Building a Three Dimensional Model of Plio-Quaternary Basin of Argostoli (Cephalonia Island, Greece) From an Integrated Geophysical and Geological Approach to Perform Numerical Simulations of Seismic Motion

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SUMMARY

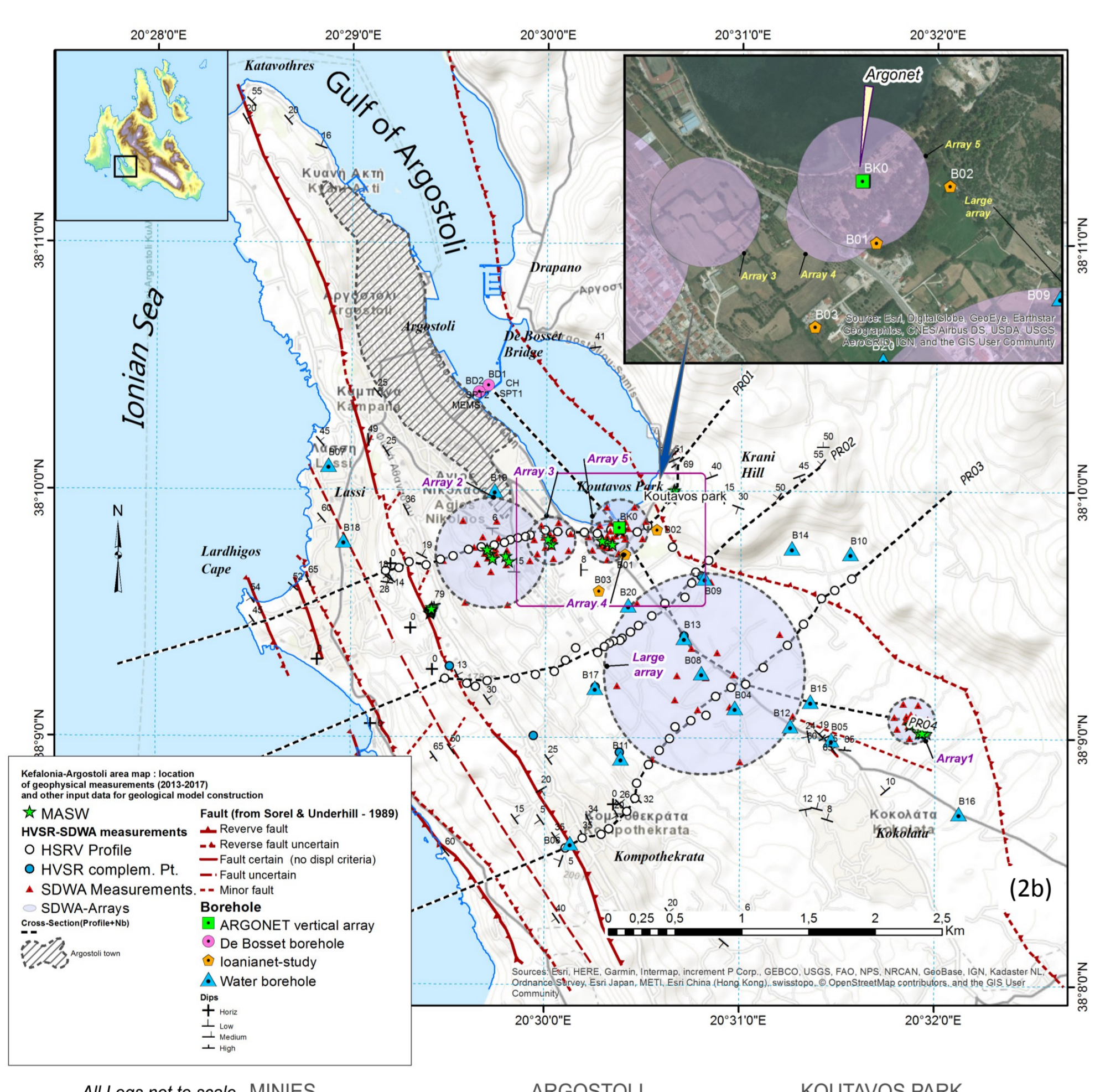Particular shallow geological configurations introduced by significant lithological and/or geometrical variations may cause ground motion amplification such as for sedimentary basins and covers overlying rock basements, where a large impedance contrast between the superficial soft layers and the harder deeper rocks. For the safety assessment of critical facilities, site effects associated with such geological conditions have to be quantified. In the framework of the PIA SINAPS@ project of the French Research Agency (ANR), a narrow Plio-Quaternary sedimentary basin next to Argostoli capital of Cephalonia (Greece) was selected as a test site for studying site effects and the nonlinear behavior of soil. We present here the geological and geophysical characterization that has led to the definition of the 3D structure and the different stratigraphic units of the Argostoli basin. From the 3D model, a numerical code (i.e. SEM3D) has been developed. The seismic phenomenon is simulated in its entirety: from the seismic source to the site using a representative model of the complexity of the wave path. In order to validate the proposed numerical model, several recorded earthquakes issued from the accelerometers array database are compared with the numerical simulated ones. The first obtained results show the importance of the in-situ measures on the regional scale simulations.

(1a)

(1b)
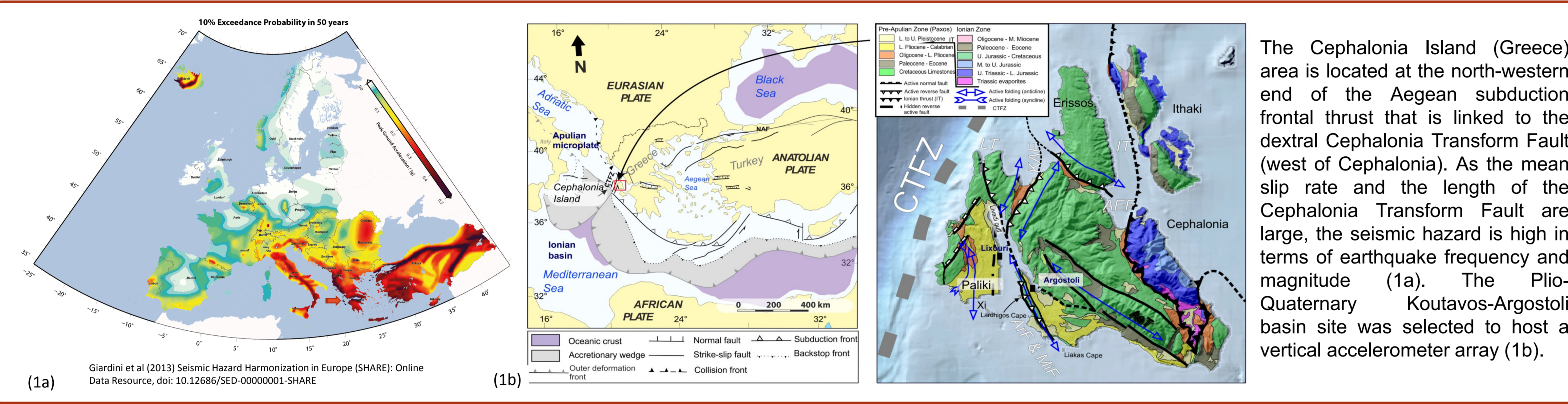
The Cephalonia Island (Greece) area is located at the north-western end of the Aegean subduction frontal thrust that is linked to the dextral Cephalonia Transform Fault (west of Cephalonia). As the mean slip rate and the length of the Cephalonia Transform Fault are large, the seismic hazard is high in terms of earthquake frequency and magnitude (1a). The Plio-Quaternary Koutavos-Argostoli basin site was selected to host a vertical accelerometer array (1b).

Giardini et al (2013) Seismic Hazard Harmonization in Europe (SHARE): Online Data Resource, doi: 10.12686/SED-0000001-SHARE

GEOLOGICAL AND GEOPHYSICAL DATA

Pre-existing mapping (2a) combined with a new geological field survey geophysical acquisitions (HVSR, SDWA and MASW) (2b,c), geological and geotechnical analysis of the ARGONET borehole (2d) allowed to performed a new upgraded geological map that details the Plio-quaternary formations in the Argostoli basin. Taking advantage of the ARGONET borehole, dating performed on corals allowed to assess the middle Pleistocene age of the base of the Quaternary unit of Koutavos that was no to date established (~411 ka).

(2a)

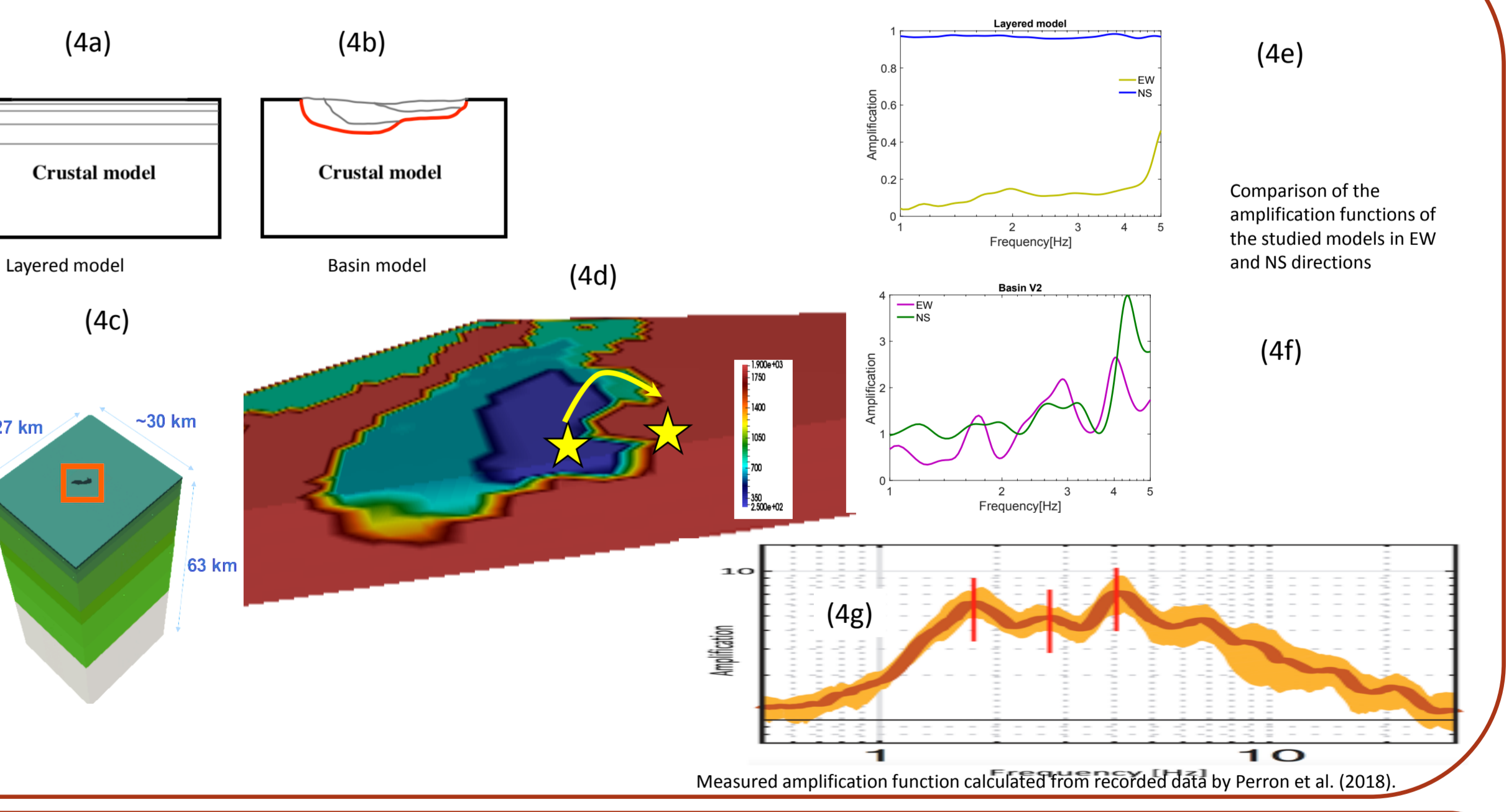Sorel, 1976 map   Underhill, 1989 map

(2b)

(2c)

(2d)
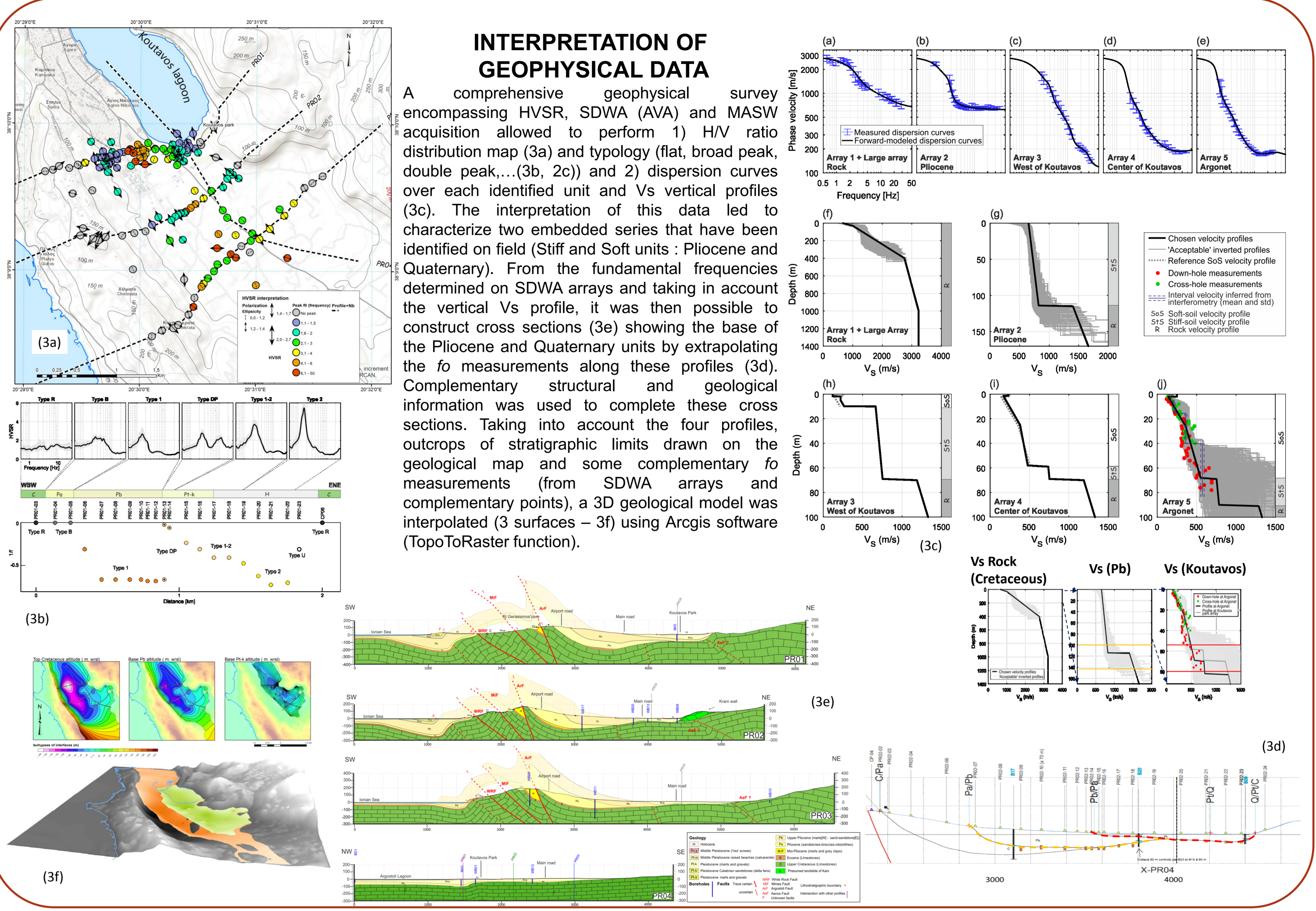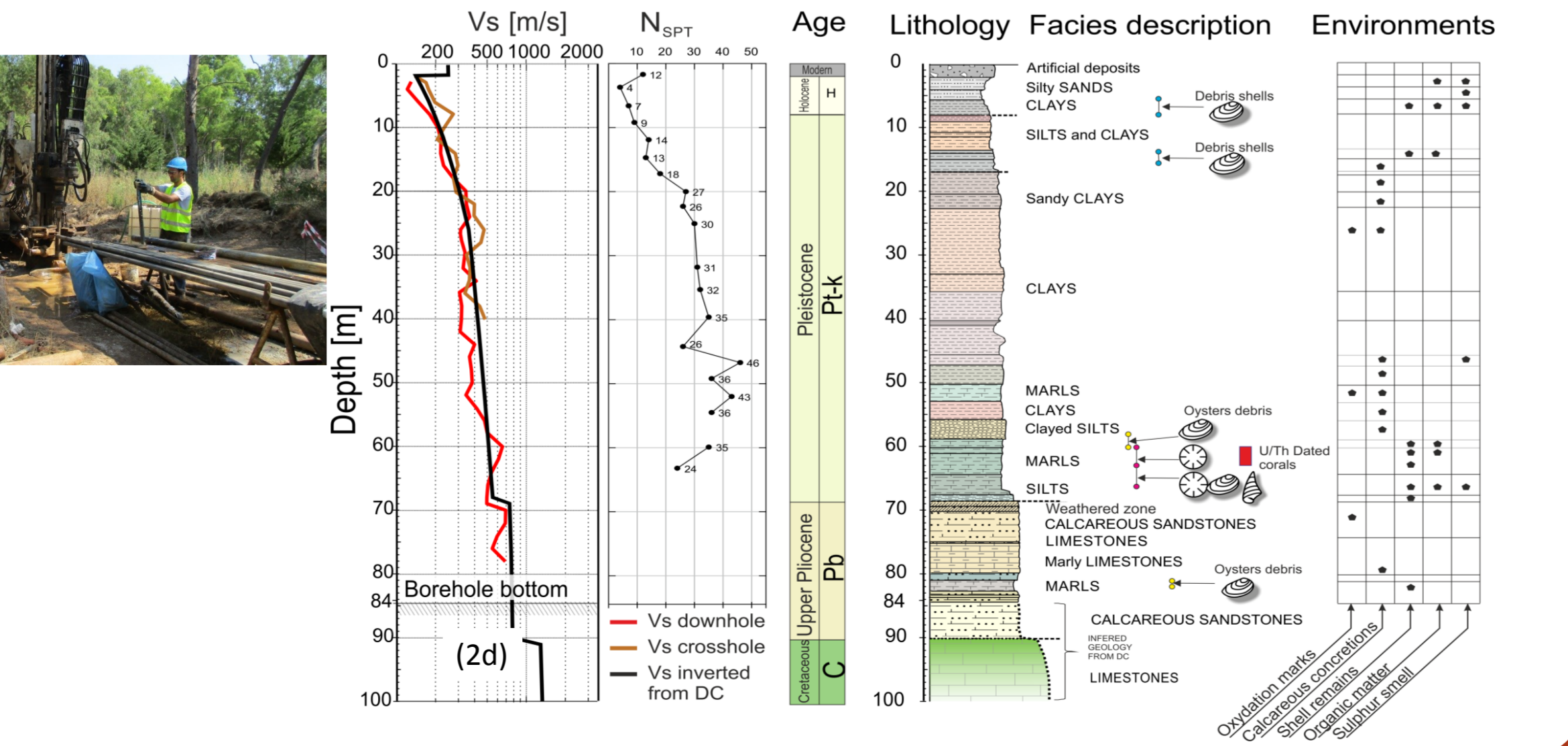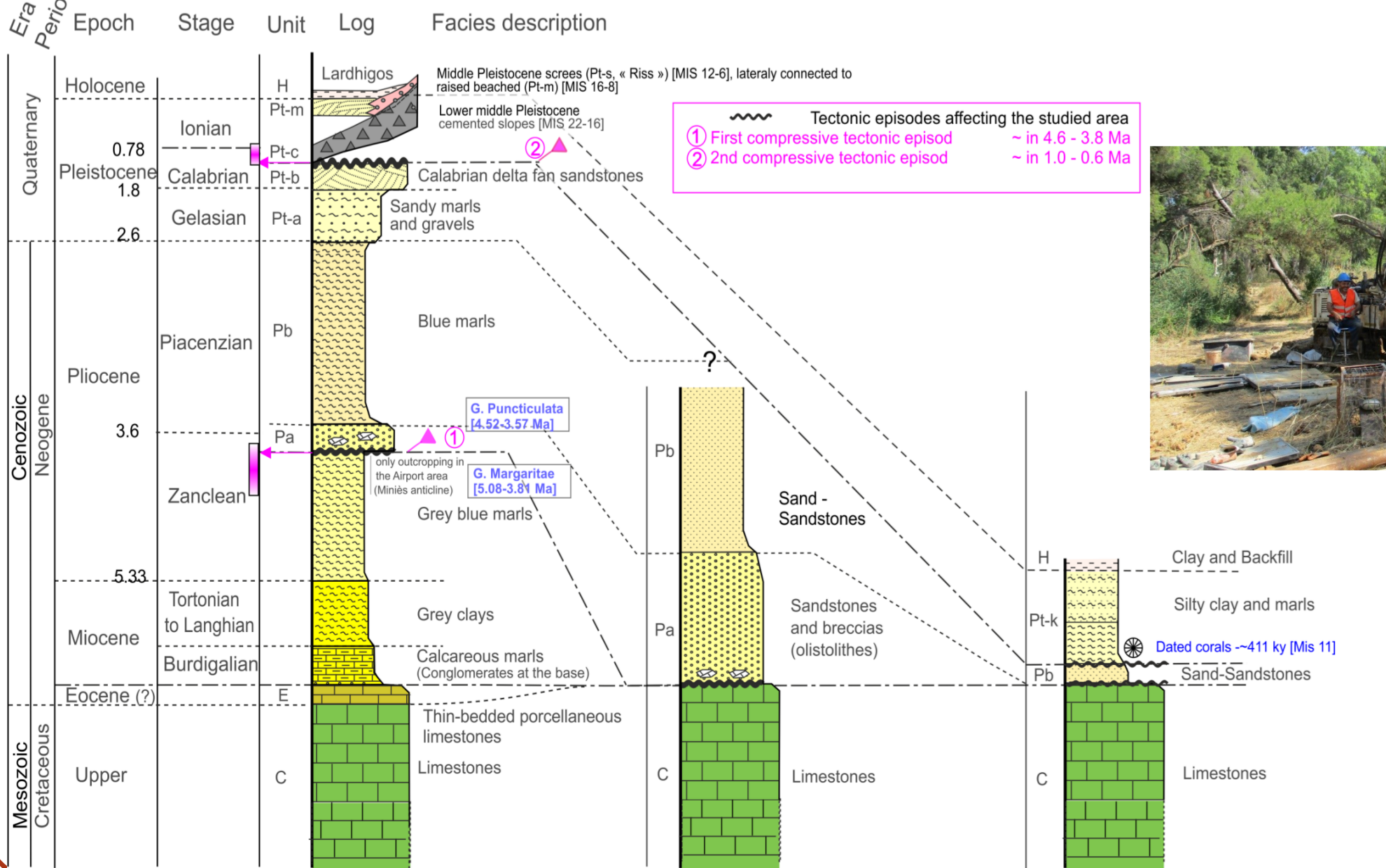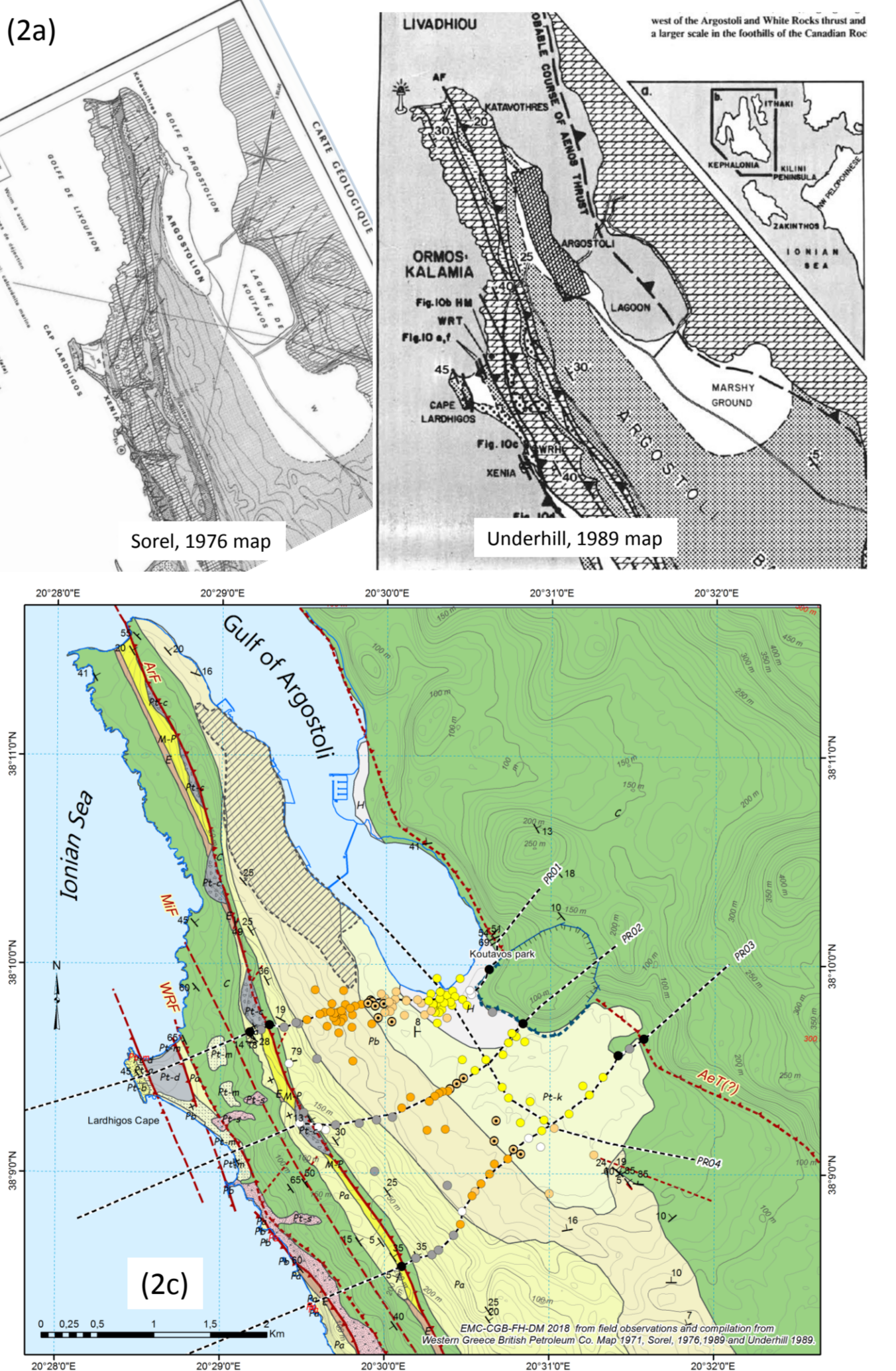
INTERPRETATION OF GEOPHYSICAL DATA

A comprehensive geophysical survey encompassing HVSR, SDWA (AVA) and MASW acquisition allowed to perform 1) H/V ratio distribution map (3a) and typology (flat, broad peak, double peak,…(3b, 2c)) and 2) dispersion curves over each identified unit and Vs vertical profiles (3c). The interpretation of this data led to characterize two embedded series that have been identified on field (Stiff and Soft units : Pliocene and Quaternary). From the fundamental frequencies determined on SDWA arrays and taking in account the vertical Vs profile, it was then possible to construct cross sections (3e) showing the base of the Pliocene and Quaternary units by extrapolating the fo measurements along these profiles (3d). Complementary structural and geological information was used to complete these cross sections. Taking into account the four profiles, outcrops of stratigraphic limits drawn on the geological map and some complementary fo measurements (from SDWA arrays and complementary points), a 3D geological model was interpolated (3 surfaces – 3f) using Arcgis software (TopoToRaster function).

(3a)

(3b)

(3c)

(3d)

(3e)

(3f)

3D VELOCITY MODEL AND GROUND MOTION SIMULATION

Two different cases were studied and compared. The first case is a layered model using the velocity model proposed by Haslinger et al. (1999) (for upper layers) (4a). This model does not allow to see the local effects. In order to take into account the geological characteristics of the site, a more refined model (4b) was studied considering the 3D geological model (4c). The two models have the size of: 27 x 30 x 50 km. The size of the elements constituting the mesh is 130 x 130 m in the horizontal directions (EW and NS). For the vertical direction, the size of the elements is adapted according to the properties of each layer. The amplification is evaluated between two sensors : one inside the basin and the other one outside the basin (4d). In the case of the stratified model there is no peak in the NS directions and the appearance of very small peaks in the EW direction (4e). In the case of the basin model the peaks appear in both directions (4f). The simulated results are compared to the amplification function calculated from the Argostoli recorded database (4g). It is noted that for the Basin model the three founded frequency peaks are practically the same as in the case of experimental data. The magnitudes, though, are less important.

(4a)   (4b)   (4c)   (4d)   (4e)   (4f)   (4g)

Comparison of the amplification functions of the studied models in EW and NS directions

Measured amplification function calculated from recorded data by Perron et al. (2018).

CONCLUSIONS

- New geological data from field survey, geophysical interpretation of fo distribution and typology and from borehole data
- Dating the base of the Quaternary basin at ~411 ka
- A 3D geological model of the Argostoli basin was performed by interpolation of depth control points coming from geological survey and interpretation of geophysical data.
- Construction of integrated 3D velocity model at # scales .
- First simulation of EQ spectral amplification is in good agreement with empirical evaluation of amplification frequencies
- Future simulation taking in account fault models (2014 Cephalonia EQ)

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Sorel, D. (1989). L'évolution structurale de la Grèce nord-occidentale depuis le miocène, dans le cadre géodynamique de l'arc égéen. Paris 11.
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