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Fluid flow in volcanic basins: the Vøring and Møre basins, mid-Norwegian margin, and the Karoo Basin, South Africa

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Intrusive volcanic complexes and associated pipe-like hydrothermal vent complexes may have an important influence on fluid flow of sedimentary basins. Sills, dykes, and vertical piercement structures have the potential to permanently perturb basin fluid flow regimes, either by permeability enhancement/reduction, or fluid production and expulsion. We have conducted detailed seismic and borehole studies of sills and hydrothermal vent complexes in the Vøring and Møre basins off mid-Norway and field work in the Karoo Basin to study fluid migration in volcanic basins. The 6607/12-1 exploration well in the Vøring Basin was drilled through the central part of a Paleocene/Eocene hydrothermal vent complex. Detailed 3D seismic mapping of this structure reveals a circular, crater-like depression with a diameter of $>$2 km at the top Paleocene level. The overlying intra-Eocene reflections are dome shaped, forming an eye-shaped lower-Eocene unit above the top Paleocene reflection. Several gas kicks were encountered during drilling of the eye structure and overlying Eocene strata. Wire-line log data and vertical seismic profiling reveal very high porosities (up to 50% neutron-neutron porosity) and low seismic velocities ($<$1.8 km/s) in this interval. The high porosities suggest that the interval has not been subjected to normal compaction processes, most likely due to sustained high fluid pressures above the vent complex since its formation. Further evidence of a long-lived seep structure above the vent complex comes from analyses of cores and cuttings. Calcites and dolomites from the Eocene-Miocene interval have isotopic signatures typical for methane seep carbonates, with low d13C signatures of -28 to -54 per mil PDB. Our data suggest that this vent complex acted as a fluid migration pathway for $>$50 m.y. after its formation, causing near-

surface microbial activity and seep carbonate formation. Similarly, high-resolution 2D and 3D seismic data in the Vøring and Møre basins show mounds, disturbed chimneys, and high-amplitude shallow reflections above many of the >700 mapped hydrothermal vent complexes. These observations are interpreted as clear indications of the existence of long-lived fluid seep systems above the hydrothermal vent complexes. This is corroborated by data from the Karoo Basin, where geochemical signatures of reducing hydrocarbon-bearing fluids are found in hydrothermal vent complexes. Field observations and geochemical studies in the Karoo Basin further reveal that the volcanic sills, dikes, and metamorphic aureoles also have an important impact on the deep fluid flow. The dikes commonly act as vertical fluid pathways, in particular along fractured margins where hydrothermal minerals are commonly identified. In contrast, sills and aureoles are more commonly low permeability zones. However, transgressive sill segments may be intensely fractures, allowing vertical migration of fluids in narrow zones.