# Plate 8.2 Geological and Hydrogeological Profiles, Part 1: Geology

## Introduction

Until a few decades ago, our understanding of the deep structure of Switzerland was relatively poor. For many years geologists tried to assess the three-dimensional geometry using profiles, surface observations and measurements and by projecting them into deeper regions. The development of deep-drilling techniques subsequently enabled them to obtain information at selected points down to a depth of up to 6000 m (e.g. well Thun-1). Such projects were preceded by extensive seismic investigations, the results of which, however, have become available to research only very recently.

Between 1985 and 1995 intensive investigations into the deep structure of Switzerland were carried out using geophysical methods (in particular near-vertical reflection seismology) as part of the Swiss National Research Project NRP 20 [4]. Among other things, these investigations revealed deep structures, including the crust-mantle boundary (Mohorovičić discontinuity).

In view of the wealth of new results [4], it seemed more appropriate to produce new, up-to-date profiles to a scale of 1:500 000 for the «Hydrological Atlas». Since the «Tectonic Map of Switzerland 1:500 000» [5] is being revised at present, a simplified tectonic overview (with the traces of the three profiles) has been added to map 8.2.

## The geological structure of Switzerland

The Alps were formed through the collision of two lithospheric plates, the European plate in the north and the Adriatic plate in the south. During this collision, parts of the upper crust were thrust up over one another, the Adriatic plate was pushed over the lower crust and the lithospheric mantle of the European plate, which was partially subducted in the process. During the last stage of the collision, the Adriatic plate wedged itself into the European plate.

## Profile 1

In the northern part of Switzerland the Plateau Molasse is dissected by some faults, and in the Hegau area and around Bischofszell it was pierced by volcanic vents. The Subalpine Molasse consists of a series of imbricated thrust slices that have been peeled off from their substratum and stacked northwards. Above them and adjacent to the south lie the Helvetic nappes, which consist of Late Paleozoic, Mesozoic and Cenozoic sediments; these nappes were detached from the southern Aar massif and the Gotthard massif and moved northwards. Their internal structure is characterised by a series of folds and thrusts: the Cretaceous limestones were separated from the underlying Jurassic sediments and carried further north on a secondary thrust fault. The Infrahelvetic complex comprises the units beneath the basal thrust of the Helvetic nappes; it includes the pre-Triassic crystalline basement of the Aar massif and its autochthonous sedimentary cover that was folded and imbricated. The Penninic basement nappes are made up of pre-Triassic crystalline rocks separated by thin sedimentary zones. Their original sedimentary cover was sheared off and now forms its own cover nappe complex. The folded thrust faults are the result of a polyphase deformation history. The klippe of the Piz Toissa, a relict of the Upper Austroalpine nappes (the highest tectonic unit), overlies the Penninic nappes. The southern part of the Penninic nappes was intruded by the Bergell (Bregaglia) pluton. South of the Insubric line, large volumes of pre-Triassic crystalline basement and Mesozoic sediments were thrust southwards to form a nappe stack.

The evolution of the Alpine nappe complex occurred in several phases. In the region of profile 1 the Lower Austroalpine nappes moved westwards during the Cretaceous. The underlying Penninic and Helvetic nappes were pushed northwards and stacked on top of each other during Eocene–Oligocene and Oligocene–Miocene times. Orogenic movements propagated northwards from the collision zone, earlier formed nappes eventually overlying the later formed ones. The Southalpine nappes were formed in a similar order, but in a southerly direction. In Oligocene times, i.e. roughly coeval with the formation of the Penninic nappes, the Bergell pluton intruded. It was during the Miocene that the Subalpine Molasse was thrust northwards, accompanied by volcanic activity in the Hegau area.

### Profile 2

This section stretches from the Rhine graben through the Black Forest basement uplift and the folded Mesozoic sediments of the eastern Folded Jura. The edges of the Permo-Carboniferous graben beneath the Jura Mountains influenced the formation of the folds and thrusts. The formation and structure of the Plateau and Subalpine Molasse are similar to eastern Switzerland. A Cretaceous and a Jurassic stockwerk can be distinguished in the Helvetic nappes. The large-scale folding of the Jurassic stockwerk (Axen nappe) is due to the large thickness of incompetent Dogger shales. In the Infrahelvetic complex, the overturned southern limits of the Aar and Gotthard massifs point to important horizontal shortening of the two basement blocks. The Aar massif is shown to be allochthonous, i.e. thrust over the foreland. The southern part of the Penninic nappes is intensively folded and nappe contacts are almost vertical. South of the Insubric line an almost complete section through the Adriatic lower crust is exposed in the Ivrea zone; the upper crust and its sedimentary cover was dismembered in the course of Alpine deformation and now forms a south-vergent nappe stack. The uplifted upper mantle is now located at shallow depth below surface.

The chronology of the formation of the Alpine nappes is comparable with that of eastern Switzerland. Profile 2 crosses an older structure, the Pogallo line. This line cuts the Permian intrusive complex of the Baveno granite and is likely to be the result of Mesozoic rifting associated with the opening of the Tethys Ocean. The Austroalpine Sesia zone was emplaced onto the Penninic Zermatt–Saas Fee zone, a relict of the Tethys Ocean, during the Cretaceous. The Penninic nappes were formed in Eocene–Oligocene, the Helvetic nappes in Oligocene–Miocene and the Subalpine Molasse imbricates in Miocene times. The Folded Jura was compressed in the late Miocene–Pliocene, whereas the Rhine graben subsided during the Oligocene.

### Profile 3

This profile stretches from the Bresse graben across an area of horizontal Mesozoic (epivariscan) platform sediments to the allochthonous external Jura. The latter consists of internally intact Mesozoic plateaus that are bounded by narrow, strongly deformed belts («faisceaux»). The formation of these belts was influenced by the presence of Permo-Carboniferous troughs within the basement. Shortening of the Folded Jura is clearly visible by the fold and thrust structures. The Subalpine Molasse forms a thick imbricate nappe stack; in contrast to profiles 1 and 2, it is overlain by the Penninic cover nappes of the Prealps, which were pushed much further to the NW in this profile. In comparison, the Helvetic nappes remained a long way behind; in western Switzerland they are less important in volume, although it must be taken into account that large parts of the highest Helvetic nappe, the Wildhorn nappe, have been eroded. The Morcles nappe, a large recumbent fold, formed in response to the great thickness of shaly Lias and Dogger sediments. The Aiguilles Rouges massif is separated from the Mont Blanc massif by a thin zone of Mesozoic sediments. The structure of the Penninic nappes of the Valais Alps is characterised by a number of large isoclinal folds. Backfolding affected the earlier formed thrust faults. The Lower Austroalpine Dent Blanche nappe overlies the Penninic nappes. This klippe is a relict of a once continuous orogenic lid; its erosion products can be found in the conglomerates and sandstone of the Molasse Basin.

The Austroalpine nappes were thrust westwards during the Cretaceous, as were the higher Penninic nappes in the course of formation of the Franco–Italian Western Alps. The lower Penninic nappes resulted from a SE–NW compression during the Eocene–Oligocene. The Helvetic nappes were formed in the Oligocene–Miocene, coeval with backfolding in the Penninic nappes. Imbrication of the Subalpine Molasse and compression and uplift of the Aiguilles Rouges massif occurred on the course of the Miocene, while the Jura mountains were folded in the late Miocene–Pliocene and the Bresse graben subsided in Oligocene times.

## Geology and hydrogeology

Ground-water circulation depends largely on geological conditions. The flow pattern of ground water shown on map 8.3 is based on data obtained from a three-dimensional mathematical model of northern Switzerland realised in the frame of a previous study [3]. Table 1 in map 8.2 shows the relation between geology and hydrogeology and describes the hydrogeological characteristics of each geological formation, including permeability values as are used in map 8.3. These values have been estimated from various hydrogeological investigations and are based on lithological data and available pumping tests. The results thus obtained were subsequently verified by means of various three-dimensional mathematical models.

## References


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