Abh. Geol. B.-A. 26e C. G. I.	34	p. 287—325	23 figures	Wien 1. 5. 1980

International Geological Congress
26th Session
Excursion 129 C

The Complex Basins of the Calcareous Alps and Palaeomargins

by

A. BOSELLINI, H. LOBITZER, R. BRANDNER, W. RESCH & A. CASTELLARIN

With contributions from R. GELATI and J. OGG.

Authors adresses: Prof. Dr. A. BOSELLINI, Istituto di Geologia dell'Universitá di Ferrara, Corso Ercole l'D'Este 32, I-44100 Ferrara, Italy; Dr. H. LOBITZER, Geologische Bundesanstalt, P. O. Box 154, Rasumofskygasse 23, A-1031 Vienna, Austria; Doz. Dr. R. BRANDNER, Doz. Dr. W. RESCH, Institut für Geologie und Paläontologie, Universität Innsbruck, Universitätsstraße 4, A-6020 Innsbruck, Austria; Prof. Dr. A. CASTELLARIN, Istitutio di Geologia e Paleontologia dell'Universitá, Via Zamboni 67, I-40127 Bologna, Italy.

Day 1

Facies Distribution in the Upper Norian/„Rhaetian" of Salzkammergut, Northern Calcareous Alps

by

HARALD LOBITZER

With 2 figures.

Route: Salzburg — Bad Ischl (Siriuskogel chair lift) — Pötschenpaß — Luppitsch — Altaussee — Salzburg (overnight stop).

Introduction

The first day of the excursion will lead us to the by far most intensive studied — and nevertheless maybe in some respect the least understood — area of the Eastern Alps: the Salzkammergut. Tectonic and stratigraphic complications are so manyfold, that up to now no generally accepted model for the facies distribution of this classic area of Alpine Triassic stratigraphy is established. 77 years after the epochal IX. International Geological Congress in Vienna many of the problems pointed out by E. KITTL (1903) have been solved, new ones were born during the Congress (e. g. application of the nappe-tectonics-concept for the Eastern Alps) but also some of the principal questions still remain unsolved. During the Upper Norian (Sevatic) and "Rhaetian" stages the facies distribution shows the greatest variety and therefore has been studied by many workers up to the most recent times.

In Hallstatt facies belt sedimentation starts with clastic and evaporitic sediments of the Permian ("Haselgebirge"). During the Lower and Middle Triassic shallow water carbonates prevail — limestones and dolomites — mostly with dasycladacean algae. Sandwiched between these shallow water carbonates of predominantly Anisian age (e. g. Steinalm Limestone) and clastic sediments of the Uppermost Triassic (Upper Norian/"Rhaetian" Zlambach Formation) the Hallstatt Limestone Group is situated. Stratigraphically the Hallstatt Limestone Group comprises the time range between Upper Anisian ("Illyric") and Upper Norian ("Sevatic"). Our excursion is dealing with Upper Norian/"Rhaetian" sedimentation patterns only.

The stratigraphy of the Alpine Triassic mainly is based on the publications by F. v. HAUER (1853) and subsequent papers by E. v. MOJSISOVICS (1873—1902); 1892: Hallstatt Zone. Presently a revision of stratigraphic type localities and ammonites is carried out by L. KRYSTYN and E. T. TOZER caused by the discovery of G. SCHÄFFER and W. SCHLAGER (e. g. 1969), that most of the fossil accumulations are either due to synsedimentary tectonic fissures or to faunal condensation, the latter caused by periods of minimum sedimentation.

The tectonic fissures show evidence of repeated opening (W. SCHLAGER, 1969). Some of the fissures cut through the whole sequence of Hallstatt Limestone (e. g. fissures with Norian sediments in Anisian Hallstatt Limestone!).

Maybe as a consequence of the beautiful countryside as well as of the most complicated geology of Salzkammergut area the "Hallstatt-Zone" became a "punching-ball" for generations of sediment geologists and of tectonic speculations. In the early phase of research (between approximately 1802 — marked by L. v. BUCH's monography — and 1903, the year of the IX. International Geological Congress in Vienna) stratigraphic problems of the Alpine Mesozoic were the main goal, but also considerations regarding the bathymetric conditions, the geometry of depositional environments and lithogenesis were made. In the years 1797—1799 L. v. BUCH travelled jointly with A. v. HUMBOLDT in the Salzkammergut area (L. v. BUCH, op. cit.). The first results of the investigations of the red colour of the limestones, of the age and environmental conditions of the salt deposits and of the origin of stratification were published. The unrivaled genius of the Austrian geologists E. SUESS (1888) gave already an explanation for the bedding resp. cyclicity of Dachstein Limestone, i. e. cyclic emerging and subsequent weathering of the bedding planes — a simplified model for the "Lofer cyclothems" (A. G. FISCHER, 1964). A study by E. v. MOJSISOVICS (1874) represents an early attempt of facies zoning in Salzkammergut area. E. v. MOJSISOVICS (1903) in one of his last papers summarizes his ideas of the paleogeographic position of Hallstatt zone. He postulates an in situ position (sediments of Hallstatt type deposited in channels ("Hallstätter Kanäle") cutting through the reefoid Dachstein Limestone barrier resp. platform). One year later the fateful paper by E. HAUG & M. LUGEON (1904) marks a fundamental break through in the history of geological research in Salzkammergut area: the concept of nappe-tectonics was established. In the sequel the "nappists" entered into competition with the "autochthonists". L. KOBER and his school (e. g. W. MEDWENITSCH, A. TOLLMANN up to a few years ago, and others) plead for an extreme

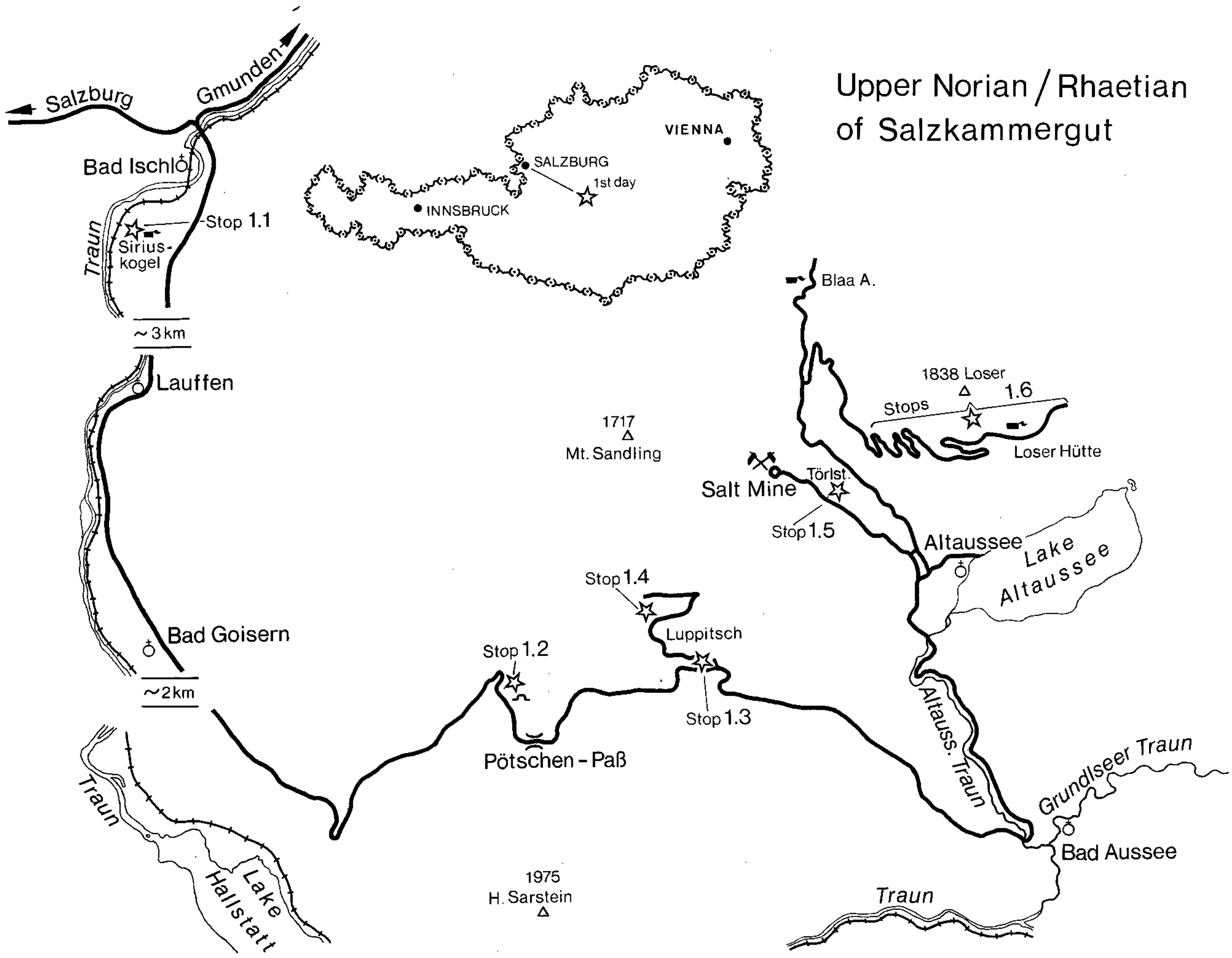


Fig. 1

nappism. On the other hand C. DIENER, K. LEUCHS, F. TRAUTH and in modern time H. ZANKL and especially W. SCHLAGER and his group followed the autochthonous concept of E. v. MOJSISOVICS (1903) in modified versions. The present author tends to accept this concept, too.

It would exceed the scope of this paper to enumerate all the famous people doing research in this area in the past century and the interested reader can refer to the book by A. TOLLMANN (1976) for this purpose or to the short review by W. JANOSCHEK & A. MATURA (1980) respectively.

References

BUCH, L. v. (1802): Geognostische Beobachtungen auf Reisen durch Deutschland und Italien. Vol. 1. — 320 p., (HAUDE & Spener), Berlin.

FLÜGEL, E., LOBITZER, H., SCHÄFER, P. & ZANKL, H. (1975): Mesozoic shallow and deeper-water facies in the Northern Limestone Alps. — In: FLÜGEL, E.: International Symposium on Fossil Algae. — Guidebook, 55—146, Erlangen.

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

HAUG, E. & LUGEON, M. (1904): Sur l'existence, dans le Salzkammergut, des quatre nappes de charriage superposées. — C. R. Acad. Sci. Paris, 130, Paris.

JANOSCHEK, W. R. & MATURA, A. (1980): Outline of the Geology of Austria. — Abh. Geol. B.-A., 34, Wien (this volume).

KITTL, E. (1903): Geologische Exkursionen im Salzkammergut (Umgebung von Ischl, Hallstatt und Aussee). — Guidebook 9. Internat. Geol. Congr., No. 4, 118 p., Wien.

KOBER, L. (1912): Der Deckenbau der östlichen Nordalpen. — Denkschr. Akad. Wiss. Wien, math.-natw. Kl., 88, 345—396, Wien.

KRYSTYN, L. (1974): Probleme der biostratigraphischen Gliederung der Alpin-Mediterranen Obertrias. — Schriftenreihe erdwiss. Kommiss. Österr. Akad. Wiss., 2, 137—144, Wien.

KRYSTYN, L. & SCHÖLLNBERGER, W. (1972): Die Hallstätter Trias des Salzkammergutes. — Guidebook 42. Jahresvers. Paläont. Ges., 61—106, Graz.

MOJSISOVICS, E. v. (1869): Über die Gliederung der oberen Triasbildungen der östlichen Alpen. — Jb. Geol. R. A., **19**, No. 1, 91—150, Wien.

MOJSISOVICS, E. v. (1873—1902): Das Gebirge um Hallstatt. 1. Theil. Die Mollusken-Faunen der Zlambach- und Hallstätter Schichten. Suppl.: Die Cephalopoden der Hallstätter Kalke. — Abh. Geol. R. A., **6**, 3 parts, 356 p., Wien.

MOJSISOVICS, E. v. (1874): Faunengebiete und Faciesgebilde der Trias-Periode in den Ost-Alpen. — Jb. Geol. R. A. **24**, 81—134, Wien.

MOJSISOVICS, E. v. (1903): Übersicht der geologischen Verhältnisse des Salzkammergutes. — In: E. SUESS (Ed.): Bau und Bild Österreichs, 383—391, Wien.

RIECHE, J. (1971): Die Hallstätter Kalke der Berchtesgadener Alpen. — Dissertation Techn. Univ. Berlin, 173 p., Berlin.

SCHÄFFER, G., VAN HUSEN, D., DRAXLER, I. & LOBITZER, H. (1976): Arbeitstagung der Geologischen Bundesanstalt: Blatt 96 Bad Ischl, Salzkammergut. — 48 p., Wien.

SCHLAGER, W. (1969): Das Zusammenwirken von Sedimentation und Bruchtektonik in den triadischen Hallstätterkalken der Ostalpen. — Geol. Rdsch., **59**, 289—308, Stuttgart.

SUESS, E. (1888): Das Antlitz der Erde. Vol. 2. — 704 p., (F. Tempsky), Wien.

TOLLMANN, A. (1976): Monographie der Nördlichen Kalkalpen. Teil II: Analyse des klassischen nordalpinen Mesozoikums. Stratigraphie, Fauna und Fazies der Nördlichen Kalkalpen. — 580 p., F. Deuticke, Wien.

TOZER, E. T. (1971): Triassic Time and Ammonoids: Problems and Proposals. — Canadian J. Earth Sci., **8**, No 8, 989—1031, Ottawa.

Topographical map:

Österreichische Karte 1 : 50.000. Sheet No. 96 (Bad Ischl).

Geological maps:

Geologische Karte der Republik Österreich 1 : 50.000. No. 96 Bad Ischl. — By G. SCHÄFFER et al. In preparation.

Geologische Spezialkarte der Österr.-Ungar. Monarchie 1 : 75.000. No. 4951 Bad Ischl und Hallstatt. — By E. v. MOJSISOVICS, Vienna 1905. Out of print.

Stop 1.1. Hallstatt Limestone of Siriuskogel-Summit

The look-out tower on "Siriuskogel" reveals an excellent panorama of Emperor Franz Joseph I favorite landscape, i. e. the town and surroundings of Bad Ischl. It can be reached by a chair-lift. This point is ideally suited to explain the geology of the Hallstatt-zone of the area of Bad Ischl.

Up to recent times the Hallstatt limestones of Siriuskogel were considered to represent Upper Norian (Sevatic) age only (e. g. E. v. MOJSISOVICS, 1902 "Zone of *Pinacoceras metternichi*", E. KITTL, 1903; E. FLÜGEL, 1967). H. MOSTLER & P. PARWIN (1973) reexamined the sections and — based on conodonts — report an age ranging from (? Langobardian) Cordevolian-Upper Norian.

We shall exclusively visit the rather poor outcrops of Upper Norian Hallstatt limestone with interlayering coquinas of the pelecypod *Monotis salinaria* on Siriuskogel — summit. W. SCHWARZACHER (1948) has given a most stimulating paper on the carbonate petrography resp. sedimentology of these sediments. Because of void filling cements in the bio(pel)micritic Hallstatt limestones SCHWARZACHER believes in an immediate paleogeographic neighbourhood of this sediment with the Dachstein Limestone. More recent investigations by E. FLÜGEL (1967) and H. MOSTLER & P. PARWIN (1973), however, suggest a "deeper water" — basinal — origin.

The macrofauna (E. KITTL 1903) comprises ammonites [*Rhabdoceras suessi*, *Cochloceras amoenum*, *Megaphyllites insectus*, *M.* cf. *transiens*, *Rhacophyllites debilis*, *Placites* div. sp.; *Cladiscites* div. sp., *Arcestes* div. sp.; E. MOJSISOVICS (1873) also reports *Pinacoceras insectum*], pelecypods (coquinas of Halobiids and Monotids) and brachiopods of Norian age. The microfauna was studied by E. FLÜGEL (1967) and H. MOSTLER & P. PARWIN (1973) in thinsections as well as in acid — dissolved samples: conodonts (11 species), holothurians (24 species), foraminifera (predominantly nodosariids; textulariina and miliolina are rather scarce). Sponge spicules are ubiquitous; fragments of crinoids, echinids, ophiures, ostracods, fish-remains and microproblematica occur in alternating frequency. A small sequence of thinsections of proved Upper Norian limestone in the vicinity of the look-out tower on Siriuskogel shows biomicrites, partly with peloids and well rounded lithoclasts ("mud aggregates"). The latter can be encrusted by foraminifera. Excellent void filling cementation and geopetal fabric are common features. Filaments and calcispheres occur occasionally.

References

FLÜGEL, E. (1967): Conodonten und Mikrofazies der Hallstätter Kalke (Nor) am Sirius-Kogel in Bad Ischl, Oberösterreich. — N. Jb. Geol. Paläont. Mh., **1967**, 91—103, Stuttgart.

KITTL, E. (1903): Geologische Exkursionen im Salzkammergut (Umgebung von Ischl, Hallstatt und Aussee). — Guidebook 9. Internat. Geol. Congr., No. **4**, 118 p., Wien.

MOSTLER, H. & PARWIN, P. (1973): Ein Beitrag zur Feinstratigraphie der Hallstätter Kalke am Sirius-Kogel (Bad Ischl, Oberösterreich). — Geol. Paläont. Mitt. Innsbruck, **3**, No. 7, 47 p., Innsbruck.

SCHWARZACHER, W. (1948): Sedimentpetrographische Untersuchungen kalkalpiner Gesteine. Hallstätterkalke von Hallstatt und Ischl. — Jb. Geol. B.-A., 1946, **91**, H. 1/2, 1—48, Wien.

Stop 1.2. Pötschen Formation at Pötschenhöhe-Quarry

Probably the bathymetrically deepest sediments of the Upper Norian/"Rhaetian" of Salzkammergut are represented by the "Pötschen-Schichten" (Pötschen Formation). The locality "Pötschenhöhe-Quarry" is the

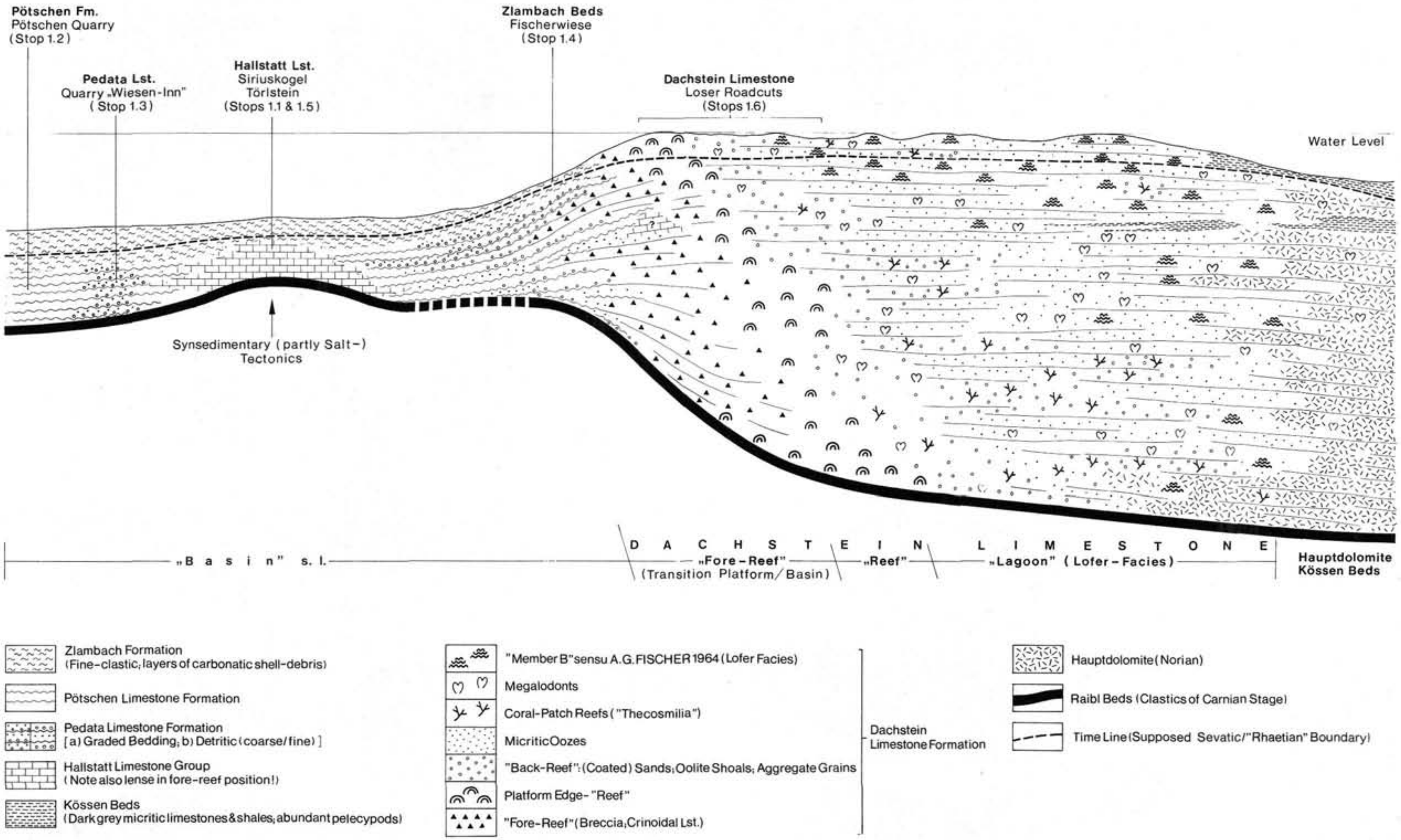


Fig. 2: Schematic paleogeographic reconstruction showing the supposed facies distribution during the Upper Norian (Sevatic) — Rhaetian of Salzkammergut. Subsidence rates between the platform — and basin — complex are different and generally increased during the Rhaetian which probably caused pronounced clastic influx (Zlambach Formation), the latter covering more or less the total Norian basinal sequence. Interpretation based on the papers cited and the author's observations.

locus classicus of this formation and has been studied by many authors. Stratigraphically there is no consensus yet. According to E. v. Mojsisovics (1902) the "Pötschenkalk" demonstrates the ammonite zone of *Sirenites argonautae* (Upper Sevatic). The Pötschen Limestone covers the period from the Upper Carnian (Tuvalic) to the Upper Norian (L-M Sevatic) as shown by the paper of H. Mostler (1978), based on conodonts.

The "Pötschen Schichten" are a sequence of about 120 m thickness comprising a monotonous series of grey, well bedded micritic "deeper water"-limestones (sensu J. L. Wilson, 1969) alternating with argillaceous — marly layers. The average thickness of the limestone beds is around 15 cm, the clayey interlayers are in the range of a few centimeters. The limestone beds often show nodular upper bedding surfaces caused by pressure solution. Occasionally chert occurs; biogenic burrowing is common.

Under the microscope the thin sections generally show a very uniform habitus: Biomicrites, frequently peloidal with more or less abundant "filaments" (probably protoconchs of pelecypods). "Spheres" (generally "calcisphere") could be calcified radiolarians. Euhedral dolomite rhombs ("clear rim-cloudy center") often are abundant in zones of pressure solution or in burrows. These zones generally are enriched in quartz and pyrite-growth is common. Microspar and "clotted structure" (structure grumeleuse) seem to be products of neomorphism and recrystallization respectively, the latter of peloidal limestone. Geopetal fabrics are indicated by infillings of rest-lumina by sparry calcite.

The macrofauna is rather poor. Ammonites of the higher Middle Norian (*Columbianus*-zone; *Watsoni*-Subzone) and the Upper Norian (Sevatic) pelecypod *Monotis salinaria* are stratigraphic fixpoints of the sequence. The following ammonites are listed in E. v. Mojsisovics (1893): *Acanthinites excelsior* (most probably identical with *Himavatites hogarti*), *Distichites minos, Sirenites* (= *Argosirenites*) *argonautae, Tropites* nov. f. ex. aff. *pithoides* (probably identical with *Jellinekites hoveyi*). E. Kristan-Tollmann (1960) describes a foraminifer-faunula from washed samples of the argillaceous interlayers (*Variostoma crassum, V. catilliforme* are predominant). In thinsections agglutinating foraminifera, duostominids, lagenids and extremely scarcely miliolids and involutinids occur. H. Mostler (1978) describes a rich assemblage of silicisponge-spicules from the upper part (Sevatic) of Pötschen limestone, the demospongea dominate the hexactinellida. In acid-dissolved and washed samples radiolarians, and ostracods occur, echinoderms (crinoids, ophiurids, echinids, holothurians) are relatively common. According to A. G. Fischer, S. Honjo & R. E. Garrison (1967) probable nannofossils are important as rock-building agents. H. Zankl (1971) reports similar spherical calcite aggregates of 5 micron thickness composed of micron-sized peculiarly spit plates occuring in Hallstatt Limestones.

References

Fischer, A. G., Honjo, S. & Garrison, R. E. (1967): Electron micrographs of limestones and their nannofossils. — Monographs in Geology and Paleontology, 1, 141 p., Princeton, N. J.

Kristan-Tollmann, E. (1960): Rotaliidea (Foraminifera) aus der Trias der Ostalpen. — Jb. Geol. B.-A., Spec. Vol. 5, 47—48, Wien.

Mostler, H. (1978): Ein Beitrag zur Mikrofauna der Pötschenkalke an der Typlokalität unter besonderer Berücksichtigung der Poriferenspiculae. — Geol. Paläont. Mitt. Innsbruck 7, No. 3, 28 p., Innsbruck.

Stop 1.3. Pedata Limestone Quarry near Gasthof "Wiesen" (Luppitsch).

The name "Pedata-Schichten" is derived from the brachiopod *Halorella pedata.* Lithologically the "Pedata Formation" comprises bedded limestones, mostly cherty, sometimes also bituminous of "deeper water" facies and marly interlayers. In the quarry at Gasthof Wiesen dark grey or brown-greenish micritic cherty limestone beds with thin, sometimes graded arenitic debris layers (allodapic limestones) predominate. Irregular, thin brittle marly interlayers separate the limestone beds. The limestone beds are rich in biota and show typical basin-slope faunal associations, containing elements derived as well from a shallow water carbonate platform (Dachstein Limestone) as from "deeper water" origin. The indigenous macrofauna is dominated by brachiopods of the genus *Halorella,* but echinoderm-fragments (crinoids, echinidspines) are common as well. Thinsections show a jumbled mass of varied shell debris and intraclasts including an accumulation of shallow and deeper water foraminifera (e. g. *Variostoma, Tetrataxis,* miliolids and encrusting forms). Sponge spicules, ostracods, pelecypod shells, radiolarians and questionable calcispheres, bryozoans and ? *Tubiphytes* are less frequent components. Clastic influence (quartz and glauconite) is subordinate. Stylolitization and pyrite growth (in fossils) is common.

Summarizing it can be concluded, that the Pedata Limestone in part represents sediments of the outer neritic, with a distinct indigenous fauna. The above mentioned "microhorizons" of graded beds containing coarser platform-derived skeletal and nonskeletal debris are believed to be the result of submarine fans, transporting the material down to the deeper basin slopes. This avalanches were probably initiated by spasmodic tectonic impulses along the basin rim. This theory corresponds with the assumption of different subsidence-rates for platform/basin-configurations of the Salzkammergut Triassic.

References

FLÜGEL, E., LOBITZER, H., SCHÄFER, P. & ZANKL, H. (1975): Mesozoic shallow- and deeper-water facies in the Northern Limestone Alps. — In: FLÜGEL, E.: International Symposium on Fossil Algae. — Guidebook, 55—146, Erlangen.

SCHÄFFER, G., VAN HUSEN, D., DRAXLER, I. & LOBITZER, H. (1976): Arbeitstagung der Geologischen Bundesanstalt: Blatt 96 Bad Ischl, Salzkammergut. — 48 p., Wien.

Stop 1.4. Zlambach Formation of locality "Fischerwiese" at Alt Aussee

Clay-marl dominated grey sediments with subordinate interlayers of limestone beds of Upper Norian (Sevatic) and "Rhaetian" age are called "Zlambach Schichten". The most famous locality is a small creek on a place called "Fischerwiese". Besides the locality "St. Cassian" in Italy the Norian ?/"Rhaetian" marls of Fischerwiese contain by far the richest and unusually well preserved and therefore best studied fauna (and flora) of the Alpine Triassic. Monographic descriptions have been given on the corals (53 taxa), foraminifera (E. KRISTAN-TOLLMANN, 1964: approx. 250 taxa), ostracods (70 taxa), pelecypods (H. ZAPFE, 1967 ff.: approximately 30 taxa). Additionally cephalopods (10 spec.), brachiopods (7 spec.), gastropods (15 taxa), echinoderms (crinoids, echinids, holothurians, ophiurs) and scarcely calcareous sponges, scaphopods, bryozoans, hydrozoans (spongiomorphids), fish teeth, radiolarians and trace fossils occur. Calcareous algae (dasycladaceans and solenoporaceans) are subordinate.

From the viewpoint of paleoecology the Zlambach beds of Fischerwiese are, to my opinion, sediments of the open marine shelf. A macrofauna with abundant biota comparable to locality Fischerwiese will be also seen at outcrop No. 1/6 (hanging Dachstein limestone along Loser roadcuts). Fischerwiese outcrops seem to demonstrate the bathymetrically shallowest portion of Zlambach beds in Salzkammergut area. Paleotemperatures based on $^{18}O/^{16}O$-ratios carried out on aragonite-preserved fossils, are in the range between 21,5°—24,5° C. A modern study on the paleoenvironmental conditions of Zlambach Formation has been performed by H. BOLZ (1974).

References

BOLZ, H. (1974): Die Zlambach-Schichten (alpine Obertrias) unter besonderer Berücksichtigung der Ostrakoden, 2: Zur Stratigraphie und Fazies der Zlambach-Schichten. — Senckenbergiana lethaea, **55**, 1/5, 325—361. Frankfurt.

FLÜGEL, E., LOBITZER, H., SCHÄFER, P. & ZANKL, H. (1975): Mesozoic shallow- and deeper-water facies in the Northern Limestone Alps. — In: FLÜGEL, E.: International Symposium on Fossil Algae. — Guidebook, 55—146, Erlangen.

KRISTAN-TOLLMANN, E. (1964): Die Foraminiferen aus den rhätischen Zlambachmergeln der Fischerwiese bei Aussee im Salzkammergut. — Jb. Geol. B.-A., Spec. Vol. **10**, 189 p., Wien.

SCHÄFFER, G., VAN HUSEN, D., DRAXLER, I. & LOBITZER, H. (1976): Arbeitstagung der Geologischen Bundesanstalt: Blatt 96 Bad Ischl, Salzkammergut. — 48 p., Wien.

ZAPFE, H. (1967): Beiträge zur Paläontologie der nordalpinen Riffe. Die Fauna der Zlambach-Mergel der Fischerwiese bei Aussee, Steiermark (exkl. Coelenterata und Mikrofossilien). — Ann. Naturhistor. Mus. Wien, **71**, 413—480, Wien.

Stop 1.5. Hallstatt Limestone of „Törlstein" Northwest of Altaussee

There exist many excellent outcrops of Norian Hallstatt Limestone showing all sedimentological patterns mentioned above and rich in fossils, but none of them is within easy reach. Doubtless the most spectacular exposure of Hallstatt Limestone Group is the section of Sommeraukogel above Hallstatt village. The Törlstein (924 m) is situated about 2 km Northwest of Altaussee village on the road to the salt-mine and represents rather poor outcrops in wooded area. It shows "Hangendrotkalk", a well bedded red to reddish-grey wavy to nodular limestone of Upper Norian (Sevatic) age dipping slightly to the West. The first mention of this outcrop is given by E. v. MOJSISOVICS (1873—1902). He reports the Upper Norian ammonites *Stenarcestes orbis* and *Stenarcestes subumbilicatus.*

As proved by subsurface data (tunnels of Altaussee salt-mine) the "Hangendrotkalk" sends extended very fossiliferous neptunian dikes into the underlying "Massiger Hellkalk". The fauna obtained from this outcrop points clearly to Sevatic age, as already stated by MOJSISOVICS. Ammonites: *Rhabdoceras suessi, Sagenites* cf. *giebeli, Pinacoceras metternichi, Arcestes intuslabiatus, Placites oxyphyllus, Cladiscites tornatus, Paracladiscites multilobatus, Rhacophyllites debilis;* conodonts (det. L. KRYSTYN): *Epigondolella abneptis, Gondolella navicula steinbergensis, Epigondolella bidentata, Hindeodella* sp. In unsoluble residues a very poor foraminifera-assemblage could be identified by J. HOHENEGGER: *Haplophragmoides* sp., *Verneuilinoides* sp., *Lituotuba* sp. The probable hydrozoan *Heterastridium conglobatum*, a coquina with the pelecypod *Monotis salinaria* and gastropods sporadically are abundant in the subsurface outcrops.

I thank W. FRIEDEL (Geol. Inst. Univ. Vienna) for supplying field data.

Reference

MOJSISOVICS, E. v. (1873—1902): Das Gebirge um Hallstatt. 1. Theil. Die Mollusken-Faunen der Zlambach- und Hallstätter Schichten. Suppl.: Die Cephalopoden der Hallstätter Kalke. — Abh. Geol. R. A., **6**, 3 parts, 356 p., Wien.

Stops 1.6. Dachstein Limestone along Loser roadcuts

The last stop of the day, the Loser at Altaussee is a very suitable spot to review and summarize the complicated facies relationship of the Norian/"Rhaetian" of Salzkammergut.

On our drive downhill to Altaussee spectacular outcrops of cyclic bedded "lagoonal" Dachstein Limestone of Lofer type can be seen in roadcuts along Loser road. Most of the features demonstrated are described in the epoch-making paper by A. G. FISCHER (1964) and can easily be related to modern tidal flat sedimentation patterns (e. g. Andros Island, Bahamas). Because of the permanent changing outcrop situation intentionally here no topographically fixed exposures are indicated. What will we see?

Cyclic bedded Loferitic Dachstein Limestone, partly cyclothem member A and/or B are lacking.

Oncolithic shoals; oolite-pockets.

Reworked (partly "blackened pebbles"), brecciated limestone of different origin (subaerial exposure in salina areas; storm layers; peeled and curled mud chips, a. o.).

Neptunian dikes with several generations of Liassic sediments cutting through megalodontid limestone.

Stratigraphically the Dachstein Limestone of Loser is proved Upper Norian by ammonites (*Stenarcestes subumbilicatus, Rhabdoceras suessi, Placites* sp.). Megalodontid pelecypods (*Conchodus infraliassicus*) are very common in this stratigraphic level.

References

FLÜGEL, E., LOBITZER, H., SCHÄFER, P. & ZANKL, H. (1975): Mesozoic shallow- and deeper-water facies in the Northern Limestone Alps. — In: FLÜGEL, E.: International Symposium on Fossil Algae. — Guidebook, 55—146, Erlangen.

KRYSTYN, L. & SCHÖLLNBERGER, W. (1972): Die Hallstätter Trias des Salzkammergutes. — Guidebook 42. Jahresvers. Paläont. Ges., 61—106, Graz.

SCHÄFFER, G., VAN HUSEN, D., DRAXLER, I. & LOBITZER, H. (1976): Arbeitstagung der Geologischen Bundesanstalt: Blatt 96 Bad Ischl, Salzkammergut. — 48 p., Wien.

Acknowledgements

Field work in Pötschenhöhe quarry (stop 1.2.) and in Pedata Limestone quarry (stop 1.3.) has been performed jointly with Dr. W. E. PILLER and Dr. J. HOHENEGGER (Vienna). The facies model (fig. 2) was draftet by Dr. G. SCHÄFFER (Vienna) and the author. Very useful discussions and fieldtrips in Salzkammergut were carried out with the following colleagues: Prof. E. FLÜGEL (Erlangen), Dr. W. JANOSCHEK (Vienna), Dr. L. KRYSTYN (Vienna), Dr. U. PISTOTNIK-WEIGERT (Vienna), Prof. W. SCHLAGER (Miami), Dr. W. SCHÖLLNBERGER (Houston), Dr. F. TATZREITER (Vienna).

Day 2

The Steinplatte Carbonate Platform/Basin-Complex (Norian/„Rhaetian", Northern Calcareous Alps)

by

HARALD LOBITZER

With figures 3 and 4

Route: Salzburg — "Deutsches Eck" — Lofer — Paß Strub — Steinplatte (Waidring) — Innsbruck (overnight stop).

Introduction

E. v. MOJSISOVICS was not only the most successful investigator of the Hallstatt zone of Salzkammergut, but he also was the first who recognized the reef-nature of Steinplatte carbonate complex (E. v. MOJSISOVICS, 1871). W. VORTISCH (1926) performed a very thorough facies study on Steinplatte reef-complex which formed the basis for the most detailed investigations by H. R. OHLEN (1959). This study was initiated by A. G. FISCHER (Princeton University, N. J.). In 1971, H. ZANKL gives an excellent review on Upper Triassic carbonate facies as well of Hallstatt zone and also of Steinplatte complex. Steinplatte is also one of the classic localities for shelf margin profiles, the "Framebuilt Reef Rim" (J. L. WILSON, 1975). In the frame of a Geological Survey programme in 1977 the present author started a reinvestigation of the large Upper Triassic carbonate platforms of Salzburg Calcareous Alps including Steinplatte area and subsequently was joined by W. E. PILLER (University of Vienna). The presentation of a modified facies concept could be achieved (W. PILLER & H. LOBITZER, 1979, W. E. PILLER, in press) which will give us a useful tool for a better understanding of tectonically complicated situations in the eastern parts of the Northern Calcareous Alps. Apart from small scale tectonic complications and erosion, the large carbonate platform comprising Steinplatte in the North and the plateaus of Dachstein Limestone towards the South respectively Southeast (Loferer- and Leoganger Steinberge, Steinernes Meer, Hochkönig) represent the only larger area within the Northern Calcareous Alps which is relatively untouched by Alpine nappe tectonics (A. TOLLMANN, 1969).

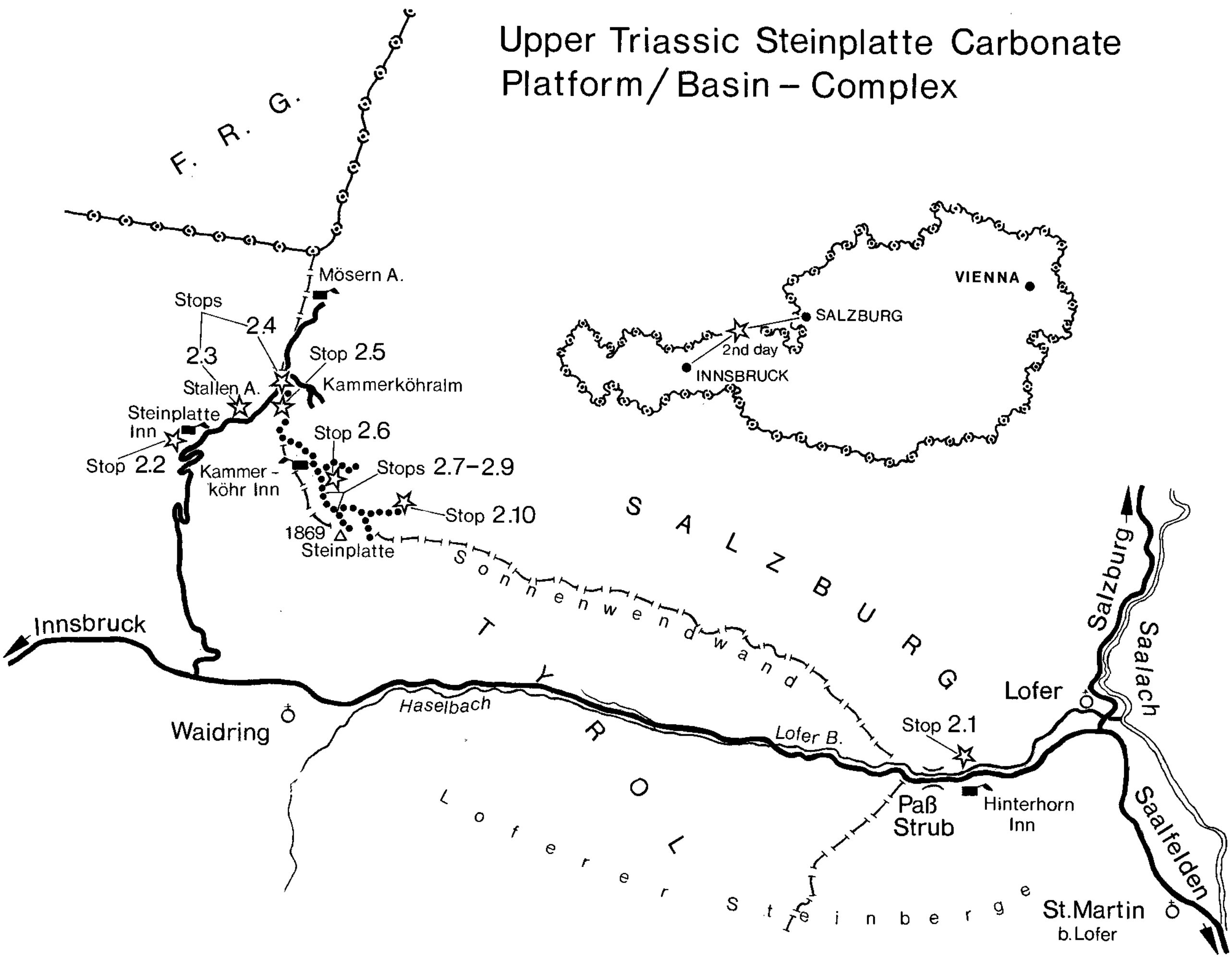


Fig. 3

According to the recommendation by W. Schlager & W. Schöllnberger (1975) the term "Steinplatte Limestone" is used in this paper replacing "Oberrhätkalk" and "Rätolias-Riffkalk" (F. H. Fabricius, 1966; introduced in 1959), a. o.

References

Fabricius, F. H. (1966): Beckensedimentation und Riffbildung an der Wende Trias/Jura in den Bayerisch-Tiroler Kalkalpen. — Internat. Sedim. Petrogr. Series, **9**, 143 p., Leiden.

Mojsisovics, E. v. (1871): Beiträge zur topischen Geologie der Alpen. — Jb. Geol. R. A., **21**, Nr. 2, 189—210, Wien.

Ohlen, H. R. (1959): The Steinplatte reef complex of the Alpine Triassic (Rhaetian) of Austria. — Dissertation Univ. Princeton, 122 p., Princeton, N. J.

Piller, W. E.: The Steinplatte Reef Complex (Tyrol/Salzburg; Austria) — Part of an Upper Triassic Carbonate Platform. — Typewritten manuscript submitted for print to Society of Economic Paleontologists and Mineralogists, Tulsa.

Piller, W. E. & Lobitzer, H. (1979): Die obertriassische Karbonatplattform zwischen Steinplatte (Tirol) und Hochkönig (Salzburg). — Verh. Geol. B.-A., **1979**, 171—180, Wien.

Schlager, W. & Schöllnberger, W. (1975): Das Prinzip stratigraphischer Wenden in der Schichtfolge der Nördlichen Kalkalpen. — Mitt. Geol. Ges. Wien, **66—67**, 165—193, Wien.

Tollmann, A. (1969): Tektonische Karte der Nördlichen Kalkalpen 2. Teil: Der Mittelabschnitt. — Mitt. Geol. Ges. Wien, **61**, 123—181, Wien.

Vortisch, W. (1926): Oberrhätischer Riffkalk und Lias in den nordöstlichen Alpen. 1. Teil. — Jb. Geol. B.-A., **76**, No. 1/2, 1—64, Wien.

Wilson, J. L. (1975): Carbonate Facies in Geologic History. — 409 p., (Springer), Berlin — Heidelberg — New York.

Zankl, H. (1971): Upper Triassic Carbonate Facies in the Northern Limestone Alps. — In: Müller, G. (Ed.): Sedimentology of parts of Central Europe. Guide Book, VIII. — Internat. Sed. Congr. Heidelberg, 147—185, Kramer, Frankfurt.

Topographical maps:

Österreichische Karte 1 : 50.000. Sheets No. 91 (Sankt Johann in Tirol). No. 92 (Lofer).

Geological maps:

Geologische Spezialkarte der Republik Österreich 1 : 75.000. No. 4949 Lofer und St. Johann. — By O. AMPFERER, Wien 1927, (Geol. Bundesanst.). Out of print.

Geologische Karte von Bayern 1 : 100.000. No. 666 Reit im Winkl. — By O. GANSS, München 1975.

Stop 2.1. Loferitic Dachstein Limestone at Paß Strub Quarry

A small abandoned quarry North of Gasthof Hinterhorn will be visited to have a quick look at and obtain samples of Dachstein Limestone in the classical area of Lofer facies (B. SANDER, 1936, A. G. FISCHER, 1964). A most comprehensive regional study on the petrography and isotope-chemistry of Dachstein Limestone, including this quarry, has been carried out by H. GÖKDAG (1974).

References

FISCHER, A. G. (1964): The Lofer Cyclothems of the Alpine Triassic. — Bull. Geol. Surv. Kansas, 169, 107—149, Lawrence.

GÖKDAG, H. (1974): Sedimentpetrographische und isotopenchemische (O^{18}, C^{13}) Untersuchungen im Dachsteinkalk (Obernor-Rät) der Nördlichen Kalkalpen. — Dissertation Univ. Marburg/Lahn, 156 p., Marburg/Lahn.

SANDER, B. (1936): Beiträge zur Kenntnis der Anlagerungsgefüge. (Rhythmische Kalke und Dolomite aus der Trias). I. Nordalpine Beispiele. — II. Südalpine Beispiele, Hauptdolomit, Allgemeines. — Mineral. Petrogr. Mitt., **48**, 27—139, 141—209, Leipzig.

Stop 2.2. Bituminous Hauptdolomite

Some 50 meters below Gasthof Steinplatte along roadcuts good outcrops of the hanging section of Hauptdolomite (Norian) are exposed. A 60 centimeters thick bed of bituminous rock with pronounced petroliferous odour is sandwiched in a sequence of lagoonal limestone (typus Dachstein Limestone) and dolomite (in part laminated). The bed is parted in three layers, each of them 20 cm thick. Between thinbedded dark grey resp. brown shales and dolomites, a massive dolomitic bed is intercalated. On some of the bedding plane surfaces pelecypods (? "*Posidonia*") are abundant. Washed samples proved as devoid of microfossils. A chemical analysis performed by the Chemical Laboratory of the Austrian National Oil Company (ÖMV-AG) indicates a bitumen content of 510 ppm.

References

CZURDA, K. (1973): Parameter und Prozesse der Bildung bituminöser Karbonate (Bituminöser Hauptdolomit). — Mitt. Ges. Geol. Bergbaustud., **21**, 235—250, Innsbruck.

ZANKL, H. (1971): Upper Triassic Carbonate Facies in the Northern Limestone Alps. — In: MÜLLER, G. (Ed.): Sedimentology of parts of Central Europe. — Guidebook, VIII. Internat. Sed. Congr. Heidelberg, 147—185, Kramer, Frankfurt.

Stop 2.3. Dachstein Limestone ("Plattenkalk") exposures West of Stallen Alpe

These outcrops demonstrate the vertical transition from the Hauptdolomite/Dachstein Limestone carbonate platform to the initial stage of Kössen basin.

Description of exposure from base to top (partly after H. ZANKL, 1971):

120 cm bright, strongly fractured and dolomitized massive limestone.

55 cm wavy-nodular, micritic flaser-limestone with beds of 5—15 cm thickness. In zones of pressure solution abundant dolomite-growth is present.

130 cm recrystallized, partly laminated limestone.

80 cm crossbedded grey oolite. The lower section of the bed is strongly recrystallized, partly dolomitized and flasered by pressure solution. In thin sections coprolites can be seen. The bedding plane surface represents a hardground, which indicates changing conditions of the depositional environment.

50 cm: the hanging bed of this outcrop demonstrates sediments of the transitional stage to Kössen beds; i. e. a light coloured, dolomitized, bioturbated flaserlimestone. The dolomitization is concentrated on zones of pressure solution. On the hardground of the upper surface borings can be found. Echinoderm fragments and pelecypod shell-hash frequently occurs.

Following the road to Stallen Alpe we can study the basal beds of Kössen Formation (limestones with pelecypod-coquinas and shales). Carbonate production could not keep abreast of subsidence because of the permanent decrease resp. absence of biogenic carbonate producing organisms and increasing terrigenous influence. Oscillating environmental conditions are documented by a repetition of a few meters bedded Dachstein Limestone with megalodonts and "*Thecosmilia*".

On Stallen Alpe weathered karst surfaces of lagoonal Dachstein limestone with small heads of "*Thecosmilia*" and some megalodonts will be visited en route.

Reference

ZANKL, H. (1971): Upper Triassic Carbonate Facies in the Northern Limestone Alps. — In: MÜLLER, G. (Ed.): Sedimentology of parts of Central Europe. — Guidebook, VIII. Internat. Sed. Congr. Heidelberg, 147—185, Kramer, Frankfurt.

Stop 2.4. Upper Kössen Beds near old tri-state corner

Roadcuts approximately 450 meters northeast of Stallen Alpe show a sequence of alternating limestones, shales and marls, respectively. The limestone beds show smooth bedding planes and wavy-nodular surfaces on the bottom of the beds. As already stated by H. ZANKL 1971, concretionary lithification in an early stage of diagenesis is represented by the uppermost beds of the sequence. The clayey-marly interlayers either are fine clastic sediments with a deeper marine microfauna or — less frequent — are the product of pressure solution. Field observations, sedimentological and paleontological data prove the environment as outer neritic with water depths in the range of 100—120 meters.

Fauna: The macrofauna is very poor. Besides a small brachiopod-faunula, traces of soft bodied burrows and burrows of "*Zoophycos*"-type are well preserved in some of the marly beds. They indicate a low rate of compaction, caused by fast lithification. The microfauna of this profile-section presently is studied by Frau Dr. E. KRISTAN-TOLLMANN. Washed samples and thinsections partly show echinoderms (ophiurids, echinoids, crinoids) and ostracods as dominating skeletal elements, foraminifers are scarce (lagenids, nodosariids). All in all a microfauna poor in individuals and taxa. From the faunistic point of view the ostracods (e.g. "*Hungarella*" *martini*) demonstrate connections with the Rhaetian of England and Germany but not with the Zlambach Formation of the Tethys. However, the foraminifers do not show this pronounced paleogeographical restrictions. For instance *Variostoma crassum*, very scarce in thinsections of this section, proves abundant in Upper Norian tethydial sediments of Hallstatt Facies Group and was found recently also in Kössen beds from Persia (Waliabad).

Reference

ZANKL, H. (1971): Upper Triassic Carbonate Facies in the Northern Limestone Alps. — In: MÜLLER, G. (Ed.): Sedimentology of parts of Central Europe. — Guidebook, VIII. Internat. Sed. Congr. Heidelberg, 147—185, Kramer, Frankfurt.

Stop 2.5. Kössen Beds of Kammerköhr-Alm

R. v. KLEBELSBERG (1935) was the first author mentioning Kössen Beds with chert. This chert is a curiosity from the regional point of view. Dark grey well bedded micritic limestone with changing amounts of fine-grained crinoid debris; devoid of macrofossils, constitutes the "normal" Kössen sediment of Kammerköhr-Alm. This sediment according to the regional situation must have been deposited in water depths in the range between 80—130 meters.

References

KLEBELSBERG, R. v. (1935): Geologie von Tirol. — 872 p., (Borntraeger), Berlin.

OHLEN, H. R. (1959): The Steinplatte reef complex of the Alpine Triassic (Rhaetian) of Austria. — Dissertation Univ. Princeton, 122 p., Princeton, N. J.

VORTISCH, W. (1926): Oberrhätischer Riffkalk und Lias in den nordöstlichen Alpen. 1. Teil. — Jb. Geol. B.-A., **76**, No. 1/2, 1—64, Wien.

Stop 2.6. Kössen Beds southeast of Gasthaus Kammerköhr

Southeast of the Gasthof Kammerköhr (through the tunnel) irregular bedded (cm — 1 m) medium brown or dark grey Kössen beds, in part with conspicous bituminous odour, are the typical sediments. The microscope reveals, that this wavy-nodular arenitic limestone is a bio(intra)pelsparite, respectively, less common -micrite with abudant crinoid fragments (partly with "syntaxial overgrowth") and pelecypod-debris; sporadic dasycladeans also occur. Narrow calcite veins are common as well as some pyrite. This type of sediment represents the lower portion of the already relatively flat fore-reef slope (better: basin-solpe), resp. the gradual transition to the micrite dominated basinal Kössen beds. Upwards the fore-reef slope shows inclinations up to 35 degrees and the still crinoid dominated sediments gradually become brighter-coloured and more indistinct bedded, grain sizes increase, and also some coarser grained reef-derived debris is present. The indigenous slope dwelling macrofauna besides the ubiquitous crinoids is dominated by pelecypods; brachiopods are rather scarce. It remains a still unsolved problem how steep slopes are stabilized. Perhaps thickets of stalked crinoids offered effective obstacles to gentle currents which heaped fine mud in lee areas in roughly conical piles (D. TOOMEY, 1978).

References

OHLEN, H. R. (1959): The Steinplatte reef complex of the Alpine Triassic (Rhaetian) of Austria. — Dissertation Univ. Princeton, 122 p., Princeton, N. J.

PILLER, W. & LOBITZER, H. (1979): Die obertriassische Karbonatplattform zwischen Steinplatte (Tirol) und Hochkönig (Salzburg). — Verh. Geol. B.-A., **1979**, 171—180, Wien.

TOOMEY, D. (1978): Geologic fieldtrip guide to selected areas in West Texas and Southeastern New Mexico. — Cities Service Company, Guidebook No. 1, 188 p., Midland.

Stop 2.7. Fore Reef-Coquina

A partly interrupted band of coquina interfingers downslope with the forementioned relatively bright greyish Kössen Beds, rich in crinoid debris. Upslope the coquina interfingers with the mud mounds of the reef slope. According to W. E. PILLER (in press) the fauna is constituted mainly by lamellibranchs (*Chlamys, Oxytoma, Lima, Atreta, Rhaetavicula, Modiolus*) and some brachiopods. The void-cementation shows in thinsections partly scalenoedric calcite crystals; pinkish or greenish micritic sediment geopetally covers the floors of the interstices and the concave-up pelecypod shells.

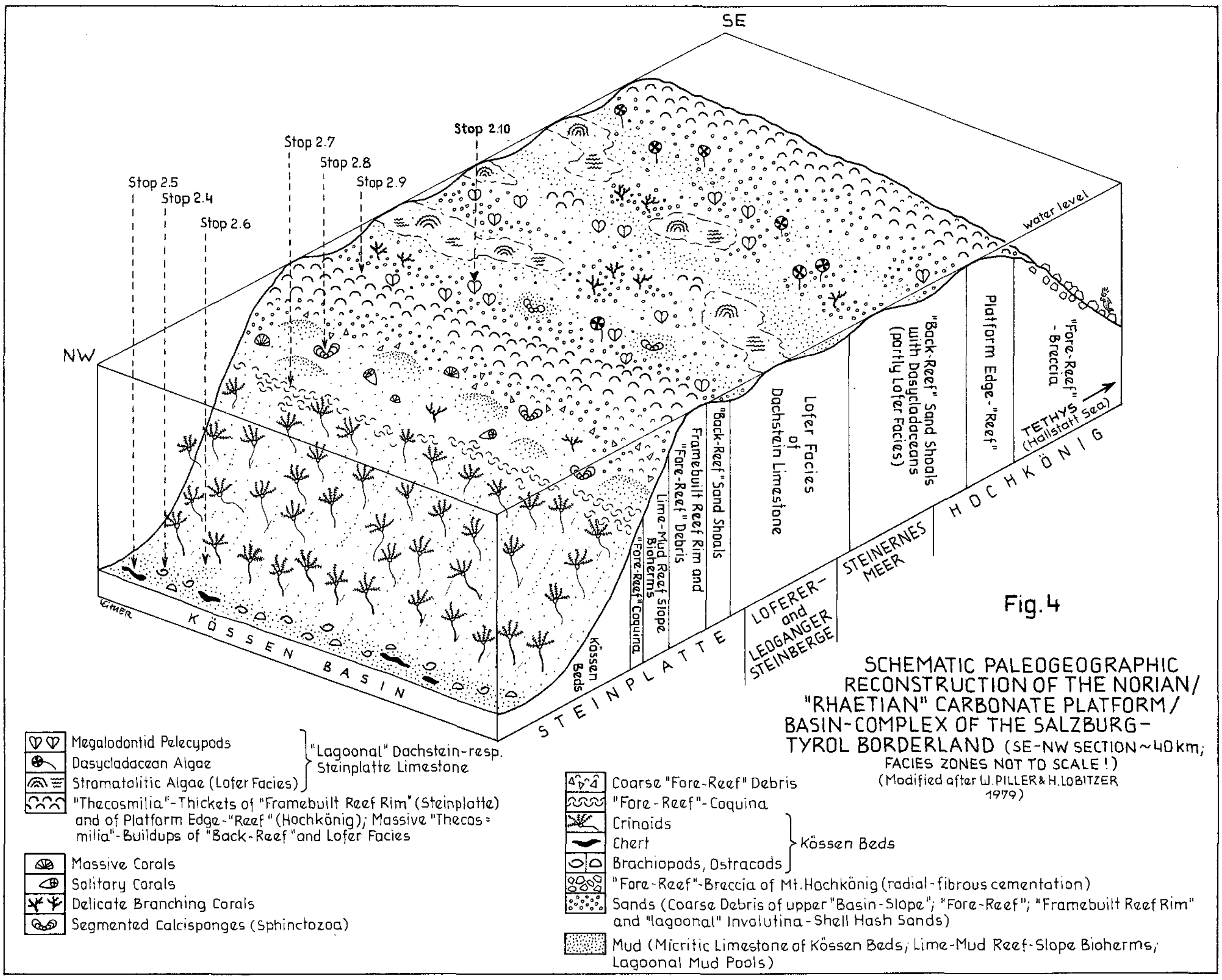


Fig. 4

Reference

Piller, W. E.: The Steinplatte Reef Complex (Tyrol/Salzburg; Austria) — Part of an Upper Triassic Carbonate Platform. — Typewritten manuscript submitted for print to Society of Economic Paleontologists and Mineralogists, Tulsa.

Stop 2.8. Lime-Mud Reef-Slope Bioherms

W. E. Piller (in press) discerned a zone situated between the fore-reef (coquina resp. crinoidal limestone) and the conspicuous outcrops of the framebuilt reef rim (stop 2.9.) which is characterized by muddy grey, yellowish or pinkish limestones with a high diversity in reef-associated biota. Calcisponges, hydrozoans, corals, solenoporaceans and microproblematics constitute the main "frame-building" or better "mud-baffling" biota. These sediments can be attributed to a zone, maybe up to a few tens of meters wide formed by irregularly shaped still water bioherms situated on the reef slope.

Upslope a narrow belt of debris, derived from the Framebuilt Reef Rim, generally separates the reef slope bioherms from the Framebuilt Reef Rim.

References

Ohlen, H. R. (1959): The Steinplatte reef complex of the Alpine Triassic (Rhaetian) of Austria. — Dissertation Univ. Princeton, 122 p., Princeton, N. J.

Piller, W. E.: The Steinplatte Reef Complex (Tyrol/Salzburg; Austria) — Part of an Upper Triassic Carbonate Platform. — Typewritten manuscript submitted for print to Society of Economic Paleontologists and Mineralogists, Tulsa.

Stop 2.9. Framebuilt Reef Rim North of Steinplatte Summit

H. ZANKL (oral communication 1976) created the term "Fischer's Coral Garden" (dedicated to Professor A. G. FISCHER, Princeton, N. J.) for the very impressive outcrops of dense reef framework formed by thick branching corals — mainly "*Thecosmilia*" *clathrata* form B (OHLEN, 1959). The irregularly shaped coral heads are situated on the border between the less declined uppermost reef slope and the carbonate platform sensu strictu and have dimensions up to a few cubic meters. They form a SW/NE-striking zone in some places more than 50 meters wide. The faunal diversity is very low compared to the Reef-Slope Bioherms (W. E. PILLER in press). The main sediment between the single reef knolls (in the surge channels — "grooves") is micritized reef-debris of arenitic to ruditic grain size together with micritized clasts derived from the zone of the back reef closest to the Framebuilt Reef Rim. (e. g. megalodont-hash and large involutinid foraminifera). In protected areas between the reef framework also pinkish and yellowish micritic sediments were trapped. Similar sediments with calcareous algae and the problematicum *Cheilosporites tirolensis* can also be found deposited in shallow pools in the back reef close to the Framebuilt Reef Rim.

References

OHLEN, H. R. (1959): The Steinplatte reef complex of the Alpine Triassic (Rhaetian) of Austria. — Dissertation Univ. Princeton, 122 p., Princeton, N. J.

PILLER, W. & LOBITZER, H. (1979): Die obertriassische Karbonatplattform zwischen Steinplatte (Tirol) und Hochkönig (Salzburg). — Verh. Geol. B.-A., **1979**, 171—180, Wien.

VORTISCH, W. (1926): Oberrhätischer Riffkalk und Lias in den nordöstlichen Alpen. 1. Teil. — Jb. Geol. B.-A., **76**, No. 1/2, 1—64, Wien.

WILSON, J. L. (1975): Carbonate Facies in Geological History. — 409 p., (Springer), Berlin — Heidelberg — New York.

Stop 2.10. Megalodontid Limestone of Steinplatte Back-Reef

The area from Steinplatte summit to the east and southeast and the summit itself belongs to the back reef (Steinplatte Limestone in back-reef facies). We shall visit outcrops with megalodontid pelecypods (*Conchodus infraliassicus*) and patch-reefs of "*Thecosmilia*" *clathrata* along Wieslochsteig. The sediments are dominated by bioclastic (arenitic to ruditic) limestones, generally the grains are micritized (micritic envelopes) or coated by micro-problematica. Besides corals, megalodonts, various echinoderms, calcareous algae (dasycladaceans), a foraminifera assemblage — dominated by involutinids — is characteristic.

The sediments of the eastern part of Steinplatte lagoon interfinger with the carbonate plateau of Loferer Steinberge. They show many different types of lagoonal sediments described by H. R. OHLSEN (1959), A. G. FISCHER (1964), H. GÖKDAG (1974), W. PILLER & H. LOBITZER (1979) and W. E. PILLER (in press).

Downhill from Steinplatte summit we follow a skiing-track east of Plattenkogel. In recently blasted excellent outcrops we can observe the same facies zonation of Steinplatte Limestone in the direction of the basin of the Kössen beds.

References

OHLEN, H. R. (1959): The Steinplatte reef complex of the Alpine Triassic (Rhaetian) of Austria. — Dissertation Univ. Princeton, 122 p., Princeton, N. J.

PILLER, W. E.: The Steinplatte Reef Complex (Tyrol/Salzburg; Austria) — Part of an Upper Triassic Carbonate Platform. — Typewritten manuscript submitted for print to Society of Economic Paleontologists and Mineralogists, Tulsa.

PILLER, W. & LOBITZER, H. (1979): Die obertriassische Karbonatplattform zwischen Steinplatte (Tirol) und Hochkönig (Salzburg). — Verh. Geol. B.-A., **1979**, 171—180, Wien.

En route we will make a short stop out of programme to have a look at the classic Jurassic sequence of "Unken syncline" which covers parts of the northern slope of Steinplatte-platform.

Kössen Beds seem to continue without any disconformity into Jurassic "deeper water" — facies of Adnet beds on locality "Bäreck" (close to Kammerköhr-Gasthaus). A change of colour from grey to red more or less signals the transition into the Liassic.

References

GARRISON, R. E. (1967): Pelagic limestones of the Oberalm-beds (Upper Jurassic-Lower Cretaceous), Austrian Alps. — Bull. Canad. Petrol. Geol., **15**, 21—49, Calgary.

GARRISON, R. E. & FISCHER, A. G. (1969): Deep-water limestones and radiolarites of the Alpine Jurassic. — Soc. Econ. Pal. Miner., Spec. Publ. **14**, 20—56, Tulsa.

WILSON, J. L. (1969): Microfacies and sedimentary structures in "deeper water" lime mudstones. — Soc. Econ. Pal. Miner., Spec. Publ. **14**, 4—19, Tulsa.

Acknowledgements

Data concerning Steinplatte carbonate platform/basin-complex generally are part of a joint field programme carried out together with Dr. W. E. PILLER (Inst. of Paleontology, Univ. Vienna). Dr. E. KRISTAN-TOLLMANN (Vienna) did a very comprehensive study on the microfauna of Kössen Beds from excursion stop 2.4. and discussed the paleogeographic implications. The idea to restudy the paper by H. R. OHLEN (1959) was born on an excursion to Steinplatte, performed together with Dr. G. SCHÄFFER (Vienna) and Dr. W. SCHÖLLNBERGER (Houston). Last but not least I thank Prof. H. ZANKL (University of Marburg) for stimulating fieldtrips and discussions.

Day 3

Mid-Triassic Carbonate Platform Margin. Wetterstein Reef Limestone north of Innsbruck, Tyrol

by

RAINER BRANDNER and WERNER RESCH

with figures 5—8

Introduction

Upper Triassic and Mid-Triassic of the Northern Limestone Alps show a common affinity to closely-spaced facies patterns formed by isochronous platforms alternating with basinal facies. The facies development as investigated along the margin of such a platform (i. e. Wetterstein reef limestone) provides the major topic of this field trip which takes us to the well-exposed Hafelekar reef complex. This is a truly prominent representative of Mid-Triassic reefs in the Northern Limestone Alps.

Geological setting and stratigraphy

The target of this field trip is the Nordkette range to the north of the city of Innsbruck. The range runs along the southern border of the Northern Limestone Alps (Upper Austroalpine) which form an intricately structured pile of nappes thrust onto the Northern Flysch Zone. The strata of principal concern are located in the highest structural unit of the western part of the Northern Limestone Alps (Inntal nappe). In reversing the process of alpine tectonics, one arrives at the conclusion that there existed in the Mid-Triassic a pattern of longitudinal platforms and basins.

The Triassic sequence in the western part of the Northern Limestone Alps features a cyclical formation (see fig. 5) of three carbonate platforms (Steinalm limestone, Wetterstein limestone, and Hauptdolomit-Dachstein limestone). Their common feature is a slow buildup followed by an abrupt ending. Favorable conditions for lime-secreting organisms in basinally exposed regions of platform margins made for speedy and massive accumulation of carbonate material. The three platforms are linked with basinal sediments (Reifling beds, Partnach beds, Hallstatt beds) through interfingering patterns. Large areas show an abrupt ending of platform buildups. Block faulting tectonics and sea level changes caused sudden irregular changes in the course of sedimentation.

Regressive tendencies are a dominant feature of the Mid-Triassic platform basin assemblage. In the Cordevolian, the adjacent basins of argillaceous Partnach beds give way to growing Wetterstein limestone platforms. Prograding reefs are increasingly superimposed by evaporitic lagoon sediments of central platform parts. Such regressive tendencies climax in pre-Raibl regression, a frequent occurrence in the Tethys area, i. e. emersions of large platform sections and simultaneous block faulting tectonics. A rejuvenation of hinterland reliefs is followed by terrigenous clastic facies of Raibl beds. The long-range effects on the shelf area of this tectonic phase, as well as sea level changes, may be traced to rifting activities in the southeast, i. e. Turkey and Cyprus.

Reef development along the Innsbruck Nordkette range

The platform margin of the Wetterstein Limestone north of Innsbruck was repeatedly affected by such tectonic events and by sea level changes. They proved to be decisive factors in reef formations along the gentle slope, their forms and size. Generally, there are two distinct types of reef formation (fig. 8A): Patch reefs ("Knoll reefs", sensu WILSON) in the lower part of the slope (1), and extensive reefs along the platform margin (2).

Patch reef growth developed in the lower parts of the slope in an area of transition. Their down-slope limits were imposed by deeper water; their up-slope was limited by increasing accumulations of debris from the shallow-water reef margin.

This area of transition shows significant effects of relative sea level changes — all of them detrimental — on the growth of patch reefs. Increasing depth of water halts the growth of patch reefs because they are "drowned" and their framework is super-imposed by basinal sediments. Shallowing has a stimulating effect on patch reef growth — but only to the point where debris produced by prograding shallow-water reefs along the margin invades the area of patch reefs and stifles their growth.

The patch reef sequence, some 200 meters thick, shows evidence of recurrent developments as outlined above. Eventually the generally regressive sequence arrives at the shallow-water reef along the Hafelekar platform margin.

The Hafelekar reef complex signifies the first massive reef development along the Nordkette range. Apart from local complications due to synsedimentary tectonics along the margin of the platform, the reef shows differentiation in the forereef and central reef area with a zonal pattern of a reef front and a wide reef flat as a result of varying water turbulence and food supplies. The main barrier between the reef and the hypersalinar lagoon in the north was formed by sand shoals which show tepee structures and symptoms of vadose diagenesis. To the east the reef belt disintigrates. Its wedge is clearly visible in fig. 6 A. The consequently required passage in the reef girdle may have been caused by a similar inlet in the sand shoal barrier. This may have caused the exit of hypersaline, low nutritious water from the lagoon, thus prompting a drastic reduction of the reef growth rate.

The Nordkette forereef features a gentle slope of limited extent. Nowhere in the Northern Limestone Alps is there a so-called "Übergußschichtung" comparable to the contemporary Dolomite reefs. The angles of inclination of massive beds of breccia and of the reef itself show only a slight difference.

The early stages of reef growth coincide with a decrease in the rate of deposition of block rubble. Fine sand was locally entrapped by scattered small coral heads, *Tubiphytes* and calcisponges. In the central reef area the reef structure is remarkably homogenous over long stretches. The reef structure consists of an organic framework and interstitial grainstone. Significantly, there are no deposits of mud. Fields of coarse rubble are interspersed with these homogenous reef structures. The primary framework consists mainly of corals, hydrozoans, calcisponges and *Tubiphytes*. The prime function of *Tubiphytes* lies in their capacity as framebuilders in calm-water zones as well as encrusting organism in areas of strongly agitated water.

Dasycladaceae are practically non-existent in contrast to the Wetterstein limestone lagoon which accommodates masses of various Dasycladaceae. Spongiostromata algae dominate the reef flat as sediment-binding organism which is known to have determined the location of large quantities of fine-grained sediment.

The pattern of distribution of assemblages of reef-building organisms shows dependance upon water energy. Reef space exposed to water energy is populated by massive forms of corals, calcisponges and hydrozoans, whereas sheltered reef zones offer refuge to thin-branched corals, catenulate sphinctozoans, dendroid *Tubiphytes* and to a certain type of codiaceans. A generally simple pattern of ecological zones attests to a smooth course of biotopical adaption of reef organisms. The same applies to foraminifers and other microfossils.

Reef stabilization is achieved by the cementing effects of encrusting organisms, mainly *Tubiphytes*, as well as rapid submarine cementation. Recurrent reworkings and cementations led to a coarsening of particles. Strong currents prevented the formation of mud deposits. All these factors created enormous pore volume, often ex-

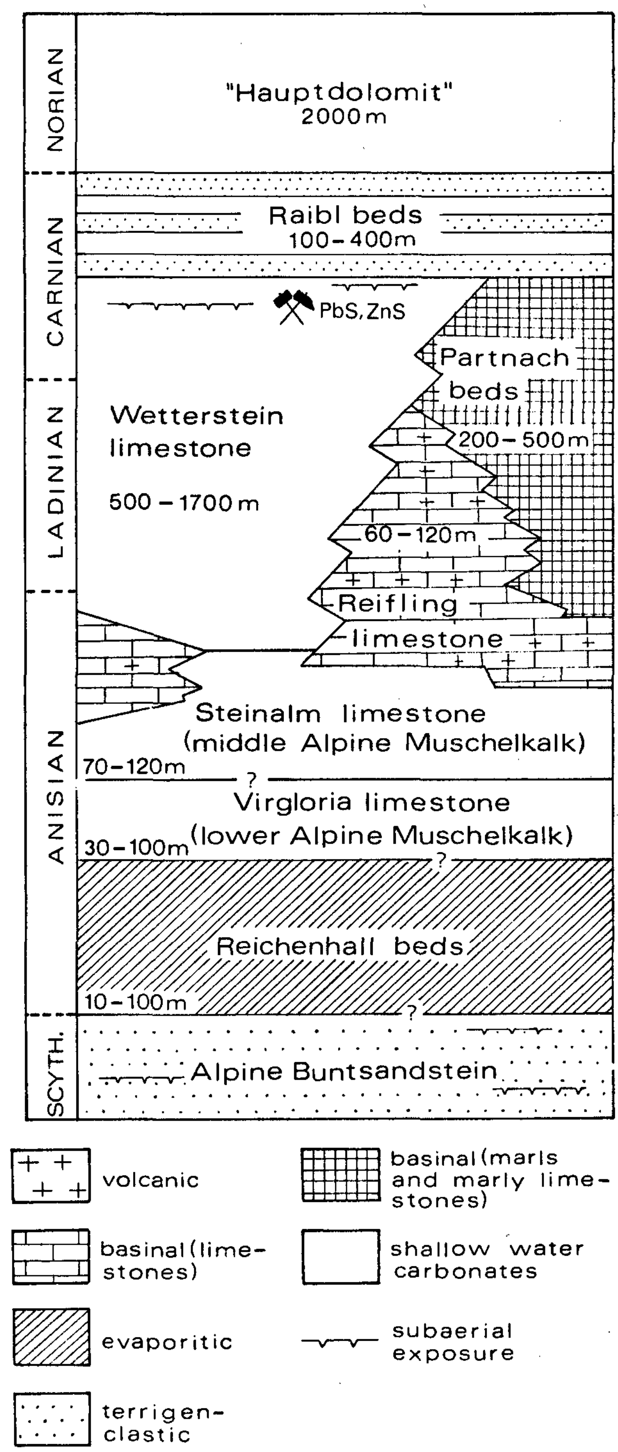


Fig. 5: Stratigraphic relationships and general facies pattern in the western part of the Northern Limestone Alps. Modified after BECHSTÄDT et al. (1978).

ceeding 50 per cent, which was later filled with fibrous spar. In the low burial stage, hyper-salinary water from

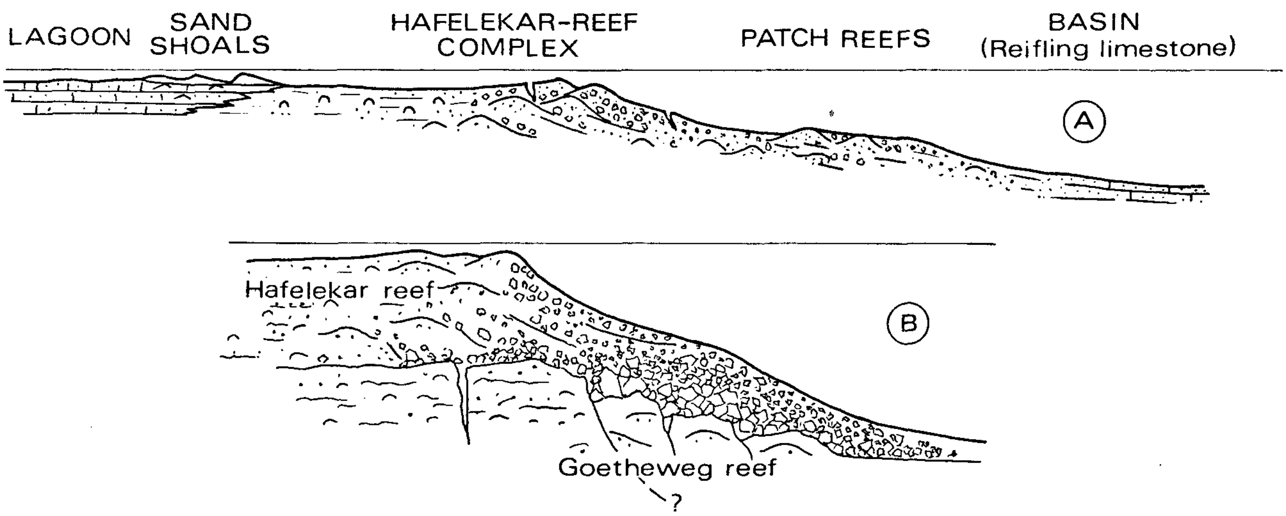


Fig. 6: Reef development at the edge of the Wetterstein limestone platform near Innsbruck. A — Stratigraphic modell showing two different reef configurations on the gentle slope. Patch reefs grow above or below wave base Note the gradual transitions of the wide facies belts. B — In the Cordevolian the regressive reef development was disturbed by block faulting tectonics, causing a steepening of the slope and a collapse of lithified reef rock.

lagoonal areas seeped into permeable reef areas to prompt early dolomitization according to primary structures. This early diagenetic lagoonal influx points also to a subsequent main cementation phase in which thick ?aragonite coatings were accumulated in cavities to alternate with dolomit layers (= so-called "Großoolith").

The platform margin was a zone of permanent tectonic activity. Blockfaulting tectonics become evident from neptunian dykes and megabreccias as well as irregular subsidence. Accelerated subsidence caused the reef

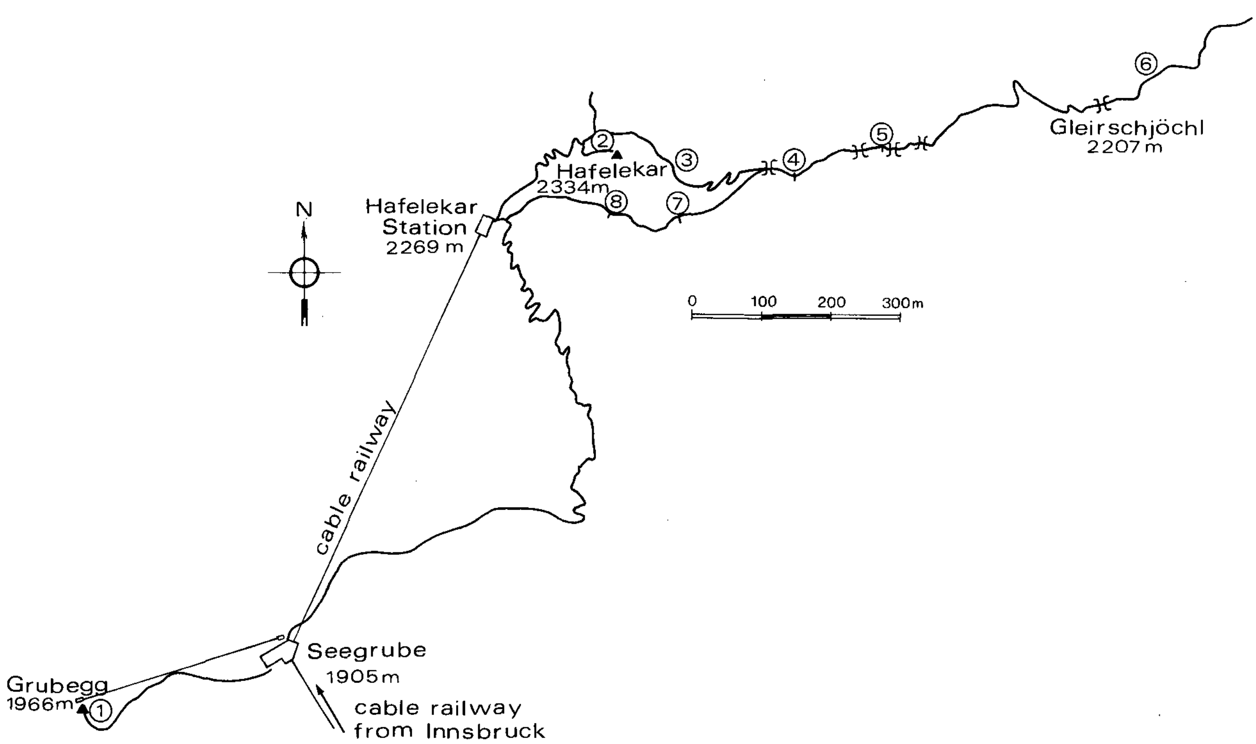


Fig. 7: Excursion route in the surroundings of Innsbruck.

body (Goetheweg reef), previously cemented, to submerge and disintegrate into blocks of several meters in diameter. This in turn re-created a forereef position in the general regressive sequence. The self-supporting block framework left open pore space and fissures several meters long and decimeters wide. A relief filling of tens of meters of block rubble was required to allow the new reef growth of the Hafelekar reef (fig. 8 B).

Route (fig. 7): From Innsbruck short bus drive on the hillside road up to Hungerburg (868 m). On the wayside a abondoned quarry, situated in the famous Hötting breccia, a reddish thick bedded building-stone of Pleistocene interglacial position.

From Hungerburg by cable railway to the station Seegrube (1905 m) on the Nordkette range, north above Innsbruck.

(Note: All the excursion moves in a nature reserve).

Stop 3.1. Grubegg (1966 m) W of Seegrube cableway station

Walking westward along a Late Würmian moraine deposit subsequently we pass outcrops of lower Anisian Reichenhall beds, a cyclic sequence of arenitic limestones, laminated dolomites and evaporitic cavernous breccias. Reichenhall beds locally are superimposed by interglacial slope breccias (Hötting breccia).

From Grubegg view of Innsbruck and the Central Alps in the south. Ahead the Sill valley with the "Europabrücke", leading the motorway to the Brenner Pass and to Italy. East of the mentioned pass the Zillertal Alps (western end of the Tauern window; Penninic nappe system) and nearer to us the area of the Innsbruck quartz-phyllite (Lower Austroalpine system) of the Tux Alps. West of the Brenner Pass the Stubai-Ötztal Alps, a crystalline nappe of the Middle Austroalpine system, partially covered by Permo-Mesozoic sediments of the so-called Brenner Mesozoic. The Inn valley and the Sill valley — both following important fault zones — are lined by Late Pleistocene gravel terraces, often with cores of much older rocks.

Looking to the east one can see the southern slope of the Hafelekar summit, showing a northward dipping sequence from the Anisian (Reichenhall beds, Steinalm beds, Reifling beds) to the Ladinian-Cordevolian Wetterstein limestone.

Back to Seegrube and by cablecar to the Hafelekar station.

Stop 3.2. Hafelekar summit (2334 m) Central reef area and reef flat of the Hafelekar reef

From Hafelekar station (2269 m), short ascent to the Hafelekar summit. On the way Wetterstein limestone of a distinctly reef influenced facies; the occurrence of cephalopods in this marginal reef limestone is conspicous.

Brief introduction to the Middle Triassic reef development in the excursion area. View to the north and to the east: Karwendel mountain ranges with well bedded Wetterstein limestone of lagoonal facies.

Immediately west of the Hafelekar summit the initial stage of the Hafelekar reef is placed on top of a block rubble sequence. Scattered catenulate spinctozoans, inozoans and corals are embedded in layered arenitic reef debris.

On a short trip to the north the central reef area and the reef flat facies can be studied. At the weathered surface of the massive beds of the central reef a very rich framebuilding fauna is preserved (*Holocoelia* sp., bladed hydrozoans, cylindrical Inozoa, diverse corals etc.). Growth-cavities (∅ up to dm) are filled by alternating layers of fibrous spar. The reef flat is characterized by layered arenitic reef detritus with cavities (?genesis), similar to sheet cracks, filled by fibrous spar and sometimes by sediments of geopetal fabrics. Early dolomitization of parts of the reef limestone is mainly concentrated on areas of primary porosity. As inhabitants of the reef flat environment more frequently were observed: sphinctozoans, ?Squamariacea, small corals heads.

Stop 3.3. Eastern slope of the Hafelekar summit; Interfingering of Hafelekar reef and coarse rubble breccia

Along the way different reef communities can be studied; remarkable are large solenoporaceans with *Tubiphytes* (fig. 8 B) and the occurrence of cephalopods in a marginal reef position.

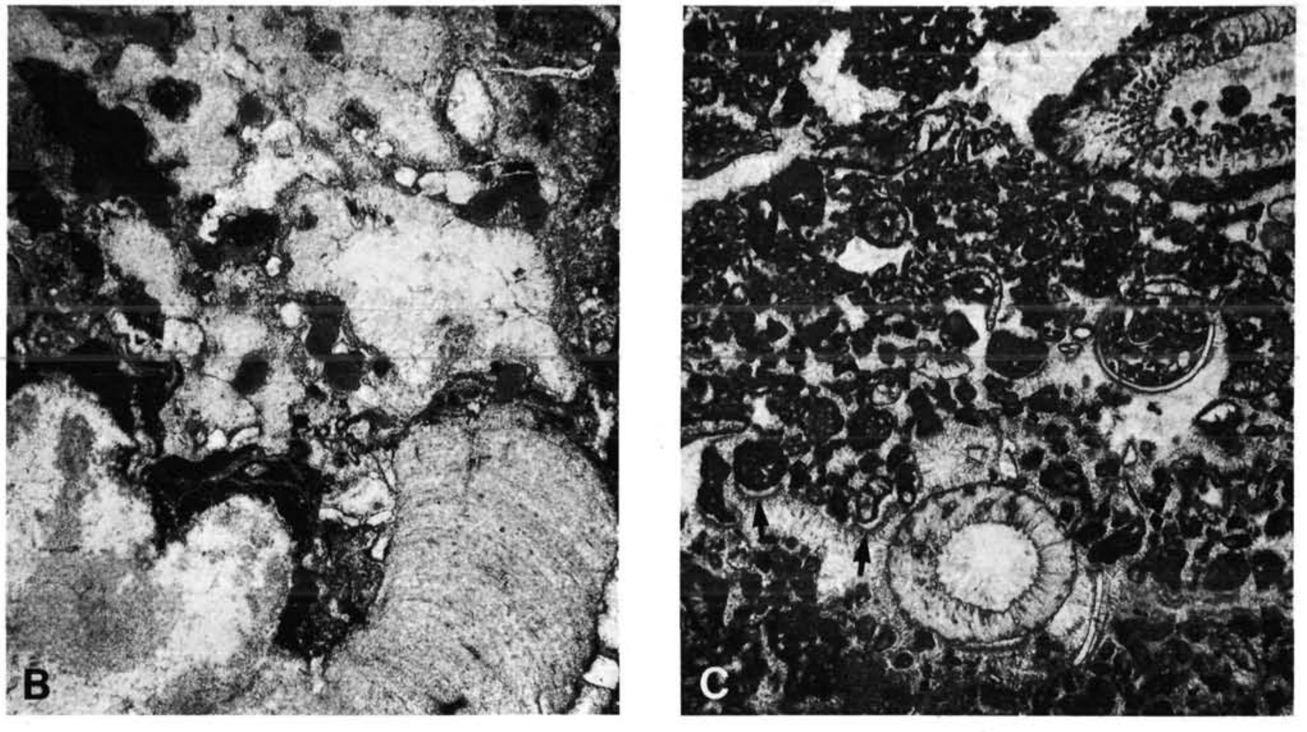
Stop 3.4. Goetheweg; Exposure of reef-front facies

After a short descent to the "Goetheweg" we pass by a gap in the crest; note here an outcrop of coarse reef breccia with pockets of basinal filament limestone. On the Goetheweg, further to the east we reach the underlaying Goetheweg reef. An exposure of reef front facies is represented by a corals-echinoderms-*Tubiphytes* community (heads of *Thecosmilia, Montlivaltia,* massive platy thamnasteriids, thick crinoid stalks, large pelecypods et.). The rubble of broken and highly diversified framebuilders and reef dwellers is mainly cemented by *Tubiphytes.*

Stop 3.5. Goetheweg; Tubiphytes boundstone

Some 150 meters eastward, more or less along the strike of the Goetheweg reef, an outcrop of sheltered reef facies with *Tubiphytes* boundstone can be studied. *Tubiphytes obscurus* Maslov, here predominantly growing as a ramifying type, is believed to be a bluegreen alga. As an encrusting organism, *Tubiphytes* is to be found in nearly the whole central reef.

Fig. 8: A — Oblique aerial view of the Nordkette range north of Innsbruck with reef facies in the Hafelekar area (arrow: wedging-out of the Goetheweg reef) and the well bedded lagoonal facies. Some large patch reefs are exposed in the lower part. x-marks: exposures of types of reefal and lagoonal facies as shown in B and C. B— Marginal facies of the central reef. Framework of solenoporaceans encrusted by *Tubiphytes* (black) and *Ladinella* (grey); growth-cavity filled by fibrous spar and blocky calcite. N 186; thin section 4,5x. C — Lagoonal facies adjacent to backreef area. Grainstone with *Teutloporella herculea*, gastropods, grapestone lumps, etc. Typical signs of vadose diagenesis (arrows: dripstone cement). N 198 b; thin section 4,4 x.



Stop 3.6. Goetheweg; Lagoonal facies E of "Gleirschjöchl"

Crossing hanging parts of the Goetheweg reef, its reef flat facies and overlaying breccias of the prograding Hafelekar reef, we reach the "Gleirschjöchl" (2207 m) which is coinciding with a N-S striking fault. On the saddle, traces of transfluence of ice of the Inn valley glacier (Pleistocene glaciation). Immediately east of the "Gleirschjöchl", lagoonal facies of the Hafelekar reef complex: Well bedded sequence of graded grainstones with remarkable thick dasycladaceans, chiefly *Teutloporella herculea* (STOPP.) (fig. 6 C) and masses of fragments of "*Zonotrichites*" (?blue-green algae). Rapid cementation, partly vadose and different compaction caused an early diagenetic fracturing (sheet cracks, etc.). Note red colored siltitic to micritic internal sediments in cavities and fissures. Further to the east typical loferites are intercalated with massive beds of mudstone with signs of evaporation ("Messerstichkalke").

Stop 3.7. Goetheweg; Codiaceae biocoenose in the Goetheweg reef

Going back on the Goetheweg, finally we cross the southern slope of the Hafelekar summit with different biocoenoses of the Goetheweg reef. A biocoenose, characterized by the crowded occurrence of algal tufts is remarkable because of its similarity to *Tubiphytes* biocoenose. The tufts, up to 15 cm high and preserved in growth position are supposed to be a new codiacean species. In the wave protected environment certain foraminifers (e. g. thin-walled Lituolacea species) are typical.

Stop 3.8. Goetheweg; Megabreccia with very large "Großoolith" structures

Synsedimentary tectonic activities caused the disintegration of the Goetheweg reef body and probably the formation of a submarin cliff (see fig. 8 B). The cavities of the megabreccia, up to several meters long and decimeters wide, are filled with thick layers of fibrous spar (calcite, partly dolomite). Remaining central voids are filled with blocky calcite crystalls ore remained open to this day as primary voids.

If there is time enough, a sequence of the lower Mid-Triassic can be studied along a path downslope Hafelekar summit to the Seegrube station.

Selected References

BRANDNER, R. and RESCH, W.: Reef development in the Ladinian and Cordevolian of the Northern Limestone Alps near Innsbruck, Austria. — In: European Fossil Reef Models (ed. TOOMEY, D. F.). — Spec. Publ. Soc. Econ. Paleont. Mineral., (in press).

DONOFRIO, D. A., HEISSEL, G., and MOSTLER, H. (1979): Zur tektonischen und stratigraphischen Position des Martinsbühel bei Innsbruck. — Geol. Paläont. Mitt. Innsbruck, 7, 1—43, Innsbruck.

HEISSEL, G. (1980): Karwendel — geologischer Bau und Versuch einer tektonischen Rückformung. — Geol. Paläont. Mitt. Innsbruck, 8, 227—288, Innsbruck.

HEUBERGER, H. (1975): Innsbrucker Nordkette. Forstprobleme und Lawinenschutz, Trinkwasserversorgung, Höttinger Breccie. — Innsbrucker Geogr. Studien, 2 (Tirol. Ein Geographischer Exkursionsführer), 43—65, Innsbruck.

OTT, E. (1973): Mitteltriadische Riffe der Nördlichen Kalkalpen und altersgleiche Bildungen auf Karaburun und Chios (Ägäis). — Mitt. Ges. Geol. Bergbaustud., **21/1**, 1972, 251—275, Innsbruck.

SARNTHEIN, M. (1965): Sedimentologische Profilreihen aus den mitteltriadischen Karbonatgesteinen der Kalkalpen nördlich und südlich von Innsbruck. — Verh. Geol. B.-A., **1965**, 119—162, Wien.

Topographical maps:

Österreichische Karte 1 : 50.000, Nr. 118 Innsbruck (and Nr. 148 Brenner). Umgebungskarte Innsbruck 1 : 25.000.

Geological maps:

Geologische Spezialkarte der Republik Österreich 1 : 75.000, Nr. 5047 Innsbruck und Achensee. — Geol. B.-A., Wien 1912 (O. AMPFERER and T. OHNESORGE).

Day 4—9

The Southern Limestone Alps of Italy

by

ALFONSO BOSELLINI

with figures 9—23

Introduction *)

The Southern Alps of Italy preserve — almost intact — a cross section of a Jurassic passive continental margin (figs. 9 and 10), where one can see in the details of the stratigraphy the history of progressive foundering and drowning of the margin as a small oceanic basin was being created to the west, between the Southern Alps (Apulian Plate) and the French Alps (European Plate). The unique quality of the region is that since

*) This introduction is largely from a paper by E. L. WINTERER and A. BOSELLINI, in press.

Jurassic times it has remained a more or less stable block, a kind of quiet tectonic island in the maelstrom of alpine tectonics. The rocks are only mildly deformed by folding and faulting and the region has not been caught up in the large nappes that telescope most other alpine areas; thus a map of present-day facies patterns can be interpreted more less directly as a paleogeographic map, without major palinspastic correction.

During Permian and Triassic times, following the Hercynian orogeny, the western part of the present-day Mediterranean region was part of a more-or-less coherent continental block comprising Africa, Europe and North America. Shallow continental seas covered parts of this continent and the Tethyan Ocean lay to the east. Localized Permian and Triassic block faulting, commonly accompanied by volcanism, fragmented the crust. In the Southern Alps Permian rifting and magmatism produced a strong NNE structural grain that controlled later Permian and Triassic differential subsidence rates. The rapidly subsiding Lombard Basin was filled with more than 5 km of shallow-water and non-marine Permian and Triassic sediments while on the adjacent highs the equivalent strata are only one or two km thick. Along the eastern margins of the region, close to the Tethyan Ocean, some of the Triassic rift basins became the sites of deep-water sedimentation, e. g., in the Middle Triassic in the Dolomites and during the Late Triassic in Greece, Yugoslavia and Austria.

During early Jurassic time, when the Central North Atlantic Ocean began to open, fragmentation of the Western Mediterranean region accelerated. Beginning in early Jurassic (Sinemurian) times, new rift basins were created, and in many of the older basins the subsicence rates increased. In these basins deep-water sediments, commonly in the form of limestone turbidites, replaced platform carbonates.

By the beginning of Middle Jurassic time, rifting and transform faulting had created deep-water corridors,

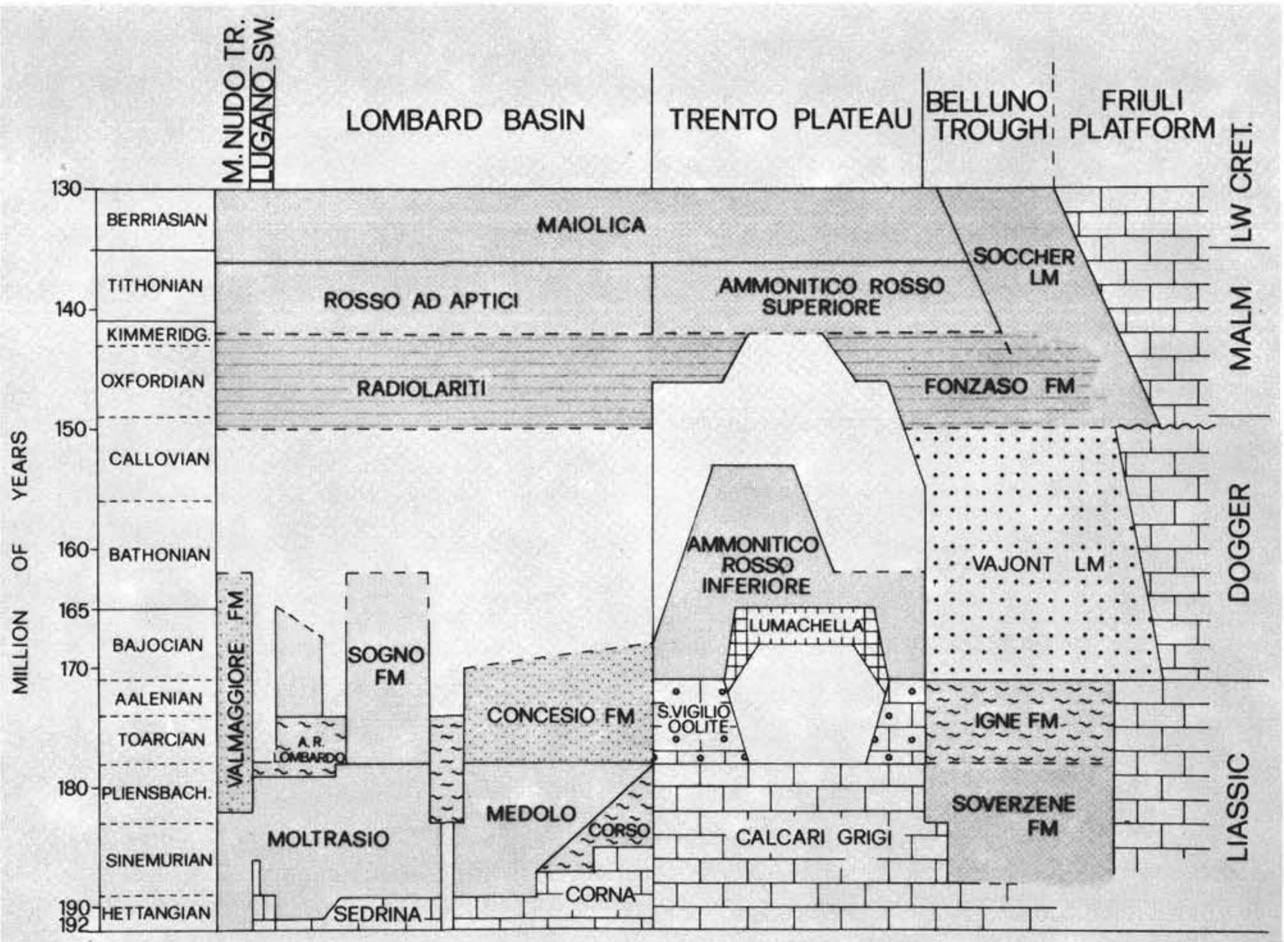


Fig. 9: Age relationships of lithologic units, Southern Alps. The extensive hiatus shown in the Lombard Basin during Bathonian-Callovian may not be real: strata between well dated Bajocian and Bathonian beds and Kimmeridgian beds do not contain diagnostic megafossils.

linked the early Atlantic to Tethys the Tethyan Ocean and had isolated several new lithosperic plates in what had formerly been a coherent block. And the Southern Alps became a sector of the north-west Apulian Plate promontory.

The life span of passive continental margins along the west edge of the Apulian Plate was essentially the Jurassic Period. The early Jurassic was a time of establishment of the rift system; during parts of Middle and perhaps late Jurassic times there was spreading in the new ocean basin, with the creation of oceanic crust; during the late Jurassic there was relative tectonic calm, with pelagic sedimentation; and finally at the close of the Jurassic the tectonic tide began to turn, causing a quickening of the pace of terrigenous sedimentation in the ocean basin, and perhaps a change in the controls on subsidence rates on the former passive margin.

The structural and paleogeographic situation at the beginning of the Jurassic consisted of four major blocks, with different subsidence rates, and having different Triasic and Permian stratigraphic sections. From east to west there are 1) the Friuli Platform, an area of moderate rates of subsidence (~ 130 m/m.y.); 2) the Trento Platform, underpinned by Permian acid volcanic and hypabyssal rocks, and having a relatively slower rate of subsidence (~ 50 m/m. y.); 3) the Lombard Basin, where subsidence rates were mainly very rapid (~200—300 m/m. y.): and 4) Arbostora Swell, also underlain by Permian volcanic rocks, and having slow subsidence rates, comparable to the Trento Platform area. Farther west, in what is now a tectonically very disturbed zone, there was very likely a slightly emergent region: Triassic strata thin toward this area from both the east and the west.

During early Jurassic times, rifting fragmented the crust even further, and some formerly shallow areas subsided rapidly enough to carry them into relatively deep water, that is, out of the photic zone and into

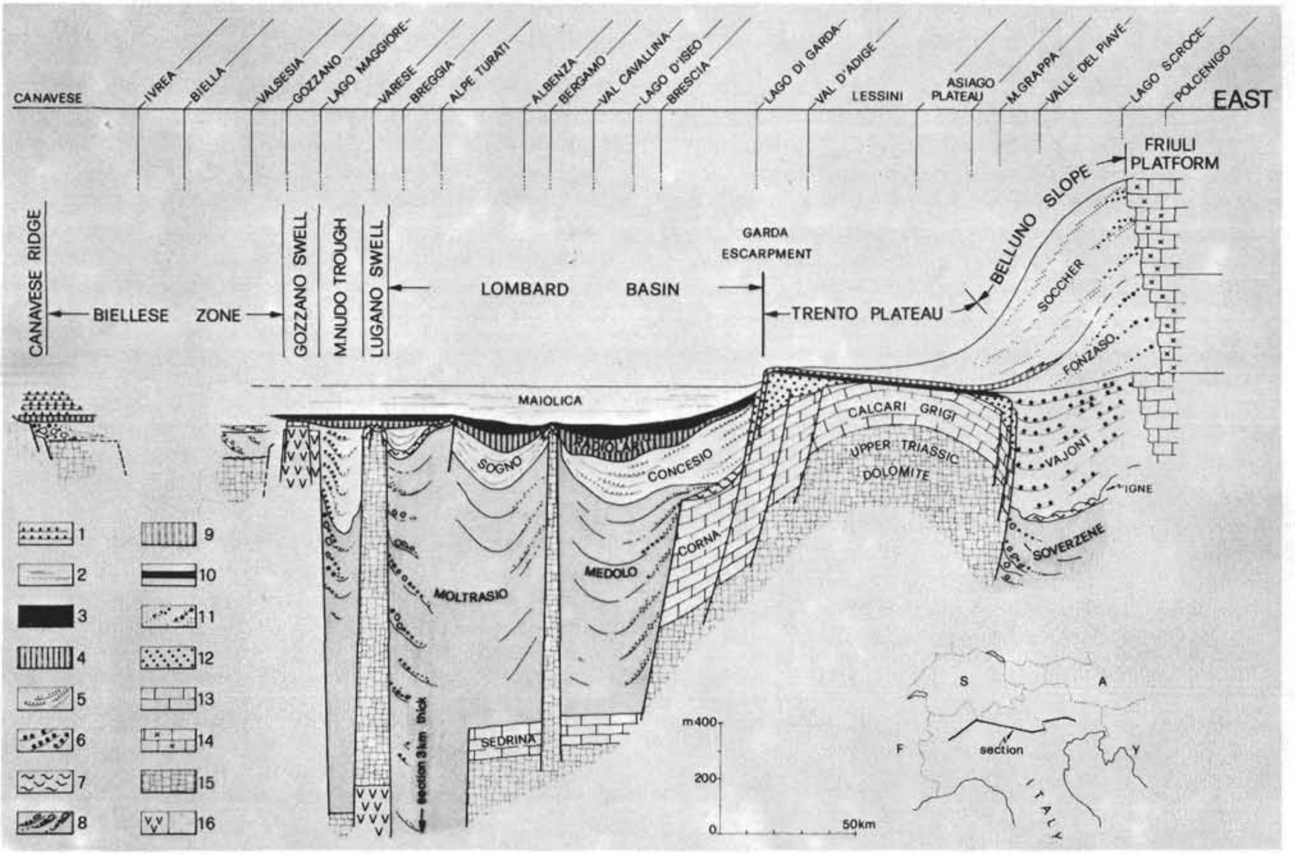


Fig. 10: Lithologic units in the Southern Alps, shown in their relative thicknesses. The Moltrasio Limestone is about 3 Km thick at Breggia. Lithologic symbols: 1, calcareous flysch; 2, calpionellid limestone and bioclastic turbidites; 3, aptychus limestone; 4, radiolarite; 5, bioclastic turbidite and basinal limestone; 6, oolithic turbidites and debris flows; 7, red nodular limestone (Toarcian); 8, basinal limestone; 9, red nodular limestone (Malm); 10, red nodular limestone (Dogger); 11, siliceous basinal limestone and bioclastic turbidites; 12, oolitic limestone; 13, platform limestone; 14, reef limestone; 15, Triassic platform carbonates; 16, Permian volcanics and granite.

water deep enough for turbidity currents to be an important process of sediment transport. The earliest collaps of former carbonate platform areas took place during the middle and late Hettangian, in the westernmost part (Monte Generose Trough) and the northeastern part (Sebino Trough) of the Lombard Basin. During the next few million years, during the Sinemurian, not only did most of the rest of the Lombard Basin area also subside rapidly into deep water but other platform areas outside the Basin foundered. To the west, the Monte Nudo Trough formed west of the Lugano Swell, between Lakes Maggiore and Lugano, and far to the east, the Belluno Trough began to form, between the Trento Platform and the Friuli Platform.

The rapid subsidence was probably mainly between faults, which may be listric, i. e., flattening with depth. The presence of very coarse debris along the margins of the basins suggests steep slopes during the early Liassic; indeed, some of the same slopes were reactivated in later Liassic times as mappable syngenetic faults. The fault blocks commonly show erosional gaps and an asymmetry in their stratigraphy that may be due to rotational movements.

Detailed studies by CASTELLARIN (see description of Day 7) along the syngenetic fault system that separated the Trento Platform from the Lombard Basin, show that the faults were active in the Hettangian and Sinemurian, and during Pliensbachian time the fault zone widened, with the activation of new normal faults a few kilometers back of the edge of the Platform.

Large masses of submarine slide breccia occur next to the syngenetic faults between the Lugano Swell and the Monte Generoso Trough, and near the faults between the Trento Platform and the Belluno Trough.

The early and Middle Liassic history of the remaining platform areas — the Trento Platform and the Friuli Platform — is straightforward. On the Trento Platform, peritidal limestones (Calcari Grigi) were widespread in the early Liassic, and during the Middle Liassic, a rim of oolite barrier bars protected a large lagoonal complex in which the huge pelecypod *Lithiotis* thrived, and in which coaly deposits formed. Peritidal limestones probably accumulated during most of this time on the Friuli Platform.

Late Liassic (Domerian-Toarcian) facies record a special turning point in the history of drowning and foundering of the Southern Alps. In the basins in the western part of the area (the Monte Nudo Trough and the western part of the Lombard Basin) and in the Belluno Trough, accumulation rates abruptly slowed from hundreds of meters to less than ten meters per million years, and red or greenish nodular limestones and marlstone (Ammonitico Rosso Lombardo and Igne Formation) commonly replaced the grey cherty marly limestone.

On the Trento Platform, the late Liassic is represented by an outwardthickening wedge of cross-stratified oolite around the rim of the Platform, but the northern part of the Platform (Dolomites) was already sunken by that time: by a very condensed section of pelagic limestone with Toarcian-Aalenian ammonites occurs there. A hardground, with ferromanganese crusts and nodules separates the oolitic from the pelagic facies. In the southern interior part of the Platform, no sediments of latest Liassic and early Dogger age are preserved. Whether this is due to emergence, as suggested by STURANI (1971) or to drowning of the platform and by-passing of sediments by currents is not clear; but the next sediments of Bajocian age, above the unconformity are of pelagic facies. We lean to the view that during the late Liassic there was rapid drowning of the Platform (wich become now a submerged Plateau) except for a belt close to the rim, which was kept in shallow water by rotational movements on the faults bounding the Plateau.

During Middle Jurassic (Dogger) time, the locus of rapid sedimentation shiftet eastward. From the Friuli Platform, which had remained continuously a region of shallow-water carbonate accumulation, great submarine oolite fans (Vajont Formation) prograded westward into the Belluno Trough (see Day 5), reaching a thickness of about 1000 meters in one lobe. The fans originated on a steep (faulted ?) slope to the east and they terminate westward against the faulted edge of the Trento Plateau. Building of the fans decreased the relief across this fault scarp toward the north, so that finally the uppermost beds of the oolite fan spilled over the escarpment onto the edge of the plateau, where they interrupted the slow accumulation of red nodular limestones there.

On the plateau, the Middle Jurassic was a time of subsidence of an already drowned platform. Above a karst-like surface, locally encrusted with manganese, there accumulated a thin (0—10 m) formation of red nodular limestone (Ammonitico Rosso Inferiore), locally containing small "stromatolitic" mounds, but completely lacking in shallow-water fossils. Ammonites, belemnites, pelagic bivalves, foraminifers and echinoderm ossicles are the metazoan remains, while nannofossils and variable amounts of hematite-stained illite make up the matrix.

To the west, in the Lombard Basin, thin turbidites (Concesio Formation) continued to fan out westward from the escarpment at the west edge of the Trento Plateau, but no big submarine slides occurred. The debris in the resedimented beds is different from that in the underlying Liassic turbidites, consisting mainly of pelagic bivalves and echinoderm ossicles rather than of oolites and shallow-water fossils. Westward, similar resedimented limestones, commonly rich in radiolaria, accumulated in the troughs of the Lombard (Sogno Formation) and Mt. Nudo Basins (Valmaggiore Formation), while ammonite-rich marls were deposited on the highs.

For the remainder of the Jurassic, slow pelagic sedimentation prevailed over most of the region. On the Friuli Platform, shallow-water limestone, including reefs, continued to accumulate (Monte Cavallo Formation), and debris from this platform continued to spill west into the Belluno Trough (Fonzaso and Soccher Formations). In the Lombard Basin and over the Trento Plateau, the succession of Upper Jurassic pelagic facies (radiolarite — aptychus limestone — nannofossil limestone in the Basin; and aptychus limestone — red nodular limestone — nannofossil limestone on the Plateau) record changing oceanographic conditions (i. e. currents, dissolution levels, fertility) rather than subsidence history.

No record of syngenetic faulting is given by upper Jurassic facies: pelagic facies can be traced right up to the old Garda Escarpment without change in thickness, and pelagic formations drape against, and finally over all the former horsts such as the Lugano Swell and the Monte Cavallo Ridge. It was a time of relative tectonic calm, although it is plausible that slow subsidence continued.

During the latest part of the Jurassic, the Tithonian, there was a change over both the Lombard Basin and Trento Plateau to accumulation of nearly white nannofossil limestone containing calpionellids and radiolarians, and commonly studded with gray replacement chert nodules (Maiolica, Biancone Formation). The bedding is slightly wavy, and stytolitic boundaries are common. Clay is rare. Virtually no sorting effects by currents are visible, but burrow mottles are common — indeed some of the chert nodules appear to be replaced burrows. We interpret this formation to reflect a general slowing of bottom currents and a large (~ 1000 m) and fairly rapid deepening of the CCD at about the beginning of the Tithonian.

Early Cretaceous time saw the rejuvenation of faulting along the old Garda Escarpment, as evidenced by submarine slide breccias intercalated in pelagic nannofossil limestone near the base of the escarpment, and detachment scars left as hiatuses at the top of the escarpment. Sliding recurred repeatedly throughout the entire Cretaceous period along this line.

Elsewhere, sedimentation during Early Cretaceous times continued the pattern of the latest Jurassic: pelagic nannofossil limestone (Maiolica and Biancone Formations) continued to be deposited all the way from Lake Maggiore to the east edge of the Trento Plateau. Reef limestones still accumulated on the Friuli Platform, and resedimented shallow-water debris, along with both in situ and resedimented pelagic material, formed a slope between the deep (probably ~ 1200 m) Trento Plateau and the Platform.

In the middle Cretaceous, black shale was deposited over parts of the Lombard Basin, but by this time the paleogeography had begun to change significantly. The old Jurassic depositional troughs, oriented more-or-less north-south, were replaced with a set of troughs trending more east-west and into these new troughs poured huge thicknesses of terrigenous turbidites, derived mainly from the north from areas uplifted during the closing of the narrow oceanic basins between the Apulian and the European Plates. The passive margin that existed during most of the Jurassic thus probably ended its "normal" evolution at the end of the Jurassic and began to be destroyed during the Late Cretaceous, even though pelagic sediments (Scaglia Rossa) continued to accumulate in protected areas, away from the influence of turbidity currents.

In resumé, the subsidence history begins in the Permian, when the basic pattern of plateaus and basins was set. From here on until the final filling and reorientation of the basins in Late Cretaceous time, the facies and thickness patterns reflect the old morphology. Differential subsidence was greatest during the early and middle Liassic, when deep-water conditions first appeared in the Lombard Basin and Belluno Trough and huge thicknesses of calcareous turbidites poured in, fed from vigorous carbonate platforms on the Arbostora Swell, the Trento and the Friuli Platforms. Final drowning of the Arbostora Swell occurred in the late Liassic and of the Trento Platform in the early Dogger. From here on, subsidence continued but sedimentation was slow everywhere except next to the still-thriving Friuli carbonate platform.

Day 4

Route: Innsbruck — Brenner Pass — Cortina. From Brenner Pass, along the Isarco Valley, through the Tauern window (i. e. the Penninic metamorphic complex with ophiolites) to Mules. From there, entering into Southern Alps, through the Paleozoic Brixen granite and through the metamorphic phyllitic basement to Ponte Gardena (Waidbruck). Turning east along the Gardena Valley, through the Permian ignimbrites, at Ortisei (St. Ulrich), we enter into the Dolomites with their famous and spectacular Triassic peaks.

Introduction to Middle Triassic Geology of the Dolomites

The Alpine region in general was subjected to the Hercynian Orogeny during Carboniferous time; large parts of it were subsequently upliftet and eroded. In the Southern Alps, the seas transgressed from the east during the Late Permian and earliest Triassic, starting a new sedimentary cycle. The sedimentary sequence of the Dolomites lies, therefore, on a peneplaned metamorphic basement and begins with Middle Permian continental deposits (alluvial fan conglomerates, fluviatile sandstones arranged in point bar sequences, fining upward to flood plain siltstones) with a variable thickness of 50—200 m. In the Western Dolomites a thick slab (up to 1500 m) of prevalently rhyolitic and rhyodacitic ignimbrites underlies the Permian alluvial sediments. Transitional rocks (evaporites, black shales, dolomites) and marine sediments (micritic skeletal limestones) of Late Permian age follow upward in the section. The Lower Triassic (Werfen Formation) overlaps the Permian sequence and is represented by marine sediments of very shallow depth and by tidalites.

In response to basement black faulting, large areas of the Dolomites were uplifted and underwent severe subaerial erosion during Anisian time. Following the subsequence transgression, and under the control of the still active synsedimentary tectonics, several Anisian carbonate bodies and related basinal sediments set up.

The overlying Ladinian and Carnian sediments are characterzied by a great variety of facies (fig. 11). Thick carbonate bodies, the socalled "reefs", of relatively restricted extent, are surrounded and in some places covered by volcanics, clastics, and dissimilar carbonate sediments. The central part of these carbonate bodies lies directly on the Anisian carbonate platforms but a sequence of cherty micritic limestones (Buchenstein Formation) separates the peripheral parts of the blocks from the underlying Anisian shelf. Between the carbonate bodies this same basinal Buchenstein Formation is directly covered by volcanics. The interreef basins were dumped with a huge pile of pillow lavas, pillow breccias and hyaloclastites up to 1000 m thick.

A major rifting phase occurred with the beginning of submarine basaltic eruptions. Pronounced fault scarps developed along the margins of some carbonate platforms, triggering huge gravity displacements. Admixtures of volcanic and sedimentary materials, including thick and large uprooted sedimentary slabs, occur mostly as sliding assemblages of late Ladinian age. These chaotic complexes ("agglomerates") occur commonly in the basal part of the volcanic sequence and reach thicknesses up to 200 m.

Once the main phase of basaltic volcanism ceased, thick volcanogenic epiclastics (conglomerates and sand-

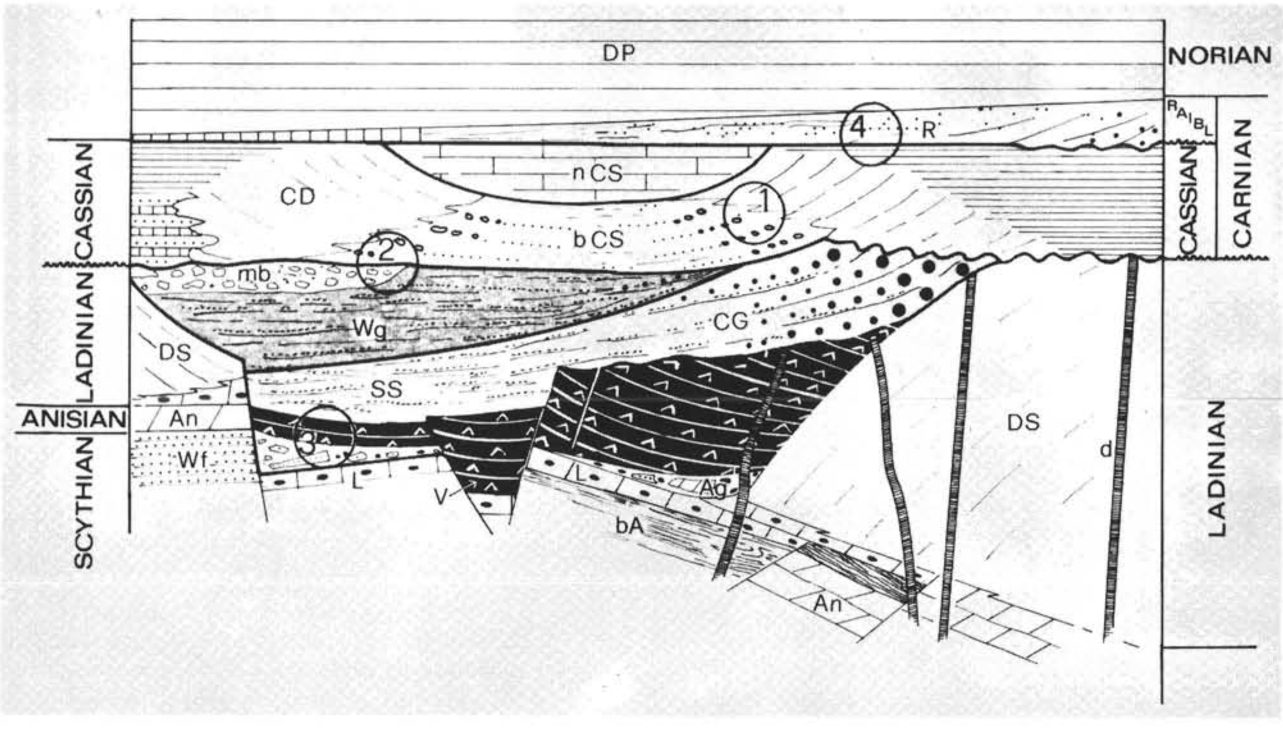


Fig. 11: Schematic representation of stratigraphic relationships existing in some localities of the Western Dolomites. Numbered circles indicate the four stops. Lithologic symbols: DP, Dolomia Principale; R, Raibl Formation; nCS, lagoonal (interreef) Cassian Formation; CD, Cassian Dolomite represented by fore-reef prograding beds, back-reef peritidal carbonates and lagoonal terrigenous-carbonate sequences; bCS, basinal Cassian Formation (turbidites); mb. megabreccia sheet; Wg, Wengen Formation; CG, Conglomerato della Marmolada; SS, turbiditic sandstone; V, volcanics; DS, Schlern Dolomite; L, Livinallongo (Buchenstein) Formation; An, Anisian platform; bA, basinal Anisan limestone; WF, Werfen Formation; d, basaltic dikes.

stones) poured into the basin. Coming from a strongly uplifted region to the southwest, they prograded northward as fandeltas and deep submarine fans. An angular unconformity occurs commonly between the conglomerates (Marmolada Conglomerate) and the underlying basinal rocks. Below the Marmolada Conglomerate the whole "geology" is more complex.

During the Lower Carnian, new carbonate platforms started to develope on the most shallow zones (uplifted and eroded Lower Ladinian buildups, volcanic islands, megabreccia piles etc.) and prograded on the now moderately deep (300—400 m) basinal areas. When these basins became too shallow and narrow, reefal progradion stopped and they were infilled by normal lagoonal sediments. Meanwhile, peritidal cyclic sequences with stromatolites, vadose pisolites and tepees were forming in the back-"reef" area.

The Raibl Formation (Upper Carnian) lies unconformably above the various formations previously described. In some places it starts with cross-bedded sandstones, in others with reddish argillaceous beds or with skeletal limestones. Finally in Norian time a uniform lithology was produced throughout the region. This is the Dolomia Principale (Hauptdolomit), a thick sequence of cyclical alternations of peritidal dolomites.

Stop 4.1. Sella Pass
Carnian basinal sediments and geologic panorama

With good weather and clear sky, a spectacular geologic panorama is visible from this pass. Ladinian buildups, basinal volcanoclastics, Carnian platforms and related fore-"reef" sequences will be shown. Basinal volcanogenic sediments, platform-derived olistoliths and carbonate turbidites of Cassian age are beautifully exposed on road cut (fig. 12).

Stop 4.2. Gardena Pass
Carnian platform and underlying channelized megabreccia body

One of the most famous localities of the Triassic geology of the Dolomites. Since the last century up to

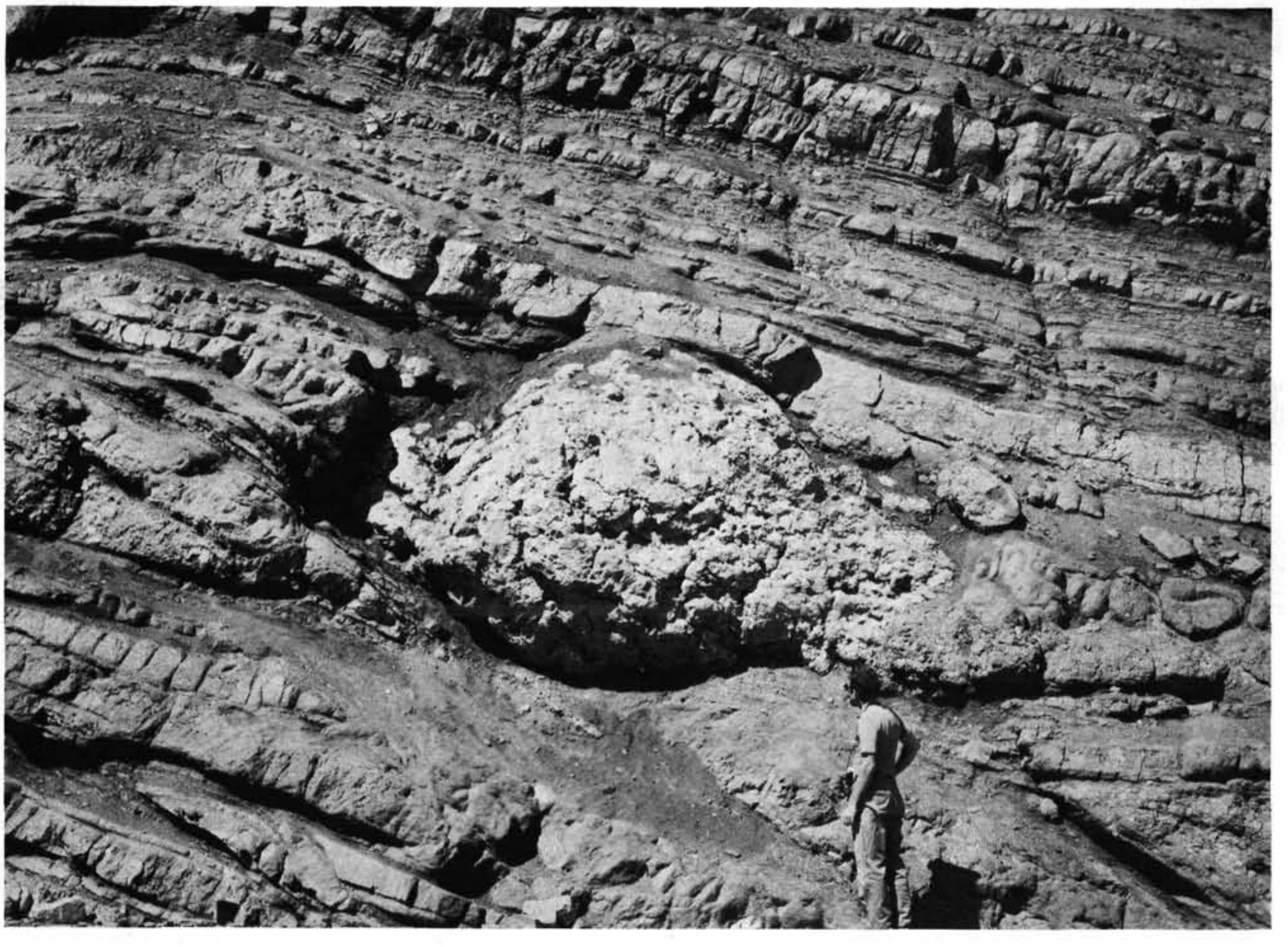


Fig. 12: Gravity displaced carbonate boulder in flyschlike sequence of basinal Cassian Formation at Sella Pass.

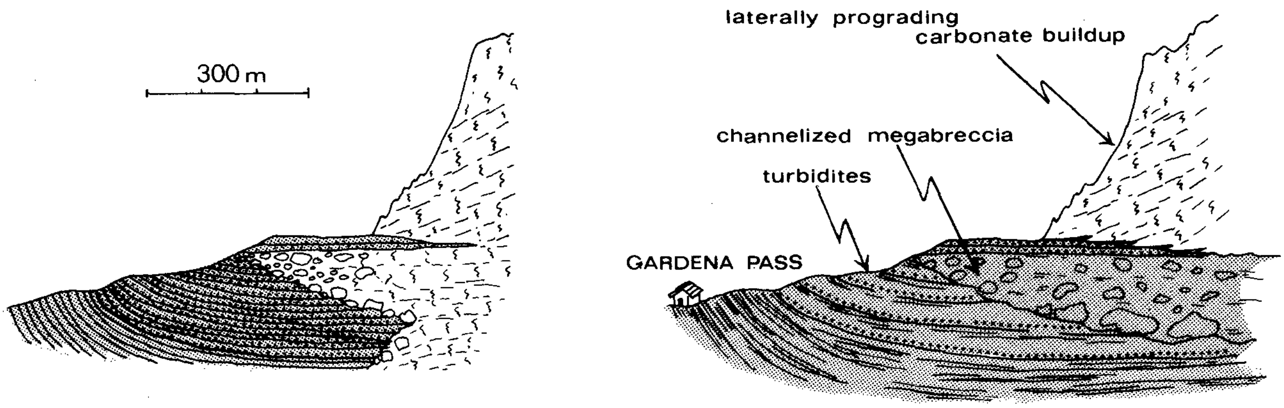


Fig. 13: Stratigraphic relationships at Gardena Pass. Two different interpretations: on the left the old (classic) one, on the right the interpretation supported by the writer.

the most recent papers, the Gardena Pass has been considered a classic locality for lateral facies change (facies heteropy): a mushroom-like interfingering between a reef and the basinal sediments. As shown in fig. 13 the interpretation presented here considers two quite different carbonate bodies. The lower one is a megabreccia slide channelizing (flat top and concave base) Cassian turbidites and other basinal sediments. The upper carbonate body instead is a prolific platform prograding laterally onto the flat bottom of the Cassian basin.

Stop 4.3. Falzarego Pass
Tidalites of the Cassian platform and Raibl Formation

The upper fifty meters of the Cassian carbonate platform are represented by peritidal cycles. Stromatolites, vadose pisolites and tepee structures are typical of supratidal horizons whereas vuggy, crystalline dolomite with burrows and mollusce molds characterizes the subtidal member.

The Falzarego Sandstone, which occurs in the basal part of the Raibl Formation (Upper Carnian) lies unconformably on the carbonate platform. Facies association and paleocurrents show that this sedimentary complex represents a differentiated and indented shoreline environment.

Day 5

Route: Cortina — Bassano. From Cortina, through Permian and Triassic terrains, to the Piave Valley and across the Val Sugana Line (a very important WSW-ENE trending fault) to Longarone, through Cretaceous and Jurassic of the Belluno Basin.

Introduction to: The Belluno Trough, a Jurassic „Tongue of the Ocean“

The Belluno Trough is a narrow and elongated basin which occur on the north-western corner of the Apulian Plate continental margin. It acquired topographic identity in early Liassic time, during the breakup of a widespread Upper Triassic carbonate shelf. Structurally it is a block which subsided much faster than the adjacent high-standing elements — the Trento Platform to the west and the Friuli Platform to the east.

From the paleogeographic point of view, the Belluno Trough was a relatively deep water furrow, closed to the south and parallel to the strike of the continental margin. It was bounded mainly by fault scarps, in place dissected by submarine canyons, and surrounded by shallow water carbonate banks with fringing oolite-skeletal shoals.

This typical Bahamian physiography lasted until Upper Liassic time, when the shallow water Trento Platform underwent a tectonic collapse and suddendly drowned, tilting northward and breaking along an old tectonic feature — the Valsugana Line. By Dogger time the Trento Platform was already a submerged plateau (Trento Plateau), swept by currents, while the still highstanding Friuli Platform was now facing a larger sea and stronger tidal currents encroached its edge which became a locus of extensive and prolific oolite shoals. Starting from this edge, great submarine oolite fans (Vajont Limestone) prograded westward, gradually infilling the Belluno Trough. The fans terminated westward against the faulted edge of the Trento Plateau, where, above a karst-like surface, locally encrusted with manganese, red nodular ammonitic limestone was slowly accumulating. Northward, where the topographic relief decreased, the oolite fan could spill over the escarpment onto the edge of the plateau (fig. 14).

By the end of Middle Jurassic, the Belluno Trough, completely infilled with oolitic sand, was no more

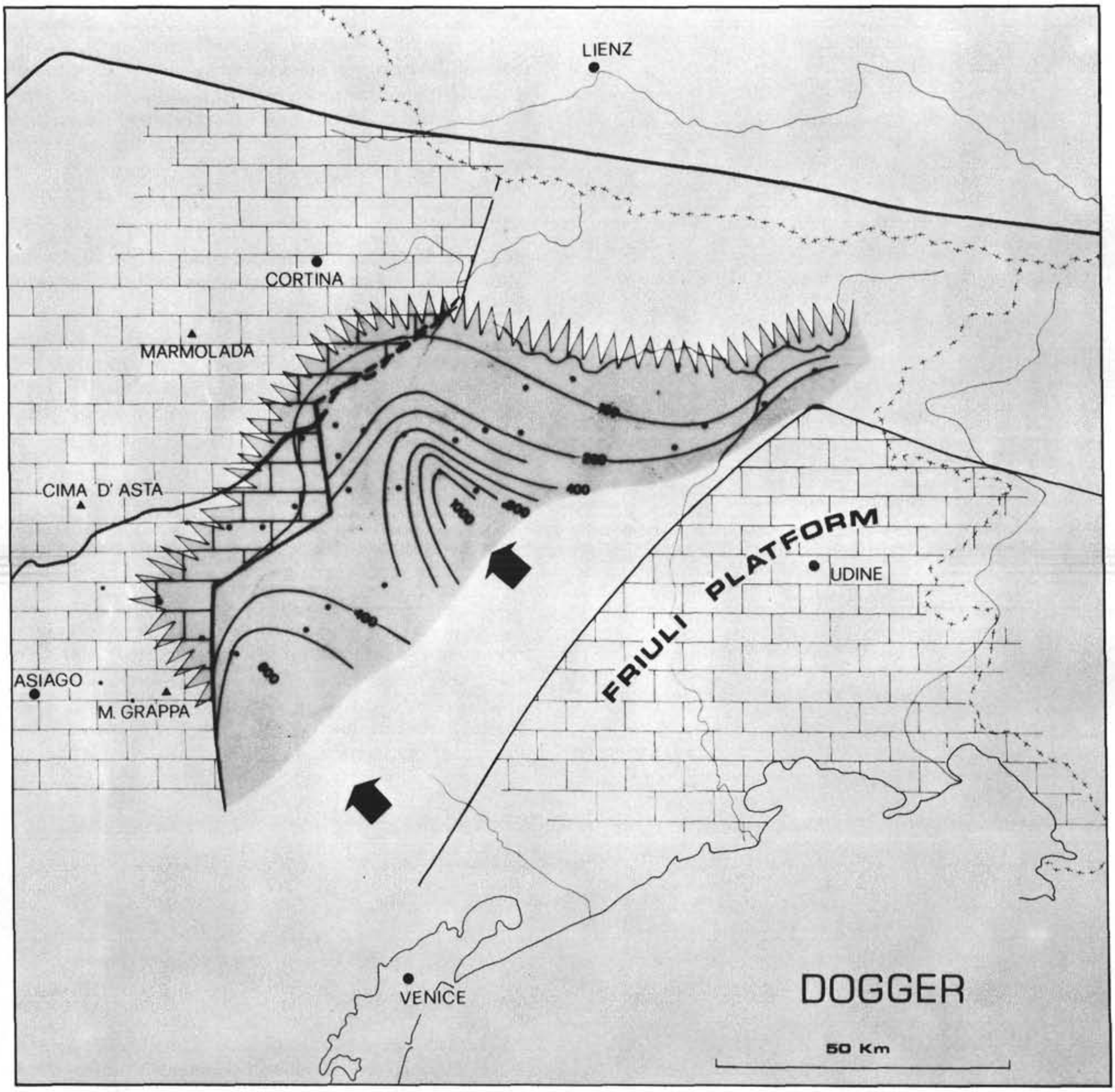


Fig. 14: Paleogeographic map of the Vajont Fan (Middle Jurassic), spilling onto the western edge of the drowned Trento Platform. Isopach contour intervals are in meters.

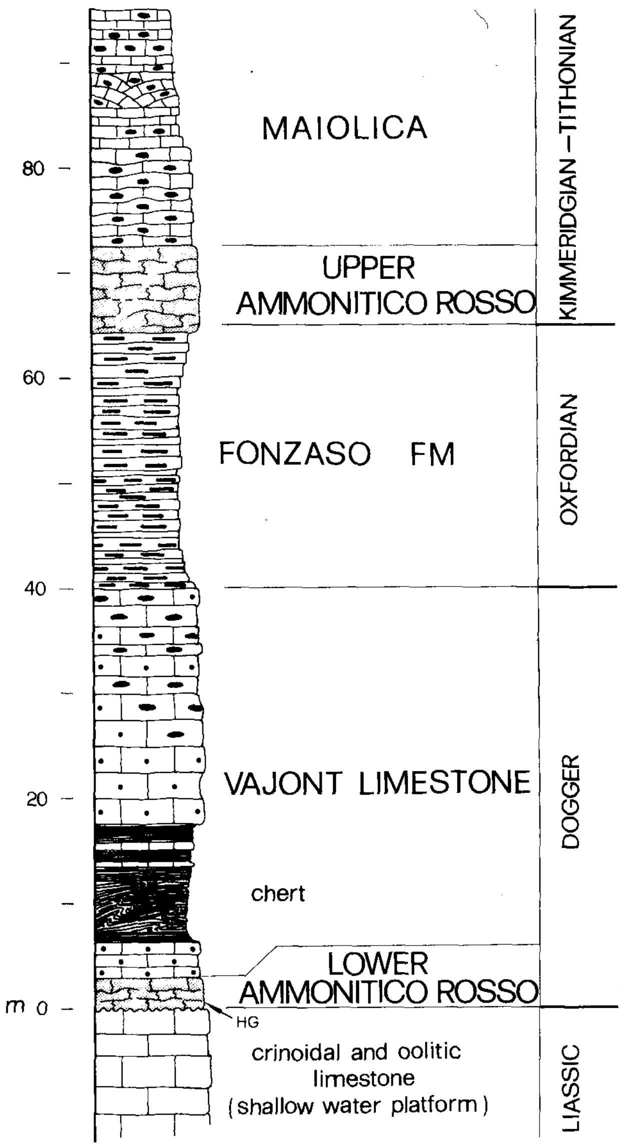


Fig. 15: Stratigraphic section of Ponte della Serra (Fonzaso).

a trough but a gentle slope (Belluno Slope) connecting the shallow water Friuli Platform to the deeper water Trento Plateau. From the beginning of Upper Jurassic to the Upper Cretaceous, the Friuli Platform was fringed by reefs (corals, rudists) and the Belluno Slope was fed with gravity-displaced skeletal sands and breccias.

Stop 5.1. Roadcut at Longarone
The Vajont Limestone and its relationships with underlying basinal sediments

The Vajont Limestone, a 400 m thick oolitic lithosome of Dogger age, shows here its basal contact with the underlying Liassic cherty, well bedded, micritic limestones. These basinal sediments are deeply channelized by the overlying oolitic limestone; coarse breccias occurs in the deepest part of the channel.

Stop 5.2. Roadcuts along the road to Col Visentin
The Vajont Limestone: a sequence of gravity displaced sediments

A beautiful, freshly exposed, 350 m section of Vajont Limestone. The massive oolitic beds appear to be graded, with breccias at the base. Intercalations of dark semipelagic mudstones occur frequently in the section. The basinal formation (Fonzaso Formation) overlying the Vajont Limestone will be visited.

Stop 5.3. Ponte della Serra, 3 km west of Fonzaso
Ponte della Serra section

This is the type section of the Fonzaso Formation (fig. 15). The Liassic shallow water carbonates (Trento Platform) are overlain by the Ammonitico Rosso Inferiore, and by the distal facies of the Vajont Limestone. It is here documented the late Liassic drowning of the Trento Platform and the spilling of the oolite fan onto the edge of the submerged plateau.

Day 6

Middle and Late Jurassic Condensed Facies on the Trento Plateau

(Jim Ogg)

R o u t e: Bassano — Verona. From Bassano, at the foothill of the Venetian Prealps, the road crosses Tertiary volcanics and sedimentary terraines, steeply dipping to the south, and rises to the Asiago Plateau, where Cretaceous and Jurassic sequences are widely exposed.

Stop 6.1. Road cut 2,5 km east of Foza
Typical stratigraphic Sequence and Nodule Limestone Formation

This road cut exposes the Jurassic plateau sediments from Liassic to Cretaceous. In the valley to the south can be seen the massive Triassic Dolomia Principale. During the Liassic a lagoonal environment persisted into the Pliensbachian allowing the accumulation of 16 m of oolite shoals, "oyster" beds, ostracod muds, and occasional coal deposits. This Calcari grigi formation ends

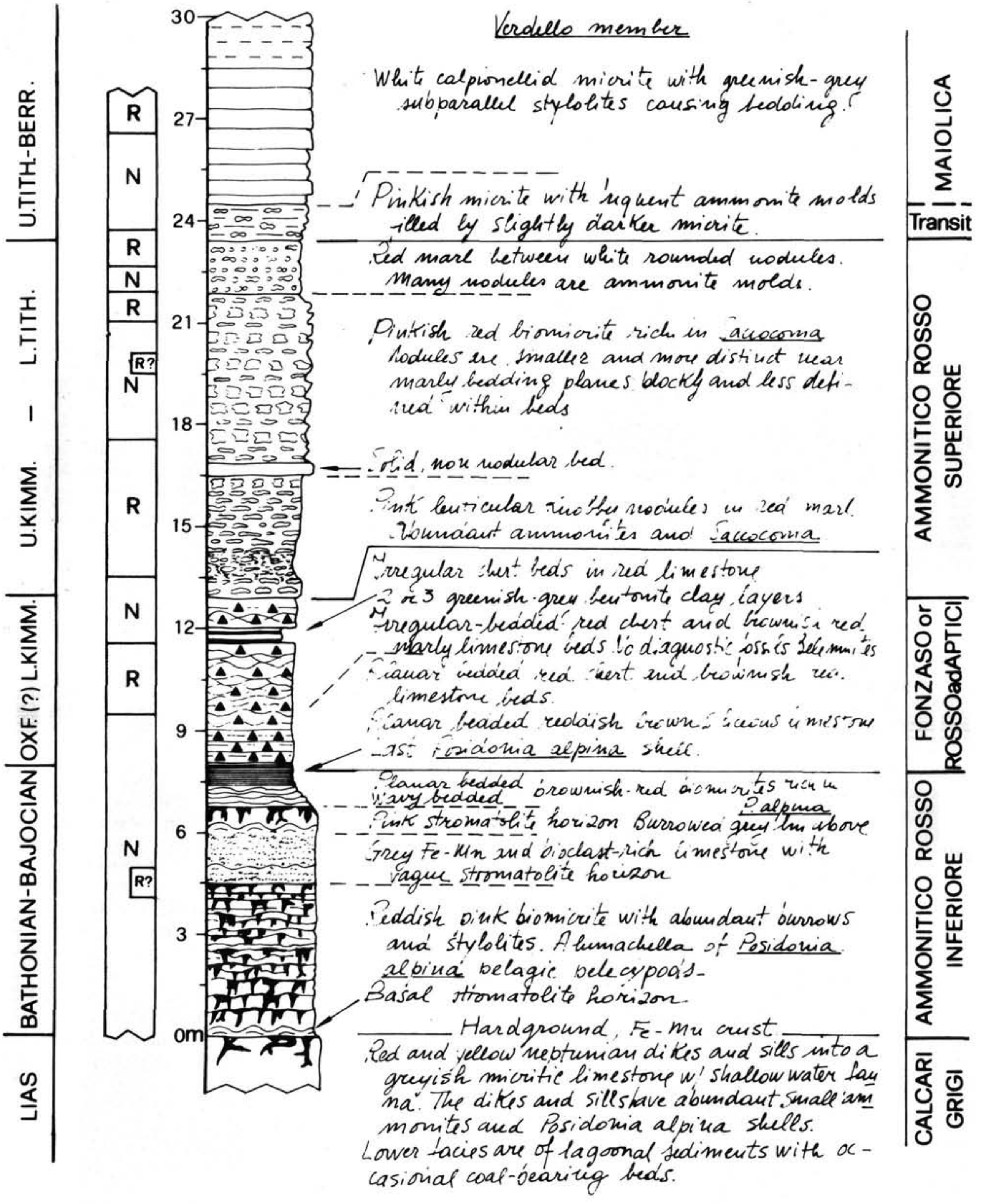


Fig. 16: Stratigraphic and paleomagnetic section of Middle-Upper Jurassic near Foza (east of Asiago).

abruptly when the plateau subsided during the Toarcian.

The Toarcian-Aalenian, absent at this exposure, is represented on the plateau only by local thin crinoidal sands, shallow cracks into the Liassic carbonates that were filled by small shells and mud, and oolite shoals in the region of Lake Garda. Apparently strong currents prevented significant deposition until the Bajocian, though subaerial exposure has also been suggested. This submergence will be examined at the next stop.

During the Bajocian and Bathonian, a pink biopelmicritic limestone, rich in fine pelagic pelecypods (*Bositra buchi* or *Posidonia alpina*), was deposited. This "Ammonitico Rosso Inferiore" unit is typically 8 m in thickness and has a strictly pelagic fauna including ammonites, belemnites, protoglobigerinae radiolaria, and crinoidal material. Often it has a nodular appearance, partially from stylolitic condensation of an original inhomogenous burrowed texture and partially from the accumulation of the *Bositra* shells in stylolite or flazer zones to yield residual nodules separated by coarse marl.

The Callovian has not been identified from fossils on the plateau and the Oxfordian is often missing also. Deposition of the Ammonitico Rosso Inferiore may have been terminated by a strong current regime induced when filling of the Belluno Trough (as seen at Stop 5.2. and 5.3.) diverted a boundary current onto the plateau.

During the Oxfordian and Early Kimmeridgian, a cherty red limestone of highly variable texture and thickness (0—10 m, typically 3 m), was deposited. This Fonzaso Formation (or Scisti ad Aptici) lacks ammonite phragmocones (aragonite shell) but retains the apthychi (calcite portion that guards the opening) indicating deposition below the aragonite compensation depth. The red chert occurs in the limestone as nodules, burrow fillings, or solid beds. The chert nodules formed prior to the main compaction diagenesis as shown by belemnites crushed between them. In the late stages of the accumulation of this unit a couple ash falls occurred and were preserved as thin bentonite clay layers in many sections.

The Ammonitico Rosso Superiore of Late Kimmeridgian-Early Tithonian age begins above the last red chert bed. This red limestone unit is rich in *Saccocoma*, a pelagic crinoid, and ammonites plus brachiopods, radiolaria, and *Globochaete alpina* LOMBARD. It has a uniform 10—15 m thickness across the plateau and can be subdivided into at least three members — a basal very nodular facies (2—3 m), a central zone with alternations of well-defined small nodules and poorly-defined larger nodules and of stylolite-rich solid beds (6—9 m), and a thin zone (1 m) of marly limestone with fine-grained oval nodules of generally fossil-mold origin. Above this is a transition zone (1—2 m) lacking any nodularity in which the red color disappears and *Saccocoma* are replaced gradually by Late Tithonian Calpionellids.

The medium to thick-bedded (15 cm — 2 m) white Late Tithonian limestone is the basal member of the Biancone or Maiolica formation on the plateau and is known as the Verdello member from ist greenish-gray stylolites. After 10 meters, light brown chert bands and thinner bedding mark the beginning of the main Biancone formation with its abundant synsedimentary slumping. This unit continues through the Early Cretaceous.

Nodularity of the Ammonitico Rosso Superiore

The origin of nodular limestones has been discussed for decades and it can be concluded that they can form in a variety of ways. Unfortunately, the term "Ammonitico Rosso" has been applied to a variety of red nodular limestones with different textures. Petrographic studies support a late diagenetic origin for the dominant nodularity of this Ammonitico Rosso Superiore formation. During stylolitic condensation, the single-crystal calcite *Saccocoma* particles accumulate in the stylolite zones, thus causing a simple stylolite to develop into an anastomosing zone packed with inconsumable *Saccocoma*. This process yields coarse marl zones surrounding residual nodules of original texture. The variations in nodularity are due to variations in the initial *Saccocoma* (clay) micrite ratios, which may reflect differential current winnowing. In addition, there are abundant ammonites that contribute fossil mold nodules to the sediment.

Stop 6.2. Ghelpach gorge and nearby quarries, 5 km SE of Asiago
Drowning of the Liassic Platform

The contact of the Bajocian Ammonitico Rosso Inferiore on the Liassic Platform carbonates is complex. Often a zone of fissures extends up to one meter into the Liassic deposits. The pelagic filling of these fissures is of variable composition and age. These fissures were filled prior to deposition of the overlying Ammonitico Rosso Inferiore and are often sealed by a Fe Mn crust. On rare occasions, Fe Mn nodules occur within the fissure filling also. The early explanation was that the fracturing is a karst texture created during a Toarcian through Aalenian subaerial exposure and the fillings were due to occasional high water events. An alternative is submarine fracturing during subsidence tectonics. When a crack opened, it would trap the loose bioclastic debris available at that time. The undulatory sill-like form of some of these fissures fillings is difficult to explain by any process other than suction infill of a soft Toarcian-Aalenian sediment which was later stripped off. Three diverse exposures of these fissures will be visited.

At the base of the Bajocian Ammonitico Rosso Inferiore is often a thin zone of convex laminated mounds.

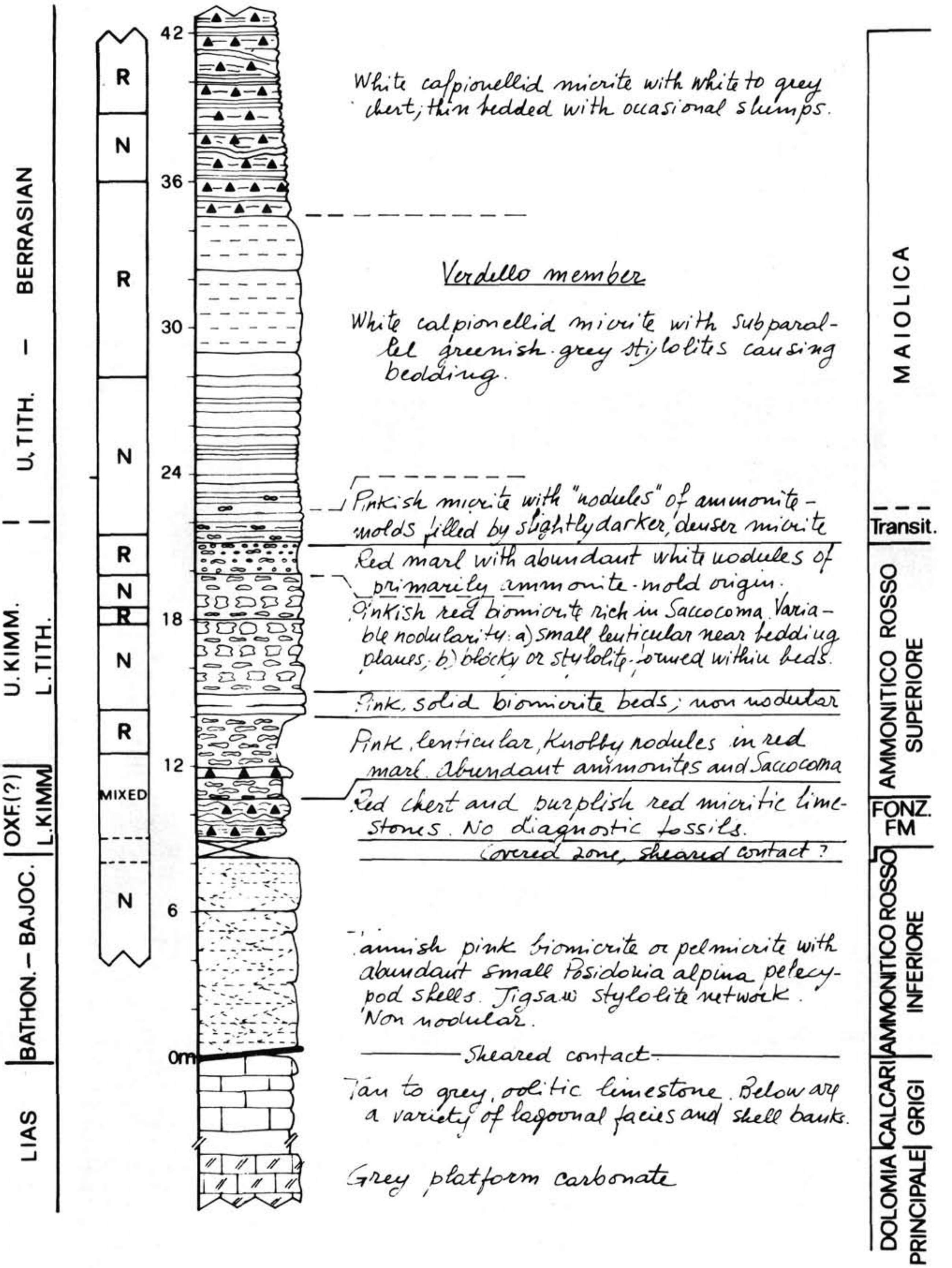


Fig. 17: Stratigraphic and paleomagnetic section of Middle-Upper Jurassic at Ghelpach gorge (west of Asiago).

These are typically 10 cm high and 15 cm across and coalesce with each other. The laminae are caused by variable density of pellets and bioclastics. Identical forms in condensed Jurassic pelagic sediments of Sicily and Poland have been described as stromatolites with an origin in the photic zone implied. Similar "stromatolite" zones occur in the middle of the Ammonitico Rosso Inferiore and in the Upper Kimmeridgian Ammonitico Rosso Superiore near Verona (Erbezzo Section). If these are of photic zone algal origin then the plateau remained shallow (< 500 m) throughout most of the Middle and Upper Jurassic after the continental margin formed; a history difficult to reconcile with normal continental margin subsidence and the strictly pelagic nature of all the sediments. The direct association of these "stromatolite" forms with Fe-Mn nodules and crusts and slowing of sedimentation suggested possible origin from a deep water bacterial or bacterial-algal film such as has been hypothesized for some spreading ridge hydrothermal deposits. The basal and central "stromatolite" zones of the Ammonitico Rosso Inferiore will be examined.

In addition to the above, some of the sedimentary features of the Ammonitico Rosso Inferiore and chert apthycus beds (Fonzaso Formation) described at the Foza stop will be available for examination.

Stop 6.3. Road cut 2 Km west of Rotzo Shallow water Liassic Sequence (Calcari grigi Formation), (A. Bosellini)

This road cut exposes the Jurassic platform sediments, from the basal Triassic Dolomia Principale to the Ammonitico Rosso Superiore. A very detailed stratigraphic column will be distributed to the partecipants during the trip.

The section has been subdivided into three members; the upper member has been formally named the Member of Rotzo.

The lower member is composed of cyclic sequences which are developed in stratigraphic continuity with those sequences present in the underlying Dolomia Principale Formation. The dominant characteristics of these cycles are: the prevalently regressive character, the occurrence of oolitic limestones and the exiguity of the laminated horizons, rarely of the true stromatolitic type.

The middle member is composed of oolitic calcarenites, commonly with current structures; the thickness is approximately 35 meters. These calcarenites are considered to represent a barrier island complex. In such a physiographic complex, the oolitic sands constituted subtidal and inter-tidal bars and shoals, and here and there they probably emerged to form small keys with dunes (eolianites) and beaches. The middle member, as here defined, is easily recognizable in a large part of the depositional area of the Calcari grigi.

The Member of Rotzo is composed of a marked variety of lithological types which alternate in a very complex and, at first glance, very irregular manner. However, these types can be grouped in five main facies: (1) oolitic and bioclastic calcarenites; (2) micritic limestones with Molluscs, Brachiopods, Foraminifera and Algae; (3) micritic and micriticpelletoidal limestones with subordinate presence of organism; (4) limestones with "*Lithiotis*" and lumachelle (coquinas); (5) grey or black marls, sometimes rich in vegetal deposits (coal). All these facies can be inserted in the general physiographic environment represented by the Member of Rotzo: a lagoon protected from the open sea by the barrier island complex of the middle member.

Day 7

Route: Verona — Brescia. From Verona along the Adige Valley to Trento, then westward to the Sarca Valley. We will cross mainly Mesozoic terraines (Upper Triassic to Cretaceous) of the western margin of the Trento Platform.

The Garda Escarpment: shelf edge of the Trento Platform and margin of the Lombard Basin

Alberto Castellarin

The Lombard Basin and Trento Platform are two different sedimentary domains whose sequences are in contact in the area located north of Riva del Garda (fig. 20). The sharp boundary between these two paleogeographic areas was believed in the past to have been produced either by a Neogene N-S trending wrench fault, or by a gradual environmental transition along a slope. On the contrary, the contact is the effect of early Jurassic synsedimentary block-faulting, essentially along a N-S trending master fault line (Linea di Ballino). The following evidence supports this assumption: 1) the Jurassic and Cretaceous units of the two areas are separated by N-S, NNE-SSW oriented, subvertical and normal faults, fossilized under Late Jurassic and

Cretaceous deposits; 2) numerous extensive and thick bodies of "megabreccias", formed mostly by blocks and boulders of rocks coming from the Trento Platform, are found withing the easternmost basin sediments as products of sliding along marginal fault lines; 3) evidence of huge submarine denudation along the border of the Trento Platform is given by large stratigraphical gaps recognizable over detachment areas or scars from which the submarine slides originated; 4) proximal calcareous turbidites are intercalated within the Liassic basin succession as penecontemporaneous redeposited bahamian sands derived from a shelf border; 5) distensional fault activity and neptunian dykes are often closely connected. Frequency and depth of the dykes increase towards the west of the platform.

Stop 7.1. Gorge of the Sarca River and road cuts at Km 96—97
Onset of the Lombard Basin succession of Ponte Pià

A one-thousand m thick section ranging from Liassic to early Oligocene and formed by basin deposits is located along the Sarca river near Ponte Pià. The lowermost section contains essentially liassic oolitic-skeletal turbidite beds of bahamian sand reworked from a carbonate shelf border. The turbiditic deposition of these beds is supported by their structures (graded bedding, parallel laminations, groove — and load casts) and by the scarce indigenous intercalations (gray marly micritic limestones bearing Radiolaria and Sponge

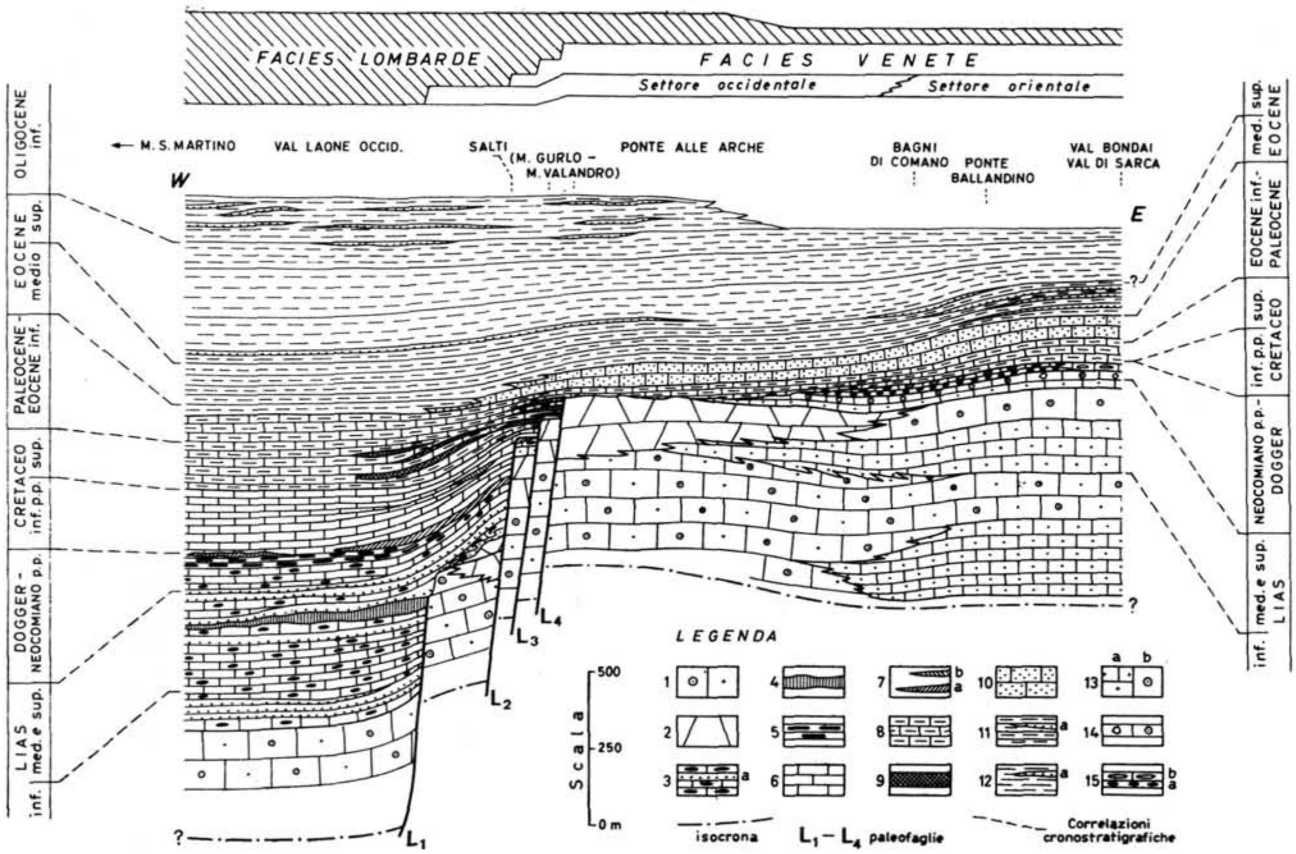
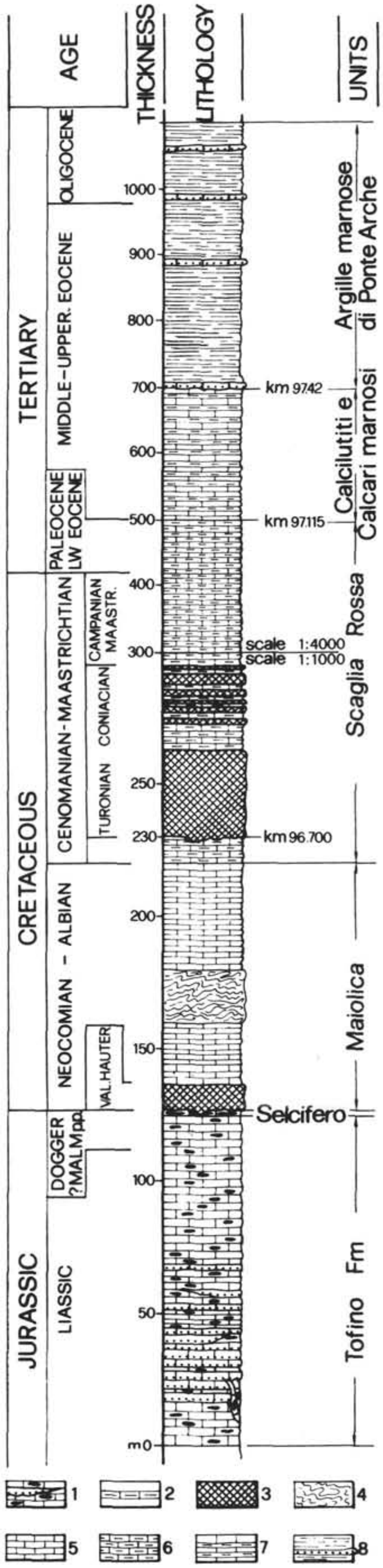


Fig. 18: Stratigraphic and paleotectonic scheme for the area located to the N of Ponte Pià and Ponte Arche village. L_1—L_4 are the Liassic-Lower and Upper Cretaceous synsedimentary faults mapped in the field. L_1 corresponds to the northern continuation of the Liassic Ballino Line (for more details see CASTELLARIN, 1972). Key for the Legend numbers: 1, Calcari grigi Fm.; 2, Calcare del Misone Fm.; 3, Tofino Fm., with carbonatic turbidites (a); 4, Liassic "megabreccias"; 5, Radiolarites; 6, Maiolica Fm.; 7, Lower Cretaceous "megabreccias" (a, Neocomian; b, Aptian-Albian); 8, Scaglia rossa Fm.; 9, Upper Cretaceous "megabreccias"; 10, coarse micritic limestones; 11, marly limestones and marls with intercaled carbonatic turbidites (a); 12, Ponte Arche clays with carbonatic turbidites (a); 13, Calcari grigi Fm. (east side of the fig. 20), skeletal (a), oolitic (b); 14, S. Vigilio, oolitic beds; 15, *Posidonia alpina* beds and Apticus cherty beds (15 a); "Ammonitico rosso" Fm. and Biancone Fm. (15 b). The thickness scale is indicative.



Spicules). Some geometrical characteristics are also consistent with a proximal turbiditic sedimentation: the lenticular bedding association can be regarded as superposition of numerous channelized carbonate sand bodies (E-W trending), whose pitching out is often connected to lateral erosional truncation of the underlying basin beds down to a depth of 1 m. Along the river, the Upper Jurassic radiolarites are reduced to about 2 m. They are overlain by Lower Cretaceous poligenic breccias (7 m thick) in which abundant slabs of pale green and brown-red radiolarites are present within the chaotic assemblages. The upper portion of the sequence runs along the national road n. 237 (Km 96.700), where seven bodies of Upper Cretaceous "megabreccias" outcrop in a 70-meter thick intervall (with a basal major body 28 m thick). Blocks and boulders of rocks in the Venetian facies of different ages (from Lower Liassic to early-Middle Cretaceous) testify to a sliding activity along the boundary zones caused by a strong reactivation of previous faults. The persistence of block-faulting during Lower and Upper Cretaceous times is a unique feature of this region well-documented by field data. Basinal deposits with carbonate turbidite intercaltions from a renewed Tertiary platform can be observed in the uppermost part of the sequence up to the early Oligocene top beds near the village of Ponte Arche.

Stop 7.2. 1 Km north of the Tenno Lake Liassic breccias connected to the synsedimentary tectonics of the Ballino fault (Tenno Lake)

The "megabreccias" (blocks and boulders of rocks in the Venetian facies) pinch out rapidly to the south and erode about 10 m of the basinal cherty limestone sequence. They can be interpreted as E-W channelized sliding products discharged from the shelf border. The tectonic line (Ballino Line), corresponding to the facies boundary between the Lombardy and Trento domains, is located about 200 m to the east of the "megabreccias" deposits. These, moreover, include clastics belonging to an extensive Liassic interval (about 300 m thick) which indicate wall detachements from an elevated fault escarpment. The Ballino fault is thus interpreted as a Liassic steep relief, at least 300 m high, overhanging the basinal area.

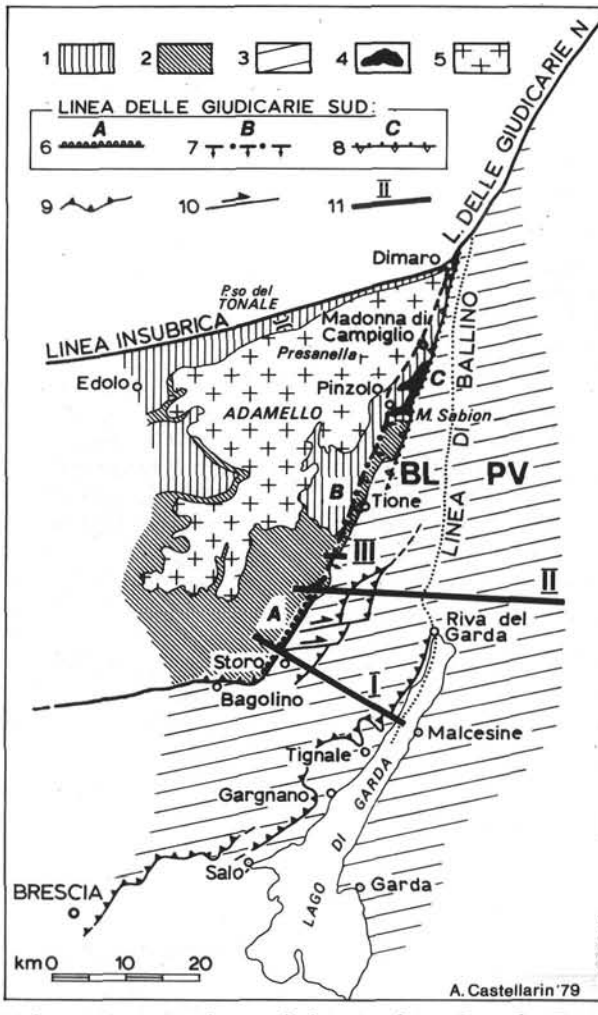
Fig. 19: Stratigraphic log of the Ponte Pià section (Castellarin, Ferrari and Sartori, unpublished); Key for the Legend numbers: 1, cherty limestones with turbiditic intercalations of biocalcarenitic limestones (a); 2, radiolarites; 3, poligenic breccias; 4, intraformational slides; 5, hemipelagic micritic limestones; 6, hemipelagic marly limestones; 7, alternance of hemipelagic micritic limestones and marls; 8, marls, clays and thin micaceous quarzarenitic beds with scarce turbiditic intercalations of biocalcarenite limestones (a).

Stop 7.3. Location: near the village of Tignale, along the path from the Sanctuary to the top of Mt. Cas
Jurassic basinal sequence along the westside of Lake Garda

A Jurassic succession in the Lombard basinal facies outcrops in this area. Cherty radiolarian limestones and red-brown radiolarites followed by Tithonian "Ammonitico rosso" nodular limestones are present near the church. Numerous field data indicate that the "Ammonitico rosso" facies can be considered as an indigenous equivalent of the radiolaritic one, since it was deposited on a structural high of the basin. Nevertheless, very frequent clasts of "Ammonitico rosso" limestones occur within Lower Cretaceous breccias which are widely distributed in this zone (Breccia di Pregasio). The Middle Liassic sequence of Mt. Cas (hanging side of a vertical NW-SE trending fault) contains a set of cherty limestones folded by slumpings, as well as channelized "megabreccias" (8 m thick) with blocks and boulders from a carbonatic shelf border. Such deposits are thus comparable to the ones the previously examined zone (Stop 7.2.).

The Tignale area favours the observation of the tectonic style of the Judicaria structural system (fig. 20). The N-S, NE-SW tectonic directions, nearly orthogonal to the W-E major south-Alpine structural trends, are connected to the Judicaria Lineament. This Lineament does not correspond to a regional strike-slip movement as believed in the past; on the contrary, it can be considered a strong flexure-fault system connected to the vertical uplift of the Adamello massif area. Folds and thrusts in the Judicaria belt can thus be regarded as detachment structures of the sedimentary cover.

In the Tignale and Tremosine sections, the contact between the overthrusted Triassic rocks and the underlying Cretaceous and Jurassic basinal beds are widely exposed. The nearly horizontal tectonic surface, which can be observed along the valley, cuts several km behind the overthrust front.



Figl. 20: Tectonic scheme of the area located to the E and S of the Adamello massif. Key for the Legend numbers: 1, Hercynian crystalline-metamorphic basement rocks; 2, Permo-Scythian and Middle Triassic volcanic and sedimentary deposits; 3, Mesozoic and Tertiary sedimentary rocks; 4, Hercynian plutons; Tertiary intrusive of the Adamello massif; 6, 7, 9, respectively normal fault (A), flexure (B) and overthrust (C) of the Southern Judicaria Line; 9, thrust front; 10, strike-slip faults; 11, traces of geologic profiles (for more details see Castellarin and Sartori, 1979).

Day 8

R o u t e: Brescia — Como. From Brescia, along the highway to Bergamo and from there to Albenza area, along the road to Lecco.

Stop 8.1. Road cut near the village of Sogno, on the new road from Sogno to Colle di Sogno Middle-Upper Jurassic of the Lombard Basin (Sogno section), ALFONSO BOSELLINI

The Jurassic sequence of the Albenza mountains was deposited in a trough of the larger Lombard Basin. This trough was bordered by the two sills of Corni di Canzo and M. Cavallo-M. di Nese. The basinal sequence between the top of the Domaro Limestone (early Toarcian) and the base of the radiolarite (Selcifero Lombardo) is represented by two different units: a red marly nodular limestone (Rosso Ammonitico Lombardo) occurs on the flanks, while a much thicker grey-brown, well bedded succession of marly limestone and clayey marl (Sogno Formation) is represented in the deeper part of the trough. The age span of this formation extends from lower Toarcian to Middle Jurassic.

The Sogno Formation is overlain abruptly by radiolarite, completely lacking in calcium carbonate except as a replacement mineral. The radiolarite (Selcifero Lombardo) begins with beds of greenish radiolarite 5—10 cm thick separated by layers of siliceous shale a few milimeters thick. The beds are slightly lenticular and show small-scale very low-angle cross bedding in the wispy internal laminations, indicating that bottom currents were moving and sorting the clay and radiolarians. Graded bedding is rare. Burrow mottles and tracks are common. Normally, the green radiolarite is about 20 m thick and is overlain gradationally by a few meters of very lenticular to knobby-bedded reddish radiolarite, with paper-thin siliceous shale seams outlining the knobs and lenses. In some areas, probably representing old submarine highs, only this red knobby facies is developed. Upward, the radiolarites passes gradually into lenticular-bedded reddish siliceous pelagic limestone crowded with replacement chert lenses that become less and less abundant upward. Tracks are ubiquitous on bedding planes, and belemnites and ammonite aptychi are common as megafossils, while recrystallized nannofossils, radiolaria and ossicles of the pelagic crinoid *Saccocoma* are visibly at the microscopic level.

The siliceous facies are succeded upward by less dissolved Kimmeridgian facies. The red cherty aptychus limestone above the knobly radiolarite passes upward gradationally into alternating chert-free red aptychus pelagic limestone and marlstone (Rosso ad Aptici formation).

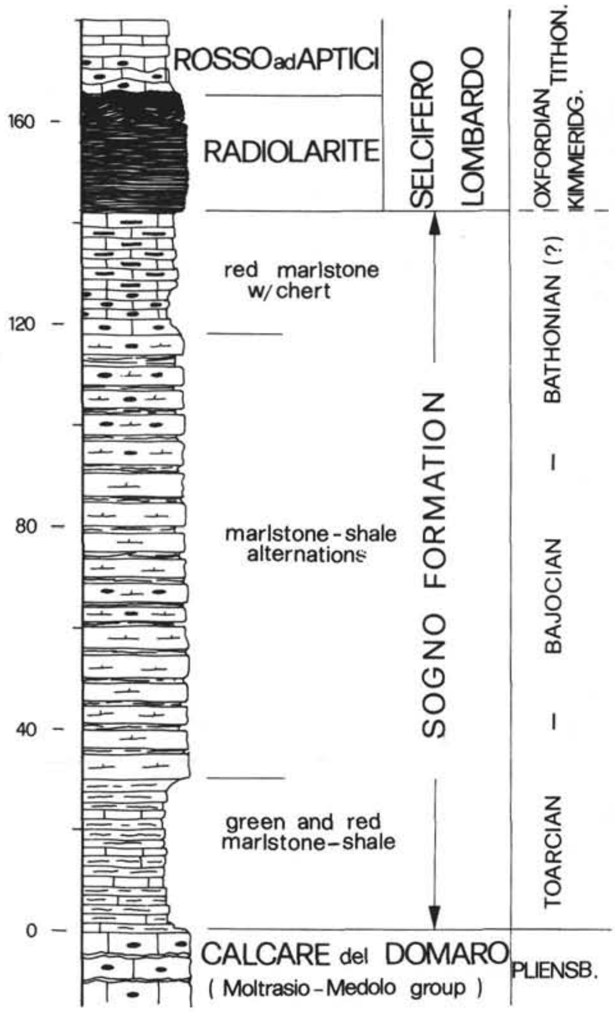


Fig. 21: Stratigraphic section of basinal Jurassic along the road Sogno-Colle di Sogno, northern slope of Mt. Brughetto (west of Bergamo) (modified from GAETANI and POLIANI, 1978).

Day 9

Route: Como — Milano. From Como to Torre de' Busi; from there to Bergamo-Gavarno and finally to Milan.

The Aptian-Coniacian stratigraphic succession in the Bergamo region

ROMANO GELATI

The succession, which lies in stratigraphic continuity upon the Maiolica formation, forms the hills to the south of the Mt. Albenza flexure. It is a terrigenous sequence formed primarily by turbiditic and hemipelagic facies associated with black shales. The distribution of these facies suggests the subdivision of the basin in sections of different paleogeographic configuration, especially as related to intense synsedimentary tectonics.

Stop 9.1. Village of Torre de' Busi
Aptian-Albian succession with black shales (Marne di Bruntino) and calcareous-marly turbidites (Sass della Luna)

The succession, which is stratigraphically superimposed on the Maiolica, includes: a) dark gray or light brown calcilutites alternating with blackish pelites, which are sometimes red (10 m); b) pelites ranging from red with greenish spots to black (30 m); c) gray to black calcareous-marly turbidites (70 m), with flat-parallel bedding and with thickness from decimeters to meters. They are arenaceous at the base of the interval becoming more and more clayey towards the top; d) calcareous turbidites in flat-parallel beds with thickness from decimeters to meters.

Horizon a) records episodes of stagnation during the Barremian. Horizon b) and c) represent the most typical facies of Marne di Bruntino which, during the Aptian-Albian, not only express the expanding stagnation throughout the entire Lombard Basin, but also contain significant terrigenous deposits whose origin is clearly turbiditic. The content of organic carbon varies from maximum values of 7,92% in black mudstones to 1,0 to 2,5% in marlstones.

Starting from the middle-lower part of horizon b), towards the top one finds: *Leupoldina cabri, Hedbergella trocoidea, H. rischi* and *Ticinella breggiensis,* indicating Upper Aptian and Middle Albian. Horizon d) represents the formation called Sass della Luna (Albian-Cenomanian); the frequent occurrence of graded sequences, although not easily discernable due to the fine texture of the sediment, makes an origin from turbidity currents most likely.

The Sass della Luna with its overlying Cenomanian-Turonian units outcrops repeatedly along the road from Torre de' Busi to Caprino Bergamasco. This succession, normally covered by extensive glacial and glacial-lacustrine deposits, may be observed in the incision of the Sommaschio Stream near Caprino Bergamasco.

Stop 9.2. Sommaschio Stream near Caprino Bergamasco
Cenomanian-Turonian black shales and arenaceous-marly turbidites

The following horizons may be recognized: a) black shales overlying silty-marly turbidites (sequences of few decimeters); b) black shales (Scisti marnosi neri, carboniosi a Pesci in VENZO 1954) (13 m); c) red pelites, subordinately gray and green, overlying marly-arenaceous turbidites (Scaglia marnosa rossa in VENZO 1954) (28 m); d) marly limestone, Sass della Luna type, coarse grained at the base (4 m); e) gray, arenaceous-marly turbidites (Flysch scistoso argilloso grigo, Turoniano in VENZO 1954).

Horizon a), which follows upsection the Sass della Luna, and horizon b) represent the Upper Mantelliceratan, characterized by the *Mantelliceras* fauna and plant and fish remains. These two horizons show a renewal of stagnation whose evidences are clearly recognizable at least as far as the east-central Bergamo region (zone of Gavarno). In horizon c), the red and green pelites probably represent the hemipelagic portion of thin bedded "distal" turbidites with an arenaceous base reaching a maximum thickness of 10 cm and sometimes thinning laterally. The classic turbidites of horizon e), with flat-parallel bedding, constitute the base of an essentially Turonian succession occupying the central part of the Bergamo basin with thicknesses that can also exceed 500 meters.

Between the Brembo and Serio Valleys, the lacustrine plain of Petosino partially covers the above-mentioned succession which continues upwards on the Bergamo Hill with the Coniacian-Santonian arenaceous flysch and with the Campanian-Maastrichtian marly-calcarenitic flysch.

Stop 9.3. Southern slope of the Costone di Gavarno (Gavarno Ridge)
Reduced Turonian-Coniacian succession (Flysch scistoso-argilloso rosso mattone, VENZO, 1954)

This succession overlies the upper black shales which may be dated with certainty as Cenomanian (Foraminifera of the *Rotalipora cushmani* Zone in their middle part). The sequence can be compared with the coeval basinal one of the west-central Bergamo region. It probably developed on the Mt. Misma structural high as a lateral prosecution of the Turonian flysches observed previously.

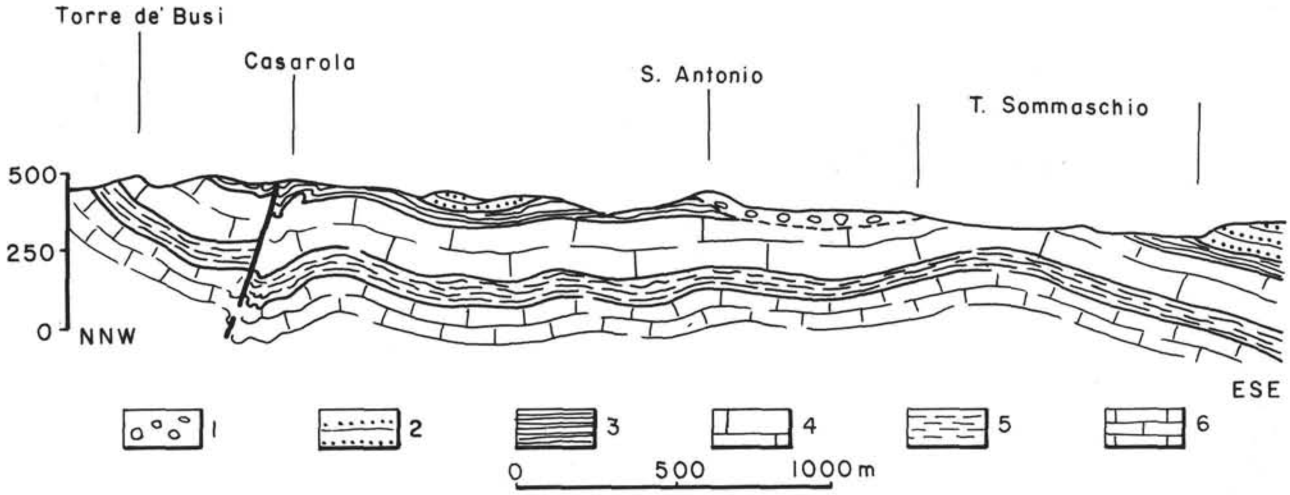


Fig. 22: Geological cross-section of the area between Torre de' Busi and Sommaschio Stream (Caprino Bergamasco). Lithologic symbols: 1, Glacial and glacial-lacustrine deposits; 2, Turonian flysch; 3, Scaglia rossa and upper black shales (Sommaschio Formation) (Cenomanian); 4, Sass della Luna (Cenomanian-Albian); 5, Marne di Bruntino (Albian-Aptian); 6, Maiolica (Barremian-Tithonian).

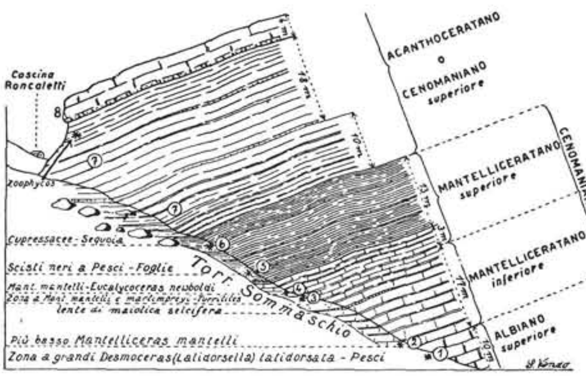


Fig. 23: Stratigrapic succession of the Sommaschio Stream (Caprino Bergamasco) according to S. VENZO, 1954.

The succession is characterized by thin pelitic-arenaceous turbidites with greenish or red pelites. Towards the top, the pelitic component clearly dominates with clayey marls and marly limestones in thin beds. At the top of the succession, two sandy-marly (meter-thick) turbiditic horizons mark the new drowning of the structural high which will realize from the Coniacian with the Sarnico Sandstone. The sequence is dated by planktonic Foraminifera; in the lowermost part *Rotalipora cushmani* and *Whiteinella aprica* indicate the Upper Cenomanian — Lowermost Turonian. In its upper part, *Globotruncana sigali*, *Whiteinella archaeocretacea* and *Globigerinelloides escheri* occur together and can coexist until the end of the Lower Coniacian.

References

BOSELLINI, A. & BROGLIO LORIGA, C. (1971): I "Calcari Grigi" di Rotzo (Giurassico Inferiore, Altopiano d'Asiago). — Ann. Univ. Ferrara, **5**, n. 1, 1—61, Ferrara.

BOSELLINI, A. & ROSSI, D. (1974): Triassic Carbonate Buildups of the Dolomits, Northern Italy. In: L. F. LAPORTE ed. "Reefs in time and space". — S. E. P. M., Spec. Publ. **18**, 209—233, Tulsa.

BOSELLINI, A., MASETTI, D., ARDIZZONI, F. & SARTI M. (1980): A Jurassic "Tongue of the Ocean": the Belluno Trough and its adjacent carbonate platforms, Venetian Alps Italy (abstr). — 26th Int. Geol. Congress, Paris.

CASTELLARIN, A. (1972): Evoluzione paleotettonica sinsedimentaria del limite tra "Piattaforma veneta" e "Bacino lombardo" a nord di Riva del Garda. — Giorn. di Geol., **38**, 11—212, Bologna (with quotations therein included).

CASTELLARIN, A. & SARTORI, R. (1980): Struttura e significato della Linea delle Giudicarie Sud. — Rendiconti Soc. Geol. Ital., **2**, Roma (in press), with quotations therein included.

GAETANI, M. & POLIANI, G. (1978): Il Toarciano e il Giurassico medio in Albenza (Bergamo). — Riv. Ital. Paleont., **84**, 349—382, Milano.

PISA, G., CASTELLARIN, A., LUCCHINI, F., ROSSI, P. L., SIMBOLI, G., BOSELLINI, A. & SOMMAVILLA, E. (1980): Middle Triassic Magmatism in Southern Alps. In: A review of general data in the Dolomites. — Riv. Ital. Paleont., Milano (in press).

STURANI, C. (1971): Ammonites and Stratigraphy of the "Posidonia alpina" Beds of the Venetian Alps. — Mem. Ist. Geol. Min. Univ. Padova, **28**, 1—190, Padova.

VENZO, S. (1954): Stratigrafia e tettonica del Flysch (Cretacio-Eocene) del Bergamasco e della Brianza orientale. — Mem. descr. Carta Geol. d'Italia, **31**, 7—134, Roma.

WINTERER, E. L. & BOSELLINI, A. (1980): Subsidence and Sedimentation on a Jurassic Passive Continental Margin, Southern Alps, Italy. — AAPG Bull., Tulsa (in press).

Zeitschrift/Journal: Abhandlungen der Geologischen Bundesanstalt in Wien

Jahr/Year: 1980

Band/Volume: 34

Autor(en)/Author(s): Bosellini A., Lobitzer Harald, Brandner Rainer, Resch Werner, Castellarin A.

Artikel/Article: The Complex Basins of the Calcareous Alps and Palaeomargins 287-324