# Geoloogia instituudi 2019. aasta teadus- ja arendustegevuse aruanne

**Department of Geology**

Director/direktor Professor **MICHAEL HITCH**, michael.hitch@taltech.ee

Geoloogia instituudi kooseisu kuulub 5 uurimisrühma, teaduskogude osakond ja Särghaua maateaduste õppekeskus:

- aluspõhjageoloogia osakond
- isotoopgeoloogia osakond
- kvaternaarigeoloogia osakond
- maavarade- ja rakendusgeoloogia osakond
- mäeosakond

The Department of Geology consists of five research groups, the Division of Collections and Särghaua Earth Science Centre:

- Division of Bedrock Geology
- Division of Isotope Geology
- Division of Mineral Resources and Applied Geology
- Division of Mining
- Division of Quaternary Geology

**TEADUSTEGEVUSE ÜLEVAADE UURIMISRÜHMADE LÕIKES**

## Aluspõhjageoloogia osakond

Juht: professor OLLE HINTS, olle.hints@taltech.ee
Liikmed: Tõnu Martma, Peep Männik, Jaak Nõlvak, Aivo Lepland, Linda Hints
Järeldoktor: Yan Liang
Doktorant: Ursula Toom, Garmen Bauert, Heikki Bauert

Uurimisrühma tegevust iseloomustavad võtmesõnad:
Paleosoikumi geoloogia, paleontoloogia, paleokeskkond, geokeemia, stratigraafia

Aluspõhja geoloogia, sh stratigraafia ja paleontoloogia, on olnud Geoloogia Instituudi üheks keskseks uurimisvaldkonnaks alates instituudi loomisest. 2019. a oli osakonnaga seotud 4 teadustöötajat, järeldoktor Hiinast ja 3 doktoranti, teadustegevus toimus Eesti Teadusagentuuri uurimistoetuse jt projektide toel. Osakonna töötajad osalevad mitmete loengukursuse läbiviimisel "Maapõueressursside" õppekava üliõpilastele.
Aluspõhja osakonna põhikompetentside hulka kuulub Eesti geoloogilise ehituse, kivimite, kivististe ja arenguloo põhjalik tundmine. Sellised teadmised on vajalikud praktilises geoloogias, kuid põhiliselt leiavad kasutust siiski alusuuringutes, enamasti tihedas rahvusvahelises koostöös. Osakonna peamiste uurimissuundade hulka kuuluvad:

- mikropaleontoloogia ja kõrglahutusega biostratigraafia;
- paleoelurikkuse dünaamika modelleerimine ja selle seosed kliima ja keskkonnamuutustega;
- erinevate organismirühmade evolutsioon ja paleobiogeograafilise leviku analüüs;
- paleokliima modelleerimine kasutades sedimentoloogilisi ja geokeemilisi indikaatoreid;
- Paleosoikumi vulkanism, bentoniidikihtide levik ja geokeemia ning stratigraafiline rakendus;
- süsiniku aineringe muutused Paleosoikumis ning isotoopgeoloogiliste meetodite kasutusvõimalused selle selgitamiseks.

Oluline osa aluspõhja osakonna teadustööst baseerub instituudi geoloogilistel ja paleontoloogilistel kollektsioonidel, mida haldab teaduskogude osakond.

Olulisemad 2019. a teadustulemused:
Uudne talliumi isotoopide uuring näitas Siluri ajastu Balti ürgmeres redutseerivaid keskkonnatingimusi, mis viitasid globaalsele hapnikupuudusele ookeanis. Hapnikuvaese ja väävelvesinikurikka vee jõudmine madalasse šelfimerre põhjustas järk-järgulise massilise väljasuremise, mida tuntakse nn Lau sündmusena. Sama keskkonnamuutuste mehhanism on toiminud tõenäoliselt ka mitmete teiste elurikkuse kriiside põhjustajana viimase 500 mln a jooksul. Esimene detailne ja pikka geoloogilise aja lõiku käsitlev orgaanilise aine ja karbonaatsete mineraalide süsiniku isotoopkoostise uuring Balti regioonist näitas ajalist trendi ja järsku muutust aineringes u 453 mln a tagasi, mis võib olla seotud globaalse GICE'i keskkonnasündmuse ja ökosüsteemide muutusega. Tundmatu päritoluga kitiinikute ja tänapäevaste mereselgrootute võrdlev morfomeetriline uuring tuvastas kitiinikute oluliselt suurema liigisisese variaabluse, mis lubab arvata, et (erinevalt enamlevinud hüpoteesist) võib olla tegemist iseseisvate organismidega, mitte mereloomade arengustaadiumiga. Alam- ja Kesk-Ordoviitsiumi kitiinikufauna analüüs tõestas seniarvatust suurema taksonoomilise mitmekesisuse Baltika kontinendil ning tihedad biogeograafilised sidemed Lõuna-Hiina jt piirkondadega. Töö käigus avastati maailma suurim kitiinik: 2,7 mm pikkune *Rhabdochitina*.

## Division of Bedrock Geology

Head: Professor OLLE HINTS, olle.hints@taltech.ee
Members: Tõnu Martma, Peep Männik, Jaak Nõlvak, Aivo Lepland, Linda Hints
Postdoc: Yan Liang
Doctoral students: Ursula Toom, Garmen Bauert, Heikki Bauert

Keywords: Paleozoic geology, paleontology, paleoenvironment, stable isotope geochemistry

Bedrock geology, including paleontology and stratigraphy, have been among the key research areas of the Department of Geology since 1950s. In 2019, the group included five researchers, one postdoc and three PhD students, who work in close collaboration with partners worldwide, notably from US, Russia, Sweden, China, Canada, France, Belgium, Germany and UK.

The main research topics of the group are related to deciphering Earth history through the latest Proterozoic and early Paleozoic times, ca 600–400 million years ago. During this period, the planet underwent major transitions in climate systems and environments, related to changing oxygen levels and perturbations in carbon cycle rarely seen on Earth since then. This interval moreover embraced key events in biological evolution and biodiversification, such as the Cambrian explosion and the Great Ordovician Biodiversification Event but witnessed also one of the largest mass extinctions in the history of life. The group is interested in better understanding the interactions between geo- and biosphere processes, in particular, addressing the following:

- paleobiodiversity dynamics and its relationships with climate and environmental changes;
- paleobiology and evolution of various groups of organisms during early Palaeozoic;
- global paleobiogeographic patterns and the role of the Baltic faunal province;
- paleoclimate perturbations using multiple proxy indicators (such as conodont apatite);
- changes in carbon, oxygen and sulfur stable isotope composition, reflecting of atmosphere and hydrosphere in deep time.

The group holds leading palaeontological competence in Estonia, and for some fossil groups, leading expertise worldwide (notably for conodonts, chitinozoans and scolecodonts). The main applications of the group's work are related to high-resolution biostratigraphy of Early Paleozoic sedimentary rocks, which has resulted in numerous collaborative publications. Most high-impact studies are based on material from the Baltoscandian bedrocks, renowned by little alteration and good preservation of primary Paleozoic environmental signatures. Studies conducted at the division have been published in leading research journals including Nature, PNAS and Geology.

The group is responsible for running the mass spectrometry lab for stable isotope geochemistry, SEM for imaging and express geochemistry as well as paleontology lab for extracting microfossils. The group makes also excessive use of the geological and paleontological collections held at the department. These are largest in Estonia and curated at a high international level.

Main results in 2019:

A novel approach using thallium isotope records revealed reducing conditions in the Silurian Baltic Basin and documented the earliest onset of global marine deoxygenation. The expansion of anoxia coincided with the onset of stepwise mass extinction and appears to be its main driver. Similar mechanism might have been responsible for other marine extinction events in the Phanerozoic.

First detailed and stratigraphically extensive paired carbonate and organic matter carbon isotope records were identified from the Ordovician of Baltoscandia filling gaps in the global data compilation. The revealed trends suggest time-constrained changes in carbon fractionation and an abrupt shift close to the GICE Event, ca 453 m.y. ago, possibly related to changes in primary producer communities.

Morphometric comparison of enigmatic chitinozoans and eggs of various extant marine invertebrates showed that chitinozoans had much higher interspecific variation and thus may represent shells of individual organisms rather than eggs of unknown marine animals. Analysis of Early and Middle Ordovician chitinozoan communities revealed their higher richness and more gradual diversification on Baltica than previously identified; the largest chitinozoan in the world was discovered from Estonia.

Major publications in 2019:


- Bowman, C. N., Young, S. A., **Kaljo, D.**, Eriksson, M. E., Them, T. R., **Hints, O.**, **Martma, T.**, Owens, J. D., 2019. Linking the progressive expansion of reducing conditions to a stepwise mass extinction event in the late Silurian oceans. *Geology* **47**, 968-972. https://doi.org/10.1130/G46571.1

- **Liang, Y.**, Bernardo, J., Goldman, D., **Nõlvak, J.**, Tang, P., Wang, W., **Hints, O.**, 2019. Morphological variation suggests that chitinozoans may be fossils of individual microorganisms rather than metazoan eggs. *Proceedings of the Royal Society* **286**, 1-8. https://doi.org/10.1098/rspb.2019.1270
- **Nõlvak, J., Liang, Y., Hints, O.**, 2019. Early diversification of Ordovician chitinozoans on Baltica: new data from the Jägala waterfall section, northern Estonia. *Palaeogeography, Palaeoclimatology, Palaeoecology* **525**, 14-24. https://doi.org/10.1016/j.palaeo.2019.04.002
- Popov, L., Álvaro, J., Holmer, L., **Bauert, H.**, Ghobadi Pour, M., Dronov, A., Lehnert, O., **Hints, O.**, **Männik, P.**, Zhang, Z., Zhang, Z., 2019. Glendonite occurrences in the Tremadocian of Baltica: first Early Palaeozoic evidence of massive ikaite precipitation at temperate latitudes. *Scientific Reports* **9**, 1-10. https://doi.org/10.1038/s41598-019-43707-4
- Richardson, J. A., Keating, C., **Lepland, A.**, **Hints, O.**, Bradley, A. S., Fike, D. A., 2019. Silurian records of carbon and sulfur cycling from Estonia: The importance of depositional environment on isotopic trends. *Earth and Planetary Science Letters* **512**, 71-82. https://doi.org/10.1016/j.epsl.2019.01.055


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## Isotoopgeoloogia osakond


Uurimisrühma juht: vanemteadur REIN VAIKMÄE, rein.vaikmae@taltech.ee
Liikmed: Tõnu Martma (kuni 02.2019), Alla Šogenova, Kazbulat Šogenov, Enn Kaup, Jüri Ivask
Joonas Pärn


Uurimisrühma tegevust iseloomustavad võtmesõnad:

stabiilsed isotoobid, põhjavesi, paleoklimatoloogia, $CO_2$ kinnipüüdmine ja ladustamine

Isotoopgeoloogia osakond moodustati Geoloogia Instituudis eelmise sajandi 70ndate aastate algul eesmärgiga kasutada isotoop-geokeemilisi analüüsimeetodeid ja -indikaatoreid globaalsete kliima- ja keskkonnamuutuste uurimisel. Osakonna algusaastatel kujunes põhiliseks uurimissuunaks Kvaternaari jäätumiste ajaloo uurimine ning paleoklimatoloogia ja eelkõige polaaralade jääpuursüdamikes talletunud isotoopandmestiku dešifreerimine. Viimase aastakümne jooksul on osakonna isotoopuuringud laienenud ja hõlmavad Balti arteesiabasseini (BAB) põhjavee isotoopkoostise, vanuse ja päritolu probleeme ning numbriliste mudelite rakendamist. Jätkuvalt ollakse edukad isotoop-geokeemiliste andmete abil polaaralade paleokliima- ja keskkonnamuutuse rekonstrueerimisel, sealjuures osakonna stabiilsete isotoopide analüüsi laboratooriumi koostöö kaudu instituudi teiste osakondade ning partneritega Eestis ja välismaal. Uue uurimissuunana on lisandunud $CO_2$ sidumise ja geoloogilise ladustamise temaatika.

2019. a alguse seisuga oli osakonnaga seotud 5 teadustöötajat ja 2 teaduskraadiga inseneri. Teadustöö toimus Eesti Teadusagentuuri uurimistoetuste ja välisprojektide, sh Rahvusvahelise Aatomienergia Agentuuri (IAEA) ning EL Horisont 2020 projektide toel. 2018. a sõlmiti Keskkonnaministeeriumiga uurimisleping nitraatide ja pestitsiidide kõrgendatud sisalduse põhjuste ja leviku ulatuse väljaselgitamiseks Siluri-Ordoviitsiumi põhjaveekogumis Ida-Eesti vesikonnas. Osakonna töötajad osalevad mitme õppeaine õpetamisel „Maapõueressursside“ õppekava üliõpilastele. Kolm osakonna teadustöö raames koolitatud ja doktorikraadi kaitsnud noort teadlast moodustavad praegu hiljuti taasloodud eesti Geoloogiateenistuse hüdrogeoloogia osakonna tuumiku.

Osakonnal on teadustööks välja arendatud kaasaegne isotoop-geokeemiliste analüüside infrastruktuur, sh kaks Thermo Fisher DeltaV stabiilsete isotoopide suhte mõõtmise massispektromeetrit koos proovide ettevalmistussüsteemidega (GasBench II $\delta^{18}O$ ja $\delta^{13}C$ määramiseks karbonaatkivimitess; FlashEA 1112 $\delta^{13}C$ ja $\delta^{15}N$ analüüsiks organilises aines ja TC/EA kõrgtemperatuurne elementanalüsaator, aga samuti vee $\delta^{18}O$ ja $\delta^{2}H$ isotoopanalüüsi laserspektromeeter Picarro L2120-i ning ioonkromatograaf ICS-1100.

Välispartnerite, sh IAEA kaudu on osakonnal vajadusel juurdepääs ka unikaalsele veeproovide väärisgaaside sisalduse ning väärisgaaside isotoopanalüüside aparatuurile.

2019. lõppes Eesti Teadusagentuuri rahastatud projekt IUT19-22 „Balti Arteesiabasseini põhjavee geofiltratsiooni ajalugu, selles salvestunud paleokliima ja inimmõju andmed: hüdrogeokeemilise teabe ja modelleerimise süntees“.

Olulisemad 2019. a teadustulemused:
1. Ordoviitsium-Kambriumi põhjaveekompleksi vee dateeringutega tehti kindlaks, et vee isotoop-hüdrogeokeemiline muster, mis on välja kujunenud Pleistotseenis korduvalt vaheldunud jäätumise-jäävaheagade tsüklite jooksul, on säilinud ka Holotseenis, mis kinnitab, et tänapäevase pinnavee infiltratsioon põhjaveekompleksi on piiratud, mida on oluline arvestada veemajandusplaanide kavandamisel ja tähendab ka seda, et Eesti põhjavee kasutamist reguleerivad põhimõtted ja seadusandlus vajavad ülevaatamist (Pärn et al., 2019).
2. Tehti kindlaks, et varasemate uuringute käigus leitud ebatavaliselt kõrge metaanikontsentratsioon Kambriumi-Vendi põhjaveekompleksis tuleneb Skandinaavia jääkilbi edasiliikumisel liustikualuse survelise sulavee poolt jääkilbi ees formeerunud märgaladest pärineva orgaanilise materjali põhjaveekompleksi sissekande ja sellest edasise anaeroobse oksüdatsiooni teel metaani formeerumisest (Pärn et al., 2019).
3. 30 aastaks väljatöötatud süsinikdioksiidi kinnipüüdmise, kasutamise ja ladustamise (CCUS) piiriülene stsenaarium hõlmab Kunda Nordic Tsemendi ning kolme Eesti ja Läti suurima energiatootja toodetud süsinikdioksiidi heitkogused. Kinnipüütud $CO_2$ emissioonid transporditakse torujuhtmete kaudu Põhja-Blidene ja Blidene ladustamiskohtadesse Lätis. Stsenaarium võimaldab jätkata kohalike põlevkivide kasutamist energiatootmiseks, säilitades energeetilise sõltumatuse, ja ühtlasi saavutada süsinikuneutraalsus aastaks 2050. $CO_2$ kasutamise võimalus hõlmab selle mineraalset karboniseerimist põlevkivituha abil koos edasise kasutamisega tsemendi tootmisel ja ehitustöödel (Šogenova jt 2019, Fantini jt 2019).
4. Uus kulukonkurentsivõimeline kontseptsioon, mis kombineerib süsinikdioksiidiga nafta täiendavat tootmist ($CO_2$-EOR) Ülem-Ordoviitsiumi Salduse ladestust, geotermilise energia täiendavat tootmist (süsinikdioksiidi geotermiline voog – CPG) Kambriumi Deimena ladestust ja süsinikdioksiidi geoloogilist ladustamist (CGS) nendes kahes ladestus, on välja arendamisel E6 struktuuri jaoks Läti rannikumeres. CGS ja CPG sünergia kindlustab vajaliku rõhu geotermiliste puuraukude jätkusuutlikule tootlikkusele, suurendab süsinikdioksiidi säilitusmahtu ja parandab CGS puuraukude jaoks sisestatavust. Samuti vähenevad võimalikud riskid seismilisusele ning süsinikdioksiidi ja soolase põhjavee leketele. Sisestatud süsinikdioksiidi saab kasutada töövedelikuna nafta ja soojuse täiendavaks tootmiseks tõhusamalt (võrreldes soolase põhjaveega). $CO_2$ kasutamisest saadav tulu vähendab projekti kulusid (Šogenov ja Šogenova, 2019).

**Kliimamuutused ja CCUS Eesti meedias**

Esmakordselt pälvis Eesti meedias nii eesti kui ka vene keeles märkimisväärset tähelepanu CCUS kui tõhus kliimamuutuste leevendamise tehnoloogia. Alla Šogenova ja Kazbulat Šogenov andsid intervjuude seeria süsiniku kinnipüüdmise, kasutamise ja ladustamise tehnoloogia kohta eesti- ja venekeelsetes telekanalites, raadios ja ajakirjanduseses. Mõnda neist intervjuudest võib näha, kuulda ja lugeda järgmistel linkidel:

https://www.youtube.com/watch?v=Sia_EuWod74&list=PLOvt8evVkUwKI8phQHV0-J...
https://rus.err.ee/989738/kto-kogo-jekologicheskaja-vojna-nachalas
https://r4.err.ee/988861/podrobnosti/984460
https://epl.delfi.ee/kliima/teadlane-ka-eesti-maapoues-saaks-co-sub-2-su...
https://rus.postimees.ee/6804289/uchenye-znayut-kak-spasti-slancevuyu-en...
https://r4.err.ee/988861/podrobnosti/984460?fbclid=IwAR0CuBQnB1rYdqITjuk...
https://www.dv.ee/novosti/2019/11/06/gruppa-zahvata-co2
https://epl.delfi.ee/kliima/co-sub-2-sub-matmine-kogub-tuure-kas-eesti-jaab-rongist-maha?id=87918603

**Division of Isotope Geology**

Head: senior researcher REIN VAIKMÄE, rein.vaikmae@taltech.ee
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Keywords: stable isotopes, groundwater, paleoclimatology, $CO_2$ capture and storage

The Division of Isotope Geology was formed in the early 1970s with the aim to study the history of Quaternary glaciations and for using isotopic and geochemical indicators in polar ice-cores for the study of global climatic variability and environmental changes back in time. Over the years, the division's main research areas have been expanded to hydrogeology, arctic paleoclimatology and environmental change, high-resolution stable isotope Paleozoic chemostratigraphy as well as $CO_2$ capture and storage.

In 2019, the division's research work was carried out on Estonian Research Council projects, several international projects (including the IAEA, EU Horizon 2020) and contracted projects.

The research staff includes five researchers and two engineers holding PhD degrees.

The division holds a modern research facility with an international client base including: two Thermo Fisher Delta V Advantage and DeltaV Plus IRMS, with three sample preparation lines (GasBench II for $\delta^{18}O$ and $\delta^{13}C$ from carbonate rocks; FlashEA 1112 for $\delta^{13}C$ and $\delta^{15}N$ analyses from organic matter and TC/EA High Temperature Conversion/Elemental Analyzer), a Picarro L2120-i laser spectrometer for water $\delta^{18}O$ ja $\delta\ ^{2}H$ analyses and Thermo Dionex ion chromatograph ICS-1100.

Through our international partners, including the IAEA, we have access, if needed, to the unique equipment for water noble gas composition and/or isotope composition analyses.

In 2019, Estonian Research Council funded project IUT19-22 "Groundwater flow conditions, global paleoclimate signals and anthropogenic influence in the Baltic Artesian Basin: a synthesis of numerical hydrogeological models and hydrogeochemical data" was completed;

Main results in 2019:

1. Dating of palaeogroundwater in the Ordovician-Cambrian aquifer system in the northern Baltic artesian basin showed that the isotope-geochemical composition of groundwater in the aquifer system still exhibit patterns established in the Pleistocene, even though the hydraulic heads have already evolved to steady-state conditions with respect to modern topographically driven groundwater flow. The study of age tracers in the aquifer system indicates that the observed composition of groundwater has developed through several glacial–interglacial cycles. Thus, to sustainably manage such a groundwater reservoir, it has to be taken into account that steady-state with respect to modern day flow conditions does not mean that an aquifer is receiving significant amounts of modern recharge (Pärn et al., 2019).
2. It was shown that relatively high methane concentrations in the Cambrian-Vendian aquifer system in Estonia, established in the frame of our earlier studies, originate from the organic material overridden by the Fennoscandian Ice Shield during the Late Weichselian glaciation, and the methane was carried into the aquifer system with infiltrating glacial meltwater. In various parts of the aquifer system, methane has formed by oxidation of dissolved/disseminated organic material. The results of our study show that Cm-V palaeogroundwater of glacial origin and its analogues in the world could serve as palaeo-environmental archives that can be used to study the variations in climatic and environmental conditions during glacial–interglacial cycles in the Pleistocene (Pärn et al., 2019).
3. The developed onshore Carbon Capture, Use and Storage (CCUS) transboundary scenario for 30 years includes Estonian $CO_2$ emissions produced by Kunda Nordic Tsement and three largest energy producers from Estonia and Latvia, which will be transported by pipelines to North-Blidene and Blidene storage sites in Latvia. Such scenario permits to use local oil-shales for energy production, reach energy independence and carbon-neutrality in Estonia by 2050. $CO_2$ use option includes mineral carbonation of the waste oil shale ash with its further use for cement production and construction works (Shogenova et al, 2019, Fantini et al, 2019).
4. A new cost-competitive concept of the project combining $CO_2$ Geological Storage (CGS), $CO_2$-Enhanced Oil Recovery ($CO_2$-EOR) and geothermal energy recovery, or $CO_2$ plume geothermal (CPG) in Cambrian Deimena Formation and Upper Ordovician Saldus Formation of the E6 structure offshore Latvia is developed. Synergy of CGS and CPG will provide pressure support for sustainable productivity of geothermal wells, improvement of $CO_2$ storage capacity and increased injectivity of the CGS wells. It will also reduce the risks of induced seismicity and decrease $CO_2$ and brine leakage. Injected $CO_2$ will be utilized as a more efficient (than brine) working fluid for geothermal heat recovery (Shogenov and Shogenova, 2019).

**Major publications in 2019:**

- **Pärn**, J.; Walraevens, K.; van Camp, M.; Raidla, V.; Aeschbach, W.; Friedrich, R.; **Ivask**, J.; **Kaup**, E.; **Martma**, T.; Mažeika, J.; Mokrik, R.; Weissbach, T.; **Vaikmäe**, R. (2019). Dating of glacial palaeogroundwater in the Ordovician-Cambrian aquifer system, northern Baltic Artesian Basin. Applied Geochemistry, 102, 64−76. https://doi.org/10.1016/j.apgeochem.2019.01.004.
- Raidla, V.; **Pärn**, J.; Aeschbach, W.; Czuppon, G.; **Ivask**, J.; Kiisk, M.; Mokrik, R.; Samalavičius, V.; Suursoo, S.; Tarros, S.; Weissbach, T. (2019). Intrusion of Saline Water into a Coastal Aquifer Containing Palaeogroundwater in the Viimsi Peninsula in Estonia. Geosciences, 9 (1). https://doi.org/10.3390/geosciences9010047.
- Raidla, V.; **Pärn**, J.; Schloemer, S.; Aeschbach, V.; Czuppon, G.; **Ivask**, J.; Marandi, A.; Sepp, H.; **Vaikmäe**, R.; Kirsimäe, K. (2019). Origin and formation of methane in groundwater of glacial origin from the Cambrian-Vendian aquifer system in Estonia. Geochimica et Cosmochimica Acta, 251, 247−264. https://doi.org/10.1016/j.gca.2019.02.029.
- **Shogenova**, A.; Uibu, M.; Gastaldi, D.; **Shogenov**, K.; Canonico, F.; Trikkel, A.; Kuusik, R.; **Ivask**, J.; Cinti, G.; Simmer, K. (2019). Transport, utilization and storage of CO2 emissions produced by cement industry: CCUS study of the CLEANKER project. *14th International Conference on Greenhouse Gas Control Technologies, GHGT-14, Melbourne, Australia, 21-25 October, 2018.* SSRN: Elsevier, 1-9. http://dx.doi.org/10.2139/ssrn.3378578.
- **Shogenov**, K.; **Shogenova**, A. (2019). Cost-competitive and self-supporting geothermal energy, CO2-EOR and CO2 storage concept: case study of E6 structure in the Baltic Sea. *SSRN: 14th Greenhouse Gas Control Technologies Conference Melbourne 21-26 October 2018 (GHGT-14).* Elsevier, 1−8. https://ssrn.com/abstract=3366151.
- Fantini, M.; Spinelli M.; Romano, M. C.; Campanari, S.; Consonnia, S.; Balocco, M.; Canonico, F.; Abanades, C.; Arias, B.; Hammerich, J.; Myöhänen, K.; Sessa, F.; **Shogenova**, A.; Zhenshan, L.; Spörl, R.; Hoenig, V.; Baldassarri, D.; Cinti, G. (2019). CLEANKER – Clean Clinker by Calcium Looping Process for Low CO2 Cement Production. *14th Greenhouse Gas Control Technologies Conference Melbourne 21-26 October 2018 (GHGT-14).* SSRN: Elsevier, 1−9. https://ssrn.com/abstract=3366108.
- Hong, W.-L.; Lepland, A.; Himmler, T.; Kim, J.-H.; Chand, S.; Sahy, D.; Solomon, E. A.; Rae, J. W. B.; **Martma**, T.; Nam, S.-I.; Knies, J. (2019). Discharge of meteoric water in the eastern Norwegian Sea since the last glacial period. Geophysical Research Letters, 46 (14), 8194−8204. https://doi.org/10.1029/2019GL084237.
- Himmler, T.; Sahy, D.; **Martma**, T.; Bohrmann, G.; Plaza-Faverola, A.; Bünz, S.; Condon, D. J.; Knies, J.; Lepland, A. (2019). A 160,000-year-old history of tectonically controlled methane seepage in the Arctic. Science Advances, 5 (8), #EAAW1450. DOI: 10.1126/sciadv.aaw1450.
- Bowman, C. N.; Young, S. A.; Kaljo, D.; Eriksson, M. E.; Them, T. R.; **Hints**, O.; **Martma**, T.; Owens, J. D. (2019). Linking the progressive expansion of reducing conditions to a stepwise mass extinction event in the late Silurian oceans. Geology, 47. https://doi.org/10.1130/G46571.1.

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## Maavarade- ja rakendusgeoloogia osakond

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Doktorandid: Siim Pajusaar, Tõnu Tomberg

Uurimisrühma tegevust iseloomustavad võtmesõnad:

maavarad, geotehnika, andmebaasid, seismoseire

Uurimisrühma tegevuses on kesksel kohal Eesti nn tuleviku maavarade geokeemilise koostise, geneesi ja leviku uuringud. Teisteks olulisteks valdkondadeks on kaevandamisega ja militaarobjektidega seotud

geotehnilised teadus- ja arendustööd ning seismoloogilised uuringud. Neile lisanduvad maapõue ja merekeskkonna keskkonnaseisundit, settekivimite mineraloogia ja geokeemia ning geoloogiliste andmete digitaalset kättesaadavust edendavad projektid ning uuringud.

Esiletõstmist väärib rühma mitmekülgne kompetents orgaanikarikaste setteliste maavarde, sh põlevkivide ja metallirikaste mustade kiltade, aga ka karbonaatsete kivimite geoloogilistes uuringutes. Töörühm omab ühtlasi pikaajalist kogemust paleokeskkondade ja settekivimite tekkeprotsesside käsitlemises, sealhulgas paleosoiliste vulkaanilis-setteliste kivimite stratigraafia ja elementide mobiilsuse ning mereliste keskkonnatingimuste interpreteerimise vallas. Geotehniliste uuringute valdkonnas on töögrupi põhifookuseks lõhketööd ja viimastega seotud vibratsiooni uuringud.

Osaletakse RITA strateegilise TA toetamise projekti raames Eesti fosforiidi rikastamise ja aluskorra potentsiaalsete metalliressursside uuringutes. 2019. a lõppenud projekti EUROCORE (EIT RawMaterials) käigus arendati välja unikaalne maagiotsingute kompleksteabe jagamist ja analüüsi toetav veebipõhine õppeotstarbeline infosüsteem. Riikliku keskkonnaseire programmi seismoseire alamprogrammi raames teostati 2019. aastal seismilist seiret Eesti territooriumil ja selle lähialadel, kasutades andmeid kümnest seismojaamast.

Osakonna T&A tegevus tugineb kaasaegsel analüütilisel laborikompleksil (XRD, XRF, ICP-MS, SEM-EDS), mis lubab teostada mitmekülgseid kivimite ja maavarade geokeemilisi, mineraloogilisi ja petrograafilisi uuringuid. Analüütilise kvaliteedi tagamiseks jätkati 2019. a osakonna hallatavates röntgenfluoresents-spektromeetria ja induktiivsidestatud plasma-massispektromeetria laborites iga-aastast osalemist rahvusvahelistes võrdluskatsetes. Olemas on ka võimekus maavarade füüsikalis-keemiliste omaduste *in situ* uuringuteks välitöödel ja puursüdamikest ning geoloogiliste protsesside analoogmodelleerimiseks.

Uurimisrühma aktiivsete koostööpartnerite hulka kuuluvad töögrupid Eesti Geoloogiateenistusest, Tartu Ülikoolist, Soome Geoloogiateenistusest, Potsdami geouuringute keskusest ning mitmest välisülikoolist ja tehnikaülikooli allüksusest, sh materjali- ja keskkonnatehnoloogia instituudist ning põlevkivi kompetentsikeskusest. Seismoseiret viiakse läbi koostöös Helsingi Ülikooli Seismoloogia Instituudiga.

Olulisemad 2018. a teadusprojektid:

- RITA1./01-01. Sillamäe piirkonna graptoliitargilliidi ja Jõhvi rauamaagi leiukoha metallide leviku kaardistamine ja geneesi uuringud, eskiislahendused Tallinn-Helsingi tunneli läbindamistöödeks settekivimites;
- EIT RM EUROCORE VA17082. Õppeotstarbelise maagiotsingu andmebaasi arendus;
- KIK 15918. Liiva ja kruusa uuringutes lõimise teisendamise meetodi väljatöötamine ja analüüs.

### Division of Mineral Resources and Applied Geology

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Doctoral students: Siim Pajusaar, Tõnu Tomberg

Keywords: mineral resources, geotechnical engineering, databases, seismic monitoring

The research group mainly deals with subjects concerning future mineral resources of Estonia, targeting issues related to geochemistry, genesis and distribution of the potential deposits, but also with geotechnical problems related to mining and military applications and seismological research. Moreover, a number of projects and research activities connected with various aspects of mineralogy and geochemistry of sedimentary rocks, with environmental geology, as well as with development of data systems for digital sharing of geological information, have been carried out during last few years.

The core competences of the work group are related to geology of sedimentary organic rich mineral resources (metalliferous black shales, oil shales) as well as sedimentary calcareous rocks. On the field of the geotechnical engineering, studies on blasting technique and vibration have been the primary focus of the work group.

Under the umbrella of EU-funded strategic R&D initiative RITA1/01, a number of major research activities on the topics such as enrichment of Estonian shelly phosphorite resources, geochemical-lithological characteristics and metallogenesis of Ordovician black shales and ore mineralogy of the Jõhvi magnetite quartzite deposit, continued during 2019. As part of the project funded by EIT Raw Materials initiative (Horizon 2020), the work group developed a web-based educational information system for sharing core logging data. The system was designed to provide a common access point to complex analytical datasets of mineral exploration collected with traditional and novel core logging techniques. Seismic monitoring of the Estonian territory and the surrounding areas was performed during 2019 using data from ten seismic stations.

The work group manages modern analytical facilities including ICP-MS, XRF and XRD labs, allowing complex set of geochemical, mineralogical and petrological studies to be carried out. The quality of laboratory analyses is assured on a yearly basis through participation in proficiency testing programme of the International Association of Geoanalysts. Other research capabilities include fieldwork instruments for *in situ* studies of geochemical properties of rocks, complemented by analogue modelling of geological processes.

The active collaboration partners of the work group come from numerous organisations from Estonia and abroad, including Estonian Geological Survey, University of Tartu, Finnish Geological Survey, University of Lorraine and GFZ German Research Centre for Geosciences. Seismic monitoring is carried out in integrated operation with the University of Helsinki Institute of Seismology.

Main projects in 2019:

- RITA1./01-01. Studies of metallogenesis in graptolite argillite from the Sillamäe region and in the Jõhvi magnetite-quartzite deposit, primary solution for tunnelling in the sedimentary rock section of the Tallinn-Helsingi tunnel;
- EIT RM EUROCORE VA17082. Creation and implementation of educational ore exploration database;
- KIK 15918. Developing methods and guidelines for conversion of particle size distribution data of sand and gravel deposits.

Major publications 2019:


- Järvelill, J.-I., **Kallaste, T.**, Kleesment, A., **Pajusaar, S**., Raukas, A. (2019). Provenance of heavy minerals in the Quaternary deposits of the Lemme outcrop, Estonia, based on optical microscopy, X-ray diffractometry and scanning electron microscope microanalysis. *Estonian Journal of Earth Sciences*, 68, 76−87. DOI:10.3176/earth.2019.07.

- **Kiipli, T.**, **Hints, R.**, **Kallaste, T.**, Nielsen, A.T., **Pajusaar, S.**, Schovsbo, N.H. (2019). Tectono-magmatic division of the Late Ordovician (Sandbian) volcanism at the south-western margin of Baltica using immobile trace elements: Relations to the plate movements in the Iapetus Palaeo-Ocean. *Geological Journal*, 1−11. Published online: 25. December 2019. DOI:10.1002/gj.3737.

- Kiipli, E., **Kiipli, T.** (2020). Hirnantian sea-level changes in the Baltoscandian Basin, a review. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 540, no. 109524. 1-13. Published online: 13. December 2019. DOI:10.1016/j.palaeo.2019.109524.

- Liblik J., Küppers, J., Just, A., Maaten, B., **Pajusaar, S.** (2019) Material properties of clay and lime plaster for structural fire design. *Fire and Materials*, 1-11. Published online: 18 December 2019. DOI:10.1002/fam.2798.

- Martins, J.E., Ruigrok, E., Draganov, D., Hooper, A., Hanssen, R. F.; White, R. S., **Soosalu, H.** (2019). Imaging Torfajökull's Magmatic Plumbing System With Seismic Interferometry and Phase Velocity Surface Wave Tomography. *Journal of Geophysical Research: Solid Earth.* Published online: 19. February 2019. DOI:10.1029/2018JB016002.

## Mäeosakond

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Doktorant: Karin Robam, Andrus Paat, Nthati Monei

Uurimisrühma tegevust iseloomustavad võtmesõnad:

kaevandustehnika; ringmajandus; virtuaalne- ja liitreaalsus

TalTech geoloogia instituudi mäeosakonnale pandi alus 1938. a, kui ülikoolis loodi mäeinseneride koolitamiseks mäeosakond. Ülikooli viimase struktuurireformi käigus liideti 2016. a septembris senine energeetikateaduskonna mäeinstituut omaette osakonnana geoloogia instituudiga. 2019. aastal töötas osakonnas viis doktorikraadiga teadustöötajat/õppejõudu. Mäeosakonna õppejõud annavad olulise panuse „Maapõueressursside" õppekava õpetamisel, seda nii bakalaureuse- kui ka magistritasemel. Osakonna teadustöö toimub peamiselt läbi riiklike, aga ka ettevõtete rahastatud rakendusuuringute projektide. Osakonna tegevusega on tihedalt seotud riiklikult akrediteeritud mäendustingimuste labor, mille kompetentside hulka kuulub muuhulgas maavõngete seismograafiline uurimine, müra mõõdistamised läbi helirõhu taseme mõõtmiste, markšeidermõõtmised, kivimite ja täitematerjalide geomeetriliste omaduste määramine ning purunemiskindluse määramine Los Angeles meetodil jmt.

Mäeosakonna kompetentsi kuulub :

- kaevanduste ja maavarade töötlemise tehnoloogiate projekteerimine;
- ressursitõhususe meetmete ja tehniliste lahenduste leidmine ning hindamine;
- ringmajandusega seotud ettevõtlussuundade arendamine maavarade kontekstis (sh uusettevõtlikkus);
- erialaste täienduskoolituste läbiviimine ja uute valdkondade arendamine koolitustes.

2019. a T&A olulisematest arendusprojektidest väärivad märkimist:

- Markšeideritööde kaugseiremeetodite abil efektiivistamise võimalused (põlevkivikaevandamisel);
- Mehhaniseeritud laavakomplekstist tuleva kaevise rikastamismeetodid;
- Turbaalaste uurimistulemuste digitaliseerimine ja andmebaasi koostamine II etapp (jätkuprojekt);
- Eesti Energia Estonia kaevanduse lubjakivi killustiku ning tuha tehniline sobivus ja majanduslik põhjendatus *Rail Baltic* raudtee muldkeha ja kõrvalteede alusmaterjalina või stabiliseerimiseks;
- Eesti esimese maapõuenädala tegevustes kaasalöömine ja seeläbi maapõuepoliitika korraldamine;
- Maapõueressursside efektiivsemate, keskkonnasõbralikumate ja säästvamate kasutusvõimaluste väljatöötamine;
- Eesti prioriteetsete maapõueressursside (põlevkivi, fosforiit, turvas, metallide toore) väärindamise kriitilised tehnoloogilised, geoloogilised, keskkonna- ja sotsiaalmajanduslikud küsimused ning nende lahendamise võimalused;
- ettevõtlikkus ringmajanduse suunaga integreeritud materjalide töötlemises.

Mäeosakonna dotsent Veiko Karu, kes on Euroopa Tehnoloogia- ja Innovatsiooninstituudi (EIT) teadus- ja innovatsiooni kogukondade teaduskoostöö võrgustiku EIT Raw Materials TalTech poolsete tegevuste koordinaator, algatas ja viis läbi mitmeid maavaratööstuse innovatsiooniga seotud alamprojekte (2019. aastal kokku 23 erinevat projekti):

- Visual3D projekt, mille raames tegeleti kolmemõõtmeliste geoloogiliste visualiseerimismudelite loomise ning analüüsiga;
- VR-MINE projekt, mille raames loodi virtuaalreaalsuse kaevandusprojekt, mida kasutatakse õppetöös uute innovaatiliste kaevandamistehnoloogiate arendamiseks;
- RM@Schools3.0 projekt on kooliõpilastele suunatud maapõuealane projekt;

- ADMA2 on doktoriõppeprogramm, kus doktorandid uurivad ja arendavad uusi tehnikaid ja tehnoloogiaid materjalitehnoloogia valdkonnas.

### Division of Mining

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Doctoral students: Karin Robam, Andrus Paat, Nthati Monei

Keywords: mining engineering; circular economy; virtual and augmented reality

Division of Mining has a long history. The division was established in 1938. In autumn 2016, in the course of structural reformation, the independent Department of Mining was joined to Department of Geology. Nowadays, research and education staff of the Mining Division run research and lecture topics by occupational qualifications system of mining engineering (permissions given by Estonian Qualifications Authority), developing the necessary skill set for mining engineers. In 2018, TalTech elected Michael W. Hitch to tenure track position professor of mining.

The competences of the Division of Mining are in the field of geotechnology and mining engineering, economical evaluation in mineral exploration, mineral processing (design of separation technologies), sustainable use of mineral resources, environmental protection and circular economy in mineral usage. The division is equipped with Laboratory of Mining Conditions and mining related softwares for design and modelling mining works and plans. Laboratory equipment is widely used in education and research projects.

The more prominent R&D projects in 2019 were:

- Find efficient ways to use remote monitoring methods for oil shale mining;
- Methods for enrichment of mechanised lava complex excavation;
- Digitization and database creation of peat research studies in Estonia, phase II (a follow-up project);
- Technical suitability and economic rationale of crushed limestone originating from the Estonia Mine of Eesti Energia and oil-shale ash for the use as a base material or stabilisation agent for the Rail Baltic track bed and side roads;
- Contributing to the first Estonian Raw Materials Week activities;
- Developing more efficient, environmentally friendly and sustainable use of underground resources;
- Upgrading and solving critical technological, geological, environmental and socio-economic issues of Estonia's priority mineral resources (oil shale, phosphate, peat, raw materials of metals);
- Facilitate entrepreneurship for materials processing integrated with circular economy.

Department of Geology is responsible for representing TalTech in EIT Raw Materials network, initiated by the EIT (European Institute of Innovation and Technology) and funded by the European Commission. The network is the largest and strongest consortium in the raw materials sector worldwide. Its vision is the European Union where raw materials are a major strength. TalTech is a core member of EIT Raw Materials. TalTech had partnership in 23 educational and research oriented projects in 2019.

Some significant innovation projects in EIT Raw Materials include:

- Visual3D – a tool to trigger a higher degree of investment in exploration and to ultimately secure the domestic supply of both main commodities and critical raw materials is to enhance our understanding of the Earth’s crust below the surface;
- VR-MINE – the project addresses integrating Virtual Reality into European mining education. The underground environment of VR-Mine will be based on a real tungsten mine in Mittersill (Austria). Application of VR enriches didactic approaches used in raw materials teaching and mining education;

- RM@Schools3.0 is a Wider Society Learning project, focused on an innovative program to make science education and careers in RM attractive for youngsters. An active learning will be proposed to schools by RM Ambassadors by involving students in experiments with RM-related hands-on educational kits, in excursions in industries, and in science dissemination activities.
- ADMA2 develops the doctoral training in the existing Advanced Materials Doctoral Programme (ADMA-DP) to fulfill the quality criteria of the EIT-labelling in doctoral training.

Major publications 2019:


Wang, X.; Ni, W.; Li, J.; Zhang, S.; **Hitch, M.**; Pascual, R. (2019). Carbonation of steel slag and gypsum for building materials and associated reaction mechanisms. Cement and Concrete Research, 125, 105893. https://doi.org/10.1016/j.cemconres.2019.105893.

Li, J.; Jacobs, A. D.; **Hitch, M.** (2019). Direct aqueous carbonation on olivine at a CO2 partial pressure of 6.5 MPa. Energy, 173, 902−910. https://doi.org/10.1016/j.energy.2019.02.125.

Tost, M.; Murguia, D.; **Hitch, M.**; Lutter, S.; Luckeneder, S.; Feiel, S.; Moser, P. (2019). Ecosystem services costs of metal mining and pressures on biomes. The Extractive Industries and Society. https://doi.org/10.1016/j.exis.2019.11.013.

Endl, A.; Tost, M.; **Hitch, M.**; Moser, P.; Feiel, S. (2019). Europe's mining innovation trends and their contribution to the sustainable development goals: Blind spots and strong points. Resources Policy, 101440. https://doi.org/10.1016/j.resourpol.2019.101440.

Gonzalez, F. R.; Raval, S.; Taplin, R.; Timms, W.; **Hitch, M.** (2019). Evaluation of Impact of Potential Extreme Rainfall Events on Mining in Peru. Natural Resources Research, 28 (2), 393−408. https://doi.org/10.1007/s11053-018-9396-1.

Lytle, M.; **Hitch, M.** (2019). Miners and mendicants: A cautionary tale. The Extractive Industries and Society. https://doi.org/10.1016/j.exis.2019.02.005.

Pascual, R.; Román, M.; López-Campos, M.; **Hitch, M.**; Rodovalho, E. (2019). Reducing mining footprint by matching haul fleet demand and route-oriented tire types. Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2019.04.069.

Hagan, A. J.; Tost, M.; Inderwildi, O. R.; **Hitch, M.**; Moser, P. (2019). The license to mine: Making resource wealth work for those who need it most. Resources Policy, 101418. https://doi.org/10.1016/j.resourpol.2019.101418.


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## Kvaternaarigeoloogia osakond


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Doktorandid: Ansis Blaus, Vladimir Karpin

Järeldoktorid: Olga Lisitsyna

Uurimisrühma tegevust iseloomustavad võtmesõnad:

geoökoloogia, keskkonna ja kliima areng, paleomitmekesisus, Läänemeri, kronoloogia

Kvaternaarigeoloogia ja sellega liituvad erialad on olnud geoloogia instituudi üheks oluliseks uurimisvaldkonnaks alates instituudi loomisest. 2019. a on osakonnaga seotud üheksa teadustöötajat, järeldoktor ja kaks doktoranti, teadustegevus toimub peamiselt Eesti Teadusagentuuri uurimistoetuste toel.

Osakonna kõik töötajad osalevad mitmete loengukursuse läbiviimisel "Maapõueressursside" õppekava üliõpilastele.

Töögrupi teadustulemused on pälvinud rahvusvahelise tunnustuse ja on võimaldanud viljakat ühistööd mitmete oma ala maailma juhtivate teaduskollektiividega, pakkudes uudseid lahendusi pärastjääaegse taimestiku, kliima, inimtegevuse ja keskkonnamuutuste vaheliste seoste väljaselgitamisel. Töögrupi arendustöö on avardanud võimalusi koostööks teiste teadusharudega nagu klimatoloogia, ökoloogia ja arheoloogia. Osakonna teadurid publitseerivad oma teaduseriala tippajakirjades nagu *Nature Communications*, *Global Change Biology*, *Quaternary Science Reviews*, *Journal of Quaternary Science*, *Journal of Biogeography* ja *Journal of Vegetation Science*.

Osakonna peamiste uurimissuundade hulka kuuluvad:

- Pärastjääaegse kliima rekonstrueerimine eri analüüsimeetoditega;
- Pärastjääaegse maakatte ja taimestiku rekonstrueerimine;
- Õietolmuandmetepõhised ökoloogilised seosed ja paleomitmekesisus;
- Mineviku maakasutus ning ökosüsteemide kohanemine põllundusliku maakasutuse muutustega;
- Pärastjääaegne jäätaande kronoloogia ja paleogeograafia;
- Läänemere varasemate staadiumite areng ning keskkonnaseisund.

Töörühmal on uurimistööks vajalik uurimiskeskkond: puurimisvarustus, setteproovide külmhoidla, ettevalmistuslaborid proovide eeltöötlemiseks ning biogeokeemiline teadusaparatuurikompleks.
Töögrupp alustas uue projektiga PRG323, mis ühildab interdistsiplinaarse lähenemisviisi kaudu tänapäevastel paleoökoloogistel andmetel põhinevad mineviku taimestiku- ja kliimamuutuste rekonstruktsioonid ja taimestiku modelleerimise, et selgitada bioloogiliste protsesside (ränne ja konkurents) ja abiootiliste tegurite (kliima, toiteainete ja häiringute hulk, inimtegevus) mõju taimestiku dünaamikale hilis- ja pärastjääajal Põhja-Euroopas.

Olulisemad 2019. a teadusprojektid:

- PRG323 "Keskkonnategurite mõju pärastjääaegse taimkatte levikule: paleoökoloogiline rekonstruktsioon ja modelleerimine (TrackLag) (1.01.2019−31.12.2023)"
- LEP19003LG (RITA1/02-60-04) "Eesti mereala keskkonna ja loodusväärtuste hindamise ja seire innovaatilised lahendused (1.01.2019−31.12.2021)"
- MOBJD313 "Kliima ja inimtegevuse mõju Euroopa kirdeosa boreaalsele ökosüsteemile viimase aastatuhande jooksul. (1.12.2019−30.11.2021)"
- PUT1173 "Funktsionaalne ja fülogeneetiline mitmekesisus sette õietolmu ja taimsete makrofossiilide andmetes – metoodika hindamine ning seosed mineviku kliima ja inimmõjuga (1.01.2016−31.12.2020)"
- VA19029 "Pärastjääaegsete keskkonnamuutuste signaalid Eesti ja Poola setteis (30.04.2019−31.03.2021)"
- MOBTP140 "Pärastjääaegsete kliima soojenemisperioodide mõju taimestikule ja veestikule Atlandi ookeani mõlemal kaldal (1.11.2019−31.10.2021)"

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Post-docs: Olga Lisitsyna

Keywords: geoecology, paleoclimate and environment, paleodiversity, Baltic Sea, chronology

Quaternary geology, paleoecology and related research disciplines explaining the current paradigm of actualism in geology, have been one of the principal targets of research at the Department of Geology since the 1950s. At present, the research group comprises of nine researchers, one postdoc and two PhD students, who work in close collaboration as a targeted team, as well as with other groups in the department. We have fruitful collaboration worldwide, notably in US, Russia, Sweden, Finland, Canada, Germany, UK, Netherlands, Switzerland, Latvia, Lithuania and Belarus.

The main research aim of the Quaternary group is reconstruction of past ecosystems, vegetation history, climate and environmental change, both natural and manmade, at high temporal resolution during the last 15,000 years through multidisciplinary and multiproxy studies of natural archives such as lake, bog and marine sediments. The Quaternary is known for rapid climate change, glacial advances and retreats, constant drift of biota between glacial and warm refugia, sea level fall and rise with each period of freezing and thawing. It's also known as the period of the rise of mankind and its progressively increasing impact upon the environment. The group focusses on better understanding the interactions between Quaternary geo- and biosphere processes, in particular, addressing the following:

- Paleoclimate variation using multi-proxy analyses (such as pollen and chironomid based inference models);
- Paleo-biodiversity (terrestrial and aquatic), functional and phylogenetic diversity dynamics and relationships with climate and environmental changes;
- Past human impact upon landscapes, waterbodies, vegetation structure and land-cover;
- Postglacial retreat of the ice sheet;
- Shoreline displacement of the Baltic Sea.

The group holds leading position in Quaternary and palaeoecological studies in the Baltic realm. The main strengths of the group's work are related to the high-resolution paleo-datasets of geographically and climatically constrained area. Results of the studies conducted at the department have been published in leading research journals including Nature Communications, Geology, QSR, Geobiology and Science of the Total Environment.

The group hosts several labs of biostratigraphy, dating, geochemistry, granulometry, and makes use of the department's mass spectrometry lab for stable isotope geochemistry.

Projects in 2019:

- PRG323 "Tracking the time-lags of species response to environmental change using palaeo-proxy data and modelling (TrackLag) (1.01.2019−31.12.2023)
- LEP19003LG (RITA1/02-60-04) "Innovative approaches to monitoring and assessing marine environment and nature values in Estonian sea area (1.01.2019−31.12.2021)
- MOBJD313 "Reconstruction of vegetation dynamic and land-use changes in pristine boreal forest in Northern Ural (Komi republic, Russia) (1.12.2019−30.11.2021)
- PUT1173 "Functional and phylogenetic diversity in sedimentary pollen and plant macrofossil data – evaluation of methods and associations with past climate and human impact (1.01.2016−31.12.2020)"
- VA19029 "Paleoenvironmental changes recorded by Estonian and Polish postglacial sediment (30.04.2019−31.03.2021)"
- MOBTP140 "Lessons of the past climate warming episodes: Changes of the postglacial climate, vegetation and hydrology in both sides of the Atlantic Ocean (1.11.2019−31.10.2021)"

Main results: The personal research funding: Team grant project PRG323 started in 2019, within this and subprojects **15** WoS cited journals papers (ETIS 1.1) were published in 2019.

**Major publications 2019:**

- **Blaus**, A., **Reitalu**, T., **Amon**, L., **Vassiljev**, J., **Alliksaar**, T., **Veski**, S. 2019. From bog to fen: palaeoecological reconstruction of the development of a calcareous spring fen on Saaremaa, Estonia. Vegetation History and Archaeobotany xx, xx-xx. Published online: 17. September 2019. https://doi.org/10.1007/s00334-019-00748-z [WoS IF2018 - 2.482; Rank2018 - Q1/Q2]
- Brown, A., **Poska**, A., Pluskowski, A. 2019. The environmental impact of cultural change: Palynological and quantitative land cover reconstructions for the last two millennia in northern Poland. Quaternary International 522, 38-54. Published online: 14. May 2019. https://doi.org/10.1016/j.quaint.2019.05.014 [WoS IF2018 - 1.952; Rank2018 - Q3]
- Feurdean, A., Vannière, B., Finsinger, W., Warren, D., Connor, S.C., Forrest, M., Liakka, J., Panait, A., Werner, C., Andrič, M., Bobek, P., Carter, V.A., Davis, B., Diaconu, A.-C., Dietze, E., Feeser, I., Florescu, G., Gałka, M., Giesecke, T., Jahns, S., Jamrichová, E., Kajukało, K., Kaplan, J., Karpińska-Kołaczek, M., Kołaczek, P., Kuneš, P., Kupriyanov, D., Lamentowicz, M., Lemmen, C., Magyari, E. K., Marcisz, K., Marinova, E., Niamir, A., Novenko, E., Obremska, M., Pędziszewska, A., Pfeiffer, M., **Poska**, A., Rösch, M., Słowiński, M., Stančikaitė, M., Szal, M., Święta-Musznicka, J., Tanţău, I., Theuerkauf, M., Tonkov, S., Valkó, O., **Vassiljev**, J., **Veski**, S., Vincze, I., Wacnik, A., Wiethold, J., Hickler, T. 2019. Fire risk modulation by long-term dynamics in land cover and dominant forest type in Eastern and Central Europe, Biogeosciences Discussion xx, xx-xx. Discussion started: 13. August 2019. https://doi.org/10.5194/bg-2019-260 [WoS IF2018 - 3.951; Rank2018 - Q1]
- Florescu, G., Brown, K., Carter, V., Kunes, P., **Veski**, S., Feurdean, A. 2019. Holocene rapid climate changes and ice-rafting debris events reflected in high-resolution European charcoal records. Quaternary Science Reviews 222, xx–xx. Published online: 6. September 2019. https://doi.org/10.1016/j.quascirev.2019.105877 [WoS IF2018 - 4.641; Rank2018 - Q1]
- Latałowa, M., Święta-Musznicka, J., Słowiński, M., Pędziszewska, A., Noryśkiewicz, A.M., Zimny, M., Obremska, M., Ott, F., **Stivrins**, N., Pasanen, L., Ilvonen, L., Holmström, L., Seppä, H. 2019. Abrupt Alnus population decline at the end of the first millennium CE in Europe – The event ecology, possible causes and implications. The Holocene 29, 1335-1349. Published online: 6. May 2019. **https://doi.org/10.1177/0959683619846978** [WoS IF2018 - 2.547; Rank2018 - Q2/Q3]
- **Liiv**, M., **Alliksaar**, T., **Amon**, L., Freiberg, R., **Heinsalu**, A., **Reitalu**, T., Saarse, L., Seppä, H., **Stivrins**, N., Tõnno, I., **Vassiljev**, J., **Veski**, S. 2019. Late glacial and early Holocene climate and environmental changes in the eastern Baltic area inferred from sediment C/N ratio. Journal of Paleolimnology 61, 1-16. Published online: 28. June 2018. https://doi.org/10.1007/s10933-018-0041-0 [WoS IF2018 - 2.009; Rank2018 – Q2/Q3]
- **Reitalu**, T., Bjune, A.E., **Blaus**, A., Giesecke, T., Helm, A., Matthias, I., Peglar, S.S., Salonen, S.J., Seppä, H., Väli, V., Birks, H.J.B. 2019. Patterns of modern pollen and plant richness across northern Europe. Journal of Ecology 107, 1662-1677. Published online: 21. January 2019. https://doi.org/10.1111/1365-2745.13134 [WoS IF2018 - 5.687; Rank2018 - Q1]
- **Stivrins**, N., Aakala, T., Ilvonen, L., Pasanen, L., Kuuluvainen, T., Vasander, H., Gałka, M., Disbrey, H.R., Liepins, J., Holmström, L., Seppä, H. 2019. Integrating fire-scar, charcoal and fungal spore data to study fire events in the boreal forest of northern Europe. The Holocene 29, 1480-1490. Published online: 11. June 2019. https://doi.org/10.1177/0959683619854524 [WoS IF2018 - 2.547; Rank2018 - Q2/Q3]
- **Stivrins**, N., **Liiv**, M., Brown, A., Banerjea, R.Y., **Heinsalu**, A., **Veski**, S. 2019. Investigating the impact of anthropogenic land use on a hemiboreal lake ecosystem using carbon/nitrogen ratios and coupled-optical emission spectroscopy. Palaeogeography, Palaeoclimatology, Palaeoecology 518, 1-9. Published online: 7. January 2019. https://doi.org/10.1016/j.palaeo.2019.01.007 [WoS IF2018 - 2.616; Rank2018 - Q1/Q2]
- **Stivrins**, N., Cerina, A., Gałka, M., **Heinsalu**, A., Lõugas, L.,**Veski**, S. 2019. Large herbivore population and vegetation dynamics 14600–8300 years ago in central Latvia, northeastern Europe. Review of

Palaeobotany and Palynology 266, 42-51. Published online: 17. April 2019. https://doi.org/10.1016/j.revpalbo.2019.04.005 [WoS IF2018 - 1.674; Rank2018 - Q2]

- Tõnno, I., Nauts, K., Belle, S., Nõmm, M., Freiberg, R., Kõiv, T., **Alliksaar**, T. 2019. Holocene shifts in the primary producer community of large, shallow European Lake Peipsi, inferred from sediment pigment analysis. Journal of Paleolimnology 61, 403-417. Published online: 24. January 2019. https://doi.org/10.1007/s10933-019-00067-3 [WoS IF2018 - 2.009; Rank2018 - Q2/Q3]
- Veski, R., **Veski**, S. 2019. Aliphatic dicarboxylic acids from oil shale organic matter – historic review. Oil Shale 36, 76-95. https://doi.org/10.3176/oil.2019.1.06 [WoS IF2018 - 1.041; Rank2018 - Q3/Q4]
- **Amon**, L., **Blaus**, A., **Alliksaar**, T., **Heinsalu**, A., Lapshina, E., **Liiv**, M., **Reitalu**, T., **Vassiljev**, J., **Veski**, S. 2020. Postglacial flooding and vegetation history on the Ob River terrace, central Western Siberia based on the palaeoecological record from Lake Svetlenkoye. The Holocene 30, xx-xx. Published online: 5. January 2020. DOI:10.1177/0959683619895582 [WoS IF2018 - 2.547; Rank2018 - Q2/Q3]
- Jeliazkov, A., Mijatovic, D., Chantepie, S. *et al.* A global database for metacommunity ecology, integrating species, traits, environment and space. *Sci Data* **7,** 6 (2020) doi:10.1038/s41597-019-0344-7 (**Reitalu**)
- Pirzamanbein, B., **Poska**, A., & Lindström, J. (2020). Bayesian reconstruction of past land cover from pollen data: Model robustness and sensitivity to auxiliary variables. Earth and Science, 7, e2018EA00057. https://doi.org/10.1029/2018EA000547.

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## EIT Raw Materials koostöövõrgustik TalTech'is

Uurimisrühma juht: dotsent VEIKO KARU, veiko.karu@taltech.ee
Liikmed: professor Michael Hitch, Andrus Paat, Karin Käär, Tõnis Liibek, Andres Trikkel, Rutt Hints

TalTech oli kaasatud konsortiumi, kes võitis õiguse luua *EIT Raw Materials*, mis tegevusega alustas juba 2015. aastal, kuid esimesed projektid algasid alles 01.01.2016. Hetkel kuulub *EIT Raw Material*si umbes 130 põhipartnerit ning 190 projektipartnerit. Võrgustiku liikmed jagunevad võrdeliselt ülikoolideks, iseseisvateks teadusasutusteks ja ettevõteteks. *EIT Raw Materials* on jagunenud kuueks piirkonnaks. TalTech kuulub *Baltic Sea Innovation Hub* alla, kuhu kuuluvad partnerid Soomest, Lõuna-Rootsist ning Baltimaadest. Kuni 2018 aastani oli TalTech ainus asutus Baltimaadest, nüüdseks on partnereid lisandunud Lätist ja Leedust ning loodud *RIS HUB Baltic* (Riia Tehnikaülikool; TalTech; Kaunase Tehnikaülikool).

Partnerlus: Soome on tuntud oma suure mineraalse toorme uurimise ja kaevandamise poolest, samuti Rootsi. *Baltic Sea Innovation Hub* piirkonnas on esindatud suured mäetööstusettevõtted (Sandvik, Metso, Outotec jt) koos juhtivate piirkonna ülikoolidega (KTH, Aalto, TalTech jt). TalTechi osalemine võrgustikus *EIT Raw Materials* on andnud võimaluse koostööks just nende tööstus- ja ülikoolieliidiga, suunata ja arendada vastavat tööstust edukamaks ja veel rohkem kaasaegsemaks läbi mitmete erinevate projektide ja koostöövormide. Ilma võrgustikku kuulumata oleks TalTechi parimate teadmiste tutvustamisel ning heade projektiideede algatamisel koostöös piirkonna ja laiemalt üle Euroopa EIT Raw Materialsi konsortsiumi kuuluvate partneritega väga piiratud võimalus. Konsortsiumis osalemiseks on vajalik partnerite liikmemaksu maksmine, mis on *Core Partner*ile 100 kEUR/aastas ja *Associate Partner*ile 30 kEUR/aastas, alates 2018. aastast on võimalus olla *Project Partner* ja liikmemaks alates 2020. aastast on 10 kEUR/aastas. *Core Partner*il ei ole aastast eelarvepiirangut. *Associate Partner*i aastane eelarvepiirang on 300 kEUR/aastas ja *Project Partner*il 100 kEUR/aastas.

Alates 01.01.2018 on TalTech *EIT Raw Material*si *Core Partner*.

**Sisulise koostöö areng:** Kui 2016. aastal alustas TalTech viie ühise projektiga, siis 2017. aastal oli neid projekte juba 14. 2018. aastal oli TalTech kaasatud 19nesse projekti ning 2019. aastal on projektide koguarvuks 23.

Pannes need projektid ja tegevused rahalisse vääringusse, näeme järgmist tulemit: Tabel 1 EIT RawMaterials projektid, aasta eelarve ja liikmemaks.

*Tabel 1 EIT RawMaterials projektid, aasta eelarve ja liikmemaks*

| | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|
| Projektid | 5 | 14 | 19 | 23 | 24 | 17 | 3 |
| Aastaeelarve | 30 386 | 141 641 | 480 962 | 488 085 | 760 942 | 669 593 | 100 143 |
| Liikmemaks | 30 000 | 30 000 | 100 000 | 100 000 | 100 000 | 100 000 | 100 000 |

NB! Aastad 2021 ja 2022 on ilma uute taotlusvoorudeta.

**Tulevik:** Projektide raames on mitmed ülikoolide, teadusasutuste ja ettevõtete esindajad käinud TalTechi kampuses ning tutvunud meie infrastruktuuri ja võimalustega, mis on rajanud tee nii mõnegi täiendava teadustaotluse (*INTERREG*; Horisont 2020) ja isegi rahastuseni. Seega on väga hea olla *EIT Raw Material*si ja sealsetele partnerite koostööpartner ning seda tegevust on võimalik jätkata ja koos teiste EIT KIC võrgustikega arendada samuti valdkondade ja KICide üleseid teadus-, õppe- ja ühiskonnateemasid.

### TalTech EIT Raw Materials Team

Head: Associated Professor VEIKO KARU, veiko.karu@taltech.ee
Members: Professor Michael Hitch, Andrus Paat, Karin Käär, Tõnis Liibek, Andres Trikkel, Rutt Hints

TalTech was the founding member of the EIT Raw Materials in 2015. First projects started in 2016. EIT Raw Materials have six different Innovation sub-hubs and many RIS-related hub's. TalTech is part of the Baltic Sea Innovation Hub, where we have partners from Finland, south Sweden and the Baltic countries. Until 2018, TalTech was the only member from the Baltic countries. In 2019, together with Riga Technical University and Kaunas University of Technology the RIS HUB Baltic was founded to attract innovation activities in the Baltic countries, physically the RIS HUB is located in Riga, Latvia.

TalTech activities and responsibilities have gradually grown (Table 1). In 2016, we started with only 5 projects and in 2019 we were part of 23 different projects and activities. Since 2018, TalTech is a Core Member of the EIT Raw Materials. In 2019, TalTech tenure-track professor Michael W. Hitch was elected as Executive Board Member from the Baltic Sea Innovation Hub to represent partners from the area.

In 2019, a TalTech-related start-up called Mining Sandbox AR was awarded the Third prize in the EIT Jumpstarter competition.

*Table 1. EIT RawMaterials projects, annual budgets and membership fees*

| | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|
| Projects | 5 | 14 | 19 | 23 | 24 | 17 | 3 |
| Annual budget | 30,386 | 141,641 | 480,962 | 488,085 | 760,942 | 669,593 | 100,143 |
| Membership | 30,000 | 30,000 | 100,000 | 100,000 | 100,000 | 100,000 | 100,000 |

NB! Year 2021 and 2022 is without the Project call.

### Geoloogia instituudi 2019. a teadusartiklid (1.1 kategooria)

1) Ausich, W.I., Wilson, M.A., **Toom**, U. 2019. Early Silurian recovery of Baltica crinoids following the end-Ordovician extinctions (Llandovery, Estonia). *Journal of Paleontology* **xx**, xx-xx. Published online: 12. November 2019. https://doi.org/10.1017/jpa.2019.89 [WoS $IF_{2018}$ - 1.584; $Rank_{2018}$ - Q2]

2) Balthasar, U., Jin, J., **Hints**, L., Cusack, M. 2019. Brachiopod shell thickness links environment and evolution. *Palaeontology* **xx**, xx-xx. Published online: 15. October 2019. https://doi.org/10.1111/pala.12450 [WoS $IF_{2018}$ - 2.632; $Rank_{2018}$ - Q1]

3) Birski, Ł., Słaby, E., Wirth, R., Koch-Müller, M., Simon. K., Wudarska, A., Götze, J., **Lepland**, A., Hofmann, A., Kuras, A. 2019. Archaean phosphates: a case study of transformation processes in apatite from the Barberton greenstone belt. *Contributions to Mineralogy and Petrology* **174**, 25. Published online: 09. March 2019. https://doi.org/10.1007/s00410-019-1560-z [WoS $IF_{2018}$ - 3.230; $Rank_{2018}$ - Q2]

4) **Blaus**, A., **Reitalu**, T., **Amon**, L., **Vassiljev**, J., **Alliksaar**, T., **Veski**, S. 2019. From bog to fen: palaeoecological reconstruction of the development of a calcareous spring fen on Saaremaa, Estonia. *Vegetation History and Archaeobotany* **xx**, xx-xx. Published online: 17. September 2019. https://doi.org/10.1007/s00334-019-00748-z [WoS $IF_{2018}$ - 2.482; $Rank_{2018}$ - Q1/Q2]

5) Bowman, C.N., Young, S.A., **Kaljo**, D., Eriksson, M.E., Them, II, T.R., **Hints**, O., **Martma**, T., Owens, J.D. 2019. Linking the progressive expansion of reducing conditions to a stepwise mass extinction event in the late Silurian oceans. *Geology* **47**, 968-972. Published online: 30. August 2019. https://doi.org/10.1130/G46571.1 [WoS $IF_{2018}$ - 5.006; $Rank_{2018}$ - Q1]

6) Bremer, O., Jarochowska, E., **Märss**, T. 2019. Vertebrate remains and conodonts in the upper Silurian Hamra and Sundre formations of Gotland, Sweden. *GFF* **141**, xx-xx. Published online: 27. September 2019. https://doi.org/10.1080/11035897.2019.1655790 [WoS $IF_{2018}$ - 1.076; $Rank_{2018}$ - Q3]

7) Brown, A., **Poska**, A., Pluskowski, A. 2019. The environmental impact of cultural change: Palynological and quantitative land cover reconstructions for the last two millennia in northern Poland. *Quaternary International* **522**, 38-54. Published online: 14. May 2019. https://doi.org/10.1016/j.quaint.2019.05.014 [WoS $IF_{2018}$ - 1.952; $Rank_{2018}$ - Q3]

8) **Chen**, Z.-Y., **Männik**, P., Wang, X., Li, C., Wang, J. 2019. First documentation of Llandovery (Silurian) conodont genus *Astropentagnathus* in China (Langao, Shaanxi Province) and the age of Baiyaya Formation. *Palaeoworld* **xx**, xx-xx. Published online: 29. November 2019. https://doi.org/10.1016/j.palwor.2019.11.002 [WoS $IF_{2018}$ - 1.142; $Rank_{2018}$ - Q3]

9) Cole, S.R., **Toom**, U. 2019. New camerate crinoid genera from the Upper Ordovician (Katian) of Estonia: evolutionary origin of family Opsiocrinidae and a phylogenetic assessment of Ordovician Monobathrida. *Journal of Systematic Palaeontology* **17**, 597-611. Published online: 27. March 2018. https://doi.org/10.1080/14772019.2018.1447519 [WoS $IF_{2018}$ - 2.315; $Rank_{2018}$ - Q1/Q3]

10) Deev, E., Turova, I., Borodovskiy, A., Zolnikov, I., Pozdnyakova, N., **Molodkov**, A. 2019. Large earthquakes in the Katun Fault zone (Gorny Altai): Paleoseismological and archaeoseismological evidence. *Quaternary Science Reviews* **203**, 68−89. Published online: 19. November 2018. https://doi.org/10.1016/j.quascirev.2018.11.009 [WoS $IF_{2018}$ - 4.641; $Rank_{2018}$ - Q1]

11) Endl, A., Tost, M., **Hitch**, M., Moser, P., Feiel, S. 2019. Europe's mining innovation trends and their contribution to the sustainable development goals: Blind spots and strong points. *Resources Policy* **xx**, xx-xx. Published online: 10. July 2019. https://doi.org/10.1016/j.resourpol.2019.101440 [WoS $IF_{2018}$ - 3.185; $Rank_{2018}$ - Q2]

12) Feurdean, A., Vannière, B., Finsinger, W., Warren, D., Connor, S.C., Forrest, M., Liakka, J., Panait, A., Werner, C., Andrič, M., Bobek, P., Carter, V.A., Davis, B., Diaconu, A.-C., Dietze, E., Feeser, I., Florescu, G., Gałka, M., Giesecke, T., Jahns, S., Jamrichová, E., Kajukało, K., Kaplan, J., Karpińska-Kołaczek, M., Kołaczek, P., Kuneš, P., Kupriyanov, D., Lamentowicz, M., Lemmen, C., Magyari, E. K., Marcisz, K., Marinova, E., Niamir, A., Novenko, E., Obremska, M., Pędziszewska, A., Pfeiffer, M., **Poska**, A., Rösch, M., Słowiński, M., Stančikaitė, M., Szal, M., Święta-Musznicka, J., Tanţău, I., Theuerkauf, M., Tonkov, S., Valkó, O., **Vassiljev**, J., **Veski**, S., Vincze, I., Wacnik, A., Wiethold, J., Hickler, T. 2019. Fire risk modulation by long-term dynamics in land cover and dominant forest type in Eastern and Central Europe, *Biogeosciences Discussion* **xx**, xx-xx. Discussion started: 13. August 2019. https://doi.org/10.5194/bg-2019-260 [WoS $IF_{2018}$ - 3.951; $Rank_{2018}$ - Q1]

13) Florescu, G., Brown, K., Carter, V., Kunes, P., **Veski**, S., Feurdean, A. 2019. Holocene rapid climate changes and ice-rafting debris events reflected in high-resolution European charcoal records. *Quaternary Science Reviews* **222**, xx-xx. Published online: 6. September 2019. https://doi.org/10.1016/j.quascirev.2019.105877 [WoS $IF_{2018}$ - 4.641; $Rank_{2018}$ - Q1]

14) Hagan, A., Tost, M., Inderwildi, O., **Hitch**, M., Moser, P. 2019. The license to mine making resource wealth work for those who need it most. *Resources Policy* **xx**, xx-xx. Published online: 16. June 2019. https://doi.org/10.1016/j.resourpol.2019.101418 [WoS $IF_{2018}$ - 3.185; $Rank_{2018}$ - Q2]

15) Himmler, T., Sahy, D., **Martma**, T., Bohrmann, G., Plaza-Faverola, A., Bünz, S., Condon, D.J., Knies, J., **Lepland**, A. 2019. A 160,000-year-old history of tectonically controlled methane seepage in the Arctic. *Science Advances* **5**, eaaw1450. Published online: 07. August 2019. DOI: 10.1126/sciadv.aaw1450 [WoS $IF_{2018}$ - 12.804; $Rank_{2018}$ - Q1]

16) **Hints**, L. 2019. The Ordovician brachiopod genus *Cyrtonotella*: taxonomy and distribution in the Baltic Basin. Estonian *Journal of Earth Sciences* **68**, 147-159. Published online: 12. August 2019. https://doi.org/10.3176/earth.2019.10 [WoS $IF_{2018}$ - 0.825; $Rank_{2018}$ - Q4]

17) Hong, W.-L., **Lepland**, A., Himmler, T., Kim, J.-H., Chand, S., Sahy, D., Solomon, E.A., Rae, J.W.B., **Martma**, T., Nam, S.-I., Knies, J. 2019. Discharge of meteoric water in the eastern Norwegian Sea since the last glacial period. *Geophysical Research Letters* **46**, 8194-8204. Published online: 03. July 2019. https://doi.org/10.1029/2019GL084237 [WoS $IF_{2018}$ - 4.578; $Rank_{2018}$ - Q1]

18) Järvelill, J.-I., **Kallaste**, T., **Kleesment**, A., **Pajusaar**, S., Raukas, A. 2019. Provenance of heavy minerals in the Quaternary deposits of the Lemme outcrop, Estonia, based on optical microscopy, X-ray diffractometry and scanning electron microscope microanalysis. *Estonian Journal of Earth Sciences* **68**, 76-87. Published online: 07. May 2019. https://doi.org/10.3176/earth.2019.07 [WoS $IF_{2018}$ - 0.825; $Rank_{2018}$ - Q4]

19) **Kiipli**, E., **Kiipli**, T., 2019. Hirnantian sea-level changes in the Baltoscandian Basin, a review. *Palaeogeography, Palaeoclimatology, Palaeoecology* **xx**, xx-xx. Published online: 13. December 2019. https://doi.org/10.1016/j.palaeo.2019.109524 [WoS $IF_{2018}$ - 2.616; $Rank_{2018}$ - Q1/Q2]

20) Koit, O., Barberá, J.A., Marandi, A., Terasmaa, J., Kiivit, I.-K., **Martma**, T. 2019. Spatiotemporal assessment of humic substance-rich stream and shallow karst aquifer interactions in a boreal catchment of northern Estonia. *Journal of Hydrology* **xx**, xx-xx. Published online: 19. October 2019. https://doi.org/10.1016/j.jhydrol.2019.124238 [WoS $IF_{2018}$ - 4.405; $Rank_{2018}$ - Q1]

21) Korsakova, O., **Molodkov**, A., Yelovicheva, Y., Kolka, V. 2019. Middle Pleistocene marine deposits on the Kola Peninsula (NW Russia). *Quaternary International* **509**, 3-16. Published online: 16. September 2018. https://doi.org/10.1016/j.quaint.2018.09.019 [WoS $IF_{2018}$ - 1.952; $Rank_{2018}$ - Q3]

22) Latałowa, M., Święta-Musznicka, J., Słowiński, M., Pędziszewska, A., Noryśkiewicz, A.M., Zimny, M., Obremska, M., Ott, F., **Stivrins**, N., Pasanen, L., Ilvonen, L., Holmström, L., Seppä, H. 2019. Abrupt *Alnus* population decline at the end of the first millennium CE in Europe – The event ecology, possible causes and implications. *The Holocene* **29**, 1335-1349. Published online: 6. May 2019. https://doi.org/10.1177/0959683619846978 [WoS $IF_{2018}$ - 2.547; $Rank_{2018}$ - Q2/Q3]

23) Li, J., Jacobs, A.D., **Hitch**, M. 2019. Direct aqueous carbonation on olivine at a $CO_2$ partial pressure of 6.5 MPa. *Energy* **173**, 902-910. Published online: 18. February 2019. https://doi.org/10.1016/j.energy.2019.02.125 [WoS $IF_{2018}$ - 5.537; $Rank_{2018}$ - Q1]

24) **Liang**, Y., Bernardo, J., Goldman, D., **Nõlvak**, J., Tang, P., Wang, W., **Hints**, O. 2019. Morphological variation suggests that chitinozoans may be fossils of individual microorganisms rather than metazoan eggs. *Proceedings of the Royal Society B, Biological Sciences* **286**, 20191270. Published online: 31. July 2019. http://dx.doi.org/10.1098/rspb.2019.1270 [WoS $IF_{2018}$ - 4.304; $Rank_{2018}$ - Q1]

25) **Liang**, Y., **Hints**, O., Servais, T., Luan, X.C., **Nõlvak**, J., Tang, P., Wu, R.-C. 2019. Palaeoenvironmental and biostratigraphical implications of selected Floian and Dapingian (Ordovician) chitinozoans of the South

China Palaeoplate. *Lethaia* **52**, 220-231. Published online: 28. September 2018. https://doi.org/10.1111/let.12308 [WoS $IF_{2018}$ - 1.736; $Rank_{2018}$ - Q1]

26) **Liang**, Y., Wang, G.-X., Servais, T., Wu, R.-C., **Nõlvak**, J., **Hints**, O., Wei, X., Gong, F.-Y., Yan, G.-Z. 2019. Age constraints of the Hungshihyen Formation (Early to Middle Ordovician) on the western margin of the Yangtze Platform, South China: New insights from chitinozoans. *Palaeoworld* **xx**, xx-xx. Published online: 12. June 2019. https://doi.org/10.1016/j.palwor.2019.05.008 [WoS $IF_{2018}$ - 1.142; $Rank_{2018}$ - Q3]

27) Liblik J., Küppers J., Just A., Maaten B., **Pajusaar** S. 2019. Material properties of clay and lime plaster for structural fire design. *Fire and Materials* **xx**, xx-xx. Published online: 18. December 2019. https://doi.org/10.1002/fam.2798 [WoS $IF_{2018}$ - 1.173; $Rank_{2018}$ - Q4]

28) **Liiv**, M., **Alliksaar**, T., **Amon**, L., Freiberg, R., **Heinsalu**, A., **Reitalu**, T., **Saarse**, L., Seppä, H., **Stivrins**, N., Tõnno, I., **Vassiljev**, J., **Veski**, S. 2019. Late glacial and early Holocene climate and environmental changes in the eastern Baltic area inferred from sediment C/N ratio. *Journal of Paleolimnology* **61**, 1-16. Published online: 28. June 2018. https://doi.org/10.1007/s10933-018-0041-0 [WoS $IF_{2018}$ - 2.009; $Rank_{2018}$ – Q2/Q3]

29) Lytle, M., **Hitch**, M. 2019. Miners and mendicants: A cautionary tale. *The Extractive Industries and Society* **6**, 498-503. Published online: 20. March 2019. https://doi.org/10.1016/j.exis.2019.02.005 [WoS $IF_{2018}$ - 2.064; $Rank_{2018}$ - Q3] Scopus

30) Mekki, F., Zhang, L.-J., Vinn, O., **Toom**, U., Benyoucef, M., Bendella, M., Bouchemla, E., Bensalah, M., Adaci, M. 2019. Middle Jurassic *Zoophycos* and *Chondrites* from the Mélah Formation of Saharan Atlas, Algeria. *Estonian Journal of Earth Sciences* **68**, 190−198. Published online: 17. October 2019. https://doi.org/10.3176/earth.2019.13 [WoS $IF_{2018}$ - 0.825; $Rank_{2018}$ - Q4]

31) **Märss**, T. 2019. Silurian cyathaspidid heterostracans of Northern Eurasia. Estonian *Journal of Earth Sciences* **68**, 113-146. Published online: 13. August 2019. https://doi.org/10.3176/earth.2019.11 [WoS $IF_{2018}$ - 0.825; $Rank_{2018}$ - Q4]

32) **Molodkov**, A. 2019. The Late Pleistocene palaeoenvironmental evolution in Northern Eurasia through the prism of the mollusc shell-based ESR dating evidence. *Quaternary International* **xx**, x-x. Published online: 29. May 2019. https://doi.org/10.1016/j.quaint.2019.05.031 [WoS $IF_{2018}$ - 1.952; $Rank_{2018}$ - Q3]

33) **Nõlvak**, J., **Liang**, Y., **Hints**, O. 2019. Early diversification of Ordovician chitinozoans on Baltica: New data from the Jägala waterfall section, northern Estonia. *Palaeogeography, Palaeoclimatology, Palaeoecology* **525**, 14-24. Published online: 4. April 2019. https://doi.org/10.1016/j.palaeo.2019.04.002 [WoS $IF_{2018}$ - 2.616; $Rank_{2018}$ - Q1/Q2]

34) **Pärn**, J., Walraevens, K., van Camp, M., **Raidla**, V., Aeschbach, W., Friedrich, R., **Ivask**, J., **Kaup**, E., **Martma**, T., Mažeika, J., Mokrik, R., Weissbach, T., **Vaikmäe**, R. 2019. Dating of glacial palaeogroundwater in the Ordovician-Cambrian aquifer system, northern Baltic Artesian Basin. *Applied Geochemistry* **102**, 64-76. Published online: 15. January 2019. https://doi.org/10.1016/j.apgeochem.2019.01.004 [WoS $IF_{2018}$ - 2.894; $Rank_{2018}$ - Q2]

35) Pascual, R., Román, M., López-Campos, M., **Hitch**, M., Rodovalho, E. 2019. Reducing mining footprint by matching haul fleet demand and route-oriented tire types. *Journal of Cleaner Production* **xx**, xx-xx. Published online: 22. April 2019. https://doi.org/10.1016/j.jclepro.2019.04.069 [WoS $IF_{2018}$ - 6.395; $Rank_{2018}$ - Q1]

36) Pirzamanbein, B., **Poska**, A., Lindström, J. 2019. Bayesian reconstruction of past land cover from pollen data: Model robustness and sensitivity to auxiliary variables. *Earth and Space Science* **xx**, xx-xx. Published online: 06. December 2019. https://doi.org/10. 1029/2018EA000547 [WoS $IF_{2018}$ - 2.152; $Rank_{2018}$ - Q2/Q3]

37) Pohle, A., Klug, C., **Toom**, U., Kröger, B. 2019. Conch structures, soft-tissue imprints and taphonomy of the Middle Ordovician cephalopod *Tragoceras falcatum* from Estonia. *Fossil Imprint* **75**, 70-78. Published online: 28. September 2019. DOI:10.2478/if-2019-0006 Scopus

38) Popov, L.E. Álvaro, J.J., Holmer, L.E., **Bauert**, H., Pour, M.G., Dronov, A.V., Lehnert, O., **Hints**, O., **Männik**, P., Zhang, Z., Zhang, Z. 2019. Glendonite occurrences in the Tremadocian of Baltica: first Early Palaeozoic evidence of massive ikaite precipitation at temperate latitudes. *Scientific Reports* **9**, 7205. Published online: 10. May 2019. https://doi.org/10.1038/s41598-019-43707-4 [WoS $IF_{2018}$ - 4.011; $Rank_{2018}$ - Q1]

39) Raidla, V., **Kaup**, E., Hade, S., **Ivask**, J., Soesoo, A. 2019. Geochemical processes controlling ionic composition of water in the catchments of lakes Saana and Saanalampi in the Kilpisjärvi area of north Scandinavia. *Geosciences* **9**, 174. Published online: 16. April 2019. https://doi.org/10.3390/geosciences9040174 [WoS $IF_{2018}$ - NA; $Rank_{2018}$ - NA]

40) Raidla, V., **Pärn**, J., Aeschbach, W., Czuppon, G., **Ivask**, J., Kiisk, M., Mokrik, R., Samalavičius, V., Suursoo, S., Tarros, S., Weißbach, T. 2019. Intrusion of saline water into a coastal aquifer containing palaeogroundwater in the Viimsi Peninsula in Estonia. *Geosciences* **9**, 47. Published online: 17. January 2019. https://doi.org/10.3390/geosciences9010047 [WoS $IF_{2018}$ - NA; $Rank_{2018}$ - NA]

41) **Raidla**, V., **Pärn**, J., Schloemer, S., Aeschbach, W., Czuppon, G., **Ivask**, J., Marandi, A., Sepp, H., **Vaikmäe**, R., Kirsimäe, K. 2019. Origin and formation of methane in groundwater of glacial origin from the Cambrian-Vendian aquifer system in Estonia. *Geochimica et Cosmochimica Acta* **251**, 247-264. Published online: 21. February 2019. https://doi.org/10.1016/j.gca.2019.02.029 [WoS $IF_{2018}$ - 4.258; $Rank_{2018}$ - Q1]

42) **Reitalu**, T., Bjune, A.E., **Blaus**, A., Giesecke, T., Helm, A., Matthias, I., Peglar, S.S., Salonen, S.J., Seppä, H., Väli, V., Birks, H.J.B. 2019. Patterns of modern pollen and plant richness across northern Europe. *Journal of Ecology* **107**, 1662-1677. Published online: 21. January 2019. https://doi.org/10.1111/1365-2745.13134 [WoS $IF_{2018}$ - 5.687; $Rank_{2018}$ - Q1]

43) Richardson, J.A., Keating, C., **Lepland**, A., **Hints**, O., Bradley, A.S., Fike, D.A. 2019. Silurian records of carbon and sulfur cycling from Estonia: The importance of depositional environment on isotopic trends. *Earth and Planetary Science Letters* **512**, 71-82. https://doi.org/10.1016/j.epsl.2019.01.055 [WoS $IF_{2018}$ - 4.637; $Rank_{2018}$ - Q1]

44) Siveter, D.J., Tanaka, G., Williams, M., **Männik**, P. 2019. Japan's earliest ostracods. *Island Arc* **28**, e12284. Published online: 09. November 2018. https://doi.org/10.1111/iar.12284 [WoS $IF_{2018}$ - 0.893; $Rank_{2018}$ - Q4]

45) Sokołowski, R.J., Janowski L., Hrynowieck, A., **Molodkov**, A. 2019. Evolution of fluvial system during the Pleistocene warm stage (Marine Isotope Stage 7) – A case study from the Błądzikowo Formation, N Poland. *Quaternary International* **501**, 109-119. Published online: 4. October 2017. https://doi.org/10.1016/j.quaint.2017.09.042 [WoS $IF_{2018}$ - 1.952; $Rank_{2018}$ - Q3]

46) **Stivrins**, N., Aakala, T., Ilvonen, L., Pasanen, L., Kuuluvainen, T., Vasander, H., Gałka, M., Disbrey, H.R., Liepins, J., Holmström, L., Seppä, H. 2019. Integrating fire-scar, charcoal and fungal spore data to study fire events in the boreal forest of northern Europe. *The Holocene* **29**, 1480-1490. Published online: 11. June 2019. https://doi.org/10.1177/0959683619854524 [WoS $IF_{2018}$ - 2.547; $Rank_{2018}$ - Q2/Q3]

47) **Stivrins**, N., **Liiv**, M., Brown, A., Banerjea, R.Y., **Heinsalu**, A., **Veski**, S. 2019. Investigating the impact of anthropogenic land use on a hemiboreal lake ecosystem using carbon/nitrogen ratios and coupled-optical emission spectroscopy. *Palaeogeography, Palaeoclimatology, Palaeoecology* **518**, 1-9. Published online: 7. January 2019. https://doi.org/10.1016/j.palaeo.2019.01.007 [WoS $IF_{2018}$ - 2.616; $Rank_{2018}$ - Q1/Q2]

48) **Stivrins**, N., Cerina, A., Gałka, M., **Heinsalu**, A., Lõugas, L.,**Veski**, S. 2019. Large herbivore population and vegetation dynamics 14600–8300 years ago in central Latvia, northeastern Europe. *Review of Palaeobotany and Palynology* **266**, 42-51. Published online: 17. April 2019. https://doi.org/10.1016/j.revpalbo.2019.04.005 [WoS $IF_{2018}$ - 1.674; $Rank_{2018}$ - Q2]

49) Tonarová, P., Vodrážková, S., **Hints**, O., **Männik**, P., Kubajko, M., Frýda, J. 2019. Llandovery microfossils and microfacies of the Hýskov section, Prague Basin. *Fossil Imprint* **75**, 25-43. Published online: 28. September 2019. DOI:10.2478/if-2019-0002 Scopus

50) Tõnno, I., Nauts, K., Belle, S., Nõmm, M., Freiberg, R., Kõiv, T., **Alliksaar**, T. 2019. Holocene shifts in the primary producer community of large, shallow European Lake Peipsi, inferred from sediment pigment analysis. *Journal of Paleolimnology* **61**, 403-417. Published online: 24. January 2019. https://doi.org/10.1007/s10933-019-00067-3 [WoS $IF_{2018}$ - 2.009; $Rank_{2018}$ - Q2/Q3]

51) **Toom**, U., Vinn, O., **Hints**, O. 2019. Ordovician and Silurian ichnofossils from carbonate facies in Estonia: a collection-based review. *Palaeoworld* **28**, 123-144. Published online: 17. July 2018. https://doi.org/10.1016/j.palwor.2018.07.001 [WoS $IF_{2018}$ - 1.142; $Rank_{2018}$ - Q3]

52) **Toom**, U., Vinn, O., Isakar, M., Madison, A., **Hints**, O. 2019. Small faecal pellets in Ordovician shelly fossils from Estonia, Baltoscandia. *Estonian Journal of Earth Sciences* **xx**, xx-xx. Published online: 19. December 2019. https://doi.org/10.3176/earth.2020.01 [WoS $IF_{2018}$ - 0.825; $Rank_{2018}$ - Q4]

53) Tost, M., Murguia, D., **Hitch**, M., Lutter, S., Luckeneder, S., Feiel, S., Moser, P. 2019. Ecosystem services costs of metal mining and pressures on biomes. *The Extractive Industries and Society* **xx**, xx-xx. Published online: 24. December 2019. https://doi.org/10.1016/j.exis.2019.11.013 [WoS $IF_{2018}$ - 2.064; $Rank_{2018}$ - Q3] Scopus

54) Trinajstic, K., Long, J.A., Ivanov, A.O., **Mark-Kurik**, E. 2019. A new genus of ptyctodont (Placodermi) from the Late Devonian of Baltic area. *Palaeontologia Electronica* 22.2.23A, 1-19. https://doi.org/10.26879/890palaeo-electronica.org/content/2019/2490-a-new-baltic-ptyctodont [WoS $IF_{2018}$ - 1.366; $Rank_{2018}$ - Q2]

55) Vandenbroucke, T.R.A., **Hints**, O., Williams, M., Wallis, S., Velleman, J., Kurihara, T., Tanaka, G., Komatsu, T., **Männik**, P., Siveter, D.S., de Backer, T. 2019. Chitinozoans and scolecodonts from the Silurian and Devonian of Japan. *Island Arc* **28**, e12294. Published online: 17. February 2019. https://doi.org/10.1111/iar.12294 [WoS $IF_{2018}$ - 0.893; $Rank_{2018}$ - Q4]

56) Veski, R., **Veski**, S. 2019. Aliphatic dicarboxylic acids from oil shale organic matter – historic review. *Oil Shale* **36**, 76-95. https://doi.org/10.3176/oil.2019.1.06 [WoS $IF_{2018}$ - 1.041; $Rank_{2018}$ - Q3/Q4]

57) Vinn, O., Ernst, A., Wilson, M.A., **Toom**, U. 2019. Symbiosis of conulariids with trepostome bryozoans in the Upper Ordovician of Estonia (Baltica). *Palaeogeography, Palaeoclimatology, Palaeoecology* **518**, 89-96. Published online: 14. January 2019. https://doi.org/10.1016/j.palaeo.2019.01.018 [WoS $IF_{2018}$ - 2.616; $Rank_{2018}$ - Q1/Q2]

58) Vinn, O., Wilson, M.A., **Toom**, U. 2019. A crustoid graptolite lithoimmured inside a Middle Ordovician nautiloid conch from northern Estonia. *Annales Societatis Geologorum Poloniae* **89**, 285-290. https://doi.org/10.14241/asgp.2019.17 [WoS $IF_{2018}$ - 0.767; $Rank_{2018}$ - Q4]

59) Vinn, O., Wilson, M.A., **Toom**, U. 2019. Earliest *Petroxestes* borings from Sandbian (earliest Late Ordovician) bryozoans of northern Estonia. *Palaios* **34**, 453−457. Published online: 11. October 2019. https://doi.org/10.2110/palo.2019.054 [WoS $IF_{2018}$ - 1.636; $Rank_{2018}$ - Q2]

60) Wang, X., Ni, W., Li, J., Zhang, S., **Hitch**, M., Pascual, R. 2019. Carbonation of steel slag and gypsum for building materials and associated reaction mechanisms. *Cement and Concrete Research* **125**, xx-xx. Published online: 7. September 2019. https://doi.org/10.1016/j.cemconres.2019.105893 [WoS $IF_{2018}$ - 5.618; $Rank_{2018}$ - Q1]

61) Wudarska, A., Słaby, E., Wiedenbeck, M., Birski, Ł., Wirth, R., Götze, J., **Lepland**, A., Kusebauch, C., Kocjan, I. 2019. Chlorine isotope composition of apatite from the >3.7 Ga Isua supracrustal belt, SW Greenland. *Minerals* **xx**, xx-xx. Published online: 28. December 2019. https://doi.org/10.3390/min10010027 [WoS $IF_{2018}$ - 2.250; $Rank_{2018}$ - Q2]

62) Zaretskaya, N., Panin, A., **Molod'kov**, A., Trofimova, S., Simakova, A., Baranov, D. 2019. Pleistocene stratigraphy of the Vychegda River basin, European North-East. *Quaternary International* **xx**, xx-xx. Published online: 19. September 2019. https://doi.org/10.1016/j.quaint.2019.09.020 [WoS $IF_{2018}$ - 1.952; $Rank_{2018}$ - Q3]