IODP Expedition 361: Southern African Climates
Site U1474 Summary

Background and Objectives

Site U1474 is located in the northernmost Natal Valley (31°13.00′S, 31°32.71′E), ~88 nmi south–southeast of Durban, South Africa, in a water depth of 3045 m below sea level (mbsl). The north–south trending Natal Valley is a sediment-filled basin between the coast of Southeast Africa and the Mozambique Ridge. At its northern end the shoaling valley passes into the extensive coastal plains of Southern Mozambique (Dingle et al., 1978; Goodlad, 1986), while towards the south the deepening Natal Valley merges with the Transkei Basin below 4500 m water depth. Terrigenous sediment supply into the basin is dominated by the seasonal discharge from the numerous short, but fast-flowing, rivers that characterize the drainage system of the Natal coast (e.g. the Tugela River), as well as contributions from the Limpopo River and possibly the Zambezi River. Surface sediment dispersal is strongly affected by the (~100 km wide) Agulhas Current, flowing southward close to the continental shelf edge and transporting ~70 Sv at 32°S (Beal and Bryden, 1999) with surface velocities up to 1.5 m/s. At depth, the northward flowing Agulhas Undercurrent hugs the continental slope, currently transporting North Atlantic Deep Water (NADW). The currents related to this northward flow have led to the formation of a network of elongate, north–south orientated sediment drifts.

According to Lutjeharms (2006) the Agulhas Current can be considered to be fully constituted at about 26°S, around Ponto do Ouro, close to the border between Mozambique and South Africa. Here the East Madagascar Current converges with Mozambique Channel throughflow to form the Agulhas Current. The northern section of the Agulhas current system, above Site U1474, is extraordinarily stable owing to the steep, nearly rectilinear continental shelf that topographically steers the current flow southwards (de Ruijter et al., 1999; Lutjeharms, 2006; Lutjeharms, 2007).

Several high-resolution orbital- to millennial-timescale records from shallow-penetration marine sediment cores located near Site U1474 (Ziegler et al., 2013; Simon et al., 2013, 2015a, 2015b) have provided multi-proxy reconstruction of hydrographic variability within the main flow of the Agulhas current as well as river discharge from the catchments of the Natal coast over the past 250 k.y. In particular, Simon et al. (2013)

have demonstrated a strong connectivity between the upstream Agulhas current hydrographic variability and the phasing of temperature, salinity, and planktonic foraminiferal-based Agulhas leakage changes in the Agulhas leakage corridor, plausibly linked to the influence of recirculation within the southwest Indian Ocean sub-gyre as predicted from physical oceanography (e.g. Gordon, 1985; Stramma and Lutjeharms, 1997). Additionally, it has been shown that changes in terrestrial climate (hydroclimate) are related to regional precession-paced insolation changes and the effects associated with high-latitude abrupt climate forcing (Simon et al., 2015b). When considered in combination with archaeological records, these records appear to provide evidence for links between climate and human settlement in South Africa during the Middle Stone Age (Ziegler et al., 2013).

Our primary objective was to recover a key Pliocene–Pleistocene sedimentary succession, including the early Pliocene warm period, mid-Pliocene expansion of northern hemisphere ice sheets, and the mid-Pleistocene transition, formed under the influence of the upper reaches of the Agulhas Current. The site is ideally located to provide (i) a reconstruction of Agulhas Current warm-water transports close to the start of the fully constituted Agulhas Current, (ii) an upstream record that may allow discerning connections between Agulhas leakage and its headwater variability, (iii) evidence to understand the connections between southern African terrestrial climates and SE Indian Ocean heat budgets, notably Agulhas Current warm water transports and associated ocean-atmosphere heat and moisture transfer, (iv) a record of the vigor and hydrography of NADW (or its precursors) transported to the Circumpolar Deep Water and the southwest Indian Ocean, and (v) an interstitial water profile of $\delta^{18}O$ and chloride ion concentration that can enhance the understanding of temperature, salinity, and density of deep waters bathing Site U1474 by providing an additional data point to the presently available pore water LGM temperature and salinity inventory.

Operations

Site U1474 consisted of eight holes, ranging in penetration depth from 3.1 to 254.1 m DSF. Overall, 111 cores were recovered at this site. The advanced piston coring (APC) system penetrated 794.0 m and recovered 809.79 m of core (102% recovery). The half-length APC (HLAPC) system penetrated 102.4 m and recovered 100.96 m of core (99%

recovery). A total of 910.75 m of sediment was recovered from the 896.4 m interval cored (102% recovery) at Site U1474. The total time spent at Site U1474 was 7.6 d.

Principal Results

Sedimentology

The sediment at Site U1474 consists of two lithologic units:

Unit I is composed of brown foraminifer-bearing clay with nannofossils. This unit is found between 0 and 0.5 m CSF-A.

Unit II is characterized by greenish gray foraminifer bearing clay with nannofossils alternating with intervals of greenish gray nannofossil-rich clay with or without foraminifera. Unit II is found between 0.5 and 254.07 m CSF-A. Nannofossil-rich clay is more common downhole. Dark gray, foraminifer-bearing fine sand layers, ranging in thickness from a few centimeters to over 2 m, are common in Unit II (typically one to three per core). The composition of these sandy layers is predominately quartz with carbonate and many have erosional bases. Sediments in Unit II include dark gray mottling that we interpret as bioturbation. The relative intensity of the bioturbation typically increases with depth throughout Unit II. Sediments in Unit II also include millimeter- to centimeter-scale green layers that contain pyrite and glauconite based on XRD and smear slide observations. These layers represent diagenetic alterations.

Significant drilling disturbance is observed in the first section of most of the cores and in the base of partial-stroke APC cores.

Physical Properties

Despite the relatively homogenous lithology, different physical parameters show variations along the entire sequence. Porosity increases with depth from 0 to 12.8 m CCSF-A reaching a maximum of 72%, followed by a decrease to values under 50% at the bottom of the cored section. This decreasing trend towards the bottom is likely due to compaction. Variations in gamma ray attenuation (GRA) density reflect the same compaction pattern. Natural gamma radiation (NGR) and magnetic susceptibility (MS) show a marked decrease in the upper 10 m CCSF-A and increase to 130 m CCSF-A. Below 130 m, values of NGR and MS decrease to the base of the section. This decreasing trend occurs in spite of compaction and thus likely reflects a decreasing abundance of clay and magnetic minerals within the sediments. Superimposed on the general trends are

cyclic variations in the NGR values of typically ~10–15 counts/s, which may be related to the variable mixtures of terrigenous and biogenic sediment components. Fine sand layers found throughout the cored section are clearly identified by peaks in MS and GRA density values. Spectral reflectance shows a marked cyclic pattern downhole and broadly corresponds with the trends in RGB values.

Micropaleontology

Analysis of calcareous nannofossils, planktonic and benthic foraminifers, and diatoms from core catcher and split-core samples of Hole U1474A indicates that Site U1474 spans the Late Pleistocene to the latest Miocene (~6.2 Ma). Calcareous microfossils show good to moderate preservation in the upper 180 m CSF-A of the site. Below this depth, the preservation and fossil group abundance decrease. A complete sequence of calcareous nannofossil zones was found from the late Miocene (NN11 to NN21) to Late Pleistocene. Evidence for reworking of calcareous nannofossils is found throughout the entire sequence in the persistent presence of early Miocene species. The calcareous nannofossil assemblages are typical of tropical to subtropical settings, although the temperate species, *Coccolithus pelagicus,* is found throughout the cored interval. Planktonic foraminifers also record a complete sequence of tropical biozones that span Miocene biozone M13 to Late Pleistocene biozone Pt1b. The planktonic foraminifer fauna are dominated by *Globorotalia inflata,* indicative of transitional environments between subtropical and polar water masses and, in deeper parts of the sequence, the assemblage contains elements of the globoconellid group that are typical of subtropical convergence zones. The benthic foraminifer fauna is diverse and includes numerous suboxic components characteristic of a lower bathyal to abyssal environment. Siliceous microfossils are characteristic of a modern Indian Ocean assemblage and make up a minor component of the mudline sample. Below the mudline sample sponge spicules are rare to trace until they disappear completely below Sample U1474A-10H-CC (90.19 m CSF-A).

The age-model for Site U1474 is based on the biozonation of calcareous nannofossils, planktonic foraminifers, the extinction of the benthic foraminifer *Stilostomellia*, and magnetostratigraphy (see below). These data reveal that sedimentation rates are nearly constant throughout the recovered sequence, without major hiatuses. A long-term linear sedimentation rate of approximately 3.7 cm/k.y. is estimated.

Paleomagnetism

Paleomagnetic and rock magnetic analyses were carried out on sediment cores from Holes U1474A to U1474H. Analyses of discrete samples taken from Hole U1474A indicate that the magnetic mineralogy is dominated by magnetite. The relatively high saturation isothermal remanent magnetization (SIRM) and high and stable S-ratio further reveal that magnetic minerals are well-preserved throughout the sequence. Below ~100 m CSF-A, an increase of magnetic minerals is expressed by high SIRM. Inclination and declination records were obtained by measuring and demagnetizing the natural remanent magnetization (NRM) of archive core halves and discrete samples. The majority of the APC cores were oriented using the IceField tool. The inclination record is of good quality and nine polarity zones can be identified. The boundaries of the Brunhes, Matuyama, Jaramillo, Olduvai, Gauss, Gilbert, C3n, and C3r (sub) paleomagnetic chrons constrain the chronology of the sediments, and are in good agreement with the biostratigraphic data.

Stratigraphic Correlation

Continuous and distinctive variations in MS were used make hole-to-hole correlations among Holes U1474A to U1474F. Confidence in these correlations is high, because they can be cross-checked with the continuous downcore measurements of reflectance (L*) and NGR. A complete affine table to the base of Hole U1474A was constructed to provide tabulated offsets for all cores relative to core depths (CSF-A). A continuous splice was constructed down to 234 m CCSF-D using cores from Holes U1474D–U1474F where possible. For some intervals, it was necessary to use sections from Hole U1474A, but sequences in which whole-round samples had been removed were avoided. All sections of disturbed sediment were also avoided for construction of the splice. The continuity of the splice was confirmed with MS, GRA density, NGR, and reflectance. Core intervals not included in the splice may be correlated to CCSF-D using within-core variations of these data.

Geochemistry

Interstitial water chemistry shows a moderate degree of early sediment diagenesis at Site U1474. Profiles of Mn and Fe indicate suboxic conditions from the seafloor to 5 m CSF-A. Sulfate reduction occurs throughout much of the sediment column. The overall low organic carbon content, on average below 0.5%, does not support complete removal of sulfate by 250 m CSF-A, and methane concentrations remain at background levels.

Carbonate content of the pelagic sediments is moderate, averaging 40%. The sandy layers contain significantly less carbonate than the nannofossil-rich clays, with values ranging between 20%–30%. Profiles of conservative elements (K, Mg) downhole suggest either fluid flow or clay mineral alteration reactions at depths below 250 m CSF-A.

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