



EESTI
GEOLOOGIAATEENISTUS

Mineral exploration in crystalline basement rocks of Estonia

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Mission

- The research work necessary for collecting geological information, and using and creating maximum value for extractable land resources, is executed in the volume and with the directions which at least maintain the existing knowledge base and keep it updated. The knowledge base is preferably enhanced with information characterising extractable land **resources with economic potential**.
 - General principles of Earth's crust policy until 2050

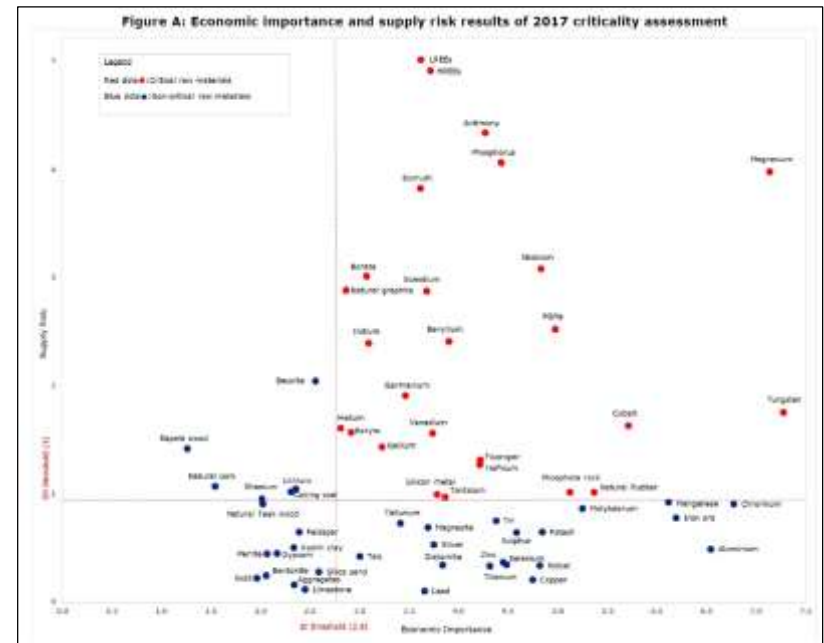
Mission

- **Resources with economic potential** – critical raw materials
- 30 year gap in ore exploration of crystalline rocks – our knowledge about critical resources from that time

Progress in technology



New critical raw materials



Study on the review of the list of Critical Raw Materials
2017, Executive summary

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New critical raw materials

Energy critical elements:

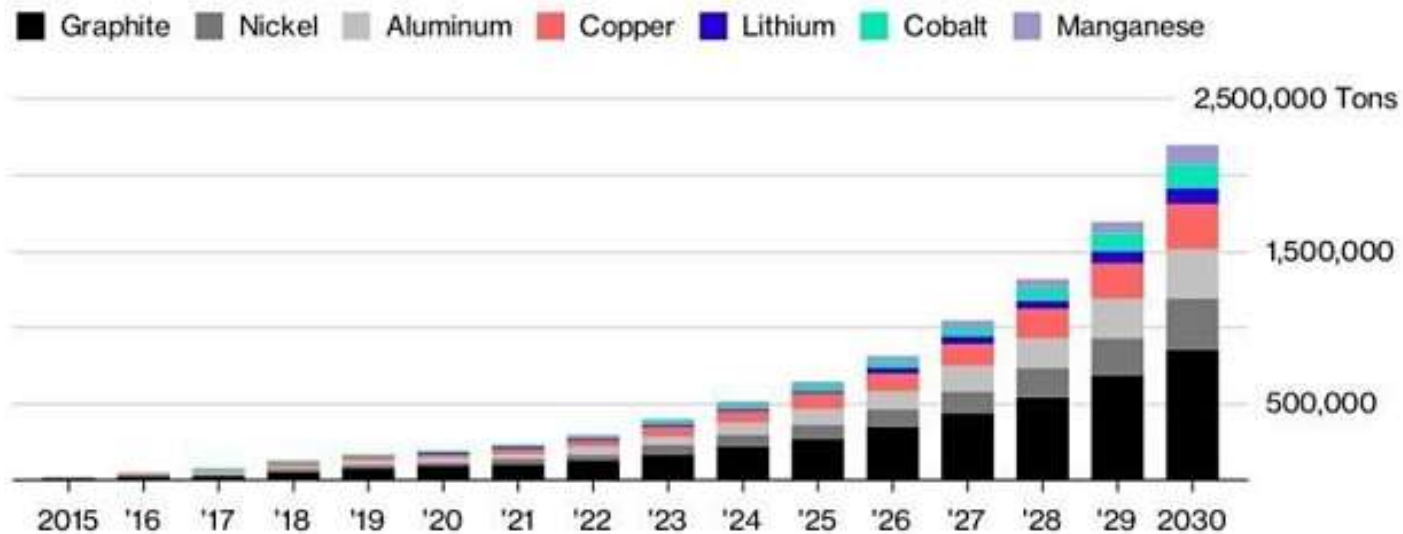
1 H Hydrogen 1.01																	2 He Helium 4.00				
Platinum Group Elements Rare Earth Elements Other ECEs Photovoltaic ECEs																					
3 Li Lithium 6.94	4 Be Beryllium 9.01															5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.31															13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.87	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.38	31 Ga Gallium 69.72	32 Ge Germanium 72.64	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80				
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.60	53 I Iodine 126.90	54 Xe Xenon 131.29				
55 Cs Cesium 132.91	56 Ba Barium 137.33	57 La Lanthanum 138.91	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)				
87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (265)	109 Mt Meitnerium (268)													
58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.97								
90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)								

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Metal Winners

Cobalt to lithium demand is forecast to soar as electric vehicle markets expand



Source: Bloomberg New Energy Finance.

From the beginning

- Engelhardt (1820): „Crystalline rocks that can be seen in Finland continue under sedimentary rocks of Estonia“
- 1899. Water well in Aseri intersecting 31.7 m crystalline rocks
- 1930... Beginning of magnetometric surveys
- 1937-1939 – First exploration drill holes in magnetic anomaly near Jõhvi (505 and 721.5 metres)

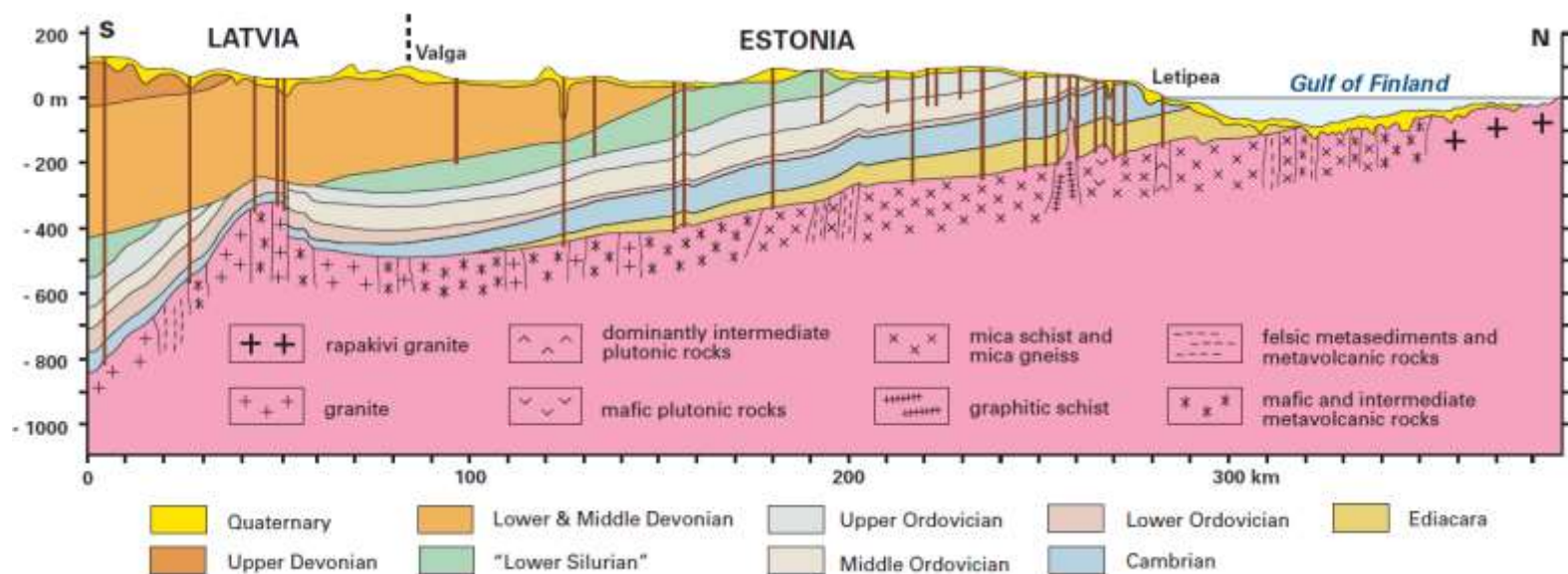
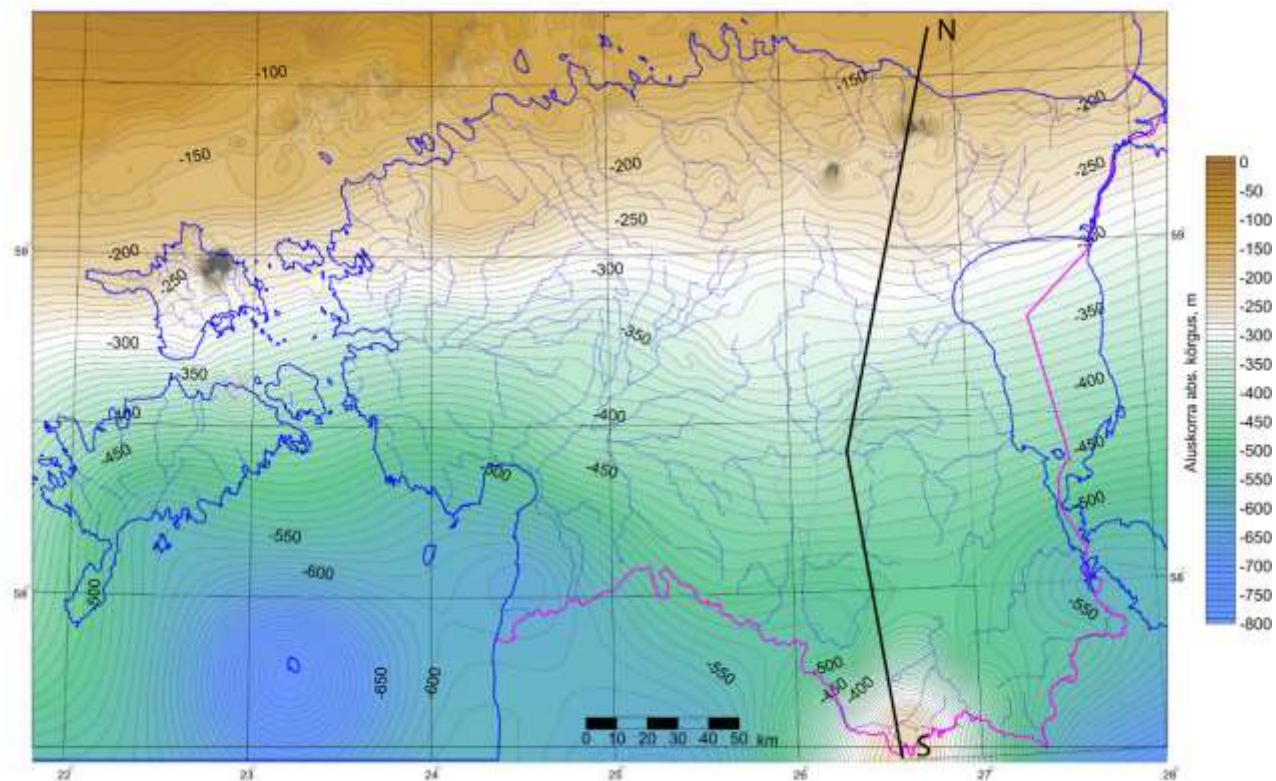


**Otto Moritz Ludwig von
Engelhardt**

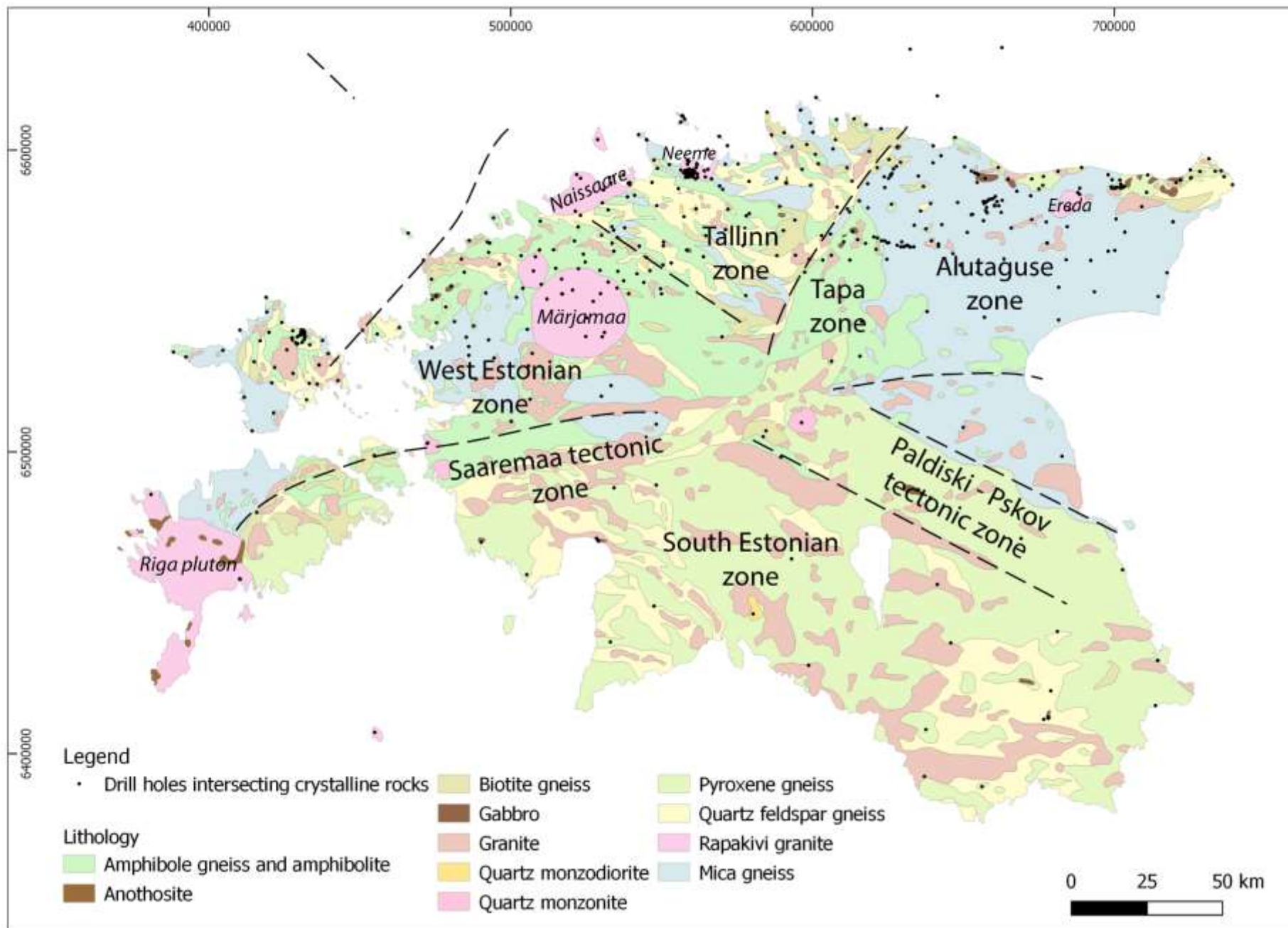
Exploration and bedrock mapping

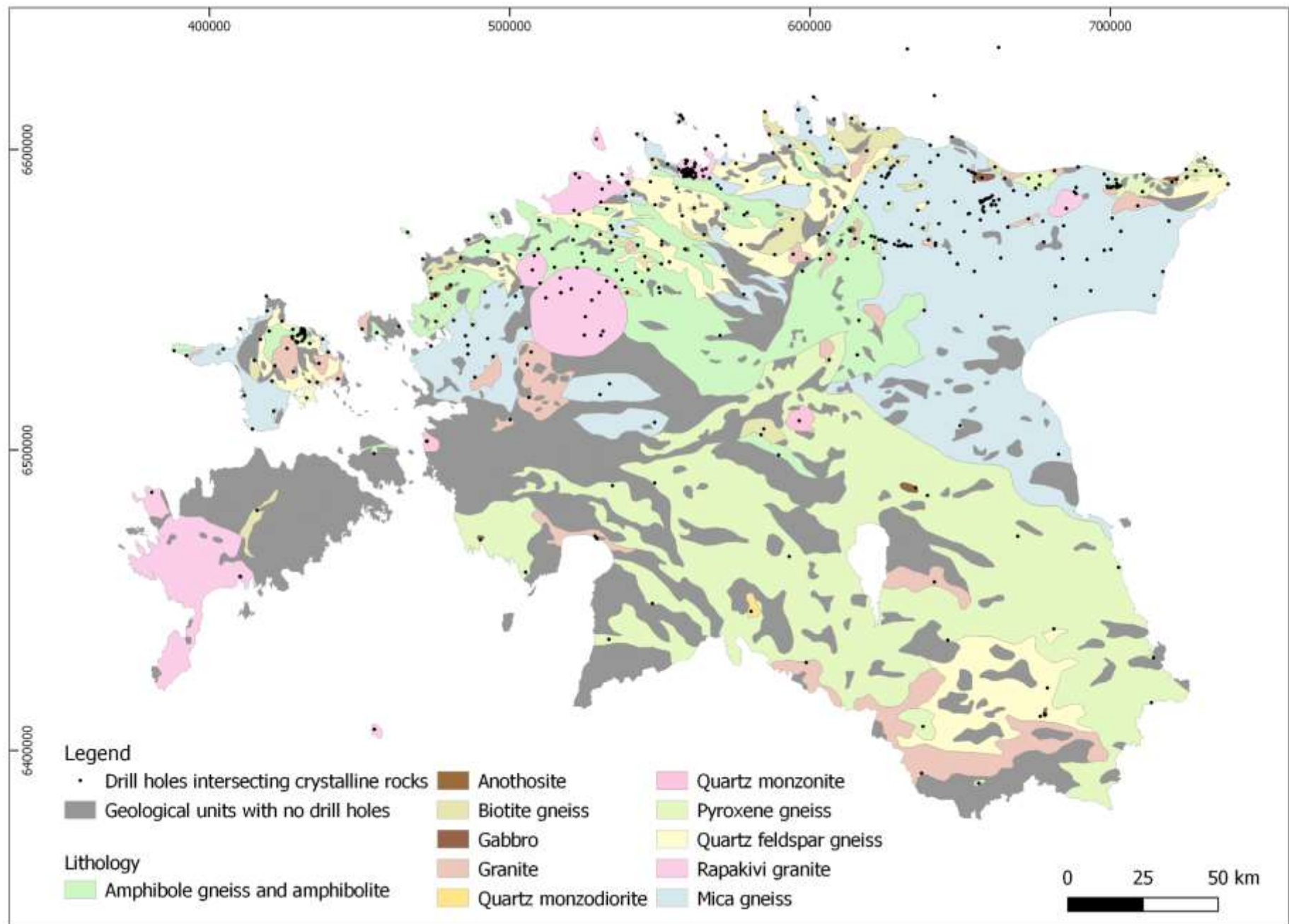
- 1960s - Soviet Union started investigating potential ore occurrences to the depth of 300 m
- Simultaneous bedrock mapping was carried out
- 508 holes drilled
- Thorough studies (10,000+ thin sections; 25,000+ chemical analyses)
- Highly uneven distribution of drillholes

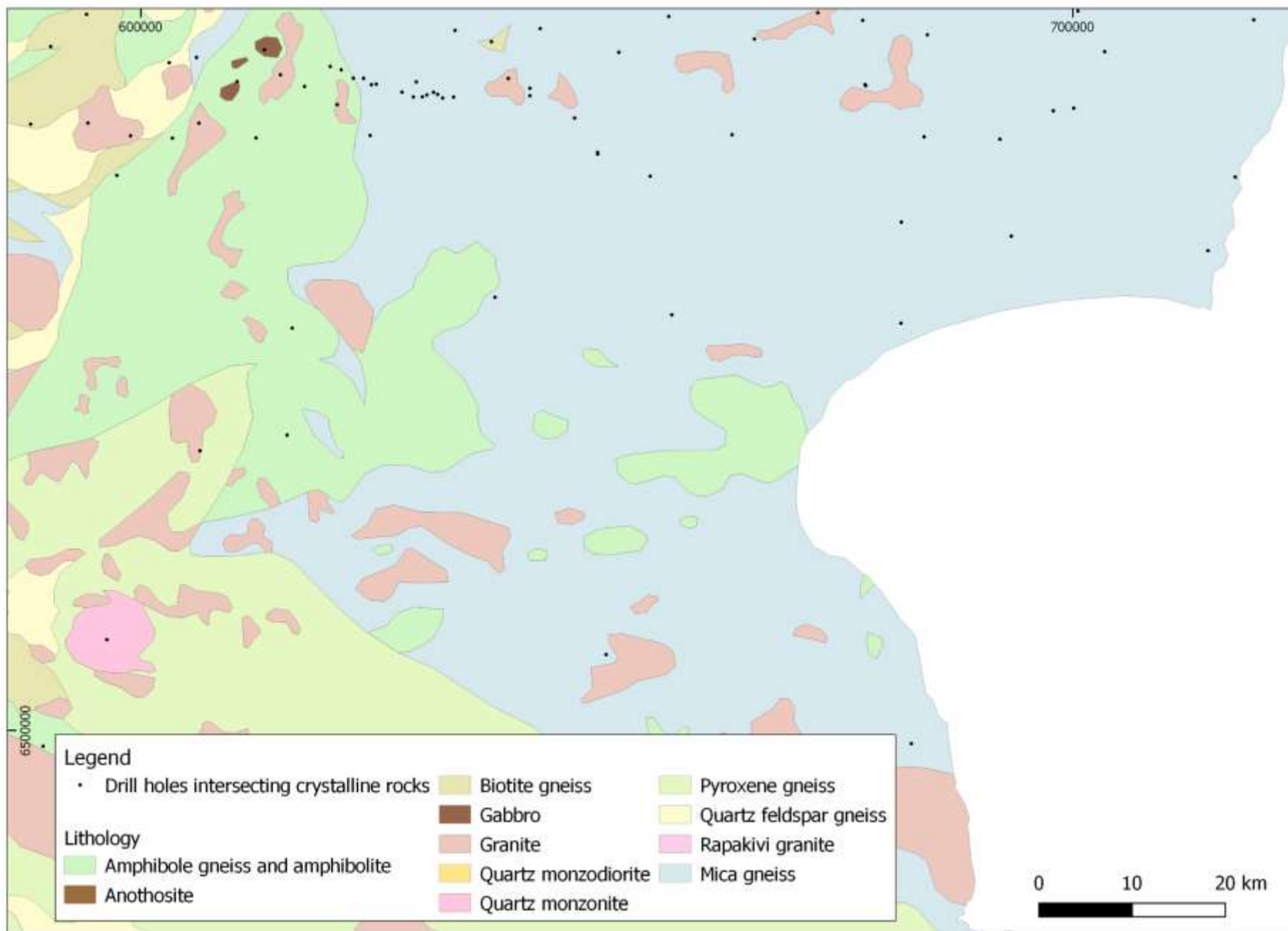
Reason – relief characteristics

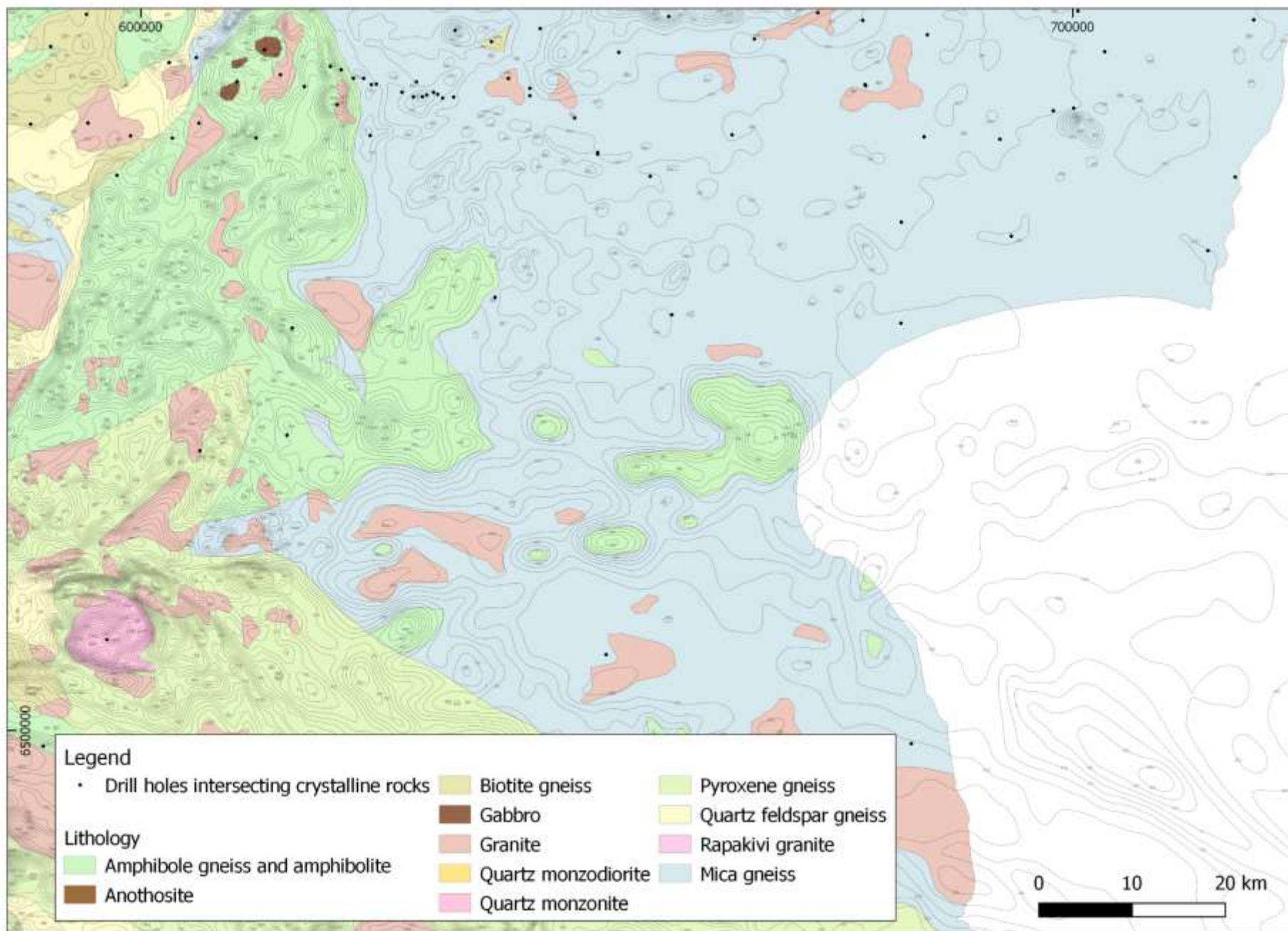


(Puura & Vaher 1997)









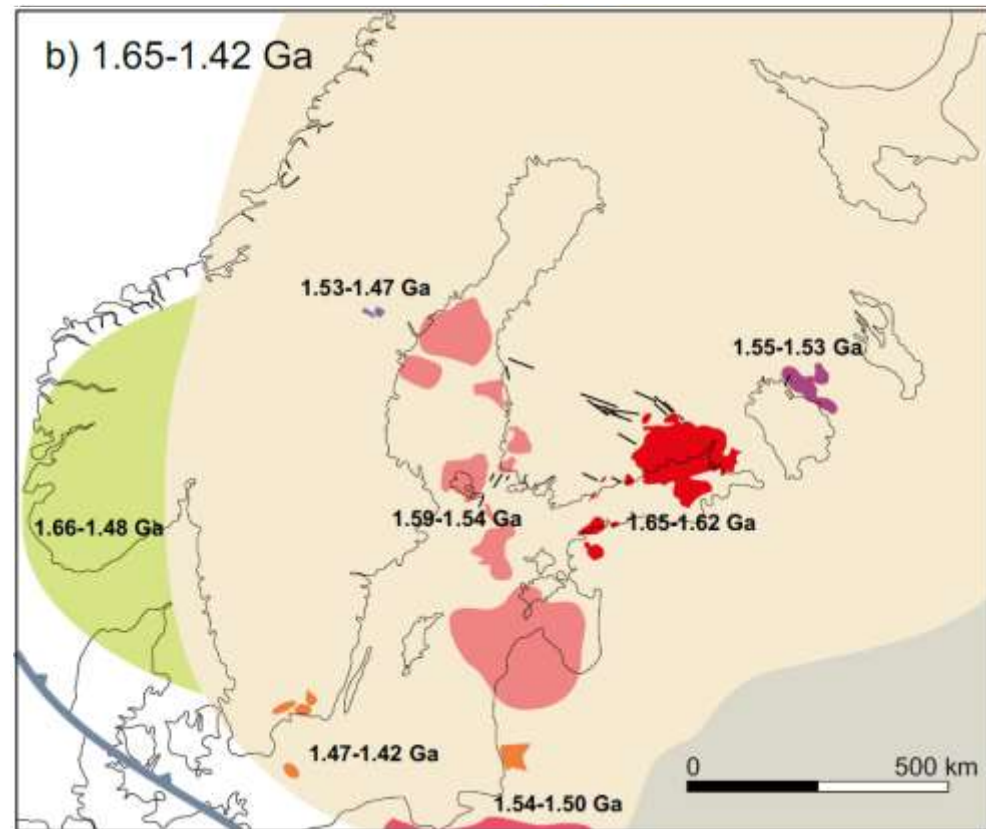
Geological processes

- Ore genesis during two separate periods:

- Svekofennian orogeny (1,92 – 1,86 Ga):
Magnetite quartzites
Sulphides in alumo-gneisses

- Hogland formation (1,65 – 1,42 Ga)
Rapakivi granite massifs (potential REE source)
Apatite
Polymetallic ore

high



Jõhvi magnetite deposit

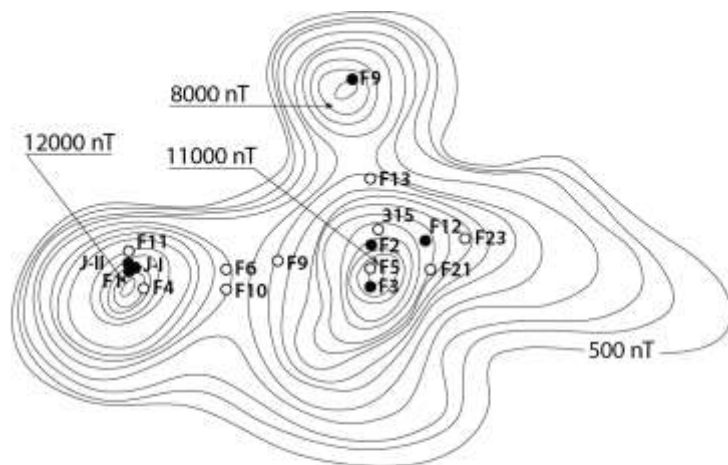
- Magnetite quartzite
- Garnet-cordierite gneiss
- Pyroxene gneiss
- Granulite facies metamorphism (T 600 –700 °C, ca 4 kbar)
- Intersected with 7 drill holes



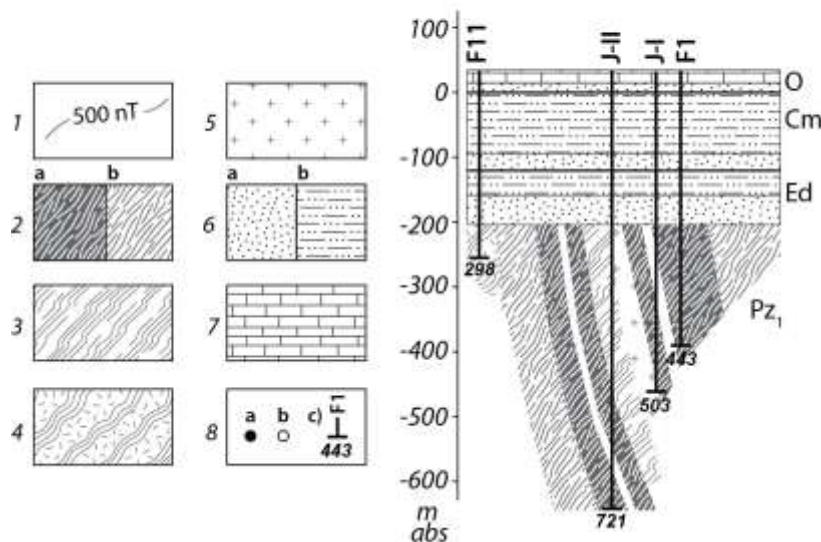
Drilled holes in the area of magnetic anomaly. Drill cores intersecting ore body are shown in red.

Source: Estonian Land Board

Jõhvi magnetite deposit



Anomaly	No of samples	Content of Fe_2O_3 , %
Western	28	34.4
Eastern	43	26.5
Northern	12	23.4



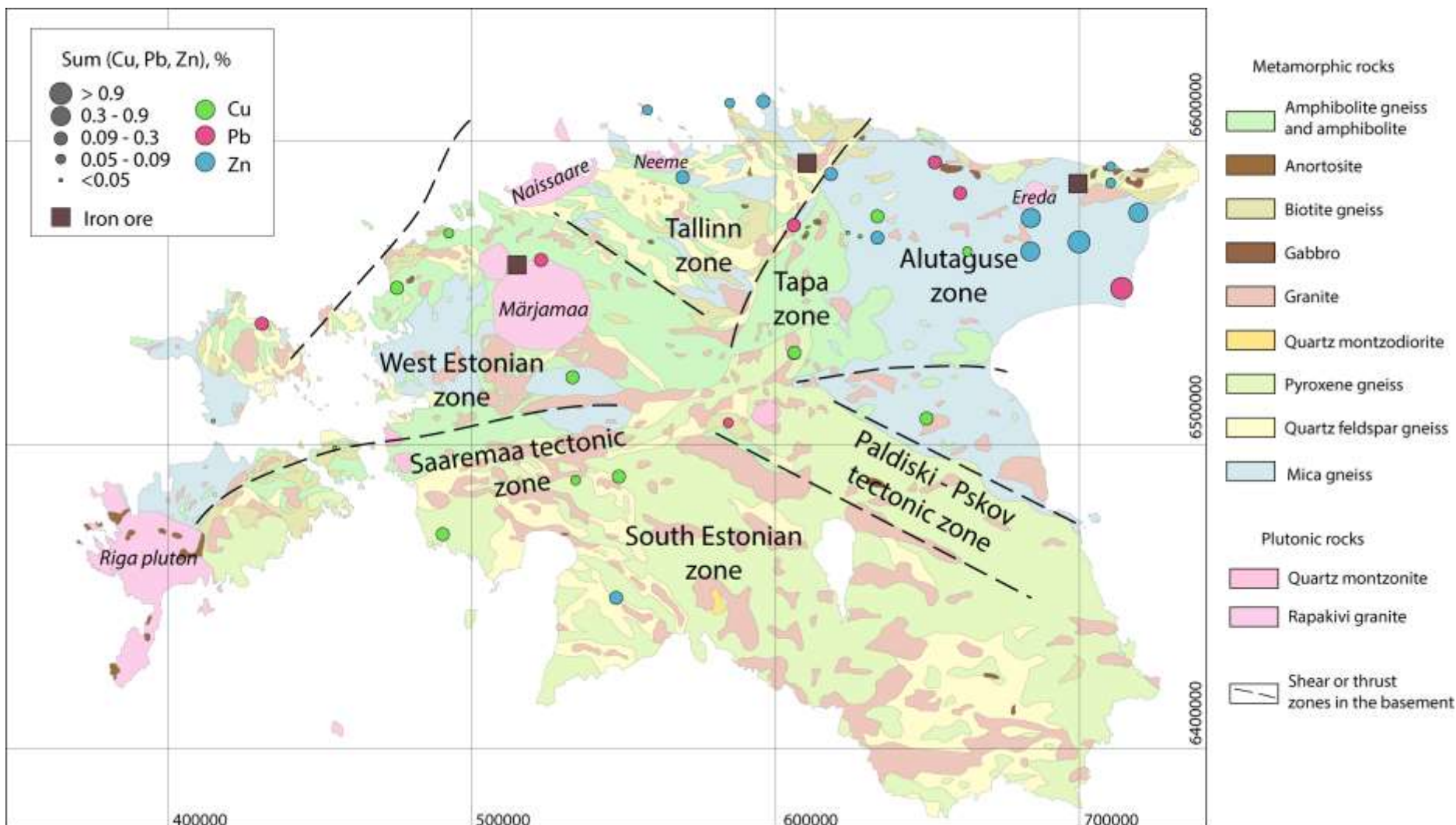
Schematic geological cross-section of the sedimentary and crystalline rocks in Jõhvi magnetic anomaly.

1 – isolines of the magnetic field strength, 2 – magnetite quartzite (a – drilled, b – suggested), 3 – mica-alumogneiss, 4- biotite-amphibole gneiss, 5 – pegmatoid granite, 6 – terrigenous sedimentary rocks (a – sandstone, b – claystone), 7 – carbonate rocks, 8 – drillholes (a – intersecting magnetite quartzite, b - drillcore into country rocks, c - depth of the core in meters. After Petersell et al. (1985).

Sulphide minerals

- More than 70 separate anomalies
- Majority occur in Tallinn and Alutaguse zones
- Mineralization associated with graphite gneisses (Graphite up to 15%, Palamuse drill hole up to 36%)
- Main ore minerals:
 1. Stage: Iron sulphides – pyrite (FeS_2) and pyrrhotite Fe_7S_8
 2. Stage: sphalerite (ZnS), chalcopyrite (CuFeS_2), galena (PbS)

Geochemical anomalies



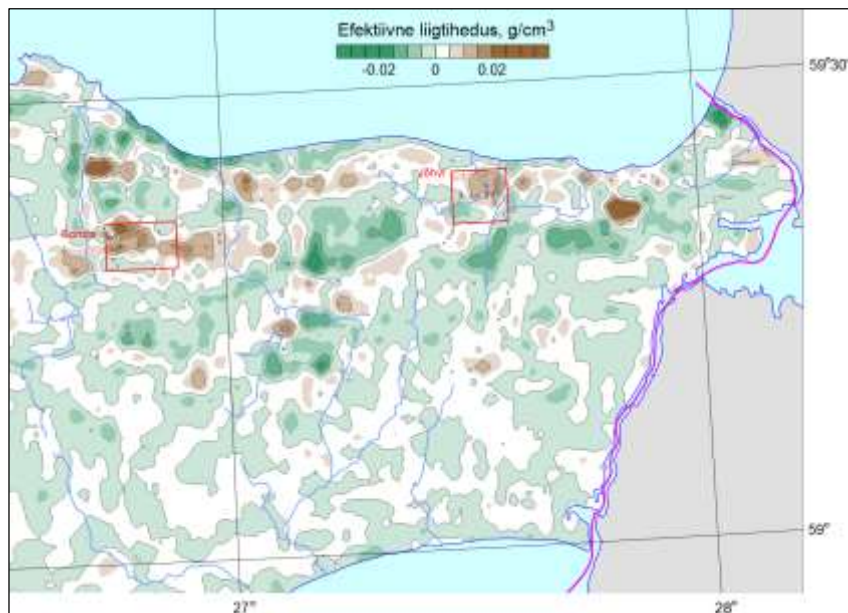
Quality of data

- Magnetic anomalies base on data with variable quality
- All drilled holes vertical
- Most anomalies checked with one drill hole – difficult to contour the bodies
- Many drill holes intersected only weathering crust of crystalline rocks – geochemical anomalies could be result of weathering
- Semi-quantitative analysis methods – results show only indications because of high error
- Intervals of ore occurrences sampled completely – reanalysing drill core with modern methods not possible.

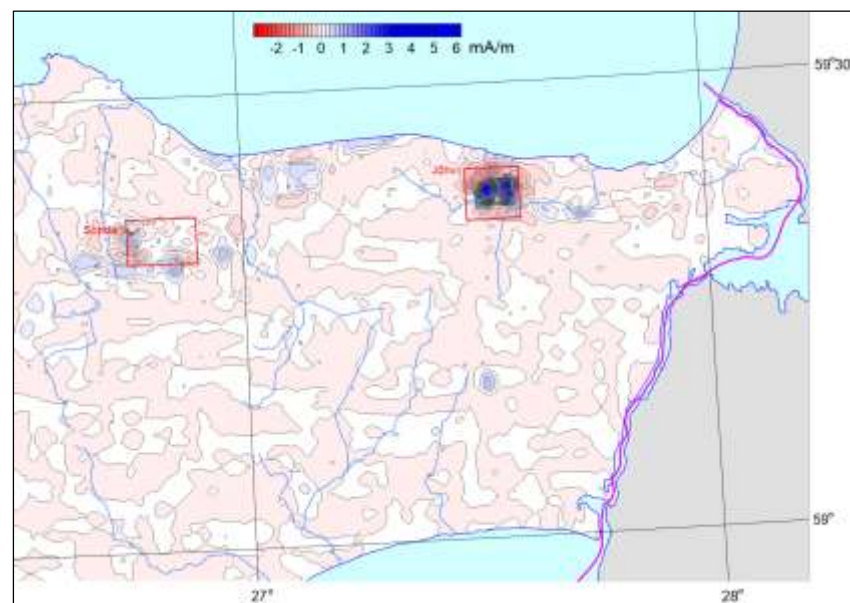
New studies - Jõhvi and Uljaste

- To get better understanding of ore body properties and distribution of elements
- Verification of old geophysical data – additional surveys if needed
- Analysis of old geochemical data and descriptions
- Drilling program

Gravimetry

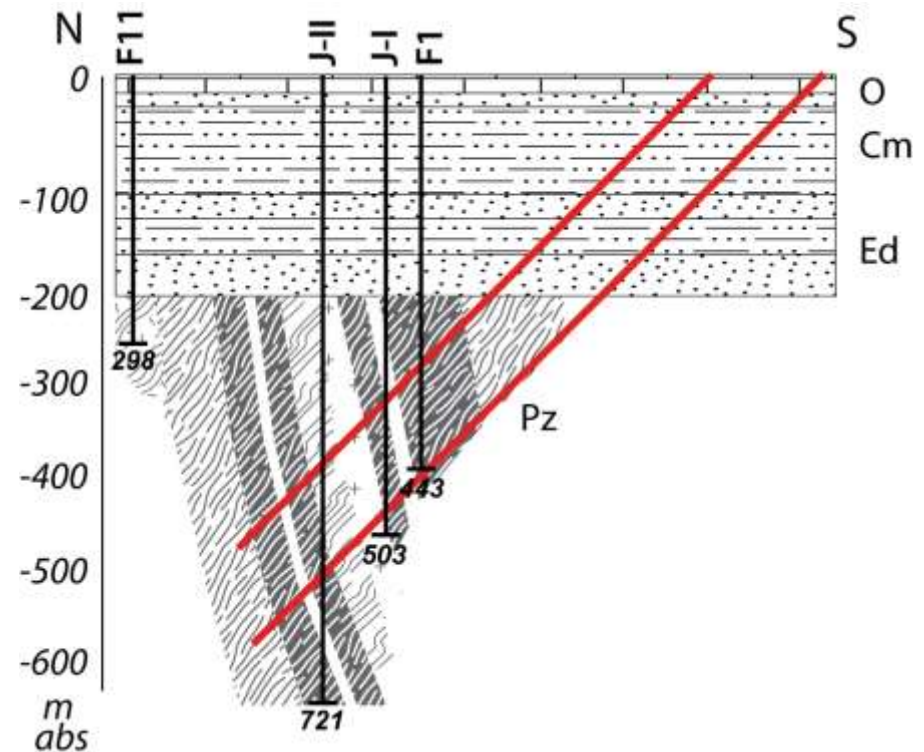


Magnetometry



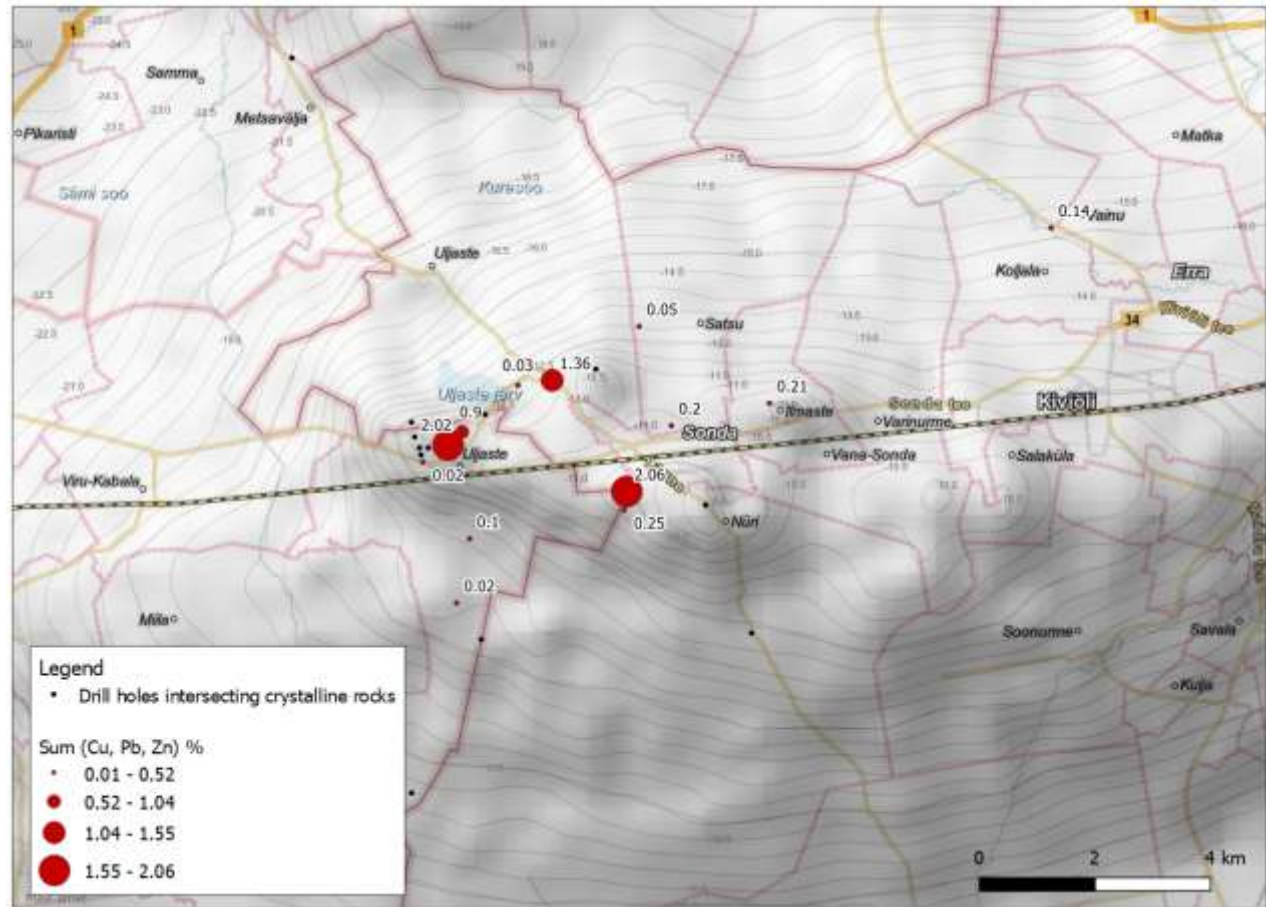
Drilling program - Jõhvi

- Inclined hole
 - Oriented drill core
 - Perpendicular intersection
- Drill core analysis
 - Standard procedures for logging
 - Sampling for geochemical and petrophysical analysis



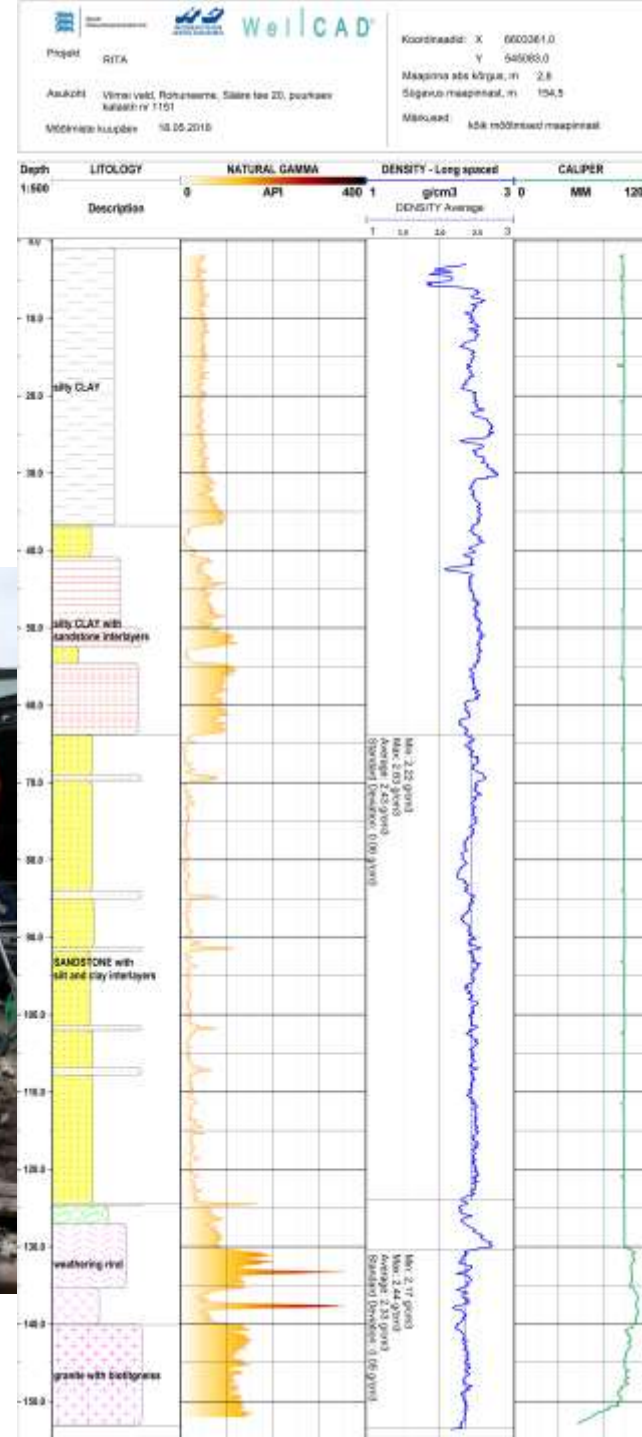
Drilling program - Uljaste

- Twinning drill hole
- Local Bouguer anomaly
- Objective: resampling and analysing



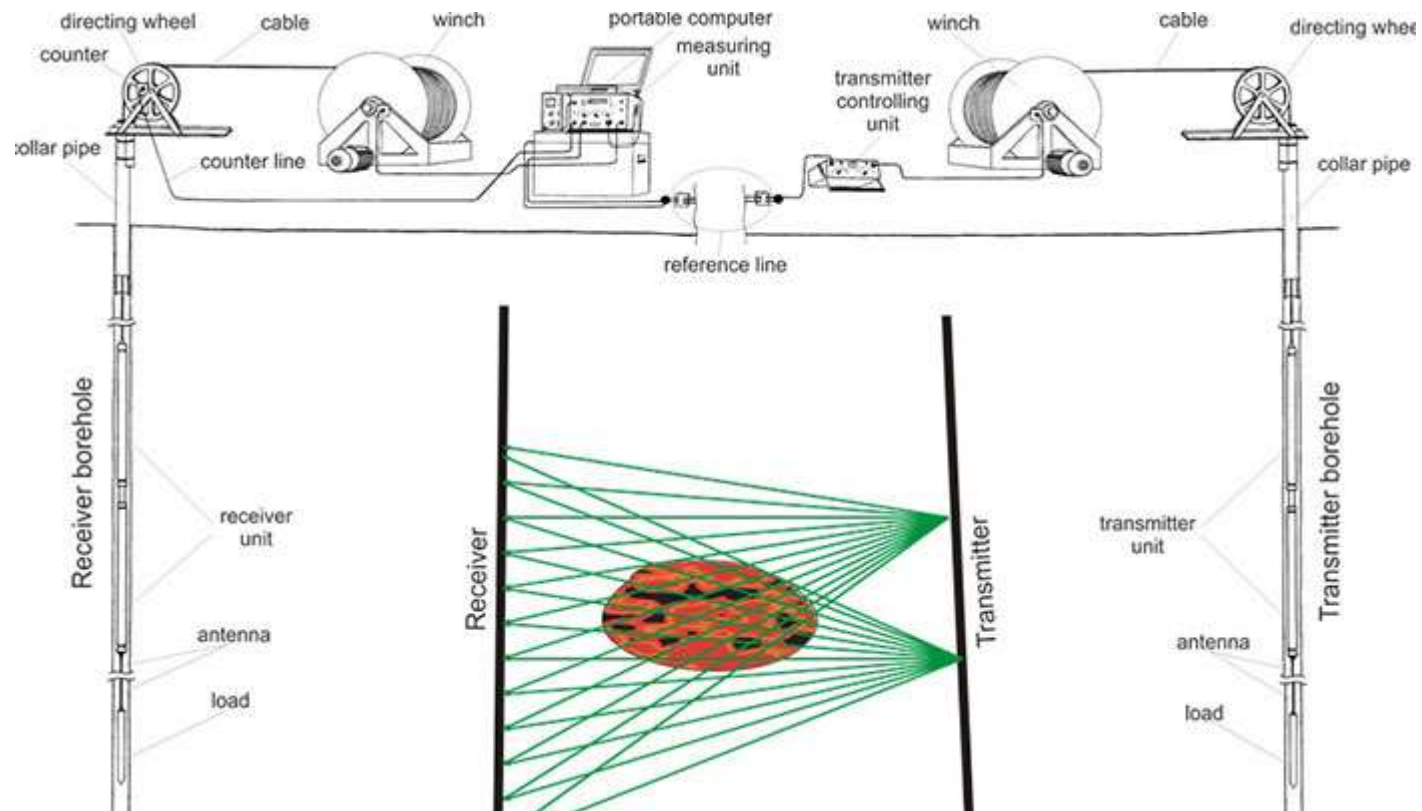
Drill hole geophysics

- Continuous data from drill hole
- Drill hole properties – essential for modelling



Drill hole geophysics

- Drill hole EM survey



Outcome

- Fresh data from crystalline basement
- More detailed map of crystalline rocks
- Better understanding about the value of our crystalline bedrock for government and citizens
- Important to have an overview of elemental distribution in rocks to be competitive whenever the raw material market changes



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Thank you!