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Recent, deep-sourced methane/mud discharge at Carmen mud volcano, Alboran Sea, West Mediterranean

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Carmen MV is known to be the most active structure within the West Alboran Basin (WAB; westernmost Mediterranean). Active mud volcanism in the WAB is closely associated with tectonically mobilized recent shale-diapirism of overpressurized shales, which in turn conditioned mud expulsion and active hydrocarbon venting (mud volcanoes and pockmarks). We present a comprehensive study on the geochemical composition of fluids, gas, and clay minerals in mud breccia from Carmen mud volcano (MV). We focus on piston core GP05PC, recovered at the summit of the MV. It consists of mud breccia sediments showing a dramatic change between enhanced methane concentrations (>1.5 mmol/wet sediment) in the lowermost core-interval and enhanced dissolved SO_4^{2-} in the uppermost core-interval. This indicates rapid anaerobic oxidation of methane and recent fluid seepage activity of the MV. The depletion of major elements (i.e., $Ca^{2+}$and Mg^{2+}), the enrichment of trace species (i.e., Li+ and B), and a δ^{87}Sr of 0.70902 $\pm$ 0.00002 in the porewater of the lowermost interval all point to a deep fluid source. The interstratified clay minerals, which range from randomly interstratified illite-smectite (R0) to illitic ordered ones (R1-R3) indicate a smectite to illite transformation at considerable depth. This transformation and the porewater $\delta^{18}O_{pw}$ (5.7‰ VSMOW) and δD_{pw} (-10‰ VSMOW) in the lowermost interval support smectite dehydration as a significant pore water freshening mechanism. Water-formation temperature calculated with empirical geo-thermometers (K-Na and K-Mg) reveals that fluids were generated at temperatures of $\sim$ 140 ºC $\pm$ 20 ºC. Considering a geothermal gradient of 25-27 ºC/km occurring in the WAB, this water formation temperature suggests that the fluid source is located at 5 $\pm$ 1 km deep. This depth is consistent with the location of overpressured shales and megabreccia strata (Lower to Middle Miocene age) existing in the WAB. The δ^{87}Sr of the porewater also fits well with the Upper/Middle-Miocene oceanic signature. The $\delta^{13}C_{methane}$ and $\delta D_{methane}$ composition of methane (-59.0‰ VPDB and -184‰ VSMOW, respectively) in the lowermost core-interval is consistent with the mentioned deep origin. The absence of hemipelagic sediment draping, the distinctive seawater-like pore water composition in the uppermost core-interval of the mud breccia, as well as the abrupt boundaries of the core-interval with a typical deep-source fluid signature, point to a very recent and rapid gas outburst/ mud flow. Such outburst may lead to downward core intrusion of seawater coincident with the gas expulsion event. We apply a numerical transport-reaction model to the distinctively kink-shaped pore-water profiles from the core (i.e. Cl, SO_4^{2-}-CH_4) to derive the timing for such eruptive event. This event appears to have occurred very recently, namely 12 $\pm$ 4 yrs prior to the sampling year 2012, thus in the year 2000 AD.