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During Sea-Level Highstands:
A Global Synthesis with implications
for management of future coastal change

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Dating Holocene estuarine successions using Aspartic Acid Racemisation

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Abstract

Amino acid racemisation is a chemical dating method that measures the relative abundance of amino acid isomers preserved within organic materials (expressed as a D/L ratio). It has been successfully applied to the dating of marine and terrestrial molluscs, teeth, bone, and aeolanites (Rutter and Blackwell 1995). Traditionally, amino acid racemisation has been used in the dating of Quaternary sedimentary successions (e.g. Murray-Wallace and Kimber, 1987; Murray-Wallace, 2000 and references therein). Goodfriend (1992) has shown that the fast racemising acid, aspartic acid (Asp) may be applied in the dating of recent sedimentary successions younger than 600 years (Goodfriend et al., 1992; Goodfriend et al., 1996; Goodfriend and Stanley, 1996). Thus, the racemisation of aspartic acid has the potential to provide a geochronology for Late Holocene to recent sedimentary successions that are otherwise difficult to date using more conventional dating techniques such as radiocarbon dating.

For example, aspartic acid racemisation can provide a chronology for sedimentary successions that are >120a where ^{210}Pb has reached its limit, and <600a where dating marine and estuarine material with the radiocarbon method is complicated by the marine reservoir effect. The potential of aspartic acid to provide a chronology for geologically-young sedimentary successions was confirmed by comparing the kinetic trend of Asp observed in laboratory-induced racemisation established by simulated aging (heating) experiments and the degree of Asp racemisation observed in radiocarbon dated fossil specimens of *Anadara trapezia* and *Notospisula trigonella* both common species of estuarine bivalve molluscs (Fig. 1 , 2). This was achieved using eight fossil samples of *A. trapezia* and five fossil samples of *N. trigonella* that were analysed by the radiocarbon and amino acid racemisation methods. This permitted a direct comparison between the degree of aspartic acid racemisation under ambient diagenetic temperatures and fossil age established by the radiocarbon dating method (Fig. 1 , 2).

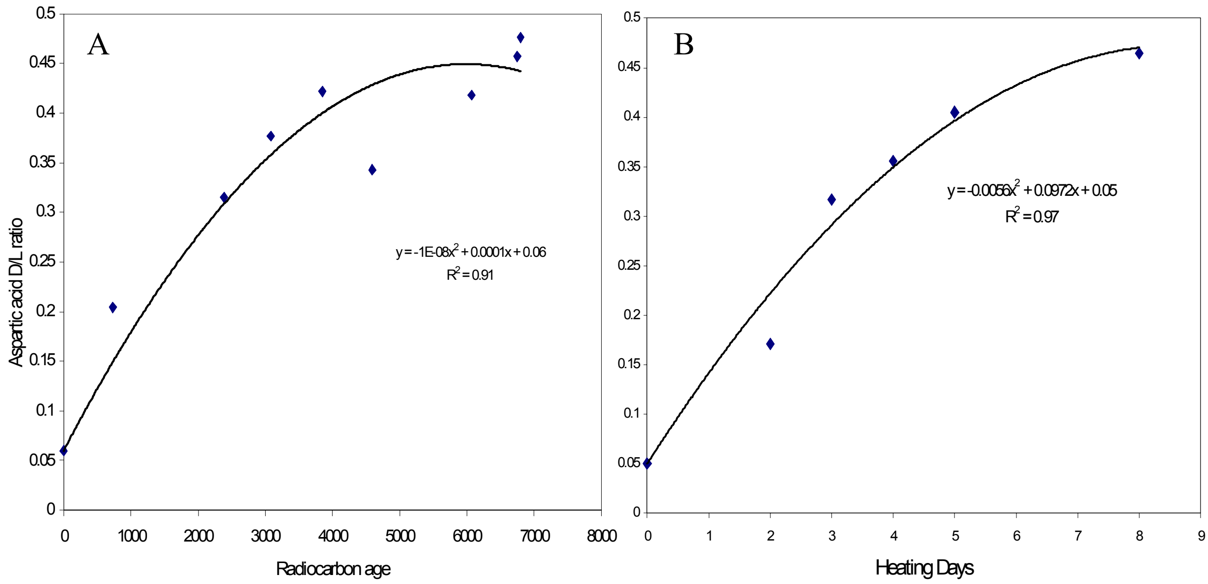

Figure 1. *A. trapezia* radiocarbon dating and aspartic acid dating techniques on the same sample. 1b: Kinetic trend observed in heating experiment conducted on *A. trapezia*

The results from the time-series experiments on fossil molluscs, together with the initial modern aspartic acid D/L value, support the apparent parabolic kinetic trend of aspartic acid for both *A. trapezia* and *N. trigonella*.

The apparent parabolic nature of the time series experiment can also be seen in the relationship between D/L ratios and the square-root of radiocarbon ages which yielded a near-linear relationship within the reaction range (cf. Mitterer and Kriausakul 1989; Goodfriend 1990; Fig. 3). The high R^2 values of 0.93 for *A. trapezia* and 0.95 for *N. trigonella* indicate that there is only a minor deviation from the trend line. Using the fossil time series data for *A. trapezia* and similar results for the estuarine mollusc *Notospisula trigonella*, numeric ages based on the degree of aspartic acid racemisation were determined using an apparent parabolic kinetic model (Mitterer and Kriausakul 1989; Goodfriend 1990; Murray-Wallace and Kimber 1993). Accordingly, for both *A. trapezia* and *N. trigonella*, numeric ages based on the degree of aspartic acid racemisation were calculated using the following formula (Mitterer and Kriausakul, 1989):

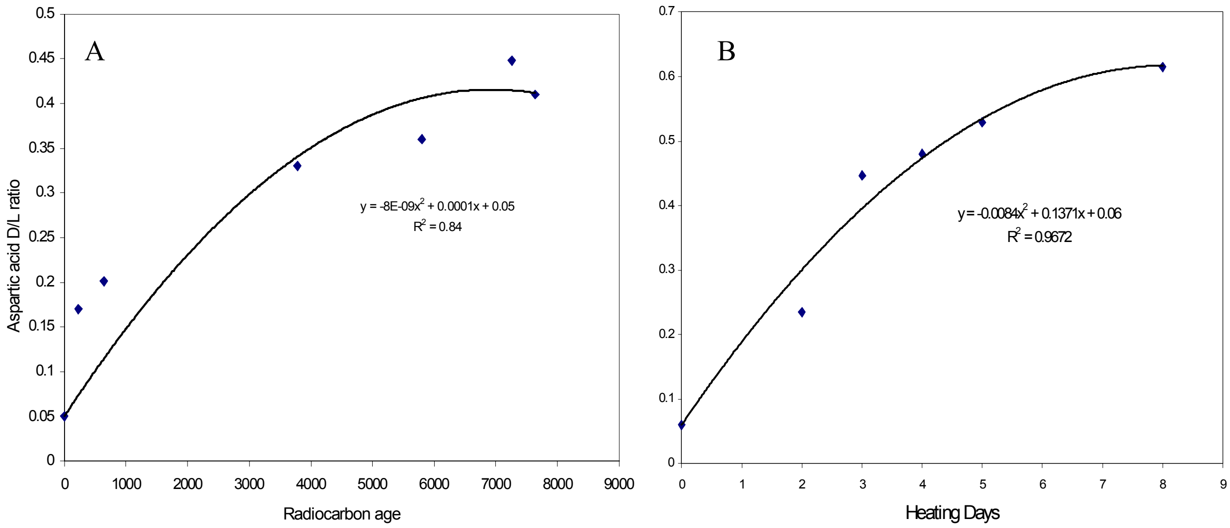

Figure 2. *N. trigonella* radiocarbon dating and aspartic acid dating techniques on the same sample. 2b: Kinetic trend observed in heating experiment conducted on *N. trigonella.*

$$t = [(D/Ls - D/Lm) / Mc]^2$$

where:

- *t* is age
- D/Ls is the average D/L ratio of the sample of unknown age
- D/Lm is the D/L ratio for a modern sample of the same species as D/Ls, and
- Mc is the slope

Using the above formula, a total of twenty-eight aspartic ages calibrated by the radiocarbon method were determined

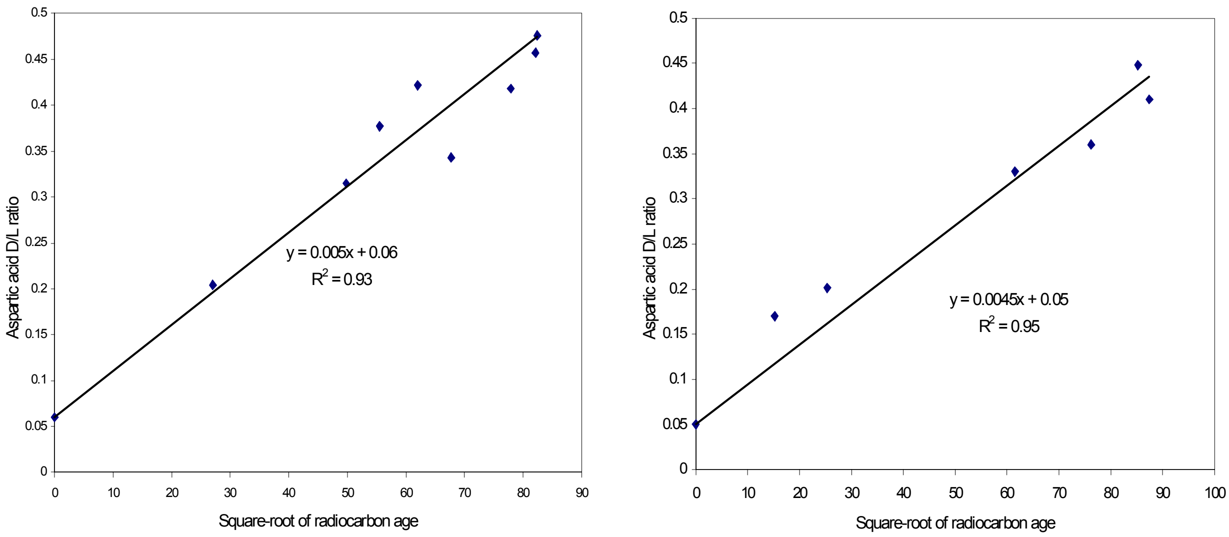

Figure 3. Square root of radiocarbon age plotted against D/L ratio of equivalent sample observed in A) *Anadara trapezia*; and B) *Notospisula Trigonella*

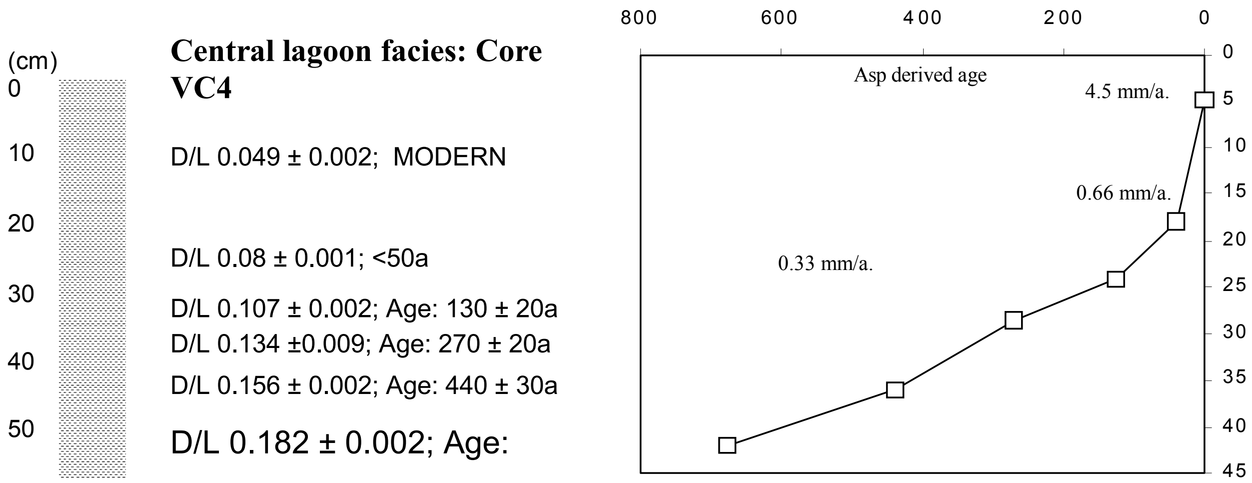

Figure 4. A) Asp D/L ratio and calculated age down core from central lagoon facies, Lake Illawarra. B) sedimentation rates calculated for the central lagoonal facies

to establish a geochronology for the Holocene sedimentary successions of Lake Illawarra.

When examined within a lithostratigraphic framework, racemisation data permit the comparison of pre- and post-European sedimentation rates for Lake Illawarra (Fig. 4a & b). For example, sedimentation rates using the top 50 cm of a core collected from the central lagoon of Lake Illawarra have been calculated using Asp-derived ages obtained from *in situ N. trigonella*. The results indicate that the rate of sedimentation was ca 0.33 mm/a for 500 years prior to European settlement. The period between 130 and ca 50 years BP, which corresponds with primary land clearing for agricultural development, shows an increase in sedimentation rate to 0.66 mm/a.

The period from 50 years ago to the present, corresponding with an increase in urban and industrial development within the Lake Illawarra catchment, shows a dramatic increase in sedimentation rate to 4.5 mm/a, however, some of this can be attributed to lower compaction within the upper portion of the core (Fig. 4).

References

Goodfriend G.A. (1991). *Patterns of racemization and epimerization of amino acids in land snail shells over the course of the Holocene.* Geochimica et Cosmochimica Acta, 55, 293-302.

Goodfriend G.A. (1992). *Rapid racemization of aspartic acid in mollusc shells and potential for dating over recent centuries.* Nature, 357, 399-401

Goodfriend G.A., Hare P.E., Druffel E.R.M. (1992). *Aspartic acid racemization and protein diganesis in corals over the last 350 years.* Geochimica et Cosmochimica Acta, 56, 3847-3850.

Goodfriend G.A., Brigham-Grette J.B., Miller G.H. (1996). *Enhanced age resolution of the marine quaternary record in the artic using aspartic acid racemization dating on bivalve shells.* Quaternary Research, 45, 176-187.

Goodfriend G.A., Stanley D.J. (1996). *Reworking and discontinuities in Holocene sedimentation in the Nile Delta: Documentation from amino acid racemisation and stable isotopes in mollusk shell*. Marine Geology, 129, 271-283.

Mitterer R.M., Kriausakul N. (1989). *Calculation of amino acid racemization ages based on apparent parabolic kinetics*. Quaternary Science Reviews, 88, 353-357.

Murray-Wallace C.V. (1993). *A review of the application of the amino acid racemisation reaction to archaeological dating*. The Artefact. 16, 19-26.

Murray-Wallace C.V. (2000). *Quaternary coastal aminostratigraphy: Australian data in a global context*. In: Goodfriend G.A., Collins M.J., Fogel M.L., Macko S.A., Wehmiller J.F. (eds.). *Perspectives in Amino Acids in Amino Acid and Protein Geochemistry*, pp.279-300. Oxford University Press, Melbourne.

Murray-Wallace C.V., Kimber R.W.L. (1987). *Evaluation of the amino acid racemisation reaction in studies of Quaternary marine sediment in South Australia*. Australian Journal of Earth Sciences, 34, 279-292.

Murray-Wallace C.V., Kimber R.W.L. (1993). *Further evidence for apparent 'parabolic' racemization kinetics in Quaternary molluscs*. Australian Journal of Earth Sciences, 40, 313-317.

Rutter N.W., Blackwell B. (1995). In Rutter N.W., Catto N.R. (eds), D*ating Methods for Quaternary Deposi*ts, pp. 125-164. Geological Association of Canada, Toronto.

Wehmiller J.F. (1982). *A review of amino acid razemisation studies in Quaternary mollusks: stratigraphic and chronological applications in coastal and interglacial sites, Pacific and Atlantic coasts, United States, United Kingdom, Baffin Island and Tropical islands*. Quaternary Science Reviews, 1, 83-120.