The Ordovician–Silurian boundary in the Carnic Alps of Austria

H. P. Schönlaub

Geologische Bundesanstalt, PO Box 154, Rasumofskygasse 23, A 1031 Vienna, Austria

Synopsis

Although the Ordovician–Silurian boundary is represented in some places by a considerable unconformity in the Carnic Alps, in other sections a *Hirnantia* fauna in the Plocken Formation and possibly *persculptus* Zone graptolites are succeeded by the Bischofalm facies which in places has yielded graptolites of the *acuminatus* Zone. The shallow-water facies and unconformities at and near the boundary were partly caused by the global eustatic fall and rise in sea level and partly by Caledonian tectonic activity.

Introduction

The long geological history of the Carnic Alps of Austria and northern Italy lasts from the late Ordovician to middle Triassic times. For many years in this region several sections which cross the Ordovician–Silurian boundary and represent different environmental settings have been well known. Based on earlier studies by Gaertner (1931), Walliser (1964), Flügel (1965), Serpagli (1967), Schönlaub (1969, 1971), Vai (1971), and Jaeger *et al.* (1975), a brief summary of knowledge of this interval up to the year 1975 was submitted and published in an earlier circular of the Ordovician–Silurian Boundary Working Group.

Based on the final decision of the Commission on Stratigraphy that the base of the Silurian System shall be at the base of the *A. acuminatus* Biozone, the present paper revises the stratigraphy of the boundary beds in the Carnic Alps. In addition new field data are presented and summarized in this updated version of previous reports. I acknowledge the help of H. Jaeger, Berlin, and R. Schallreuter, Hamburg, who kindly provided unpublished data on graptolites and ostracods.

Upper Ordovician sediments and stratigraphy

All known late Ordovician and early Silurian boundary sequences show clear evidence of a regressive–transgressive relationship. Except for one section representing the deep water 'Bischofalm graptolite facies', for which, however, biostratigraphical data are missing for the late Ordovician, the lithology and faunal composition in the upper Ordovician reflect a stable environment of shallow to moderate depths with a considerable clastic influx in the Caradoc Stage. During this time the fossiliferous Uggwa Shales, up to 100 m thick, were deposited. They comprise sandy shales and pass laterally into greenish and brownish mudstones and siltstones, the latter being widely distributed in the Central Carnic Alps in the surroundings of Plöckenpass and Lake Wolayer. In contrast to the typical Uggwa Shales, in these beds only very few fossils occur. This shale and siltstone sequence grades laterally and in part also vertically into 40–60 m of thick well-bedded and locally cross-bedded sandstones also known as the Himmelberg Sandstone. Fossils, if any, are extremely rare except for the under- and overlying strata which suggest a late Caradoc age for this unit. Hence, this sandstone is in part equivalent to the Uggwa Shale, which is also supported by field observations. The fauna of the clastic upper Ordovician sequence is dominated by bryozoans and less frequently brachiopods, trilobites, gastropods and cystoids occur. According to Vai (1971) and Havlíček *et al.* (1987), this fauna suggests a close relationship to middle Caradoc sequences of Sardinia and other regions of southern Europe as well as to Bohemia.

The Caradoc Uggwa Shale and its equivalent, the Himmelberg Sandstone, are overlain by distinctive limestones of Ashgill age. Two lithological types are developed in the Carnic Alps,

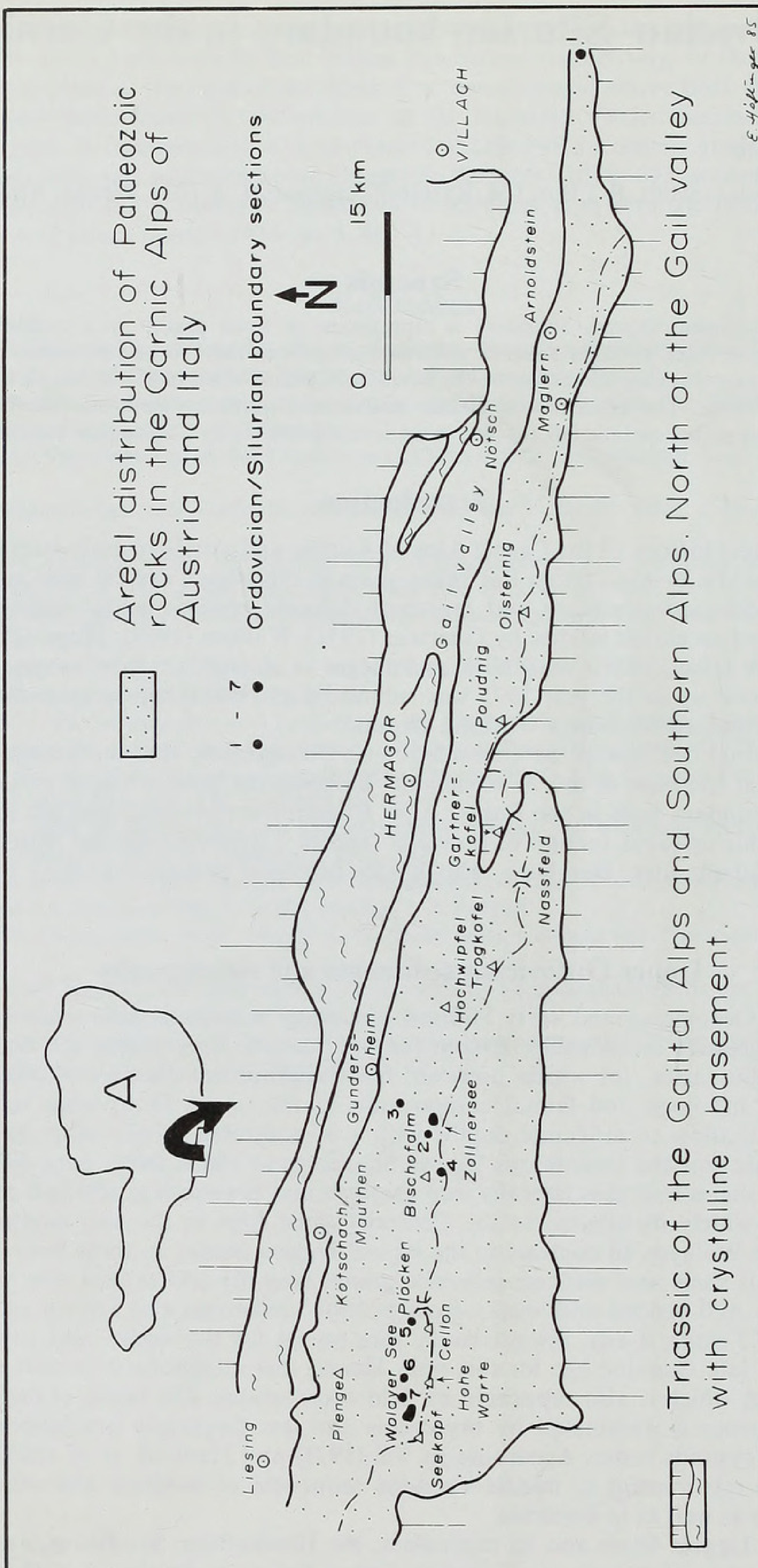


Fig. 1 Map of the Carnic Alps area in south Austria and north Italy.

the first being the nodular Uggwa Limestone and the other its lateral equivalent, the coarse-grained biodetrital Wolayer Limestone. The Uggwa Limestone represents a quiet water shelf environment and contains relatively abundant microfossils, for example conodonts, ostracods and foraminiferans, but also a few trilobites, bryozoans, brachiopods and cephalopods. Yet age assignments within the Ashgill are not precisely known except for its upper part, in which the *Hirnantia* fauna is found.

The second type, the Wolayer Limestone, comprises biodetrital cystoid-bearing light grey limestones which may be up to 18 m thick, three times as much as the Uggwa Limestone. Its palaeogeographic setting suggests carbonate mud mounds on the outer shelf surrounded by rather uniform and more widely distributed shelf carbonates of the Uggwa Limestone. There is no indication of close proximity to a land area for either type. In the Carnic Alps lateral changes between the two limestone types can occur over a few km in the same tectonic unit. In other places they are tectonically separated. As shown in the diagrams (Figs 1, 2) the individual boundary sections exhibit significant differences in thickness and lithology, as far as the latest Ordovician is concerned.

The Boundary Beds

At the top of the Ordovician sequence in the Carnic Alps a widespread sandy facies occurs, the so-called Plöcken Formation. In the old literature this horizon was termed 'Untere Schichten'. It succeeds the Uggwa Limestone but is missing at the top of the coeval Wolayer Limestone (see below). Reinvestigation of the Plöcken Formation indicates that it represents a regressive sequence starting with offshore shaly mud intercalations in the uppermost Uggwa Limestone and above, and developing into shoreface calcareous sands. In these beds contorted deformation structures are very common. In the lower parts they are associated with channel fillings of coarse bioclastic material.

The Hirnantian fauna which first occurs in laminated greenish-greyish mudstones overlying the Uggwa Limestone at Cellon shows evidence of transportation. The same is true for the Hoher Trieb section east of Cellon (Figs 4E, 4F). The poorly sorted, mostly disarticulated fossil debris occurs in several layers. They are characterized by internal erosional surfaces, small-scale channelling, reworking of sediment, bioturbation with subsequent infilling of fossils, and pronounced load deformation structures. Higher up in the sequence channelling and reworking of the sediment increase, although laminated mudstones are here less abundant. Usually channels are connected with contorted beds the thickness of which is usually between 10 and 20 cm but which may reach 60 cm.

The channel filling consists of coarse-grained bioclastic limestones which cut into the underlying mudstones and shales. Fossils include representatives of the *Hirnantia* fauna (mainly brachiopods and trilobites), pyritized ostracods and spicules. According to Jaeger *et al.* (1975) and Schönlaub (1980: fig. 27 and 1985: fig. 25a) the following taxa have been found in the latest Ordovician Hirnantian Stage:

Kinnella kielanae (Temple)	*Dalmanitina mucronata* (Brongniart)
Rafinesquina sp.	*Icriodella* sp.
Clarkeia sp.	*Quadrijugator harparum* (Troedsson)
Hirnantia sagittifera (M'Coy)	*Scanipisthia rectangularis* (Troedsson)
Dalmanella testudinaria (Dalman)	*Eocytherella troedssonia* Bonnema
Cryptothyrella sp.	*Dornbuschia ostseensis* Schallreuter

At Cellon (Fig. 3) and Hoher Trieb (Figs 4E, 4F) the channels are connected or grade into contorted beds composed of less pure limestones. They are irregularly coloured brownish and greyish marls with floating brachiopod valves and loosely packed matrix-supported subangular clasts of different rock types including carbonates of different size up to 20–30 cm in diameter, sandstone pebbles, shales or small black phosphorite nodules. At the Nölblinggraben section at the base of the Plöcken Formation there is even a layer with clasts of granitic composition (Schönlaub & Daurer 1977).

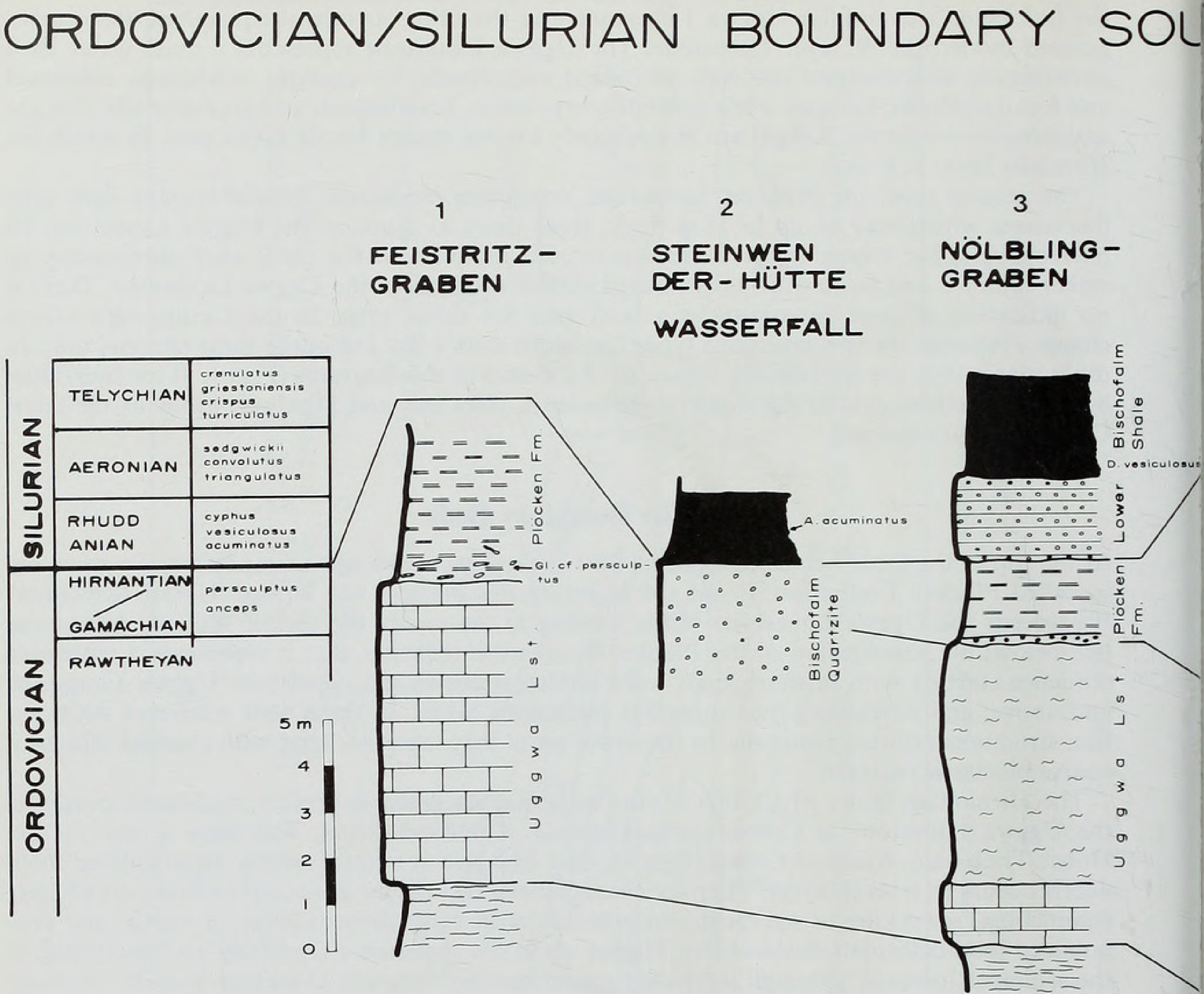
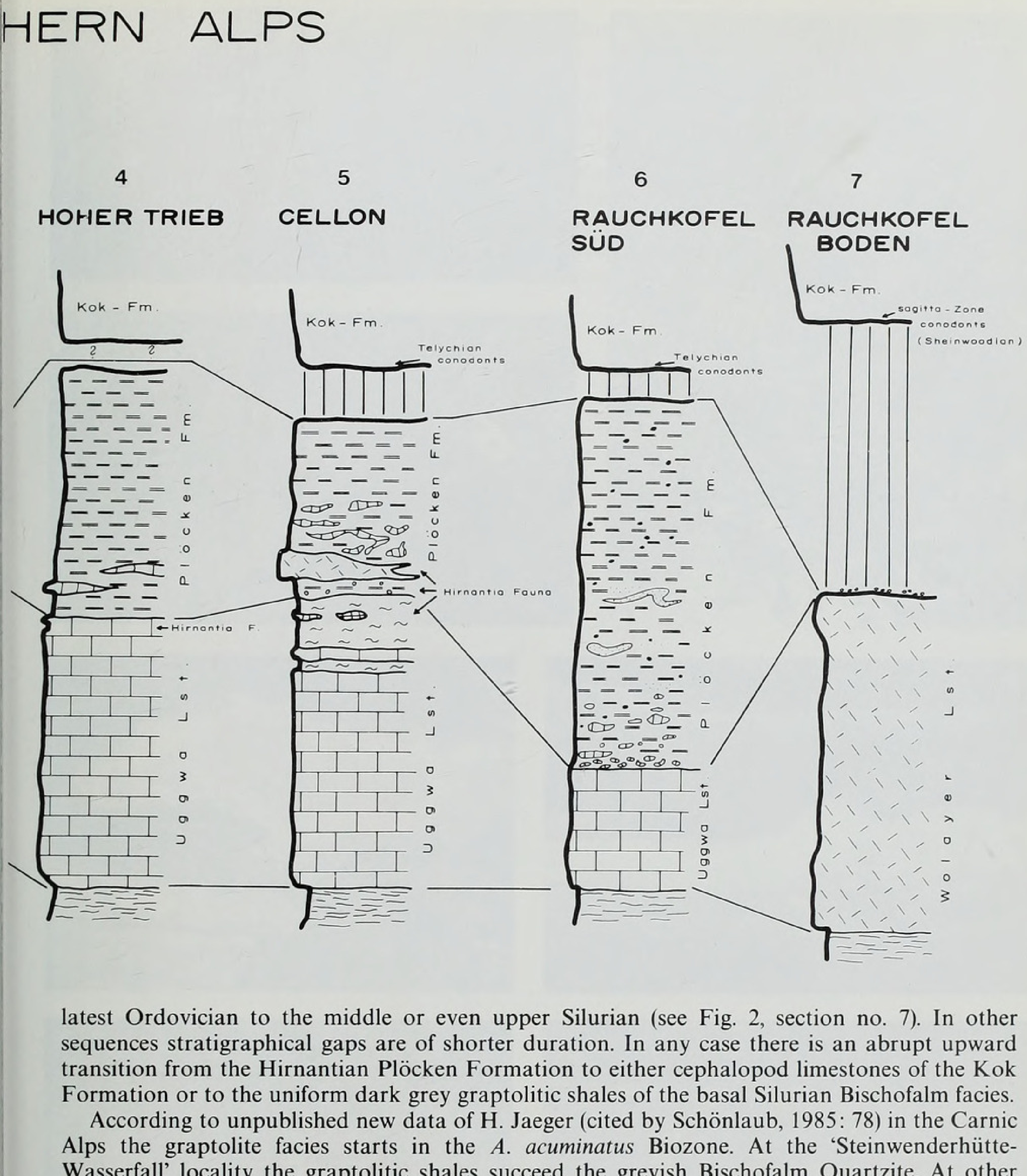


Fig. 2 Comparative sections through the Carnic Alps near the Ordovician–Silurian boundary.

The Plöcken Formation has a thickness of between 1·5 and 9 m, the latter occurring on the southern slope of Mount Rauchkofel. Based on the occurrences of the *Hirnantia* faunal assemblage at the Cellon, Hoher Trieb and Uggwa sections, a late Ashgill age, i.e. the Hirnantian Stage, is deduced for the Plöcken Formation. This is in agreement with earlier reports of *Glyptograptus* cf. *persculptus* (Salter) from the 'Feistritzgraben' section in the Western Karawanken Alps (Jaeger *et al.* 1975). We correlate this level with the basal Plöcken Formation in the Carnic Alps, although the lithologies are slightly different.

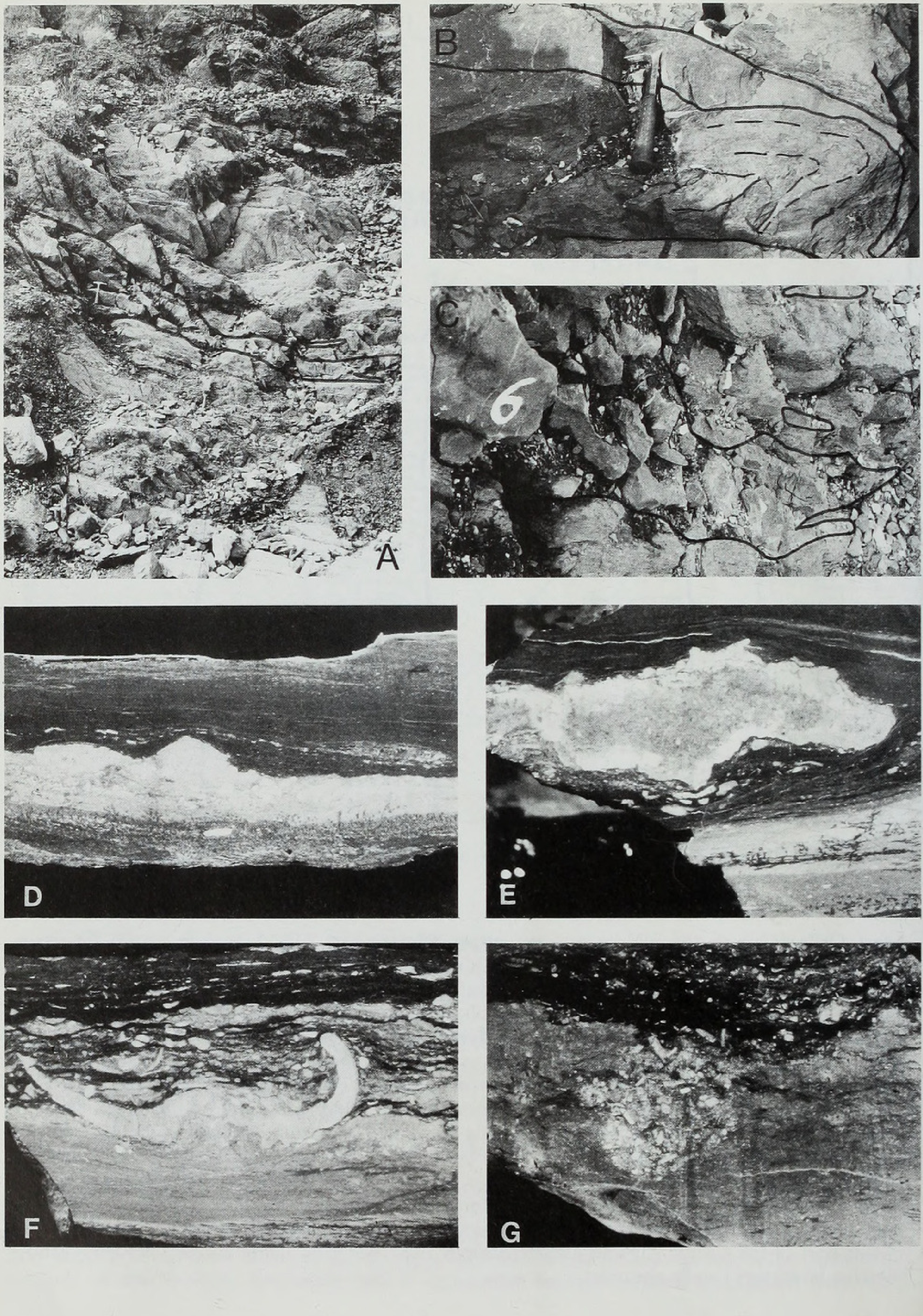
The Base of the Silurian

On the carbonate shelf which was already shallow in pre-Hirnantian times the shallow water carbonate facies was re-established in the Silurian. However, in this facies disconformities with distinct karst surfaces are widely developed and depositional hiatuses are well known. The relief may be several cm or more. In particular this phenomenon can be seen on top of the carbonate mounds of the Wolayer Limestone which apparently became subaerially exposed from the



latest Ordovician to the middle or even upper Silurian (see Fig. 2, section no. 7). In other sequences stratigraphical gaps are of shorter duration. In any case there is an abrupt upward transition from the Hirnantian Plöcken Formation to either cephalopod limestones of the Kok Formation or to the uniform dark grey graptolitic shales of the basal Silurian Bischofalm facies.

According to unpublished new data of H. Jaeger (cited by Schönlaub, 1985: 78) in the Carnic Alps the graptolite facies starts in the *A. acuminatus* Biozone. At the 'Steinwenderhütte-Wasserfall' locality the graptolitic shales succeed the greyish Bischofalm Quartzite. At other places, for example at Nölblinggraben, *D. vesiculosus*, the index graptolite of the lower Silurian graptolite zone 17, has been reported overlying an almost 2 m thick quartzitic rock. Due to the lack of fossils the stratigraphical relationship between the two quarzitic members is yet poorly understood. They may represent fan deposits of different ages, the lower one being deposited in basin areas of the Hirnantian low sea level stand and the latter at or near the beginning of the transgressive graptolite sequence at the presumed base of the Rhuddanian Stage. In either case, in this part of the Carnic Alps an almost complete succession of strata across the Ordovician–Silurian boundary can be assumed.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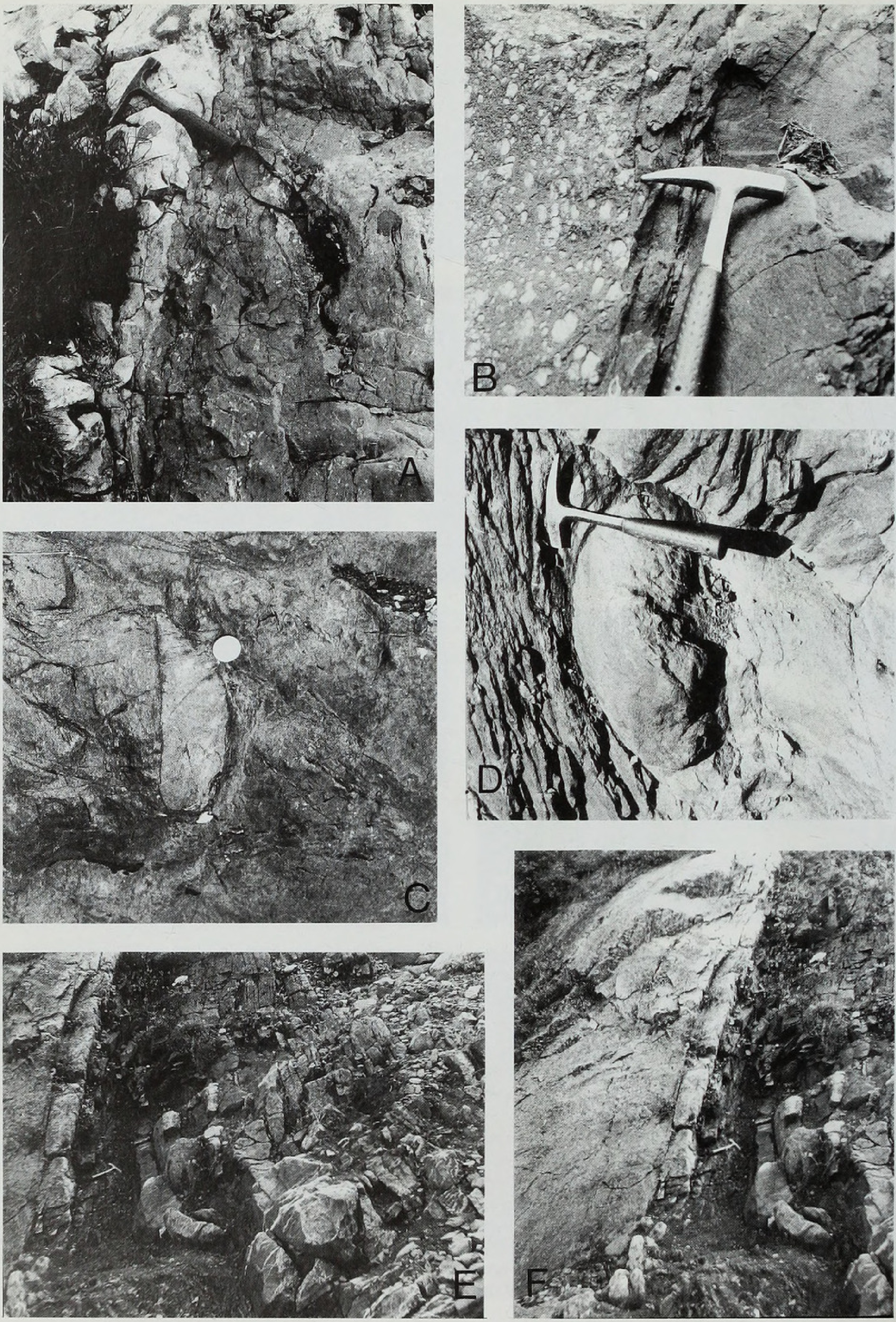
Conclusion

The Ordovician–Silurian boundary beds in the Carnic Alps reflect a regressive–transgressive cycle. Alongside probably continuous sedimentation across the systemic boundary in sections representing deeper environments, in the shallow carbonate shelf areas stratigraphical gaps are very common. This relation is in accordance with data from other regions in the world. However, this event was not solely caused by worldwide eustatic changes of sea level attributed to the famous glacial event in the southern hemisphere. Vertical block movements of Caledonian age also affected the Carnic Alps in the late Ordovician and, consequently, were also responsible for differences in thickness of closely-related sections as well as for greatly differing facies that developed in the Silurian after a less pronounced facies pattern in the Ordovician.

Fig. 3 Ordovician–Silurian boundary beds at the Cellon section in the central Carnic Alps of Austria. A: Cellon section, lower part showing Uggwa Limestone in the lower portion and Plöcken Formation above. Indicated is a coarse grained channel filling limestone bed at the base of the Plöcken Formation. B: Detail from A in the upper portion of the Plöcken Formation showing a multilayered fold. C: Detail from A. Coarse-grained limestone bed at the base of the Plöcken Formation (no. 6 is a reference point of O. H. Walliser's conodont-based collection). D: Internal erosional surface in the uppermost Uggwa Limestone Formation at level no. 5 of Walliser (1964). Length of the cut approx. 4 cm. E: Reworked limestone clast at the same horizon as Fig. D. Long axis approx. 3·5 cm. F: Fossil debris representing components of the *Hirnantia* fauna in the uppermost Uggwa Limestone Formation at horizon no. 5 of Walliser (1964). Width of the brachiopod valve is 3 cm. G: Same horizon as Figs D–F showing bioturbation and infilling at an internal erosional surface in mudstones. Length of the cut approx. 4 cm.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References

Flügel, H. 1965. Vorbericht über mikrofazielle Untersuchung des Silurs des Cellon-Lawinenrisses (Karnische Alpen). *Anz. öst. Akad. Wiss. mat.-nat. Kl.*, Wien, **1965:** 289–297.

Gaertner, H. R. von 1931. Geologie der Zentralkarnischen Alpen. *Denkschr. Akad. Wiss. Wien* **102:** 113–199.

Havlíček, V., Kříž, J. & Serpagli, E. 1987. Upper Ordovician Brachiopod assemblages of the Carnic Alps, Middle Carinthia and Sardinia. *Boll. Soc. paleont. ital.*, Modena, **25:** 277–311, 9 pls.

Jaeger, H., Havlíček, V. & Schönlaub, H. P. 1975. Biostratigraphie der Ordovizium/Silur-Grenze in den Südalpen—Ein Beitrag zur Diskussion um die *Hirnantia*-Fauna. *Verh. geol. Bundesanst., Wien* **1975:** 271–289.

Schönlaub, H. P. 1969. Das Paläozoikum zwischen Bischofalm und Hohem Trieb (Zentrale Karnische Alpen). *Jb. geol. Bundesanst. Wien* **112:** 265–320.

—— 1971. Palaeo-environmental studies at the Ordovician/Silurian boundary in the Carnic Alps. *Mém. Bur. Rech. géol. minièr.*, Paris, **73:** 367–376.

—— 1980. Field Trip A: Carnic Alps. *In* H. P. Schönlaub (ed.), Guidebook, Abstracts. Second European conodont symposium. *Abh. geol. Bundesanst.*, Wien, **35:** 5–60, 10 pls.

—— 1985. Das Paläozoikum der Karnischen Alpen. Exkursion Wolayersee. *Arbeitstag. geol. Bundesanst.*, Wien, **1985:** 34–69.

—— **& Daurer, A.** 1977. Ein auffallender Geröllhorizont an der Basis des Silures im Nölblinggraben (Karnische Alpen). *Verh. geol. Bundesanst., Wien* **1970:** 361–365.

Serpagli, E. 1967. I conodonti dell'Ordoviciano Superiore (Ashgilliano) delle Alpi Carniche. *Boll. Soc. paleont. ital.*, Modena, **6:** 30–111, 25 pls.

Vai, G. B. 1971. Ordovicien des Alpes Carniques. *Mém. Bur. Rech. géol. minièr.*, Paris, **73:** 437–450, 4 pls.

Walliser, O. H. 1964. Conodonten des Silurs. *Abh. hess. Landesamt. Bodenforsch.*, Wiesbaden, **41:** 1–106, 32 pls.

Fig. 4 Ordovician–Silurian boundary sections at Rauchkofel-Boden, Rauchkofel-Süd and Hoher Trieb in the central Carnic Alps. A: Rauchkofel-Boden section, disconformity between the Ashgill Wolayer Limestone (left) and the darker cephalopod-bearing Kok Formation (right). At the base of the latter *sagitta*-Zone conodonts of middle Wenlock age occur. B: Rauchkofel-Süd section showing contact between the nodular Uggwa Limestone (left) and the overlying Plöcken Formation (right). C, D: Reworked limestone clasts containing an *Amorphognathus ordovicicus* conodont fauna in the lower part of the Plöcken Formation at the Rauchkofel-Süd section. E, F: Hoher Trieb section. Uggwa Limestone (left) and basal part of the Plöcken Formation (right). Note channel filling coarse-grained bioclastic bed near the base of the Plöcken Formation. This bed contains representatives of the *Hirnantia* fauna (*Hirnantia sagittifera, Dalmanella testudinaria, Kinnella kielanae, Cryptothyrella* sp. and also *Clarkeia* sp.).