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Basement Uplift and Decollement in the Molasse Basin

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ABSTRACT

Vertical movements of the top of the marine Miocene, as recently (LEMCKE 1974) inferred from well data in the Molasse basin, increase from several hundred meters in the north and east to over 2,000 m in the southwest behind the Jura. They may be attributed to the superposition of the effects of two different processes: slow basement deformation of the northern limb of the Molasse basin and of the Rhine and Bresse graben system, which is still going on, and fast, episodic decollement of the sedimentary cover, which produced the high values in the southwest.

ZUSAMMENFASSUNG

Vertikale Bewegungskomponenten der Obergrenze des marinen Miozäns im Molassebecken nehmen von einigen hundert Metern im Norden und Osten zu auf über 2000 m im Südwesten (LEMCKE 1974). Sie sind das Ergebnis einer Überlagerung von zwei ganz verschiedenen Bewegungen: Einerseits einer während des ganzen Tertiärs andauernden und auch heute noch fortwirkenden Krustendeformation in der Nordflanke des Molassebeckens sowie im Rhein–Bresse-Grabensystem, anderseits der kurzen und intensiven Abscherbewegung der Sedimenthaut im Jura und seinem Hinterland. Dieser letzteren sind die abnormal hohen Werte im Südwesten zuzuschreiben.

One of the implications of the decollement, thin-skin ("Fernschub") theory of Jura folding is that south of the Jura mountains the surface of the Molasse basin, and indeed of all stratigraphic units above and dipping less than the decollement zone, must have been uplifted above a stationary basement because a southward thickening wedge has been pushed to the north (Fig. 1, after LAUBSCHER 1961; compare also Fig. 2). I have not pursued the matter beyond this statement.

Now LEMCKE has recently (1974; cf. also 1973) published some of his very interesting results concerning original thicknesses of formations in wells of the Molasse basin. He concludes that the present elevation of the top of basement combined with the original thickness of the Mesozoic and Tertiary sequence proves a Pliocene–Quaternary uplift of the sub-Molasse basement reaching and probably exceeding 2.5 km in western Switzerland (Fig. 3).

The question, though not considered by LEMCKE, arises whether the abnormal uplifts in the Molasse basin behind the Jura may not be largely due to decollement on

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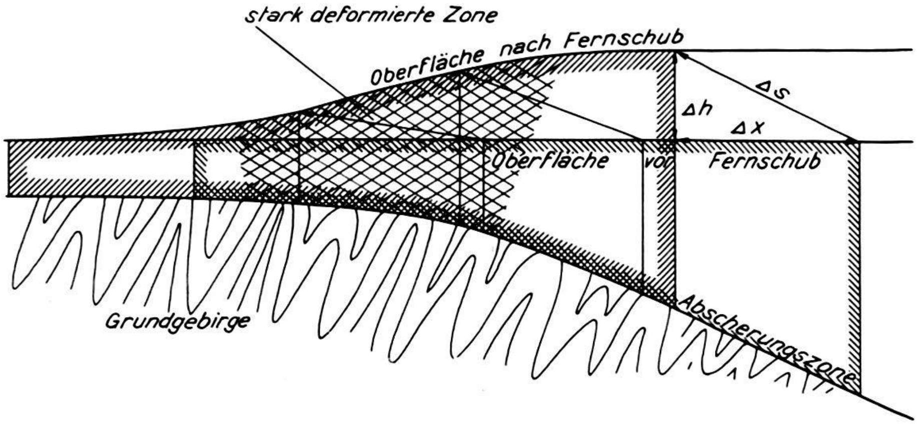

Fig. 1. Surface uplift above a stationary basement, due to decollement (uphill translation of a sedimentary wedge). From LAUBSCHER (1961).
Δs = total translation, Δx = horizontal component, Δh = vertical component = surface uplift.

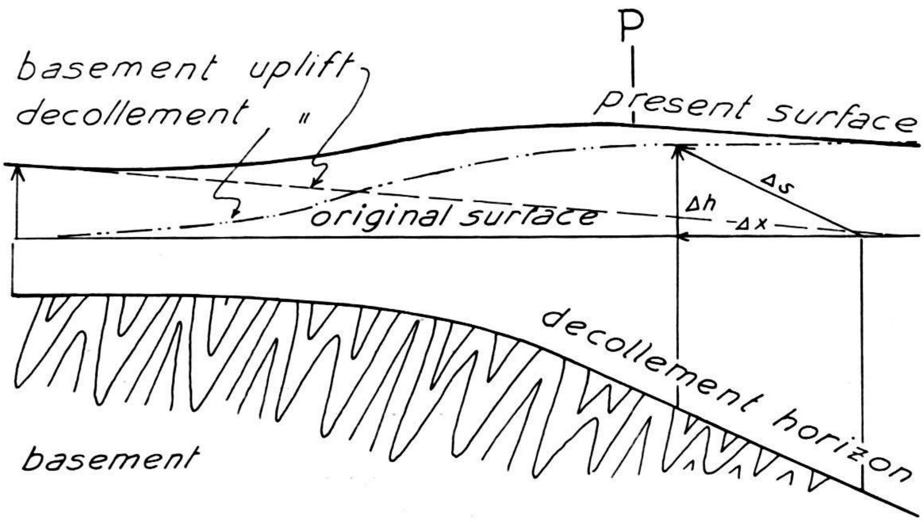

Fig. 2. Superposition of decollement induced uplift and true basement uplift which transcends the boundary of decollement.

a stationary basement, leaving only a regional residue for true basement uplift, independent of and transcending the boundaries of the Jura decollement sheet. A closer analysis brings out the likelihood that this is indeed the case.

Consider, first, the excellently documented cross-section (S in Fig. 3) passing through the Birs gorges and the Grenchenberg tunnel (BUXTORF 1916). The compression here, and consequently the total amount of the uphill push of the Molasse basin sediments, is on the order of 14 km (LAUBSCHER 1965). The south dip of the decollement surface, estimated from LEMCKE'S Figure 1, is 5.3°, and this corresponds to a vertical uplift Δh = 1.3 km (compare Fig. 1), affecting every horizon above the decollement surface to the south of the internal border of the Jura. This would leave a regional residue of true basement uplift of 200–300 m, as LEMCKE'S figure for this area is about 1500–1600 m.

There is direct evidence at the northern end of the cross-section for such a post-Helvetian basement uplift. FISCHER (1965) has discovered marine Miocene at an

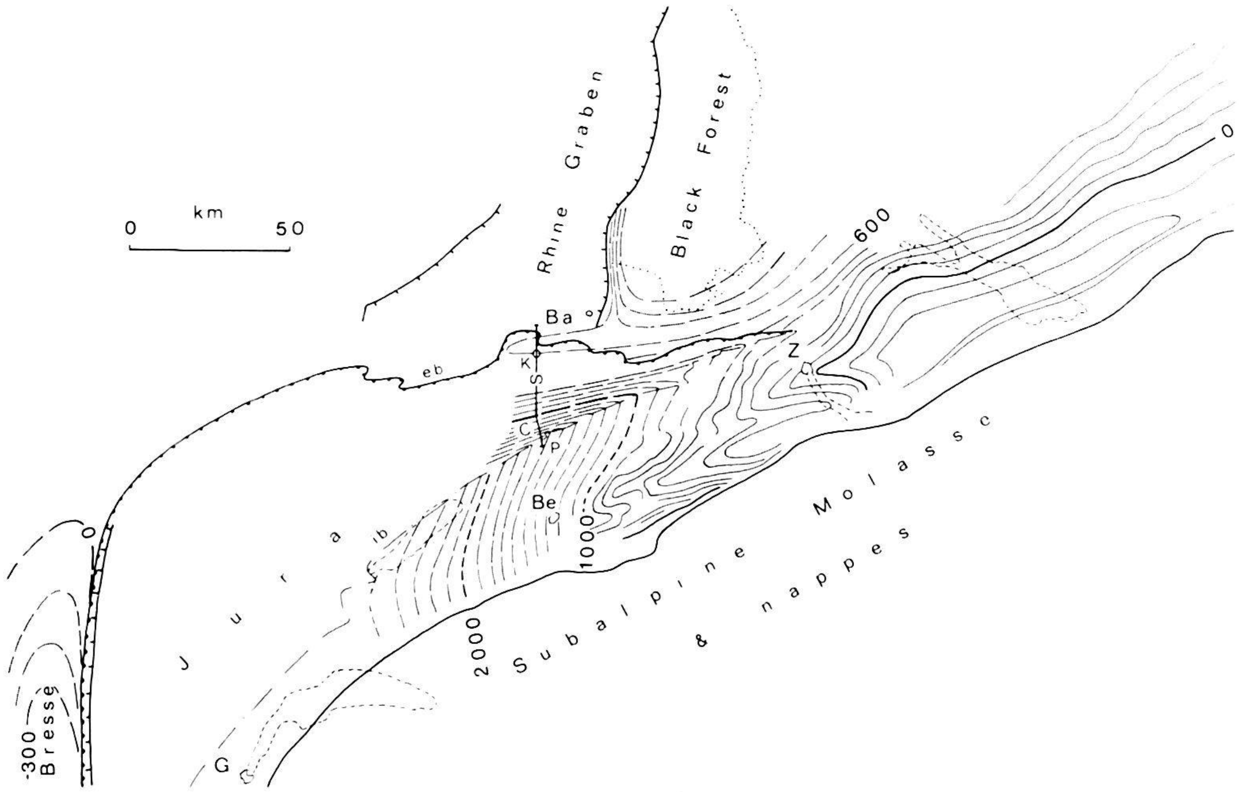

Fig. 3. Present position (in meters) of the top of marine Miocene = total uplift since deposition which was close to sea level. *Solid contours* after LEMCKE (1974). Additions (*broken contours*) are based on data along the northern border of the eastern Jura, on information given by LEFAVRAIS-RAYMOND (1962) for the Bresse graben, and on interpolation between LEMCKE's contours and Essertines-1 (the value for Pfaffnau-1 is too high, that of Courtion-1 too low in this simple interpolation map). S = cross-section through the Birs gorges and the Grenchenberg tunnel, K = Kiffis, C = syncline of Court, Ba = Basel, Be = Berne, G = Geneva, Z = Zurich, eb = approximate external boundary, ib = approximate internal boundary of folded Jura. The dotted line around the Black Forest marks the boundary of basement outcrops.

altitude of 600 m in the unfolded tabular syncline of Kiffis (K in Fig. 3), immediately behind the northernmost small fold of the Jura. This value fits closely those of uplifted marine Helvetian north and east of the Jura, particularly those of the tabular Jura of northern Switzerland and southern Germany, see Figure 3. Extrapolating from the area north and east of the Jura (Fig. 3), we obtain a true basement uplift component of 200–300 m at point P in Figures 2 and 3 – in excellent agreement with predictions.

It goes without saying that such rough overall estimates are inadequate for details. For instance, in order to account for the value of about 750 m obtained in the syncline of Court (C in Fig. 3; compare e.g. BUXTORF 1916, Plate 2) the following special considerations are necessary:

- compression north of the syncline is about 10 km;
- the average dip of the decollement horizon in the southern half of section *C* is only 2.3° as estimated after BUXTORF (1916, Plate 4). This implies a decollement induced uplift of only 400 m, leaving 350 m for true basement uplift, again in excellent agreement with regional extrapolation.

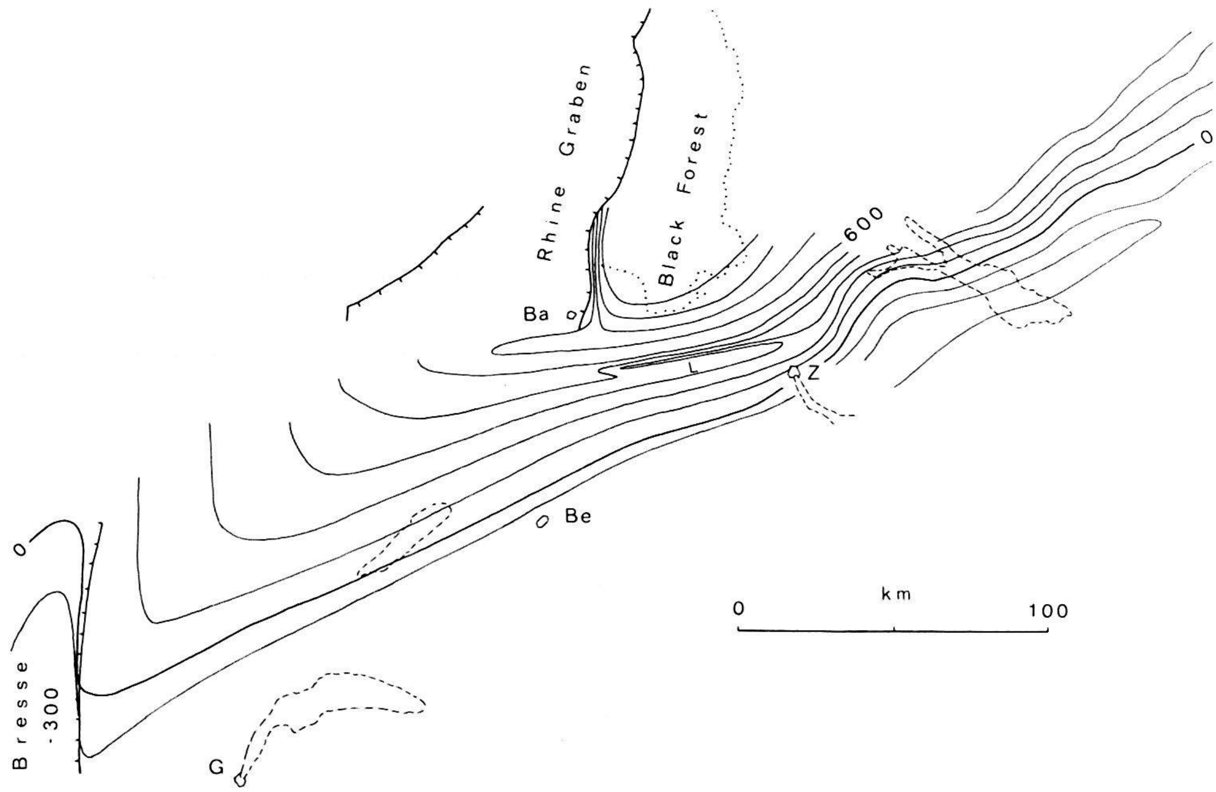

Fig. 4. Regional basement uplift of the marine Miocene, extrapolated from the area outside the Jura decollement sheet (Fig. 3). The comparatively smooth regional picture (basement fold paralleling the Alps) is modified by the superposition of special movements in the Rhine graben system, particularly uplift in the Black Forest and subsidence in the Rhine and the Bresse graben. These movements were very pronounced already in the Upper Miocene (Jura-Nagelfluh), before Jura decollement; they continue at present, several million years after Jura decollement has come to rest. Basement deformation was concentrated along some faults or flexures of which only one is shown (L = Lägern lineament), as suggested by the attitude of Miocene sediments at the southern border of the Tabular Jura.

The flattening on the decollement horizon in the north – essentially an Oligocene feature – causes the highest values for post-Miocene uplift to be shifted a little to the south of the internal margin of the Jura where the decollement horizon begins to dip more steeply, as may readily be appreciated on Figures 1 and 2. It has not been taken into account for the simplified construction of the contour maps as it is irrelevant for the main thesis of this article.

We may generalize our argument by considering separately maps of known basement uplift since Helvetian times (Fig. 4), and of uplift due to Jura decollement (Fig. 5), and superposing them for the combined effect (Fig. 6). Figure 4 shows the somewhat simplified map of basement uplift, obtained by extrapolation of values north and east of the Jura. Figure 5 is a map of uplift due to uphill push of the sedimentary cover, schematically estimated for a model of linear increase of Jura compression from the east end north of Zurich to the area of lake Neuchâtel (LAUBSCHER 1965). Figure 6 is the map of superposed effects. Its main features are an external ridge with a culmination along the internal border of the Jura (compare Fig. 2), in agreement with Figure 3. This ridge would also show on LEMCKE's Figure 6 though somewhat

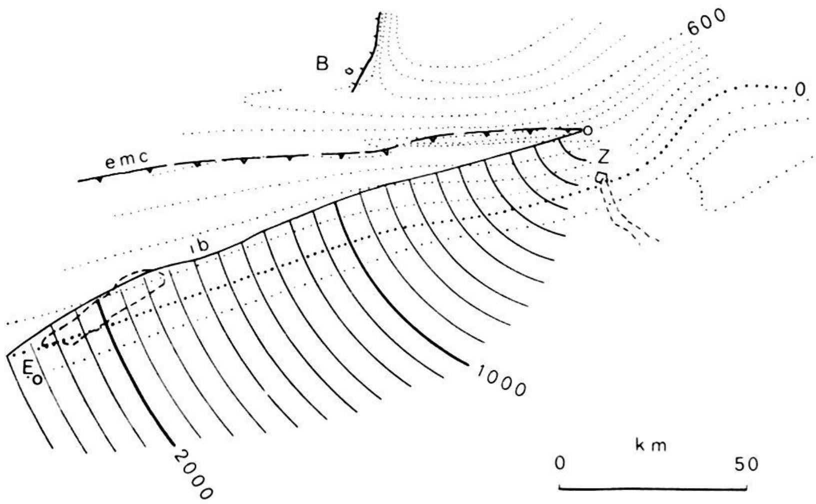

Fig. 5. Decollement induced uplift (*solid lines*) based on a linear westward increase of movement of the decollement sheet (rotation around the eastern tip of the Jura), the decollement horizon being uniformly inclined 5.3° against the direction of movement. Complications must be expected particularly south of the center of rotation (cf. LAUBSCHER 1961), but no subsurface information allowing a definition of these complications has been published. See also Figures 1 and 2. *Dotted contours* represent true basement uplift (Fig. 4).
emc = simplified external boundary of main Jura compression. ib = approximate internal boundary of folded Jura. E = Essertines, B = Basel, Z = Zurich.

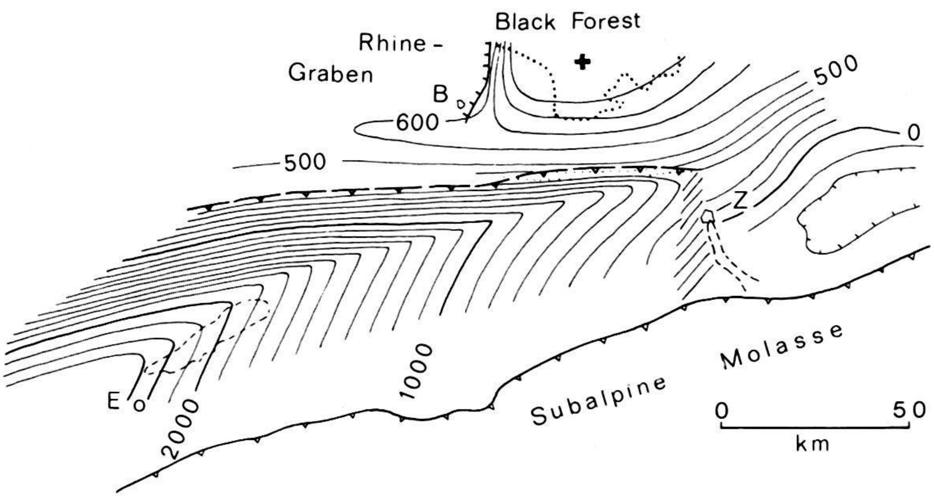

Fig. 6. Total uplift since the marine Miocene, obtained by addition of the values of Figures 4 and 5. Individual values within Jura synclines are not used. They increase towards the internal (southern) margin of the Jura, and this trend is represented here by linear interpolation between the internal margin and the approximate northern limit of intensive compression, compare Figures 2 and 5. Since this is a synthetic map based on extrapolations and simplified models, it does not agree exactly with Figure 3. However, the characteristic features are strikingly similar:

- Turning of contour direction from WSW (in the eastern Molasse basin) to SSW at the boundary of the decollement sheet (the irregular boundary zone south of the center of rotation is hatched).
- The ENE plunging ridge with its steep northern flank, corresponding to the Jura fold belt.

The implications of this pattern of uplift for the development of the drainage pattern are obviously enormous.

displaced to the south, if he had added (see p. 533) the values of Kiffis and several outcrops of marine Miocene inside the Jura, and completed the contours to the northwest.

I should like to add one remark about the continuation to the south-west, see Figures 3 and 4. The top of the marine Miocene in the Bresse graben is at about – 50 m to – 300 m (LEFAVRAIS-RAYMOND 1962). There has evidently been a slight post-Miocene subsidence in the Bresse graben, part of it possibly due to differential compaction. On the other hand the wells prove that the large frontal thrust of the Jura has not been significantly deformed; consequently there has been no significant differential basement uplift between Jura and foreland; I have rather exaggerated it on the maps. Seismic work and drilling in the high internal Jura have revealed that the pronounced rise of the surface towards the interior chains of the Jura is due to large-scale thrusting, there being no corresponding uplift of the basement, which continues its regional dip to the southeast (WINNOCK 1961; BITTERLI 1972; see also LAUBSCHER 1965, p. 294–297). The total compression of the Jura in this section is on the order of 20 to 30 km, corresponding to a decollement induced uplift of 1.8 km to 2.7 km, which is in good agreement with LEMCKE'S value for Essertines-1 (2.5 km; see also "E" in Fig. 5). In view of the low elevation of the Miocene in the Bresse graben and the apparent absence of noteworthy differential basement uplift southeast of it, it is well possible that practically all of the apparent uplift in Essertines-1 is decollement induced.

Conclusions

The distribution of post-Miocene uplift of sedimentary markers in the Molasse basin and the adjacent region to the north may be attributed to the superposition of two entirely different effects: true basement movements which affect the whole region in a rather mild way (a few hundred meters), and decollement induced uplift above a stationary basement which increases with the amount of compression in the Jura, reaching a maximum of over 2 km, and is restricted to the folded Jura and its hinterland. I have recently (LAUBSCHER 1973) called attention to the superposition in this region of two entirely different tectonic processes: protracted slow and comparatively mild basement folding north of the Molasse basin, and episodic, fast, and intensive epidermic movements in the Jura. The first has been acting throughout the Tertiary and is still going on, giving rise to frequent crustal earthquakes; the second, after a lifetime of probably not much more than one million years, has been dead for perhaps 5 million years. The values for post-Miocene uplift which LEMCKE (1974) has derived from analysis of well data harmonize with this view. Indeed, they constitute one more body of observational facts – in addition to those enumerated elsewhere (LAUBSCHER 1961, 1965, 1973) – which are hard to explain by any but the thin-skin theory of Jura folding.

BIBLIOGRAPHY

BITTERLI, P. (1972): *Erdölgeologische Forschungen im Jura.* Bull. Ver. schweiz. Petroleum-Geol. u. -Ing. *39*/95, 13–28.

BUXTORF, A. (1916): *Prognosen und Befunde beim Hauensteinbasis- und Grenchenbergtunnel und die Bedeutung der letzteren für die Geologie des Juragebirges.* Verh. natf. Ges. Basel *27*, 184–254.

FISCHER, H. (1965): *Geologie des Gebietes zwischen Blauen und Pfirter Jura (SW Basel).* Beitr. geol. Karte Schweiz [N.F.] *122*.

LAUBSCHER, H.P. (1961): *Die Fernschubhypothese der Jurafaltung*. Eclogae geol. Helv. *54*/1, 221–282.

– (1965): *Ein kinematisches Modell der Jurafaltung*. Eclogae geol. Helv. *58*/1, 231–318.

– (1973): *Faltenjura und Rheingraben: zwei Großstrukturen stossen zusammen*. Jber. Mitt. oberrh. geol. Ver. [N.F.] *55*, 145–158.

LEFAVRAIS-RAYMOND, A. (1962): *Contribution à l'étude géologique de la Bresse d'après les sondages profonds*. Mém. Bur. Rech. géol. min. *16*.

LEMCKE, K. (1973): *Zur nachpermischen Geschichte des nördlichen Alpenvorlandes*. Geologica bavar. *69*, 5–48.

– (1974): *Vertikalbewegungen des vormesozoischen Sockels im nördlichen Alpenvorland vom Perm bis zur Gegenwart*. Eclogae geol. Helv. *67*/1, 121–133.

WINNOCK, E. (1961): *Résultats géologiques du forage Risoux I*. Bull. Ver. schweiz. Petroleum-Geol. u. Ing. *28*/74, 17–26.