Introduction

The urgency to mitigate global climate changes caused by the increased greenhouse gas emissions especially from the large amount of CO_2 greenhouse gases released from burning the fossil fuels and industrial process has highlighted the interest in a developing study of Carbon Capture, Utilization, and Storage (CCUS) technologies to reduce atmospheric CO_2 levels around the world (Bachu, 2000; Singh et al., 2024). CO_2 Storage through various geological formations such as Depleted hydrocarbon Fields, Deep Saline Aquifers, Coal Seams, and Basalt formations hold the potential for geological sequestration of CO_2. CO_2 Mineralization is an one such techniques for the sequestration of CO_2 through mineral carbonation processes via various mineralization methods especially In-situ, Surficial and Ex-situ methods which has the potential to store CO_2 gases as Carbon storage for long-term stability in the Geological conditions (Bhavsar et al., 2023; Kirmani et al., 2024). The CO_2 Storage through the Igneous Mafic Basaltic rocks offers a particular promising pathway among geological storage options due to their ability to convert CO_2 into stable, solid carbonates through mineral carbonation and due to their fast reaction rate with the other minerals. The Presence of divalent cations especially the $Mg^{2+,}$ $Fe^{2+,}$ Al^{2+} and Ca^{2+} in the Basalts hold the potential for rapid CO_2 Mineralization compared to the Sedimentary rocks (Ajayi et al., 2019; Kim et al., 2023; Kirmani et al., 2024; Raza et al., 2022; Singh et al., 2024). The study targets the India's Deccan Traps, one of the world's largest continentals flooded volcanic provinces, has an immense potential capacity—estimated at several hundreds of gigatons—for permanent CO_2 Storage. Yet, despite this potential, there are currently no pilot or commercial-scale CCUS projects targeting Deccan basalt formations. For CO_2 storage as a supercritical fluid, target formations must exceed CO_2's critical pressure and temperature (7.4 MPa, 31.1°C), requiring injection depths over 750 m. Only 28% of Deccan basalt meets this, limiting suitable injection locations. Imposing significant geographical constraints on available injection locations. Also, Dike swarms in the Deccan Traps form vertical barriers, limiting horizontal connectivity. Regions with basalt at suitable CCS depths align with high dike prevalence, challenging the feasibility of sustained CO_2 injection (Prasad et al., 2009; Rani et al., 2013; Raza et al., 2022; Singh et al., 2024).

Method

The methodology of the study includes multidisciplinary approach to access the potential of CO_2 storage in the Basalts of DVP, near Nashik, Igatpuri area and Southwestern Part of Maharashtra, India through geological field scale observations, geological mapping, collection of rock samples from the locations.

1.Geochemical Experiments

- The rock characterization is examined by the Laboratory experiments such as (XRD, XRF, thin section) analysis to study the crystal structure parameters, oxide & elemental analysis such as major, minor, trace elements composition, and mineralogical composition.

- The FESEM, BET (SAP) analysis is being conducted to examine the morphology, grain boundaries, fracture surfaces of the minerals and surface area using the Stubbs and powdered Basalt rock samples.

- The petrophysical properties such as (porosity & relative permeability) has been evaluated using the Mercury Porosimeter instrument.

2. Geomechanical Experiments

- The core rock samples with 1.5inch Dia and 3inch length has been used to calculate the rock strength/integrity using Uniaxial & Triaxial Compression machine.

- The tensile strength and P-wave velocity are calculated using the Brazilian Tensile Strength machines and P-wave velocity instruments to evaluate the stress/strain behaviour.

3. Fluid-Rock interaction Experiments

- The fluid-rock interaction studies are being conducted using the core-flooding and Batch reactors to evaluate the mineral trapping efficiency of the Basalts using CO_2 gas and brines.

- The Core flooding experiments using Relative Permeability System (RPS) is being conducted for quantifying the relative permeability, pore size distribution, wettability, and impact on fluid flow.

- The Batch experiments using the High pressure & temperature reactors are conducted to evaluate the reaction kinetics, pH of the basalts encompassing the dissolution rates of primary minerals and precipitation of carbonates upon injection of CO_2.

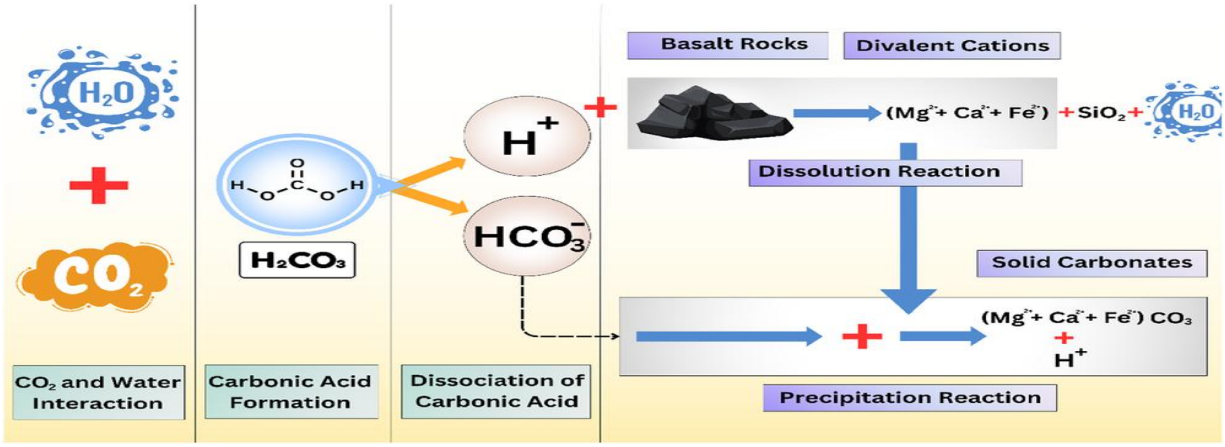

Figure 1 Carbon Mineralization Process in Basalts R.K. Singh et al., 2024

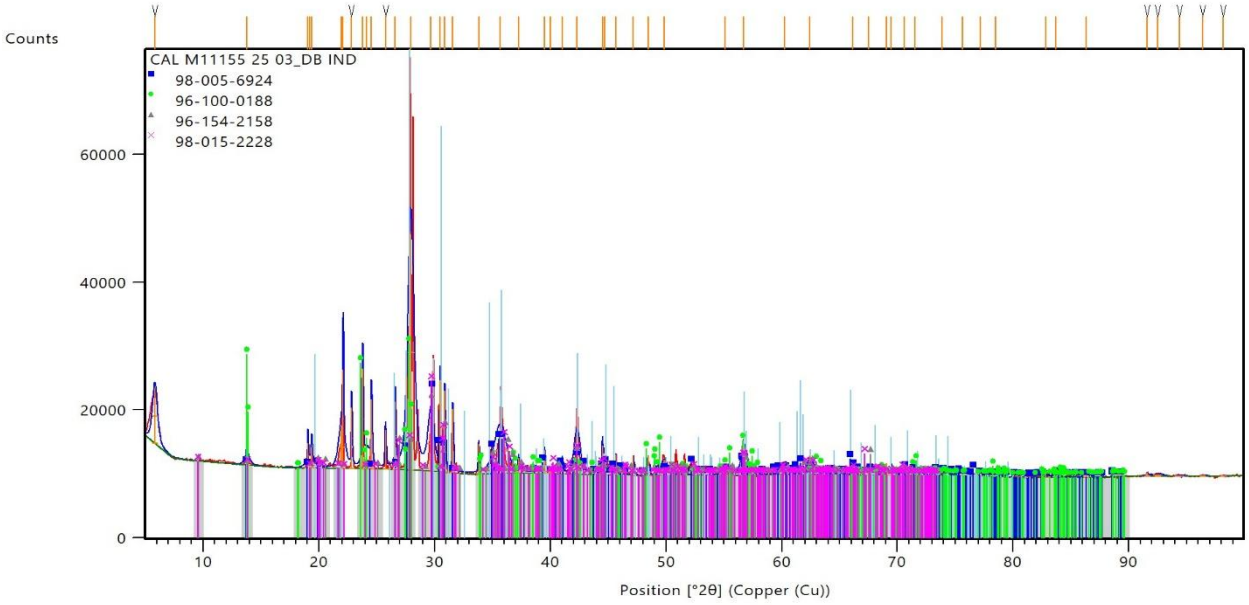

Figure 2 XRD Analysis of the Rock sample showing Si, Fe, Mg, Al %

Conclusions

The CO_2 sequestration Potential in the Terrestrial Flood Basalts of (DVP) Deccan Volcanic Provinces provides a establishing outcome with geochemical & geo-mechanical parameters such as rock characterization, injection rates, mineralization, geochemical reactions, strength & integrity, petrophysical properties, stress/strain rates using acoustic emissions & pulse wave velocity, establishing a scalable storage model such as Reactive Transport Modelling, which will enhance to generate scalable protocols for CO_2 injection and developing a robust monitoring framework in the Basalt rock formations for upscaling into pilot-scale projects.

The anticipated outcomes include identifying suitable injection sites, possible mineralization potential of CO_2 & developing protocols for scalable storage and providing a framework for the development of India's future CCUS projects, advancing India's commitment to climate action and sustainable resource management industry standards. In the long term, effective implementation will require comprehensive monitoring of CO_2storage sites to ensure environmental safety, assess containment integrity, and refine storage methodologies. This research will establish protocols for long-term monitoring, setting the foundation for India's transition toward sustainable carbon management and positioning the Deccan Traps as a critical asset in global climate mitigation efforts.

This study aims to assess the feasibility of CO_2storage in Deccan basalt by investigating the favorable sites, establishing the reaction kinetics, trapping mechanisms specifically focusing on the carbonation rate of basaltic minerals like calcium and magnesium silicates under varied temperature, pressure, and fluid saturation conditions. The influence of CO_2 Mineralization through chemical trapping mechanisms especially a.) Solubility and b.) Mineral trappings.

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