IODP Expedition 378: South Pacific Paleogene Climate

Site U1553 Summary

Background and Objectives

Site U1553, located at 1221.2 m water depth, provided the opportunity to continuously core multiple holes of a critical sequence of Paleogene sediments on the southern Campbell Plateau. The primary objectives of Site U1553 were (1) recover a continuous Paleogene through uppermost Cretaceous sequence using modern coring techniques to reconstruct the surface and deepwater temperatures, as well as vertical temperature gradients through the Paleogene and late Cretaceous, with particular emphasis on the major events that punctuate this long-term record (Eocene–Oligocene transition, Middle Eocene Climatic Optimum, Early Eocene Climatic Optimum [including Eocene hyperthermal events], Paleocene/Eocene Thermal Maximum [PETM], Cretaceous/Paleogene boundary); (2) develop a common chronostratigraphic framework for Paleogene Southern Ocean magnetostratigraphy, biostratigraphy, and cyclostratigraphy; (3) refine our understanding of the evolution of seawater chemistry; (4) evaluate Paleogene biological productivity and determine nutrient exchange and mixing of surface and subsurface waters; and (5) track the development and variability of South Pacific intermediate-water composition and its role in overturning circulation during the Paleogene and late Cretaceous, with emphasis on refining the timing and development of the Antarctic Circumpolar Current.

Operations

After a 2249 nmi transit from Lautoka, Fiji, the vessel stabilized over Site U1553 at 1210 h (all times are local; UTC + 13 h) on 15 January 2020. Five holes were cored at Site U1553. The operations plan was to triple core the upper portion of the sedimentary sequence using the advanced piston corer/extended core barrel (APC/XCB) system and then rotary core two deep holes to a maximum depth of 670 mbsf, followed by logging of the final hole. Hole U1553A was cored with a total of 27 cores taken over a 216.4 m interval with 98.9% recovery. Temperature measurements using the advanced piston corer temperature tool (APCT-3) were taken on Cores 4H, 7H, and 10H, and all full-length APC cores were oriented using the IceField orientation tool. Total time on Hole U1553A was 34.00 h (1.4 d).

After repairs to the top drive brake were concluded, operations resumed at 0915 h on 17 January. Hole U1553B recovered a total of 29 cores over a 243.0 m interval with 95.4% recovery. Total time on Hole U1553B was 42.50 h (1.8 d), with 10 h spent repairing the top drive. With weather systems moving in, the third APC/XCB hole was deferred in favor of an attempt to reach the deeper objectives with the rotary core barrel (RCB) system. Hole U1553C was spudded at

0010 h on 19 January and drilled ahead without core recovery to 234.0 mbsf. A total of 43 cores were taken over a 334.6 m interval with 47.4% recovery. Anomalously low C_1/C_2 ratios in Cores U1553C-43R and 44R forced termination of coring at 567.5 mbsf. Total time at Hole U1553C was 82.75 h (3.4 d).

Hole U1553D was drilled ahead to 178.3 mbsf. The center bit was pulled and the Sediment Temperature 2 (SET2) tool was lowered to obtain a fourth temperature measurement with the goal of refining the thermal gradient at Site U1553. After recovering the SET2 temperature probe, the center bit again was deployed and the hole was drilled to 399.4 mbsf. During coring operations, clearance was provided by the Environmental Protection and Safety Panel (EPSP) to advance Hole U1553D deeper than Hole U1553C on a core-by-core basis pending headspace gas analysis. Hole U1553D was terminated at 581.16 mbsf and the vessel was offset 20 m west for Hole U1553E. Hole U1553E was spudded at 0845 h on 25 January. A total of 27 cores were taken over a 237.6 m interval with 88.3% recovery. Total depth for Hole U1553E was 237.6 mbsf and total time on Hole U1553E was 33.25 h (1.4 d).

The total time spent at Site U1553 was 11.02 d, which includes 10 h lost to repair of the top drive. The vessel then began the 531 nmi transit to Timaru, New Zealand, to pick up fuel filters before continuing to Papeete, Tahiti, French Polynesia. The detour to Timaru added ~13 h to the originally planned transit to Papeete, Tahiti.

Principal Results

Lithostratigraphy

Coring at Site U1553 reached a maximum depth of 584.3 mbsf and recovered a 581.16 m long sedimentary succession of deep-sea pelagic sediment of Pleistocene and Oligocene to early-Paleocene age from the Campbell Plateau. The recovered sections comprise five lithostratigraphic units. About ~4 m of Plio-Pleistocene foraminifer-rich nannofossil ooze (Unit I) overlies an expanded sequence (~200 m thick) of late Oligocene through early Oligocene nannofossil ooze with foraminifers (Unit II). The nannofossil ooze of Unit II gradually transitions into nannofossil chalk of Unit III over 50 m from ~175 to 225 mbsf. Lithification of carbonates continues downhole until it results in limestone, categorized as Unit IV. Finally, the bottom ~100 m of the sediment column contains siliciclastic Unit V, characterized by alternating mudstone, sandy mudstone, and very fine to medium grained sandstone.

Biostratigraphy

A thin veneer of Pleistocene sediments overlies a sedimentary succession that spans the early late Oligocene to early Paleocene. The upper portion of this succession (Units I through III) is an expanded ~250 m thick Oligocene–late Eocene interval characterized by good preservation of all microfossil groups reported here, namely calcareous nannofossils, foraminifers, and radiolarians.

Diatoms and sponge spicules are also abundant and well-preserved throughout this interval. The Eocene and Paleocene intervals of Units IV and V are less expanded with more variable microfossil abundance and preservation, but biostratigraphic and lithological evidence indicates the presence of the Eocene–Oligocene transition (EOT) and Paleocene–Eocene (P/E) boundary. Low calcareous and siliceous microfossil abundance and poor preservation in the basal muddy sandstone unit (Unit V) hampers exact age determination of the basal part of the section.

All planktonic microfossil groups lack the low-latitude species that form the basis of standard zonation schemes. For this reason, correlation and age assignments are based primarily on Southern Ocean and Southwest Pacific zonations. An integrated biozonation was created for the five holes and shows overall good agreement between the observed bioevents in different microfossil groups.

Paleomagnetism

Much of the recovered section is characterized by a very low abundance of magnetic carriers. Consequently, only the upper 120 m of Hole U1553A is suitable for magnetostratigraphic reconstruction. This ~120 m preliminary magnetostratigraphy is composed of six pairs of normal and reversed polarity patterns (n1/r1 to n6/r6 down section). Two reversals identified in Hole U1553B (~290 and 443 mbsf) likely correlate to the base of Chron C18n.2n (40 Ma) and the base of Chron C24n.3n (54 Ma), respectively. The high abundance of carbonate in Units I through IV has likely diluted the abundance of magnetite, hence contributing to weak overall remanent magnetization.

Geochemistry

The geochemical composition of the sediment and water samples from Site U1553 reflects the lithostratigraphic composition and downhole diagenetic processes. Downhole changes in the abundance of carbonate and aluminosilicates mirror the lithologic transition between Units IV and V. The presence of occasional glauconite, manganese nodules, pyrite, and chert suggest possible subseafloor changes in the aluminosilicates, siliceous, and carbonaceous components of the sediment. Interstitial water profiles compiled from the five holes resolve the first-order diagenetic impact on the sedimentary record that may affect paleoceanographic proxies.

Headspace gas analyses for the uppermost 480 mbsf of Site U1553 indicate very low hydrocarbon concentrations, suggesting the lack of biogenic and/or thermogenic gas production, or their upward migration. A sudden increase in methane concentration occurs at the Unit IV/V transition. The methane increase is accompanied by the detection of thermogenic hydrocarbons (C_2, C_3, and C_4), suggesting in situ methane production, possibly by microbial activity, and thermogenic gas upward migration. Gradually decreasing C_1/C_2 ratios with depth led to the termination of drilling operations in Hole U1553C at 568 mbsf. Recalculation of C_1/C_2 ratios and an additional temperature measurement provided a better constraint for the deeper drilling in Hole U1553D.

Analyses of interstitial water taken from whole-round core samples and Rhizons indicate an increase in total alkalinity from 2.5 mM at the seafloor to 3.6 mM at 200 mbsf. Ammonium increases from ~20 mM at the seafloor to 650–700 mM at 420 mbsf, suggesting organic matter degradation. Carbonate dissolution could explain the increase in calcium and strontium with depth. Ba concentrations are very low, and trends in the downhole profile possibly suggest low amounts of sulfate reduction that dissolves barite. K and Mg concentrations decrease downhole, reflecting alteration and uptake into clays formed within the seafloor (e.g., glauconite) or due to uptake into recrystallizing carbonates or authigenic clays forming within the seafloor.

Solid phase analyses indicate that the sediments predominantly consist of carbonate that ranges from 78% to 99% (90% on average) in the uppermost 420 mbsf of Site U1553 (Units I through IV). Carbonate weight percent drops to <10% at the top of Unit V (~480 mbsf), and this decrease coincides with an increase in Al, Si, and trace elements associated with aluminosilicates. Overall, organic carbon (OC) content is low (<0.4%).

Physical Properties and Downhole Measurements

Variations in physical properties data correspond with transitions between major lithological units. A slight increase in bulk density and natural gamma ray (NGR) at 180 mbsf corresponds with the transition between Units II and III. A significant increase in *P*-wave velocity and bulk density at 423 mbsf marks the top of Unit IV. A large increase in NGR counts, decrease in *P*-wave velocity and bulk density, and change in color at 477 mbsf are reflective of the higher silica and clay content of Unit V.

Stratigraphic Correlation

Cores recovered using the APC and XCB coring systems in Holes U1553A, U1553B, and U1553E, while seemingly in good condition and with reasonable recovery rates, were difficult to correlate due to combined effects of the carbonate-rich lithology, age of the sediments, their postdepositional history, and occasional drilling disturbance, namely at the top of the cores. Preliminary core offsets to align Holes U1553A, U1553B, and U1553E were assigned, but no continuous splice was attempted during the expedition. Correlation of the two deeper Holes U1553C and U1553D drilled using the RCB coring system was not possible for much of the section at the usual meter and decimeter scale due to poor recovery and the recovery of nonoverlapping intervals. An exception was a series of cores surrounding the possible PETM interval and in the early Paleocene.