4. The Dachstein-Hallstatt-Salzkammergut Region

4.1. A brief history of geological research of the Dachstein-Hallstatt-Salzkammergut Region

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Besides its unique scenic beauty, the area around Hallstatt is well known for its long tradition in salt mining. Underground mining of rock salt - the "white gold" - commenced around 4500 years ago. Also the name "Salzkammergut" refers to the traditional economic resources of this region, the salt mining. In addition, the Salzkammergut - and in particular the region around Hallstatt and Bad Aussee - has been a classical area for geoscientific research in the Tethyan Mesozoic for over 200 years. It is recorded in early travel reports, that the salt miners of Hallstatt collected ammonites and sold them to tourists and also to museum collections. Most of the ammonites were collected in the famous red limestones of Upper Triassic age ("Hallstatt limestone"), close to the Hallstatt salt mine or from Liassic red limestones ("Hierlatz Limestone"), more rarely from "Klauskalk", a red limestone of Dogger age, both also from the surroundings of Hallstatt. Already in 1782 the Bohemian naturalist J. BOHADSCH mentions the nearby fossil-rich rock formations, in particular in the area of Gosau. Gastropods, corals, ammonites and other petrefacts from this Upper Cretaceous Gosau Group could be purchased from local commercial collectors; this is true even for today !

Leopold von BUCH

The first remarkable geognostic study of the Salzkammergut dates back to the year 1802, when the renowned German naturalist Leopold von BUCH published his 2-volume booklet *"Geognostische Beobachtungen auf Reisen durch Deutschland und Italien"* (volume 2 was published in 1809). An extensive treatise in Volume 1 entitled *"Geognostische Uebersicht des Oesterreichischen Salzkammerguths"* deals with observations in this region, which he carried out in part together with his fellow and mentor Alexander von HUMBOLDT in the years 1797-1799. BUCH noticed the dominance of limestone and speculated on its striking colour variations. He attributes the variations of colour to different levels in altitude of the exposed limestones: "The red colour of limestones seems more common in the deep valleys, it disappears uphill and on the summits of the mountains only white limestones are exposed, while in the intermediate altitudes they show mostly a pale smoky greyish hue". This "phenomenon" is explained by BUCH by the fact that the metal solutions which extensively stained the lower part of the limestone masses - were either not sufficient quantitatively or too heavy to follow the newly formed limestone masses to the higher altitudes. BUCH also realized the abundance of fossils in the red limestones, which never occur as individual specimens but always as clusters. As a consequence of the aforementioned concentration of red limestones in the valleys, BUCH draws the conclusion, that the rich "Fossil-Lagerstätten" are concentrated in the red limestones of the valleys, while the white limestones are widely devoid of fossils. However, besides these odd hypotheses, BUCH identified already coquinas of *Pecten*-like bivalves in the region of the Hallstatt salt mine (named by BRONN 1830 *Halobia* and *Monotis*) and mentions orthoceratids, ammonites and nautiloids.
BUCH also deals with the origin of limestone bedding and the reasons for varying dipping directions, the latter he attributes to variable underground conditions, which force the beds

to change their striking and dipping directions. There is no evidence, that BUCH understood already the primary sedimentary or diagenetic origin of limestone bedding, respectively the effect of tectonic forces in respect to mountain building.
Of course BUCH dealt also extensively with the origin, mineralogy and the age of the Hallstatt salt mine. The discussion about the origin and age of the Haselgebirge persists up to the present and only due to more sophisticated geochemical and paleontological methods has a better understanding been obtained during the last decades. The key questions, tectonic versus sedimentary origin, respectively Permian versus Lower Triassic age will be discussed in extent during our trip to the salt mine!
BUCH showed also interest in hydrogeological questions, such as the water balance of Lake Hallstatt, where he considers hidden subsurface springs as important contributors. Last but not least, he records an earthquake in Hallstatt on March 12, 1789, which lasted 4-5 seconds. It started with a bang, while the shock wave spread from south to north, accompanied by sonorous humming.
Astonishingly enough, the pioneer paper by Leopold von BUCH (1802) did not trigger immediate further research activities, but only almost twenty years later were the next studies on this region published, showing already the considerable progress made in our science.

1821-1845: Laying the foundation-stone

The following period of research in Salzkammergut was largely dominated by the excellence of British geoscientists. William Buckland´s *"Uebersicht über die Struktur der Alpen"* (1821) is one of the first attempts to subdivide the "Alpenkalk" into several lithologic units. According to him the Alpenkalk comprises the complete stratigraphic sequence from the Magnesian Limestone (Upper Permian) till the Chalk (Upper Cretaceous). The evaporitic sediments of the Haselgebirge are already considered to be of Upper Permian age, the red marly sandstones (Werfen Formation) from Hallstatt are equivalent to the New Red Sandstone, while the ammonites from Hallstatt represent the Liassic.
The famous Bavarian geologist Ch. KEFERSTEIN edited a journal entitled *"Teutschland, geognostisch-geologisch dargestellt"*. In volume 5 of this journal, KEFERSTEIN (1828) describes in detail a walking tour from Hallstatt over the Salzberg to Gosau. For him the formation of the salt and gypsum deposits occurred due to "osmotic respiration processes" within the clays. Besides this odd hypothesis, KEFERSTEIN gains merit in that he introduces the comparison of fossils as a new stratigraphic method. He studied and compared especially the fauna of Gosau with stratigraphically well dated faunas from abroad. This approach represents an enormous step forward! However, his main error was, that he considered the "Sandstone Formation" (Gosau Group) as older/underlying rock unit superimposed by the "Limestone Formation" of the Alpenkalk.
In 1828 the Bohemian born Carl Lill von LILIENBACH published his paper on *"Allgemeine Lagerungsbeziehungen der Steinsalz-Lagerstätten in den Alpen"*. He lists many fossils, however, is very cautious about their stratigraphic significance. Subsequently there was a rapid series of publications. In 1829 the famed British geologists SEDGWICK & MURCHISON published their paper *"On the Tertiary deposits of the Vale of Gosau in the Salzburg Alps"*, followed in 1830 by the papers by the French born Ami BOUÉ entitled *"Description du Basin de Gosau"* and by C. Lill von LILIENBACH *"Ein Durchschnitt aus den Alpen mit Hindeutungen auf die Karpaten"*. SEDGWICK & MURCHISON´s paper represents the first detailed stratigraphic study of the Gosau locus classicus, however, they considered the sequence as being Tertiary in age. BOUÉ considers the Gosau Group as stratigraphically coeval with the Greensand. Lill von LILIENBACH´s paper from 1830 represents the first attempt to subdivide the sequence of the Northern Calcareous Alps

into clearly defined rock units, comparable to the present "Groups". For instance he coined the name "Werfen Shales", into which he also placed the evaporitic Haselgebirge. Lill´s paper is also fundamental as a first attempt to compare rock units of the Northern Calcareous Alps with coeval ones from the Carpathians.
The paper by SEDGWICK & MURCHISON from 1831 *"A sketch of the structure of the Eastern Alps"* can be considered a real milestone in the history of research of the Austrian Alps. It demonstrates the progress in the application of new methods, as for instance using fossils as useful tools in biostratigraphy, or the comparison of sequences on an European wide scale. In addition, SEDGWICK & MURCHISON were drawing a series of geo-traverses through the Eastern Alps perpendicular to the striking direction of geological units. The main axis of the Eastern Alps ("Zentralzone") was already recognized, as well as the existence of the Northern and Southern Calcareous Alps. In the Salzkammergut the British in cooperation with Lill von LILIENBACH (who accompanied them in the field), continued the subdivision of the rock units, in particular of the Alpenkalk. The red shales of the Werfen Formation were seen in close association with the evaporitic Haselgebirge. Furthermore they introduced terms such as Lower and Upper Alpine Limestone and Greensand respectively Cretaceous Deposits; all these terms were later replaced by new and more precise ones.

1846-1853: Disenchanting the Alpenkalk

For a long period the Alpenkalk was considered to be of Liassic age by some workers (especially the formation called Dachstein Limestone from 1847 onwards) and by others as being Jurassic in general. The famous German geo-scientist F.A. QUENSTEDT still believed in 1845, that the Alpenkalk represents the Neocomian - based on (incorrect) ammonite determination. The breakthrough came closer, when HAUER started detailed systematic studies of the ammonite fauna of the Hallstatt Limestone in 1846. It became more and more evident that Triassic formations contribute substantially to the sequence of the Northern Calcareous Alps. The first definite short references, regarding the important role of the Triassic in the sequence of the Northern Calcareous Alps, we owe to the Swiss geologist A.v. MORLOT, 1847 and also to HAUER, 1848. Following these initial findings, new lithostratigraphic units were defined in the following years, replacing the obsolete term Alpenkalk. In his classical paper from 1853 "Ueber die Gliederung der Trias-, Lias- und Juragebilde in den nordöstlichen Alpen" Franz von HAUER presents the following sequence for the Triassic of the Northern Calcareous Alps: Werfen Formation (including the Haselgebirge) = Buntsandstein, Guttenstein Formation = Lower Muschelkalk, Hallstatt Formation = Upper Muschelkalk, Dachsteinkalk = Lower Liassic. The Liassic age of the Hierlatz Limestone was confirmed by Eduard SUESS in 1852 while the Upper Jurassic age of the Plassen Limestone was already recognized by HAUER in 1850. The fauna of the Plassen Limestone was described by MOJSISOVICS in 1868.

The Haselgebirge - source of the "white gold"

The so called Haselgebirge is represented by a mélange of evaporitic minerals - mostly rock salt - and clays. For a long time it was argued, that the primary sediments of this mélange represent an environment, where biota cannot live, respectively cannot be preserved, and therefore the stratigraphic age of the Haselgebirge remained speculative. Due to the mobility of this clay/salt mixture - diapirism included - the question of stratigraphy was still more obscured. The mineralogy of the Haselgebirge has been well studied since the last century and a tremendous amount of papers deal with genetic questions, i.e. tectonic versus sedimentary origin of the mélange. Also tholeitic basalts

have been found in association with the Haselgebirge (FOULLON, 1889, C.v. JOHN, 1899, GÖRGEY, 1914, SEIDL, 1927, AMPFERER, 1928, HIMMELBAUER, 1931, PETRASCHECK, 1947, SCHAUBERGER, 1949 f., ZIRKL, 1957, MEDWENITSCH, 1968, a.o.).
Concerning the stratigraphy of the Haselgebirge, a breakthrough was achieved by Wilhelm KLAUS (1953, ff.). It was already known since 1913, that in salt-clays of the North-German Zechstein sporomorphs had been found and also PETRASCHECK (1947) reports the first findings of palynomorphs in washing residues from the Haselgebirge in Hallstatt. Finally KLAUS systematically investigated all Alpine salt deposits for pollen and spores. He found, that the preservation of palynomorphs is best in pure salt and also still acceptable in the salt-clays, however, in the latter strong fragmentation of the palynomorphs can be occasionally observed. Already in his first paper concerning these investigations (1953), KLAUS proudly stated: "In the Eastern Alps palynology became the paleontology of the salt". Later on, sulfur-isotope studies (e.g. HOLSER & KAPLAN, 1966, PAK, 1974 ff.) confirmed the Upper Permian age, which KLAUS postulated, for a large part of the Haselgebirge. Recently Christoph SPÖTL was also successful in confirming, that the main part of the Haselgebirge is of Permian age and only a comparatively small portion shows an early Triassic age (SPÖTL & PAK, 1996).

Hallstatt - The Standard for the Upper Triassic Substages

The region around Hallstatt and Bad Aussee is famous for its "Fossil-Lagerstätten" in the Hallstatt Limestone Group. The Hallstatt Limestone Group comprises variegated coloured (mostly red) micritic limestones from the Upper Anisian (Schreyeralm Limestone) till the Upper Triassic Carnian and Norian Hallstatt Limestones sensu strictu. Franz von HAUER with his famous paper from 1846 *"Die Cephalopoden des Salzkammergutes aus der Sammlung seiner Durchlaucht des Fürsten von Metternich"* opened the Austrian participation in Mesozoic biostratigraphic research. With HAUER and later on by his contemporary, the brilliant Eduard SUESS, an incredible story of success started. In 1849, the Geologische Reichsanstalt was established and soon HAUER and SUESS jointly established a Mesozoic working group, which later on became famous as the "Viennese School of Paleontology/Geology", among them scientists such as M.V. LIPOLD, Edmund von MOJSISOVICS, Alexander BITTNER, Ferdinand STOLICZKA, Melchior NEUMAYR, Moriz HOERNES, Dionys STUR, Georg GEYER, Gustav von ARTHABER, (later also Carl DIENER), and others. However, also German scientists contributed a substantial share to early stratigraphic research in the Triassic and Liassic of Salzkammergut, as for instance GÜMBEL, KOKEN, OPPEL, ZITTEL, FRECH, and others. Even though grave stratigraphic errors still persisted, the monographic studies on Triassic ammonites by MOJSISOVICS remain unrivaled to the present day (e.g. *"Das Gebirge um Hallstatt"*, 1873 ff. and *"Cephalopoden der mediterranen Triasprovinz"*, 1882). However, also the facies relations of various rock units were attracting attention, as for example in the spectacular paper by MOJSISOVICS from 1868 *"Faunengebiete und Faciesgebilde der Trias-Periode in den Ostalpen"*. It was only about 30 years ago, that the classical profiles by MOJSISOVICS were re-investigated (e.g. KRYSTYN et al., 1969, 1971; KRYSTYN, 1973; SCHLAGER, 1969, a.o.). Since these modern studies, the complex interplay of sedimentation and synsedimentary tectonics is evident and many of the classical sections in the Hallstatt Triassic and Liassic have been shown to represent not concordant sequences, but neptunian dykes. More recently Tim TOZER from Canada has studied this fascinating period of research, which can be apostrophized as a high point in systematic-paleontological research, however, which was somehow overshadowed by insufficient understanding of the sedimentological parameters. At present, out of 13 Upper Triassic

Tethyan ammonite zones, 10 are described from the Salzkammergut, respectively all Upper Triassic substages, except the Lower Carnian ones, are also defined in this region (KRYSTYN, unpubl. Manuscript). The Salzkammergut also contains the richest Upper Triassic ammonite sites in the world. From the Feuerkogel nearby Bad Aussee more than 500 ammonoid taxa of Carnian to Norian age have been described (HAUER, 1846 f., MOJSISOVICS, 1873 f., DIENER, 1923) and from the Sommeraukogel an additional 100 Norian ammonoid species have been described by MOJSISOVICS, 1873 ff. (KRYSTYN, l.c.).

The Dachstein Limestone

The determining rock formation of the Hallstatt region, however, is the Dachstein Limestone, which shows exposures in the Hallstatt environs of more than 1500 m thick (e.g. Hierlatz-Wand). The classical region of the Dachstein Limestone is the large karst plateau of Mt. Dachstein (2996 m). The Dachstein Limestone is represented for the main part by well bedded "lagoonal" limestones (see chapter cy), which are bordered to the south by a reef development (we will visit the reef-tract of the Gosaukamm and the lagoonal facies along Loser panorama road).
The plateau of Mt. Dachstein is not only the classical region of the Dachstein Limestone (name coined by Friedrich SIMONY, 1847), but is also a spectacular area of Alpine limestone karst research. Also the geomorphological studies of the Dachstein limestone karst, which represents an important water resource, are closely bound to the name Friedrich SIMONY, who dedicated his life to the study of the glacial phenomena and the influence of the atmosphere on limestone weathering in higher altitudes.
The most characteristic fossils of the Dachstein Limestone are the heart-shaped cross-sections of megalodontid bivalves. Depending on the area, these conspicuous bivalve sections are called in vernacular language "lithified hearts" or "cow traces" or "red deer traces". The famous Bavarian geologist C.W. GÜMBEL (1862) was the first to give a detailed description of these characteristic bivalves in the Northern Calcareous Alps. It was also GÜMBEL, who pleaded for an Upper Triassic (Norian/Rhaetian) age of the Dachstein Limestone; before a Liassic age seemed already generally accepted!
The question, which bivalve genus or species did the "Dachstein-bivalve sensu strictu" represent started already in the 18th century, when HACQUET (1781) and WULFEN (1793) gave the first systematic descriptions. The next generation, which dealt intensively with this "causa prima", were geo-scientists from Lombardy and Veneto, especially CATULLO, CURIONI and STOPPANI. In Switzerland Escher von der LINTH and MERIAN participated in this discussion and SCHAFHÄUTL in Bavaria. In Austria the French born all-round scientist Ami BOUÉ and later on Franz von HAUER dealt with this question. Finally Leopold von TAUSCH pleaded in his monography from 1892 *"Über die Bivalvengattung Conchodus und Conchodus Schwageri n.f. aus der obersten Trias der Nordalpen"* for this genus to represent the one and only "Dachsteinbivalve" - the real thing sensu strictu. Several of the specimens described and figured by TAUSCH were collected in the vicinity of Hallstatt, in particular in Echernthal, Wiesberg Höhe, Mitterwand and Hierlatz. Also in modern papers by ZAPFE (1957, 1964), TICHY (1974) and VÉGH-NEUBRANDT from Budapest, the species *Conchodus infraliasicus* is considered one of the main representatives of the "Dachstein-bivalves". Probably the last word has not yet been spoken on this (local) key question for geosciences.

Studies on carbonate facies

Two phenomena of eminent importance drew the attention of many sedimentologists to the Dachstein region, i.e. the origin of the bedding, respectively cyclicity of the lagoonal Dachstein Limestone and the phenomenon of neptunian dykes. The latter caused tremendous long lasting misinterpretations in Triassic and Liassic stratigraphy, because many of the classical ammonite localities in the Hallstatt region are bound to neptunian dykes or - in some cases - represent stratigraphic condensation of faunas (Feuerkogel).
Eduard SUESS (1888) explained the bedding, respectively cyclicity of the Dachstein Limestone, as a consequence of subaerial exposition of the beds and subsequent weathering of the bedding planes. In 1928 Kurt LEUCHS assumed, that the variegated coloured thin intercalations in the Dachstein Limestone represent a rudimentary Hallstatt facies, while SCHWARZACHER (1948) studied the Norian Hallstatt Limestone of the Steinberg- und Sommeraukogel. The well-known study by Alfred G. FISCHER (1964) on the cyclicity of the Dachstein Limestone is explained in detail in the chapter on Loserstraße road cuts.
In addition, the working group led by Alfred G. FISCHER also carried out early studies of deeper water limestones by means of electron microscope in the Salzkammergut region (e.g. paper by HONJO, GARRISON & FISCHER), which opened a new dimension in lithogenetic studies.

Early micropaleontological studies

The study of rock thin-sections was probably established in England as a consequent follow-up of microtomic botanical and medical studies. In the Austrian Northern Calcareous Alps Karl PETERS was the first geoscientist to apply these new techniques. In his classical study from 1863 *"Über Foraminiferen im Dachsteinkalk"*, PETERS reports on planktonic foraminifers ("Globigerinas") in the Dachsteinkalk of Echerntal in the vicinity of Hallstatt. Later on, the finding of these early Globigerinas was thought to be dubious by KITTL (1903), who considered the limestones to be Upper Jurassic Plassenkalk. In 1913 A. HEINRICH reports on Globigerinas in the Carnian Hallstatt-Limestone of Feuerkogel/Rötelstein, close to Bad Aussee. In more recent times Rudolf OBERHAUSER (1960) and Edith KRISTAN-TOLLMANN (1964) describe early "Globigerinas" from the Rhaetian Zlambach Marls of Salzkammergut and finally Werner FUCHS (1967, 1969, 1975) provides a systematic description of this rather neglected group of planktonic foraminifera from material from the Italian Dolomites and from the Salzkammergut region. One of the systematic groups (family Oberhauserellidae) is currently under revision by Donato DI BARI from Modena.
The region around Hallstatt and Bad Aussee is also a classical area for Triassic conodont research. The first review paper was published by the German R. HUCKRIEDE in 1958: *"Die Conodonten der mediterranen Trias und ihr stratigraphischer Wert"*, followed by the papers by the American L. MOSHER in 1968. MOSHER succeeded in using the evolutionary trend of platform conodonts for worldwide stratigraphic correlation. His reference sections also include the classical Upper Triassic ammonite localities Sommeraukogel and Steinberg-kogel, nearby Hallstatt, which were previously described by MOJSISOVICS. Later on, Walter C. SWEET and especially Leopold KRYSTYN successfully continued this challenging work on a worldwide scale, including also the classical key sections in the Salzkammergut.
MOJSISOVICS (1903) in one of his last papers summarized his ideas of the palaeogeographic position of the Hallstatt zones. He postulated an in situ position of the sedi-

ments of Hallstatt type deposited in "channels" cutting through the Dachstein Limestone platform.
One year later the paper of HAUG & LUGEON (1904) marks a fundamental break through in the history of geological research in the Salzkammergut area: the concept of nappe tectonics was established. In the sequel the "nappists" entered into competition with the "autochthonists". KOBER and his school (e.g. MEDWENITSCH, 1958, TOLLMANN, 1960 and others) plead for an extreme nappism. On the other hand DIENER, LEUCHS, TRAUTH and in modern time ZANKL and SCHLAGER followed a modified version of the autochthonous concept of MOJSISOVICS. PLÖCHINGER, 1974, 1976 and SCHÄFFER, 1976 revealed the significance of Jurassic gravitative nappe movements in the Salzkammergut area for the geodynamic history of the Northern Calcareous Alps. TOLLMANN, 1976, 1981 has briefly summarized all the contradictory models (see Fig. 4.1.), which have been suggested to explain the complex geology of this exciting part of the Northern Calcareous Alps.

References

ASSERETO, R.: Die Binodosus-Zone. Ein Jahrhundert wissenschaftlicher Gegensätze.- Sitzber. Österr. Akad. Wiss., mathem.-naturwiss. Kl., Abt. I, 179, 25-53, 5 Abb., Wien 1971.

BOHADSCH, J.: Bericht über seine auf allerhöchsten Befehl im Jahre 1763 unternommene Reise nach dem oberösterreichischen Salzkammergut.- Abh. Privatges. Böhmen, 5, 209-222, Prag 1782.

BUCH, L.v.: Geognostische Beobachtungen auf Reisen durch Deutschland und Italien.- Vol. 1, Kap. II: Geognostische Übersicht des österreichischen Salzkammerguths.- 133-180, 2 Abb. Vol. I, Kap. III: Reise durch Berchtoldsgaden und Salzburg.- 181-250, 1 Karte, Berlin (Haude & Spener) 1802.

DIENER, C.: Die Fossillagerstätten in den Hallstätterkalken des Salzkammergutes.- Sitz.ber. Akad. Wiss., mathem.- natwiss. Kl., 135, 73-101, Wien 1926.

FENNINGER, A. & HOLZER, H.: Fazies und Paläogeographie des oberostalpinen Malm.- Mitt. Geol. Ges. Wien, 63 (1970), 52-141, 15 Abb., 1 Tab., 2 Beil., Taf. 1-19, Wien 1972.

FUCHS, W.: Über Ursprung und Phylogenie der Trias-„Globigerinen" und die Bedeutung dieses Formenkreises für das echte Plankton.- Verh. Geol. B.-A., 135-176, 3 Abb., 8 Taf., Wien 1967.

GÜMBEL, C.W.: Die Dachsteinbivalve (Megalodon triqueter) und ihre alpinen Verwandten.- Sitzber. Akad. Wiss., mathem.- naturwiss. Kl., Abt. 1, 55, 325-377, Taf. 1-7, Wien 1862.

GÜMBEL, C.W.: Mikroskopische Untersuchungen alpiner Triaskalke und Dolomite.- Verh. Geol. R.-A., 7, 141-144, Wien 1873.

HAUER, F.v.: Über die Gliederung der Trias-, Lias- und Juragebilde in den nordöstlichen Alpen.- Jb. Geol. R.-A., 4, 715-784, 8 Abb., 8 Tab., Wien 1853.

HEINRICH, A.: Untersuchungen über die Mikrofauna des Hallstätter Kalkes.- Verh. Geol. R.-A., 225-234, Wien 1913.

HLAUSCHEK, H.: Beobachtungen über das Lagerungsverhältnis des Hierlatzkalkes zum Dachsteinkalk im Dachsteingebirge.- Lotos, 70, 111-123, 1 Abb., Taf. 3-4, Prag 1922.

HOLSER, W.T. & KAPLAN, R.: Isotope Geochemistry of Sedimentary Sulfates.- Chemical Geology, 1, 93-135, 8 Abb., Amsterdam 1966.

HUCKRIEDE, R.: Die Conodonten der mediterranen Trias und ihr stratigraphischer Wert.- Paläont. Z., 32, 141-175, 1 Tab., Taf. 10-14, Stuttgart 1958.

KITTL, E.: Geologische Exkursionen im Salzkammergut. (Umgebung von Ischl, Hallstatt und Aussee).- IX. Internat. Geologen-Kongress, Führer für die Exkursionen Nr. IV, 118 S., 8 Profile, 3 Tab., 6 Foto-Taf., 1 kolorierte geol. Karte 1:200.000, Wien (Geol. R.-A.) 1903.

KLAUS, W.: Mikrosporen-Stratigraphie der ostalpinen Salzberge.- Verh. Geol. B.-A., 161-175, 3 Abb., 1 Tab., Wien 1953.

KOKEN, E.: Die Gastropoden der Trias um Hallstatt.- Abh. Geol. R.-A., 17, 4, 1-112, 31 Abb., 23 Taf., Wien 1897.

KRYSTYN, L.: Zur Ammoniten- und Conodonten-Stratigraphie der Hallstätter Obertrias (Salzkammergut, Österreich).- Verh. Geol. B.-A., 113-153, 7 Abb., 5 Taf., Wien 1973.

KRYSTYN, L.: Die Fossillagerstätten der alpinen Trias.- In: Golebiowsky, R., KRYSTYN, L. & Vasicek, W.: Exkursionen im Jungpaläzoikum und Mesozoikum Österreichs, 23-78, Wien (Österr. Paläont. Ges.) 1991.

KRYSTYN, L., SCHÄFFER, G. & SCHLAGER, W.: Stratigraphie und Sedimentationsbild obertriadischer Hallstätterkalke des Salzkammergutes.- Anz.Österr.Akad.Wiss., math.-natwiss.Kl., 105 (1968), 329-332, Wien 1969.

KRYSTYN, L., SCHÄFFER, G. & SCHLAGER, W.: Über die Fossil-Lagerstätten in den triadischen Hallstätter-Kalken der Ostalpen.- N. Jb. Geol. Paläont. Abh., 137, 284-304, 9 Abb., 1 Tab., Stuttgart 1971.

KRYSTYN, L., SCHÄFFER, G. & SCHLAGER, W.: Der Stratotypus des Nor.- Annales Inst. Geol. Publ. Hungar., 54, 2, 607-629, 7 Abb., Budapest 1971.

KRYSTYN, L. & SCHLAGER, W.: Der Stratotypus des Tuval.- Annales Inst. Geol. Publ. Hungar., 54, 2, 591-605, Budapest 1971.

LAHODYNSKY, R.: Lithostratigraphy and sedimentology across the Cretaceous/Tertiary boundary in the Flyschgosau (Eastern Alps, Austria).- Revista Espanola de Paleont., no. Extraordinario: Palaeontology and Evolution: Extinction Events, 73-82, 4 Abb., Madrid 1988.

LEUCHS, K.: Beiträge zur Lithogenesis kalkalpiner Sedimente. I. Teil: Beobachtungen an Riffgesteinen der nordalpinen Trias.- N. Jb. Miner. Geol. Paläont., B, 59, 357-408, Taf. 25-35, Stuttgart 1928.

LILL von LILIENBACH, A.: Ein Durchschnitt aus den Alpen, mit Hindeutungen auf die Karpathen.- Leonhard Jb. Mineral., Geognosie, etc., 1, 153-220, Taf. 3 (kolorierte Lithographie „Durchschnitt der Felsgebilde an dem Nordrande der Alpen in der Richtung des Salza Thales von Werfen bis Teisendorf"), Heidelberg 1830.

LIPOLD, M.: Geologische Stellung der Alpenkalksteine, welche die Dachsteinbivalve enthalten.- Jb. Geol. R.-A., 2, 108-121, 5 Abb., Wien 1851.

LOBITZER, H.: Die geologische Erforschung des Ausseerlandes von Leopold von BUCH bis zum „IX. Internationalen Geologenkongress" in Wien (1903).- res montanarum - Zeitschrift des Montanhistorischen Vereines für Österreich, 20, 23-24, Leoben 1999.

MEDWENITSCH, W.: Zur Geologie der Hallstätter Zone I (Hallein-Aussee). - Mitt. Geol.Ges. Wien, 50 (1957), 355-356, Wien 1958.

MOJSISOVICS, E.v.: Über den Malm des Salzkammergutes.- Verh. Geol. R.-A., 124-128, Wien 1868.

MOJSISOVICS, E.v.: Faunengebiete und Faciesgebilde der Trias-Periode in den Ost-Alpen.- Jb. Geol. R.-A., 24, 81-134, 5 Abb., 5 Taf., Wien 1868.

MOJSISOVICS, E.v.: Das Gebirge um Hallstatt. Eine geologisch-paläontologische Studie aus den Alpen. I. Theil. Die Mollusken-Faunen der Zlambach- und Hallstätter-Schichten.- Abh. Geol. R.-A., 6, VII+174 S., 32 Taf., Wien 1873.

MOJSISOVICS, E.v.: Die Cephalopoden der mediterranen Triasprovinz.- Abh. Geol. R.-A., 10, 322 S., 1 Abb., zahlr. Tab., 94 Taf., Wien 1882.

MORLOT, A.v.: Erläuterungen zur geologischen Übersichtskarte der nordöstlichen Alpen. Ein Entwurf zur vorzunehmenden Bearbeitung der physikalischen Geographie und Geologie ihres Gebietes.- VIII + 212 S., 25 Abb., 1 kolor. Faltprofil, Wien (Braumüller & Seidel) 1847.

MOSHER, L.: Triassic Conodonts from western North-America and Europe and their correlation.- J. Paleont., 42, 895-946, 14 Abb., Taf. 113-118, Tulsa 1968 a.

MOSHER, L.: Evolution of triassic platform Conodonts.- J. Paleont., 42, 947-954, 8 Abb., Taf. 119-120, Tulsa 1968b.

PENCK, A.: Friedrich Simony-Leben und Wirken eines Alpenforschers. Ein Beitrag zur Geschichte der Geographie in Österreich.- Geograph. Abh., 6, 3, 308 S., 11 Abb., 22 Taf., Wien 1898.

PETERS, K.F.: Über Foraminiferen im Dachsteinkalk.- Jb. Geol. R.-A., 8, 293-298, Wien 1863.

PLÖCHINGER, B.: Gravitativ transportiertes permisches Haselgebirge in den Oberalmer Schichten (Tithonium, Salzburg). - Verh. GeoL B.-A., 1974, 71-88, 5 Abb., 1 Tab., 3 Taf., Wien 1974.

PLÖCHINGER, B.: Die Oberalmer Schichten und die Platznahme der Hallstätter Masse in der Zone Hallein-Berchtesgaden. - N. Jb. Geol. Paläont. Abh., 151, 304-324, 7 Abb., Stuttgart 1976.

PREISINGER, A., ZOBETZ, E., GRATZ, A.J., LAHODYNSKY, R., BECKE, M., MAURITSCH, H.J., EDER, G., GRASS, F., RÖGL, F., STRADNER, H. & SURENIAN, R.: The Cretaceous/Tertiary boundary in the Gosau Basin, Austria.- Nature, 322, 794-799, 6 Abb., 1986.

SCHÄFFER, G.: Einführung zur geologischen Karte der Republik Österreich, Blatt 96 Bad Ischl - (In:) GATTINGER, T. et al.: Arbeitstagung der Geologischen Bundesanstalt 1976, 6-26, Abb. 4-24, 3 Tab., Wien (Geol. B -A.) 1976.

SCHAUBERGER, O.: Bau und Bildung der Salzlagerstätten des ostalpinen Salinars. - Arch. f.Lagerst.forsch. Geol. B.-A., 7, 217-254, Wien (Geol.B.-A.) 1986.

SCHLAGER, W.: Das Zusammenwirken von Sedimentation und Bruchtektonik in den triadischen Hallstätterkalken der Ostalpen.- Geol. Rundschau, 59, 289-308, 2 Abb., Stuttgart 1969.

SCHWARZACHER, W.: Sedimentpetrographische Untersuchungen kalkalpiner Gesteine. Hallstätterkalke von Hallstatt und Ischl.- Jb. Geol. B.-A., 91, 1-48, 15 Abb., Wien 1948.

SPENGLER, E., mit Beitrag von PIA, J.: Geologischer Führer durch die Salzburger Alpen und das Salzkammergut.- Sammlung geolog. Führer, 26, X + 152 S., 17 Abb., 10 Taf., Berlin (Borntraeger) 1924.

SPÖTL, Ch. & PAK, E.: A strontium and sulfur isotopic study of Permo-Triassic evaporites in the Northern Calcareous Alps, Austria. - Chemical Geology, 131 (1996), 219-234, 4 Abb., 1 Tab., Amsterdam (Elsevier), 1996.

TAUSCH, L.v.: Über die Bivalvengattung Conchodus und Conchodus Schwageri n.f. aus der obersten Trias der Nordalpen.- Abh. Geol. R.-A., 17, 1-8, Taf. 1-3, Wien 1892.

TICHY, G.: Beiträge zur Palökologie und Stratigraphie der triassischen Megalodonten (Bivalven).- Schriftenreihe Erdwiss. Komm. Österr. Akad. Wiss., 2, 177-182, 1 Abb., 1 Tab., Wien 1974.

TOLLMANN, A.: Die Hallstätterzone des östlichen Salzkammergutes und ihr Rahmen. Jb. Geol. B.-A., 103, 37-131, 4 Abb., Taf. 2-5, Wien 1960.

TOLLMANN, A.: Monographie der Nördlichen Kalkalpen, Teil III: Der Bau der Nördlichen Kalkalpen. Orogene Stellung und regionale Tektonik. - IX +457 S.,130 Abb., 7 Taf., Wien (Deuticke) 1976.

TOLLMANN, A.: Analyse des Klassischen Nordalpinen Mesozoikums. - Monographie der Nördlichen Kalkalpen, Bd. 2. - XVI+580 S., 256 Abb., 3 Taf., Wien (Deuticke) 1976a.

TOLLMANN, A.: Oberjurassische Gleittektonik als Hauptformungsprozeß der Hallstätter Region und neue Daten zur Gesamttektonik der Nördlichen Kalkalpen in den Ostalpen. - Mitt. österr. geol. Ges., 74/75 (1981/82), 167-195, 4 Abb., Tab., Wien 1981.

WURM, D.: Mikrofazies, Paläontologie und Palökologie der Dachsteinriffkalke (Nor) des Gosaukammes, Österreich. - Facies, 6, 203-296, Taf. 27-41, 32 Abb., Erlangen 1982.

ZANKL, H.: Die Karbonatsedimente der Obertrias in den nördlichen Kalkalpen. - Geol. Rundschau, 56, 128-139, 1 Abb., Stuttgart 1967.

ZAPFE, H.: Dachsteinkalk und „Dachsteinmuscheln". - Natur und Volk, 87, 87-94, 8 Abb., Frankfurt a.M. 1957.

ZAPFE, H.: Zur Kenntnis der Megalodontiden des Dachsteinkalkes im Dachsteingebiet und Tennengebirge.- Annalen Naturhist. Mus. Wien, 67, 253-286, 4 Abb., 7 Taf., Wien 1964.

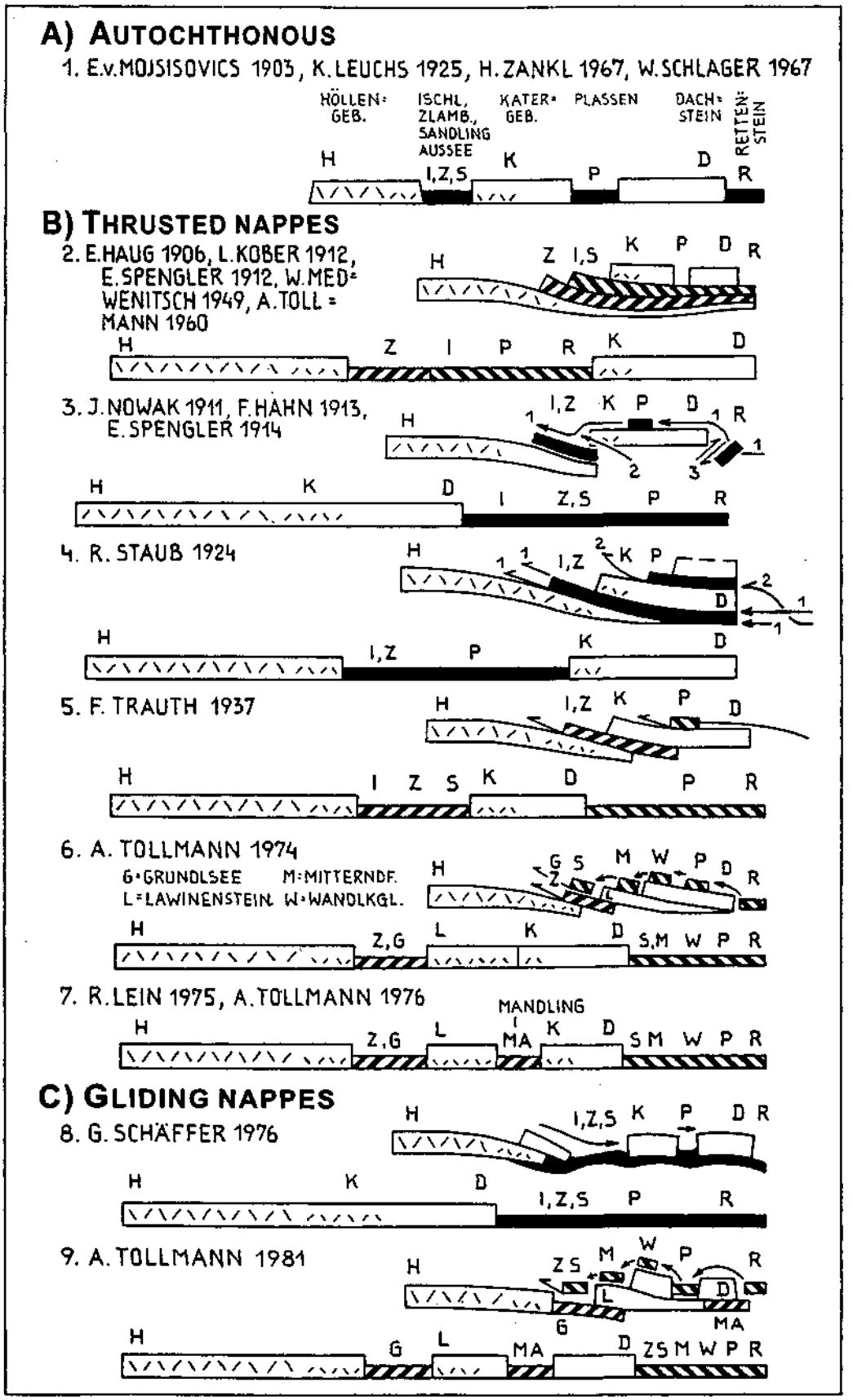

Fig. 4.1.: Schematic representation of different models of the palaeogeographic and/or tectonic relation between Triassic platforms and basinal sediments of the Salzkammergut. After TOLLMANN (1981).