Anisotropy of magnetic susceptibility (AMS): an objective method to define provenance flow directions in turbiditic systems (Apennines, Italy)

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The IAS Postgraduate Grant was used to cover field activity and data acquisition expenses. Nearly 920 samples were collected in the field, 900 core samples for paleomagnetic analyses, and 20 larger samples from which thin-sections have been obtained for microscopic observations and image analyses.
The sampling was conducted in different areas of the Northern Apennines (Italy) during 4 field expeditions.
The two basins studied until now are the Marnoso Arenacea Formation (Ricci Lucchi et Ori, 1985) from Emilia Romagna (Fig.1 – A), and the Castagnola Formation (Stocchi et al., 1992) from the Piedmont Tertiary Basin (Fig.1 – B).
The aim of this project is to apply the Anisotropy of Magnetic Susceptibility (AMS), in concert with classic sedimentological analyses, to define provenance flow direction in these well-exposed Oligo-Miocene turbiditic systems.

Fig.1: studied areas

Deep-water turbiditic systems are volumetrically the most important accumulations of sand in deep sea and represent one of the frontier areas for hydrocarbon exploration and exploitation. Recent advances in field-based facies analysis have shown that turbiditic systems are characterized by a great variability in terms of size, geometry, facies, and stacking patterns. This variability is the result of the interplay between several factors, such as sea-level change, local and regional tectonic settings, basin size and shape, sediment type and frequency of depositional events, and volume of gravity flows. The evaluation of paleocurrent directions within turbiditic systems is essential to construct depositional models at the basin scale.
While much work has been done to predict facies heterogeneities that could be expected in deep-sea deposits, relatively few methods are available to estimate paleocurrent directions. Traditionally, sedimentological current indicators (*ripple marks*, *flute marks*, etc.) are used, but these are not always present in outcrop sections and are virtually absent from drill cores. This limitation raises the need to identify an alternative, objective method to define paleocurrent directions in turbiditic successions.
The integration of experimental (AMS) data and classic sedimentological analyses on selected case studies from the Marnoso Arenacea and Castagnola formations confirmed the existence of a tight correlation between sedimentological current indicators such as flute marks and AMS data. We were also able to determine which sediment composition and texture (grain size and sedimentary structures) work best for the application of the AMS methodology to estimate flow directions in turbiditic systems. Indeed, these new analyses could help to refine the history of sediment provenance (and physical processes involved in sediment dispersal) in these classic turbiditic systems of the Northern Apennines.

Sampling

The Marnoso-Arenacea and Castagnola formations have been systematically sampled in different depositional intervals (e.g. massive, parallel-laminated, cross-laminated intervals) on vertical and horizontal logs, in order to study the behavior of the magnetic signal in time and space. The samples for paleomagnetic analyses have been collected with a water-cooled rock drill and oriented using a magnetic compass.

Laboratory analyses

Sedimentological analyses

Oriented thin sections have been cut parallel and perpendicular to provenance flow direction and *optical observations* have been carried out to define textural and mineralogical characteristics of grains parallel or perpendicular to current provenance direction.

Paleomagnetic analyses

Paleomagnetic analyses have been carried out on cylindrical samples with a 2,5 cm diameter and 2,2 cm height (total volume ≈ 10,7 cm^3). These are:

- *AMS*: anisotropy of magnetic susceptibility analyses, using an *Agico KLY-3 Kappa-Bridge* susceptivimeter; with this analysis, the average orientation of magnetic minerals have been studied.
- *AIRM*: anisotropy of isothermal remanent magnetisation analyses, using a *Molspin* Demagnetizer, an *Agico PUM-1* Pulse Magnetizer and an *Agico JR-6* Spinner Magnetometer; this analyses allows to pick out the anisotropy due to ferromagnetic particles in weakly magnetic rocks (Tarling & Hrouda, 1993);
- *IRM*: isothermal remanent magnetization analyses, using an *ASC Scientific IM 10-30* pulse magnetizer, and a *755 2G-Enterprises* cryogenic magnetometer; The IRM allows to define the bulk rock magnetic mineralogy;
- *ThIRM*: thermal demagnetization of IRM analyses, using an *ASC Scientific IM 10-30* pulse magnetizer, a *TD4 ASC* thermal demagnetizer and a *755 2G-Enterprises* cryogenic magnetometer; The ThIRM gives a clearer interpretation of the ferromagnetic mineral content of a rock than the IRM experiments (Lowrie, 1990).
- *NRM*: natural remanent magnetization analyses, using the cryogenic magnetometer already mentioned and a *TD4 ASC* thermal demagnetizer; with this analysis, the paleomagnetic directions of studied units can be determined.

RESULTS

Preliminary result has been recently presented in two international confererences:

- *27th IAS Meeting of Sedimentology* -Alghero, Italy - 20th-23rd September 2009 (Dall'Olio et al., 2009);
- *Deep-water Circulation: Processes & Products* – Baiona, Spain – 16th-18th June 2010 (Dall'Olio et al., 2010).

The study confirms the existence of a tight correlation between provenance direction as indicated by sedimentological structures (e.g., flute marks) and AMS data. The agreement between paleocurrent directions measured in situ from sedimentological indicators and the orientation of the maximum susceptibility axis of the AMS determined in the laboratory is in most of the cases excellent. In several cases, however, a minor offset of 10°–20° between flute marks and AMS directions has been observed (Fig. 2). To explain this divergence, additionalanalyses will be carried out in the near future.

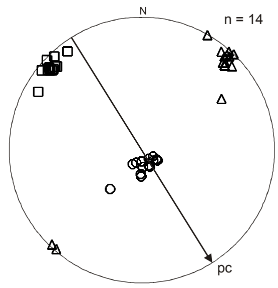

Fig. 2: example of steroplot

REFERENCES

Dall'Olio E., Felletti F., Muttoni G. (2009). *Anisotropy of magnetic susceptibility (AMS): an objective method to define provenance direction of flow in turbiditic systems (Northern Apennines, Italy).* In: 27th IAS Meeting - Abstract book - [s.l.]: EDES, 2009. - ISBN 978-88-6025-123-7, p. 124.

Dall'Olio, E., Felletti, F., & Muttoni, G.. (2010). *Hemipelagites, hemiturbidites or muddy contourites? The contribute of magnetic fabric analysis to discriminate depositional mechanisms in fine-grained sediments (Marnoso Arenacea Fm., Miocene, North Italy)" (Late Oligocene, Italy.).* In: Geo-Temas - Spanish Geological Society (Sociedad Geológica de España, SGE)- ISSN: 1567-5172, vol. 7, pp. 21-22.

Lowrie, W. (1990). *Identification of Ferromagnetic Minerals in a Rock by coercitivity and unblocking temperature properties.* Geophysical research letters, vol. 17, no. 2, pp. 159-162.

Ricci Lucchi, F. & Ori G.G. (1985). *Field excursion D: syn-orogenic deposits of a migrating basin system in the NW Adriatic foreland.*

Stocchi, S., Cavalli, C. & Baruffini, L. (1992). *I depositi torbiditici di Guaso (Pirenei centro meridionali), Gremiasco e Castagnola (settore orientale del BTP): geometria e correlazioni di dettaglio.* Atti Tic. Sci. Terra, 35, pp. 154-177.

Tarling, D.H. & Hrouda , F., 1993. *The Magnetic Anisotropy of Rocks.* Chapman & Hall, London.