

## SUPPLEMENTAL INFORMATION

 *$^{238}\text{U}$ - $^{234}\text{U}$ - $^{230}\text{Th}$ - $^{206}\text{Pb}$  Mass Spectrometry Dating*

Approximately 150 mg of calcite milled from each interval of interest were dissolved, spiked with a mixed  $^{229}\text{Th}$ - $^{233}\text{U}$ - $^{236}\text{U}$  tracer, and processed using standard column chemistry methods (Chen et al., 1986). Isotopes of interest ( $^{236}\text{U}$ ,  $^{235}\text{U}$ ,  $^{234}\text{U}$ ,  $^{233}\text{U}$ ,  $^{232}\text{Th}$ ,  $^{230}\text{Th}$ ,  $^{229}\text{Th}$ ) were measured using a Micromass Sector 54 thermal ionization mass spectrometer in ion counting mode or a Thermo Neptune multi-collector inductively coupled plasma mass spectrometer in the Radiogenic Isotope Laboratory at the University of New Mexico. For MC-ICP-MS, U and Th fractions were dissolved and combined in a 3%–5%  $\text{HNO}_3$  4 ml solution which was then aspirated into the Neptune using a Cetac Aridus II low flow (50–100  $\mu\text{l}/\text{min}$ ) desolvating nebulizer system. Static measurements were made with the following Faraday cup (resistor) counting arrangement:  $^{229}\text{Th}$  ( $10^{12} \Omega$ ),  $^{232}\text{Th}$  ( $10^{11} \Omega$ ),  $^{233}\text{U}$  ( $10^{12} \Omega$ ),  $^{235}\text{U}$  ( $10^{11} \Omega$ ),  $^{236}\text{U}$  ( $10^{12} \Omega$ ),  $^{238}\text{U}$  ( $10^{10} \Omega$ ), and with  $^{230}\text{Th}$  measured in a channeltron ion counter and  $^{234}\text{U}$  in an SEM. SEM and channeltron yields were monitored by spiked standard bracketing. Corrections for initial  $^{230}\text{Th}$  are smaller than the analytical uncertainties based on counting statistics.

All Pb isotopic ratios were measured by TIMS. For samples other than GH6A and GH7A, isotopes of interest ( $^{208}\text{Pb}$ ,  $^{207}\text{Pb}$ ,  $^{206}\text{Pb}$ ,  $^{205}\text{Pb}$ , and  $^{204}\text{Pb}$ ) were measured in the Daly ion multiplier in peak hopping mode. Static measurements were made in the analysis of GH6A and GH7A, with  $^{205}\text{Pb}$ ,  $^{206}\text{Pb}$ ,  $^{207}\text{Pb}$ , and  $^{208}\text{Pb}$  measured in Faraday cups and  $^{204}\text{Pb}$  in the Daly

multiplier. The U blank was 50 pg U for all samples, and the Pb blank was 20 pg for all samples except GH6A and GH7A for which it was 340 pg. The NBL-112A U standard was measured during the course of this study and was in the range of 1‰ of the accepted  $^{234}\text{U}/^{238}\text{U}$  ratio.

U and Pb isotopic ratios were also used to construct a  $^{238}\text{U}/^{208}\text{Pb} - ^{206}\text{Pb}/^{208}\text{Pb}$  isochron which yields an age of  $5.34 \pm 0.15 \text{ Ma}$  with an  $\text{MSWD} = 0.69$  (Fig. 1).

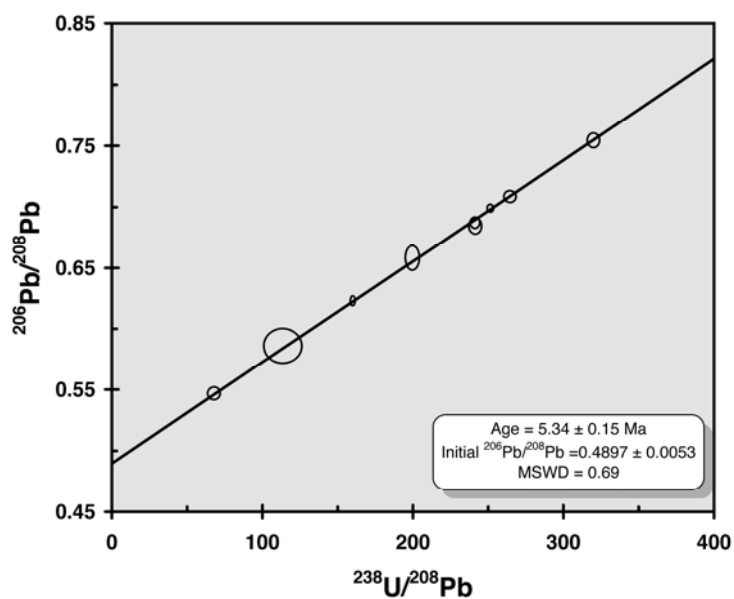


Fig. 1.  $^{238}\text{U}/^{208}\text{Pb} - ^{206}\text{Pb}/^{208}\text{Pb}$  isochron.

<sup>87</sup>Sr/<sup>86</sup>Sr Analysis

A fraction of the freshly broken coral pieces was dissolved in 3N HNO<sub>3</sub>. Sr was

Sample	<sup>87</sup> Sr/ <sup>86</sup> Sr <sup>1,2</sup>
GH2	0.709005 (18)
GH24	0.708966 (18)
GH6	0.709000 (18)
GH7	0.709000 (18)

<sup>1</sup> Values in parentheses are 2σ errors in the last decimal place.

<sup>2</sup> In order to adjust for offset between SRM-987 Sr standard values of Hodell et al. (1990) and UNM Rad. Isotope Lab, measured <sup>87</sup>Sr/<sup>86</sup>Sr ratios were subtracted by 15 ppm.

separated in a column filled with Eichrom Sr-spec resin and loaded onto a single out-gassed rhenium filament with tantalum oxide powder. All Sr isotopes and <sup>85</sup>Rb (to check for <sup>87</sup>Rb interference on <sup>87</sup>Sr) were measured in static mode by TIMS. The <sup>87</sup>Sr/<sup>86</sup>Sr ratios were normalized to <sup>86</sup>Sr/<sup>88</sup>Sr = 0.1194. No significant <sup>85</sup>Rb was measured and therefore the results did not require Rb correction. NBS-987 Sr isotope standard was measured at the same time, obtaining <sup>87</sup>Sr/<sup>86</sup>Sr = 0.710250 ± 10 (2σ-absolute error) (N=11). The data, presented in Table 1 and plotted in Fig. 2, have been corrected down by 15 ppm to account for the differences in

the measured values of NBS-987 standard between our laboratory and those assumed by Farrell et al. (1995), <sup>87</sup>Sr/<sup>86</sup>Sr = 0.710235.

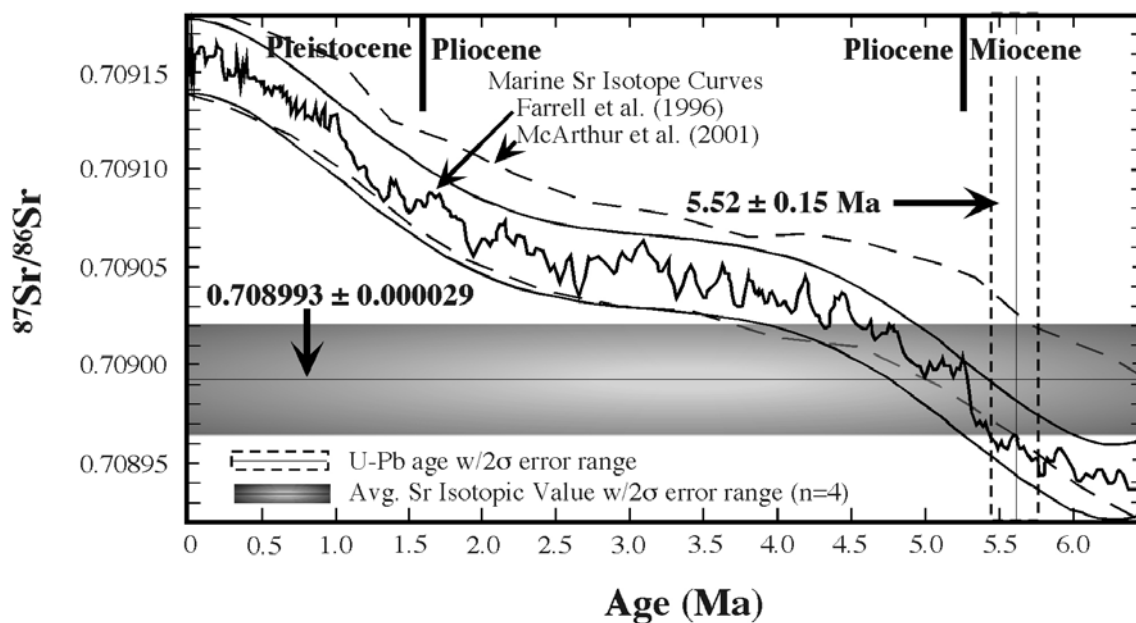


Fig. 2. Marine Sr isotopic curve for the last 6.5 Ma from Farrell et al. (1995) (solid lines) and McArthur et al. (2001) (dashed lines). Horizontal line represents the average Sr-isotopic ratio obtained from four subsamples of *G. hilli* and grey box denotes 2σ error. Vertical dashed rectangle denotes 2σ uncertainty about the U-Pb age (vertical solid line) calculated from *G. hilli*.

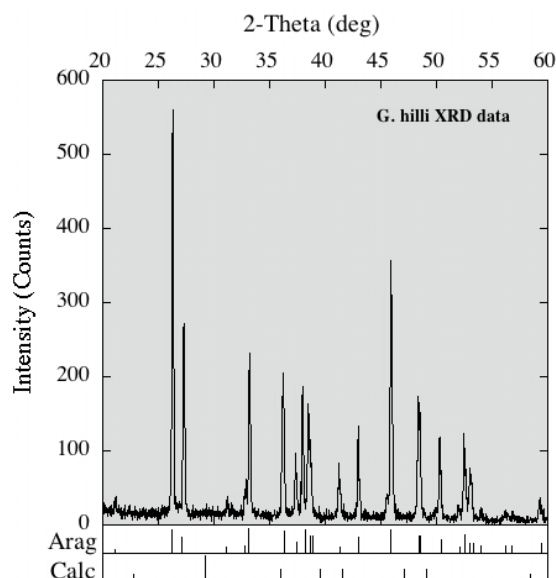


Fig. 3. XRD spectrum of *G. hilli*. Vertical lines at bottom denote expected positions of peaks associated with aragonite (Arag) and calcite (Calc). Note absence of calcite peaks.

### X-Ray Diffraction

Powdered samples were analyzed by X-ray diffraction in the XRD laboratory in the Department of Earth and Planetary Sciences at the University of New Mexico using a Scintag Pad V diffractometer with DataScan 4 software (from MDI, Inc.) for system automation and data collection. Cu-K-alpha radiation (40 kV, 35 mA) was used with a Bicorn Scintillation detector (with a pyrolytic graphite curved crystal monochromator). Data were analyzed with Jade 7.5 Software (from MDI, Inc.) using the ICDD (International Center for Diffraction Data) PDF4 database (rev. 2005) for phase identification. Data collection utilized a step

scan over a 2-theta range of 20° to 60° with a scan rate of 1°/minute (Fig. 3).

### Stable Isotopic Analysis

Stable isotope analyses were performed at the University of Michigan Department of Geological Sciences using either a Finnigan MAT Kiel I preparation device coupled directly to the inlet of a Finnigan MAT 251 triple collector isotope ratio mass spectrometer, or in a Finnigan MAT Kiel IV preparation device coupled to the inlet of a MAT 253 mass spectrometer. Precision and accuracy of data were monitored through daily analysis of a variety of powdered carbonate standards. At least six standards were reacted and analyzed daily, bracketing the sample suite at the beginning, middle, and end of the day's run. Measured precision

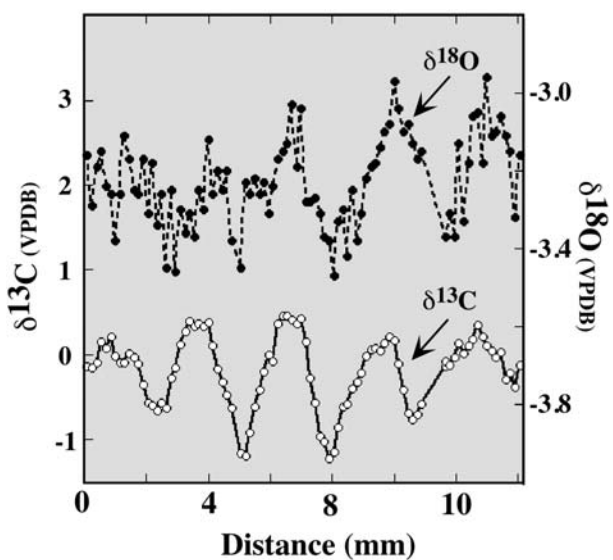


Fig. 4. Stable isotopic ratios of micromilled coral aragonite. Note well-defined sinusoids suggesting a high degree of preservation and a lack of secondary cementation.

was maintained at better than 0.1‰ (1 $\sigma$ ) for both carbon and oxygen isotope compositions with isotopic ratios reported relative to the Vienna Pee Dee Belemnite (VPDB) standard. Samples powders for stable isotope analysis were micromilled in parallel traverses across the entire corallite using a Merchantek micromill. Powder was collected at the end of each pass and transferred to stainless steel vials for analysis. Sample powders were not baked prior to analysis (Fig. 4).

### *References*

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