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Sea level and the carbonate sand factory of South Australia

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Abstract
Stable parts of the South Australia coast show that the last interglacial sea level was 2 m higher than present, but elsewhere there has been relative subsidence up to 7 m and uplift of 18 m. Estimates of changing sea level, and future projections, should state the time period involved and the tectonic background to be of any use. The coast contains 'carbonate sand factories' where organisms produce vast amounts of sand by fixing carbon dioxide as carbonates. Far from dissolving carbonate by acidification, carbon dioxide is an essential part of carbonate production and the continued maintenance and growth of coasts and reefs. Government policies to adapt renewable energy are unlikely to affect the system.

Keywords
sea level, carbonate production, renewable energy

Two areas of argument about climate change are sea level and 'acidification' of oceans. Important data on these topics come from an unexpected source, a new book about the coast of South Australia.[1] It is essentially about coastal geomorphology and includes topics such as tectonics, coastal processes, coastal management and human impacts on coasts that are not relevant here. This brief note presents, largely in their own words, what the authors have to say about aspects of sea level and carbonate production, which is very relevant to 'acidity' of oceans.

Sea level

The South Australian coast originated with the separation of Antarctica and Australia about 43 million years ago, but the continental margin is well to the south of the present coast. During higher sea levels of the Late Eocene (37 to 34 Ma), the coast lay several 100 kilometres landward of its present location.

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Some parts of the South Australian coast are exceptionally stable, while other parts have moved up and down as a series of fault blocks. The stable parts give a fairly simple record of sea level change, which can be used to work out the relative movements of the moving parts. The Last Interglacial (130–118 ka ago) shoreline stood ~2 m higher than present sea level on the stable parts. Sediments deposited at that time are called the Glanville Formation. For example, fringing the coast of Eyre Peninsula on the stable Gawler Craton, the Glanville Formation lies at 2 m above present sea level. Elsewhere, it has been tectonically modified. It is depressed −7 m at Port Adelaide: uplifted on Fleurieu Peninsula (+10 m at Normanville; +6 m at Victor Harbor); depressed at Goolwa (−0.8 m) in the Murray Estuary and progressively uplifted on the Coorong Coastal Plain to a maximum of +18 m near Mount Gambier.

The Glanville Formation contains inter-tidal, warm water fauna, including the mollusc *Anadara trapezia* (now locally extinct) which shows that at the time of the high sea level, the temperature was warmer than at present, as would be expected.

At the height of the Last Glacial Maximum, some 22,000 years ago, sea level was about 125 m below the present level. Large areas of continental shelf were exposed as dry land, and strong winds blew sediment inland. After that sea level rose and reached present levels about 7000 years ago.

In modern debates on changing sea level (and its possible relationship with changing atmospheric carbon dioxide content) too much is made of very short time scales. Some extreme calculations of world sea level changes have been based only on satellite information, which covers a miniscule amount of time but can be used to reach alarming conclusions. To understand what is happening anywhere you need to know the long-term tectonic situation, and then see what modern changes may be happening. In South Australia, there were seven long-term tide gauges, two of which have been closed.

> The tide gauges, sited in different geological settings, are affected by varying geological, isostatic and anthropogenic inputs, which can be corrected to produce more reliable global sea level indicators. If mean sea level trends are established purely on tide gauge data for the seven stations, there are large differences. For example at Port Pirie the data show a fall in sea level of 0.19 mm/yr, whereas Outer Harbour reveals a rise in sea level of 2.27 mm/yr.

They provide a table of sea level trends for the 'seven tidal stations adjusted for geologic, isostatic and anthropogenic impacts'. The adjusted sea level trends are all positive, and less than 1 mm/yr.

Any discussion of sea level rise should indicate the time period involved, and any estimates of future sea level rise should indicate what prior history has been taken into account. The presentation of South Australian data in this book is a fine example of how it may be done.

The carbonate sand factory

Apart from bedrock areas the coasts are dominated by carbonate sands in the form of beaches and dunes. At many points in the book the authors refer to the 'carbonate factory' that produces carbonate sand, and even claim that the South Australian coast is '... part of the world's largest temperate carbonate factory'.

> The sources of the sediment for these coastal successions were the Lacepede and Bonney Shelves, which represent a subtidal carbonate factory with the prolific growth of calcareous marine

> invertebrates such as molluscs, bryozoans, coralline algae, echinoids, and foraminifers. The *post mortem* attrition of these organisms leads to the formation of sand-sized sedimentary particles of calcium carbonate.
> In Gulf St Vincent seagrasses thrive in the subtidal and intertidal shallow warm waters, with extremely productive calcareous algae, foraminifers and molluscan organisms manufacturing vast amounts of calcareous sediment. The accumulation of these . . . sediments has generated the resultant wide intertidal and supratidal flats visible today by causing the shoreline to aggrade (build up) and prograde (build seawards).
> The dominant processes of coastal development in the protected, tidally dominated waters of the northern Spencer Gulf are related to the massive production and accumulation of biogenic skeletal carbonate fragments derived from coralline algae, foraminifers, molluscs and bryozoans; the site is a 'major carbonate factory', sequestering much CO_2.

Furthermore, aeolianite dunes also depend on the process. 'The aeolianites are primarily composed of marine carbonate, reflecting the absence of streams delivering terrestrial, quartzose sediments to the coast'.

> The sand-sized particles of calcium carbonate derived from the mechanical abrasion of marine invertebrates were entrained landwards by inner-shelf currents, and subsequently brought on land by aeolian processes to form thick dune deposits, which are interbedded with relict soil profiles (paleosols) that formed during periods of lower sea levels. The presence of aeolianite reflects the prolonged history of aridity of the Australian continent and the paucity of terrigenous-clastic sediment delivered to much of the coastline of southern Australia.
> The coastline of South Australia is part of the world's largest aeolianite (dune limestone) temperate sedimentary carbonate province, which extends from western Victoria to north of Shark Bay, Western Australia. The aeolianite deposits attest to the high calcium carbonate bioproductivity of the surrounding continental shelf environments.

Furthermore, the carbonate sand is important even offshore:

> It has been demonstrated that the Murray Canyons Group [submarine canyons] is still being actively modified, with sediment transport to the oceanic deeps more than 100 km from the foot slope. Given the lack of river sediment supply, the marine carbonate 'factories' of the Lacepede Shelf provide the main supply of sediments for turbidity currents. Initially, canyon erosion involved mainly land-sourced sediment, with later cutting predominantly by biogenic carbonates produced on the continental shelf.

Implications

In the debates about Global Warming, now usually referred to with the less specific title Climate Change, the alarmists place much emphasis on the role of carbon dioxide. First its role as a greenhouse gas was supposed to cause warming. Then to demonise it further, it was supposed to cause 'acidification' of the oceans, despite the fact that the oceans have been alkaline throughout their existence on Earth. We are implored to reduce the production of anthropogenic carbon dioxide to 'protect' the ocean.

Yet, carbon dioxide is essential for all carbonate fixing organisms, and marine life flourishes, where CO_2 is abundant. Leaving South Australia for the moment Professor Walter Starck[2] wrote about the 'Bubble Bath' near Dobu Island, Papua New Guinea. Here, CO_2 of volcanic origin is bubbling visibly through the water so that the water is saturated with CO_2. Abundant life flourishes to make the spot a spectacular scuba diver's delight. He reported many accurate measurements of pH in the area and concluded 'It seems

that coral reefs are thriving at pH levels well below the most alarming projections for 2100'. It is quite possible that in much of the ocean the carbonate fixers are suffering CO_2 starvation to some extent.

The 'carbonate factories' described here show that carbon dioxide is vital for the production of carbonate sands and ultimately limestone, and of course for the formation of many past and presents coasts. It is part of the big geochemical picture: carbon dioxide originates from volcanic eruptions and is fixed by limestone formation. Trying to reduce the carbon dioxide content of the ocean by reducing emissions by human activities is not only futile, but if it could be done it would have harmful consequences on all the carbonate fixing animals and plants in the ocean, and ultimately on the shape of the continent. This conclusion is by no means restricted to South Australia. The Great Barrier Reef, like coral reefs all over the world, depends on corals and other plants and animals fixing carbon dioxide as part of their skeletons, and as part of the carbon cycle. Carbon dioxide in sea water does not dissolve coral reefs, but is essential to their survival.

Energy and carbon dioxide

Nevertheless, the South Australian Government is trying to reduce the production of carbon dioxide, as is the Government of the neighbouring State of Victoria, and the Australian Federal Government. In South Australia, they blew up their last coal-fired power station and now rely on wind and solar energy (plus back-up support from coal-generated electricity in Victoria). There are high economic costs in this decision, and there has already been one State blackout due to failure which proved damaging and expensive. To give one example, it was a $30 million blow to Whyalla steelworks. Molten steel was solidifying in four 180-tonne ladles and there were other problems in the plant which had 3500 tonnes of steel in various phases of production. The situation will get worse as South Australia will soon lose its coal-generated back up from Victoria, because that state plans to close Hazlewood, its last coal-fired generator. Back-up support is needed for the times when the wind does not blow and the sun does not shine. Referring to the South Australian blackout The Energy Policy Institute of Australia warned of '... the weakening of system security by allowing it to build up an excessive level of dependence on intermittent renewable energy'.

South Australia and Victoria see their actions in moving to alternative energy as a noble move to reduce carbon dioxide. Unfortunately, this action will have very little impact on real carbon dioxide reduction as Australia is only responsible for 1.5% of emissions worldwide. Nowadays, we can measure carbon dioxide by satellite, and it turns out that Australia is not a producer of excess carbon dioxide, but sequesters it.[3] GOSAT data show that Australia is one of the top sequestering countries in the world. Meanwhile, Australia is selling $3billion worth of coal a month for other people to burn, which adds to world production of carbon dioxide just as surely as if it were burnt in South Australia.

South Australia provides us with a fascinating ongoing experiment relevant to both environment and energy.

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Cliff Ollier was born in England and educated at Bristol University (B.Sc., D.Sc.). He spent most of his life in Australia as a geomorphologist, geologist and soil scientist. He is the author of 12 books including Weathering and over 300 scientific papers. He was employed by many universities including Melbourne, Australian National, Oxford, Papua New Guinea, East Anglia, and The South Pacific. He has travelled to over a 100 countries and lectured at over a 100 different universities.