

Reliable High Resolution Physical Properties Correlation in sediments as a Powerful Tool for Geological Exploitation and Natural Hazard Issues

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Abstract – We report the standardized procedures, developed in the last fifteen years at the IAMC-CNR Petrophysical Laboratory, with the aim to obtain reliable High Resolution Petrophysical Properties (HRPP) correlation in marine and terrestrial sediment. In the frame of a multidisciplinary approach, and depending of used scale correlation (which can vary from centimetric to decimetric/metric), the correlated petrophysical parameters combined with high resolution seismic and geoelectric profiles interpretation, sedimentological and geochronological data, may be a powerful tools to give new insight in geological exploitation and natural hazard. Several examples of geological applications are here presented and discussed.

I. INTRODUCTION

Physical properties of deposits are generally considered as good indicators of sediment's composition, formation and environmental conditions.

The GEOTEK Multi-Sensor Core Logger (MSCL) enables physical properties measurements to be made on both whole cores and split cores (see <http://www.geotek.co.uk> for very detailed technical information).

Most stratigraphic applications of MSCL logs in marine and deep oceanic cored sediments rely on the relative values of logged parameters to furnish proxies for high resolution correlations over wide oceanic and volcanic district marine areas, providing information on geological events, such as for examples depositional and erosional processes, regional stratigraphy, oceanographic and climatic changes.

II. METHODOLOGY

The standard MSCL (MSCL-S) available at the IAMC-CNR Petrophysical Laboratory includes sensors to

measure low field magnetic susceptibility, bulk density, reflected light in the range from 400 to 700nm, P-wave velocity, core and environment temperature, chemical elements and electrical resistivity of sediments and rocks. The method, developed at the IAMC-CNR Petrophysical Laboratory during the last fifteen years, to reach reliable High Resolution Physical Properties (HRPP) correlation, consists of several standardized procedures which are applied during the acquisition and analyses of petrophysical data log.

In particular, the petrophysical observations of cored sediments are acquired continuously at centimetric scale. After that the repeatability of the obtained physical properties values are tested along the core (Fig 1).

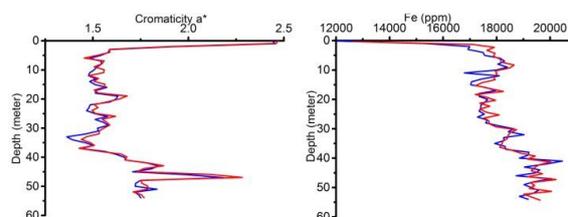


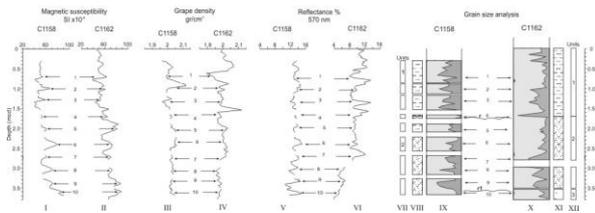
Fig. 1. Examples of physical properties measurements repetition for a section of Core C1134 (Gaeta Gulf). Analyzed parameters: Color reflectance (a^*) and FE content.

As soon as all petrophysical parameter logs for each core are obtained, the attention is focused on to the general pattern of each log, (i.e. decreasing- increasing values trend respect mean value, relative extreme high or low peaks, etc.) in order to verify data quality and identify the macroscopic variations, at the metric scale.

Afterwards, the data of the most reliable parameter (which is for example, in an area close to a volcanic district, the Volume Magnetic Susceptibility) are analyzed more in detail, trying to pinpoint single prominent peaks as well as characteristic patterns, needed for establishing

a high-resolution correlation between cores. The preliminary one parameter-based correlation is subsequently checked versus all other measured parameters. Thus, from all homologous pinpoint peaks and patterns only the values that are recognized to vary accordingly and at the same depths in at least 3 on 6 parameters are confirmed as linkable and are utilized to build the final HRPP correlation (more details and application in Fig. 2 A).

A



B

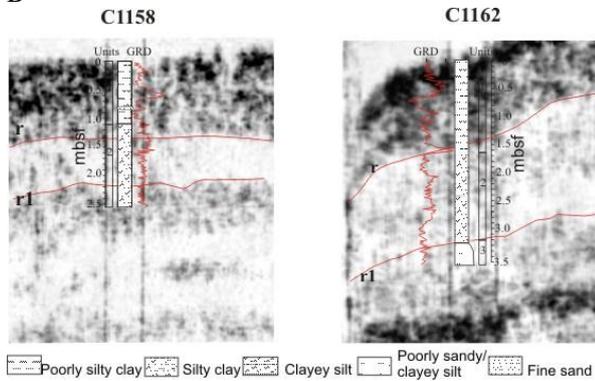


Fig. 2 Gaeta Gulf- Eastern Tyrrhenian margin. A) HRPP correlation and comparison of petrophysical-sedimentological data sets from two (C1158 and C1162), several kms apart cores. The cores were collected into a slow sliding sedimentological body. The numbers 1 to 10 indicate synchronous events of petrophysical (I to VI) and grain size (IX and X) variations, occurring in the measured cores. B) Core C1158 and C1162 projected on seismic profiles and showing the seismic horizons (*r* and *r1* respectively) correlated by mean of HRPP. In such case the HRPP correlation was aimed to detect the preservation of the internal geometry (decimetric scale) of the sedimentological body in order to better understand the sliding processes. (From [1, 2]).

So far, the obtained HRPP correlation, when combined with sedimentological and seismostratigraphic analysis and dating methods (i.e. ¹⁴C, Earth's Field Paleo Secular Variation Curves, Tephrochronology), shows to be an extremely powerful tool to highlight knowledge into coastal and volcanic hazard, paleoclimatic and global events which drive marine sediment deposition processes, or moving to continental depositional environment, they show to give evaluable contribute to seismic hazard and geothermal exploitation research. In

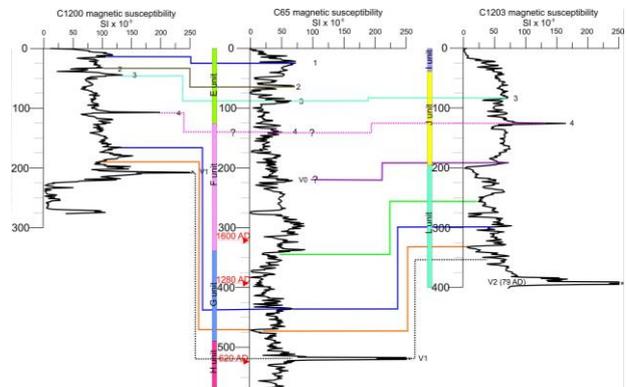
the next some chosen cases history, of such multidisciplinary studies, are reported:

III. RESULTS

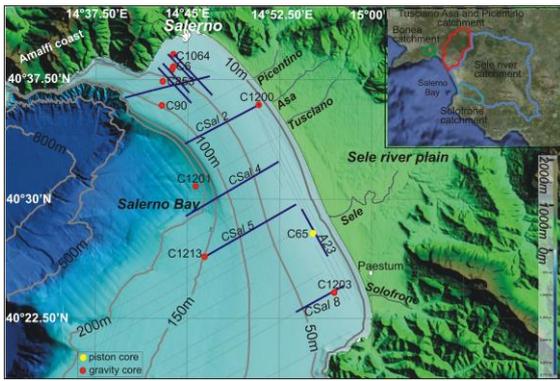
A. Coastal hazard

The coastal areas are among the most responsive systems to environmental changes and may therefore be impacted by anthropogenic disturbance, morpho-climatic variations (storms and floods) and tsunami events, in particular extreme events may causes major physical changes and expose coastal communities and human activity to hazard with loss of lives and potential damage to infrastructures. All these impacting factors may be recorded in offshore sedimentary record as event beds.

During the last ten years new insights on depositional processes in hazardous coastal area such as that of Gulf of Salerno, comes out from high-resolution seismic survey, gravity-core HRPP petrophysical-sedimentological correlated data and high resolution geochronology. The internal stratigraphic architecture of a series of prodeltas that develop at the mouth of minor streams (Bonea, Tusciano/Asa, Solofrone) and Sele river were documented (Fig. 3 and 4). The present day prodelta system, mostly recording the last 2-3 ky, displays various phases of development associated with periods of high sediment supply from the adjacent river basins. Depositional processes on the foresets were dominated by seastorms events, floods and tephra layers interbedded in the pelitic sediment. (From [4] and [7])



A



B
 Fig. 3 A) HRPP correlation of event beds (sea storms and floods) in shallow marine cores of Salerno Gulf and time constrains by ¹⁴C and tephra layers and B) Localization of the HRPP correlated cores and related high resolution Subbottom Chirp profiles on the Gulf of Salerno digital terrain model. (From [4])

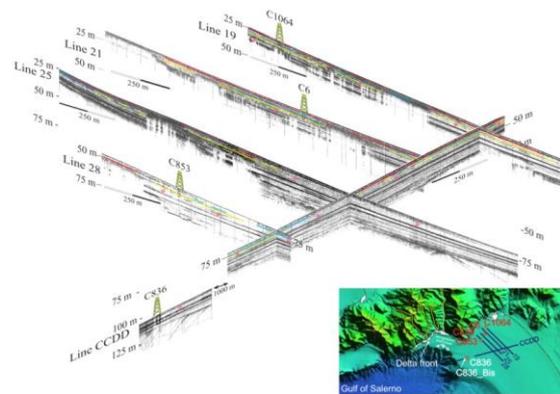
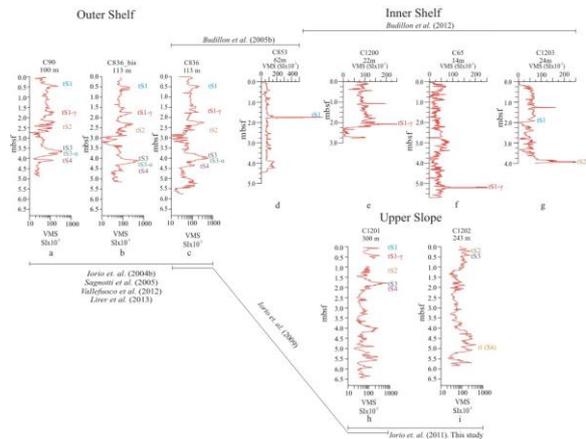


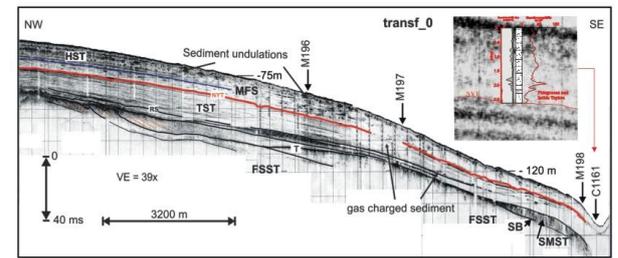
Fig. 4 High resolution Subbottom Chirp lines show the Holocene stratigraphic frame of the Salerno Bay northern sector. Three reflectors bouncing back from T1, T2 and T3 storm events are outlined with red, light blue and yellow lines; the one from the pumice deposit of the 79 A.D. Vesuvius plinian eruption is pointed out with red arrows. The recognition and correlation of T layers among cores where obtained by mean of HRPP correlation (From [7])

B. Volcanic hazard

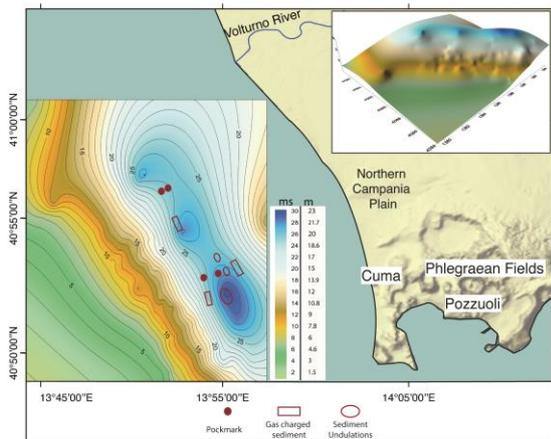
Volcanic ash fallout subsequent to a possible renewal of the Vesuvius and Phlegraean Field (PF) activity represents a serious threat to the highly urbanized area around the volcanos. In order to assess the relative hazard it is important to obtain the fallout distribution of recent PF and Vesuvius eruptions along the Campanian margin. Below two examples from Salerno (Fig. 5) and Gaeta (Fig. 6) gulfs are shown:



A
 Fig 5 A) tS1, tS1- γ , tS2, tS3, tS3- α , tS4 and t1 are tephra layers from Vesuvius and PF district for the last 106ky, identified in the Gulf of Salerno by HRPP correlation and geochemical data and dated by PSV and radiometric methodology after [3] and [6] B) The obtained distribution and stratigraphic thickness of the tephra layers are shown over the digital terrain model.



A



B
 Fig. 6: A) The seismo-stratigraphic architecture of Northern Phlegraean Field offshore showing the Neapolitan Yellow Tuff (NYT) deposits and B) its distribution in the southern Gaeta Gulf as individuated after HRPP – sedimentological correlation (inset in Fig. 6 A) and geochemical analysis (modified by [3] and [1])

C. Seismic hazard

The HRPP correlation has been integrated in a multidisciplinary high resolution geophysical study aimed to investigate the Monte Aquila fault behavior in the Val D’Agri fault system (Southern Apennines). The paleoseismological investigation documented at least three recent (<20 ky) deformation events [5]. In this case study a small-scale HRPP correlation has been applied to sediment cored in the footwall and hanging wall of the ERT detected fault zone (Fig. 7) in order to investigate displacement events (Figs 8 and 9).

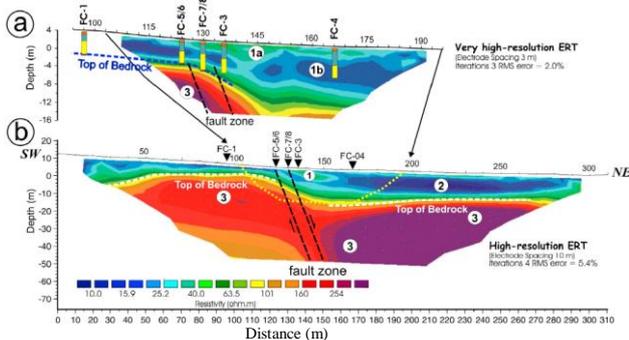


Fig. 7. Fornace site: a) Very high-resolution shallow ERT in colluvial package and localization of boreholes FC06 and FC08 of Fig. 8. b) high-resolution ERT (colluvial package, 2 saturated alluvia, 3 limestone bedrock). (From [5])

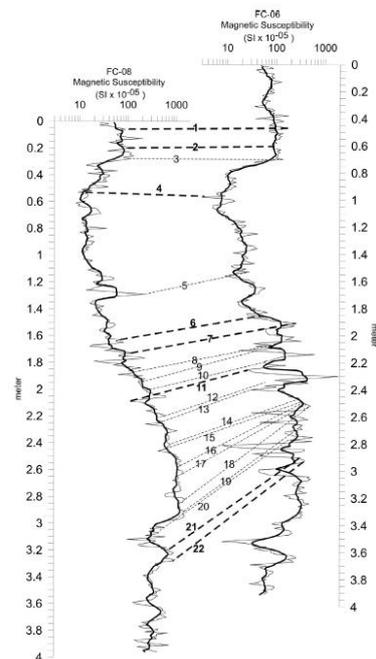


Fig. 8 Magnetic susceptibility logs for cores FC-06 and FC-08 with the 22 homologous points identified in at least three of the physical logs and used for HRPP correlation (dashed lines). (From [5])

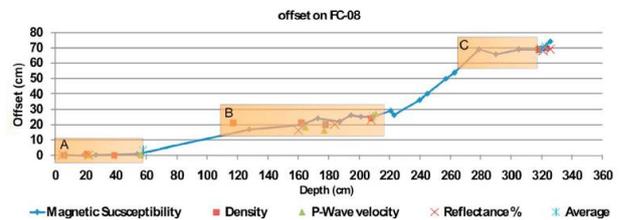
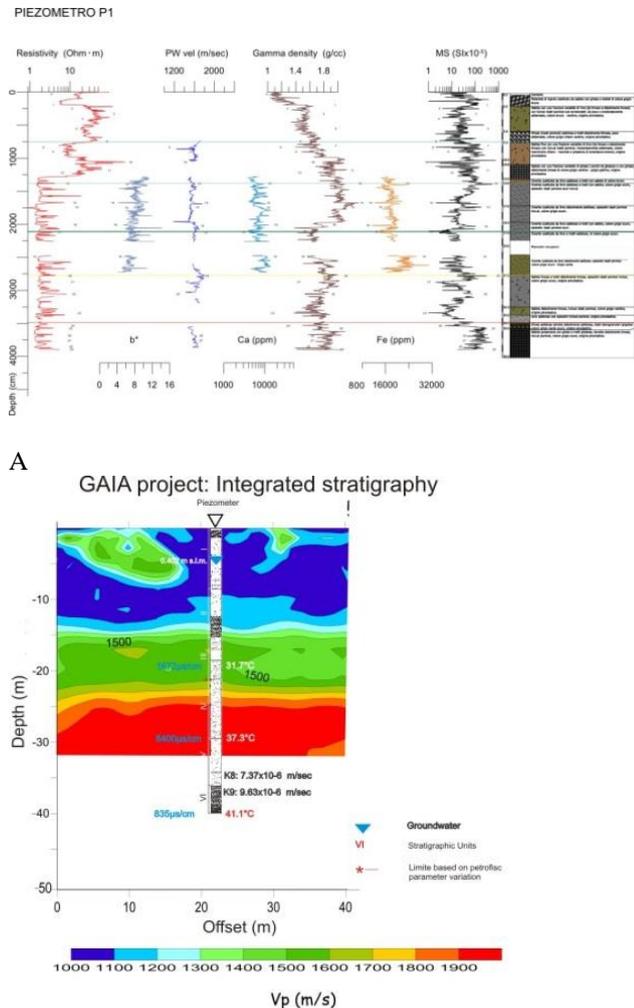


Fig. 9. The Vertical offset versus depth in FC-08 borehole, as inferred from the depth difference of all the homologous piercing points identified by HRPP correlation. Offset values, distinguished according to the measured physical property, shown a staircase pattern which was interpreted as due to two events of displacement able to produce a vertical separation at the surface of about 30-40 cm each. (From [5])

D. Geothermal exploitation

In the frame of the Gaia PON project (founded by the Italian Minister of Development and Economy aimed to test a new prototype of modular heat exchanger) a geothermal potential evaluation of a chosen sector of Phlegraean Fields was required. In order to achieve such goal a high resolution stratigraphic model (Fig. 10 B) of the geothermal reservoir was built combining HRPP correlation of three piezometers with sedimentological,

electrical resistivity tomography (ERT), seismic tomography and physical-chemical water analysis.



B
 Fig. 10 – A) HRPP correlation of Electrical Resistivity, Pwave velocity, Gamma Ray Density, Magnetic Susceptibility, Colour reflectance (b^*), Ca and Fe content for piezometr P1. B) A chosen sector of the geothermal reservoir showing temperature and electrical conductivity of the groundwater and lithostratigraphic units as obtained from the piezometer correlated by mean of HRPP to the underground Pwave velocity layer distributions (Colour scale at the bottom).

IV. DISCUSSION AND CONCLUSION

The multidisciplinary case studies here presented, represent, for HRPP correlations, only few examples of larger applications that can be made in geological research.

In fact it is possible to hypothesize that HRPP

correlations may represent a powerful tool wherever the trend and age of sedimentary layers reconstruction are important, as for example, in archeological or environmental pollution studies.

However there are some crucial points respect to the application of the HRPP correlations method, in fact if it is true that the MSCL Petrophysical measurements are non-destructive and quickly obtained, the data processing is time consuming and with some uncertainty linked to human analysis. For this reason the HRPP correlations need to be always integrated with sedimentological analysis and where it is possible to be combined with geophysical survey. Finally it is suggested that, in case of petrophysical signals not characterized by distinguishable patterns, the HRPP correlation process could be performed with cross correlation software support (i.e. [8]).

Future work will be aimed to investigate among marine sediment petrophysical properties that one, fully or partially, driven by global events (i.e. climatic change) in order to build, over wide marine areas, referring curves that can be used as relative dating tools.

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