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Dating and Constraining Leakage Rates from a Natural Analogue for CO2 Storage - The Little Grand Wash and Salt Wash Fault

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SUMMARY

Capture and Storage of CO2 could decrease global carbon emissions on short time scales. Leakage rates from geological formations are poorly constrained, and are therefore an unknown factor in CCS feasibility studies. Natural CO2 reservoirs in the Colorado Plateau, USA, are analogues for geological storage. In places CO2 has migrated to the surface along fault zones, forming CO2-charged springs and geysers. Recent drilling for oil and water has also provided rapid pathways for CO2 migration. Uranium-series dating of travertine mounds along two fault zones in Utah has provided insight to the timing and rates of leakage along these faults. A continuous record of leakage has been preserved over the last 315ka, with the oldest dated mound at 413ka. The position of leakage has switched through time, and individual pathways have been utilised more than once for flow. Combining dates with volume measurements from these mounds it is possible to calculate the rates and volumes of flow in individual pathways and the long-term time-averaged CO2 leakage rate for the entire system. The observation that leakage of CO2-rich groundwater from a fault can occur for hundreds of thousands of years has implications for geological storage of CO2.

Carbon Capture and Storage (CCS) could be a vital component to decrease global carbon emissions on short time scales. Validation of future international climate change treaties will rely on the ability to monitor the fate of injected CO_2 and reliable data on likely flux rates of any leaked CO_2. However, rates of CO_2 leakage from geological formations have as yet, been poorly constrained, and are therefore an unknown factor in CCS feasibility studies.

The numerous natural CO_2 reservoirs that exist in the Colorado Plateau region of the USA are natural analogues for geological storage of anthropogenic CO_2. Carbon dioxide-charged groundwater has migrated to the surface along two fault zones near Green River, Utah: the Little Grand Wash fault (LGW) and the Salt Wash Graben (SWG). Travertine mounds (spring-related carbonates) have been deposited around the CO_2-rich springs. Shipton et al. (2004; 2005) and Dockrill (2006) showed that modern and ancient travertines are localised along footwall of both fault zones, consistent with ponding of southward-directed regional groundwater flow in a three-way anticlinal trap. Geochemical and structural analyses have shown that CO2-rich groundwater is stored in a series of shallow sandstone reservoirs capped by impermeable shale rich caprock, and that the CO_2-rich groundwater moves to the surface through fractures in the footwall damage zone of the faults (Heath 2004; Dockrill 2006). Recent drilling for oil and water has also provided rapid pathways for CO_2 migration, inducing new springs, geysers and travertine mounds.

Dating of the travertine mounds provides constraints on the timing of leakage to the surface along the faults and allow us to constrain the spatial and temporal evolution of fluid flow pathways in the faults. Uranium series dating from a total of 30 individual travertine mounds has constrained the timing of initial spring activity to greater than 413,000 years (the oldest mound along the SWG). Although some erosion of the ancient deposits has occurred, the data suggests almost continuous leakage to the surface since 135ka. The variation in ages between mounds along both faults shows that pathways for CO_2-rich waters to the surface through the caprock switch repeatedly through time. Multiple dates from a single spring deposit on the LGW show that an individual mound can have a life span of at least 10,000 years. However, at least one location on the LGW has three distinct travertine mounds with distinct ages that range over 40,000 years, suggesting that a single pathway can be re-used many times (Fig. 1).

Combining the ages of the travertine mounds with estimates of the volume of carbonate contained within the mounds it is possible to calculate the total volume of CO_2 leaked from this system. Minimum total travertine volumes are calculated for each mound from thickness measurements and travertine areas from digitised maps in Arcview (Figure 1). These values are conservative estimate of leakage because all the ancient deposits have been eroded to varying degrees. Geochemical modelling by Heath (2004) suggests that, at the present day groundwater temperatures and compositions, approximately 10% of the CO_2 is precipitated, while the remaining CO_2 is either vented as free gas into the atmosphere or retained in solution. Assuming the ratio between the CO_2 precipitated as travertine and vented into the atmosphere is constant, the rates and volumes of flow in individual pathways and the long-term time averaged CO_2 leakage rates can be calculated for the entire system. An estimate of CO_2 mass leaked to the surface enables a calculation of leakage flux and suggests that a significant amount of CO_2 has leaked to the surface over the last 413,000 years. The observation that leakage of CO_2-rich groundwater from a fault can last for up to 10ka at a single point and up to hundreds of thousands of years along the entire length of a fault has significant implications for geological storage of CO_2.

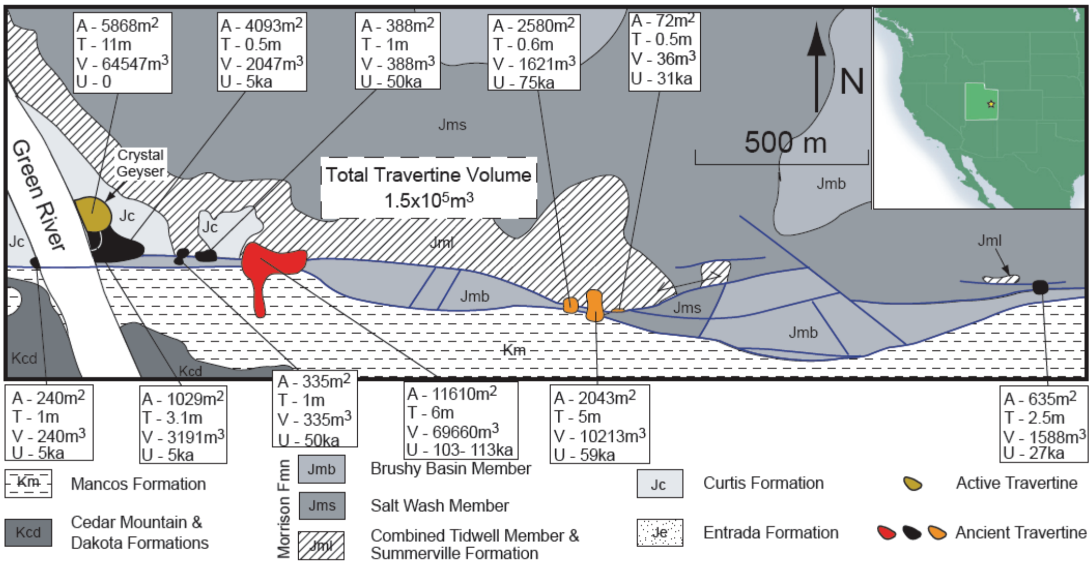

Figure 1 *Estimated thicknesses (T), areas (A), volumes (V) and U-series ages (U) of travertine mounds in the footwall of the Little Grand Wash Fault (after Dockrill 2006). Thickness and area values calculated from field mapping. The thickness of Crystal Geyser travertine (highlighted in yellow) which erupts from the Glen Ruby #1 well drilled in 1935 was taken from drilling records in Baer and Rigby (1978). For clarity U-series ages are rounded to the nearest thousand years. Errors are known to 2σ on analytical precision. Three dates from the travertine mound highlighted in red show that it was active for over 10ka. The three ages of the distinct mounds highlighted in orange range over 40ka showing that this pathway for flow was occupied repeatedly. Inset shows the location of the field areas, represented by the yellow star, in relation to the rest of the USA.*

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