Geophysical Service Company **"GM-Service" Ltd.**

GM SERVICE

Independent expert

<u>*Ермолин Е Ю*</u>

<u>*Olex Ingerov*</u>

New approach for mineral exploration by using geophysics

http://GeophysMethod.com

http://GeophysMethod.ru

1. New approach for mineral exploration by using geophysics

2. GM-Service technologies

Relevance and study objective

Relevance

Recently established relationship between the deep conductors in the Earth's crust and upper mantle and location of mining regions and new mineral deposits

Objective

To prove that the 5-component measurements allow to expedite exploration for certain types of minerals

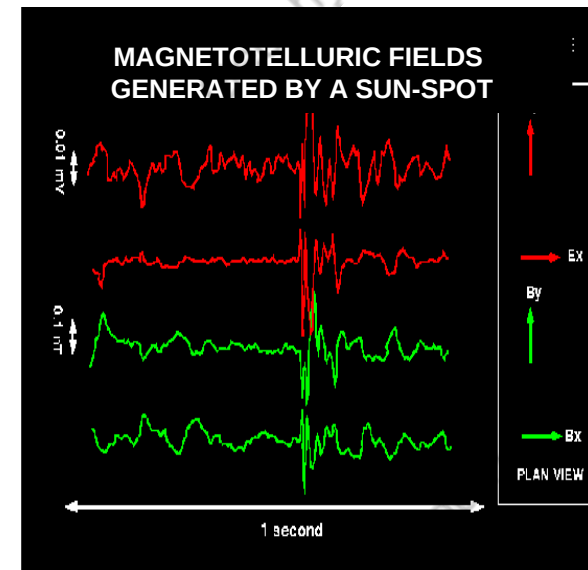# Energy source

Audiomagnetotellurics:

Role of energy source play continuously occurring on the Earth tropical thunderstorms. Created EM energy is propagated between the ionosphere and Earth's surface, inducing high frequency from 20000 to 8 Hz telluric currents in the Earth

There are 100-1000 lightning a second in the World;

MAGNETOTELLURIC FIELDS GENERATED BY A DISTANT LIGHTNING STRIKE
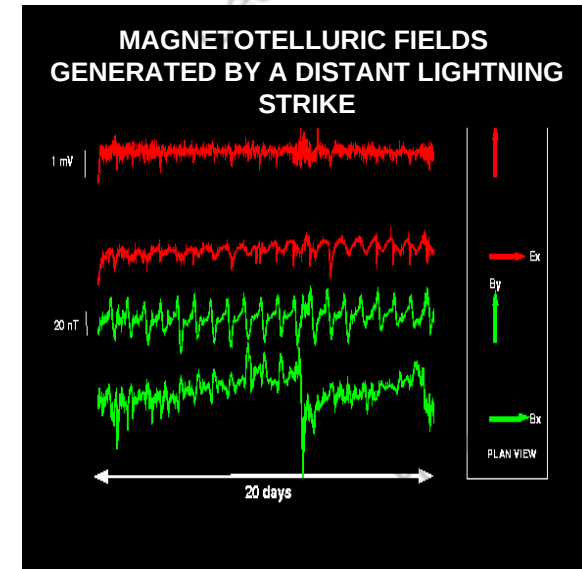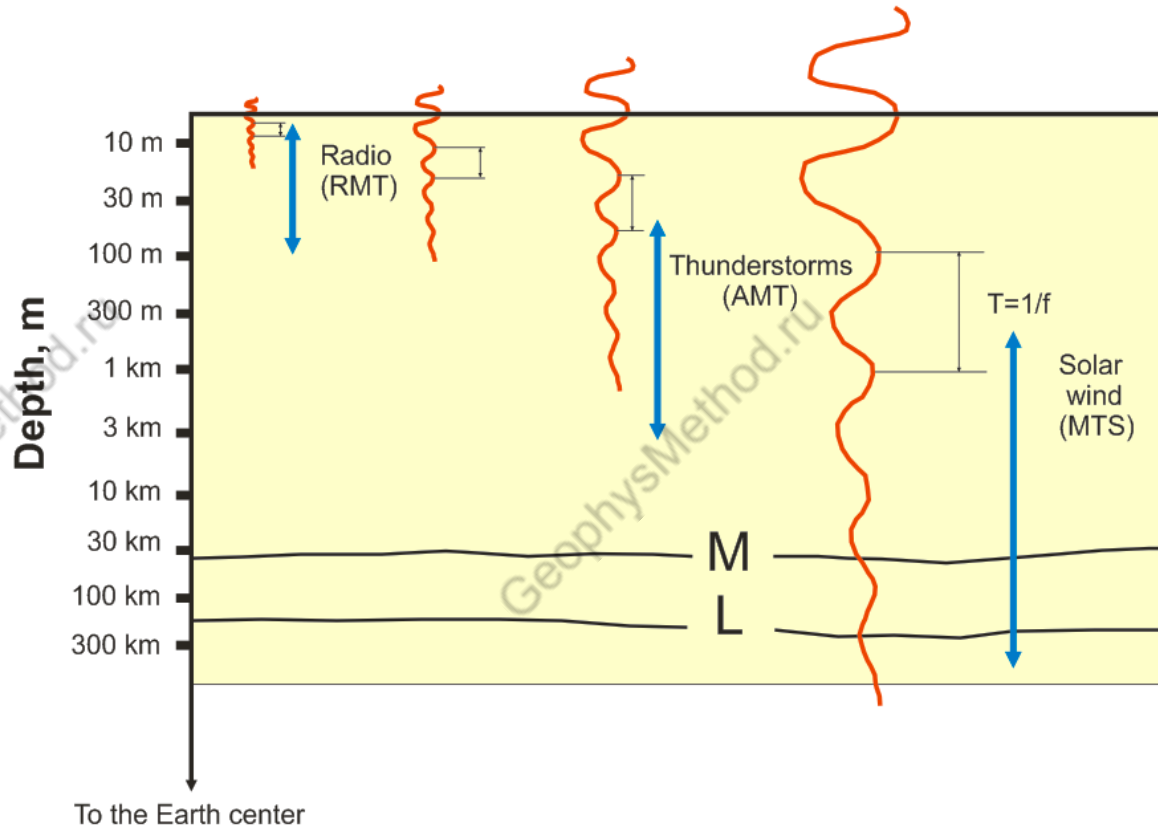
Magnetotelluric:

Nature provides perfect powerful energy source - solar wind, which interacts with the Earth's magnetic field and creates an alternating electromagnetic (EM) field with the frequency band from 10 to 0.000001 Hz
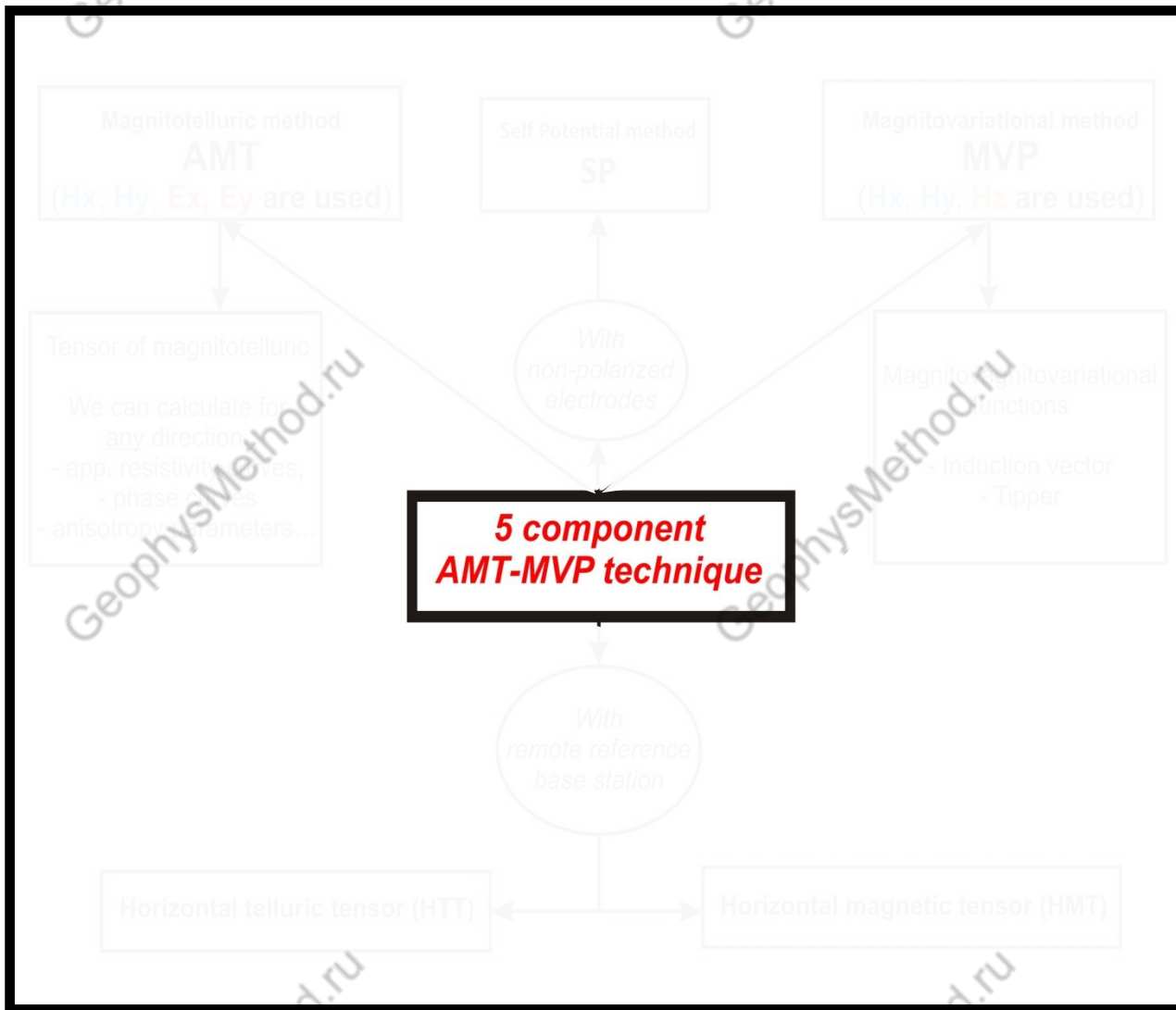
MAGNETOTELLURIC FIELDS GENERATED BY A SUN-SPOT

Energy source

EM waves penetration

Conductivity of the rocks is function of

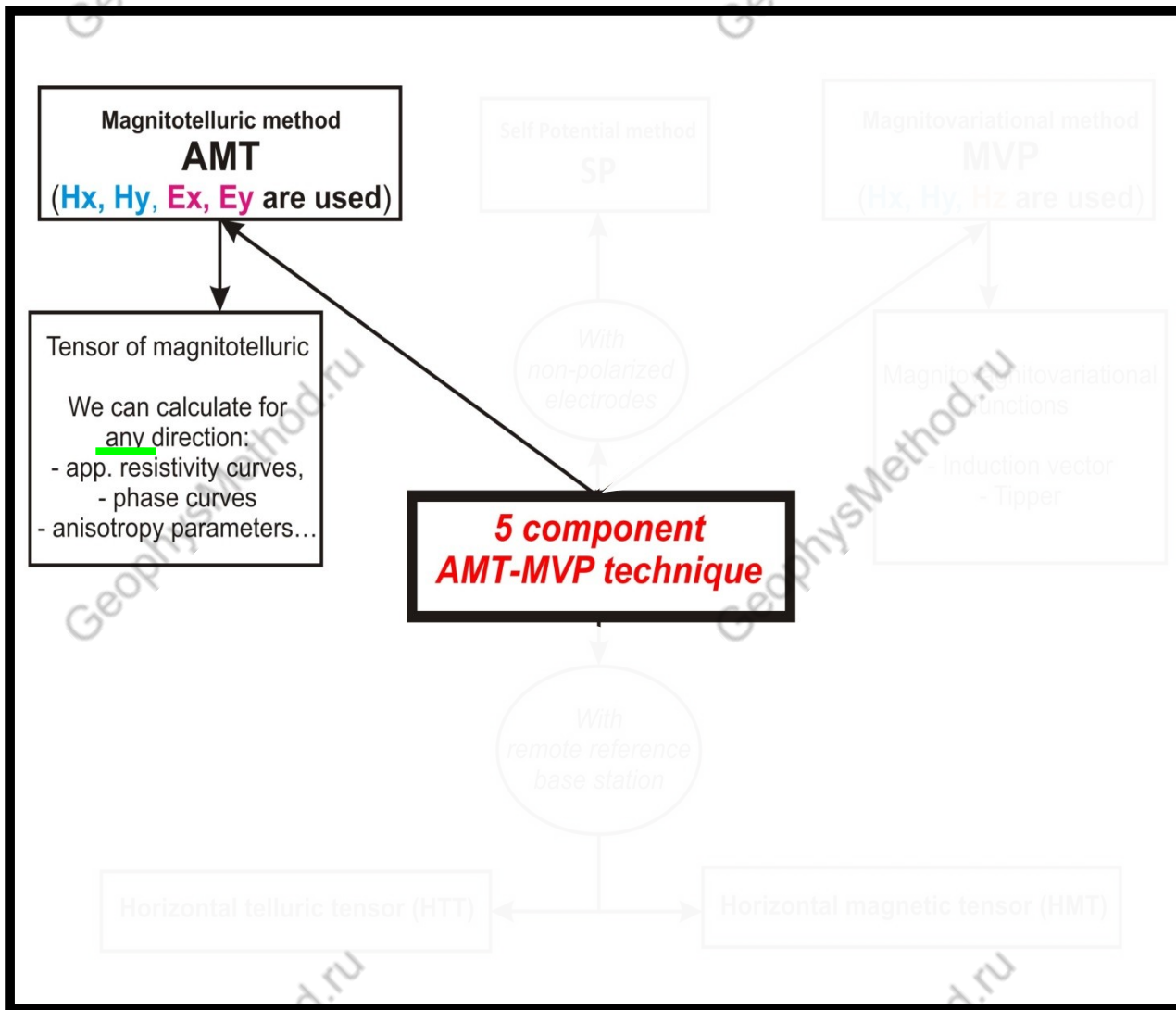$$\frac{\text{Electric component (induced in the Earth) (named \textbf{telluric} component)}}{\text{\textbf{Magnetic} component (field on Earth surface)}}$$

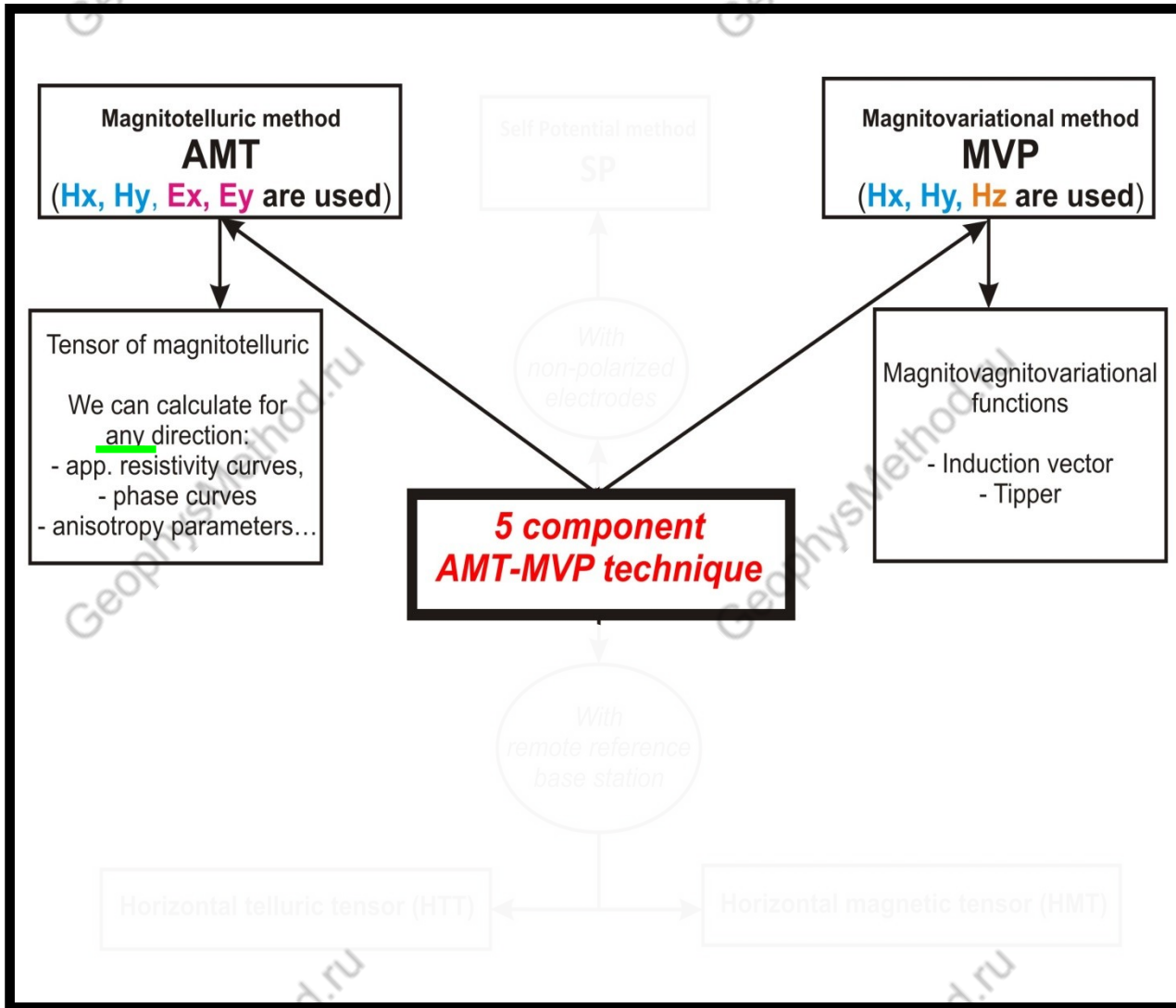# 5 – component (A)MT-MVP technique
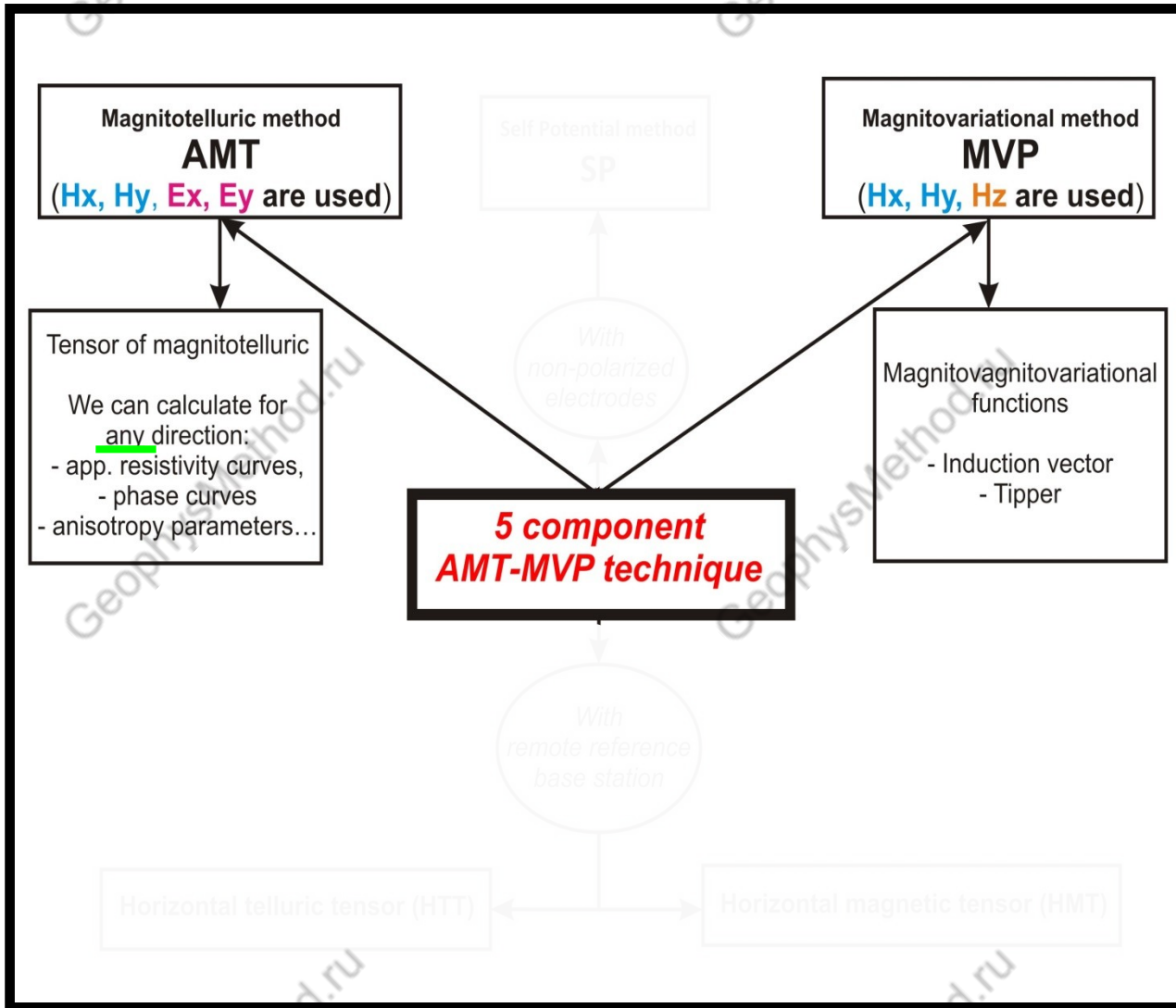

5 component AMT-MVP technique

- ❑ Magnetotelluric methods describe well the sub-horizontal boundaries

- ❑ Magnetovariational methods are sensitive to sub-vertical boundaries (in a horizontally layered medium, the response functions are zero)

- ❑ Joint application of the (A)MT-MVP makes it possible to describe detailed the 2-D and 3-D medium in a wide depth interval (from the first meters to 1000 km)
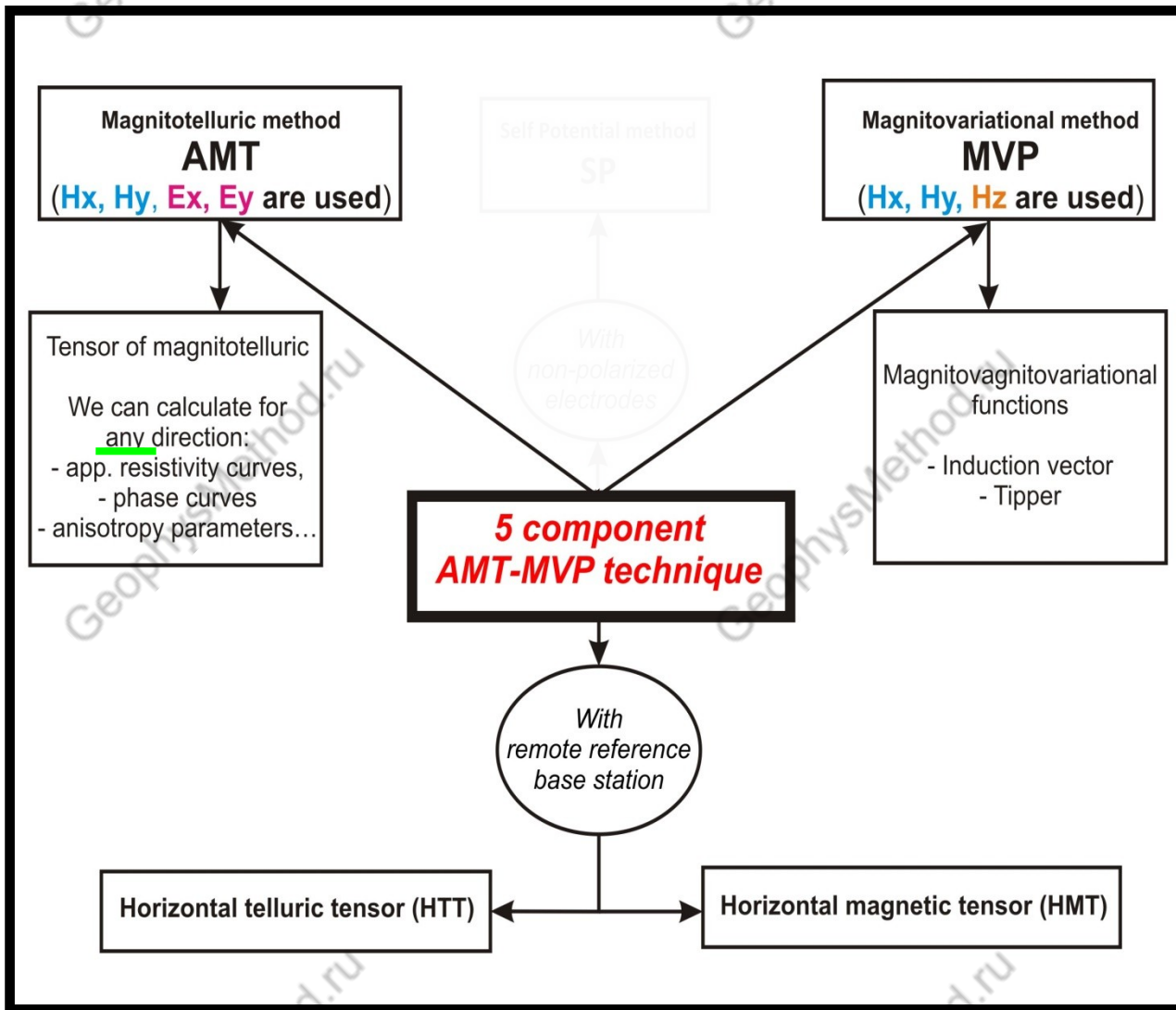
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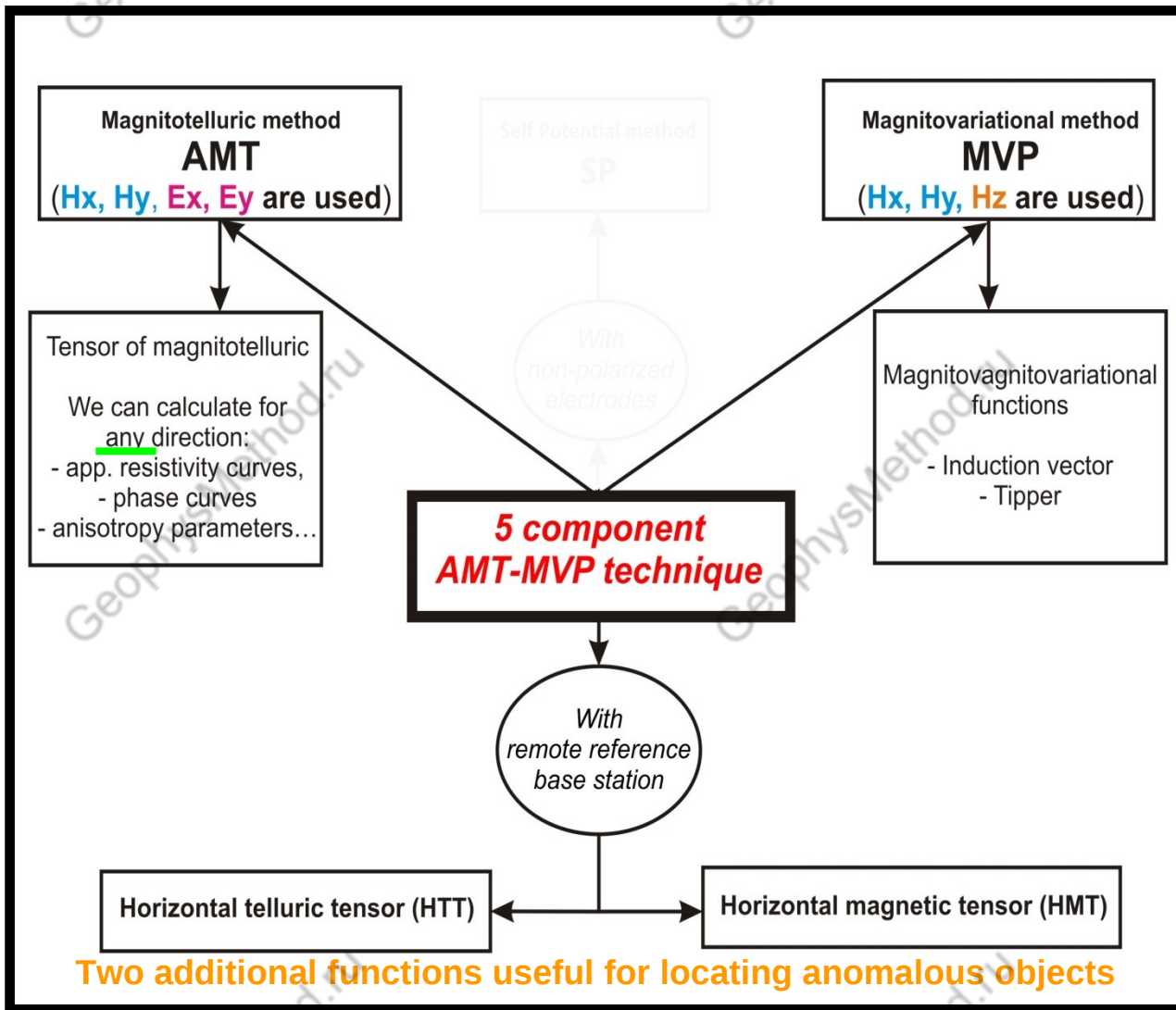
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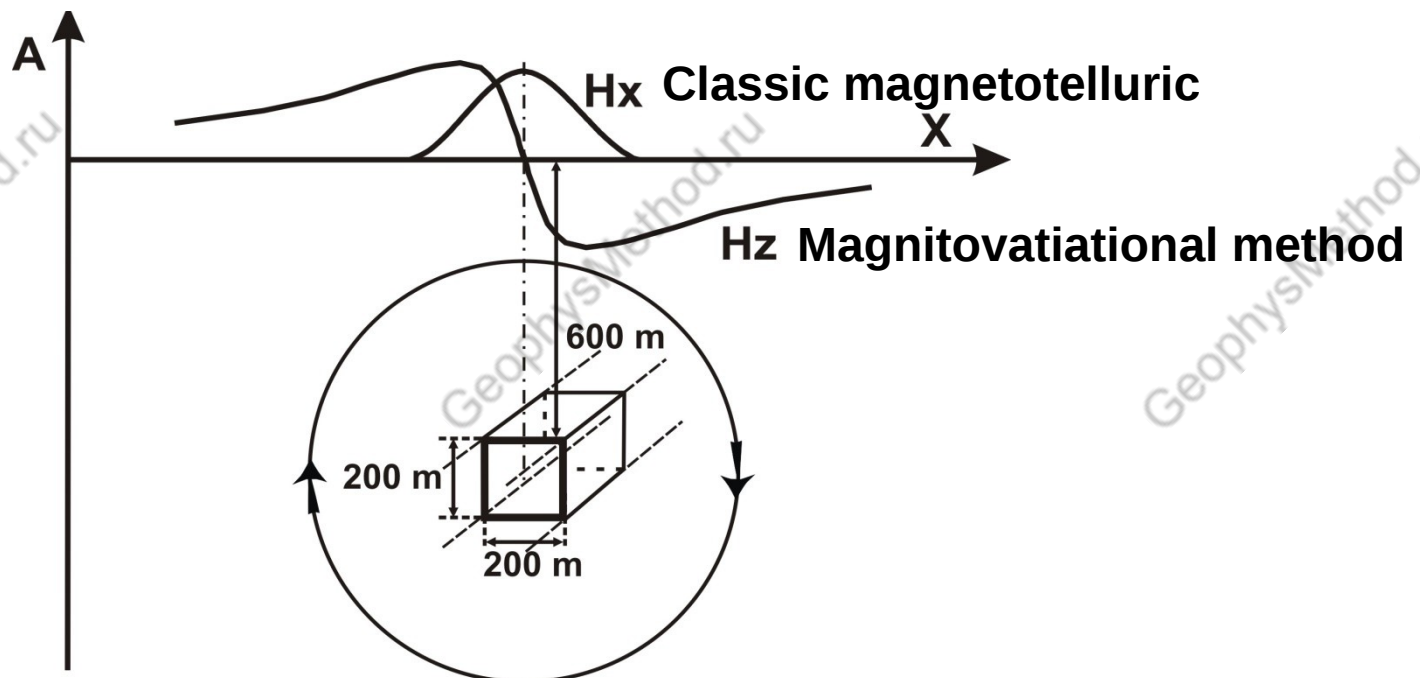
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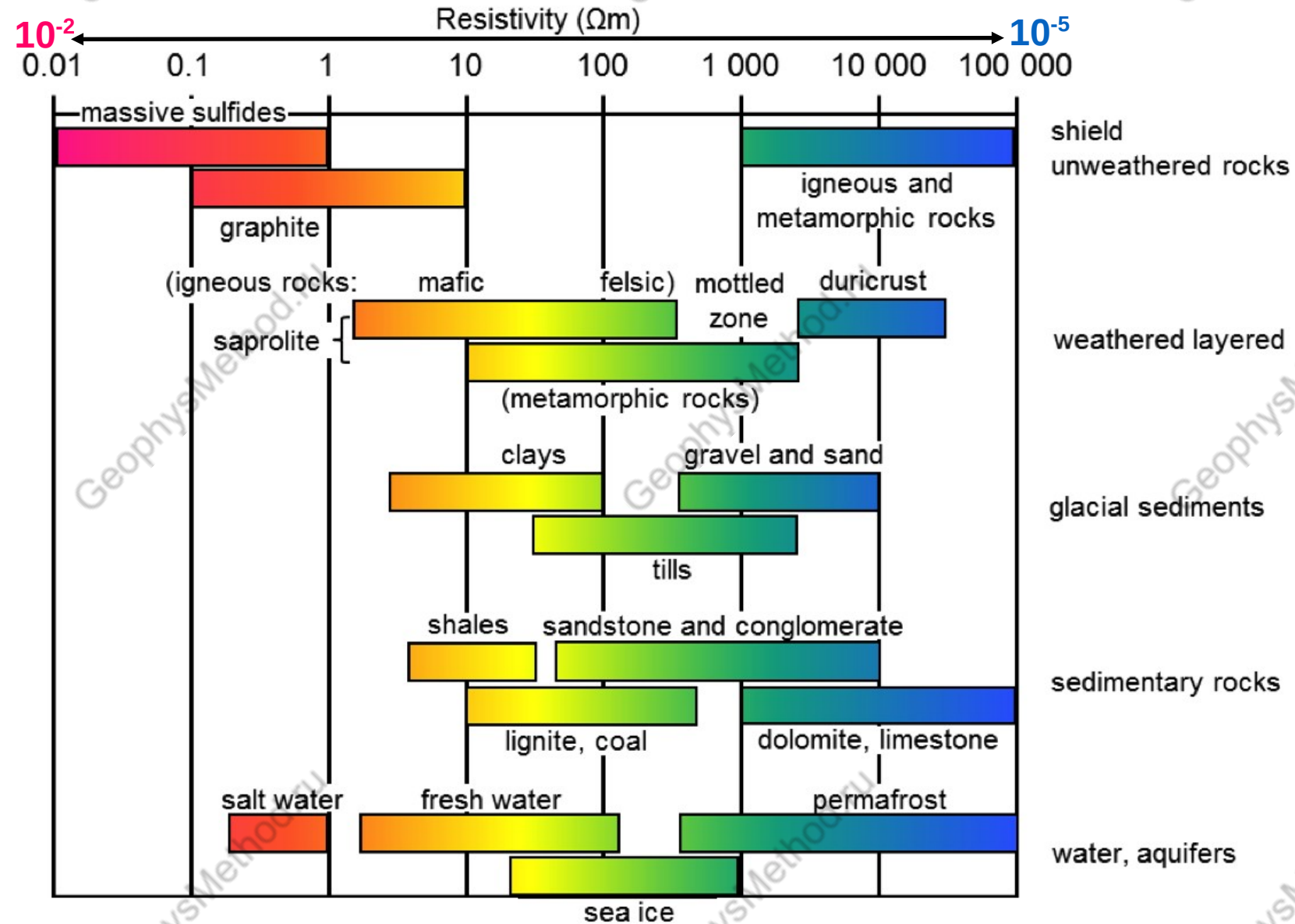
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Physics of methods

Variation of rock resistivity

Resistivity (Ωm)

10^{-2} ← → 10^{-5}

0.01 0.1 1 10 100 1 000 10 000 100 000

massive sulfides

graphite

(igneous rocks: mafic felsic) mottled zone duricrust

saprolite

(metamorphic rocks)

clays gravel and sand

tills

shales sandstone and conglomerate

lignite, coal dolomite, limestone

salt water fresh water permafrost

sea ice

shield
unweathered rocks

igneous and metamorphic rocks

weathered layered

glacial sediments

sedimentary rocks

water, aquifers

Typical 5–component station field setup

Magnetic sensors installation in precision tripod

Multifunction EM receiver
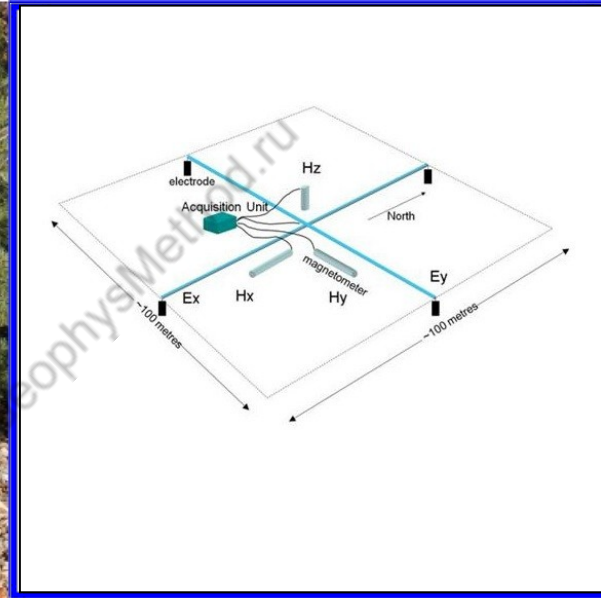
Tripod transportation

International tendencies of small-sale magnetotelluric investigations - New connection between conductive structures in the Earth crust and mineral deposits

Olympic Dam IOCG deposit
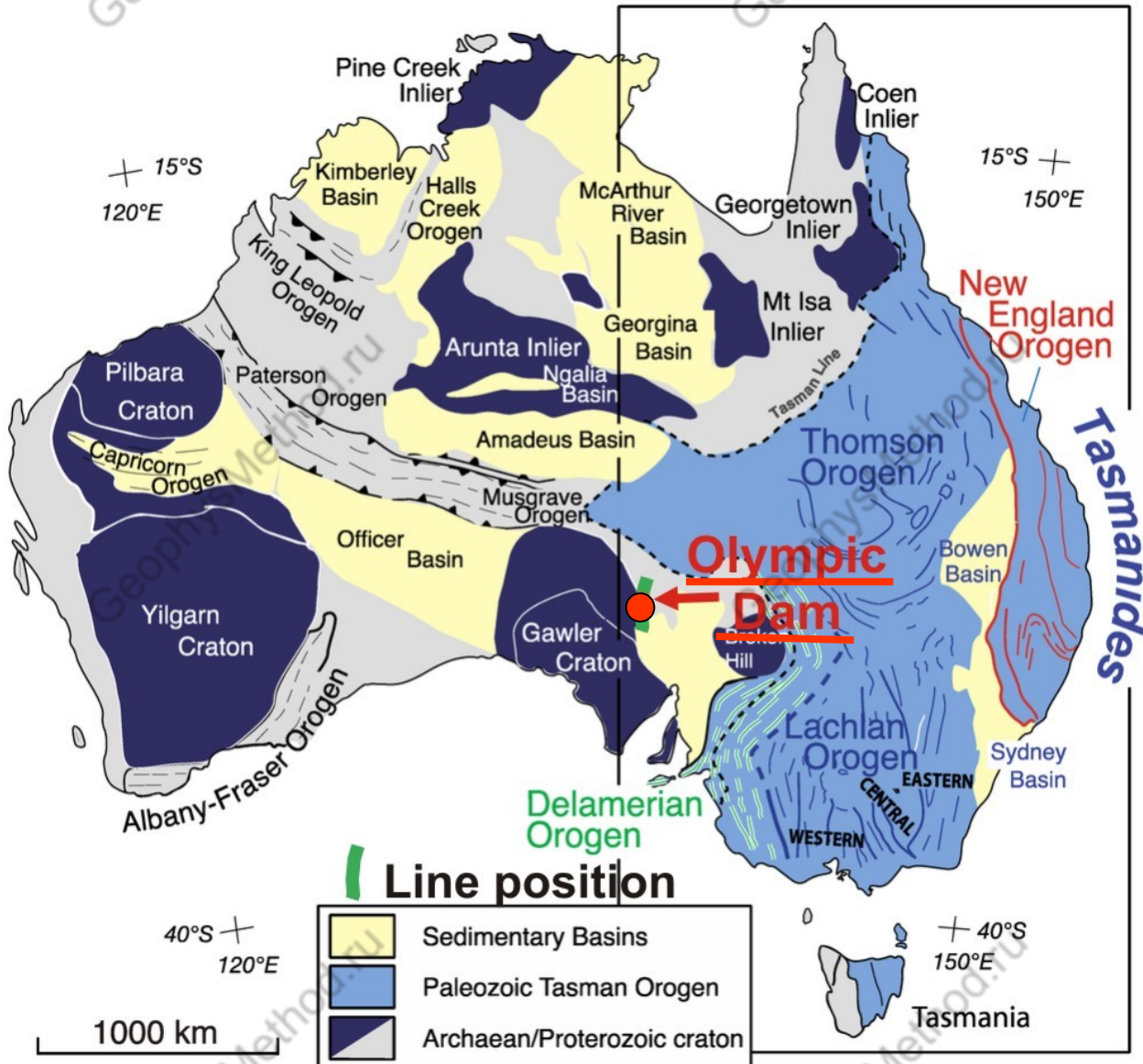
Opened: 1988

[Smith M. and Ionno P, Darwin 2012]

[According to D. Foster and B. Goscombe, 2013]

Olympic Dam IOCG deposit

Opened: 1988

[Smith M. and Ionno P, Darwin 2012]
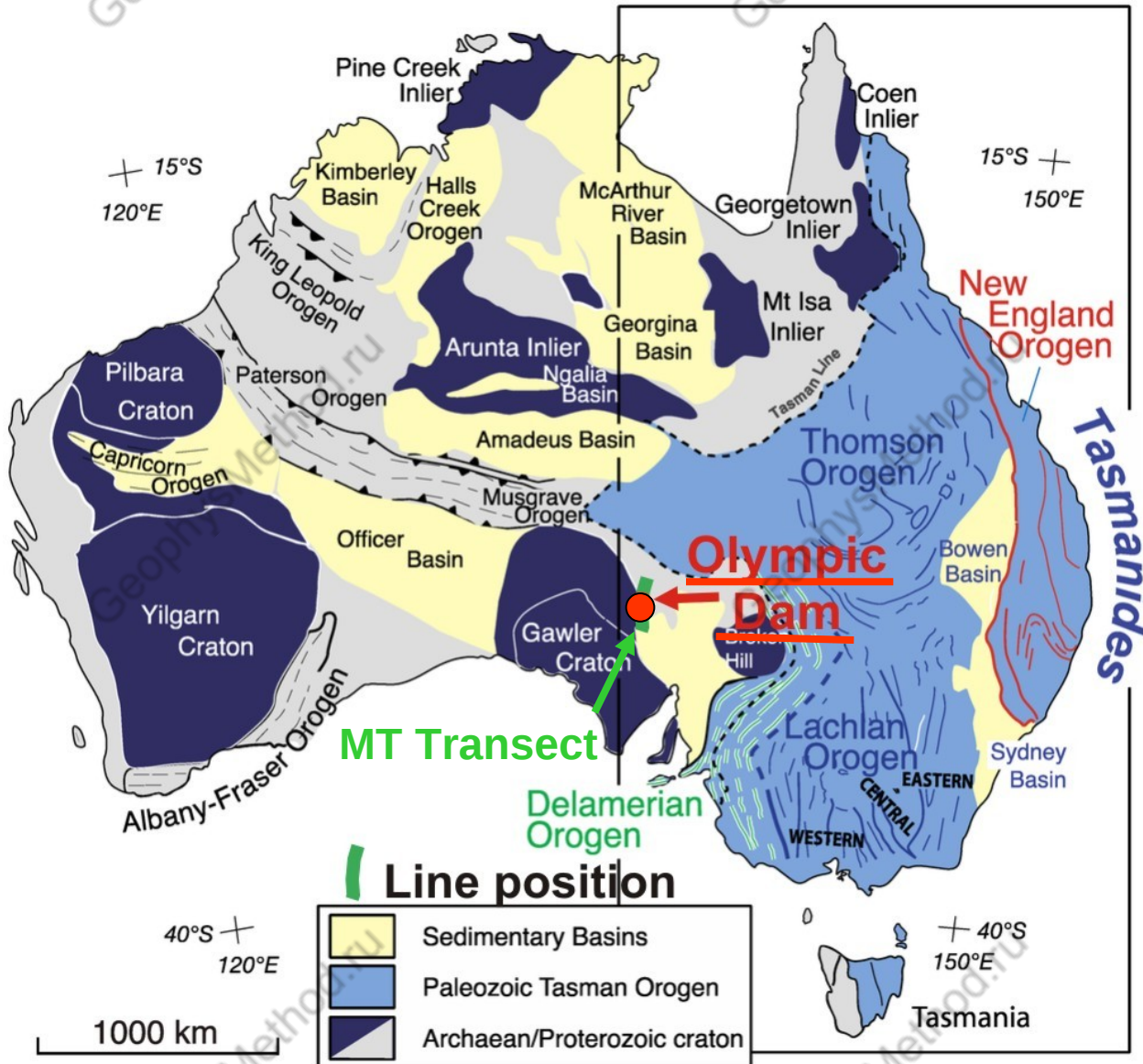
[According to D. Foster and B. Goscombe, 2013]

Olympic Dam IOCG deposit

[According to D. Foster and B. Goscombe, 2013]

Opened: 1988

Location:
NE edge of Gawler craton (AR)

Approximate age of structure:
1600 millions years

Olympic Dam (2012)
Mineral Resources Status
[Smith M. and Ionno P, Darwin 2012]

Cu - 80 million tonnes.

U_3O_8 -   2.4 million tonnes
(300 g/t)

Au - 2 500 tonnes
(90 million oz)
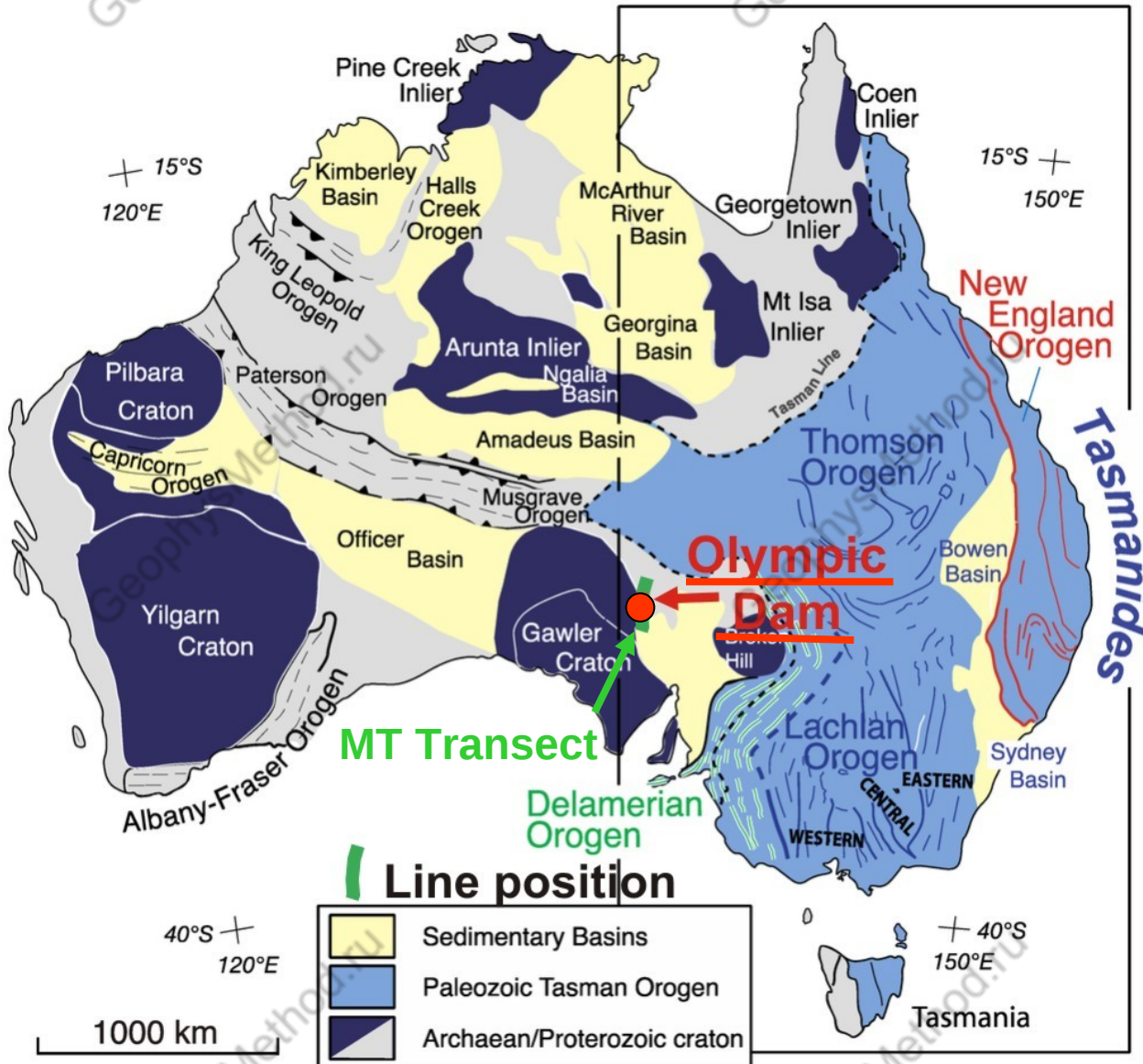
Mineral Systems - Olympic Dam IOCG deposit

Resistivity cross-section
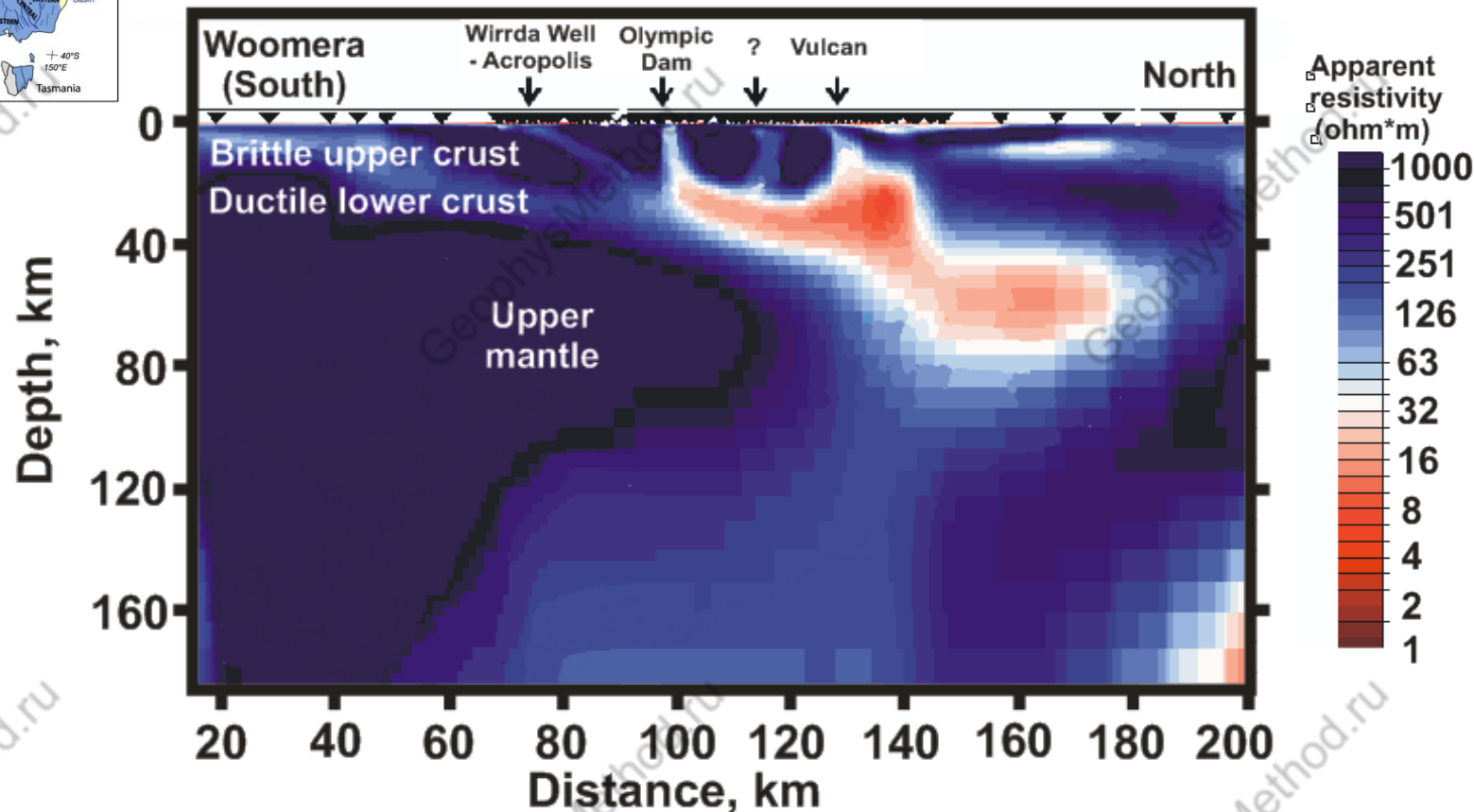
[According to M. Dentith, 2017]

Mineral Systems - Olympic Dam IOCG deposit
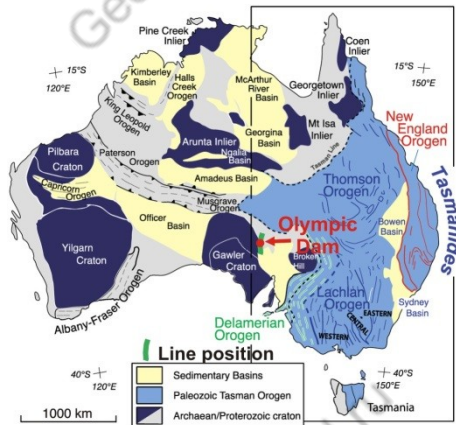
Resistivity cross-section
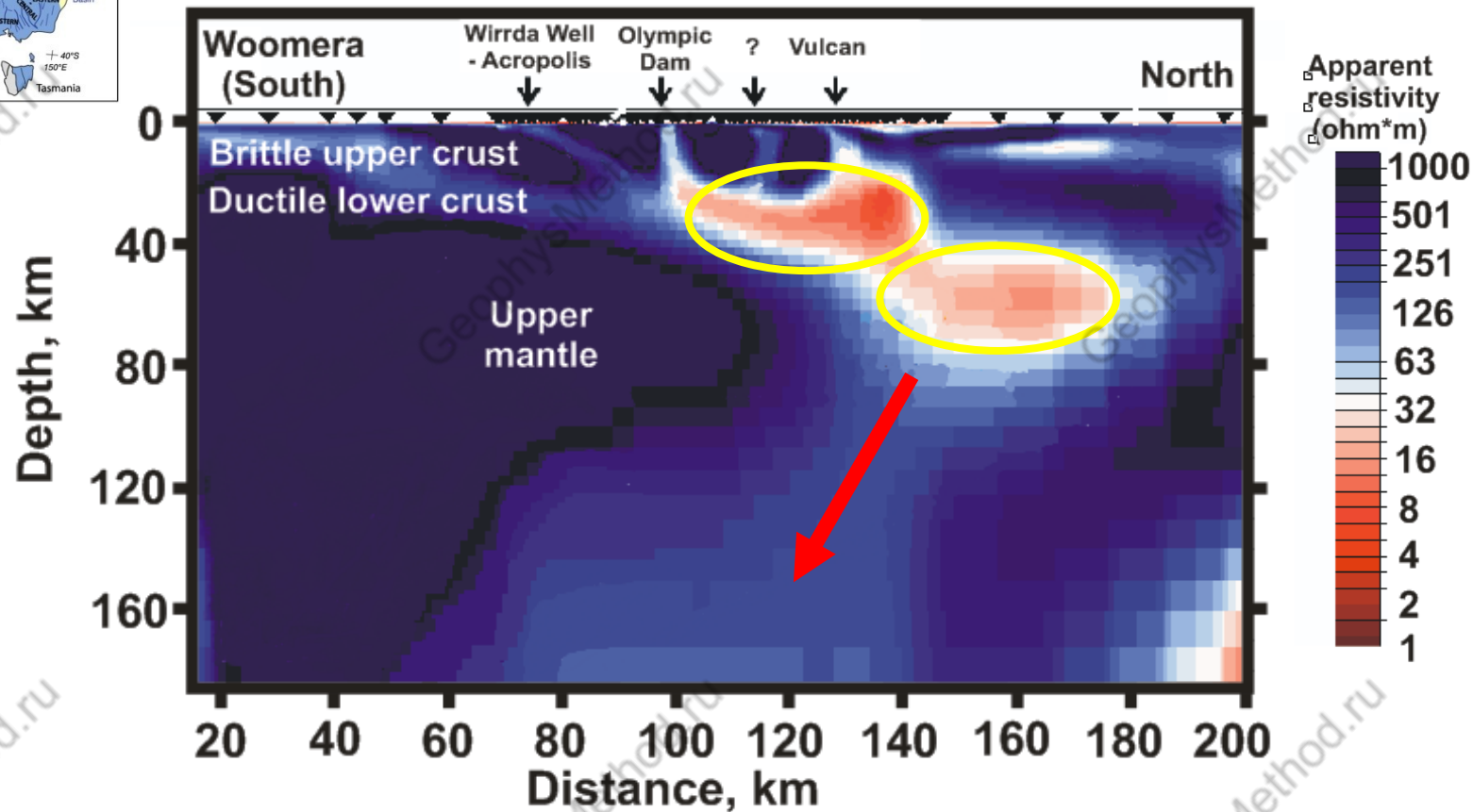
[According to M. Dentith, 2017]

Mineral Systems – AusLAMP
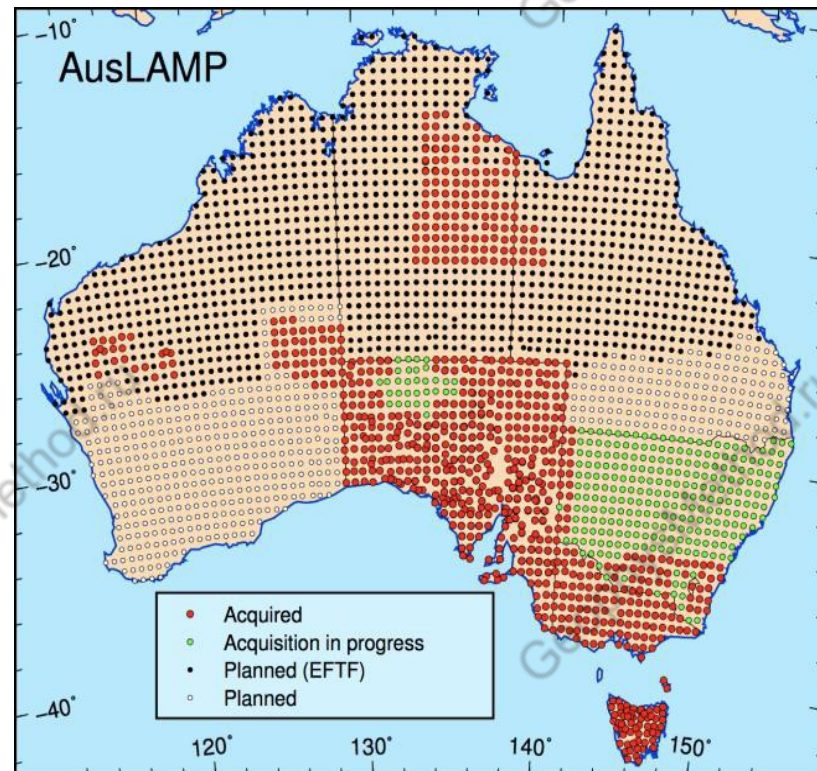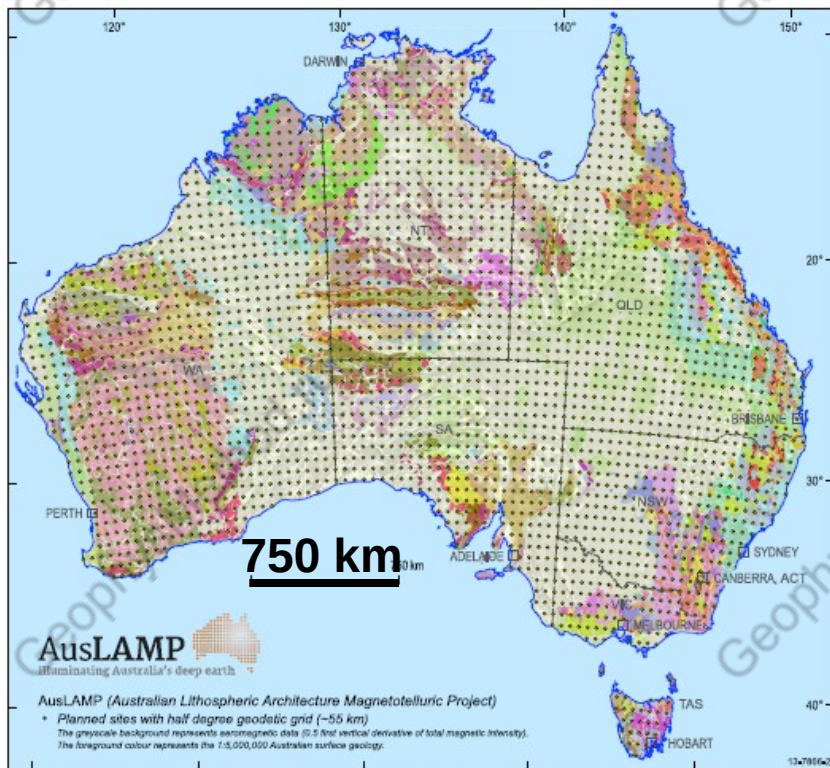
+ Planned sites with half degree geodetic grid (-55 km)

● Planned sites (EFTF)
○ Planned sites
● Acquisition in progress
● Acquired

[Geoscience Australia 2017]

Short overview of small-scale international MT investigations in Russia

World experience of regional works
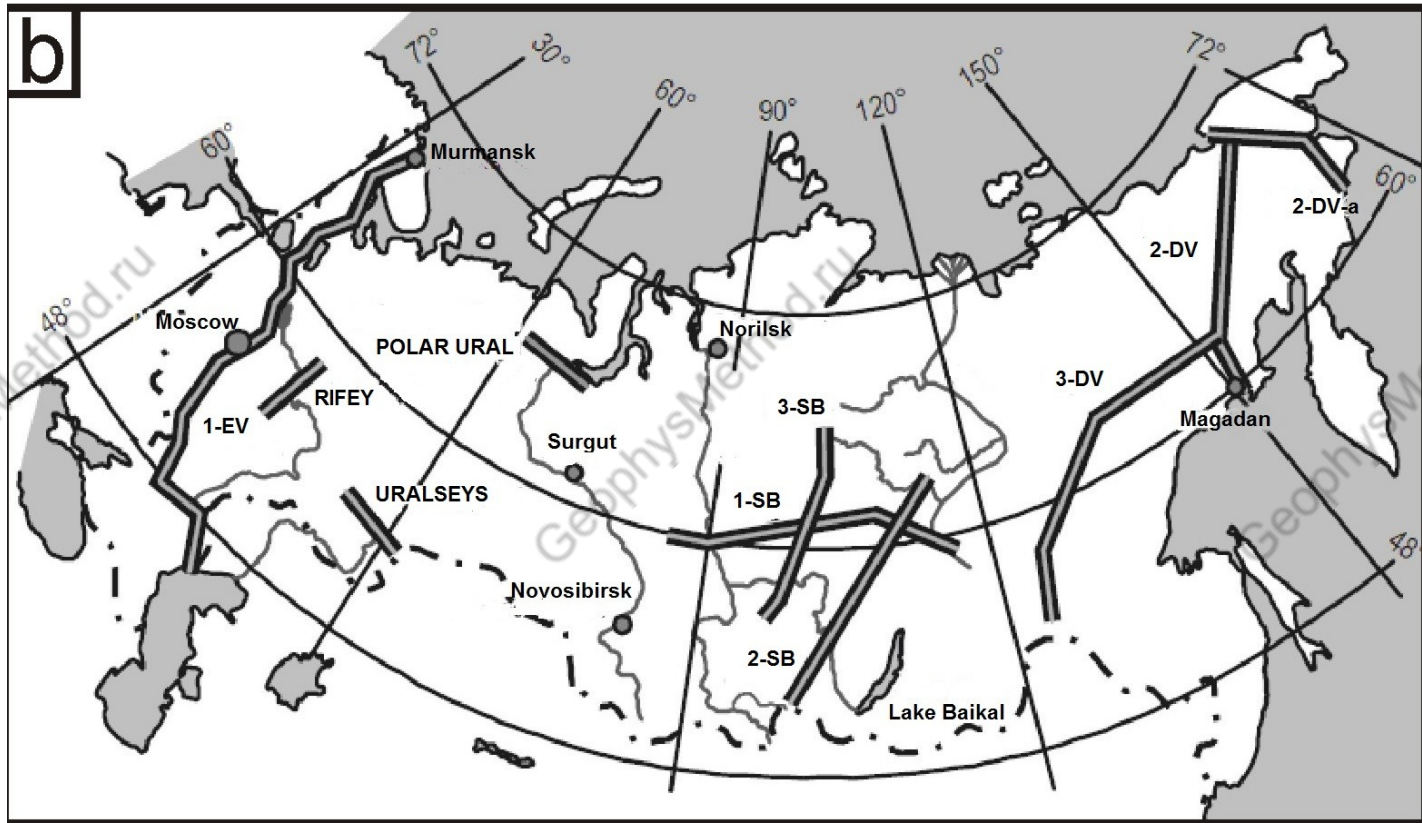
Russia

Location of the main regional profiles in Russia
[According to Palshin et. al., 2017]

World experience of regional works
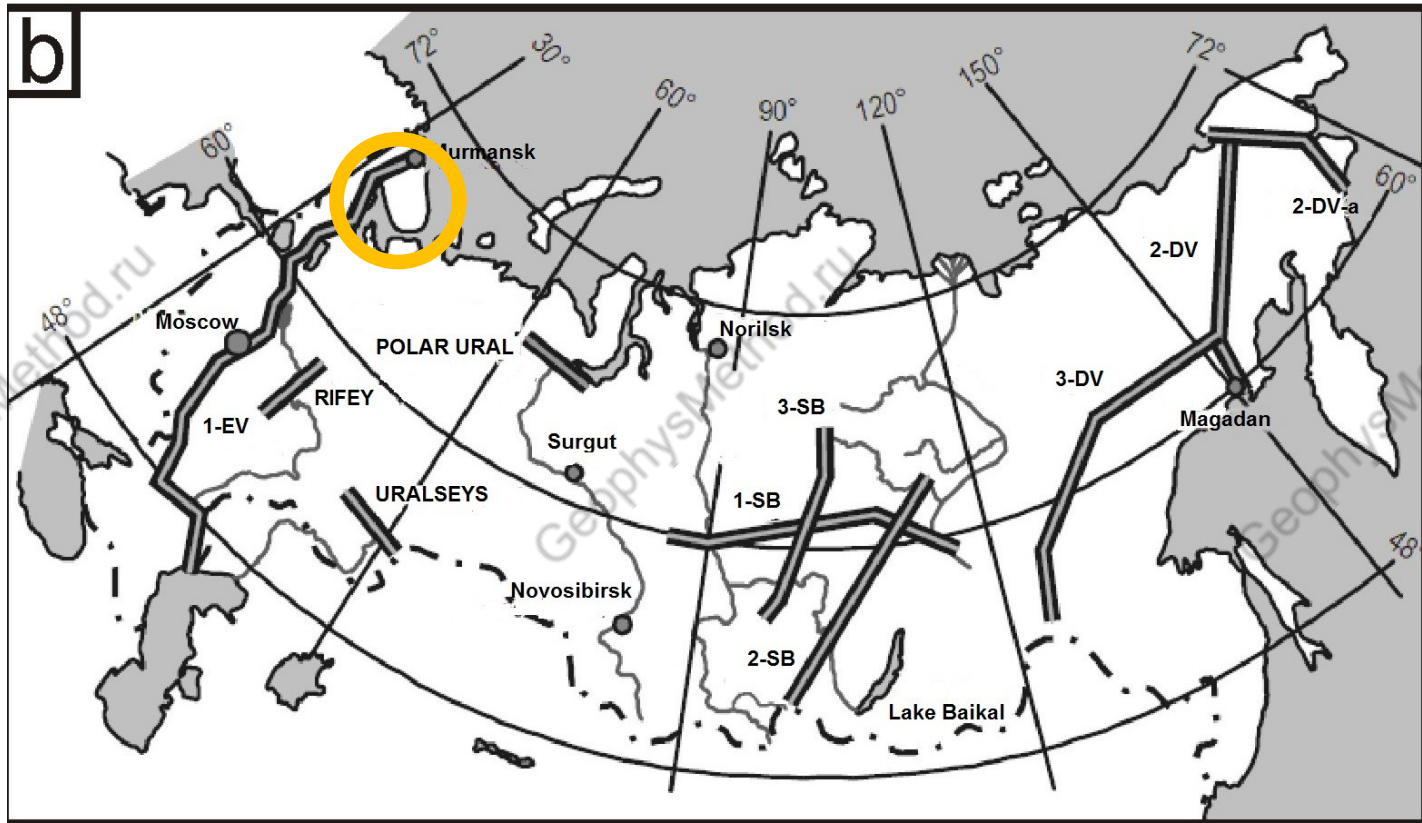
Russia

Location of the main regional profiles in Russia
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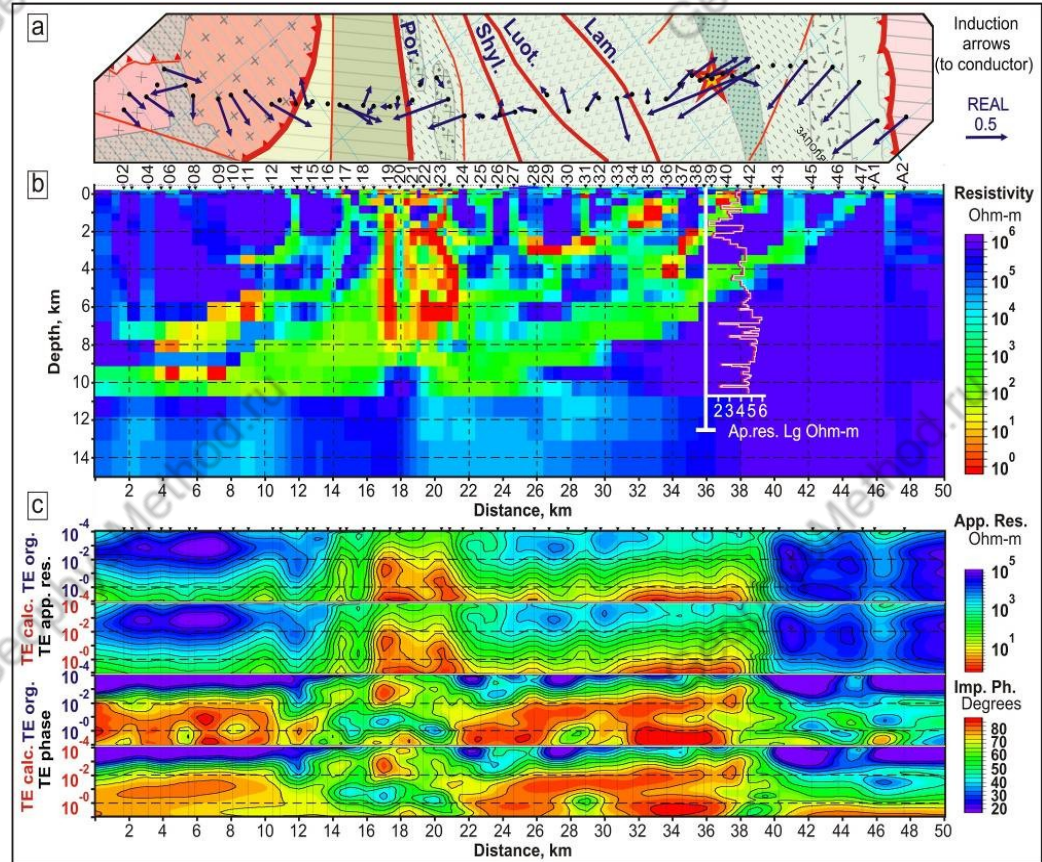# Comparison of deep magnetotelluric with Kola SG-3 borehole of the (the work of the Mining University)
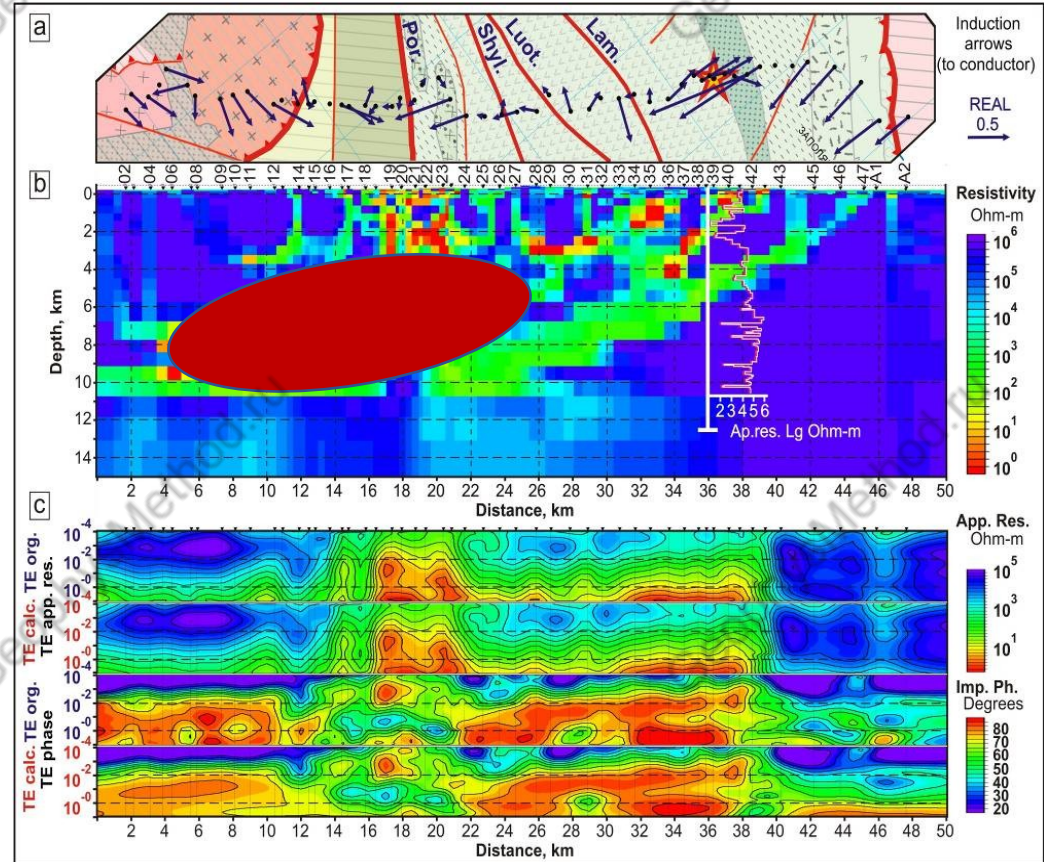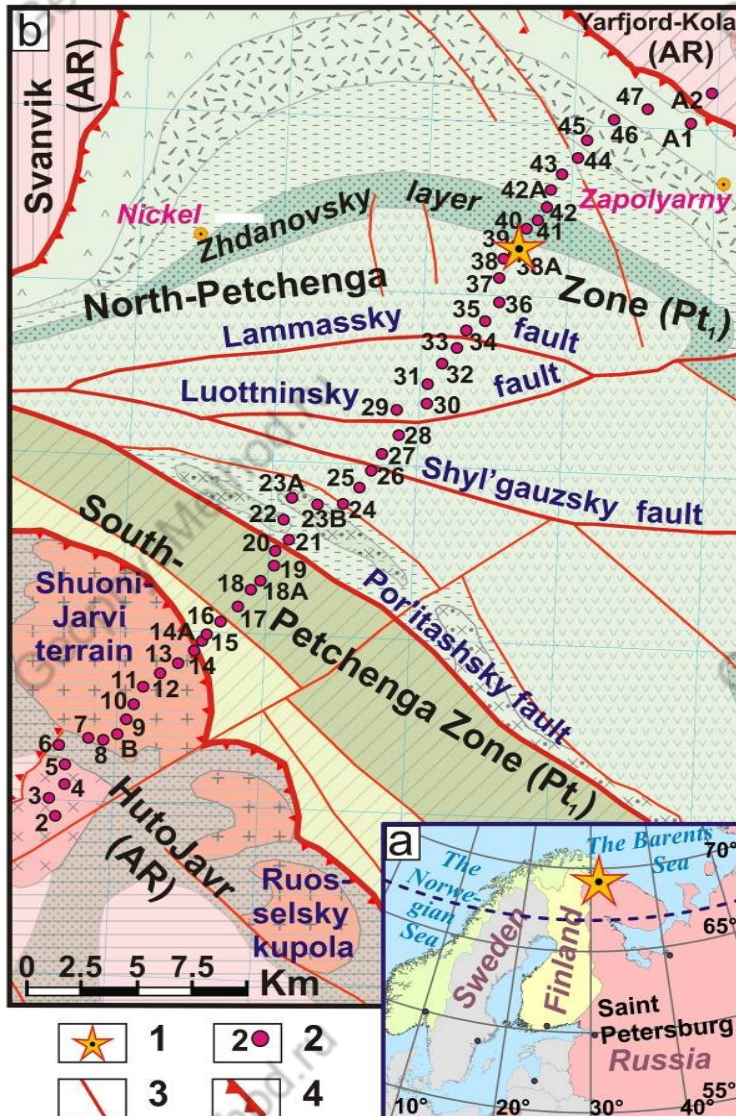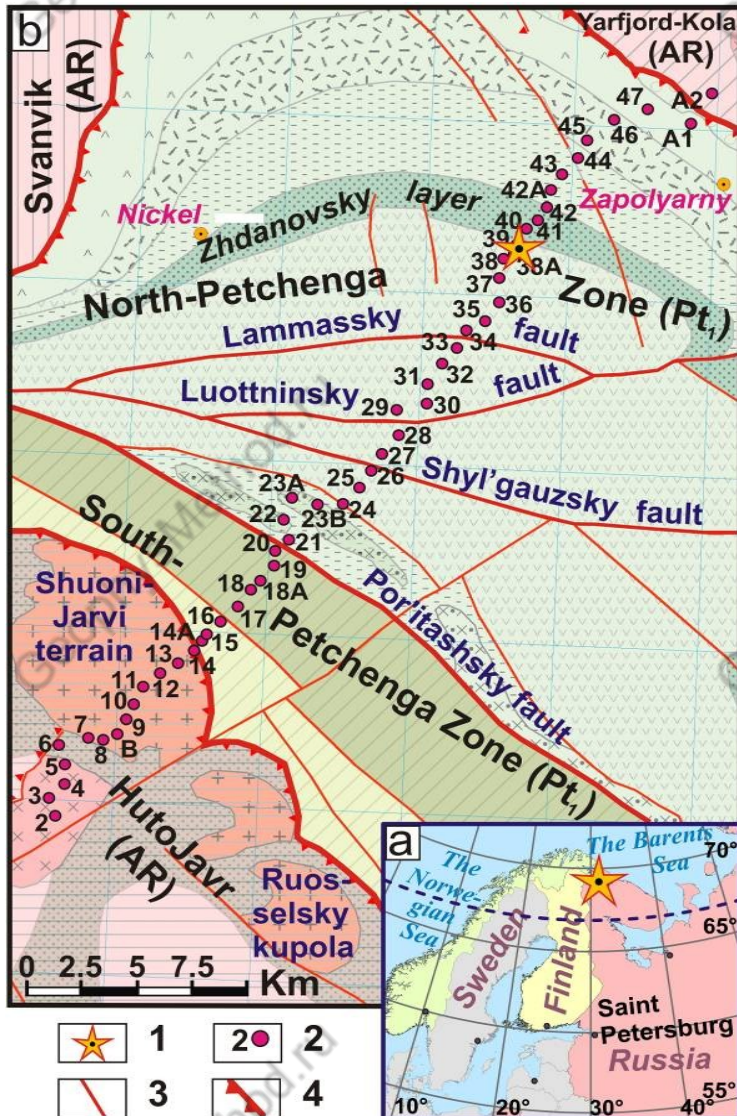

[According to Ermolin at el., 2014]

a – induction arrows at a frequency 10 Hz
b – geoelectrical cross-section through Pechenga structure and Kola Superdeep Borehole
c – apparent resistivity pseudo sections

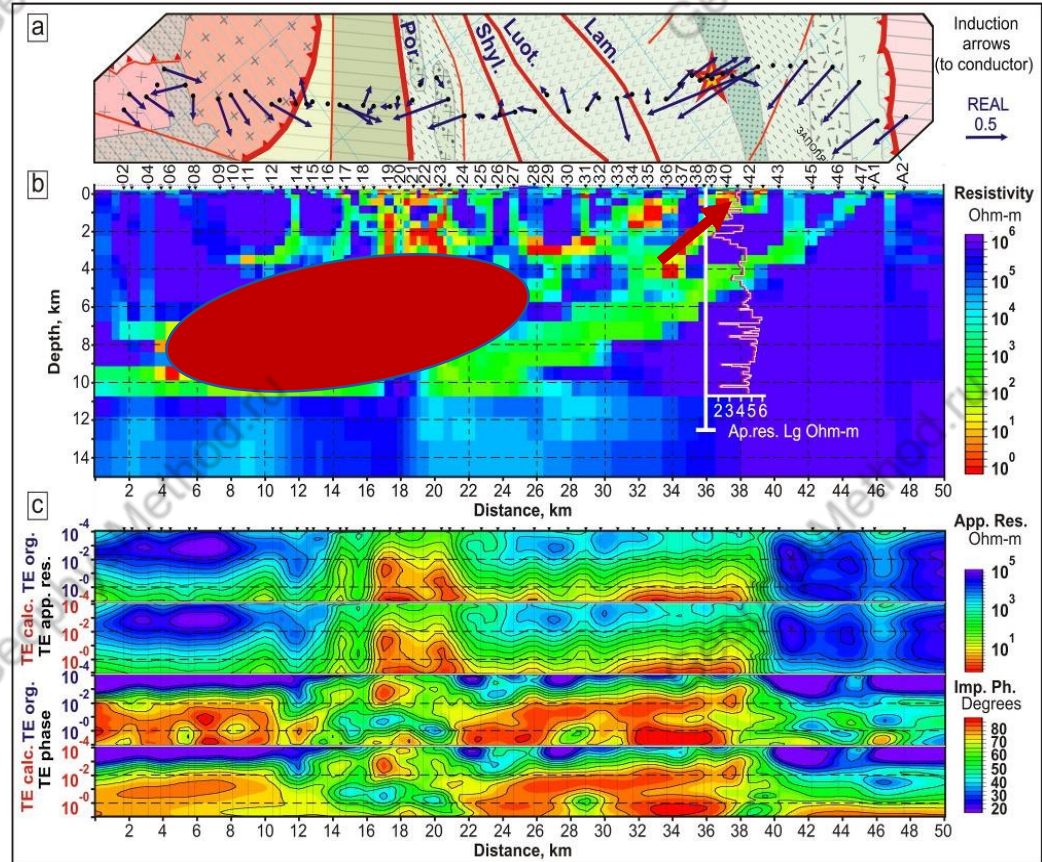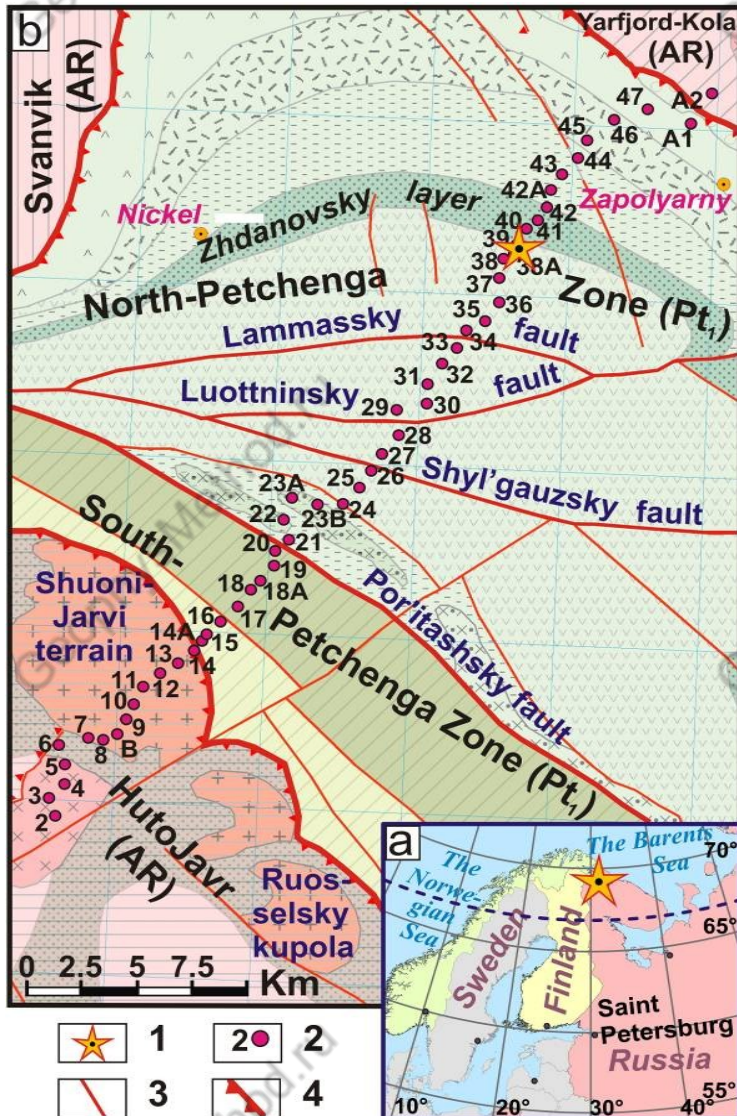# Comparison of deep magnetotelluric with Kola SG-3 borehole of the (the work of the Mining University)

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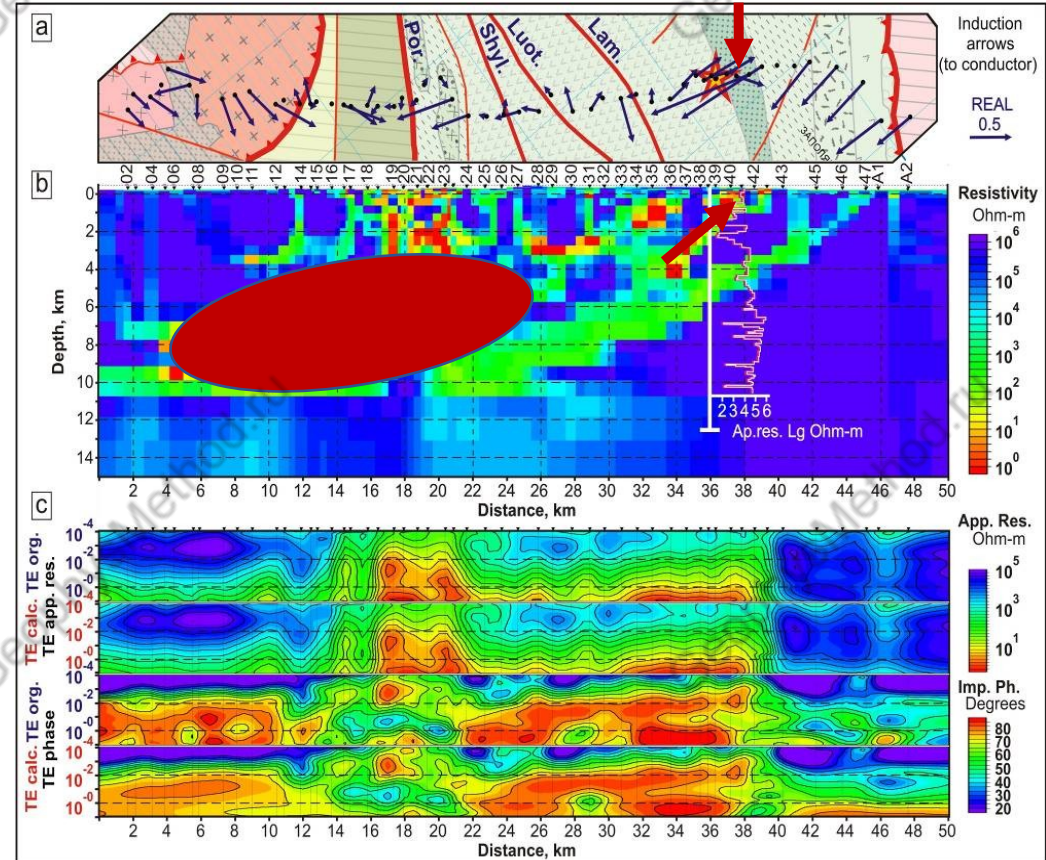# Comparison of deep magnetotelluric with Kola SG-3 borehole of the (the work of the Mining University)

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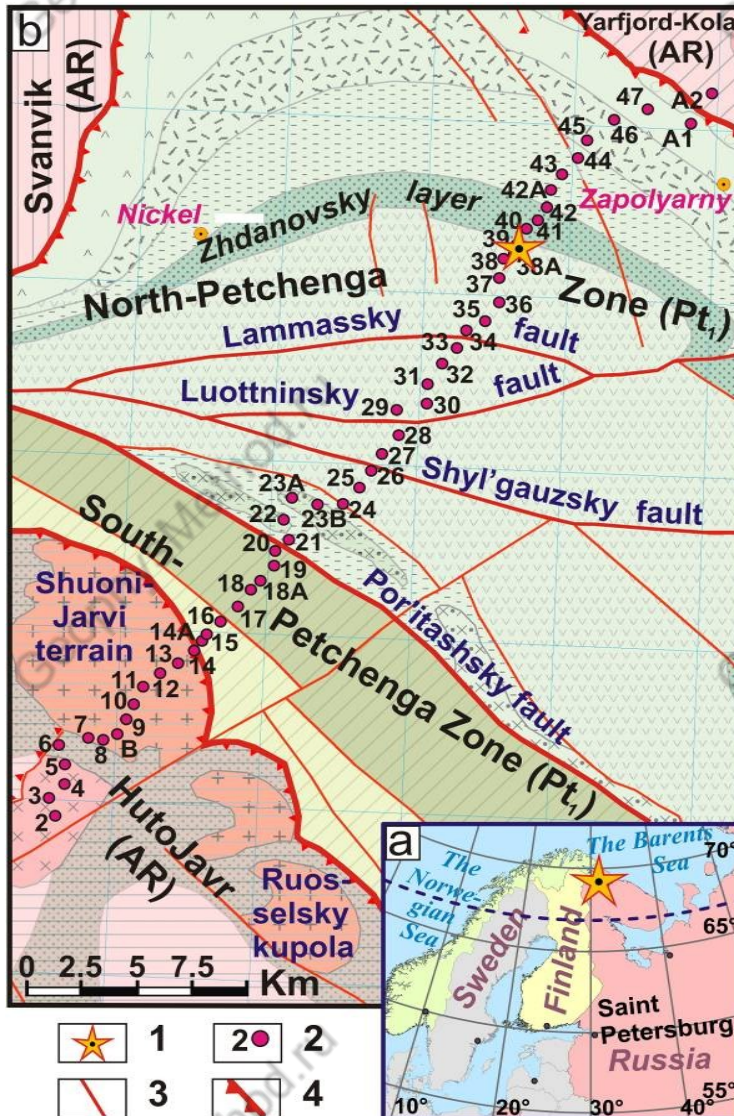c – apparent resistivity pseudo sections

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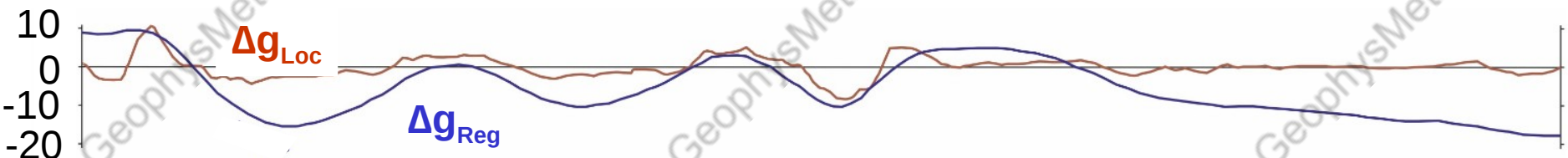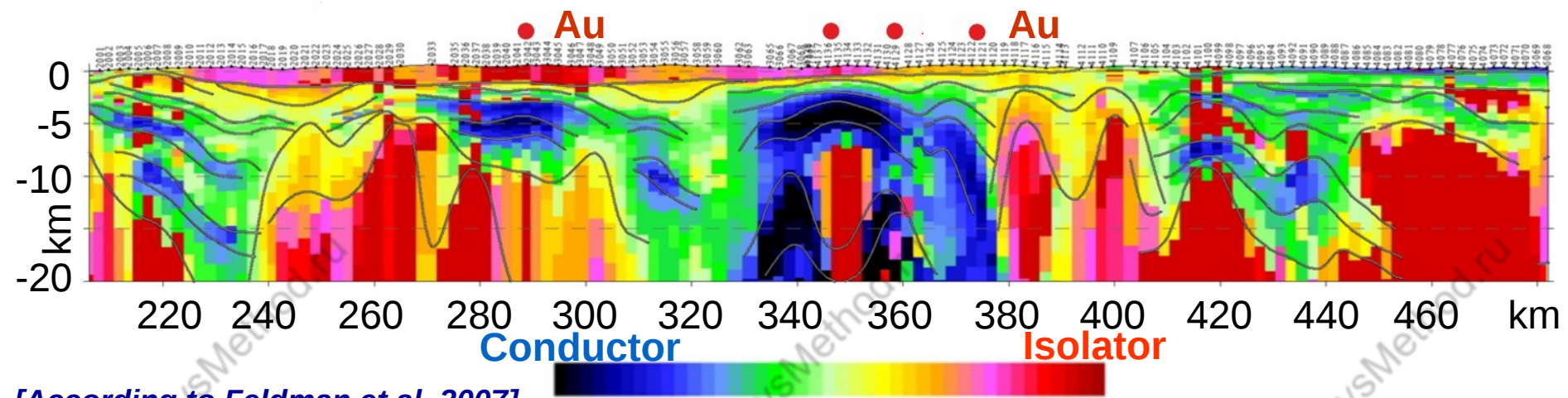c – apparent resistivity pseudo sections

Unique deposit

a – induction arrows at a frequency 10 Hz

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c – apparent resistivity pseudo sections

[According to Ermolin at el., 2014]

Regional MT surveys - International experience
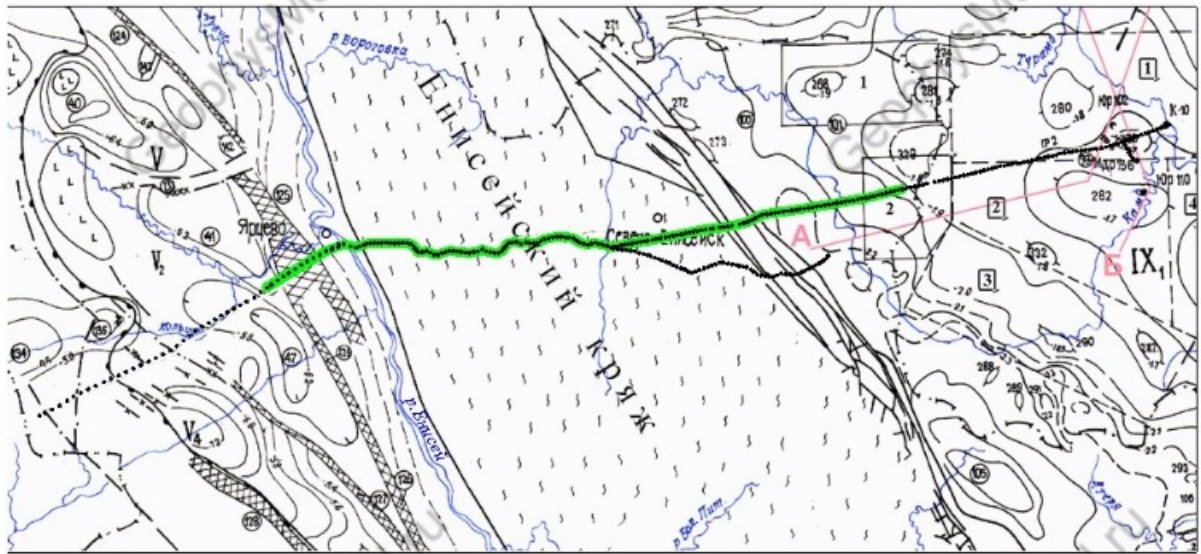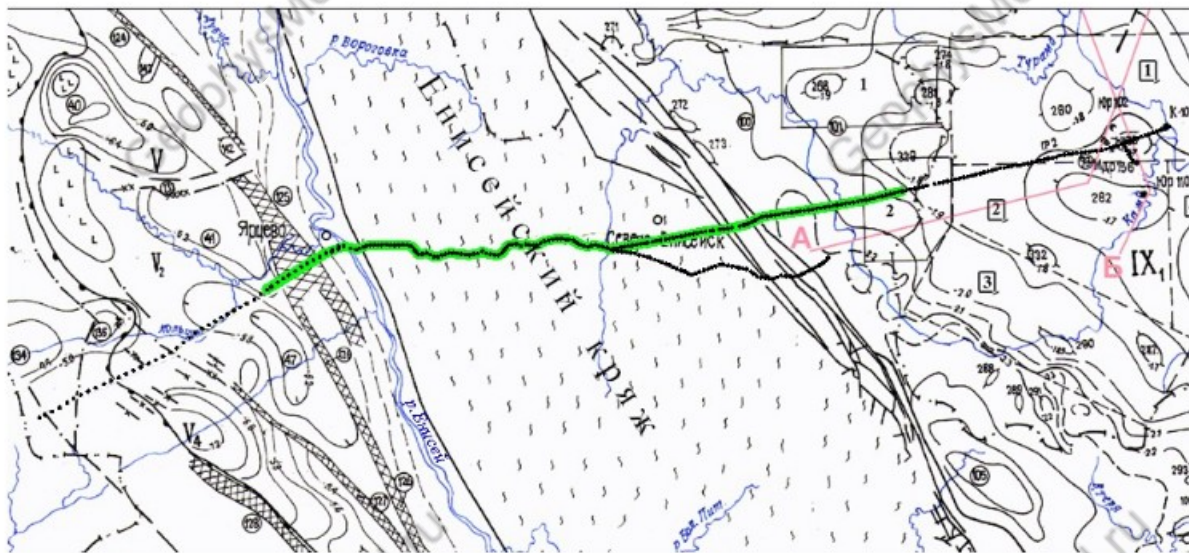
Russia

Position of the MT Profile

Δg_Loc

$$\Delta g_{Loc}$$

$$\Delta g_{Reg}$$

10
0
-10
-20

Geoelectrical cross-section across Yenisei Range

Au   ● ● ●   Au

0
-5
-10
km
-20

220 240 260 280 300 320 340 360 380 400 420 440 460 km

Conductor   **Isolator**

[According to Feldman et al. 2007]

Regional MT surveys - International experience
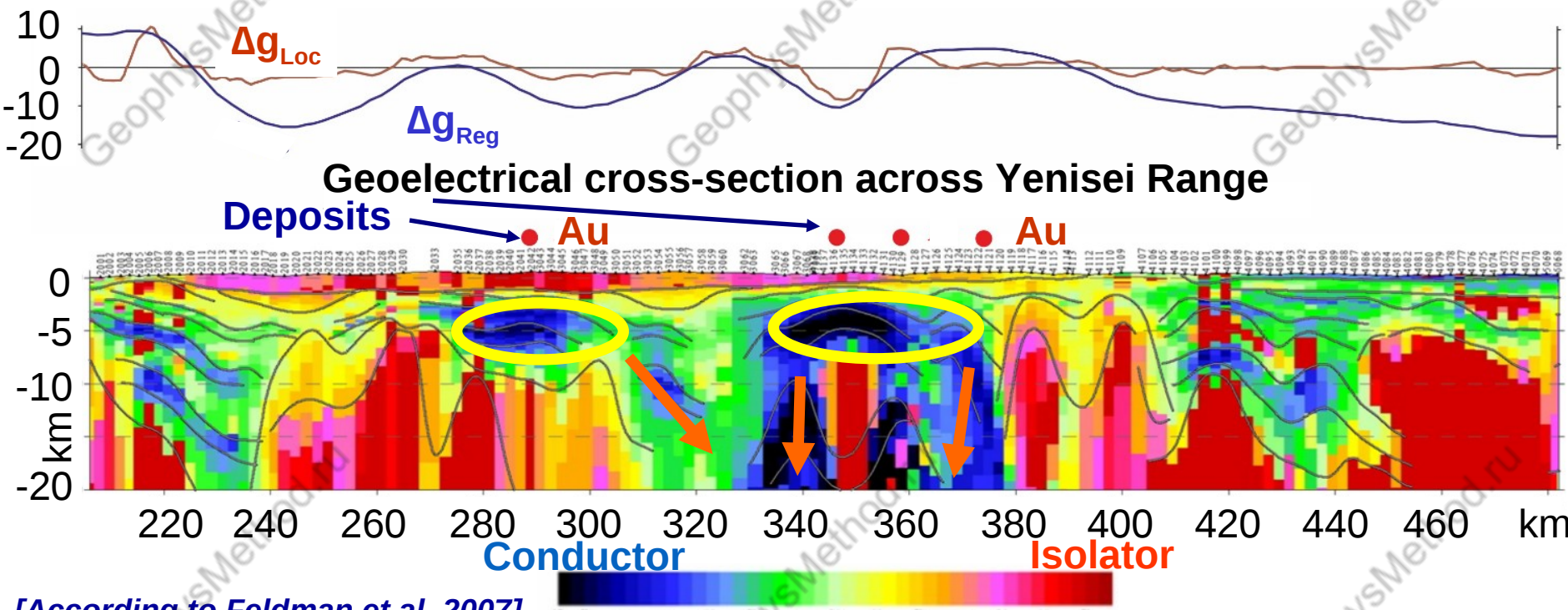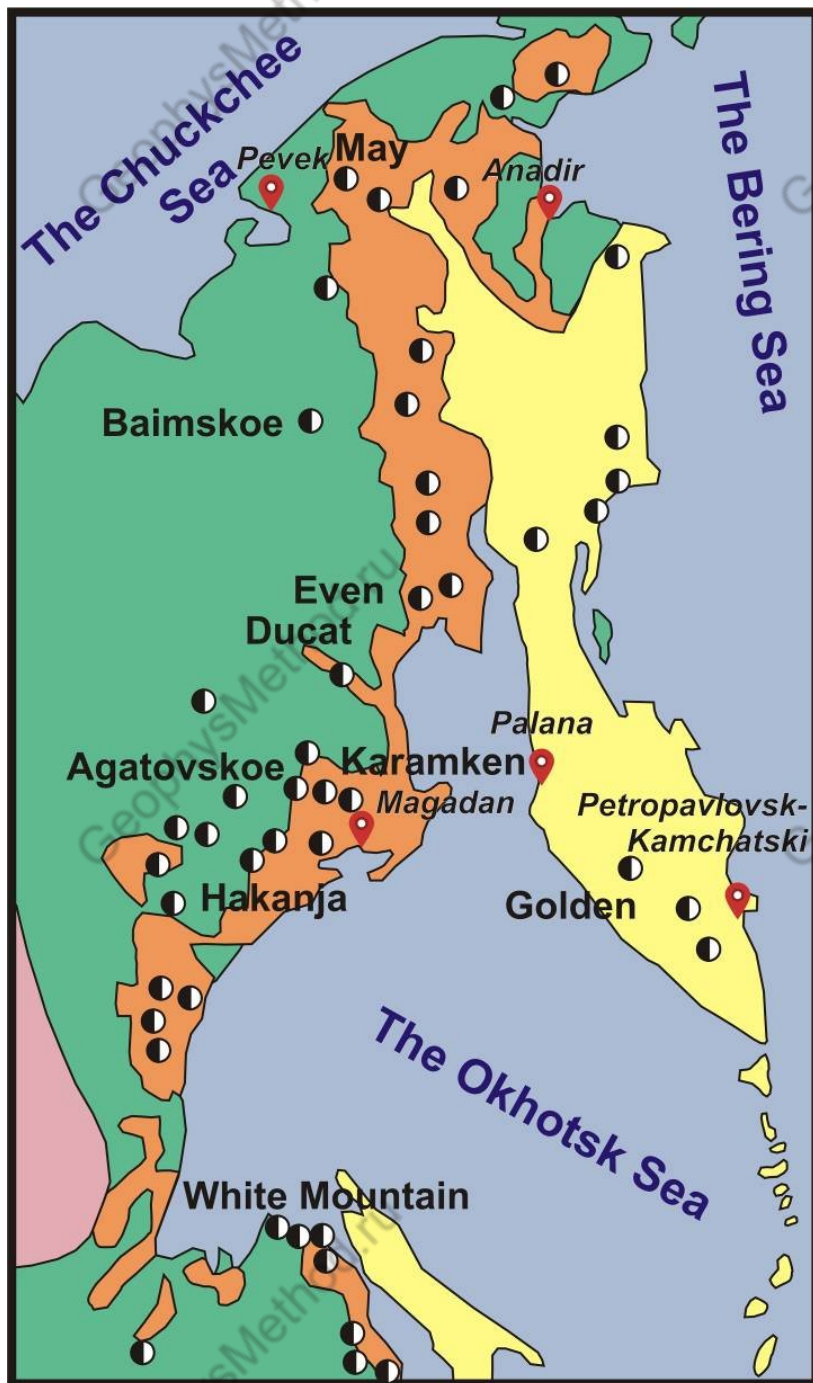
Russia

Position of the MT Profile

$Δg_{Loc}$

$Δg_{Reg}$

10
0
-10
-20

Geoelectrical cross-section across Yenisei Range

Deposits

Au   **Au**

0
-5
-10
-15
-20

220 240 260 280 300 320 340 360 380 400 420 440 460 km

Conductor   **Isolator**

[According to Feldman et al. 2007]

The position of gold deposits within the Okhotsk-Chukotka volcanic belt

There are a lot of low-sulfidation epithermal gold deposit inside the belt

Okhotsk-Chukotka volcanic belt

Verkhoyansk-Chukotka thrust-fold belt

Koryak-Kamchatka thrust-fold belt

Siberian platform

City

Au-Ag deposit

The position of gold deposits within the Okhotsk-Chukotka volcanic belt

There are a lot of low-sulfidation epithermal gold deposit inside the belt

Study area

Okhotsk-Chukotka volcanic belt

Verkhoyansk-Chukotka thrust-fold belt

Koryak-Kamchatka thrust-fold belt

Siberian platform

City

Au-Ag deposit
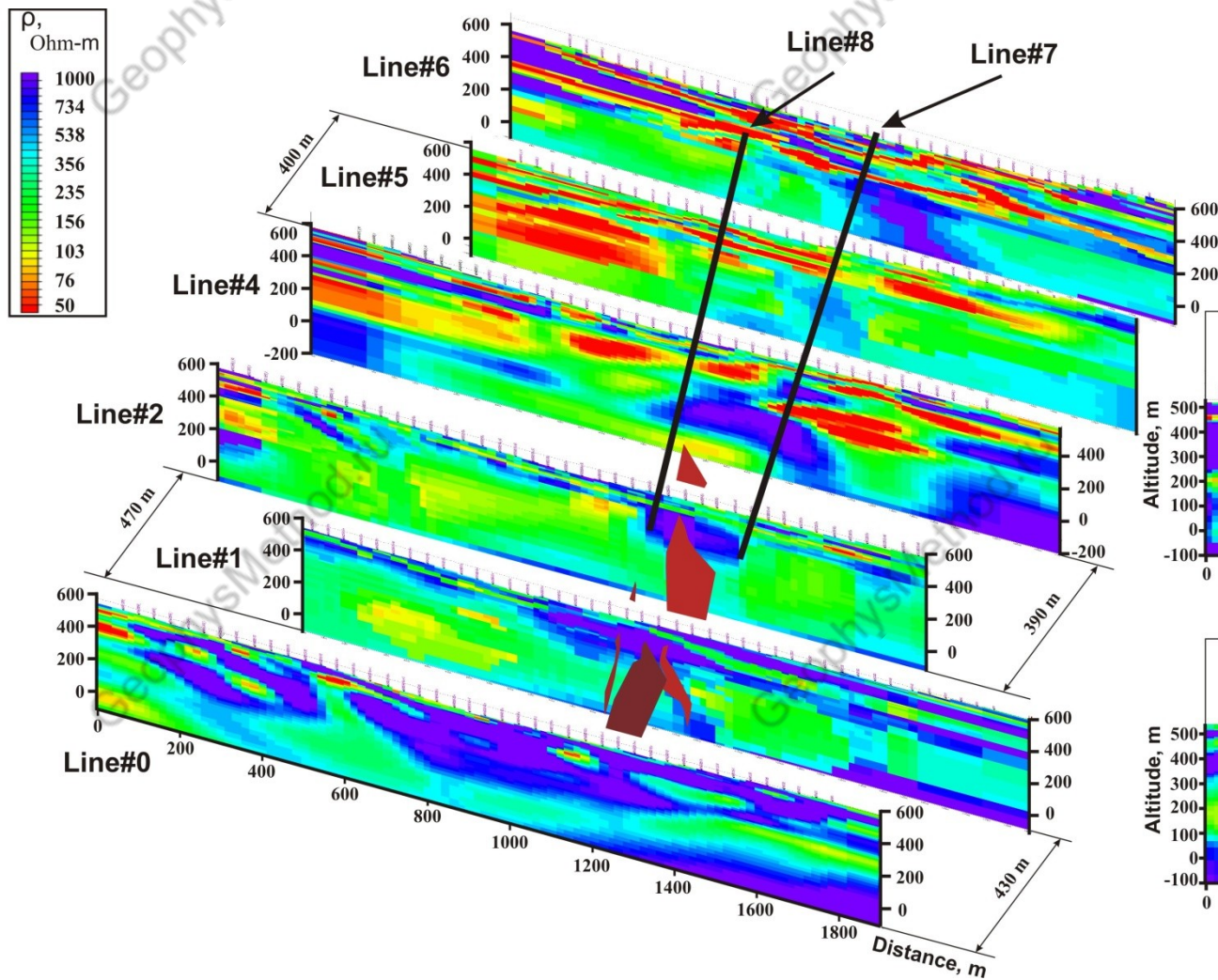
3D visualization of geoelectrical cross-sections
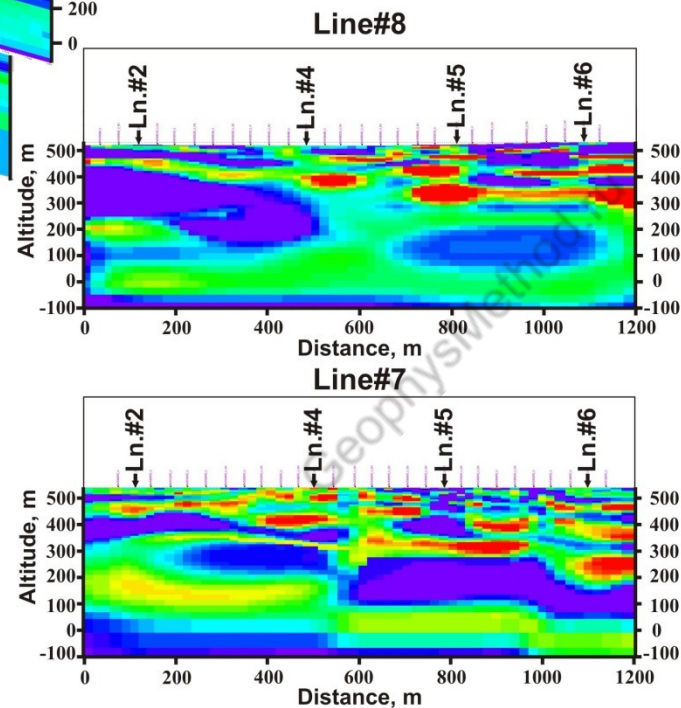
(This vein was detected before Geophysics forecast).
It is located inside the isolator structure
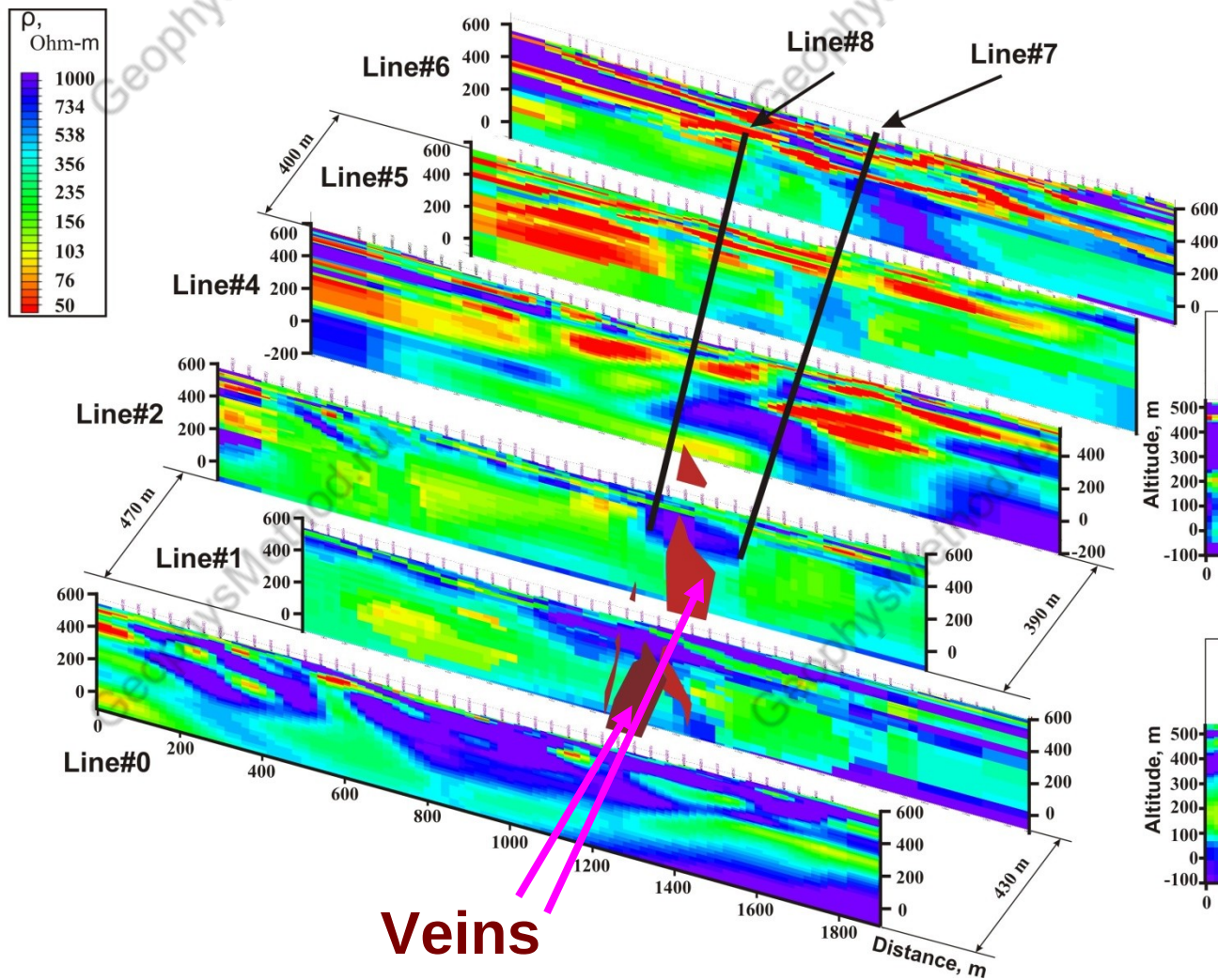
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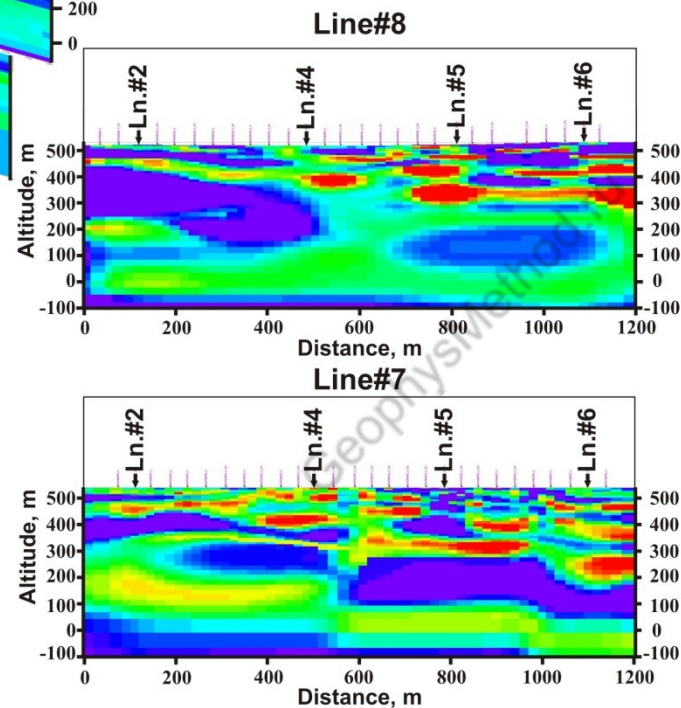
Veins

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35 days for field work and report in 2013
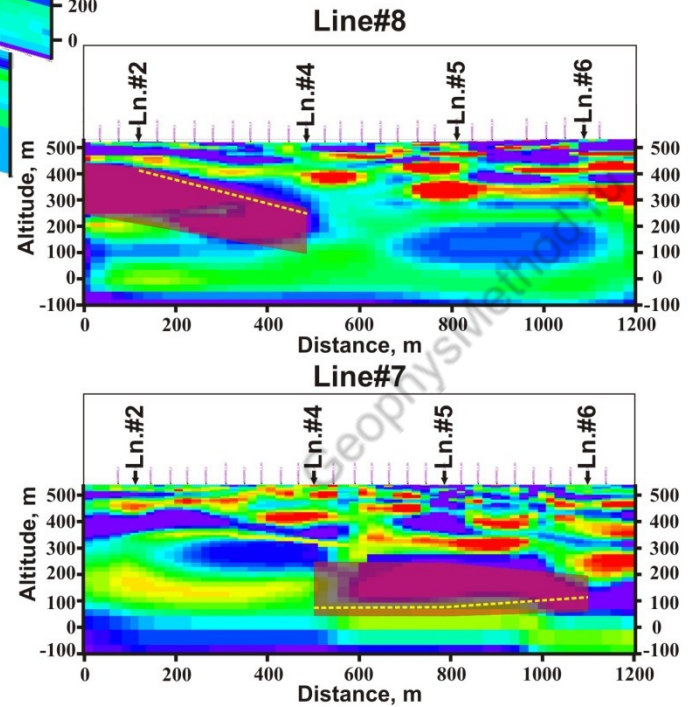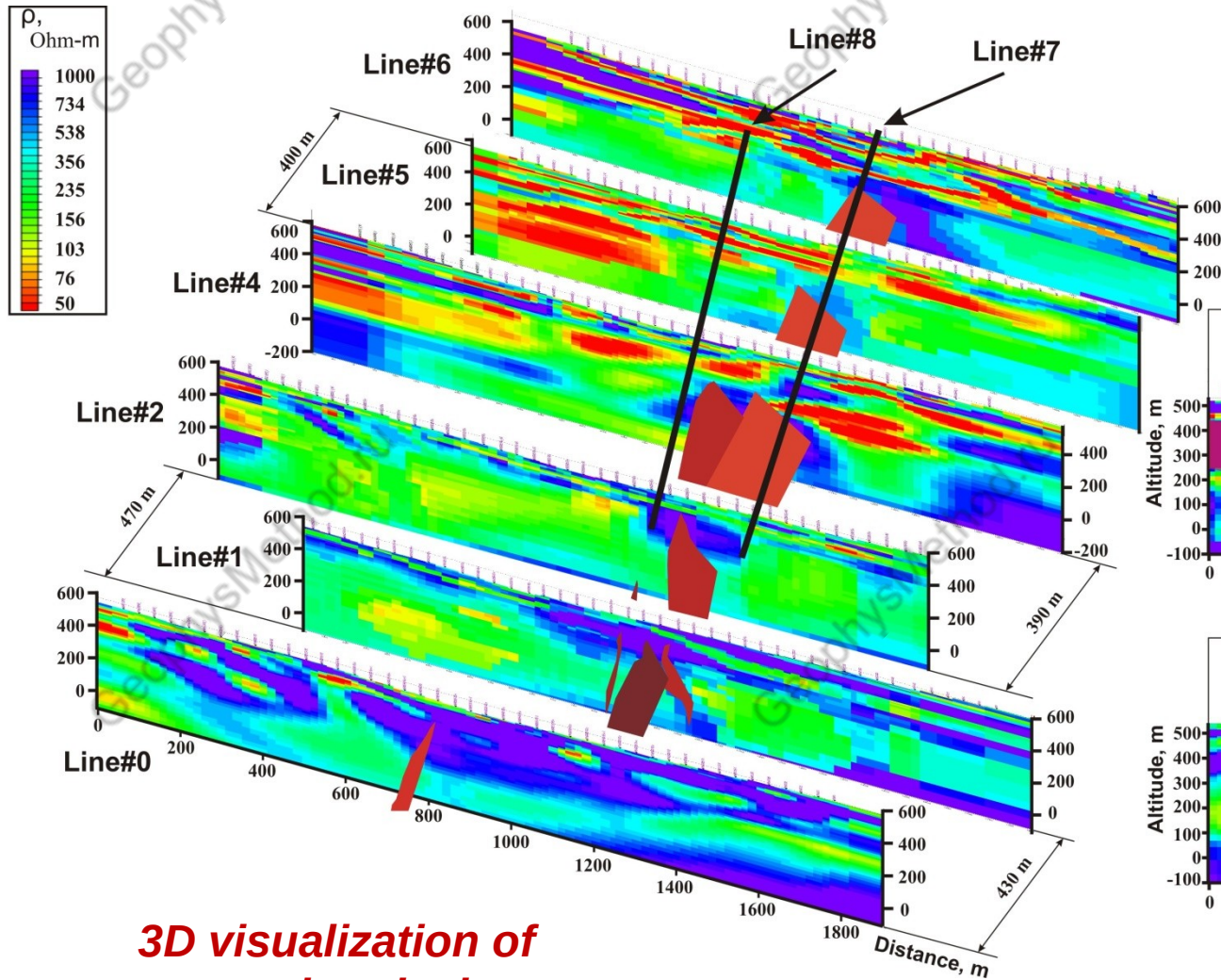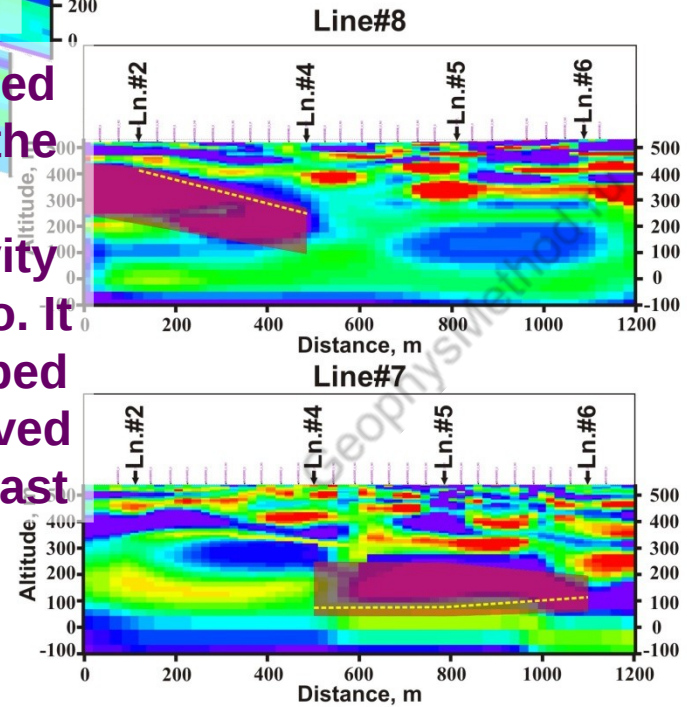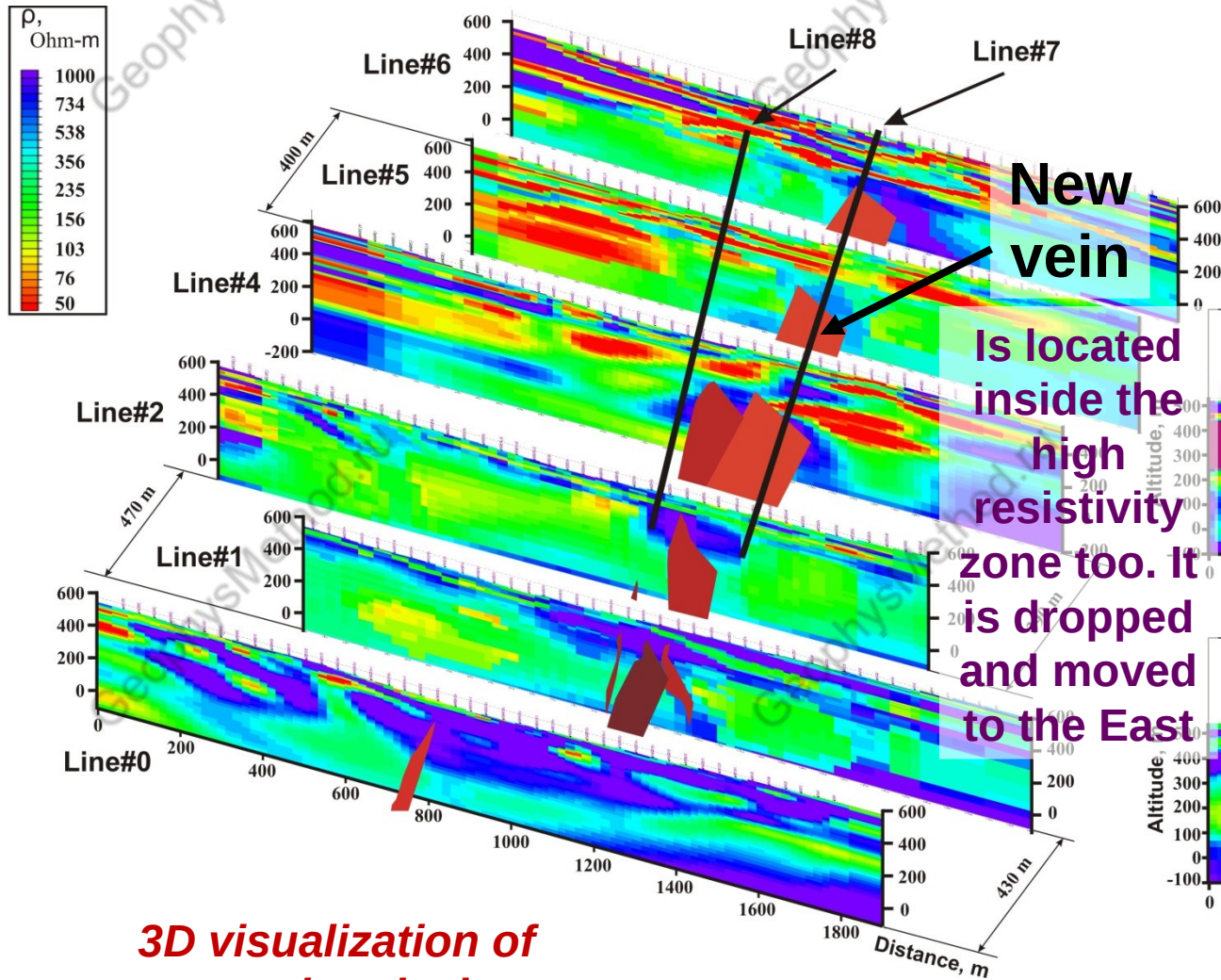
300 AMT stations of the best quality
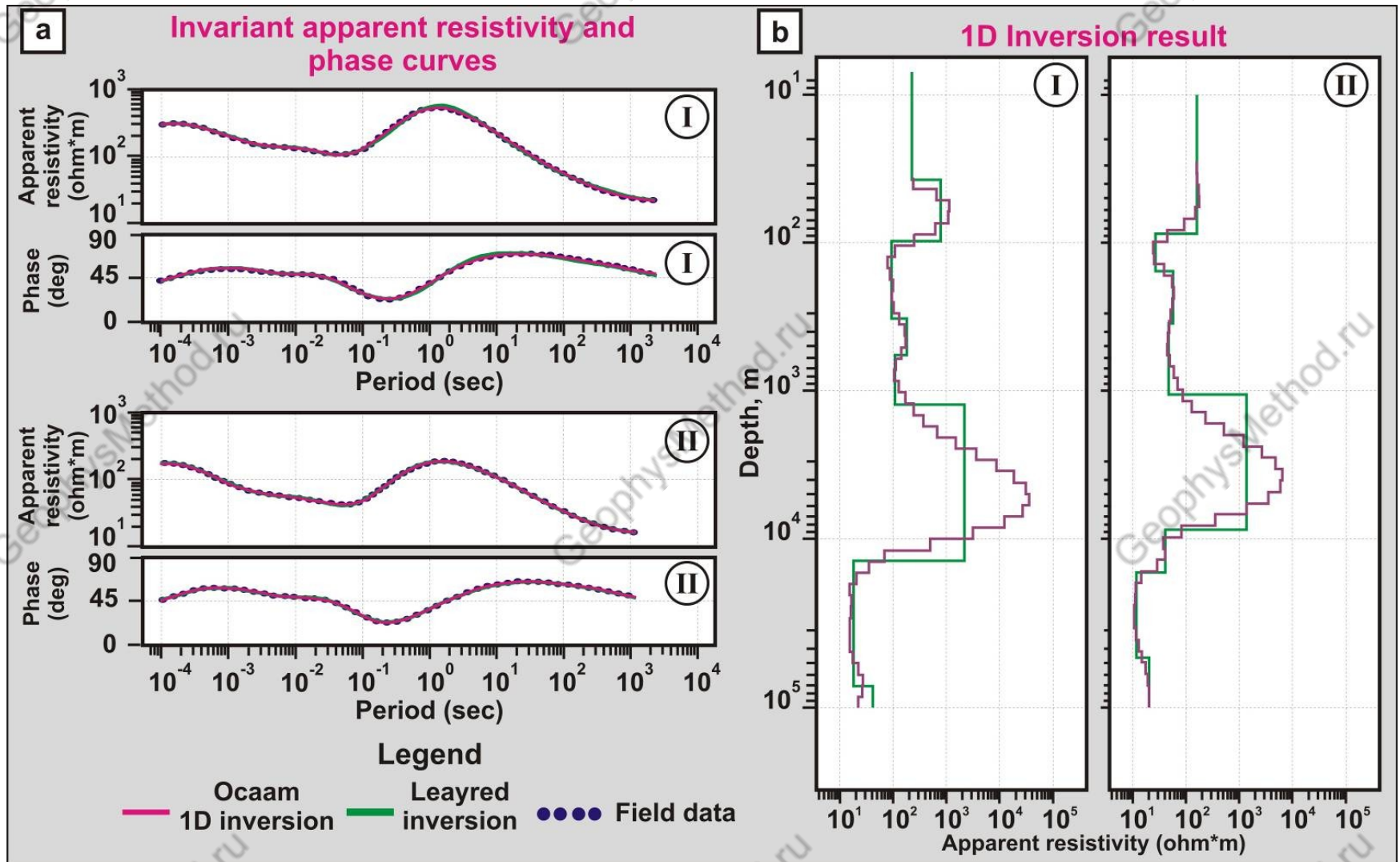
3D visualization of geoelectrical cross-sections

New vein

35 days for field work and report in 2013
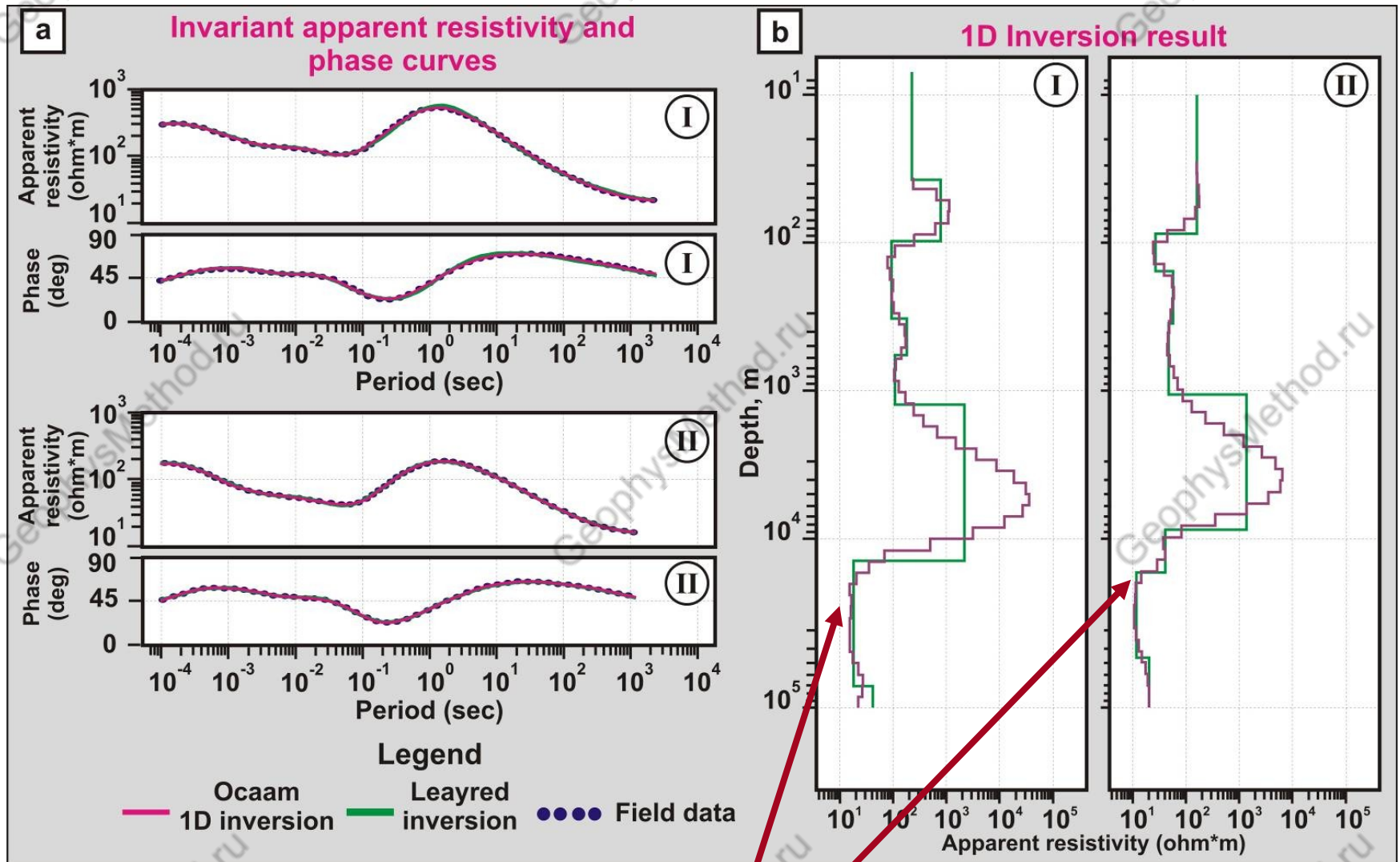
300 AMT stations of the best quality

Is located inside the high resistivity zone too. It is dropped and moved to the East

3D visualization of geoelectrical cross-sections

MT curves in Okhotsk-Chukotka volcanic belt
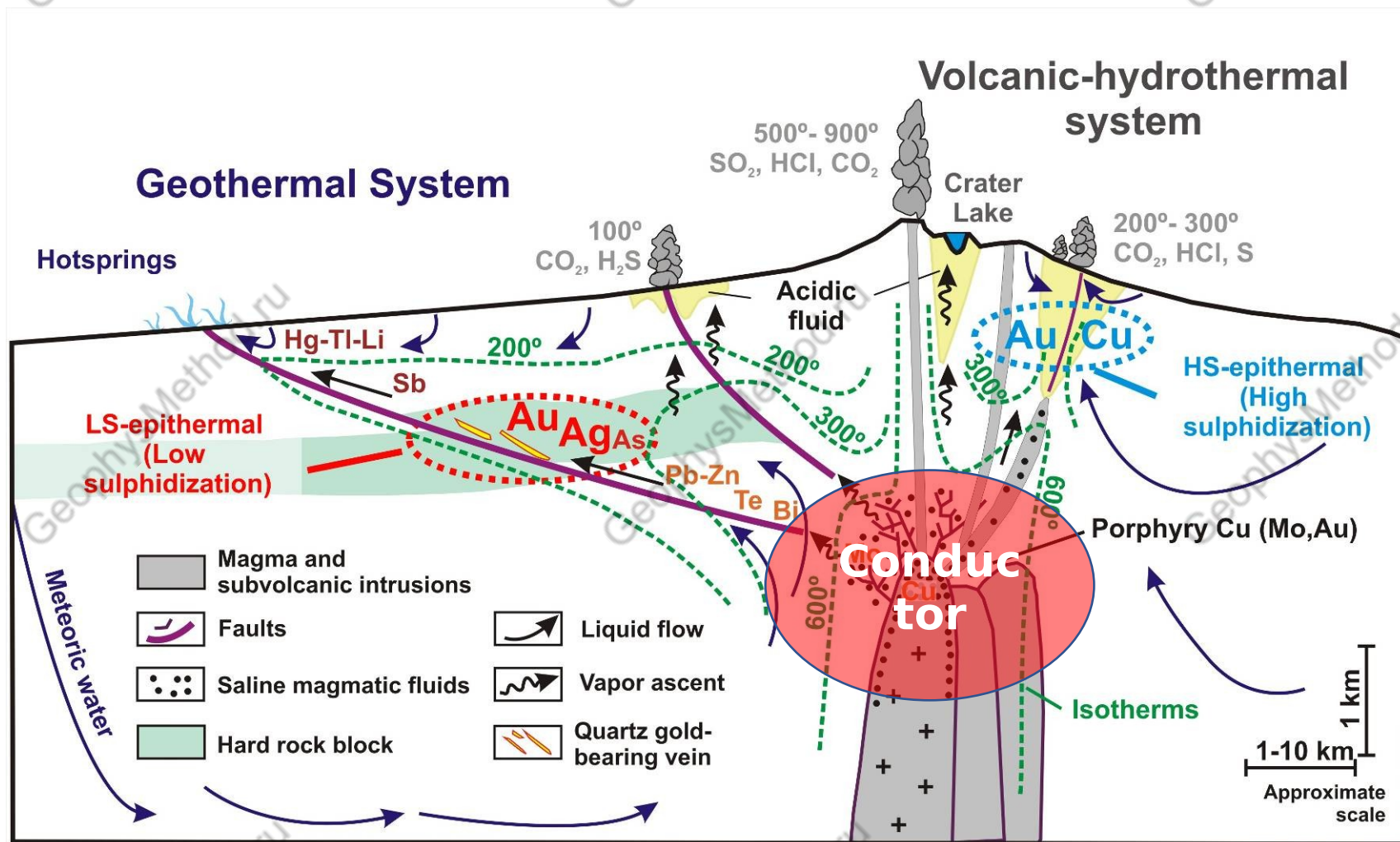
MT curves in Okhotsk-Chukotka volcanic belt

a Invariant apparent resistivity and phase curves

b 1D Inversion result

Legend

Ocaam 1D inversion — Leayred inversion — Field data

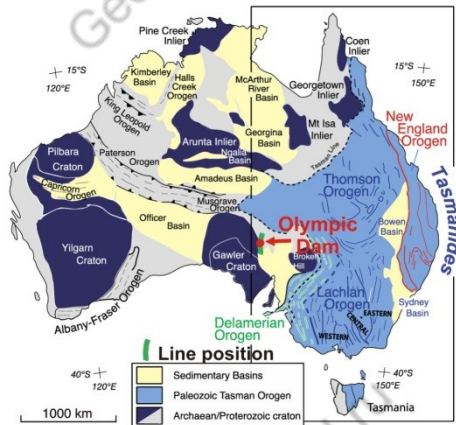**Conductor**

Schematic geological-genetic model of the epithermal deposit
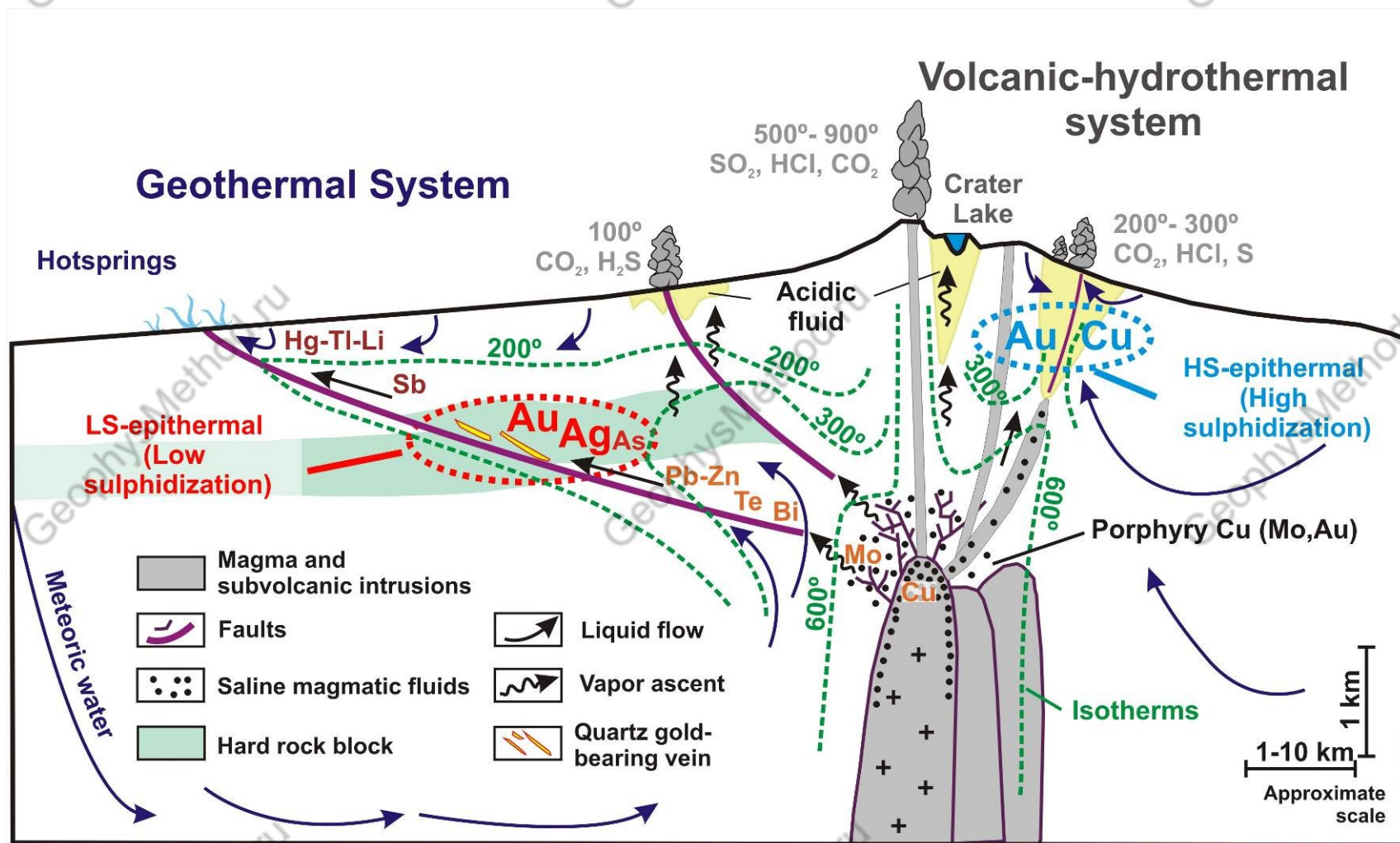
(Hedenquist et al. 2000, modified Ermolin and Savichev 2018)

# *Schematic geological-genetic model of the epithermal deposit*

Volcanic-hydrothermal system

Geothermal System

$500°- 900°$
SO_2, HCl, CO_2

Crater Lake

$200°- 300°$
CO_2, HCl, S

Hotsprings

$100°$
CO_2, H_2S

Hg-Tl-Li
$200°$

Sb

Acidic fluid

Au Cu

$200°$

HS-epithermal (High sulphidization)

$300°$

LS-epithermal (Low sulphidization)

Au Ag As

$300°$

$600°$

Pb-Zn
Te Bi

Porphyry Cu (Mo,Au)

Conductor

Cu

Magma and subvolcanic intrusions

Faults

Liquid flow

$600°$

Saline magmatic fluids

Vapor ascent

Meteoric water

Hard rock block

Quartz gold-bearing vein

Isotherms

1 km

1-10 km

Approximate scale

(Hedenquist et al. 2000, modified Ermolin and Savichev 2018)

Mineral Systems - Olympic Dam IOCG deposit
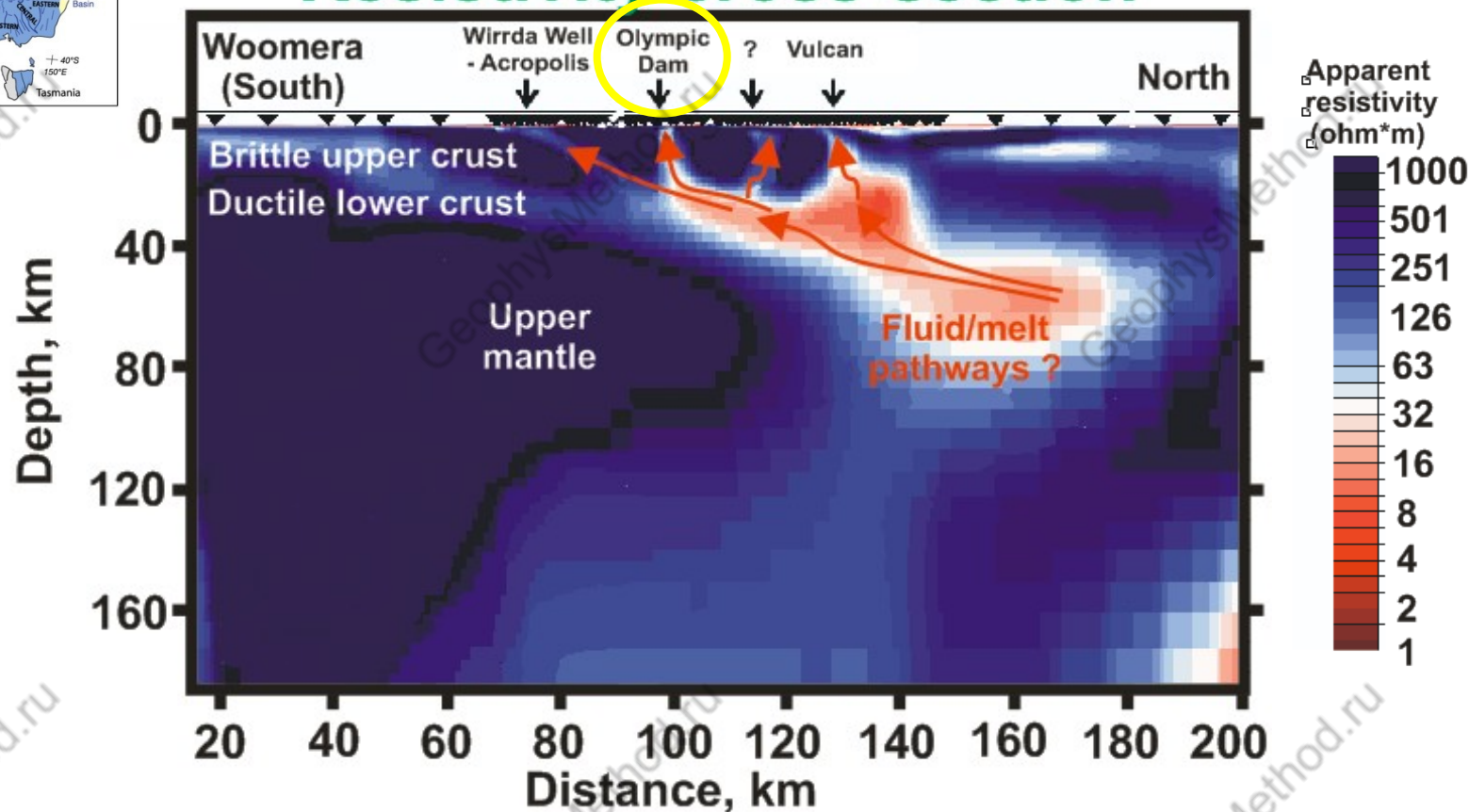
[According to M. Dentith, 2017]

Mineral Systems - Olympic Dam IOCG deposit

Geoelectrical cross-section across Olympic Dam
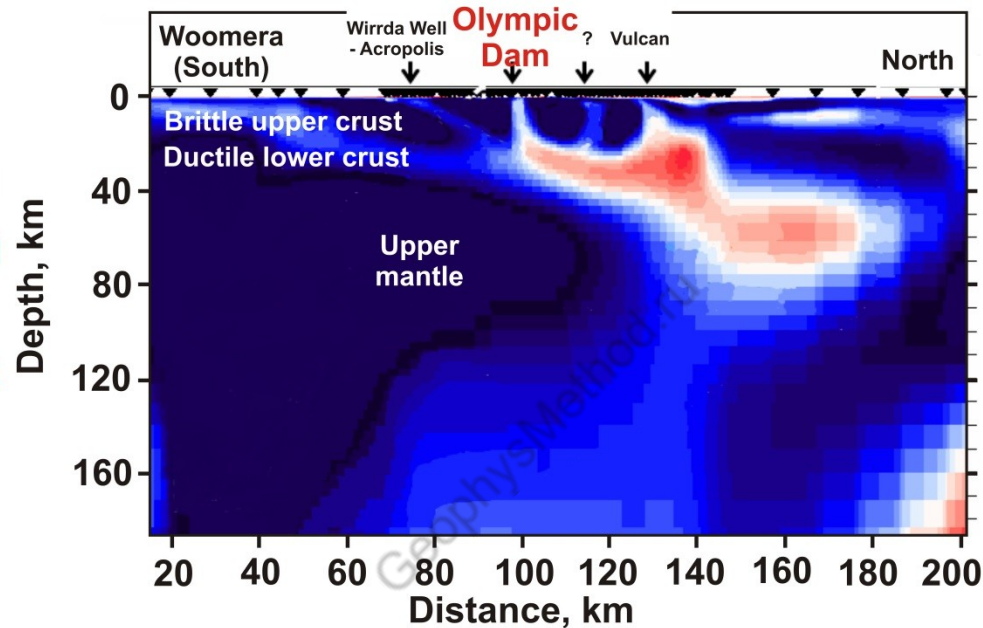
[According to Mike Dentith, 2017]
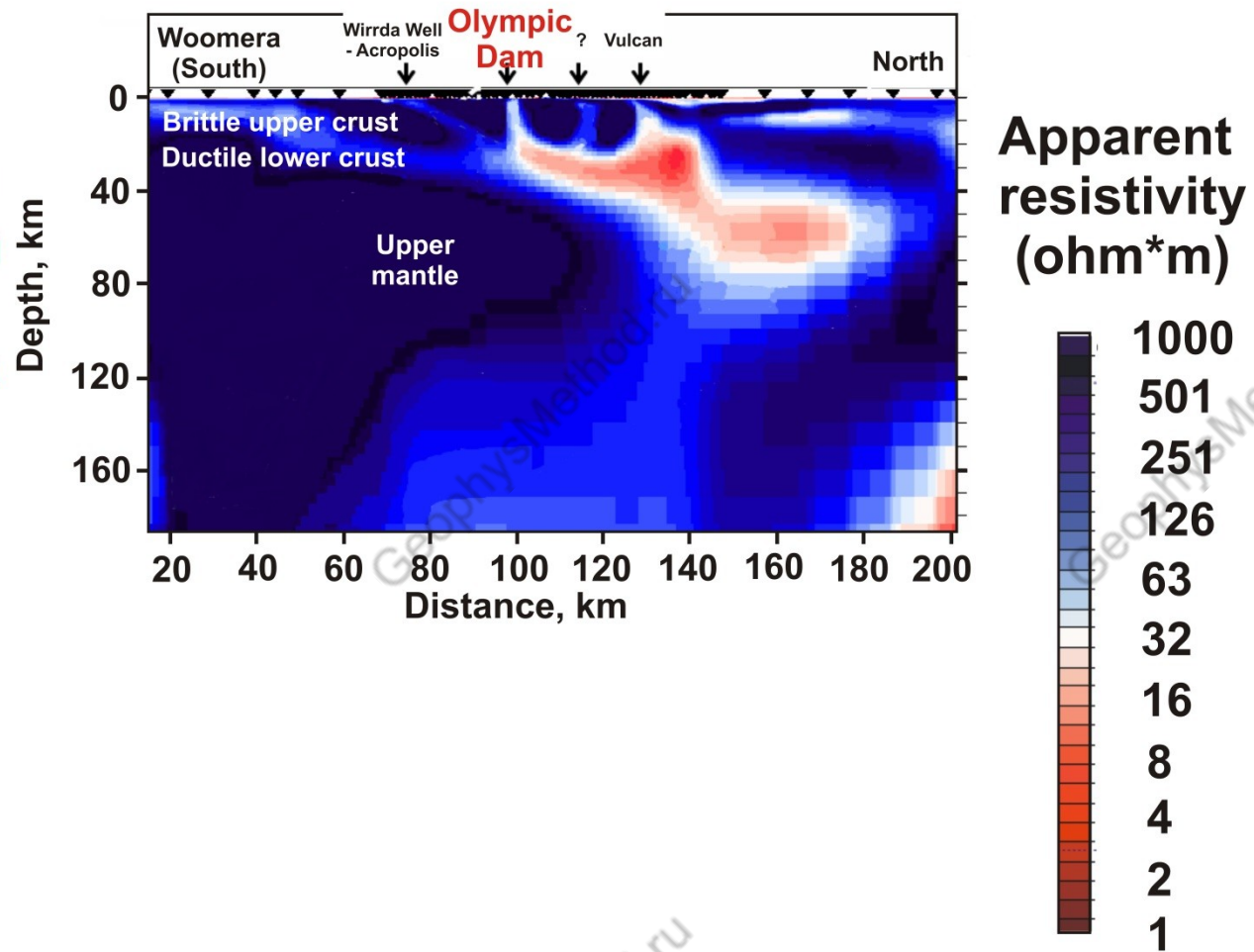
Mineral Systems - Olympic Dam IOCG deposit

Geoelectrical cross-section across Olympic Dam

[According to Mike Dentith, 2017]

Geoelectrical model for MT-MVP modeling
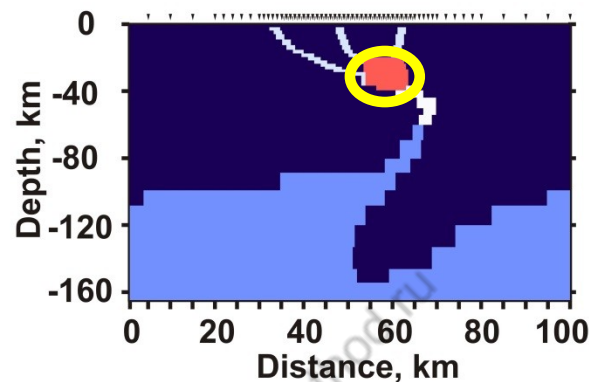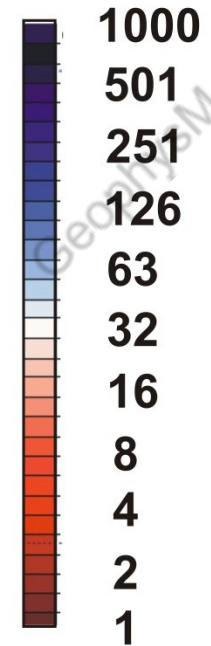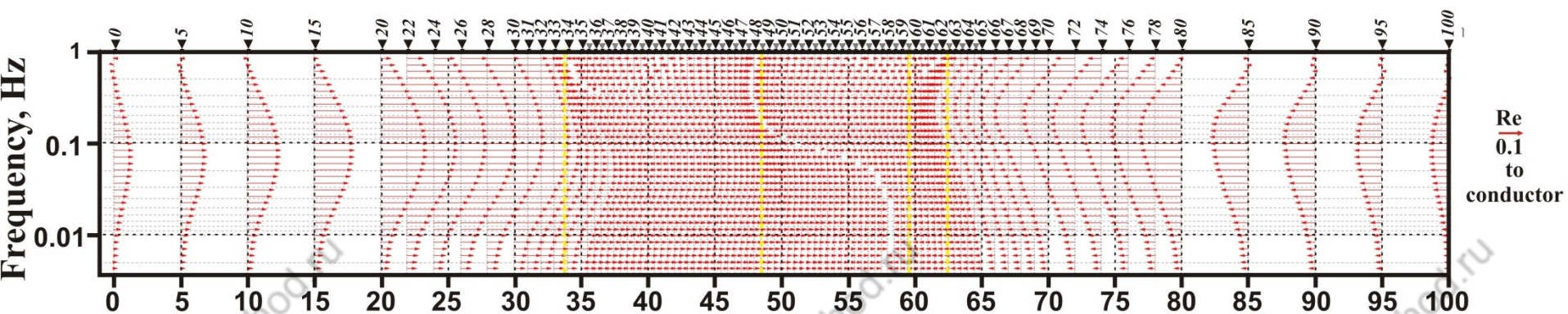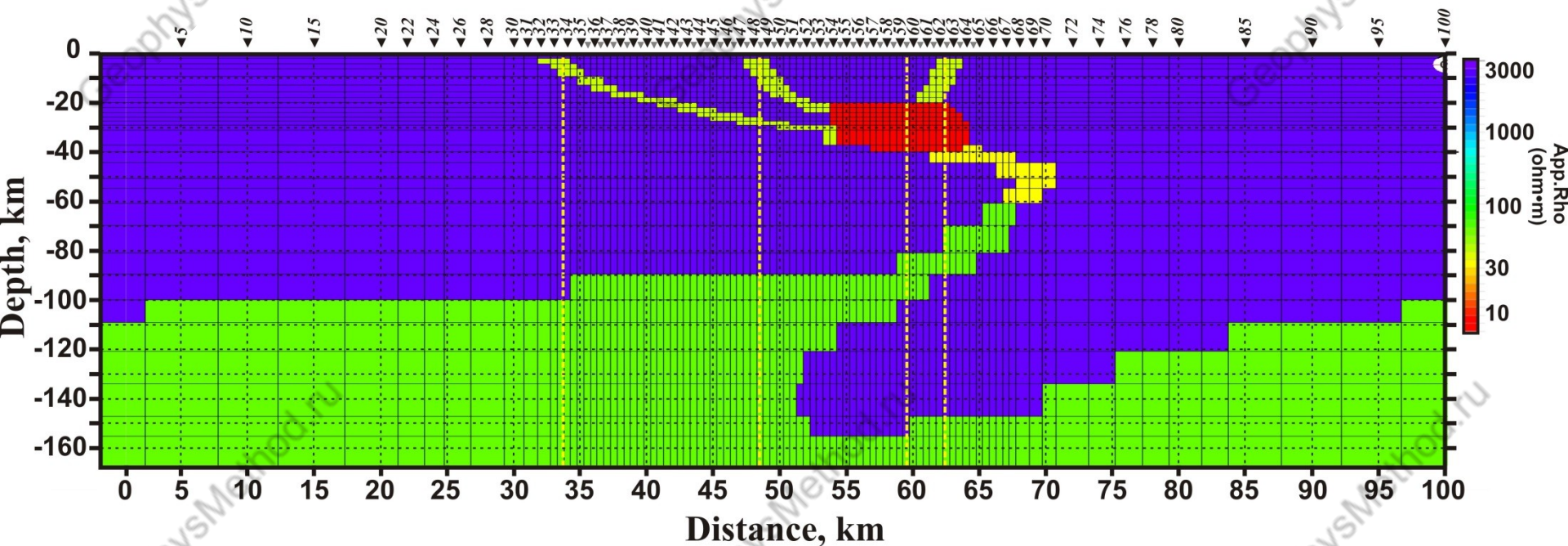
Mineral Systems - Olympic Dam IOCG deposit

Geoelectrical cross-section across Olympic Dam

[According to Mike Dentith, 2017]

Geoelectrical model for MT-MVP modeling

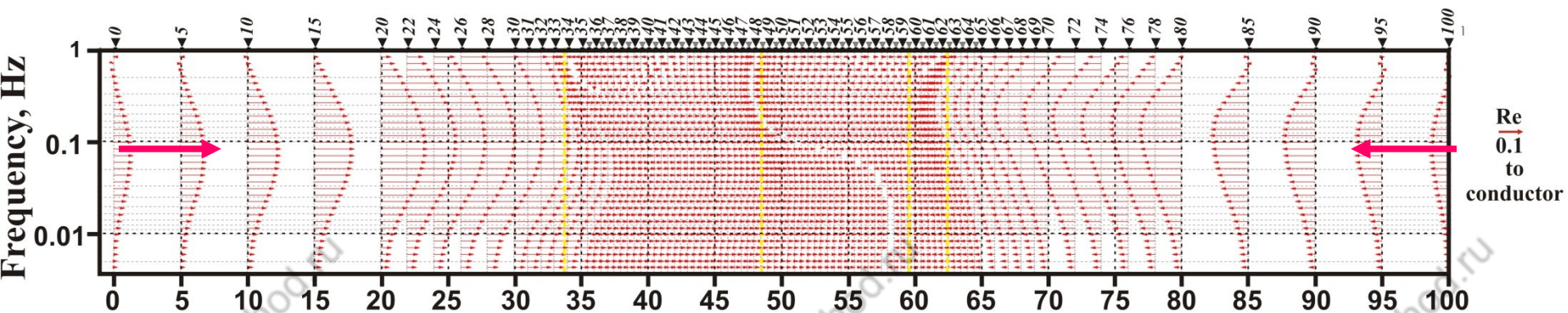# Analysis of modeling results

Induction arrows cross-section

Geoelectrical cross-section (model)

Distance, km

Analysis of modeling results
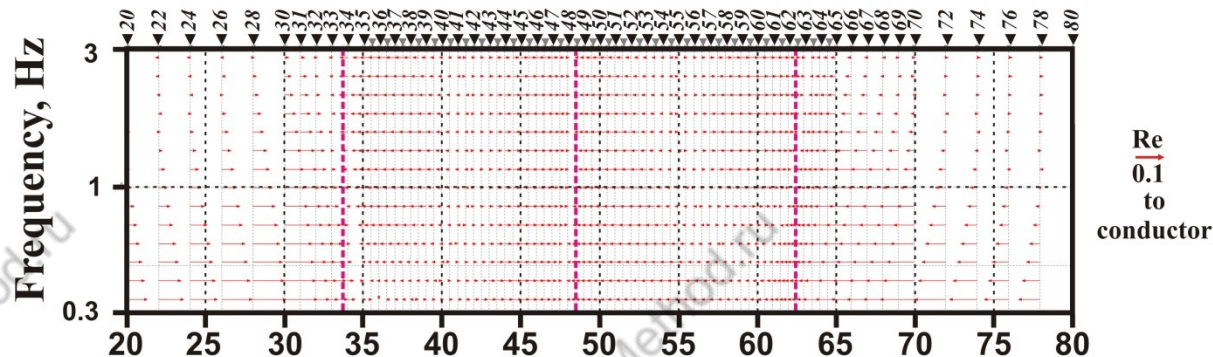
Induction arrows cross-section

Geoelectrical cross-section (model)
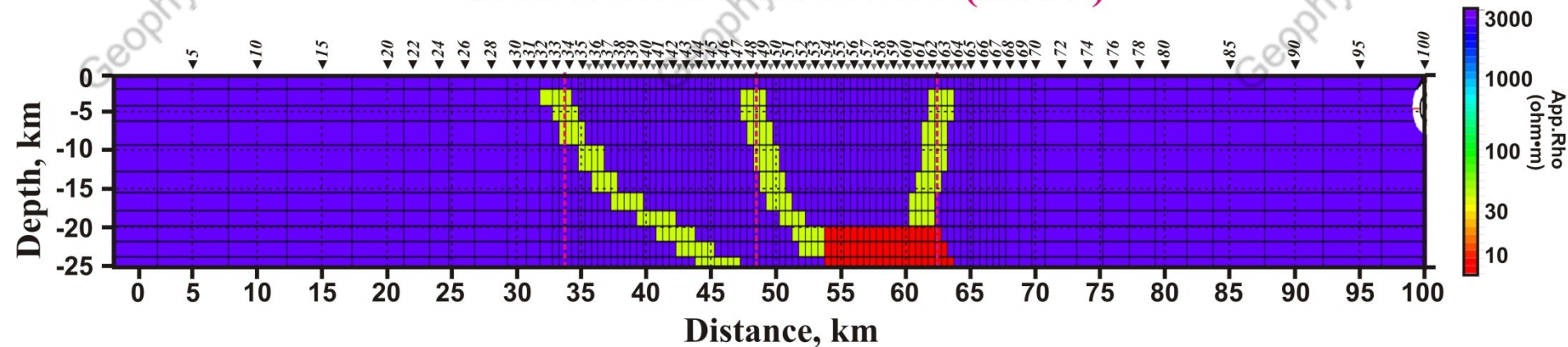
60 km   40 km

Distance, km
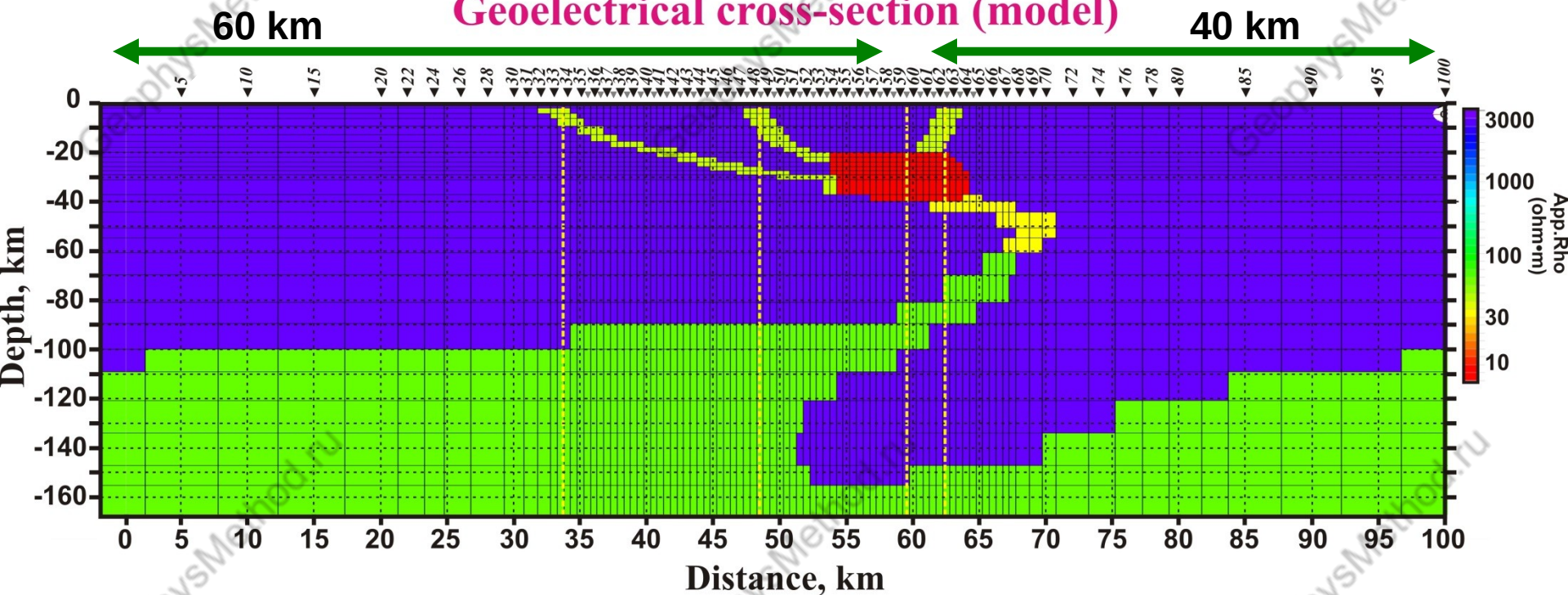
Analysis of modeling results

Induction arrows cross-section

Geoelectrical cross-section (model)

Analysis of modeling results

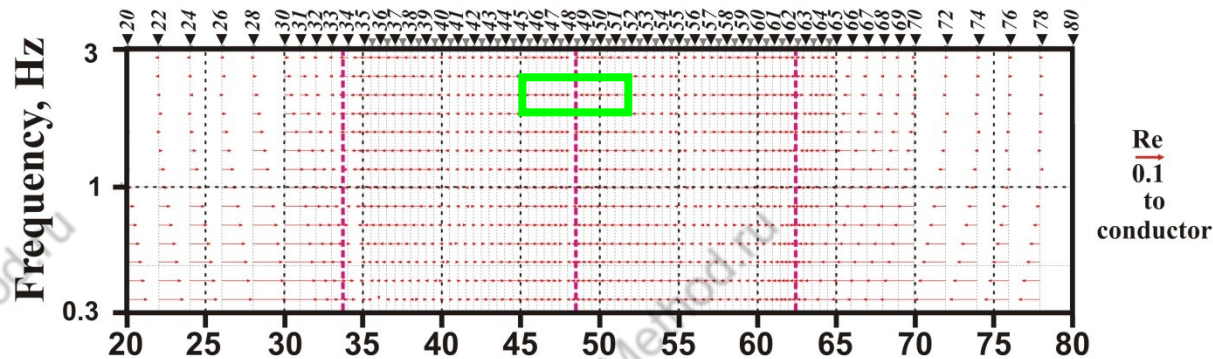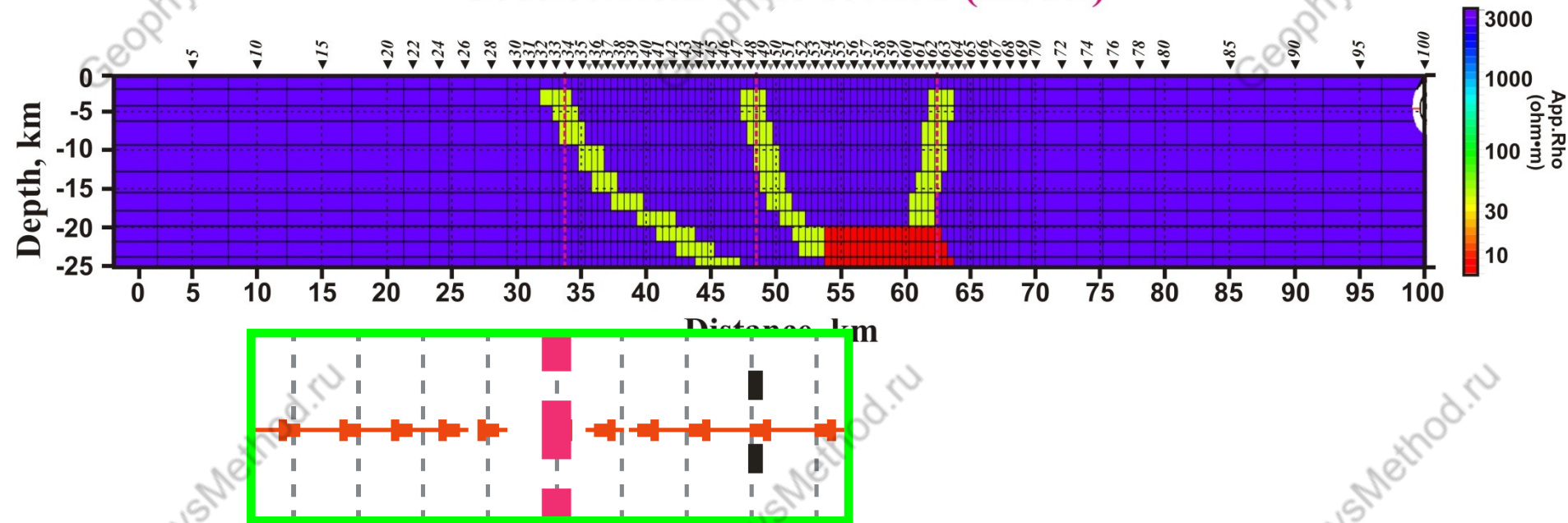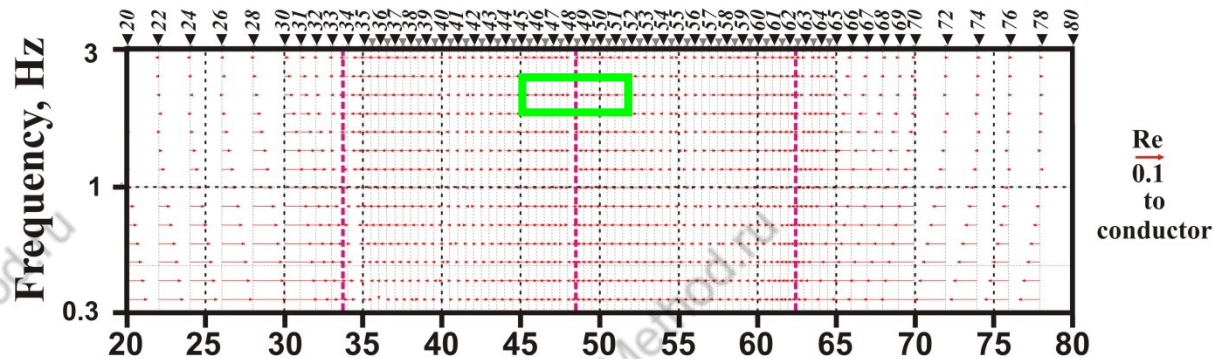## Induction arrows cross-section
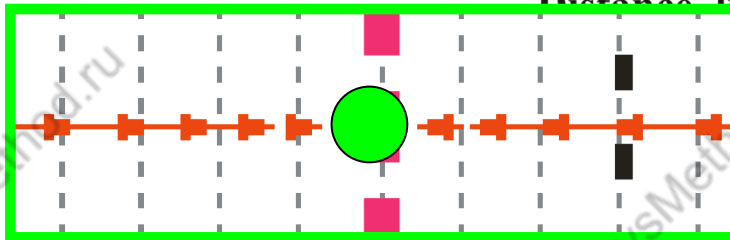

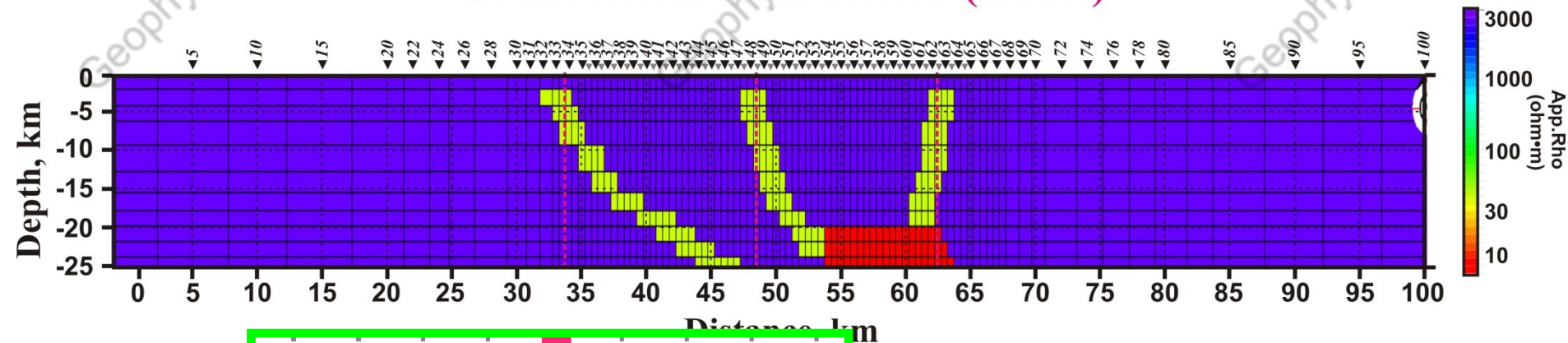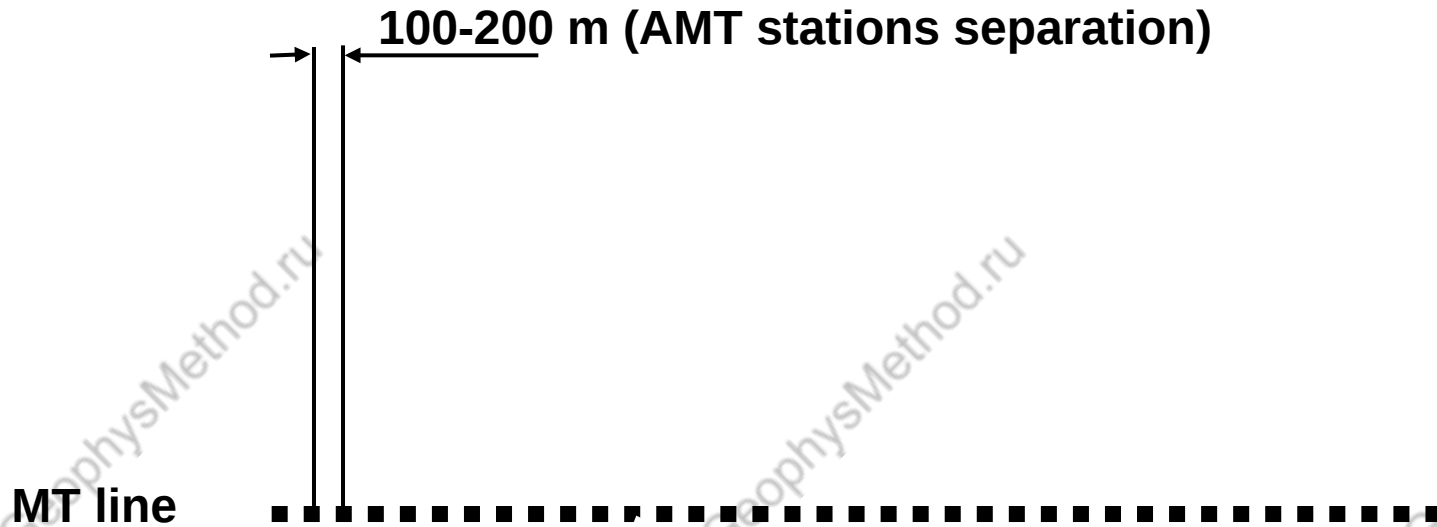## Geoelectrical cross-section (model)

Analysis of modeling results

Induction arrows cross-section

Geoelectrical cross-section (model)

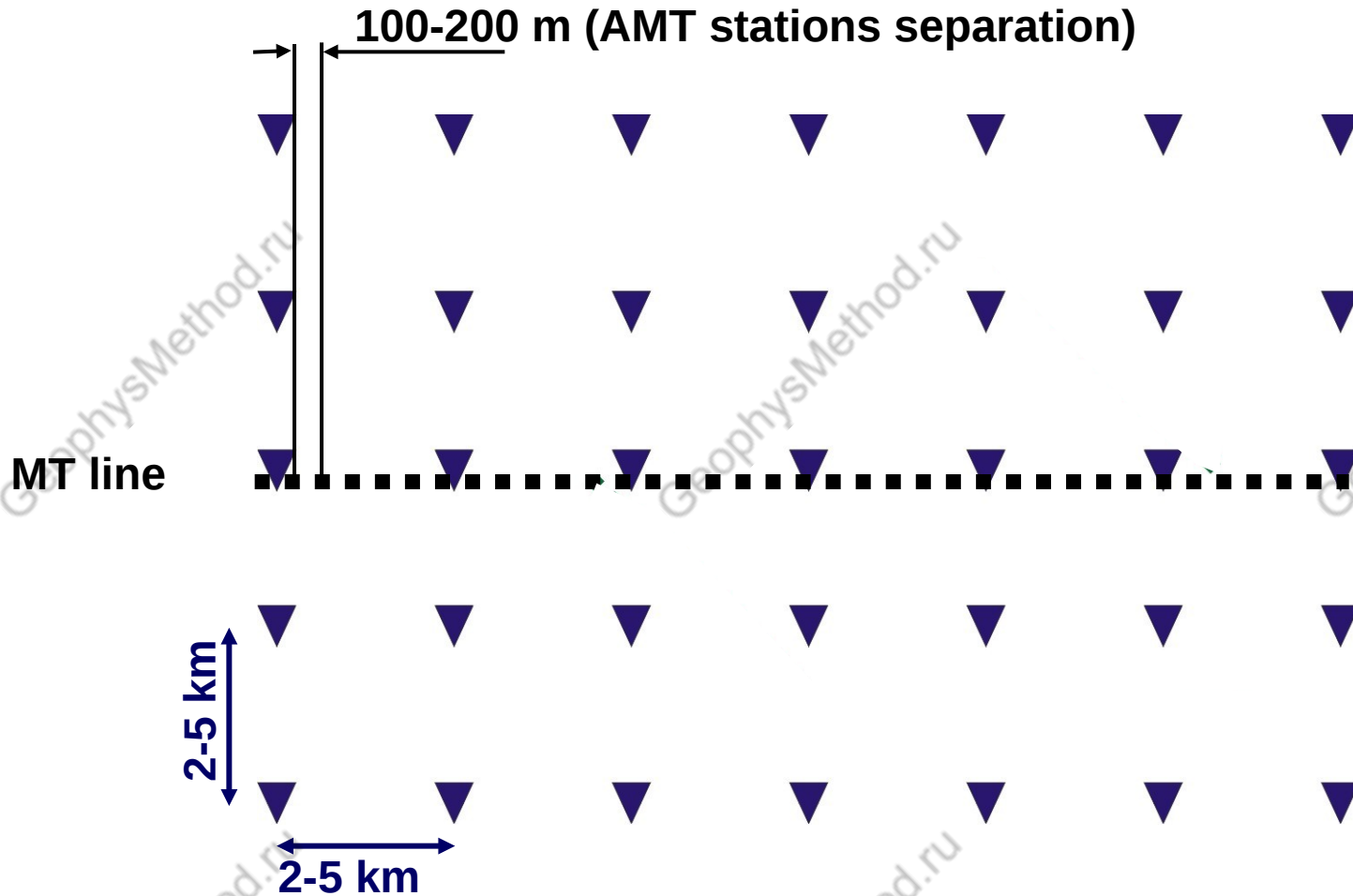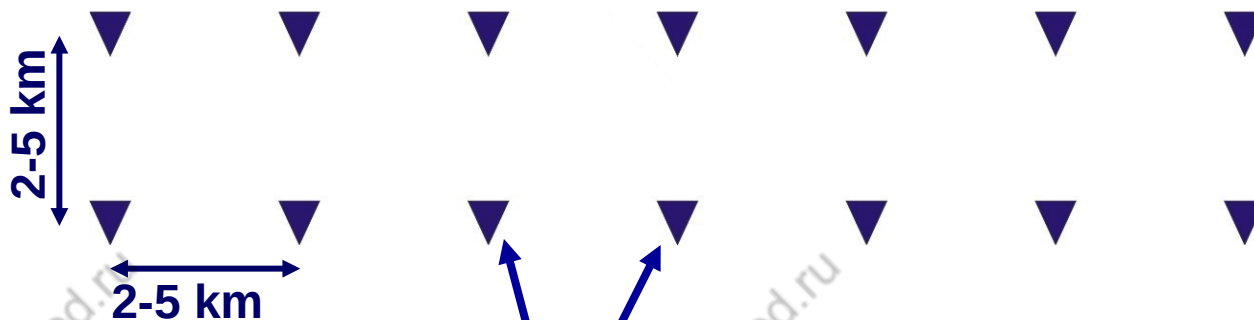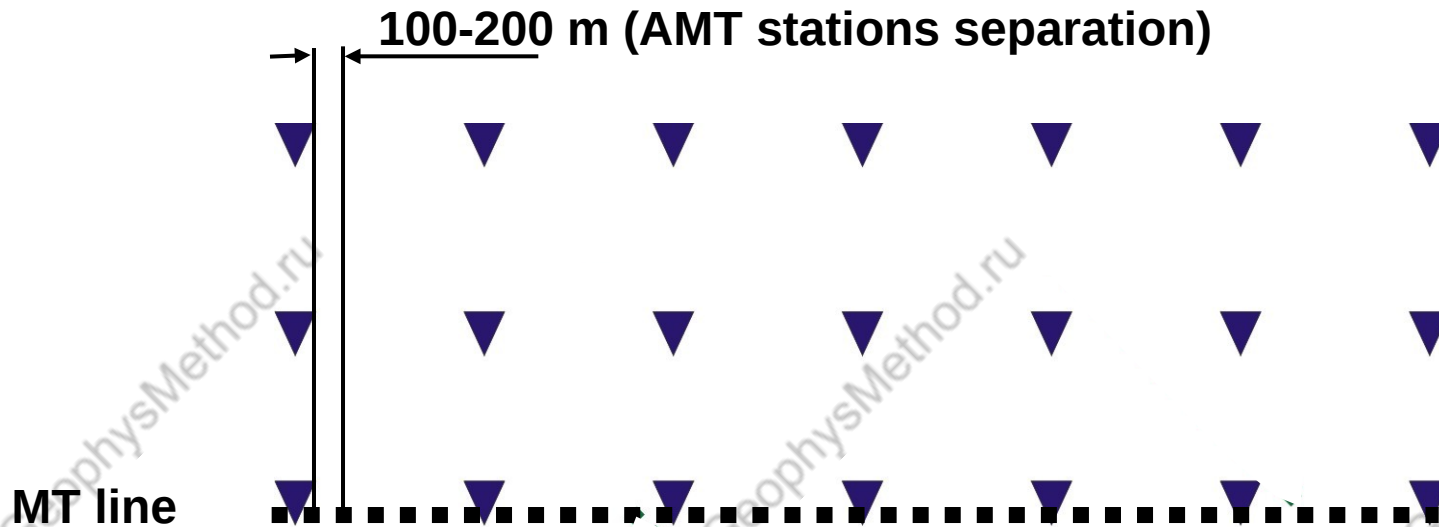# Strategy for new licensed area to find giant deposit

MT line ▪▪

Strategy for new licensed area to find giant deposit

100-200 m (AMT stations separation)

MT line ■

Strategy for new licensed area to find giant deposit

100-200 m (AMT stations separation)

MT line

2-5 km

2-5 km

Strategy for new licensed area to find giant deposit

100-200 m (AMT stations separation)

MT line

2-5 km

2-5 km

24-hours measurement sites

New strategy

By using 5 component measuring:

1. Find conductors in middle Earth crust

2. Find conductive channels

By using effective geophysical methods

3. Find mineral deposit

1. New approach for mineral exploration by using geophysics

2. GM-Service technologies

«GM-Service» technologies

Detailed ground magnetic survey

ΔT, нТл

Overlap
gold-bearing
quartz vein
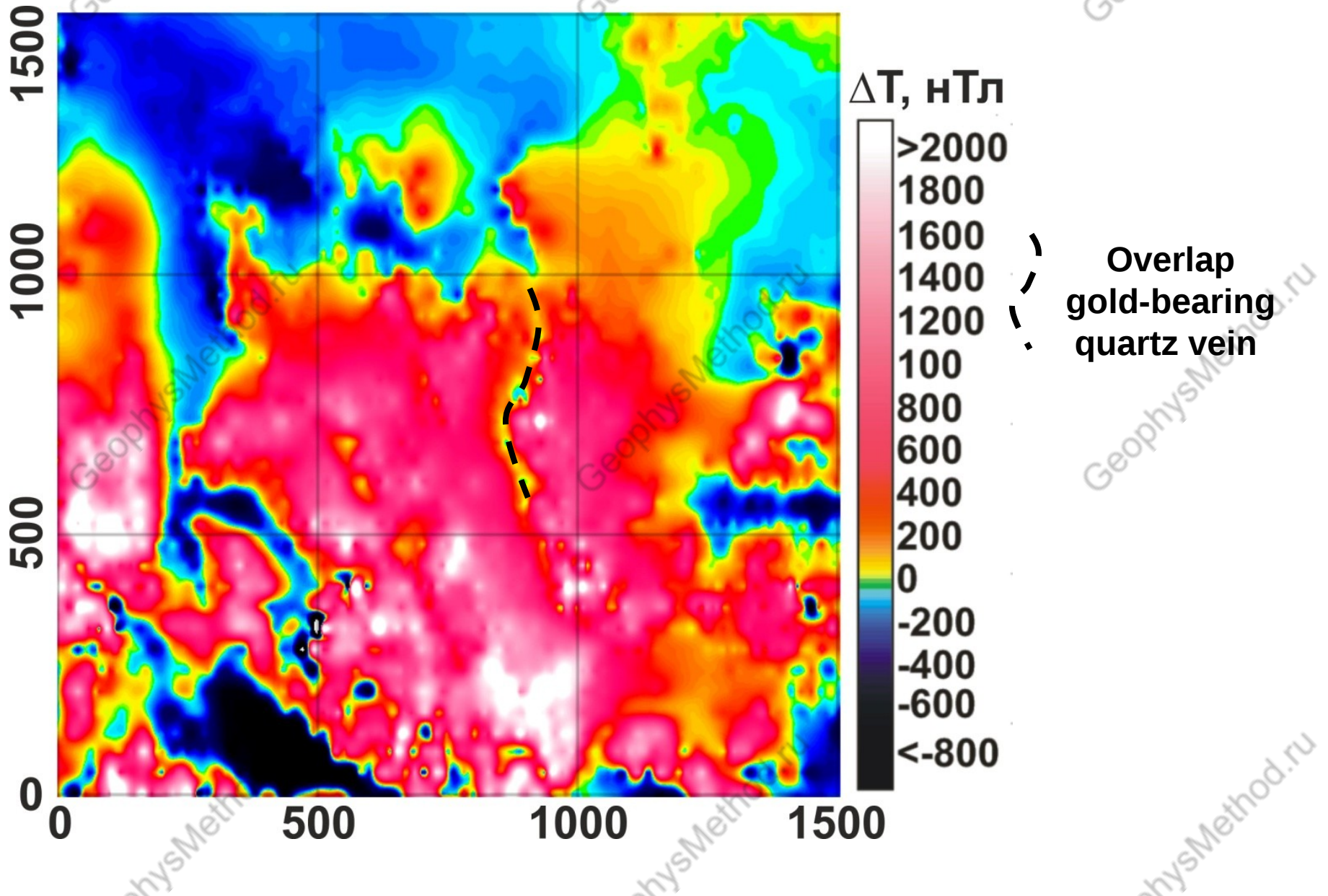
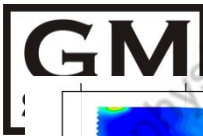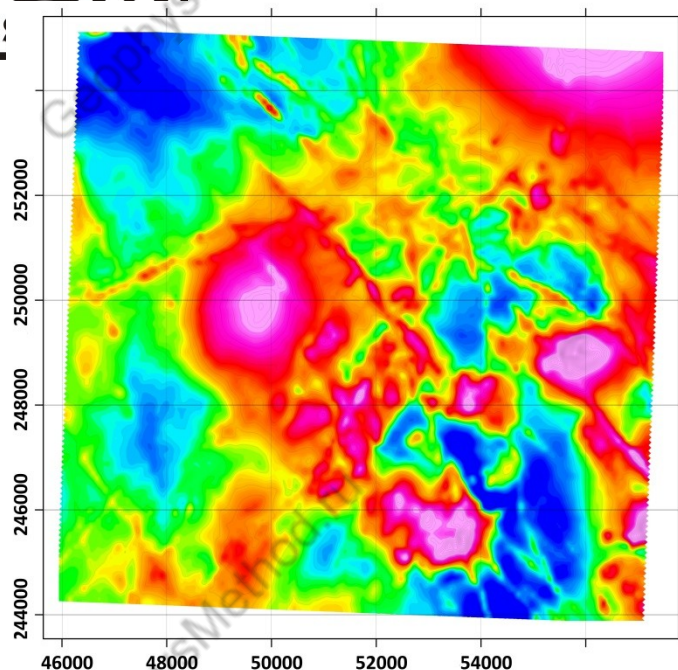UAV-based magnetic survey (flying height 20 m)
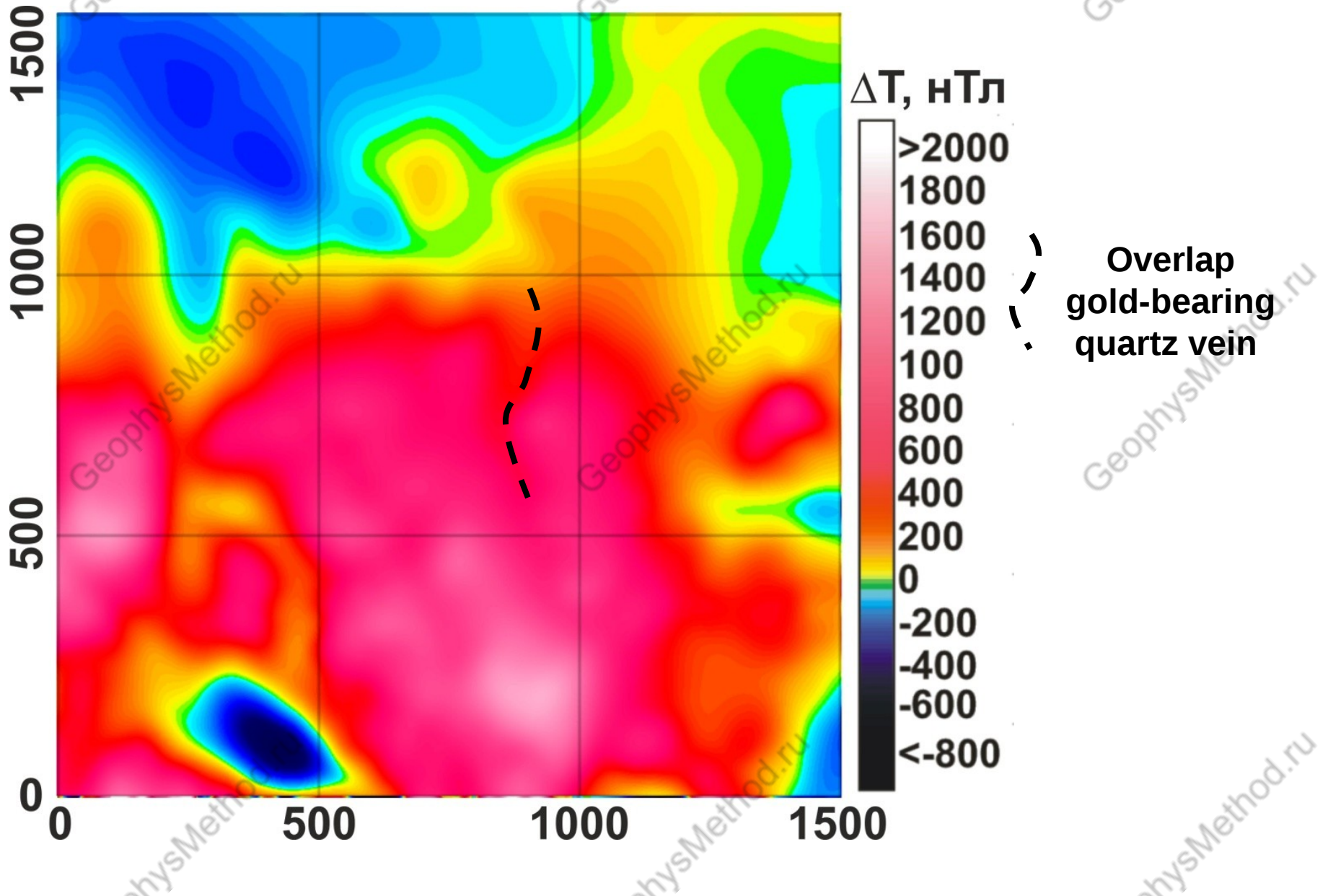
Precise UAV-based magnetic survey
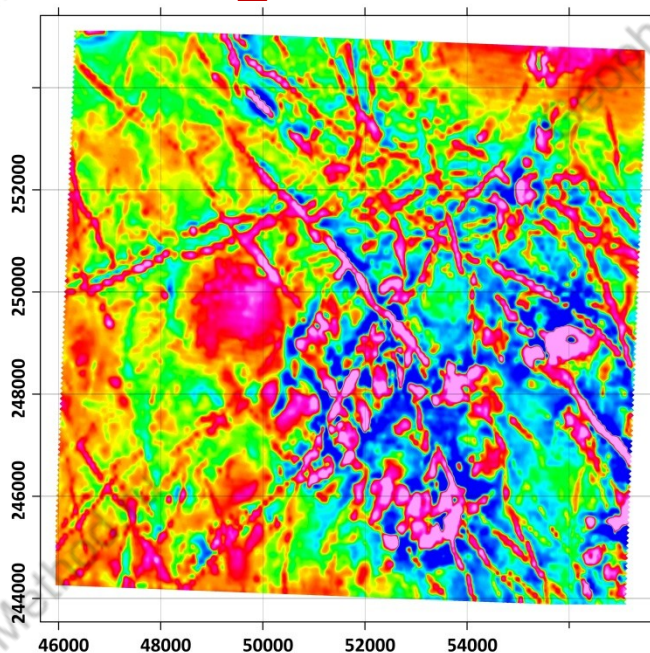

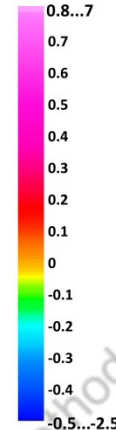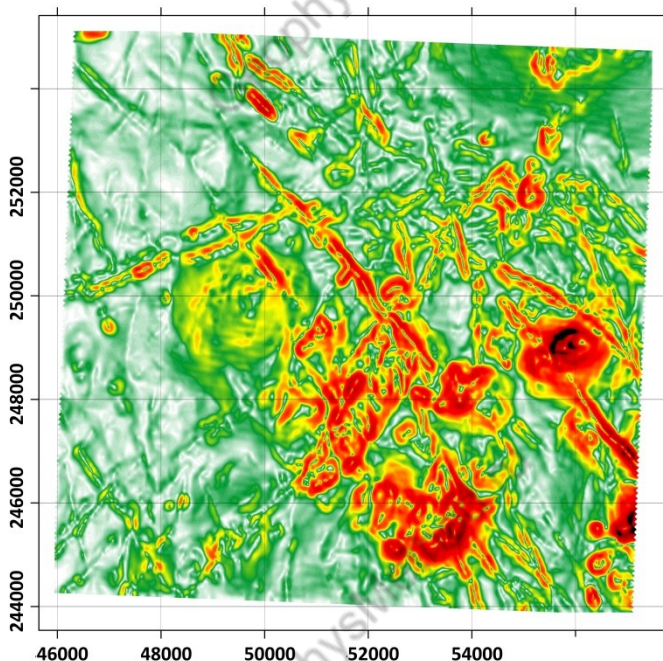**Flight time UP TO 1 HOUR**

Precise UAV-based magnetic survey
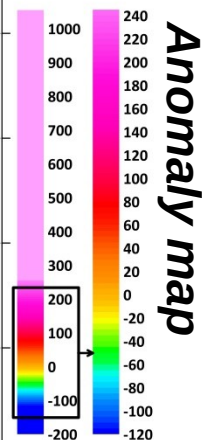
12 days = 120 km²

(field work)
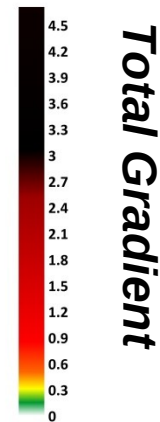
3 days
(for data processing)

Line separation:

100 meters

Gravity survey

Any terrain

Any weather
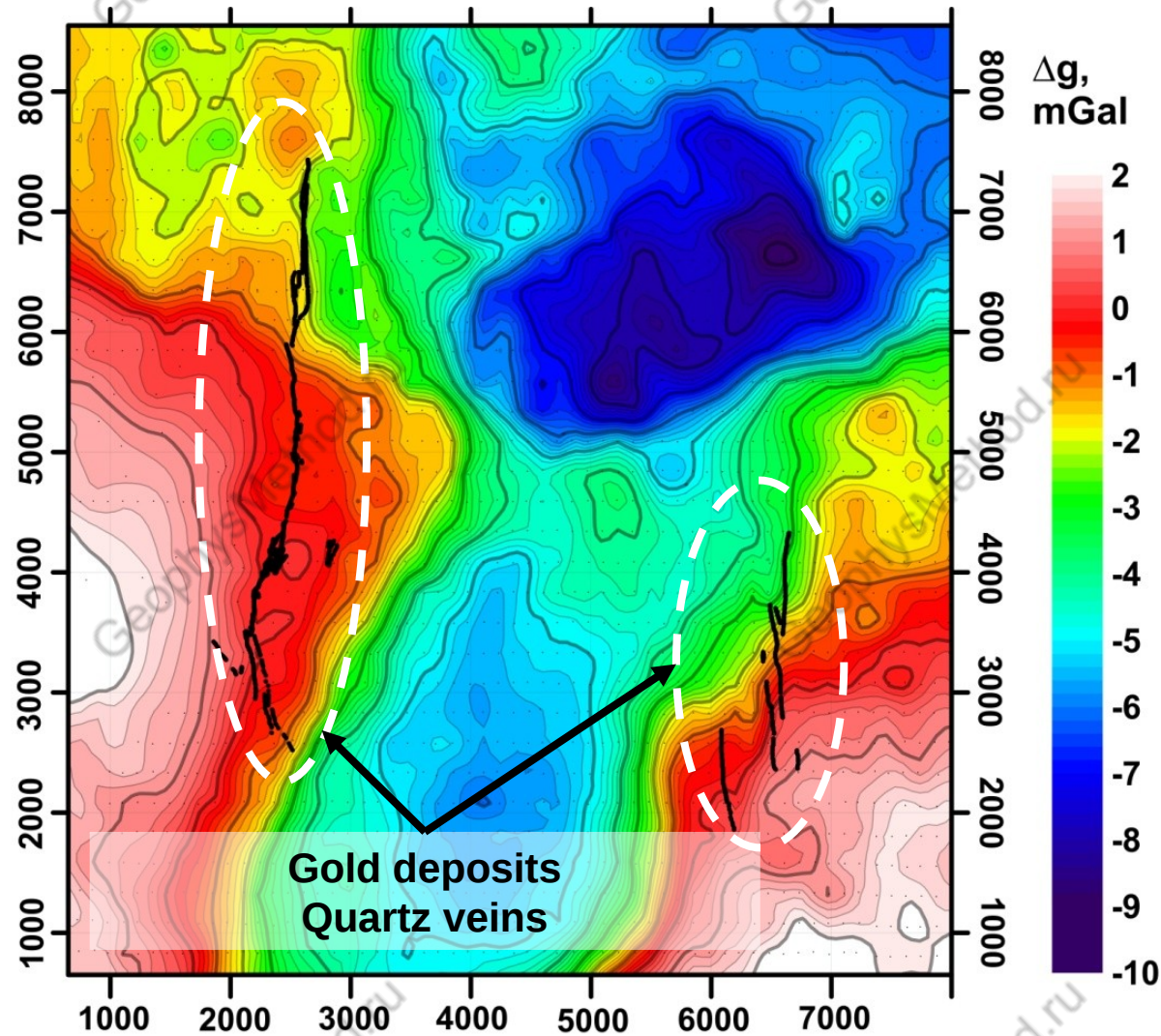
Graben structure

Gravity response of graben structure

Gold deposits
Quartz veins

Graben structure

Earth pulled apart along big faults

Meandering river and oxbow

Boundary fault

Step valley

Boundary fault

Gravity response of graben structure

Graben structure

Gold deposits
Quartz veins

Gradient
Δg,
mGal/m

Earth pulled apart along big faults

Meandering river and oxbow

Boundary fault   Step valley   Boundary fault
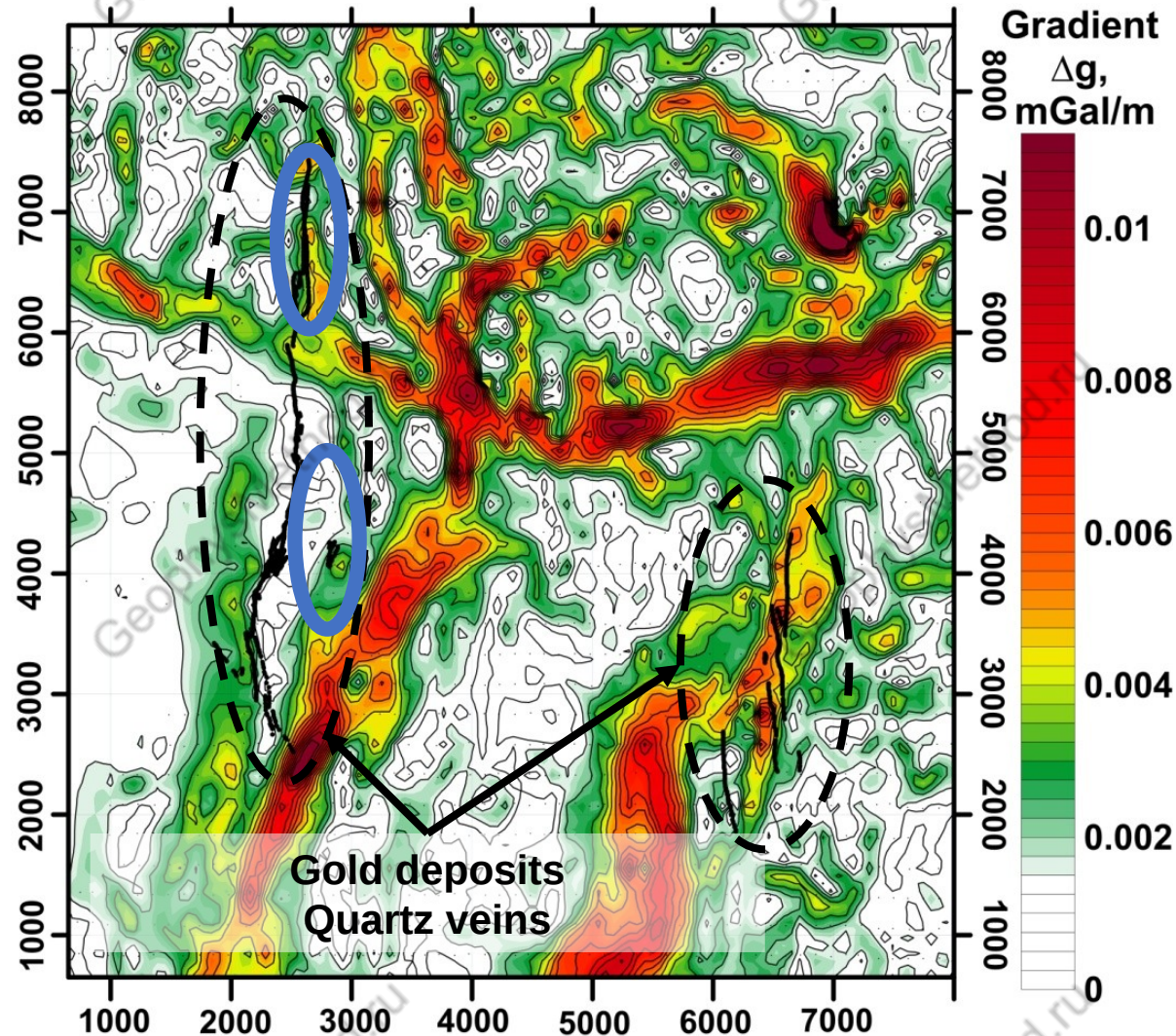
Electrical and electromagnetic methods
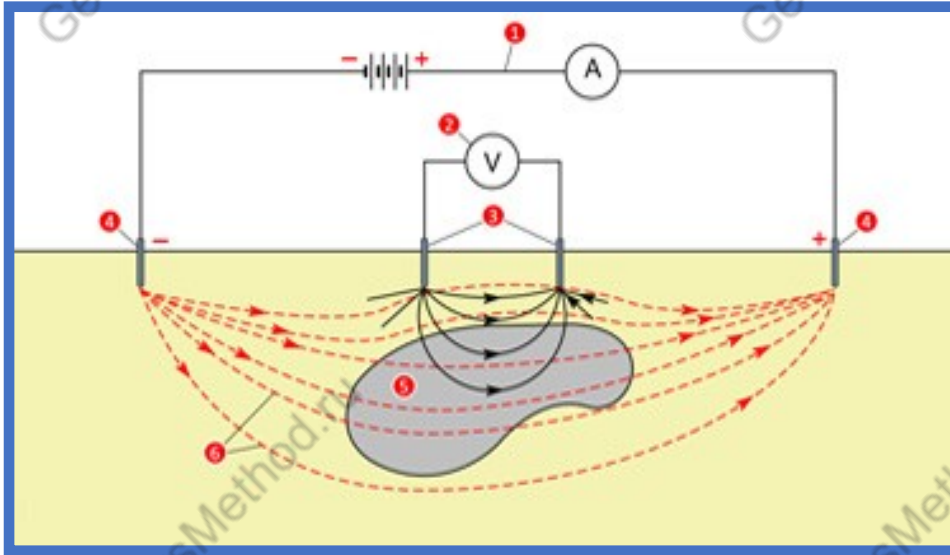
Methods:

- **Resistivity**
- **Induced Polarization (IP)**
- **Deep IP**
  (Join AMT-ET inversion)
- **AMT-MVP**
- **Frequency Domain EM Soundings (FDEMS)**
- **TDEM**
- **Self Potential (SP)**
- **Ground Penetrating Radar (GRP)**

Deep IP technology

Geoelectrical cross-section

Chargeability cross-section
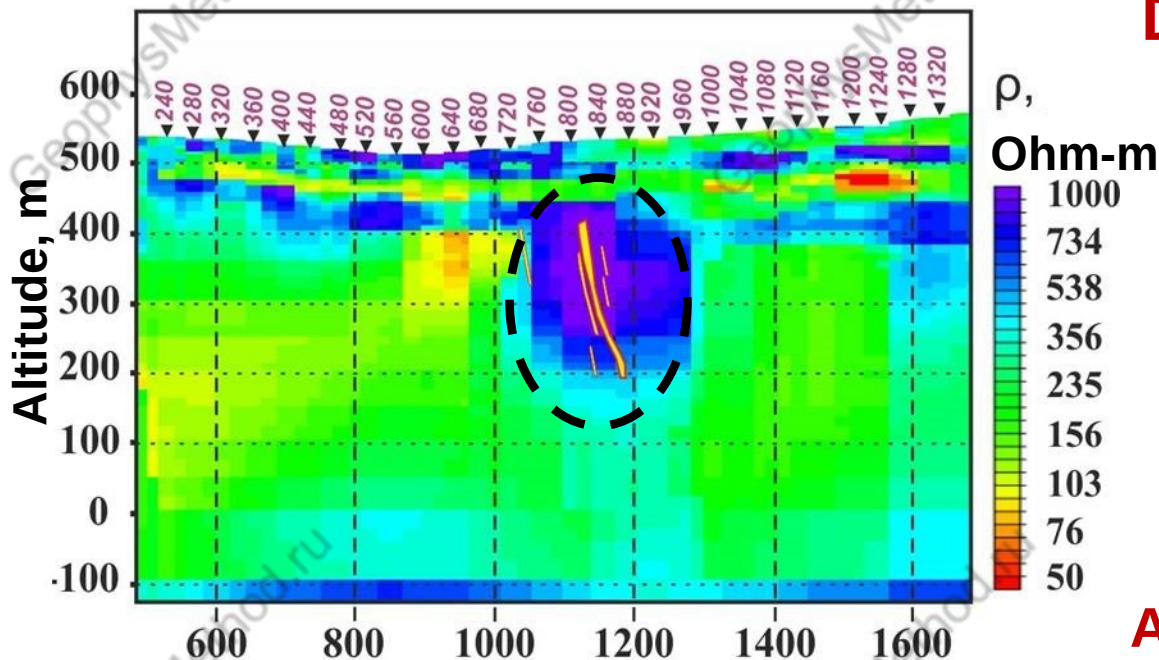
As result of joint 2D inversion AMT and IP

Depth of IP investigation is 600-700 meters

AMT 5-component

Induction arrows map at 10 Hz

Summer 2002 ● ─── Re ── to conductor
Winter 2003 ● ─── 0.3

⬭ The main ore zone

0   0.5   1   1.5   km

N
5 km

Prospecting for new mineral deposits – Quebec, Canada

-Detection of a massive sulphide body outside initial observation network - advantage of the 5-th component measurements

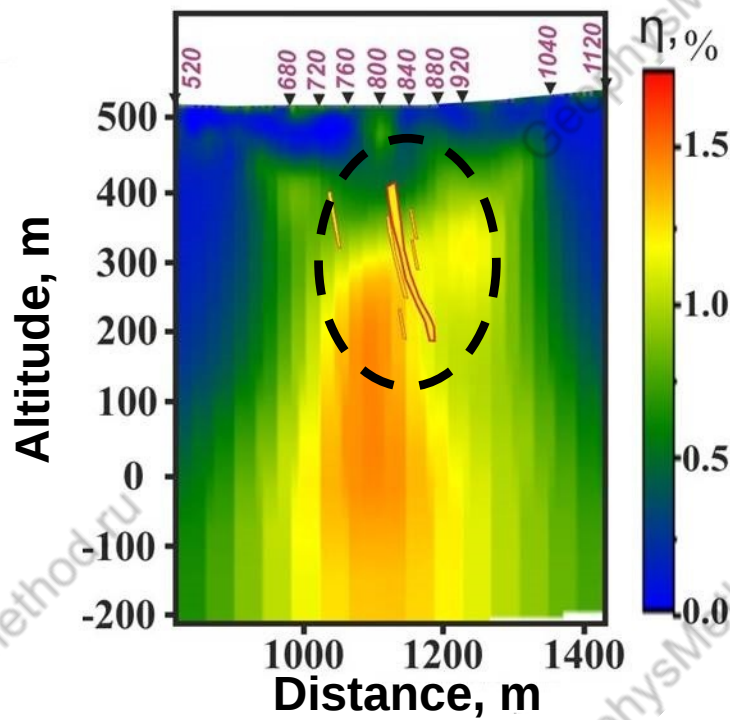-The initial observation network consisted of three observation profiles. Field work carried out in the winter and summer

-There were no significant anomalies detected within the original latitudinal profile network

-Induction vectors indicated the presence of a conductive object in the north-west direction

-MVP survey performed in winter (lake & swamp area) and allowed to accurately map anomaly detected by measurement sites located 3-5 km away

19
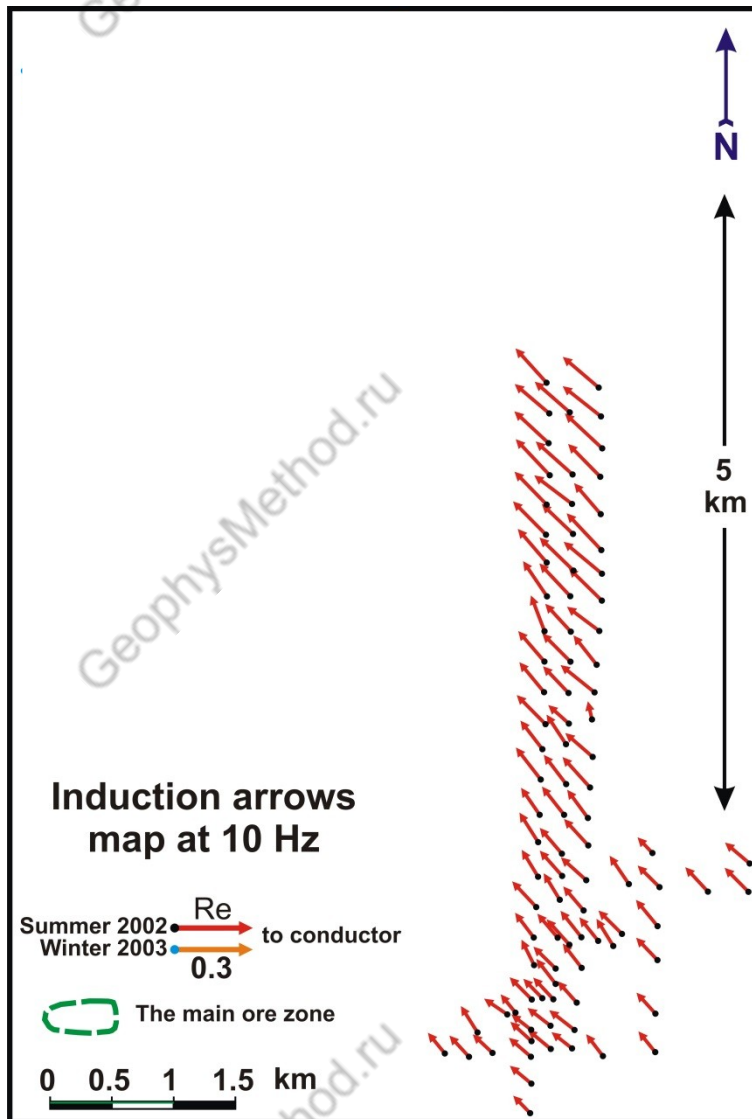
AMT 5-component

Prospecting for new mineral deposits – Quebec, Canada

Induction arrows map at 10 Hz

Summer 2002 ● — Re → to conductor
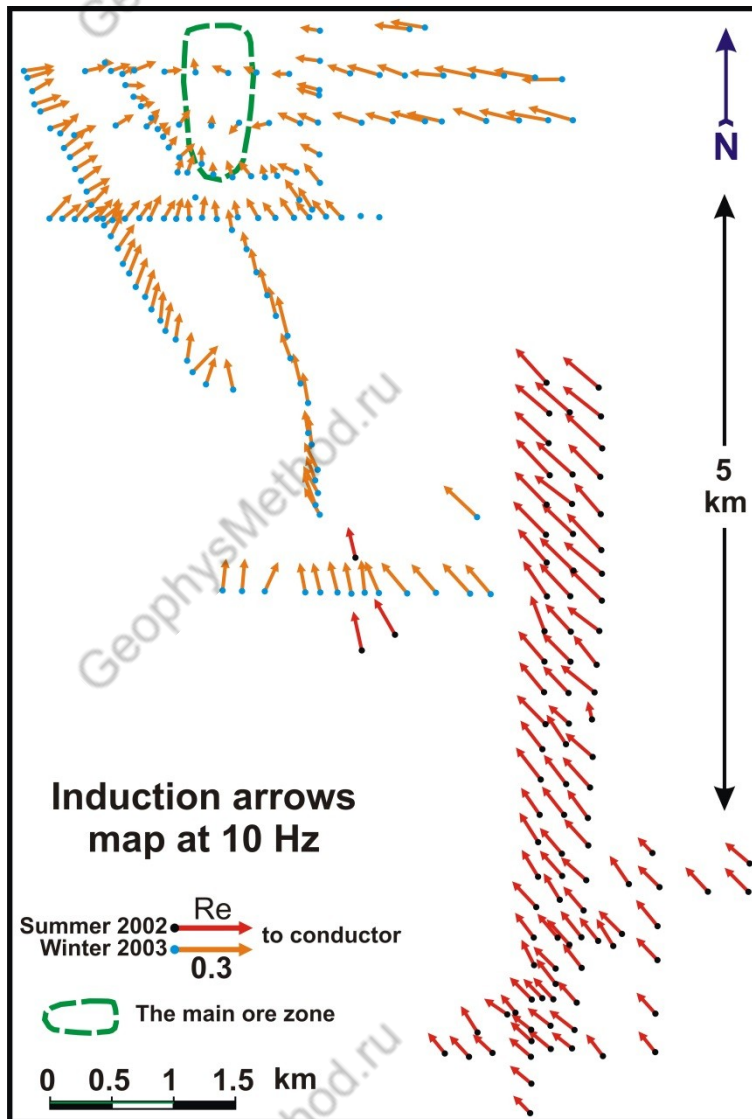Winter 2003 ● — 0.3 →

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[According Ingerov 2004]

Thanks for your attention!

http://GeophysMethod.com

http://GeophysMethod.ru　　　　　E.Ermolin.GMS@gmail.com