Arbeitsbericht NAB 22-01

TBO Stadel-3-1: Data Report

Dossier II
Core Photography

June 2022

National Cooperative
for the Disposal of
Radioactive Waste

Hardstrasse 73
P.O. Box
5430 Wettingen
Switzerland
Tel. +41 56 437 11 11

www.nagra.ch

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Dossier II Core Photography

June 2022

D. Kaehr[1] & M. Gysi[2]

[1] Maya & Daniele
[2] Nagra

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STA3-1, 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 March 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-3-1 borehole.

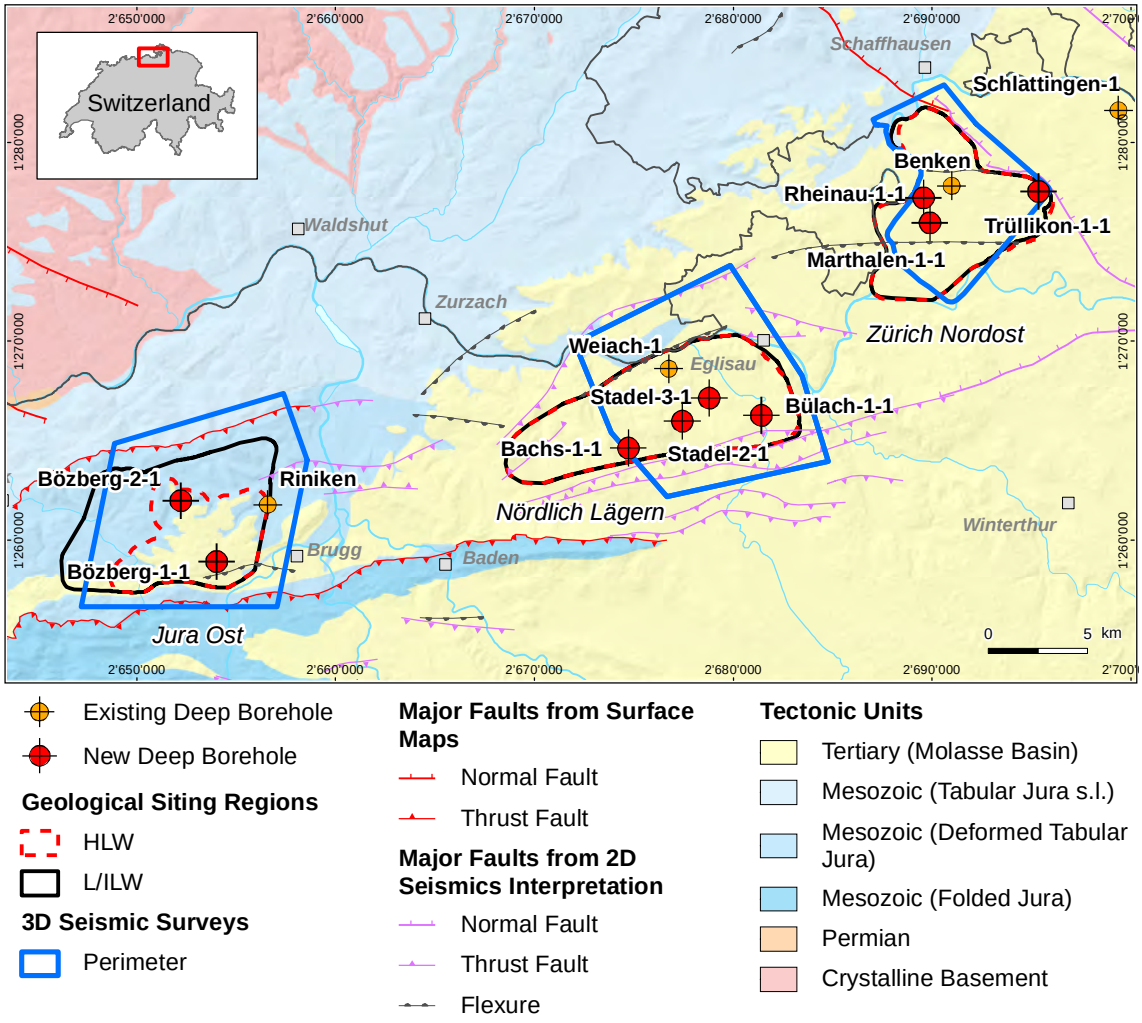


Fig. 1-1: Tectonic overview map with the three siting regions under investigation

1.2 Location and specifications of the borehole

The Stadel-3-1 (STA3-1) 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 1'280.88 m (MD)[1]. The borehole specifications are provided in Tab. 1-1.

Tab. 1-1: General information about the STA3-1 borehole

Siting region	Nördlich Lägern
Municipality	Stadel (Canton Zürich / ZH), Switzerland
Drill site	Stadel-3 (STA3)
Borehole	Stadel-3-1 (STA3-1)
Coordinates	LV95: 2'678'792.885 / 1'267'161.988
Elevation	Ground level = top of rig cellar: 408.74 m above sea level (asl)
Borehole depth	1'280.88 m measured depth (MD) below ground level (bgl)
Drilling period	17. December 2020 – 6. July 2021 (spud date to end of rig release)
Drilling company	PR Marriott Drilling Ltd
Drilling rig	Rig-16 Drillmec HH102
Drilling fluid	Water-based mud with various amounts of different components such as:[2] 0.0 – 439.0 m: Polymers 439.0 – 640.0[3] m: Sodium chloride & polymers 640.0 – 1'035.0 m: Potassium silicate & polymers 1'035.0 – 1'101.0 m: Polymers 1'101.0 – 1'280.9 m: Sodium chloride & 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 STA3-1 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] Borehole uncased below casing shoe at 437.4 m after drilling fluid exchange.

[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.

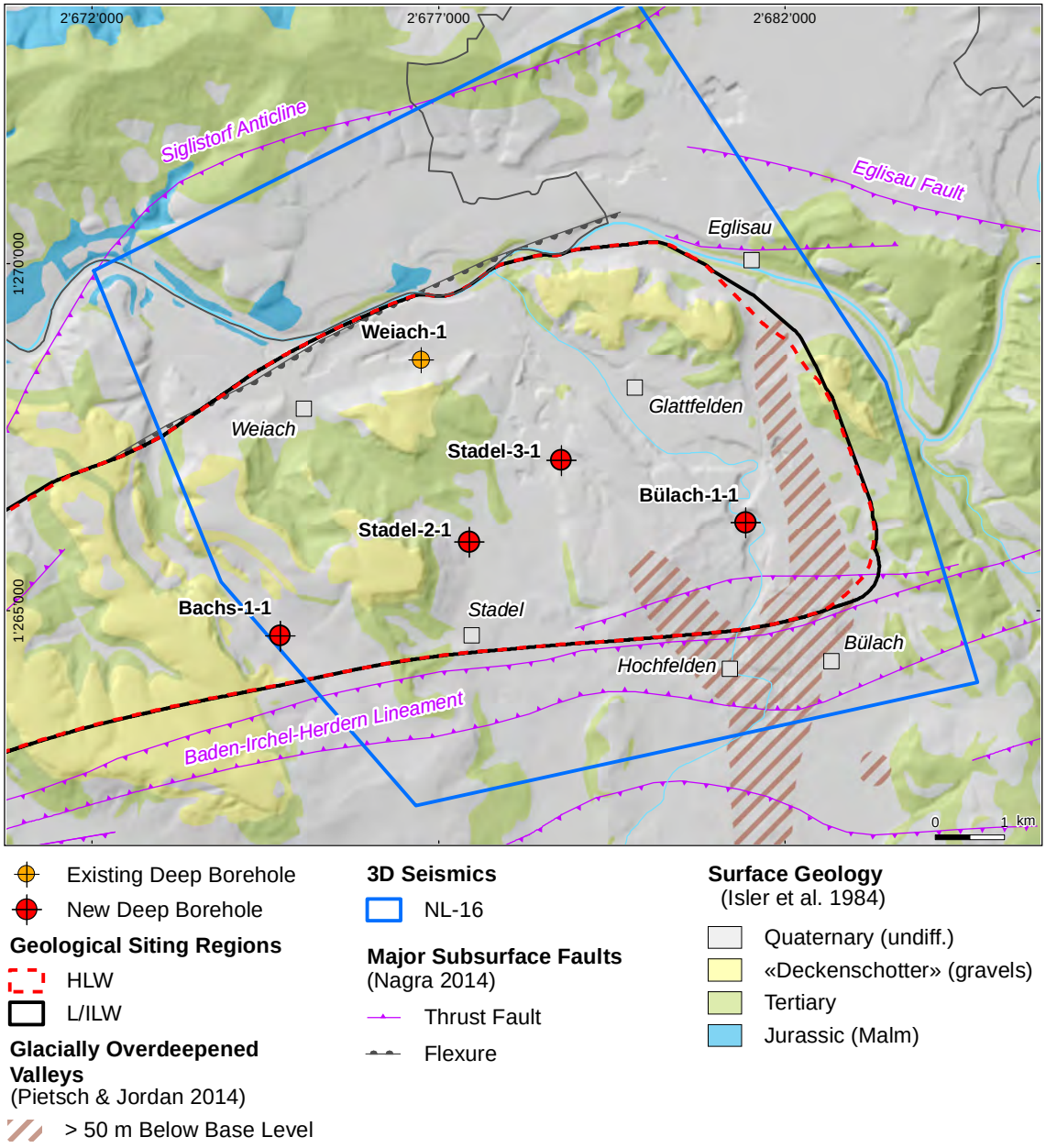


Fig. 1-2: Overview map of the investigation area in the Nördlich Lägern siting region with the location of the STA3-1 borehole in relation to the boreholes Weiach-1, BUL1-1, STA2-1 and BAC1-1

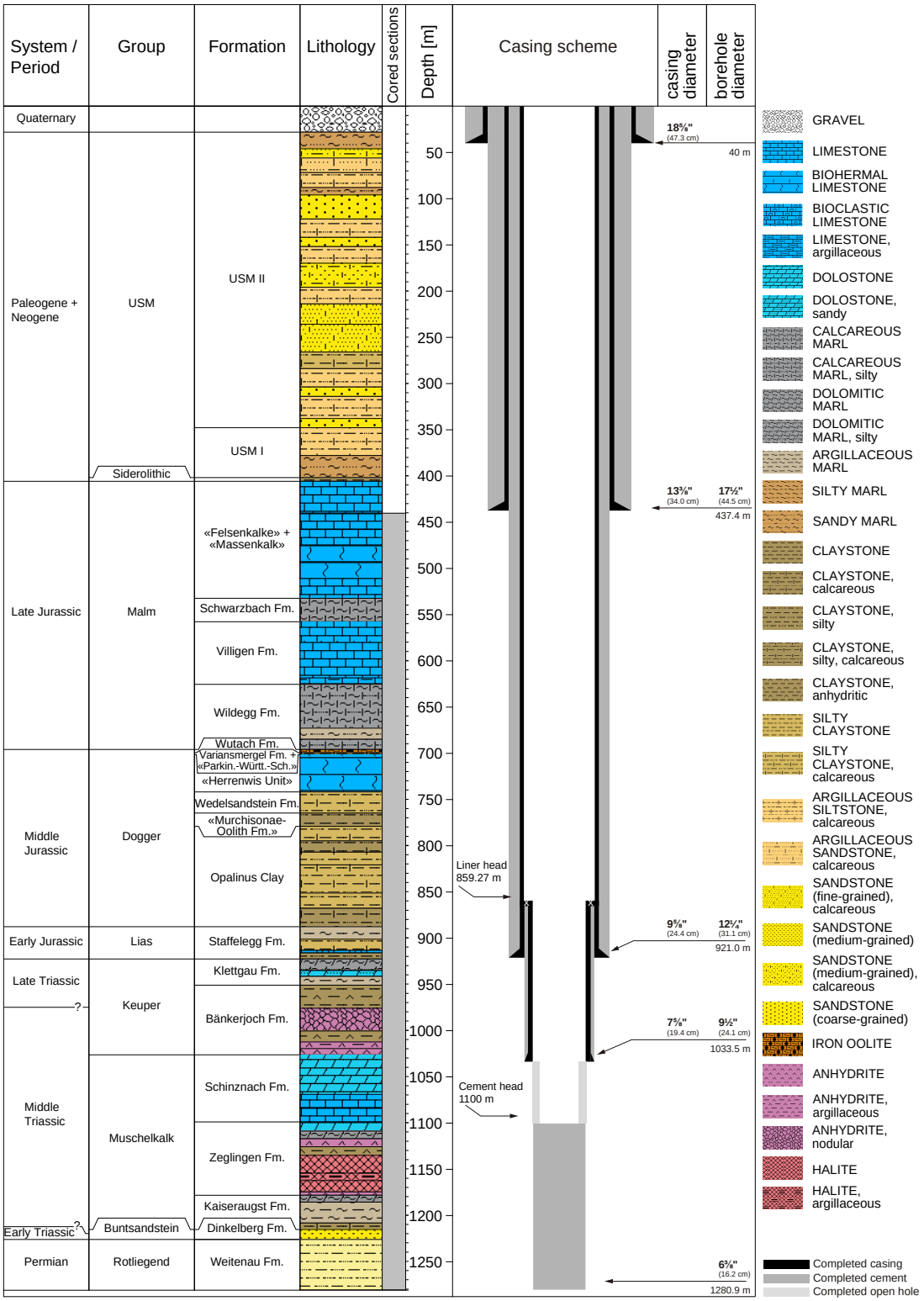


Fig. 1-3: Lithostratigraphic profile and casing scheme for the STA3-1 borehole[5]

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

Tab. 1-2: Core and log depth for the main lithostratigraphic boundaries in the STA3-1 borehole[6]

System / Period	Group	Formation		Core depth in m (MD)	Log depth in m (MD)	
Quaternary				**28.0**		—
Paleogene + Neogene	USM			402.0		—
	Siderolithic			**406.0**		—
Jurassic	Malm	«Felsenkalke» + «Massenkalk»		532.55	532.65	—
		Schwarzbach Formation		557.93	558.11	—
		Villigen Formation		625.58	625.64	—
		Wildegg Formation		696.03	696.15	—
	Dogger	Wutach Formation		699.47	699.59	—
		Variansmergel Formation + «Parkinsoni-Württembergica-Schichten»		701.65	701.77	—
		«Herrenwis Unit»		742.00	742.03	—
		Wedelsandstein Formation		764.97	764.94	—
		«Murchisonae-Oolith Formation»		779.26	779.16	—
		Opalinus Clay		887.94	887.72	—
	Lias	Staffelegg Formation		**922.71**	**922.44**	—
Triassic	Keuper	Klettgau Formation		951.13	951.57	—
		Bänkerjoch Formation		1026.62	1026.96	—
	Muschelkalk	Schinznach Formation		1099.03	1099.64	—
		Zeglingen Formation		1178.43	1178.73	—
		Kaiseraugst Formation		1215.50	1215.74	—
	Buntsandstein	Dinkelberg Formation		**1226.38**	**1226.68**	—
Permian	Rotliegend	Weitenau Formation	final depth	1280.88	1281.08	

[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 STA3-1 borehole

NAB 22-01 documents the majority of the investigations carried out in the STA3-1 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 STA3-1 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 22-01

Black marks the dossier at hand.

Dossier	Title	Authors
I	TBO Stadel-3-1: Drilling	M. Ammann & P.-J. Palten
II	**TBO Stadel-3-1: Core Photography**	**D. Kaehr & M. Gysi**
III	TBO Stadel-3-1: Lithostratigraphy	P. Schürch, P. Jordan, M. Schwarz, H. Naef, R. Felber, T. Ibele & M. Gysi
IV	TBO Stadel-3-1: 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-3-1: Structural Geology	A. Ebert, S. Cioldi, E. Hägerstedt & M. Gysi
VI	TBO Stadel-3-1: Wireline Logging, Micro-hydraulic Fracturing and Pressuremeter testing	J. Gonus, E. Bailey, J. Desroches & R. Garrard
VII	TBO Stadel-3-1: Hydraulic Packer Testing	R. Schwarz, M. Willmann, H. Fisch, M. Voß & A. Pechstein
VIII	TBO Stadel-3-1: Rock Properties, Porewater Characterisation and Natural Tracer Profiles	L. Aschwanden, L. Camesi, E. Gaucher, T. Gimmi, A. Jenni, M. Kiczka, U. Mäder, M. Mazurek, D. Rufer, H.N. Waber, P. Wersin, C. Zwahlen & D. Traber
IX	TBO Stadel-3-1: Rock-mechanical and Geomechanical Laboratory Testing	E. Crisci, L. Laloui & S. Giger
X	TBO Stadel-3-1: Petrophysical Log Analysis	S. Marnat & J.K. Becker
	TBO Stadel-3-1: 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 STA3-1 from 2 m to 1'280.88 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

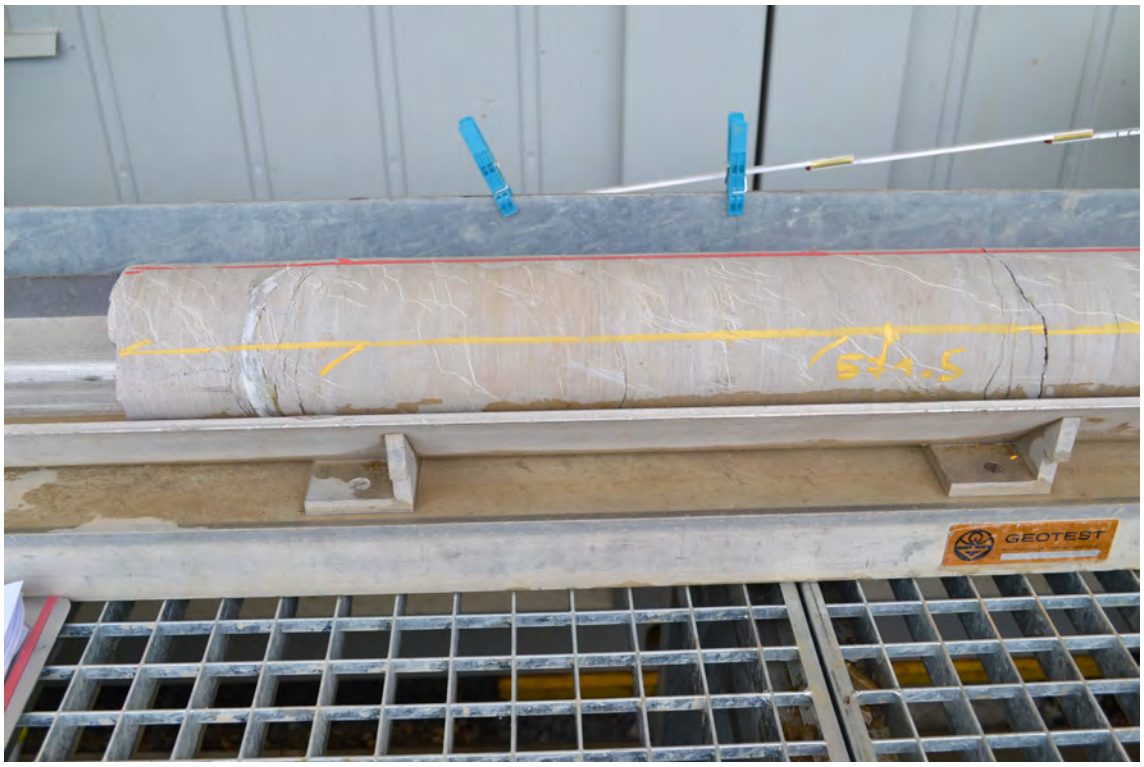


Fig. 2-6: Cleaned, measured and marked core

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

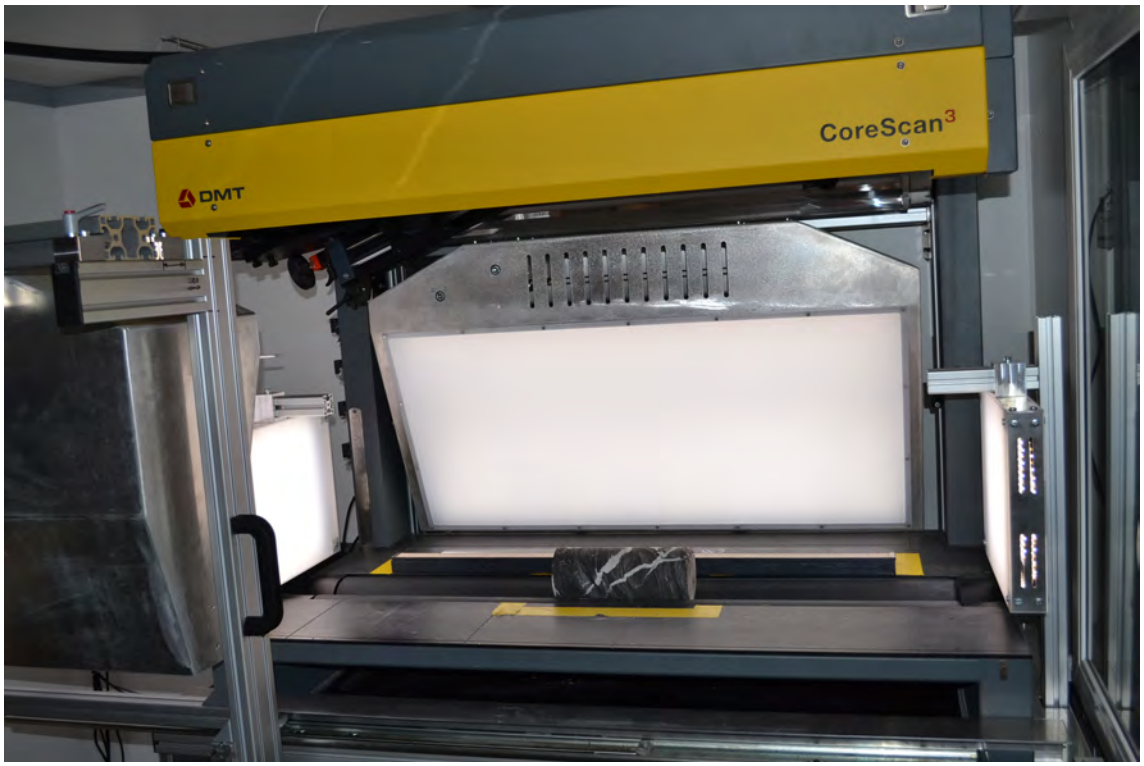


Fig. 2-7: Modified DMT CoreScan^3 system at the drill site

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: CoreScan^3 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 CoreScan^3 system
2. ICC profiling of the noise-reduced reference photographs, shot with the CoreScan^3 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)

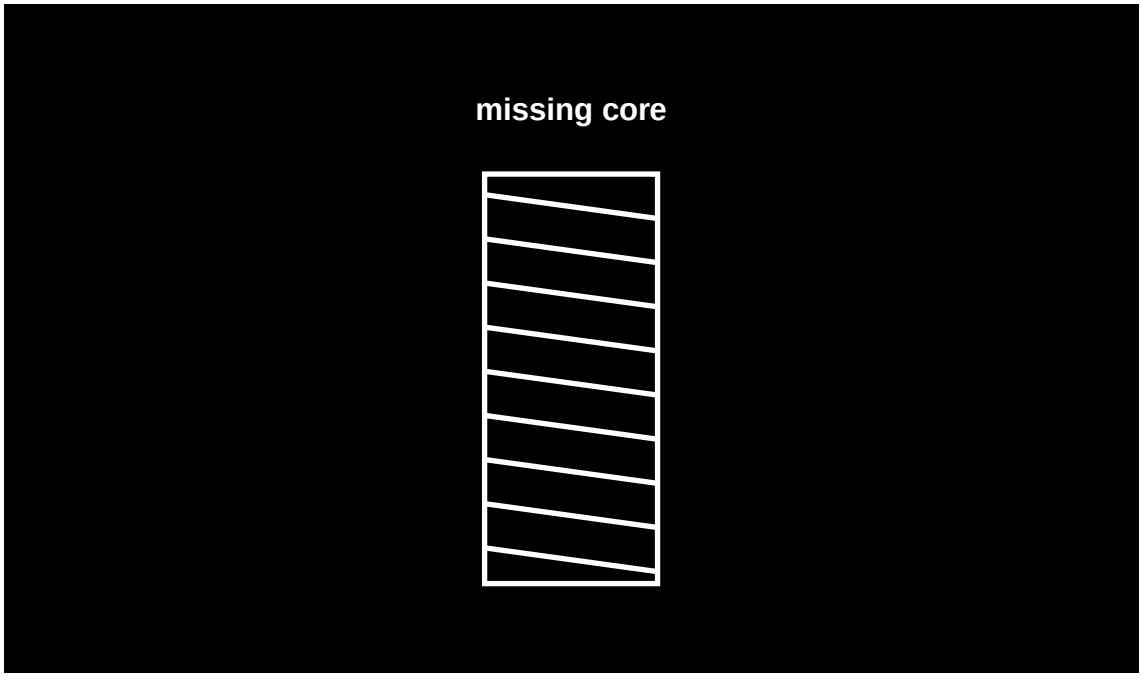


Fig. 2-10: White hachures signature used for missing core due to FIT pilot hole or drilling related technical issues in the composite displays

3 Stadel-3-1 core- and cuttings composites

2.00m 18.00m 34.00m



16.00m 32.00m 40.00m

42.00m 82.00m 122.00m



80.00m 120.00m 160.00m


162.00m
202.00m
242.00m
162.00m
164.00m
166.00m
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270.00m
272.00m
274.00m
276.00m
278.00m
280.00m
200.00m
240.00m
280.00m

282.00m 322.00m 362.00m



320.00m 360.00m 400.00m

402.00m



438.00m

440.50m 440.83m 441.68m 442.39m 443.34m 444.29m



440.83m 441.68m 442.39m 443.34m 444.29m 445.24m


445.24m
446.06m
446.97m
447.88m
448.44m
449.11m
446.06m
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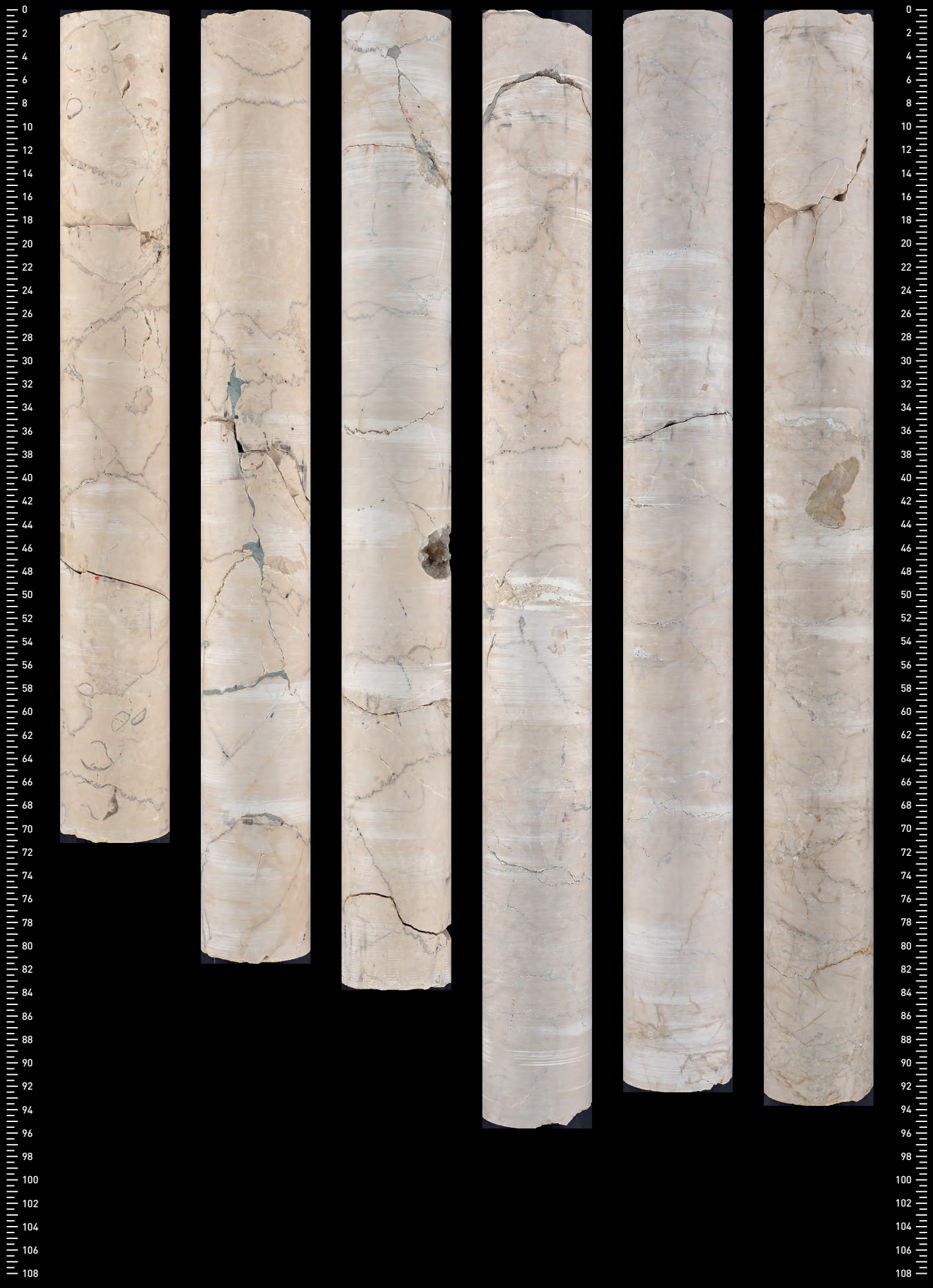

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452.16m
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454.50m 455.08m 456.00m 456.95m 457.50m 458.13m



455.08m 456.00m 456.95m 457.50m 458.13m 458.81m

458.81m 459.50m 460.30m 461.12m 462.05m 462.95m



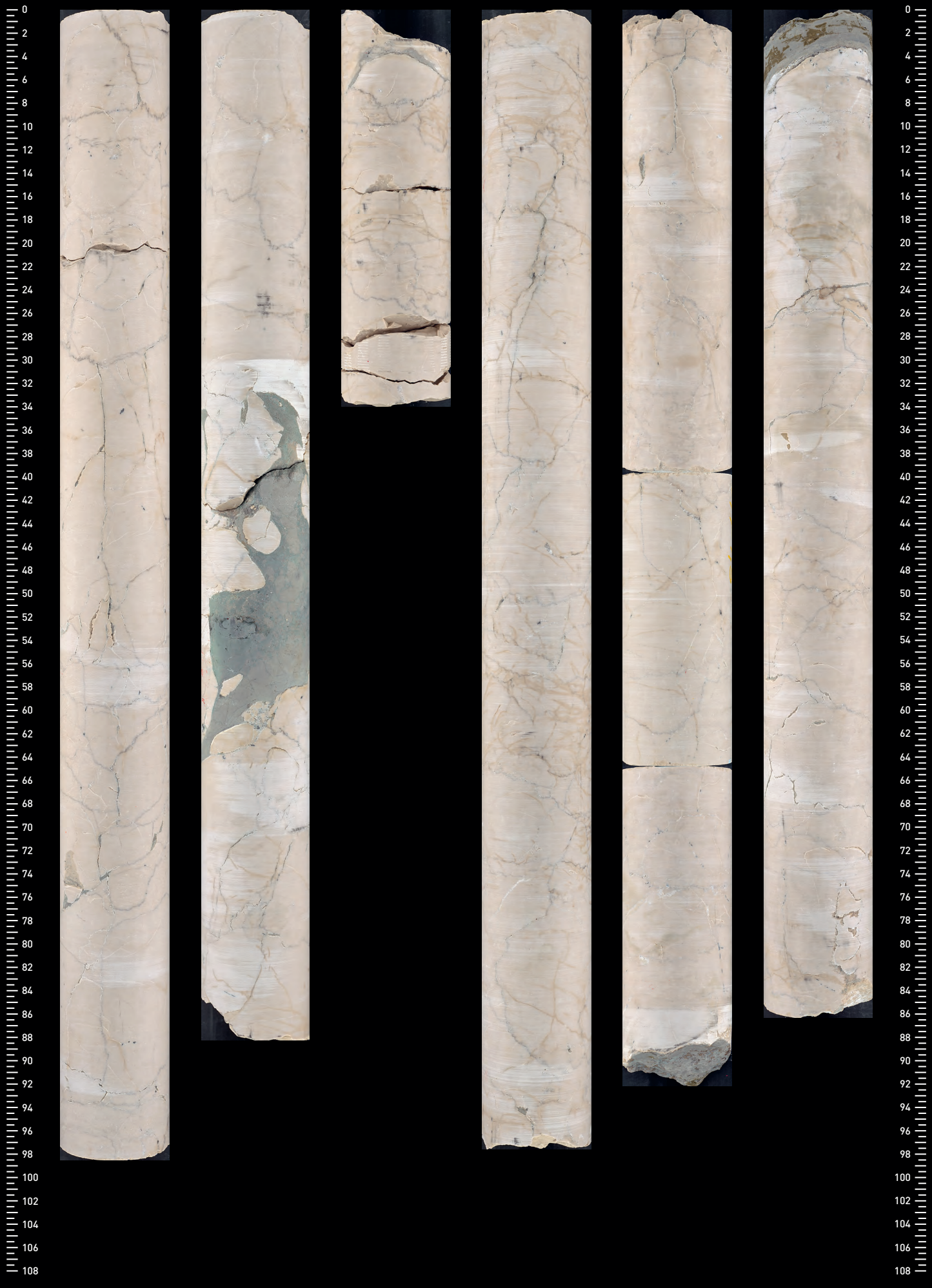
459.50m 460.30m 461.12m 462.05m 462.95m 463.86m

463.86m 464.12m 465.01m 465.90m 466.86m 467.12m

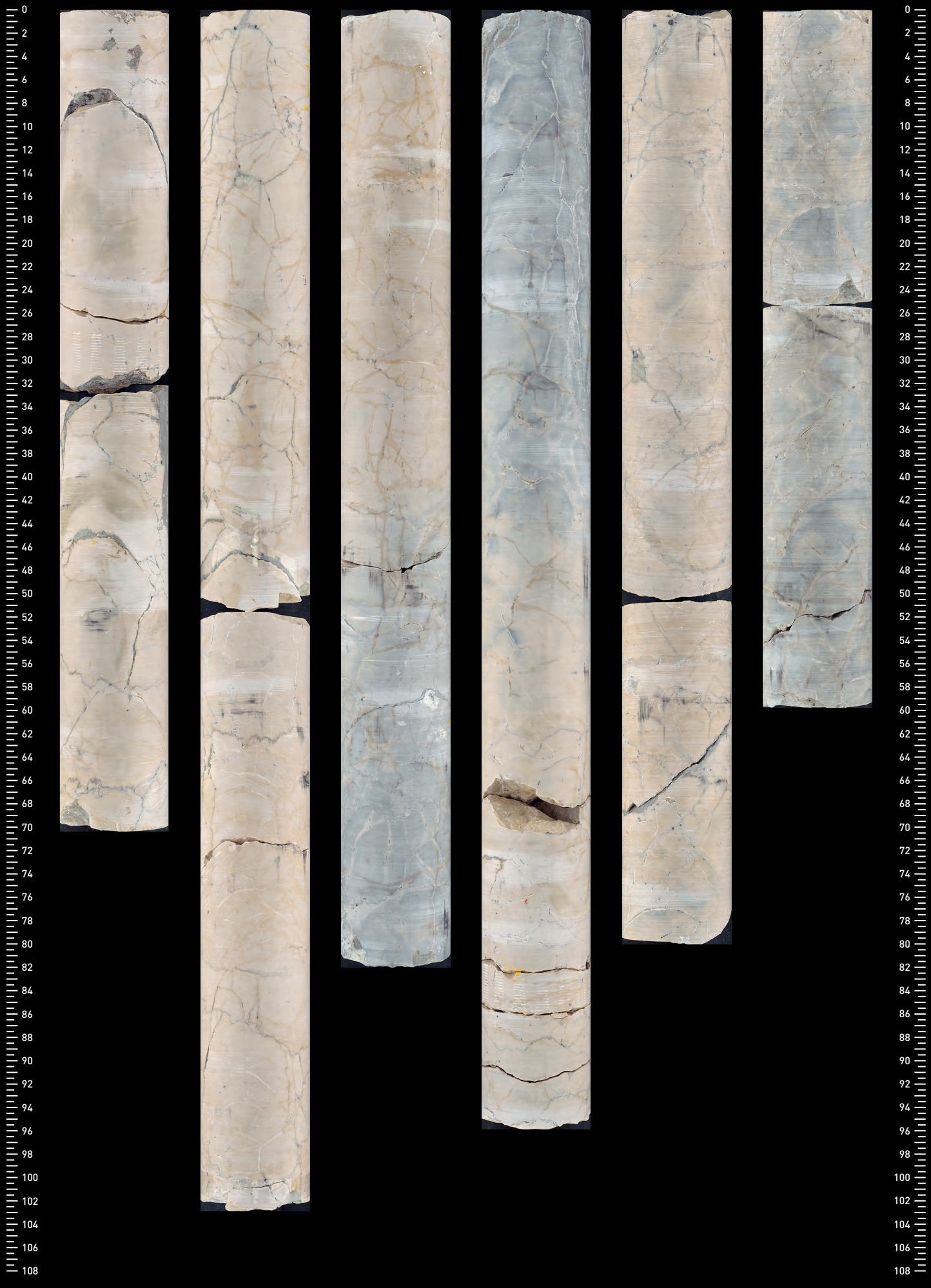


464.12m 465.01m 465.90m 466.86m 467.12m 468.04m

468.04m 469.02m 469.87m 470.17m 471.11m 472.00m



469.02m 469.87m 470.17m 471.11m 472.00m 472.82m

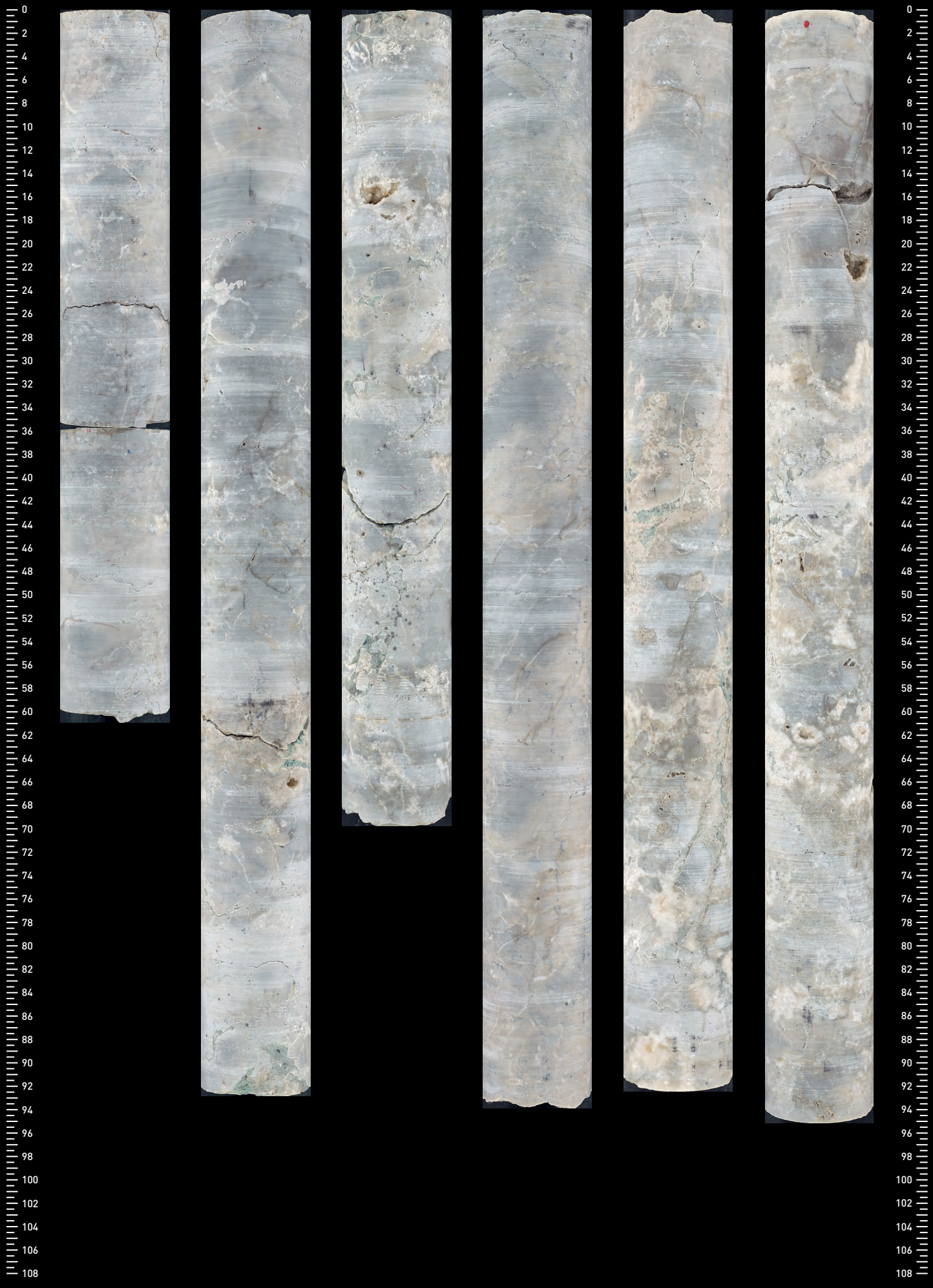

472.82m
473.50m
474.50m
475.30m
476.23m
477.00m
473.50m
474.50m
475.30m
476.23m
477.00m
477.60m

477.60m 478.50m 479.31m 480.15m 481.10m 482.09m



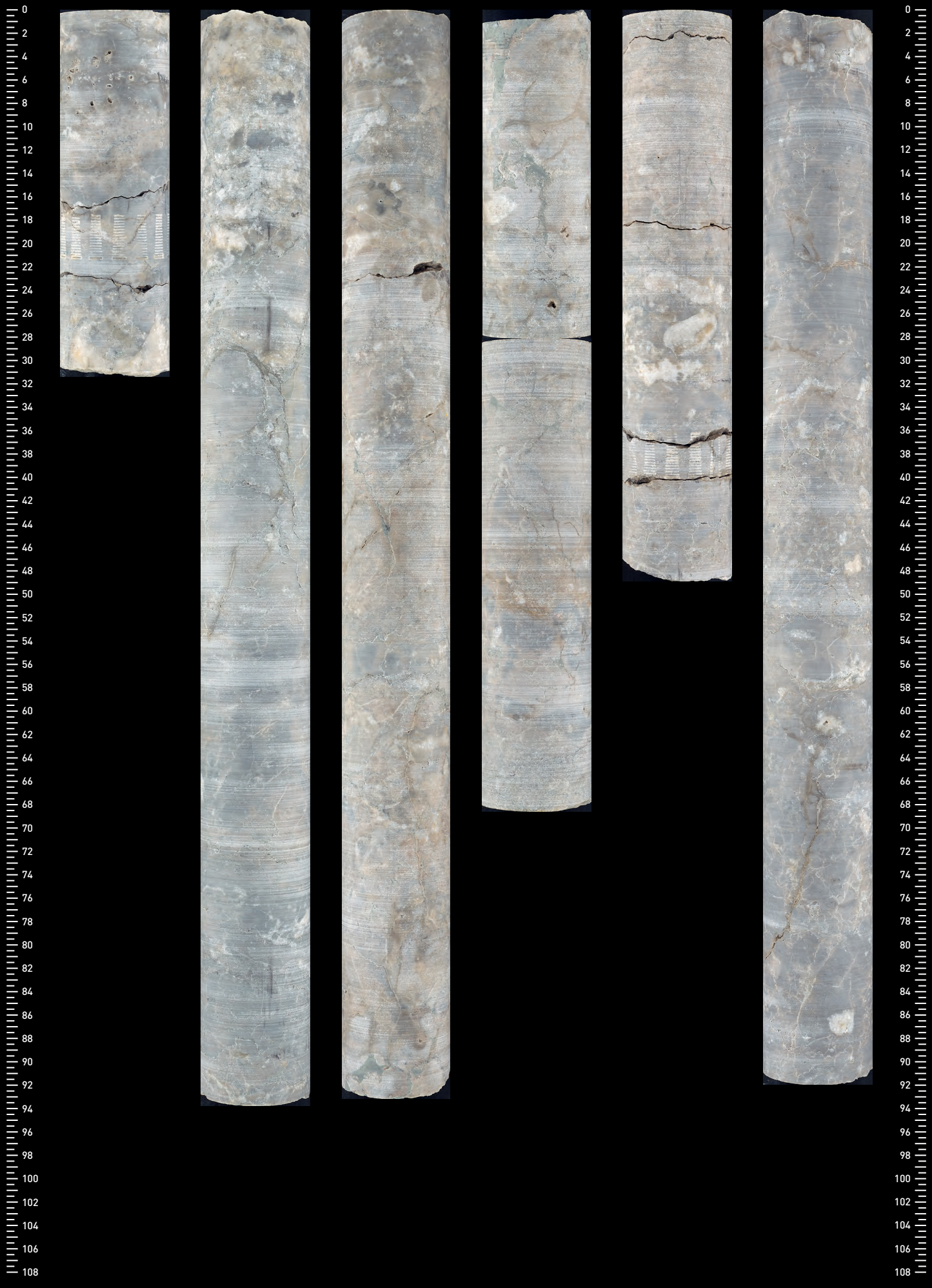
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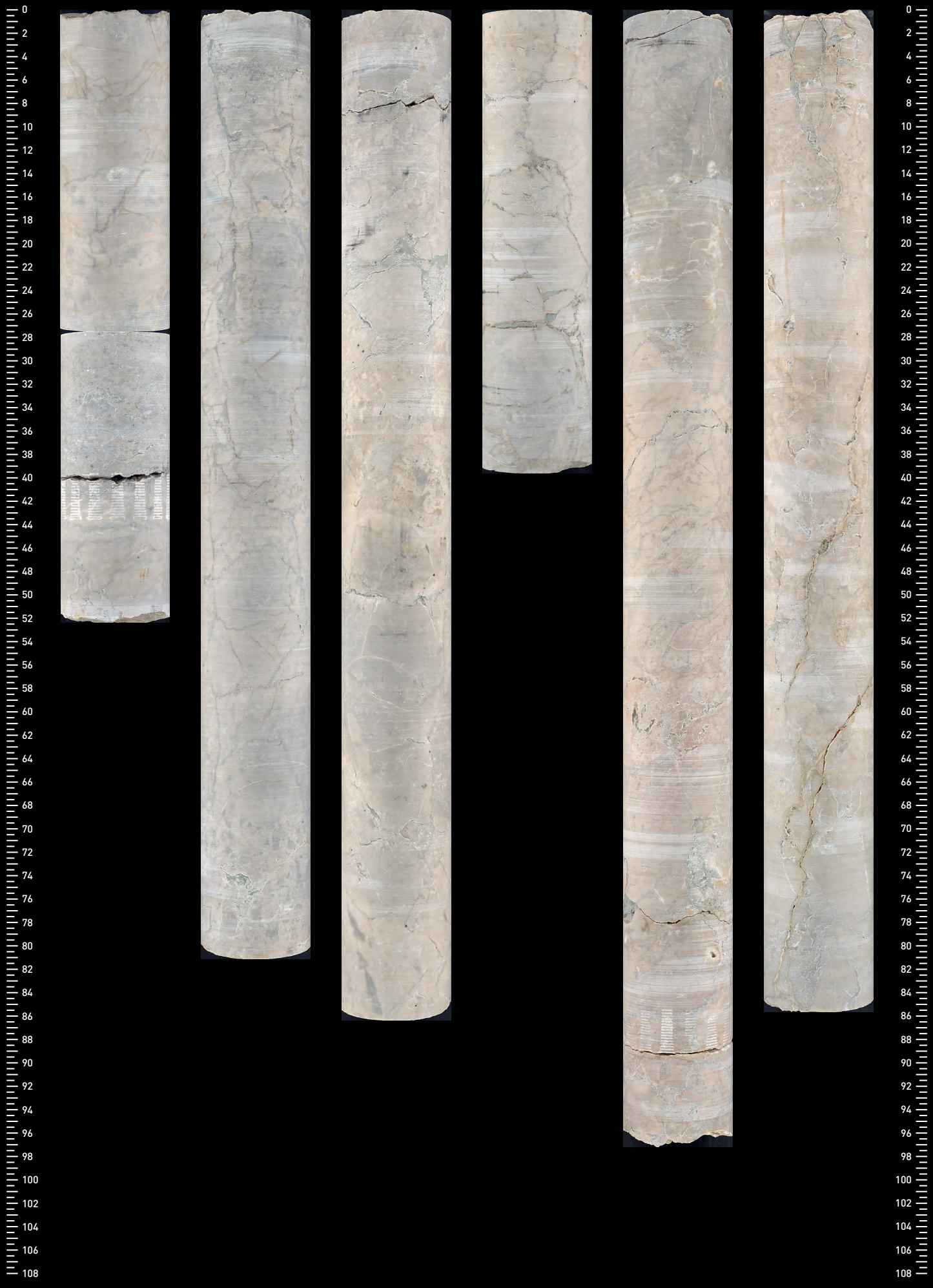
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496.70m 497.21m 498.00m 498.84m 499.23m 500.16m



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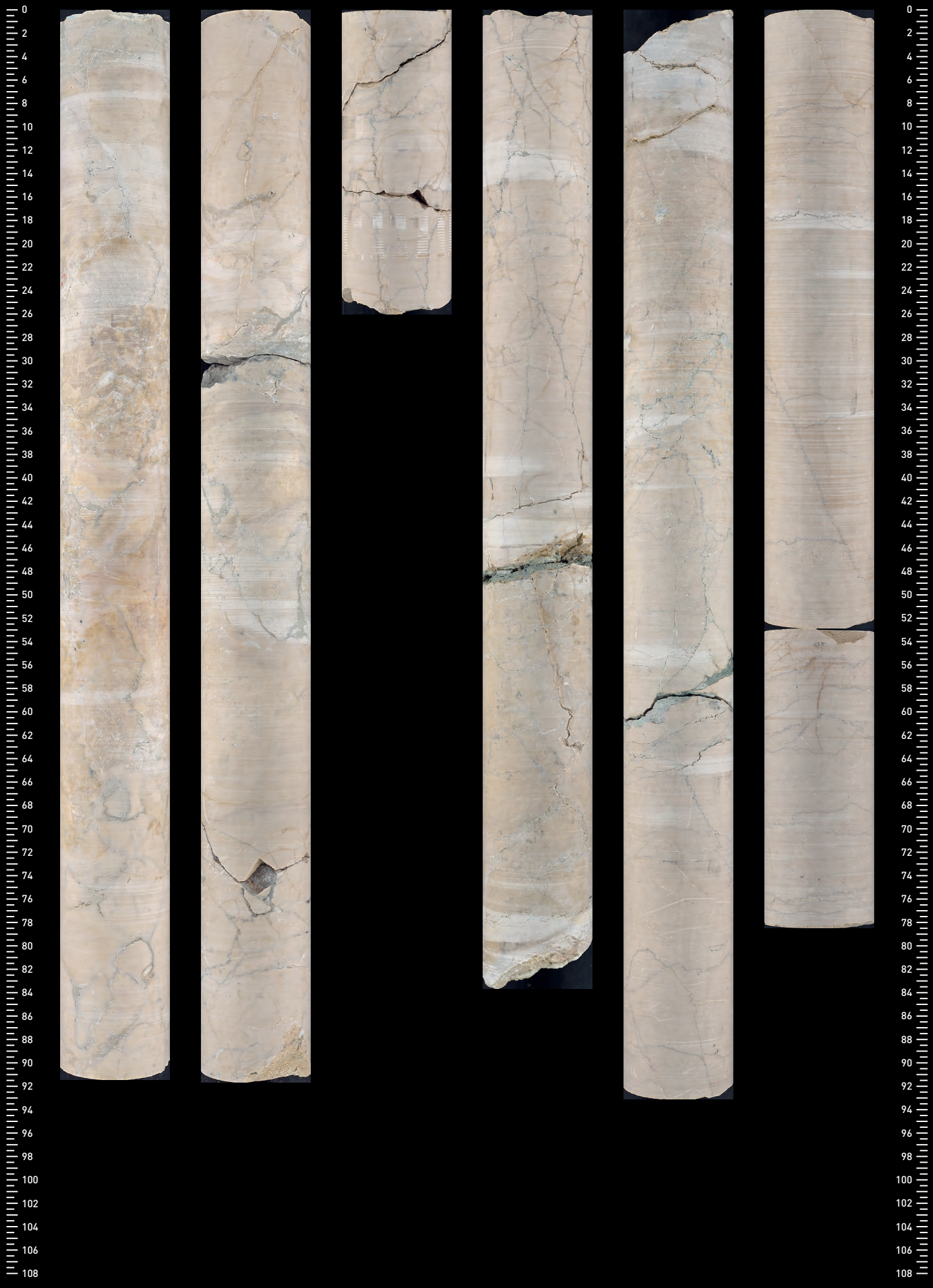
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514.62m 515.22m 516.12m 516.74m 517.24m 518.12m



515.22m 516.12m 516.74m 517.24m 518.12m 518.76m


518.76m
519.72m
520.71m
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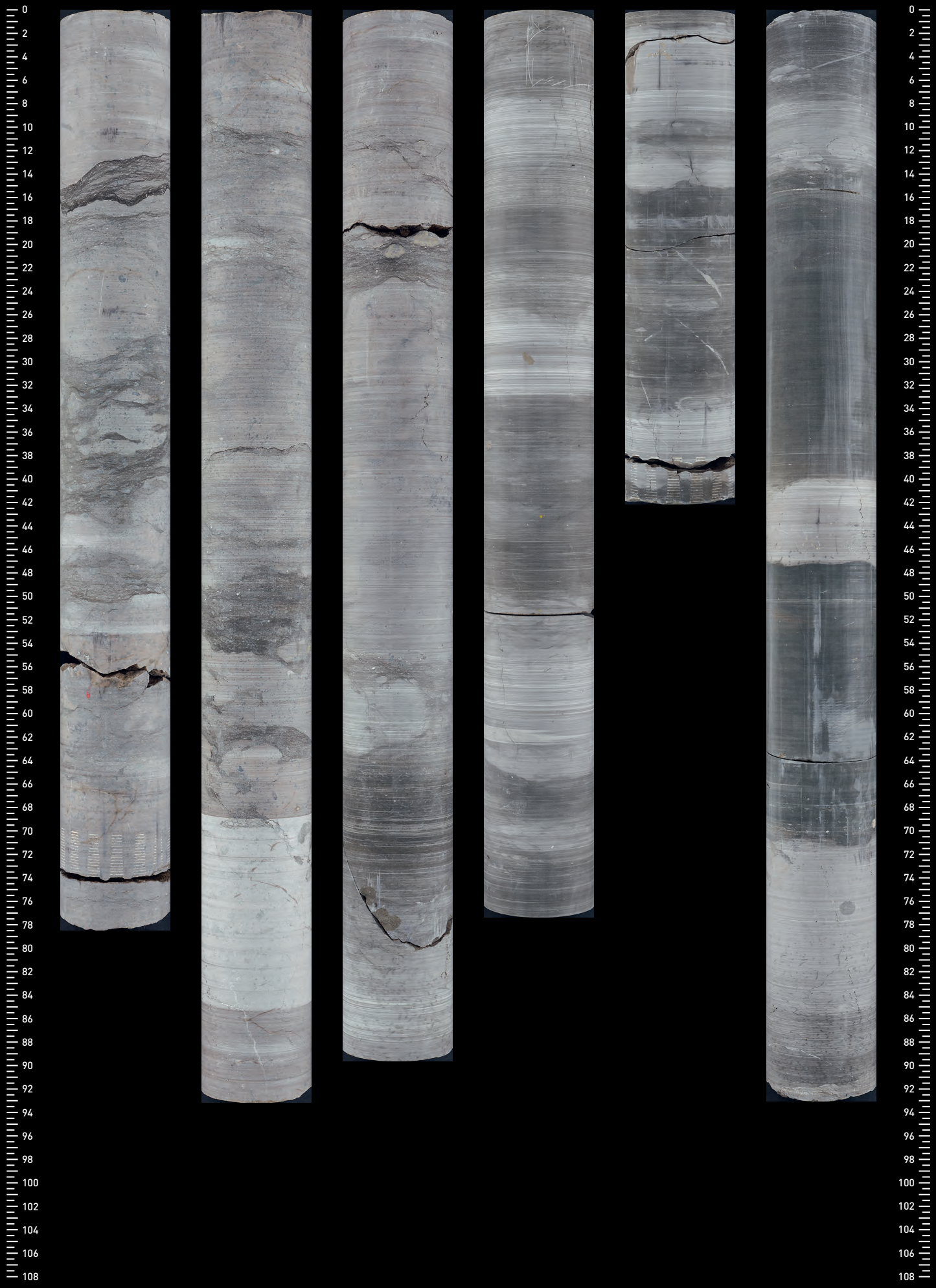
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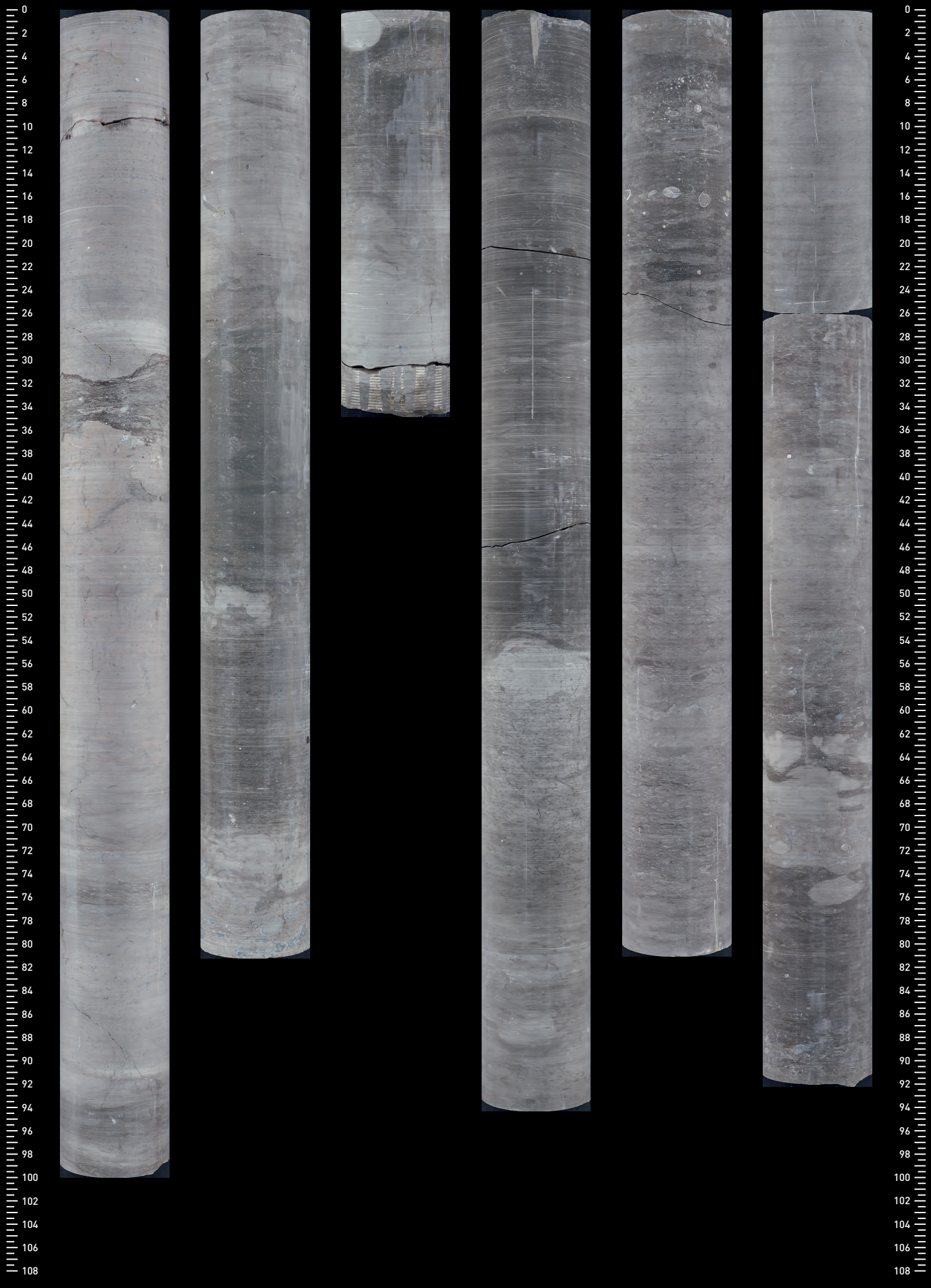
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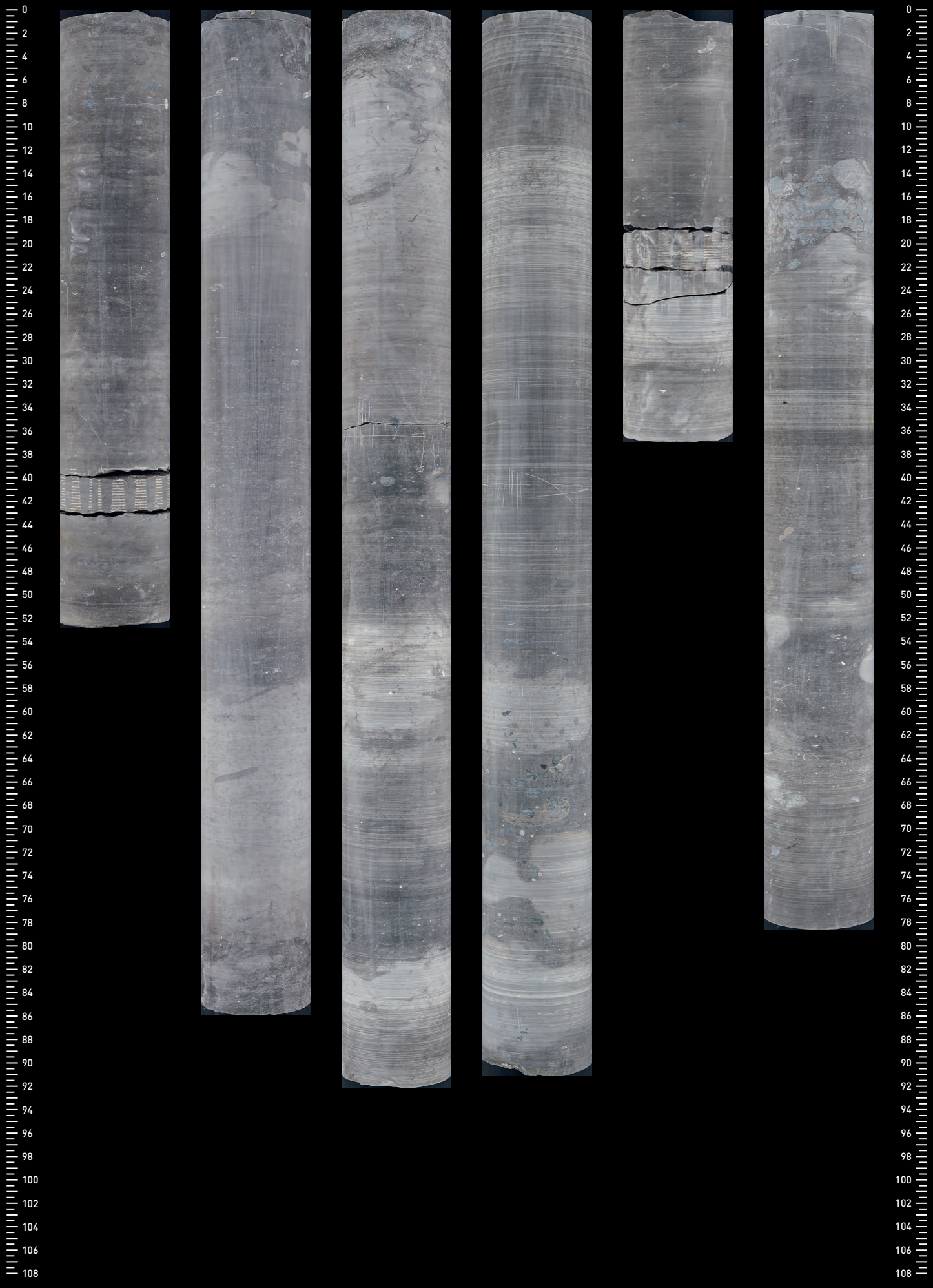
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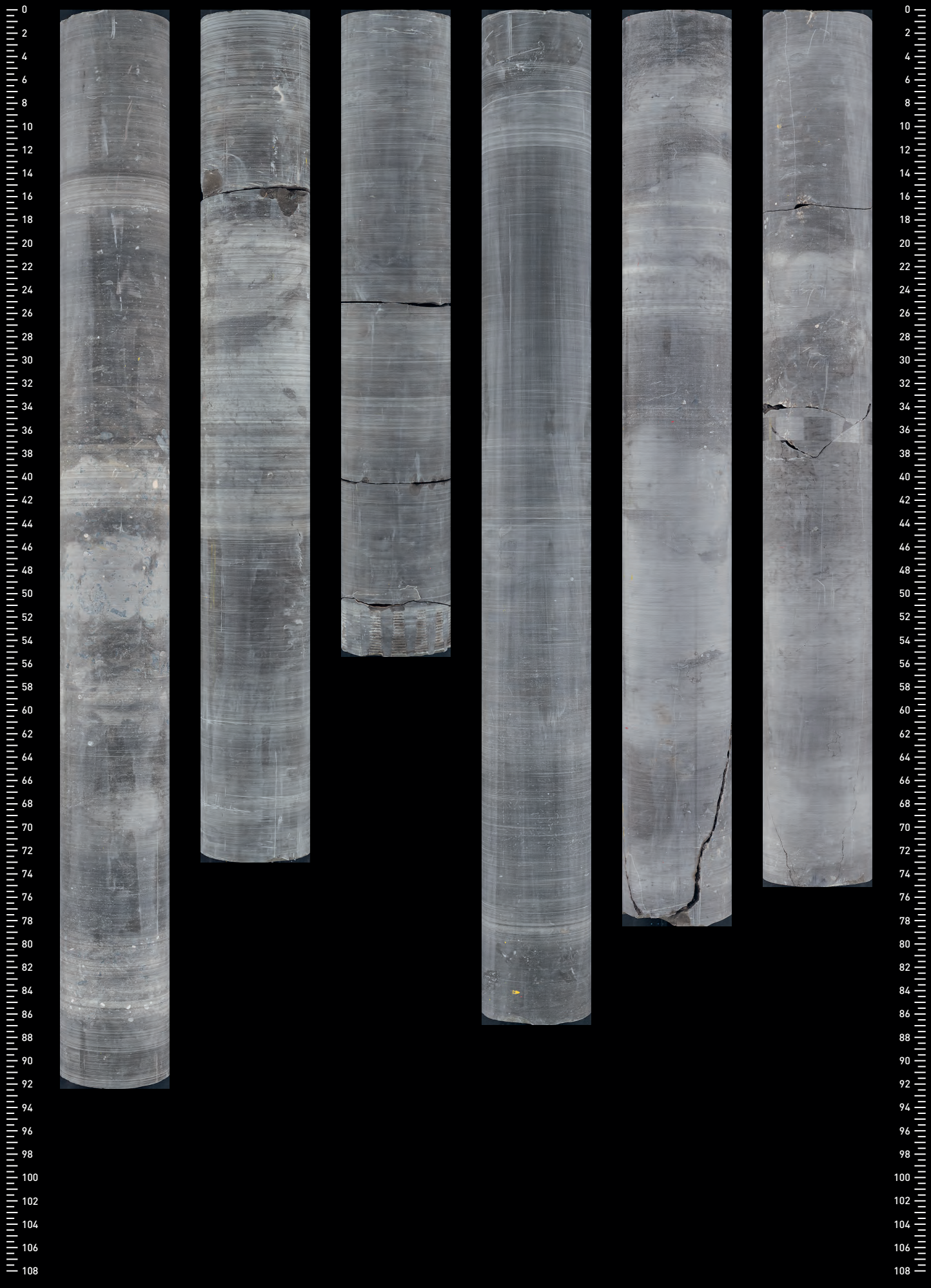
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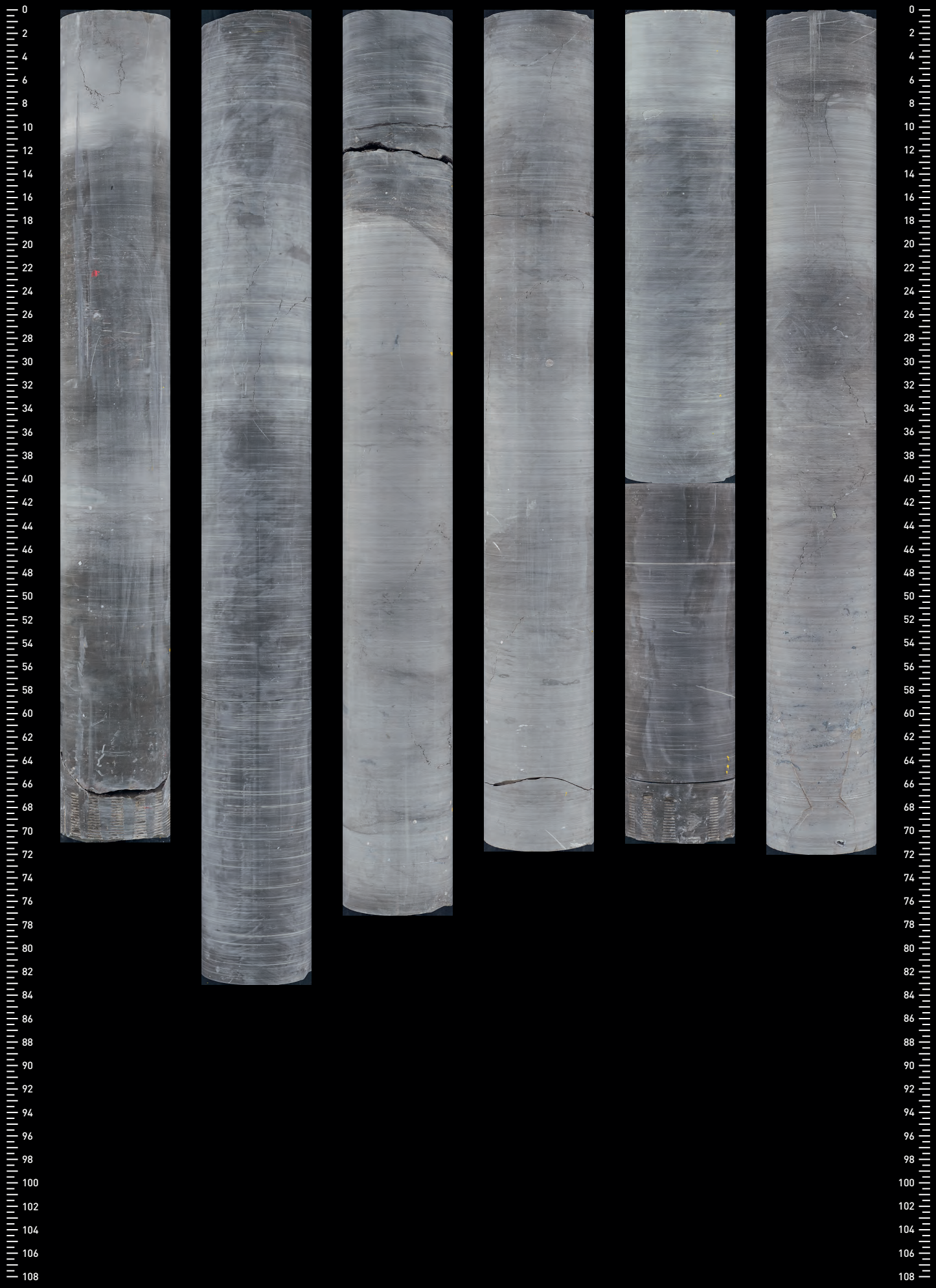
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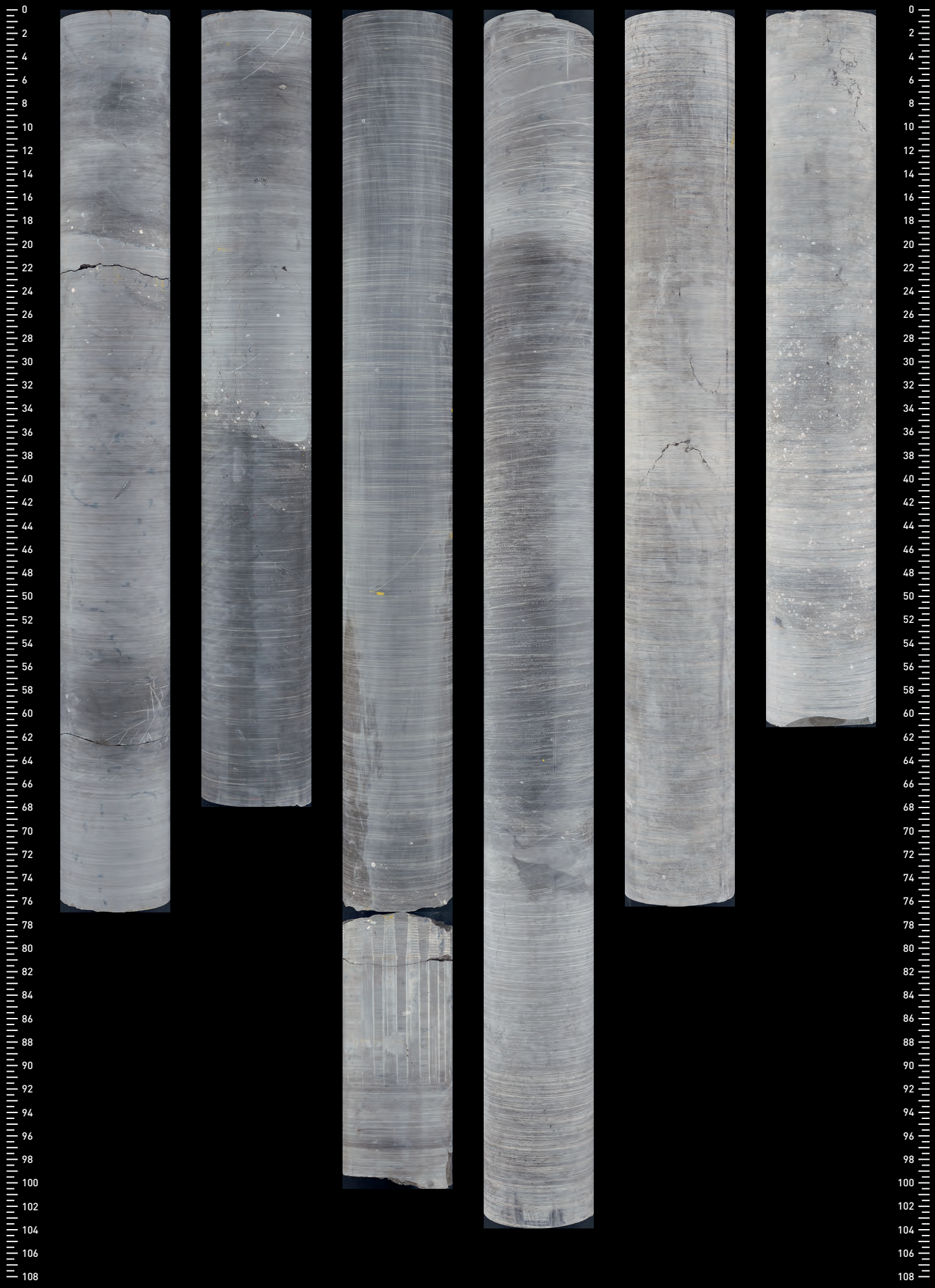
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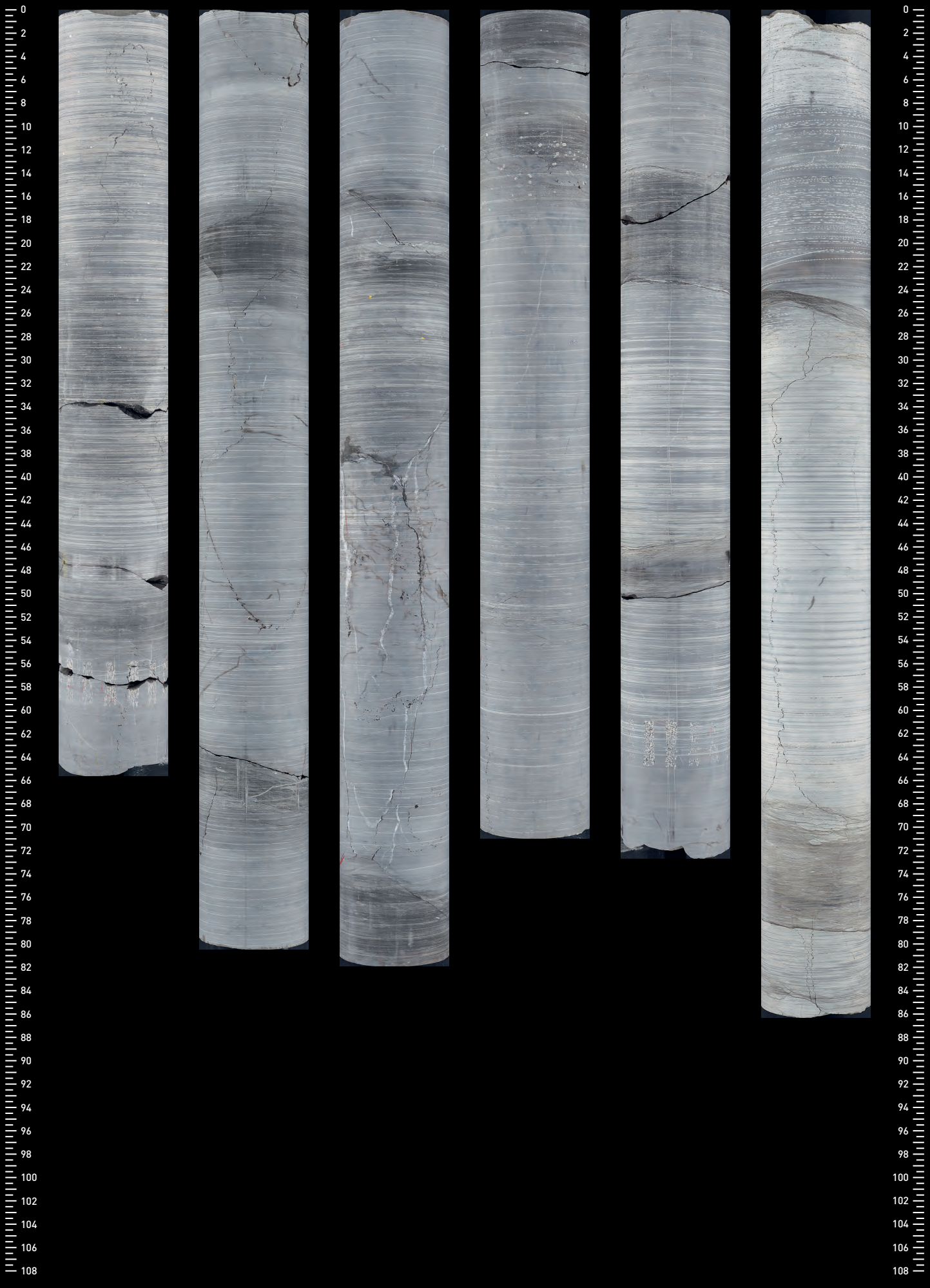
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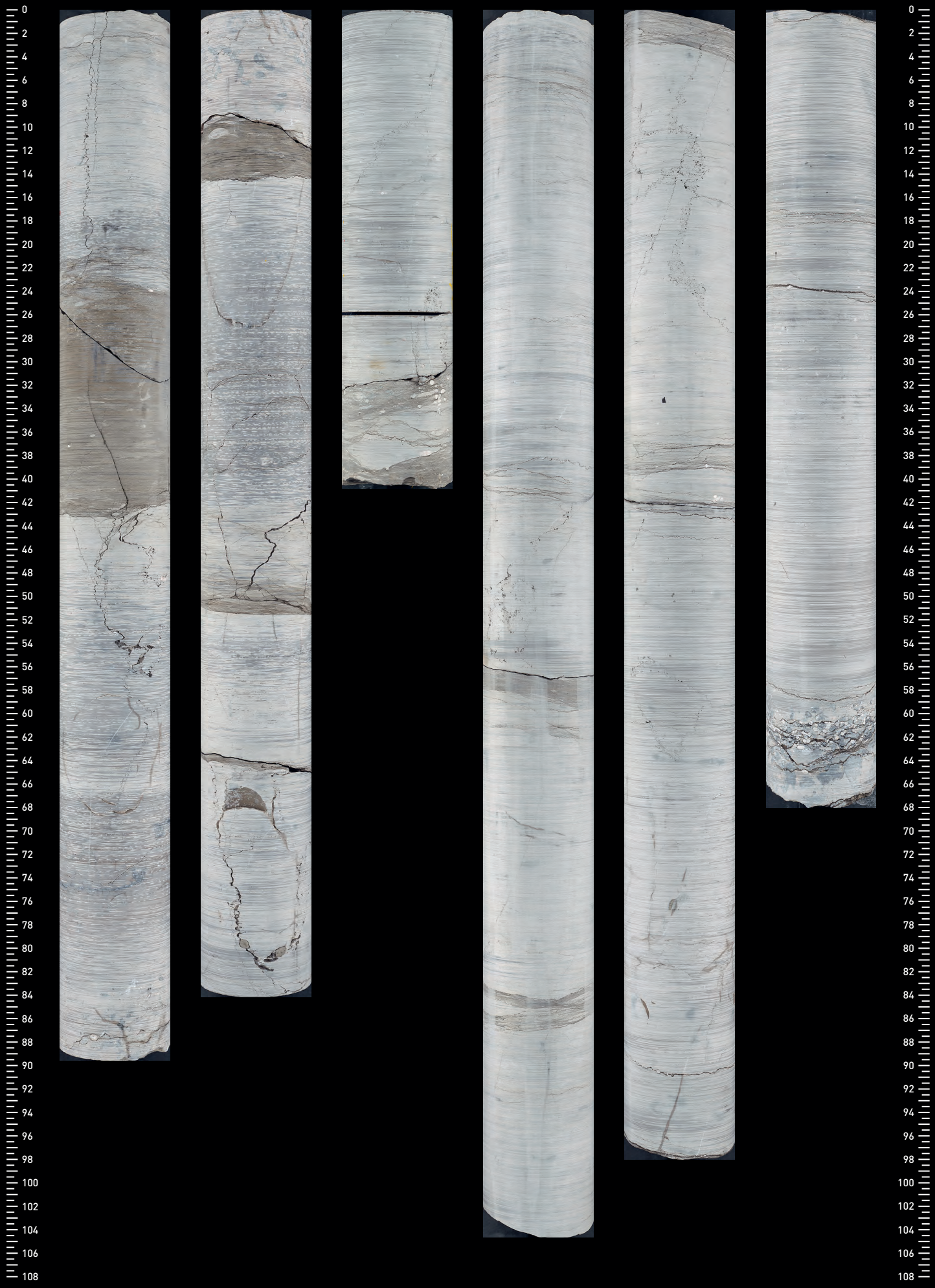
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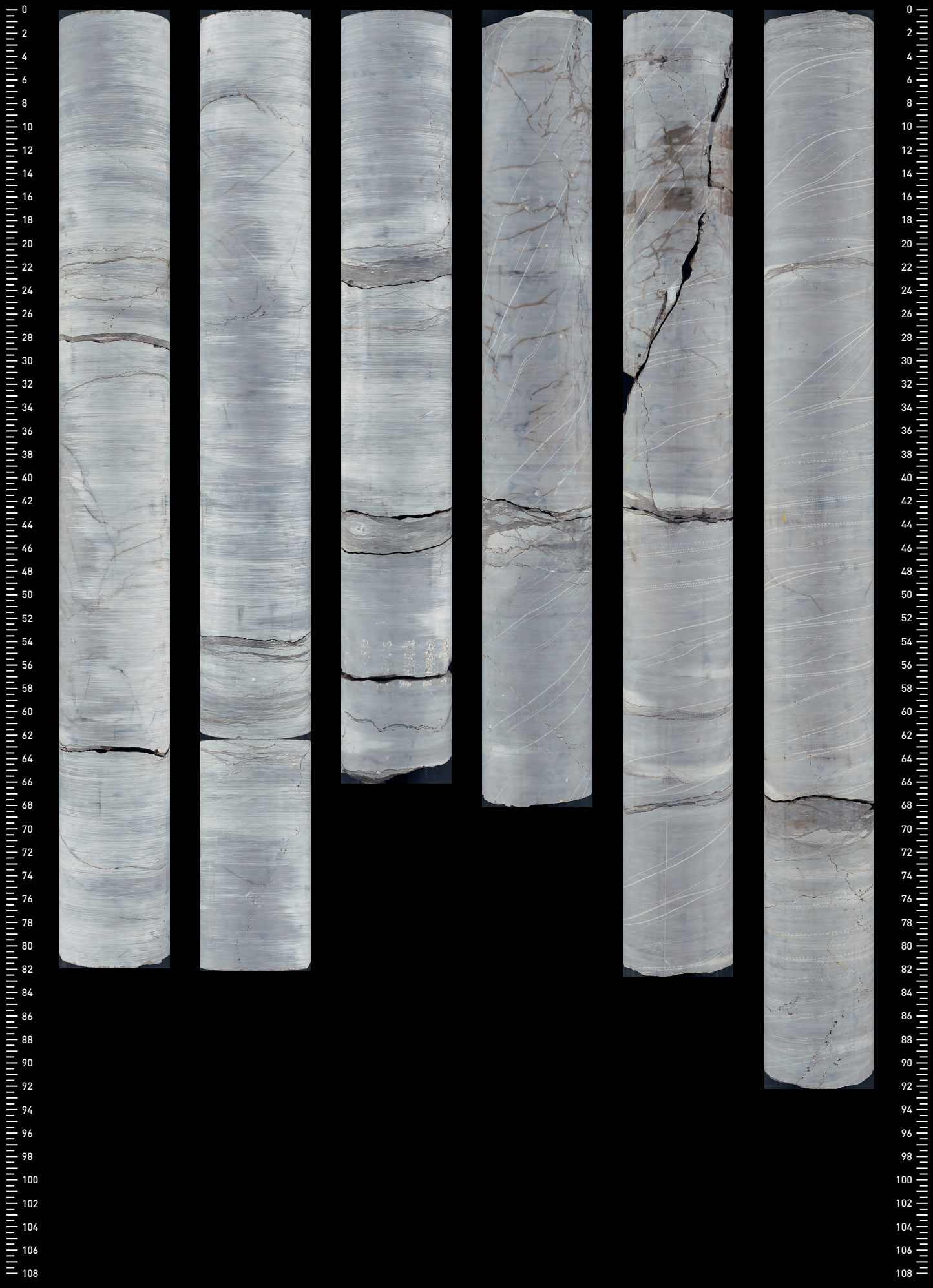
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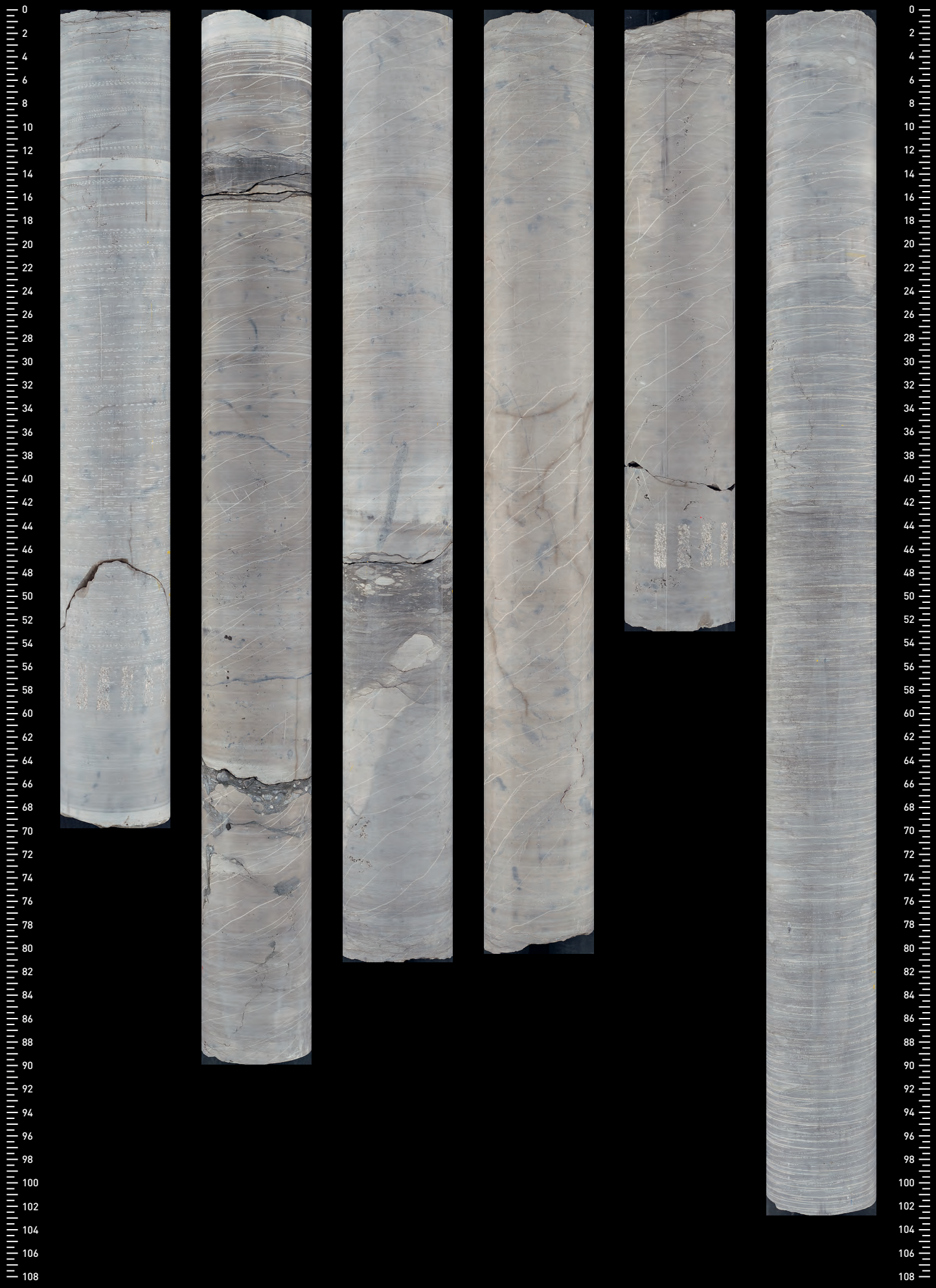
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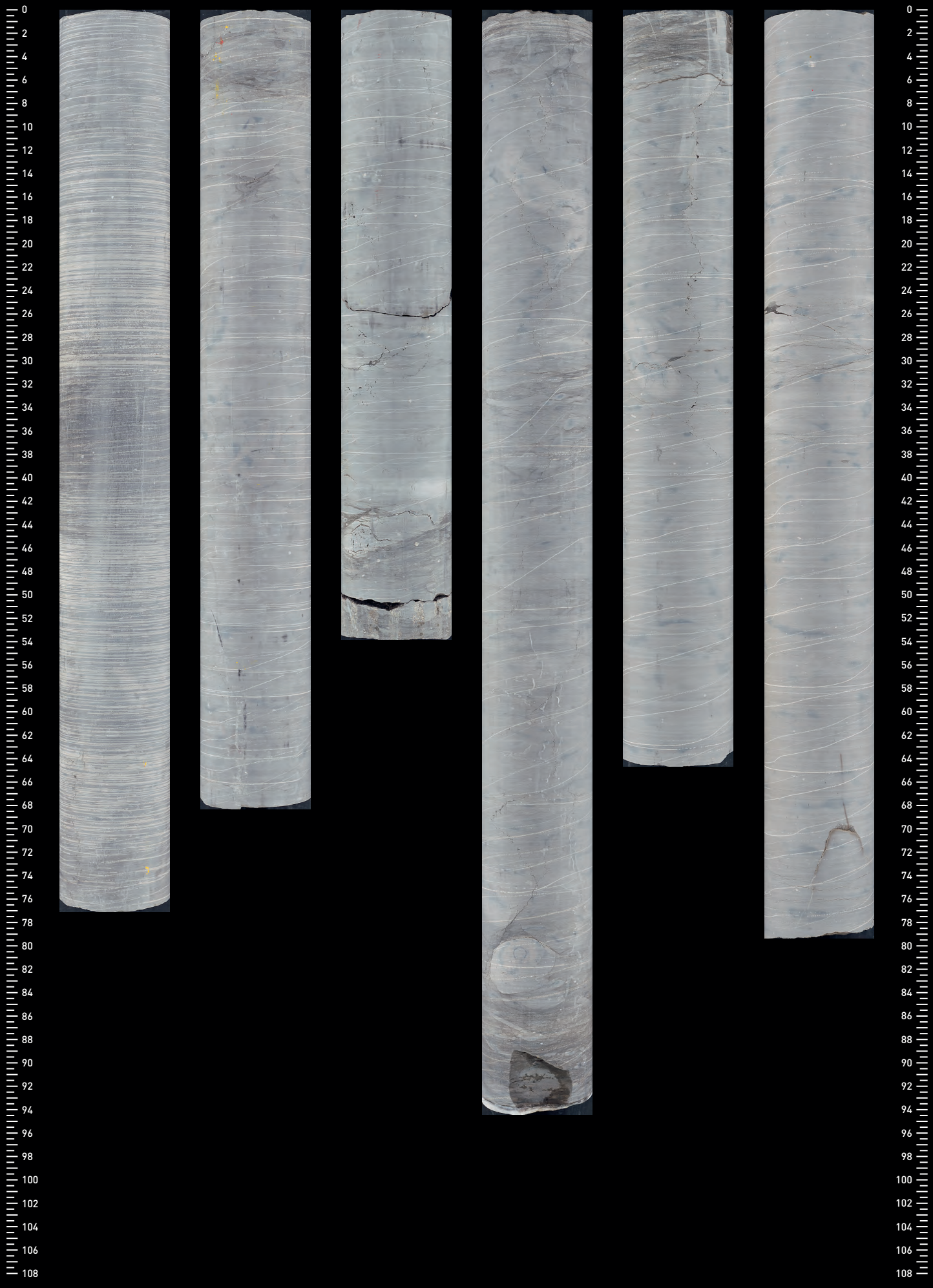
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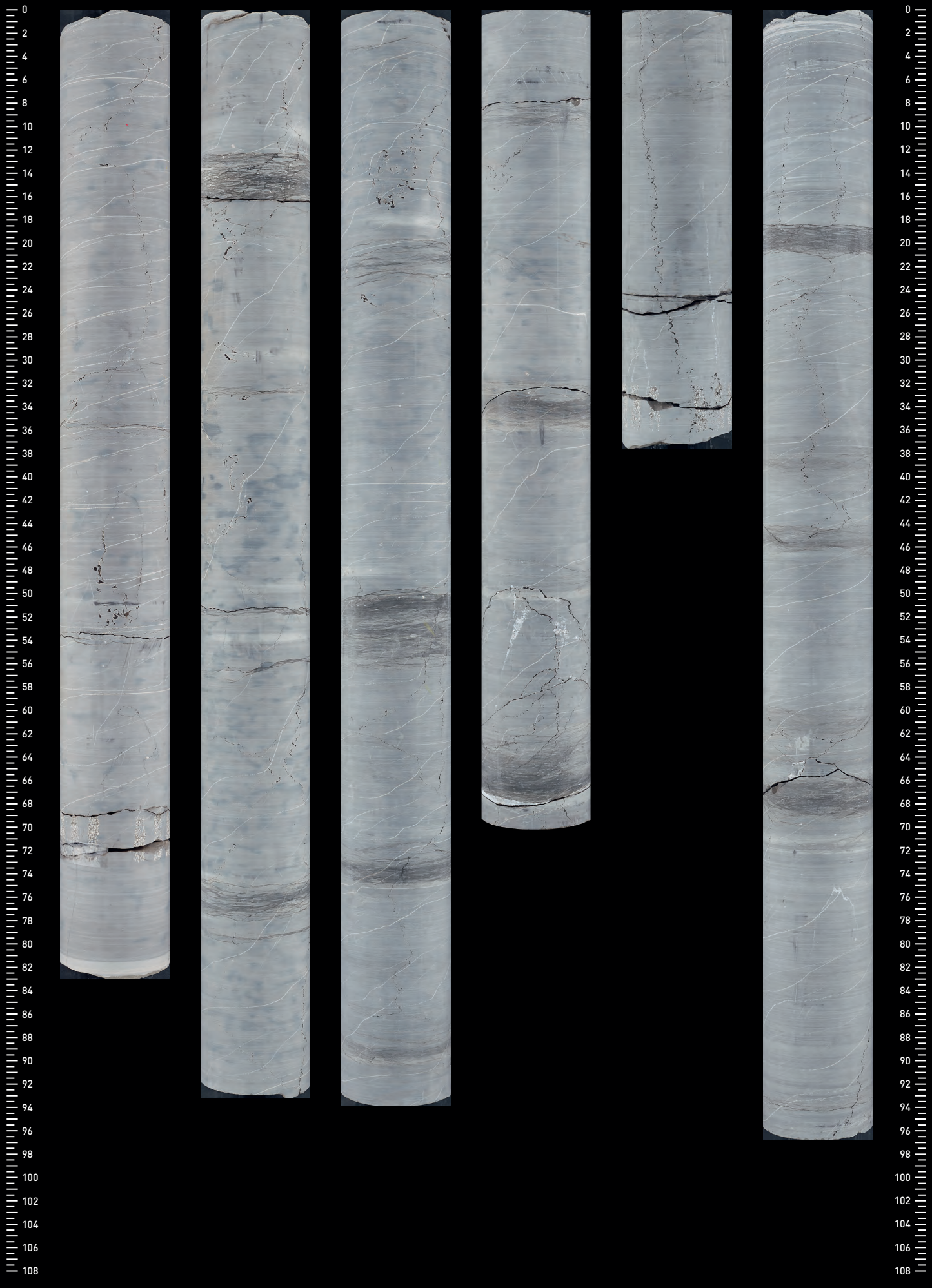
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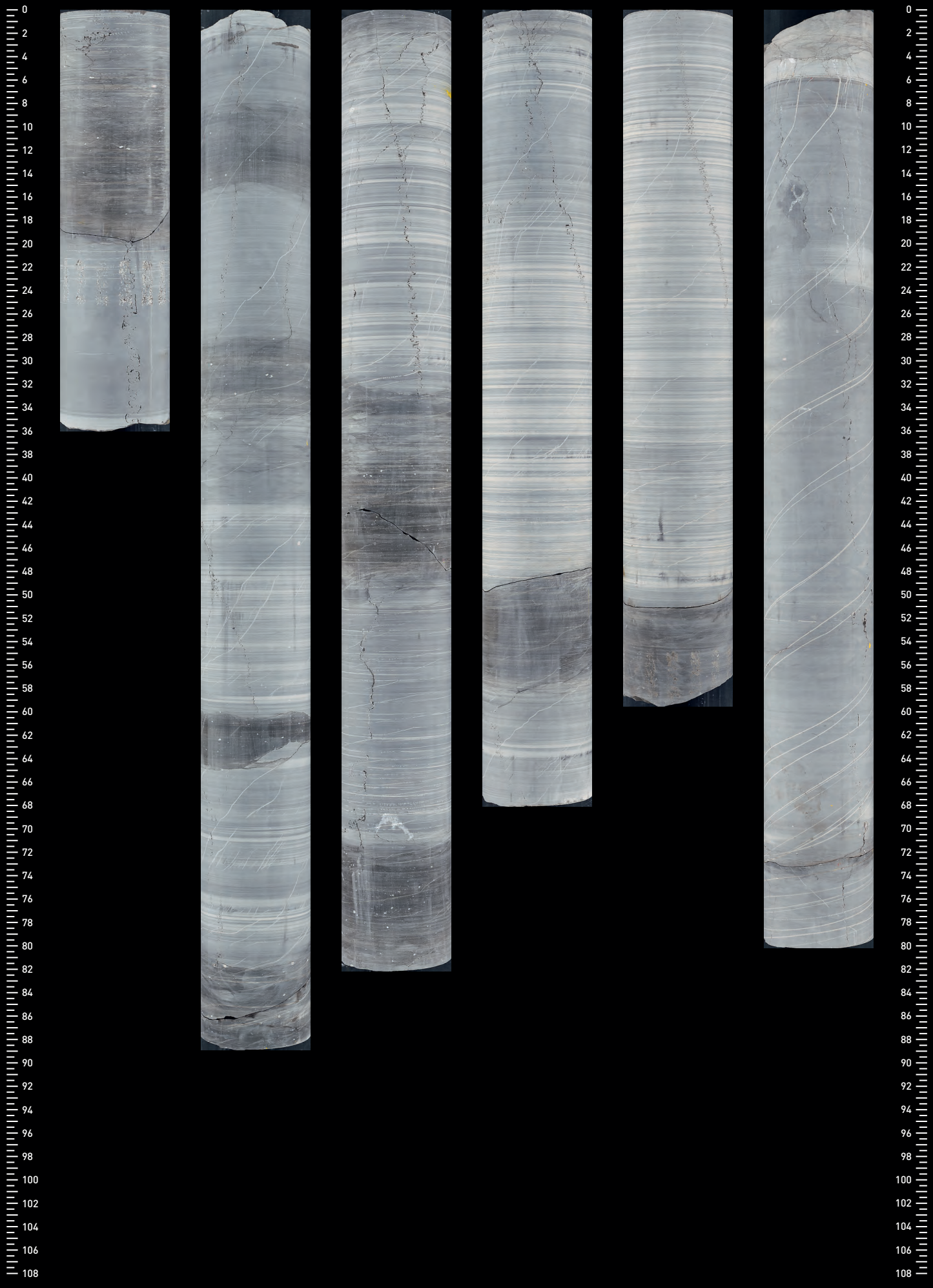
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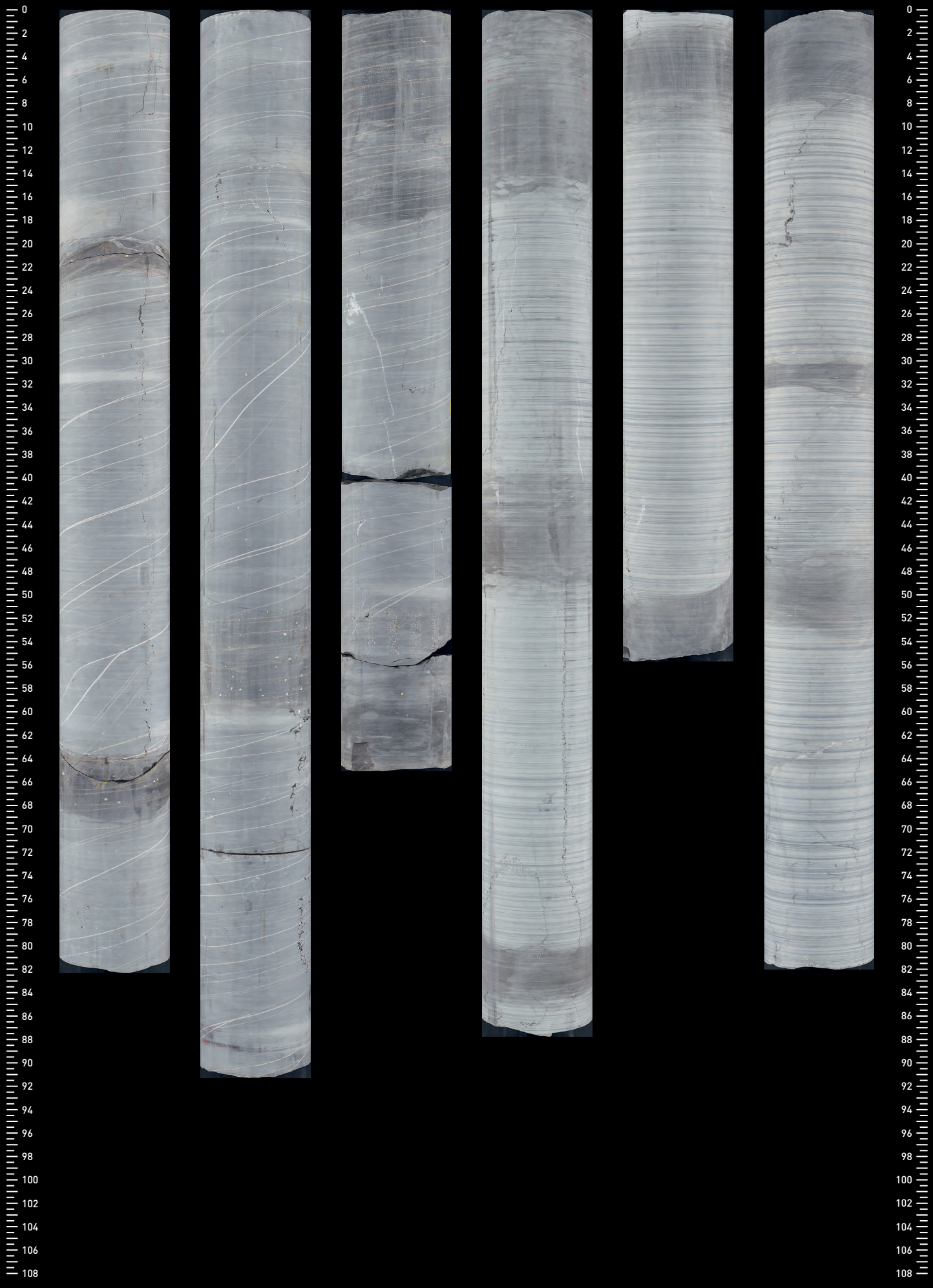
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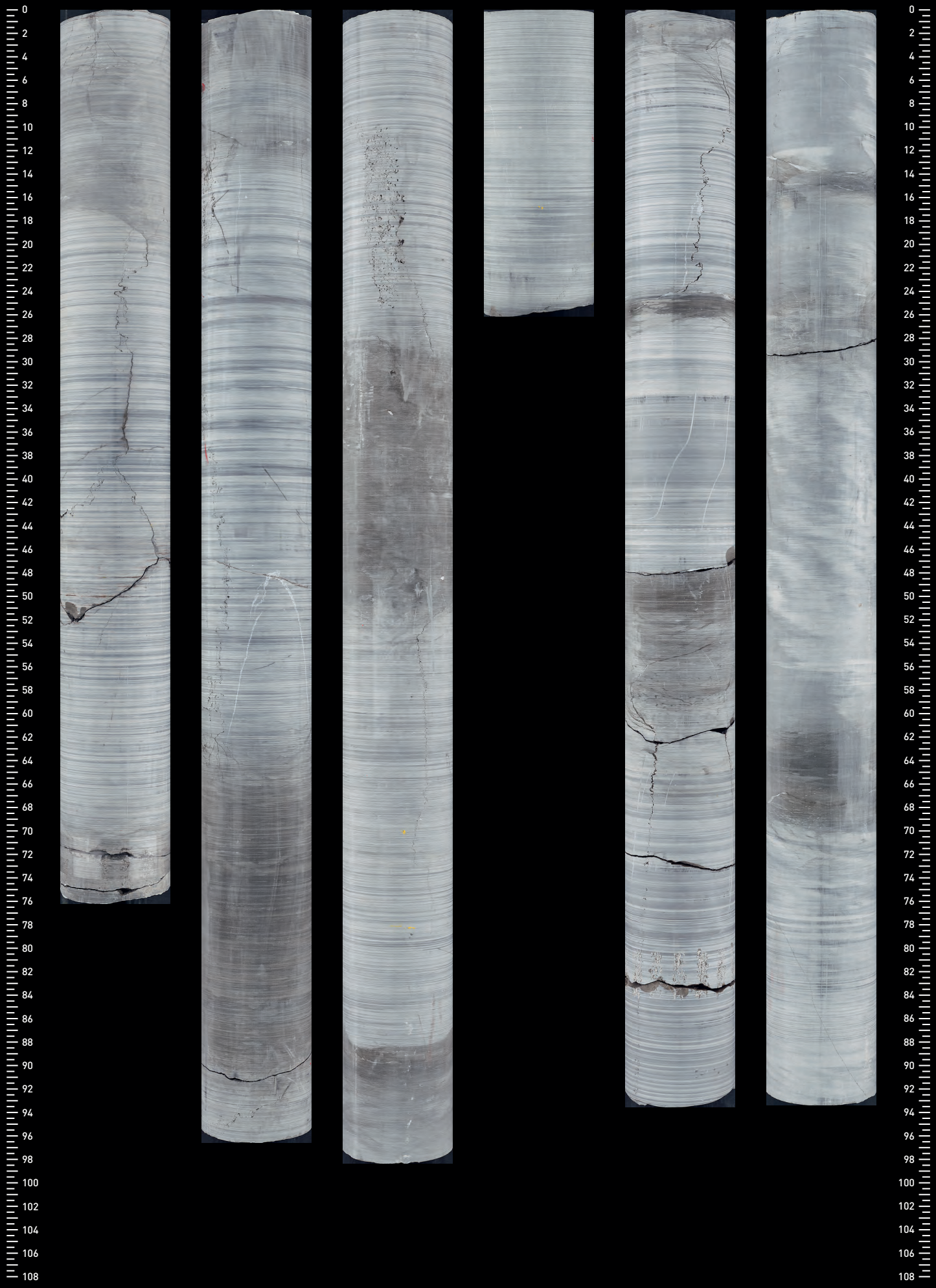
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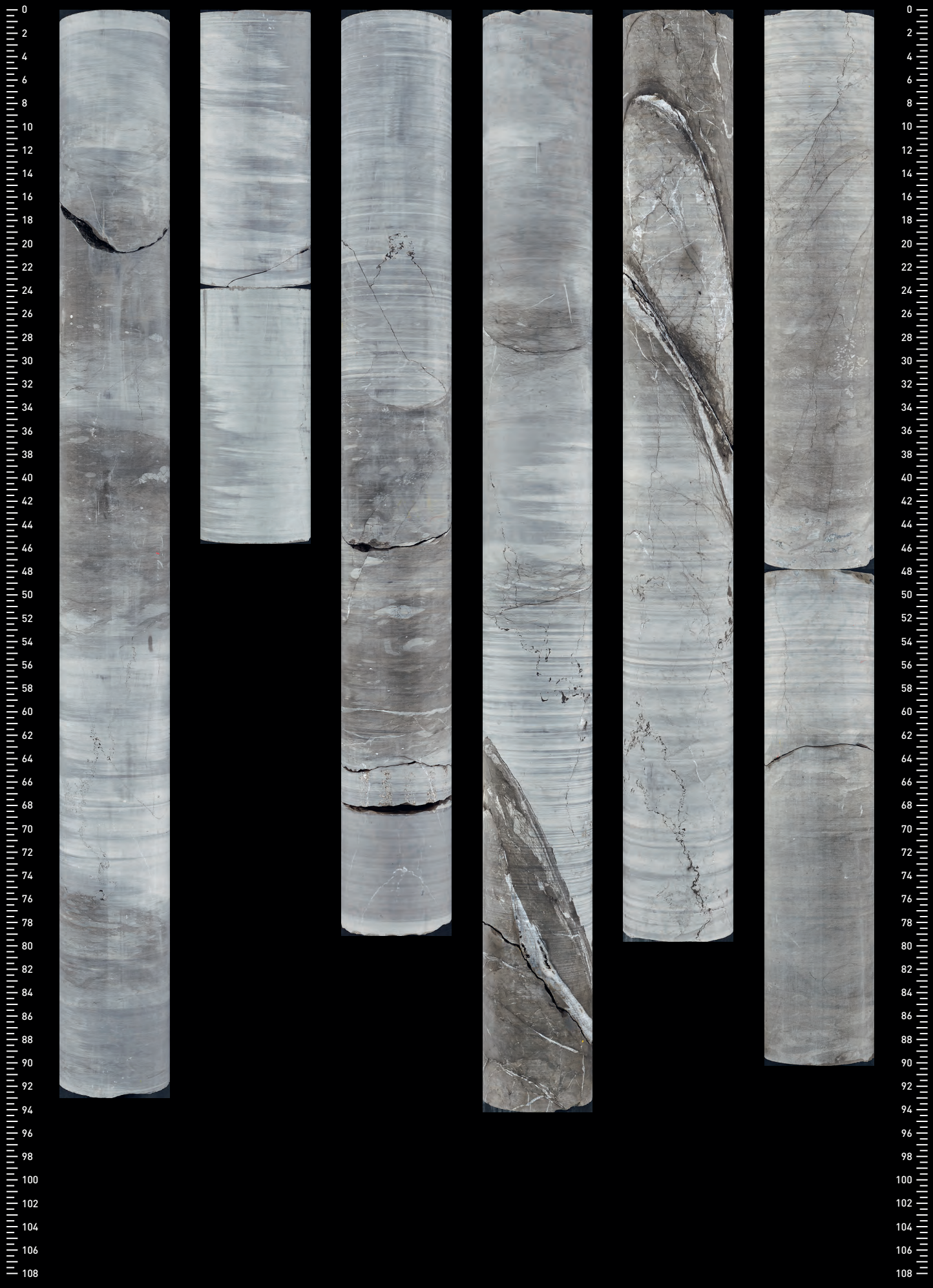
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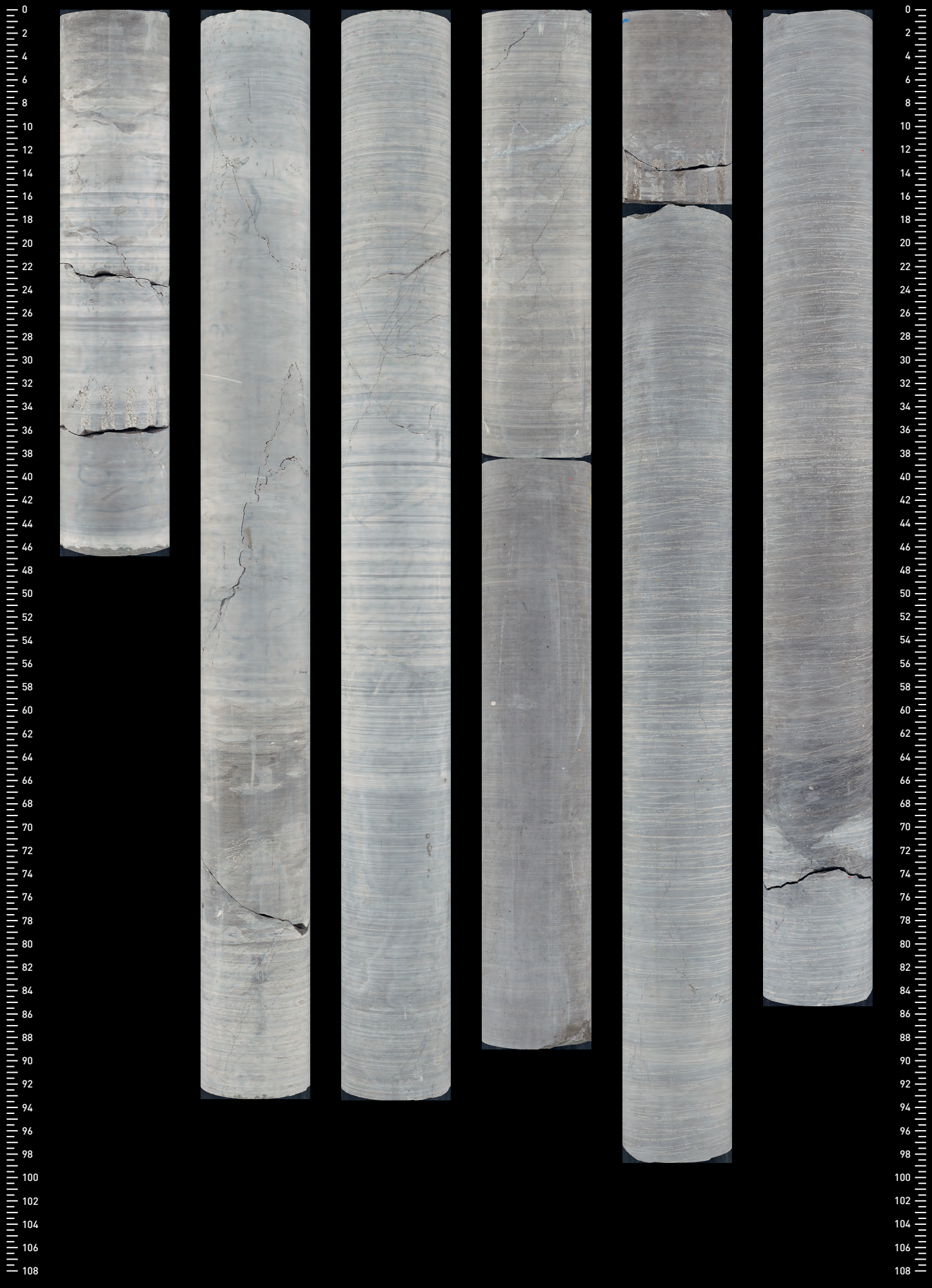
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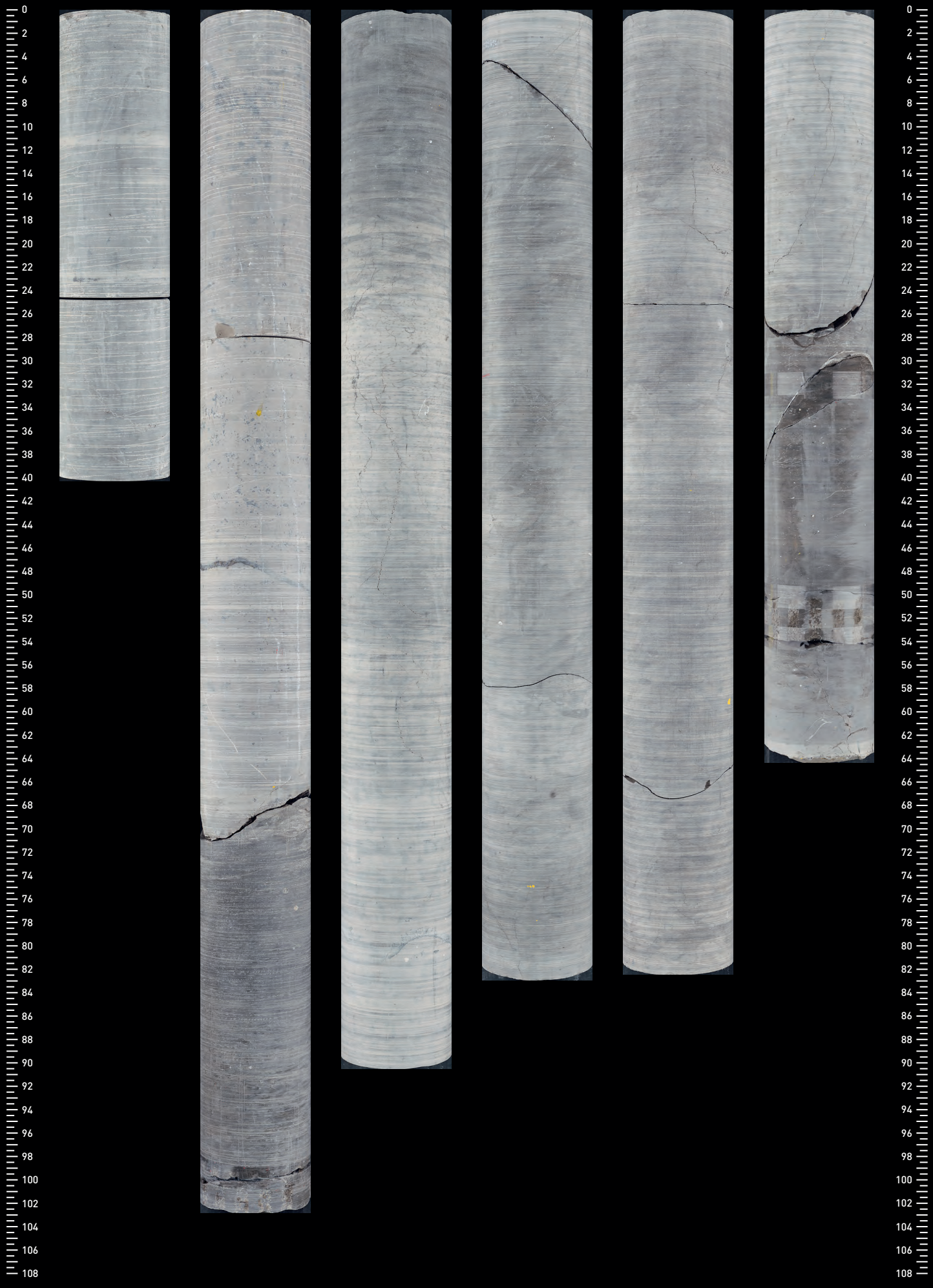
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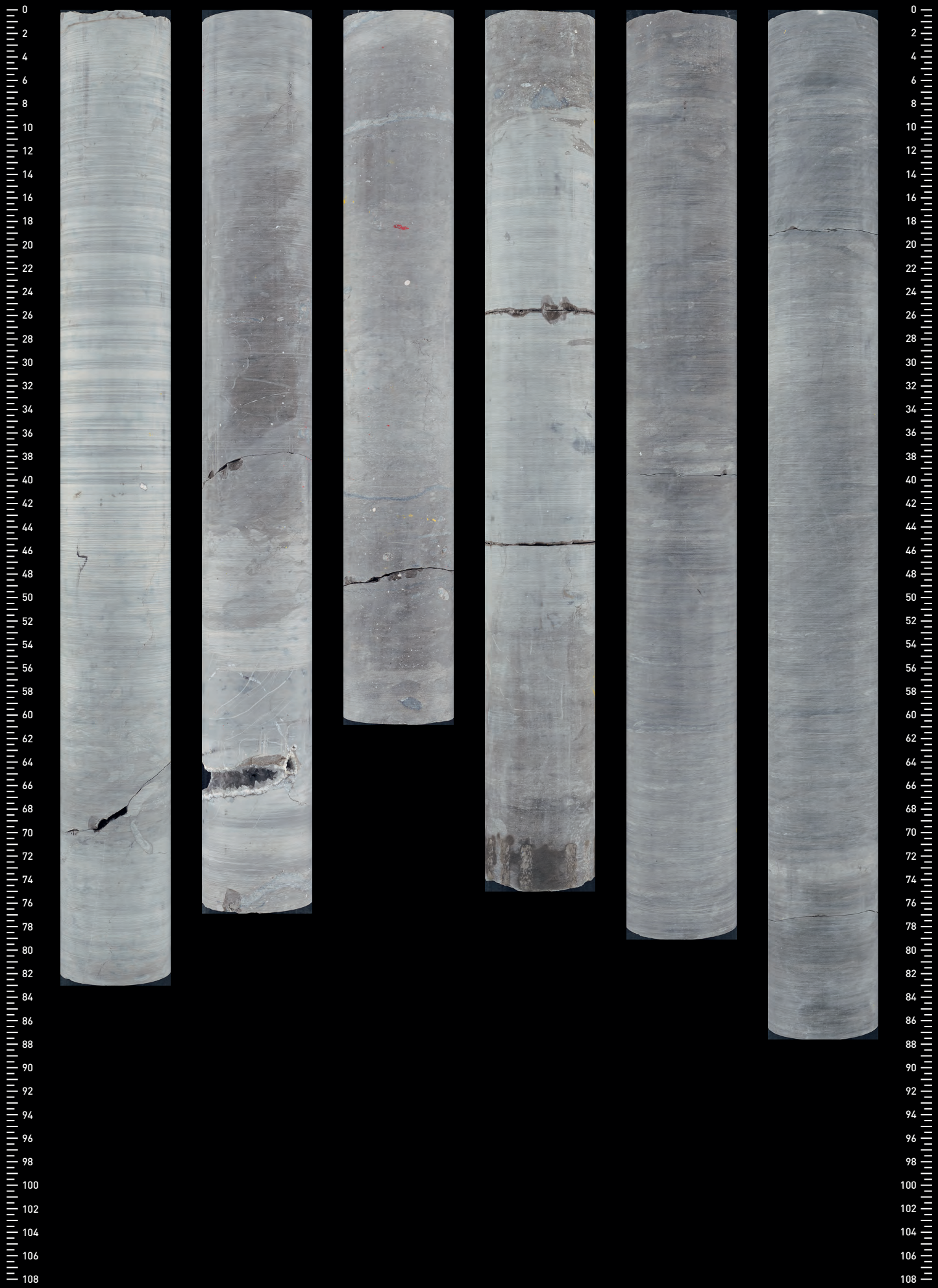
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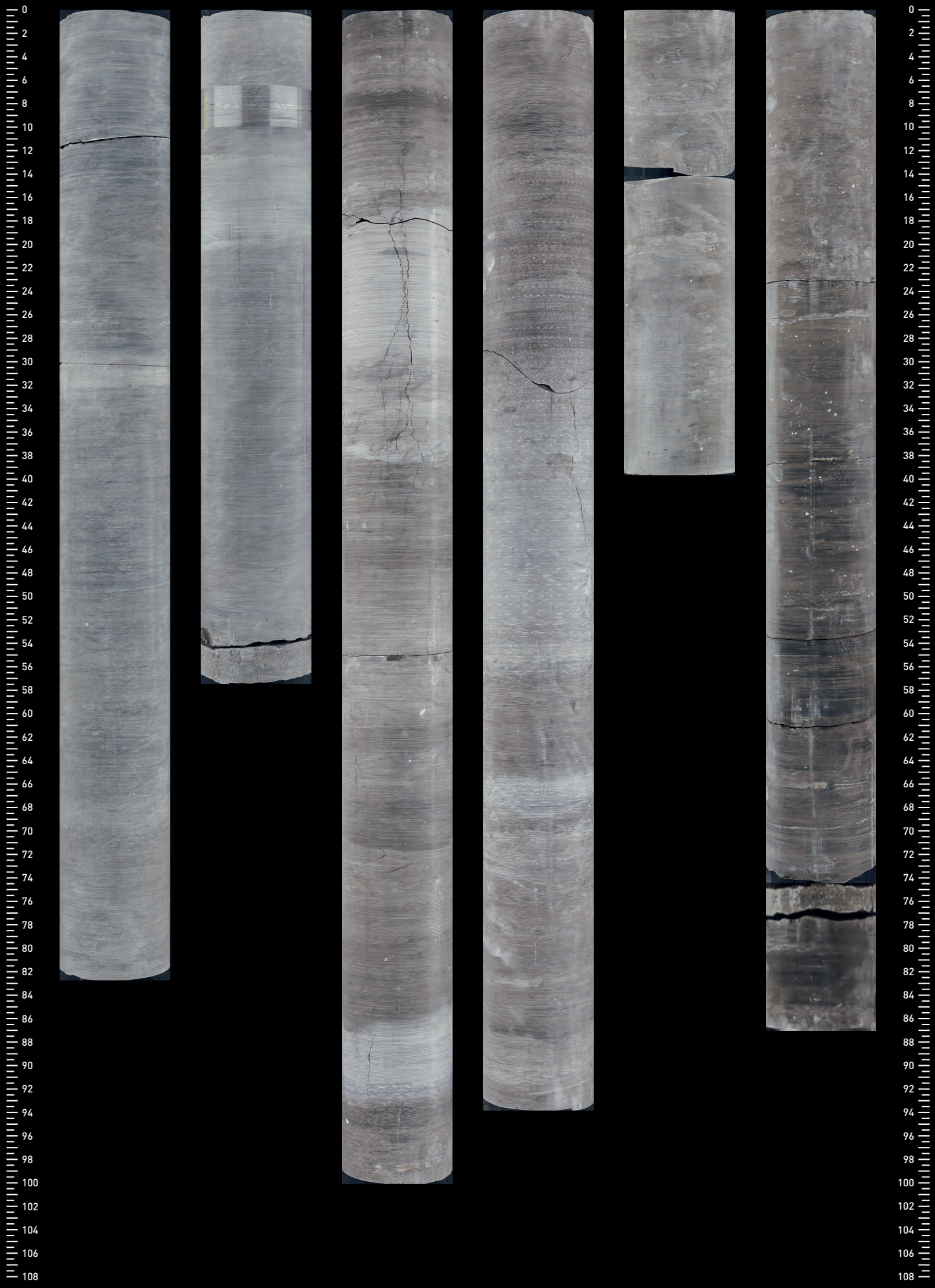
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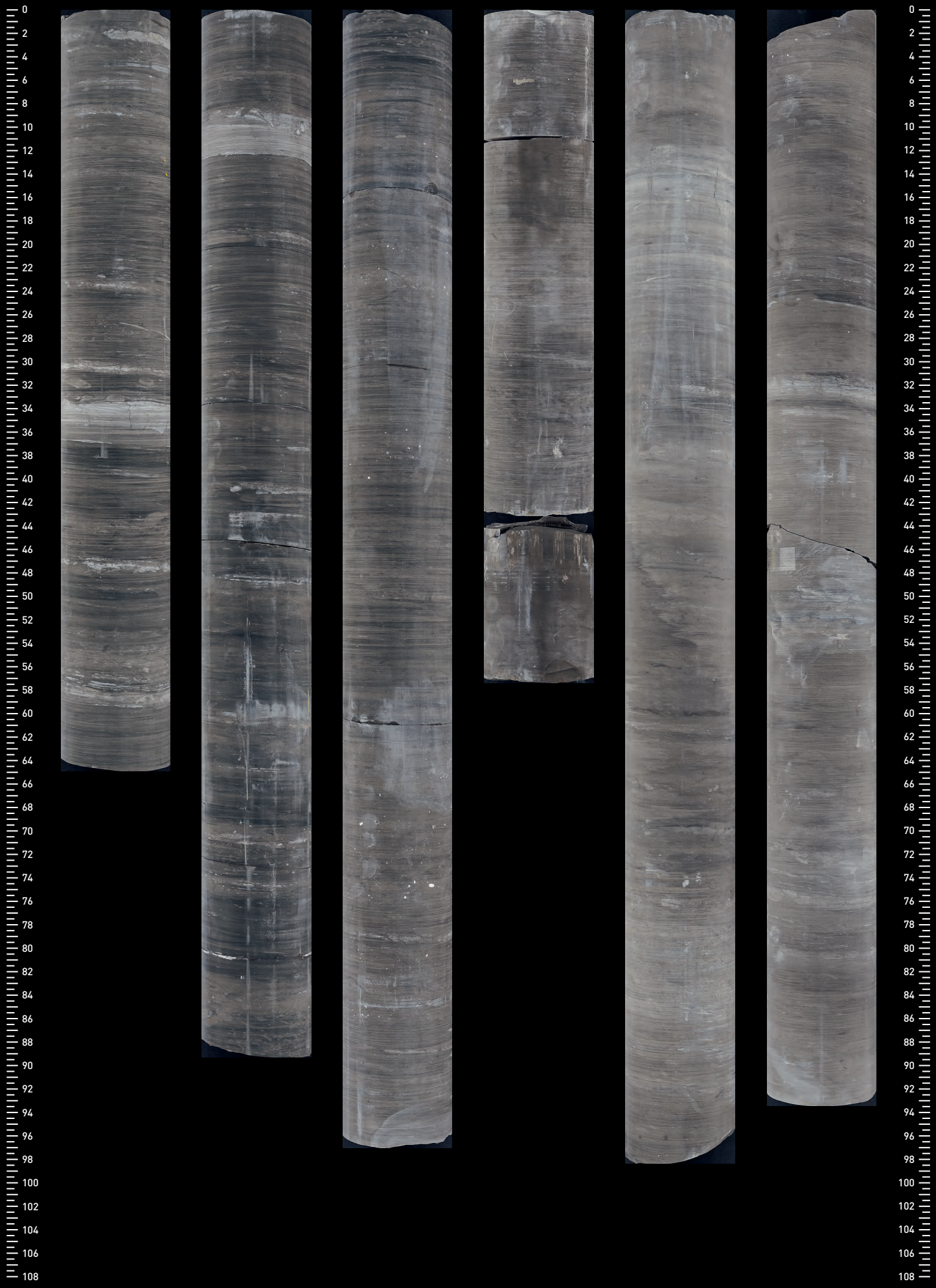
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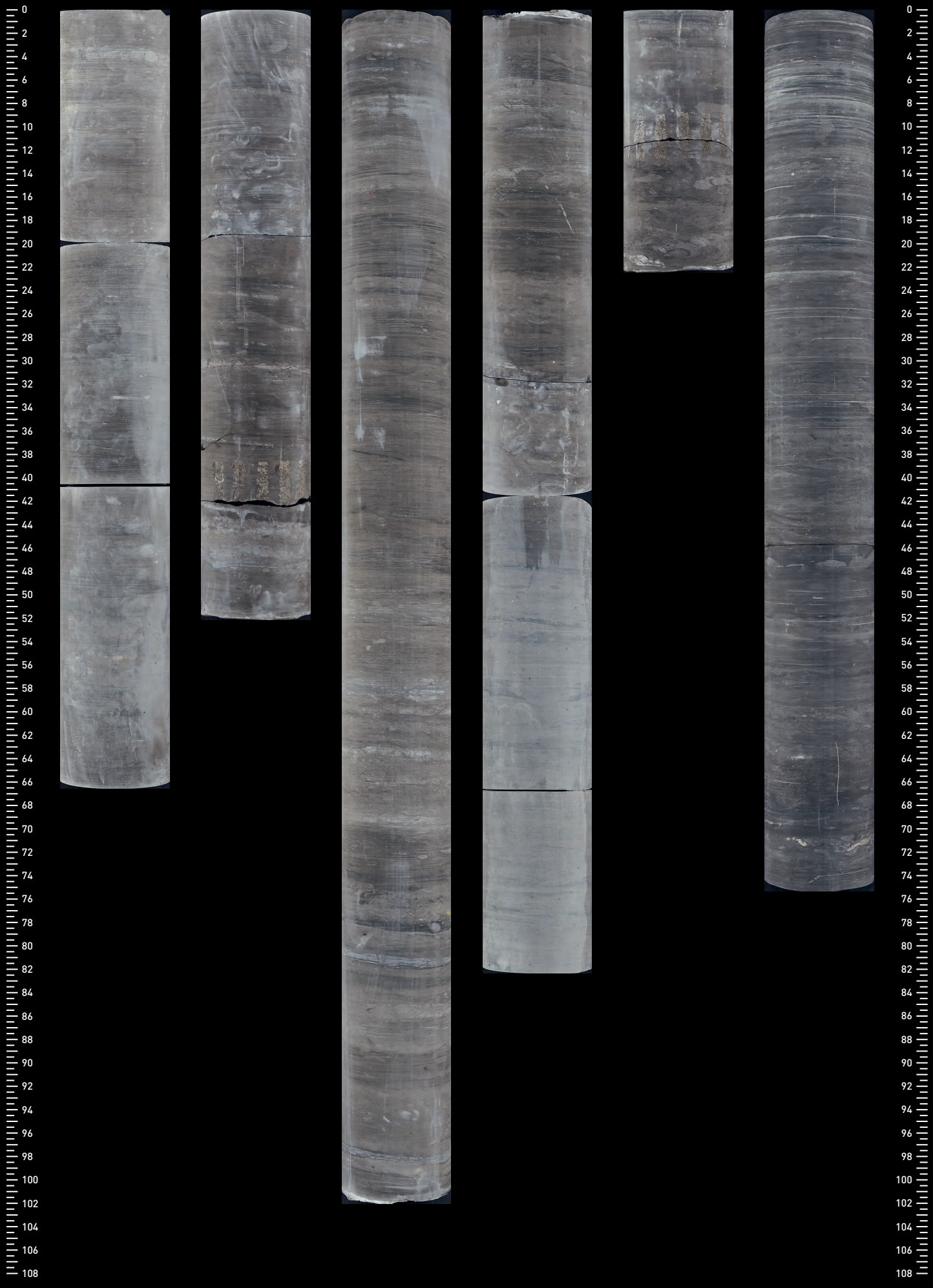
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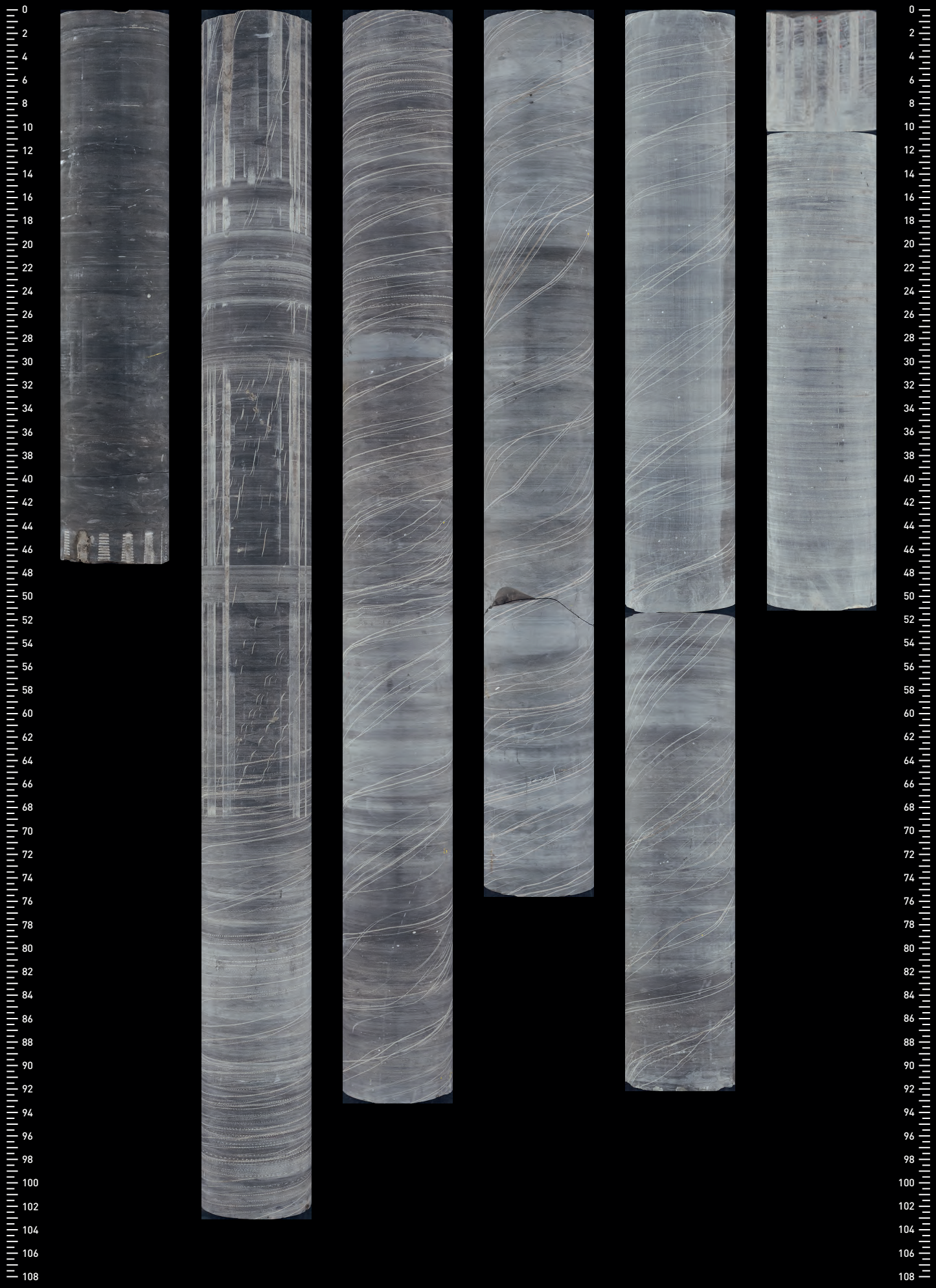
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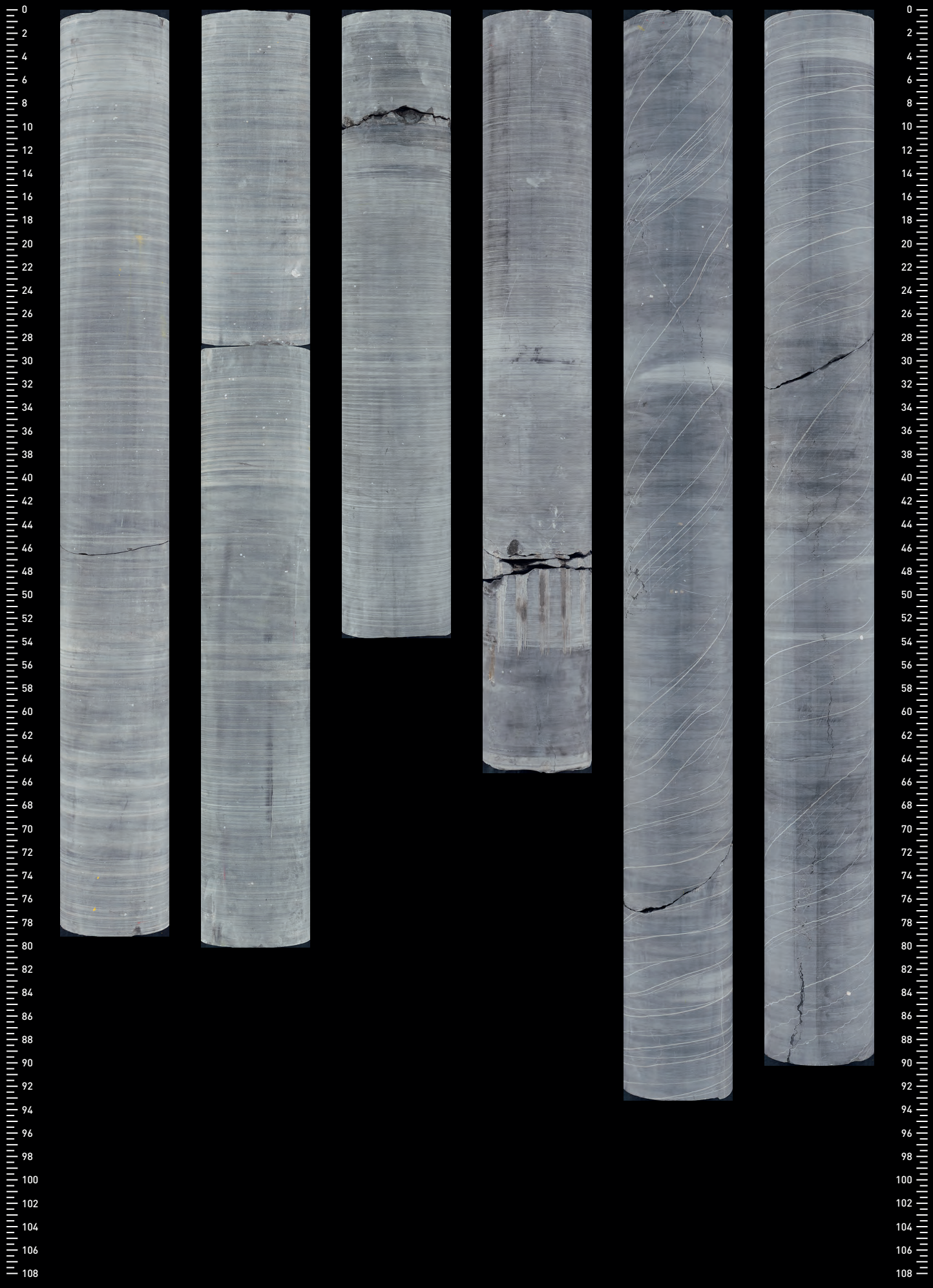
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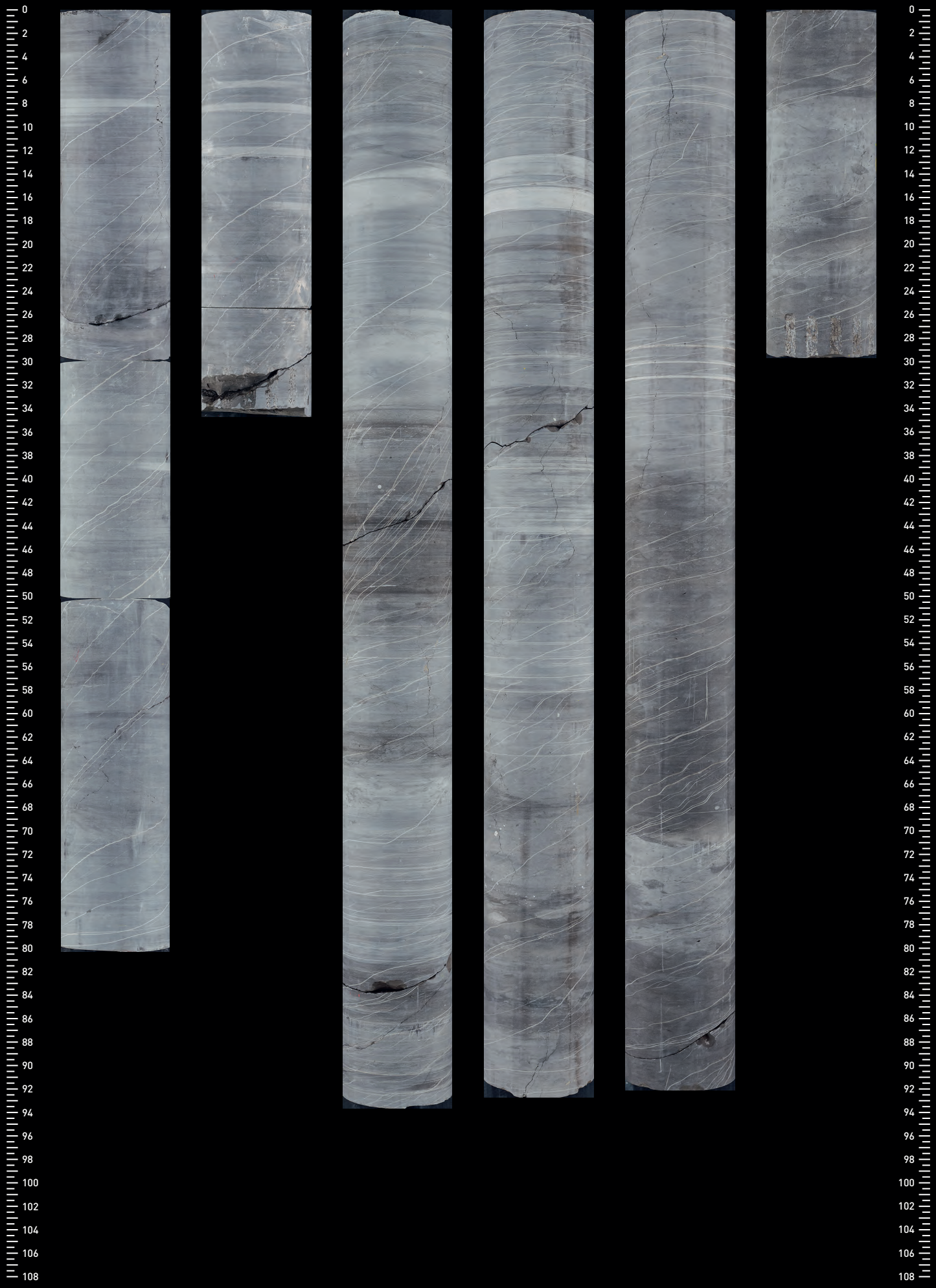
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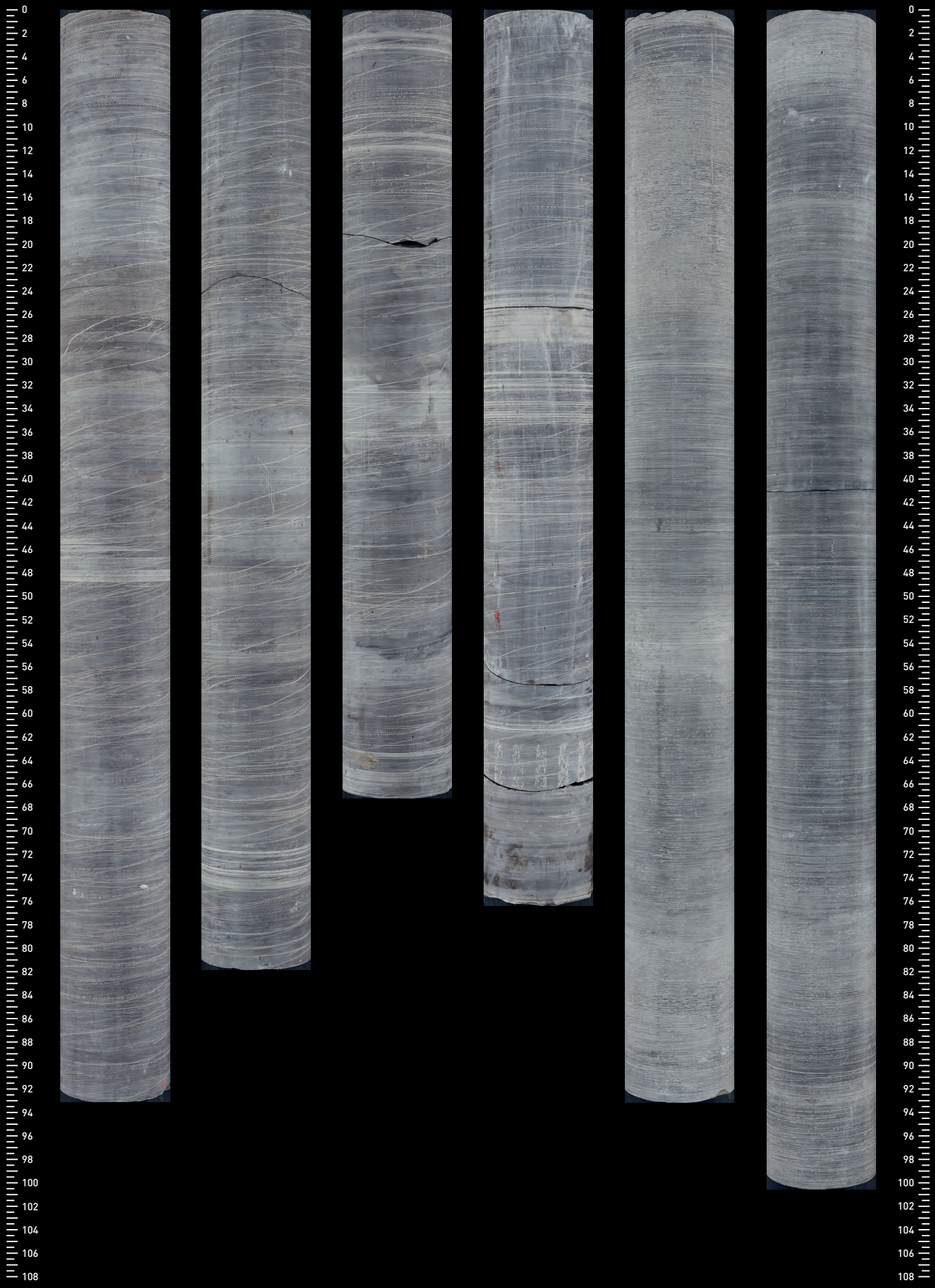
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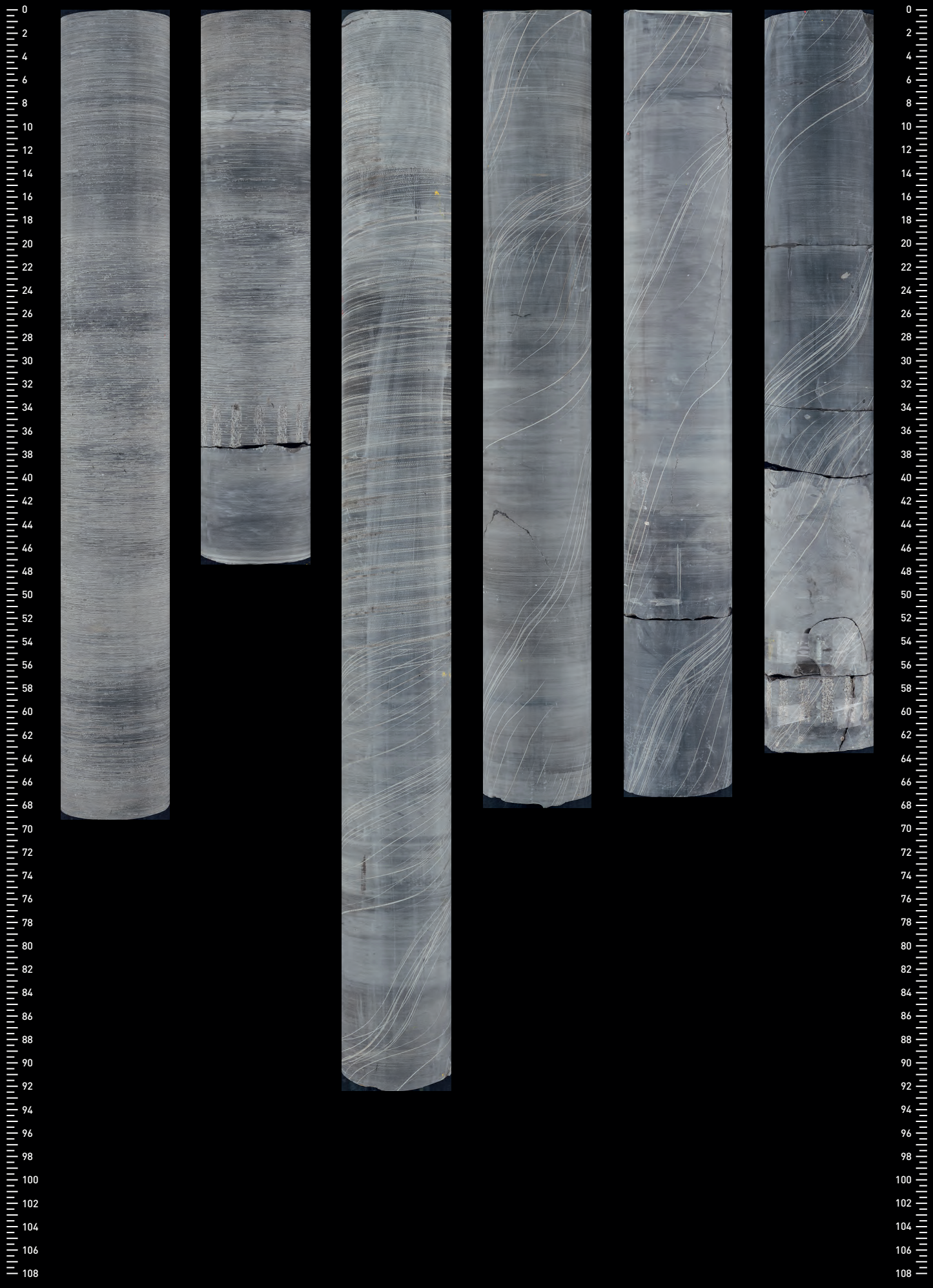
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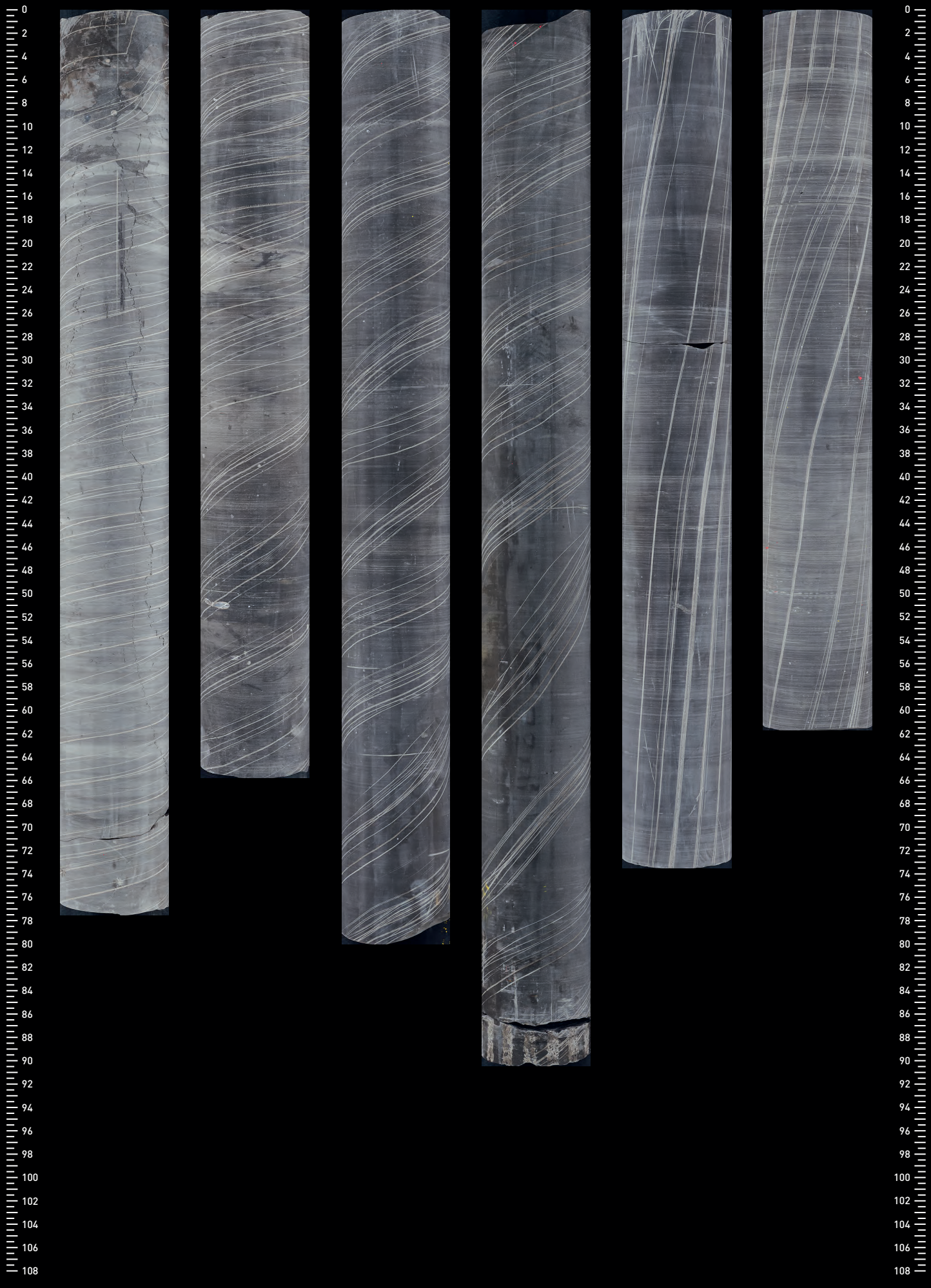
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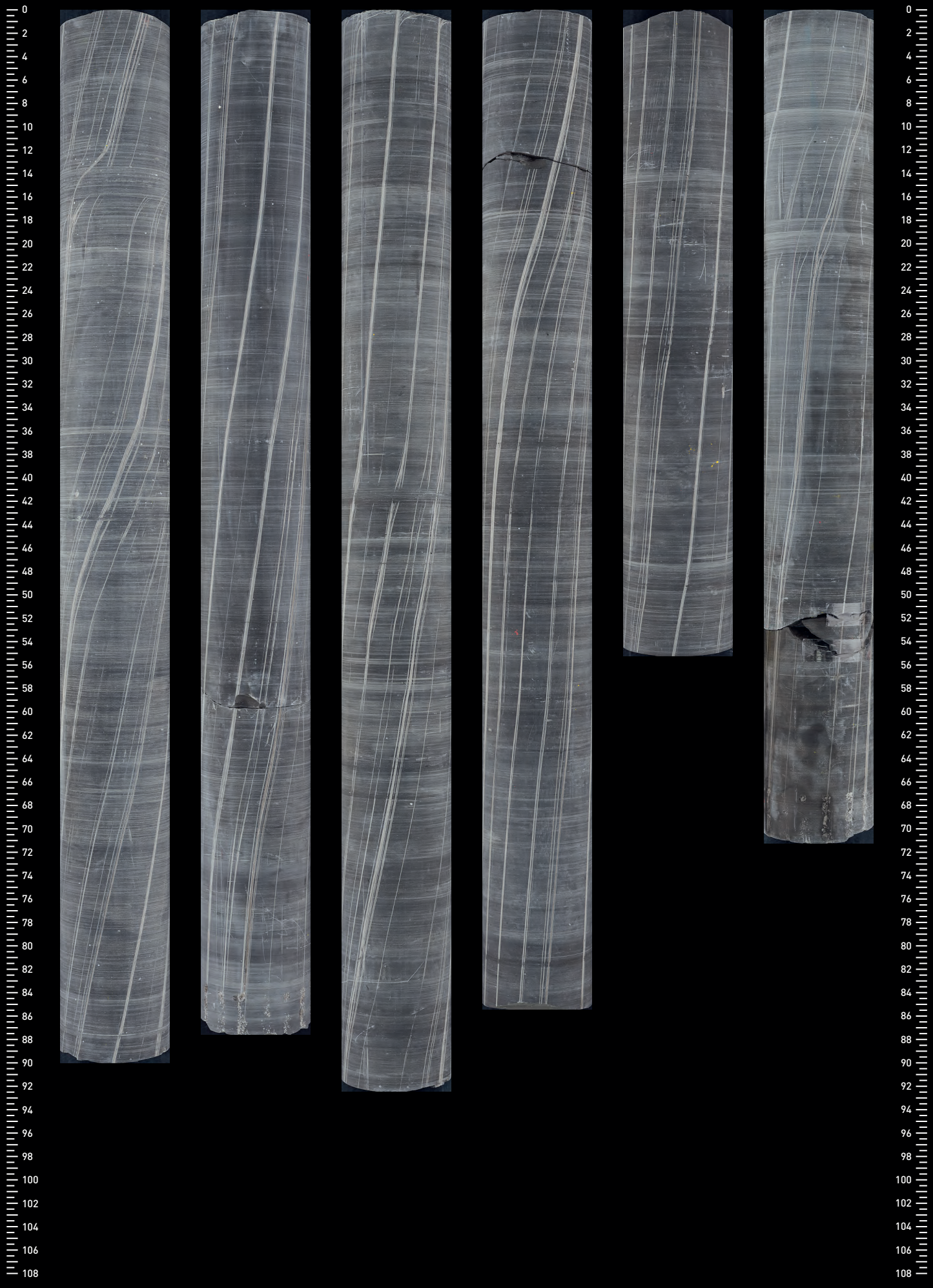
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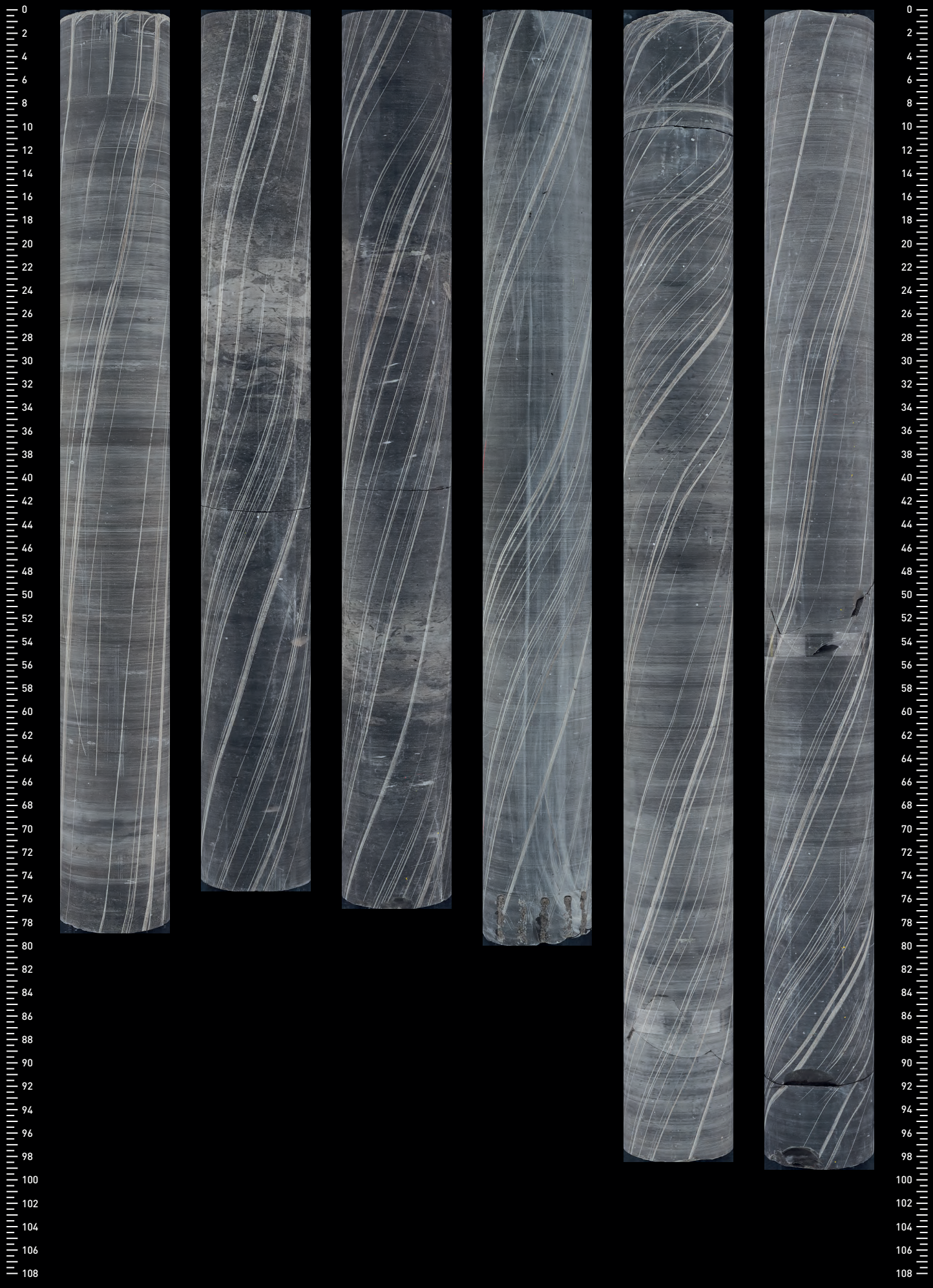
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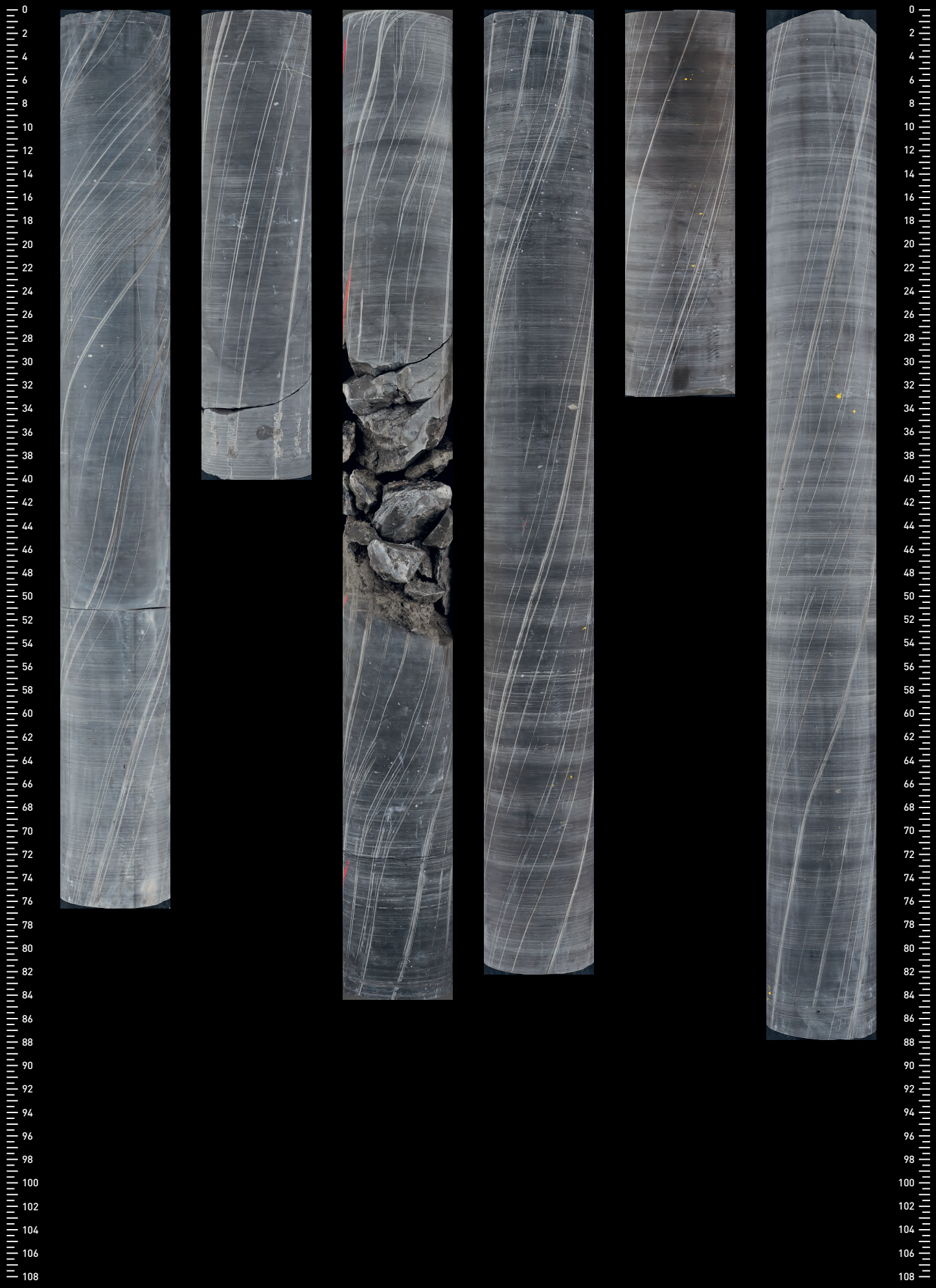
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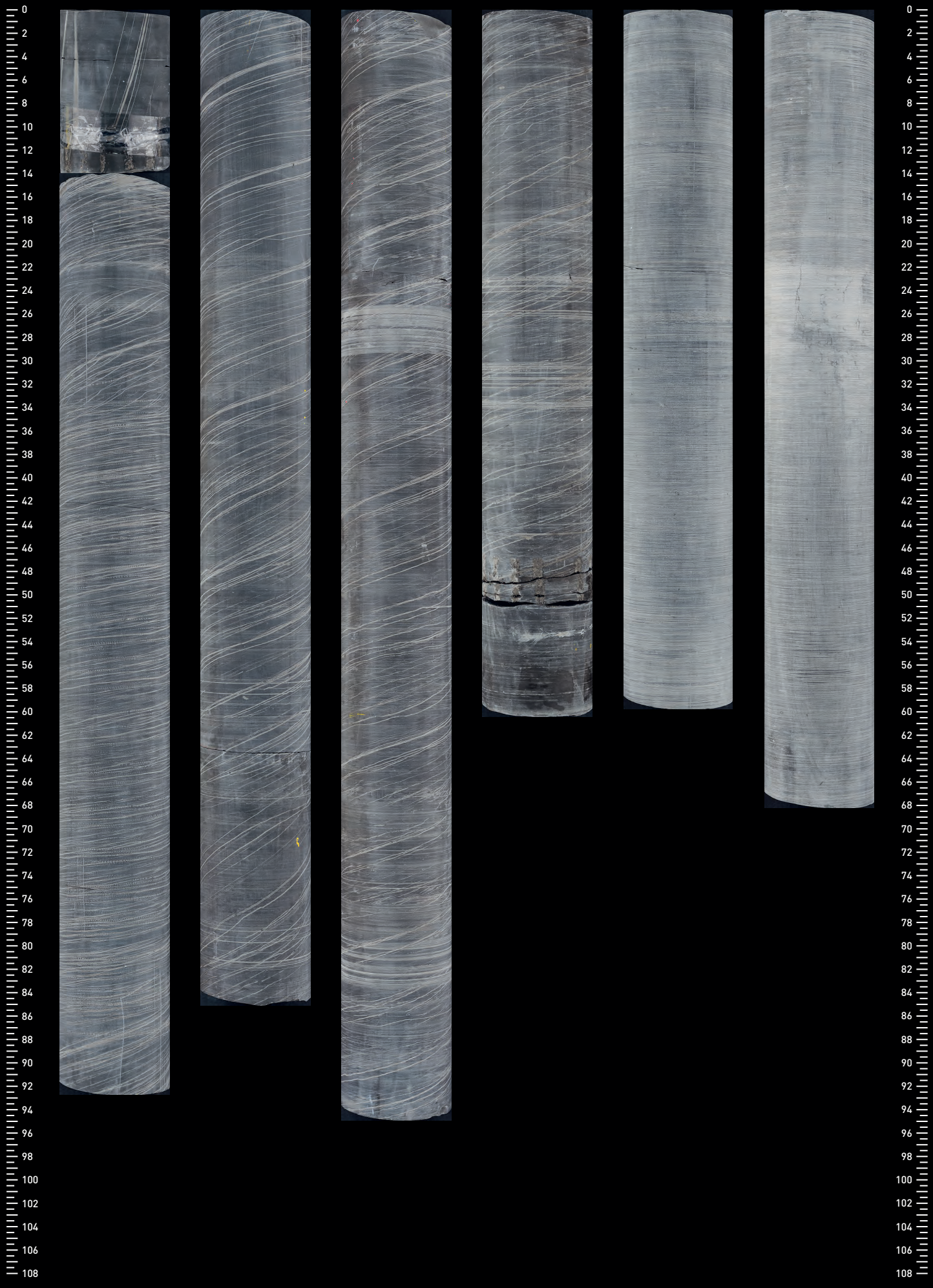
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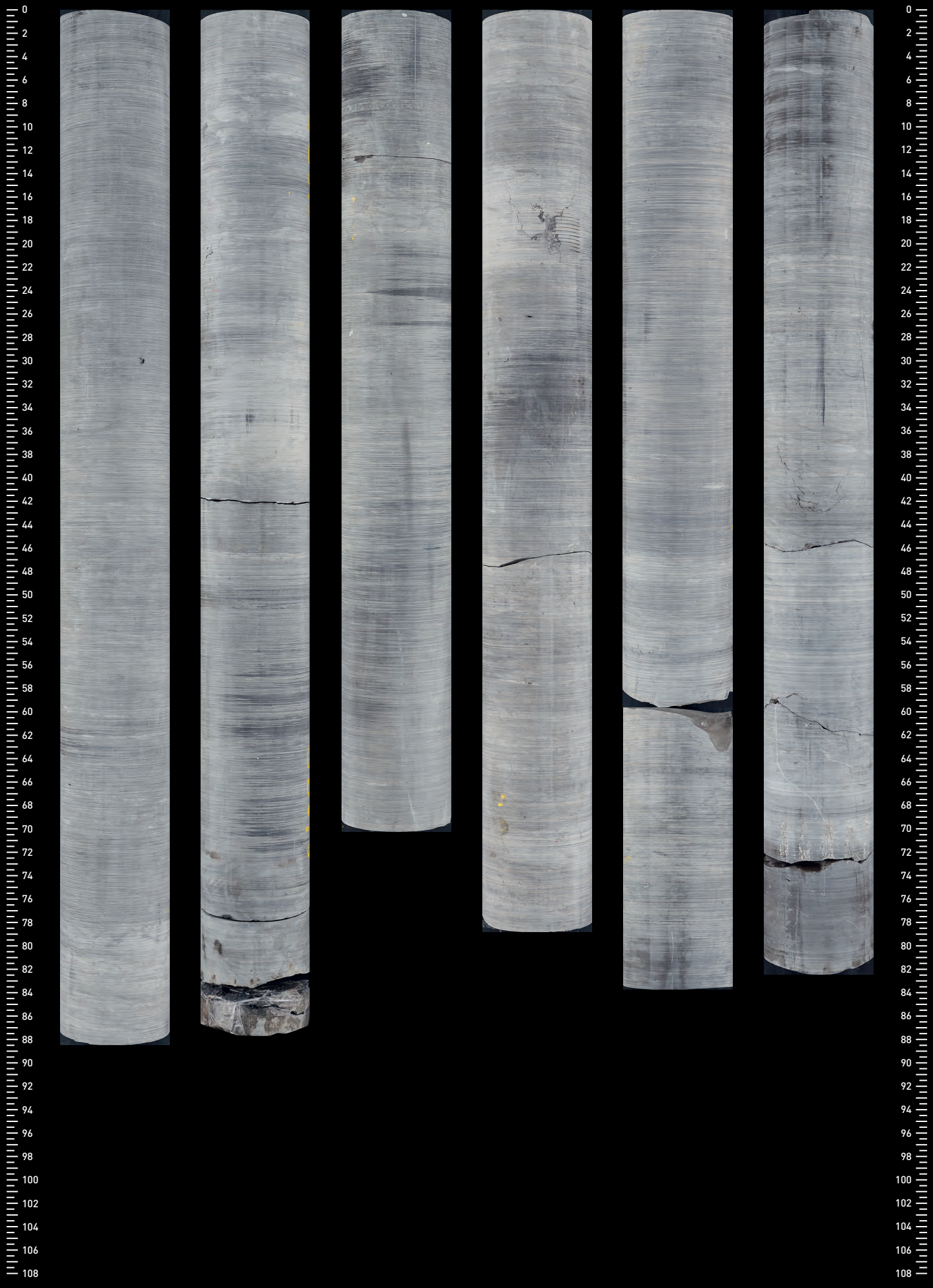
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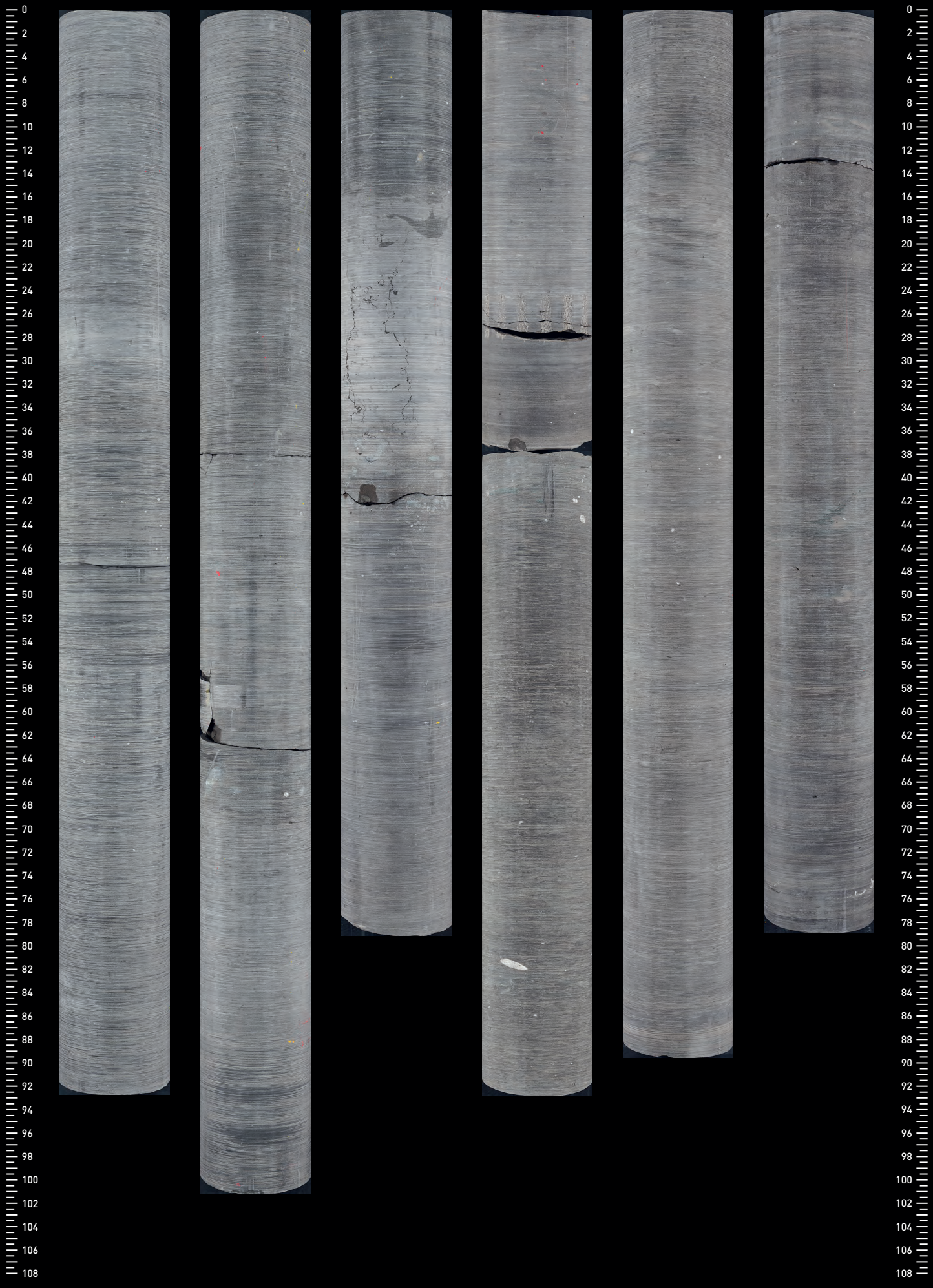
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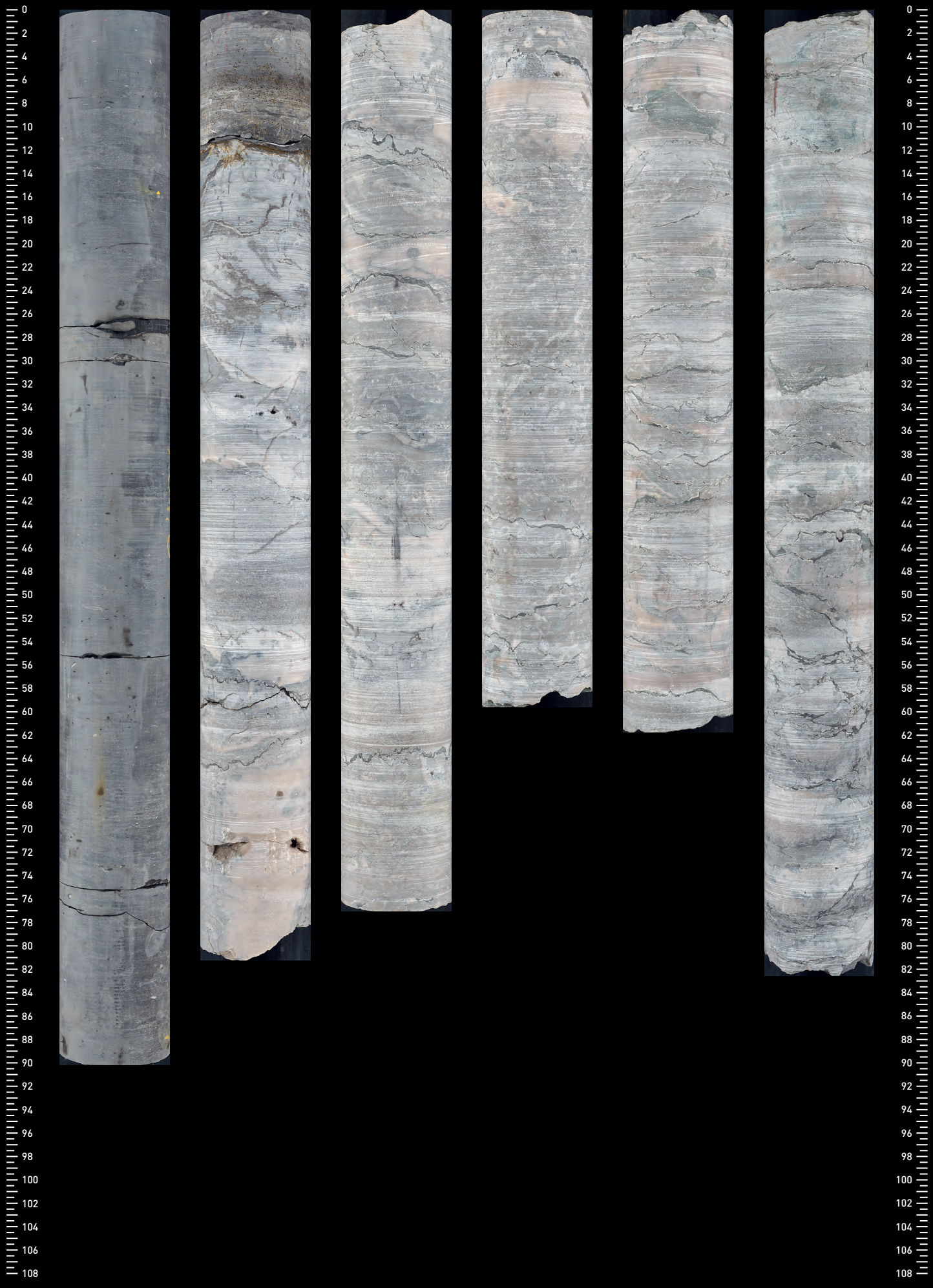
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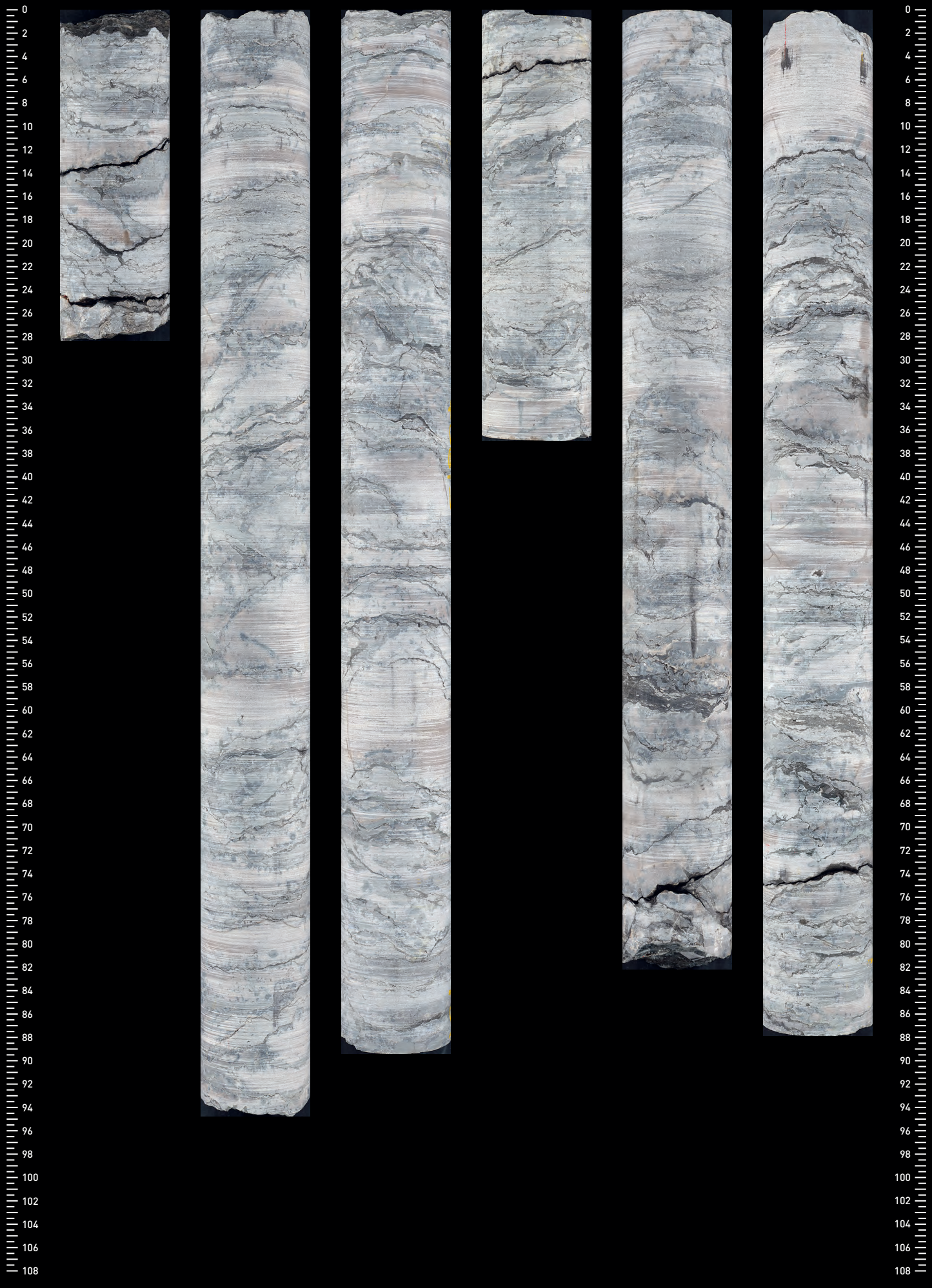
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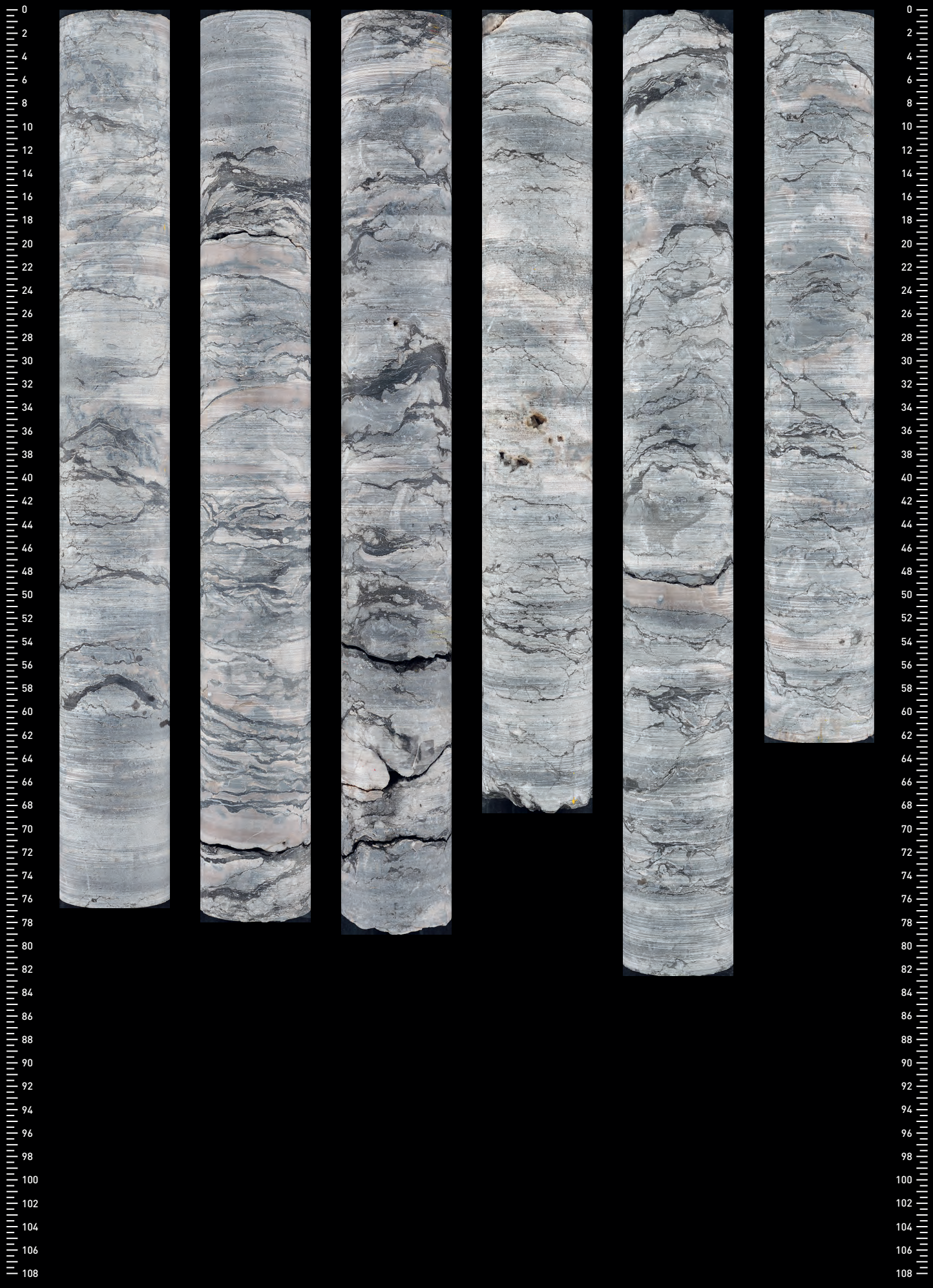
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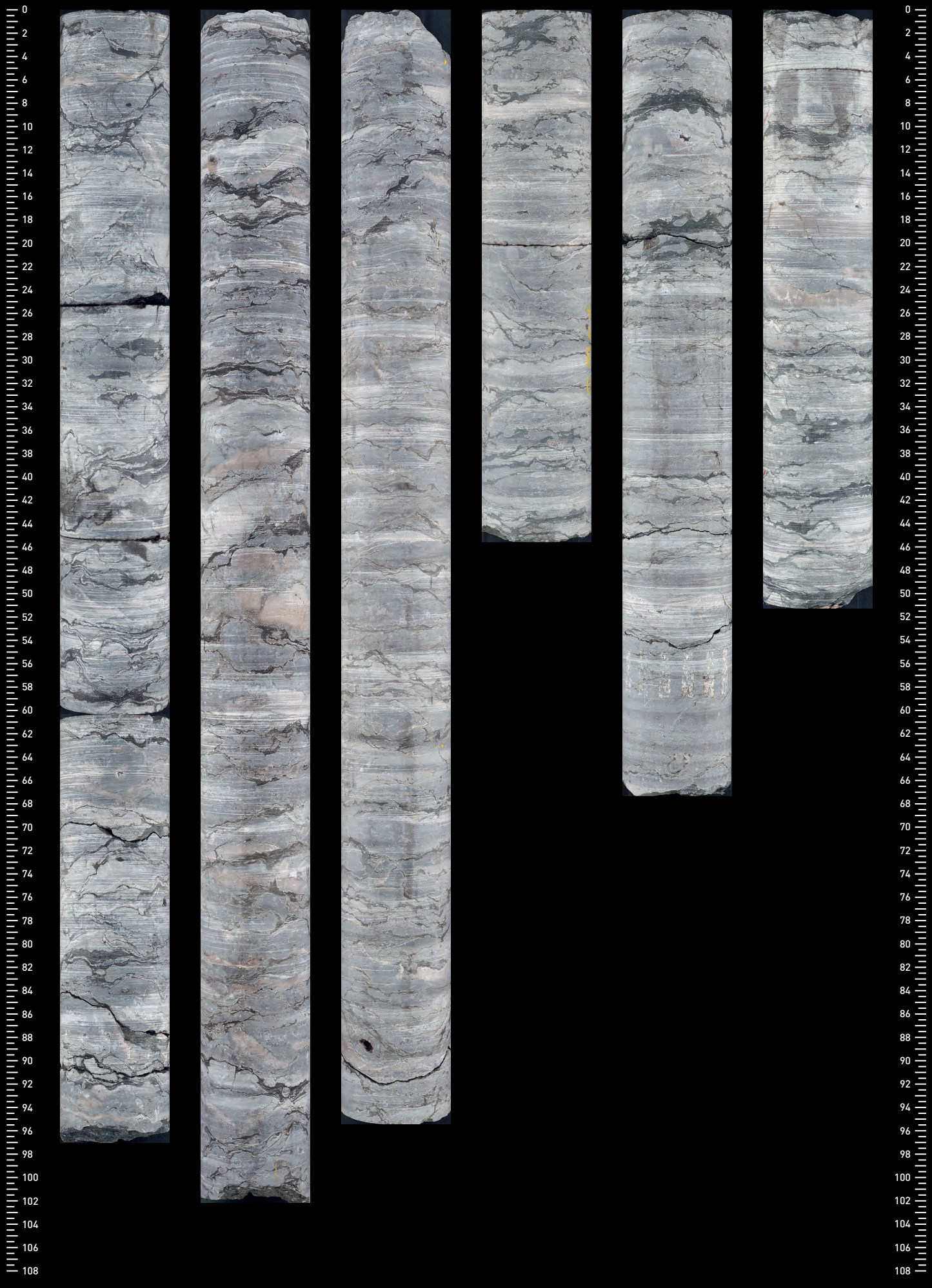
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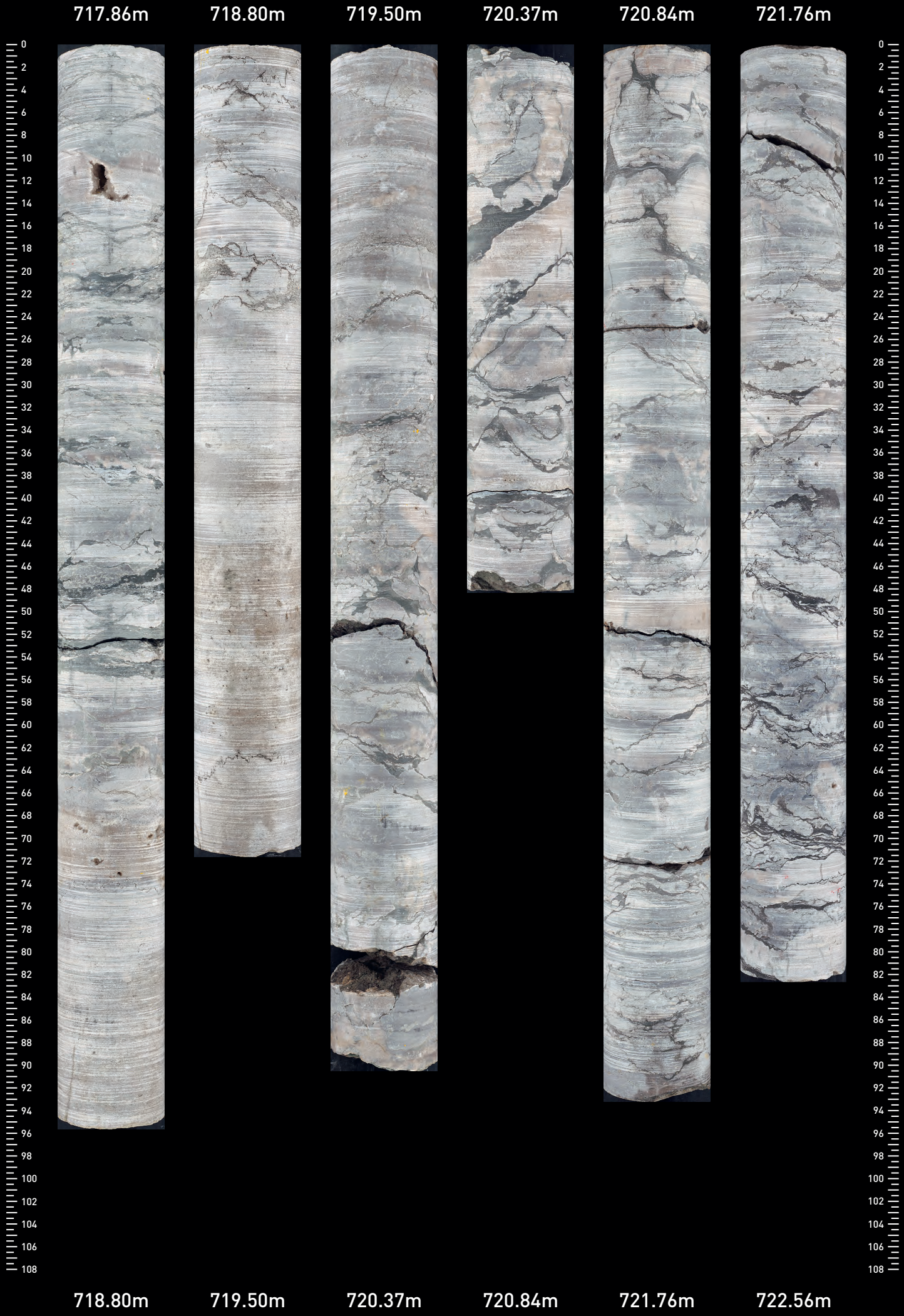


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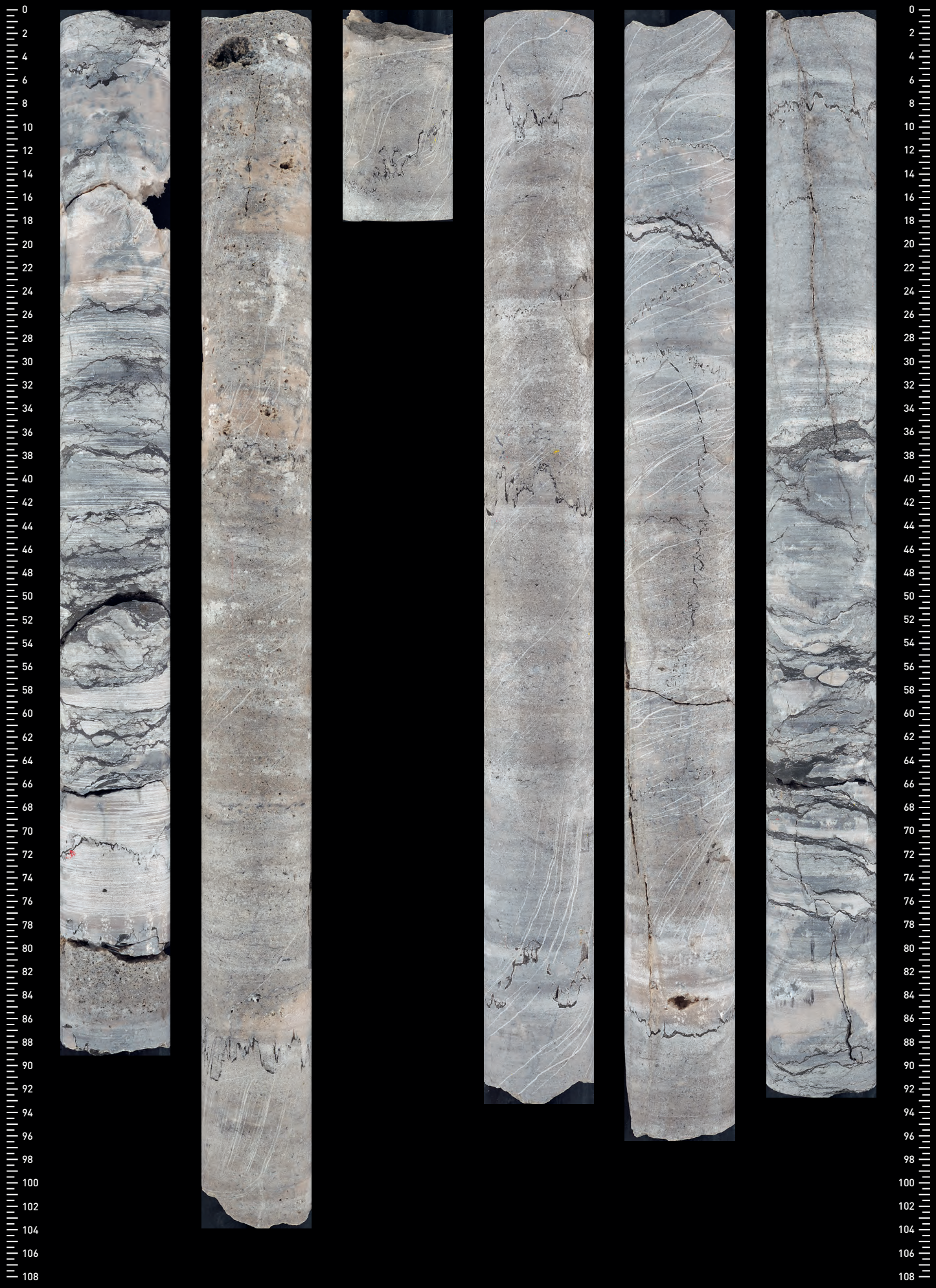
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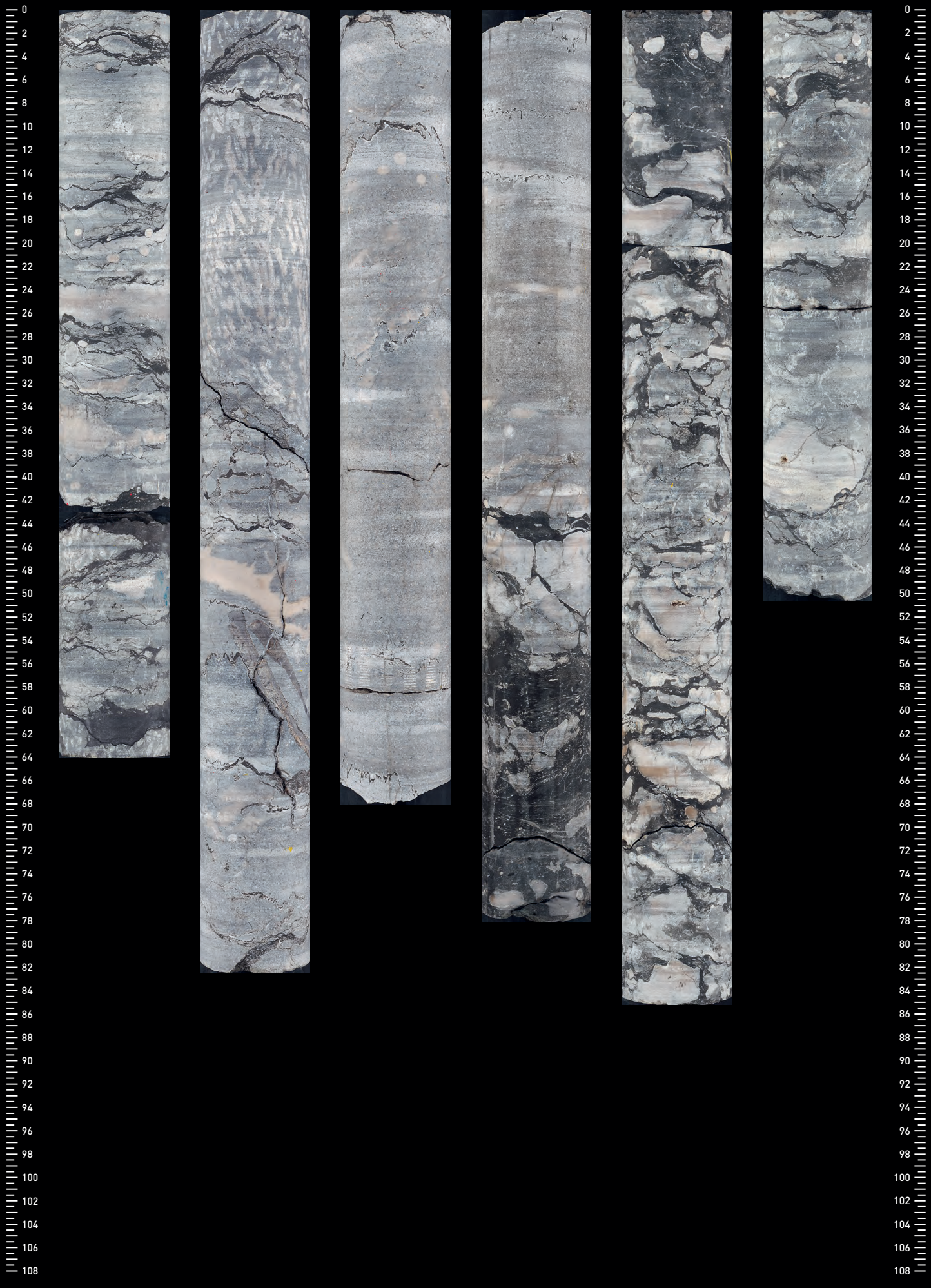

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722.56m 723.44m 724.44m 724.60m 725.50m 726.43m



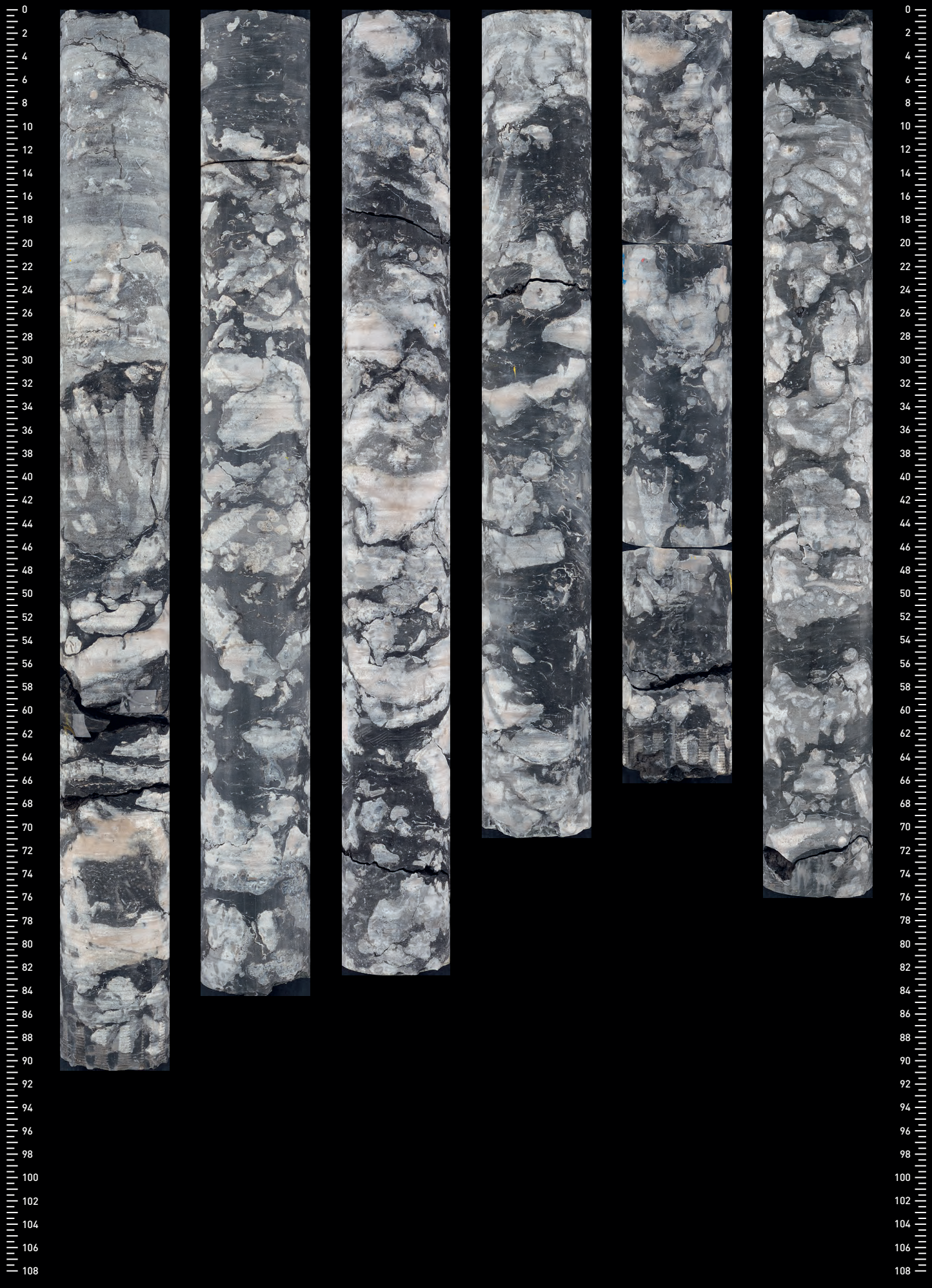
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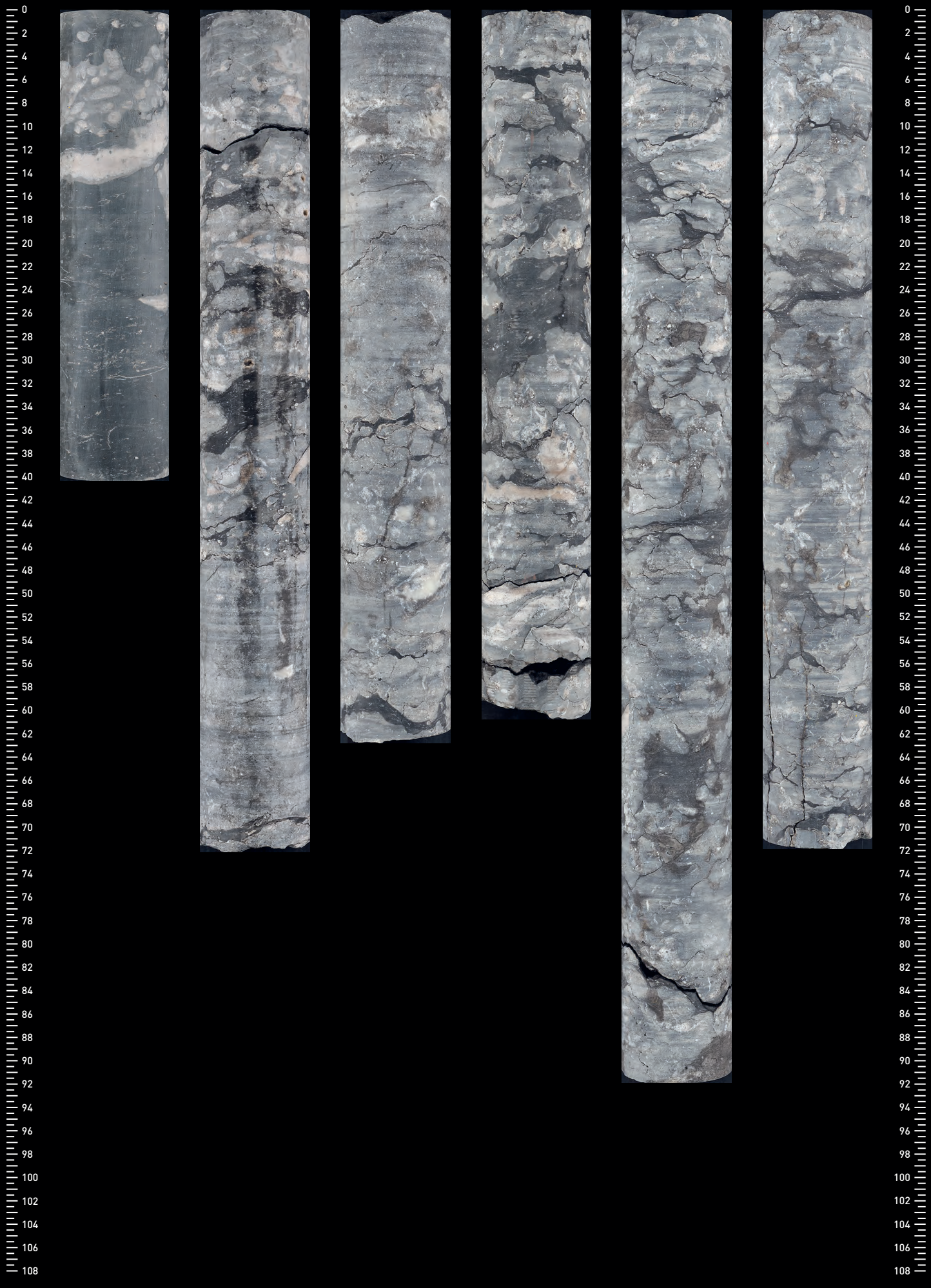
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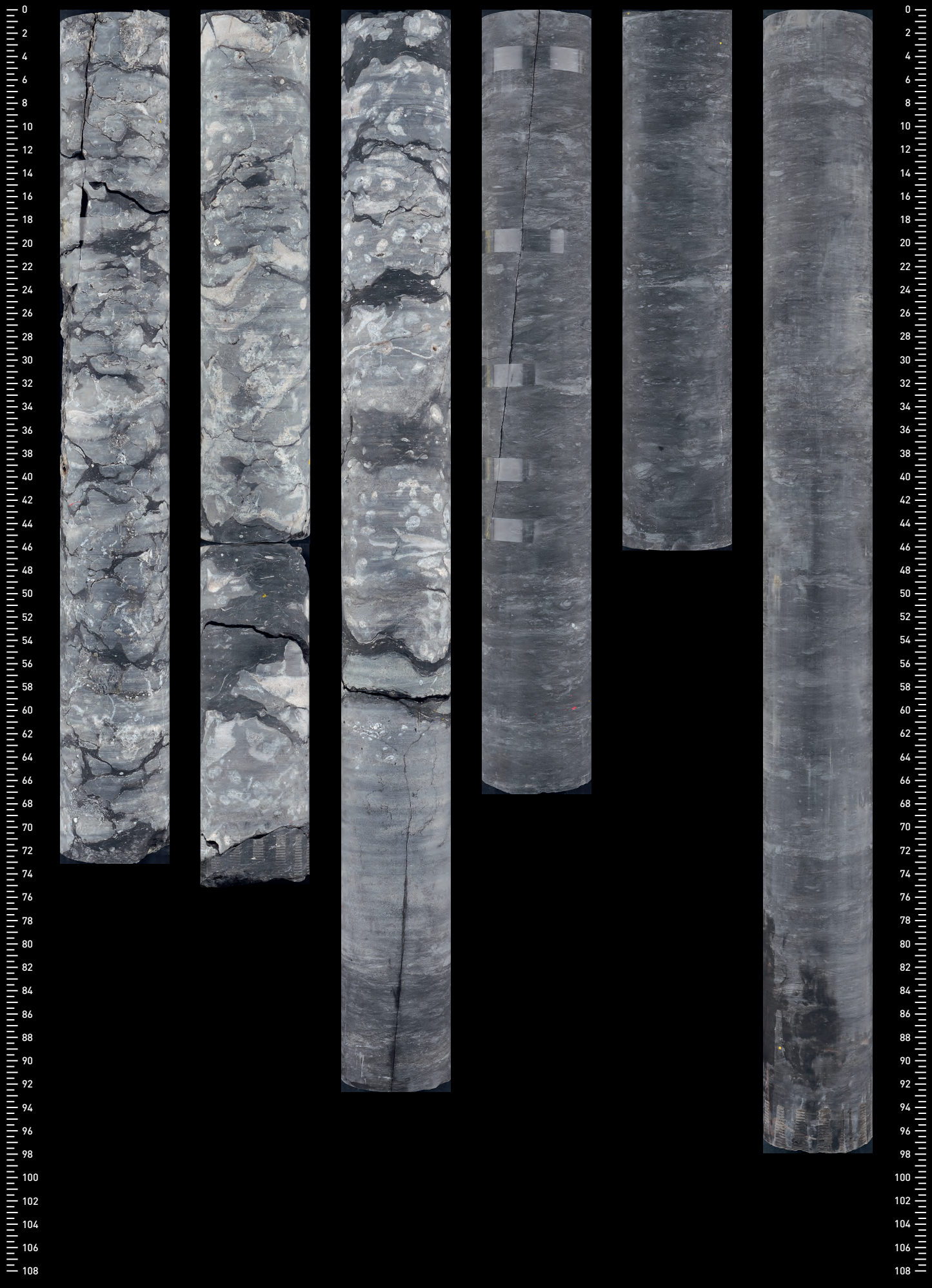
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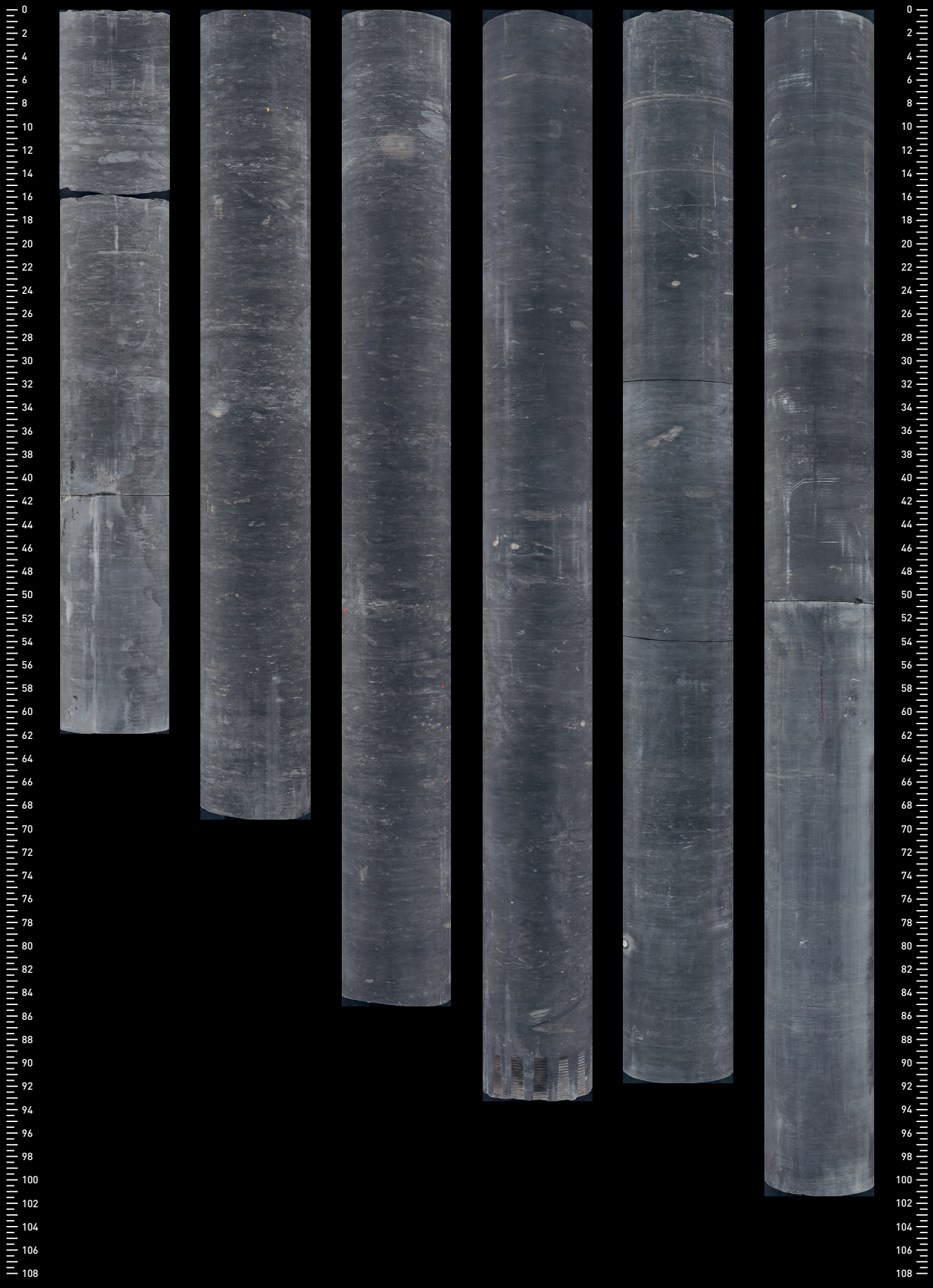
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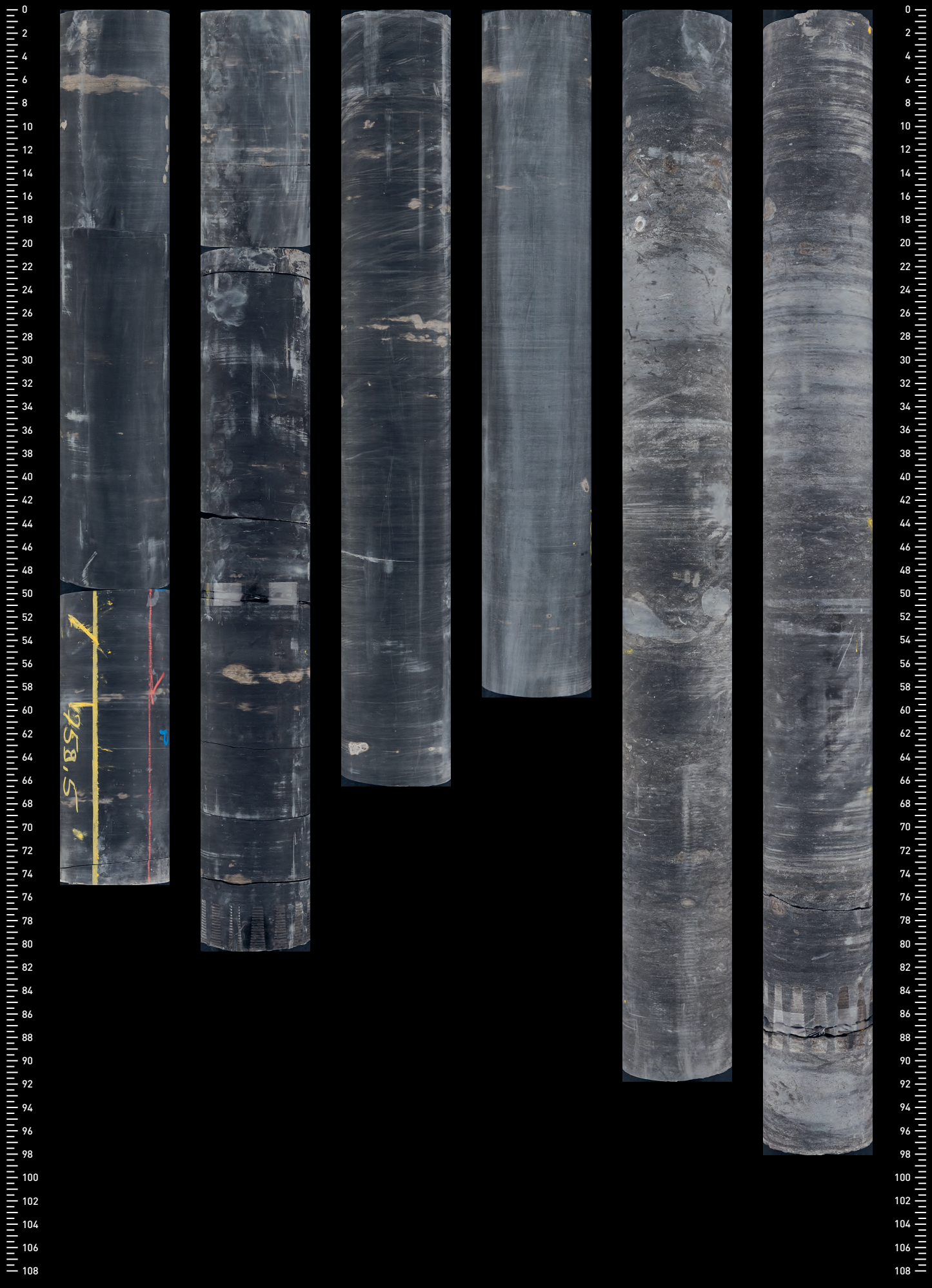
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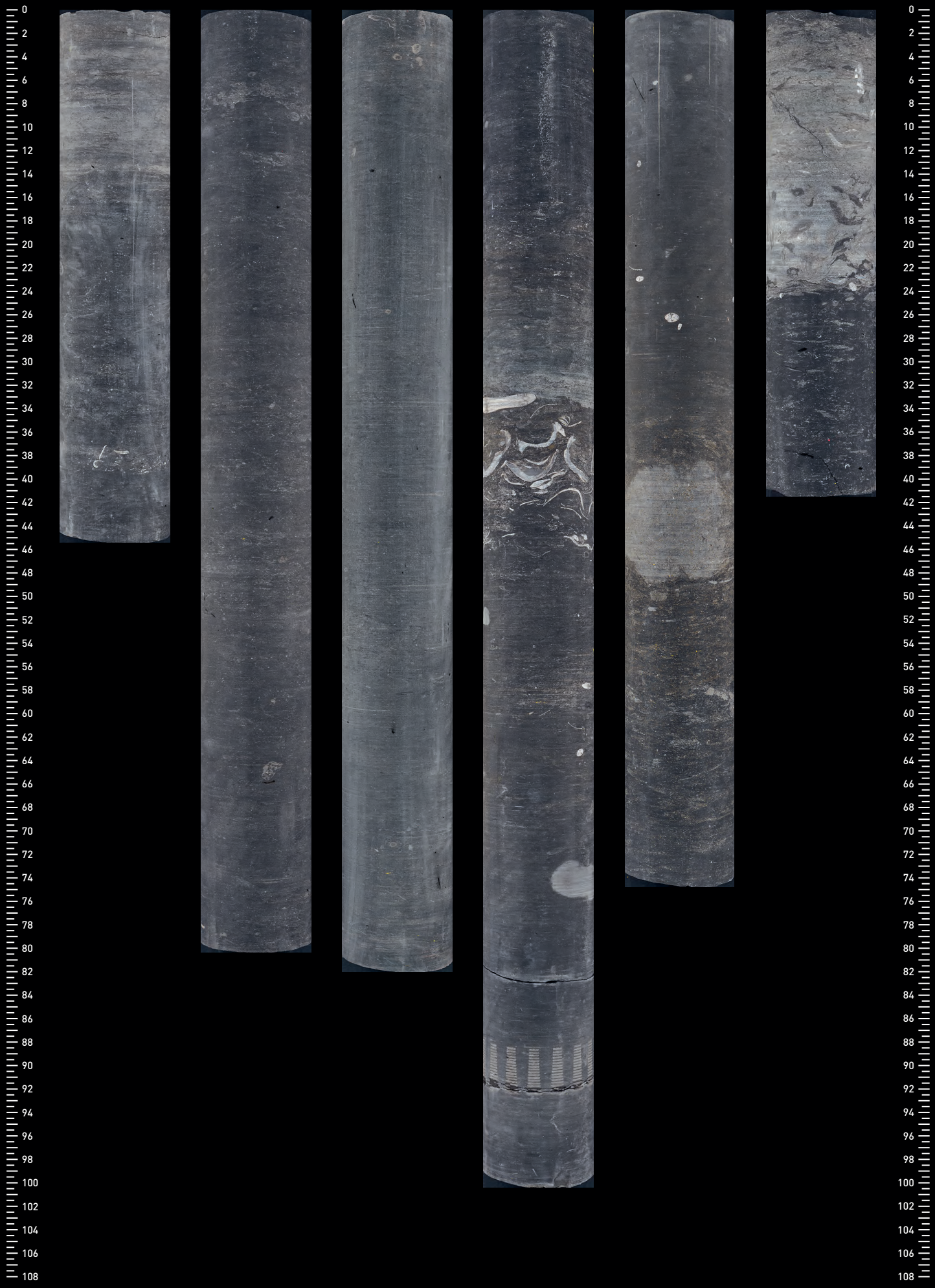
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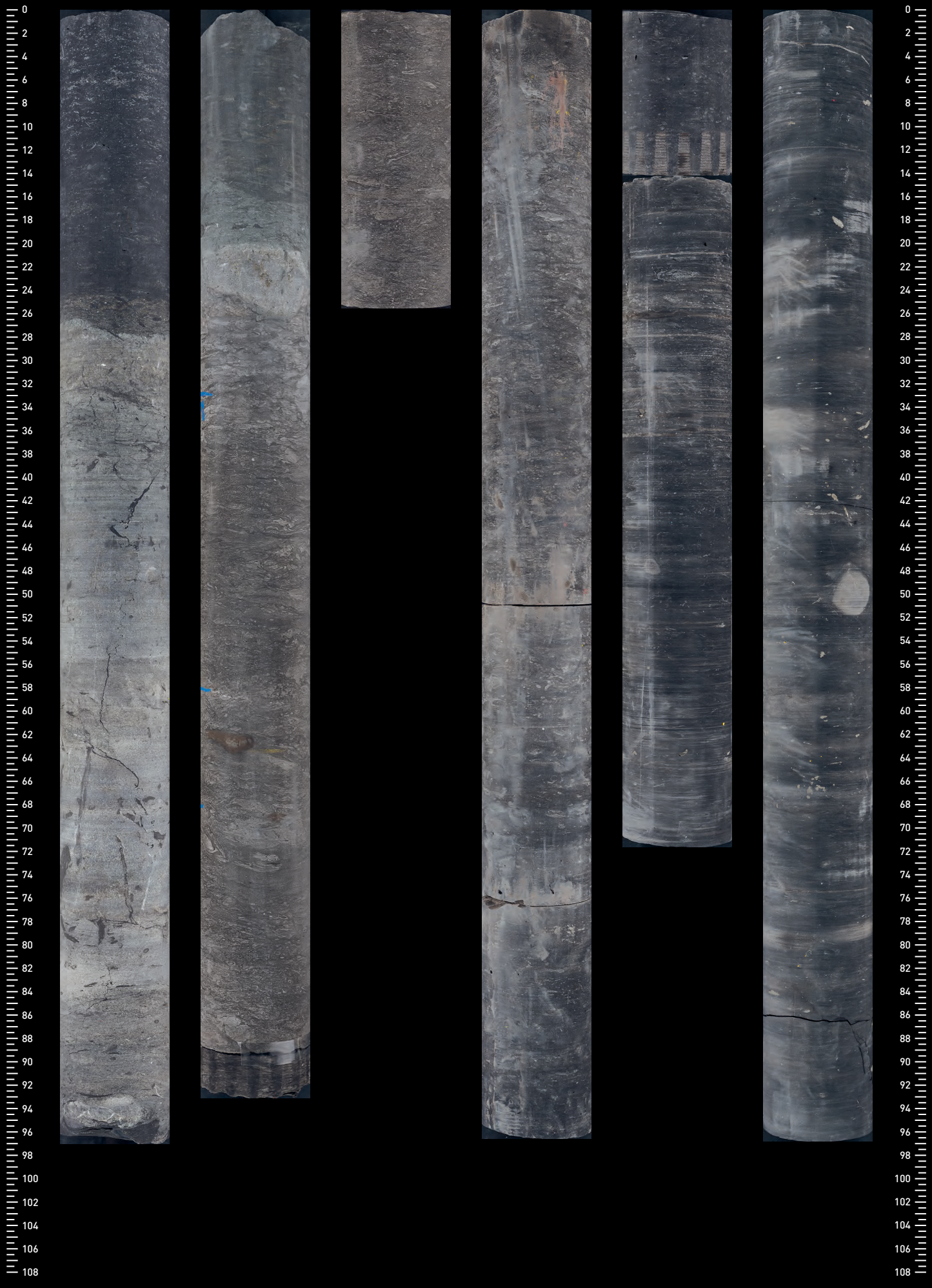
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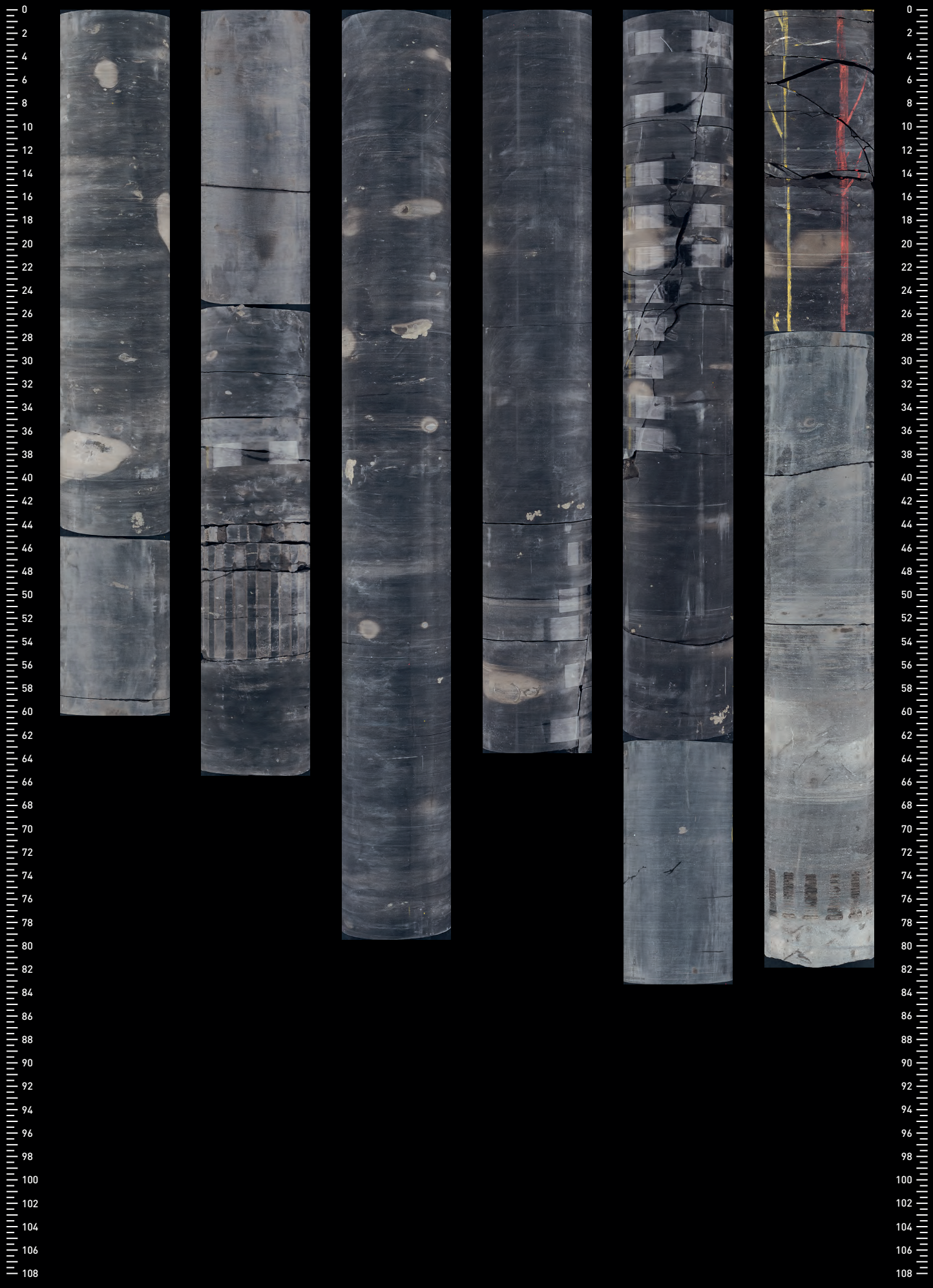
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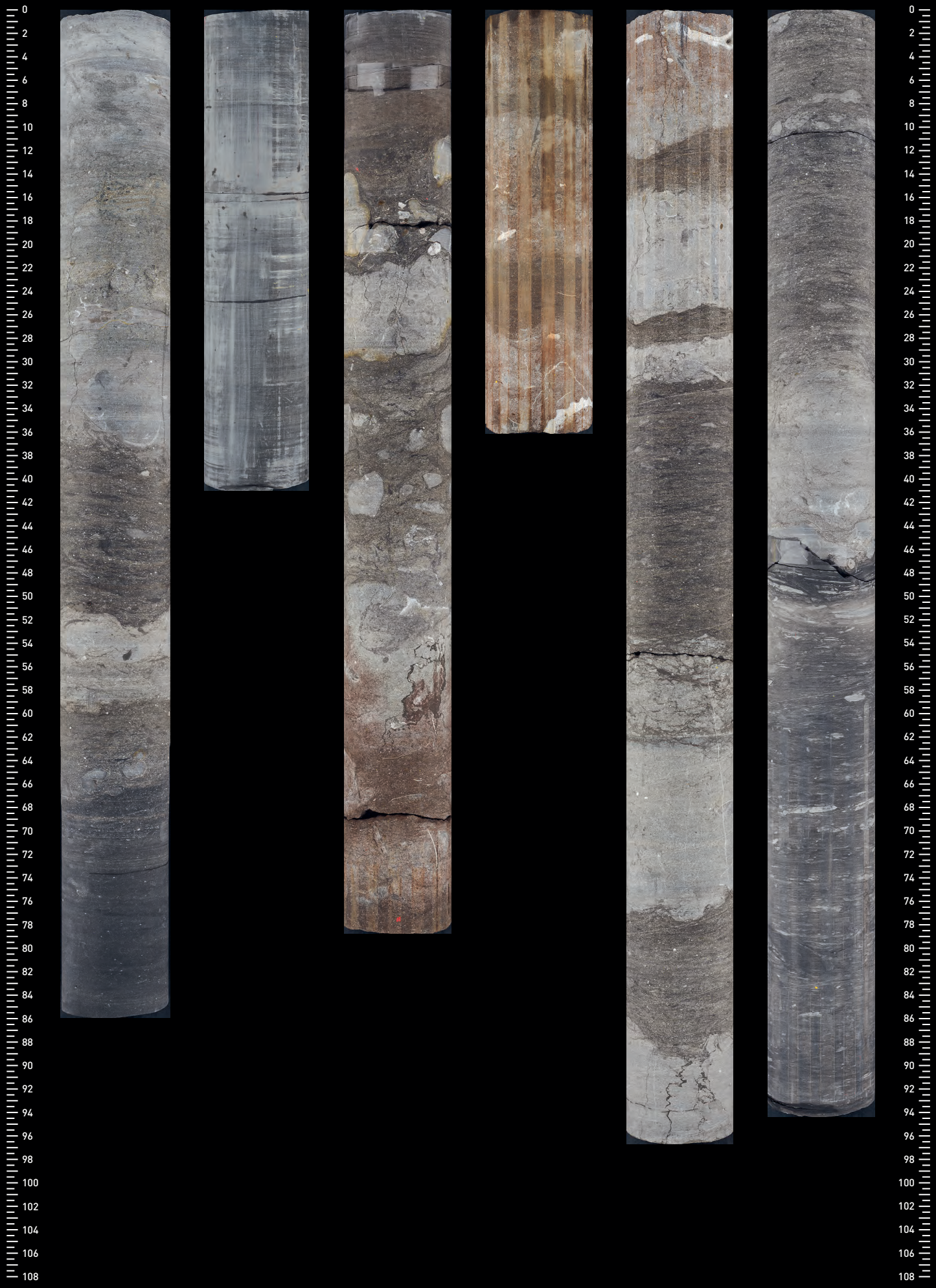
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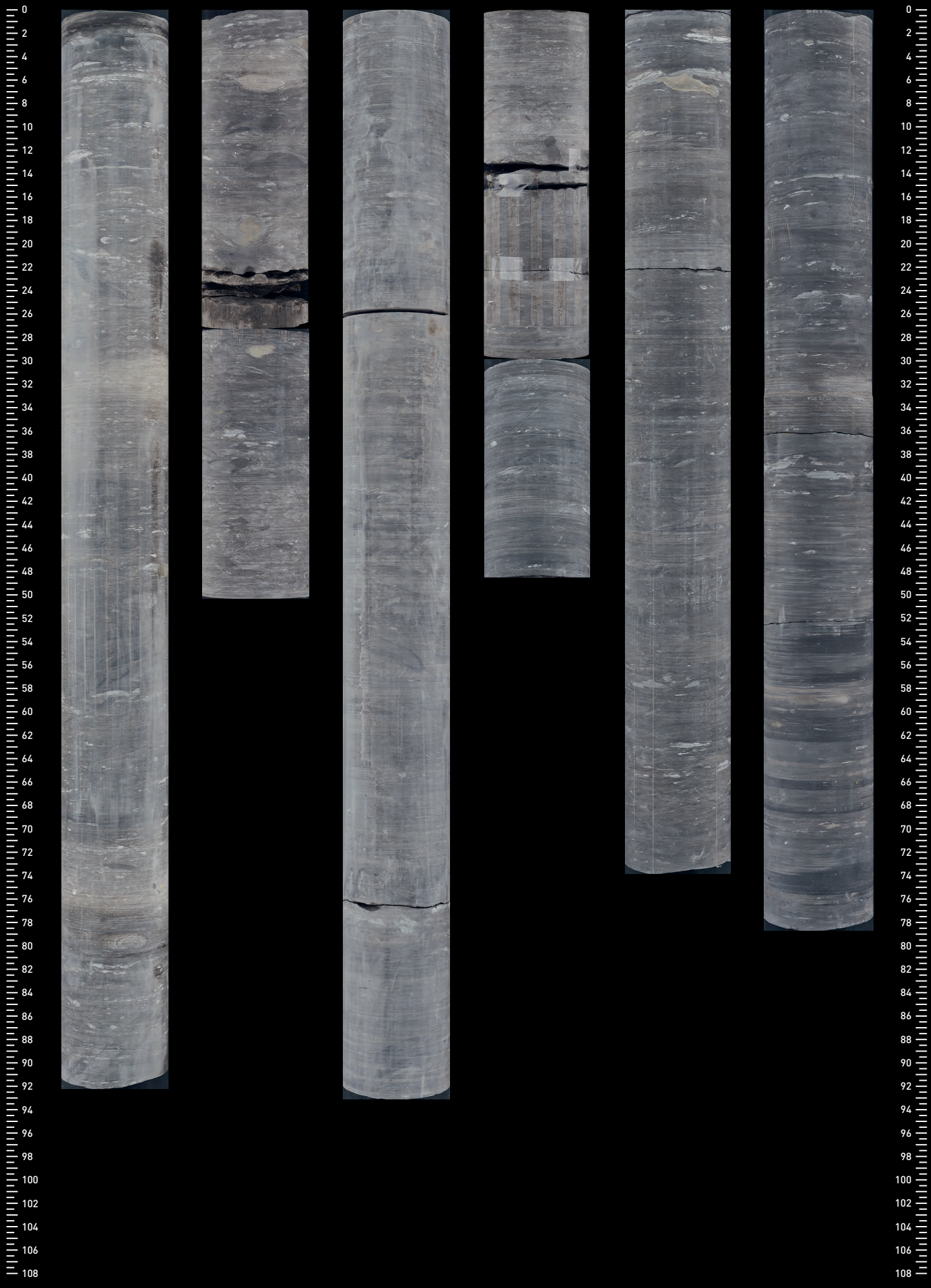
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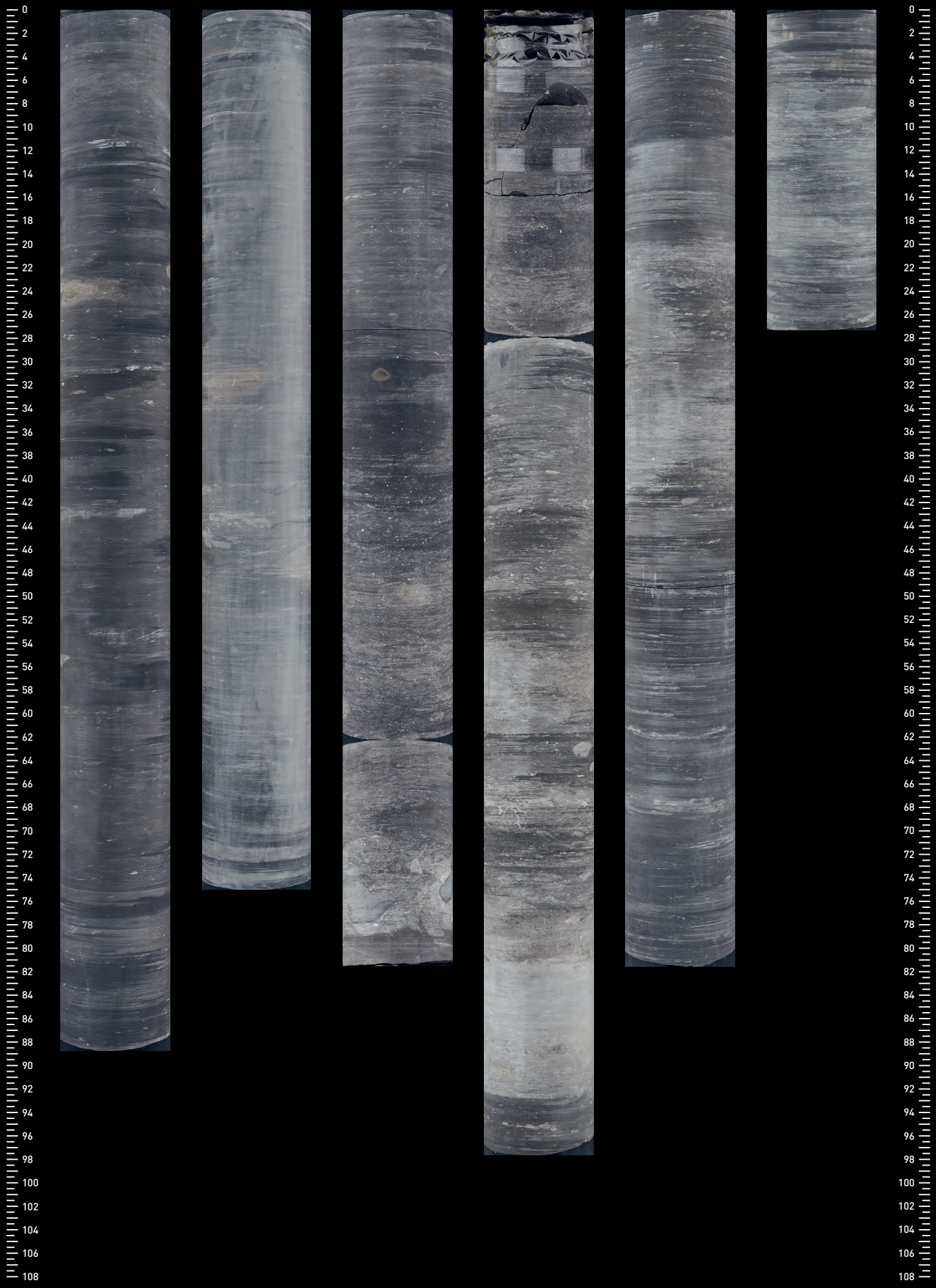
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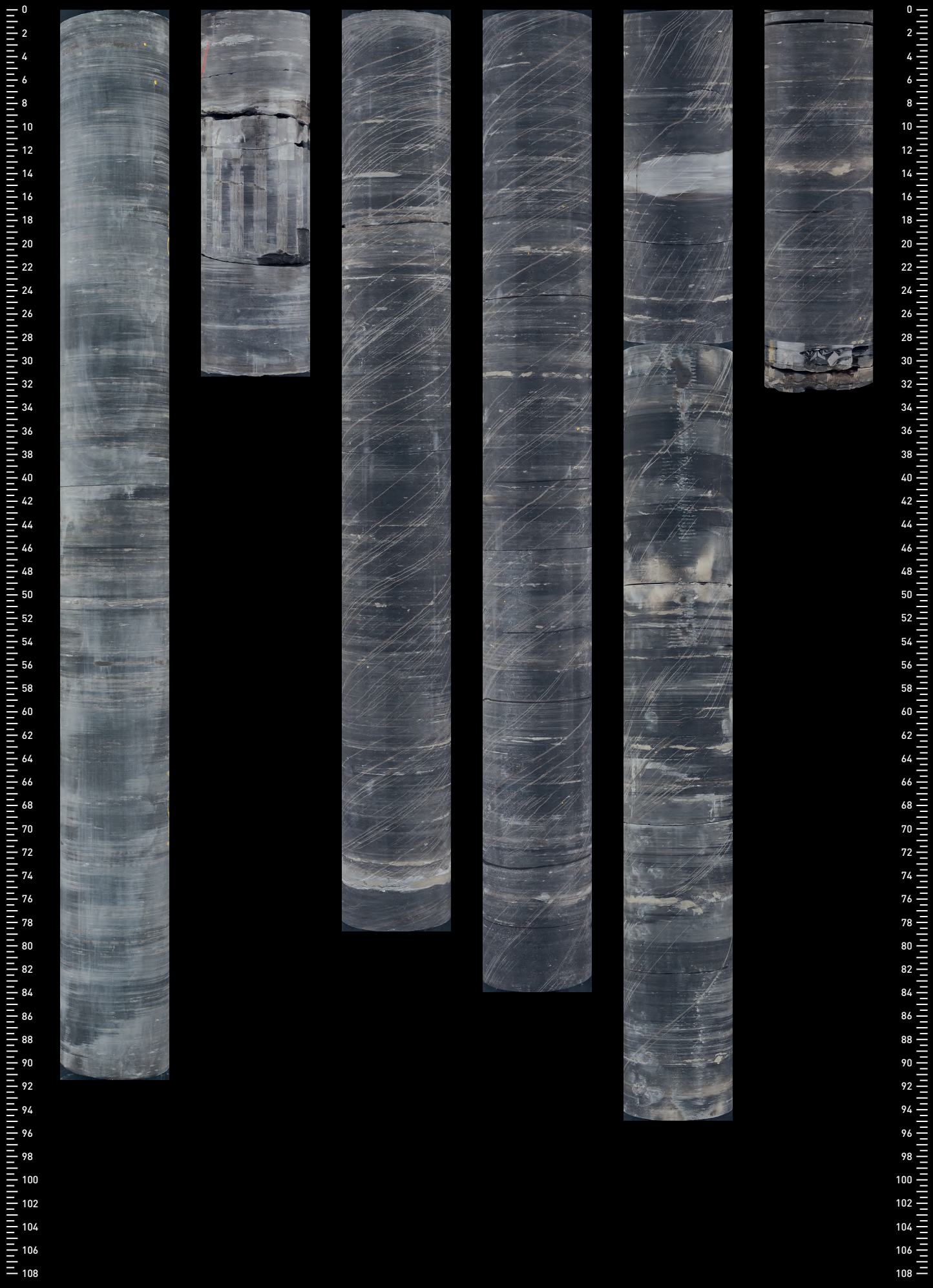
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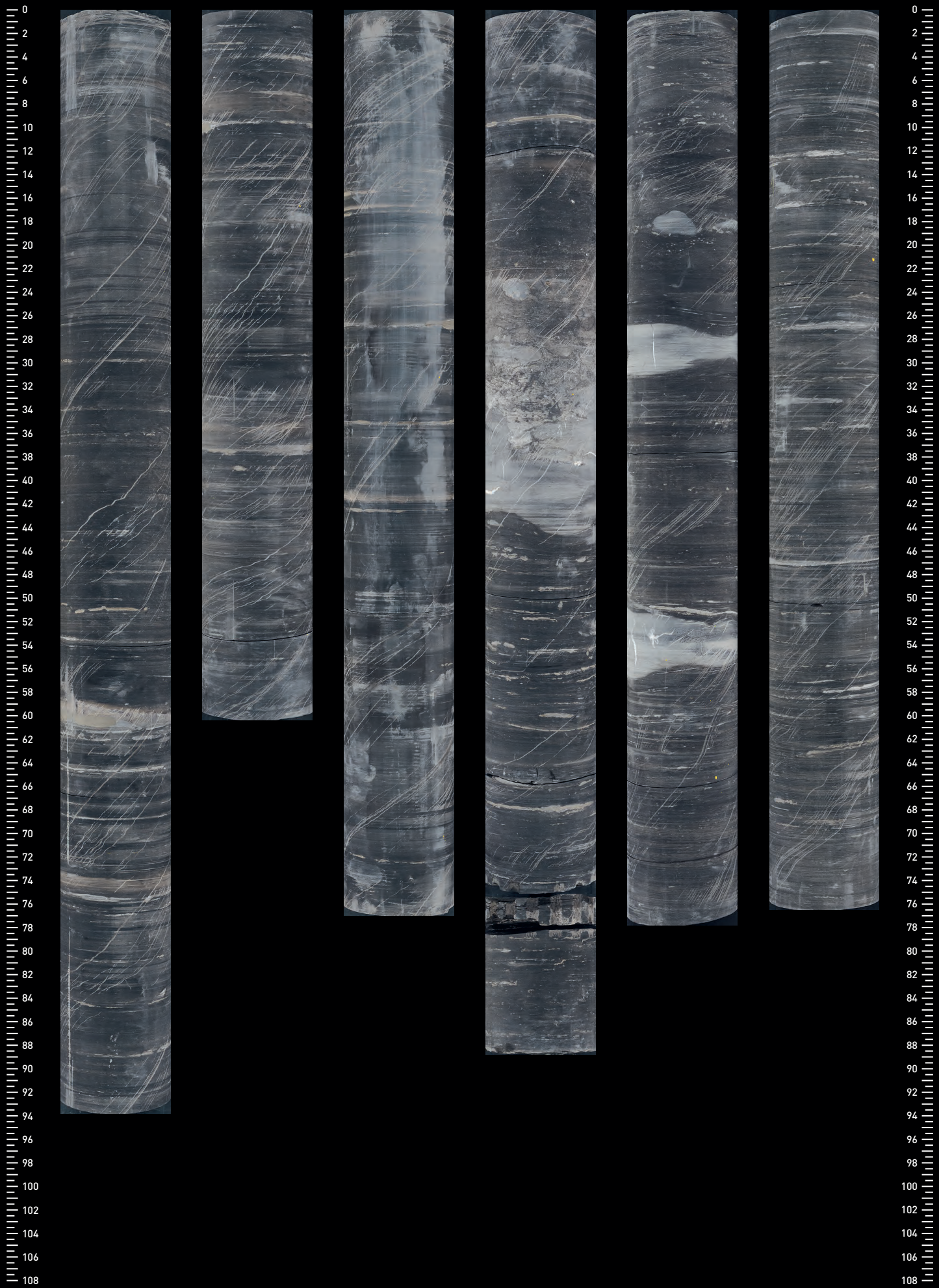
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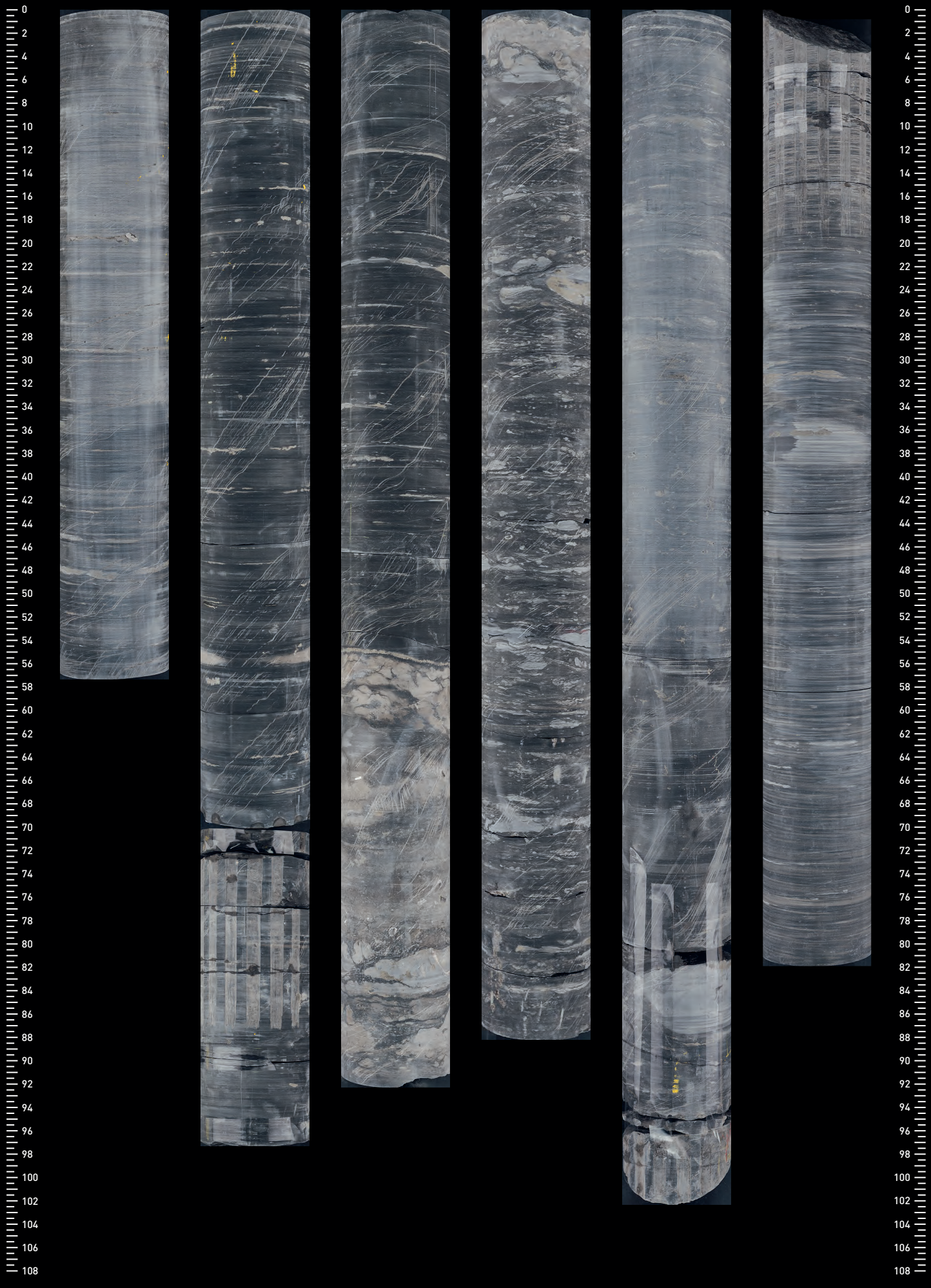
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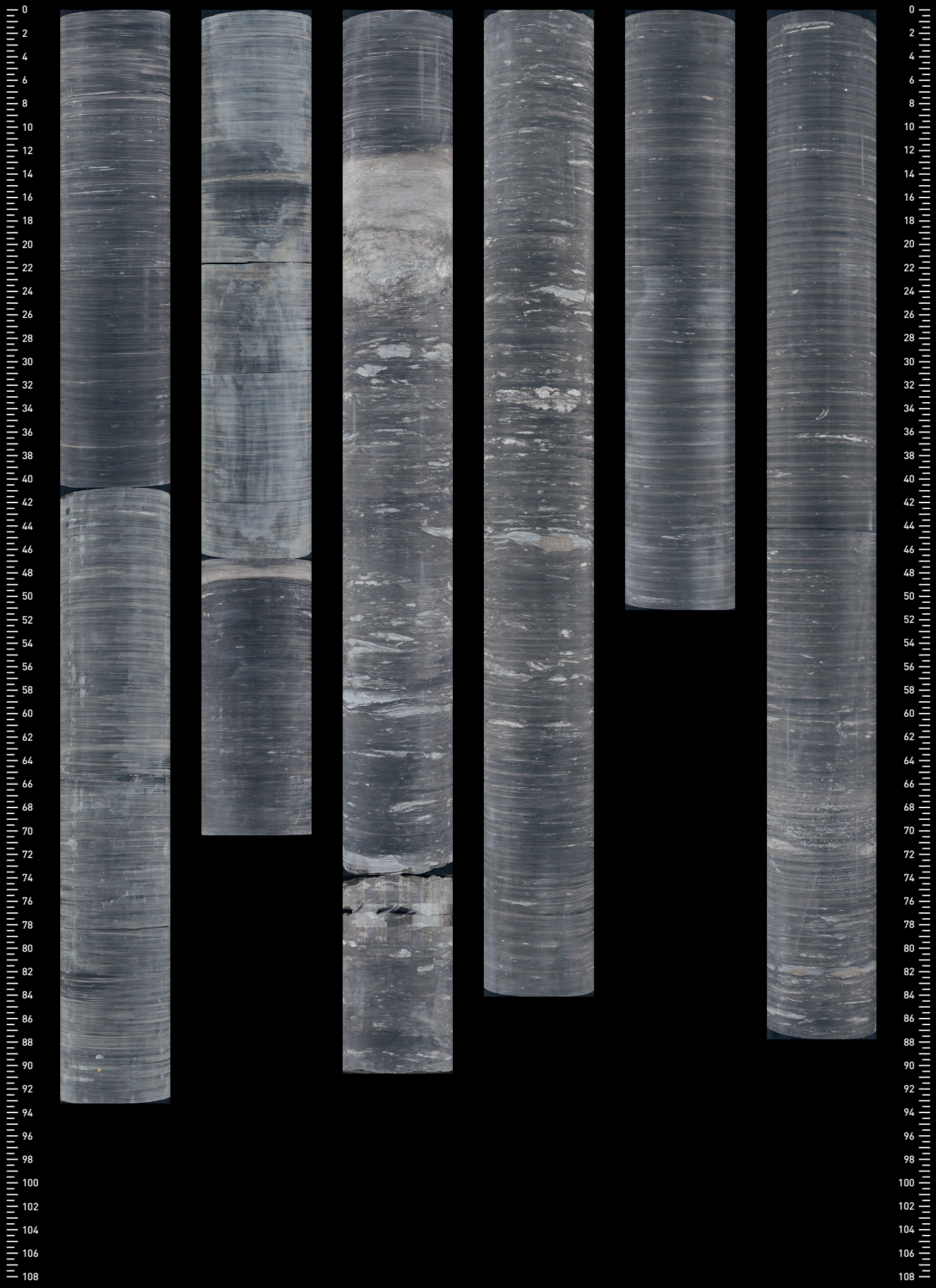
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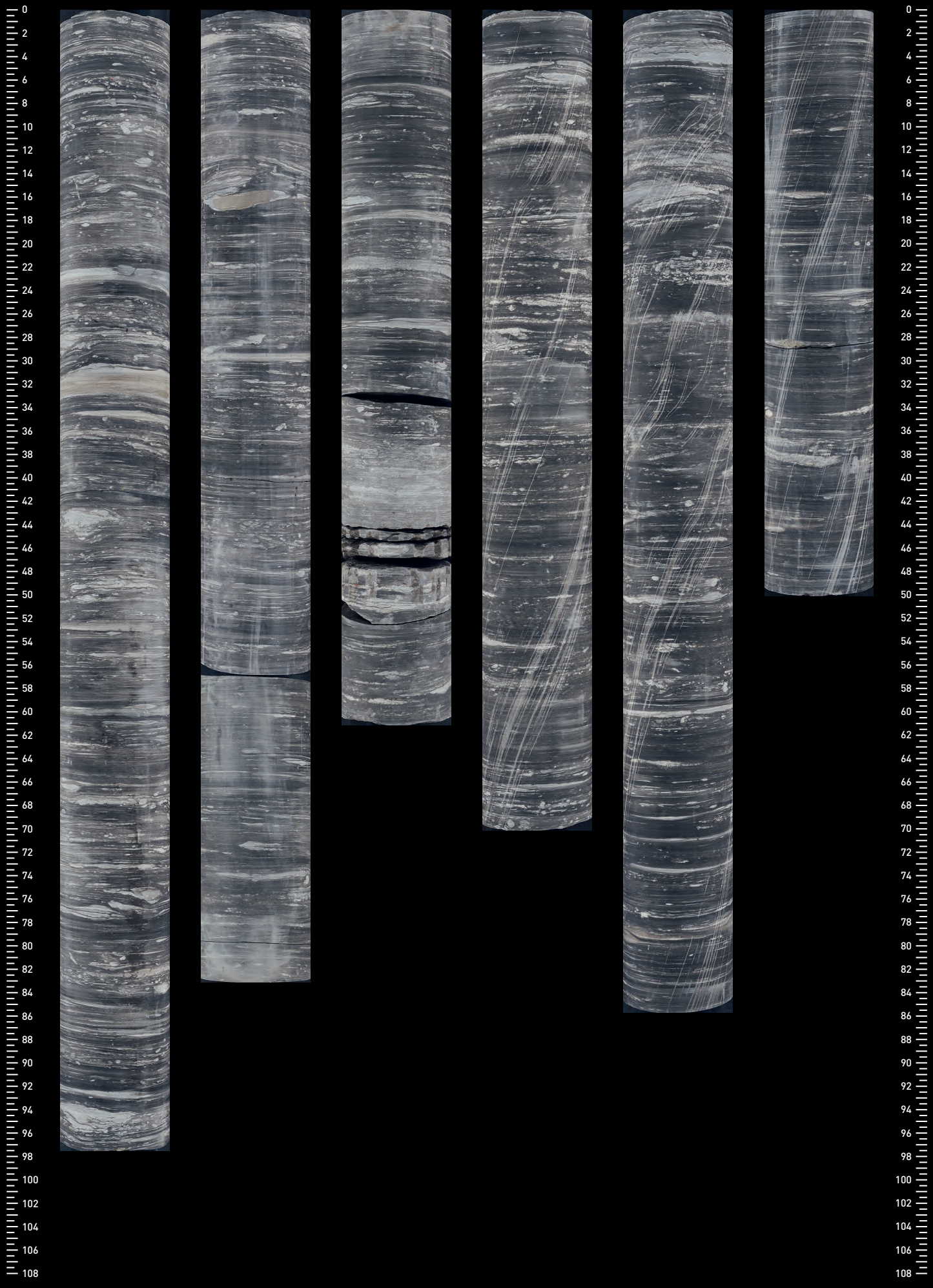
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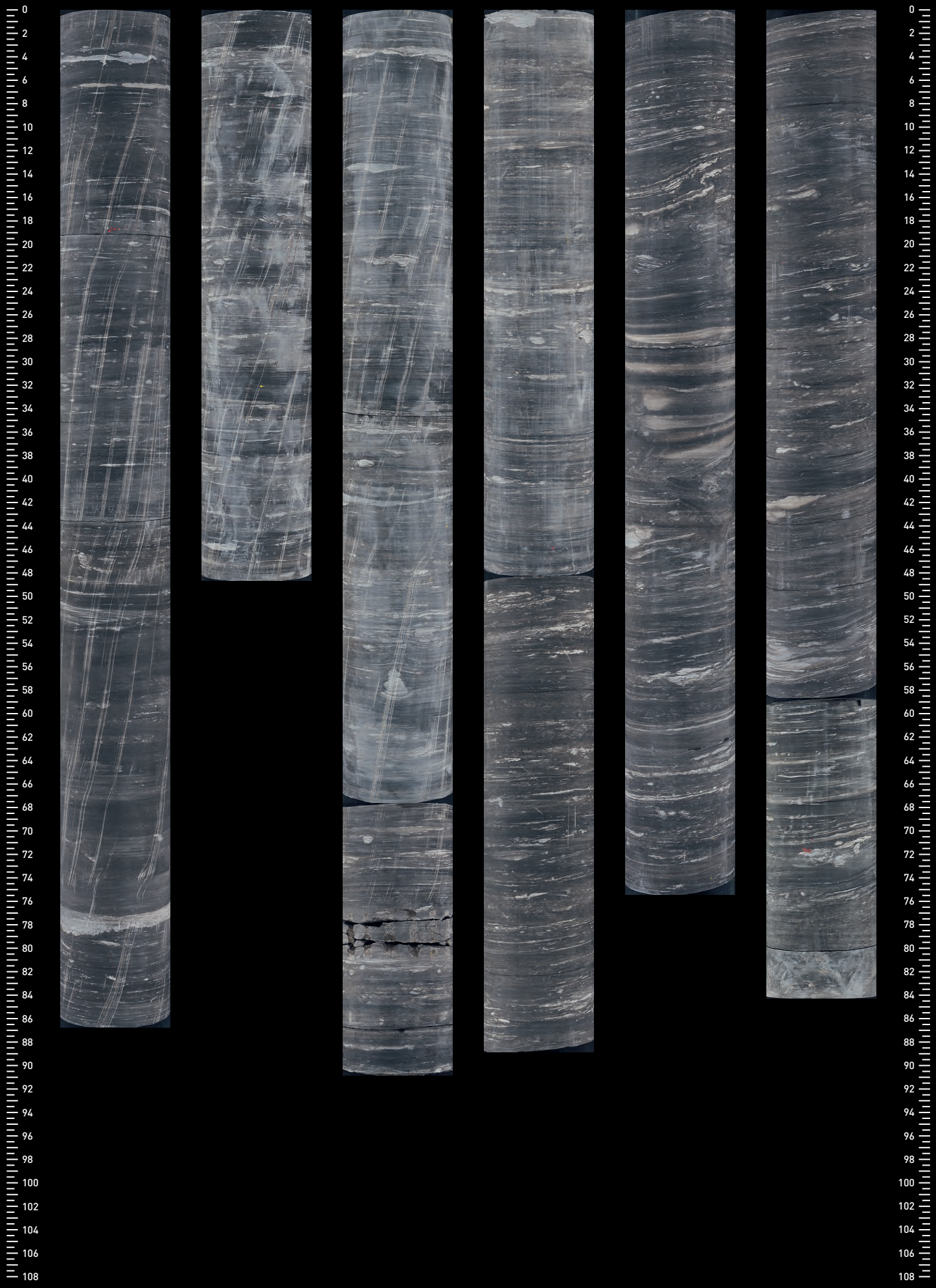
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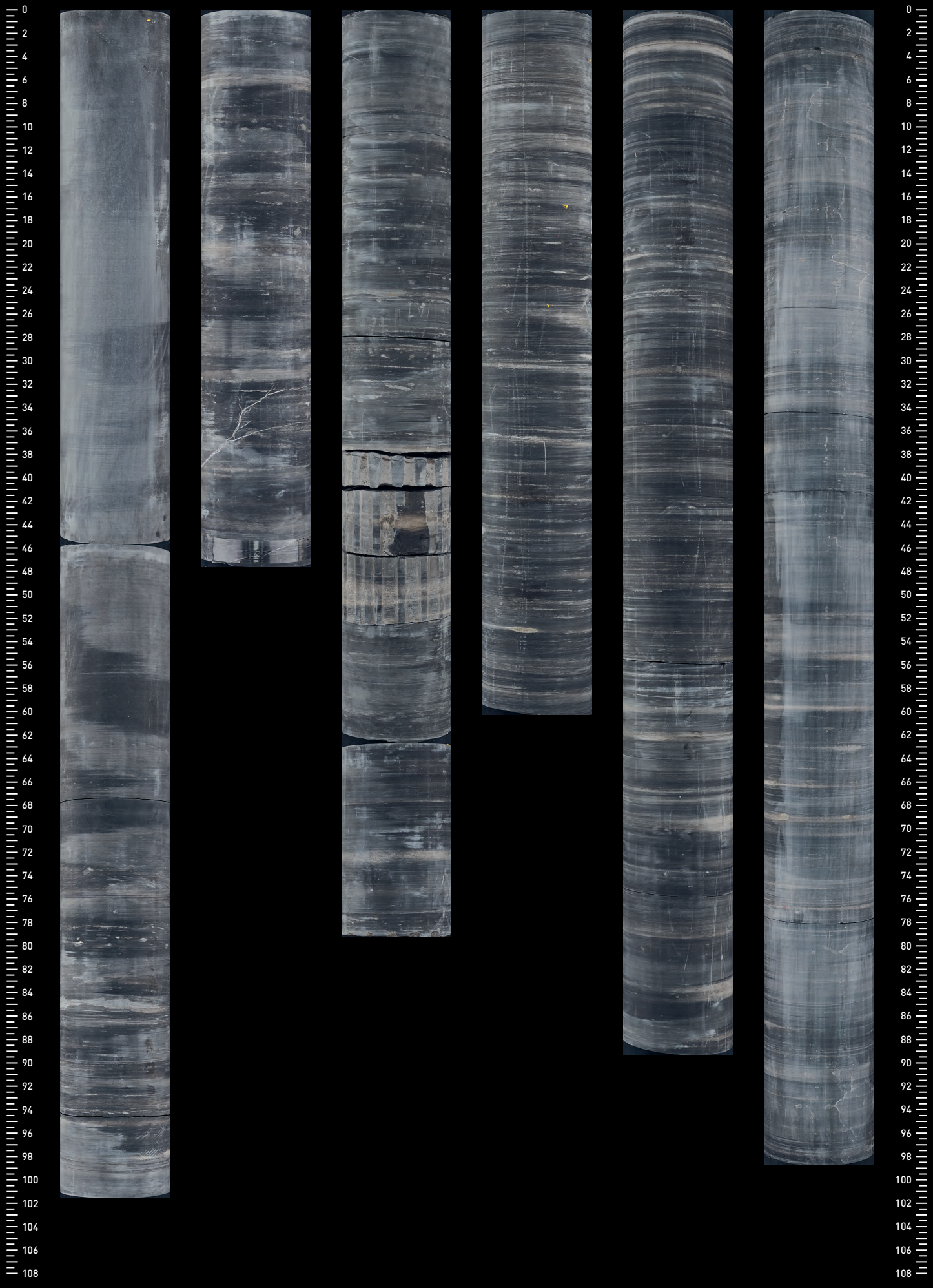
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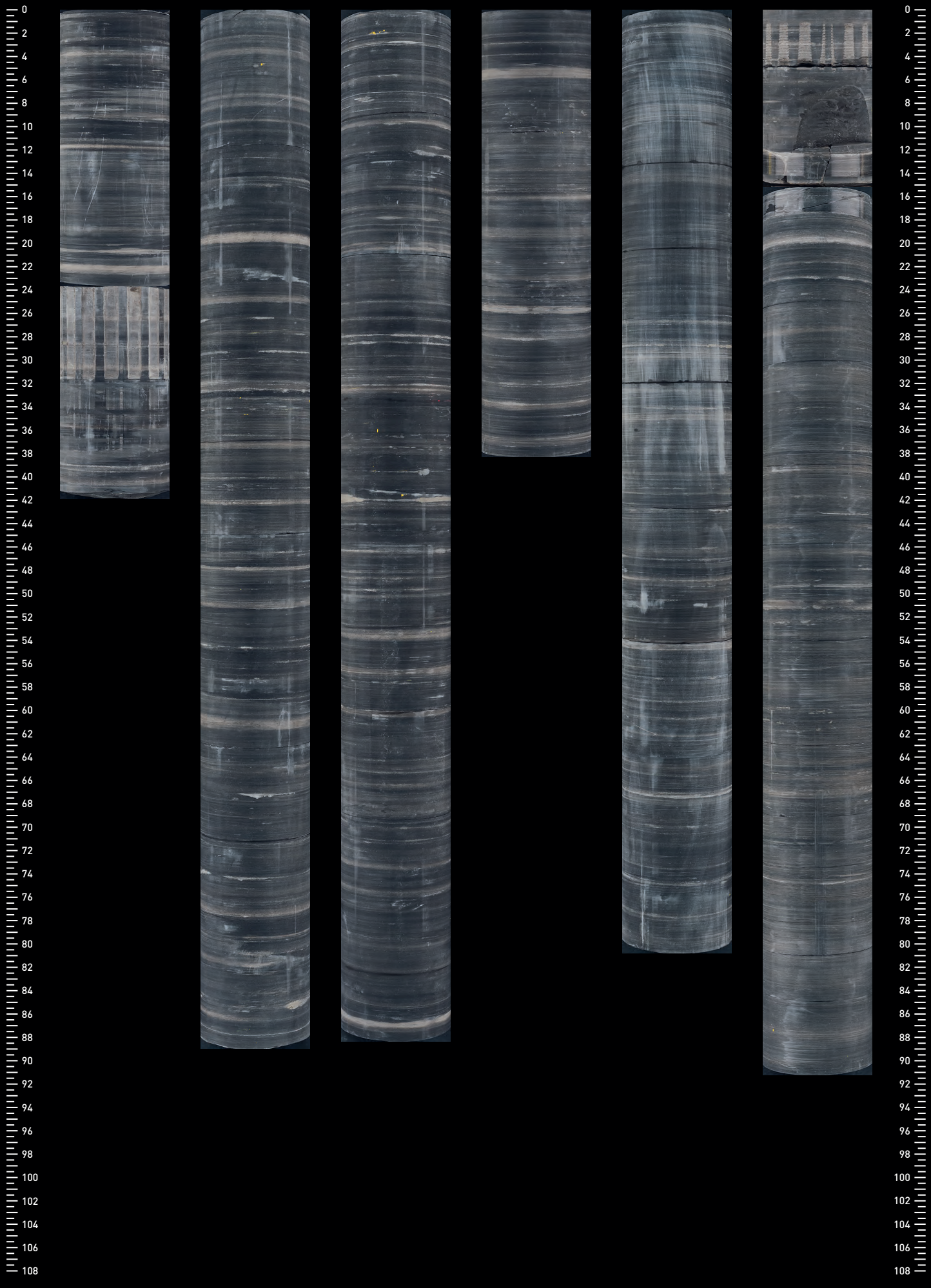
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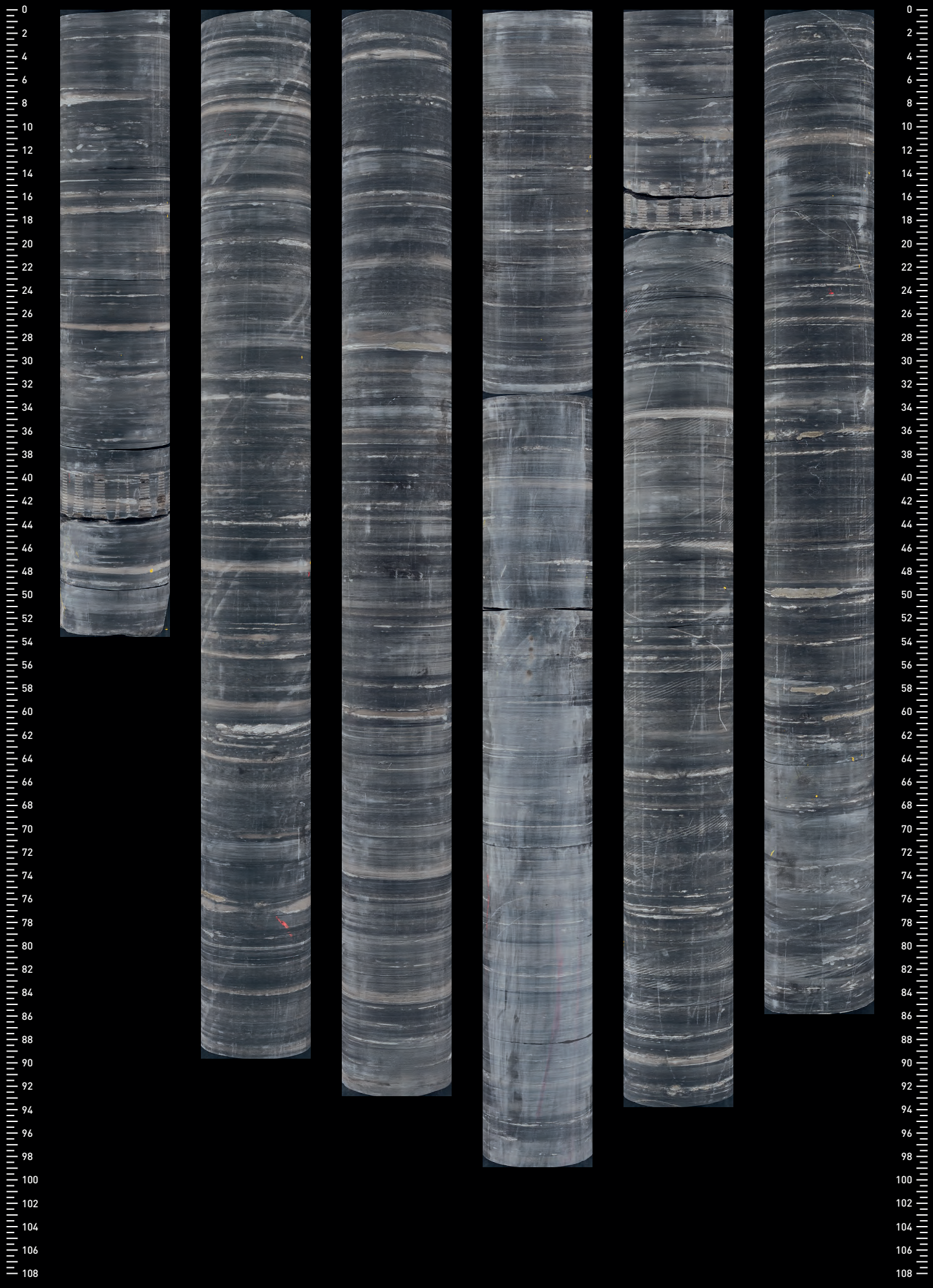
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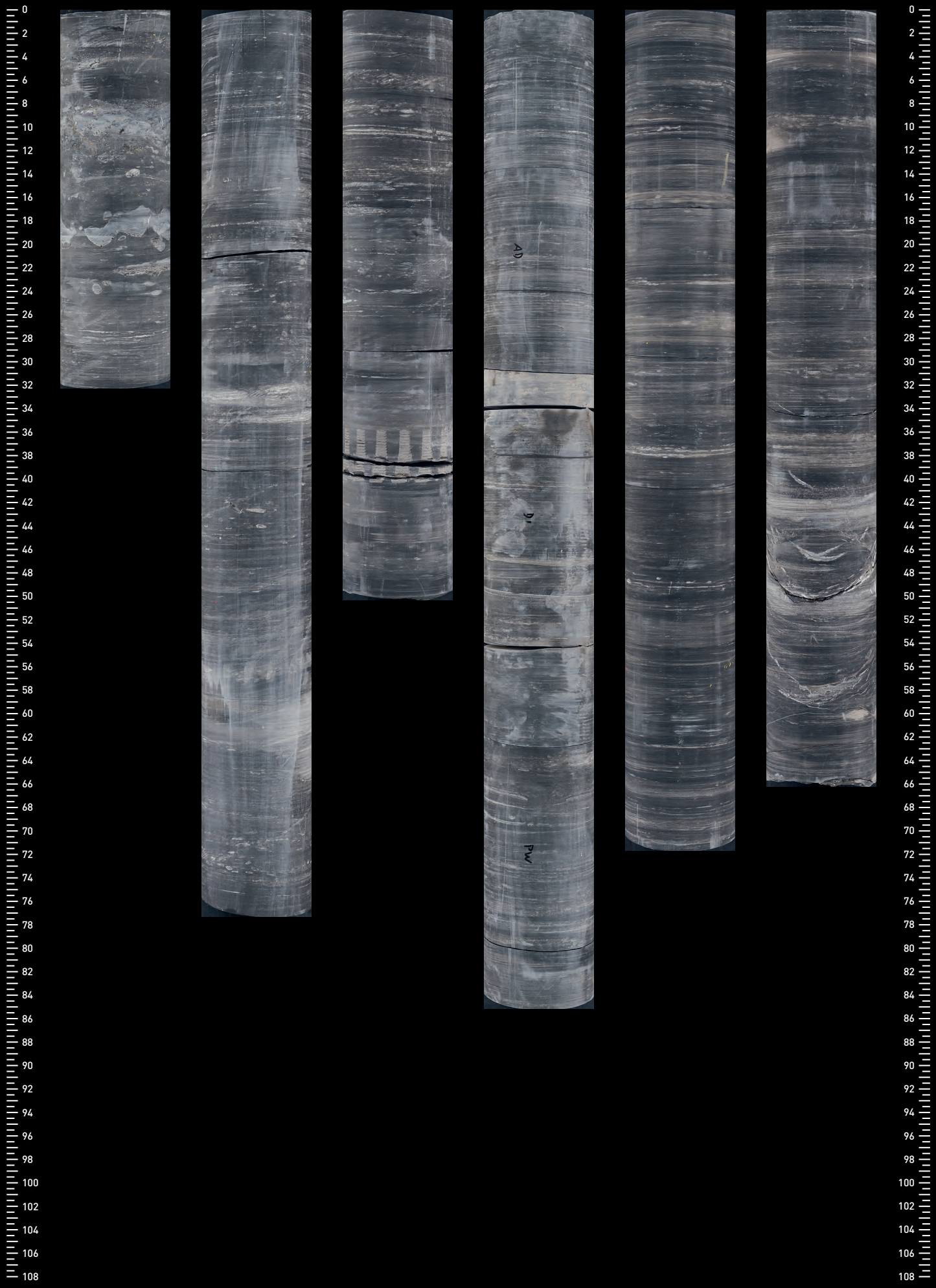
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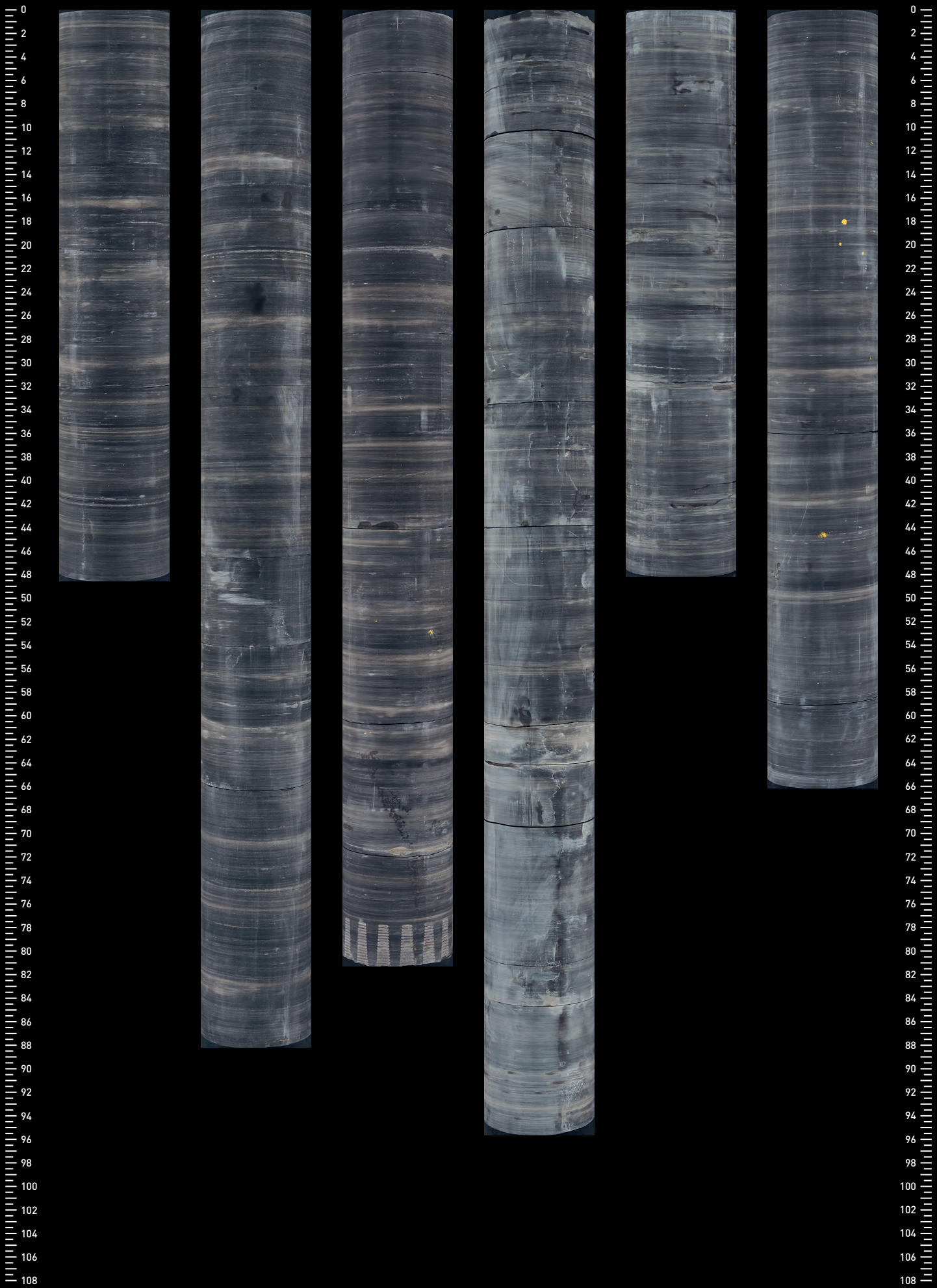
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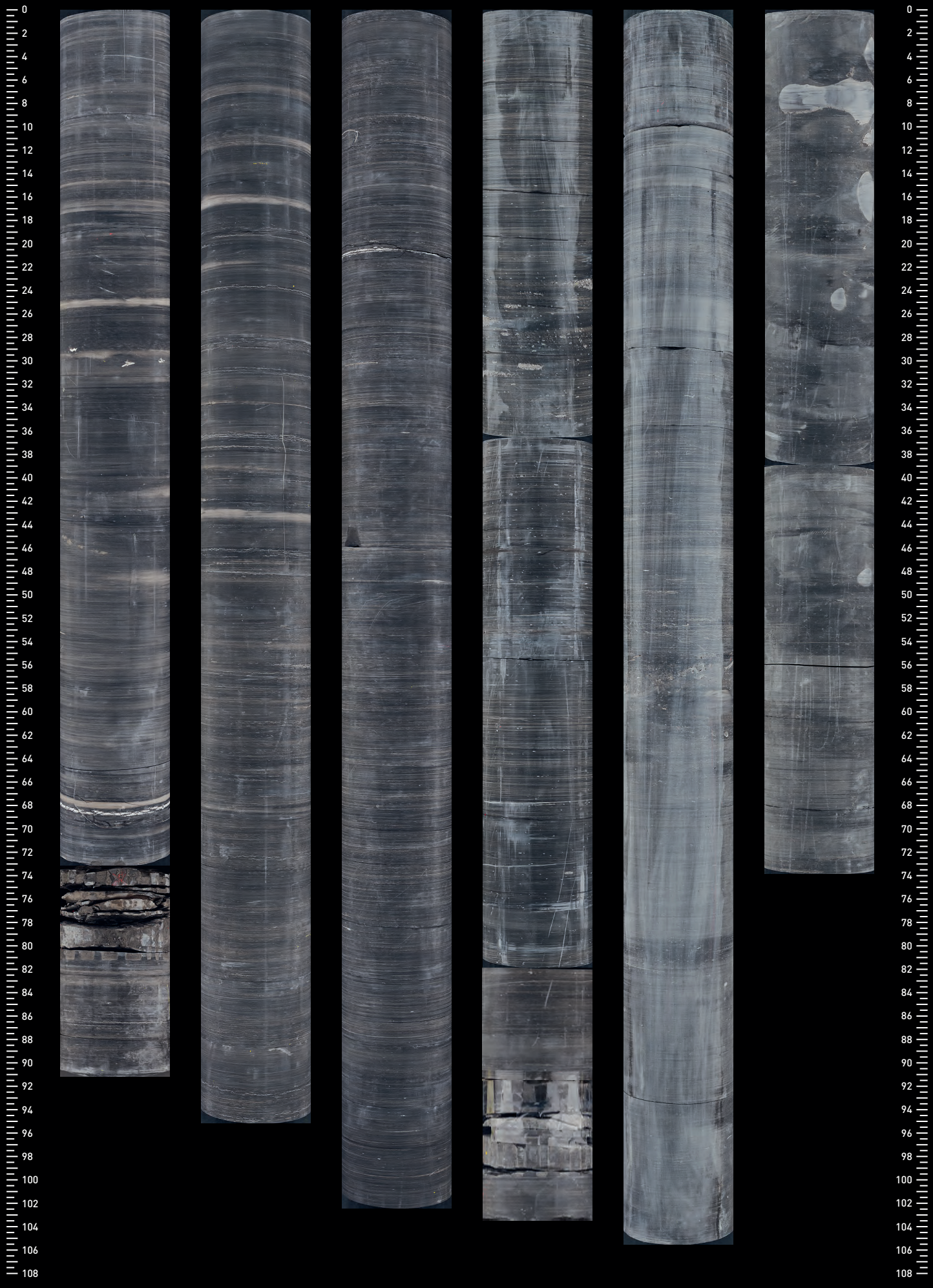
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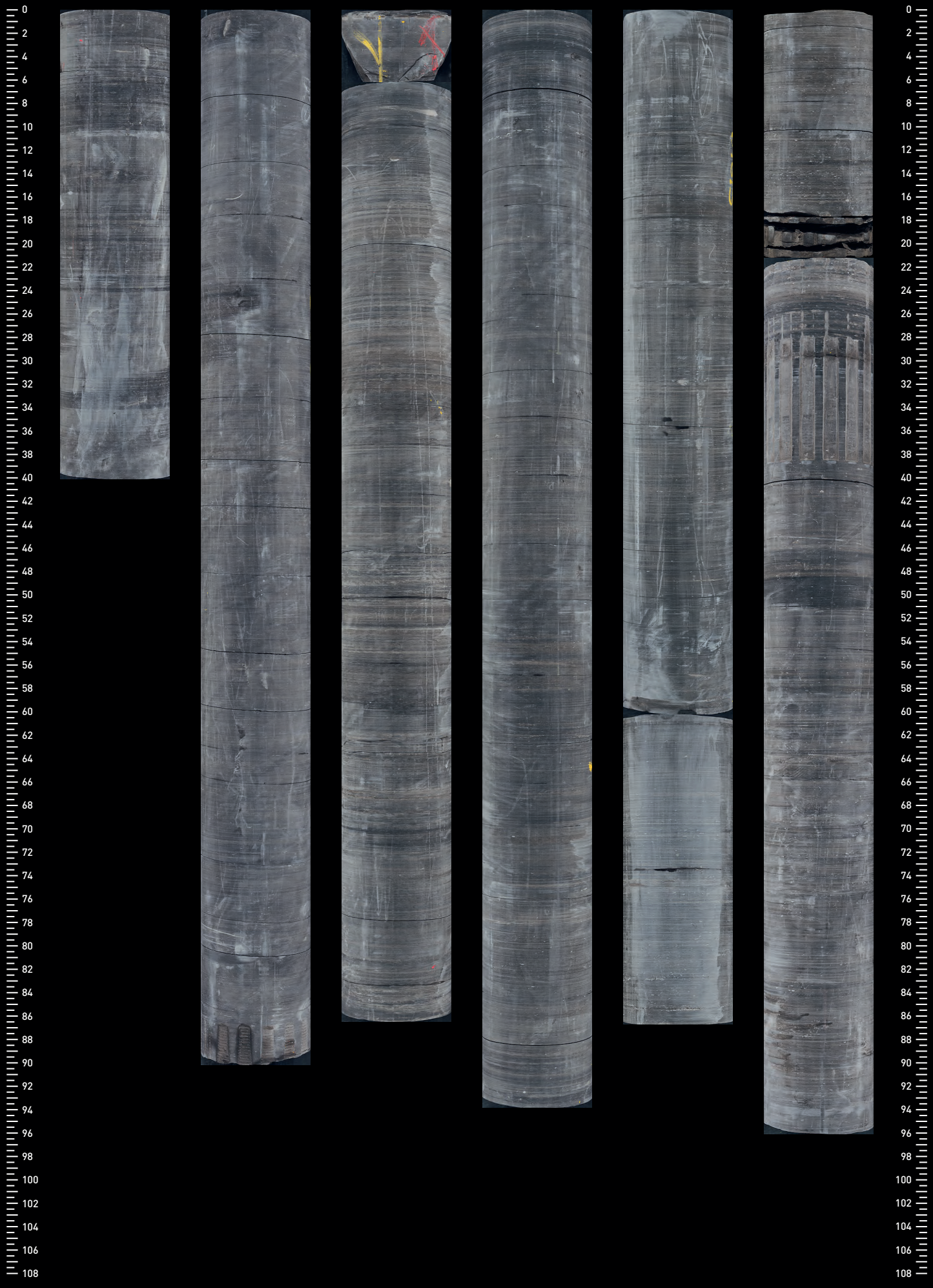
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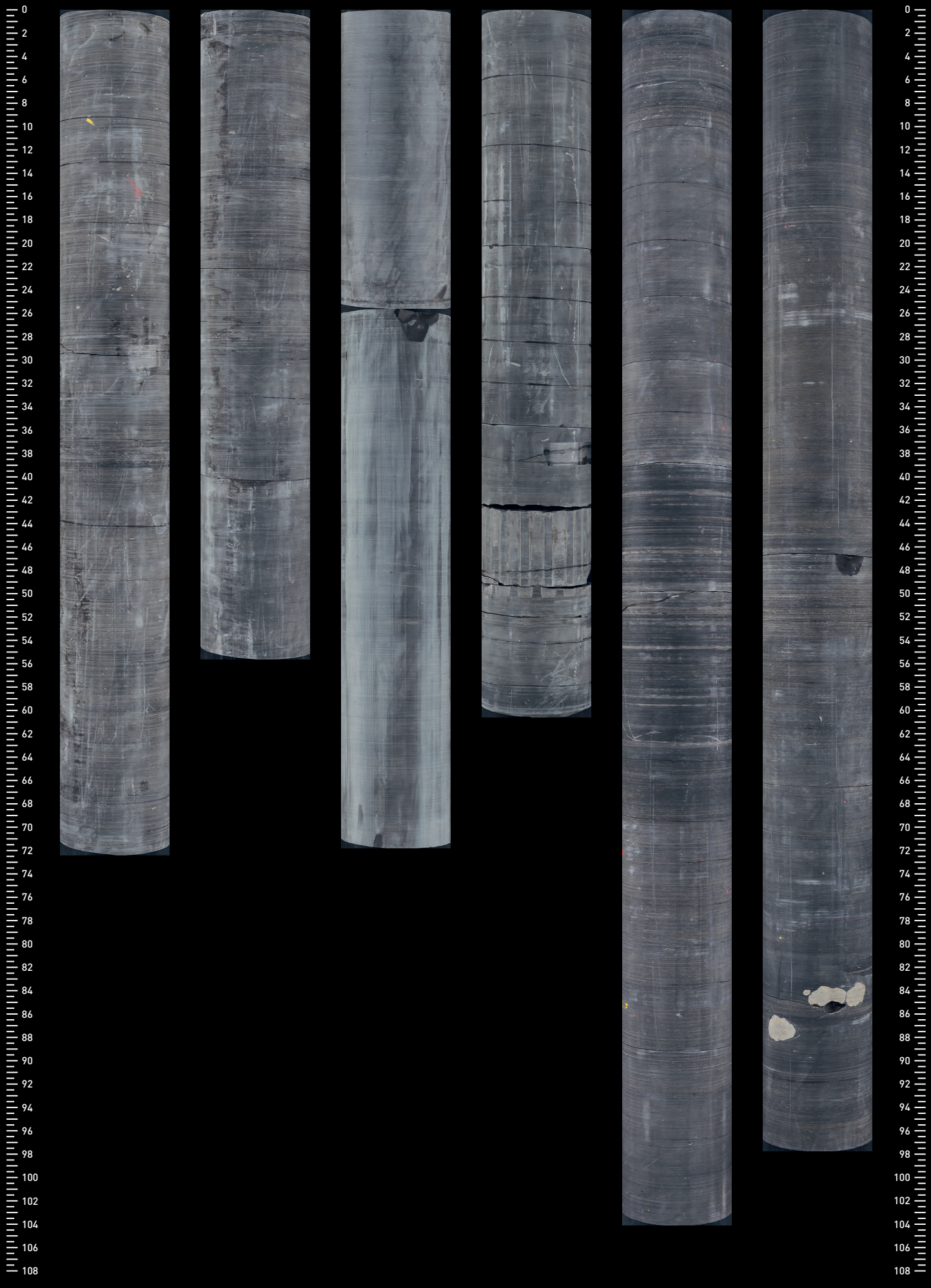
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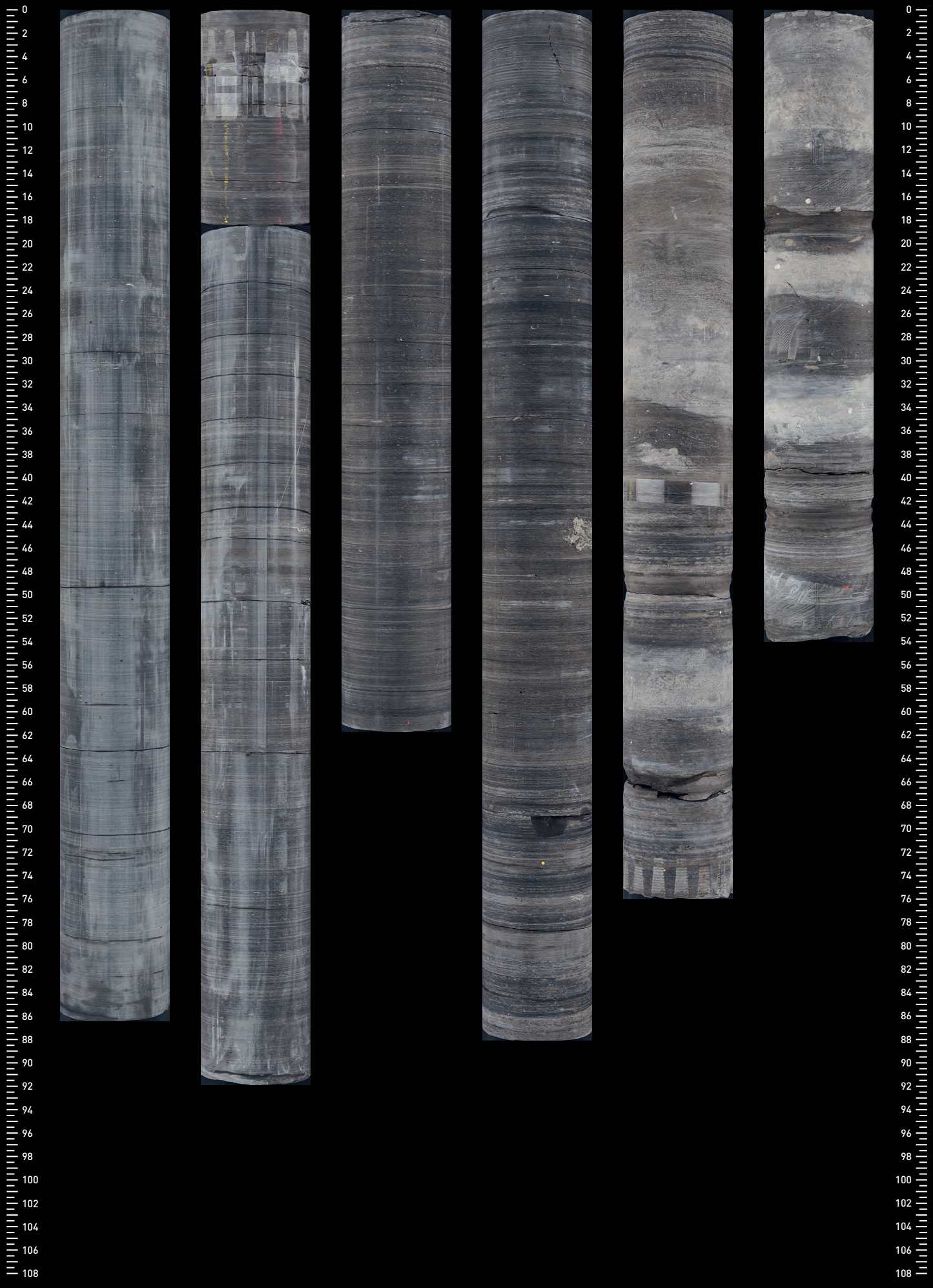
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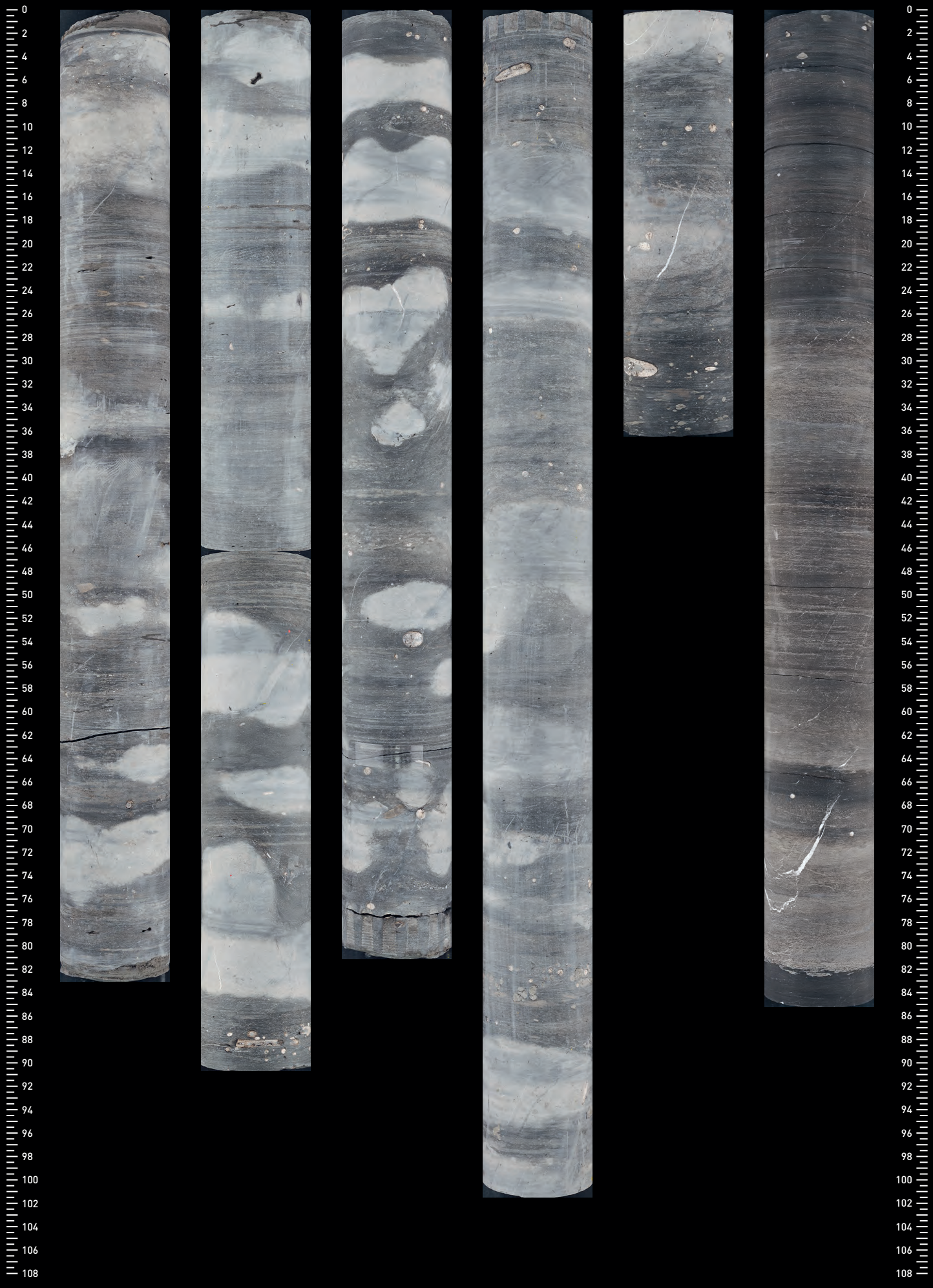
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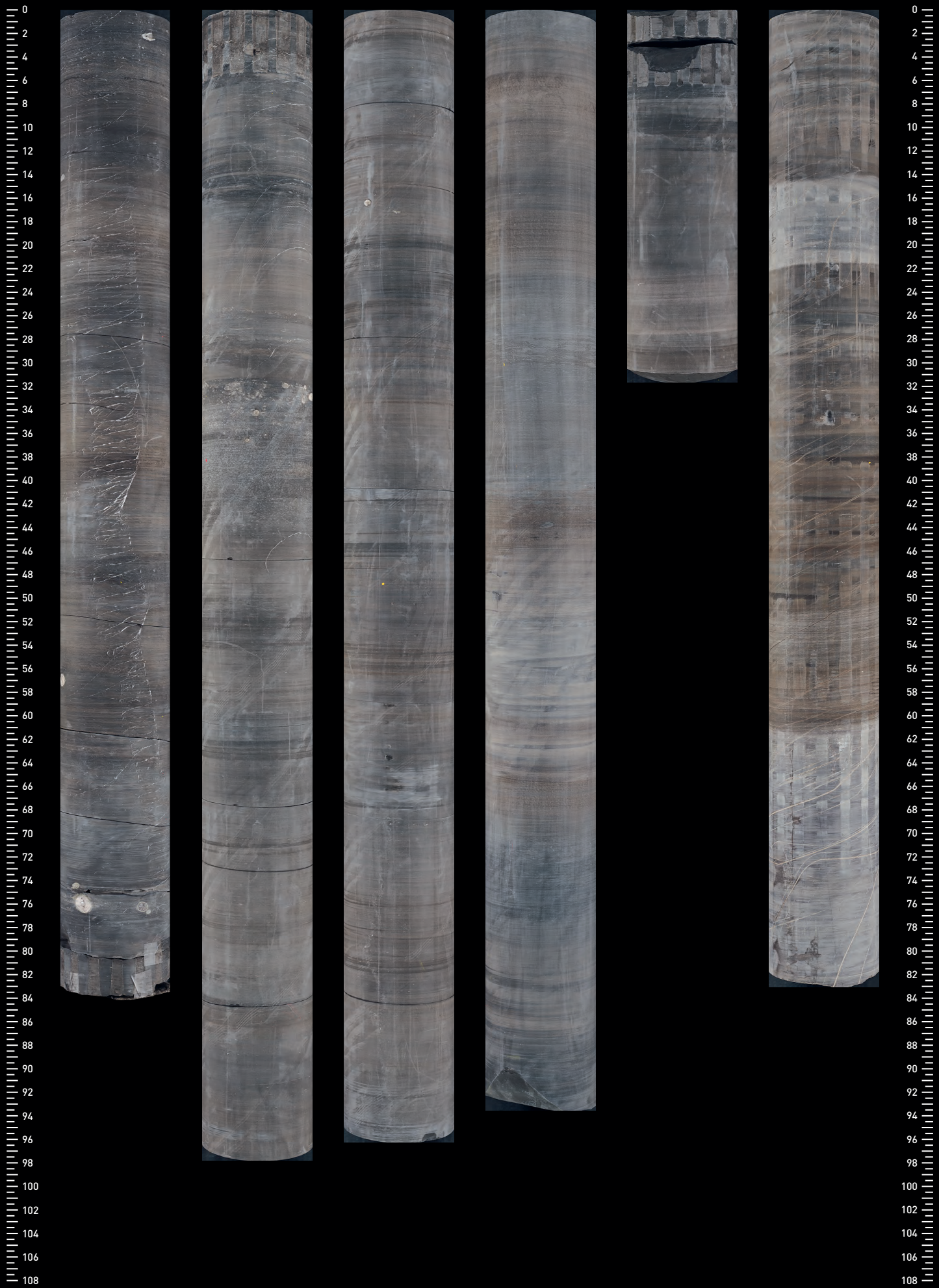
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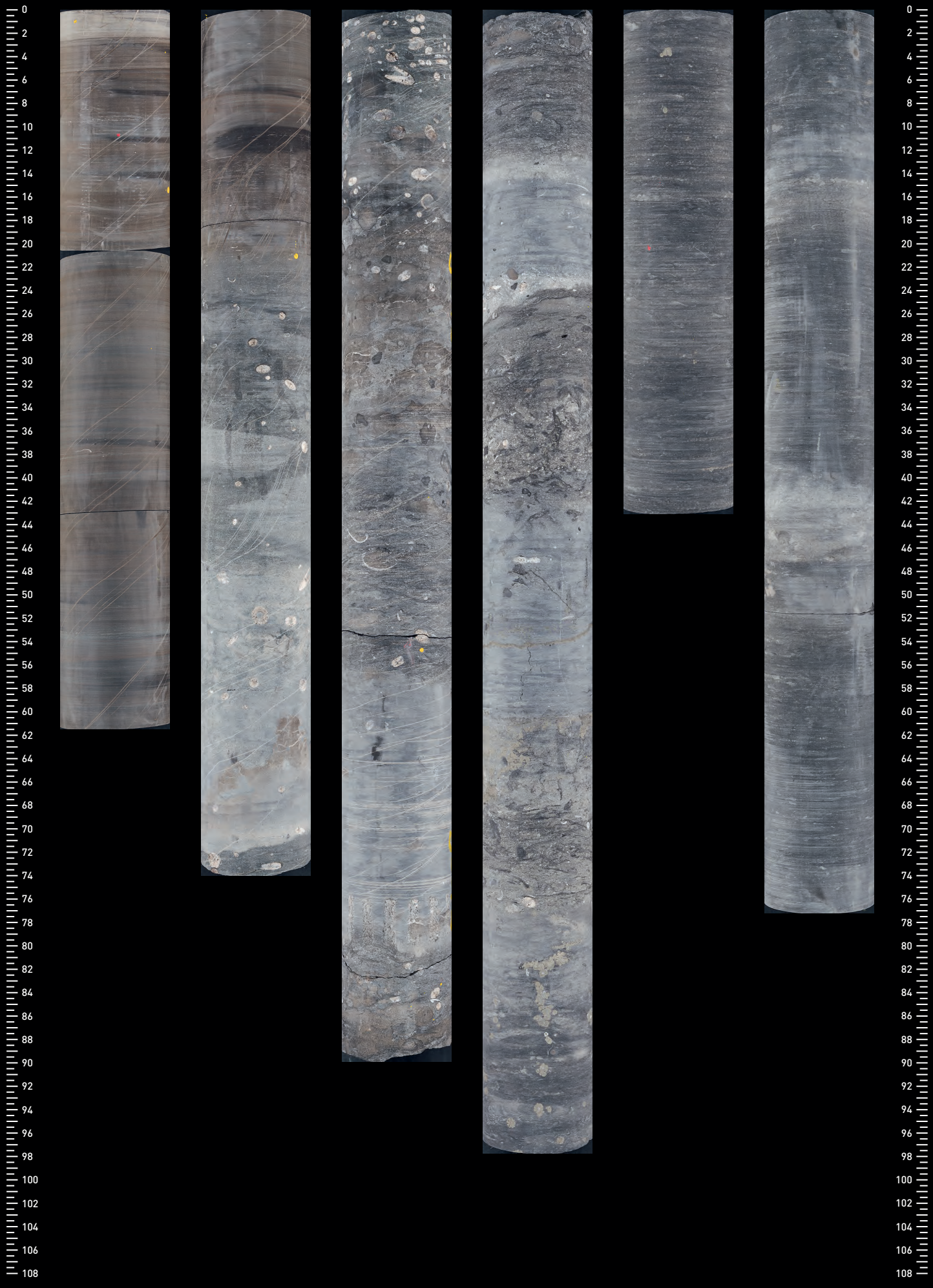
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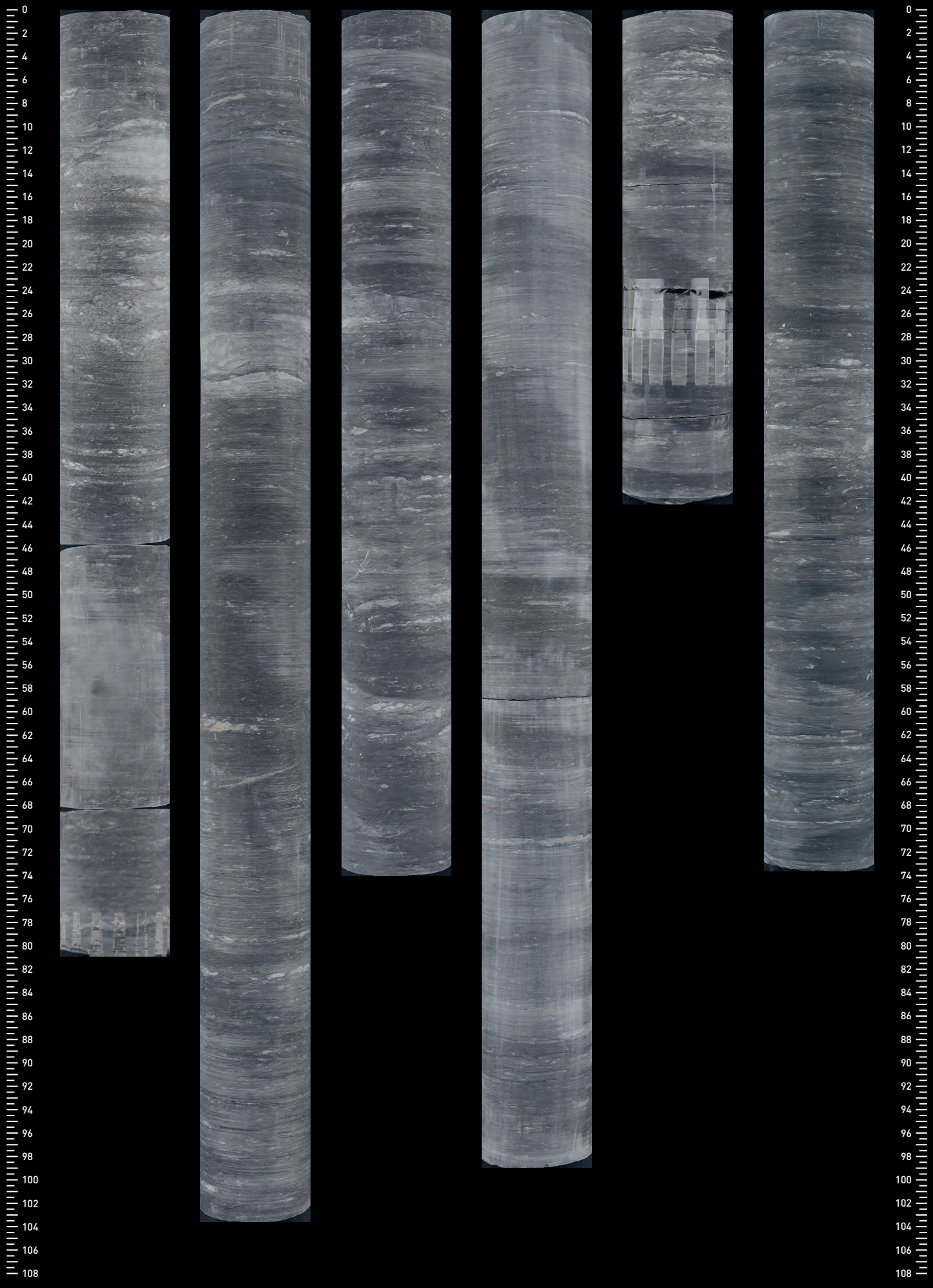
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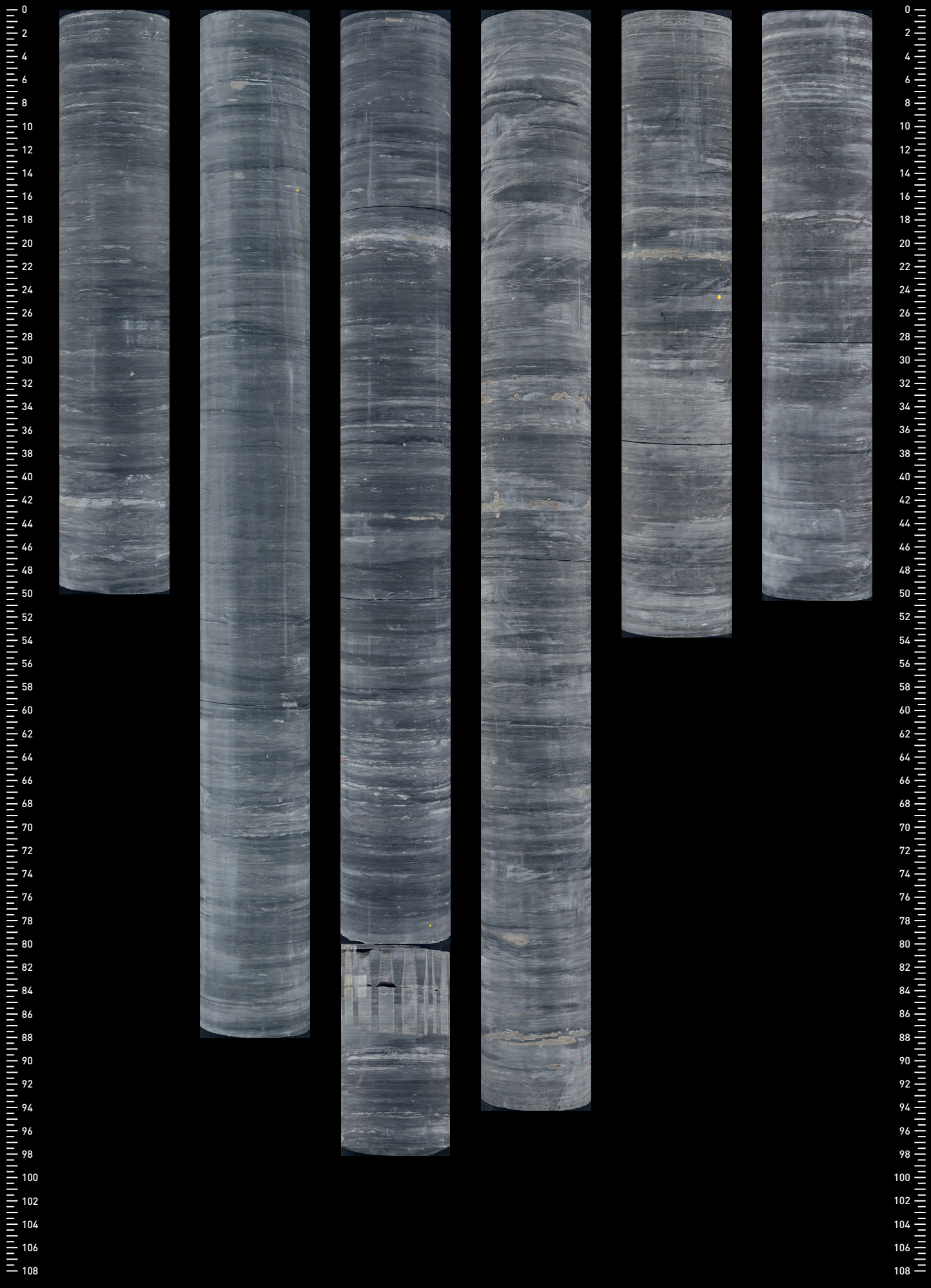
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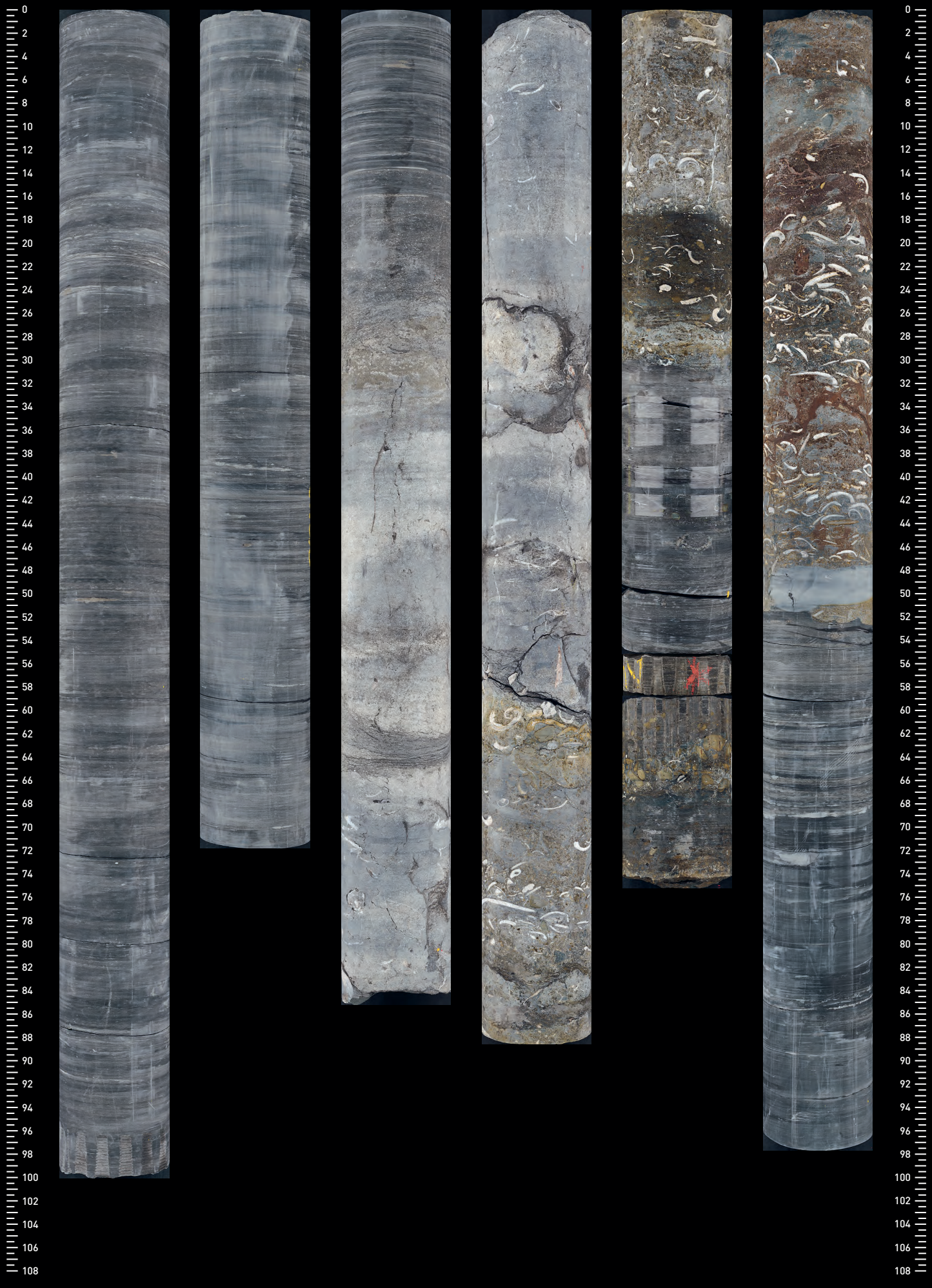
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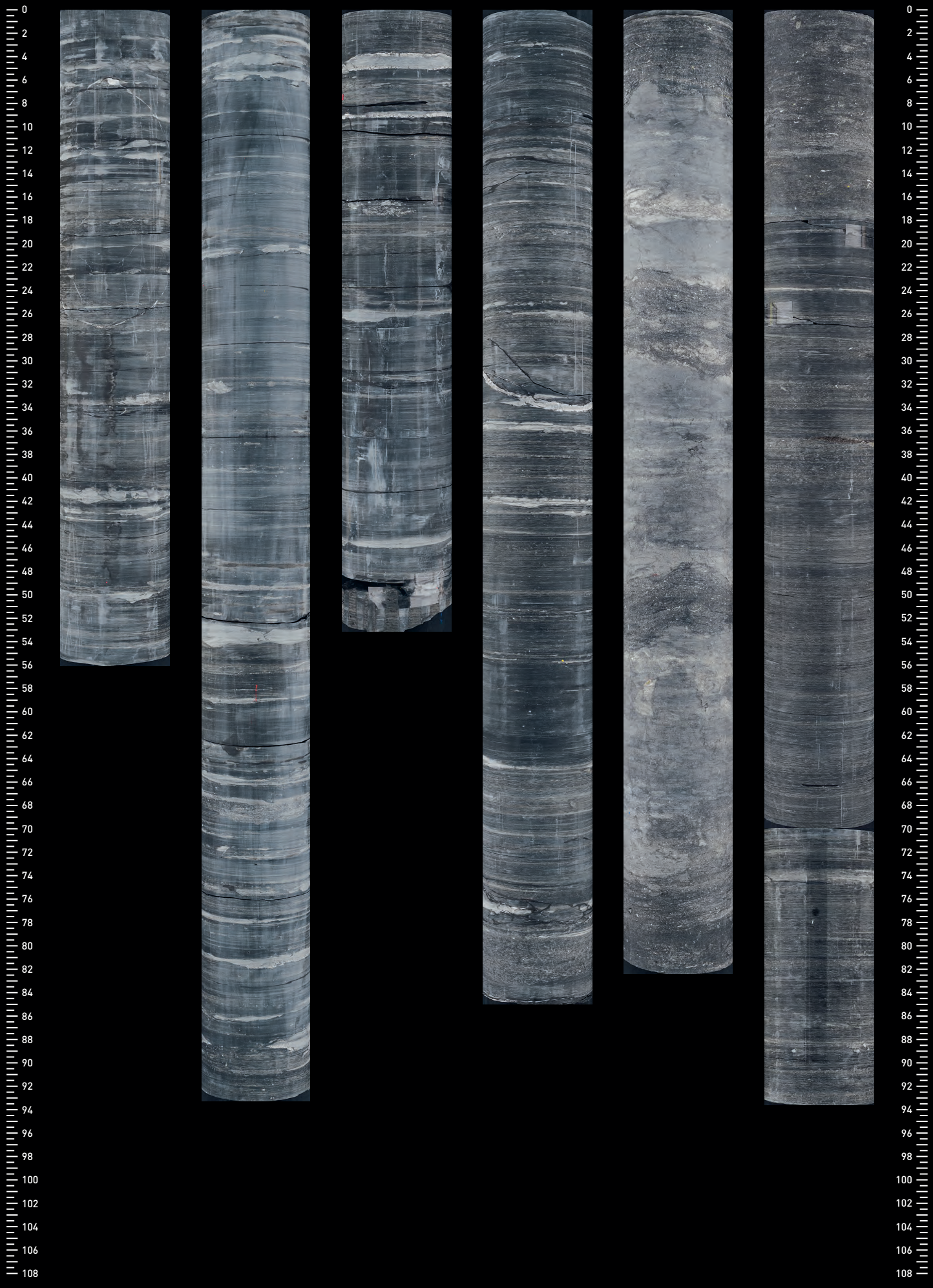
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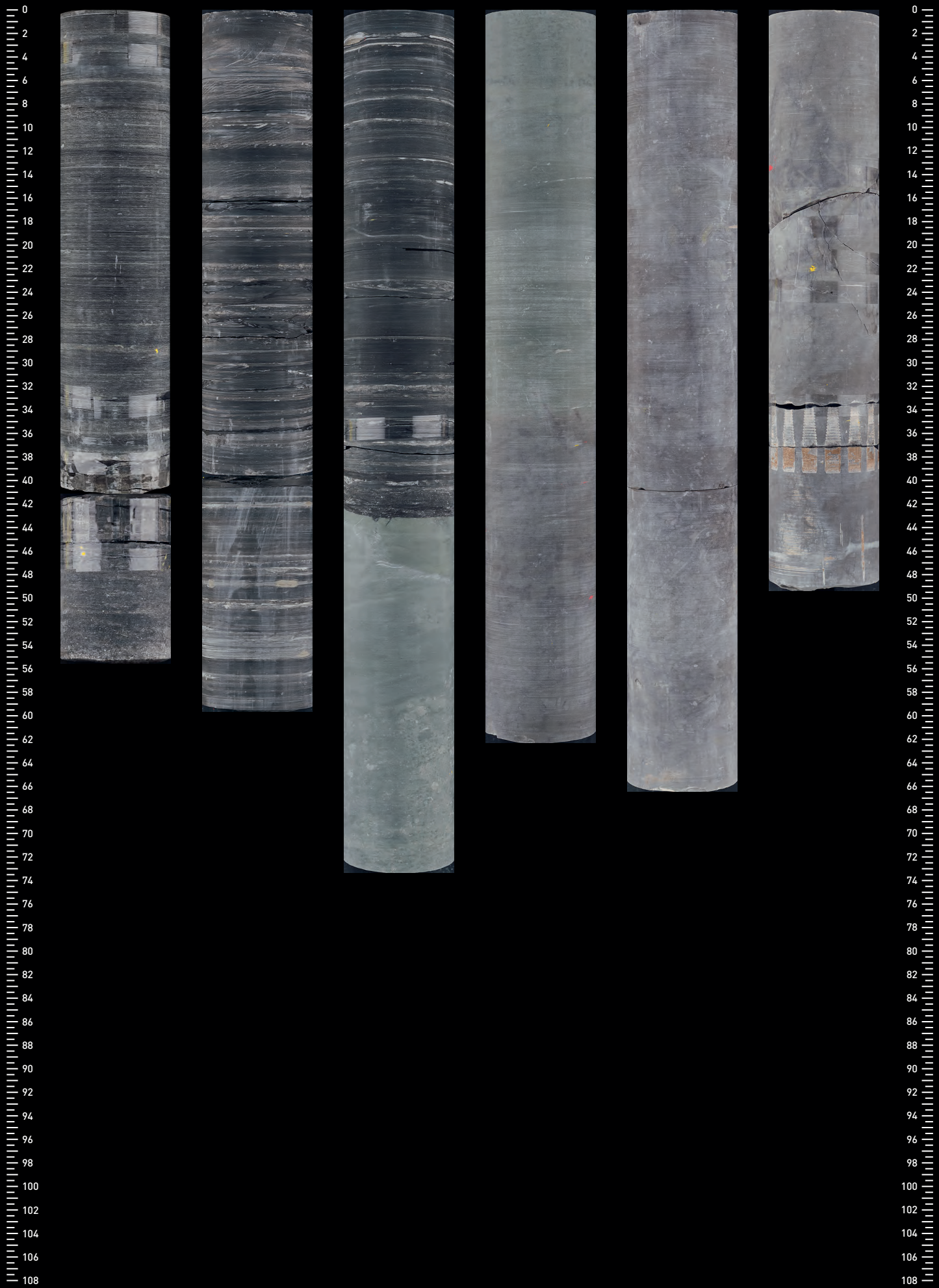
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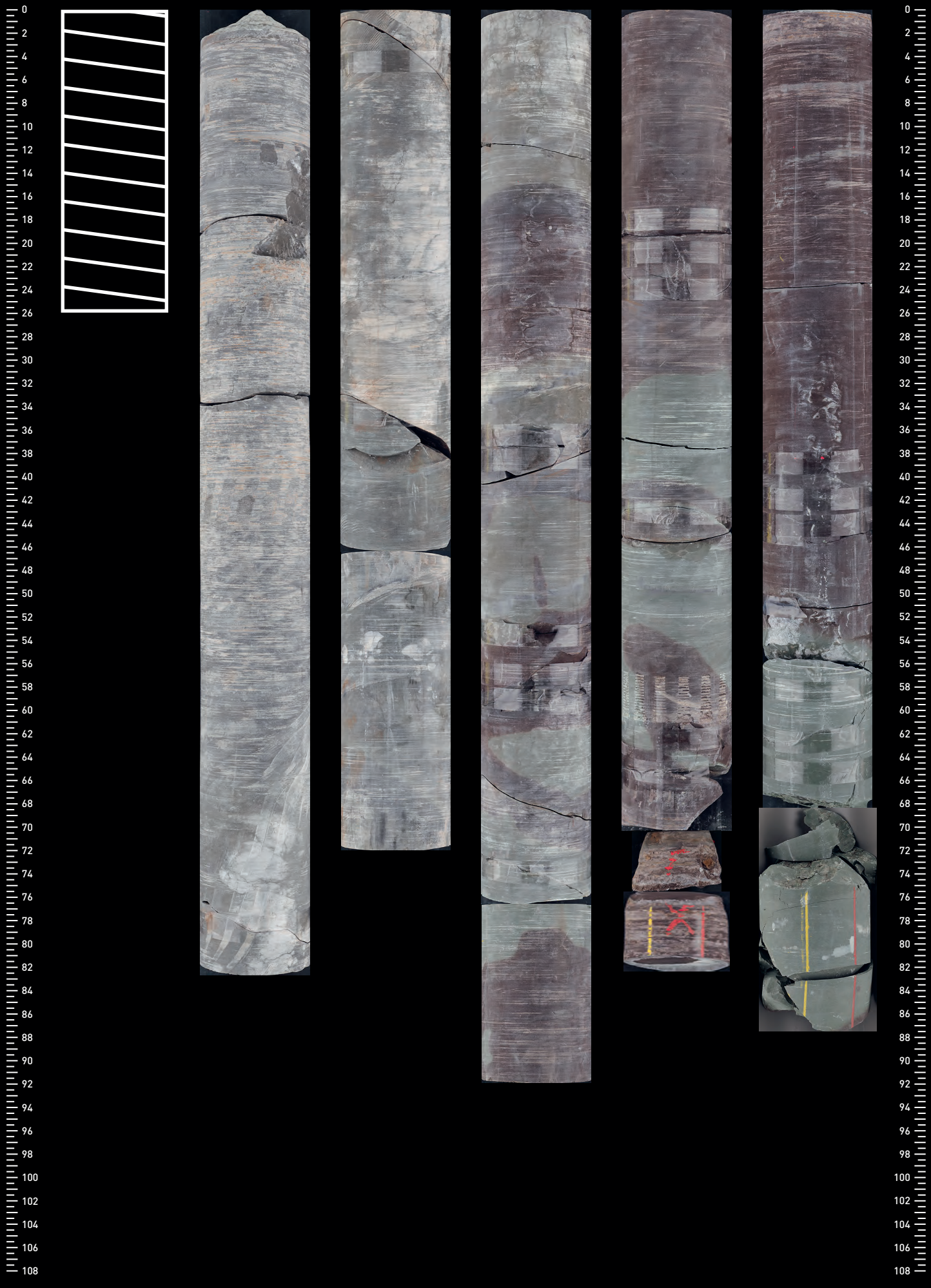
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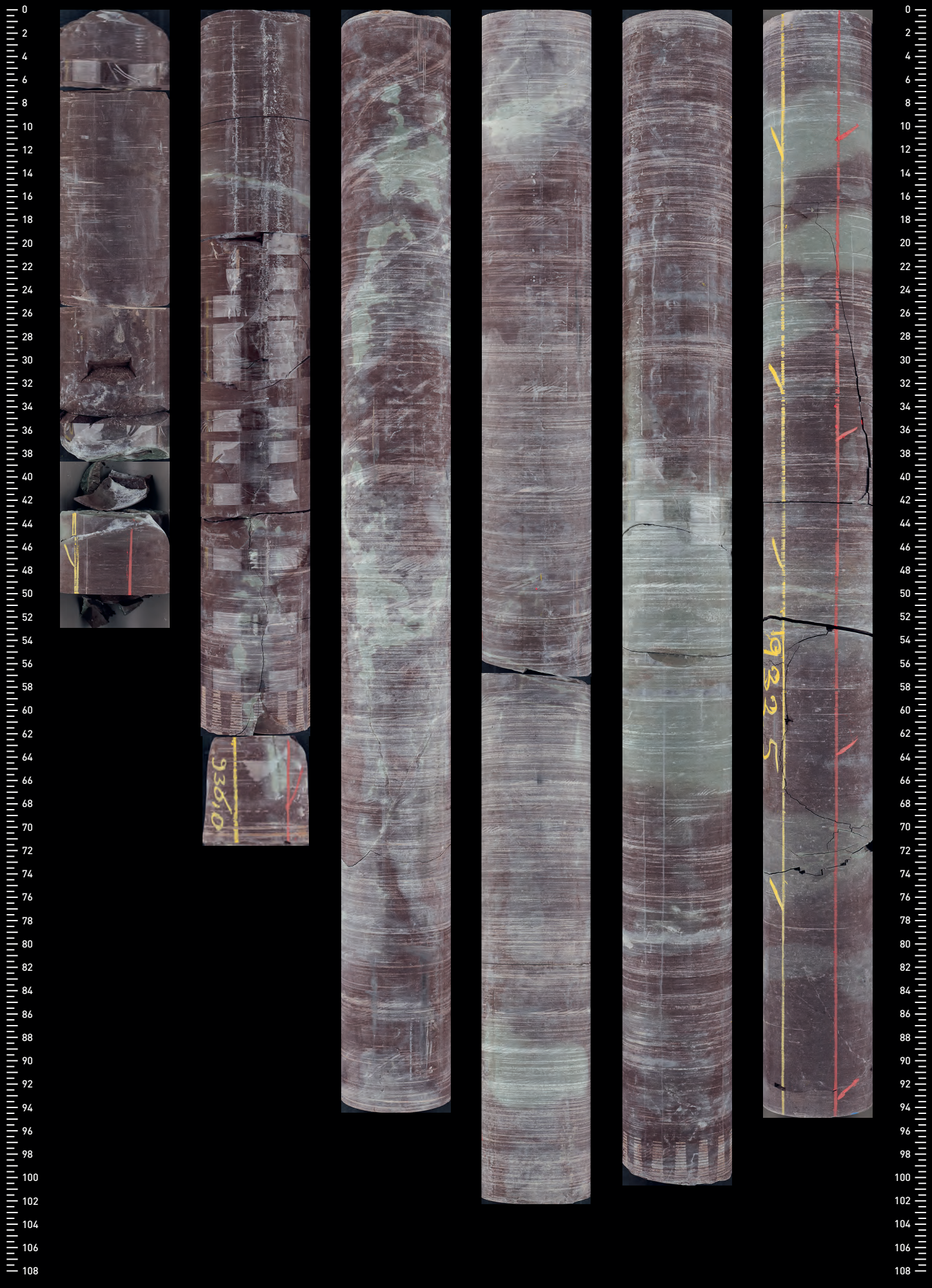
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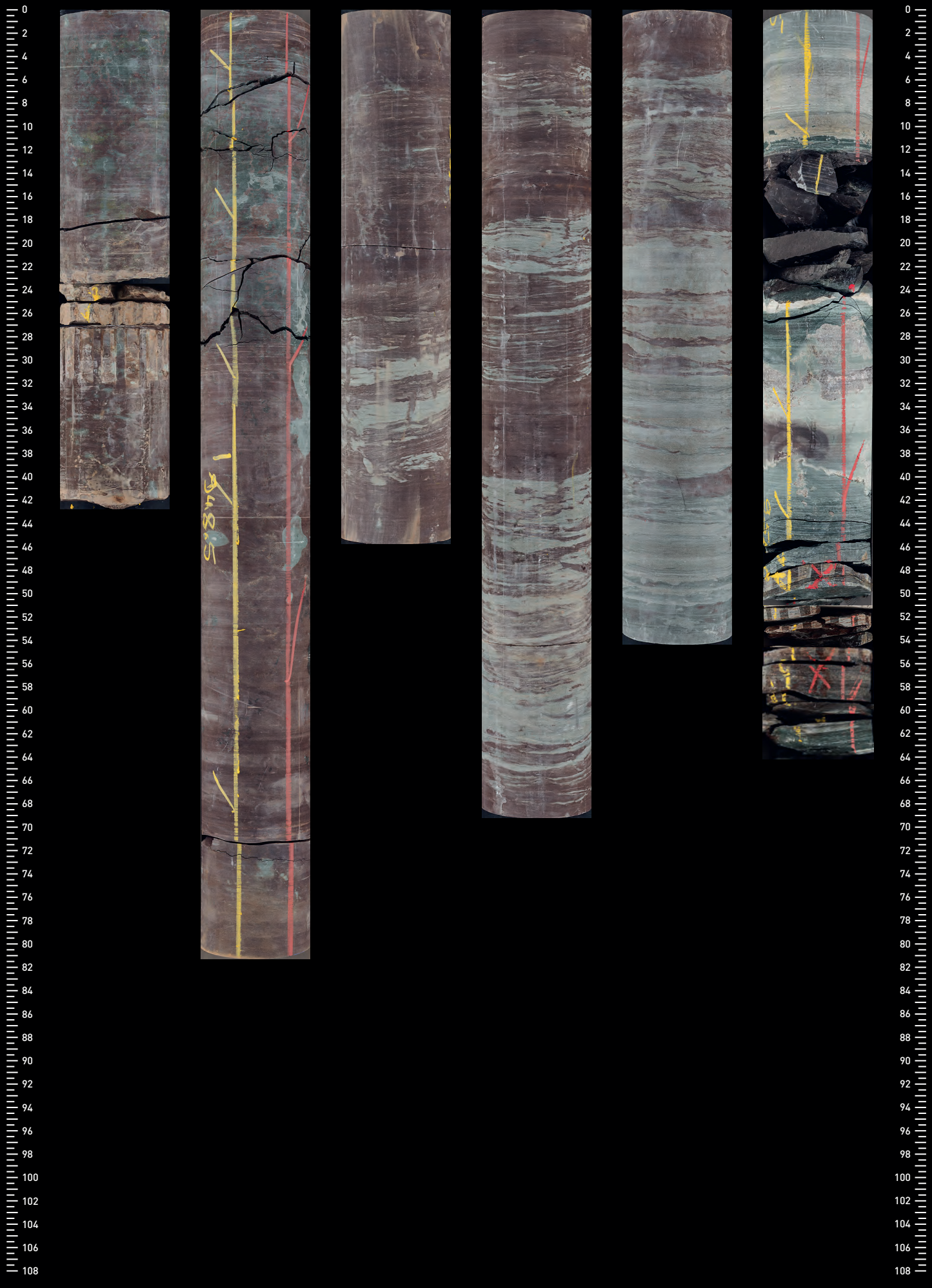
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947.74m 948.14m 948.92m 949.37m 950.05m 950.57m



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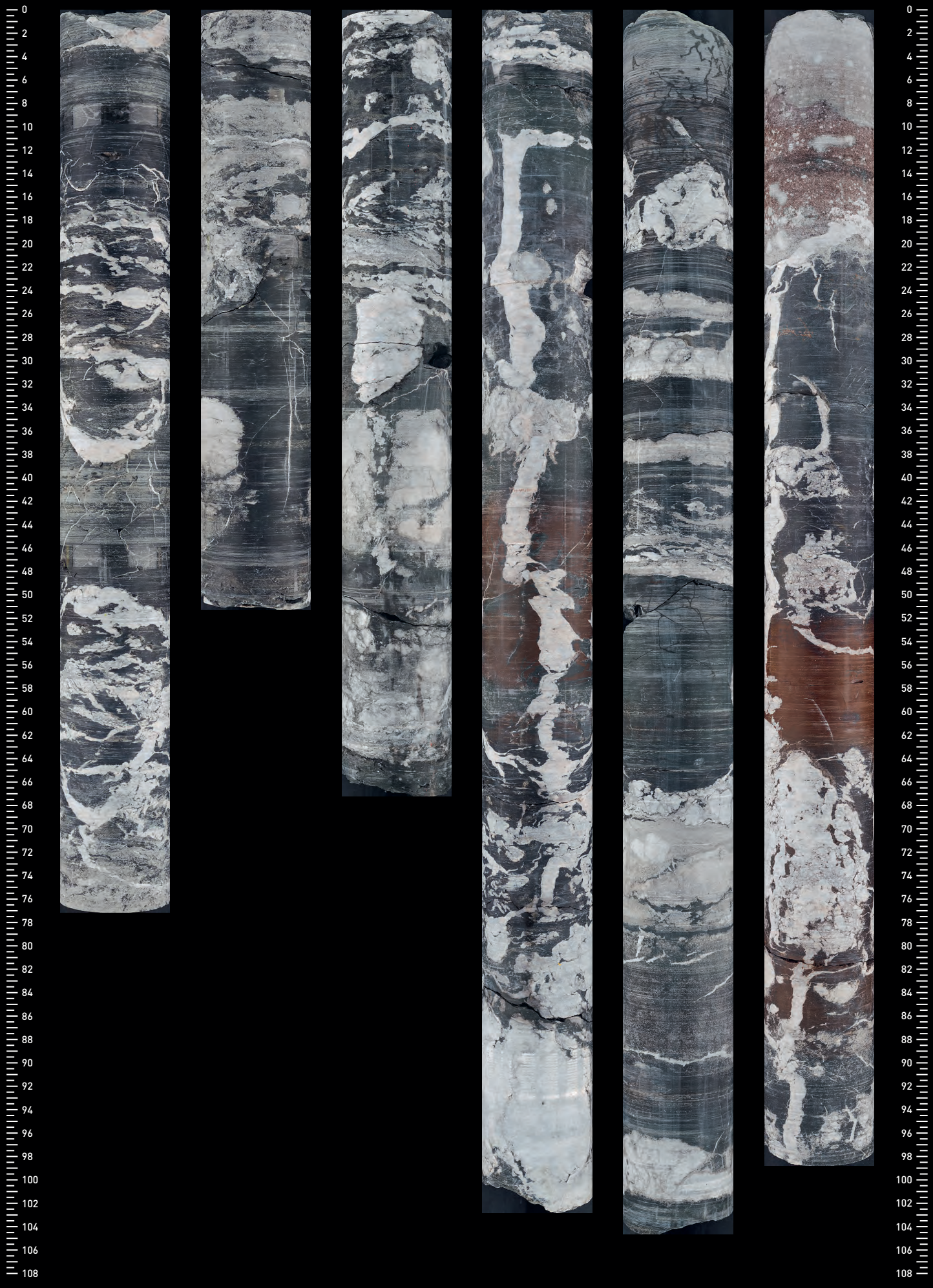
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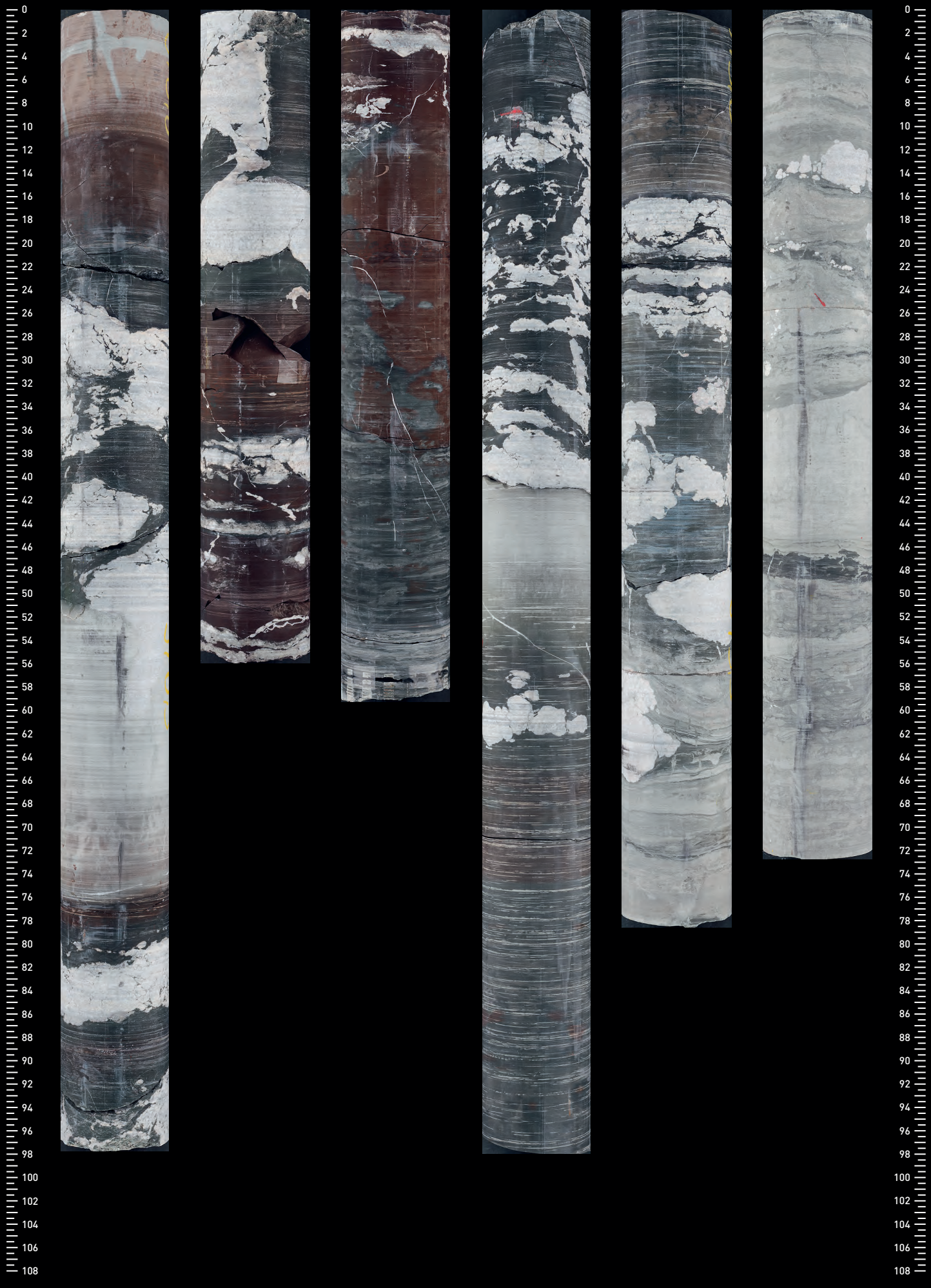
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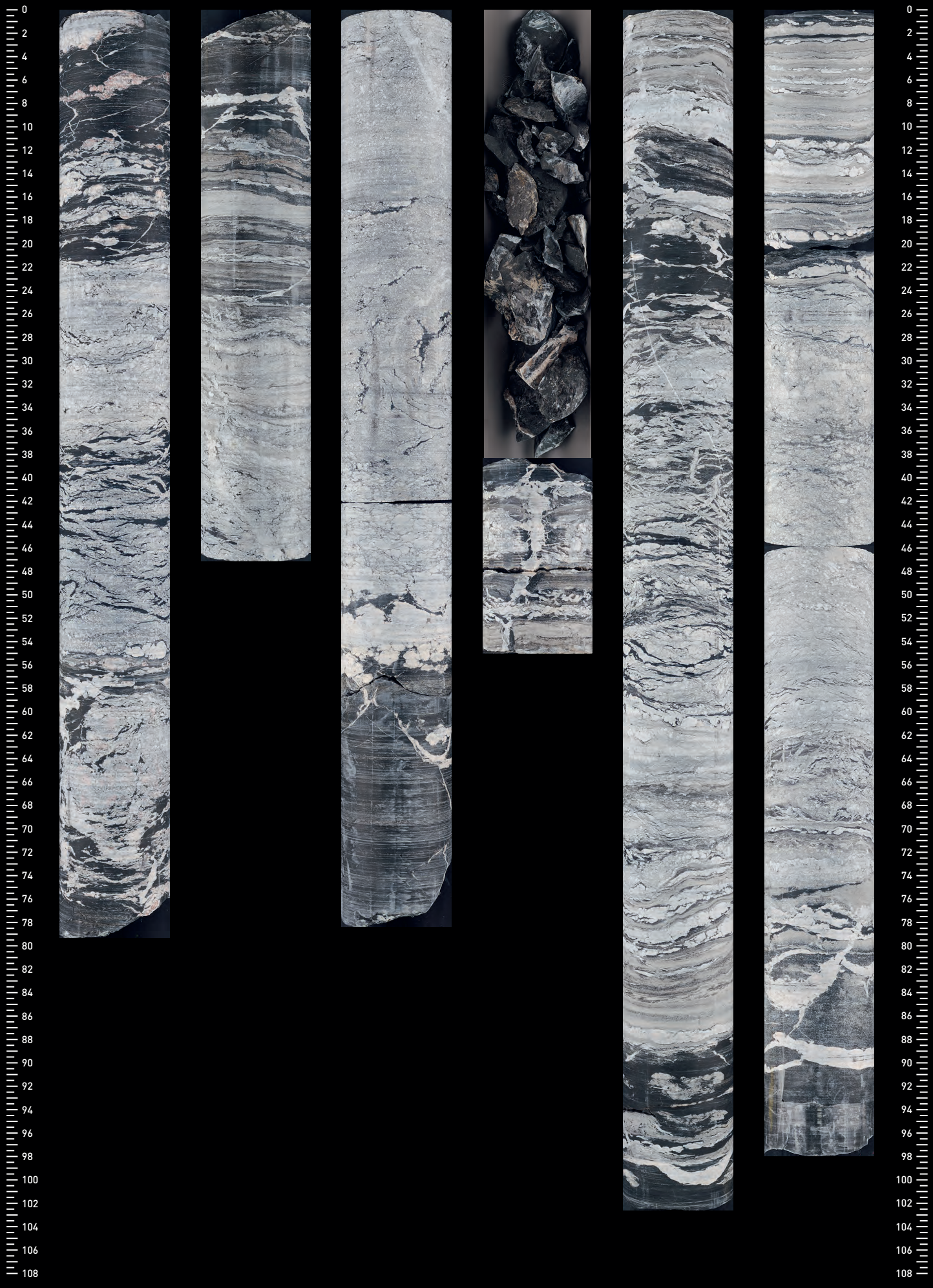
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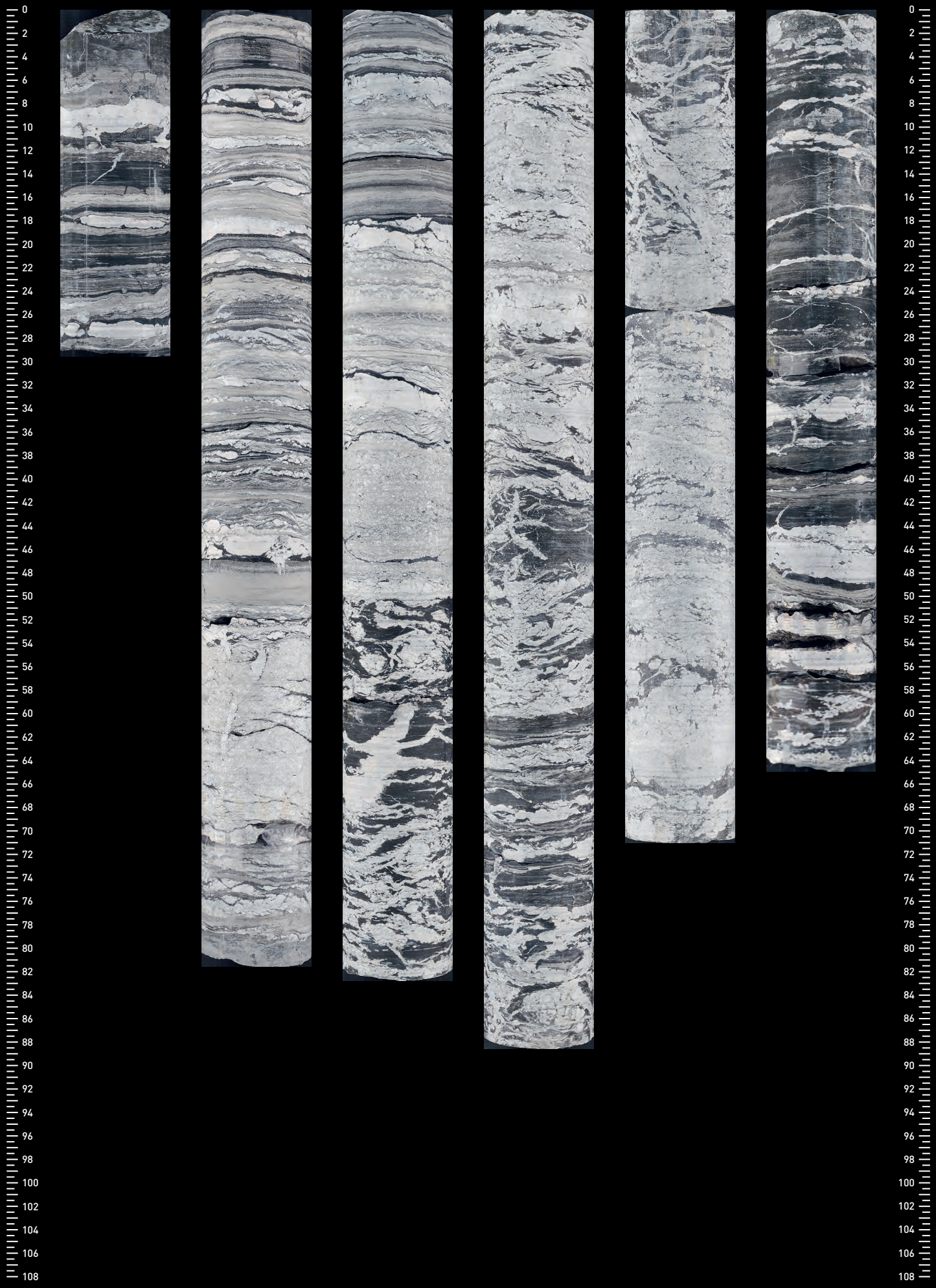
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979.83m 980.29m 981.04m 981.35m 982.34m 983.26m

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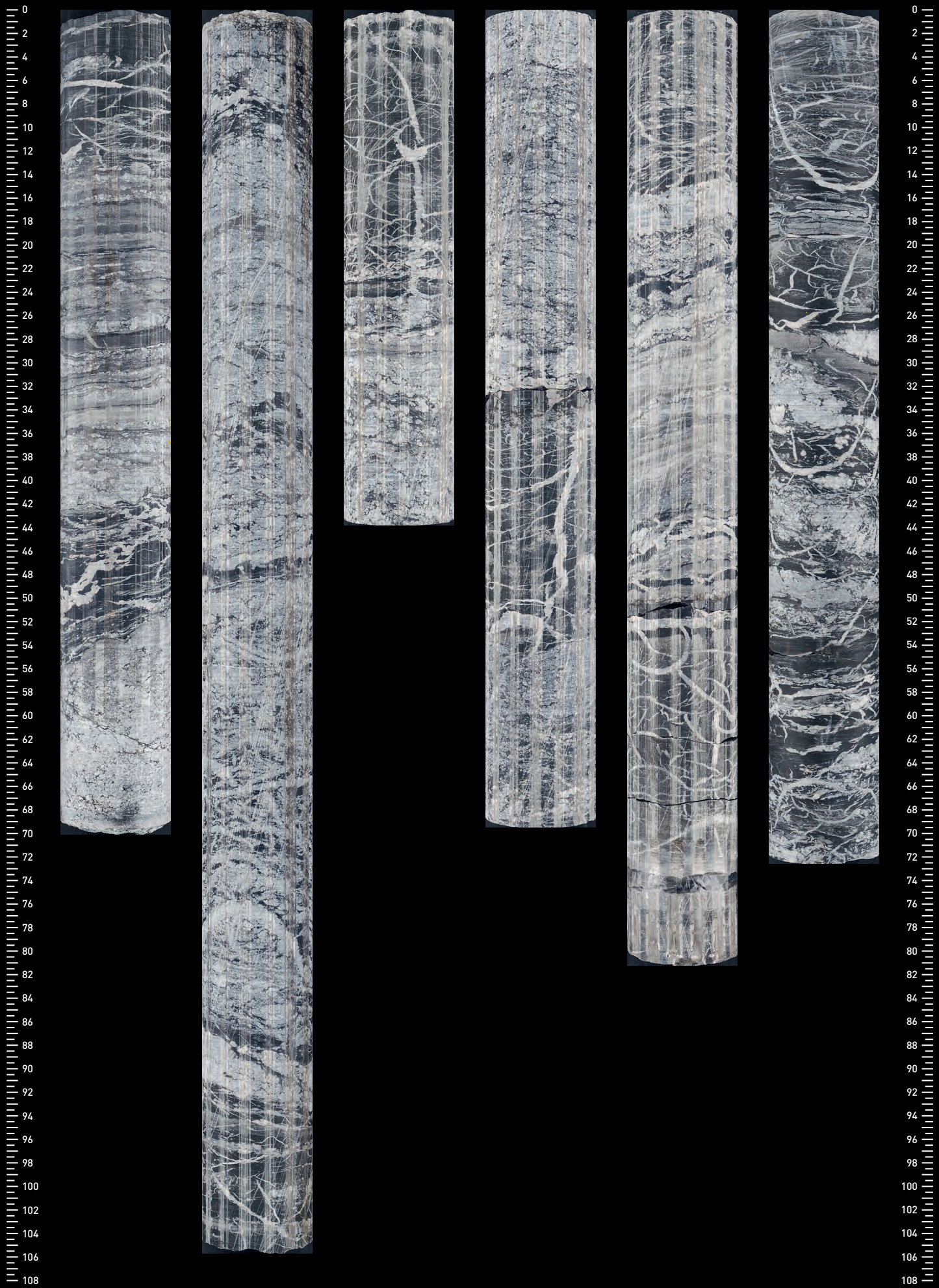
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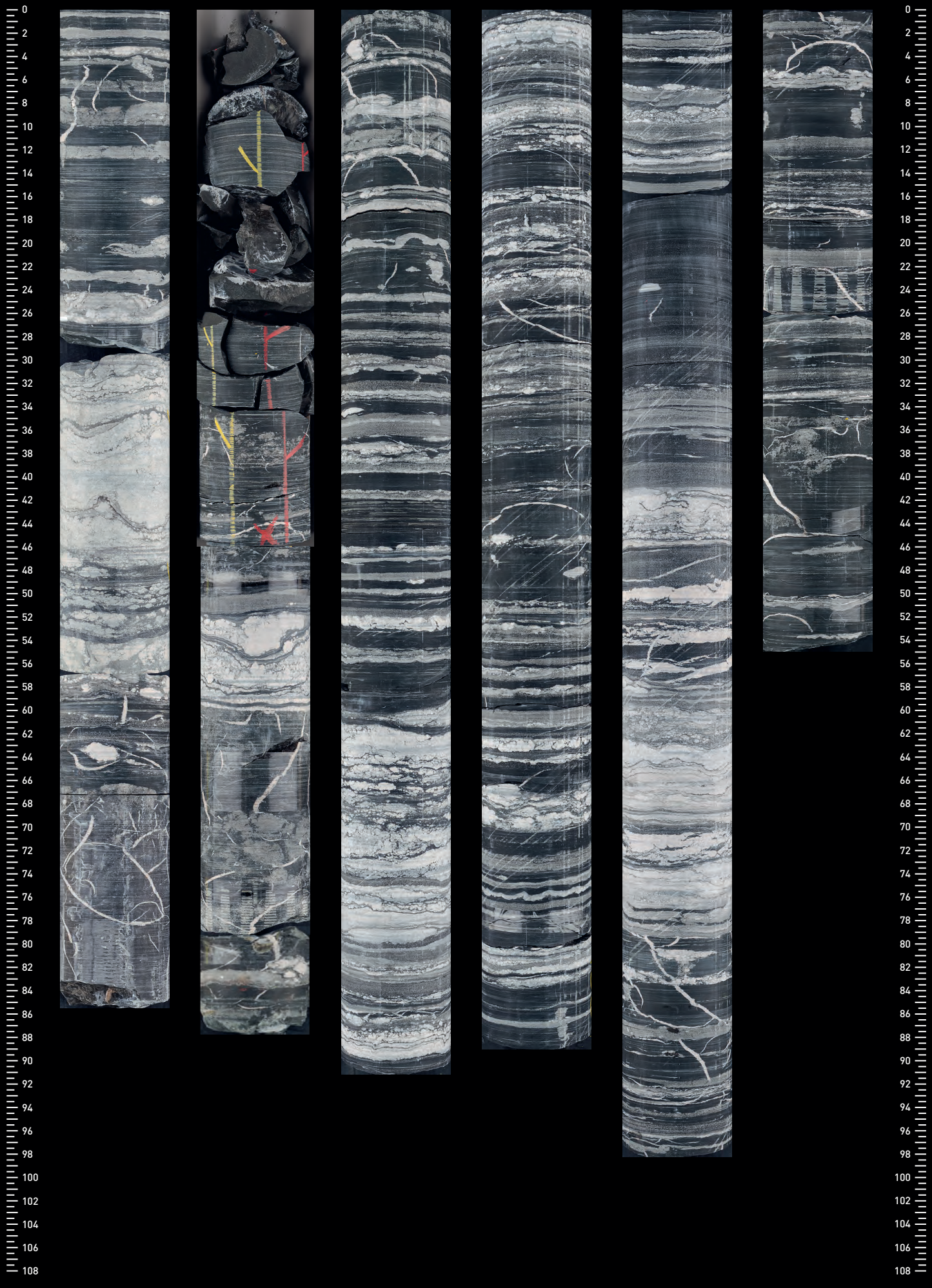
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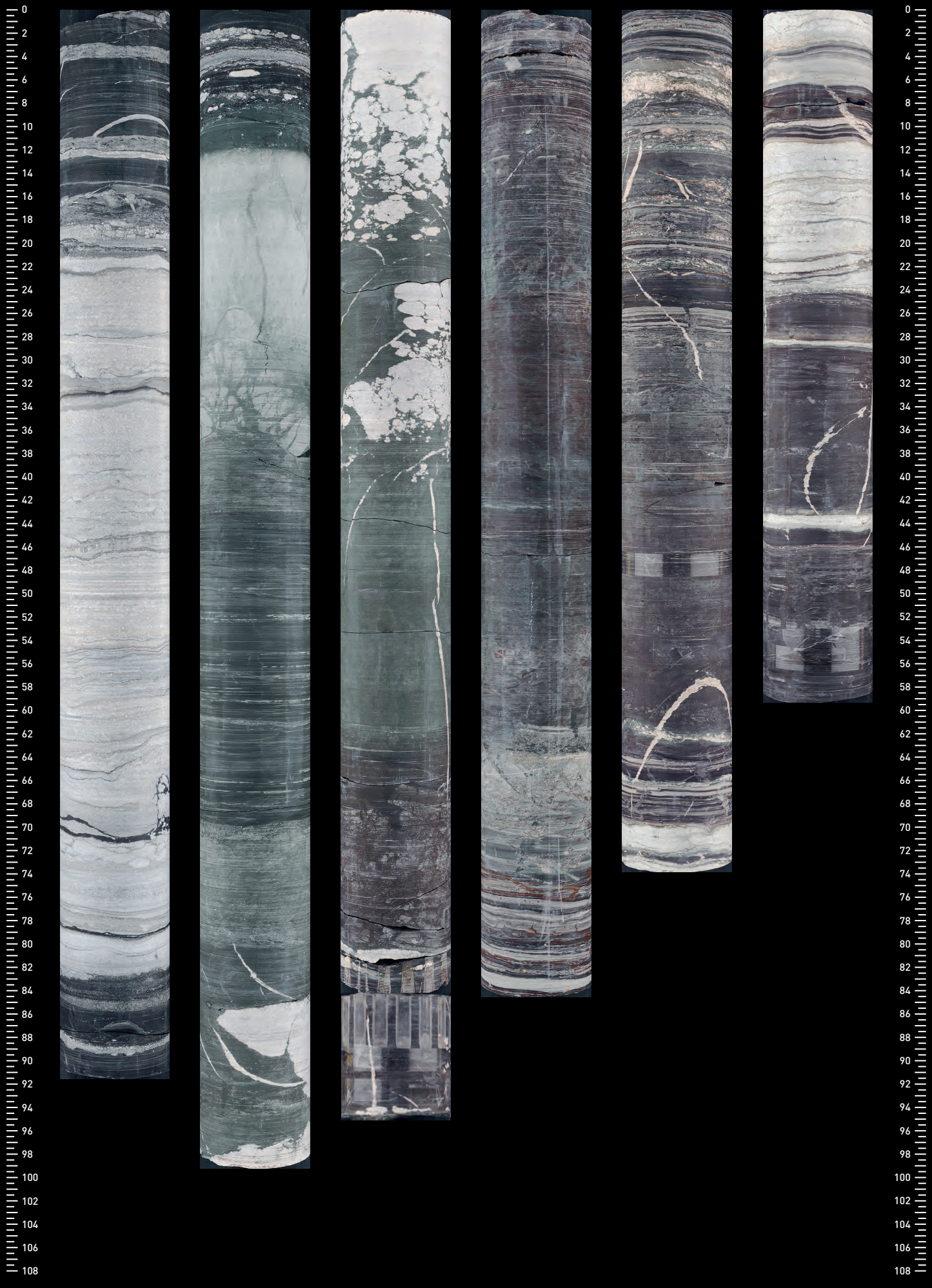

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1000.84m

1000.84m 1001.68m 1002.35m 1003.22m 1004.08m 1005.04m



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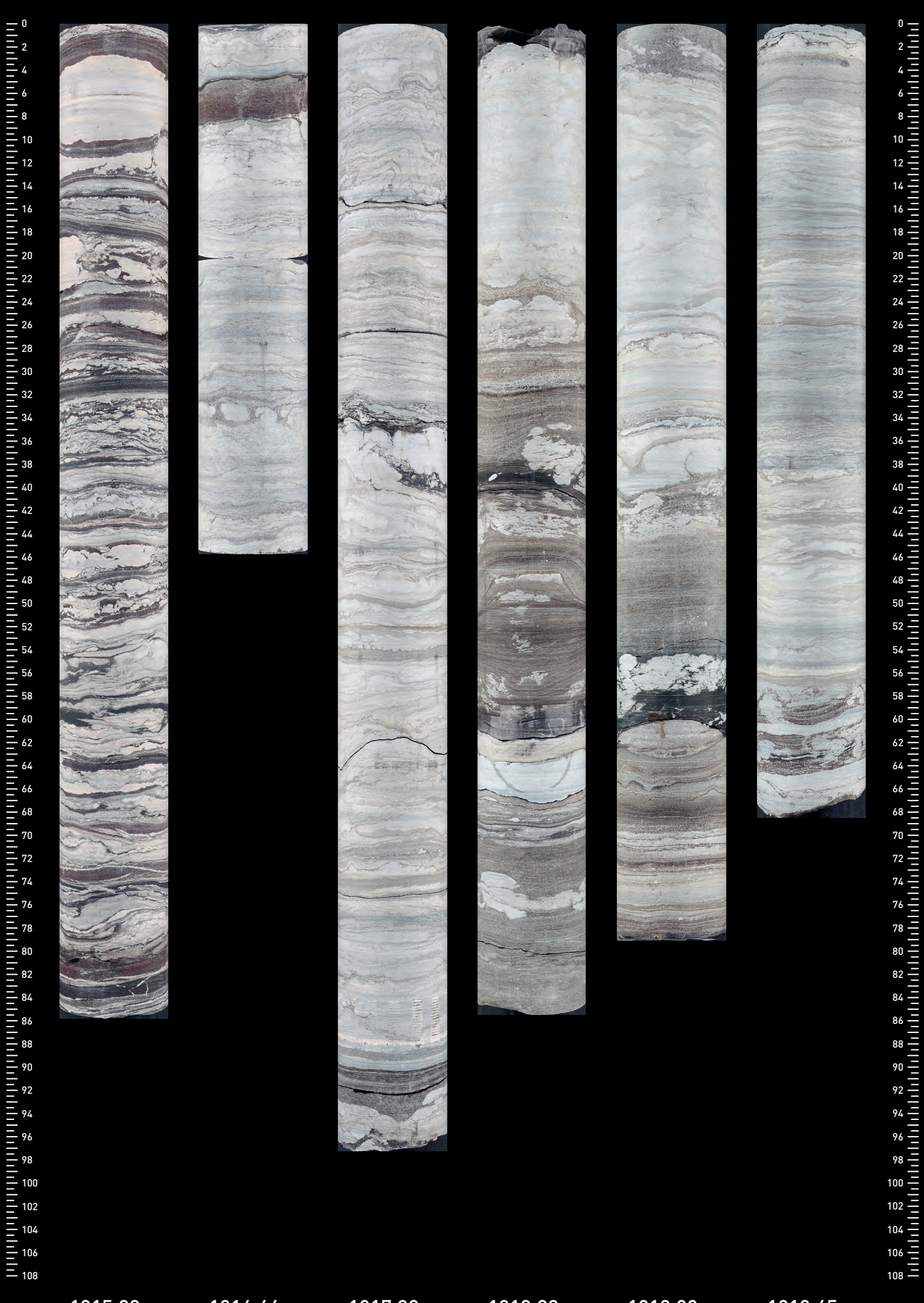


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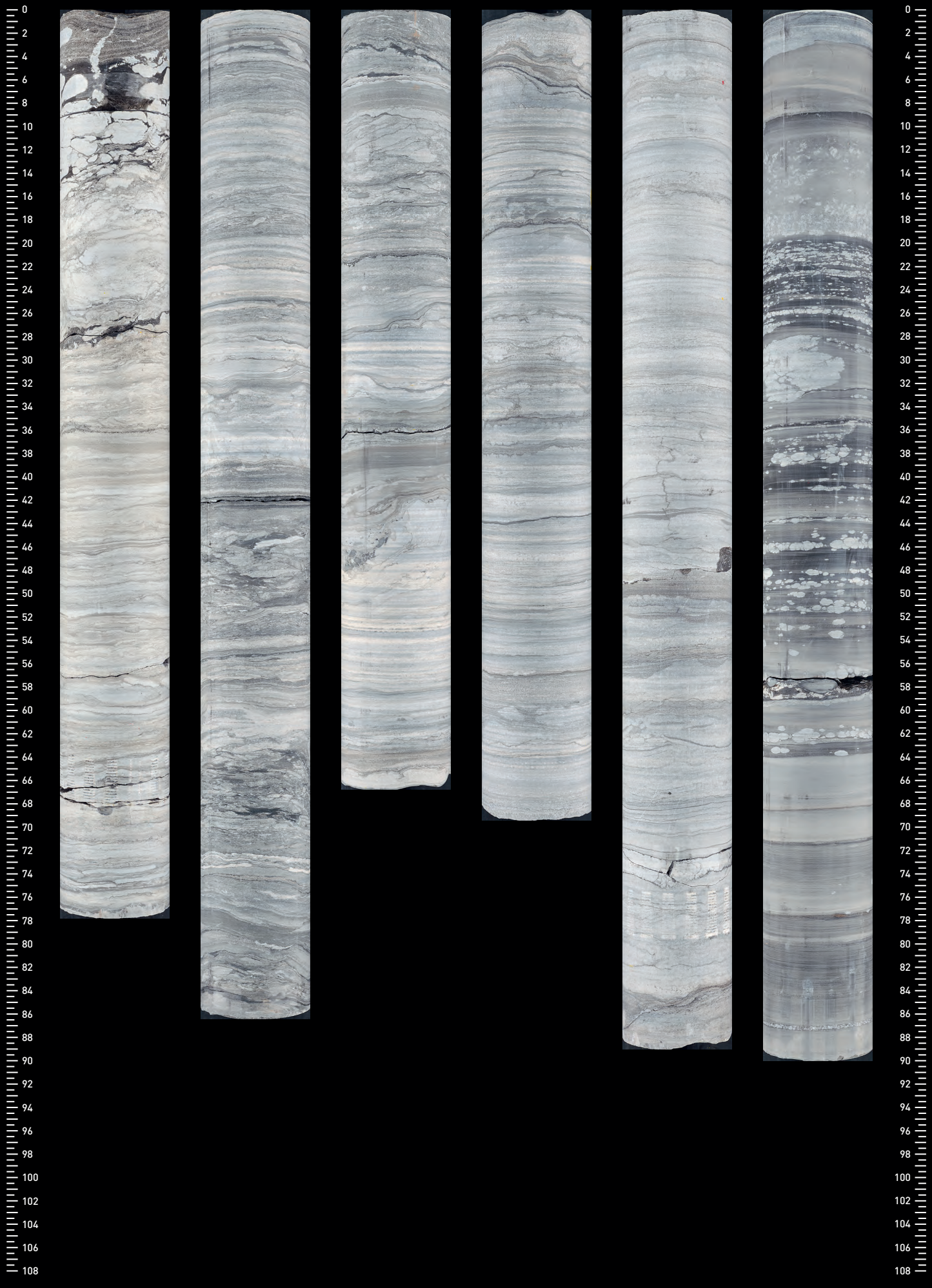
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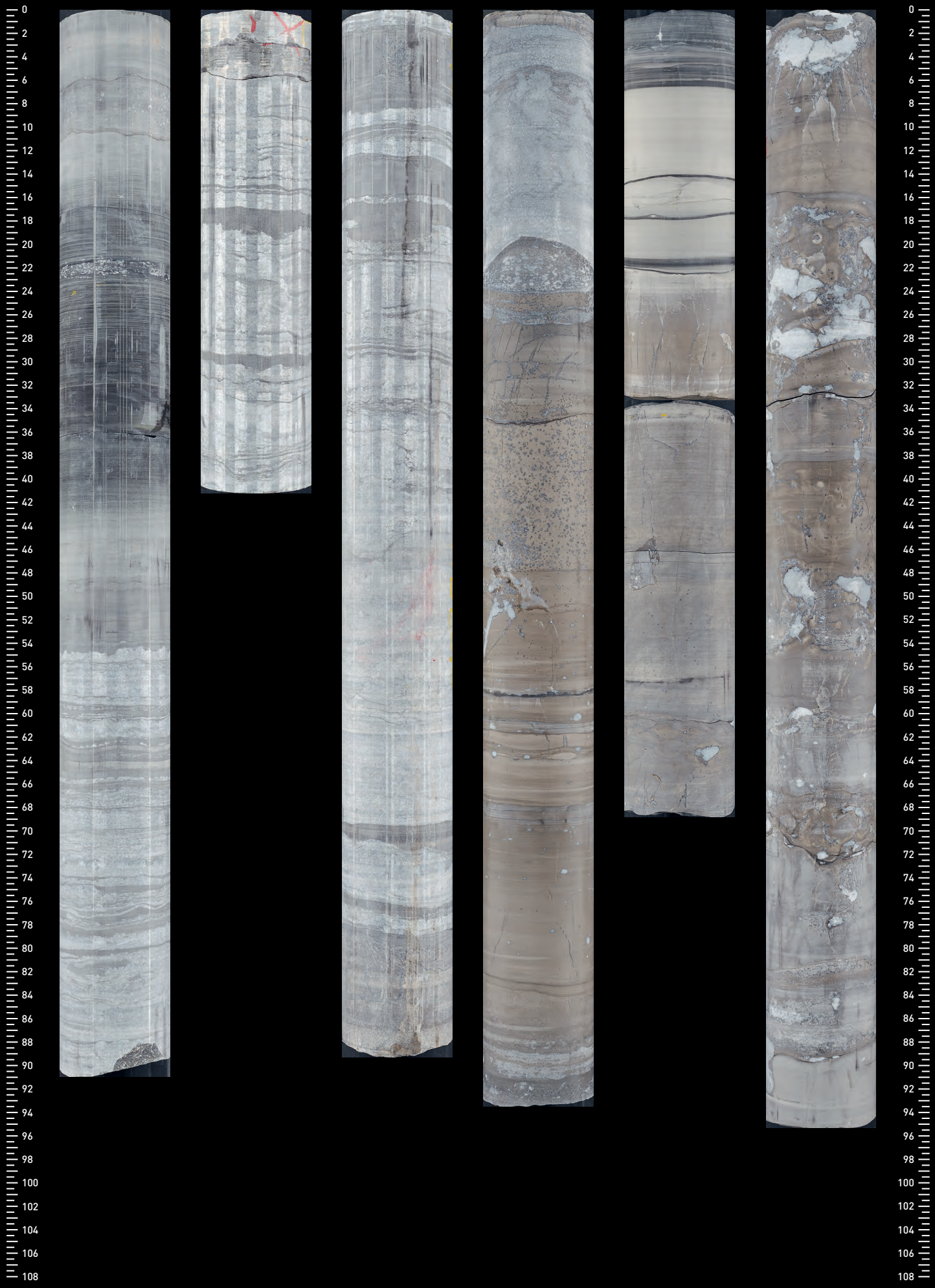

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1019.65m 1020.41m 1021.24m 1021.90m 1022.56m 1023.42m



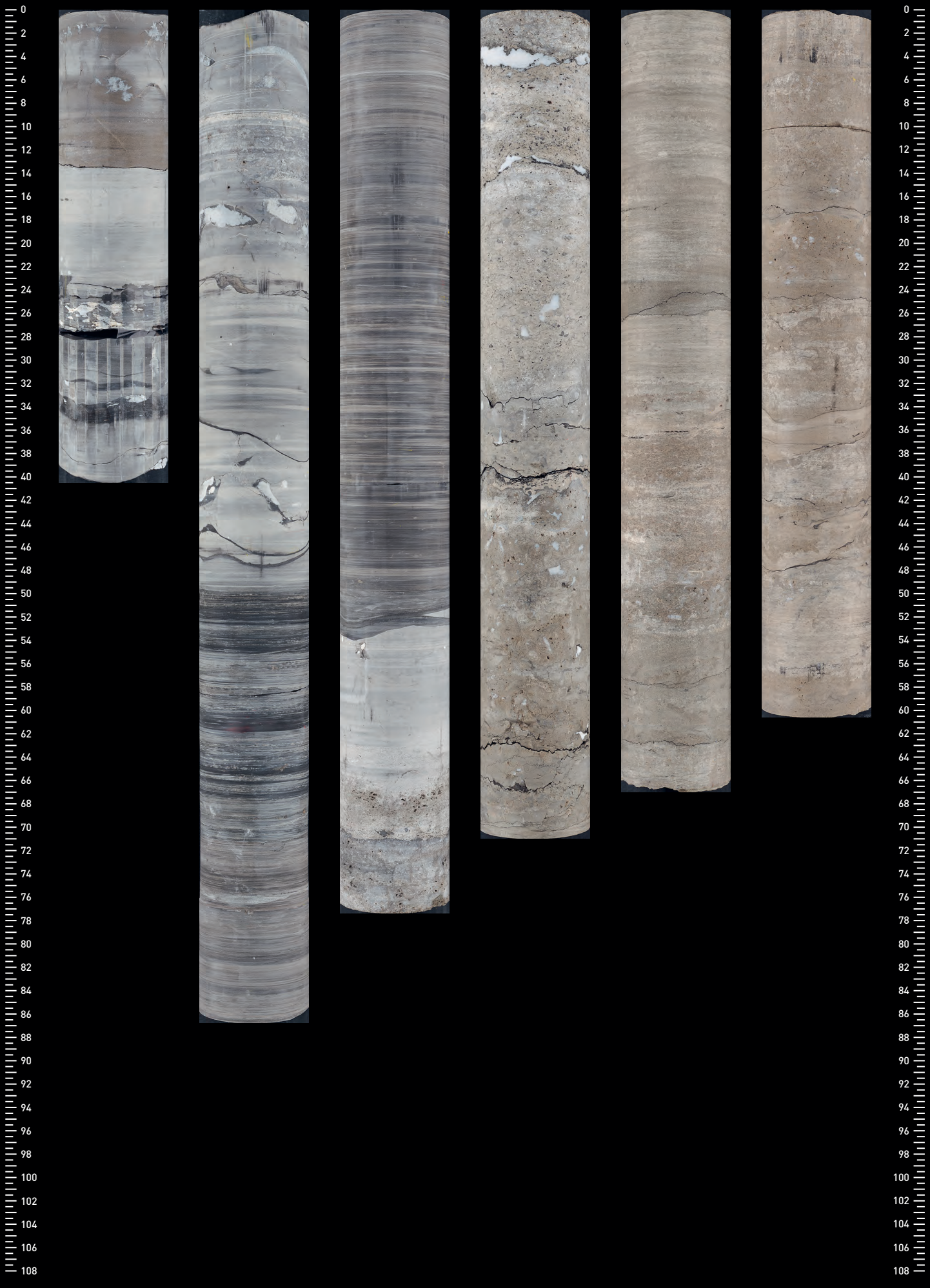
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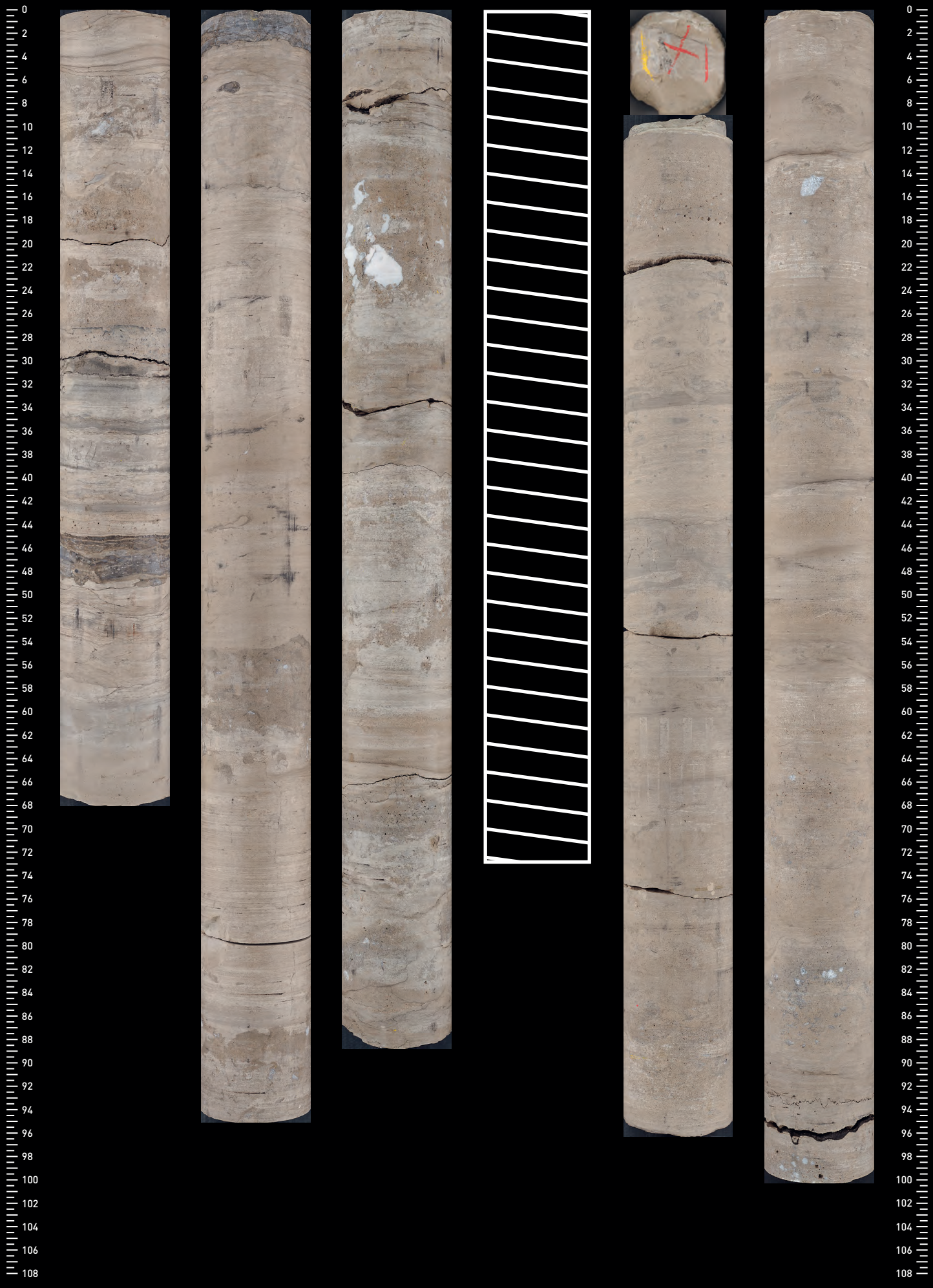
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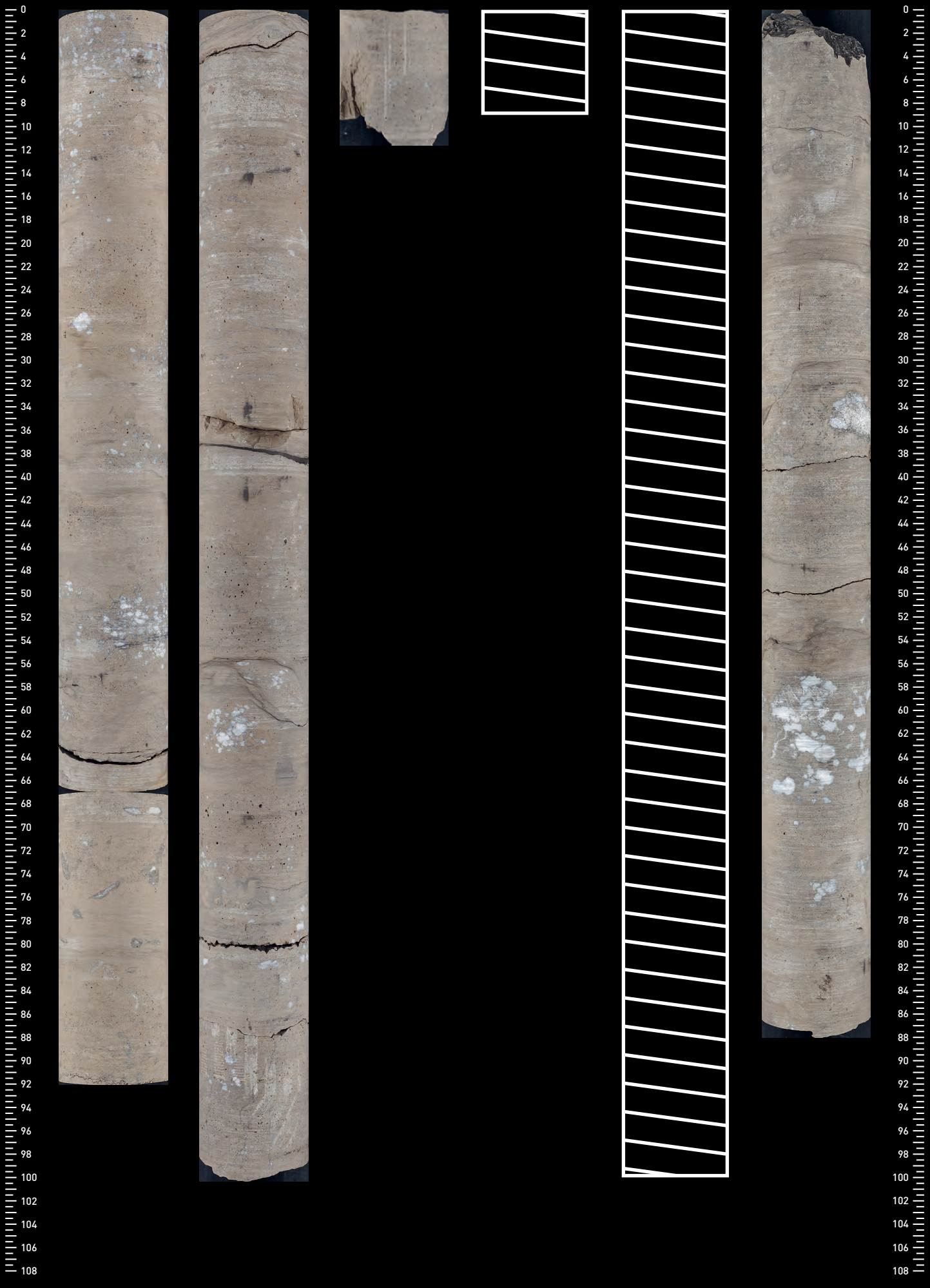
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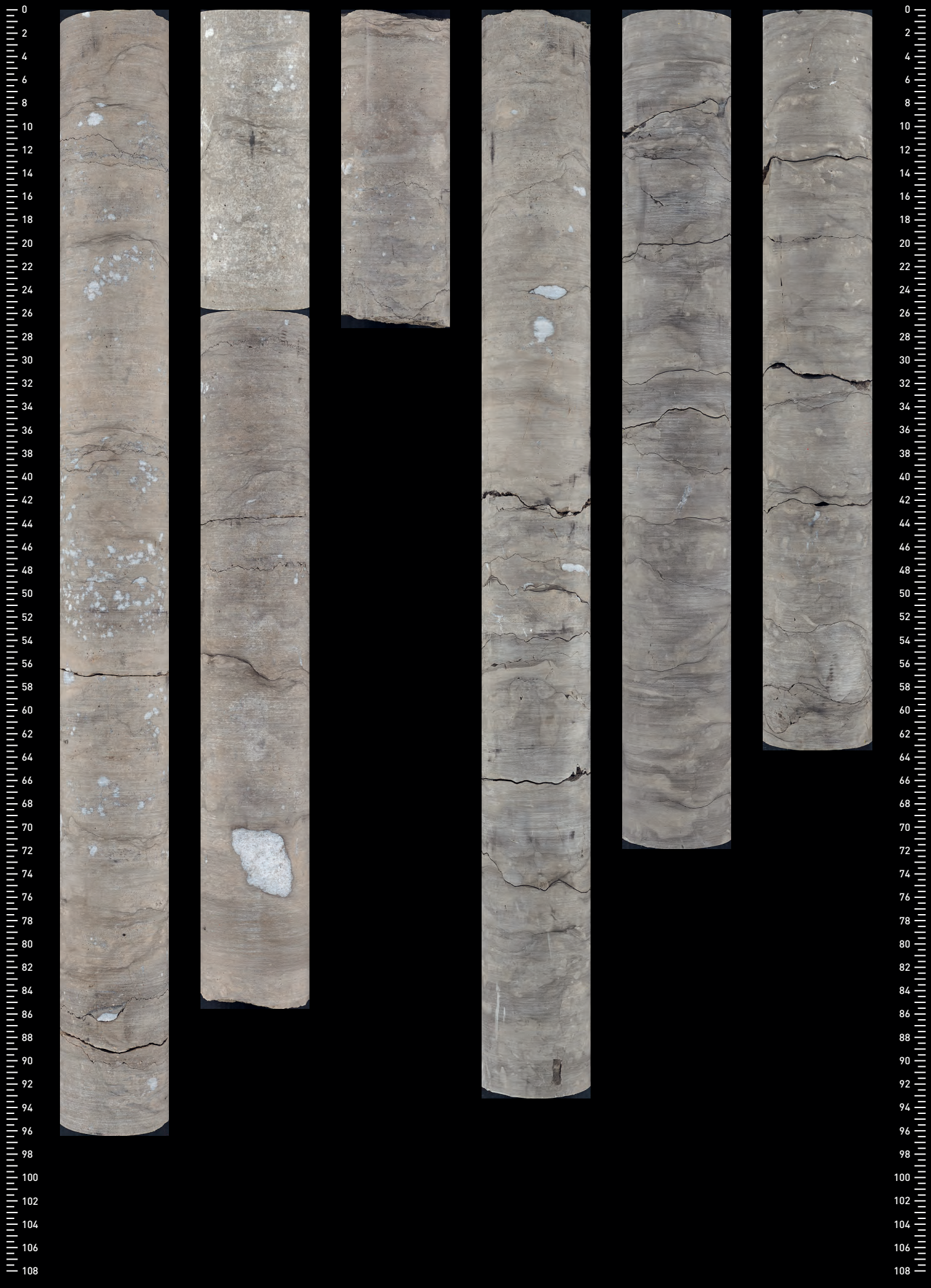
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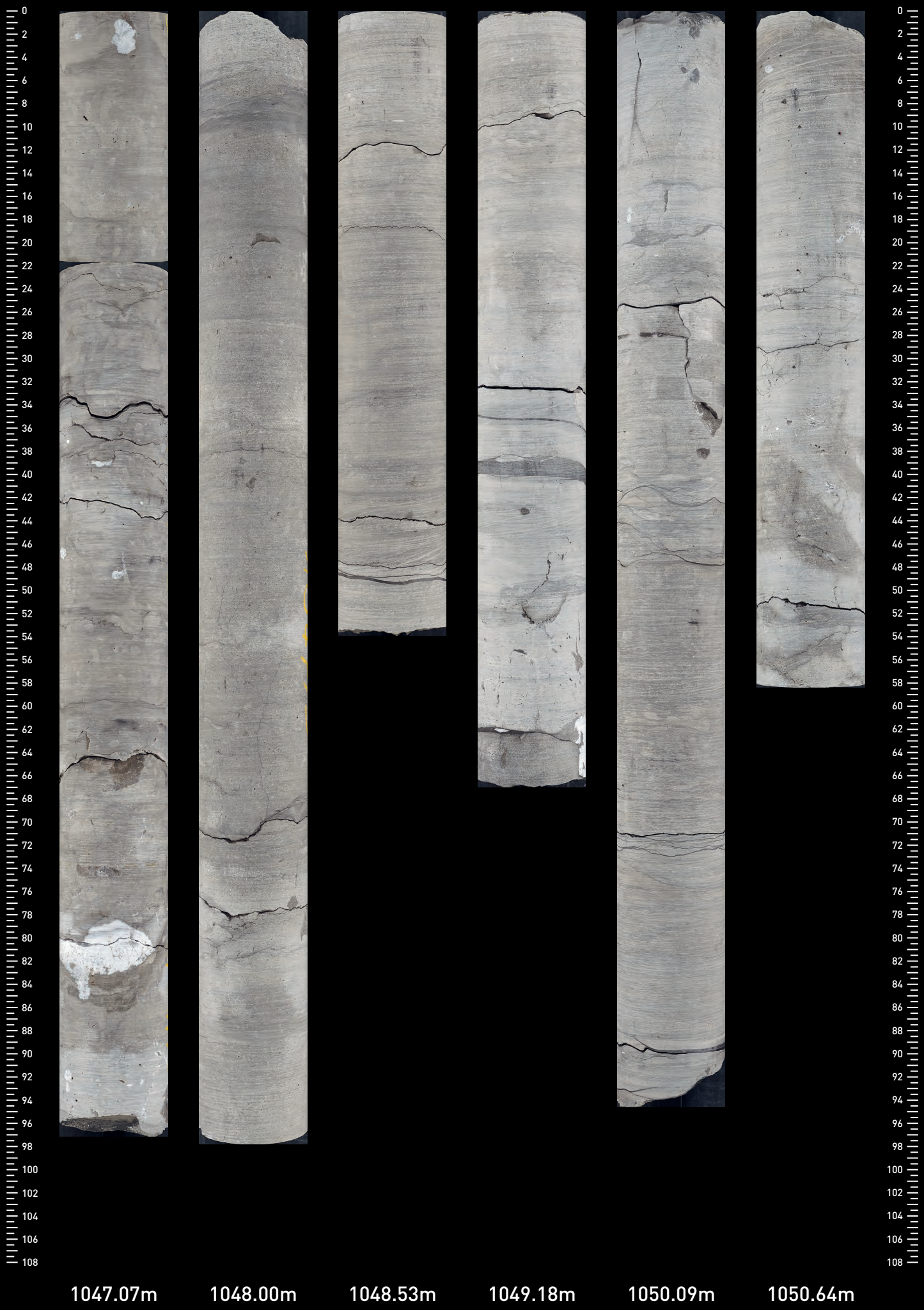


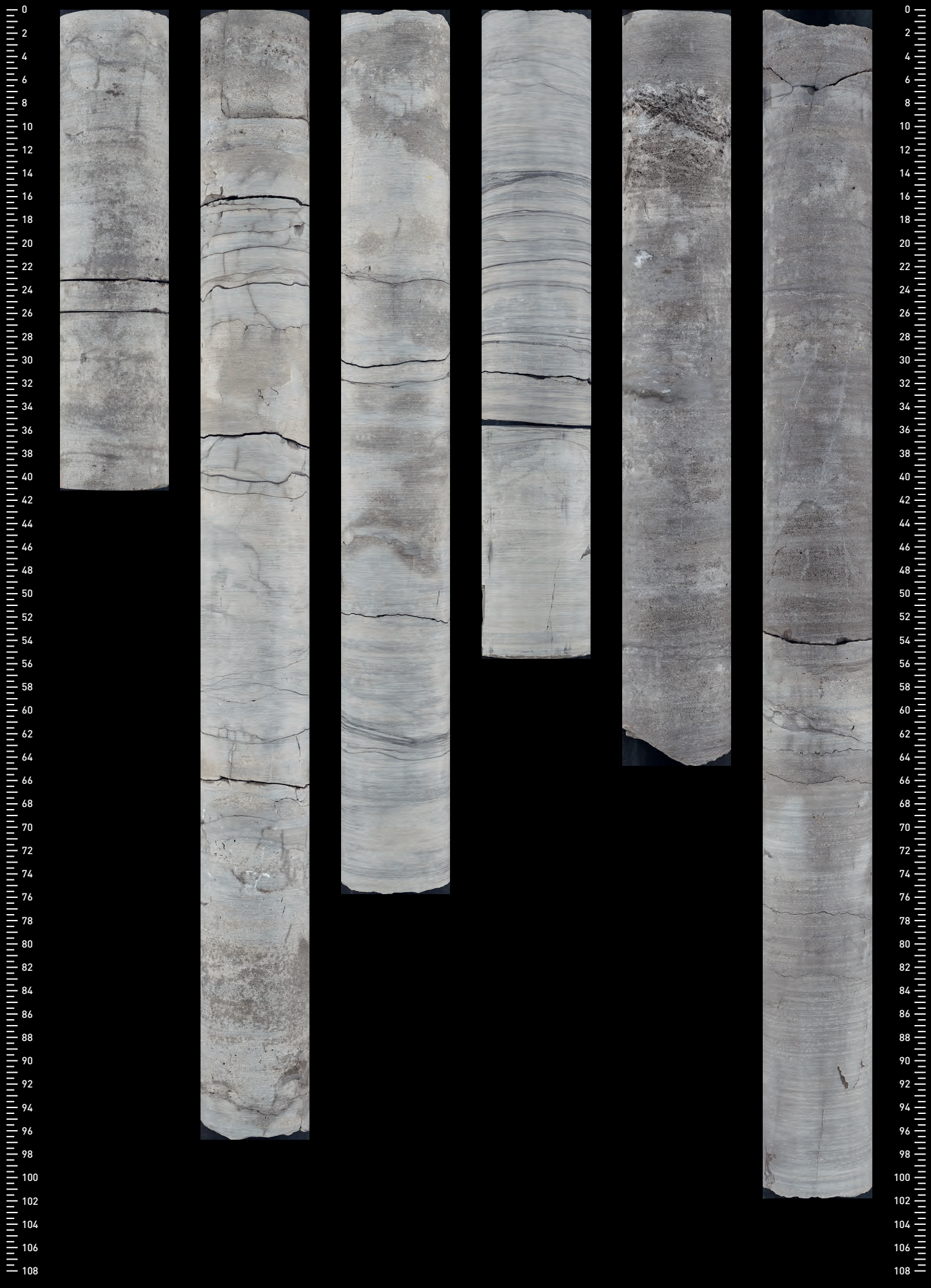
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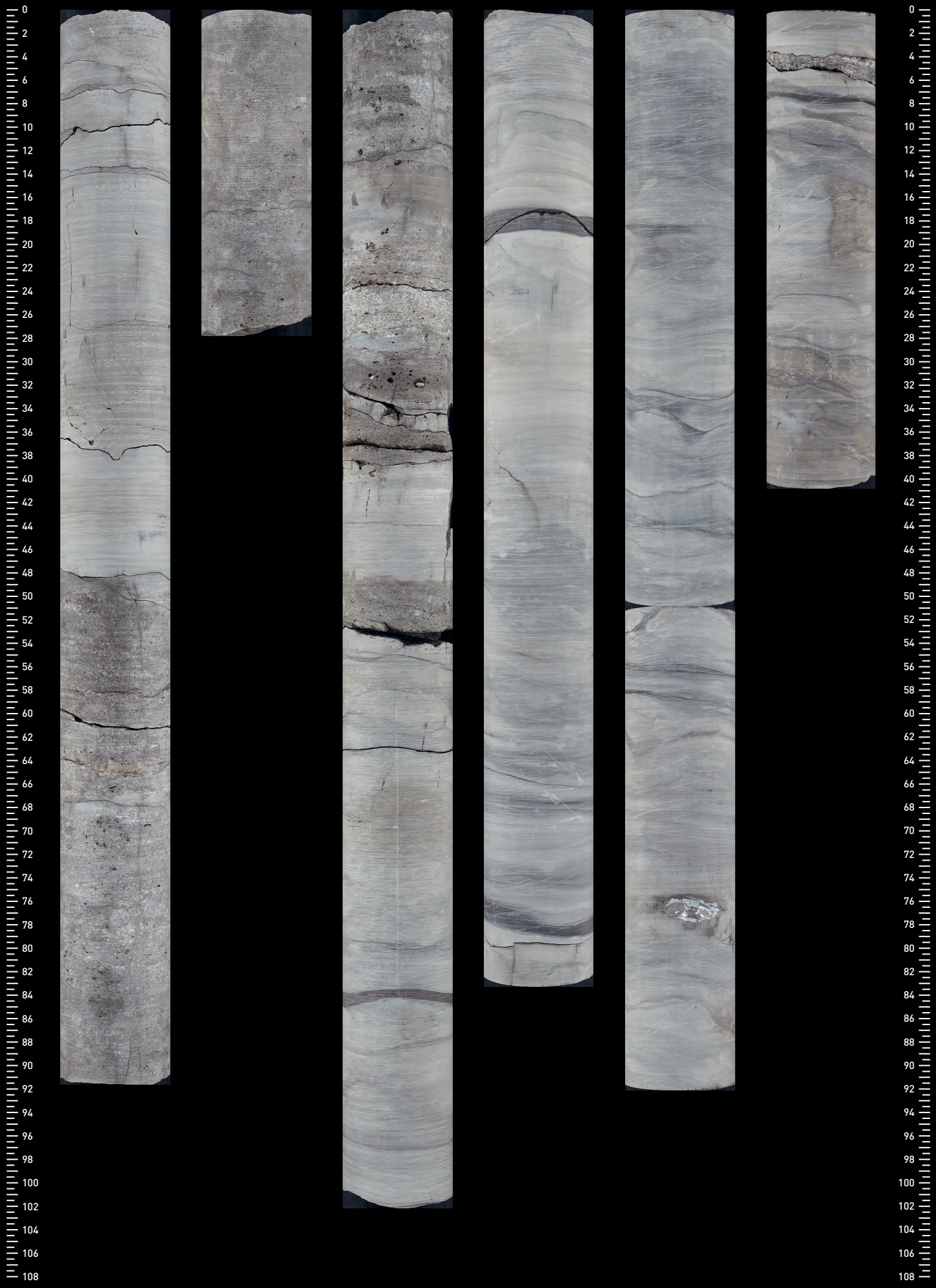


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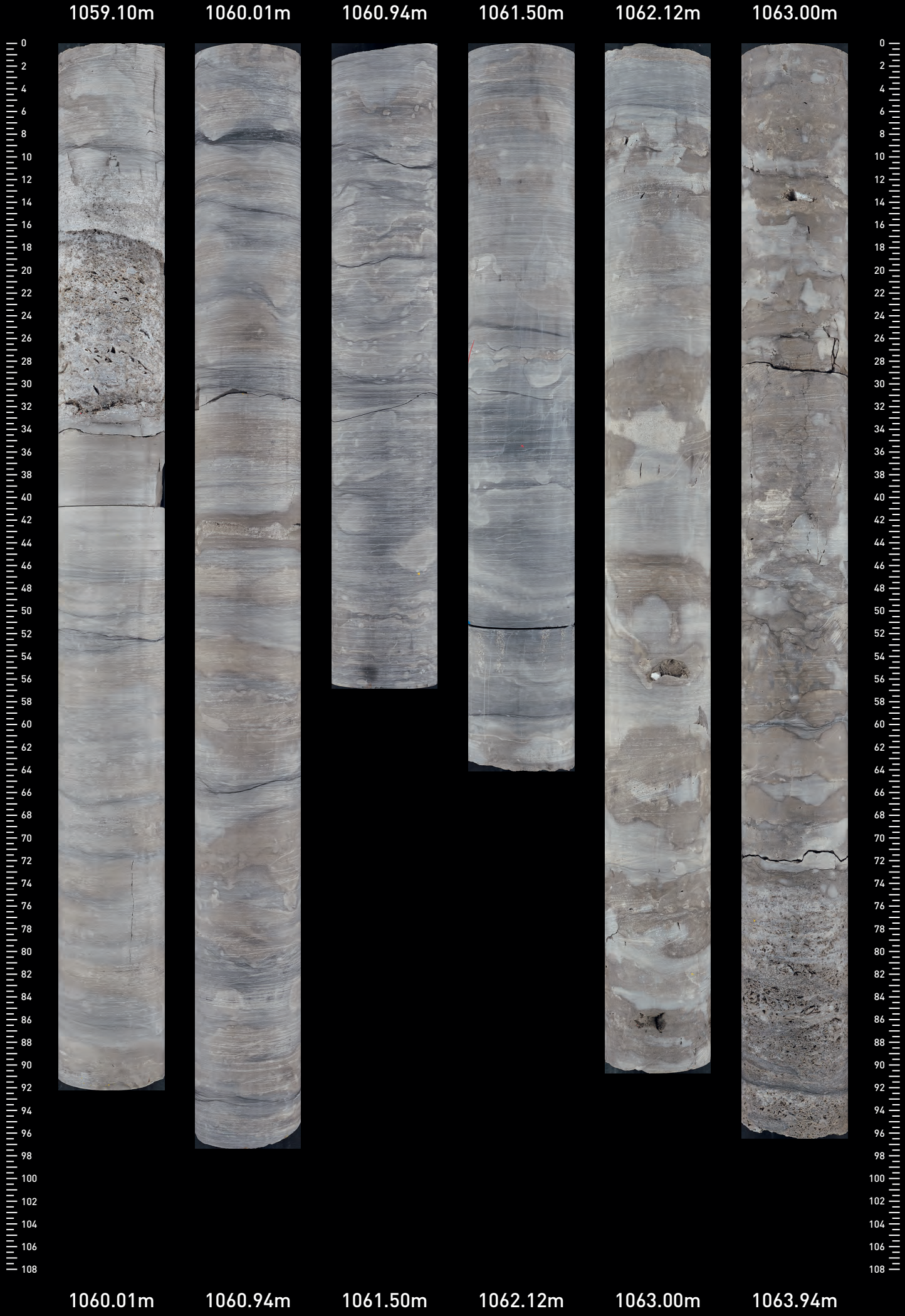

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1050.64m
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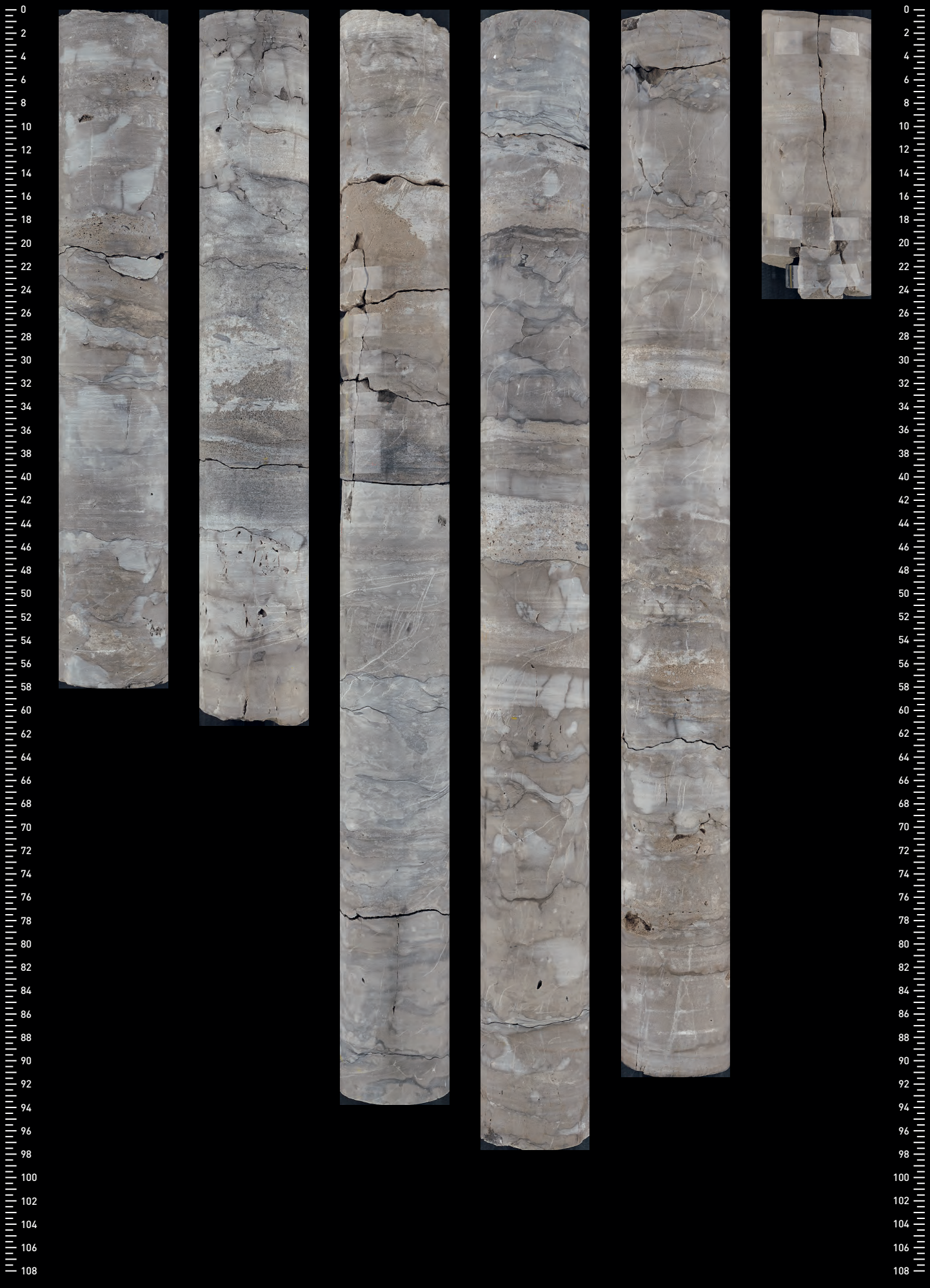
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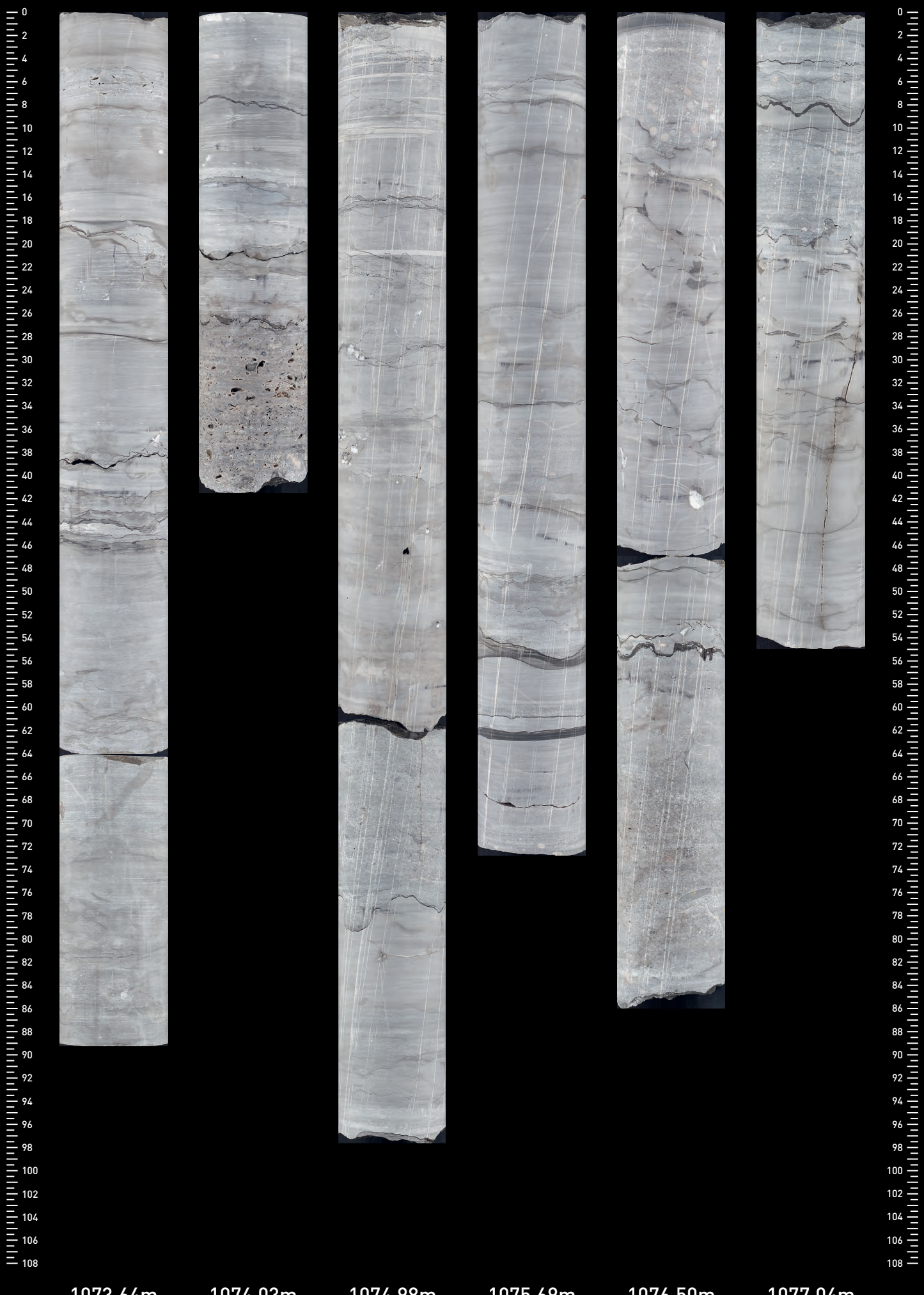


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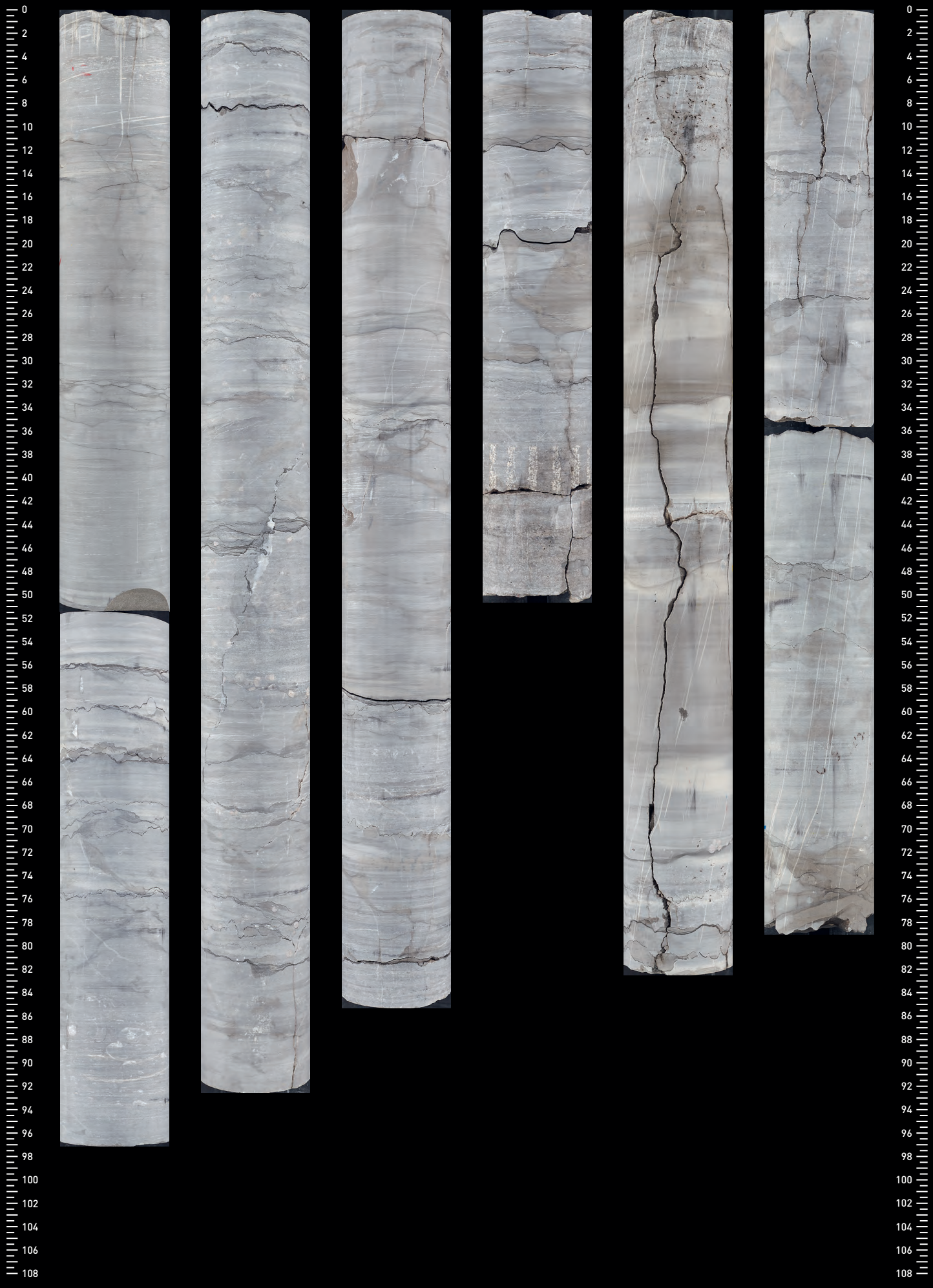
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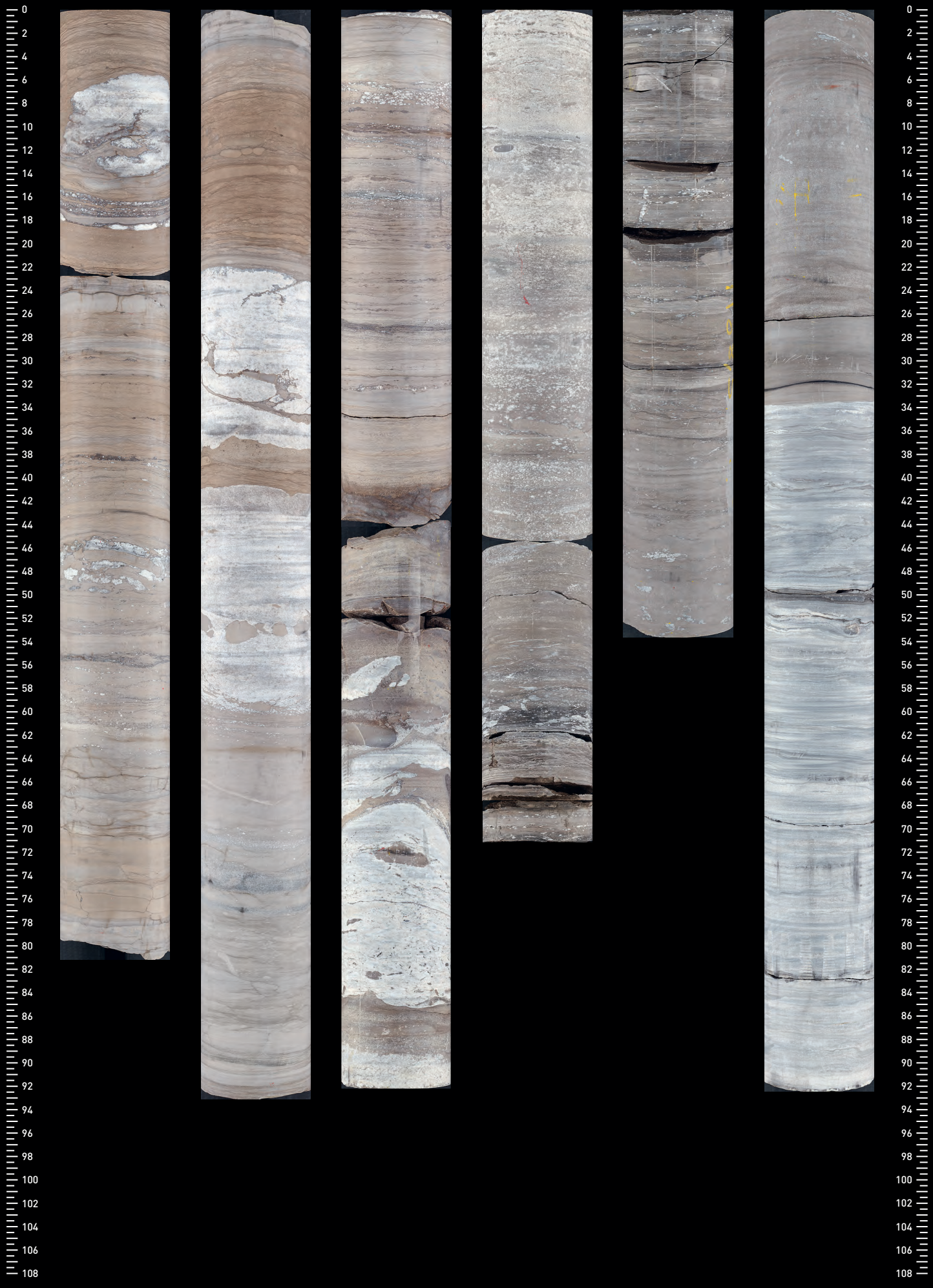

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1101.20m 1102.04m 1102.81m 1103.45m 1104.11m 1105.00m

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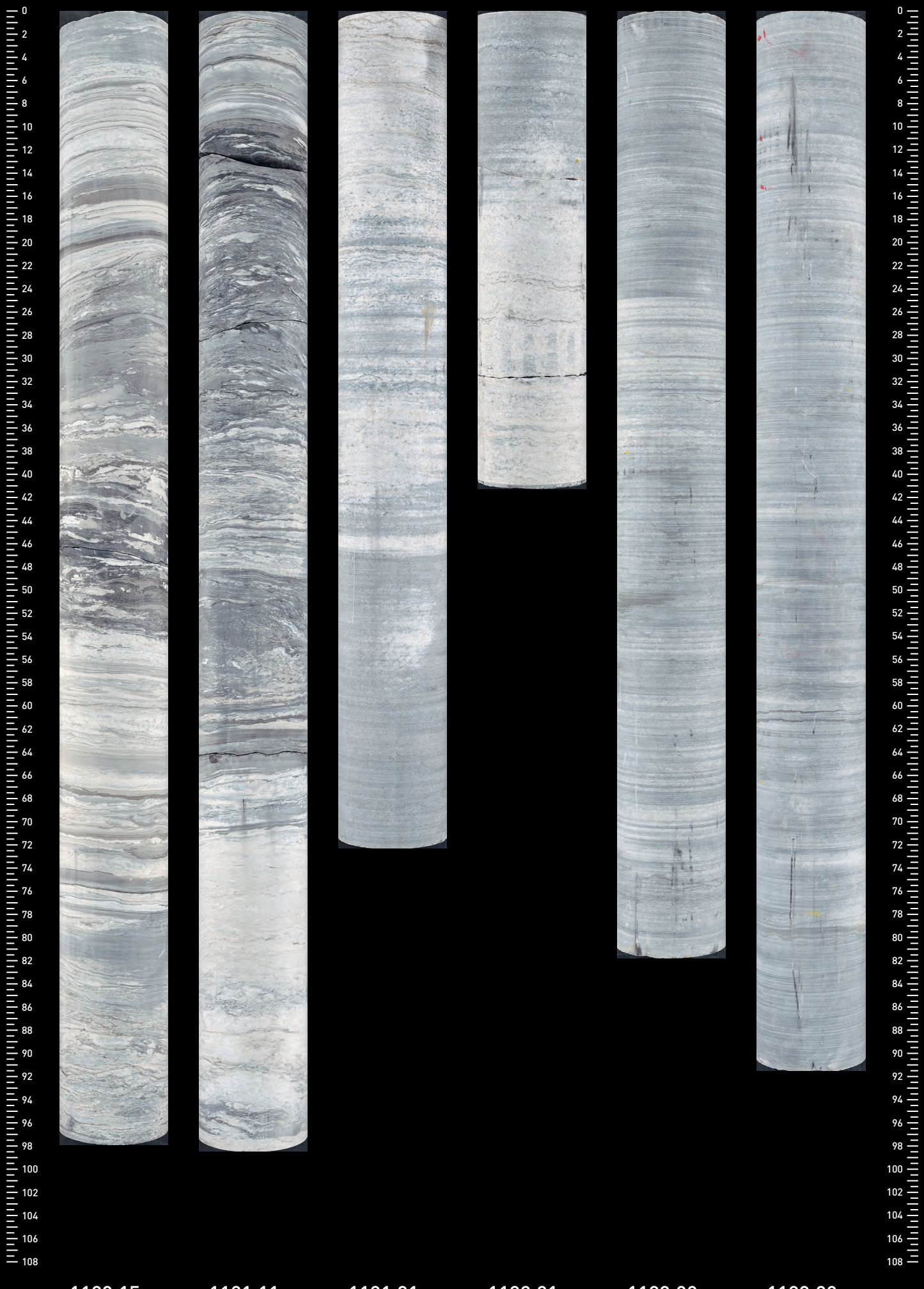


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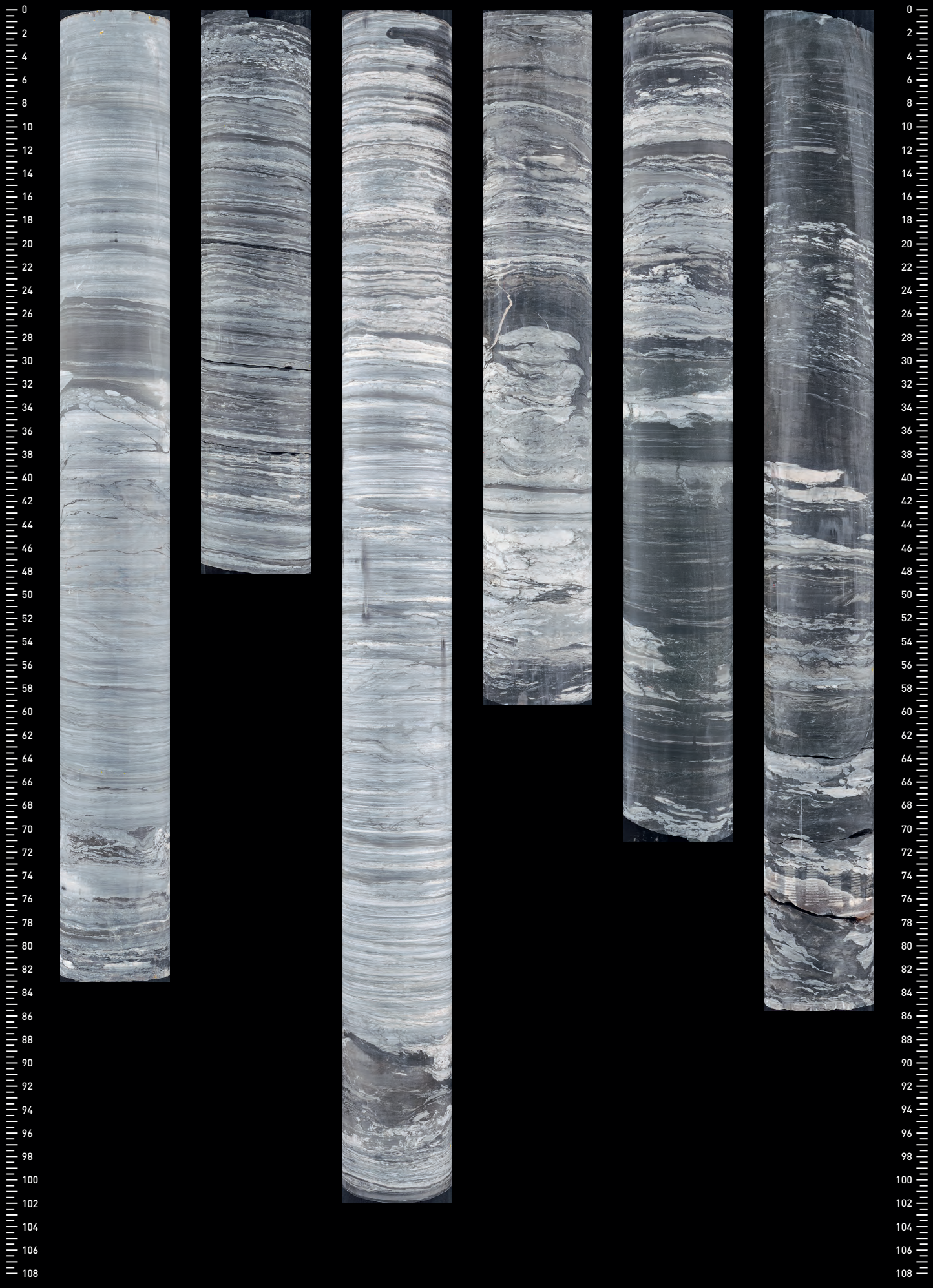
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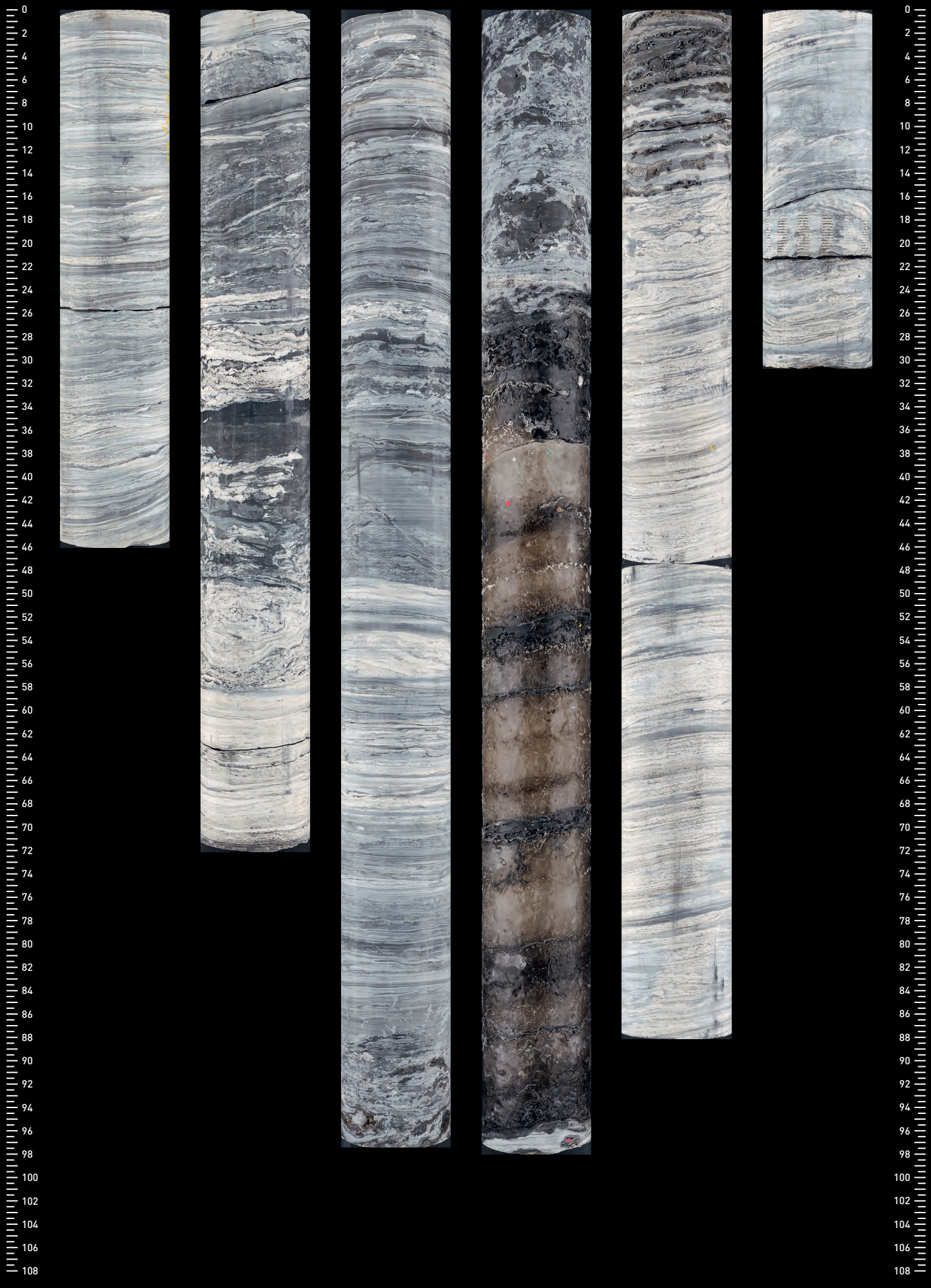
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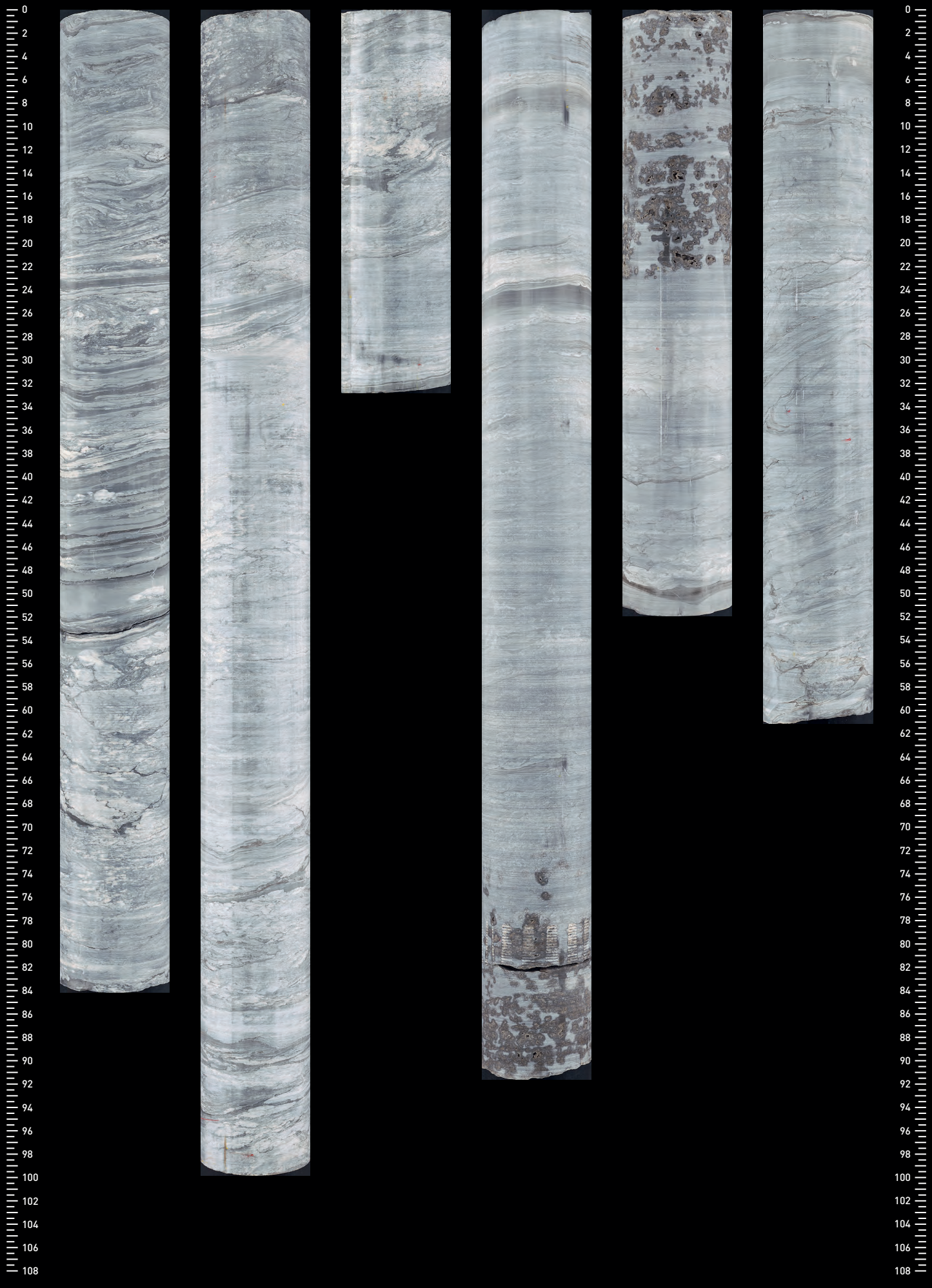
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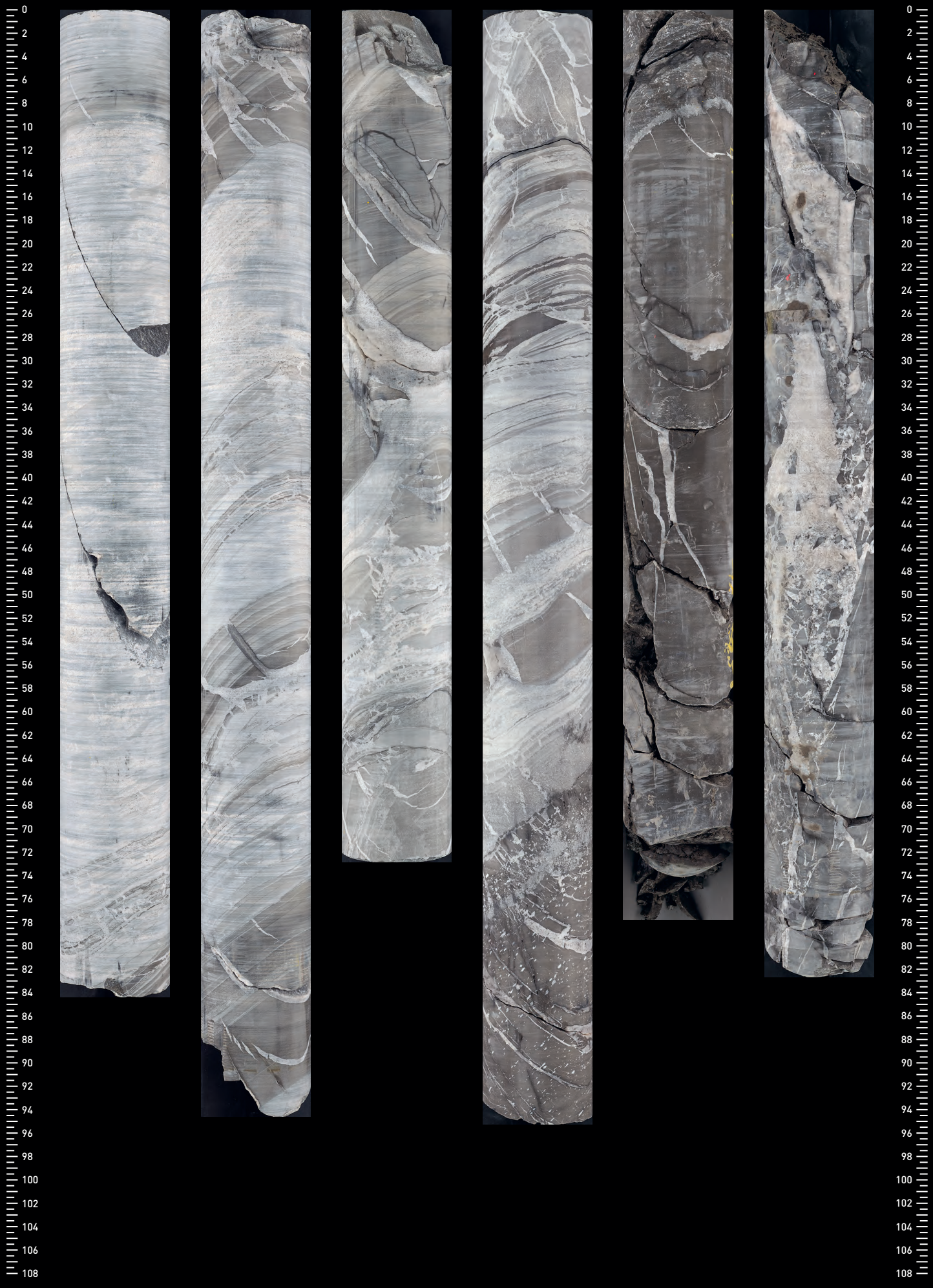

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1171.94m
1172.59m
1169.70m
1170.43m
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1172.59m
1173.55m

1173.55m 1174.13m 1175.00m 1175.77m 1176.40m 1177.00m



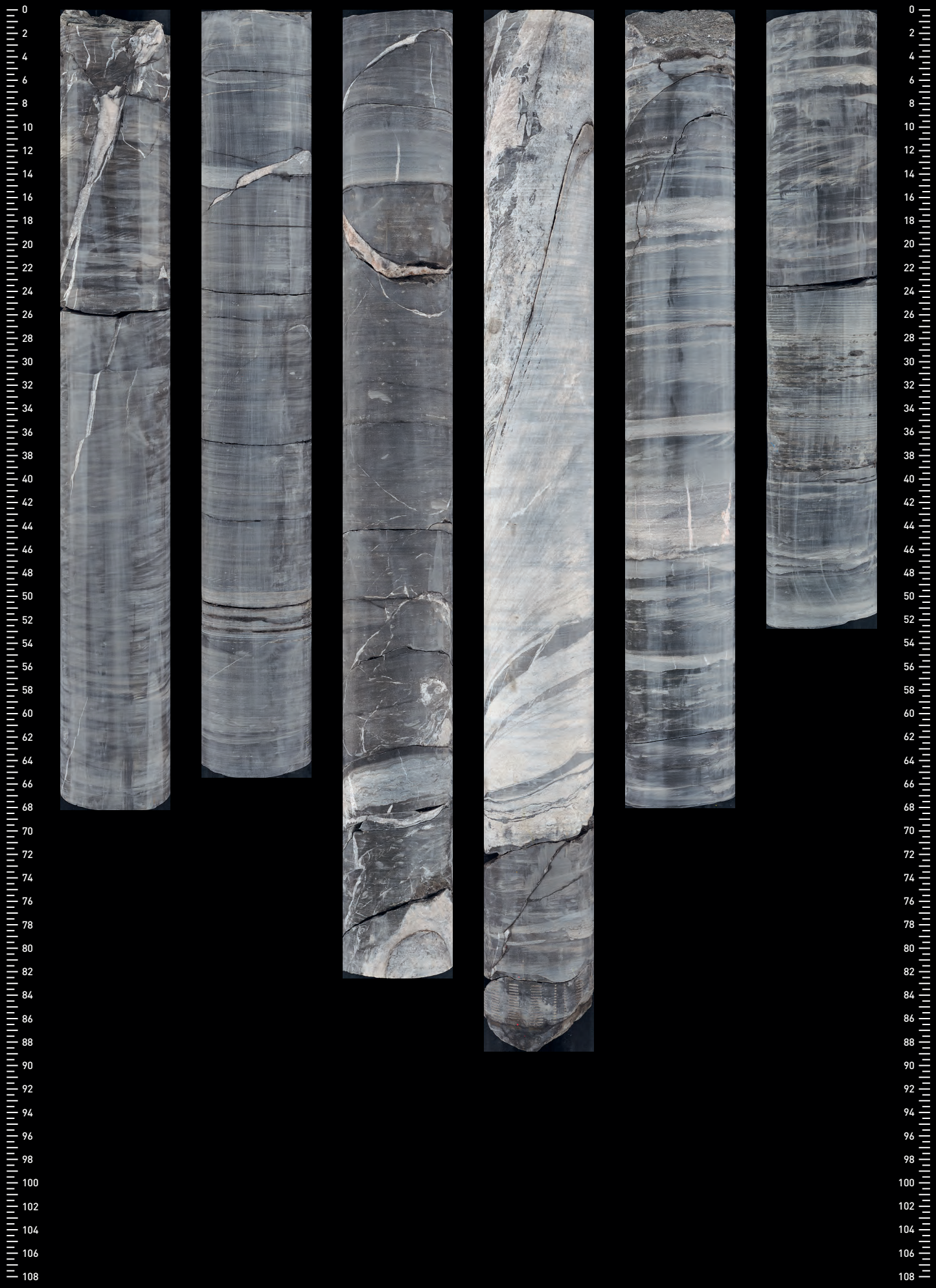
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1178.43m 1179.30m 1180.00m 1180.93m 1181.61m 1182.40m

1182.40m 1183.05m 1183.69m 1184.50m 1185.35m 1186.02m



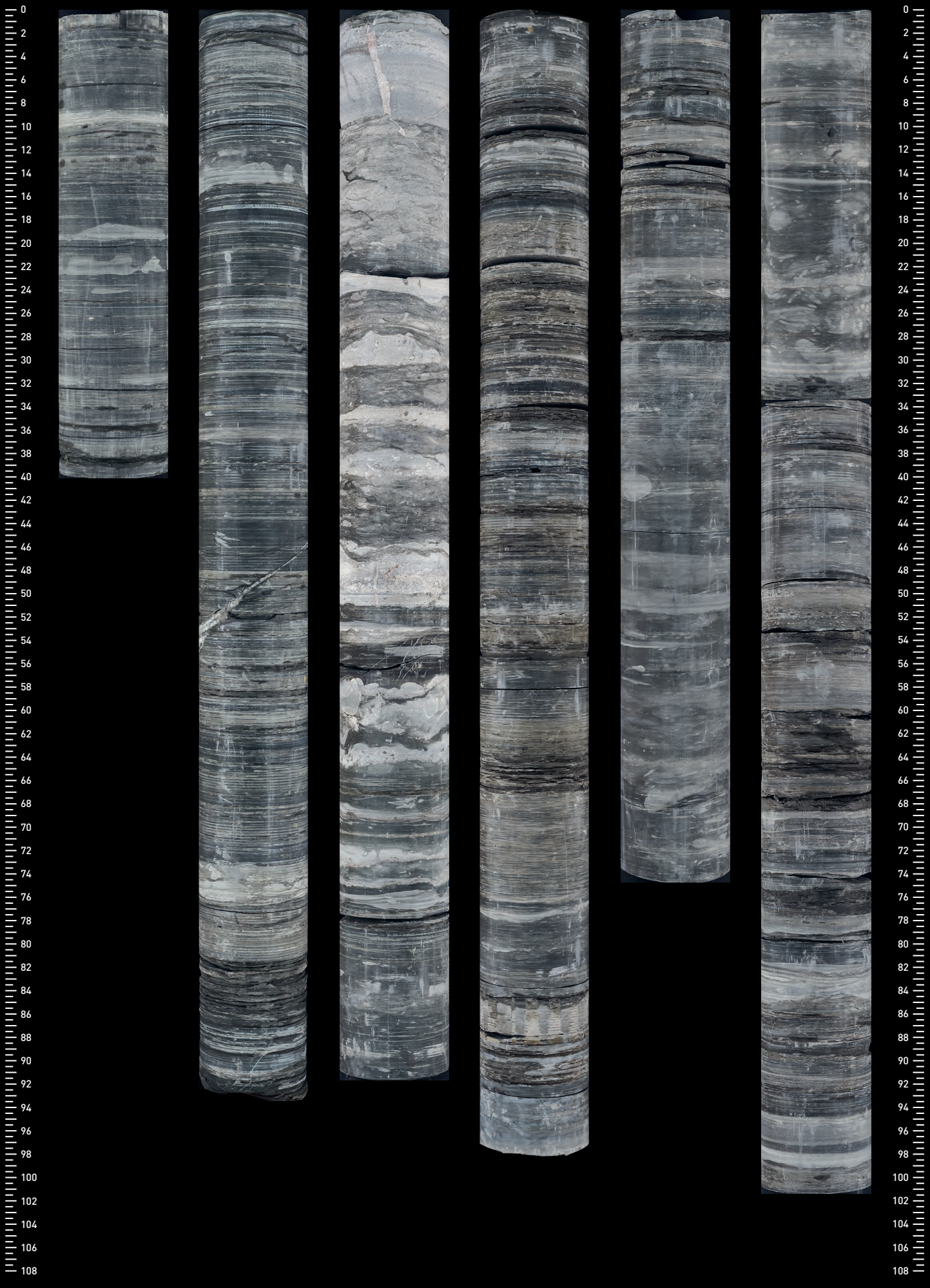
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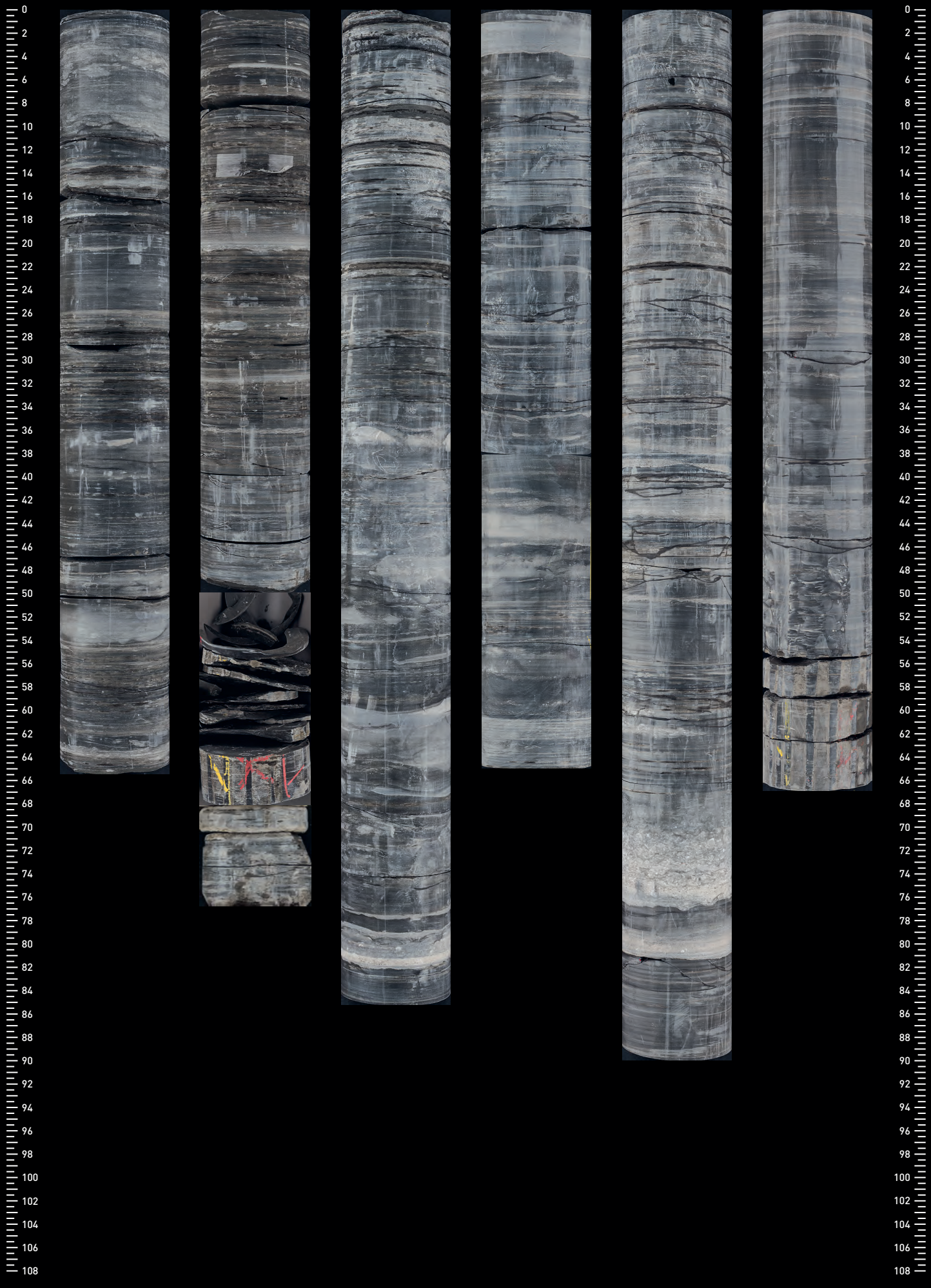


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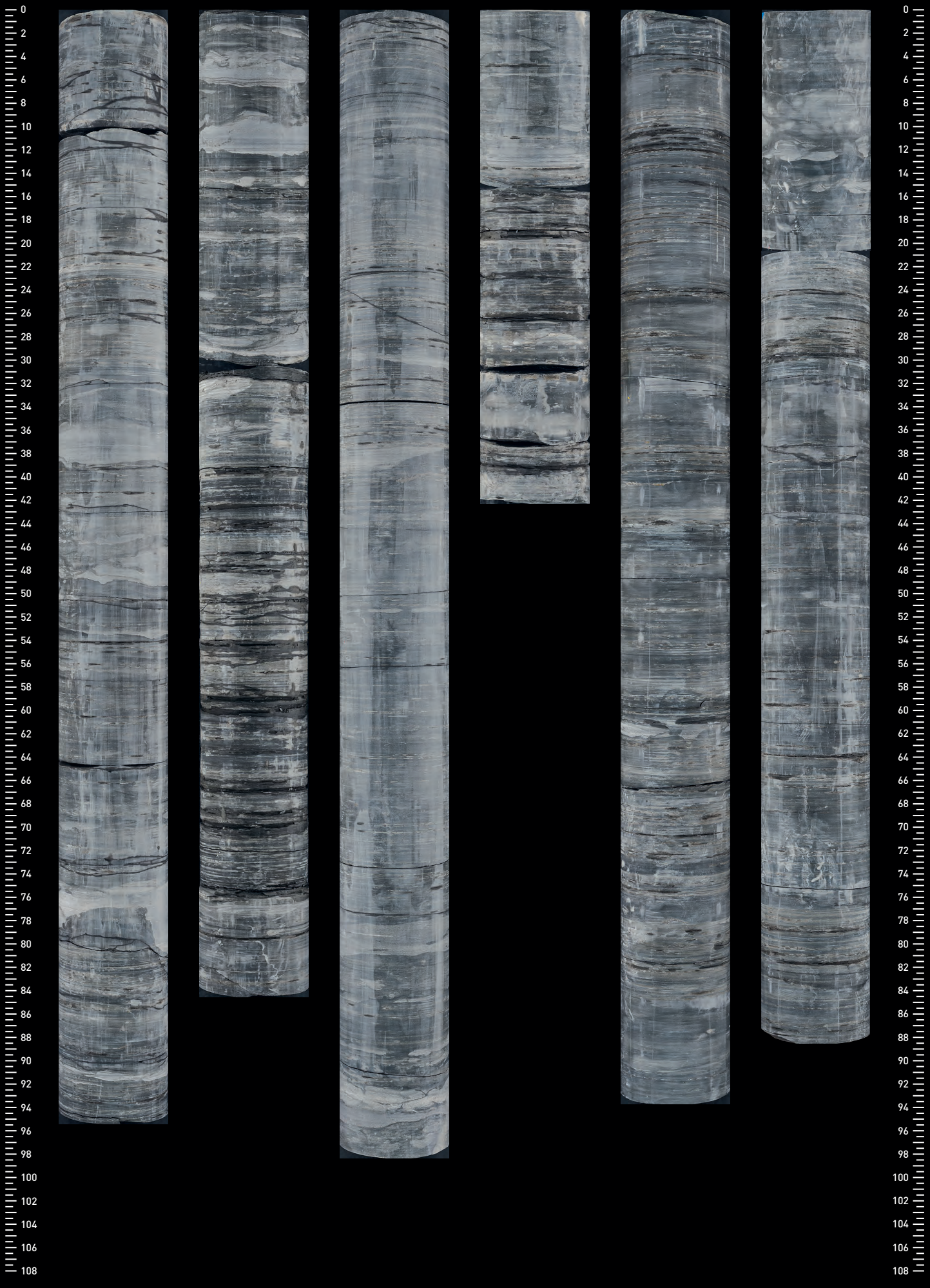
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1191.71m 1192.61m 1193.50m 1194.45m 1195.16m 1196.16m

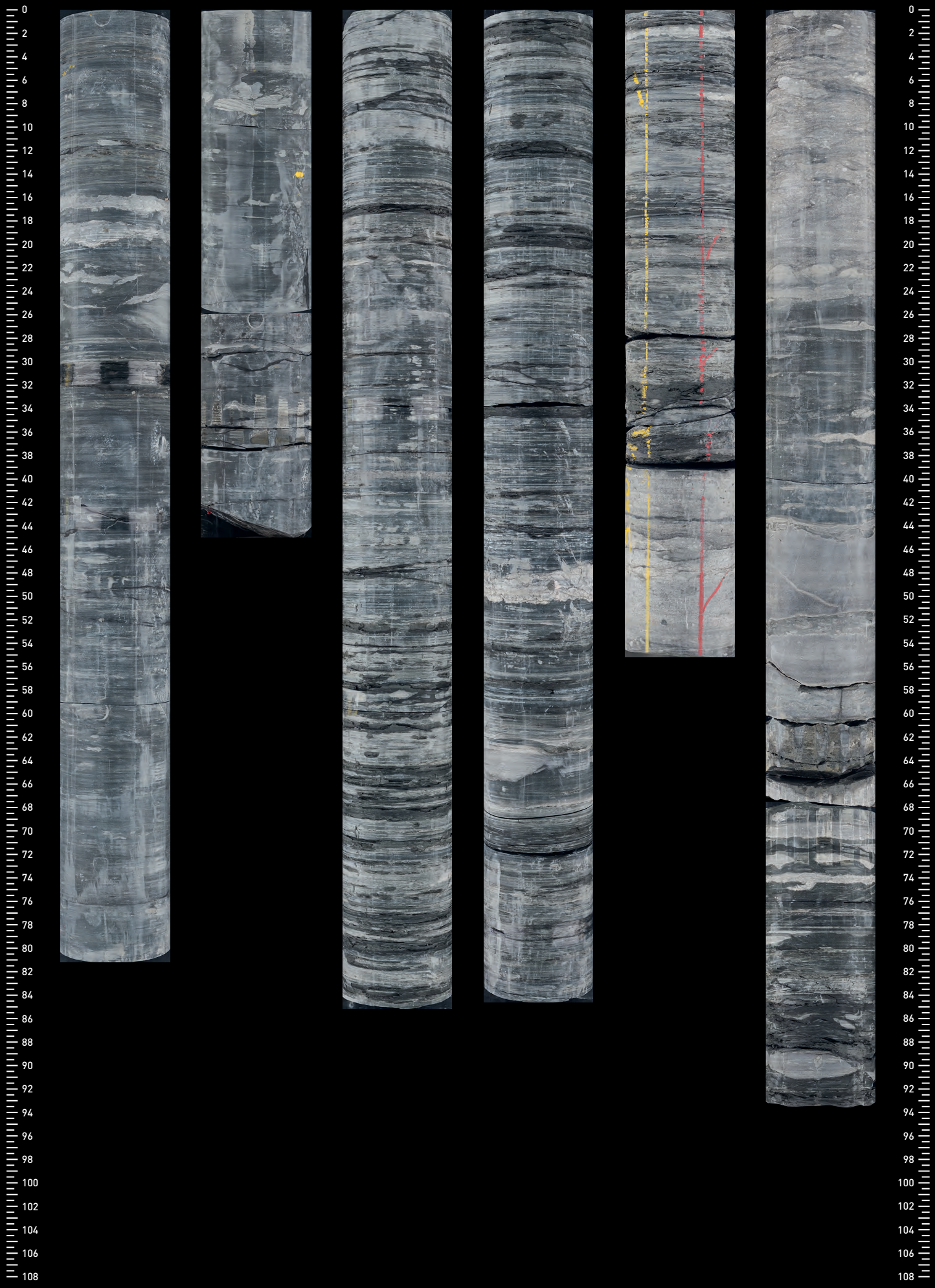

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1196.78m
1197.45m
1198.27m
1198.91m
1199.78m
1196.78m
1197.45m
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1199.78m
1200.42m

1200.42m 1201.35m 1202.17m 1203.12m 1203.52m 1204.42m

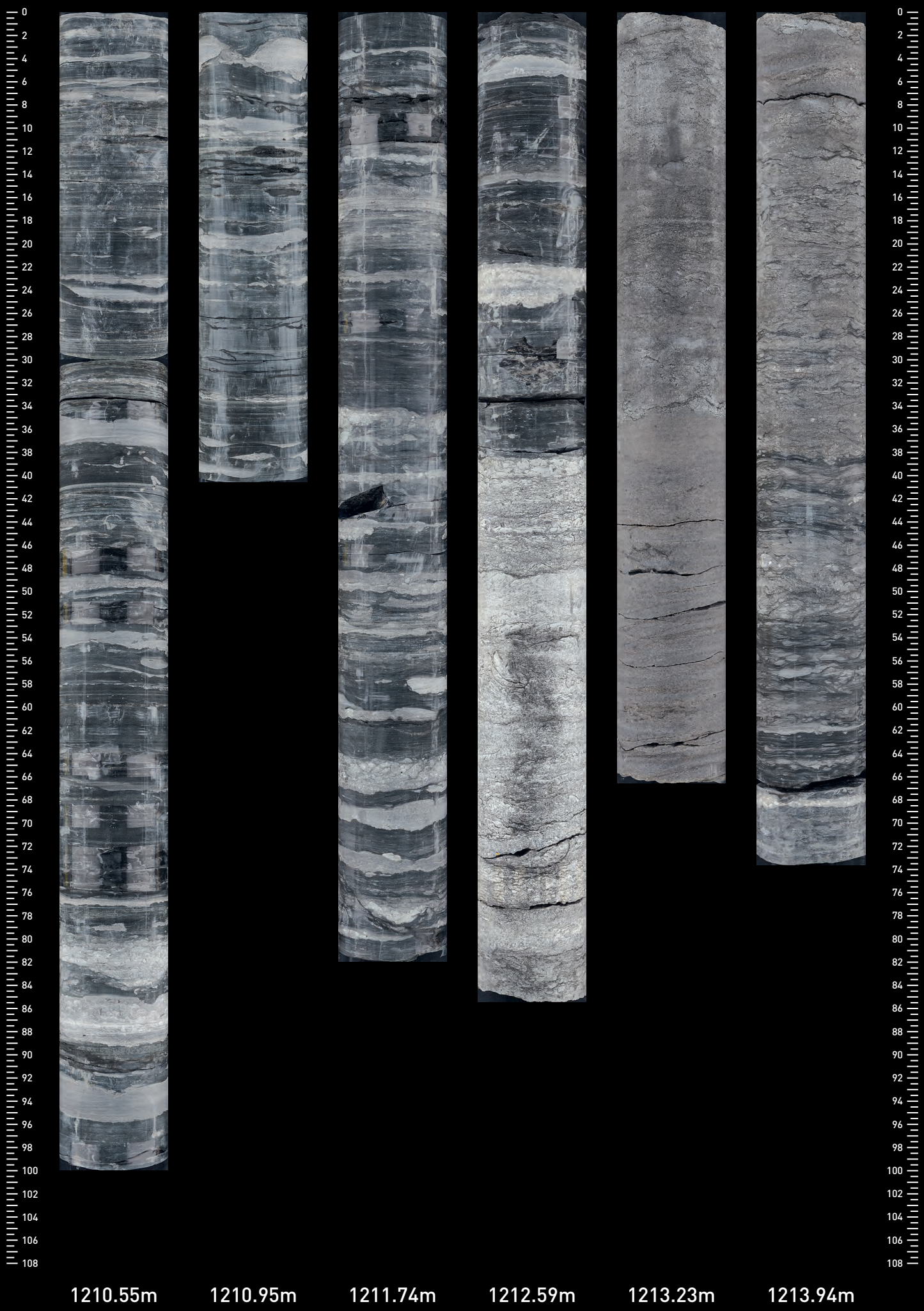


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1206.09m 1206.52m 1207.32m 1208.14m 1208.67m 1209.59m


1209.59m
1210.55m
1210.95m
1211.74m
1212.59m
1213.23m
1210.55m
1210.95m
1211.74m
1212.59m
1213.23m
1213.94m

1213.94m 1214.80m 1215.52m 1216.31m 1217.20m 1217.77m



1214.80m 1215.52m 1216.31m 1217.20m 1217.77m 1218.59m

1218.59m 1219.50m 1220.08m 1220.78m 1221.47m 1222.13m



1219.50m 1220.08m 1220.78m 1221.47m 1222.13m 1223.10m

1223.10m 1223.88m 1224.72m 1225.55m 1226.13m 1226.93m



1223.88m 1224.72m 1225.55m 1226.13m 1226.93m 1227.57m

NAB 22-01

200

1227.57m 1228.48m 1229.04m 1229.49m 1230.18m 1230.53m



1228.48m 1229.04m 1229.49m 1230.18m 1230.53m 1231.38m

1231.38m 1232.10m 1232.69m 1233.53m 1234.40m 1235.18m



1232.10m 1232.69m 1233.53m 1234.40m 1235.18m 1235.69m

NAB 22-01 202

1235.69m 1236.51m 1237.48m 1238.21m 1238.81m 1239.55m



1236.51m 1237.48m 1238.21m 1238.81m 1239.55m 1240.20m

1240.20m 1241.10m 1241.73m 1242.58m 1242.99m 1243.97m



1241.10m 1241.73m 1242.58m 1242.99m 1243.97m 1244.80m


1244.80m
1245.56m
1246.33m
1247.23m
1247.98m
1248.52m
1245.56m
1246.33m
1247.23m
1247.98m
1248.52m
1249.10m

1249.10m 1249.95m 1250.57m 1251.40m 1251.64m 1252.41m



1249.95m 1250.57m 1251.40m 1251.64m 1252.41m 1253.14m

1253.14m 1253.96m 1254.23m 1255.23m 1256.20m 1257.03m



1253.96m 1254.23m 1255.23m 1256.20m 1257.03m 1257.89m

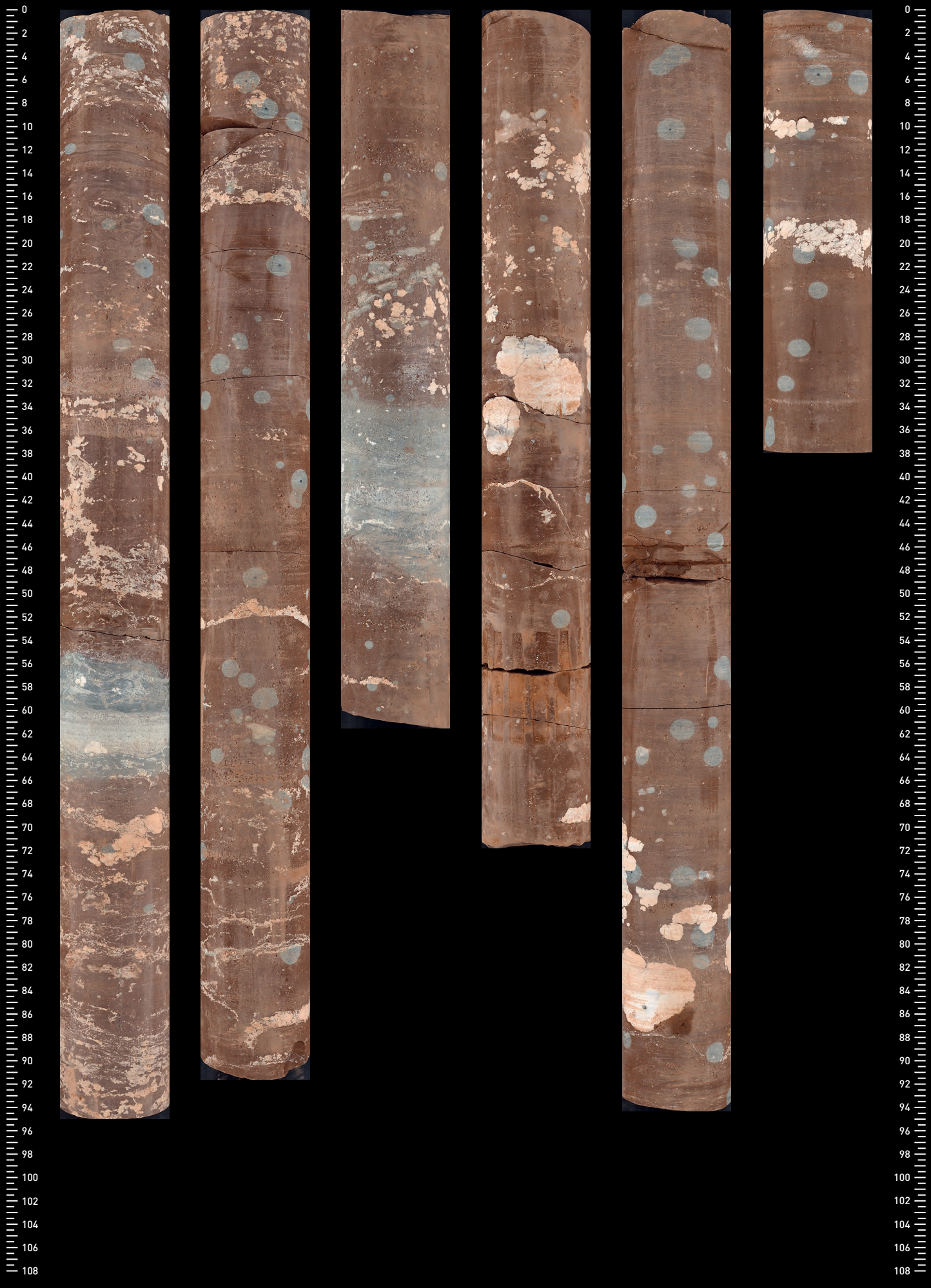

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1261.50m
1262.08m

1262.08m 1263.06m 1263.71m 1264.66m 1265.26m 1265.81m



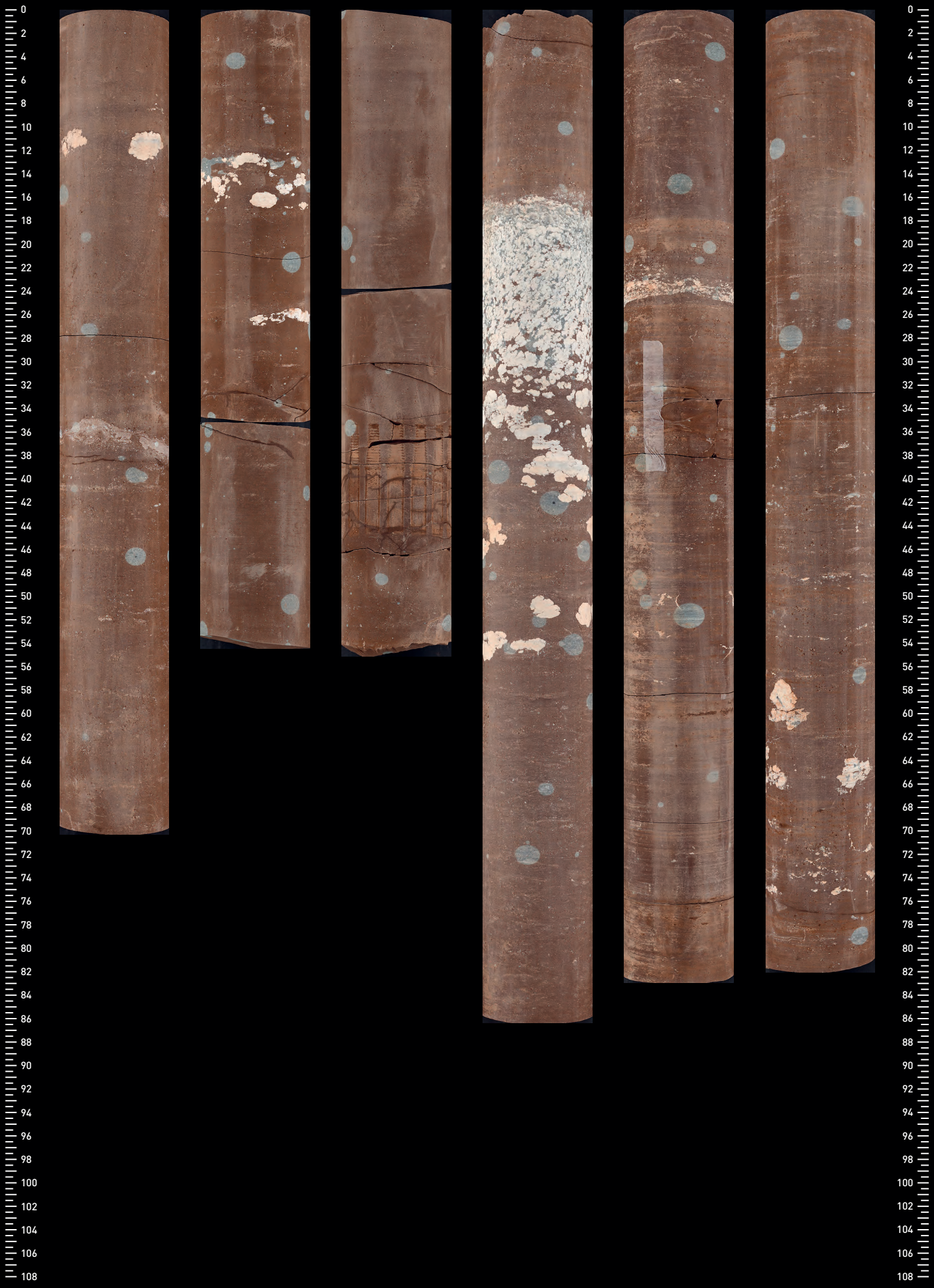
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1266.58m 1267.50m 1268.39m 1268.99m 1269.68m 1270.60m

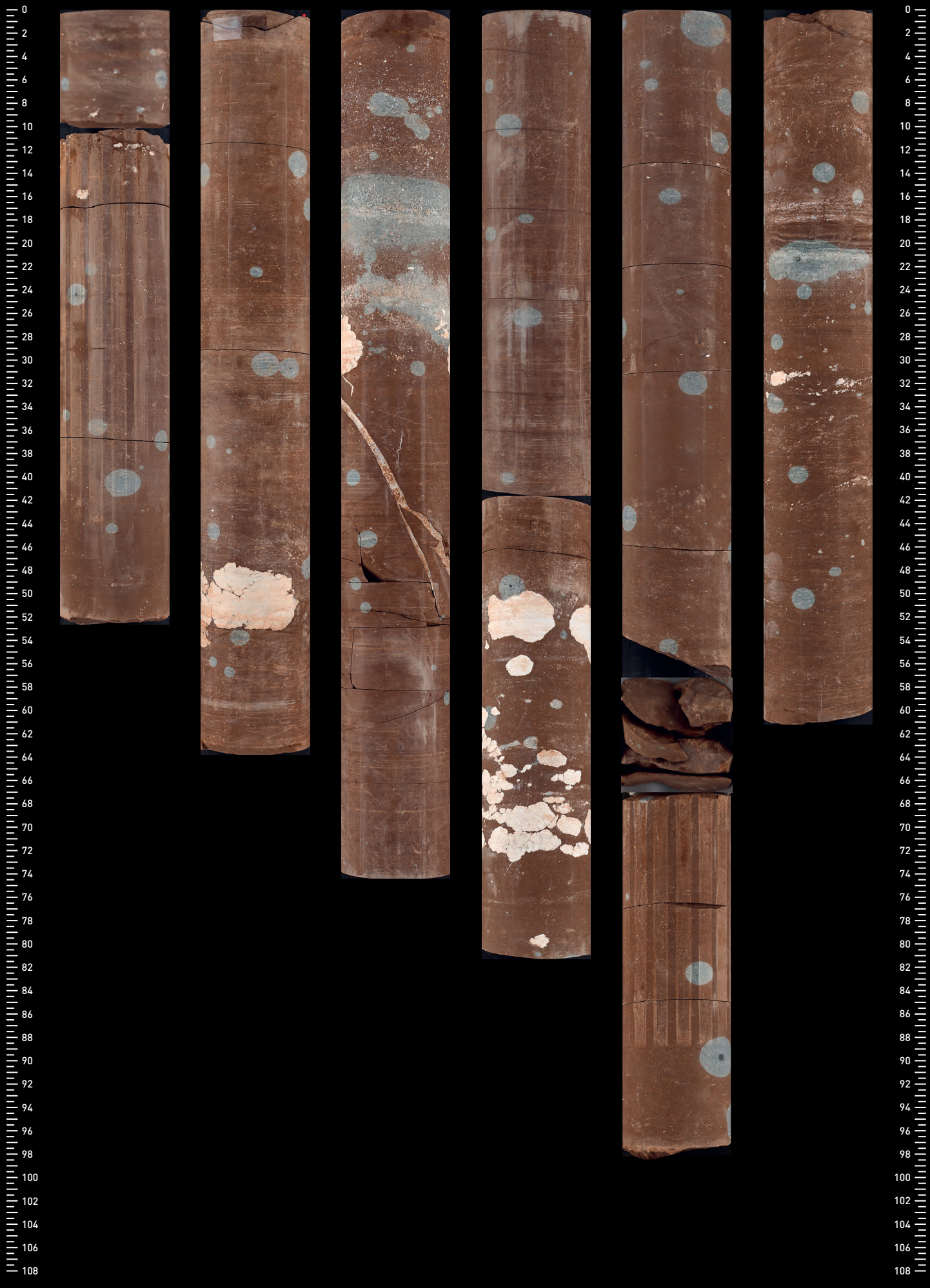


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1271.65m 1272.17m 1272.68m 1273.53m 1274.32m 1275.12m


1275.12m
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1276.98m
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1276.25m
1276.98m
1277.76m
1278.63m
1279.22m

1279.22m 1279.99m



1279.99m 1280.88m

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