Faziesanalyse der obereozänen bis unteroligozänen "Cixerri-Formation" im Becken von Narcao (SW-Sardinien)

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Mit Hilfe verschiedener Parameter ist versucht worden Rückschlüsse auf die diagenetische Entwicklung des Beckens von Narcao, sowie der dort Abgelagerten "Cixerri-Formation" zu ziehen.
Bei der obereozänen bis unteroligozänen "Cixerri-Formation" handelt es sich um eine kontinental entwickelte Fazies, deren Hauptverbreitungsgebiete sich im wesentlichen auf Südwest Sardinien, die Sulcis (Narcao-Becken), Iglesiente (Cixerri-Tal) und dem östlichen Rand des Campidano-Grabens beschränken.
Im Hauptuntersuchungsgebiet dem Becken von Narcao läßt sich die "Cixerri-Formation" in zwei unterschiedliche fluviatil-lakustrische Fazieseinheiten untergliedern, die eine Gesamtmächtigkeit bis ca. 200 Meter erreichen können. Zum Hangenden hin wird sie durch oligozäne Vulkanite überlagert (andesitische bis trachytische Laven sowie Pyroklastika).
Im östlichen bis nordöstlichen Beckenteil befindet sich die Feinklastischefazies und im westlichen bis südwestlichen Beckenteil die Grobklastischefazies. Beide Einheiten werden einem alluvialen Schwemmfächer mit einer von N-NE nach S-SW verlaufender Paläoströmungsströmungsrichtung zugeordnet.
Das sich so darstellende Bild läßt sich nur mit Hilfe der regionalen Geologie und der regionalen Tektonik erklären, da ansonsten die Paläoströmungsrichtung nicht mit den Ablagerungsbedingungen übereinstimmen würde.

Geodynamic sedimentology - interrelations between sedimentation and tectonics

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There is manifold interrelation between the sedimentary record, especially of clastic sequences, and tectonic processes which take place in the source region of the sediment. An active orogen is a highly appropriate area to study these interrelations. Synorogenic clastic sediments like flysch or molasse can provide important information about the evolving mountain chain, especially when they have not been thermally overprinted. We like to focus on the young, post-collisional history of the Alps, in order to highlight appropriate procedures for the reconstruction of paleogeological, paleotopographic and paleogeodynamic settings during the uplift stage of the orogen from information stored in the sedimentary record. This period was characterized by large-scale tectonic movements due to continuing thrusting, lateral escape of blocks, and extensional tectonics, as well as by a complex uplift (and thus erosion) history. Syntectonic sediments derived from the Alps are widespread and are found from the Rhone delta to the Black Sea and from the North Sea to the Apennines. The information stored in these sediments is largely destroyed in the orogen.

Sediment mass budgets steered by tectonic processes

Precise sediment mass budgets of the circum-Alpine basins are able to give valuable information on the erosional history of the orogen. Together with the exhumation history in the orogen, as derived from thermochronological studies, tectonic processes can be constrained. An example from the Tauern window in the Eastern Alps shows that the great part of the Miocene exhumation of the window was performed by tectonic rather than by erosive denudation. Large-scale extension led to pull-apart of the rigid Austroalpine orogenic lid in the order of 170 km, which enabled rapid exhumation of the Penninic strata below. Sediment mass balances reflecting the erosion in the Alps and reasonable assumptions on erosion rates in the areas outside the exhuming window lead to the conclusion that erosion contributed only by about 20 % to the denudation of the window, which is in line with an independent tectonic reconstruction. During Miocene exhumation of the Lepontine dome in the Central Alps, the part of erosion was in the order of 30-40 %.
Sediment mass budgets in combination with provenance studies of detrital material can contribute to the reconstruction of river catchment areas and thus to changes in the position of water divides. In the Eastern Alps, the rearrangement of the river system due to a tectonic revolution in late Early Miocene time and the gradual northward shift of the main Alpine water divide from south to north from Late Miocene times on can thus be reconstructed. In the Swiss Alps, there are two abrupt shifts of the water divide, which are revealed by antagonistic changes in sedimentation rates north and south of the Alps. Such abrupt shifts must have their roots in tectonic events, probably they are connected to fore- and backthrusting.
In a first approximation, a simple relationship can be established between orogenic-scale tectonic movements and syntectonic sedimentation. Orogenic contraction will lead to crustal thickening and surface uplift, enhanced erosion and sedimentation, orogenic collapse will result in the opposite procedures. However, other factors like processes affecting the lithospheric mantle, may have severe effects on uplift and erosion. A mid-Oligocene event caused doubling of the synorogenic sedimentation rate and was responsible for the first buildup of large fluviatile fans with coarse gravel in in the Molasse zone, reflecting a marked surface uplift event in the Alpine body. The climate-induced mid-Oligocene sea-level drop is not able to explain these phenomena, all the more so as the onset of coarse clastic sedimentation shows a gradual shift over several Ma from west to east. A possible explanation for this event, with which the modern history of mountain building in the Alps started, is slab breakoff, which is probably also reflected by the Periadriatic magmatism. Thus, isostatic, geomorphological, and sedimentary response to crustal thickening could only become effective after breakoff of the heavy subducting slab.
The orogenic collapse in the Eastern and Central Alps in Early and Middle Miocene times is reflected by a drastic decrease in the erosion and thus sedimentation rates. Pliocene increase in the sedimentation rates cannot be directly related to known tectonic or other processes but may be the result of conversion of eclogitic into less dense material in the deeper crust causing surface uplift and enhanced erosion. Lowering of the timber line due to climatic changes may have contributed to the increase of erosion. Strongly enhanced erosion in Quaternary times, in contrast, is clearly the climatic signal of the ice age.
The actual erosion rate in the Eastern Alps is around 0.18 mm/a and was about twice that value during glaciation. The interrelation of Pleistocene glaciation, uplift and erosion/sedimentation is not well understood. While glaciation and deglaciation will cause oscillating isostatic response, glaciation must have caused increased erosion and thus a permanent isostatic effect resulting in net lowering of the average elevation. An average removal of about 600 m by Pleistocene erosion, as revealed by sediment budgeting in the formerly glaciated areas of the Eastern Alps, would result in a decrease in the average elevation of about 100 m. However, summits with very low erosion rates would then experience uplift of up to 500 m due to the isostatic response. Elevation of the summit level and overdeepening of the valleys led to relief enhancement and slope steepening thus reinforcing erosion. Present surface uplift corresponds with thick crust (mostly >45 km), Pleistocene glaciation, and rugged and high relief, and thus with high erosion

rates. Causes for surface uplift may be a combination of isostatic rebound due to the crustal overthickening as well as deglaciation, and of continuing tectonic push.

Sediment provenance and hinterland dynamics

Thermochronological studies of sand and pebble material can provide direct information on the paleogeodynamics of the orogen. Fission track (FT) age distributions of clastic apatite or zircon populations reveal age provinces in the catchment area and define „FT source terrains" (Brandon 1992). The difference between the youngest age cluster and the sedimentation age (termed „lag time") is a measure for the cooling history and thus for exhumation processes in the source area. FT source terrains can be defined by „hard rock thermochronology" within the orogen in terms of distinct tectonic units with distinct temperature-time profiles. A more comprehensive information is attained if pebble populations, i.e., pooled pebbles representing one distinct lithology within the pebble spectrum of one single outcrop, are considered. Pebble population dating (PPD) is able to characterize the catchment area in terms of „FT litho-terrains" (Dunkl et al., submitted) in that they are litho-specific. That is to say, certain dynamic porperties (exhumation paths) revealed by the pebbles can be related to distinct thermotectonic units exposed in the source area and distinct lithologies contained therein.

In contrast to classical geochronological methods, which use multi-grain samples, the FT technique is applicable to single grains so that every grain gives an individual (apparent) age. This is extremely useful for provenance studies in sedimentary material, because information from a large area in the catchment of a river is scanned. A valuable complement to this technique is Ar/Ar laser dating on micas, because this technique is also applied to single grains and is able to extend the reconstructed thermochronological paths obtained from material in clastic sediments in direction to higher temperatures.

A study in the Swiss Molasse zone may serve as an example for the reconstruction of an evolving orogen from a thermochronological and provenance study in conglomerate fans. Apparently contradicting information from FT ages, pebble provenance and heavy minerals are finally brought together to form a coherent picture of evolution. In these sediments, apatite FT dating cannot be used for hinterland information due to thermal overprint. Therefore, only zircon FT dating was performed. Increasing zircon FT ages from Molasse sandstones with decreasing sedimentation ages between 31 and 25 Ma are in contradiction with a progressively eroding (exhuming) hinterland. Pebble analysis shows that flysch was widely exposed in the hinterland. Thus, redeposition of zircon grains from the flysch sequence can easily explain the reverse behaviour of ages. Sudden input of epidote around 25 Ma was interpreted as the signal for the first appearance of Penninic metabasic rocks in the hinterland, although the FT ages do not give this Penninic signal (Oligocene to Miocene cooling ages). The correct conclusion appears to be that only high Penninic levels had been denuded, in which zircon-free or zircon-poor ophiolites (responsible for the supply of epidote) and Bündner Schiefer are the predominant lithologies. Zircons with a lag time of ca. 10 Ma appear around 18 Ma, when Penninic basement rocks became exposed. Zircons with a lag time of ca. 6 Ma appear around 13 Ma, when Penninic basement rocks of deeper levels belonging to the footwall of the Lepontine core complex became exposed by mainly tectonic denudation. The appearance of the signals in the sediments is in accordance with the age distribution in and around the Lepontine dome. Differences in the provenance and thermo-chronological record in different fans of the Swiss Molasse zone can be explained by non-synchronous exhumation in the catchment areas and by the location of the water divides between them. They allow to reconstruct the exhumation history of the orogen in terms of differential movements.

In the Eastern Alps, high-precision provenance data enabled us to define the catchment area of the Paleo-Inn river for Early and Middle Miocene times. The course of the Paleo-Inn river had a similar middle section as today, following the Inntal fault zone, but a larger catchment area than today. Pebble material from Periadriatic volcanoes (topping the presently exposed intrusives), probably as far to the south as the Adamello massif, and adjacent South Alpine material was transported to the deep-marine molasse of eastern Bavaria and Upper Austria over distances of about 200 km. This gives evidence that the source area of these rocks had already been mountainous more than 20 Ma ago. The combination of provenance determination and thermochronology on pebble populations also enabled us to determine the time of the first arrival of Penninic rocks of the Tauern window and to discern between gneiss and quartzite pebbles of Penninic and of Austroalpine provenance, since the cooling paths of these units are distinctly different. Thus we could establish several litho-terrains, which contributed to the Paleo-Inn river system around the Middle/Late Miocene boundary (ca. 13-10 Ma).

In an earlier phase, in Late Oligocene times around 26 Ma, when the Inn river system unloaded its freight into an embayment of the Molasse zone known as Inntal Tertiary, a strong quasi-synsedimentary signal from FT ages of clear, euhedral zircon in sandstone is in apparent contradiction with systematically older apatite FT ages. This contradiction can be resolved in terms of a synsedimentary volcanic source providing the zircon crystals. This interpretation is confirmed by the presence of according volcanic pebbles and a gneiss PPD sample, which shows a clearly different signal and no synsedimentary fast exhumation. Comparison of the gneiss PPD samples from the same Austroalpine source in Late Oligocene and Late Miocene times reveals that in the catchment area of the Inn river gradually deeper levels of the gneisses were denuded by progressive erosion.

Early post-collisional sediments like the Inntal Tertiary or Oligocene sediments of the Augenstein formation on top of parts of the Northern Calcareous Alps (NCA) sampled high levels of the orogenic stack, largely eroded today, and thus allow insight into the pre-Alpine evolution of the upper-plate (the Austroalpine) unit. Variscan, late-Variscan and Mesozoic thermochronological data reflect thermodynamic events like mountain building, extensional response, and rifting before and during formation of the Penninic ocean.

In contrast, the geometry of local, fault-bounded intramontane basins of late Early to Middle Miocene age in the eastern Eastern Alps, and the strongly differing composition of their sediments as compared to the Augenstein formation, which sampled the same region, allow to specify the geodynamic scenario for the considered time and region in terms of a small scale tectonic pattern, in which local debris was sedimented in deep, fault-bounded basins. The combination of heat-flow modelling at the margins of the Penninic Rechnitz window and thermochronological and thermal data from the syntectonic sedimentary cover indicate that the low-lying parts of the central eastern Eastern Alps were drowned by a more than 1 km thick sediment sheet in Middle Miocene time, which was removed by erosion in Late Miocene to Pliocene time. Such sediment cannibalism has a considerable effect on sediment budget calculations.

The Oligo-Miocene sediments in the eastern part of the Eastern Alps sealed paleosurfaces, from which remnants are still preserved. The preservation of paleosurfaces indicates very low erosion and thus very low contribution to synorogenic sediments and poses the question, how it is possible to preserve land surfaces over many millions of years in an overall uplifting orogen. The Oligocene Dachstein paleosurface is preserved on elevated karst plateaus of the central and eastern NCA. After sealing by the Augenstein formation and renewed exhumation, the surface was uplifted since Late Miocene times to the present elevations between roughly 1500 and 3000 m. Preservation of large areas of only moderately modified surface remnants was possible due to predominating subsurface erosion by karstification. The testimonies are huge cave systems. In contrast, the Early Miocene Nock surface is formed on crystalline basement rocks and weakly metamorphosed Paleozoic volcano-sedimentary sequences. Preservation of moderately modi-fied remnants of this surface is due to burial under sediments, then limited uplift and concentration of erosional incision in fault-boun-ded valleys. Temporary subsidence and limited overall uplift was due to crustal thinning in the course of the orogenic collapse. The same area is actually characterized by positive isostatic anomalies and approximately zero surface uplift. Apatite fission track ages are Paleogene, indicating very limited overall exhumation since then.

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Geowissenschaftliche Fachinformation, Archivauswertung, Datenakquisition, Datenmanagement. Vorstellung einer CD ROM Version "Werksteine Sachsens"

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Vorgestellt wird eine CD-ROM Version, die zusammengeführte und aktualisierte Datenbestände über Werksteine Sachsens enthält. Die Daten stammen aus den unterschiedlichsten Archiven des Sächsischen Landesamtes für Umwelt und Geologie sowie fachnahen geowissenschaftlichen Instituten Sachsens. Es sind Daten der Rohstoffgeologie, Petrographie, Technische Parameter, Abbautechniken sowie eine historische und aktuelle Übersicht. Der Datenbestand soll einem breiten Nutzerkreis zugänglich gemacht werden.
Neben einer allgemeinen Einleitung über die Geologie Sachsens, die technischen Gesteinseigenschaften, die Gewinnung und Verwendung werden im einzelnen 519 bekannte Werksteinbrüche beschrieben. Ziel der Werkstein CD-ROM ist die

- Gesteinsbestimmung an Bauten und Denkmälern
- Auswahl und Anwendung brauchbarer/n Gesteine/Materials für neue Objekte
- Vorsorgliche oder nachträgliche Beurteilung des Verwitterungsverhaltens
- Verhütung und/oder Sanierung von Schäden
- Hilfe bei der Beschaffung geeigneten Steinersatzes
- Werbung für die Anwendung von Naturstein
- Darstellung der Geowissenschaften in der Öffentlichkeit.

Unterkarbon im östlichen Saxothuringikum - Geodynamik und Sedimentation

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Diverse tektonometamorphe p/T/t-Pfade des Saxothuringischen Terranes (vgl. LINNEMANN et al. 1999) belegen ab dem Oberdevon komplexe Deformationen ganzer Krustenstockwerke. Ursache dessen ist die Kollision der Nordkontinente (Baltika, Laurentia) mit der Amorikanischen Terrane-Collage. Subduktion, Stapelung und Exhumierung bei anhaltender Kompression bedingen bis zum Unterkarbon die Herausbildung von allochthonen Deckenkomplexen. Klastisch-biogene Ablagerungen des Asbian (Unterkarbon, Viséan V3b) im Top dieser Deckenstapel werden von kompressiven Deformationen nicht mehr betroffen. Dazu gehören die "Frühmolassen" von Delitzsch (Sachsen), Borna-Hainichen (Sachsen) und Doberlug-Kirchhain (Brandenburg). Bildungsräume der Klasite sind die Schelfareale des Saxothuringischen Terranes, einer Externzone der Varisciden am Nordrand des Böhmischen Massivs. Es handelt sich um Ablagerungen von Fan-Deltas, Tidal flats, Estuaren bzw. alluvial plains mit geringmächtigen Einschaltungen von Kohlelagen. Die rezente Abgrenzung der Sedimentationsräume erfolgt ausschließlich tektonisch in Form von **Abschiebungen**. Auf syn- bis postsedimentäre **Extension** ist auch das zwischen 30-70° wechselnde Schichteinfallen zurückzuführen, es handelt sich **nicht** um kompressive Deformationen im Zuge der Sudetischen Hauptfaltungsphase der Varisciden. Neueste palynologische (BEK 1997) und geochronologische (GEHMLICH et al. 1999) Analysen präzisieren mit dem Nachweis der NM-Zone (CLAYTEN et al. 1978) in Klastiten und den Zirkonaltern um 330 ± 4 Ma in Tuffen der "Frühmolassen" ihre bisherige Einstufung (Makropaläontologie und -paläobotanik) in das hohe Unterkarbon. Modalbestandsanalysen nach DICKINSON (1985) oder ROSER & KORSCH (1986) sollten in einer Terran-Collage zwangsläufig mehrdeutig sein. Relativ sicher kann allerdings für die Frühmolassen Sedimentation an einem aktiven Kontinentalrand bzw. in einem back-arc Bekken ausgeschlossen werden. Art und Ausbildung der Sedimente lassen auf zyklisch gesteuerte Sedimentation infolge veränderlicher Meeresspiegel schließen, besonders deutlich sind diese Signaturen im Unterkarbon von Doberlug zu erkennen. Ursache zyklischer Sediment-Akkumulation im hohen Unterkarbon ist nach VEEVERS & POWELL 1987 die im Bereich der Südkontinente einsetzende Gondwanavereisung. Die o.g. "Frühmolassen" stellen somit Ablagerungen am Nordrand des Böhmischen Massivs dar, die im Zusammenhang mit Trans- und Regressionsprozessen des global nachweisbaren *crenistria*-events (MESTERMANN 1999) im Asbian (V3b) etwa um 330 Ma entstanden. Gleichalte Sedimente beschreibt HERBIG (1998) aus den Sudeten und dem Moravosilesikum im E und SE des Böhmischen Massivs. Diese werden analog der hier untersuchten "Frühmolassen" als postkollisionale Ablagerungen der Oberplatte interpretiert. Sie dokumentieren auch für den Südostrand des Böhmischen Massivs Flachschelf-Verhältnisse im ausgehenden Unterkarbon.

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