Sedimentologika

10.57035/journals/sdk.2026.e42.2550

Straits: stargates for the future

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CRediT statement: *Writing-original draft*: DC, SGL. *Writing-review & editing*: DC, SGL.

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Abstract

The current economic and geopolitical scenario, once again, indicates straits as the focus of international headlines. These narrow passageways have an impact on the global economy, but foremost they are ecological, environmental and geological elements fundamental for the future of Earth and its environments. A better understanding of their role, evolution and peculiarities is needed.

Opinion Piece

Executive Editor
Stéphane Bodin

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Copy Editor
Elizabeth Mahon

Received: 2026-06-08
Accepted: 2026-07-22
Published: 2026-08-04

Keywords
straits
geologic evolution
geopolitics

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Plain language summary

We need a better understanding of these narrow waterways known as straits, not only because they currently make headlines due to global trade concerns, but also because protecting their unique health is essential for the natural world and Earth's future environments.

1 Straits: natural systems in a global scenario

Straits are natural systems of remarkable geological, natural, economic, and geopolitical value. However, they are overlooked when compared to other depositional environments and ecological systems identified as socially important within the scientific community (e.g., deltas and deep-water areas; Anthony et al., 2024; Kane et al., 2020). Straits struggle to be recognised as stand-alone depositional environments, and they have recently been ignored in the new edition of what is widely considered one of the most influential sedimentology books (Levell, 2026). Although recent attempts at spreading a common nomenclature and reference hydrodynamic and depositional models (Hernández-Molina et al., 2026; Longhitano, 2025; Longhitano & Chiarella, 2020; Rossi et al., 2023a, 2023b), studies on straits are sparse, restricted to specific case studies, or subsumed to broader, well-established depositional environments, losing their characteristics as individual, complex, and dynamic sedimentary systems. This makes it difficult to assess the variety of environmental issues that impact strait equilibrium, including not only geological processes, such as sedimentary dynamics, subaqueous landslides and erosion, active tectonics, volcanic eruptions, seismicity, etc., but also anthropogenic activity, such as the impact of military and geopolitical actions on the straits, natural environment, or the development of infrastructures like submarine cabling or energy farming. In science, straits are ecological, environmental, and geological elements characterised by narrow passages of water linking marine areas separated by extensive landmasses. Like a 'Stargate', straits are natural bridges transferring what passes through them to another point, and their geographic distribution can be responsible for political tensions (Figure 1). Straits also have an impact on climate change, controlling the exchange of water masses, migration of terrestrial and marine species, and distribution of microplastics, with impact at the global scale (Chiarella & Hernández-Molina, 2021; Flecker et al., 2015; Hernández-Molina et al., 2022; Hill et al., 2022; Nicholls & Russell, 1990; Pierdomenico et al., 2019). From a naturalistic viewpoint, straits can be regarded as one of the high-risk areas for whale sharks to be killed in collision with ships (Womersley et al., 2023), or for the environmental consequences of oil spills related to oil tanker collision due to military-grade spoofers interfering with the GPS of ships (Pandi-Perumal & Saravanan, 2026). Furthermore, straits could be important to produce renewable energy related to turbines capable of generating power from tidal flows (Cossu et al., 2021), but this aspect raises the need to implement our knowledge on the stability of their rocky substrates and mobile bottoms to minimise risks related to turbine anchorage. Although geological characterisations of modern and ancient straits are patchy, recent studies started to define the distribution of sediments and depositional facies in a continuum setting from margin to the deeper areas (Longhitano, 2013, 2025; Longhitano & Chiarella, 2020 and references therein), indicating several modern and ancient straits as reference case studies (Figure 1). Among them, two straits that have recently attracted considerable international attention due to their strategic importance in the ongoing economic, military and political tensions, are the Strait of Hormuz and the Bab-al-Mandeb strait (Figure 2).

The Strait of Hormuz and the Bab-al-Mandeb strait connect the Persian Gulf and the Red Sea to the Indian Ocean respectively (Figure 2). In the current economic and geopolitical scenario, they are the focus of international headlines as they represent two of the world's most important routes for global seaborne shipments located in economically and militarily strategically vulnerable areas. In particular, the Strait of Hormuz is currently a critical area because it represents the political border between Iran and Oman – the control of which is disputed between Iran and the USA, while the closure of the Bab-al-Mandeb strait is under threat by Houthi and Iranian officials.

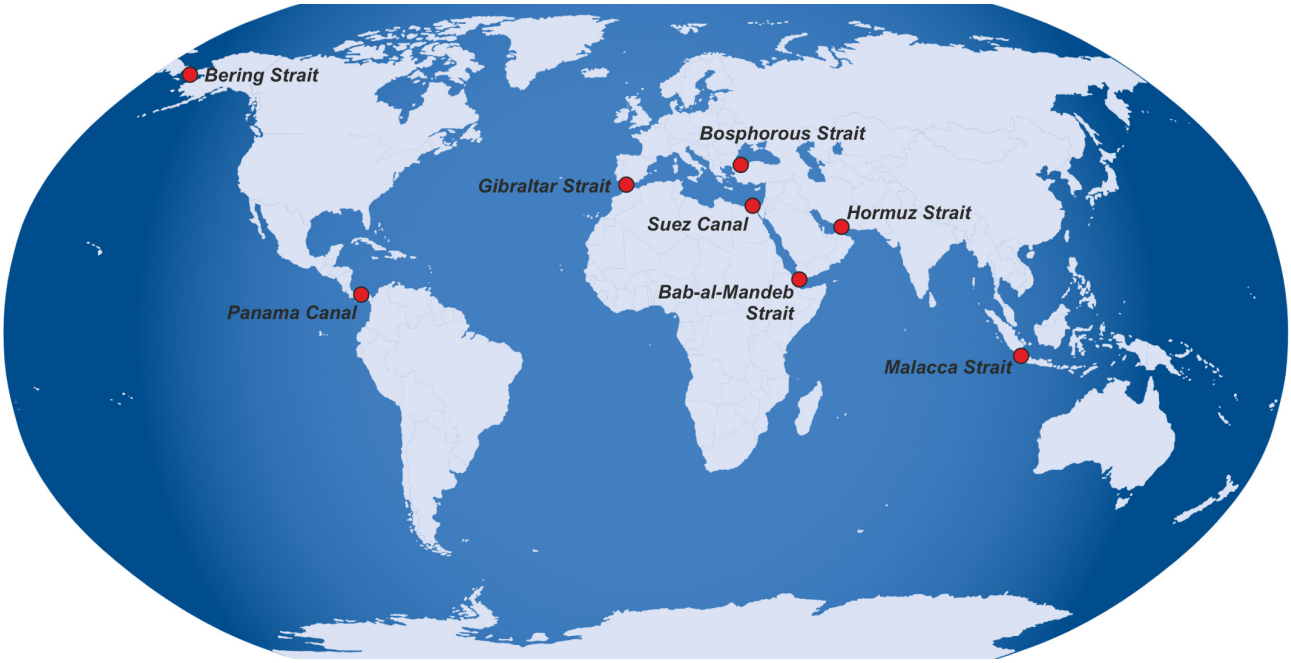

Figure 1 – Overview of main strategic straits for climatic, marine, political and economic purposes.

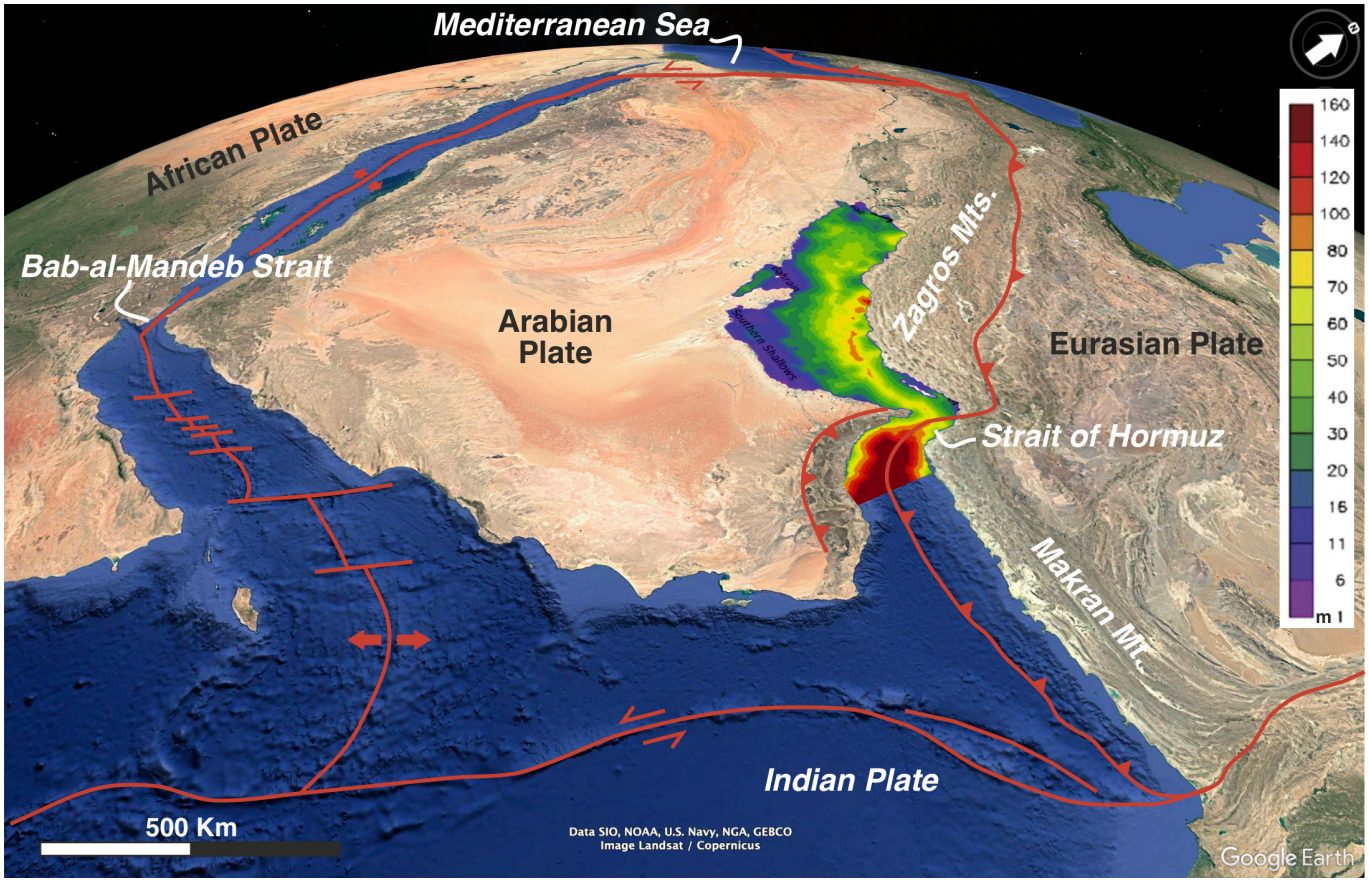

Figure 2 – Regional map of the Arabian Plate and surrounding areas controlling the evolution of the Bal-al-Mandeb and Hormuz straits. Bathymetry of the Strait of Hormuz and related colour scale bar is after Hosseini et al. (2025).

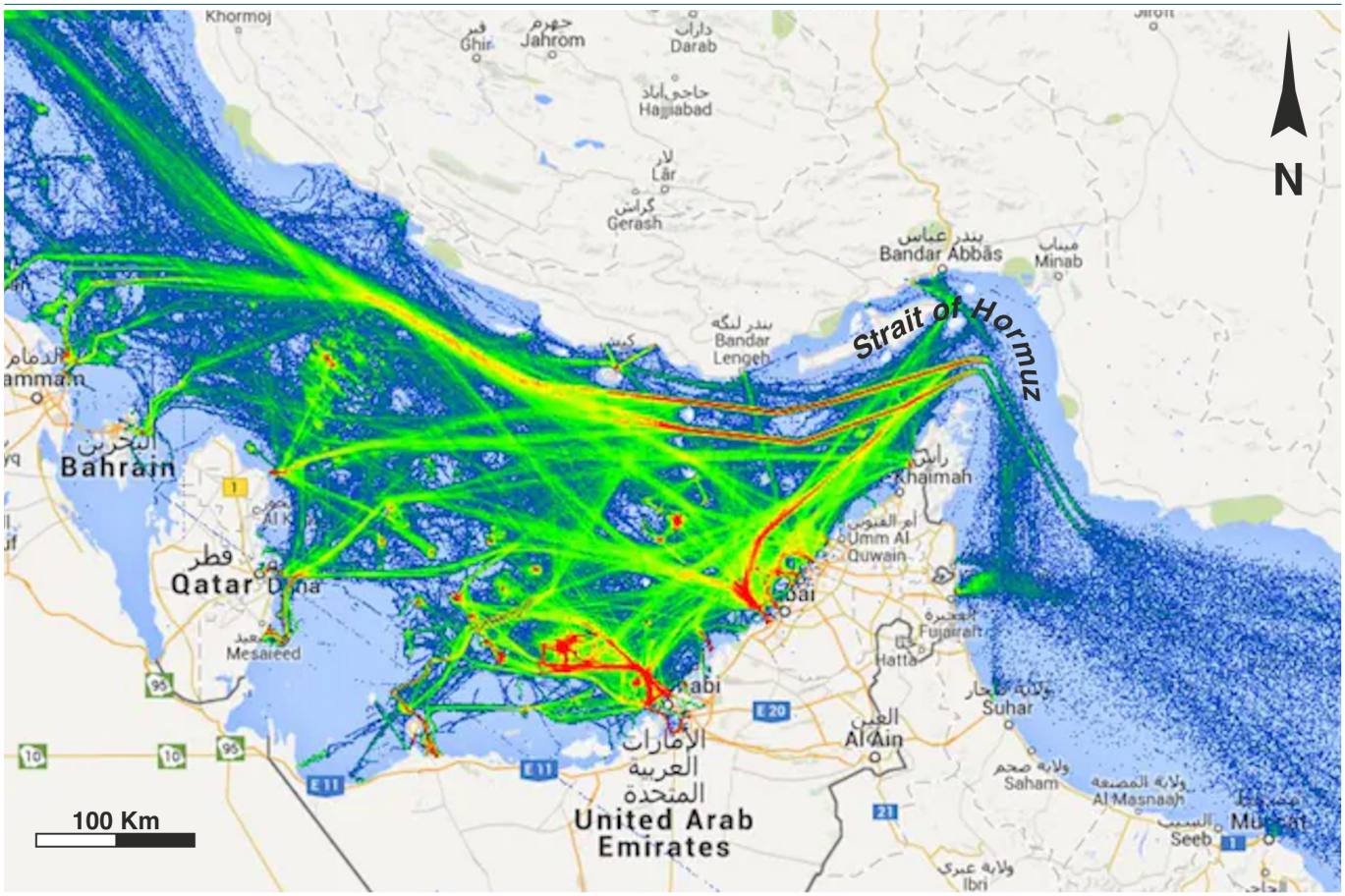

Figure 3 – Ship traffic density map of the Strait of Hormuz (From www.marinevesseltraffic.com).

1.1 The Strait of Hormuz in the sedimentological context

From a geological point of view, the Strait of Hormuz formed during the closure of the ancient Tethys Ocean, whose seabed units have been deformed until recent times by the tectonic activity of the Zagros and Makran thrust-and-fold belts accreted between the Arabian and Eurasian plates (Figure 2; Khalil & McClay, 2001; Powers et al., 1966; Scharf et al., 2025). The seismicity of the area, with frequent earthquakes related to the movements of the colliding Arabian and Eurasian plates, adjacent to the margins of the African, and Indian plates, has the potential to rapidly and unpredictably alter the morphology of the seabed. A seismic event of significant magnitude could trigger underwater landslides that would suddenly move large volumes of sediment over specific areas, making current nautical bathymetric data obsolete within hours. From an oceanographic perspective, the deepest portion of the Strait of Hormuz is characterised by dense, warm, and hypersaline waters produced by intense evaporation from the Persian Gulf, which flows towards the Gulf of Oman and, from there, towards the Indian Ocean. This hydrodynamic asymmetry is the main mechanism governing the distribution of seabed sediments and, consequently, the safe navigability of the strait in the medium and long term (Figure 3).

Sedimentological models of the Strait of Hormuz developed since the 1980s show sediment distribution is closely related to the intensity of bottom currents (Figures 2 and 4). The access channels to the main oil terminals, such as Larak, Sirri, and Kish along the Iranian side, pass through areas where the sedimentation rate is very high (Al-Ghadban et al., 1998). Periodic dredging operations are needed to maintain the seabed at depths suitable for the navigation of loaded oil tankers having a draft (i.e., depth of the vessel below the waterline) up to 30 m. Accordingly, a prolonged interruption of dredging operations related to political tensions could result in the progressive silting up of the canals and a reduction in transit capacity regardless of any political or military action. In this context, the geological and geopolitical frameworks are intertwined. From a hydrodynamic point of view, the Strait of Hormuz behaves as a two-layer, estuarine-type exchange system (Pous et al., 2015). The relatively fresher Indian Ocean surface

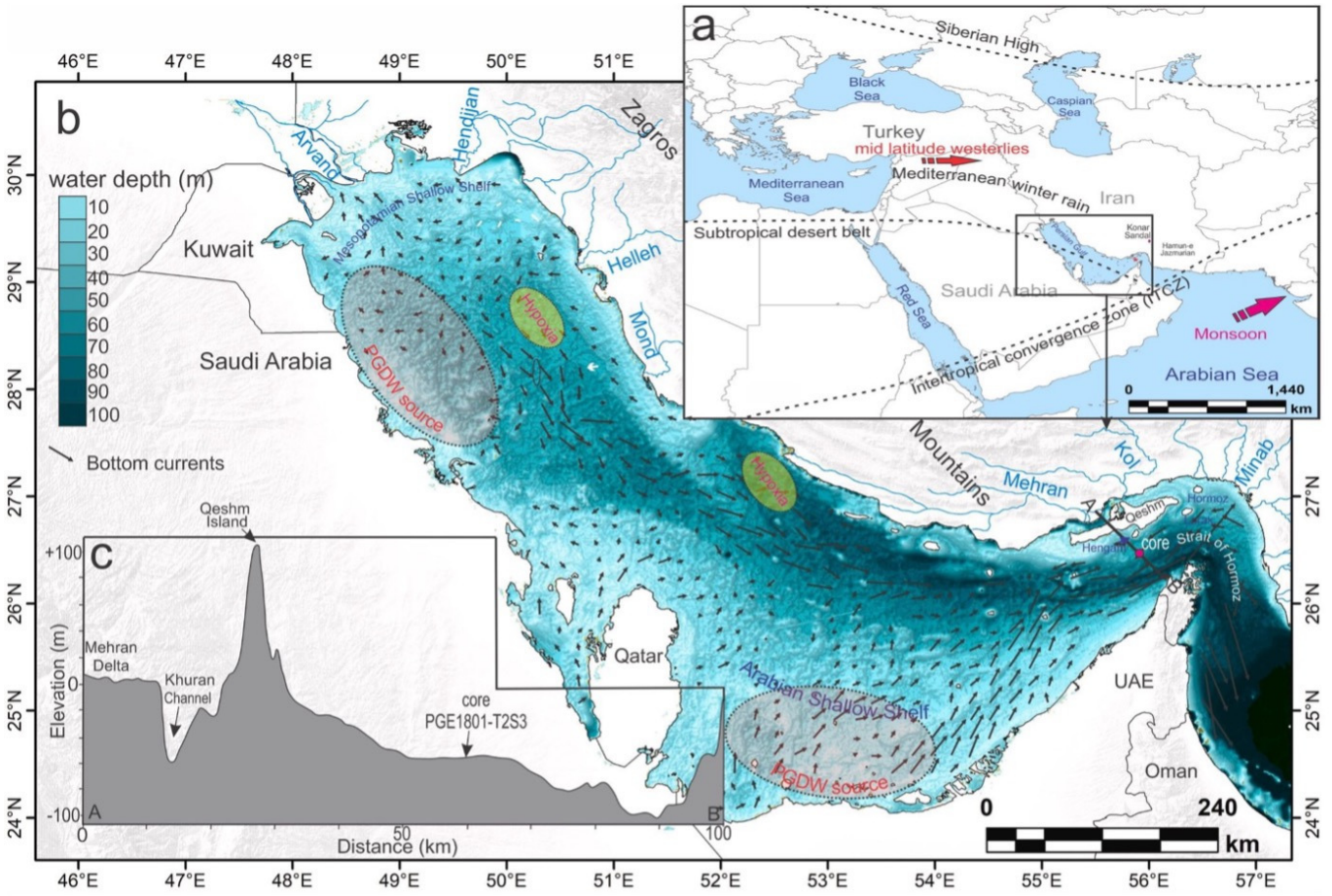

Figure 4 – **(a)** Regional location of the Strait of Hormuz in the Arabian Peninsula. **(b)** Circulatory pattern in the Persian Gulf, where black arrows indicate current patterns of dominant bottom currents. **(c)** Morpho-bathymetric cross section showing the major bottom features (after Pous et al., 2015).

water enters the Persian Gulf, while a denser, warm and hypersaline bottom current, produced by intense evaporation within the Gulf, exits toward the Gulf of Oman (Hosseini et al., 2025). Superimposed on this residual density-driven circulation, semidiurnal and diurnal tidal currents flow through the strait, locally exceeding 1 m s^{-1} along its western margin (Hosseini et al., 2025). The combination of a persistent density-driven asymmetry and strong, tidally modulated bottom shear stress exposes the seafloor to high and spatially variable current energy: within the strait axis and along its deepest channels this favours winnowing and removal of fine-grained particles, whereas lower-energy sectors and the access channels to the Iranian oil terminals act as depocentres where suspended fines and terrigenous material preferentially accumulate (Al-Ghadban et al., 1998). This hydrodynamic asymmetry is therefore the principal control on the present-day distribution, reworking, and long-term stability of the seabed sediments of the strait.

Consistent with this hydrodynamic framework, modern surface sediments of the Strait of Hormuz define a coarse-grained, current-swept depositional pattern that contrasts with the finer, better-sorted silty deposits of the central Persian Gulf basins (Jalali-Nezhad et al., 2024). Surface-sediment surveys show that the strait and the adjacent south-eastern gulf are dominated by poorly to very poorly sorted silty sand and, locally, gravelly, muddy sand rich in shell fragments and relict coarse particles, a signature attributed to winnowing of fine material by the high-energy, density-driven bottom outflow described above (Hamzeh et al., 2021). Sediment cores recovered within the strait corroborate this current-dominated control at depth, recording grain-size and magnetic-susceptibility variations that track fluctuations in the intensity of the Persian Gulf deep-water outflow through the Holocene. The sedimentation rate has been calculated on the order of a few tenths of a millimetre per year during phases of reduced bottom-current energy (Hamzeh et al., 2021). At the seabed, this energetic regime is expressed by mobile sandy

Figure 5 – ESRI satellite image of the Qeshm Island in the northern Strait of Hormuz (after EMODnet Bathymetry Consortium, 2024). Lighter marine areas correspond with fields of subaqueous bedforms, most of which are elongated in the same direction as bottom currents, indicating highly mobile strait bottoms.

bedforms, tidal sand ridges and dunes typical of tide-dominated straits, particularly evident in the northern Strait of Hormuz, where Qeshm Island forms a minor strait into the larger strait (Figure 5).

Bedform migration and internal grain-size sorting, coarser and better winnowed at the crests versus finer and muddier in the troughs, are continuously reworked by surficial waves and bottom currents, delineating sedimentary dynamics consistent with reference depositional models proposed for modern and ancient tidal straits (Longhitano, 2025; Longhitano & Chiarella, 2020).

1.2 Straits at the crossroads between geopolitics and geoscience

Now more than ever, straits are under the spotlight due to military and piracy acts, and their closure puts pressure on the global economy (Al-Sarihi, 2026). However, their role and importance for our planet go beyond these disputes, and citizens and scientists should recognise their value and promote research projects aiming to better understand their dynamics, and preserve their natural peculiarities. In this context, sedimentological studies based on different ancient and present-day straits are crucial to better define and predict sediment dynamics and evolution through time. When a natural hotspot becomes military and geopolitical, usually the natural aspects are the losers. Will we be able to dispel this myth?

Acknowledgements

The authors thank Stéphane Bodin for handling the submission and providing critical suggestions that improved the paper.

Data and code availability

Data used to draw figures in this opinion piece are available via the appropriately cited reference for that figure.

Conflict of interest statement

Domenico Chiarella is co-founder and member of the steering committee of Sedimentologika.

Artificial intelligence use statement

All research, analysis, writing, and editing were performed without generative AI assistance.

Funding

No external funding sources.

Citing this Opinion Piece

To cite this paper use the following information:

Authors
Domenico Chiarella, Sergio G. Longhitano

Title
Straits: stargates for the future

Short Title
Straits: stargates for the future

Publishing Information
Publication: Sedimentologika
Volume: 4
Issue: 2
Year: 2026
DOI: 10.57035/journals/sdk.2026.e42.2550
Language: en
License: CC-BY 4.0

References

Al-Ghadban, A. N., Abdali, F., & Massoud, M. S. (1998). Sedimentation rate and bioturbation in the Arabian Gulf. *Environment International*, *24*(1–2), 23–31. https://doi.org/10.1016/S0160-4120(97)00118-9

Al-Sarihi, A. (2026). How the war in Iran is reshaping the energy landscape. *Nature*, *651*(8107), 856–856. https://doi.org/10.1038/d41586-026-00932-y

Anthony, E., Syvitski, J., Văinescu, F., Nicholls, R. J., Cohen, K. M., Marriner, N., Saito, Y., Day, J., Minderhoud, P. S. J., Amorosi, A., Chen, Z. Y., Morhange, C., Tamura, T., Vespremeanu-Stroe, A., Besset, M., Sabatier, F., Kaniewski, D., & Maselli, V. (2024). Delta sustainability from the Holocene to the Anthropocene and envisioning the future. *Nature Sustainability*, *7*(10), 1235–1246. https://doi.org/10.1038/s41893-024-01426-3

Chiarella, D., & Hernández-Molina, F. J. (2021). Go with the flow: the role of gateway and straits on plastic distribution. *Geology Today*, *37*(2), 66–69. https://doi.org/10.1111/gto.12345

Cossu, R., Penesis, I., Nader, J.-R., Marsh, P., Perez, L., Couzi, C., Grinham, A., & Osman, P. (2021). Tidal energy site characterisation in a large tidal channel in Banks Strait, Tasmania, Australia. *Renewable Energy*, *177*, 859–870. https://doi.org/10.1016/j.renene.2021.05.111

EMODnet Bathymetry Consortium. (2024). *EMODnet Digital Bathymetry (DTM 2024)* [GeoTIFF,NetCDF,XYZ File]. EMODnet Bathymetry Consortium. https://doi.org/10.12770/CF51DF64-56F9-4A99-B1AA-36B8D7B743A1

Flecker, R., Krijgsman, W., Capella, W., De Castro Martíns, C., Dmitrieva, E., Mayser, J. P., Marzocchi, A., Modestou, S., Ochoa, D., Simon, D., Tulbure, M., Van Den Berg, B., Van Der Schee, M., De Lange, G., Ellam, R., Govers, R., Gutjahr, M., Hilgen, F., Kouwenhoven, T., … Yousfi, M. Z. (2015). Evolution of the Late Miocene Mediterranean–Atlantic gateways and their impact on regional and global environmental change. *Earth-Science Reviews*, *150*, 365–392. https://doi.org/10.1016/j.earscirev.2015.08.007

Hamzeh, M. A., Khosravi, M., Carton, X., Yarahmadi, D., & Safarkhani, E. (2021). Paleoceanography of the Strait of Hormoz and its link to paleoclimate changes since the mid-Holocene. *Continental Shelf Research*, *226*, 104507. https://doi.org/10.1016/j.csr.2021.104507

Hernández-Molina, F. J., Davoli, G., Stirling, E. J., Chiarella, D., & Viana, A. R. (2026). An introduction to oceanic gateways: modern and ancient analogues, and their conceptual and economic implications. In F. J. Hernández-Molina, G. Davoli, E. J. Stirling, D. Chiarella, & A. R. Viana (Eds.), *Oceanic Gateways: Modern and Ancient Analogues and their Conceptual and Economic Implications: Special Publications: 553*. The Geological Society of London. https://doi.org/10.1144/gslspecpub2026-43

Hernández-Molina, F. J., Hüneke, H., Rodríguez-Tovar, F. J., Ng, Z. L., Llave, E., Mena, A., Gibb, A., Chiarella, D., Sammartino, S., & De La Vara, A. (2022). Eocene to middle Miocene contourite deposits in Cyprus: A record of Indian Gateway evolution. *Global and Planetary Change*, *219*, 103983. https://doi.org/10.1016/j.gloplacha.2022.103983

Hill, J., Avdis, A., Bailey, G., & Lambeck, K. (2022). Sea-level change, palaeotidal modelling and hominin dispersals: The case of the southern Red Sea. *Quaternary Science Reviews*, *293*, 107719. https://doi.org/10.1016/j.quascirev.2022.107719

Hosseini, S. T., Stanev, E., Pein, J., Schrum, C., & Jacob, B. (2025). Tidal impacts on volume and salt transport through the Strait of Hormuz and on Persian Gulf salinity. *Ocean Dynamics*, *75*(11), 88. https://doi.org/10.1007/s10236-025-01735-x

Jalali-Nezhad, T., Masoumi, H., Dehghanian, M., & Tarrah, J. (2024). Textural and mineralogical characteristics of sediments originated from salt domes in the northern part of the Hormuz Strait. *Geosciences Journal*, *28*(6), 827–843. https://doi.org/10.1007/s12303-024-0025-1

Kane, I. A., Clare, M. A., Miramontes, E., Wogelius, R., Rothwell, J. J., Garreau, P., & Pohl, F. (2020). Seafloor microplastic hotspots controlled by deep-sea circulation. *Science*, *368*(6495), 1141–1145. https://doi.org/10.1126/science.aba5899

Khalil, S. M., & McClay, K. R. (2001). Tectonic evolution of the NW Red Sea-Gulf of Suez rift system. *Geological Society, London, Special Publications*, *187*(1), 453–473. https://doi.org/10.1144/GSL.SP.2001.187.01.22

Levell, B. (Ed.). (2026). *Reading's Sedimentary Environments: Processes, Facies and Stratigraphy* (4th ed.). Wiley.

Longhitano, S. G. (2013). A facies-based depositional model for ancient and modern, tectonically–confined tidal straits. *Terra Nova*, *25*(6), 446–452. https://doi.org/10.1111/ter.12055

Longhitano, S. G. (2025). Tidal strait depositional model revised. *Earth-Science Reviews*, *270*, 105250. https://doi.org/10.1016/j.earscirev.2025.105250

Longhitano, S. G., & Chiarella, D. (2020). Tidal straits: basic criteria for recognizing ancient systems from the rock record. In N. Scarselli, J. Adam, & D. Chiarella (Eds.), *Regional geology and tectonics: principles of geologic analysis* (2nd ed., pp. 365–415). Elsevier. https://doi.org/10.1016/B978-0-444-64134-2.00014-6

Nicholls, E. L., & Russell, A. P. (1990). Paleobiogeography of the Cretaceous Western Interior Seaway of North America: the vertebrate evidence. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *79*(1–2), 149–169. https://doi.org/10.1016/0031-0182(90)90110-S

Pandi-Perumal, S. R., & Saravanan, K. M. (2026). Marine life is a silent casualty of armed conflicts. *Nature*, *651*(8107), 1124–1124. https://doi.org/10.1038/d41586-026-00942-w

Pierdomenico, M., Casalbore, D., & Chiocci, F. L. (2019). Massive benthic litter funnelled to deep sea by flash-flood generated hyperpycnal flows. *Scientific Reports*, *9*(1), 5330. https://doi.org/10.1038/s41598-019-41816-8

Pous, S., Lazure, P., & Carton, X. (2015). A model of the general circulation in the Persian Gulf and in the Strait of Hormuz: Intraseasonal to interannual variability. *Continental Shelf Research*, *94*, 55–70. https://doi.org/10.1016/j.csr.2014.12.008

Powers, R. W., Ramirez, L. F., Redmond, C. D., & Elberg Jr, E. L. (1966). *Geology of the Arabian Peninsula: Sedimentary geology of Saudi Arabia* (Professional Paper No. 560; pp. D1–D147). United States Geological Survey. https://doi.org/10.3133/pp560D

Rossi, V. M., Longhitano, S. G., Olariu, C., & Chiocci, F. L. (2023a). Straits and seaways: controls, processes and implications in modern and ancient systems. In V. M. Rossi, S. G. Longhitano, C. Olariu, & F. L. Chiocci (Eds.), *Straits and Seaways: Controls, Processes and Implications in Modern and Ancient Systems: Special Publications: 523* (pp. 1–15). The Geological Society of London. https://doi.org/10.1144/SP523-2022-271

Rossi, V. M., Longhitano, S. G., Olariu, C., & Chiocci, F. L. (2023b). Straits and seaways: end members within the continuous spectrum of the dynamic connection between basins. In V. M. Rossi, S. G. Longhitano, C. Olariu, & F. L. Chiocci (Eds.), *Straits and Seaways: Controls, Processes and Implications in Modern and Ancient Systems: Special Publications: 523* (pp. 85–109). The Geological Society of London. https://doi.org/10.1144/SP523-2022-159

Scharf, A., Al-Kindi, M., & Racey, A. (2025). An introduction to geology, tectonics and natural resources of Arabia and its surroundings. *Geological Society, London, Special Publications*, *550*(1), 1–10. https://doi.org/10.1144/SP550-2025-5

Womersley, F. C., Loveridge, A., & Sims, D. W. (2023). Four steps to curb 'ocean roadkill.' *Nature*, *621*(7977), 34–38. https://doi.org/10.1038/d41586-023-02729-9