ROCZNIK POLSKIEGO TOWARZYSTWA GEOLOGICZNEGO
ANNALES DE LA SOCIÉTÉ GÉOLOGIQUE DE POLOGNE

Tom (Volume) XXXIX — 1969 Zeszyt (Fascicule) 1—3 Kraków 1969

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ON THE STRATIGRAPHY AND LITHOLOGY OF THE FLYSCH ZONE IN THE SURROUNDINGS OF THE HAGENBACH-VALLEY (NORTHERN VIENNA WOODS, AUSTRIA)

(2 Figs.)

Über die Stratigraphie und Lithologie der Flyschzone in der Umgebung des Hagenbachtales (nördlicher Wienerwald, Österreich)

(2 fig.)

Abstract: This study on the stratigraphy and lithology of the flysch sediments of the Hagenbach area is supplementing the paleontological papers in this volume by W. Grün and H. Stradner. The topographical and tectonical chapters are followed by the detailed descriptions of those outcrops which are treated in the paleontological papers. The mapping by the author resulted in the establishment of a system of tectonic slices in the northernmost tectonic unit of the north-alpine flysch zone („Greifensteiner Schuppenzone"). The northernmost lowest slice shows a stratigraphic profile ranging from the Lower Cretaceous Wolfpassing Beds to the Upper Greifenstein Beds (upper part of the Lower Eocene). A lower and an upper complex can be distinguished within the Greifenstein Beds. Between these complexes a minor tectonic phase can be assumed.

The sedimentological study of the heavy mineral contents proved furthermore, that a structural stratigraphic hiatus lies between the Wolfpassing Beds and the Wördern Beds. Within the Altlengbach Beds a gradual change of the heavy mineral associations can be observed. The Lower Greifenstein Beds are conformably overlying the Altlengbach Beds and show similar heavy mineral associations. The Upper Greifenstein Beds lying in structural discordance over them indicate a new cycle of sedimentation. Determinations of the carbonate contents supplement the data of the lithology. In Upper Cretaceous and Lower Paleogene sediments flysch facies is predominating, as can be proved by cases of graded bedding and convolute bedding. The relation of quartz arenites to clays and clayey marls in the average is 4 : 1 (Upper Cretaceous to Lower Eocene) in the Hagenbach Area.

1. INTRODUCTION

A team of Austrian geologists and paleontologists has been studying the flysch zone near Vienna during the last years. We welcome the occasion of the centenary of J. Grzybowski's birthday to contribute the preliminary results of our work. The area of the Hagenbach-Valley

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near St. Andrä in the northern part of the Vienna Woods was chosen by the authors dividing their topics as follows: F. Brix, Lithology and Stratigraphy; W. Grün, Microfauna (p. 305) and H. Stradner, Nannoflora (p. 403). The enclosed maps inform on the topography and geology of the area and are also intended to be used with the papers by W. Grün and H. Stradner.

With the paleontological and stratigraphical research on this area already in progress, corresponding lithological studies of this part of the flysch zone are still in an initial phase. Thus it is possible to contribute a short survey only. All three papers have the character of preliminary notes and research work is being continued.

Generalized Geological Map of the Surroundings of Vienna

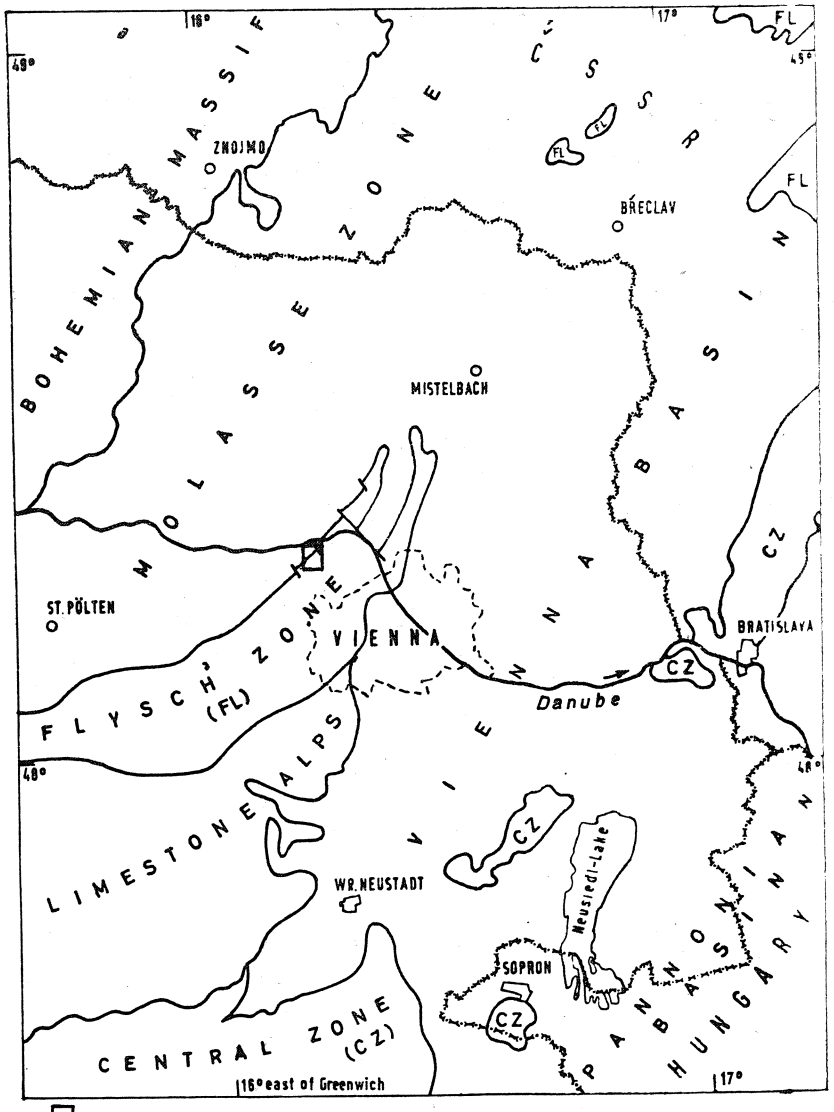

Fig. 1

Thanks are due to the General Direction of the Österreichische Mineralölverwaltung AG for permission granted to publish scientific results by F. Brix and partly by H. Stradner, which were carried out as

GEOLOGICAL MAP OF THE HAGENBACH-AREA (VIENNA WOODS)
by F. Brix 1969

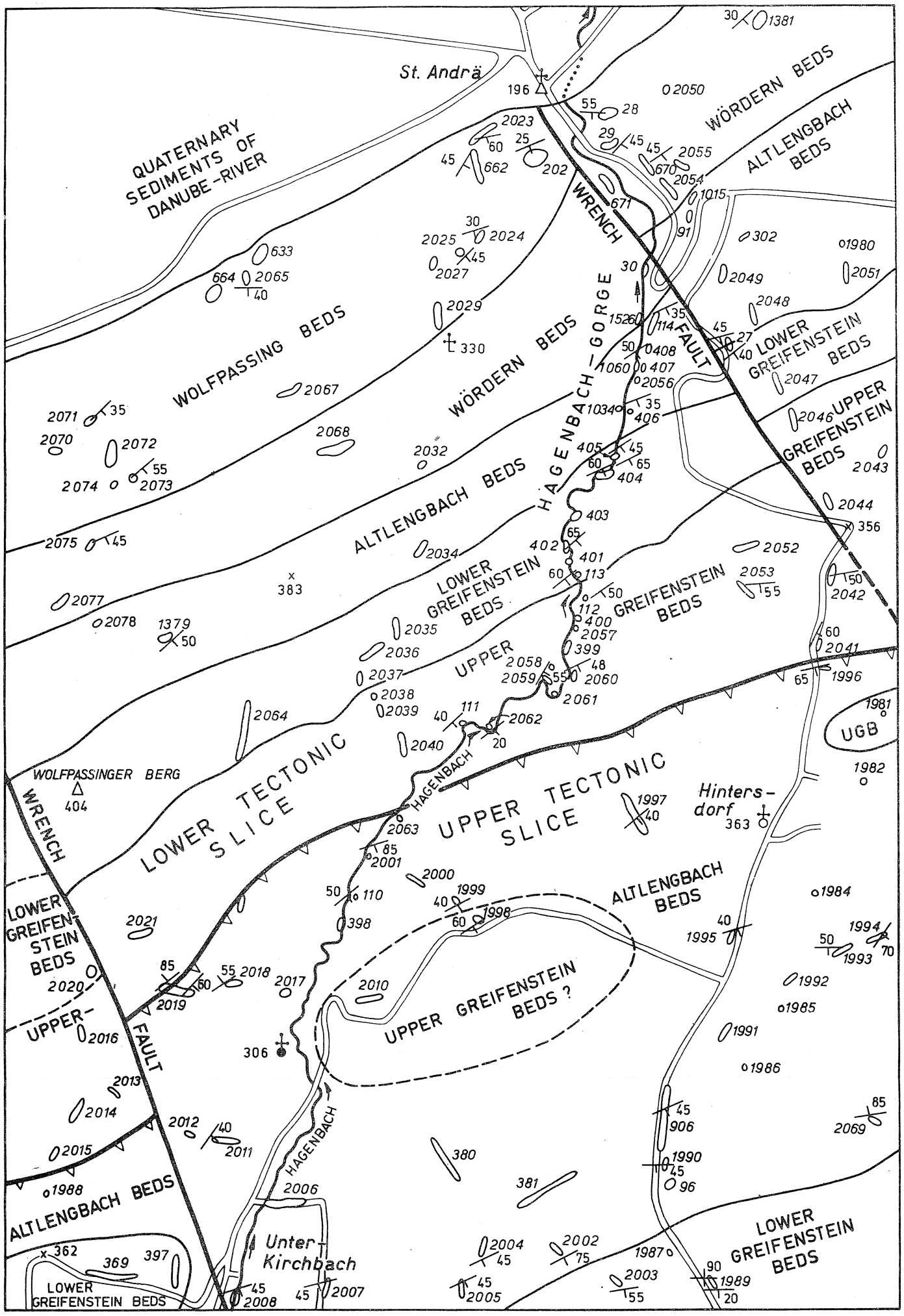

Fig. 2

UGB — UPPER GREIFENSTEIN BEDS

29 — EXPOSURE

BOUNDARY OF BEDS UNCERTAIN

80 — DIPPING 80°

△ X 383 — ALTITUDE ABOVE ADRIA SEA – LEVEL

ROADS

OVERTHRUST LINE

BOUNDARY OF BEDS CERTAIN

0 200 400 600m

part of the company's exploration projects. The evaluation of the seismic shotpoints and the results obtained by the „Laboratory for exploration and production of the ÖMV AG" deserve special acknowledgment. Also many thanks to Dr. I. Maurer for heavy mineral analyses as well as to Dr. K. Turnovsky for micropaleontological analyses, to Dr. H. Hawle for chemical and other laboratory tests, and to Dr. H. Stradner, Geological Survey of Austria, for his assistance in translating the text into English.

2. TOPOGRAPHICAL CHARACTERISTICS OF THE AREA

The Hagenbach-Gorge and its surroundings lie appr. 16 to 17 km to the NW of the City of Vienna. The Hagenbach (a small creek) is flowing through this gorge from SSW to NNE. In its upper course near the village of Unterkirchbach, the valley is wide and flat as are many of the valleys in the flysch area of the Vienna Woods. West of the village of Hintersdorf the valley changes into a gorge extending to the northern margin of the flysch zone near St .Andrä. This gorge is appr. 2.500 meters in length. The difference in level from the gorge floor to the old landscape on either side of the gorge ranges from 70 to 100 meters.

The altitude above sea-level at the southern entrance of the gorge is appr. 290 meters, at its exit in the north near St. Andrä appr. 190 meters. The conditions of the geological outcrops within the gorge are excellent compared to other parts of flysch zone. The structure of the northernmost tectonic unit of the Northalpine flysch zone is exposed in this gorge to such an extent that essential features of geology and tectonics are revealed.

3. HISTORICAL REVIEW

A short survey of the more important papers published since 1898 is to supplement the bibliography given at the end of this paper. C. M. Paul (1898) has considered the entire area as of Paleocene age. He assumed however the existence of Upper Cretaceous beds in the environment of St. Andrä.

R. Jaeger (1914) established a sound basis for the stratigraphy of the Northalpine flysch zone after collecting a large number of fossils. Near St. Andrä, for example, he discovered Aptychi, which proved Lower Cretaceous age for the Wolfpassing Beds. At the northern exit of the Hagenbach-Gorge R. Jaeger proved Upper Cretaceous by finding *Orbitoides*. He also was the first to discover wrench faults near Königstetten and St. Andrä at the northern margin of the flysch zone.

K. Friedl (1921) published a map in the scale of 1 : 75.000 covering also the Hagenbach area. He distinguished between „Neocomian flysch", „Orbitoidenkreide" of Upper Cretaceous age, and „Greifensteiner Sandstein" of Eocene age. Later papers by the same author (1922 a, b, 1931) are dealing with tectonical problems mainly.

G. Götzinger has been studying the Vienna Woods since about 1920. Larger comprehensive papers were published by him (the first together with H. Becker) in 1932, in 1945 (Götzinger, 1945 a, b) and 1951. The „Geological Map of the Surroundings of Vienna", in which the eastern part of the Vienna Woods is included, was published in 1952, the explanations to that map in 1954. G. Götzinger tried a detailed zonation by making use of newly collected fossils and by means of

lithological comparisons. Further progress was achieved by the introduction of heavy mineral analyses by G. Woletz (1950, 1963) and by H. Wiesenedер (1952). R. Noth supplied valuable micropaleontological data. G. Götzinger introduced the term „Altlengbacher Schichten" (Altlengbach Beds, Upper Senonian) and also applied it for certain parts of the Hagenbach area. The limits of the Greifenstein Sandstones thus were more restricted. 1949 F. Brix has begun to study the Flysch zone near Vienna. The northern part between Riederberg and Danube River was mapped by him for the ÖMV AG (internal report 1956 by F. Brix and R. Milles). During these investigations the discordant bedding of the Lower Eocene over the Cretaceous beds was discovered. Micropaleontological analyses (K. Turnovsky), heavy mineral analyses (I. Maurer) and carbonate analyses (H. Hawle) were worked out to supplement the results of the field work. A compilation of the results gained in the northern part of the flysch zone is given in the paper by F. Brix and K. Götzinger (1964).

Since 1954 A. Papp has studied *Orbitoides* from Alpine localities. In 1956 he published on the *Orbitoides* of the Upper Cretaceous flysch of the Vienna Woods. Several species of *Orbitoides* were described from the Hagenbach — Gorge and from St. Andrä, some of them were new for the science. A series of strata of Upper Campanian age (Hagenbach--Gorge) could be distinguished from a series of strata of Maestrichtian age (St. Andrä).

The *Nummulites* of the Greifenstein Sandstone at the outer margin of the flysch zone were described by A. Papp (1962) and were classified as Lower Eocene (Cuisian) species.

Since 1960 H. Stradner and F. Brix began to check nannofossils from the flysch of the Vienna Woods for their stratigraphic significance. Soon more than 50% of the samples taken from marl exposures could be evaluated (F. Brix, 1961; H. Stradner, 1961; H. Stradner & A. Papp, 1961). For numerous exposures new age determinations could be given by the nannofossil method. Tectonical problems are treated in a paper by S. Prey, 1965. He attempts to connect the tectonic units of the Western Carpathians with those of the Eastern Alps. The Greifenstein Sandstones, as they are occurring in the Hagenbach — Gorge are correlated with the Ciężkowice Sandstones of the Silesian nappe. A survey of his views on the stratigraphy of the flysch zone of the Vienna Woods is offered in S. Prey, 1968. He uses the following units of strata: Greifenstein Sandstone (Lower to Middle Eocene), Altlengbach Beds (Maestrichtian — Paleocene), Gault — flysch and Neocomian — flysch.

4. TECTONIC POSITION

As mentioned before the Hagenbach — Gorge is situated in the northernmost tectonic unit of the Northalpine flysch zone. This unit was called „Greifensteiner Decke" (Greifenstein nappe) by K. Friedl (1921), „Greifensteiner Teildecke" (Greifenstein partial nappe) by G. Götzinger (1945 a) and „Greifensteiner Schuppenzone" (Greifenstein zone of tectonic slices) by F. Brix in F. Brix & K. Götzinger (1964). As became evident in the Mauerbach 1a deepwell (ÖMV AG) the flysch zone was thrust over the molasse zone over a distance of at least 4 kilometers, probably even 10 to 15 kilometers, the overthrust plane being comparatively flat (F. Brix, 1966).

The Hagenbach — Gorge is crossed by a wrench fault (fig. 1 and 2). This wrench fault is only of small dimensions and extends from St. Andrä in SSE direction. A parallel wrench fault is found in the west of the Wolfpassinger Berg. The eastern flanks of these faults have been moved in NNW direction. This type of faulting is to be observed frequently near the northern margin of the Alpine flysch zone (K. F r i e d l, 1922 b). The Greifenstein zone of tectonic slices is represented by two slices in

Table 1

HEAVY MINERAL ASSOCIATIONS IN SANDSTONES

Exposure no.	Beds	zir-con	ruti-le	tour-mali-ne	stau-roli-te	gar-net	other heavy minerals
	a) LOWER TECTONIC SLICE						
662/1	Wolfpassing B.	73	18	6		3	
662/2	Wolfpassing B.	43	39	4		14	
29/2	Wördern B.	16	18	1		64	1 (monazite)
670/1	Wördern B.		1	1	10	87	1 (chlorite)
670/2	Wördern B.	4	7		1	87	1 (titanite)
2054/1 o	Wördern B.	5	6	2	3	83	1 (apatite)
2054/2 u	Wördern B.	5	5	1	4	85	
114/4	Altlengbach B.	20	2		2	75	1 (chlorite)
406/2 o	Altlengbach B.	46	23	10	4	17	
406/3 u	Altlengbach B.	57	17	17		8	1 (anatase)
27/2	Lower Greifenstein B.	47	23			27	3 (monazite)
405/2 o	Lower Greifenstein B.	41	26	5		27	1 (anatase)
405/1 u	Lower Greifenstein B.	67	24	3		5	1 (apatite)
402/4	Lower Greifenstein B.	44	8	9		39	
402/3	Lower Greifenstein B.	45	12	5	1	37	
112/10	Upper Greifenstein B.	70	7	18		4	1 (spinel)
400/1 o	Upper Greifenstein B.	68	15	8		9	
400/2 u	Upper Greifenstein B.	58	32	4		5	1 (spinel)
399/2 o	Upper Greifenstein B.	61	23	12		2	1 (spinel)
399/3 u	Upper Greifenstein B.	68	11	17		4	1 (brookite)
2060/1 u	Upper Greifenstein B.	89	9	1		1	
	b) UPPER TECTONIC SLICE						
1996/1	Altlengbach B.	21	7	6	1	64	1 (monazite)
2007/1	Altlengbach B.	28	6	4	1	60	1 (epidote)

Percentage of non - opacous heavy minerals; o - overlying part of the layer; u - underlying part of the layer; B. - Beds

the Hagenbach area. The northern, lower slice consists of beds of Lower Cretaceous, Senonian and Paleogene age. This is the slice in which the Hagenbach — Gorge is situated. The southern, upper slice has its northern margin near Hintersdorf and consists of Upper Senonian and Paleogene. Other dislodged slices are to be found further to the south, beyond the area dealt with in this paper.

The dip of the strata of the lower slice is flattening near the contact with the upper slice, the dip being normally SE to SSE. At one location NW of Unterkirchbach there is even a steep dip to NW due to the pressure exerted by the overthrusting upper slice on the capping beds of the lower slice (exposure no. 2019, fig. 2). Generally it can be said, that the sliding planes of the flysch slices are flat.

It deserves special emphasis, that the Lower Cretaceous beds of the lower slice differ from the overlying younger beds by being more intricately folded and by showing only few characteristics of the typical flysch facies.

5. STRATIGRAPHY AND LITHOLOGY

a) General Remarks

The following chapter brings lithological descriptions of characteristic strata of the lower slice. Points from which fossils were collected, are listed. The position of exposures and the dipping of the beds is given in the geologic map (fig. 2). Only points, where fossils were found, are listed from the upper slice, which resembles the lower slice regarding its lithology.

The heavy mineral contents are shown in table 1, the carbonate analyses in table 2. As the geologic age is not so well established for some strata involved, the following collective terms are applied:

Wolfpassing Beds: Neocomian + Gaultian
Wördern Beds: Santonian to Lower Campanian
Altlengbach Beds: Upper Campanian to Lower Paleocene
Lower Greifenstein Beds: Upper Paleocene to lower part of Lower Eocene
Upper Greifenstein Beds: Upper part of Lower Eocene.

The reasons for distinguishing two complexes of different age within the Greifenstein Beds are the following: In the Hagenbach — Gorge as well as in the area of Greifenstein and Höflein (two villages appr. 5—6 km ENE of the Hagenbach — Gorge) a sequence of thick bedded and massive Greifenstein Sandstones, partly with graded bedding, without nannofossils, but with *Nummulites* and other foraminifera of Lower Cuisian age (= Lower Greifenstein Beds) is being overlain by thin bedded sandstones with many intercalations of clayey marls or marly shales, the upper part of the Greifenstein Beds. In these upper Beds, especially in the marls, nannofossils are rather frequent and so are arenaceous foraminifera (= Upper Greifenstein Beds).

Typical for the Lower Greifenstein Beds with only rare thin layers of clay are the exposures no. 401—405 in the Hagenbach — Gorge (fig. 2), the big quarry between Greifenstein and Höflein, that is the socalled „Hollitzer — Steinbruch", type locality, and the rocks exposed beneath the mediaeval castle of Greifenstein.

Typical for the Upper Greifenstein beds are the exposures no. 112, 400, 2057, 399, 2058, 2059 and 2060 in the Hagenbach — Valley (fig. 2)

and the quarries in the area within a distance of appr. 1 km ESE from the village of Höflein. The beds between the exposures no. 400 and 2060 in the Hagenbach — Valley are proposed as type locality.

Another important argument for distinguishing the Lower from the Upper Greifenstein Beds is given by the tectonical discordance which

Table 2

AVERAGE CARBONATE CONTENTS in % (LOWER SLICE)

Exposure no.	Beds	samples	average carb. conts. of sandstones	samples	average carb. conts. of clays and marls	total number of samples	average percentage of all samples
662	Wolfpassing B.	2	4,0	2	10,7		
202	Wolfpassing B.	1	43,0	1	23,5		
2025	Wolfpassing B.			1	0		
	Wolfpassing B.					7	16,2
29	Wördern B.	2	6,2	1	0		
2054	Wördern B.	2	21,1				
	Wördern B.					5	9,1
114	Altlengbach B.	3	24,6	2	10,5		
406	Altlengbach B.	2	12,8	1	0		
27	Altlengbach B.	1	19,7				
	Altlengbach B.					9	13,5
27	Lower Greifenstein B.	1	0				
405	Lower Greifenstein B.	2	3,6				
402	Lower Greifenstein B.	2	0,1	2	0		
	Lower Greifenstein B.					7	0,9
112	Upper Greifenstein B.	3	0	1	25,8		
400	Upper Greifenstein B.	2	9,2	2	1,5		
399	Upper Greifenstein B.	2	24,3	2	10,4		
111	Upper Greifenstein B.	1	5,9				
2060	Upper Greifenstein B.	2	33,6	2	6,8		
	Upper Greifenstein B.					17	13,1

B. - Beds

separates these two complexes. In the Hagenbach — Valley the Lower Greifenstein Beds of the lower slice are dipping 60—65°, whereas the Upper Greifenstein Beds show a dip of 20—55° only (fig. 2).

In the upper slice the Upper Cretaceous Altlengbach Beds are also overlain by Lower Greifenstein Beds (exposure no. 1987). The Upper Greifenstein Beds are lying discordantly above the lower part of the Altlengbach Beds in the area E of Hintersdorf (exposure no. 1981). Here Lower Greifenstein Beds are absent. Thus a weak tectonic phase can be assured during the Lower Eocene (between Lower and Upper Cuisian) for the flysch strata of the Vienna Woods.

In the Hagenbach area hitherto no beds of Cenomanian to Coniacian age have been discovered. This hiatus leads to the conclusion that the Wolfpassing Beds and the Wördern Beds are not a continuous sequence. In the Mauerbach 1a well (ÖMV AG) the entire flysch — nappe was penetrated to a depth of 2.364 meters. Neither in cores nor in cuttings any paleontological indications of the lower part of the Upper Cretaceous age were found.

The ratio of sandstones (mostly quartz arenites) to clay, clayey marls and marls is rather variable in the different groups of beds. The Wolfpassing Beds show a ratio of appr. 1 : 2, the Wördern Beds a ratio of appr. 6 : 1, the Altlengbach Beds a ratio of appr. 3 : 1, the Lower Greifenstein Beds of appr. 6 : 1, and the Upper Greifenstein Beds of appr. 1 : 1.

In the average the flysch rocks of Upper Cretaceous to Lower Eocene age show a sandstone to clay and marl ratio of about 4 : 1. This fact explains why in poorly exposed areas of the northern flysch zone of the Vienna Woods layers of marls or clays suited for paleontological investigations are only rarely found.

Those samples of marls and clays which are cited in the papers by H. Stradner (1969) and by W. Grün (1969) were taken from exposures which in position and station number correspond to those mentioned in the present paper.

b) Lower slice of the Greifenstein Zone of Tectonic Slices

Wolfpassing Beds:

Exposure no. 662: sandstones, light brownish-grey to light blueish-grey, fine-grained; sandstones, yellowish-brown, fine- to medium-grained, marly, friable (defile, sunken road).

Fossils: *Aptychus pusillus* Pet., *Aptychus* cf. *seranonis* Cqd. *Aptychus cf. undatocostatus* Pet., a fish — tooth ((R. Jaeger, 1914), *Coccolithus barnesae* Black & Barnes, *Parhabdolithus embergeri* (Noël) (H. Stradner, internal report).

Exposure no. 202: calcarenites, blueish-grey to reddish-grey, fine-grained, many veins of calcites, partly transitions to limestones; marly schists, grey to dark grey, thin bedded (abandoned quarry).

Fossils: The same as no. 662, besides *Lenticulina* sp., *Quinqueloculina* sp., *Textularia* sp., *Virgulina* sp., *Ammodiscus* sp. (K. Turnovsky in F. Brix and R. Milles 1956).

Exposure no. 2024: sandstones, light greyish-yellow, fine- to medium-grained; calcarenites, grey and light brown, fine-grained, hard (floor of a path).

Exposure no. 2025: sandstones, greyish-blue to greyish-brown, a little marly, fine-grained; sandstones, blackish-grey, hard, splintery, fine-grained; calcarenites to limestones, light-grey, partly with dark grey, chest nodules, hard, compact, many thin veins of calcites; shales, black, thin bedded (floor of a path).

Wördern Beds:

Exposure no. 29: Alternation of sandstones, grey, medium-grained, micaceous, friable; sandstones, greyish-brown, very coarse-grained, friable; marly shales, dark grey, arenaceous, bituminous (scarp near the road).

Fossils: *Bathysiphon* sp. (K. Turnovsky in F. Brix and R. Milles, 1956).

Exposure no. 670: sandstones, grey, coarse-grained, hard; sandstones, light brown, medium-grained, friable (scarp near the road).

Fossils: *Orbitoides* sp. (R. Jaeger, 1914); *Orbitoides* sp., *Pecten* sp. (G. Götzinger, 1951); *Orbitella apiculata* Schlumb. (A. Liebus, 1938); *Dendrophrya robusta* Grzyb., *Trochamminoides* sp. (R. Noth in G. Götzinger, 1954).

Exposure no. 671: rocks like in no. 670 (scarp near the creek bed).

Fossils: *Orbitoides* sp. (R. Jaeger, 1914).

Exposure no. 2054: sandstones, light grey, medium- to coarse-grained, very friable, thick bedded (scarp near the road).

Exposure no. 30: sandstones, brown, very coarse-grained, friable, with thin lenses of grey marls (in the creek bed).

Altlengbach Beds:

Exposure no. 114: alternation of: calcareous sandstones, blueish-grey to grey, fine- to medium-grained, micaceous, small pieces of lignites, veins of calcites; sandstones, grey, coarse-grained, friable; sandstones, blueish-grey, coarse-grained, hard, veins of calcites; calcareous sandstones, grey to dark brownish-grey, fine- to medium-grained, much mica and fossils plants on the bedding planes, veins of calcites; marls, greyish-brown, arenaceous; shales, grey, thin bedded; marls to marly shales, grey, foliated (scarp above the path).

Fossils: *Ammodiscus incertus* (d'Orb.), *Trochammina* sp., *Bathysiphon* sp. (K. Turnovsky in F. Brix and R. Milles, 1956). *Micula staurophora* (Gard.) (F. Brix, 1961); *Arkhangelskiella cymbiformis* Veksh. (H. Stradner, internal report), W. Grün 1969 (in this volume).

Exposure no. 1034: sandstones, grey, coarse-grained, friable, partly conglomeratic; sandstones, greenish-grey, medium-grained, very friable; clayey marls, dark grey, soft (creek bed).

Fossils: *Orbitoides media* (Papp), *Orbitoides media megaloformis* (Papp & Küpper), *Orbitoides jaegeri* (Papp & Küpper), *Lepidorbitoides bisambergensis* (Jaeger) (A. Papp, 1956, W. Grün 1969).

Exposure no. 406: alternation of: sandstones, light brown, medium-grained; marls, grey, partly violet-brown (scarp near the path).

Fossils: W. Grün 1969.

Exposure no. 1980: seismic shotpoint ÖMV AG 102/2,0: sandstones, light grey, medium-grained, veins of calcites; clayey marls and shales, dark grey to grey, hard.

Fossils: *Arkhangelskiella cymbiformis* Veksh., *Micula staurophora* (Gard.), *Cylindralithus* sp., *Zygodiscus spiralis* (Br. & M.), *Coccolithus gallicus* (Strad.), *Deflandrius intercisus* (Defl.) (H. Stradner, internal report); *Rhabdammina* sp. (K. Turnovsky, internal report);

Exposure no. 27 (basal part): calcareous sandstones, blueish-grey to grey, fine-grained to medium-grained, hard; marls: light grey to dark grey (abandoned quarry).

Lower Greifenstein Beds:

Exposure no. 405: sandstones, brown to light brown, medium-grained to coarse-grained, thick bedded; layers of marls are rare (scarp near the path).

Exposure no. 404: sandstones, brown to light brown, medium- to coarse-grained, very friable, thick bedded (to 4 meters); layers of marls rare (scarp near the path).

Exposure no. 402: sandstones, brown to brownish-grey, medium-grained, hard; marls, greyish-green, soft, thin bedded (high bank of the creek).

Fossils: *Psammosiphonella cylindrica* (Glaessner), *Psammosiphonella rzehaki* (Andreae), *Glomospira* sp., ? *Dendrophrya* sp., *Reophax* sp., ? *Psammosphaera* sp. (K. Turnovsky, internal report).

Exposure no. 401: sandstones, greyish-brown, coarse-grained, friable, mostly thick bedded (bank of the creek).

Fossils: W. Grün 1969.

Upper Greifenstein Beds:

Exposure no. 112: sandstones, brown to yellowish-brown, coarse-grained, hard; sandstones, light grey to light brown, medium-grained, hard, carbonate-matrix, micaceous; marls, grey to brownish-grey (scarp near the path, slide slope).

Fossils: *Cibicides* cf. *cushmani* Nutt., *Globigerina* sp., *Asterigerina* sp., *Nodosaria* sp., rests of Ostracodae (K. Turnovsky in F. Brix, 1961); *Discoaster lodoensis* Br. & R., *D. barbadiensis* Br. & R., *D. mirus* Defl., *D. binodusus* Mart., *D. kuepperi* (Strad.), *Coccolithus pelagicus* (Wall.) Sch., *C. grandis* B. & R., *C. eopelagicus* Br. & R., *Marthasterites tribrachiatus* (Br. & R.) Defl. (F. Brix, 1961; H. Stradner, 1961).

Exposure no. 400: sandstones, greyish-brown to grey, medium-grained to coarse-grained, hard, micaceous, thick bedded; marls, grey, thin bedded (bank of the creek).

Fossils: H. Stradner, 1969; W. Grün, 1969; *Rheophax splendidus* Grzyb.; *Psammosiphonella cylindrica* (Gl.), *Dendrophrya* sp., *Haplophragmoides* sp. (K. Turnovsky, internal report).

Exposure no. 2057: rocks like no. 400; bank of the creek.

Fossils: W. Grün 1969 (in this volume).

Exposure no. 399: sandstones, brown, medium-grained, friable; marls, grey, partly shaly, thin bedded (bank of the creek).

Fossils: H. Stradner 1969.

Exposure no. 2059: sandstones, brownish-grey, medium-grained, soft; marls, grey, partly thick bedded (bank of the creek).

Fossils: H. Stradner 1969.

Exposure no. 2060: alternation of: sandstones, grey, medium-grained, micaceous, on the lower bedding plane trails of *Palaeobullia sp.*; clayey marls, dark grey, thin bedded (bank of the creek).

Fossils: H. Stradner, 1969; W. Grün, 1969.

c) Upper Slice of the Greifenstein Zone of Slices.

In this chapter only those exposures are listed where new fossil-findings could be made.

Altlengbach Beds:

Exposure no. 2063: W. Grün 1969; bank of the creek.

Exposure no. 2001: W. Grün 1969; bank of the creek.

Exposure no. 110: W. Grün 1969; bank of the creek.

Exposure no. 1982: seismic shotpoint, ÖMV AG 108/26,5. *Rhabdammina abyssorum* M. Sars, *Trochamminoides* sp., *Dendrophrya* sp.

(K. Turnovsky, internal report). *Coccolithus barnesae* Black, *Micula staurophora* (Gard.) (H. Stradner, internal report).

Exposure no. 1984: seismic shotpoint, ÖMV AG 108/30,5. *Dendrophrya* sp., *Trochamminoides folium* (Grzyb.). (K. Turnovsky, internal report). *Coccolithus barnesae* Black, *Micula staurophora* (Gard.), *Eiffellithus turriseiffeli* (Defl.); (H. Stradner, internal report).

Exposure no. 1985: seismic shotpoint, ÖMV AG, 108/34,5, *Arkhangelskiella cymbiformis* Veksh. (H. Stradner, internal report).

Exposure no. 1986: seismic shotpoint, ÖMV AG 108/36,0. *Coccolithus barnesae* Black, *Micula staurophora* (Gard.); (H. Stradner, internal report).

Exposure no. 1988: seismic shotpoint, ÖMV AG 107/8,0. *Arkhangelskiella cymbiformis* Veksh., *Micula staurophora* (Gard.); (H. Stradner, internal report).

Lower Greifenstein Beds

Exposure no. 1987: seismic shotpoint ÖMV AG 108/42,0. *Trochamminoides folium* (Grzyb.), *Placentammina grandis* (Grzyb.); (K. Turnovsky, internal report). *Thoracosphaera deflandrei* KPT., *Coccolithus helis* Strad, *C. consuetus* Br. & Sull., *C. crassus* Br. & Sull. (H. Stradner, internal report).

Upper Greifenstein Beds

Exposure no. 1981: seismic shotpoint, ÖMV AG 108/24,5. *Discoaster lodoensis* Br. & R., *D. barbadiensis* Tan Sin Hok. (H. Stradner, internal report).

d) Lithology

Heavy minerals:

Among the samples of sandstones from the Hagenbach area, which were checked for their heavy mineral contents, twenty-three were found to contain more than 100 grains each. The results of these analyses are shown in table 1. In the lower tectonic slice four different groups of heavy mineral associations could be observed.

The Wolfpassing Beds show a zircon-rutile maximum with little garnet present (first group). In the Wördern Beds as well as in the basal part of the Altlengbach Beds a maximum of garnet with rutile is found (second group).

The upper part of the Altlengbach Beds and the Lower Greifenstein Beds have zircon more frequent than garnet and rutile, which are also numerous (third group).

The Upper Greifenstein Beds have a zircon-rutile-tourmaline maximum, with garnet being rare (fourth group).

It appears, that these four groups are connected with separate cycles of sedimentation. A distinct hiatus is to be seen between the Wolfpassing and the Wördern Beds. During this stratigraphical break three tectonical phases must have occurred: the Austrian, the Pregosauian and the Subhercynian phase.

The Wördern Beds and the Lower Altlengbach Beds form the next cycle. After these the Laramian phase appears to have followed, because in the Upper Altlengbach Beds (Lower Paleocene) another heavy mineral association exists. As can be seen in exposures and outcrops at certain parts of the Hagenbach-Gorge, the Upper Altlengbach Beds and Lower Greifenstein Beds show gradual transition. Therefore these two complex-

es are to be considered as a new sedimentation cycle. After a weak tectonic phase, the last cycle follows with the sedimentation of the Upper Greifenstein Beds.

Carbonate Contents:

The results of carbonate contents, analyses of 28 sandstones and 17 clay and clayey marl samples, are shown in table 2. All these samples were taken from exposures in the lower tectonic slice. The sandstones of the Lower Greifenstein Beds are rather poor in carbonate matrix or carbonate components. This is also the case in other areas of the flysch zone which are stratigraphically corresponding. The sandstones of the Upper Greifenstein Beds however often are cemented with a carbonate matrix.

The sandstones of the Wördern Beds are also poor in carbonate matrix. This is the reason why they are weathering easily and therefore occasionaly they are mistaken for weathered Greifenstein Sandstones.

Table 3

Exposure no.	Beds	tectonic slice	Exposure no.	Beds	tectonic slice
27	overl.: Lower Greifenstein B.	1	1980	Altlengbach B.	l
			1981	Upper Greifenstein B.	u
	underl.: Altlengbach B.	1	1982	Altlengbach B.	u
29	Wördern B.	1	1984	Altlengbach B.	u
30	Wördern B.	1	1985	Altlengbach B.	u
110	Altlengbach B.	u	1986	Altlengbach B.	u
111	Upper Greifenstein B.	1	1987	Lower Greifenstein B.	u
112	Upper Greifenstein B.	1	1988	Altlengbach B.	u
113	Lower Greifenstein B.	1	1994	Altlengbach B.	u
114	Altlengbach B.	1	1996	Altlengbach B.	u
202	Wolfpassing B.	1	2001	Altlengbach B.	u
399	Upper Greifenstein B.	1	2007	Altlengbach B.	u
400	Upper Greifenstein B.	1	2019	overl.: Altlengbach B.	u
401	Lower Greifenstein B.	1		underl.: Upper Greifenstein B.	l
402	Lower Greifenstein B.	1			
403	Lower Greifenstein B.	1	2024	Wolfpassing B.	l
404	Lower Greifenstein B.	1	2025	Wolfpassing B.	l
405	Lower Greifenstein B.	1	2054	Wördern B.	l
406	Altlengbach B.	1	2057	Upper Greifenstein B.	l
662	Wolfpassing B.	1	2058	Upper Greifenstein B.	l
670	Wördern B.	1	2059	Upper Greifenstein B.	l
671	Wördern B.	1	2060	Upper Greifenstein B.	l
1034	Altlengbach B.	1	2063	Altlengbach B.	u

B. - Beds; overl. - overlying; underl. - underlying;

l - lower; u - upper

6. LIST OF EXPOSURES

The exposures mentioned in the text of this paper are in numerical sequence to facilitate finding them in the geological map (fig. 2). The names of the Bed and the tectonic slices from which samples were taken are listed (Table 3).

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ZUSAMMENFASSUNG

Diese Arbeit über die Stratigraphie und Lithologie der Flyschsedimente des Hagenbachgebietes ist die Ergänzung zu den paläontologischen Arbeiten von W. Grün und H. Stradner, die im gleichen Band abgedruckt sind.

Die topographischen und tektonischen Kapitel werden von einer detaillierten Beschreibung jener Aufschlüsse gefolgt, die in den genannten paläontologischen Arbeiten behandelt werden. Frühere, aus der Literatur bekannte Fossilfunde, wurden bei der Aufschlußbeschreibung mit angeführt. Die Kartierungsarbeiten des Autors ergaben einen Schuppenbau in dieser nördlichsten tektonischen Einheit der nordalpinen Flyschzone („Greifensteiner Schuppenzone"). Die nördlichste und tiefste Schuppe zeigt ein stratigraphisches Profil, das von den unterkretazischen Wolfpassinger Schichten, zu den Wörderner Schichten (Santon bis Campan),

den Altlengbacher Schichten (oberes Campan bis unteres Paleozän), den Unteren Greifensteiner Schichten (oberes Paleozän bis unteres Untereozän) und den Oberen Greifensteiner Schichten (oberes Untereozän) reicht. Wie erwähnt, kann in den Greifensteiner Schichten ein unterer und oberer Komplex voneinander getrennt werden. Zwischen diesen beiden Komplexen wird eine schwache tektonische Phase angenommen.

An weiteren Ergebnissen sind die Angaben über die Schwermineralführung zu nennen, die zeigten, daß sich die strukturelle und stratigraphische Schichtlücke zwischen den Wolfpassinger Schichten mit einem Zirkonmaximum und den Wörderner Schichten mit einem Granatmaximum manifestiert. Innerhalb der Altlengbacher Schichten vollzieht sich ein langsamer Übergang in der Schwermineralassoziation von einem Granatmaximum zu einem Zirkonmaximum mit noch starkem Granatanteil. Die Unteren Greifensteiner Schichten überlagern die Altlengbacher Schichten konkordant und zeigen auch eine ähnliche Schwermineralvergesellschaftung.

Nach einer tektonischen Diskordanz folgen die Oberen Greifensteiner Schichten, die einen neuen Sedimentationszyklus darstellen und ein Zirkon-Rutil-Turmalin-Maximum haben (mit sehr wenig Granat). Die lithologischen Daten werden durch Angaben der Karbonatgehalte ergänzt. Die oberkretazischen und paläogenen Gesteine zeigen, daß in diesem Zeitraum die Flyschfazies vorherrschte, was z.B. durch das Auftreten von „graded bedding" und „convolute bedding" demonstriert wird. Das Verhältnis zwischen dem Auftreten von Quarzareniten zu Tonen und Tonmergeln beträgt im Hagenbachgebiet im Durchschnitt 4 : 1 (Oberkreide — Untereozän).