

Ocean sediments
Interstitial waters
Calcium
Magnesium
H₂¹⁸O

Sédiments océaniques
Eaux interstitielles
Calcium
Magnésium
H₂¹⁸O

Geochemical significance of diagenetic reactions in ocean sediments : an evaluation of interstitial water data (extended abstract)

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ABSTRACT

The gradients of dissolved calcium and magnesium, as well as those of $\delta^{18}\text{O}$ of the interstitial waters in deep sea sediments imply fluxes of material from layer 2 (oceanic basalts) into layer 1 (sediments) and *vice versa*. Especially the flux of H₂¹⁸O into layer 2 is significant and allows an estimate of the degree of alteration of layer 2 of the oceanic crust.

Oceanol. Acta, 1981. Proceedings 26th International Geological Congress, Geology of oceans symposium, Paris, July 7-17, 1980, 111-113.

RÉSUMÉ

Signification géochimique des réactions diagénétiques dans les sédiments océaniques à partir des données sur les eaux interstitielles.

L'étude des gradients de dissolution du magnésium et du calcium, ainsi que celle des anomalies en oxygène 18, dans les eaux interstitielles des sédiments océaniques profonds, impliquent un échange de matière entre la couche 2 (basaltes océaniques) et la couche 1 (sédiments). Un aspect particulier du phénomène est le flux de H₂¹⁸O dans la couche 2, qui indique et permet une estimation du degré d'altération de la croûte océanique.

Oceanol. Acta, 1981. Actes 26^e Congrès International de Géologie, colloque Géologie des océans, Paris, 7-17 juil. 1980, 111-113.

In this paper we briefly summarize some of the major results that have been obtained from interstitial water studies during the last 12 years of the Deep Sea Drilling Project (DSDP). We focus on the concentrations of dissolved calcium, magnesium, potassium (all major seawater components), as well as the ¹⁸O/¹⁶O ratio of the oxygen in the interstitial waters.

Many drill sites — almost 400 — have been studied for their interstitial water chemistry and, notwithstanding the fact that drilling has been slightly biased towards sites of particular geophysical relevance, a reasonably general picture has emerged.

One can subdivide the drill sites into two major categories :
1) " Coastal ocean " drill holes : these are characterized by

high sediment accumulation rates as a result of high inputs of biogenic and weathered detrital materials. These sites generally show complex concentration-depth gradients as a result of sulfate reduction processes, leading to large dissolved sulfate depletions and minima in dissolved calcium as a result of carbonate precipitation reactions (see also Gieskes, 1981);

2) "Open ocean" drill holes: these are located away from the coast in more "pelagic" settings, characterized by moderate to slow sediment accumulation rates ($\leq 50 \text{ m}/10^6 \text{ years}$). Here we are concerned mainly with the latter category. In the "open ocean" sites we distinguish:

A) sites without concentration gradients, i.e., interstitial water compositions do not differ significantly from those of seawater. These sites usually occur; a) near ocean ridges and b) where sedimentation rates are extremely slow;

B) sites with well established concentration changes, in which, in general: calcium concentrations increase; magnesium concentrations decrease; potassium concentrations decrease; $\delta^{18}\text{O}$ of the interstitial waters decreases.

A typical example is given in Figure 1, which represents interstitial water data obtained in site 239 (Mascarene Basin). McDuff and Gieskes (1976) demonstrated the conservative nature in this site of the calcium and magnesium gradients and inferred that reactions occurring in the basement are the source of calcium and the sink for magnesium (see also McDuff, in press). McDuff and Gieskes (1976), McDuff (in press), and Gieskes and Lawrence (in press) demonstrated that for many "open ocean" sites alteration reactions involving basalts of layer 2 and to a lesser extent alteration reactions involving volcanic matter dispersed in the sediments of layer 1 of the oceanic crust were responsible for much of the observed increases in dissolved calcium, and decreases in magnesium and $\delta^{18}\text{O}$.

In Figure 2 we present a map delineating the mean calcium gradient ($\text{mM}/100 \text{ m}$) in "open ocean" holes — sites with G indicate increasing calcium concentrations with depth, but with poorly defined gradients. With the knowledge of increasing calcium gradients with distance from oceanic spreading ridge (McDuff, in press), we estimate that about 50% of the ocean floor shows calcium gradients, which average $8 \text{ mM}/100 \text{ m}$ (Lawrence, Gieskes, in prep.). Thus the average calcium gradient for the entire ocean floor is $4 \text{ mM}/100 \text{ m}$.

We have studied oxygen isotopic compositions of the pore water on more than 30 drill holes (Lawrence, Gieskes, in

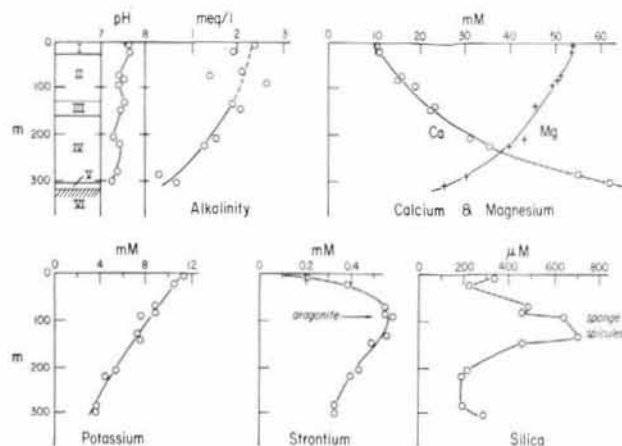


Figure 1
Interstitial water chemistry, site 239 — Mascarene Basin. Lithology: I: silty clay; II: nanno ooze nanno clay; III: green and gray silty clay and nanno ooze; IV: brown silty clay and clayey silt; V: nanno clay; VI: basalt. The decrease in potassium is to a large extent due to uptake in the sediments; dissolved strontium is the result of carbonate recrystallization; dissolved silica reflects the presence of biogenic silica (c.f., Gieskes, 1981).

prep.), and generally a good correlation is found between changes in the calcium concentration and $\delta^{18}\text{O}$, as is demonstrated in Figure 3. Though clearly there is some variability in the correlation slopes, we estimate that a slope of $-0.08 \text{ ‰}/\text{mM Ca} \pm 0.03$ is a good average. Based on this slope and on the average calcium gradient one can estimate an average $\delta^{18}\text{O}$ gradient of $-0.32 \text{ ‰}/100 \text{ M}$ for the world ocean.

Most of the observed gradients in calcium, magnesium, and $\delta^{18}\text{O}$ indicate that diffusive transport of material is the only important transport processes in open ocean drill sites, with the possible exception of those sites that are near ocean ridges (McDuff, in press). In the neighborhood of oceanic ridges substantial advective transport may occur in the sediment column. Thus, the average $\delta^{18}\text{O}$ gradient allows an estimate of the flux of ^{18}O into layers 1 and 2. For this calculation an average diffusion coefficient of H_2^{18}O of $6 \times 10^{-6} \text{ cm}^2/\text{sec}$. is used (Lawrence *et al.*, 1979). The flux of H_2^{18}O into layers 1 and 2 is then estimated to be 2×10^5 moles of ^{18}O per million years. Lawrence and Gieskes (in prep.) calculate that this flux implies low temperature

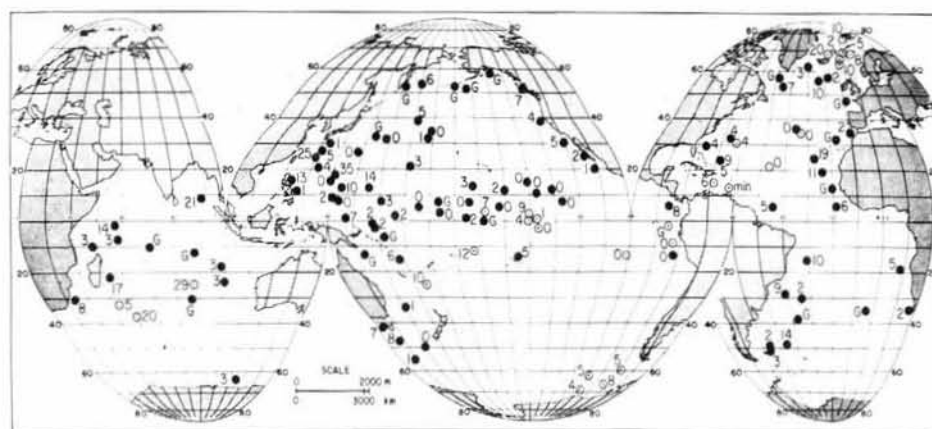


Figure 2
Average calcium concentration-depth gradients in pelagic DSDP cores ($\text{mM}/100 \text{ m}$). Points with circles have $\delta^{18}\text{O}$ data (Lawrence, Gieskes, in prep.); G = gradient positive, but ill-defined.

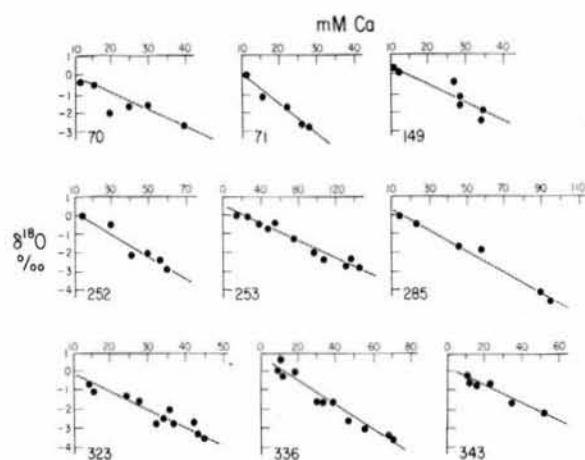


Figure 3
Calcium- $\delta^{18}\text{O}$ correlations from pore waters for some selected DSDP sites (Lawrence, Gieskes, in prep.).

alteration of between 10-30% of the first kilometer of basalts over a period of 60×10^6 years.

The above calculations show that the flux of ^{18}O into layers 1 and 2 is by no means trivial and implies considerable alteration of the oceanic crust. Calculation of the flux of Mg and K into the crust, and of Ca out of the crust (Gieskes, 1981; McDuff, in press) indicate that for these seawater constituents the fluxes are only of minor importance compared with the average river fluxes (ca~1%; Mg~2%; K~10%). However, if oceanic steady state is to be maintained for ^{18}O , a significant return flux is necessary, which must be located in oceanic spreading centers (high temperature rock-water interactions) and/or in oceanic subduction zones. Lawrence and Gieskes (in prep.) estimate that if hydrothermal activity at ridge crests were responsible for the return flux of ^{18}O , up to 40% of a 6 km thick layer of layer 2 would be required to balance the flux of ^{18}O into layers 1 and 2 as a result of low temperature alteration reactions. This flux should in principle be determinable from hydrothermal emanations from ridge crests (Edmond *et al.*, 1979; Rise Project Group, 1980).

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