Diffraction imaging to understand the internal fabric of mass-transport complexes from Gulf of Cadiz, south west Iberian Margin

Jonathan Ford (jford@inogs.it)\textsuperscript{1,3}  Roger Urgeles\textsuperscript{2}  Eulàlia Gràcia\textsuperscript{2}  Angelo Camerlenghi\textsuperscript{1}

\textsuperscript{1}Istituto Nazionale di Oceanografia e Geofisica Sperimentale (OGS)
\textsuperscript{2}Institut de Ciències del Mar (ICM-CSIC)
\textsuperscript{3}University of Trieste
Model of the seismic wavefield

Conventional seismic reflection image = Specular reflections + Diffracted energy + Noise

Before migration:

After migration:
Mass-transport complexes as diffraction generators?

Requirements

✓ Impedance contrasts
✓ Lateral heterogeneity
✓ ...on the scale of the seismic wavelength (10s of m)
Mass-transport complexes as diffraction generators?

Yamamoto et al. (2009)

Requirements

✓ Impedance contrasts
✓ Lateral heterogeneity
✓ …on the scale of the seismic wavelength (10s of m)
Apply diffraction separation and imaging to seismic images of mass-transport complexes:

1. Do MTCs generate significant diffraction energy?
2. Can we use this to image internal structure?
3. Do we resolve things we cannot see in conventional images?

Ford, J., Urgeles, R., Gràcia, E., Camerlenghi, A. (in prep). *Diffraction imaging to understand the internal fabric of mass-transport complexes: examples from Gulf of Cadiz, south west Iberian Margin*
Diffraction imaging

Conventional seismic reflection image = Specular reflections + Diffracted energy + Noise

Before migration:

After migration:

**Principle:** separate reflected and diffracted wavefields, migrate the diffractions only to form a diffraction image
INSIGHT cruises (May 2018 and October 2019)

**INSIGHT**

Imaging large seismogenic and tsunamigenic structures of the Gulf of Cadiz with ultra-high resolution technologies

- PIs: Roger Urgeles and Eulàlia Gràcia
- Acquisition: “2-D HR”, 350 m streamer, 930 cu. in. airgun array

B/O Sarmiento de Gamboa

Gulf of Cadiz (Urgeles, 2019)
Diffraction separation and imaging (normal fault example)
Diffraction separation and imaging (normal fault example)

- Conventional pre-stack time migration
- Dip estimation
- De-migrate dip (Ford et al., in prep)
- Diffraction separation (offset domain plane-wave destruction; Fomel et al., 2007)
- Pre-stack time migration of diffractions
Diffraction separation and imaging (normal fault example)

- Conventional pre-stack time migration
- Dip estimation
- De-migrate dip (Ford et al., in prep)
- Diffraction separation (offset domain plane-wave destruction; Fomel et al., 2007)
- Pre-stack time migration of diffractions
Diffraction separation and imaging (normal fault example)

- Conventional pre-stack time migration
- Dip estimation
- De-migrate dip (Ford et al., in prep)
- Diffraction separation (offset domain plane-wave destruction; Fomel et al., 2007)
- Pre-stack time migration of diffractions
Diffraction separation and imaging (normal fault example)

- Conventional pre-stack time migration
- Dip estimation
- De-migrate dip (Ford et al., in prep)
- Diffraction separation (offset domain plane-wave destruction; Fomel et al., 2007)
- Pre-stack time migration of diffractions
Diffraction separation and imaging (normal fault example)

- Conventional pre-stack time migration
- Dip estimation
- De-migrate dip (Ford et al., in prep)
- Diffraction separation (offset domain plane-wave destruction; Fomel et al., 2007)
- Pre-stack time migration of diffractions
Diffraction separation and imaging (normal fault example)

- Conventional pre-stack time migration
- Dip estimation
- De-migrate dip (Ford et al., in prep)
- Diffraction separation (offset domain plane-wave destruction; Fomel et al., 2007)
- Pre-stack time migration of diffractions
Diffraction separation and imaging (normal fault example)

- Conventional pre-stack time migration
- Dip estimation
- De-migrate dip (Ford et al., in prep)
- Diffraction separation (offset domain plane-wave destruction; Fomel et al., 2007)
- Pre-stack time migration of diffractions
Diffraction separation and imaging (normal fault example)

- Conventional pre-stack time migration
- Dip estimation
- De-migrate dip (Ford et al., in prep)
- Diffraction separation (offset domain plane-wave destruction; Fomel et al., 2007)
- Pre-stack time migration of diffractions
Geological setting: extensive contouritic deposits (from Mediterranean Outflow Water), salt diapirism = mass-wasting
Portimao Bank – Lolita salt diapir

Conventional PSTM (PB3)
Portimao Bank – Lolita salt diapir

Diffraction PSTM (PB3)

TWTT [s]

2 km
Portimao Bank – Lolita salt diapir

Conventional PSTM (PB3)

Diffr energy

TWTT [s]

2 km
Marques de Pombal Fault

Geological setting:

- Monoclinal thrust cutting the Plio-Quaternary (potential source of 1755 Lisbon earthquake + submarine landslide + tsunami; Zitellini et al., 2001)
- Thick succession of MTCs in basin – record fault activity?
Marques de Pombal Fault

Conventional PSTM (MP06)

Stacked MTCs

Slump

Marques de Pombal fault

~0.5 km

3 km
Marques de Pombal Fault

Identify small MTCs (<a wavelet thick), better constraint of lateral extent
Identify small MTCs (<a wavelet thick), better constraint of lateral extent
Identify small MTCs (<a wavelet thick), better constraint of lateral extent
Applications:

- Screening for MTCs, delimiting lateral extent (energy attribute)
- Kinematic indicator from distribution of diffraction energy – sensitive to downslope disaggregation of flow?
- Resolve structure inside “transparent” bodies

Limitations:

- Out-of-plane energy on 2-D profiles (3-D effect of MTCs)
- Seismic processing – care needed to preserve diffractions, avoid aliasing
- Noise

Note: works on short-offset and post-stack data (also for velocity model building)
Conclusions

1. MTCs do produce lots of diffraction energy, relative to unfailed sediments
2. Diffraction image is sensitive to heterogeneous structure inside MTCs
3. New tool to characterise MTCs
   • Image heterogeneous internal structure
   • Screen for thin bodies
Acknowledgements and references

Thanks to the crew, technicians and science party of INSIGHT (Leg 1 and 2) cruises, particularly the onboard MCS processing group: E. Piazza, R. Bartolomé, P. Brito and A. Calahorrano

Diffraction separation and imaging was performed using Madagascar (http://reproducibility.org)

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 721403.

This presentation is licensed under a Creative Commons Attribution 4.0 License.


https://doi.org/10.1190/1.2781533

Yamamoto et al., 2007. Large-scale chaotically mixed sedimentary body within the Late Pliocene to Pleistocene Chikura Group, Central Japan. Island Arc
https://doi.org/10.1111/j.1440-1738.2007.00587.x

Zitellini et al., 2001. Source of 1755 Lisbon earthquake and tsunami investigated. Eos Trans. AGU.
https://doi.org/10.1029/EO082i026p00285-01