Natural (White) Hydrogen Potential in the Red Sea Region

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Abstract

This type of Natural “white” hydrogen is abundant and if economic resources are discovered, it could be viable alternative to fossil fuels and a credible option for achieving net zero emissions by 2050. It is produced and trapped by geological processes, and recent discoveries worldwide (e.g., Australia, Mali, France) have drawn attention to this clean energy resource. Natural hydrogen has been reported in several geological settings, including mid-ocean ridges, ophiolites, coal beds, gas fields, iron formations, kimberlite pipes, and deep wells in Precambrian rocks. However, most of the natural hydrogen leaks by diffusion, and is lost through abiotic or microbial consumption. So far, evidences of natural hydrogen have not been demonstrated in western Saudi Arabia. In this study, we focus on the possibilities of natural hydrogen generation and entrapment in the Red Sea basin based on our knowledge of its subsurface geology.

Three sources are known to generate natural hydrogen. (1) Radiolysis, a slow process in which water molecules are split by the radiation emitted from radioactive elements in rocks. (2) Serpentinization of mantle rocks that are exhumed in ultra-slow mid-ocean ridges. This is a fast and renewable process that occurs at low temperatures (200°C), resulting in the production of significant quantities of hydrogen. Lastly, (3) deep-seated hydrogen from the Earth’s core or mantle may ascend along tectonic plate boundaries or faults.

The Red Sea is mainly floored by oceanic crust, covered in part by an allochthonous sequence of massive salt and post-rift sediments. In the northern Red Sea where ultra-slow spreading occurs, indications of mantle exhumation in the Mabahiss Deep provide a very favorable environment for hydrogen generation. A few kilometers north, where the oceanic basement is fully blanketed by allochthonous salt and sediments, the hydrogen generated could be trapped below this regional seal. Moreover, between the Mabahiss deep and the Jeddah latitude, the apparent chaotic pattern of the magnetic anomalies reveals sub-sediment intrusions whose reactions with seawater could generate hydrogen, again potentially trapped by the abundant salt and anhydrites. Ultimately, the basement situated at the footwall of the rift faults bordering the basin comprises metamorphic rocks extensively intruded by felsic and/or mafic to ultra-mafic bodies of diverse ages. These intrusions have the capacity to generate hydrogen through processes like radiolysis or reactions between iron-rich rocks and groundwater. This structural setup bears resemblance to other locations, such as Western Australia and Mali, where evidences of hydrogen seepage ("fairy circles") have been observed and monitored. Nevertheless, unlike Australia and Mali, the widespread presence of salt and anhydrites in the Red Sea serves as an effective regional seal, that could explain the absence of surface evidences with potentially significant (economic ?) accumulations of hydrogen in the sub-surface.

The Red Sea region thus presents a conducive setting for the production and accumulation of hydrogen, making it an exciting prospect for future exploration.