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Metamorphism in the Austroalpine Units between Innsbruck and Salzburg (Austria) — A Synopsis.

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With 1 Figure

Summary

This paper presents the results on metamorphic petrology, which have been carried out on igneous and sedimentary rocks of the Lower Austroalpine Innsbrucker Quarzphyllit, the Middle Austroalpine Altkristallin, the Upper Austroalpine Grauwackenzone, and the Northern Calcareous Alps. Regional distribution and intensity of metamorphism will be discussed as well as questions concerning the relative timing of the Alpine metamorphic events. The synopsis also summarizes the special papers, provided by the authors in this volume separately.

Content

1. Introduction

Lower Paleozoic and Permoskythian rocks have been studied in the course of the scientific program N 25 "Geologischer Tiefbau der Ostalpen" within the last five years. These investigations included metamorphic petrology of selected basic and acid igneous rocks as well as clastic sedimentary rocks from Austroalpine units between Innsbruck and Salzburg.

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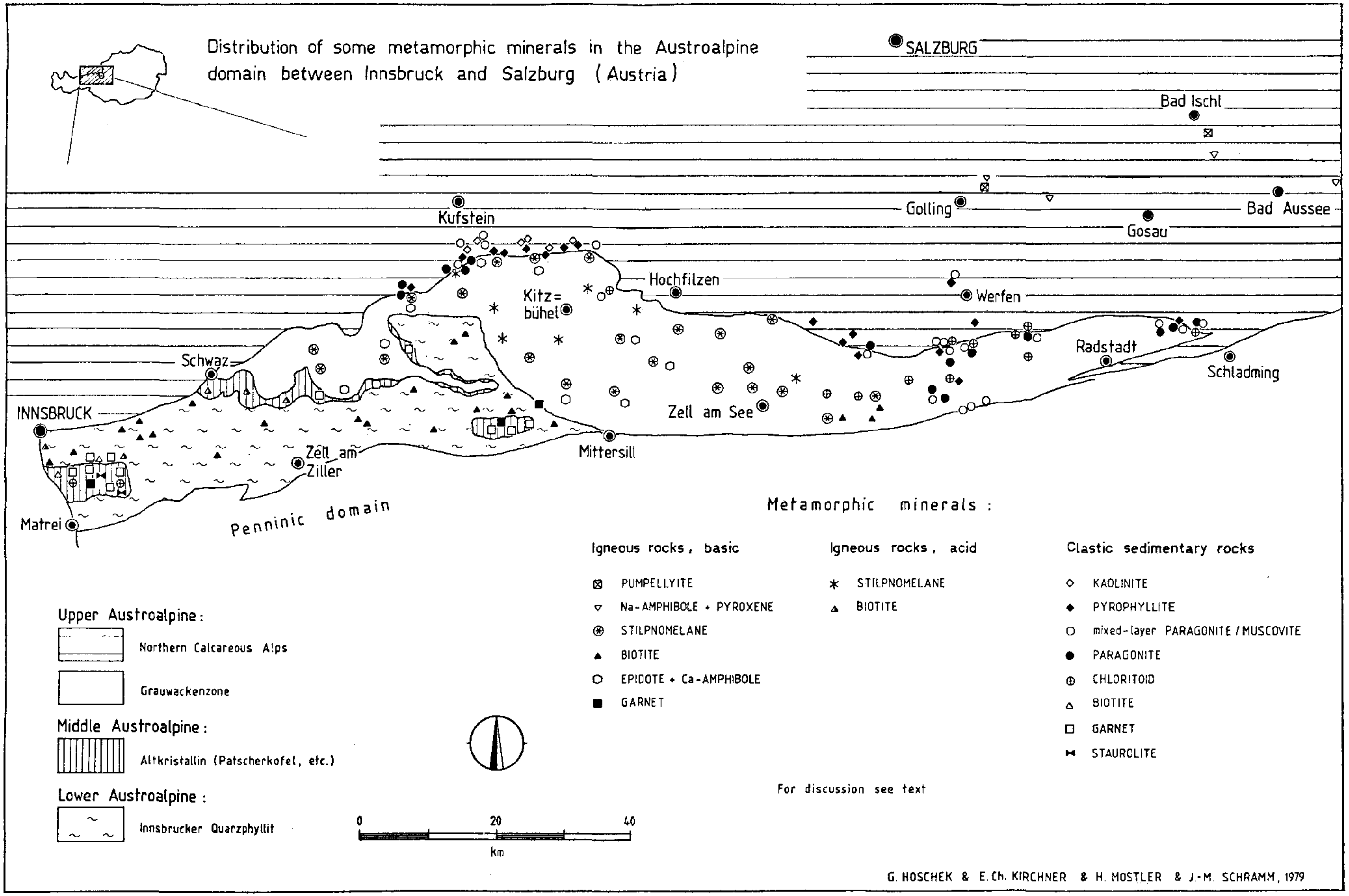
Distribution of some metamorphic minerals in the Austroalpine domain between Innsbruck and Salzburg (Austria)
SALZBURG
Bad Ischl
Golling
Bad Aussee
Gosau
Kufstein
Hochfilzen
Werfen
Kitz=bühel
Radstadt
Schladming
Schwaz
INNSBRUCK
Zell am See
Zell am Ziller
Mittersill
Matrei
Penninic domain
Metamorphic minerals :
Igneous rocks, basic
PUMPELLYITE
Na-AMPHIBOLE + PYROXENE
STILPNOMELANE
BIOTITE
EPIDOTE + Ca-AMPHIBOLE
GARNET
Igneous rocks, acid
STILPNOMELANE
BIOTITE
Clastic sedimentary rocks
KAOLINITE
PYROPHYLLITE
mixed-layer PARAGONITE / MUSCOVITE
PARAGONITE
CHLORITOID
BIOTITE
GARNET
STAUROLITE
Upper Austroalpine :
Northern Calcareous Alps
Grauwackenzone
Middle Austroalpine :
Altkristallin (Patscherkofel, etc.)
Lower Austroalpine :
Innsbrucker Quarzphyllit
0
20
40
km
For discussion see text
G. HOSCHEK & E. Ch. KIRCHNER & H. MOSTLER & J.-M. SCHRAMM, 1979

Accordingly, results from the Lower Austroalpine Innsbrucker Quarzphyllit (HOSCHEK, MOSTLER), the Middle Austroalpine Altkristallin (HOSCHEK, MOSTLER), the Upper Austroalpine Grauwackenzone (HOSCHEK, MOSTLER, SCHRAMM), and the Northern Calcareous Alps (KIRCHNER, SCHRAMM) can be presented in the following.

The "Map of distribution of metamorphic minerals" (figure 1) comprehends these results, being the basis for the following discussion. It shows a more detailed and modified situation as outlined in the "Metamorphic map of the Alps" (1 : 1,000.000), which had presented a rather good synopsis of the state of knowledge up to 1973.

The regional density of findings required a generalized presentation, so that each symbol indicates the occurrence of a metamorphic mineral in a group of rock samples. Beforehand it is to say, that isogrades do not depend on special P-T-conditions only, but also on the chemical environment. For the interpretation of mineral zones this fact has to be considered in any case. Due to that fact, the formation of pyrophyllite is to be observed in rocks of different chemistry, such as carbonate-bearing siltstones (Skythian) and phyllites (Ordovician), etc.

For this paper tuffs and tuffitic rocks will be counted to the igneous rocks. The evaluation of metamorphic conditions corresponds with the concept of H. G. F. WINKLER (1976).

2. Lower Austroalpine

Innsbrucker Quarzphyllit

A tectonic separation of the Innsbrucker Quarzphyllit and the Grauwackenzone has been proposed due to the intercalation of the Schwazer Augengneis and equivalents (A. TOLLMANN, 1959). Moreover, the different metamorphic grade of both series was stated by H. MOSTLER (1967). In contrast to the widespread occurrence of stilpnomelane and the paucity of biotite in metabasic rocks of the Grauwackenzone, no stilpnomelane has been observed in metabasic rocks of the Quarzphyllit area and biotite often becomes a dominant member of mineral assemblages in the latter rocks. Furthermore, the common appearance of zoned brown-green-colourless amphiboles in the Grauwackenzone is not recognized in the Quarzphyllit area. The main constituents of metabasic rocks of the latter zone are actinolitic amphibolite, chlorite, epidote, biotite, albite, calcite, quartz, and sphene. Therefore higher metamorphic conditions can be deduced for metabasic rocks of the Quarzphyllit area compared to the Grauwackenzone.

For most parts of the Quarzphyllit area phase assemblages in metapelitic sediments (quartz, albite, muscovite, chlorite, and calcite) are similar to metasediments of the Grauwackenzone. However, stilpnomelane and chloritoid are obviously restricted to the latter zone. Mean diameters of sheet silicates in the Quarzphyllit area are distinctly higher than in the Grauwackenzone. Recently biotite and garnet were observed in the southwestern part of the Quarzphyllit

← Fig. 1

zone (Voldertal). Both minerals are affected by later retrograde formation of chlorite. From these observations metamorphic conditions around the middle greenschist facies can be inferred at least for parts of the Quarzphyllit area. Compared with the Grauwackenzone in the north and the Penninic zone in the south, the generally higher metamorphic conditions of the intermediate situated Quarzphyllit area rocks are confirmed.

3. Middle Austroalpine

Patscherkofelkristallin

A first metamorphic stage was preceded by a deformation. This follows from thin section observations of microfoliation pattern, preserved by graphitic matter, opaques and tourmaline (with clastic cores). The following growth of staurolite, kyanite, garnet, biotite, plagioclase, and microcline took place at P-T-conditions of the medium grade (amphibolite facies). A later event produced cataclastic deformation and various retrograde mineral reactions (staurolite → chloritoid, garnet → chlorite, biotite → chlorite, plagioclase → clinozoisite + muscovite). According to obviously still stable biotite (due to specific rock chemistry and consequently incomplete reactions like staurolite + biotite → chlorite + muscovite) metamorphic conditions of the middle greenschist facies should have prevailed during this stage. Complete breakdown of biotite to chlorite in basal parts of the Patscherkofelkristallin, in the vicinity of the Silltal, is supposed to be due to still younger tectonic movements and corresponding lower temperatures.

4. Upper Austroalpine

Grauwackenzone – Metabasic rocks

A polymetamorphic history is inferred from observations of mineral assemblages. A first high temperature stage is documented by brown and green amphibole, partially resorbing primary clinopyroxene. The lack of corresponding high grade mineral assemblages in metasediments of this area is in accordance with autometamorphism restricted to the igneous rocks. Such processes leading to breakdown reactions of primary magmatic minerals under the influence of decreasing temperatures and hydrothermal solutions must have been operated from high grade to low grade metamorphic conditions (low grade greenschist facies). After deformation a later metamorphic event produced stilpnomelane, phengitic muscovite, biotite (without coexisting muscovite), chlorite, albite, and actinolite-tremolite. Together with the lack of prehnite, pumpellyite, and lawsonite, physical conditions around 350–400° C, $P > 3$ kb and $< 4{,}5$–8 kb can be deduced from experimertally studied mineral equilibria. Similar P-T-conditions of the lower greenschist facies are indicated from mineral assemblages in metasediments of the Grauwackenzone (J.-M. SCHRAMM, 1977). At least parts of these low temperature assemblages are supposed to be products of an alpine regional metamorphic event. A more detailed discussion of metabasic rocks is given by E. COLINS, G. HOSCHEK & H. MOSTLER in this volume.

Grauwackenzone – Metasediments

The varied phyllites of the Wildschönauer Schiefer-Serie have been exposed to more than one low grade Variscan and Alpine metamorphic events. Metamorphic minerals are widespread. Besides to the well known blastoids of chloritoid, this mineral – without exception postkinematic – was detected in some new localities. Beyond that, by means of X-ray diffractometer, the phyllosilicates pyrophyllite, mixed-layer paragonite/muscovite, and paragonite were identified in many samples.

These metamorphic minerals indicate low grade subfacies of the greenschist facies (= "low grade metamorphism" sensu H. G. F. WINKLER, 1976). Measurements if illite crystallinity (index after B. KUBLER, 1967) are corresponding with these results. Values a altogether below 4.0 point out the field of epizone.

The above-mentioned minerals are more or less uniformly distributed in the Grauwackenzone, indicating approximatively the same metamorphic conditions. Illite crystallinity values, on the other hand, show statistically slightly decreasing intensity of metamorphism from south to north, e.g. in the area Semmering–Rax (Lower Austria), and in the section between Zell am See and Bischofshofen (Salzburg) (J.-M. SCHRAMM, 1977).

An order of crystallization might be observed in thin sections. Besides, two or three generations of white micas are followed by postkinematic chloritoids. Chloritoids are in any case the youngest metamorphic minerals. The formation of stilpnomelane as well as green and brown biotite (postkinematic blastoids in the metabasic rocks of the Grauwackenzone) might be compared with the growth of chloritoid, regarding their age of formation.

Although the timing of Alpine metamorphic events is not subject of considerations in this paper, one of the authors (SCHRAMM) supposes – only in the region of Bischofshofen (in connection with the Werfener Schuppenland, as discussed later) – a young metamorphic event. Indeed, in order to get a definitive answer, studies about the local structural feature are necessary to distinguish pre- and postgosauic tectonic movements in detail.

Deformed white micas, more or less parallel to s_1, may be interpreted as Variscan metamorphic relicts in the phyllites of the Grauwackenzone.

Northern Calcareous Alps – Mafic rocks

Mafic volcanic rocks and sediments can be found within the Northern Calcareous Alps, including mineral generations. Their local occurences indicate a low grade and/or very low grade metamorphism (sensu H. G. F. WINKLER, 1976), e.g. in the Salzkammergut region. They confirm and complete the results from the clastic sedimentary rocks of the Northern Calcareous Alps (J.-M. SCHRAMM, 1977, 1978). Pumpellyite with chlorite and quartz as paragenesis was observed in the pillow lava breccia of Grundlsee (Styria) (E. Ch. KIRCHNER, 1977, 1979). Suggesting a low pressure, a temperature of 345° C (2,5 kb) (K.-H. NITSCH, 1971) can be stated. Na-amphiboles and -pyroxenes (crossite, glaucophane, Mg-riebeckite, and aegirine), which were found in the mafic volcanic rocks and in the adjacent sedimentary rocks confirm the effect of a very low grade metamorphism. Occasionally two generations of glaucophane can be distinguished in the same sample. The minerals actinolite and epidote with pumpellyite indicate a low grade metamorphism in some types of volcanic rocks. E. Ch. KIRCHNER provides a detailed genetic interpretation of these mineralization phases in the same volume.

Northern Calcareous Alps – Sedimentary rocks

The clastic series of the Permoskythian, overlying the Grauwackenzone, have been metamorphosed in very low grade intensity (sensu H. G. F. WINKLER, 1976) at least. This is manifested by metamorphic minerals such as pyrophyllite, mixed-layer paragonite/muscovite, and paragonite as well as by illite crystallinity from 4.0 up to 7.5 (J,-M. SCHRAMM, 1977, 1978), and is followed by thin section observations, e.g. spiny-like structures, etc.

During early alpine orogenetic events the nappe structure of the early Calcareous Alps have been formed. Thus, very low grade metamorphism has its origin in a pile of nappes, which had a regionally different total thickness. The decreasing intensity in the western part of the Northern Calcareous Alps (in relation to the middle and eastern part) may be interpreted with the "nach Westen hin allmählichen Zuendegehen des oberostalpinen Deckensystems" (S. PREY, 1978). Due to that fact, the remarkable diagonal course of the epi-/anchizone border – regarding to the general trend (E–W) of the Grauwackenzone and the Northern Calcareous Alps – will be comprehensible.

According to a regionally greater thickness of overburden, the early Alpine metamorphism (it has been a transported metamorphism) has locally reached low grade intensity (= low grade subfacies of greenschist facies).

Postkinematic blastoids of chloritoid on the southern side of the Tennengebirge and Hochkönig (Salzburg) indicate a younger metamorphic event in this region. Thus, a low grade metamorphic overprint has affected Lower Paleozoic Wildschönauer Schiefer as well as Skythian Werfen beds in the same manner, both being intensively imbricated with one another near Hüttau. As A. TOLLMANN (1976, p. 244) summarized, the postgosauic imbrication tectonics is widely acknowledged for the Werfener Schuppenland. Due to that fact, there is a certain degree of probability for associating the postkinematic chloritoids with a late Alpine metamorphic event here. For a more detailed discussion see J.-M. SCHRAMM in this volume.

The northwards decreasing very low grade metamorphism can be studied only in a few sections. Suitable rocks are lacking over wide areas. However, it was possible to localize the kaolinite-pyrophyllite isograde in clastic rocks at the base of the Kaisergebirge (Tyrol). Illite crystallinity corresponds with this result and lies within the anchizone (4.0 up to 7.5).

With regard to illite crystallinity, white micas from Werfen beds indicate very low grade metamorphism (anchizone) as far as twenty kilometers north of the Grauwackenzone/Northern Calcareous Alps border (e.g. near Abtenau im Lammertal, Salzburg and Naßwald an der Rax, Lower Austria). The surrounding carbonate rocks do not show any indication of alteration, so that most findings within the anchizone may be interpreted only locally. Therefore, a metamorphic zonation can only be stated for clastic sedimentary and volcanic rocks on the other hand (E. Ch. KIRCHNER, 1979).

Nevertheless, an increasing knowledge on the burial history of various sedimentary and volcanic horizons of the Northern Calcareous Alps can be expected in connection with further investigations of stratigraphically higher levels.

More details concerning this survey will be discussed by the authors in separate articles within this volume. The references of this study are quoted in these special papers.