Tectonic evolution of the northern Verkhoyansk Fold-and-Thrust Belt: insights from palaeostress analysis and U-Pb calcite dating

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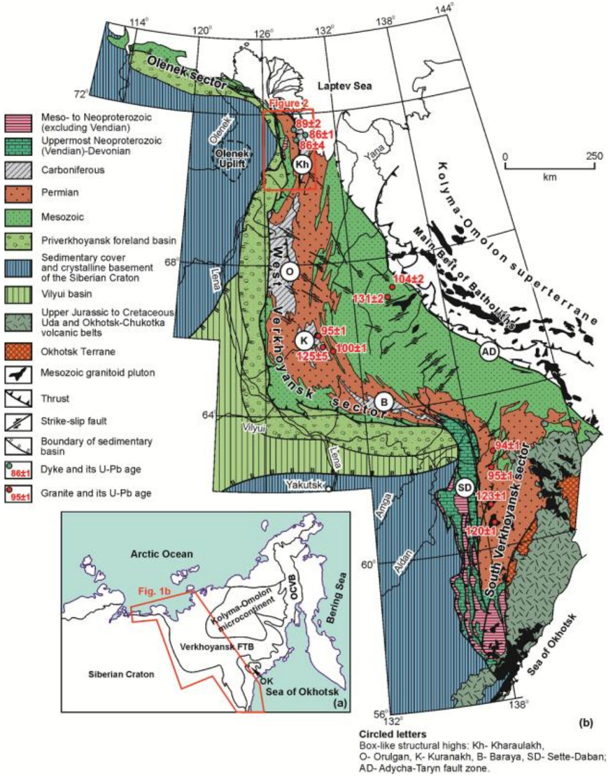
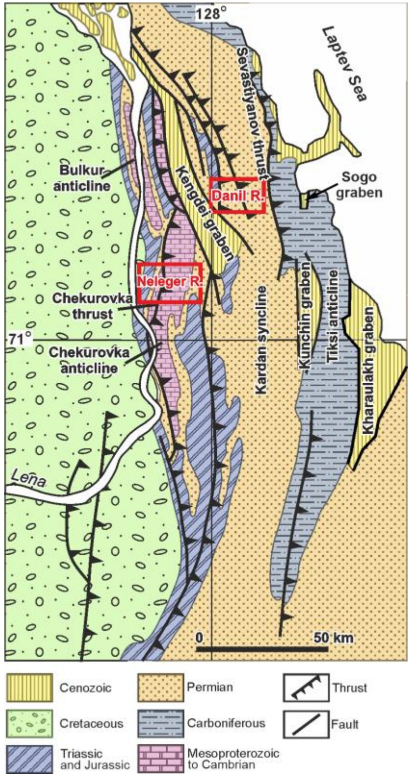
Verkhoyansk Fold-and-Thrust Belt



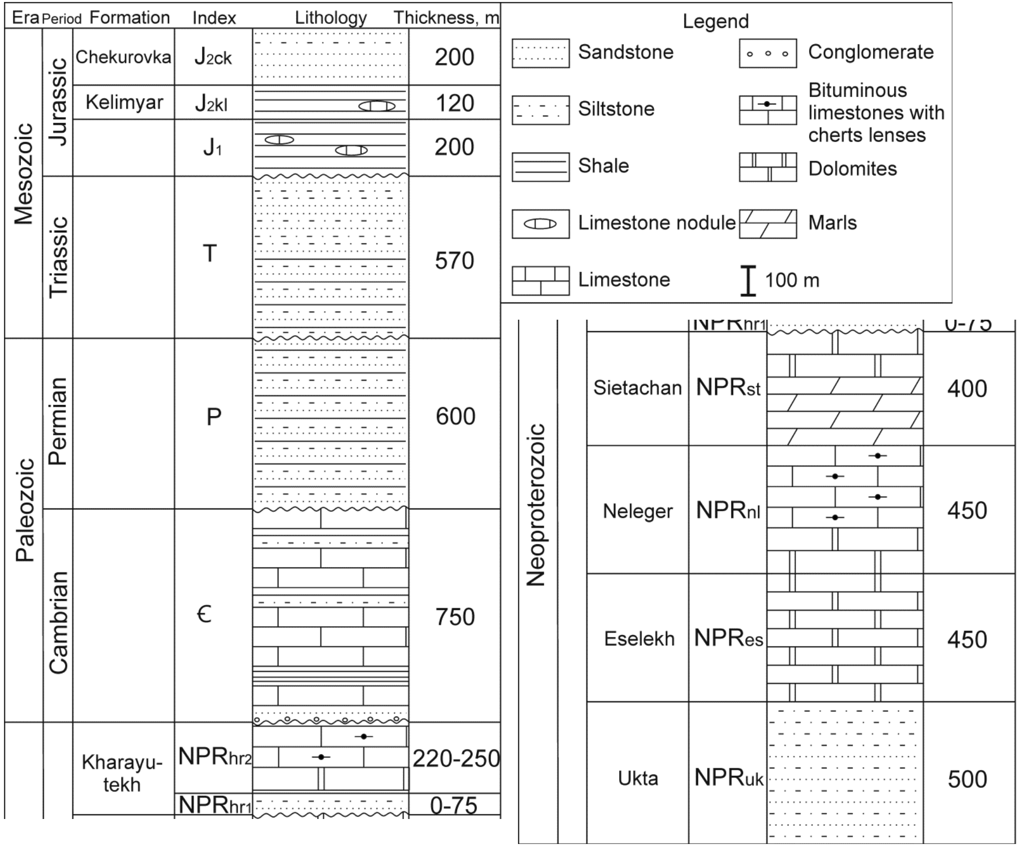
(a) Northeast Asia. OK – Okhotsk terrane, OCVB – Okhotsk-Chukotka Volcanic Belt. (b) Geological map of the Verkhoyansk Fold-and-Thrust Belt (after Prokopiev & Deikunenko, 2001, modified). Age of intrusions after Prokopiev et al. (2009, 2013, 2018), Gertseva et al. (2016), Shishkin et al. (2017).

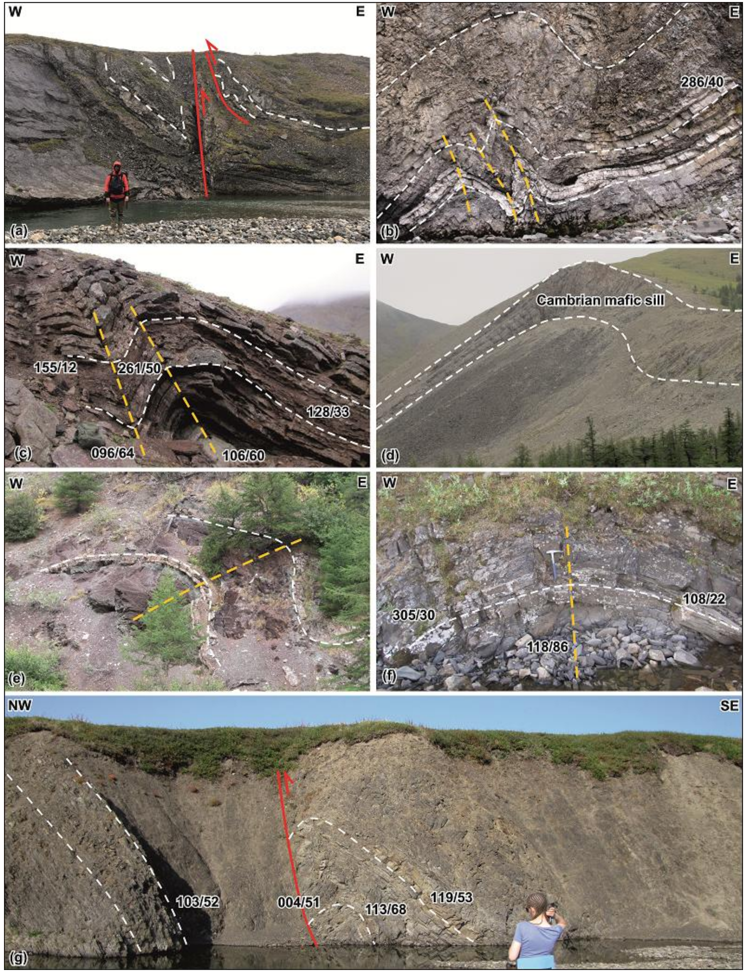
- Fieldwork in the basins of the Danil and Neleger rivers in the central and western parts of the northern Verkhoyansk FTB.
- Structural study: statistics on bedding, orientation of hinges and axial planes of folds, and slickensides.
- Paleostress reconstruction using the multiple inversion method (Yamaji, 2000).
- Geochronological study: U-Pb dating of calcite samples from slickensides to determine the age of faults activity.
- U-Pb dating of calcite was carried out by LA-ICP-MS at ETH Zurich and supported by the *Leading House for Swiss Science and Technology Cooperation with Russia and the CIS Region* grant.



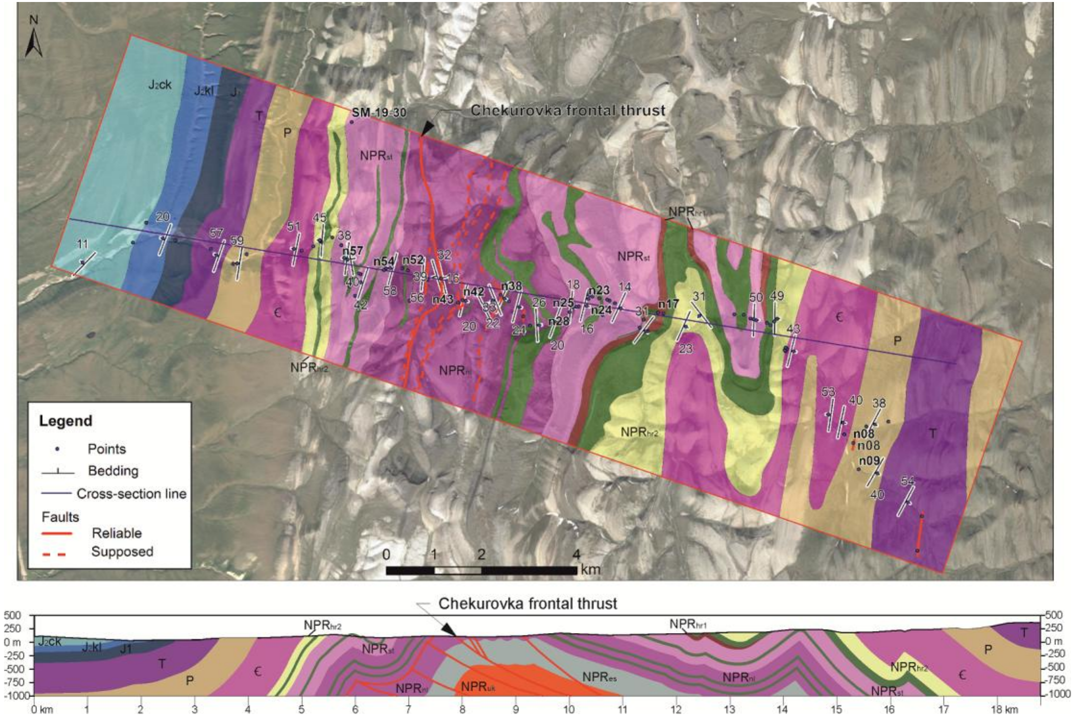
Geological map of the Kharaulakh segment (after Prokopiev et al., 1999; Prokopiev & Deikunenko, 2001; Imaev et al., 2018; Gonchar, 1998).

Neleger River area

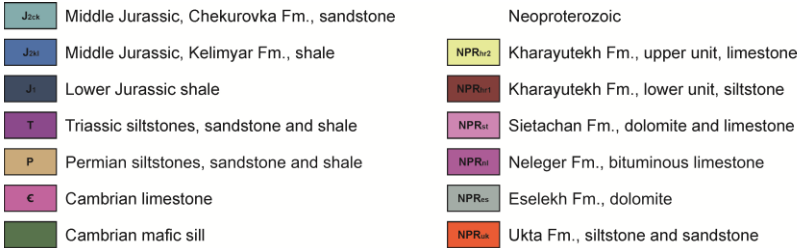


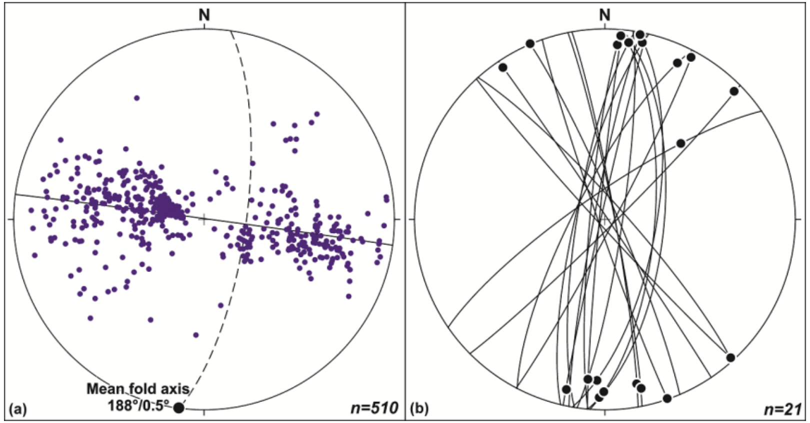


Structural study of the Neleger River area



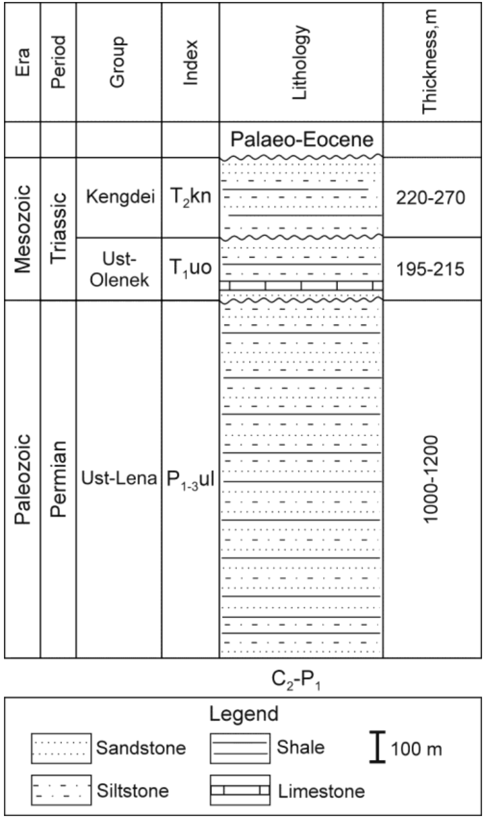
Geological map and cross-section of the Neleger River area. Satellite image from google.com/maps

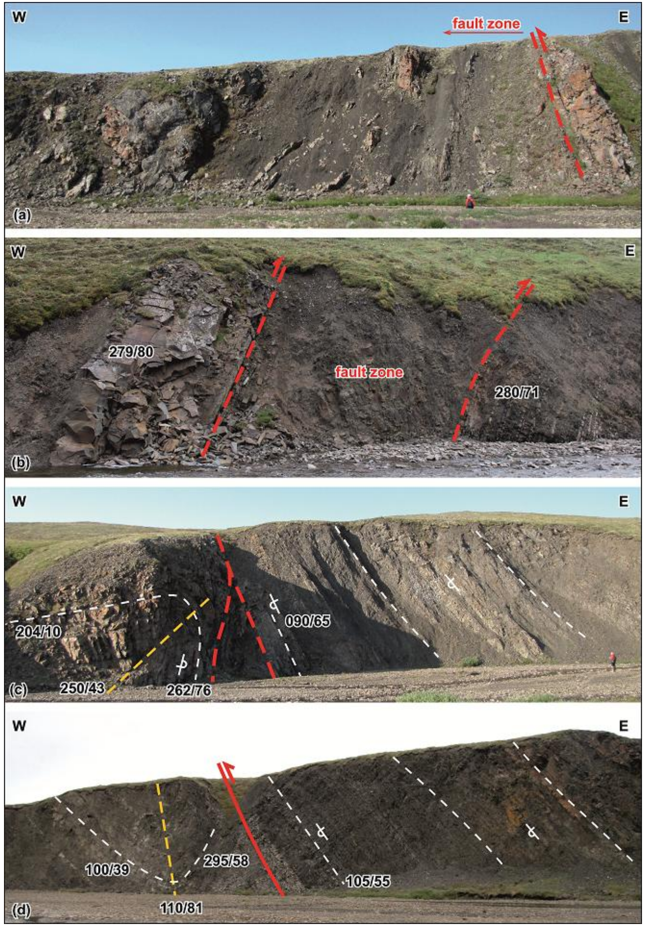


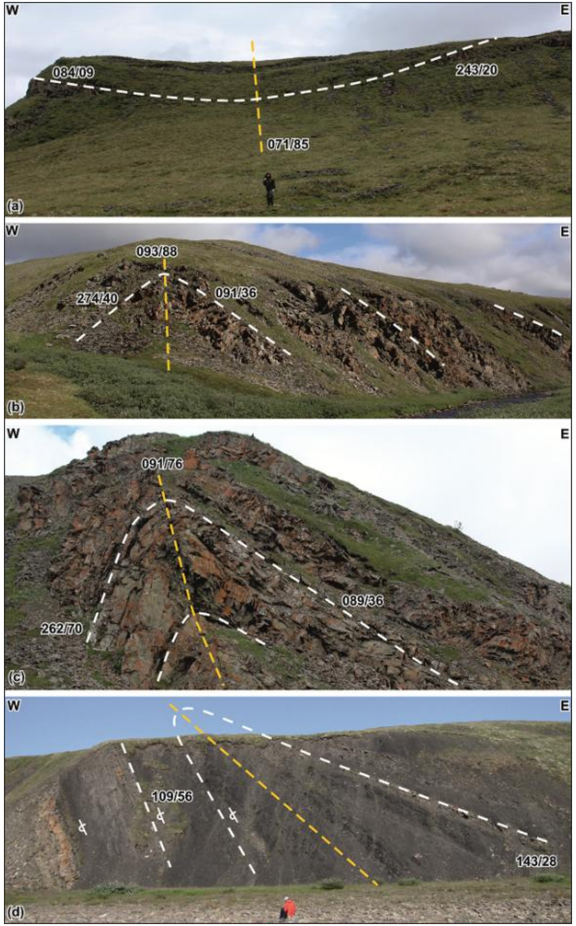


Pole to bedding (a) and minor folds axes and axial planes (b) plots, Neleger River area. Schmidt stereographic net, lower hemisphere projection, plotted in Orient Spherical Data Analysis Software and Stereonet Software. The solid line on plot (a) is the best fit great circle, the dashed line is calculated axial plane, the black point shows the fold hinge. Great circles on plot (b) are axial planes of 21 small folds, black points are folds hinges.

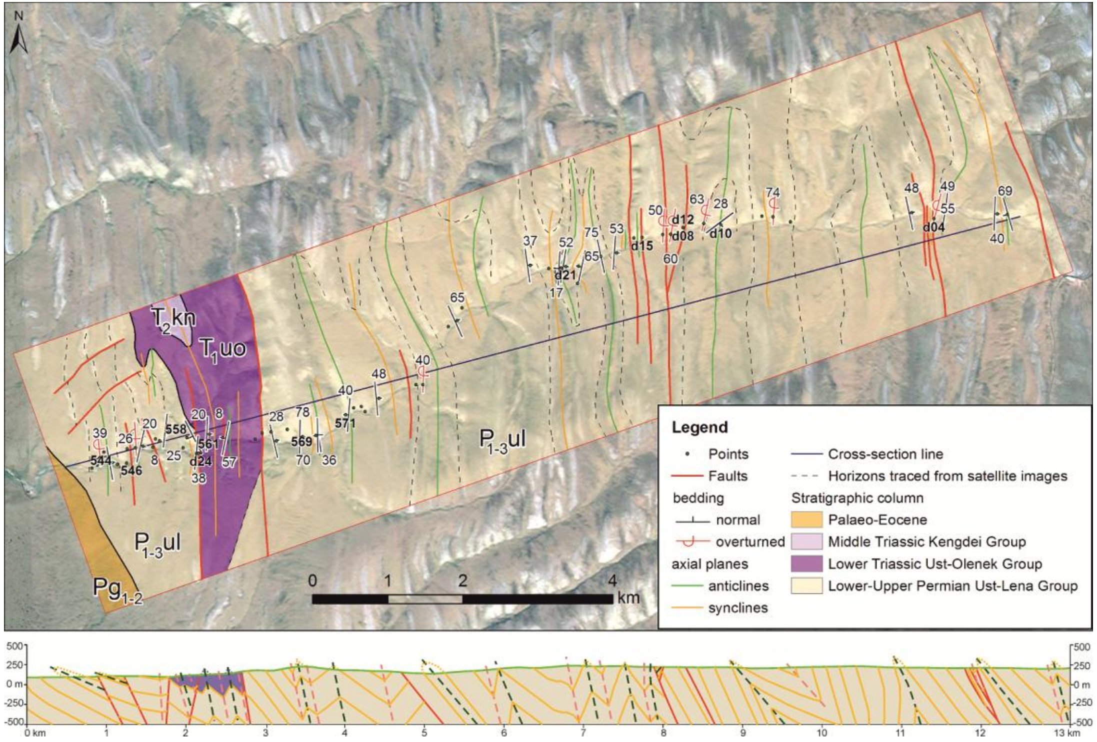
Danil River area



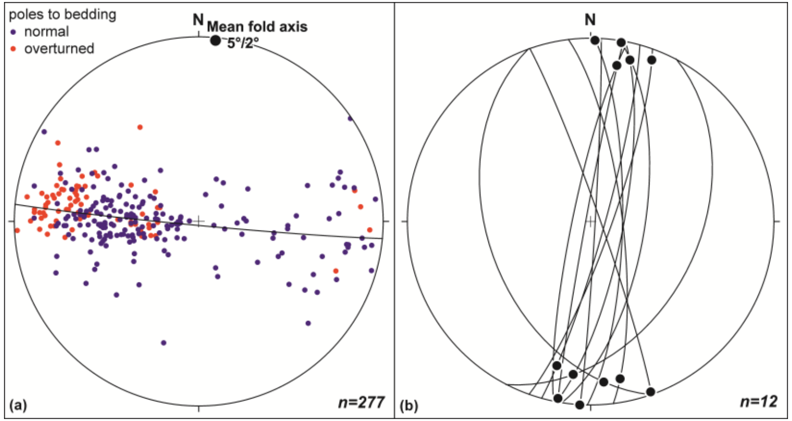




Structural study of the Danil River area

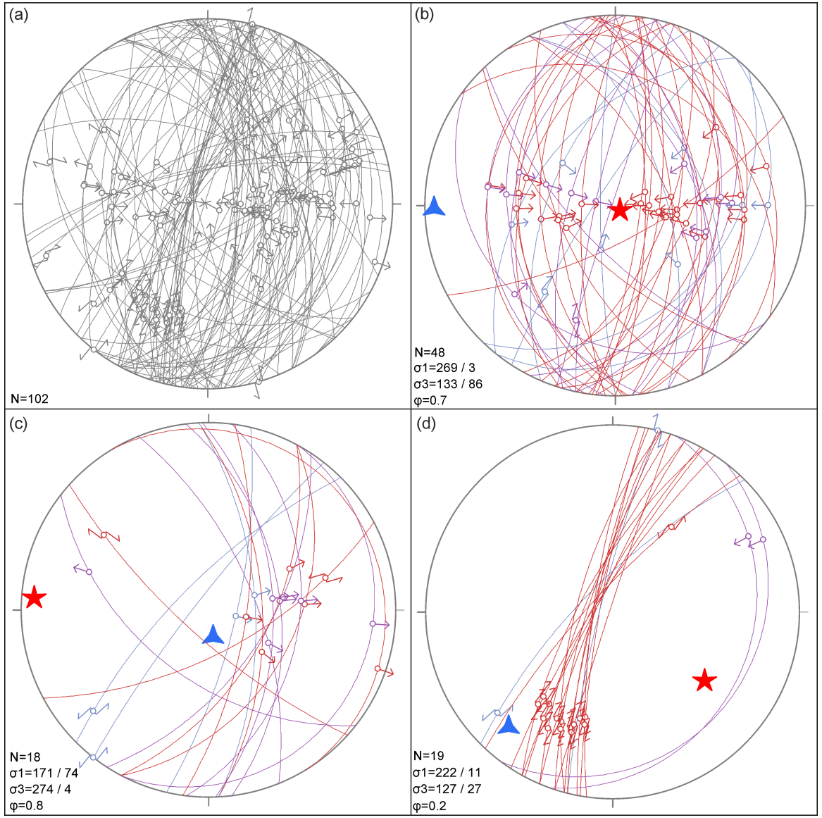


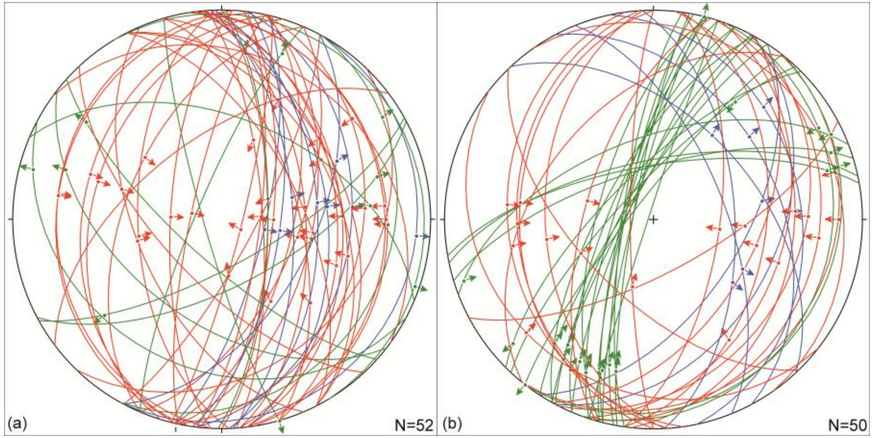
Geological map and cross-section of the Danil River area. Satellite image from google.com/maps



Pole to bedding (a) and minor folds axes and axial planes (b) plots, Danil River area. Schmidt stereographic net, lower hemisphere projection, plotted in Orient Spherical Data Analysis Software and Stereonet Software. Blue dots are normal bedding (199 measurements), red are overturned (78 measurements). The solid line on plot (a) is the best fit great circle, the black point shows the fold hinge. Great circles on plot (b) are axial planes of 12 small folds, black points are folds hinges.

Paleostress reconstruction

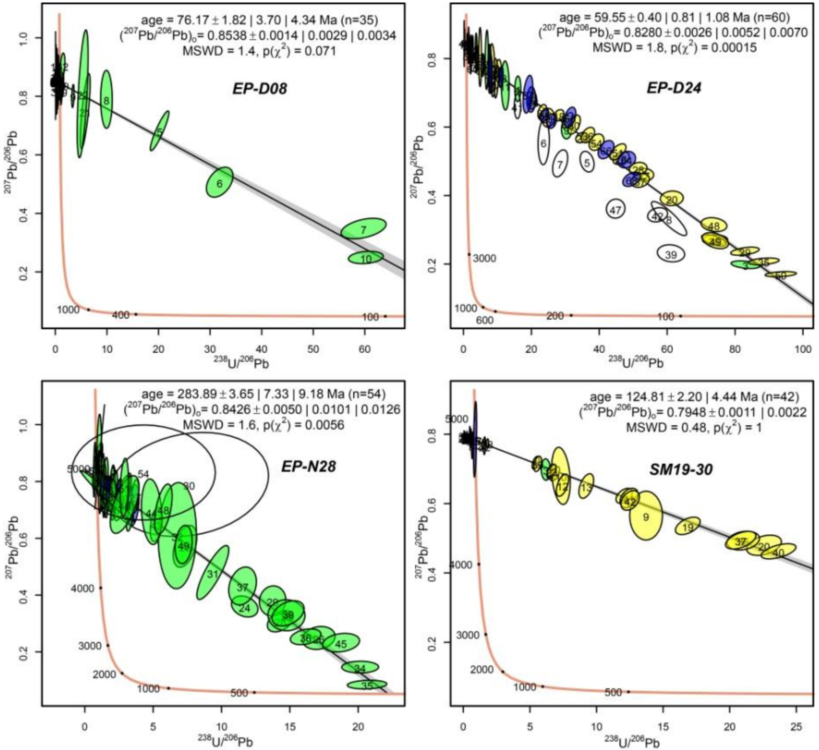




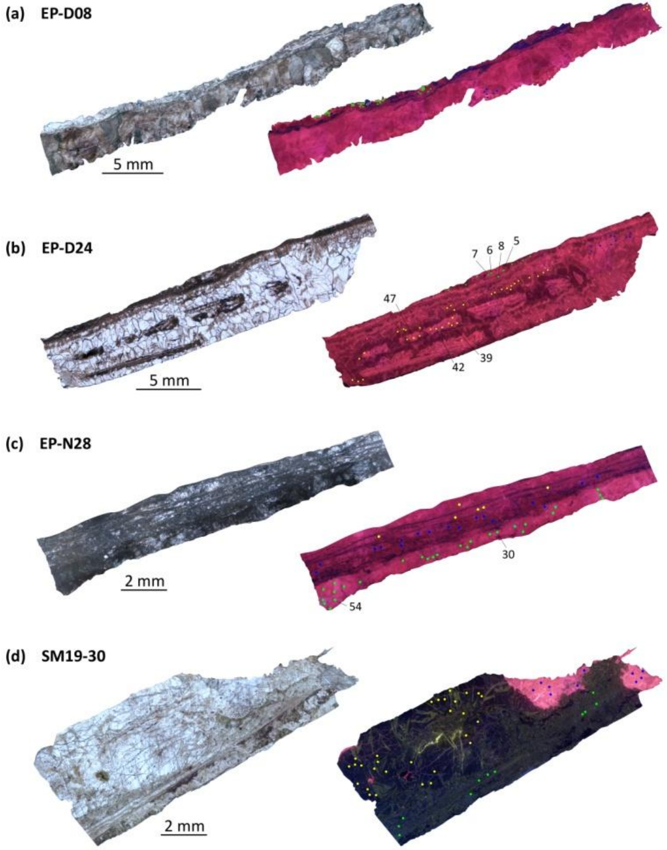
Composite fault-slip data on equal-angle lower-hemisphere projection from the Danil (a) and Neleger (b) rivers areas. Slip data are related to faults with predominant thrust (red), normal (blue) and strike-slip (green) displacements.

Equal-angle lower-hemisphere projection. (a) Composite fault-slip data. Thrust (b), normal (c) and strike-slip (d) faulting stress fields. Red, purple, and blue arrows (corresponding to measurements with a misfit of 10°, 20° and 30° respectively) show movements of the hanging wall blocks. Blue triangle is axis of maximum compression (σ_1), red star is axis of minimum compression (σ_3), $\varphi = (\sigma_2 - \sigma_3)/(\sigma_1 - \sigma_3)$ is the stress ratio.

Calcite dating

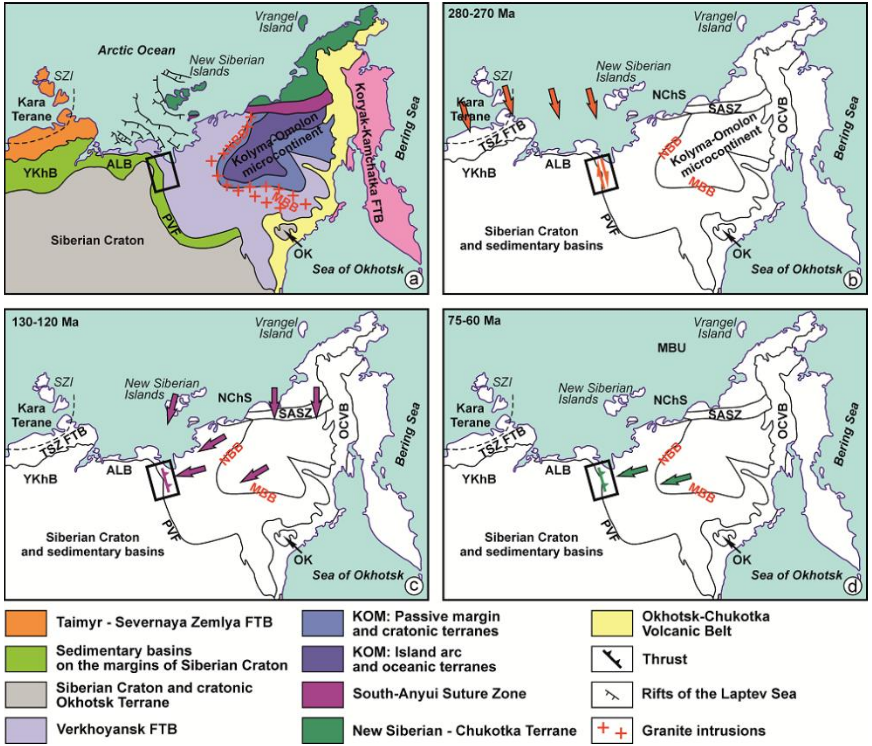


Tera-Wasserburg concordia diagrams for the studied samples. Colours of ellipses refer to the equally-coloured domains in the CL images. White ellipses show measurements not involved in the age calculation. Ages are given with 1σ and 2σ uncertainties. Additionally, uncertainty with overdispersion is given in case of overdispersion.



Optical and cathodoluminescence (CL) photomicrographs of calcite slickensides used for U-Pb dating. (a) Sample EP-D08. (b) Sample EP-D24. (c) Sample EP-N28. (d) Sample SM19-30. Blue, green and yellow dots in CL images indicate laser ablation points for U-Pb dating in different domains.

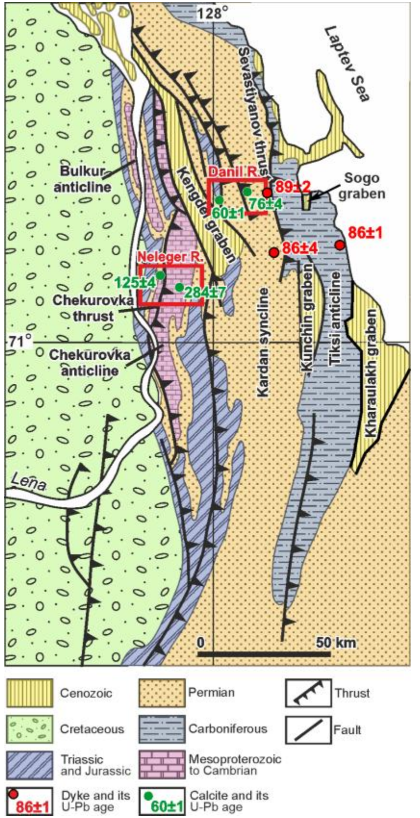
Tectonic evolution



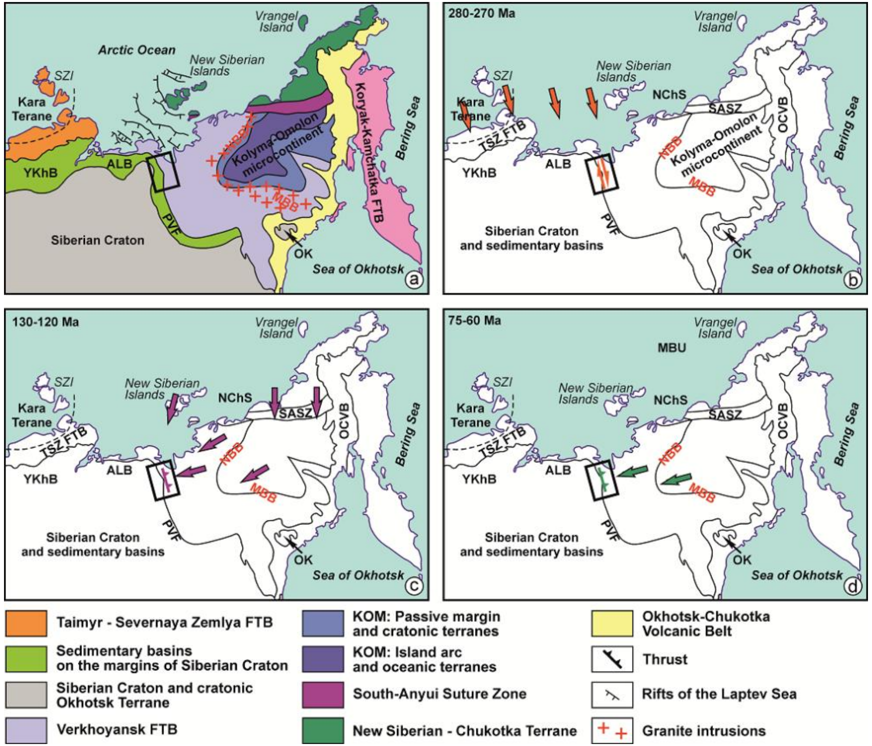
Tectonic evolution of the northern and eastern margin of Siberian Craton and adjacent areas. (a) Tectonic map. (b) 280-270 Ma: Kara Terrane – Siberian Craton collision. (c) 130-120 Ma: closure of the South Anyui Suture zone and late stages of the Kolyma-Omolon microcontinent and Siberian Craton collision. (d) 75-60 Ma: Kolyma-Omolon microcontinent and Siberian Craton post-collision interaction. TSZ FTB – Taimyr – Severnaya Zemlya FTB, NChS – New Siberian – Chukotka superterrane; SASZ – South-Anyui Suture Zone, KOM – Kolyma-Omolon microcontinent (superterrane), OK – Okhotsk cratonic terrane, OCVB – Okhotsk-Chukotka Volcanic Belt, YKhB - Yenisey-Khatanga Basin, ALB – Aldan- Lena basin, NBB – Northern Belt of batholiths, MBB – Main Belt of batholiths, MBU – Mid-Brookian Unconformity, SZI – Severnaya Zemlya Islands, PVF - Priverkhoyansk foredeep. Arrows show approximate tectonic transport direction.

•The oldest tectonic event is represented by the **strike-slip faulting stress field** and brittle-ductile shear zones in the hinge zone of the Chekurovka anticline. The estimated age of deformation (U-Pb calcite) is early Permian (**283.89±9.18 Ma**). Correlates with the main stage of the late Palaeozoic collision of the Kara terrane and northern margin of the Siberian Craton (Kurapov et al., 2021).

•130-60 Ma – two major deformation events of the Verkhoyansk FTB in the Early and Late Cretaceous (Galabala, 1971; Parfenov et al., 1995). The U-Pb calcite age **124.81±4.44 Ma** related to **thrust faulting stress field** is attributed to the most widespread and intense compression event (130-120 Ma). This tectonic event likely reflects closure of the South Anyui Suture zone and final stages of the Kolyma-Omolon microcontinent – Siberian Craton collision (Sokolov et al., 2021).

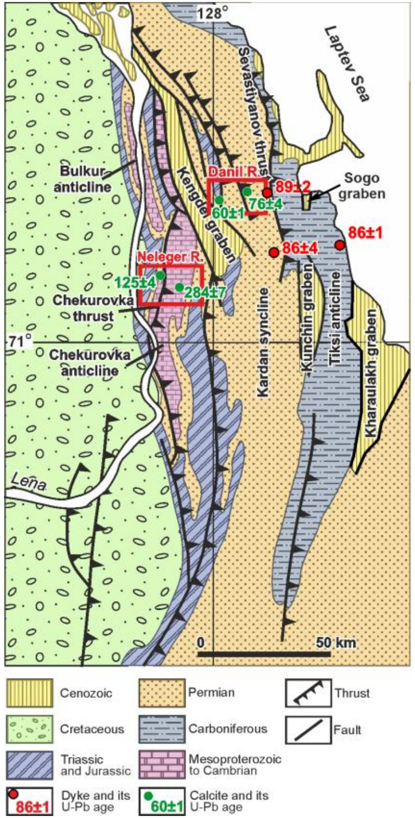


Tectonic evolution



Tectonic evolution of the northern and eastern margin of Siberian Craton and adjacent areas. (a) Tectonic map. (b) 280-270 Ma: Kara Terrane – Siberian Craton collision. (c) 130-120 Ma: closure of the South Anyui Suture zone and late stages of the Kolyma-Omolon microcontinent and Siberian Craton collision. (d) 75-60 Ma: Kolyma-Omolon microcontinent and Siberian Craton post-collision interaction. TSZ FTB – Taimyr – Severnaya Zemlya FTB, NChS – New Siberian – Chukotka superterrane; SASZ – South-Anyui Suture Zone, KOM – Kolyma-Omolon microcontinent (superterrane), OK – Okhotsk cratonic terrane, OCVB – Okhotsk-Chukotka Volcanic Belt, YKhB - Yenisey-Khatanga Basin, ALB – Aldan- Lena basin, NBB – Northern Belt of batholiths, MBB – Main Belt of batholiths, MBU – Mid-Brookian Unconformity, SZI – Severnaya Zemlya Islands, PVF - Priverkhoyansk foredeep. Arrows show approximate tectonic transport direction.

- Three mafic dykes cutting N-S trending folds were mapped to the east from the Danil River area and yielded 86±1, 86±4, and 89±2 Ma U-Pb zircon ages (Prokopiev et al., 2013; Gertseva et al., 2016). AFT study of detrital apatite from Jurassic and Lower Cretaceous siliciclastic rocks in the Priverkhoyansk foreland basin near the Chekurovka anticline points to a main cooling event at ca. 75-60 Ma, related to the final displacement and uplift along the Chekurovka thrust (Vasiliev et al., 2019).
- The U-Pb calcite ages of **76-60 Ma** related **to thrust faulting stress field** are interpreted as related to the Late Cretaceous – Palaeocene tectonic event during which thrusts were reactivated, but did not significantly modify the already established fold-and-thrust structure of the Kharaulakh segment. Post-collisional interaction between the Kolyma-Omolon microcontinent and Siberian Craton triggered the fault reactivation (Khudoley, Prokopiev, 2007).
- From Palaeocene onwards, extensional environments related to the formation of the Laptev Sea rift structures predominated (Drachev & Shkarubo, 2018). Within the Kharaulakh segment, extension settings are supported by formation of a set of grabens (Prokopiev et al., 2013) and clearly recognized **normal faulting stress field**.



Thank you for your attention!

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