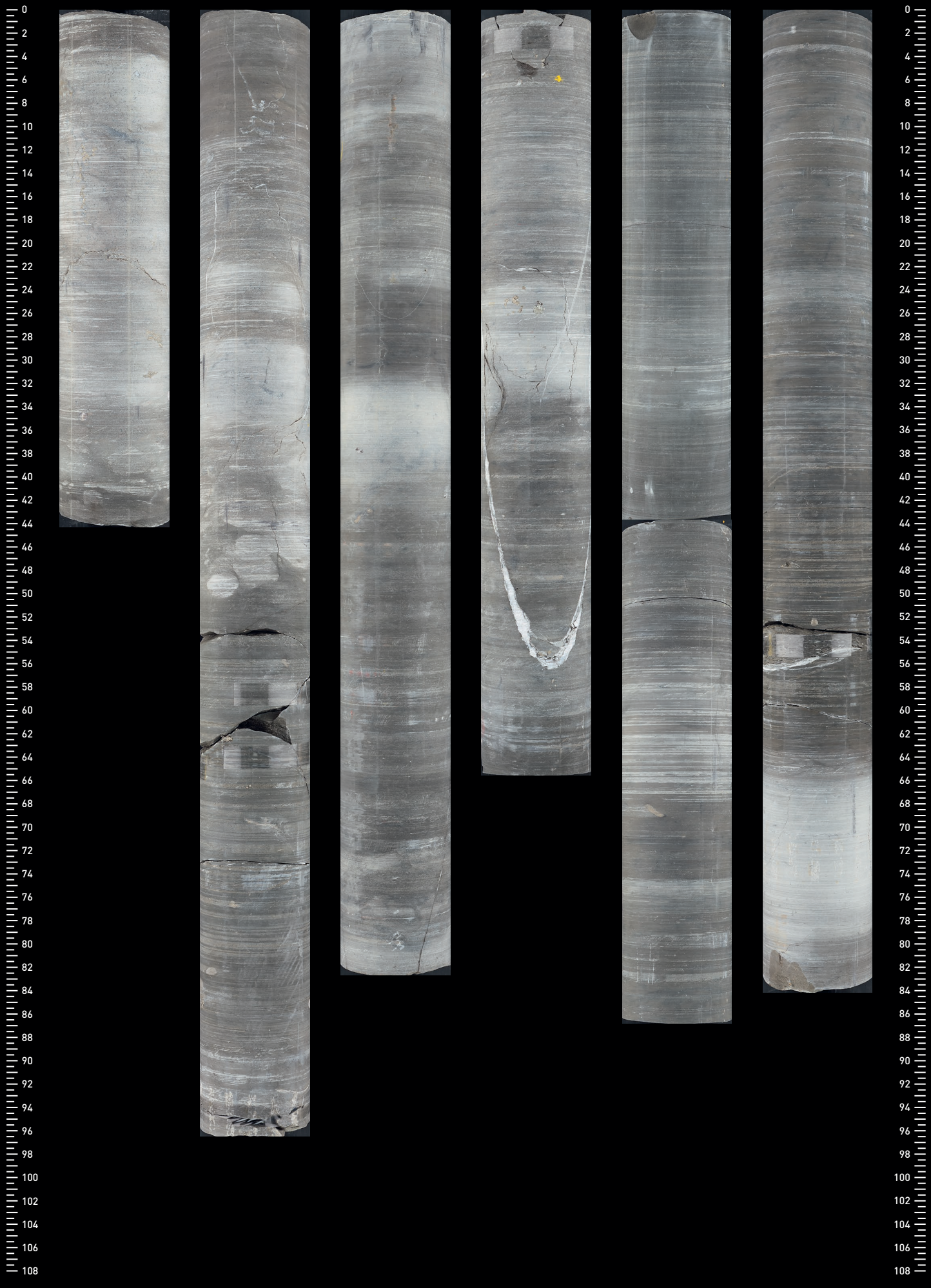
531.10m 531.99m 532.72m 533.63m 534.49m 534.95m

534.95m 535.80m 536.70m 537.20m 537.98m 538.85m



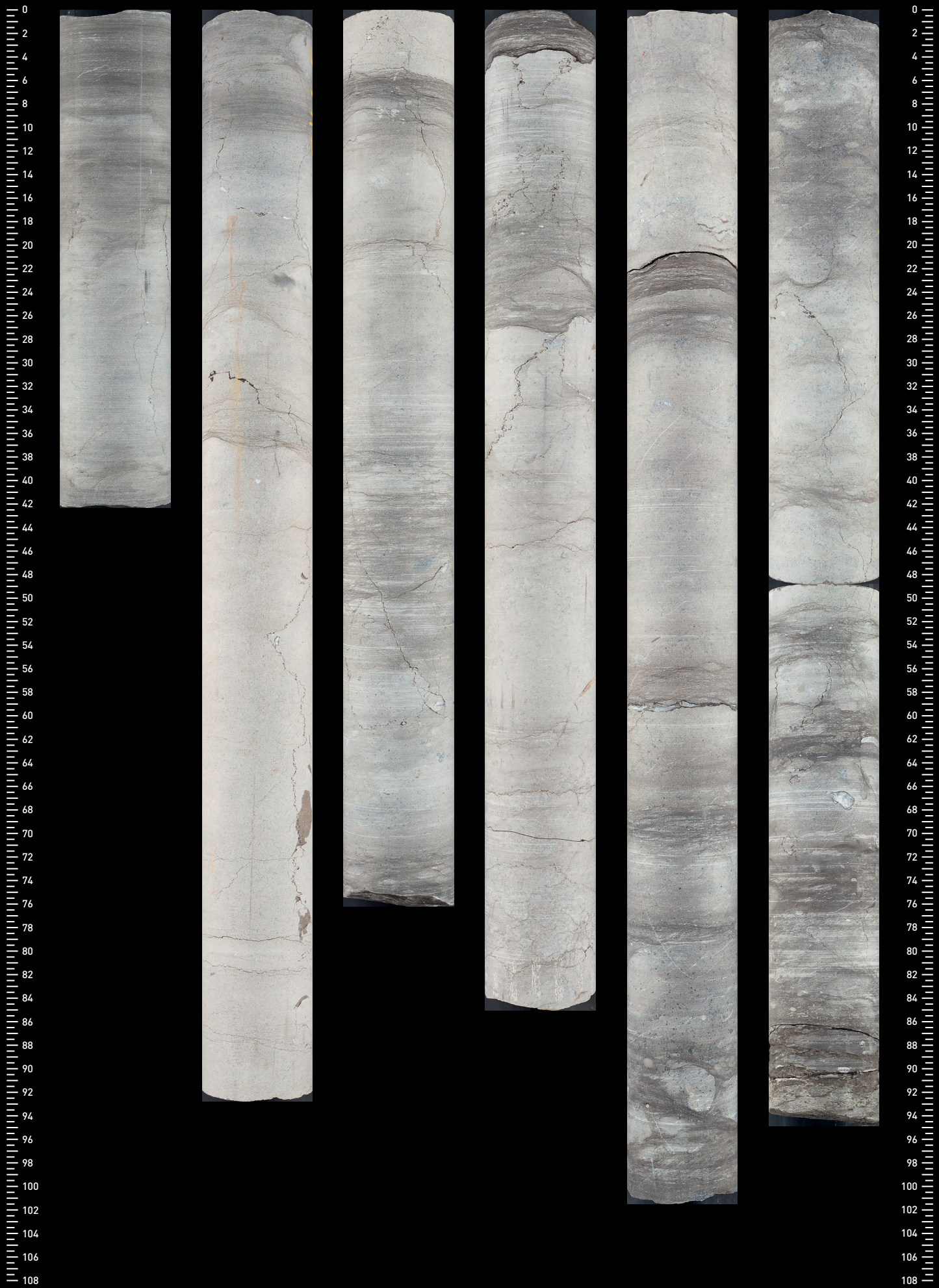
535.80m 536.70m 537.20m 537.98m 538.85m 539.58m

539.58m 540.00m 540.94m 541.75m 542.40m 543.24m



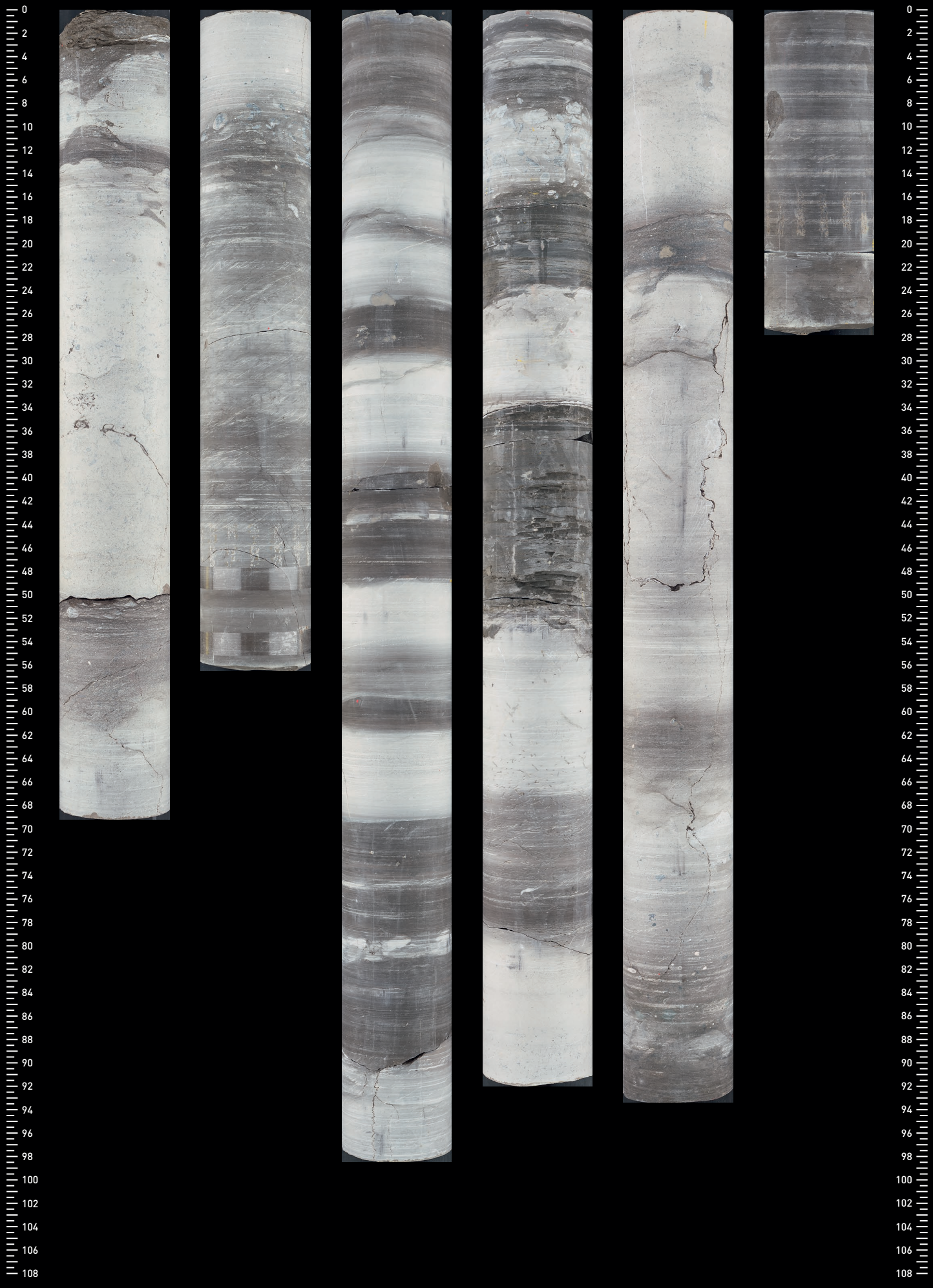
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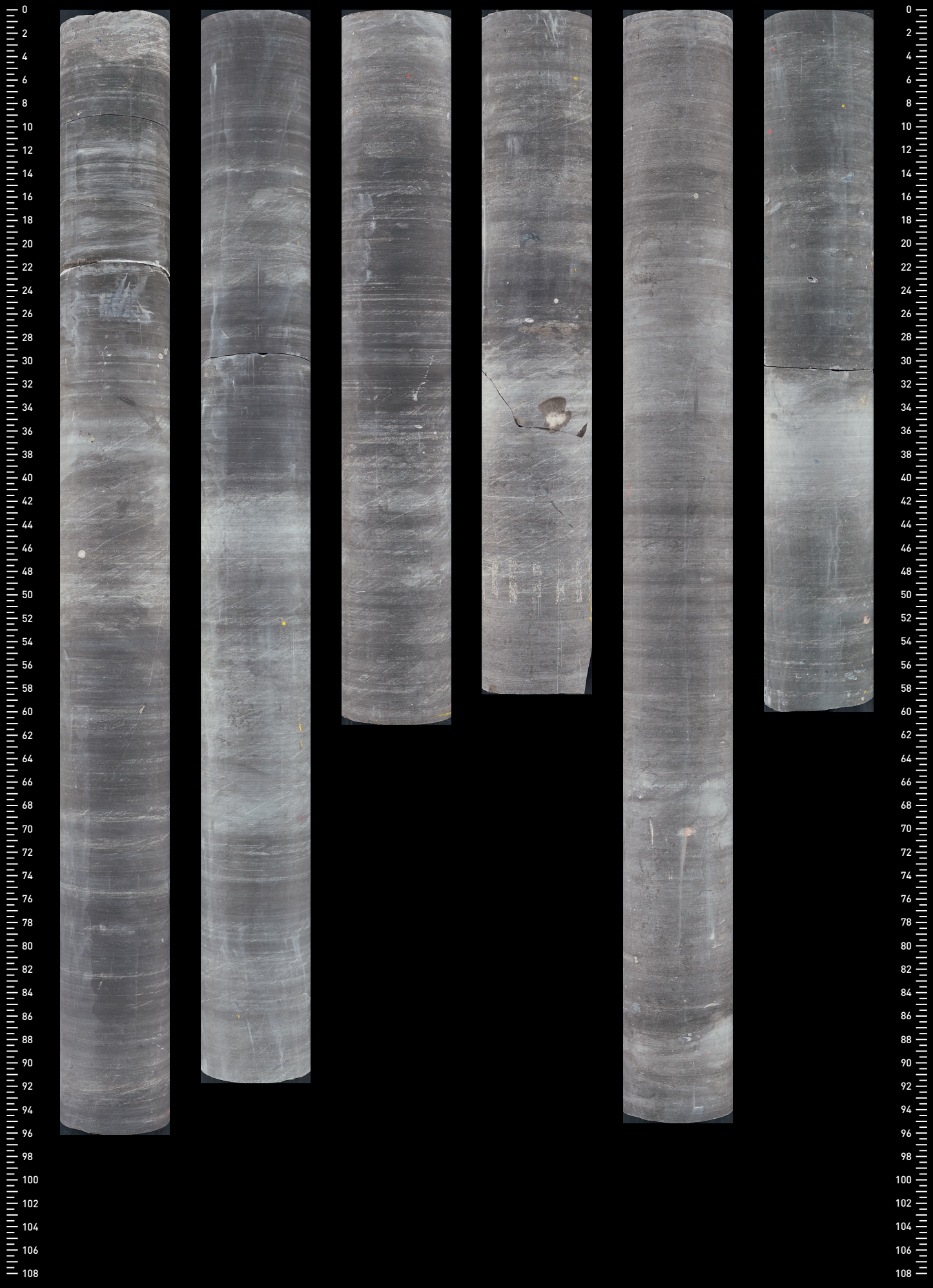
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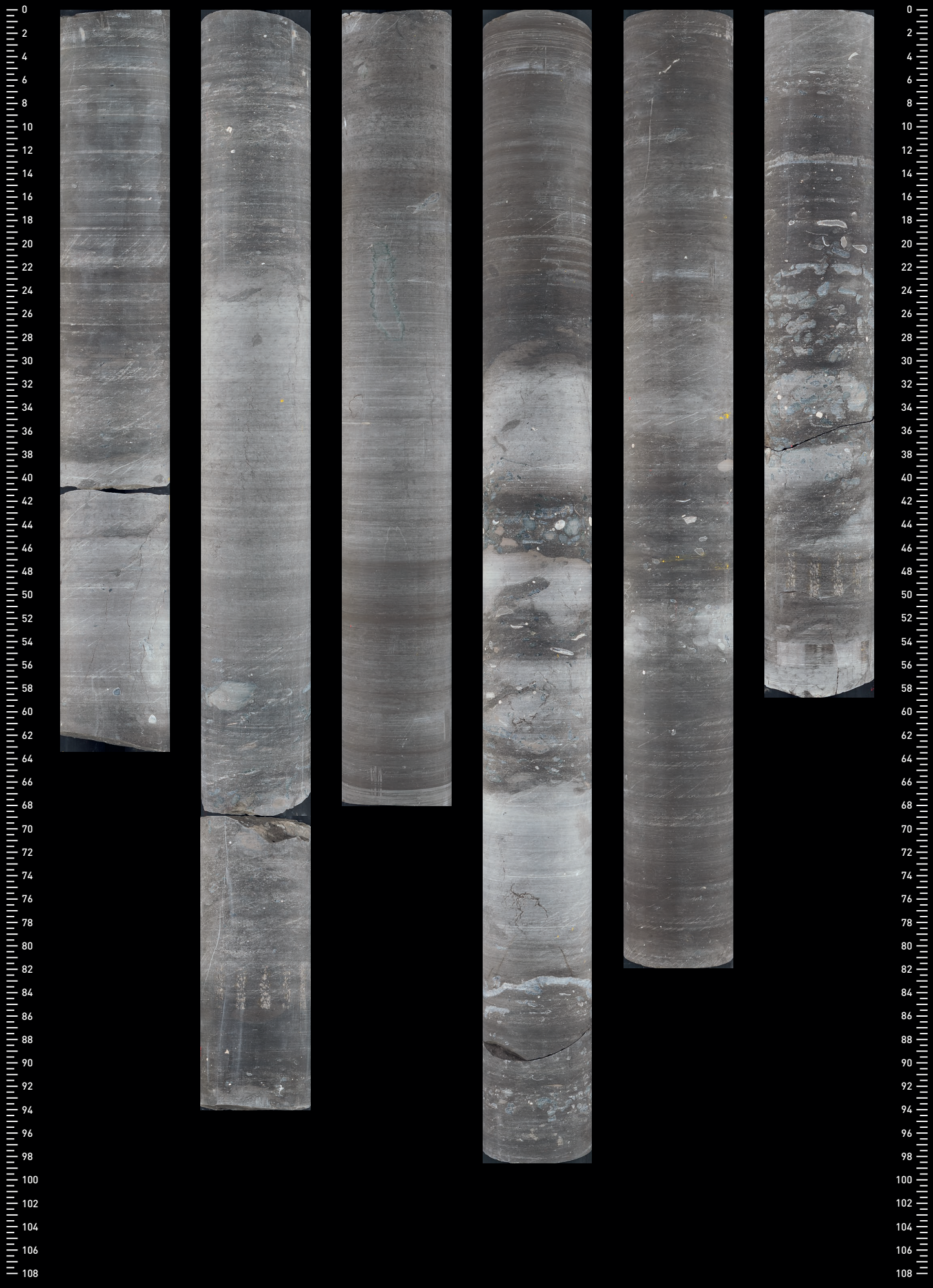
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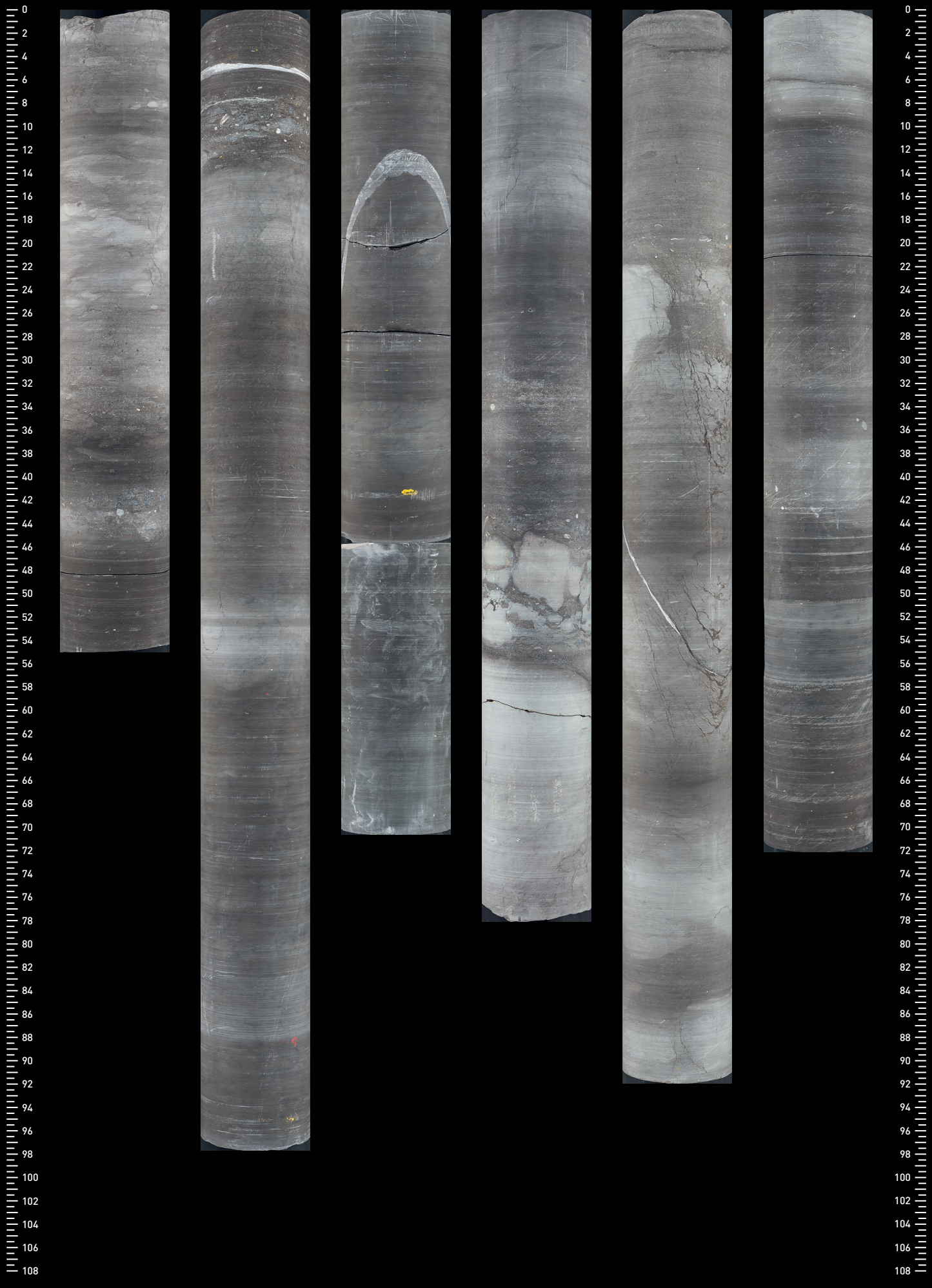
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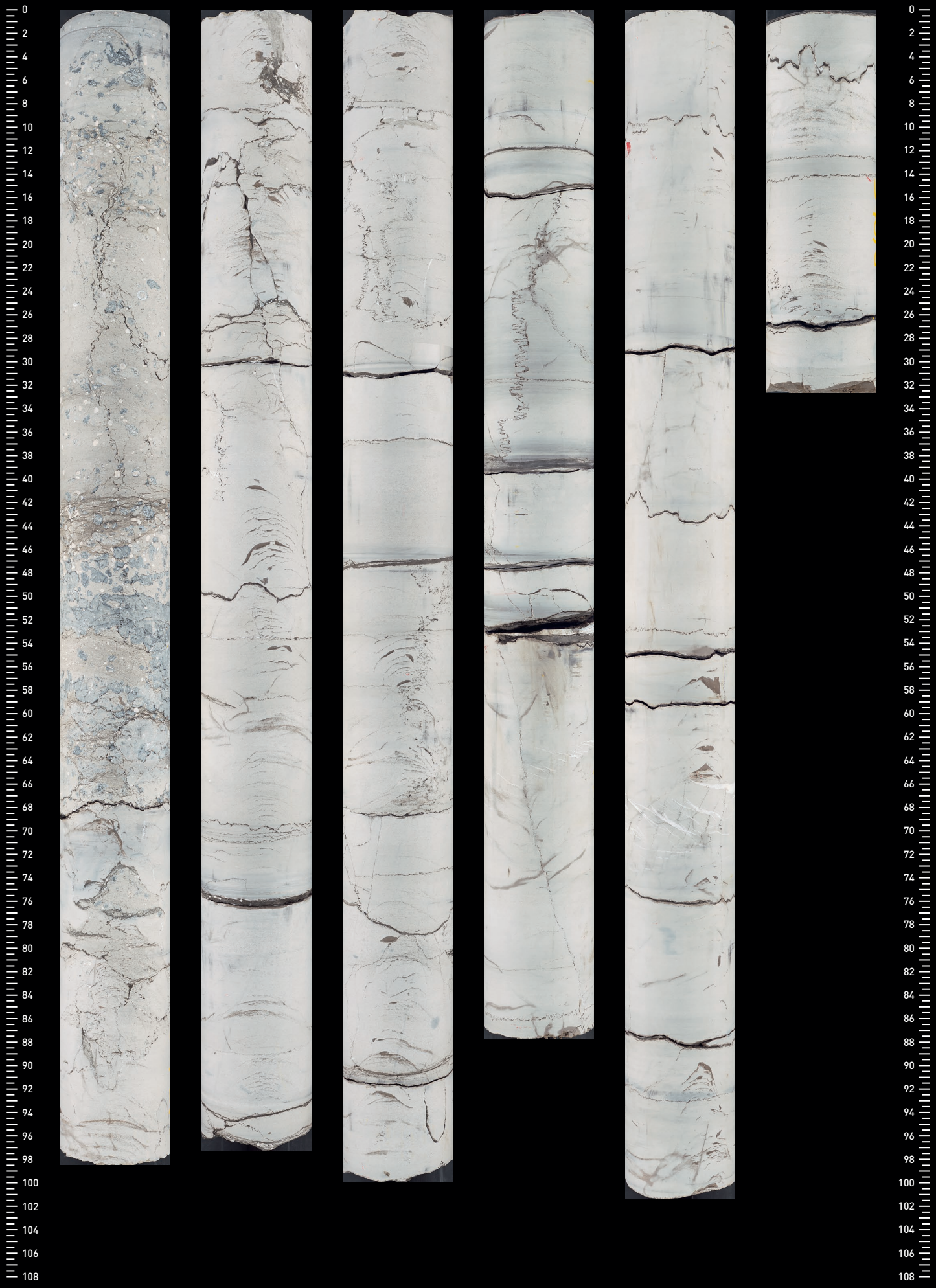
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571.08m 572.03m 572.98m 573.95m 574.80m 575.78m



572.03m 572.98m 573.95m 574.80m 575.78m 576.10m

576.10m 577.09m 577.98m 578.90m 579.58m 580.12m



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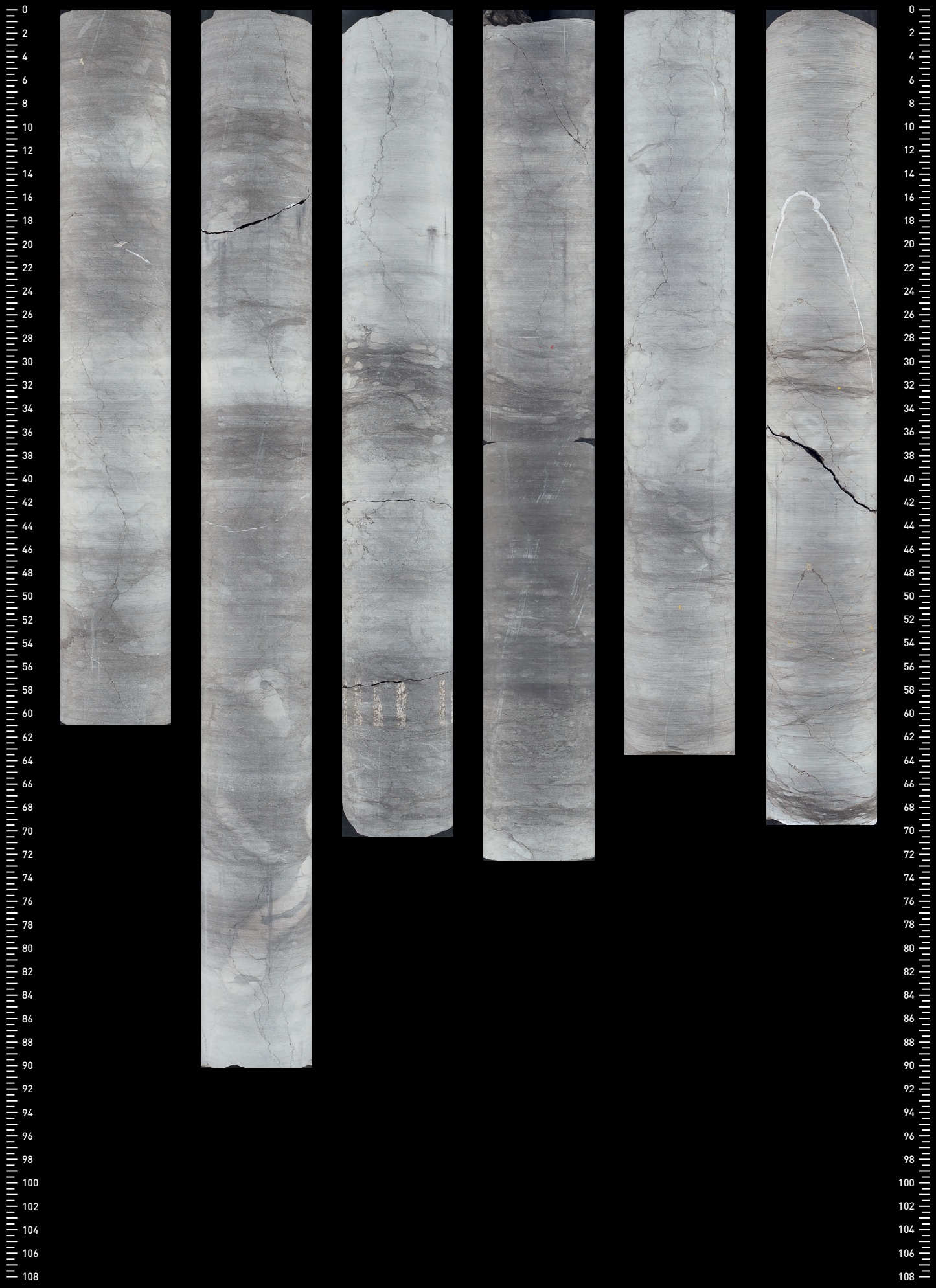
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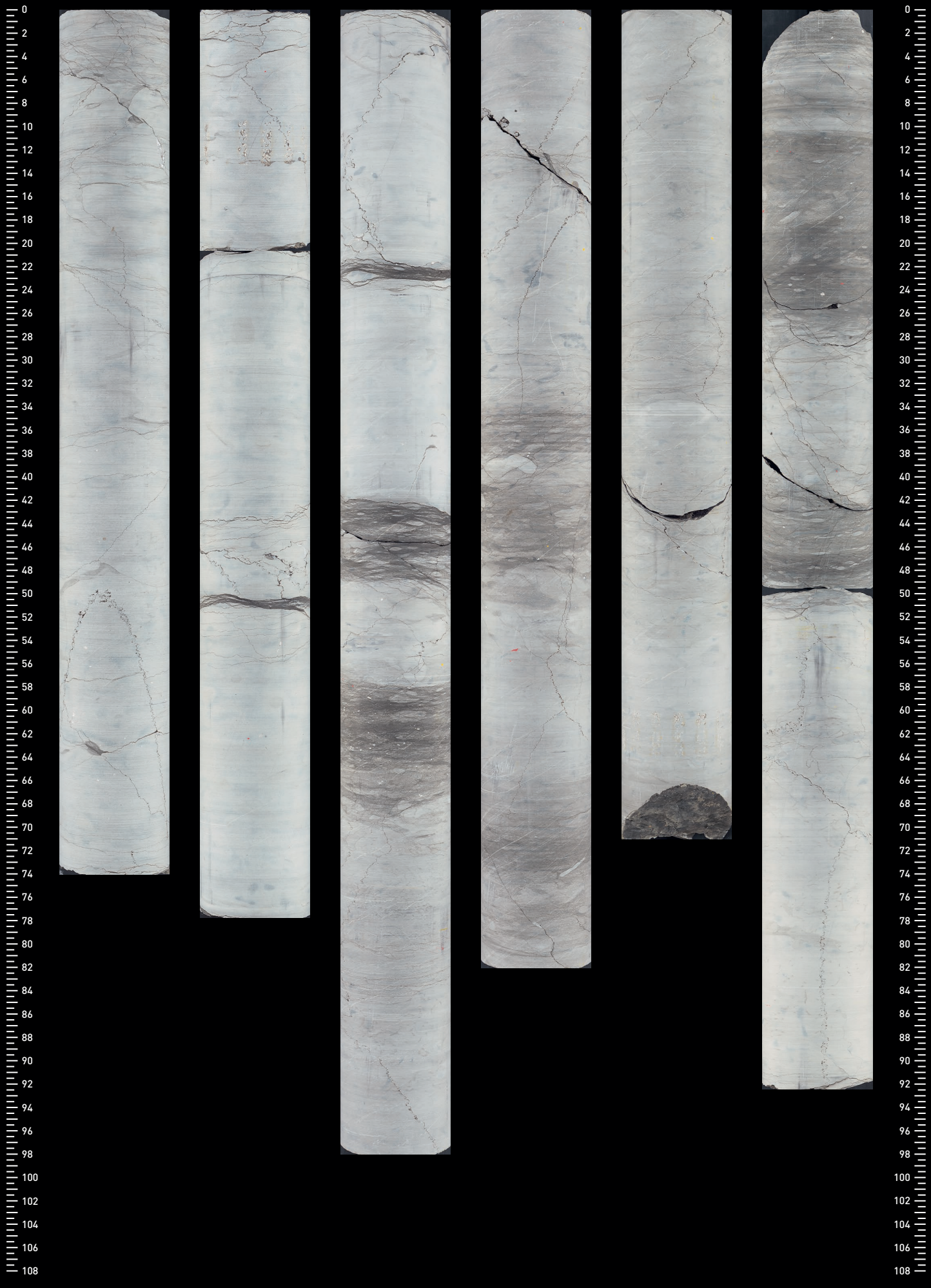


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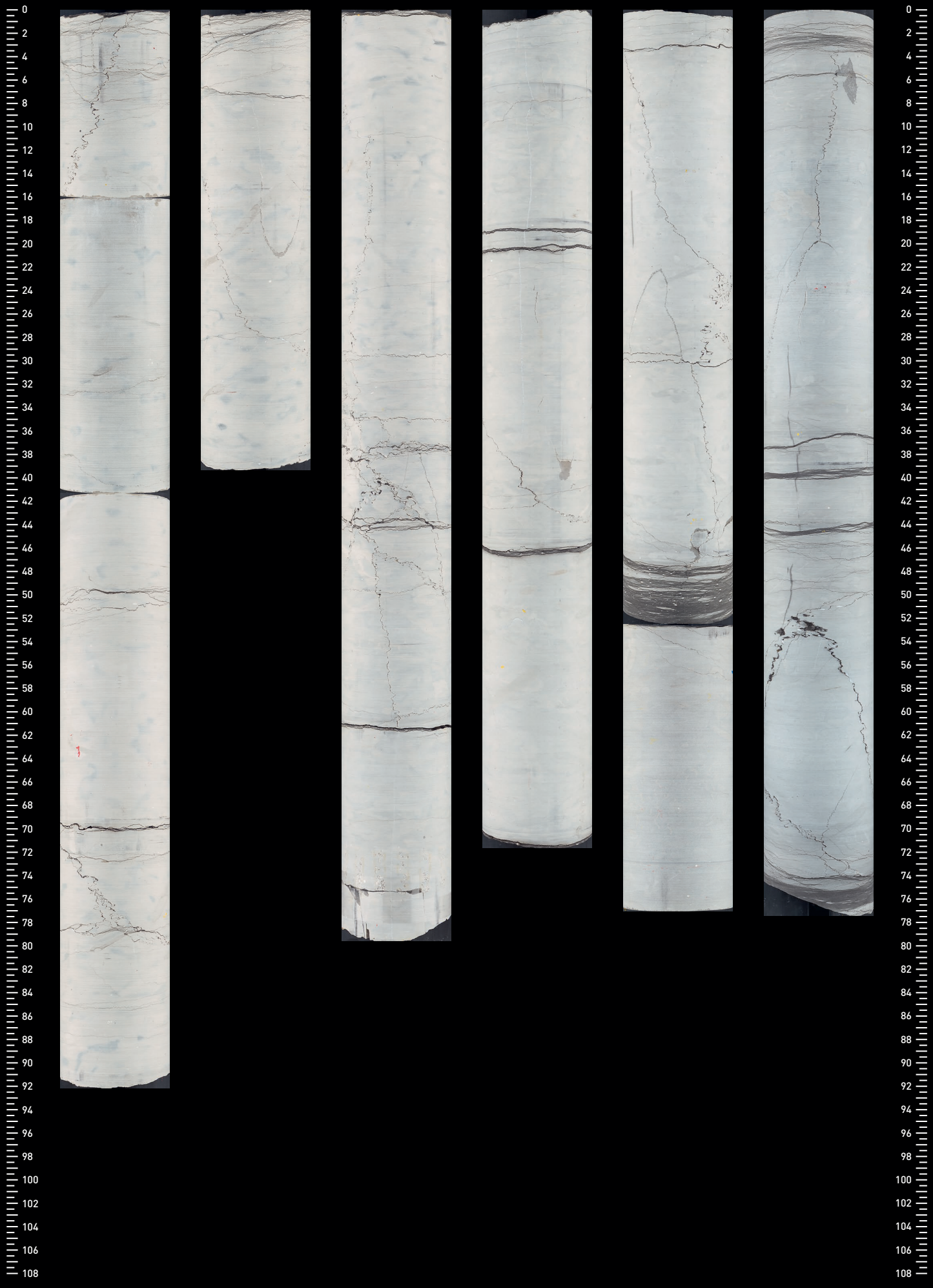
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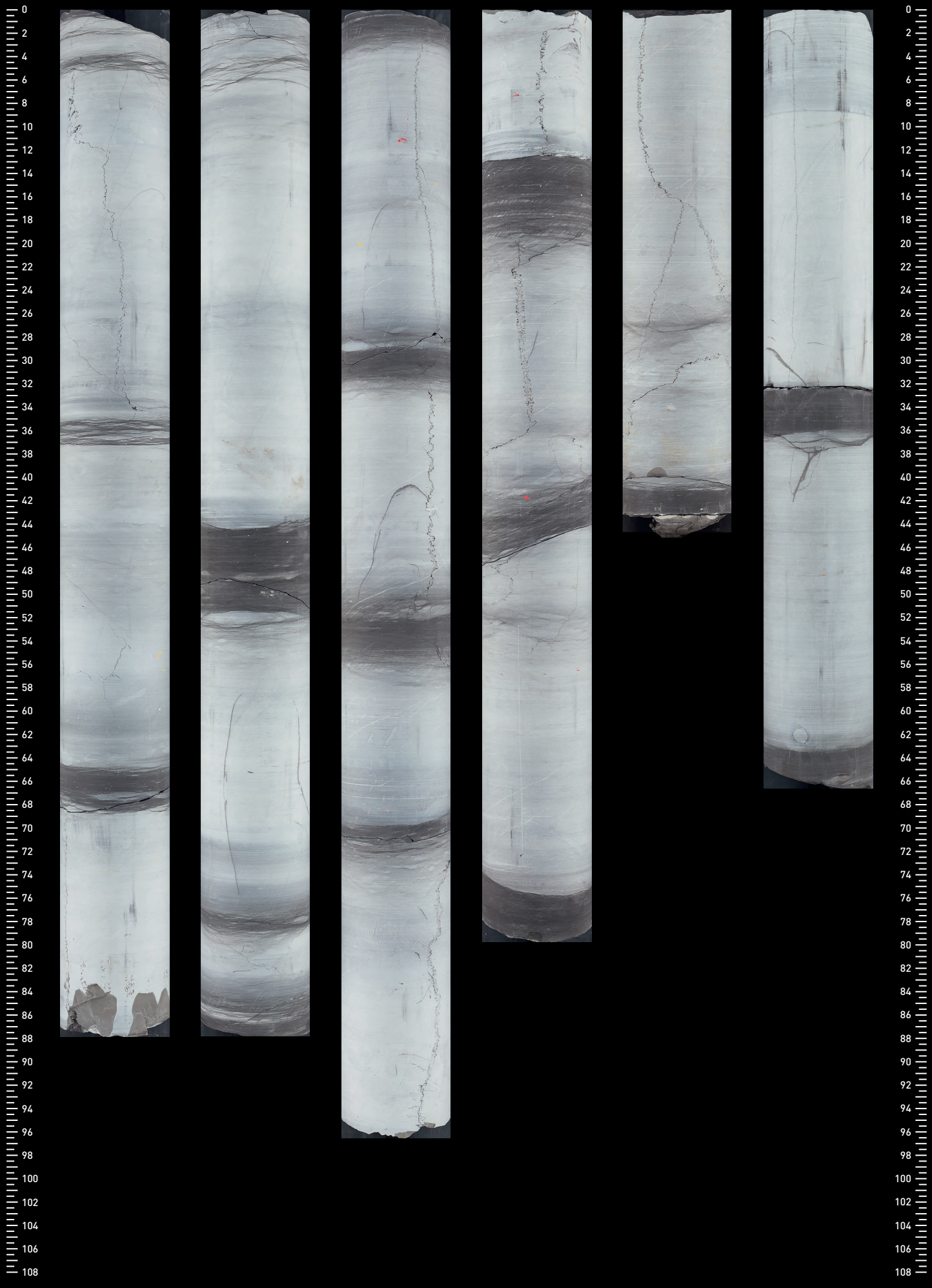

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595.60m
596.55m
597.35m
598.04m
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598.89m 599.78m 600.16m 600.95m 601.65m 602.40m



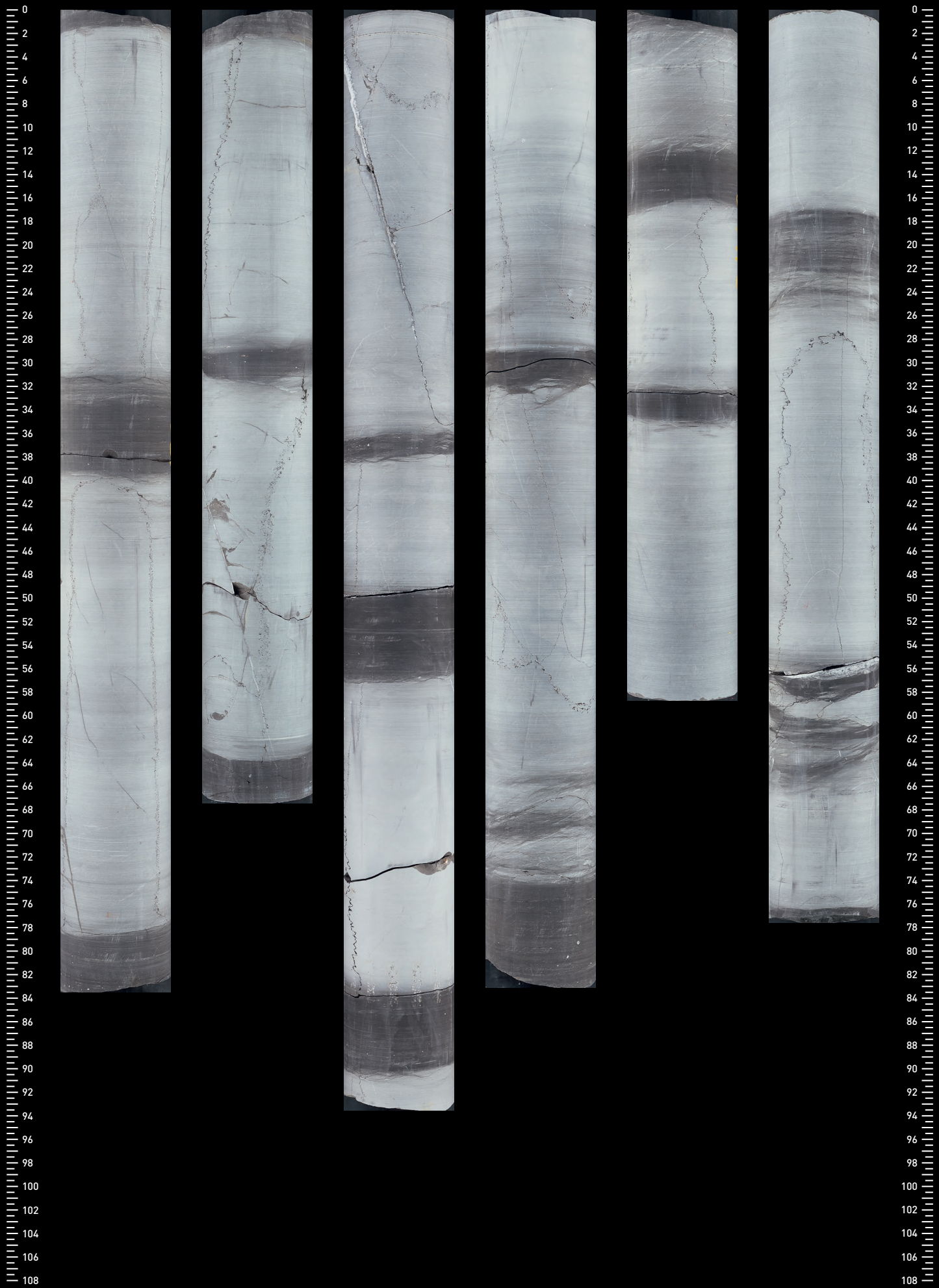
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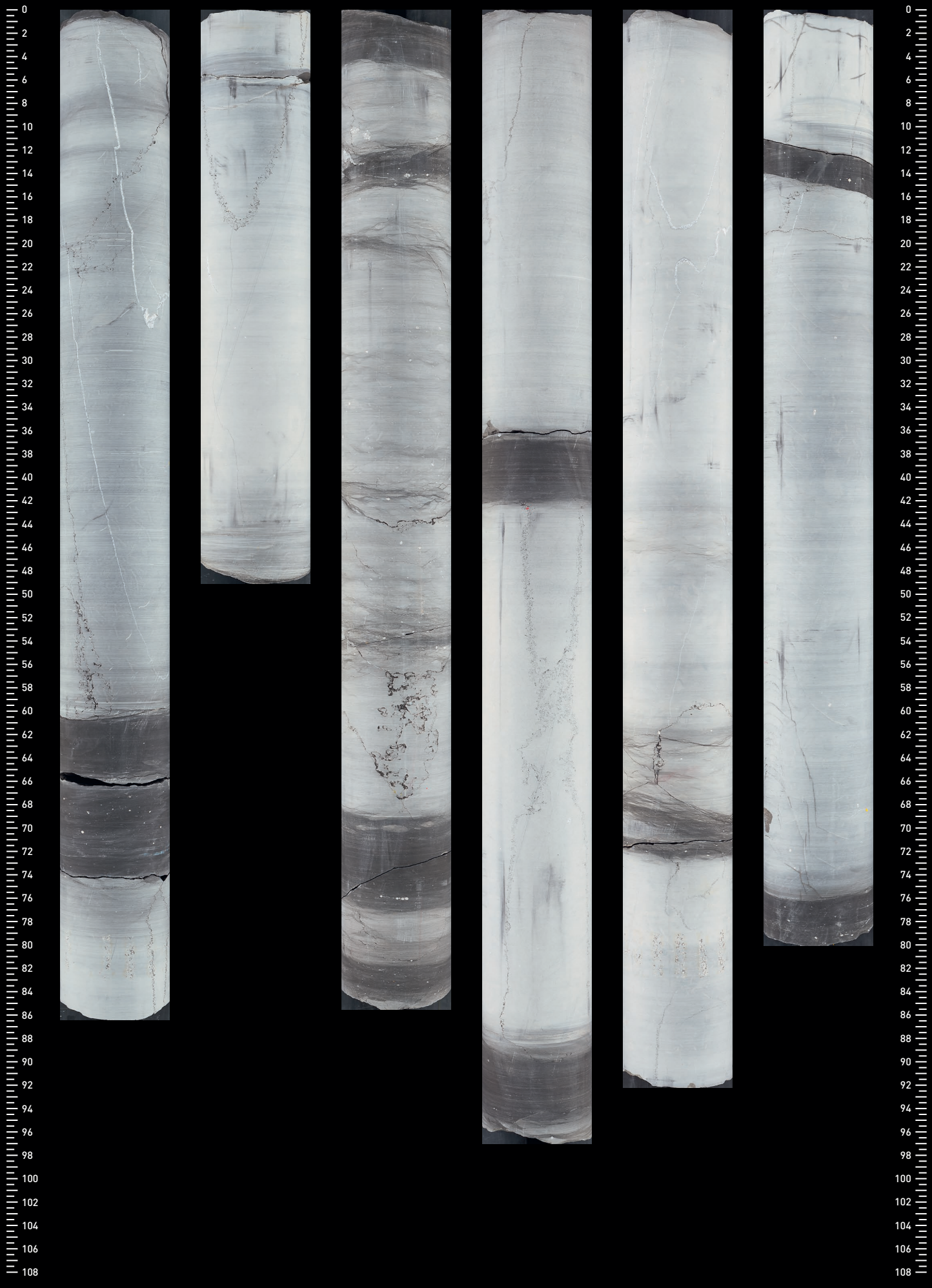
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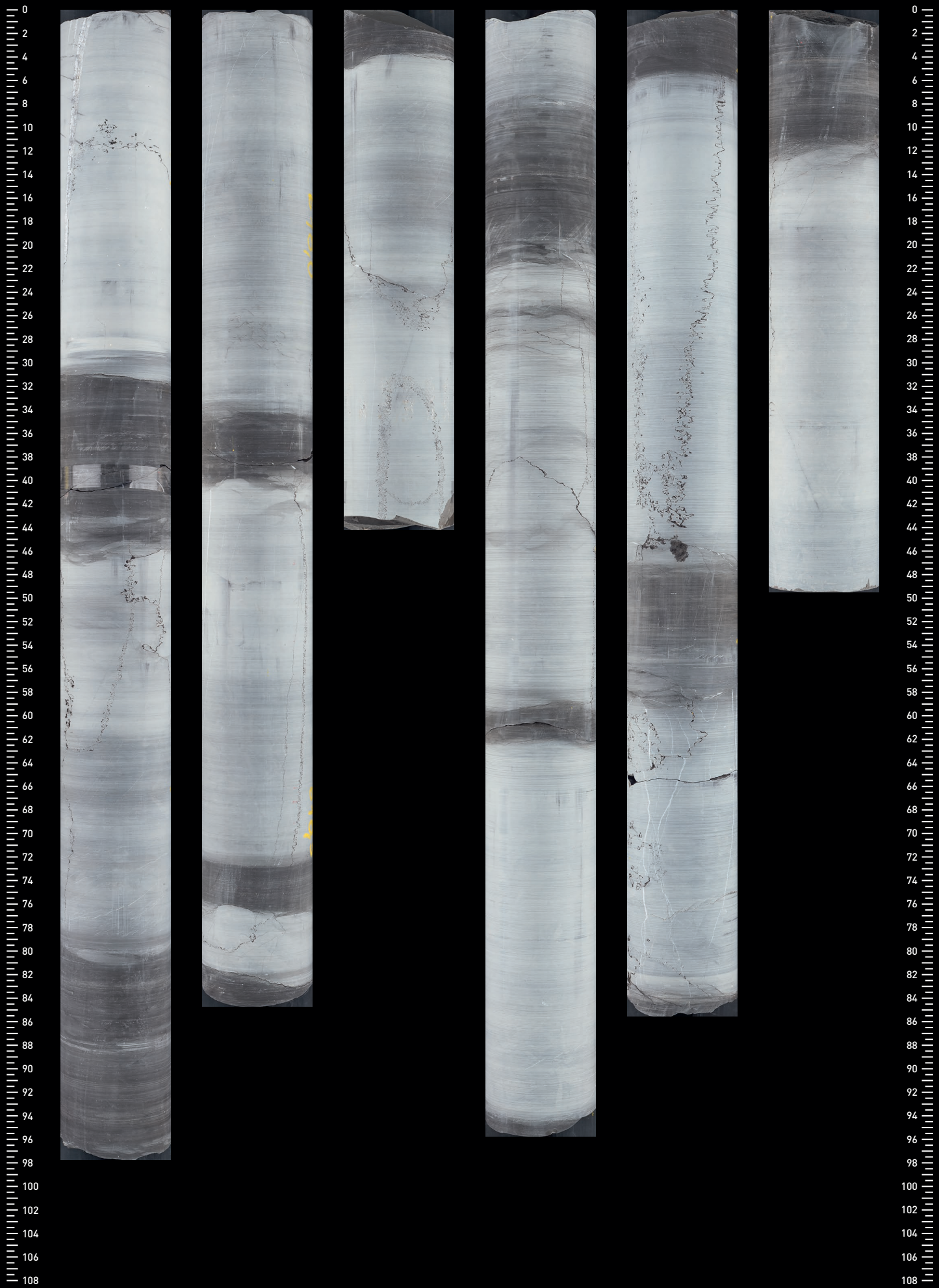
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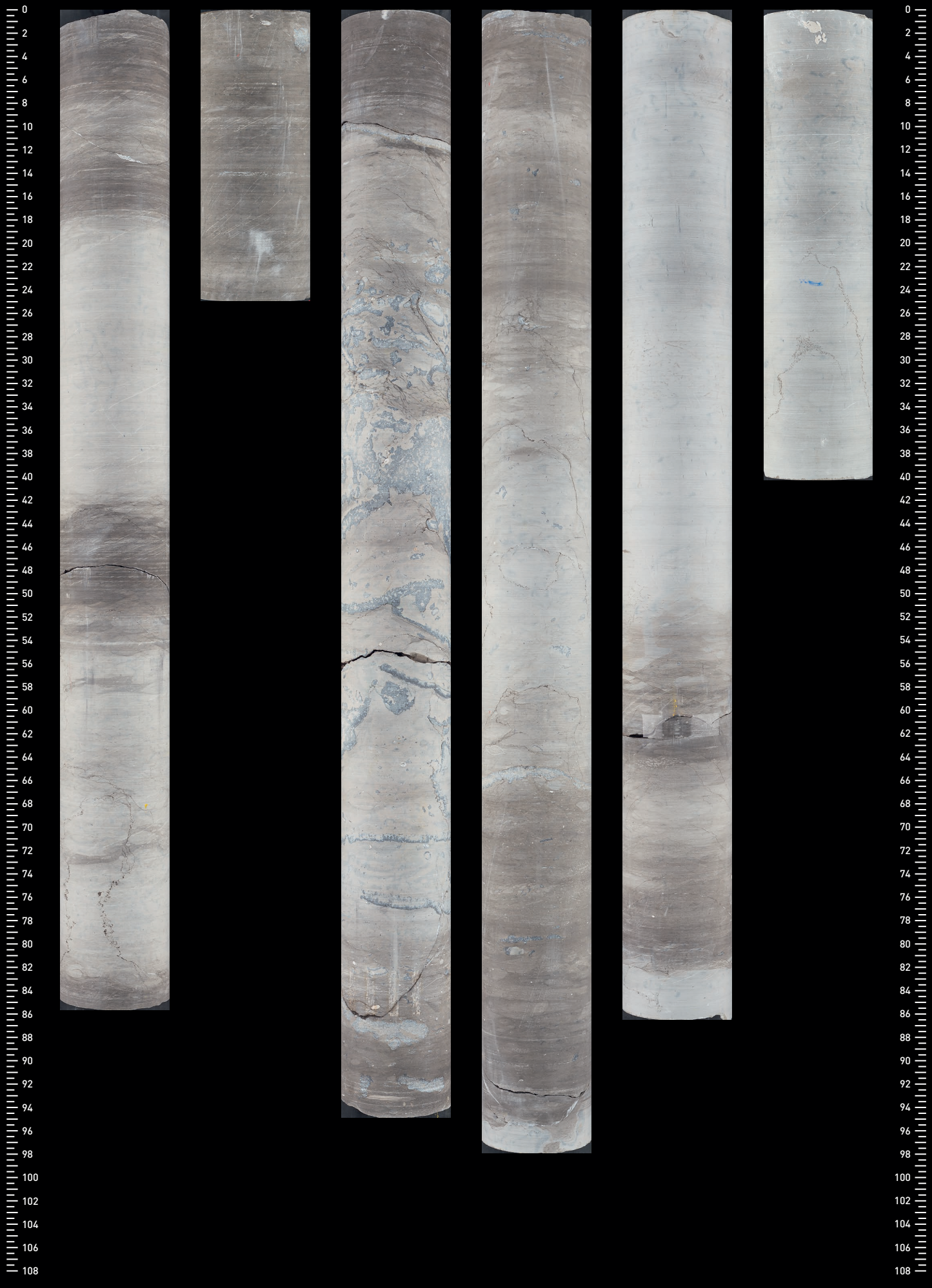
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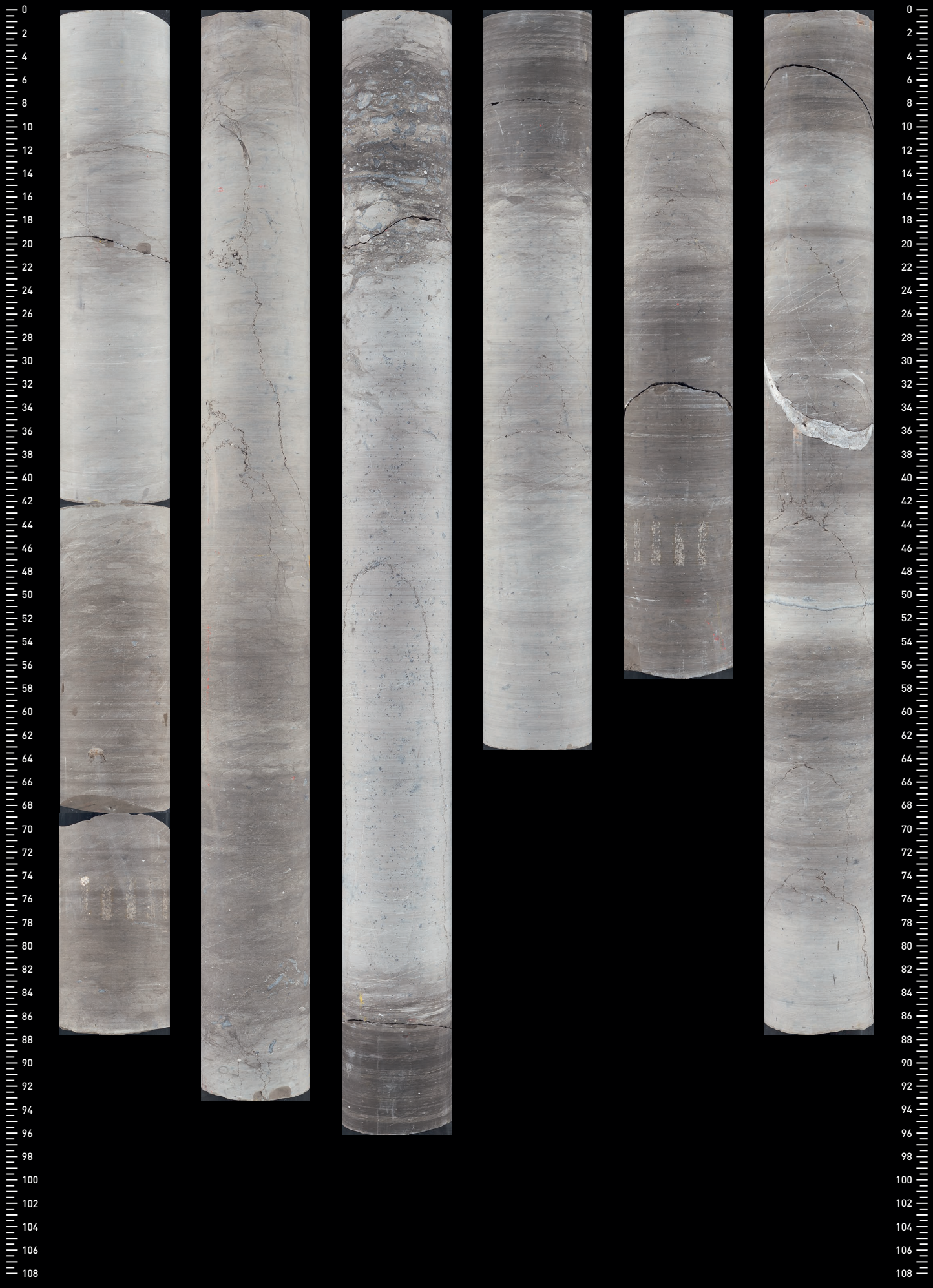
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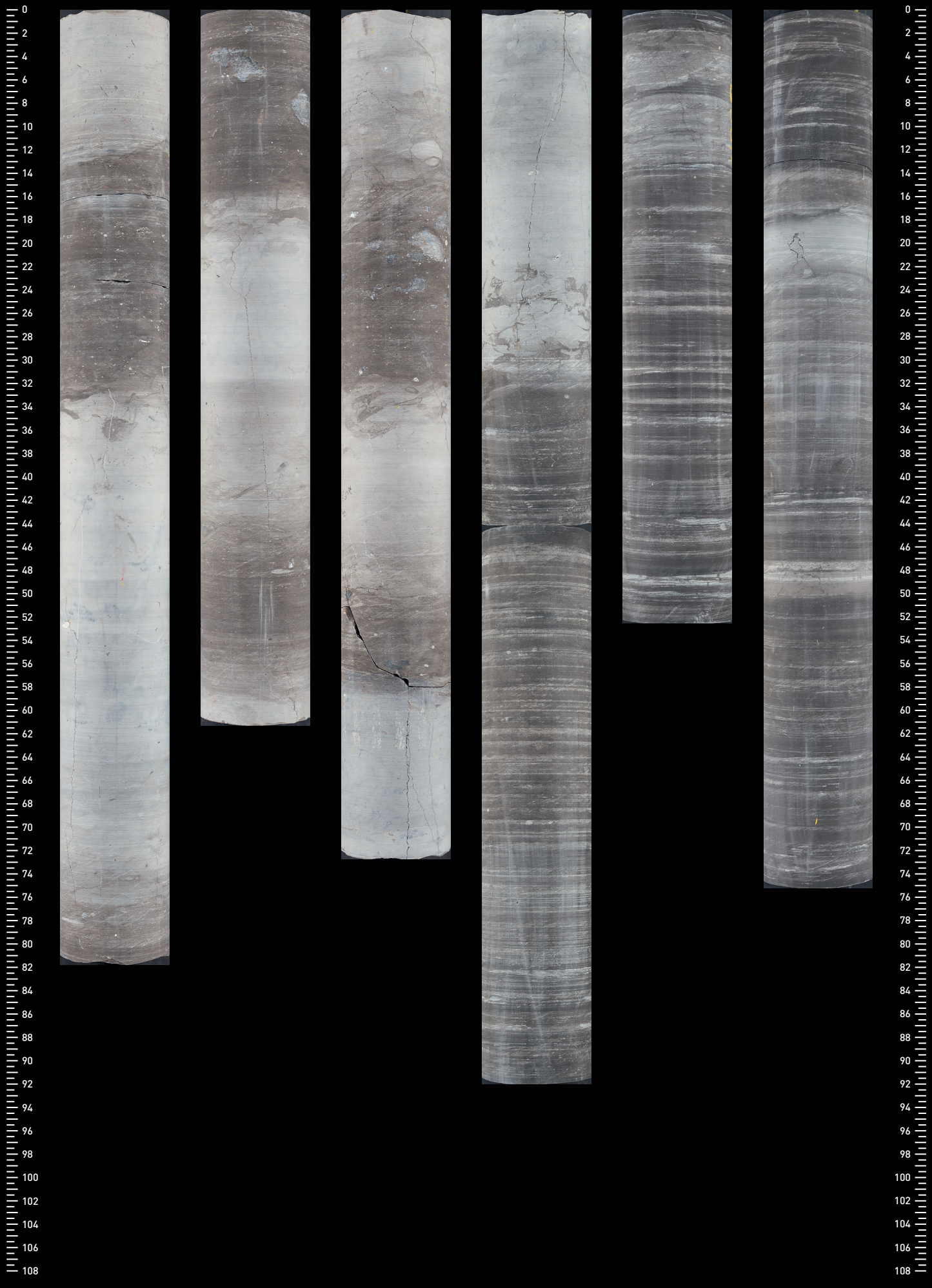
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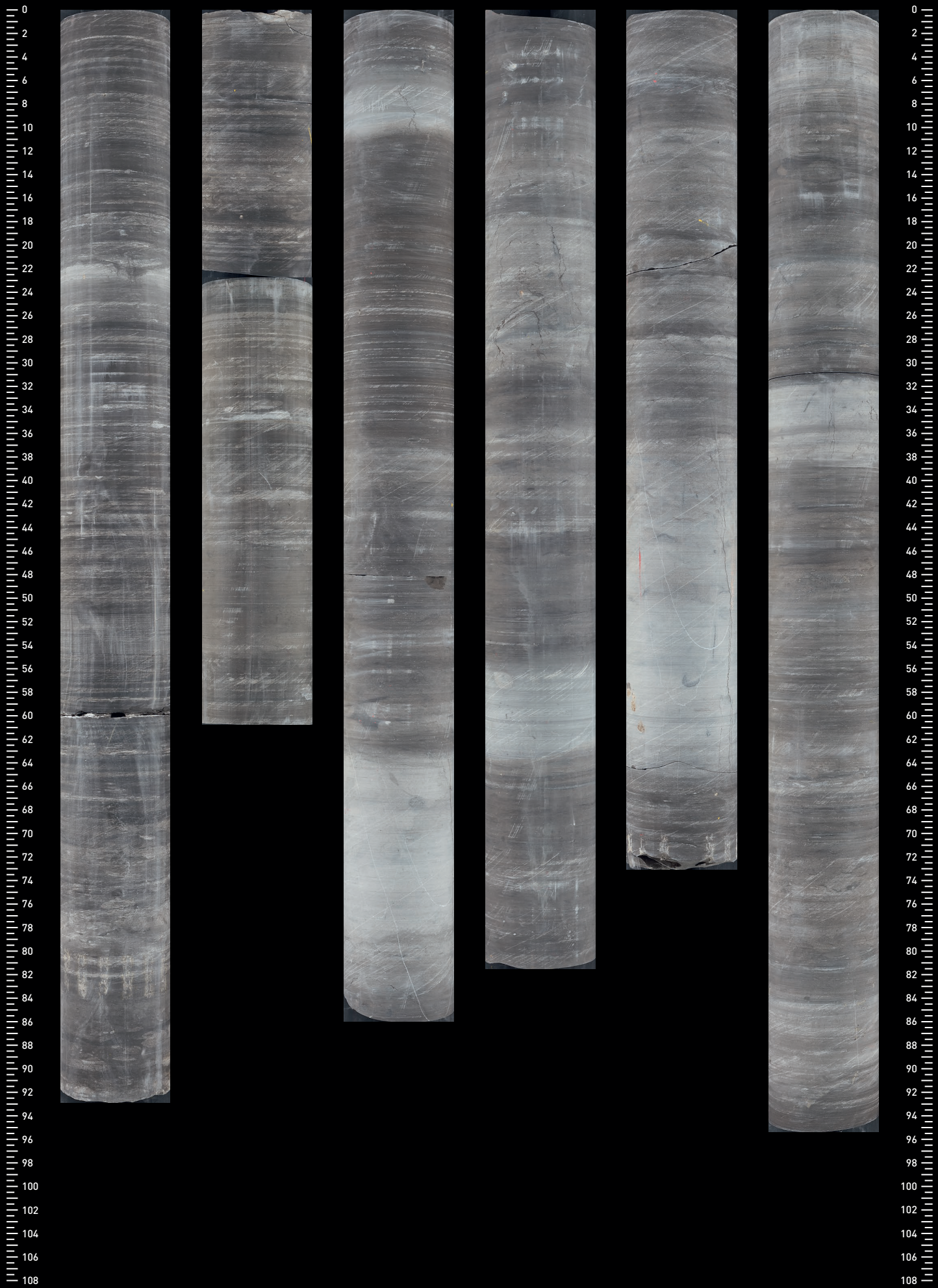
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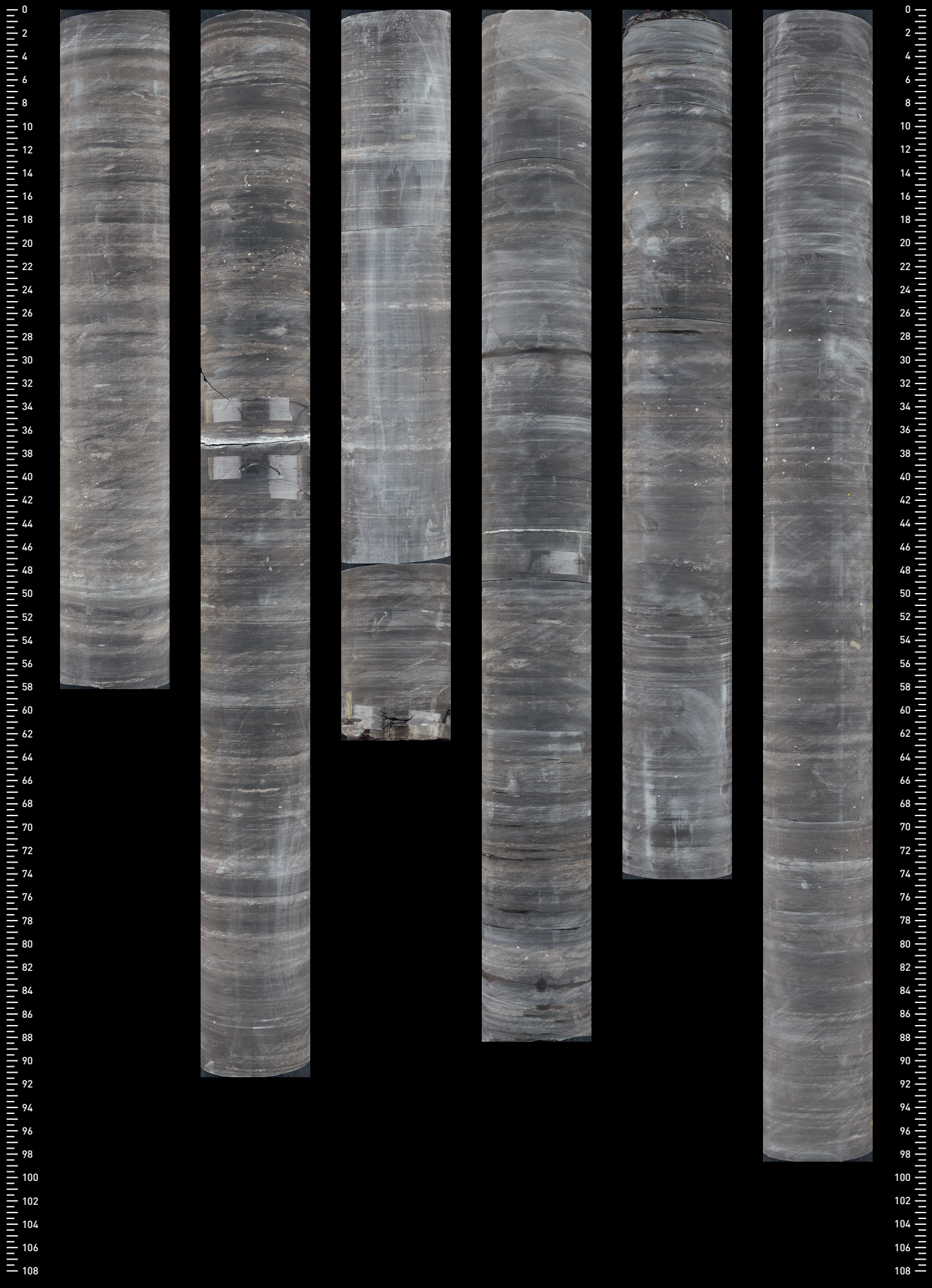
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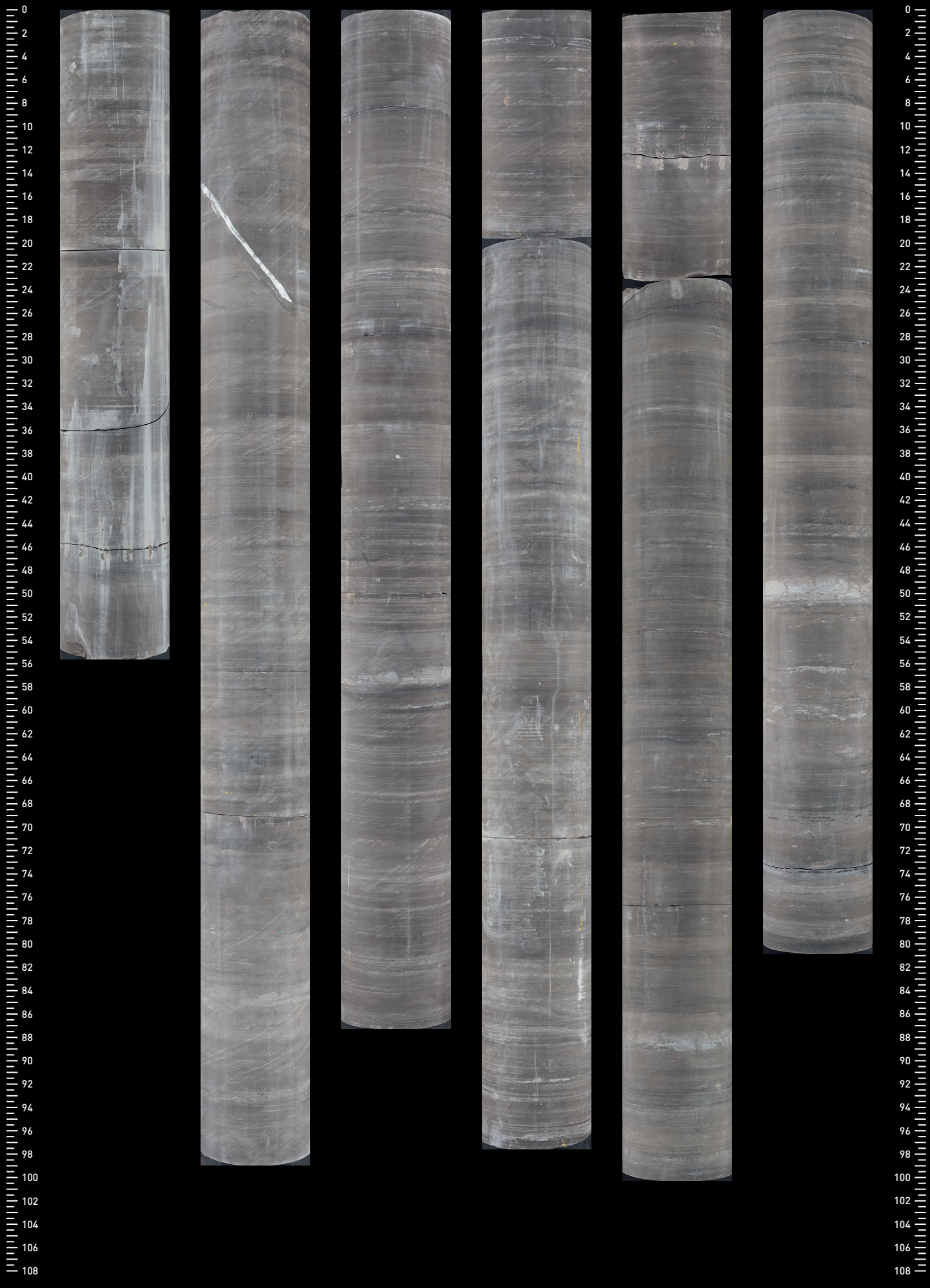


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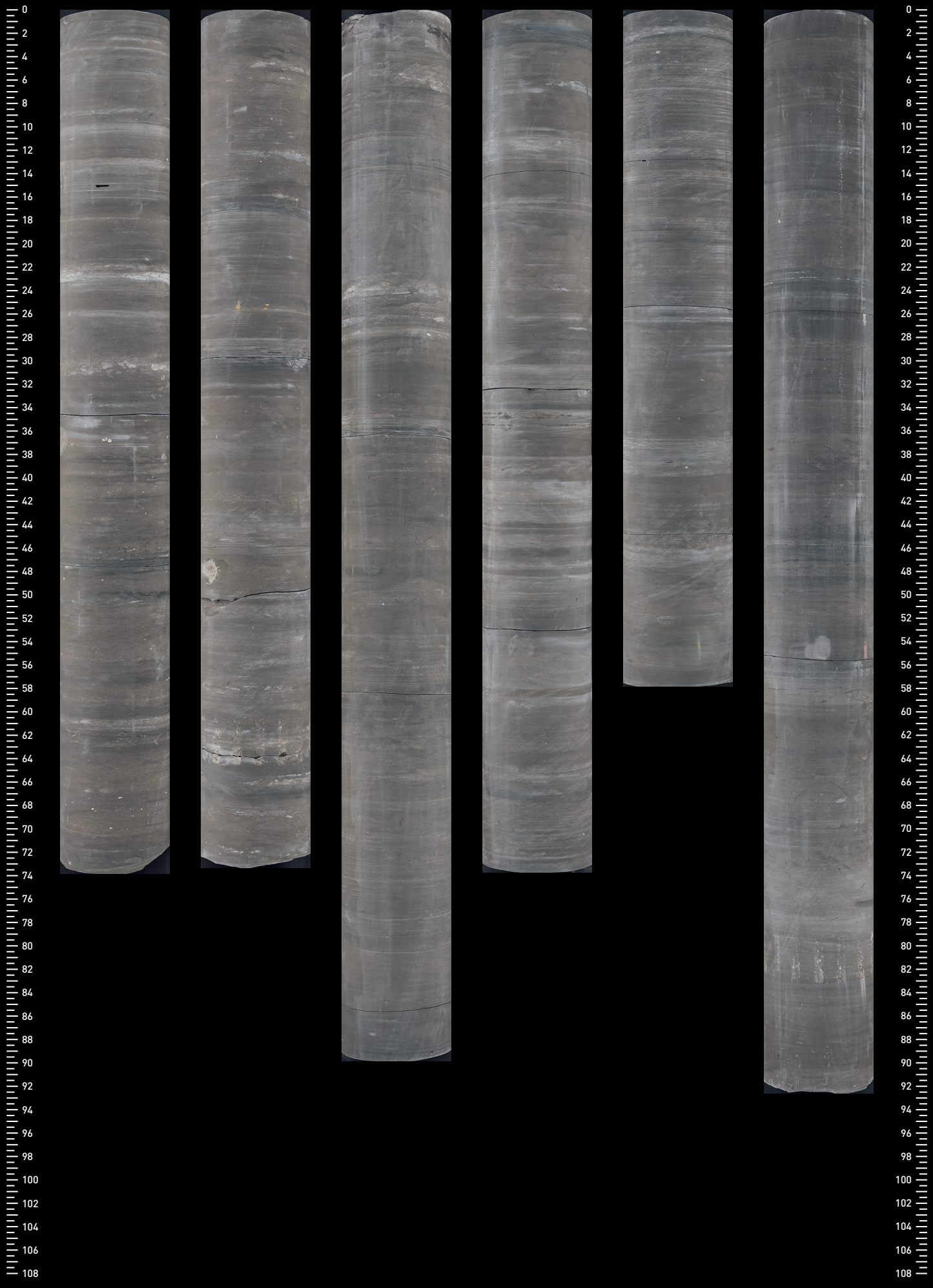
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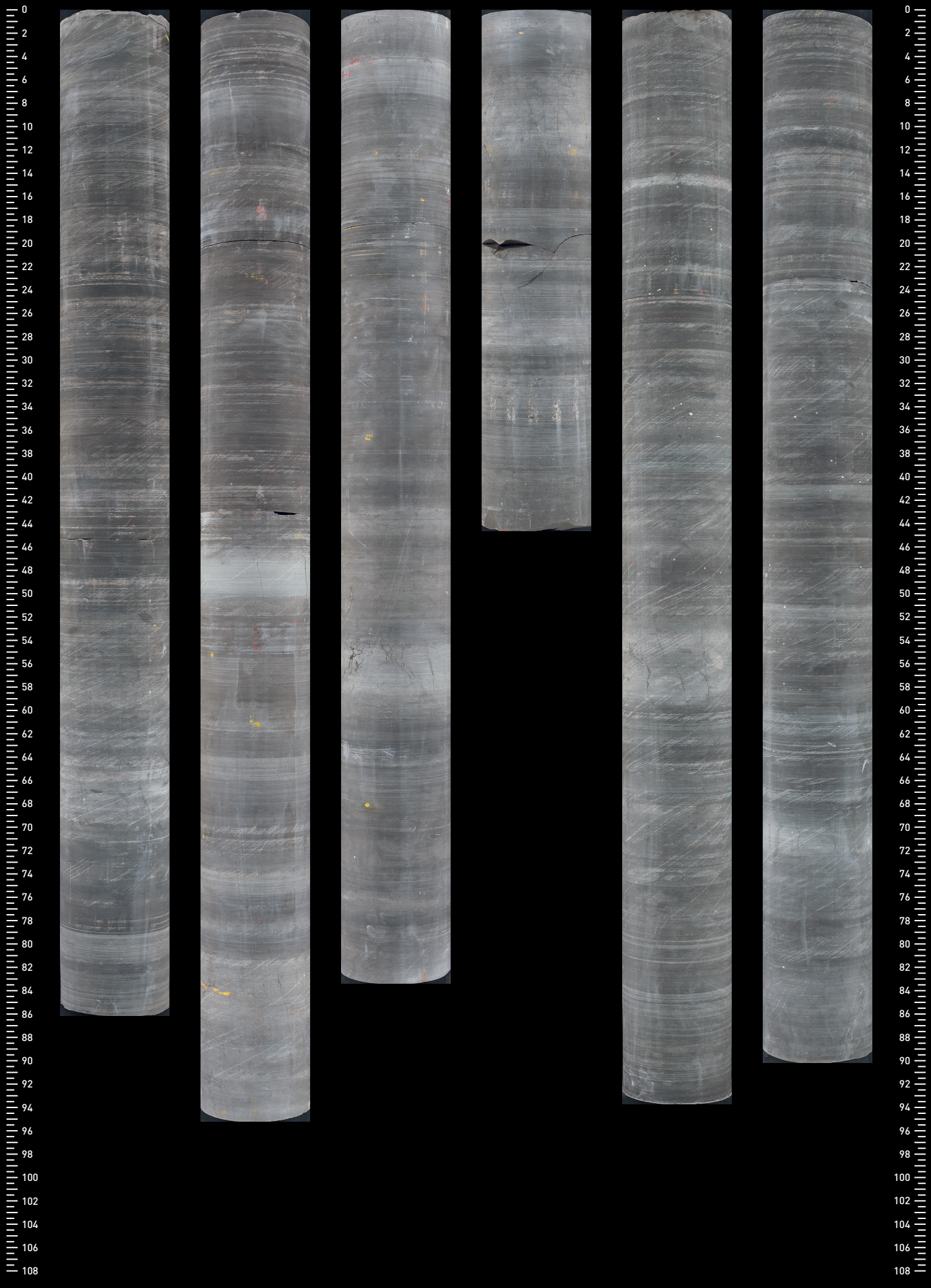

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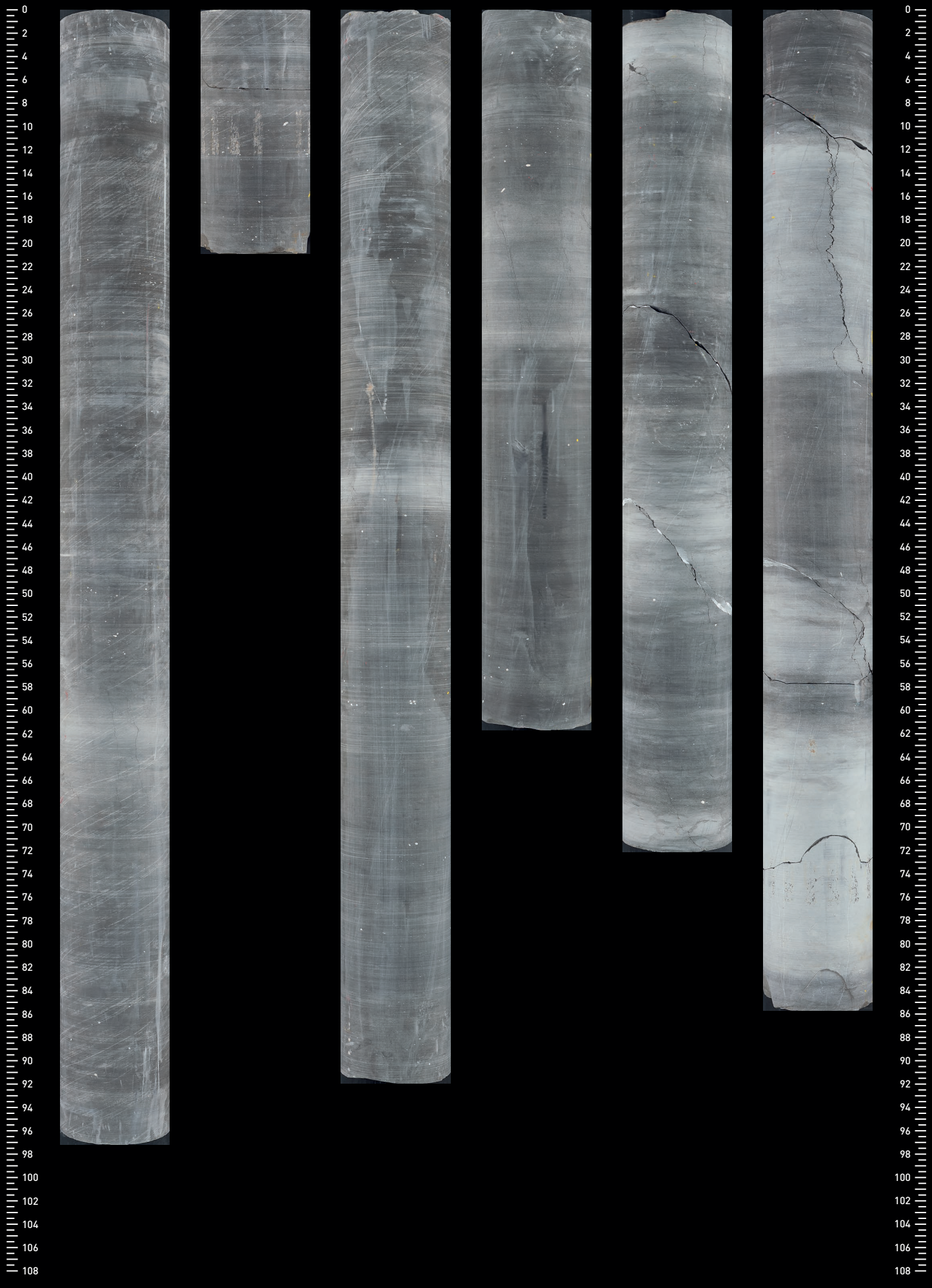
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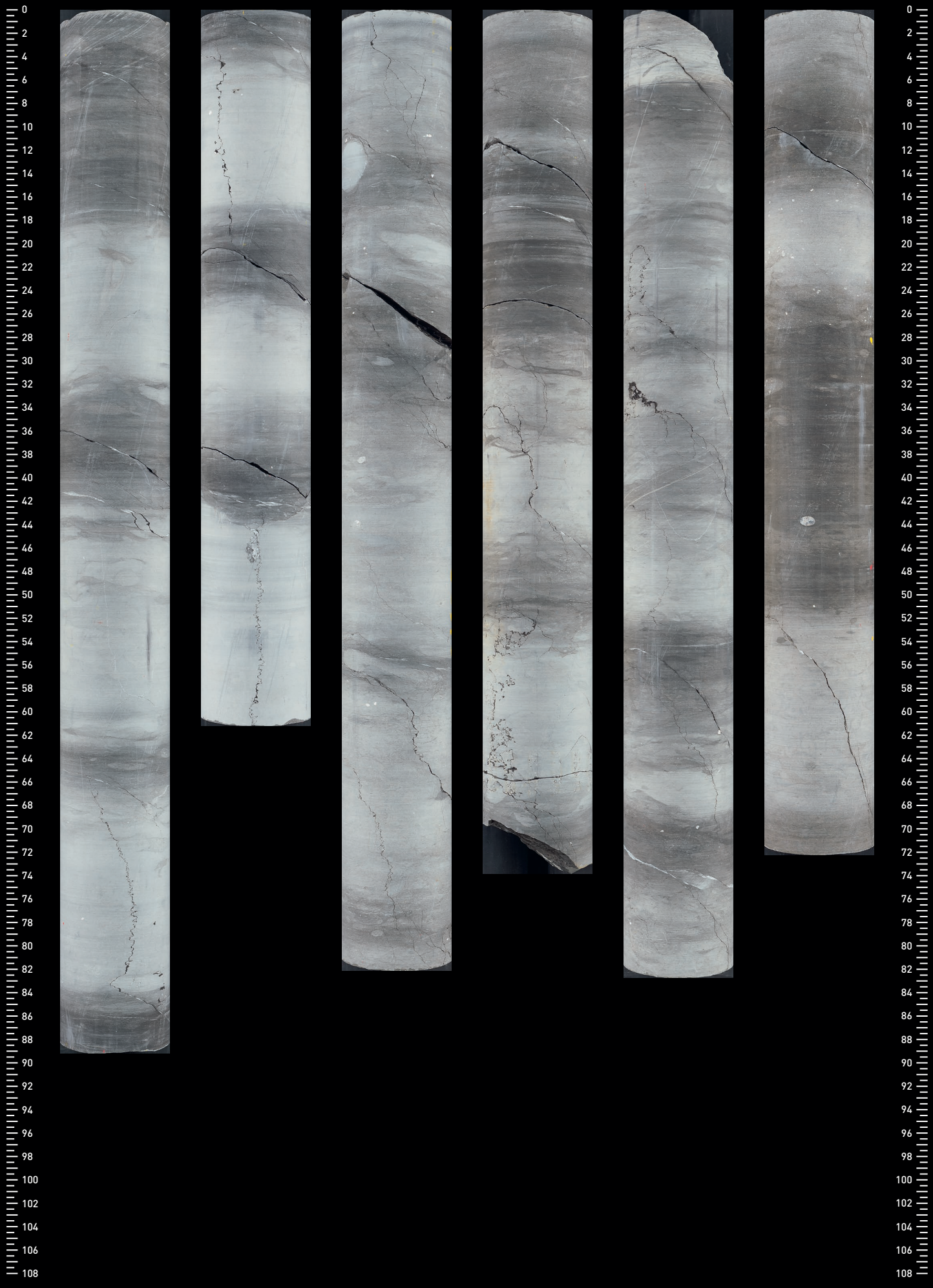
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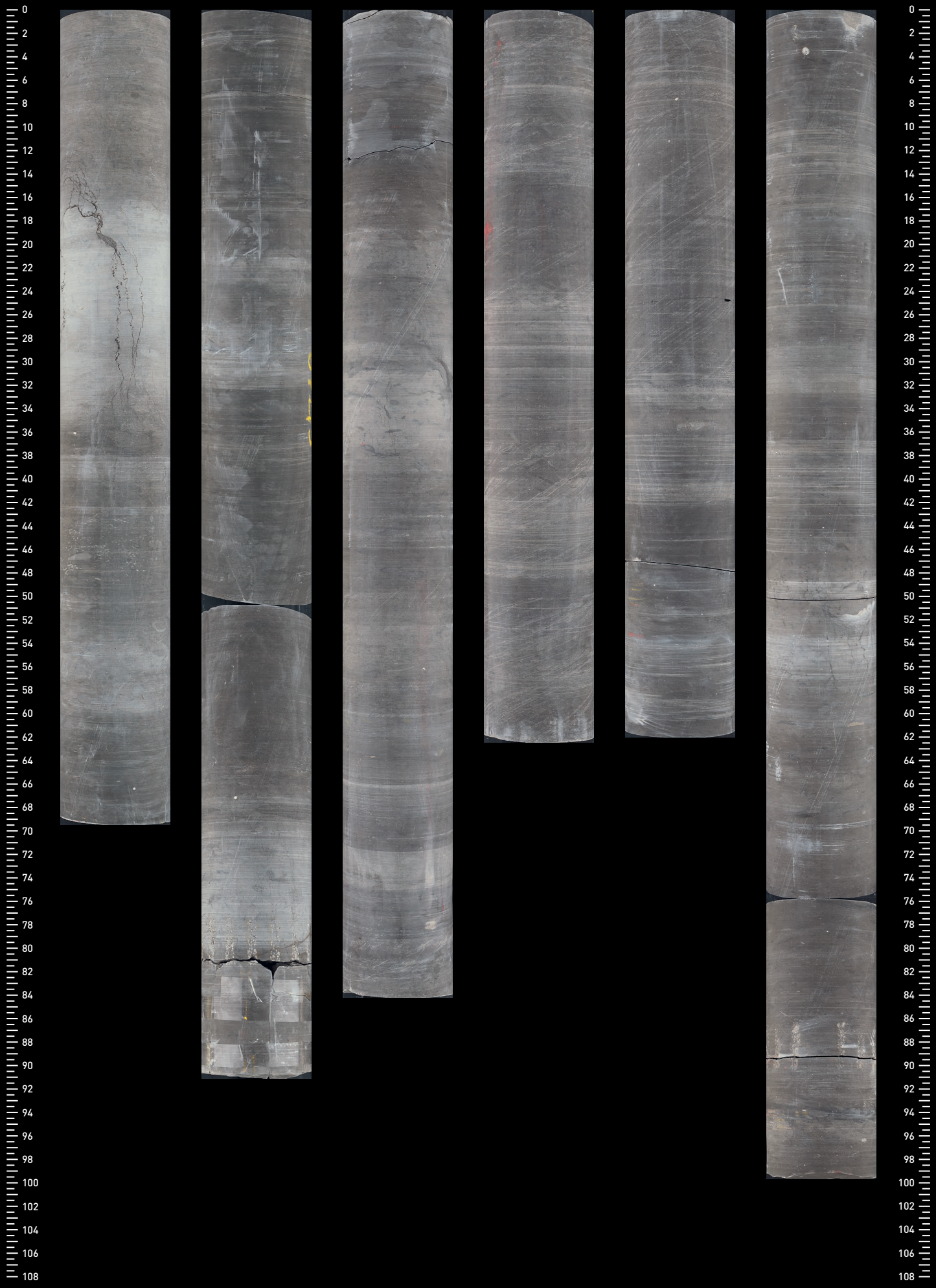
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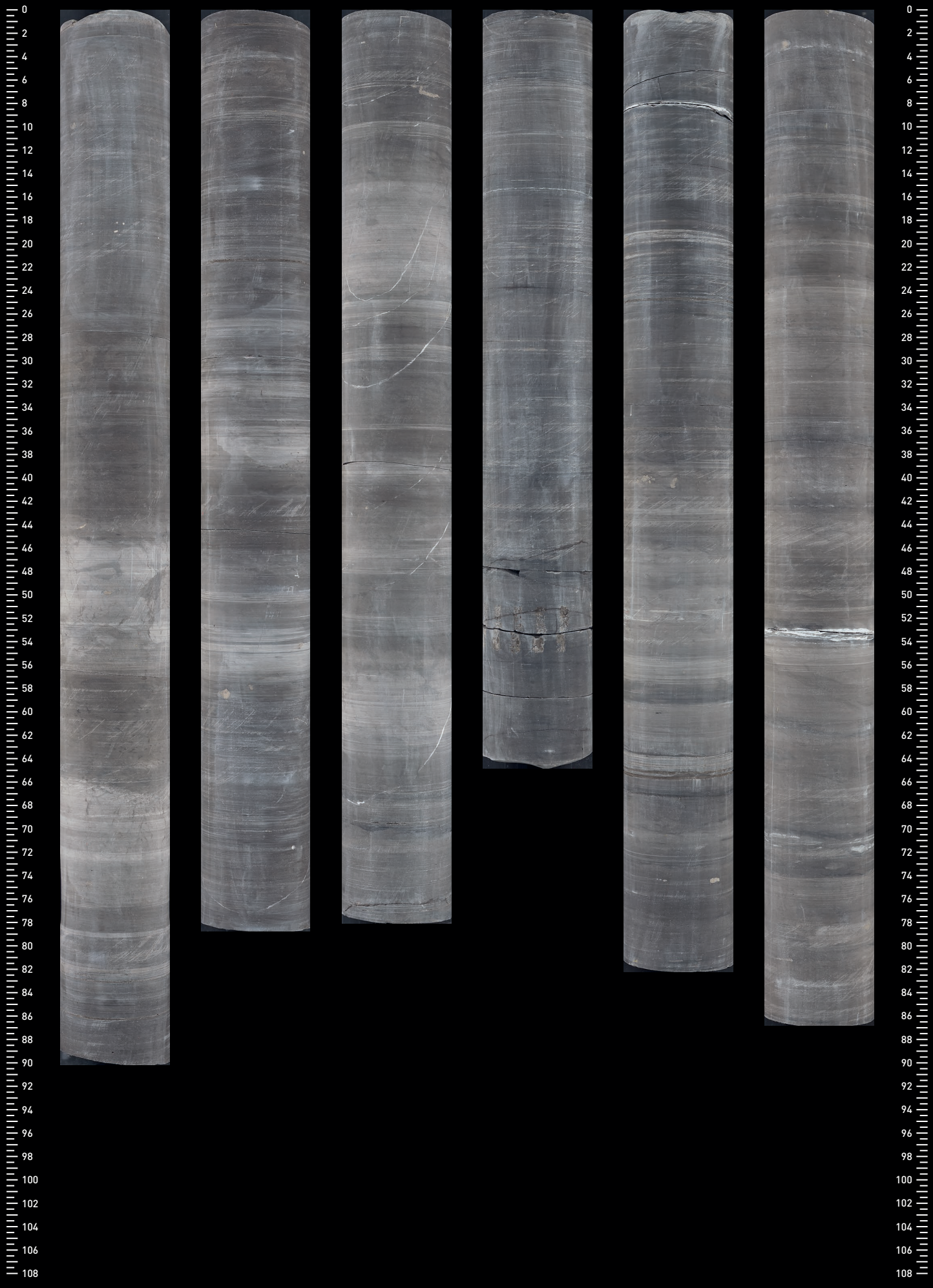
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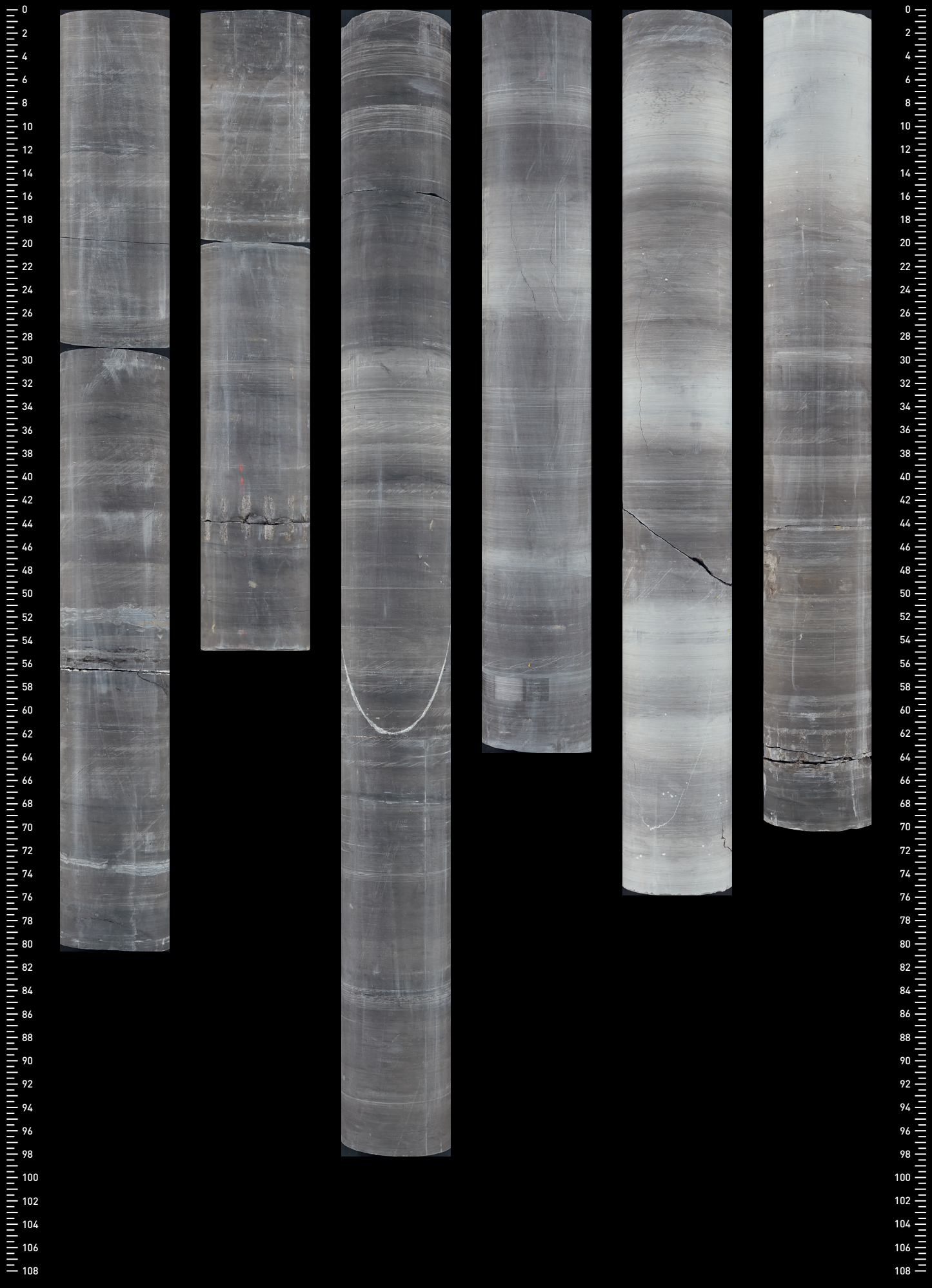
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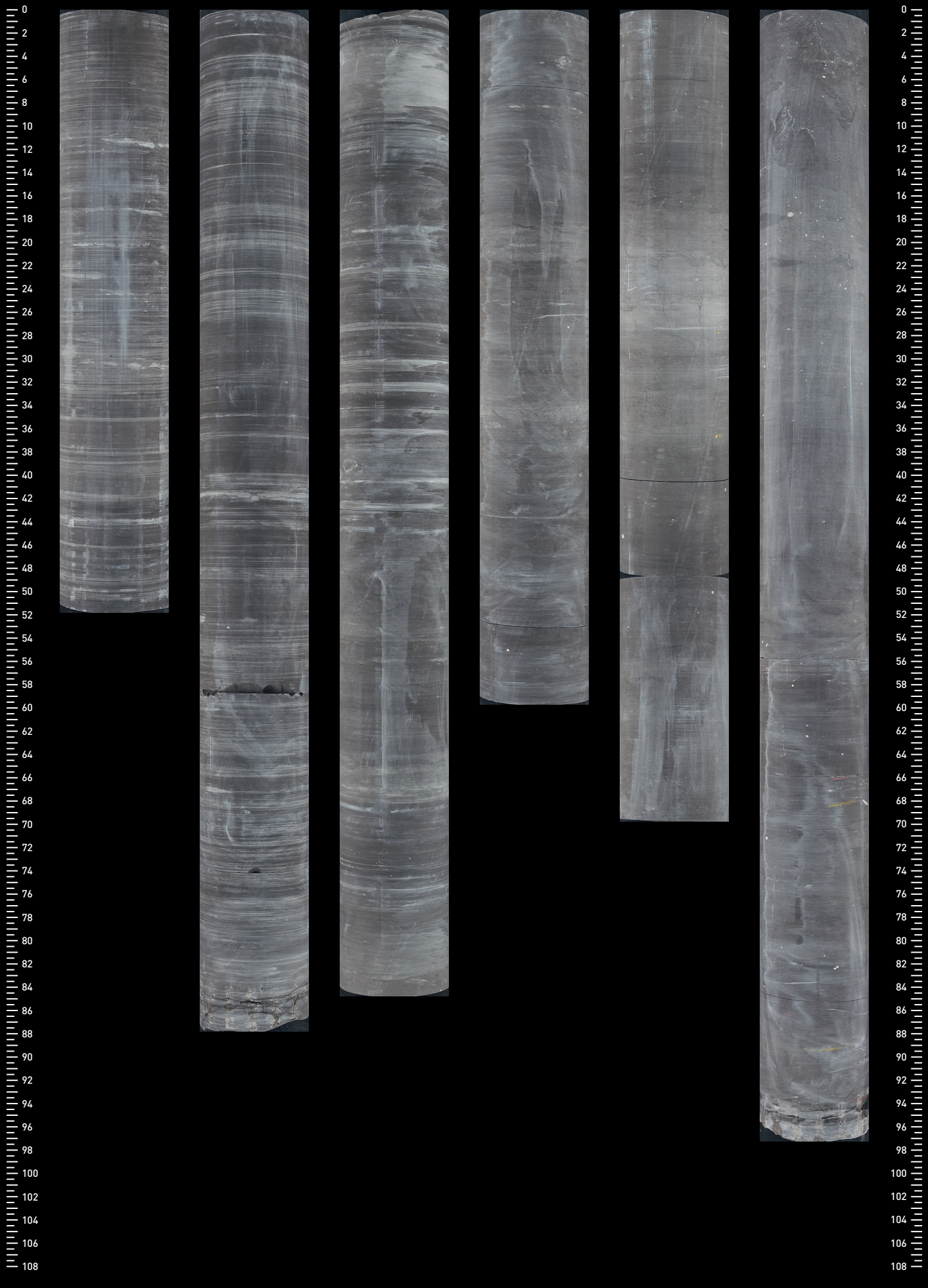
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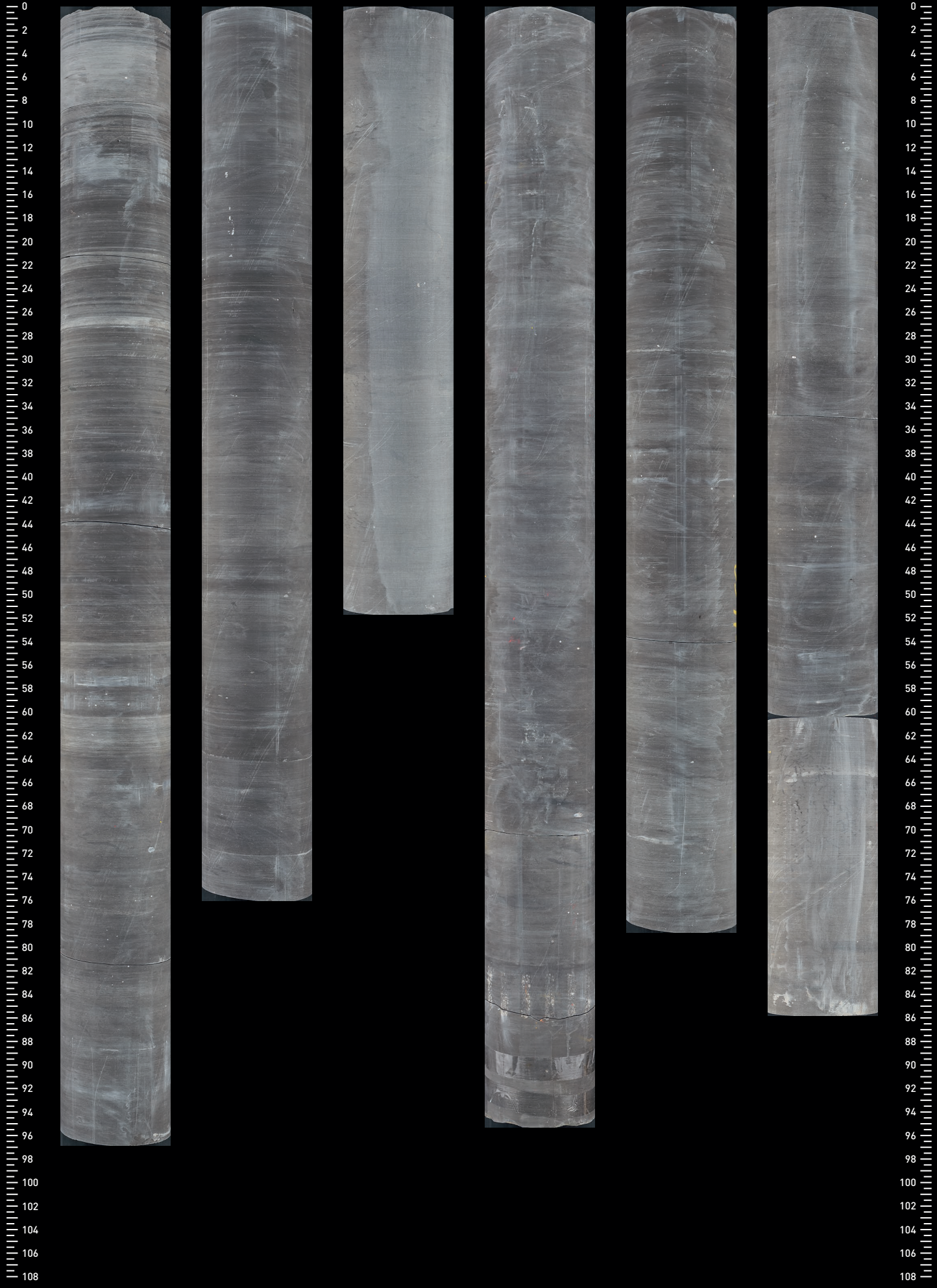
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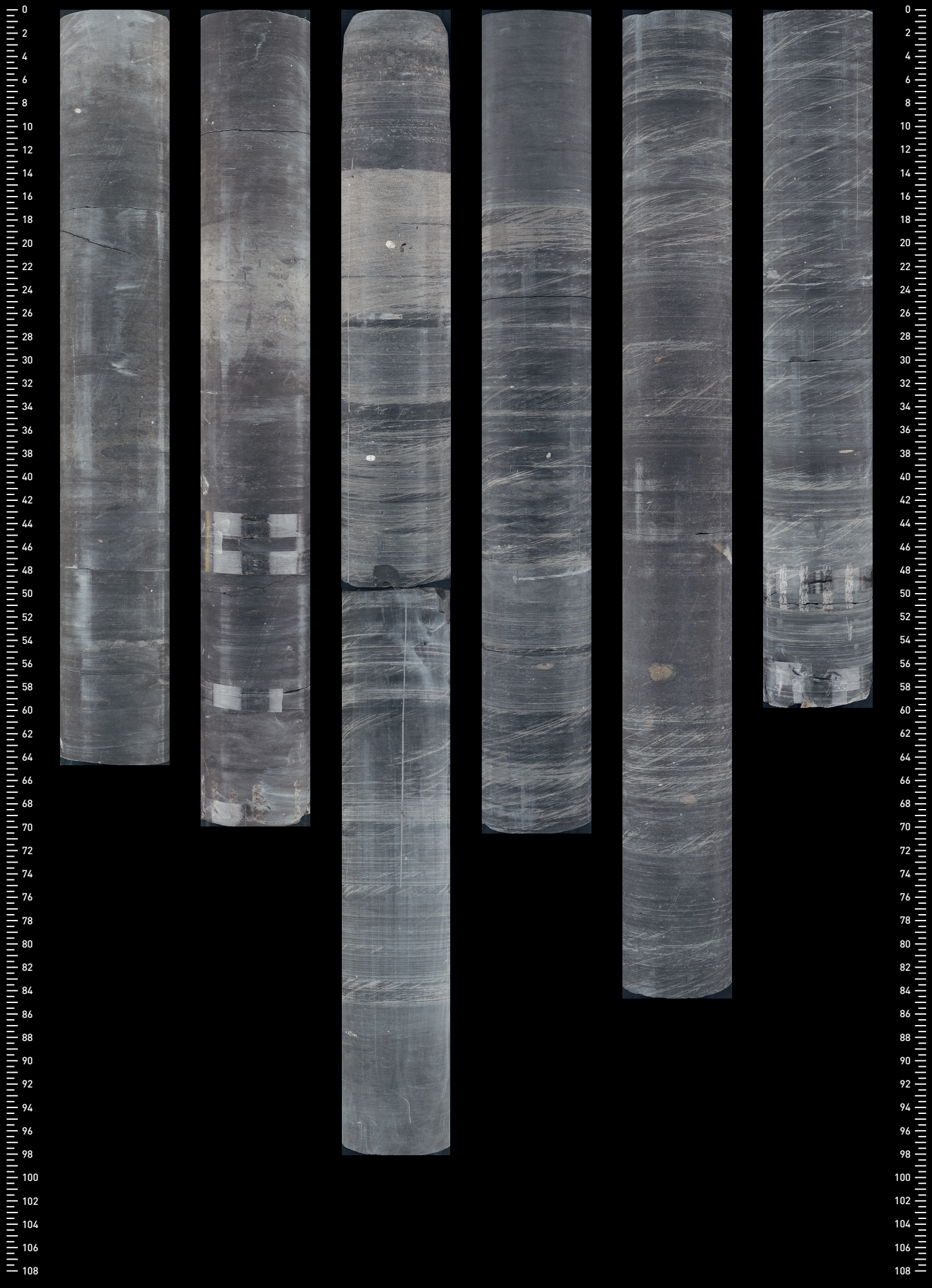
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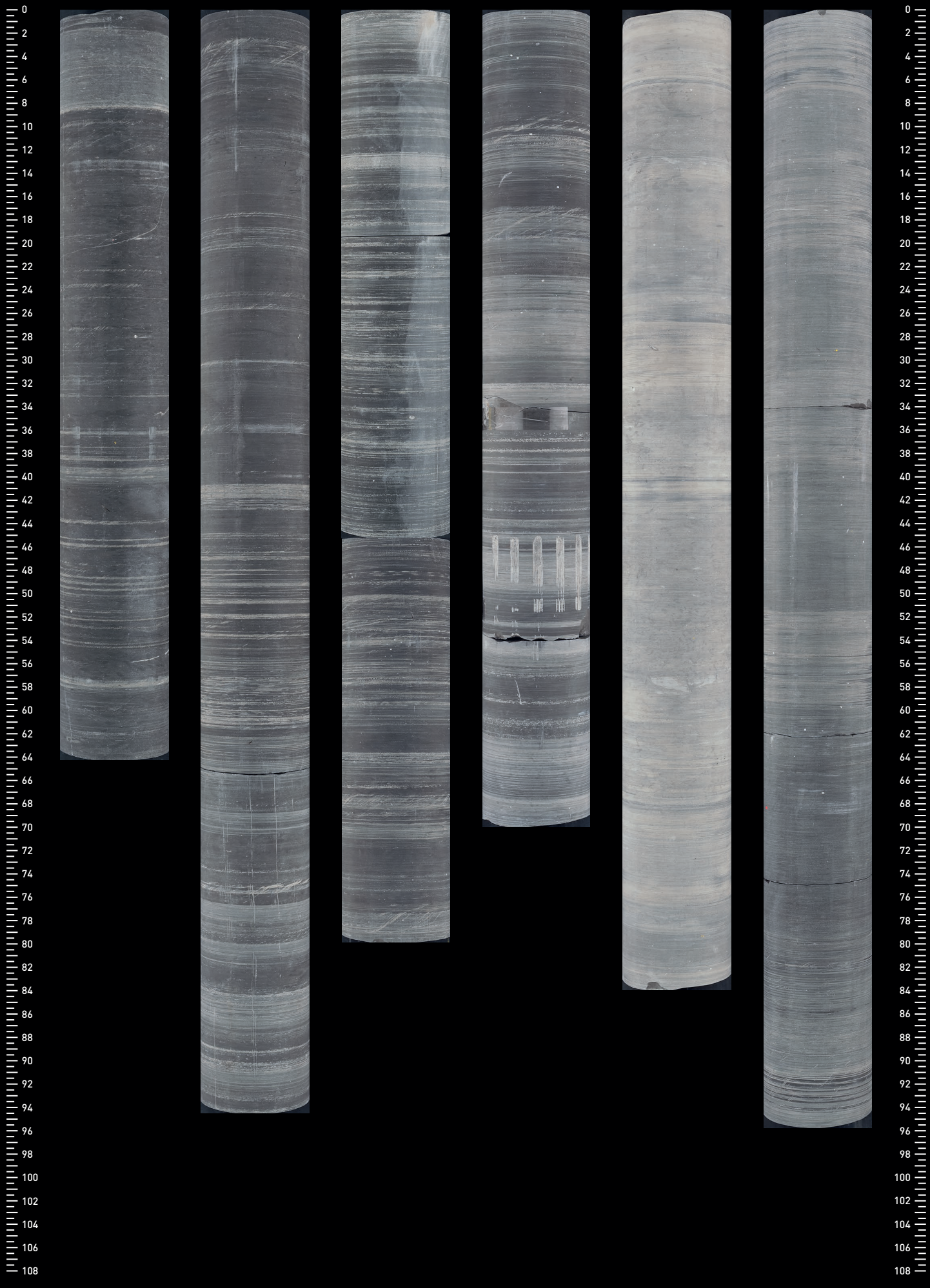


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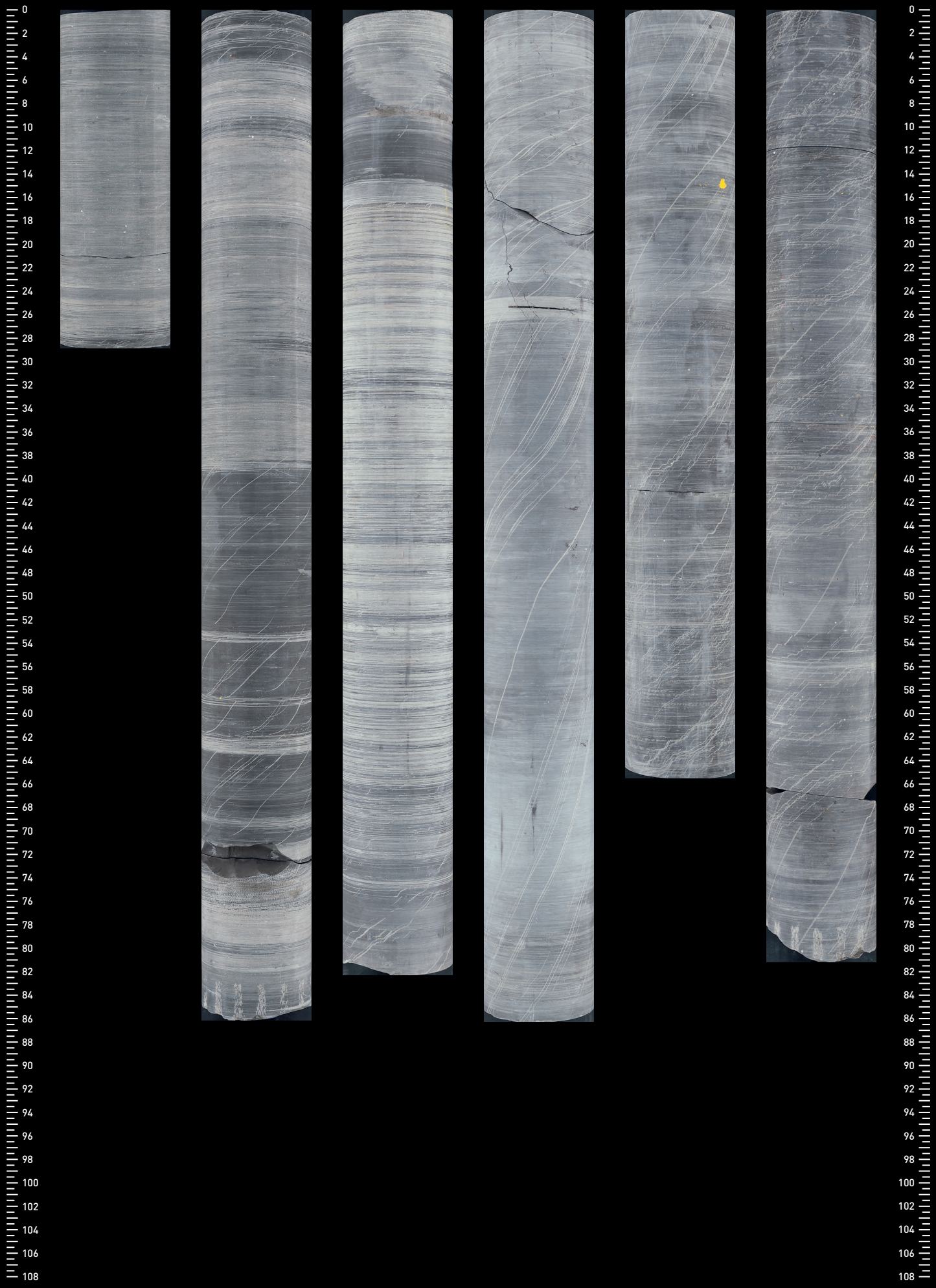
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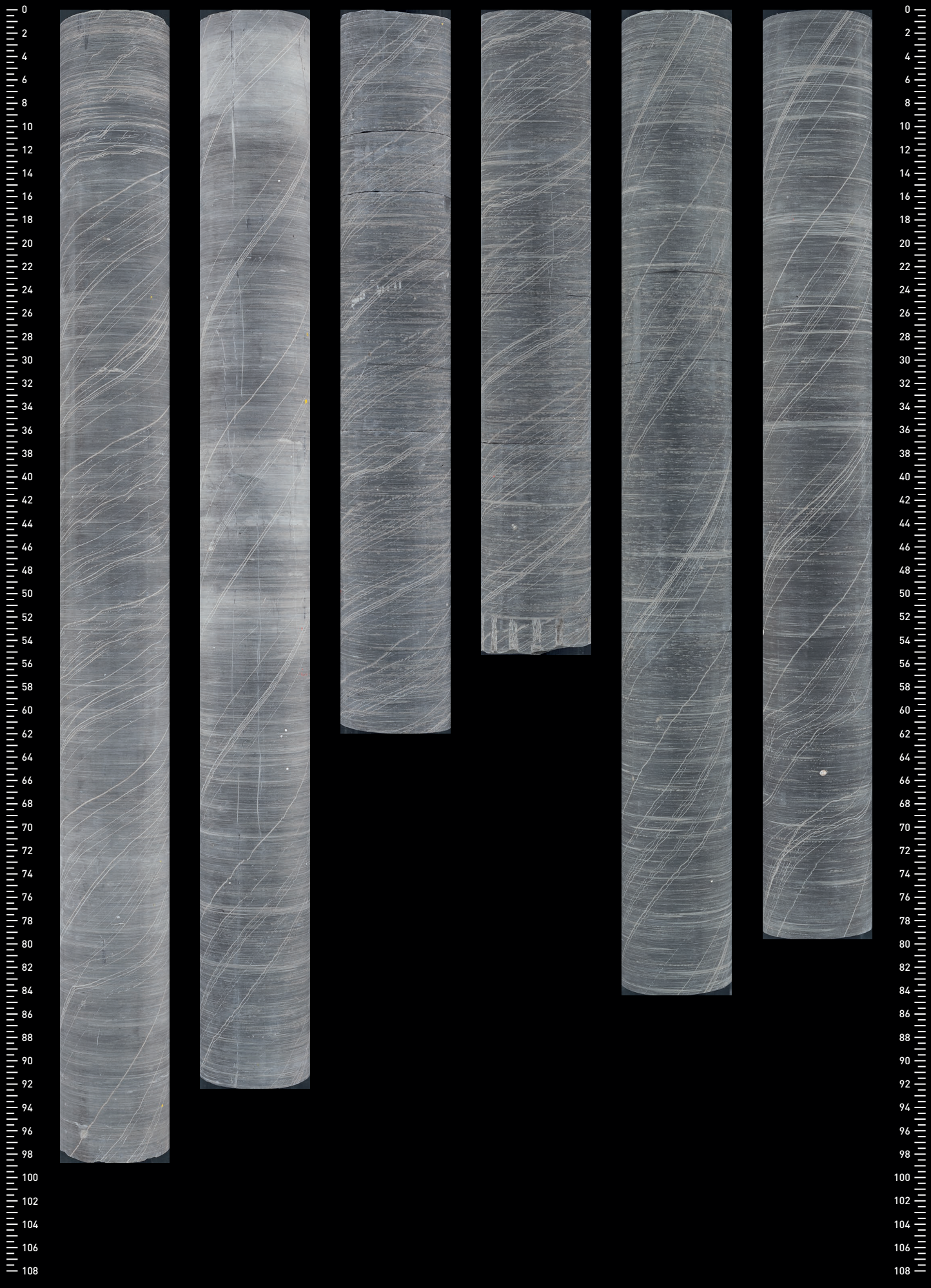

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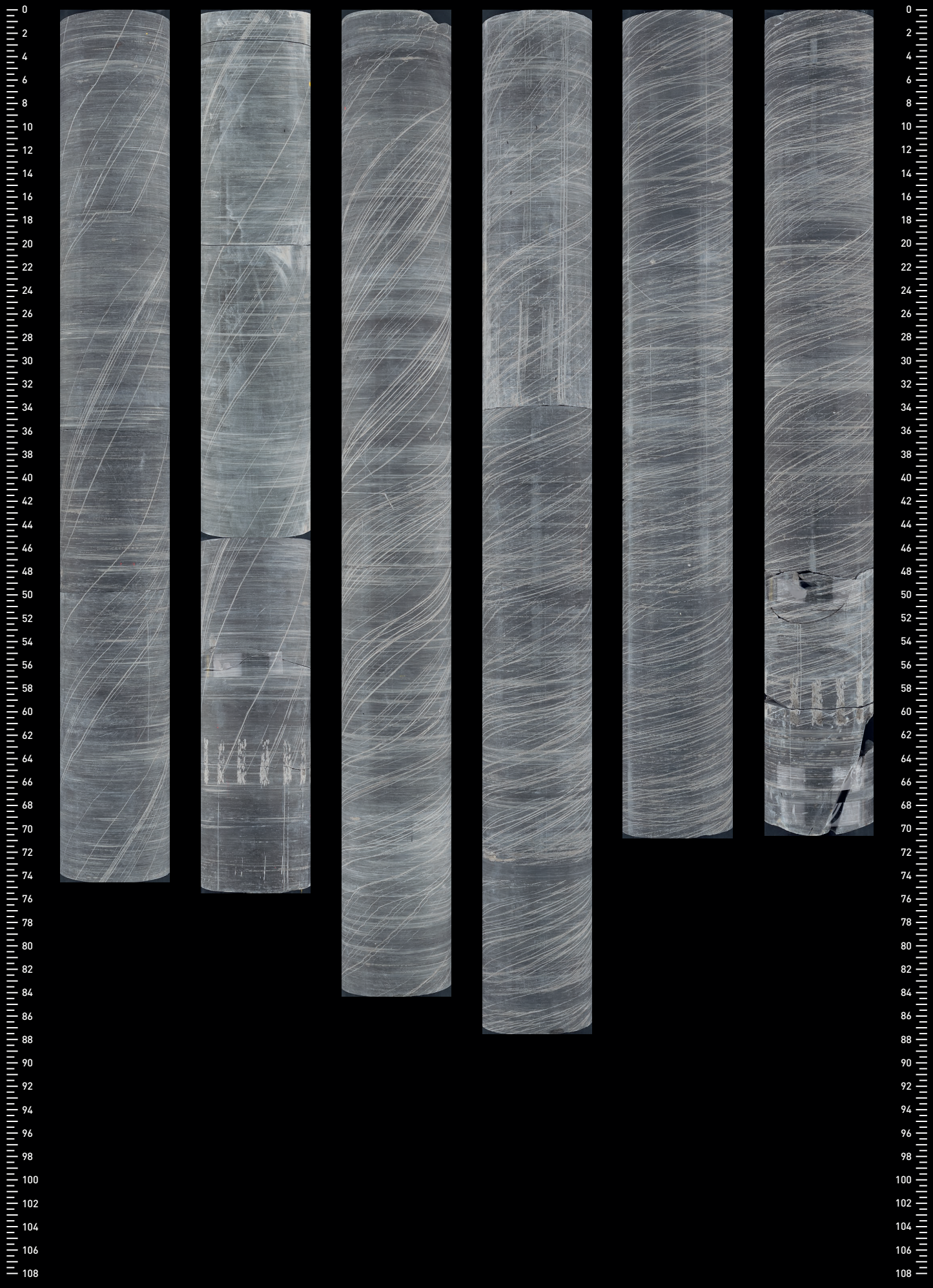
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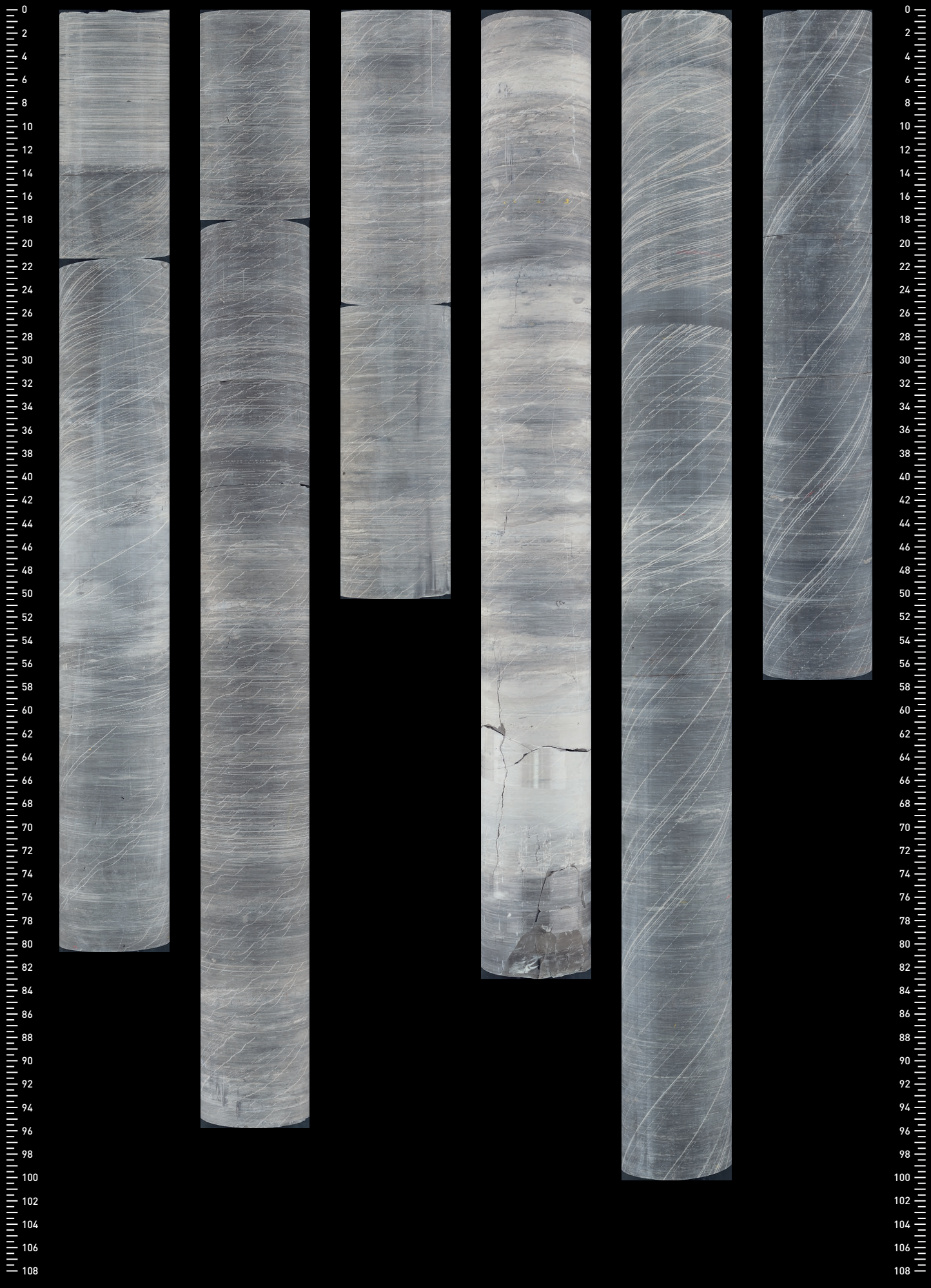
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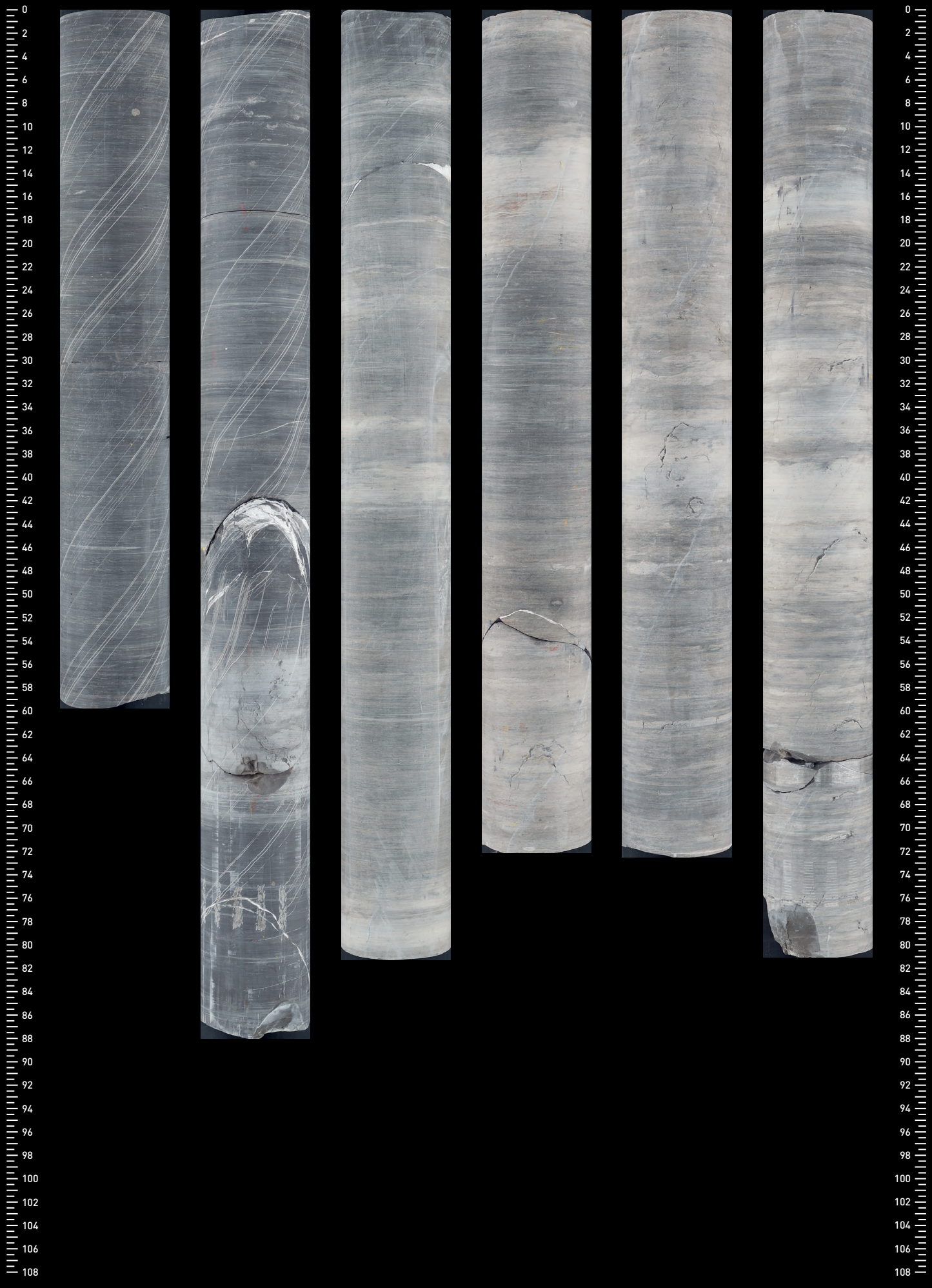
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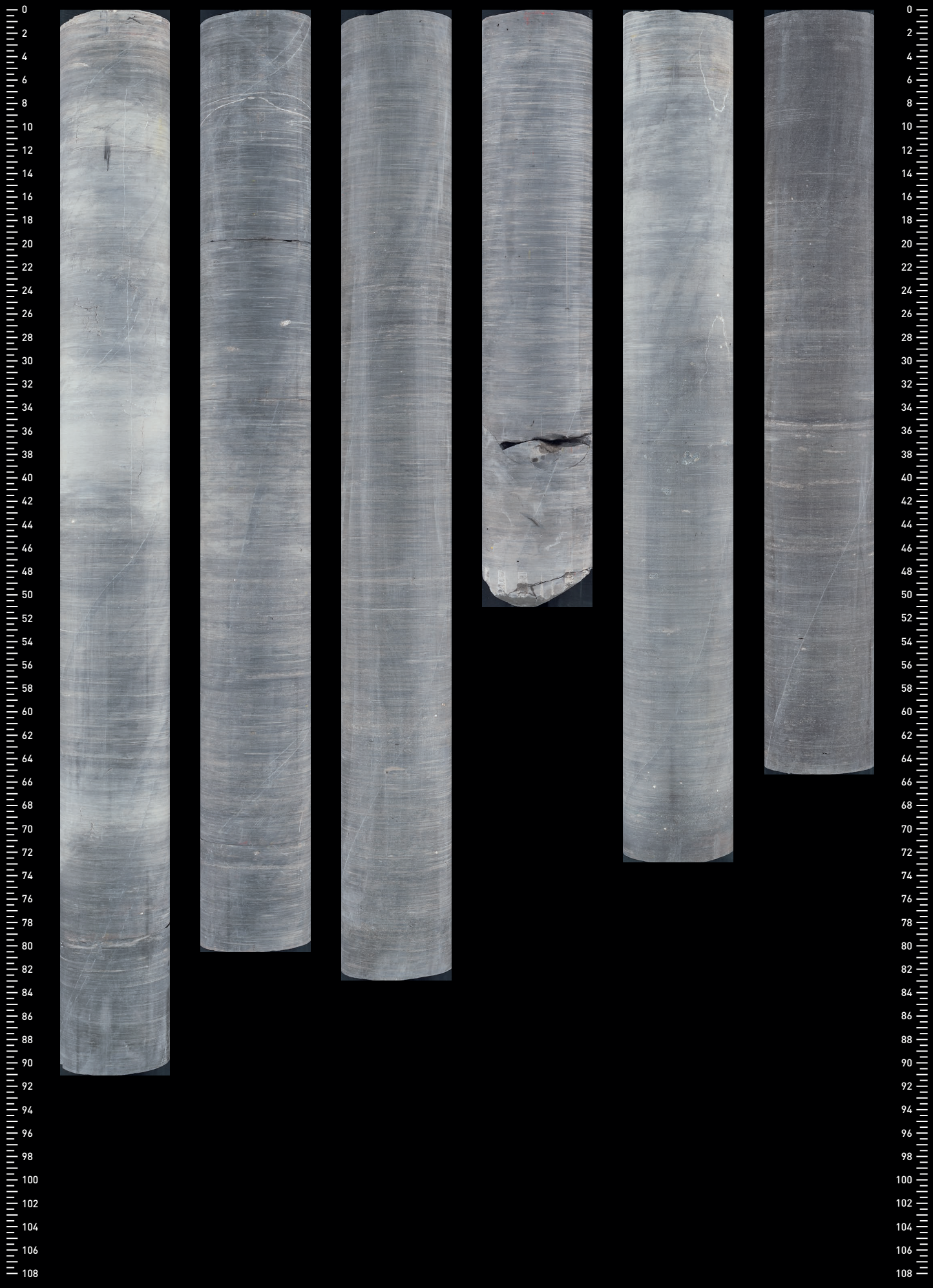
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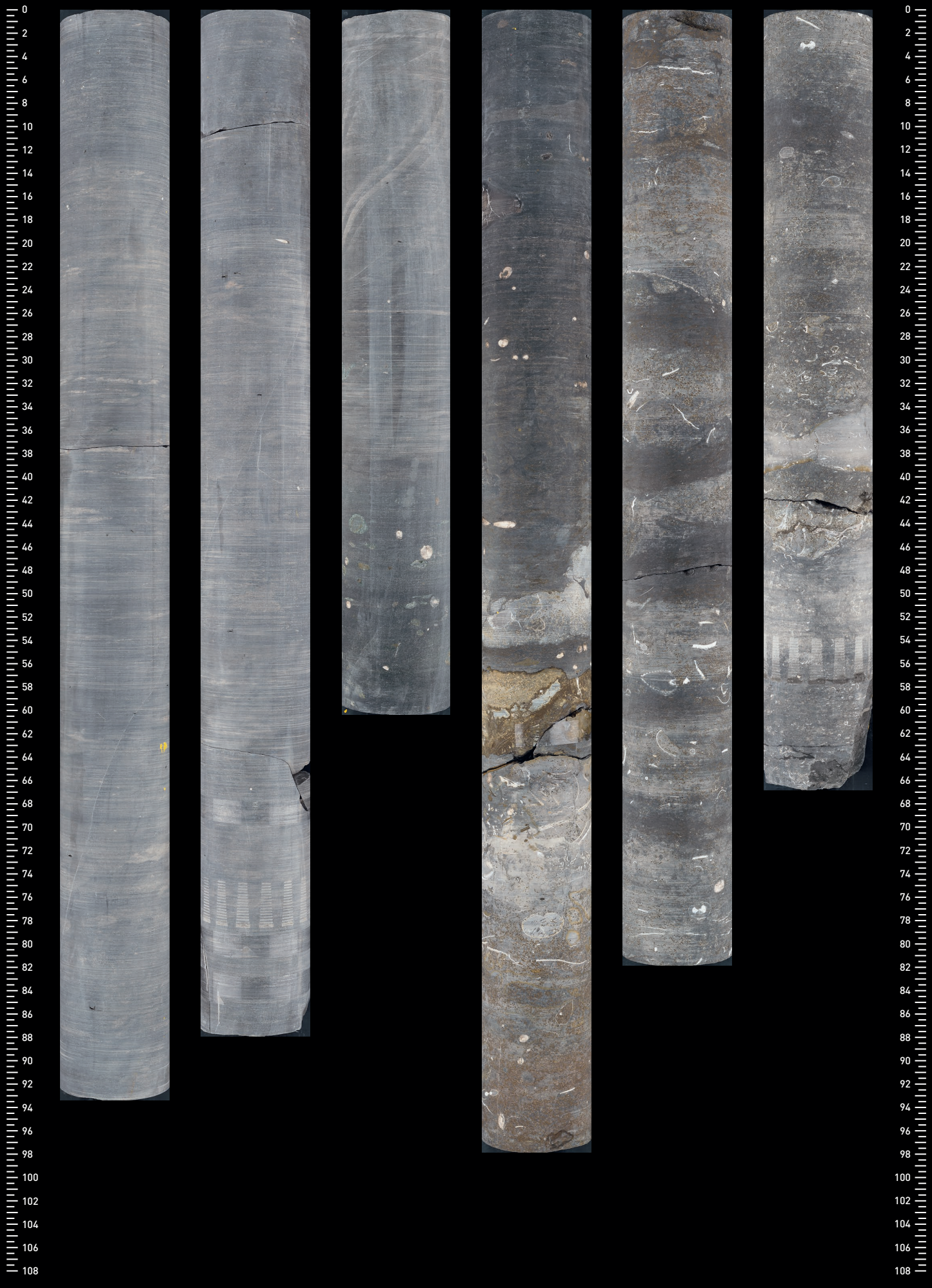
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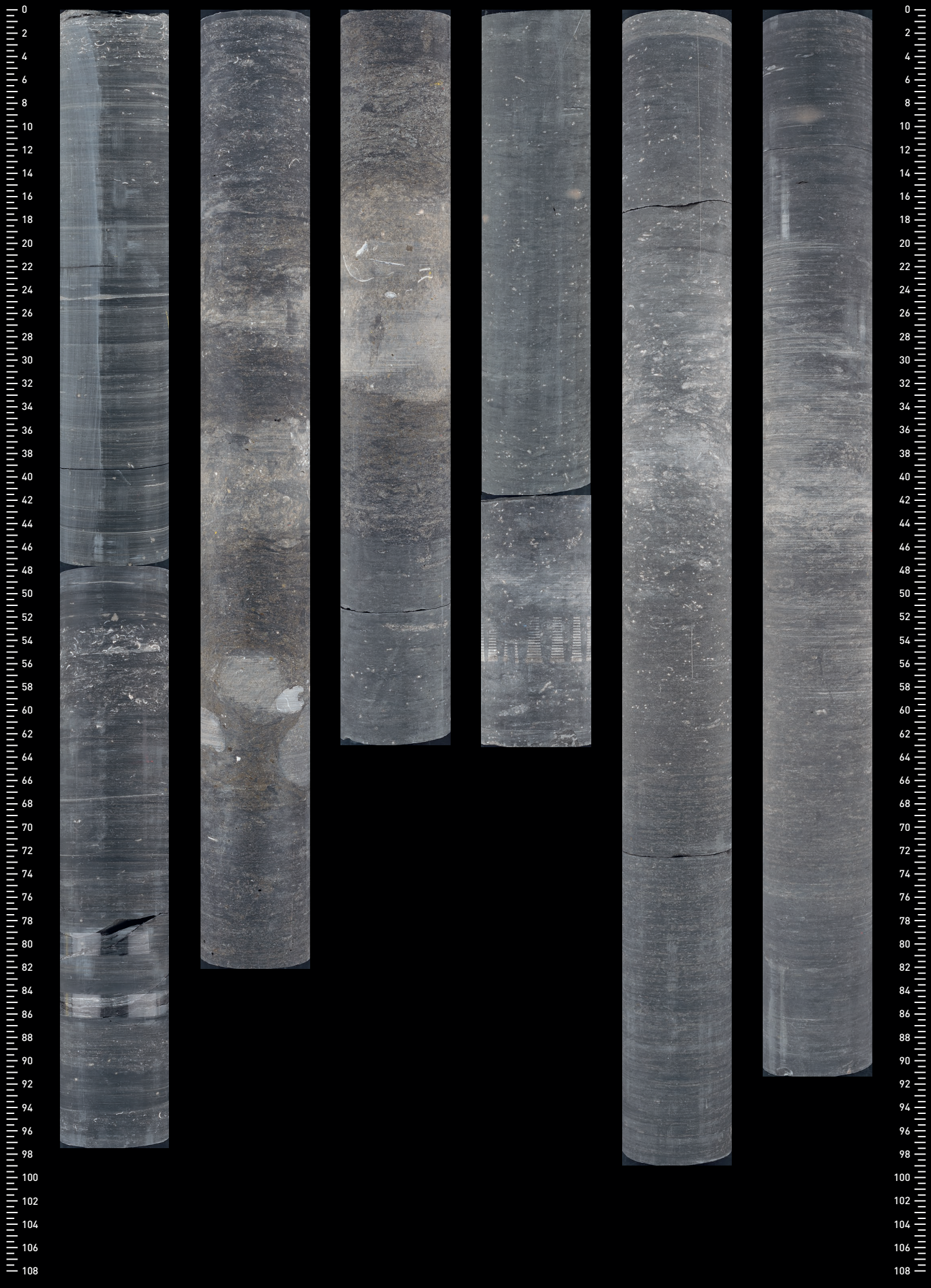
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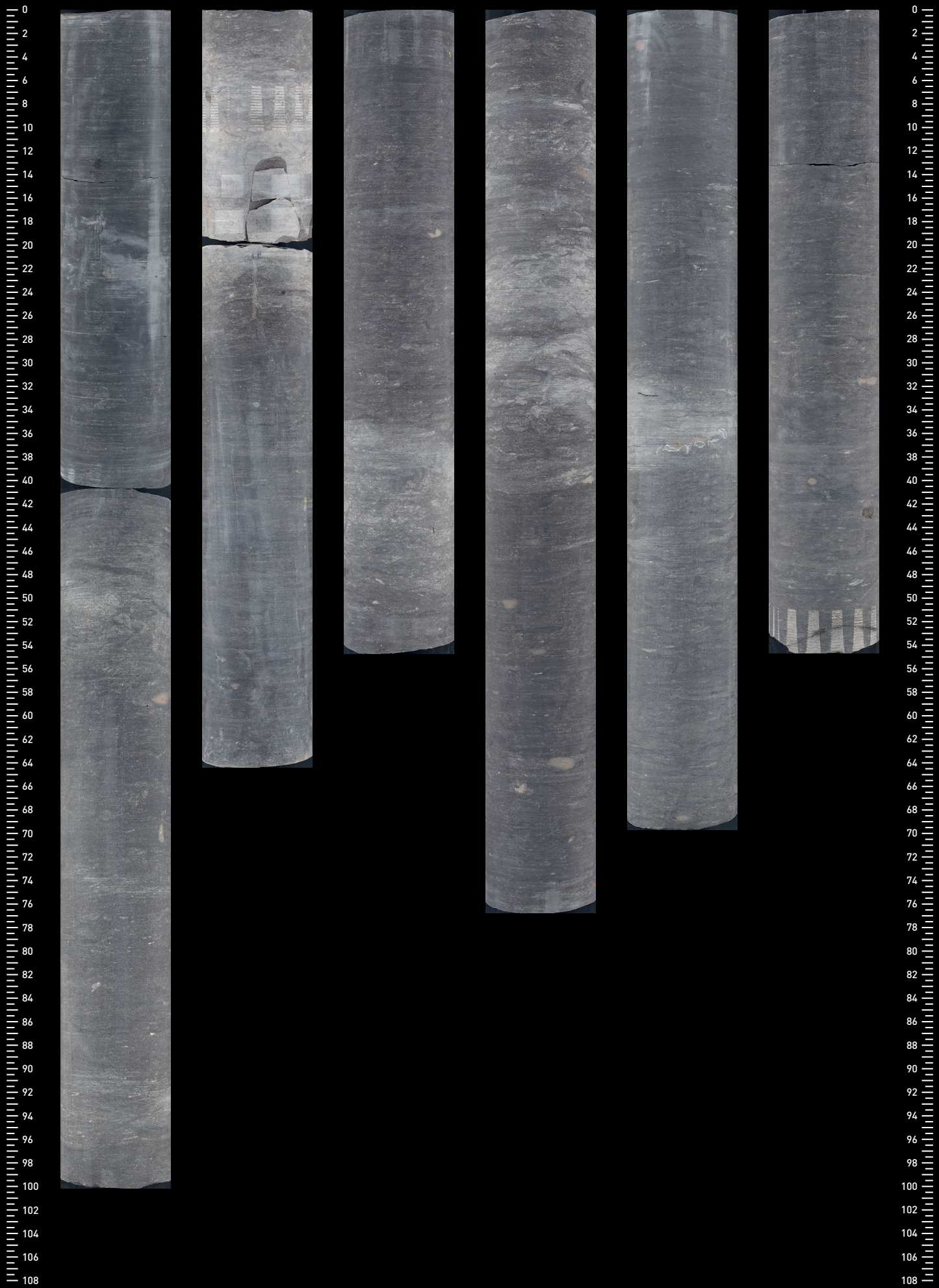
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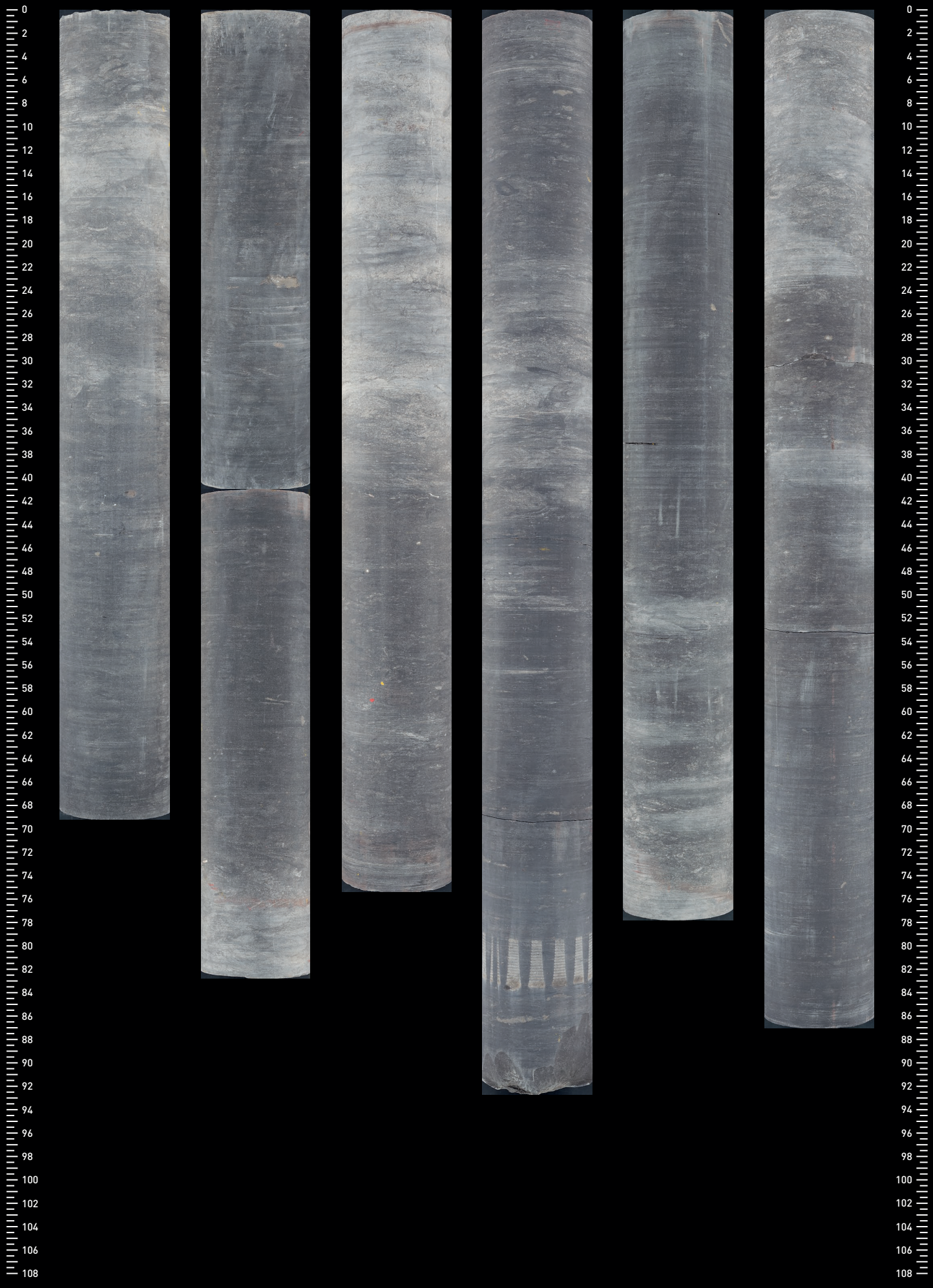
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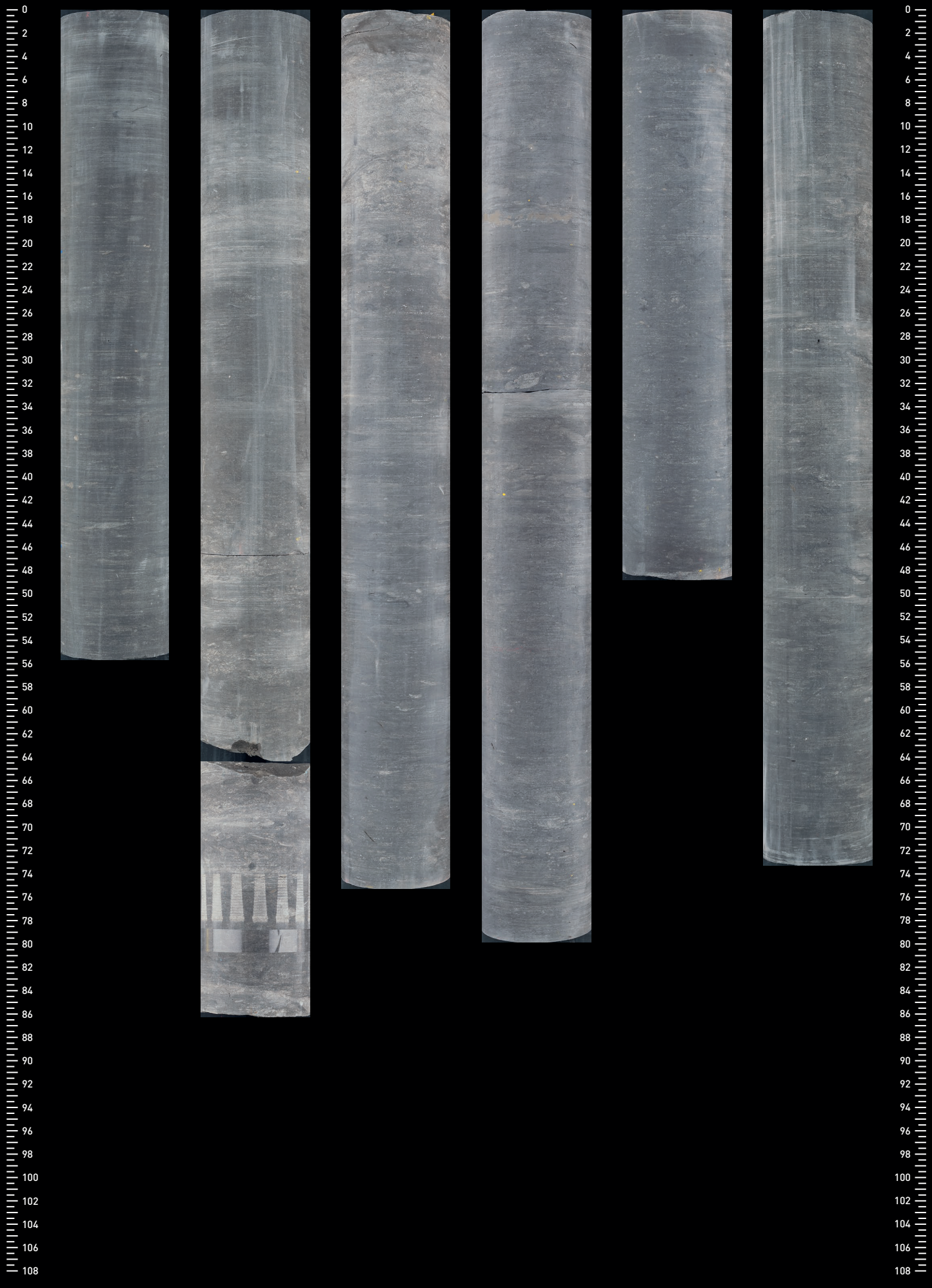
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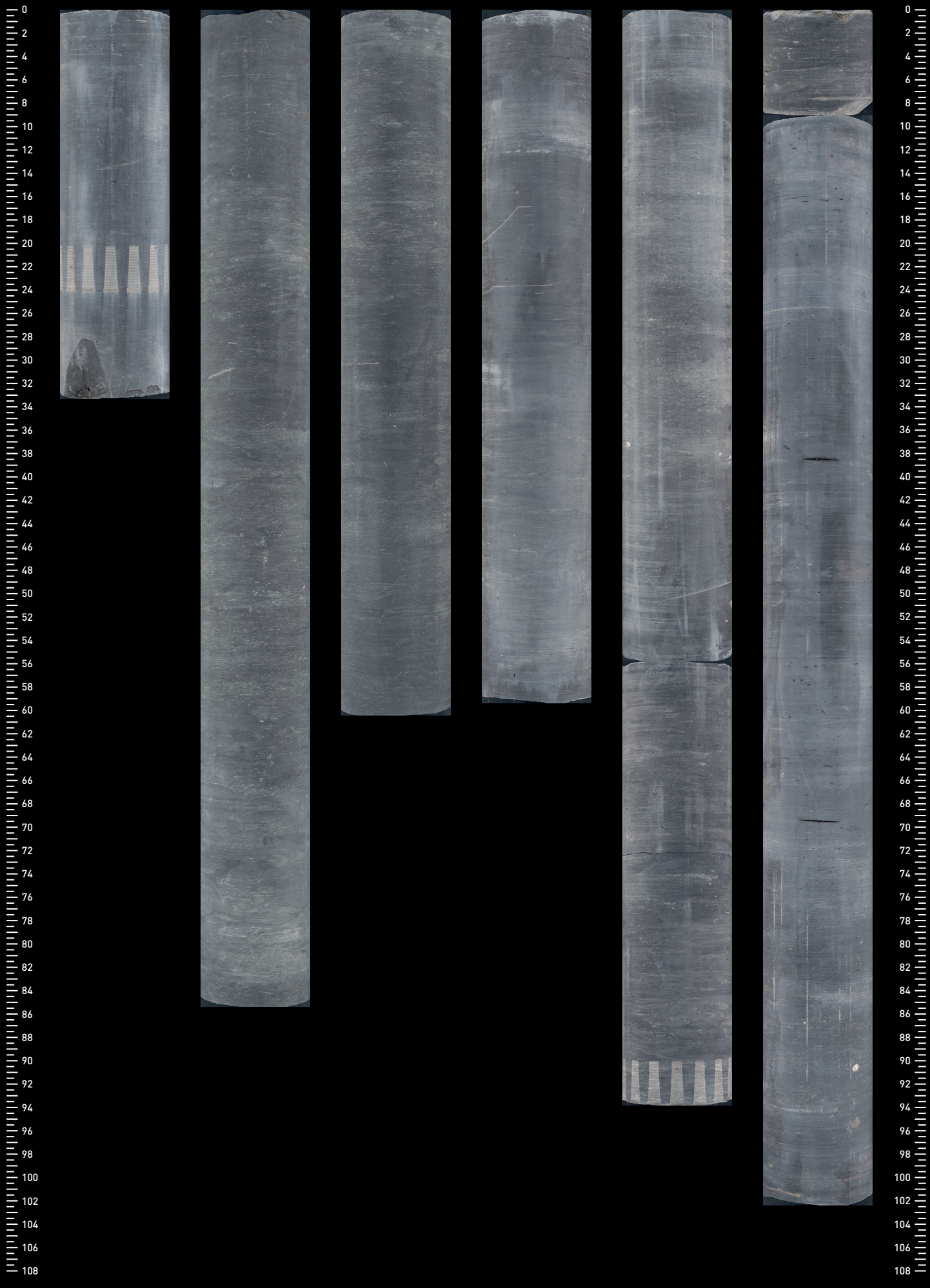


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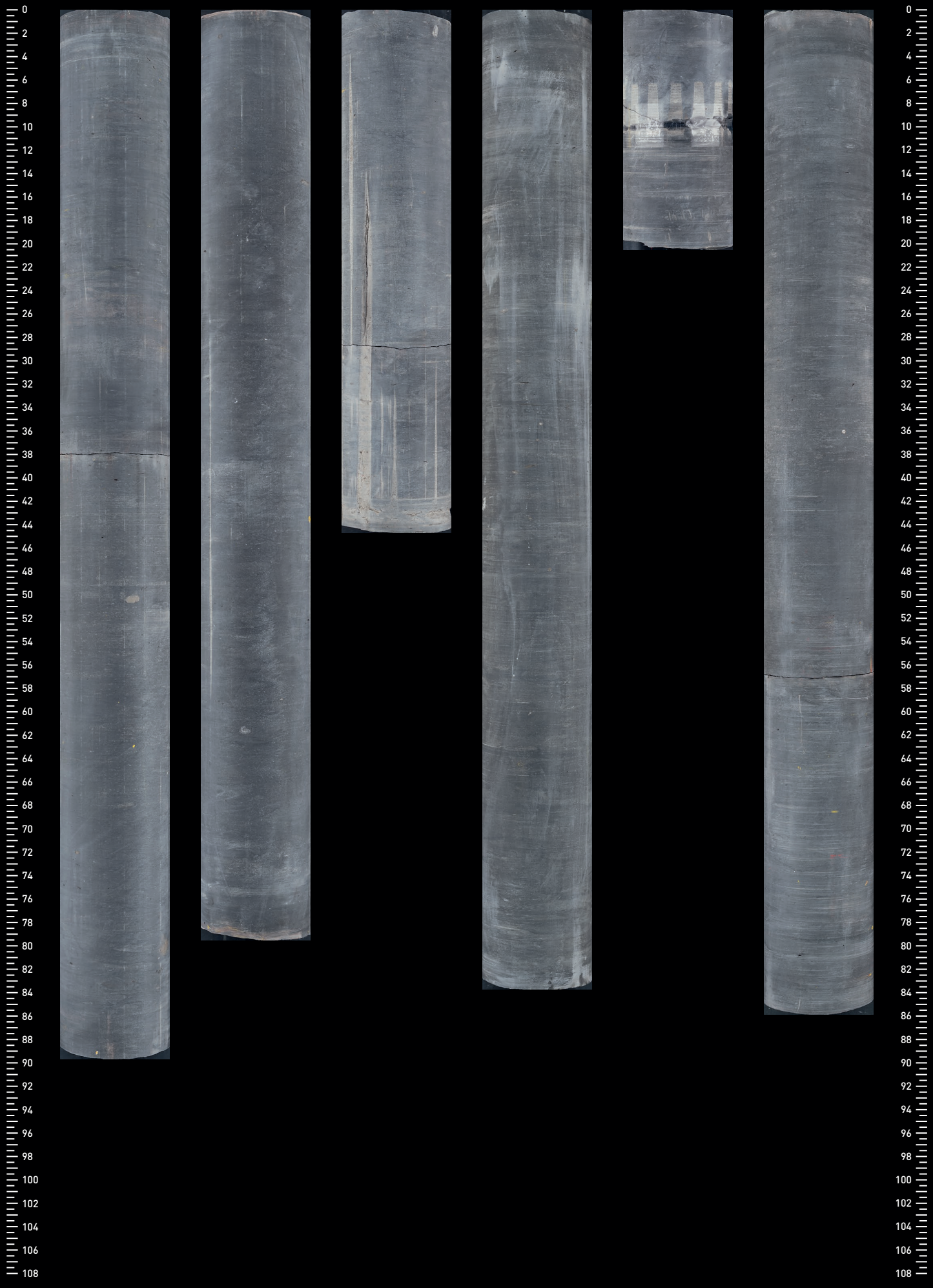
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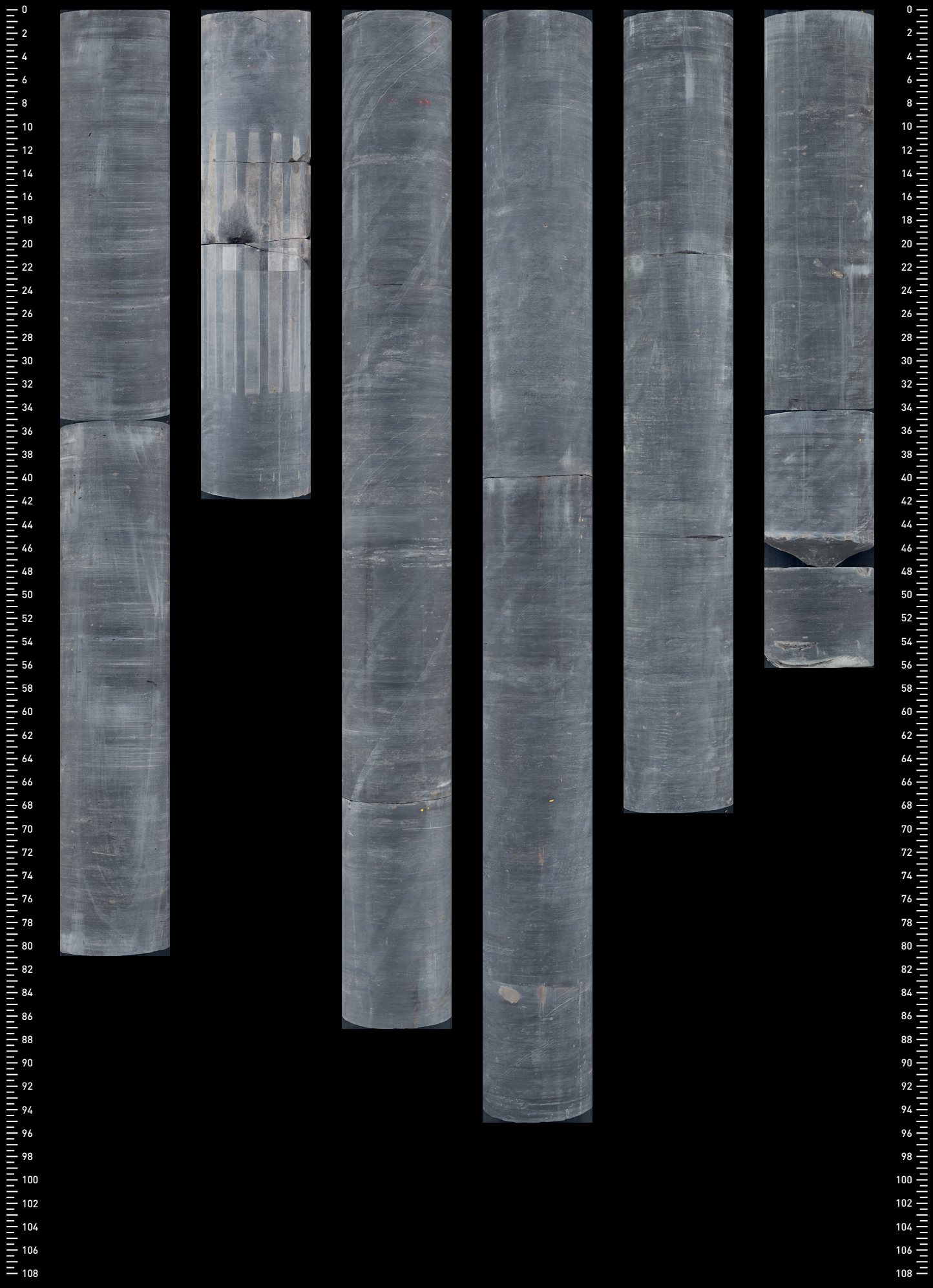

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760.96m 761.83m 762.61m 763.04m 763.86m 764.05m



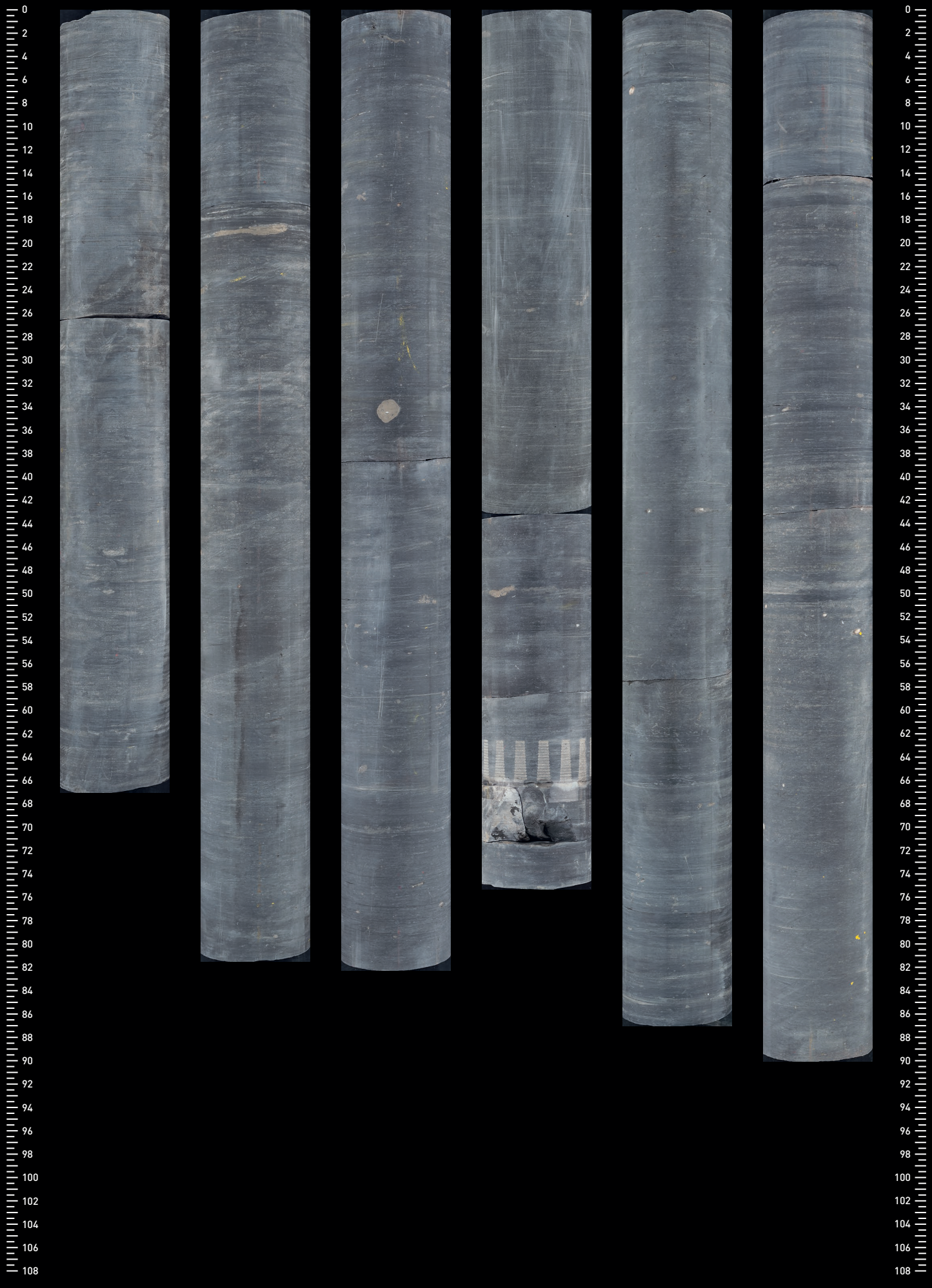
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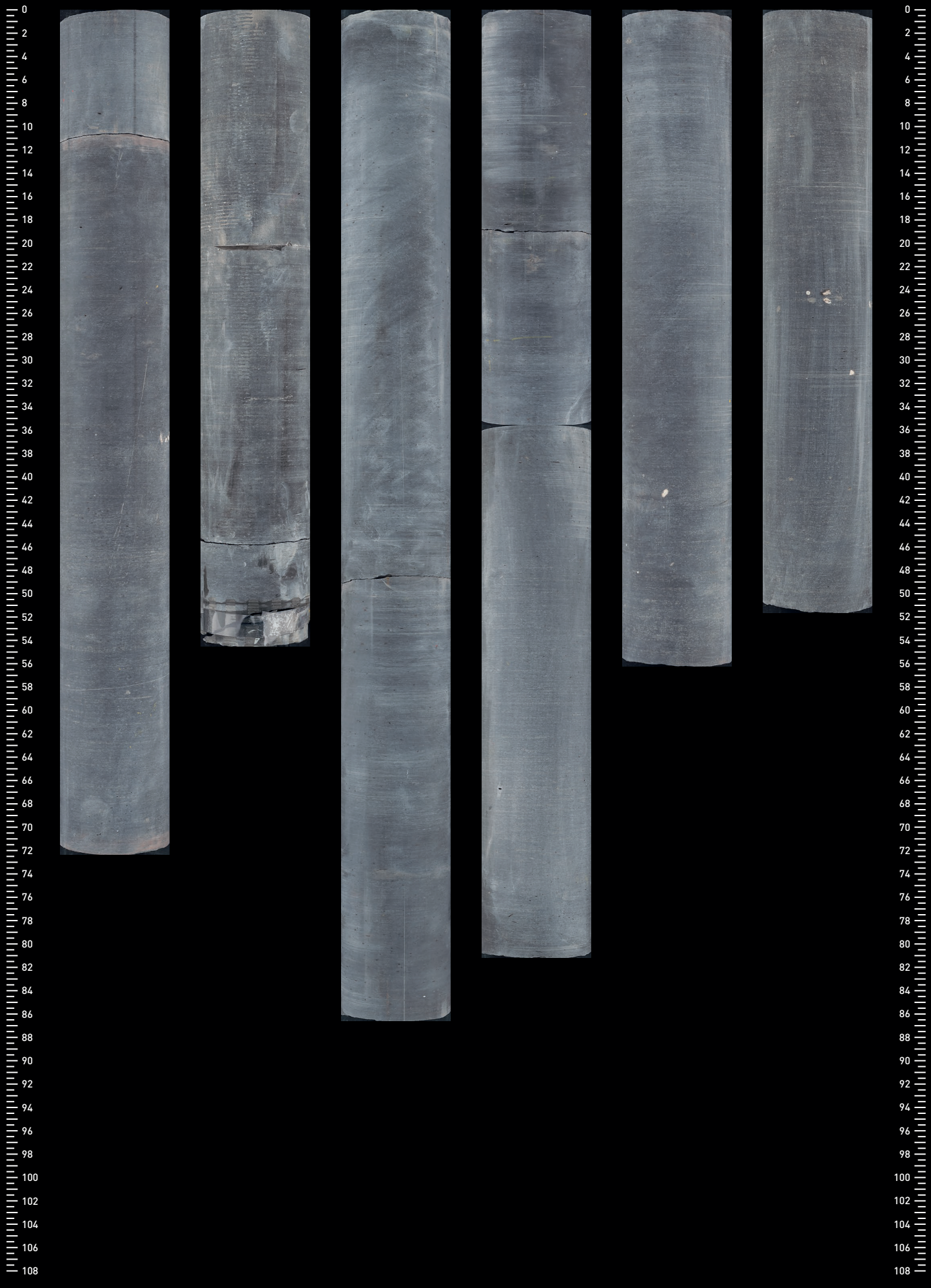
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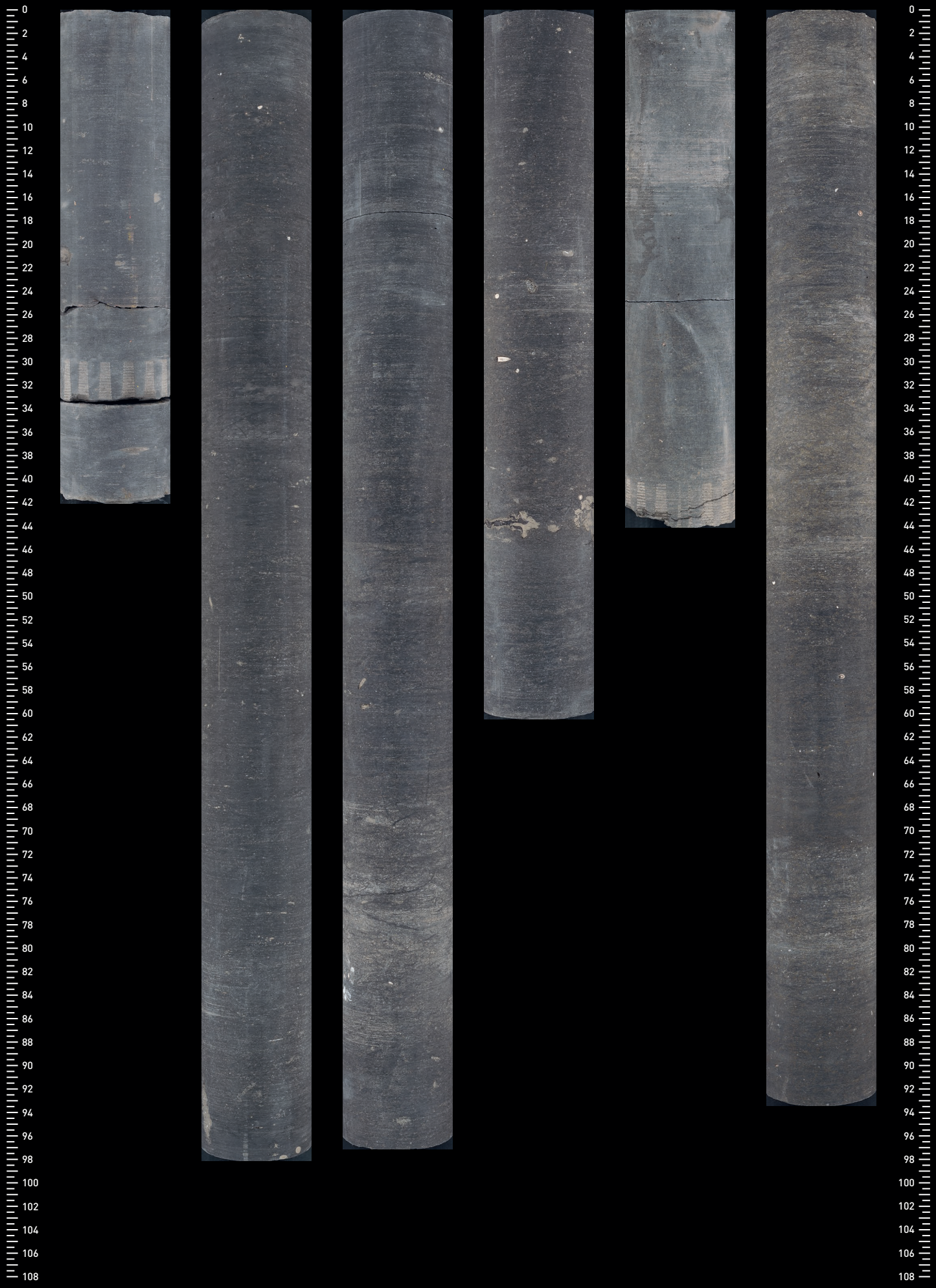
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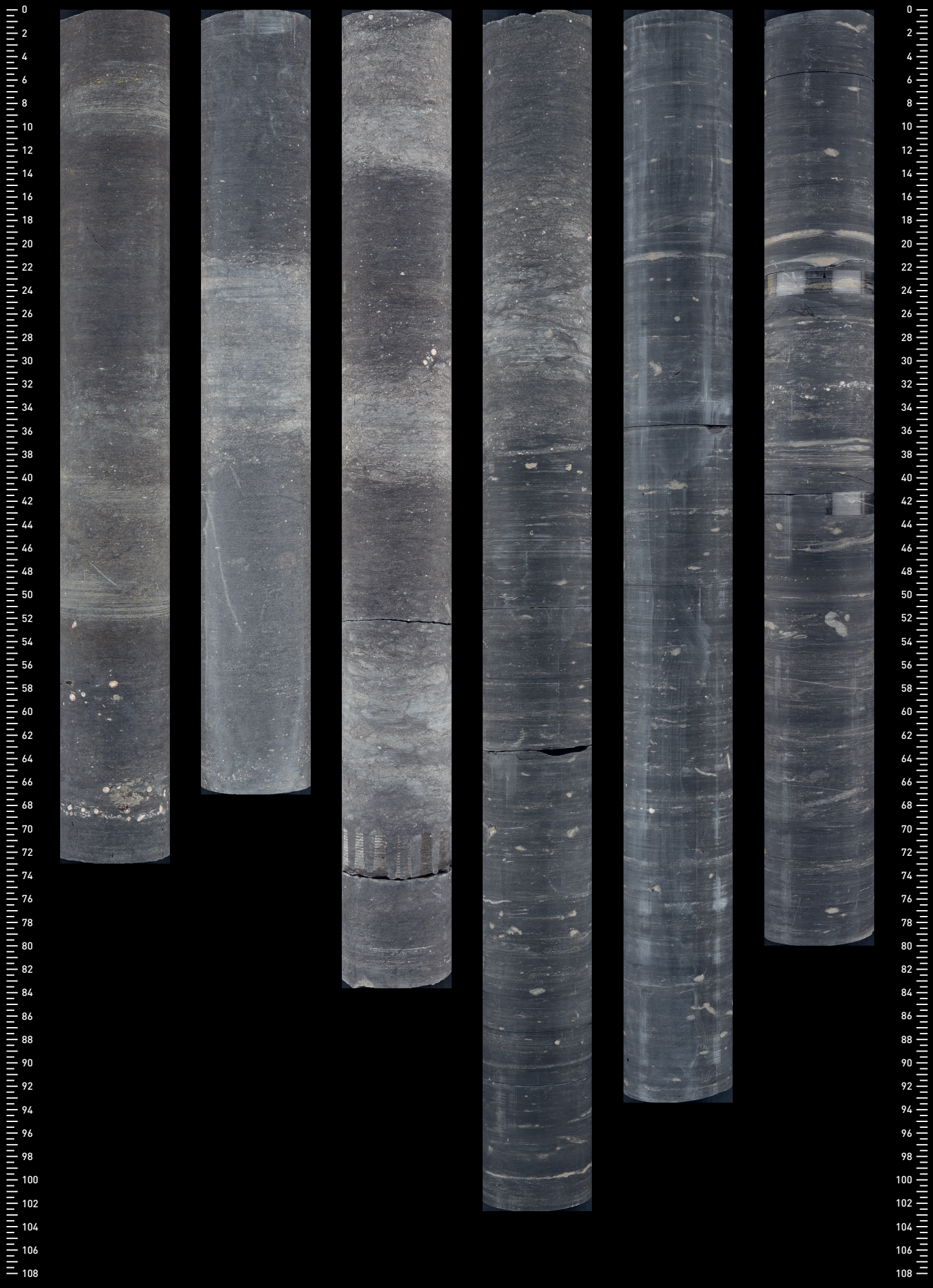
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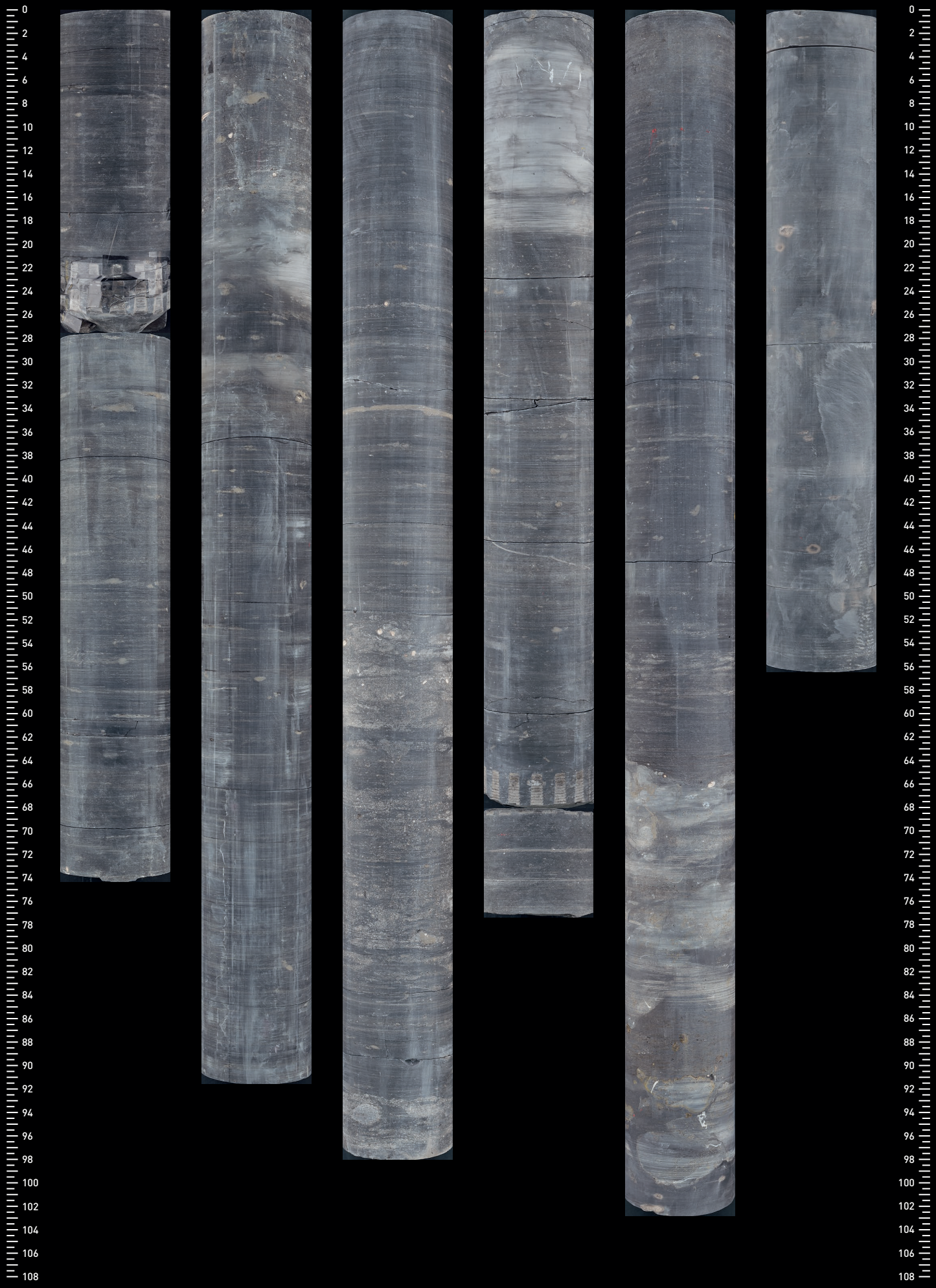
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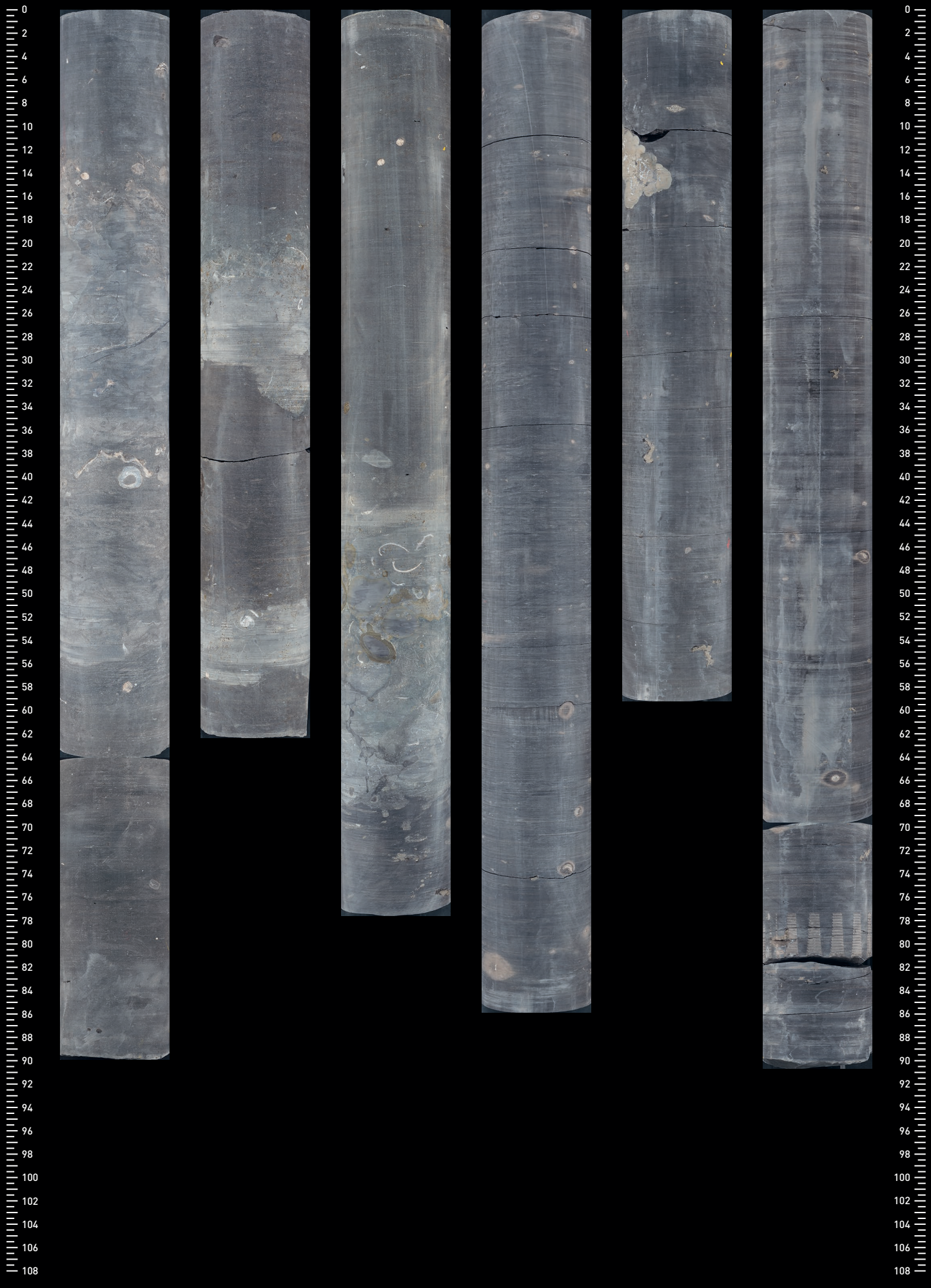
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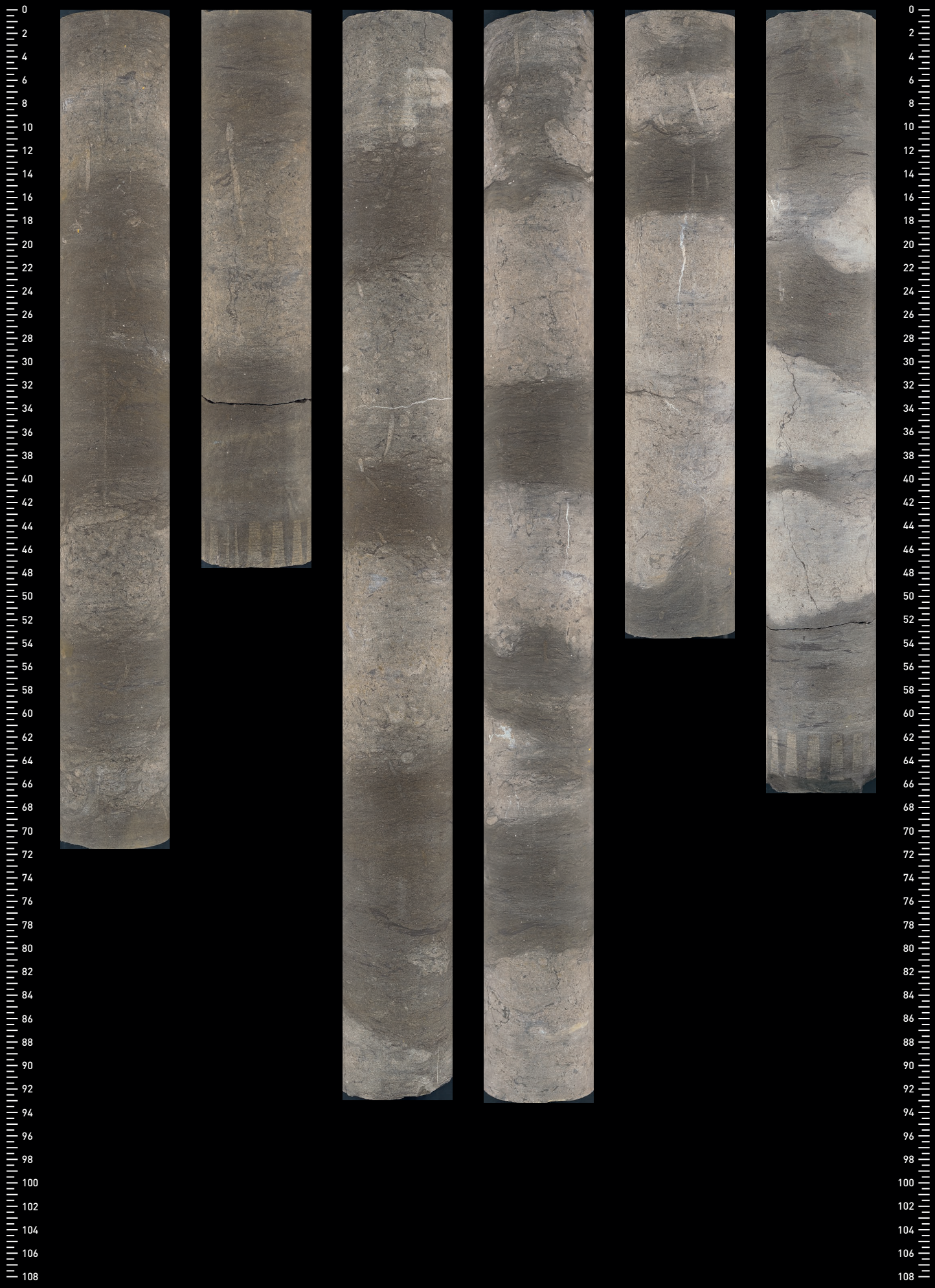
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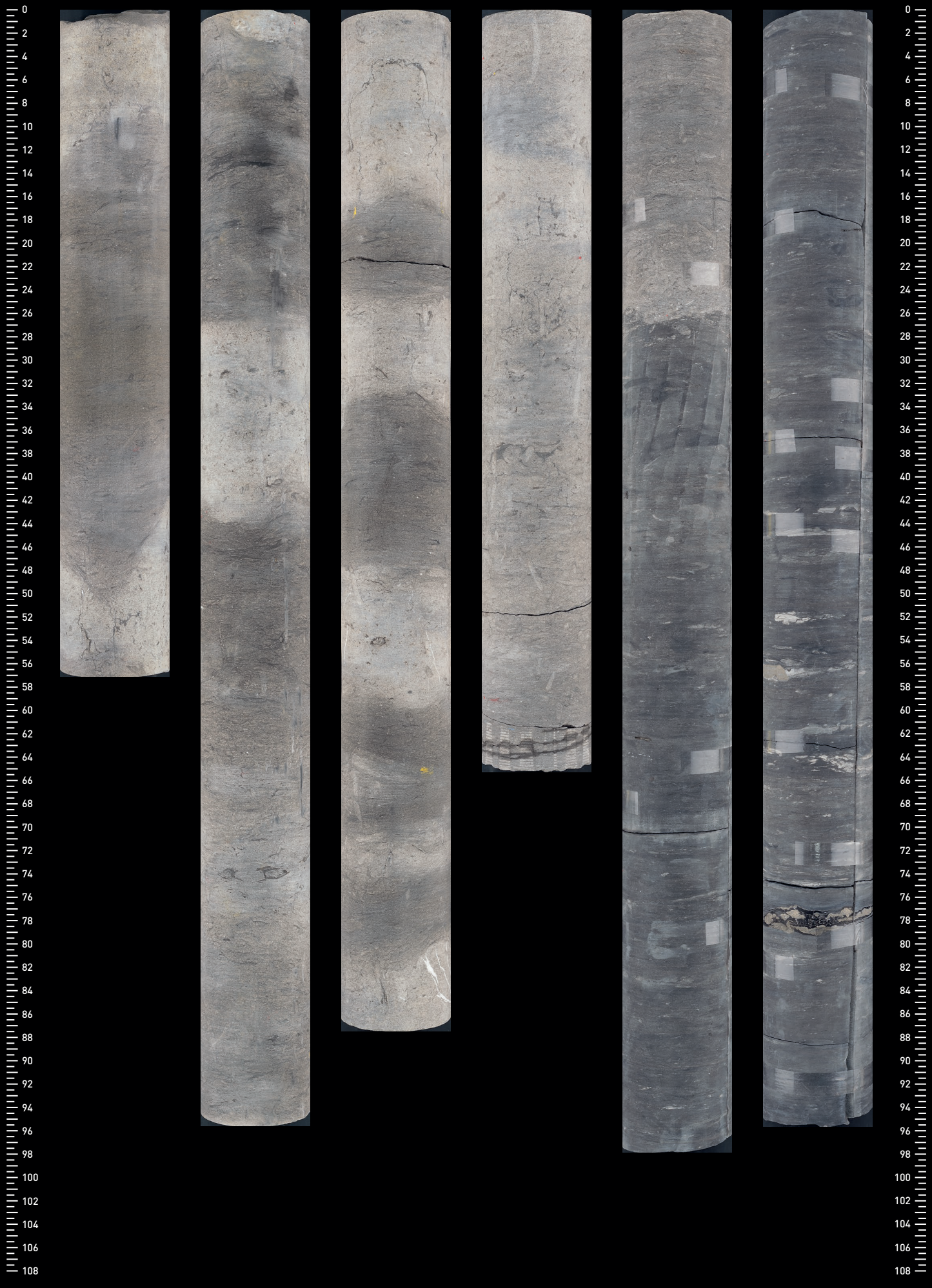
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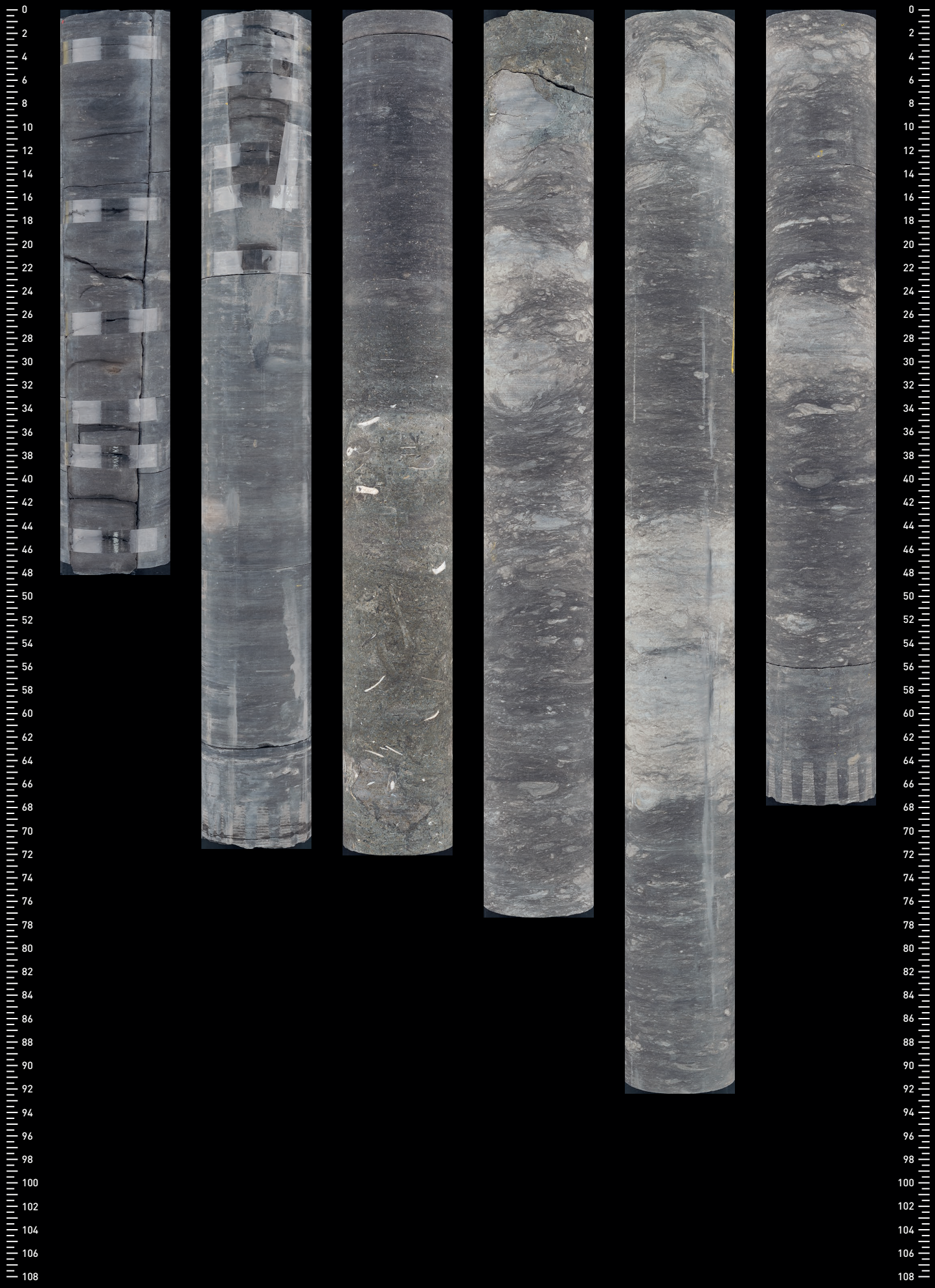
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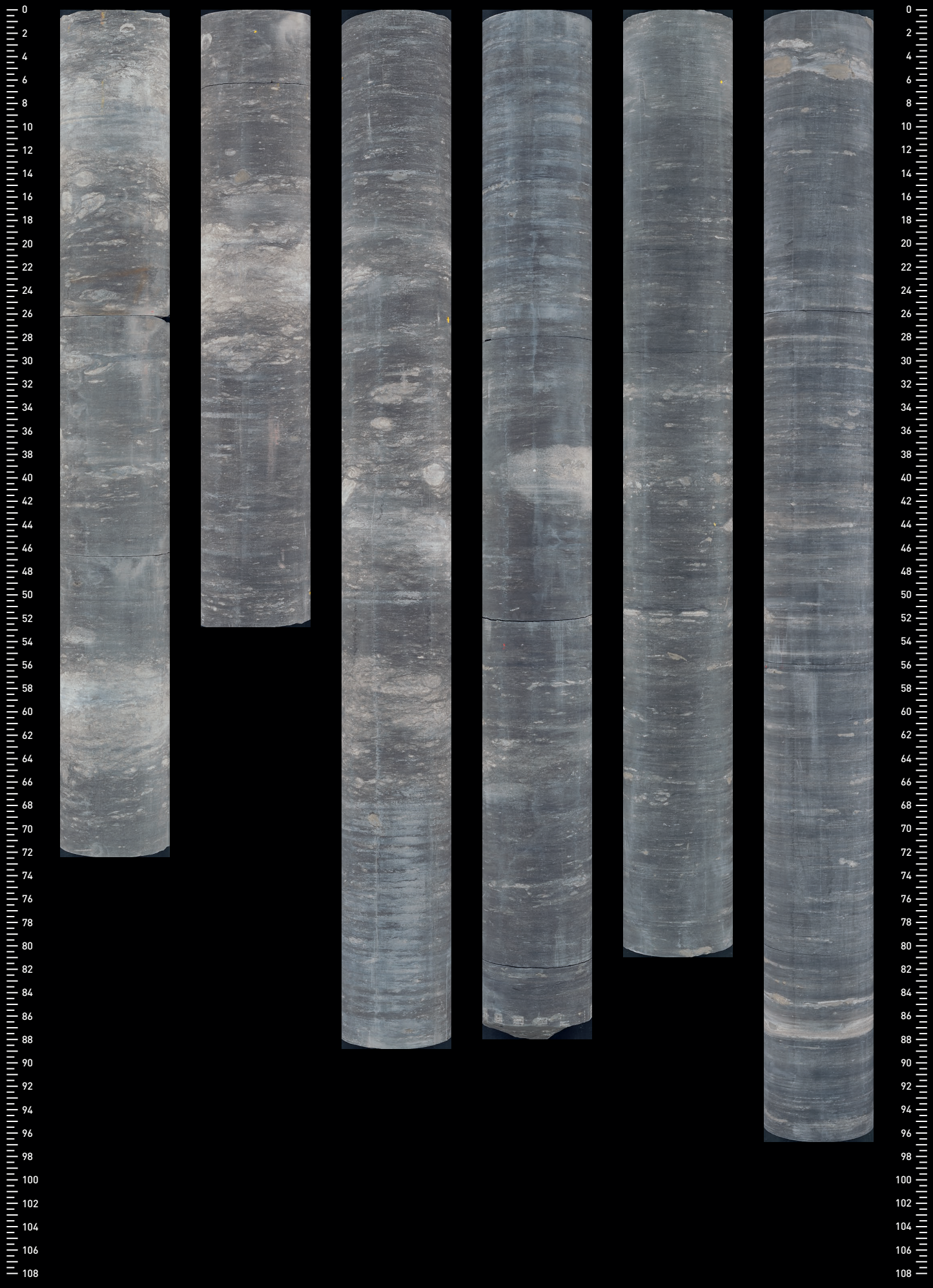
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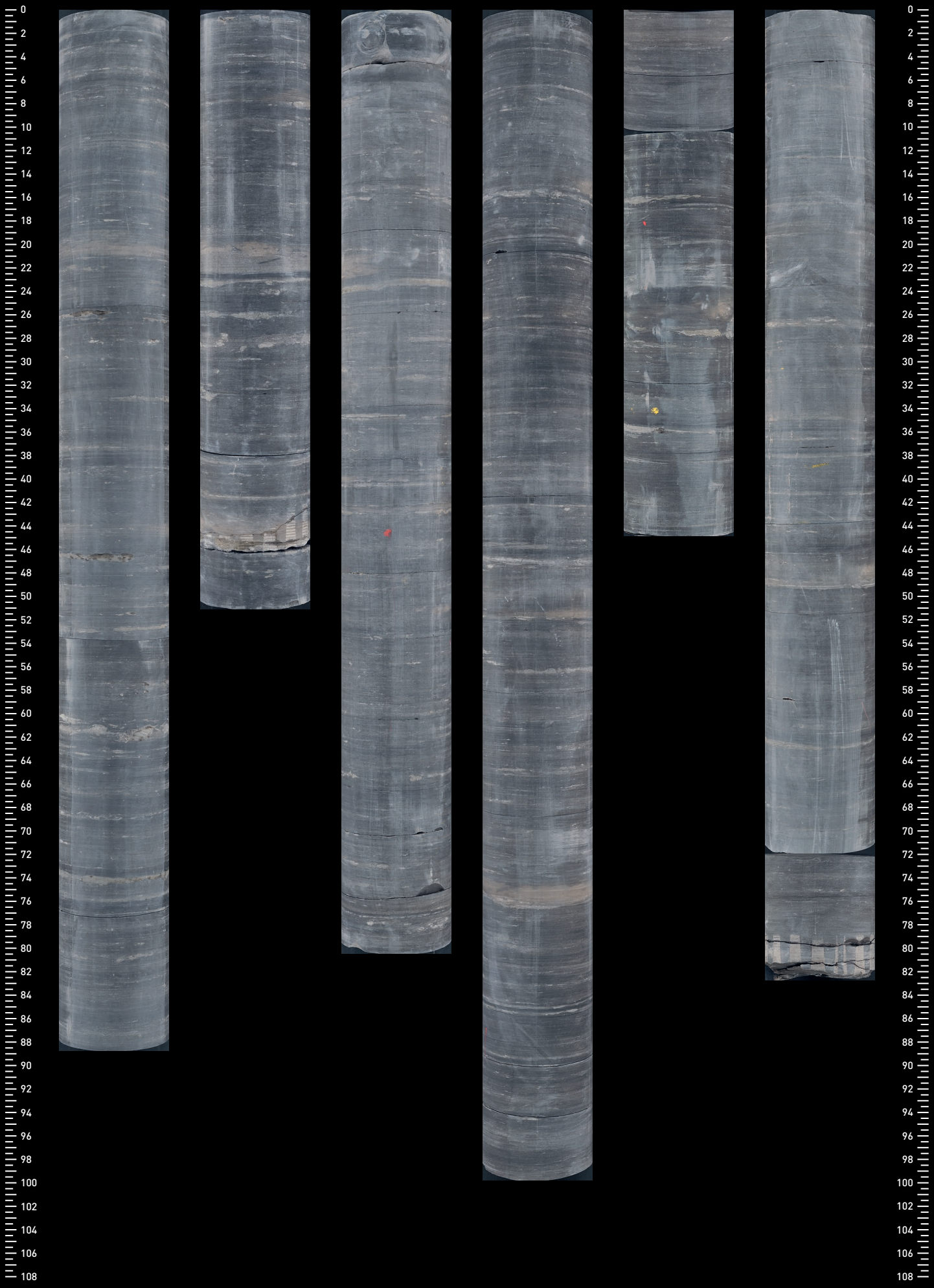
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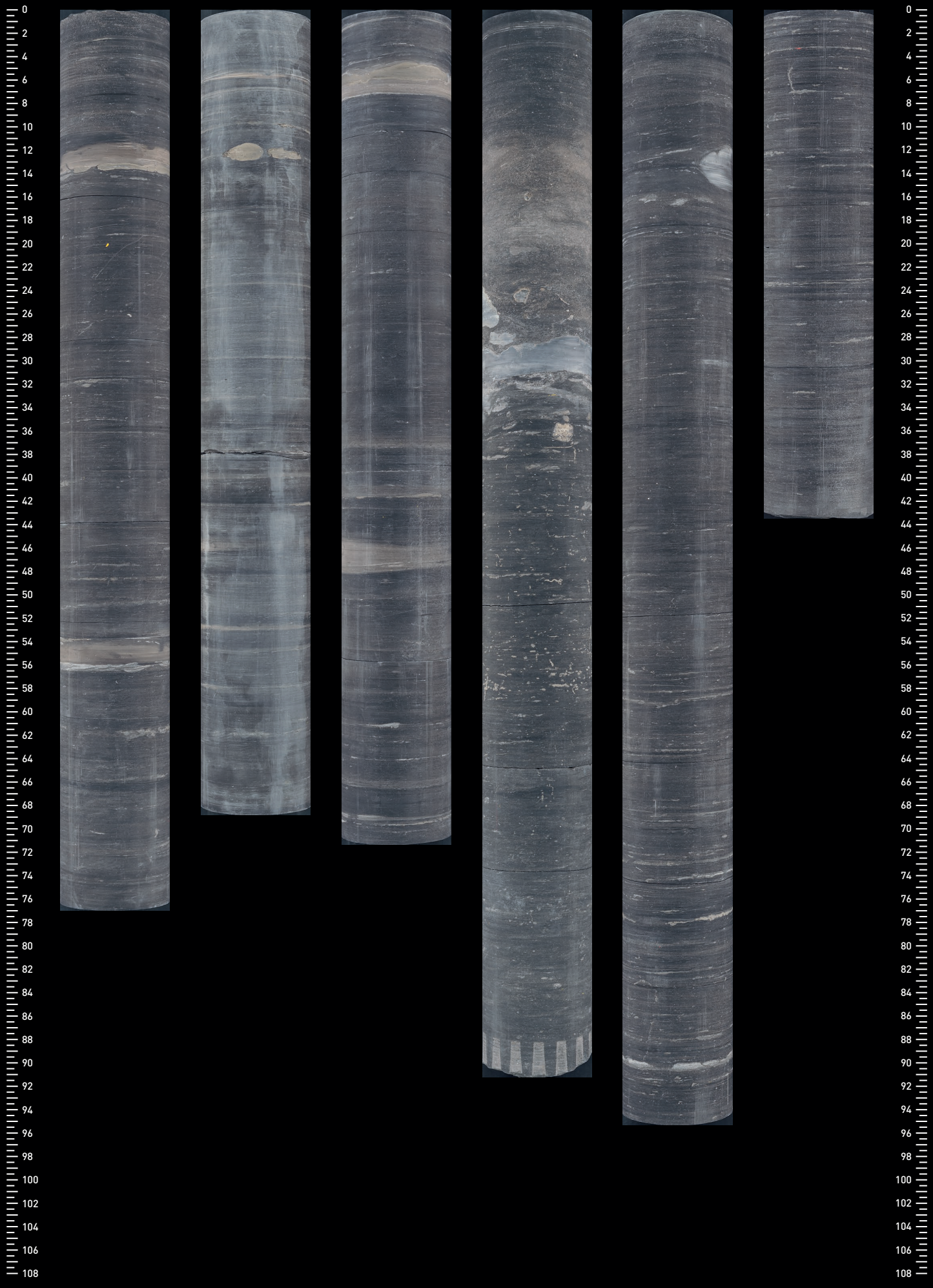
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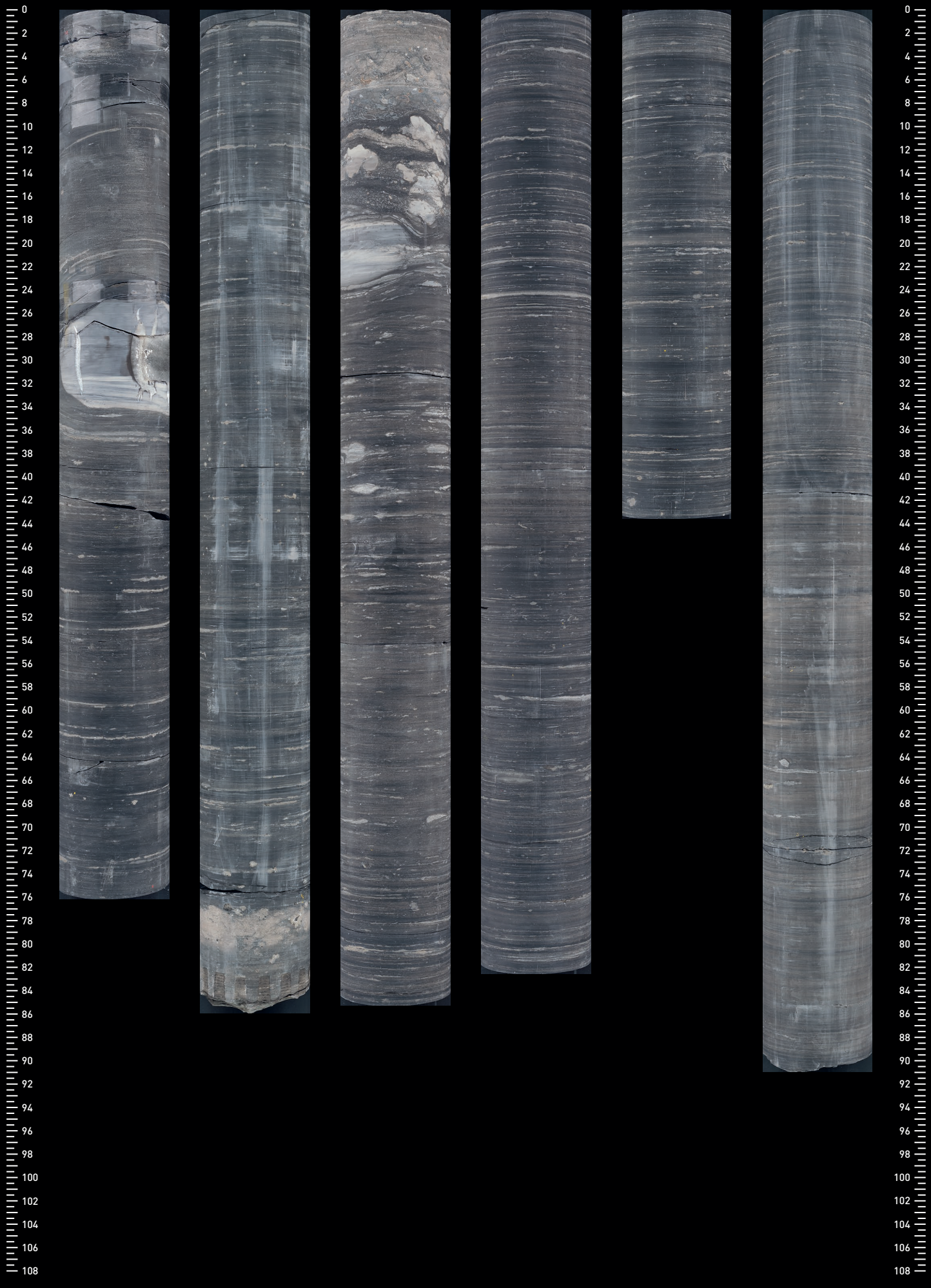
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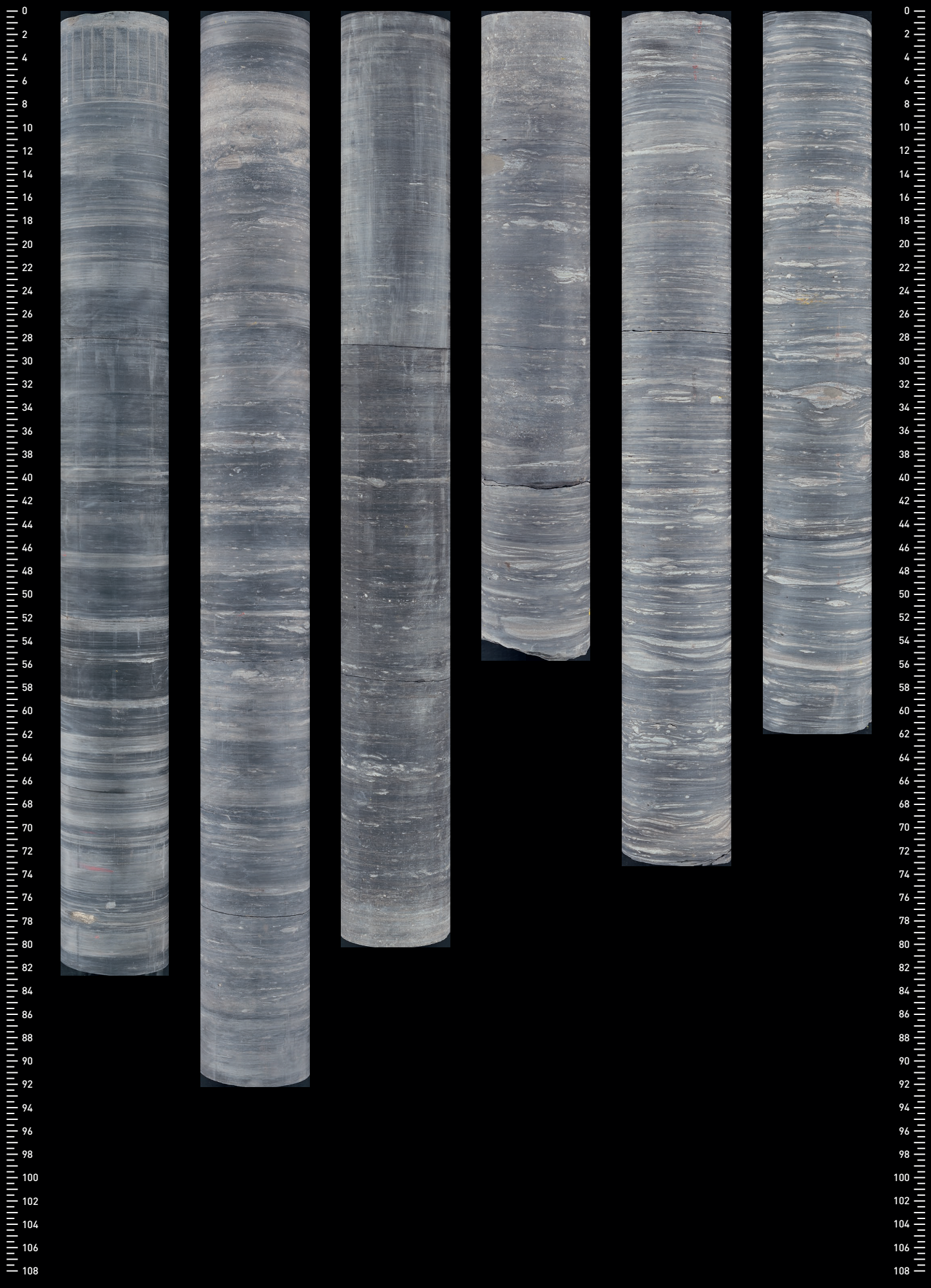


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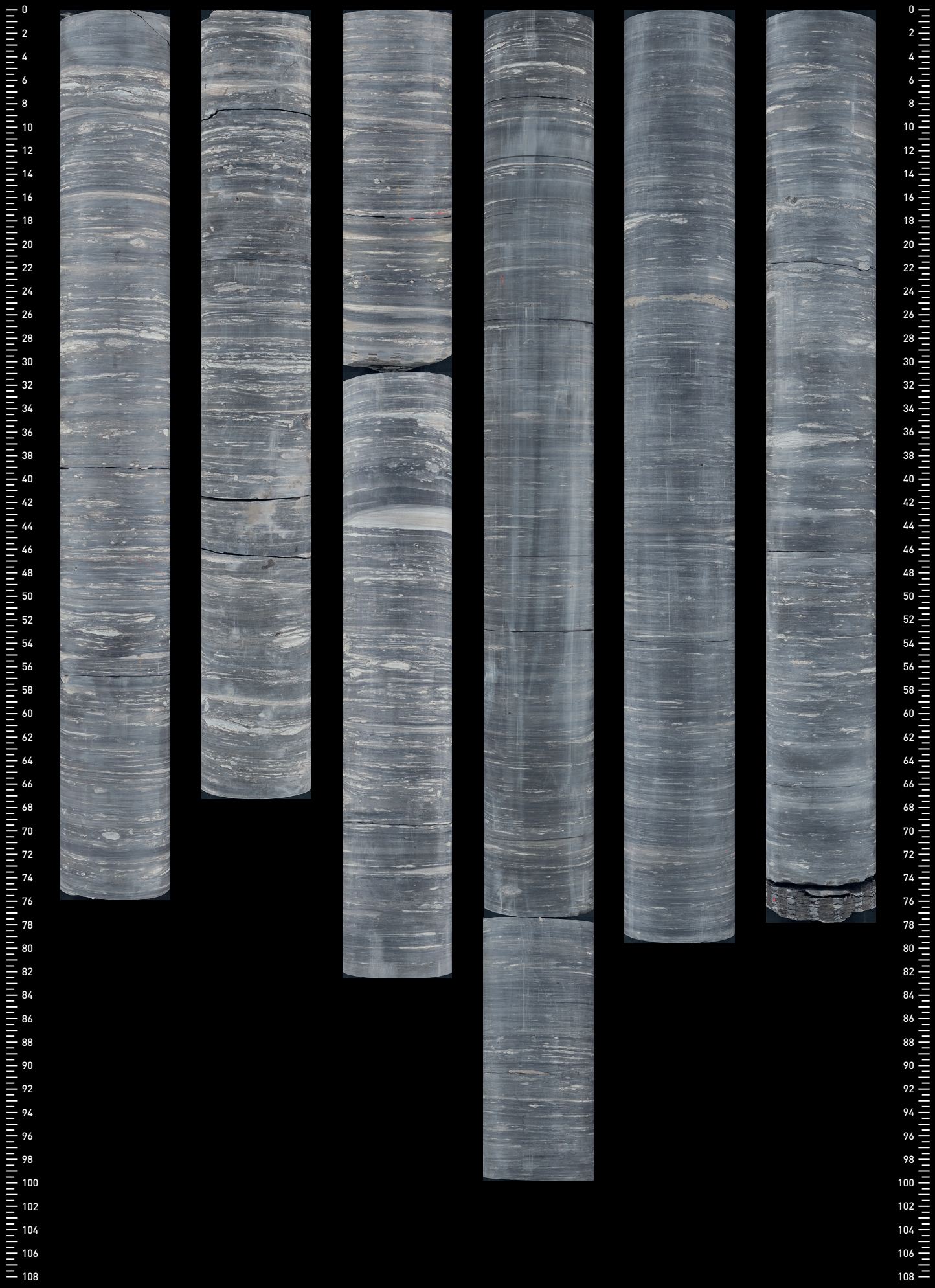
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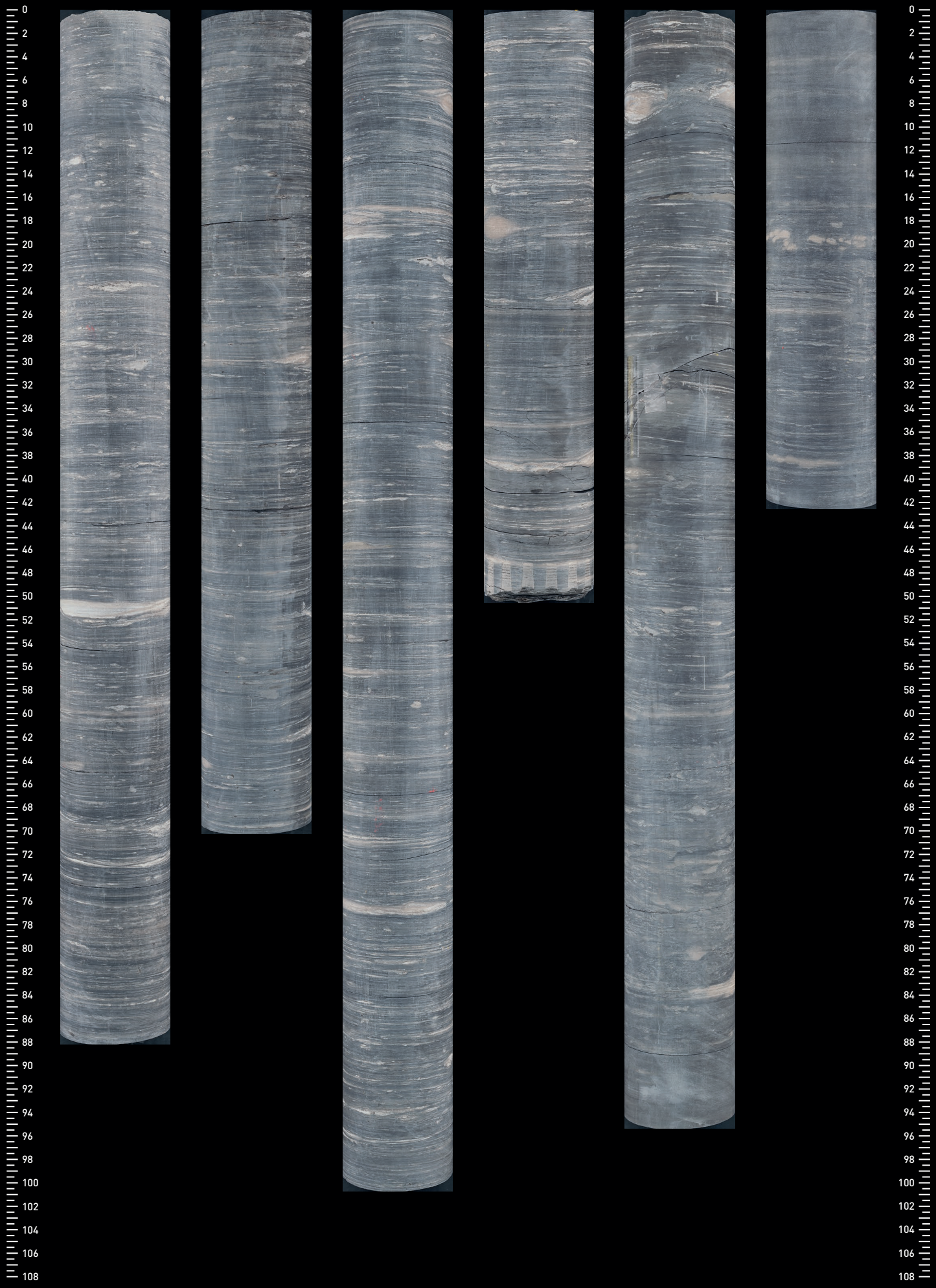

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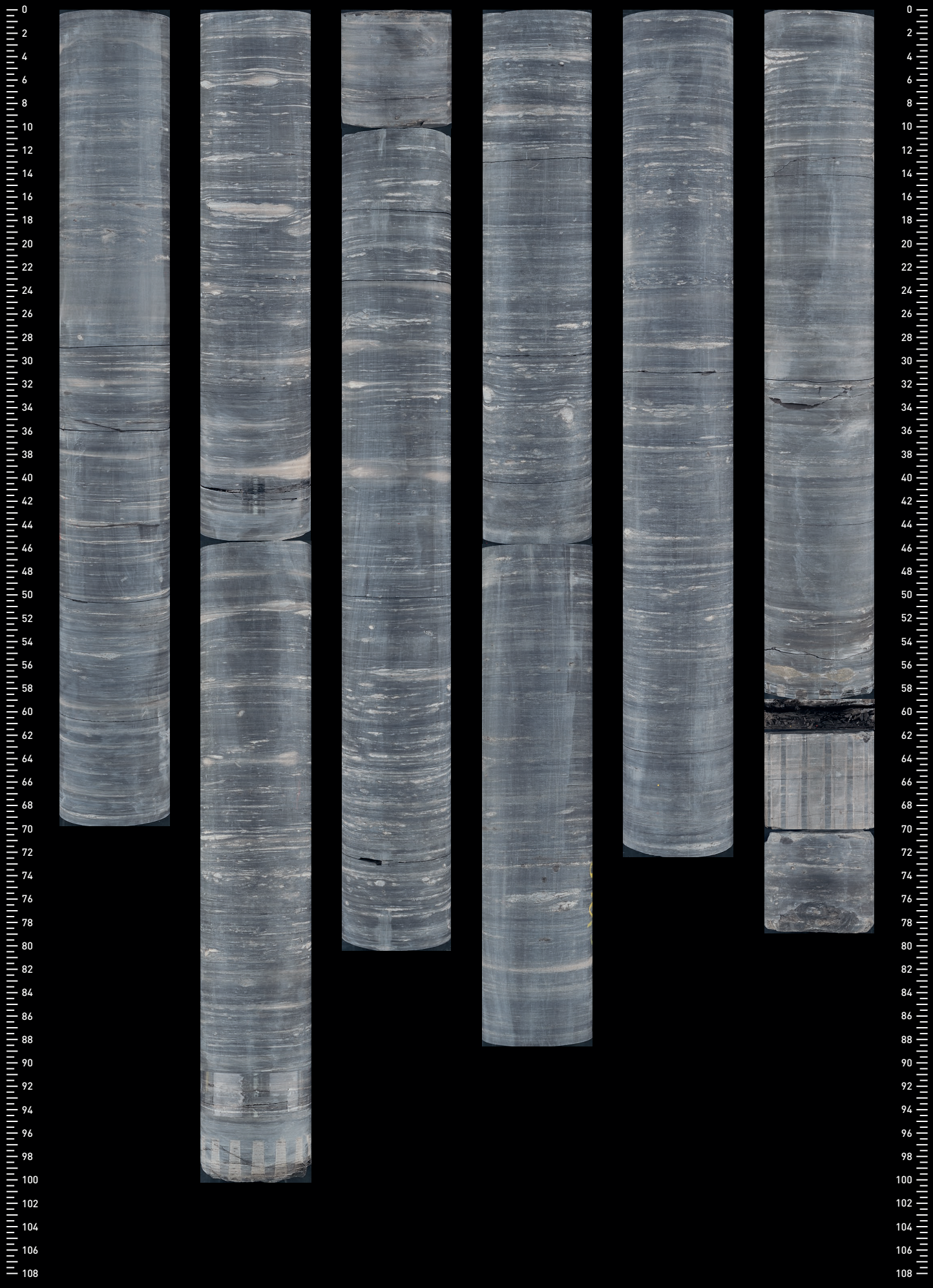
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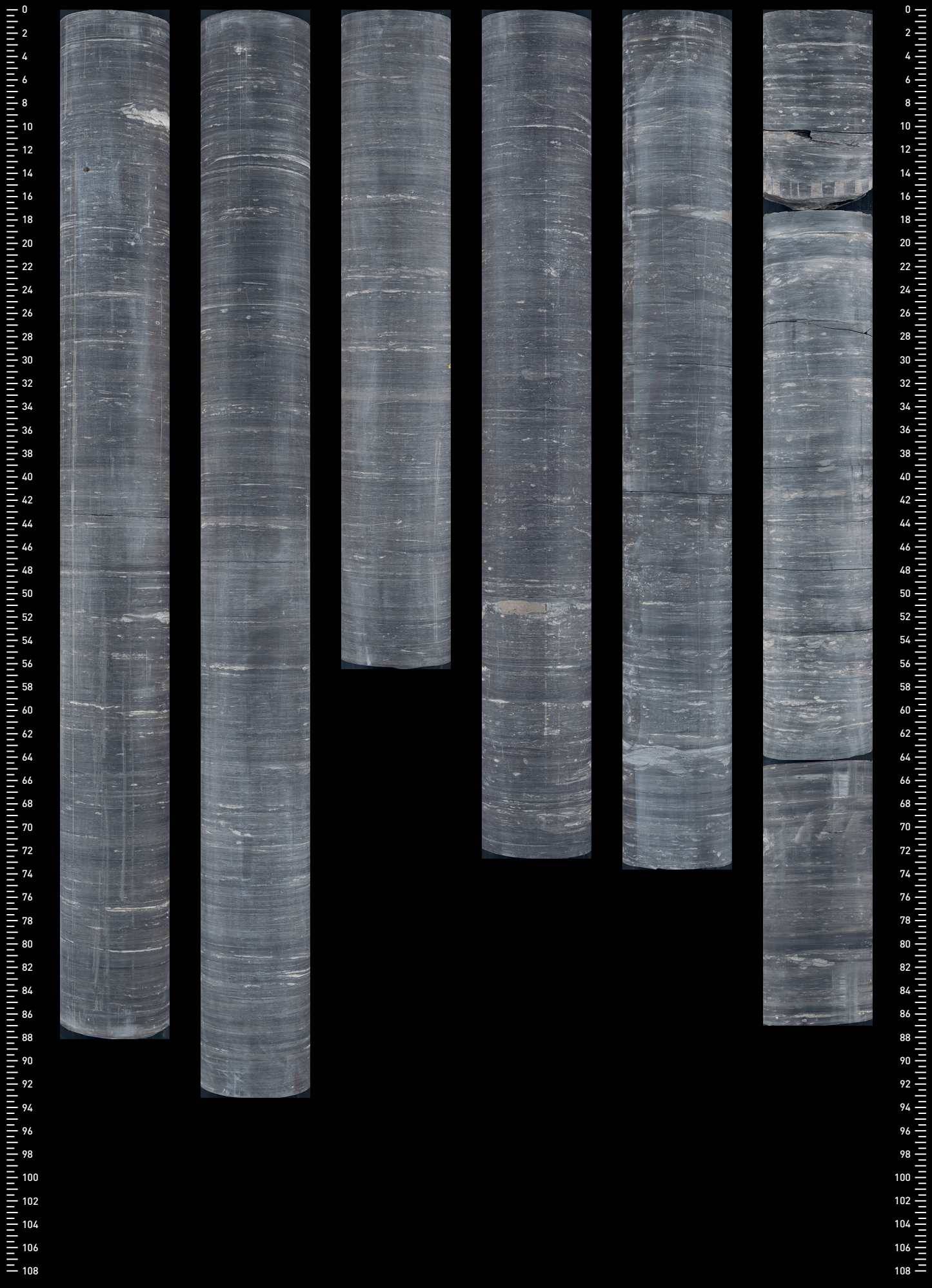
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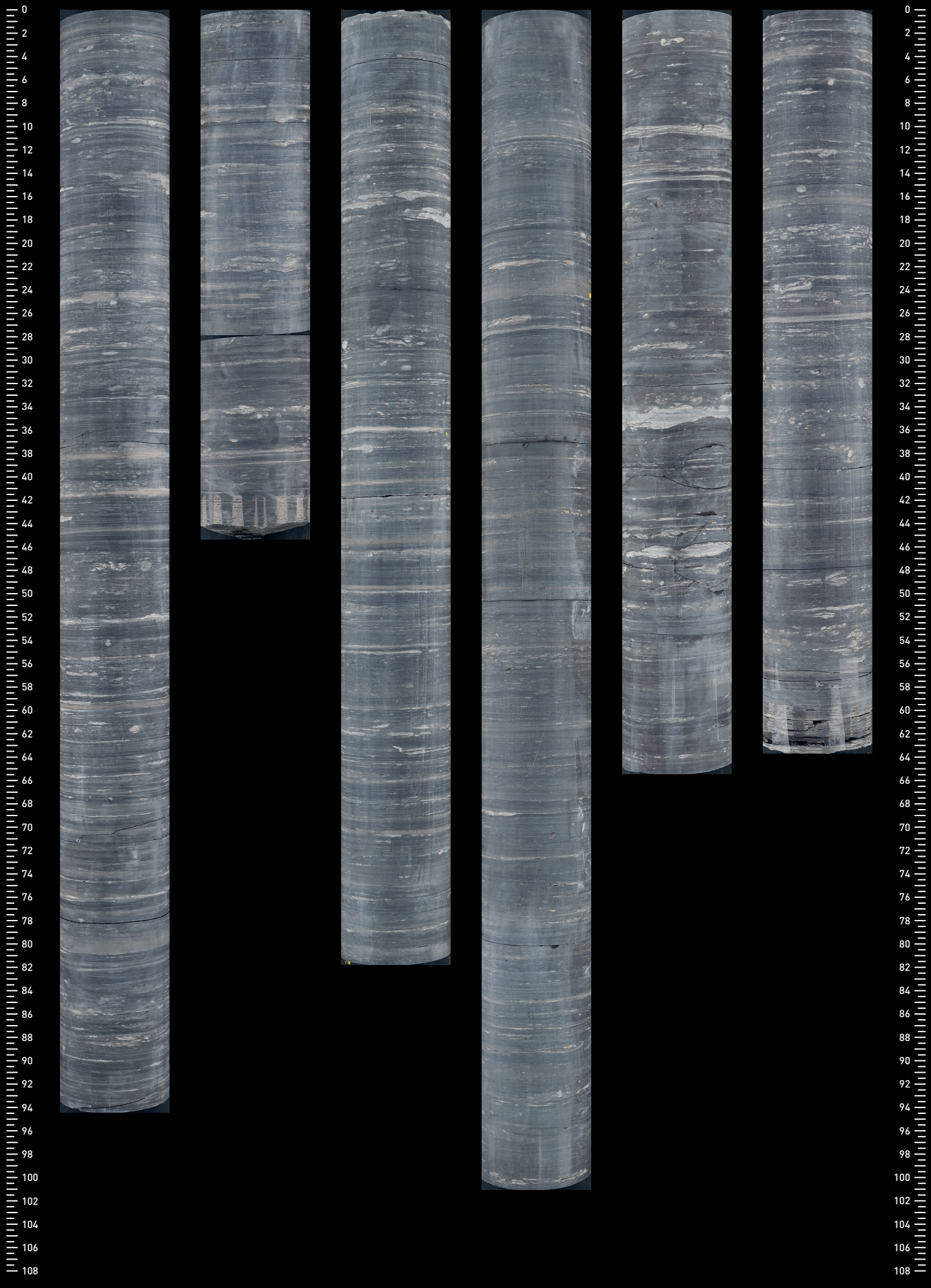
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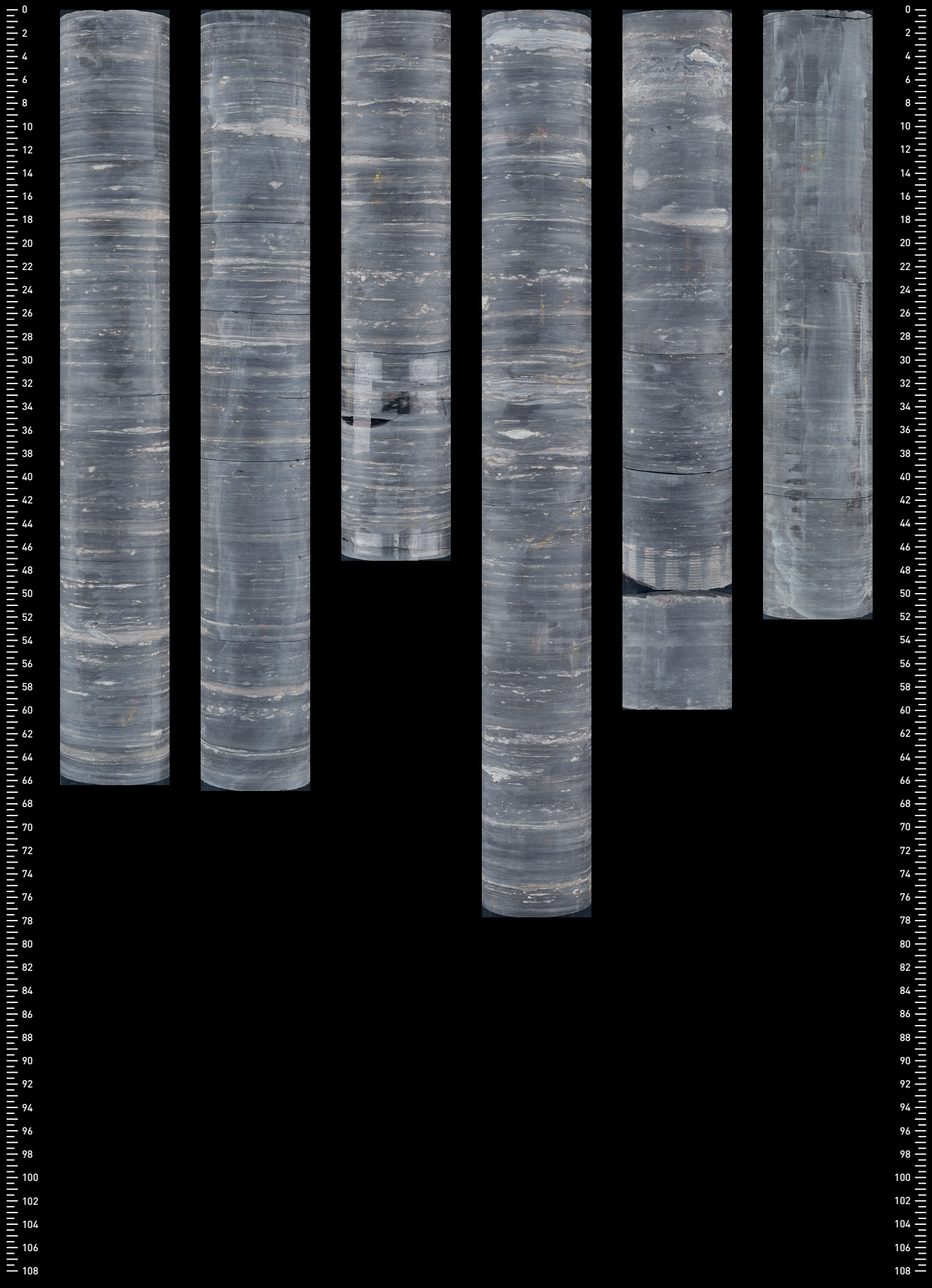
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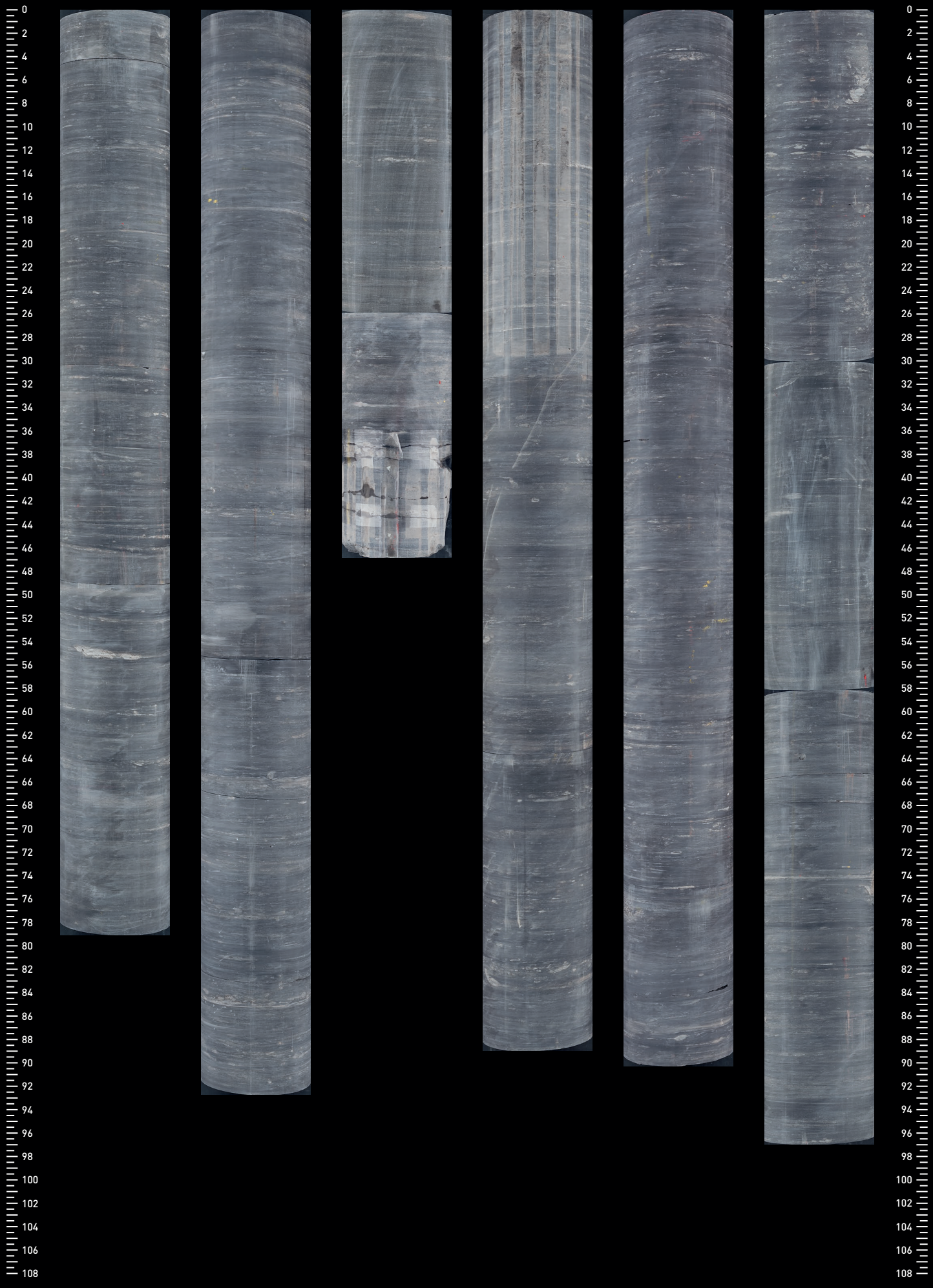
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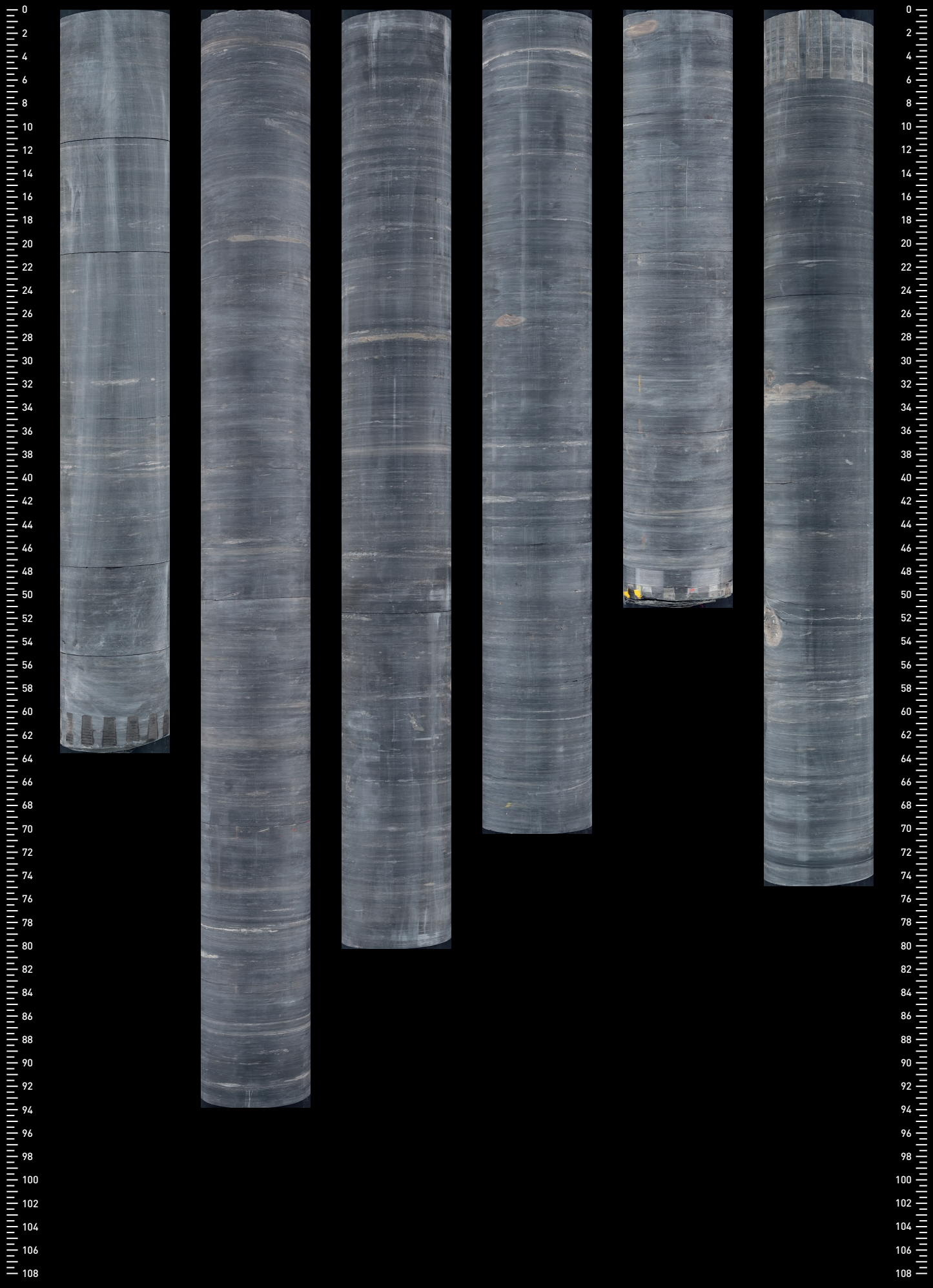
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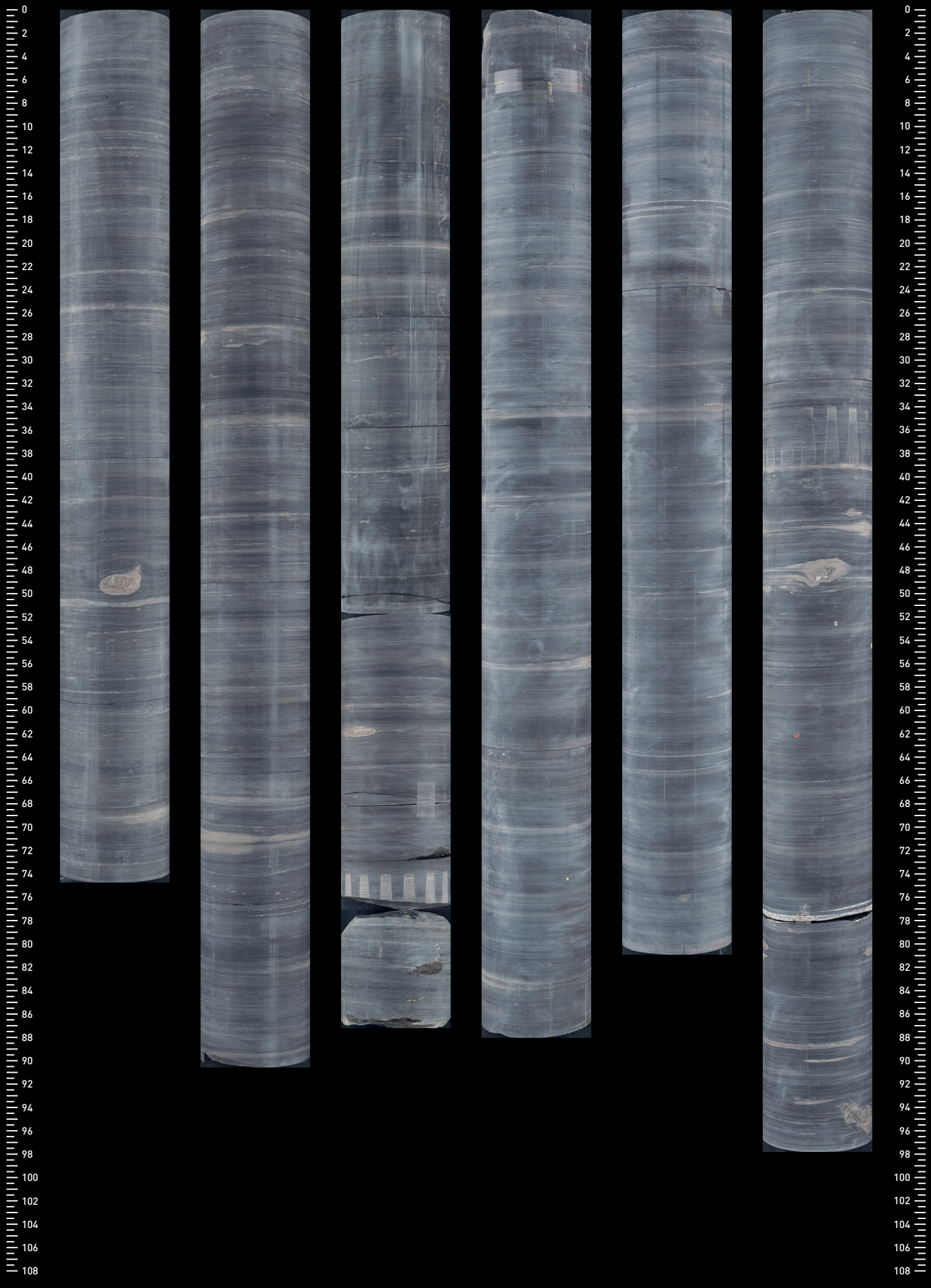
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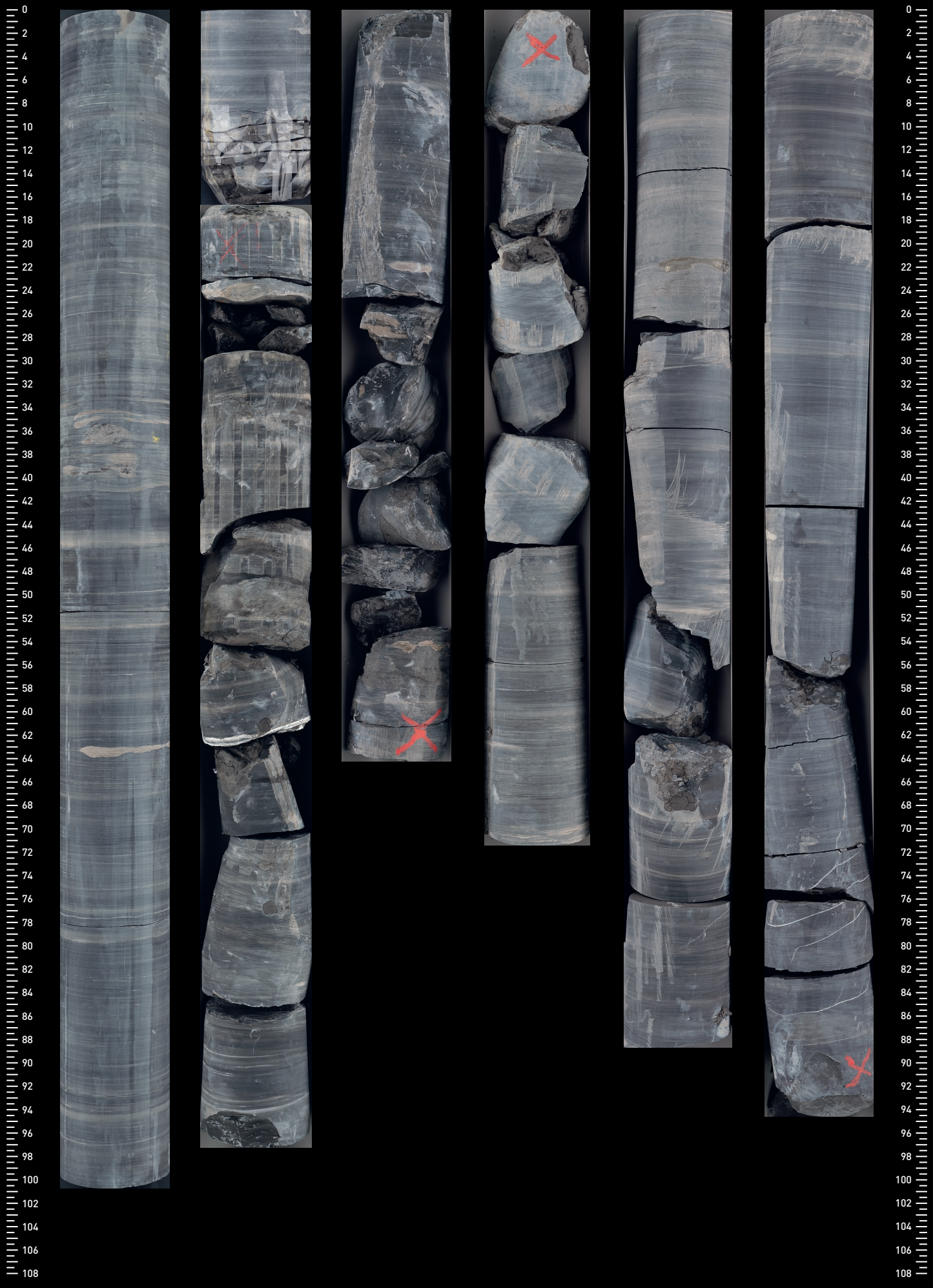
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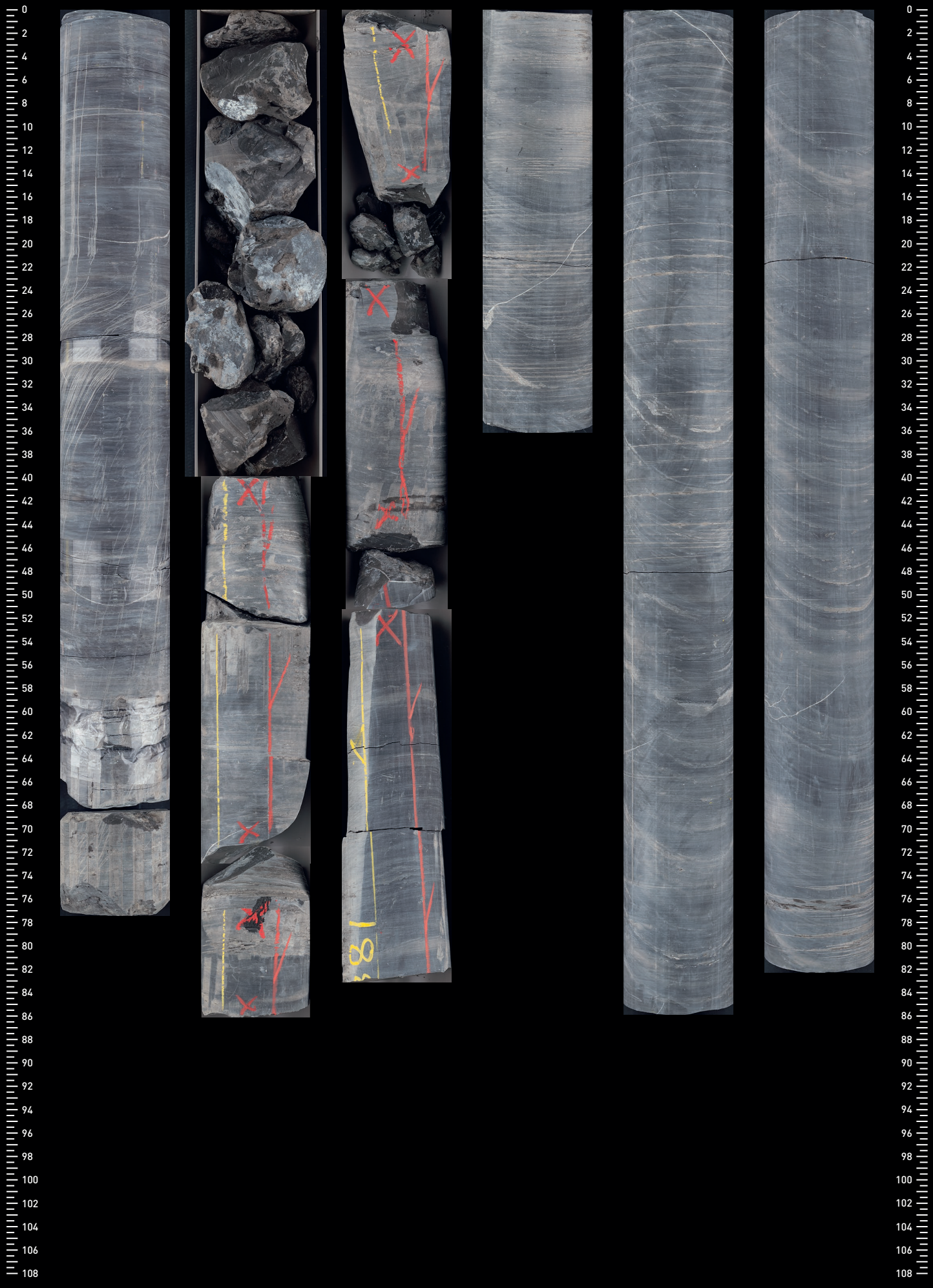
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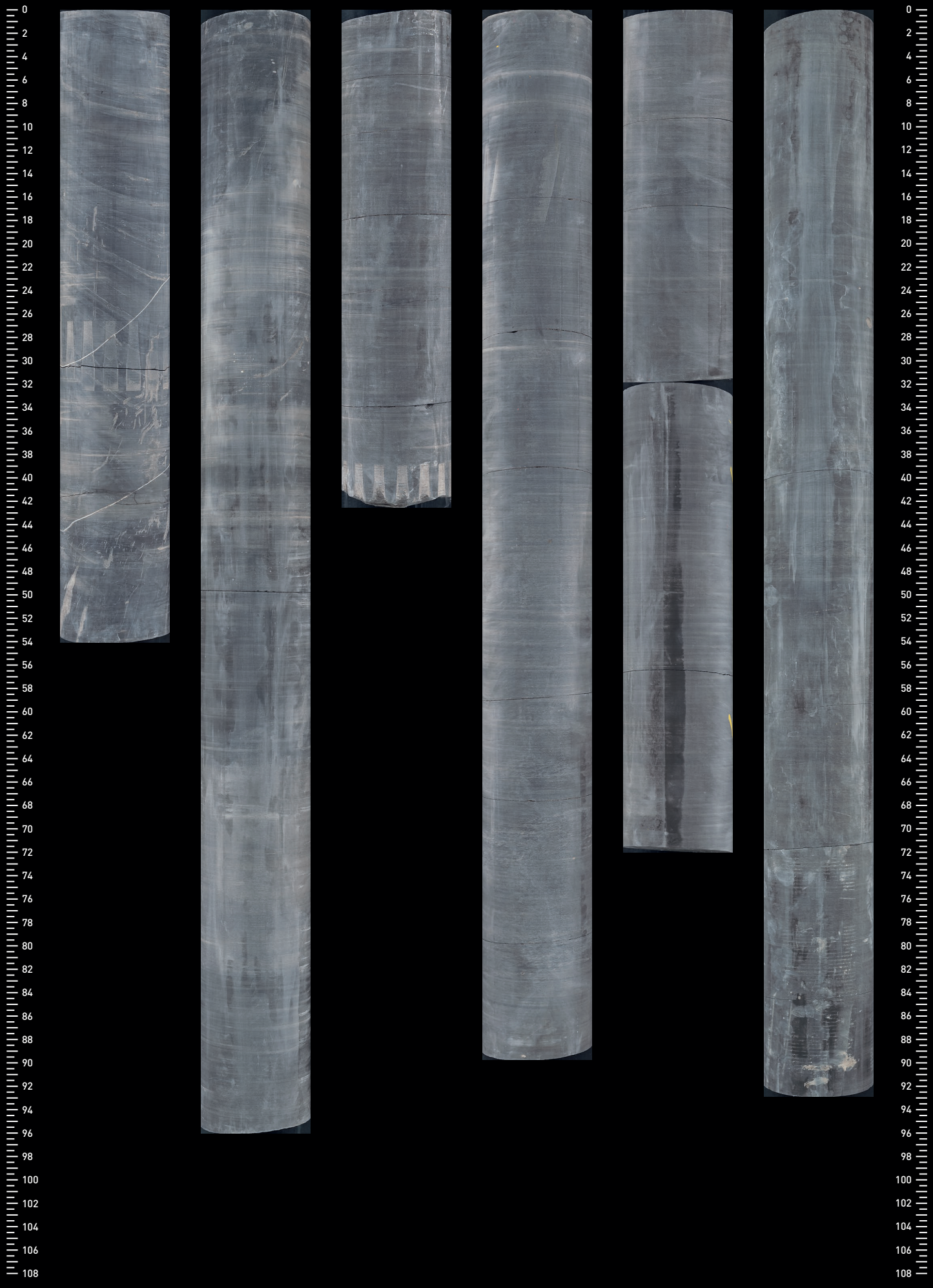
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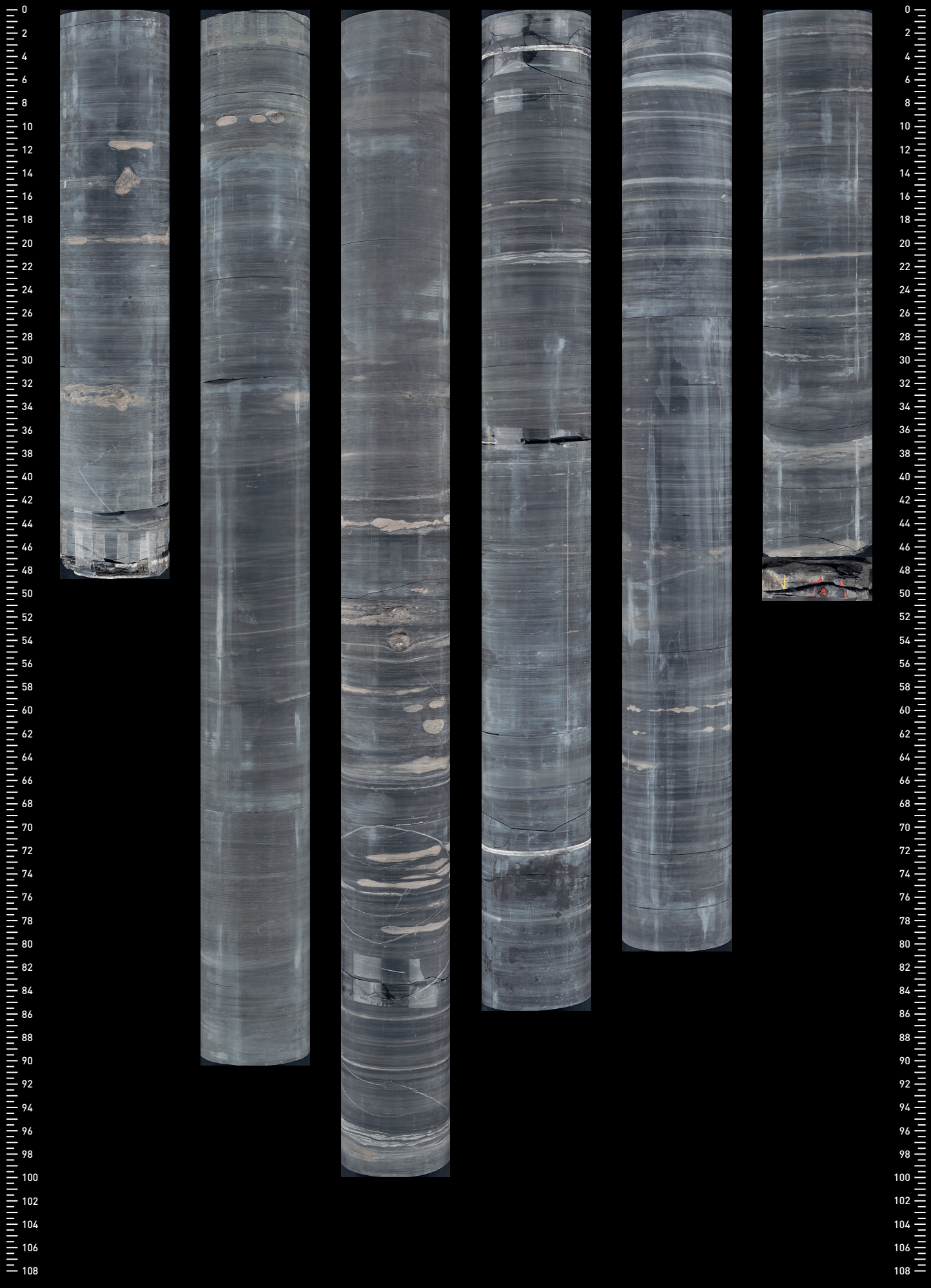
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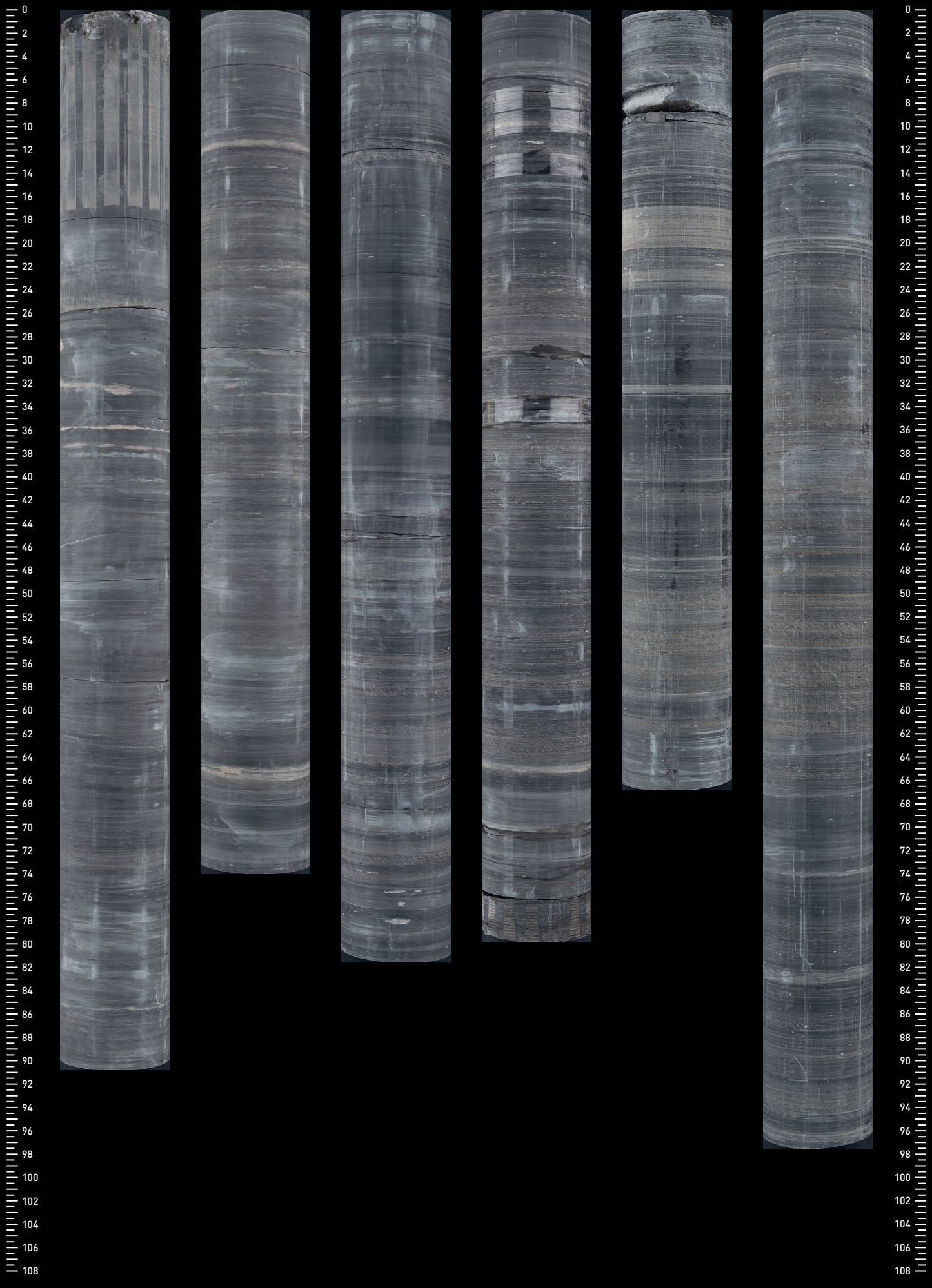
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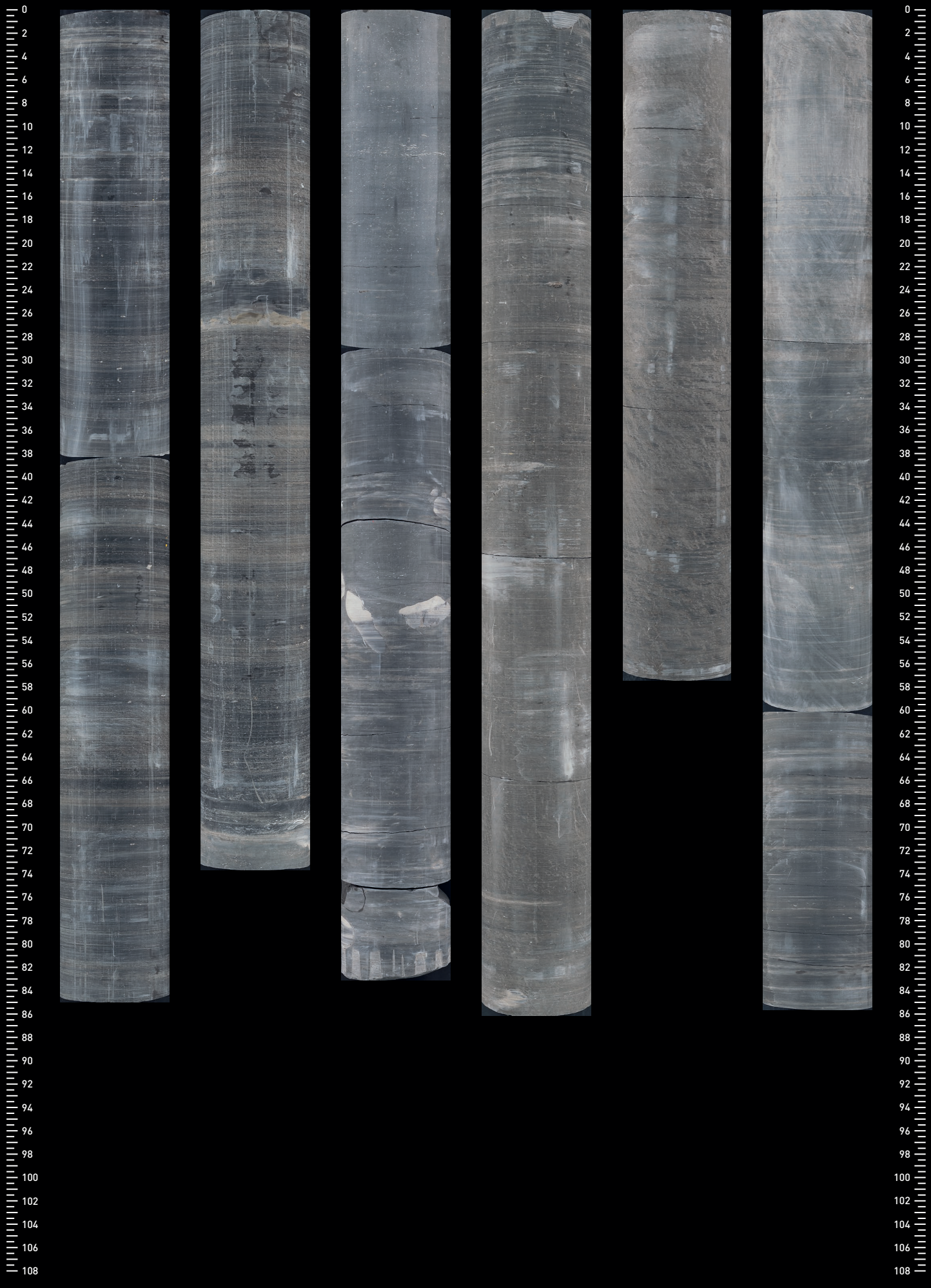
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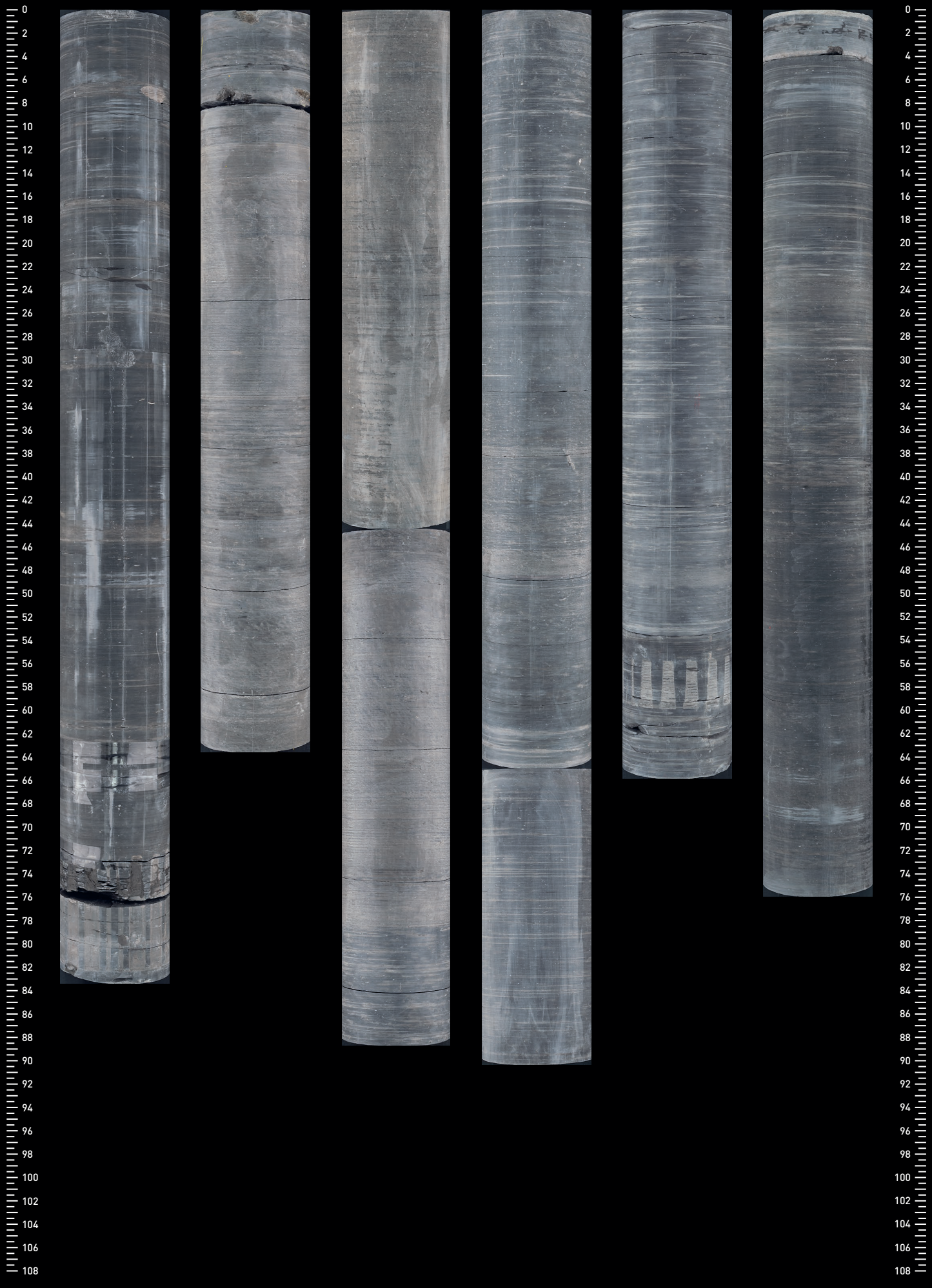
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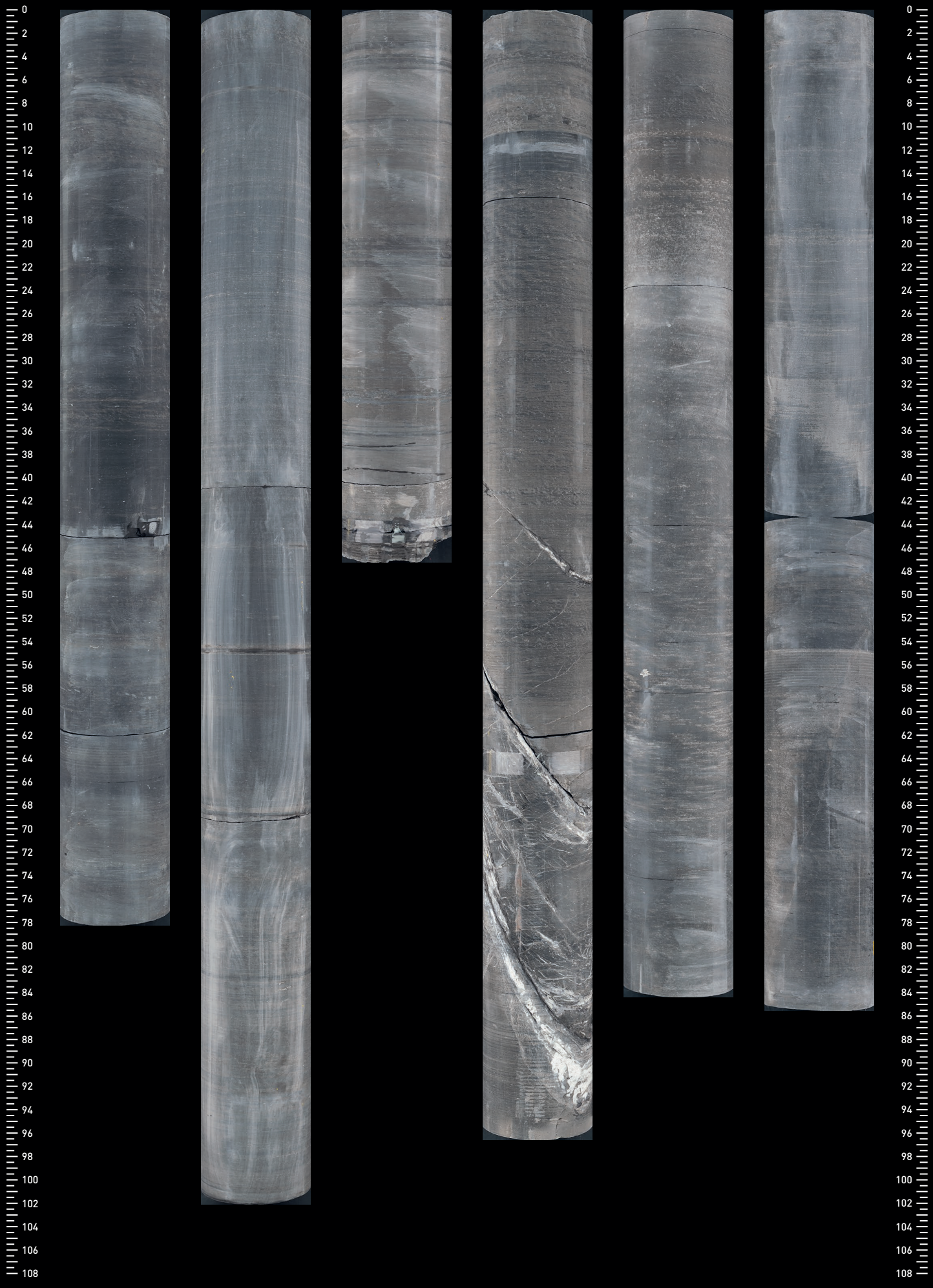
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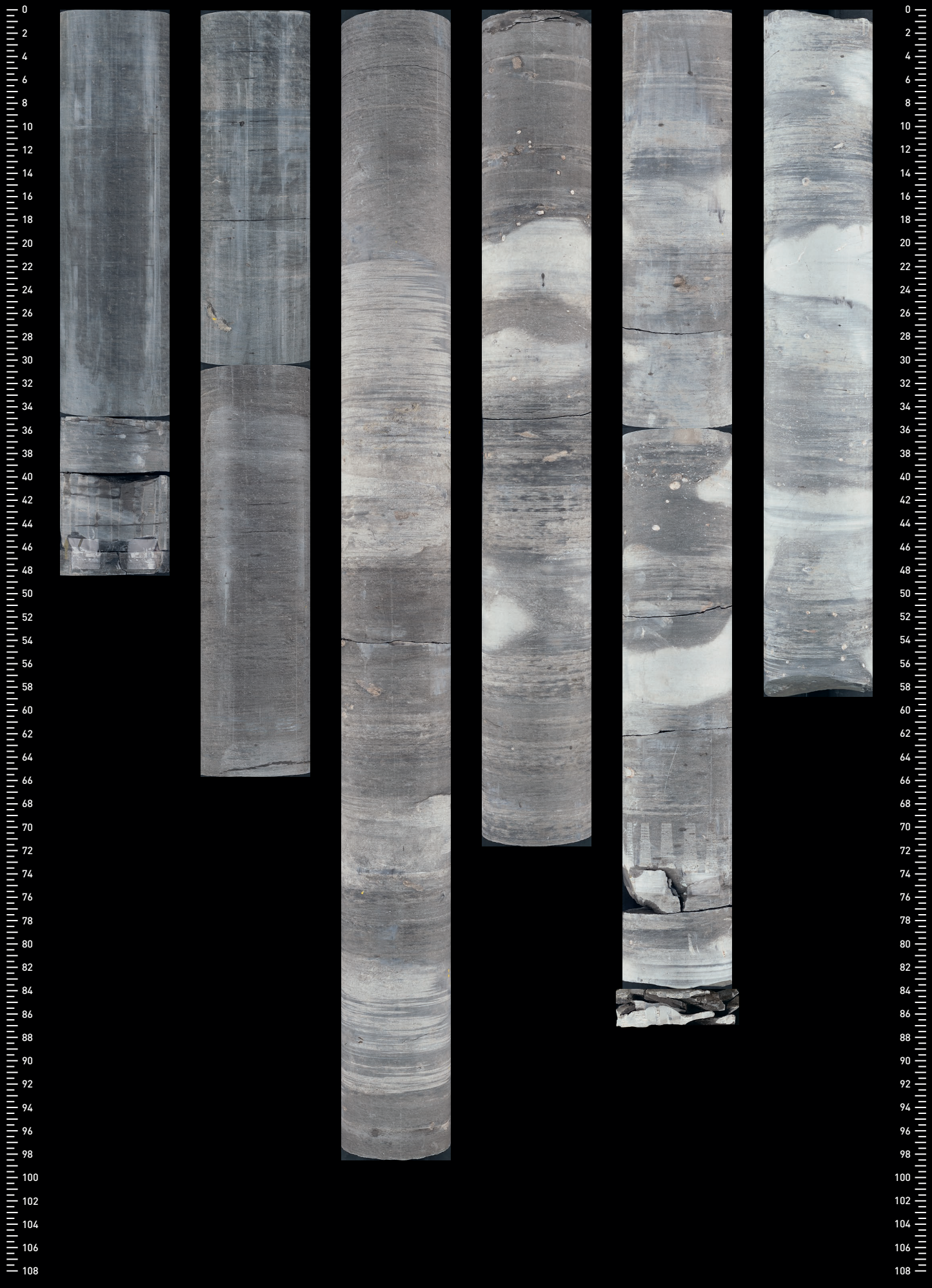
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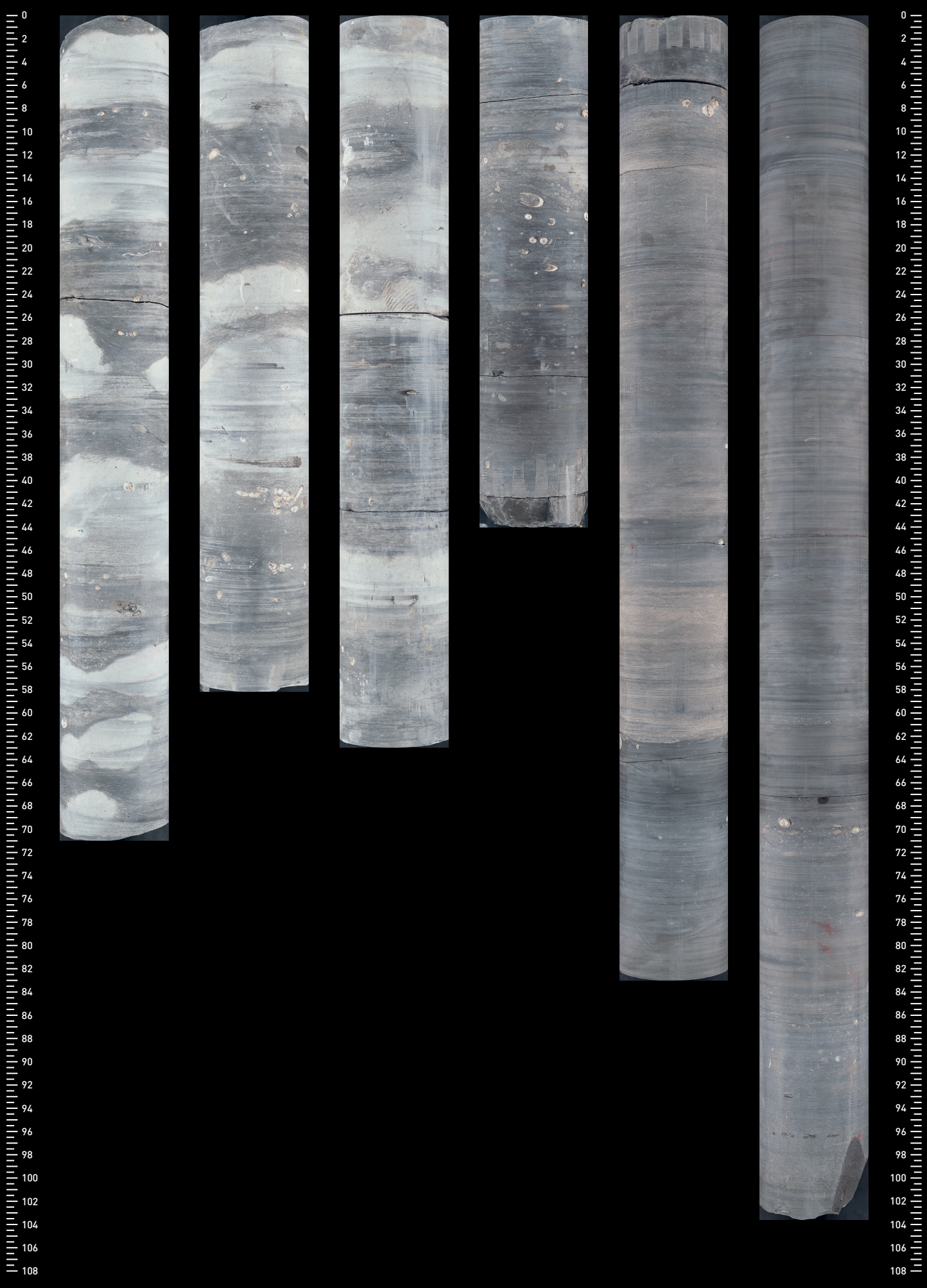


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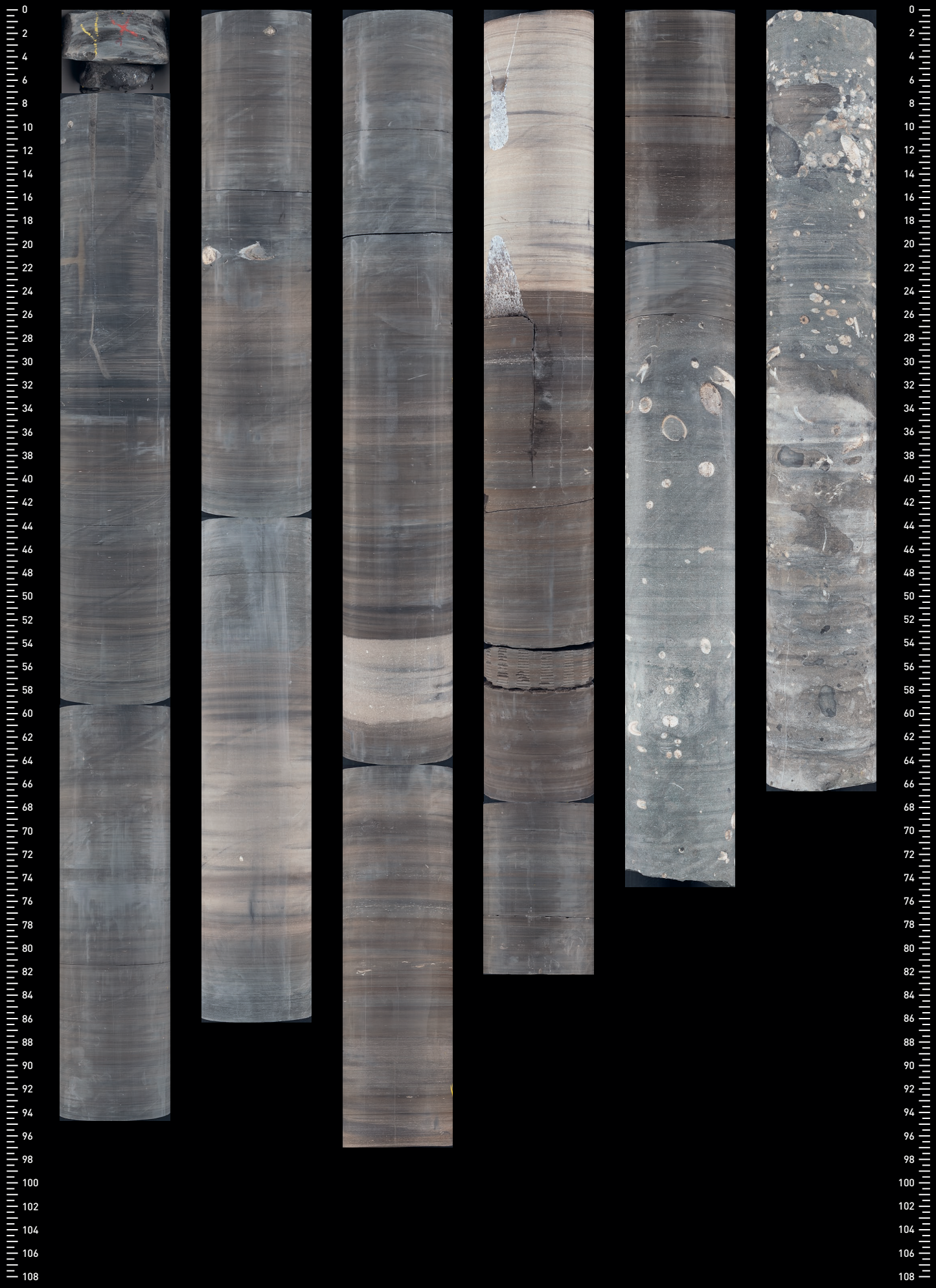
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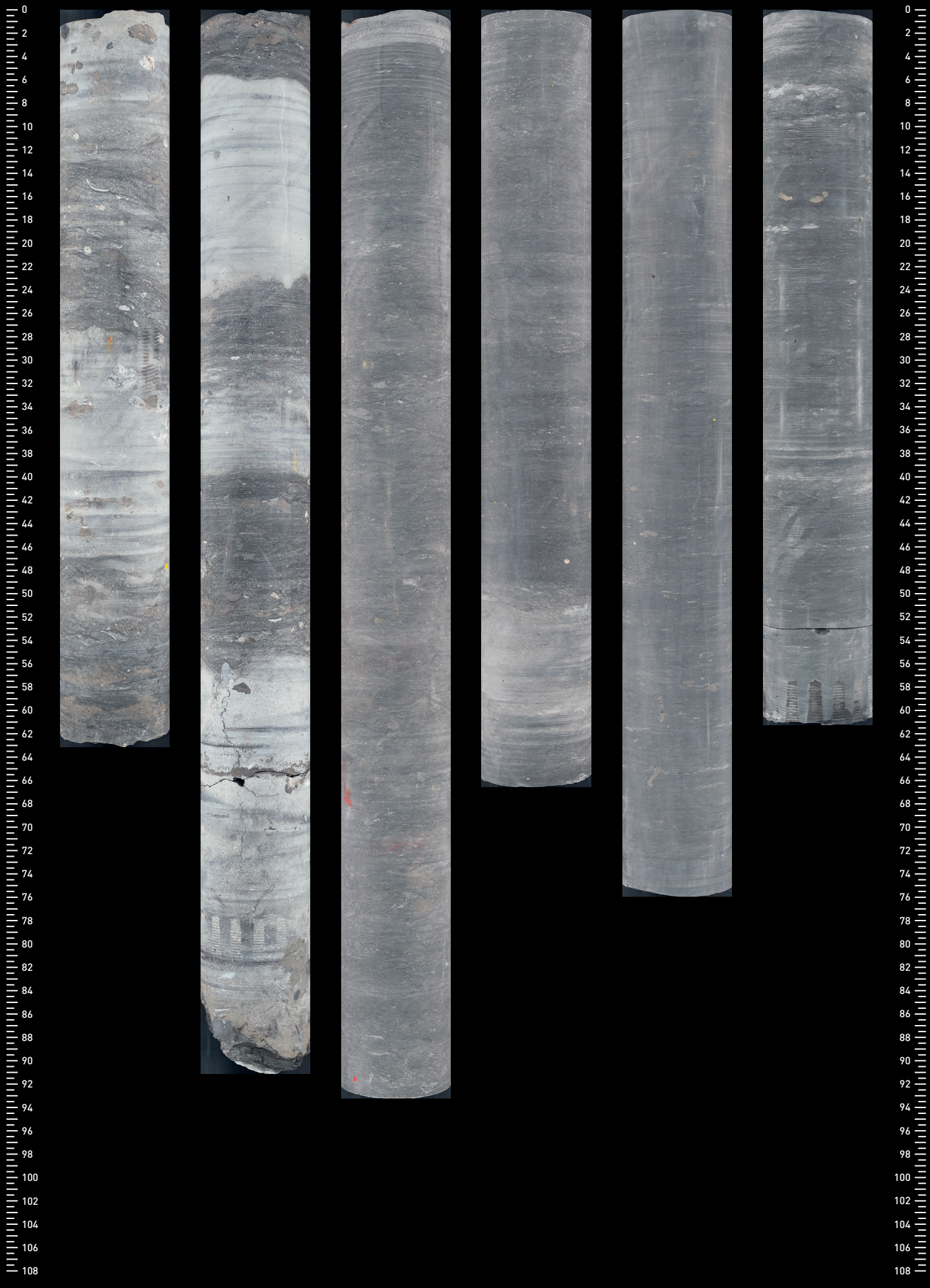
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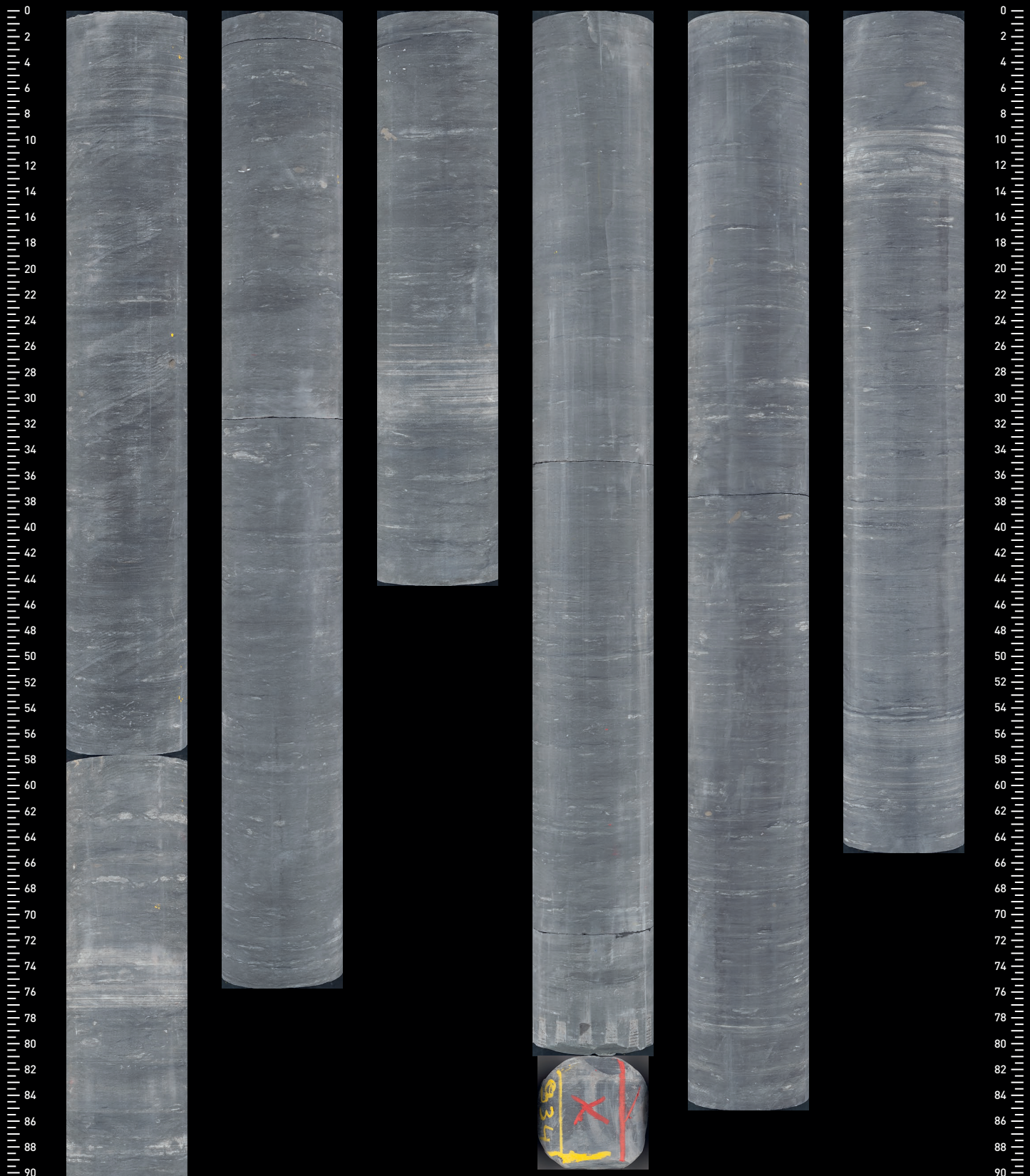
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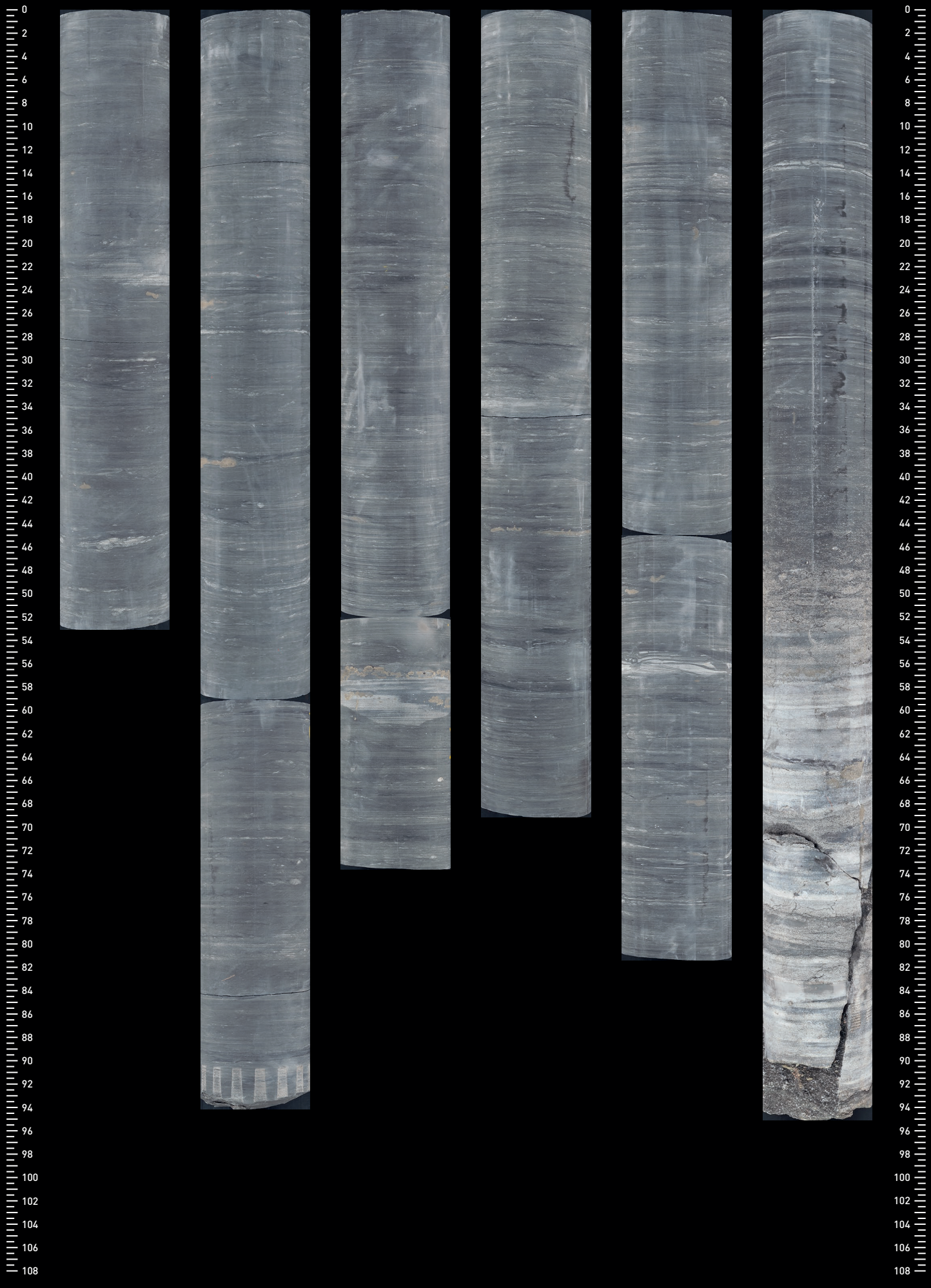
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926.60m
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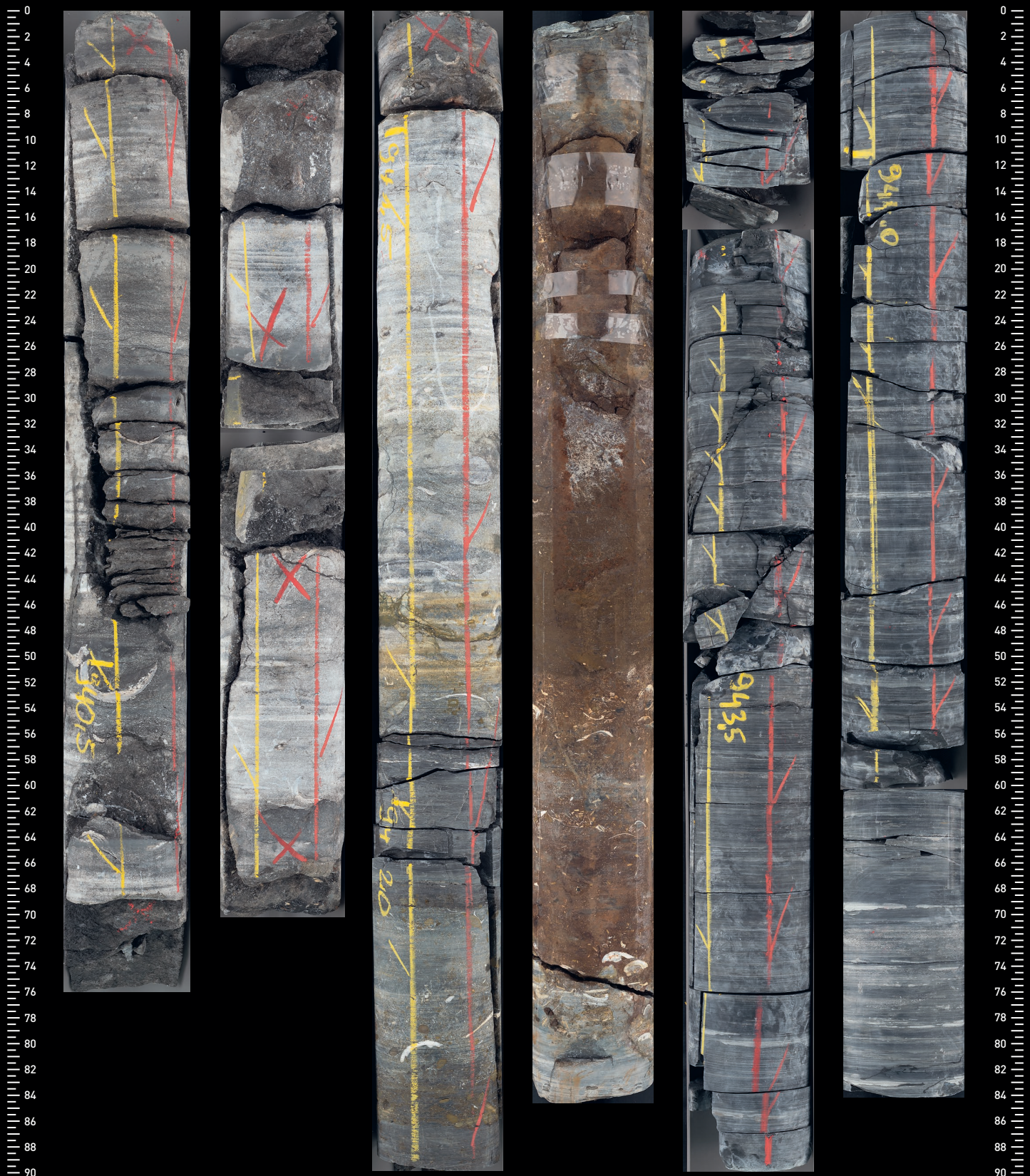
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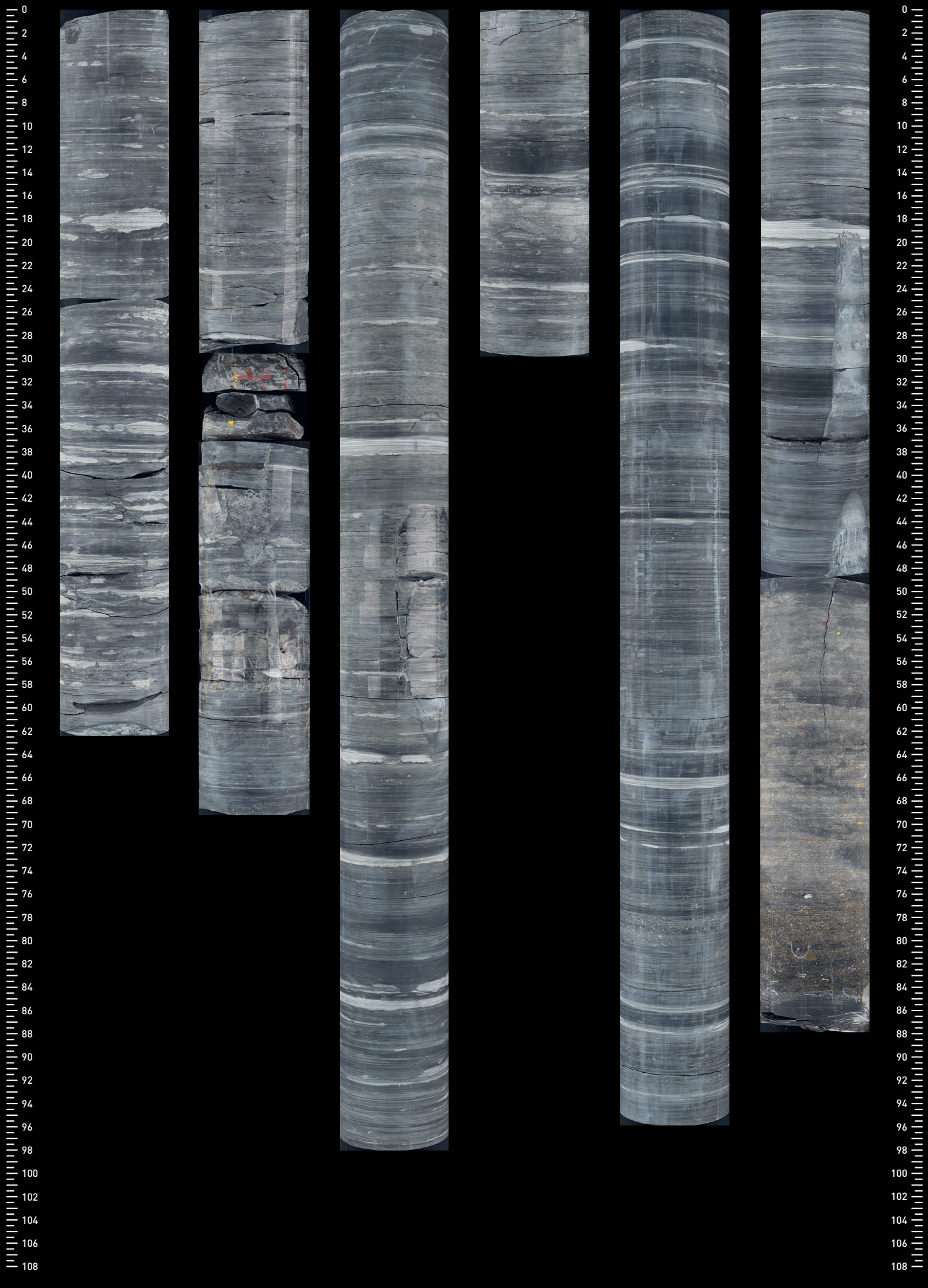
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936.90m
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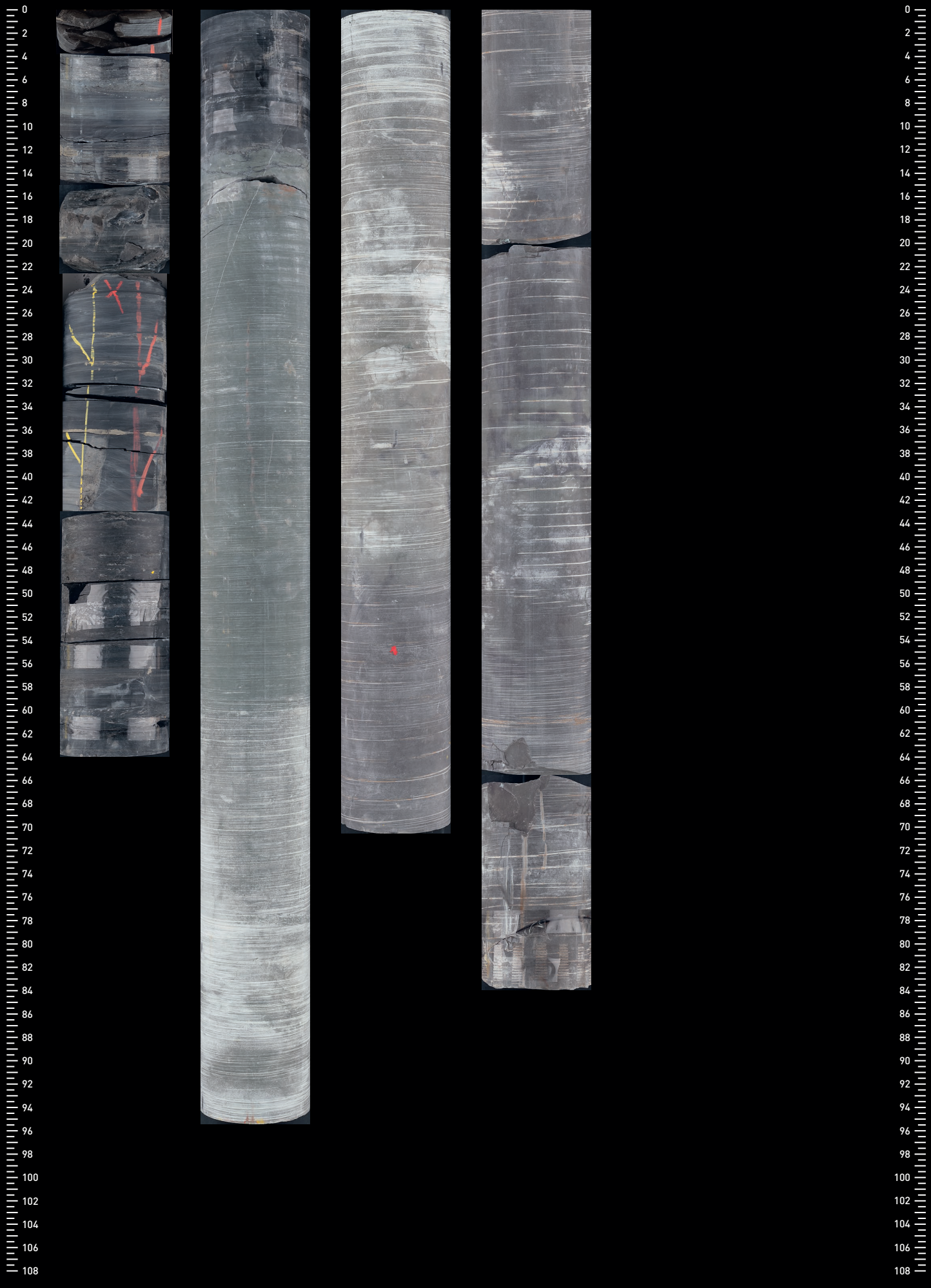
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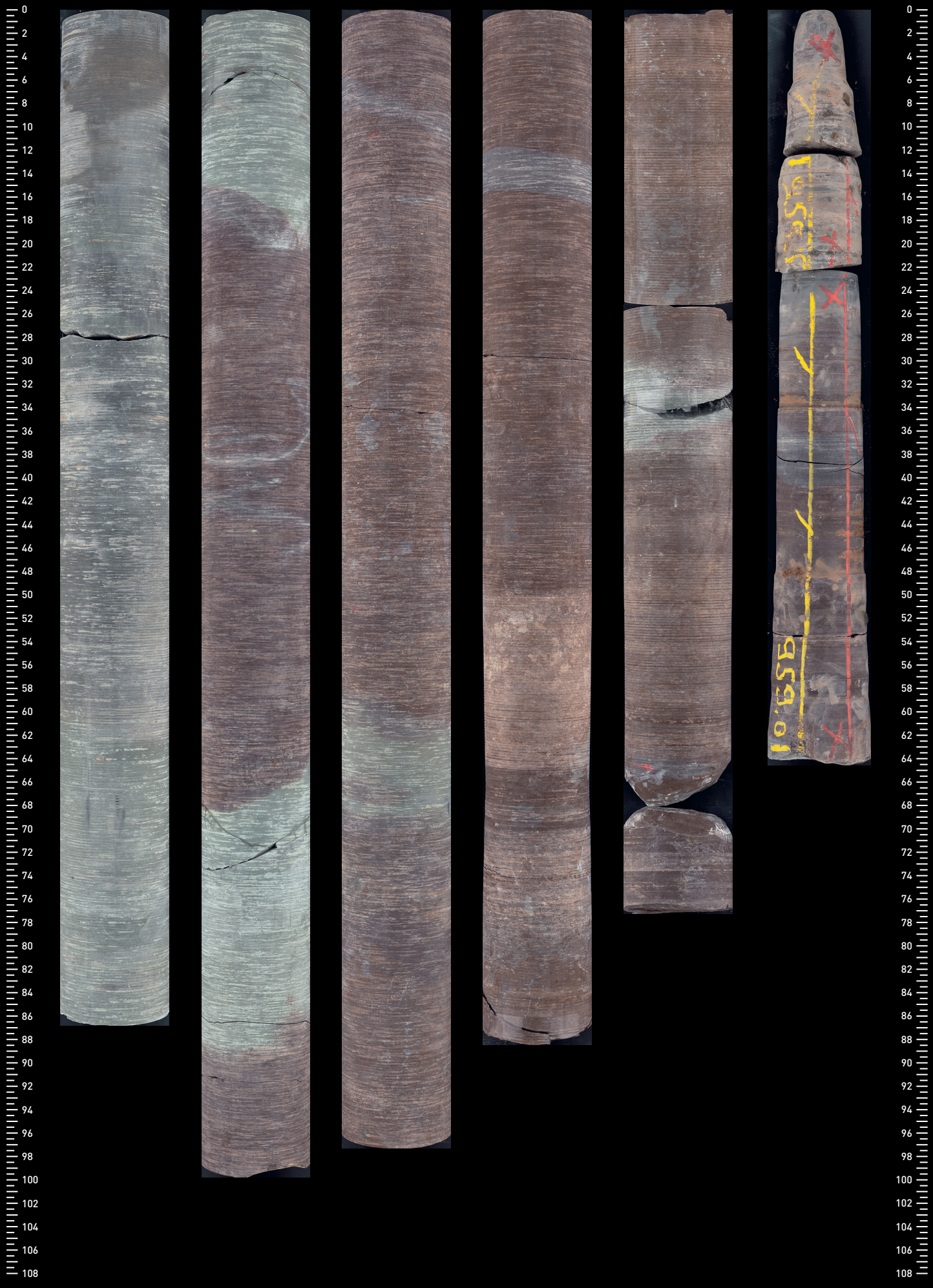

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947.23m
948.15m
949.01m

949.01m 949.62m 950.55m 951.24m



949.62m 950.55m 951.24m 952.05m

954.00m 954.84m 955.82m 956.77m 957.63m 958.37m



954.84m 955.82m 956.77m 957.63m 958.37m 959.01m

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959.26m 959.90m 960.75m 961.33m 962.31m 963.18m

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968.59m 969.38m 970.25m 970.78m 971.26m 971.92m

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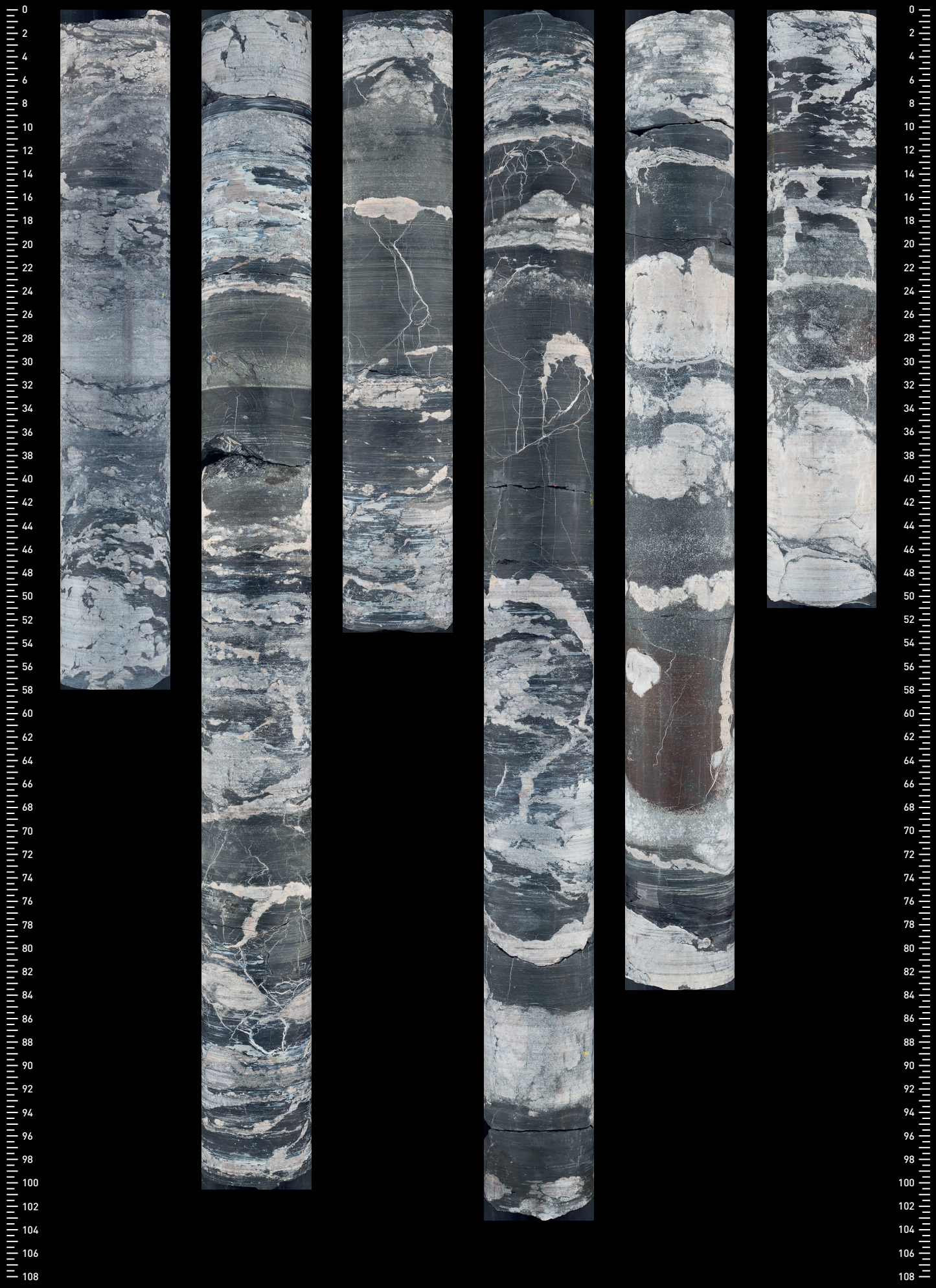
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982.90m
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981.93m
982.90m
983.84m
984.16m
985.07m

985.07m 985.64m 986.61m 987.13m 988.11m 988.91m



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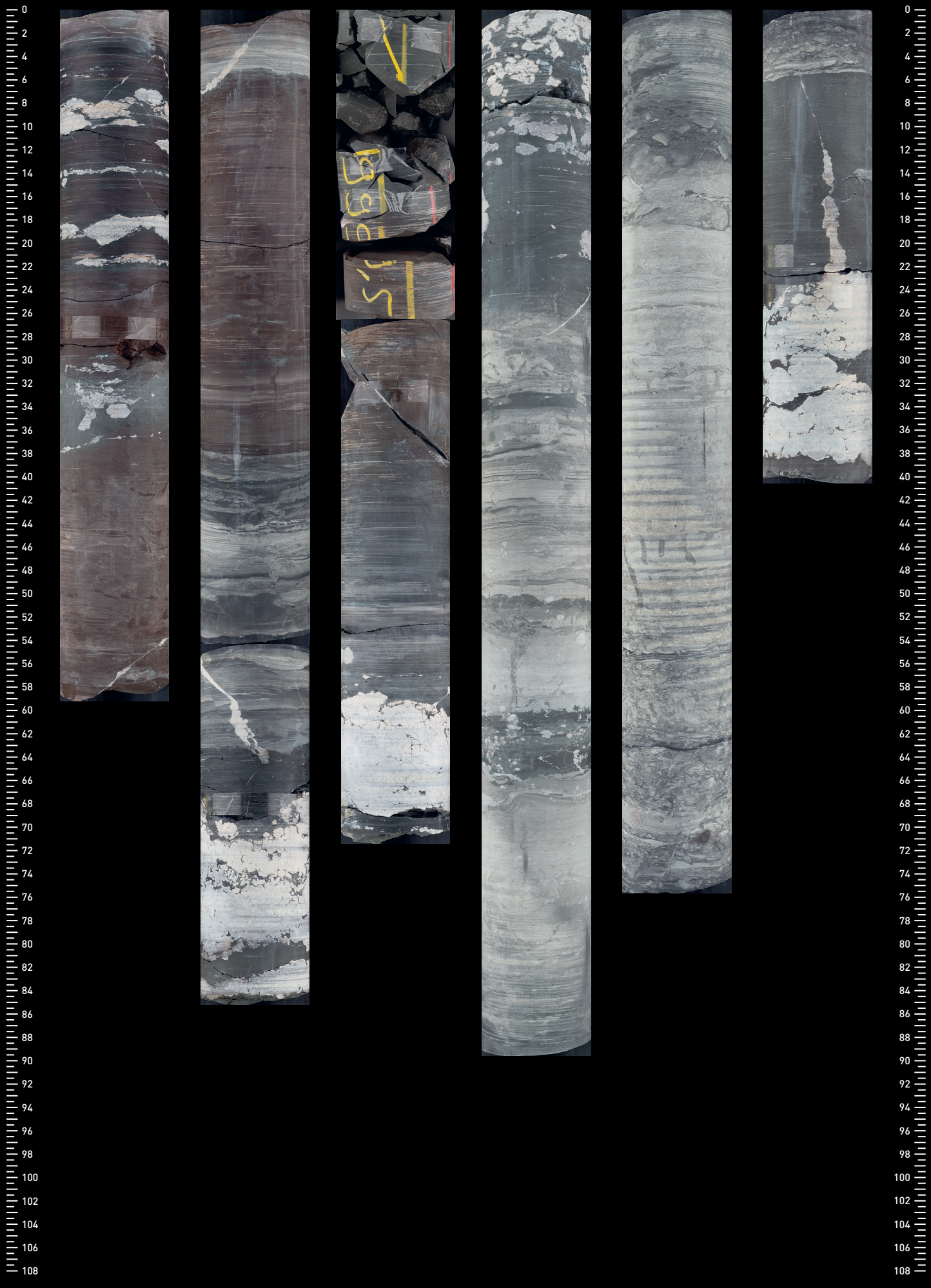
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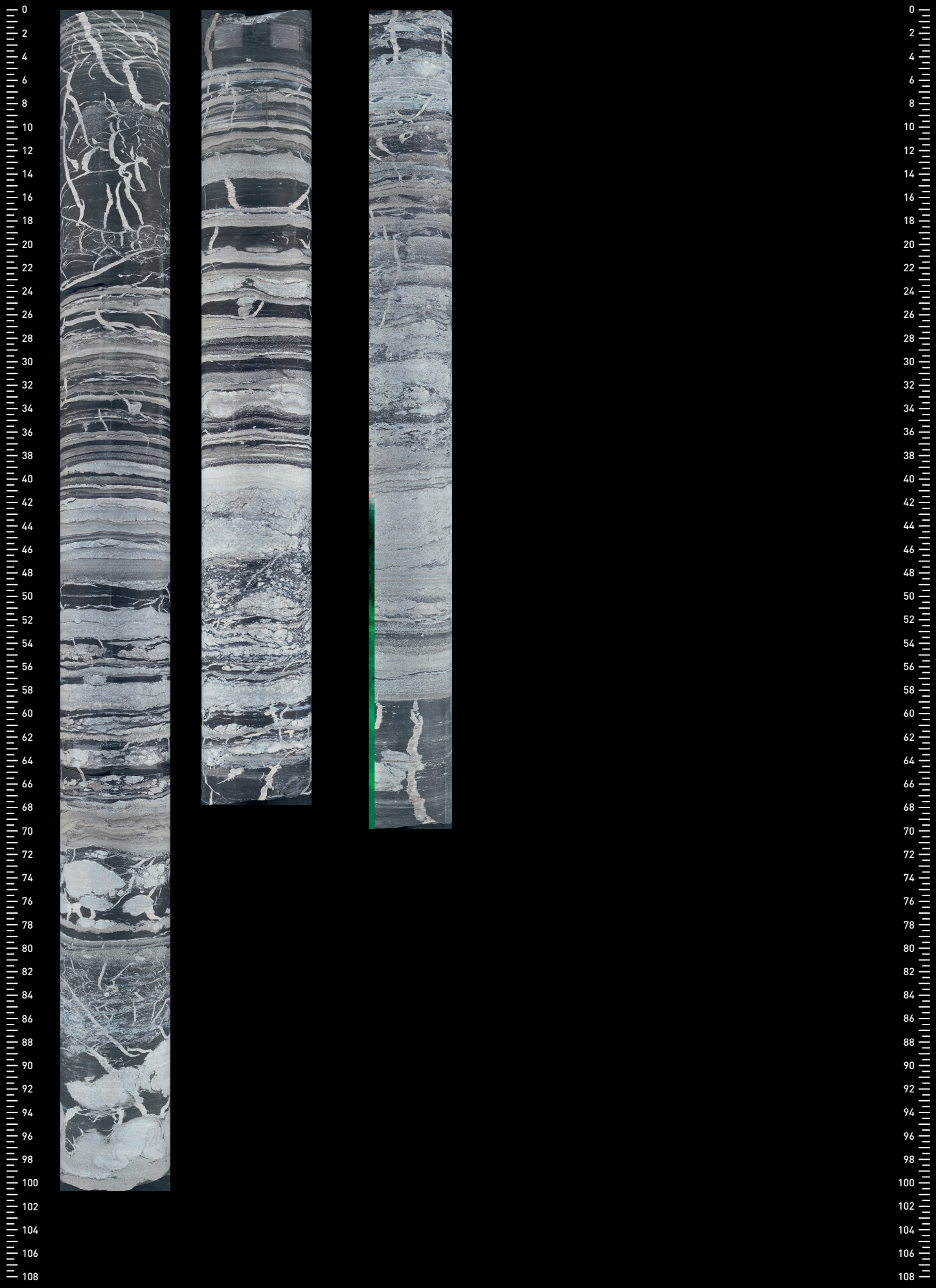
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1006.63m
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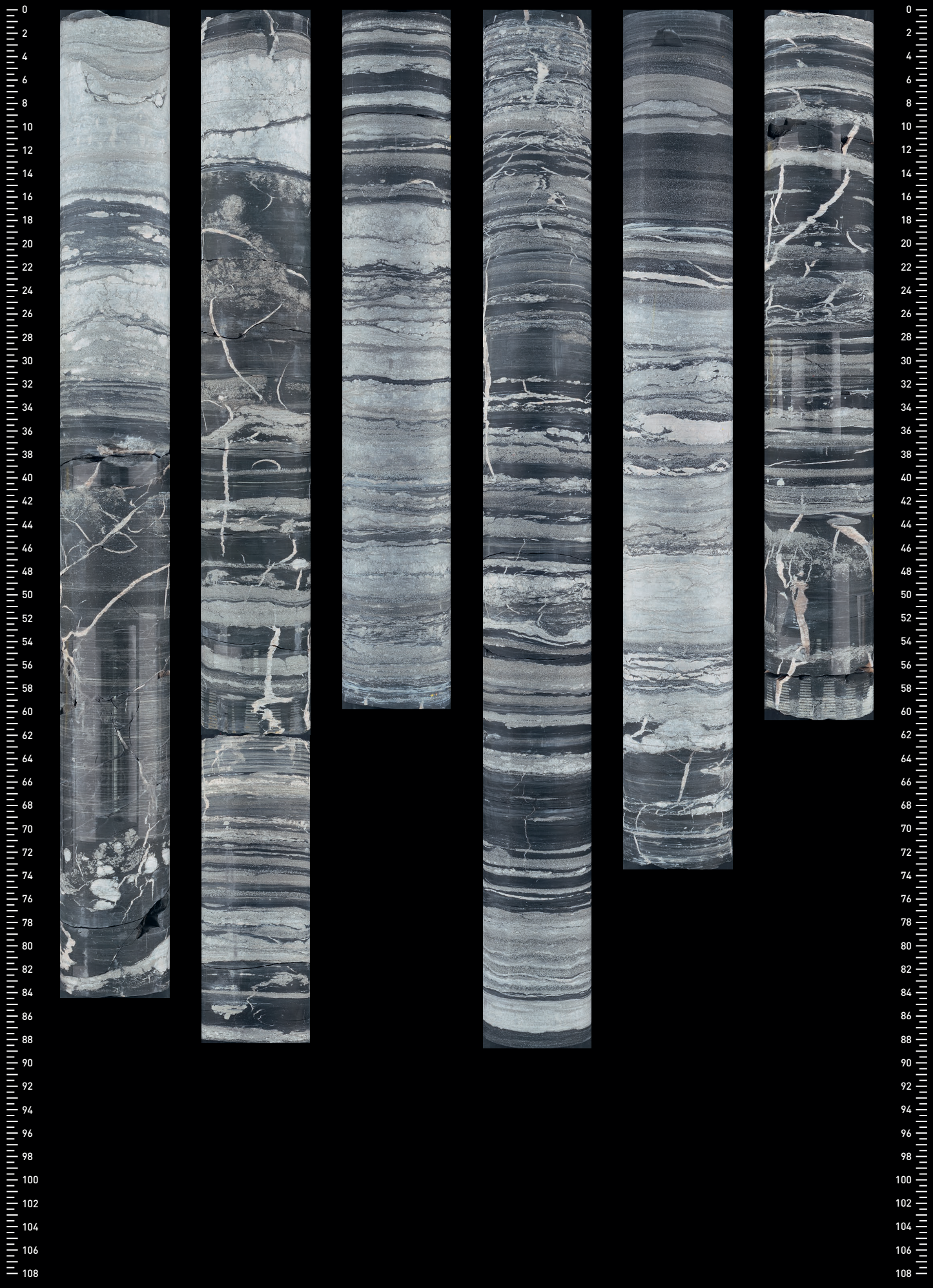

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1015.06m
1015.67m

1024.12m 1025.10m 1025.76m 1026.43m 1027.23m 1028.11m



1025.10m 1025.76m 1026.43m 1027.23m 1028.11m 1028.72m

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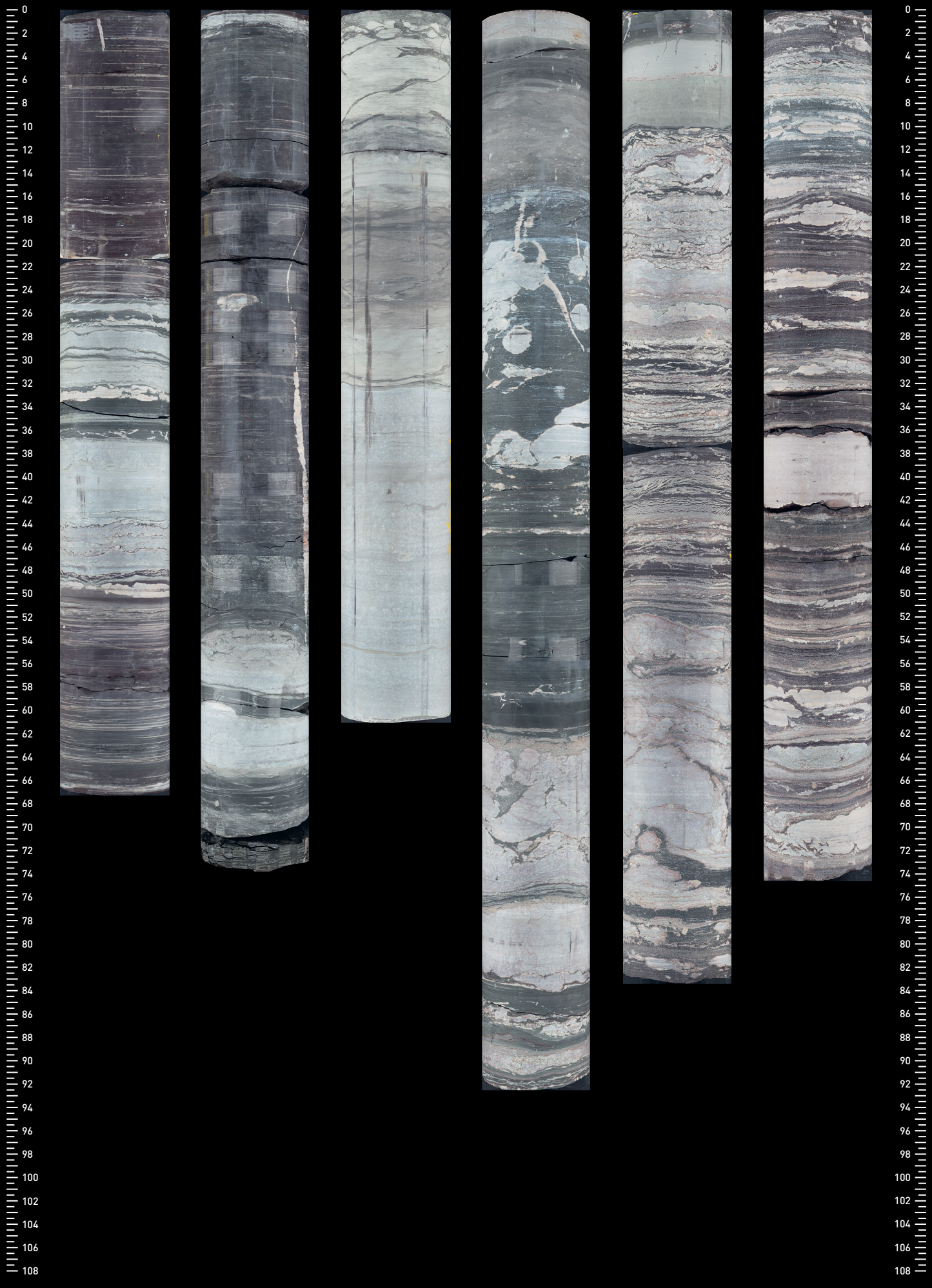
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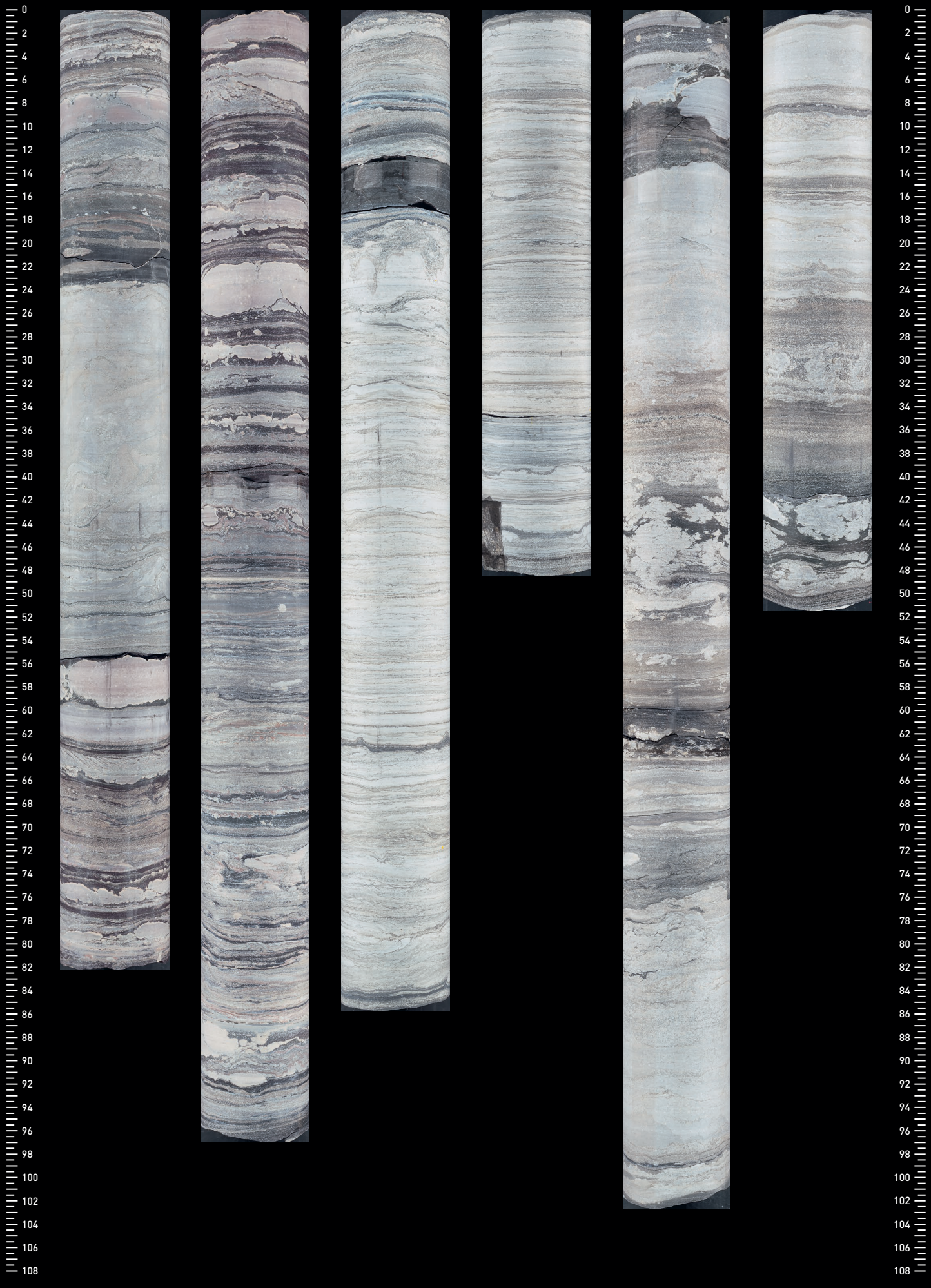


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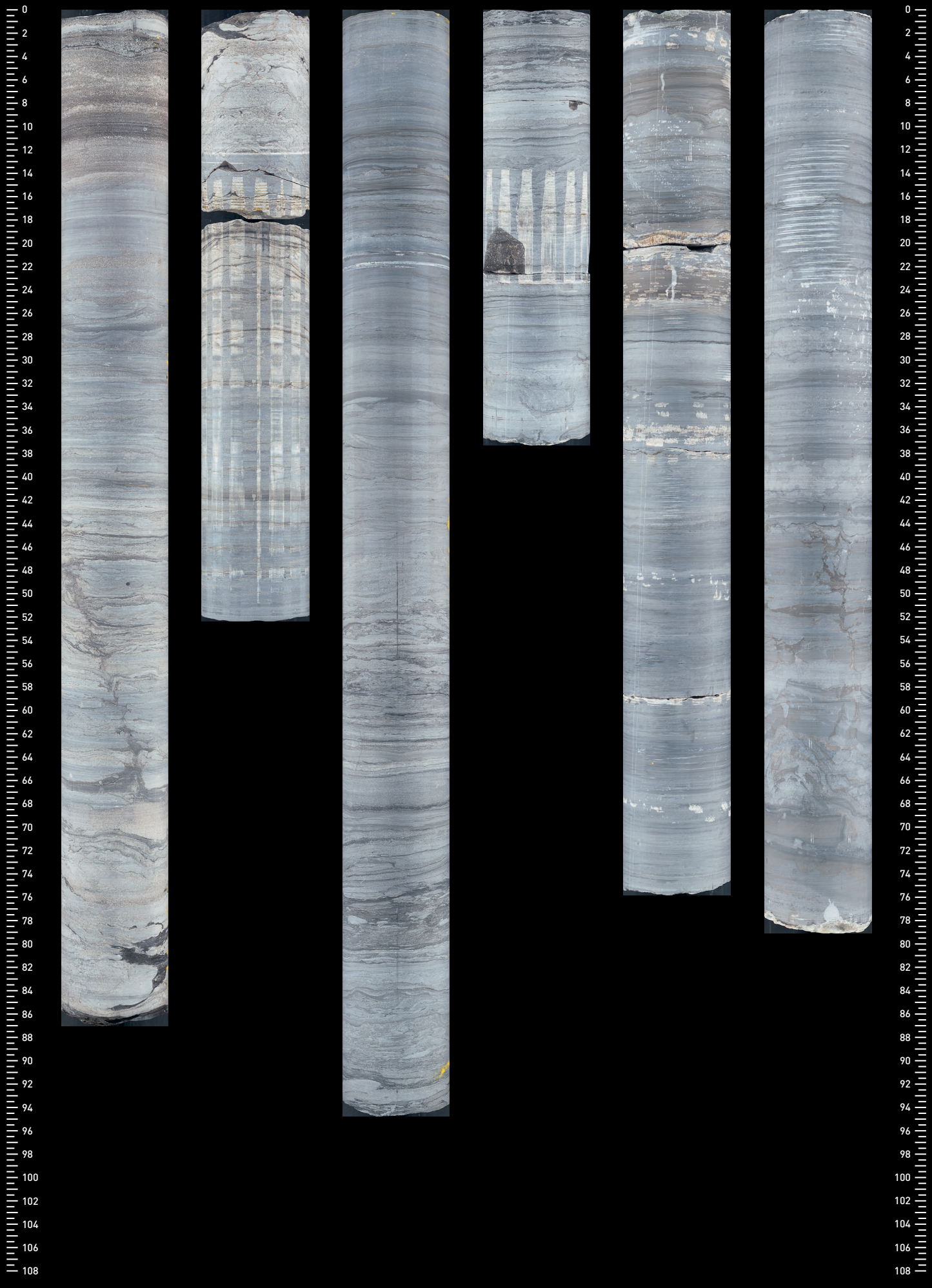
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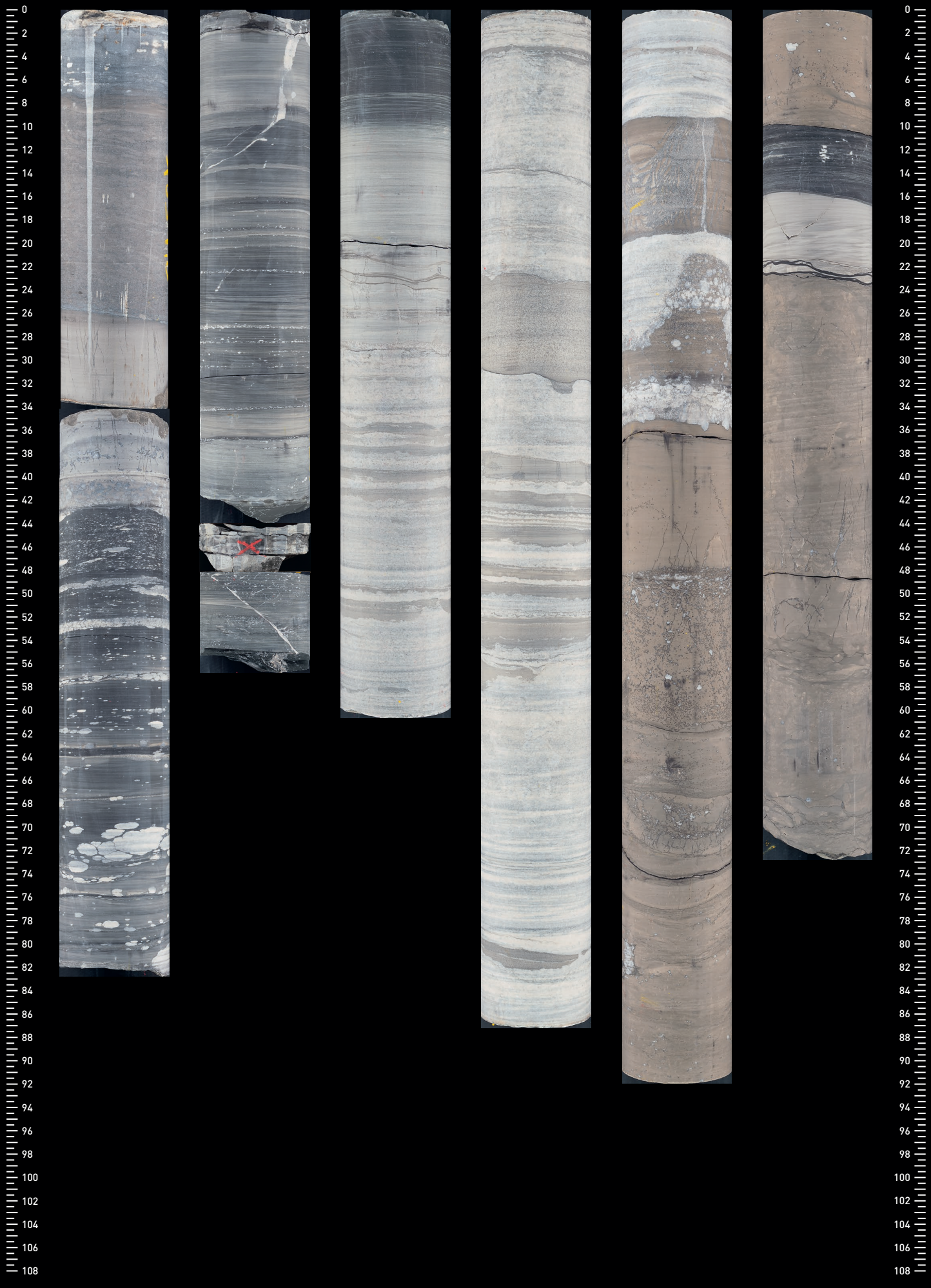
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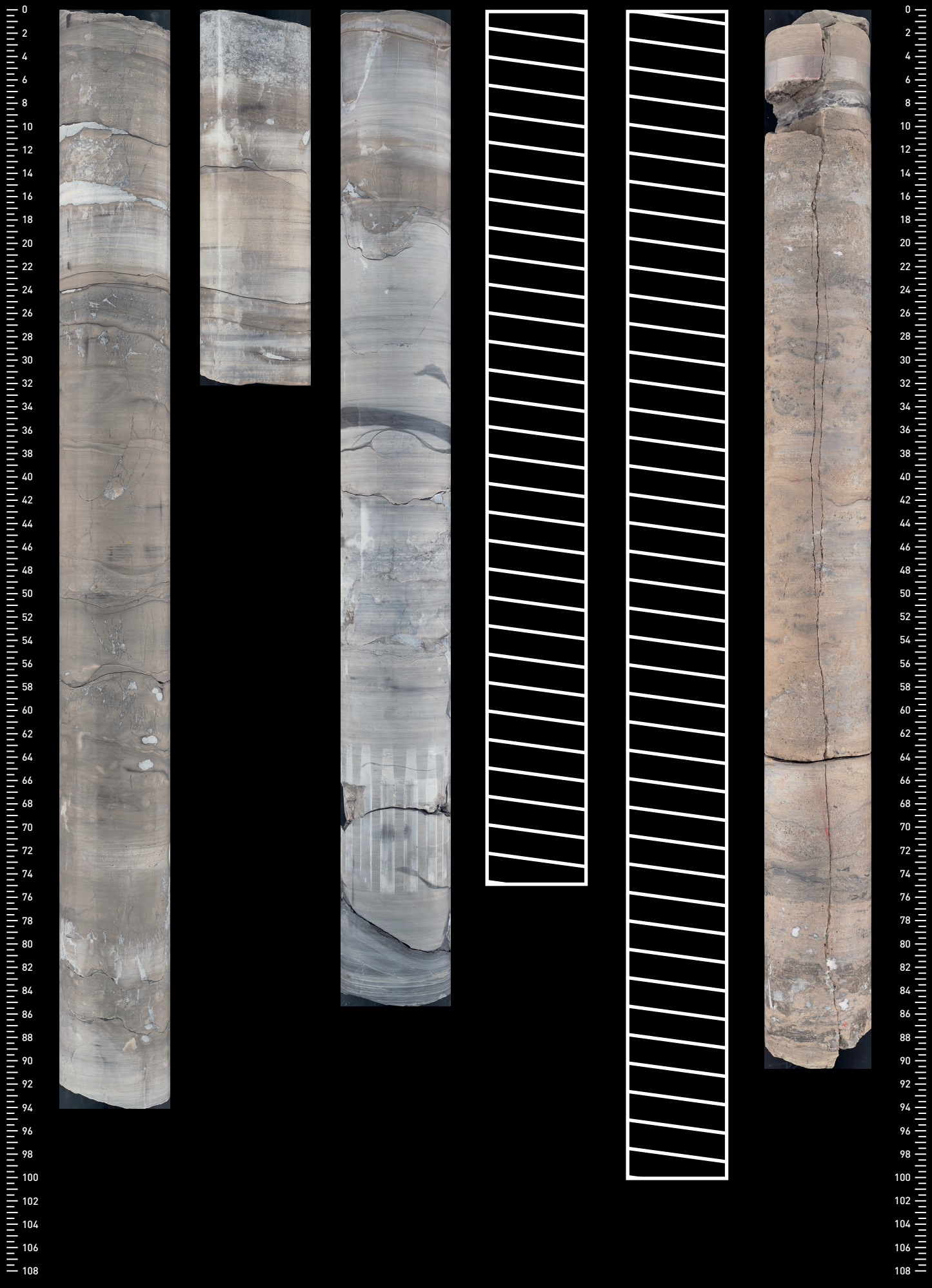
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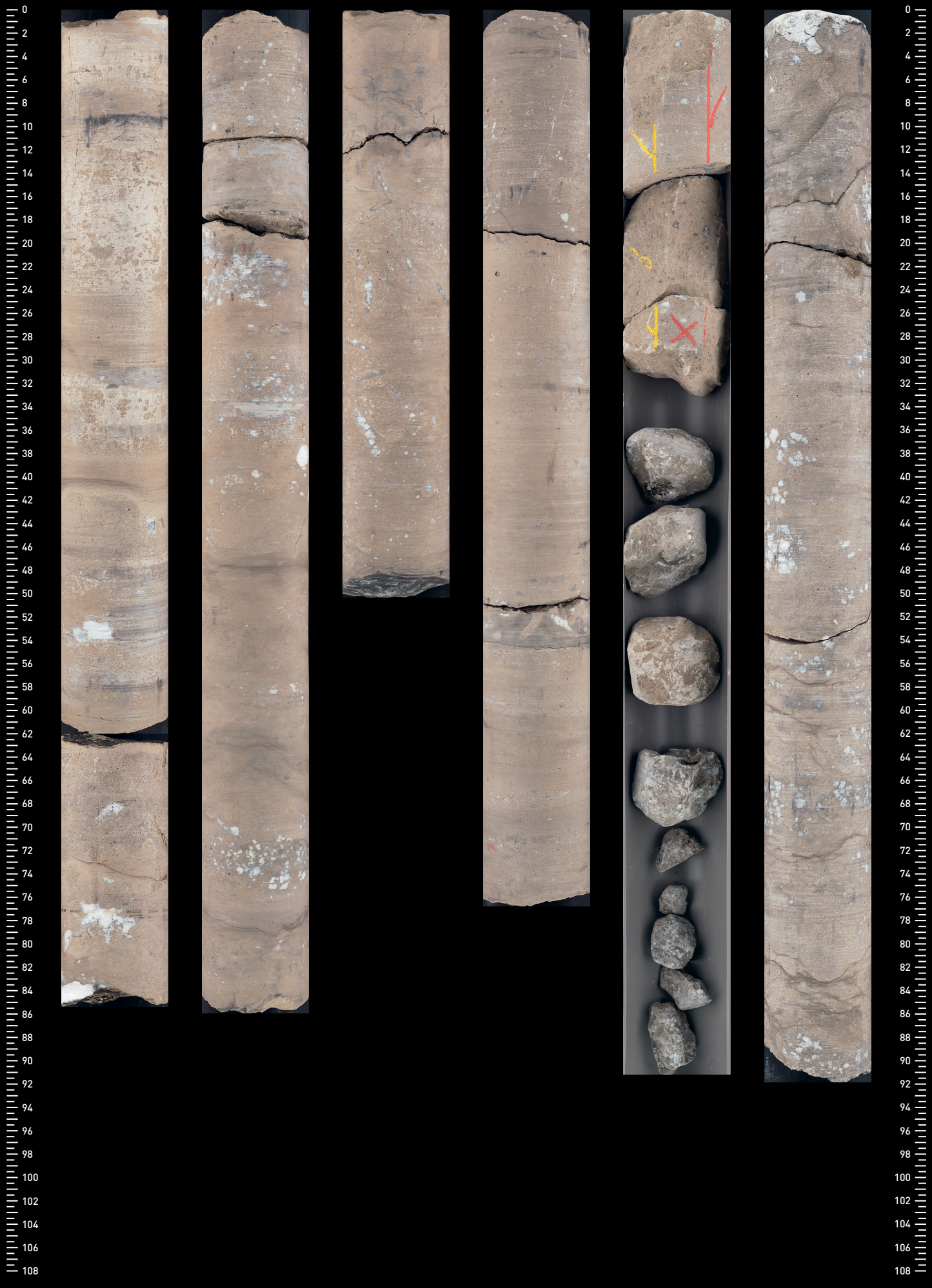
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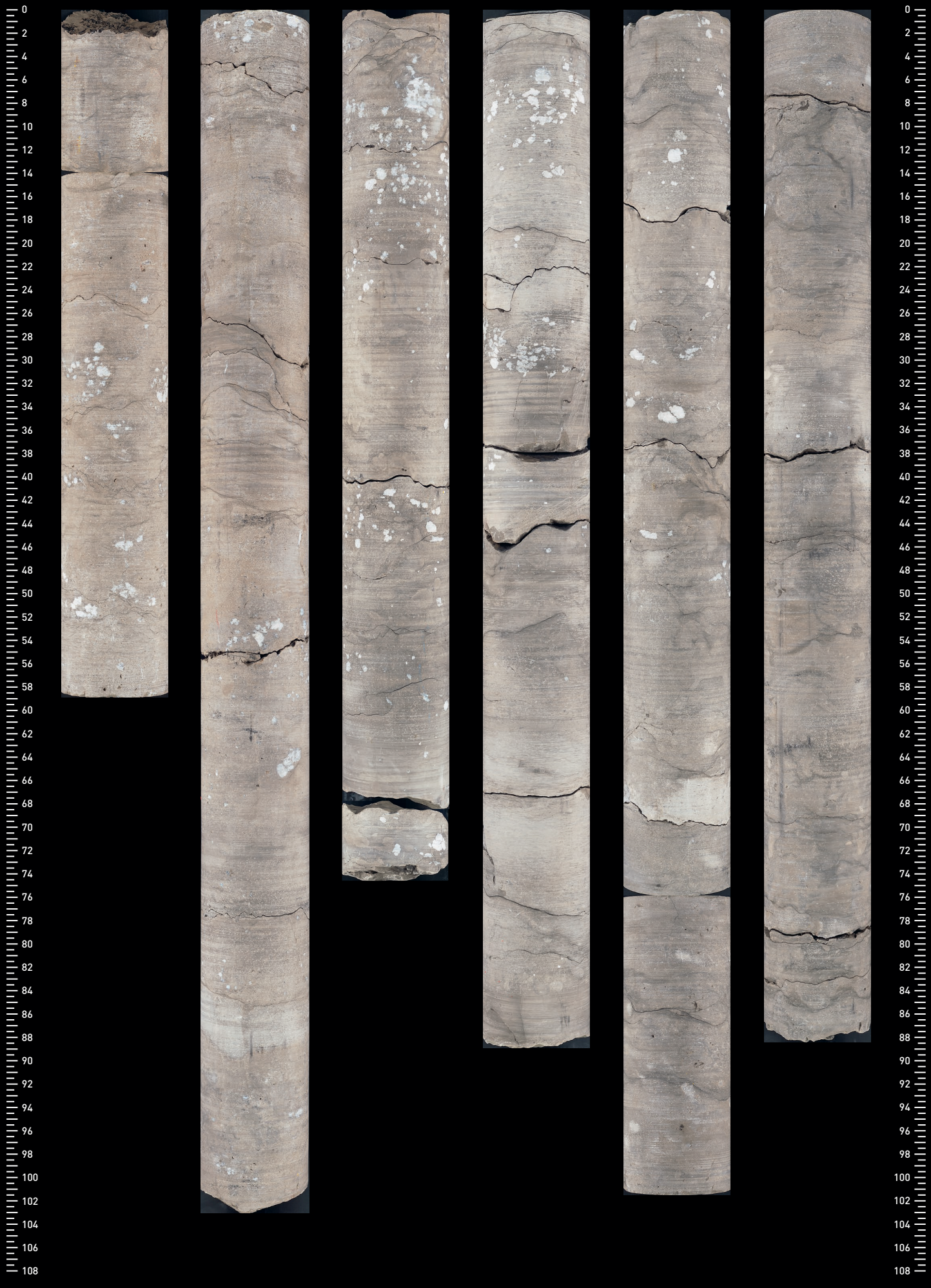
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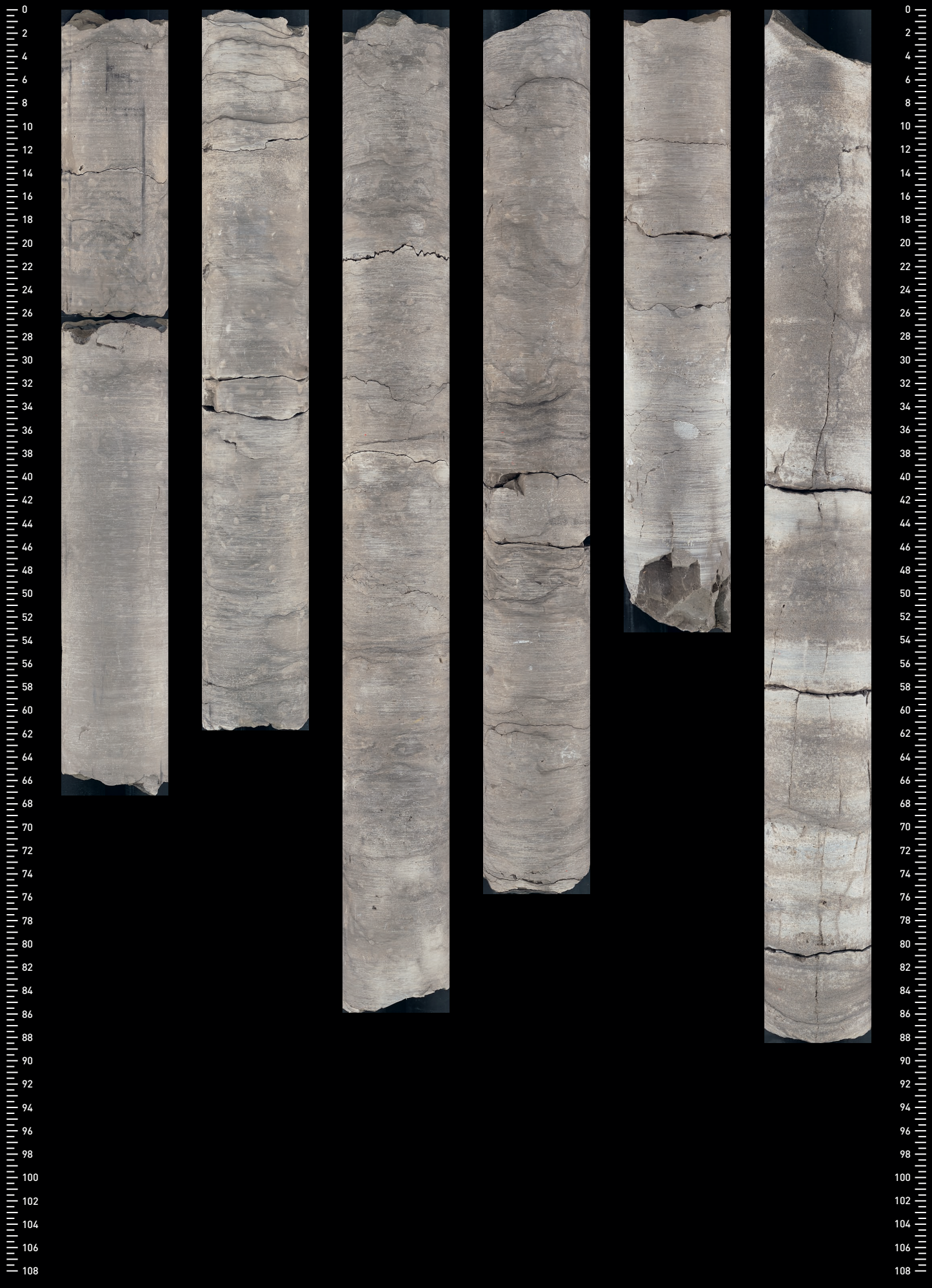
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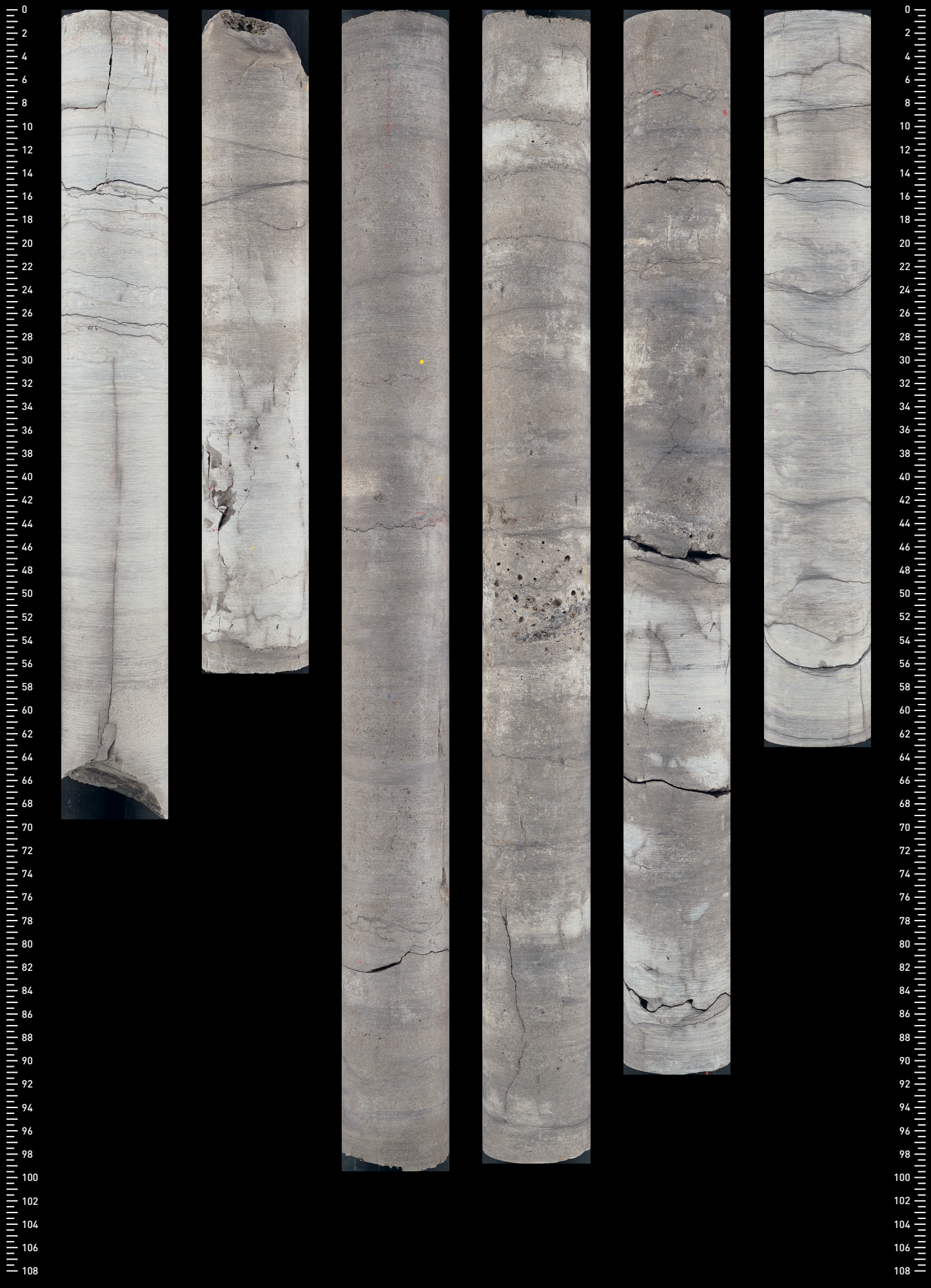
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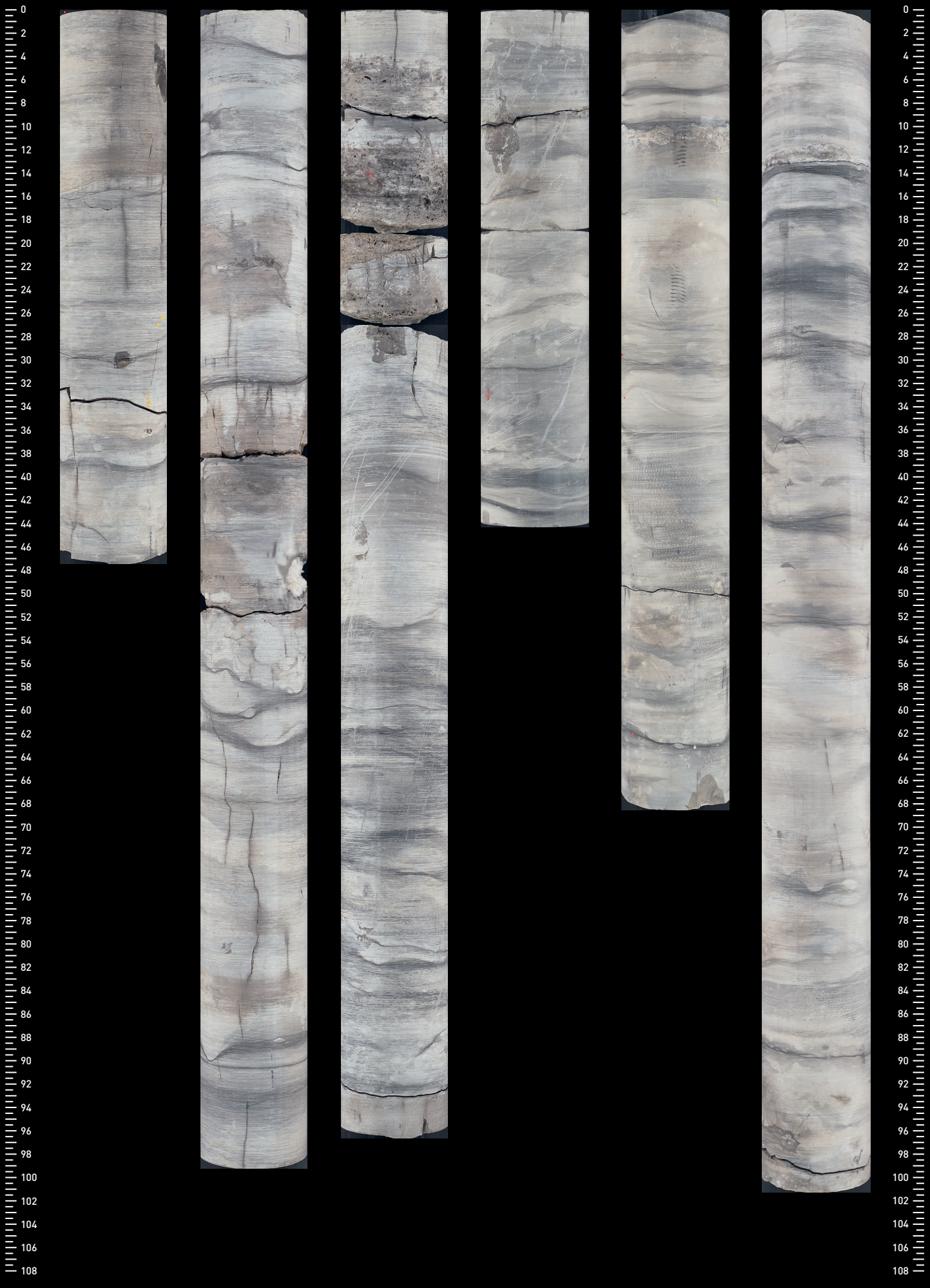
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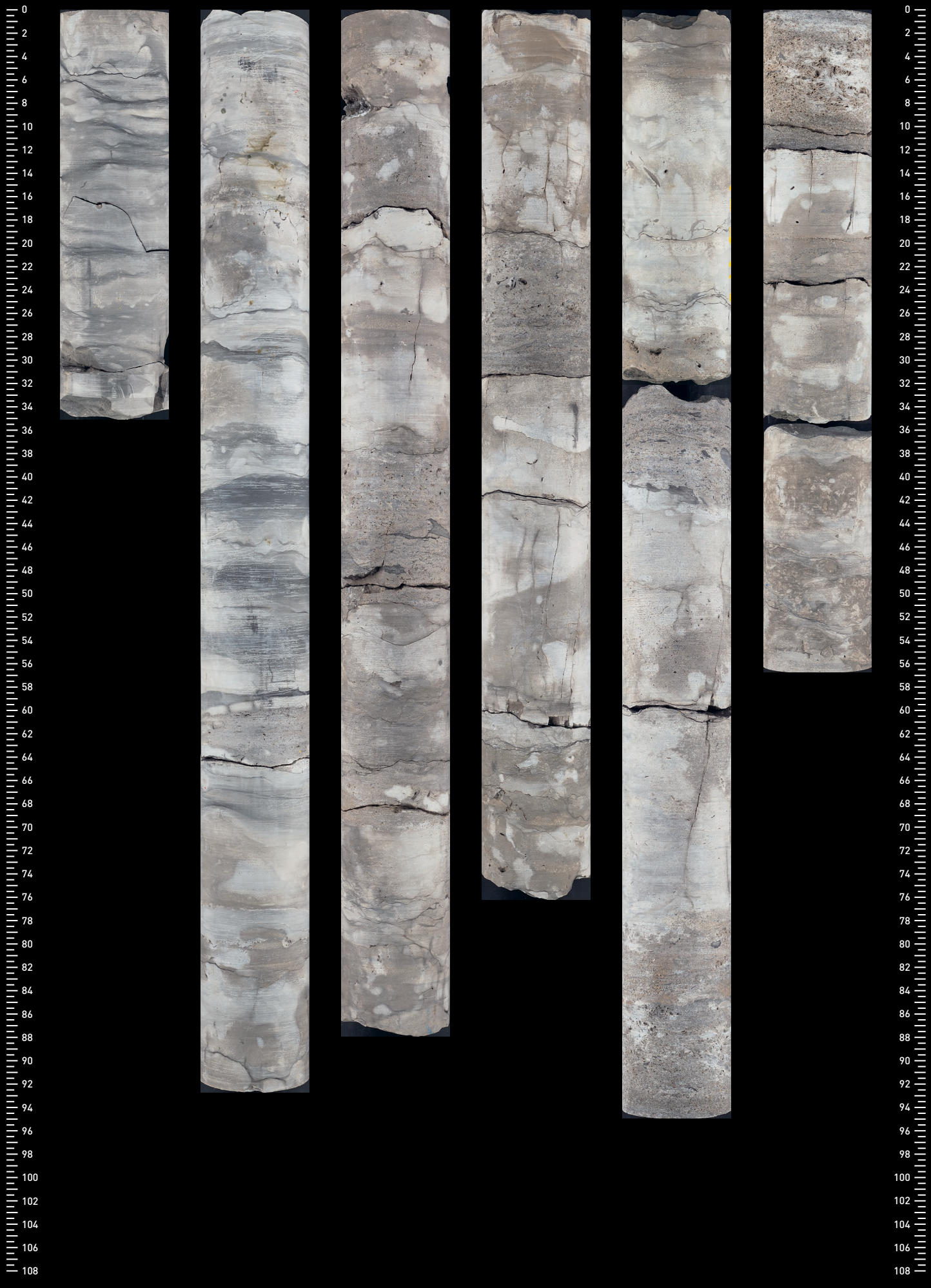

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1082.00m
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1083.50m

1083.50m 1083.97m 1084.95m 1085.90m 1086.34m 1087.00m



1083.97m 1084.95m 1085.90m 1086.34m 1087.00m 1087.99m

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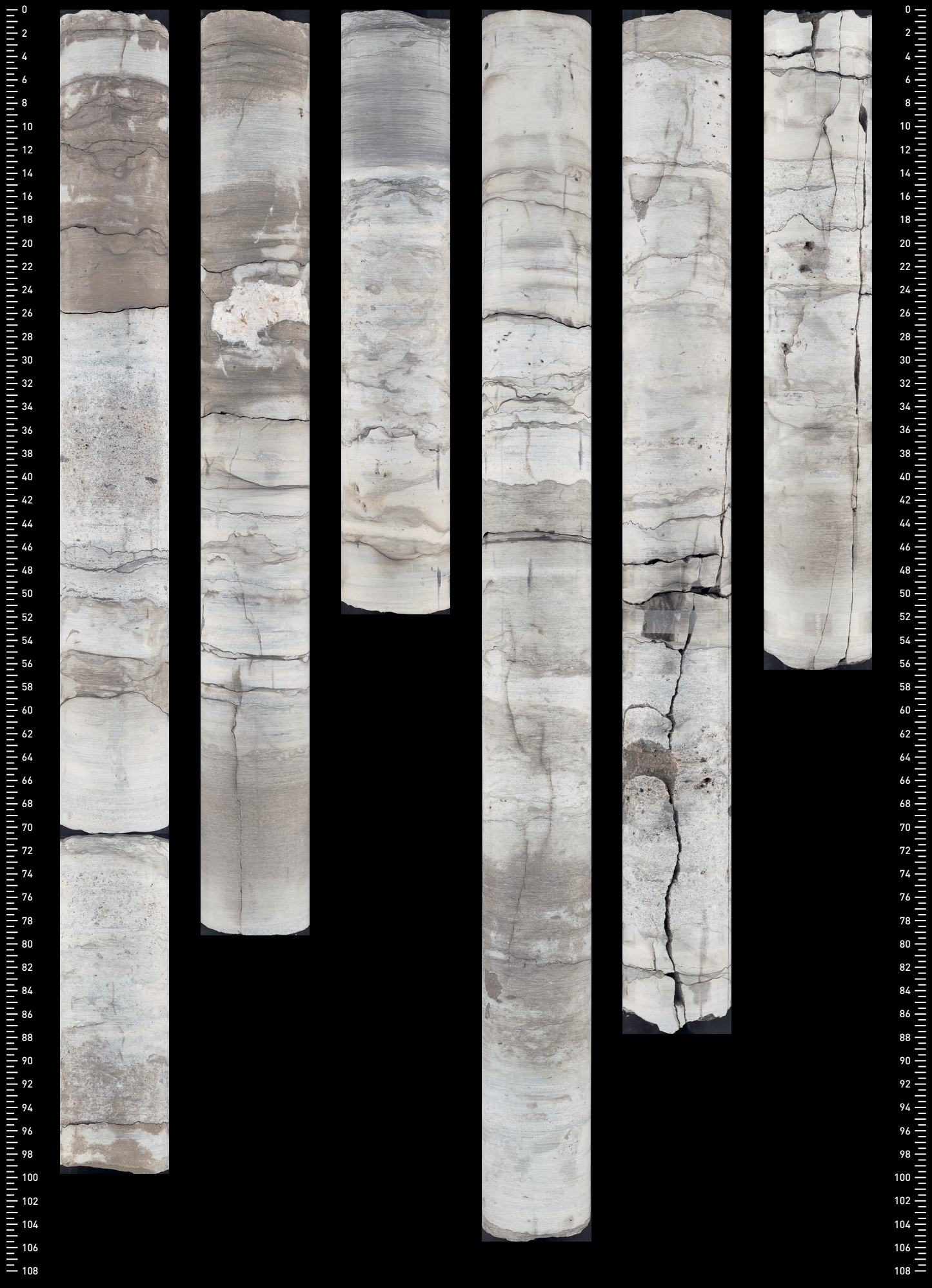
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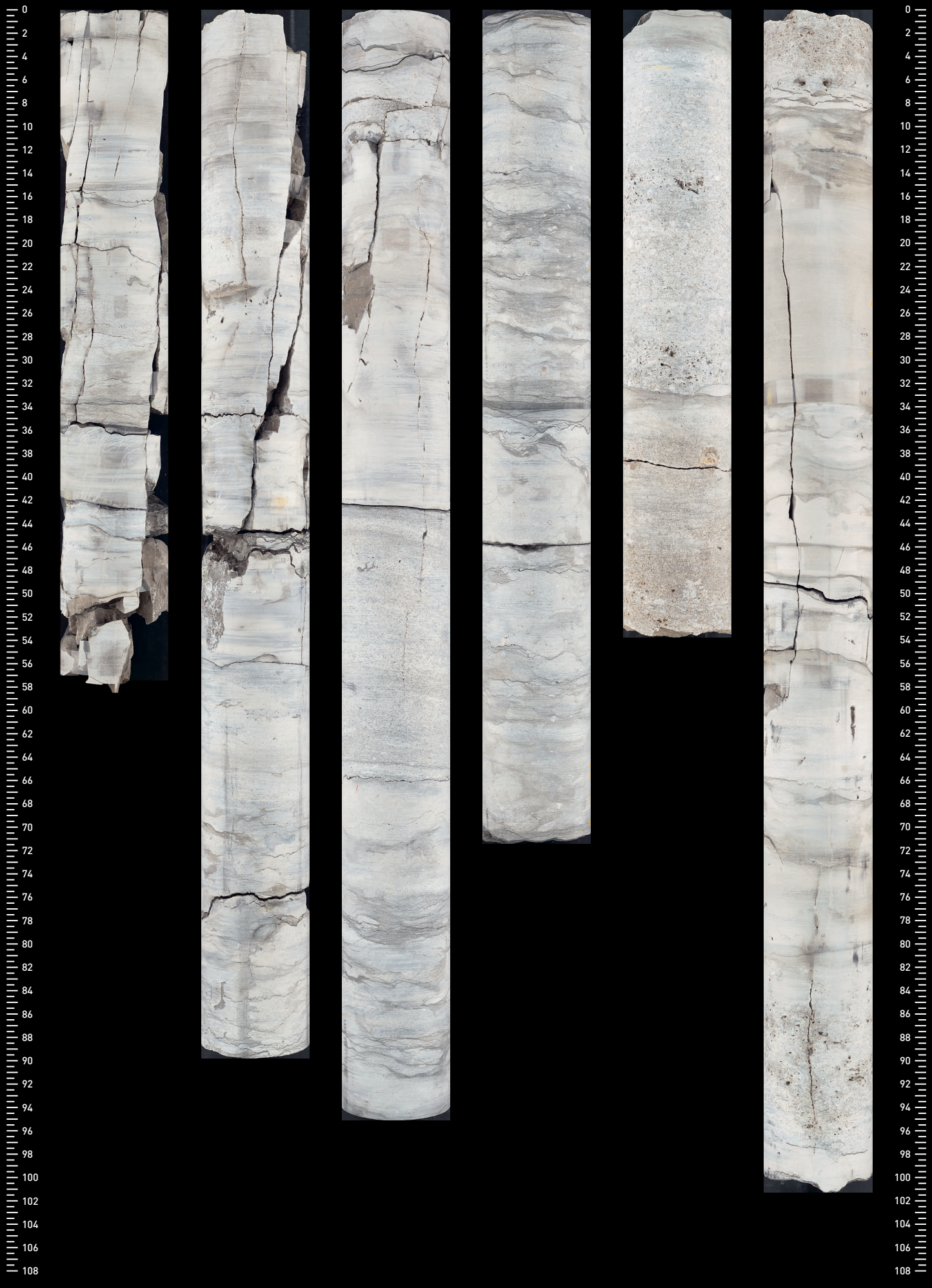
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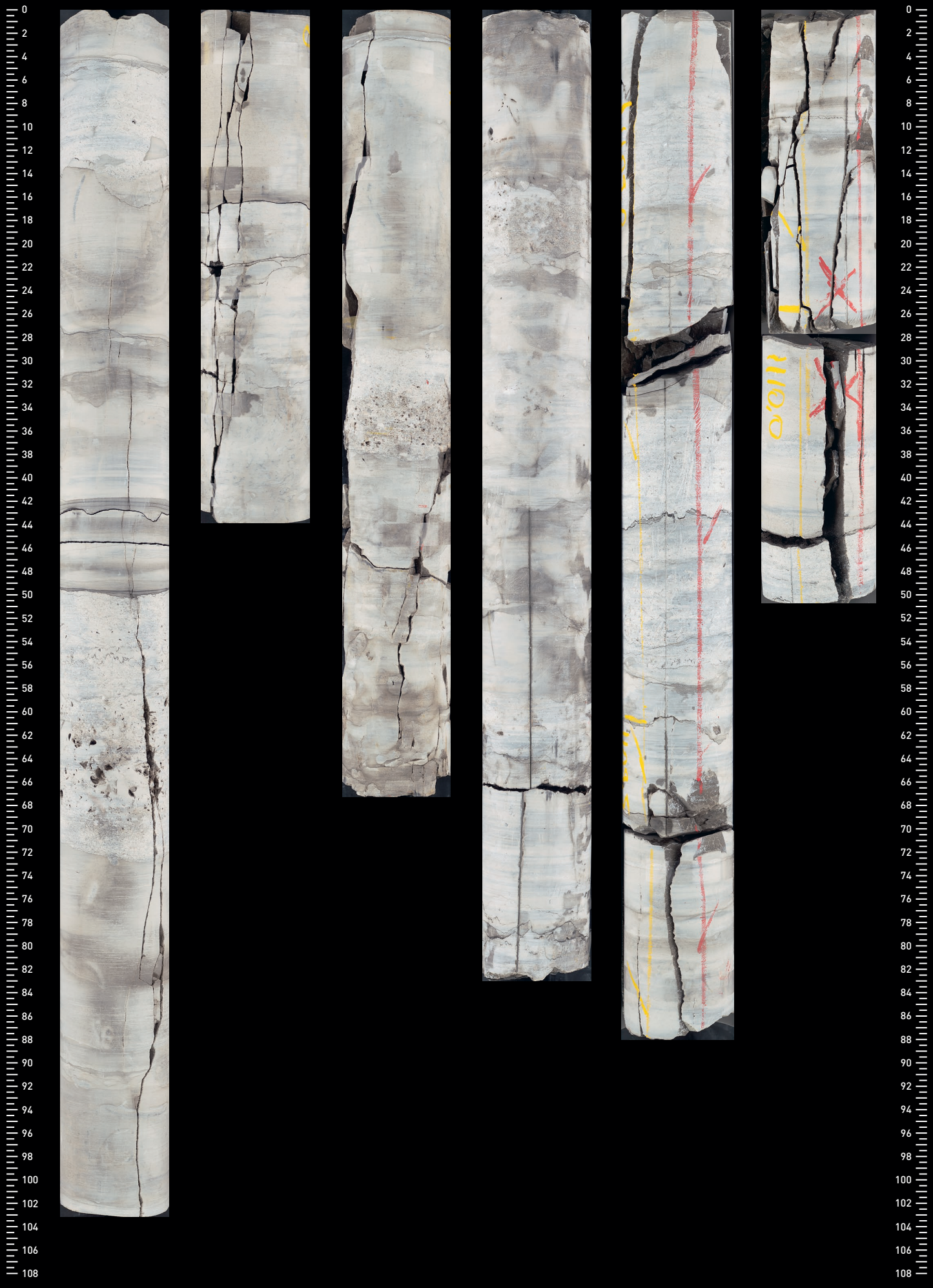
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1102.09m 1102.95m 1103.87m 1104.57m 1105.10m 1106.07m

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1107.08m 1107.50m 1108.13m 1108.93m 1109.76m 1110.25m

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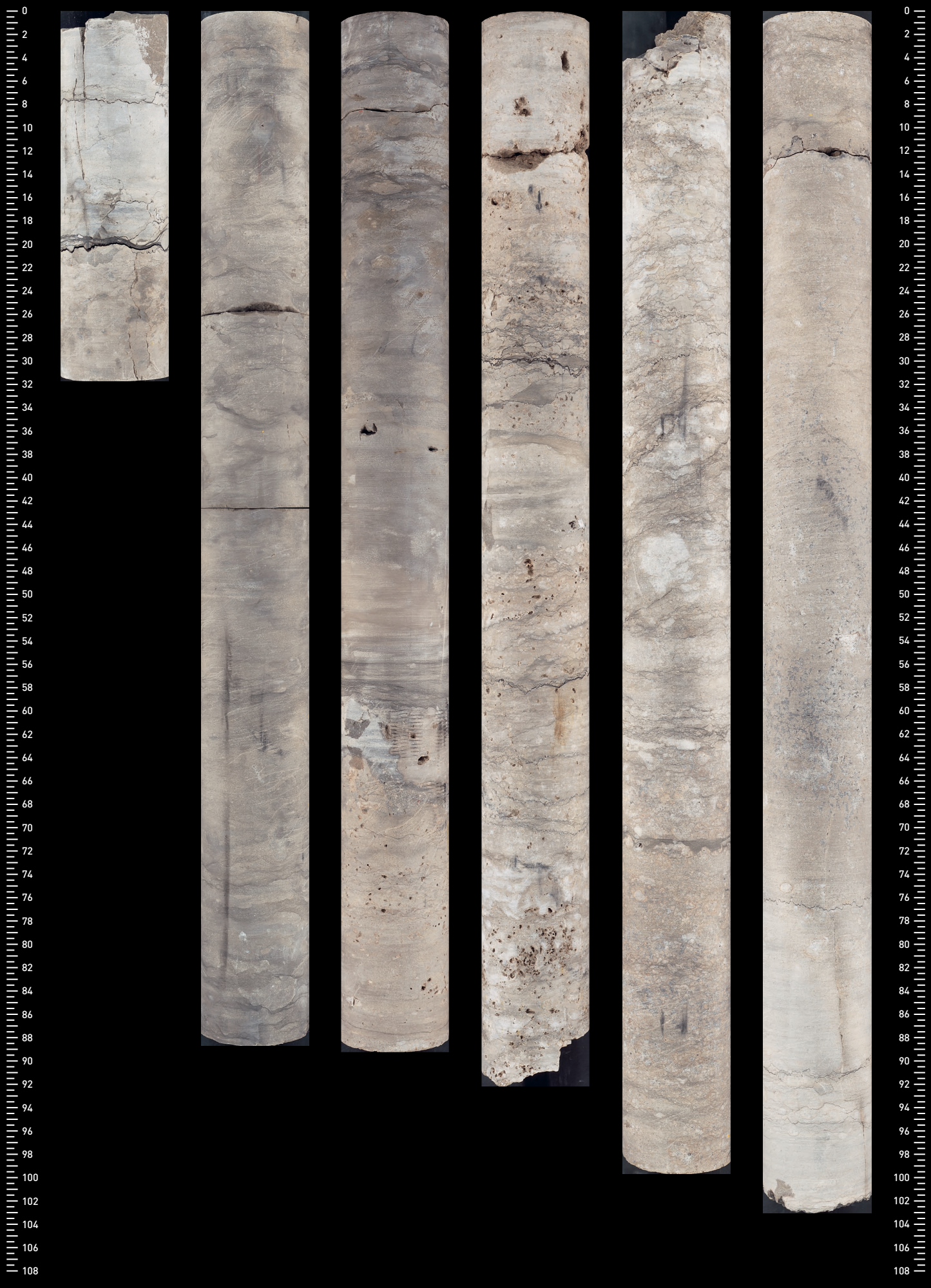


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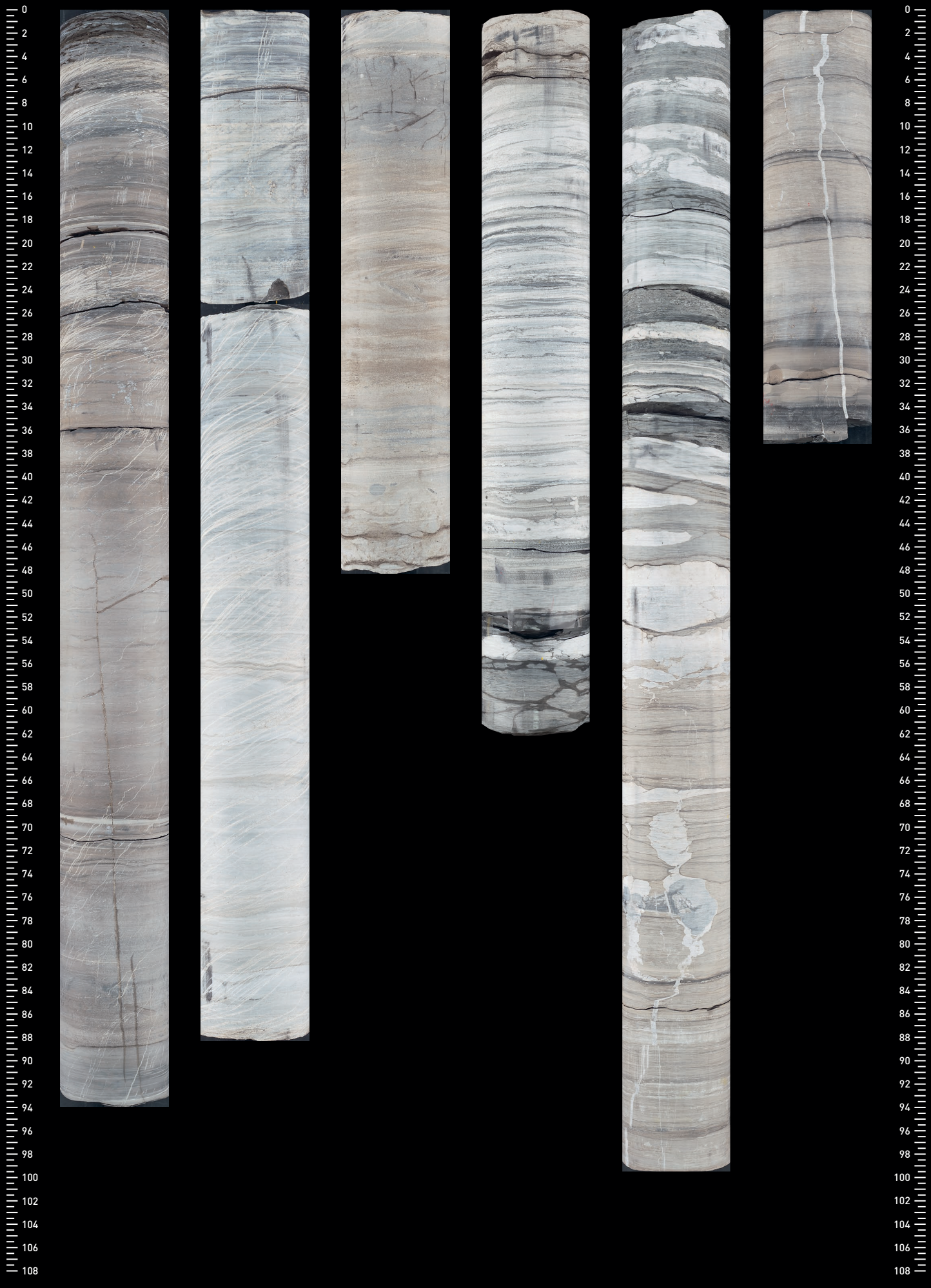

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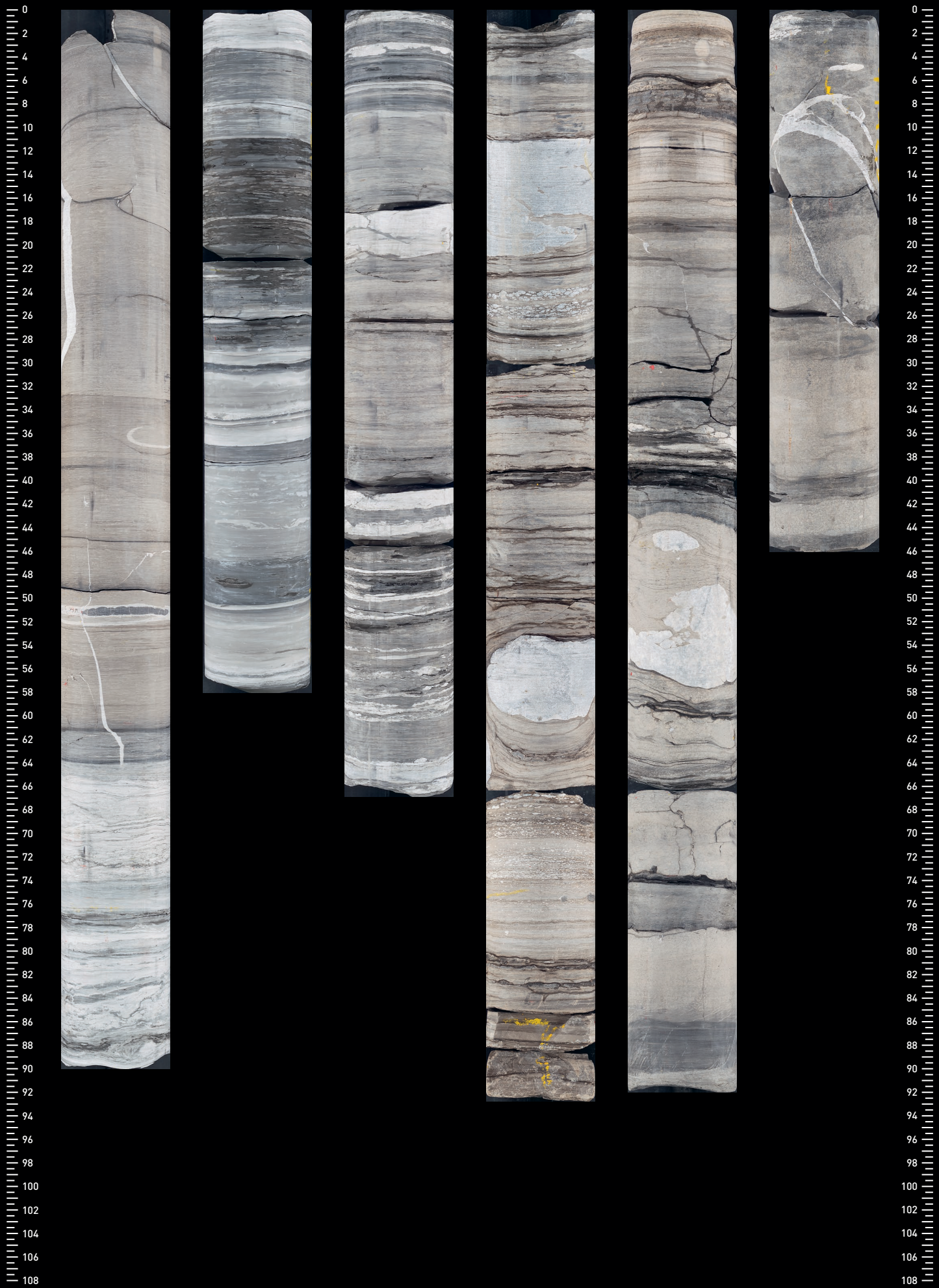
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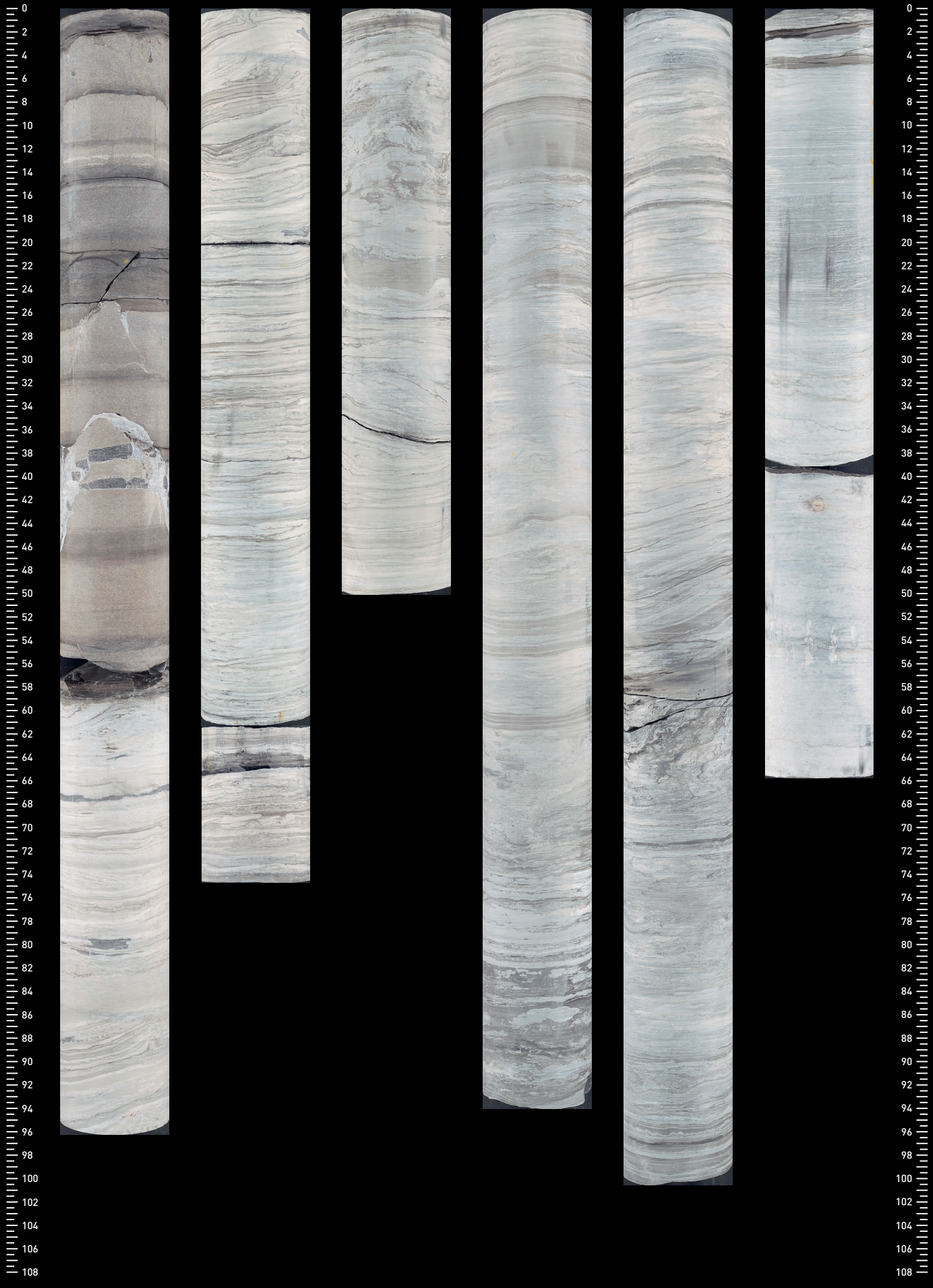

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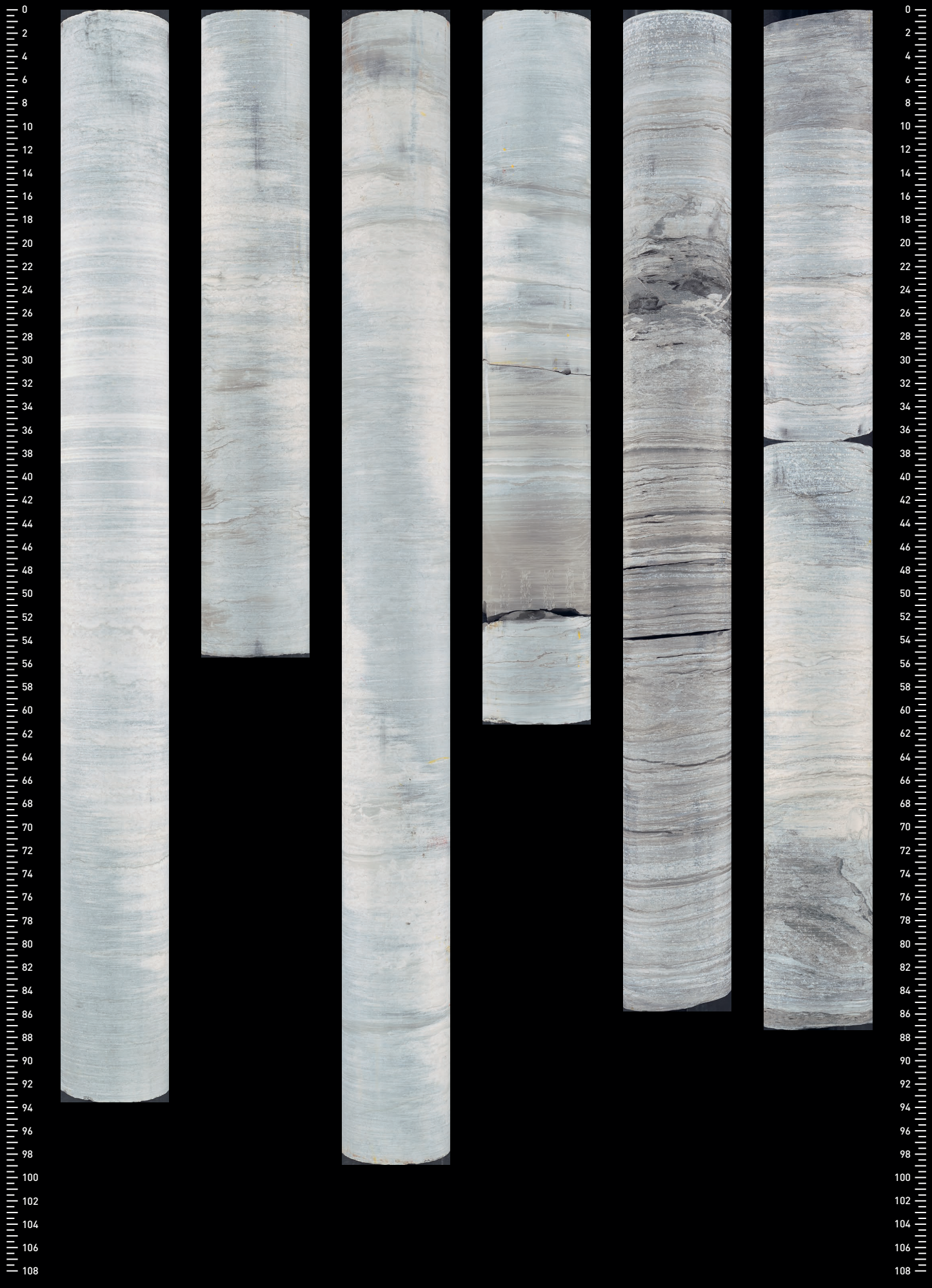
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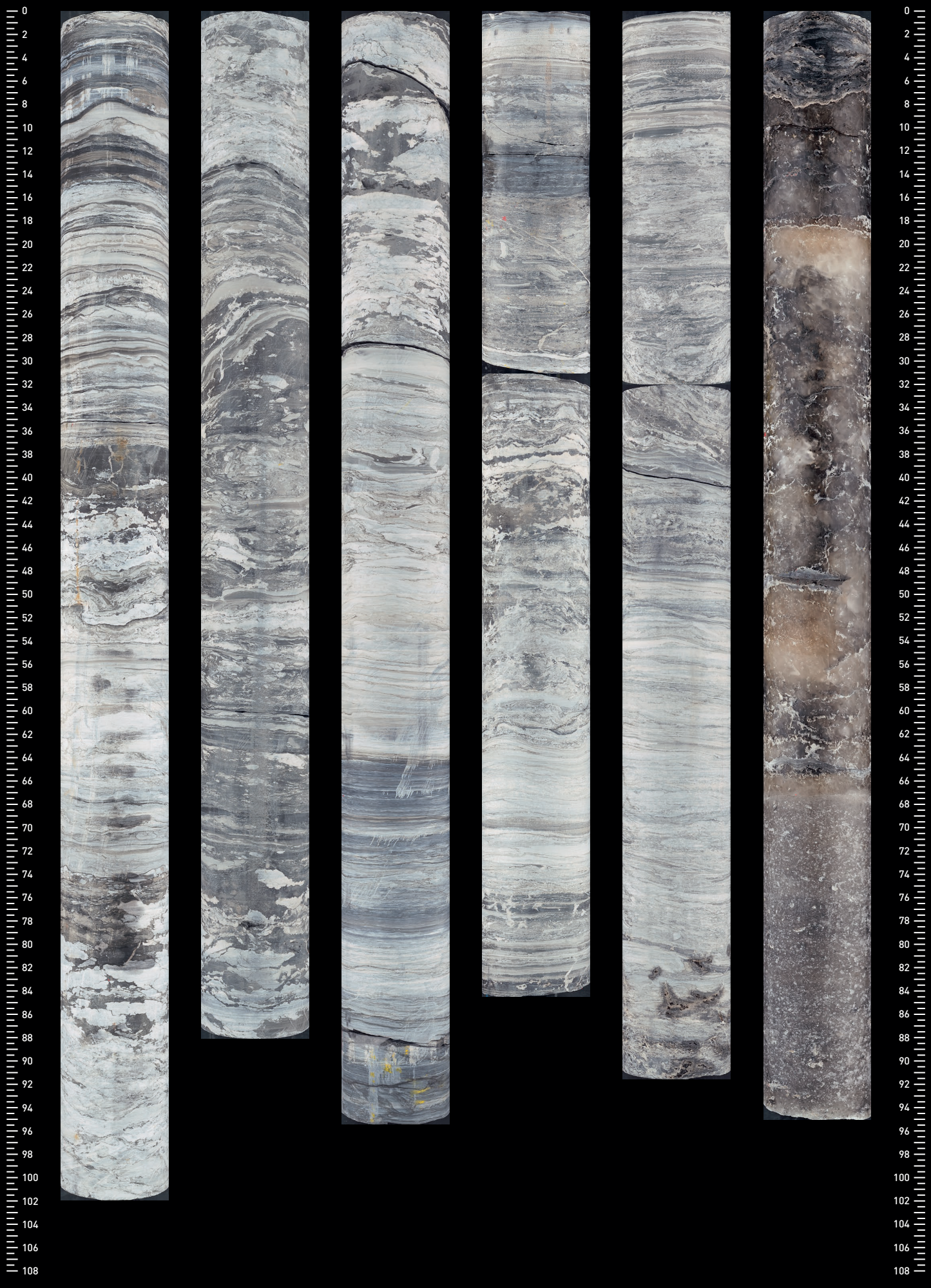
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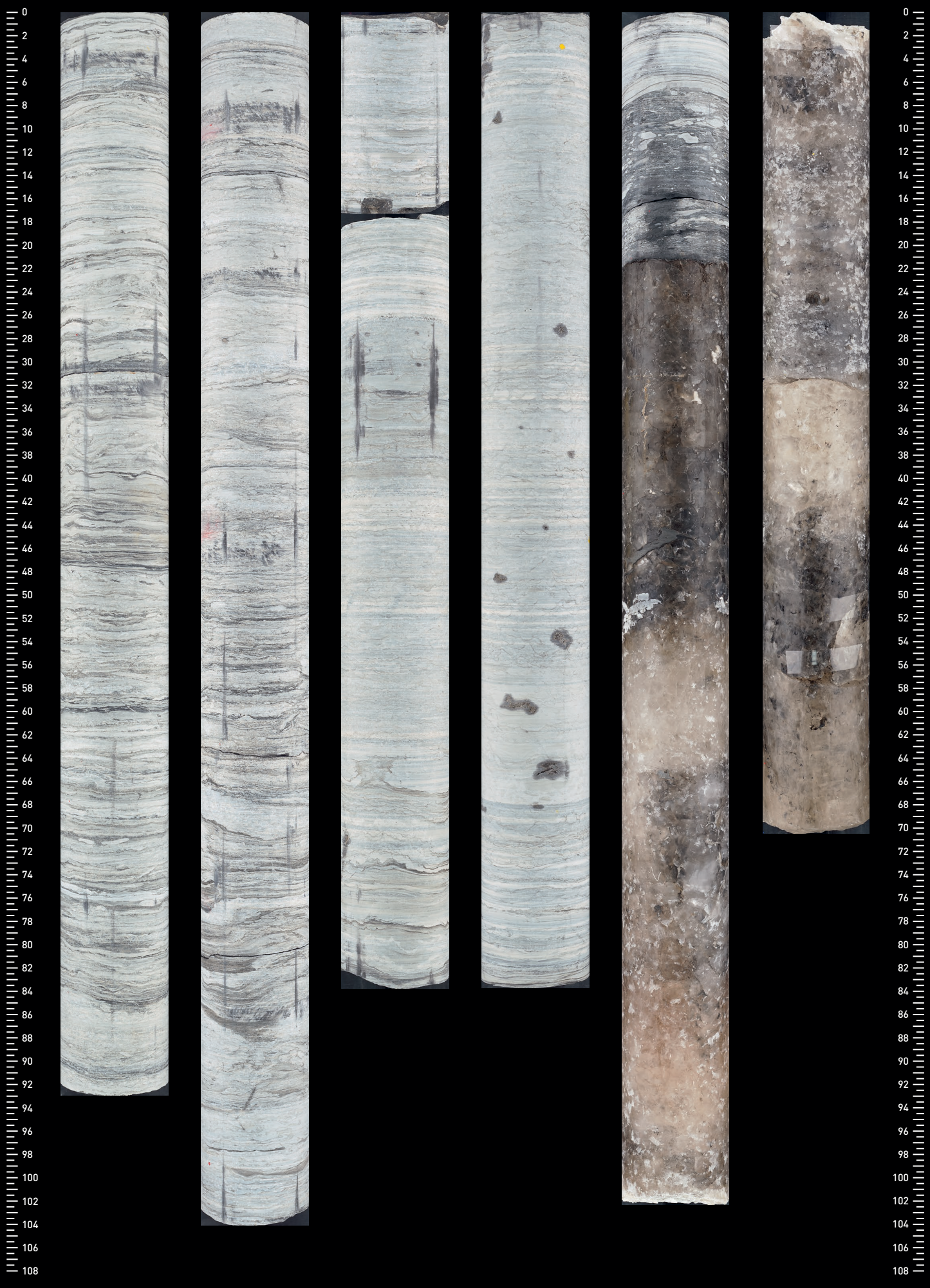

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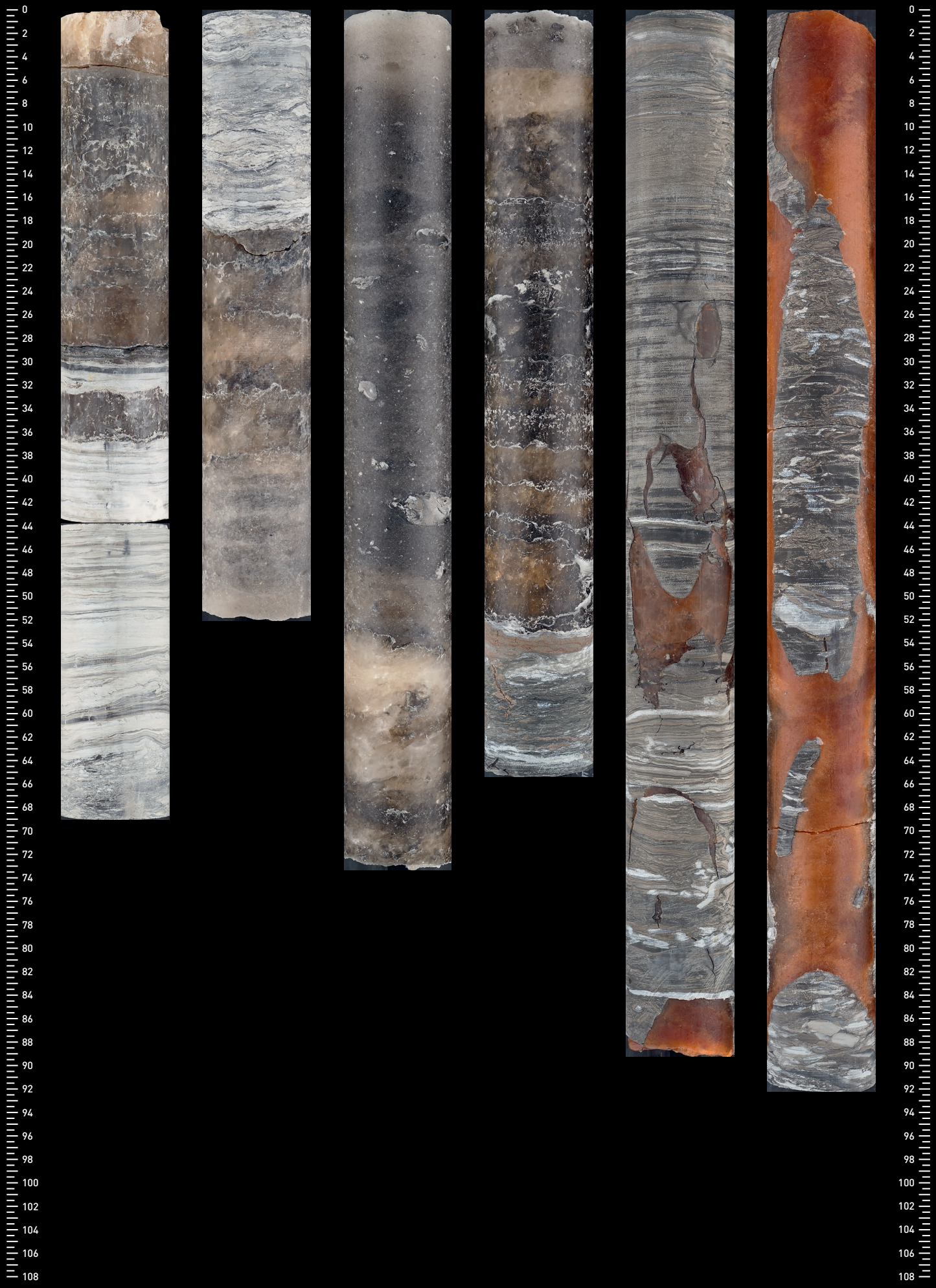
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1180.22m
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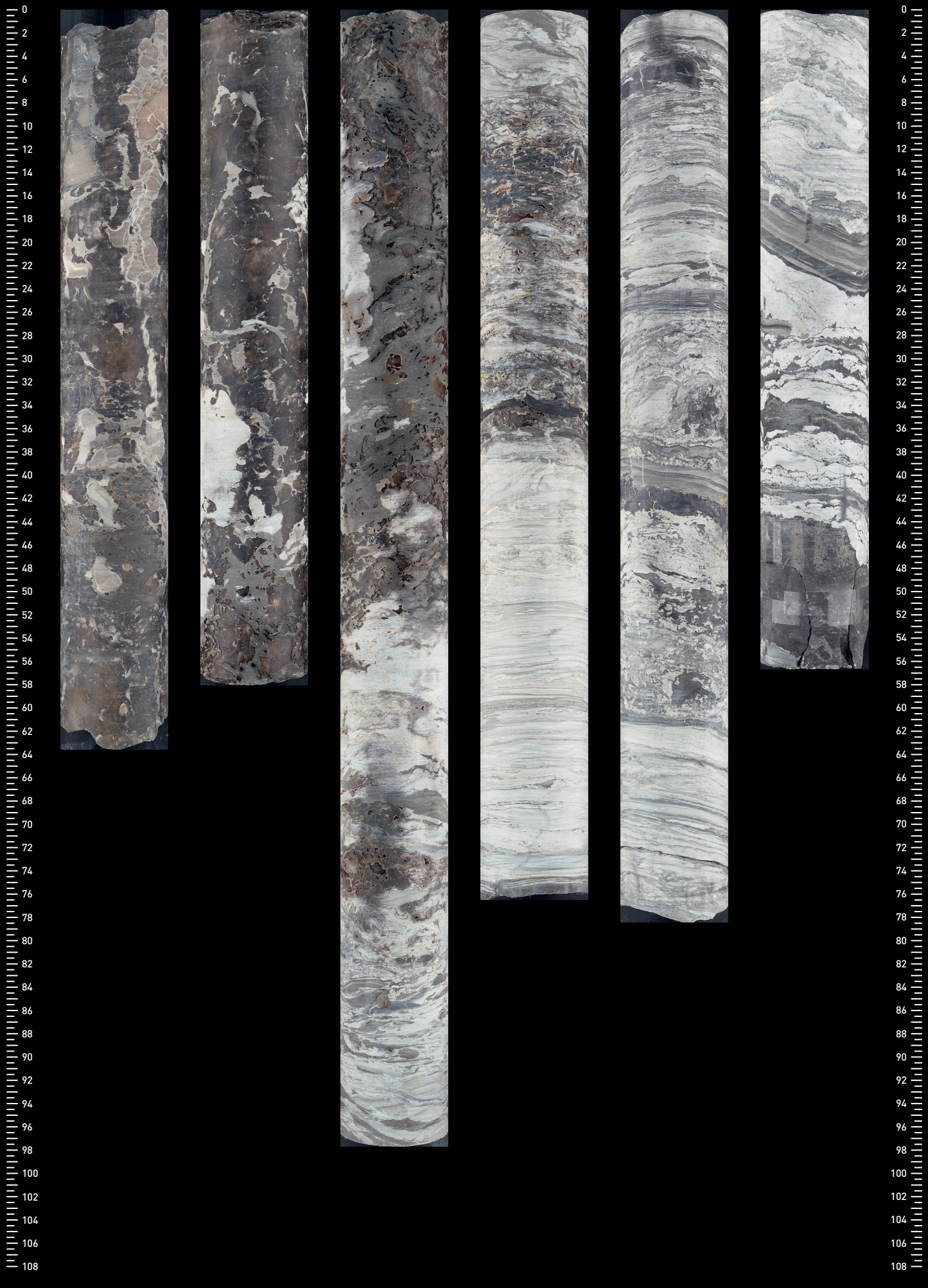
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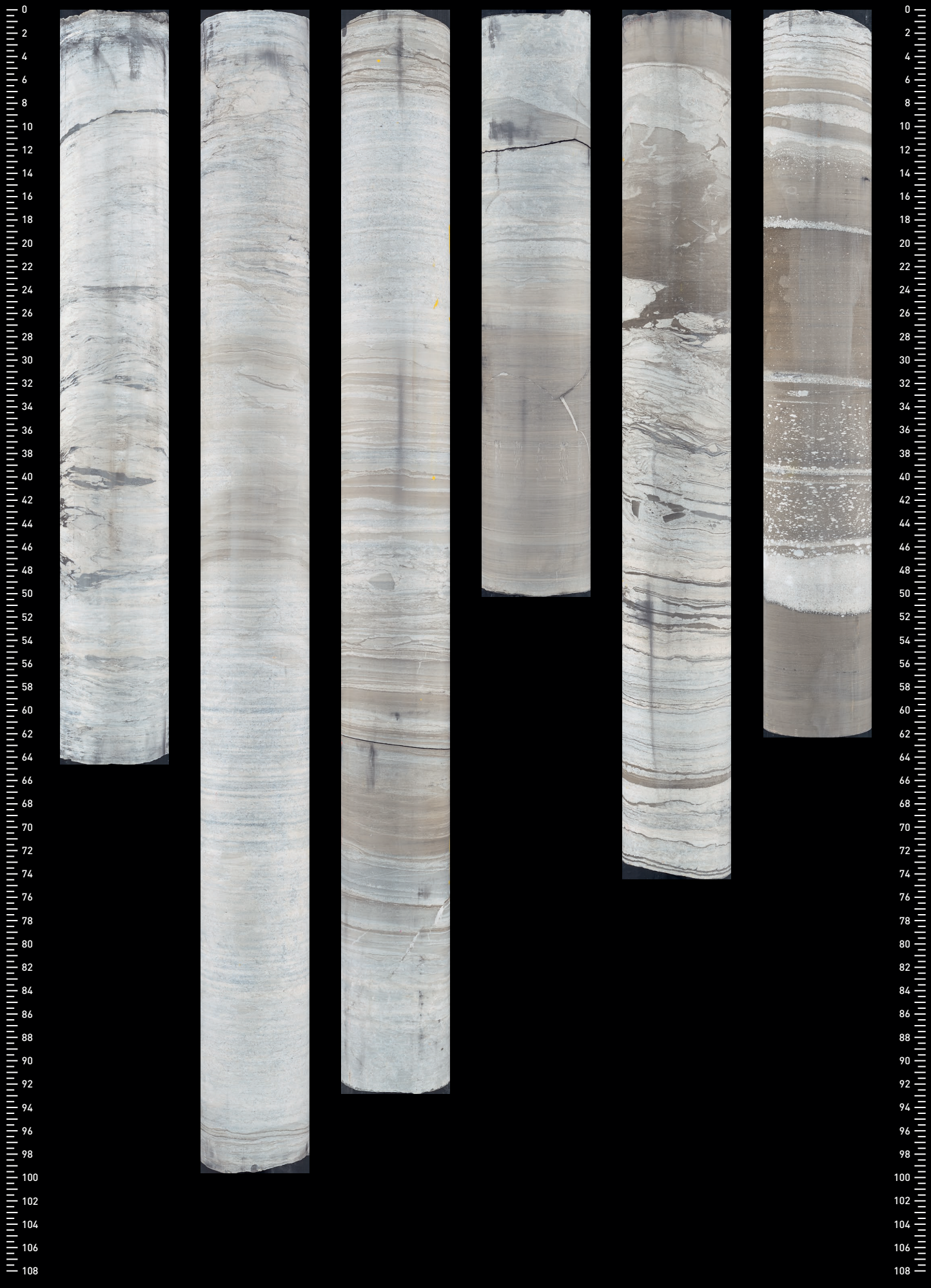

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1191.30m
1192.28m
1193.16m
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1193.16m
1194.14m

1194.14m 1194.73m 1195.29m 1196.25m 1197.01m 1197.75m



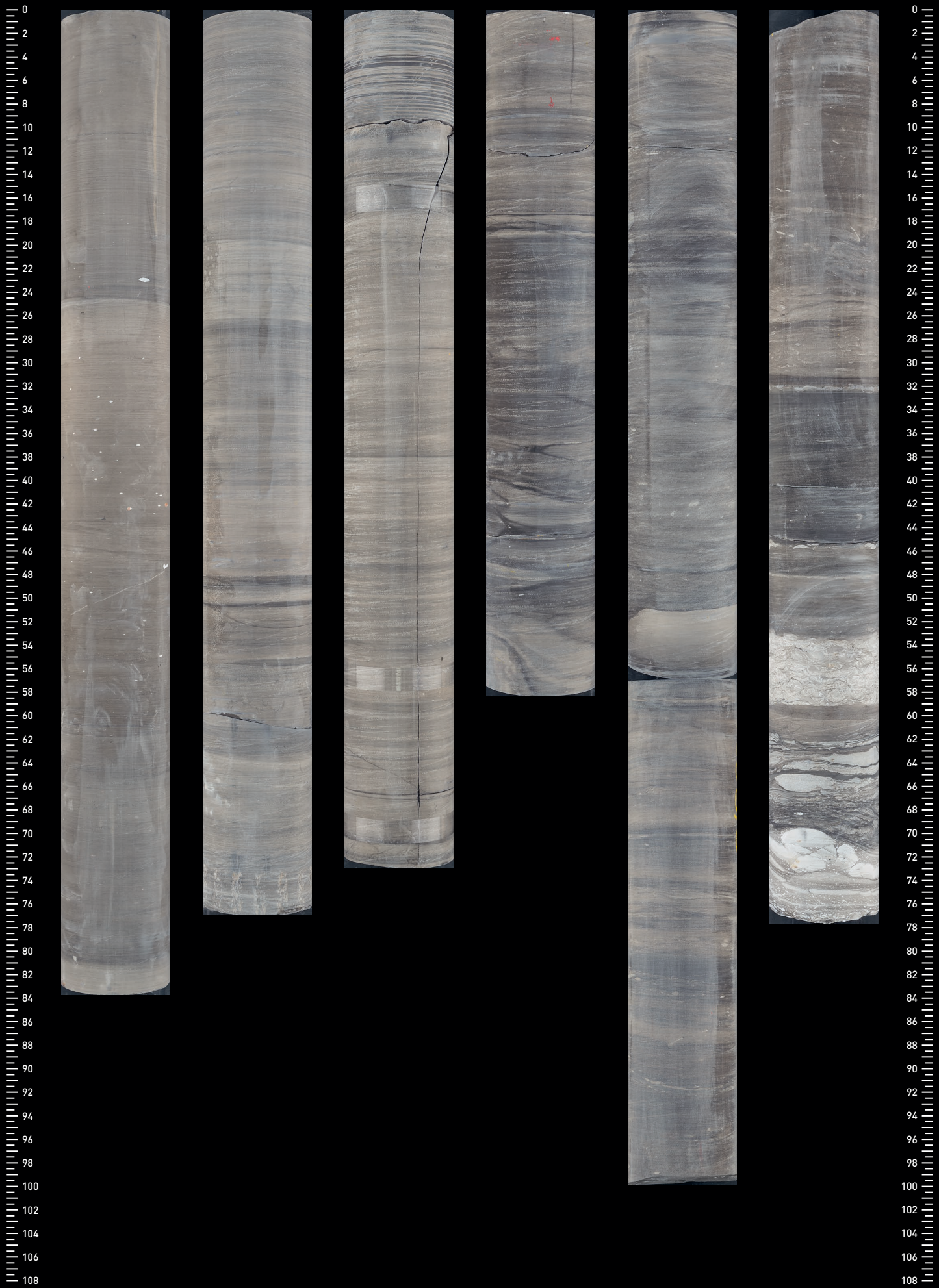
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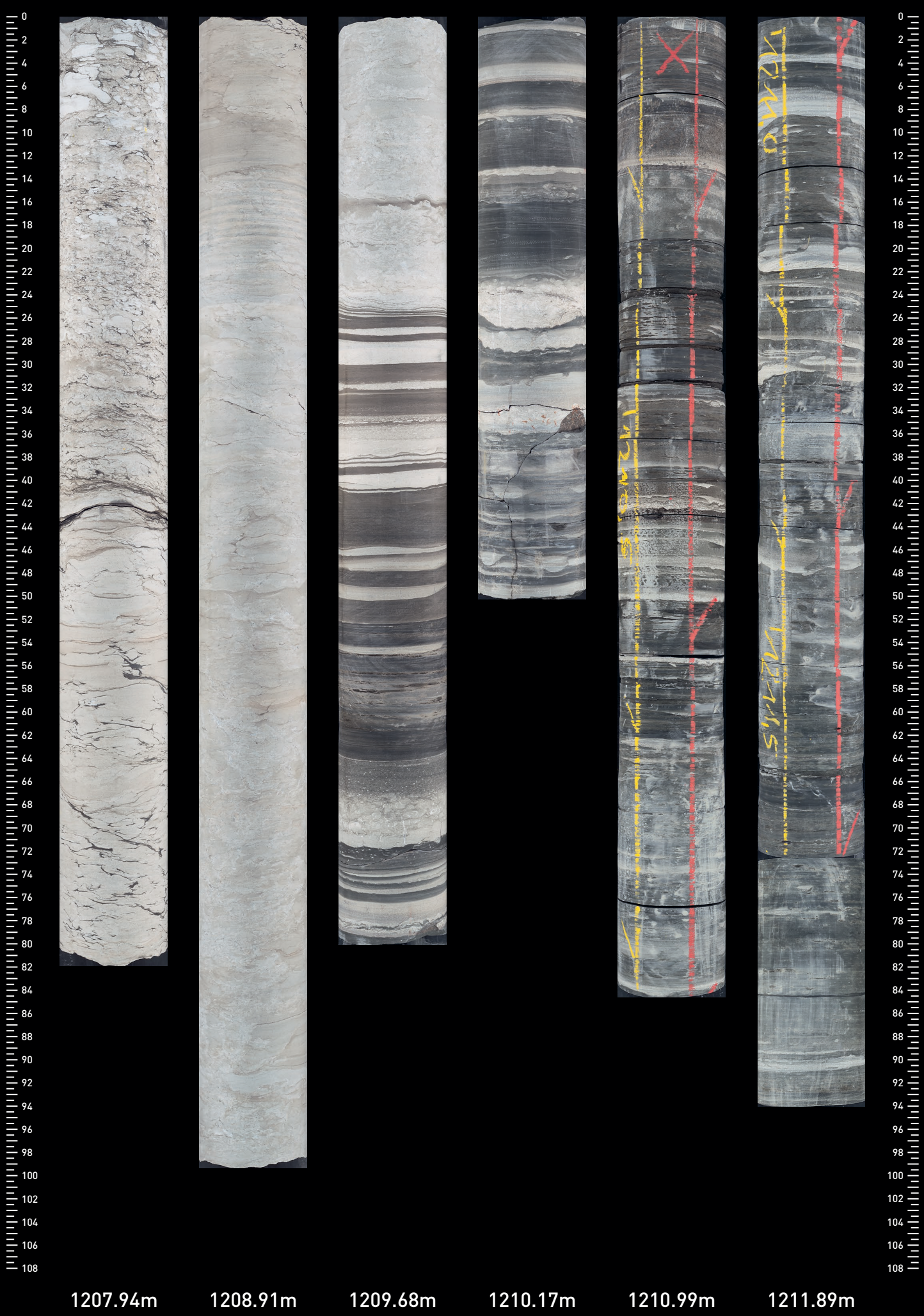


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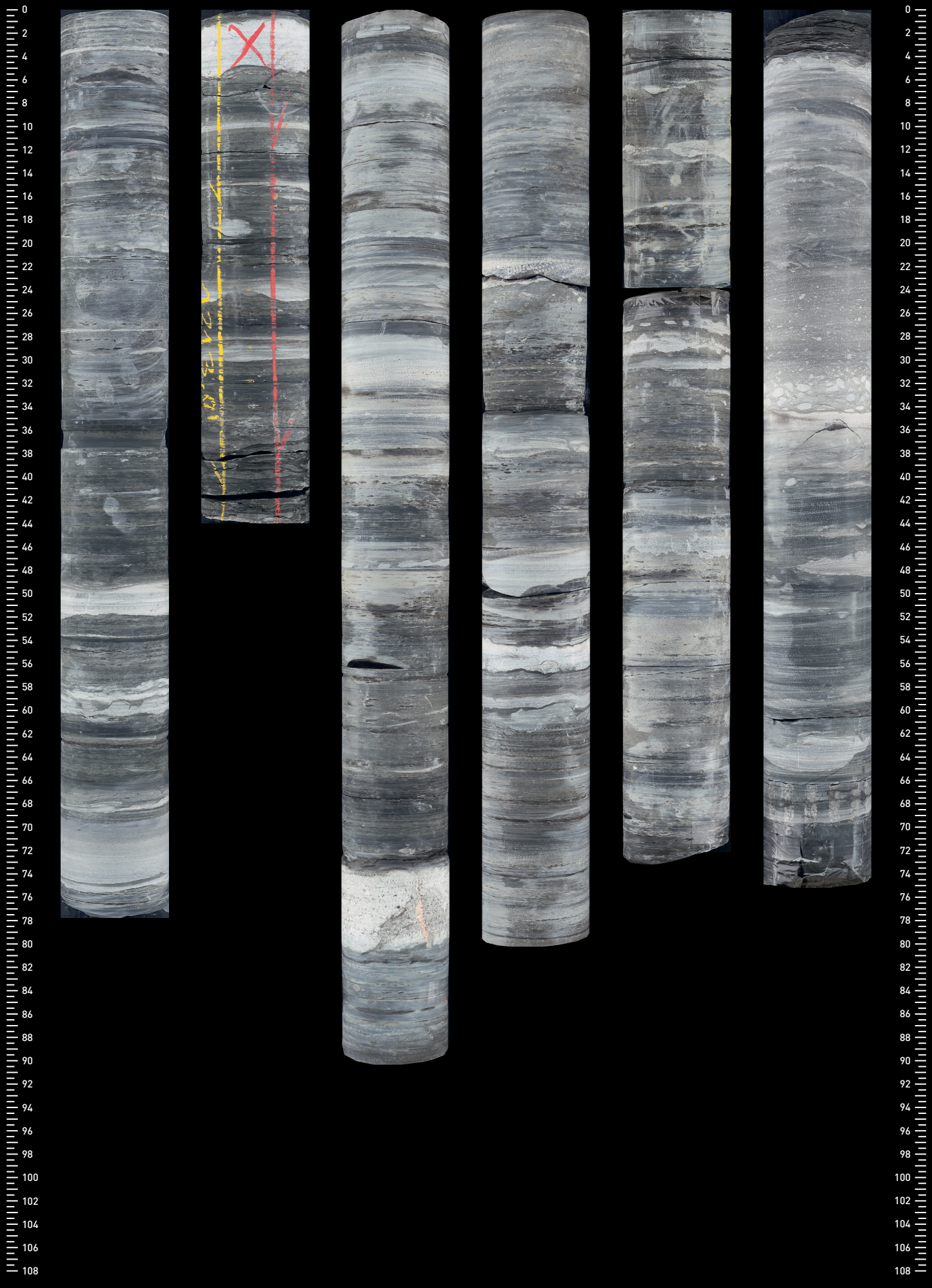
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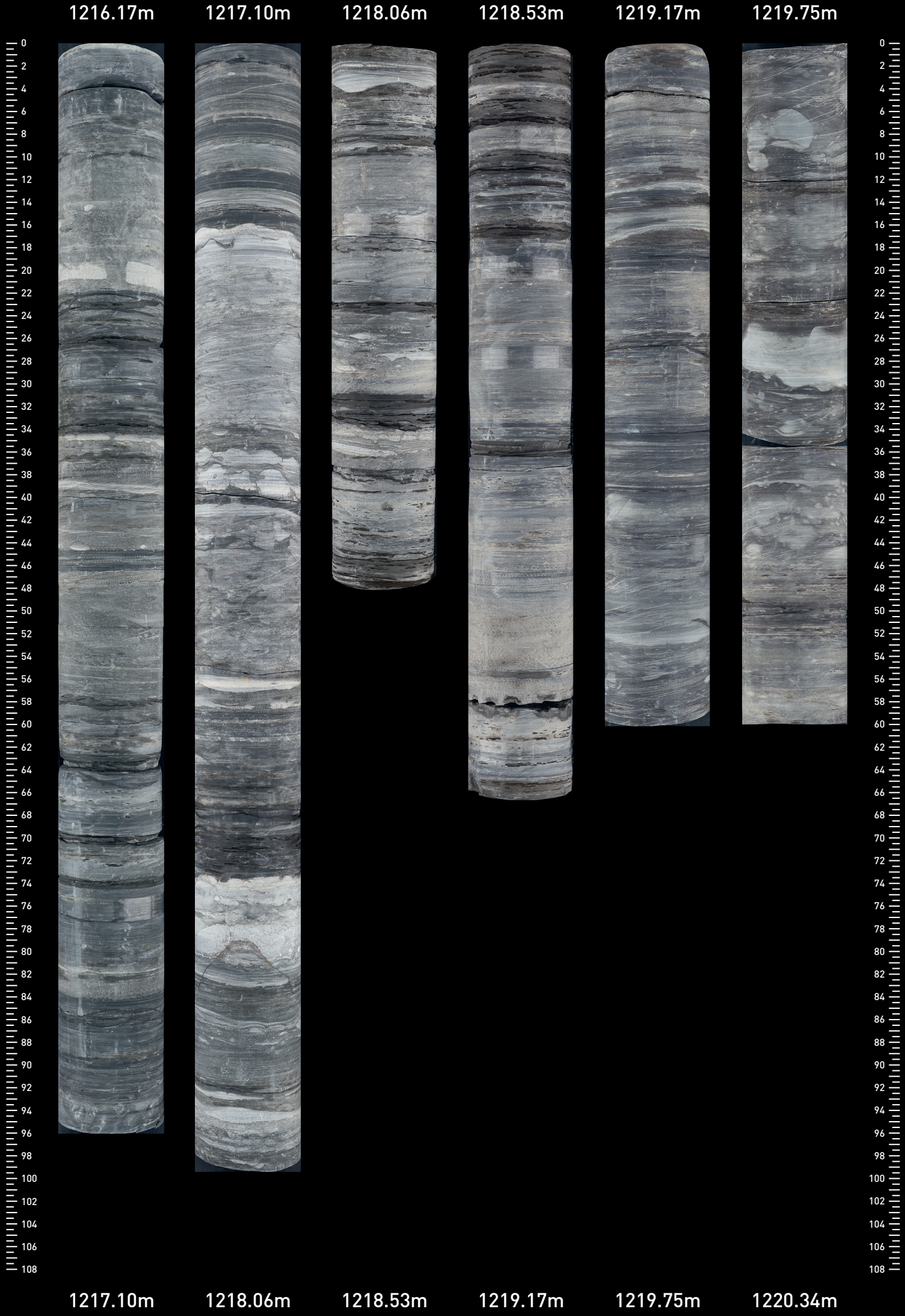
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1211.89m

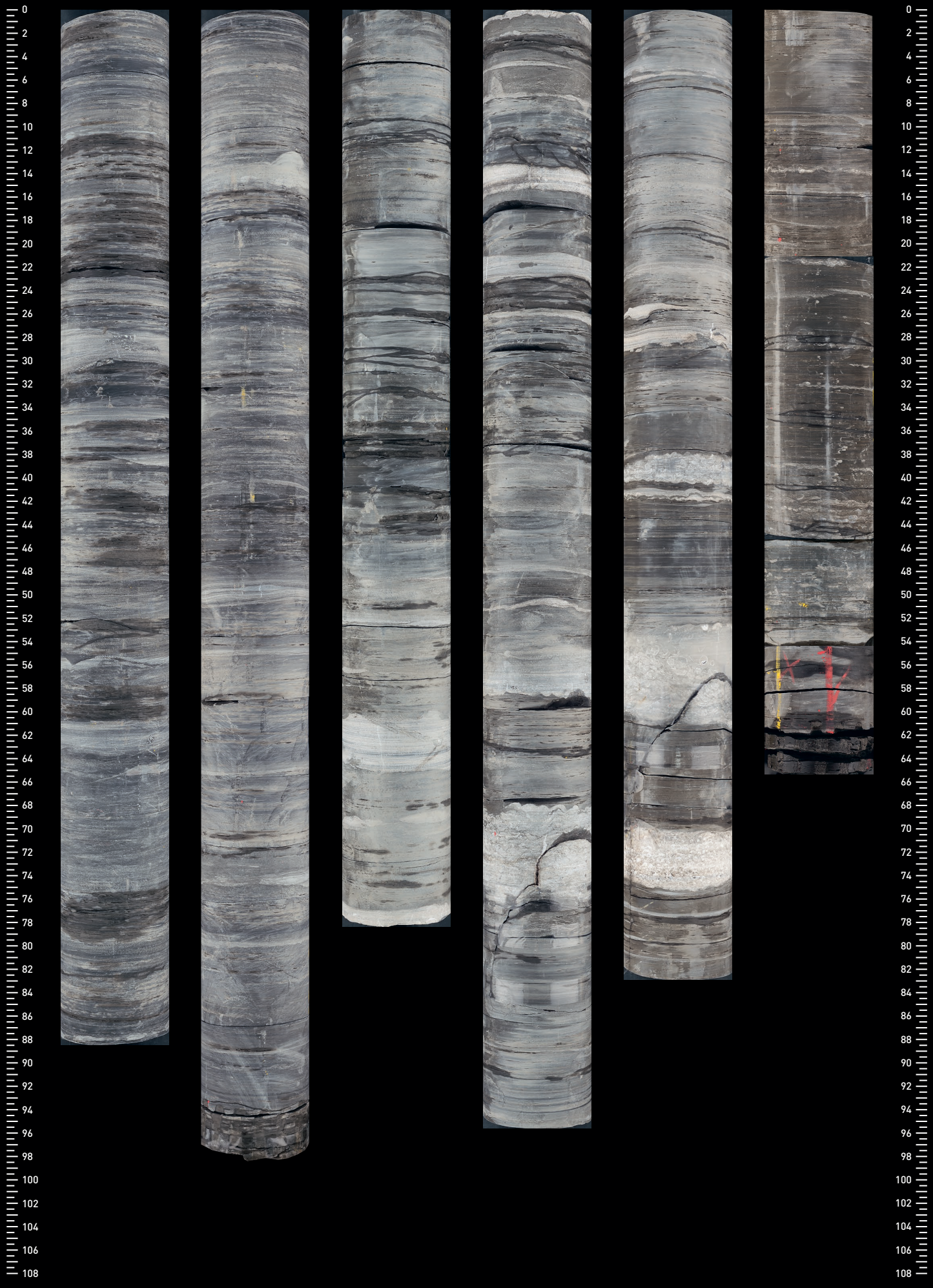
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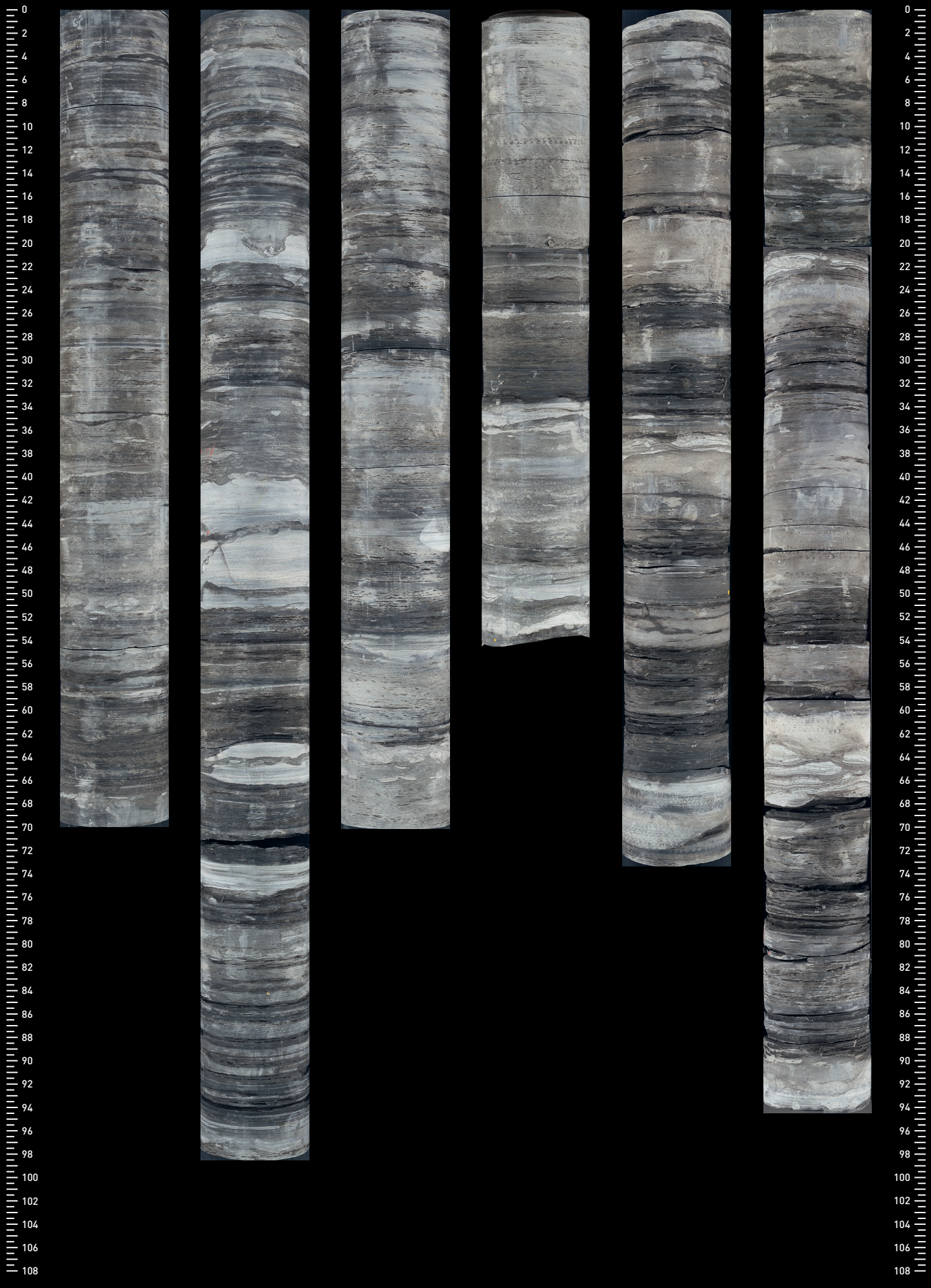
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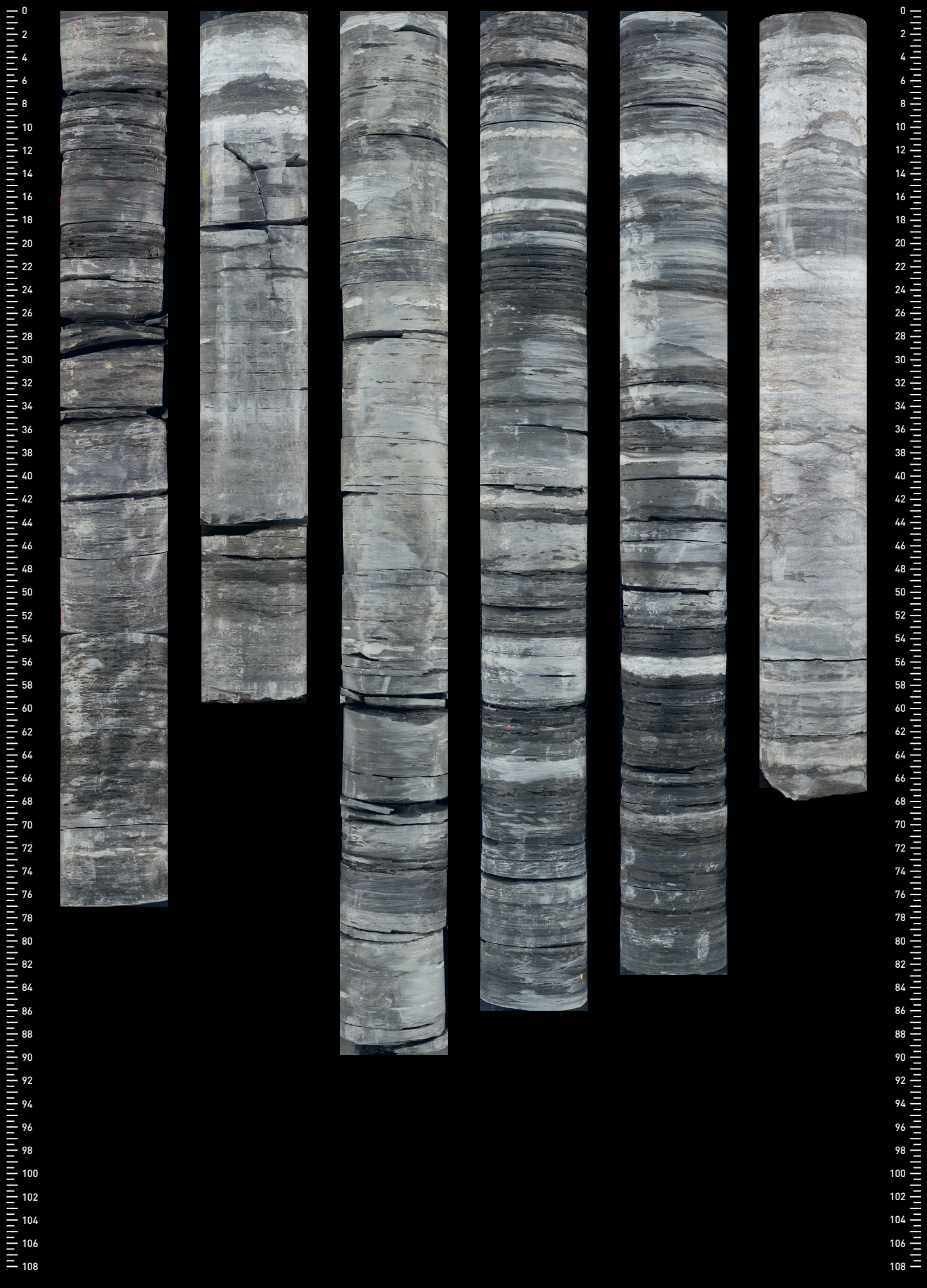

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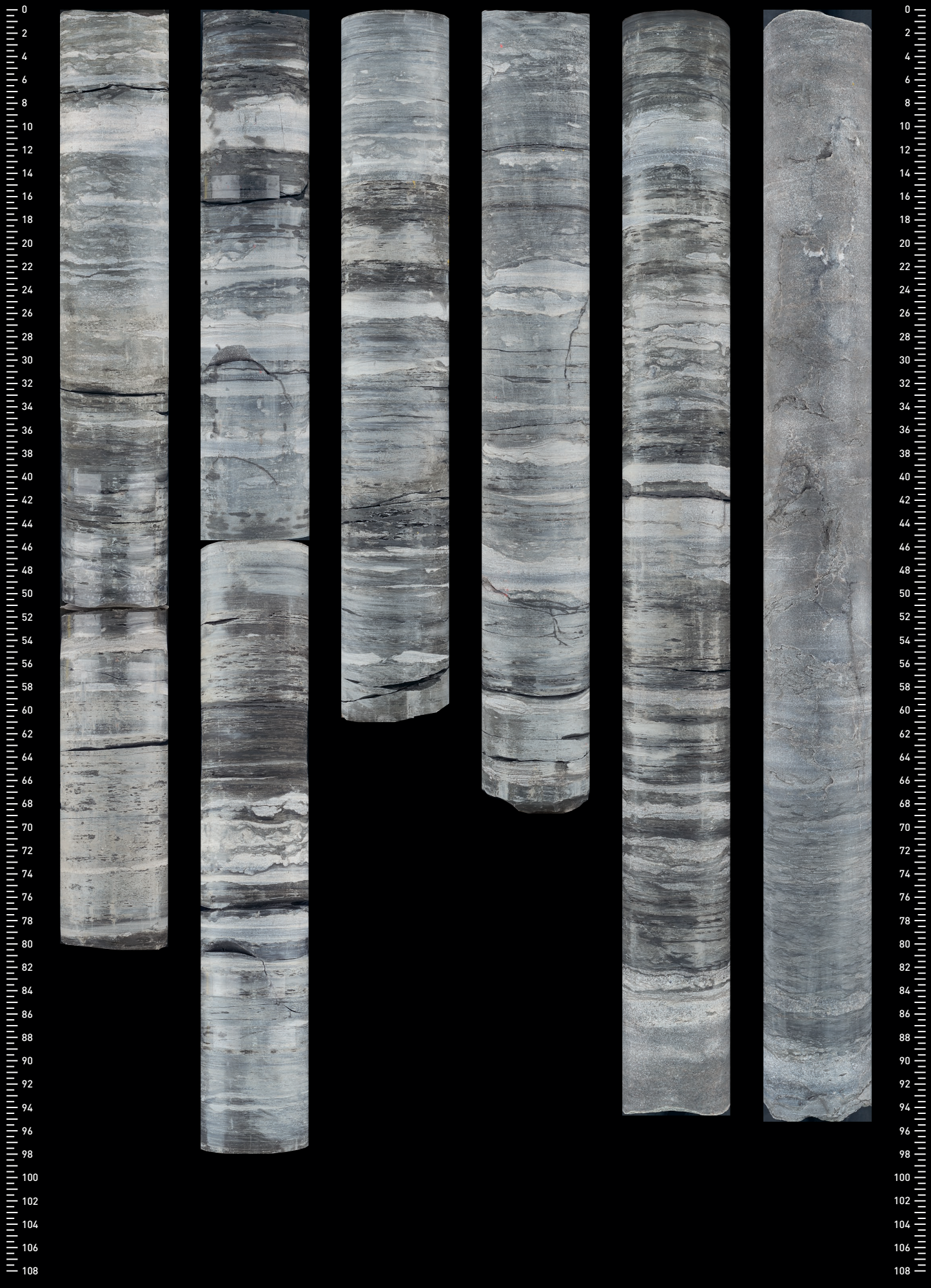
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1225.25m
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1226.88m
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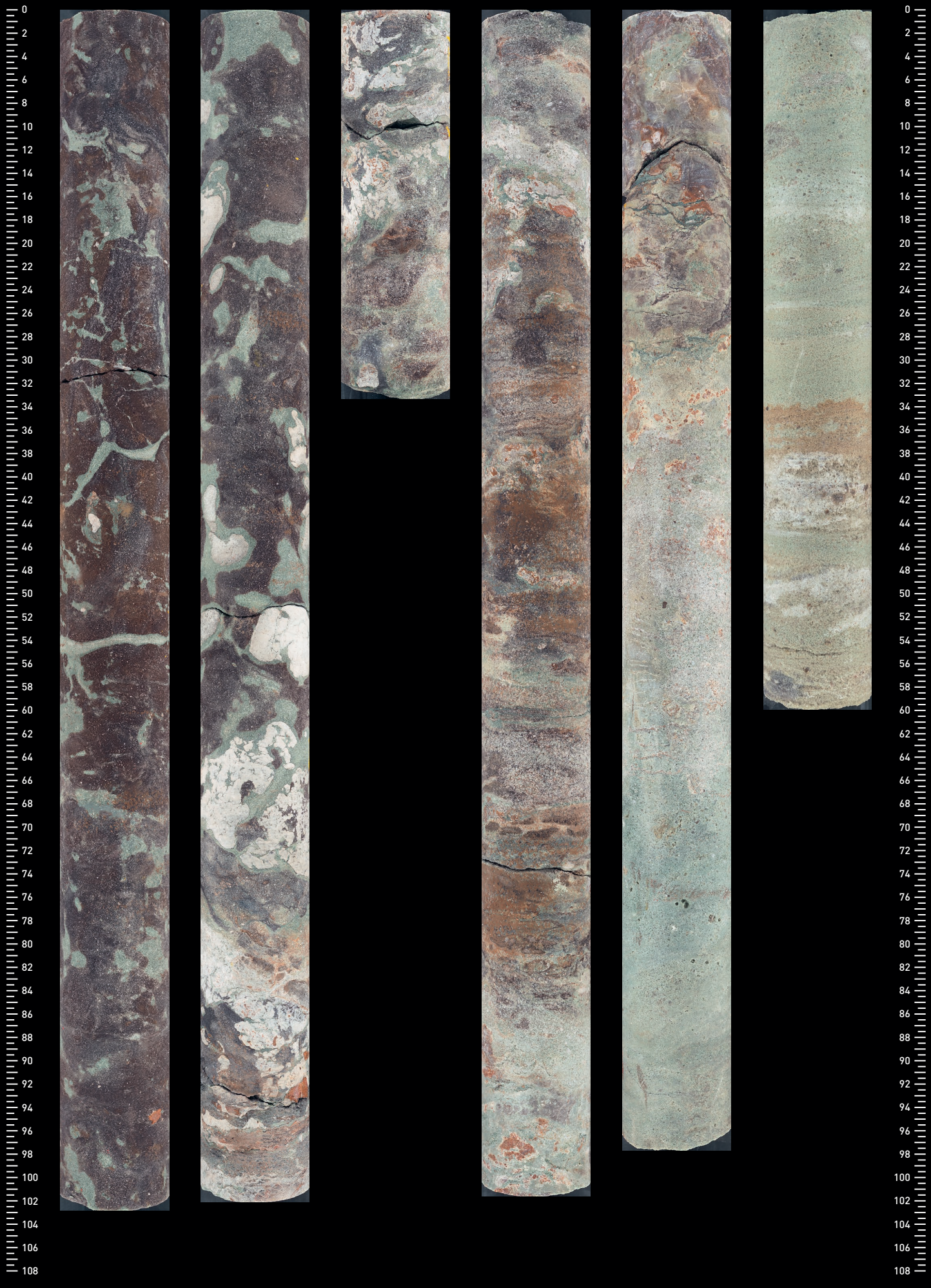

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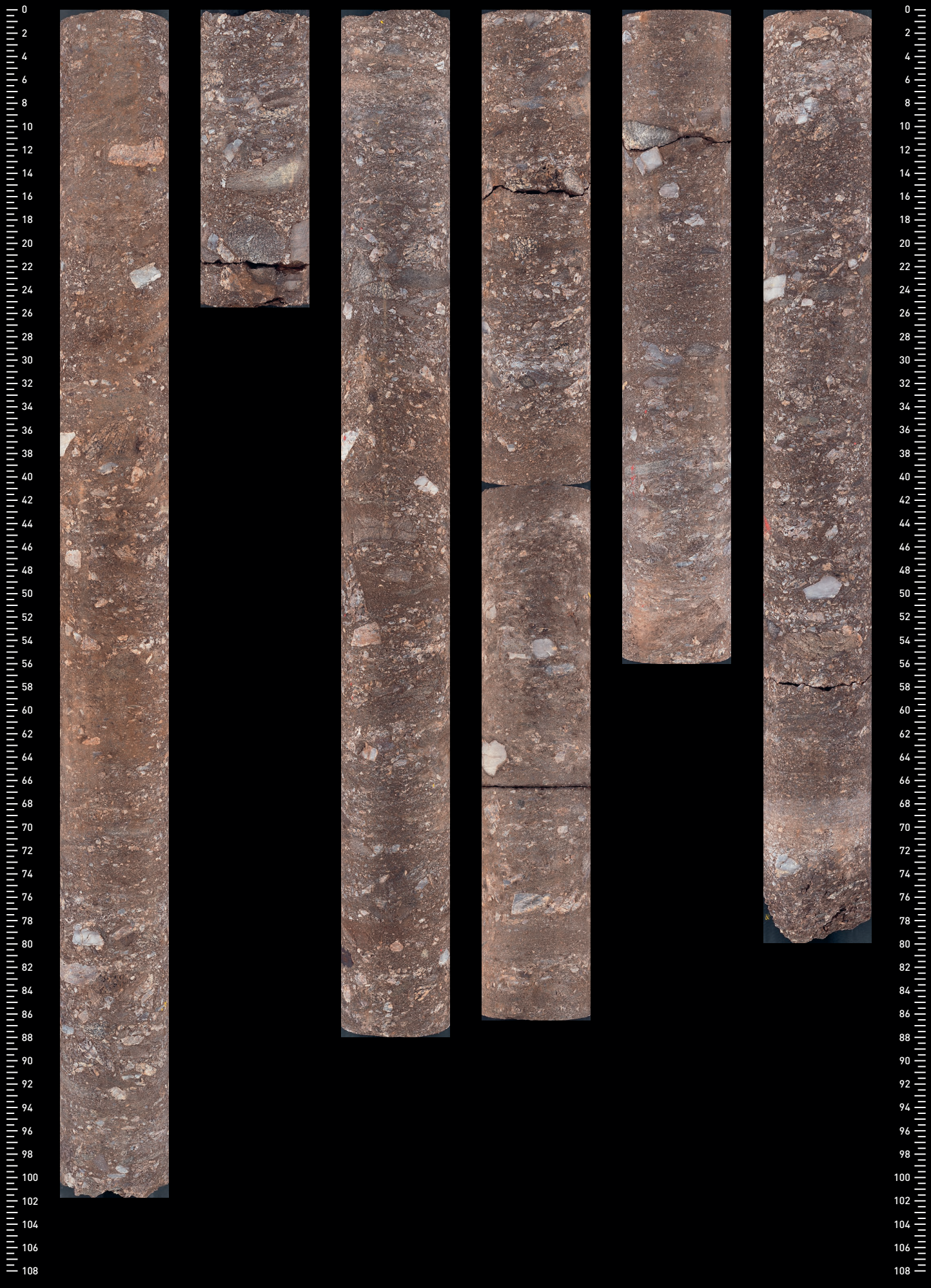
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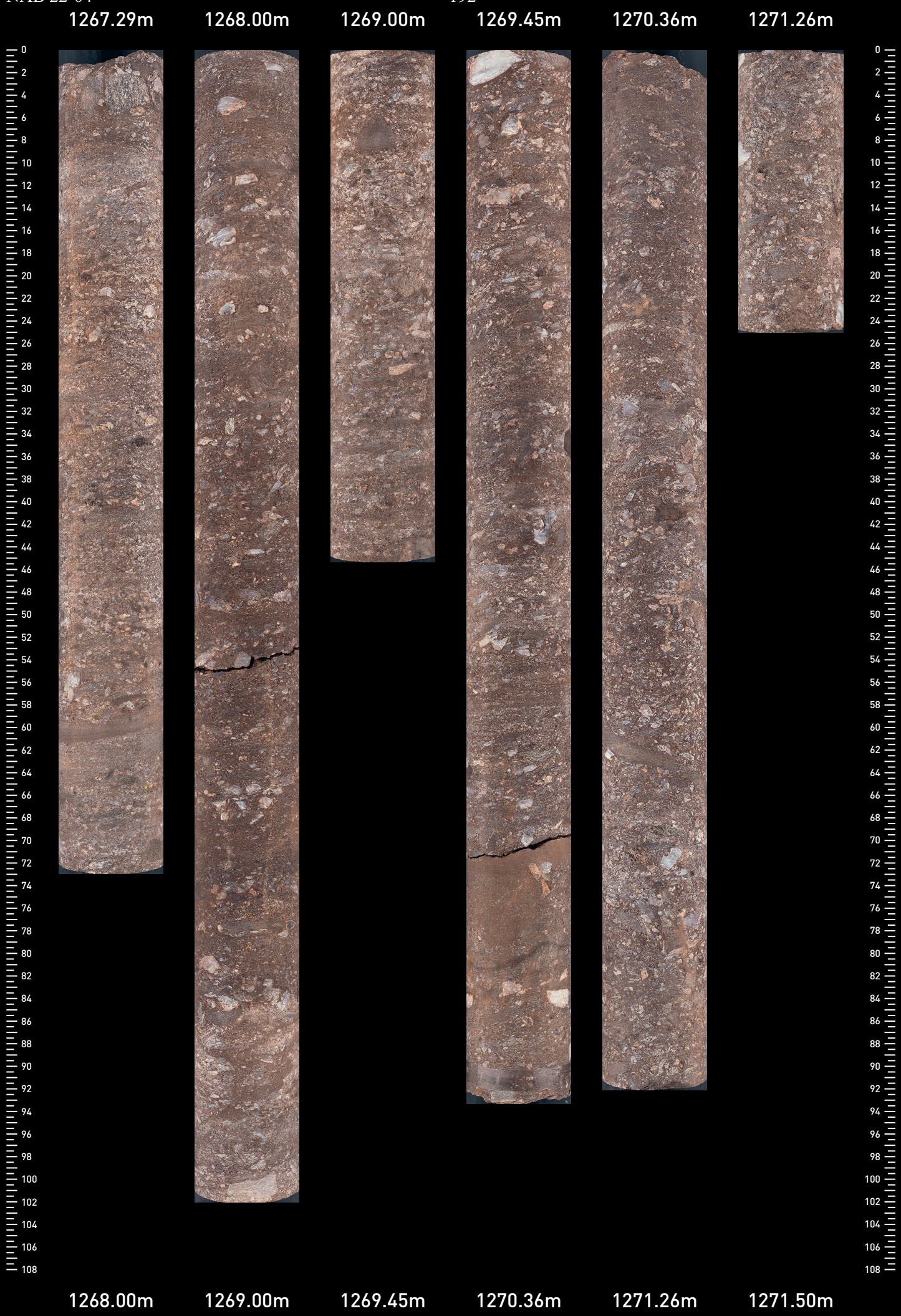

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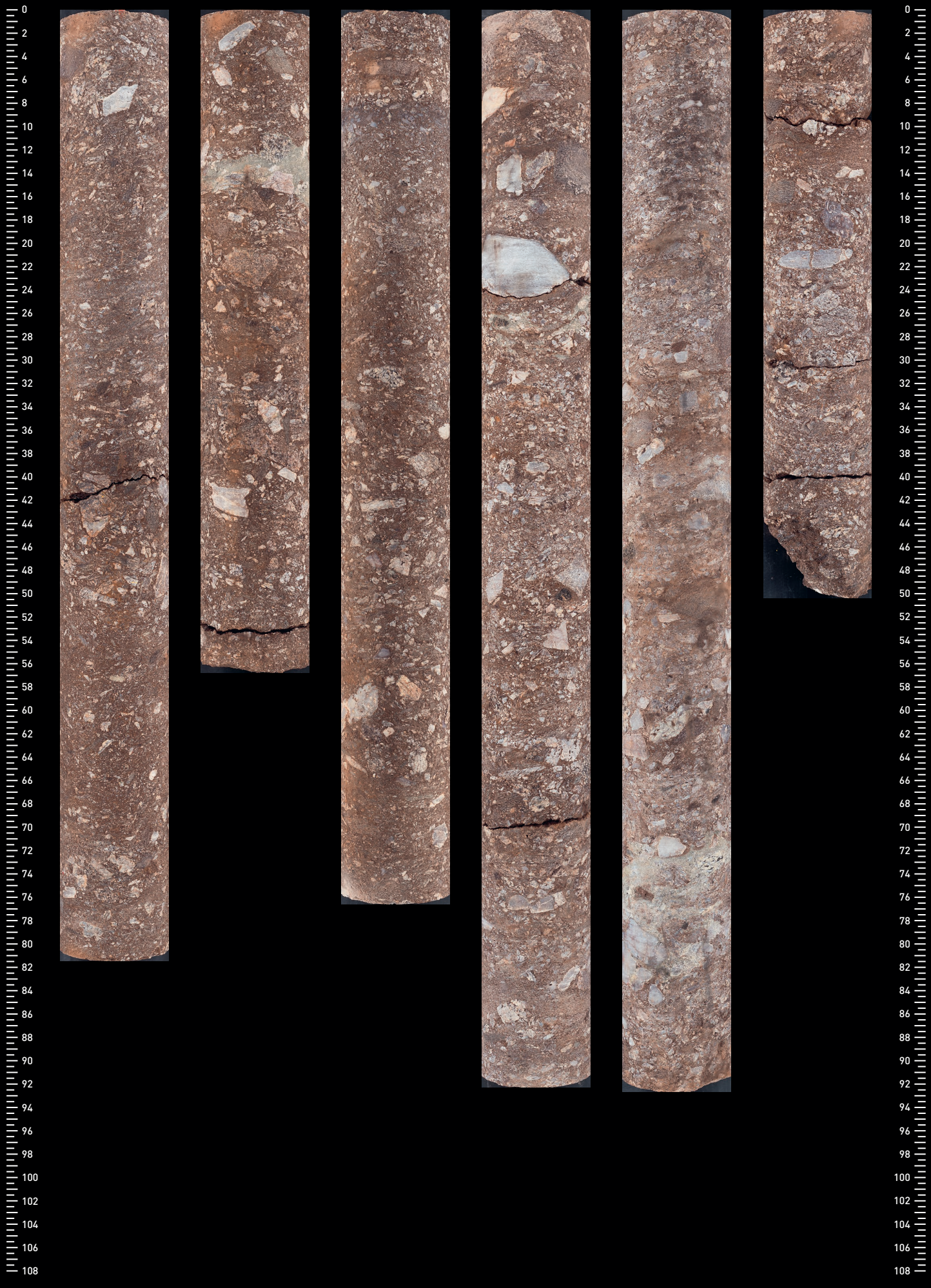

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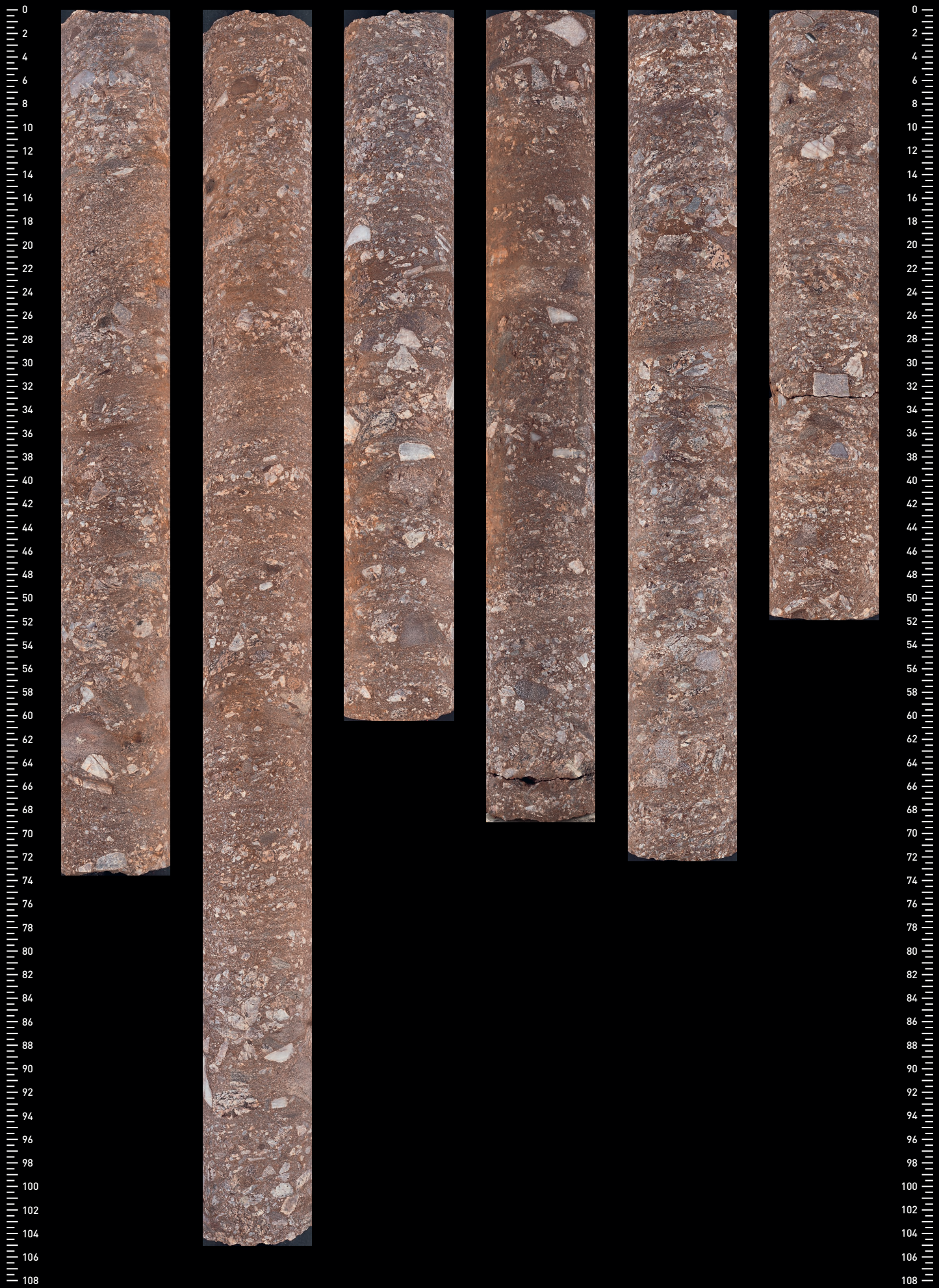

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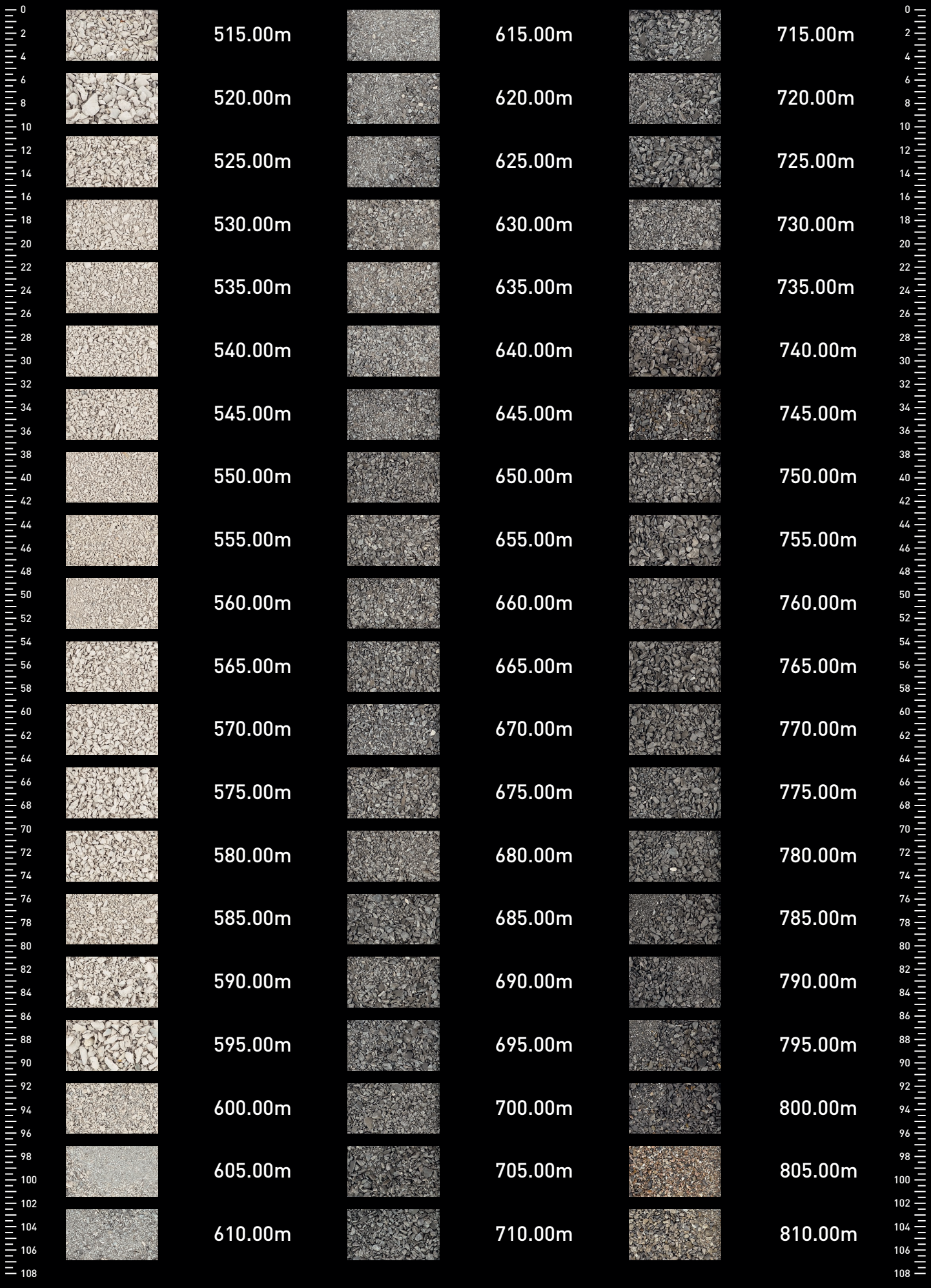
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1304.30m 1305.30m 1306.26m

4 Bachs-1-1B core- and cuttings composites

515.00m 615.00m 715.00m



610.00m 710.00m 810.00m

815.00m 915.00m



910.00m 952.00m

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