IODP Expedition 340: Lesser Antilles Volcanism and Landslides
Site U1400 Summary

Background and Objectives

Integrated Ocean Drilling Program Site U1400 (CARI-07C, 14°32.58'N, 61°27.55'W, 2745 m below seafloor) is located west of Martinique. Site U1400 was dedicated to the study of debris avalanche emplacement and associated erosional processes. The evolution of the active Montagne Pelée volcano on Martinique is characterized by three major flank collapse events (~0.1 Ma, ~25 ka, and ~9,000 years ago), which systematically destroyed the western flank of the volcano (Le Friant et al., 2003; Boudon et al., 2005, 2007). The volume of material displaced by these collapses varies from 2 to 25 km^3. The debris avalanches caused by these events were transported into the Grenada Basin. The Pitons du Carbet Volcano also experienced a sector-collapse at 0.3 Ma (Boudon et al., 1992; 2007; Samper et al., 2007). The bathymetric and seismic data obtained during several pre-site surveys, we expected coring to 510 mbsf would penetrate through volcanic and biogenic sediments with intercalated large chaotic debris avalanche deposits (deposit 1 and 2). A special focus of this site is to study the contacts between the different avalanche units not only to distinguish between the different deposits but also to better understand avalanche transport dynamics, especially in the basal part of the avalanche. This will provide fundamental constraints on friction parameters needed for realistic avalanche propagation models. The sediments above the avalanche deposit will be dated using O^{18} chronostratigraphy to better constrain the age of this event. The seismic profiles show that a ~70-m-thick well-bedded sedimentary layer overlies deposit 2 and that it increases in thickness towards the NE. We will test the hypothesis that, following a flank collapse, the on land drainage system was drastically modified resulting in increasing erosion and thus sedimentation rates in the Grenada Basin.

Scientific Results

Site U1400 (CARI-07C) consisted of three holes. The original plan called for two holes to be cored to a depth of ~510 mbsf. The first hole, Hole U1400A, was terminated at 51.3 mbsf because of unstable hole conditions. After offsetting the vessel 750 meters in a direction 160° from Hole U1400A, Hole U1400B was piston cored to 212.5 mbsf. After the core barrel became stuck, the drill string had to be tripped to surface and the core barrel freed from the upper landing sub. A shear pin had become wedged between the removable landing seat and the core barrel assembly. After offsetting 20 meters further in a 160° direction, Hole U1400C began with two failed attempts at spudding into the seafloor. The first failed attempt broke off the lower section of a non-magnetic core

barrel. The second attempt, this time with a steel core barrel, bent the steel barrel enough that it was unable to be pulled back through the bottom hole assembly (BHA). The drill string had to be pulled to the surface again. After the BHA was re-assembled for another attempt, we advanced 15 meters into the seafloor before we started APC coring. APC coring continued through Core U1400C-22H at 191.1 mbsf. APC coring was terminated when the formation became so stiff that the plastic core liner was deformed and had to be pumped out of the core barrel. We then switched to the XCB coring system and successfully cored to 436 mbsf. Three suites of wireline logs were planned for this hole, but hole problems did not allow this and ultimately the BHA became stuck and had to be severed. A total of 58 APC cores were taken at Site U1400 and recovered 447 meters of material (102%). The XCB coring system was deployed 27 times at Site U1400 and recovered 124 meters of material (51%). The overall recovery for Site U1400 was 84%. Total time spent on Site U1400 was 207.00 hours.

The sediments retrieved at Site U1400 were divided into seven lithostratigraphic units (Unit A to Unit G). Generally, this site is dominated by a combination of hemipelagic mud with interbedded tephra, volcaniclastic turbidites and deformed sediments. Units A to G consist of varying proportions of these different lithologies. Unit A (0 to 27 mbsf) consists of dark-grey, massive volcanic sand, followed by hemipelagic mud and alternating layers of hemipelagic mud, tephra and turbidite layers. Pumice is present in variable amounts (5 to >60%) throughout the entire unit. Unit B (27 to 51.3 mbsf in Hole U1400A; 3 to 26 mbsf in Hole U1400B; 15 to 22 mbsf in Hole U1400C) is composed of volcaniclastic sand. Pumice and scoria clasts are observed throughout the entire unit. Unit C (26 to 35 mbsf in Hole U1400B; 22 to 25 mbsf in Hole U1400C) is dominantly composed of grey-green hemipelagic mud with several tephra and two thin turbidite layers. Pumice is abundant in both the tephra layers and the turbidites; some of the layers contain up to 90% pumice. Unit D (35 to 85 mbsf in Hole U1400B; 25 to 59 mbsf in Hole U1400C) consists of grey and in some places of highly mottled grey-green-brown hemipelagic mud with interbedded tephra layers; a few turbidites are also present in Hole U1400C. With the exception of the uppermost 3 m of Unit D where layers are inclined ~60°-70°, most the sediments are weakly deformed (inclinations of ~20°) or contorted. Despite their relatively shallow present day burial depth, the sediments are occasionally highly indurated. Most of the tephra layers contain pumice in various proportions. Unit E (58 to 154 mbsf in Hole U1400B; 59 to 190 mbsf in Hole U1400C) is composed of primarily hemipelagic mud with numerous interbedded tephra and turbiditic layers, ranging in thickness from a few tens of centimeters to several meters. Most of the tephra layers as well as the turbidites contain a significant amount of pumice (varying between 5% and 60%). Generally, the degree of sediment deformation in this unit is much higher (bedding inclination averages 40°, but ranges up to 70°) than in the other units. Unit F (190 to 390 mbsf in Hole U1400C) is composed of a succession of deformed and lithified hemipelagic sediment with bedding and contact inclinations of up to 80°. The unit locally

contains many tephra layers. A few muddy-sand debrite intervals, frequently rich in pumice clasts, are observed at different depths within the unit. Unit G (390 to Hole U1400C total depth of 436 mbsf) consists mainly of hemipelagic mud and partly lithified mudstone lacking any signs of sediment deformation. The top of this unit marks the lower boundary of the deformed sediment.

Seventy-eight samples were taken to determine the mineralogical composition (XRD) and the carbonate content of the cored sediments. In general, the mineralogy is very similar to the mineralogy obtained from Sites U1398 and U1399. There are, however, subtle variations in the relative proportions of volcanic minerals present, with quartz and Fe-Ti-oxides being more abundant than seen in the deeper sites. Clay minerals (typically smectite, kaolinite and glauconite) were identified in virtually every sample, and are present in high abundance in some samples. As is typical for sediment cores taken near volcanic islands, carbonate concentrations are highly variable and are lower in intervals with higher proportions of volcanic material. Maximum carbonate concentrations are ~35% and reflect the large proportion of volcanic input and the absence of significant aragonite preservation. An unusual aspect of the organic carbon data is that there is a general increase in concentrations with depth. The concentrations in the upper 250 m are generally low (mostly less than 0.5 wt%) compared to previous sites, whereas approximately half the samples from below this depth contain higher organic carbon concentrations, with some samples reaching 0.8 wt%.

Core catcher samples collected at Site U1400 for shipboard biostratigraphic studies contain calcareous nannofossils and planktic and benthic foraminifera of varying abundances. Calcareous nannofossil and planktic foraminifera datums both resolve Late Pleistocene ages for the majority of samples. However, at the base of each hole, species indicative of older material are present. Major to minor reworking is evident throughout the entire material cored at this site. The observed calcareous nannofossil species characteristic for the Late Pleistocene are mainly: *Emiliania huxleyi, Gephyrocapsa parallela*, *Gephyrocapsa oceanica*, *Ceratolithus cristatus*, *Ceratolithus cristatus*, *Ceratolithus telesmus*, and *Ceratolithus simplex.* The assemblages observed at the base of the site characteristic for the Late Pliocene are: *Discoaster brouweri, Discoaster surculus, Calcidiscus macintyrei* and *Discoaster asymmetricus.* These samples correlate with zone CN12d *D. brouweri*, subzone *D. surculus*, suggesting an age of between 2.54-2.74 Ma. *Globigerinoides ruber* (white and pink), *Globigerinoides sacculifer,* and *Neogloboquadrina dutertrei* (dextral) dominate the assemblage of the planktic foraminifera. Other abundant species include *Pulleniatina obliquiloculata* and *Sphaeroidinellopsis dehiscens.* In all holes at this site, the population changes towards the base to reflect a likely Pliocene assemblage. This is most obvious in U1400C where in Sample U1400C-36X-CC, *Pulleniatina obliquiloculata* is reduced in number, and then absent in Sample U1400C-38X-CC, and *Globorotalia miocenica* and *Globorotalia exilis*

become more abundant. All these changes reflect a Late Pliocene, rather than an Early Pleistocene foraminiferal assemblage. All species present are indicative of warm sub-tropical waters. Several datum species were found in all three holes. The most frequently encountered datum species was *Globigerinella calida* (base of occurrence at 0.22 Ma). At the base of Hole U1400A (Sample U1400A-7H-CC), Hole U1400B (Sample U1400B-28H-CC), and Hole U1400C (Samples U1400C-33X-CC to -49X-CC), *Globigerinella miocenica* (top of occurrence 2.39 Ma) is quite abundant and most likely reflects the true age of sediments at the base of each hole. Other Late Pliocene markers present include *Globigerinoides extremus* (top of occurrence 1.99 Ma) and *Globigerinoides exilis* (top of occurrence 2.10 Ma), further corroborating the assigned PL5 zonation. The early Pliocene datum species *Globorotalia cibaoensis* (top of occurrence 4.60 Ma) was also found in low numbers throughout the Late Pliocene sediments in Hole U1400C.

Interpretation of the behavior of the geomagnetic field during the deposition of the cored sediments to derive a magnetostratigraphy is solely based on data from the sediment deeper than ~385 mbsf due to substantial deformation of sediment in the overlying chaotic unit. Based only on inclination data, negative values suggest reversed polarity and ages greater than 780 kyrs. This agrees with biostratigraphic ages for the site.

Generally, the physical property data obtained from the cored material show consistent changes depending on the lithology recovered. The magnetic susceptibility data show high values in the volcaniclastic material and relatively low values (mostly $<400 \times 10^{-5}$) in the hemipelagic sediments. Compressional wave velocity (P-wave) increases with depth. In the upper 80 m, P-wave velocities are consistent with expected velocities for hemipelagic sediment undergoing normal compaction. Below 80 mbsf, P-wave velocity increases at a lower rate. The highest P-wave velocities are measured in the volcaniclastic sediment (1700–1840 m/s) and the lowest in the hemipelagic sediments (1650-1750 m/s). The proportion of volcaniclastic sand is much lower at Site U1400 resulting in lower mean P-wave velocity. Discrete measurements of P-wave velocity also indicate a downhole velocity increase in the hemipelagic muds. The porosity observed in the hemipelagic samples ranges between 51.5% and 73.0%, and shows a weak decrease in porosity with depth. The porosity in the volcaniclastic sand ranges between 36% and 51%. As mentioned before, the porosity of the loose sands may be underestimated to up to 20% due to draining of pore water during coring, splitting and sampling. Observed bulk density in the hemipelagic sediment ranges between 1.50 and 1.82 g/cm^3 and displays a very weak positive correlation with depth. Sandy samples have bulk densities as high as 2.18 g/cm^3, quite distinct from the density of the hemipelagic samples. As in all previous sites, porosity and bulk density display a clear negative correlation. Grain density in the hemipelagic sediment varies between 2.64 and 2.77 g/cm^3. Grain density in the volcaniclastic material varies between 2.74 and 2.87 g/cm^3. Downhole formation temperature was measured using the APCT-3 at the bottom of Cores U1400C-5H, -8H,

and -12H (48, 76, and 103 mbsf, respectively) and yielded temperatures of 6.94°±0.03°C, 8.45°±0.03°C, and 9.68°±0.09°C, respectively. The temperature of ocean water at the seafloor is 4.26°C. A best-fit linear relationship between depth and the four temperature measurements gives a temperature gradient of 52.9°±1.6°C/km. Using the average thermal conductivity of 1.050±0.075 W/mK obtained from our cores the implied heat flow, if conductive, is 55.5±4.3 mW/m^2. This estimate should not need a correction for bathymetry. However, the correction for sedimentation rate may be appreciable owing to the high sedimentation rates. There is no evidence for fluid flow affecting temperature.

Samples for headspace analyses were taken from 49 cores throughout all three holes at this site. In contrast to the two previous sites in the basin, not a single sample had a methane concentration of greater than 4.1 ppm, and the vast majority had concentrations of less than 3 ppm. No higher hydrocarbons were detected in any of the samples.

The pore water profiles can be, with the exception of the deepest sample from 427 mbsf, readily interpreted in terms of a classic diagenetic profile driven by the oxidation of organic carbon. There is a little more scatter in the Mg data than has been observed at previous sites, but this may reflect the much higher abundance of clay in the sediment. This interpretation is consistent with the Cl data, which show a steady increase in concentration from the modern seawater value at the surface (560 mM) to 570 mM at 120 mbsf – this likely reflects progressive hydration of volcanic material as it is altered to clay minerals. It is interesting to note that the chemical composition of the deepest sample deviates from this interpretation; in particular, it has a much lower sulphate concentration than the rest of the samples. This sample comes from much older sediment (~2 million years old) that appears to be separated from the younger overlying sediments by a hiatus of at least a million years. The two deepest samples also contain the highest organic carbon concentrations. Thus, the pore water geochemistry of the deepest sample seems to reflect a diagenetic environment distinct from that observed in the overlying sediments. This either reflects changes in environmental conditions at this site over time, or transport of the upper sediments to this area from a site of lower organic carbon deposition.

References

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