limbs made of Triassic and Jurassic terrigenous rocks. Drilling revealed Riphean–Lower Paleozoic carbonate rock units and Carboniferous–Permian terrigenous rocks at depth. The anticlines are concentric rootless folds which originate when a detachment is present at their base. Southward the deposits lie subhorizontally indicating that detachment dies out in this direction to zero in the area of southern bends of marginal monoclines where a tip-line occurs. Detachment is either traced along the crystalline basement surface where it dies out or rises to upper stratigraphic horizons and the line on which the displacement is lost is at the boundary between the Riphean–Early Paleozoic carbonate rocks and Late Paleozoic terrigenous rocks units. The Kharaulakh branch has a similar structure and is characterized by a deeper erosion level. Here, Riphean and Cambrian carbonate deposits are exposed at the surface in the cores off the Bulkur and Chekurovka anticlines, and detachment, which firstly follows the surface of the crystalline basement, then rises to upper levels dying out in the tip-line, also at the boundary of the carbonate and terrigenous rock complexes. To the south of the Kharaulakh branch there are thrusts with a vergency opposite to tectonic transport, which compensates the horizontal movement in the wedge-type structures (passive-roof duplexes) or triangle zones. Thus, the Lena–Anabar and Kharaulakh branches combine II-and IV-type: buried thrust fronts or structures with a tip-line. The more southerly North Orulgan branch is a strongly emergent thrust front belonging to type I. Large horizontal displacement (up to a few tens of kilometers) is established along the Uel–Siktyakh and Orulgan thrusts in the front area. The Uel–Siktyakh nappe is comprised of Middle–Late Carboniferous–Early Permian rock units overlying Cretaceous sediments of the Priverkhoyansk foredeep. The South Orulgan branch is characterized by a frontal monocline of Triassic-Cretaceous rocks disturbed by small thrusts. In the central part of branch, the main displacements occurred along the more westerly Sobolokh–Mayan thrust the tip-line of which was higher than the present-day erosion level. In the northern and southern limbs, the tip-line is not exposed on the surface, detachment is restricted to pelite horizons at the base of the Triassic. According to calculations, the point where displacement on the detachment was lost is 50 km to the west of the frontal monocline. Thus, the South Orulgan branch belongs to IV-type buried thrust fronts: frontal monoclines and structures with a tip-line. In the central part of the Kitchan branch there are exposed fold-thrusts for which positions of tip-lines were previously calculated. It was established that the formation of frontal thrusts here was accompanied by synsedimentary growing folds. To the north and south of the branch there are blind fold-thrusts overlain by Late Jurassic and Cretaceous rocks. The Kitchan branch refers to III-type – weakly emergent thrust fronts (after Morley) and to buried thrusts (after Vann et al.). The Baraya branch is characterized by back thrusts in the hinterland of the frontal monocline which are roof thrusts in the passive-roof duplex. The formation of the front here was accompanied by accumulation of a thick series of Cenozoic deposits in the Lower Aldan basin sealing the early low-angle thrusts. Detachment seems to disappear in Permian clayey horizons. Compensation for shortening is also due to imbricated fan developed ahead of the passive-roof duplex. The Baraya branch combines II- and III- type thrust fronts: buried and weakly emergent. The Kyllakh branch is a typical example of a strongly emergent thrust front (I-type) represented by a margin of the allochthonous sheet with the horizontal displacement up to 90 km. Detachment is restricted to the bottom of the Lower Riphean.

Growth of experimental viscous orogenic wedges

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We have investigated the effects of convergence rate variations and backstop geometry on the evolution of thick-skinned orogenic wedges. We use the temperature-dependent variations in viscosity of commercial 52/54 EN type paraffin as analogue to the natural strength distribution in the continental crust. The crust is treated as a material with a Newtonian viscosity varying with depth (temperature). Experiments are performed in a thermomechanical shortening box, where a 3 °C vertical temperature difference (from 37 to 40 °C) in the paraffin models is attained. In our experimental configuration a velocity discontinuity is imposed at the subduction slot, where the base plate is pulled below a rigid backstop. The mobile base plate dips 5°. Three different backstop dips are used, 90°, 60° and 30° (measured clockwise from the base plate), for constant convergence rates of 10^{-5} and $5x10^{-5}$ s^{-1}. The length, stress, and time scale factors are $6x10^5$, $2x10^6$ and $3x10^{10}$, respectively. Model results show that: (i) fast convergence rates produce steep surface tapers and narrow deformed areas; (ii) low convergence rates produce lower taper topographies and wider deformed areas during self-similar growth; and (iii) a decrease in the backstop dip angle corresponds to a widening of the deformed areas, with two deforming regions facing in opposite directions. In doubly vergent models, the stable tapers are a function both of backstop configuration and imposed convergence rate. Slow convergence rates and shallow-dipping backstops produce shallow-dipping surface slopes for both the retrowedge and prowedge.

The Variscan orogeny in Central Europe: strength evolution of the orogen through time

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We discuss the evolution of the Variscan orogeny as an equivalent of the Tibetan system in terms of a visco-elastic type of deformation of continents using the concept of a thin-viscous sheet deformation in front of an indenter. This is discussed using structural, metamorphic, geochronological and geochemical data combined with thermo-mechanical modeling.

The first stage is marked by Silurian to early Devonian subduction of oceanic lithosphere in front of a Saxothuringian/Armorican continent (SA) below an easterly peri-Gondwana (PG) derived continent. Back-arc Palaeozoic basins developed on Upper-Proterozoic (PG) foreland crust associated with abundant calc-alkaline volcanism. Early Devonian continental underthrusting, with obduction of blueschists and eclogites over the Armorican domain is connected with pure-shear ductile to brittle–ductile shortening and moderate thickening of the foreland, development of Barrovian metamorphism and inversion of the back-arc Palaeozoic basin.

The continuous underthrusting of SA lithosphere below the sub-continental mantle wedge generates a calc-alkaline to shoshonitic Andean-type magmatic belt of early Carboniferous age which is emplaced into a compressional regime about 100–150 km distant from the SA–PG suture zone. Thickening of the orogenic root in front of the subducting SA continent reached 60 to 70 km, leading to development of HP granulites, HT eclogites and to metamorphism of sub-crustal mantle due to intense thermal weakening during thickening.

Final deformation of the orogenic root system is due to its distinct nature with respect to the rest of stable continental lithosphere, which acted as a rigid indenter that compressed the weak orogenic root. Lateral compression led to the development of vertical high-grade fabrics and to vertical extrusion of rocks. The system collapsed gravitationally at the conditions of mid-pressure granulite facies, where a flat high-grade fabric developed due to sideways sub-horizontal flow. At the margin of the eastern continent an inverted typical Barovian metamorphism developed due to overthrusting of the hot orogenic root.

The early obductional period of orogeny is a strong one, and is related to the transmission of stress over large distance, deformation of the foreland and widening of the deformed zone. It is not excluded that at this period an Andean type orogenic root formed. The second period is not related to the important horizontal stress transfer, but rather the stress is consumed by building of a deep orogenic root. This is also the period of maximum topography change, which is reflected by clastic sedimentation first of low-grade rocks then of deep high-grade gneisses and granulites in the Lower–Culmian foreland basin. The collapsed root is finally extruded over the Culmian deposits in the form of a second generation of crustal nappes.