| Mitt. österr. geol. Ges. | 80<br>1987 | S. 173–183<br>7 fig., 1 tab. | Wien, Dezember 1987 |
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# Palaeomagnetism of Lower Triassic Red Sandstones in the Southern Kaisergebirge (Austria)

H. C. SOFFEL and D. WOHL*)

With 7 figures and 1 table

## Abstract

On the southern rim of the Kaisergebirge, Austria (12,3° E, 47,5° N) two long profiles (about 300 m) and one short profile (6 m) in the Lower Triassic Buntsandstein formation have been sampled for a palaeomagnetic and magnetostratigraphic study. While the rocks at the short profile near Hüttling show a certain degree of epizonal metamorphism, those of the other two profiles near Mühlbach and Seebach, respectively, are more or less unaltered.

Thermal demagnetization studies and rock magnetic measurements indicate that the main carrier of remanence is hematite. The remanence of rocks from sites Mühlbach and Seebach is monocomponent with negligible viscous magnetization components.

The mean remanence direction of both sites ($D = 35,8°$, $I = 30,6°$, $\alpha95 = 6,5°$) yields a pole position at 136,5°E, 47,3° N, which is near the Central European Lower Triassic pole position (153° E, 48° N, according to IRVING, 1977). This result indicates that no significant residual rotational movements took place in the central part of the Northern Calcareous Alps.

In the upper part of the mostly normal Mühlbach profile reversed polarities could be identified which allow a correlation of the profile with the Central European Lower Triassic polarity time scale. The exclusively normal Seebach profile must be placed entirely within the lower part of the normal sequence of the Skythian.

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## 1. Introduction

### *1.1. Palaeomagnetic data from the Northern Calcareous Alps*

The Mesozoic rock sequence in the Northern Calcareous Alps consists mainly of sedimentary rocks like limestones and sandstones. The palaeomagnetic data obtained

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*) Address of the authors: Institut für Allgemeine und Angewandte Geophysik, Universität München, Theresienstraße 41, D-8000 München 2, FRG.

sofar in this area have been reviewed recently by BECKE and MAURITSCH (1985). The palaeoremanence directions are in general not in agreement with Central European directions (SOFFEL, 1975, 1979; MAURITSCH and FRISCH, 1978; BECKE and MAURITSCH, 1985). They have been interpreted by rotations (anticlockwise in the western and clockwise in the eastern part of the Northern Calcareous Alps) leading to the assumption that the sedimentary basin was originally concave towards the North and has been bent into its present geometry during the northward movement of the nappes.

The investigations presented here were made on Lower Triassic sandstones from the Central part of the Northern Calcareous Alps south of the Kaisergebirge in a zone where little or no rotational movements have been detected in an earlier study (SOFFEL, 1979).

### *1.2. Geological situation and sampling*

The Alpine Buntsandstein formation forms the lowermost part of the nappe system of the Northern Calcareous Alps. In connection with the northward transport, the unit consisting of a basal breccia, red siltstones and grey, green and red sandstones has been deformed internally in many places. However, at some places, the profiles are quite undisturbed and suitable for a palaeomagnetic study. The stratigraphy in the sampling area south of the Kaisergebirge has recently been reviewed by STINGL (1983, 1984).

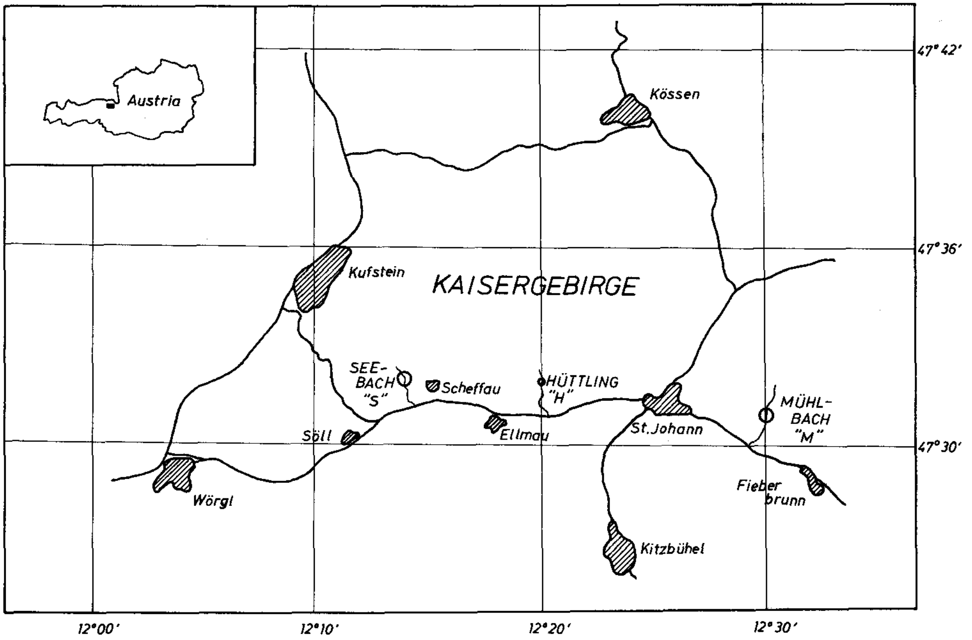

Fig. 1: Sketch map of the sampling area and the position of the profiles at the sites Seebach ("S"), Hüttling ("H") and Mühlbach ("M") south of the Kaisergebirge (Austria).

The Buntsandstein formation has been affected in some places by a low grade metamorphism during the alpine orogeny with a tendency to decrease towards the North (SCHRAMM, 1978, 1980, 1982).

Sampling was made with portable drilling machines along three creeks where fresh material was exposed (see Figure 1). From each stratigraphic level (banked sandstones) two short cores (3–4 cm) or one longer core (5–8 cm) were taken. Two or more sister specimens are available from each stratigraphic layer.

The westernmost site "S" is near the hamlet of Grub along a creek called Seebach. The profile covers a sedimentary pile of 310 m in thickness. 187 samples were taken yielding about one sample per 1.7 m and 419 specimens. The rocks at site "S" show strong internal deformation with folding on a small scale and shear zones. The uppermost part of the Quartz Sandstone is not present in this profile.

The central site "H" near the village of Hüttling is only a short section in the Quartz Sandstone. Here only 7 samples (with 19 specimens) from a sedimentary pile of 6 m in thickness were taken, yielding about 1 sample per meter. The rocks of this site show the highest degree of metamorphic alteration of all three sites.

The easternmost site "M" is situated along a creek named Mühlbach. From the stratigraphic point of view it is the most complete and undisturbed profile. It has also been used by STINGL (1983, 1984) for a new definition of the lithostratigraphy of the Alpine Buntsandstein. Sampling started in the quite well marked transition from the red silt stone series to the Quartz Sandstone. This transition was defined by STINGL (priv. comm.) as the border between the Permian and the Triassic (Skythian) in this area. The sampled profile covers a thickness of 268 m from which 214 samples with 536 specimens were taken (about one sample per 1.3 m). The rocks of this profile show the lowest degree of metamorphic alteration of all three sites.

The two long profiles "S" and "M" were divided into 10 and 14, respectively, subsections of about equal thickness. The mean geographic coordinates of the sampling area are: 12.3° E and 47.5° N.

## 2. Rock magnetic measurements

### 2.1. *Magnetic susceptibility and its anisotropy*

The susceptibility k of 879 reasonably well shaped specimens was measured prior to the measurements of the remanent magnetization with a susceptibility bridge (Kappabridge KLY-2). A mean value of 50 × 10 (exp −6) SI units was obtained. On 172 specimens of perfect cylindrical shape, evenly distributed over the profiles, the anisotropy was also measured. The axes of minimum (crosses), intermediate (triangles) and maximum (circles) susceptibility with respect to the bedding plane are plotted in Fig. 2a for the specimens of site "M" and in Fig. 2b for site "H". As has been recently shown by SCHULTZ-KRUTISCH and HELLER (1985) on Upper Triassic Buntsandstein and BERES and SOFFEL (1985) on Lower Triassic Buntsandstein from Northern Bavaria, the anisotropy of the magnetic susceptibility can be used to control whether the sedimentary fabric of the magnetic minerals is still present or has been replaced by secondary minerals. An undisturbed magnetic susceptibility fabric is present when the axis of minimum susceptibility k(min) is normal to the bedding plane with an either random or preferred orientation of the axes of intermediate k(int) and of maximum susceptibility k(max) within the bedding plane. Fig. 2a shows clearly a completely random distribution of susceptibility anisotropy for the specimens of site "M". (The specimens of site "S" show the same behaviour as those of site "M"). In comparison with the sandstones from Northern Bavaria, where a pronounced sedimentary fabric has been found, the rocks of sites "S" and "M" must have suffered some alteration of the magnetic mineralogy after deposition. Site "H", on the other hand, shows a well grouped direction of the axis of k(min) and a random distribution of k(int) and k(max) with respect to the bedding plane. However, this is also the plane of foliation of the rocks at this site and the formation of sericite so that the anisotropy at site "H" is rather due to epizonal metamorphism.

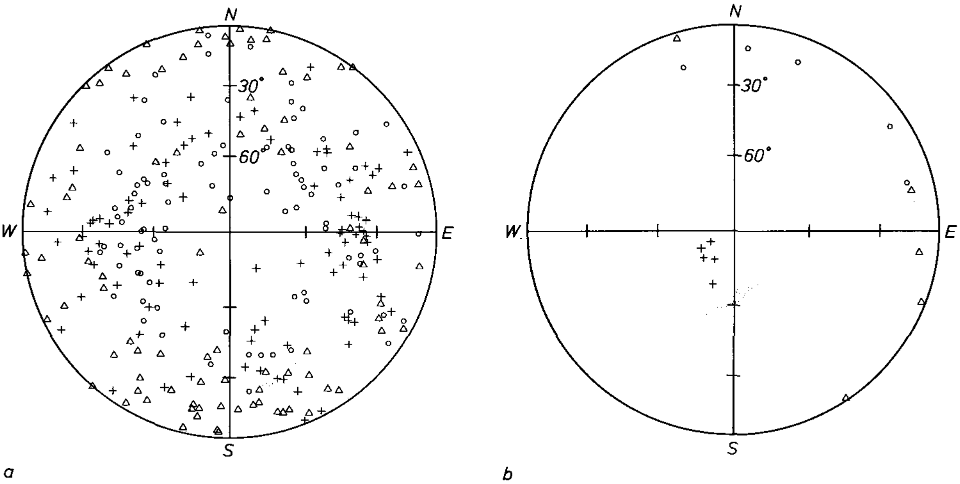

Fig. 2: Anisotropy of the magnetic susceptibility k with reference to the bedding plane. Crosses: k(min); triangles: k(int); circles: k(max). a) Specimens from site "M". b) Specimens from site "H".

At sites "S" and "M" we believe that the formation of pigmentary hematite in these rocks in connection with oxidation processes after deposition are responsible for the loss of a clearly defined susceptibility anisotropy. This interpretation is supported by the quite small P-value (P = k(max)/k(min)) of only 1.03 which means almost absent anisotropy. Schultz-Krutisch and Heller (1985) found average values of 1.05 for the sandstones in Northern Bavaria.

## 2.2. *Isothermal remanent magnetization*

In order to determine the carrier of remanence in the sandstones, the acquisition of remanent magnetization was measured in fields up to about 1.2 Tesla using a method proposed by Dunlop (1972). Fig. 3 shows several curves for samples of the sites "S" and "M". The IRM acquisition curves indicate that magnetite is present, but only in a very small fraction. The main magnetic mineral is obviously hematite. Goethite seems to be absent indicating that the rocks have not been affected by recent weathering. The dominance of hematite is also evident from the thermal demagnetization experiments (see 3.2.).

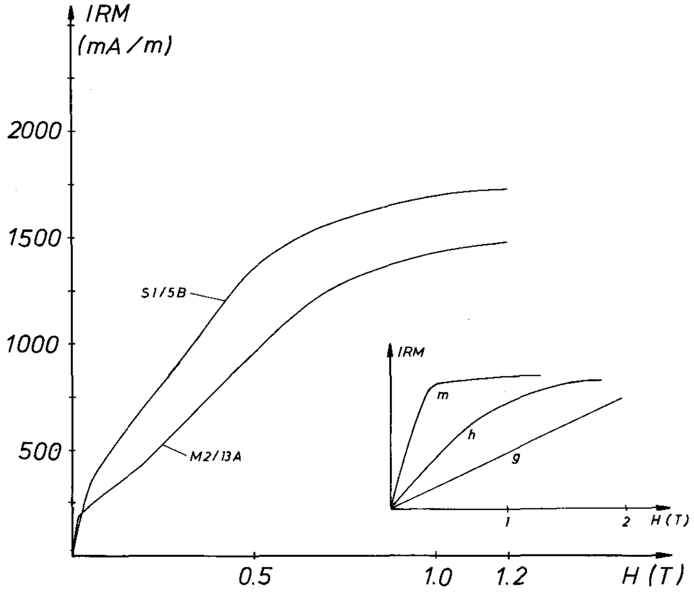

Fig. 3: Acquisition of isothermal remanent magnetization (IRM) in fields up to 1.2 Tesla. Specimens from sites "S" and "M". Insert: typical curves for magnetite (m), hematite (h) and goethite (g).

## 3. Palaeomagnetic measurements

### *3.1. Natural remanent magnetization (NRM)*

Most specimens had a NRM intensity in the range between 0.5 and 2 × 10 (exp −3) A/m. They were measured with a cryogenic magnetometer. The NRM directions of the subsections of the sites "S", "M" and "H" are plotted in Fig. 4 before (triangles) and after (circles) tilt correction. The NRM directions of sites "S" and "M" are quite well grouped and their mean directions are significantly away from the present day geomagnetic field direction in the sampling area (asterisk in Fig. 4). All reversed directions of sites "S" and "M" have been inverted to normal polarity. A considerable scatter of the NRM directions has been found for site "H". As pointed out earlier, the rocks of this site show the highest degree of metamorphic alteration of all three sites. The scatter for site "H" is so large that the computation of a mean direction can hardly be justified.

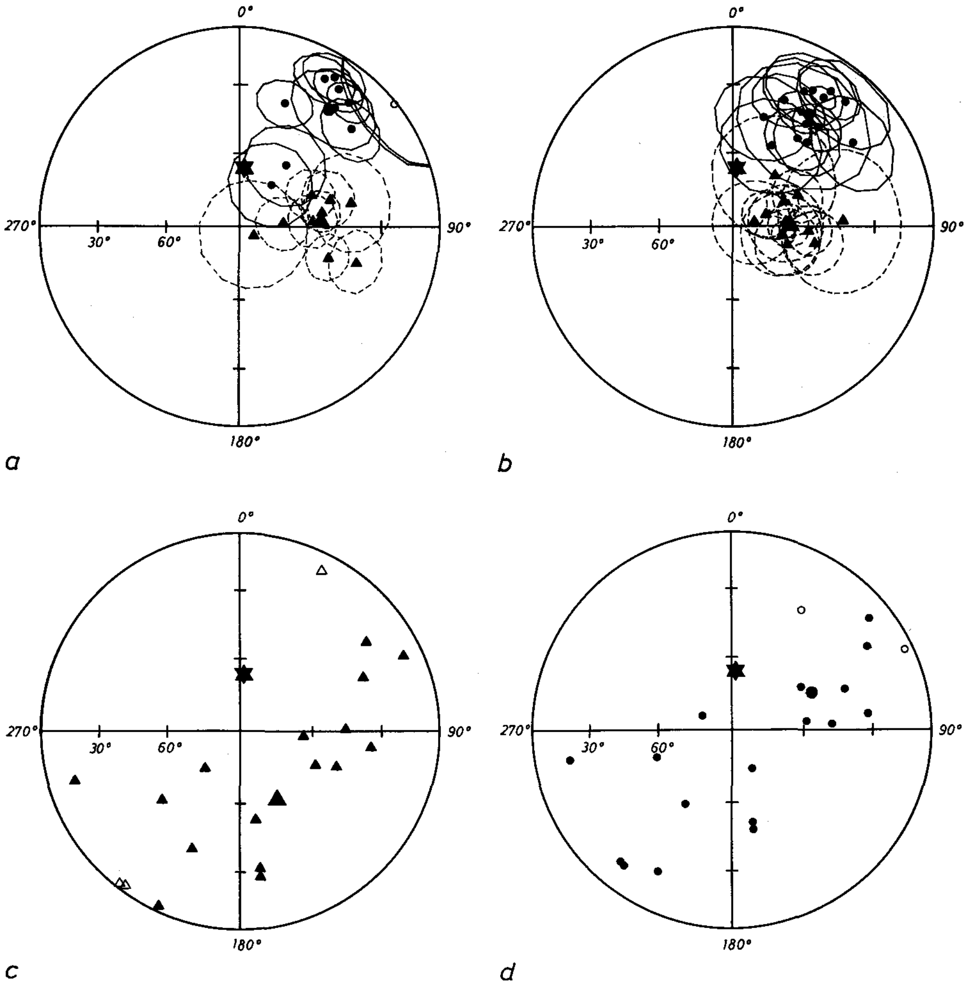

Fig. 4: Equal area projection of the mean NRM directions with their cones of 95% confidence of sites "S" (4a) and "M" (4b) before (dashed ovals, triangles) and after (solid ovals, circles) tilt correction. Mean values can be taken from Table 1. Asterisk: present geomagnetic field direction in the sampling area. NRM data of individual specimens of site "H" are shown before (4c) and after (4d) tilt correction. Closed symbols: positive inclination; open symbols: negative inclination.

### *3.2. Thermal Demagnetization experiments*

The stability and character of the natural remanent magnetization was tested by thermal demagnetization using a Schonsted TSD 1 furnace with permalloy shielding. For these experiments the cryogenic magnetometer was no more at our disposal. We had to use a Digico fluxgate magnetometer instead. Due to the lower sensitivity of this intrument some scatter was introduced into the later shown vector diagrams (Fig. 5), where Zijderveld plots are shown for specimens from sites "S" and "M". It

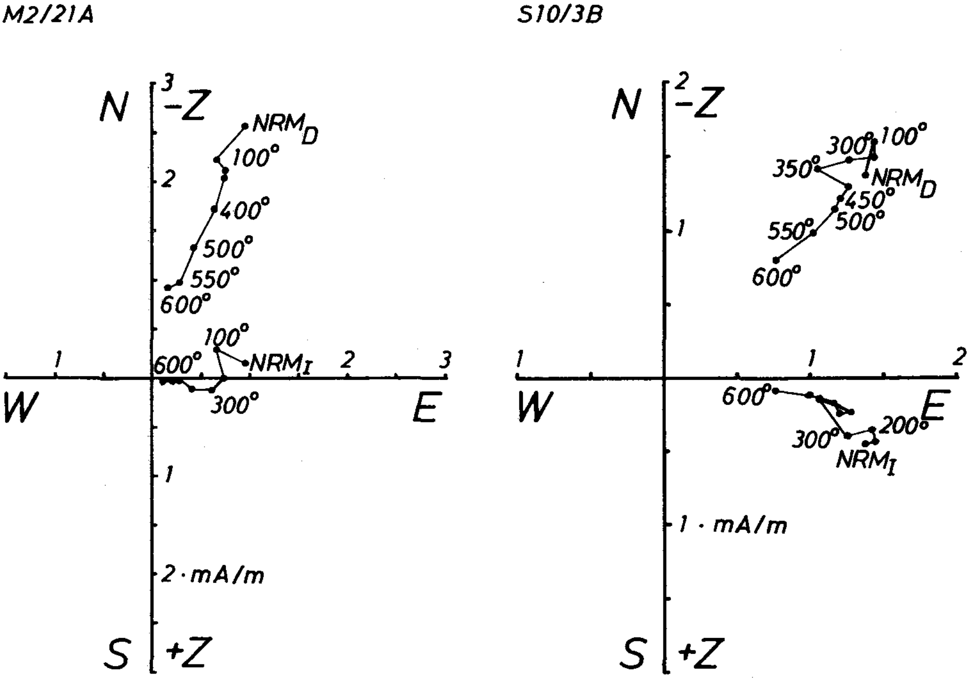

Fig. 5: Vector diagrams (Zijderveld plots) showing the decay of the NRM during thermal demagnetization. Temperatures are given in ° C. Specimens are from sites "S" and "M".

is evident that the rocks of both sites have a NRM with simple properties. Viscous components are of minor importance. The NRM consists in almost all cases of a single component. In the Zijderveld plots straight lines towards the origin can be drawn, however, with some scatter due to the limited sensitivity of the fluxgate magnetometer. The blocking temperatures are in all cases above 600° C indicating that hematite is the main magnetic mineral. This is in agreement with the IRM acquisition curves (see 2.2.).

In addition to the study of pilot specimens the mean NRM directions of specimen collections of sites "S" and "M" were compared with directions obtained after each demagnetization step up to 600° C. Neither the mean directions nor the scatter varied during thermal demagnetization. From this we conclude that the well grouped and tilt corrected NRM directions of sites "S" and "M" can be regarded as the characteristic remanence directions (CARM) of these two sites. The susceptibility anisotropy and other rock magnetic properties indicate that the CARM is not a DRM (detrital remanent magnetization, acquired at the time of deposition) but rather a CRM associated with the diagenetic processes of rock compaction and oxidation of primary magnetite to hematite.

At site "H", a considerable reduction of the scatter could not be obtained by thermal demagnetization up to 600° C.

### *3.3. Mean directions of characteristic remanent magnetization (CARM)*

Following the discussion of the preceeding chapter the mean CARM directions listed in Table 1 were obtained. In order to average out secular variation the sites "S" and "M" have been subdivided into sections consisting of about 20 samples (yielding about 40 specimens). Specimens with reversed polarity have been inverted to normal polarity. Unit weight was given to each section. A mean value of the reversed specimens has been calculated as well.

For site "H" the mean value of 19 specimens is tentatively given despite of the large scatter (k = 2.5) which makes the result quite unreliable.

## 4. Magnetostratigraphy

Only in the profile Mühlbach (site "M") reversals could be identified with certainty. Within the limits of error the magnetization of 18 reversed specimens within sections M12–M14 is antiparallel to the normal direction (see Table 1) which is a strong argument in favour of the NRM being more or less the CARM. The sites "S" and "H" show only normal magnetization or few specimens with doubtful reversals.

Profile "M" begins in its lower part with normal magnetization and has its reversed specimens only in the uppermost part. The section was compared with the polarity sequence of the Lower Triassic which has recently been reviewed by BERES

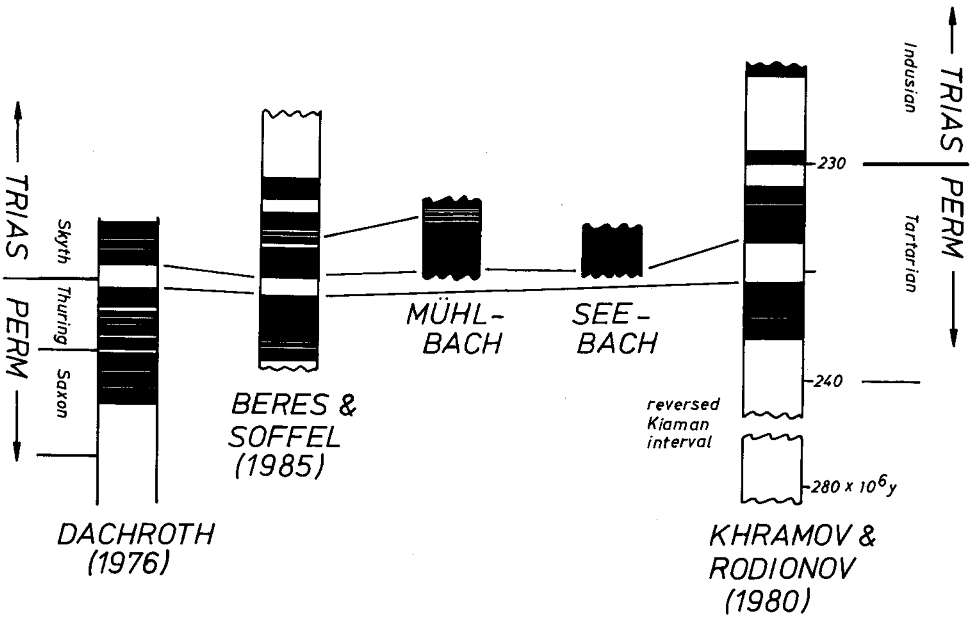

Fig. 6: Magnetostratigraphy at the Permian-Triassic boundary in Central and Eastern Europe, taken from BERES and SOFFEL (1985). The magnetostratigraphy of the Mühlbach profile fits well into the Lower Triassic section. Profile Seebach must be placed into the normal sequence within the Skythian.

and SOFFEL (1985). The Central European Permo-Triassic boundary is characterized by a clearly defined reversed zone (DACHROTH, 1976; BERES and SOFFEL, 1985), followed by a longer normal period with a sequence of short reversals on top (see Figure 6). This normal period with the onset of short reversals can be identified as well in the Mühlbach profile. A comparison with the magnetostratigraphy for Eastern Europe and Central Asia (KHRAMOV and RODIONOV, 1980) shows the general agreement of the polarity pattern of Europa around the Permian-Triassic boundary. However, the Russian authors place their Permian-Triassic boundary at a later time.

## 5. Virtual geomagnetic pole positions, palaeoremanence directions and tectonic conclusions

From the mean CARM direction of sites "M" and "S" and the mean geographic coordinates of the sampling area (see Table 1) a mean pole position of 136.5° E and 47.3° N was determined, which is plotted in Fig. 7 together with the European apparent polar wander path after IRVING (1977). Within the limits of error there is an agreement with the Central European Lower Triassic pole position, for which IRVING (1977) gives a value of 153° E and 48° N. However, there is an indication for a slight rotation of the nappes in a clockwise sense which we do not regard as significant. The latitude of our pole position is in perfect agreement with the Lower Triassic pole of IRVING (1977) yielding another argument in favour of the NRM being the CARM. On the Basis of these results we believe that the Central part of the Northern Calcareous Alps has not undergone rotational movements during the northward transport of the nappes. However, this is not in contradiction to the model proposed by BECKE and MAURITSCH (1985) of an originally bent sedimentary basin, because the central part of the Northern Calcareous Alps should not have been affected by rotational movements according to this model.

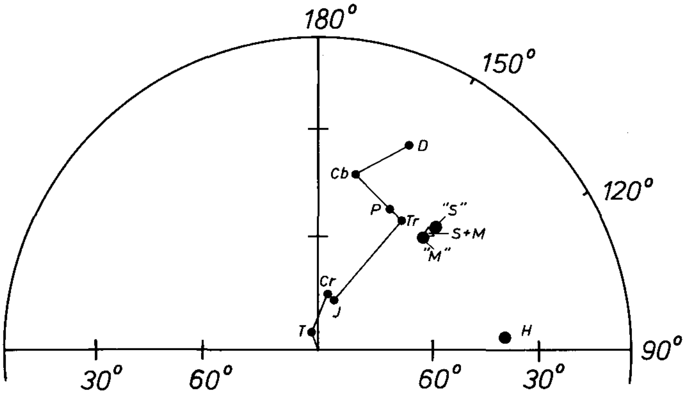

Fig. 7: Apparent polar wander path of Central Europe according to IRVING (1977). Virtual geomagnetic pole positions of sites "S" and "M" individually as well as combined (S + M) agree quite well with the European Lower Triassic pole position. Site "H" has a pole position which has some affinity with Upper Mesozoic poles of Central Europe indicating a younger age of remanence at this site.

The palaeoremanence direction of site "H" (see Table 1) has an inclination of I = 52.7° which is too steep for Triassic rocks of Central Europe. Despite of the extreme scatter even of the thermally cleaned specimens (k = 2.5) a tentative pole position at 94° E, 40° N (see Table 1) has been calculated and plotted in Fig. 7. This pole position has some affinity with other Mesozoic (Jurassic/Cretaceous?) poles of Central Europe. We conclude therefore that the rocks at site "H", which show also the highest degree of epizonal metamorphism, have been remagnetized in part or entirely during the alpine orogeny.

The good palaeomagnetic properties of sites "S" and "M" suggest to sample the same rocks in other places within the Northern Calcareous Alps.

Tab. 1: Mean CARM directions for the sites Mühlbach ("M"), Seebach ("S") and Hüttling ("H"), which have the following mean geographic coordinates: 12.3° E, 47.5° N. N: number of subsections at sites "S" and "M"; n: number of specimens; I: inclination; D: declination; α95: semiangle of 95% confidence; k: precision parameter

| Site Mühlbach Section | I (Ø) | D (° E) | Site Seebach Section | I (°) | D (° E) |
|---|---|---|---|---|---|
| M 1 | 22.1 | 30.4 | S 1 | 16.5 | 35.8 |
| M 2 | 22.3 | 35.1 | S 2 | 26.7 | 48.9 |
| M 3 | 53.1 | 25.8 | S 3 | 12.7 | 32.5 |
| M 4 | 17.8 | 36.0 | S 4 | – 0.4 | 51.6 |
| M 5 | 32.6 | 22.3 | S 5 | 18.4 | 41.2 |
| M 6 | 44.8 | 36.5 | S 6 | 58.4 | 37.6 |
| M 7 | 43.2 | 41.5 | S 7 | 34.3 | 20.5 |
| M 8 | 43.0 | 16.2 | S 8 | 68.1 | 37.7 |
| M 9 | 24.9 | 28.0 | S 9 | 24.3 | 39.0 |
| M 10 | 33.9 | 31.4 | S 10 | 15.3 | 30.0 |
| M 11 | 35.2 | 40.7 | | | |
| M 12 | 27.6 | 55.5 | Site Hüttling | | |
| M 13 | 17.4 | 42.5 | | | |
| M 14 | 37.2 | 35.7 | "H" | 52.7 | 65.4 |

Mean direction for site "M": N = 14; I = 32.8°; D = 34.5°; α95 = 6.3°; k = 35.6;
Virtual geomagnetic pole at: 136.8° E, 49.1° N.
Mean direction for site "S": N = 10; I = 27.3°; D = 37.7°; α95 = 12.2°; k = 13.2;
Virtual geomagnetic pole at: 136.1° E, 44.6° N.
Mean direction for sites "M" and "S": N = 24; I = 30.6°; D = 35.8°; α95 = 6.2°; k = 21.3;
Virtual geomagnetic pole at: 136.5° E, 47.3° N.
Mean direction for site "H": n = 19; I = 52.7°; D = 65.4°; α95 = 33.2°; k = 2.5;
Virtual geomagnetic pole at: 93.8° E, 39.8° N.
Mean direction of 18 reversed specimens of sections M12–M14: n = 18; I = −22.7°; D = 235.3°; α95 = 20°; k = 6.1.

## 6. Acknowledgements

We thank Prof. Kopp from the Geological Institute of the Technical University in Munich for his interest in the study. The valuable advice of the colleagues from the Geological Institute of the University in Innsbruck, above all Dr. Stingl and M. Riml, is gratefully acknowledged. Thanks are also due to Prof. Bleil from the University of Bremen for the possibility to measure on the cryogenic magnetometer.

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Manuscript received May 5th, 1986

Zeitschrift/Journal: Austrian Journal of Earth Sciences

Jahr/Year: 1987

Band/Volume: 80

Autor(en)/Author(s): Soffel Heinrich C., Wohl D.

Artikel/Article: Palaeomagnetism of Lower Triassic Red Sandstones in the Southern Kaisergebirge (Austria). 173-183