Designação do Projeto|	Resolvendo o enigma dos megatsunamis: usando os impactos proximais para constrager a geração de tsunamis despoletados por colapsos vulcânicos
Código do Projeto|	LISBOA-01-0145-FEDER-028588 - PTDC/CTA-GEO/28588/2017
Objetivo Principal|	Reforçar a investigação, o desenvolvimento tecnológico e a inovação
Região de Intervenção|	Lisboa e Açores
Entidade Beneficiária|	FCiências.ID – Associação para a Investigação e Desenvolvimento de Ciências, Instituto Hidrográfico, Fundação Gaspar Frutuoso, FP e IST-ID – Associação do Instituto Superior Técnico para a Investigação e o Desenvolvimento
Data de Aprovação|	03-05-2018
Data de Início|	01-08-2018
Data de Conclusão|	31-07-2022
Custo Total Elegível|	239.998,00€
Apoio Financeiro da União Europeia|	FEDER – 94.179,44€
Apoio Financeiro Público Nacional/ Regional|	OE – 145.849,16€

Objetivos

Large volcanic islands are intrinsically unstable edifices. During their evolution they may collapse gravitically.
Huge rock masses, involving tens to hundreds of km3, may slide rapidly into the sea producing large tsunamis -
megatsunamis - which constitute one of the most extreme natural hazards. However, despite significant advances in
numerical simulation of tsunamis, the real dimension of their associated risks is still ill-constrained. The resolution of
this problem is, thus, high priority due to the enormous implications of a trans-oceanic tsunami in a world where 44%
of the population lives in low-lying coastal regions. The key to unravelling this uncertainty lies in a solid reconstruction

of the source characteristics and of the impact of these tsunamis in proximal regions; these data will contribute to
enhanced simulations of their propagation to more distant areas. The proposed multi-disciplinary approach will allow
studying, with unprecedented detail, the proximal impact of the tsunami triggered by the collapse of the Island of Fogo
(Cabo Verde Islands) ~73 thousand years ago, one of the largest in the geological record. The aim of this proposal is
to use the effects of this tsunami in the Island of Santiago - just 55 km away from the source - to calibrate numerical
models of generation of such type of tsunamis, their propagation to and inundation of proximal areas. To achieve this
goal onshore and offshore data will be combined in order to reconstruct the inundation of Santiago and constrain the
magnitude and physical characteristics of the megatsunami in the proximal region. The integration of these parameters
in high-resolution simulations will allow testing the possible scenarios of the tsunami generation/propagation. The
project will acquire the detailed bathymetry of Santiago's insular platform (fundamental for precise simulations of the
inundation), analysis of the tsunami sediments preserved onshore, its stratigraphy and palaeontology, conjugated
with numerical modelling. Hopefully these results will contribute to a more robust perspective on the generation of
megatsunamis triggered by island collapses, on the expectable destruction in adjacent coasts and to establish a base
line to more robust predictions of their effects is distal areas. This study will be developed in synergy with projects FIRE
and MEGAWAVE funded by FCT and a research cruise funded by DFG (Germany), which will be complementary to a
wider strategy to evaluate the real dimension of the risks associated to this kind of events. This research is particularly
relevant and opportune to Portugal and Europe given their vulnerability to the impact of megatsunamis generated in one of the peripheral volcanic archipelagos (Azores, Madeira, Canaries, Cabo Verde), furthermore taking into account
the recent unrest in volcanoes such as Fogo and El Hierro.

Atividades

1. Coordination, Management & Dissemination
2. Remote sensing analyses
3. Acquisition of marine geophysical data (multibeam and seismic reflection data) and shelf sediment sampling
4. Geomorphological reconstruction of Santiago's paleo-topography
5. Quantitative sedimentological analyses of onshore tsunami deposits
6. Paleontological/biological analyses of onshore tsunami deposits and offshore shelf

Sediments
7. Development of numerical models for the generation, propagation and inundation of landslide megatsunamis
8. Analyses of Hazard & Risk scenarios 2020-01

Resultados Esperados / Atingidos

In terms of implementation, the project – as originally scheduled in the proposal – was heavily impacted by the COVID19 pandemic and related lockdowns and restrictions on international travelling. The pandemic not only forced a sudden interruption of the bathymetry acquisition of Santiago Island but also significantly restricted field work in Cape Verde for almost 2 years, also causing extensive delays in the release of results by external geochronology labs. This inevitably led to delays in the acquisition of field data and the release of geochronology results, holdups that cascaded into subsequent WPs that depended on these data for their implementation. Consequently, the project timeline had to be significantly revised, with FCT granting a one-year extension, after which only one WP (WP8 Analyses of Hazard & Risk scenarios) is yet to be complete and will have to be completed after the official date of conclusion of the project.
Notwithstanding the impact of the pandemic, we consider that the majority of the aims of the project (about 85%) were fully achieved within the project´s official timeframe, with the remaining (15%) expected to be achieved up to 1 year after the date of its official conclusion. More importantly the research leveraged by UNTIeD delivered – and is still delivering – significant scientific outcomes, both in terms of new knowledge and key datasets, and in usable tools with a strong societal relevance (such as improved tsunami modelling code).
One of the first and more tangible outcomes of the project was the mapping – in synergy with the M155 cruise and the international cooperation mission “Mar Aberto” by the Portuguese Navy – of over 40,000 km2 of high-resolution bathymetry, covering the totality of the Fogo-Santiago channel, was well as the whole submarine pedestal of Santiago Island up to -40 m on the northern and eastern side of the island, and up to -15 m on the western and southern sides (see Fig1). This bathymetry constitutes a curated dataset available at IH and will be used to produce new hydrographical charts for the region. An additional satellite-derived shallow-water bathymetric dataset was also derived, covering from 0 to approx. -15 m. The analysis of this bathymetry is the focus a paper currently in prep (Teixeira et al., Marine Geology, in prep).

Another major outcome concerns the detailed characterisation of the source characteristics of Fogo’s collapse correlative to the tsunami deposits mapped on land, in synergy with M155 research cruise. This work allowed us to identify and map at least 2 large-scale mass-transport deposits derived from Fogo, attesting to the occurrence of two collapse events, with 120-130 km3 and 180-190 km3 for the younger and older slides, respectively. This work set the floor for a detailed numerical reconstruction of Fogo´s collapse, also being the focus of a paper (Barrett et al 2020, Geol Soc Spec Pub) and a MSc Thesis (E. Klein).
A full sedimentological and paleontological characterisation of Santiago’s tsunami deposits was also achieved. The preliminary results of this analysis were published in Costa et al. (2020) Earth-Science Reviews and will be the focus of another more detailed paper now currently in prep (Ramalho et al. Earth-Science Reviews, in prep). This work revealed an unexpectedly high fossil biodiversity of the deposits, allowing for the establishment of more solid criteria to distinguish tsunami deposits (Ramalho et al. Sedimentology, in prep) also providing key insights into glacial-age faunas (transported by the tsunami) and their biogeographic range (Ávila et al. PNAS, in review; Melo et al. J. of Biogeography, in review). One of the key deliverables of this endeavour is also one of the most extensive curated reference marine fossil

collections (housed at the Univ. of Azores) for Cape Verde, which is directly contributing to the PhD projects of C.S. Melo, L. Baptista, and C. Alves and already contributed to the MSc thesis of A.S. Reeb.
The research supported by UNTIeD also provided improved constraints on the timing and number of tsunamis impacting Santiago Island. Fieldwork combined with a comprehensive coral U-Th disequilibrium age dataset for Santiago's deposits confirmed the presence of 2 sets of deposits of different ages (Fig 2). The older deposits yielded an age >200 ka, with a large spread on the possible age interval and large uncertainties in individual coral ages, possibly due to alteration of corals. The younger set of deposits yielded a vast spread in ages (as expected for a tsunami deposit that transported corals from different sources and ages) but – critically – its younger ages (indicative of the age of the transport event) all cluster at around 59-65 ka (Fig 3). This significantly narrows the existing timing interval for the main Fogo tsunami, which is a critical achievement, given that the narrower time interval yielded by the coral ages in conjunction with the cosmogenic 3He geochronology results allow us to more accurately constrain the sequence of events that took place because of Fogo's flank collapse and tsunami, simultaneously allowing us to better reconstruct relative sea-level at the time of the event, and consequently the inferred run-up height of the tsunami that impacted Santiago. It is expected that a new dataset of cosmogenic 3He geochronology will narrow even further the inferred likely age interval for the event, this however will have to take place outside the timeframe of completion of the project, given the significant delays in cosmogenic geochronology labs. Currently, 1 manuscript is being prepared that report these results (Ramalho et al. Earth-Science Reviews, in prep).
Critically, the numerical tools developed in the remit of UNTIeD are already having an enormous impact in our capability of modelling volcanic tsunamis and their impacts. This is demonstrated by the application of the model to the study of tsunamis created by smaller coastal landslides, such as the 1930 Cabo Girão tsunami (see Omira et al, EPSL, 2022). More importantly, these numerical tools – jointly with those developed under the remit of the project FAST – also allowed us to unlock the generation and propagation mechanism behind the recent Tonga global tsunami, as demonstrated by our recent paper in Nature (Omira et al. 2022). The numerical simulations of Fogo's megatsunami are now being finalised and will be the focus of another high-impact publication during 2023, which will also combine the outputs of the hazard & risk analysis of WP8 (Ramalho et al Nature Geoscience, in prep).
Finally, and more broadly, the synergetic work between the research in the remit of UNTIeD and other projects in Portugal and abroad is also delivering knowledge in other domains, e.g. an improved understanding of Fogo volcano and its structure (e.g. Carvalho et al. 2022 JVGR; Dumont el at. 2022, Bul. of Volcanology, in review) as well as the consolidation of international cooperation between Portugal, UK, US, Germany, Spain and Cape Verde in the domains of volcanology and tsunami hazard, risk and resilience.