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Correlated Uranium and Sea-Level Fluctuations in Late Quaternary Oceans

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Residence time of Uranium in the oceans with respect to riverine inflow is estimated to be about 300-600 thousand years, a time span accessible to U-series disequilibrium dating of corals which concentrate U from seawater in their skeletons. The principal supply of dissolved U to the oceans is derived from chemical weathering of continents and is transported by rivers. Radioactive decay and alpha recoil of ^{238}U and subsequent preferential leaching from damaged sites results in excess of ^{234}U relative to equilibrium levels and $^{234}U/^{238}U$ activity ratios greater than unity are found in river waters.

The $^{234}U/^{238}U$ ratio in seawater, at the time of coral growth, can be derived from coral age measurements and provides a precise chronology of ^{234}U abundance in seawater. Uranium is highly soluble under oxidising conditions, in reducing environments it can be particle reactive and insoluble. Therefore, global climatic changes influencing the extent of oxic, anoxic zones in ocean sediments can influence U concentrations. Variations in the $^{234}U/^{238}U$ ratio of corals, ranging in age from 80 to 200ka, have been identified but are attributed to diagenetic effects (Bard et al, 1992, Gallup, et al., 1994). Last Interglacial coral reefs in Western Australia show a tight clustering of ages between 128ka and 122ka at elevations of +3 m relative to present sea-level. When strict selection criteria are applied to select samples, they form a band that is displaced higher from the modern 149 per mil value by about 4 per mil. As several different WA reefs have consistent distribution of similar LI ages, the data is best explained by assuming a 4 per mil difference in the ^{234}U abundance of the oceans between 125,000 years ago and at present (Stirling et al., 1998). In contrast to positive excursions in $\delta^{234}U$, systematic negative variations have not been clearly established.

We have measured $^{234}U/^{238}U$ ratios of 30,000 to 50,000 year old corals from the Huon Peninsula terraces II and III, including sub-terraces, that have systematically low $\delta^{234}U$. Additional coral data from the last two major terminations, from the last glacial to Holocene and from the penultimate glacial to Last Interglacial show significant and rapid fluctuations in $\delta^{234}U$ correlated with sea level change and require mechanisms to allow global variations in $\delta^{234}U$ on short, millennial timescales. Results from Huon Peninsula ranging in age from 90ka to 140ka that include the transition from the penultimate glacial to last interglacial and the 105ka interstadial are shown in the Figure (Esat et al., 1999). The lower panel represents the sea level curve, derived mainly from consideration of ages and location of corals, mainly from reef tract VI. There is no input in this curve from $\delta^{234}U$ except for quality control in selecting unaltered corals. The upper panel shows the variation in $\delta^{234}U$ over the same time interval. There is a striking resemblance between the variations in $\delta^{234}U$ and changes in sea-level that is unlikely to be coincidental. All of the major features of the sea-level curve are reproduced in $\delta^{234}U$ and there is a 25 per mil difference between the highest and lowest values or a 17% variation relative to the present concentration. Corals from reef tract VI record several snap-shots of sea-level change as the sea level transited at least four times from 145 to 90ka. Because of the uplift rate of 1.6 m/ky at this location the reef kept up with sea-level rise for longer periods than would be the case for a stable site. Conversely, during periods of sea-level fall the time window for coral growth at a particular elevation would be shorter. Assuming that $\delta^{234}U$ was rapidly changing, corals that grew at this site during any one transit, but at slightly different times, would be expected to record variable $\delta^{234}U$ concentrations as shown in the Figure 1. There are no variations in $\delta^{234}U$ during interglacial periods, when sea levels are relatively stable and $\delta^{234}U$ is constant over periods of 10,000 years. This observation imposes severe constraints on any proposed mechanism to explain the connection between sea-level change and $\delta^{234}U$. Presumably, a linear relationship between sea-level change and $\delta^{234}U$ is not called for. However, the correspondence between $\delta^{234}U$ and sea-level change as depicted in the Figure 1 is remarkable.

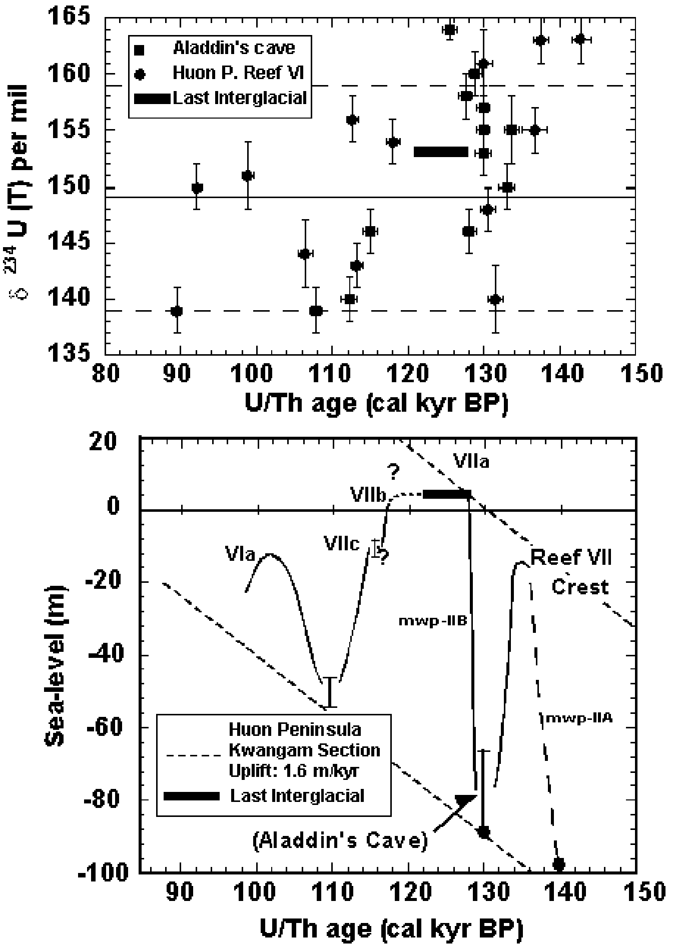

Figure 1: Sea-level and 234-U variations before and after the Last Interglacial

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