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Questions of global tectonics

Abstract. *Important tectonic structures such as isoclinal folds, reverse and thrust faults have been scrutinized by the author in order to reveal the mechanism of their coming into being. They are shown to be clearly related to vertical movements originating from secondary isostatic movements along strike-slip faults by juxtaposition of blocks of differing buoyancy during the orogenesis of folded mountain ranges. This reveals that gravitation is the originator of the structures. The geodynamic model generally used at present is dominated by the hypothesis that plates of lithosphere are floating on top of the mantle due to the activity of convection currents in the asthenosphere and therefore attributes the generation of isoclinal folds and thrusts to stresses acting horizontally. There is, however, no indication recognizable that would require the existence of convection currents.*

Since Wadati-Benioff zones are always observed between blocks of continental and oceanic crust, i. e. blocks of differing density, the author examined the possibility if those structures could have the same origin as thrust faults in the orogens on the continents. Their development exhibits clear evidence that their coming into being is also triggered by the activity of a strike-slip fault juxtaposing continental crust with oceanic crust. This mechanism was active also during the creation of the proto-Alpine fault or paleo-fault of New Zealand. The specifically lighter continental crust is thrust onto specifically heavier oceanic crust. Such behaviour is restricted to the marginal parts of the Pacific and further oceanic areas where inliers of continental crust do exist. The prequisites to accomplish the initiation of a Wadati-Benioff zone, such as the existence of inliers of continental crust and of a strike-slip fault juxtaposing both types of crust, are absent in areas composed exclusively of oceanic crust such as the Atlantic Ocean. Moreover, a number of further seismological properties of Wadati-Benioff zones confirms that these cannot be the sites of lithosphere merging into the mantle. Thrusting of continental blocks onto oceanic crust is of a much greater dimension than thrusting within orogens because of the larger difference of specific weight between the two kinds of crust. Thus, Wadati-Benioff zones are, like reverse faults in orogens, unequivocally local phenomena, but not the result of global migrations of plates of lithosphere. The tectonics of the Earth's lithosphere is doubtlessly dominated by vertical tectonics.

Introduction

The basic concept of plate tectonics is that plates of lithosphere of up to 100 km thickness migrate above convection currents within the asthenosphere. This assumption is based on an idea of Hopkins (1839) which was taken over by Holmes (1944) and later by Isacks et al. (1968) who proposed a migration of the plates from zones of divergence, i. e. oceanic ridges, to zones of convergence, i. e. Wadati-Benioff zones. This proposal has not been able to be substantiated. Various possibilities have remained undiscussed, e. g. an origin of zones of divergence caused by a possible extension of the Earth. On the other hand, the zones of „convergence“ have not been

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clearly identified as the sites of downgoing lithosphere. Their genereal correspondence with the appearance of reverse faults has been entirely neglegted. Many details of plate tectonics are still considered to be enigmatic and are explained by vague auxiliary hypotheses. Another problem is that plate tectonics seems to be applicable to the Earth but to none of the other planets. Thus the Earth would be unique among the planets of the solar system. Although this concept still poses a lot of questions and unsolved problems needing a large amount of tentative solutions it seems to have been accepted unanimously by the geoscientific community. The unclear situation is aggravated due to the fact that no satisfactory, conclusively underpinned mechanisms have been proposed which would suffice the requirements needed for the conclusive explanation of those frequent phenomena within the Earth's crust like isoclinal folding and thrusting. They are nowadays considered to be generated by horizontal compressive stress which would match the general horizontal-tectonic concept. However, a mechanically founded mechanism has not been presented. Instead of attempting to unravel the insufficiently known mechanisms controlling the main tectonic structures, these are now, reversely, believed to obey the geodynamic concept in vogue. This scientifically inadmissable kind of approach has its repercussions not only on the view of the mechanism of Wadati-Benioff zones, but also on the generation of important tectonic structures such as isoclinal folds, reverse and thrust faults which are associated with the orogenesis of folded mountain ranges. The result is a grave misconception of the basic tectonic processes active in the outer Earth. In order to examine the reliability of the plate-tectonic concept the author scrutinized the structures concerned in respect to their possible coming into being on the basis of a rich literature and own observations.

Strike-slip faults

It is remarkable that the whole of Eurasia and probably of Africa as well and large regions of North America are dominated by systems of conjugate NW-SE striking strike-slip faults indicating exactly north-south directed maximum compressive stress, and simple strike-slip faults formed under north-south directed compressive stress in southern South America. This regularity is interpreted by the author to be related to the rotation of the Earth. Further sets of conjugate faults developed on the slopes of the European and other orogens and are clearly related to compressive stress parallel to the topographic gradient of the orogens which reveals them as products of gravitation. They can be considered only as morphotectonic features. The same holds true for strike-slip faults on the slope of the ocean bottoms where they indicate compressive stress parallel to the topographic gradient as will be shown further down for the paleo-fault and the Alpine fault of New Zealand.

Thrusting and folding in folded mountain ranges

Apart from strike-slip, reverse and thrust faults and isoclinal folds are the most common tectonic structures. These structures turn out to be iso- or cogenetic since they are the result of the same process in that the ductile shearing movement of isoclinal folds is often seen to be continued by the brittle movement of reverse faults (**Fig. 1**), or isoclinal folds change to thrust faults along strike. In both cases their character as shear folds is clearly manifested.

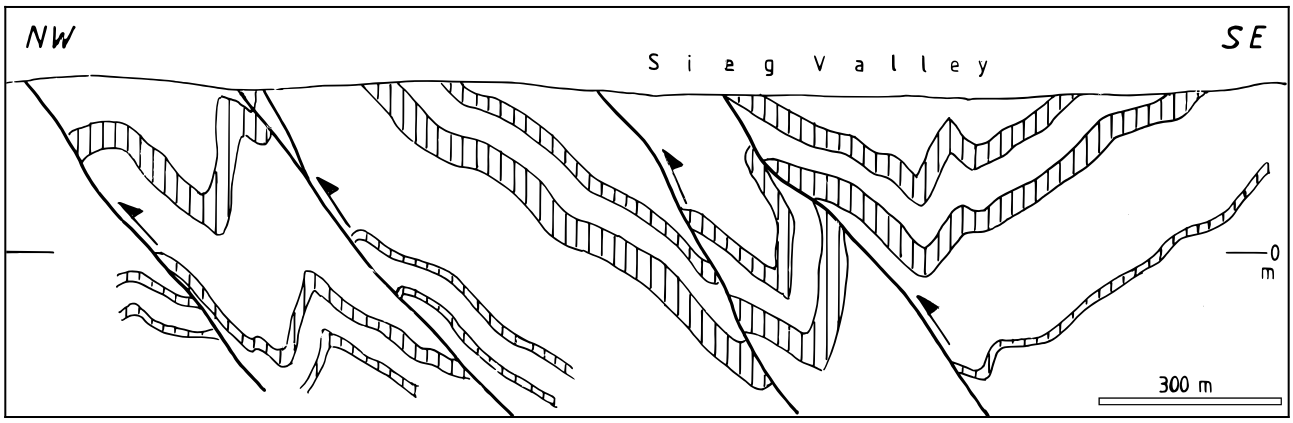


***Fig. 1**: In this cross-section from the Siegerland (Rhenohercynian; after Denckmann & Quiring 1931) the iso-/cogenetic origin of the older shear folds and younger thrust planes is evidenced by the fact that the latter are oriented parallel to the axial planes of the folds.*

If isoclinal folds and reverse faults are associated with each other it becomes apparent that the reverse faults parallel the axial planes of the folds. This is apparent not only in the outcrop scale (**Fig. 1**) but also in the regional scale (**Fig. 2**) and elucidates the iso-/cogenetic origin of reverse faults and isoclinal folds. It provides clear evidence that the isoclinal folds are shear folds. This conclusion is furthermore confirmed by the fact that the thickness of the strata in folded rock sequences remains constant when measured parallel to the axial plane of the folds.

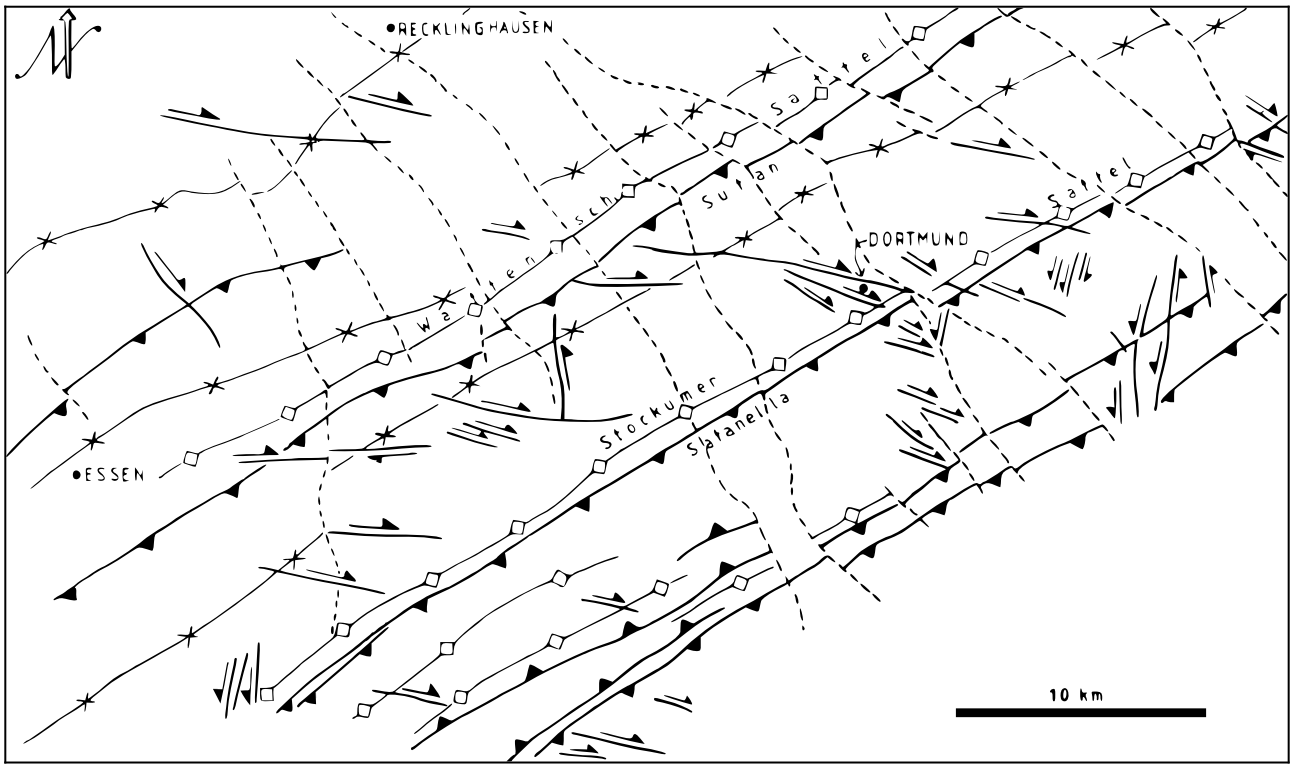


***Fig. 2**: In the Ruhr coal basin (after Pilger 1965, Wrede 1992) the folds and the teverse faults such as Satanella and Sutan strike parallel to each other which implies the congruent character of their movement by steep upward shearing. A conjugate set of strike-slip faults crosses the fold architecture diagonally and resulted in ENE-WSW extension which was also effective at the NNW striking extensional faults (hatched lines). Sattel: anticline.*

Another convincing regional example of the mechanism of thrusting is the distribution of reverse faults in the sedimentary cover of the Rhenohercynian domain (Rhine Massif) and of strike-slip faults in the adjoining crystalline basement of the Saxothuringian domain of the Variscan Mountains (Central German Crystalline Rise; **Fig. 3**). The strike of both kinds of faults is identical. Apparently the upper, inclined segments of the reverse faults in the cover rocks join the vertical roots of the faults in the crystalline basement, but their dip does not continue to depth, as presupposed in the plate tectonics model of thrusting. This again confirms the conclusion that the reverse faults are derived from strike-slip faults, whose flanking blocks differed in their average density and therefore developed different buoyancy.

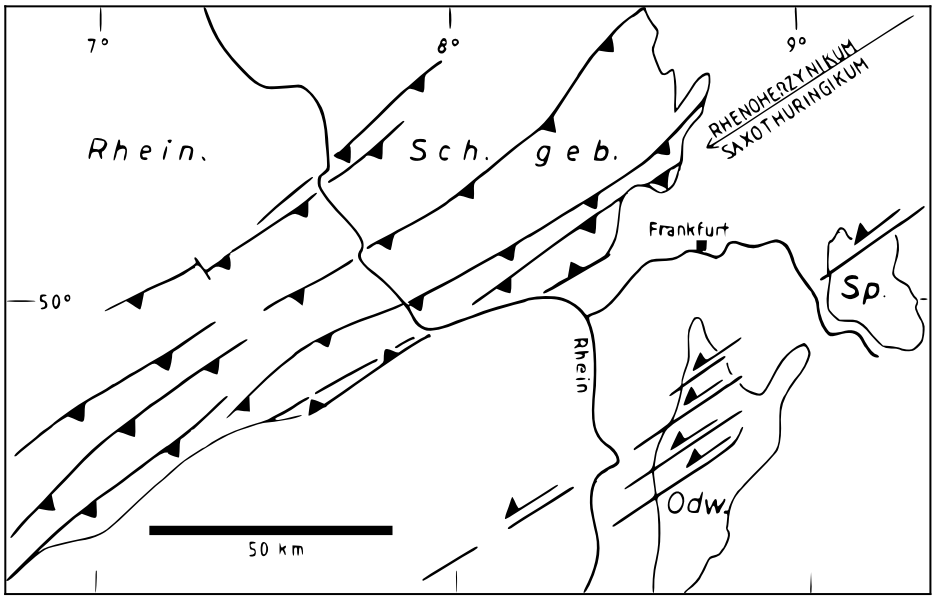


***Fig. 3**: The thrust faults in the southern Rhine Massif (Rhenohercynian) are oriented parallel to the strike-slip faults in the Central German Crystalline Rise (CGCR; Saxothuringian; after Willmer et al. 1991). This implies that thrusting within the cover rock pile of the Rhine Massif was triggered by strike-slip faults within the Variscan crystalline basement. Consequently the thrust faults within the Rhine Massif must be considered to root in the strike-slip faults of the crystalline basement. They cannot continue their dip downwards which is presupposed in plate tectonic terms. The NW vergence of the reverse faults in the Rhine Massif can be only explained by the influence of gravitation on the slope of the Variscan Mountains and thus is a feature of morphotectonics. Sp: Spessart Mts., Odw.: Odenwald Mts.*

The coming into being of a vertical strike-slip fault in an orogen often causes isostatic imbalances in that the flanking blocks may differ in their average specific weight so that the specifically lighter block will be elevated. This happens during orogenesis, i. e. during the formation of a folded mountain range by the isostatic uplift of the filling of a geosyncline. The buoyant block becomes subject of gravitational extension and develops an overhang. If the uplift of the rising block continues by further vertical offset on the strike-slip fault the overhang is truncated so that an imbricate wedge is formed. This process can be repeated several times so that more imbricate wedges are generated. The result is an imbricate thrust nappe of fan-like shape. This is clear evidence of a vertical-tectonic process whereas in the plate-tectonic concept both structures are considered to be products of compressive stress but without any physical or experimental evidence being presented. Reverse faulting is always controlled by the topographical gradient in that it is directed down-hill. This characterizes thrusting as a morphotectonic process. It is always orthogonal to the strike of the strike-slip fault triggering reverse faulting and thrusting.

The generation of a thrust nappe is demonstrated by two examples from the Variscan Mountains. The imbricate nappes of the Taunus Mountains (Taunus nappe; **Fig. 4**) and Harz Mountains (Wippra nappe; **Fig. 5**). Both nappes are located at about 300 km distance from each other in slope position of the Variscan Mountains, close to their culmination, the Central German Crystalline Rise. In both nappes the imbricate wedges show the typically increasing elevation of stratigraphic (or metamorphic) levels toward the most rearward imbricate wedge. Both thrust nappes are characterized by a vertical fault at their rear boundary. This is typical of all imbricate thrust systems, also of those of a large order of magnitude, as e. g. the Longmen Shan thrust system of China (**Fig. 6**). In this example imbricate thrusting affected the uppermost ca. 20 km of the crust. The strike-

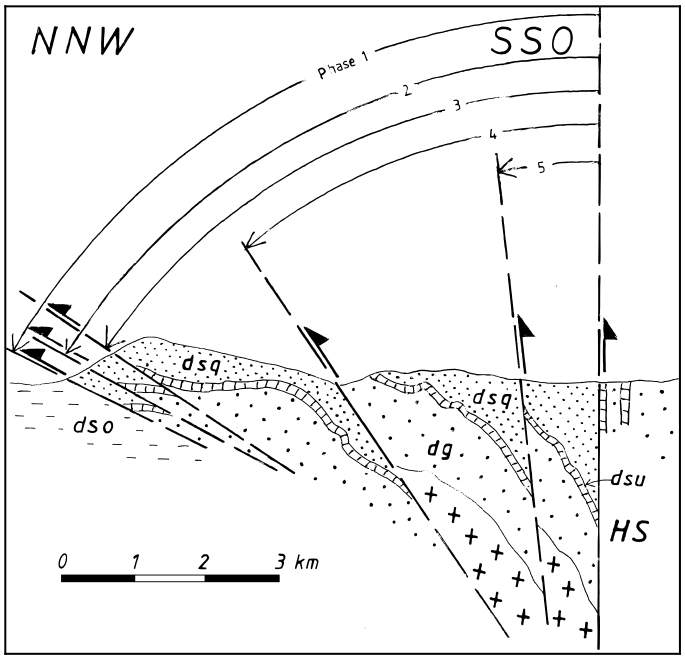


Fig. 4*: The fan-shaped Taunus structure on the right bank of the Rhine river is characterized by its triangular cross-section, the wedge-shape of its individual components, steepening of the individual thrust planes from the front to the rear, and the vertical reverse fault as the rear boundary of the thrust nappe. The basic mechanism producing this structure is explained conclusively by the uplift of consecutively deeper stratigraphic units along the vertical strike-slip and reverse fault together with gravity spreading of the unsupported upper parts of the upthrown block (IHS) during each phase of uplift. In every new phase of uplift the overhangs produced in this way were truncated by the upwards propagating vertical fault. Cross-section after Meyer & Stets (1975). dg: Gedinnean, dsu: Lower Siegenian, dsq: Middle Siegenian, dso: Upper Siegenian, crosses: Crystalline basement, HS: uplifted block.*

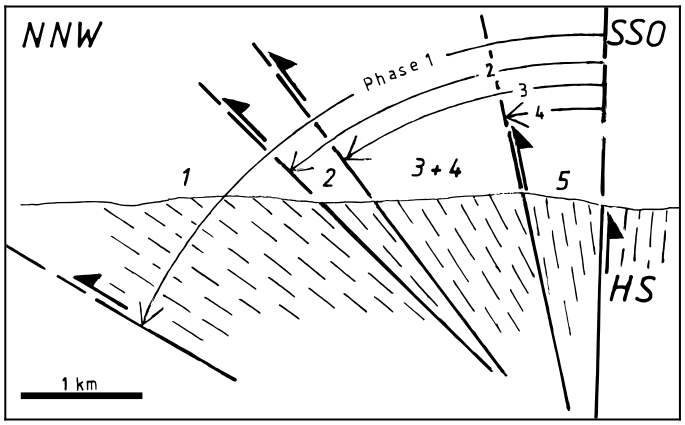


Fig. 5*: The Wippra imbricate thrust nappe (Harz Mountains; after Jacob & Franzke 1992) displays the same fan-shaped arrangement of the thrust planes as observed in the Taunus structure. The dip of the thrust planes between the imbricate wedges decreases towards the front of the nappe. This is explained here also by the consecutive truncation of the individul overhangs produced by the gavitative extension of the uplifted block (HS) due to the loss of its buttress during the various phases of uplift. The orientation of the cleavage within the imbricate wedges, too, changes from vertical in the hindmost wedges to dips shallowing towards the frontal wedge. This corroborates the inferred morphotectonic process of emplacement of the wedges. 1: Lower Caboniferous, 2: Silurian, 3 + 4: Ordovicean, HS uplifted block.*

slip fault triggering thrusting displaced the Moho discontinuity by about 20 km, and the transport width amounts to again 20 km. This confirms the generation of thrust nappes by truncation and tilting of the imbricate wedges and characterizes them as products of morphotectonics. The elevated

Tibetan block is covered by a thicker sequence of Precambrian and Paleozoic rocks than the Yangtse block so that an isostatic cause of the uplift of the Tibetan block is obvious.

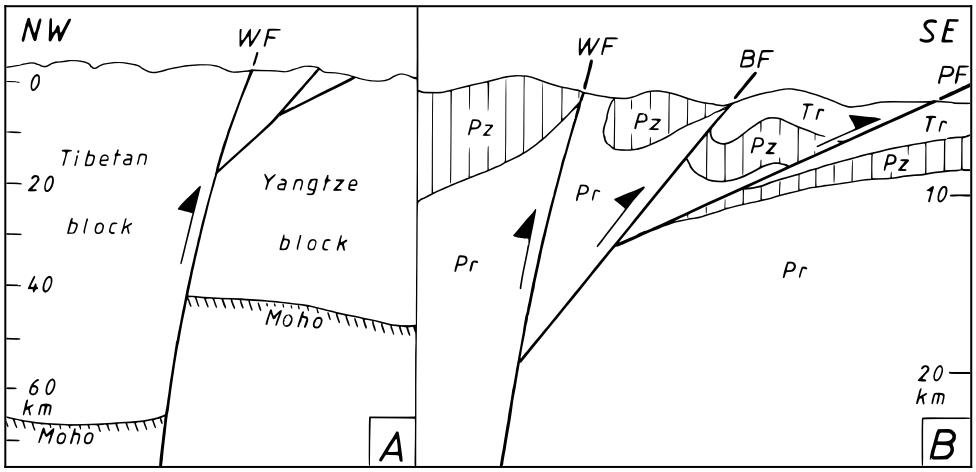


***Fig. 6**: (**A**) Cross-section of the Longmen Shan thrust system (after Robert et al. 2010) illustrating the different crustal thicknesses between the northwestern, Tibetan block and the southeastern, Yangtse block. Note that the inclined thrust planes are restricted to the uppermost 20 km of the crust which is inferred to be indicative of gravitative extension. (**B**) Cross-section of the Longmen Shan imbricate thrust system (slightly modified after Hubbard & Shaw 2009). The exposed stratigraphic units become increasingly older back from the frontal imbricate wedge. This is the consequence of the separation of imbricate wedges of increasingly deeper stratigraphic levels of the rising block and is typical of imbricate thrust systems in general. - WF: Wenchuan, BF: Beichuan, PF: Pengguan faults; Pr. Precambrian, Pz.: Paleozoic, Tr: Triassic.*

The general mechanism of thrusting is illustrated in **Fig. 7.** Thrusting is characterized as a morphotectonic process initiated by body forces, but not by far-field stresses.

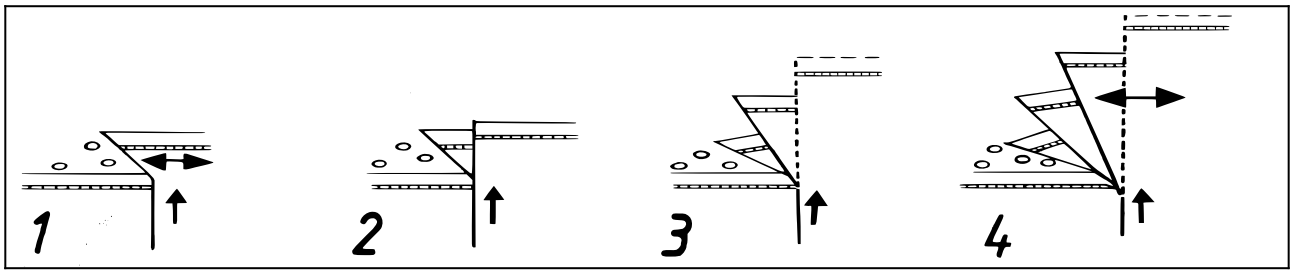


***Fig. 7**: Scheme of the thrusting mechanism - **1.** Uplift of the buoyant block flanking a vertical strike-slip-fault. By gravitative extension (horizontal double-arrow) the rising block develops an overhang thus pushing aside and and pressing down the unconsolidated sediments on the lower block. **2.** Due to further isostatic uplift of the buoyant block the vertical fault cuts through the overhang thus truncating the first imbricate wedge. **3.** Formation of another overhang. **4.** Formation of a third imbricate wedge by continued uplift and extension of the buoyant block. Folding within the imbricate wedges and erosion are not considered. The sequence of events is confirmed by the truncation of wedges at increasingly deeper stratigraphic levels with time.*

The gravity nappes of the Eastern Alps are characterized by the same spacial arrangement of their stratigaphic units as the thrust nappes. Their most rearward parts exhibit the deepest stratigraphic units at their basis (Tollmann 1973). This is explained by the exceedingly vigorous isostatic uplift during orogenesis of those parts of the geosyncline where the thickest sedimentary sequences are accumulated. Thus, there exists a high probability that the gravity nappes were formed originally by the same mechanism as thrust nappes, but, due to their extraordinarily strong uplift, were tilted exceedingly downhill and slid downward on the slope of the orogen.

The **vergence** of isoclinal folds has the same cause as that of reverse faults. Both are shown to be caused by the topography of an orogen so that they are characterized as morphotectonic features restricted to the uppermost parts of the orogen. This is documented by the fact that folds at deep crustal levels exhibit vertical axial planes (e. g. in the Tauern window, the most elevated area of the Eastern Alps) whereas the axial planes in the uppermost level of an orogen are inclined downhill. Reverse faults show the same behaviour in that they parallel the axial planes of isoclinal folds (figs. 1, 2) . Accordingly, the originator of every thrust nappe is manifested by the existence of a vertical strike-slip fault as its rear boundary. It served as the trajectory to adjust to the isostatic imbalance caused by its installation. The imbricate wedges of a thrust nappe and their thrust planes show decreasing dip angles towards the front of the thrust nappe due to the increase of burdening of the older by the younger imbricate wedges. This process is alleviated by the poor compaction of the young foreland sediments overridden by the foreland thrust nappe.

Isoclinal folding and thrusting are clearly vertical-tectonic processes caused by vertical movements and cannot be claimed to be caused by compressive stress as assumed by plate-tectonic considerations. The bivergence of reverse faults and isoclinal folds in orogens turns out not to be the result of compressive stress but to be a morphotectonic feature induced by the impact of gravitation on the two slopes of an orogen.

Thrusting and folding in the forelands of folded mountain ranges

In the forelands of orogens, the features of folds and thrusts differ, to a certain degree, from those of the interior parts of an orogen. As far as the tectonics of the forelands of folded mountain ranges is concerned, new insights have come out from thorough analysis. The outermost thrust nappe of an orogen generated during orogenesis has been formed in the foreland, e. g. of the Bavarian Alps (Germany) or the Northamerican Cordillera, and involved exclusively the foreland sediments. In both areas the foreland thrust nappe as well as the subjacent and adjoining sediments show some structural features which are different from those in the orogen. This refers to the nappe itself as well as to the material beneath and adjacent.

The Molasse nappe of Bavaria, e. g. (**Fig. 8**) is composed of the same sediments as those underlying and adjoining the nappe. It was formed in the same way as usual in orogens, but the nappe as well as the underlying and adjoining sediments underwent a peculiar kind of deformation. The nappe structure differs apparently from the normal structure observed in orogens in that frontal thrust planes between the imbricate wedges have attained a listric shape instead of the even thrust planes of nappes within orogens.

The foreland sediments underlying the foreland nappe also show some peculiar features in that they apparently were squeezed out by the weight of the advancing Molasse nappe. Subterraneous sliding or „blind“ thrusting was alleviated by the existence of a layer of clayey marl. The overridden and squeezed-out sediments thus are in a parautochthonous position. Within the Molasse nappe, however, the same even horizon responsible for sliding and underthrusting in the parautochthonous Molasse was folded. At their front the squeezed-out strata develop two different structures. The lower strata penetrated the flat-lying foreland Molasse sequence unaffected by the Alpine

orogenesis parallel to its strata Thereby the originally flat-lying sediments on top of the penetrating wedge were bent upwards.

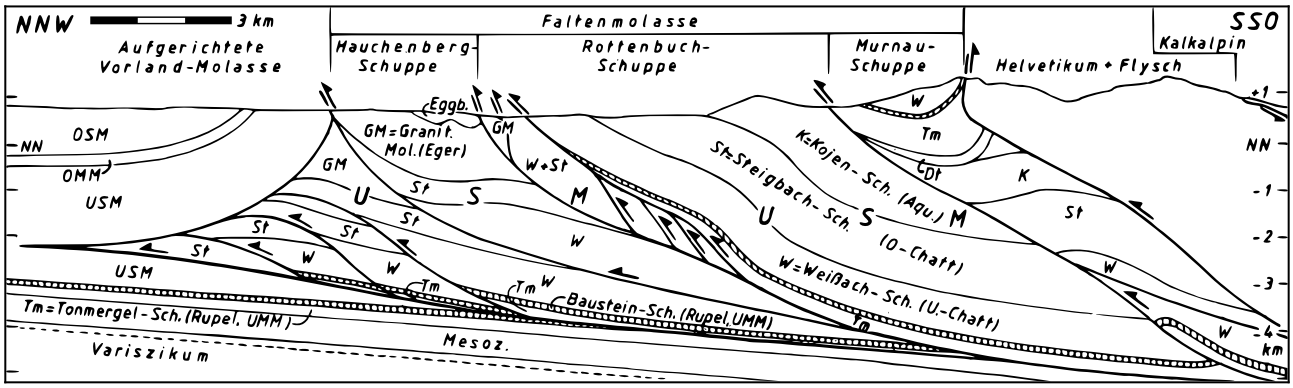


Fig. 8: *The stratigraphic level of the bases of the imbricate wedges descending towards the rear of the Molasse nappe is clearly developed in this seismological-geological cross-sectin (after Schwerd et al. 1995, fig 10, cross-section 2). The flat squeezed-out wedge penetrates the Molasse of the foreland parallel to the strata thus turning them up. Additionally, the apex pointing upwards follows the path of the least hydrostatic pressure.Thereby the front of the foreland nappe was bent upwards.*

In several cases higher members of the squeezed-out strata trended to reach the surface by advancing in direction of the least hydrostatic pressure and thus developed an apex pointing to the surface. They got jammed so that several slivers of them piled up and formed a „triangle zone“. This process forced the frontal parts of the foreland nappe to bend upwards so that the originally even, more frontal thrust planes attained a listric shape. This kind of deformation has been observed exclusively in forelands of orogens, but never in an orogen proper. It is clearly the result of squeezing-out of poorly compacted foreland sediments on a ductile layer of clayey marl under the weight of the advancing foreland nappe. The same features are also observed in the foreland of the Northamerican Cordillera.

The knowledge of the marked differences between the tectonic processes of folded mountain ranges and their forelands is of fundamental importance. Unfortunately the extraordinary tectonics of several forelands (Scottish Caledonides, Appalachians, Northamerican Cordillera) are considered by Boyer & Elliot (1982) to be characteristic of the tectonics of orogens so that these authors drew the wrong conclusion in establishing a model for the generation of thrusting in orogens proper. In fact the features typical of underhrusting by squeezing-out are met with in forelands only but never in folded mountain ranges. This misinterpretation seemed to corroborate the horizontal-tectonic concept of plate tectonics and still remains to be an integrate part of this hypothesis.

Wadati-Benioff zones

Grave objections against plate tectonics arise from the concept of lithospheric plates migrating on the Earth’s surface. The basic idea of this concept is that those hypothetically migrating plates have their origin on ocean ridges as zones of „divergence”, are floating on convection currents active within the asthenosphere and are swallowed („subducted“) in zones of convergence („subduction

zones“) thus merging into the mantle (Isacks, et al. 1968). Neutrally those zones are called Wadati-Benioff zones.

Wadati-Benioff zones are characterized by their location beneath continental crust overthrusted onto oceanic crust. They are absent in areas composed exclusively by oceanic crust. The true tectonic processes leading us to the formation of Wadati-Benioff zones are elucidated in an illustrative way by the special tectonic situation of the two Wadati-Benioff zones of New Zealand whose tectonic and geophysical properties have been investigated to a large extent. They exhibit some peculiarities which suggest a conclusive explanation of the tectonic processes effective in Wadati-Benioff zones in general. A remarkable feature of these two seismoactive zones is that their deepest segments exhibit the same strike of about 30 degrees and are furthermore located in mutual

continuation, interrupted only beneath the continental crust of South Island and the adjoining Challenger Plateau (**Fig. 9**). This fact is the clue to the understanding of their coming into being. Since we know from continental thrusting that thrust nappes have their origin in isostatic adjustment movements on the two flanks of a strike-slip fault, we can infer that this fact also holds true for Wadati-Benioff zones. It has been shown by Gurnis & Hager (1988) that a Wadati-Benioff zone is the steeper already from shallow depth downward the younger it is. In such a zone of very young age, only the uppermost segment is bent whereas the deeper segments still remain in a vertical position. Concomitantly with the advance of thrusting of the continental block onto oceanic crust, bending of the seismic zone propagates towards depth only with gradual delay until most of the seismic zone is bent. The trace of the deepest segment of the seismic zone thus can be reliably considered to indicate the original surface outcrop of the paleo-strike-slip fault of New Zealand which triggered thrusting along the two Wadati-Benioff zones. This consideration is the basis to identify the location of the paleo-fault. Thus there is no indication that the seismic zone would be the upper limit of a migrating lithospheric plate. This fallacious idea has its origin in a proposal of Hopkins (1839) which was taken over by Holmes (1944) and traditioned to Isacks et al. (1968).

The reason why the continental mass of South Island of New Zealand and the adjacent Challenger Plateau has not been involved in the initiation of a throughgoing segment connecting the two seismoactive zones is that there exists a coherent continental mass where thrusting was effective only at an intracontinental magnitude which comes out by minor thrusting on the Alpine fault. This evidences that Wadati-Benioff zones are only initiated where continental crust is juxtaposed with oceanic crust by strike-slip faulting and thus substantiates that those zones are the product of isostatic adjustment movements. Furthermore we know from continental conditions as described above that thrusting at strike-slip faults starts as soon as the buoyant block on its flank rises to adjust to the changed isostatic conditions and, due to gavitational extension, develops an overhang. Such is also clearly observed along the two Wadati-Benioff zones of New Zealand.

As clearly results from the compilation of the seismological situation presented by Anderson & Webb (1994), the reach of the bend of the Hikurangi seismic zone towards depth decreases from north to south (**Fig. 9**). This means, in agreement with the finding of Gurnis & Hager (1988) in respect to Wadati-Benioff zones in general, that the stronger bending towards depth in the north of the Hikurangi zone indicates a higher age of its installation. Further southward the age of thrusting

decreases since the bending of the seismoactive zone is reduced gradually to shallower depths. This can be ascribed to a gradual temporal progress of sequentional thrusting of continental crust onto oceanic crust concomitantly and commensurably with the dextral displacement on the strike-slip fault and can only be explained by nothing else than that the rise of the thrusted continental block was caused by its lower average density.

Along the Puysegur zone, too, thrusting is directed from the continental block onto the oceanic block, and it is observed that the downward bend of the seismoactive zone increases towards north. The Puysegur zone thus indicates the same dextral shear sense on a NNE trending strike-slip fault as the Hikurangi zone. This implies that the deepest segments of both seismic zones represent the traces of parts of an ancient fault whose coming into being triggered isostatic movements. This finding is substantiated by the fact that the deep trace of this paleo-fault has its immediate and rectilinear continuation in the dextral Puysegur fault (**Fig. 9**) south of South Island. This fault is surely a remnant segment of the paleo-fault which was not integrated into the Puysegur Wadati-Benioff zone. It escaped thrusting because it crosses exclusively oceanic crust so that no isostatic adjustment was required. This is the first time that the former existence of an ancient fault has been detected and identified as a precursor of the Alpine fault. It becomes apparent that the paleo-fault triggered thrusting when it juxtaposed continental crust with oceanic crust sequentionally in the course of its dextral displacement. The initiation of the two seismic zones of New Zealand thus is clearly a product of isostatic adjustment and cannot be claimed to be the site of a downgoing lithospheric plate. The Alpine fault (e. g. Berryman 1979) as well as the older paleo-fault have been very probably generated by the exposure to WNW-ESE compressive stress acting parallel to the topographic gradient on the slope of the Pacific Basin. This is in agreement with the observation that the slopes of orogens (e. g. Pyrenees, Jura Mts., Northern and Southern Calcareous Alps, Carpathians, Rocky Mts.) are deformed by strike-slip faults caused by compressive stress parallel to the topographic gradient and thus can be best explained by the effect of gravity on the western slope of the Pacific Basin. The total displacement of the paleo-fault amounts to approximately 500 km. A strike-slip fault conjugate with the paleo-fault has not yet been localised but its existence cannot be excluded.

The unique example of New Zealand tectonics is a clear proof that Wadati-Benioff zones are nothing else but zones of isostatic adjustment between blocks of continental and oceanic crust flanking a strike-slip fault. The non-existence of „subduction“ is furthermore corroborated by the general lack of a seismic zone beneath the postulated downgoing lithospheric plate, i. e. the zone of high Q or zone of low attenuation of seismic waves (Q = reciproke value of the specific attenuation factor). Instead, in the Wadati-Benioff zones of New Zealand and a number of other zones we observe a more or less gradual transition of material properties from the area beneath the seismic zone towards “normal“ mantle as indicated by the Vp/Vs-distribution (Reyners et al. 2006; **Fig. 10)**.

The isostatic solution of the problem of initiation of Wadati-Benioff zones becomes apparent by the fact that those zones are met with only in oceanic areas where fragments of continental crust exist. They nowhere developed in areas composed exclusively of oceanic crust such as the Atlantic Ocean which are devoid of continental crust so that no isostatic adjustments are required.

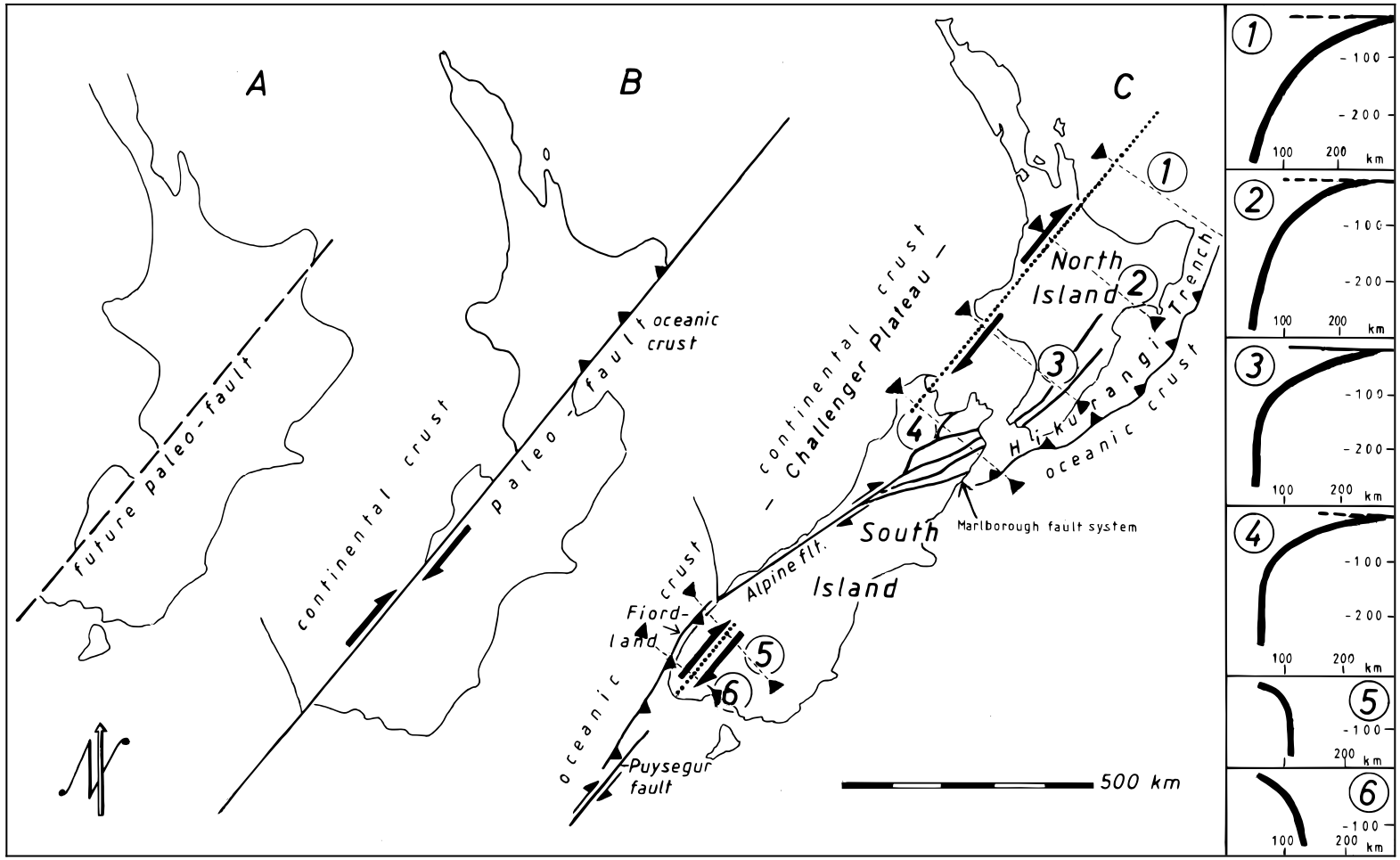


***Fig. 9**: **A**: Ancient New Zealand (pre-Miocene, paleogeographic reconstruction from Steven & Suggate (1978), **B**: Intermediate stage; **C**: Present New Zealand. The history of the two Wadati-Benioff zones of New Zealand points to their generation at the site of a strike-slip fault, along which continental crust was juxtaposed with oceanic crust. Both seismic zones steepen towards depth, and the trace of their deepest segments forms a straight line (stippled line in C) indicating the location of the ancient strike-slip fault. It is interrupted on South Island only. The bend of the the Hikurangi zone (insets **1-4** ; after Anderson & Webb 1994) sets in towards the south at increasingly shallower depth, and at the Puysegur zone (Fiordland; insets **5-6** ; after Reyners et al. 2002) in contrast towards north. This implies in both cases the decreasing age of thrusting commensurably with right-latereal displacement by roughly 500 km along the ancient strike-slip fault which thus can be identified as having triggered thrusting. Like at continental strike-slip faults, the buoyant (here continental) block was thrust upon the opposing (here oceanic) block. The bulk of South Island is excepted from the initiation of a Wadati-Benioff zone, because the ancient fault did not juxtapose continental with oceanic crust. The Alpine fault is apparently younger than the paleo-fault and came into being as a reaction to the initiation of the two Wadati-Benioff zones. The compressive directions responsible for the generation of both strike-slip faults differ only insignificantly and are considered to be caused by the topographic gradient on the western slope of the Pacific Basin. Note the considerable amount of southeastward migration of North Island after its complete separation from South Island. This is most probably due to major gravity sliding on the subhorizontal seismoactive plane below North Island (as documented by Anderson & Webb 1994), and only to a minor extent by thrusting (see text) .*

This is confirmed by the fact that andesitic magmatism is restricted to Wadati-Benioff zones, i. e. oceanic areas containing inliers of continental crust. Those highly explosive, overheated mingled magmas are not produced in oceanic areas devoid of continental crust.

As is apparent, the amount of thrusting in the Wadati-Benioff zones of New Zealand is restricted to a certain measure. In the special case of North Island, the amount of transport by about 300 km distance from the deep trace of the paleo-fault clearly exceeds the amount of thusting to be expected. The explanation is most probably given by the existence of a subhorizontal seismic zone beneath North Island at about 35 km depth (Anderson & Webb 1994) which joins the frontal end of the Hikurangi seismic zone (Fig. 8). The excessive amount of transport can be, in high probability, attributed to a mechanism acting additionally to thrusting which the author ascribes to a sliding process being active on the western slope of the Pacific Basin which continues the sliding of the whole of ancient New Zealand after separation from Australia.

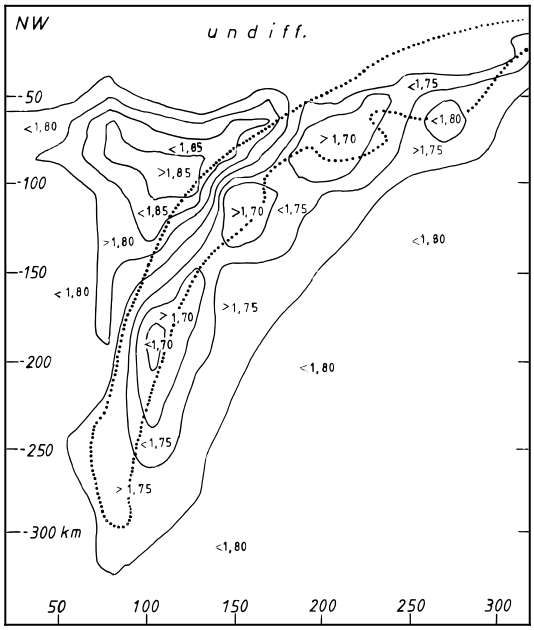


Fig. 10 *: The 3-D Vp/Vs distribution in a cross-section through the central Hikurangi high-Q zone (after Reyners et al. 2006) evidences that, between the seismoactive reverse fault and normal mantle, a gradual transition from higher to lower values of depletion in partial melts s developed.. In consequence of this and due to the lack of a seismoactive zone below the high-Q zone, there is no indication of a downgoing lithospheric plate. Within the mantle wedge above the seismoactive zone, the Vp/Vs values increase due to the increasing accumulation of ascending melts. Dotted line: area of localized earthquake hypocentres.*

Initiation of Wadati-Benioff zones is apparently controlled by the same mechanism as is documented for thrust faulting in continental orogens. Thus in the Bavarian Molasse thrust nappe, Schwerdt (1996) reports sinistral displacement between the ENE striking imbricate wedges which means that horizontal displacement indicates continuous movement along the strike-slip fault during the whole process of multiple thrusting. Thrusting is the result of secondary vertical isostatic movement on a strike-slip fault and gravitational spreading of the raised block. In the same way, along a number of Wadati-Benioff zones thrusting has been observed simultaneously with horizontal displacement. This caused Fitch (1972) to draft a speculative model of „oblique convergence“ in order to explain this seemingly simultaneous coincidence of two manners of seismically indicated movement. He attributes the mechanism of Wadati-Benioff zones (zones of “plate consumption”) to a process of decoupling in which only the component of slip normal to the plate margin is considered to be represented by underthrusting whereas at least a fraction of slip

parallel to the plate margin results in transcurrent movements. This model of two simultaneous movements caused exclusively by compressive stress has never been substantiated by experiments. Instead it is now shown that there are two different kinds of movement being active simultaneously. The newly inferred mechanism corroborates that Wadati-Benioff zones are triggered by a vertical strike-slip fault causing the specifically lighter continental block to rise. This results in gravitational extension of the raised block and leads to its thrusting onto the opposite lower oceanic block. Just as in the orogens, thrusting in the realm at the contact of oceanic and continental crust is clearly a morphotectonic process, too.

Conclusions

The spherical shape of the Earth is obviously caused by gravitation. This force is responsible for isostatic movements which result in the generation of isoclinal folds and reverse/thrust faults during an orogenesis. Gravitation also causes morphotectonic features such as vergences and conjugate strike-slip faults in slope position of orogens. The centrifugal force is not only responsible for the flattening of the polar regions, but also for the installation of sets of conjugate strike-slip faults indicating north-south directed compressive stress in Eurasia, North America an probably in further eregions. This force has been entirely neglected in the plate-tectonic considerations.

For the activity of a force effectuating the migration of lithospheric plates no evidence can be substantiated. There is not the least proof or indication of the activity of convection currents in the asthenosphere. Wadati-Benioff zones cannot be the site of a downgoing lithospheric plate migrating on the Earth’s surface due to a number of circumstances:

- There is no proof of zones of „divergence“, i. e. mid-oceanic ridges, from where continental blocks could originate. Those zones are, with high probalility, of a different origin. Remnants which could prove the former existence of continental blocks in zones of “divergence” are entirely missing;
- There is no evidence of a downgoing plate in a zone of “convergence” (Wadati-Benioff zone). This would require a second seismic zone at the bottom of the hypothetical plate. Instead there is, at least in some better investigated cases, a gradual transition of the material properties from the high-Q zone down to the „normal“ mantle; Wadati-Benioff zones are entirely local phenomena and cannot be attributed to imaginary global migrations of lithospheric plates on top of imaginary convection currents;
- There is no conclusive explanation of a force being capable to press a plate of 80-100 km thickness down into the mantle;
- There is no explanation of the fact that Wadati-Benioff zones are not developed in areas exclusively composed of oceanic crust such as the Atlantic Ocean or the bed rocks of the Puysegur fault of New Zealand. The simple reason is that, **in oceanic areas devoid of continental crust, no isostatic adjustments are required.** This is supported by the fact that andesitic magmatism is restricted to oceanic areas containing inliers of continental crust, as is the case in Wadati-Benioff zones.

The concept that horizontally directed compressive stress would produce folding and thrusting is not confirmed by the genesis of these structures. Both are clearly related to each other. This is frequently evidenced by their close spacial association with each other in that the younger thrust faults are oriented parallel to the axial planes of older shear folds. The vergences of both structures are the result of gravitative extension at the Earth's surface during the orogenic uplift. This is also demonstrated by the fact that the roots of thrust faults and the axial planes of shear folds turn to attain a vertical attitude towards depth. Thus the vergences are clearly characterized as morphotectonic features, and a plate-tectonically postulated origin by horizontal compressive stress can be entirely excluded.

At a closer view it becomes apparent that plate tectonics is based only on wholesale assumptions but has not been capable to present concrete examples of the validity of assertions concerning the coming into being of structures such as folds, reverse and thrust faults, or Wadati-Benioff zones. That concept turns out to be just a rough sketch of immature ideas lacking a relation to the physical reality.

The findings of the author are in no way reconcilable with plate tectonics. The analyses presented above reveal that thrusting in orogens as well as in Wadati-Benioff zones is an exclusively gravitational, isostatically induced process being triggered by the activity of a strike-slip fault. Plates of lithosphere migrating on the Earth's surface are nothing but a pure illusion. In the foregoing it has been shown that the adventurous concept of plate migrations has the disastrous consequence that the complete tectonic fundament has been turned upside down. By accepting the plate tectonic hypothesis, a number of physical laws and geological facts has been heavily violated. However, this hypothesis has been generally accepted and celebrated as the final solution of the geotectonic problems. From the final conclusion of the author's analyses it turns out that geodynamics is not dominated by horizontal but by vertical tectonics.

There is no doubt that the conclusions drawn from the tectonic facts are realistic and easily verifyable. They do not exhibit any discrepancies and are consistent with each other. The findings presented above reveal that a fundamental paradigm change is needed in order to bring about a really scientific solution of the questions of global tectonics. This includes a turn away from the mobilistic concept and towards a stationary model which complies with the real observations and the physical laws.

This and much more in: Die globale Tektonik – neu analysiert (Global tectonics – newly analysed), with 61 figures (explanations also in English) and a synopsis in English.

Literature

Anderson, H. & T. Webb: New Zealand seismicity: patterns revealed by the upgraded National Seismograph Network – N. Z. J. Geol. Geophys., 37, 477-493, 1994

Berryman, K.: Active faulting and derived PHS directions in the South Island, New Zealand – In: R. I. Walcott & M. M. Cresswell (Eds.): The origin of the Southern Alps, Bull. 18, The Royal Society of New Zealand, Wellington, 29-34, 1979

Boyer, S. E. & D. Elliot: Thrust systems – Am. Ass. Petr. Geol. Bull., 66, 9, 1196-1230, 1982

Denckmann & Quiring: Erläuterungen zur Geol. Kte. Preussen Nr. 2979, Blatt Siegen, 81 pp., 1931

Fitch, T. J.: Plate convergence, transcurrent faults, and internal deformation adjacent to Southeast Asia and the western Pacific – J. Geophys. Res., 77, 23, 4432-4460, 1972

Gurnis, M. & B. H. Hager: Controls of the structure of subducted slabs – Nature, 335, 3217-321, 1988

Hubbard, J. & J. H. Shaw: Uplift of the Longmen Shan and Tibetan plateau and the Wenchuan eartthquake – Nature, 458, 194-196, 2009

Isacks, B., J. Oliver & L. R. Sykes: Seismology and the new global tectonics – J. Geophys. Res., 73, 18, 5855-5899, 1968

Jacob, G. & H. J. Franzke: Die tektonische Entwicklung der Wippraer zone im Unterharz – Zbl. Geol. Paläont. part I, 1-2, 51-61, 1992

Meyer, W. & J. Stets: Das Rheinprofil zwischen Bonn und Bingen – Z. dt. geol. Ges., 126, 15-29, 1975

Pilger, A.: Beziehungen der kleintektonischen zu den großtektonischen Formen im Ruhrkarbon – Clausthaler geologische Abhandlungen, 1, 129-167,1965

Reyners, M., R. Robinson, A. Pancha & P. McGinty: Stresses and strains in a twisted subduction zone – Fiordland, New Zealand – Geophys. J. Int., 148, 637-648, 2002

Reyners M., D. Eberhart-Phillips, G. Stuart & Y. Nishimura: Imaging subduction from trench to 300 km depth beneath the central North Island, with Vp and Vp/Vs – Geophys. J. Int., 165, 1373-1388, 2006

Robert, A., M.Pubellier, J. de Sigoyer, J. Vergne, A. Lahfid, R. Cattin, N. Findling & J. Zhu: Structural and thermal characters of the Longmen Shan (Sichuan, China) – Tectonophys., 491,165-173, 2010

Schwerd, K.: Alpen – In: Freudenberger & Schwerd, Bayer. Geol. Landesamt: Erläuterungen zur Geologischen Karte von Bayern 1:500,000, 266-269, 1996

Schwerd, K., K. Huber & M. Müller: Tektonik und regionale Geologie der Gesteine in der Tiefbohrung Hindelang 1 (Allgäuer Alpen) – Geologica Bavarica, 100, 75-115, 1995

Steiner, L.: Die globaleTektonik – neu analysiert, 2nd ed., 201 pp., 2024

Stevens, G. R. & P. R. : Suggate: Atlas of paleogeographic maps – In: P. R. Suggate, M. T. Te Punga & G. R. Stevens: The Geology of New Zealand, Wellington, Government Printer, 197-210, 1978

Tollmann, A.: Grundprinzipien der alpinen Deckentektonik – 404 pp., Vienna (F. Deuticke) 1973

Willner, A. P., H.-J. Massonne & A. Krohe: Tectono-thermal evolution of a part of a Variscan magmatic arc: the Odenwald in the mid-German crystalline rise – Geol. Rdsch., 80, 2, 1991

Wrede, V.: Störungstektonik im Ruhrkarbon – Z. angew. Geol., 28, 2, 94-104, 1992