A reconstruction of temperature, sea level and CO_2 over the past 20 million years

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Over the past 20 Million years, a set of 1-D ice-sheet models, forced with benthic $\delta^{18}O$ data, has been used to reconstruct a mutual consistent record of Northern Hemispheric (NH) continental mean temperature, sea level and marine $\delta^{18}O$. A comparison is made between temperature and several proxy based CO_2 records, from which it is shown that the Dome C, B/Ca and $\delta^{11}B$ records are consistent with modeled temperature data. A CO_2 record over the past 20 Million years is derived from a linear regression of temperature, indicating a gradual decline of only 120 ppmv over the past 15 Myrs. This decrease coincides with a cooling of the NH temperatures by 12 °C. The sensitivity of the climate system is therefore much higher over this geological period than for CO_2 induced changes during the present day climate as inferred from climate models.

Furthermore, we show that modeled sea level is roughly constant from 13 to 3 Myrs before present, as the Antarctica ice sheet is fully grown and major ice sheets in the NH are not yet developed. In addition, it is shown that the sea level (ice volume) response to temperature ($\Delta S/\Delta T$) varies through time, with the largest response found for the Antarctic ice sheet during the Oligocene to Early Miocene.

Moreover, the ice-sheet contributions to sea level and to $\delta^{18}O$ variations are examined with 1-D and with 3-D ice-sheet models. From these analyses it follows that the scaling factor of sea level to $\delta^{18}O_w$ is not constant, but closely approaches the generally assumed 100 m per 1.1 ‰ relation. Finally, we show that the critical assumption of a linear response of deep-water temperature to $\delta^{18}O$ variations holds for the commonly used paleotemperature equation.

Laboratory experiments on quartz cementation during burial of mudstone

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During diagenesis chemical compaction involves dissolution and precipitation of solids therefore changing petrophysical and seismic properties of the rock. The illitization of smectite results in formation of smaller and stiffer crystals influencing mudstone physical properties.

The dissolution of smectite releases significant amounts of silica and is replaced by illite. The released silica must be precipitated as quartz for the clay mineral reaction to proceed. The study of Thyberg *et al*. [1] reported direct petrographic evidence of fine-grained micro-quartz crystals (1–3 μm) as micro-pore-filling cement. The micro-quartz crystals have been found as discrete grains, short chains and small nests/clusters part of a larger inter-connected micro-quartz networks and interlocking aggregates of micro-quartz and clay crystals at the critical depth for pervasive micro-quartz formation (2500 m/80–85 °C). The formation of micro-quartz networks (quartz skeletons) and aggregates increase the rock density and strength.

Our experiments aimed at reproducing those observation in a controlled environment. Wyoming bentonites (WMB) were reacted with K-oxalate at 200°C, WMB and K-Feldspar reacted at 175°C and kaolinite and K-feldspar were reacted at 175°C for 3 to 4 weeks in batch reactors. The solution was sampled at regular intervals to record the chemical evolution of the fluid. Our results show the transformation of the smectite into K-feldspar in the experiments at 200°C and into illite, qtz and minor amount of K-feldspar in experiments conduced at 175°C. Both the neoformed K-feldspar and quartz precipitated in agregates, short chains and discrete grains.

[1] Thyberg *et al*. (2009) *Marine & Petroleum Geology*, in press.