General description

Along the period under evaluation, GeoBioTec comprises 5 research groups: Complex Environmental Systems; Basin Analysis and Paleontology; Agro-industrial; Lithospheric Evolution; and 3G - Georesources, Geotechnics and Geomaterials, at 3 poles AVEIRO, NOVA and UBI. GEOBIOTEC is one of the best equipped national Unit for research in earth sciences, with several specialized facilities: X-ray Difraction (XRD), 2 X-ray Fluorescence Spectrometer (XRF), TIMS mass spectrometer, Inductively coupled plasma mass spectrometry (ICP-MS), Gas chromatography/mass spectrometry (GC/MS), 2 scanning electron microscope and energy-dispersive X-ray spectroscopy (SEM/EDS), 2 Gas chromatography, 2 Atomic absorption spectrometer (AAS), elemental analyzer (CHNS), X-ray micro-grainsize analyzer (Sedigraph), Geo-materials characterization (several viscosimeters, abrasivimeter), Agrofood (and Geo) materials characterization (texturometer) as well as equipments for Cation Exchange Capacity, Plasticity, Expandability, Specific Surface Area) and others for field geosurvey (UAV DJI Phantom 4 Pro+ drone), geophysical (electric, magnetic, seismic, georadar) survey, geomechanics/geotechnics, hydrology/hydraulic, rheological and textural properties. We also own 3 4wd vehicles and several diversified equipment.

Particular attention has been given to the characterization and management of resources and guarantee supply of raw materials, coordinated with territorial planning, seeking a reduction in environmental liabilities through a more rational exploration and mining. The emergence of new geomaterials, as well as more diversified applications and eco-efficiency, are fields of opportunities to develop. Our focus is on Geo-Resources and Geo-Environment, taking advantage of our skills and resources on industrial minerals, geostatistics, geochemistry, geophysics, mineralogy, medical geology and geomaterials and strengthens fundamental geological disciplines such as sedimentology, stratigraphy, structural geology, petrology, isotope geology. We are fully committed to the new trends of research and exploitation of raw materials: Sustainable exploitation; Remining; Reuse; Recycling, putting particular emphasis on development of new materials and/or new applications for traditional materials; Medical Geology (Bio and Geo availability, Dust mineralogy and geochemistry, Healing minerals, Waste Waters), Radiogenic Isotope Geology (isotope signature/provenience), new Georesources and Geomaterials (Geopolymers, Marine Resources, Secondary Raw Materials), Soil Sciences (Mineral improved chain food production), Environmental Geophysics and Geochemistry (risk assessment, climatic changes, geochemical groundwater modeling), Geotechnics (soil stability and integrated water management, mobility, transport, construction geomaterials and built heritage) and Geotourism and Geoheritage. Collaboration has been promoted and incremented with food industry stakeholders playing a vital role in advancing scientific knowledge, driving innovation, and promoting the transfer of technology, which are undoubtedly primary objectives. Special research focus is the interactions in Earth's surface systems, i.e., Geo-Bio-analysis of Soil, Water, and Air integrated into Ecological, Societal, and Health, aiming sustainable resource management and environmental impacts obtaining high-quality and innovative results in applied (hydro)geochemistry. Running the unique TIMS in Portugal, applications of Sr and Nd radiogenic isotope analyses were applied to a significant variety of subjects, which included not only those already mentioned, but also others like archaeology, hydrogeochemistry, stratigraphy, characterization of wines.

Identification and brief description of up to 5 contributions the the R&D Unit considers to be the most important during 2018-2023.

1) Topics related to Sustainable Supply and Consumption, through the life cycle of Sustainable Mining (Green Mining and Urban Mining) of primary raw materials (SDGs 12 and 15), environmental and medical geology studies, particularly in urban environments (SDG 11), and climate change and its interactions with geoenvironments (SDG 13). Fundamental and applied research aiming to transform fine rejects into raw material; the rejects essentially alumino-silicate materials, allow the development of 3 product lines: Silica, for the ceramic and glass industries; Alumino-silicate, feldspathic and clayey white pastes for the white ceramic industry; Geopolymers, alumino-silicate materials (with high Si content), with new but growing application in industry (potential cement substitutes). This is being done within several projects (such as GEOSULF ERA-MIN project and the project New Generation Storage - NGS, REF[a] C644936001-00000045, financing under Invitation Notice no. 02/C05-i01/2022 regarding the development of projects within the scope of the Mobilizing Agendas for Business Innovation, framed and financed within the scope of component no. 5 - Capitalization and Business Innovation of the Business Plan Recovery and Resilience of Portugal), resulting several papers (such as, DOI: 10.3390/su11040995; 10.1016/j.clay.2016.03.009; 10.1016/j.matdes.2013.05.058), 2 PhDs are underway and 3 MSC have been completed. Mineral resources for geomedicine and geopharmacy applications, focused on development of new applications and new products, putting forward formulations of clays/organoclays to be used on dermocosmetics and drugs. Innovative research in the field of pelotherapy and iontophoresis integration to optimize the utilization of peloids in therapeutic application, such as: assessment of long-term safety and efficacy of peloid treatments; impact of different peloid formulations (mineral-medicinal waters/clay compositions and emollients formulations affect the chemical characteristics and transport properties of peloids); interaction between specific skin conditions and peloid therapy; effectiveness of peloid therapy for specific therapeutic indications (musculoskeletal disorders, dermatological conditions, or wound healing); clinical trials and randomized controlled trials. Several papers have been published, and 3 PhD and 6 MSc thesis have been concluded. Special attention has been put on development of innovative delivery methods for pelotherapy and iontophoresis integration with research focused on the design and optimization of electronic devices specially tailored for pelotherapy, incorporating the features of controlled heating, precise current delivery, and real-time monitoring of skin response. These innovative delivery methods and optimizide treatment protocols enhanced the therapeutic potential, opening new possibilities for the treatment of various conditions and improving patient care. Two industrial prototypes were developed, two trade-marks are registered and a patent is underway.

2) Leading Estarreja International Human-Environment Observatory (OHMi), supported by CNRS, resulted in several publications, such as the paper https://doi.org/10.1002/wat2.1703. Participation in the BARGE Group allowed the implementation of UBM-gastric and lung bioaccessibility methods, particularly through fostering direct collaboration and joining student supervision (https://doi.org/10.1016/j.envres.2021.111988). Our researchers have been devoted to water quality assessment studies, aligned with EU legislation, and have improved the criteria for water body classification in Portugal (report published on the CIRCABC page). R&D in fire ecohydrology has further deepened our understanding of runoff generation and soil (fertility) losses in burnt forest areas and their mitigation by combining high-resolution field measurements and mathematical modeling (https://doi.org/10.1016/j.scitotenv.2023.163825). The link to environmental health research allowed the participation in the International Medical Geology

Association (IMGA), a research network bringing together the combined expertise of geologists, environmental scientists, toxicologists, epidemiologists, medical specialists, to characterize the geological processes, agents, and geomaterials in human health either benefits or harmful effects.

3) Within the scope of 6 PDR 2020 Projects (in collaboration with near 25 industrial companies), 6 Innovative Technical Itineraries to produce biofortified foods enriched in Ca, Fe, Mg, Se, and Zn have been developed. The Technical Reports meanwhile published and available to farmers, allowed the mitigation of deficiencies in various elements important to human diet. Regarding the Project CFD4CHEESE ALT20-03-01-0145-FEDER 023356, it was possible to strengthen the technological development and innovation between the academy and the traditional cheese industry(https://www.iniav.pt/images/publicacoes/2020/AplicacaomecanicafluidosLivro_CFD4.pdf). Also, two plant-based food supplements were developed in a business context to help prevent diseases of the urinary system (in the scope of a Master Thesis), which get sale approval by the Directorate General for Food and Veterinary (https://biotop.pt/produto/vitalenzym-ur-feminino/) (https://biotop.pt/produto/vitalenzym-ur-masculino/). The Project "BreedCafs – BREEDing coffee for agroforestry systems" (2017-2021) encompasses 17 participants and 8 countries with a total funding of approximately 4 M€. https://cordis.europa.eu/project/rcn/210503/factsheet/en. The technology transfer for clonal propagation, the promotion of direct trading between roasters and farmers, and the promotion of new hybrids adapted to Agroforestry Systems was the main achievement.

4) Topics related to Earth Evolution and GeoHistory, reconstructing the pre–Variscan puzzle of Ediacaran and Cambro–Ordovician basement rocks in the Iberian massif and its positioning within the global geodynamics of the Archean to Neoproterozoic times. Mesozoic Vertebrate Paleontology, especially the evolution and taxonomy of reptiles from the Lusitanian basin and other regions of the globe, different taxonomic groups and geological ages. Advances were made in the understanding of the taxonomy, evolution and paleobiology of pterosaurs of Angola, Brazil and Portugal, dinosaurs from Portugal and Spain, plesiosaurs of Angola and Portugal, Mesozoic crocodylomorphs from Portugal and turtles. Highlight can be given to the recognition that Neanderthal humans were fisher-hunter-gatherers and the study of small fauna associated with Neanderthals. Cenozoic mammals received special attention, such as the Eocene Sirenian in Spain, small mammals of Romenia and Quaternary hippopotamid from Europe and Eritrea. A new subject, recent volcanism in Morocco, started with post-graduate internships of Moroccan collegues, with focus shifted from an essentially volcanological/geomorphological approach to a broader perspective with a very strong component of petrography, mineralogy and geochemistry, allowing discussion of recent processes in the mantle under northern Morocco, which may be relevant not only regarding general knowledge, but also in regional terms, due to the proximity between Morocco and the Iberian Peninsula.

5) Soil stabilization studies and development of waste-based coatings, to assess change in physical, chemical and geomechanical characteristics of residual soils after the use of water treatment waste, plant biomass ash, blast furnace slag and fines of quarry. The results led to find mixtures allowing their use without significantly changing the mechanical properties of soils. Assessment of the hydromechanical performance associated with compaction techniques in residual soil landfills and modeling of their long-term geomechanical behavior. Modeling of geohydraulic systems, which allowed evaluating the variation in the physical and chemical characteristics of groundwater, and assessing its potential for medicinal applications and the production of geothermal energy.

Main publication in 2018-2023 by integrated PhD holder Researchers registered in the application.

1. Costa, C.; Cerqueira, Â.; Rocha, F.; Velosa, A. The Sustainability of Adobe Construction: Past to Future. *Int. J. Archit. Herit.* 2019, 13, 639–647. DOI10.1080/15583058.2018.1459954.
2. H. Paiva, J. Yliniemi, M. Illikainen, F. Rocha, V. Ferreira, Mine tailings geopolymers as a waste management solution for a more sustainable habitat. *Sustainability* 11 (2019) 995, https://doi.org/10.3390/su11040995.
3. Candeias C, Vicente E, Tomé M, Rocha F, Ávila P, Célia A (2020). Geochemical, mineralogical and morphological characterisation of road dust and associated health risks. *Int J Environ Res Public Health* 17:1563. https://doi.org/10.3390/ijerph17051563.
4. Bastos CM, Rocha F, Patinha C, Marinho-Reis P (2023) Bioaccessibility by perspiration uptake of minerals from two different sulfurous peloids. *Environ Geochem Health* 45:6621–6641. https://doi.org/10.1007/s10653-023-01639-z.
5. Silva M., Reboredo F., Lidon F. (2022) Food colour additives: A synoptical overview on chemical properties, applications in food products and health side effects. *FOODS*, 11, 379 https://doi.org/10.3390/foods11030379
6. Reboredo F., Barbosa A., Silva M., Carvalho M., Santos JP, Pessoa MF, Lidon F, Ramalho JC, Guerra M (2020) Mineral content of food supplements of plant origin, by energy dispersive X-ray fluorescence. A risk assessment. *Exposure and Health* 12: 917-927 https://doi.org/10.1007/s12403-020-00354-9
7. Lidon F et al. (2018) Selenium biofortification of rice grains and implications in the nutritional quality. *J. Cereal Sci.* 81: 22-29. https://doi.org/10.1016/j.jcs.2018.03.010
8. Amaral, J.L, Mata, J. Santos, J.F. (2022). The Carboniferous shoshonitic (s.l.) gabbro-monzonitic stocks of Veiros and Vale de Maceira, Ossa-Morena Zone (SW Iberian Massif): Evidence for diverse subduction-related lithospheric metasomatism. *Geochemistry*, 82, 125917, 29 pp. https://doi.org/10.1016/j.chemer.2022.125917
9. Martins, F., Azevedo, M.R., Valle Aguado, B., Gomes, M.E.P., Tassinari, C., Nogueira Neto, J.A. (2020). SHRIMP U-Pb Ages and REE Patterns for Zircon from an Anatectic Variscan Two-Mica Granite from the Bemposta Migmatite Complex (Central Iberian Zone). *Canadian Mineralogist*, 58(6), 847-861. https://doi.org/10.3749/canmin.2000015
10. Moghadam, H.S., Griffin, W.L., Santos, J.F., Chen, R.-X., Karsli, O., Lucci, F., Sepidbar, F., O'Reilly, S.Y. (2022). Geochronology, geochemistry and petrology of the Oligocene magmatism in SE segment of the UDMB, Iran. *Lithos*, 416-417, article 106644, 15 pp. https://doi.org/10.1016/j.lithos.2022.106644
11. Zilhão, J., Angelucci, D. E., Araújo Igreja, M., Arnold, L. J., Badal, E., Callapez, P., Cardoso, J. L., d'Errico, F., Daura, J., Demuro, M., Deschamps, M., Dupont, C., Gabriel, S., Hoffmann, D. L., Legoinha, P., Matias, H., Monge Soares, A. M., Nabais, M., Portela, P., … Souto, P. (2020). Last Interglacial Iberian Neandertals as fisher-hunter-gatherers. *Science*, 367(6485). https://doi.org/10.1126/SCIENCE.AAZ7943
12. Beccari, V., Pinheiro, F. L., Nunes, I., Anelli, L. E., Mateus, O., & Costa, F. R. (2021). Osteology of an exceptionally well-preserved tapejarid skeleton from Brazil: Revealing the anatomy of a curious pterodactyloid clade. *PLoS ONE*, 16(8 August). https://doi.org/10.1371/JOURNAL.PONE.0254789

13. Mennecart, B., Dziomber, L., Aiglstorfer, M., Bibi, F., DeMiguel, D., Fujita, M., Kubo, M. O., Laurens, F., Meng, J., Métais, G., Müller, B., Ríos, M., Rössner, G. E., Sánchez, I. M., Schulz, G., Wang, S., & Costeur, L. (2022). Ruminant inner ear shape records 35 million years of neutral evolution. *Nature Communications* 2022 13:1, 13(1), 1–11. https://doi.org/10.1038/s41467-022-34656-0
14. Bourliva, A.; Aidona, E.; Papadopoulou, L.; Ferreira da Silva, E.; Patinha, C., 2021. Levels, oral bioaccessibility and health risk of sand-bound potentially harmful elements (PHEs) in public playgrounds: exploring magnetic properties as a pollution proxy. *Environmental Pollution* 290, 118122. https://doi.org/10.1016/j.envpol.2021.118122
15. Feio, M.J., Serra, S.R.Q., Mortágua, A., Bouchez, A., Rimet, F., Vasselon, V., Almeida, S.F.P., 2020. A taxonomy-free approach based on machine learning to assess the quality of rivers with diatoms. *Science of the Total Environment*, 722: 137900. https://doi.org/10.1016/j.scitotenv.2020.137900
16. Prats, A., Serpa, D., Santos, L., Keizer, J.J., 2023. Effects of forest residue mulching on organic matter and nutrient exports after wildfire in North-Central Portugal, *Science of The Total Environment*, 885, 163825. https://doi.org/10.1016/j.scitotenv.2023.163825.
17. Barbosa, S.; Dias, A.; Durão, D.; Grilo, J.; Baptista, G.; Cagiza, J.; Pessanha, S.; Simão, J.; Almeida, J. (2022). Exploring High-Resolution Chemical Distribution Maps of Incompatible and Scarce Metals in a Nepheline Syenite from the Massif of "Serra de Monchique" (Portugal, Iberian Peninsula). *Minerals*, 12, 1178, 20p. https://doi.org/10.3390/min12091178
18. Almeida, S.; Gomes, L.; Oliveira, A.; Carreira, P. (2022). Contributions for the understanding of the São Pedro do Sul (North of Portugal) geohydraulic and thermomineral system: hydrochemistry and stable isotopes studies. *Geosciences*, 12, 84. DOI: 10.3390/geosciences12020084
19. Trota, A.; Ferreira, P.; Gomes, L.; Cabral, J.; Kallberg, P. (2019). Power production estimates from geothermal resources by means of small-size compact climeon heat power converters: Case studies from Portugal (Sete Cidades, Azores and Longroiva spa, mainland). *Energies*, 12 (14), 2838. DOI: 10.3390/en12142838
20. Zeini, H.A.; Al-Jeznawi, D.; Imran, H.; Bernardo, L.; Al-Khafaji, Z.; Ostrowski, K. (2023). Random forest algorithm for the strength prediction of geopolymer stabilized clayey soil. *Sustainability*, 15(2), 1408. DOI: 10.3390/su15021408

Description of other relevant activities carried out in 2018-2023.

New generation of earth-rammed construction, for heritage conservation - The research on alkali-activated materials (essential to find pathways to explore mining wastes and low-grade minerals as to support a research based on production of low-cost materials.) "opened a window" for the field of conservation and restoration of cultural property focused on protection and care of cultural property (tangible cultural heritage), in the areas of ceramics and tiles, painting, sculpture and earth construction, previously just a subsidiary activity (essentially focused on ancient ceramics) and now a paramount one, namely on the development/design of new, more efficient/resilient (inc. seismic) earth-rammed construction as well as new mortars (more compatible), both for heritage conservation. Working with Tomar Polytechnic Institute, Lisbon (CTN), NOVA Lisbon, Granada, CadiAyad Marrakech, Tunis (CERTE) Universities, several papers have been

published, and 1 PhD and 2 MSc thesis have been concluded; 1trade-mark (on mortars) is registered.

Concerning Agro-industry - In the scope of the of the PDR 2020 Projects, several partnerships with national enterprises (ca 25) were established as well as collaborations with international institutions such as the University of Extremadura - Spain, Agricultural University of Plovdiv - Bulgaria, Wageningen University – Netherlands, Nottingham University - UK, Osijek University - Croatia, Norwegian University of Life Sciences – Norway, beyond national Research and University institutions. Six PDR 2020 Projects in the total amount of 1.5M€ funded by the European Agricultural Fund for Rural Development were awarded and in the scope of these Projects, 5 grants were offered to 5 young PhD students. Two PhD Thesis were concluded in this framework, while 3 others are just finishing. Six Innovative Technical Itineraries to produce biofortified foods enriched in Ca, Fe, Mg, Se, and Zn have been developed and the results dispersed by all the stakeholders involved in the Projects. The transfer of technology to the enterprises or useful scientific information's may strength companies to compete in the global world, allowing them to face societal challenges.

Interdisciplinary collaboration for holistic environmental solutions – our researchers participated in/coordinated EU R&D-funded projects (HORIZON-MISS-2023-SOIL-01), as well as projects from FCT (PTDC/CTA-GQU/29185/2017), INTERREG-Europe, FEDER (POCI-01-0145-FEDER-029557), and CNRS (SASI and HYDECO), among others. On the other hand, our staff were actively engaged in scientific and technological services for public and private entities, local, regional and Government. Environmental impact studies and biomonitoring plans were carried out using the expertise in diatoms as bioindicators, particularly for water assessment. Our commitment to knowledge transfer was evident through various initiatives such as papers publications, conferences, field trips, and short courses (Summer Academy and S&T Open Week). These efforts aimed to promote Geobiosciences and disseminate research outcomes to society, emphasizing their relevance for ODS and Earth understanding. In response to the 2022 wildfire crisis, 2 team members contributed to the fire expert panel established by the Portuguese Government, one leading working group C on fire damage and post-fire land and water management strategies.

Continuous development of our post-graduation platform – has been a powerful tool to the increasing participation, as supervisors, of junior PhD staff from all the different Host Institutions. Special attention will be also given to the development of joint PhD courses in Geosciences (namely we reorganized the PhD in Geological Engineering, now running jointly by AVEIRO and NOVA) , as well as to the former Erasmus Mundus M.Sc. course, the 'IMACS - International Master in Advanced Clay Science' (with the universities of Poitiers, Xania, Federal of Rio Grande do Sul, and Ottawa), taking advantage of ERASMUS+ tools. Several PhD theses submitted by national and foreigner students were supervised by our researchers, as well as some post-doctoral projects, mainly from foreign researchers (mainly from Brazil, Iran, Morocco and Tunisia). In 2023, a new doctorate in the area of "Environmental Sustainability and Resilience" has been proposed in the context of the development of research in various areas of earth sciences for the sustainability of cities and communities.

Recognizing the importance of LLL – we offered microcredentials and specialization courses tailored for non-academic professionals to keep them updated, such as the interdisciplinary courses on Soil Science applied to Agronomy, on Mineral Resources for the Ornamental Rocks Industry, and on Mineral Resources for the Ceramic Industry.

Internationalization has also been improved - some groups are clearly international in outlook and approach whereas others seem to have been less so. Geobiotec is already a very active member of several national and international initiatives/networks, such as EIT/KIC Raw-Materials, C4G co-laboratory (EPOS), Portugal Mineral Resources Cluster), all developed having in mind the H2020 and 2030 societal concerns. Four projects developed in the scope of the EIT KIC Raw materials (RM), three already finished and one on going: 2019/2021, OpenYourMine – Educational project at master level dedicated to the mineral resources and sustainability with Grenoble-Alpes University, FCT-NOVA, Wroclaw University and KGHM CUPRUM); 2019/2022, BioLeach – Innovative Bio-treatment of RM, RIS project; 2020/2021, 3DBRIEFCASE. Learning the use of minerals through non-conventional and digital tools; 2023/25: SkiComCu: lifelong learning project, concerning the mining and metallurgy industry of copper. Scientific Expeditions to Portugal, Angola, Wyoming (USA), Aragon (Spain) and Greenland with acquisition of hundreds of vertebrate fossils now on museum collections. Several international projects were runned such as "Gênese e evolução do magmatismo offshore brasileiro (GEMOBRA): o exemplo da Cadeia Vitória-Trindade (CVT)", "CNPq-INCT- 2022 Instituto GeoAtlantico No 58/2022", "Odissey Sensing Project", funded by CRESC Algarve 2020, Portugal 2020 and FEDER, "EXPLOSEA - Exploration of submarine hydrothermal vents and associated mineralizations and geobio-systems", funded by Spanish R+D+I Project CMT2016-75947-R, ReMe-diation in PRIMA-HORIZON 2020, EPOS-SP in H2020-INFRADEV, Geosphere INfrastructures in HORIZON-INFRA-2021-SERV-01, and "Estudo e caracterização dos níveis argilosos do PréSal e análogos" funded by Petrobras.

Services for the industry and knowledge transfer activities - Private and public contracts are common ensuring funding of the centre; there are many valuable knowledge transfer opportunities; relevant support staff is in place and are clearly experienced in providing back-up to collaborative projects. Several contracts with mining, geotechnics and geoenvironmental companies, concerning: Geological mapping and modelling (PROMOGIM; Sifucel; SOLVAY; ALMINA, Lusorecursos), Database and Mine Planning (Lundin Mining; Panasqueira Mines), Geoenvironmental Engineering (AMARSUL; Baía do Tejo; EDP; EGIAMB; GALP; Panasqueira Mines; TRATOLIXO), Slope Stability and Geotechnics (ALMINA; PROMOGIM; SOVENA; TRATOLIXO), acid mine drainage and geochemical mapping (São Domingos and Caveira old mine sites - Cybele-lawgical). INOVSTONE 4.0 – Developing Industry 4.O for Natural Stone, Portugal 2020: LISBOA-01-0247-FEDER-024535, POCI-01-0247-FEDER-024535. Cooperation with ACPMR – Association Cluster Portugal Mineral Resources. (2018-20). Concerning Geopharmacy and Geomedecine, two industrial prototypes were developed, two trade-marks are registered and a patent is underway; another trade-mark on mortars is also registered.

Organization of conferences, colloquia or seminars – Our staff (co-)organized International Conferences incl.: EUROCLAY 2007 (Aveiro), MEDGEO 2015 Intern. Conf. Medical Geol. (Aveiro), 27th Coll. African Geology (2018, Aveiro), and been organizing/scientific committee member in several events, incl.: XVII Intern. Clay Conf. (2022, Istambul), EUROCLAY 2015 (Edimburg), 2019 (Paris) and 2023 (Bari), ICAM 2019 (Belgorod), 2018 Middle Eur. Clay Conf. (Zagreb), EAVP- European Association of Vertebrate Paleontology Annual Meeting (Caparica, 2018), International Meeting on The Panafrican and Cadomian Orogenies in North Africa and western Europe (online, 2021), 4th Palaeontological Virtual Congress (2023), 8th International Wildland Fire Conference held (Porto, 2023), TAIEX TSI Online Workshop on Post-fire biodiversity & biotic natural capital recovery (2022), XIII Congreso Ibérico de Geoquímica (2022, Puertollano), XV Congresso de Geoquímica dos Países da Língua Portuguesa (Porto

Galinhas, 2021), and e 3 Symposia about "Production and Food Processing in a Sustainable Environment".

Active participation on Scientific Societies and Contributions to Citizen Science – Members of our team has been members of the board of several societies, such as Geological Society of Portugal (President of Direction and President of General Assembly), ICAM/IMA (Vice-President of Direction), International Medical Geology Association IMGA (members of the board), European Clay Groups Association ECGA (Board of Directors), International Phycological Society (Board of Directors), Portuguese Society of Paleontology (members of the Board). Team members supported five museum displays, named 13 new species to science, and the research in paleontology and tectonics in the Lusitanian Basin created the scientific background of Oeste Geopark as UNESCO world heritage. Several activities of Open Science/Citizen Science were (co)organized by team members, within framework of, for example, Summer Academy and S&T Open Week.

Objectives and strategy of the R&D Unit for 2025-2029

Our main goal is to improve a particular research program (applied and fundamental research focused on primary raw materials for environmental and economic sustainability) as a strategic vector for the mobilization of all researchers aiming not only a more consistent integration but also a substantial increase of productivity. Research focus on primary raw materials life cycle: fundamental geological (regional and local) knowledge; availability of minerals; prospection and recognition; study of potential environmental impacts; exploitation of mineral deposits; treatment and beneficiation, processing; disposal, treatment and recycling of mineral wastes; decommissioning, closure and abandonment; geo-environmental technologies and still on any supporting science or technology such as geodynamics, basin analysis, rock mechanics, geophysics, geochemistry and geostatistics. GeoBioTec will carry out policy actions to improve access to primary resources: exploration techniques, regarded as research activities; research on mineral processing, extraction from old mine dumps, mineral extraction from deep deposits, and mineral exploration in general; sustainable exploitation/extraction. Aiming: increased knowledge of the national potential, with preliminary identification of exploitable resources, fostering a mining view; pilot projects of treatment of minerals complementary to the main extraction; development of new methodologies for resource assessment and new uses; conservation of resources and guarantee of supply of raw materials; demarcation of areas of geological interest and respective geological characterization; disclosure of mineral resources as non-renewable natural resources, placing them in the context of national natural heritage that must be known, preserved and enhanced; support for new activities geared to build in situ resources; demarcation of areas for future exploration.

Mineral raw materials are increasingly Critical. Thus, we will improve geological mapping algorithms for complex geometries of mineral deposits such as vein and stockwork types as well as evaluation and mapping of metal grades in mineral deposits and mining residuals, combining several sources of data, highlighting specific multivariate calibrations for LIBS spectra and lithium measurements, aiming to improve mine ores and reuse mining and quarry residuals for new products: examples of basalt fibers and extract phosphorus of iron ores and promote circular economy mining. Use of satellite images (Sentinel-2) for monitoring acid mine drainage in old mine sites, characterization and remediation of soils in polluted sites with heavy metals and organic compounds and characterization of recycled wastes – construction and demolition wastes

and electric furnace steel slags, namely its geotechnical durability, to use as aggregates replacement for drainage layers of infrastructures will also among our targets.

We will promote interdisciplinary collaboration for holistic environmental solutions. Nature-based and circular economy approaches offer sustainable resource management, ecosystem restoration, and climate adaptation. The 2025-2029 plan harnesses interdisciplinary expertise for innovative, sustainable natural resource management, ensuring societal well-being and environmental protection. Research will focus on integrating technology and ecological knowledge for biodiversity conservation, sustainable land use, water management, and circular economy practices. The R&D and supervising activities will focus on:

Characterizing Environmental Processes: understanding natural environments and how organisms interact within these processes provides a holistic understanding of environmental dynamics and is essential as a starting point for developing applied science or implementing various measures. This will analyse nutrient cycling, mineral weathering, and contaminant transport. Assessing Environmental Quality: Geochemical and biological analyses to monitor environmental systems, evaluate ecological health, and identify stressors to inform effective management decisions. Tracing Environmental Pathways: applying isotopes to trace substance movement and studying these substances' biological uptake and transformation enables tracking pollutants, nutrients, and other substances, fosters pollution remediation, and informs ecosystem management efforts. Modelling Environmental Processes: Developing and testing models that simulate environmental processes such as groundwater flow and integrate ecological interactions, predicting future environmental conditions, assessing management strategies, and providing decision support for policymakers and stakeholders. Contributing to Remediation Strategies: Using previous tasks to evaluate, develop, and implement cleanup technologies that best serve remediation and/or restoration purposes to ensure effective and sustainable environmental management.

Geotechnical modelling and the use of geoscientific data, namely modelling of geotechnical behaviour of offshore sediments as foundation layers of renewable energy structures as well as modelling of geotechnical soft soils behaviour, aiming, namely, the management of geotechnical assets in infrastructures by using expert systems and assessing landslide hazard and risk assessment of natural and anthropic slopes and use of remote sensing data.

Special attention will be devoted to “Sustainable Management of Resources”, related to UN SDG 11, i.e. on making cities and communities inclusive, safe, resilient, and sustainable, enabling the rational use of ecosystem services and life-giving services to the built environment, within the UI objectives. The aim is to develop innovative research that allows for the geo-environmental recovery of contaminated territories, the circularity of solid and liquid waste, the adaptation of cities and communities to climate change and the use of renewable energy sources, with support of digital technologies (e.g., software, IoT, GIS, UAV, sensors, AI, machine learning and robotic means).

Most of our main contributions are focused on Sustainable Development Goals (SDG) nº 9, 12 and 13, beyond the socio-economic and cultural development, where technology transfer and on job training, are included. Thus, we will try to enlarge the collaboration with the industry and designing projects of mutual interest and seeking co-financing in regional programs or European programs, beyond the advanced training mainly in foreign institutions or even in Portuguese ones. This will allow to conceive more scholarships to young students to perform their thesis within our PhD programs as well our Long Life Learning programs (microcredentials and

specialization courses tailored for non-academic professionals to keep them updated, such as the interdisciplinary courses).

Special attention will continue to be given to radiogenic isotope geology, geodynamics of crustal provinces, marine geology, palaeontology, soil sciences and geophysical support not only to georesources and geoenvironments but also to cultural heritage, geoheritage and geoconservation. We will promote the collaborative contributions of fundamental and applied geoscience and new sightings to improve the geological infrastructure knowledge of the country and the assessment of endogenous/exogenous resources, attending SDGs 4 and 13 and also commitment to SDGs 5, 8, 10, 11 and 17, in order to continue the research of the paleobiodiversity (invertebrates and vertebrates) from the Paleozoic to the Quaternary, build a complete petrological, geochemical and geochronological GIS database for the Iberian Massif domains, their respective Peri-Gondwanan equivalents in Central Europe and the cratonic sources in paleocontinents Gondwana and Laurasia, and improve knowledge, evaluation and tourism promotion of Portugal geoheritage.

Agro-industrial research will try to enlarge the collaboration with the industry and designing projects of mutual interest and seeking co-financing in regional programs or European programs, beyond the advanced training mainly in foreign institutions or even in Portuguese ones. This will allow to conceive more scholarships to young students to perform their thesis within the Agro-industrial PhD program. The technology transfer was a great success in the past and the research we endeavour must have a direct link with the food industry mainly through innovations or serving as an alert as verified in the import of raw materials for food supplement manufacturer, in which it was detected harmful elements such as arsenic or lead in a few cases.

On Marine Geology, we will improve our efforts on sedimentological, geochemical, mineralogical and micropaleontological studies on bottom sediments and on suspension particulate material to characterize deposits and to assess paleocirculation, productivity and pollution. The same concerning Medical Geology and Urban Geochemistry, with special focus on Atmospheric, Industrial and Urban Dust.

Finally, we will continue our research activities on: Environmental risk assessment, Restoration and rehabilitation of built heritage, using geophysical, (bio)geochemical and mineralogical approaches; Studies on Traditional Earth Construction (such as adobe) and Traditional Mortars, to improve conservation and rehabilitation; petrological, structural and metallogenic studies in the Iberian Variscan basement; magmatism, metamorphism and geodynamic evolution of crustal provinces of Brazil and Iran; Mineralogy and chemistry of Martian samples and their analogs.

11.2 Organization of the R&D Unit for 2025-2029 7000

Geobiotec Leading Host Institution is the University of AVEIRO; Geobiotec will have poles located at the universities NOVA de Lisboa and Beira Interior UBI. Geobiotec has not been immune to the transformations that have taken place in Portuguese research and higher education institutions with regard to human resources, with profound negative consequences in terms of retirements and positive consequences in terms of the recruitment of young PhDs researchers. Thus, although the number of integrated PhD researchers has stabilized (compared to the recent

past), several changes in scientific interests, combined with the normal re-adjustments typical of the emergence of new objectives, have led to some changes in the internal structure.

GeoBioTec comprises now the following 6 research groups: Complex Environmental Systems @Aveiro; Basin Analysis and Paleontology @NOVA; Agro-industrial @NOVA; Sustainable Management of Cities and Communities @UBI; and 3G - Georesources, Geotechnics and Geomaterials @AVEIRO and @NOVA. Thus, we have a new Group (Sustainable Management of Cities and Communities @UBI) and another (Lithospheric Evolution) merged with Complex Environmental Systems (@Aveiro). As for 3G - Georesources, Geotechnics and Geomaterials, although its integrity is maintained at the scientific level, the administrative management (namely material and financial execution) will be carried out autonomously by the 2 institutions (Univ. AVEIRO and NOVA) so there are, in practice for management, 2 Groups (3G@AVEIRO and 3G@NOVA). Each group defines its scientific and financial strategy, in accordance to the global lines of action and budgetary constraints approved by *Geobiotec Coordination Committee* of the Geobiotec composed of one member per group. The activities of each group are coordinated by the PI of the Group who is elected by its members; each group is represented by its PI in the Coordination Committee.

To boost internal cooperation, unformal several lines of research will be put forward covering, in a way transversal to the 6 Groups, cutting-edge topics defined by Coordination Committee. The implementation of the Research Lines, transversal to the Groups and putting emphasis on multipolar teams, is a way we try to assure internal cohesion and cooperation, as well as the development of a more active coordination of inter-Groups activities, with emphasis on cross-activities, information share and dissemination, as well on common upgrade of skills and capacities (human and materials). Implementation of coordination policies will favour the preparation and submission of Research Projects (national and international) gathering researchers from as most groups as possible, in order to reduce the risk of individual researchers continue to do their research without integration into our main objectives. Implementation of Annual Research Workshops, together with publication of a "Review of Research at Geobiotec" with the Web Page acting also as Repository of papers and projects.

The continuous development of our post-graduation platform is also a powerful tool to these objectives through the increasing participation, as supervisors, of junior PhD staff from all the different Host Institutions. Special attention will be also given to the development of joint PhD courses in Geosciences.

To better develop our Program and to achieve our goals, we will mobilize all researchers around a common (multidisciplinary) ground; thus, the strategic programme has straight focus but also with a high level of multi- and inter-disciplinarity, ensuring that research themes are crosscutting, involving different participants having wide range of skills, being a vector for the mobilization of all researchers aiming not only a more consistent integration but also a substantial increase of productivity. Actually, Geobiotec focuses on a multidisciplinary, advanced and comprehensive approach to scientific or technological issues involved in the life cycle of mineral resources, with particular emphasis on Industrial Minerals, certain Critical Raw Materials and the Soil and Water as resources for Agriculture purposes. Policies will be put forward to strongly encourage projects and supervision of thesis involving researchers from at least two groups and institutions. Implementation of policies boosting productivity, creating positive discrimination for researchers publishing more papers, on better journals. Material support policies will be put forward to boost submission of papers to journals having higher IF, and simultaneously awarding the most active members to quick disseminate research results.

To implement all these goals, our organization need to be more robust; thus, we will put forward:

A *Coordination Office*, providing technical and scientific advisory in the planning, organization, analysis, development, and implementation of scientific and technological strategies, guidelines, and activities; support in preparing applications for R&I and Career Development activities for funding programs; organization of information sessions for the scientific community related to specific calls; management and update of the research team.

An *Office for Cooperation and Tech Transfer*, aiming to extend the process of scientific creation to societal actors beyond the traditional scientific community, seeking to foster science culture on ordinary citizens, transfer awareness and critical thinking to society and inspire future generations of scientists. It will be responsible for the promotion of science and knowledge, aiming to foster critical thinking and engagement in the general public, as well as for dissemination of national and international Research and Innovation (R&I) funding

A *Council of PhD students and young researchers*, acting as advisory body elected by Geobiotec doctoral students and young researchers (<5 years degree) aiming to give voice to their concerns and recommendations.

Our selection of deliveries reflects the special focus on the increase of quality of the integrated members, being expected that in the next years staff members and full time researchers will participate in international projects, PhD supervisions and publish in indexed scientific journals:

- Publication of a minimum of 2 Scopus indexed papers per year per member (at least one Q1)
- 50% increase on number of national and international Research Project Proposals (involving always at least 2 groups)
- 25% increase on number of Doctoral and PosDoctoral Fellowships applications (at least half of them involving 2 groups on supervision)
- 25% increase on number of RD contracts with Regional and Local entities as well on contracts with industry (at least 25% of them involving 2 groups)