Revised and updated translation of
Geologie der Alpen, Second Edition

Geology of the Alps

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► Figure 3.31 The ‘Bündnerschiefer’ of the Penninic nappe complex in Graubünden. In the stratigraphic columns, the Nolla Shale Formation, as an example, can be traced from Prättigau (Valais Trough) all the way into the Falknis and Schams nappes (Briançon Rise). The basin model displays two small oceanic domains. The northern one opened in the Jurassic, the southern one in the Early Cretaceous.

Chapter 04

▲ Figure 4.1 Schematic overview of the Cenozoic rock suites in the Alps. Sediments accumulated in the foreland of the Alps (Flysch basins, Molasse Basin and Po Basin) as well as in intramontane basins. Some of the sedimentary sequences developed continuously from the underlying Cretaceous sequences. Magmatic rocks include the Peri-Adriatic plutons and associated dyke swarms, as well as volcanic rocks in the northern foreland.

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◄ Figure 4.12 Palaeogeographical map of the future Alpine realm in the Early Eocene (55 Ma). The present-day outcrop shapes of the various basement units are given as a frame of reference. The Northpenninic flysch basins were narrow troughs in the northwestern Alpine foreland. A rise separated two flysch basins and acted as the source of detritus. Continental conditions existed on a regional bulge to the northwest of the flysch basins.

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Chapter 05

► Figure 5.2-7 Geological cross-section through the Helvetic nappe system along the transect of Sanetschpass. The internal structure is characterized by an interplay of isoclinal folds and thrust faults. The photograph gives a view of the frontal folds in the Cretaceous limestones of the Wildhorn nappe in the western flank of the Schluchhorn. Light coloured cliff is Schrattenkalk Formation. Drusberg Marl form the core of the fold.

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Figure 5.2-13 The Glarus Thrust in the Tschingelhoren (looking South), a center piece of the UNESCO World Natural Heritage site ‘Tectonic Arena Sardona’. The Quinten Limestone beneath the Glarus Thrust is a sliver dragged along the base of the Helvetic nappes, which came to lie on top of the Sardona Flysch. This sliver consists itself of smaller slivers as indicated by the tongue of Sardona Flysch near the Martin’s Hole.

Figure 5.2-14 Fold-and-thrust tectonics in the Helvetic nappe system. (A) Inverted limb of Morcles fold in the Dents de Morcles (western Switzerland). (B) Recumbent folds at the front of the Doldenhorn nappe (Gasterntal, Canton Bern, Switzerland). Late Jurassic and Early Cretaceous are folded more or less harmonically. Qi, Quinten Limestone; Ze, Cementstone Formation; Öh, Öhrli Limestone; Kk, Kieselkalk Formation. View is to the east-northeast. (C) Plunging fold in the flank of Graustock (west of Engelberg, central Switzerland). The recumbent fold with a core of (Early and) Middle Jurassic sediments was tilted in the course of the latest updoming of the Aar massif. EJ, Early Jurassic; MJ, Middle Jurassic; Qi, Quinten Limestone (Late Jurassic); Ax, Axen thrust. View is to the West. (D) Imbricate thrusting in the area of Vättis (Canton St Gall, Switzerland). Thrust fault (marked red) puts two normal sequences on top of each other. Qi, Quinten Limestone; Öh, Öhrli Limestone; Kk, Kieselkalk Formation; Sr, Schrattenkalk Formation; Se, Seewen Limestone; Bü, Bürgen Formation; Gl, *Gobigerina* Marl. The Garschella Formation forms the thin dark band between Schrattenkalk Formation and Seewen Limestone. View is to the north. Asterisk, location of Drachenberg Cave with bones of extinct cave bears assembled some 45 000–40 000 years ago (see Fig. 7.4). (E) Imbricate thrusting in the eastern flank of

Crap Mats (north-northwest of Reichenau, canton Graubünden, Switzerland). Tschep thrust (marked red) places Late Jurassic Quinten Limestone onto a manifold stack of Cretaceous limestones. The imbrication is outlined by the repetition of the Schrattenkalk–Garschella pair (light Schrattenkalk Formation and dark Garschella Formation above). The pairs are marked by a black filled circles. View is to the west. (F) Thrusting and folding in the western flank of Piz d'Artgas (north of Breil/Brigels, canton Graubünden, Switzerland). The inclined north-vergent anticline beneath the summit of Piz d'Artgas is well outlined by the brown Bürgen Formation (Eocene). The summit area above the thrust fault marked in red consists of an inverted sequence with crystalline basement (diorite) forming the peak and overlying Triassic Röti Dolostone. The Val Nauscha mélange (VN) in the footwall of the thrust fault consists of multiple repetitions and blocks of Cretaceous and Eocene strata. View is to the east. X, crystalline basement (Punteglias submassif of Aar massif); Rö, Röti Dolostone; Sr, Schrattenkalk Formation; Ga, Garschella Formation; Se, Seewen Limestone; Bü, Bürgen Formation; Gl, *Globigerina* Marl; VN, Val Nauscha mélange.

► Figure 5.2-15 Palaeogeographical map of the pre-Triassic basement (upper diagram) and the Mesozoic sediments of the Helvetic nappe system (lower diagram) in the Central Alps (redrawn and supplemented after Kempf & Pfiffner 2004). Ax, Di, Do, Dr, Ge, Gl, Mo, Wi: Axen, Diablerets, Doldenhorn, Drusberg, Gellihorn, Glarus, Morcles, Wildhorn nappes; Chs, Chaînes subalpines (allochthonous); Bc, Border chain (of the Drusberg nappe).

Figure 5.2-16 Stockwork tectonics in the area Walensee–Sichelchamm (canton St Gall, Switzerland). The Cretaceous limestones of the Säntis nappe are detached from their Jurassic substratum and folded as detachment folds above the Säntis thrust. The Jurassic limestones in the footwall of the Säntis thrust display a completely different style characterized by imbricate thrusting. The individual imbricates are detached along shales at the base of the Middle Jurassic.

▲ Figure 5.2-17 Geological cross-section through the Penninic Klippen nappe in the transect of Gantrisch (canton Bern, Switzerland). Imbricate thrusting prevails in the rear (south), whereas thrust faults at the front are associated with folds.

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◄ Figure 5.2-19 Geological cross-section through the Penninic nappes along the seismic lines of the Eastern Transect of NRP20. Cover rocks were detached from their crystalline substratum and form a nappestack of their own (Vals, Grava, Tomül, Schams). The crystalline basement was piled up to four major nappes (Simano, Adula, Tambo, Suretta).

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and mantle structure after Lippitsch et al. (2003) and Kissling (personal communication, 2013). The Conrad discontinuity between lower and upper crust is taken at a seismic velocity of 6.5 kilometres per second.

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Chapter 06

► Figure 6.1 Simplified metamorphic map of the Alps – based on Oberhänsli et al. (2004). Regional Barrovian type metamorphism is of Cretaceous age in the Eastern Alps and of Cenozoic age in the Western and Central Alps. The Eastern Alps are characterized by a Cretaceous aged high-pressure metamorphic overprint dated at around 100 million years ago. In the Western Alps a high-pressure metamorphic overprint occurred between 45 and 35 million years ago.

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◄ Figure 6.12 Tectonic evolution of the Central Alps of eastern Switzerland depicted as a series of palinspastic cross-sections. Note that because of strike-slip motion along the Insubric Fault, some units of the Southalpine nappe system disappear with time and are replaced by others. Growth of the orogen is accomplished by successive incorporation of detached upper crustal blocks (e.g. Simano, Lucomagno, Gotthard, Aar). The sedimentary cover of these units was stripped off and moved to the north in an earlier stage. The core of the orogen made up of Penninic basement nappes was uplifted by retro-thrusting along the Insubric Fault and basal accretion of Simano, Lucamagno, Gotthard and Aar basement blocks. Uplift was aided by erosional removal of the Austroalpine nappe pile.

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◄ Figure 6.17 Kinematic evolution of the Central Alps in western Switzerland. Bernhard nappe complex after Scheiber et al. (2013), Prealps of western Switzerland after Wissing & Pfiffner (2002). Growth of the orogen was accomplished by successive basal accretion of upper crustal blocks (e.g. Verampio, Gotthard, Aar). The sedimentary cover of the upper crustal units was stripped off in an earlier phase and piled up at the front of the orogen by frontal accretion. Out-of-sequence thrusting during frontal accretion was responsible for the Southpenninic, Piemont derived Gurnigel nappe now being beneath the Middle Penninic, Briançon derived Klippen nappe. In the core of the orogen, the Penninic basement nappes (Monte Rosa, Bernhard nappe complex) were intensively squashed,

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