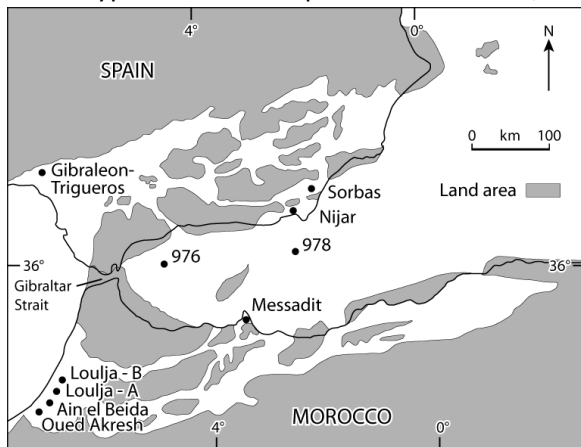


**Work Package 4: Evaluating environmental impact**  
**Work package coordinator, Paul Meijer, Utrecht**

There are four distinct, but related modelling strategies that will be applied in **Work Package 4**: (1) Box-modelling which explores the evolution of the Mediterranean's lithological and geochemical response to gateway change through time-dependent equations that express the conservation of salt and water and geochemical proxies such as Sr isotopes (e.g. Meijer, 2006; Topper et al., 2011). (2) The use of an ocean general circulation model to investigate the circulation patterns within the Mediterranean that result from double versus single gateway configurations; (3) Flexural modelling to evaluate the vertical motions resulting from loading (by evaporites) and unloading (through desiccation) of the lithosphere in and around Mediterranean (Govers et al., 2009). The flexural strength of the lithosphere results in the transfer of vertical movements outside the basinal area to adjacent coastal regions including sites of existing and past Atlantic-Mediterranean gateways (Fig. 1); (4) The application of General Circulation Models (GCMs) to evaluate the impact of gateway opening and closure on global climate (Lunt et al., 2008) and the repercussions of Mediterranean Outflow on thermohaline circulation in the North Atlantic.

Importantly, the modelling work package MEDGATE is not simply an add-on feature which allows the new constraints on gateway evolution to be tested. Modelling studies will be used both to provide important tests of the hypotheses developed from new data, and to guide the collection of new data itself.



*Figure 1 Map of the pre-Gibraltar Atlantic-Mediterranean gateways 5-10 million years ago and the location of the astronomically tuned sections to be used in this study.*

**M-1 Modelling gateway evolution and its impact on Mediterranean salinity and circulation** (Primary supervisor Paul Meijer, *Utrecht*; secondment to Bristol): This project has two components: (1) the mechanism of the Mediterranean-Atlantic exchange through time and (2) the role of tectonics and induced vertical motions.

Mechanism of the Mediterranean-Atlantic exchange through time: The objective of this part of the project is to complement the available geological/geochemical observations with the physics that govern gateway flow, in order to obtain a detailed quantitative understanding of the evolution of exchange between the Mediterranean and Atlantic prior to, during, and after the salinity crisis. This project will tailor existing box models to incorporate new geochemical proxies used in the MEDGATE programme. The existing box models will also be extended by implementing alternative, more realistic representations of the gateway exchange. Sensitivity analysis will be used to assess the feasibility of using the new proxies to test the various hypotheses. The new models serve to test interpretations and hypotheses based on existing and new observations. In addition, use will be made of oceanic general circulation modelling (OGCM) to address issues that lie beyond the reach of the simpler box models. An important question concerns the impact of the double-corridor configuration on Mediterranean circulation patterns. This builds on an on-going OGCM-based study of the single gateway situation and will address questions such as, what happens to the Mediterranean when you close one gateway? Does it make a difference to the Mediterranean which gateway you close? What triggers the transition from two-way flow to one-way flow and back again?

The role of tectonics and induced vertical motions: The evolution of both the gateway region and the basins accommodating the Messinian evaporites has been affected by tectonic activity and large-scale vertical motions induced by the deposition of these evaporites. In the gateway region these processes may have contributed to the restriction of the water exchange. In the basins these same processes could be responsible for some of the unconformities present within the sequence. The aim of this part of the project is to try and understand these aspects better, again from the vantage point of modelling. The role of tectonics in the region of the Atlantic corridors will be studied using finite-element models for the deformation of the lithosphere. Vertical motions—at the gateway but also elsewhere in the Mediterranean—as induced by deposition of the evaporites and sea-level lowering requires modelling the flexural response of the lithosphere. Evaporite deposition and the flexural response of the lithosphere may occur on the same timescale (a few thousand years) which makes it especially interesting to study their interaction in a time-dependent fashion.

**M-2 Modelling the impact of Late Miocene Mediterranean Outflow Water (MOW) on ocean circulation in the Atlantic** (Primary supervisors Dan Lunt *Bristol*; secondment to Utrecht): The significance of Mediterranean Outflow Water (MOW) in regulating global THC today remains contentious (Artale et al., 2002; Bigg and Wadley, 2001; Chan and Motoi, 2003; Mariotti et al., 2002; Mauritzen et al., 2001) and no consensus has been reached over how MOW interacts with the formation of North Atlantic Deep Water. Insight into the important mechanisms can be gained by investigating long-term changes (timescales of millions of years) as reconstructed by isotopic analysis of ancient marine sediments. This project will build on on-going research in Bristol to explore the impact of the changing physical properties of MOW on global climate on long timescales. Nd isotopes will be added to the GENIE climate model (e.g. Lenton et al., 2007) as an ocean tracer, to allow comparison with isotopic proxy records. Initially, a suite of 'snapshot' simulations will be carried out, every 1 million years. This will allow us to test the resulting predictions for the flow pathways of Mediterranean-sourced water in the Atlantic with existing and new analytical isotopic data. A major part of the project will also involve exploring the sensitivity of these initial results to uncertain parameters in the model, such as ocean diffusivity, or uncertain boundary conditions, such as gateway configuration. The results will also be evaluated by comparing the snapshots with results from higher resolution state-of-the-art models, HadCM3 and HadGEM2 (e.g. Collins and al, 2008) - models used in the forthcoming IPCC fifth assessment report.

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