Die Koordinatenzeitreihen der GPS-Auswertung sind in sehr guter Näherung Gerade, die in den jeweiligen Fallinien liegen. Die geringen Abweichungen zeigen aber eine überraschende Systematik, die durch die Skalierung der drei Hauptbewegungskomponenten (Fallinie, Hangnormale und Horizontale normal zu beiden) mit dem Kehrwert ihrer Streuungen sichtbar gemacht werden kann (Abb. 2). Die Punkte MA und MD bewegen sich schraubenförmig im Uhrzeigersinn um die Gerade, MB und MC aber gegen den Uhrzeigersinn. Während der kurzen Perioden schneller Hangbewegungen befinden sich die Punke bis zu 10 cm über der Geraden, sonst bis zu 5 cm darunter. Zum Vergleich: die Hauptbewegungskomponente (parallel zur Fallinie) beträgt etwa das 10fache, die seitlichen Abweichungen dagegen nur einige mm. Die Höhenabweichung während schneller Hangbewegung kann als Querausdehnung als Antwort auf die Kompression durch das von oben auflaufende Rutschmaterial angesehen werden.

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The Werfen Imbricate zone in central southern sectors of Northern Calcareous Alps revisited: Permian to Triassic facies evolution and Cretaceous to Paleogene tectonics

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The origin of the Werfen Imbricate zone of central southern Northern Calcareous Alps is still an unresolved issue. We conducted a preliminary field survey along the southern edge of Tennengebirge (Werfenweng region) in order to reveal the lithostratigraphy, the structure and the structural evolution of the Werfen Imbricate zone in this peculiar region. The main results deviating from previous knowledge are as follows: The entire region comprises several major tectonic nappes with mainly Permian to Middle Triassic formations, which are cut along their hangingwall margins, and remnants of the Haselgebirge formation are common on top the uppermost nappe of the Werfen Imbricate zone. Our new data show that the Permian to Lower Triassic portion of the sections of all nappes are dominated by siltstones and subordinate fine-grained, thin-bedded sandstones. In purple fine-grained sandstones considered to represent part of the Fellersbach Formation we detected a shell fauna (molluscs) with a number of distinct species. A hitherto unknown several tens of meters thick formation of greyish siltstones with intercalated thin-bedded sandstones is directly overlain by thin-bedded greyish to beige Werfen Limestone. This new formation also yielded a mollusc fauna in tempestitic sandstones. We interpret this facies as offshore facies below storm-wave base deposited in a local off-shore depression. The uppermost nappe of the Werfen Imbricate zone comprises abundant Hallstatt facies type limestones, which were not found in lower nappes. Furthermore, the main body of the overlying Tirolic Tennengebirge nappe comprises spectacular evidence for synsedimentary pre-Dachstein Formation block tilting, and upper portions of Middle to lowermost Upper Triassic formations were eroded before deposition of the Dachstein Formation.

The siliciclastic Permian to Lower Triassic formations show abundant E-W trending folds with axial plane foliation and, therefore, evidence for N-S shortening during Cretaceous very-low grade conditions of metamorphism. However, stratigraphic relationships thrust ramps of nappes show evidence for ca. E-W transport as an important mechanism of formation of the Werfen Imbricate zone. The thrust surfaces were later reactivated by Cenozoic strike-slip faults and back-thrusts. Consequently, the present-day structure of the Werfen Imbricate zone is the result of superimposed deformation stages.

The sinistral Innsbruck-Salzburg-Amstetten strike-slip fault system in Salzburg (Austria): a structural study

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The ENE-trending sinistral Innsbruck-Salzburg-Amstetten (ISAM) strike-slip fault system transects the northern central sectors of Eastern Alps and is part of the northern wrench corridor, which led to eastward extrusion of blocks of central Eastern Alps during Miocene times. We conducted a field survey between Reichenhall and Mondsee with the main emphasis of the Salzburg city area in order to discuss the structure and the structural evolution of the ISAM strike-slip fault system in this area. At the SW edge of the Salzburg-Reichenhall Gosau basin and in the area of Salzburg city, the ISAM fault system is represented by several ENE-trending secondary faults, which represent the northern margin of the Salzburg-Reichenhall Gosau basin and which partly interfere with the thrust fault at the northern margin of Northern Calcareous Alps (NCA). Peculiarly the Kapuzinerberg and the Kühberg are confined both along northern and southern edges by well exposed strike-slip faults and the ISAM fault system includes therefore the NCA hills within Salzburg city as shear lenses. The Kapuzinerberg exposes a fold structure cut by above mentioned strike-slip faults.

A kinematic study allows deduce the post-Gosau deformation history along this segment of the ISAM strike-slip fault system. The following paleostress tensor groups were observed in Triassic-Jurassic formations of NCA and in Upper Cretaceous-Eocene rocks of the Salzburg-Reichenhall Gosau basin along the ISAM fault. However, the sequence of activation is in part still uncertain. Paleostress tensor group A (N-S thrust compression) is characterized by mainly S-dipping thrust faults. Paleostress tensor group B (N-S strike-slip compression) comprises mainly NNE-trending sinistral and NNW-trending dextral strike-slip faults. Together, these result in ca. N-S strike-slip compression. Paleostress tensor group C (NW-SE strike-slip compression) is also only found in a few examples. Paleostress tensor group D (NE-SW strike-slip compression) is found in a several examples and would fit into kinematics needed to activate the ISAM strike-slip fault system. Paleostress tensor group E (E-W extension): includes mainly WSW-dipping normal faults with a dominantly E-dipping lineation and subordinate ca. E-dipping normal faults, which could be explained by ca. E-W extension.

Gravity tectonics and emplacement mechanisms of evaporite mélanges: conceptual models and application to the central Northern Calcareous Alps

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Evaporite mélanges often form detachment respectively decollément surfaces of major extensional and contractional allochthons because of their very low shear resistance. Due to the deposition of evaporites during an early stage of passive continental margin formation, they are commonly overlain by thick successions of carbonates and/or siliciclastic rocks from the main thermal subsidence stage of passive margin formation, and these rocks are commonly resistant against penetrative internal deformation. The most common cases of evaporite mélanges are such (1) at passive continental margins, where they are deformed during gravity-driven extension, commonly raft tectonics, in an extensional geodynamic setting, and (2) in external foreland fold-thrust belts within a convergent geodynamic setting. In the following, we review first the most important features of both settings and then we apply these to the central Northern Calcareous Alps.

In gravity-driven raft tectonics at passive continental margins, an upper extensional domain is distinguished from a lower compressional domain at the toe (e.g,. Butler & Paton 2010). Activation of translation is at low temperature (commonly within ca. the oil window), mainly driven by thickness differences of the overburden. Motion is ocean-wards in intermediate stages of the depositional history of the passive continental margin and may last over a long period as long a topographic surface gradient is in existence. The resulting structure of the extensional allochthon is characterized by pronounced thickness variations of the syn-tectonic overburden within the extensional domain, particularly of the infill of halfgraben structures. In contrast, external foreland fold-thrust belts are generally transported continent-wards in episodic shortening at the termination of the sediment deposition, and no pronounced thickness variations occur in the overburden except in syn-sedimentary wedge-top basins. In nature, extensional deformation may have been overprinted by subsequent contraction causing complications in the structure of the thin-skinned fold-thrust belt.

The central and eastern Northern Calcareous Alps are called to have formed by gravity-driven sliding of thick masses of mainly Middle-Upper Triassic carbonate platform on the Permian-Lower Trassic evaporite mélange during Mid-Late Jurassic times. Main arguments for this interpretation are the presence of Haselgebirge clasts in mainly Upper Jurassic and also Lower Cretaceous formations and the presence of major up to mountain-sized blocks in a Haselgebirge matrix, particularly of limestones of the Hallstatt facies realm. This interpretation also assumes a continent-ward motion, considered as sliding in local basins, e.g., the Lammer basin. We challenge the interpretation of gravity-driven emplacement of the present structural edifice and present the following basic arguments for an essentially an Early to early Late Cretaceous age of emplacement of cover nappe with the Permian-Lower Trassic evaporitic Haselgebirge mélange at the base. These units were transported continent-wards against gravity on ductile evaporite mylonite zones partly over the Lower Cretaceous Rossfeld Formation, which includes many clasts derived from the Haselgebirge Fm. and its exotic blocks deposited in front of the incoming nappe. Ductile mylonite zones are well preserved mainly in sulphates (anhydrite, polyhalite), partly dated at ca. 110 Ma. Such mylonitic high-temperature shear zones were mapped in several areas from the southern margin (e.g., Rettenstein and Werfen Imbricate zone) to close to the northern margin of the Northern Calcareous Alps (Berchtesgaden - Dürrnberg). According to fluid inclusions, the Haselgebirge sulphates experienced a relatively high-temperature (>240 °C). Except differences between facies domains like Hallstatt and Dachstein facies realms, no significant thickness variations and wedge-shaped are known either in the Middle-Upper Triassic nor Jurassic stratigraphic units virtually excluding exclusively Jurassic raft tectonics as mechanism for evaporitic mélange emplacement. Of course, the new interpretation does not exclude earlier stages of local gravity sliding, e.g., during Late Jurassic, likely on front of convergent allochthons. However, the main body (Juvavic tectonic units) emplaced along a „high“-temperature ductile shear zone Haselgebirge evaporite mélange) as preserved in sulphate mylonites in a Cretaceous fold-thrust belt. Furthermore, the evaporite mélange includes abundant tectonic clasts of rift-related plutonic and volcanic rocks, which were partly dated as Early Permian. These, together with a high variety of Permian to Jurassic sedimentary rocks, were incorporated during nappe emplacement.

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