ADVANCED METHODS FOR ELECTROMAGNETIC IMAGING, INVERSION AND RECOGNITION OF THE SUBSURFACE PARAMETERS

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WHO WE ARE?

- Geoelectromagnetic Research Centre of the Institute of the Physics of the Earth, Russian Academy of Sciences (GEMRC IPE RAS) is situated in the scientific center Troitsk just 20km South of Moscow

- Founded in 1993 as a spin-off from the Institute for Geomagnetism, Ionosphere and Radiowave Propagation (IZMIRAN)

- 54 staff (22 staff at PhD and 10 at doctorate level)

- 5 Laboratories:
  - magnetotellurics,
  - interaction of EM field and rocks
  - EM data interpretation methodology
  - environmental studies
  - marine EM

GEMRC SCIENTIFIC PROFILE

- theory, algorithms and software for modeling and inversion of EM data in 3-D inhomogeneous media;
- joint analysis and interpretation of EM and other geophysical data;
- indirect estimation of the physical and petrophysical properties from the ground EM data;
- EM monitoring macro-parameters of the sub-surface targets;
- 3-D EM mapping geothermal zones, volcanoes, active faults, etc.;
- EM forecasting seismic and volcanic activity

OUTLINE

- Methods of geophysical data interpretation and software
- 3-D mapping volcanoes, geothermal and faulted areas

  - Komagatake volcano (Hokkaido, Japan) and Kilauea volcano (Hawaii);
  - Minamikayabe geothermal area (Hokkaido, Japan);
  - Minou faulted area (Kyushu, Japan)

- Advanced techniques for joint analysis and interpretation of EM and other geophysical data

  - maximal correlation similitude technique (filling the gaps in the data, mapping seismically active zones);
  - SOM technology (petrophysical clasters from EM and other geophysical data);

- Indirect temperature estimation from the surface EM data (EM goethermometer)

  - Bishkek geodynamic area (Northern Tien Shan);
  - Hengill geothermal area (Iceland);
  - Travale geothermal area (Italy);
  - Soultz-sous-Forets geothermal area (Project)

INTELLIGENT GEOPHYSICAL DATA INTERPRETATION

- joint inversion of various geophysical data
- explicit account for prior geological and geophysical constraints
- noise management
- allowance for formalized expert estimates
- three-dimensional models
- quantification of resulting uncertainties
- decision support tool

MODERN METHODS FOR GEOPHYSICAL DATA INVERSION

- **BAYESIAN STATISTICAL INVERSION**

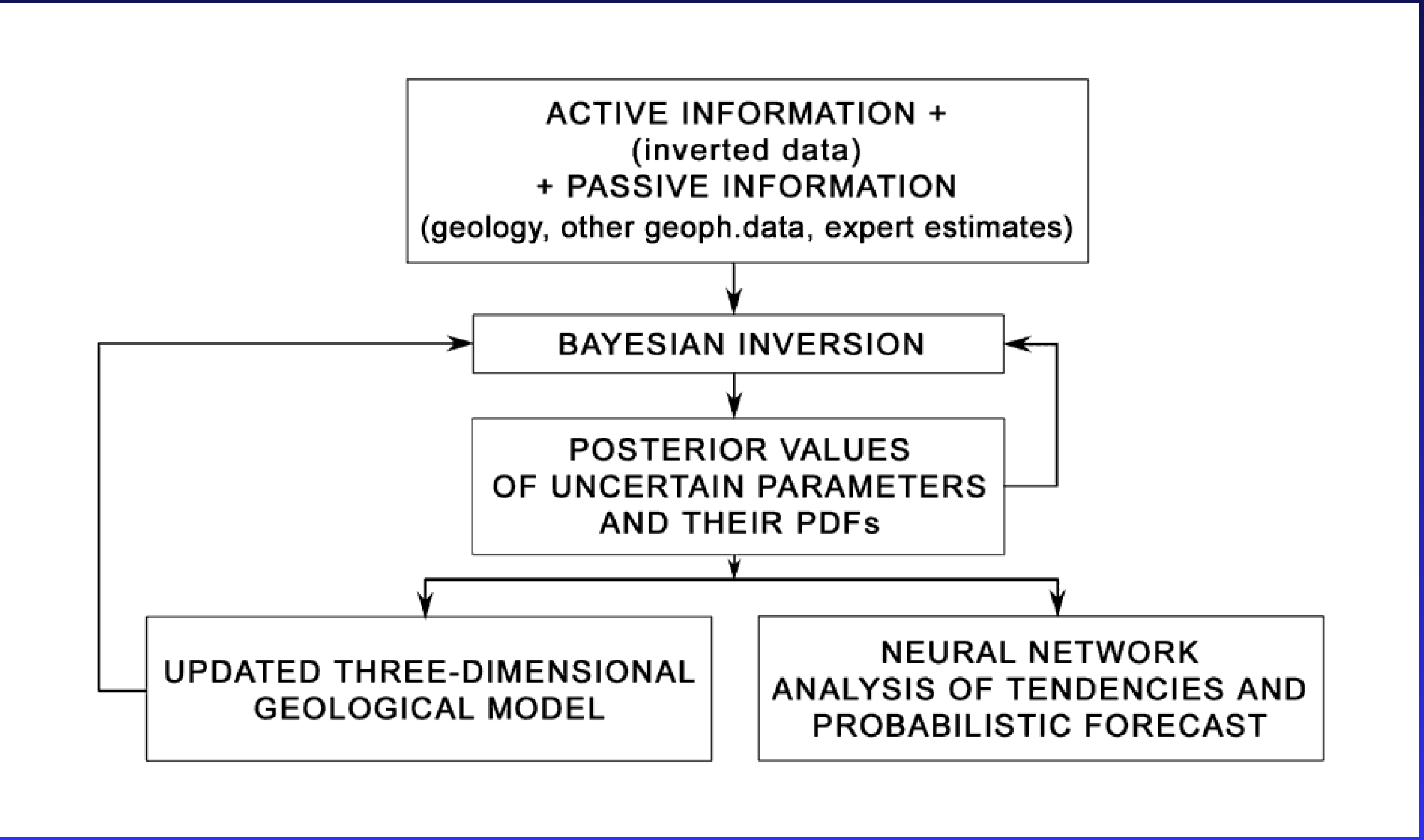
FEATURES: **enables** construction of 3-D electrical resistivity models taking into account the EM data, prior geological and geophysical info and formalized expert's experience

- **ARTIFICIAL NEURAL NETWORK RECOGNITION**

FEATURES:

- three-dimensionality is not a problem
- noisy and interrelated data are welcome
- non - traditional parameterization
- extremely fast inversion and self - education in the process of monitoring

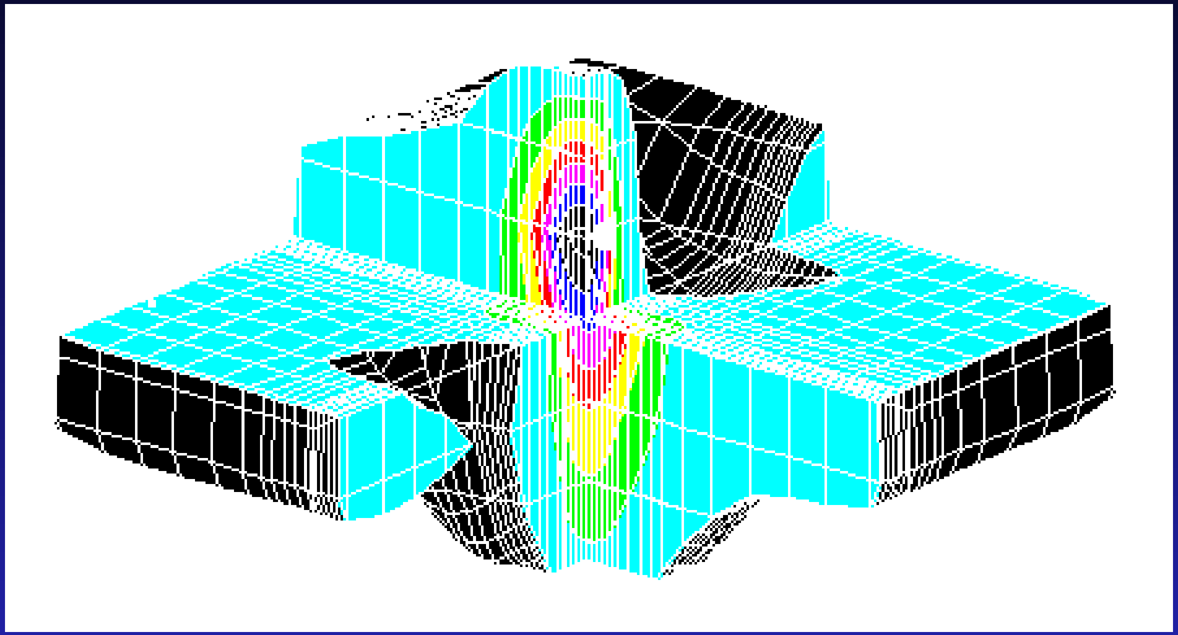
GEOPHYSICAL DATA INTERPRETATION

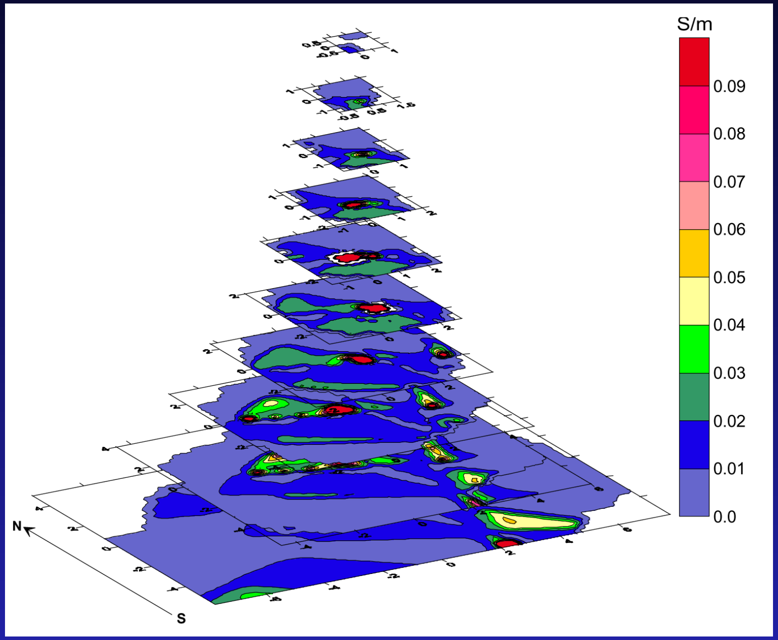


SOFTWARE FOR EM DATA ANALYSIS AND 3-D INTERPRETATION

- FORWARD NUMERICAL MODELING (*FDM-3D*)
- FOCUSING TRANSFORMATIONS (*TRANS*)
- INTERACTIVE COMPUTER GRAPHICS (*GRAPH*)
- 3-D IMAGING (*IMAGE*)
- ANN PARAMETERS' RECOGNITION (*NET*)
- 3-D INVERSION / INTERPRETATION (*INVERS-3D*)
- JOINT GEOPHYSICAL DATA ANALYSIS (*INTEGRO-3D*)

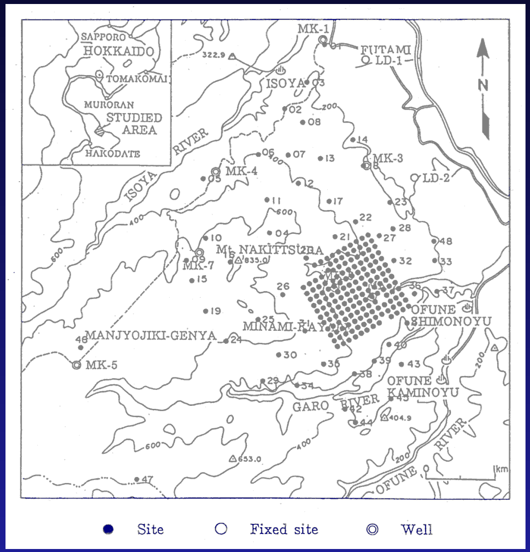
EM MAPPING VOLCANOES

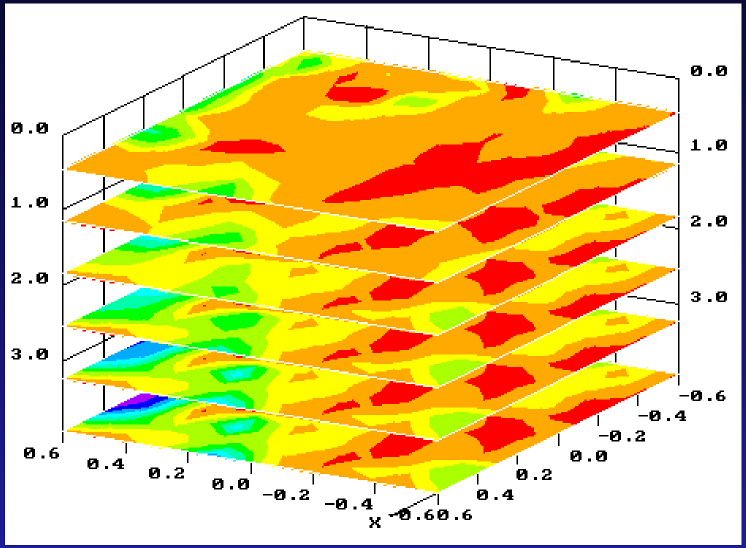


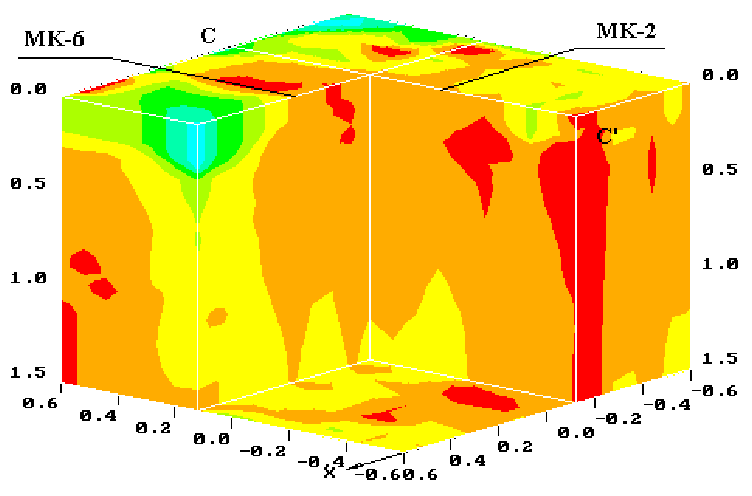


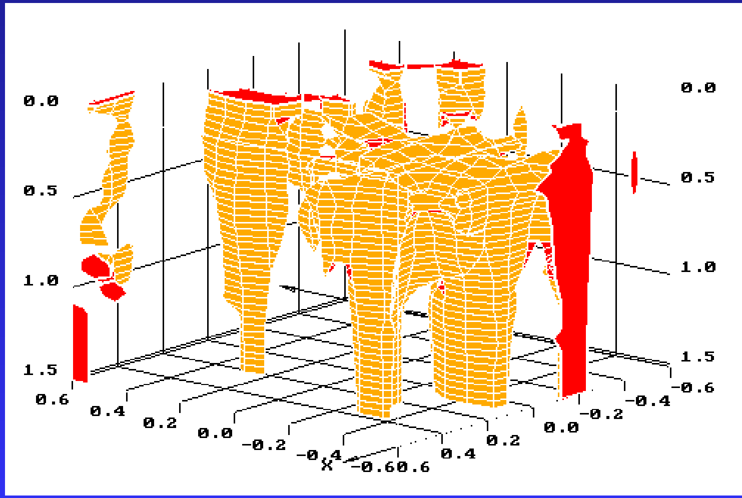
- LEFT: EM image of the Kilauea volcano's magma chamber (Hawaii)
- RIGHT: electrical conductivity model of the Komagatake volcano (Hokkaido, Japan)

3D MAPPING GEOTHERMAL RESERVOIR (Hokkaido, Japan)

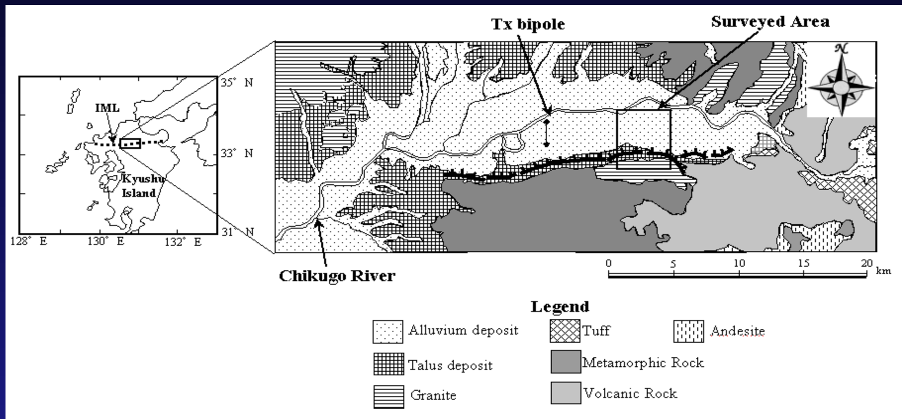




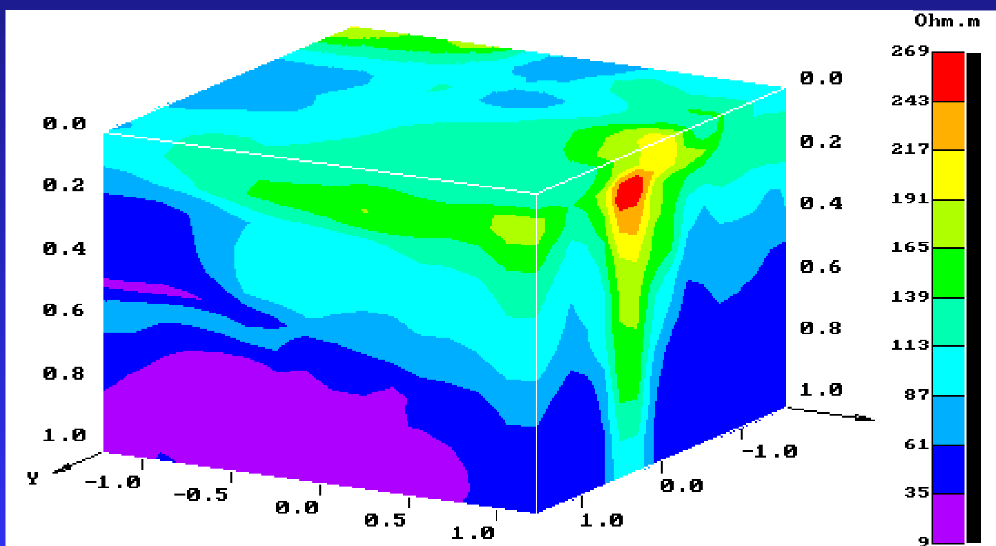




3D MAPPING MINOU FAULTED AREA

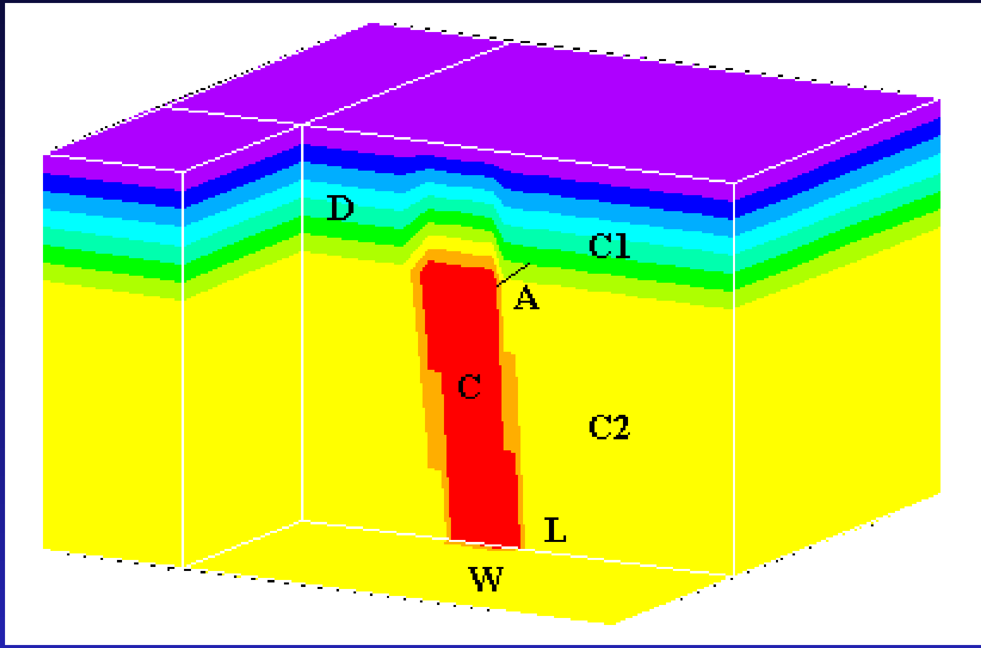


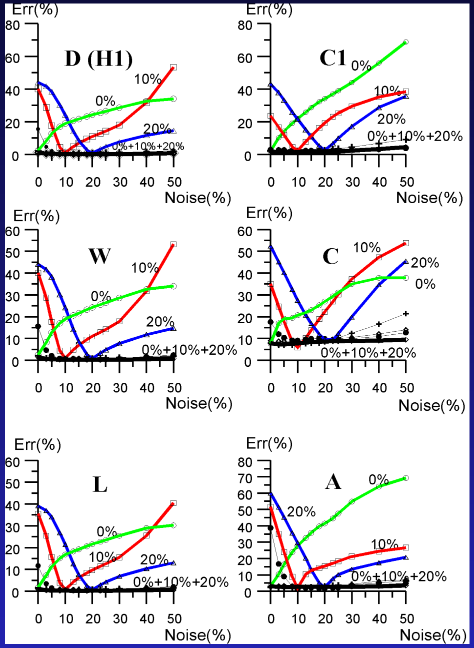
Geological map of the Minou fault zone (the rectangle restricts the CSAMT survey area; IML- Imari-Matsuyama Line)



Resistivity model of the faulted area

EM MONITORING OF THE TARGET MACRO-PARAMETERS

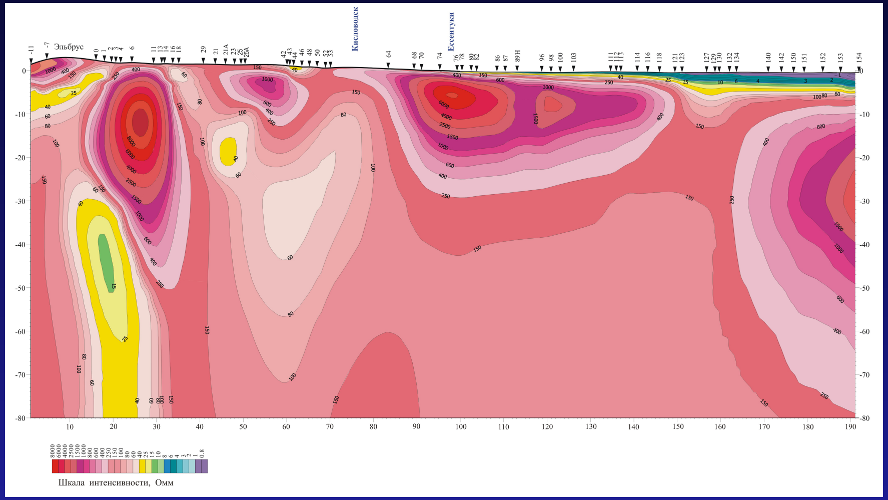


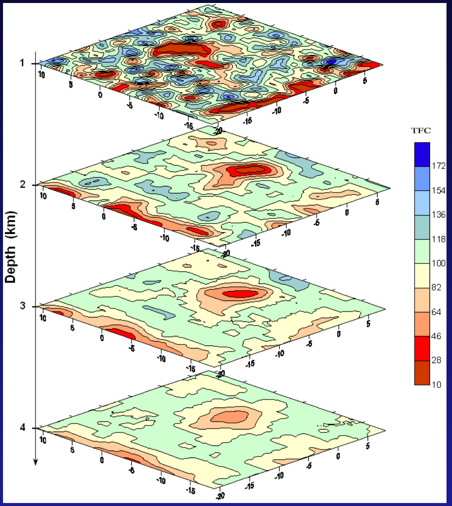


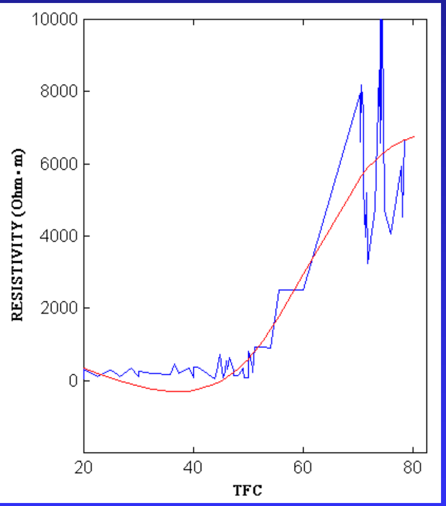
- LEFT: Fault model
- RIGHT: Recognition errors of the fault macro-parameters depending on the noise level in the MT data

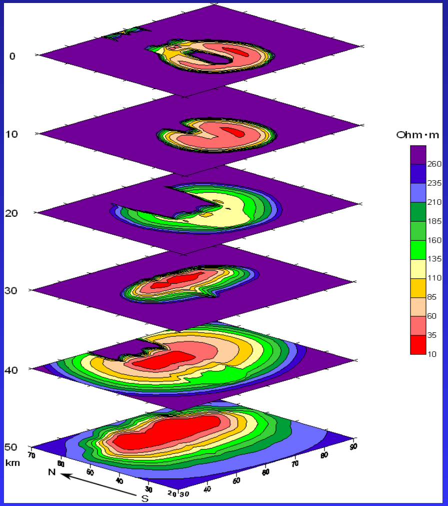
FILLING THE GAPS IN THE GEOPHYSICAL DATA

(Elbrus volcano model, Northern Caucasus)

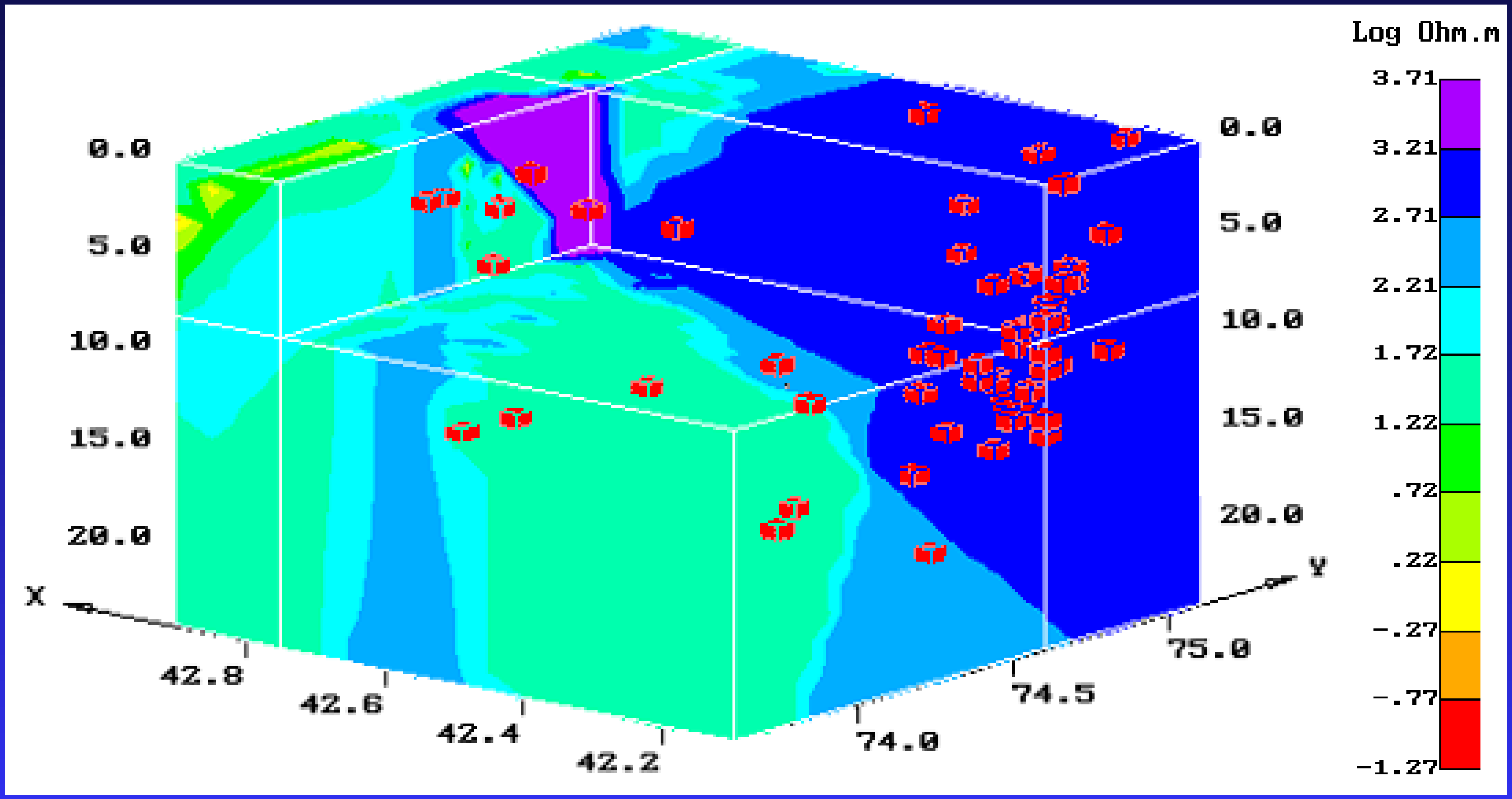




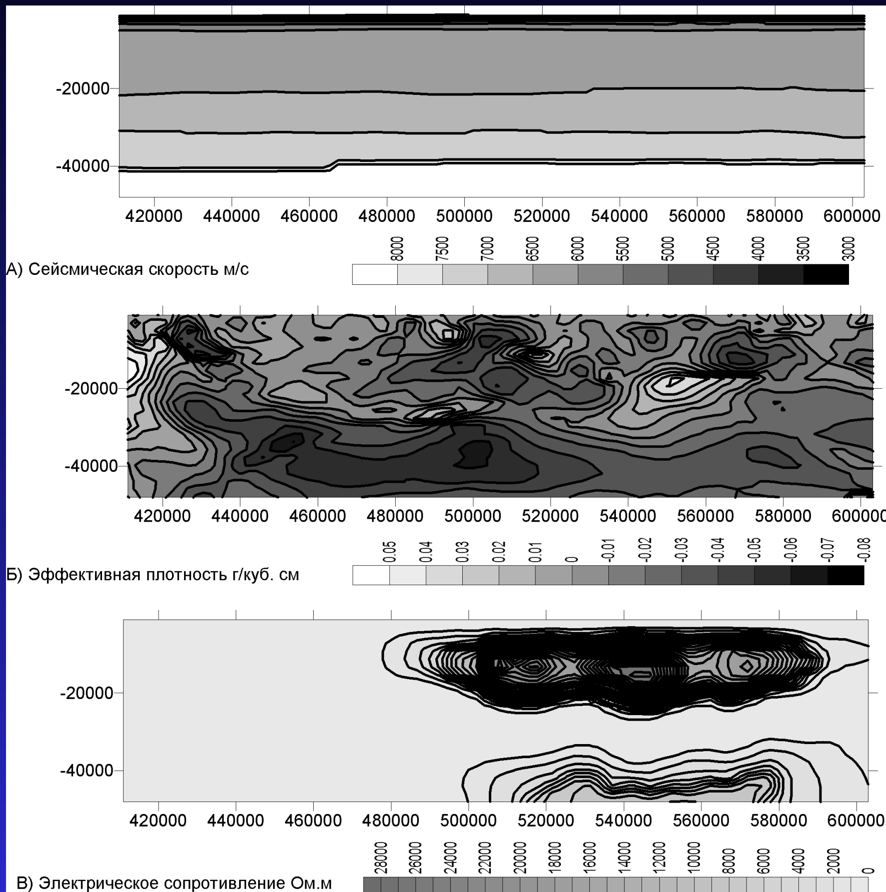


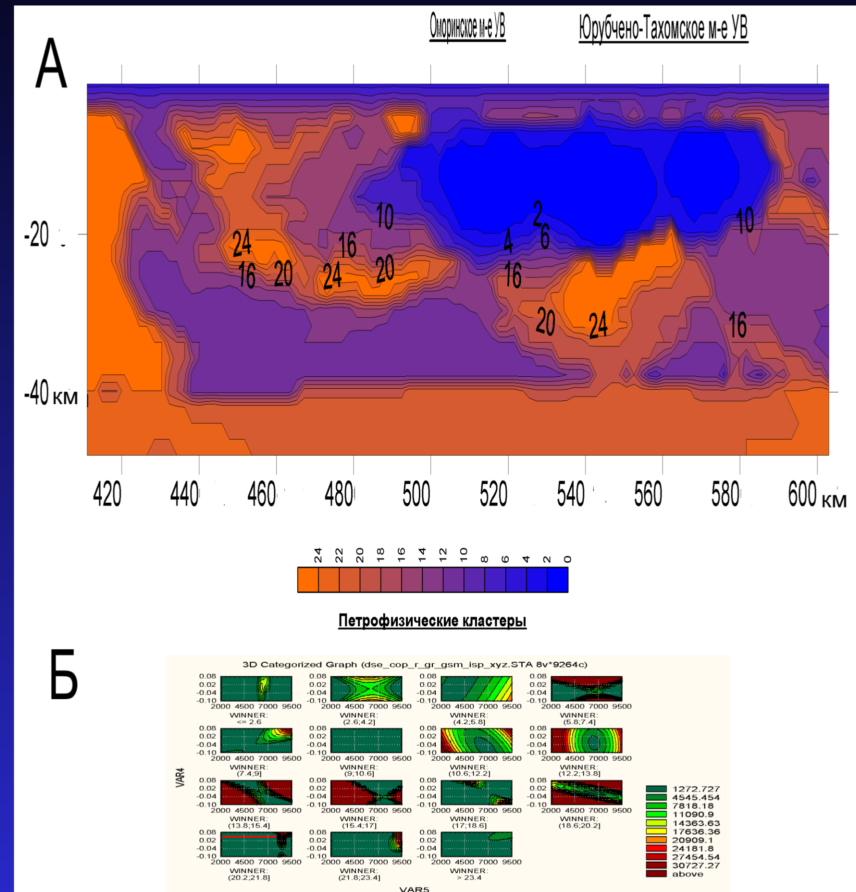


BULK RESISTIVITY AND HYPOCENTERS' DENSITY MAXIMAL CORRELATION ZONES



JOINT ANALYSIS OF DIFFERENT GEOPHYSICAL DATA USING SOM TECHNOLOGY





Geophysical prospecting of the oil deposits in the Eastern Siberia

(LEFT: sections of physical properties, RIGHT: claster petrophysical section)

INDIRECT TEMPERATURE ESTIMATION USING EM GEOTHERMOMETER

Measurement of the EM data

⇓

Inversion of EM data

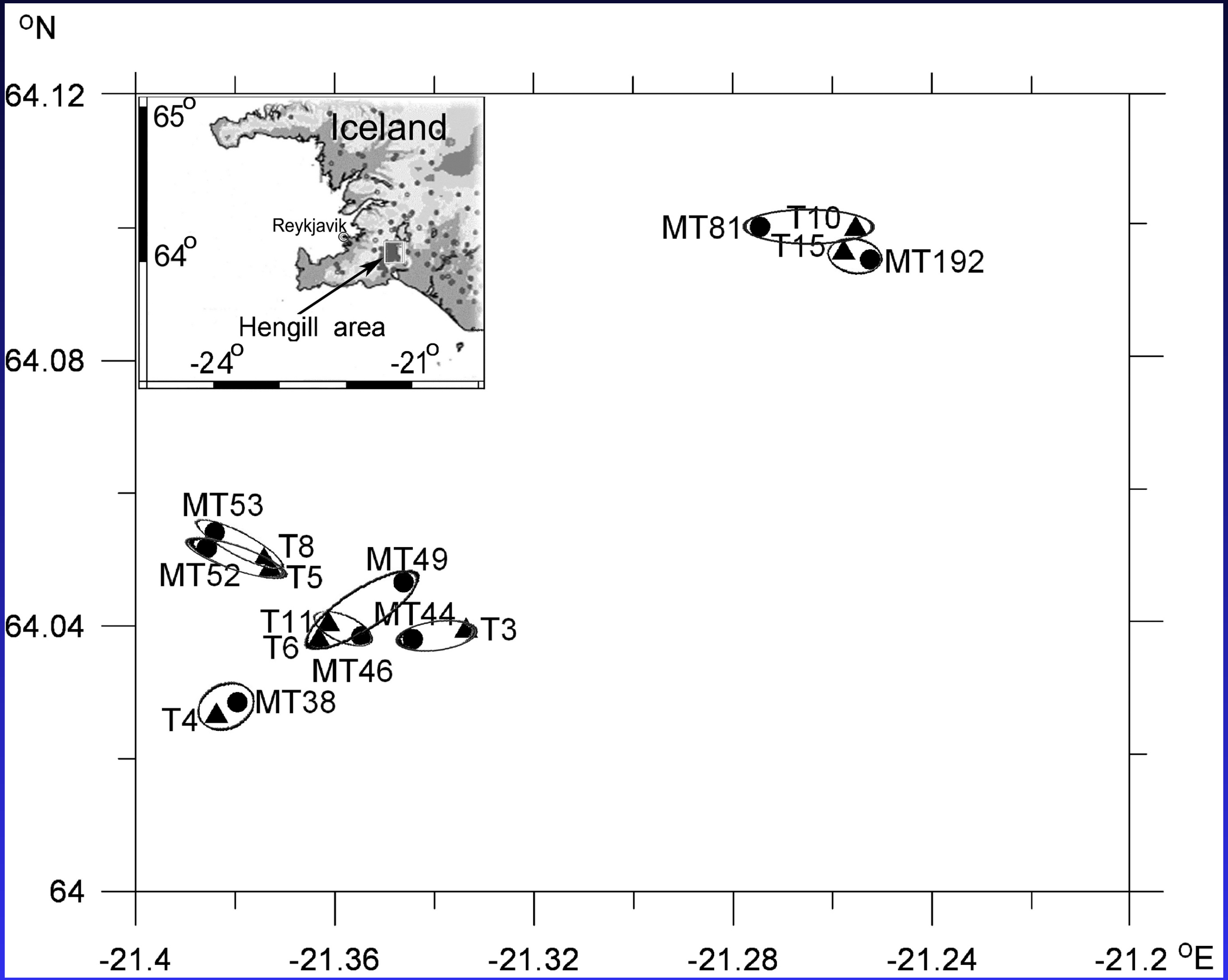
⇓

Calibration of geothermometer using available well log temperature data)

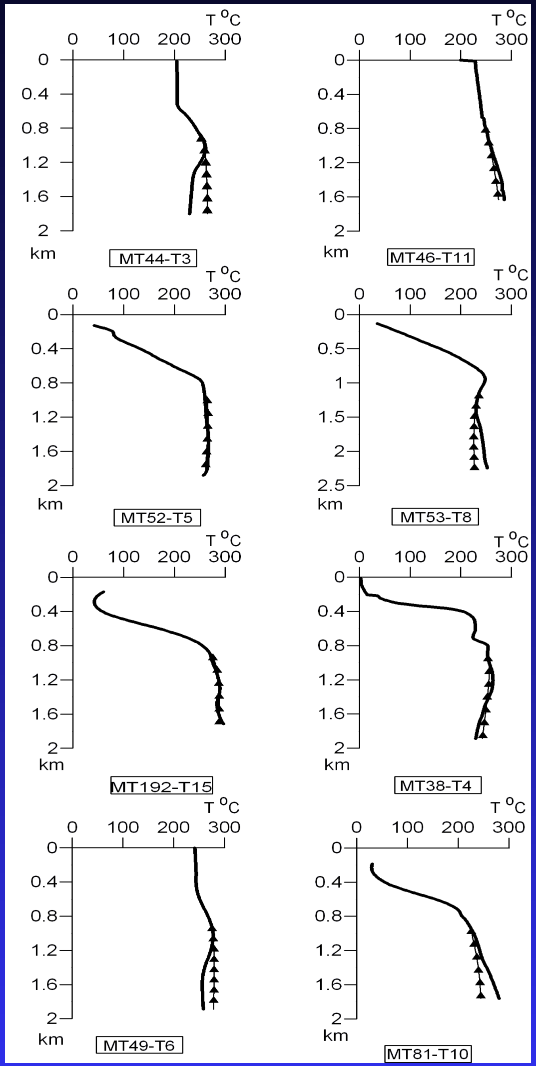
⇓

Temperature reconstruction in the studied area

MAP OF MT SITES AND ADJACENT BOREHOLES IN THE HENGILL GEOTHERMAL AREA

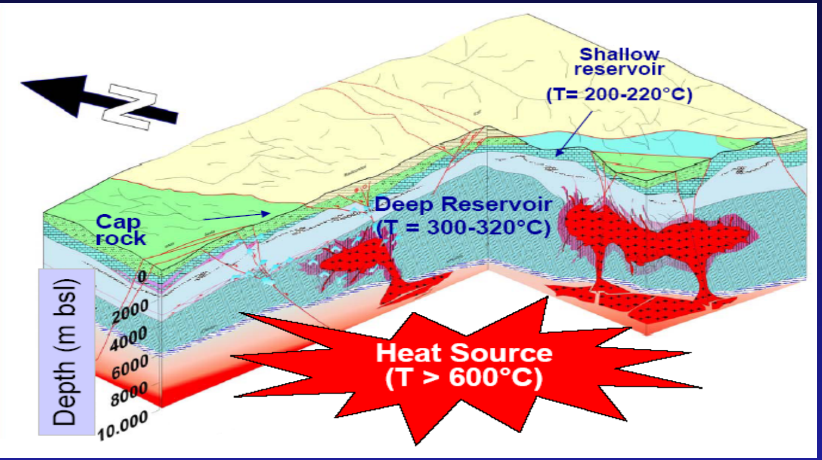


EM TEMPERATURE EXTRAPOLATION IN DEPTH



- **solid line** – measured temperature,
- **line with triangles** – temperature model based on the extrapolation of the upper half of the geotherm

TRAVALE TEMPERATURE CROSS-SECTION REVEALED FROM MT DATA



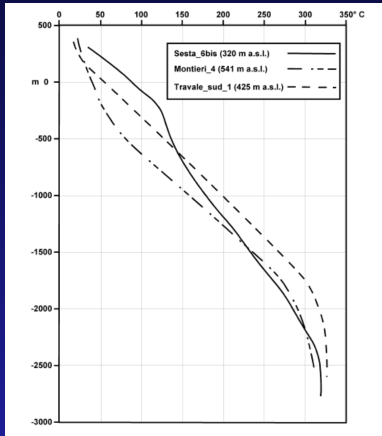
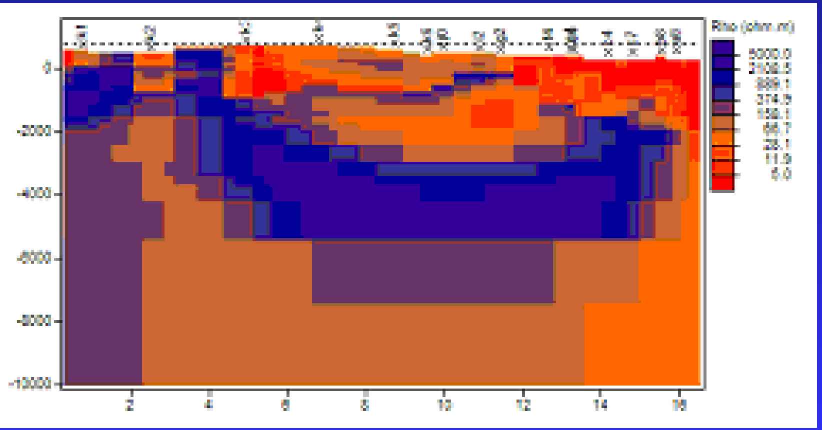
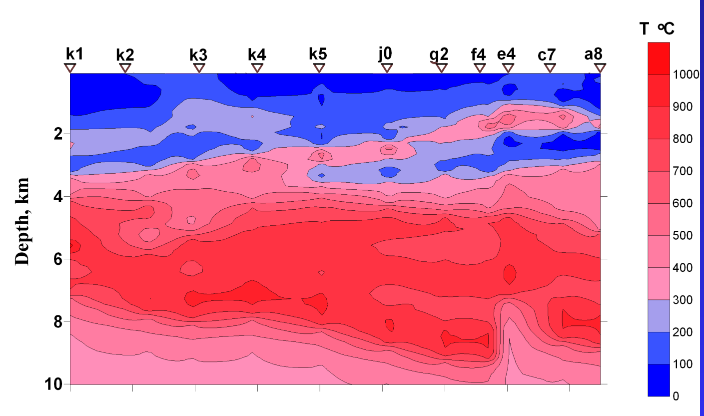


Fig. 4 Temperature versus depth in the exploration geothermal wells.





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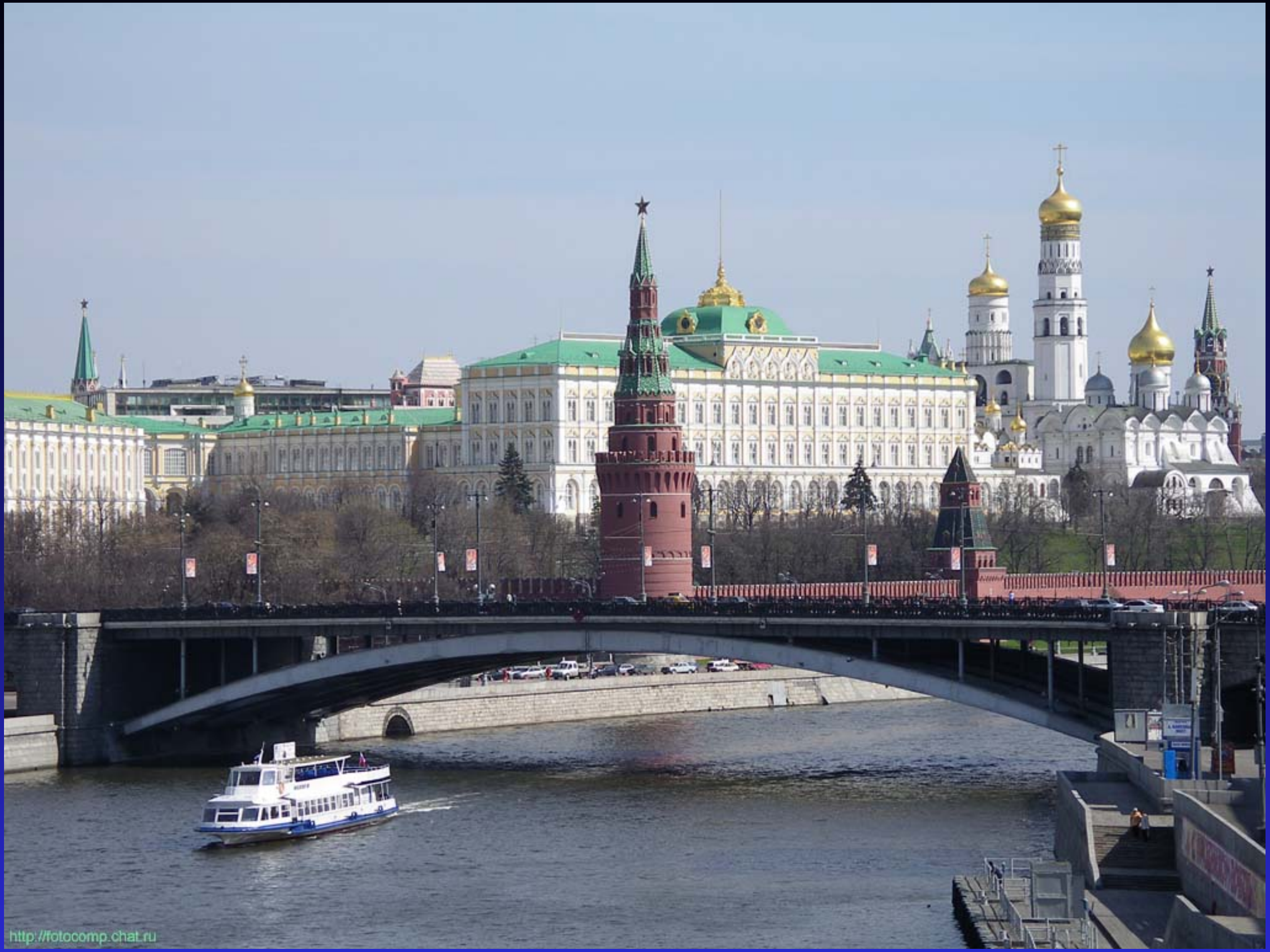

THANK YOU!