IODP Expedition 340: Lesser Antilles Volcanism and Landslides

Site U1398 Summary

Background and Objectives

Integrated Ocean Drilling Program (IODP) Site U1398 (CARI-09B, 14°16.70'N, 61°53.34'W, 2935 mbsl) is located west of Martinique. The objective of this site is to characterize the sedimentation processes (related to volcanic activity or not) in the back-arc Grenada Basin. It is planned to drill through hemipelagic sediments and turbidites and retrieve a complete sedimentation record down to a depth of ~264 mbsf. The site survey seismic data show that we might penetrate through sedimentary reflectors indicative of the deposition of hemipelagic sediments and turbidites. With the recovered material we hope to be able to distinguish the turbidites related primarily to debris avalanche deposition. One focus is to evaluate whether submarine debris avalanches can generate voluminous turbidites long after their emplacement, and if so how far such turbidites can travel. We also expect to improve the reconstruction of the post collapse eruptive activity of Pitons du Carbet (Boudon et al., 2007). This will provide better constraints on the transition of activity between the Pitons du Carbet and the Montagne Pelée volcanoes. Finally, we also expect to sample turbidites with volcanic material coming from Dominica (e.g. Roseau tuff).

Scientific Results

Site U1398 (CARI-09B) consisted of two holes. The original plan called for 2 holes to be cored to a depth of ~264 mbsf. Hole U1398A was successfully cored and was terminated at a total depth of 268.6 mbsf. Hole U1398B was cored to a depth of 263.4 mbsf. Downhole logging was planned but hole problems encountered during the first logging attempt forced the cancelation of all logging. In total we retrieved 64 cores with 302 m of material (57% recovery). The total time spent on Site U1398 was 103.5 hours.

Generally, the upper parts of both holes at this site are dominated by volcaniclastic turbidites, whereas the lower portions are composed of various combinations of hemipelagic sediments with intercalated volcaniclastic turbidites and tephra. The retrieved sediments have been divided into seven lithostratigraphic units (Unit A to G). The upper 70 cm of Unit A (0 to 40 mbsf) are composed of hemipelagic mud, below this depth Unit A is composed of a series of thick (mainly massive) volcaniclastic turbidites, consisting of massive, normally graded sand sized minerals, lava particles and detrital carbonates interrupted by thin layers of hemipelagic mud. Abundant pumice clasts are common throughout the entire unit. The upper part of Unit B (40 to 57 mbsf) consists of hemipelagic sediments with interbedded thin tephra layers, whereas the lower part is

comprised of a succession of massive normally graded turbidite sequences, which can be up to 6 m thick. Turbidites occasionally display compositional laminations, grain-size layering, and parallel stratification at the upper part of each layer. Unit C (57 to 80 mbsf) consists of hemipelagic mud interbedded with multiple thin tephra layers and thin turbidites. The turbiditic sequences, exhibiting mainly normal grading, generally contain pumice clasts and hemipelagic clay. Unit D (80 to 100 mbsf) is composed of a succession of massive turbidites that are a few meters thick. The turbidites, often displaying normal grading, are separated by hemipelagic sediments interbedded with thin tephra layers. The upper of two distinctive pink-colored ash layers forms the lower boundary of Unit D. Unit E (100 to 115 mbsf) is characterized by multiple tephra layers. It also contains a few turbidites that are generally less than one meter thick, interbedded with hemipelagic sediments. Two pinkish, 1 cm thick, glassy ash layers are present in the upper half of Unit E. They occur at 99 to 100 mbsf in Hole U1398A, and at 103-104 mbsf in Hole U1398B. The top of Unit F (115 to 171 mbsf), only fully recovered in Hole U1398B, is composed of a 3 m-thick debrite followed by a succession of thick massive turbidites. Below the sequence of massive turbidites Unit F comprises a sequence of intercalated multiple thin tephra layers and small-scale turbidites. Unit G (171 to 265 mbsf) mostly comprises well lithified, heavily bioturbated, hemipelagic mud. The unit occasionally contains interbedded volcaniclastic sand layers. A whitish to pinkish colored, 1 cm thick, glassy ash layer occurs at 232 m in Hole U1398A and at 246 m in Hole U1398B.

XRD data obtained from discrete samples throughout the cores show that quartz and plagioclase minerals dominate the volcanic material, whereas the marine sediment is dominated by calcite and lesser amounts of aragonite. Amphibole is less frequently present than in the cores obtained from previous sites. Smectite, kaolinite and to a lesser extent glauconite are also ubiquitously present. Clay abundance increases roughly with depth. Pyrite has often been observed in the cored material that is rich in volcanic particles but could not be identified by XRD. Calcium carbonate concentrations are highly variably and are generally lower in intervals with higher proportions of volcanic material. Maximum concentrations are around 35%, reflecting the greater proportion of terrestrial clay minerals and the absence of significant aragonite preservation. Although the organic carbon concentrations are not high when compared to open ocean sites from similar water depths from elsewhere in the world, they are consistently higher than observed at any of the other sites sampled during this expedition. It is unlikely that these generally higher organic carbon levels are due to greater input from surface water, they more likely reflect transport from shallower shelf regions during sediment mass transport events.

Based on the detailed biostratigraphic studies done on Site U1398, using calcareous nannofossil as well as planktic foraminifera datums, the cored material could be assigned to the Late Pleistocene, indicating extremely high sedimentation rates. However, as

observed in the cored material of previous sites, reworking of much older (Early Pleistocene and Late Pliocene) material is evident in several of the studied samples. This is consistent with the shallow water benthic foraminifera, fragments of shells and corals, pteropods, heteropods shells, otoliths, and sponge spicules (Demospongiae) observed throughout the entire set of core catcher samples studied. The nannofossil record observed at this site (*Emiliania huxleyi*, *Gephyrocapsa oceanica*, *Gephyrocapsa caribbeanica*, *Gephyrocapsa parallela*, *Ceratolithus cristatus* and *Ceratolithus telesmus*) is characteristic of Late Pleistocene sediment. Thus, the entire sequence was placed in the zone CN15, *Emiliania huxleyi*, which has a maximum age of 0.25 Ma. The presence of Late Miocene to Early Pliocene species (*Sphenolithus neoabies*/*abies*, *Calcidiscus macintyrei*, *Discoaster asymmetricus*, *Reticulofenestra umbilicus*, and *Pseudoemiliania lacunosa*) throughout the sampled sediments indicates extensive reworking of the sediments retrieved at this site. Planktic foraminifera were present in all samples, although some were found at very low abundances, possibly due to the high volume of volcanic material. In samples with abundant specimens, the assemblage of planktic foraminifera was diverse, but dominated by *Globigerinoides ruber* (white and pink), *Globigerinoides sacculifer* and *Neogloboquadrina dutertrei* (dextral). Other abundant species include *Globorotalia truncatulinoides* and *Globorotalia tumida*. The fauna does not change significantly throughout the section recovered at Site U1398 and all species present are indicative of warm sub-tropical waters. The presence of *Globigerinella calida* (base of occurrence at 0.22 Ma) at the base of this site dates the sediments to younger than 0.22 Ma, within the Pleistocene. Datum species being characteristic for Early Pleistocene and Late Pliocene (*Globorotalia tosaensis* (top of occurrence 0.61 Ma), *Globorotalia exilis* (top of occurrence 2.10 Ma), *Globorotalia multicamerata* (top of occurrence 2.99 Ma)) times were also found in the planktic foraminifera assemblage and point again towards the reworked nature of the deposited sediment.

Generally, the magnetostratigraphic record obtained from the cored material is in accordance with the biostratigraphic observations, even though creating the stratigraphy was quite difficult due to the discontinuous appearance of measurable hemipelagic sediments throughout the holes of this site. Expected inclination for the site is 27° during normal polarity and -27° during reversed polarity assuming a Geocentric Axial Dipole (GAD). Between 0 and ~170 mbsf at this site all SRM and discrete inclination data show scattered but positive inclination, clustering around the expected GAD inclination. Declination shows little variation suggesting that all sediment shallower than ~170 mbsf was deposited under normal polarity conditions. Using the GPTS of Cande and Kent (1995) all of these sediments were deposited in the Brunhes Chron and are younger than 780 kyrs. Below this depth polarity interpretation is restricted to inclination and more specifically discrete samples of inclination at roughly 10 m intervals. Inclinations are generally shallower than would be expected based on the GAD at this location, however, without declination data to reinforce these shallow inclination data interpretation of

polarity is difficult. Some sections of the core show evidence for post depositional deformation, however this cannot account for all the observed negative inclination intervals. If these consistently negative values are showing true geomagnetic behavior it would suggest that the sediments below ~170 mbsf have been deposited during the Matuyama Chron – but this is not consistent with the biostratigraphic data.

Similar to the other sites sampled so far the physical properties of the material retrieved at Site U1398 can be correlated to the lithological variations observed in the recovered material. Magnetic susceptibility varies between $1000x10^5$ to $2500x10^5$ (max of $6700x10^5$) in sediments containing considerable amounts of volcanic clasts (mainly andesitic in composition) and is mostly below $700x10^5$ in the hemipelagic sediments. Usually, magnetic susceptibility also decreases with grain size in normally graded volcaniclastic layers. The natural gamma radiation varies inversely compared to the magnetic susceptibility. It shows high count-rates on hemipelagic sediments (up to 35 cps) and low count-rates (down to 8 cps) in volcaniclastic sediments. P-wave velocities vary between 1650-1850 m/s in volcaniclastic sediments and 1500-1600 m/s in hemipelagic sediments, respectively. Bulk density as well as P-wave velocities decreases with grain size in the normally graded turbiditic sequences. Un-drained shear strength measurements were not performed in the upper 40 and 60 mbsf of Holes U1398A and U1398B, respectively, due to the presence of sandy and gravelly sediments. Below these depths, although the shear strength measurements show considerable scatter, a general trend of increasing shear strength is observed. Porosity in the hemipelagic sediments ranges between 60 and 75% and, as at the other sites, no trend with depth could be observed. Porosity in the volcaniclastic deposits varies between 39 and 67%, however, the porosity of theses loose sandy layers may be underestimated to up to 20% due to draining of pore water during coring, splitting and MAD sampling. Bulk Density of the hemipelagic sediment ranges between 1.46 and 1.77 g/cm^3. Volcanic sands and the fine mass flow deposit have bulk densities as high as 2.2 g/cm^3. As in all previous sites, porosity and bulk density display a clear negative correlation. The grain density of the hemipelagic sediment and the volcaniclastic sand shows a range between 2.6 and 2.8 g/cm^3. Temperature was measured by APCT-3 at the bottom of Cores U1398A-6H and -8 H (45.6 m and 60.4 m, respectively) and the bottom of Cores U1398B-4H, -8H and -10H (26.5 m, 58.1 m and 73.8 m, respectively). Temperature was calculated from these time series of temperature measurements and a best-fit linear relationship between depth and our six temperature measurements gives a temperature gradient of 57.4±5.0°C/km. Using the thermal conductivity value of 1.035±0.085 W/mK measured on the retrieved cores, the implied heat flow, if conductive, is 59.4±7.0 mW/m^2. Small deviations of measurements from a straight line may be indicative of fluid flow.

Twenty-three headspace samples were analyzed for gas content. Methane concentrations are very low (few ppm) in the upper parts of the sediments retrieved from this site but

increase rapidly below 180 mbsf to a maximum value of 4700 ppm at 240 mbsf. Despite these elevated methane levels, the concentrations of the higher hydrocarbon remained close to detection limits, with between 0.4-1.4 ppm ethane and ethene measured in seven samples. Due to the coarse-grained nature of the sediments it was not possible to take any pore water samples in the upper 60 m at this site. Hence, the uppermost pore water data come from 62.5 mbsf. At this point pore water alkalinity values are close to 10 meq and remain at this level until a depth of 150 mbsf. The alkalinity then gradually decreases to 5 meq at 180 mbsf and remains at this value to the deepest sample at 254 mbsf. Ammonia concentrations increase steadily from 800 μM in the shallowest samples to 1500 μM in the deepest sample. Calcium concentrations decrease from 4.5 mM at 62.5 mbsf to 3.5 mM at 140 mbsf and then show a steep increase to 10.9 mM in the deepest sample. Magnesium concentrations also show a gradual decrease from 51 mM in the shallowest sample to 42.5 mM at the base of the hole. Chloride concentrations show a consistent increase from close to the seawater value in the shallowest sample to 674 mM at 254 mbsf. Even the shallowest sample has sulphate concentrations that are less than half the seawater level, and sulphate falls to zero at a depth of 85 mbsf. Overall, the data are consistent with diagenetic processes controlled by organic carbon oxidation and alteration of volcanic material. The increase in chloride with depth may reflect hydration of clay minerals.

References

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