2.3. The Austrian sector of the North Alpine Molasse: A classic foreland basin

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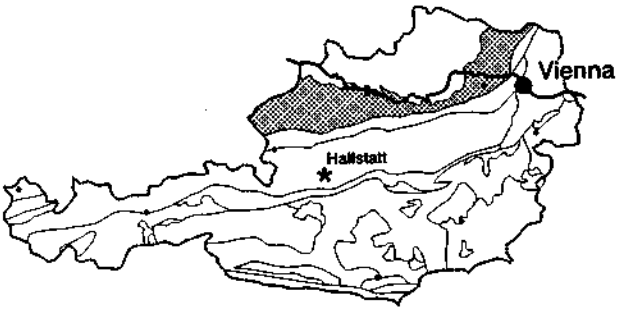


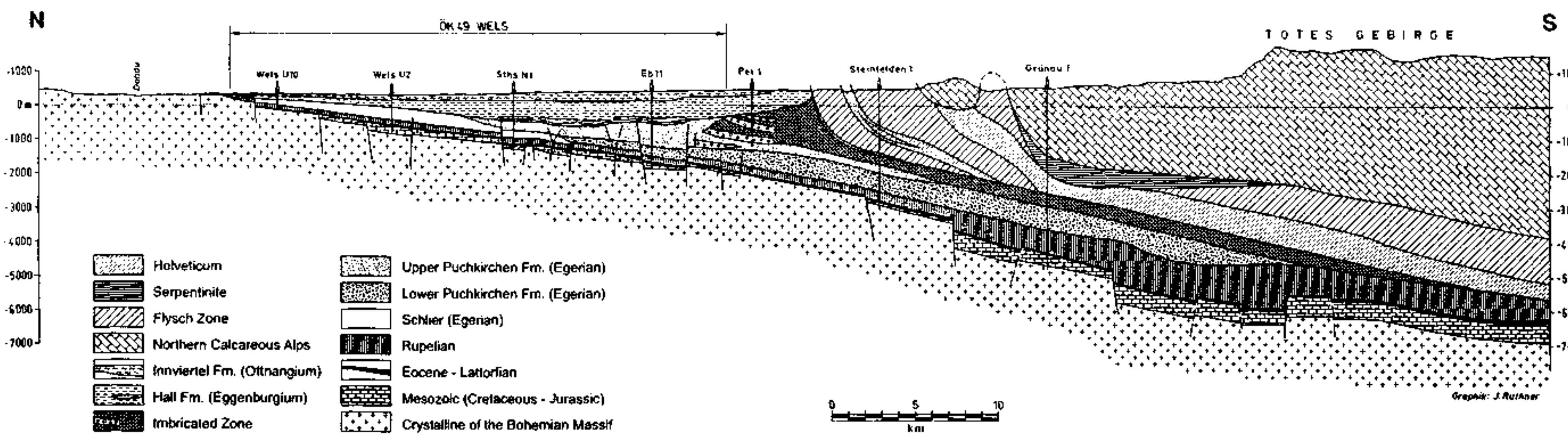
The North Alpine Molasse extends from the French Maritime Alps to the area of Vienna, where the Alpine nappe pile largely disappears below the intra-orogenic Vienna Basin. The "North Alpine" Molasse extends northeastward from the Danube west of Vienna and farther into the Carpathian Foredeep.

> The term "molasse" was introduced into the scientific literature by H.B. DE SAUSSURE in 1779. Etymologically it can either be inferred from the latin „mola" (whetstone or grindstone) or from the french "molasse" (slack or very soft), which refers to the widespread occurrence of soft sandstones and loose sands.

The Austrian Molasse is of considerable scientific interest due to the occurrence of hydrocarbons, which created the somehow paradox situation, that the subsurface of the basin is partly better known than the surface geology. In recent times special attention has been paid to the Molasse Basin because of its mirror function of Alpine uplift history.
Throughout the Austrian sector of the Molasse Basin the southern edge of the Variscan Bohemian Massif forms the northern bordering zone of the Tertiary basin fill. The metamorphic and magmatic basement rocks continue far below the Alpine nappe wedge to at least 50 km behind the northern thrust front. Structural depressions of the basement locally contain relicts of Late Carboniferous (?) to Permian molasse-type sediments of the Variscan orogenic cycle, whereas wide regions of the basement to the west and east of the southward extending so called "spur" of the Bohemian Massif are covered with epi-continental Jurassic and Cretaceous sedimentary rocks.
The Austrian Molasse Basin is strongly assymetric in two respects. There is a marked increase of basin depth and thickness of Tertiary strata towards the south, with a maximum value of >4000 m at the Alpine thrust front, which is a typical feature of foreland basins (Fig. 2.3.1.). Secondly, in a W-E profile the basin is shallowing and narrowing (~500 m deep and ~10 km wide in the region of the town of Amstetten) towards the spur of the Bohemian Massif.
Southern parts of the Molasse Basin have been overthrusted by the Alpine nappe wedge. A palinspastic reconstruction of the area northeast of Salzburg shows that the present zone of outcropping Tertiary strata between the Alpine thrust front and the Bohemian Massif, which is about 60 km wide, corresponds to less than a quarter of the former basin width. This situation requires the definition of three tectonic settings of Tertiary Molasse deposits:

1. The Authochthonous Molasse: comprises mainly flat-lying Molasse sediments underneath and in front of the Alpine body.

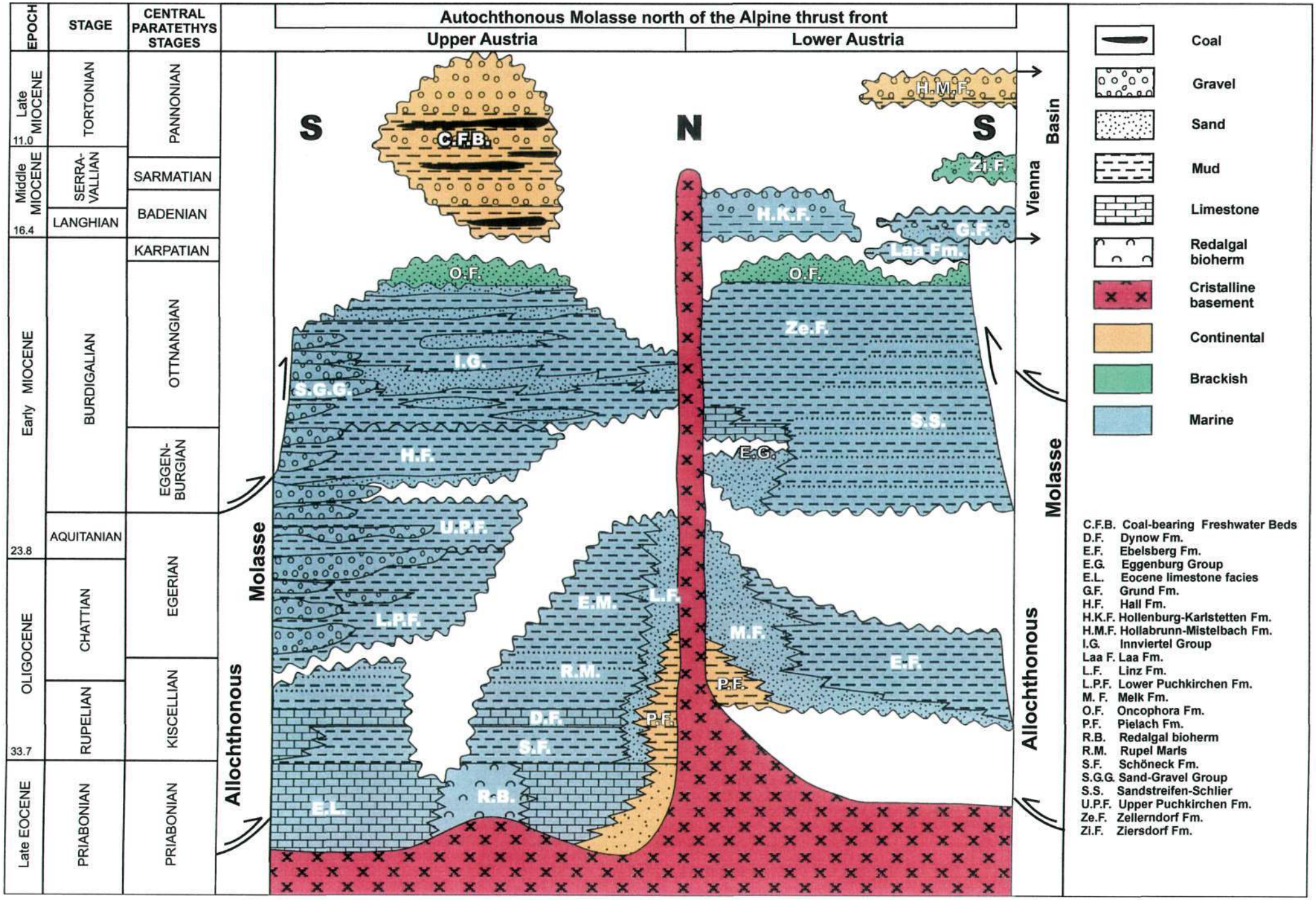
Fig. 2.3.1.: Geological Cross-section of the Molasse Zone in the region of map sheet GÖK 49 Wels from the Bohemian Massif to the Northern Calcareous Alps (from WAGNER, 1996). ➔


N
S
ÖK 49 WELS
TOTES GEBIRGE
Donau
Wels U10
Wels U2
Sths N1
Eb 11
Pet 1
Steinfelden 1
Grünau 1
+1000
0m
-1000
-2000
-3000
-4000
-5000
-6000
-7000
Helveticum
Serpentinite
Flysch Zone
Northern Calcareous Alps
Innviertel Fm. (Ottnangium)
Hall Fm. (Eggenburgium)
Imbricated Zone
Upper Puchkirchen Fm. (Egerian)
Lower Puchkirchen Fm. (Egerian)
Schlier (Egerian)
Rupelian
Eocene - Lattorfian
Mesozoic (Cretaceous - Jurassic)
Crystalline of the Bohemian Massif
0
5
10
km
Graphik: J. Ruttner

2. The Allochthonous Molasse: comprises folded and/or imbricated Molasse sediments underneath and in front of the Alpine body, which have been sheared off from the subalpine Autochthonous Molasse. Regionally (e.g. in the Waschberg Zone, N of Vienna) slices of the Mesozoic basement cover are incorporated within the imbricates. Along the strike of the Alpine thrust front the imbricates are partly covered by sediments postdating the Authochthonous Molasse. This is especially the case in the provinces of Upper Austria and Salzburg, where the Molasse imbricates form text-book-like triangle zones on seismic lines.
3. The Parautochthonous Molasse: this term refers to rare erosional relics of Molasse deposits resting on top of the Alpine nappe wedge (e.g. the „Unterinntal Tertiär", SW of Kufstein in the Northern Calcareous Alps). They have been subjected to block-faulting, northward transport and wrench-faulting together with their stratigraphic basement units in partly synsedimentary to postsedimentary times.

Post-Cretaceous sedimentation in the area of the Molasse Basin (Fig. 2.3.2.) started with a Late Eocene (Priabonian) transgression, as a consequence of a major tectonic event of the evolving Alpine orogen, which resulted in the partial elimination of the Penninic flysch troughs and integration of their sedimentary infill into the northward advancing nappe pile. Sedimentation at that time was still dominated by shallow to deep-marine carbonate facies, including red-algal bioherms. In Late Eocene times large parts of the East Alpine realm were below sea-level.
The onset of „Molasse-sedimentation", which coincides with the emergence of the Paratethys-bioprovince, can be defined with the appearance of the typical deep-marine anoxic facies of the "Fish Shale" (= Schöneck Fm.; source rocks for hydrocarbons!) in the lowermost Oligocene. Isolation of the basin can be explained by the further advance of Alpine nappes across the relictic Penninic as well as Helvetic realm and uplift of southern parts of the Alpine body above sea-level. The simultaneous subsidence of the foreland basin was triggered by tectonic loading and flexural downbending of the European lithosphere by the Alpine nappe body. Additionally a pronounced eustatic sea-level rise (Tejas A 4.4) at that time may have enhanced this process. The Fish Shale is overlain by a thin package of nannoplankton ooze (Dynow Fm.). Sedimentation of thick terrigenous units, already influenced by turbidites commenced only in Late Kilcellian (Late Rupelian) times („Rupelian Marls").
A first pulse of imbrication of Molasse sediments, caused by another northward shift of the Alpine nappe complex correlates with a distinct eustatic sea-level fall (Tejas A 4.5/B 1.1) and the incision of a slope-parallel, deep-marine trough by strong bottom currents. The sedimentary infilling of this depression (Lower Puchkirchen Fm.; Early Egerian [~Chattian]) was largely achieved by huge slump masses from both the passive northern and tectonically oversteepened southern slope of the basin. Sandy turbidites play only a minor role, however, they display important reservoir rocks for natural gas. After another re-gression (Tejas B 1.3/ B 1.4) and northward shift of the Alpine nappe pile around the Oligocene/Miocene boundary the described processes repeated once again, documented in the Upper Puchkirchen Fm. of Late Egerian (~Aquitanian) age and the lowermost part of the Hall Fm. of Eggenburgian (lowermost Burdigalian) age. Contemporaneous sediments of the Lower and Upper Puchkirchen Fm., representing the northern margin-facies of the basin comprise coal-bearing continental to brackish clays and sands (Pielach Fm.), shallow-marine sands (Linz Fm., Melk Fm.) and dark, partly diatomit-bearing offshore shales (e.g. Ebelsberg Fm.). In Bavaria, west of the Inn river, the Paratethys is nearly totally dominated by continental sedimentary successions within the same time interval.

Fig. 2.3.2.: Stratigraphic chart of the Austrian sector of the North Alpine Molasse Basin →


EPOCH
STAGE
CENTRAL PARATETHYS STAGES
Autochthonous Molasse north of the Alpine thrust front
Upper Austria
Lower Austria
Late MIOCENE
11.0
Middle MIOCENE
16.4
Early MIOCENE
23.8
OLIGOCENE
33.7
Late EOCENE
TORTONIAN
SERRA-VALLIAN
LANGHIAN
BURDIGALIAN
AQUITANIAN
CHATTIAN
RUPELIAN
PRIABONIAN
PANNONIAN
SARMATIAN
BADENIAN
KARPATIAN
OTTNANGIAN
EGGEN-BURGIAN
EGERIAN
KISCELLIAN
PRIABONIAN
Allochthonous Molasse
S
N
S
Vienna Basin
Allochthonous Molasse
C.F.B.
H.M.F.
Zi.F.
H.K.F.
G.F.
Laa Fm.
O.F.
Ze.F.
I.G.
S.G.G.
S.S.
E.G.
H.F.
U.P.F.
E.M.
L.F.
L.P.F.
M.F.
E.F.
R.M.
P.F.
D.F.
P.F.
S.F.
R.B.
E.L.
Coal
Gravel
Sand
Mud
Limestone
Redalgal bioherm
Cristalline basement
Continental
Brackish
Marine
C.F.B. Coal-bearing Freshwater Beds
D.F. Dynow Fm.
E.F. Ebelsberg Fm.
E.G. Eggenburg Group
E.L. Eocene limestone facies
G.F. Grund Fm.
H.F. Hall Fm.
H.K.F. Hollenburg-Karlstetten Fm.
H.M.F. Hollabrunn-Mistelbach Fm.
I.G. Innviertel Group
Laa F. Laa Fm.
L.F. Linz Fm.
L.P.F. Lower Puchkirchen Fm.
M. F. Melk Fm.
O.F. Oncophora Fm.
P.F. Pielach Fm.
R.B. Redalgal bioherm
R.M. Rupel Marls
S.F. Schöneck Fm.
S.G.G. Sand-Gravel Group
S.S. Sandstreifen-Schlier
U.P.F. Upper Puchkirchen Fm.
Ze.F. Zellerndorf Fm.
Zi.F. Ziersdorf Fm.

This might be due to an existing mountainous relief in the western part of the Eastern Alps and the resulting strong clastic input during the Oligocene.
This is followed by the Eggenburgian-Ottnangian (Early to Late Burdigalian) transgressive cycle (Tejas B 2.1) across a basinwide erosional surface which was created by deep-marine bottom currents and strong tide-induced currents. Possibly an uplifting event in the northern part of the basin is jointly responsible for the prominence of this surface. The uplifting event could be due to the evolution of a foreland-bulge, which can develop as a result of a visco-elastic relaxation of the lithosphere, when the thrust front of the orogen remains largely stationary. This was the case in Upper Austria since Eggenburgian (Early Burdigalian) times, whereas in Lower Austria even Carpathian (Late Burdigalian) strata are affected by imbrication processes. Sediments of the Eggenburgian-Ottnangian transgressive cycle are characterized by a multiple change of complexely interfingering, mostly shallow-marine sands and offshore muds (e.g. Hall Fm., Innviertel Group, Zellerndorf Fm., "Sandstreifen-Schlier"). These include the famous fossil-rich strata of the facially strongly diversified Eggenburg Group, which rest on the eastern margin of the Bohemian massif. Storm-influenced and tide-influenced deposits play a dominant role throughout the basin. Coarse-grained fan-delta sediments are known from the area northeast of Salzburg ("Sand-Gravel group").
In Late Ottnangian (Late Burdigalian) times fully-marine sedimentation ceased in the major part of the basin documented by brackish sands and silts (Oncophora Fm.). Following above a major hiatus, which includes the Carpathian (Latest Burdigalian) a thick succession of continental coal-bearing clays and fluviatile gravels and sands was deposited from Badenian to Pannonian (Langhian and Tortonian) times in Upper Austria ("Coal-bearing Freshwater beds"). No more relation to eustatic sealevel changes can be recognized in this succession. However, in Lower Austria (north of the Danube) a transgressive cycle (Tejas B 2.2) of Carpathian (Latest Burdigalian) age is evidenced by shallow-marine sands, muds, and gravels (Laa Fm.). The early Badenian (Early Langhian) sediments are again transgressive in character (Hollenburg-Karlstetten Fm., Grund Fm.) and a short incursion from the intra-alpine Vienna Basin reached the Molasse Basin in the Early Sarmatian (Upper Serravallian) for the last time (Ziersdorf Fm.). The latter sedimentary cycles do not satisfactorily match the eustatic sea-level chart. Sediments of the Pannonian (Tortonian) north of the Danube correspond to the limnic-fluviatile deposits of Upper Austria and can be ascribed to a Proto-Danube discharge system (Hollabrunn-Mistelbach Fm.).
Significant uplift of the Rhenodanubian Flysch and the Northern Calcareous Alps in the eastern part of the Eastern Alps did not start before the Pannonian (Tortonian), as is expressed by the gravel material in the foredeep. In the corresponding time interval the eastward directed drainage-pattern of the Danube developed. Widespread erosion of Molasse deposits commenced in Pliocene times. During the Quaternary both glacial and periglacial processes operated in the North Alpine Molasse Basin leaving huge masses of moraines, fluviatile gravels, loess, solifluidal material and a strongly overprinted landscape.

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