Vibracores at the Mouth of the Columbia River
FY2003
Initial Report

November 2003
Ecology Publication #03-06-031

US Army Corps of Engineers

Washington State Department of Ecology

Prepared in support of US Army Corps of Engineers
and Washington Department of Ecology
Cooperative Agreement

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Purpose and Objectives

In support of a cooperative agreement between the US Army Corps of Engineers and the Washington Department of Ecology, a vibracoring project was developed in July and August and implemented in September, 2003. This work supports the collaborative Benson Beach Phase III studies and other alternatives to improve the beneficial use of dredged material.

The vibracores were needed to provide vital seafloor surface and subsurface sediment data to further evaluate the proposed dredged material re-handling area along the Columbia River north jetty. Determining the composition and distribution of subsurface material is essential to determining the feasibility of dredging a sump area to bypass sand to the north side of the north jetty. The information obtained from the vibracores will be used to calibrate new seismic data which should enhance the spatial coverage of the vibracore data, and help to optimize the location of the potential sump.

Vibracores in the vicinity of the Columbia River south jetty were needed to begin to assess the suitability of the existing subsurface for supporting the jetty foundation, and provide greater insights into the severity of erosion problems and the existing habitat that could be affected by dredged material placement operations.

The specific purposes of the project were to:

- document the dredgebility of the seabed substrate south of the Columbia River north jetty, in support of the dredged material alternatives for Benson Beach placement,
- document in situ changes in seabed substrate along the Columbia River south jetty for the proposed south jetty dredge material disposal site, and
- determine foundation characteristics at select locations along the south and north jetty.

Through discussions with the Corps of Engineers, 7 locations were selected to collect vibracores to 20 ft length as shown on Fig. 1, sites A-G. The plan included collecting two cores at sites A, C, F, and G; 1 core for minimum disturbance of sample, not to be driven to absolute refusal, and 1 core driven to refusal or to the entire extent of sampling tube to determine gross changes in sediment profile. The total number of cores intended for collection was 11 cores for the 7 sites.

Although there had been preliminary discussions with others that suggested obtaining 30-ft cores would be beneficial, in follow-on discussions with the Corps of Engineers, the determination was made that 6-m (20-ft) cores would be sufficient to make the assessments required. The potential sump would likely be dredged to a maximum of 15 ft into the subsurface. While obtaining deeper cores is possible, it would likely require utilizing a larger vessel, which would then compromise the ability to collect shallow water cores.

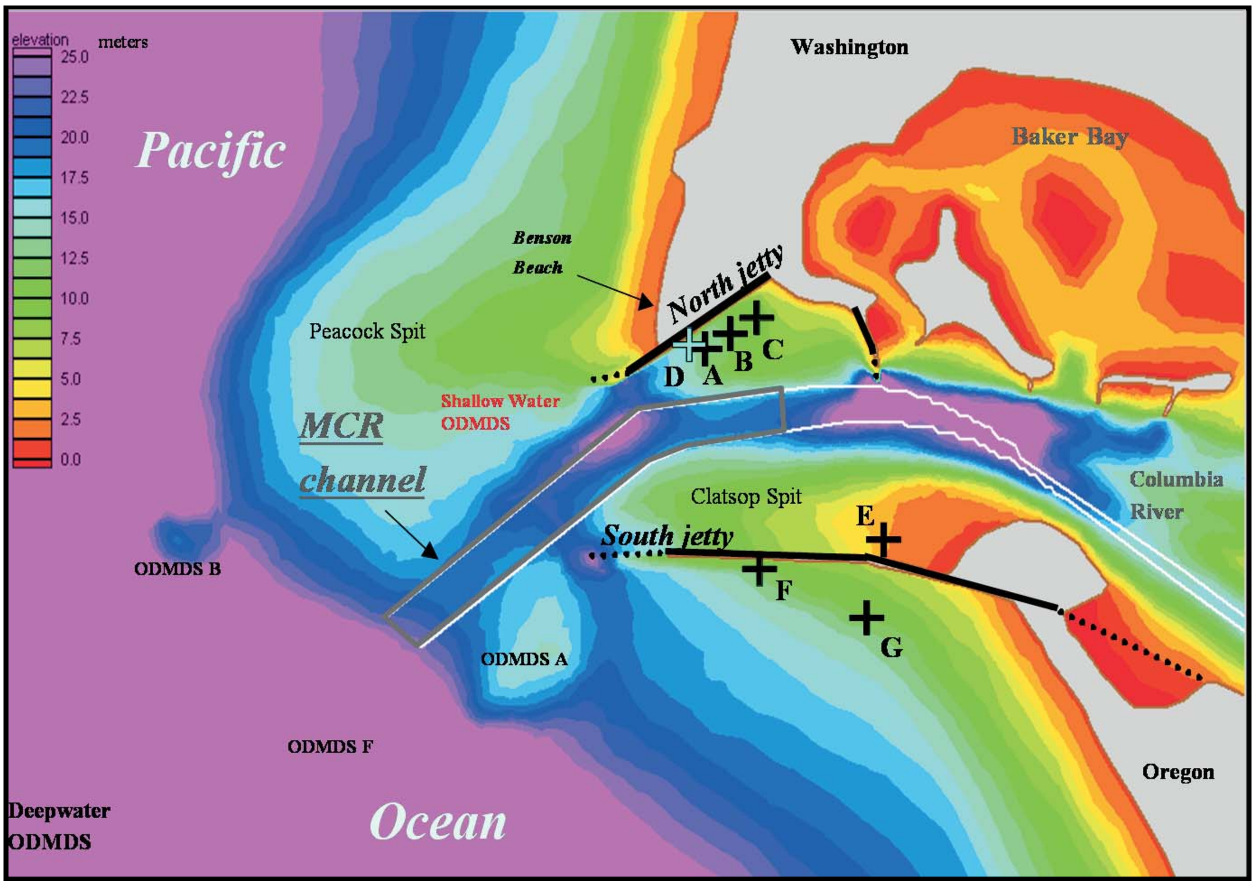

Fig. 1. Planned locations of vibracore sites of this project (figure by R. Moritz).

Planning and Preparation

The planning and preparation of the vibracoring project began in July 2003. Tasks involved in this effort included: a competitive cost and performance evaluation, solicitation of bids, mobilization planning of vibracorer gear; arranging for the manufacturing and acquisition of core barrels; acquisition of research vessel services; scheduling of core laboratory facilities; preparation of GIS database; acquisition of field and laboratory equipment and supplies; and making of various other logistical arrangements.

The evaluation of cost and performance of contracting various vibracoring equipment and operational services revealed that the most cost-effective means to implement the vibracoring project was for the Washington Department of Ecology to organize a program similar to that performed by the Washington Department of Ecology in 2002. This program included the mobilization of a light-weight, portable Australian-designed vibracorer, trained operators, and a vessel and crew to deploy the vibracorer. The Australian-designed vibracorer has successfully obtained 6-m cores in many other sandy shoreface environments, including along the inner- to mid-shelf of the Columbia River littoral cell in August 2002. Other vibracorer systems capable of obtaining 6-m cores typically require a larger vessel, which often can not operate in the shallow water depths required in this project. The 75-ft research fishing vessel, "Olympic", based in Newport, Oregon, and utilized by the Washington Department of Ecology in 2002, was retained for charter services to deploy the vibracorer. The mobilization and operation of the vibracorer was made possible through arrangements with the Virginia Institute of Marine Science.

The Oregon State University (OSU) core laboratory in Corvallis, OR was selected for core processing based on lab availability, overall facilities, and proximity to the Port of Newport. The OSU core lab is funded by the U.S. National Science Foundation and has state-of the art facilities for core processing, analyses, and archival. For this coring program, initial core processing included splitting, brief logging (visual descriptions) and photography. OSU also has facilities for x-radiography of cores.

Coring Methodology

Vibracores were collected using the vessel "Olympic" (Fig. 2) which has an elaborate rigging system, large aft working deck and capacity for cold storage to maintain core quality for the period of field work. The starboard outrigger and three-point lift system enabled the vibracorer to be deployed over the starboard side. A stabilizer, suspended from the port outrigger, reduced roll and thereby improved the stability of the boat as a coring platform. The use of this vessel enabled the collection of cores in water depths as shallow as 7 m. The captain and crew had an excellent working knowledge of the Columbia River entrance channel and jetty areas which was essential for successful completion of the project.

The Australian-designed vibracorer (Fig. 3) has a lightweight, 7-m high aluminum frame fitted with 3 retractable legs and 6.1 m aluminum barrels. The relatively light vibrating head delivers maximum vibration energy to the barrel, with little energy expended on vibrating the head. A special feature of this system is that the barrel and head are contained within, but not attached to, the frame. Their ability to freely rotate within frame improved the capability of the corer to penetrate quickly through difficult substrates. Typical vibrating times for this corer have ranged from 90-125 seconds depending on seabed conditions, substrate and response of the corer.

The electrically driven vibracorer system consisted of:

- 5kVA, 220 Volt, 3-phase vibrating head with 100 m cable and driven with power supply from the vessel
- 7 m aluminum tower with 3 collapsible legs
- 6.1 m (20 ft) extruded aluminum core barrels (80 mm OD, 76 mm ID, 2 mm wall thickness)
- stainless steel core catchers
- support equipment including tools
- miscellaneous supplies including end caps, tape, string, and gillnet floats.

Fig. 2. Photo of the 75-ft vessel "Olympic" used to collect the vibracores.

Fig. 3. Photo of the 7-m high vibracorer (Quaternary Resources, Ltd.) suspended from the starboard outrigger of the "Olympic". The upper 4 m of the tower are shown.

Fig 4. Photo of the vibracorer suspended above the deck of the "Olympic" for deployment over the starboard side of the vessel.

Fig. 5. Photo of crew adjusting the retractable legs of the vibracorer.

The core barrel, with the core-catcher installed, was painted with red paint prior to being attached to the vibrating head (rationale discussed below). After the barrel was attached to the head, within the coring frame, the entire rig was raised from the deck and deployed over the starboard side (Fig. 4). The corer was brought alongside the vessel where the three legs were lowered and secured (Figs. 5 and 6).

The coring tower was then lowered several meters into the water to allow the frame to fill with water. As the coring tower was lowered to the seabed, the electric cable was paid out slowly. The length of cable let out was based on the water depth and local currents so that only the necessary length of cable was deployed (extra cable could have become tangled around the corer and resulted in difficulty raising the corer and/or damage to the equipment).

Fig. 6. Photo of vibracorer suspended at starboard side of the "Olympic".

Operators determined the rate of progress of the corer in penetrating the seabed through a "gillnet float" indicator system. Small 6-inch foam floats were attached at 1.5-m intervals through the center of the coring tower, so that the vibrating head released the float as it passed a particular point (1.5 m, 3.0 m, 4.5 m of penetration. The operator monitored the time that it took the floats to rise to the surface, as well as measured the length of cable deployed. If the floats did not release, or a substantial time elapsed since the last release, and no additional cable was paid out, then the barrel was not penetrating the seabed and the operator would cease vibration (see discussion on page #15 for potential negative consequences of extended vibration without continual penetration).

Once the vibracorer was on deck and secured, the red paint on the barrel was examined closely to determine the depth of core penetration into the seabed (Fig. 7). (Note: A spring-action "gate" at the base of the coring tower scraped the barrel as it passed, just before it entered the sediment, which removed the paint and scored the barrel.) The penetration depth (i.e. length along the barrel from the core catcher) was measured and recorded, for later comparison with the length of recovered sediment in the core barrel. Cores were labeled, placed in the vertical position to settle and drain, and secured to the aft A-frame net spool of the vessel (Fig. 8). Later, the cores were cut into 1.5-m sections, the sediment at the cuts between sections was briefly described and recorded, and the ends of each core section were sealed with an end cap and electrical tape (blue at the top of each section, green at the bottom). The core sections were then stored in the refrigerated hold of the vessel until removal for transit to OSU.

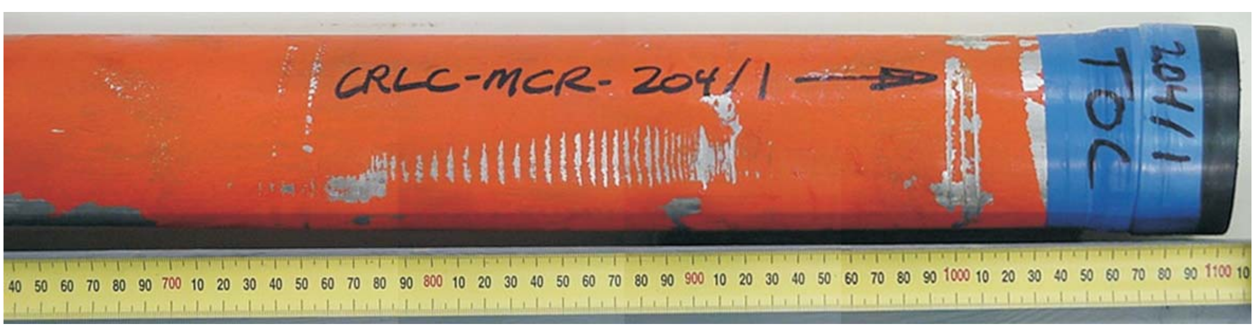

Fig. 7. Photo of scrape marks along a core barrel indicating progressive penetration into the seabead, with the abrasion mark closest to the top of the barrel denoting maximum penetration.


Fig 8. Photo of core processing aboard the "Olympic" while docked at the Port of Astoria. Immediately after collection, cores were secured in an upright position to settle and drain, and within several hours, final measurements of recovery and penetration were made, and each core was then cut into 1.5-m sections for storage in the refrigerated hold of the vessel (photo by R. Gammisch).

The core labeling scheme in this project followed the scheme developed for the August 2002 vibracoring project in order to facilitate the addition of this project's cores to the vibracore database and archiving system.

The core identification and labeling scheme was:

Columbia River Littoral Cell – sub-cell location identifier – Core No. / Section No.

*Example: CRLC-CP-107 /1 (*CRLC-Clatsop Plains-Core No. 107/Section 1)

Sept. 2003 Project:

CP: Clatsop Plains	100 series (cores 107-109)
MCR: Mouth of the Columbia River	200 series (cores 201-207)

August 2002 Project:

LB: Long Beach	300 series
GL: Grayland Plains	500 series
NB: North Beach	700 series
MS: Midshelf	900 series

Other core identifiers included:

- arrow points to top of core,
- end cap tape color code:
  - ◻ blue = top of section
  - ◻ green = bottom of section.
- TOC: top of core
- EOC: end (bottom) of core

Shipboard Coring Operation

Mobilization of the vessel *M/V Olympic* and vibracorer equipment occurred at the Port of Newport, Oregon on September 3-4, 2003. The Washington Department of Ecology and Central Washington University provided overall coordination, direction, and technical support including materials for the coring operations. The Virginia Institute of Marine Sciences (VIMS) was responsible for mobilization and operation of the vibracorer. The *M/V Olympic* captain and crew navigated the vessel and operated the rigging for deployment and recovery of the vibracorer.

All personnel on the vessel were involved with vibracorer operations. Personnel:

Chief Scientist	George Kaminsky (Washington State Dept of Ecology)
Geologist	Marie Ferland (Central Washington University)
Vibracorers	Robert Gammisch and Wayne Reisner (VIMS)
Captain & Winch	Terry N Thompson, *M/V Olympic*
Vessel Crew & Winch	Todd Gidlund, *M/V Olympic*
Vessel Crew	Al Davis, *M/V Olympic*

The timing and length of each coring day was determined by a combination of core location, weather (wind speed and direction as well as visibility due to fog), sea state (seas/swell), velocity of local surface and bottom currents, and time restrictions to pass over the Columbia River entrance bar based on tidal elevation and cycle. Figs. 9 and 10 show the predicted tides and tidal currents near the mouth of the Columbia River during the period of field operations. Table 1 provides relevant meteorological and wave data measured by the National Data Buoy Center station 46029. The likely presence of dense fog can be surmised when the dew point temperature is significantly less than the water temperature.

The timing and duration of the coring project were constrained by a large weather front moving onshore, whereby the light northwest winds (~3 m/s) would be changing to moderate southwest winds (> 6 m/s) by mid-day on Saturday, September 6. The National Weather Service forecast indicated that the southwest winds would increase substantially beginning on Monday, September 8 and persist for over 4 days. Within these overall project duration constraints dictated by the large weather patterns, the operating window for the collection of cores within the mouth of the Columbia River (MCR) was further constrained by the influences of local and tidal currents on the vibracorer and vessel anchorage. Typically, vibracoring in the MCR was performed during a flooding tide.

The vessel was positioned by the vessel's GPS system. No corrections have been made for the offset between the GPS antennae and the vibracorer location – these were within 6-8 m of each other (acceptable "target" circle). The core position fix was taken when the vibracorer just touched the seafloor; readings were recorded in latitude (N) and longitude (W). These were later converted to Washington State Plane coordinate system. Water depth was determined from the vessel's fathometer, with readings recorded in fathoms. The depth indicated was from hull transducer to seabed. A correction factor of 2.74 m (9 ft) needs to be added to recorded water depth to bring it to correct water depth. Water depth listed in Table 1 is not corrected for transducer or for tide.

To maintain the vessel on site while coring, a one or two point anchoring system was used. The decision to use one or two anchors was based on currents speed and direction relative to wind and wave direction and safe operating distance from structures and/or shallow shoals. At most coring sites, a single bow anchor was used with the boat oriented into the (sometimes strong) currents.

Vessel positioning was significantly affected by locally variable, and sometimes opposing, surface and bottom currents, and wind speed and direction. Due to the spatial and temporal variability of currents within the MCR, the boat captain favored the use of a single bow anchor, particularly while operating in the vicinity of the jetties. On a few occasions the vessel drifted off-target more than was desired. However, due to the significant time constraint imposed by a shift in weather conditions, repositioning the vessel closer to the target location was not feasible in most cases. Opposing currents did, on occasion, affect vibracorer operations during extraction from the seabed. Prior to extraction of the core barrel from the seabed, the vessel was maneuvered into position over the vibracorer, to ensure slow winch hoisting and vertical pullout. The corer was lifted and lowered via an overhead line attached to the main winch, and the operator independently lowered the power cable so that he could sense when the rate of penetration slowed or the corer encountered resistance.

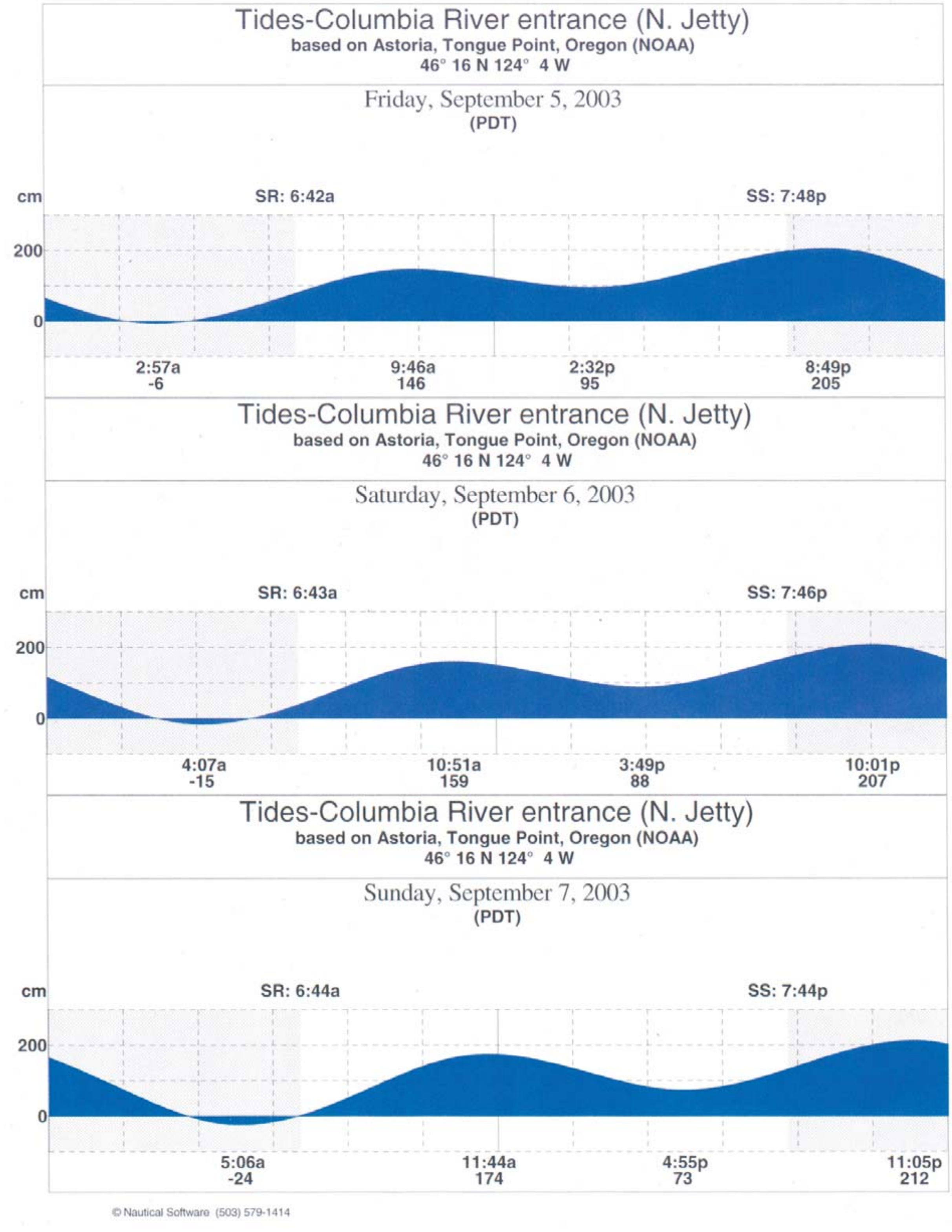

Fig. 9. Predicted tides at the mouth of the Columbia River during the coring operations.

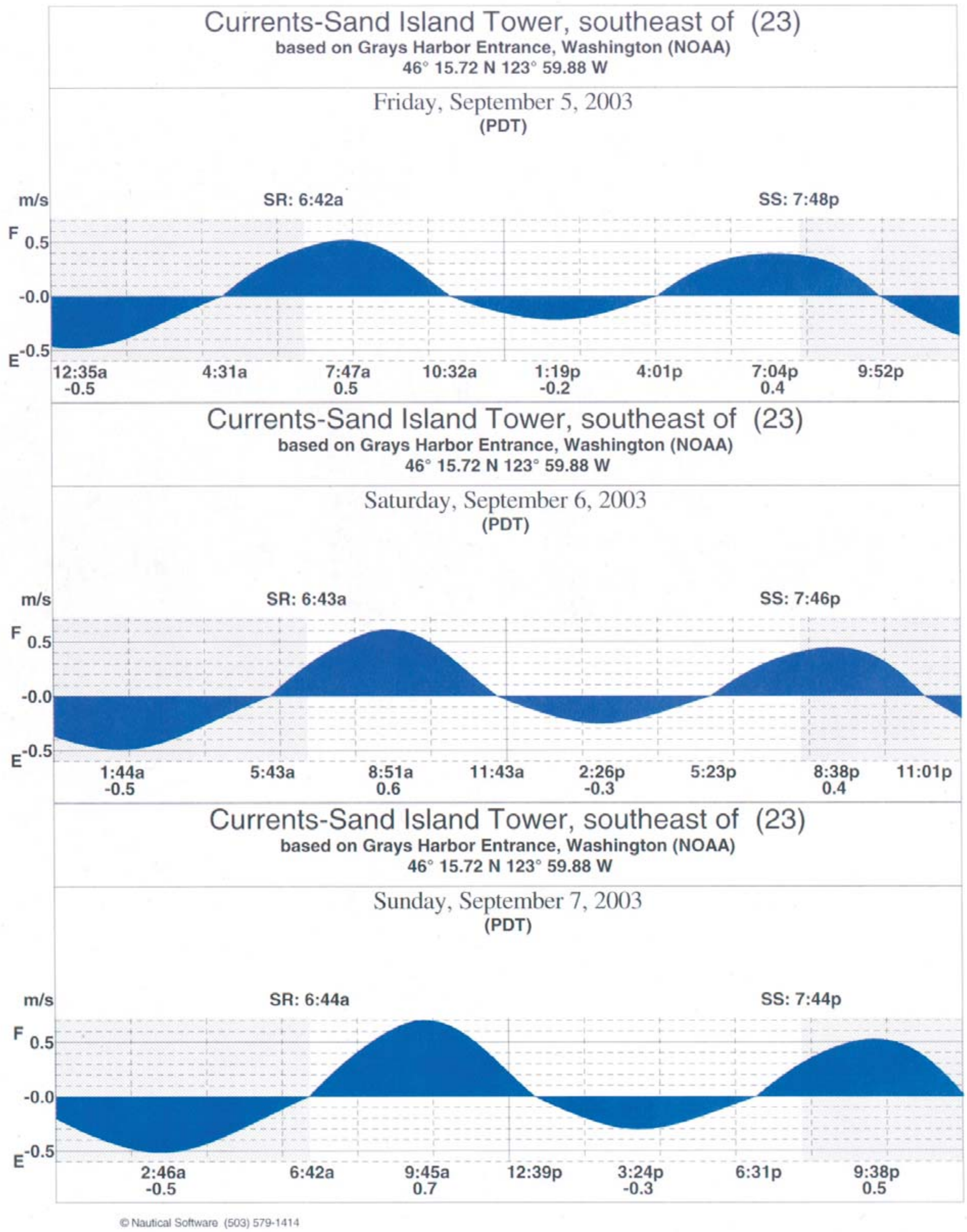

Fig. 10. Predicted tidal currents at the mouth of the Columbia River during the coring operations.

Table 1. Measurements of meteorological and wave conditions from the National Data Buoy Center Station 46029, Columbia River Bar during the coring operations.

Date	Time (PDT)	Wind Direction		Wind Speed & Gust (m/s)	(m/s)	Wave Height (meters)	Wave Period (sec)	Atmos Pressure (mm)	Air Temp (°C)	Sea Temp (°C)	Dew Point (°C)	Cores taken
9/5/2003	12:00 AM	340°	NNW	5	5	1.7	10	1015.0	14.8	13.4	13.8	
9/5/2003	1:00 AM	340°	NNW	5	5	1.5	10	1014.7	14.8	13.4	13.9	
9/5/2003	2:00 AM	340°	NNW	5	5	1.4	10	1014.7	14.5	13.6	13.7	
9/5/2003	3:00 AM	340°	NNW	4	5	1.3	9	1014.8	14.4	13.6	13.8	
9/5/2003	4:00 AM	340°	NNW	4	4	1.4	9	1015.3	14.1	13.7	13.7	
9/5/2003	5:00 AM	340°	NNW	5	5	1.3	10	1015.5	14.1	13.6	13.5	
9/5/2003	6:00 AM	340°	NNW	4	5	1.4	9	1015.7	14.1	13.6	13.6	
9/5/2003	7:00 AM	350°	NNW	2	3	1.3	10	1016.2	13.7	13.6	13.2	
9/5/2003	8:00 AM	340°	NNW	2	3	1.2	9	1016.1	13.6	13.4	13.3	
9/5/2003	9:00 AM	350°	N	2	2	1.1	9	1016.3	13.6	13.4	13.5	
9/5/2003	10:00 AM	350°	N	5	6	1.3	9	1016.4	13.3	13.3	13.2	
9/5/2003	11:00 AM	350°	N	3	5	1.2	9	1016.4	12.9	13.3	12.9	
9/5/2003	12:00 PM	360°	N	4	5	1.1	9	1016.1	12.7	13.3	12.6	
9/5/2003	1:00 PM	10°	N	3	4	1.1	9	1016.3	12.2	13.4	12.1	
9/5/2003	2:00 PM	10°	N	3	3	1.1	9	1016.1	11.7	13.3	11.7	
9/5/2003	3:00 PM	20°	NNE	2	2	1.0	8	1016.2	11.4	13.3	11.3	
9/5/2003	4:00 PM	40°	NE	2	2	1.0	9	1016.0	11.4	13.3	11.3	
9/5/2003	5:00 PM	340°	NNW	2	2	1.0	8	1016.0	11.7	13.4	11.6	203 at 5:05 PM
9/5/2003	6:00 PM	340°	NNW	3	3	1.0	8	1016.5	12.1	13.6	12.0	
9/5/2003	7:00 PM	340°	NNW	2	3	0.9	9	1016.3	12.7	13.7	12.6	204 at 7:03 PM
9/5/2003	8:00 PM	330°	NNW	4	4	0.8	8	1016.3	13.3	14.1	13.0	205 at 7:41 PM, 201 at 8:26 PM
9/5/2003	9:00 PM	320°	NW	4	5	0.9	14	1016.3	13.6	14.2	13.2	
9/5/2003	10:00 PM	340°	NNW	4	5	0.8	14	1015.6	13.6	14.4	13.5	
9/5/2003	11:00 PM	330°	NNW	5	6	0.8	9	1015.6	13.9	14.8	13.9	
9/6/2003	12:00 AM	350°	N	4	5	0.8	9	1015.0	13.3	14.9	13.2	
9/6/2003	1:00 AM	350°	N	3	4	0.8	14	1014.0	13.3	14.9	13.2	
9/6/2003	2:00 AM	320°	NW	3	3	0.9	9	1014.1	12.9	14.8	12.9	
9/6/2003	3:00 AM	340°	NNW	3	4	0.9	8	1013.4	12.5	14.4	12.5	
9/6/2003	4:00 AM	300°	WNW	2	3	0.9	8	1014.0	12.1	14.1	12.1	
9/6/2003	5:00 AM	---	---	0	1	0.9	9	1014.3	12.1	14.1	12.0	
9/6/2003	6:00 AM	---	---	0	1	0.9	7	1014.2	12.1	14.1	12.1	
9/6/2003	7:00 AM	190°	S	3	3	0.9	8	1014.5	12.3	14.1	12.2	109 at 6:52 AM
9/6/2003	8:00 AM	180°	S	4	5	0.9	8	1014.0	12.8	14.1	12.8	107 at 7:58 AM
9/6/2003	9:00 AM	180°	S	4	5	0.9	7	1014.1	12.9	14.1	12.9	108 at 8:37 AM
9/6/2003	10:00 AM	180°	S	3	4	1.0	8	1013.7	13.3	14.1	13.3	207 at 9:55 AM
9/6/2003	11:00 AM	180°	S	4	5	0.9	8	1013.5	13.4	14.1	13.3	
9/6/2003	12:00 PM	170°	S	5	7	0.9	8	1012.6	13.3	13.7	13.2	
9/6/2003	1:00 PM	180°	S	5	6	0.9	7	1012.3	13.3	13.7	13.2	
9/6/2003	2:00 PM	190°	S	5	6	1.0	8	1012.4	13.3	13.7	13.2	
9/6/2003	3:00 PM	200°	SSW	6	7	1.0	7	1012.6	13.3	13.9	13.2	
9/6/2003	4:00 PM	200°	SSW	5	6	1.0	8	1012.8	13.5	14.1	13.5	
9/6/2003	5:00 PM	200°	SSW	5	6	1.0	7	1012.7	13.6	14.1	13.6	
9/6/2003	6:00 PM	190°	S	4	5	0.9	8	1013.2	13.7	14.1	13.6	
9/6/2003	7:00 PM	180°	S	6	7	0.9	7	1012.8	13.7	13.9	13.6	
9/6/2003	8:00 PM	180°	S	5	6	1.0	7	1013.3	14.0	13.6	14.0	
9/6/2003	9:00 PM	170°	S	6	7	1.1	13	1013.1	14.1	13.6	14.0	
9/6/2003	10:00 PM	190°	S	6	7	1.1	7	1013.3	14.4	13.6	14.1	
9/6/2003	11:00 PM	180°	S	7	9	1.3	8	1012.7	14.2	13.7	14.1	
9/7/2003	12:00 AM	180°	S	8	9	1.4	7	1012.1	14.1	13.7	14.1	
9/7/2003	1:00 AM	200°	SSW	8	9	1.6	8	1012.2	14.2	13.7	14.1	
9/7/2003	2:00 AM	190°	S	8	9	1.8	8	1011.8	14.1	13.3	14.0	
9/7/2003	3:00 AM	190°	S	7	8	1.7	8	1011.6	14.3	13.4	14.1	
9/7/2003	4:00 AM	190°	S	7	8	1.7	6	1011.6	14.2	13.3	13.9	
9/7/2003	5:00 AM	180°	S	7	8	1.6	8	1011.8	13.9	13.5	13.8	
9/7/2003	6:00 AM	170°	S	7	9	1.7	8	1011.3	13.9	13.6	13.8	
9/7/2003	7:00 AM	220°	SW	5	6	1.7	6	1011.9	14.1	13.3	14.0	
9/7/2003	8:00 AM	200°	SSW	5	6	1.6	8	1012.3	14.2	13.6	14.0	
9/7/2003	9:00 AM	190°	S	4	5	1.6	8	1012.5	13.7	13.4	13.6	
9/7/2003	10:00 AM	200°	SSW	3	3	1.5	6	1012.6	13.6	13.3	13.6	
9/7/2003	11:00 AM	190°	S	3	4	1.5	6	1013.0	13.7	13.3	13.6	
9/7/2003	12:00 PM	190°	S	3	4	1.5	6	1013.2	14.1	13.3	14.0	202 at 12:00 PM
9/7/2003	1:00 PM	180°	S	4	4	1.5	8	1012.9	13.7	13.3	13.6	206 at 12:38 PM
9/7/2003	2:00 PM	180°	S	4	5	1.5	6	1013.1	13.7	13.3	13.6	
9/7/2003	3:00 PM	190°	S	5	6	1.4	8	1013.3	13.7	13.3	13.6	
9/7/2003	4:00 PM	180°	S	5	5	1.3	8	1013.2	13.7	12.9	13.6	
9/7/2003	5:00 PM	170°	S	5	6	1.2	7	1013.5	14.1	13.3	14.0	

Given the initial ideal weather conditions that would not persist past Saturday afternoon, the coring operations began as early as possible on Friday, September 5, during slack water and rising tide at the north side of the Columbia River entrance, when light northwest winds were favorable to operating in the vicinity of the North Jetty. Coring began at site C at approximately 1700 hrs on September 5. Core MCR-203 vibrated for 2:18 minutes to refusal. The core barrel did not penetrate any further for 1 minute of vibrating. The core barrel was extracted, and close examination revealed that it had rotated repeatedly in place without further penetration, which deeply "scored" the barrel at that depth position. In an attempt to obtain additional recovery, the next core was vibrated for 2:39 minutes on the second attempt at site C. Upon hoisting the vibracorer to the surface, we found that the barrel had broken off at the collar (where it meets the vibrating coring head). On the third attempt, we allowed the corer to vibrate for 1:57 minutes and again we found that the barrel had broken off at the collar (Fig. 11). On the fourth attempt we vibrated for 1:30 minutes, yet obtained slightly greater recovery for core MCR-204 (366 cm) than for core MCR-203 (338 cm). This result indicated that it was not necessary, or even desirable, to vibrate the core for an extended period because the vibracorer achieved maximum penetration quite quickly and extended vibrating might easily result in loss of the entire core. At this point a decision was made to stop vibrating the corer once the corer stopped penetrating for a substantial time (approximately 30-45 seconds) to avoid subjecting the core barrel to intense stress which could result in either breakage or reduced recovery.

Once two cores (MCR-203 and MCR-204) were collected at Site C, the vessel was navigated to site B, further to the west along the North Jetty. Upon anchoring at approximately 1940 hrs, a slight increase in wind speed from the north drifted the vessel further to the south than anticipated, however, due to the approaching fog and setting sun (1948 hrs) and the forecast of a reversal of wind direction by the following morning, it was decided to collect the core at this location, rather than invest more time in positioning the vessel closer to the target. At site B, core MCR-205 penetrated rather quickly with 470 cm of recovery obtained in only 39 seconds.

As the end of daylight approached and with the fog density increasing, core MCR-201 was collected at Site A at 2026 hrs. The core barrel penetrated to its full extent (580 cm) in 2:02 minutes. Due to this maximum penetration obtained and the deteriorating visibility, it was decided to not take an additional core at this site, but to proceed to site D nearby. However, by the time the vessel approached site D a thick fog severely limited visibility and the captain determined that it was too unsafe to anchor in such close proximity to the north jetty.

Coring operations continued the following day at site G with light southerly wind and wave conditions. The vessel was positioned on site at 0650 hrs and the collection of core CP-109 began at 0652. The first two gillnet floats, indicating penetration to over 3.0 meters, surfaced within 1:30 minutes. Subsequent penetration was slower and the third float, indicating an additional 1.5 m of penetration, surfaced after an additional 2:15 minutes. The total vibrating time was 3:49 minutes, the longest for the entire project. The core barrel penetrated to its full extent of 580 cm.

The vessel was stationed at site F at 0746 hrs. By this time, the wind speed and gusts from the south increased by 1-2 m/s however the vessel did not drift to the north as much as expected upon anchoring. Core CP-107 was vibrated for 1:46 minutes to

refusal with indications of difficult penetration. The core barrel penetrated to 300 cm with a significant abrasion ring noted on the barrel at 205 cm. A second core, CP-108, was then collected, penetrating to 250 cm in 1:31 minutes.

Following the collection of core CP-108 at 0838 hours, the vessel was navigated around the Columbia River south jetty along its north side to site E, located on Clatsop shoal within the inlet. With favorable winds from the south and slack tide, the vessel carefully navigated to very shallow water of less than 7 m. Core MCR 207 was collected at 0956 hrs with the top of the corer tower just above water level. The core barrel penetrated 430 cm in 1:45 minutes.

With increasing southerly wind speeds, the vessel departed the site for the Port of Astoria to process the collected cores and wait for more favorable conditions to continue collection of cores along the north jetty. Strong southerly winds and increasing seas prevented the feasibility of attempting the collection of additional cores on September 6. Core processing commenced at the Port of Astoria and continued until approximately 2000 hrs (Fig 8). Measurements of penetration and recovery were made, core catchers were removed, and cores were cut into 1.5 meter sections and stored in the refrigerated hold of the vessel. It was decided to not open the core sections in the field for two reasons. The forecast change to unfavorable operating conditions necessitated collecting as many cores as possible as quickly as possible. Secondly, it appeared that we were collecting high quality cores, based on limited vibration period due to the determination that extended vibrating was not desirable.

With approaching daylight and slack tide on September 7, the vessel navigated to the mouth of the Columbia River to resume coring operations. However, strong southerly winds and wave heights approaching 2 m prevented the feasibility of safely attempting the collection of cores close to the north jetty. A phone call was made to Mr. Rod Moritz, coastal engineer of the Portland District Corps of Engineers, to discuss the status of the coring operations and the priorities for collection of the remaining cores. It was decided that as soon as the weather conditions would allow, we would attempt the collection of a core at site D, as close to the north jetty as the Captain deemed safe, and the collection of an additional core approximately 100 m to the southeast of Site C.

Fortunately, by the time of the next slack tide, the southerly wind speed decreased significantly from about 8 m/s to 3 m/s, providing more favorable conditions to attempt coring operations adjacent to the north jetty. The vessel was positioned on site at the alternate location for site C at 1159 hrs. Core MCR-202 penetrated 491 cm with 2:00 minutes of vibration. During coring the vessel drifted over the corer and it was difficult to reposition the vessel precisely to obtain a vertical pullout. The core barrel kinked at 334 cm upon pullout and had to be cut in two sections to remove the barrel from the corer tower. The barrel was significantly scored at 360 cm, indicating that it had remained at that depth for some time before penetrating further.

Fig. 11. Photo of vibracorer at site C with core barrel broken off at the collar, located below the vibracorer head (photo by R. Gammisch).

The vessel was then quickly navigated to as close to Site D as possible. The vessel was on station at 1233 hrs and core MCR-206 quickly penetrated to its full extent of 580 cm with 1:30 minutes of vibration. The recovery of this core was 572 cm, the maximum for the entire project.

With the changing tide and increasing wind speed and wave heights, it was determined not feasible to attempt an additional core at Site A, where two cores had been originally proposed. Due to the strong northward current and forecast for worsening wind and wave conditions over the next few days, it was not economically justified to attempt additional cores. A total of 10 vibracores from 12 attempts were obtained during the field operations of September 5-7, 2003. Figs. 12 and 13 show the locations of the collected cores and Table 2 provides specific information about each core.

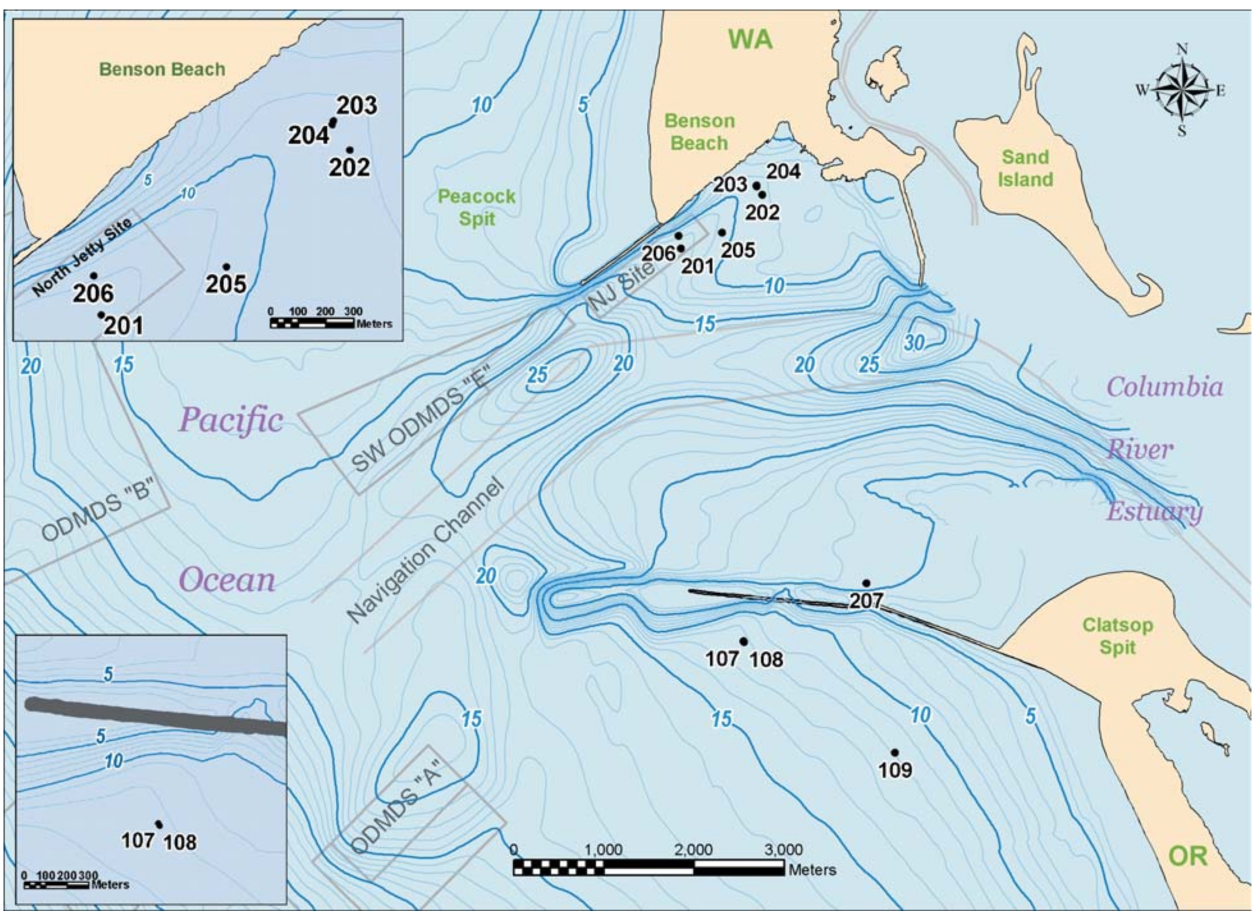

Fig. 12. Map of the locations of the cores collected in this project.

Table 2. Information on cores collected in this project.

Transect name and Core ID		COE Site	Position (decimal degrees) Latitude (N)	Longitude (W)	Water Depth (uncorrected) (Fathoms)	(Feet)	(Meters)	Date (m/d/yr)	Start Time (PDT)	Vibration Time (sec)	Penetration (cm)	Recovery (cm)
CRLC-MCR	201	A	46.26795	-124.07287	6.60	39.6	12.1	9/5/2003	20:26:47	122	580	530.0
CRLC-MCR	202	C-Alternate	46.27367	-124.06158	4.70	28.2	8.6	9/7/2003	12:00:09	120	491	456.0
CRLC-MCR	203	C	46.27460	-124.06240	4.50	27.0	8.2	9/5/2003	17:05:11	138	382	338.0
CRLC-MCR	204	C	46.27447	-124.06245	4.70	28.2	8.6	9/5/2003	19:03:04	95	360	366.0
CRLC-MCR	205	B	46.26970	-124.06712	5.50	33.0	10.1	9/5/2003	19:41:49	39	374	470.0
CRLC-MCR	206	D	46.26915	-124.07337	---	---	---	9/7/2003	12:38:43	90	580	572.0
CRLC-MCR	207	E	46.23547	-124.04410	2.60	15.6	4.8	9/6/2003	9:55:05	105	430	423.0
CRLC-CP	107	F	46.22913	-124.06135	5.80	34.8	10.6	9/6/2003	7:58:27	106	300	301.0
CRLC-CP	108	F	46.22903	-124.06125	5.90	35.4	10.8	9/6/2003	8:37:00	91	250	219.0
CRLC-CP	109	G	46.21868	-124.03888	5.45	32.7	10.0	9/6/2003	6:52:10	229	580	509.0

Laboratory Processing

The core sections (of up to 1.5-m lengths) were removed from the vessel's cold storage at the Port of Newport on Monday afternoon, September 8. Table 3 lists the number of sections per core and the length of each section. The inventory was checked to ensure that all sections were present. The core sections were placed vertically in barrels and transported to OSU for core logging, storage, and archiving. Once the vibracore sections arrived at the OSU core lab, they were immediately placed in the 36,000 cubic foot refrigerated storage facility.

Fig. 14. Photo of core logging. Sediment properties and sedimentary structures are observed and recorded on core logs.

Core processing began Tuesday morning, September 9 and continued through Saturday, September 13. For initial core processing, the cores were split (Fig. 13), photographed, briefly logged (visual descriptions; Fig. 14) and sampled. The archive half of each core section was placed on a horizontal platform illuminated by four bright lights. Digital photographs were taken at 10 cm intervals with approximately 50 percent overlap between successive photos. This overlap ensured that no distortion would be seen when the individual frames were joined together to construct the photomosaic image (Appendix A). The digital core photos were downloaded to CDs and catalogued.

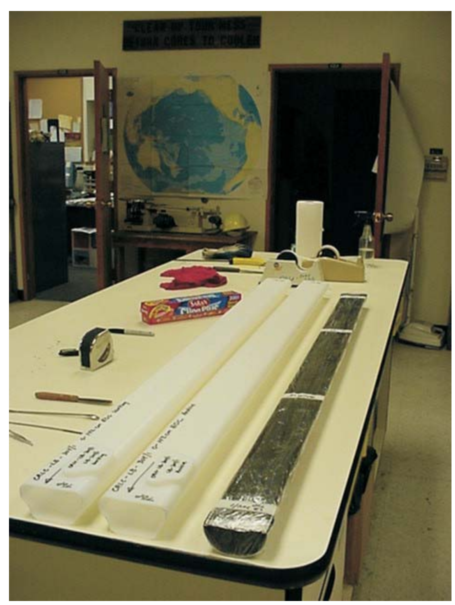

Fig. 15. Photo of core half sealed and labeled for archiving in "D-tube".

After the photographs for each core section were completed, the archive half of the core sections was placed alongside the working half and a measuring

Fig. 13. Photo of cutting core sections length-wise. Once the core barrel was cut on opposite sides, a wire was pulled through the sediment to split the core in half; one half used for sampling and the other half kept as an archive.

tape on a work table (Fig. 14). Visual descriptions of the cores included disturbance (if any), color using the Munsell Color Classification Chart, grain size at various depths, occurrence of shells and other organic material, and general observations/comments. Samples were also identified for possible future grain-size analysis and dating by the radiocarbon technique. After logging, both core halves were covered with plastic wrap, sealed, put in labeled plastic "D tubes" (Fig. 15), and placed in the OSU cold storage room (Fig. 16).

Comparison was made between penetration depth and the length of recovered sediment in the core (Table 2) as a means of evaluating the reliability of the core data and the actual depth to various sediment horizons. While ideally, penetration depth would equal length of recovered sediment, differences between the two values are common and may be attributed to a number of causes:

- Recovery less than penetration could be due to compaction of sediment during the coring process (common with most corers and especially common when a hard substrate is encountered

Fig. 16. Photo of the set of archived- and working-half core sections stored in "D-tubes" in the refrigerated facility of the OSU Core Laboratory.

which causes the sediment within the barrel to be compacted until the corer penetrates that particular layer, or the vibrating is halted).

- Recovery more than penetration could be due to *expansion* of the sediment in the barrel as the core is brought to the surface and the pressure is reduced (especially common in organic-rich muddy sediment that contained gas).
- Recovery less than penetration could be due to *loss of sediment* as the corer is raised to the surface (especially when particularly fine sand was cored and/or sea conditions resulted in surging of the vessel during recovery of the coring tower). Attempts to minimize this loss were made by plugging or capping the core catcher/cutter as soon as vibracorer was on deck.

Table 3. Core sections and section lengths.

Site Name	Section	Depth Interval
COE Site A MCR 201	201/1	0-150 cm
	201/2	150-300 cm
	201/3	300-450 cm
	201/4	450-530 cm
COE Site C-Alternate MCR 202	202/1	0-135 cm
	202/2	135-285 cm
	202/3	285-435 cm
	202/4	435-456 cm
COE Site C MCR 203	203/1	0-120 cm
	203/2	120-241 cm
	203/3	241-338 cm
COE Site C MCR 204	204/1	0-150 cm
	204/2	150-300 cm
	204/3	300-366 cm
COE Site B MCR 205	205/1	0-101 cm
	205/2	101-214 cm
	205/3	214-329.5 cm
	205/4	329.5-470 cm
COE Site D MCR 206	206/1	0-150 cm
	206/2	150-300 cm
	206/3	300-450 cm
	206/4	450-572 cm
COE Site E MCR 207	207/1	0-150 cm
	207/2	150-300 cm
	207/3	300-423 cm
COE Site F CP 107	107/1	0-150 cm
	107/2	150-301 cm
COE Site F CP 108	108/1	0-150 cm
	108/2	150-219 cm
COE Site G CP 109	109/1	0-150 cm
	109/2	150-300 cm
	109/3	300-450 cm
	109/4	450-509 cm

In all cores collected for this project, the recovery was within +/- 15% of penetration (see Table 2), which is better than average based on the cumulatively averaged experience of the geologist and operators on board (MF, RG, and WR) and similar to results obtained throughout the CRLC in 2002. Together with the descriptive comments about 'disturbance' made when each core section was opened, the R/P indicates that these cores are of a high quality.

Coring Results: *Core Photos, Logs and Preliminary Interpretation*

The vibracores collected along the North Jetty (MCR-201 to 206) were largely comprised of either very fine-fine sand, or fine-medium sand (Fig. 17), depending on location. Most of the vibracores contained intervals of finely-laminated (interbedded) mud and sand, with sharp contacts between the laminated mud/sand and the clean sand intervals. In some cases these laminated intervals were very thin (several 'couplets' of mud/sand in 5-10 cm of core length; core 201) whereas in other cores, the laminated intervals were 20-40-cm thick (many more mud/sand couplets in thicker intervals in cores 206, 205, 204, 203). Cores 205 and 203 also contained relatively thin intervals (~ 5-15 cm) of pebbles and/or shell fragments (Fig. 17). These intervals occur between 60-75 cm and 85-95 cm in core 203, and between 90-100 cm, 175-183 cm, and 445-465 cm in core

205. Core 202 contained a basal unit of very well sorted, very fine sand (bottom 70 cm of the core). This was apparently responsible for the lack of easy penetration of the core barrel into the seabed. During coring operations, the barrel progressed well until that depth and then slowed markedly. In addition the barrel was heavily 'scored' at that penetration depth. Experience elsewhere indicates that such fine, well-sorted sand does inhibit penetration because the well-packed fine sand grains are effectively inter-locked

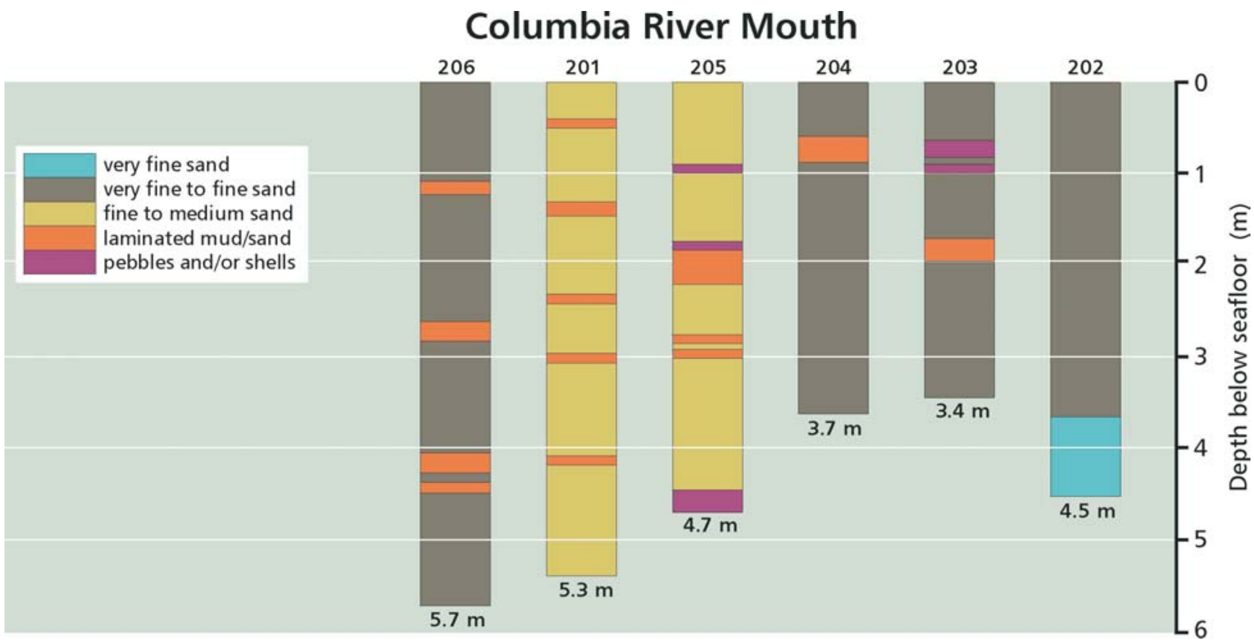

Fig. 17. Core logs showing basic sedimentary units observed in the cores collected along the Columbia River north jetty.

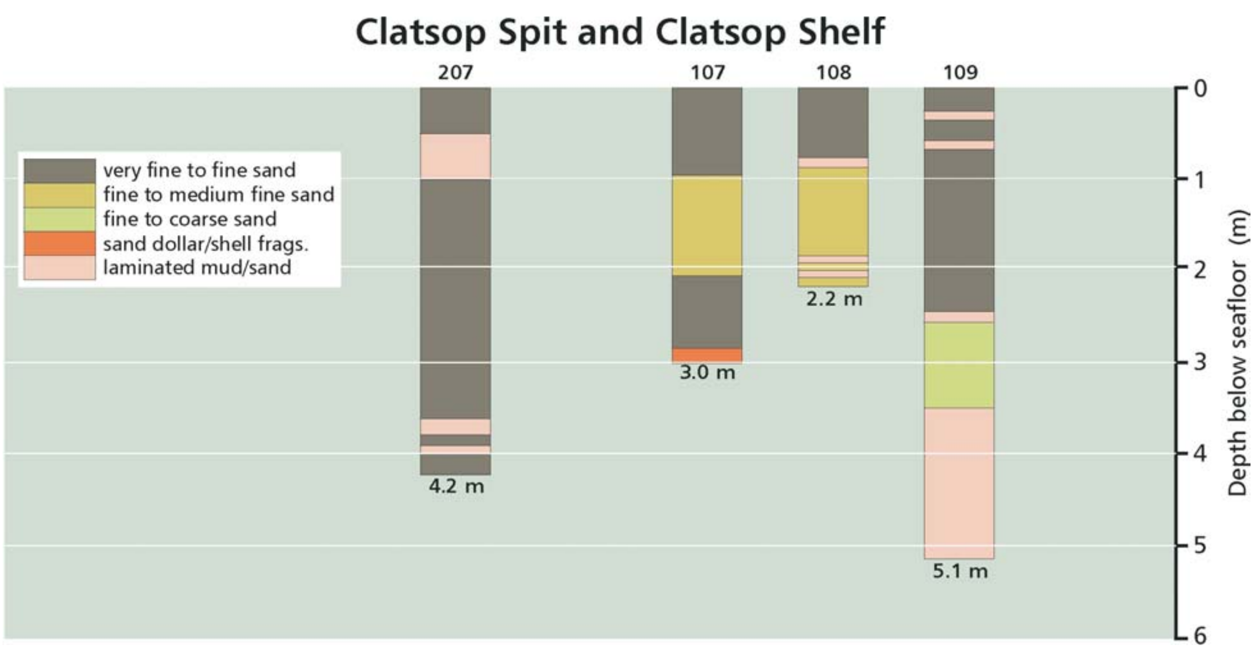

Fig. 18. Core logs showing basic sedimentary units observed in the cores collected along the Columbia River south jetty.

and not able to be rearranged over very small distances to allow the barrel to move through the sediment. Photos of each core section are provided in Appendix A.

The vibracores collected near/south of the Columbia River south jetty (Fig. 18) included one core collected on Clatsop Spit in very shallow water (< 7 m at time of coring, site 207). The two cores collected at site F (core 107 and 108) show generally similar subsurface sedimentary units. Both cores are comprised of very fine-fine sand overlying fine to medium sand, although core 107 extended deeper into another fine sand unit with sand dollar and shell fragments at the base of the core. The contacts between the sand units in core 107 were gradational. Core 108 was shorter, but contained several thin intervals of laminated mud/sand, as described above. Moderately thick intervals of the laminated mud/sand unit were encountered near the top of core 207 and the base of core 109, in which the bottom 1.7 m of the core is mostly mud. Core 109 also contained an unusual moderately sorted, fine-coarse sand that was not identified in other cores.

None of the vibracores contained evidence of hardpan or other cemented sands, and none contained readily identifiable relict Pleistocene sediment (commonly heavily oxidized). All of the sediment was unconsolidated sand, silt or mud, with no gravel intervals identified other than occasional pebbles. There were few erosional surfaces identified, although the sharp contacts between clean sand and the mud/sand units are difficult to differentiate from erosional contacts.

Most cores contained only scattered shells, shell fragments, pieces of wood, or sand dollar fragments, except at a few discrete intervals where higher concentrations were identified. There is sufficient biogenic material to allow for radiocarbon dating to determine rates of sediment accumulation and/or locations where relatively 'old' sediment is located near the tops of the cores. If old sediment is near the surface, these locations might be erosional and hence, new 'young' sediment is not accumulating. It is not possible to draw any conclusions about the specific age of these deposits without radiocarbon dating of multiple intervals. Some of the laminated mud/sand intervals contained thin organic-rich layers which could be dated by the radiocarbon method. It is important to determine whether these units are old (pre-industrialization) and hence not likely to contain anthropogenic contaminants which would be released if the fine sediment was dredged.

In terms of jetty stability, the cores fundamentally indicate that the jetties have been built on sand shoals that have many laminated mud/sand units interspersed over various depths. It is not clear what environments and processes have resulted in the formation of these units. There does appear to be a significant spatial variability of these units over short distances both in terms of presence/absence of the units, depth intervals of the units among adjacent cores, and the thickness of the units. It is not clear the extent to which the structural stability of jetties might be affected, but differences in the subsurface material (e.g. sand vs. clay) might account for some of the subsidence. The mud units could potentially be compacted with further loading (e.g. through placement of additional rock or dredged material), thus exacerbating jetty subsidence.

Future Work and Recommendations:

The cores and the initial processing described in this report provide the most essential information on the vertical structure and bulk grain properties of the subsurface.

The preliminary core logs provide the overall pattern of visually observed transitions between different material, e.g. mud/sand contacts, and transitions from coarse to fine, etc. However, more detailed logs could provide additional information such as evidence of bioturbation, descriptions of finer-scale sedimentary structures, contacts, and gradients, composition and abundance of shell material and tracer sediments or minerals, and interpretations of depositional processes and environments found within the cores.

X-radiography

It would be very advantageous to obtain x-rays of most of the collected cores and OSU has the facilities to readily and affordably accomplish this work. Previous x-radiography work through OSU has shown that high quality images are produced by labeling distance units (decimeters) along cores during filming, subsequently scanning the x-ray film using OSU's high resolution x-ray scanner, and finally creating digital images for further analysis. While much can be seen directly from the x-ray images that is not visually apparent, sophisticated software programs can also be utilized to enhance and demarcate fine-scale sedimentary structures. These techniques can substantially aid with the interpretations of the cores.

In many cores, particularly in the fine sand units, x-rays are needed to look for indications of disturbance. For example, core MCR 203/3 had a 1-cm gap along the edge of the barrel, but there was no visual confirmation of any disturbance. Core CP-107 had hints of a bivalve burrow structure within the top meter, but no other apparent sedimentary structures. The x-rays could also confirm whether the laminated mud units are at their original depth intervals in the subsurface or if they have broken apart and/or migrated during the collection of the core. For example in core MCR-201/3 it was not possible to conclude whether or not the mud clasts broke apart and migrated. In core MCR 205/3 a single 4-5 cm thick mud lense had rotated 90 degrees, but no other evidence of disturbance was visually apparent.

Radiocarbon dating

It would be very beneficial to determine the age of several key sediment intervals and units in order to infer deposition or erosion signals and relative accumulation rates within and among the cores. Radiocarbon dating of biogenic material would allow comparisons between pre- and post-jetty sediment accumulation and the relationship of these trends to sediment budget and morphological changes observed over the historical period. A follow-on proposal could provide more explicit details, however, in general, obtaining on the order of a dozen dates would reveal much information and the lab costs would range between $4,000 and $7,000 depending on which samples are dated, which lab dates them, and how quickly results are required.

One example where radiocarbon dates would be of particular value is in core CP-109, which contained pebbles, rip-up clasts, and a laminated mud unit within the top 25 cm of the surface. This near-surface sediment composition suggests that the surface may have an erosional trend (potential lag above a relict deposit with minimal accumulation of fine sand above). However, the environment and age of the apparently relict mud units has yet to be confirmed. Obtaining radiocarbon dates on organic-rich material and shell to determine the ages of these units is therefore recommended. If the near surface sediments can be confirmed to be old, this would indicate that the shoreface is either a low-depositional or erosional environment. The older the near surface material is, the more likely it is that the shoreface has undergone erosion, in which case the disposal of sand in this region could be considered as beneficial nourishment. Without radiocarbon dates, it is not possible to determine whether the deposits are recent (e.g. post-jetty) or older (pre-jetty) or very old (few thousand years). The ability to obtain information on long-term stability/rate of change through radiocarbon dates should be of substantial value.

Most of cores from the mouth of the Columbia River contain mud units, and if these units are recent, they may contain contaminants that could be released when dredged. Alternatively, pre-industrial dates would suggest that that the mud units do not contain contaminants. The bulk volume of most of the cores is fine sand, but mud will be definitely be released during dredging which may be a water quality issue.

Grain size analysis

In anticipation for potential future analyses, one to three sediment samples were collected from each core section in preparation for further analyses. Collecting the samples was relatively minimal effort, and having the samples on hand helps with the interpretation of the cores.

Grain size analysis would provide greater certainty about the qualities of the subsurface sediments near the Columbia River north jetty, and their suitability for use as beach fill material. In addition, grain size analysis would likely help determine whether some of the material in cores represents 'original' deposition by river/floods, or re-deposition from estuary (this would need to be done in combination with dates). Vertical gradients in grain size could also tell possibly indicate where there are changes in deposition or erosion.

Summary

It is recommended that addition work on the cores be performed including grain size analysis, x-radiography of most cores, selected radiocarbon dating from key subsurface intervals, construction of detailed core logs, and a synthesis report that provides interpretation of environments and processes that is made possible through this additional work.

The cores collected in this project should be further analyzed along with the cores collected in 2002 (Kaminsky and Ferland, 2003). The locations of cores collected from both projects are shown in Figs. 19, 20, and 21 along with the results of regional bathymetric change analysis over three historical periods completed by Buijsman et al. (2003). The historical bathymetric changes reveal a substantial erosion trend along much of the inner-shelf along Clatsop Plains.

Relict units of laminated clay and sandy mud were identified in 4 of the 7 shoreface cores (101, 102, 105, 106) collected in 2002. A single radiocarbon date of 5470 ± 40 BP on an organic layer at 329 cm below the surface within the laminated sediment in core 105 (25 m water depth) suggests that the unit was deposited during the mid-Holocene transgression. A date of 3870 ± 40 BP was obtained on a shell lag from an adjacent core 104 (17 m water depth) at 464 cm below the seabed. We believe that this represents the transgressive lag, although additional radiocarbon dates are required. Together these dates provide evidence for relatively low rates of accumulation (6-12 cm/100 years) on this shoreface. In addition, the two cores collected on the inner-mid shelf (903 and 904) contain less than 30 cm of modern shelf sediment accumulation over relict deposits.

Closer to the Columbia River south jetty along the northern transect of the Clatsop Plains inner shelf, both cores 102 and 102 contain laminated clay and mud units in the shallow subsurface. In core 101, the relict unit is less than 10 cm below the seabed and it is only 85 cm below the seabed in core 102 (Fig 22 a, b). The cores corroborate historical bathymetric data that indicate net lowering of the shoreface at 18 m water depth (core 101) and modest aggradation on the upper shoreface in water depths shallower than 12 m (core 102, 8 m) (Fig. 22c). The shoreface steepening is a response to the construction of the jetties which reduced ebb tidal currents across the Clatsop shoal and increased wave-driven onshore sediment transport (Kaminsky *et al*., 1999). Evidence of relict material just below the seabed also supports the conclusions of Kaminsky *et al*. (2001) that, as the supply of sand from the Columbia River has rapidly declined (and possibly been eliminated over the historical period), the Clatsop Plains lower shoreface is deflating towards a deeper equilibrium profile. As erosion of the lower shoreface into relict consolidated mud deposits continues, the availability of the shelf to supply beach-quality sand will be diminished.

The collection of additional cores in the future may provide additional information on key questions that may remain. For example, if more information is required deeper in the substrate and or in deeper water, this should be possible to obtain. In some cores, e.g. MCR 201 and 206, penetrated the maximum extent of the core barrel (580 cm) in 2:02 and 1:30 minutes, respectively. The rate and depth of penetration indicates that it is likely that longer cores (by approximately 1 m) could be obtained in these locations using this vibracoring system. Deeper cores would require longer core barrels, a tower extension, vessel modifications or a different coring platform.

Any future collection of additional cores within or adjacent to the mouth of the Columbia River should be performed in August when there is getter probability of a high pressure system maintaining stable and favorable operating conditions. Additional time and calm wind and sea conditions would greatly enhance the ability to collect cores closer to the jetties.

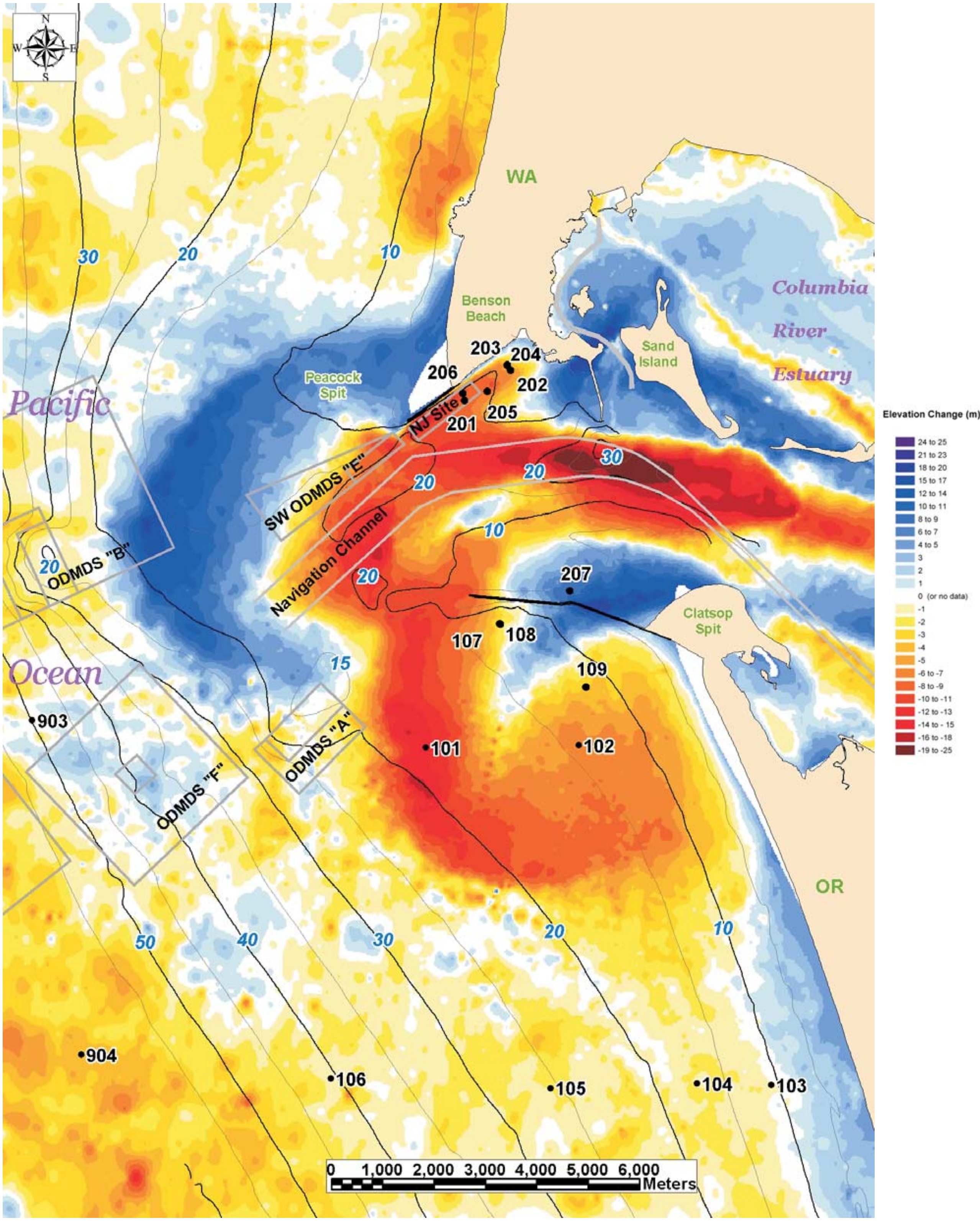

Fig. 19. Locations of vibracores collected in previous study in 2002 by the authors and this project shown with historical bathymetric change from Buijsman et al. (2003) during the period 1868 to 1935 (1877 to 1926 for shelf; 1868 to 1926 for delta; and 1868 to 1935 for entrance and estuary). Bathymetric contours in meters NAVD88 derived from data from 1998-2003.

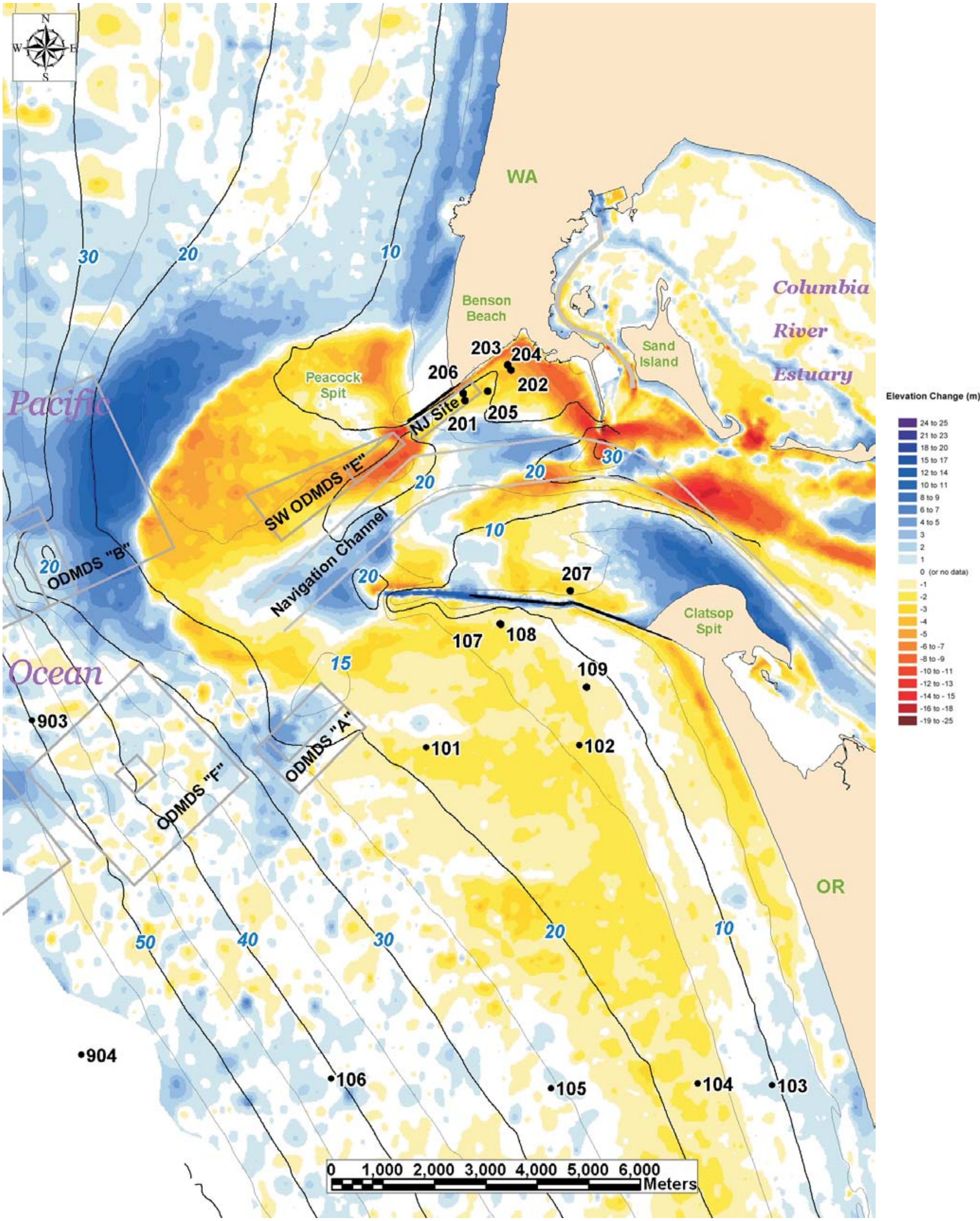

Fig. 20. Locations of vibracores collected in previous study in 2002 by the authors and this project shown with historical bathymetric change from Buijsman et al. (2003) during the period 1926 to 1958 (1935 to 1958 for entrance). Bathymetric contours in meters NAVD88 derived from data from 1998-2003.

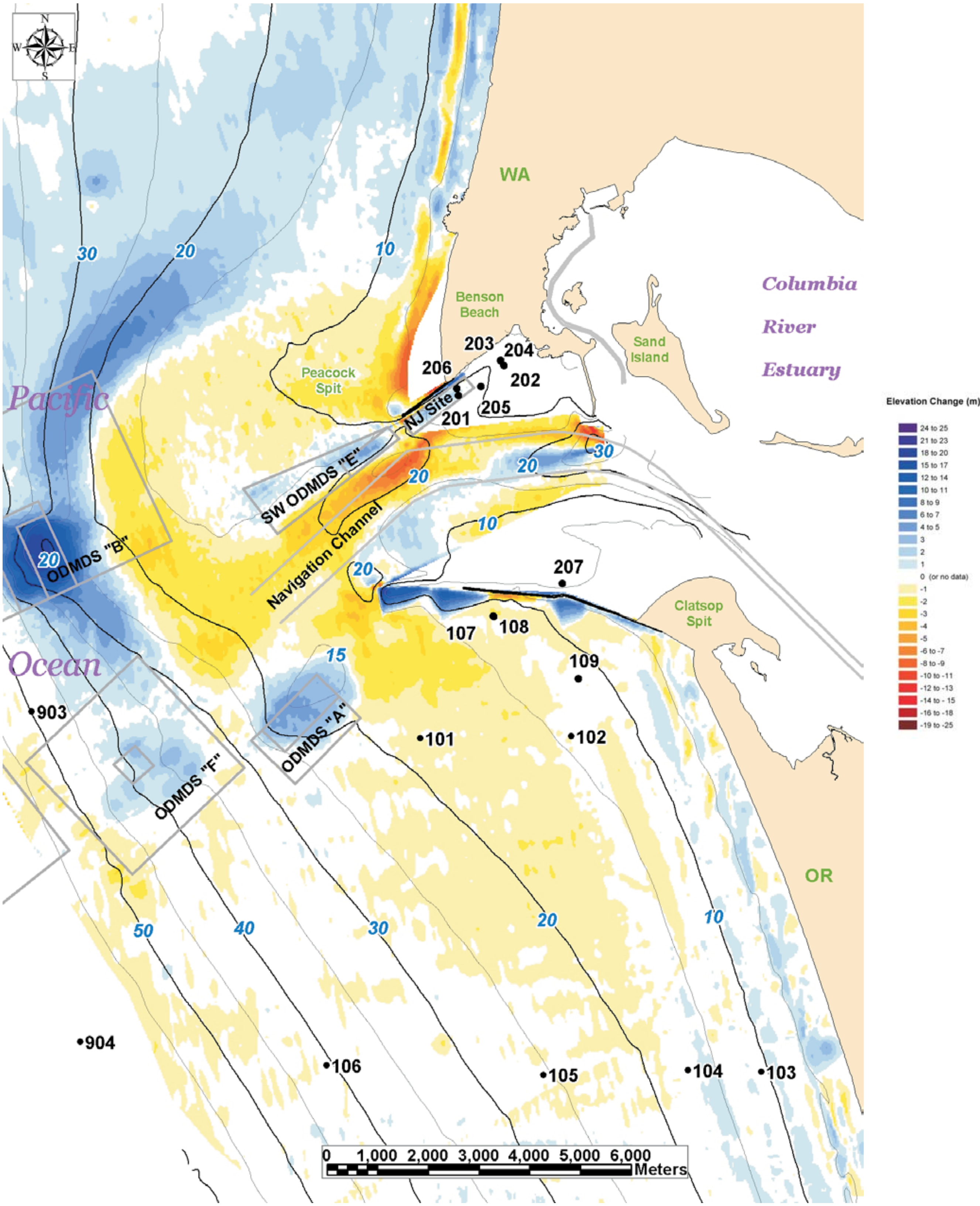

Fig. 21. Locations of vibracores collected in previous study in 2002 by the authors and this project shown with historical bathymetric change from Buijsman et al. (2003) during the period 1958 to 2000. Bathymetric contours in meters NAVD88 derived from data from 1998-2003.

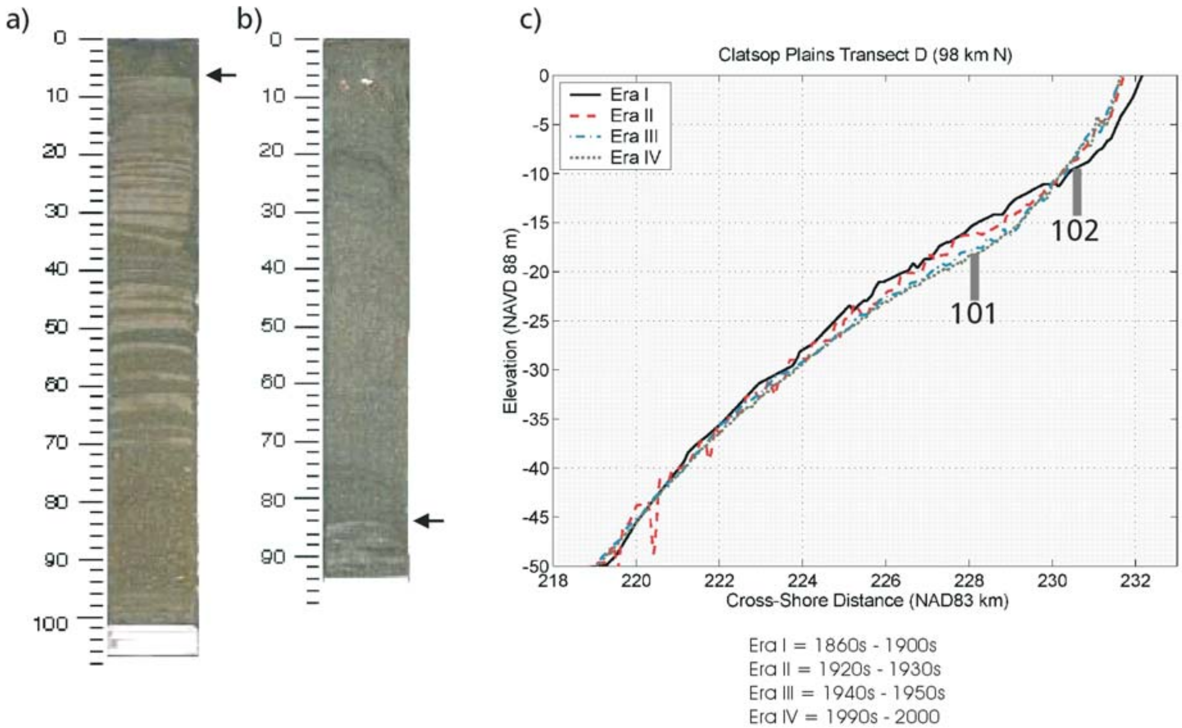

Fig. 22. a) Photograph of core 101 in 18 m water depth, b) photograph of core 102 in 9 m water depth, and c) historical profile change from Buijsman et al. (2003) showing shoreface lowering above core 101 and shoreface aggradation above core 102. Top of relict unit shown by ←

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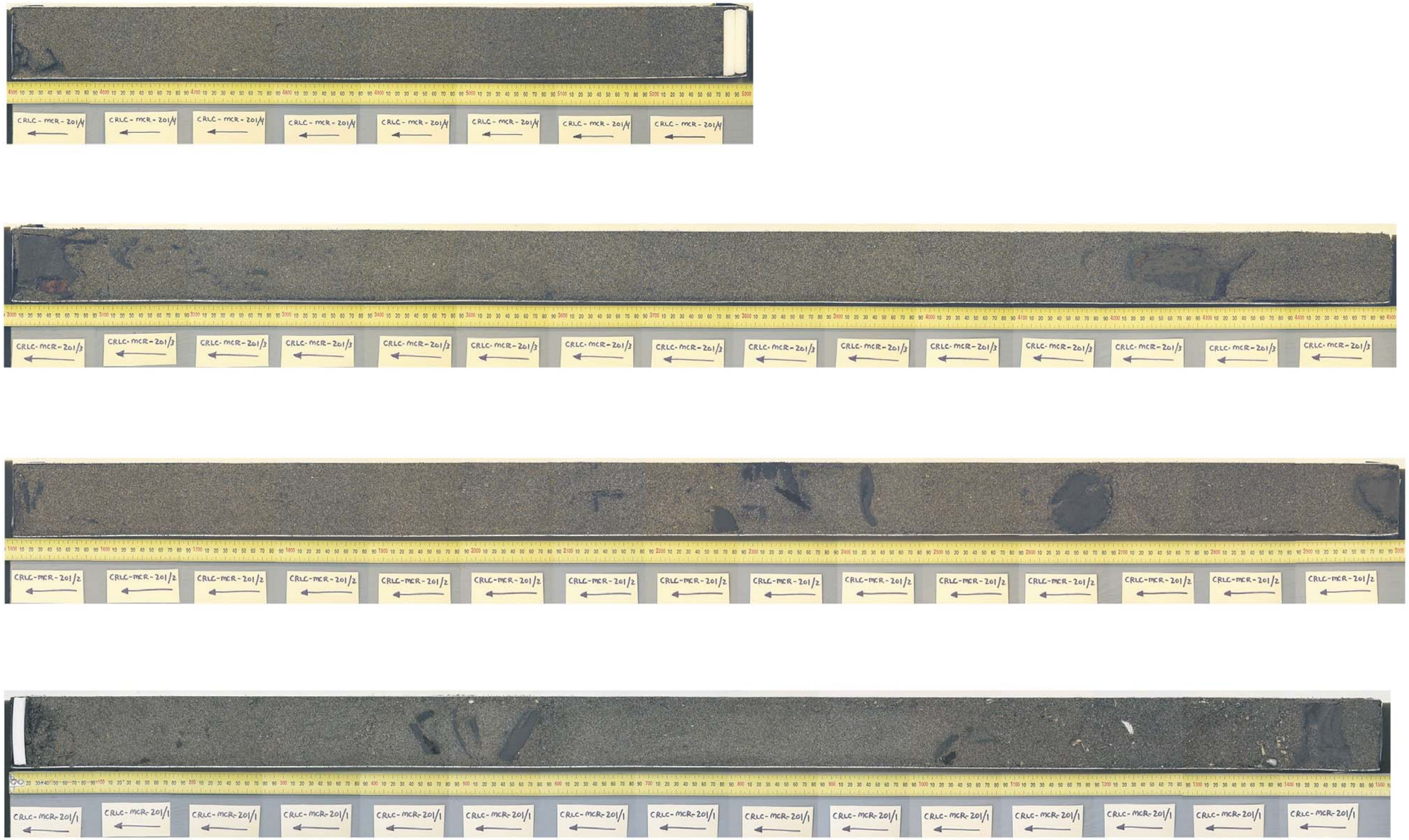
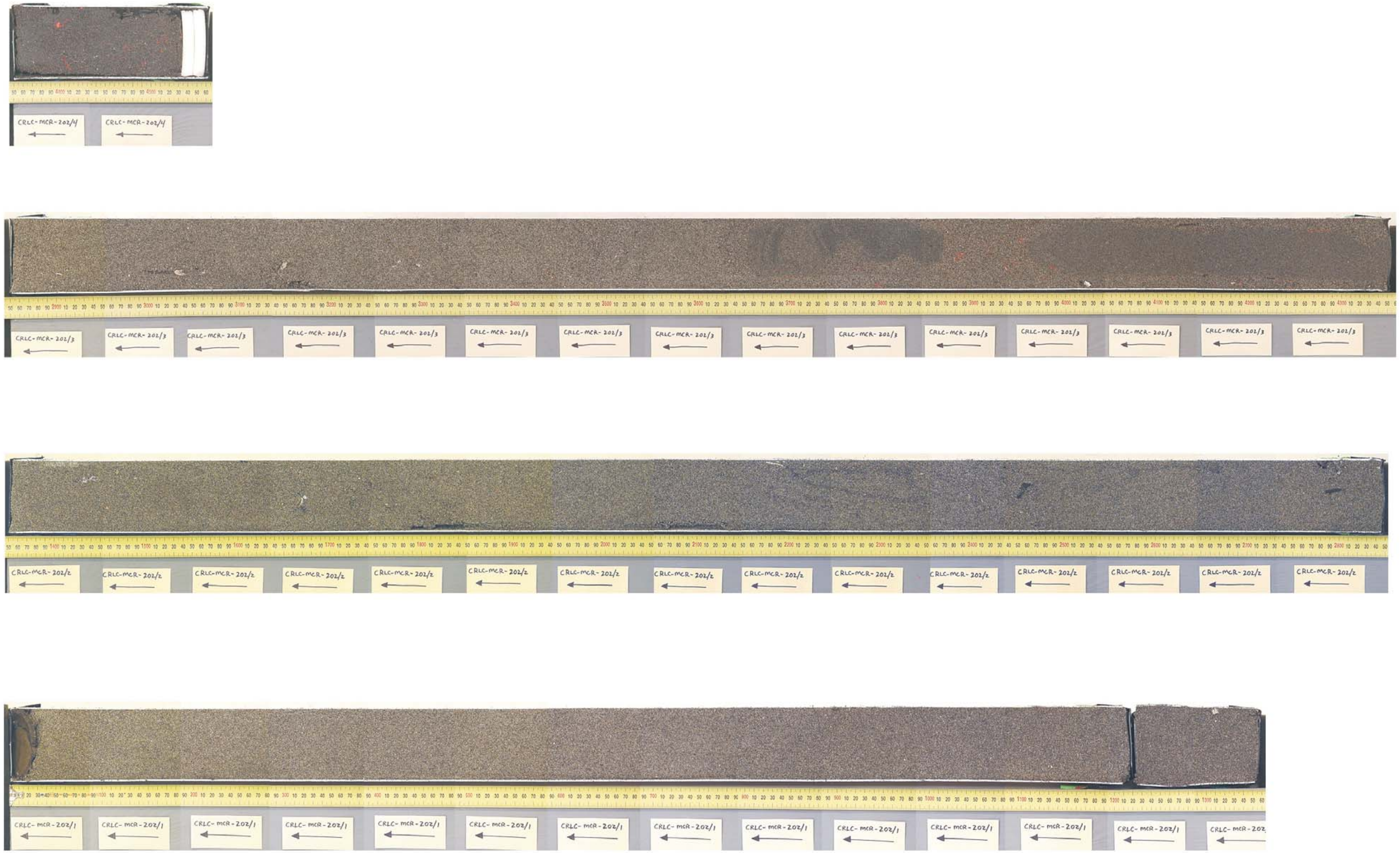
Appendix A

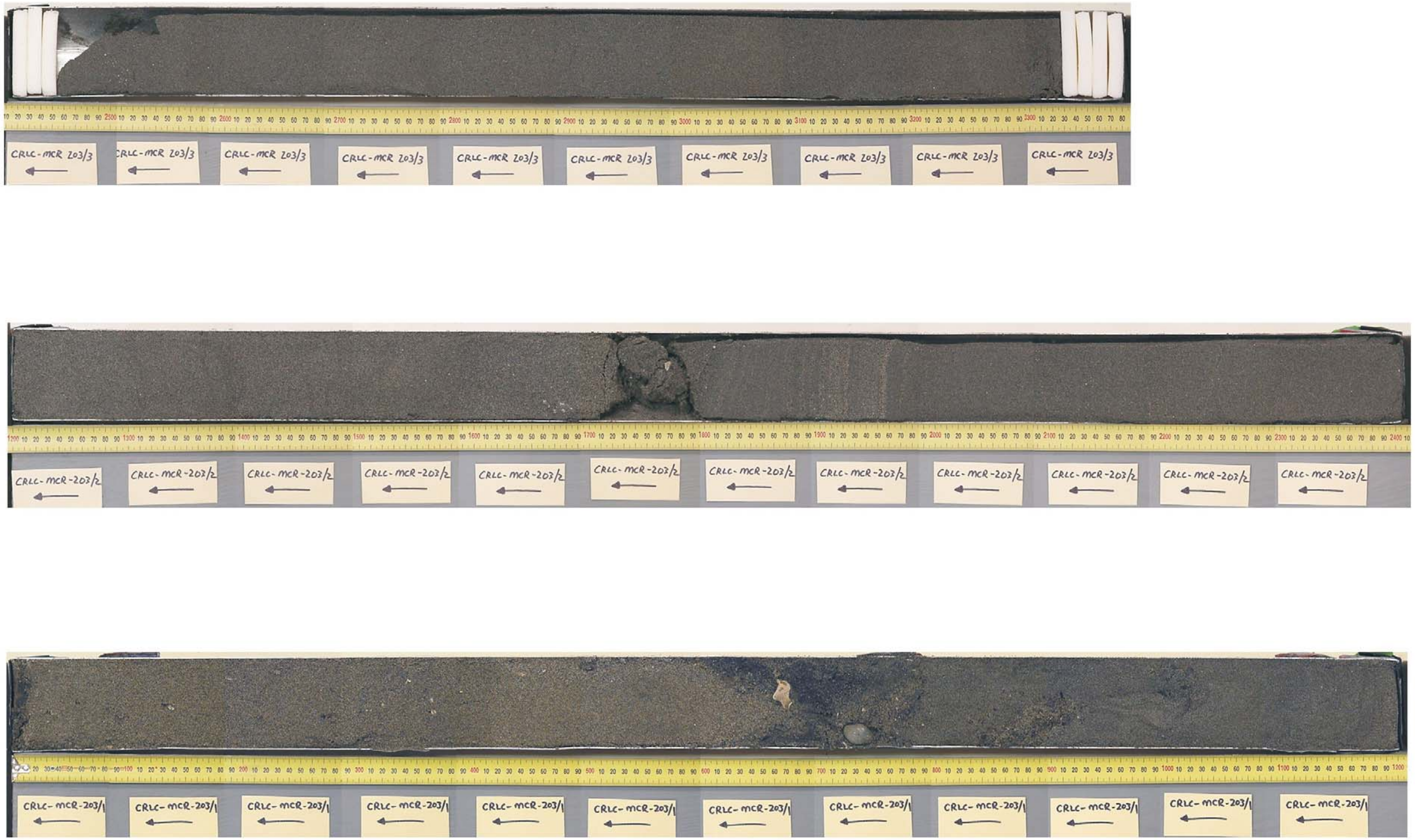
Core Photographs



MCR-201



MCR-202



MCR-203


CRLC-MCR-204/3
CRLC-MCR-204/3
CRLC-MCR-204/3
CRLC-MCR-204/3
CRLC-MCR-204/3
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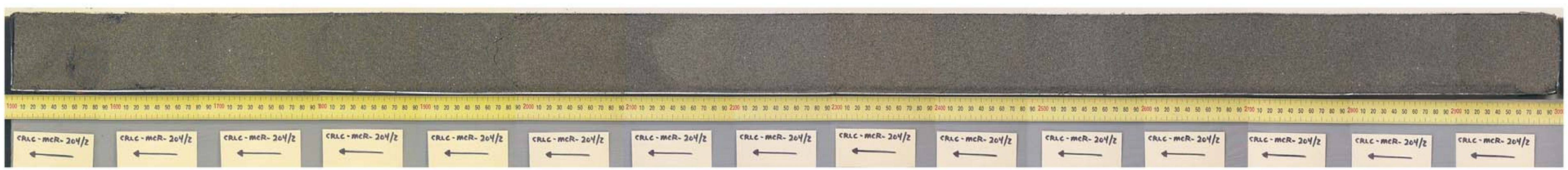
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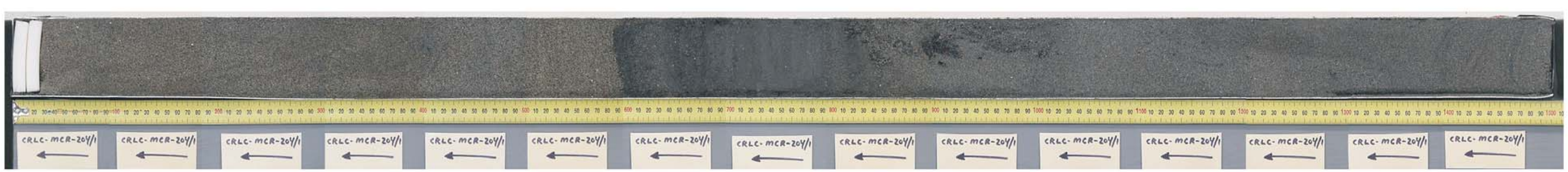
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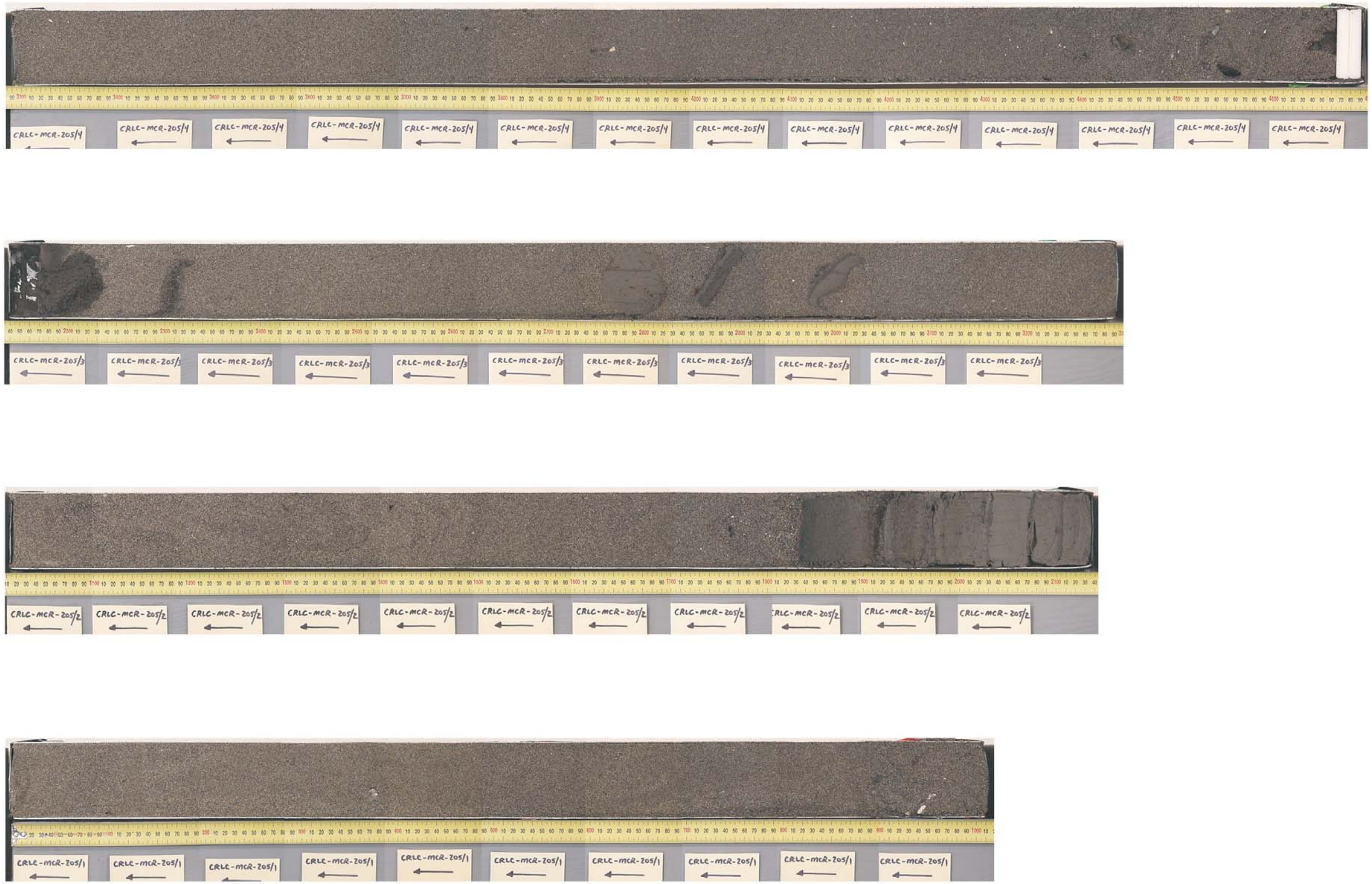

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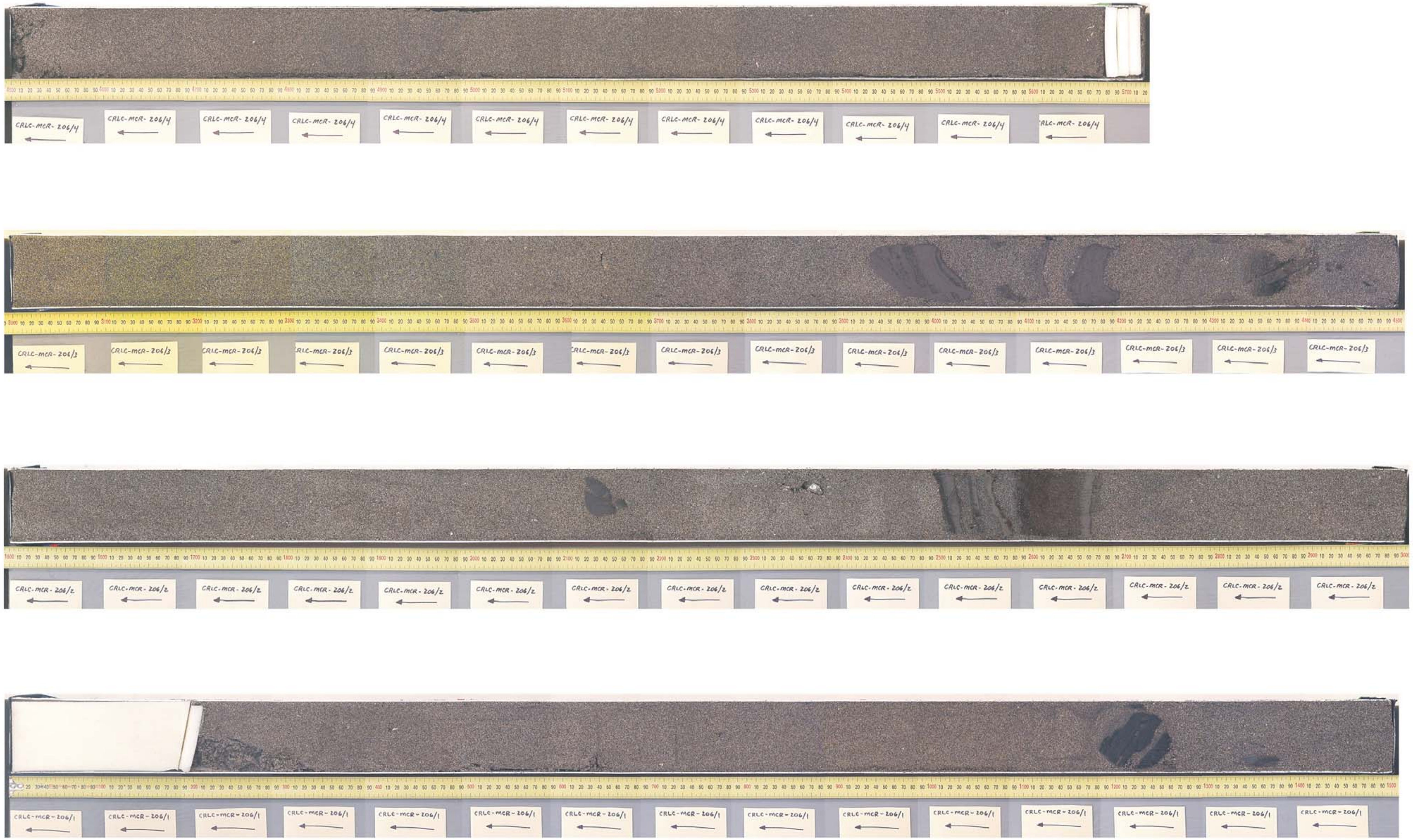

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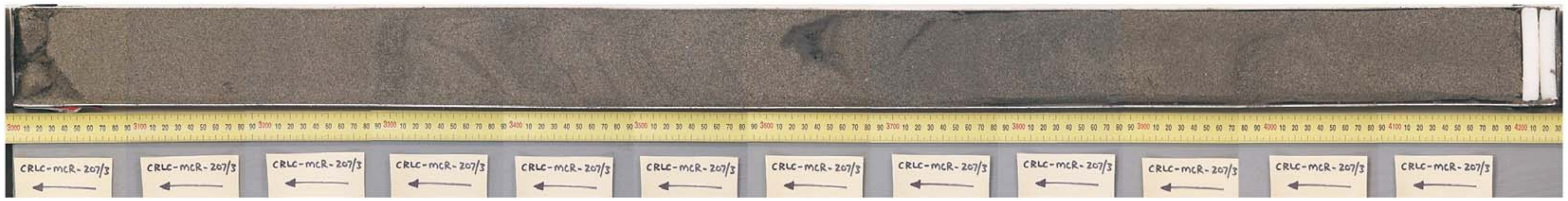
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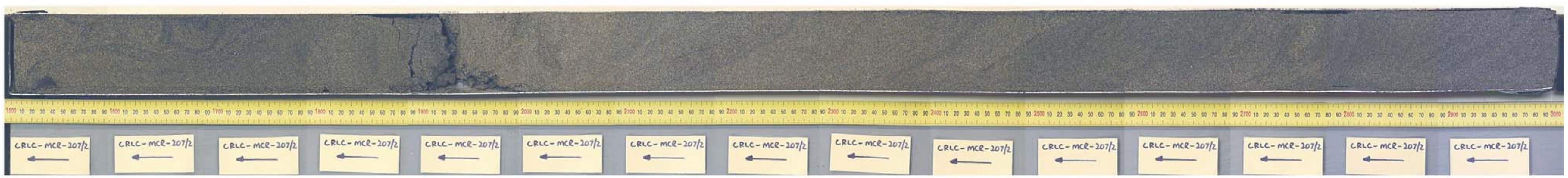
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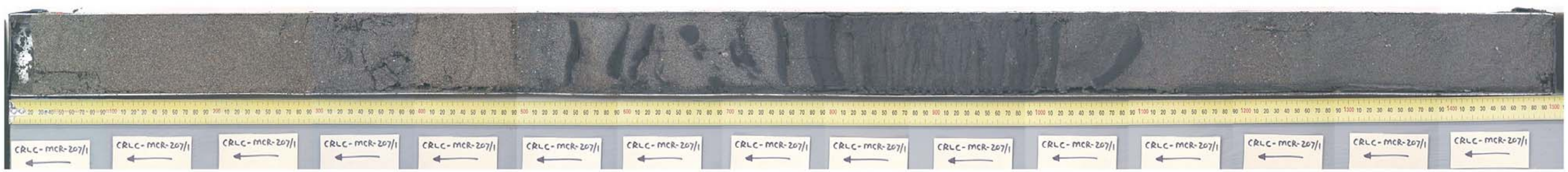
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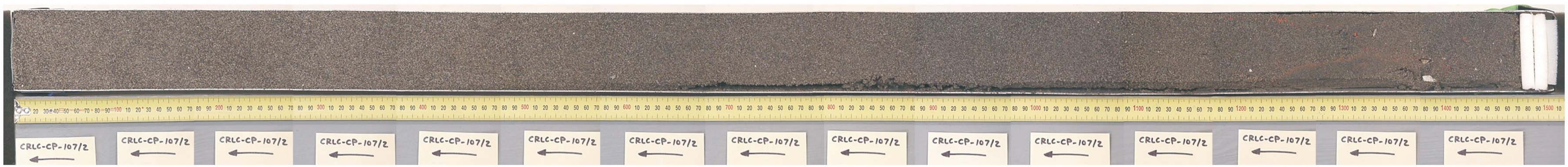
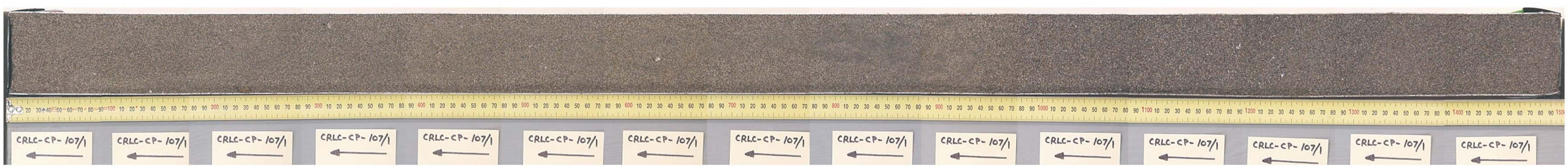
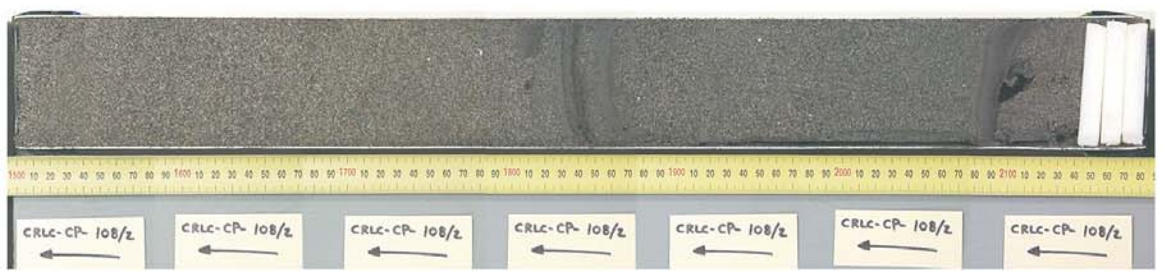
MCR-207





CP-107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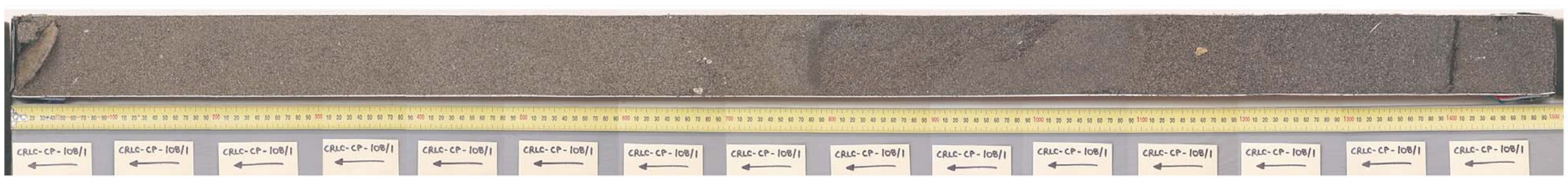
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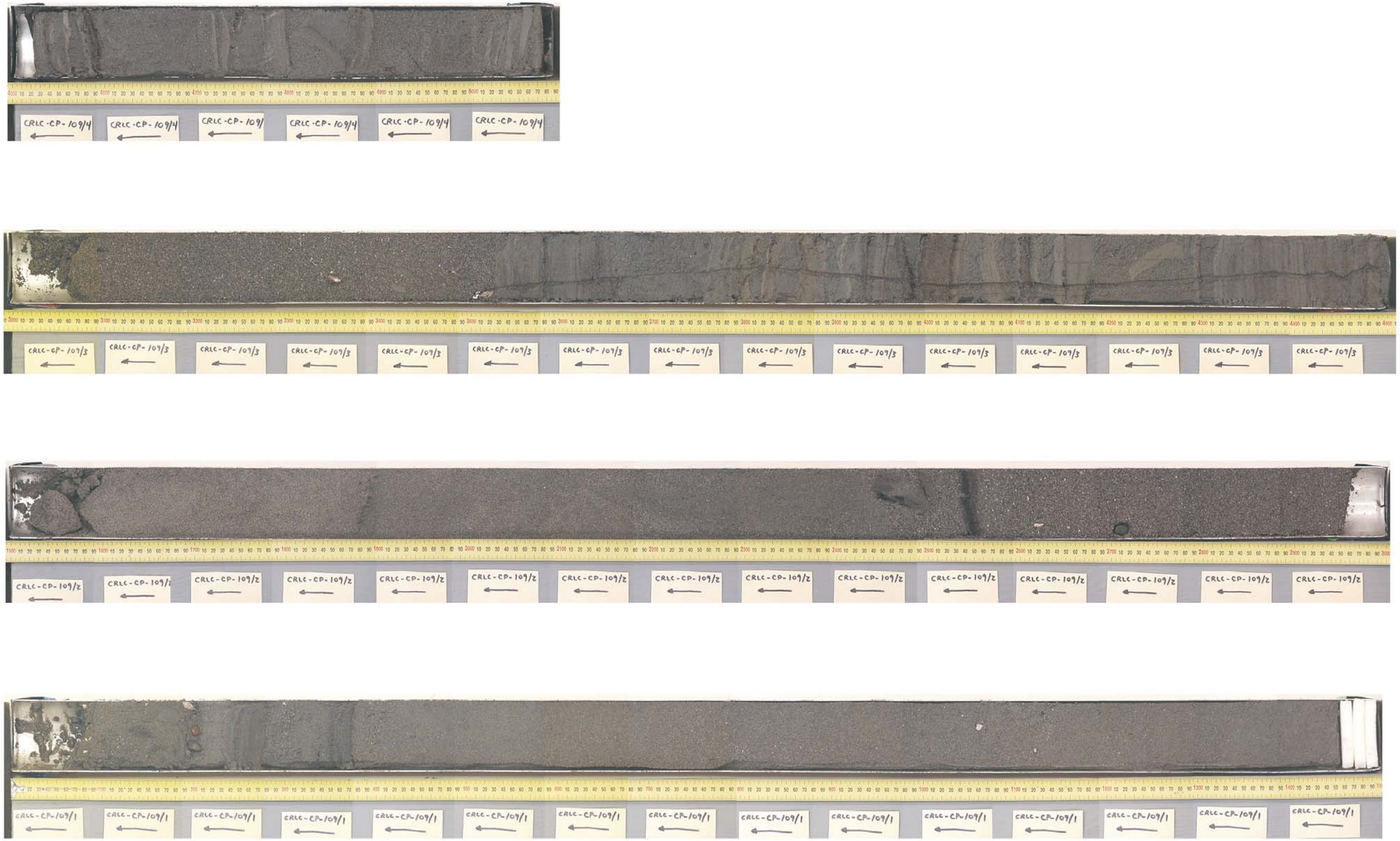
CP-108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CP-109