The foreland of the Verkhoyansk fold-and-thrust belt (Russian North-East): evolution and tectonic structure

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The belt stretches longitudinally for about 2000 km along the eastern Siberian platform boundary and is made of a thick (up to 15 km) wedge of deformed clastic rocks of Carboniferous, Permian, Triassic, and Jurassic ages representing typical accumulations of a passive continental margin. These are shelf and deltaic sediments which, on and near the platform, are replaced by deposits of the coastal accumulation plain wedging out to the west, and prograde into deep-water black shales and turbidites of the continental slope and its rise to the east. The formation of the Verkhoyansk passive margin is related to Devonian rifting. In the southern sector of the belt there are thick clastic and carbonate shelf rock sequences of Early to Middle Paleozoic and Later pre-Cambrian age. The sequences show the same changes in composition and thickness away from the platform edge as the Late Paleozoic and Mesozoic deposits do. One can assume that Devonian rifting merely modified the passive continental margin (carbonate platform) which had existed here since the Early Vendian. The formation of the continental margin related to the detachment of Siberia from another large continental block, probably North America, likely occured in the Late Riphean–Early Vendian due to the preceding Riphean rifting.

The belt is subdivided into a number of segments, each with its own geometry of thrust systems. Balanced cross-sections for each segment based on the structural study of a surface geology and availbale gravity, seismic and drilling data are presented. It seems possible that large anticlinoria of the central and nothern Verkhoyansk belt have a duplex structure. The structure of the southern Verkhoyansk belt is defined by the Kyllakh thrust with a horizontal displacement of up to 90 km. The frontal thrusts to the west of the belt were initiated during sedimentation as early as in Late Jurassic time.

This period marks the beginning of the collision between the Siberian continent and the Kolyma–Omolon superterrane located 500 km to the east of the Verkhoyansk front and the accretion of the Okhotsk terrane to the southern Verkhoyansk belt. The deformation ended by the late Late Cretaceous. The frontal thrust structures formed in Late Cretaceous time were rejuvenated during the Middle to Late Pleistocene reactivation which produced the modern high mountain topography. The general configuration of the Verkhoyansk foldbelt and its frontal structures is defined by the geometry of the Devonian rift-related structures on the eastern platform margin under the conditions of general compression in latitudinal direction in Late Cretaceous time.

Types of fronts of the Verkhoyansk fold-and-thrust belt

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The Verkhoyansk fold-and-thrust belt extends along the eastern margin of the Siberian platform and belongs to the external zone of the Verkhoyansk-Chersky collisional orogenic belt. The belt is subdivided into the West Verkhoyansk and South Verkhoyansk sectors. Within the West Verkhoyansk sector three zones are distinguished: frontal, middle, and inner. The frontal zone mainly includes fold-thrusts. The middle zone has a passive roof duplex. Main detachment in these zones is traced at the base of the Late Paleozoic–Mesozoic clastic complex. The inner zone represents a blind autochthonous roof duplex of the Late Precambrian–Middle Paleozoic carbonate complex and imbricate fans and pop-up structures in the clastic complex. The structure of the South Verkhoyansk sector is defined by the high-amplitude Kyllakh thrust and an allochthonous roof duplex in its central part. We used two classifications of thrust fronts, one of I. Vann et al. (1988) and the other of C. Morley (1986), which complement each other. The front of the Verkhoyansk fold-and-thrust belt is divided into a number of branches which, in some cases, coincide with western terminations of previously established segments. The northern Lena–Anabar branch includes frontal monocline and anticlines with steeper southern 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