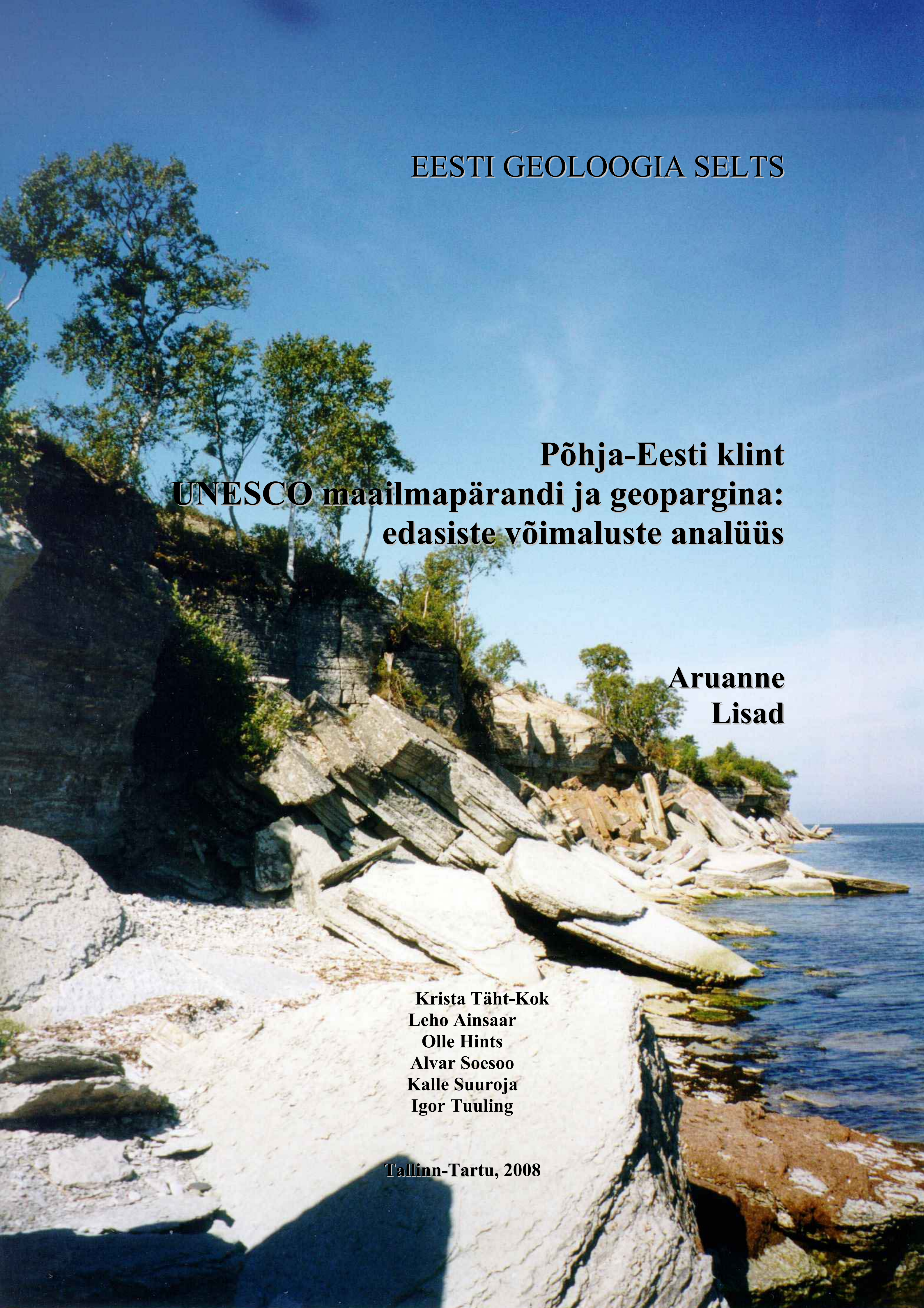

EESTI GEOLOOGIA SELTS

Põhja-Eesti klint UNESCO maailmapärandi ja geopargina: edasiste võimaluste analüüs

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Sisukord

1. Sissejuhatus

UNESCO maailmapärandi nimistu (World Heritage List) hõlmab maailma kultuuri- ja loodusobjekte, mis UNESCO maailmapärandi komitee hinnangul on äärmiselt olulised kogu inimkonna kultuuri- ja looduspärandi seisukohalt. Kuulumine sellesse nimistusse peab aitama kaitsta erakordse väärtusega loodus- ja kultuuriobjekte hävimisohu eest kiiresti muutuvas maailmas. Maailmapärandi nimistu sai alguse ülemaailmse kultuuri- ja looduspärandi kaitse konventsioonist, mis võeti vastu UNESCO peakonverentsil 16. novembril 1972. Maailmapärandi nimistusse kuulub 2006. aasta juuli seisuga 830 objekti: 644 kultuuripärandina, 162 looduspärandina ja 24 segapärandina (Kink, 2006).

Eesti geoloogide, Eesti Geoloogia Seltsi, Keskkonnaministeeriumi ja paljude loodushuviliste ühenduste arvamuse kohaselt on Põhja-Eesti klint väärt kuuluma UNESCO maailmapärandi nimistusse. Aastatel 2004-2005 valmistati Eesti Vabariigi Keskkonnaministeeriumi juhtimisel ette materjal Põhja-Eesti klindi esitamiseks UNESCO maailmapärandi nimekirja (Miidel jt. 2005). Maailmapärandi nimekirja esitati kandideerima Balti klindi kaheksa silmapaistvamat ja riikliku kaitse all olevat pangalõiku: Osmussaare, Pakri, Türisalu, Ülgase, Tsitre-Muuksi, Ontika, Päite ja Udria pangad. Esildis nimekirja esitamiseks valmis Keskkonnaministeeriumi, TTÜ Geoloogia Instituudi ja Eesti Geoloogiakeskuse koostöös.

Balti klint on üks pikimaid, katkematuid ja terviklikumaid järsakuid maailmas. Klindi pikkus on 1100-1200 km, sellest 250 km pikkune maismaaosa asub Põhja-Eestis. Eesti elanikud tunnevadki klinti just Põhja-Eesti pankranniku nime all ja see on ka üks Eesti rahvussümbolitest. Klint algab Rootsis Ölandi saare läänerannikult, kulgeb saare põhjaosast alates merepõhjal ja tuleb uuesti nähtavale Osmussaarel ja Pakri saartel. Läbi Eesti kulgeb klint Venemaale, kus ta Laadoga järve lõunakaldal kaob nooremate devoni kivimite alla. Suurim on klindi kõrgus (55,6 m) Ida-Eestis Ontikal. Balti klint on maailmas ka ainus nii ulatuslik, erakordselt rikkaliku ja hästi säilinud faunat sisaldavate Kambriumi ja Ordoviitsiumi kivimite paljand, kus saab jälgida varase Paleosoikumi kivimkihtide peaaegu täielikku läbilõiget - seega Maa geoloogilist ajalugu umbes 100 miljoni aasta vältel.

2004–2005 ettevalmistatud taotlus ei suutnud klindi unikaalsust rahvusvahelises mõõtmes kahjuks piisavalt põhjendada. Esildis oli üles ehitatud ühele kriteeriumile - rõhutati Balti klinti kui silmapaistvat Maa ajalugu kajastavat geoloogilist objekti. UNESCOt nõustava Ülemaailmse Looduskaitseorganisatsiooni IUCN antud hinnang sellele kandidatuurile oli lühidalt järgmine: Balti klint on küll huvipakkuv ja oluline geoloogiline objekt, kuid selle tähtsus on regionaalne, seda ei saa nimetada unikaalseks maailma mastaabis. Eitava hinnangu saanud objekti uuesti kandideerima esitada ei saa. Seetõttu otsustas Keskkonnaministeerium pankranniku maailmapärandi nimekirja kandmise esildise tagasi võtta 2006 a. Leiti, et võiks kaaluda pankranniku esitamist maailmapärandi nimekirja tulevikus, kuid siis uue ülesehitusega argumentatsiooni ning mitmekülgsema sisuga taotlusena.

Kujunes seisukoht, et alternatiivina või ühe etapina protsessis sobiks Balti klint suurepäraselt ka UNESCO koordineeritavasse geoparkide programmi, mille eesmärgiks on just geoloogiliste loodusmälestiste kaitsmine ja tutvustamine. Otsustati, et oleks vajalik olemasolevate geoloogiliste uuringute ning kujunenud situatsiooni igakülgne analüüs, mis näitaks võimalikke riske ja võimalusi uue UNESCO maailmapärandi taotluse ettevalmistamisel või/ja alternatiivina Euroopa Geopargi loomise võimalusi.

Käeoleva projekti ülesandeks ongi analüüsida kujunenud olukorda ning väljavaateid ja planeerida tegevusi Põhja-Eesti klint UNESCO võimalikuks esitamiseks maailmapärandi nimekirja ja/või geopargina/geoparkidena.

Käesoleva projekti esimese etapi ülesandeks on kujunenud situatsiooni riskianalüüs, võimaluste hindamine uue taotluse esitamiseks Põhja-Eesti klindi UNESCO maailmapärandi nimistusse vastuvõtmiseks või alternatiivina Euroopa Geoparkide Võrgustikku kuuluva UNESCO poolt tunnustatud Geopargi loomiseks. Hinnati ka vajadust täiendavate uuringute, varasemate tulemuste sünteesi ja vajalike lisategevuste osas. Selle etapi resultaadiks ongi riskide ja võimaluste hinnang mõlema variandi (maailmapärand vs. Geopark) puhuks ja vajalike lisategevuste defineerimine.

Teise etapi ülesandeks oli nimetatud teadmiste- ja tegevuslünkade täitmine.

Kolmas etapp kontsentreeruks rahvusvahelisele laiapõhjalisele idee tutvustamisele ja UNESCO maailmapärandi taotluse kirjutamisele või alternatiivina Geopargi organiseerimisele või mõlemale tegevusele. Juhul, kui esimese etapi tulemused oleks näidanud, et Põhja-Eesti (Balti) klindi viimine maailmapärandi nimistusse peaks olema vähepõhjendatud, siis kontsentreerutakse Geopargi loomise võimalustele. Juhul kui mõlemal ideel puuduks piisav kandepind, oleks projekt peataud.

Erinevalt varasema taotluse projekti ettevalmistamisest kaasati kõigi kolme suurema geoloogiaasutuse (Tallinna Tehnikaülikool, Tartu Ülikool, Eesti Geoloogiakeskus) spetsialistid, ekspertarvamus telliti ka ühelt väliseksperdilt, Dr. Chris Wood'ilt, kellel on olemas kogemus UNESCO maailmapärandi objektide hindamisest. Töös osalesid ekspertidena:

- Leho Ainsaar (PhD, Tartu Ülikooli ökoloogia ja maateaduste instituut, direktor)
- Igor Tuuling (PhD, Tartu Ülikooli ökoloogia ja maateaduste instituut, dotsent)
- Alvar Soesoo (PhD, TTÜ Geoloogia Instituut, direktor, professor)
- Olle Hints (PhD, TTÜ Geoloogia Instituut, osakonnajuhataja)
- Kalle Suuroja (MSc, Eesti Geoloogiakeskus, osakonnajuhataja)
- Krista Täht (MSc, Eesti Geoloogiakeskus, vanemgeoloog)

2. Põhja-Eesti klint UNESCO maailmapärandina: Varasema taotluse analüüs ja uue taotluse perspektiivid

2.1. Taotluse tugevad küljed

Nii käesolev analüüs kui kasutatud eksperthinnangud kontsentreeruvad taotluse nõrkadele külgedele, tuues välja vastamist vajavad küsimused. Siiski võib märkida, et taotluse puhul pole tegemist „päris lootusetu juhtumiga” ja siin on potentsiaalseid tugevaid külgi, mis vajaksid siiski paremini esile toomist. Tuuakse näiteks välja Balti klindi (mille osa on Põhja-Eesti klint) mastaapsus. Kuigi kõrgust sellel astangul napib, on pikkuse poolest maailmas vähe võrreldavaid pinnavorme. Toodud näited on põhiliselt tektoonilised murrangud (nt riftiorud, kontinendiservad).

Teine muljetavaldav fakt on geoloogiline vanus. Avanevate kivimite vanuse alusel on tegemist ühe vanemaga selletaoliste settekivimi-astangute hulgas. Sama kehtib klindil esinevate fossiilide suhtes. Näiteks, konkureerivas Gros Morne RP-s leiduvad küll ligikaudu samaaegsed, kuid sügavamamerelised fossiilikooslused ja samaaegsel Mali klindil pole üldse fossiilide leiukohana tähtsust. Positiivsena tuuakse ka esile Põhja-Eesti klindi komplekssus loodusliku ja kultuuriloolise objektina (ainus sarnane näide on Malist). Samuti on oluline, et suur osa klindist on haaratud toimivasse loodus- ja keskkonnakaitse süsteemi (kaitsealad, Natura alad).

2.2. Taotluse nõrgad küljed ja nende parandamise perspektiivid

Taotluse nõrkusena võrreldes olemasolevate maailmapärandi nimekirja objektidena on rahvusvahelised eksperdid (vt. C. Woodi kiri, lisa 3) välja toonud järgmised punktid:

1. Geomorfoloogilise astanguna on Põhja-Eesti klint huvitav nähtus, kuid visuaalselt mitte haaratav. See moodustab küll tähtsa geoloogilise piiri Euroopas, kuid samasugune roll on ka kilbi ja lava piiril olevatel astangutel Põhja-Ameerikas.

2. Maailmas on palju kohti, sh. UNESCO maailmapärandisse kuuluvaid objekte, kus avanevad Kambriumi ja Ordoviitsiumi settekivimid. Nõrgalt on põhjendatud, mis on Põhja-Eesti klindi geoloogilises läbilõikes erilist võrreldes teistega.

3. Neugrundi meteoriidikraater on huvitav, kuid teda on raske seostada teiste argumentidega Põhja-Eesti klindi esiletoomiseks. Objekti koostisosade komplekssus on UNESCO maailmapärandi lahutamatu nõue.

4. Klindi bioloogilise väärtuse põhjendatus on nõrk võrreldes teiste samasse biogeograafilisse regiooni kuuluvate kohtadega.

5. Esitatud argumendid klindi nimetamiseks maailmapärandi hulka viitavad regionaalsele (Euroopalisele) tähtsusele ja ülemaailmse tähtsuse põhjendus on puudulik ning mitteveenev.

6. Klindiläbilõike paleontoloogiline väärtus tundub olema suur, kuid argumendid ülemaailmsele unikaalsusele on nõrgad. UNESCO nimekirjas on juba mitmed unikaalsed Alam-Paleosoikumi paleontoloogilised leiukohad, näiteks Burgess Shale ja Gros Morne RP Kanadas.

Alltoodud peatükkides on püütud tuua argumente nende puudulike argumentide paremaks esitamiseks võimalikus tulevases taotluses või siis selgitatud nende vähest perspektiivikust.

2.2.1. Põhja-Eesti klindi kui geomorfoloogilise objekti unikaalsus

Põhja-Eesti klint on klindimaastiku, unikaalse Läänemere-äärse rannamaastiku parim näide maailmas. Klindimaastik – see on lubjakiviplatood ääristava rannaastangu poolt kujundatud maastik. Balti klindil võib sarnaseid maastikke kohata veel Ölandil ja Siluri klindil Gotlandil ja Saaremaal, kuid kusagil ei ole nende leviala nii suur (üle 300 km linnulennult, u 650 km astangujoont pidi), astang nii kõrge (kuni 55 m) ja üksikud lõigud nii ulatuslikud (Saka-Ontika-Toila pangal kuni 20 km) kui seda Põhja-Eesti klindil. Muul maailmal on sarnastest maastikest vastu pakkuda vaid Michigani sünklinaali ja Kanada kilpi ääristavad astangud (Niagara astang, Black Riveri astang jne), kuid need kulgevad enamjaolt sisemaal ja aluspõhja kivimid paljanduvad neil vaid aruharva. Võrdluseks, Põhja-Eesti klindil on paljanduvat astangut enam kui 100 km. Põhja-Eesti klint on ulatuslikum ja tähelepanuväärsem osa ligi 1200 km pikkusest (astangujoont pidi kuni 1700 km) Balti klindist.

Vaivara Sinimägede jt klindisaared-pangaskerked Vaivara vallas, mis on tekkinud ilmselt sinisavi voolamise (diapiiristumisel) mandiliustiku surve all tektooniliste rikete piires, on samuti ainulaadsed maailmas. Sarnase geneesiga struktuure on veel Ingeri klindil Peterburi ümbruses (Duderhoffi ja Kirshoffi mäed jne), kuid need on Vaivara Sinimägede pangastest palju väiksemad. Tornimäe panka pikkus Vaivara Sinimägedes on ligi 1 km ja Laagna pankal isegi kuni 1,5 km.

2.2.2. Balti klindi geneesi uued aspektid

Balti klindi genees ei olnud esimeses taotluses esitatud piisavalt selgelt ja veenvalt. See on olnud elavaks diskussiooniobjektiks pea viimased poolteist sajandit. Erinevate autorite poolt esitatud klindi võimalikke tekkeviise ja nende eelistusi on käsitletud väga põhjalikult mitmetes viimase aja kirjutistes (Miidel, 1992; Suuroja 2005, 2007), mistõttu neid siin eraldi lahata pole tarvidust.

Uut mõtlemisainet klindi ehituse ja geneesi küsimustes on pakkunud viimastel aastakümnetel tehtud ulatuslikud seismo-akustilised uurimustööd Läänemere keskosas. Nende tööde tulemusena on koostatud Läänemere keskosa, Balti (ja Siluri klindi alasid kattev aluspõhjareljeefi kaart ja kõrgusmudel (Tilk 2006), ning samuti detailselt uuritud mõlema klindi geoloogilist ehitust (Troon, 2001; Tilk, 2006; Tuuling jt., 2007; Tuuling & Tilk 2007). Ehkki Balti kilbi lõunanõlva kuestalaadne morfostruktuur oli teada juba 19 saj. lõpu geoloogilistelt läbilõigetelt, pole see varem kusagil sellisel klassikalisel kujul avaldunud nii nagu Läänemere keskosa aluspõhjareljeefis. Piki Eelkambriumi-Kambriumi, Ordoviitsiumi ja Siluri avamusi nõrgalt lõunasse/edelasse laskuvad platood ja neid lahutavad, Balti ja Siluri klinte hõlmavad astangute ja terrasside süsteemid, moodustuvad põhja lõunasihis vahelduvate kuestaorundite lauge põhja- ja järsu lõunaveeru.

Selline selgus lubab Balti klindiga seoses rõhutada kahte, varemgi korduvalt mainitud, kuid teenimatult tahaplaanile jäänud tõsiasja, milledest lähtumata pole aga ükski klindi geneesi käsitlev kirjutis tõsiseltvõetav:

1. Balti klint osutub ainult üheks, kõige märkimisväärsemaks aluspõhjaliseks astanguks ulatuslikus astangute ja terrasside süsteemis;

2. Astangute ja terrasside süsteem on üks osa regiooni kuestareljeefist, moodustades asümmeetrilise kuestaorundi järsema lõunaveeru.

Lisaks sellele näitavad nii merealuse aluspõhjareljeefi üldpilt kui ka Siluri klindi detailsem morfoloogia üheselt, et Balti - ja Siluri klindid ning nendega kaasnevad astangute ja terrasside süsteemid on kaks võrdväärset, ühesuguse geneesi ning ühel geoloogilisel ajahetkel tekkinud regionaalse kuestareljeefi elementi. Lähtuvalt kuestareljeefist ning astangute ja terrasside süsteemist kuestaorundi järsul veerul analüüsiti käesoleva projektiga ka põhjalikumalt klindi tekkevõimalusi, mis on detailides lahti kirjutatud käesoleva aruande juurde kuuluvas lisas (lisa 1). Kui varasema käsituse kohaselt kujunes kuestaorundi järsk veer peamiselt küljeerosiooni toimel lõunasse migreeruva ja süveneva jõe ette (sellega ei saa seletada astangute ja terrasside süsteemi teket), siis uue arusaama järgi kujundas selle aga tektooniliselt kerkival alal vahelduvate põhja- ja küljeerosiooni etappide toimel maapinda lõikuv jõgi. Kuestaorundi lauge põhjaveer hakkas arenema juba maapinda lõikunud jõeorundis toimima hakkavate nõlva protsesside ja erosiooni tulemusena. Selline lähenemise abil saab põhjendada miks klint on osaks astangute ja terrasside süsteemist ja kuidas selline astangulis-terrassiline reljeef kujunes.

2.2.3. Põhja-Eesti klindi kui geoloogilise läbilõike ja kivististe leiukoha unikaalsus

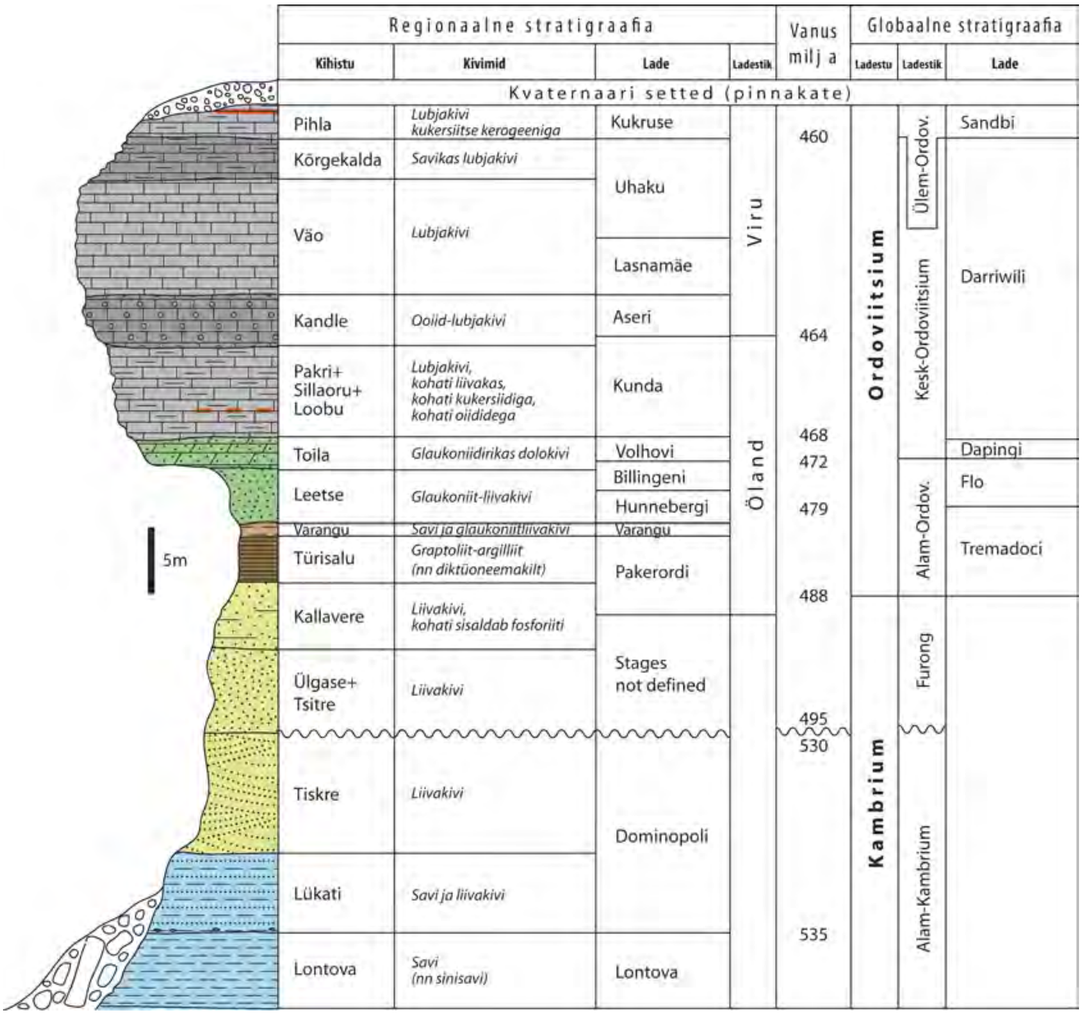
Põhja-Eesti klint on Vara-Paleosoiliste settekivimite ulatuslik paljand (enam kui 100 km ja kuni 55 m kõrge) ning Baltika ürgmandrit katva settekivimite lasundi parim paljand, mis märgistab enamasti Fennoskandia (Balti) kilbi ja Ida-Euroopa platvormi vahelist piiri. Põhja-Eesti klindil paljanduvad kivimid jäävad vanusevahemikku 540–460 milj aastat; seega on klindi geoloogilise läbilõike ajaliseks ulatuseks umbes 80 milj aastat. Võrreldes Põhja-Eesti klindiga on paljudel tuntud astangutel paljanduvate kivimite vanuseline ulatus tunduvalt väiksem. Näiteks Black River'i astangul Põhja-Ameerikas paljandub Ordoviitsiumi läbilõige ainult 5 miljoni aasta ulatuses.

Klindiastangu jalamil paljanduv sinisavi puhul on tegu maailma vanima saviga, mis vaatamata suurele vanusele (enam kui 530 mln aastat) on ta säilitanud kõik savile iseloomulikud omadused (veeimavus, platsus jne). Kõik teised nii vanad savid maailmas on muutunud juba kiviks ning kaotanud savi omadused. Sinisavilasundis ilmutab end ka Kambriumi "evolutsioonilise plahvatus" (*Cambrian Explosion*), st suhteliselt lühike ajalõik (kuni 10 mln a) Kambriumi ajastu alguses, mil eluvormid Maal plahvatusliku kiirusega mitmekesistusid ja mil ilmusid paljud tänapäevalgi esinevad hõimkonnad. Tõsi, faunarikkuse poolest jääb sinisavi alla Kanadas, Briti-Kolumbia kaljumägedes Burgessi Shale'i leiukohale ning Hiina Chengjiangi leiukohale, kust on leitud pehmekehafossiile (nn *Fossil Lagerstätten*). Sinisavi peal paljanduvad mitmed kirjuvärvilised maavaralist väärtust omavad kivimikihid. Kambriumi liivakivi pealt leiame oobolusliivakivi (lukuta brahhiopoodide kodasid ja nende purdu sisaldava liivakivi) kuni 10 m paksuse lasundi, mis kohtades kus fosfori sisaldus liivakivis saavutab maavaralise väärtuse, nimetatakse fosforiidiks. Tegemist on ühe osaga Euroopa suurimast fosforiidileiukohast.

Oobolusliivakivi peal lasub omakorda kuni 6 m paksune tumepruun kiht kerogeenset argilliiti ehk diktüoneemakilta. Peale selle, et tegemist on madala kütteväärtusega põlevkiviga, sisaldab kilt maavaralises või selelähedases kontsentratsioonis veel uraani, molübdeeni, vanaadiumi jne. Viimase peal on 0,1–5 m paksune kiht tumerohelist nõrgalt tsementeerunud galukoniitliivakivi. Peale selle, et just glaukoniitliivakivi pehmus (kergesti kulutatus) on see, mis paneb murrutustsoonis oleva klindiastangu varisema, saaks seda kasutada ka absorbeeriva materjalina filtrites ja kaaliväetiste tootmiseks.

Klindi läbilõiget kroonib 3–15 m paksune Ordoviitsiumi lubjakivist paelasund.

Sedimentoloogiliselt on huvipakkuvad klindi ülaosas paljanduvad Ordoviitsiumi jahedaveelised karbonaadid, kuna enamus Paleosoikumi lubjakividest on tekkinud troopilistes meredes. Need külmaveelised setted on kuhjunud erakordselt aeglaselt, peamiselt põhjaelustiku skeletiosakeste settimise teel. Hulgaliselt leidub veealuseid settekatkestusi, sh keemiliselt kristalliseerunud kaljupõhjakeskkonda.



Joonis 2.2.3.1. Põhja-Eesti klindi koonläbilõike stratigraafiline liigestus ja geoloogiline vanus.

Paleontoloogilised aspektid

Põhja-Eesti klindil paljanduvad varapaleosoilised settekivimid sisaldavad rohkesti kivistisi ja viimased reeglipäraselt hästi säilinud – vaatamata vanusele ei ole siinsed settekivimid moondele allunud ega kurrutatud, mis on kahtlemata tähelepanuväärne ka maailma mastaabis. Klindilt leitud fossiile on uuritud juba alates 19 saj. keskpaigast ning hulgaliselt on kirjeldatud uusi taksoneid, mis on kujunenud klassikaliseks võrdlusmaterjaliks teiste piirkondade uurijatele (vt põhjalikum ülevaade Lisas 2).

Kogu Ordoviitsiumi läbiõige klindil peegeldab hüppelist bioloogilise mitmekesisuse kasvu, mis oli sellele ajajärgule globaalselt iseloomulik. Seetõttu on Balti basseini andmestik kesksel kohal nn Suure Ordoviitsiumi Bioloogilise Mitmekesistumise (*Great Ordovician Biodiversification Event*) uurimisel.

Näiteks brahhiopoodide puhul on silmatorkav haruldane mikrostruktuuride säilivus lingulaatidel Kambriumi/Ordoviitsiumi piirikihtides. Molluskitest võib esile tõsta *Aldanella kunda*'t, kui ühte vanimat gastropoodi maailmas (Vara-Kambrium). Karpvähiliste (ostrakoodide) fauna klindiläbilõigetes kuulub maailma vanimate ja paremini uuritute hulka. Eesti Ordoviitsiumi läbilõiked on ka oluline orgaanilise kestaga mikrofossiilide leiukoht. Näiteks klindi Alam-Ordoviitsiumist leitud kitiinikud ja skolekodondid kuuluvad maailma vanimate hulka.

Siiski on raske esile tõsta globaalse tähtsusega faunaleide. Paleontoloogiline andmestik klindi kohta on siiani puudulik. Enamik vastavat ajalõiku käsitavatest paleontoloogilistest töödest ei ole keskendunud ainult klindile vaid käsitavad materjali ka teistest aluspõhjalistest paljanditest ja puuraukudest. Just tänu puursüdamike suurele hulgale ning nende geograafilisele ja stratigraafilisele ulatusele on Põhja-Eesti klindi läbilõige alates 1960ndatest aastatest pälvinud suhteliselt tagasihoidlikku paleontoloogide tähelepanu ning vaid üksikud teadustööd keskenduvad klindi paljanditele. Tänapäeval kui uue puursüdamikumaterjali kogunemine on praktiliselt lõppenud tuleb paleontoloogidel üha enam keskenduda paljanditele millest alam-Paleosoikumi osas on Eestis klint kindlasti väärikaim.

Kuigi kivististe säilivus klindi läbilõigetes on suurepärane, seda eriti mikrofossiilide osas, siis paljud makrofosiilid (näit trilobiidid) on Põhja-Eesti klindil esindatud enamasti fragmentidena, mitte tervikliku skeletina, milliseid võib rohkelt leida nii Loode-Venemaa kui Rootsi samaealistest läbilõigetest. Siingi on tegemist paleokeskkonna iseloomuga – aktiivse lainetuse vööndis kuhjunud skeletid on juba enne mattumist osadeks lagunenud.

Balti klindi fossiiliderikkas lubjakiviosas (Kesk-Ordoviitsium) on säilunud lubiskeletiga fossiilid (enamus brahhiopoode, trilobiidid, sammalloomad, okasnahksed, molluskid jne) ning fosfaatseid või orgaanilisest ainest skeletielemente, kesta või hambaid omavad fauna- ja floorarühmad (lingulaadid, konodondid, kitiinikud, skolekodondid, akritarhid jne). Pehmete kudede jäljendeid (nn *body fossils*) Balti Klindi läbilõigetest seni leitud ei ole. Samas peetakse just selliseid leide (nn *Fossil Lagerstätten*) maailma mastaabis unikaalseteks ning mitmed neist on ka UNESCO Maailmapärandi nimekirjas (Burgess Shale Kanadas) või sinna kandideerimas. Ainult sellistes leiukohtades, mida iseloomustab orgaanilise aine ja setendi kiire mineraliseerumine, on esindatud vastava ajalõigu ja keskkonna kogu elurikkus. Tavaläbilõigete puhul, mille hulka tuleb liigitada ka Balti klindi paljandid, on fossiilidena säilunud ainult suhteliselt väike osa kunagisest elustikust – ainult need liigid, mis omasid fossiliseeruvat skeletti või muid vastavaid osiseid.

Kuigi seni pehmekehafossiilid Balti klindilt puuduvad pole siiski välistatud, et edasised uuringud võivad seda olukorda muuta. Kõige perspektiivsem intervall selliste otsingute puhul on Alam-Ordoviitsiumi vanusega Türisalu kihistu e nn diktüoneemakilt. Selle peeneteralise orgaanikarikka kivimi settimise ja mineraliseerumise tingimused võinuksid teatud juhul olla sobivad ka pehmekehafossiilide säilumiseks. Ei ole siiski tõenäoline, et Balti klindi läbilõigetest ilmnevad sellised fossiilid mida võrrelda seni maailmas tuntud erakordse säilivuse näidetega nagu Burgess Shale või Chengjiang.

Seega tuleb tõdeda, et kuigi Balti klindi fossiiliderikkus ja hea säilivus on maailmas tuntud ning iseloomustab hästi Kambriumi-Ordoviitsiumi elustikku ja selle arengut Baltika kontinendil, ei ole klindi fossiilide leiukohad ega ka nende uurituse tase võrreldavad mitmete teise unikaalsete leiukohtadega nagu Burgess Shale Kanadas, Messel Pit Saksamaal, Dorseti rannik Inglismaal jt. Edasiste paleontoloogiliste tööde võib küll ilmneda uut ja huvipakkuvat materjali, kuid on vähe tõenäoline, et see saaks olla peamiseks argumendiks Põhja-Eesti klindi edaspidisel edukal kandideerimisel UNESCO maailmapärandi nimekirja.

Stratigraafilised aspektid

Põhja-Eesti klindil on püstitatud mitmeid regionaalse tähtsusega stratigraafilisi üksuseid, sh kronostratigraafilisi e ajalisi ning litostratigraafilisi e kivimilisi üksuseid. Klindil on defineeritud Pakerordi, Varangu ja Aseri lademed, samuti mitmed alamlademed. Kuna nimetatud üksused on kasutuses terve Baltika paleokontinendi jaoks siis leiavad need tihti viitamist ka rahvusvahelise globaalse ajaskaalaga seoses (vt Geoloogiline Ajaskaala 2004, Cooper ja Sadler, 2004). Klindil defineeritud litostratigraafiliste üksuste loetelu on oluliselt pikem kuid samal ajal on nende tähtsus ja tuntus eelkõige regionaalne (näit. Kallavere, Türisalu, Varangu, Leetse, Toila, Pakri, Sillaoru, Loobu ja Kandle kihistud).

Globaalse ajaskaala põhiüksuste – globaal-lademete – stratotüüpe e tüüpläbilõikeid Eestis ega Balti klindil ei ole ning sellel on oma selge põhjus. Tulenevalt Eesti geoloogilisest ehitusest ning Kambriumi ja Ordoviitsiumi ürgmerede konfiguratsioonist esindab Põhja-Eesti klint üldiselt madalmerelisi tingimusi (erandiks Alam-Kambriumi sinisavi, mis on aga paleontoloogiliselt võrdlemisi halvasti iseloomustatud). Madalmeres ei ole setete kuhjumine reeglina pidev ning seetõttu on Põhja-Eesti klindil paljanduvates kivimites esindatud vaid osa geoloogilisest ajast – läbilõige on lünklik. Globaalse geoloogilise ajaskaala üksuste täpne defineerimine toimub piiristratotüüpide ja piiripunktide (nn GSSP, Global Stratotype Section and Point) abil ning eeldab pidevat settimist, st igale ajahetkele piiriintervallis on teoreetiliselt võimalik leida kivimiline vaste. Sobivad läbilõiked on seega seotud eelkõige sügavamaveelistes keskkondades kuhjunud settelasunditega. Balti Paleobasseini sügavamaveeline osa on esindatud Lõuna-Eestis, Lätis ja Rootsis ning enamasti kaetud nooremate setetega – Põhja-Eesti klindil ja Eestis globaal-lademete püstitamiseks sobivaid paljandeid ei esine.

Seetõttu on Põhja-Eesti klindi läbilõike stratigraafiline tähtsus eelkõige regionaalne ning tulenevalt geoloogilisest ehitusest ei ole globaalset-universaalset väärtust klindile võimalik omistada. Ka täiendavad uuringud ning edasine töö siin reaalset olukorda muuta ei võimalda.

2.2.4. Klindläbilõikega seotud geoloogilised katastroofid

Neugrundi klindisaar on osa maailmamere kõige paremini säilinud ja ka kõige atraktiivsemast ning kergemini ligipääsetavast meteoriidikraatrist. Umbes 535 mln aasta eest tekkinud kuni 21 kilomeetrise läbimõõduga meteoriidikraatri kristalsetest kivimitest ringikujulised ahelikud paljanduvad mere põhjas Neugrundi madala ümbruses. Ringikujuline klindisaar on erosiooniline jäänuk meteoriidikraatrit mõne miljoni aasta eest katnud settekivimite lasundist. Koos kõrvalasuva Osmussaarega moodustab Neugrundi meteoriidikraater Odini haua nimelise looduslik-mütoloogilise kompleksi. Osmussaart (rootsi keeles Odensholm) on saareelanikud tõlkinud ka kui Odini hauda ja ennemalt oli saarel ka Odinstain (Odini kivi), mille alla osmussaarlaste uskumuste kohaselt too muinasskandinaavlaste ja viikingite pea- ning sõjajumal olla maetud. Seda uskumust kinnitavad ka mõned saagad, mis väidavad, et pärast Ragnarökki (Viimsepäevalahing, milles hukkusid nii jumalad kui inimesed) olla Odin maetud Inimeste maa (Midgard) äärele, viimasele maalapile kus kaljud veel välja paistavad. Ka sellesse ossa sobib Osmussaar suurepäraselt. Saar, kust on leitud viikingite laagripaikade jälgi, oli kindlasti tähtis peatuspaik viikingite Bütsantsi ja Kreekasse viival Idateel (Austervegr).

Neugrundi meteoriidikraatri juurde kuuluvaks tuleb lugeda ka **neugrund-bretšast** (Neugrundi meteoriidipahvatusel tekkinud kivim) rändkivide hajumisoreooli. Tänu kivimi äratuntavusele ja lähteala (meteoriidikraater) selgepiirilisusele on neugrund-bretšast ideaalilähedane juhtkivimi ja selle hajumisoreool üheks kõige paremini jälgitavaks rändkivide hajumisoreooliks Põhja-Euroopa kvaternaarse jäätumise alal. Neugrundi meteoriidikraatri merepõhjas avanevailt struktuuridelt mandriliustiku poolt lahti kistud rändkivid on lehvikujuliselt laiali kantud enam kui 10 000 km2-le erineva suurusega (munakatest kuni enam kui 10 000 m3 hiidrahnudeni merepõhjas Osmusaare süvikus).

Osmussaar-bretša sooned-kehad, 475 mln aasta eest Ordoviitsiumis toimunud katastroofilise maavärina tunnistajad, on ainulaadsed maailmas. Osmussaare idarannikul klindiastangu jalamil on lubjakivilasundisse tunginud omapärased brektsia-laadse lubiliivakivi sooned ja kehad. Need levivad vaid kuni 1,5 m paksuses lubjakivikihis, mis jääb kuni 5 m paksuse pudedavõitu glaukoniitliivakivilasundi peale. Osmussaare lähedal (saarest umbes 4 km kirdes) on 1976. aasta 25. oktoobril toimunud Läänemere äärse ala teadaolevalt tugevaima (4,7 magnituudi) maavärina epitsenter.

2.2.5. Põhja-Eesti klindi maastikuline ja kultuuriajalooline unikaalsus

Kindimets on unikaalne, Põhja-Eesti klindile ainuomane laialeheline mets, milles rohkesti jalakat, saart, vahtrat, pärna, leppa ja tamme. Klindimets on justnagu põhjamaine džungel, sellele iseloomuliku alusmetsa ja sõnajalgadest ning mets-kuukressist alustaimestikuga. Klindimetsa teket on soodustanud mikroelementide ja toitainete rikas kasvupinnas, omapärane veerežiim (üheltpoolt rohked astangust väljavoolavad allikad ja teisalt vettpidavad aluskivimid sinisavi) ja iseäralik mikrokliima (kitsas maariba kõrge astangu ja mere vahel). Põhja-Eesti klint Balti klindi osana on enam kui 9000 aastat vältel olnud Põhja-Euroopas loodusest antud sillaks ida ja lääne vahel.

Mesoliitiliste Kunda (Kunda Lammasmäe rändpangas) ja Narva kultuuride asulakohad Narva klindiorus ja selle kallastel on tihedalt seotud Põhja-Eesti klindiga.

Klindiplatoo oma õhukese pinnakattega (alvarid) olid üheks varasemaks maaviljeluse piirkonnaks Põhja-Euroopas. Iidsed põllud Kallavere klindipoolsaarel Rebalas pärinevad enam kui 4000 aasta tagusest ajast. Pronksiajast tuntud, ilmselt viljakusmaagiaga seotud väikelohukivide (cupstones) kultuuri levik Taanist-Rootsist itta Põhja-Eesti klindi idaosani, jälgib üsna täpselt Balti klindi astanguid, st jätab kõrvale lõunapoolsed alad Poolas, Leedus ja Lätis.

Viikingiaeg (8.–11. saj.) oli Balti klindi suuraeg. Klindi lääneosast Rootsist Idateed alustanud viikingid orienteerusid Idatee alguses (kuni Volhovi jõeni Ingeri klindil) Balti klindi astangute järgi ja klindi lähedusse rajasid nad ka oma tugipunkte. Balti klindi paeplatoolt võib leida nii Rootsi (Borgholm) kui Venemaa (Laadoga) suurriikluse algeid ja siin heitlesid nad aastasadade jooksul ülevõimu pärast. Põhja-Eesti klindi idapiiril Narva klindioru kallastel alustas Peeter I oma kuulsat Euroopasse akna raiumist.

2.3 Kokkuvõtteks

Põhja-Eesti klindi esitamisel UNESCO maailmapärandiks on peaprobleemiks, kuidas näidata selle väljapaisvtat universaalset väärtust (*Outstanding Universal Value*). See tähendab, et see objekt peab olema väga unikaalne mingis valdkonnas kogu maailmas. Paraku pole selle tõestamine lihtne, sest, nagu eksperdid viitavad, on maailmas palju suurepäraseid ja maalilisi astanguid, mis on pikemad ja kõrgemad kui Põhja-Eesti klint, sealhulgas neid, kus paljanduvad Alam-Paleosoikumi kihid ja kus on suurepäraseid fossiilide leiukohti.

Ülaltoodud analüüsis toodi välja Põhja-Eesti klindi võimalikud väärtused, mida täiendavalt rõhutades saaks 2005 a taotlust parandada, ning ühtlasi aspektid kus edasine perspektiiv kaheldav. Sellele vaatamata jõudis töögrupp äratundmisele, et edulootused pole siin esialgu ülearu suured. Peeti vajalikuks toetada alternatiivseid teid klindi tuntuse suurendamiseks ja esile tõstmiseks ning laialdasemaks kasutamiseks looduhariduse ja geoturismi edendamisel, pidades eelkõige silmas perspektiivi geopargi või geoparkide loomiseks. Sealjuures võiksid need pargid taotleda UNESCO geopargi staatust ning võimalik, et kogu ettevõtmine võiks tulevikus viia ka uue taotluse esitamiseni UNESCO maailmapärandi nimistusse kandideerimiseks.

3. UNESCO geopargi loomise võimalustest Põhja-Eesti klindile

3.1. Geopargi kontseptsioon

Geoparkide loomine on maailmas küllaltki uus ettevõtmine. Esimesed geopargid loodi Euroopas aladele, kus suuri territooriumeid hõlmavad looduskaitsealad pärssisid majandustegevust ja pidurdasid nende piirkondade arengut. Idee rakendada geoloogilised loodusmälestised piirkonna majanduse elavdamiseks kerkis üles Rahvusvahelisel Geoloogia Kongressil geoloogiliste loodusmälestiste sektsioonis 1997. aastal. Seal formuleeriti geopargi peamine idee rakendada piirkonna geoloogilised loodusmälestised jätkusuutlikult majanduse teenistusse. 2000. aasta juunis moodustasid 4 Euroopa kaitseala (*Reserve Geologique de Haute-Provence*, Prantsusmaa; *Natural History Museum of the Lesvos* Petrified Forest (Lesbose saar), Kreeka; *Geopark Gerolstein/Vulkaneifel*, Saksamaa ja *Maestrazgo Cultural Park*, Hispaania) esindajad Euroopa Geoparkide Võrgustiku (*European Geoparks Network*). Nad formuleerisid ka põhiprintsiibid, millele geopark peaks vastama:

- tagama unikaalsete geotoopide e geoloogiliste loodusmälestiste säilimise järeltulevatele põlvedele.
- jagama teavet laiale avalikkusele Maa geoloogilise arengu kohta ja olema teadustöö baasiks erialateadlastele.
- tagama piirkonna jätkusuutliku arengu.

2001. aasta aprillis kirjutas UNESCO alla memorandumile koostööst Euroopa Geoparkide Võrgustikuga. 2004. aasta 13. veebruaris võeti UNESCO peakorteris Pariisis vastu mitu konkreetset otsust "Euroopa Geoparkide Võrgustiku" programmi toetamiseks. Tunnustussertifikaat "UNESCO Geopark " pidi hakkama tähistama looduskeskkonna kaitset ja jätkusuutlikku majandust. UNESCO võttis endale ülesande toetada geoparkide rajamist kogu maailmas.

Geoparkidele täiesti ühtseid ja väga selgeid nõudmisi ei ole esitatud, kuid soovitavalt peaks seal asuma ülemaailmse tähtsusega geotoop (*World Heritage Site*) ja territoorium peaks olema küllalt suur majandustegevuse arendamiseks. Tänaseks loodud Euroopa geoparkide suurus kõigub 15 000 ha ja 320 000 ha vahel. Vastavalt UNESCO dokumentidele võiks need nõudmised esitada järgnevalt.

UNESCO poolt tunnustust pälvivale geopargile esitatatavad nõudmised:

- geopark peab olema selgelt piiritletud ala;
- alal asub üks või rohkem eriti silmapaistvat geotoopi (geoloogilist loodusmälestist), millel on nii teaduslik kui ka esteetiline väärtus. Arheoloogiliste ja kultuuriliste mälestusmärkide olemasolu geopargi territooriumil tõstavad geopargi väärtust;
- alal kohta on koostatud jätkusuutliku tegevuse kava, edendamaks sotsiaalmajanduslikku arengut (sh geoturismi);
- on olemas meetmed geoloogilise pärandi kaitseks ja säilitamiseks ning geoloogiateaduste õpetamiseks ja keskkonnateadlikkuse süvendamiseks;
- geopargi loomise ettepanek tuleneb avalikkuse, kohaliku omavalitsuse ja eraettevõtete ühishuvist;
- iga geopark on osa ülemaailmsest võrgustikust, kus demonstreeritakse looduskasutuse parimat praktikat arvestades geoloogilise pärandi (*Earth heritage*) kaitset ja selle integreerimist jätkusuutliku arengu strateegiatesse.

Analüüsides missugused võimalused on Eestis rajada geoparki, mis võiks saada vastu võetud Euroopa Geoparkide Võrgustikku ja pälvida UNESCO tunnustuse, tuleks vaadata, missuguseid peatükke peab sisaldama Euroopa Geoparkide Võrgustikule ja seejärel UNESCO'le tunnustussertifikaadi saamiseks esitatav aruanne. Olgu rõhutatud, et Euroopas asuv geopark, peab eelkõige leidma tunnustuse Euroopa Geoparkide Võrgustiku poolt ja alles seejärel on võimalik esitada sooviavaldus UNESCO-sse.

Geopargi taotluseks esitatava aruande struktuur

1) Piirkonna kirjeldus. Part A. Description of the area
    a) Administratiivne osa. *Administrative part*
    b) Territooriumi määratlemine. *Identification of the territory*
        i) Geoloogia ja pinnamood. *Geology and Landscape*
        ii) Korralduse struktuur. *Management Structure*
        iii) Keskonnaalane informatsioon ja kasvatus. *Information and Environmental Education*
        iv) Geoturism. *Geotourism*
        v) Regionaalne jätkusuutlik majandus. *Sustainable Regional Economy*
2) Geopargi edasine areng. Part B. Geoparks Progress Evaluation
    a) Suhted Euroopa Geoparkide Võrgustikku kuuuvate ja teiste geoparkidega maailmas. *Relationship with the European/Global Geoparks Network*
    b) Korralduse struktuur ja majanduslik status. *Management Structure and Financial Status*
    c) Geoloogiliste loodusmälestiste kaitse korraldus. *Geoconservation Strategy*
    d) Strateegiline partnerlus. *Strategic Partnerships*
    e) Geopargi tutvustamine ja reklaamimine ning marketing. *Marketing and Promotion*
    f) Jätkusuutlik majandamine ja selle arenguplaan. *Sustainable Economic Development*

Esitatud punktid annavad ülevaate geopargile esitatavatest nõudmistest ja tegevustest, mis peavad olema esindatud tulevases geopargis. Lähtudes Põhja-Eesti klindi tunnustatud teaduslikust väärtusest, tuntusest ja uuritusest, eeldatakse, et oma unikaalsuse poolest väärib suurem osa kaitsealuseid klindi panku UNESCO sertifikaadi taotlemist. Seega on käesoleva töö peamine ülesanne määratleda tulevase geopargi piirkonnd või piirkonnad.

UNESCO ei esita geopargi territooriumile kindlaid nõudmisi, on siiski öeldud, et geopark peab olema küllalt suur, et selle territooriumil saaks arendada majandustegevust. Seega looduskaitseala, kuitahes suur, ei ole geopark. Geopark on ala, kus geoloogilised loodusmälestised on rakendatud piirkonna jätkusuutliku majanduse teenistusse. Geopargi territooriumil soodustatakse eelkõige jätkusuutliku põllumajanduse, turismi ja väikeettevõtluse arengut.

3.2. Geoparkide perspektiiv Põhja-Eesti klindi aladel

Eesti üks silmapaistvamaid geoloogilisi loodusmälestisi on Põhja-Eesti klint, mis kulgeb ligikaudu 250 km piki Soome lahe lõunarannikut moodustades Soome lahe lõunakaldal kõrge pankranniku. Põhja-Eesti klindi tutvustamist Euroopa Geoparkide Võrgustiku kaudu UNESCO poolt tunnustatud geopargina on soovitanud UNESCO ekspert Chris Wood. Põhja-Eesti klint moodustub paljudest eraldiasetsevatest pankadest, kus paljanduvad Kambriumi ja Ordoviitsiumi ajastute kivimid. Klint kujutab endast suurepärast geoloogilist ajaraamatut. Mitte paljudes paikades maailmas ei saa vahetult jälgida nii ulatuslikku lõiku Maa geoloogilisest arengust (joonis 2).

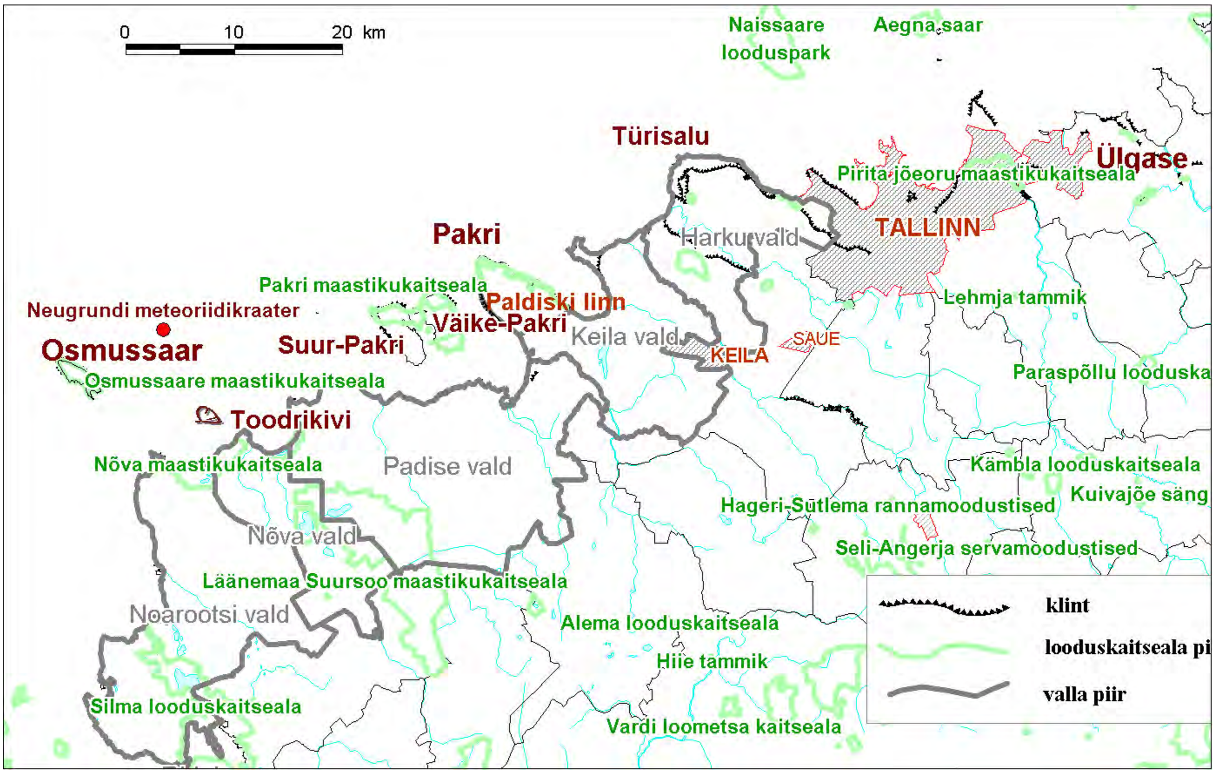
Joonis 3.2.1. Põhja-Eesti klindi esinduslikumad pangad.

Kõige kuulsam osa Põhja-Eesti klindist on kahtlemata Toompea, kuid efektsemad pangad asuvad Tallinnast läänes ja Ida-Virumaal. 8 kõige esinduslikumat klindilõiku on võetud looduskaitse alla maastikukaitsealadena, need on:

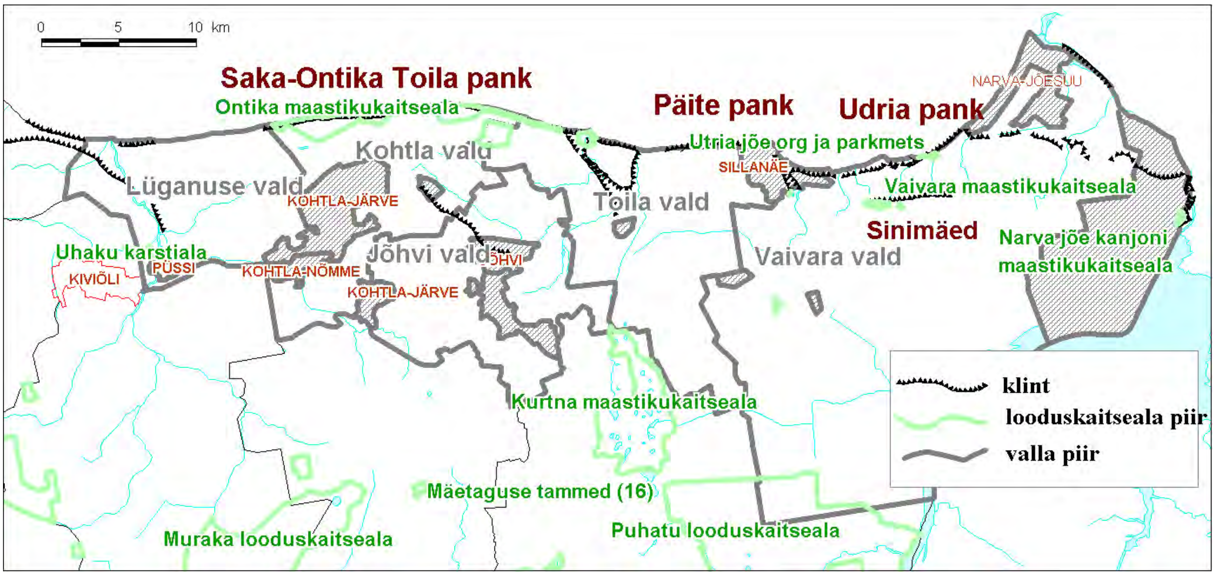
- Osmussaare maastikukaitseala, mis hõlmab kogu saare
- Pakri maastikukaitseala, mille koosseisu kuuluvad: Pakri saarte ja Pakri poolsaare pangad
- Türisalu maastikukaitseala, mis hõlmab Türisalu panka
- Ülgase looduskaitseala, Ülgase pank ja koopad
- Tsitre-Muuksi pank Lahemaa Rahvuspargis
- Saka-Ontika-Toila, Ontika maastikukaitseala
- Päite maastikukaitseala, Päite pank
- Udria maastikukaitseala, Udria pank

Vaadates kaardile on üsna selge, et ühtsete majanduslike huvidega territooriumit Põhja-Eesti klindil ei ole. Põhja-Eesti on majanduslikult kõige arenenum piirkond. Siin asub meie pealinn, suurimad sadamad, tehased ja kaevandused. Suuremal osal klindialast ei ole otsest majanduslikku survet arendada turismi, kui kõige perspektiivikamat või isegi ainsat tegevust piirkonna jätkusuutlikuks arenguks. Samal ajal on kõik piirkonnad siiski huvitatud oma atraktiivsuse tõstmisest. Seda näitavad omavalitsuste arengukavad, kus on eraldatud summad puhkekohtade ja matkaradade rajamiseks, kodukandi tutvustamiseks ning mitmesuguseid teisi ettevõtmisi, mis haakuvad geopargi eesmärkidega.

Lähtudes geograafilisest asendist võiks klindialale luua 2 geoparki, lääne ja idapoolse (joonis 3.2.2. – 3.2.3.).



Joonis 3.2.2. Põhja-Eesti klindi läänepoolne geopark.



Joonis 3.2.3. Põhja-Eesti klindi idapoolne geopark.

Läänepoolsesse geoparki peaks geoloogilisi väärtusi silmas pidades kuuluma piirkond Osmussaarest kuni Türisalu pangani ja idapoolsesse piirkond Saka-Ontika-Toila, Päite ja Udria panku. Niisugused geopargid võimaldaksid tutvustada Põhja-Eesti klindi kogu geoloogilist pärandit alates 560–440 miljoni aastani ladestunud kivimitest kuni hetkeliste geoloogiliste sündmusteni, nagu 475 miljonit aastat tagasi toimunud Osmussaare maavärina jäljed või 535 miljonit aastat tagasi Neugrundi meteoriidikraatrist välja paiskunud meteoriitbretša. Allveeujumise varustust kasutades on võimalik tutvuda ka Neugrundi meteoriidikraatriga.

Vaadates väljapakutud klindi läänepoolse geopargi territooriumit, näeme, et see langeb 3 valla territooriumile. Osmussaar Noarootsi vallas Lääne maakonnas, Pakri saarte ja Pakri poolsaare klint Paldiski linnas ning Türisalu pank Harku vallas, viimased 2 omavalitsust kuuluvad Harjumaa koosseisu. Võttes arvesse geopargile esitatavat ühtse territooriumi nõuet, tuleks geopark moodustada 6 väga erineva omavalitsuse territooriumitele (Noarootsi, Nõva, Padise, Keila ja Harku vallad ning Paldiski linn).

Põhja-Eesti klindi kõige läänepoolsem ja üks efektsemaid klindilõike on Noarootsi valla haldusalasse kuuluv Osmussaar. Osmussaarega koos tuleks geopargi kosseisu arvata läheduses meres asuv Neugrundi madal, mis teatavasti kujutab endast meteoriidikraatrit (koordinaadid 59°20'N ja 23°32'E) ja Eesti suurima rändrahn Toodrikivi, mis samuti paikneb meres Osmussaare ja mandri vahel (koordinaadid 59°15,2'N ja 23°24,5'E).

Osmussare klindiastang (8 m) ei kuulu küll kõrgeimate hulka, kuid kuna pank allub mere murrutusele, siis on kõik piirkonnas toimunud geoloogilised protsessid, pangal hästi näha. Leidub palju fossiile, kauneid kaltsiidistunud-püriidistunud lõhesid, rannaastangu jalamil võib jälgida 475 miljonit aastat tagasi toimunud katastroofilise maavärina tagajärjel tekkinud lubiliivakivi sooni ja kehasid. Viimased on Põhja-Eesti klindil täiesti erakordsed. Madala veeseisu korral võib neid näha veel vaid Pakri saartel. Osmussaarel on näha ka 535 miljonit aastat tagasi tekkinud Neugrundi meteoriidikraatrist välja paiskunud meteoriitbretšarahne. Allveeujumise varustust kasutades on võimalik tutvuda Neugrundi meteoriidikraatriga. Neugrundi meteoriidikraater tuleks võtta looduskaitse alla.

Osmussaarel on väga huvitav ajalugu. Legendi järgi paikneb saarel viikingite pea- ja sõjajumala Odini haud. Osmussaar oli kogu nõukogude aja suletud territoorium kuid pärast Nõukogude armee lahkumist 1993. aastalal on saar muutunud atraktiivseks turismiobjektiks. 1996. aastal loodi Osmussaare maastikukaitseala. Osmussaare maastikukaitsealal on tähistatud geoloogilised, bioloogilised ja ajaloolised mälestised. Saarele on rajatud 3 telkimiskohta. Regulaarne ühendus saarega puudub, kuid suvekuudel saab Dirhami sadamast saarele tellida paadireise. Osmussaare kohta võib internetist leida materjali mitmes keeles. Aastateks 2008–2013 on Noarootsi vallavalitsus planeerinud investeerida 7,2 mln krooni Osmussaare sadama ehitamiseks, aastateks 2011–2012 on planeeritud 2 mln krooni koduloomuuseumi rajamiseks, aastateks 2009–2013 4 mln kombi(elektri)jaama ehituseks ning aastateks 2009–2013 3 mln krooni interneti püsiühenduse loomiseks. Osmussaar oleks suurepärane geopark, kui seal oleks elanikke, kes seda vajaksid. Praegu on saarel vaid 3 elanikku.

Nõva ja Padise valdade territooriumil Põhja-Eesti klindi pangad puuduvad, kuid arvestades ühtse territooriumi printsiipi peaks vähemalt rannikuala kuuluma klindi läänepoolse geopargi koosseisu. Kuna väike (474 elanikku) Nõva vald näeb oma arengukavas ette kämpingute rajamist ja turismi soodustamist, võiks vallal olla huvi geopargiga liituda. Padise vallal võiks tulevikus olla samuti motivatsiooni geopariga ühineda, sest kuulumine UNESCO poolt tunnustatud geopargi koosseisu elavdaks kindlasti ka kloostri külastamist. Padise klooster, kui tähelepanuväärne ajaloomälestis, tõstaks igati geopargi väärtust. Pakri Saarte ja Pakri panga paljandid asuvad Paldiski linna territooriumil ja Türisalu pank Harku vallas. Viimased 5 omavalitsust asuvad Harju maakonnas ja on oma suuruselt ja majanduslike huvide poolest väga erinevad. Harku vallas on üle 10 000 elaniku, Nõva vallas ainult 474. Nende valdade võime ja huvi turismi arendamiseks on väga erinev. Paldiski linna omavalitsuspiirkond, kus asuvad Põhja-Eesti klindi ühed efektsemad pangad, on edukas majanduspiirkond ja turism ei kujuneks selles piirkonnas kunagi väga oluliseks tulu toovaks majandusharuks. Paldiski omavalitsuse huvi geopargi vastu võiks olla eelkõige kodukandi suuremas väärtustamises, Paldiski linna kunagise kuulsuse taastamises ja Põhja-Eesti klindi ühe efektseima panga tutvustamises kogu maailmale.

Harku ja Keila vallad, mis on suures osas kujunenud Tallinna elu- ja suvilarajooniks, huvi geopargi vastu võiks seisneda oma elanikkonnale paremate vaba aja veetmise võimaluste pakkumises. Türisalu panga suurem väärtustamine ja parem tutvustamine võiks sobida valla arengukavasse, kuhu on lähiaastateks planeeritud meetmed puhkevõimaluste arendamiseks. Läänepoolse geopargi loomiseks on eeldusi kõikides loetletud valdades, kuid geopargi loomise aluseks on kohalik huvi ja aktiivsus.

Idapoolse geopargi pangad Saka-Ontika-Toila, Päite ja Udria pank jäävad Kohtla, Toila ja Vaivara valdade territooriumile. Kõige idapoolsem Vaivara vald on kolmest loetletud vallast suurim (390 km^2), elanikke on vallas 1800. Läänepoolseim Kohtla vald on nii territooriumi kui ka elanike arvu poolest väikseim 101 km^2 ja 1600 elanikku. 159 km^2 suuruses Toila vallas on kõige rohkem elanikke, 2500. Vallad, mille territooriumile jäävad Põhja-Eesti klindi idapoolsed pangad ei erine üksteisest niipalju kui läänepoolsed. Need vallad asuvad Ida-Virumaa tööstuslinnade vahetus läheduses ja on juba pikka aega olnud linnaelanike lähimaks väljasõidupiirkonnaks. Ontika pank on olnud populaarne turismiobjekt juba aastakümneid ja mitte ainult eestlastele vaid ka meie lähemates naabermaadest saabunud turistidele.

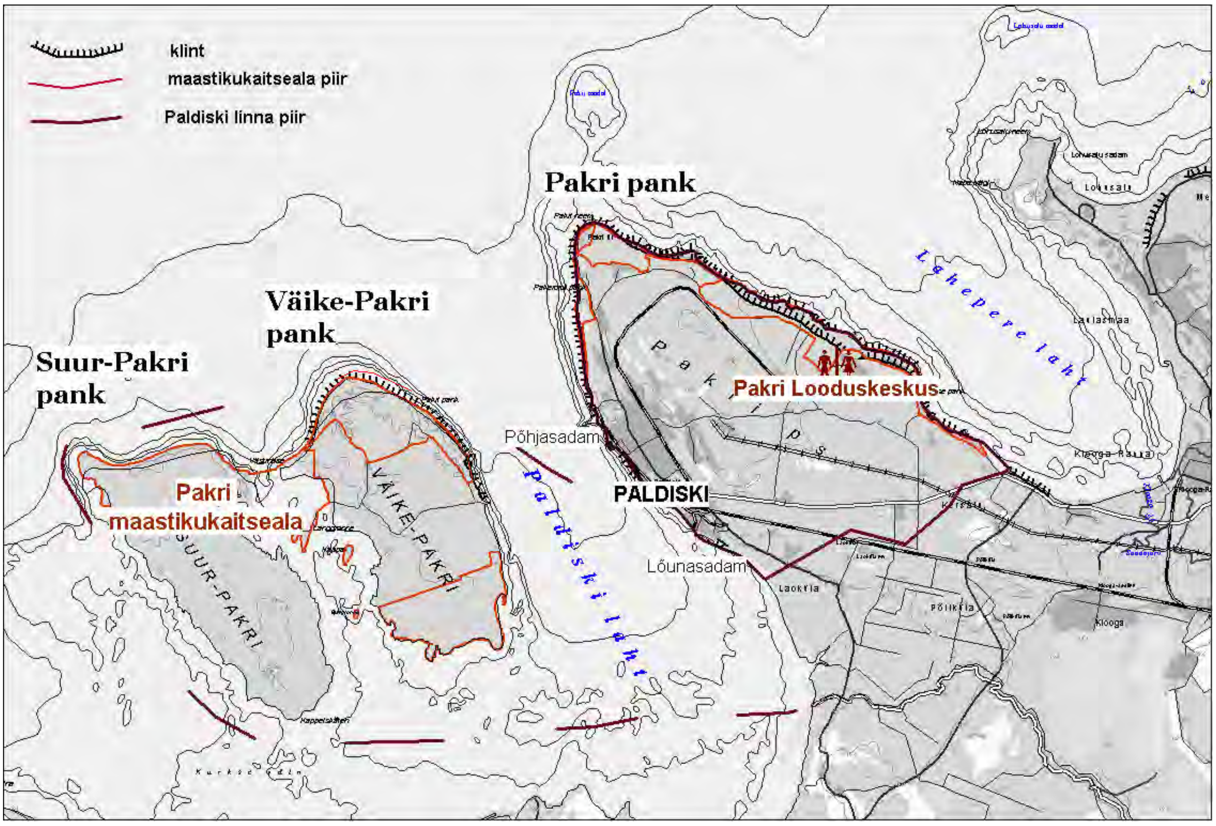
Toila vald on olnud kuulus suvituskoht alates XIX sajandist. Oru loss, mis ehitati aastail 1897.–1899. ja oli alates 1935. aastast Eesti esimese presidendi Konstantin Pätsi suveresidents. Pikki aastaid oli Toilas pioneerilaager. 1989. aastal avati Toila Sanatoorium, mille juurde kuulub ka kämping. Toilas asub väike sadam, mis võiks osutada turismiteenuseid kuna klint on hästi jälgitav just merelt. Toila vald on Ida-Virumaa valdadest tõenäoliselt kõige tuntum.

Kohtla vallas on viimasel kahel kümnendil tehtud palju klindi paremaks eksponeerimiseks. Üheks atraktiivseks ettevõtmiseks oli 1999. aastal Valaste joale vaateplatvormi ja trepi rajamine. Pankranniku miljööväärtuse tõstmiseks on aastatel 2002–2007 investeeritud 10 mln krooni, Saka-Ontika pangale on rajatud kaks kaunist treppi ning matka- ja seiklusrada, korrastatud on pangapealne maastik ja teedevõrk. Aastatel 2002–2007 investeeris OÜ Net Systems Saka mõisakompleksi arendamisse 18 mln krooni, selle raha eest on ehitatud 60-kohaline hotell koos restorani ja veekeskusega, telkimiskohad ja karavanide parkimiskohad koos pesemis- ja tualettruumidega. Rajatud on tennise-, võrkpalli- ja petankiväljakud ning 400 kohaga vabaõhulava. Rajatud on ka kogu kompleksi teenindav infrastruktuur. Tööd on käimas muinsuskaitsealuse Saka mõisa peahoone renoveerimiseks kuhu on plaanis rajada Klindi külastuskeskus koos klinti tutvustava ekspositsiooniga.

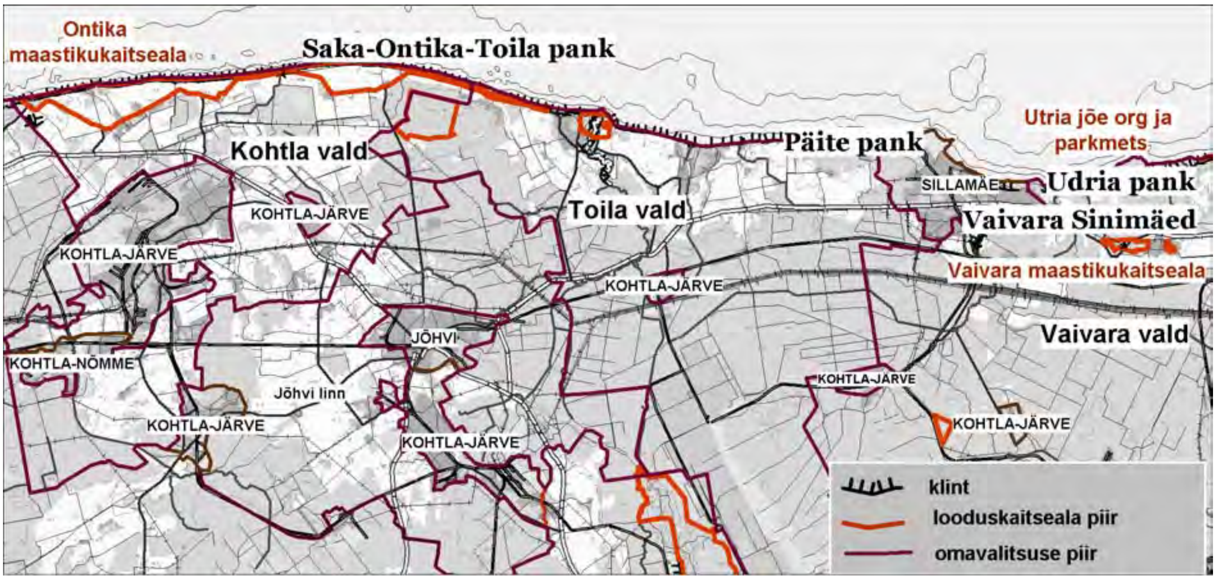
Eelpoolöeldust nähtub, et kui Toila vallas rajati puhkekompleks eelmise sajandi kaheksakümnendatel aastatel (Toila Sanatoorium), siis Kohtla vallas on puhkemajandust ja turismi arendav tegevus hoogustunud just käesoleval kümnendil ning suund on võetud aktiivsematele vaba aja veetmise vormidele ja looduse tutvustamisle.

Vaivara vald on turismi sihtmärgina eelkõige kuulus oma sõjaajaloo mälestiste poolest. Siin asuvad ka kaks Põhja-Eesti klindi tähelepanuväärset juga, Langevoja ja Tõrvajõe joad ning Utria ja Meriküla pangad. Viimased on Saka-Ontika-Toila ja Päite pankadest küll madalamad, küündides 20 kuni 38 m ümp, kuid tänu sellele, et nad asuvad vahetus mere murrutusvööndis, on geoloogiline läbilõige jälgitav Kambriumist kuni Ordoviitsiumini. Merikülas eemaldub klint merest lõplikult. Kõikides valdades on viimastel aastatel tehtud investeeringuid turismi arendamiseks, kerkinud on majutuskohad, rajatud on matkaradu. Geopargi loomiseks on eeldusi kõigis kolmes vallas.

Käesoleva töö eesmärgiks on analüüsida geopargi või geoparkide rajamist Põhja-Eesti klindialale. Nagu eelpoolöeldust nähtub, on eeldusi geopargi moodustamiseks kõikides käsitletud valdades, kuid geopargi loomiseks on vaja suurt kohalikku huvi, et mitte öelda entusiasmi, ettevõtlikkust ja ka majanduslikku suutlikkust. Lähtudes mitme Euroopas loodud geopargi kogemustest ja Saaremaa-Silurimaa geopargi algatamisel saadud kogemustest, otsustas töögrupp valida välja piirkonnad, kus kohalike omavalitsuste ja ettevõtluse huvid geopargi moodustamiseks kõige paremini kokku langevad ja on ka juba praktikas rakendunud. Nendeks omavalitsusteks on Paldiski linn klindi lääneosas (joonis 5) ning Kohtla ja Toila vallad klindi idaosas (joonis 6).



Joonis 3.2.4. Põhja-Eesti klindi läänepoolne geopark.



Joonis 3.2.5 Põhja-Eesti klindi idapoolne geopark.

Paldiski omavalitsusüksuse pindala koos akvatooriumiga on 102 km^2, millest Pakri poolsaare pindala hõlmab 34 km^2 ja Pakri saared 25 km^2. Paldiski omavalitsuse territooriumil elab 3800 inimest. Paldiski omavalitsuse territooriumile jäävad Põhja-Eesti klindi pangad Suur- ja Väike-Pakri ning Pakri pank on looduskaitse all kui maastikukaitseala. Nii Pakri pank kui Pakri saared on atraktiivseteks turismiobjektideks. Geopargi loomise heaks eelduseks on MTÜ Pakri Looduskeskus. Looduskeskus on seadnud endale ülesandeks arendada piirkonnas geoloogilise suunitlusega turismi, rajada matkaradu ja pakkuda loodusõpet koolilastele. Looduskeskuses on majutusvõimalus ja telkimiskohad.

Projekti käigus on Eesti Geoloogia Selts saatnud kirja Paldiski Linna valitsusele ja küsinud nende arvamust ja huvi geopargi rajamise kohta. Kahjuks ei ole Paldiski linnavalitsus oma seisukohta teatanud ega palunud ka projektis osalejailt selgitusi, küll on Paldiski linnavalitsus avaldanud toetust MTÜ Pakri Looduskeskuse ettevõtmistele. Kogu Pakri panga, kui ühe parima klindi läbilõike, demonstreerimisele on suureks takistuseks pangakaljudes pesitsevad krüüslid. sest need linnud on looduskaitse all ja pesitsuse ajal, 1. maist kuni 31. augustini, ei või neid häirida. Seega ei ole Pakri pank täies ulatuses jälgitav kõige levinumal puhkuseperioodil. Viimastel kuudel on MTÜ Pakri Looduskeskus, oma tegevust edasi arendanud ja võetnud suuna Loode-Eesti geopargi moodustamisele. Viimane hõlmaks kõik töös välja pakutud klindi läänepoolsed pangad, sealhulgas mere alla jääva Neugrundi meteoriidikraatri ja Eesti suurima rändrahnu "Toodrikivi". Pakri Looduskeskuse initsiatiivi tuleks igati toetada, sest sellisel juhul jääks geopargi territooriumile ka silmapaistev ajaloomälestis: Padise klooster. Geopargi loomisesse peaks juba algfaasis hõlmama ka muinsuskaitse.

Teine piirkond, kus leidub piisavalt huvi ja entusiasmi geopargi moodustamiseks, on Kohtla ja Toila vallad (joonis 6). Mõlemad vallad on investeerinud turismi arendamisse, milles üheks peamiseks atraktsiooniks on Põhja-Eesti klindi pangad. Kohtla ja Toila valdadel on ühistegevuseks loodud ettevõtted: MTÜ Kirderanniku koostöökogu ning MTÜ Toila-Ontika Merekuurort, seega on neil valdadel ühistegevuse eesmärk ja kogemus juba olemas. Mõlemas vallas on ettevõtlust, mis on tegelevad turismiga ja Põhje-Eesti klindi parema eksponeerimisega. Neil ettevõtetel on nii huvi kui majanduslikku suutlikkust piirkonda arendada, ka on sihtasutus Saka-Ontika Pank, mis arendab Saka-Ontika klindilõiku, MTÜ Kirderanniku koostöökogu liige.

Töögrupp leiab, et nii Eesti loodeosa, kus geopargi moodustamise eestvedajaks on MTÜ Pakri Looduskeskus kui ka Kohtla ja Toila vallad oleksid perspektiivised piirkonnad geopargi moodustamiseks. ja mõlemad piirkonnad omavad potentsiaali saada vastu võetud Euroopa Geoparkide Võrgustikku ja pälvida UNESCO tunnustust. Perotsessi käigus tuleks üritada veenda eelkõige Euroopa Geoparkide Võrgustiku funktsionääre, tunnustama Põhja-Eesti klindi aga võib-olla Balti klindi geoparki, vaatamata sellele, et selle osad on üksteisest eraldatud ja funktsioneerivad iseseisvalt ka majanduslikult.

Nii Euroopa Geoparkide Võrgustikuu kui ka UNESCO tunnustus on ihaldusväärsed ja aitavad leida tuntust maailmas, kuid kõige olulisem geopargi moodustamisel on ikkagi see moraalne ja majanduslik kasu, mida peaks saama geopargi piirkond ja kogu Eesti.

4. Kokkuvõte

Põhja-Eesti klindi esitamisel UNESCO maailmapärandi nimekirja osutus põhiprobleemiks silmapaistva universaalse väärtuse (*Outstanding Universal Value*) näitamine ja tõestamine. Maalimapärandi nimekirja kandmiseks tuleb võistelda paljude suurepäraste astangutega, mis on pikemad ja kõrgemad kui Põhja-Eesti klint, sealhulgas neid, kus paljanduvad Alam-Paleosoikumi kihid ja kus on unikaalseid fossiilide leiukohti.

Seetõttu jõudis nii töögrupp kui kaasatud välisekspert äratundmisele, et edasiste tegevuste planeerimisel tuleks põhitähelepanu suunata teistele võimalustele klindi esiletõstmiseks ja selle kohaliku ning rahvusvahelise tuntuse suurendamiseks. Eelkõige tuleks silmas pidada klindi perspektiivi geopargi või geoparkide loomisel. Viimane/viimased võiksid taotleda UNESCO geopargi staatust, mis ei välista uut maailmapärandi nimekirja kandmise taotlus tulevikus.

Analüüsides võimalusi geopargi moodustamiseks Põhja-Eesti klindil jõudis töögrupp järeldustele, et üht ning kõikehõlmavat geoparki klindile moodustada ei ole esialgu võimalik.

Geoparkide rajamist tuleks alustada piirkondadest, kus Põhja-Eesti klindi pangad on kõige efektsemad ja kohalik huvi ning majanduslik suutlikkus juba toetavad geopargi rajamist või võiksid hakata seda toetama lähitulevikus. Seetõttu oleks mõistlik moodustada esmalt kaks rahvuslikku geoparki – Põhja-Eesti klindi idapoolne geopark keskusega Sakal ning läänepoolne geopark keskusega Paldiskis – mille laienemine ja ühinemine oleks võimalik edaspidi. Kuna planeeritavad geopargid asetseksid üksteisest võrdlemisi kaugel, peaks mõlema eesmärk olema kõikide klindilõikude atraktiivne tutvustamine. Samas oleks nii infomaterjale, õppevahendeid kui kompetentsi ja kogemusi võimalik jagada juba projekti algstaadiumis.

Geoparkide peamiseks eesmärgiks peab olema kohaliku (loodus)turismitööste arendamine ning loodushariduse edendamine, mis saab sündida ainult kohalike omavalitsuste ja ettevõtjate ning riigiasutuste ja ülikoolide tihedas koostöös. Kindlasti vajaks kaalumist planeeritavate geoparkide sidumine Keskkonnaministeeriumi ning Haridus- ja Teadusministeeriumi eestvedamisel loodavate loodushariduskeskuste ning neis pakutavate programmidega.

Tallinna Tehnikaülikoolil ning Tartu Ülikoolil on olemas kompetents geoparkidele teadusliku ja haridusliku tausta loomiseks. Geoparkide loomisel kaasa löömisest ja seal tegevuste arendamisest on huvitatud ka mitmed valdkonnas tegutsevad kolmanda sektori esindajad sh MTÜ Eesti Geoloogia Selts, MTÜ GeoGuide Baltoscandia, MTÜ Pakri Looduskeskus, SA Saka-Ontika Pank, MTÜ Loodusring jt. Eraettevõtluse huvi projekti vastu on praegu veel tagasihoidlik. Samas on ettevõtjate huvi ja panus geoparkide loomise ning edasise toimimise eelduseks. Seetõttu peaks eraettevõtluse huvi äratamine olema geoparkide planeerimisel üheks esmaseks ülesandeks.

Keskkonnaministeerium võiks töötada välja mõned Eestis kehtivad reeglid, mis toetaksid mitmes piirkonnas juba olemasolevat algatust geopargi rajamiseks. Üks väga hea kohaliku aktiivsuse näide on Pandivere Paeriik "Allikate allikal", kus Laekvere, Rakke, Tamsalu ja Väike-Maarja vallad moodustasid 2006. aastal MTÜ, mille eesmärk on kaasa aidata kohaliku elu ja initsiatiivi arengule. Selline reeglistik ei peaks tähendama mingite riiklikult kehtestatud nõudmiste täitmist vaid tunnustuse jagamist. Sertifikaat "Eesti Geopark" võiks täpselt samuti tähistada loodushoidlikku elustiili ja eeskujulikku jätkusuutliku majanduse arendamist.

On päris selge, et UNESCO ei anna oma tunnustussertifikaati kahele samateemalisele geopargile. Seepärast on just eriti vajalik mõlemas klindile loodavas geopargis tutvustada kõiki Põhja-Eesti klindi panku, suunamaks turisti täiusliku ülevaate saamiseks külastama mõlemaid klindi geoparke.

4.1 Edasised tegevused

4.1.1 Partnerid

Geoparkide loomiseks on vajalik erinevate asutuste, organisatsioonide ja huvigruppide tihe koostöö. Eesti geoparkide loomisel peaksid kaasa lööma:

A. Kohalikud omavalitused
B. Erasektor
C. Kolmas sektor (mittetulundusühingud, sihtasutused ja organisatsioonid)
D. Riigi- ja avalik-õiguslikud asutused sh
    1. Keskkonnaministeerium
    2. Haridus- ja Teadusministeerium
    3. Tartu Ülikool
    4. Tallinna Tehnikaülikool
    5. Eesti Geoloogiakeskus

4.1.2 Tegevused ja ajakava

Eeltööd 2008-2009

- Initsiatiivgruppide loomine
- Aktiivne omavalitsuste informeerimine geoparkidega seonduvatest võimalustest ja vajadustest
- Eraettevõtluse huvi äratamine ja kasvatamine
- Geoparkide loomiseks vajaliku juriidiliste ja formaalsete aspektide väljatöötamine (Keskkonnaministeerium, kohalike omavalitsuste esindajad, Eesti Geoloogiakeskuse, TTÜ GI ja TÜ Geoloogia Instituudi esinsdajad, looduskaitse esindajad ja muinsuskaitse esindajad + …..)

Eesti Geopargid, 2009-2014

- Projektitaotlused
- Teadusliku ja haridusliku sisu tootmine, sh turismimarsruudid, õppevahendid, infomaterjalid, ekspositsioonid (MTÜd, ülikoolid, muuseumid, loodushariduskeskused, eraettevõtjad)
- Infrastruktuuri väljaarendamine
- Geotoopide atraktiivne tähistamine
- Seotud inimressursi arendamine (turismitöötajate koolitused jms)
- Geoparkide ja neis pakutavate teenuste laiaulatuslik reklaamikampaania
- Infovahetus ja koostöö mõne/de teise/te EuroopaGeoparkide Võrgustikku kuuluva geopar-giga/kidega
- Rahvusvahelise toetuse hankimine (eelkõige ülikoolid oma teaduslike sidemete kaudu)
- ...

UNESCO Balti klindi geopark, 2015-...

- Taotluse esitamine ühinemiseks Euroopa Geoparkide Võrgustikuga
- UNESCO geopargi staatuse taotlemine

4.1.3 Finantseerimine

Geoparkide väljaarendamiseks on esimeses etapis vaja märkimisväärseid investeeringuid, mis saavad vaid osaliselt tulla Eesti erasektori omafinantseeringute ning siseriiklike projektide arvelt. Seetõttu on möödapääsmatu vahendite taotlemine Euroopa Liidu abiprogrammidest. Geopargi loomist on võimalik toetada erinevatest rogrammidest sh näit Leader+, Interreg ja ERDF. Näiteks Leader programmi toetusel on Saksamaal väljaarendatud kaks terviklikku geoparki. Positiivseid näiteid on ka Eestist, kus Saka keskuse infrastruktuuri ja ekspositsiooni väljaehitamiseks on Euroopa Liidu fondidest edukalt vahendeid taotletud.

Peale geoparkide väljaarendamist ja tegevuste käivitamist peaksid need edaspidi toimima ilma välise abita, tootma seotud ettevõtjatele kasumit ning arendama kohalikku majandust.

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EESTI GEOLOOGIA SELTS

Põhja-Eesti klint
UNESCO maailmapärandi ja geopargina: edasiste võimaluste analüüs

Lisad

Krista Täht-Kok

Leho Ainsaar
Olle Hints

Alvar Soesoo

Kalle Suuroja

Igor Tuuling

Tallinn-Tartu, 2008

Lisad

Lisa 1. Balti klindi tekkehüpoteesid viimaste uuringute valguses

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Balti klindi tekkehüpoteesid viimaste uuringute valguses

Igor Tuuling, TÜ geoloogia osakond

Pinnavormina on Eestimaa sümboliks vaieldamatult Põhja-Eesti rannikut palistav klint (foto 1). Arvatavasti jõudis sõna *klint* Eestimaale koos läänepoolt saabunud sõjakate viikingitega ning vaatamata selle erinevatele tähendustele ajaloos (Paatsi, 1995), seostab tänapäeval enamus meist klindiga mererannikut ääristava või siis selle läheduses paikneva järsu astanguga. Järskude ja kõrgete rannaastangute tähistamisel esineb see sõna tänapäevalgi sagedasti just Rootsi rannikumere saarte, Gotlandi (Högklint, Jungfryn Klint jt.) (foto 2), Ölandi (Köpings Klint, Aboda Klint jt.) ning Taani idaosa (Møns Klint) kohanimedes, kust see ilmselt ka paljudesse Läänemere ümbruse maadesse (Saksamaa, Holland, Venemaa, Läti jt.) leviski. Kuigi ka inglise keeles ei ole sõna *clint* (Martinsson, 1958) või *klint* (Encyclopedia of Coastal Science, 2005) Läänemere äärsete aluspõhjaliste rannaastangute nimetamisel tundmatu, tuntakse maailma levinuimas keeles sellist pinnavormi pigem termini *cliff* kaudu. Viimane on ka teistes Läänemere ümbruse maades *kliff* (rootsi k) *das Kliff* (saksa k) laialt levinud.

Foto1. Eestimaa sümbol Balti klint Pakerordi neemel

Klint ja Läänemeri

Niisiis on juba klindi mõistesse kätketud piisavalt mere hõngu, mistõttu selle pinnavormi teke meie alateadvuses iseenesestmõistetavalt ka mere murrutusega seostub. Sellist arusaama kinnistab veelgi võimsate, tormist paisutatud Läänemere voogude kogemine rannikulõikudes, kus mere mässavad lained vastu klinti paisatuna tuhandeiks pritsmeiks pihustuvad, jättes endast järele klindijalamisse uuristatud sügavaid murrutuskulpaid ja kaldajärsakult alla langenuid suuri paeplaate (foto 3). Ent piisab põgusast pilgust Läänemere põhjareljeefi kaardile ja säärane lihtne ning loogiline seletus Balti klindi kujunemisest puruneb kildudeks.

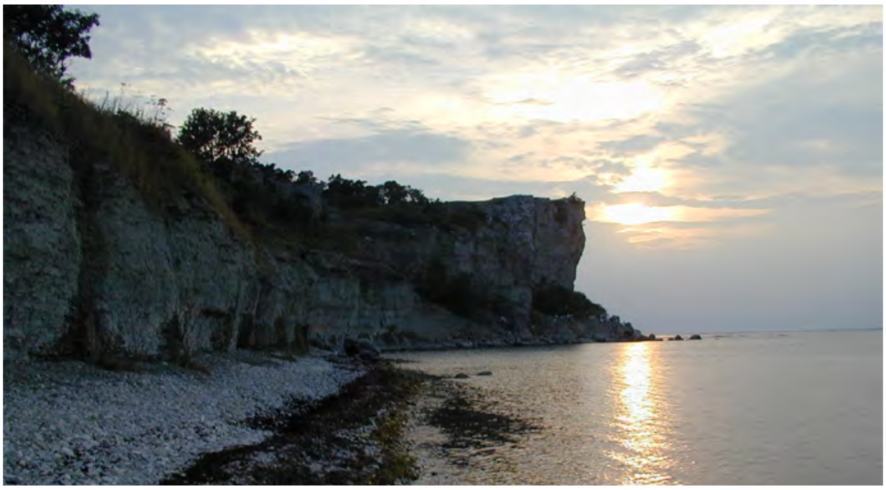
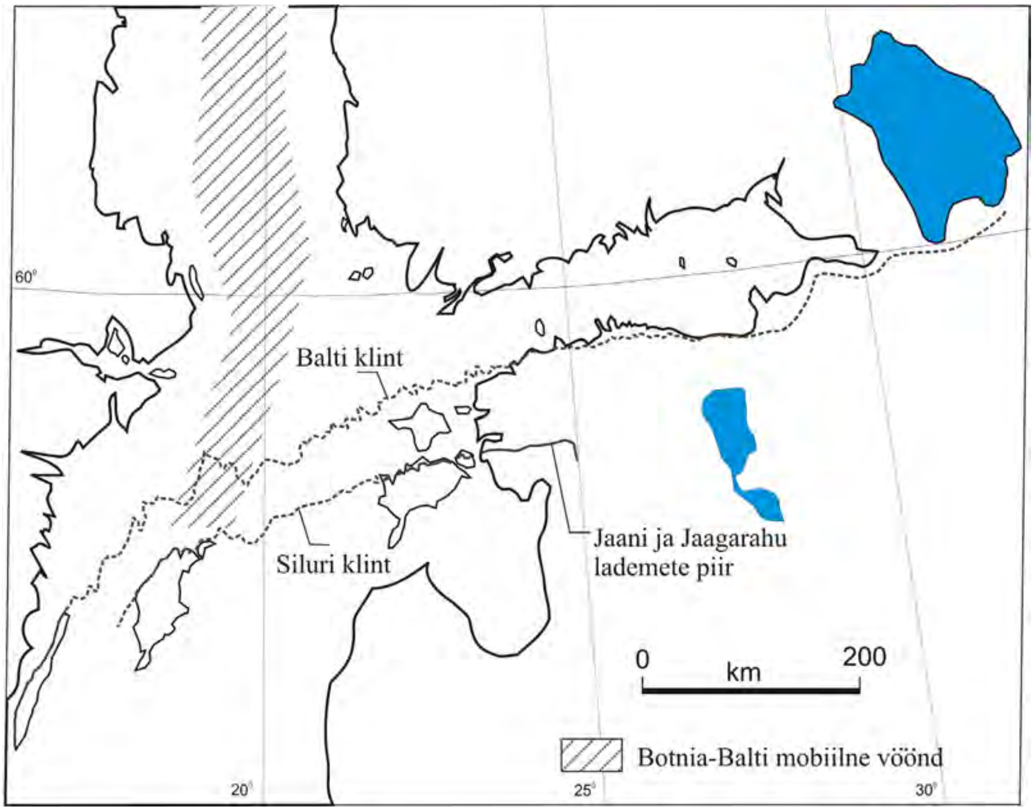


Foto 2. 48 m kõrgune Högklint on nii Gotlandi kui ka kogu Siluri klindi kõrgeimaks astanguks

Vetesügavusest, alalt mis pole eales Läänemere tasemest kõrgemale ulatunud ega seega ka selle rahutute voogude meeltevallas olnud, kõrgub vastu seesama, stoiliselt oma kulgu läänesihis jätkav klindiastang. Merealuse klindi ja seda ümbritseva aluspõhjareljeefi täpsem uurimine (Tuuling, 1998; Troon, 2001; Tilk, 2006; Tuuling, jt., 2007; Tuuling & Tilk, 2007) on näidanud, et ka detailides erinevad need vähe maismaal nähtust ning pärastjäääaegne kulutus ja Läänemere murrutus on juba varem eksisteerinud ja üle mere kerkinud aluspõhjalisi astanguid peamiselt puhastanud, neid viimase jäätumise aegsetest - ja järgsete setete alt välja prepareerinud ja veidike nihutanud. Lisaks Läänemere murrutuse ja Balti klindi tekke omavahelise seose välistamisele, seisame nüüd silmitsi ka dilemmaga; kas astangut Läänemere all, mis pole eales ääristanud ei selle rannikut ega olnud ka ta murrutuse meelevallas, on üldse korrektne nimetada klindiks? Kui järgime alateadvust, kus klint seostub rannaastanguga, siis kindlasti mitte, kui lähtume aga definitsioonist, kus klinti käsitletakse kui aluspõhjalist astangut, mille genees pole üheselt määratletud (Martinsson, 1958), siis on Laadoga kallastelt Ölandi lõunatipuni kulgev astang (joonis 1) kõikjal, nii maismaal kui mere all, ikka seesama Balti klint, mille algsel tekkel pole Läänemerega miskit seost. Siin jõuame aga taas aastasadu mõtlemisainest andnud küsimuseni – milliste protsesside tulemusena on suhteliselt tasase pinnamoega Läänemere äärsesse regioonis kujunenud selline märkimisväärne astang?

Foto 3. Meremurrutuse tulemusel paeplaatidest palistatud klindiastang Väike Pakril



Joonis 1. Balti ja Siluri klindi levik

Loobudes tavapärasest, erinevate tekkevõimaluste poolt ja vastu argumentide vaagimisest (Miidel, 1992; Suuroja, 2003, 2005, 2006, 2007), pöörame allpool esmalt suuremat tähelepanu sääraste astangute tekkimisvõimalustele looduses. Lähtudes teoreetilistest teadmistest ja tuginedes tänapäeva Balti klindi uuritusele, arutleme hiljem klindiastangu erinevate tekkevõimaluste üle. Selle probleemi käsitlemisel on aga ülioluline tugineda varasemates aruteludes liialt tahaplaanile jäänud kahele tõsiasjale, milleta ükski klindi geneesi käsitlus ei saa olla tõsiseltvõetav; 1. Balti klint osutub ainult üheks, kõige märkimisväärsemaks astanguks ulatuslikus astangute ja terrasside süsteemis, 2. Astangute ja terrasside süsteemid (analoogne süsteem esineb ka Siluri klindil) on aga osaks siinsest regionaalsest kuestalaadsest morfostruktuurist, moodustades asümmeetriliste kuestaorundite järsema lõunaveeru. Selline kompleksne pilt on eriti ilmekalt esile tulnud viimastel aastakümnetel tehtud Läänemere aluste uurimustööde käigus (Tuuling, 1998; Tuuling & Flodén, 2001; Tuuling & Tilk, 2007; Tuuling jt., 2007).

Ulatuslikud järsuseinalised astangud, astangute ja terrasside süsteemid looduses

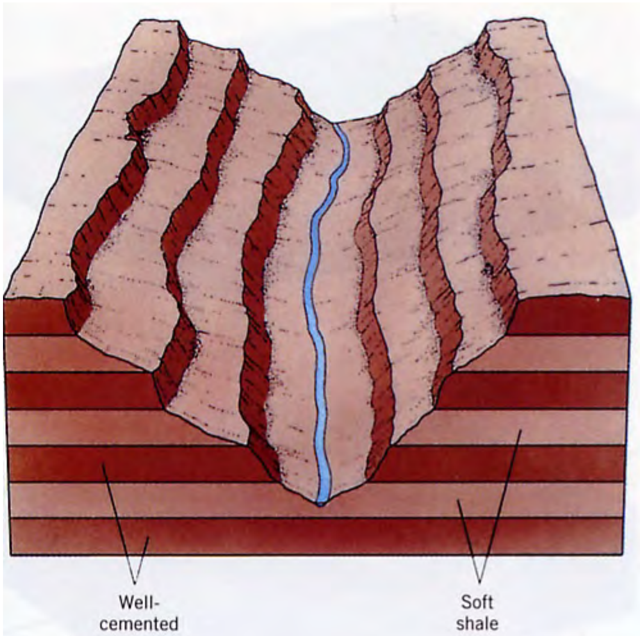
Looduses võivad ulatuslikud ja püstloodsed astangud moodustuda kaheti; kas piki maakoore plokkide vertikaalsetel liikumistel tekkivaid murrangpindu või siis maapinna erosioonil. Viimasel juhul on kulutavaks faktoriks enamasti vesi, mille maapinda purustav ja erodeeriv jõud võib olla koondunud kas uuretesse, kanalitesse ja jõesängidesse kogunevatesse vooluvetesse või siis rannikut räsivatesse lainetesse. Voolava vee kineetilisest energiast tulenevalt on kulutuse intensiivsus piki selliseid voolusänge ümbritsevatest aladest tunduvalt suurem, mistõttu aegamisi maapinna sügavusse lõikuvate jõgede kallastel ja tekkivate orgude veerudel võivad moodustuda märkimisväärsed astangud. Sarnaselt võivad ulatuslikud püstloodsed astangud tekkida üle merepinna kerkinud/kerkivates rannikulõikudes, mis on lainemurrutuse otseses meelevallas.

Foto 4. Järsunõlvaline rannaastang fluvioglatsiaalsetes setetes Gotska Sandönil

Foto 5. Püstloodne rannaastang Järve ranna luidetes Saaremaal vahetult peale 2005 a. jaanuaritormi

Järskude seintega astangud püsivad looduses ainult kõvades erosioonikindlates kivimites, kuna vähese kulumiskindlusega pehmed kihid kalduvad sõltuvalt nõlvapüsivusest moodustuma järsemaid/laugemaid nõlvu (foto 4). Viimastes võivad väga järsud või isegi püstloodsed lõigud püsida üksnes lühiaegselt nende jalamiosas, kas jõevooluse või merelainetuse vahetu kulutuse piirkonnas (foto 5). Seega eeldab kõrgemate püstloodsete astangute olemasolu kindlasti erosioonikindla(te), nõlvapüsivate kivimkihti(de) olemasolu maismaa geoloogilises läbilõikes. Looduses esinevad imposantsed, maa ja mere piiril kõrguvad astangud seetõttu kas täielikult kõvades aluspõhjakivimites või siis markeerivad need kitsama/laiema ribana püstloodsena langevate astangute ülaosa. Sarnane nõlvakallakuse sõltuvus litoloogilisest läbilõikest tuleb selgelt esile ka jõeorgude morfoloogias. Kui homogeensesse pehmesse kivimkompleksi lõikuv jõeorg on ristiprofiilis V-kujuline, ühtlaselt langevate veerudega, mille kallakus sõltub kivimi kõvadusastmest/nõlvapüsivusest (joonis 2), siis erosioonikindluselt kontrastsete kihtide vaheldumine geoloogilises läbilõikes toob jõe ristiprofiilis kaasa järskude astangute ja laugenõlvaliste lõikude vaheldumise (joonis 3).

Joonis 2. Pehmetesse kivimitesse lõikuv jõeorg on ristprofiilis V-kujuline (Press & Siever, 1998)



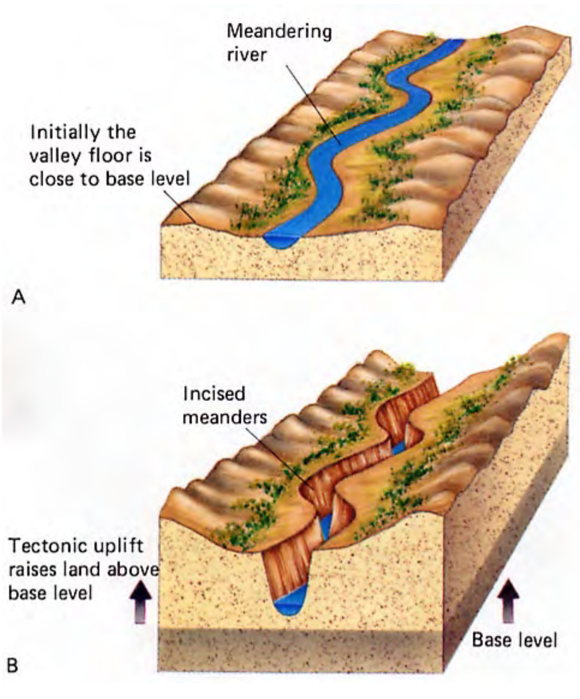
Joonis 3. Kõvade ja pehmete kivimkihtide vaheldumisel tekib V-kujulise jõeorus laugete nõlvade ja järskude astangute süsteem (de Blij & Muller, 1996)

Tektoonika ja eustaasia – erosiooni ulatust ja intensiivsust kontrollivad faktorid

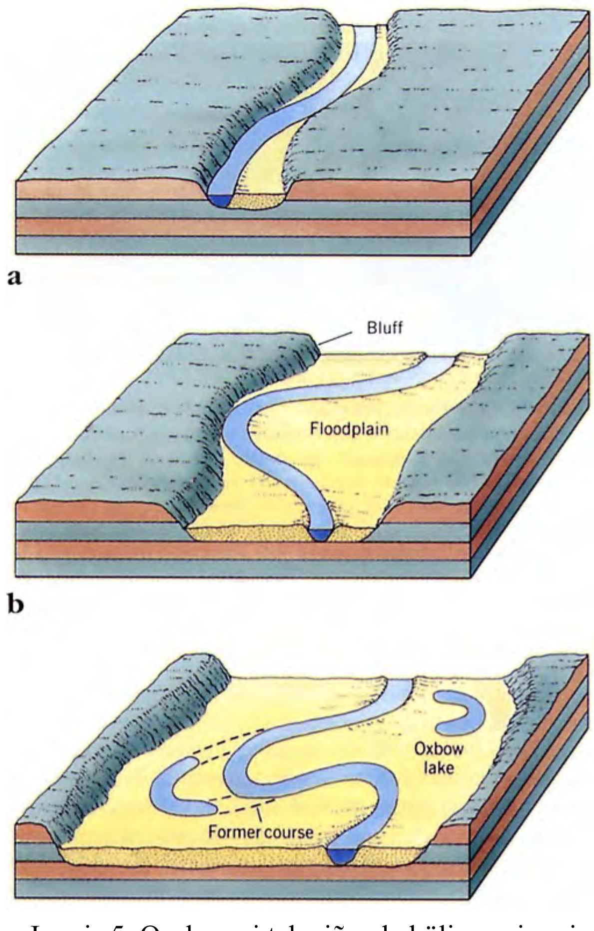
Dünaamilistes ja isereguleeruvates looduslikes süsteemides nagu jõed, rannikud, jmt., püüdlevad kulutusprotsessid saavutada tasakaalu setteid kuhjavate protsessidega. Kulutuse intensiivsus ja ulatus on alati otseses sõltuvuses maakoore tektoonilistest liikumistest või/ja maailmamere kõikumistest (eustaasiast), mis määravad ära nii maismaa ja ookeanitaseme absoluutsed kui ka omavahelise suhtelise kõrguse. Jämedates joontes – mida suurematesse absoluutsetesse kõrgustesse on kerkinud maismaa seda intensiivsemalt murendavad seda paljud looduslikud-klimaatilised faktorid, mida kõrgemal asub maismaa maailma mere taseme e. erosiooni baasi suhtes, seda suurem on maapinda kulutavate liustike, vooluvete jmt. faktori potentsiaalne ja kineetilise energia nivelleerimaks maapinda maailmamere tasemeni. Tektoonilis-eustaatiliste liikumiste poolt ajendatud kulutusprotsesside intensiivsuse muutused toovad kaasa ka selgeid teisenemisi jõeorgude ja rannikute morfoloogias. Nende faktorite korduvatel muutustel pikema geoloogilise ajaloo kestel võib aga nii rannikutel kui ka jõeorgudes välja areneda ulatuslik astangute ja terrasside süsteem.

Jõgedega seotud astangud ja terrassid

Regiooni aktiivne kerkimine ja/või erosioonibaasi langus toovad kaasa seal paiknevate jõgede pikiprofiilis kõrguste vahe suurenemise ja seeläbi vooluvee kineetilise energia kasvu ning kulutusvõime intensiivistumise. Kuigi pikemas perspektiivis püüdlevad kulutusprotsessid mistahes kerkivat piirkonda kõikjal maailma mere tasemeni nivelleerida, suureneb esmalt sealsete jõgede pikiprofiili diferentseeritus ja seeläbi nende põhjaerosioon sedavõrd, et pinnamoe üldine liigestatus kogu regioonis hoopiski kasvama hakkab. Seetõttu iseloomustavad tektooniliselt kerkivat ala enamasti sügavale maapinda lõikunud jõed, mis nõlvade piisava püsivuse korral püstloodsete astangutega piiritletud kanjonites voolavad (joonis 4). Tänapäeval tuleb see väga ilmekalt esile USA `s paikneval Colorado platool, kuhu viimase 40 miljoni aasta jooksul on ligi 3 km kerkimise tulemusena lõikunud Colorado jõgi ja selle lisajõed (kohati kuni 1.6 km sügavusse) moodustanud ulatusliku kanjonite süsteemi, mille markantseimaks esindajaks on Suur Kanjon.



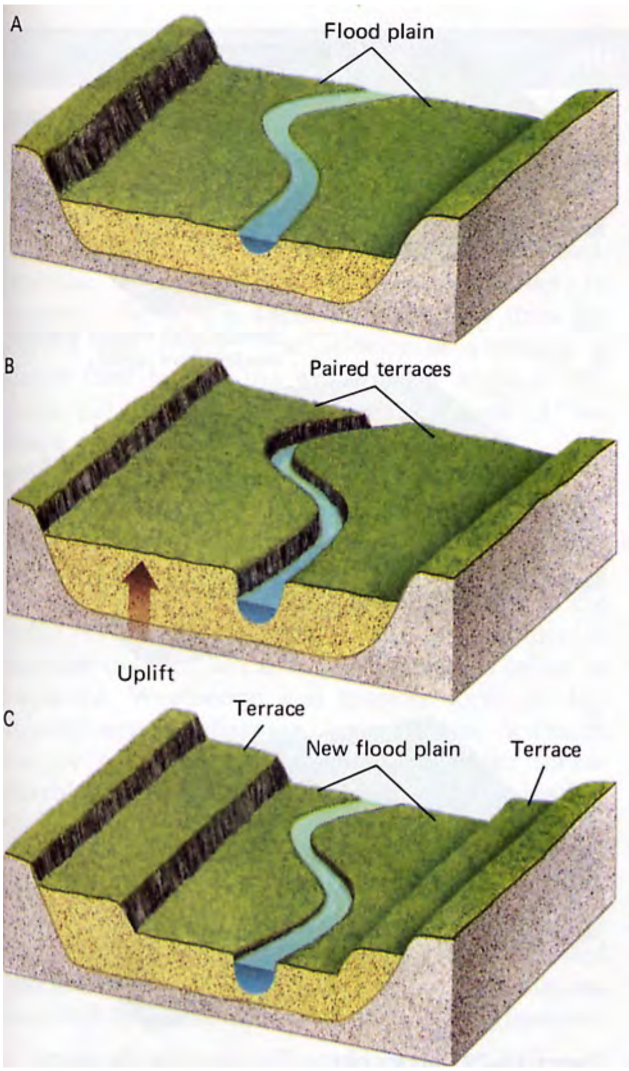
Joonis 4. Kanjonorundi teke ala tektoonilisel kerkimisel (Thompson & Turk, 1991)



Joonis 5. Orulammi teke jõgede küljeerosiooni ja meandreerumise tulemusel (de Blij & Muller, 1996)

Liikumatu maakoore ja püsiva erosioonibaasi tingimustes väheneb jõgede põhjaerosioon aegamisi miinimumini, nende lõikumine maapinda aeglustub/lakkab ja tähtsat rolli orgude arengus hakkavad mängima jõgede küljeerosioon ning meandreerumine. Samaaegselt meandriloogete laienemisega külgsuunas toimub nende migratsioon allavoolu, mis järk-järgult viib orundi laienemisele ja jõesängi ääristava laia ning tasase orulammi tekkele (joonis 5).

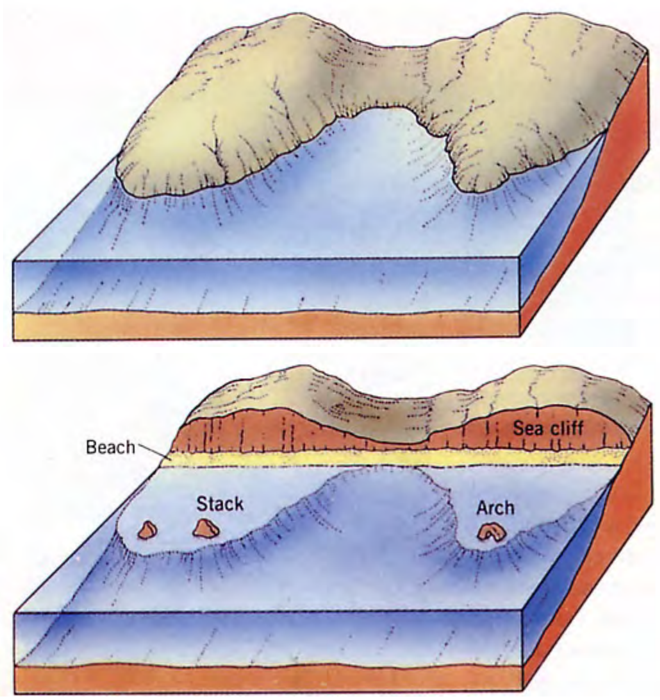
Kui jõe arengus eristuvad erosioonibaasi alanemise või/ja tektoonilise kerkimise muutustest tingituna selgelt vahelduvad põhja ja küljeerosiooni etapid, kujuneb oru veerudel välja astangute ja neid lahutavate terrasside süsteem (joonis 6). Enamasti moodustuvad sellised astangute terrasside paarid kummalgi pool jõesängi, kuid teatavates põhja ja küljeerosiooni tingimuste kombinatsioonis võib selline reljeef areneda ainult orundi ühel veerul.



Joonis 6. Astangulis-terrassilise jõeoru teke tektoonilistest kerkimistest tingitud põhja ja küljeerosiooni etappide vaheldumise tulemusena (Thompson & Turk, 1991)

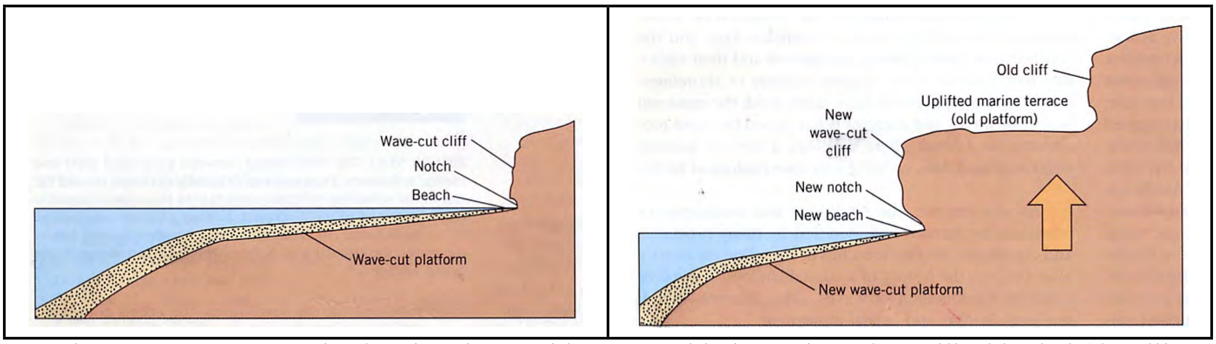
Astangud ja terrassid mererannikul

Mereranniku ilme, seal valitsevate protsesside ja moodustuvate reljeefivormide tüübi määravad suuresti ära maapinna tektooniliste liikumiste ja meretaseme muutuste vastastikused tendentsid ja kiirused. Järsud rannaastangud tekivad abrasioonilistes rannikulõikudes, seal kus võimas murd- või avamere lainetus pääseb vahetult ligi üle merepinna kõrguvale maismaale.



Joonis 7. Rannajoone õgvendumine ja järsakranniku ning murrutusplatoo kujunemine (de Blij & Muller, 1996)

Nii nagu jõgi püüdleb tasakaalustatud pikiprofiili suunas, pürgib lainetuse energia ja erosioon liigestatud rannajoone õgvendamisele (joonis 7). Seepärast moodustuvad käärulise rannajoone puhul järsuastangulised lõigud esmalt lainemurrutusele avatud, kaugele merre ulatuvate neemikute tippudes, samas kui lahtede päraosades valdab setete kuhjumine. Enamasti ulatub lainetuse otsene abrasioon ainult moodustuva rannaastangu allossa, kus lõheliste kivimite ja pehmemate kihtide kulumise tulemusena moodustuvad sageli murrutuskulpad ja koopad. Tühimikele toetuv astangu ülaosa muutub gravitatsiooniliselt järjest ebastabiilsemaks, kuni lõpuks toimub selle sissevarisemine. Selliselt, lainetuse ja gravitatsioonilise kollapsi koostöös toimub maaninade järk-järguline taandumine, nendevaheliste lahesoppide hääbumine, üksikute järsuseinaliste rannikulõikude pikenemine ja liitumine, mis lõpptulemusena viib ulatuslike, sirgjooneliste, kõrgete ning püstloodsete rannaastangute moodustumiseni (joonis 7). Maa pideval taandumisel moodustuva astangu ette kujuneb aga aluspõhjaline, kergelt mere poole kallutatud abrasiooniline terrass (joonised 7, 8). Erosioonibaasi alanemisel või maapinna tektoonilisel kerkimisel nihkuvad/kerkivad juba moodustunud abrasiooni terrass ja astang maismaale, samas kui meretasemel hakkab kujunema uus astang ja selle esine terrass (joonis 8).



Joonis 8. Rannaastangute ja abrasiooniterrasside süsteemi kujunemine tektoonilisel kerkel (de Blij & Muller 1996)

Veel üsna hiljuti, Pleistotseeni jäätumise viimase maksimumi ajal (u. 15000 aasta eest) asus maailmamere tase tänapäevasest ligi 130 m madalamal. Madal meretase ja võimsad liustikud soodustasid kontinendi äärealadel laialdast ja intensiivset maismaa erosiooni ja ulatuslike, sügavale maismaasse lõikunud kulutusvormide teket. Liustike sulamisele järgnenud kiire meretaseme tõus ja rannikualade ning seal paiknevate kulutusvormide üleujutamine võimaldas paljudes kohtades süvamere vahetu ligipääsu kõrgele maisimaale. See on soodustanud abrasiooniliste rannikulõikude ja kõrgete rannaastangute teket ja laialdast levikut tänapäeva rannikupildis (fotod 6, 7). Üleujutatud erosioonivormide ilmekaimaks näiteks on sügavale maismaasse sopistuvad fjordid, mis kujutavad endast ookeani veega täitunud järsuveerulisi liustikulisi ruhiorge (fotod 8, 9).

Foto 6. Cap Blance - järsakrannik rifflubjakivides Mallorcal

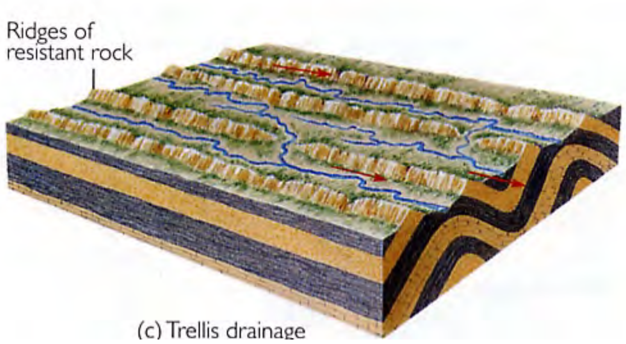
Foto 7. Na Pali rannikut Kauail loetaks üheks kauneimaks püstloodsete seinadega rannikulõiguks Havail

Foto 8. Clintoni org - järsuseinaline liustiku tekkeline ruhiorg Uus Meremaa Fjordides

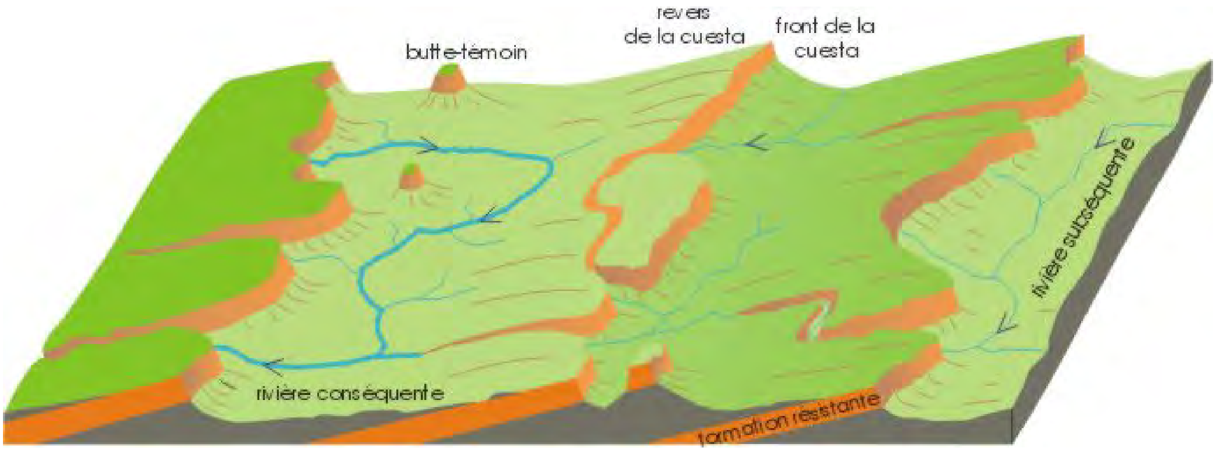
Foto 9. Järsuseinaline, ripporgude ja koskedega ääristatud Milford Sound on Uus Meremaa tuntuim fjord

Jõestik ja piirkonna struktuurne taust

Regiooni valgala dreeniva jõestiku mustri, seal moodustuvate üksikute pinnavormide morfoloogia ja kujuneva morfostruktuurse põhiplaani määratlevad suuresti ära piirkonna geoloogilise (litoloogilise) läbilõike ja struktuurse tausta kombinatsioon. Maakoore struktuurse tausta kujundavad nii üksikud struktuurid (kurrud, murrangud jmt.) kui ka nende süsteemid, mis määratlevad ära seda moodustavate kivimkihtide üldise ruumilise paiknemise, kulgemise ja orienteerituse. Erinevate struktuur-litoloogilis faktorite koosmõjul tekivad kindla morfoloogiaga pinnavormid, mis struktuursest taustast tingituna omavad sageli korrapärast ruumilist paigutust (joonised 9, 10). Neist kuesta tüüpi reljeef (joonis 10) omab väga olulist osa Balti kilbi lõunanõlva pinnamoes.



Joonis 9. Sümmeetrilisest kurrusüsteemist ja litoloogiliselt eriilmeliste kivimite vaheldumisest tingitud paralleelselt kulgevate jõgede, orgude ja ahelike vaheldumine looduses (Press & Siever, 1998)

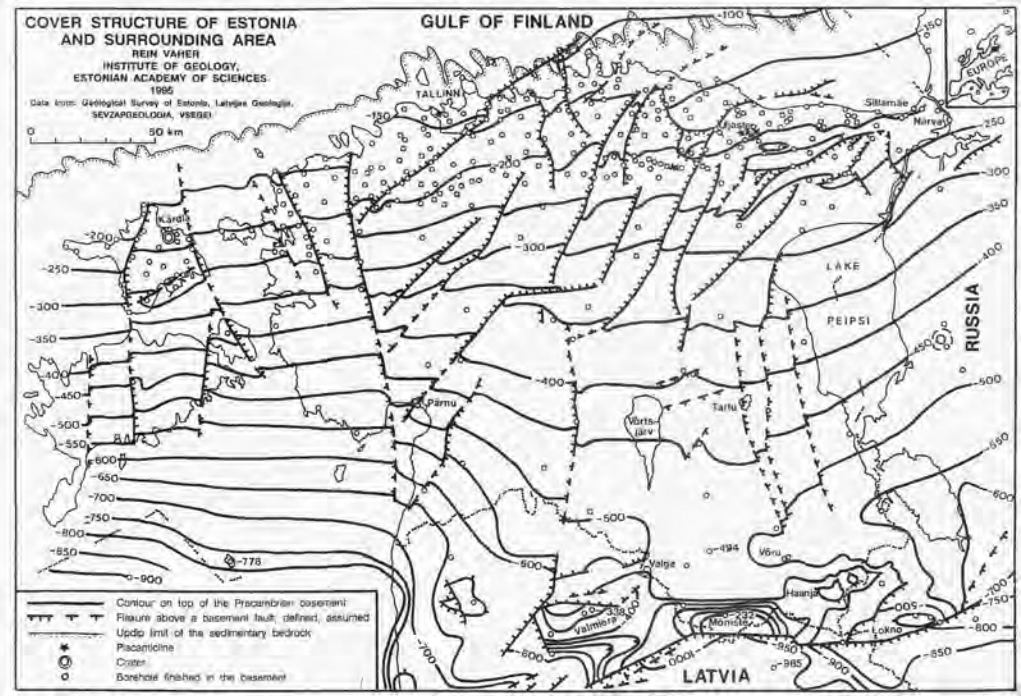


Joonis 10. Kuesta reljeef kujuneb vooluvete ja nõlvaprotsesside toimel homoklinaalidel/ monoklinaalidel, kus läbilõikes vahelduvad erosioonile vastupidavad ja kergesti kulutatavad kihid

Balti klint ja selle kujunemine

Tektoonika roll

Vaagides ülalpool toodud järskude astangute kujunemisvõimalusi looduses, võib Balti klindi puhul kindlalt välistada selle seotust vertikaalse(te) murrangu(te) pinna(dede)ga. Tänini ei ole üheski Balti klindi lõigus tuvastatud klindiastangu(te) otsest kokkulangemist murrangu(te)ga ja sääraste ulatuslike vertikaalmurrangute arvukus nii Balti klindi lähikonnas kui ka Balti kilbi lõunanõlval üldse on pea et olematu. Klindivööndis laialt levinud 1-8 km laiused, 20-100 km pikkused, viie kuni paarikümne meetrise amplituudiga ja valdavalt kirde-edela või põhja-lõuna suunalised joonelised rikkevööndid (joonis 11) on ennekõike fleksuurilaadsed painded, mis ristuvad selgelt ida-läänesihis kulgeva klindiastanguga (Vaher, 1983; Tuuling, 1990). Vaatamata klindiastangu ja murrangute otsese seotuse puudumisele, ilmneb sellel väga selge seos regiooni tektoonilise arengu ja sellest tuleneva geostruktuurse taustaga.



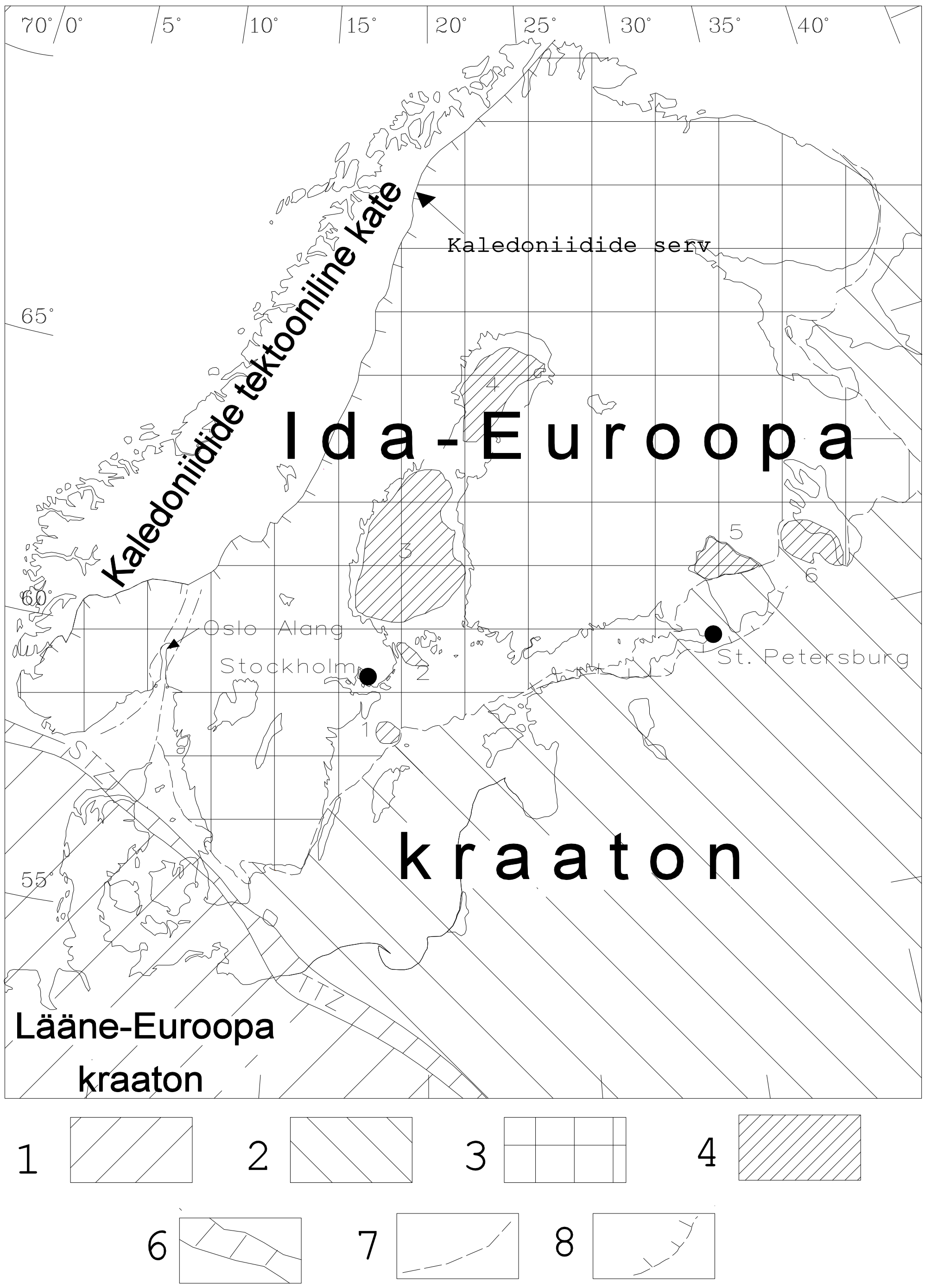
Joonis 11. R. Vaheri koostatud Balti kilbi lõunanõlva katva Paleosoilise settekompleksi struktuurikaart

Regionaalne geostruktuurne taust ja kuestalaadne morfostruktuur

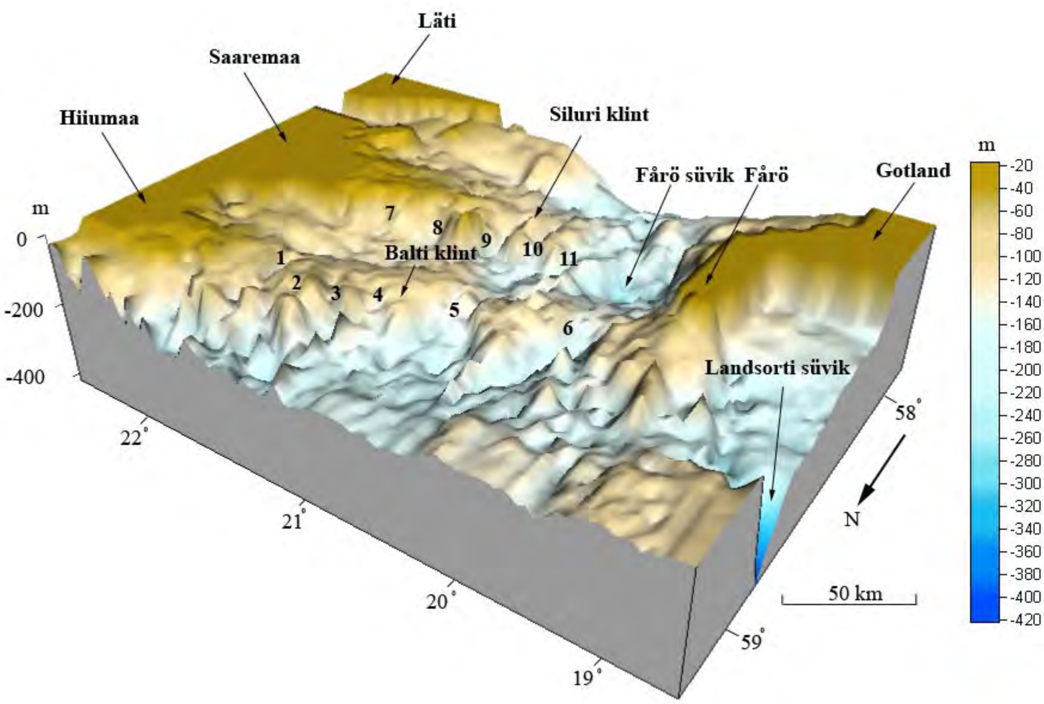
Paleosoilistesse settekivimitesse kujunenud ulatusliku, valdavalt ida läänesuunalise astangu, Balti klindi, geograafiline asukoht, teke ja areng on suuresti seotud tema geostruktuurse taustaga. Paiknedes ulatusliku, suuresti juba varajases Proterosoikumis konsolideerunud ning tänapäeval tektooniliselt vähe aktiivse kontinentaalse ploki, Ida Euroopa kraatonil, jääb klint kahe suure regionaalse struktuuri, Balti kilbi (põhjas) ja Ida Euroopa platvormi (lõunas) siirdealale, e. Balti kilbi lõunanõlvale (joonis 12). Kooskõlas kristalliinse aluskorra pealispinnaga laskuvad ka seda katvad settekivimid siin nõrgalt, 10-15`, lõunasse/lõunakagusse, mis tingib settekompleksi paksenemise ja üha nooremate kihtide avanemise lõunasuunas. Lisaks laugele, ühetaolisele kallakusele e. homoklinaalsele lasuvusele, iseloomustab kilbi nõlva katvat settekompleksi erosioonile vastupidavate ning kergesti kulutatavate kihtide vaheldumine geoloogilises läbilõikes. Selline litoloogilis-geostruktuurne taust on pikaaegse erosiooni tingimustes soodustanud Balti kilbi lõunanõlval kuestareljeefi kujunemist.

Kuestalaadse reljeefi põhijoontele siinses regioonis - piki erosioonikindlaid kihte nõrgalt lõunasuunas laskuvate tasandike ning põhjasuunas kallutatud järskude nõlvade (või/ja vertikaalsete astangute) vaheldumisele põhja lõunasihis ja Balti klindile, kui ühele astangule selles süsteemis on alates Schmidtist (1882) viidanud paljud autorid (Giere 1938, Tammekann, 1949, Martinsson, 1958; Issatšenkov, 1969, 1970; Možajev, 1973; Tavast ja Raukas, 1982, jt.). Ilmekamalt kui kusagil mujal tuleb selline morfostruktuur Balti kilbi lõunanõlval esile Läänemere keskosa aluspõhjareljeefis (Tuuling, 1998; Tuuling & Flodén, 2001; Tuuling & Tilk, 2007; Tuuling jt., 2007) (joonised 13, 14). Põhja lõunasihis eristuvad siin selgelt; piki Eelkambriumi/Kambriumi kivimite pealispinda lõunasse kallutatud ala, Balti klint, Ordoviitsiumi platoo, Siluri klint ja Siluri platoo (joonised 13, 14). Kaugemal lõunas jätkab Läänemere all seda rida Siluri platoole järgnev Devoni astang (Kumpas, 1977). Maismaal, kus Siluri klint ja selle eelne kuestaorund puudub, on Venemaa loodeosa aluspõhjareljeefis jälgitav Ordoviitsiumi platoole järgnev Devoni astang ja Devoni platoole järgnev selge astang Karboni kivimites (Isaatšenkov, 1969, 1970;, Možajev 1973).

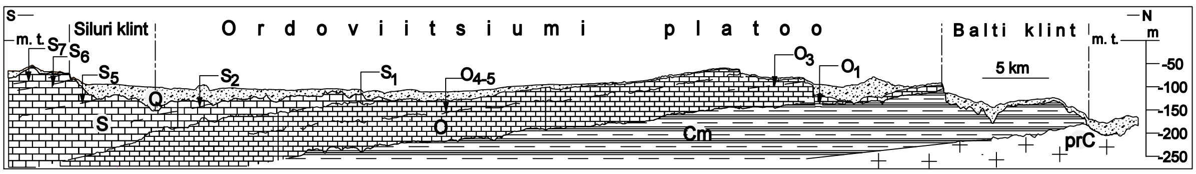
Läänemere keskosa pärastjääaegsetest kulutusprotsessidest puutumata aluspõhjareljeefi jälgides (Tuuling, 1998; Tuuling & Tilk, 2007) saab ilmselgeks, et Balti - ja Siluri klint ning nendega kaasnevad astangud ja terrassid on kaks võrdväärset, ühesuguse geneesi ning ühel geoloogilisel ajahetkel tekkinud regionaalse kuestareljeefi elementi. Balti klint, kaheldamatult kõige ulatuslikum ja markantseim kuestaorundi järsu veeru astang kogu Ida Euroopa lauskmaa loodeosas, tuleb maismaal kõige ilmekamalt esile piki Eest põhjarannikut (fotod 1, 3); analoogne Siluri klint, pea et olematu idapool Läänemerd, on Gotlandi läänerannikul (foto 2) kohati sama võimas kui Põhja Eesti klint.



Joonis 12. Balti klindi geostruktuurne asend: 1. Ida Euroopa platvorm; 2. Lääne Euroopa platvorm; 3. Balti kilp; 4. Rifi-Jotniumi setetega täidetud alangulaadsed struktuurid - 1. Landsorti süvik 2. Ålandi meri, 3. Botnia meri, 4. Botnia laht, 5. Laadoga järv, 6. Oneega järv ; 6. TTZ- Tornquist-Teisseyre ja STZ – Sorgenfei-Tornquist murranguvööndid, 7. Kilbi ja platvormi piir; 8. Balti klint



Joonis 13. Läänemere keskosa aluspõhjareljeefi kõrgusmudelil eristuvad asümmeetrilised kuestaorundid (numbritega märgitud klinte lõikavad orundid)



Joonis 14. Kuestareljeefi põhijooned Läänemere keskosast piki seismilist profiili 9210 (profiili asukoht vt. joonis19*)*

Balti klint ja liustike tegevus

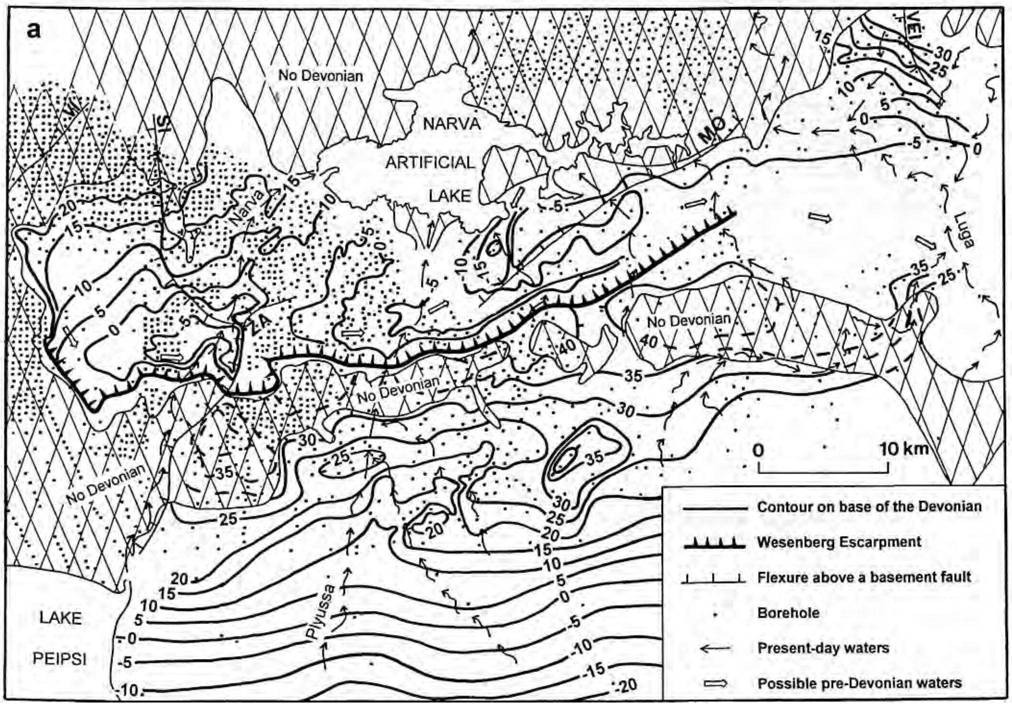
Balti klindi tekke ja arengu käsitlemisel on alati suurt tähelepanu pööratud mandriliustike kulutuslikule tegevusele e. eksaratsioonile. Tänapäeval tõendavad kõik teadaolevad faktid, et kusagil loodes/põhjas, Botnia lahe päraosa ümbruses paiknenud jäätumiskeskmest lähtunud liustikud liikusid üle meie ala valdavalt põhjaloode-lõunakagu või põhja-lõuna sihis, mis ristub klindi ida läänesuunalise orientatsiooniga. Maismaa klindilahtesid (Tammekann, 1940) või merealuseid, liustikuliste setete ning pinnavormidega täidetud suuri eksaratsioonilisi orundeid vaadates (joonis 13), ei ole kahtlust, et liustikud juba olemas olnud klinti hoopiski kulutanud on. Diskusiooni on pigem tekitanud küsimus, kui palju on liustikud jääaja eelse klindiastangu algset morfoloogiat ümber kujundanud ja seda lõunasse nihutanud?
Mõnede autorite arvates (Giere, 1938; Tammekann, 1949) oli see märkimisväärne. Nii arvab esimene et jääaja eelne klint Soome lahe idaosas asus hoopiski kusagil Tütarsaarte, Lavansaare ja Seiskari joonel. Läänemere keskosa andmed (Tuuling, 1998) kinnitavad aga Frommi (1943) arusaama, et lustike osa klindi morfoloogia kujundamisel on olnud väga selektiivne. Liustikest praktiliselt puutumata klindi lõigud vahelduvad ulatuslike ja laiade glatsiaalsete orunditega, mis suuresti kattuvad varasemate jõeorgude või tektooniliste rikete ning purustusvöönditega

(Tuuling, 1998; Tuuling & Flodén 2001) (joonis 13). Eelneva reljeefi, ennekõike orundite olulist rolli liustike purustusjõu selektiivsel suunamisel peab väga oluliseks ka Miidel (1992), kes põhjendab klindi vähest eksaratsiooni Soome lahe ja klindiastangu kohal paiknenud liustike aktiivse tegevuse lühiajalisusega. Lisaks oletab ta, et esialgselt klindi taha pidama jäänud liustik pigem kasvas kui liikus kiirelt üle klindi. Hiljem hakkas jäätumiskeskmes kasvav surve selle alust maapinda ja liustiku allosa liustiku liikumisele vastassuunas kallutama, mistõttu liustiku põhi ei ületanud arvatavasti kunagi klinti, vaid hoopis konserveeris selle pikaks ajaks mitme kilomeetri paksuse jäämassi alla.

Balti klint kui võimalik rannaastang

Lähtudes kuestareljeefist ning tuginedes tavaarusaamale sellise pinnamoe kujunemisest, jääb Balti kilbi lõunanõlval esinevate järsuseinaliste astangute võimalik tekkeviiside hulk veelgi ahtamaks. Soodsate geoloogilis-geostruktuursetel tingimustel kujunevad reljeefis vahelduvad asümmeetrilised kuestaorundid samaaegselt, peamiselt vooluvete ja nõlvaprotsesside pikaajalise erosiooni tagajärjel (de Blij & Muller, 1996). See välistab ka meremurrutuse kui võimaliku protsessi siinsete järskude klindiastangute algsel kujundamisel. Samas on ka raske ette kujutada kuidas saanuks meremurrutus üheaegselt vormida Balti ja Siluri klinte hõlmavaid astangute ja terrasside süsteeme kuestaorundi järsul veerul ning nende esiseid laugeid kuestapaloosid. Ja kui arvukad terrassid ning kuestaplatood oleksid murrutusliku tekkega, siis ei tohiks need abrasiooniterrassile omaselt langeda mitte astangute poole, vaid hoopiski nendest eemale süvamere suunas (joonis 8).

Balti klindi merelise tekke vaagimisel satuksime suurde kimbatusse ka siis, kui hakkame geoloogilisest minevikust otsima sellist pikaajalist ja püsiva rannajoonega veekogu, mis klindi astangud murrutada võinuks. Paiknedes Kambriumi-Ordoviitsiumi kivimites, võib Balti klindi vahetust lähedusest, Narva ümbruskonnast leida ka Kesk-Devoni transgressiivseid madalmere setendeid, mis on enda alla matnud tugevasti liigestatud Vara-Devoni aegse reljeefi. Viimane kujunes Siluri-Devoni vahetusel toimunud Kaledoonia kurrutusepohhi kulmineerumise (Laurentia ja Baltica kontinentide põrkumise) järel, mil kulutusprotsessid Balti kilbi lõunanõlval, selle kerkimise tulemusena märkimisväärselt intensiivistusid. Markantseimaks sellest perioodist säilinud erosioonivormiks on kümmekond km läänepool Narva jõge algav ja ligi 60 km idasihis kulgev Wesenbergi astang (Tuuling, 1988; Puura et al., 1999), piki mida Devoni eelne reljeef põhja lõunasihis kohati järsult 30-45 m kerkib (joonis 15). Kuna Ordoviitsiumi-Devoni ajal asus merelise basseini kese Wesenbergi astangust lõunas, ei saa viimane kuidagi markeerida tolleaegse mere rannikut ning ilmselgelt tähistab see Vara Devonis ida-idakagusse langevat jõeorundit. Analoogselt ei saa ka järsult põhja lõunasihis kerkiv Balti klint olla kujundatud tolleaegsete rannikuprotsesside poolt. Kuid samas ei saa Balti klint kuidagi markeerida ka Vara-Devoni aegset jõeorgu. Erinevalt Rakvere astangust langeb reljeef Balti klindi ees hoopiski läände ning raske oleks ette kujutada kahte üheaegset, geograafiliselt pea et kattuvat, kuid 180º erinevatesse suundadesse voolavat jõge. Sellele teadmisele tuginedes on raske nõustuda ka arvamusega, et tänapäevane kuestareljeef Baltikumis kujunes põhijoontes välja juba Vara-Devonis (Giere, 1938).



Joonis 15. Kesk-Devoni eelne reljeef ja Wesenbergi astang

Alates Kesk-Devonist välistab kaugele lõunasse taandunud meri ning selles esiletulev fatsiaalsus igasuguse võimaluse merebasseini ulatumiseks ja seega ka murrutuse esinemiseks Balti klindi lähikonnas. Siinsed alad sattusid ligi 400 miljoniks aastaks kulutusprotsesside meelevalda. Alles Kainosoikumi lõpust on Balti klindi lähikonnast, Läänemere nõost ja maetud orgudest jälle leitud merelisi, viimase jäätumise aegse Eemi mere (eksisteeris u. 120-90 tuhande aasta eest) setteid (Raukas & Kajak, 1997). Kuid lisaks abrasiooni ja kuestareljeefi kujunemise kokkusobimatusele, oleks raske ette kujutada, kuidas sellise lühikese ajaga saanuks kujuneda säärane ulatuslik rannaastang nagu Balti klint ning selle ette lauge, klindiastangu poole kallutatud, kümnete kilomeetrite laiune murrutusterrass. Veelgi ebapiisavam oleks antud ajavahemik aga ulatusliku astangute terrasside süsteemi kujundamiseks, mille üheks osaks Balti klint ju tegelikult on. See eeldaks lisaks pikaajalistele ühel tasandil stabiliseerunud murrutuse etappidele, mil kujunesid ulatuslikud eritasandilised abrasiooniterrasid, ka järk-järgulist erosioonibaasi või tektoonilise režiimi muutust. On ebatõenäone, et selline maapinna ja meretaseme suhtelise kõrguse astmeline muutus saanuks toimuda taanduvate liustike tingimustes, ühe lühikese jäävaheaja kestel kujunenud merebasseinis. Eemi setete esinemine klindilähedastes, sügavates ja kitsastes maetud orgudes, millede teke ja esinemine on ilmselgelt seotud klindi ja klindieelse orundiga, viitab maetud orundite ja klindi olemasolule juba enne selle mere olemasolu.

Jõgede erosioon Balti kilbi lõunanõlval

Balti klindi kui murrangulise või abrasioonilise tekkega astangu olematu tõenäosus sunnib sügavamalt vaagima olemasolevaid fakte ja jõe(gede) võimaliku rolli selle pinnavormi tekkimisel ja kujundamisel. Jõelise tekkeviisi kasuks räägib ennekõike tõsiasi, et klint on osaks regionaalsest kuestaorundist, mis ilmselgelt on kujunenud vooluvete ja nõlvaprotsesside erosiooni tulemusel. Kunagi Soome lahe põhjas voolanud jõele viitavad ühemõtteliselt ka paljud sinna suubuvad, sügavale aluspõhjakivimitesse lõikunud ja klindiastangut läbivad maetud orundid Põhja Eestis (Harku kuni -145 m). Õigupoolest pole klindi kui jõeorgu ääristava astangu idees miskit uut ja Soome lahe piires kunagi voolanud oletatava jõe, Ürg-Neeva, nimigi on paljudele tuttav. Jõgede otsustavat rolli Balti klindi tekkimisel ja arengus toetavad ka paljud teadaolevad regionaal-, struktuurgeoloogilised ja tektoonilised faktid.

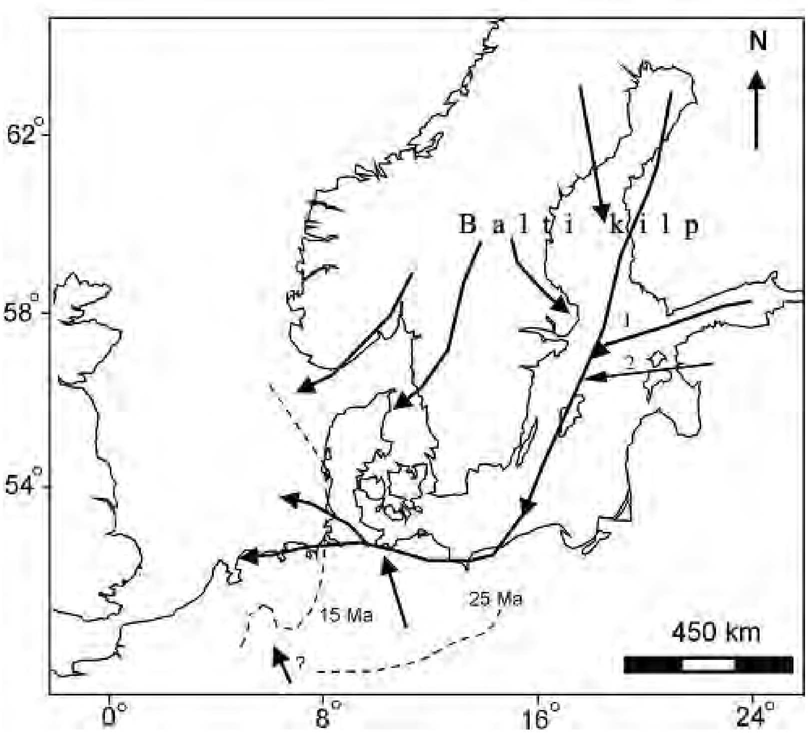
Vastupidi merelise murrutuse pea et olematutele võimalustele, oli Kaledoonia kurrutuse järgne, ligi 400 miljonit aastat kestnud kontinentaalne periood Balti kilbi lõunanõlval väga soodus jõelisteks kulutusprotsessideks. Kuna alates Kesk-Devonist puudub sellest kulutusperioodist Balti klindi vahetust ümbrusest igasuguse kivimiline materjali, on ka selle täpsete geoloogiliste olude ja protsesside ning nendest tuleneva reljeefi arengu ja muutuste taastamine siin praktiliselt võimatu. Küll saame aga tugineda naaberaladelt teadaolevatele faktidele ja nende põhjal tehtud regionaalgeoloogilistele üldistustele.

Kaledoonia kurrutusel Eestist vahetult loodesse kerkinud kõrgmäestik (joonis 4) määratles järgnevaks 350 miljoni aastaks suuresti ära ka meie ala tektoonilis-geostruktuurse tausta ning sellest johtuva paleogeograafia ja geoloogiliste protsesside iseloomu. Kõrgmäestikust ja koos sellega kerkinud Balti kilbilt alguse saanud jõed kulgesid just üle kilbi nõlvaalade, meist lõunakaartes asuvatesse settebasseinidesse. Kui mitte arvestada ala mõningast tektoonilist aktiviseerumist Permis, mil meist kaugemal lõunas kulmineerus Hertsüünia kurrutus, leidsid Balti kilbi lõunanõlval, nii hilises Paleosoikumis kui ka Mesosoikumis aset Kaledoonia kurrutuse järgsed, valdavalt jõelised kulutusprotsessid. Viimaste intensiivsus vaibus aegamisi kooskõlas mäetekke protsessidest tingitud maakoore pingete järeleandmise ja ala üldise madaldumisega. Lisaks eespool mainitud Vara-Devoni jõeorundi jäänukile on sellel perioodil Balti kilbi lõunanõlva ületanud ja kulutanud jõgede otseseks tõendiks veel ulatuslik, laiadel aladel Lõuna Eestis, Baltikumis ning Loode-Venemaal jälgitav Kesk- ja Ülem-Devoni deltasetete kompleks.

Milline oli tolle perioodi jõgede kulg ja mis tüüpi oli kujuneva reljeefi üldpilt pole teada. Hilises paleosoikumis ja Mesosoikumis meist kagus, edelas ja lõunas asunud settebassein(id) pakub(vad) jõgede kulgemiseks erinevaid võimalusi. Kuid arvestades pikka kulutusperioodi ja Kriidi ajastu lõpu paleogeograafilist situatsiooni, paiknes tänapäevane Eestimaa siis kaugel kontinendi sisemuses ja kujutas endast arvatavasti paarsada meetrit üle merepinna paiknevat, vähe liigestatud tasandikku (Martinsson, 1958; Miidel, 2004). Kuid missugune ka ei olnud Mesosoikumi lõpuks kujunenud reljeefi üldilme, on järgnevaid Kainosoikumi sündmusi silmas pidades praktiliselt võimatu uskuda, et sellest tänaseni miskit suurt säilinud on.

Balti kilbi uus tektoonilise elavnemise, geostruktuursete-paleogeograafiliste muutuste etapp on seotud juba Mesosoikumi esimesel poolel alanud Pangaea superkontinendi riftistumise ja lagunemise ning Atlandi ookeani avanemise protsessidega. Nende jätkumine põhjasuunas viis Kainosoikumi alul, u. 50 milj. aasta eest, pea et 350 miljonit aastat koos/lähestikku püsinud Põhja Ameerika, Gröönimaa ja Skandinaavia üksteisest eraldumisele ja Atlandi ookeani põhjaosa avanemisele. Viimaste sündmuste kulmineerumisega Neogeenis hoogustus u. 23-25 milj. aasta eest Balti kilbi kerkimine ja Põhjamere alade vajumine, mille tulemusena kujunenud geostruktuurse foon on suuresti olnud aluseks ka tänapäevase Läänemere regiooni valgala ja jõestiku kujunemisele (Gibbard, 1998).

Miotseenist kuni Kvaternaari alguseni domineeris siinses regioonis kerkivalt Balti kilbilt ja selle nõlvadelt alguse saav ja läbi tänapäevase Läänemere lõunasse kulgenud nn. Balti jõgi, mis kandis oma veed koos kilbilt pärineva rikkaliku purdmaterjaliga Põhja Poola, Põhja Saksamaa, Taani, Hollandi ja Põhjamere aladel paiknenud settebasseini (Blijsma, 1981). Jõe algsel suudmealal, Põhja Poolas, arenes välja ulatuslik delta, mida seal leiduva merevaigu tõttu on hakatud nimetama Eridanose deltaks (Kosmowska-Ceranowiczc, 1988) (Vana Kreeka legendi „ Helios ja Phaeteon“(7 saj. E.K) kohaselt hukkus sellenimelises, kusagil kaugel põhjas paiknevas jões päikesejumala Heliose poeg Phateon ja merevaik on venda leinanud õdede kivistunud pisarateks). Purdmaterjaliga täituvas settebasseinis hakkas settimiskese/deltaala vähehaaval migreeruma läänesuunas, üle Saksamaa, Taani ja Hollandi, kuni see umbes 12 miljoni aasta eest jõudis tänapäeva Põhjamere lõunaossa. Seal on ligi 44 0000 km^2 alal tuvastatud seismiliste uurimustöödega 1.5 km paksune Kesk Miotseeni (10.7 milj a.) - Kesk Pleistotseeni (~1.0 milj a.) vanusega Eridanose deltasetete kompleks (Overeem et al., 2001). Setete Skandinaavia päritolu kinnitavad neis esineva raskete mineraalide fraktsiooni ja kvartsi iseärasused, aga samuti ka Vara-Pleistotseenis siia fluviaalsete jääpangastega kantud rändrahnud. Ilmselt just koos Pleistotseenis alanud mandrijäätumisega sai alguse ka selle hiiglasliku jõe lätete hääbumine Skandinaavia mägedes. Jätkuvate jäätumiste/liustike pealetungide ning jäävaheaegade/liustike taandumiste vaheldumine viis umbkaudu 0.7-1 milj eest ka Eridanose lõplik hääbumise ning kujunenud vooluteede hävitamiseni (Overeem et al., 2001)



Joonis 16. Balti kilbilt lähtuv Eridanose jõgi koos oletatavate lisajõgedega (Overeem et. al., 2001 järgi). Katkendjoon tähistab rannajoone asendit 15 ja 25 Ma tagasi. 1 – Ürg-Neeva, 2 – jõgi Siluri klindi ees.

Eridanose aimatavad jäljed Läänemeres

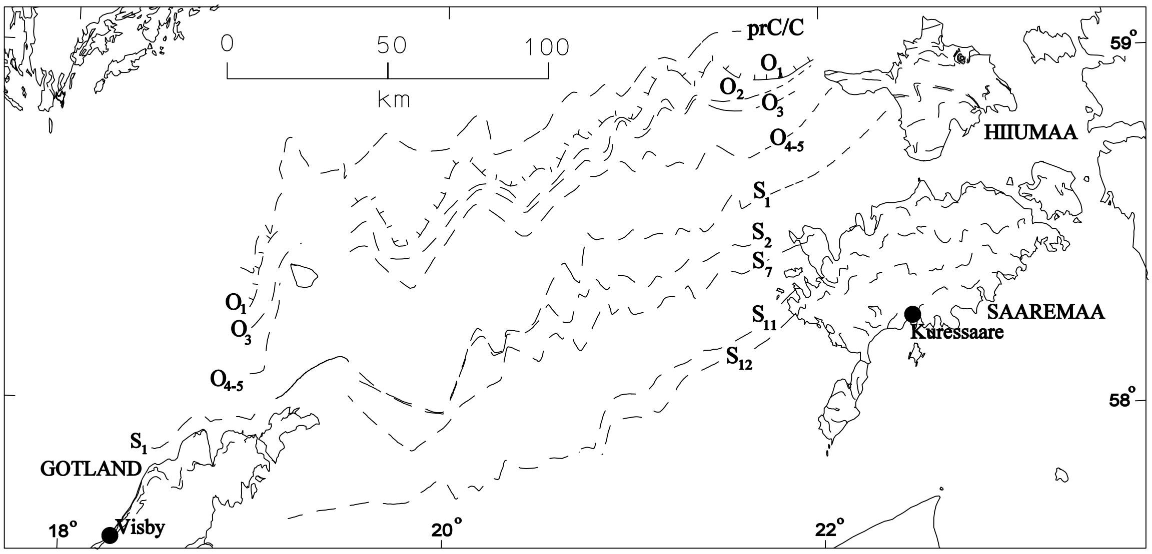
Balti kilbilt pärinevast settematerjalist koosnev hiiglaslik, Põhja-Euroopa ja Põhjamere alasi hõlmav Neogeeni vanusega delta jätab vähe ruumi kõhklusteks - kas geoloogilises lähiminevikus voolas ikka läbi Läänemere keskosa suur jõgi? Tänapäevaks Pleistotseeni liustike poolt suuresti hävitatud ja mere alla peidetud Eridanose jõesängi täpse kulgemise, rääkimata siis morfoloogiliste detailide taastamine on praktiliselt võimatu. Lisaks on korduvalt peale tunginud ja taandunud massiivsed liustikud tugevasti mõjutanud ja diferentseerinud siinse maakoore liikumisi, muutes seeläbi oluliselt ka regiooni jäätumise eelseid kõrgussuhteid. Seetõttu pole võimalike lõunasse suunduvate vooluteede otsimisel suurt abi loota ei tänapäeva- ega ka aluspõhja reljeefi kõrgussuhetest.
Tõenäoliselt markeerib Eridanose põhjaosa kulgu Botnia laht, mille põhjas esineb rida Kesk-Proterosoikumis ja Hilis-Paleosoikumis elavnenud murrangutega piiritletud alangulaadseid struktuure (joonis 12). Botnia lahe piirkonna pikaajalisele tektoonilisele aktiivsusele osutavad veel ka paljud siin Kambriumi–Siluri kestel laiunud merelise basseini paleogeograafilis-fatsiaalsed iseärasused (Tuuling & Flodén, 2000, 2001). Need faktid viitavad piki lahte kulgevale, nn. Botnia-Balti tektooniliselt mobiilsele vööndile (Puura & Flodén, 1997; Tuuling & Flodén, 2000, 2001) (joonis 1), mis kujutab endast arvatavasti tektoonilis-struktuurset murde-e. üleminekuala Ida-Euroopa kraatoni ääre- ja sisealade vahel, kus läbi pika geoloogilise ajaloo on toimunud laamade vastastikusest liikumistest ja kokkupõrkumistest tingitud regionaalsete pingete maandamine. Regiooni tektoonilisel aktiviseerumisel Neogeenis kujutas see vöönd endast arvatavasti struktuurselt madalamat ala, kuhu kerkivalt Balti kilbilt ja selle nõlvaaladelt

valgusid pinnase ja vooluveed ning mille põhjas voolas tolle aja võimsaim Balti kilbilt lõunasse lähtuv jõgi, Eridanos.
Säärane, põhjast lõunasse orienteeritud madalam ala koos selle põhjas paikneva Eridanose sängiga, oli kahtlemata väga soodsaks liikumisteeks hiljem lõunasse laskuvatele Pleistotseeni mandriliustikele. Suurte liustike kulgemist Botnia lahe mõttelisel lõunasse pikendusel märgistavad piki Gotlandi kirde- ja idarannikut paiknevad suured, klindiastanguid nivelleerivad eksaratsioonilised orundid ja suuresti liustikealuste surveliste vete toimel tekkinud isoleeritud aluspõhjareljeefilised süvikud (Fårö, Gotland, Slupsk jt.) (joonis 13). Lisaks kulgeb siitkaudu ka üks ulatuslikem Läänemere alune glatsiaalsetete kuhjevormide ala (Noormets & Flodén 2002; Tilk 2006), kus Kvaternaari setete paksus kohati ligi 100 m ulatub. Ühel sellisel, põhjaloode-lõunakagu sihis kulgeval fluvioglatsiaalsel, ligi 70 km pikkusel ja kohati kuni 25 km laiusel ahelikulaadsel kuhjevormil asub ka Gotlandist vahetult põhja jääv Gotska Sandöni saar (foto 4).
Tingituna suuresti just liustike eksaratsioonils-kuhjelisest tegevusest, aga samuti ka nende diferentseeritud mõjust maakoore liikumistele, on Eridanose võimalik kulg Botnia lahest lõunasse, kas ida või lääne poolt Gotlandi, pakkunud palju poleemikat. Balti ja Siluri klindiastangute esinemine piki Gotlandi läänerannikuid (joonis 1) ei tekita esmapilgul mingit kahtlust, et neid kujundanud jõgi(ed) jäi(d) Gotlandi ja Rootsi mandriosa vahele. Samas, nii mõlema klindi hääbumine kui ka tänapäevase ja aluspõhjareljeefi kerkimine kaugemal lõunas (Repetška et al., 1991) viitavad ka võimalusele, et läänepool Ölandit ja Gotlandi kulgenud ning klindiastanguid kujundanud jõgi(ed) suundus(id) algul hoopiski põhja ning ühines(id) idapoolt Gotlandi üle Läänemere keskosa suunduva peajõega alles kusagil Landsorti süviku lähedal (Martinsson 1958). Paraku satume Eridanose voolusängile Gotlandist idapoolt teed otsides sarnastele, kõrgussuhetest tulenevatele raskustele. Lisaks eespool mainitud isoleeritud ja väljavooluta aluspõhjalistele süvikutele, tõkestab aluspõhja - ning tänapäeva reljeefis kerkiv merepõhi kaugemal lõunas jälle Eridanose väljavoolu tema deltaaladele. Viimased aluspõhjareljeefi andmed, mis viitavad Balti ja Siluri klindi katkematule kulgemisele ka Gotlandist kirdesse jäävates eksaratsioonilistes orundites (joonis 3), muudavad Eridanose idapoolse kulgemistee siiski sisuliselt võimatuks. Markeerides Eridanose lisajõgesid, suunduvad mõlemad klindiastangud selgelt Gotlandi läänepoolsele küljele, viidates ühemõtteliselt, et Gotlandi lääneranniku sihis, põhjast lõunasse kulgevad klindiastangud on ikkagi lõunasse voolanud peajõe, Eridanose, jäänukiteks.
Ükskõik milline ka ei olnud Eridanose kulgemistee, ei kajastu see tänapäeva Läänemere aluse aluspõhjareljeefi kõrgussuhetes. Eridanose segamatuks kulgemiseks tema deltaalale Põhja Euroopas, tuleks igal juhul märkimisväärselt kergitada Läänemere põhjaosa; Martinssoni (1958) arvates rohkem kui 200 m. Samas ei esine sellist aluspõhjareljeefi kõrgussuhetest tulenevat takistust ida-läänesihis, Balti ja Siluri klintide ees kulgenud Eridanose lisajõgedel. Seega avalduvad Neogeeni aegse jõgede võrgu kõrgussuhete muutused tänapäeval Läänemere aluspõhjareljeefis eriti kontrastselt üksnes põhja-lõunasihis. Mis on põhjustanud ja kui suurt rolli sellistes kõrgussuhete muutuses on mänginud liustike kulutus, kui palju glatsioisostaatilis-tektoonilis liikumised vajab täpsemat analüüsi.

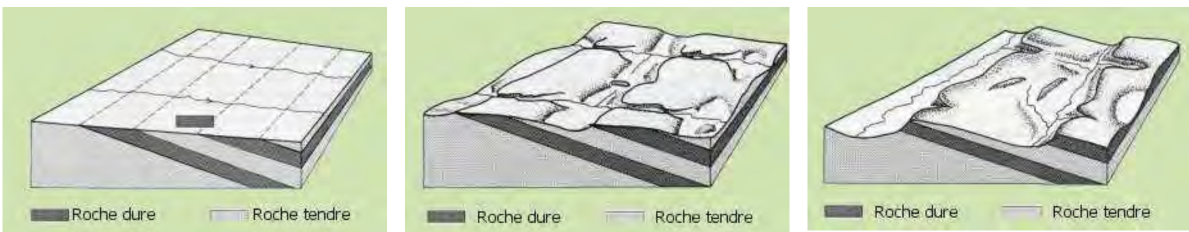
Soome laht, Balti ja Siluri klint – Eridanose lisajõgede hästisäilinud kuestavormid

Kui jäätumise eelne, Pleistotseeni liustike liikumissihis kulgenud Eridanose org on tänapäeva reljeefis ja kaardipildis seostav üksnes Botnia lahe ja Gotlandi lääneranniku klindiastangutega, siis Balti kilbi lõunanõlval laialdaselt levinud ja liustike liikumisteedega ristuvad kuestareljeefi vormid, on nii maismaal, eriti aga Läänemere keskosas, väga hästi säilinud. Lõunasse laskuvatel liustikel ei ole õnnestunud klindiastanguid täielikult nivelleerida isegi kõige ulatuslikumates, Gotlandist vahetult kirdesse jäävates eksaratsioonilistes orundites (joonis 13). See kinnitab liustike väga selektiivset rolli klindiastangute kulutamisel ning toetab arvamust, et liustikupõhi enamasti ei ületanudki selliseid astanguid, vaid liustik pigem kasvas nendest üle ja konserveeris

klindi paksu jäämassi alla (Miidel, 1992).
Kui lõunasse voolavale Eridanosele on väljavool deltaalale nii tänapäevases kui ka aluspõhja reljeefis suletud, siis Balti ja Siluri klintidega markeeritud lisajõgede kulgemine ida-läänesihis on ka tänapäevases Läänemere alustes kõrgussuhetes hästi jälgitav. Geoloogilises lähiminevikus, Balti kilbi lõunanõlval idast-läände, Botnia-Balti vööndi suunas madalduvale struktuursele foonile ning sinna laskunud jõgede kasvavale erosioonilisele aktiivsusele, viitab veel terve rida geoloogilisi fakte (Tuuling, 1998; Tuuling & Flodén, 2001)**.** Kõige ilmekamalt avalduvad sellised tendentsid just Balti klindi ees, kus kunagises Ürg-Neeva orus on ida-läänesihis selgelt jälgitav ära kulutatud kivimkoguse suurenemine. See avaldub ennekõike Vendi-Kambriumi ja kristalliinsete kivimite avamuste vastavalt läänesuunalises kitsenemises ja laienemises. Samal põhjusel muutub ka Balti klindi astangu ja Ordoviitsiumi-Siluri stratigraafiliste üksuste avamusjoonte orientatsioon; mõlemal juhul omandab ligikaudu ida-läänesuunaline orientatsioon Eesti mandriosas, selgelt kirde loodesihilisema suunitluse Läänemere all (joonised 1, 17). Sellest tingituna on Läänemere all palju intensiivsemalt kulutatud ka Ordoviitsiumi ja Siluri kivimite avamusi ning erinevalt maismaast on välja kujunenud selged lõunasse-lõunaloodese kallutatud Ordoviitsiumi ja Siluri kuestaplatood ning Siluri klint (joonised 13, 14)**.** Viimase ees kulges suure tõenäosusega Ürg-Neevast lõunasse jääv ja sellega paralleelselt kulgev Eridanose lisajõgi (joonis 16). Kui kunagise Eridanose idapoolsete lisajõgedest on Ürg-Neeva, Soome lahe ja Balti klindi näol selgelt hoomatav ka maismaal, siis Siluri klindi kujundanud jõe sängi võib Eestis üksnes aimata maismaasse tungiva Matsalu lahe ja Soela väina joonel. Ka Siluri klint ise, ilmnedes väga katkendlikult loode Saaremaa panganeemikutel, ilmutab end täies võimsuses alles Läänemere all ja Gotlandil.



Joonis 17. Stratigraafiliste üksuste avamuste piirid Läänemere keskosas. prC/C – Eelkambriumi ja Kambriumi, 2. O_1 - terrigeense ja karbonaatse kompleksi (Balti klint), 3. O_2 – Idavere lademe Tatruse ja Vasavare kihistike, 4. O_3 –Oandu ja Rakvere lademe, O_{4-5} – Pirgu ja Vormsi lademe, 5. S_1 – Ordoviitsiumi Siluri, 6. S_2 – Raikküla ja Adavare lademe, 7. S_7 - Jaani ja Jaagarahu lademe (Siluri klint), 8. S_{11} – Jaagarahu Rootsiküla lademe, 9. S_{12} – Rootsiküla Paadla lademe



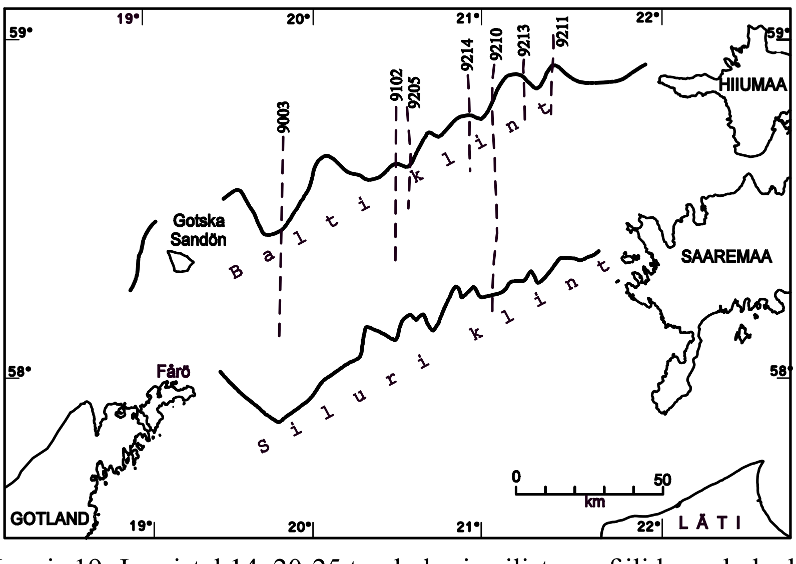
Joonis 18. Kuestaorundi lauge ja järsu veeru teke ja areng homoklinaalselt lasuvatesse kihtidesse lõikuva jõeorundi arengu tulemusel

Balti klindi kujunemine jõgede erosioonil

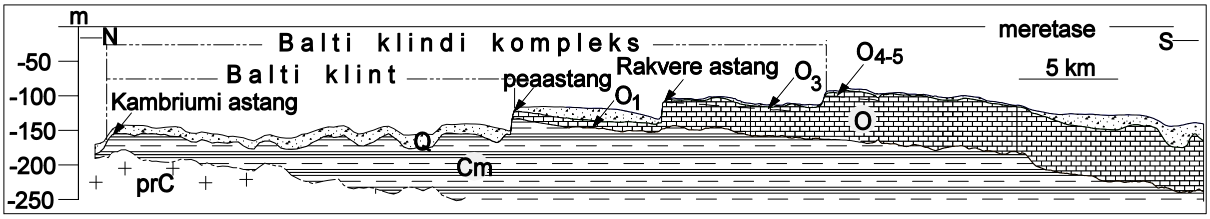
Vaatamata eespool toodud arvukatele ja veenvatele faktidele, esineb siiani Balti klindi jõelise tekke käsitlemisel suuri raskusi mõningate morfoloogiliste detailide seletamisel. Ennekõike on ületamatud probleemid tulenenud arusaamast, et tingituna regiooni katvate paleosoliste kihtide nõrgast lõunasuunalisest kallakusest ja valitsevast samasuunalisest küljeerosioonist, kujunesid lõunasse laienev Soome laht ja selle ette kerkiv Balti klint samaaegselt, ühe suure jõe, Ürg-Neeva, pideva lõunasse migreerumise tulemusena. Sellise lähenemise abil võib küll hästi ära seletada piki kristalliinsete kivimite pealispinda lõunasse süveneva Soome lahe nõo kui kuestaplatoo kujunemise, kuid pea et võimatu on ette kujutada kuidas sel moel sai samaaegselt kujuneda Balti klint ja sellega külgnevate astangute ja terrasside süsteem kuestaorundi järsul veerul. Käsitledes aga Soome lahte kui ulatuslikku asümmeetrilist kuestaorundit, mis on moodustunud tektooniliselt kerkivas regioonis, homoklinaalse lasuvusega kivimkihtidesse lõikuva jõe pikaajalise arengu tulemusena, saaksime edukalt seletada nii selle lauge põhja- kui ka astangute ja terrasside rikka järsu lõunaveeru samaaegset kujunemist. Tingituna kujuneva jõeorundi nõlvade ja seal paljanduvate kivimkihtide kallakuse omavahelistest suhetest, nende ühildumisest ja vastassuunalisusest oru põhja- ja lõunaveerul, moodustusidki kestva vooluvete erosiooni ja nõlvaprotsesside tulemusena üheaegselt, koos süveneva jõeoruga, ka selle lauge põhja ja järsk astangulis-terrassiline lõunanõlv (joonis 18) .

Astangulis- terrassilise reljeefi kujunemine kuestaorundi lõunaveerul

Balti klindi ja selle morfoloogia kirjeldamisel käsitletakse enamasti terrigeensete - ja karbonaatsete kivimite avamuste kontaktil asuvat võimsaimat astangut, mida selle ette ja taha jäävate arvukate väiksemate kõrvalastangute ja terrasside tõttu sageli ka klindi peaastanguks nimetatakse (joonised 14, 20, 21, 22, 23, 24, 25). Kui kõrvalastangud asuvad klindi vahetus läheduses, räägitakse mitmeastmelisest klindist (Tammekann, 1940) või - peaastangust (Tuuling, 1998; Tuuling jt., 2007) (joonis 21, 22). Kaugemal asuvaid kõrvalastanguid vaadeldakse peaastangu domineerimise tõttu enamasti kui teisejärgulisi, klindist eraldiseisvaid reljeefivorme, mis koos peaastanguga klindi kompleksi (Tuuling, 1998; Tuuling & Flodén, 2001) või siis klindivööndi (Suuroja, 2005) moodustavad (joonis 20**).** Kuna selline pilt on tõene ühteviisi nii maismaal kui ka Läänemere all, ei saanud ka kõrvalastangute ja terrasside algsel kujunemisel kuidagi osaleda pärastjääaegsed kulutusprotsessid ega Läänemere murrutus ning analoogselt Balti klindile ka mõni muu varasemast geoloogilisest ajaloost pärinev meri. Seega on tõenäone, et nii Balti klint kui ka sellega kaasnevad kõrvalastangud ja terrassid on moodustunud ühe ja sama jõeoru arengu tulemusena.



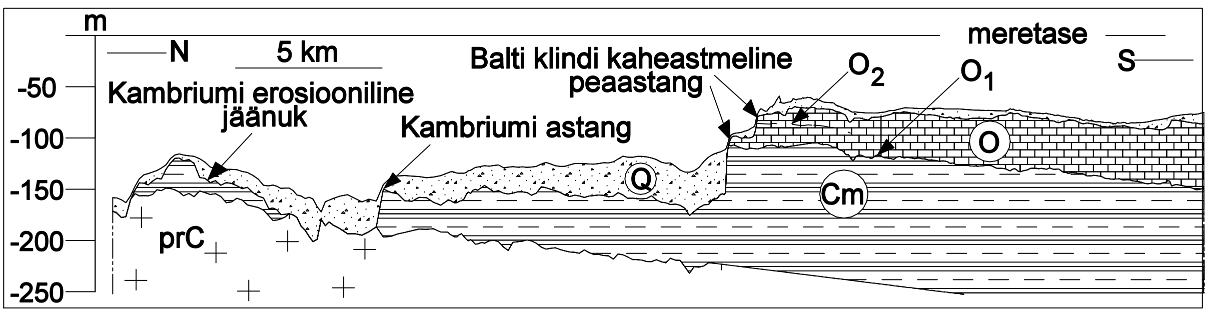
Joonis 19. Joonistel 14, 20-25 toodud seismiliste profiilide asukohad.



Joonis 20. Balti klint ja sellega kaasnev astangute ja terrasside süsteem Läänemere keskosast piki seismilist profiili 9102 (profiili asukoht vt. joonis 19)

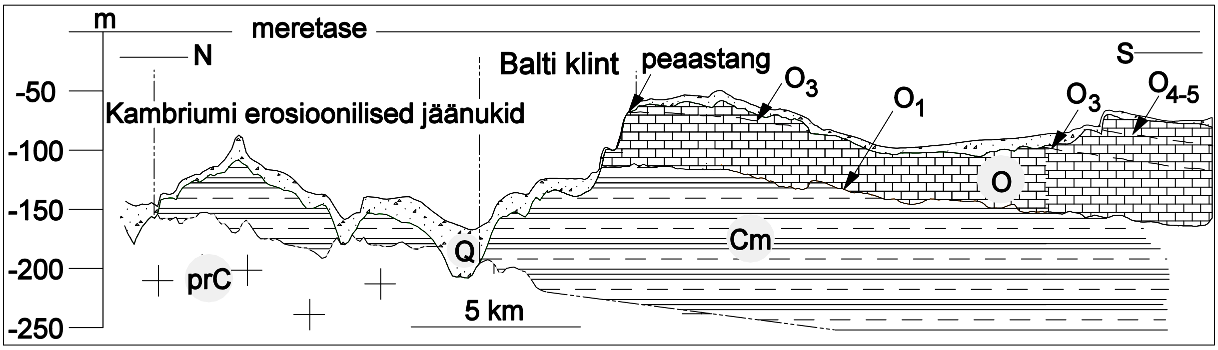
Lähtudes eespool kirjeldatud regiooni tektoonilis-erosioonilisest arengust võib suure tõenäosusega eeldada, et sellised kuestaorundid ning astangute ja terrasside süsteemid hakkasid Balti kilbi lõunanõlvale moodustuma selle tektoonilise aktiviseerumise ja kerkimise tulemusena Kainosoikumis. Lääne-lääneloode suunas alanev erosioonibaas, homoklinaalselt lõunasse kallutatud ja litoloogilis-erosioonilistelt omadustelt varieeruv settekompleks lõid siin soodsad tingimused ida-läänesuunaliste jõeorundite tekkeks. Kerkimise ja intensiivistuva põhjaerosiooni käigus uuristasid siinsed jõed end üha sügavamale paleosoilisse settekompleksi ning areneva jõeoru veerudel võisid piiratud levikuga, ilma selgete terrassideta nõlva- või astangulaadsed struktuurid tekkida juba litoloogiliselt kontrastsete kihtide piiridel (joonis 3). Kerke lakkamisel, kui põhjaerosioon stabiliseerus ja jõeoru arengus võttis võimust küljeerosioon ning meandreerumine, hakkasid orud laienema ning moodustusid ulatuslikud orulammid ja neid piiritlevad astangud (joonis 5). Iga järgnev kerkeetapp käivitas jõe uue süvenemise faasi, selle hääbumine aga järgmise jõelammi ja astangute formeerumise eelnevast madalamal tasemel (joonis 6). Mida kauem domineeris kerkimine ja põhjaerosioon, seda kõrgemaks kujunesid astangud ja mida kestvam oli stabilisatsiooni etapp ja küljeerosioon, seda enam laienes moodustuv jõelamm, samas kui eelneva tsükli lammi e. terrassi üha kitsamaks kulutati. Tekkinud astangute kõrgused ning kaldenurgad, nii nagu ka kujunevate jõelammide laiused sõltusid otseselt kulutatavate kivimite omadustest. Kõvadesse lubjakividesse tekkinud astangud olid madalad ja järsuseinalised, samas kui pehmetesse purdkivimites moodustunud astangud olid kõrgemad, kuid laugenõlvalised.

Just sellise, tsükliliselt areneva jõeoru üheks ja kõige võimsamaks astanguks osutub ilmselt ka Balti klindi peaastang. Viimase selge domineerimine teiste karbonaatkivimitesse kujunenud astangute seas on seotud põhjaerosiooni hüppelise suurenemise ja jõesängi süvenemisega peale seda, kui jõgi end läbi katva lubjakivi all lamavatesse pehmete liivakivide ja savideni oli murdnud. Erinevalt hiljem, ainult purdkivimitesse kujunenud kõrgetest astangutest, oli Balti klindi peaastang, selle ülaserva markeeriva kõva ja erosioonikindla lubjakivi lasundi tõttu palju paremini kaitstud edasise kulutuse eest. Ennekõike seetõttu on Balti klindi peaastangu esialgne kõrgus, iseäranis aga püstloodsus võrreldes teiste Kambriumi ja Vendi astangutega ka palju paremini säilinud.



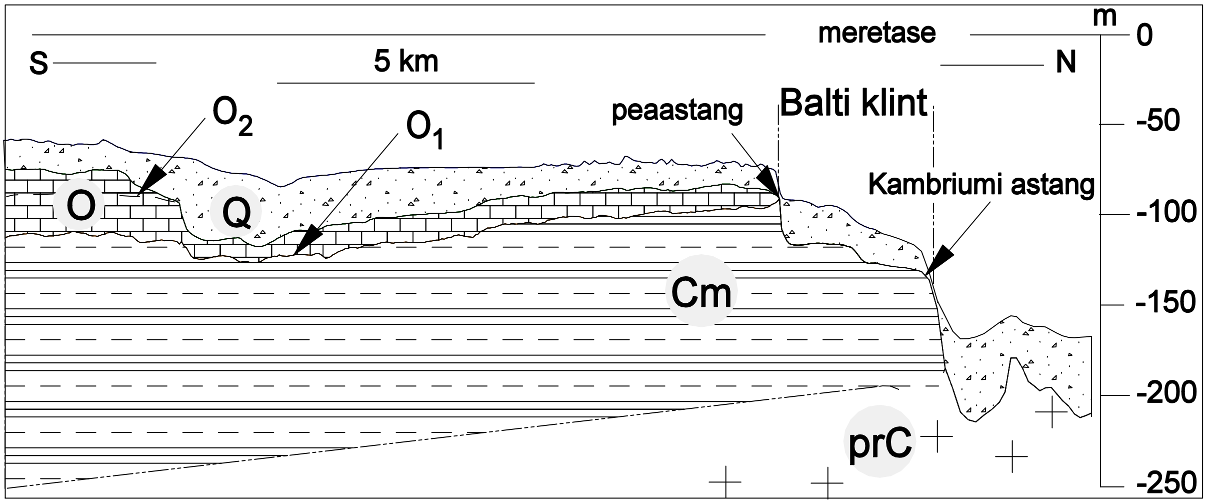
Joonis 21. Balti klint Läänemere keskosast piki seismilist profiili 9205 (profiili asukoht vt. joonis 19)

Suuresti hilisema kulutuse tõttu ongi kõrvalastangute esmane morfoloogia, kõrgus ja pidevus tugevasti muutunud, mistõttu nende jälgitavus tänapäeva reljeefis suuresti varieerub ja täpse arvukuse tuvastamine komplitseeritud on. Korrapärasem ning ulatuslikum astangute ja terrasside süsteem tuleb esile kulumiskindlamal ja nõlvapüsivamal lubjakivide avamusel. Nii maismaal kui ka mere all eristub siin Ordoviitsiumi läbilõikes selgemini kolm litoloogiliselt kontrastset taset (joonistel 20-25 O_2, O_3 ja O_{4-5} reflektorid), milledest lähtuvad nn. – Jõhvi (Kukruse), Rakvere ja Porkuni astangud ja nendevahelised terrassid. Kui maismaal jäävad kõrvalastangud peaastangust kaugele sisemaale, siis Läänemere all võib mitmetel profiilidel märgata, et Balti klindi peaastang algab kas O_2, O_3 või O_{4-5} reflektori, e. vastavalt Jõhvi (Kukruse), Rakvere ja Porkuni astangu pealt (joonised 20, 21, 22). See viitab juba eespool mainitud ida-läänesihis suurenevale settekompleksi kulutusastmele Balti klindi ees.



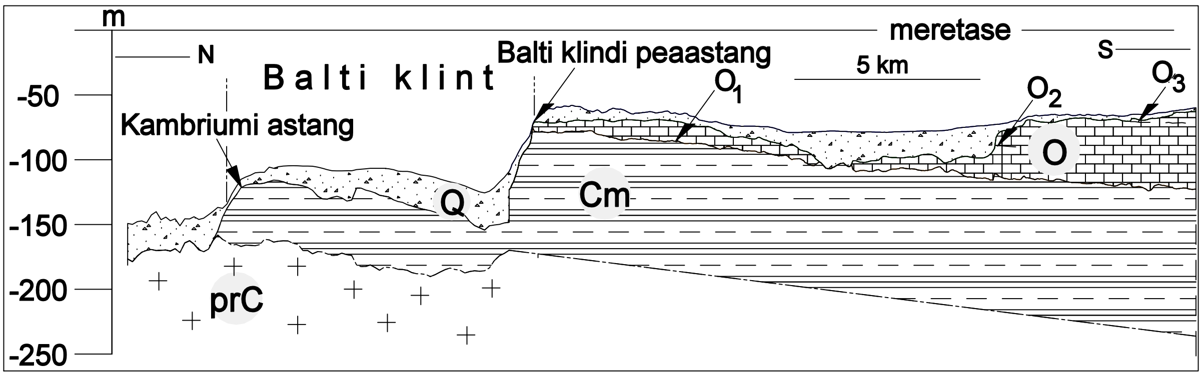
Joonis 22. Balti klint Läänemere keskosast piki seismilist profiili 9214 (profiili asukoht vt. joonis 19)

Võrreldes lubjakivi platooga on klindi esine Kambriumi-Vendi liivakivide-savide avamus tugevamini kulutatud ja liigestatud, mistõttu püsivate astangute ja terrasside tasemed on siin ebamäärasemad ja raskemini jälgitavad (joonised 14, 20, 21, 22). Nende arvukus ja ilme, nii nagu ka terrigeense kompleksi avamuse laius on ida läänesihis muutlikud ning Läänemere keskosa ja Põhja Eesti vahel selgelt erinevad. See on ennekõike tingitud Kambriumi-Vendi kompleksi kihtide paksuste, litoloogia ja stratigraafia samasuunalistest muutustest (Tuuling et al., 1997; Tuuling jt., 2007). Valdavalt 3-10 km laiune, tugevasti liigestatud Kambriumi avamus moodustab Läänemere keskosas enamasti ühe terrassi (joonised 14, 20, 21, 22, 24, 25), mis põhjapoolt on Eelkambriumi kristalliinsete kivimite avamusest alati eraldatud laugema/vähemlaugema, harva kuni 50 m kõrguse astanguga (joonised 14, 20, 21, 23, 25). Neil harvadel juhtudel kui Kambriumi avamusel esineb lisaastang ja teine terrass, on Balti klindi peaastang alati madal, ulatudes terrigeense kompleksi ülaossa (joonis 23). Enamasti 5-10 m kõrgune Kambriumi lisaastang on lauge ning selle ulatus läbilõikes varieeruv, millest tulenevalt ka moodustuvate terrasside stratigraafiline tase muutuda võib. Üksnes Fårö lähistel, kus Kambriumi avamusel esineb üks terrass, võib täheldada selle selget ühildumist Viklau liivakivi kompleksi pealispinnaga (Soela Formatsioon Eestis) (joonis 24).



Joonis 23. Balti klint Läänemere keskosast piki seismilist profiili 9213 (profiili asukoht vt. joonis 19)

Erinevalt Läänemere keskosast on Põhja-Eestis Kambriumi kompleks paksem ja litoloogiliselt varieeruvam ning klindi esisel alal esinevad siin ka Vendi kivimid. Loetletud põhjustest ja väiksemast kulutusastmest tingituna on Balti klindi ees paljanduva terrigeense kompleksi avamus Põhja-Eestis laiem ja morfoloogiliselt mitmekesisem. Soome lahe idaosas küünib Kambrium-Vendi avamuse laius enam kui 50 km (joonis 12), olles põhjapoolsest kristalliinsete kivimite avamusest kõikjal piiritletud 20-60 m kõrguse Vendi astanguga (Tavast & Amantov, 1992). Maismaal on klindi ees avanevates terrigeensetes kivimites esinev astangute ja neid lahutavate terrasside arv lõiguti suuresti varieeruv. Suuroja (2005) eristab Lahemaa, Lääne – ning Ida Viru klindilõikudel astangu Ordoviitsiumi fosforiidilasundi, Kambriumi Tiskre liivakivi (Kambrium I) ja Lükati liivakivi - Lontova sinisavi (Kambrium II) tasemetel. Neist on ulatuslik, 1-5 km laiune terrass seotud üksnes Kambriumi I liivakivi astanguga, mis esineb rohkem kui 60 km ulatuses Kolga-Kalvi vahemikus. Ida – ja Lääne Virus, kus fosforiidilasundi, Kambriumi I ja II astangute tasemed sagedasti kõik klindi peaastangusse on koondunud, esinevad ka Balti klindi kõige kõrgemad lõigud (Ontikal 54.6 m).

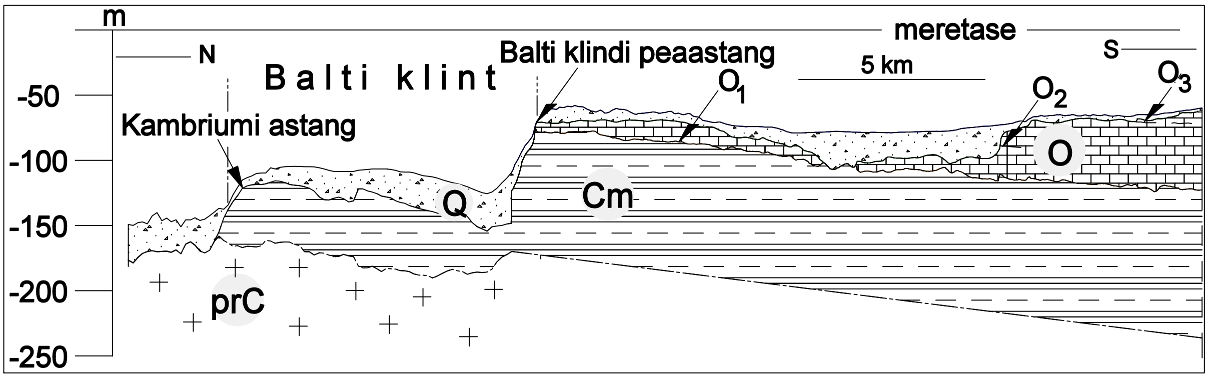


Joonis 24. Balti klint Fårö lähedalt piki seismilist profiili 9003 (profiili asukoht vt. joonis 19)

Erosiooniprotsessid kujuneva kuestaorundi nõlvadel

Oletatavasti toimis kihtide nõrga lõunasuunalise kallakuse tõttu Balti kilbi lõunanõlva lõikuvate jõesängide lõunaveerul alaline küljeerosioon, s.t. ka kerkeetappide kestel. Jõgede stabilisatsiooni etappidel oli aga küljeerosioon lõunaveerul selgelt prevaleeriv, mistõttu ulatuslike astangute ja terrasside moodustumine kujunevate orgude põhjaveerul oli vähem tõenäoline. Kui need seal ka tekkisid, nivelleerinuks hiljem põhjanõlvale moodustuv kuestaplatoo kõik suuremad reljeefi

ebatasasused.
Samaaegselt settekompleksi lõikuva jõega, hakkasid kujuneva oru veerudel aset leidma ka pidevad erosiooniprotsessid, millede ilme põhja- ja lõunaveerul üksteisest selgelt erinesid. Järsul, põhjasuunas laskuval lõunaveerul, kus kujunes astangute ja terrasside süsteem, langesid seda moodustavad kivimkihid kõikjal lõunasse, s.o. oruveerule ja astangutele vastupidises suunas (joonised 10, 18). Piki terrasse kulgevad vooluveed liikusid siin seetõttu valdavalt orunõlvale vastupidises suunas, mistõttu nende osakaal astangute nivelleerimisel ja kogu oruveeru tasandamisel oli minimaalne. Astangute kulutamisel mängisid peamist rolli gravitatsioonilised nõlvaprotsessid ning siin-seal neisse lõikunud suuremad lisajõed (joonised 10, 18). Terrassi kulutavate protsesside küündimisel all lamava erosioonikindla kihini, hakkas piki viimast arenema põhjasuunas langevale oruveerule vastupidise kallakusega platoo.
Esmalt hakkas terrassi lõunaservas asuva astangu ette liikuvatest ja kogunevatest vetest moodustuma ajapikku võimust koguv voolus (jõgi), mis põhja ja küljeerosiooni toimel terrassi pidevalt lõunasuunas laiendas/süvendas, uuristades samaaegselt enese ette üha kõrgeneva astangu. Sellega seletub ka mitmetel profiilidel Balti klindi peaastangu taga esile tulev, kuni paarikümne kilomeetri laiune, lõunasse kallutatud terrass (platoo), mida lõunast piiritleva astangu(te) ette on kujunenud kuni kümnekonna kilomeetrine laiune ja kolmekümne meetri sügavune orulaadne süvend (joonised 14, 22, 23, 25). Kohati uuristas voolus end läbi lubjakivilasundi all lamavatesse purdkivimitesse, eraldades Ordoviitsiumi platoo põhjaservas siin-seal välja isoleeritud lubjakivi jäänukeid (joonised 14, 25). Sellise oru jätkuval laienemisel ja süvenemisel eraldus selle ette jääv terrassilõik klindist täielikult, mille tulemusena klindi peaastang nihkuks kümneid kilomeetreid lõunapoole. On tõenäone, et klint niiviisi, s.o. ennekõike jõgede põhjaerosiooni tulemusena, osaliselt ka lõunasse liikus ja paljud mere alused lubjakivi erosioonilised jäänukid klindi peaastangu ees on just sellise tekkega.



Joonis 25. Balti klint Läänemere keskosast piki seismilist profiili 9211 (profiili asukoht vt. joonis 19)

Vastupidiselt lõunaveerule võimaldas kihtide lõunasuunaline kallakus samas sihis langeval põhjaveerul pinna- ja vooluvete vaba liikumist kogu moodustuva orunõlva ulatuses, soodustades nii nõlvasetete pidevat ärakannet all asetsevasse jõesängi (joonised 10, 18). Pideva erosiooni ja gravitatsiooniliste nõlvaprotsesside, ennekõike maalihete tulemusena toimus üheltpoolt oruveeru pidev madaldumine, teisalt aga laienemine põhjasuunas (joonis 18). Erosiooniprotsesside küündimisel all lamava kulumiskindla kihini hakkas piki seda oruveerule kujunema ulatuslik, põhjasuunas avarduv kuestaplatoo. Ürg-Neeva Pikaajalise erosiooni tulemusena hakkas kuestaplatoo lõplik tase formeeruma piki erosioonikindlate kristalliinsete kivimite pealispinda.

Ürg-Neeva

Homoklinaalselt lasuvasse Paleosoikumi settekivimitesse lõikunud jõe, Ürg-Neeva, kuestaorundi, selle astangulis-terrassilise lõunaveeru ning lauge põhjaveeru kujunemine eeldab miljoneid aastaid kestnud kulutusprotsesse kerkiva tektoonilise režiimiga piirkonnas. Milline oli Balti kilbi lõunanõlva katva Paleosoiline settekompleks paksus ja stratigraafia ajal, kui sinna kümnete miljonite aastate eest hakkas lõikuma Ürg-Neeva, on hilisemate kulutusprotsesside ulatuslikkuse tõttu väga raske oletada. Sellest tulenevalt on ka võimatu öelda milliselt tasemelt algas Ürg-Neeva lõikumine Paleosoikumi settekivimitesse. Tänapäevaks säilinud aluspõhjareljeefis on Ürg-Neeva lõunaveeru, e. kuestaorundi järsu nõlva piir Eesti mandriosas ebaselge, kuna siin ei tule selgelt esile ei järgmist lõunapoole jäävat asümmeetrilist kuestaorundit ega seega ka üleminekut sellele. Läänemere all on aga piir Ürg-Neeva kerkiva lõunaveeru ja lõunasse laskuva Ordoviitsiumi platoo e. järgmise kuestaorundi lauge veeru vahel selge. Balti klinti hõlmava kuestaorundi järsem veer tõuseb astangute ja terrassidena kõikjal O_{4-5} reflektori peale (vastab Porkuni astangule maismaal), millest lõunapoole hakkab aluspõhjareljeef piki Ordoviitsiumi platood madalduma Siluri klindi suunas (joonised 14, 20, 22, 24).

Kui sügavale paleosoilisse settekompleksi uuristas end aga Ürg-Neeva? Vaadates klindi peaastangu ees astmeliselt langevat purdkivimite kompleksi ja selle avamuse laiust, võib suure tõenäosusega oletada, et alates Soome lahe keskosast, kusagilt Kunda joonelt läänepoole, küündis Ürg-Neeva põhi juba kristalliinsete kivimiteni. Soome lahe idaosas ei jõudnud see jõgi end ilmselt aga läbi terrigeense settekompleksi uuristada ning sealne lai Kambriumi-Vendi avamus (joonis 12) jääb suures osas juba Ürg-Neeva laugele põhjaveerule. On võimalik et tänapäevase Soome lahe, kui asümmeetrilise kuestaorundi lauge põhjaveeru kujundamisel osales lisaks eelpool kirjeldatud protsessidele veel ka mõni suurem, Ürg-Neevaga paralleelselt kulgenud jõgi põhjas. Ehk siis Soome lahest põhjapoole jäi kunagi sealseid alasi katnud Paleosoilisse settekompleksi järgmine asümmeetriline kuestaorund, mille põhjas voolanud jõgi end kestva erosiooni toimel piki kristalliinsete kivimite pealispinda lõpuks Ürg-Neevani läbi murdis. Soome lahe idaosas järsult itta laienev Kambrium-Vendi avamus (joonis 12) jääks sel juhul suuresti juba Ürg-Neeva põhjaveerule ja seda põhjast piiritlev Vendi astang tähistaks oletatava põhjapoolse jõe kulgemist. Analoogia põhjal võib oletada, et sarnaste geostruktuursete tingimuste ja jõgede võrgu jätkuva püsimise korral jätkunuks ka pidev Ürg-Neeva nihkumine ja Ordoviitsiumi platoo ahenemine lõunasse, mis lõpptulemusena viinuks Ürg-Neeva liitumiseni Siluri klindi eelse jõega. Põhjapoolse kuestaorundiga võrreldes nõudnuks Balti klindi esise kuestaorundi hääbumine suurema settekompleksi paksuse tõttu lihtsalt tunduvalt pikemat ajavahemikku.

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Lisa 2
aruandele **Põhja-Eesti klint UNESCO maailmapärandi ja geopargina: edasiste võimaluste analüüs**

Balti klindi esitamine UNESCO Maailmapärandi nimekirja: taotluse lisamaterjalid

Estonian Ministry of the Environment
Institute of Geology at Tallinn University of Technology
The Geological Survey of Estonia
Institute of Botany and Ecology, University of Tartu

BALTIC KLINT

REPRESENTED BY 8 SELECTED SECTIONS IN NORTH ESTONIA

Nomination for inclusion
on the World Heritage List

SUPPLEMENTARY
INFORMATION

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BALTIC KLINT

REPRESENTED BY 8 SELECTED SECTIONS IN NORTH ESTONIA

NOMINATION FOR INCLUSION ON THE WORLD HERITAGE LIST

SUPPLEMENTARY INFORMATION

Compiled by:

Avo Miidel, Olle Hints, Kalle Suuroja, Tõnis Saadre, Hella Kink,
Urve Sinijärv, Nele Ingerpuu, Tõnis Kaasik, Hanno Zingel

Photos and illustrations by:

Olle Hints, Arne Maasik, Gennadi Baranov, Aavo Miidel,
Tõnis Saadre, Sten Suuroja, Jaak Nõlvak

Cover illustration:

Baltic Klint on Pakri Peninsula, NW Estonia
Photo by Arne Maasik

Tallinn 2005

Supplementary information on the Nomination of the Baltic Klint for inclusion on the World Heritage List

This document was compiled after, and in response to, the evaluation mission of the property conducted in November 2005 by IUCN.

It provides supplementary information on the Baltic Klint with regard to nomination for the inclusion on the World Heritage List. It should not be viewed on its own but as an integral and updated part of the original nomination documents supplied earlier in 2005.

Contents

Identification of the property

Päite Cliff, which was previously proposed as a part of Udria Landscape Reserve, was established as a separate Päite Landscape Reserve with its own protection rules (State Gazette RT I 2005, 42, 354) in 2005. Therefore it is necessary to correct the serial nomination table and clarify that the nominated property is composed of eight serial sites.

SERIAL NOMINATION TABLE:

Site element No	Name	County	Coordinates of centre point	Area of core zone (ha)	Buffer zone	Map annex
001	Osmussaar Landscape Reserve	Lääne	59°17′19″N 23°23′36″E	480	none	2
002	Pakri Landscape Reserve	Harju	59°20′49″N 23°52′03″E	1453	none	3
003	Türisalu Landscape Reserve	Harju	59°25′03″N 24°18′52″E	27	none	4
004	Ülgase Nature Conservation Area	Harju	59°29′09″N 25°05′41″E	22	none	5
005	Tsitre-Muuksi Escarpment in Lahemaa National Park	Harju	59°30′33″N 25°28′50″E	62	none	6
006	Ontika Landscape Reserve	Ida-Viru	59°26′22″N 27°13′32″E	1212	none	7
007	Päite Landscape Reserve	Ida-Viru	59°25′16″N 27°34′37″E	128	none	8
008	Udria Landscape Reserve	Ida-Viru	59°24′14″N 27°55′53″E	377	none	8
			Total	**3761**		

Fig. 1. Locality map showing the full extent of the Baltic Klint from Öland, Sweden, through North Estonia to NW Russia and the eight sites from North Estonia included in the nomination.

Justification for inscription

Criteria

In order to more clearly point out the universal and outstanding value of the Baltic Klint, the State Party has decided to revise the original document regarding the criteria for which the property is nominated. Being an outstanding example of earth's history, the Baltic Klint will be nominated for inclusion on the World Heritage List in accordance with criterion (viii) of the current operational guidelines of 2005 (natural criterion (i) according to the 2002 operational guidelines). The other two criteria, (vii) and (x) according to 2005 operational guidelines (N (iii) and N (iv) according to 2002 operational guidelines), that were initially included add extra value to the property but do not testify to the outstanding universal value in the same way as the criterion (viii) does.
Therefore the Baltic Klint will be nominated for inclusion on the World Heritage List only for criterion (viii) as an outstanding example representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features.

Significance of the property

The Baltic Klint is a large and complex geological structure featuring one of the best Cambrian-Ordovician successions in the world. It represents the best preserved and accessible example of Cambrian-Ordovician epicontinental basin with developing paleogeography and climate and evolving biota. The time span of the klint covers the "Cambrian Explosion" and the major episode of the "Great Ordovician Biodiversification Event". For several invertebrate groups the Baltic Klint is where the earliest discoveries were made or the oldest or most diverse faunas recovered.
Moreover, the Baltic Klint is one of the longest and still actively developing coastal escarpments in the world constituting a well developed structural boundary between the shield and an old platform. It also features one of the five submarine meteorite craters, obviously the best preserved old crater in the world. The Baltic Klint has a prominent study history and many scenery landscapes. Modern biotopes with rich flora and fauna add further value for the property.
In addition it should be noted that the individual sites of the Baltic Klint are easily accessible, and contain many examples of different geological and ecological processes which strongly support its educational as well as scientific value.

The most important aspects that make the Baltic Klint universal and outstanding or contribute to its significance worldwide are more thoroughly summarized below.

Geomorphology and structural setting

The Baltic Klint is one of the longest and still actively developing coastal escarpments in the world constituting a well developed structural boundary between the shield and an old platform.

Morphology

The Baltic Klint (escarpment) has a total length of approximately **1200 km** in a bee-line but stretches up to **1750 km** along the edge of the escarpment.
The total length breaks down into the **Öland Klint** – 150 km, the **Läänemeri Klint** (under the Baltic

Sea) – 500 km, the **North Estonian Klint** – 300 km, and the **Ingermanland Klint** (in Russia) – 250 km (Suuroja 2005). The length of exposed sections amounts to 280 km, with 240 km of this located in Estonia.

Both the relative and absolute height of the klint increase from the west to the east. On the Island of Osmussaar, where the klint emerges from the waters of the Baltic Sea, it is 6 metres high. Its first point on the mainland, on Cape Pakri, has an absolute height of 25 metres. In Estonia the klint is at its highest (66 – 67.5 m a.s.l.) between Sagadi and Kandle villages in Lahemaa National Park. To the east the height decreases, being only 28 – 30 m a.s.l. in Narva, but in Russia the klint rises again, reaching the height of 90 or more metres at Kotly and even more than 140 m a.s.l. near Koporye (Tammekann 1940). The relative height appears to be the greatest at Ontika (**55.6 metres**) and at Päite (43 metres).

Morphologically, the klint is divided into different structural parts: **klint peninsulas**, **klint bays** and **valleys**, **coastal plain**, **klint islands**, **the talus** (Tammekann 1940, Suuroja 2003, 2005).

The klint peninsulas are NW-SE and N-S oriented elongated stretches of land with their steep extreme points often washed by the sea. Their orientation is determined by the prevailing systems of joints. Their length reaches 10 – 15 km and width up to 7 km. The height of the escarpment decreases from the north-west to the south-east in proportion to the dip of bedrock strata, until the klint ultimately disappears or becomes buried under Quaternary deposits. The best example of a klint peninsula is the **Pakri Peninsula**.

Fig. 2. The Narva waterfall was the largest in Europe with maximum flow extending to 2000 m3/s (before the construction of hydropower plant). Postcard from 1930s.

Fig. 3. The Narva waterfall in 2000s. Photo by T. Saadre.

Between klint peninsulas there are klint bays with various length (up to 15 km) and width (up to 6 km). In klint bays, the bedrock often lies several dozens of metres below sea level. The bays are filled with up to 150-metre-thick Quaternary sediments. The oldest of these belong to the Middle Pleistocene (Raukas 1978, Kadastik 2004). They are overlain by Baltic Sea sediments. Beach ridges of the Baltic Ice Lake (mainly in the east), Ancylus Lake, Litorina and Limnea Sea (mainly in the west) often run across the bays (Tammekann 1940). In the deepest of the bays the bedrock lies at least 145 metres below sea level (Tavast, Raukas 1982). Klint bays are considered to be pre-Quaternary river valleys deepened and widened by the ice sheet (Tavast, Raukas 1982).

A vast majority of **North Estonian modern rivers** flow in these ancient valleys (klint bays). These young rivers have formed 20–35-metre-deep V-shaped and canyon-like valleys during the Holocene. Spilling over the edge of the klint, the rivers and their tributaries formed numerous waterfalls, which are part of the extensive Baltic Fall Line. In North Estonia there are **32 waterfalls** with a height of one metre or higher (Suuroja 2005). The highest waterfall (30 metres) is situated at **Valaste**, in the Saka-Ontika-Toila Landscape Reserve. Some waterfalls (**Keila**, **Jägala**, **Langevoja** a.o.) are typical cap-rock falls, *i.e.* their uppermost part is resistant to erosion and forms a protective cap. Upstream migration of waterfalls is marked by canyons exceeding 12 – 20 metres in depth. The total distance of migration ranges from some hundred metres to some kilometres (Narva Falls). By means of old maps it was established that from 1862 to 1977 the Keila Fall regressed 11 metres (9.7 cm per year), and the Jägala Fall regressed 42 metres or 17.2 cm per year between 1688 and 1931.
Before the construction of the Narva Hydropower Plant, the **Narva Waterfall** used to be the largest waterfall in Europe, with the maximum flow extending to **2000 m^3/s**. Currently, however, it is surpassed by Rheinfalle in Swizerland (1250 m^3/s) and Dettifoss in Iceland (400 m^3/s).
The development of North Estonian rivers has been significantly affected by the klint. With its cap made up of resistant carbonate rocks, the klint became a permanent local base-level for rivers. Together with the associated waterfalls, the klint prevented regressive erosion from penetrating further inland. This explains why under the conditions of lowering sea-level and continuous land uplift numerous terraces were formed only in the fore-klint reaches of North Estonian valleys.

In places, the steep high escarpment becomes divided into several (2–4) minor scarps, with the distance between the edge of the klint and the lowest scarp amounting to a few kilometres. The formation of the smaller scarps is connected with bedrock's different resistance to denudation. Thus, there are scarps consisting of Ordovician carbonate rocks and Cambrian and Ordovician terrigenous rocks (Suuroja 2005). The height of Cambrian cliffs sometimes exceeds 20 metres. Such minor scarps are seen, for example, in Türisalu Landscape Reserve and Ülgase Nature Reserve.

Several **morphological types** are distinguished in the escarpment (Giere 1932, Tammekann 1940, Suuroja 2003, 2005). According to the classification by Suuroja (2005), it is possible to distinguish 10 morphological types. Of these, four types are represented in the sections included in the proposal: 1) **Öland type** – vertical cliff with no talus, consists of carbonate rocks, open to wave erosion, 2) **Väike-Pakri (Small-Pakri) type** – vertical cliff, carbonate cap underlain by Ordovician glauconite sandstones with a rather deep wave-cut notch in. Large fallen slanty limestone blocks slow down the retreat of the cliff, 3) **Pakri type** – high vertical cliff, composes of Cambrian terrigenous, Ordovician terrigenous and carbonate rocks. The hardest carbonate strata hang as a cornice above softer ones. In Cambrian rocks there are large wave-cut caves, 4) **Ontika type** – high escarpment, consists of Cambrian and Ordovician terrigenous (Cambrian blue clay included) and carbonate rocks. Between the escarpment and the sea there is a talus – up to 200 metres wide and covered with klint forest. The uppermost part of the klint forms a vertical wall (15 – 20 metres in height). Also the middle part composed of Cambrian sand- and siltstones is steep.

In front of the klint there are some **klint islands** – denudational remnants of an Ordovician carbonate plateau, which are detached from the plateau by a strait or valley in bedrock topography. A well-known klint island is located in Tallinn. This is Toompea – a small hillock, actually the top of a central elevation in bedrock topography. Its relative height reaches 25 – 31 metres. The klint island lies adjacent to two deep buried valleys in the west and east. Counting from the valleys` bottom, its relative height exceeds 160 metres. In the postglacial time, the Toompea klint island was long an island in the Baltic Sea. Historically, Toompea is the heart of Old Tallinn and the castle of Toompea is the seat of the Estonian Parliament (the Riigikogu).

Geologically, the most interesting and complex klint islands are located in Northeast Estonia. The **Vaivara Sinimäed (Blue Hills)** – a ridge with the length of 5 km and relative height of up to 50 metres – compose of large bedrock blocks. The Middle and Lower Ordovician and Cambrian rocks here, blue clay included, extend some dozens of metres higher than their normal position. The rocks are strongly folded – in places the strata are vertical, and fractured by dense jointing (10 – 20 joints per metre). In front of the hills there are some narrow linear structures – anticlines with a core of blue clays. Apparently, the claystone was squeezed upward along the lines of minimum resistance (Puura & Vaher 1997). It has been supposed that the Vaivara Blue Hills are of glaciotectonic origin and their formation was favoured by pre-existing tectonic disturbances, which are widely distributed in the area (Miidel *et al.* 1969, Rattas & Kalm 2004, Suuroja 2005). The Vaivara Blue Hills have been considered a pushmoraine formed at the glacier margin in the time of the Pandivere Stage about 12 400 – 12 230 14C years ago (Raukas et al. 2004).

Based on the morphology, bedrock exposes, the extent of talus and width of coastal plain, Suuroja (2003, 2005) has divided the North Estonian Klint into nine regions (**Northwest Estonia, West Harju, Tallinn, East Harju, Lahemaa, West Viru, East Viru, Vaivara, Narva**). According to this division, Osmussaar Landscape Reserve and the Pakri Islands belong to Northwest Estonia; Pakri Peninsula and Türisalu Landscape Reserve – to West Harju; Ülgase Nature Reserve and Tsitre-Muuksi Escarpment – to East Harju; and Ontika, Päite and Udria Landscape Reserves – to East Viru Region.

Coastal development

After the retreat of continental ice, the North Estonian Klint was shaped by wave action during different stages of the Baltic Sea. Depending on topography and the rate of **glacioisostatic uplift**, different parts of the klint emerged from the sea at a different time (Orviku, Orviku jun. 1969).

At Ontika in Northeast Estonia, the klint was subject to wave action already from the beginning of the **Baltic Ice Lake** more than 11 000 years ago. At that time, large beach ridges were formed along the edges of klint bays. These ridges consist of very coarse carbonate material (pebbles and cobbles) transported from the klint to the south, southeast or southwest by littoral drift. According to Orviku and Orviku jun. (1969), in the Baltic Ice Lake stage BIII (ca 10 300 14C years ago) the klint already existed at Ontika as an about 17 metres high cliff with waves eroding both carbonate rocks and *Dictyonema*-argillite. At the same time the Island of Osmussaar was still at a depth of 75–77 metres. Cape Pakri emerged above sea level 7000 years ago and the Islands of Väike-Pakri and Osmussaar in Northwest Estonia – only some 4000 and 2000 years ago. Thus, the duration of sea erosion along

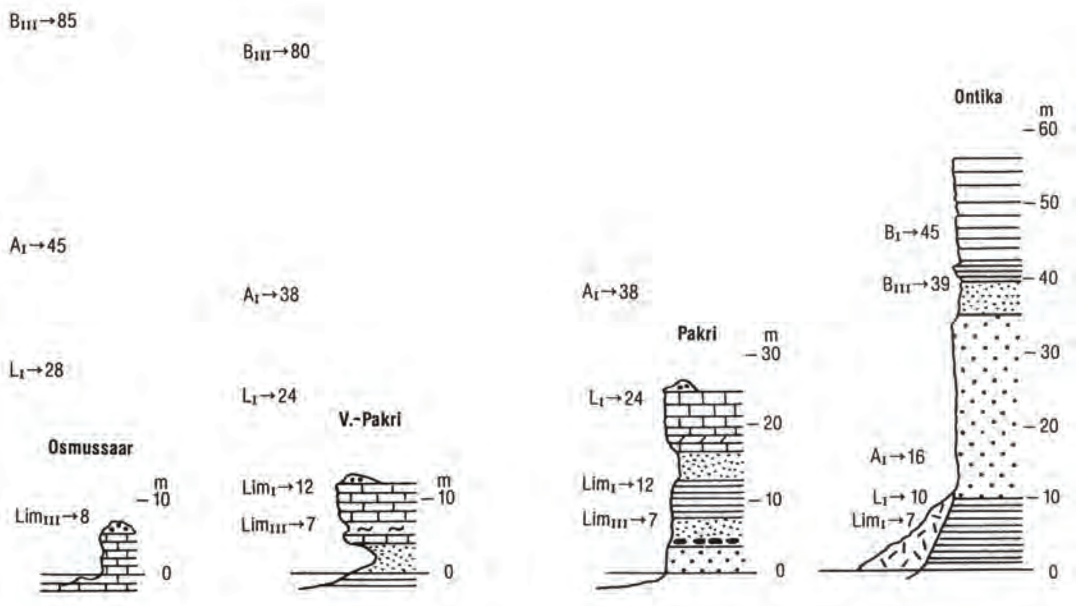

Fig. 4. Emergence of the klint from the sea after Orviku & Orviku (1969). For further explanation see in text.

the klint varies greatly – in total by approximately 9000 years. This may be the reason why the klint gets straighter towards the east at Saka.

At Cape Pakri, intense sea erosion commenced at the time of the regression of the **Litorina Sea** about 6000 – 4000 years ago. It was the time when soft glauconitic sandstone and sand came into the sphere of wave influence. By the way, on the Island of Väike Pakri the erosion of the same layer started 2000 – 1700 years ago. As a result of nearly 7000 years of erosion the klint has retreated, leaving behind a few hundred metres wide flat rocky wave-cut bench. The material loosened by wave erosion at the cliff was usually transported southwards by longshore drift. Thus, numerous beach ridges and spits were formed on the Islands of Pakri and Osmussaar (Öpik 1927, Tammekann 1940). The ridges are separated by brackish or freshwater lakes or marshy depressions. The same process took place also in the klint bays that got filled with marine deposits with a considerable thickness (up to 20 metres in Vääna and Tallinn Bays).

After one or another part of the klint had emerged from the sea, slope processes started there. Undoubtedly these processes commenced also in the east, as told – 11 000 or more years ago. It is likely that rock falls were the most frequent at the time. Later, when sea level lowered and a permanent talus had formed, other types of mass movement were added. In the region of the North Estonian Klint, the following types of mass movement can be distinguished: rock falls, rock slides (or rock glides), rotational slips, and talus creep (Miidel & Raukas 2005).

Rock falls dominate in the western part of the klint but they are frequent also in the east. In East Estonia, where the talus zone overlies Cambrian clayey rocks, rotational slips, rock slides and talus creep occur. Joints and freeze-thaw processes in them, different resistance of rocks and wave action are the main factors responsible for rock falls. Several large rock falls took place lately on the Pakri Cliff. One of the largest rock falls occurred on 22 April 1996. It caused such strong quaking of the ground that an earthquake was suspected at first. In December 2003, an arch-like block (9.4 metres wide and 27 metres long and some 1500 – 2000 tonnes in weight) fell down. Rock falls can also be triggered by earthquakes. The Osmussaar earthquake of 1976 (4.7 magnitudes on Richter`s scale) caused rock falls along the klint of the island. Judging by the extensive stone fields and heaps, rock falls are frequent on the klint between Saka and Päite.

Rock slides (or block glides) have a slip surface generally formed by joint planes and they are mostly associated with terrigenous rocks in the lower part of the klint. As a result of rock falls and slides, the klint is retreating also in East Estonia in spite of the fact that it is protected from direct wave erosion by a wide talus.

Rotational slips and creep are related to the talus. These processes are widely distributed in the east, between Saka and Päite, where the talus is underlain by Cambrian clayey rocks. In most cases, the slips are of the single rotational type. Multiple rotational slips are rare. Such landslides are triggered by heavy storms and rainfalls, during which the toe of the talus is eroded away. The most recent landslide took place in May 2001. The landslide was about 180 metres long and the main scarp was 3 metres high. Rotational slips occur at the talus and in the clayey rocks at the sea. In both cases, sea erosion during the high-water stand plays a significant role.

The creep involves a very slow downslope movement of the layers of talus. Its contact with the underlying Cambrian clays serves as a drainage pathway for groundwater percolating through bedrock and discharging at the foot of the klint. The boundary acts as a lubricant favouring the creep. As a result, large blocks of Ordovician and Cambrian rocks are found at the shore, 50 – 100 metres off the klint.

Geological boundary between shield and platform area

Geologically, the Baltic Klint is situated on the border of crystalline rocks of the **Fennoscandian Shield** and sedimentary rocks of the **East-European Platform** and serves as an important exposed natural boundary. This boundary is actually represented by a questa landscape partly hidden under the Baltic Sea (Tammekann 1940, 1949, Martinsson 1958, Tuuling & Floden 2001, Suuroja 2003, 2005). The submarine depression is located in the area of Vendian and Cambrian outcrops, which together with the Baltic Klint form a transition between the crystalline bedrock in the north and sedimentary rocks in the south. Along the border of crystalline and Cambrian sedimentary rocks, an escarpment is traceable in places (Tammekann 1949, Tuuling & Floden 2001), with its relative height reaching sometimes even 100 m.

Still, the Baltic Klint is the most prominent geomorphological feature in the northwestern area of the East European Platform. The escarpment separates the Cambrian outcrop area from the Ordovician one.

The Baltic Klint or, more specifically, the **scarpland** in its border zone, is an important geographical boundary in Northern Europe. To the north and northwest of it lies the Fennoscandian Shield. The basic characteristic of the Shield is the presence of numerous linear features resulting from parallel and orthogonal joint and fracture systems, which divide the bedrock into blocks of various size and shape. The landscape of magmatic and metamorphic rocks, in general highly resistant to denudation, was sculptured by Pleistocene glaciers. Features with strong structural control were exploited by the ice and their morphological role in the topography was enhanced.

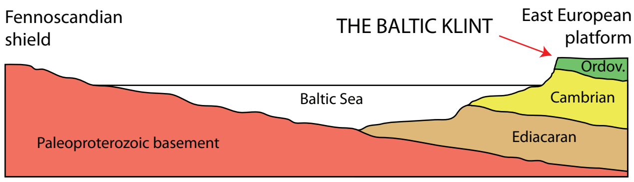

Fig. 5. N-S cross section of the structural boundary between the shield and sedimentary platform.

In the south and south-east, the flat slightly terraced landscape of the East European Craton contrasts with the more dissected and hilly Fennoscandian Shield. The even character of the scarpland prevailing at the northern and northwestern edge of the craton was caused above all by homoclinal occurrence of Palaeozoic strata. The sedimentary cover has a very gentle (6 – 8') southward dip. Horizontal and non-dislocated strata outcrop in parallel-running east-west directed belts. An important factor favouring the development of scarplands was the different resistance to denudation of not only hard crystalline and softer sedimentary rocks but also terrigenous and carbonate sedimentary rocks. The general flatness of the scarpland, which is mainly of pre-Quaternary origin and age, was not significantly affected by the ice sheet in spite of the fact that the scarpland fell within the area of glacial erosion.

As it is known, the **Canadian Shield** is surrounded by platform rocks, folded belts and coastal plains. Throughout the platform areas, the predominant element of the landscape is often scarpland. The best example of this kind of landscape, situated in the transition zone from the shield to the platform, may be traced in Southern Ontario Lowland, where Palaeozoic rocks form three major escarpments between Lakes Ontario and Huron (Bird 1972, Verma 1979). The northernmost of them – the **Black River Escarpment** – consists of Gull River and Bobcaygeon Formations represented by limestones and shaly limestones of the Upper Ordovician (Mitchell et al. 2004). The Black River Escarpment separates the shield from the platform. The height of the scarp ranges from 7 to 23 m. The scarp breaks into several small scarps but the well-developed ones are located in the east, near Lake Ontario. Between the scarp and the shield there is a depression with the Kawartha Lakes and several smaller ones.
Ordovician correlation charts (Mitchell et al. 2004, Webby et al. 2004) suggest that the Gull River and Bobocaygeon formations correspond to Upper Ordovician stages in Estonia from Haljala to Oandu Stage. Consequently, the geological structure of the Black River Escarpment and the Baltic Klint is different. The latter exposes Lower and Upper Cambrian and Lower and Middle Ordovician rocks.

Although the Baltic Klint as a borderland between the Fennoscandian Shield and East-European Platform has an analogue in North America, this does not lessen its scientific value. Moreover, some morphological features (length, height, sea cliffs, many good exposes) are even better exposed here.

Terminology

Since the term "klint" and its usage arose several questions during the evaluation mission, the background will be shortly explained below.

In Swedish and Danish languages, *klint* means a coastal escarpment. In Swedish it also means a 'steep-sloped mountain top' or 'cornflower'. Driven by the eastward aspirations of the Danes and Swedes in the Viking time, the word *klint* spread also into the languages of the countries of the east coast of the Baltic. As supposed by a well-known Swedish geologist and klint researcher A. Martinsson (1958), the word *klint* comes from the Swedish-Danish primal language word *klev*, which denoted an escarpment, be it on a seacoast or riverbank. From there the word was supposedly adopted through Scotland into the English language, where it has transformed into *clint*. The word exists also in Scottish but is not used in the meaning of a bedrock escarpment in English. *Encyclopaedia of Geomorphology* uses the word *clint(s)* together with *grike* to characterize a karren landscape with widened joints (*grikes*) formed through the dissolution of jointed limestone surfaces, and smaller limestone blocks (*clints*) between them. Nowadays the word *klint* in the meaning of a coastal escarpment in sedimentary rocks is rare in mainland Sweden but in use in the south of Sweden (Skåne) and on the islands of Öland and Gotland.

The authors of professional literature have used both *glint* (Tammekann 1940), *clint* (Martinsson 1958 a.o.) and *klint* (Miidel 1997, Suuroja 2005). In Norwegian the word spells *glint* and in German – *Glint* or *Kliff*, in Russian – *glint*, in Lithuanian – *klintis* (means also limestone), in Latvian – *klinšu* (eng. coastal escarpment) or *klints* (eng. cliff). In English-language professional literature, the term has been conveyed with the words *klint*, *clint*, *glint* but also *cliff*, *coastal cliff*, *coastal escarpment*, *escarpment*. Americans use either the word *escarpment* (*Niagara Escarpment*) or *scarp* (*Niagara Scarp*) when speaking or writing of the escarpment systems in the area of the Great Lakes, which are rather similar to the Baltic Klint.

The words *klint* and *glint* were in use in Estonian already in the 14th century (Paatsi 1995) in the meaning of a sharp coastal cliff, cliff, hill top, sandbank, fence and border. In a border dispute of 1349, it is mentioned in the meaning of both a fence (*Glint dictum in vulgari*) and a limestone wall (*glintmure*).

Stratigraphy of the succession

The Baltic Klint represents the best exposure of Cambrian and Lower and Middle Ordovician rocks of the Baltica palaeocontinent and is among the best ones in the entire world.

The stratigraphic succession of the klint is most complete in North Estonia and best represented by the individual serial parts included in the nomination. The succession starts with Lower Cambrian "blue clay", 530–540 My old (Mens *et al.* 1990, Moczydlowska & Vidal 1988) and spans through the rest of the Cambrian and Lower Ordovician, which are represented mostly by siliciclastics, and through Middle Ordovician limestones, which extend to the basal Upper Ordovician Kukruse Stage, 460 My old (Cooper & Sadler 2004). The total time span of the klint succession is therefore remarkable, amounting to nearly **80 million years**.

The lowermost strata exposed on the klint are time equivalent to the well-known "**Cambrian Explosion**" of body plans and major phyla (Zhuravlev and Riding 2001). The Baltic Klint spans also across the major episode of the "**Great Ordovician Biodiversification Event**" (Webby *et al.* 2004), which was characterized by the most rapid rise in the family-, genus-, and species-level diversity of marine biota (there was almost no terrestrial life at that time) in Earth history.
Another noteworthy feature of the Ordovician is that the global sea level was at its highest during the entire Phanerozoic (Hallam 1992), allowing extremely widespread distribution of epeiric (shallow epicontinental) seas.

The global Cambrian stratigraphy is still largely under discussion, except for the base of the Cambrian and base of the Furongian (Upper Cambrian), which are fixed by GSSPs (Shergold & Cooper 2004). Several regional stratigraphic schemes exist around the world. The one used in Estonia is includes several type sections on the Baltic Klint or the adjacent sections (Lontova, Lükati, Tiskre, Ülgase, Tsitre, Kallavere).

The global Ordovician stratigraphy is currently in the final stage of formalization (Webby 1998, Cooper & Sadler 2004, Finney 2005). Two of the international stratotypes are located in the Baltic region but not in the klint area. The name **Volkhovian**, proposed for the Third Global Stage (Dronov *et al.* 2003), comes from the Baltic Klint area in NW Russia.
Out of the five commonly quoted regional Ordovician timescales (Cooper & Sadler 2004), the Baltic stage-level timescale, which has been largely elaborated in Estonia, stands out by its greater detail

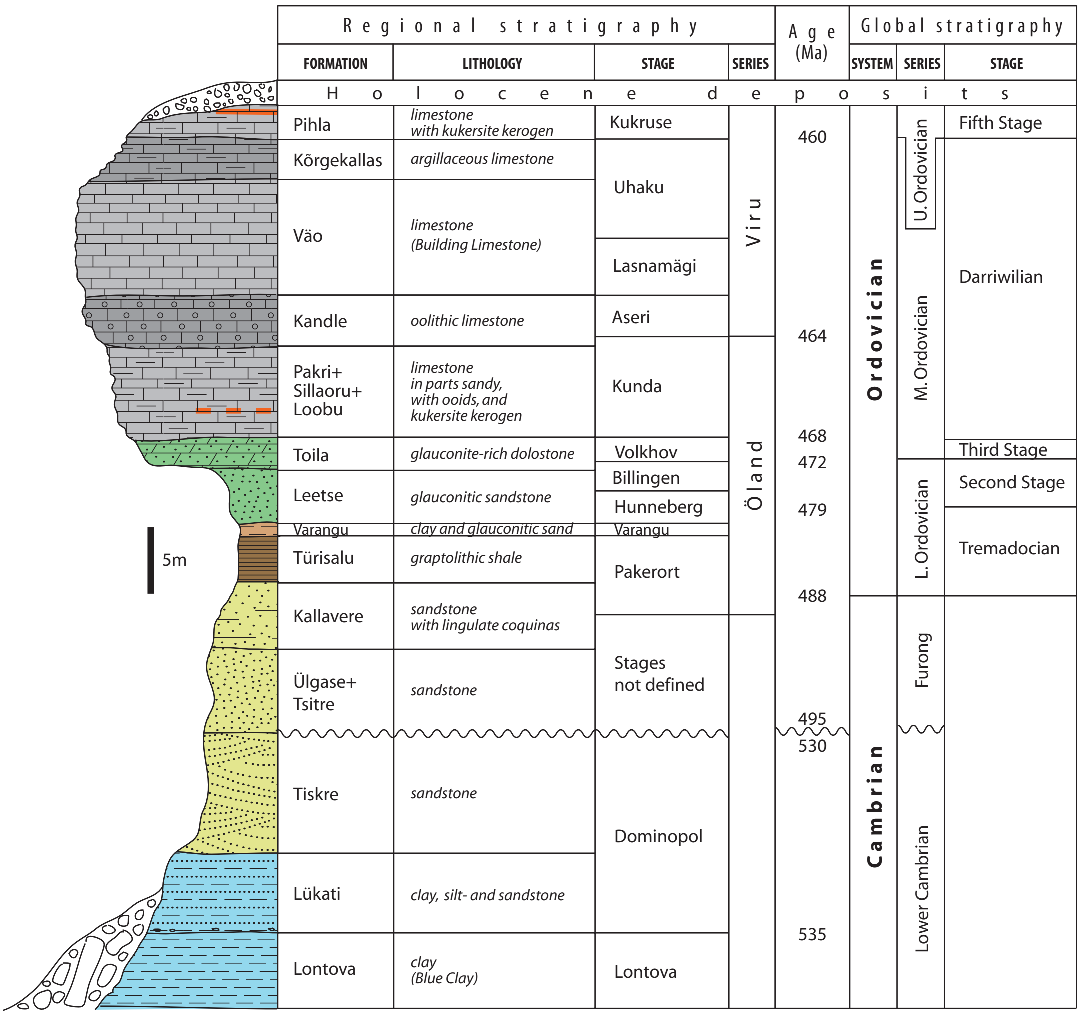

Fig. 6. Composite section of the Baltic Klint showing regional and international stratigraphy and general rock types (compiled from various sources). In most cases maximum thicknesses observed in the klint sections are used in this figure. Due to the fact that individual rocks units show marked variations in thickness, the total height of the composite is larger than any one real section of the klint.

and long study history and is well known to all Ordovician students (Webby 1998, Cooper & Sadler 2004). For the Lower and Middle Ordovician, several type sections for Baltic stages (**Pakerort, Varangu, Kunda, Aseri, Lasnamägi**) are located at the Baltic Klint or closely adjacent to it. The same applies to a number of rock formations but these have a more regional use (Kallavere, Türisalu, Varangu, Leetse, Toila, Pakri, Aseri, Väo).

The **biostratigraphy** of the sequence exposed at the Baltic Klint has been traditionally grounded on shelly faunas such as trilobites and brachiopods. Although trilobites are still a very useful group in the klint area, more attention is currently being paid to graptolites, conodonts, chitinozoans and acritarchs. The Baltic Klint succession has been invaluable in developing the Baltic biostratigraphic schemes, which have utility beyond the Baltic region. For chitinozoans, the Baltic scheme is the first and most detailed one in the world (nearly a half of world Ordovician chitinozoan data currently come from the Baltic region, see below). Biostratigraphy allows the Baltic timescale, including the

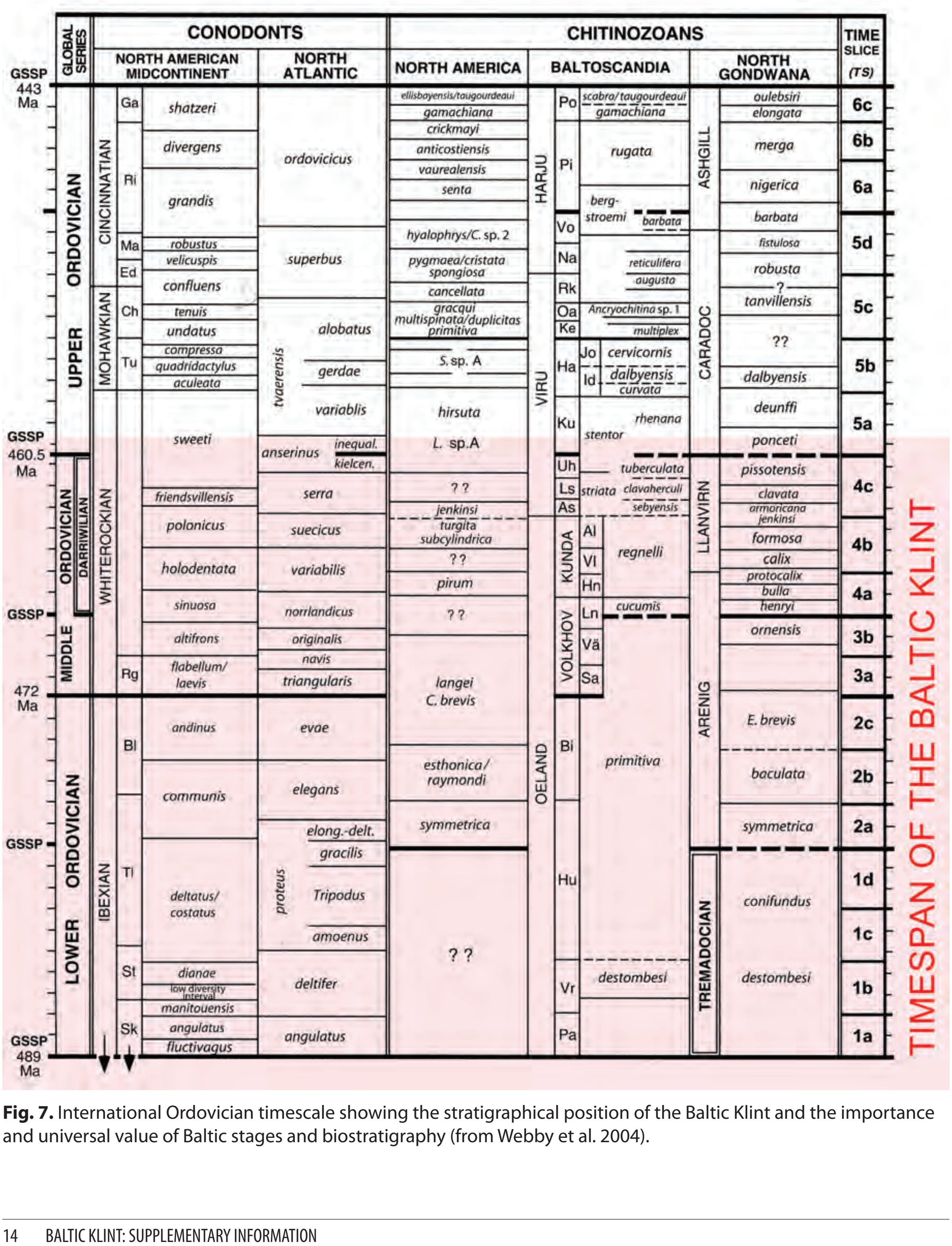

Fig. 7. International Ordovician timescale showing the stratigraphical position of the Baltic Klint and the importance and universal value of Baltic stages and biostratigraphy (from Webby et al. 2004).

Lower and Upper Ordovician exposed on the klint, to be tied precisely to those of other regions and to the global scale. The time-span of the Baltic Klint succession is illustrated on Figs. 6-7.

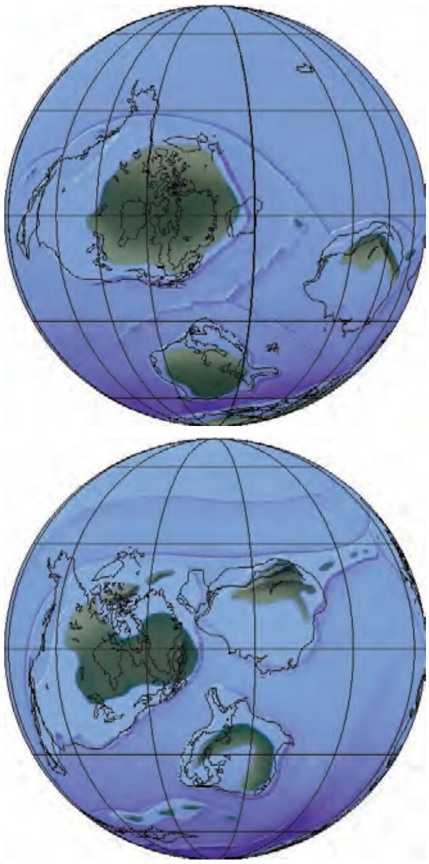

Fig. 8. Drift of the Baltica continent from lower to temperate southern latitudes during the Cambrian (upper image) and Early to Middle Ordovician (lower image) From C. Scotese's Paleomap project 2003, http://www.scotese.com.

During the time period observable at the Baltic Klint, the **Baltica continent** drifted from lower to temperate southern latitudes (from ca 60˚ to 30˚, Fig. 8; see e.g., Scotese & McKerrow 1990, Cocks & Torsvik 2004). The changing **palaeogeographical position** is well reflected in regional sedimentology as a transition from siliciclastic to carbonate deposition. The same is implied from biogeographical patterns. For instance, Early Ordovician microfossil assemblages share elements with North Gondwana, whilst from the Upper Ordovician on there appear the first elements of Laurentian faunas.

Deposition in the Baltic area took place in the **shallow epicontinental sea** of the time, known since the middle Early Cambrian as the Baltic Palaeobasin (Männil 1966, Jaanusson 1976, Nestor & Einasto 1997, Mens & Pirrus 1997). The succession contains a variety of different rock types (claystone and organic-rich shale, silt- and sandstones with a varying mineralogical composition, limestone, and mixtures of these) representing a rather broad range of depositional environments.
Stratigraphic completeness of the succession varies. In the Cambrian and Early Ordovician siliciclastic interval, the corresponding time-span is only partly represented by rocks, while the Middle Ordovician carbonate part is much more complete, with only minor breaks in the deposition and gaps in the sequence. It is beyond the scope of this overview to describe individual rock units in detail but the relevant data can be found in several published works (see Raukas & Teedumäe 1997 and references therein). Fig. 6 gives a rough picture of the regional stratigraphic units exposed at the Baltic Klint.

Due to the fact that the Baltic Klint in North Estonia is located more or less perpendicular to the palaeobasin gradient (i.e. parallel to the shoreline) for the most of the time in question, facies changes are relatively small. In this respect the lowermost Cambrian is exceptional when the basin configuration was different and the depth gradient was in E-W rather than S-W direction (Figs. 9–10). Also the Baltic Klint sections on Öland, Sweden, are represented by relatively deeper-water settings

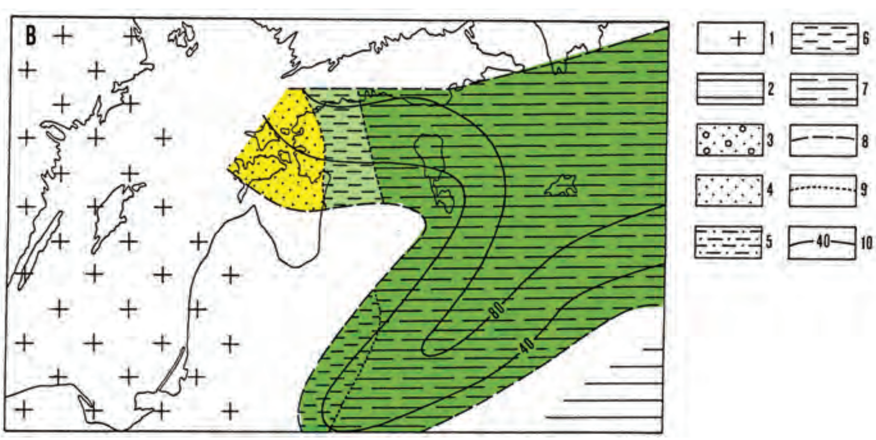

Fig. 9. General configuration of the palaeobasin during the Early Cambrian Lontova age (after Mens & Pirrus 1997). Yellow marks shallow-water environments were sandstones deposited and darker green denotes deeper water settings characterized by clays. Note that the Baltic Klint is perpendicular to facies zones.

and accordingly different rocks than in North Estonia (cf. Männil 1966). For instance, in lower Middle Ordovician the rocks on Öland are red-coloured and contain somewhat different faunas indicating notable facies difference.
Generally, the Baltic Palaeobasin was extremely flat, especially in the Middle Ordovician (Jaanusson 1973), therefore also the changes in onshore-offshore transect are gradual. Due to the regional palaeogeography and the flat seabed, the Ordovician succession is very condensed but still notably complete.

It is noteworthy that many **individual beds** are traceable along the entire Baltic Klint from St. Petersburg region to Öland, that is, across more than 1000 km (Dronov *et al.* 2000). An ultimate example is the "püstakkiht" surface with *Amphorichnus* burrows at the lower boundary of the Volkhov Stage, which has the same morphology in NW Russia, Estonia and Sweden (Fig. 11). No comparable examples of lateral tracing of individual beds are known elsewhere in the Paleozoic world (except for some marker K-bentonite layers). Moreover, this particular **discontinuity surface** was the first such feature to be described and associated with a break in the deposition (Kupffer 1876). Similar features at the Cambrian-Ordovician boundary and from e.g., Mesozoic-Cenozoic boundary were described well after that (see overview and further references in Jaanusson 1961). The studies by Orviku (1940, 1960) on the lithology of Baltic Klint sections are still the most detailed ones with respect to description and interpretation of discontinuity surfaces in the entire world.

Another very important aspect that makes the Baltic Klint unique in the world is the fact that the entire Baltic area has been **tectonically very stable** and thus the Cambrian-Ordovician rocks exposed in the Baltic Klint are not folded and disturbed but lie horizontally bedded, with only a slight southward dip (on an average 3 m per km; ca 0˚10'). The succession has also remained completely unaltered by magmatic intrusions and metamorphism.

Moreover, it has never been buried deeply under younger sediments. Although Devonian marine sediments might have been covering the Early Paleozoic strata exposed in the klint, data from the conodont and acritarch alteration index (Löfgren et al. 2005) and clay mineralogy (Kirsimäe et al. 1999) indicate that the thickness of this cover never exceeded 1000 m. All this has ensured excellent preservation of both the rocks and the fossils. The best example to illustrate this is **Lower Cambrian**

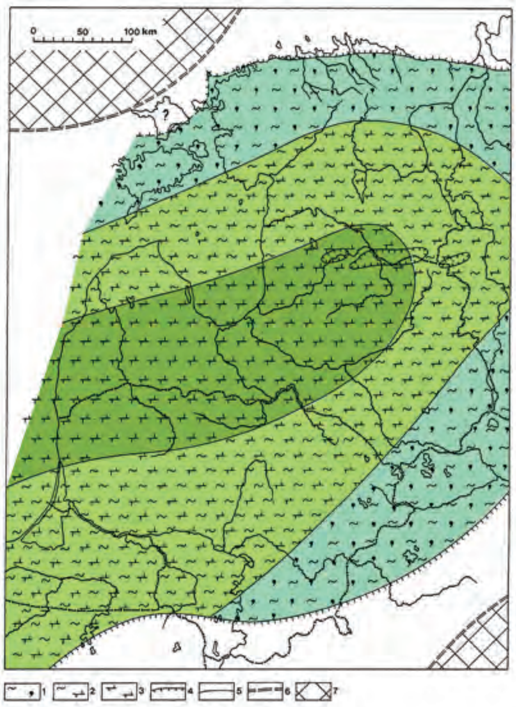

Fig. 10. General configuration of the Baltic Palaeobasin during the lowermost Middle Ordovician Volkhov age (after Nestor & Einasto 1997). Darker green marks relatively deeper part of the basin. Note that the shoreline is more or less parallel to the Baltic Klint.

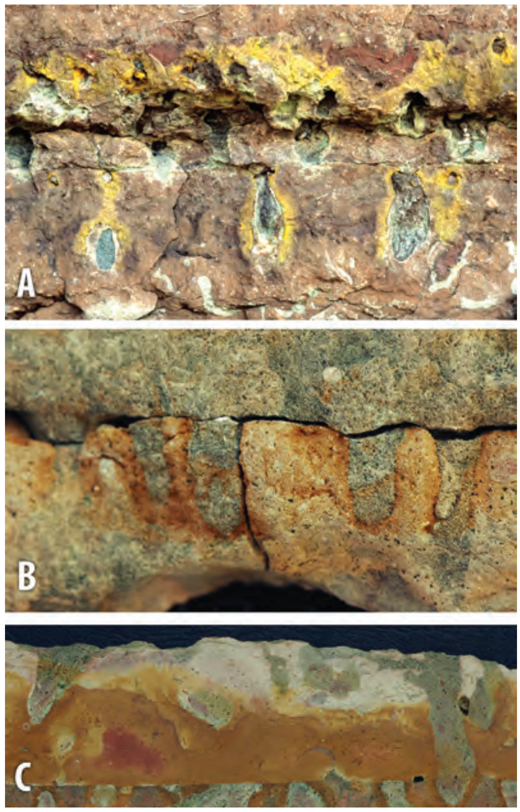

Fig. 11. The lower boundary of the Volkhov Stage is a spectacular surface with Amphorichnus borings traceable over 1000 km along the Baltic Klint on Öland (A), in North Estonia (B) and in St. Petersburg region (C). Note that this was the first discontinuity surface described and associated with a hiatus in the world. See additional comments in the text. Photos by T. Saadre.

“blue clay” (Lontova Formation), which, despite its more than 500 My age, has retained typical properties of clays, plasticity in particular (Mens & Pirrus 1997). Such preservation is unique in the world — comparable deposits elsewhere have been lithified and transformed into shales during diagenesis.

In summary, it should be noted that the Baltic Klint is among the best outcrops of Cambrian-Ordovician rocks, which are well preserved here, tectonically undisturbed and still easily accessible over an unprecedented length along the klint. It provides an outstanding example of Early Paleozoic siliciclastic and carbonate depositional basins, reflecting the changing palaeogeography and climate and spanning across the key events in the evolution of life.

The fossil record

The rocks of the Baltic Klint contain rich and well-preserved fossil record of Early Cambrian to Middle Ordovician biota, spanning also across the “Cambrian Explosion” and the major episode of the “Great Ordovician Biodiversification Event”.

The geological succession of the Baltic Klint is richly fossiliferous. Considering the time-span covered, it becomes clear nevertheless that the fossil remains are not evenly distributed and hence their diversity and abundance varies between individual beds.

Cambrian fossils are represented by **trilobites**, **brachiopods**, **mollusks**, **conodonts**, **acritarchs**, several groups with problematic origin, and **trace fossils**.

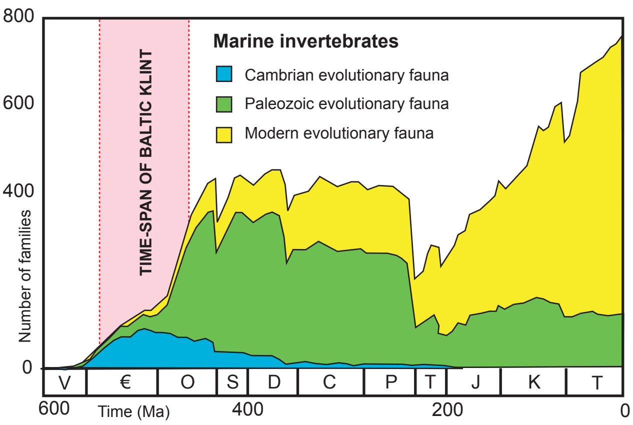

Fig. 12. Diversity changes in marine invertebrates during the Phanerozoic (After Sepkoski 1984). Note that the Ordovician biodiversification is the most profound diversification event and the Baltic Klint encompasses its major part in the Middle Ordovician.

The Ordovician record, which is generally much more diverse, is characterized by fossil assemblages containing typical members of Paleozoic marine fauna: **brachiopods**, **trilobites**, **cephalopods**, **gastropods**, **bryozoans**, **echinoderms**, **sponges**, **graptolites**, **ostracods**, **conodonts**, **chitinozoans**, **scolecodonts**, **acritarchs**, several smaller and as yet imperfectly studied groups, and **trace fossils**.

Two particularly important biotic events fall into the time-span of the klint: the “**Cambrian explosion**” of body plans and major phyla (Zhuravlev & Riding 2001 and references therein) and the “**Great Ordovician Biodiversification Event**” (Webby *et al.* 2004, and references therein). Whilst the Cambrian fossil record of the klint is not particularly representative in this respect, the Ordovician part of the succession has significantly contributed to the understanding of the most rapid increase in marine biodiversity during the entire Phanerozoic.

As regards the **preservation of fossils**, it should be mentioned that the *Fossil Lagerstätten sensu* Whittington & Convay Morris (1985), including the preservation of soft-bodied fauna, are yet to be found in the Baltic Klint sections. However, the very low alteration of the rocks and, in parts, the specific conditions of early diagenesis have resulted in the preservation of features not observable elsewhere for that period. A good example is the preservation of the internal structures of cephalopods — a group which holds the topmost position in the Ordovician ecological pyramid. These structures have preserved due to early phosphatization of originally aragonitic shells, which would otherwise turn into calcite, loosing all fine

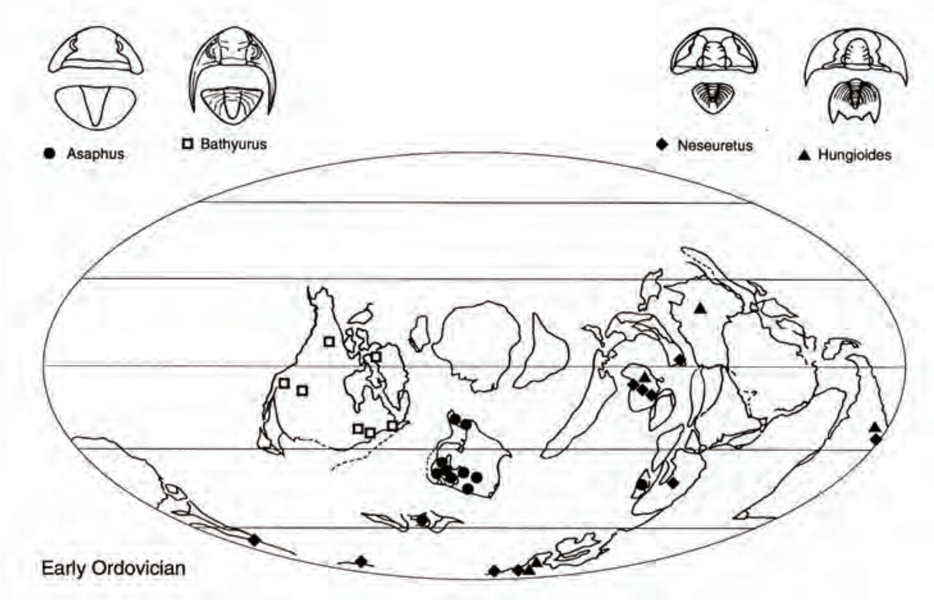

Fig. 13. Biogeography of Early Ordovician trilobites. Note that the Baltic Klint represents the Baltic Faunal Province providing the best exposures for studying trilobites in this region. From Klaesner (1997).

details that are extremely useful for palaeobiological and phylogenic interpretations (Mutvei 1997, 2002). Also the preservation of various microfossils (e.g. chitinozoans, conodonts, polychaete jaw apparatuses) is noteworthy and outstanding worldwide (Hints & Nõlvak 2006).

In addition to collections obtained directly from the Baltic Klint sections, it should be noted that numerous pioneering studies have been based on **erratic boulders** of Early and Middle Ordovician age, whose source area is the Baltic Klint. In particular, this concerns microfossils such as ostracods (e.g. Bock 1867, Krause 1891, Bonnema 1909), chitinozoans (Eisenack 1931), scolecodonts (Kozlowski 1956, Kielan-Jaworowska 1966), but also several other groups.

The fossils collected from the Baltic Klint sites are deposited in various museums around the world: **The Natural History Museum** (London), **Peabody Museum of Natural History at Yale University** (USA), **The National Museum of Natural History** (Smithsonian Institution, USA), **Swedish Museum of Natural History** (Stockholm), **Palaeontological Museum of Russian Academy of Sciences** (Moscow), just to name a few.
In Estonia, rock and fossil material from the Baltic Klint has been deposited in three main institutions: **Institute of Geology at Tallinn University of Technology**, **Geology Museum of the University of Tartu** and **Estonian Museum of Natural History**. The latter two museums have also public displays in Tartu and Tallinn, respectively. Two of the collection holders also make their data and images accessible online.
Special exhibitions and displays with an emphasis on the Baltic Klint and its fossil content are currently being organized.

The species diversity can be illustrated with the aid of generalized data from Rõõmusoks (1970). For instance, in the 4–8 m thick limestones of the Väo Formation, 14 species of bryozoans, 34 species of brachiopods, up to 20 species of gastropods, 17 species of cephalopods, 15 species of trilobites, 6 species of echinoderms, 13 species of ostracods and representatives of various other groups have been found (note that the knowledge on individual groups has considerably increased in recent decades, hence also these numbers have increased).

Some of these groups that notably contribute to the universal value of the Baltic Klint succession are further discussed below (in no particular order).

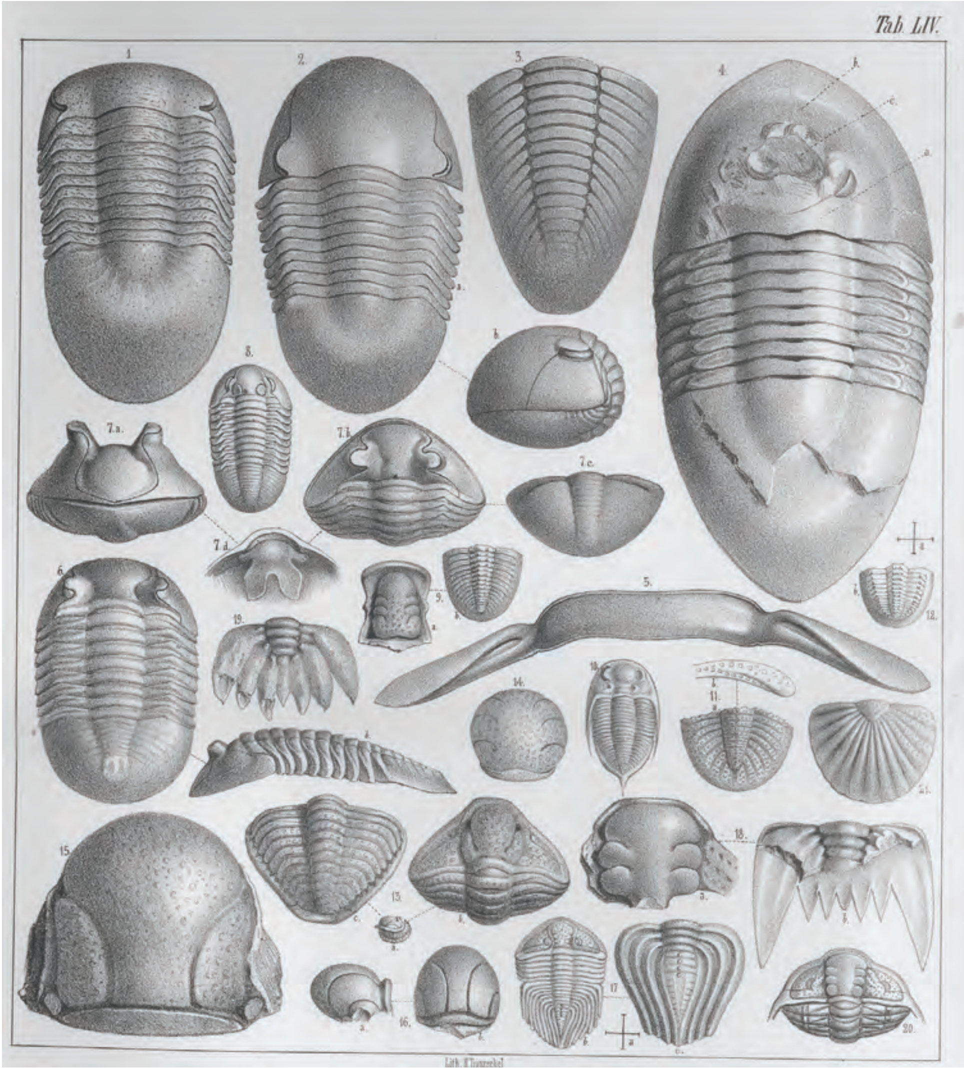

Fig. 14. Historical drawing of Ordovician fossils, many of which derive from the Baltic Klint, by Eichwald (1855).

Trilobites

The record of trilobites in the Baltic Klint sections starts with Early Cambrian redlichiids (Bergström 1973, Kaesler 1997) recovered from the clayey Lükati Formation. Cambrian trilobite record is nevertheless scarce in North Estonia. Ordovician trilobites, in contrast, are varied and often abundant, particularly from the Billingen Regional Stage on, and have been treated in several monographs and research papers (e.g., Nieszkowski 1857, Schmidt 1881, 1894, 1901, 1904, 1906, Lamanski 1905, Öpik 1937, Männil 1957, 1958, Pärnaste 2003, 2004, 2006).

Trilobites have been, and still are, very useful for stratigraphy and the early versions of Baltic stratigraphy were largely based on trilobites (Schmidt 1881, Lamansky 1905; see also Pärnaste 2006 and references therein).

The Ordovician trilobite fauna recovered from the klint represents the endemic Baltic Faunal Province (cf. Jaanusson 1973), which, in particular is characterized by large asaphids (such as *Megistaspis*, *Ptychopyge* and *Neoasaphus*).

The total number of trilobite genera recovered from the klint amounts to nearly 50. The exact number of species cannot yet be adequately calculated since several revisions are currently in progress but, for instance, in ca 0.5 m thick Mäeküla Member (Billingen Stage) nearly 30 different trilobite species has been recovered. The studies on Lower and Middle Ordovician trilobites in klint area are in progress and new discoveries are expected, especially regarding juvenile forms that are invaluable for phylogenetical analysis.

Brachiopods

Brachiopods are common in the Cambrian and constitute the most diverse and abundant element in Ordovician shelly faunas. The earliest Brachiopods recovered from the Baltic Klint sections derive from the Lower Cambrian (*Paterina*, *Mickwitzia*). The entire brachiopod fauna of the klint is represented by at least 30 genera of Linguliformea (~Inarticulata) and more than 50 different genera of Rhynchonelliformea (~Articulata). The research history of brachiopods of the klint goes back to 19th century (Pander 1830, Eichwald 1853, 1860, Kutorga 1848, Walcott 1898). Particularly important are the contributions by Öpik (1934) and Rubel (1961), the data from which have been incorporated into the Treatise of Invertebrate Palaeontology (Rubel & Wright 2000). The most recent publication devoted on brachiopods is a monograph by Rõõmusoks (2005) partly based on material from the Baltic Klint.

Fig. 15. Ordovician brachiopods *Panderina pakriensis*, recovered from the Väike-Pakri Island. Brachiopods constituted the most common shelly faunas in the Ordovician.

Numerous endemic forms in brachiopod faunas have allowed the distinguishing of the Baltic (or Baltoscandian) faunal province (Williams 1973, Jaanusson 1973), which is clearly distinct from the faunas of Laurentia, Gondwana and other major Ordovician terranes. Especially characteristic of the Baltic brachiopod fauna are the clitambonitaceans.

For the Cambrian and Early and Middle Ordovician brachiopods of the Baltica terrane, the klint is the best and in many cases the only source for studies. Considering the role of brachiopods in Palaeozoic faunas and the Ordovician endemism, this obviously implies the universal value of the Baltic Klint.

Mollusks

Mollusks are represented in the klint gastropods, cephalopods and occasionally bivalves and rostroconchs. They were well known to earliest student of klint sections (e.g., Eichwald 1860, Schmidt 1858).

The Early Cambrian *Aldanella kunda* is among the oldest known gastropods in the world (Posti 1978). In the Upper Cambrian and Lower Ordocician siliciclastic rocks mollusks have not been recovered. In the limestones, however, gastropods and large cephalopods are some of the most common macrofossils and first attract the attention of non-palaeontologists.

The Ordovician record of gastropods begins in the Volkhov Stage (Koken 1925), where the diversity is very low. In the overlying Kunda Stage (up to 8 m thick) gastropods are abundant and diverse and more than 40 species of 20 genera have been recovered (Isakar 1997).

Fig. 16. Early Cambrian gastropod *Aldanella kunda*, and Ordovician cephalopod *Trocholites depressus*, both from the Baltic Klint. Note that *Aldanella* is one of the oldest gastropods in the world.

The cephalopod fauna is still inadequately studied in Estonia and only few papers have been published on this group. However, at least 20 different genera are known from the klint sections (Stumbur 1959, 1962). It is also noteworthy that the preservation of the rocks and early phosphatization of aragonitic shells of large cephalopods has enabled studying fine morphological details and use them for phylogenetic interpretations (Mutvei 1997, 2002). Comparable preservation is not known from elsewhere in the world. The Baltic Klint sections therefore provide the best opportunities for future research of Middle Ordovician mollusks in the entire Baltic realm.

Bryozoans

Bryozoans were often major component of Ordovician benthic assemblages. In the Baltic Klint area, the bryozoans were first described by Pander (1930) and Eichwald (1829).
The oldest undoubted bryozoans are of late Tremadocian of China (Hu & Spjeldnaes 1991). However, the oldest diverse bryozoan fauna comes from the Baltic Klint area (Pushkin & Popov 1999).

Conodonts

Conodonts are early vertebrates that first appeared in the Late Cambrian and became extinct in the Permian. They constitute the most useful biostratigraphic tool next to graptolites in Ordovician-Silurian strata. In the Baltic Klint sections, conodonts are common and varied starting from the Upper Cambrian and widely utilized in regional and global time-correlations. The Cambrian-Ordovician boundary in Estonia can be identified based on the finds of *Iapetognathus* and *Cordylodus lindstromi* (Puura & Viira 1999). Correlation of other global Ordovician stages (Second Stage, Third Stage, Darriwillian, Fourth Stage) also is based on conodonts. Moreover, several regional stages and their correlations ground on conodont biostratigraphy.
The history of conodont studies in the klint area dates back to 1850s, when Pander (1956) described the first conodonts. Although they were initially interpreted as fish teeth, this was the earliest record of conodonts in the world (for this reason the society of conodont students was named after C. Pander). Conodont research in the klint area has been active ever since and various aspects of the taxonomy, biostratigraphy, palaeoecology and phylogeny of conodonts have been studied (see Viira *et al.* 2001 and references therein). A recent contribution by Löfgren et al. (2005) provides a good example of joint biostratigraphical and sedimentological study, which may be influential for future research elsewhere.
The abundance of conodonts in some intervals of the klint succession is remarkable (exceeding 4000 elements per kg, which is among the highest recorded densities in the world). Several events in the evolution of conodonts can be traced in the Baltic Klint (e.g., the appearance of platform elements). Moreover, several successive phylogenetical lineages (e.g., successive populations of *Eoplacognathus*; cf. Viira et al. 2001) can be observed. The total number of conodont species in the Baltic Klint is difficult to estimate, however, Viira et al. (2001), report more than 50 species from ca 12-m interval from Varangu to Aseri regional stages.

Ostracods

Ostracods are a long-standing group of Ordovician to Recent crustaceans. The earliest ostracod fossils come from the Tremadocian of Norway. In the Baltic Klint sections, ostracods are relatively rare in Lower Ordovician strata. In the lower Middle Ordovician, which is the major diversification episode for Palaeozoic ostracods, their diversity and abundance increases considerably and they become an important chain in benthic assemblages.
The early Middle Ordovician ostracod faunas of the klint are the most thoroughly studied in the world (Bock 1867, Krause 1889, 1891, Bonnema 1909, Öpik 1935, 1939, Sarv 1959, 1963, Meidla *et al.* 1998, see Tinn & Meidla 2004 for additional references). In recent years, ostracod studies of the klint have been focusing on biostratigraphy, palaeoecology, biofacies and, most importantly in the global sense, on phylogeny. The fact that the Ordovician sequence in klint is condensed but

notably complete (cf. discussion on condonts) makes it easy to recover successive ostracod faunas and trace the evolutiony trends. For the first time, a modern cladistic approach was used in an analysis of the evolution of Palaeozoic ostracods (Tinn & Meidla 2004).

The total number of ostracod species in the Öland Series is approximately 50, but no reliable data can be provided for younger strata. The klint sections have a great potential for continuing ostracod research and making it even more important globally.

Fig. 17. Tremadocian chitinozoans from the Baltic Klint in Tallinn (from Hints & Nõlvak 2006). This assemblage is one of the oldest and most diverse chitinozoan assemblages in the world. Note that chitinozoans play an important role in Ordovician biostratigraphy and the best record of Ordovician chitinozoans comes from the Baltic area.

Chitinozoans

Chitinozoans constitute an enigmatic fossil group found from the Lower Ordovician to the Devonian. In recent decades chitinozoans have become very useful index fossils and both regional and global chitinozoan zonations have been established (Nõlvak & Grahn 1993). Approximately a half of all Ordovician chitinozoan data come from the Baltic area. For the Lower and Middle Ordovician, the Baltic Klint forms an important source of chitinozoan data (Grahn 1980, 1984, Nõlvak & Grahn 1993). The first chitinozoans from the Baltica continent and some of the earliest ones in the world have been recovered from the Tremadocian of the klint sections (Nõlvak 1999). A recent discovery from the latest Tremadocian (Hints & Nõlvak 2006) appears to be the hitherto most diverse and among the most abundant finds of chitinozoans in the world, bearing implications for stratigraphy and palaeobiogeography.

In post-Tremadocian strata, particularly starting from the carbonate sequence, chitinozoans constitute the most common acid-resistant microfossils and provide a good basis for high-resolution biostratigraphy (Webby *et al.* 2004). There is a great potential in the klint sections to expand the scope of chitinozoan research to cover also palaeoecological and palaeobiological studies and further illuminate the diversification history of the group.

Fig. 18. A Middle Ordovician scolecodont (polychaete jaw). The Baltic material is the largest and most thoroughly studied in the world. From the Baltic Klint area also some of the world oldest scolecodonts derive (Hints & Nõlvak 2006).

Annelids

The fossil record of annelids is extremely rare, except for the jaws (scolecodonts) that many polychaete worms possessed. The abundance of these jaws in Ordovician and younger rocks indicates their significant role in fossil communities, which has been commonly overlooked by palaeontologists. The Baltic region is the best studied in the world, and for Early and Middle Ordovician forms the Baltic Klint sections have provided the bulk of the material (Eisenack 1976, Hints 2000, Hints *et al.* 2004). Altogether more than 20 genera and 50 species have been recovered from North Estonian klint area. A recent discovery of scolecodonts and well preserved jaw apparatuses from the Lower Ordovician klint section in Tallinn is so far the oldest record of this group and makes it possible to illuminate the early evolution and diversification of jawed annelids (Hints & Nõlvak 2006, Hints & Eriksson 2006). Further discoveries from the Lower Ordovician can be expected and, considering this, the Baltic Klint sections are especially promising and may further contribute to our understanding of the phylogeny of annelids.

Concluding this short review of the fossils of the Baltic Klint, it should be once again emphasized that the time span of the succession covers the "Great Ordovician Biodiversification Event" (see Webby *et al*. 2004 for details) and that for several fossil groups some of the earliest representatives have been found and/or the most thorough research has been carried out in the Baltic Klint area. Therefore the klint represents an important site for documenting the evolution and diversification of Early Paleozoic shallow-water biota. Due to the high degree of endemism in the Ordovician, the faunas are characteristic particularly of the Baltic faunal province, for which the klint is undoubtedly the best available exposure.

Neugrund meteorite crater

The Baltic Klint features the best preserved old meteorite crater, and the only accessible submarine crater in the world.

Neugrund Klint Island in the middle of the circular ridges of the Neugrund Meteorite Crater is an erosional remnant of the limestones formerly covering the area. The crater is up to 21 km in diameter and came into being about 535 million years ago, in the Early Cambrian (Suuroja & Suuroja 2004). Its ring-shaped ridges crop out at the sea bottom in the south of the Gulf of Finland, in the surroundings of the Neugrund Shallow. The outcropping structures of the crater (central plateau, circular depression, circular rims) lie at a depth of 2–25 m, being accessible to divers.

Fig. 19. Underwater Neugrund Crater constitutes one of the most interesting underwater sites in the area and is attainable even for hobby divers. Image courtesy to S. Suuroja.

Boulders of the **Neugrund-breccia**, an easily recognizable type of rock formed by the impact, are widespread in Northwest Estonia. Since the source area of these boulders – the crater rim – is clearly delineated, the Neugrund breccia is an ideal index rock and provides one of the best-traceable boulder trains in area of North European glaciation (Suuroja & Suuroja 2004). Erratic boulders of different size

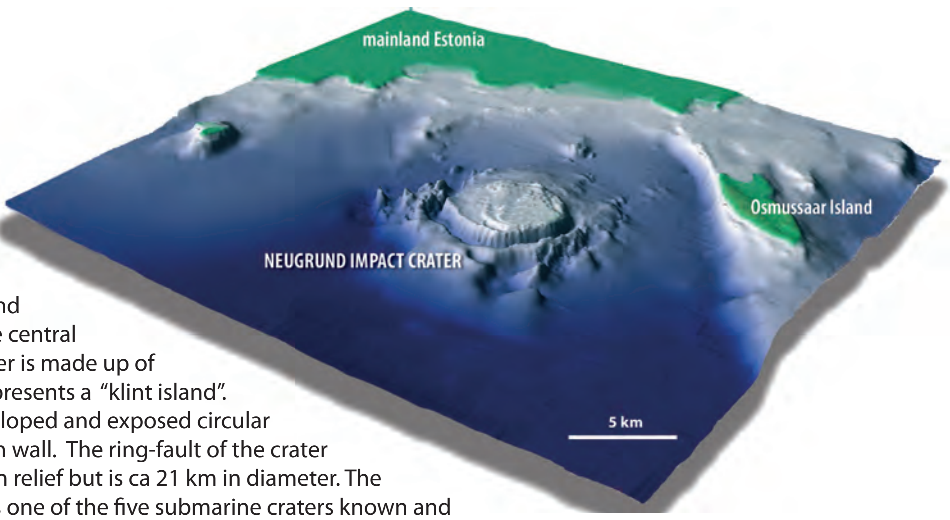

Fig. 20. 3-D relief of Neugrund Meteorite Crater and adjacent areas. The central plateau of the crater is made up of limestones and represents a "klint island". Note the well developed and exposed circular canyon and the rim wall. The ring-fault of the crater is not observable in relief but is ca 21 km in diameter. The Neugrund Crater is one of the five submarine craters known and the best preserved old crater in the world. Illustration by S. Suuroja.

(from cobble to a nearly 100 000 m^3 giant boulder at the sea bottom near Osmussaar) torn loose by the glacier from the structures of Neugrund Crater, are spread in a fan shape over a 10 000 km^2 area. Although meteorite craters are some of the world's most significant natural monuments and the best ones to illuminate the planet's turbulent past and possible future threats, we still do not find them on the UNESCO World Heritage List. The age-old but young-looking Neugrund Crater at the North Estonian Klint is the best preserved old crater (more than 100 Ma) in the world, adding universal and outstanding value to the property.

Study history and educational value

The Geology of the Baltic Klint has a remarkably long study history dating back to early 19th Century. Since then the klint and its rock succession has attracted many Estonian and foreign researchers providing an invaluable scientific and educational source.

Fig. 21. The rock succession on Pakri Cliff by Ozersky (1844) is the first scientific illustration of the Baltic Klint.

A. W. Hupel (1737 – 1819) was probably the first researcher to provide a longer description of the Baltic Klint – a high escarpment on the southern coast of the Gulf of Finland. Hundreds of articles, brochures and books on the geology, geomorphology and evolution of the Baltic Klint (North Estonian Klint) and the associated mineral resources, vegetation, human settlement and cultural history have been published since.

The strata outcropping in the escarpment attracted the attention of not only local but also foreign geologists. Already in the first half of the 19th century, a meritorious English diplomat and geologist **W. T. H. F. Strangways** (1795 – 1865) published a number of works on the geology of Northwest Russia, in particular the surroundings of St. Petersburg. Already in his first work (Strangways 1821) he describes the rocks outcropping on the klint (blue clay, sandstones, Dictyonema argillite), noting that these are distributed at least until Tallinn. Strangways already correlated these strata to the ones distributed in Sweden. This and the subsequent works were supplemented also with geological maps – the first ones in Russia.

Perhaps the most famous geologist who has worked on the Baltic Klint, although briefly and only in the eastern part, was Sir **R. I. Murchison** (1792 – 1871). Together with **E. Verneuil** and **A. Keyserling** (who lived and died in Estonia), he studied the geology of European Russia and the Urals at an expedition in 1840 – 41. The expedition resulted in a comprehensive monograph (Murchison, Verneuil, Keyserling 1845). In this and several other works, Murchison correlates to each other the Palaeozoic rocks outcropping in the Baltic countries (naturally, also on the klint), in Scandinavia and on the British Isles, successfully using fossils for the correlation.

In 1858 a comprehensive study of the Cambro-Silurian area in northern Estonia came out. This was the monograph by **Friedrich Schmidt** (1832 – 1908) known as "the father of Estonian geology". In this work the first rather detailed stratigraphic division of the Ordovician and a bedrock map were presented. In the region of the klint blue clay, ungulites-sandstone, clayey shale, green sand, chorite- and vaginatum-limestone were established. His stratigraphic chart and indices were used by the following generations of geologists for a long time.

Among the geologists who worked in Estonia in the first half of the 20th century and studied also the klint, **R. S. Bassler** (1878 – 1961), **P. E. Raymond** (1879 – 1952), **W. T. Twenhofel** (1875 – 1957), **W. Lamansky** and **C. Teichert** (1905 – 1996) should certainly be mentioned.

In the beginning of the 20^{th} centuary **W. Lamansky** (1905) presented a detailed bio- and lithostratiphic chracterization of the Lower Ordovician (B stages) in Ingermanland and used his stratigraphic classification also in northern Estonia. An important result of his work was the recognition of numerous discontinuity surfaces (breaks in sedimentation) in the North Estonian sequence. He correlated Estonian sequence with those in Norway and Sweden.

On the basis of the gathered materials and collections, an American palaeontologist **Bassler** composed a comprehensive monograph on Bryozoans (Bassler 1911). In this work he finds that a big part of the Ordovician of the Baltic Sea countries can be correlated to the Black River strata of North America. He also presents a correlation table for the Early Palaeozoic of these countries (from blue clay to Porkuni limestones).

Americans **P. E. Raymond** and **W. T. Twenhofel** worked in Estonia in 1914. The latter studied mainly Silurian rocks. In the work that summarizes the results of this expedition (Raymond, Twenhofel 1916), Raymond proposes that the Lower Cambrian be named „Estonium". He describes also the Ordovician rocks outcropping on the klint in Narva, Aseri, Ontika and Tallinn.

In the late 1920ies, a German geologist **C. Teichert**, who was just beginning his scientific career at the time, worked in Estonia. Later he became a world-renowned palaeontologist and edited an international manual "Treatise on Invertebrate Palaeontology". In addition to Silurian stratigraphy and palaeontology, he also took interest in the Baltic Klint (Teichert 1927). His study on the fracturing of Ordovician (incl. on the klint) and Silurian rocks still has not lost its value.

Armin Öpik (1898 – 1983) did much in studying the Cambrian sequence in Estonia. He contributed important biostratigraphic data on the Lower Cambrian and revised its terminology (Öpik 1925, 1926, 1929, 1933). He was of the opinion that the terrigenous beds dated as the basal of the Ordovician could be of the Late Cambrian age.

Karl Orviku (1903 – 1981) published an excellent monograph on the lithostratigraphy of Aseri, Lasnamägi and Ukaku stages (Orviku 1940), which are exposed in the upper part of the klint. He described the morphology of discontiniuty surfaces in detail and gave their typology. He laid great emphasis on their importance as markers of stratigraphic breaks. In some postwar papers (Orviku 1960, 1962) he dealt with the lithostratigraphy of Volkhov and Kunda stages in the region of the klint.

After World War II numerous borings made it possible to extend geological investigations south of the Cambro-Ordovician outcrop area. Thus, the geology of the klint sank to some extent into oblivion.

It should be mentioned that the Baltic Klint as a geomorphologic feature has deserved much less attention than as a geologic-stratigraphic object. In the first half of the 20th century, the morphology of the klint was described only in two comprehensive papers – Giere (1932) and Tammekann (1940). **W. Giere** focussed on the contemporary development of the coast. To the klint itself he paid less attention, although he dealt with it among the other shore types he had distinguished. He stressed the importance of land uplift in the development of the klint. **A. Tammekann** reviewed the Baltic Klint in a wider regional context. According to him, it was a coastal terrace with series of characteristic Glint landscapes in the transition from the crystalline landmass of Fennoscandia to the Russian plain. It seems that his work was planned as the first part of a more generalizing monograph, unfortunately, never completed. In this work (Tammekann 1940) he proposed a morphologic and regional classification of the klint. In accordance with his classification he described morphologically the klint from the Island of Osmussaar to the River Syas in Russia.

Many geologists have been familiarized with the geology of the Baltic Klint at excursions organised in the frames of international meetings. Already in 1897 the excursion of the **7th International Geological Congress** held in St. Petersburg visited the Pakri and Leetse cliffs under the guidance of a worldwide known geologist Fr. Schmidt. At the time of the **27th International Geological Congress** held in Moscow in 1984, again a group of participants visited some klint sections in Tallinn and in its vicinity.

Fig. 22. Participants of the 7. International Geological Congress in 1897, after visiting several Baltic Klint sites. Another excursion of the International Geological Congress visited the Baltic Klint in 1984.

Another big scientific excursion to the Baltic Klint localities was organized in 1958, in the frames of a meeting devoted to the memory of Fr. Schmidt. This was long the last visit to the klint. From 1958 to the end of the Soviet occupation, organization of excursions to the klint area was impossible because the klint fell within a border zone, where entrance and working was restricted or often prohibited at all. It was only in 1990, when the Field Meeting of the Ordovician and Silurian Subcommissions was held in Estonia, that the participants were allowed to study the klint again, but still only in Tallinn and some places nearby. After the restoration of Estonia's independence in 1991, many scientific excursions have been arranged to the Baltic Klint. In 1997, the Annual Meeting of the European **Association for the Conservation of Geological Heritage** (ProGeo) was held in Estonia and the klint was demonstrated to the guests in connection with this event.
In past few years several field trips of international conferences have visited the Baltic Klint sections: **8th Meeting of the Working Group on the Ordovician Geology of Baltoscandia** (2004), **IGCP503 Ordovician Palaeogeography and Palaeoclimate Meeting** (2004), **The Fifth International Brachiopod Congress** (2005), **The Sixth Baltic Stratigraphical Conference** (2005).

Being easily accessible and containing various rock types that represent different environments, the Baltic Klint in North Estonia has been serving as a teaching and training resource for students of geology and other natural history disciplines. In recent decades also foreign students, particularly from Latvia, Russia, Sweden, Germany, and UK, have been visiting the sites.

Modern biotopes

Baltic Klint is a region of an extraordinarily high habitat variety and a high diversity of plants and lichens. The Baltic Klint as a macrohabitat provides numerous meso- and microhabitats used by a multitude of different bryophyte and lichen taxa.

Mesohabitats such as broad-leaved and coniferous forests, grasslands of several types, various outcrops, spring rivulets, spring fens and coastal shingle ridges can be found on top of the Klint, on the escarpment and on the talus.
Every mesohabitat includes many microhabitats important for species with preferences for different ecological niches. The most specific microhabitats are found on the Klint escarpment – a number of calcareous, sandstone and clay layers with different shade and moisture conditions. Microhabitats in the forests include trunks of different tree species of different age and bark characteristics, logs, snags and stumps of different size and stage of decay, erratic boulders and rocks fallen from the escarpment. Soils of different thickness, moisture and pH occur in the forests (Rooma & Paal 2001) and on the meadows at different parts of the Klint.

It is characteristic that a great number of different meso- and microhabitat types can be found in close vicinity to each other along the Klint due to the specific structure of the Klint itself. It is also remarkable that the majority of the habitats are relatively unaffected by human activity since the Klint escarpment and the talus have been rather poorly accessible due to natural reasons (steep slope) and political reasons (having been closed to the public as parts of the border zone of the Soviet Union).

More than **180** different **bryophyte species** have been found in the Klint area (Kannukene 1998, Ingerpuu & Leis 1999, Vellak & Ingerpuu 1999), several of them being rare or threatened in the surrounding countries. At least two of them are noteworthy on the global scale. One of them – *Seligeria patula* (Lindb.) Broth. – is endemic to Europe. It grows on moist limestone outcrop on Väike-Pakri Island (Vellak *et al.* 2001). The other species is *Tortella rigens* Alb., which grows on alvar meadows on the islands of Väike-Pakri and Suur-Pakri (Kannukene *et al.* 1997). Aside from Estonia and Sweden, *Tortella rigens* has been found only at a few localities in the Czech Republic and the USA (the region of the Great Lakes). Of rare species on Osmussaar and the Pakri Islands, *Brachythecium turgidum, Didymodon tophaceus* and *Mannia sibirica* can be mentioned.

Also the diversity of **lichen species** is noteworthy. The number of known epiphytic species amounts to **81** (Jüriado 2004). The total number of lichen species must be even greater because epilithic and epigeic species have not been studied yet.

The **vascular plant** diversity is highest on alvars on top of the Klint on the islands and in the broad-leaved forests at the slope and foot of the Klint on the mainland.

Klint forest (*Estonia clivosa*) at the foot of the North Estonian Klint (Lippmaa 1935, Paal 1997, Paal *et al.* 2005) is a unique forest characteristic only of the North Estonian Klint, a real northern jungle with a unique under-storey and ground vegetation. The character of klint forest is determined by a growth substrate rich in several micro- and macro-elements, a specific water regime (springs emanating from the escarpment on the one hand and watertight blue clay on the other hand) and a specific microclimate (a narrow strip of land between a high escarpment and the sea).
These broad-leaved forests are good representatives of the *Galeobdolon-Asperula-Asarum* community (Kalda 1978, Lippmaa 1938). In total, more than **150** different vascular plant species have been recorded in the broad-leaved forests of the Baltic Klint (Ingerpuu *et al.* 2003). Such species-rich forests of elm *(Ulmus glabra)*, ash *(Fraxinus excelsior)*, lime (*Tilia cordata*), maple (*Acer platanoides*), grey alder (*Alnus incana*) and black alder (*Alnus glutinosa*) grow along a very narrow (some 100 metres

wide) and clearly distinct belt at the klint talus of North Estonia. Tree trunks in these forests are often covered with thick mat of bryophytes, among them *Neckera pennata*, a moss belonging to the Red Data Book of European Bryophytes (ECCB 1995). Also the ground vegetation in these forests is rich in species, as different parts of scree provide diverse growth conditions: in the upper part of the scree the soil may dry out fully in places in summer, while the lower parts are often influenced by spring water seeping out of the limestone wall and its foot (Paal 2004). Several species that are threatened or rare in the surrounding countries, such as *Cystopteris sudetica* (Kuusk 1970), have also been found here.

The total number of vascular plant species found on the Pakri Islands and Osmussaar Island exceeds **600** (Ploompuu & Kukk 1998, Kukk & Kuusk 1999). Many of the species are rare or protected. Noteworthy among them are *Polygonum oxyspermum* and *Oxytropis pilosa* from Osmussaar Island, and *Scabiosa columbaria* from Small-Pakri Island.

The **invertebrate** fauna of klint habitats is dominated by calciphilous species. Molluscs have a high species diversity here, the butterfly fauna is dominated by *Lycaenidae* (Blues and Hairstreaks). The beetle fauna here is characteristic for broad-leaved forests, uncommon for other parts of Estonia.

Vertebrates. The characteristic reptile here is the Common Viper (*Vipera berus*). The caves are good hibernation sites for bats, while the klint forests with their hollow broad-leaved trees provide summer roosts for them. The great number of different meso- and microhabitats provides good hunting and breeding grounds for small predators like weasel (*Mustela erminea*) and hermelin (*Mustela nivalis*). The near surroundings of the klint provide important staging areas for migrating waterbirds like Divers, Swans, Geese, Ducks and Waders.

NATURA 2000 habitats (Council Directives 92/43/EEC and 79/409/EEC)

1. Pakri Landscape Reserve has been included in the European protected area network Natura 2000 to protect the following habitats of EU importance: coastal lagoons, annual vegetation of drift lines, perennial vegetation of stony banks, vegetated sea cliffs of the Baltic coasts, semi-natural dry grasslands, Nordic alvar and precambrian calcareous flatrocks, wooded meadows, *Juniperus communis* formations on calcareous grasslands, mineral-rich springs, alkaline fens, hemiboreal old broad-leaved deciduous forests and *Tilio-acerion* forests of slopes, screes and ravines.
In addition, the alvar on Pakri Peninsula supports a viable population of an Annex II species of the EU Habitats Directive, the Sand Pink (*Dianthus arenarius*). Our main populations of the protected Perennial Honesty (*Lunaria rediviva*) grow in klint forests.
Also the bird fauna of the area is significant. The klint escarpment of Cape Pakri hosts a colony of Black Guillemots (*Cepphus grylle*), being one of the world's southernmost nesting grounds of the species and one of the southernmost seabird colonies in the world. Black Guillemots inhabit mostly the coastal cliffs of the Atlantic, Pacific and Arctic Ocean. In the 1930ies the number of nesting pairs on Cape Pakri amounted to 100 and in 2001 – to 15–25 pairs. The Black Guillemot is an endangered species listed as a protected species of category II. The special management zone of Pakerort has been established in Pakri Landscape Reserve for the protection of the guillemot colony. Human presence in this zone is prohibited from 01 May to 31 August.
The following numbers of species endangered in the EU have been counted in the Important Bird Area of European Union importance in Pakri (21039 ha, 59°21'N; 24°13'E): Bewick's Swan (*Cygnus columbianus*, 300 specimens), Whooper Swan (*Cygnus cygnus,* 700), Greater Scaup (*Aythya marila*, 7000), Long-tailed Duck (*Clangula hyemalis,* 60 000), Goldeneye (*Bucephala clangula*, 10 000).

2. Osmussaare Landscape Reserve was established for the protection of the following Natura 2000 habitats: coastal lagoons, annual vegetation of drift lines, perennial vegetation of stony banks, vegetated sea cliffs of the Baltic coasts, semi-natural dry grasslands on calcareous substrates, Nordic alvar and precambrian calcareous flatrocks, boreal coastal meadows, lowland species-rich dry to mesic grasslands, alkaline fens, lowland hay meadows and hemiboreal old broad-leaved deciduous forests.

The Island of Osmussaar is situated on the East Atlantic Flyway of migratory birds. The most abundant passage migrants are Divers (*Gavia*), Barnacle Geese (*Branta leucopsis)*, Long-tailed Ducks (*Clangula hyemalis)* and Velvet Ducks (*Melanitta fusca)*, totalling as much as a million in the second half of May. More than 200 000 Long-tailed Ducks (*Clangula hyemalis)*, 20 000 Common Scoters (*Melanitta nigra*) and 10 000 Greater Scaups (*Aythya marila)* and Goldeneyes (*Bucephala clangula)* pass the area during their migration. Osmussaar together with the surrounding sea area has been listed as an Important Bird Area of EU importance.

3. Ülgase Nature Reserve is a Natura 2000 site established for the protection of the following habitats of EU importance: lowland hay meadows and *Tilio-acerion* forests of slopes, screes and ravines.
The adits in Ülgase Cliff (1920–1938) provide a second largest wintering place in Estonia for protected bat species: Brown Long-eared Bat (*Plecotus auritus*), Daubenton's Bat (*Myotis daubentonii*), Pond Bat *(Myotis dasycneme*), Whiskered Bat (*Myotis mystacinus*), Northern Bat *(Eptesicus nilssonii)* and Natterer's Bat (*Myotis nattereri*). All these species are protected by the Estonian legislation and also in the EU.

4. Türisalu Landscape Reserve encompasses the following habitats of EU importance: vegetated sea cliffs of the Baltic coasts, boreal Baltic sandy beaches with perennial vegetation, Nordic alvar and precambrian calcareous flatrocks and *Tilio-acerion* forests of slopes, screes and ravines. The Reserve hosts two protected plant species: Shrubby Cinquefoil (*Potentilla fruticosa*) and White Stonecrop (*Sedum album*). The sea adjacent to Türisalu Landscape Reserve is an Important Bird Area of EU importance.

5. Tsitre-Muuksi Escarpment is located in the territory of Lahemaa National Park. The following communities of EU importance are associated with this stretch of the Klint: *Juniperus communis* formations on calcareous grasslands, Nordic alvar and precambrian calcareous flatrocks and *Tilio-acerion* forests of slopes, screes and ravines.

6. Saka-Ontika-Toila Landscape Reserve hosts the following valuable communities: calcareous rocky slopes with chasmophytic vegetation, *Tilio-acerion* forests of slopes, screes and ravines, Fennoscandian deciduous swamp woods and embryonic shifting dunes.

7. Päite Landscape Reserve was established for the protection of the following Natura 2000 habitats: semi-natural dry grasslands on calcareous substrates and *Tilio-acerion* forests of slopes, screes and ravines.

8. Udria Landscape Reserve aims to protect the following habitats important both from the point of view of Estonian biodiversity protection and as habitats of EU importance: annual vegetation of drift lines, vegetated sea cliffs of the Baltic coasts, boreal Baltic sandy beaches with perennial vegetation, semi-natural dry grasslands on calcareous substrates, lowland species-rich dry to mesic grasslands, calcareous rocky slopes with chasmophytic vegetation, hemiboreal old broad-leaved deciduous forests and *Tilio-acerion* forests of slopes, screes and ravines.

Cultural values

The North Estonian Klint has acted as a natural bridge between the East and the West in Northern Europe for at least 9000 years. The type areas of the Mesolithic cultures of Kunda and Narva (Lammasmägi Erratic Block at Kunda and Narva Klint Valley) are connected with the structures of the North Estonian Klint.

Fig. 23. Centre of the Old Town of Tallinn, the Toompea Hill, is a klint island. The Building Limestone (Väo Formation, Darriwilian) from the klint and adjacent areas has been extensively used in buildings of the Old Town, which was inscribed in the World Hertitage List in 1997. Photo by J. Nõlvak.

Shallow-soiled klint plateaus were the first agricultural areas in Northern Europe. Ancient fields on the Kallavere Klint Peninsula at Rebala date back to more than 4000 years ago.

The eastward spread of the fertility magic related Pitted Ware Culture of the Bronze Age, which first developed in Denmark and Sweden and reaches as far as the eastern edge of the North Estonian Klint, follows rather precisely the escarpments of the Baltic Klint.

The Viking time (8th–11th century AC) was the time of prosperity of the Baltic Klint. The Vikings, who commenced their Eastern Path from the lands of present-day Sweden, from the areas of the Baltic Klint escarpments there and their vicinity, navigated as much as possible by the escarpments of the Baltic Klint at the beginning of the journey (up to the Volkhov River on the Ingermanland Klint) and established also their stronghold posts on the klint. The sources of both the Swedish (Brogholm) and Russian (Laadoga) superpowers can be sought from the escarpments of the Baltic Klint and also their battles over supremacy were held on the very same escarpments during more than half a millennium. It was in this very place, on the eastern border of the North Estonian Klint, on the banks of the Narva Klint Valley, that Peter the First started the famous action to "cut a window into Europe".

The Swedish name for Osmussaar, *Odensholm*, has been translated as 'Odin's Grave'. In Scandinavian mythology the island was believed to be the grave of Odin, the Scandinavian and Germanic chief god and war god (Peil 1999). A Neugrund-breccia erratic boulder (which was blasted in 1941) was believed to mark Odin's burial site. Traces of a Viking-time settlement have been found from the central part of the island, on the bank of a lakelet (former inland bay) near the ruins of a chapel built in 1765. This, too, can be seen as proof of the fact that Osmussaar is worth the name of Odin's Grave.

Ordovician carbonate rocks as a building material has been used during centuries in northern Estonia. Actually, in all the buildings, made of stones, limestones, dolomitized limestones and dolomites, mainly of the Väo Formation of the Lasnamägi and Uhaku stages, can been seen. These thick-bedded, often multi-coloured, hard bioclastic carbonate rocks abounding in discontinuity surfaces are known as Building Limestone. Their thickness is 4 – 10 metres. Naturally, carbonate rocks of the other stages of the Lower and Middle Ordovician were also used, but to a lesser extent.

Until the 13th century, flagstone was used in burial constructions ("tarandkalme"), fences, wells, strongholds, etc. without any binder (Einasto, Matve 1989). After the lime mortar was taken into use the utilization of carbonate rocks increased remarkably and they became the main construction material of castles, monasteries, churches, strongholds, towns, farmhouses, etc. Many small and large quarries were laid out in the vicinity of the klint. In all likelihood, the first small quarries in

the region were founded on Toompea Hill in Tallinn. In 1954 a quarry was discovered under the building of the Dome Church.The amount of broken flagstone, calculated by Zobel (1991), might have reached 6000 – 7000 cu m. Although the date of the church`s construction is not clear, the stone pit was founded presumably by ancient Estonians and in 1227–1229 used for building of the castle by the Order (Zobel 1991). The Old Tallinn was entirely built from Building Limestone. From the second half of the 13th century up to the second half of the 20th century the main quarry was situated at Lasnamägi, at the edge of the klint. Its greatest deapth was 14 metres. The most valuable historical and architectural monuments, including the Toompea Castle (built in the 13th - 14th centuries), St. Nicholas' Church (the first record from 1316), St. Olaf's Church (dating back to1267), the Town Hall (construction completed in 1404), and the fortified town wall with numerous defence towers (construction started in the 13th century and lasted two centuries) were made of local limestones.
However, carbonate rocks of the klint were used not only in Tallinn, but all over northern Estonia. In the 13th–15th centuries, limestone served as the building material for the construction of many churches (Viru-Nigula, Kose, Keila, Jõelähtme, Madise, Risti a.o.), manor houses with adjacent buildings (storehouses, distilleries, forges a.o.), castles and fortresses (e.g. Toolse in 1471–1473, Narva in the 13th century, Ivangorod in 1492), post stations, lighthouses, and farmhouses. In the Paldiski Town the walls of the Peter' fortress were carved into the bedrock in 1718–1725. It is interesting that the St. George`s Church in Paldiski is built from glauconitic limestone of the Volkhov Stage, which in general , is rarely used for the purposes of construction. And, finally, there are numerous tombstones, crosses of various types and gravestonesin the churchyards. Carbonate rocks are used for constructional purposes up to date. In 2001 the new building of the St. Bridget's Convent was completed. It was made of the Building Limestone and built next to the ruins of the old monastery (1407–1436).

Many scenic sites of the Baltic Klint in Estonia are beloved by Estonians as well as foreign tourists. The limestone cliffs and their fossil content are especially fascinating for Finnish tourists, which is a good example of how the aforementioned structural boundary between the shield and platform area is also reflected in the culture and people's understanding of the environments both recent and past.

Comparative analysis

As of July 2005, 628 cultural and 160 nature monuments and 24 of those belonging to both types in the total of 137 States Parties had been inscribed on the World Heritage List. Of nature monuments, about 50 are to a greater or lesser extent outstanding in their geological features. Among them there are very large areas, such as the Canadian Rocky Mountain Parks (Nii, iii, iv, 1983) – 44 807 km2, and very small ones, e.g. Macquaire Island (Ni, iii, 1997) – only 190 km2. Nature monuments vary greatly also in their geological structure, processes and development. Several of the monuments constitute a significant example of the action of flowing water (Iguazi National Park, Niii, iv, 1984; Mosi-on-Tunya / Victoria Falls, Nii, iii, 1989; Grand Canyon National Park, Ni, ii, iii, iv, 1979). Some are localities of very well preserved fossils (Dinosaur Provincial Park, Ni, iii, 1979; Messel Pit Fossil Site, Ni, 1995; Miguashi Park, Ni, 1999). Of karst related nature monuments, Plitvice Lakes National Park (Nii, iii, 1979, 2000), Caves of the Aggtelek Karst and Slovak Karst (Ni, 1995, 2000) and Carlsbad Caverns National Park (Ni, iii, 1995) can be mentioned. Monuments closest connected with sea erosion are Dorset and East Devon Coast (Ni, 2000) and the Giant's Causeway and Causeway Coast (Ni, iii, 1986), to some extent also the High Coast (Ni, 2000). As the latter three are best comparable to the Baltic Klint in their certain geological features, they are described below in more detail.

Geomorphology

The **Giant's Causeway and Causeway Coast** lies along the seacoast in Northern Ireland, at the foot of the basalt cliffs bordering the edge of the Antrim Plateau. Solidified lava forms picturesque columns here, mainly hexagonal but also quadrangular, pentagonal and even octagonal in shape. The number of the massive black columns amounts to 40 000. The columnar basalt cliffs are the result of pronounced vertical jointing. The tallest columns are over 10 m in height but the lava layer in the cliffs is even up to 28 m thick in places. The basalt lava resulted from a volcanic eruption in the Palaeogene and Neogene some 50–60 million years ago. As the sea erodes the basalts, tall eroded escarpments have formed in the basalt layer. Yet these are the only geological features that the Baltic Klint and the Giant's Causeway and Causeway Coast have in common. The two still cannot be treated as analogues because the Baltic Klint consists of Palaeozoic sedimentary rocks and is completely different in its origin and evolution.

Dorset and East Devon Coast is somewhat more similar to the Baltic Klint in this regard. The up to 155-km-long cliffed coast is situated in SW England. The cliff exposures provide an almost continuous sequence of marine and continental Mesozoic rocks from the Triassic up to Cretaceous. Also Palaeozoic, e.g. Permian rocks crop out in places. Thus, it is possible to study the history of ancient sea basins, continents and life over the span of 185–200 million years. The exposed rocks are characterised by great variety – from terrigeneous (clay, siltstones, sandstones) to carbonate (mainly limestones). The rocks are rich in well-preserved fossils, such as ammonites, belemnites, ichthyosaurs, plesiosaurs, pterosaurs, gastropods a.o.

The multi-coloured cliffed coast is a classic example of strong sea erosion. Depending on the composition and deformation of the rocks, morphological features of the coast vary greatly between different locations. One can see high vertical towering cliffs, interesting sea stacks, sections with landslides, structural terraces, classic examples of large excavated coves and embayments.

Dorset and East Devon Coast is a very imposing and important geological-geomorphological feature in the world. Comparing the Baltic Klint with Dorset and East Devon Coast, some important differences should be mentioned. First, the Baltic Klint provides a continuous sequence of Lower Palaeozoic rocks not represented in Dorset and East Devon Coast, and second, the Baltic Klint is a denudational escarpment whose development progressed in the Palaeo-, Meso- and Cenozoic and mainly in continental conditions. It should be mentioned that from the point of the contemporary sea erosion, the Dorset and East Devon Coast is more impressive, and the variety of erosional forms is greater. This is a very good example of the cliffy coast developed in the conditions of the rising sea level. However, the development of the Baltic Klint is connected with a lowering sea level with its different parts beingof different age. In places, there is a rather wide and high talus between the escarpment and the sea. In length, the Baltic Klint exceeds the Dorset and East Devon Coast.

The **High Coast** on the west shore of the Gulf of Bothnia in Sweden is the geographically closest natural monument inscribed on the World Heritage List. The area covers 142,500 ha, including a marine area with offshore islands. The High Coast and the adjacent islands consist of Proterozoic volcanic, plutonic and metamorphic rocks. The Phanerozoic sedimentary cover is missing or has eroded away. The irregular topography is the result of long-term geological history, largely still being shaped by Pleistocene glaciers and land uplift. Since the final retreat of the ice 9600 years ago, the glacioisostatic uplift has been in the order of 285 m. The extent of the uplift has been established by the aid of metachronous highest shoreline. Today the highest shoreline of the Litorina Sea (age 7000 years) in this region lies at the altitudes of over 100 m a.s.l. However, some calculations evidence that the total glacioisostatic uplift amounts to 850 m. The rate of recent uplift is 9 mm per year, which is the highest in the area of the last glaciation. The High Coast is a relatively earthquake active area. The area is characterized by a great variety of glacial and fluvioglacial landforms, numerous shorelines of ice lakes and the Baltic Sea. There is no doubt that the site is very important for understanding glacial processes, deglaciation history and glacioisostatic uplifting, being in this sense possibly the best studied area in the world.

What are the differences between the High Coast and the Baltic Klint? The High Coast is an areal site, while the klint is a linear one. However, the main difference lies in their geological composition. The High Coast is formed of Precambrian igneous and metamorphic rocks, while the klint consists of Upper Cambrian, Lower and Middle Ordovician sedimentary rocks. It should be noted that the different rate of uplift played also an important role in the development of both areas. Due to faster uplift the influence of sea processes was shorter in the High Coast than in the region of the Baltic Klint. In North Estonia the eustatic rise of sea level exceeded the glacioisostatic uplift several times. Thus, the klint was subjected to marine erosion. In some places it lasted thousands of years and the klint retreated a hundred meters towards the mainland. In summary, the two sites do not duplicate each other.

The **Bandiagara Escarpment** (Mali) is one of the most imposing sites in West Africa. It is over 150 km in length and its height varies from 100 m in the south to 500 m and more in the north. The horizontally bedded terrigenous rocks (mainly sandstones) belong to the Cambrian and Ordovician Periods. The escarpment is dissected by numerous ravines, gorges, promontories.
The Bandiagara Escarpment is a very important archaeological, ethnological and geological site. It was inscribed on the UNESCO World Heritage List in 1989. The Baltic Klint has a more complex history and is characterized by a much greater variety of rocks. The Bandiagara Escarpment is an inland feature and unlike the Baltic Klint there are no traces of sea erosion.

Considering the general appearance and geological history, the **Niagara Escarpment** is the closest analogue to the Baltic Klint. However, the rocks exposed there are much younger (ca 420–445 Ma) than those cropping out on the Baltic Klint (ca 460–540 Ma). Thus, unfolding the history of Early Palaeozoic Earth and life, these two extensive outcrops do not duplicate but compliment each other.

There are other imposing and well-known escarpments or klints in the world still not inscribed on the World Heritage List. Among those some escarpments (Black River, Niagara, Helderberg a.o.) are located in North America. These inland-located escarpments are partially buried under younger sediments. In terms of the age of rocks, the Black River Escarpment in the Southern Ontario Lowland, at the border between the Canadian Shield and platform, is the closest to the Baltic Klint. However, as the latter exposes rocks from the Cambrian up to the Middle Ordovician, which are absent in the Black River Escarpment, these escarpments cannot be considered analogous landforms.

The **Helderberg Escarpment** marks the margin of the Helderberg Plateau in Albany and New York counties. The lower part of the escarpment and the lowland in front of it consist of Upper and Middle Ordovician shales and other soft beds, while Silurian carbonate rocks crop out in the upper part. In places Silurian rocks are capped by Devonian limestone. The escarpment was formed as a result of peneplanation in Tertiary. It is a good example of an inland escarpment but it cannot be handled as an analogue to the Baltic Klint because the specific features of their development – the age and time-span of the rocks, – are different. Besides, unlike the Helderberg Escarpment, the Baltic Klint has been eroded by sea during thousands of years. The Helderberg Escarpment is "dead" to date, while development of the Baltic Klint continues.

The **Danish Klint**, over 100 m in height, exposes Meso- and Cenozoic rocks that formed more than 35 million years ago. The escarpment itself developed in the Pleistocene and is overlain by glacial deposits. The best known parts of the klint are the Lonstrup and Moens Cliffs, which have been designated as protected areas. The klint is unique because of the numerous glaciotectonic phenomena long studied there. The cliffs provide many examples of thrust sheets similar to classic ones. Alpine nappes, laterally extensive imbricate thrust faults and deformations of other kind can be seen. Nevertheless, the differences in their geological composition, origin and history evidence that the Baltic and Danish klints are not analogical landforms. From the geomorphological point of view, the Danish Klint is a noteworthy feature – an intensely eroded and high cliff, but it is shorter than the Baltic Klint. Their development also ran under different conditions: the Danish coast has been mainly sinking during last thousands of years, while the Estonian coast, in contrary, has been rising during the past 10000-11000 years.

Some sites (Canadian Rocky Mountain Parks, Grand Canyon National Park, Gros Morne National Park) differ so much from the Baltic Klint in their area, geology and origin that they cannot be compared with the latter. These sites are comparable only in the age and time-span of rocks (see below).

The present comparative analysis shows that the Baltic Klint is one of the longest escarpments in the world and the only huge one where Cambrian and Ordovician rocks with well-preserved fossils can be traced and studied in wide geographical and geological extent, making it possible to follow the the geological history of the Earth during ca 80 million years.

Stratigraphy and palaeontology

The WHL currently includes twelve sites inscribed primarily for their fossil content, and over 20 sites where fossils are, or could be, a supporting value. The most recent additions to the list of fossil sites are Wadi Al-Hitan, Egypt (2005), Monte San Giorgio, Switzerland (2003), Dorset and East Devon Coast, UK (2001), and Ischigualasto / Talampaya Natural Parks, Argentina (2000). Concerning the Cambrian-Ordovician time interval, however, only three properties of the WHL (two from Canada and one from the USA) can be compared with the Baltic Klint. These are the Canadian Rocky Mountain Parks, which include the famous Middle Cambrian Burgess Shale, the Gros Morne National Park, which is inscribed as a prominent geological site but contains also fossiliferous Cambrian-Ordovician sedimentary rocks, and the Grand Canyon, where the Cambrian succession can be observed.

The fossils of the **Burgess Shale** (British Columbia, Canada) have been known for nearly a century and since the discovery this site has become probably the best known fossil site in the world, at least for the Paleozoic Era. The Burgess Shale fauna is extraordinarily diverse, containing more than 140 species, most of them being soft-bodied or thin-shelled and having preserved only due to very specific conditions during their burial and diagenesis. Many of the fossils found in the Burgess Shale cannot as yet be confidently assigned to any known phylum (see overview in Conway-Morris 1979).
Compared to the Burgess Shale, the Cambrian part of the Baltic Klint contains less diverse and abundant fossil assemblages, which is partly due to different climates (high *versus* equatorial latitudes) and different depositional environments (flat and shallow siliciclastic basin *versus* deep water slope near limestone bank). The finds of several fossil groups (gastropods, brachiopods, trilobites) in Baltic Kint sections are among the earliest in the world and pre-date Burgess Shale faunas, documenting Cambrian life in higher latitudes and in largely different environmental settings. Also, the Cambrian rocks of the Baltic Klint are not folded and thermally altered but lay horizontally and are traceable over hundreds of kilometers.
It is nevertheless clear that the overall significance of the Baltic Klint is, with respect to Cambrian fossils, inferior to that of the Burgess Shale.

The main value of **Gros Morne National Park** (Newfoundland, Canada) lies in its unique tectonic setting portraying the development of an oceanic basin and continental margin (closure of the Iapetus Ocean). Additional value is provided by the Upper Cambrian to Lower Ordovician sequence of shale and carbonates (Cow Head Group), which has preserved in several allochthonous thrust sheets that represent a transect across the continental slope. It is noteworthy that the global stratotype section and point for the base of the Ordovician System is defined in Gros Morne (the Green Point section, Cooper *et al.* 2001) and that the Early Ordovician graptolite collection of Gros Morne is one of the largest and most thoroughly studied in the world (Cooper *et al*. 1998).
Although the sedimentary sequence of Gros Morne falls broadly into the same time-span as that of the Baltic Klint, several notable differences between the two can be delineated. First, the Baltic Klint represents a large and flat epicontinental sea preserved on an old platform, whilst the Gros Morne characterizes a narrower pericratonic basin with a well-defined slope and subsequent active

tectonics, which folded and overturned the Cambrian-Ordovician sequence. By the stratigraphic and geographical extent, the Baltic Klint is a far larger "window in time" than Gros Morne. On the other hand, the Gros Morne includes deeper water deposits and thus the geological record is more continuous there than in the Baltic Klint sections. Several conodonts and some graptolites are common for both areas and can be used for precise correlation of Baltic and Laurentian sequences. The shelly faunas are, however, rather different, which is mostly due to biogeographic separation (Laurentian and Baltic provinces) and different climatic conditions. The diversity and abundance of shelly faunas as well as several microfossil groups are higher in Baltica but this may partly be due to the much longer study history in the Baltic area.
It needs also to be pointed that Laurentia continent stayed more or less in the same position during the time-span in question whereas Baltica drifted towards lower latitudes, which is reflected in changes in the faunas and sediments.
In consequence, although Gros Morne and Baltic Klint share the time span, they represent largely different geological situations and faunas and, eventually, do not duplicate but complement each other.

In the **Grand Canyon** (Arizona, USA) sandstones, shales and limestones of the Tanto Group (total thickness up to 500 m) are cropping out in one of the most spectacular gorges in the world. Cambrian deposits in the Grand Canyon and throughout the Rocky Mountains have long been cited as representing a classic transgressive sequence of sandstone, mudstone, and limestone. During Early and Middle Cambrian time, a north-south trending shoreline migrated progressively eastward across the craton, resulting in deposition of coarse clastics in shallow water areas to the east and finer clastics and carbonates in more offshore areas to the west (Middleton & Elliot 1990). The Cambrian fauna in the Grand Canyon is dominated by trilobites (nearly 50 species) but includes also brachiopods, primitive molluscs, one species of 'primitive' echinoderms, algal structures, two species of gastropods, some sponges and a varied ichnofauna. The specific assemblages of fossils found in the Tonto Group suggest an Early to Middle Cambrian age.
When compared to the Baltic Klint, it appears that the Uppermost Cambrian and Ordovician rocks are not represented in the Grand Canyon succession. The Lower and Middle Cambrian are nevertheless richer in fossils and most probably more complete with respect to sedimentary gaps. Being located in a mountain area, the Grand Canyon rocks are overprinted by the subsequent geological processes and thus deposits similar to the Baltic "blue clay" cannot be found in the Grand Canyon. It also needs to be pointed that, like the Burgess Shale and Gros Morne, the Grand Canyon represents the Laurentia plate, characterized by different biogeographic province and climate than Baltica.

In addition to the properties already inscribed on the WHL, two other Ordovician sites that have world-significance and might be considered as WHL candidates have been proposed by Wells (1996). These are the **Utica Shale** of New York (USA), which is famous for its preservation of soft body parts of Late Ordovician trilobites, and the Stairways Sandstone of **Mt Watt** (Australia), where jawless fishes are found.
Although both of these sites are important palaeontologically, they are not directly comparable with the Baltic Klint, which, as a whole, represents a much wider and more representative environmental and palaeontological spectrum of the Cambrian-Ordovician world. The Utica Shale is also somewhat younger than the rocks exposed at the Baltic Klint.

Other Cambrian fossil sites that have not been mentioned in the WHL context but contain an exceptional record of life on Earth include **Chengjiang** (China), **Sirius Passet Formation** (Greenland), and **Baltic "Orsten"-Alum Shale** (Southern Sweden, including Öland, in close vicinity of the Baltic Klint). All of them represent *Fossil Lagerstätten*, where soft-bodied fossils have preserved.
The Chengjiang fauna, dated as Early Cambrian (530 Ma), is particularly famous, being the oldest Cambrian occurrence of abundant, well-preserved soft-bodied metazoan fossils. Although it is more than ten million years older and located on a different continent, the Chengjiang fauna is rather similar to that of the Burgess Shale.
Comparing these sites with the Baltic Klint area, much the same applies as already mentioned above.

Also the Upper Ordovician **Soom Shale** (South Africa) is a frequently quoted *Fossil Lagerstätte* where impressions of conodont animals and other soft-bodied creatures have been recovered (Gabbot 1998). However, this site cannot be directly compared with the Baltic Klint since it is much younger and represents only a very restricted time interval, only a specific depositional environment and a limited diversity of typical Paleozoic fossils.

With respect to the international timescale, the localities with stratotype sections and points (GSSP) for global stages need to be reviewed and compared with the Baltic Klint.
For the Cambrian, only the basal stage of Lower Cambrian and the basal stage of the Upper Cambrian are defined.

Out of the seven Ordovician global stages, GSSPs have been approved for five:
- base of the Tremadocian Stage is located in the **Green Point**, Gros Morne (see discussion above),
- base of the "Second Stage" is defined in **Diabasbrottet Quarry**, Västergötland, Southern Sweden,
- base of the Darriwilian (4. Stage) is defined in **Huangnitang**, Zhejiang Province, Southeast China,
- base of the "Fifth Stage" (and the Upper Ordovician Series) is fixed in **Fågelsång**, Scane, Southern Sweden,
- base of the "Sixth Stage" is fixed in **Black Knob Ridge**, Oklahoma, USA.

All these localities have been chosen by the good record of index fossils (graptolites and/or conodonts) and essentially continuous deposition. The stratigraphic as well as spatial extent of these sections has not been the primary consideration. Although the Baltic Klint is for the most part less suitable for defining a globally usable timescale, it is a far larger "window in time" and a more representative example of the Ordovician sedimentary basin and the corresponding biota than any of the global stratotypes.

There are indeed numerous other places in the world where Cambrian–Ordovician sedimentary rocks are exposed and fossils are found and which are not inscribed or proposed for inscription on the WHL and not considered as global stratotypes. In fact, Cambrian and Ordovician successions with a different extent, completeness and fossil content exist in all ancient as well as present-day continents.
Even in the Baltica continent, Cambrian and Ordovician rocks are exposed in many other places in addition to the Baltic Klint: Oslo region, mainland of Sweden, Denmark, Sub-Polar Urals, Podolia (the Ukraine), Poland, and as patches in a few other places.
However, none of them come close to the Baltic Klint in their geographical and stratigraphic extent, degree of preservation and accessibility. Therefore, there is no doubt that the Baltic Klint is the best site to represent the biological and environmental diversity of the entire Baltica continent during the Cambrian and Ordovician.

In most other (palaeo)continents the sequence as old as Cambrian-Ordovician is strongly overprinted by subsequent geological processes, the rocks are often metamorphosed and tectonized and found in mountain areas. Horizontal bedding and as well preserved a Cambrian-Ordovician sequence as observed in the Baltic Klint is very rare in the world. In this respect, the only comparable area is the **North American Midcontinent region** in the east of the United States and Canada, to the west of the Appalachian Mountains, where a vast area was covered by shallow epicontinental sea during the same time period. Similarly to the Baltic area, strata are mostly horizontally bedded and rocks and fossils are well-preserved in this old platform. The fossil record is rich, although it varies between individual places and beds. The general rock types and even the morphology of individual bedding planes and discontinuity surfaces are sometimes very similar in both areas.
Differences from the Baltic palaeobasin are related to the different palaeogeographical position and climatic settings. Many fossils were endemic in both areas and also the fossil assemblages differed in several aspects (e.g. the lack of coral faunas in Baltica). But even more importantly, there are no continuous outcrops of Cambrian to Lower and Middle Ordovician strata in North America that could be compared with the over 1000-km-long Baltic Klint. Silurian rocks, on the other hand, are well exposed in, for instance, the ca 800-km-long and spectacular Niagara Escarpment, which

resembles the Baltic Klint in many geomorphological aspects.

In consequence, it should be noted that despite Cambrian-Ordovician rocks and fossils are found in many other places around the world, including some sites that are already inscribed in the World Heritage List, the Baltic Klint stands out in its stratigraphical and geographical extent, fossil record, excellent preservation, study history and accessibility. It therefore provides the best example of Cambrian-Ordovician epicontinental basin with developing paleogeography and climate and evolving biota.

Neugrund meteorite crater

There are nearly 170 meteorite craters of proven origin in the world and only 50 of these are older than 100 million years (Abels et al. 2002, Dence 2002, Deutch & Shärer 1994, French 1998, Grive & Pesonen 1996, Koeberl & Martinez-Ruiz 2002, Melosh 1989, Montanari & Koeberl 2000). The so-called old meteorite craters have usually preserved only as indistinct traces in the form of rocks affected by meteorite explosion but the Neugrund Crater has almost fully maintained also its circular ridges. Although the World Ocean makes up over 2/3 of Earth' surface, only 5 meteorite craters have been found in it (Dypvik et al. 2004), with Neugrund being the unrivalled best preserved and also easiest accessible of these. When comparing meteorite craters by their degree of preservation, the crater located near Kärdla could compete with Neugrund to some extent but, unlike Neugrund, it is fully buried (Suuroja et al. 2002).

Below we provide additional information in response to the letter from IUCN dated 17 November 2005

Management

[We understand that the Nature Conservation Division of the Ministry of Environment is being re-organised into new regions. Please can you clarify how the nominated serial property will be managed and resourced if it were to inscribed on the World Heritage List?]

The State Nature Conservation Centre (SNCC) – an agency administered by the Ministry of the Environment and dealing with the management of nature conservation in Estonia – commenced operation on 1 January 2006. The operation costs of the Centre will be covered from the state budget.

With the commencement of operation of the Centre, a uniform system has been created for the organisation and management of work related to protected natural objects, for distribution of financial resources and planning of activities. The Centre will be coordinating also the conservation activities for all 8 protected areas proposed for inscription on the UNESCO World Heritage List, so it will be the administrative body responsible also for the management of the possible future Word Heritage Site (WHS).

As all of the 8 candidate areas are Natura 2000 sites due to their various nature values, the Nature Conservation Centre will be responsible also for regular reporting on the conservation management of these areas to the European Commission.

The structure of the Centre is made up of regional departments, which may include separate divisions, and staff members working outside the regional departments, under direct subordination of the administration of the Centre. In total, there are 8 regional departments dealing with conservation management.

The greatest change that will take place with the establishment of the new Centre consists in the following:

Until the present there were 16 protected areas with administration and 373 unstaffed protected areas in Estonia (including 7 candidates for the World Heritage List, one site was managed by Lahemaa National Park Administration). Management of the protected areas with administration was the responsibility of the administrations, while unstaffed protected areas were managed by County Environmental Departments. According to the new system, there will be 8 regional departments, which will organise work in all protected areas falling within their territory. The staff of the regional departments will be formed of the staff of the present protected areas with administration. Thus, the establishment of the new Centre will mean that the scope of their activity will be expanded to cover all protected natural objects in the region. In addition, new staff will be recruited in all regions.

The new Centre will be dealing mostly with the management of practical nature conservation work. Administration of the protected objects – making of decisions on planned activities, provision of approvals, etc. – will still lie with the Environmental Department of the county concerned. The functions of regional departments will also include counselling of County Environmental Departments and provision of opinions to assist decision-making. The division of administrative and management functions between County Environmental Departments and regional departments of the SNCC is regulated by the Nature Conservation Act.

The 8 protected areas proposed for inscription on the World Heritage List are divided between four regions to be established as follows:

Lääne-Hiiu Region:
- Osmussaar Landscape Reserve

Harju-Rapla Region:
- Pakri Landscape Reserve
- Türisalu Landscape Reserve
- Ülgase Nature Reserve

Lääne-Viru – Järva Region:
- Tsitre-Muuksi Escarpment in Lahemaa National Park

Ida-Viru Region:
- Ontika Landscape Reserve
- Päite Landscape Reserve

Management plans

It is natural that dignifying of those areas with the title of UNESCO World Heritage allows us to organise their wider introduction and envisage more detailed and comprehensive management plans. This would mean, in essence, a review of the existing management plans and drawing up of a unified management plan on their basis in the framework of the World Heritage Site.

The status of management plans as of the end of 2005:
1. Osmussaar Landscape Reserve – management plan in effect until 2008
2. Pakri Landscape Reserve – previous management plan was in effect until 2004, new management plan for 2006 – 2015 has been prepared

3. Türisalu Landscape Reserve – previous management plan for 2001–2004 needs updating
4. Ülgase Nature Reserve – management plan for bats in effect in 2005–2009
5. Tsitre-Muuksi Escarpment – management plan for Lahemaa National Park under preparation
6. Ontika Landscape Reserve
7. Päite Landscape Reserve
8. Udria Landscape Reserve
For the three protected areas located in Ida-Viru County, a joint management plan will be drawn up because these areas are similar both in their natural conditions and conservation management measures.

One of the aims of the Nature Conservation Centre will be to ensure that all spheres of activity connected with protected areas (e.g. nature education, forest management, landscape management, etc.) will from now on be dealt with horizontally across Estonia. Working groups of the relevant spheres of activity will be established at the Nature Conservation Centre for the purpose. These groups will develop a concept and action plan, which will be implemented by specialists of the relevant sphere in regions. Thus, the reform will imply that both a specialist body to work out plans and provide expert opinions and recommendations and special structural units responsible for the implementation of day-to-day conservation activities will be established in the frames of one agency.

In case the Baltic Klint is inscribed on the UNESCO World Heritage List, it is necessary to establish a similar working group for the development of a concept for unified management of the 8 protected areas or to establish a separate structural unit to deal with the issues of protection and public display of the future WHS in as integrated a manner as possible. This working group or unit would be located directly at the Nature Conservation Centre in Tallinn.

It has to be noted that the list will possibly be supplemented with additional protected areas – a protected area is currently being established for the protection of the klint and the nearby habitats in Aseri Municipality of Ida-Viru County and the establishment of a protected area in Viimsi Municipality in Harju County is being considered.

Cooperation with **local municipalities** and **county governments** is very important, in terms of both work division and financing. Conservation activities have been so far and will continue to be planned in cooperation and also their financing has been shared. Local municipalities and county governments give regard to the restrictions arising from the specific nature of protected areas in their planning activity and contribute to improving and ensuring access and visiting conditions.

The 8 protected areas proposed for inscription on the World Heritage List are located in the territories of the following municipalities and counties:

Osmussaare Landscape Reserve – Noarootsi Municipality, Läänemaa County
Parkri Landscape Reserve – Paldiski Town, Harju County
Türisalu Landscape Reserve – Harku Municipality, Harju County
Ülgase Nature Conservation Area – Jõelähtme Municipality, Harju County
Tsitre – Muuksi Escarpment – Kuusalu Municipality, Harju County
Ontika Landscape Reserve – Kohtla and Toila Municipalities, Ida-Viru County
Päite Landscape Reserve – Toila Municipality, Ida-Viru County
Udria Landscape Reserve – Vaivara Municipality, Ida-Viru County

Some examples of the contribution of municipal governments to ongoing activities connected with protected areas (both project-based and continuous financing from the municipality budget):

- Noarootsi Municipality organises in Osmussaare Landscape Reserve:
    Restoration of Lõunasadam Port (Southern Port), 1 000 000 EEK (64 102 EUR)
    Creation of conditions for sheep breeding (facilities) 50 000 EEK (3 205 EUR)

- Kohtla Municipality in Ontika Landscape Reserve:
  - Construction of a view platform at Valaste Fall, 3 000 000 EEK (192 307 EUR)
  - Maintenance costs of the view platform at Valaste Fall, 50 000 EEK/yr (3 205 EUR)
  - Construction of stairs in Ontika Village, 70 000 EEK (4 487 EUR)

- Vaivara Municipality in Udria Landscape Reserve
  - Annual maintenance of international hiking trail E-9, 5000–7000 EEK/yr (450 EUR)
  - Clean-up of military pollution in coastal area, 300 000 EEK (19 230 EUR)
  - Annual landscape management works, 40 000 EEK/yr (2 564 EUR)

All 8 protected areas are already now connected with each other by an international hiking trail E-9, whose establishment, marking and maintenance has been organised by a non-profit organisation – the Estonian Ramblers' Association – in cooperation with municipalities.

Management activities

The primary goal of the future WHS is to ensure the development of the klint through natural processes only.

Conservation management works on protected areas can be divided between four main spheres:
1. Maintenance
2. Development of visiting conditions
3. Scientific research and monitoring
4. Administration and supervision

These activities, in turn, can be divided into two according to their character and financing possibilities:

Continuous activities:
- Landscape management works: mowing and grazing of seminatural communities, brushwood cutting
- Area cleaning
- Scientific research and monitoring
- Administration and supervision

Single activities:
- Clean-up of military pollution
- Construction: harbours, buildings (visitor centres)
- Establishment of visitor facilities: marking, stairs, roads and trails, parking lots, view platforms
- Studies

The financing of continuous activities is planned through the Nature Conservation Centre (state budget), the Environmental Investment Centre and in cooperation with municipalities and counties. Scientific research is also financed through the Ministry of Education and Research.

Single activities are mostly project-based and can be financed e.g. through the Environmental Investment Centre, various funds and EU structural assistance to the projects initiated by the Nature Conservation Centre, local municipalities or non-profit organisations.

Threats

[What concrete measures are in place or envisaged to ensure that any possible future oil spill (e.g. Paldiski) or leakage of polluted water (e.g. from Sillamäe pond) will not affect the property and what is proposed to reduce the potential of such occurrences?]

In Paldiski Port, which is located close to Pakri Landscape Reserve, a potential threat is posed by transit traffic of oil. Oil tanks are located 100–200 metres from the southwest coast. Possible pollution is prevented from reaching the Reserve by port facilities geared to localize the pollution. According to the Ports Act, port authorities are required to ensure compliance with various safety requirements in importation, warehousing, storage, and trans-shipment of dangerous goods. Coastal and seawater monitoring is carried out on a continuous basis.

According to the Act, port authorities are required to plan precautionary measures and prepare a plan of action for preventing possible accidents and taking the appropriate response measures. For **Paldiski Port** and the adjacent **Alexela Oil Terminal**, there exists a joint abatement plan for oil pollution, which was approved by the Port Director on 21 October 2003. Three scenarios have been worked out for localising and eliminating pollution, taking into account the location or area of pollution and the weather conditions and wind direction.

State supervision over the receipt, processing and storage of dangerous goods in ports and release thereof from ports is exercised by the Estonian Maritime Administration. Requirements for the receipt, processing, storage and release of dangerous goods in ports have been established by the Minister of Economic Affairs and Communications in concert with the Minister of Environment.

The **Sillamäe Radioactive Tailings Pond** is located adjacent to the shoreline of the Baltic Sea in Ida-Viru County between Päite and Udria Landscape Reserves. It has an area of 50 ha and a volume of 8 million m^3. The tailings deposit is built up of residues of uranium and rare earth ore processing and oil-shale ashes from the local power plant. The facility is surrounded by a ring dam of 2.7 km in length and up to 25 m in height.

Already the initial assessments in the early 1990ies identified that the tailings pond was inadequate to meet the international standards of radiological, environmental and geotechnical safety.

To remedy this situation, a multi-national Programme for Remediation of the Sillamäe Radioactive Tailings Pond was launched in 1998. The financing was provided by the EU, bilateral contributions of the Nordic Countries and the Estonian Government, totalling at EUR 20 million.

The Project concentrates on dry remediation of the Tailings Pond since this is the only solution that will ensure the long-term stability of the dam. This means no longer use of it as a tailings pond for wastewater, and dehydrating of the content.

The most important specific targets of the Project are as follows:

1. <u>Stabilizing the Tailings Pond's unstable seaward dam against failure.</u>

In 2002, the 1.1 km long seaward dam of the Tailings Pond was stabilized by means of a double row of 15 – 18 m deep concrete drilled piles along the dam toe in all parts of insufficient safety.

2. <u>Protection of the Tailings Pond's seaward dam against sea erosion and wave attack.</u>

A shore protection system armored with granite stones was constructed along the Tailings Pond's full length of 1,1 km of the shoreline in the years 2001 – 2002.

3. Cut-off of groundwater inflow from the hinterland into the Tailings Pond.

A water diverting system consisting of a 580 m long cut-off wall and a 520 m long deep drainage trench was built over a length of 1.1 km along the south and west side of the Tailings Pond in 2002 – 2003. Such water diverting system is intended to block groundwater from following its normal path via the water carrying layers above the Cambrian clay formation and to redirect the groundwater to the Baltic Sea along the southern dam of the tailings pond.
No more than 5 per cent (30 000 m^3) of the yearly groundwater inflow in wet years will flow from the hinterland into the basement area of the Tailings Pond.

4. Minimizing of seepage from the Tailing Pond's interior into the Baltic Sea to a sustainable and acceptable level, in compliance with international standards and agreements.
Seepage limits are guided by EC Council Directive 1999/31/EC on the Landfill of Wastes.

To facilitate the prerequisite (percolation from 5 to 10 per cent of the total amount of natural precipitation), in the years 2001 – 2004 the Tailings Pond has been reshaped into a hill type landform and integrated into the surrounding natural landscape.
Further, in the years 2005 – 2007, the reshaped Tailings Pond area will be covered with a 2.3 m thick final cover: a system of layers of five different natural materials, which contains, in all, ca 1.2 million of m^3 of glacial till, macadam, sandy soil and vegetation soil, and which guarantees water tightness of the former Tailings Pond. The surface of the final cover will be vegetated.

5. Elimination of radiation in the Tailings Pond area, prevention of the spreading of radioactive dust to the surrounding environment and minimizing of emission of radon to the town of Sillamäe down to acceptable limits.

The guiding principles for tailings pond remediation from the radiation protection point of view are driven by the Basic Safety Standard by International Atomic Energy Agency and EC Directive 96/29/Euratom. The basic requirement is set at no higher than 1 mSv effective dose for the general public in any area.

The main goal of the project – to reduce emissions to water and air and to attain compliance with the EU directives on nuclear safety, radiation protection and waste water and with the Council Decision regarding the Protection of the Marine Environment of the Baltic Sea (Helsinki Convention, 94/157/EC) – will be fully achieved by autumn 2007.

An Environmental Monitoring Programme has been drawn up under the project in cooperation with the Ministry of the Environment with the aim of assessing the progress and results of the project. Long-term geotechnical, hydrogeological, hydrochemical and radiometric monitoring is being carried out. The monitoring will yield reliable long-term high-quality data series allowing the assessment of environmental sufficiency of the closure project of the tailings pond and the effect achieved.
Stage I of monitoring of the Sillamäe Tailings Pond is part of the remediation project.

Considering the international importance of monitoring of the radioactive tailings pond of Sillamäe and the specific nature of the tailings, Stage II of monitoring – monitoring after the completion of the remediation project – should be included in long-term monitoring under the Estonian National Environmental Monitoring Programme.

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Lisa 3
aruandele **Põhja-Eesti klint UNESCO maailmapärandi ja geopargina: edasiste võimaluste analüüs**

Viliseksperdi arvamus Balti klindi edasise staatuse kohta (ingl k)

Possible World Heritage Site

I have looked at the papers you sent, the original nomination documentation (includes excellent supplementary information on the Klint fossils), and I also reminded myself of the evaluation report I wrote for the IUCN (this is different from the draft IUCN paper to the WH Committee, which you may have seen). Although my report was confidential to IUCN, I have attached section 3, which compares the geology and geomorphology of the Klint with those of other similar sites around the world. I have left this in draft form, with editing comments in MS Word 'track changes', to illustrate that this was a developing document, particularly after I received 'supplementary information'. The supplementary information provided me with important new details of the palaeontology of the Cambrian and Ordovician strata. You will notice that I tried to present a positive view of the Klint, but you will also be aware that the field evaluator's report is just one of a number of scientific reviews of a nomination considered by the IUCN WH Review Panel - and it is the Panel, not the field evaluator, that makes the recommendation to the World Heritage Committee.

The original WH Site nomination did not succeed principally because the arguments for Outstanding Universal Value (OUV) were poor. OUV means that the site is the very best of its type in the world. This must be demonstrated by means of comparison with 'competitors', both similar sites that already exist on the World Heritage List, and in the world generally. While the Klint is a most impressive feature, there are many places in the world with good exposures of Lower Palaeozoic strata, with longer and taller escarpments, and fossil assemblages from the same time period. The arguments are laid out in my attachment.

So if you are to considered a new submission for WH Site status, you must think very carefully and define what makes the Klint special on the world scale (not just regional). On the negative side, in comparison with other similar world features:
1. As an escarpment geomorphological feature the Klint is very interesting, but it is not visually spectacular, and while it forms an important geological boundary in Europe, the escarpments in N. America hold a similar position on that continent (boundary between shield and platform).
2. There are many parts of the world and many existing WH Sites with Cambrian and Ordovician bedrock - so what makes the strata of the Estonia Klint more significant than these?
3. The Neugrund meteorite crater is extremely interesting, but it is difficult to place it within the arguments promoting the 'integrity' of the Klint (site integrity is a concept outlined in UNESCO's World Heritage Site Operating Guidelines and a criterion that must be met by all WH Site nominations).
4. The biological values are very weak in comparison with existing WH Sites located in the same biogeographical region.
5. The arguments presented in the original nomination and your recent attachment build a case of regional importance (Europe), but the case for world importance is very limited and not convincing.

6. The palaeontological values appear to be very high, but the arguments for world importance of these are weak, and anyway there are already some excellent Lower Palaeozoic palaeontological sites on the WH List (e.g., Burgess Shale and at Gros Morne N.P., Canada).

It is clear that you and your team must further develop arguments that support the claim that the geology of the Klint has OUV- i.e., where are the strengths (world-class values) and how can they be proven? In marketing terms, in a world 'market', what is the Klint's USP (unique selling point)? If you can identify this, you must also build robust supporting arguments.

It is not necessarily a question of scientific value, because the Klint does have high scientfic values, but what are the relevent or appropriate arguments and how should they be promoted. I personally feel the Klint's USP, or OUV, is not so much in the landform or stratigraphy, but in what the stratigraphy and palaeontology tell us about the palaeogeography and history of life of one of the most important periods of geological time - albeit that your evidence comes from an epicontinental environment (as opposed to a deep ocean or ocean margin). The discussion points in the section of your recent attachment entitled 'The Potential' are relevant here - particularly points (3), (4) and (5). Yet even at (5) the paragraph ends -'The scientific study standard of these fossils is very high in international meaning' - but what does this mean? - we are left hanging for more substantial facts.

One way to tease out the USP/OUV might be for your team to hold a workshop, to identify some new lines of approach to a WHS nomination and debate the level of evidence that is available, or must be generated/researched to support each approach. In doing this you will be constrained by the definitions of OUV and integrity to be found in the UNESCO WHS Operational Guidelines, and more especially comparable sites already listed on the WH List. You might also solicit the comment and support of leading world scientists in the field, and of the relevant international geological bodies.

So in summary I do think that the Klint is a most interesting feature and has the potential to be inscribed as a future WH Site. However, the current arguments are poor and require substantial re-working, based not only on the excellent science, but also an understanding of what UNESCO/IUCN are looking for in a natural WHS and most particularly what particular niche the Klint will fill in the existing list of stratigraphical and palaeontological WH sites. As we have already seen, the process of gaining an inscription is tough and highly competitive, therefore the justification for nominating a site must be indisputable.

One other point, any potential fossil WH sites will be evaluated by IUCN against a checklist. The questions on this checklist are:

- Does the site provide fossils which cover an extended period of time - how wide is the time window?
- How rich is the site in species diversity?
- How unique is the site in yielding fossil specimens for that particular period of geological time? - ie, would this be the type locality for study or are there other similar areas that are alternatives?
- Are there comparable sites elsewhere?
- What is the site's contribution to our understanding of life on Earth?
- What are the prospects for ongoing discoveries?
- How international is the level of interest in the site?
- Are there associated features of natural value?
- What is the state of preservation of specimens from the site?
- What arrangements are there for curation, study and display of fossils?

I have not checked recently, but the last time I did there were only about 15 sites on the current WH List inscribed specifically as fossil sites, and only three of these in the Lower Palaeozoic - Miguasha (Canada)/Devonian, Gros Morne (Canada)/Ordovician, Burgess Shale (Canada)/Cambrian. Furthermore, only three sites are in Europe - Monte San Giorgio

(Switzerland)/ Triassic, Dorset & East Devon Coast (UK)/Cretaceous & Jurassic, Messel Pit (Germany)/Eocene.

The implication is that there is a gap in the existing WH List relating to the evolution of life and palaeogeography in the Lower Palaeozoic, although any arguments for a new (Estonia Klint) site must acknowledge, embrace and complement, not duplicate, the Canadian sites. The part that the evidence from the Klint can tell is that of evolution in a shallow continental sea, the great abundance and diversity of fossil species, and that it has one of the best continuous records in the world (??? - is it?) of the Cambrian Explosion of life and the Great Ordovician Biodiversification event - the latter being themes not developed by any site on the current WH List.

Possible National/Global Geopark

I read your paper about the establishment of one or more geoparks in N. Estonia and I recognised the administrative difficulties that might be encountered. I am pleased that you have found information from the European Geoparks Network, which is responsible for regulating membership to UNESCO's Global Network of Geoparks. You will know that the ENG has many supporting papers and an application form downloadable from its website (www.europeangeoparks.org). You might also note that other European countries have found EU funds through LEADER or INTERREG programmes to help with the establishment of Geoparks (Geoparks fit well with the objectives of LEADER).

My view is that Geoparks and WH Sites are different kinds of designated area and I can see no reason why you should not press ahead with the establishment of one or more geoparks, while also developing your case for WH nomination. Indeed, having a geopark(s) across the Klint (or parts of it) will by a positive feature in any possible new WHS nomination. You are quite correct that the administration of a geopark and a WHS is quite different, and that in oder to progress the geopark idea the local community must become more of a driving force, while a WHS is a state and provincial government responsibility. Insofar as a geopark is intended to assist with sustainable development (greatly through geotourism) in the local community, perhaps your next step in promoting the idea to the relevant communities is to meet with and inspire their local authority (local govt) economic development or tourism officers to explain what the economic benefits of a geopark might be and to recruit them and their Councils to the cause. As you correctly say in your paper, the support of the local council's and their officers is important in building the application and continuing commitment to the 'brand'.

With regard to boundaries of selected Geopark sites, I note your view that there could be a western and an eastern park. Certainly one park for the whole of the Klint coast would be extremely difficult to form and administer and anyway I do not know of a geopark based on series of sites (rather than as a single site). However, this is something that could be explored. Another consideration is that I doubt the EGN would accept two national geoparks that displayed common geological features, so a preferable route might be to work towards the establishment of a single site that is representative of the whole coastline.

Dr Chris Wood, IUCN expert of Geological Heritage
School of Conservation Sciences,
Bournemouth University,
Talbot Campus,
Poole BH12 5BB, UK
Tel: +44 (0)1202 965134
E-mail univ.: cwood@bournemouth.ac.uk
E-mail private: chriswood@tiscali.co.uk

Lisa 4
aruandele **Põhja-Eesti klint UNESCO maailmapärandi ja geopargina: edasiste võimaluste analüüs**

Väljavõte IUCN aruandest Balti klindi kohta UNESCO maailmapärandi nimekirja kandideerimisel

(ingl k, saadud väliseksperdilt mitteametlikuks kasutamiseks)

WORLD HERITAGE NOMINATION - IUCN TECHNICAL EVALUATION

BALTIC KLINT

...

3. COMPARISON WITH OTHER AREAS

The candidate site is claimed to be significant in respect of its landform, stratigraphy and fossil record.

Escarpment landform

An escarpment, alternatively called a Scarp or Cuesta, denotes a transition from one series of rocks to another series of a different age and composition. In such cases the escarpment usually represents the line of erosional loss of the newer rock over the older. Escarpments may also be formed by faults, either by normal or reverse faulting that lowers or raises one area of land against the other, or by a strike-slip fault that in a horizontal movement moves higher ground to a position adjacent to lower ground. The Baltic Klint is an erosional, not structural, scarp and represents a significant geological boundary in Europe between the Lower Palaeozoic sedimentary deposits and the older crystalline Precambrian basement of the Fennoscandian shield.

Escarpments are very common landscape features and ubiquous throughout the world. They are so common that they are very often taken for granted by geologists and only a few have a classical record in the literature. The Mesozoic escarpments in England (the Cretaceous chalk escarpments of the North and South Downs and the Chiltern Hills, the Jurassic limestone escarpment of the Cotwolds Hills, etc) are particularly well known. These are the product of gently inclined strata, where river erosion has picked-out and lowered the surfaces of the softer beds, leaving the more resistant beds upstanding. These escarpments are characterised by a steep erosional slope - the scarp slope - cut across (through) the succession of strata, and a shallower slope - the dip slope - eroded parallel to the inclination (dip) of the strata. Escarpments of this type are also present in the Paris Basin.

The Baltic Klint is certainly a very long escarpment, even though a significant part lies beneath the surface of the Baltic Sea. However, it does not rise to any great height (maximum of 55.6m in the Ontika Landscape Reserve). The English escarpments rise to greater heights (up to 300m in the Cotwolds), but are not so long (max. 200km). Some other escarpments in the world are longer, usually higher and far more spectacular than the Baltic Klint. These include, the Great Escarpment of South Africa (up to 1000m high) the escarpments of the African Rift Valley (fault scarps), and the Great Escarpment that parallels virtually the entire east coast of Australia. The nomination document describes a number of comparable escarpments. The Bandiagara Escarpment is an existing World Heritage Site in Mali, formed in Cambrian/Ordovician sandstones. It is higher (100-500m), but not as long (150km) as the Baltic Klint, and does not have the same scientific value in its geomorphology, stratigraphy and palaeontology. The escarpments of the Southern Ontario Lowlands (Black River Escarpment, the Magnesium Limestone Escarpment and the Niagara Escarpment), Canada, like the Baltic Klint have formed at the transition zone between shield and platform. The Black River Escarpment is a low (7-23m high) cuesta formed in Upper Ordovician limestones, while the longer (750km) and higher (540m) Niagara Escarpment.contains 'some of the best exposures of rocks and fossils of the Ordovician and Silurian Periods (405-500 million years old) to be found anywhere in the world' (Niagara Escarpment Commission). The NiagaraEscarpment was designated a Biosphere Reserve by UNESCO in 1990. Another well known North American example is the 300m high Helderberg escarpment, near Albany, New York State. This is formed of Middle and Upper Ordovician rocks, in places with a capping of Silurian and occasionally Devonian strata.

The majority of these escarpments have formed inland and result from erosion of the bedrock by fluvial or glacial erosion. Historically the early Klint may have had a similar origin, although its present form is attributable to thousands of years of marine erosion, the effectiveness of which will have been influenced by differential isostatic adjustments during the Quaternary. It is further notable that the other well-known escarpments that were formed in Lower Palaeozoic rocks have strata younger in age than the Klint - no-where else in the world can there be found a long escarpment with strata of comparable age...Developing this argument, the point was made in the previous section (2.1.) that the Klint may have been a significant landform even at the end of the Ordovician, making it one of the oldest landforms in the world. No evidence could be found of an older escarpment landform, the nearest best documented example being the Niagara Escarpment, which may have begun to form about 300 million years ago (Carboniferous Period). There is therefore some justification to the claim that the Klint is possibly the oldest and one of the longest escarpments in the world. As shown in Table 1, the only escarpment at present inscribed on the World Heritage List is The Cliff of Bandiagara, Mali, inscribed as a mixed natural/cultural site (although many other sites on the World Heritage List may have escarpments which have not been described because they were deemed to be unimportant in supporting the principal values for which the site was inscribed).

Table 1: Comparable sites on the World Heritage List

World Heritage Site	Escarpment	Sea cliff	Cambrian/Ordovician strata	Fossil record
Dinosaur Provincial Park, Canada	No	No	No - Late Cretaceous	60 species of dinosaur
Grand Canyon National Park, USA	No	No	No - late Cambrian, Ordovician and Silurian are missing	Not significant
Canadian Rocky Mountain Parks	No	No	Yes - but Burgess Shale is Middle Cambrian	Significant sof bodied animals and Cambrian adaptive radiation
Gros Morne National Park, Canada	No	Yes	Yes	Yes - complete palaeontological sequence proposed as world stratotype for Cambrian/Ordovician boundary
Australian Fossil Mammal Sites (Riversleigh/Naracoorte)	No	No	No - Late Tertiary (Oligo-Miocene) cave deposits	Mammal fossils

Messel Pit, Germany	No	No	No - Tertiary (Middle Eocene) continental deposits?	Mammal fossils
Miguasha National Park, Canada	Yes	Yes	No - Upper Devonian	Fish fossils
Ischigualasto/ Talampaya Natural Park, Argentina	No	No	No - Late Triassic	Continental fossil record - mammals, dinosaurs and plants
Dorset & East Devon Coast, UK	No	Yes - 155 km	No - Triassic, Jurassic and Cretaceous	Marine and terrestrial, vertebrate and invertebrate animals and plants
Monte San Giorgio, Switzerland	No	No	No - Triassic	Marine and terrestrial fossils
Wadi Al-Hiton, Egypt	No	No	No - Late Tertiary (Eocene)	Whales
The Cliffs of Bandiagara, Mali	Yes	No	Yes - Cambrian/Ordovician sandstone	Not significant

Cliff-lines

The scarp face of the Klint in Estonia (and indeed on Swedish Öland) is a marine eroded cliff. While this cliff has impressive physical form, particularly in the east of the country, offering splendid vistas of the coast, it never rises more than 56m above sea level and rarely is the unbroken face more than 30m high. As a physical feature it does not rank with the great sea cliffs of the world, such as Ireland's cliffs of Moher (230m high) or the Giant's Causeway Coast; the Kalaupapa peninsula, Molakai, Hawaii; Disembarco del Granma, Cuba; the Nullabor coast, Australia; or even the post-glacial raised cliff-line that border the southern coast of Iceland.

Stratigraphy

The Klint is formed of Upper Cambrian and Lower and Middle Ordovician marine deposits. There are many other exposures of strata of these ages around the world, but the Klint deposits are special to Europe because they are a pre-eminent record of the palaeogeography of the early Baltica Craton (Baltica now forms the resistant crystalline core of the European continent). The sedimentary deposits are an invaluable and unusual historical record, because they have great lateral extent (1200km) and have not been deformed by tectonic movements. They record a period when north-east Europe was covered by a shallow sea, the deposits marking a gradual warming of climate due to the northward drift of Baltica to a position south of the Equator. The Lower Palaeozoic strata that are found elsewhere in Europe (for example, in the UK and Norway), were influenced more greatly by the opening and then closing of the Iapetus Ocean between the Laurentia and Baltica cratons, and so represent a different environment of deposition than that of the epicontinental seas in which the Klint strata were deposited.

Stratigraphy as a value for inscription is not represented strongly on the World Heritage List, although as shown in the Table 1, there are fossil or other geological sites on the List that are representative of this value. Nevertheless, only two of these sites - Canadian Rocky Mountain Parks and Gros Morne National Park, Canada - have Lower Palaeozoic strata. The strata of both of these sites differ from those of the Klint in being deep ocean and/or continent/ocean margin deposits and of course they are representative of the Laurentia, rather than Baltica, palaeocontinent.

Palaeontology

The fossil record in the Klint provides important evidence to support the idea of the planet-wide Cambrian Explosion of Life and particularly the succeeding Great Ordovician Biodiversification Event. There are other sites of international significant that contain Lower Palaeozoic fossils, but not of the exact time period, nor displaying the same species diversity as the Baltic Klint. Furthermore, other world sites do not contain a record of the evolution of life specific to the Baltica palaeocontinent. The most important of the world's Lower Palaeozoic fossil sites are Chengjiang (China), the Sirius Passet Formation (Greenland), the Baltic 'Orsten'-Alum Shale (Sweden), the Soom Shale (South Africa), the the Utica Shale of New York State (USA), the Burgess Shale in Yoho National Park (Canada), and the Gros Morne National Park (Canada). The last two are existing World Heritage Sites in Canada. In comparison with the Baltic Klint, with the exception of Gros Morne, all of these are sites where soft-bodied animals have been preserved.. In contrast, there is a greater diversity of fauna at Gros Morne National Park, and deposits here have been proposed as the world stratotype for the Cambrian-Ordovician boundary. Nevertheless, although occupying a broadly similar time-zone, there are important differences between the palaeography and palaeontology of the Gros Morne and Baltic Klint sites. The rocks at Gros Morne represent a deeper water, oceanic (pericratonic or continental edge) environment, in which graptolites and shelly faunas flourished, while the rocks of the Klint were deposited in a shallow epicontinental basin and have a higher diversity of shelly faunas and microfossils. Furthemore, while the Laurantia palaeocontinent stayed more or less in the same global position, Baltica at this time drifted northward towards the Equator, which is reflected in the changes observed in its fauna and sediments.

The World Heritage List contains other notable fossil sites (Table 1), including Messel Pit, Germany; Dorset and East Devon Coast, UK; Miguasha and Dinosaur Prov. Park, Canada; Ischigualasto/Talampaya Argentina; Monte San Giorgio, Switzerland; Wadi Al Hiton, Egypt; Australian Fossil Mammal Sites (Riversleigh/Naracoorte) and Lake Turkana, Kenya. However only the Canadian Rocky Mountain Parks (Burgess Shale) and Gros Morne National Park have strata and fossils of Lower Palaeozoic age, but even then only Gros Morne is directly comparable to the Klint for the diversity of its fossil assemblage (although the Gros Morne National Park was not added to the World Heritage List because of its fossil record). Thus, the fossil assemblages of Gros Morne and the Baltic Klint differ because of the different palaeoenvironments they represent. They therefore do not duplicate, but complement one another in their fossil record.

4. INTEGRITY

4.1. Ownership and legal status

The eight reserves in the serial nomination have the following status, although it should be noted that land reform is still underway in Estonia (Table 2).

Table 2. Ownership of the reserves

Reserve	**State ownership**	**Private ownership**	**Comment**
Osmussaar Landscape Reserve	100%		
Pakri Landscape Reserve	30%	70% private ownership or due to be released to private hands	All still in state use. Area beneath the Klint (Special Management Zone) to remain in state ownership
Türisalu Landscape Reserve		100%	
Ülgase Nature Cons. Area		100%	
Tsitre-Muuksi Escarpment in Lahemaa National Park	100%		State ownership as part of Lahemaar National Park
Ontika Landscape Reserve	90%	10%	More land above Klint likely to pass to private ownership. Area beneath the Klint

			(Special Management Zone) to remain in state ownership.
Päite and Udria Landscape Reserves	57%	43%	

In legal terms, Osmussaar, Pakri, Türisalu and Ontika Landscape Reserves were designated under the Act on Protected Natural Objects (1994 and 1998). The Tsitre-Muuksi escarpment forms a part of the territory of Lahemaa National Park, revised protection rules for which were approved in 1997. The Ülgase Nature Conservation Area and Päite and Udria Landscape Reserves are currently subject to temporary restrictions of economic activity under Ministerial Regulation 24, April 2004, until protection rules receive state approval.

4.2. Boundaries

The boundaries of the properties are clear and uncontroversial. None of the reserves has a buffer zone, which because they are primarily geological and landscape reserves is not deemed necessary. The sensitive zone of each reserve is the seaward facing cliff, the Klint forest and the beach, these being naturally protected between the cliff and the sea. As there is negligible tide in the Baltic, there is no intertidal zone to protect and the property stops at the shore line. The only properties that do not have a coastline are Ülgase and Tsitre-Muuksi escarpments, but these are buffered within other protected areas (Rabala Historical/Cultural Reserve and Lahemaa National Park respectively).

4.3. Management

All of the properties are protected under the Act on Protected Natural Objects (1994 and 1998) and the Nature Conservation Act (2004) and as such are subject to special protection measures. They are each zoned into special or limited management zones. In Special Management Zones all use of natural resources is prohibited, while in Limited Management Zones some economic activity is allowed but is regulated. Permissible or non-permissible activities in these zones are the subject of protection rules and each protected area has its own set of protection rules, as follows (Table 3):

Table 3: Management of the reserves

Reserve	Legal protective measures	Special designations	SNCC Regional Management
Osmussaar Landscape Reserve	Divided into Special and Limited management zones. Birds are especially protected in SMZ May-June		Lääne-Hiiu Regional Office
Pakri Landscape Reserve	Divided into Special and Limited management zones. The SMZ includes the klint and foreland on Pakri Cape which is nesting site of black guillemot. Visitors prohibited from SMZ May-July	Important Bird Area (IBA) Klint forest and spring bogs candidate sites Habitat 2000	Harju-Rapla Regional Office
Türisalu Landscape Reserve	Protected as a Limited Management Zone		Harja-Rapla Regional Office
Ülgase Nature Cons. Area	Protection rules under construction - currently		Harja-Rapla Regional Office

	protected by temporary legal measures controlling economic activities		
Tsitre-Muuksi Escarpment in Lahemaa National Park	Protected as a part of Lahemaa National Park, with the escarpment falling within Limited Management Zone	Turjekelder sping proposed as candidate Habitats 2000 site	Lääne-Viru-Järva Regional Office
Ontika Landscape Reserve	Divided into Special and Limited management zones. In deciduous forest and Uikala SMZ all economic activities are prohibited	Klint forest and spring bogs candidate sites Habitat 2000	Ida-Viru Regional Office
Päite and Udria Landscape Reserves	Protection rules under construction - currently protected by temporary legal measures controlling economic activities		Ida-Viru Regional Office

The management authority of the reserves lies with the Ministry of the Environment and is executed centrally through its recently formed (1 January, 2006) State Nature Conservation Centre (SNCC). The SNCC is also the body responsible for administering the overall management of any possible future World Heritage Site. As all the 8 candidate areas are Natura 2000 sites, the SNCC is responsible for regular reporting on the conservation management of these areas to the European Commission.. Day-to-day management of the reserves is undertaken by staff of the relevant SNCC Regional Departments, of which there are four, as shown in Table 3. Should the Baltic Klint be inscribed on the World Heritage List it is proposed that an SNCC Working Group will develop a concept for the unified management of the serial site, with the establishment of a separate administrative unit to deal with protection issues and public access and information in an integrated manner. Co-operation with local municipalities and county governments in the management of the reserves remains an important priority. Under these new arrangements on-going ecological research and monitoring, and conservation and recreational management tasks, will continue to be funded by the state (Environment Ministry and Environmental Fund), local authorities, and with the help of volunteers. A specific budget for the management of the proposed WHS so far has not been decided.

Management plans and site-specific protection rules have so far been agreed for three reserves (Osmussaar, Pakri and Türisalu Landscape Reserves). Management plans for Ontika Landscape Reserve and Lahemaa National Park (Tsitre-Muuksi Escarpment) are under preparation, while those for the Ülgase Nature Conservation Area, and the Päite and Udria Landscape Reserves, remain to be started.

4.4. Human uses of the area

The only reserve with any permanent residents is the Ontika Landscape Reserve, which has about 200 residents in the Limited Management Zone and Osmussaar which has 3 permanent residents. The main economic pressures in the reserves come from animal grazing (mainly sheep) and recreation. The most intensively visited reserves are Pakri, Türisalu and Ontika. Visitor numbers are also high at the Tsitre and Muuksi escarpment. From evidence seen during the field evaluation neither grazing pressure nor recreational impacts on the reserves are serious. The only exception is at Türisalu, which is a site adjacent to a principal road and car park, which suffers from high seasonal visitor numbers to the beach, with resulting trampling and littering. The dumping or wind-blow of litter (and in some cases substantial objects, such as cars) over the cliff of most reserves remains a problem. There are good attempts throughout the site to manage visitors through construction of designated pathways and the distribution of interpretation panels and leaflets, while visitor viewing platforms have been constructed at the Pakri and Ontika reserves.

As noted above, many of the reserves are beginning to experience increased visitor pressure. The Lahemaa National Park receives an estimated 100,000 visitors annually, while the Türisalu and Ontika landscape reserves are heavily visited, especially the former which is located near Tallinn and has a good beach. The national and regional authorities are investing in the interpretation of sites, with all now displaying good information panels. There is also a range of very good interpretive literature and a number of visitor centres have been opened in recent years. Perhaps of greatest influence in linking all of the reserves is the opening of the Estonian section of the E9 European Long-distance Footpath, which traverses the whole of the north Estonian coastline.

4.5. Other threats

Due to their coastal locations, all of the reserve areas were formerly in the possession of the Soviet Army. While there have been considerable efforts to clean-up the most seriously polluted sites, residual impacts remain (e.g., abandoned buildings and military hardware littering sites, and possible residual ground pollution). In the Pakri and Türisalu reserves old military debris remains a problem, while material dredged from the Paldiski harbour occasionally washes ashore. A principal concern is the impact that a possible future oil spill related to the Alexela Oil Terminal, Paldiski,might have on the Pakri Landscape Reserve, although a contingency plan to protect the geology and wildlife of this reserve is apparently in place. At the eastern end of the site a similar threat occurs at Sillamäe, where a large tailing pond for settling the highly polluted water (radio-active waste and oil shale ashes) discharged from the SILMET plant has been built into the Baltic Sea. This site is currently undergoing clean-up, but until this is complete there remains the threat of leakage into the Gulf of Finland. In the same area, the Ontika Landscape Reserve suffers from poor air quality because of the nearby Kohtla-Järve chemical and thermal power plants.

Lisa 5
aruandele **Põhja-Eesti klint UNESCO maailmapärandi ja geopargina: edasiste võimaluste analüüs**

Väljavõtteid kohalike omavalitsustega toimunud kirjavahetusest

Geopargi idee arendamiseks klindi regioonis saadeti kirjad valdadesse, kus eeldused huvi ning majanduslik suutlikkus geopargi rajamiseks tundus olevat kõige suurem. Need olid Kohtla ja Toila vald ning Paldiski linn.

Arno Rossman
Järve küla 2-10
Kohtla vald 30331
Ida-Viru maakond

Etti Kagarov
Järve küla 2-10
Kohtla vald 30331
Ida-Viru maakond

27.02.2008

Kohtla ja Toila valla territooriumile UNESCO geopargi loomise kava.

Lugupeetud härra Rossman
Lugupeetud proua Kagarov

Pöördume teie poole Eesti Geoloogia Seltsi nimel ning soovime teada teie seisukohta Kohtla ja Toila valla territooriumile pankrannikule ja sellega piirnevale alale UNESCO nõuetele vastava geopargi loomiseks. Geopargi loomist kaalutakse põhjusel, et UNESCO eksperdid ei ole toetanud Balti klindi lülitamist UNESCO maailma looduspärandi nimekirja, kuid on soovitanud luua klindi piirkonda UNESCO poolt esitatavatele kriteeriumitele vastav geopark.
Geopark ei sea mingeid täiendavaid looduskaitselisi piiranguid kohaliku majanduse arengule. Geopargi põhieesmärk on luua täiendavaid võimalusi geoloogiliste loodusväärtuste rakendamiseks kohaliku arengu huvides. Peamiselt puudutab see turismi ja väikeettevõtlust. Geopark on kohalikuks õppe- ja loodusteaduskeskuseks. Iga UNESCO poolt tunnustust leidnud geopark osa Euroopa Geoparkide Võrgustikust. UNESCO tunnustus geopargile avaks uusi võimalusi piirkonna tutvustamisel ja arendamisel ning aitaks teadvustada Põhja-Eesti klindi, kui silmapaistva loodusmälestise väärtust. Geopargi moodustamine tõstab piirkonna väärtust ja tuntust nii Eestis, Euroopas kui maailmas.
Initsiatiiv geopargi moodustamiseks peab tulema kohaliku ettevõtluse ja kohalike omavalitsuste poolt. Kohtla ja Toila valdades on juba tehtud palju Põhja-Eesti klindi paremaks tutvustamiseks. Kohalikud ettevõtjad on investeerinud turismi, eelkõige just geoturismi arendamisse.
Geopargi moodustamiseks oleks vajalik kohalike ettevõtjate ja omavalitsuste toel moodustada organisatsioon, mis oleks võimeline geopargi ideed arendama ja administreerima, sealhulgas

esitama tunnustuse saamiseks taotluse Euroopa Geoparkide Võrgustikule ja UNESCO-le. (Euroopas on Euroopa Geoparkide Võrgustiku tunnustus eelduseks UNESCO tunnustussertifikaadi saamiseks).

Lugupidamisega
Alvar Soesoo
President

Eesti Geoloogia Seltsi president
telefon: 6203 012
faks: 6203 011

Kontaktisik
Krista Täht-Kok

Eesti Geoloogiakeskus
telefon: 6 720 093, 53 30 8729
faks: 6 720 091

Kalle Lehismets

Pikk 13a,
Toila
Ida-Viru maakond

Tiit Salvan

Pikk 13a,
Toila
Ida-Viru maakond

27.02.2008

Toila valla territooriumile UNESCO geopargi loomise kava.

Lugupeetud härra Lehismets
Lugupeetud härra Salvan

Pöördume teie poole Eesti Geoloogia Seltsi nimel ning soovime teada teie seisukohta Toila ja Kohtla valla territooriumile pankrannikule ja sellega piirnevale alale UNESCO nõuetele vastava geopargi loomiseks. Geopargi loomist kaalutakse põhjusel, et UNESCO eksperdid ei ole toetanud Balti klindi lülitamist UNESCO maailma looduspärandi nimekirja, kuid on soovitanud luua klindi piirkonda UNESCO poolt esitatavatele kriteeriumitele vastav geopark.
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Lugupidamisega
Tarmo All, Juhatuse liige

Eesti Geoloogia Selts
telefon: 6720371
faks: 6720091

Kontaktisik
Krista Täht-Kok
Eesti Geoloogiakeskus
telefon: 6 720 093, 53 30 8729
faks: 6 720 091

Jaan Mölder

Sadama 9
Paldiski linn
76806 Harjumaa

Sven Põder
Sadama 9
Paldiski linn
76806 Harjumaa

27.02.2008

Paldiski linna vallatavale territooriumile: Pakri saartele ja Paldiski poolsaarele UNESCO geopargi loomise kava

Lugupeetud härra Mölder
Lugupeetud härra Põder

Pöördume teie poole Eesti Geoloogia Seltsi nimel ning soovime teada teie seisukohta Pakri poolsaarele ja Pakri saartele, pankrannikule ning sellega piirnevale alale UNESCO nõuetele vastava geopargi loomiseks. Geopargi loomist kaalutakse põhjusel, et UNESCO eksperdid ei ole toetanud Balti klindi lülitamist UNESCO maailma looduspärandi nimekirja, kuid on soovitanud luua klindi piirkonda UNESCO poolt esitatavatele kriteeriumitele vastav geopark.
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Lugupidamisega

Alvar Soesoo, president
Eesti Geoloogia Selts
telefon: 6203 012
faks: 6203 011

Kontaktisik
Krista Täht-Kok
Eesti Geoloogiakeskus
telefon: 6 720 093, 53 30 8729
faks: 6 720 091

Ametlikku vastust töögrupp omavalitsustelt ei saanud, kuid Toila vald kutsus töögrupi liikmeid1 tutvustama geopargi põhimõtteid 6. aprillil toimunud valla volikogu koosolekule. Koosolekust võttis osa Krista Täht-Kok.

Nii Toila kui Kohtla valdadesse saadeti täiendavat informatsiooni geoparkide kohta.

From: Krista Täht-Kok

To: Tiit Salvan

Sent: Monday, April 21, 2008 3:32 PM

Subject: Täiendavat infot geopargi kohta

Lugupeetud Toila vallavalitsus ja volikogu,

tänan teid väga, et kutsusite mind valla volikogu koosolekule. Loodan, et geopargi loomise mõte äratas teis huvi. Oleksin pidanud rõhutama asjaolu, et Keskkonnaministeeriumi huvi ja toetus geopargi loomisele on olemas, kuid ministeerium ei anna otseselt selleks raha. Küll aga toetaks geopargi moodustamisega seotud projekte.
Sain ka aru, et selleks, et midagi konkreetsemalt teha, on vaja praktilist juhist. Saadan teile punktid, mis peavad olema UNESCO-le esitatavas avalduses.
Mul on olemas Wales'is asuva "*Fforest Fawr Geopark* avaldus "*Application for European Geopark Status*" ja ka juurdekuuluvad lisad. Mõlemate PDF failide suurus on üle 5 Mb. Kui teil on huvi ja teie postkast selle info vastu võtab, võin saata need materjalid näidiseks. Avalduse tegemine on tükk tööd ja seda tehakse tavaliselt kastööna mõne projekti finantseerimisel. Avaldus saadetakse inglisekeelsena 7 eksemplaris Prantsusmaal Digne-les-Bains linnakeses asuvasse Euroopa Geoparkide Võrgustiku peakorterisse.
(*When and where to send the application dossier*
The application dossier can be sent at anytime and will be evaluated during the next European Geoparks Network coordination committee meeting. These meetings are held three times per year.
The dossier must be sent (in 7 copies in English) to the Cellule de coordination.Please contact the Cellule de coordination to obtain more information on the application dossier (address following).

Cellule de coordination du réseau des European Geoparks
Réserve Géologique de haute Provence
B.P 156
O4005 DIGNE LES BAINS- Cedex
FRANCE
Tel: 00 33 4 92 36 70 72
Fax: 00 33 4 92 36 70 71
or by e-mail: s.giraud@resgeol04.org)

Saadan teile veel mõned Euroopa Geoparkise Võrgustiku weebilehtede aadressid, et saaksite rohkem otsest inot ja vajadusel oteseseid kontakte luua. Ka on väga kasulik käija EGV konverentsidel.
Sellel aastal toimub konverents Saksamaal Osnabrück'is (http://www.geoparks2008.com/). Olen saatnud sinna ettekande, kahjuks pole mul raha osaleda. Juhul, kui teil peaks olema võimalusi kedagi Osnabrücki lähetada, andke palun teada, kuni 15. maini on osavõtumaks veel 395 eurot.

Tänu ja lootusega koostööle

Krista Täht-Kok

Lisa: vt allpool.

From: Krista Täht-Kok

To: kohtlavv@kohtlavv.ee

Sent: Monday, April 21, 2008 4:05 PM

Subject: Täiendavat infot geopargi kohta

Lugupeetud Kohtla vallavalitsus ja volikogu,

Saadan teile täiendavat informatsiooni geopargi kohta. Tutvustasin 17. aprillil Toila valla volikogul geopargi põhimõtteid ja mulle jäi mulje, et huvi on olemas, kuid oleks vaja palju rohkem infot praktilise tegevuse kohta. Seda infot Eestis ei olegi ja kontakti peab võtma juba loodud geoparkidega Saksamaal, Tsehhimaal või Suurbritannias, kus olud on ehk Eestile lähemad. Meile lähim geopark asub Norras. (http://www.geanor.no/).
Euroopa geoparkide nimekiri:
http://www.europeangeoparks.org/isite/page/3,1,0.asp?mu=1&cmu=6&thID=0
Peaks rõhutama asjaolu, et Keskkonnaministeeriumi huvi ja toetus geopargi loomisele on olemas, kuid ministeerium ei anna otseselt selleks raha. Küll aga toetataks geopargi moodustamisega seotud projekte.
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Sellel aastal toimub konverents Saksamaal Osnabrück'is (http://www.geoparks2008.com/). Olen saatnud sinna ettekande, kahjuks pole mul raha osaleda. Juhul, kui teil peaks olema võimalusi kedagi Osnabrücki lähetada, andke palun teada, kuni 15. maini on osavõtumaks veel 395 eurot.

Lootusega koostööle

Krista Täht-Kok

Lisana saadeti mõlemale vallale väljavõte koostatavast aruandest:
UNESCO geopargi loomise võimalustest Põhja-Eesti klindile

Geoparkide loomine on maailmass küllaltki uus ettevõtmine. Esimesed geopargid loodi Euroopas aladele, kus suuri territooriumeid hõlmavad looduskaitsealad pärssisid majandustegevust ja pidurdasid nende piirkondade arengut.
Idee rakendada geoloogilised loodusmälestised piirkonna majanduse elavdamiseks kerkis üles Rahvusvahelisel Geoloogia Kongressilgeoloogiliste loodusmälestiste sektsioonis 1997. aastal. Seal formuleeriti geopargi peamine idee rakendda piirkonna geoloogilised loodusmälestised jätkusuutlikult majanduse teenistusse.
Peamiseks eesmärgiks geopargis on geoloogiliste loodusmälestiste kaitse ja säilitamine olemasoleval kujul ning piirkonna jätkusuutlik areng. Kõige sobivamateks tegevusvaldkondadeks geopargis on turism, põllumajandus ja mitmesugune käsitööndus ja väikeettevõtlus.
Analüüsides missugused võimalusi on Eestis rajada geoparki, mis võiks pälvida UNESCO tunnustuse, tuleks vaadata, missugused on UNESCO poolt esitatavad

nõudmised. Need nõudmised peegelduvad kõige paremini aruandes, mis UNESCO sertifikaadi saamiseks tuleb esitada eelkõige Euroopa Geoparkide Võrgustikule ja seejärel UNESCO-le. Euroopas asuv geopark peab eelkõige leidma tunnustuse Euroopa Geoparkide Võrgustiku poolt.

Part A) Description of the area
A osa) Piirkonna kirjeldus

1. Administrative part
1. Administratiivne osa. – tulevase geopargi administratsioon.

2. Identification of the territory
2. Territooriumi määratlemine – kohalike omavalitsuste, huvigruppide, … ja geoloogide ühistöö.

I. Geology and Landscape
I. Geoloogia ja pinnamood – geoloogide osa.

II. Management Structure
II. Korralduse struktuur – see on valdkond, kus tuleb koguda täiendavat infot teistest geoparkidest.

III. Information and Environmental Education
III. Keskonnaalane Informatsioon ja kasvatus – geoloogide ja kohaloke haridustöötajate osa (õpetajad nii koolis kui lasteaias).

IV. Geotourism
IV. Geoturism – tuleb võtta ühendust turismiettevõtetega, geoloogid, kohalikud giidid.

V. Sustainable Regional Economy
V. Regionaalne jätkusuutlik majandus – kohalikud omavalitsused ja kohalikud ettevõtjad.

Part B) Geoparks Progress Evaluation
Osa B) Geopargi edasine areng

1. Relationship with the European/Global Geoparks Network
1. Suhted Euroopa Geoparkide Võrgustikku kuuuvate ja teiste geoparkidega maailmas – kohalikud omavalitsused, geoloogid.

2. Management Structure and Financial Status
2. Korralduse struktuur ja majanduslik status kohalikud omavalitsused ja kohalikud ettevõtjad.

3. Geoconservation Strategy
3. Geoloogiliste loodusmälestiste kaitse korraldus – see on kaitseala haldaja töö

4. Strategic Partnerships
4. Strateegiline partnerlus – kohalikud omavalitsused ja kohalikud ettevõtjad

5. Marketing and Promotion
5. Geopargi tutvustamine ja reklaamimine ning marketing – kõik osalejad, geoloogid teevad seda teaduringkondades üle maailma pidevalt (artiklid Balti klindist, neugrundi meteooriidikraatrist jne).

6. Sustainable Economic Development
6. Jätkusuutlik majandamine ja selle arenguplaan – geopargi admin.

Paldiski linn ei ole võtnud töögrupiga kontakti, kuid Krista Täht-Kok on 10. märtsil osalenud Pakri Looduskeskuse töönõupidamise, kus looduskeskuse asutaja Hella Kingu, akadeemik Anto Raukase, Keskkonnaministeeriumi Keskkonnakorralduse ja tehnoloogia osakonna juhataja Rein Raudsep ning paljud teised. Tõdeti, et Pakri looduskeskus on valmis alustama ekskursioonide korraldamisega Pakri poolsaarele ja osutama majutusteenust.

Põhja-Eesti klindi tutvustamine rahvusvahelistel konverentsidel

Projekti käigus on tutvustati Põhja-Eesti klinti 2007 aasta mais Vaasas toimunud ProGEO ja Soome Geoloogi Keskuse (*Geologian tutkimuskeskus*). poolt korraldatud konverentsil (*Geodiversity and Geology for Nature Heritage. Vaasa, Finland, May 20–24, 2007*). Konverentsil esitati ettekanne: North-Estonian Klint – worthy candidate of the UNESCO World Cultural and Natural Heritage List or member of the European Geoparks Network?, mille autoriteks olid töögrupi liikmed: K., Täht-Kok, L, Ainsaar,O., Hints, A., Soesoo, K., Suuroja ja I., Tuuling, I.

Abstract:

North-Estonian Klint – worthy candidate of the UNESCO World Cultural and Natural Heritage List or member of the European Geoparks Network?

Krista Täht, Leho Ainsaar, Olle Hints, Alvar Soesoo, Kalle Suuroja and Igor Tuuling

Key words: geological heritage, nature protection, geosite, geotope, geotourism.

North-Estonian klint is the nature monument, that most Estonians consider as the Symbol of Estonian landscape. It runs nearly 300 km by North coast of Estonia and is certainly the most impressive part of 1200 km long Baltic Klint that takes its first forms in western part of Öland Island in Sweden, runs across the Baltic Sea to the North Estonian coast up to the vicinity of Lake Ladoga in Russia.
North Estonian Klint is obviously outstanding nature monument that exposes the Earth history about 560–440 million years in Cambrian and Ordovician. The sedimentary rocks here have not been subjected to metamorphosis or folding being remarkable in that regard. The Lower Paleozoic rocks of North-Estonian klint expose in big amount well-preserved fossils. Blue clay outcropping on the North Estonian Klint is unique in the world.
Neugrund Klint Island of the Estonian Klint is part of the best preserved meteorite crater of Paleozoic Era.
North-Estonian Klint have had remarkable role in Estonian history. The best example is our capital that was founded on klint island and towers over Tallinn up to today.
Alvars on the klint plateau with their thin but fertilr soils (Rendzinas) wher the first agricultural areas in Northern Europe. Ancient fields at Rebala (close to Tallinn) date back to more than 4000 years BP.

The Vikings also navigated by Baltic Klint escarpments at the beginning of their journeys to Russia 8th–11th century. On the eastern border of North Estonian Klint, on the banks of Narva Klint Valley, Peter the I st started to "break the window into Europe".
The North Estonian Klint is outstanding nature and cultural heritage for Estonians but also for most of geologists who visited it. The aim of UNESCO Estonian National Committee, Ministry of the Environment and geologists of different institutions is to see North Estonia Klint in the list of UNESCO World Heritage list.
Group of geologists are working on two directions to achieve the goal. It is considered the possibilities to submit the UNESCO World Heritage Committee a proposal to inscribe the North Estonian Klint (8 protected klint areas) on the World Cultural and Natural Heritage List or chose more longer way. Organize geopark on the areas on 8 protected klint areas and apply the North-Estonian Klint geopark to be admitted to the European Geopark Network and to get recognized by UNESCO as a geopark.

Klindi projekti tulemust tutvustatakse Ülemaailmsel Geoloogia Kongressil, mis toimub 2008. a augustis Oslos. Krista Täht-Kok teeb geoparkide ja geoturismi sektsioonis ettekande *North Estonian Klint: one landform two geoparks*.

Abstract

North Estonian Klint: one landform two geoparks

Krista Täht-Kok, Geological Survey of Estonia

The North Estonian Klint is a 300 km long central and the most impressive part of the 1200 km long escarpment system known as the "Baltic Klint". The Baltic Klint appears first in the western part of the Öland Island in Sweden; it then runs across the Baltic Sea to the northern coast of Estonia to finally reach the vicinities of Lake Ladoga in Russia.
The North Estonian Klint is an outstanding nature monument that exposes Earth's history of the Cambrian and Ordovician eras, from about 560 to 440 million years ago. The time span of the Klint covers the „Cambrian Explosion" and the major episode of the „Great Ordovician Bio diversification Event". For several invertebrate groups the North Estonian Klint is the place where the earliest discoveries for a wide variety of species originating in this age bracket were made.
Until today the North Estonian Klint is unveiling coastal escarpments that represent the very well developed structural boundary between the Fenno-Scandian shield and the East European craton. The North Estonian Klint has a prominent place in the history of the study of geological features and it brings to day many outstanding landscapes.
The idea to turn the North Estonian Klint into a Geopark is more and more taking shape. But Geoparks must not only highlight geological features, they must also be embedded in the interests of the local population in a variety of ways. Even though the North Estonian Klint is a continuous geological feature, there is a distinct social difference between the more rural Western part and the more urban Central and Eastern part. Any final decision on the creation of a Geopark must take the ambition of the local population into account.

Lisaks tutvustati Balti Klinti kahe rahvusvahelise geoloogilise konverentsi ja vastavate ekskursioonide raames:

MAEGS-15, 16–20 september 2007
15th Meeting of the Association of European Geological Societies "Georesources and public policy: research, management, environment". Excursion Guidebook. Edited by Anne Põldvere & Heikki Bauert. Geological Society of Estonia, Tallinn 2007. Valaste Vaterfall by Kalle Suuroja, lk 40-42; Baltic Klint in North Estonia by Kalle Suuroja, lk 58-63.

BSC-2007, 15–22 mai 2008
Seventh Baltic Stratigraphical Conference. Abstracts and Field Guide. Edited by Olle Hints, Leho Ainsaar, Peep Männik & Tõnu Meidla. Geological Society of Estonia, Tallinn 2008. Pakri cliff by Tarmo Kiipli & Olle Hints, 91-92; Baltic Klint at Saka and Valaste by Oive Tinn, lk 105-106.

Balti klint oli teemaks ka **Vabariikliku Noorgeoloogide kokkutuleku** ekskursioonil leides kajastust ekskursioonijuhis.

MAEGS-15
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15th Meeting of the Association of European Geological Societies

Georesources and public policy: research, management, environment

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Excursion Guidebook

Edited by Anne Põldvere & Heikki Bauert

EXCURSION STOP: VALASTE WATERFALL

Kalle Suuroja

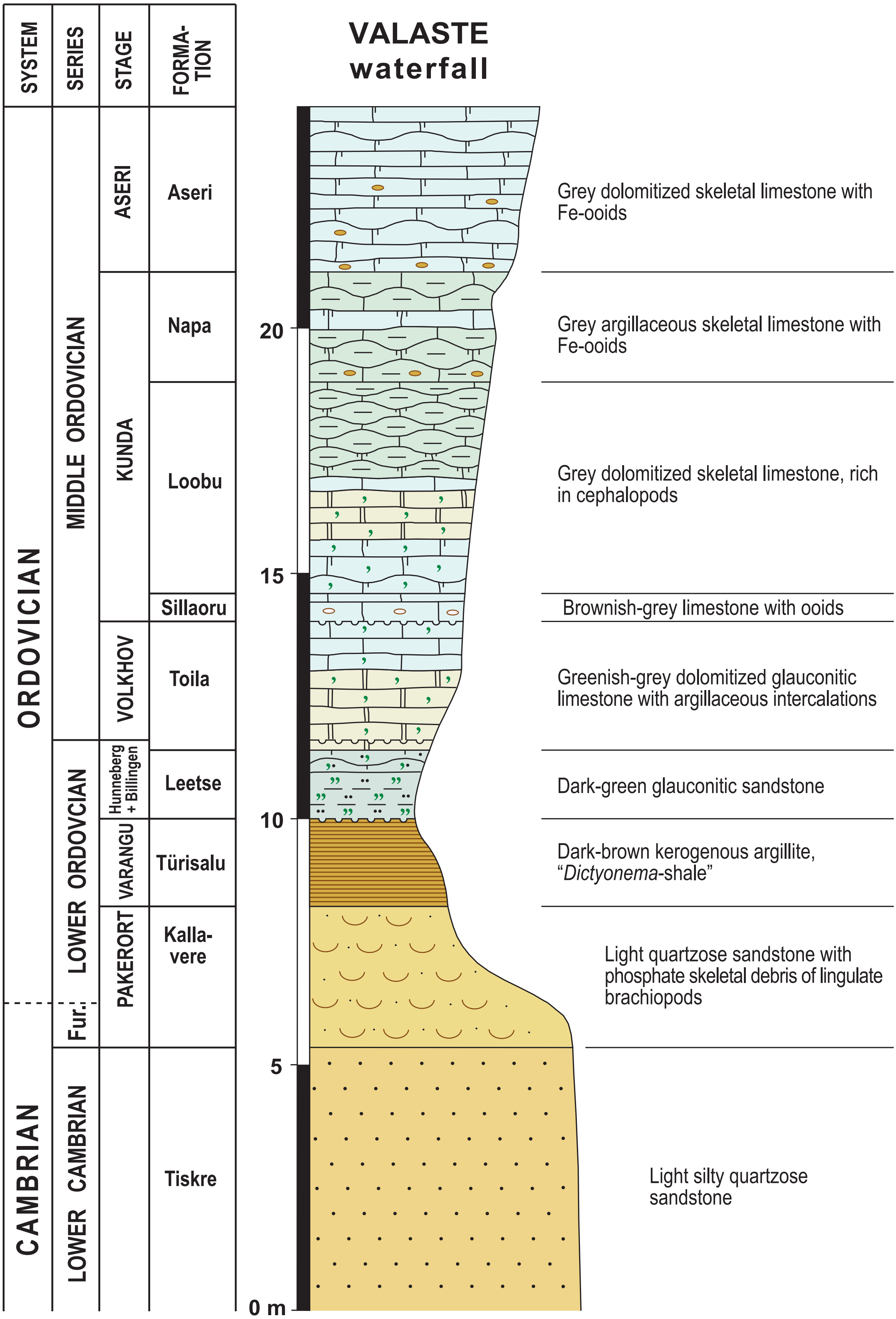
Valaste, the highest waterfall in Estonia, is on the western edge of Valaste village, Kohtla Municipality, Ida-Viru County, 2 km east of the Ontika Manor House. The water of the 7 km-long Kaasikvälja main ditch (also known as Valaste Brook), which comes from a 16 km^2 catchment area, runs in a canal more than 2 m deep cut into the limestone. The water from the canal falls off the edge of the 54 m high Saka-Ontika Klint plateau. The Valaste Waterfall has existed for more than 160 years. As early as 1840 the local German newspaper Inland wrote about it, calling it a "world wonder." A maximum height of the waterfall of 30 m was measured in the rainy month of August 1998, when the surging water cleared fallen rocks from the area underneath the falls and carved a cavity up to 3 m deep into the soft sandstone. The height of the waterfall has been 26 to 28 m. After the water tumbles from the main falls, it reaches a lower fall of 10 to 15 m, below which it turns into rapids just before reaching the sea. Of course, this happens only when there is enough water. At times (as during the dry summers of 1999 and 2002), not a single drop of water makes it over the falls. With ample water, the Valaste Waterfall is beautiful and powerful; without water it is just beautiful. This applies mostly to the wall behind the fall, which is more than 35 m high. Here multicolored rock layers of Estonia's crust are exposed. They layers formed over 80 million years (460 to 540 million years ago).

A beautiful bridge has been built directly in front of the waterfall. From the bridge, a complete and panoramic view can be had of the water as it falls from the plateau. The bridge is called *The Bridge of Sighing*.

The cross-section of the earth's crust revealed in the Valaste Waterfall escarpment starts with a layer almost 2 m thick of the surface cover consisting of both moraine and sea shingles. The presence of moraine shows that the continental glacier was once here. The shingles tell us that the sea has followed the glacier. The surface cover is succeeded by a layer more than 13 m thick of Middle Ordovician limestone. The upper 3.5 m is grey limestone (Aseri Stage), which is followed by 6.5 m of the limestone of the Kunda Stage containing numerous petrified cephalopods, and 2.5 m of glauconite limestone (Volkhov Stage). The limestone is underlain by softer Lower Ordovician layers comprising 0.6 m of multi-colored glauconite limestone (Päite Member of the Billingen Stage), 1.3 m of green glauconitic sandstone of the Leetse Formation of the Hunneberg Stage, 2 m of dark brown Dictyonema Shale of the Türisalu Formation of the Varangu Stage, and 0.5 m of Obolus sandstone or phosphorite of the Pakerort Stage corresponding to the Kallavere Formation. Below that level lie Lower Cambrian rocks reaching 530 million years in age. The rock succession is composed of 12 m of yellowish-grey quartz sandstone of the Tiskre Formation followed by 11 m of quartz sandstone, with the layer of blue clay corresponding to the Lükati Formation. When the water level is normal, the upper layers of the latter formation are the last ones that are exposed. However, during the spring melt, the upper part of the blue clay layer can be exposed within the range of a couple of meters. On the shores of the valley downstream of the waterfall the *blue clay* (Lontova Formation) is exposed; the thickness is about 10 m. That layer is a famous feature of the Estonian Cambrian, even though the clay is not as blue as the name implies. Rather, it is greenish-grey with some purple stains.

During the spring melt in the afternoon sunlight it is possible to see the extent to which the seawater around the mouth of the brook has obtained a reddish color. The reddish color is probably caused by floating particles that have broken loose from the brook bed and been carried out to sea. Sometimes the fan-shaped discoloration in the sea around the mouth of the brook can cover an area up to half a kilometer wide.

Everything described above can be recognized, admired, and even touched in the waterfall's steps



Geological section of the Baltic Klint at Valaste waterfall (Tinn, O., Stop 10. Valaste waterfall, WOGOGOB-2004 Conference Materials, Tartu 2004, modified after Fig. 138)


View of the Valaste waterfall

and the walls of the valley underneath it. However, an even more striking experience can be obtained when standing at the foot of the waterfall with one's head tilted back, looking up at the amphitheatre-shaped falls. If one hears the rushing sound of falling water and sees the rainbow in the mist among the trees, then one has experienced everything that Valaste has to offer.

With the first serious frosts, a huge ice monument begins to form, extending down from the top of the falls. It is surrounded by a shiny lace of icicles that hang down for about 5 m against the backdrop of the cliff. Any substantial melt or more serious temperature drop adds new details to the construction. In early spring nothing new might be seen, yet a faint noise of rushing water somewhere underneath the thick icicle covering can be heard. Then, without notice, the invisible becomes visible once again, as the water that comes from underneath the ice castle gives it a final push off the edge and down the side of the cliff.

BALTIC KLINT IN NORTH ESTONIA

Kalle Suuroja

The Baltic Klint is a system of erosional escarpments in Lower Paleozoic (Vendian to Ordovician) sedimentary rocks. The system generally follows the boundary between the Fennoscandian (Baltic) Shield and Russian Plate. The Baltic Klint, 1,200 km long in a beeline, starts from the sea bottom near Öland Island in Sweden and runs across the bottom of the Baltic Sea and the North Estonian coast up to the vicinity of Lake Ladoga (the Syass River) in Russia.

The Baltic Klint is a *cuesta*-like structure (Spanish *cuesta*, "escarpment"), formed largely due to a slight (1 to 5 m/km) southward dip of the sedimentary rocks cropping out on the escarpments. Even more important in the formation of the escarpments than the dip of strata has been the resistance of the rocks to weathering. The escarpments have formed in largely the same rock complexes regardless of their altitude. The boundary between limestone and sandstone complexes lies more or less at the sea level on Osmussaar Island, while in the depression of the Neugrund meteorite crater it lies at 24 m below sea level. East from the northern part of Väike-Pakri Island, it is above sea level everywhere: elev. 1 m on Cape Pakri, 38 m at Lasnamäe in Tallinn, 32 m at Jägala Waterfall, 40 m on the Muuksi Klint Cape, 60 m at Sagadi, 50 m near Kunda, 43 m at Ontika, and 10 m in Narva. On the Öland Klint, this surface is 20 m below to 30 m above sea level, dropping down to 170 m below sea level at the bottom of the Baltic Sea. On the Ingermanland Klint, in the vicinity of St. Petersburg in Russia (in Koporye), which is the highest point of the limestone plateau of the Baltic Klint, this boundary rises to 130 m above sea level. Thus, the differences in altitude of this boundary surface at the Baltic Klint range up to 300 m!

The formation of escarpments on the Baltic Klint is associated with several long-term processes: land uplift has alternated with subsidence, rise of sea level with fall, invasion of glaciers with melt, formation of escarpments with leveling. A great part of the North Estonian Klint visible on land has been shaped during the period following the latest glaciation (i.e., during the last 12,000 years or so). The Baltic Ice Lake began to abrade escarpments on the side of the North Estonian

Limestone Plateau at the levels that currently extend to the slope of the Pandivere Upland, at up to 70 m above sea level. Escarpments are never formed in an empty place; they all presuppose the existence of an earlier, steeper slope. Postglacial abrasion has strongly reshaped the earlier escarpments; they have decreased in number and become steeper and higher. In the higher areas of the Ingermanland Klint (elev. 60 m and more) and at the bottom of the Baltic Sea, where the escarpments have not been reshaped by postglacial abrasion, they slope gently; that is, they slope more or less as they sloped after the retreat of the last continental glacier.

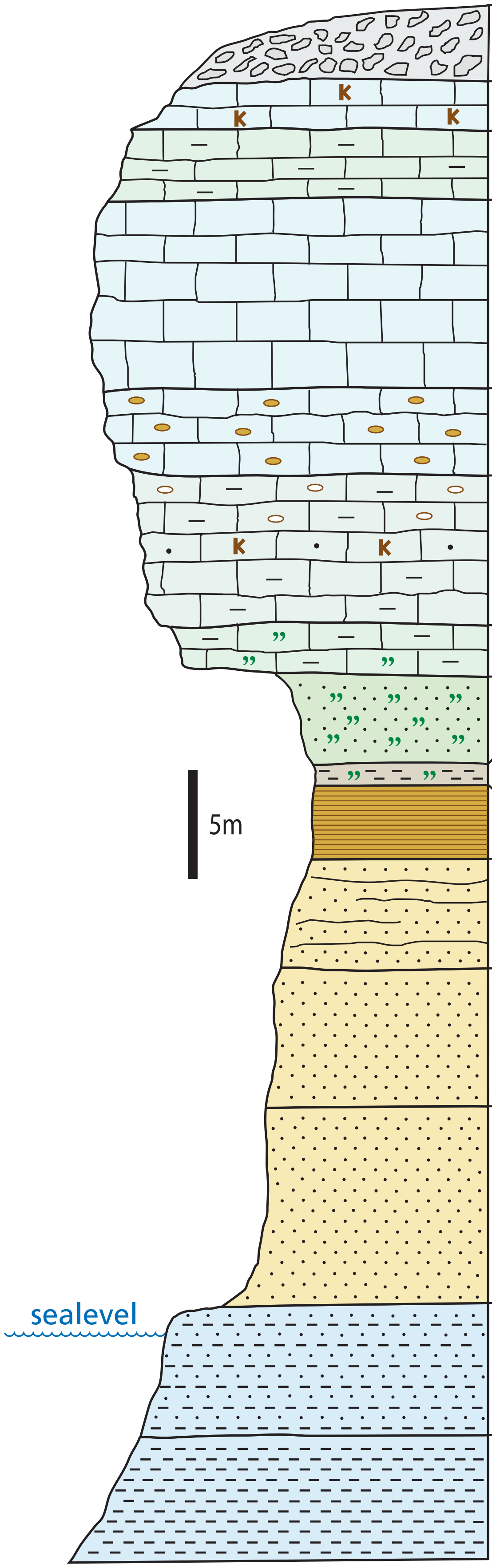
The few places on the Baltic Klint the sea is still abrading escarpments into bedrock: in just about 160 km of the 1,700 km of the escarpment line, with most of it (about 130 km) located on the North Estonian Klint and the remaining 30 km on the Öland Klint. The 130 km are distributed across the North Estonian Klint as follows: 17 km fall within the North–West Estonian Klint section (Osmussaar, Suur-Pakri and Väike-Pakri Islands), 43 km in the West Harju Klint section (Pakri, Türisalu, Suurupi, and Kakumägi Klint Peninsulas) and 70 km in the East Viru section between Kalvi and Udria.

Abrasion was particularly intensive in places where hard Ordovician limestones are underlain by softer Lower Ordovician and Cambrian sandstones. Here the rate of the retreat of the escarpments is determined by the resistance of relatively soft sandstones to weathering. Good reference points for measuring the rate of the retreat of escarpments, which is a rather slow process, are scarce. Still, the lighthouse built on Osmussaar in 1765 provides one such reference point. E. Eichwald writes in his travelogue (1840) that the lighthouse is said to have been built at a distance of 7 fathoms (1 Russian fathom = 2.16 m) from the escarpment edge. Today, the retreating klint escarpment has "swallowed" the old lighthouse so that only a few blocks of its foundation have been preserved. Thus, the klint escarpment has retreated by nearly 17 m in 240 years, or about 7 cm per year.

The speed of the retreat of the klint varies, reaching in places up to 10 and even more centimeters per year. For instance, during the storm of

Baltic Klint from air

Composite section of North Estonian Klint

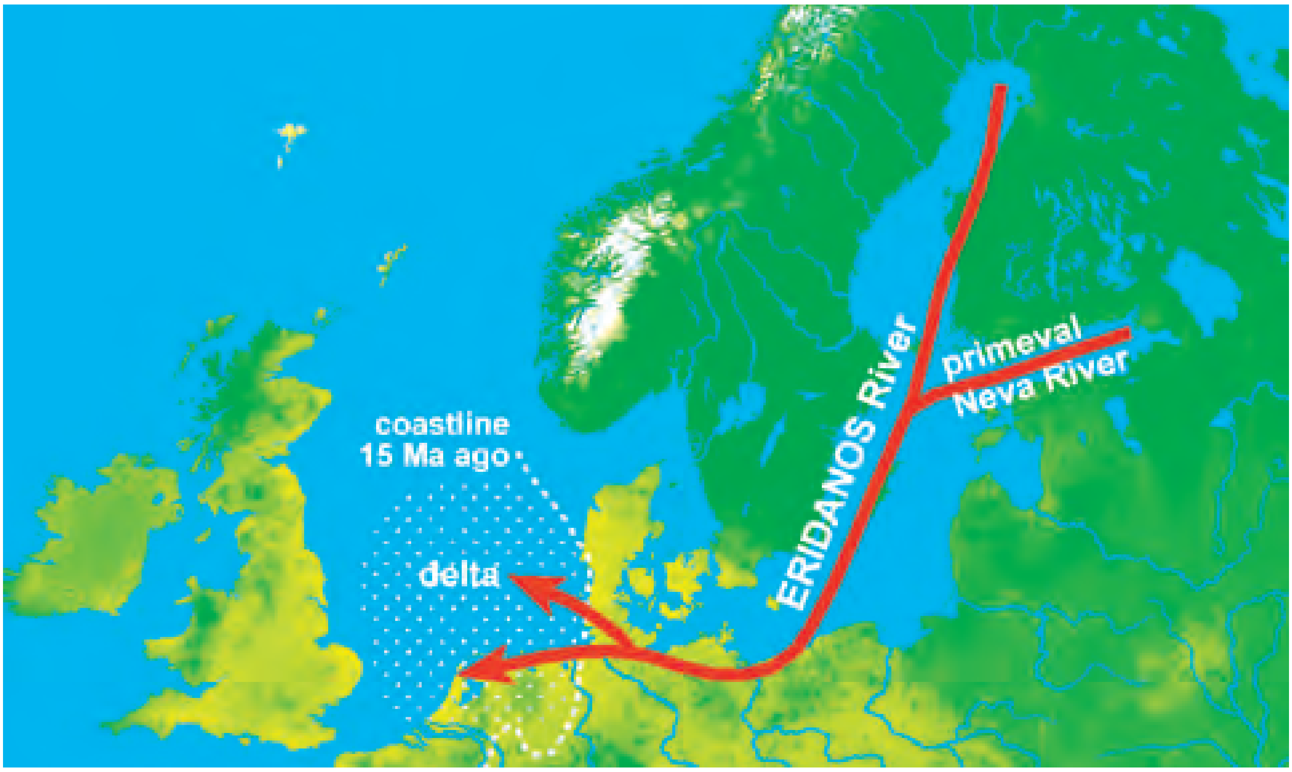


FORMATION		System	Series
Pihla	limestone (may contain kukersite kerogen)	ORDOVICIAN	Upper Ordovician
Kõrgekallas	argillaceous limestone	ORDOVICIAN	Middle Ordovician
Väo	limestone *"building limestone"*	ORDOVICIAN	Middle Ordovician
Kandle	limestone with Fe-ooids	ORDOVICIAN	Middle Ordovician
Pakri + Sillaoru + Loobu	limestone - sandy at certain levels, contains ooids and kukersite kerogen	ORDOVICIAN	Middle Ordovician
Toila	glauconitic dolostone	ORDOVICIAN	Middle Ordovician
Leetse	glauconitic sandstone	ORDOVICIAN	Lower Ordov.
Varangu	clay ja glauconite sand	ORDOVICIAN	Lower Ordov.
Türisalu	dark-brown kerogenous graptoliteargillite	ORDOVICIAN	Lower Ordov.
Kallavere	sandstone with interbeds of graptoliteargillite and shelly phosporite	CAMBRIAN	Furongian
Ülgase + Tsitre	silty sandstone with shells of lingulate brachiopods	CAMBRIAN	Furongian
Tiskre	mostly silty sandstone	CAMBRIAN	Lower Cambrian
Lükati	interbedded clay and silty sandstone	CAMBRIAN	Lower Cambrian
Lontova	clay *"blue clay"*	CAMBRIAN	Lower Cambrian

January 2005, the sandstone escarpment at the top of the Kakumägi Klint Peninsula retreated by up to a meter in places (Suuroja & Suuroja 2005), and not only due to the downfall of single mega-blocks but as a general process.

The Baltic Klint emerged from the last continental glacier some 11,000 years ago, with the Öland Klint and Ingermanland Klint emerging somewhat earlier and the Baltic Sea Klint and North Estonian Klint a bit later still. If we knew the position of the klint immediately after the retreat of the ice, it would be easy to calculate the rate of its retreat. In the North–West Estonian Klint section (Osmussaar and Pakri islands) and the West Harju section (Pakri Peninsula, Türisalu, etc.) and in some more places farther to the east, limestone or sandstone terraces a few dozen to a few hundred meters wide occur in the sea in front of the klint. On klint peninsulas extending far into the sea (Osmussaar, Pakri, etc.), this terrace can be even wider than a kilometer. It is possible that this is where the escarpments of the Baltic Klint started their postglacial retreat after their emergence above sea level.

Baltic Klint at Martsa, NE Estonia



Several hypotheses on the reasons for and time of the formation of the Baltic Klint have been put forth, with most of them associating it with the erosive action of water, either in its fluid or solid state. Few authors have made an attempt to associate the formation of the Baltic Klint with a single phenomenon, yet one reason has usually been preferred to others. The following names, rather arbitrarily attributed to the hypotheses, refer to the phenomenon regarded as the dominating one.

The **tectonic hypothesis** is one of the most widespread hypotheses explaining the formation of the klint. Supporters of this hypothesis suggest that the formation of the Baltic Klint (and, naturally, the North Estonian Klint also) is in one way or another connected with a tectonic fault running nearby along the southern border of the klint zone.

The joints and faults shaping the formation of the klint have been sought from the zone of the Baltic Klint with a variety of methods, mainly from the sea bottom, but they have not been found. There exist joints and faults there, of course, yet their direction does not coincide with that of the Baltic Klint but intersects with it at some angle. Besides, it is difficult, if not impossible, to explain the multitude of escarpments in the klint zone and the formation of the broad (up to 40 km) terraces in between with faults only.

According to the **glacial hypothesis**, continental glaciers contributed to the formation of the Baltic Klint. As supposed, the North Estonian Klint was lifted up by a glacier arriving from the north across the Gulf of Finland and gliding along the surface of Cambrian sandstones.

There is no doubt that continental glaciers have swept over the Baltic Klint repeatedly and shaped it in some way. But their impact has been a secondary factor (i.e., it has leveled the already existing escarpments rather than created new ones). When depicting the Baltic Klint as a bank of a glacier valley, as the supporters of the glacial hypothesis have done, one is immediately faced with difficulties, as the more or less southwest-northeast trending Baltic Klint runs transverse to rather than parallel with the roughly north–south movement of continental glaciers that once swept across it. The action of continental glaciers is traceable also in klint bays and valleys incised into klint escarpments, but this action has been limited to the reshaping of the already existing (i.e., preglaciation), valleys and bays.

The supporters of the **abrasional hypothesis** state that the escarpments of the Baltic Klint were shaped primarily by abrasion, with waves abrading the rocks and currents carrying off the clast. This hypothesis is weak. It fails to explain where the huge quantity of clastic matter from the abraded escarpments has gone, because it is not found at the bottom of the Baltic Sea.

According to the **denudational hypothesis**, the Baltic Klint was formed mainly by denudation – the leveling of ground surface by external impacts (temperature, wind, water). The escarpments of the Baltic Klint began to form about 40 million years ago in the Paleogene. The supporters of that hypothesis associated the process with the jointing and divergence of the Earth's crust in the East Atlantic (west of Norway) in this period, which in turn led to a significant rise (up to 400 m) in the Earth's surface in the region of the future Baltic Sea. The escarpment on the boundary between the crystalline basement and sedimentary rocks was formed first, and the other, more southerly escarpments were formed later, as the invasion of the sea progressed or the erosional basis of the giant river increased.

According to the **Pra-Neva hypothesis**, the Pra-Neva River emanated from the area of the White Sea and flowed west along the boundary between hard crystalline rocks of the Baltic (Fennoscandian) Shield and the softer sedimentary rocks covering the Russian Plate. The Pra-Neva, flowing on a hard, more weathering resistant crystalline basement (gneisses, granites, migmatites, etc.) with a slight southward dip (2 to 3 m per km), was denuding its southern bank (consisting of softer sedimentary rocks) more intensively and therefore itself shifted, too, gradually southward. The Pra-Neva hypothesis explained the removal of the clastic matter from the Baltic Klint area but failed to explain where it went. A giant complex (up to 1.5 km thick, on about 100,000 km^2) of clastic deposits about 1 to 10 million years old has been found in recent years at the bottom of the North Sea west of the Danish Straits, in an area called the Eridanos Delta. This has been supposed to be the "lost material" carried off the denudation area of the Baltic Klint by the hypothetic giant (up to 2,700 km long) river Eridanos, which began somewhere in the area of Lapland and ran across the eastern part of the Gulf of Bothnia and the western part of the Baltic Sea down to the Polish coast and from there across Denmark and the north German coast into the North Sea. The Pra-Neva was merely one of the few eastern tributaries of this giant river. The Eridanos River ceased to exist about a million years ago, after the invasion of a continental glacier.

The Eridanos River got its name from an Old Greek legend according to which Phaeton (Faeton), son of Helios, was pushed down from the Vault of Heaven by Zeus with a lightning bolt and fell into this very river invisible to the human eye. The Heliades (daughters of Helios, god of the sun) came to the banks of the river to bewail their slain brother. Their bodies turned into poplars and their tears into amber. In the legends, the Eridanos River has been most often associated with the River Daugava (or Gauja). However, it is difficult, if not impossible, to explain the formation of both the Baltic Klint and the other klint escarpments on the Baltic Sea as well as the terraces separating them with the Eridanos only. If it was the Eridanos, then why did it not flow across the Baltic Deep but across a limestone plateau more than 100 m higher? Neither the Eridanos nor the tectonic fault zones at the bottom of the Baltic Sea cared about the Baltic Klint, as both of them intersected it without leaving any traces. Also the formation of the high escarpments and broad terraces abraded into limestones and clays is difficult to explain by river erosion only.

Geological Society of Estonia
Baltic Stratigraphical Association
Institute of Geology at Tallinn University of Technology
Institute of Ecology and Earth Sciences, University of Tartu
Geological Survey of Estonia

THE SEVENTH BALTIC STRATIGRAPHICAL CONFERENCE

ABSTRACTS & FIELD GUIDE

7th Baltic Stratigraphical Conference

17-18 May 2008
Tallinn, Estonia

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Stop A9: Pakri cliff (see also stop B3)

by Tarmo Kiipli and Olle Hints

The coastal cliffs on Pakri Peninsula provide some of the best exposures of Cambrian and Lower- and Middle Ordovician rocks in Estonia. They are part of the Baltic Klint (or North Estonian Klint) — a nearly 1200 km long escarpment that runs from Öland, Sweden, through the Baltic Sea and North Estonia to NW Russia. The scenery Pakerort cliff, to be visited during the excursion, is up to 24 m high and one of the most important geoturism sites in Estonia (Figs A13 and A14). The following succession from base to top can be observed (after Mens & Puura, 1996):

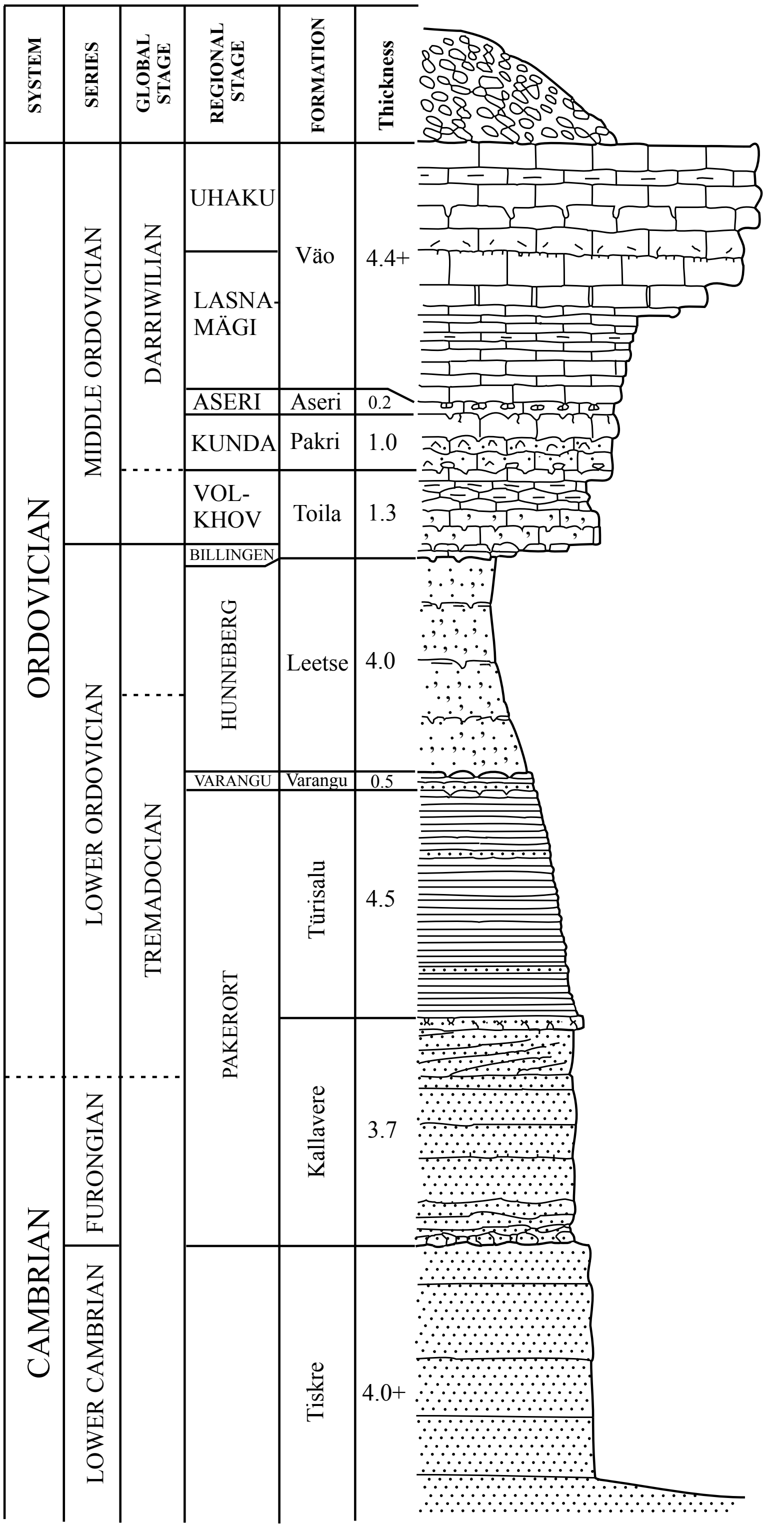

Fig. A13. Composite section of the Baltic Klint in Pakri Peninsula after Mens & Puura (1996)

Tiskre Formation (Lower Cambrian) is represented by light gray silty sandstones of which up to 4 m is exposed.

Pakerort Stage (Furongian–Tremadocian) consists of sandstones of the Kallavere Formation (3.7 m) and dark brown graptolite argillite (Dictyonema Shale) of the Türisalu Formation (ca 4.5 m). The Cambrian-Ordovician boundary lies within the sandstones.

Varangu Stage (Lower Ordovician, Tremadocian) is represented by greenish-gray clay and silty sandstone (0.5 m, poorly exposed).

Hunneberg and Billingen stages (Lower Ordovician, Tremadocian-Floian) is represented by greenish-gray glauconitic sandstones of the Leetse Formation (ca 4 m) and calcareous silty sandstones and glauconitic packstone of the lowermost Toila Formation (0.3 m).

Volkhov Stage (Middle Ordovician, Dapingian) consists of highly condensed grey limestone with glauconite (ca 1 m).

Fig. A14. Uuga cliff on Pakri Peninsula where Early Ordovician glauconitic sandstones and Middle Ordovician limestones can be easily reached. Photo by O. Hints.

Kunda Stage (Middle Ordovician, Dariwillian) is represented by sandy limestones of the Pakri Formation (1 m). In this interval the oldest kukersite, which in Uhaku and Kukruse stages forms the commercial oil shale deposits in NE Estonia, has been found.

Aseri Stage (Middle Ordovician, Dariwillian) is represented by 0.2 m of oolithic limestone.

Lasnamägi and Uhaku stages (Middle Ordovician, Dariwillian) make up the main limestone part of the top of the cliff composed of argillaceous limestone and dolomite of the Väo (ca 5 m) and Kõrgekallas formations (up to 1.5 m in southern part of the cliff).

No bentonites have been recorded in the Pakri cliff. However, some authors (Petersell, 1997 and references therein) have suggested that the K-feldspar-rich Türisalu Formation (graptolite argillite or Dictyonema Shale) may be related to volcanic activity.

Stop A10: Peetri outcrop

by Tarmo Kiipli

The Peetri outcrop is located north of the Tallinn-Keila road near Hüüru. In a small quarry and entrance into subsurface tunnels altogether 13 metres of Upper Ordovician argillaceous limestones are exposed. The lower part of the section corresponds to the Kukruse Stage and includes also small intercalations of kukersite oil shale. The thickness of kukersite oil shale interbeds grows eastwards and in NE Estonia they are heavily mined for chemical industry and for power plants.

The upper part of section belongs to the Haljala Stage, the lower part of which (Idavere Substage) contains two 5 cm thick volcanic interbeds. They belong to the Grefsen series of K-bentonites of Bergström et al. (1995).

Stop B3: Baltic Klint at Saka and Valaste

by Oive Tinn

The Baltic Klint is one of the most extensive outcrops of the Lower Palaeozoic rocks in the world. The length of the Baltic Klint is 1100–1200 km, the height reaches 56 meters. The Klint emerges at the western coast of the Öland Island in Sweden, extends along the southern coast of the Gulf of Finland and reaches up to the Ladoga Lake in Northwest Russia. The nearly 300 km long North Estonian Klint is a part of

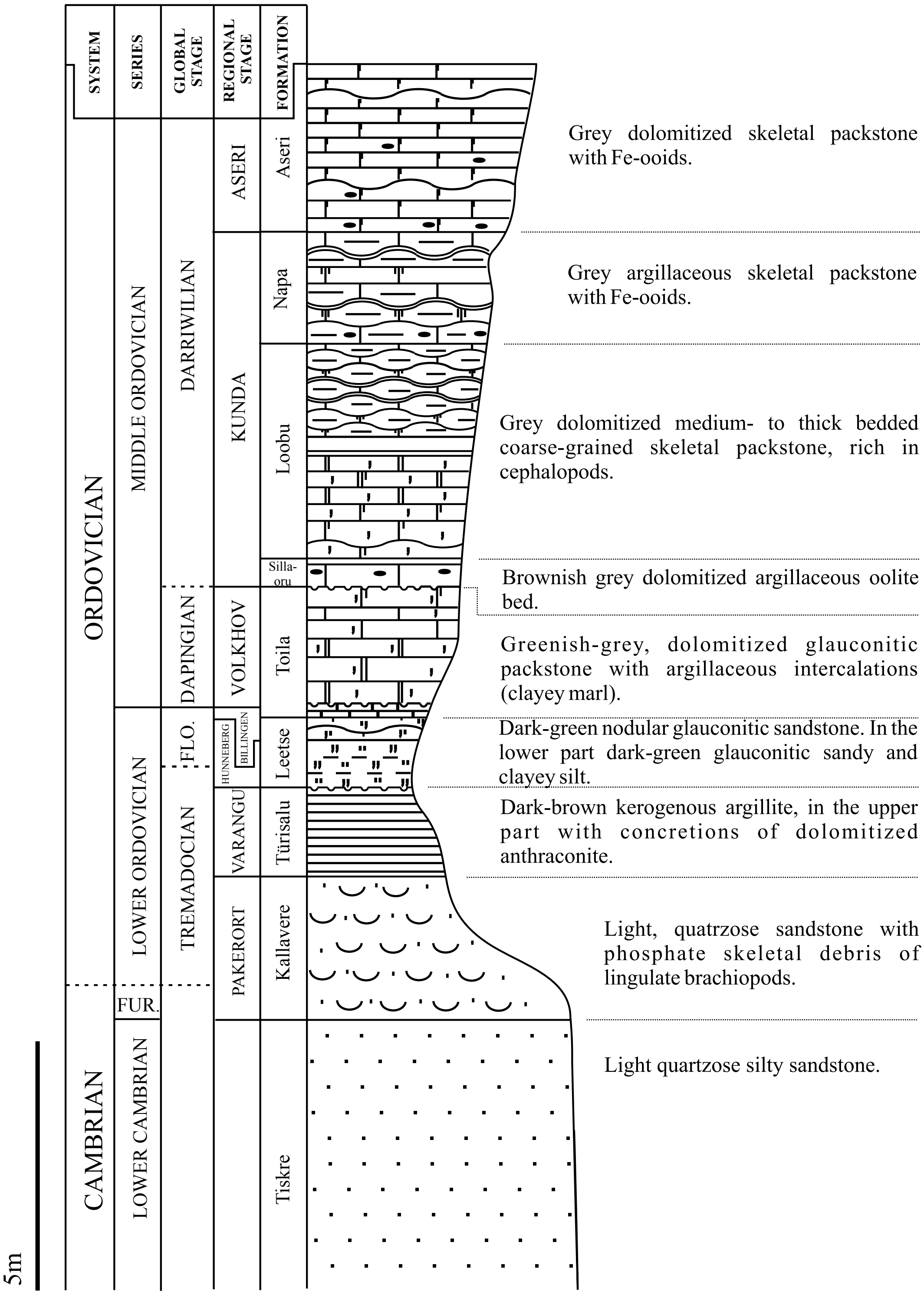

Fig. B10. The Valaste section.

Fig. B11. A View of the Saka trench section. Photo by T. Meidla.

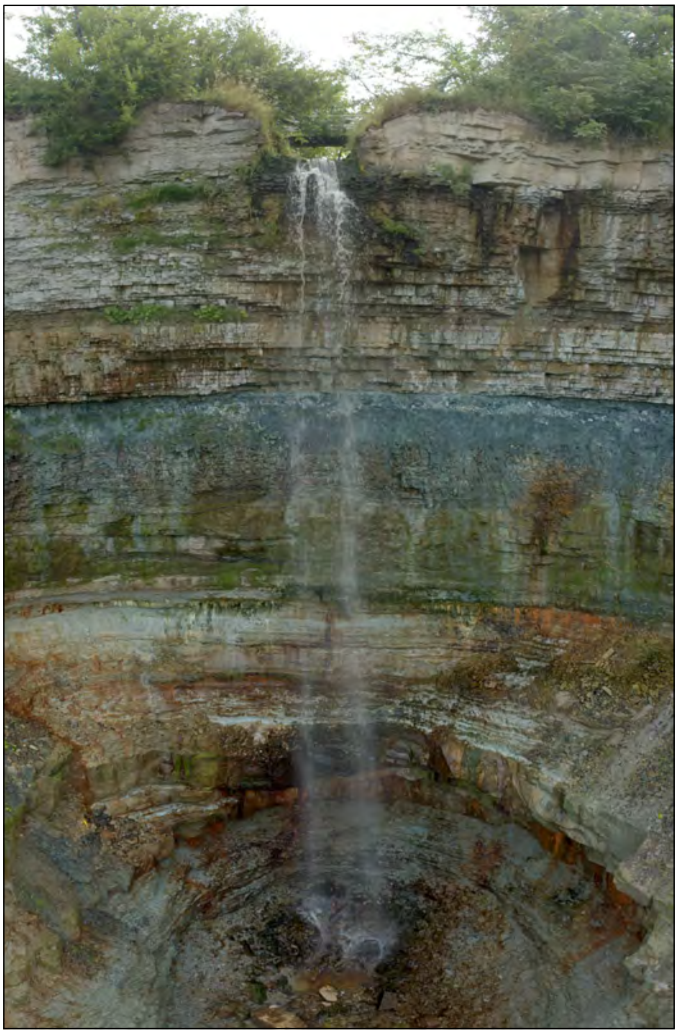

Fig. B12. Valaste waterfall. Photo by O. Hints.

this large structure. The Estonian National Committe of the UNESCO has accepted the Baltic Klint as a candidate for the world heritage site. Geologists value the Baltic Klint mostly because of the extraordinary preservation of the Lower Palaeozoic rocks that have not been subject to deep burial or folding.

The artificial Valaste waterfall (Figs B10 and B12), falling from the 54 m high North Estonian Klint is the highest waterfall in Estonia. Its height is usually between 26 and 28 m, but after exceptionally heavy rainfalls the strong flow may erode a deep pit into the sandstone on the foot of the Klint and the total height of the waterfall can reach up to 30 meters. Downwards, the waterfall continues as a rapid, flowing into the sea 10–15 m below.

Due to the slight southward dip of the limestone layers (3–4 m per 1 km) and the absence of water outlet, the fields in the Klint area have been suffering from excessive water during rainy seasons. At the beginning of the 19th century, a 7 km long and up to 2 m deep drain was made to aid water run off the manor's fields nearby. As a result, the water flow has cleaned and eroded the Klint wall, exposing the wonderful Lower Cambrian to Middle Ordovician sedimentary section.

The section (Fig. B10) is stratigraphically similar to that described in the Ontika Klint, 3 km west of Valaste (Mägi, 1990). It exposes the Lower Cambrian Ordovician sandstone (Tiskre Formation), Furongian to Lower Ordovician Sandstone (Kallavere Formation), black shale (Türisalu Formation), glauconitic sandstone (Leetse Formation) and Middle Ordovician limestone and dolomite (Volkhov, Kunda and Aseri stages). The banks of the stream below the Klint expose locally the "blue clay" of the Lower Cambrian Lükati formation. In 1999 a platform was constructed in front of the waterfall in order to make the observation of the site safer and more attractive.

The Saka section is situated 2 km west of the Saka village. The trench section — a 20–30 meter wide, as much deep and about 200 m long opening (Suuroja, 2006) — was cut into the Klint to lead the sewerage pipe from the nearby Kohtla-Järve city into the sea (Fig. B11) Basically, the seaward part of the trench shows the section from the Lower Cambrian Tiskre Formation up to the Middle Ordovician Aseri Formation (Fig. B10). However, a large part of the section is overgrown and so only the uppermost portion of the section (starting from the Volkhov Stage) is well observable.