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Data report: X-ray fluorescence scanning of Site U1574, Vøring Plateau, IODP Expedition 396[1]

Carlos A. Alvarez Zarikian,[2] Stacy L. Yager,[2] Dustin T. Harper,[2] Marialena Christopoulou,[2] Vincent J. Clementi,[2] Natalia Varela,[2] and the Expedition 396 Scientists[2]

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[2] **Expedition 396 Scientists' affiliations.** Correspondence author: **zarikian@iodp.tamu.edu**

Contents

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Abstract

Semiquantitative elemental results from X-ray fluorescence (XRF) scanning of sediment cores from International Ocean Discovery Program (IODP) Site U1574 in the Vøring Plateau, Norwegian Margin, are presented in this report. XRF elemental data were collected every 1 cm from a stratigraphically complete and continuous cored section with 102% recovery from the sea bottom to ~170 meters below seafloor in Hole U1574C. We report raw element intensities (counts) for Al, Si, K, Ca, Ti, Fe, Br, Sr, and Zr and identify covariation patterns consistent with lithofacies variations. Our high-resolution XRF scanning was conducted to better characterize the sediment depositional history at Site U1574 and to aid interpretation of past environmental and oceanographic conditions in the Norwegian Margin, targeting the earliest incursion of deep water into the young North Atlantic Ocean during the Early to Middle Eocene. The high-resolution XRF data also may help improve the age-depth model for the sediment succession at Site U1574.

1. Introduction

Site U1574 was drilled during International Ocean Discovery Program (IODP) Expedition 396 on the top of Eldhø, an Outer High on the northern flank of the Vøring Plateau at 2825 m water depth (Figure **F1**; see **Planke et al.**, 2023). Outer Highs are distinctive features of volcanic rifted margins and are located seaward between the Inner and Outer Seaward Dipping Reflector (SDR) facies units (Hopper et al., 1992; Planke et al., 2000; **Planke et al.**, 2023; Franke et al., 2019). Their presence can provide clues on volcanic rifted margin evolution, as they may represent specific geologic processes (**Planke et al.**, 2023). Eldhø rises more than 1500 m above the adjacent Inner SDR in the southeast and about 650 m above the Outer SDR in the northwest.

The primary goals for drilling Site U1574 (**Planke et al.**, 2023) were to enhance geodynamic models of intense breakup volcanism by gathering data on Eldhø's emplacement environment through observations of the drilled volcanic facies. Additionally, the objectives included constraining the mantle composition prior to melting and determining the ambient temperature and pressure conditions in the melt region during the late stages of breakup volcanism in the North Atlantic by analyzing the geochemical composition and petrology of the volcanic rocks encountered. Furthermore, the drilling aimed to provide information on the suitability of the breakup basalt sequences and interbedded sediments for permanent geologic storage of CO_2, and last, to obtain information on the earliest incursion of deep water into the North Atlantic and the extent of freshwater incursions into the young ocean during the Early to Middle Eocene (Brinkhuis et al., 2006; **Planke et al.**, 2023) by coring the overlying sedimentary strata.

Site U1574 consisted of three boreholes. The first, Hole U1574A, was drilled using the R/V *JOIDES Resolution*'s rotary coring system to 260 meters below seafloor (mbsf), penetrating ~70 m deep into the basaltic basement and successfully sampling the volcanic facies. Hole U1574B was aborted after the first core because it did not recover an adequate sediment/water interface. Hole U1574C was cored using the ship's advanced piston corer (APC) system to ~170 mbsf to improve recovery of the overlying sediments. A complete and continuous record of high-quality cores was obtained with an overall recovery of 102%. Our X-ray fluorescence (XRF) core scanning of Hole U1574C was conducted to aid the interpretation of the depositional environment of the overlying sediments and facilitate more detailed paleoceanographic studies. In this report, we present high-resolution raw count data for elements commonly used to identify changes in lithofacies, sediment provenance, and paleoproductivity.

1.1. Site U1574 lithostratigraphy and biostratigraphy

The sediment and rock cores from Site U1574 were described and examined on board during Expedition 396 (**Planke et al.**, 2023). The recovered sediments consist of brown and brownish gray unconsolidated and consolidated clay with intervals of sandy layers, volcanic ash, isolated pebbles, minor and sparsely distributed intervals yielding calcareous microfossils, and abundant organic microfossils. The sedimentary succession in Hole U1574C above the igneous basement was divided into four lithostratigraphic units and spans from the late Early Eocene to the present (see **Planke et al.**, 2023, for details):

- Unit I (0 to ~30 mbsf) is brown and brownish gray unconsolidated mud with intervals of rare to common planktonic foraminifers of Quaternary age.
- Unit II (~30–38 mbsf) is pale yellow and grayish green consolidated clay. The lithologic transition from Unit I to Unit II is well defined by an unconformity with distinct change in the clay consolidation accompanied by the disappearance of calcareous microfossils and a marked increase in age (latest Early Eocene) based on organic microfossils (dinoflagellates).
- Unit III (~38–149.64 mbsf) is very dark gray claystone with interbedded sandstone and ash. Sand content decreases with depth and organic content increases. The ages of adjacent units indicate a latest Early Eocene age.

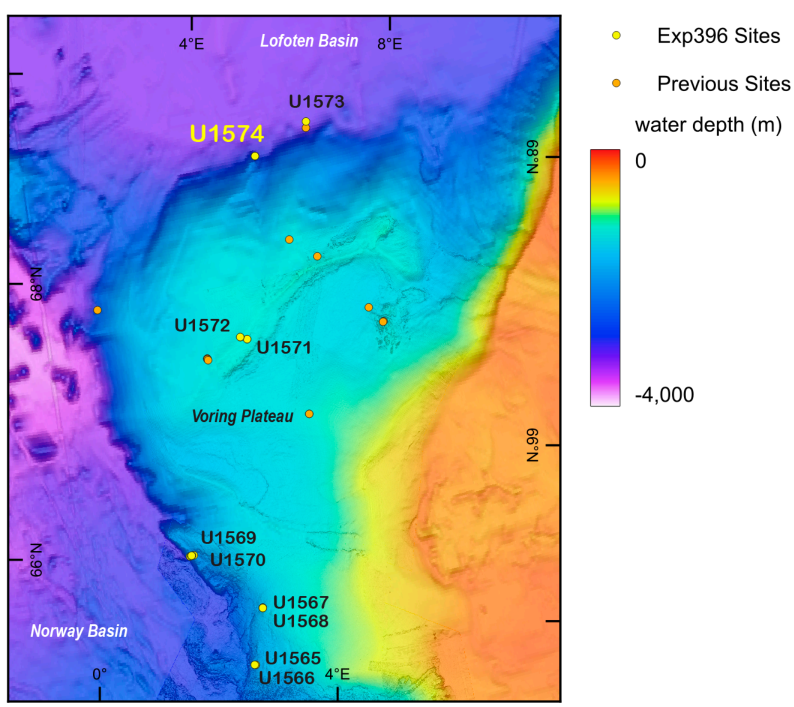

Figure F1. Bathymetric map of Vøring Plateau in Norwegian Sea, Expedition 396 sites including Site U1574.

- Unit IV (149.64–169.22 mbsf) lies above the basaltic basement and consists of very dark gray to very dark grayish brown organic-rich mudstone with thin parallel laminations and authigenic pyrite. Rare calcareous micro and nannofossils (e.g., foraminifers, micromollusks, and coccoliths) are sparsely distributed at the base of the unit. Organic and calcareous microfossils suggest a latest Early Eocene age.
- Unit 5 (169.22–171.50 mbsf) consists of aphyric to plagioclase phyric pillow basalt with localized hyaloclastite and rare interbedded mudstone.

2. Methods and materials

Data in this report were acquired in 2022 on a fourth generation Avaatech XRF core scanner (XRF-2) at the IODP Gulf Coast Repository (GCR) at Texas A&M University in College Station, Texas (USA). The XRF core scanner provides nondestructive elemental identification (major and minor elements) from the surface of split core sections for elements between aluminum (Al) and uranium (U) (**https://www.avaatech.com**). All sediment cores (396-U1574C-1H through 19H) collected in Hole U1574C, except for Section 1H-3 (see below), were scanned at 1 cm intervals at the three excitation levels of 10, 30, and 50 kV, resulting in a continuous, high-resolution ~170 m long elemental record spanning from the late Early Eocene to the present (Figures **F2**, **F3**).

Three scans were completed for each core section. The 10 kV scan (8 s count time, 0.16 mA tube current, and no filter) was for the elements Al, Si, P, S, Cl, Ar, K, Ca, Ti, Cr, Mn, and Fe. The 30 kV scan (10 s count time, 1.25 mA tube current, and Pd filter) was for K, Ca, Ti, Mn, Fe, Ni, Cu, Zn, Ga, As, Br, Rb, Sr, Y, Zr, Nb, and Mo. The 50 kV scan (13 s count time, 0.75 mA tube current, and Cu filter) was for Ca, Fe, Ni, As, Br, Rb, Sr, Y, Zr, Nb, Mo, Ag, and Ba. The sample irradiation area was 10 mm in the downcore direction and 12 mm in the crosscore direction. All XRF data are presented in counts per second in XRF in **Supplementary material**.

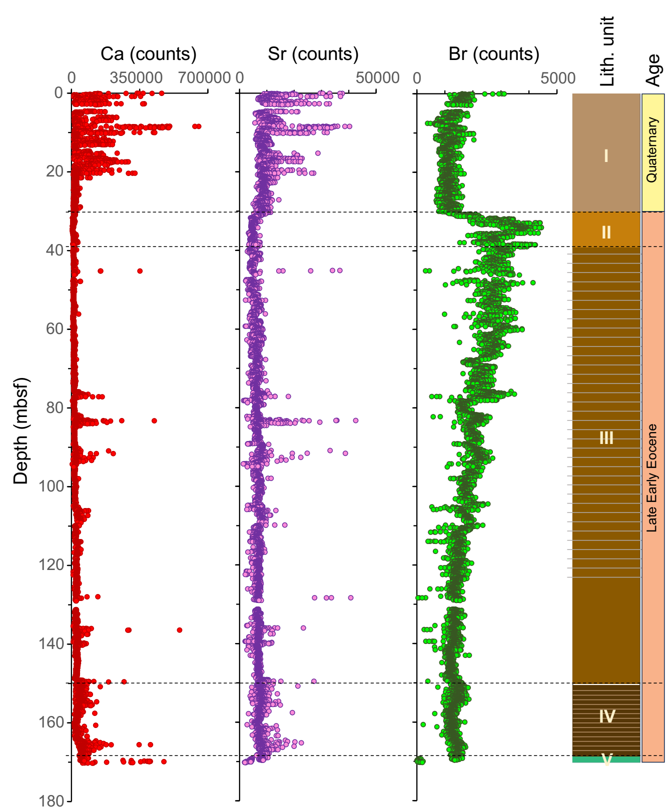

Figure F2. Raw XRF scanner counts for biogenic elements Ca, Sr, and Br compared to sediment age and lithostratigraphic units (see text for explanation), Hole U1574C. Dashed lines = lithostratigraphic boundaries.

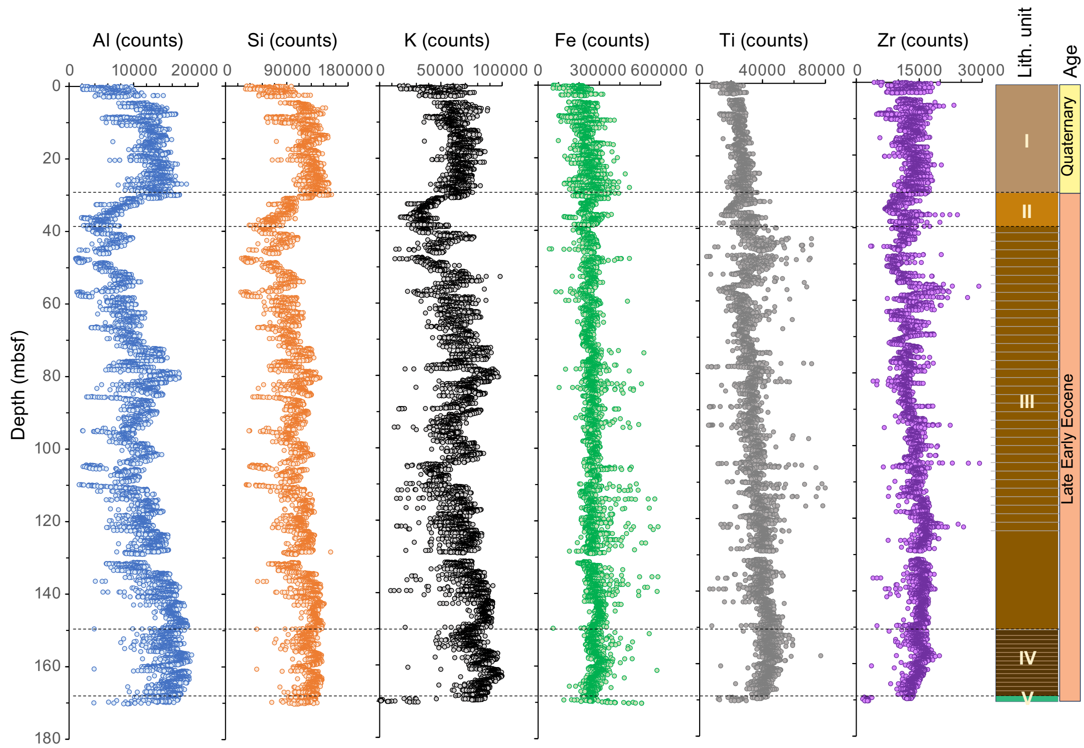

Figure F3. Raw XRF scanner counts for lithogenic elements Al, Si, K, Fe, Ti, and Zr compared to sediment age and lithostratigraphic units (see text for explanation), Hole U1574C. Dashed lines = lithostratigraphic boundaries.

2.1. Core preparation

Prior to scanning, each core section was allowed to equilibrate to room temperature, scraped with a glass slide to clean the core surface, and covered with 4 µm thick Ultralene plastic film to prevent contamination of the measuring prism. Allowing the cores to warm to room temperature before covering with the film prevented condensation underneath the plastic, which can affect X-ray attenuation (Tjallingii et al., 2007).

Section 396-U1574C-1H-3 (1.51 m long, 3.0–4.51 mbsf) could not be measured on the XRF scanner because the cut face of the split section exhibited a groove running longitudinally across the center of the entire section that prevented the detector prism from landing flush with the sediment and free of air. The groove was caused by the cutting wire dragging a large sediment particle down during core splitting aboard the ship.

2.2. Quality control

To ensure consistent data quality from the XRF core scanner, standards were run at all three excitation levels at the beginning and the end of each scanning day. In the morning, 20 replicates were run at each excitation level to warm up the machine; in the evening, no replicates were run.

3. Results

The scanning XRF data in this report provide a continuous high-resolution record of the elemental composition of the sedimentary section in Hole U1574C. Based on the shipboard age model, the 1 cm measurement interval suggests a temporal spacing of ~3.5 ky between data points from the basal sediments at 169.22 to ~30 mbsf, and ~1 ky between data points from ~30 mbsf to the seafloor (**Planke et al.**, 2023). Figures **F2** and **F3** show the downhole distributions of selected elements typically associated with biogenic and lithogenic sources, respectively. Ca, Sr, and Br reflect the biogenic sedimentary components. Ca and Sr, which are expected to record the relative abundance of calcareous microfossils, show positive covariance with each other with maximum values in Unit I, moderate increases in Unit IV, and three distinct peaks around 80 mbsf in Unit III. In contrast, there is a largely inverse relationship with Br, which increases upcore, reaching highest values in Unit II (at ~32 mbsf) followed by a sharp decrease at the transition between Units II and I and consistently low values in Unit I (Figure **F2**). In marine sediments, Br can be used as a proxy for the total organic carbon (TOC) content (Ziegler et al., 2008; Seki et al., 2019; Peterson and Schimmenti, 2020).

When comparing detrital elements (Figure **F3**), Al, Si, and K and to a lesser extent Zr positively covary with each other, a relationship illustrated for several of the element pairs (Si versus Al; K versus Al) by the crossplots shown in Figure **F4**. The similar nature of downhole patterns of these elements is consistent with a common terrigenous origin. Notably, Fe and Ti appear to show a different pattern than the other terrigenous elements, both displaying, overall, less variability and a gentle decreasing trend upcore.

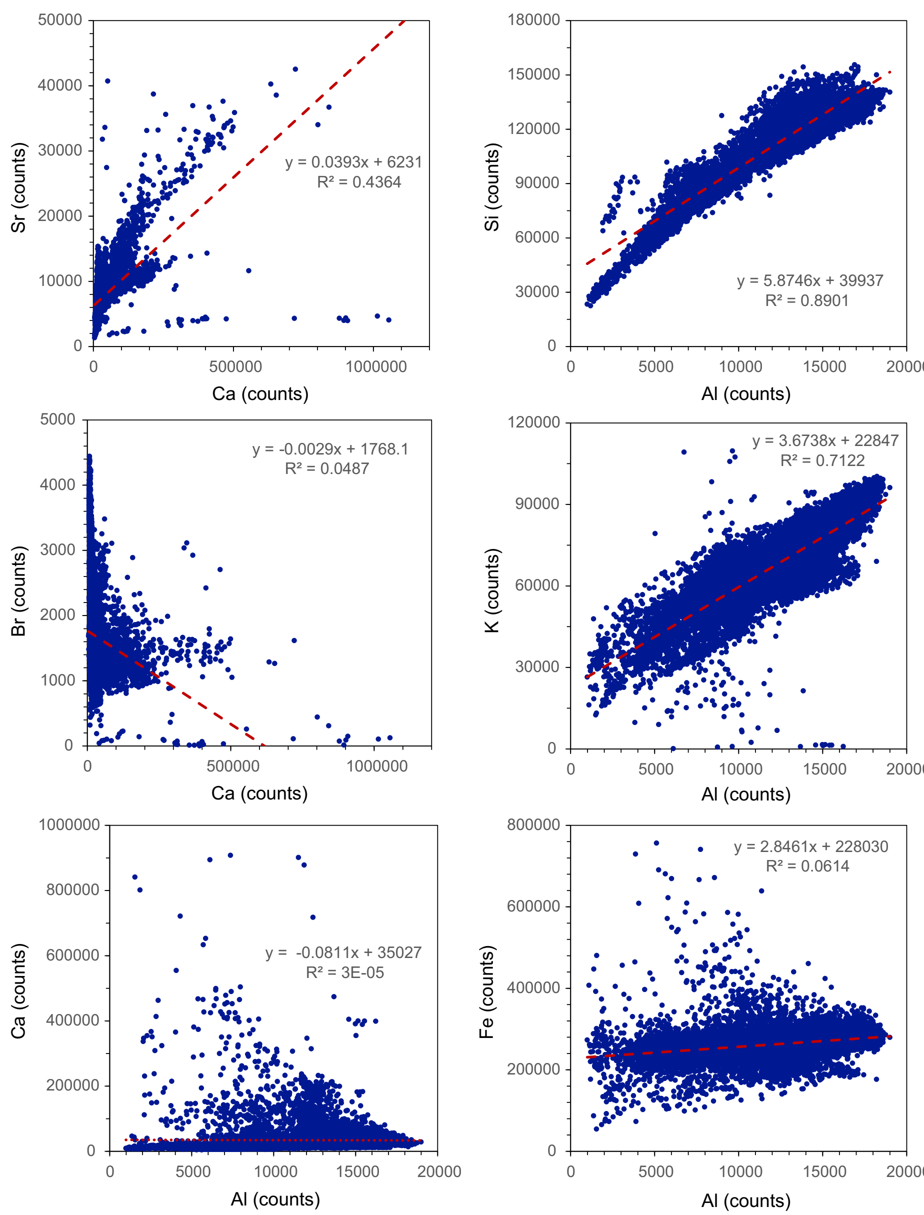

Figure F4. Crossplots of selected elements typically associated with biogenic and detrital inputs to marine sediments, Hole U1574C.

The high-resolution XRF data presented here may help to better characterize the sediment depositional history and the environmental and oceanographic evolution at Site U1574 and in the Norwegian Margin since the earliest incursion of deep water into the young North Atlantic Ocean during the Early to Middle Eocene. The data also may aid to improve the age-depth model for the sediment succession at Site U1574 and the rate of change of the environmental and oceanographic conditions using cyclostratigraphy.

4. Acknowledgments

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