Supporting Information for **Frings et al.**

(2023 - TEKTONIKA)

Constraining the 3-D Geometry of Fold-Thrust Belts Using Section Balancing vs. 3-D Interpolative Structural and Probabilistic Modeling

K. A. Frings[1,2], C. von Hagke[2*], F. Wellmann[3], E. Heim[3], M. de la Varga[4], H. Ortner[5], and E. Luijendijk[6]

[1]*Geological Institute, RWTH Aachen University, Aachen, 52062, Germany*

[2]*Department of Geology, Salzburg University PLUS, Salzburg, 5020, Austria*

[3]*Institute for Computational Geoscience, Geothermics and Reservoir Geophysics (CGGR), RWTH Aachen University, Aachen, 52074, Germany*

[4]*Terranigma Solutions GmbH, Aachen, 52062, Germany*

[5]*Institute of Geology, University of Innsbruck, Innsbruck, 6020, Austria*
[6]*Department of Earth Science, University of Bergen, Bergen, 5020, Norway*

**Correspondence to: Kevin A. Frings (e-mail: frings@geol.rwth-aachen.de)*

Geological overview of the study area:

Alpine mountain building affected the sedimentary succession of the basin, leading to tectonic stacking of the Rhenodanubian Flysch and the European margin sediments (Helvetic Thrust Sheets) (Herb, 1988; Kempf and Pfiffner, 2004; Lihou and Allen, 1996; Pfiffner, 1986; Pfiffner et al., 2002; Schmid et al., 1996). Continued thrusting at the tip of the Alpine orogen affected the Molasse sediments, creating the deformed part, called Subalpine Molasse (Ganss and Schmidt-Thomé, 1955, 1953; Schmidt-Thomé, 1957; Paulus, 1963). The Subalpine Molasse at present forms a fold and thrust belt extending from Lake Geneva, Switzerland to eastern Bavaria, where it tapers off and completely disappears east of Salzburg (Götzinger, 1955). Structurally, it can be regarded as northernmost nappe of the Helvetic units (Ortner et al. 2022).

Extensive seismic, borehole, and outcrop data exist (Stephan and Hesse, 1966; Pflaumann and Stephan, 1968; Ostheimer and Schröder, 2016; Grottenthaler, 1978/1979, 1985; Paulus, 1963; Thomas et al., 2006; Müller, 1975/1976; Lüschen et al., 2006). Furthermore, the foreland basin stratigraphy has been established in many local studies at high resolution (Hesse, 1982; Gümbel, 1875; Hesse, 1961; Heyng, A. M., 2009a, 2009b, 2009c; Hölzl, 1962; Paulus, 1963; Rasser and Piller, 1999; Zöbelein, 1962). However, despite the large data set, different models of the subsurface geometries exist (Sissingh, 1997; Berge and Veal, 2005; Thomas et al., 2002; Thomas et al., 2006; Ortner et al., 2015; Ganss and Schmidt-Thomé, 1953).

Whereas on the orogen scale, the Subalpine Molasse and the thrust sheets of the Rhenodanubian Flysch and the Helvetic units appear to be relatively cylindric, the system is much more complex in the study area (Figure 1, Ortner et al., 2015; Stephan and Hesse, 1966; Pflaumann and Stephan, 1968; Ostheimer and Schröder, 2016). In the western part, the Rhenodanubian Flysch and Helvetic Thrust sheets together are about nine kilometers wide in map view. This width decreases towards the east to only 2.5 kilometers at the eastern end of the study area. Existing profiles across the Helvetic units and Rhenodanubian Flysch show a relatively simple nappe stack in the west, whereas in the central part of the study area, between Lake Tegernsee to Lake Schliersee, a tectonic window of the Helvetic units within the Rhenodanubian Flysch is present (Figure 1, Ostheimer and Schröder, 2016; Pflaumann and Stephan, 1968; Stephan and Hesse, 1966; Ortner et al., 2015).

Previously published stratigraphic data of the study area differ in subdivision and naming of the stratigraphic units in all three major tectonostratigraphic units (Rhenodanubian Flysch, Helvetic Thrust Sheets, Molasse) (e.g., Ostheimer and Schröder, 2016; Pflaumann and Stephan, 1968; Stephan and Hesse, 1966; Paulus, 1963, Ganss and Schmidt-Thomé, 1953).Establishing a stratigraphic column applicable for the entire study area is difficult, especially for the Subalpine Molasse, and complicated by two factors: firstly, the paleo-facies-boundary from terrestrial to marine environments shifted through the study area during most of the time of deposition. Secondly, previous studies used different names for the same units and different degrees of detail in defining sub-units. Furthermore, high resolution studies, as for instance carried out for mining projects, introduce stratigraphic units of only local importance. Therefore, we chose to approach a common stratigraphy

(Figure 2) in two steps. As a first step, we established the stratigraphy for the western and the eastern part separately (west and east of the dominant paleo-coastline). In a second step, the two separate columns were joined to one column that accounts for all formations occurring in both parts.

The formations of the Rhenodanubian Flysch that are present in the study area range from Barremian to Maastrichtian age. The Cenomanian to Priabonian Ultrahelvetic Units are outer shelf-sediments of the European Margin, while the Helvetics comprise more proximal sediments (Freudenberger and Schwerd, 1996). Helvetic units of the study area were deposited from Barremian to Priabonian times, with Paleocene Helvetic rocks missing (Figure 2). The succession comprises marls and limestone in the lower part, which are overlain by sandstones (Ostheimer and Schröder, 2016; Pflaumann and Stephan, 1968; Stephan and Hesse, 1966). In the western part of the study area, Cretaceous Helvetic units are mostly absent, while Eocene deposits are dominant. In contrast, the central and eastern parts lack Eocene Helvetic units, but preserved most of the Cretaceous record. The highly differentiated Upper Campanian and Maastrichtian formations show the importance of local facies variabilities, rendering along-strike correlations challenging (Ostheimer and Schröder, 2016; Pflaumann and Stephan, 1968; Stephan and Hesse, 1966).

The youngest tectonostratigraphic unit of the study area is the Molasse. Its age ranges from the Rupelian to the Lower Tortonian. Lithologically, sandstones dominate, while marls and conglomerates are also present (Paulus, 1963; Zöbelein, 1962; Hölzl, 1962; Ostheimer and Schröder, 2016; Pflaumann and Stephan, 1968; Stephan and Hesse, 1966, Ortner et al. 2021).

Stratigraphic complexity within the Molasse deposits exists at all scales as during most of the time of deposition the area marks the facies transition zone from terrestrial environments (west) to marine environments (east), related to two regressive megacycles (e.g., Kuhlemann and Kempf, 2002). The Rupelian Tonmergel Beds and Lower Chattian Baustein Beds can be traced through the whole study area. The younger Chattian and Aquitanian units are most affected by the facies boundary shifting along strike the study area, which resulted in multiple local sub-units (e.g., Ostheimer and Schröder, 2016; Pflaumann and Stephan, 1968; Stephan and Hesse, 1966). On top of the Baustein Beds, formation names vary, accordingly. In the Bad Tölz area, the formations are named “Untere Cyrenenschichten” (Ostheimer and Schröder, 2016), while differentiation to coal mining related names is made in the Tegernsee area. For the Hausham Syncline local names are “Mariensteiner Flözgruppe” west of the Mangfall river and “Liegendflözgruppe”, Philipp-Flözgruppe” and Groß- und Kleinkohlgruppe” east of the Mangfall river (Pflaumann and Stephan, 1968). Within the Miesbach Syncline, equivalent formations are called “Lower and Middle Chattian”. For our stratigraphic column, we summarize all these terms to “Lower Chattian Cyrena Beds” (Figure 2). In the western and central part of the study area these deposits are followed by the freshwater deposits of the “Lower Bunte Molasse”, while the brackish coal bearing facies continued in the eastern part (e.g., Paulus, 1963). On top of this regressive sequence the brackish facies spread over the study area again. The deposits are again named differently throughout the study area. The formations are referred to as “Hauptcyrenenschichten” in the west (Ostheimer and Schröder, 2016), “Middle and Upper Chattian” within the Hausham Syncline, and “Haupt-

und Sattelflözgruppe" within the Miesbach Syncline. We summarize these formation names as "Upper Chattian Cyrena Beds". As the continuous brackish environment in the Chattian of the easternmost part makes it impossible to distinguish the Upper and Lower Chattian Cyrena Beds, we define the whole terrestrial and brackish formations as "Chattian Cyrena Beds" for modeling purposes. The uppermost Chattian is dominated by marine sands in the east and brackish facies in the west, separated from the Upper Chattian Cyrena Beds by a thin marine sand layer (Paulus, 1963). We summarize these time-equivalent horizons as "Top Chattian Beds". The Aquitanian marine sandstones of the Promberg Beds can be traced throughout the whole study area, while another regression-transgression cycle affected the study area for the remaining Aquitanian. The single units are the "Upper Bunte Molasse", "Daser Beds" and "Heimberg Beds" (Paulus, 1963). To account for the younger cycle in the models, we define it as "Aquitanian Cyrena Beds". The Burdigalian to Tortonian formations are consistently the Upper Marine Molasse, followed by the Upper Freshwater Molasse for the entire study area (Paulus, 1963; Ostheimer and Schröder, 2016; Pflaumann and Stephan, 1968; Stephan and Hesse, 1966). Immediately north of the frontal thrust system, in the central part of the study area, the Taubenberg alluvial fan is located, a competent block of Upper Freshwater Molasse conglomerates (Ortner et al., 2015).