Integrated interpretation of downhole geophysical measurements of the Lower Continental Crust in the Ivrea-Verbano Zone (Western Alps, Italy) at the DIVE DT-1B borehole

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The Drilling the Ivrea-Verbano Zone (DIVE) project completed its first borehole DT-1B in December 2022, recovering a continuous drill core to 578.5 m depth. The objective of DT-1B is to explore the upper part of the Lower Continental Crust. The 100% core recovery provides an excellent opportunity to integrate downhole geophysical measurements with core observations in rarely drilled lithologies. The primary goal of this integrated study is to characterize the rock mass and constrain the factors that influence seismic velocity variations and the origin of reflectivity in lower crustal rocks. For this purpose, we have collected a comprehensive suite of downhole measurements, comprising of natural gamma ray, magnetic susceptibility, dual laterolog resistivity, single point resistance, mud parameter, full waveform sonic, acoustic and optical televiewer, and vertical seismic profiling data. Complementary bulk density measurements have been performed on 96 core sections with a multi-sensor core logger as well as laboratory ultrasonic velocity and bulk density measurements on 15 selected core samples at ambient conditions. To characterize the rock mass mechanically and structurally, a detailed analysis of the acoustic televiewer data was carried out, which identified several natural and drilling-induced fractures. Natural fractures have two predominant azimuthal orientations: NW to NE and SSE to SE. Their dips range from 10° to 85°, with a higher average dip in the upper section that decreases in the lower section of the borehole. Fractures correlate with an abundance of anomalies in the electrical logs and affect sonic velocities. Due to the impact of fractures on these logs, only natural gamma ray and magnetic susceptibility logs are used for lithological classification of the rock masses, into three distinct clusters by fuzzy c-means clustering. Two of the clusters, 1 and 3, are attributed mainly to felsic metasediments, while cluster 2 is attributed to metamafics identified in the cores. Cluster 1 is characterized by high magnetic susceptibility and natural radiation, while cluster 3 is characterized by low magnetic susceptibility and natural radiation, indicating two distinct groups of metasediments. Concerning the elastic properties, it is expected that the velocities of the metamafics are higher than those of the metasediments. However, a systematic
correlation between velocities and lithologies (or clusters) is not observed. To investigate the factors contributing to seismic velocity variations, velocities from core measurements, sonic logging, and vertical seismic profiling are compared. The velocities are consistent across the three scales, with P-wave velocities ranging from 5 to 6 km/s and S-wave velocities around 3 km/s, however, the values are much lower than expected. One reason might be the presence of microcracks, as indicated by the P-wave velocity difference between saturated and dry core samples. Together with the observed impact of fractures on the sonic log data, this suggests that the velocities are governed by brittle deformation at various scales, which explains their low values and overprints the lithological response. Consequently, reflections are expected to be caused by large scale fractures, but lithological reflections may still be observed due to the density contrast between metasediments and metamafics.