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# 14. *DATA REPORT:* TEMPORAL VARIATIONS OF BIOGENIC COMPONENTS ON THE NORTHERN CALIFORNIA MARGIN SINCE THE LATE PLEISTOCENE, SITE 1020[1]

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**ABSTRACT**

The California Current and associated coastal upwelling have changed with the growth and decay of the North American ice sheets since 2.5 Ma. Because the coastal upwelling has a close relationship with biogenic productivity in surface water, analyses of biogenic components in sediments of the upwelling region enable us to reconstruct the past changes of the productivity and/or the current systems.

In this study, we analyzed biogenic silica and carbonate as well as organic carbon in sediments from the northern California margin, Hole 1020B. The results show that terrigenous-free content of biogenic silica is high during interglacial periods since 800 ka and varies in correspondence with 100-k.y. glacial–interglacial cycles. On the other hand, terrigenous-free content of biogenic carbonate is high during glacial periods. These temporal variations may have been caused by changes in the origin of deep water.

## INTRODUCTION

Seasonal and latitudinal shifts of the regime of the meteorological North Pacific high result in strong seasonal changes in the California Current system, in which upwelling caused by westward Ekman transport is intensified during the summer at high latitudes and weakened during the winter at low latitudes. Variation in surface biological productivity connected with the upwelling should be recorded in sediment cores in these regions. In fact, the content of biogenic components changed significantly during the last glacial cycle (Karlin et al., 1992; Gardner et al., 1997). We wanted to understand how and why the current systems changed during glacial–interglacial cycles in the late Pleistocene and what processes determine major components in the sediments. For this, we analyzed biogenic components in sediments of Hole 1020B recovered during Leg 167 spanning the last 800 k.y., and we report variations of biogenic components. The site is located on the east side of the Gorda Ridge, 170 km west of Eureka, and has a water depth of 3040 m (Fig. 1).

## MATERIALS AND METHODS

In this study, we analyzed 96 samples from Cores 167-1020B-1H through 8H that were taken on the drill ship at intervals of ~70 cm. The sediments consist of alternating pelagic and nannofossil clay. Wet samples of 10 $cm^3$ were vacuum packed after sampling and stored in a refrigerator at 4°C. After freeze drying for 24 hr, samples were ground to powder in an aluminum mortar.

Biogenic opal contents of bulk samples were measured according to a method modified from the one described in Mortlock and Froelich (1989; Fig. 2A). Both total carbon (TC) and total organic carbon (TOC) contents were measured by using a LECO WR-112 carbon analyzer. Total inorganic carbon (TIC) content was calculated by subtracting TOC from TC content. TIC content represents biogenic carbonate carbon content because TIC content distinctly correlates with the peak intensities of calcite as determined by powder X-ray diffractometry (Fig. 2B). No dolomite was detected in any X-ray diffractograms, and terrigenous calcite was rare in the sediments, according to smear-slide observation. Biogenic calcium carbonate contents were therefore calculated by using the formula

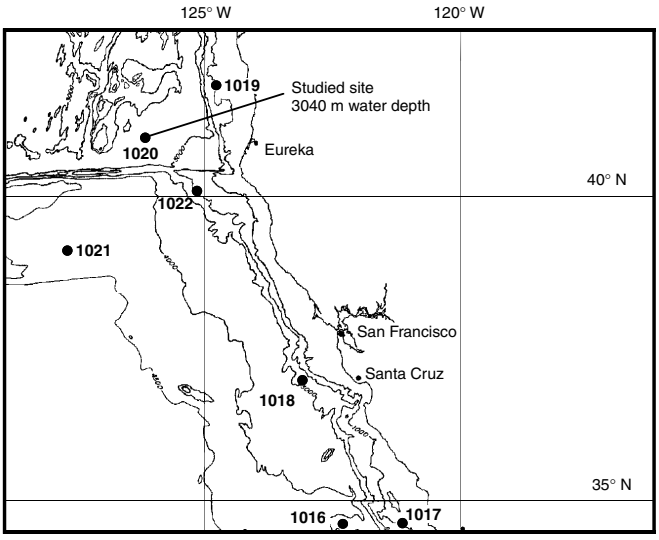


Figure 1. Location map of Leg 167 sites.

$$\text{biogenic } CaCO_3 \text{ (wt\%)} = \text{TIC (wt\%)} \times 8.34.$$

Bulk mineralogies were also analyzed by powder X-ray diffractometry using a MacScience MXP3HF X-ray diffractometer to estimate the ratios between terrigenous and biogenic components. Major minerals in the samples are quartz, feldspar, calcite, and clay minerals. Quartz correlates negatively with calcite and positively with feldspar and clay minerals. Accordingly, the peak intensities of quartz were used as indices of terrigenous input. Total terrigenous material content were further calculated using the formula

$$\text{total terrigenous materials content (wt\%)} = 100 - [\text{biogenic silica (wt\%)} + \text{biogenic carbonate (wt\%)} + \text{TOC (wt\%)}].$$

An age model for Hole 1020B was constructed by using the oxygen isotope stratigraphy of Mix et al. (1995) during the past 340 k.y., the last appearance datum of *Pseudoemiliania lacunosa,* and the Brunhes/Matuyama magnetic boundary described by the Leg 167 shipboard scientific party (Lyle, Koizumi, Richter, et al., 1997) from 340 to 800 k.y. The age at the bottom of Core 167-1020B-8H is calculated to be ~800 ka.

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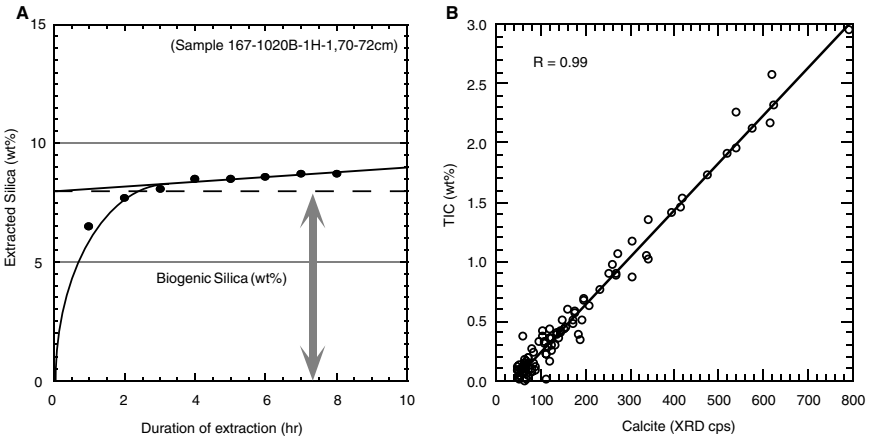


Figure 2. **A.** Extraction curve of silica for Sample 167-1020B-1H-1, 70–72 cm. The high extraction rates during the early stage of alkali extraction represent biogenic silica such as diatom and radiolarian opal. Biogenic silica concentration in each sample was determined as the y-axis intercept after fitting a line for the low extraction rate of detrital silica (Mortlock and Froelich, 1989). **B.** Correlation between the intensity of the calcite (001) peak from X-ray diffractometry (XRD) and content of total inorganic carbon (TIC) of 96 samples from Hole 1020B. Biogenic carbonate was determined as $CaCO_3$ and calculated by TIC × 8.34.

## RESULTS AND DISCUSSION

Sediments in Hole 1020B consist of biogenic and terrigenous components, of which biogenic components occupy ~10 wt% of bulk sediments. The biogenic component includes ~1 wt% TOC, 0–5 wt% biogenic carbonate, and ~3 wt% biogenic silica (Table 1).

In the interval from 400 to 600 ka, high values of biogenic carbonate and silica indicate only limited dilution by terrigenous materials; this is also evident from low quartz abundance and low values for calculated terrigenous input (Fig. 3). To normalize the data with respect to the dilution effect, terrigenous-free percentages of biogenic carbonate, biogenic silica, and TOC have been calculated by using the following equation from Gardner et al. (1997):

$$\%X(\text{tf}) = \%X/(\%\text{biogenic carbonate} + \%\text{biogenic silica} + \%\text{TOC}) \times 100,$$

where %biogenic silica, %biogenic carbonate, and %TOC are substituted for $X$ to calculate the respective terrigenous-free values.

The resulting variations of terrigenous-free biogenic silica and carbonate are depicted in Figure 4 compared with the oxygen isotope ratio of benthic foraminifers at Site 849 in the Eastern Equatorial Pacific, a representation of global ice-volume change (Mix et al., 1995). The terrigenous-free biogenic silica concentration record correlates with global ice-volume change and shows high concentrations during most interglacial isotope stages and low concentrations during most glacial stages. The temporal pattern of biogenic carbonate, in contrast, shows high concentrations in glacial periods over the last 800 k.y. Variations in terrigenous-free organic carbon concentrations are less obviously tied to glacial–interglacial changes but have a more similar variation than terrigenous-free biogenic silica.

The observed temporal variations of biogenic components may be caused by changes in the character of deep water. In general, variations in carbonate and silica concentrations are influenced by production, dissolution, and dilution. Carbonate productivity in this region has been reported to have been high in glacial periods and low in the interglacial periods (Karlin et al., 1992). In addition, these authors pointed out that carbonate dissolved because the carbonate compensate depth (CCD) was shallower during the interglacial periods. In this region, the CCD has varied significantly on glacial–interglacial time scales: its depth has been estimated at a water depth of 2700 m during the last interglacial period and 4400–4500 m during last glacial period (Karlin et al., 1992). These authors suggested a change in deep-water characteristics as one factor of this remarkable CCD change. During glacial periods, $CO_2$-depleted North Pacific Deep Water (NPDW) would have formed in the North Pacific region and would have caused a deepening of the CCD. On the other hand, the CCD would have been shallower during interglacial times because of the inflow of $CO_2$-rich deep water derived from North Atlantic Deep Water (NADW). Our results on the variation of biogenic carbonate during the last 800 k.y. agree with this model developed for the last glacial–interglacial cycle.

The variation in terrigenous-free biogenic silica in this study may be an indication for NPDW production during glacial periods. Young and Si-unsaturated NPDW would rapidly dissolve biogenic silica during glacial times; on the other hand, old and Si-saturated NADW should enhance preservation of biogenic silica during interglacial times. Moreover, the productivity of biogenic silica in this high-latitude region would increase during strong upwelling comparable to the present summer situation during interglacial times and would decrease during weakened upwelling under glacial conditions.

## CONCLUSIONS

The sediments of Hole 1020B have high biogenic carbonate concentrations during glacial periods and high biogenic silica concentrations during interglacial periods. This variability should be caused by glacial–interglacial variations in the origin and character of deep-water masses. Future work, such as calculating mass accumulation rates for each component and analyses of other proxies, is necessary to confirm the observed changes in the production and burial of biogenic components.

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**Table 1. The contents of biogenic and terrigenous components for Cores 167-1020B-1H through 8H.**

| Core, section, interval (cm) | Depth (mbsf) | Depth (mcd) | Age (ka) | Bio. silica (wt%) | Bio. carb. (wt%) | TOC (wt%) | Total terri. (wt%) | Qz (101) (cps) | Bio. silica-tf (wt%) | Bio. carb.-tf (wt%) | TOC-tf (wt%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1H-1, 70-72 | 0.7 | 0.76 | 6 | 7.91 | 0.96 | 1.30 | 89.84 | 927 | 77.81 | 9.44 | 12.75 |
| 1H-1, 140-142 | 1.4 | 1.44 | 12 | 3.36 | 3.65 | 1.03 | 91.97 | 913 | 41.79 | 45.39 | 12.83 |
| 1H-2, 70-72 | 2.2 | 2.22 | 16 | 3.62 | 8.77 | 1.18 | 86.43 | 850 | 26.66 | 64.61 | 8.73 |
| 1H-2, 140-142 | 2.9 | 2.90 | 20 | 3.70 | 7.34 | 0.91 | 88.04 | 845 | 30.97 | 61.42 | 7.61 |
| 1H-3, 70-72 | 3.7 | 3.68 | 24 | 4.00 | 5.24 | 0.86 | 89.90 | 886 | 39.58 | 51.93 | 8.49 |
| 1H-3, 140-142 | 4.4 | 4.36 | 31 | 3.21 | 4.30 | 0.74 | 91.75 | 854 | 38.89 | 52.16 | 8.95 |
| 1H-4, 70-72 | 5.2 | 5.13 | 39 | 4.95 | 1.26 | 0.97 | 92.82 | 914 | 68.92 | 17.55 | 13.53 |
| 1H-4, 140-142 | 5.9 | 5.81 | 47 | 5.11 | 2.55 | 1.05 | 91.28 | 862 | 58.64 | 29.27 | 12.09 |
| 1H-5, 70-72 | 6.7 | 6.59 | 54 | 4.93 | 3.72 | 1.00 | 90.36 | 929 | 51.12 | 38.53 | 10.35 |
| 1H-5, 140-142 | 7.4 | 7.27 | 58 | 6.55 | 4.24 | 1.03 | 88.18 | 824 | 55.43 | 35.85 | 8.72 |
| 2H-1, 70-72 | 8.5 | 8.39 | 64 | 3.69 | 2.98 | 0.76 | 92.57 | 935 | 49.68 | 40.15 | 10.17 |
| 2H-1, 140-142 | 9.2 | 9.12 | 68 | 4.17 | 2.33 | 0.70 | 92.80 | 900 | 57.88 | 32.43 | 9.69 |
| 2H-2, 70-72 | 10.0 | 9.95 | 73 | 5.57 | 2.84 | 0.98 | 90.61 | 923 | 59.33 | 30.25 | 10.42 |
| 2H-2, 140-142 | 10.7 | 10.68 | 78 | 4.58 | 8.57 | 1.03 | 85.83 | 799 | 32.33 | 60.44 | 7.23 |
| 2H-3, 56-58 | 11.5 | 11.52 | 86 | 4.26 | 0.39 | 1.00 | 94.36 | 1033 | 75.47 | 6.88 | 17.65 |
| 2H-3, 140-142 | 12.2 | 12.25 | 93 | 5.05 | 1.95 | 1.43 | 91.58 | 923 | 59.89 | 23.17 | 16.94 |
| 2H-4, 70-72 | 13.0 | 13.08 | 100 | 3.09 | 0.62 | 1.08 | 95.21 | 905 | 64.51 | 12.88 | 22.62 |
| 2H-4, 140-142 | 13.7 | 13.81 | 107 | 3.45 | 0.94 | 0.73 | 94.89 | 950 | 67.40 | 18.40 | 14.21 |
| 2H-5, 70-72 | 14.5 | 14.64 | 118 | 4.92 | 0.81 | 1.09 | 93.18 | 925 | 72.15 | 11.87 | 15.98 |
| 2H-5, 140-142 | 15.2 | 15.37 | 128 | 3.05 | 1.83 | 1.07 | 94.06 | 962 | 51.29 | 30.73 | 17.99 |
| 2H-6, 70-72 | 16.0 | 16.21 | 137 | 3.28 | 3.31 | 0.82 | 92.59 | 902 | 44.27 | 44.73 | 11.00 |
| 3H-1, 70-72 | 18.0 | 18.39 | 149 | 3.21 | 7.53 | 0.78 | 88.49 | 794 | 27.87 | 65.40 | 6.73 |
| 3H-1, 140-142 | 18.7 | 19.23 | 154 | 3.63 | 2.48 | 0.70 | 93.19 | 932 | 53.27 | 36.41 | 10.32 |
| 3H-2, 70-72 | 19.5 | 20.18 | 163 | 2.86 | 0.33 | 0.87 | 95.95 | 748 | 70.51 | 8.11 | 21.38 |
| 3H-2, 140-142 | 20.2 | 21.02 | 171 | 3.41 | 1.02 | 0.79 | 94.79 | 950 | 65.40 | 19.48 | 15.12 |
| 3H-3, 70-72 | 21.0 | 21.97 | 181 | 3.02 | 1.38 | 0.76 | 94.84 | 915 | 58.52 | 26.69 | 14.78 |
| 3H-3, 140-142 | 21.7 | 22.80 | 189 | 3.25 | 1.14 | 0.57 | 95.04 | 888 | 65.56 | 22.89 | 11.55 |
| 3H-4, 70-72 | 22.5 | 23.76 | 205 | 3.12 | 1.26 | 0.78 | 94.83 | 933 | 60.48 | 24.36 | 15.16 |
| 3H-4, 140-142 | 23.2 | 24.59 | 217 | 2.70 | 0.54 | 0.73 | 96.04 | 953 | 68.03 | 13.65 | 18.32 |
| 3H-5, 70-72 | 24.0 | 25.54 | 227 | 4.11 | 0.18 | 1.08 | 94.63 | 931 | 76.64 | 3.26 | 20.10 |
| 3H-5, 140-142 | 24.7 | 26.38 | 233 | 2.04 | 0.00 | 0.85 | 97.11 | 930 | 70.57 | 0.00 | 29.44 |
| 3H-6, 70-72 | 25.5 | 27.33 | 240 | 3.15 | 0.09 | 0.76 | 96.00 | 887 | 78.81 | 2.25 | 18.94 |
| 3H-6, 140-142 | 26.2 | 28.17 | 247 | 3.15 | 0.15 | 0.95 | 95.75 | 951 | 74.08 | 3.57 | 22.35 |
| 4H-1, 70-72 | 27.5 | 29.66 | 258 | 1.82 | 4.04 | 0.63 | 93.51 | 946 | 28.12 | 62.22 | 9.66 |
| 4H-1, 140-142 | 28.2 | 30.44 | 265 | 2.28 | 0.94 | 0.55 | 96.24 | 1010 | 60.59 | 24.86 | 14.55 |
| 4H-2, 70-72 | 29.0 | 31.33 | 273 | 1.91 | 0.71 | 0.59 | 96.80 | 988 | 59.52 | 22.08 | 18.41 |
| 4H-2, 140-142 | 29.7 | 32.11 | 281 | 2.48 | 0.96 | 0.56 | 96.01 | 933 | 62.03 | 23.96 | 14.01 |
| 4H-3, 70-72 | 30.5 | 33.00 | 290 | 2.20 | 2.09 | 0.98 | 94.73 | 942 | 41.80 | 39.63 | 18.57 |
| 4H-3, 140-142 | 31.2 | 33.78 | 300 | 1.96 | 4.73 | 0.70 | 92.61 | 954 | 26.55 | 64.01 | 9.44 |
| 4H-4, 70-72 | 32.0 | 34.67 | 306 | 3.23 | 2.29 | 0.65 | 93.83 | 940 | 52.34 | 37.16 | 10.50 |
| 4H-4, 140-142 | 32.7 | 35.45 | 312 | 2.47 | 1.60 | 0.82 | 95.11 | 892 | 50.55 | 32.77 | 16.68 |
| 4H-5, 70-72 | 33.5 | 36.34 | 326 | 1.79 | 0.05 | 0.82 | 97.34 | 905 | 67.26 | 1.82 | 30.93 |
| 4H-5, 140-142 | 34.2 | 37.12 | 340 | 1.52 | 3.20 | 1.06 | 94.23 | 861 | 26.26 | 55.41 | 18.33 |
| 4H-6, 70-72 | 35.0 | 38.01 | 348 | 2.74 | 3.00 | 0.89 | 93.38 | 1003 | 41.34 | 45.27 | 13.39 |
| 4H-6, 140-142 | 35.7 | 38.79 | 354 | 2.18 | 1.50 | 0.67 | 95.66 | 996 | 50.20 | 34.46 | 15.34 |
| 5H-1, 70-72 | 37.0 | 40.29 | 367 | 2.25 | 2.60 | 0.81 | 94.34 | 966 | 39.78 | 45.94 | 14.29 |
| 5H-1, 140-142 | 37.7 | 41.12 | 374 | 3.30 | 0.82 | 0.59 | 95.29 | 934 | 70.11 | 17.31 | 12.58 |
| 5H-2, 70-72 | 38.5 | 42.07 | 382 | 2.57 | 2.00 | 0.88 | 94.55 | 901 | 47.21 | 36.70 | 16.09 |
| 5H-2, 140-142 | 39.2 | 42.90 | 389 | 3.30 | 2.99 | 0.70 | 93.01 | 905 | 47.18 | 42.76 | 10.07 |
| 5H-3, 70-72 | 40.0 | 43.85 | 397 | 3.18 | 15.97 | 0.70 | 80.14 | 760 | 16.02 | 80.44 | 3.54 |
| 5H-3, 140-142 | 40.7 | 44.68 | 404 | 2.61 | 7.37 | 0.90 | 89.12 | 802 | 23.97 | 67.79 | 8.24 |
| 5H-4, 70-72 | 41.5 | 45.62 | 412 | 6.64 | 14.50 | 0.79 | 78.08 | 831 | 30.29 | 66.12 | 3.59 |
| 5H-4, 140-142 | 42.2 | 46.45 | 419 | 7.80 | 12.14 | 0.61 | 79.45 | 906 | 37.96 | 59.09 | 2.95 |
| 5H-5, 70-72 | 43.0 | 47.40 | 427 | 7.93 | 4.28 | 0.57 | 87.22 | 814 | 62.02 | 33.50 | 4.48 |
| 5H-5, 140-142 | 43.7 | 48.23 | 434 | 7.93 | 11.82 | 0.84 | 79.41 | 824 | 38.54 | 57.40 | 4.06 |
| 5H-6, 70-72 | 44.5 | 49.18 | 442 | 2.05 | 17.72 | 0.67 | 79.57 | 801 | 10.04 | 86.71 | 3.25 |
| 5H-6, 140-142 | 45.2 | 50.01 | 449 | 7.56 | 18.87 | 0.60 | 72.98 | 750 | 27.96 | 69.82 | 2.23 |
| 5H-7, 70-72 | 46.0 | 50.94 | 457 | 9.15 | 1.42 | 0.74 | 88.70 | 986 | 80.90 | 12.59 | 6.51 |
| 6H-1, 70-72 | 46.5 | 51.49 | 462 | 3.25 | 3.27 | 0.96 | 92.52 | 768 | 43.51 | 43.67 | 12.82 |
| 6H-2, 70-72 | 48.0 | 53.15 | 478 | 9.69 | 1.79 | 1.05 | 87.48 | 876 | 77.38 | 14.26 | 8.36 |
| 6H-2, 140-142 | 48.7 | 53.93 | 486 | 2.35 | 9.86 | 0.49 | 87.30 | 780 | 18.50 | 77.66 | 3.84 |
| 6H-3, 70-72 | 49.5 | 54.81 | 494 | 2.68 | 11.32 | 0.44 | 85.56 | 800 | 18.57 | 78.39 | 3.04 |
| 6H-3, 140-142 | 50.2 | 55.58 | 502 | 7.54 | 24.70 | 1.02 | 66.75 | 613 | 22.67 | 74.27 | 3.06 |
| 6H-4, 70-72 | 51.0 | 56.47 | 510 | 2.36 | 18.12 | 0.79 | 78.73 | 670 | 11.10 | 85.19 | 3.71 |
| 6H-4, 140-142 | 51.7 | 57.24 | 518 | 8.01 | 21.49 | 0.76 | 69.74 | 685 | 26.47 | 71.01 | 2.52 |
| 6H-5, 70-72 | 52.5 | 58.13 | 527 | 7.13 | 19.32 | 0.75 | 72.80 | 704 | 26.21 | 71.05 | 2.74 |
| 6H-5, 140-142 | 53.2 | 58.90 | 534 | 8.95 | 16.34 | 0.78 | 73.93 | 747 | 34.35 | 62.66 | 2.99 |
| 6H-6, 70-72 | 54.0 | 59.78 | 543 | 1.81 | 5.81 | 0.86 | 91.53 | 769 | 21.34 | 68.55 | 10.11 |
| 6H-6, 140-142 | 54.7 | 60.56 | 550 | 10.50 | 0.84 | 0.87 | 87.79 | 823 | 86.03 | 6.84 | 7.13 |
| 6H-7, 70-72 | 55.5 | 61.46 | 559 | 8.12 | 12.82 | 0.81 | 78.25 | 744 | 37.34 | 58.92 | 3.74 |
| 7H-1, 70-72 | 56.0 | 62.05 | 565 | 9.78 | 0.64 | 0.86 | 88.72 | 842 | 86.71 | 5.66 | 7.63 |
| 7H-1, 140-142 | 56.7 | 62.88 | 573 | 3.21 | 2.75 | 0.98 | 93.07 | 830 | 46.30 | 39.64 | 14.06 |
| 7H-2, 70-72 | 57.5 | 63.84 | 582 | 2.54 | 0.54 | 0.95 | 95.97 | 860 | 63.07 | 13.34 | 23.59 |
| 7H-2, 140-142 | 58.2 | 64.67 | 590 | 8.70 | 1.13 | 0.91 | 89.26 | 873 | 81.03 | 10.54 | 8.43 |
| 7H-3, 70-72 | 59.0 | 65.62 | 600 | 7.97 | 5.06 | 0.89 | 86.09 | 891 | 57.24 | 36.34 | 6.42 |
| 7H-3, 140-142 | 59.7 | 66.45 | 608 | 2.32 | 7.50 | 0.79 | 89.39 | 818 | 21.84 | 70.72 | 7.44 |
| 7H-4, 70-72 | 60.5 | 67.40 | 617 | 2.25 | 8.89 | 0.78 | 88.09 | 816 | 18.85 | 74.59 | 6.56 |
| 7H-4, 140-142 | 61.2 | 68.23 | 625 | 1.65 | 8.13 | 0.84 | 89.38 | 836 | 15.52 | 76.54 | 7.95 |
| 7H-5, 70-72 | 62.0 | 69.18 | 635 | 2.56 | 3.45 | 1.02 | 92.97 | 880 | 36.36 | 49.09 | 14.56 |
| 7H-5, 140-142 | 62.7 | 70.01 | 643 | 1.56 | 6.42 | 0.84 | 91.18 | 812 | 17.71 | 72.80 | 9.49 |
| 7H-6, 70-72 | 63.5 | 70.97 | 652 | 2.44 | 3.50 | 0.91 | 93.15 | 880 | 35.58 | 51.12 | 13.30 |
| 7H-6, 140-142 | 64.2 | 71.80 | 660 | 2.28 | 3.42 | 0.85 | 93.45 | 836 | 34.83 | 52.20 | 12.98 |
| 7H-7, 70-72 | 65.0 | 72.76 | 669 | 2.75 | 0.93 | 0.86 | 95.46 | 782 | 60.51 | 20.47 | 19.02 |
| 8H-1, 70-72 | 65.5 | 73.39 | 676 | 3.21 | 0.34 | 0.92 | 95.53 | 862 | 71.82 | 7.63 | 20.55 |
| 8H-1, 140-142 | 66.2 | 74.28 | 684 | 2.79 | 3.03 | 1.10 | 93.08 | 906 | 40.27 | 43.77 | 15.96 |
| 8H-2, 70-72 | 67.0 | 75.28 | 694 | 3.91 | 3.60 | 0.82 | 91.66 | 882 | 46.94 | 43.21 | 9.85 |
| 8H-2, 140-142 | 67.7 | 76.17 | 703 | 2.22 | 3.55 | 0.77 | 93.47 | 960 | 33.93 | 54.30 | 11.76 |
| 8H-3, 70-72 | 68.5 | 77.18 | 713 | 3.25 | 1.69 | 1.20 | 93.87 | 908 | 53.05 | 27.47 | 19.49 |
| 8H-3, 140-142 | 69.2 | 78.06 | 721 | 2.78 | 3.14 | 1.04 | 93.05 | 933 | 39.96 | 45.10 | 14.94 |
| 8H-4, 70-72 | 70.0 | 79.07 | 731 | 3.11 | 2.75 | 1.09 | 93.05 | 908 | 44.76 | 39.58 | 15.66 |

**Table 1 (continued).**

| Core, section, interval (cm) | Depth (mbsf) | Depth (mcd) | Age (ka) | Bio. silica (wt%) | Bio. carb. (wt%) | TOC (wt%) | Total terri. (wt%) | Qz (101) (cps) | Bio. silica-tf (wt%) | Bio. carb.-tf (wt%) | TOC-tf (wt%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8H-4, 140-142 | 70.7 | 79.95 | 740 | 3.12 | 0.76 | 0.95 | 95.17 | 938 | 64.64 | 15.74 | 19.62 |
| 8H-5, 70-72 | 71.5 | 80.96 | 750 | 4.80 | 0.59 | 0.77 | 93.84 | 933 | 77.97 | 9.50 | 12.53 |
| 8H-5, 140-142 | 72.2 | 81.84 | 758 | 4.34 | 0.56 | 0.85 | 94.26 | 648 | 75.53 | 9.73 | 14.75 |
| 8H-6, 70-72 | 73.0 | 82.85 | 768 | 4.09 | 1.03 | 0.93 | 93.95 | 896 | 67.65 | 17.02 | 15.33 |
| 8H-6, 140-142 | 73.7 | 83.73 | 777 | 2.56 | 5.72 | 1.05 | 90.67 | 840 | 27.47 | 61.30 | 11.23 |
| 8H-7, 70-72 | 74.5 | 84.73 | 786 | 3.44 | 4.94 | 0.82 | 90.79 | 907 | 37.41 | 53.67 | 8.92 |

Note: Bio. = biogenic, carb. = carbonate, TOC = total organic carbon, terri. = terrigenous materials, Qz =quartz, cps = counts per second by X-ray diffraction, tf = terrigenous free.

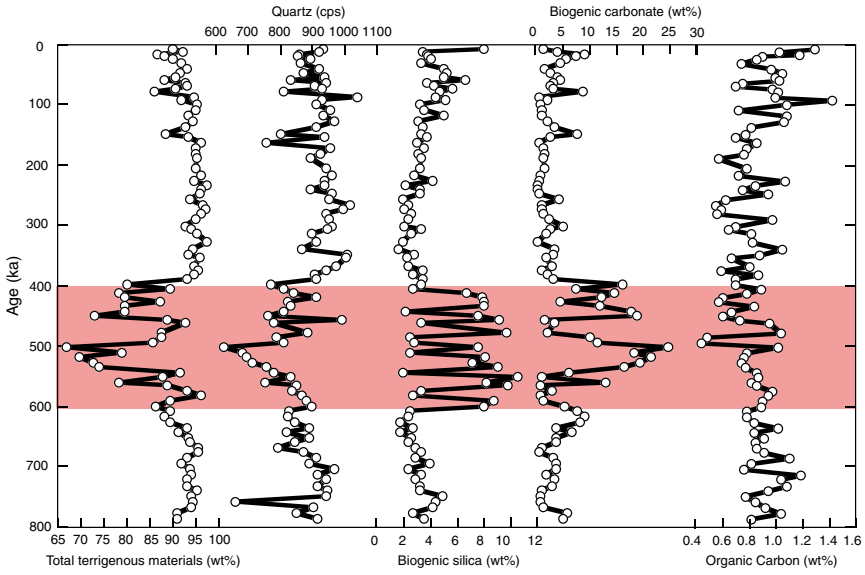


Figure 3. Variations of biogenic and terrigenous components of Hole 1020B since 800 ka. In the interval from 400 to 600 ka, biogenic silica and carbonate are diluted by terrigenous materials. The gray region shows the depth interval where biogenic components have been diluted by terrigenous materials.

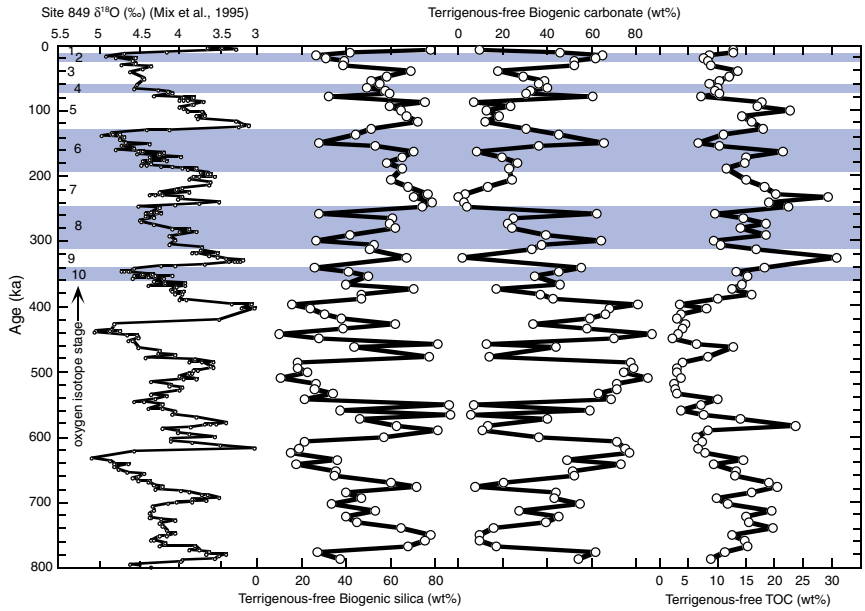


Figure 4. Variations of terrigenous-free biogenic components and the oxygen isotope ratio of benthic foraminiferal calcite at Site 849 (Mix et al., 1995). TOC = total organic carbon. Shaded areas indicate cold intervals based on oxygen isotopic ratios.