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The resistivity structure of the North Alex Mud Volcano as derived from the interpretation of CSEM data

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Active mud volcanoes, where changing salinities of pore fluids, large temperature gradients and occurrences of free gas are frequently observed, should potentially exhibit significant variability in their internal resistivity structure. This is due to the fact that the bulk resistivity is mainly determined by the porosity of sediments and the electrical resistivity of the pore filling contained therein. The resistivity variations may be derived from controlled source electromagnetic (CSEM) measurements. CSEM systems consist of an electric dipole transmitter producing a time varying source field and electric dipole receivers, which measure the earth´s response to this signal.

For a RWE Dea funded investigation of fluid and gas leakages at the North Alex Mud Volcano (NAMV) - a comparatively small target with an area of about 1km^2 - we have developed a new high resolution CSEM system. The system consists of several autonomous electric dipole receivers and a lightweight electric dipole transmitter, which can be mounted on a small remotely operated underwater vehicle (ROV). The use of a ROV allows for a precise placement of the transmitter, which is a necessary prerequisite for the investigation of such a small target. Furthermore, electromagnetic signals may be transmitted from different directions with respect to the stationary receivers, allowing for a 3D-style tomographic experiment. In this experiment, ten receivers were deployed over the surface of NAMV at a total of 16 receiver locations. During three successful dives with a Cherokee ROV (Ghent University, Belgium), the transmitter was deployed at a total of 80 locations. Here we present first quantitative results consisting of apparent resistivity estimations from the CSEM time domain data for each transmitter-receiver pair. The apparent resistivity map shows that the NAMV indeed has a heterogeneous resistivity structure with apparent resistivities varying by at least a factor of two: low apparent resistivities ($\approx 0.8\Omega$m) are found towards the center of the MV, whereas higher apparent resistivities ($\approx 1.6\Omega$m) prevail away from the center. In a second step, we interpret the time-domain data based on 1D inversions. Good data fits can be achieved by models containing 2-3 layers. Generally, the models indicate low resistivities at the surface, which can be associated with penetrating salt water and/or high temperatures. Toward greater depths, increasing resistivities presumably are due to a combination of compaction of sediments (i.e. reduced pore space), an increased presence of fresh water and possible occurrences of free gas. For some 1D models, the increase in resistivity exceeds a factor of 10 or more and layer interfaces are indicated down to depths of up to 70m.

The derived resistivity variations observed at the NAMV will be interpreted in conjunction with temperature (Feseker, this session), fluid flow (Brückmann et al., this session) and seismic data (Bialas et al., this session) acquired. Temperature variations measured in the upper few meters are related to fluid flow, where high temperatures are indicative of upwelling fluids of low salinity and low temperature of either a downward flow of saline fluids or no flow activity. This type of surface measurement constitutes an integrative fluid flow gauge, which we can resolve vertically with our resistivity models. Seismic data yield a background structure to our resistivity model. New analysis of seismic data shows that seismic activity may also be linked to fluid flow activity, which we aim to match with resistivity variations and oscillations, which were observed in the electric and magnetic fields (Lefeldt et al., this session).