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ORIGINAL PAPER

R. P. Allenbach · A. Wetzel

Spatial patterns of Mesozoic facies relationships and the age of the Rhenish Lineament: a compilation

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Abstract The age and the southern continuation of the Rhenish Lineament, and its relation to the Bressegraben has been an elusive problem for a long time. Sedimentological data are presented in this paper, which show that a major fault zone associated with the Rhenish Lineament extends southwards underneath the Jura Mountains of northern Switzerland. Mesozoic facies boundaries occur along this lineament and indicate that the Tertiary Upper Rhinegraben may be an ancient inherited structure, which was repeatedly reactivated during Mesozoic time. While reactivated Paleozoic faults seated in the basement are now known to play an important role in defining east–west trending facies boundaries and depocenters, north–south facies boundaries were attributed to autocyclic effects. This north–south component found in facies boundaries is now attributed to subsidence variations, which took place along the Rhenish Lineament. To distinguish increased local subsidence from eustatic sea level rise (i.e. development of accommodation space) it is necessary to reinterpret the sedimentary record accordingly. This study demonstrates that some sedimentary facies boundaries follow the Rhenish Lineament over the Paleozoic basins of northern Switzerland into the Bressegraben, thereby indicating an ancient structure, which had been reactivated during Mesozoic time. Sedimentological analysis shows that there is a relationship between facies boundaries, isopach anomalies, and basement structure.

Keywords Rhinegraben · Lineament · Reactivation · Jurassic · Facies

R. P. Allenbach (✉) · A. Wetzel
Geologisch-Paläontologisches Institut, Bernoullistr. 32, 4056, Basel, Switzerland

Present address: R. P. Allenbach
Proseis AG, Siewerdtstr. 7, 8050, Zürich, Switzerland
E-mail: robin.allenbach@proseis.com

Introduction

In recent years, a series of sedimentological studies of the Mesozoic deposits in the Jura Mountains have demonstrated or at least suggested that the reactivation of Permo-Carboniferous basins of northern Switzerland is reflected in the depositional environment of Mesozoic strata (Gonzalez 1993; Wetzel et al. 1993; Allia 1996; Burkhalter 1996; Pittet 1996; Allenbach 2002). Most of the examined stratigraphic units consist of either deep-water shales or platform carbonates. Their distribution offers the possibility to map facies boundaries, while isopach maps of the shale basins define basin depocenters. Due to limited thickness variations of the individual Mesozoic lithostratigraphic units, reflection seismic data are unable to accurately resolve isopach anomalies.

The subsurface data referred to in this study were acquired by the Swiss Cooperative for the Disposal of Nuclear Waste (Diebold et al. 1991). As a result of an exploration campaign, a system of Late Paleozoic basins was defined in the eastern Jura Mountains of northern Switzerland. These basins are evident on reflection seismic data calibrated by wells. In general, the basins strike ENE to WSW and are about 10 km wide (Diebold and Naef 1990). Sedimentary fill of the basins is Permian and Carboniferous in age and is composed of continental siliciclastics (Matter 1987). At the end of the Permian many of these basins were inverted and their sedimentary fill truncated (Ziegler 1990). Thereafter the basins ceased to subside differentially.

This publication is a part of a study examining the Oxfordian (early Late Jurassic) deposits of northern Switzerland (Figs. 1, 2). The original goal was to determine whether differential subsidence played a role in the development of two neighboring Oxfordian epicontinental basins. First results showed that increased subsidence rates along reactivated Paleozoic basement structures did indeed provide the accommodation space of these epicontinental basins (Allenbach 1997). Further

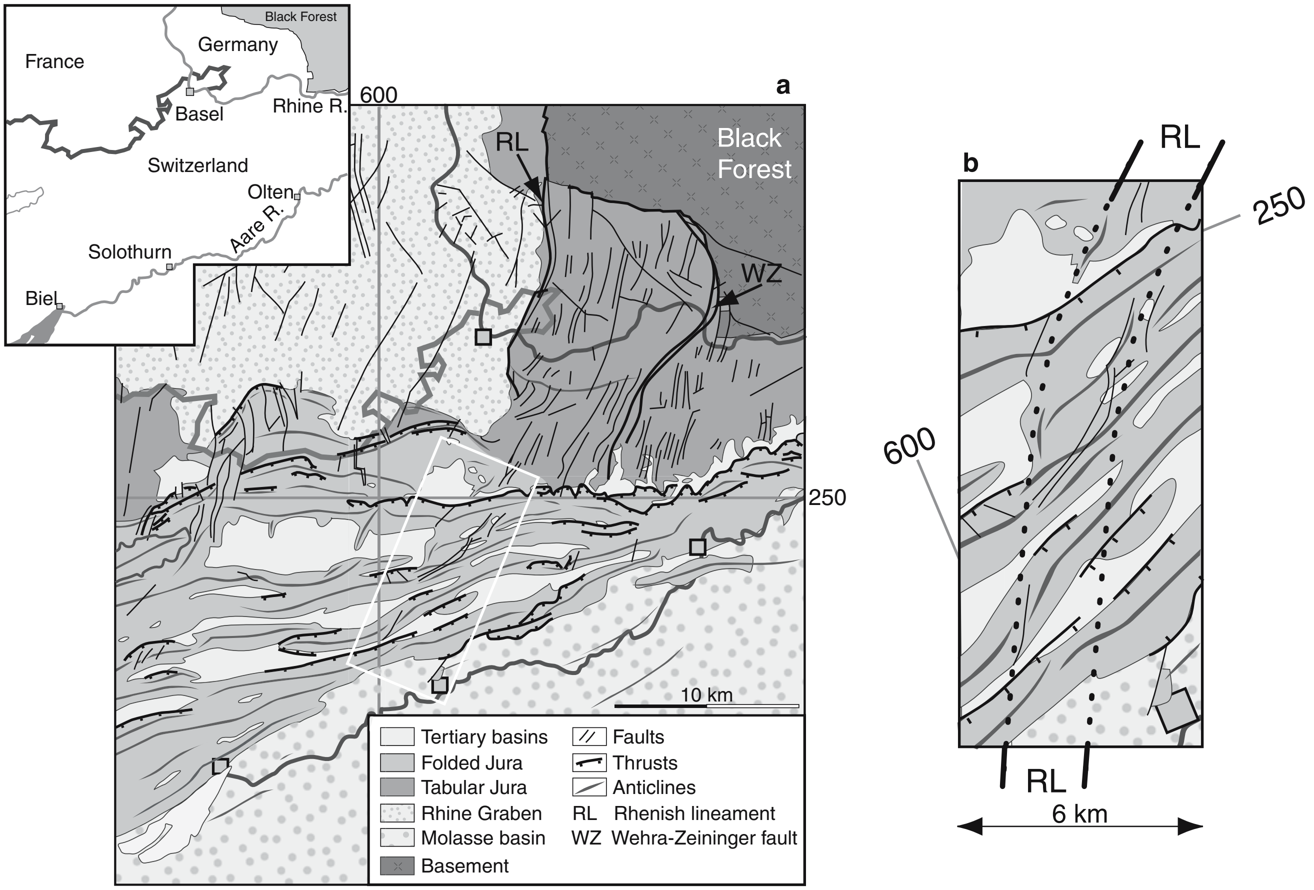


Fig. 1 **a** Study area with major geological elements. The *white box* encloses the Rhenish Lineament continuation based on tectonic elements of the Jura Mountains and is enlarged in **b**. Compiled from Spicher (1980) and Pfirter (1982). **b** Detail of the Rhenish Lineament (*RL*) mentioned in **a**. The lineament can be followed along the curved anticlines and their lateral terminations. The margins of the larger Tertiary basins follow this lineament as well

observations then revealed that the margins of both basins follow the ENE–WSW orientation of the Permo-Carboniferous basin, but also include a north–south component. Comparison of the Oxfordian facies and thickness distribution with other Mesozoic and Recent (uplift) data (Thury et al. 1994) show that pre-existing Permo-Carboniferous basins appear to have significantly influenced the Mesozoic facies pattern. However, another important structural element was missing. While the Permo-Carboniferous basins define the ENE–WSW orientation of the depocenters, the Oxfordian platform boundary shows an additional north–south element, which cannot be related to the Permo-Carboniferous basins. This north–south orientation is also recognized in the virtual southern extension of the eastern Rhinegraben masterfault into the Jura Mountains where it forms the eastern and western margins of Tertiary basins and north–south striking faults which cut through the anticlines and Tertiary basins. Whether the Rhinegraben lineament extends into the Jura Mountains has been a matter of debate since the days of Steinmann (1902) and Heim (1919). Several publications describe some form of continuation to the south (Theilen-Willige 1997) and into the Jura Mountains (Laubscher 1981; Thury et al. 1994; Philippe 1995) or an earlier evolution of the lineament (Ziegler 1990; Loeschke et al. 1998; von Raumer 1998). However, there is no clearly visible evidence for this southward continuation in the surface geology of the southern Rhinegraben and the Jura Mountains. Within the folded Jura, a number of north–south lineaments are suggested by the geometry of the anticlines (Fig. 1a, b). These are attributed to the reactivation of Tertiary extensional faults, which developed together with the emplacement of the Rhinegraben (Bitterli 1990). This study demonstrates that, while these structures where certainly active during the graben formation, they actually correspond to much older crustal discontinuities within the basement. Correlation of Mesozoic facies patterns and thickness distribution with the structural geology and uplift history of the study area suggests that the Rhenish Lineament (Boigk and Schöneich 1974) is an ancient, pre-Mesozoic structure, which was repeatedly reactivated, finally culminating in the Tertiary formation of the Rhinegraben. This lineament was already identified by Steinmann (1902) who named it the “Schwarzwaldlinie”.

In this paper, the effects of reactivated basement faults on Oxfordian sedimentation in central northern Switzerland are studied. Facies analysis revealed that the development of epicontinental basins was initiated by the reactivation of Paleozoic basement faults and that the Oxfordian basin margins follow the same lineaments as can be identified in the structure of the Jura Mountains. Thus, these lineaments are ancient, reactivated structures which were of importance during the Mesozoic as well as during the Tertiary folding of the region.

Geological framework

Study area and stratigraphy

The study area is located in the central Jura Mountains of northern Switzerland and extends northwards into France and Germany. Major present-day structural elements are the Jura Mountains, the Rhinegraben, and the Black Forest. Lithologically, most of the study area is covered by carbonates and siliciclastic deposits of Mesozoic and Tertiary age (Fig. 2). Variscian basement is exposed in the Vosges and Black Forest Massifs, from where it plunges beneath the Jura Mountains and Tertiary Molasse Basin until it is again exposed in the Aar Massif of the central Swiss Alps (Labhart 1992).

During the Permo-Carboniferous, the paleostress field resulted in the formation of pull-apart basins filled with fluvial and lacustrine siliciclastics (Boigk and Schöneich 1974; Diebold 1988). With the onset of the Triassic transgression, coastal and marine conditions developed. The principal décollement horizons of the Jura Mountains are Middle and Late Triassic evaporites. From the Late Triassic until the end of the Mesozoic, marine conditions prevailed resulting in a sedimentary stack between 1,000 and 1,500 m thick,

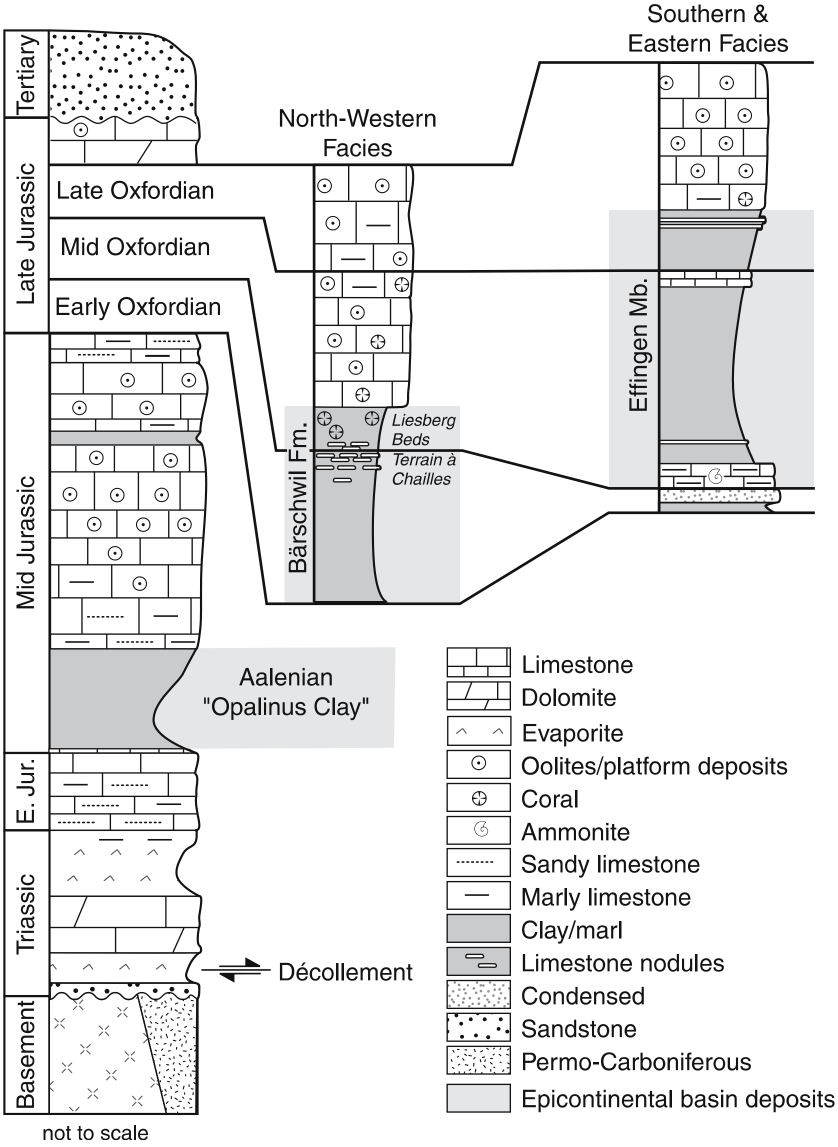


Fig. 2 Generalized stratigraphic columns of the Swiss Jura Mountains with epicontinental basins marked in *gray*. Even though the two Oxfordian basins are loosely referred to as the "Early" (Bärschwil Fm.) and "Mid" Oxfordian basins (Effingen Mb.), their upper boundaries are not within these ages

consisting mainly of limestones, marls, and clays. Cretaceous deposits occur only west of the study area. Tertiary deposits are conserved in the Bresse and Rhinegrabens as well as in the Molasse Basin. In the Jura Mountains, erosional remnants of Tertiary deposits are only found within synclines.

Analysis of the available data concerning large-scale facies patterns and thickness distributions reveals trends, which persisted through time. An overview of the time intervals and corresponding lithologies and environments studied is given below. The Early Jurassic has not been re-investigated in detail to date.

Triassic (Philippe et al. 1996)

The Triassic Muschelkalk (Fig. 3a) found in the study area is composed of shallow marine carbonates and evaporites belonging to the Germanic facies. Isopach maps reveal depocenters located in the southern Rhinegraben and the area around Olten.

Early Mid-Jurassic (Allia 1996)

During the Early Aalenian open marine clays were deposited in a shallow epicontinental basin. Although a coeval carbonate platform does not occur in the study area, paleocurrents indicate the presence of slopes dipping towards the depocenters in the area of the southern Rhinegraben, Olten and to the east of study area (Fig. 3b).

Late Mid-Jurassic (Gonzalez 1993)

During the Bajocian and Bathonian an oolite platform covered much of the study area. Coeval shales occur to the south and east of the study area in deeper water facies. Depocenters are again located in the area of the southern Rhinegraben, Olten and in the eastern Jura Mountains.

Early Late-Jurassic (Gygi 1969, 1990; Allenbach 2002)

During the Oxfordian two shale basins developed, the Early Oxfordian with a coeval submarine swell on which

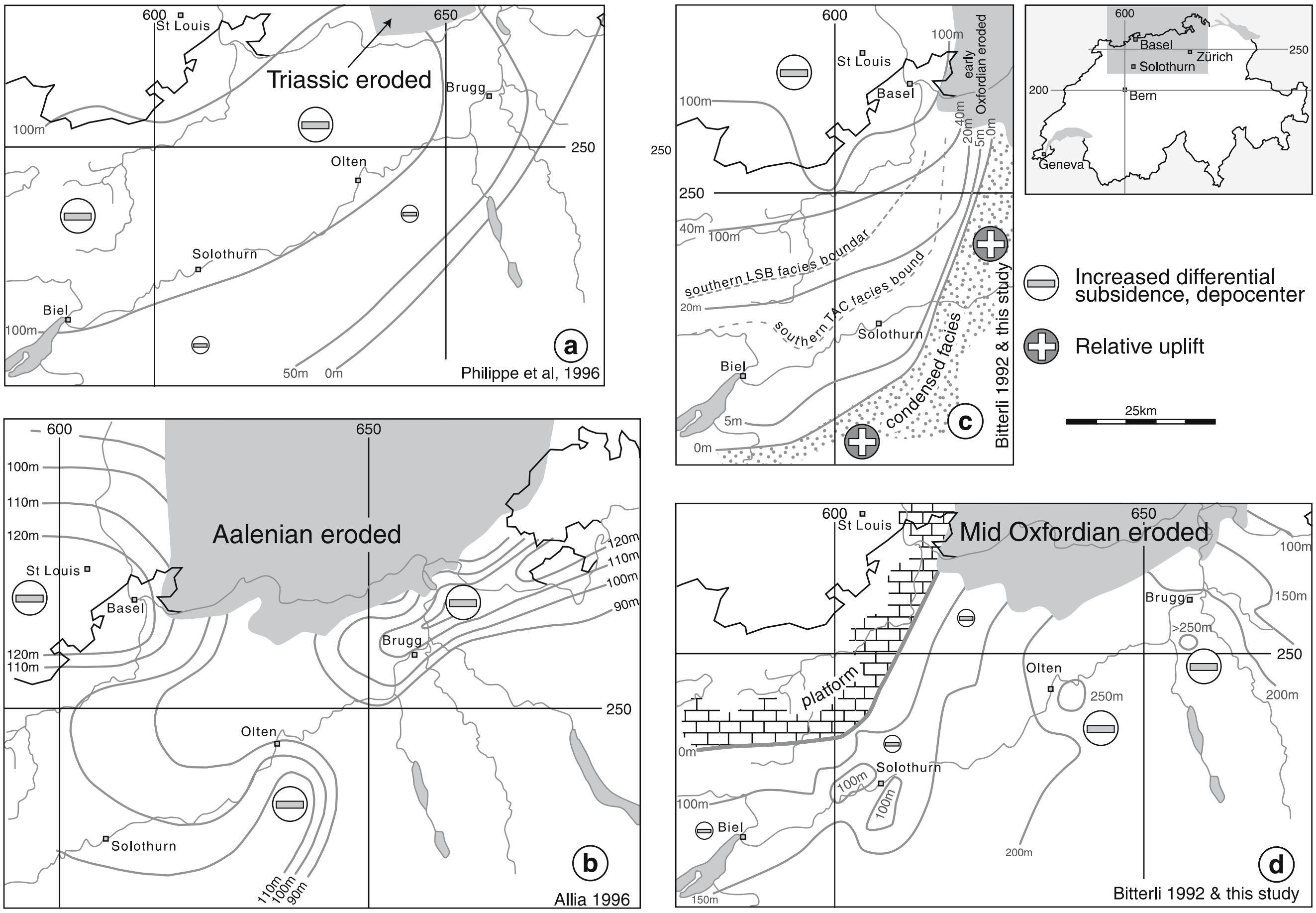


Fig. 3 Isopach maps of the Triassic Muschelkalk (**a**), Mid Jurassic Opalinus Clay (**b**) and Late (**c**, **d**) Jurassic epicontinental shale basins (see also Fig. 2). Depocenters occur near the city of St. Louis in France as well as near Olten and Brugg in Switzerland. The basin boundaries (0 m contours) of the Early Oxfordian (**c**) and Middle Oxfordian (**d**) point out that relief inversion took place along parallel lineaments. The *dashed lines* in **c** represent the shallow water facies found on top of the Bärschwil Formation; *TAC* represents the limestone nodule interval (Terrain à Chailles) and *LSB* the coral bearing top of the formation (Liesberg Beds) shown in the stratigraphic column. These facies boundaries are again parallel to the basin margin (0 m isopach)

deposition was inhibited through by-passing (Allenbach 2002) and the Mid-Oxfordian with a coeval carbonate platform. Depocenters of the shale basins are again located in the area of the southern Rhinegraben, Olten and in the eastern study area. Towards the end of the Early Oxfordian a shallowing-up trend is recognized in the basinal succession as is evident by the transition from basin muds through tempestites to hermatypic corals embedded in marls (Figs. 2, 3c). During the Mid-Oxfordian the depocenters shifted eastward, while the location of the basin margin remained similar to the Early Oxfordian one (Fig. 3d). The Mid-Oxfordian basin margin oversteps the Early Oxfordian one by as much as 20 km.

Basement

The basement underlying the study area is intensely faulted. Surface exposures of a few of these faults can only be seen in the Vosges and Black Forest mountains to the north. Within the Jura Mountains, surface morphology reflects some basement structures (Fig. 1). Subsurface information on the basement under the Jura Mountains is mainly restricted to northeastern Switzerland. Due to the erosional and weathered nature of the top of the basement, caused by exposure during the Late Paleozoic, the contact between the Triassic deposits and the basement is often obscured in seismic lines. Nevertheless, the basement is thought to be only marginally involved in the architecture of the Jura fold and thrust belt and underlies it as an evenly SE dipping (1°–3°) surface (Sommaruga 1997). In the eastern Jura Mountains, where the basement is transected by a number of faults and Permo-Carboniferous basins, the seismic resolution at the basement level is very poor and thus it is nearly impossible to construct structural maps of the basement (Diebold et al. 1991). According to Sommaruga (1997) strike-slip faults seen in the folded Mesozoic cover cannot be traced into the basement and appear to bend into detachment faults within the Triassic rocks. While this is probably true for the majority of the strike-slip faults seen in the Jura Mountains, sedimentological analysis shows that vertical basement movements must have taken place along some of these faults in the central Jura Mountains. Such vertical movement along the Wehra-Zeininger fault is evident in the Bajocian and Bathonian as drastic changes in facies and thickness are recorded (Gonzalez 1993) as well as Early and Mid-Oxfordian facies boundaries, which in their palinspastic position are overlying the same lineaments as the present-day faults. Faults associated with the Wehra-Zeininger fault zone (Figs. 1, 4) crop out in the southern Black Forest and have been dated to 320 Ma (Krohe 1996). Today this fault zone cannot explicitly be traced into the Jura Mountains due to the lack of data in this area (Fig. 6 in Gonzalez 1990; Bonjer 1997).

Facies correlations based on well logs of Permian rocks across the Rhenish Lineament and the Wehra-Zeininger fault indicate that these are Late Paleozoic structures. To the east and west of the Rhenish Lineament and the Wehra-Zeininger fault distinct changes in formation thickness are recognized in Permo-Carboniferous fan and playa deposits (Fig. 5). These variations in thickness and facies are interpreted as resulting from fault-controlled subsidence variations during the development of the basin system. The top of the playa sediments was selected as a tentative datum line as this stratigraphic horizon most likely represents the only horizontal line in these continental deposits, thereby giving the most realistic indication of vertical movements within the basement.

Tectonic setting

The Jura Mountains are a thin-skinned, fold and thrust belt that formed during the late Miocene and Pliocene phases of the Alpine Orogeny with middle Triassic evaporites providing a basal décollement horizon for the Mesozoic sediments above the basement (Buxtorf 1907; Laubscher 1965). Fold nucleation is often thought to occur along basement involving normal faults, which were active during the Permo-Carboniferous, Mesozoic, and/or Tertiary (Laubscher 1965, 1986; Pfirter 1982; Naef and Diebold 1990; Küehni 1993; Diebold and Noack 1997; Laubscher and Noack 1997).

On the tectonic map of Switzerland (Spicher 1980), curvature and offset of anticlines is clearly visible in a zone forming the southern continuation of the Wehra-Zeininger fault and the Rhenish Lineament (Fig. 1). The spatial coincidence of anticline strike changes in the SSW prolongation of the Rhenish Lineament, as mapped by surface geology in the Jura Mountains, is clearly visible in Fig. 1b. Moreover, satellite images clearly show this lineament and the associated fault zone.

Closer inspection of the surface morphology and geology shows that these NNE–SSW structures form the margins of Tertiary basins, are followed by rivers, and are characterized by strike-slip zones. The strike-slip faults represent reactivated Oligocene normal faults, which were formed during the development of the Rhinegraben proper.

In order to correctly determine the effect of reactivated basement faults on the deposition of Mesozoic strata it is necessary to palinspastically restore the Jura fold belt. This was done in accordance with Laubscher (1965) by rotating the locations situated within the southernmost folded Jura Mountains counterclockwise by 7° around the easternmost tip of the mountain chain. The other locations were rotated with decreasing amounts to account for the decreasing amount of shortening towards the north. This method is elaborately explained by Laubscher (1965) and has also been applied by more recent authors (Philippe 1995).

Subsidence rates

Tectonic subsidence rates calculated by Wildi et al. (1989) show rapid increases during Mid and Late

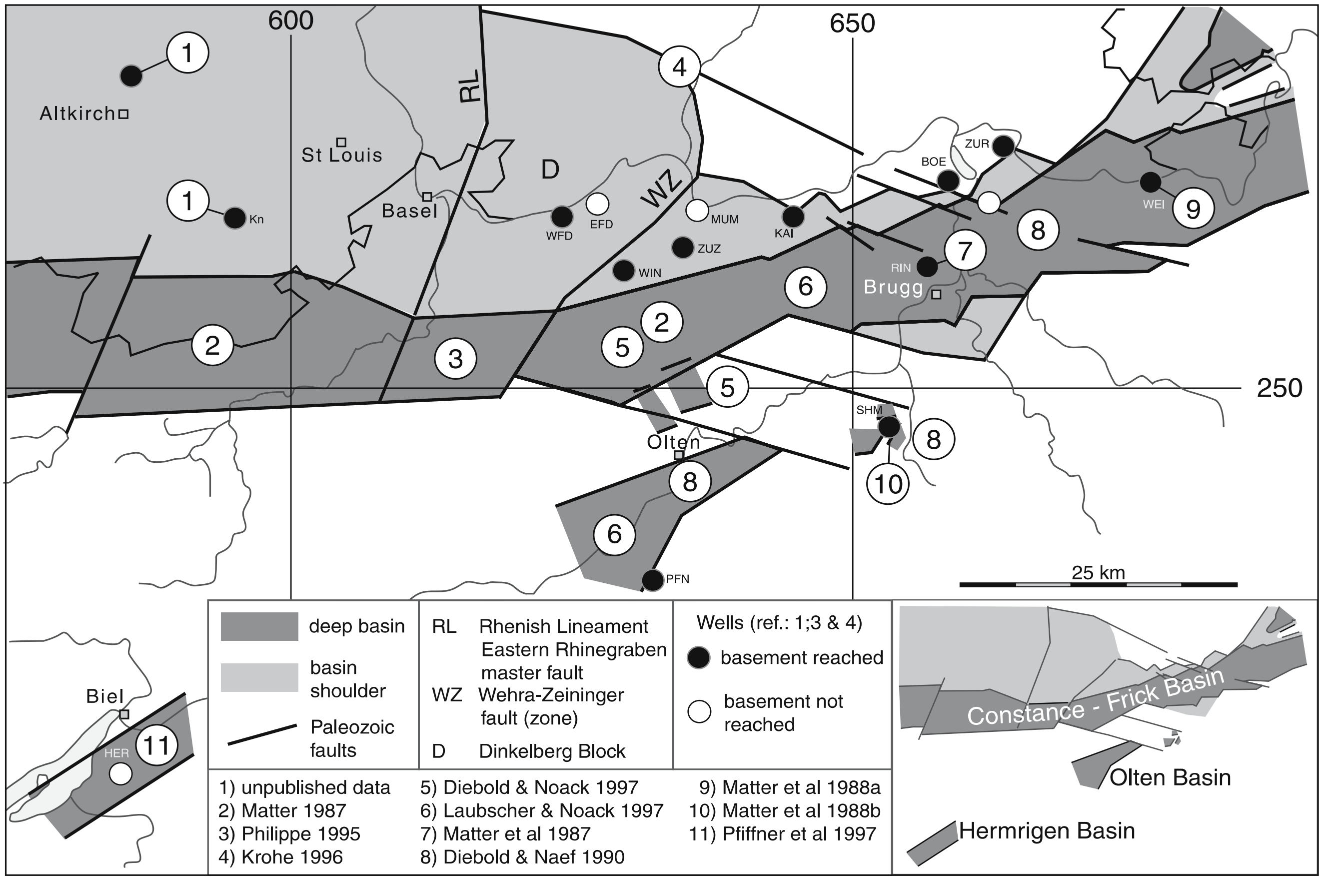


Fig. 4 Permo-Carboniferous basins as compiled from various sources based on subsurface data. West of Olten subsurface data is too sparse to allow for a precise tracking of the Paleozoic basins and thus the basin location is interpreted from the Jura Mountains architecture. The Hermrigen basin is only known from a single seismic line; the indicated well did not reach the base of the Triassic (Pfiffner et al. 1997). Whether the Olten and Hermrigen basins form one continuous basin is not known to date

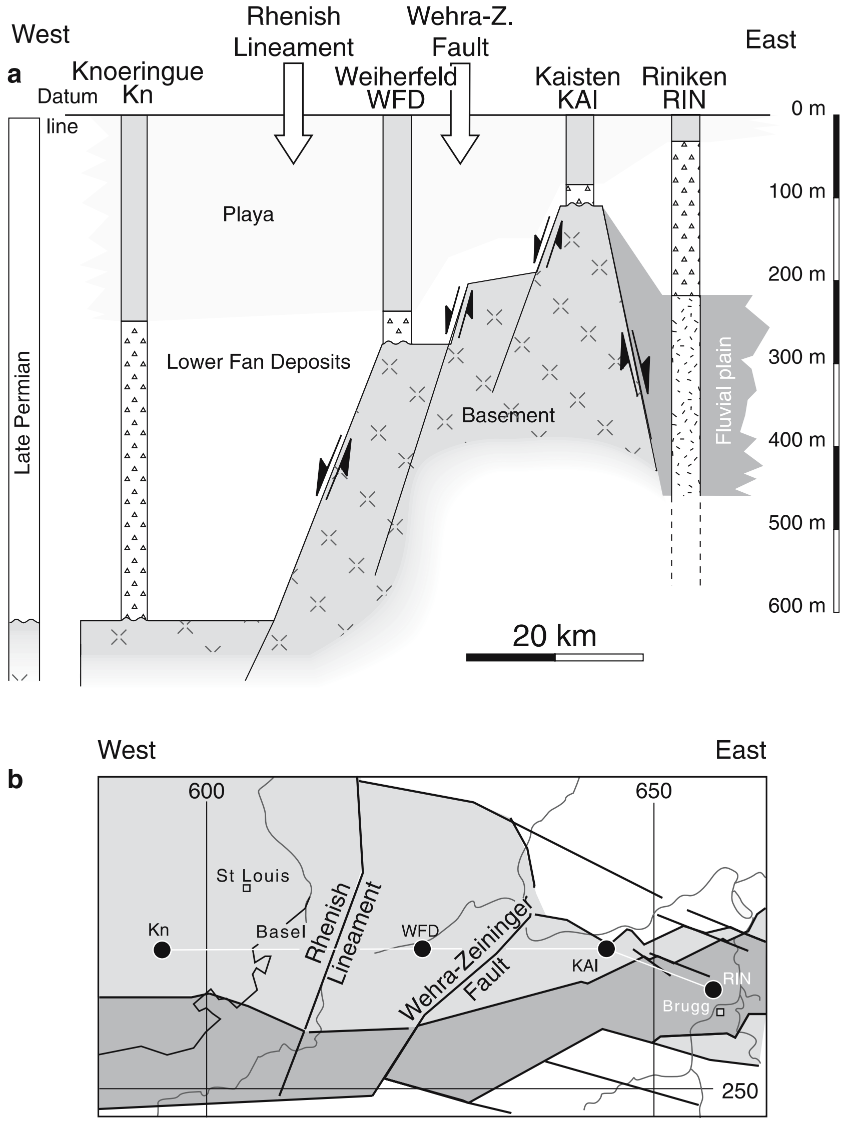
Jurassic times, which corresponds to the periods of development of epicontinental basins in the study area (Fig. 2). Additional subsidence rates were calculated for a series of wells in the vicinity of the Paleozoic basins (Fig. 6) using the application “Basinworks” (now called “Petrodynamics”). In order to calculate subsidence curves the following parameters were taken into account: compacted thickness of the sediments, absolute age of the deposits, eustatic sea level fluctuations (Haq et al. 1987), and rock type (to allow for compaction). Thickness of lithoformations was obtained from well-log data. Ages were derived from formation boundaries within the well-log, which have been dated biostratigraphically within the study area. Porosity of the sediments (mainly shales, limestones, and evaporites) is generally less than 5% (Wildi et al. 1989).

Depocenters

The close locations of the Early and Mid Oxfordian basin margins suggest that differential subsidence was the main cause for the basin development. Even though the two Oxfordian shale basins are displaced in space and time, their margins lie parallel to each other (Fig. 3c, d). Sea level fluctuations as a factor in the development of these epicontinental basins have only minor relevance. While the Early Oxfordian rise in sea level of some 30 m (Haq et al. 1987) did form additional accommodation space and consequently the expansion of the Early Oxfordian shale basin, it does not account for the differentiation of the paleoenvironment into swells and basins. The same applies for the Mid Oxfordian when short-term variations were less than 30 m (Haq et al. 1988; Pittet and Strasser 1998).

From the Miocene until the Recent regional uplift took place under the Jura Mountains to the west of the Rhenish Lineament and subsidence under the Jura Mountains and Molasse Basin east of the Rhenish Lineament (Thury et al. 1994). In terms of vertical movement this situation is similar to what is seen during the Mid and Late Jurassic; shallow water deposits to the WNW of the Rhenish Lineament and deeper water deposits to the ESE. It is important to realize that while the area which experiences uplift or subsidence needs to be identified, it is the hinge line between a subsiding block and its relatively stationary neighbor which corresponds to deep-reaching structures in the basement.

Fig. 5 **a** Permian facies correlation reveals differential subsidence along the Rhenish Lineament and the Wehra-Zeininger fault during the Late Permian. Both of these faults are recognized in Paleozoic and Mesozoic facies patterns as well as in the structure of the Jura Mountains. The *datum line* refers to the top of the Playa sediments [Compiled from Schmassmann and Bayramgil (1945), Bitterli (1972), and Matter (1987)]. **b** Location of transect, wells and faults shown in **a**



Areas which preferentially rise or fall might experience relief inversions depending on the orientation of the regional stress field. The hinge line, along which the facies boundary will form, will remain stationary (Fig. 7).

The Mid Oxfordian platform margin closely follows the Rhenish Lineament (Fig. 3d), a clearly defined basement structure. The Mid Oxfordian is the only Mesozoic interval in which a sedimentologically clearly recognizable platform margin is evident. Mid Oxfordian sediments accumulated during stable sea level conditions. A rise or fall in sea level would leave a transgressive or regressive signature depending on whether accommodation space increased or decreased. Under more or less stationary sea level conditions, development of accommodation space can only result from differential subsidence. Thus, the observed facies boundary traces the boundary between high (subsidence rate > sedimentation rate) and low rates of subsidence (subsidence rate < sedimentation rate). In comparison to the Mid Oxfordian basin, the Early Oxfordian basin margin is shifted southward. This is the effect of sedimentation during a period of a rapidly rising sea level. With additional accommodation space being formed by an increase in sea level, the basin is able to expand. This effect left by eustatic sea level changes obscures the relationship of facies boundaries and basement tectonics. Yet the eastern boundary of the Early Oxfordian shale basin lies parallel to the Mid Oxfordian shale basin, which strongly suggests that they are caused by common or parallel structures in the basement.

Discussion

By combining the data gathered from sedimentology and structural geology, essential vertical movements of the basement by differential subsidence during the Mesozoic can be recognized. Superimposing all of this data on maps shows that the tectonic activity took place

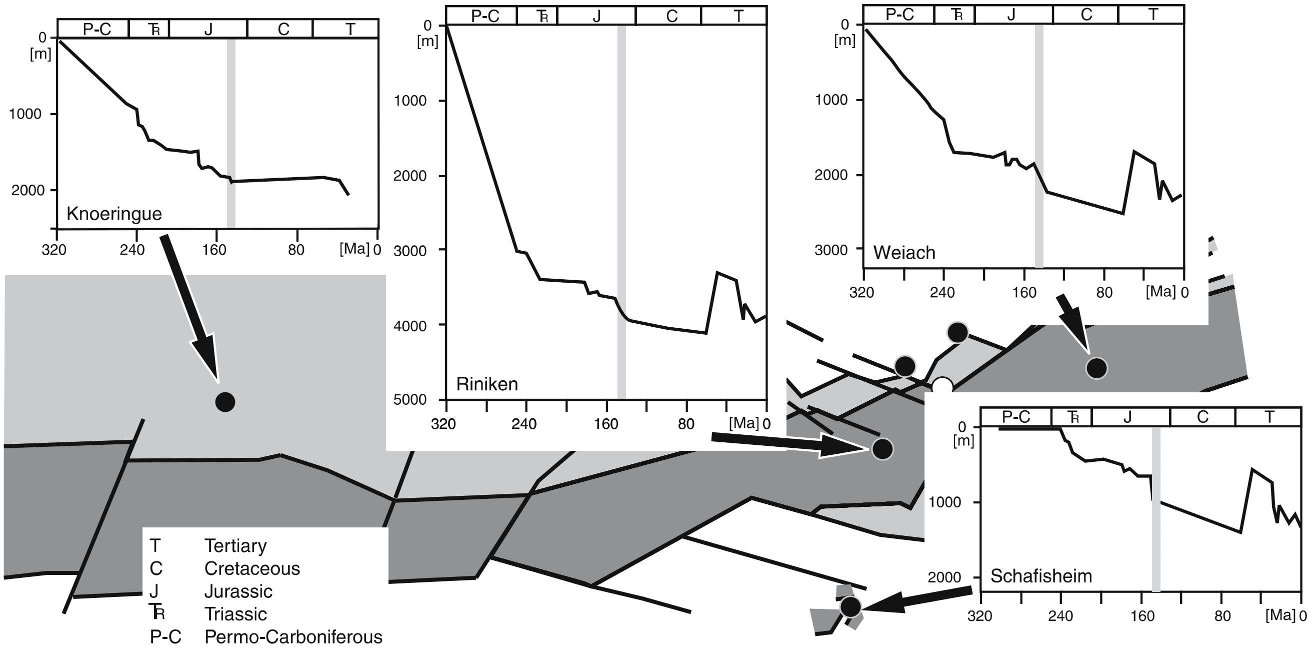


Fig. 6 Subsidence plots for four wells of the Constance-Frick Basin (Allia 1996; Allenbach 1997). All plots show an enhanced subsidence during Late Jurassic (ca. 150 Ma). In calculating the plots eustatic sea-level changes, paleowater depth, lithofacies, and differential compaction were taken into consideration. The subsidence rates from within the Oxfordian depocenter (Riniken, Weiach, and Schafisheim; see also Fig. 4) show the strongest increase during the Oxfordian and those from the basin shoulders (Knoerringue) a weaker increase. The *gray bar* marks the Oxfordian

in the same areas through time (Fig. 8). Margins of the epicontinental realms of increased subsidence during the Mesozoic are found to coincide with faults defining the Permo-Carboniferous basins in the southern part of the study area. Facies boundaries between platform and basin share similar orientations during the Bathonian and Oxfordian along a NNE–SSW strike, which coincide with Tertiary lineaments transecting the Jura Mountains. Most revealing, however, is that the basement faults which are perceived in the platform to basin boundary in the Oxfordian are again recognized in the pattern of tectonic fold axes in parts of the Jura Mountains (Fig. 1). Along the southern margin of the Jura Mountains in the study area two Permo-Carboniferous basins are defined by subsurface data, namely the Hermrigen and Olten basins (Fig. 4). The basins may either link up with each other, or terminate against the prolongation of the Rhenish Lineament and the Wehra-Zeininger fault system. For want of adequate reflection seismic control, this question could not be answered. West of the Jura Mountains, Paleozoic basins reappear from underneath the Mesozoic cover. To the north Paleozoic grabens and Permo-Carboniferous sediments are known from the southern Vosges Massif (Fig. 1 in Laubscher 1986) and the Black Forrest. The general ENE–WSW orientations of these Permo-Carboniferous basins further imply that similar structures are to be expected underneath the Jura Mountains as shown by Meier (1994) and Wetzel and Allia (2003).

Earlier in this paper, the concept of the Bressegraben being a laterally displaced continuation of the Rhinegraben was discussed. If the examined facies boundaries follow the Rhenish Lineament on their NNE–SSW strike, they should also follow the Bressegraben Lineament. This trend is indeed also recognized on facies maps of eastern France (Debrand-Passard and Courbouleix 1984). Laubscher (1971) illustrated a solution for the Rhinegraben and Bressegraben continuation (Fig. 9a, b) by displacing the grabens along the east–west trending Burgundy "transform fault zone" (see Laubscher 1970). This transform fault zone coincides with a system of Permo-Carboniferous basins of northeastern Switzerland. Moreover, it also coincides with the east–west portion of the Oxfordian facies boundaries.

Conclusions

Variations in local subsidence during the deposition of several Jurassic lithostratigraphic units reveal an overlay of depocenters. These depocenters developed above Permo-Carboniferous basins in the Hercynian basement. A major east–west boundary between two important areas of preferred subsidence is found along the southern extension of the Rhenish Lineament, which also coincides with Late Miocene structures recognized in the Jura Mountains.

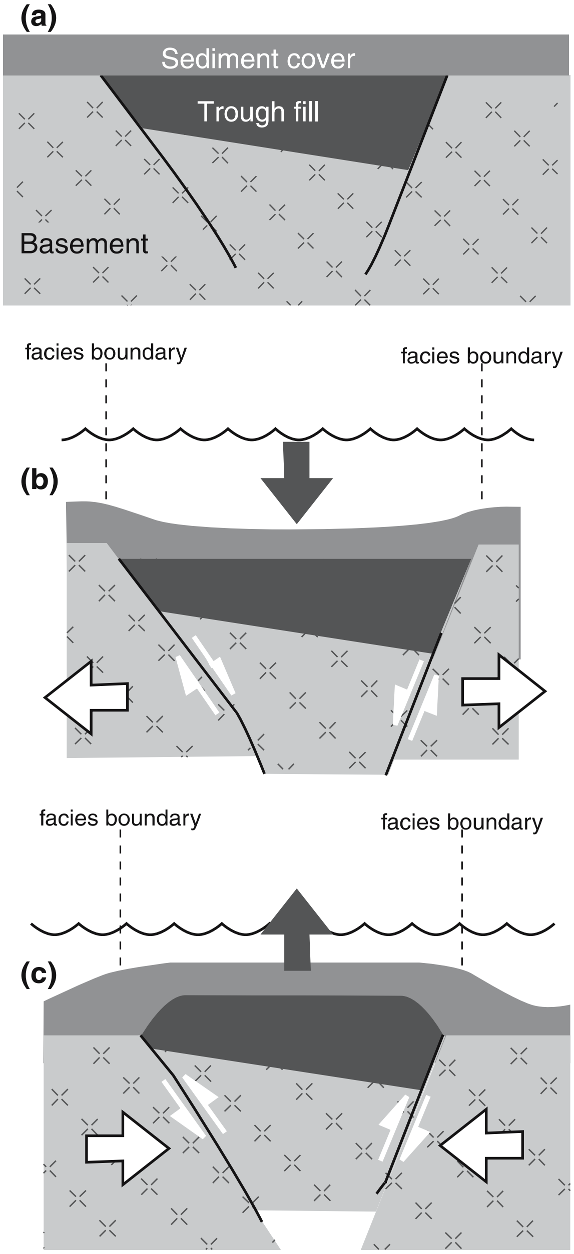


Fig. 7 A schematic basin (**a**) reactivated under an extensional stress field (**b**) and a compressional stress field (**c**). In both cases the same basin margin master faults are reactivated resulting in normal faults (**b**) and reverse faults (**c**). A compressional stress field (*white arrows* in **c**) might result in relief inversion while extension (**b**) leads to further subsidence at the former basin location. However, in both cases the location of the facies boundaries is the same. This is the effect seen in the Mesozoic deposits situated over the Paleozoic structures described (Fig. 3). Figure is not to scale

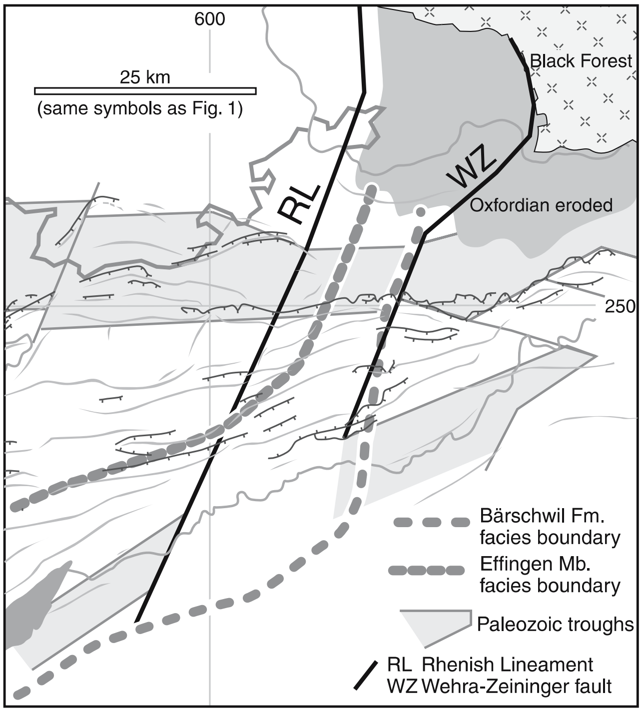


Fig. 8 Overview of the structural and facial patterns found in the Jura Mountains. The formation boundaries of the Oxfordian basin margins (see also Fig. 3c, d) follow the Rhenish Lineament and the Wehra-Zeininger Fault on a NNE–SSW strike and the Permo-Carboniferous Hermrigen Basin on an ENE–WSW strike. Also note the coincidence of fold and thrust patterns with the Paleozoic structures. Anticlines and thrusts lie on basin margins, while the anticlines situated between the Rhenish Lineament and the Wehra-Zeininger Fault appear to be rotated counterclockwise within a sinistral strike-slip fault zone (see also Fig. 1b)

Facies analysis of Oxfordian basins on palinspastically restored maps shows that facies boundaries follow Permo-Carboniferous basins along the southern study area and the Rhenish Lineament in the east. It can be demonstrated that the Mid Oxfordian facies boundaries and the Tertiary fold nucleation of the southernmost anticlines occur along the same faults bordering the Permo-Carboniferous basins. Geochemical dating gave an age of the fault zones in the Black Forest related to the Rhenish Lineament of approximately 320 Ma (Krohe 1996) indicating that the Rhenish Lineament is a Paleozoic structure. Oxfordian facies boundaries follow the NNE–SSW trending Rhenish Lineament, the E–W trending Permo-Carboniferous basin, and the N–S trending Bressegraben lineament, implying that these are all reactivated structures of a pre-Oxfordian, most likely Paleozoic, age. Subsidence data from Wildi et al. (1989) also imply that the area north of the "Rhenish Lineament-Permo-Carboniferous basin-Bressegraben lineament" zone experienced lower rates of subsidence during the Jurassic than the area south of it. This effect coincides once again with the Mid Oxfordian facies; the Effingen Basin does not have a distinct southern margin, but rather grades into the Schilt formation of the Helvetic facies encountered in the Alps due to the more rapid subsidence south of the "Rhenish Lineament-Permo-Carboniferous basin-Bressegraben Lineament". While Paleozoic ages for the Rhinegraben and Bressegraben Lineaments have already been suggested by Ziegler (1990) and von Raumer (1998), this study shows that some of the best clues may be found in the facies boundaries of the Mesozoic cover.

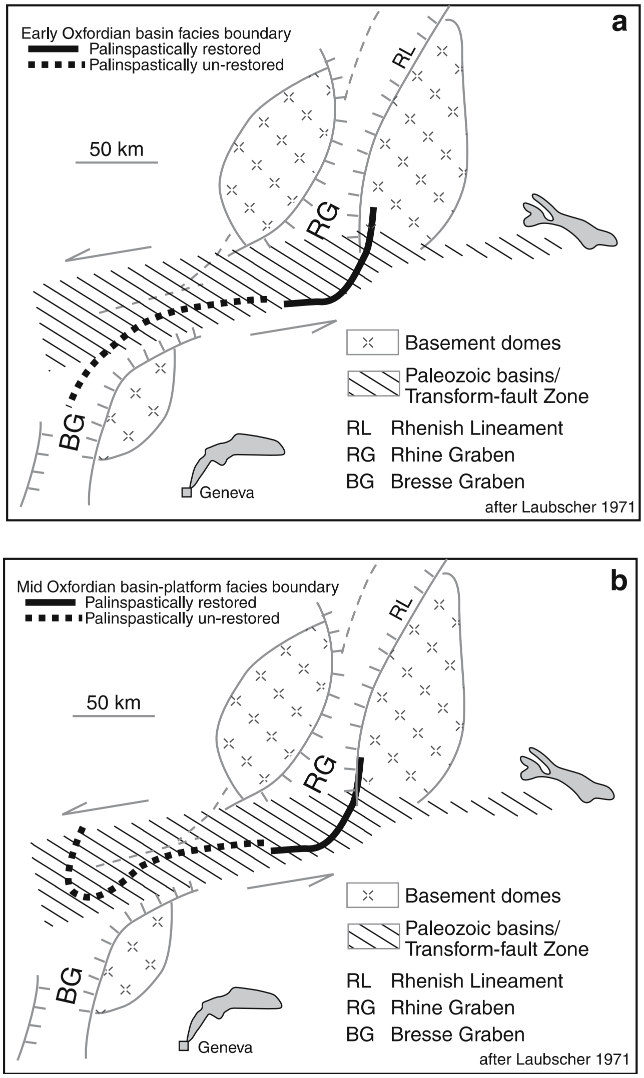


Fig. 9 Laubscher's (1971) cartoon of how the Bressegraben and Rhinegraben may be linked along a transform fault zone. Superimposed are the Early (**a**) and the Mid (**b**) Oxfordian platform (north) to basin (south) facies boundary. The sigmoid shape of the boundary follows the Rhenish Lineament and the Permo-Carboniferous basin of northern Switzerland (Fig. 8) before continuing into the Bressegraben. The illustration leaves the intended impression that the Rhenish and the Bressegraben lineaments, as well as their lateral displacement are pre-Mesozoic. See text for further discussion

With adequate knowledge of the depositional environment and related eustatic sea level behavior it is possible to show how, when, and where vertical movements in the basement affected the Mesozoic environment, and where deep-seated structures can be assumed. Comparison of the sedimentological data with other data (satellite images, earthquake data, topography, and structural geology) indicates basement structuring and fault reactivation along normal faults. The fact that the various approaches all indicate a common cause in the same areas through long periods of time is sufficient evidence for the presence and reactivation of widespread Paleozoic basement faults.

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