Origin, Formation and Environmental Significance of Sapropels in Shallow Holocene Coastal Lakes of Southeastern Australia

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ABSTRACT

Many shallow, groundwater-fed lakes along the Coorong coastal plain of southeastern South Australia contain sapropelic sediments within their Holocene calcareous mudstone successions. The deposition of similarly organic-carbon-rich sediments in marine and deep-lake settings commonly has been linked to times of wetter regional climate. Increased precipitation boosted surface runoff and tributary flow, thereby increasing the input of terrestrial organic matter and nutrients to the depocentre and potentially causing stratification of its water column. The principal effect of increasing the nutrient supply is to promote aquatic productivity, which can in turn lead to oxygen-depletion of the bottom waters and enhanced preservation of sedimentary organic matter.

The three lakes of the present investigation, North Stromatolite Lake (NSL), Old Man Lake (OML) and Lake Amy (LA), are shallow and have become increasingly ephemeral over time, yet they have continued to accumulate sapropelic intervals with high concentrations of autochthonous algal and bacterial organic matter within their sedimentary successions. NSL and OML are charged by westward-flowing saline continental groundwater that is forced toward the land surface as it rises over an underlying wedge of denser, intruding seawater. In contrast, the more elevated LA is the surface expression of a local perched water table high in the Robe Range. No permanent streams enter these lakes, nor are there any present-day surface connections with the marine system. Therefore, they represent a distinctly different aquatic environment to those in which sapropels have previously been studied. This means that traditional models of sapropel formation cannot explain the Coorong lacustrine examples and this study adds a new perspective to the dynamics of sapropel genesis.

Lacustrine sedimentary sequences represent one of the most refined archives of environmental change presently available for investigation. While bulk sedimentary geochemistry has been successfully employed to document palaeoenvironmental changes in a broad range of settings across the globe, it has not yet been widely used in the study of shallow, ephemeral lakes in Australia. Nonetheless, the elemental, molecular and isotopic analysis of sedimentary organic matter and carbonate can greatly aid palaeoenvironmental reconstructions. The present study explores the extent to which the application of bulk geochemical analyses (TOC, C/N, ^{14}C, $\delta^{13}C_{org}$, $\delta^{15}N$, $\delta^{13}C_{carb}$, $\delta^{18}O_{carb}$, ^{13}C-NMR) to the sediments of these coastal lakes reveals the Holocene environmental change that is already established for the region.

Radiocarbon dating (and correction for a local reservoir effect) indicates that sapropel deposition in NSL took place from ~6000 to ~4700 cal yr BP. Since this time the NSL basin has been accumulating organically-lean (TOC<1%) carbonate sediments. Episodic sapropel deposition recorded in the stratigraphic succession of OML ceased as recently as ~2200 cal yr BP and at LA ~1800 cal yr BP, thereby indicating that nutrient delivery or recycling continued to promote sapropel formation in these southern lakes for at least 2500 years longer than 200 km to the north, at NSL.

^{13}C-NMR analysis indicates that the sedimentary organic matter preserved in all three lakes is rich in carbohydrate and protein, and thus largely autochthonous. This agrees with the findings of previous biomarker studies of NSL and OML which indicated that their organic matter was derived mainly from lacustrine photoautotrophs, augmented by minor contributions from allochthonous terrestrial biomass. Therefore, the elemental and isotopic signatures of their organic matter, and that in LA, are considered to primarily reflect lacustrine conditions and processes, rather than alterations to the terrestrial ecosystem of their hinterland. Higher C/N ratios than those typical of algae and bacteria are interpreted as reflecting conditions of either nitrogen-deficiency or a nutrient abundance, the latter promoting primary productivity in the epilimnion and leading to oxygen depletion in the hypolimnion and preferential degradation of nitrogen-rich proteinaceous organic matter. $\delta^{13}C_{org}$ values around –20‰ reflect the photosynthetic use of bicarbonate by these aquatic biota and indicate variations in the extent of lacustrine productivity and respiration. A contribution from aquatic macrophytes, such as *Ruppia* sp., may account for some of the mixed source affinity suggested by the $\delta^{13}C_{org}$ values of these lakes. $\delta^{15}N$ values provide information on shifts in the phytoplankton and heterotroph assemblages that may be related to changes in the trophic state of the lake waters. $\delta^{13}C_{carb}$ values indicate periods of enhanced microbial contribution to the sedimentary biomass thus aiding the interpretation of secular $\delta^{13}C_{org}$ changes. $\delta^{18}O_{carb}$ values tend to increase up section in line with evaporation of shallowing lake waters in a progressively drier late Holocene regional environment.

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