Field Trip POST-3
Eustasy and sea-level changes in the footsteps of Eduard Suess

FRITZ STEININGER[1], HOLGER GEBHARDT[2] & BENJAMIN SAMES[3]

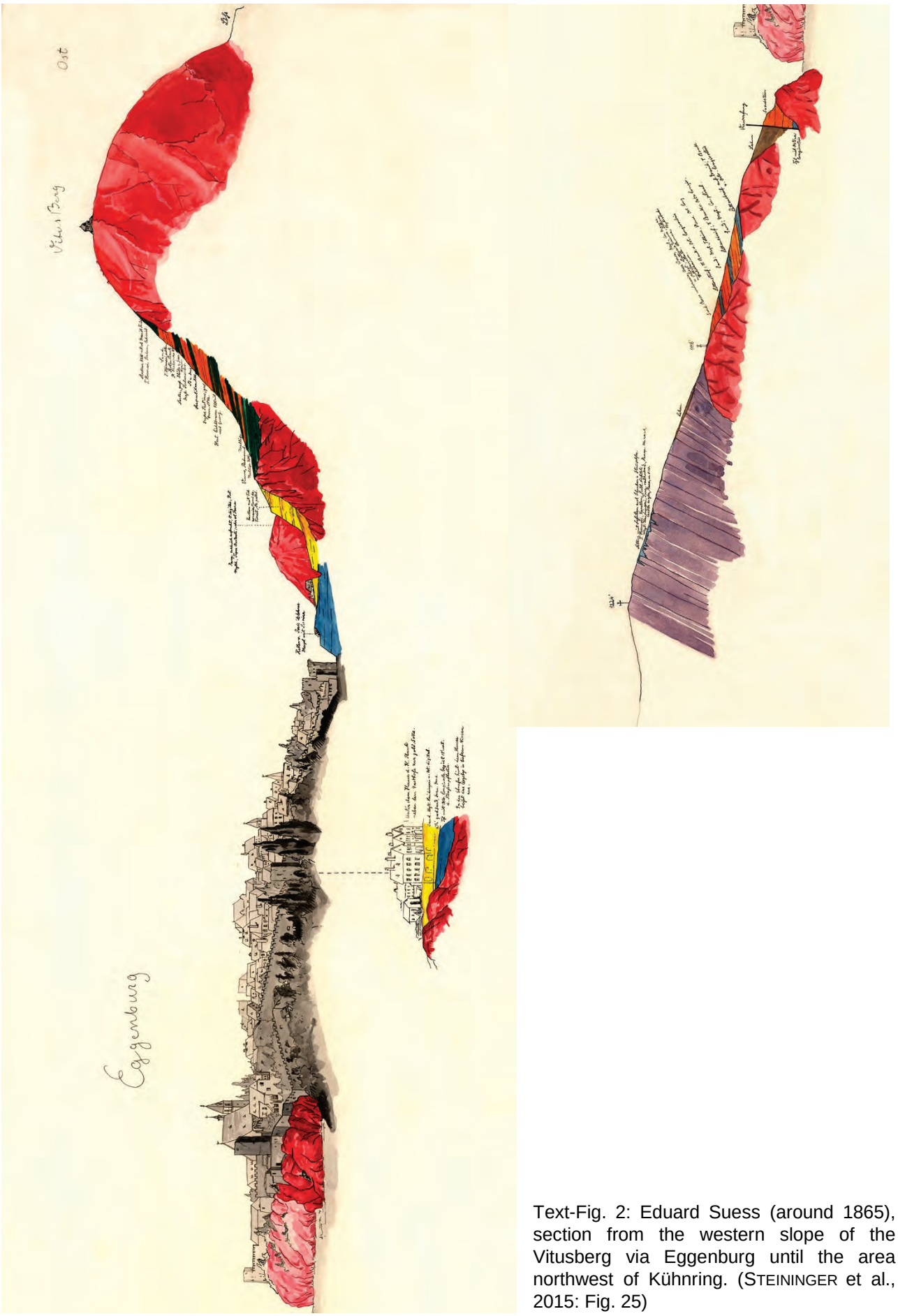
[1]Krahuletz-Museum Eggenburg, Krahuletzplatz 1, 3730 Eggenburg, Austria. [2]Geologische Bundesanstalt, Neulinggasse 38, 1030 Vienna <holger.gebhardt@geologie.ac.at>. [3]Universität Wien, Department for Geodynamics and Sedimentology, Althanstraße 14, 1090 Vienna, Austria <benjamin.sames@univie.ac.at>.

Introduction

Eduard Carl Adolph Suess (Text-Fig. 1) was born on 20th August 1831 in London and died on 26th April 1914 in Vienna. He was one of the most significant geologists in the history of this science of the second half of the 19th and the early 20th century. He published famous works such as “Das Antlitz der Erde” (The Face of the Earth; SUESS, 1883, 1888, 1901, 1909) and gave distinction to terms like Tethys or Gondwana. Eduard Suess was the inventor of the theory of “eustatic movements“ (or sea level changes). He may therefore be called the “father of sequence stratigraphy”.

Text-Fig. 1: Eduard Suess 1869 at the age of 38 years. Portrait by Josef Kriehuber, from the archive of the Geological Survey of Austria.

The idea of changing sea levels was based on Miocene marine sediments in the area of Eggenburg. Here, Suess went to field trips with interested people such as Johann Krahuletz, but also with his students. For this purpose, he drew the 4.2 km long section from Vitusberg to Kühnring (Text-Fig. 2).
Within the scope of his theory on “eustatic movements“, Suess distinguished between positive eustatic movements which we call today a sea-level rise (transgression) and a negative eustatic movement (sea-level fall or regression). According to his theory, a gradually sedimentary fill-up of marine basins leads to a positive eustatic movement (transgression) or a landward shift of the coastline. The deepening of a marine basin results in a negative eustatic movement (regression) or retreat of the coastline towards the sea.
The City of Eggenburg honored the merits of Suess by naming the path in the Zwingergraben “Eduard Suess Weg“ and created the “Window into Earth History“ which exposes the transgression of calcareous sandstones (Zogelsdorf Formation) on sandstones (Gauderndorf Formation).



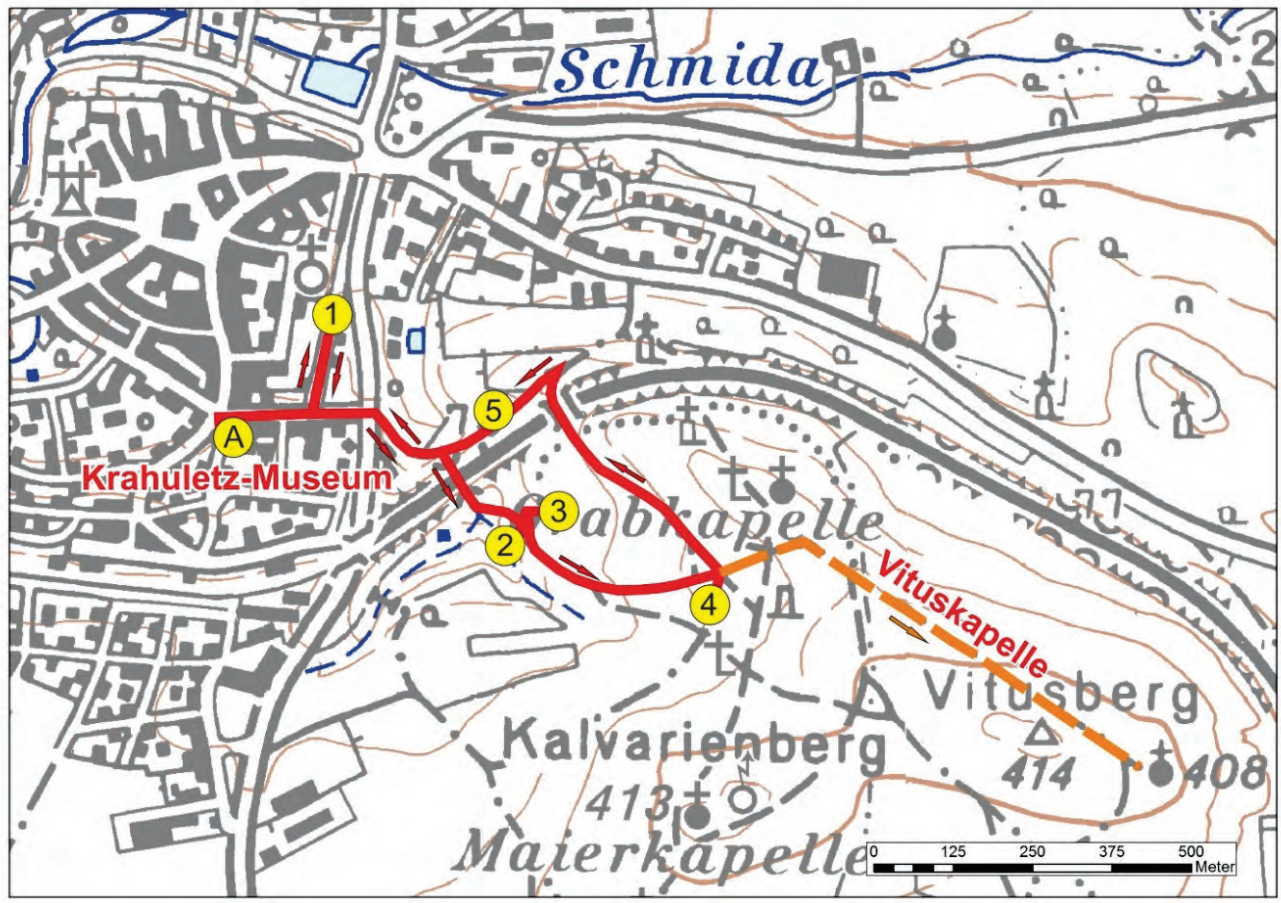
Text-Fig. 2: Eduard Suess (around 1865), section from the western slope of the Vitusberg via Eggenburg until the area northwest of Kühnring. (STEININGER et al., 2015: Fig. 25)

Field Trip

Within the Eggenburg city area: Stop 1 to 5

(text translated from STEININGER et al., 2015)

From the Krahuletz-Museum (A) we follow the Luegerring (ring road) towards the east and enter the Zwingergraben (trench) at Eduard Suess Weg (path) (Text-Fig. 3).



Text-Fig. 3: Fieldtrip and locations of Stop 1 to 5 (STEININGER et al., 2015: Fig. 11).

Stop 1. Zwingergraben Eggenburg

Coordinates: E 15°49'12.5", N 48°38'29.4".
Altitude: 322 m.

In the Zwingergraben (Text-Figs. 4, 5), we face the mighty, eastern, medieval defensive fortification of Eggenburg, build around 1300, with Hohlturm or Schwedenturm (tower), the inner wall with "Vorwerk" (front construction), the Zwingergraben, and the outer wall. Near the Hohlturm, in its southern section, the Zwingergraben was cut into the Gauderndorf Formation and quarried out of the Zogelsdorf Formation in the northern section. During construction works or on molehills one may find characteristic chips of fossil gastropods and bivalves of the Gauderndorf Formation at the beginning of the Zwingergraben near the Hohlturm. The outer wall of the bailey is completely made of calcareous sandstone of the Zogelsdorf Formation.
At the outcrop "Fenster in die Erdgeschichte (window into Earth history)" the base of the Gauderndorf Formation is exposed, with fossil remains and the bedded calcareous sandstones and interbedded sands of the Zogelsdorf Formation that crosscut the Gauderndorf Formation erosively (Text-Figs. 4, 5).

Text-Fig. 4: Outcrop at Eduard Suess Weg in the Zwingergraben in October 1978. Northward dipping sandstone beds with intercalated sand layers of the Zogelsdorf-Formation overlay fine sands and silts of the Gauderndorf-Formation. Photograph: Fritz F. Steininger, Eggenburg (STEININGER et al., 2015: Fig. 12).

Text-Fig. 5: Outcrop at Eduard Suess Weg in the Zwingergraben in October 1978. Werner Vasicek points to the fine sands and silts of the Gauderndorf Formation below the Zogelsdorf Formation. Photograph: Fritz F. Steininger, Eggenburg (STEININGER et al., 2015: Fig. 13).

We leave the Zwingergraben, ascend to the Luegerring, cross the Schubert Park with the art nouveau fountain which was built in 1908 by sculptor Wilhelm Hejda (1868–1942) on the occasion of the 60th anniversary celebration of the government of emperor Franz Josef I. (1830–1916), cross the Wienerstraße, the perimeter road and walk down towards the passages of the Franz Josefs railway and follow the passage towards Krahuletz-Ruhe (Krahuletz' rest, Text-Fig. 11).

Stop 2. Krahuletz-Ruhe in the Schindergraben

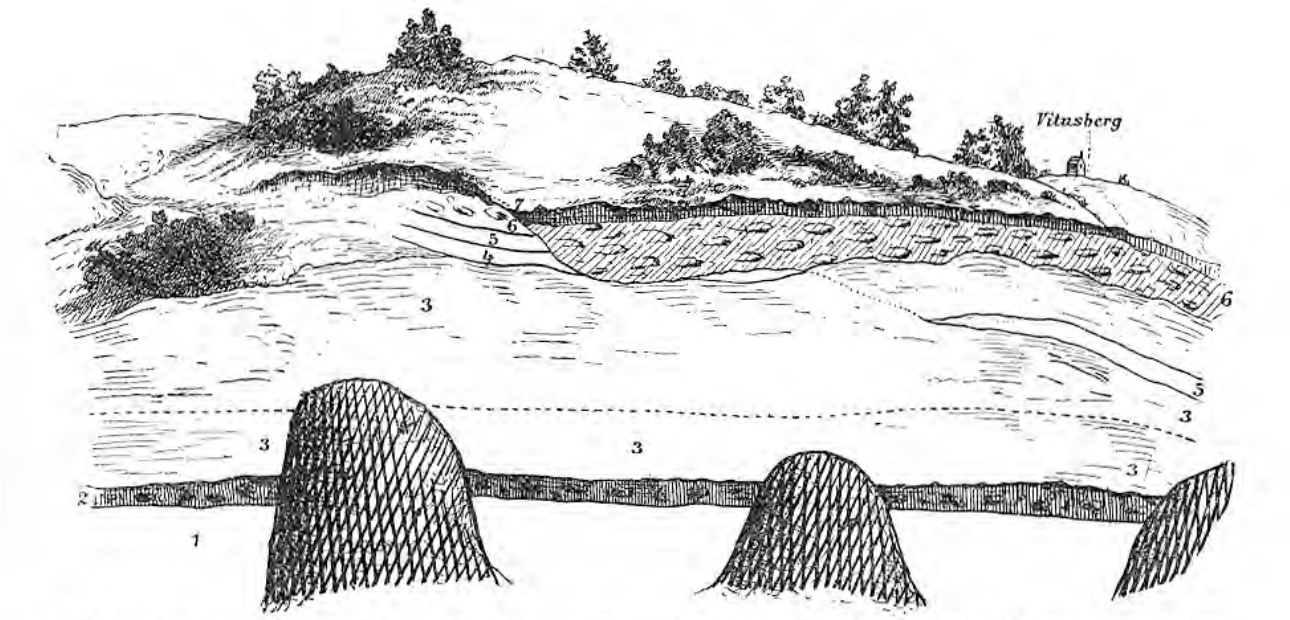
Coordinates: E 15°49'26.5", N 48°38'19.1".
Altitude at base: 337 m.

Krahuletz-Ruhe is within the so-called Schindergraben (flayers trench, Text-Fig. 6). During the railroad construction, several thousand cubic meters of sediments where excavated for the large railway dam (Text-Figs. 7, 8).
Descriptions and sketches (FUCHS, 1868, 1900; SCHAFFER, 1914; TOULA & KAIL, 1885; see Text-Figs. 8, 9, 10) show, that coarse sands of the Burgschleinitz Formation were deposited below the Guderndorf Formation. These contain a transgressive layer of gravel with bones of the sea cow *Metaxytherium*, dolphins, *Brachiodus* and turtles that was deposited on the Eggenburg granite. Also the famous crocodile skull (Text-Fig. 11) came from one of the mine galleries figured on Text-Figure 9 of TOULA & KAIL (1885). The crocodile skull is exposed together with an also remarkable skull of a dolphin (Text-Fig. 12) at the Krahuletz-Museum. Text-Figure 13 shows the minister of railways Zdenko Ritter von Forster with his spouse, Johann Krahuletz, and Franz Gamerith at the place of discovery of the crocodile skull in 1916.

Text-Fig. 6: The Krahuletz-Ruhe, todays outcrop situation. Photograph: Fritz F. Steininger, Eggenburg (STEININGER et al., 2015: Fig. 14).

Text-Fig. 7: View from northeast towards the northern side of the railway dam before 1870. Historical photograph: Krahuletz-Museum (STEININGER et al., 2015: Fig. 15).

Text-Fig. 8: View from the railway dam towards northeast near Krahuletz-Ruhe (middle-right) and the quarry northwest of the Apfelthaler Weg (upper-left). The upper limit of the quarry is at c. 356 m. Granite occurrences are visible in the lower-left corner (from SCHAFFER, 1914: Plate II). Photograph: Georg Hiesberger, Eggenburg (STEININGER et al., 2015: Fig. 16).



Aufschluss bei den Sandgruben am Westabhange des Calvarienberges bei Eggenburg („im Schindergraben").

Text-Fig. 9: Outcrop near the sand pits in the Schindergraben at the western slope of the Kalvarienberg (Calvary) near Eggenburg (TOULA & KAIL, 1885) (STEININGER et al., 2015: Fig. 17).
Explanation of the section at Krahuletz-Ruhe:
1 – "at the very bottom occurs, more than 1 m thick, grey quartz sand (without fossil remains)."
2 – "Above this is laying an about 1 m thick layer of granite gravel with larger boulders and pebbles."
3 – "Up to the roof of the mine galleries continues a grey quartz sand, ferruginous in places.
Yonder contains many larger bivalves: *Venus* sp., *Mytilus Haidingeri, Perna, Ostrea*. (*Turritella* sp., *Natica* sp., *Fusus* sp. were found in the roof of this layer). The total thickness of this horizon is more than 3 m. At the height of the roof resides a well-marked sand layer with concretions."
4 – "Above this, an about 3 cm thick layer of a fine, yellow sand is lying, strongly deformed, then follows"
5 – "a white, limy-clayey layer, about 8 cm thick and then above"
6 – "a layer with sandy calcareous concretions, which are then covered by humus (7)."

At the bottom of this section, the coarse quartz sands of the Burgschleinitz Formation (beds 1 to 3) were exposed and were apparently mined in galleries. In Text-Figure 9, three of such mine galleries were plotted within these quartz sands, at which the crocodile skull was found at the base of bed 2 in the background of one of the mine galleries. Beds 4 and 5 correspond to the Gauderndorf Formation and bed 6 to the Zogelsdorf Formation. The Quaternary cover is not shown in this figure.

In Text-Figure 10, the beds p and p' can be interpreted as Burgschleinitz Formation, above these, Gauderndorf Formation (g) and Zogelsdorf Formation (m, n) follow. The layers g', l, l' belong to the Quaternary cover.

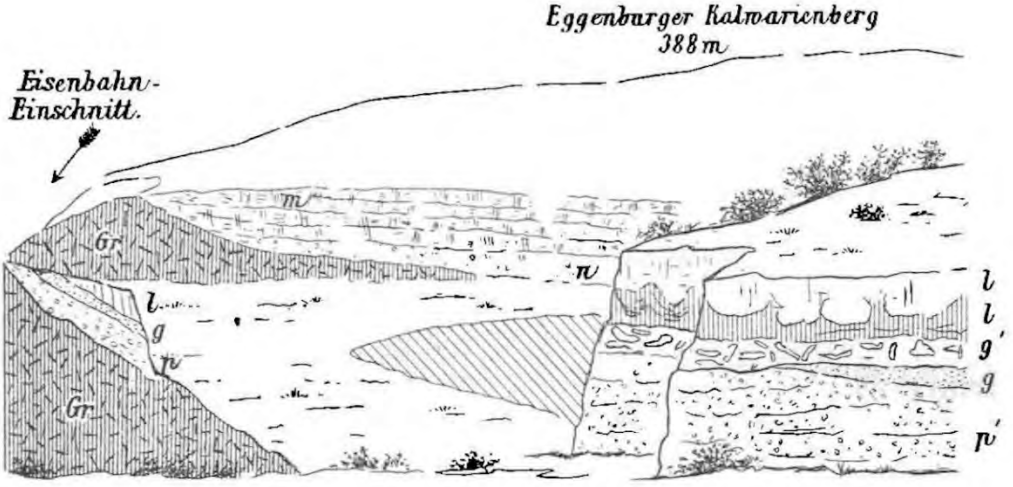


Fig. 5. Aufschlüsse im Schindergraben am Fuße des Calvarienberges.

Gr Granit.
p Pernabank mit Rippen von *Metaxitherium*.
p' Sandsteinbänke mit dem Knochenlager (Crocodil, *Brachyodon*, *Metaxitherium*).
g Gauderndorfer Tellinensande.
g' Umgeschwemmte Muggeln der Gauderndorfer Schichten.
l Löss.
l' Grauer quaternärer Letten.
m Harte Sandsteinbänke mit *Perna*.
n Grobe lose Sande mit Muscheltrümmern.

Text-Fig. 10: Outcrops in the Schindergraben at the foot of the Kalvarienberg (FUCHS, 1900: Fig. 5). Exploitation near the "Krahuletz-Ruhe" and extraction west of the Apfelthaler Weg in the Schindergraben (STEININGER et al., 2015: Fig. 18).

Text-Fig. 11: Skull of the gavial-like crocodile from the Schindergraben in Eggenburg: *Tomistoma eggenburgensis* (TOULA & KAIL, 1885). Photograph: Peter Ableidinger, Obernalb near Retz (STEININGER et al., 2015: Fig. 21).

Text-Fig. 12: Skull of a dolphin: *Schizodelphis sulcatus incurvata* (ABEL) from the pit "Bauernhanselgrube" in Eggenburg. Photograph: Peter Ableidinger, Obernalb near Retz (STEININGER et al., 2015: Fig. 20).

We walk along the overgrown wall towards northeast, cross the Josef-Wimmer-Weg and follow the cleared path continuously towards northeast (Text-Fig. 3).

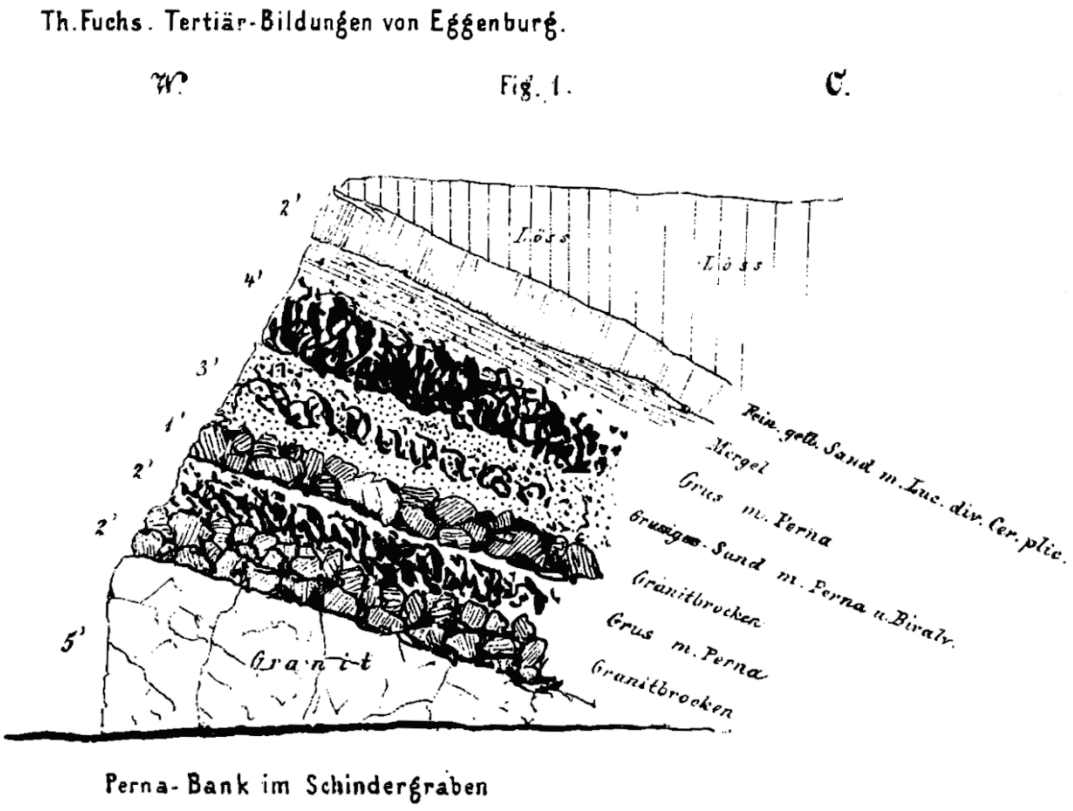
Stop 3. Material pit in the Schindergraben
Coordinates: E 15°49'29.5", N 48°38'20.0".
Altitude at base: 344 m.
Altitude at upper level: 356 m.

In a large former exploitation for the dam fill, the Zogelsdorf Formation with thick calcareous sandstone beds and intercalated sands and large down slid blocks can be found as the uppermost stratigraphic member that is still visible today (Text-Fig. 14). The following fossils were found: calcareous red algae, bryozoans, moulds of large bivalves, oysters and pectinid shells. Northwest of the pit, near the so-called *Perna*-bed (FUCHS, 1868; Text-Fig. 15), a layer of beach pebbles(?) of the Zogelsdorf Formation is transgressing directly on the granite that forms the bedrock at this position.

Starting from the material pit, the Zogelsdorf Formation continues upslope towards southeast into a narrow depression. Southwards, a planation plane extends on the granite, which can be interpreted as a wave-build platform. Again south of this granite eminence, another narrow valley in the granite is filled up with sediments of the Zogelsdorf Formation. To the east, this small basin reaches until shortly before the children playground where it merges with the depression southeast of the material pit.

Text-Fig. 13: Krahuletz-Ruhe. The minister for railways, Zdenko Ritter von Forster, and his spouse, Marianne Freiin von Ferstel, visit the place of discovery of the crocodile skull in 1916, together with Johann Krahuletz (with topper, apparently holding the coat of the spouse of the minister for railways) and Franz Gamerith (left). Photograph: Archive Krahuletz-Museum (STEININGER et al., 2015: Fig. 19).

Text-Fig. 14: Former exploitation in the Schindergraben west of Apfelthaler Weg, todays view of part of the pit. Photograph: Fritz F. Steininger, Eggenburg (STEININGER et al., 2015: Fig. 22).



Text-Fig. 15: *Perna*-bed in the Schindergraben (FUCHS, 1868) (STEININGER et al., 2015: Fig. 23).

We return to the Apfelthaler Weg and follow it uphill, change to the path of the Alten Rodelbahn (old sledge run) and follow it until the playground. Here we turn right sharply and follow the cleared path to the geographically highest occurrence of the Zogelsdorf Formation in an abandoned quarry below the playground.

Stop 4. Vitusberg – pits south of Grabkapelle

Coordinates pebble layer: E 15°49'41.6", N 48°38'15.4".
Altitude: 371 m.
Coordinates material pit: E 15°49'41.9", N 48°38'15.3".
Altitude: Upper rim 374 m.
Coordinates playground centre: E 15°49'42.9", N 48°38'16.9".
Altitude: 376 m.

Within the forest, towards the southwest, several overgrown stone pits with blocks of Zogelsdorf Formation occur below the playground. In a trench southwest of it, a pebble layer of the Zogelsdorf Formation is outcropping. Attempts were made to excavate smaller walls of the stone pit and to uncover the pebble layer (Text-Fig. 16).

Text-Fig. 16: Nearby abandoned stone pit southwest of the playground at Vitusberg. Photograph: Fritz F. Steininger, Eggenburg (STEININGER et al., 2015: Fig. 24).

The sediments of the Zogelsdorf Formation reach about until the southern end of the playground. The eastern part of the playground and the following path to the "Vituskapelle" are already above granite (Text-Fig. 3).
The Zwingergraben has an altitude of c. 322 m, the highest layer of the Zogelsdorf Formation at the Vitusberg is at c. 374 m. The onlap of the Zogelsdorf Formation on the granite of the Vitusberg and the outreach up to the playground would correspond to a sea-level rise of c. 52 m. This amount is, however, probably too high, since tectonic movements shifted the position of the Zogelsdorf Formation in the Zwingergraben to higher altitudes after its deposition, as it can be seen from a mapped E–W striking fault in the southern areas of Eggenburg.

From the playground we can continue the path to the Vituskapelle (chapel), now always on granite bedrock (Text-Fig. 3). The view from the Vituskapelle offers a gorgeous outlook over the last granite heads standing out of Molasse sediments (so-called Kogelsteine, Kirchenberg of Wartberg) and further to the east into the Alpine-Carpathian Foreland Basin.

From the playground we can follow the Josef-Wimmer-Weg to the northwest, have a splendiferous view on the city of Eggenburg before the railway bridge, passing the bridge, turn left to the southwest immediately and walk down alongside the railway towards the railway passages (Text-Fig. 3).

Stop 5. Urtlbachtal – Pit north of the railway dam

Coordinates: E 15°49'24.8", N 48°38'24.9".
Altitude: 337 m.

North of the big railway dam, along the path that leads to the railway passages, an overgrown material pit attracts attention. Its collapsed walls are probably mainly build of loess. A granite crops out at the south-western end of the pit and coarse, fossil-rich sands can be found on the granite and the along the path which probably belong to the Burgschleinitz Formation.

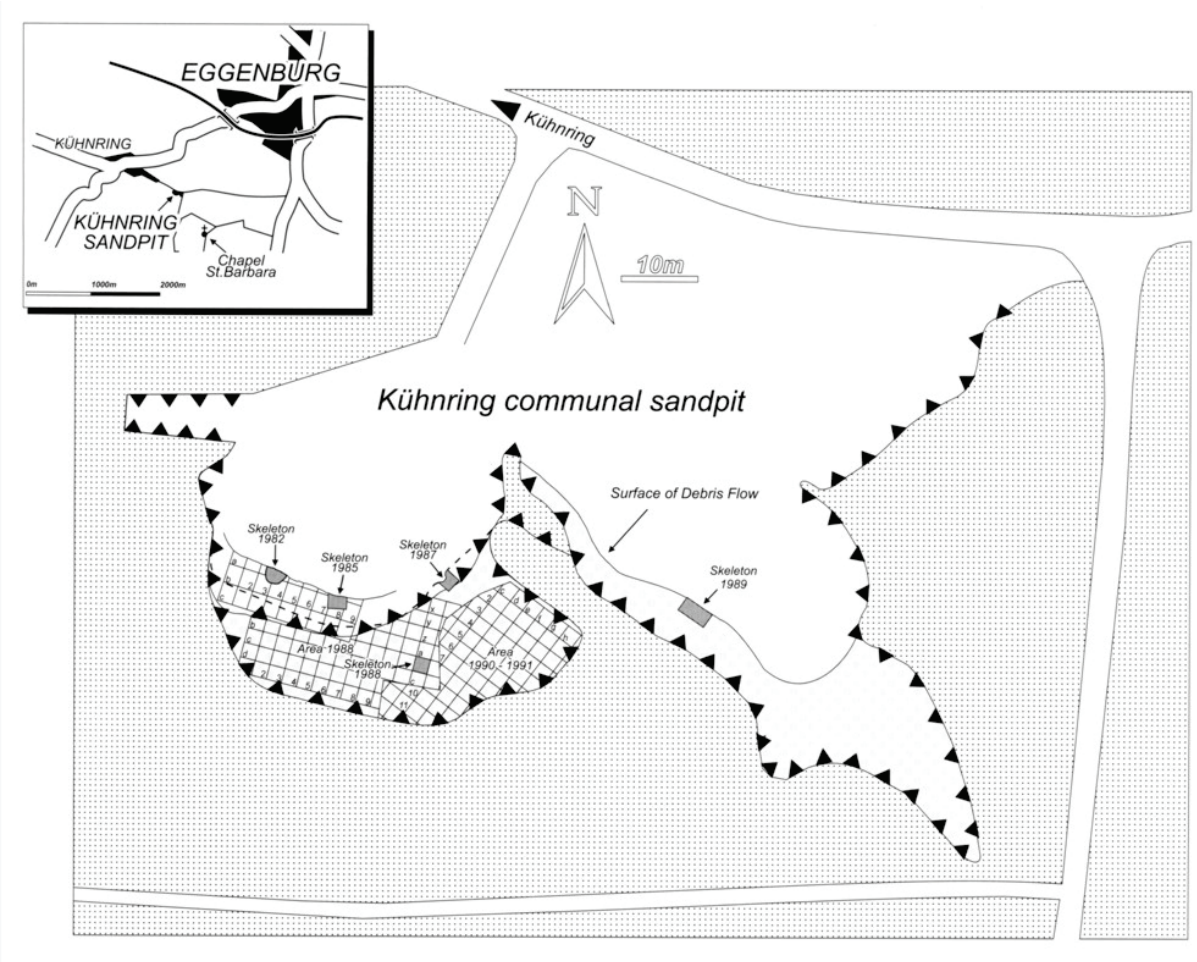
We now follow the path to the railway passages and walk back to the Krahuletz-Museum (Text-Fig. 3).

The vicinity of Eggenburg: Stops 6 to 8

Stop 6. Kühnring Gemeindesandgrube (municipal sandpit)

(text and text-figures from MANDIC et al., 2005)
Coordinates: E 15°47'34.6", N 48°37'47.3".
Location: The municipal sandpit of Kühnring is located about 2 km SW of Eggenburg and about 800 m SE of Kühnring (Text-Fig. 17), southwards of the path to the Armenseelenkreuz, on the northern slope of the Scheibenberg. The Miocene marine sediments fill a narrow W–E striking prae-Eggenburgian crystalline erosive depression, having the northern and southern boundaries defined by basement rocks. The best insight into the succession crops out in the western part of the pit to date.
Lithostratigraphic units: Burgschleinitz Formation, Gauderndorf Formation, Zogelsdorf Formation.
Age: Early Miocene (Late Eggenburgian), ~ 20 Ma.
Facies: Deepening and fining upward succession of shallow sublittoral sands and gravels including one mass flow horizon passing upsection into deeper sublittoral pelite sediments. On top the significant erosional contact is overlaid by detritic, biogenic, shallow water limestones.
References: STEININGER et al. (1991a, b), DOMNING & PERVESLER (2001), PERVESLER & ROETZEL (1991), PERVESLER et al. (1995, 1998), JENKE (1993).

Section (Text-Figs. 18, 19): The base of the Eggenburgian marine onlap is not cropping out at the site, yet according to the regional geological setting the succession must directly overlay the crystalline basement. Hence, up to 15 m of badly sorted pelitic and sandy siliciclastics termed Kühnring Member and bearing conspicuous giant *Crassostrea* reefs occupy basal parts of the marine succession in the region. The Member´s stratotype – *Judenfriedhof* – at the moment unexposed – is located about 1.5 km WNW from the site. In contrast, the crystalline basement rocks are exposed on the opposite side of the sandpit entrance. These hornfels penetrating aplite dikes represent a footwall contact of the Precambrian Thaya Batholith. The low-grade metamorphism of the formation has Variscan origin.



Text-Fig. 17: The geographic position and situation in the sandpit. The positions of the sea cow skeletons are marked by grey fields (from DOMNING & PERVESLER, 2001) (MANDIC et al., 2005: p. 28).

Burgschleinitz Formation (more than 8.5 m): The succession can be subdivided into four lithologic units. The basal part of the Unit 1 was originally studied in an artificial pit and is not exposed any more.

Unit 1 (6 m): The unit comprises yellowish brown to yellowish grey middle sands, fine sands and silty finesands. The sediments are strongly bioturbated and bear several fine gravel and mollusc coquina interlayers. The succession shows a slight fining upward trend. Hence, the lowermost 2.5 m are made of two coarse to fine sand normally graded packages, rich in mollusc fragments. In contrast, the upper part is characterized by a well preserved bivalve assemblage with representatives commonly found in life position. The following species can be find therein: *Macrochlamis holgeri, Pecten pseudobeudanti, Cardium hoernesianum, Acanthocardium moeschanum, Megaxinus transversus, Divalinga ornata, Dosinia exoleta, Pitar raulini, Cordiopsis schafferi, Cordiopsis incrassatus, Venerupis basteroti, Paphia benoisti praecedens, Peronea planata, Gari (Gobraeus) labordei, Panopea menardi, Thracia eggenburgensis*. The foraminifera are dominated by benthic species of the *Ammonia parkinsonia-tepida* group. Additionally, common are *Aubignyna simplex*, *Bucella propingua*, *Elphidium* div. sp. *Nonion commune*, *Hanzawaia boueana* and *Cibicidoides pseudoungerianus*. The scattered plankton includes *Cassigerinella globulosa* and *C. boudecensis*.

Unit 2 (massflow; 1.5 to 3 m): A mollusc coquina dominated by disarticulated, concave up oriented bivalve shells embedded in medium sand to fine gravel matrix overlays directly a low erosional relief on top of the previous unit. The horizon comprises among others

Anadara fichteli, *Glycymeris fichteli*, *Ostrea lamellosa* and *Panopea menardi*. Without a sharp boundary follows an inverse graded medium to coarse gravel sized crystalline debris horizon. The crystalline lithoclasts are badly sorted, matrix supported and chaotically, in part uprightly oriented. They comprise platy, angular aplitic schist-gneiss and quartzite although scattered rounded quartz pebbles are also present. On top the 10 to 80 cm large, preferably WNW–ENE oriented crystalline plates occur, getting more frequent and larger southeastward. Eastward, however, the inverse graded bed becomes more homogenous and thicker (up to 2 m), the basal coquina disappears and the large, chaotically embedded, disarticulated mollusc remains with *Glycymeris fichteli*, *Macrochlamis holgeri*, *Cordiopsis schaferri* and *Protoma cathedralis* become frequent. The coarse platy debris is topped by about 20 cm thick horizon of well rounded, medium to coarse quartz pebble bearing silty coarse sands. This horizon is as well variably present in different positions of the site. Hence being still thicker in the east it wedges almost completely out in the southeast.

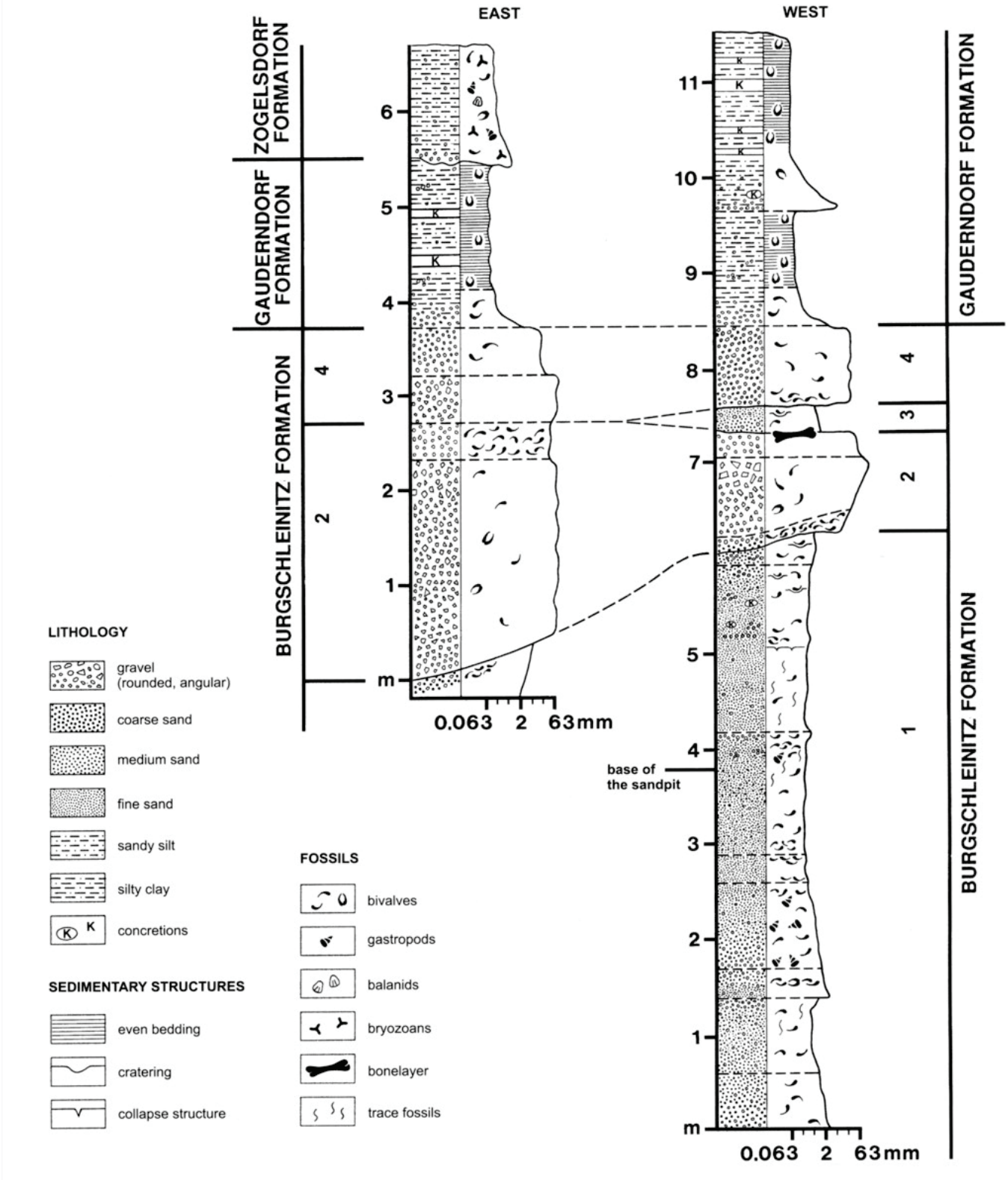
Unit 3 (0 to 30 cm): This is a grey-yellowish silty to gravel comprising fine to medium sand horizon outwedging completely in the eastern part of the pit. In the same direction the gravel components characterized by a very well rounding grade get more frequent. The base of those sands bear the sea cow *Metaxytherium krahuletzi* fossil Lagerstätte with at least six more or less articulated skeletons and many accompanied isolated bones. The bones belong to adult as well as juvenile individuals. Additionally, at the same position a skull and mandible of the dolphin *Schizodelphis sulcatus* has been found. In places where Unit 3 is outwedging the sea cow Lagerstätte comprises the base of Unit 4.

Unit 4 (max. 1 m): This horizon has, in contrast to previous units, more continuous lateral distribution within the site. It comprises fine to medium gravels embedded in a medium to coarse grained sandy matrix. The gravel components are generally very well rounded. Disarticulated, large-sized, convex up oriented bivalve shells are particularly frequent in the lower part of the horizon. Following mollusc are present therein: *Turitella gradata*, *T. vermicularis*, *Protoma cathedralis*, *Glycymeris fichteli*, *Ostrea* div. sp., *Macrochlamis holgeri*, *Pecten pseudobeudanti*, *Anomia ephippium*, *Pitar raulini*, *Cordiopsis islandicoides*, *Dosinia exoleta*, *Divalinga ornata*, *Florimetis lacunosa*, *Panopea menardi*.

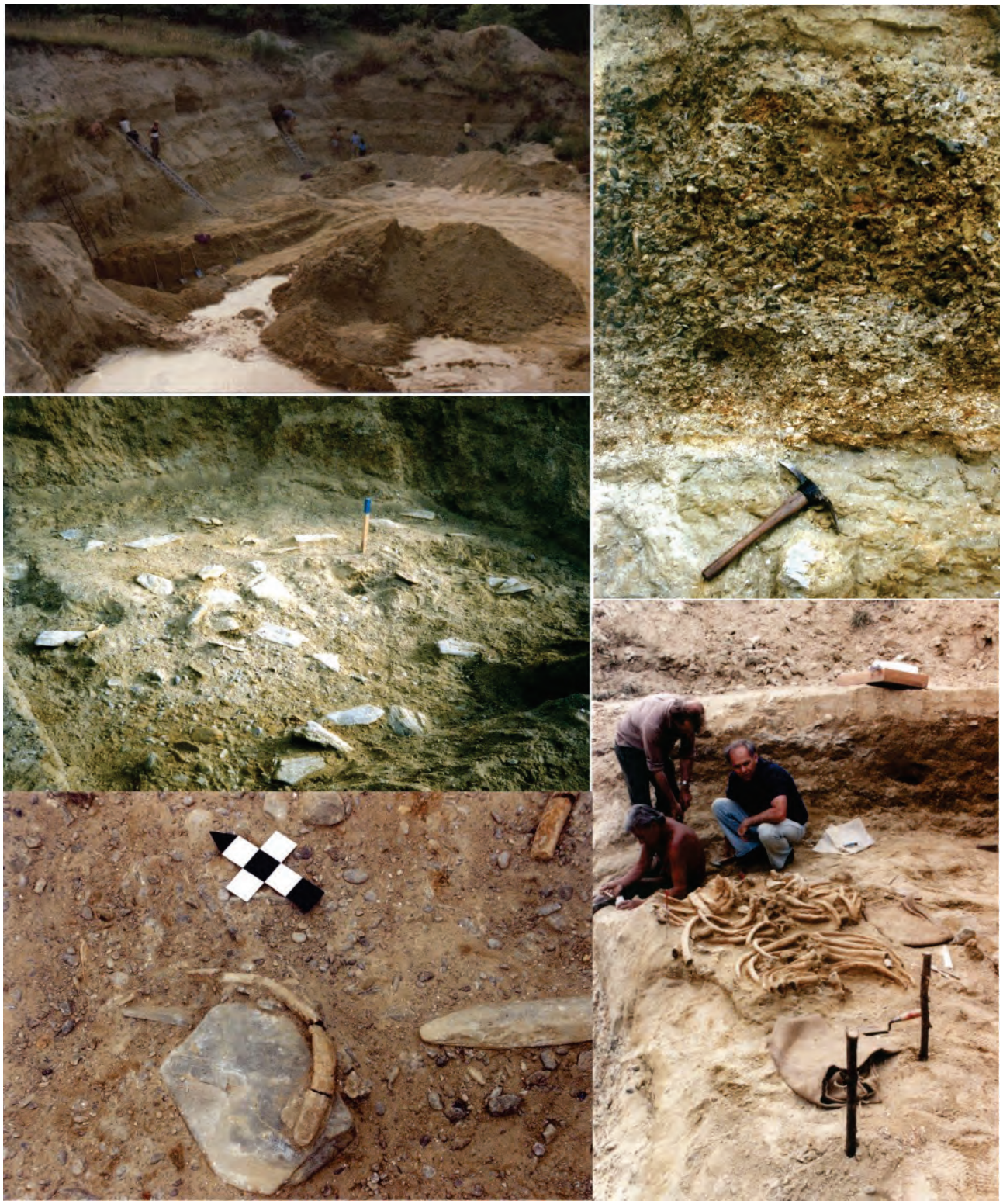
Gauderndorf Formation (max. 3 m): It comprises the green-greyish to yellow-brownish plane to light wavy, clearly cm-thick bedded clayey silt to claysilt. At the base, a gravel component is added, elsewhere fine gravel can occur scattered in form of small-scale clusters. Additionally, the middle part of the succession is interlayered by one normally graded gravel bed topping the sharp erosive contact. Additionally, the pelites bear several concrete horizons. The rich macrofossil assemblage is characterised by thin shelled, infaunal bivalves found commonly articulated and in life position.
The following mollusc species are represented therein: *Haliotis* sp., *Diloma amedei*, *Turritella* div. sp., *Ficopsis* (*Fulguroficus*) *burdigalensis*, *Euthriofusus burdigalensis*, *Cerastoderma edule*, *Acanthocardium* sp., *Cordiopsis* sp., *Paphia* sp., *Peronea planata* and *Solen marginatus.* The microfossil assemblage is strongly dominated by small-sized planktonic foraminifera, particularly *Cassigerinella globulosa* and *C. boudecensis* accompanied by *Globigerina ciperoensis ottnangensis*, *G. angustiumbilicata* and *G. brevispira*. The benthic foraminifera include particularly *Ammonia parkinsonia-tepida* gr., *Hanzawaia boueana* and *Cibicidoides pseudoungerianus* accompanied by *Lenticulina inornata*, *Caucasina cylindica*, *Elphidium granosum, Nonion commune*, *Epistominella* cf. *molassica* and *Globocassidulina oblonga*. Upsection planoconvex species (*Cibicidoides*, *Hanzawaia*) become even more frequent.

Zogelsdorf Formation (1.5 m): It is restricted to the eastern part of the sand pit, where it transgrades a well-developed, distinct erosional boundary. These quartz-gravel rich, weakly stratified, partly nodularly cemented, detritic biogenic limestones are typically white greyish to brown yellowish in color. Included gravel components are medium to fine grained, well-rounded and matrix-supported. The scattered angular crystalline lithoclasts are additionally present therein. The originally rich mollusc assemblage is secondarily diminished by means of the diagenetic leaching of aragonite shells. Hence the presence of turritellid gastropods, for example, is signalized only by typical turriform molds and shell exterior imprints. Otherwise the calcite mineralizing pteriomorph species like *Hyotissa hyotis*, *Ostrea lamellosa*, *Pecten hornensis* and *P. pseudobeudanty* are rather well preserved. In addition to the latter taxa, well-preserved balanid remains and celeporid bryozoan colonies contribute likewise abundantly to the biogenic content of the limestones. *Cibicidoides pseudoungerianus* dominates the moderately preserved foraminifera assemblage. The planktonic foramininfera are with only 6.6 % content underrepresented.

Interpretation: According to molluscs and foraminifera and along with the sedimentological character of Unit 1 the package can be at best interpreted as a typical deposit of a shallow marine subtidal environment. It represents the continuous sedimentation of a shallow marine embayment, interrupted by the deposition of Unit 2. The inverse grading, bad sorting and chaotical character of the latter sediment, comprising the large crystalline plates floating on top of the package, all point to its deposition within a single high-energy event. Hence, a sudden sea level rise of several meters, followed by its immediate retreat, ripped the blocky material from the shore and transferred it by one single debris flow onto the shallow sea bottom. The quantity of material deposited in that partly 3 m thick package indicates that the event can hardly be explained by a single heavy storm. Moreover, the storm beds are characterized usually by normally graded deposit packages. Therefor, a much better explanation would be the action of a submarine earthquake producing the tsunami wave triggering the spectacular devastation of the Eggenburg Bay within a very short period of time. The presence of occasional tsunamis in the Molasse Sea appears quite reliable. Hence the Austroalpine subduction front comprising the southern margin of the Alpine-Carpathian Foredeep represented in the Early Miocene a highly active tectonic zone under a transpressional regime. The argument that the event had to be of larger scale is provided also by the sea cow Lagerstätte, where apparently the whole herd starved to death shortly after the debris deposition finished. Apparently due to devastated marine bottom and especially due to total loss of the submarine sea grass meadows, the herd did not have enough food for living. However, if the meadows would have been destroyed only locally the herd would not have been able to find enough resources in other protected parts of the bay. Therefore, the only reliable explanation – the complete loss of all regional resources – correlate at best with the effect of a single tsunami wave.
The Gauderndorf Formation represents the end of the first siliciclastic sedimentation cycle and the maximal flooding of the environment. The enhanced content of planktonic foraminifera points therein to the improved contact to open sea. The sea level fall followed by its rise is indicated by the erosive contact and the transgression of the Zogelsdorf Formation. The mollusc fauna with the thick shelled shallow subtidal ostreids as well as common barnacle colonies and well-rounded pebble grains point to its sedimentation in a wave-agitated shallow water depositional environment.
Stratigraphically important is the occurrence of *Macrochlamis holgeri* in the Burgschleinitz Formation pointing to its Upper Eggenburgian stratigraphic position. Additionally, *Pecten hornensis* is restricted to the Zogelsdorf Formation pointing to its still younger stratigraphic position within the uppermost Eggenburgian.



Text-Fig. 18: The sections from the eastern and western parts of the sand pit in Kühnring (modified after DOMNING & PERVESLER, 2001) (MANDIC et al., 2005: p. 29).



Text-Fig. 19: The overview of the western sand pit wall (upper-left), the vertical section of the Unit 2 mud flow (upper-right), top of the Unit 2 with crystalline plates and sea cows remains hanging on them (down-left), and finally one of the articulated skeletons in original position (down-right) (MANDIC et al., 2005: p. 31).

Stop 7. Zogelsdorf Johannessteinbruch

(text and text-figures from MANDIC et al., 2005)

Coordinates: E 15°48'38.2", N 48°37'12.7".

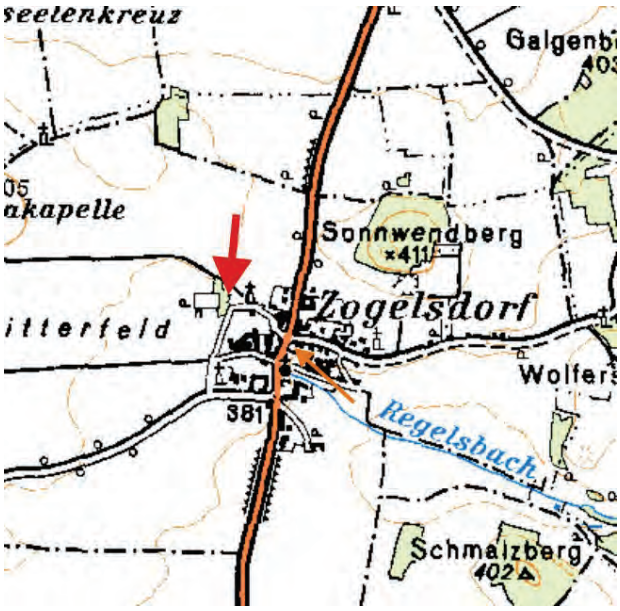
Location: The quarry is positioned on the northwestern margin of Zogelsdorf, about 2.5 km southwards of Eggenburg (Text-Fig. 20). The stone production began here around 1870 when the large-scale reconstructions around the capital´s old city, initiated by the Austro-Hungarian Emperor, triggered an outstanding demand for building materials. Among others also blocks for the four Hercules statues at the Michaelertor in the city of Vienna originate from here. The quarry was at that time the property of the famous female writer, pacifist and 1905 Nobel Peace Prize laureate, Bertha von Suttner (1843–1914), with the domicile in the neighbouring Hermannsdorf am Manhartsberg. Today the quarry represents a natural and industrial monument and contributes to the exhibition of the stonemason museum "Steinmetzhaus" on the main road of Zogelsdorf. The original traces of old production methods together with the typical ancient tools can be checked up already at the site.

Lithostratigraphic unit: Zogelsdorf Formation (on its type locality), uppermost Eggenburgian.

Age: Early Miocene (Late Eggenburgian), ~ 19 Ma.

Facies: Shallow water biogenic detritic limestone.

References: NEBELSICK et al. (1991a, b), NEBELSICK (1989a, b), VAVRA (1979, 1981), SCHAFFER (1914, 1927).



Text-Fig. 20: The position of the Johannes quarry is indicated by the red arrow. The smaller, orange arrow indicates the position of the stonemason museum (the picture length = 2 km) (MANDIC et al., 2005: p. 33).

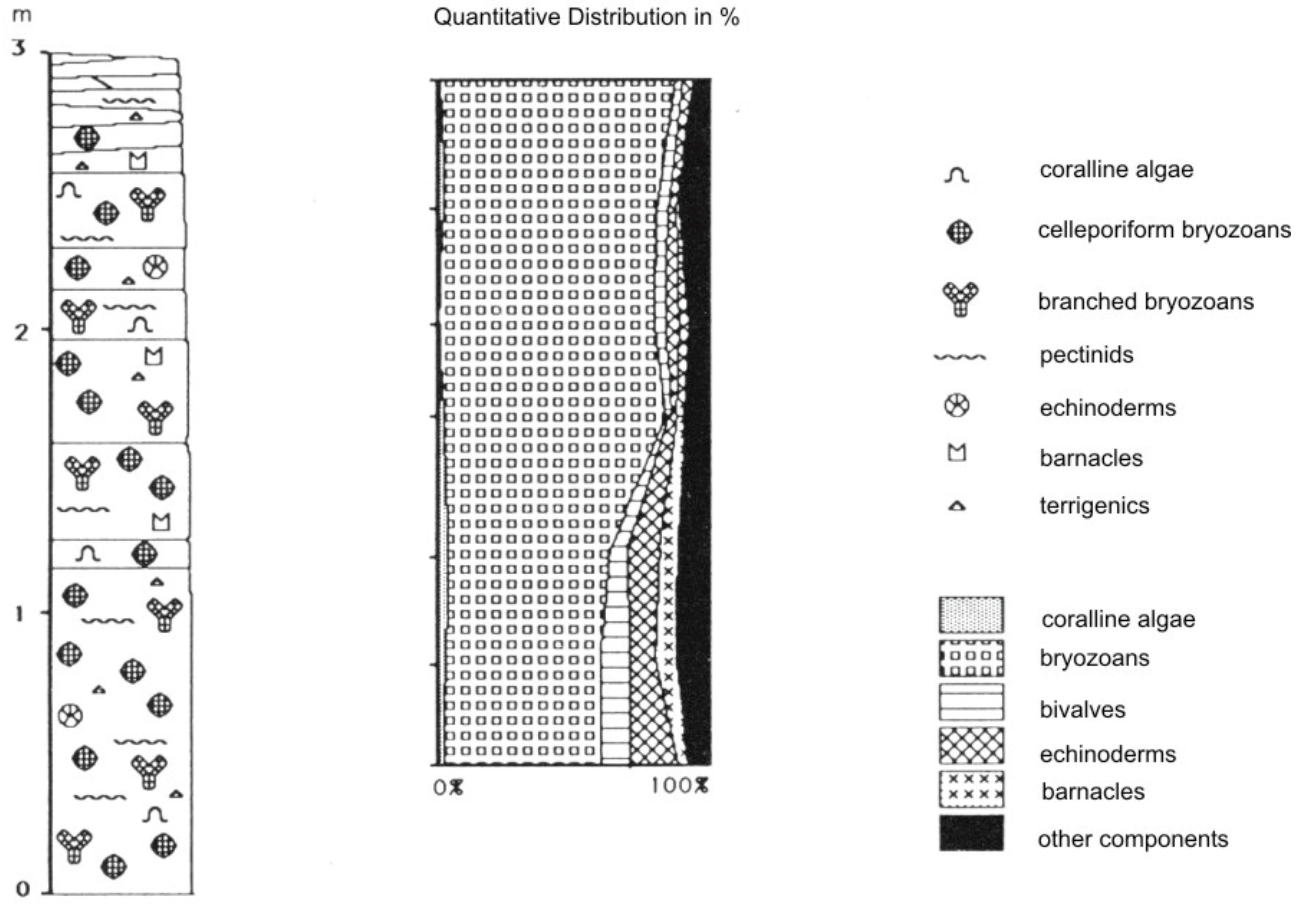
Section (Text-Figs. 21, 22): It represents the type section of the Zogelsdorf Formation showing it in the bryozoan dominated facies. This detritic, muddy biogene limestone succession with about 3 m thickness reflects a fining and thinning upward trend upsection. The position and the character of the foot wall is unknown. The basal part of the succession shows one single 1 m thick homogenous bed. It is overlain by a well-bedded part consisting of 10 to 30 cm thick packages. Finally, the topmost 50 cm are intensively bedded comprising 5 to 10 cm thick sediment packages. These rudstones are throughout dominated by bryozoan remains and characterized likewise by a high mud content. This significant content, with up to 30 % of additional biogene material in the lower half of the succession – dominated by bivalves, barnacles, echinoid and coral algal remains – diminishes definitely upsection with values going down to only 10 %. The bryozoan colonies are mostly celleporiform. Hence, they commonly form macroids built by several, interchanging bryozoan taxa as well as other incrusting organism groups like serpulids or coral algae. Accompanied by dominant Celeporidae the following bryozoan genera are additionally present in the type section: *Cellaria, Sertella, Porella, Schizoporella, Myriapora,*

Crisia, Entalopora, Lichenopora, Frondipor, Mesenteriopora, Tetrocycloecia, Tervia, and Hornera. Moreover, characteristic are monospecific pectinid layers bearing disarticulated and articulated, horizontally oriented shells of *Pecten hornensis*. Regarding echinoderms, remains of Echinoidea, Asterozoa, Ophiuroidea as well as Crinoidea can be found.

Interpretation: The site is located in the southern part of the Eggenburg Bay which was originally sheltered from the influence of the open sea by roughly north-south striking submarine, crystalline swells as well as islands and peninsulas. Thus, the Zogelsdorf Formation, topping the basal Late Eggenburgian siliciclastics is developed in a typical terrigenous poor/bryozoan rich facies.
However, the absence of the bryozoan genus *Crisia*, being otherwise common in many other sites of the Eggenburg Bay, appears indicative for the succession. This could point to the absence of submarine vegetation at the depositional site. Indeed, the common incrusting bryozoans as well as other incrusting organisms dominating the biogene composition indicate the lowered sedimentation rate resulting possibly from the missing vegetational sedimentary trap at the sea bottom. Moreover, the high mud content of limestones points to a less agitated hydrodynamic regime certainly below the fair weather wave base at the depositional site. The fining upward along with the thinning upsection reflects the deepening of the depositional environment. This involves the diminishing upsection of shallow subtidal depth indicators like barnacles or common echinoid remains. The pectinid shell beds are remains of their original colonies typically inhabiting detritic, shelly bottoms at medium subtidal depths around the storm weather wave base.

The mass occurrence of *Pecten hornensis* in the Zogelsdorf Formation represents an important regional biostratigraphic signal. Along with the remarkable facies change during the latest Eggenburgian (basal marine siliciclastic sequence in the base vs. detritic carbonate sequence on top), the FAD of that pectinid species in the carbonates enables their clear stratigraphic distinction.

Text-Fig. 21: The Johannes quarry's overview (MANDIC et al., 2005: p. 34).



Text-Fig. 22: The section of the Johannes quarry. The diagram shows the vertical distribution of the biogene. Note the increase of the bryozoan contribution upsection (MANDIC et al., 2005: p. 35).

Stop 8. Groß-Reipersdorf – abandoned Quarry Hatei

(from the Molasse Tagung 2012, 27.–28. April, Vienna, Excursion Guide (ROETZEL et al., 2012); translation of description and interpretation by HOLGER GEBHARDT)

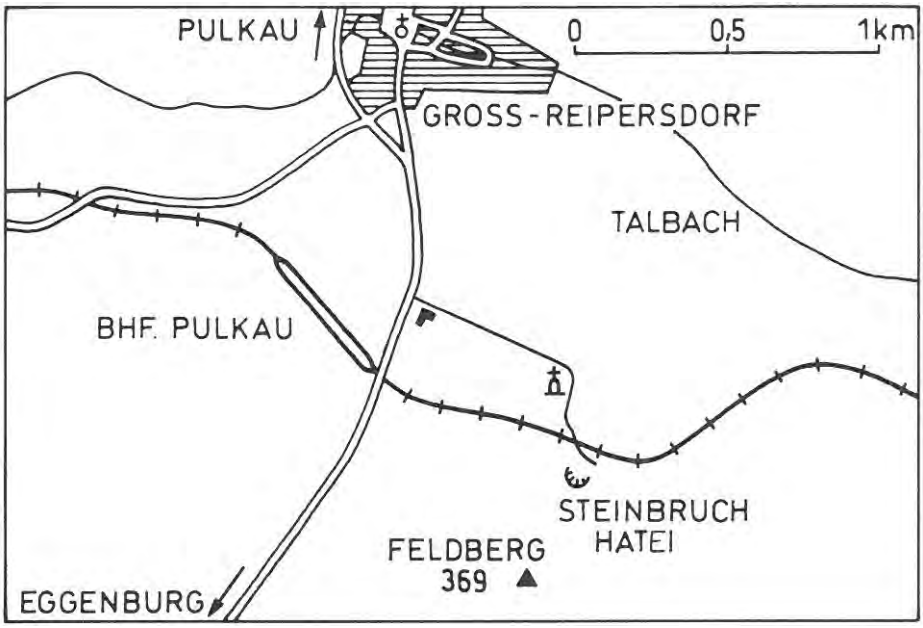
Coordinates: E 15°51'14.7", N 48°41'14.1".

Location: Groß-Reipersdorf, south of Pulkau.

Topic: Lower Miocene sediments of the Ottnangian. Corralinacean limestone of the Zogelsdorf Formation overlain by pelites of the Zellerndorf Formation.

The point known as abandoned Hatei Quarry or Pracht Quarry (after its owner) is located in Groß-Reipersdorf, south of Pulkau. There, corralinacean limestone (Zogelsdorf Formation) is overlain on top by deeper marine clay and marl of the Zellerndorf Formation. The succession represents a single transgressive sequence of the Early Ottnangian. The description below is from NEBELSICK (1989a, b) and NEBELSICK et al. (1991).

Description: The abandoned stone pit is situated at the northern slope of the Feldberg, c. 1,6 km SSE of Groß-Reipersdorf, c. 350 m NNE of the Feldberg, or c. 50 m south of the railway Zellerndorf–Sigmundsherberg, directly at the crossing of the path to Groß-Reipersdorf (Text-Fig. 23).



Text-Fig. 23: Location of the abandoned Quarry Hatei.

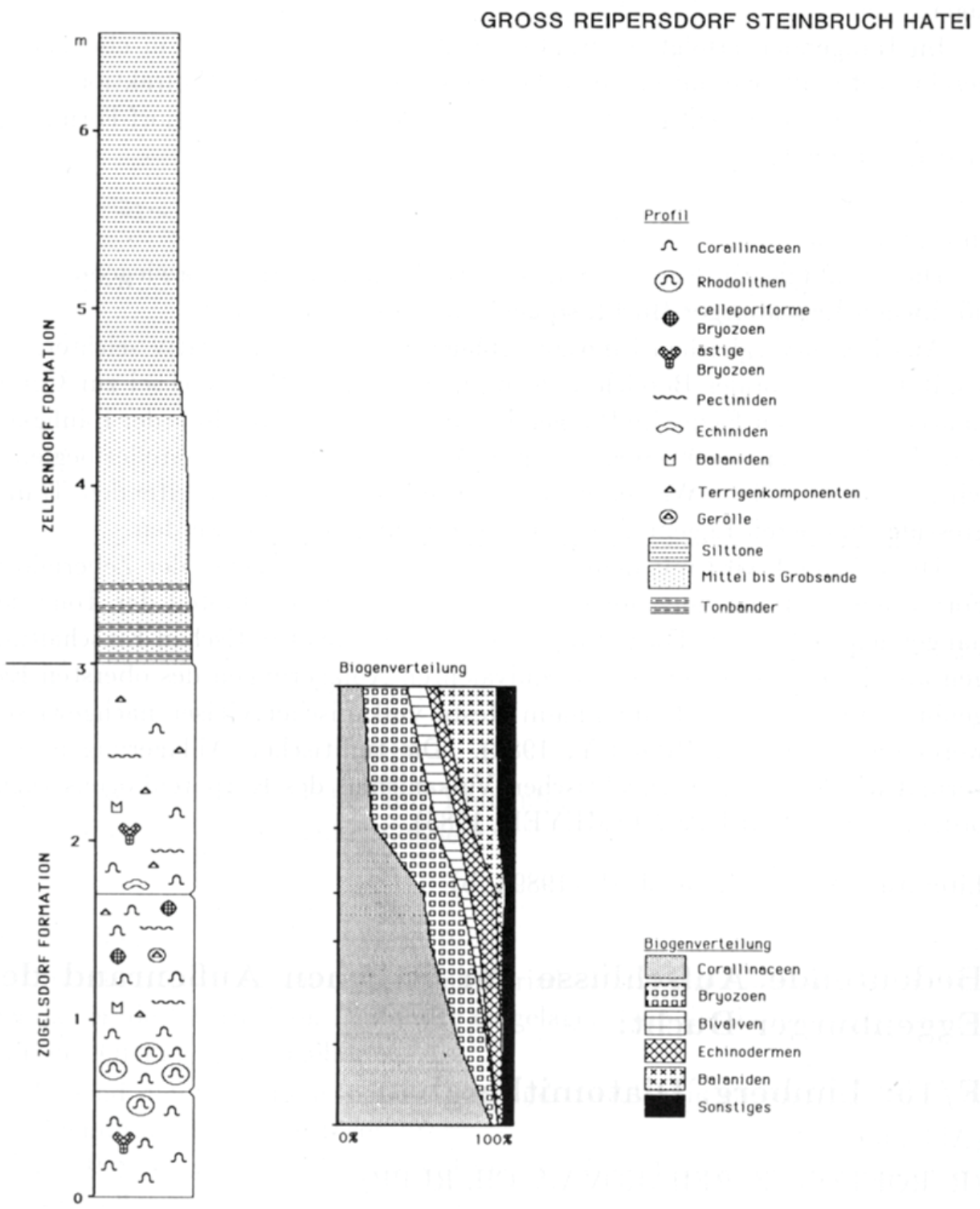
The Hatei Quarry near Groß-Reipersdorf (Text-Fig. 24) is one of the few outcrops, which shows the transition from the Zogelsdorf Formation to the Zellerndorf Formation (Upper Eggenburgian to Ottnangian). The c. 3 m thick outcropping Zogelsdorf Formation consists of largely massive, biogene-rich limestones showing a fining upward trend. The biogenic components are composed of bryozoans, bivalves (pectinids), echinoderms, balanids, and particularly frequent corallinaceans. The latter are dominant in the lower part of the outcrop and occur also as rhodoliths. They are densely branched, show ellipsoidal to spherical shapes and reach up to 10 cm in size. Towards the upper part, the frequency of the corallinaceans decreases continuously. Here they occur increasingly as fragments or encrusted particles. Also the size of the rhodoliths decreases. Other components such as bryozoans, balanids or terrigenous particles increase towards the top. Accordingly, the facies changes from a corallinacean-facies at the bottom to a corallinacean-bryozoan facies at the top (NEBELSICK, 1989a, b). The flora of the non-corallinaceans is relatively diverse but poorly preserved and contains, among others, the genera *Sporolithon*, *Lithothamnion*, ?*Palaeothamnium*, *Spongites*, *Lithophyllum* and *Titanoderma*. The foraminiferal assemblages contain smaller benthic types such as textulariids, cibididids, *Asterigerinata*, *Ammonia*, elphidiids, buliminids, bolivinids and, with better preservational conditions, Miliolidae, also *Amphistegina* and in some samples planktic foraminifera. The transition of the clay-rich Zellerndorf Formation appears relatively abrupt. Above of a wavy surface, 140 cm of very poorly sorted, clay-rich, gravelly medium to coarse sands of quartz-rich crystalline grit follows. Intercalations of cm-thick layers of sandy to silty clay show a horizontal stratification. Prominent in these deposits are large amounts of inarticulate brachiopods (*Discinisca* sp.). Above this, the transition to horizontally bedded silty clays with high smectite content occurs within 20 cm. Above the 2 m thick pelites of the Zellerndorf Formation lays quaternary loess.

Interpretation: The coralline facies of the Zogelsdorf Formation occurs mainly in the northern Eggenburg Bay, thus also in the area of Pulkau. From comparison with modern analogues, a relatively shallow, protected, sub-littoral palaeoenvironment is assumed. The change to the corallinacean-bryozoan-facies in the overlying stratum is accompanied by a decrease of the corallinacean content and a slight increase of mud and is interpreted as a deepening during the progressing transgression of the late Eggenburgian (Text-Fig. 26). This trend continues with the transition to a basinal facies of the Zellerndorf Formation later on. The high smectite content of the Zellerndorf Formation can most likely be derived from

tuffitic intercalations, particularly because volcanic gases were found in equivalent deposits of latest Eggenburgian age from the Znojmo area. The tuffitic deposits have probably to be assigned to the acidic, rhyolitic volcanism of the Carpathian Arc.

Text-Fig. 24: Groß-Reipersdorf – abandoned Quarry Hatei.

Text-Fig. 25: Groß-Reipersdorf – abandoned Quarry Hatei. Zogelsdorf Formation overlain by Zellerndorf Formation and Löss.



Text-Fig. 26: Section of the Hatei Quarry showing results of microfacies analysis of the Zogelsdorf Formation (from NEBELSICK et al., 1991).

References

DOMNING, D.P. & PERVESLER, P. (2001): The Osteology and Relationships of *Metaxytherium krahuletzi* DEPERET, 1895 (Mammalia: Sirenia). – Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft, **553**, 1–89, Frankfurt am Main.

FUCHS, T. (1868): VI. Die Tertiärbildungen der Umgebung von Eggenburg. – Jahrbuch der k. k. Geologischen Reichsanstalt, **18**, 584–598, Wien.

FUCHS, T. (1900): Beiträge zur Kenntnis der Tertiärbildungen von Eggenburg. – Sitzungsberichte der mathematisch-naturwissenschaftlichen Klasse der kaiserlichen Akademie der Wissenschaften, Abtheilung 1, **109**, 859–924, Wien.

JENKE, Y.B. (1993): Palaeoecological studies of benthic foraminifera from the Zogelsdorf Formation (Eggenburgian, Early Miocene) in the Eggenburg area (Austria). – Mededelingen van de Werkgroep voor Tertiaire en Kwartaire Geologie, **30**/3–4, 105–145, Leiden.

MANDIC, O., HARZHAUSER, M., STEININGER, F. & ROETZEL, R. (Eds.) (2005): Miocene of the eastern Alpine Foredeep – the Bohemian Massive southeastern margin. – RCMNS 2005 Excursion C, 52 pp., Vienna.

NEBELSICK, J.H. (1989a): Die fazielle Gliederung der Zogelsdorf Formation (Untermiozän: Eggenburgian) in Niederösterreich anhand mikrofazieller Untersuchungsmethoden. – Diplomarbeit Universität Wien, 242 S., Wien.

NEBELSICK, J.H. (1989b): Temperate Water Carbonate Facies of the Early Miocene Paratethys (Zogelsdorf Formation, Lower Austria). – Facies, **21**, 11–40, Erlangen.

NEBELSICK, J.H., STEININGER, F.F., VAVRA, N. & PILLER, W.E. (1991a): Zogelsdorf, Johannes-Steinbruch. – Exkursionen im Tertiär Österreichs, 97–99, Österreichische Paläontologische Gesellschaft, Wien.

NEBELSICK, J.H., STEININGER, F.F., VAVRA, N. & PILLER, W.E. (1991b): Haltepunkt 5. Zogelsdorf, Johannes-Steinbruch. – In: ROETZEL, R. (Ed.) (1991): Arbeitstagung der Geologischen Bundesanstalt 1991, Geologie am Ostrand der Böhmischen Masse in Niederösterreich, Schwerpunkt Blatt 21 Horn, 173–174, Wien.

PERVESLER, P. & ROETZEL, R. (1991): Das Leichenfeld von Kühnring. – In: STEININGER, F.F. & PILLER, W.E. (Eds.): Eggenburg am Meer: Eintauchen in die Erdgeschichte. – Katalogreihe des Krahuletz-Museums, **12**, 97–101, Eggenburg.

PERVESLER, P., ROETZEL, R. & STEININGER, F.F. (1995): Taphonomie der Sirenen in den marinen Flachwasserablagerungen (Burgschleinitz-Formation, Eggenburgium, Untermiozän) der Gemeindesandgrube Kühnring (Niederösterreich). – Jahrbuch der Geologischen Bundesanstalt, **138**/1, 89–121, Wien.

PERVESLER, P., ROETZEL, R. & MANDIC, O. (1998): Sirenenlagerstätten in den marinen Flachwasser-Ablagerungen der Eggenburger Bucht (Burgschleinitz-Formation, Eggenburgium, Untermiozän). – Geologisch-Paläontologische Mitteilungen Innsbruck, **23**, 87–103, Innsbruck.

ROETZEL, R., HARZHAUSER, M. & MANDIC, O. (2012): Early Ottnangian carbonate factory and the drowning event – Abandoned Quarry Hatai. – Molasse Tagung 27.–28. April 2012 in Wien, Excursion guide, 20–22, NHMW, Wien.

SCHAFFER, F.X. (1914): Die tertiären und diluvialen Bildungen. – In: SCHAFFER, F.X.: Das Miocän von Eggenburg. – Abhandlungen der k. k. Geologischen Reichsanstalt, **22**/4, VIII + 124 pp., Wien.

SCHAFFER, F.X. (1927): Geologische Geschichte und Bau der Umgebung Wiens. – 112 S., Leipzig–Wien (Deuticke).

STEININGER, F.F., PERVESLER, P., ROETZEL, R., RUPP, C. & JENKE, Y. (1991a): Kühnring, Gemeindesandgrube. – Exkursionen im Tertiär Österreichs, 91–97, Österreichische Paläontologische Gesellschaft, Wien.

STEININGER, F.F., PERVESLER, P., ROETZEL, R., RUPP, C. & JENKE, Y. (1991b): Haltepunkt 3. Kühnring – Gemeindesandgrube. – In: ROETZEL, R. (Ed.) (1991): Arbeitstagung der Geologischen Bundesanstalt 1991, Geologie am Ostrand der Böhmischen Masse in Niederösterreich, Schwerpunkt Blatt 21 Horn, 166–169, Wien.

STEININGER, F., ROETZEL, R. & SENGÖR, A.M.C. (2015): "Der Meeresspiegel steigt". Das Konzept der Meeresspiegelschwankungen von Eduard Suess basierend auf den Ablagerungen des Eggenburger Meeres. – Berichte der Geologischen Bundesanstalt, **110**, 1–54, Wien.

SUESS, E. (1883): Das Antlitz der Erde. – Vol. I, 779 pp., Prag (Tempsky)–Leipzig (Freytag).

SUESS, E. (1888): Das Antlitz der Erde. – Vol. II, 703 pp., Prag–Wien (Tempsky)–Leipzig (Freytag).

SUESS, E. (1901): Das Antlitz der Erde. – Vol. III, 1st half, 508 pp., Prag–Wien (Tempsky)–Leipzig (Freytag).

SUESS, E. (1909): Das Antlitz der Erde. – Vol. III, 2nd half, 789 pp., Wien (Tempsky)–Leipzig (Freytag).

TOULA, F. & KAIL, J.A. (1885): Über einen Krokodil-Schädel aus den Tertiärablagerungen von Eggenburg in Niederösterreich. Eine Paläontologische Studie. – Denkschriften der mathematisch-naturwissenschaftlichen Klasse der kaiserlichen Akademie der Wissenschaften, **50**, 299–355, Wien.

VAVRA, N. (1979): Die Bryozoenfauna des österreichischen Tertiärs. – Neues Jahrbuch für Geologie und Paläontologie: Abhandlungen, **157**/3, 366–392, Stuttgart.

VAVRA, N. (1981): Bryozoa from the Eggenburgian (Lower Miocene, Central Paratethys) of Austria. – In: LARWOOD, G.P. & NIELSEN, C.: Recent and fossil bryozoa, 273–280, Fredensborg.