

Lithological Description of Drill Core WM-5

Nodaway County, Missouri

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Kansas Geological Survey

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Subject: Lithological Description of drill core WM-5

August 1, 2025

Location: Nodaway County, Missouri

Lat/long: 40.452967, -94.935745

Archival location: Missouri Geological Survey

This memo provides a detailed lithological description and photographic documentation of a portion of drill core WM-5, spanning footages 774.0' and 1874.0' (boxes 83-204). This core was described as part of the U.S. Department of Energy (DOE) Office of Fossil Energy and Carbon Management (FECM)'s Carbon Ore, Rare Earth and Critical Minerals (CORE-CM) Initiative for U.S. Basins (DE-FOA-0002364). The core was selected to evaluate Pennsylvanian strata in support of critical mineral potential, coal-related stratigraphy, and carbon ore systems in the Midcontinent. Core WM-5 was measured and described by KGS Assistant Scientist Dr. Stephan Oborny and contributes to the geologic and geochemical characterization of the Cherokee-Forest City Basin.

WM-5 Lithological Description and Details

774'-775.95' Gray shale

775.95'-780.1' Crinoidal with bryozoans and brachiopods. Pack-to-wackestone. Osagia coatings. ~3' Fe-stained horizon at 779.3' Reworked intraclasts, brecciated.

780.1'-785.75' Flakey gray shale. 785.2'-785.75' appears reworked.

785.75'-786.65' Tempestite or reworked paleosol.

786.65'-816.65' Predominantly Wackestone

786.65'~794.5' Tan with Osagia coated grains common.

~794.5'~805' Gray w/ an abundance of fusulinids.

~805'-816.65' Phylloid algae present.

816.65'-820.34' Fissile black shale. PO⁴ observed. Friable between 819.35' and 820.34'. Lag at base. **Stark Shale**

820.34'-826.8' Lime conglomerate with shale matrix. Lime clasts are rounded.

826.8'-827.5' Birdseye calcilutite.

827.5'~829.6' Oolitic-to-fossiliferous grainstone.

~829.6'-845.2' Fossiliferous pack-to-wackestone

830.15'-830.5' Shaly lime horizon.

838.20'-838.65' Thin dark gray/black shale.

845.2'-847.9' Fissile black shale. PO⁴ observed in middle part of black shale. Upper 6" gray. **Hushpuckney Shale**

847.9'-848.8' Wackestone

848.9'-851.55' Friable gray silty shale. Flakey. Middle foot is silt dominated.

851.55'-853.15' Homogenous silty shale with lime nodules/clasts. Swells. Lime nodules may be calcretes.

853.15'-856.0' Predominantly calcilutite. Contains some birds eye, burrows, and weak mottling. Basal 3" is fossiliferous / packstone in character. An ~3' silicified horizon is observed underlying a shale parting at 853.9'.

856'-856.35' Calcareous shale with lime clasts.

856.35'-862.1' Predominantly wackestone. Some algae. Geopetal orientation changes throughout suggesting the interval may be reworked in parts.

862.1'-862.95' Friable, non-silty shale.

862.95'-870.15' Predominantly wackestone. Some algae.

870.15'-870.75' Friable, non-silty shale.

870.75'-871.55' Silty Wack-to-packstone.

871.55'-874.7' Fissile black shale. PO⁴. Upper foot somewhat friable. 0.75" lag at base. **Mound City Shale**

874.7'-876.8' Homogenous silty shale with lime nodules/clasts. Swells. Lime nodules may be calcretes.

876.8'~880' Tempestite(?). Fine sand w/ lime intraclasts.

880'~883.6' Fine sand with tidal mud drapes.

883.6'-892.35' Tidal. Predominantly wavy bedded. Flaser dominated between 885'-885.5' and 889.7'-890.4'.

892.35'-895.1' Silty fossiliferous limestone. Upper foot is very silty.

895.1'-900.65' Fossiliferous wackestone. Parts of the interval are fossiliferous packstone. Crinoids and brachiopods are common. Some algae.

900.65'-903.65' Primarily muddy siltstone (massive) w/ rip-ups above 902'. ~3" lime lag at base.

903.65'-909.9' Mottled fossiliferous wackestone

909.9'-911.55' Fissile black shale. PO⁴. Upper 2" gray. **Nuyaka Creek Shale**

911.55'-919.5' Homogenous silty shale with lime nodules/clasts. Swells. Lime clasts could be calcretes.

919.5'-920.65' Limestone intraclasts facies. Dominated by lime clasts.

920.65'-927.4' Shale. Swells above 922'.

 922'~923' Mottled green-purple. Bedded with few slickens.

 ~923'~924.5' bedded gray-green

 ~924.5'-927.4' Swells with lime clasts/calcretes(?)

927.4'-930.1' Fossiliferous grainstone. Ca-overgrowth. Possibly oolitic.

930.1'-934.3' Wackestone-to-fossiliferous calcilutite. 1.5" shale parting ~5" above the base.

934.3'-935.4' Shale

935.4'-935.95' Fossiliferous wackestone. Osagia coatings.

935.95'-938.95' Flaky shale in upper foot. Swelling silty shale w/ clasts in lower 2'.

938.95'-939.25' Wackestone w/ intraclasts of lime in lower inch.

939.25'-958.25' Clean shale. Gray-green with some purple coloration. Upper 2' silty.

958.25'-968.7' Calcareous shale w/ some weak sideritic coloration.

968.7'-970.3' Coal w/ 4" shale in middle.

970.3'-972.4' Silty swelling shale.

972.4'-976.3' Shaly siltstone.

976.3'-980.75' Limestone. Brachiopods common w/some Moldic porosity. Basal 6" is silty packstone.

980.75'-990.15' Predominantly lenticular tidal shale. Silt dominated starting at 982.6'; fines downward to ~984.3'. Shale dominated below ~984.3'.

990.15'-996.55' Weakly fissile black shale. Basal 3" fossiliferous. No PO⁴. Single siderite band @ ~992.5'.

996.55'-998' Fossiliferous siltstone.

998'-998.9' Coarsely laminated siltstone.

998.9'-1001.6' Upward coarsening tidal interval.

 1000.75'-1001.6' Silty shale

1001.6'-1006.55' Coarsening upward tidal-to-bar.

 1001.6'~1003.2' Rhizoliths and weakly turbated.

 1003.2'-1006.55' Wavy-to-lenticular.

1006.55'-1010.3' Non-silty shale. Gray-to-black in color.

1010.3'-1012.9' Silty wackestone.

1012.9'-1013.4' Silty black shale.

1013.4'-1020.6' Black shale. PO⁴ in upper part.

1020.6'-1020.9' Silty and fossiliferous.

1020.9'-1023.5' Fissile black shale. ~3" lime tongue(?) observed 1.5" above base. Could be a condensed PO⁴ lag... unclear.

1023.5'-1026.55' Silty Shale. Swells.

1026.55'-1031.9' Tan calcilutite. Silty and molding in middle part.

1031.9'-1032.6' Friable shale w/ lime rip-ups.

1032.6'-1034.05' Mottled calcilutite w/ some burrowing.

1034.05'-1035.4' Upper half shale with lime debris. Lower half is black, friable-to-fissile w/ possible few laminar PO⁴, unclear.

1035.4'-1035.9' Pack-to-grainstone.

1035.9'-1043.15' Shale. Friable. Lime stringers in upper foot. 0.5 inch black shale at 1042.75'.
1043.15'-1050.4' Burrowed Fe-stained wackestone. Upper foot is karsted. Lower 1.5' is gradational with underlying silty shale.
1050.4'-1054.4' Silty shale. Crinoid horizon at 1051' and 1058.8'. Fining upward.
1054.4'-1056.5' Fossiliferous silty wackestone w/ Moldic porosity.
1056.5'-1059.4' Fissile black shale. PO⁴ throughout.
1057.5'-1057.75' very calcareous.
1059.4'-1062.45' Shaly siltstone.
1062.45'-1073.3' Siltstone. Rhizoliths are common in the upper 2/3. Mud drapes moderate. The lower half is more shaly than upper half.
1073.3'-1079' Laminar-to-lenticular shale. Very little silt. 2" thick horizon of Fe-silt at 1076' and 1077.4'.
1079'-1080.5' Very fine sand-to-silt. Fe-rich. Some shale partings near base.
1080.5'-1081.65' Shale w/ laminar flows extending down to around 1087.65'. Fe rich silt tongues between 1081.6' and 1082.7'.
1081.65'-1102.4' Sideritic shale. Fossil lag 1090.8'.
1100.85'-1101.15' thin tongue of wackestone.
1101.15'-1102.4' fossiliferous black shale until 1101.7', then 3" Fe-stone atop a coaly shale.
1102.4'-1104.8' vf sand-to-silt w/ soft sed features and laminar bedding. Gray in color.
1104.8'-1112.7' Flaser bedded siltstone.
1112.7'-1117.9' Lenticular shale, tidal.
1117.9'-1123.05' Massive-fine sand.
1123.05'~1129' Wavy bedded tidal.
~1129'~1131' Lenticular shale.
~1131'~1139.5' Friable, weakly sideritic black shale. No PO⁴. No silt. Non-fissile.
1139.5'-1151.65' Dark gray-green shale. Appears reworked, possibly a tempestite above ~1145.5'. Calcareous nodules observed in the interval. Potentially calcretes.
1145'-1151 Bedded intraclasts
1151.65'-1153.45' Fossiliferous wackestone. Lower 3" reworked fossiliferous shale.
1153.45'-1165.4' Friable black shale. Pyritic in parts. No PO⁴. No silt.
1165.4'-1166.6' Black-to-brown wackestone. Upper and lower contacts gradational.
1166.6'-1168.3' Fissile black shale. PO⁴.
1168.3'-1170.1' Interbedded fissile shale and coal. Coal weak. Sulfur staining.
1170.1'-1178.4' Vf sand-to-silt.
1178.4'-1183.6' Flaser tidal.
1183.6'-1186.4' Dominantly lenticular tidal.
1186.4'-sharp color change to dark gray/black below this point.
1186.4'~1192.25' Friable shale. No PO⁴. No silt.
~1192.25'-1197.1' Wackestone. Black in color.
1197.1'-1222.1' Friable black shale. Non-fissile. No PO⁴. Weakly sideritic w/ brownish intercoloring below 1216'. Weakly silty ~1205'~1213'.
1222.1'-1225' Gray swelling mudstone.
1225'-1231' Gray shale with swelling interbeds. Silty between ~1227'-1231'.
1231'-1238.75' Siltstone with some trough bedding.
1238.75'-1239.9' Conglomerate. Pebbles ≤1".
1239.9'-1244.9' Siltstone with some trough bedding.
1244.9'-1246.75' Swelling mudstone/shale, bedded. Siderite stringer at top.
1246.75'-1247.35' Fissile black shale.
1247.35'-1248.9' Coal (salt precipitation and sulfur)
1248.9'-1253.25' Muddy turbated siltstone. 1250.6'-1251.2' dark black w/ 1" black shale @ top.
1253.25'-1253.5' Coal
1253.5'-1260.7' Sandy mudstone. Lower 2" much sand.
1260.7'-1272.5' Coarsening upward package

1260.7'-1265.4' Massive fine sand
1265.4'-1272.5' Tidal mud drapes, silt to vf sand.
1272.5'-1274.55' Mudstone/shale
1274.55'-1279.35' Silt-to-vf sand w/foreset
1279.35'-1280.75' Mudstone
1280.75'-1281.1' vf sand-to-siltstone
1281.1'-1287' Sideritic mudstone
1287'-1299.9' medium-to-fine sandstone. Mud drapes common w/ Fe cementation in parts. Upper 2' silt dominated.
1299.9'-1308.45' Sideritic dark gray shale. Fe banding abundant. Upper 2' silty.
1308.45'-1309.25' Fissile shale. No PO⁴.
1309.25'-1309.7' Coal
1309.7'-1316.7' Silty mudstone-to-muddy siltstone. Rhizoliths, slicken surfaces, tempestite evident in some parts.
1316.7'-1321.6' Coarsening upwards package. Medium-to-fine sand, massive, above 1320'. Tidal below 1320'.
1321.6'-1327.75' Coarsening upwards package. Massive, fine sand above 1323.55'. Tidal below 1323.55' w/ swelling mud in bottom half.
1327.75'-1337.35' Coarsening upwards package. Turbated massive med-grained sandstone above 1332.9. Tidal below this.
1337.35'-1347.4' Friable-to-weakly fissile sideritic shale. Dark gray-to-black. Siderite is well developed. 2" thick coal ~7" from bottom.
1347.4'-1348.4' Fine turbated sand. Top few inches grade into the overlying shale.
1348.4'-1350.7' Coal and organic rich black shale. Friable-to-fissile shale above 1349.8' w/ reworked coal in upper 2". Coal w/ salt precipitation and sulfur below 1349.8'.
1350.7'-1352.7' Predominantly mudstone. Blocky below 1351'.
1352.7'-1355' Blocky silty-to-vf sandy mudstone
1355'-1371.4' Sideritic shale. Black-to-dark gray. Silty above ~1359'.
1371.4'-1371.95' Coal
1371.95'-1374' Massive sand
1374'-1375.5' Silty mudstone
1375.5'-1378.7' Sideritic black shale. Swells.
1378.7'-1379.45' Massive fine sand
1379.45'-1381.5' Wavy bedded tidal, upper foot burrowed.
1381.5'-1387.8' Black sideritic shale.
1387.8'-1389.6' Coal (Removed from box. Note in box says 1.8' thick.)
1389.6'-1390.2' Mudstone
1390.2'~1395' Medium sandstone.
~1395'-1400.8' Flaser bedded tidal.
1400.8'-1401.35' Massive fine sandstone.
1401.35'-1402.35' Silty black shale.
1402.35'-1408.8' Wavy-to-flaser bedded fine sand.
1408.8'-1409.6' Coal
1409.6'-1410' Wavy tidal.
1410'-1426.3' Black sideritic shale. No PO4. More fissile above 1420'. Swells down to 1426.3'.
1426.3'-1433.6' Shaly siltstone-to-silty shale. Brownish and sideritic.
1433.6'-1435.1' Swelling shale.
1435.1'-1435.3' Coal
1435.3'-1457.5' Blocky mudstone. No bedding.
1457.5'-1449.5' Swelling gray shale with rhizoliths above 1439'. Dark gray-to-black fissile shale down to 1449.5'. No PO⁴.
1449.5'-1452.05' Wavy tidal(?). Turbated/burrowed.
1452.05'-1498.85' Black sideritic shale. Fissile w/ no PO⁴ above 1484.4'.
1484.4'-1496' Fissile-to-swelling
1496'-1498.85' silty

1455.3'-1455.9' Thin tongue of muddy wackestone.
1498.85'-1538' Tidal. Variable flaser, wavy, and lenticular bedding.
1538'-1540.9' Medium sandstone.
1540.9'-1541.15' Gray silty shale-to-shaly siltstone.
1541.15'-1607.15' Medium sandstone. Interval is sugary. Coal rip-ups are visible between 1575' and 1576'.
1607.15'-1611.55' Silty flaky shale.
1611.55'-1612.65' Coal.
1612.65'~1616' Flaser bedded siltstone.
~1616'-1625.1' Black flaky shale. Upper 1.5' grades into overlying tidal siltstone.
1625.1'-1628' Siltstone.
1628'-1631' Blocky flaky shale.
1631'-1631.95' Coal.
1631.95'-1635' Silty blocky mudstone. Leached.
1635'-1635.75' Leached shale.
1635.75'-1643.15' Wavy tidal. Burrowing is very common in upper half.
1643.15'-1648.5' Friable-to-fissile black sideritic shale.
1648.5'-1651.15' Silty black shale.
1651.15'-1655' vf-to-fine sand.
1655'-1658' Friable shale. The upper half is gray with lenticular silt stringers. Bottom half black
1658'-1659.2' Coal.
1659.2'-1661.4' Silty mudstone. Dark in color.
1661.4'-1661.8' Coal.
1661.8'-1663.1' Siltstone.
1663.1'-1665' Tidal wavy bedded siltstone
1665'-1670.5' Flakey black sideritic shale.
1670.5'-1670.65' Fissile black shale. No PO⁴.
1670.65'-1671.45' Coal.
1671.45'-1672.3' Blocky silty mudstone.
1672.3'-1675.5' Siltstone.
1675.5'-1679.85' Black shale. Tidal silt drapes between 1678' and 1678.85'.
1679.85'-1721.8' Silty black shale. Lenticular w/ horizontal burrows. Burrows most common in upper half. Some sideritic banding in top.
1721.8'-1722.1' Coal. Most of the coal was removed by 'Howe'.
1722.1'-1723.3' Blocky. vf sand w/ mud stringers.
1723.3'-1748.7' Tidal. Flaser above 1725'. Wavy-to-lenticular below 1725. Turbated and burrowing increases up section.
1748.7'-1760.8' Sideritic black shale. Fissile with minimal small horizontal burrows. No PO⁴.
1760.8'-1760.9' Weak coal.
1760.9'-1762.1' Gray leached fissile shale.
1762.1'-1790.2' Fissile shale. Sideritic in several parts. Pyritized burrows are common. 4" thick fine sand tongue at 1769.8'-1770'.
1790.2'-1791' Swelling silty shale w/ weak coal at base.
1791'-1805' Predominantly tidal.
1791'-1791.8' Black fissile shale. No PO⁴.
1791.8'-1792.15' Coal. Removed by 'Howe and Pepper'.
1792.15'-1797.3' Fissile black shale. No PO⁴.
1797.3'-1799' Muddy siltstone. Wavy tidal.
1799'-1799.2' Coal
1799.2'-1800' Flaser bedded fine sand.
1800'-1802.2' Muddy siltstone. Wavy tidal.
1802.2'-1803.4' Flaser bedded.
1803.4'-1805' Generally wavy bedded.

1805'-1807.9' Wavy-to-flaser bedded w/ black siltstone stringers.
1807.9'-1826.9' Wavy-to-flaser bedded. Horizontal burrows throughout interval. Lower 4' very burrowed w/ horizontal and vertical. Coaly and organic rich between 1807.9' and 1808.35'.
1826.9'-1834.35' Fine sand w/ mud drapes. Flaser bedded.
1834.35'-1848.1' Coarsening upward sandstone. Whole interval is sulfur stained. Upper 2" sulfur staining is prominent.

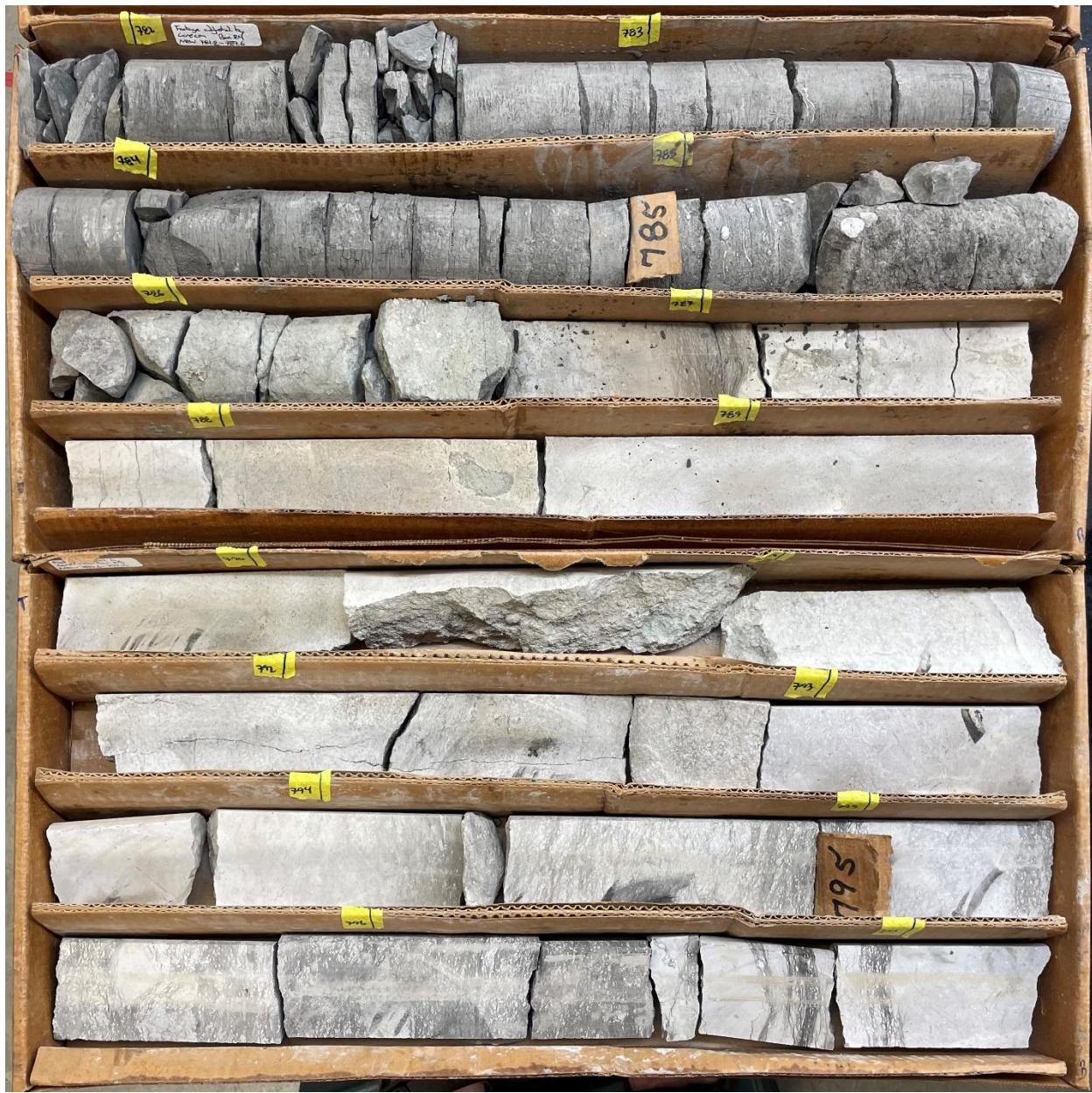
1834.35'-1842.35' Fine sandstone.
@1838.2' thin shale parting.
1842.35'-~1846' Medium sandstone.
1846'-1848.1' Coarse sandstone.
1848.1'-1850.1' Fine sandstone w/ intraclasts of lime in lower 4".
1850.1'-1850.6' Bacterial matted limestone w/ collapse features.
1850.6'-1874' Mississippian (Base of core is 1874')
1850.6'-1860.15' Silty wackestone.
1860.15'-1863.75' Tempestite. Glauconitic green shale and reworked limestone.
1863.75'-1867.3' Clean wackestone. Stylolites.
1867.3'-1868.3' vf sandstone.
1868.3'-~1873.2' Tempestite and collapsed silty wackestone.
1873.2'-1874' Silty wackestone.

WM-5 Drill Core Photos

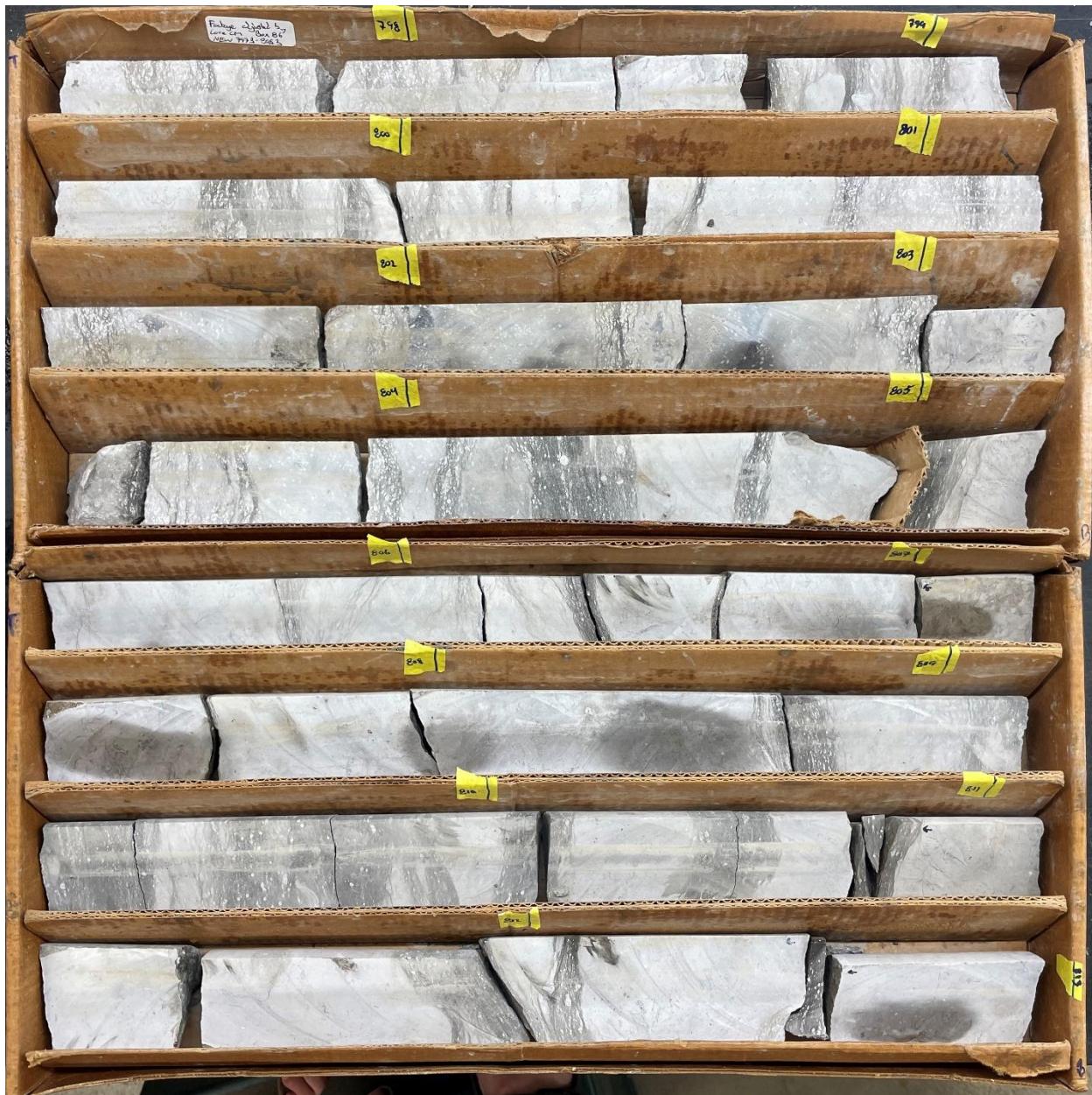
Images are in order from box 83 through box 204. Core is boxed in engineering style.



Boxes: 83-84



Boxes: 84-85



Boxes: 86-87



Boxes:

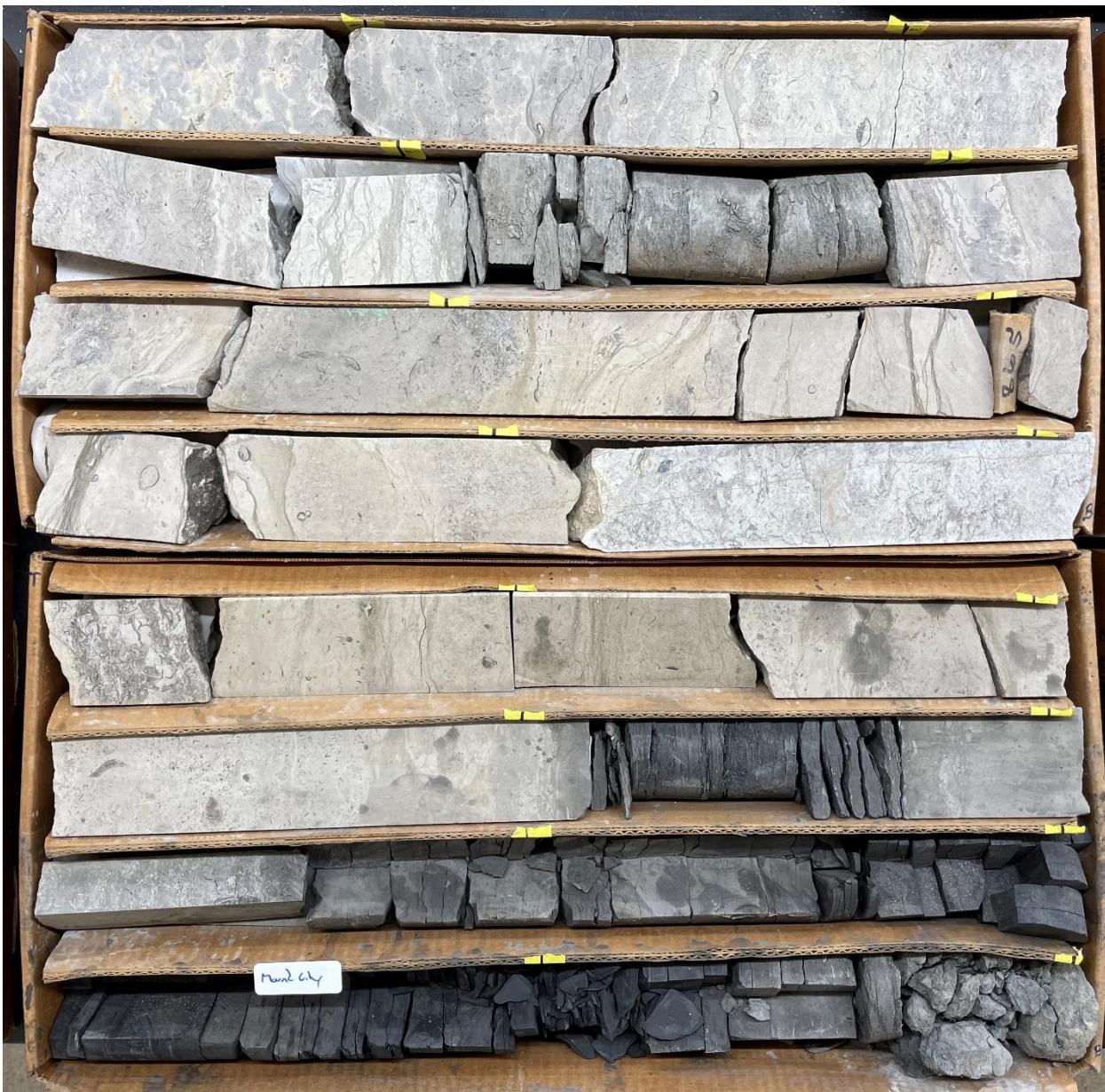
88-89



Boxes: 90-91



Boxes: 92-93



Boxes: 94-95



Boxes: 96-97



Boxes: 98-99



Boxes: 100-101



Boxes: 102-103



Boxes: 104-105



Boxes: 106-107



Boxes: 108-109



Boxes: 110-111



Boxes: 112-113



Boxes: 114-115



Boxes: 116-117



Boxes: 118-119a



Boxes: 119b-120



Boxes: 121-122



Boxes: 123-124



Boxes: 125-126



Boxes: 127-128



Boxes: 129-130



Boxes: 131-132



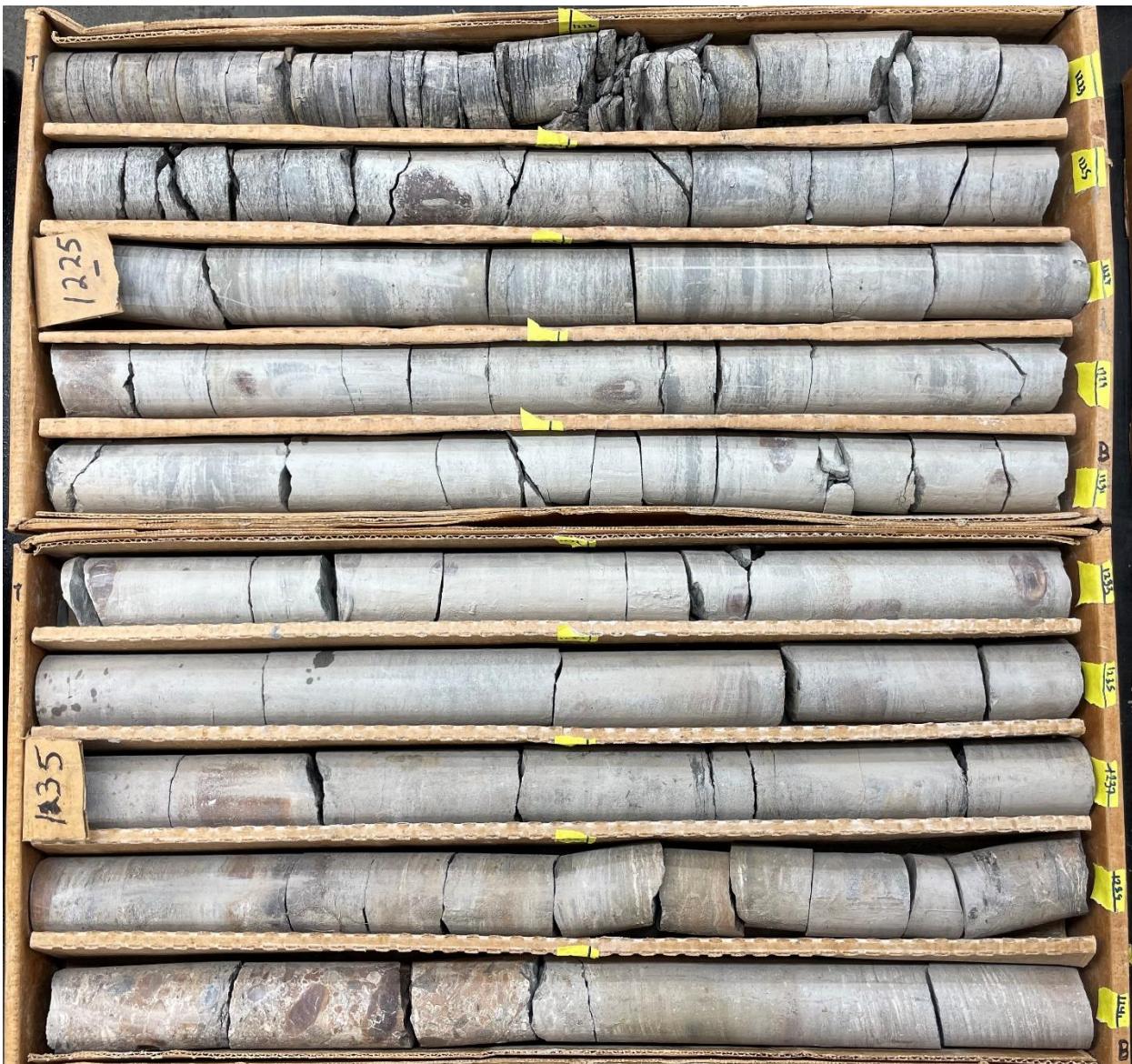
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Boxes: 135-136



Boxes: 137-138



Boxes: 139-140



Boxes: 141-142



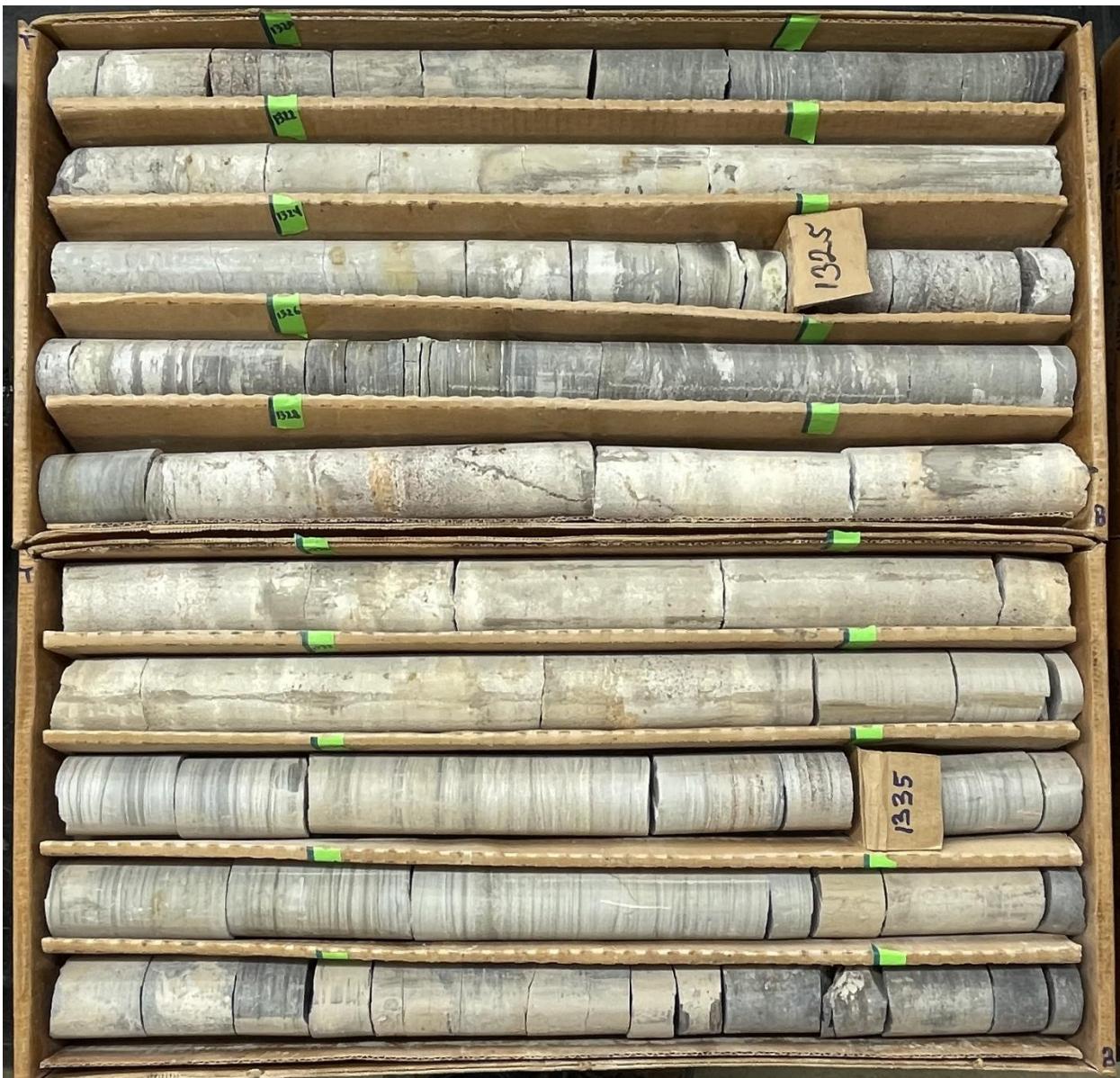
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Boxes: 145-146



Boxes: 147-148



Boxes: 149-150



Boxes: 151-152



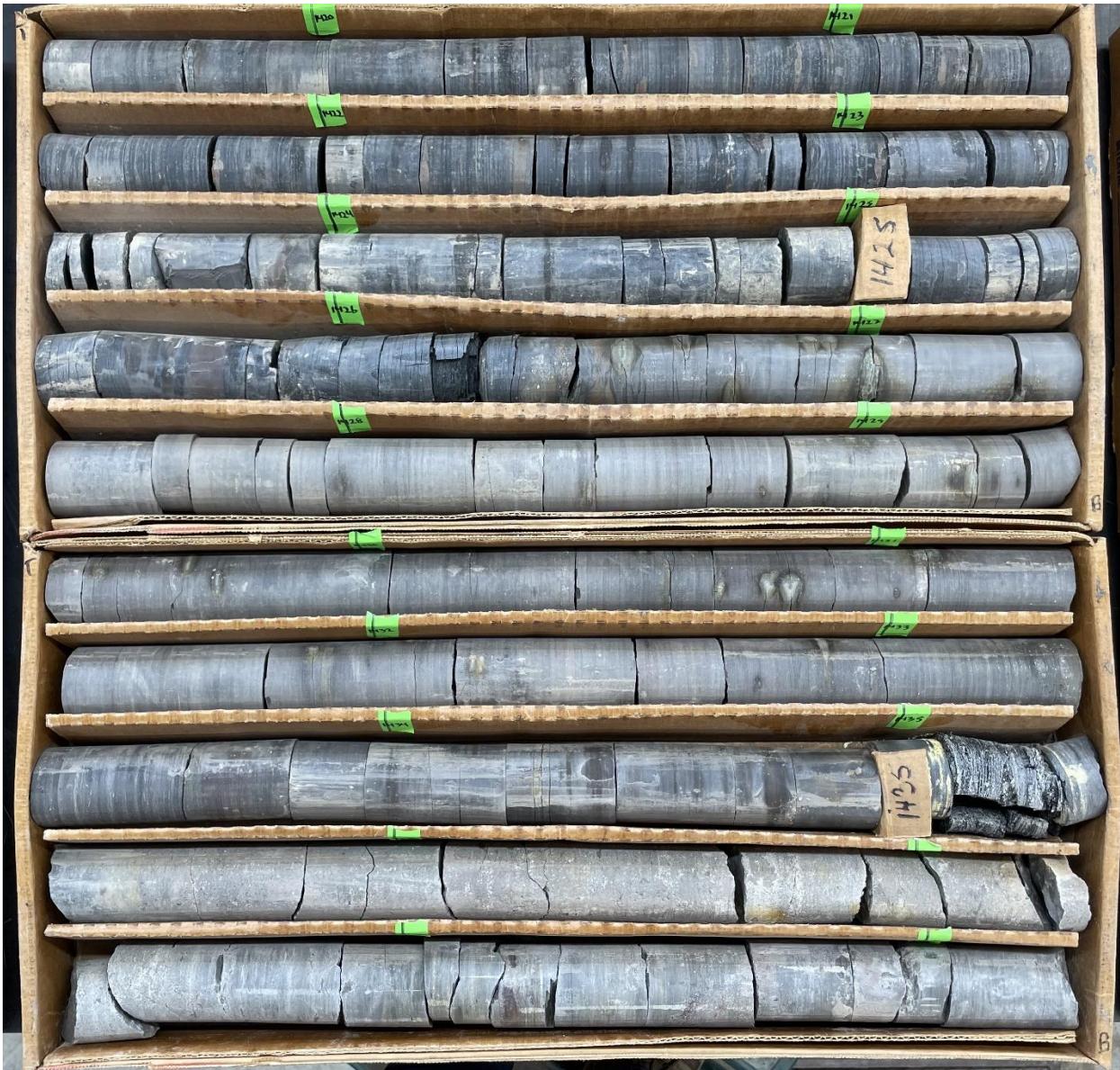
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Boxes: 155-156



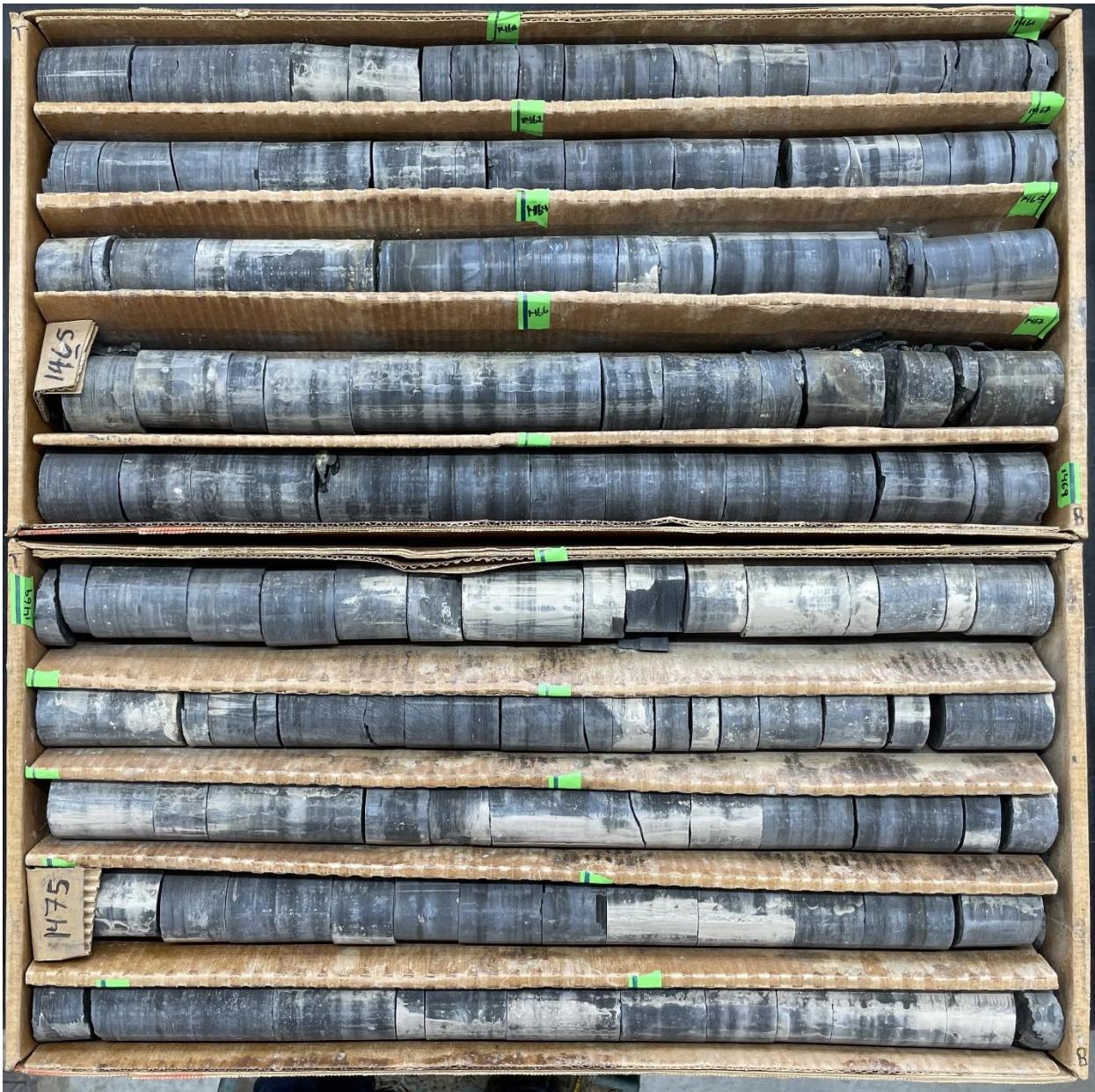
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Boxes: 159-160



Boxes: 161-162



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Boxes: 167-168



Boxes: 169-170



Boxes: 171-172



Boxes: 173-174



Boxes: 175-176



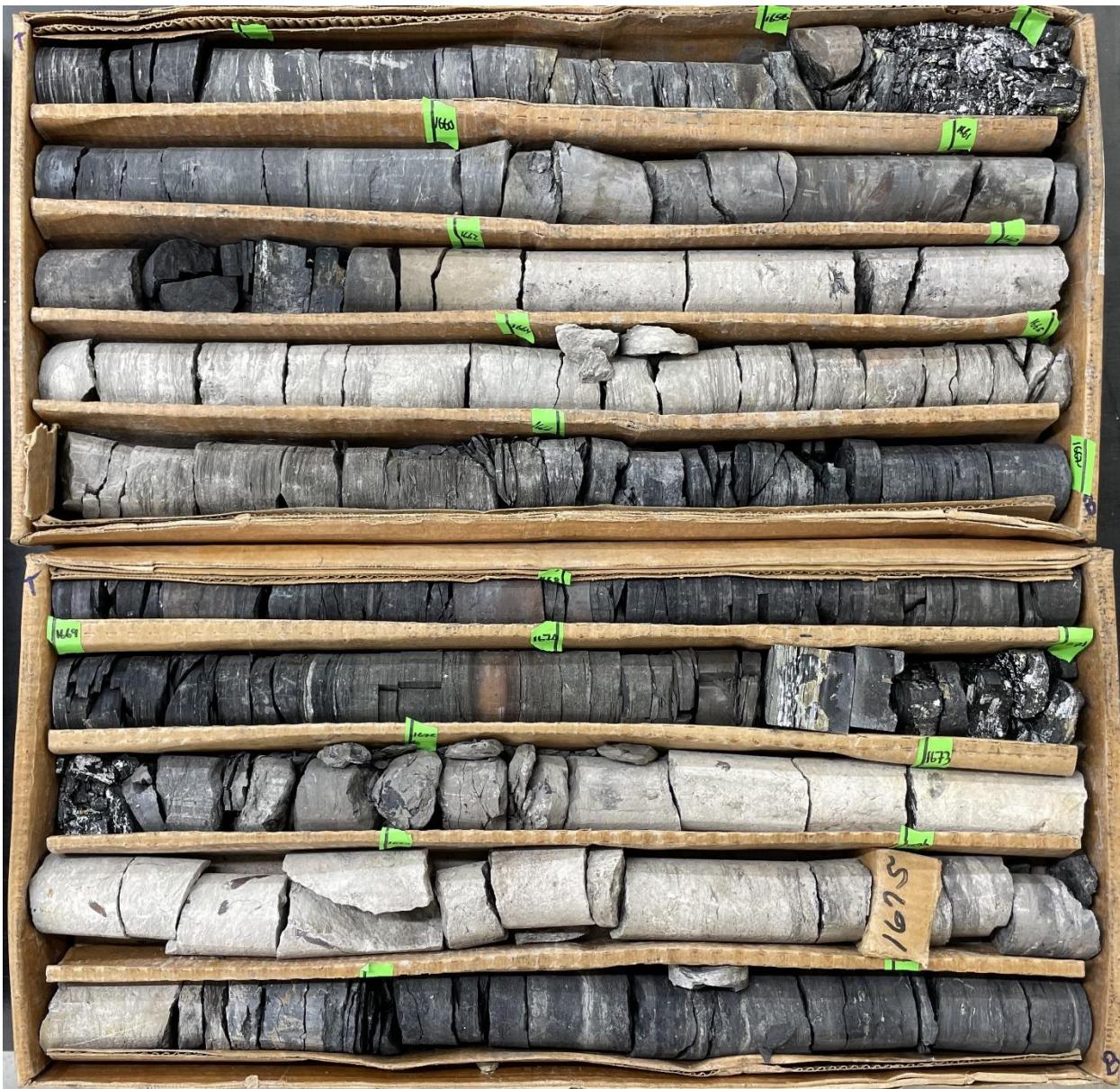
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Boxes: 179-180



Boxes: 181-182



Boxes: 183-184



Boxes: 185-186



Boxes: 187-188



Boxes: 189-190



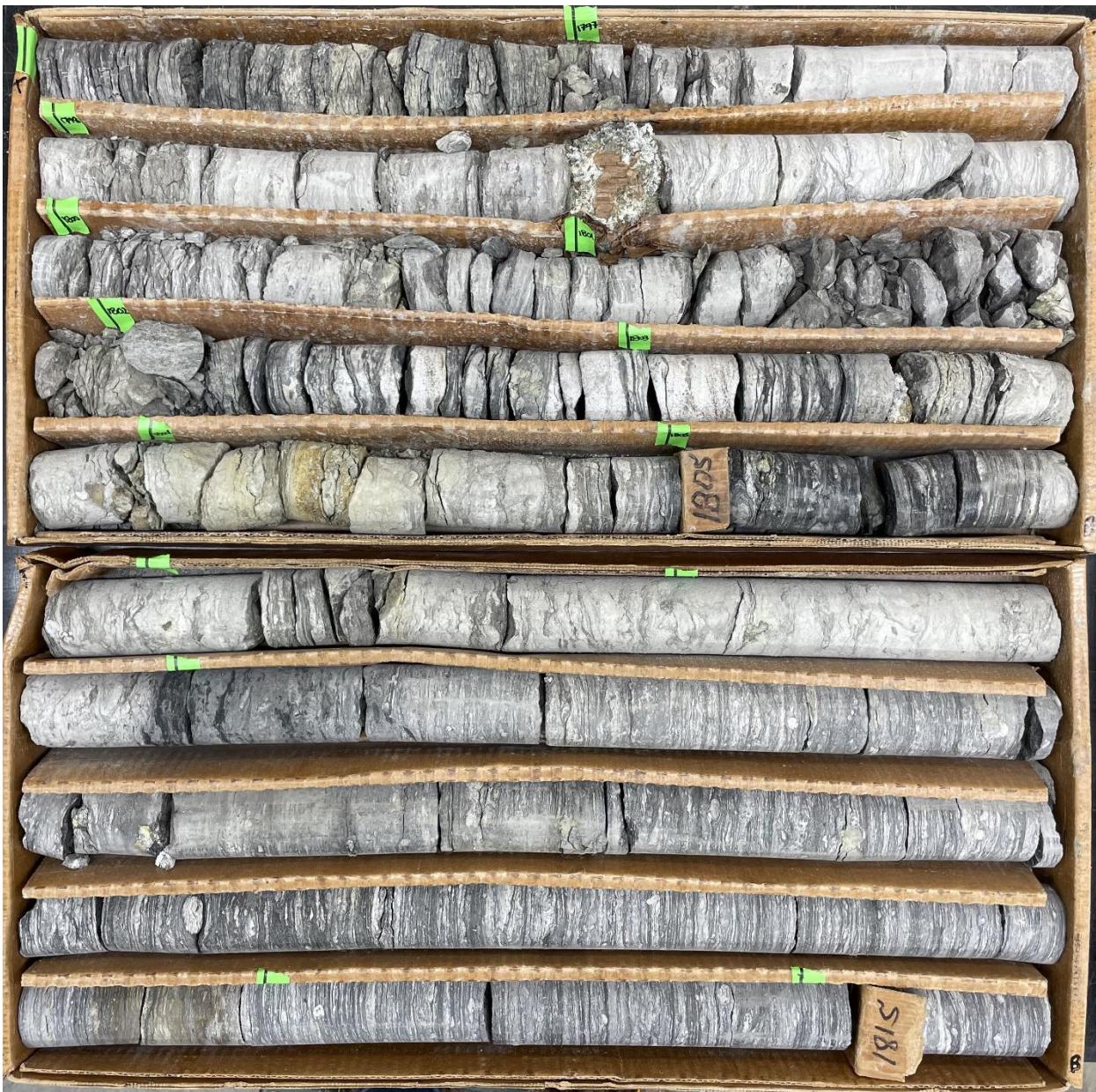
Boxes: 191-192



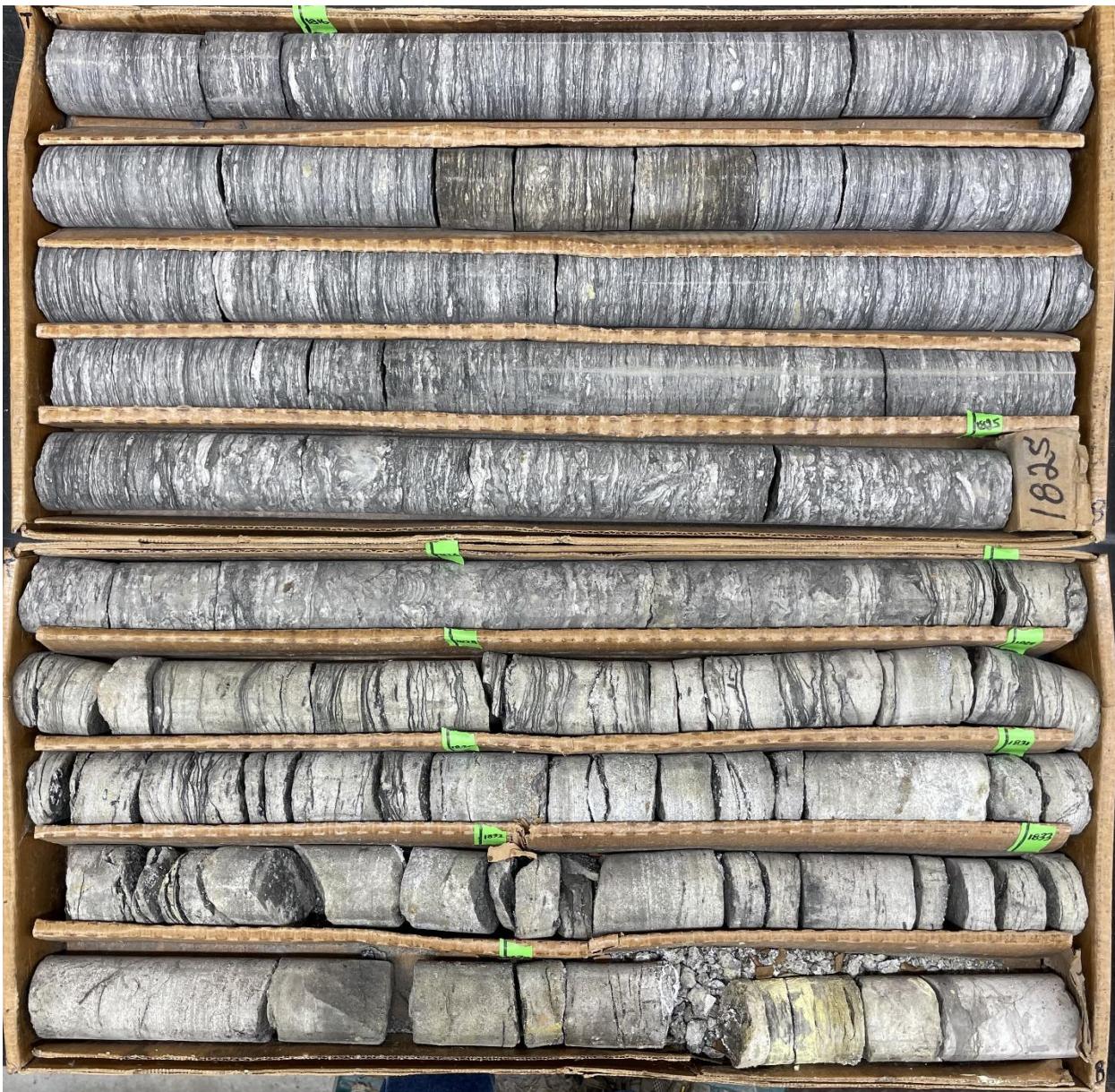
Boxes: 193-194



Boxes: 195-196



Boxes: 197-198



Boxes: 199-200



Boxes: 201-202



Boxes: 203-204