FIGURE CAPTIONS

Figure 1: a) Simplified geological map of the European Alps based on the compilation by Kissling and Schlunegger (2018) and updated using additional information from Handy et al. (2015) and Pippèrr and Reichenbacher (2017); b) Simplified geological-geophysical section through the central European Alps adapted from Kissling and Schlunegger (2018). Note location of Figure 2.

Figure 2: Detailed geological map of the area between Geneva and Zurich adapted from Kissling and Schlunegger (2018) showing the locations of data points referred to in this paper.

Figure 3: Composite stratigraphic columns illustrating sedimentary architectures at the proximal basin border in the western Molasse basin (proximal west), in the central part of the Molasse basin (Napf units) and in the eastern basin (proximal east). The composite section for the proximal west basin is based on data from the Mt. Vully- and Heitenried-sections, drillings, and from surface information from the Sense-section (Sense beds and Kalchstätten Formation) (Strunck and Matter, 2002). The composite section representative of the central part of the Molasse Basin (Napf) is mainly based on the sedimentary logs by Schlunegger et al. (1996; see their Schwändigraben- and Fontannen-sections) complemented with information from the geological map of the region (Schlunegger et al., 2016). Note that Kälin and Kempf (2009) proposed a very short hiatus recorded by magnetozone R3 within the Napf-units which we do not discuss in detail for simplicity purposes. The composite section illustrating the situation at the proximal basin border east of the Napf represents the sedimentary architecture as far east as of Lake Zurich (Fig. 2). It is based on data from Keller (1989, see his Rümlig-, Ränggloch- and

Lucerne-sections) and from Schlunegger et al., (1996, see their Fischenbach-section) and geological maps of the region (Wolhusen; Isler and Murer, 2019). Note that the Entlen section is situated immediately east of the Napf (Fig. 4a) where the lowermost part (Lucerne Formation) can be characterized by the composite section of the proximal east, whereas the topmost part is made up of conglomerates of the Napf units. Detailed sedimentological data of the Sense-beds and the Lucerne Formation are shown in Fig. 5. Note that the Molasse units shown in capitals (i.e. USM, OMM 15 and OSM) are based on lithological architecture and thus on facies associations identified in the field.

Figure 4: a) West-East chronological (Wheeler) diagram of the Molasse sequence at the proximal basin border between Fribourg and Lucerne (Fig. 2). The following magnetostratigraphic data have been used: Mt. Vully, Heitenried and Sense (Strunck and Matter, 2002), and Napf and Fischenbach (Schlunegger et al., 1996). Palaeo-discharge directions from Heitenried and the upper part of the Sense-section are taken from Strunck and Matter (2002). Note, that the Entlen-section is not calibrated with magnetostratigraphic data but has been adjusted using regional information (see text for further details and Fig. 3 for synthetic sections of the region). MFS = Maximum flooding stage. Note that Pliocene erosion removed most of the OMM II record in western Switzerland. We infer marine conditions in the western Swiss Molasse basin during OMM II times because: (i) marine conditions were present east of the Napf-units, and (ii) material transport occurred towards the west, which implies that marine conditions were also present west of the Napf megafan at that time as confirmed by mapping (e.g., Wanner et al., 2019); b) North-South chronological (Wheeler) diagram of the Molasse sequence between Entlen (site 13) and Madiswil (site 14, both on Fig. 2). See text for further details. The onlaps

(blue arrows) are based on interpretations from seismo-stratigraphic data (Schlunegger et al., 1997). MFS = Maximum flooding stage. Do Figs. 4a and 4b require legends?

Figure 5: Sedimentological logs of a) the Entlen-section and b) the Sense-section. See Fig. 2 for locations of sections, Fig. 4 for chronological framework of the deposits and Table 1 (Appendix) for further sedimentological details and abbreviations of the 5 lithofacies. The block-diagrams illustrate the palaeogeographical conditions from a conceptual point of view. Note that the palaeo-bathymetric values are minimum estimates and that the mean water depths have been inferred from the assignment of lithofacies to depositional environment. This might explain why the numerical values for water-depths based on cross-bed thicknesses and our inferred mean water-depth estimates deviate between c. 200 m and 250 m for the Sense-section.

Figure 6: Palaeogeographical reconstructions of the Molasse basin at different stages: a) USM (c. 22 Myr), b) OMM-1a (c. 20 Myr), c) OMM-1b (c. 19-18 Myr) and d) OMM-II to OSM (c. 18-14 Myr) modified after Kuhlemann and Kempf (2002). Note that all maps show present-day lithotectonic units within the Alps and the Jura mountains for orientation purposes (dashed lines and grey-coloured lines). We acknowledge that the positions of 5 these and the surface patterns (such as lakes) were different during deposition of the Molasse deposits. The location of the palaeothrust fronts (thick line) are adapted from Kuhlemann and Kempf (2002). Black dots mark study sites for orientation purposes. Please refer to Fig. 1 for the complete legend.

Figure 7: Molasse stages (USM, OMM and OSM) with mean paleoflow directions, hiatuses plotted against stable oxygen isotope stages (Miller et al., 1996) and sediment flux (Willet, 2010). Red triangles demarcate the onset of delamination and rapid exhumation of the Aar-

massif (Herwegh et al., 2017). Grey arrows demarcate falls in sea level and decreases in sediment flux possibly contributing to the related hiatuses. MFS = Maximum flooding stage.