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Remote Sensing using ArcGIS for White Hydrogen Reservoir Detection: Case Study of the Ginebra Ophiolitic Complex

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Story map & more info

Introduction

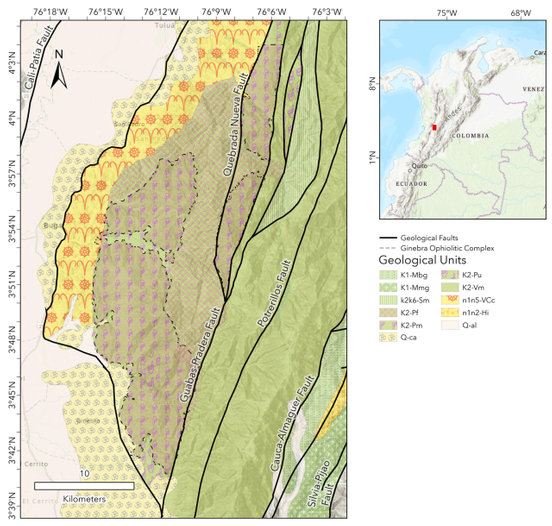


Figure 1. Geological map of the study zone. Modified from Gomez et al. (2020)

This study aims to identify areas with potential for hydrogen accumulation in the Ginebra Ophiolitic Complex (GOC) by integrating analysis of key geological processes in ultramafic rocks (radiolysis, **serpentinization(•)** and martitization) and remote sensing techniques. To define structural boundaries and characterize tectonic lineaments, such as faults and shear zones, which could act as geological traps for hydrogen. DEM and hillshade maps were used. Field data confirming hydrogen concentrations in hornblende gabbro samples were combined with multispectral analysis of a Sentinel-2 image calculating 10 vegetation indices (with emphasis on NDVI, GNDVI, SAVI, OSAVI and RDVI) to identify disturbed soils and degraded vegetation, potential indicators of hydrogen accumulation. As a result, three priority areas of the GOC were selected for future exploration.

(•) $6(Mg,Fe)_2SiO_4 + 7H_2O \rightarrow 3(Mg,Fe)_3Si_2O_5(OH)_4 + Fe_3O_4 + H_2$

Olivino — Agua — Serpentina — Magnetita

Methodology

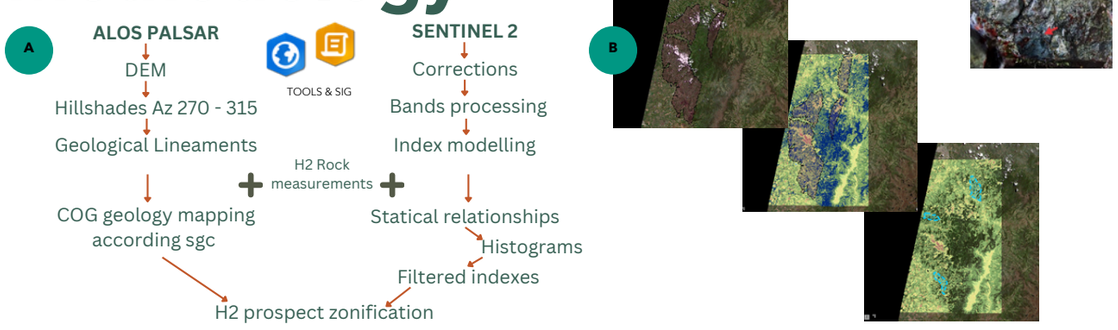


Figure 2. Methodology applied in the study. Figure A is the flow chart used in ArcGIS. Figure B are examples of the grafical output sin the GOC and field images from Nivia et al. (2019)

Results

Three samples of hornblende gabbro (Roldan, 2024), each displaying high hydrogen concentrations, were integrated into this study to validate the spectral responses observed in the vegetation indices. Buffer zones of 100 m, 200 m, and 300 m were delineated around each sampling point to capture and analyze local variations within the selected indices. Histogram analysis of these buffer zones revealed a positive correlation pattern, although indices such as NDVI and GNDVI exhibited greater data dispersion at increasing distances, indicating heightened sensitivity to terrain or vegetation cover variations. This evaluation identified a critical threshold factor of 0.54, which enhances the precision of spectral response interpretation in relation to hydrogen presence.

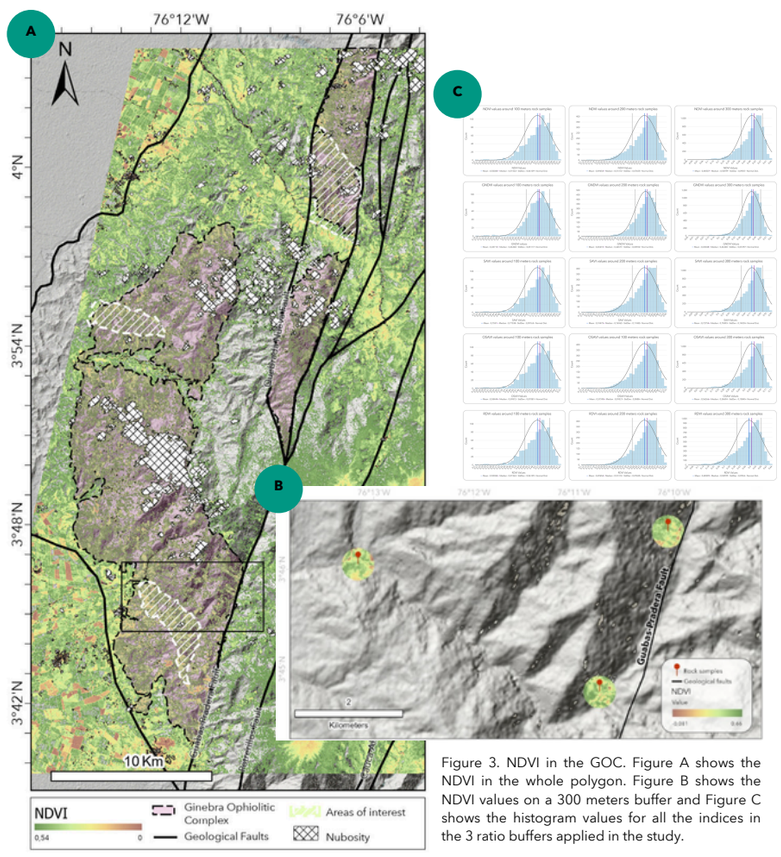


Figure 3. NDVI in the GOC. Figure A shows the NDVI in the whole polygon. Figure B shows the NDVI values on a 300 meters buffer and Figure C shows the histogram values for all the indices in the 3 ratio buffers applied in the study.

The Ginebra ophiolitic complex is structurally defined by the Palmira-Buga Fault to the west and the Guabas-Pradera Fault to the east, alongside additional N-NE-oriented lineaments exhibiting significant strike-slip displacements. As illustrated in Figure 4, truncation zones and regions of intense deformation, particularly toward the northern section, reveal lineaments aligned in three directions. These structures create geological traps that are conducive to subsurface gas migration and accumulation, indicating a potentially favorable setting for the generation and storage of hydrogen.

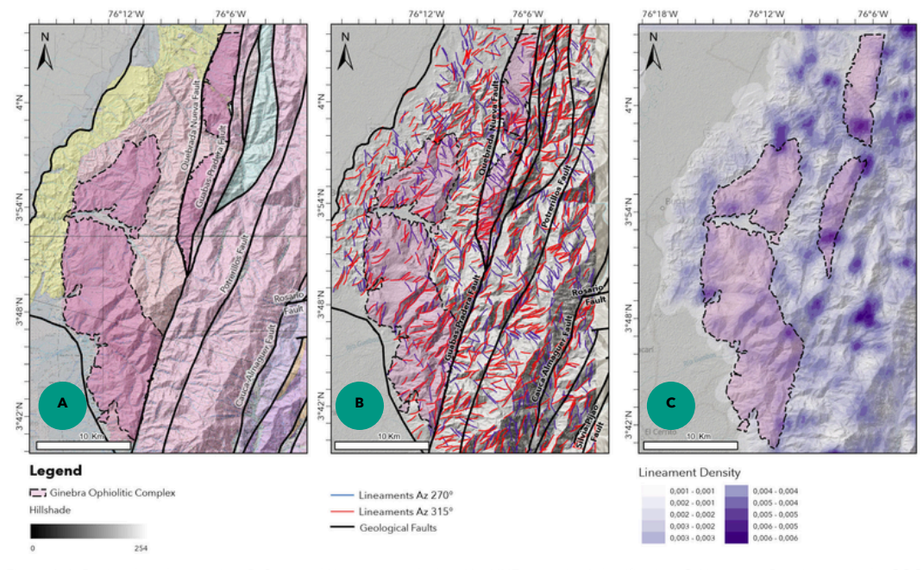


Figure 4. A. Regional geology setting; B. Structural Lineaments calculated by LINE supervised classification; C. Lineament Density map in the GOC

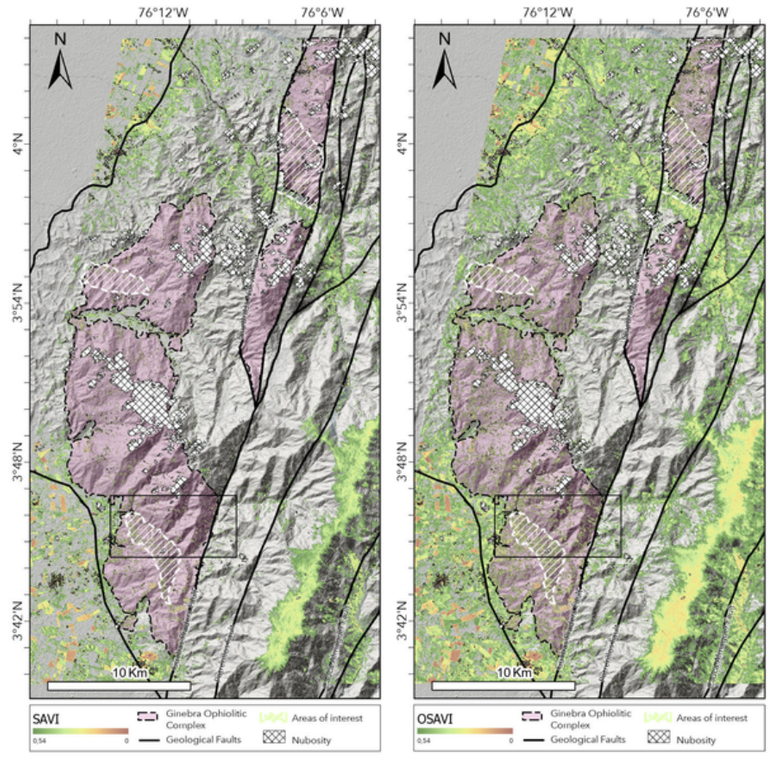


Figure 5. SAVI and OSAVI filtered in the GOC

The OSAVI index effectively detects reflectance in soils with low chlorophyll, showing low values, especially in areas of sparse or infertile vegetation, with slight increases towards the south and accumulations less than 0.3 on steep slopes.

Control areas, such as drainages and quaternary deposits, present values close to 0.1, indicating a lack of vegetation. On the other hand, the SAVI highlights areas with reduced vegetation cover and bare soils, being particularly effective in the south of the complex and towards the NW, where erosion and weathering impact the soil, especially on steep slopes. Both indices are valuable for assessing biomass and vegetation status in arid and semiarid regions.

The NDVI spectral response exhibits a broad distribution, with values around 0.1 indicating sparse vegetation or exposed soils, particularly on the steep northern slopes and in actively eroding areas. These low NDVI values are associated with amphibolite formations and are also present on a residual ridge in the southern region, where weathering processes are evident. In contrast, the GNDVI, which is less influenced by direct sunlight and moisture, provides insights into environmental stressors such as drought and vegetation health. With values below 0.3, the GNDVI reveals areas potentially correlated with hydrogen presence. This index displayed the highest spectral response among those analyzed, with lower values on sloping terrain and a notable distribution along NW-SE-oriented lineaments, suggesting diminished plant vigor and low water saturation, conditions that may be indicative of hydrogen-associated nitrogen in the soil. Additionally, the RDVI shows its lowest values in the central and eastern regions of the complex, highlighting areas of unhealthy or stressed vegetation

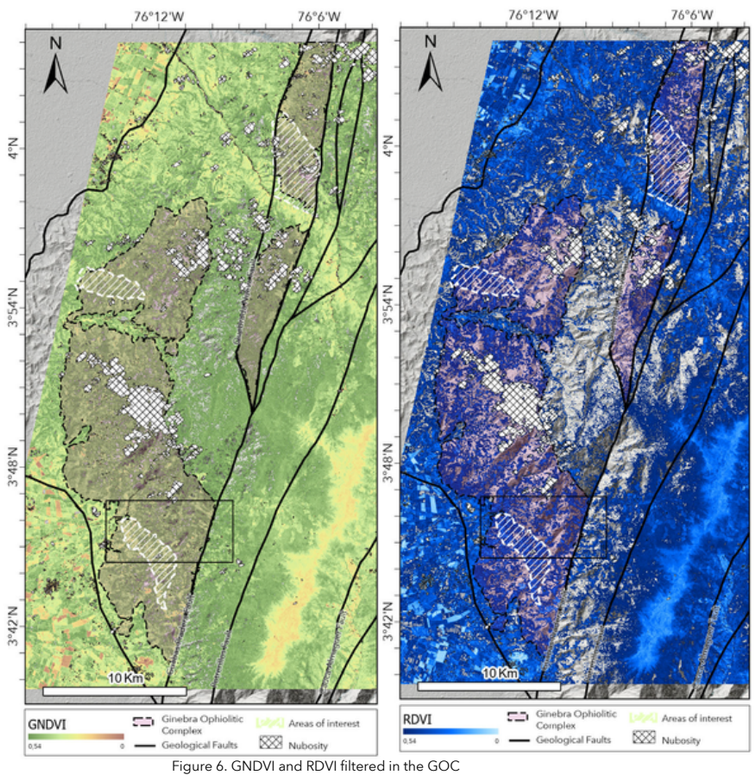
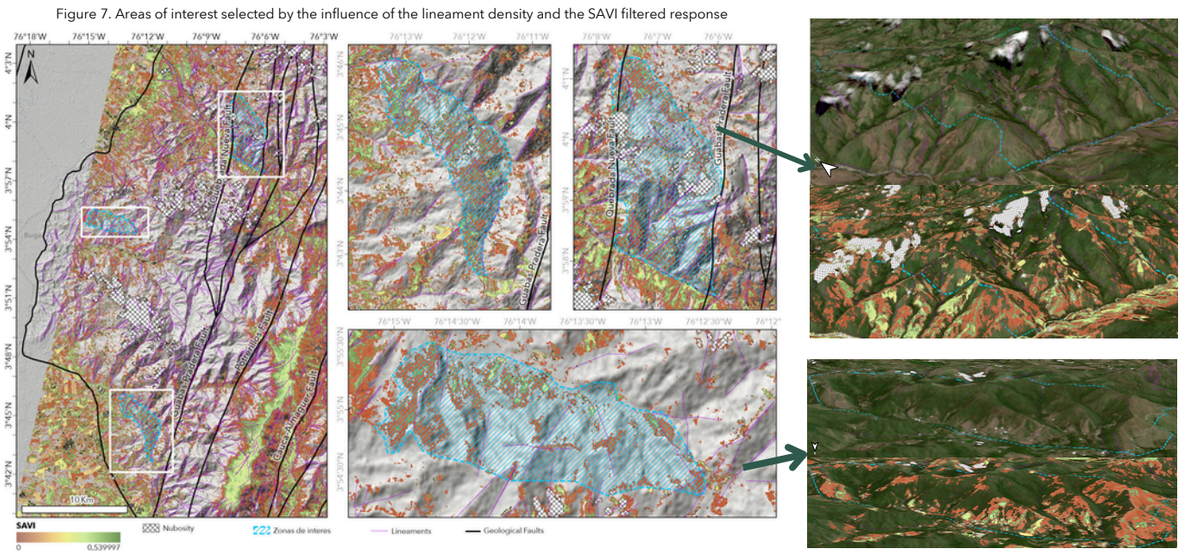


Figure 6. GNDVI and RDVI filtered in the GOC

Figure 7. Areas of interest selected by the influence of the lineament density and the SAVI filtered response



The indices reclassification proved effective, particularly within a pixel dynamic range under 0.5. Areas exhibiting index values below 0.3 suggest low biomass content, reduced chlorophyll levels, and minimal vegetation coverage or soil degradation.These prospective zones are strategically located near the Palmira-Buga and Guabas-Pradera fault systems, corresponding to residual mountain ranges or eroded ridges characterized by northern triangular facets and inclined slopes that coincide with amphibolite formations.

Conclusions

This study evaluates the potential for the presence of natural hydrogen (H_2) in the ultramafic rocks of the Ginebra Ophiolithic Complex using a proxy derived from Sentinel multispectral imagery. Specifically, NDVI and SAVI indices are used to analyze the impact of gas microseepage on vegetation. Low SAVI values suggest potential areas of geological interest within zones of ultramafic rocks, such as serpentinites, whose heavy metal-rich composition and specific mineralogy may inhibit vegetation growth. In addition, the analysis through the density of lineaments in conjunction with the Vegetation Indexes allowed us to better delimit the areas of interest found. Areas whose presence of sparse or anomalous vegetation may be indicative of geological processes associated with microseepage of gas, including hydrogen over the COG lineaments.

As a recommendation, it is suggested to perform field measurements in the identified areas of interest to find and assert how the behavior of the indices correlates with the surface H2 values in a geostatically significant way. Additionally, evaluate the possibility of implementing artificial intelligence algorithms (such as Deep Learning, Random Forest, etc) to identify better geospatial patterns. It is also recommended to follow the automation flow for the replication of the study in other areas with similar geological characteristics.