

Curriculum Vitae

Leonardo DEL SOLE, Ph.D.

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EDUCATION

Nov 2017–May 2021: **Doctoral degree** (SSD: GEO/03) in Earth, Life and Environmental Sciences, Univ. of Bologna, Italy. Evaluation: “Excellent”. Thesis: “Fracture Networks Development, Fluid Flow, and Diagenetic Processes in Sandstones and Carbonate Rocks”, DOI: [10.6092/unibo/amsdottorato/9678](https://doi.org/10.6092/unibo/amsdottorato/9678). Supervisor Prof M. Antonellini.

Oct 2015–Oct 2017: **Master** in Field and Natural Resources Geology, Univ. of Roma Tre, Italy, graduated cum laude. Thesis: “Tectonic evolution of the Rennick Fault (North Victoria Land, Antarctica) through the analysis of fault-related fractures of analogues: the case of the Val Roveto Fault (Central Apennines, Italy)”. DOI: [10.13140/RG.2.2.35924.88962](https://doi.org/10.13140/RG.2.2.35924.88962). Supervisors Prof F. Salvini, Dr P. Cianfarra.

Sept 2012–July 2015: **Bachelor** in Geological Sciences, Univ. of Bologna, Italy, graduated cum laude. Thesis: “Description of fluid flow and deformation sequence in the Monte Venere Formation (Northern Apennines, Italy)”. DOI: [10.13140/RG.2.2.27403.62246](https://doi.org/10.13140/RG.2.2.27403.62246). Supervisor Prof M. Antonellini.

PROFESSIONAL EXPERIENCE (*attività di formazione/ricerca presso qualificati istituti italiani/stranieri*)

July 2023–present: **Postdoctoral Researcher** at the Univ. of Bologna, Italy. Project: "PRIN 2020: FAST- Fault Architecture in Space and Time"; PI: Prof G. Viola.

Sept 2021–June 2023: **Postdoctoral Researcher** at the Univ. of Camerino and Istituto Nazionale di Geofisica e Vulcanologia (INGV), Italy. Project: Seismic vs aseismic slip in carbonate-hosted upper-crustal faults. Advisors Prof S. Mazzoli, Prof E. Tondi.

April 2021: **Technical collaborator**. Responsibilities: Collection of physical and water quality parameters for the monitoring of water points along the *Valle Isarco* (South Tyrol, Italy), in the project area related to the quadrupling of the railway line Fortezza – Verona.

April 2019–July 2019: **Internship** at the Univ. of Montpellier, Geosciences Montpellier, France. Project: Diagenesis of deformation bands in porous sandstones. Achieved during the PhD. Advisors Prof R. Soliva, Dr G. Ballas.

Curricular internship (75 hrs) at the GeoQuTe Lab (Univ. of Roma Tre, Italy). Responsibilities: Analysis of structural data collected in North Victoria Land (Antarctica), with focus on the inversion of fault kinematic data to infer the paleo-stress field responsible for the observed deformation. Achieved during the M.S (2016-17). Supervisor Prof F. Salvini.

Curricular internship (96 hrs) at the ISMAR-CNR, Bologna, Italy. Responsibilities: Analysis and interpretation of magnetic susceptibility data of core samples and seismic reflection profiles. Achieved during the B.S (2014-15). Supervisors Dr A. Polonia, Dr L. Gasperini.

RESEARCH INTERESTS

My general topics of interest include Structural Geology & Tectonics:

- **Fault zone analysis:** Strain localisation, fabric development and deformation mechanisms in brittle shear systems; Fracture networks characterization; Petrophysical properties and Fault zone hydrogeology.
- **Fluid / fault interaction** and **Structural diagenesis:** Interaction between deformation, fluid flow, and diagenesis.
- **Rock mechanics:** Rock geomechanical properties; Mechanics of faulting and earthquakes

PUBLICATION LIST (*acting as corresponding author)

Published papers (Peer reviewed journal articles):

Del Sole, L.*, Mazzoli, S., Carafa, M.M.C., Toffol, G., Pennacchioni, G., Giuli, G., Invernizzi, C., Tondi, E. (2024). Interseismic creep of seismogenic carbonate-hosted normal faults: Insights from Central Italy, *GSA*

Bulletin, <https://doi.org/10.1130/B36954.1>.

Basilici, M., Pedini, M., Spinaci, A., **Del Sole, L.**, Jablonskà, D., Capotorti, F., Mazzoli, S., Pierantoni, P.P. (2023). Geological map, balanced and restored cross-sections, and 3D geological model of the Monte Fema area, Umbria-Marche Apennines (Italy), *Italian Journal of Geosciences*, 142(3), 339-358, <https://doi.org/10.3301/IJG.2023.22>.

Del Sole, L.*, Antonellini, M., Soliva, R., Ballas, G., Balsamo, F., Viola, G. (2020). Structural control on fluid flow and shallow diagenesis: insights from calcite cementation along deformation bands in porous sandstones, *Solid Earth*, 11(6), 2169-2195, <https://doi.org/10.5194/se-11-2169-2020>.

Del Sole, L.*, Antonellini, M., Calafato, A. (2020). Characterization of sub-seismic resolution structural diagenetic heterogeneities in porous sandstones: Combining Ground-Penetrating Radar profiles with geomechanical and petrophysical *in situ* measurements (Northern Apennines, Italy). *Marine and Petroleum Geology*, 117, 104375. <https://doi.org/10.1016/j.marpetgeo.2020.104375>.

Antonellini, M., **Del Sole, L.**, Mollema, P.N. (2020). Chert nodules in pelagic limestones as paleo-stress indicators: a 3D geomechanical analysis. *Journal of Structural Geology*, 132, 103979. <https://doi.org/10.1016/j.jsg.2020.103979>.

Del Sole, L.*, Antonellini, M. (2019). Microstructural, petrophysical, and mechanical properties of compactive shear bands associated to calcite cement concretions in arkose sandstone. *Journal of Structural Geology*, 126, 51-68. <https://doi.org/10.1016/j.jsg.2019.05.007>.

Antonellini, M., Mollema, P.N., **Del Sole, L.** (2018). Reply to Comment by Trincherò et al. on “Application of analytical diffusion models to outcrop observations: Implications for mass transport by fluid flow through fractures”. *Water Resources Research*, 54(11), 9706-9707. <https://doi.org/10.1029/2018WR023312>.

Antonellini, M., Mollema, P.N., **Del Sole, L.** (2017). Application of analytical diffusion models to outcrop observations: Implications for mass transport by fluid flow through fractures. *Water Resources Research*, 53(7), 5545-5566. <https://doi.org/10.1002/2016WR019864>.

Papers under review:

Del Sole, L.*, Viola, G., Aldega, L., Moretto, V., Curzi, M., Xie, R., Cantelli, L., Vignaroli, G. Ultra-high-resolution investigations of fault evolution in space and time.

Papers in preparation:

Del Sole, L.*, Mazzoli, S., Gasparrini, M., Cenani, A., Giuli, G., Invernizzi, C., Tondi, E. Fluid-assisted faulting and hydrothermal mineralization under greenschist facies. (*title and author list not finalized*).

Napoleoni, S., Antonellini, M., **Del Sole, L.** From outcrop-mapped structural and diagenetic heterogeneities to a 3D numerical flow model: a workflow for a sandstone aquifer. (*title and author list not finalized*).

Contributions to volume:

Del Sole, L.*, Antonellini, M. 2020. Compactive shear bands. In: Mukherjee, S. (Ed) Atlas of Structural Geology. 2nd Edition. Elsevier, pp. 115–118. ISBN: 978-0-12-816802-8. <https://doi.org/10.1016/B978-0-12-816802-8.09995-9>.

CONFERENCE ABSTRACTS (relatore a congressi e convegni nazionali e internazionali)

Moretto, V., **Del Sole, L.**, Curzi, M., Dallai, L., Vignaroli, G., Viola, Aldega, L. (2024, April). Time-space evolution of synkinematic clay minerals in the Carboneras fault zone traced by X-ray diffraction, H and O isotopes, and K-Ar dating. BASIS Annual Meeting 2024, Amsterdam, the Netherlands, 25-26 April 2024, P10. [poster]

Del Sole L., Vignaroli, G., Moretto, V., Curzi, M., Aldega, L., van der Lelij, R., Viola, G. (2024, April) A reappraisal of the Carboneras Fault (SE Spain) from new structural, geochronological and thermal constraints. EGU General Assembly 2024, Vienna, Austria, 14-19 April 2024, EGU24-4381 [oral].

Moretto, V., **Del Sole, L.**, Curzi, M., Dallai, L., Vignaroli, G., Viola, G., Balsamo, F., Berio, L.R., Grathoff, G., Warr, L.N., Aldega, L. (2024, April). Tracing the origin of parental fluids and paleo-temperature distribution in fault zones: case studies from the Carboneras Fault (Spain) and Lemnos Island (Greece). EGU General Assembly 2024, Vienna, Austria, 14-19 April 2024, EGU24-11036.

Moretto, V., Viola, G., Vignaroli, G., Curzi, M., **Del Sole, L.**, Dallai, L., Aldega, L. (2023, Sept). The origin of neoformed clay minerals in fault zones: an example from the Carboneras Fault, Betic Cordilleras, Spain. SIMP-SGI-SOGEI-AIV Joint Congress “The Geoscience paradigm”, Potenza, Italy, Sept. 19-21, p 907.

Del Sole, L., Mazzoli, S., Carafa, M.M.C., Giuli, G., Invernizzi, C., Tondi, E. (2022, Dec). Interseismic locking

vs. aseismic slip of carbonate-hosted normal faults: Insights from the northern Apennines, Italy. AGU Fall Meeting 2022, Chicago IL, USA, 12-16 Dec. 2022, ID: 1163242 [oral].

Napoleoni, S., **Del Sole, L.**, Antonellini, M. (2022, Sept). From outcrop-mapped structural and diagenetic heterogeneities to a 3D numerical flow model: a workflow for a sandstone aquifer. SGI-SIMP Congress "Geosciences for a sustainable future", Torino, Italy, 19-21 Sept. 2022, p 1053 [poster].

Del Sole, L., Calafato, A., Antonellini, M. (2020, May). Combining Ground-Penetrating Radar profiles with geomechanical and petrophysical in situ measurements to characterize sub-seismic resolution structural and diagenetic heterogeneities in porous sandstones (Northern Apennines, Italy). EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-3118 [poster].

Del Sole, L., Antonellini, M. (2019, April). Strengthening effect of compactive shear bands and associated carbonate nodules in arkose sandstone: a natural analog of composite multilayer. EGU General Assembly 2019, Vienna, Austria, 7-12 April 2019, EGU2019-6134 [poster].

Del Sole, L., Antonellini, M. (2018, Sept). Calcite-cement precipitation mediated by cataclastic shear bands in arkosic sand: petrophysical and mechanical considerations (abs.): SGI-SIMP Congress "Geosciences for the environment, natural hazards and cultural heritage", Catania, Italy, 12-14 Sept. 2018, p 165 [oral].

AWARDS and BURSARIES (*premi e riconoscimenti nazionali e internazionali per attività di ricerca*)

2020 "Stephen E. Laubach Structural Diagenesis Research Award" (\$4,000.00) awarded from the Geological Society of America (GSA). <https://community.geosociety.org/sedimentarygeologydiv/awards/laubach>.

"MARCO POLO Program" Student Support scholarship (€3,450.00) from the Alma Mater Studiorum – University of Bologna for abroad research period (Geosciences Montpellier, France, April–July 2019).

TEACHING EXPERIENCE (*supporto attività didattica*)

Ongoing - Co-supervisor of the MSc thesis of Alessandra Cenani (Univ. of Camerino)

2022-2024 Involved in the PhD project of Sabrina Napoleoni (Univ. of Bologna)

2023 Involved in the BSc thesis of Tommaso Sanguettoli (Univ. of Bologna)

2023 Teaching assistant for practicals for MSc students, structural geology field camp: **32 hrs** (Univ. of Camerino)

2022 Teaching assistant for practicals for BSc students, structural geology field camp: **16 hrs** (Univ. of Camerino)

2021 Teaching assistant for practicals for MSc students, structural geology field camp: **32 hrs** (Univ. of Camerino)

REVIEWER ACTIVITY (<https://www.webofscience.com/wos/op/peer-reviews/summary>)

Reviewer for **scientific journals**:

Journal of Structural Geology; Tectonophysics; Marine and Petroleum Geology; Journal of Petroleum Science and Engineering; Rendiconti Online SGI.

Reviewer for **grant proposals**:

- National Science Center, Poland (NCN). Review Panel: ST10 (Earth science). Funding scheme: PRELUDIUM-22. Evaluation No. 1483238. Date of Completion: 2023-09-28.

CONVERER ACTIVITY (*convener a congressi e convegni nazionali e internazionali*)

- Co-convener of the session TS1.2: "Deformation, Fluid Flow and Diagenetic Processes involving Layered Rocks and Granular Media in the Shallow Crust" at the EGU General Assembly 2024, 14-19 April 2024, Vienna, Austria, <https://meetingorganizer.copernicus.org/EGU24/session/48657>

- Session proposal: "Interplay between Deformation, Fluid Flow and Fluid-Rock Interactions in Sedimentary Rocks: Implications for Seismicity, Basin Analysis and Reservoir Characterization" at the SGI-SIMP Joint Congress "Geology for a sustainable management of our planet", 3-5 September 2024, Bari, Italy.

- Session proposal: "Upscaling of geometric, petrophysical and mechanical properties of sub-seismic-resolution structures through Discrete Fracture Network (DFN) models" at the EGU General Assembly 2020. Proponents: Ceccato, A., Zuluaga, L.F., **Del Sole, L.** <https://meetingorganizer.copernicus.org/EGU2020/session/34948>. The session was withdrawn due to a merge with another session.

ACADEMIC RESPONSABILITIES

2023 Postdocs' representative for the School Council (Univ. of Camerino)

2013-2014 BSc students' representative for the Department Council and Degree Course Council (Univ. of Bologna)

ADVANCED COURSES

- Sixth EGU Summer School on "Structural Analysis of Crystalline Rocks" Nevessee area, South Tyrol, Italy, 21-28 August 2023 [16hrs fieldwork + 22 hrs lecture] <https://servizi.geoscienze.unipd.it/egu-summerschool-2023/index.html>

- Short course "Microtectonics of fault rocks" held by Prof R Heilbronner (Univ of Basel, Switzerland), at the Univ. of Torino, Italy, 12-13 Jan 2023 [16hrs lecture]

- Training REDI - REducing risks of Natural Disasters - co-organized by UNICAM, INGV, INFN and GSSI, at the Univ. of Camerino, Italy, 26-30 Sept 2022 [20 hrs lectures + practicals]

- Online short course "Introduction to fluid inclusion studies in sedimentary basins" held by Dr M Gasparini (Univ Milan, Italy), 23-25 Feb 2022 [12hrs lecture]

- Workshop "3D Photogrammetry and virtual outcrop models of geological structures" organized by Soc Geol Ita, co-held by Prof S Tavani (Univ of Naples Federico II - CNR), Dr A Corradetti (Univ of Trieste), Dr M Mercuri (Sapienza Univ of Rome) at the Sapienza, Italy, 31 Jan – 2 Feb 2022 [16hrs practice + lecture]

- Summer School "The role of the geoscientist in the energy transition" co-organized by UNICAM (Italy), UPPA (France), Sapienza (Italy), and RE&E, at the Univ. of Camerino, Italy, 20-24 Sept 2021 [34hrs lecture]

- Online short course on "Seal bypass structures using 3D and 4D seismic data" held by Prof D. Iacopini (Univ. of Naples Federico II, Italy), 14-16 May 2020 [12hrs lecture]

- Online short course on "The structure and growth of fault zones" held by Dr G. Camanni (Univ. of Naples Federico II, Italy), 11-13 May 2020 [12hrs lecture]

- Short Course on "Selling Science to politicians and publics - communicating technical science to non-technical audiences" held by Prof I. Stewart (Plymouth Univ., UK) at the Univ of Bologna, Italy, 25 Feb 2019 [6hrs lecture]

- Short Course on "Thermometry, chronometry, barometry and fluid geochemistry in sedimentary basins" held by Dr M. Gasparini (IFPEN, France) at the Univ. of Rome Tre, Italy, 17-21 Sept 2018 [27hrs lecture]

- "Statistics: theory and application (R software)" held by Dr A. Boattini, Dr A. Lucchetti (UniBo, Italy), 25-29 June 2018 [30hrs lecture and exercise + final exam]

- Volcanology PhD field course: Campi Flegrei and Vesuvio (Italy)" held by Dr F. Lucchi (UniBo, Italy), 9-11 May 2018 [3 days field-trip]

- Short course "Subduction: Dynamics and Tectonics" held by Prof L. Royden (MIT, US), January 19-20, 2017, Univ of Roma Tre, Italy [16hrs lecture]

- VIII Volcanology School - AIV, 7-12 Dec 2015, Bolsena, Italy [15hrs lecture, 20hrs fieldwork].

MEMBERSHIP IN PROFESSIONAL ORGANIZATIONS

European Geoscience Union (EGU) 2019 – present

Società Geologica Italiana (SGI) 2019 – present

Geological Society of America (GSA) 2023 – 2024

TECHNICAL SKILLS

Computational knowledge O.S.: MacOS, Windows.

Business Software: Microsoft Office package, LaTeX (basic knowledge), etc.

Graphic and SFM Software: Inkscape, Adobe Illustrator; Agisoft Metashape, Cloud Compare.

Scientific Software: QGIS, Stereonet/FaultKin, Daisy3, ImageJ/Fiji, MTEX; basic knowledge: MATLAB, R, MODFLOW/ModelMuse.

OTHER INFORMATION

UAS Remote Pilot Open Category - A1+A3. Issued by the European Union Aviation Safety Agency (EASA) and the

Direction de l'Aviation Civile (DAC) – Grand Duché de Luxembourg [Issued Aug 2022 – Expire Aug 2027].

Languages: Italian (native tongue), English (proficient user), Spanish (excellent knowledge).

International Driving Permit: A2; A; B.

Bologna, May 2024