Data report: Si, Al, Fe, Ca, and K systematics of volcaniclastic sediments from selected cores of Hole U1347A, IODP Expedition 324

Sandra Herrmann and Nicole A. Stroncik

Abstract

We analyzed the whole-rock Si, Al, Fe, Ca, K, Cl, and Mn content of volcaniclastic sediment cores recovered during Integrated Ocean Drilling Program Expedition 324 in Hole U1347A. Hole U1347A, located at the eastern flank of Tamu Massif, the oldest of the three volcanic edifices forming Shatsky Rise, a large igneous plateau in the western Pacific, was drilled into early Cretaceous sediments and volcanic basement. The analyzed cores represent the mainly volcaniclastic sediments lying on top of the basaltic basement, which starts at roughly 156.7 meters below seafloor. Whole-rock Si, Al, Fe, Ca, K, Cl, and Mn were obtained from a stratigraphic depth interval covering about 60 m using an Avaatech X-ray fluorescence core scanner. Data interpretation has been based on the normalization of individual element count rates to Ca. In the uppermost 110 m depth interval, increases in the Al/Ca, Fe/Ca, Mn/Ca, K/Ca, and Cl/Ca ratios can be observed. Below this depth, no clear element depth correlation is evident and the average element ratios stay relatively constant throughout the remaining depth interval. However, rhythmic patterns can be observed throughout the entire investigated core material, characterized by positive co-variations of Si/Ca, Al/Ca, Fe/Ca, Mn/Ca, K/Ca, and Cl/Ca with variable amplitudes and peak widths. The geochemical downhole trends of increasing Si/Ca, Al/Ca, Fe/Ca, Mn/Ca, K/Ca, and Cl/Ca clearly reflect the changes in the principal lithology from marine limestone with intercalated chert to volcaniclastic sediment. The observed rhythmic patterns of Si/Ca, Al/Ca, Fe/Ca, Mn/Ca, K/Ca, and Cl/Ca correlate with existing variations in the ratio of volcaniclastic material to carbonaceous material.

Introduction

This report provides the results of a geochemical study of seven cores consisting of biogenic and clastic sediments recovered during Integrated Ocean Drilling Program (IODP) Expedition 324 from Hole U1347A situated close to the summit of Tamu Massif (Fig. F1). Tamu Massif is the main edifice forming Shatsky Rise, and thus sampling this volcano was one of the main objectives of this JOIDES Resolution expedition (Sager et al., 2009). The main coring targets of Site U1347 were to recover as much as possible of the oldest sediments overlying the igneous basement and the...
Early Cretaceous igneous basement (Sano et al., 2012). The aim of coring the igneous rocks was to determine the basement age and its geochemical and isotopic characteristics to constrain the age progression and duration of volcanism at Shatsky Rise and its magma sources, temperature and depth of melting and crystallization, and degree of partial melting. Studies of the sediment overlaying the igneous basement were intended to constrain the sedimentation rates and processes atop the volcanic rise to better understand the eruption and subsidence history of the rise.

In this context we wanted to test if the geochemical characterization of cored volcaniclastic material by means of high-resolution X-ray fluorescence core scans is a useful tool to investigate the depositional history and the formation of volcaniclastic deposits.

Materials and methods

A total of 17.2 m sediment over a stratigraphic interval of ~60 m (Cores 324-U1347A-3R through 10R) was retrieved from Hole U1347A before entering basaltic basement at 157.6 meters below seafloor (mbsf). The recovered material is dominated by volcaniclastic silt and sandstone with varying proportions of biogenic material (radiolarians and foraminifers) and mainly micritic carbonate (see the “Site U1347” chapter [Expedition 324 Scientists, 2010]).

The material described above has been analyzed between 80.59 mbsf and 149.13 mbsf (68.54 m) for the Si, Al, Fe, Ca, K, Cl, and Mn contents using a third-generation Avaatech X-ray fluorescence (XRF) scanner with a Canberra X-PIPS silicon drift detector (SDD), model SXD 15C-150-500, 150 eV resolution X-ray detector located at the IODP Gulf Coast Repository in College Station, Texas (USA) (o dases.tamu.edu/index.php/research-facilities/).

The X-ray tube and detector are mounted on a moving track so that multiple spots at different depths can be analyzed on a split core during the scanning run. Multiple scans with different settings can be automatically programmed (Richter et al., 2006). Precision of the measurement positioning is 0.1 mm. For Hole U1347A core scans, the sample spacing along each core section was set at 1 cm intervals. The scans were performed at 10 kV using an Al filter. The voltage used for elements measured is determined by the energy needed to excite the appropriate characteristic X-rays. While measuring, the detector registers the emission line energies of the irradiated sample material and their frequency over the predefined measure time (30 s) as element intensities in counts, which are proportional to the element concentrations.

The processing software used, WinAxil of Canberra, applies background subtraction, sum-peak correction, escapes peak correction, and peak integration of the XRF spectrum. It uses an interactive least-squares fitting procedure of a Gaussian function to approximate the fluorescence lines. The goodness-of-fit of a process model increases if the model identifies all peaks present in the XRF spectrum, as the program does not look at individual peaks but at groups of peaks.
Results and discussion

As XRF count rates for different elements are influenced by different factors, such as sample matrix, surface topography, or porosity, not accounted for in the postprocessing of the data derived from the XRF scanner, direct count rates of individual elements can only be compared with caution. This is especially the case when comparing the count rates of elements that are far apart in the periodic system of elements (e.g., light versus heavy elements). Based on these predefined conditions, the data interpretation in this contribution is entirely based on element ratios. As the cored sediments consist of limestone and volcaniclastic material, which basically represents a three-component mixture of (1) fresh volcanic glass, (2) altered volcanic glass to mainly smectite, and (3) biogenic and micritic carbonate, Si, Al, Fe, Mn, K, and Cl count rates have been normalized to Ca count rates. Because the volcaniclastic material furthermore represents a mixture of fresh and altered glass, Al, Fe, Mn, Ca, K, and Cl count rates have been normalized to the Si count rates. For better visualization of the geochemical patterns, the element ratios displayed in Figure F3 were smoothed by a two-point moving average. Averages of the different ratios for each individual core were calculated (Fig. F4), with the error bars representing the calculated variability (variance) characterizing each core.

Generally, two different systematic patterns in Si/Ca, Al/Ca, Fe/Ca, Mn/Ca, K/Ca, and Cl/Ca were observed in the investigated core material. One trend is a rhythmic pattern of increasing and decreasing element ratios with peak widths being variable throughout the entire core material (Fig. F3). The other one is a consistent downhole pattern of constantly decreasing/increasing element ratios superimposed on these rhythmic patterns (Figs. F3, F4). The latter is most prominent in the uppermost 110 m depth interval and is characterized by a steep increase in the Al/Ca, Fe/Ca, Mn/Ca, K/Ca, and Cl/Ca ratios (Figs. F3, F4). Below this depth, no clear element depth correlation can be observed and the average element ratios stay more or less constant throughout the remaining depth interval. The rhythmic patterns observed throughout the entire investigated core material are characterized by positive co-variations of Si/Ca, Al/Ca, Fe/Ca, Mn/Ca, K/Ca, and Cl/Ca with variable amplitudes and peak widths. Occasionally, the Cl/Ca ratio is anticorrelated to the Al/Ca, Fe/Ca, Mn/Ca, and K/Ca ratios.

The sediment investigated in this study is characterized by two main lithostratigraphic sequences, a sequence of marine limestone with intercalated chert and a roughly 110 m thick volcaniclastic sediment sequence with the limestone being deposited on top of the volcaniclastic material. The geochemical downhole trends of increasing Si/Ca, Al/Ca, Fe/Ca, Mn/Ca, K/Ca, and Cl/Ca clearly reflect this change in the principal lithology (Figs. F3, F4).

The cored volcaniclastic material is characterized, as already described above, by alternating layers of variable grain size, which are consistent with varying mixtures of predominantly altered glass, fresh glass, and biogenic as well as micritic carbonate and occasional intercalated thin layers containing higher abundances of radiolarians (Fig. F3). Geochemically, the mixture of carbonaceous material with the largely altered volcaniclastic material can be visualized as a dilution of the geochemical signal coming solely from the volcanic material. Because one key effect of submarine glass alteration to smectite is the nearly total loss of Ca (e.g., Stroncik and Schmincke, 2002), the observed Si/Ca, Al/Ca, Fe/Ca, Mn/Ca, K/Ca, and Cl/Ca records show the existing variations in the ratio of volcaniclastic material to carbonaceous material. The observed rhythmic patterns of Si/Ca, Al/Ca, Fe/Ca, Mn/Ca, K/Ca, and Cl/Ca correlate with the alternating layers of variable grain sizes observed in the core. An example is the medium grained, homogeneous-looking sediment characterizing the mixture of higher amounts of carbonate with volcanic material that corresponds to lows in the specific element ratios. On the other hand, the fine-grained material, being dominated by altered volcanic glass, corresponds to highs in the specific element ratios (Fig. F3). The higher amount of carbonaceous material, as well as the larger grain size in the medium-sized volcaniclastics, is most likely an indication for a shallower water hyaloclastite emplacement compared to the fine-grained material containing only minor amounts of carbonate.

In Figure F5, Al/Si, Fe/Si, Mn/Si, K/Si, and Cl/Si ratios are plotted versus Si. Even though the data show relatively large scatter, it is evident that Fe/Si, K/Si, and Cl/Si show negative trends with increasing Si content and that Al/Si shows positive trends with Si content in individual cores. This indicates that the geochemical signal introduced by the glass alteration process is superimposed on the “carbonate-volcaniclastic mixing signal” because alteration of basaltic glass to smectite results in a relative enrichment of Fe, K, and Cl and a relative depletion of Si and Al (e.g., Stroncik and Schmincke, 2002).

Conclusions

In this study we have shown that the geochemical characterization of cored volcaniclastic material by
means of high-resolution X-ray fluorescence core scans has the potential to be a useful tool in investigation of the depositional history and the formation of volcaniclastic deposits. In a future study we want to fine-tune this method by conducting additional, detailed thin section studies of the volcaniclastic material cored during IODP Expedition 324 and by obtaining quantitative XRF data from discrete samples of the cored material.

Acknowledgments

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References


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Figure F1. Location of Shatsky Rise plateau in relation to Japan (upper right corner). Shaded area illustrates the region of the bathymetric map of the southwest area of the Tamu Massif with the location of Site U1347.
Figure F2. Examples of lithologic intervals based on the thin sections. Scale bar = 2 cm.

324-U1347A-6R-1, 38-42 cm

324-U1347A-6R-2, 10-11 cm

324-U1347A-6R-2, 59-62 cm

324-U1347A-6R-2, 81-84 cm
Figure F3. Recovery from Cores 324-U1347A-3R through 10R and Al/Ca (blue), Fe/Ca (red), Mn/Ca (brown), Si/Ca (dark green), K/Ca (light green), and Cl/Ca (gray) versus depth. (Continued on next six pages.)
Figure F3 (continued). (Continued on next page.)

![Core recovery and depth image](image)

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- 8R-3
- 8R-4
- 8R-5
- 9R-1
- 10R-1

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Figure F3 (continued). (Continued on next page.)
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Figure F3 (continued). (Continued on next page.)
Figure F3 (continued). (Continued on next page.)
Figure F3 (continued).
Figure F4. Average of Al/Si (blue), Fe/Si (red), Mn/Si (brown), Ca/Si (dark green), K/Si (light green), and Cl/Si (gray) per section with their variance as error bars. The error bars are visible if the error is larger than the symbol for the data point.
Figure F5. Element pair ratios (Al/Si, Cl/Si, Fe/Si, K/Si, Mn/Si) for all cores vs. Si. Areas of dense point accumulations are (A) shaded and (B) shown at higher resolution for the same element pair ratios. (Continued on next two pages.)
Figure F5 (continued). (Continued on next page.)
Figure F5 (continued).
Appendix

Single-element counts for Si, Al, Fe, Mn, Ca, K, and Cl and element pair ratios of those elements with Si and Ca for the analyzed Sections 324-U1347A-3R-1 through 10R-CC are listed in Table AT1.
The table below shows the single element counts and element ratios for Si, Al, Fe, Ca, and K systematics. The data is reported as depth in meters below sea floor (mbsf) and includes element pair ratios for Al/Si, Fe/Si, Mn/Si, Ca/Si, K/Si, Cl/Si, Al/Ca, Fe/Ca, Mn/Ca, Si/Ca, K/Ca, and Cl/Ca.

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The complete table is available in ASCII at: [Table AT1](#).