Planation Surfaces in the Troiseck Massif – An Attempt at Digital (Quantitative) Detection

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Contents

The concept of the "planation surfaces" and explanations of their origin appeared around the middle of the nineteenth century. Both underwent a long evolution from abrasion approach (RAMSAY, 1846), through denudation (DAVIS, 1899; PENCK, 1924) to more recent concepts based on a broad range of factors: structural, climatic, tectonic, stratigraphic etc. (e.g. BÜDEL, 1957; BAKKER & LEVELT, 1964; LOUIS, 1964).

Remnants of the planation surfaces were easily recognised in some areas of the eastern part of the Alps, particularly in top parts of the Northern Calcareous Alps (NCA). FRISCH et al. (2001) give a good review of their investigations and interpretations. The most eminent paleosurface is preserved within flat plateaux of calcareous massifs in the easternmost part of the Alps: Schneeberg, Rax, Veitsch, Hochschwab, and other massifs further to the West and is commonly referred to as the Dachstein paleosurface. It was formed between Late Eocene and Early Oligocene and, successively, covered by initially thick but now almost totally eroded sands and conglomerates of the Augenstein Formation (Early Oligocene to Early Miocene [FRISCH et al., 2001]).

The present study focuses on the Troiseck massif, located South of the NCA, within the Lower and Middle Austroalpine units (TOLLMANN, 1977), which reveal distinct, SW–NE trending alignment. The Lower Austroalpine unit stretches on the SE, along the Mürz River valley and consists mainly of orthogneiss ("Grobgneis"), with lenses of quartzite and micaschists. The metamorphic rocks are overlain by a relatively thin cover of Permomesozoic metasedimentary rocks, mainly quartzites and carbonates, significant to the landscape. The larger, central and NW part of the area is built by the Middle Austroalpine unit (Troiseck-Floning nappe), consisting of phyllonitic mica schist and paragneisses with intercalations of amphibolites and aplitegneisses and overlaying Permomesozoic metasediments.

No distinct remnants of paleosurfaces were reported in the area so far. However, many flat, horizontal or nearly horizontal surfaces on the ridges or slopes can be easily seen in the field. Moreover, surfaces located on adjacent ridges reveal strikingly similar altitudes (Fig. 1) and are partly covered with reddish loam with debris (Fig. 2), which is a few decimetres to few meters thick.

Fig. 1: Flat and horizontal area on top of ridge S of Hochreiterkogel, ca. 1100 m above sea level (a.s.l.). The ridge in the background is also ca. 1100 m a.s.l. high (level 4 in both schemes described in the text).

Fig. 2: Outcrop of loams with debris (in origin reddish) on the flat ridge S of Hochenberg, ca. 1140 m a.s.l.

Method

The digital elevation model (DEM) with 10 meters resolution (grid) was used in the analysis. Two maps were derived from it: slope angle and slope aspect. The slope map was reclassified to obtain flat areas, i.e. with slope angles $<10^{\circ}$, located on ridges and slopes (Fig. 3). Flat valley floors and low terraces, as well as small spots (≤ 5 pixels, i.e. ≤ 5 hectares), were filtered out.

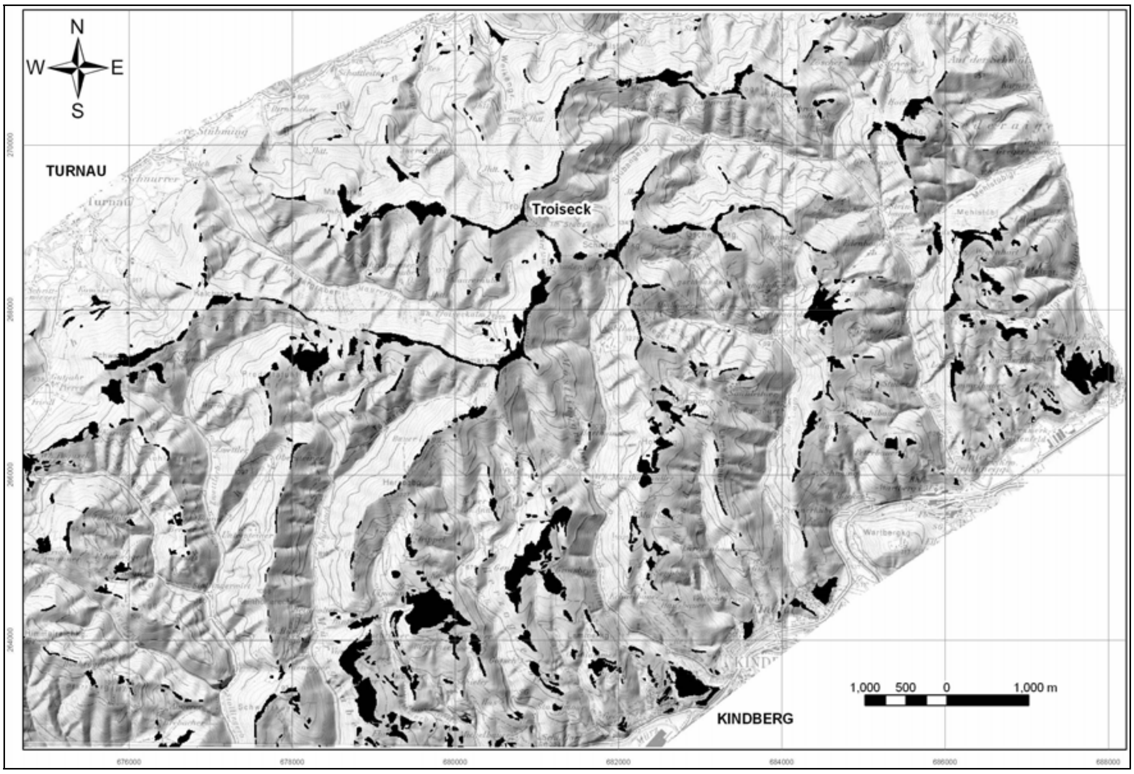

Fig. 3: Flat (<10° slope angles) areas (black) over shaded DEM and topographic map.

Heights (a.s.l.) were then extracted from the DEM for all flat areas and their distribution was calculated (Fig. 4). Local maxima were considered as indicators of heights of probable flat surfaces, while minima (breaks) among them were used for classification of their altitude ranges (Fig. 5). This procedure allowed to distinguish more or less horizontal surfaces (Fig. 6).

Dipping surfaces could be expected there as well, as a result of tilting of the whole massif after the planation period. Intensive tectonic movements and fragmentation of the Eastern Alps during Miocene are widely accepted (e.g. Ratschbacher et al., 1989; FRISCH et al., 2001). To detect the direction of tilting, a distribution of the aspect of both slopes and flat areas, was calculated (Figs. 7 and 8). The DEM was next tilted in the direction of the prevailing aspect of flat areas and in opposite direction, by 3°, 5°, 10°and 15°, to put dipping paleosurfaces to their original position. A procedure of detecting and classifying the flat areas was carried out for every tilted DEM model. One of them, revealing a relatively low number of detected surfaces and a high grade of their "compactness of heights" (Fig. 9), was used for further discussion. The heights "a.s.l." on the tilted DEM are not authentic, but are referred to the top of Troiseck (1466 m a.s.l.), where the axis of tilting was located.

Results of the analysis were finally verified in the field. Flat areas on the saddles as well as areas revealing apparent structural control were eliminated. The outcrops of bedrock and cover sediments were searched and examined.

Results

The graph of the distribution of heights of the flat areas within the original, not tilted DEM reveals 5 major and 2 minor groups of maxima (Fig. 4).

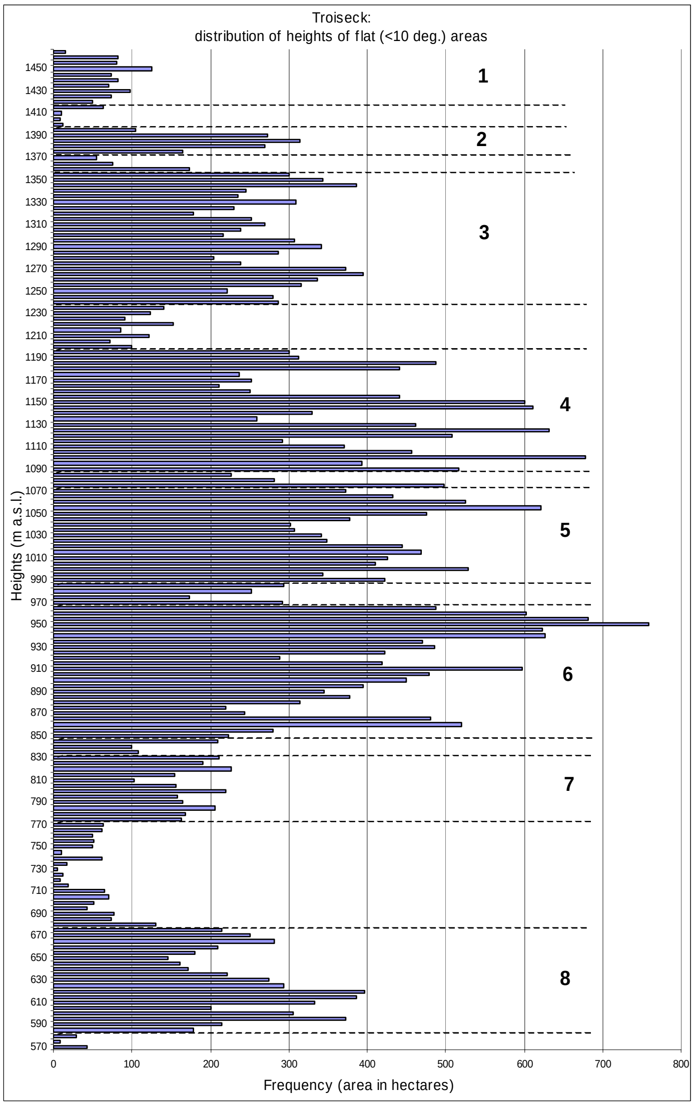

Fig. 4:
Distribution of heights of the flat areas (DEM original, not tilted)

If we accept that the range of heights within a paleosurface should not be bigger than 150 m and that the difference in altitude between adjacent surfaces is normally around 100 m (from a few tens to 200 m), we can distinguish 8 such surfaces: 1: above 1425 m, 2: 1375–1406 m, 3: 1240–1365 m, 4: 1095–1200 m, 5: 990–1075 m, 6: 850–970 m, 7: 780–830 m and 8: 580–690 m a.s.l.

It is very plausible that the two highest levels (1 and 2) are nothing more than local positive landforms that reflect more resistant rocks (gneiss) around the top of Troiseck. Moreover, the two lowest levels (7 and 8) are probably the Early Pleistocene terraces of the Mürz river. The four remaining levels may represent remnants of paleosurfaces (Fig. 5).

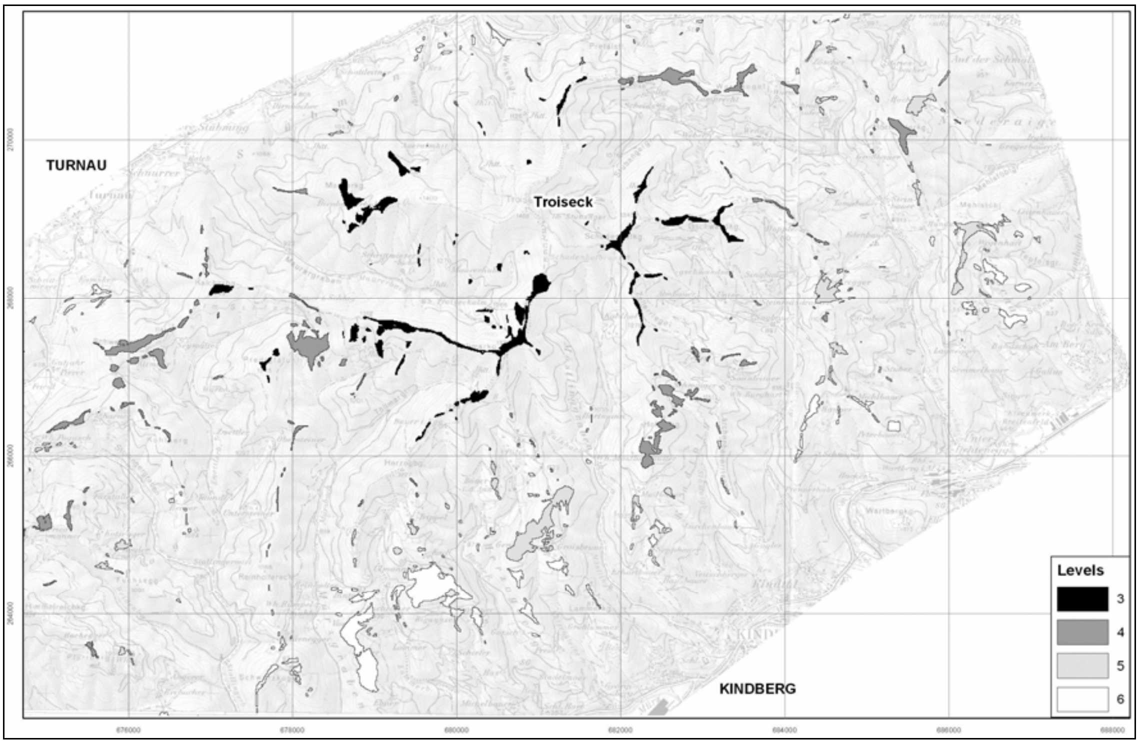

Fig. 5: Remnants of paleosurfaces in the Troiseck massif (DEM original, not tilted)

The number of 4 planation surfaces is acceptable in the light of the earlier concepts of development of the relief in the Eastern Alps (e.g. WINKLER-HERMADEN, 1957). However, it does not seem reasonable in the more recent approach, particularly in such a relatively small area as the Troiseck massif.

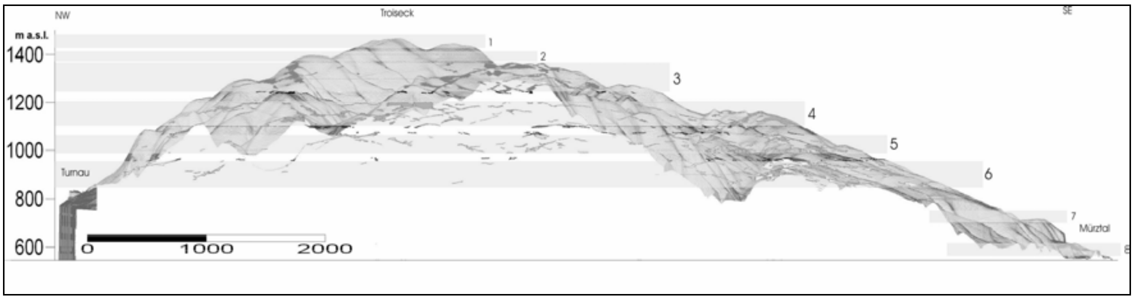

Fig. 6: The Troiseck massif and all detected levels (1–8). Horizontal view of the wireframe model towards NE (exaggerated 2x).

The distribution of the aspects of all slopes within the whole massif (Fig. 7a) reveals four weak maxima: ENE (ca. 75°), SSE (ca. 165°), WSW (ca. 240°) and NNW (ca. 320°). They probably reflect the main tectonic framework of the area, bordered with two deep tectonic-controlled valleys (Mürztal and Stübming) and cut by numerous transversal faults (BUCHROITHNER, 1984). The distribution of aspects of areas of slope angles <5° (Fig. 7b) shows a more distinct and broad maximum towards SE (from ca. 90° to ca. 225°). This maximum becomes even more pronounced and compact for slopes <10° (Fig. 7c). This means that a remarkable majority of flat or nearly flat areas, with slope angles less than 10°, dip towards SSE (in a range from ESE to SSW). This is also a hint for the existence of paleosurfaces actually dipping towards SSE.

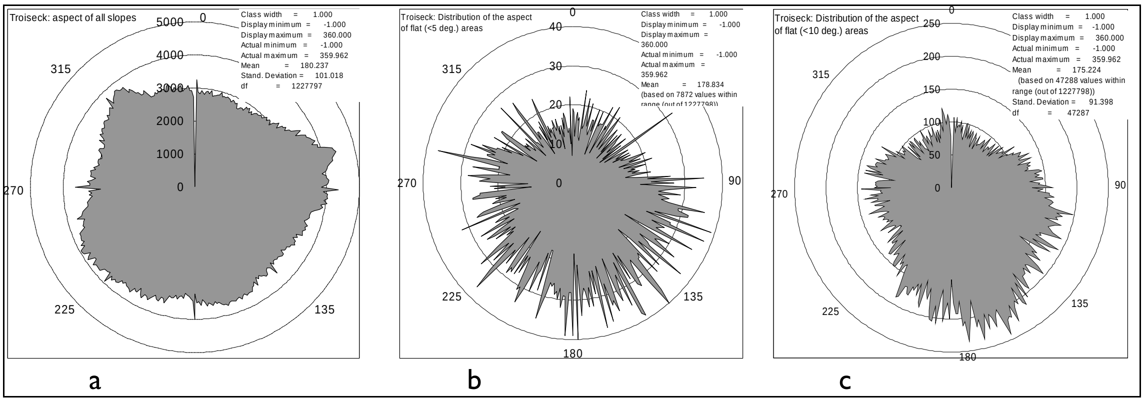

Fig. 7: Distribution of aspects of the slopes in the Troiseck massif:
a = all slopes, b = dipping at angles of <5°, c = at angles of 10°. North up.

To detect such paleosurfaces, DEM was tilted towards NNW by 3°, 5°, 10° and 15° and the procedure of detecting and classifying flat areas was carried out again, as described above.

The DEM tilted by 3° to NNW (Fig. 8a) showed very little difference to the original, horizontal DEM (Fig. 4). Increasing the tilt angle resulted in more compact arrangements of the maxima. The highest compactness was attained at the angle of 10° (Fig. 8c). At the angle of 15°, the distribution of heights showed a reversed tendency – the number of maxima and their fragmentation increased (Fig. 8d). Tilting the DEM towards SSE increased the number of maxima and their fragmentation at any angle.

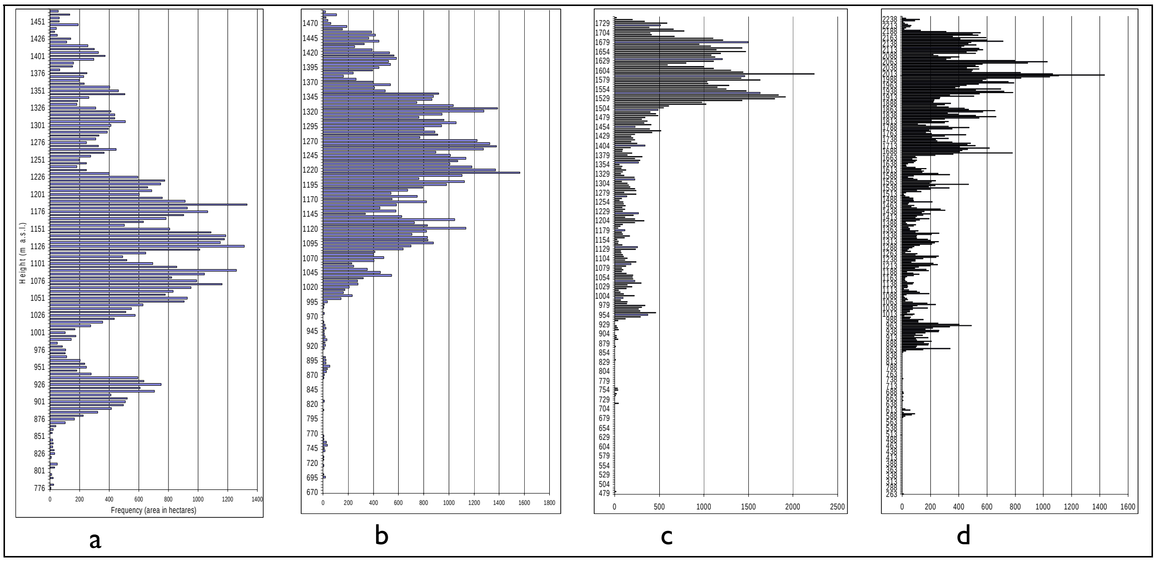

Fig. 8: Distribution of heights of the flat areas. DEM tilted towards NNW by: a = 3°, b = 5 °, c = 10° and d = 15°.

At the tilt angle of 10° four main maxima occur at ca. 1500–1560 m a.s.l., 1570–1615 m, 1630–1700 m and 1720–1750 m a.s.l. It seems apparent that two lower maxima (3 and 4) can be joined, as they reveal a total height range of around 100 m. The highest maximum belongs probably to the next lower level (2). Its slightly higher (20–70 m) position reflects probably more resistant bedrock (coarse gneiss). As a result, remnants of two paleosurfaces are detected:

higher, consisting of two steps:

1 summit step (mainly south of Hochenberg; Fig. 1),

2 in a height range 1630–1750 m a.s.l., and

lower, also comprising two steps (3 and 4) – 1500–1615 m a.s.l. (Fig. 9 and 10).

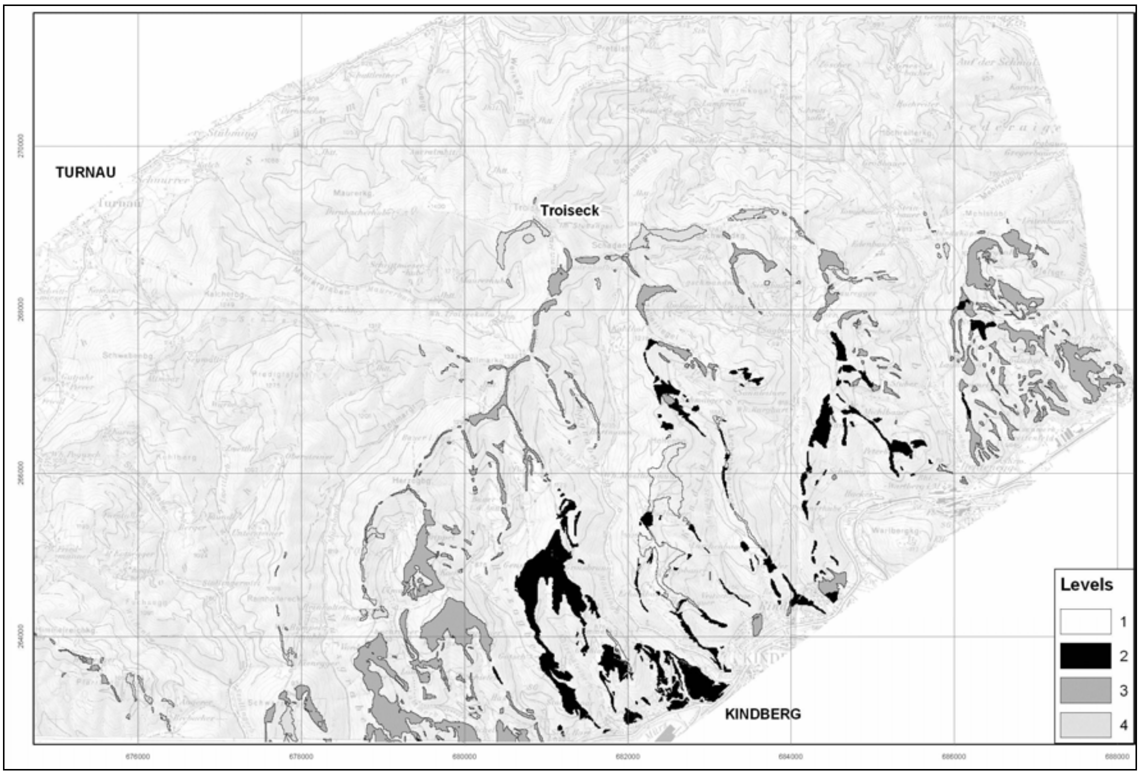

Fig. 9: Troiseck massif: remnants of paleosurfaces tilted to SSE by 10°. Higher (1 [summit level] and 2) and lower (3 and 4).

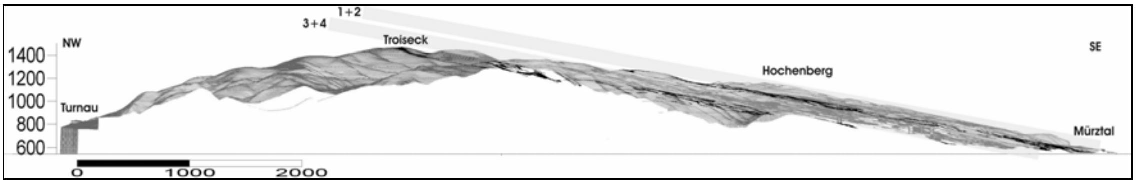

Fig. 10: Troiseck massif and two detected paleosurfaces tilted 10° to SSE (1+2 and 3+4). Horizontal view of the wireframe model towards NE. Not exaggerated.

Conclusions

Four surfaces detected in the first case of the analysis or two of them found in the second instance do not correspond to the recent interpretations which commonly accept only one vast and well pronounced paleosurface (planation surface). However, both schemes presented here are remarkably probable. The "Dachstein paleosurface" is preserved mainly on carstified limestone massifs. Rocks that built the Troiseck massif are more susceptible to erosion and thus are more easily planed, but, on the other hand, do not preserve well planed surfaces. We may expect that the planation surfaces could easily be fragmented and reduced by relatively quicker backward erosion of the slopes and back and downward erosion of the valleys. Moreover, much more differentiated resistance of the bedrock to weathering could have resulted in varying degrees of reduction of the heights of various fragments of the paleosurface. The fragments of the past paleosurface (or paleosurfaces) are therefore probably much more dispersed horizontally and vertically than surfaces developed on more homogenous carbonate bedrock. As a result, the pattern of the observed flat areas (Figs. 5, 9 and 11) may imply the existence of multiple-step polycyclic surfaces.

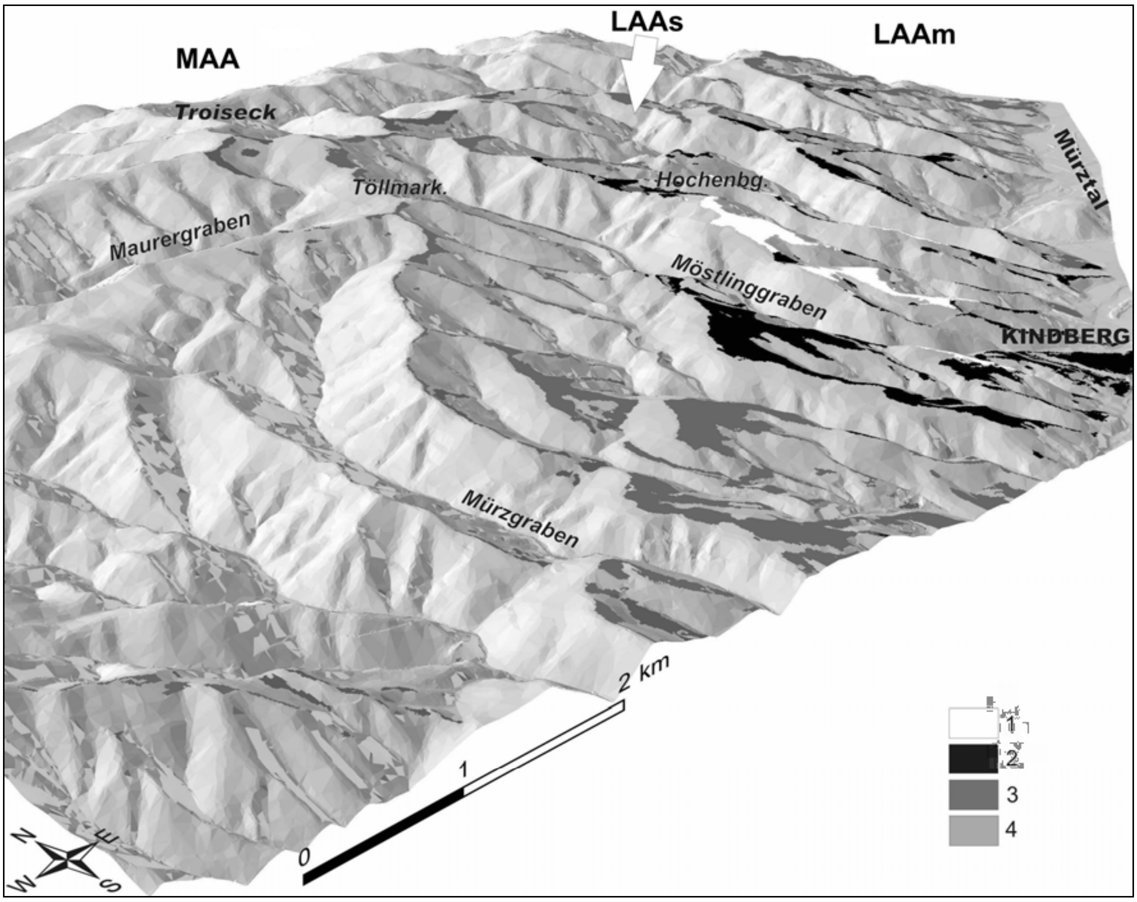

Fig. 11: Perspective view of the Troiseck massif with surfaces dipping SSE.
1 = summit level, 2 = upper level, 3 and 4 = lower levels.
Geological zones: MAA = Middle Austroalpine Unit, LAAm = Lower Austroalpine Unit – metamorphic bedrock, LAAs = Lower Austroalpine sedimentary cover.

Lithology and tectonic of the bedrock play an apparently important role in the morphology of the massif. The largest number of biggest flat areas occur in the SE part of the area formed by orthogneisses and quartzites of the Lower Austroalpine unit (LAAm in Fig. 11). Fewer and smaller flat areas are located on the softer phyllonitic mica schist and paragneisses of the Middle Austroalpine unit (MAA). A well pronounced, SW–NE directed depression marks the narrow zone of the metasedimentary cover (LAAs) topping the Lower Austroalpine unit. The questions arise here, which are traditional in a case of such study: how far are the flat surfaces controlled by the structure of the bedrock? and: to which extent are the flat surfaces a result of the real planation that cut the bedrock disregarding its structure? It seems that in the present case the "real" planation took place to an extent similar to the Northern Calcareous Alps, and that today observed flat surfaces are authentic remnants of larger flat areas. It is worth noting that the general direction of the dip of both strata and thrust surfaces is to NNW, i.e. contrary to the paleosurfaces dipping to SSE. It seems also that the lithology of the bedrock rather controlled the preservation of the paleosurfaces than their development.

Consistency and relatively small height range (200 m plus another 50 m for the summit excess) of the paleosurfaces dipping to SSE point rather to this model as being more realistic for the Troiseck massif. It assumes tilting of the whole massif towards SSE by 10 .

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