IODP Expedition 324: Shatsky Rise Formation

Site U1348 Summary

23 October 2009

Background

Site U1348 (Prospectus Site SRSH-6) was the third site completed on Expedition 324. The site location, on the northern flank of TAMU Massif, was chosen with hopes of establishing an age transect across this largest volcanic edifice of Shatsky Rise and documenting geochemical variations within this feature. The tectonic setting of Site U1348 was recognized as very different from other TAMU Massif drill sites. Whereas Sites 1213 (Leg 198) and U1347 (this expedition) are located on the southern flank or summit of the massif, on what appears to be normal volcanic slope, Site U1348 is located on the north flank where magnetic lineations and bathymetry imply that spreading ridge-related rifting occurred (Sager et al., 1999; Nakanishi et al., 1999). Thus, it was thought that the igneous rock cored at Site U1348 could be significantly different compared to the rest of TAMU Massif.

Site U1348 is located near the peak of a basement high and there was concern that drilling on a basement high might recover volcaniclastics rather than lava flows. On the other hand, the basement high is large (>30 km across), so it was thought that this is too large to be a volcaniclastic cone. Because of the limited number of available seismic lines and the necessity to drill at locations with relatively thin sediment cover, however, there where not many other choices left. Unfortunately acoustic basement turned out to be the indeed the top of volcaniclastic material, which was eventually penetrated for >120 m without reaching any sign of igneous basement (lava flows).

Like other holes planned for Expedition 324, the main goal for the site was to core lava flows of suitable freshness to determine the age and geochemical composition. So the fact that Site U1348 produced mainly sedimentary and highly altered volcaniclastic rocks came as a surprise. However, the recovered clastic succession is regarded unique in the history of scientific ocean drilling and proved to be both fascinating as well as challenging to describe. Recovery was excellent and the rocks display an intriguing variation of depositional styles and environments including macrofossils beds in certain intervals. It appears that the cores may contain considerable information about eruption processes and sedimentation, paleodepth, biostratigraphy, and paleoenvironment, so those objectives may rise to greater importance at this site. Furthermore, an important objective will be to examine the metamorphosis of the cored material to help understand not only the initial composition, but also the processes that have changed the rock over time.

Operations

After the driller tagged seafloor at 3275.0 m DRF, Hole U1348A was spudded at washed ahead with a wash barrel in place to 84.2 m DSF where rotary coring was initiated. Coring proceeded from 84.2 m to 189.9 m DSF (105.7 m) with a poor average recovery of 3.5% due mostly to the prevalence of soft sediment and chert. Once past this depth and starting with Core U1348A-13R, the recovery improved markedly as the sediments transitioned to sandstone and then to volcaniclastics. The bottom 134.2 m of the hole was cored at an average rate of penetration of 8.9 m/hr with an average recovery of 57.5%. The average recovery for the cored interval of 239.9 m was 33.7%. The washed interval was 84.2 m. This hole was terminated at 324.1 m DSF.

The hole was prepared for logging operations with a wiper trip and displacement with 86 barrel of heavy mud. Following the release of the bit at the bottom of the hole, the drillstring was pulled back and the end of pipe placed at 97.6 m DSF. At 2030 hr on 5 October, the Schlumberger equipment was rigged up and the first tool string (triple combo) successfully deployed to ~322 m DSF, only 2 m above the bottom of the hole. Once the triple combo was recovered, the second logging suite (FMS-sonic) was made up and deployed at 0700 hr on 6 October. This tool string was also able to reach within two meters of the bottom of the hole. As the tool was being drawn back into the drillstring, it became firmly stuck in the bottom hole assembly with the electrical pad arms at the level of the top connector of the mechanical bit release. For 1.5 hours, the logging winch operator attempted to advance the tool with no success.

The only option remaining was to use the Kinley crimper and cutter system to recover the recalcitrant instrument. The Kinley crimper was deployed and severed the logging line just above the cable head of the tool suite. The severed end of the logging line was recovered and the drill string retrieved. When the bottom hole assembly was at the surface, the FMS-sonic tool was still firmly pinned by the springs of the broken FMS pad arms inside the top connector of the mechanical bit release. The vessel departed for the next site at 0845 hr on 7 October.

Scientific Results

A thick sequence (~120 m stratigraphically) of volcaniclastic sediments, topped with shallow water carbonaceous sandstones, greenish clays, nannofossil ooze and chert, was recovered from Hole U1348A.

The uppermost cores (Unit I) contained red chert interbedded with a remarkably well-preserved, section of Cenozoic/Late Cretaceous nannofossil ooze over a meter long (Core U1348A-2R). Yellow brecciated cherts were also recovered stratigraphically below the red cherts and above highly silicified, altered sandstones. Below this, a sequence of shallow-water bioclastic sandstones (Unit II) with volcanic clasts was found (Cores U1348A-10R to -13R). This sequence includes an interval of bright green zeolitic clays. Although basaltic basement was not reached at this site, Cores U1348A-14R to -26R recovered a unique sequence of highly altered marine volcaniclastic rocks (Units III-VI). Based on the marine fossil content and bedding structures, these have been interpreted to represent a mixture of in situ and redeposited material that was erupted in a submarine environment.

Paleontological investigations revealed that the sediments from the upper cores of Unit I (Cores U1348A-1W to -10R) are pelagic in origin and, although dominated by chert-rich lithologies, are generally suited for calcareous microfossil studies. A few centimeters of gray ooze in the wash barrel's core catcher (Core U1348-1W) and in the uppermost centimeters of the undisrupted pelagic nannofossil ooze are rich in the Cenozoic (Miocene) calcareous and siliceous microfossils (Core U1348A-2R). The lower part of this ooze section, however, contains microfossils of Cretaceous age. The identified calcareous nannofossils are of the mid- to Late Cretaceous assemblages and are subjected to progressive reduction in abundance, diversity and preservation state with increasing burial depth. This Cretaceous part of the ooze interval (Core U1348A-2R) and a second ooze interval in Core U1348A-10R also contain, well-preserved, abundant foraminifera. A series of primary/secondary zonal marker species that correlate well to the standard biochronology are recorded by planktonic foraminifera from the early Aptian to early Campanian (120–80 Ma), and they are used for construction of the age model for this site. Therefore, the underlying units including the volcaniclastic section further downhole are considered to be >120 Ma old. Benthic foraminifera, not suitable for age dating, show remarkable changes in abundance and diversity throughout the hole, and the subsidence history of Ori Massif from the upper to lower bathyal depth can be discerned.

The ~120 m thick volcaniclasitic succession of Units III to VI (Core U1348A-14R and below) consists predominantly of hyaloclastic material. The lithology range from matrix-supported clay- or sand-sized hyaloclastites to dominantly heavily-compacted granule- or pebble-sized clast-supported hyaloclastites in the bottom of the hole. Petrography reveals that the volcanic glass shards and the larger vitric clasts to be thoroughly altered, with minor admixtures of bioclastic materials, fossil debris, and well-preserved calcitic fossils at some horizons. By contrast with other Expedition 324 drill sites, no massive or pillow lava flow successions were encountered.

The hyaloclastite succession proved difficult to interpret because of pervasive, and often complete, alteration of the volcanogenic constituents, which masks both original composition and structure. A minority of sparsely vesicular hyalobasalt fragments occur especially in the upper horizons (Units III-IV), yet high proportions of altered volcanic glass shards and clasts occur throughout, increasing to form almost completely the hyaloclastitic rocks in the clast-supported packages of Unit VI. Under the microscope these fragments originally appear to consist of only sparsely-vesicular vitric clasts, broken down into a high abundance of glass shards, which were subsequently exposed to intense alteration processes and compaction. The predominance of altered glass shards throughout Units III-VI is indicative of substantial submarine volcanism. Sedimentary reworking of these primary hyaloclastite constituents is evident in some units.

With only one unique exception, the original hyaloclastite composition has been entirely transformed to secondary palagonite, zeolite and calcite. This replacement commences with the alteration of the volcanic glass shards to palagonite, which is mainly composed of montmorillonite and nontronite. This process starts along the rims, and continues with the development of alteration spherules within the glass shards (spherulitization). Further progression of this process results in complete replacement of the edges of these shards, followed by replacement of the glass cores by a combination of zeolite and calcite. Some rare lithic fragments show similar texture and alteration degree to basaltic rocks recovered at the top of Hole U1347A. However, even these clasts are almost a complete replacement of primary phases and transformed to brown clays. Clay minerals, together with calcite and zeolites, are the predominant secondary minerals at Hole U1348A. Both vitric and lithic clasts are cemented by calcite and/or zeolites, with variations in their occurrences and proportions downhole. Fibrous and tabular zeolites (i.e., phillipsite) commonly form a corona alteration around the palagonite particle rims and cement, with or without calcite, the volcanic clasts.

In one rare occasion, cuspate sparsely vesicular fragments of volcanic glass, consisting of numerous unaltered, contiguous glass shards, were recognized in one continuous ~26 cm interval (U1348A-23R-1, 110-126 cm and -23R-2, 1-8 cm). In the rest of the core these hyaloclastite fragments are identifiable only from their pseudomorphed glass shard outlines. However, toward the bottom of the hole (in Unit VI) even these pseudomorphed forms have been mostly obliterated through alteration and by a large amount of compaction of this hyaloclastite material by overburdening of this succession. The rare preservation of the few glass fragments in Sections U1348A-23R-1 and -23R-2 seems to result from an early ‘armoring’ of these vitric clasts by impermeable calcite. In these examples, the glass clasts contain no phenocrysts, and preserve only a sparsely microcrystic primary mineralogy of fresh olivine and intergrown plagioclase and pyroxene. These clasts are only sparsely vesicular and typically show the incipient and/or partial transformation to palagonite seen so pervasively throughout this succession.

Two kinds of structures, primary structure and post-depositional structure, are observed in the volcaniclastic Units III to VI. Bedding as primary structure is often displayed by layered fine and granular hyaloclastite sequences that are interbedded in coarser hyaloclastitic breccia. Sedimentary stratification, including graded bedding and cross bedding, is observed particularly in the fine-grained hyaloclastics. Most strata, however, are parallel and show only shallow dips (<30°). Post-depositional structures cut through the bedding, including microfaults and veins. Veins are typically 0.1 to 1.5 cm thick. Both microfaults and veins show steep dip angles over 50°.

Two samples from clay-rich layers in sedimentary Unit II have relatively high concentrations of SiO_2, K_2O, and Zr, and very low concentrations of CaO, P_2O_5, and TiO_2, as determined by inductively coupled plasma – atomic emission spectroscopy. The clay-rich layers may contain a large proportion of material derived through wind or water transport from continental crust and/or one or more magmatic arcs. However, some of the SiO_2 in these two layers may have come from circulating solutions that originated in overlying or underlying beds.

Clasts and bulk samples of volcaniclastic material from Units III, V, and VI show the chemical effects of complete alteration, greater even than that at Site U1346, on average. However, the Zr-Ti relationship among the samples is similar to that seen for the tholeiitic basalts of Site U1347, and suggests that the Site U1348 volcaniclastic rocks were derived from magmas broadly similar in composition to those that fed the Site U1347 lavas.

Physical properties (magnetic susceptibility and bulk density) of clastic Units III to VI correlated well with varying concentrations of volcaniclastic material (vs. more calcite-rich intervals). Average magnetic susceptibility generally decreased downhole from around 40-45 x 10^{-5} SI near the top of Core U1348A-15R to below 20 x 10^{-5} SI near the bottom of the hole (Core U1348A-26R). A few excursions of up to 100 x 10^{-5} SI occurred in intervals U1348A-17R-1 (0-10 cm, 58-60 cm), -19R-1 (106-108 cm), -20R-1 (18-118 cm), -20R-4 (73-92 cm). GRA bulk density and bulk density of discrete samples ranged between 1.8 and 2.4 g/cm^3. Natural gamma radiation averaged between 10 and 30 counts per second, with highest spectral peaks corresponding to ^{40}K. Porosity of discrete samples was high and ranged from 27%–55%. P-wave velocity of discrete samples, ranging from 2.0–3.3 km/s, varied inversely with porosity and directly with bulk density.

Because no basaltic basement was recovered and hyaloclastites typically have week magnetism, paleomagnetic measurements were only made on 8 discrete samples from the recovered volcaniclastic sediment. These samples likely carry a depositional remanent magnetization (DRM) instead of a thermoremanent magnetization (TRM). Therefore, any directional result will be more complicated to interpret. The 2G cryomagnetometer was used for these measurements because the NRM of these samples was too weak to be measured on the Molspin Minispin magnetometer (a few tens of mA/m). Only AF demagnetizations were carried out, using the DTech Degausser. The low magnetic susceptibilities (between 4×10^{-4} SI and 8×10^{-4} SI) indicate that magnetic minerals are not abundant in these samples. Compared to the basalt samples from Holes U1346A and U1347A, the samples have a higher median destructive field (between 10 and 25 mT), which suggests that the magnetization carriers are single-domain grains. In five cases, once the low-coercivity overprint is removed, it is possible to isolate a stable component pointing towards the origin. Inclinations are mostly shallow and positive, between 4° and 23°; although, one sample gives a negative inclination (-9°).

Downhole logging data obtained from Hole U1348A included natural and spectral gamma ray, density, photoelectric factor, and electrical resistivity measurements from three depths of investigation. Interpretations of gamma ray and electrical resistivity downhole logs were used to identify a total of 15 logging units in Hole U1348A with one in the section covered by the BHA, five in the sedimentary sequences in the open hole interval, and nine in the volcaniclastic section. Electrical resistivity measurements show distinctive higher resistivity zones that likely represent less altered intervals, interspersed with low resistivity zones that mark sediment interbeds and more altered sequences. Natural gamma-ray measurements show several intervals of higher readings that indicate interbedded sediments and higher alteration. These intervals also display higher potassium, uranium, and thorium values. Formation MicroScanner (FMS) images show zones with distinct horizontal layering, dipping beds, and vesicular or brecciated intervals. Preliminary structural analyses of dipping beds show features striking northeast–southwest and dipping mostly 20°–30° to the southeast.

References

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