Figure F1. Map of Mediterranean–Atlantic gateway at Gibraltar. Red dots = Expedition 401 Site U1610 in Gulf of Cádiz and Site U1611 in Alborán Sea, blue dots = Expedition 339 sites, yellow dot = Ocean Drilling Program Site 976, green dot = Deep Sea Drilling Project Site 121 in Alborán Sea.

Figure F2. Present-day water mass circulation patterns on either side of Gibraltar Strait in relation to main topographic features and Expedition 401 sites. AMW = Atlantic Mediterranean Water.

Figure F3. A–D. Late Miocene–Pliocene paleogeographic evolution of Mediterranean–Atlantic gateways (Krijgsman et al. 2018), Site U1610. Blue arrows = paleocurrents derived from literature (e.g., Martín et al., 2014; Capella et al., 2018). Eastern Alborán volcanic arc may have created system of interconnected islands in Messinian (Booth-Rea et al., 2018). Modified after Krijgsman et al. (2018).

Figure F4. Location of Site U1610 relative to Sites U1386 and U1387, which recovered a Pliocene–Pleistocene succession. Seismic coverage across area is also shown. GuB = Guadalquivir Basin.

Figure F5. Schematic 4-stage evolutionary block model of eastern Deep Algarve Basin based on seismic interpretation and correlation with industry wells and Expedition 339 sites, Site U1610. A. Stage I distal submarine lobes. B. Stage II more proximal submarine lobes. C. Stage III migrating channel fill. D. Stage IV hemipelagic drape. Figure modified after Ng et al. (2022). MTD = mass transport deposits. AUGC = Allochthonous Unit of the Gulf of Cádiz.

Figure F6. Seismic section showing location of Site U1610 in Gulf of Cádiz. Dotted lines = projected Messinian (D5) and Tortonian (D4) surfaces.

Figure F7. Reentry and casing system, Hole U1610A. mbrf = meters below rig floor. Dimensions are in meters. NA = not applicable.

Figure F8. Lithologic synthesis, Site U1610. See SYNTHLOGS in Supplementary material for editable version of this figure. V.f. = very fine.

Figure F9. Lithologic summary, Site U1610. Curve variation in sedimentary log indicates long-term relative variations of coarser versus finer grained sediments. Black dashed lines = unit boundaries, horizontal gray dashed lines = subunit boundaries, vertical dashed line with T = transitional interval from one unit to the next unit.

Figure F10. Core and bed thickness by lithology, Site U1610. A. Composition of each lithology per core. B. Number of beds of sand grade or coarser per core. C. Bed thickness by lithology. Black dashed lines = unit boundaries, gray dashed lines = subunit boundaries, T = transitional interval between units.

Figure F11. Example facies description for each unit, Site U1610. A. Calcareous silty mud and calcareous mud, Unit I. Linescan image and RGB color are from Section Half Imaging Logger (SHIL). X-ray image is from XSCAN. Reflectance (L*a*b*) and MS are from Section Half Multisensor Logger (SHMSL). NGR data points are shown to note different sampling spacing compared to other logs. Vfs = very fine sand, fs = fine sand, Ms = medium sand, Cs = coarse sand, vcs = very coarse sand. Ch = *Chondrites*, Pa = *Palaeophycus*, Pl = *Planolites*, Th = *Thalassinoides*, Zo = *Zoophycos*. cps = counts per second, IU = instrument units. Note that boundary between two lithologies is concordant with L* and b* reflectance and RGB color variations, together with gradual NGR response. (Continued on next four pages.)

Figure F11 (continued). B. Calcareous mud and calcareous clay, Unit II. (Continued on next page.)

Figure F11 (continued). C. Calcareous mud and clayey calcareous ooze, Unit III. (Continued on next page.)

Figure F11 (continued). D. Calcareous mud, calcareous silty mud, calcareous sandy silt, and calcareous fine sand, Unit IV. (Continued on next page.)

Figure F11 (continued). E. Rapid transition from dolostone to calcareous silty mud, Unit V.

Figure F12. Vertical to subvertical, straight to slightly winding, thin burrows of *Trichichnus* (Tr), associated with pyrite nodules in Unit III, Site U1610. Left: core photograph. Right: XSCAN images. In this section, apparent dip of beds is about 25°.

Figure F13. A. Texture of different lithologies per unit from smear slide analysis (n = 200), Site U1610. Smaller diagrams show data for Units I–IV. (Continued on next page.)

Figure F13 (continued). B. Averaged texture (grain size) from smear slide data for main lithologies in Units I–V. Coarse lithologies group includes sandy silt (Units I and II only), silty sand, sandy mud (Unit I only), and very fine to medium-grained sand.

Figure F14. A. Composition of different lithologies per unit from smear slide analysis (n = 197), Site U1610. Smaller diagrams show data for Units I–IV. Compositional data were normalized to exclude minor siliceous biogenic component that is always ≤5% (Table T2). Dolostone in Unit V is not included, as it is dominantly composed of recrystallized dolomite. (Continued on next page.)

Figure F14 (continued). B. Averaged composition from smear slide data for main lithologies in Units I–IV.

Figure F15. Representative powder XRD patterns of different lithologies in Units I–V, Site U1610. Samples are arranged from shallow (top) to deep (bottom).

Figure F16. Variation in total carbonate content based on coulometry (see Geochemistry) and XRD data (calcite + dolomite + siderite), Site U1610. Some samples from same squeeze cake or stratigraphic interval were analyzed by both XRD and coulometry analyses.

Figure F17. Variations in mineralogical composition from bulk XRD patterns using Rietveld refinements method, Site U1610 (see Lithostratigraphy in the Expedition 401 methods chapter [Flecker et al., 2025a]). Organic carbon (OC) content of samples collected from same stratigraphic intervals was also included (see Geochemistry in the Expedition 401 methods chapter [Flecker et al., 2025a]).

Figure F18. Bigradational sequences of contourites in (A) Unit I and (B) top of Unit IV, showing coarsening- and fining-upward sequences, as well as some subtle sedimentary structures, such as parallel lamination and small grain size variations, Site U1610.

Figure F19. A–C, E–G. Subtle parallel and cross lamination and normal grading (arrows) in Units I–III (A, C, E: structures were observable in XSCAN images; B, F, G: structures not visible), Site U1610. Two examples from Units I and III have apparent dip of parallel lamination (about 10° and 6°, respectively). D. Very subtle organic matter laminae (arrows) in calcareous silty mud interval, Unit I.

Figure F20. Turbidites and trace fossils in Unit I, with bioturbated upper contacts (Ch = *Chondrites*, Pl = *Planolites*) and rare bioturbated lower contact (Ut = undifferentiated trace).

Figure F21. Major lithologies for (A) Units I–III, (B) Units IV and V, and (C) coarser grained lithologies, Site U1610. Dominant siliciclastic and biogenic components are annotated. Air = air bubble, Cl = clay, Cn = calcareous nannofossils, Dol = dolomite, Fd = feldspar, Fm = foraminifers, Gl = glauconite, Hm = heavy mineral, Lith = lithic fragment, Py = pyrite, Qz = quartz, Sp = sponge spicule. (Continued on next page.)

Figure F22. Increasing bioturbation intensity and ichnodiversity from calcareous mud (BI = 1) to clayey calcareous ooze (BI = 4) in Unit III close to boundary with Unit IV, Site U1610. Note crosscutting relationships between trace fossils in clayey calcareous ooze and sparse trace fossils in calcareous mud. Ch = *Chondrites*, Pl = *Planolites*, Th = *Thalassinoides*, Zo = *Zoophycos*.

Figure F23. Lithified sandstones in Subunit IVb, Site U1610. A. Sandstones in Unit IV with sharp bases and mud clasts. B. Sandstone with mud clasts and a fining-upward and later coarsening-upward interval. C–E. Sandstones with parallel and cross lamination and marked color banding. Note presence of *Macaronichnus* trace fossil in D (red box; location of TS12; Figure F25I–F25L). Dark laminae in C are caused by enrichment of glauconite. F. Mud clasts.

Figure F24. (A, H) Subunit IVb conglomerates and (B–G) Thin Section TS9 of red box in A (B–E: partly carbonate-stained areas; F, G: noncarbonate-stained areas), Site U1610. Note that polishing of thin section was finished at >30 µm thickness, so birefringence colors of quartz are higher than usual. Brown clast in red box in A is dolomite clast (Dc) in B and C. Fern-like features in F and G are crystals of epoxy resin. Fm = foraminifers, Gl = glauconite, Qz = quartz, K-spar = K-feldspar.

Figure F25. A–L. Subunit IVb sandstone thin sections (A–D, G, H: carbonate-stained areas; E, F, I–L: noncarbonate-stained areas), Site U1610. Note that polishing of thin sections was finished at >30 µm thickness, so birefringence colors of quartz are higher than usual. Dark grains in these sandstones are mostly glauconite (Gl). Red lines = lithologic contact. Cc = calcite cement, Fd = K-feldspar, Fm = foraminifers, Pl = plagioclase, Qz = quartz.

Figure F26. Unit IV turbidite deposits with evidence of reworking by bottom currents, Site U1610. A. Reworking at top of turbidite. B. Parallel lamination, color banding, and small grain size variations in turbidite. C. Reworking of turbidite, with lenticular bedding at top. D. Stacked sets of cross lamination in turbidite.

Figure F27. A–K. Subunit IVc calcareous sand and Unit V dolostone, Site U1610 (D–G: noncarbonate-stained areas; H–K: carbonate-stained areas). Space between framework particles contains negligible amount of clays and is mostly filled with calcite. Note that polishing of thin sections was finished at >30 µm thickness, so birefringence colors of quartz are higher than usual. Dol = dolomite, Gl = glauconite, Py = pyrite, Qz = quartz.

Figure F28. A, B. *Macaronichnus* trace fossil in calcareous fine sand beneath conglomerate in Subunit IVb, Site U1610. C. Typical mineralogical segregation shown between cylinder tube core (lighter colored minerals; black arrows) and surrounding rim (darker and heavy minerals; green arrows).

Figure F29. (A, B) Calcareous sandy silt, (C, D) conglomerate, (E, F) sandstone, and (G, H) bioturbated sandstone in Unit IV, Site U1610 (C: scanning electron microscopy in backscatter electron mode; star = location of D; D: energy-dispersive X-ray spectroscopy). Note that polishing of thin sections was finished at >30 µm thickness, so birefringence colors of quartz are higher than usual. Fm = foraminifers, Cc = calcite cement, Gl = glauconite, Qz = quartz, Dol = dolomite, Cal = calcite, Mrf = metamorphic rock fragment, Mq = metamorphic quartz. cps = counts per second.

Figure F30. Planktonic foraminifer and calcareous nannofossil biostratigraphic events and estimated sedimentation rates, Hole U1610A. Events are plotted at their mean depth. LrO = lowest regular occurrence, S/D = sinistral/dextral.

Figure F31. Abundance of benthonic foraminifer assemblages in core catcher samples, Hole U1610A. Shallow-water benthonic assemblage is composed of *Ammonia* spp. and *Elphidium* spp.; *Cibicidoides* spp. and *Textularia* spp. make up epibenthonic assemblage; Uvigerinids include *Uvigerina peregrina, Uvigerina elongostriata, Uvigerina mediterranea, Uvigerina proboscidea*, and *Uvigerina hispida* (Table T8).

Figure F32. AF demagnetization results, Hole U1610A. Left: vector endpoints of paleomagnetic directions measured after each demagnetization treatment on an orthogonal projection (Zijderveld) plot. Examples of normal (positive inclinations) and reversed (negative inclinations) polarity are shown in left and right panels, respectively. Squares = horizontal projections, circles = vertical projections. Right: intensity variation with progressive demagnetization.

Figure F33. AMS determinations, Hole U1610A. Left: orientation of principal AMS axes K_{max}, K_{int}, and K_{min}. Dashed circle = average dip of K_{min} axis interpreted as inclined drilling direction of ~15° for Hole U1610A. Right: shape factor of AMS ellipsoid versus AMS degree.

Figure F34. Paleomagnetic results, Hole U1610A. Red vertical line = GAD inclination at site latitude in normal polarity. Smoothed inclination used 1 m moving window. Orange band = standard deviation of smoothing results. ChRM inclination of discrete samples have α_{95} uncertainties. Blue triangles = discrete sample positions. Chron columns: black = normal polarity, white = reversed polarity, gray = zones of uncertain normal polarity. Lines and numbers along interpreted chron column = tie points between hole and GPTS. Dashed lines between hole and GPTS = best-fit correlation of uncertain polarity boundaries.

Figure F35. Sediment accumulation curve from tentative magnetostratigraphic correlations to GPTS 2020 (Raffi et al., 2020), Hole U1610A. Squares with solid lines = well-established reversals, squares with dashed lines = uncertain ages. Ages are fitted to polynomial of 3° using least squares method.

Figure F36. Headspace methane, ethane, ethene, propane, *iso*-butane, and *iso*-pentane, Hole U1610A. Locations of opportunistic void space sampling shown as nonquantitative indicator of gassiness of cores.

Figure F37. Methane:ethane ratios in headspace and void space samples downcore and as comparison of adjacent sampling within same core, Hole U1610A.

Figure F38. Comparison of several key IW chemical profiles to nearby Sites U1386 and U1387, Hole U1610A.

Figure F39. IW alkalinity, pH, and salinity, Hole U1610A. Results from Sites U1386 and U1387 shown for comparison (salinity was not reported at Site U1387). Dashed line = bottom water values.

Figure F40. IW sodium and chloride concentrations and Na/Cl ratios, Hole U1610A. Results from Site U1387 shown for comparison. Dashed line = bottom water values.

Figure F41. IW major cation concentrations (calcium, magnesium, and potassium), Hole U1610A. Results from Site U1387 shown for comparison. Dashed line = bottom water values.

Figure F42. IW major anion concentrations (sulfate and bromide), Hole U1610A. Arrow = depth of SMTZ, identified by sulfate dropping to 0 mM at Site U1387. Dashed line = bottom water values.

Figure F43. IW major nutrient concentrations (ammonium and phosphate), Hole U1610A. Results from Site U1387 shown for comparison (phosphate was not reported at Site U1387).

Figure F44. IW minor element concentrations (Li and Si), Hole U1610A. Results from Sites U1386 and U1387 shown for comparison. Dashed line = bottom water values.

Figure F45. IW minor and trace element concentrations (Ba, B, and Sr), Hole U1610A. Results from Site U1387 shown for comparison. Dashed line = bottom water values.

Figure F46. IW trace element concentrations (Fe and Mn), Site U1610A. Results from Site U1386 shown for comparison. Fe and Mn concentrations below detection limit are plotted as 0 µM.

Figure F47. $CaCO_3$, organic carbon, nitrogen, and C/N in sediments, Hole U1610A.

Figure F48. Comparison of carbonate geochemistry results, Hole U1610A. Symbol color indicates lithology of sample or lithology found immediately above and below IW whole-round sample; where they differ, interior color shows lithology above and exterior color shows lithology below.

Figure F49. Relationship between carbonate weight percent determined by analysis of XRD spectra and coulometry, Hole U1610A. Symbol color indicates lithologies found immediately above and below IW whole-round sample; where they differ, interior color shows lithology above and exterior color shows lithology below. 1:1 line = conversion of inorganic C measured during coulometry to $CaCO_3$, lower dashed line = overestimate of carbonate weight percent for sample composed of $CaMg(CO_3)_2$ (dolomite).

Figure F50. Relationships between carbonate weight percent, NGR, and MS, Hole U1610A. NGR and MS measurements represent closest analysis to carbonate sample (usually within 15 cm). cps = counts per second.

Figure F51. Carbonate Mg/Ca and Sr/Ca, Hole U1610A. Arrow = where 94R-CC, 45–50 cm, lies off scale of axis (Mg/Ca ratio = 737 mmol/mol).

Figure F52. Carbonate Mn/Ca and Fe/Ca, Hole U1610A. Arrow = where 94R-CC, 45–50 cm, lies off scale of axis (Fe/Ca ratio = 41.8 mmol/mol).

Figure F53. MS; GRA density; NGR; L*, a*, and b* color variation; and whole and split core *P*-wave velocity, Hole U1610A. MS, GRA, NGR, L*, a*, and b*: gray dots = original three data sets (with anomalous values removed from GRA, L*, a*, and b*), overlying black lines = 50 point locally weighted nonparametric regression (LOWESS) smooth run on MS, GRA, L*, a*, and b* to highlight variations and secular trends and 10 point LOWESS smooth run on NGR to highlight trends at equivalent resolution to other data sets because of wider measurement spacing. *P*-wave velocity: gray dots = WRMSL PWL, red squares = PWC *x*-direction, blue circles = PWC *y*-direction, green crosses = PWC *z*-direction. cps = counts per second.

Figure F54. MS; GRA; NGR; and L*, a*, and b* color variation, Hole U1610A. A. 515–540 m CSF-B. Note how MS, GRA, L*, and a* peaks (red arrows) correlate to troughs (blue arrows) of NGR and b*, and vice versa. B. 880–900 m CSF-B. Note how MS, GRA, and NGR peaks and troughs are in phase with one another. Correlation with color is less clear, but generally it appears that peaks/troughs in MS, GRA, and NGR correlate to troughs/peaks of L* and a*. b* values appear to switch between in- and out-phase with other data series depending on depth. cps = counts per second.

Figure F55. Thermal conductivity, MAD, GRA bulk density, grain density, and porosity, Hole U1610A. Porosity was obtained during MAD measurements. Gray dots in thermal conductivity = single nonaveraged value triple measurements.

Figure F56. NGR measurements, Holes U1610A. Corresponding three NGR components (potassium, uranium, and thorium) extracted from total NGR counts using shipboard codes based on method described by De Vleeschouwer et al. (2017). Ratio of thorium to uranium content is also shown. cps = counts per second.

Figure F57. Downhole logging data summary, Hole U1610A. All downhole data are from quad combo main upward pass unless otherwise noted. LCAL = caliper, HSGR = total spectral gamma ray, VELP = *P*-wave logs, RT_HRLT = true resistivity. cps = counts per second, gAPI = American Petroleum Institute gamma radiation units.

Figure F58. A. Age model tie points, Hole U1610A. B. Sedimentation accumulation rates for each data set (foraminifer and nannofossil bioevents; chron boundaries). C. Cycle thickness measured using MS and NGR data from core and downhole NGR data (Table T19). Only cycles not disturbed by section or core breaks were included in data set. Vertical lines = theoretical thickness of precession cycles for each interval, calculated both from linear regression through all age tie point data in that interval and from sedimentation rate using upper and lowermost tie points in each interval (Table T18; see U1610sedrates.xlsx in AGE-MODEL in Supplementary material). Generalized representation of succession showing unit and subunit boundaries is also shown.