Timing of the Exhumation Episodes and Burial/Thermal History of Kevin Dome, Northwestern Montana

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Abstract

Kevin Dome is a 320 km long structural culmination along the Sweetgrass Arch in northwestern Montana that produces both oil and gas and has trapped ≈ 85 billion cubic meter (bcm) of CO2. The Late Devonian Duperow Formation CO2 reservoir at Kevin Dome traps one of the largest known natural CO2 resource in the northwestern United States. Despite the economic importance of Kevin Dome's CO2 resource for Enhanced Oil Recovery (EOR) and Carbon Capture, Utilization and Storage (CCUS) potential in the region as well as hydrocarbon productions, the thermal evolution and exhumation history of the dome has not been constrained and the source and timing of the CO2 emplacement is uncertain. Several tectonic and structural evolution models have been proposed for the initiation of the Sweetgrass Arch and subsequent development of Kevin Dome. These models were largely based on strata distribution, erosion or non-deposition but are now constrained with new cooling age histories of constituent formations. Here we present preliminary results of low-temperature thermochronology ((U - Th)/He) analysis on apatite minerals recovered from drill cuttings in five (5) Kevin Dome historic wells. The pilot samples analyzed were selected from Precambrian basement, Three Forks, Bakken, Kootenai and Bow Island Formations at depths of 400-1430m. The obtained cooling ages range from ≈ 68 to 10 Ma indicating that the dome cooled periodically and mainly during the Tertiary. This clearly show that all units sampled reached temperatures above 70° C (apatite closure T) implying about 3 km of uplift difference and overburden thickness have been removed due to this exhumation since the Late

Cretaceous. The cooling ages were further grouped into two exhumation episodes: (1) Paleogene, 68 - 25 Ma (Late Cretaceous - Oligocene), and (2) Neogene, 23 - 10 Ma. The first exhumation episode of Paleogene cooling histories would be consistent with (1) Late Cretaceous-Paleocene emplacement of the Rocky Mountain overthrust, (2) evidence of uniform eastward tilting of the proximal Sweetgrass Hills, Bearpaw Uplift, Little Rockies Mountains and Highwood Mountains similar to the Sweetgrass Arch during Paleocene to early Eocene and (3) post Eocene uplifts related to late Laramide orogeny model. The Neogene cooling ages could also be related to the Pendroy Fault movement during Oligocene-Miocene (or younger ages) which moved a bulge on the Sweetgrass Arch's crest (≈ 48 km) eastward to form the present-day Kevin Dome. The burial and thermal history of Kevin Dome strata and how these thermal conditions drove hydrocarbon generation were also constrained by incorporating cooling age histories with available thermal maturity indices of Kevin Dome strata. This study provides new contexts for understanding how exhumation episodes controlled thermal evolution, generation and migration of associated hydrocarbons and emplacement of CO2 at Kevin Dome.