

CARLOS ALBERTO SOUSA MELO

**ORIGIN AND EVOLUTION OF COASTAL
TALUS-PLATFORMS (FAJÃS) WITH POND
SYSTEMS IN OCEANIC VOLCANIC
ISLANDS**

**ORIGEM E EVOLUÇÃO DE FAJÃS DETRÍTICAS COSTEIRAS COM SISTEMAS
LAGUNARES EM ILHAS OCEÂNICAS VULCÂNICAS**



**GEOSCIENCE DEPARTMENT
UNIVERSITY OF THE AZORES**

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**GEOSCIENCE DEPARTMENT
UNIVERSITY OF THE AZORES**

2015

Aos meus pais e irmãs

“Far better is it to dare mighty things, to win glorious triumphs, even though checkered by failure... than to rank with those poor spirits who neither enjoy nor suffer much, because they live in a gray twilight that knows not victory nor defeat.”

Theodore Roosevelt (1919[†])

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*“Nenhum homem é uma ilha isolada,
Cada homem é uma partícula do continente,
Uma parte da terra,
Se um torrão é arrastado para o mar,
A Europa fica diminuída,
Como se fosse um promontório.”*

John Donne

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IV. ABSTRACT

Coastal talus-platforms (fajãs) with pond systems - like *Fajã da Caldeira de Santo Cristo* and *Fajã dos Cubres* in São Jorge Island – constitute features of high geological, biological, and landscape value, even becoming one of the most iconic landscapes of the Azores Islands. Whilst the origin of *fajãs* is firmly established as being the product of landslides that develop along the high coastal cliffs that rim reefless volcanic islands, little is still known about the processes that interplay to shape the *fajãs* that exhibit a pond system. In particular, doubts still remain on whether *fajãs* featuring a pond system are a direct fortuitous product of mass wasting, or conversely result from marine reworking (by waves and currents) after emplacement. An exciting recent event, however, promises to revolutionize our knowledge of the subject: a landslide occurred on the Island of Corvo, during the storm of October 30th 2012, and its posterior evolution constitutes a perfect analogue for the generation of these iconic landscapes. The central aim of this MSc thesis is precisely to document the evolution of this fajã, in order to gain a better understanding on the origins of coastal talus platforms featuring a pond system and on the processes that concur to their formation. To achieve this aim, a photographic database was compiled with images that document the development of this *fajã*; based on these images a time-stamped reconstruction of the main evolutionary stages that shaped that development was performed. These observations demonstrate that this type of coastal deposits are incredibly dynamic landscapes, experiencing a very fast early evolution, as the generation and subsequent development of *Fajã dos Milagres* on Corvo (as it became known) clearly showed. Moreover, 5 main evolutionary stages were defined, on the basis of the observations: “islet stage”; “gravel spit stage”; “early pond system stage”; “mature pond system stage”; and “*fajã* stage”. Our reconstructions, when correlated with wave data, show that waves and wave-induced currents – which generate powerful onshore and longshore sediment drifts - play a key role in the evolution of the fajã, confirming that these landscapes are not a fortuitous result of the landslides, but are rather a product of post-emplacment marine reworking. The presence of a wide, shallow and gently dipping insular shelf is also found to be a necessary pre-existing condition to the formation of these *fajãs*. Finally, it is postulated that, whilst most *fajãs* with pond systems pass through all these evolutionary stages, only in exceptional conditions may *fajãs* retain their “early” or “mature pond system” morphology for a long period of time, as *Fajã da Caldeira de Santo Cristo* and *Fajã dos Cubres* in São Jorge still do.

Key words:

Coastal geomorphology; coastal talus platform (fajã); waves; photo reconstructions; Azores

V. RESUMO

Fajãs detríticas costeiras com sistemas lagunares – como as Fajãs da Caldeira de Santo Cristo e dos Cubres na Ilha de São Jorge – constituem locais de elevada riqueza geológica, biológica e paisagística, tendo mesmo se tornado um ícone paisagístico do Arquipélago dos Açores. Muito embora seja do conhecimento geral que a génese de fajãs detríticas costeiras está intrinsecamente ligada à evolução das altas arribas litorais típicas de ilhas vulcânicas, e aos processos de movimentos de massa associados a esta evolução, pouco se conhece acerca dos processos que concorrem para a génese de fajãs detríticas costeiras que exibem sistemas lagunares. Em particular, dúvidas ainda subsistem acerca da possibilidade dessas fajãs serem um resultado directo e fortuito do deslizamento que lhes deu origem, ou, por oposição, serem resultado de um retrabalhamento marinho (por ondas e correntes) após a sua implantação. Um acontecimento recente, no entanto, promete revolucionar o nosso conhecimento sobre o assunto: um deslizamento ocorrido na Ilha do Corvo durante o temporal de 30 de Outubro de 2012, e o seu desenvolvimento posterior, constitui um análogo exemplar para a génese destas morfologias. O objectivo central desta tese de mestrado é precisamente documentar a evolução desta fajã, com o intuito de avançar o nosso conhecimento sobre as origens das fajãs detríticas costeiras com sistemas lagunares, e sobre os processos que concorrem para a sua formação. Com este objectivo, foi compilada uma base de imagens que documentam este evento, e com base nestas imagens procedeu-se à reconstrução temporal das várias fases evolutivas da fajã. As observações assim efectuadas revelaram que este tipo de depósitos constituem geoformas incrivelmente dinâmicas, apresentando uma evolução inicial extremamente rápida, tal como a geração e desenvolvimento da Fajã dos Milagres (como ficou a ser conhecida) na Ilha do Corvo claramente demonstrou. Adicionalmente, com base nestas observações, foram definidas 5 fases evolutivas no desenvolvimento desta fajã: “fase de ilhéu”; “fase de cordão litoral”; “fase inicial de sistema lagunar”; “fase madura de sistema lagunar”; “fase de fajã”. As reconstruções efectuadas neste estudo, quando relacionadas com dados de ondulação, mostram que as ondas e correntes induzidas pela ondulação - responsáveis pelo acarreio de sedimentos em direcção da costa e ao longo da mesma - desempenham um papel fundamental na evolução da fajã, confirmando que estas geoformas não são um produto fortuito do deslizamento que lhes deu origem mas sim o resultado de um retrabalhamento marinho posterior à sua instalação. A presença de uma plataforma insular larga, de pouca profundidade e de fraco pendor, é igualmente considerada como uma

condição pré-existente essencial para a formação deste tipo de fajãs. Finalmente, é aqui postulado que a maioria das fajãs com sistemas lagunares passa por todas as fases evolutivas acima mencionadas, e somente em condições excepcionais é que uma fajã retêm, por um período considerável de tempo, uma morfologia de “fase inicial de sistema lagunar” ou de “fase madura de sistema lagunar”, como as Fajãs da Caldeira de Santo Cristo e dos Cubres em São Jorge ainda retêm.

Palavras chave:

Geomorfologia costeira; fajãs; ondas; foto reconstruções; Açores

1. INTRODUCTION

“Huge volcanic landslides are one of the most hazardous geomorphological processes that can occur during the evolution of volcanic ocean islands. The causes of these phenomena, however, are very complex and combine non-volcanic and volcanic factors.”

Hürlimann *et al.*, 2004

1.1. Introduction to the scientific problem

Rocky coastlines are complex dynamic geomorphological features whose evolution is frequently non-linear and event- or threshold-driven (Naylor & Stephenson, 2010). This is especially true on islands – particularly reefless volcanic islands – where coastal changes are more noticeable (Ramalho *et al.*, 2013). Island shorelines are more suitable to dramatic and rapid topographical changes than most other coastal settings, on account of volcanism, mass wasting, and exposure to the energetic conditions of the open ocean (Quartau *et al.*, 2010; Ramalho *et al.*, 2013). In these edifices, coastline evolution is intrinsically related to the competition between volcanic construction and erosional destruction, processes that typically operate at a much faster pace than those governing shoreline evolution on continental regions (Ramalho *et al.*, 2013). Coastlines are first established during island emergence, either by volcanic activity or by uplift (Menard, 1986; Ramalho *et al.*, 2013; Ramalho *et al.*, 2015). Once volcanic activity wanes, however, island coastlines immediately start decaying and receding by the action of waves, winds, rain, gravity, and living organisms – particularly if unprotected by reefs as it happens on islands at mid-latitudes such as the Azores.

Coastal zones constitute preferential areas where population centers grow. With a worldwide extension of only 500000 km, these dynamic geomorphological areas have been suffering extreme stresses along the years (Borges, 2003). Due to increasing need of land-use in coastal/waterfront areas (e.g. Singhory, 1995 *in* Johansson & Edeskär, 2014), changes in coastline topography have a direct impact in human lives, whether by natural or human-induced hazards (chapter 3) (Finkl & Makowshi, 2013). Some coastal hazards take years to develop (such as coastal landslides), but are

only those events that tend to occur rather quickly (within hours or days), and with dramatic consequences, that usually capture people's attention (Finkl & Makowshi, 2013). This thesis focus on one of those events, whose fortuitous occurrence came to shed some light on the origins of one of the most iconic landscapes in the Azores islands: the coastal talus-platforms (fajãs) featuring a pond system.

One of the most important processes through which rocky coastlines evolve – particularly on islands unprotected by coral reefs – is mass wasting. Mass wasting consists on the movement of rock and rock debris as a result of slope gravitational instability, either by landslides, rockfalls, debris flow, mudflows, soil and rock avalanching, and slow deformational creep (Coleman & Prior, 1988). Mass wasting operates at various spatial and time scales, and its impact on coastlines varies with these scales. Large-scale, catastrophic lateral flank collapses are thought to be a key process in the evolution of oceanic islands (Masson *et al.*, 2002), since they remove huge volumes from island edifices, dramatically changing coastal outlines and resetting marine erosion (Mitchell, 2003). These high-impact events, however, are extremely infrequent and operate only at the 10^5 - 10^6 year scale (McGuire, 2006). Conversely, small to medium-scale (either gradual or catastrophic) mass movements are simultaneously one of the most effective mechanisms of cliff erosion and an important source of coarse sediment to coastlines (Griggs & Trenhaile, 1994; Bird, 2008; Trenhaile, 2011). Hence, these events are usually responsible for the formation of landscapes such as coastal talus structures, boulder beaches, near-shore islets, and submarine gravel banks.

Coastal talus-platforms are detrital accumulations generated by mass wasting, found at the foot of coastal cliffs around islands and continents. These landscapes are particularly common on reef-less volcanic islands in the Atlantic Ocean, where the unprotected high-energy coastlines potentiate the generation of high coastal cliffs (Ramalho *et al.*, 2013). Examples of such features are well-known in the Portuguese-speaking archipelagos such as Azores, Madeira and Cape Verde, where they are locally called *fajãs*. *Fajãs* thus consist of large accumulations of collapsed material at the base of cliffs – resulting from cliff failures – typically with low profiles and flat or hummocky surfaces and occasionally forming small islets or coastal lagoons (Lameiras *et al.*, 2009, Ramalho *et al.*, 2013). Note that the term *fajã* is, in fact, locally used to define every flat surface near the coastline, being it an accumulation of debris or a lava flow delta. In the present work only detrital *fajãs* are in focus and considered.

Coastal talus-platforms (fajãs) are thus commonplace along the unprotected cliffed coasts of the Azores (as well as Madeira, Canaries and Cape Verde). Whilst the origins of *fajãs* are firmly estab-

lished as being the product of mass wasting and subsequent marine reworking, it is still unclear how *fajãs* featuring a pond system are formed, in detail, particularly if they are a direct and fortuitous product of mass wasting, or conversely if marine reworking is the dominant factor in their evolution post-mass wasting. Additionally, little is known about the timescales and intermediate stages that characterize their evolution. Therefore, up to date, our knowledge on the origins of one of the most iconic landscapes in the Azores is still in its infancy.

Studying the origin and evolution of coastal talus-platforms (fajãs) with pond systems takes particular importance in Azores, due the fact that it is the only place in the North Atlantic where this kind of structures can be found in relative abundance (Borges, *personal communication*). Here, the most famous features of such type are the *Fajã da Caldeira de Santo Cristo* and *Fajã dos Cubres*, both on São Jorge Island. The rarity of these structures allied to their geological and biological peculiarities have habilitated them to make part of the GeoPark network of the Azores (Geosite SJO4) (Lima, 2007; Lima *et al.*, 2014).

Historical events that led to the formation of *fajãs* are not rare in the Azorean Island Region. Since the discovery and settling of these islands during the last half of the 15th century, at least 4 large events have occurred: 1 in Terceira Island (1614); 1 in São Jorge Island (1757) and 2 on Flores Island (1847 and 1980) (Borges, 2003; Andrade *et al.*, 2006; Cabral, 2009). The 1847 event gave origin to a tsunami that has directly affected Corvo Island (2 fatalities) (e.g. Cabral, 2009).

On October 30th 2012, a new mass-wasting event took place on the western coast of Corvo, forming a new *fajã*– the *Fajã dos Milagres*. This event brought again into focus the subject of formation of *fajãs*, mainly due to the fact that events with such magnitude are rare. More importantly, this event offered for the first time a rare glimpse on how *fajãs* with a pond system form, since its evolution on the following months passed through islet stage → gravel spit stage → early pond system stage → mature pond system stage → *fajã* stage. Therefore, this event constitutes a unique opportunity to study in better detail how this type of *fajãs* form, and what are the processes – and agents – that that interplay to shape their evolution, complementing and enhancing our knowledge about coastal evolutionary process in oceanic volcanic islands. It was precisely with this insight that this MSc project was conceived, harnessing this rare opportunity.

1.2. Importance of *fajãs* with pond systems and relevancy of the proposed work

Being rare in hotspot islands, *fajãs* with pond systems became an *ex libris* of the Azores. *Fajãs* with pond systems are of the outmost importance for the Azores Island Region, not only due to their unique geomorphology, but also due to their biological and economic importance. Attesting to this importance is the length of legal protection these landscapes experienced. Since 1984 several Regional Decrees have been created in order to preserve these features. The first of those decrees was the Regional Legislative Decree no. 14/84/A, from February 21st, who has established specific laws to protect the *Fajã da Caldeira de Santo Cristo* pond system. Since this date, the place is classified as Partial Nature Reserve. As this is the only place where clams can be found – and commercially exploited – in the Azores, the Regional Legislative Decree no. 6/89/A from July 18th was then established, regulating the harvest and sale of this mollusk from this pond system. Additionally, this decree established the then called Special Ecological Area of the Pond of the “Caldeira de Santo Cristo”. Later, the Regional Legislative Decree no. 32/2000/A from October 24th went even further establishing precautionary measures to preserve and protect the natural and cultural heritage of the *fajãs* of São Jorge Island, due to their recognized importance. Following up the Regional Legislative Decree no. 15/2007/A from June 25th, another Regional Legislative Decree (no. 10/2011/A from March 28th) was published, finally creating the Natural Park of São Jorge, a structure responsible for the maintenance and application of specific law to protect the natural heritage of the island. The same also occurred in other islands of the archipelago, where Corvo was no exception (Regional Legislative Decree no. 44/2008/A from November 5th). On March 2015, the Azores Regional Government submitted a proposal to UNESCO, in order to classify these *fajãs* as Biosphere Reserves. According to this proposal, the already Biosphere Reserves (Corvo and Graciosa – 2007; Flores – 2009) would become part of the World Biosphere Reserves Network.

Therefore, the importance given to the *fajãs* and their importance to the classification of an island as a Biosphere Reserve (see UNESCO Biosphere Reserve Main Characteristics - <http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/biosphere-reserves/>) highlights the relevancy of the theme in discussion in this work, since the potential outcomes of this dissertation promised to provide a significant step forward in our scientific understanding on the origins and evolution of *fajãs* with pond systems.

The biological richness of São Jorge’s *fajãs* is well known and was the focus of several previous works (Morton & Cunha, 1993; Morton *et al.*, 1995). In contrast, so far, only one study concentrated on the geological aspects of these structures (Borges, 2003). The event of October 30th 2012 gave

the opportunity to better understand the origins and complex evolution of *fajãs* in general, and of *fajãs* with pond systems in particular. Unstable coastal areas in the Azores suitable to originate *fajãs* are not rare, and some can threaten housing areas. For example, on June 13th 2014, an unstable area on Pico Island collapsed, resulting in 31 homeless families (chapter 3), highlighting another relevant aspect of the present theme in discussion, beyond the geological/biological perspective.

1.3. Previous studies

A lot has been written about the geological evolution of Atlantic volcanic oceanic islands (Azores: Zbyszewski *et al.*, 1967; Madeira, 1986; Moore *et al.*, 1990; Madeira & Ribeiro, 1990; Serralheiro & Madeira, 1993; Gaspar, 1996; Queiroz, 1997; Lourenço *et al.*, 1998; Madeira, 1998; Azevedo, 1998; Wallenstein, 1999; Nunes, 1999; Ferreira, 2000; Coutinho, 2000; Pacheco, 2001; Dias, 2001; Serralheiro, 2003; França *et al.*, 2003; Quartau, 2007; Zanon, 2009; Quartau *et al.*, 2010; Verzhbitsky *et al.*, 2011; Mitchell *et al.*, 2012; Hildenbrand *et al.*, 2012; Tempera *et al.*, 2013; Mendes *et al.*, 2013; Pacheco *et al.*, 2013; Larrea, 2014; Quartau *et al.*, 2014 – Cape Verde: Serralheiro, 1966, 1968, 1970, 1976; Serralheiro *et al.*, 1974, 1979; Torres *et al.*, 1997; Brum da Silveira *et al.*, 1997; Skolotonev *et al.*, 2007; Martins *et al.*, 2008; Madeira *et al.*, 2010; Mourão *et al.*, 2010; Ramalho, 2011 – Macaronesia: Mitchell-Tomé, 1981), however, few works focus solely on coastal processes. Nevertheless, in the last few years, the number of works that, directly or indirectly, focus on coastal processes has increased, particularly concerning the subject of volcanic mega-collapses (Hürlimann *et al.*, 1999, 2000; Ablay & Hürlimann, 2000; Masson *et al.*, 2002; Hürlimann *et al.*, 2004; Budetta *et al.*, 2008; Watt *et al.*, 2012; Mitchell *et al.*, 2012; Seisdedos *et al.*, 2012; Costa *et al.*, 2014). Noteworthy, is the work by Ramalho *et al.* (2013), which offers the first all-encompassing review on the subject of coastal evolution on volcanic oceanic islands.

All Azorean islands have a volcanic origin (Frutuoso, 1591[†]), due to their peculiar geotectonic setting (chapter 2). With the notable exception of Santa Maria and Corvo Islands, the occurrence of volcanic activity in the last ~10 ka has been noted for all islands of the archipelago. Santa Maria and Corvo islands have no signs of volcanic activity since ~2 Ma (Madeira, 1986) and ~100 ka (Zbyszewski *et al.*, 1967), respectively. Much has been published about Santa Maria Island, especially concerning the marine fossil record existing there (e.g. Ávila *et al.*, 2010), but few works concentrated on Corvo Island. Studies about this island mostly focus on its geology and geochemistry (Berthois, 1953; Zbyszewski *et al.*, 1967; Dias, 2001; França *et al.*, 2002; Azevedo *et al.*, 2003; França *et al.*, 2006; Pueyo *et al.*, 2006; Genske *et al.*, 2012; Larrea *et al.*, 2012, 2013; Larrea, 2014), and only a

few make any reference to mass wasting (França *et al.*, 2002; Larrea *et al.*, 2013; Larrea, 2014). A first appraisal on the extreme marine erosion suffered by Corvo Island was done by the team responsible by Corvo's POOC (*Plano de Ordenamento da Orla Costeira*– Coastal Zone Management Plan) in 2006, and the first mention to the event on study in this work was made by Ramalho *et al.* (2013).

1.4. Aims and workflow

The work here presented was developed in order to obtain the MSc degree in Environmental & Societal Geology. This master's programme in Environmental & Societal Geology (Mestrado em Geologia do Ambiente e Sociedade) was held by the Geoscience Department of the University of the Azores, having as supporting scientific institution the Center of Volcanology and Evaluation of Geologic Risk (Centro de Vulcanologia e Avaliação de Riscos Geológicos – CVARG).

The central aim of this MSc project is to gain a better understanding on the origins of coastal talus platforms featuring a pond system, and the processes that concur to their formation. With this insight in mind, the following objectives for the present dissertation were defined:

- To document step-by-step the evolution of the coastal talus-platform (*fajã*) with a pond system associated created by the October 30th 2012 Corvo event;
- To establish a correlation between the several factors that led to the formation of this *fajã*, such as: initial morphology of the detrital deposit formed after the landslide and its modulation by waves, currents, etc;
- To develop an evolutionary model for this kind of structures;
- To correlate this model with other examples of *fajãs* with pond systems present in the Azores archipelago, in order to gain insight on their formation.

In order to achieve the proposed objectives, a simple workflow was followed, as it is reflected in the structure of this thesis.

In chapter 1, the scientific problem was introduced, as well as the objectives and methodologies of the present work. A brief analysis on previous works was also presented.

In chapter 2, a brief assessment about the Azores Archipelago geographic and geologic setting is presented as reference. Emphasis is given to Corvo and São Jorge islands, in terms of geology and microclimate setting.

In chapter 3, a summary of the current knowledge about coastal talus-platforms (fajãs) and *fajãs* with pond systems is presented. An overview about the *fajãs* and their typology in the Azores is presented, with focus to the islands of São Miguel, São Jorge, and Flores, where *fajãs* with pond systems are known to have occurred or occur nowadays.

In chapter 4, a characterization of the October 30th 2012 is given, in relation to the meteorological factors that helped trigger this event. A GIS reconstruction of the *fajã* is here presented, based on archive photos and satellite images, and comprising a short description about the stages of evolution of this *fajã*. Relevant wave data is also here presented, in order to facilitate a correlation between the morphological changes of the *fajã*, and the role of waves and currents in shaping this evolution.

In chapter 5, a discussion on the variables that might explain the event and its evolution is presented, based on the compilation and analysis of meteorological, bathymetric and wave data. Based on these observations, a conceptual model for the generation and evolution of *fajãs* with pond systems is proposed in this chapter.

Finally, chapter 6 presents the conclusions of this study. An extended summary about all subjects mentioned in this work is made, regarding specially chapters 5 and 6, where the main topics about the evolution of *fajãs* with pond systems are incorporated in a conceptual model.

1.5. Methods

The central focus of the work here presented concerns the morphological evolution of a newly created *fajã*, as a result of a landslide, and the research on what factors controlled that evolution. As it was not possible – for economical, logistical, and practical reasons – to fully document this evolution directly in the field, the present study is essentially based on reconstructions made remotely. These reconstructions build upon a wealth of imagery taken by locals, government officials, and visitors, under various perspectives and at different times. These images mostly correspond to oblique low-altitude aerial photos, oblique photos taken from the top of the adjacent cliff, and photos taken from offshore the collapse site. A considerable photographic record/database was thus compiled, and selected images used for particular purposes throughout this research.

In order to perform the morphological reconstructions of *Fajã dos Milagres* at any given stage, selected photos were georeferenced in ArcGIS environment using at least 4 clearly identifiable control points of known coordinates. Images with the highest/steeper oblique component (i.e. closer to the vertical) were chosen, to minimize errors of perspective and distortions in the horizontal component. In what concerns spatial data processing, ArcGIS was used to analyze and display all bathymetric and altimetric data. The use of Rectify Extreme software (Silva, 2007; Taborda & Silva, 2012), downloaded from the COSMOS website (<http://cosmos.fc.ul.pt/index.html>), was attempted, in order to orto-rectify the conical perspective of the photos. However, the orto-rectified images were very similar to the original photos (Fig.1.1), therefore this method was not employed. Also, with respect to Rectify Extreme, the fact that the photos were not taken always from the same spot and with the same camera, presented a major obstacle to the effective use of this software. Notwithstanding the limitations associated to this particular case study, this software promises to be extremely useful in future coastal monitoring efforts in the Azores. Reconstructions based on Landsat 7 and Landsat 8 satellite imagery were also used, mainly when long time gaps existed in the photo archive, and also to test and implement an Earth Observation (EO) technique in the coastal geomorphological analysis of Corvo Island. These free-access images were downloaded from the USGS website-Earth Explorer (<http://earthexplorer.usgs.gov>), in GeoTIFF format. The use of EO techniques in geological surveys is not new (e.g. Mantovani *et al.*, 1996; Siart *et al.*, 2009; Embabi & Moawad, 2014), but these techniques have been seldom applied in the Azores Archipelago. The cloud coverage that is usually found over these islands limits the application of such technique, but a sample of the visual spectrum of Landsat 7 and 8 imagery for the period from 2012-2014 for the island of Corvo has revealed an interesting and relatively large usable set of images. Notwithstanding the large size of the pixel (30 m), the reconstructions made based on those images were of great reliability (*cf.* chapter 4). Synthetic Aperture Radar (SAR) images possibly provided the most suitable type of imagery, taking into account the meteorological context of the archipelago and the availability of several algorithms to precisely calculate ground morphological changes. However, this method was not used, due to difficulties in acquiring the relevant images. The aforementioned reconstructions were also complemented by field topographic surveys on the *fajãs* with pond systems of both Corvo and São Jorge Islands, and oral testimonies in Corvo Island were collected, regarding the mass-wasting event.

To gain insight on the role played by environmental factors in triggering and shaping the event, meteorological and wave data were requested and provided by Instituto Português do Mar e da Atmosfera, and Instituto Hidrográfico. The processing of any meteorological and undulation data followed the Guide to Climatological Practices (WMO-No 100). Finally, and in order to further com-

prehend the geomorphologic setting where this type of *fajãs* gets developed, aerial photography of both São Jorge and Corvo Islands were analyzed.

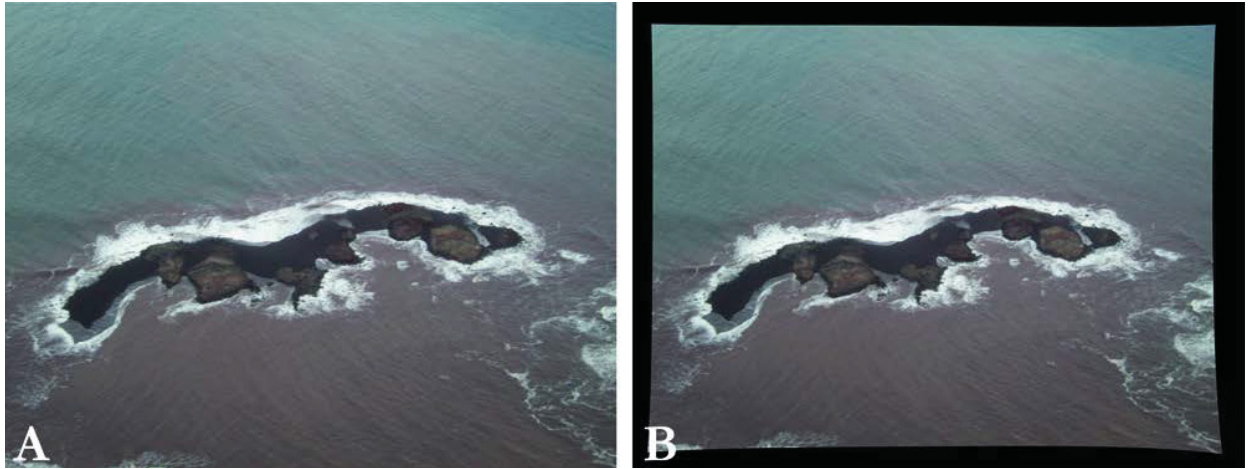


Figure 1.1 – Output example of the application of the orto-rectification technique (Silva, 2007). A-no orto-rectified photo; B-orto-rectified photo. Apart of reducing optical distortion of the lenses, no other significant change is visible, therefore the method was not used in the present work.