Airborne Geophysical Technologies for Natural Hydrogen Exploration

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Abstract

Hydrogen (H2) is gaining recognition as a pivotal energy source in the world's transition to a low-carbon economy. Industrial manufacturing of H2 as fuel is focused on production from water (electrolysis by renewable electricity: Green) or methane (steam reformation: Blue). However, these processes consume large amounts of electricity or generate large amounts of CO2. Geologic, or natural H2 (white) has a lower carbon footprint than any manufactured H2 and requires minimal energy to produce. Natural H2 is generated in the subsurface and has been identified in 3 tectonic settings: a) extensional zones. b) compressional zones involving ophiolites (e.g., Oman). c) stable intra-cratonic basins. There are 3 hypotheses for natural H2 generation: 1) Slowest generation process is radiolysis, when trace radioactive elements in rocks emit radiation splitting water to produce H2. 2) Fast and renewable reaction is serpentinization, which occurs at high temperatures, when water reacts with iron- rich rocks. 3) Deep-seated H2, involving the degassing of H2 from Earth's core or mantle in flux streams rising along tectonic plate boundaries and faults. H2 is trapped differently compared to hydrocarbon gases, e.g., pore space is created in fractured basement during abiogenic reactions. Clay minerals and evaporites act as effective adsorbents, traps, and seals. Technologies from the O&G, mining and geothermal industries are used in natural H2 exploration. Natural H2 explorers are following these phases: 1) regional screening using satellite imagery to rank areas for further exploration, identify possible H2 seep indicators, such as alteration zones and fairy circles. 2) field work including geochemistry, and petrological studies. 3) airborne geophysical surveys to map fractures, fault systems, characterize lithologies and mineralogy, and identify alteration zones. 4) quantitative assessment to identify the elements of the potential H2 system (source, reservoir, trap, seal) and modelling (timing of generation, migration, and identification of accumulation zones). 5) drilling with specialized H2 detection equipment. This paper presents the airborne geophysical technologies used during the last 2 years by companies worldwide. Radiometrics maps cratons basement enriched in radiogenic elements (K, U and Th). Satellite images have limitations at some latitudes due to climatology, and therefore, large-scale geological mapping can be completed with airborne radiometric surveys. Gravity Gradiometry anomalies delineate lithology and fault zones where natural H2 is generated and trapped or is migrating. Magnetics maps hydrothermal alteration zones of ultramafic rocks (serpentinization). Electromagnetics (resistivity data) are useful to identify aquifers and high- porosity karst systems, which are temporary H2 reservoirs. These data are acquired simultaneously and are suitable exploration tools to image subsurface geology, however none of them can directly detect H2. Advances of the Xcalibur R&D project "Hydrogen mapping airborne spectrometer", or H-MAS, based on Raman spectroscopy combined with Light Detection and Ranging (LIDAR) methods to detect H2 from the air are also presented in this publication. Jointly with the geophysical mapping technologies, the H-MAS system will tighten the focus of exploration campaigns as a de-risking tool. Airborne Raman LIDAR spectroscopy could also solve the problem of leak detection from facilities and transport infrastructure.