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STRATIGRAPHY AND HYDROCARBONS IN THE MOLASSE FOREDEEP OF UPPER AUSTRIA AND SALZBURG

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STRATIGRAPHY

The Molasse Basin of Upper Austria and Salzburg is part of the Alpine-Carpathian foredeep. It represents an asymmetric basin with an outcropping passive northern margin where the sediments are overlying the crystalline basement of the Bohemian Massif. From there the beds dip to the south. The southern part has been affected by the alpine orogeny and is overthrusted (Encl. 3 and 4). A significant area of the Molasse lies below the nappes of the Helvetic, the Flysch and the Northern Limestone Alps.

Total thickness of the Molasse sediments can reach more than 3000 m. The **Pretertiary basement** consists (from base to top) of Precambrian to Palaeozoic rocks (**Crystalline of the Bohemian Massif**). Above this crystalline rocks there are remnants of **Mesosoic sediments** (Encl. 1). In one well fluvial sandstones and clays with coal seams of probably **Permo Carboniferous** age were penetrated.

A dominant structural high (**Central Swell Zone**) passes from Bavaria in a NW-SE direction through the Molasse Basin of Upper Austria. Numerous faults are cutting the pretertiary basement and seperate it into different blocks. All these blocks are tilted to the E. The vertical displacement can amount to more than 1000 m.

The **Mesozoic sediments** indicate **two main cycles** of marine transgression and regression (Encl. 1). During the **first cycle** (Mid-Jurassic – Lower Cretaceous) the Molasse basement was part of the Middle European Carbonate platform. Sedimentation started with fluvial braided stream sandstones with coal layers, followed by shallow marine sandstones and carbonates. The salt lagoon and tidal flat deposits of the Purbeck form the upper part. Opening of the Atlantic (during Lower Cretaceous) caused uplifting of the Bohemian Massif and interrupted the sedimentation. This led to erosion and kartification of the Jurassic carbonates.

During the **second cycle** (in Aptian) the area S of the Central Swell was flooded by the sea. In Upper Cretaceous (Cenomanian) the whole Molasse basement was transgressed. Sedimentation continued to Upper Campanian. The lowest **Cenomanian** sediments are fluvial sandstones (Schutzfels beds) which infill the Jurassic karsts. They are overlain by marine sandstones and shales. The sandstones were deposited by storms in an inner shelf setting. The sedimentation turns then to outer shelf facies. Late Campanian shallow marine coarse clastics are reported from the NW part of Upper Austria. Restricted to the easternmost part, from Late Turonian onwards, fluvio – deltaic fans were deposited.

The Cenomanian is the second most important oil reservoir of Upper Austria. Uplifting of the European plate stopped the marine sedimentation. Extensive erosion flattened the tilted fault blocks.

The **Molasse Basin** is a result of the Alpine orogeny. Sedimentation started in **Late Eocene** when the Tethys Sea progressively encroached from the south. It's marine record terminated in Upper Ottnangian (Encl. 1). In Late Eocene the Central Swell Zone acted as an shallow barrier which separated the lagoon in the N from the slope to the open sea in the S. The different facies zones started in the N with fluvial floodplains cut by channel sandstones of meandering rivers. The subsiding foodplain is capped by a coal

bed (swamp) which is overlain by dark paralic Cerithian beds with tidal channels, followed by shallow marine sands. All these sediments are sourced from the Crystalline of the Bohemian Massif in the north. The red algae and coral reefs (Lithothamnium limestone) are approximately centered on the Central Swell and shed it's debris to the north (lagoon) and to the south (high energy, open marine shelf edge). On the slope, sediments of successively deeper environments are developed (Nummulitic Sandstone, Discocyclina Marl, Globigerina Limestone, ...).

Oil and thermal gas are produced from the different Eocene sandstones and partly from the Lithothamnium limestone. The Eocene is the main oil producer of Upper Austria.

Rapid subsidence during the **earliest Oligocene** provided deep – water conditions. The Molasse basin became the pelagic Alpine foredeep. The first post-eocene sediment is the **Schoeneck fish shale** (Lower Kiscellian) which was deposited under low oxygen conditions. It contains a high content of organic material and is the correlated source rock of the Upper Austrian Oil. Generation took place below the Alpine nappes starting in Miocene.

The **Dynow Marlstone** consists of nanno-ooze. In the following shales, coarse clastics of turbiditic origin are intercalated. The subsidence was accompanied by a dense network of W-E trending extensional antithetic and synthetic faults. It was caused by the subduction of the European plate under the Periadriatic plate and by the weight of the advancing Alpine nappes.

This fault pattern controls most of the Upper Austrian oil fields (Encl. 2-4). The trough axis of the basin moved northward with the shift of the Alpine units and the Molasse imbricates. The deep marine bottom currents were forced to deviate in this direction and massively eroded into older sediments. The erosional surface was rapidly filled by coarse clastics (gravity deposits and turbidites). Often the sediments were reworked (contourites). The sandstones and conglomerates of the **Upper** and **Lower Puchkirchen Formation** contain many gas fields (bacterial gas – Encl.2). The gravel of the Oligocene and Lower Miocene conglomerates (crystalline, darkgrey dolomites, ...) were derived from the Central Alps in the south. Equivalents are the "Augenstein" gravels found on the surface of the Northern Limestone Alps.

By the beginning of **Hall Formation**, the Flysch nappes and Molasse imbricates had reached their present day position. The front of the Flysch and Helveticum nappes (plus the imbricates) fromed the south rim of the deep marine environment. The base of Hall Formation follows a prominent submarine erosion across the Molasse basin (new fauna immigrated). Compressional tectonics including strike-slip movements occured and the erosional events continued. Typical Hall Formation sediments are gray, silty shales with sandstones of turbiditic origin. There are many gas fields in Hall Formation sands.

At the end of Hall Formation time and during the Innviertler Formation the basin became shallower. After a short brakish event in Late Ottnanian the sea regressed towards the east. The Molasse sediments became tilted and intensive erosion took place.

The braided river gravels of the Coal-bearing freshwater beds (Badenian-Pannonian) contain coal seams which have been mined. Since the Quarternary large areas of the Molasse basin have been covered by moraines and fluvial gravels.

OIL AND GAS FIELDS IN THE FOREDEEP OF UPPER AUSTRIA AND SALZBURG (Encl. 2)

The first gas and oil in present Austria was found in the Upper Austrian Molasse Basin (1892 gas in Wels and 1906 heavy oil in Leoprechting). Both discoveries were accidentally encountered by water wells in the shallow northern part of the Molasse Foredeep.

Many years passed by without any other hydrocarbon finds. In 1956 RAG (Rohöl-Aufsuchungs Aktiengesellschaft), Austria's oldest oil company (founded 1935), encountered oil by drilling it's first exploration well in Upper Austria. The well Puchkirchen 1 hit oil in Eocene sandstones (Cerithian beds).

Meanwhile, many oil and gas fields have been discovered. The largest oil field so far is Voitsdorf (1962/63), located a few kilometers NE of the core storage Pettenbach. Some 40 wells have been drilled in this field which is an E-W trending monocline with a major fault in the N. Erosional processes made a joint reservoir with Eocene sandstones (fluvial and marin) overlaying the Cenomanian sandstones (tempestites) which rest on Jurassic sandstones. This field is crowned by a gas cap. 3.1 MM tonnes (23 MM BBL) of oil have been produced in Voitsdorf up to the end of 1997.

The last important oil discovery was Kemating (1979) where the oil is trapped in shallow marine Eocene sandstones of a fault block. The oil fields are controlled by faults and the south dipping beds. Sometimes in addition the shale-out of the reservoir plays an important role.

RAG's first commercial gasfind happened 1962 (Schwanenstadt 2, in Miocene Hall Formation). Most of the gas (bacterial gas) is found in Oligocene and Miocene coarse clastics (turbiditic sandstones and sandy conglomerates). The gas is trapped in compaction anticlines, stratigraphic traps or in a combination.

In the last few years prospects in the area of the rather complex imbricated molasse have been drilled. So far only few gas fields have been discovered in these imbricates. Last year the well Haidach 1 found a remarkable gas field. The areal extent of this gas is small but the net pay of the massflow sediments amounts to more than 60 m.

Several gas fields were found by drilling deeper oil prospects. In most of the deeper horizons there is condensate associated with the biogenic gas. The largest gas field is Atzbach – Schwanenstadt – Zell am Pettenfirst with gas in the deep marine coarse clastics of Puchkirchen Formation and Hall Formation (cumulative production to end of 1997 4.23 BNcbm (158 BSCF)). Thermal gas is found in the eastern part of Upper Austria in Upper Cretaceous and Eocene sandstones. Some reservoirs contain a mixture of thermal and biogenic gas.

Since 1965 OMV has been successfully exploring in parts of Upper Austria. Deep prospects S of the Alpine thrustfront encountered only marginal oil and gas accumulations. One well in the imbricated zone had a good oil influx but due to a later high water cut the well was uncommercial.

The low oil price has compelled RAG to concentrate on gas prospects during the last 12 years. This caused a decline in the oil production. The gas sales have been supplied by new discoveries and development drilling. Though the big compaction structures have been drilled for many years more complex, but smaller, gas accumulations are being found.

The fault pattern is important for the occurence of the reservoirs and the traps. The Molasse Foredeep of Upper Austria and Salzburg is the second most important hydrocarbon province of Austria. At the end of 1997, RAG had produced 7.5 MM tonnes (55 MM BBL) of oil and 16.3 B Ncbm (606 BSCF) of gas. RAG installed an underground gas storage in the Puchkirchen gas field (Upper Puchkirchen Fm.). Six horizontal wells (horizontal length in the reservoir > 1000 m) have been drilled. Another gas storage project is handled by OMV. RAG has drilled more than 600 wells in the Molasse Foredeep. The basin is covered by a dense grid of 2 D-seismic lines and a relative large area by 3 D-seismic.

High temperatures (> 100°C) and appropriate reservoir rocks (karsted Jurassic carbonates) offer good geothermal potential. Some geothermal projects are already operating partially using old RAG wells. Next year, even electric power will be generated (Altheim).

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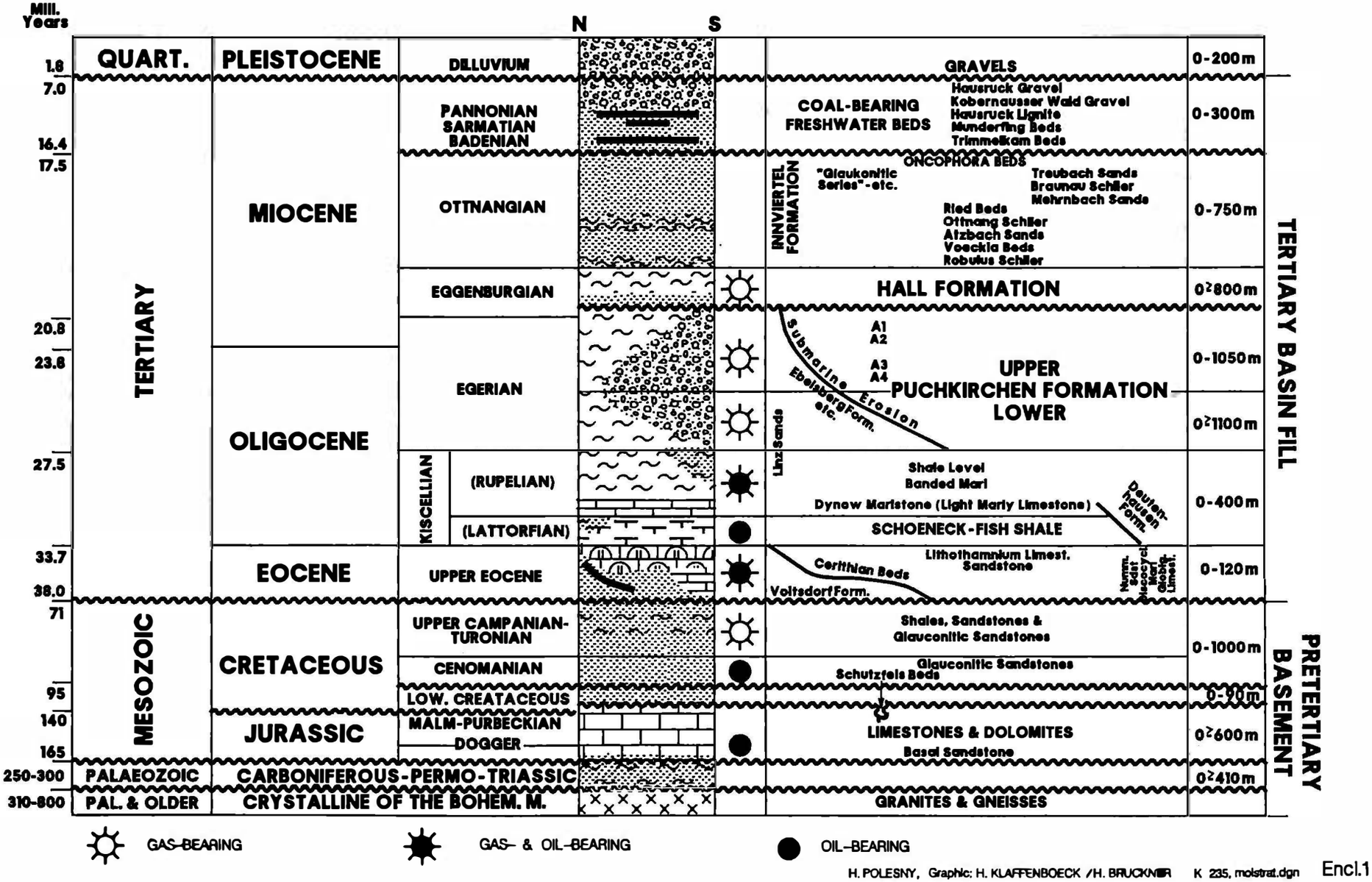
STRATIGRAPHIC CHART OF THE MOLASSE BASIN
UPPER AUSTRIA AND SALZBURG



H. POLESNY, Graphic: H. KLAFFENBOECK /H. BRUCKNER K 235, molstrat.dgn

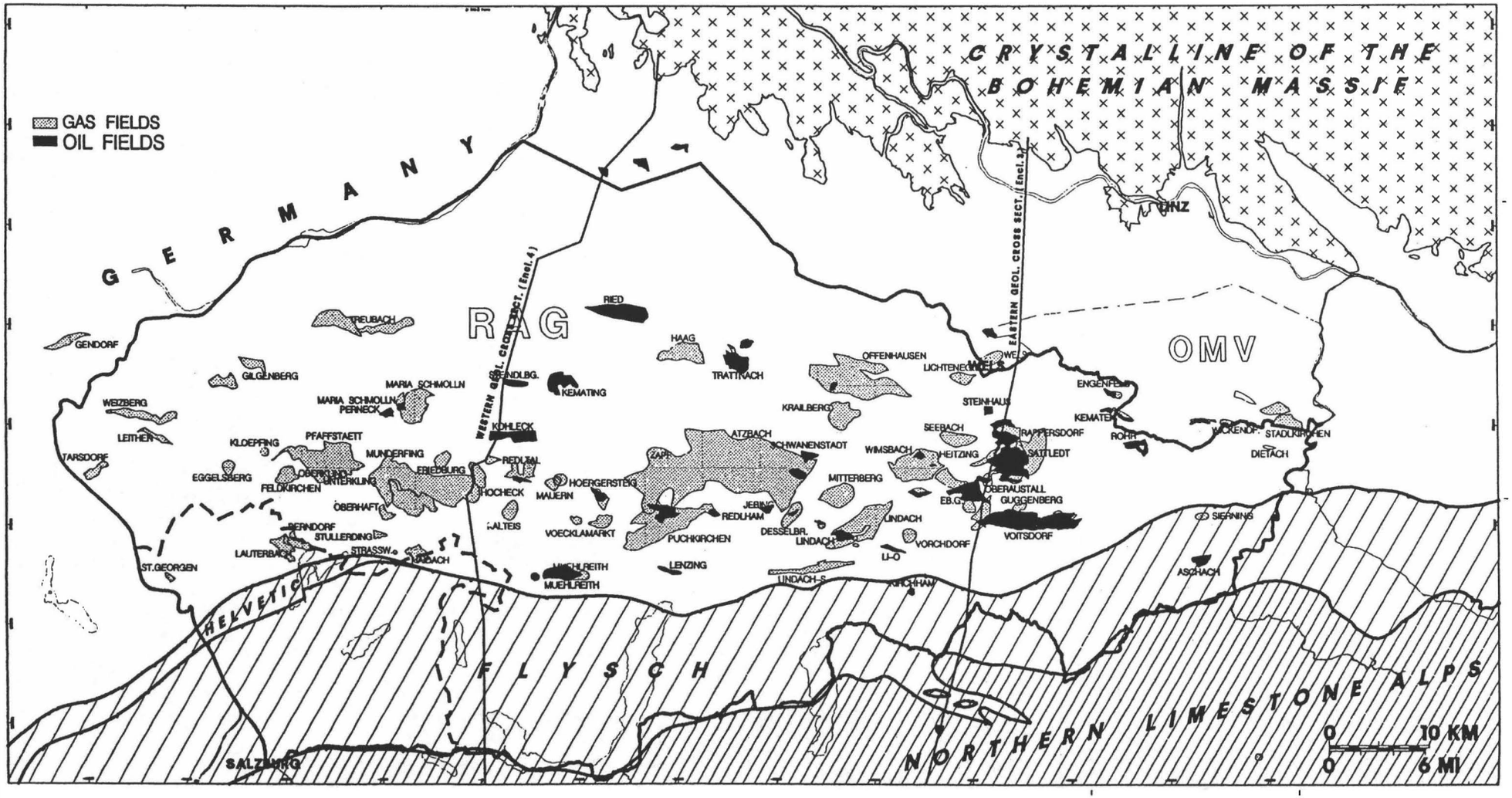
Encl.1

ROHOEL-AUFSUCHUNGS AG

UPPER AUSTRIA AND SALZBURG
GAS and OIL FIELDS

JULY 1998
Graphic: H. KLAFFENBOECK

Encl. 2



Encl. 3

GEOLOGICAL CROSS SECTION THROUGH THE EASTERN PART OF THE MOLASSE ZONE OF UPPER AUSTRIA

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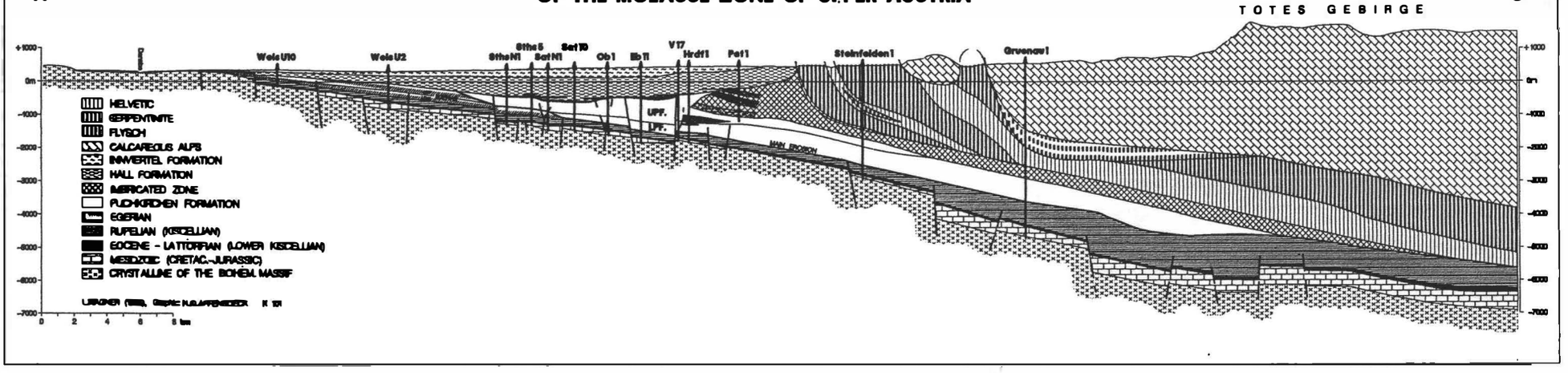

Encl. 4

GEOLOGICAL CROSS SECTION THROUGH THE WESTERN PART OF THE MOLASSE ZONE OF UPPER AUSTRIA