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# Interpretation of the origin of massive replacive dolomite within atolls and submerged carbonate platforms: strontium isotopic signature ODP Hole 866A, Resolution Guyot, Mid-Pacific Mountains

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## Abstract

Endo-upwelling is a geothermally driven convective process operating within the upper part of the volcanic foundation and overlying carbonate pile, in atolls and guyots. By this process deep oceanic water, rich in CO<sub>2</sub> and dissolved nitrates, phosphates and silicates is drawn into the pile, circulates slowly upward through the porous-permeable carbonate interior and emerges at either the reef crest or lagoon on atolls to support the primary productivity of the surficial communities, or towards the interior of the platform surface on guyots.

Continuous operation of the endo-upwelling process requires: (a) heat from the volcanic foundation; (b) an external impermeable apron on the submerged flanks to confine the convective flow within the pile; and (c) a porous cap from which water exiting the plumbing system returns to the ocean.

At ODP Hole 866A on Resolution Guyot, Mid-Pacific Mountains, the Sr isotopic signature of massive

(1963), Saller (1984), Aharon et al. (1987), Hardie (1987), Aissaoui et al. (1986), Vahrenkamp and Swart (1990), Wilson et al. (1990), Vahrenkamp et al. (1991), Hein et al. (1992), and Flood and Chivas (1995).

A general model of dolomitization associated with thermal convection within atolls and carbonate platforms has been described by Tucker and Wright (1991). It requires a zone of higher heat flow to be present beneath the carbonate platform and lateral flow operating along the platform margin. This situation is commonly referred to as 'Kohout convection'. The essence of this model is embodied in the geothermal endo-upwelling mechanism described by Rougerie and Wauthy (1988, 1993), Rougerie et al. (1992) and Rougerie and Fagerstrom (1994). This model of thermal convection operates within atolls and carbonate platforms whereby deep oceanic wa-

## 2. Dolomite

Drillings on Pacific Ocean atolls (Kita-daitojima, Enewetak, Midway, Niue, Aitutaki, Mururoa, and Fangataufa) and guyots (Resolution) have recorded the presence of dolomitization from near-surface to considerable depths. However, there is range of opinions regarding the origin of such dolomite and the mechanism of dolomitization. Results obtained from massive replacive dolomite which occurs within the Early Cretaceous age carbonate rocks recovered from ODP Leg 143 Hole 866A on Resolution Guyot, Mid-Pacific Mountains provide an insight into the potential of the geothermal endo-upwelling convection process for dolomite formation.

2. ODP Leg 143 Hole 866A

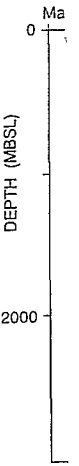


Fig. 2. The section the ini

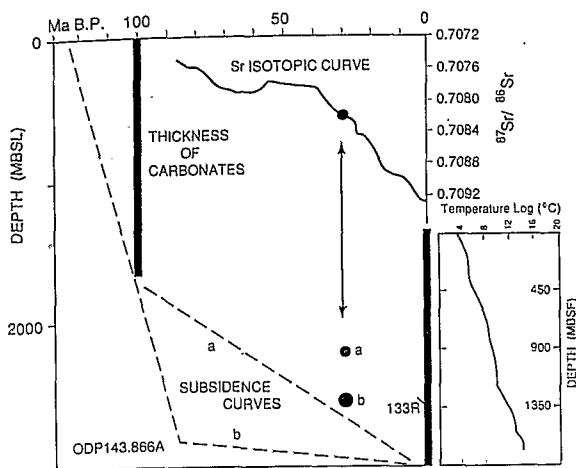


Fig. 2. Subsidence history of Hole 866A, Resolution Guyot. The heavy solid lines of the figure represent the drill hole section through the shallow-water carbonate sequence during the initial subsidence-accretion phase (upper left) and at present time (lower right). It is not known whether the subsidence proceeded according to that indicated by curve *a* or curve *b*. The samples of massive white dolomitization analysed for the strontium isotopic signature were from Core 133R. Comparison of published strontium isotopic seawater curve and the measured strontium isotopic value indicates that the massive white dolomitization occurred ca. 24 Ma (100 m.y. after deposition) when the guyot was covered by 2000 m of water. Points *a* and *b* provide age and depth of massive dolomitization corresponding to subsidence curve *a* or *b*, respectively. Irrespective of which subsidence curve is correct, the dolomitization event occurred within the carbonate platform at a depth below 2000 m. The shipboard temperature log measured within Hole 866A is indicated to the lower right.

for the following 100 m.y. the guyot slowly subsided to its present depth where the upper surface is now covered by more than 1300 m of water. A 1961-m-thick carbonate platform is surrounded by deep ocean waters and it has not been buried in basal sediments.

Massive replacive brown-coloured dolomite is

and the white-coloured dolomite have been determined by the Precise Radiogenic Isotope Services of the Research School of Earth Sciences, Australian National University, Canberra Australia, using a Finnigan MAT 261 multicollector mass spectrometer. Also the  $\delta^{18}\text{O}$  value of the dolomites was measured at the same Research School of Earth Sciences, using the Kiel preparation device manufactured by Finnigan MAT of Bermen, Germany and a Finnigan MAT 251 mass spectrometer.

A  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio of approximately 0.70735 and 0.70822 (Flood and Chivas, 1995) was obtained from the brown and white dolomites, respectively. In interpreting the Sr isotope values, all of the Sr is viewed as coming from seawater and none from any precursor limestone. Examination of seawater Sr isotope variations throughout time (Smalley et al., 1994) indicates that the brown dolomite formed during the early Aptian or early Albian (115–105 Ma) whereas the white dolomite formed about 24 Ma. That is 100 m.y. younger than the depositional age of the shallow-water carbonate sediments. The formation of the massive white dolomite occurred within the carbonate sediments in a water depth of approximately 2000 m.

Land (1985, p. 118) has published an equation for calculating the temperature of dolomite formation, based on the  $\delta^{18}\text{O}_{\text{PDB}}$  values. The equation is:

$$T \text{ (}^\circ\text{C)} = 16.4 - 4.3 [(\delta^{18}\text{O dol.} - 3.8) - \delta \text{ water}] + 0.14 [(\delta^{18}\text{O dol.} - 3.8) - \delta \text{ water}]^2$$

For the brown dolomite the  $\delta^{18}\text{O}$  values range from  $-1.6$  to  $+0.7$ ; the  $\delta^{18}\text{O}$  for the white dolomite is  $+3.7$ . In interpreting the oxygen isotope values, all of the oxygen is viewed as coming

mates the shipboard-recorded temperature of 13.6°C measured at 1671.5 mbsf (Sager et al., 1993, fig. 59) and not the near-freezing (4°C) seawater surrounding the guyot. As interstitial waters in the interior of Resolution Guyot have a major-element composition similar to seawater (Sager et al., 1993), geothermal endo-upwelling convective processes could be responsible for fluid flow (sensu Wilson et al., 1990, fig. 14c; Tucker and Wright, 1991, fig. 8.28; or Kaufman, 1994, fig. 1c) circulating throughout the guyot. Paull et al. (1995) suggest that fluid flushing by more than 10,000 pore volumes of seawater has occurred since the carbonate platform was drowned. Massive dolomite could be a by-product of the guyot plumbing system with seawater supplying the required magnesium, and removing the calcium liberated in that ionic exchange. Whilst some degree of caution should be exercised in any interpretation, the contrasting  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio and the different  $\delta^{18}\text{O}_{\text{PDB}}$  values of the two different-coloured dolomites does appear to support the proposition of different pulses of dolomitization.

support the proposal. Endo-upwelling circulation may be also responsible for the reported occurrence of dolomite on other oceanic atolls and ancient carbonate platforms.

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