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Acoustic velocities of sedimentary rocks from Southern McMurdo Sound, Antarctica, derived from downhole logging in the AND 2-2A drill hole and laboratory measurements

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The AND 2-2A borehole, drilled for the SMS Project, which is part of the ANDRILL program (ANtarctic geological DRILLing), allows access to the sedimentary rocks in the Southern McMurdo Sound, Victoria Land Basin. One of the project's objectives is to obtain knowledge about the state of stress in the Antarctic crust. To achieve this, a hydraulic fracturing test has been run at the end of the drilling campaign in the austral summer 2007. The behaviour of a formation that is exposed to high pressure, like during such a test, depends on its structure and elastic properties. Some in situ information on these can be drawn from downhole logging data. The respective parameters available for AND 2-2A, which reached a depth of 1138.54 m below the seafloor, are density, neutron porosity and sonic velocity. To support those measurements and to get additional information, a set of physical parameters was derived from core samples.

The essential parameter is the acoustic velocity. It was measured at ultrasonic frequency for both shear and compressional waves. A conventional pulse transmission method was used with a pair of transducers that can record v_s and v_p in the same run without changing the experimental assembly. All tests were run in a pressure vessel filled with hydraulic oil that allowed hydrostatic confining pressures ranging from 5 MPa to 50 MPa to be applied to the samples. The samples were dry and their pore space evacuated during a test. Pressure was increased gradually to the maximum value and thereafter decreased again gradually to the initial value. Investigating an upward and downward pressure cycle enables conclusions on the rock's general elastic behaviour and yields information on the changes of its structure caused by pressure increase. For calculation of the elastic properties and for relations between these properties and the rocks' internal structure porosity, grain density and the distribution of the pore diameters were measured.

The investigated set of samples contains specimens of the most important three lithologies intersected in AND 2-2A. These lithologies are roughly diamictite, sandstone, and mudrock (siltstone). Each of these occurs with a wide variety of grain size distributions, consolidation states, and amounts of clasts and other constituents along the whole wellbore. Those parameters directly affect the rocks' structure and thus their acoustic velocities and elastic parameters. Therefore general statements for a specific geologically defined lithology cannot be made. With respect to the hydraulic fracturing operations, which took place at the bottom part of the drill hole, the samples where also chosen with an emphasis on the borehole's bottom section.

In general, the ultrasonic velocity of a solid rock displays hysteresis when the rock is subjected to the pressure cycle described above. This behaviour is highly non linear. At a given pressure the velocity is usually greater on depressurization than at the same pressure during pressurization, due to consolidation effects mainly related to the closure of microcracks. For the AND 2-2A samples this is valid at higher pressures. For some samples, however, at lower pressures the depressurization velocity drops below that during pressurization. Additionally, the upward leg of most samples does not have the typical concave shape. With increasing pressure, the velocity increases in a convex manner. This indicates an additional process of consolidation during the pressure increase, which is not completely reversible. The expected concave drop of velocity is, however, seen on the depressurization cycle. The pressure dependent change of the velocity ranges from only a few meters per second to a few hundred meters per second for both $v_p$and v_s. Apart from the velocity behaviour the derived elastic properties and the relations between the velocities and the physical parameters describing the rocks' structure will be shown.