MAPPING BASALT THICKNESS USING CSEM AND MMT

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OUTLINE

- Motivation
  – Imaging base basalt
- Problem
  – Resolving “thin” structures
- Theory
  – MMT and CSEM sensitivity
  – Inversion
- Conclusion
  – Expanded frequency range from combining CSEM & MMT

INSPIRED BY A TRUE STORY...

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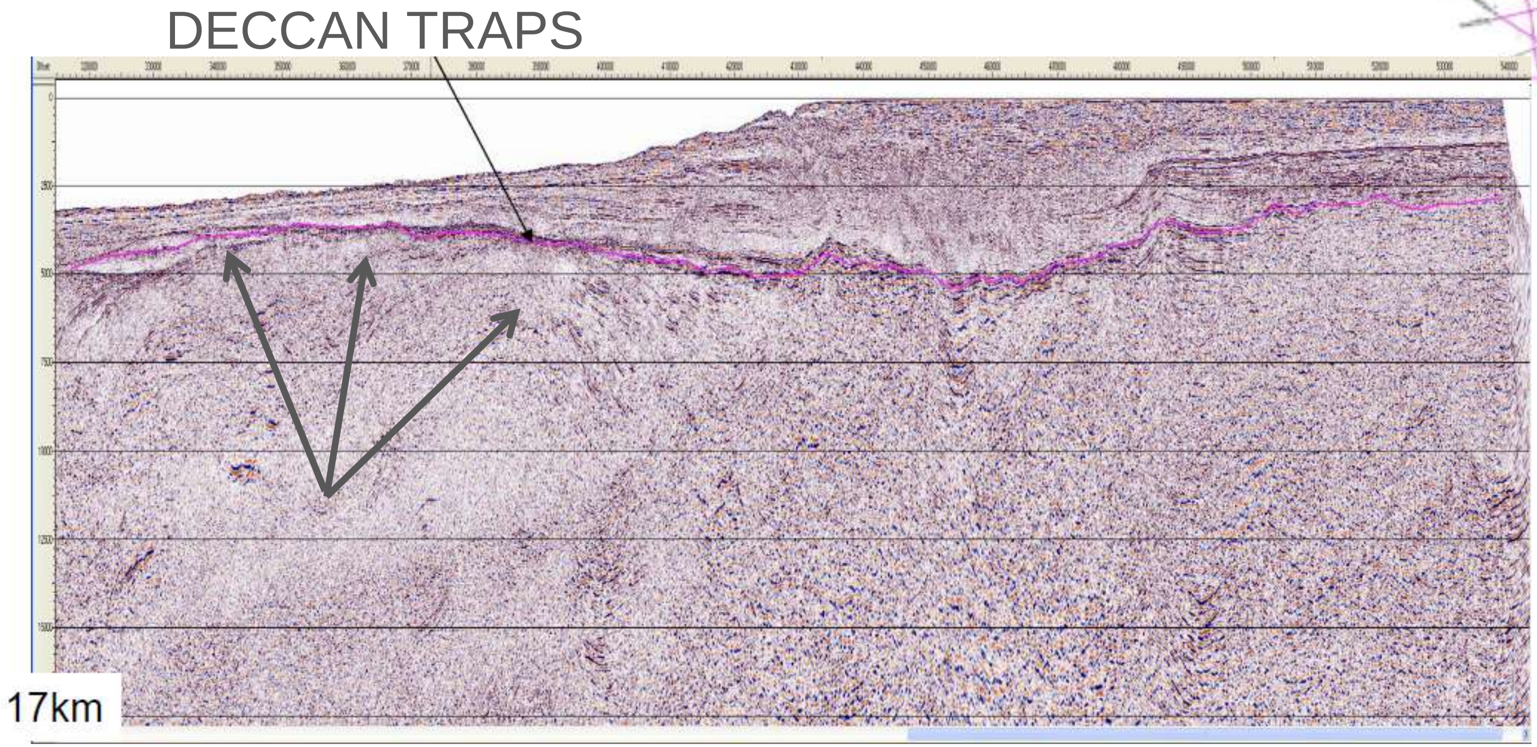
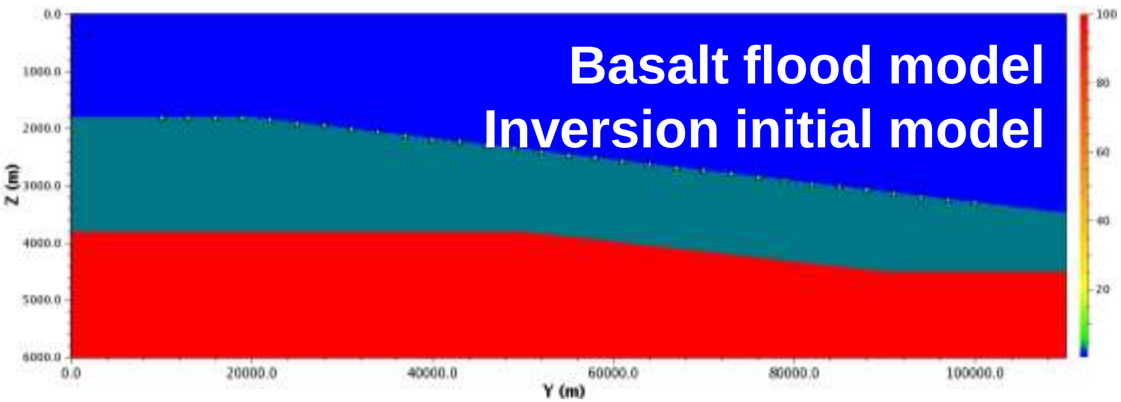
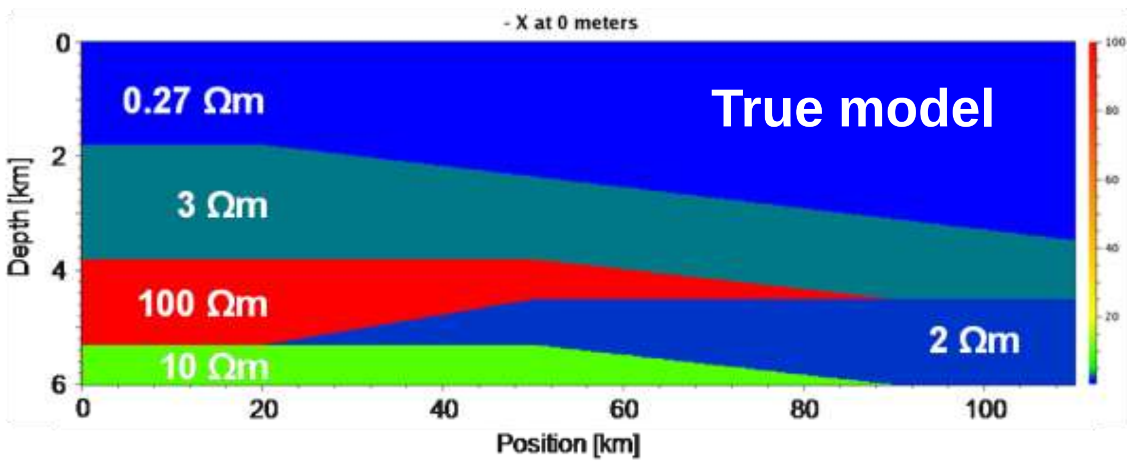


BASALT FLOOD MODEL & TRUE MODEL

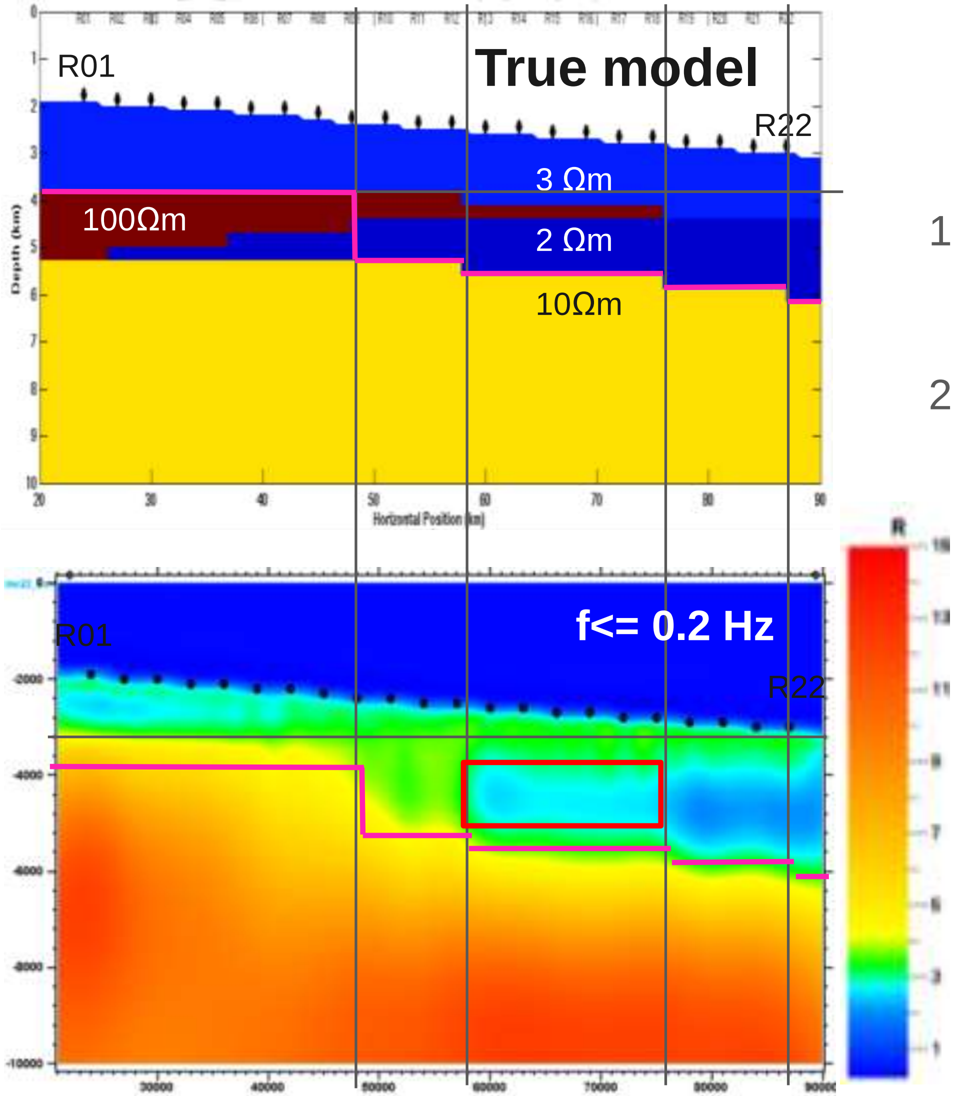


- Deep water
- Dipping seabed
  (1900 – 3000 m)
- 3 Ωm overburden
  (2000 – 1500 m)
- 100 Ωm basalt
  (1500 – 0 m)



- 2 Ωm sediment below basalt
  (1500 – 0 m)
- 10 Ωm Basement

MMT INVERSION – HIGH RESOLUTION

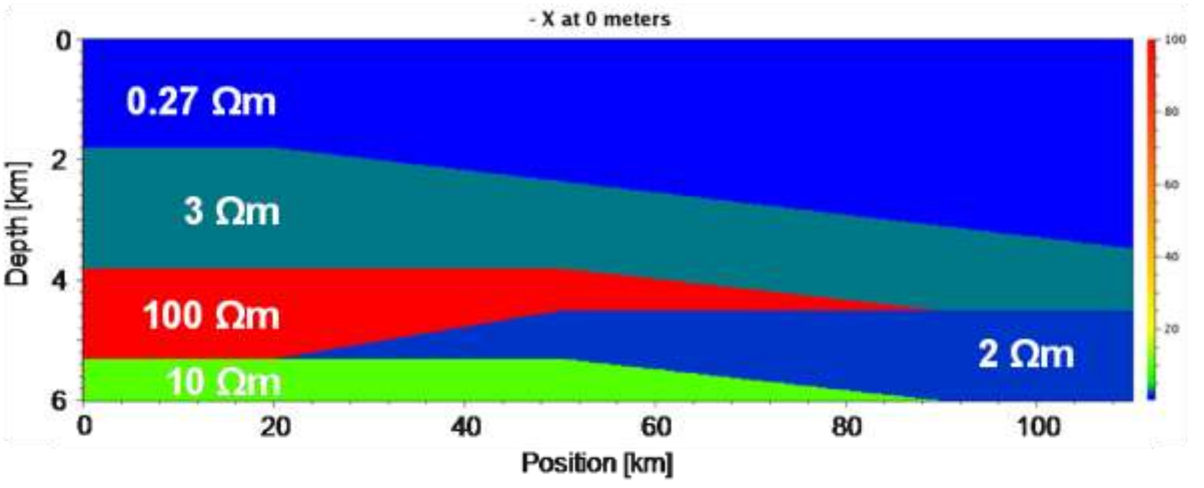


MMT results with 5 sec as lowest period (0.2 Hz highest frequency)

1. MMT resolves transition from conductive overburden to resistive basalt/basement

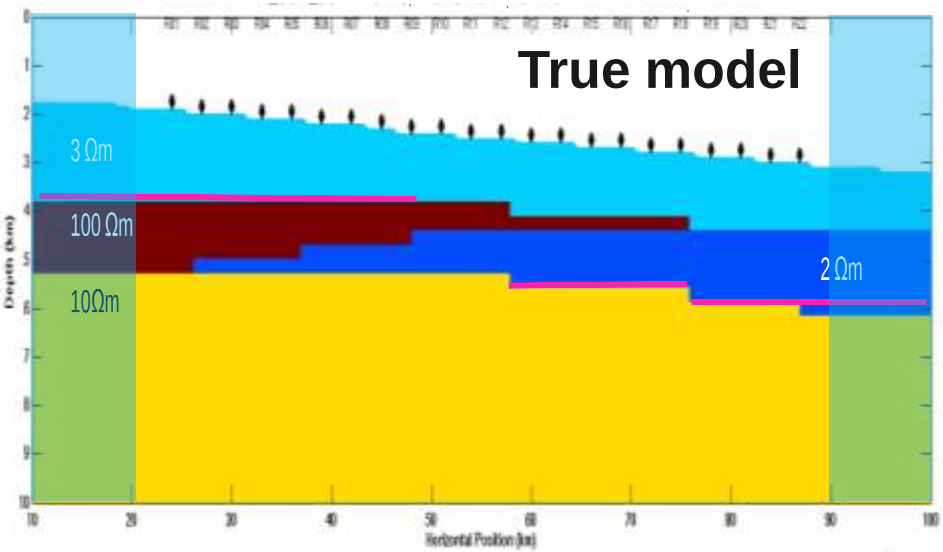
2. Presence of sediments under a thin basalt layer (red rectangle) is indicated

TRUE MODEL



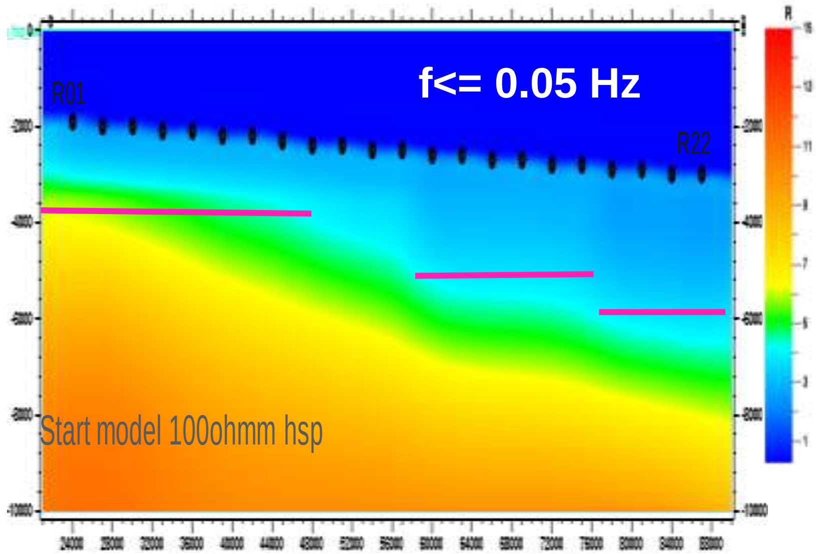
- MMT signal at low latitudes is weak.
- Deep water will attenuate higher frequencies.
- Typical MMT frequency content at 2500 m water depth: below 0.05 Hz

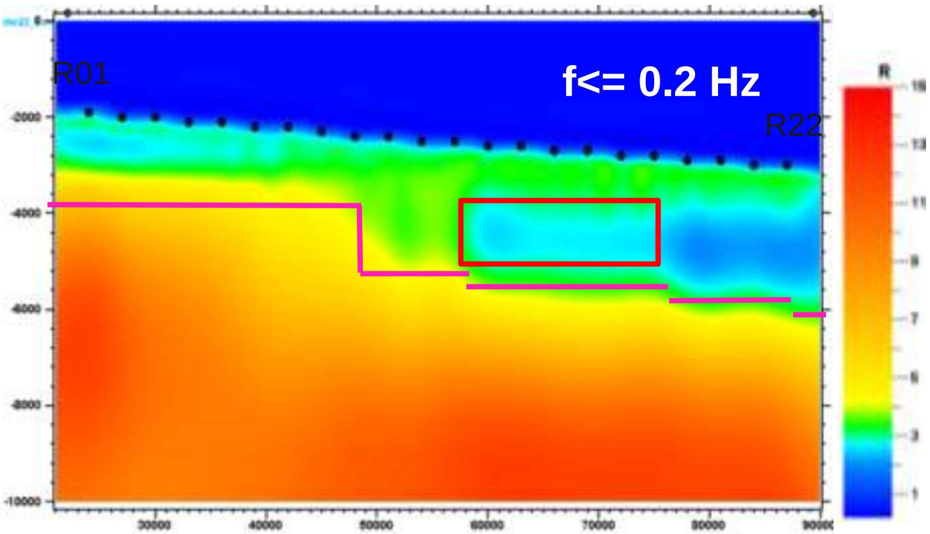
MMT INVERSION – LOW RESOLUTION



MMT results with 20 sec as lowest period
(0.05 Hz highest frequency)

1. Severe downgrade of resolution
2. Sub-basalt conductor not resolved
3. Basement still reasonably imaged





RESOLUTION PROBLEM – CAN CSEM HELP?

MT

+ Deep penetration
+ Good sensitivity to conductors

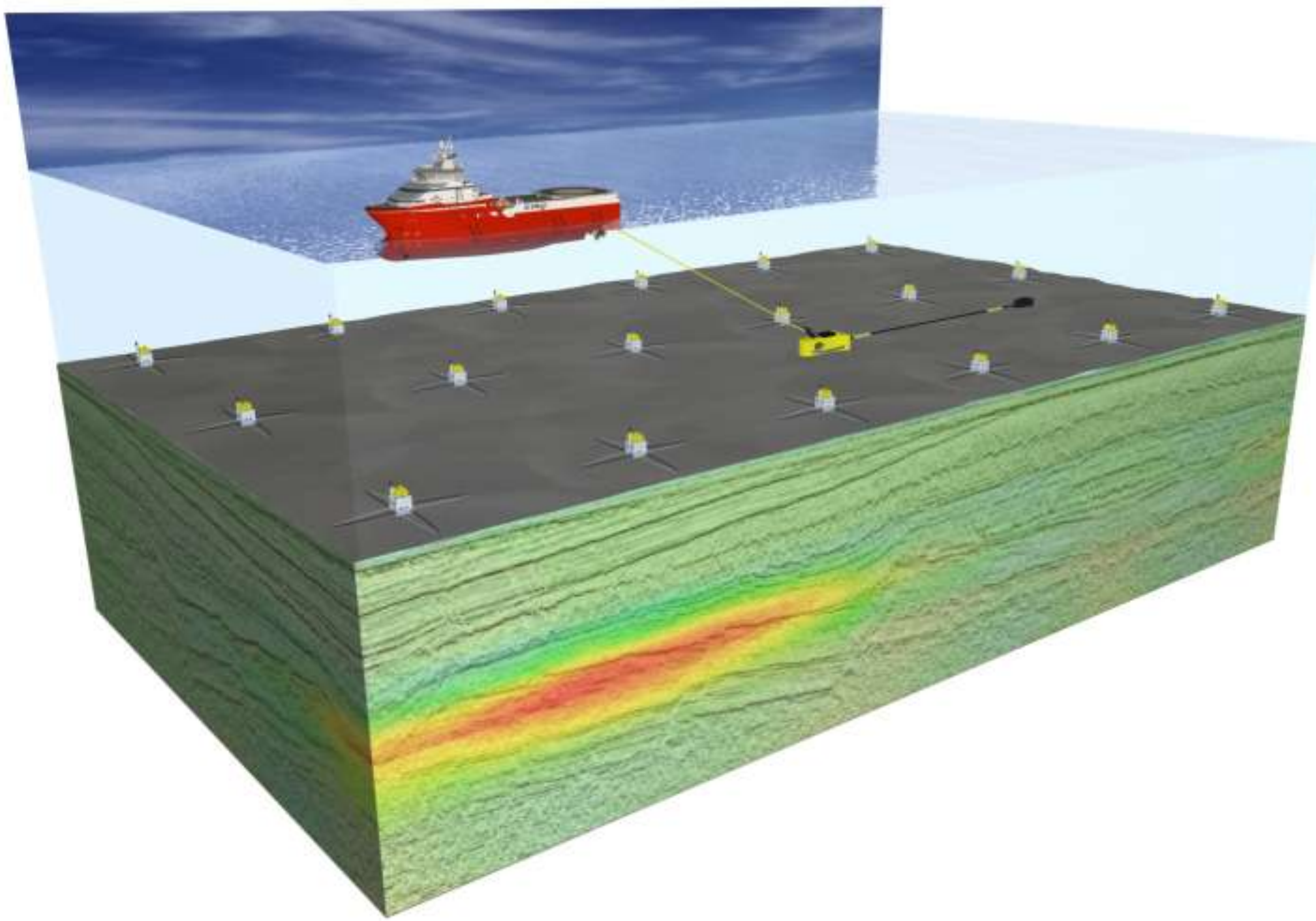
- Low frequencies, only large-scale features
- Source amplitude determined by latitude, water depth, space and earth weather

3D CSEM

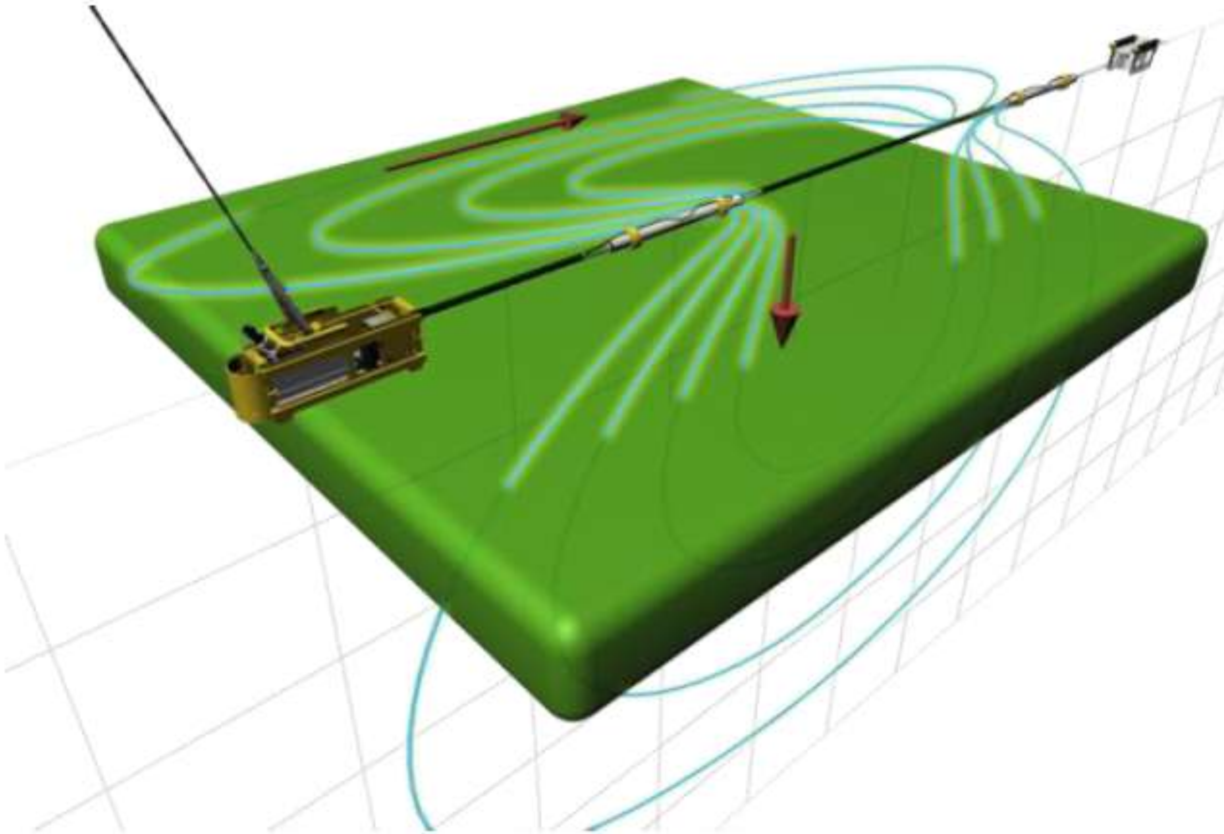
+ Frequency content controlled, can use higher frequencies
+ Can position source close to seafloor
+ Good sensitivity to (thin) resistors

- Shallower penetration

TOWED HORIZONTAL ELECTRIC DIPOLE SOURCE

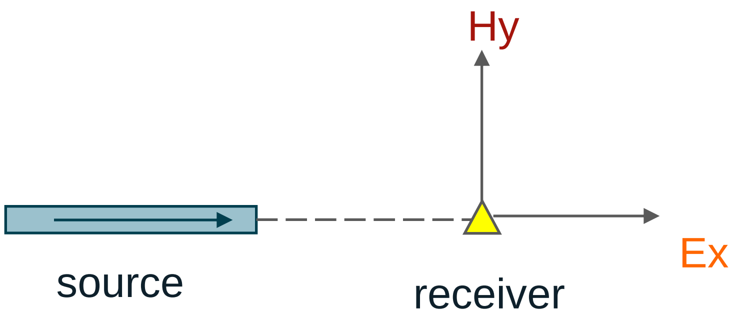


TOWED HORIZONTAL ELECTRIC DIPOLE SOURCE

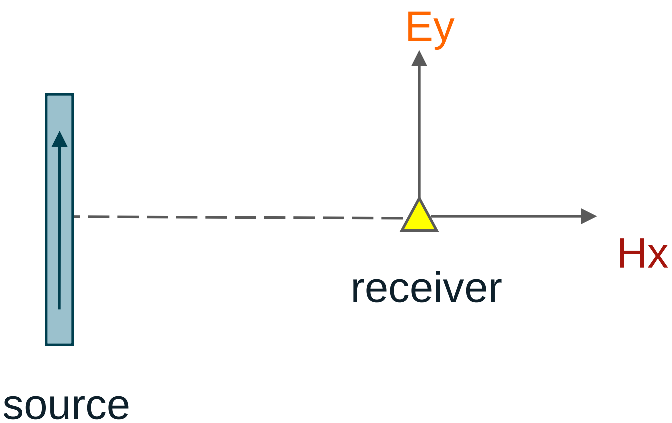


INLINE VERSUS BROADSIDE RESPONSE

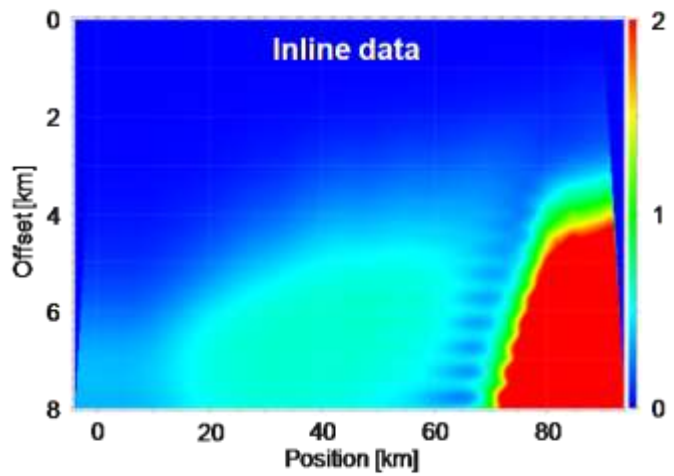
Inline response

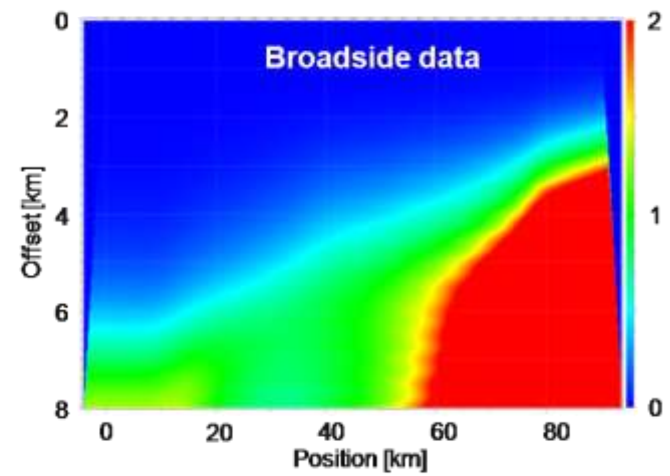


Broadside response



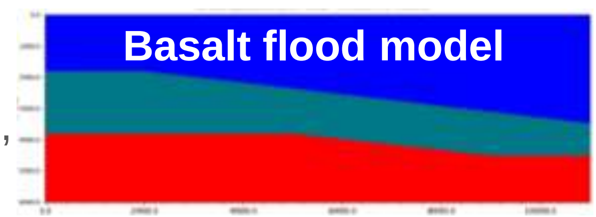
INLINE VERSUS BROADSIDE RESPONSE

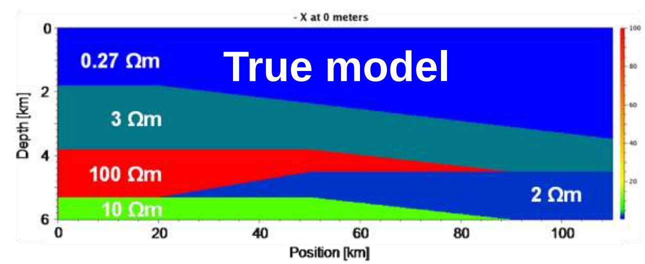




Plots show 1.5 Hz response defined as
scaled data difference between true and basalt flood model,

$$|E_{True} - E_{Flood}| / |E_{True}|$$





- Inline data response
  decays with increasing basalt thickness
- Broadside data sensitivity
  remains large at all basalt thicknesses

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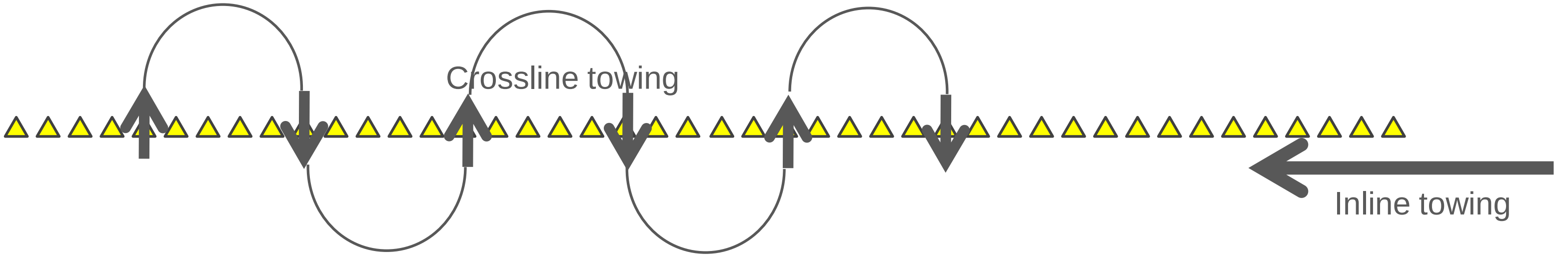
ACQUISITION SCENARIO

- 3D acquisition over a (100 km)^2 is costly – but broadside required
- Deep-towed cross-dipole not feasible today

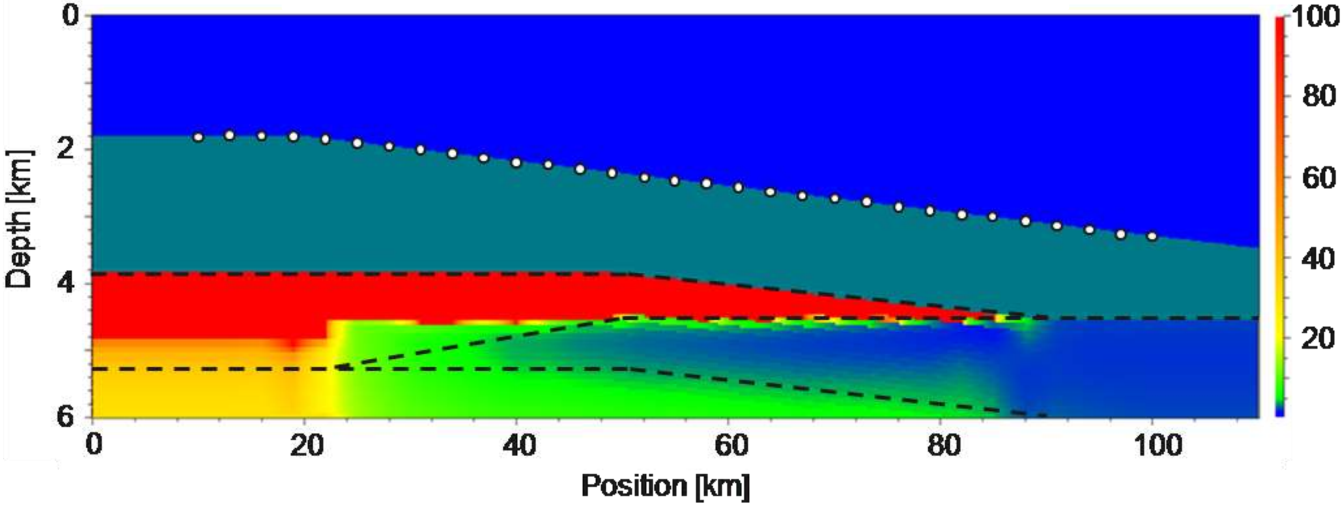
- Receiver capacity: 150
- Broadside data from cross-towing inline source
  – Source: coarser sampling
  – Receivers: denser sampling

- Frequencies1.0, 1.5, 2.5 Hz

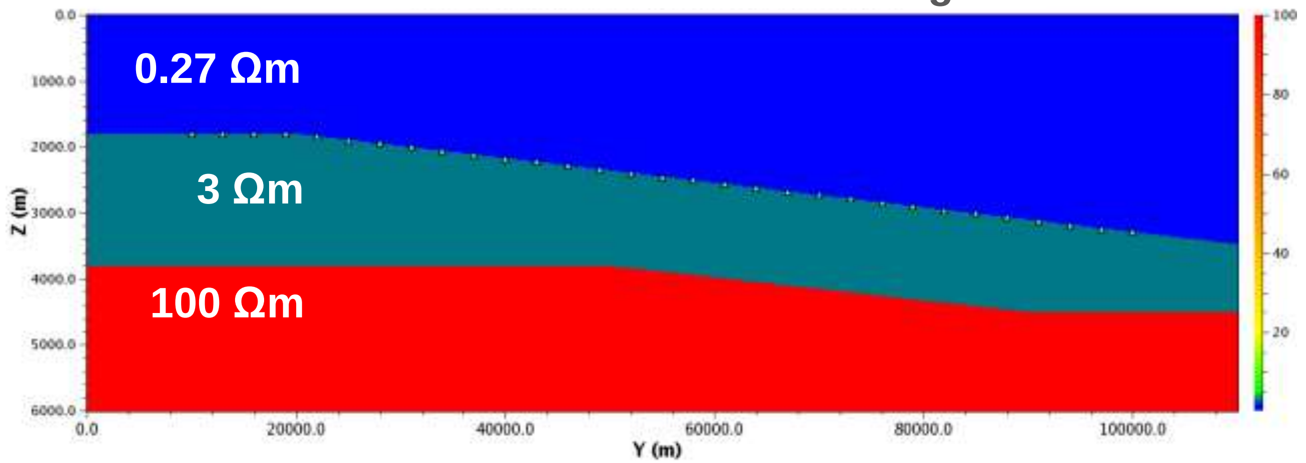


3D CSEM INVERSION, INLINE AND BROADSIDE DATA

Final model



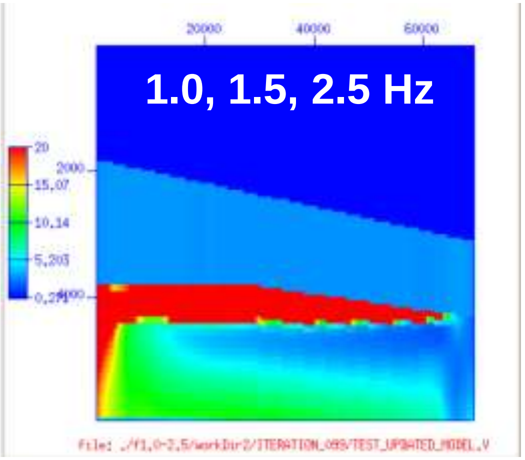
Initial model – basalt flooding

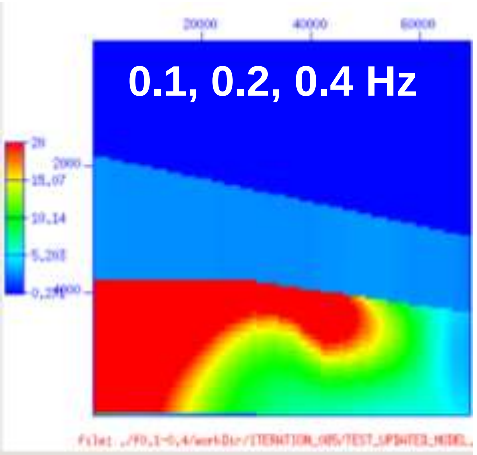


3D INVERSION FURTHER TESTS

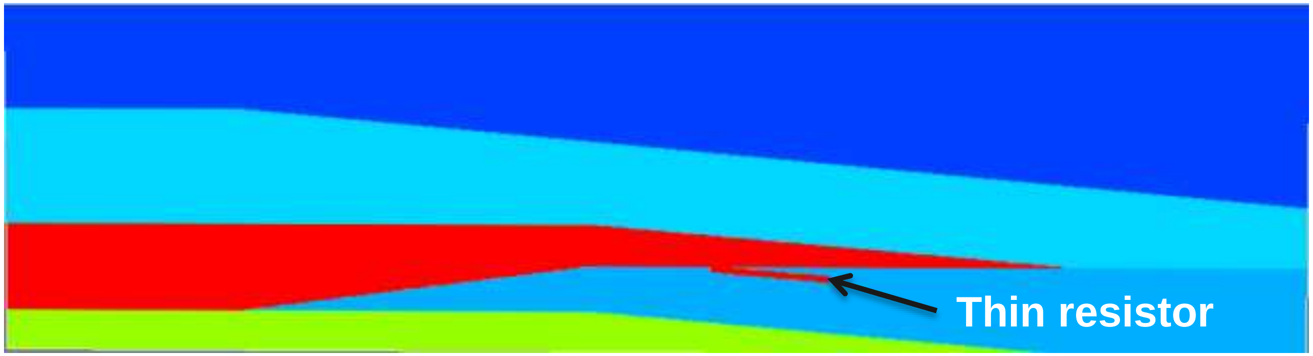
- Receiver spacing effect
  - Little difference ranging from 200-500 m
  - Degrades when spacing 1 km +

- Frequency dependence
  - Lowering frequency lowers resolution, similar to MMT



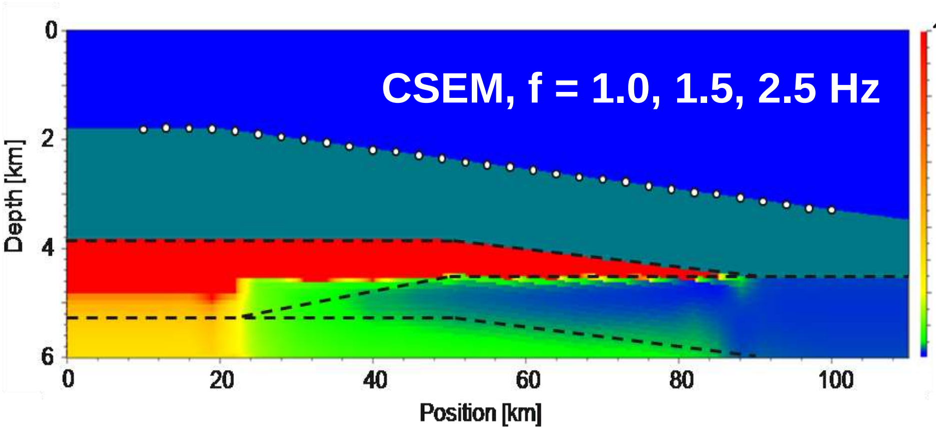


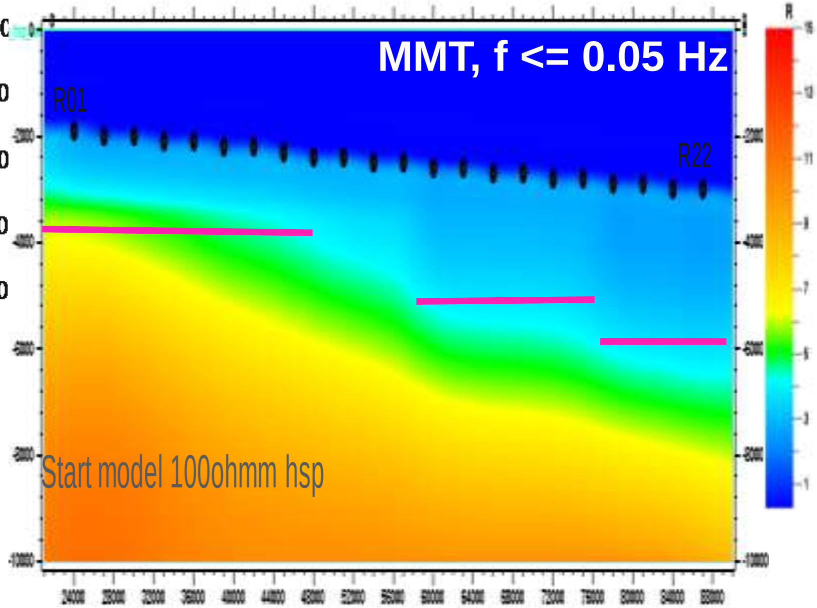
RESPONSE FROM RESERVOIR BELOW BASALT



- 3D resistor inserted below 600-400 m basalt
- 6 km diameter, 100 m thick, 100 Ωm
- Typical response 12 %

CONCLUSION





- Information on base basalt is essential in seismic processing
- MMT provides useful large-scale information, but does not identify thin basalt layer
- CSEM broadside data at high frequencies resolves conductive sub-basalt layer

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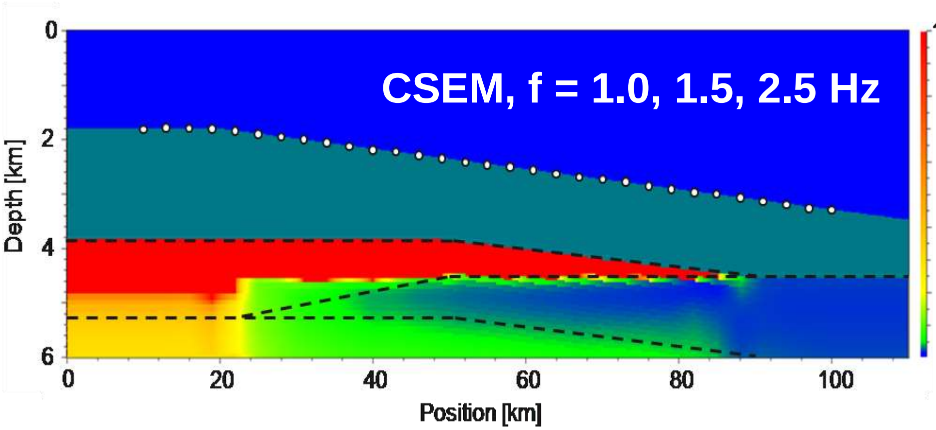
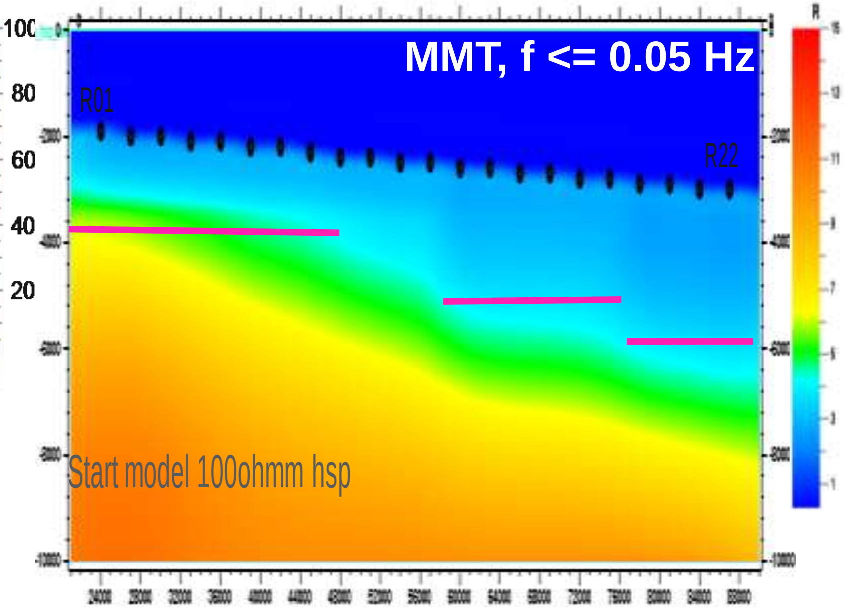
INVERSION SOFTWARE





- EMGS' 3D CSEM inversion:
  - FDTD forward solver
  - Quasi-Newton optimizer

- Scripps' 2D MMT inversion