DEPOSITIONAL PROCESSES AND PRODUCTS OF THE LOWER PUCHKIRCHEN FORMATION OF THE MOLASSE BASIN, AUSTRIA

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ABSTRACT

The Molasse Basin of Austria is an asymmetric foreland basin that contains Oligocene to lower Miocene deep-water strata, including the Puchkirchen Formation. Although the depositional history of the oil and natural gas-producing upper Puchkirchen Formation, deposited in and proximal to a deep-water axial channel belt, has been thoroughly studied, the depositional processes and stratigraphic architecture of the lower Puchkirchen Formation are much more poorly understood. We identified the deposits of low-density turbidity currents, high-density turbidity currents, debris flows, and slurry flows in approximately 250 m of drill core from the lower Puchkirchen Formation, acquired from 13 wells and graphically logged at the centimeter scale. Future work will include more detailed interpretations of depositional processes and environments, petrographic analysis of rock samples from the lower Puchkirchen Formation, and a study of the uplift history of the Austrian Alps using and thermochronologic analysis of detrital zircons from the upper and lower Puchkirchen Formation.

INTRODUCTION

Geologic background

The Molasse Basin is an asymmetric foreland basin that extends from Bavaria to the Carpathian foredeep (Fig. 1) that formed in late Eocene time by northward thrusting of the Alpine nappes against the European continental margin (Ziegler, 1982). The Oligocene to lower Miocene deep-water sediments of the Molasse Basin of Austria are approximately 2000 m thick and are overlain by shallow marine deposits (De Ruig and Hubbard, 2006).

The Oligocene to lower Miocene Puchkirchen Formation is composed of sandstone, mudstone, and conglomerate and is underlain by the Rupelian Formation and overlain by the Hall Formation (De Ruig and Hubbard, 2006). Deposition occurred in and adjacent to a low-sinuosity, west-east axial channel belt that extended for 100 km along the basin's foredeep (Fig. 2) (Linzer, 2001; De Ruig, 2003). The Puchkirchen Formation is subdivided by a semi-regional erosional unconformity into the lower (upper Oligocene) and upper (lower Miocene) Puchkirchen Formation (De Ruig and Hubbard, 2006). There are few outcrops of the Puchkirchen Formation, which is known principally from subsurface studies.

Motivation and objectives

Though the upper Puchkirchen Formation hosts reservoirs containing biogenic gas (Malzer, 1981) and has been the subject of extensive sedimentological study (Covault et al., 2009; Bernhardt et al., 2012; Masalimova, 2013), the lower Puchkirchen Formation is poorly understood. Recent drilling for natural gas has shown that the lithologies of the lower Puchkirchen Formation are laterally heterogeneous. A previous study of the Puchkirchen Formation in 3D seismic reflection data suggests that the lower Puchkirchen Formation may feature channel-form deposits (De Ruig and Hubbard, 2006). However, the low resolution of existing seismic data prevents confident identification of axial channel thalwegs in the lower Puchkirchen Formation. Moreover, it is unclear how well the lithologies identified in drill cores can be correlated with the abundant well log data. This study examines the depositional processes and products of the lower Puchkirchen Formation and addresses the uncertainties in the correlations between well log data and lithologies observed in drill core. U/Pb geochronology and U-Th/He thermochronology double-dating of detrital zircons in sandstones collected from core samples of the lower Puchkirchen Formation and upper Puchkirchen Formation will provide further insight into the uplift history of the Alps and sediment input from the Alps to the Molasse Basin, complementing an ongoing provenance study of detrital zircons from the Molasse Basin (Sharman et al., *In Prep.*).

METHODOLOGY

Approximately 250 m of drill core of the lower Puchkirchen Formation taken from 13 wells drilled in western Upper Austria (Fig. 1) were graphically logged at the centimeter scale (Figs. 3 and 4). We measured and noted trace fossils, grain sizes and shapes, and bed thicknesses. We also recorded bedforms, deformational structures, and the compositions of extrabasinal clasts and sedimentary matrix. Samples of the core were taken for petrographic analysis and for detrital zircon geo- and thermochronology. Each core was thoroughly photographed, and the photographs were stitched together to produce high-resolution images of each core (Figs. 3 and 4). Depositional elements have been identified in the drill core based on grain sizes and on the relative proportion and composition of the rock matrix (Fig. 5).

RESULTS

In the 250 m of measured core, we identify three distinctive rock types: sandstone, conglomerate, and mudstone. We further subdivide these rock types into seven depositional elements: thin- and thick-bedded sandstone; sand- and silt-matrix conglomerate; and massive, laminated, and pebbly mudstone (Fig. 5). The classifications of depositional elements will be refined as the project progresses.

The thin sandstone beds generally exhibit partial Bouma sequences, generally T_{bcd} and T_{cd} (Bouma, 1962). We interpret these beds as the deposits of low-density turbidity currents. Beds of laminated mudstone are likely also the deposits of low-density turbidity currents. The thick sandstone beds are generally massive and normally graded and are likely the sandy divisions of high-density turbidity current deposits (S3 division of Lowe, 1982).

Some sand-matrix conglomerate beds show inverse grading at their bases and are commonly normally graded, as in the S division of Lowe (1982). Thus, we interpret these as the deposits of high-density turbidity currents. Sand-matrix conglomerate beds also commonly contain rounded armored mud clasts up to 6 cm in diameter. Those beds that contain higher concentrations of mud clasts may also exhibit upwardly increasing proportions of silt content in the matrix, in some cases transitioning into matrix-supported, silt-matrix conglomerate. Silt-matrix conglomerate beds typically have a sharp, planar contact with underlying beds, which in many cases are sand-matrix conglomerate, and may exhibit upward decreases in the proportion of clasts to matrix, transitioning into pebbly or massive mudstones. Silt-matrix conglomerate beds and sand-matrix conglomerate beds that exhibit upward increases in the proportion of silt to sand in their matrix are tentatively interpreted as the deposits of slurry flows. Pebbly mudstones are interpreted as the deposits of slurry flows or debris flows. Massive mudstones lacking pebbles are interpreted as the deposits of debris flows or low-density turbidity currents.

FUTURE WORK

Future work will build upon the descriptions of the lithologies of the lower Puchkirchen Formation and preliminary depositional interpretations presented in this report with petrographic studies of the major lithologies, including analysis of the relative clay content in sandstone and conglomerate samples. The recognized lithologies will be plotted on well logs to identify potential correlations between well log signatures and identified lithologies. Detrital zircons will be extracted from sandstone samples from the upper and lower Puchkirchen Formation for U/Pb geochronology and U-Th/He thermochronology double dating. This study will build a foundation for more comprehensive investigations of the history of the lower Puchkirchen Formation.

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FIGURES

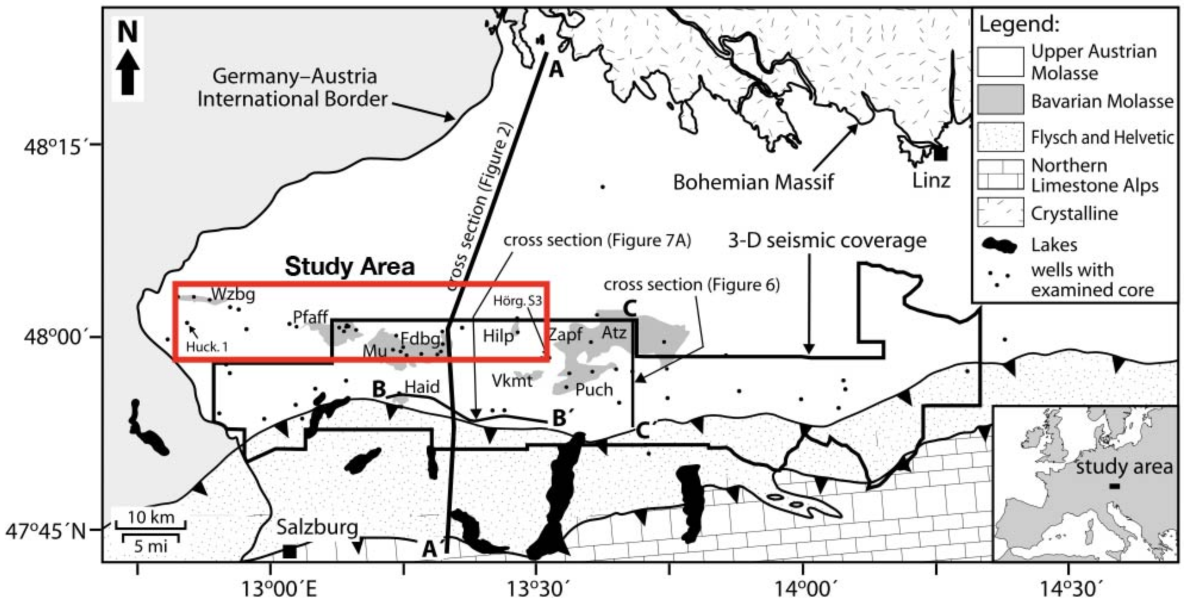


Figure 1. Gas field map of Upper Austria from De Ruig and Hubbard (2006). The study area is boxed in red.

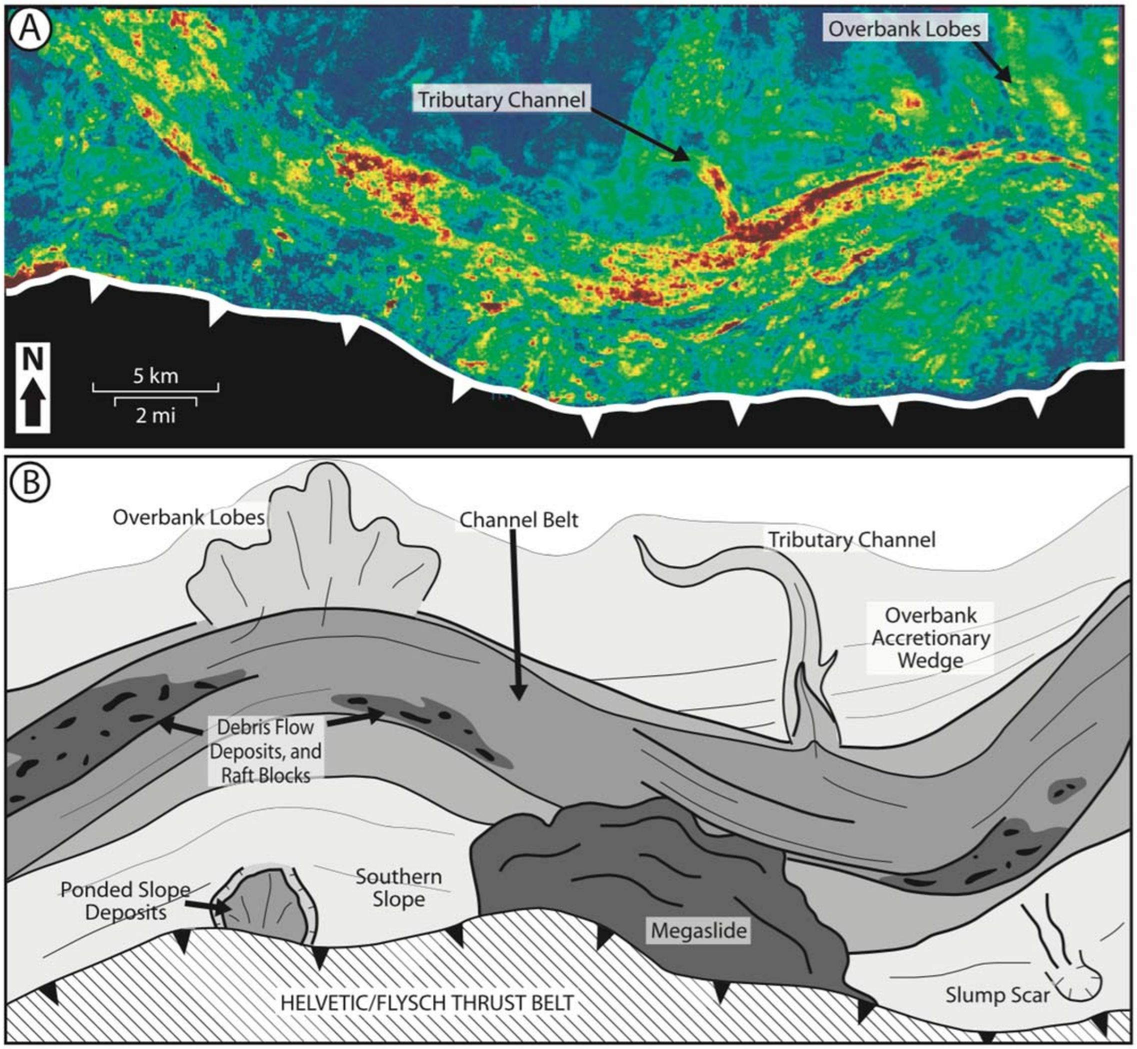


Figure 2. A. Axial channel of the upper Puchkirchen Formation seen in 3D seismic data. B. Sketch of channel architecture interpreted from seismic data. From De Ruig and Hubbard (2006).

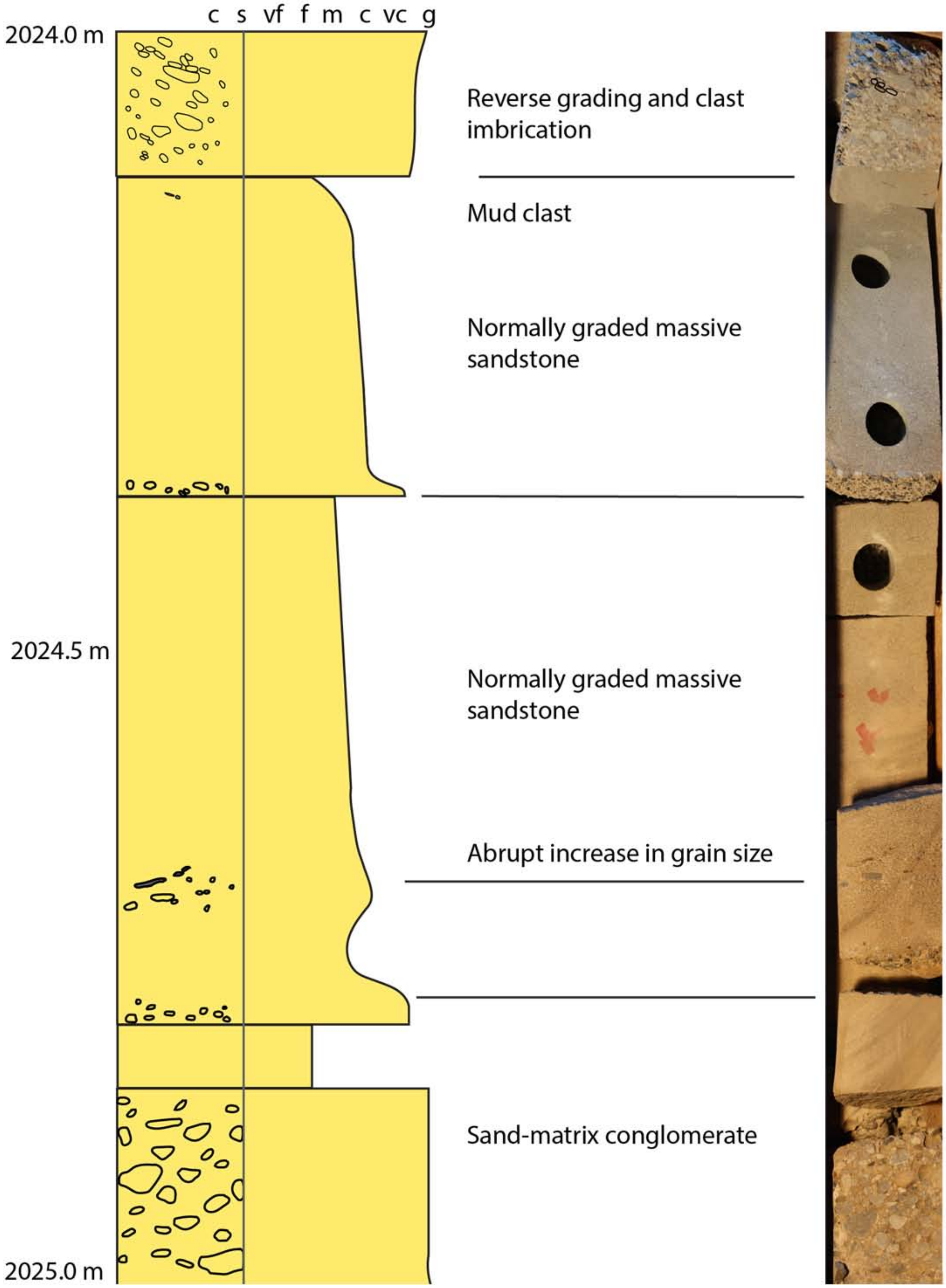


Figure 3. Sample core log of conglomerate and sandstone beds and corresponding high-resolution photographs of core.

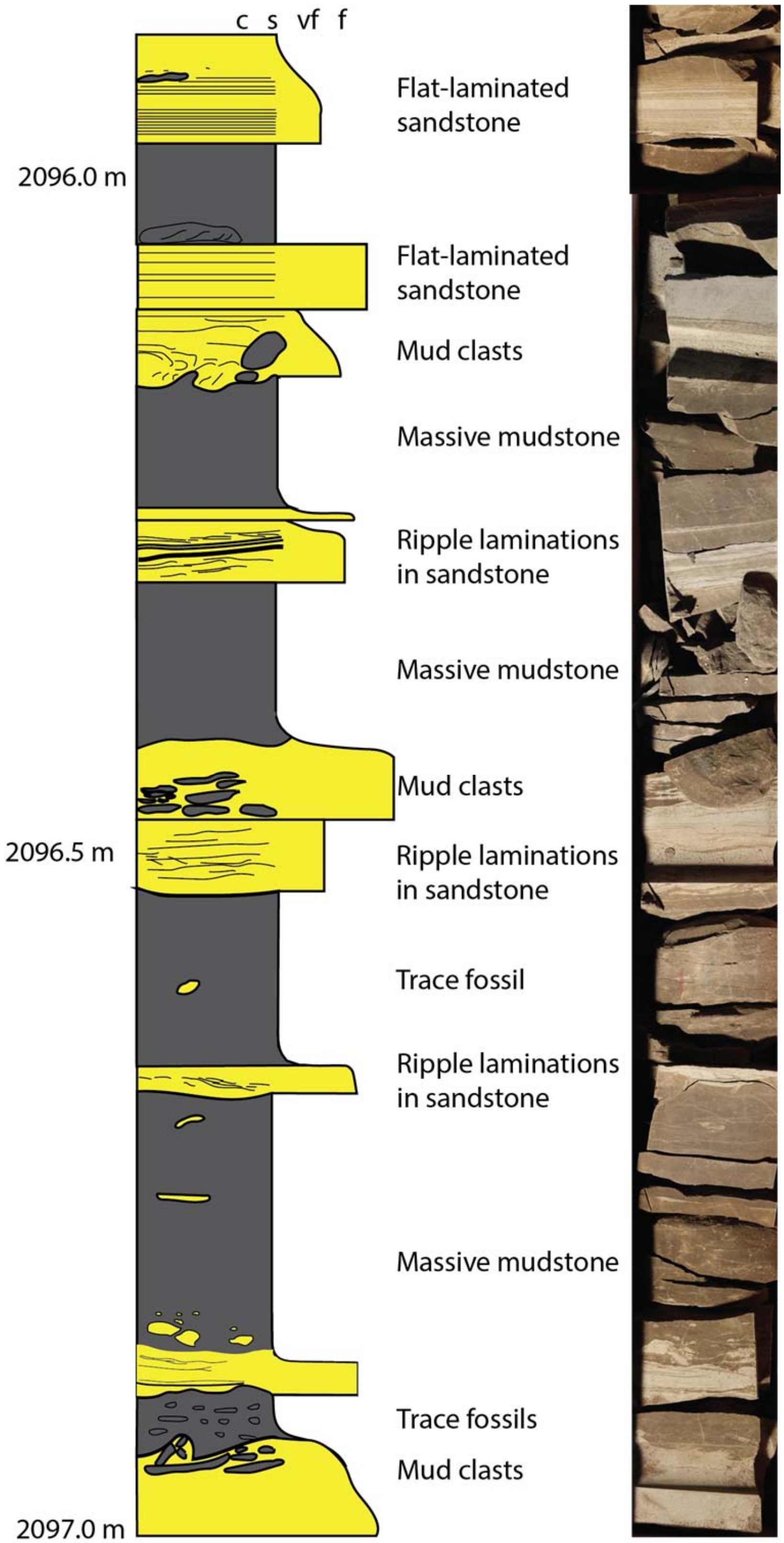
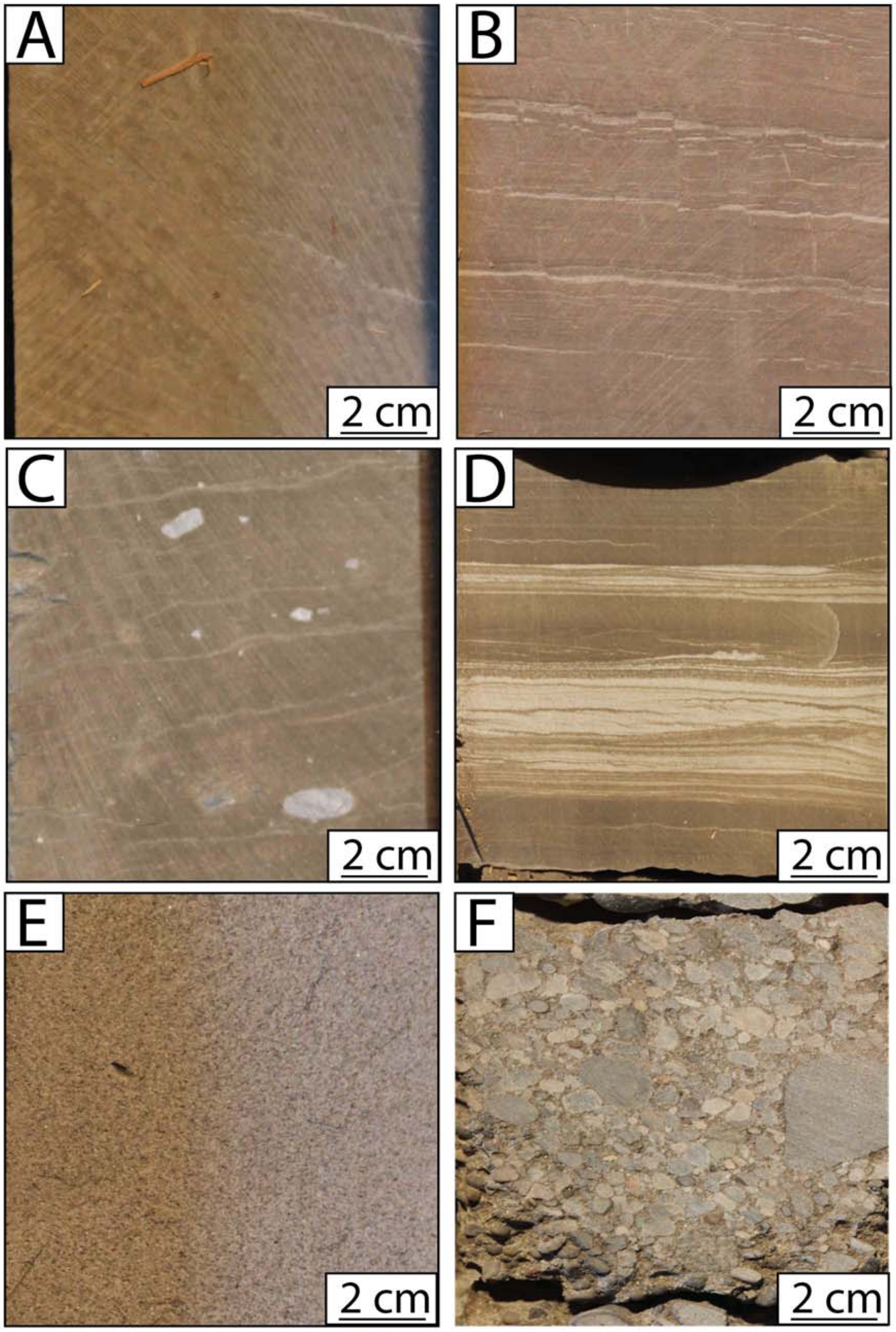


Figure 4. Sample core log of mudstone and thin-bedded sandstone and corresponding high-resolution photographs of core.



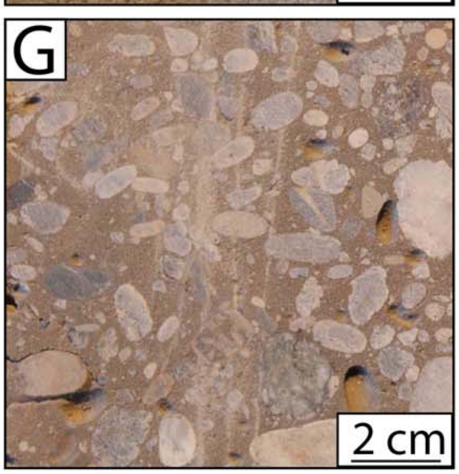


Figure 5. Bedding styles recognized in drill core samples. A. Massive mudstone. B. Laminated mudstone. C. Pebbly mudstone. D. Thin-bedded sandstone. E. Thick-bedded sandstone. F. Sand-matrix conglomerate. G. Silt-matrix conglomerate.