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COUNCIL OF EUROPE CONSEIL DE L'EUROPE

ACCORD EUROPÉEN ET MÉDITERRANÉEN SUR LES RISQUES MAJEURS

(EUR-OPA)

PROJECT TraRetro

(Coordinator: CERG; Participants: GHHD + CERU + AFEM)

European Landslide Hazard Maps: Fostering European Harmonization of Slope Movement Hazard Assessment at various spatial scales

Centro Europeu de Riscos Urbanos
Lisboa - Portugal

WP1 : Report and preliminary map of earthquake triggered landslides

Activities developed by CERU (Portugal): Paula TEVES-COSTA (Coordinator)

CERU - 2016

European Landslide Hazard Maps: Fostering European Harmonization of Slope Movement Hazard Assessment at various spatial scales (Coordinator: CERG, Strasbourg)

The proposed work to develop during 2016 in the project was directed towards the following ***Specific objectives***:

- Calculation of statistical landslide triggering thresholds (e.g. rainfall amounts, rainfall intensity, other parameters) for selected European regions

- Development of a methodology to integrate triggering thresholds in the global scale landslide hazard assessments (e.g. for scale > 1.100.000), and test in selected European regions

- Development of a methodology to integrate seismic triggering thresholds in the global scale landslide hazard assessment, and test in several European regions

The ***Associated activities*** included**:**

Work package 1 (CERU)

Description: Compilation of existing information on earthquake triggered landslides in Portugal.

Deliverable: Report and preliminary map of earthquake triggered landslides

Report of activities developed in 2016

The work initially expected for 2016 suffered considerable delay as consequence of unexpected events and very time consuming tasks at the home institution of the research team involved. In this context, the tasks performed and results obtained are referred in the corresponding work packages.

Report and preliminary map of earthquake triggered landslides in Portugal mainland

The available information on seismically triggered landslides which occurred in mainland Portugal is very scarce due to a combination of unfavourable factors.

In fact, large earthquakes with landslide triggering capacity are relatively rare events, widely spaced in time and include the 1344, 1531 and 1909 earthquakes generated in the Lower Tagus River Valley, and distant events, the 1755 and 1969 earthquakes, in the SW offshore of Portugal (Cabral, 1995). There are also other large historical earthquakes reported but the available information is so scarce that their sources and effects remain poorly known.

Most of these events, and specially the strongest one, the 1755 earthquake, occurred before the existence of seismic data acquisition equipment installed in the country, and in consequence the analysis of their effects is mostly limited to the analysis of historical descriptions, which have a strong bias due to the very unequal quality and quantity of the existing historical records along the country and also that the effects descriptions were mainly focused on towns and notable buildings destructions and number of persons killed, with effects such as landslides in non-populated areas rarely being reported.

The seismic activity recorded in Portugal has a disperse character, but with two main source areas. One of the two main sources of earthquakes is the Lower Tagus River Valley, were poor epicentre location, possible site effects, low fault slip rates and a thick Cenozoic sedimentary cover (e.g. Cabral et al., 2011) which is composed in the upper part by a thick sequence of unconsolidated soft and strongly deformable sediments (normally consolidated) prevented the positive relation of the reported large earthquakes with the known regional faults. The other source includes a large offshore region located to SW of Portugal, being only reasonably known the location of the source of the 1969 earthquake. The location of the source of most destructive 1755 event remains unknown, in spite of the strong efforts placed to solve this important problem (e.g. Cabral, 1996; Baptista et al., 1998, 2003; Terrinha et al., 2003).

Existing data on seismically triggered landslides is mainly based in the careful and detailed analysis of historical descriptions (e.g. Vaz 2010; Vaz and Zêzere, 2016), which enabled the identification of 28 events triggered by 10 earthquakes: 9 by the 1755 earthquake, 7 during the 1909 earthquake, and 3 landslides by the 1531 and 1969 earthquakes. However, the exact location at the scale of the slope could not be found in 10 of the reported landslides. Only a few of the reported landslides were object of a preliminary characterization and there is an obvious bias in the reported events, with eight landslides reported in Lisbon, contrasting with only five events reported in Algarve which is the region located closer to the major seismogenic area that affects mainland Portugal.

In addition to the landslides reported by Vaz (2010) and Vaz and Zêzere (2016), Marques (2001, 2005) made the characterization and limit equilibrium analysis of a large, deep seated landslide which affected the sea cliffs located southwards of Praia do Telheiro, approximately 2.5km to NNE of S. Vincent cape (SW Portugal) (Fig. 3, 4, 5).

The landslide affected approximately 850m of the 60m high cliffs composed by strong lower Jurassic dolomites, with thick beds (>2m) dipping 15º to 30º to south or southeast and widely spaced joints, overlaying Hetangian marls.

The geometrical reconstruction and limit equilibrium back analysis of a section of the landslide (Fig. 5) indicated that the movement could only be possible with a very strong seismic action, with the 1755 earthquake being a strong possible triggering earthquake (Marques, 2001, 2005).

The systematic inventory of sea cliff failures along the whole coast of Algarve (Marques, 1997), covering the period from 1947 to 1991, provided results that indicate that the 1969 earthquake did not produce significant impact on rates of cliff failures expressed in terms of number of events and of the horizontal area affected at the cliff top level (Marques, 1997, 2003).

The available data is thus of very limited use for seismically triggered landslide susceptibility analysis and mapping, because it does not enable the application of any statistically based approach and does not enable a validation of any susceptibility assessment made using other, physically based methods.

The available data on seismically triggered landslides in Portugal is summarised in Table 1 and Figures 1 and 2.

Table 1 – Summary of the earthquake triggered landslides reposted in mainland Portugal. Main data adapted from Vaz (2010) and Vaz and Zêzere (2016).

ID (Vaz and Zêzere, 2016)	Date	Earthquake magnitude	Local intensity	Localization (description)	Localization at the slope scale	General lithology (1:500,000 scale)	Geological categories (adapted from Delgado et al. 2011a)	Type of landslide (Keefer 1984)
1	382	7.5 (1)	-	Islands SW of Cape St. Vincent	No	Limestone/marble	Undefined	Undefined
2	28 January 1512	6.3 (1)	-	Vila Quente, Lisbon	Approximate	Stratified sedimentary and volcanic rock	Marly/clayey formations	Flow/lat. spread
3	26 January 1531	7.1 (1)	IX (4)	Rosa Convent, Lisbon	Approximate	Stratified sedimentary and volcanic rock	Marly/clayey formations	Flow/lat. spread
4	-	-	IX (4)	Forno Street, Lisbon	No	Superficial deposit	Alluvial sediments	Coherent?
5	-	-	VII (4)	Alcaçovas	No	Other volcanic rock	Volcanic soils	Coherent?
6	22 July 1597	5.7 (1)	-	Bica, Lisbon	Yes	Stratified sedimentary and volcanic rock	Marly/clayey formations	Coherent
7	13 April 1620	4 (1)	-	St. Catarina Hill, Lisbon	Yes	Stratified sedimentary and volcanic rock	Marly/clayey formations	Disrupted
8	24 June 1626	4 (1)	-	Alfândega Quay, Lisbon	Approximate	Superficial deposits	Alluvial sediments	Coherent
9	1 November 1755	8.7 (2)	VII (5)	Casal de São Simão	Approximate	Quartzite	Jointed rocks	Disrupted
10			VII (5)	River slope (Coimbrão)	no	Superficial deposits	Alluvial sediments	Disrupted
11			VII (5)	Serro Ventoso	no	Limestone/marble	Jointed rocks	Disrupted
12			VII (5)	Alegrete	Approximate	Schist and greywacke	Jointed rocks	Disrupted
13			VIII (5)	Trancão River	Approximate	Stratified sedimentary and volcanic rock	Jointed rocks	Disrupted

14	1 November 1755	8.7 (2)	VIII (5)	Cais de Pedra, Lisbon	Yes (Mineiro, 2005)	Superficial deposits	Alluvial sediments	Coherent
15	-	-	IX (5)	Trafaria	no	Superficial deposits	Alluvial sediments	Coherent?
16	-	-	VIII (5)	Rocha da Pena	Approximate	Limestone/marble	Jointed rocks	Disrupted
17	-	-	IX (5)	Penhão Fortress	Yes	Limestone/marble	Jointed rocks	Disrupted
18	12 January 1856	6 (1)	-	Nobles college, Lisbon	Approximate	Stratified sedimentary and volcanic rock	Marly/clayey formations	Disrupted
19	23 April 1909	6 (3)	VII (6)	Leiria Castle	Approximate	Stratified sedimentary and volcanic rock	Jointed rocks	Disrupted
20	-	-	IV (6)	Serro Ventoso		Limestone/marble	Jointed rocks	Disrupted
21	-	-	V (6)	Ventas do Diabo (Mira de Aire)	Approximate	Limestone/marble	Jointed rocks	Disrupted
22	-	-	VIII (6)	Tagus Islet	no	Superficial deposits	Alluvial sediments?	Disrupted?
23	-	-	VIII (6)	Tagus River	no	Superficial deposits	Alluvial sediments?	Disrupted?
24	-	-	VI - VII (6)	Tera River	no	Superficial deposits	Alluvial sediments?	Disrupted?
25	-	-	IV (6)	Barão Mount	no	Superficial deposits	Alluvial sediments	Coherent
26	28 February 1969	7.5 (1)	VII (7)	N. Sr.a da Rocha beach	no, M65? ou M66? Marques (1997)	Stratified sedimentary and volcanic rock	Marly/clayey formations	Disrupted
27	-	-	VII (7)	D. Ana beach	no, M157, 158, 159? Marques (1997)	Stratified sedimentary and volcanic rock	Marly/clayey formations	Disrupted
28	-	-	VII (7)	Sagres	no, J27, 28, 29? Marques (1997)	Stratified sedimentary and volcanic rock	Jointed rocks	Disrupted?
-	1 November 1755?	8.7 (2)		South of Praia do Telheiro	Yes (Marques, 2001, 2005)	Stratified sedimentary and volcanic rock	Jointed rocks over marls	Coherent

(1) Martins and Mendes-Victor (2001) (2) Delgado et al. (2011b) (3) Teves-Costa et al. (1999) (4) Justo and Salwa (1998) (intensity MSK)
(5) Baptista et al. (2003) (6) Choffat and Bensaúde (1912) (Mercalli Cancani scale) (7) Mendes (1970) (Rudolph scale).

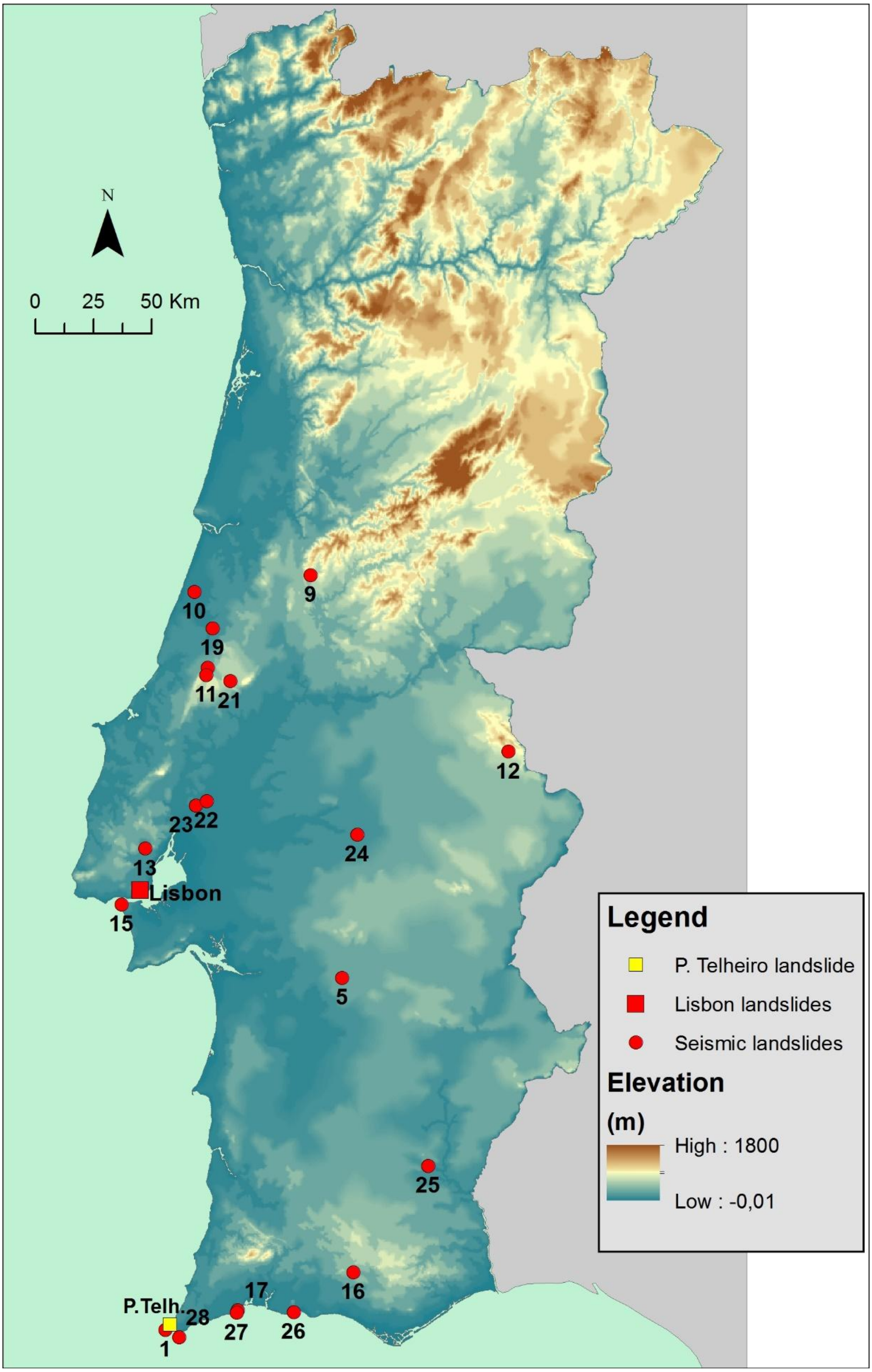


Fig. 1 – Seismically triggered landslides in mainland Portugal (adapted from Vaz and Zêzere, 2016). Landslides indications in Table 1 and Lisbon area landslides in Fig. 2.

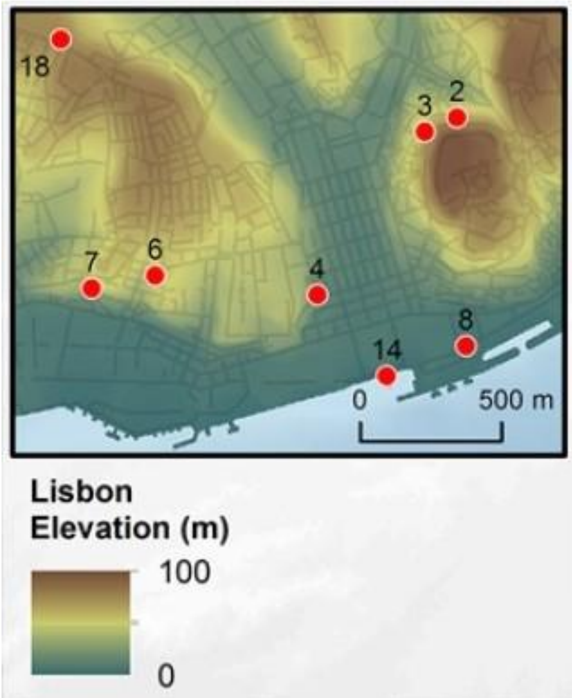


Fig. 2 – Seismically triggered landslides in Lisbon area according Vaz and Zêzere (2016). Landslides indications in Table 1.

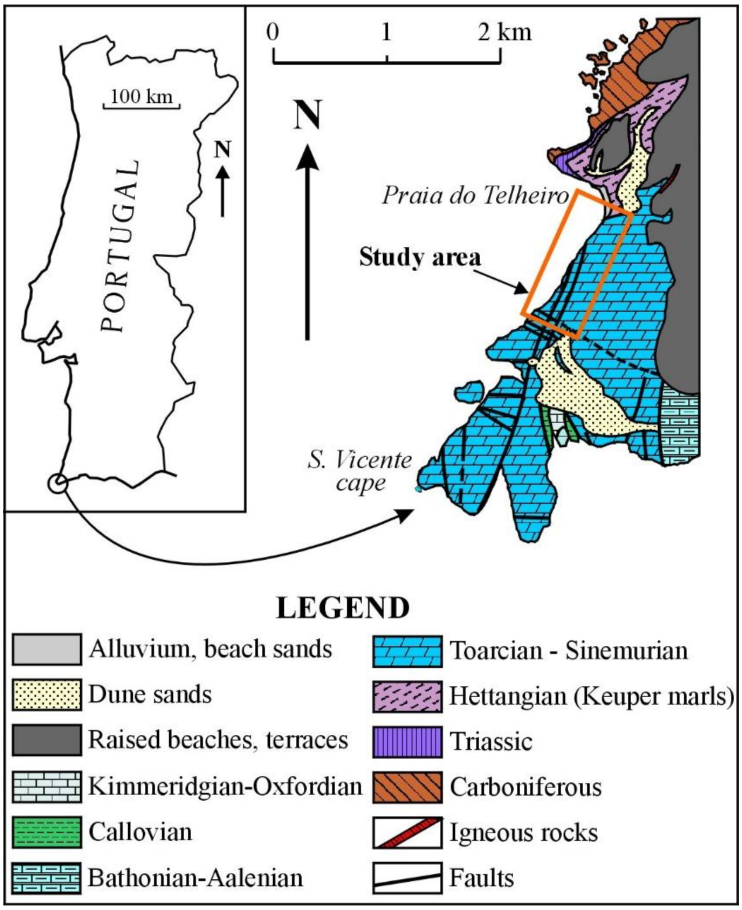


Fig. 3 – Localization and geological setting of the Praia do Telheiro landslide (Marques, 2001, 2005).

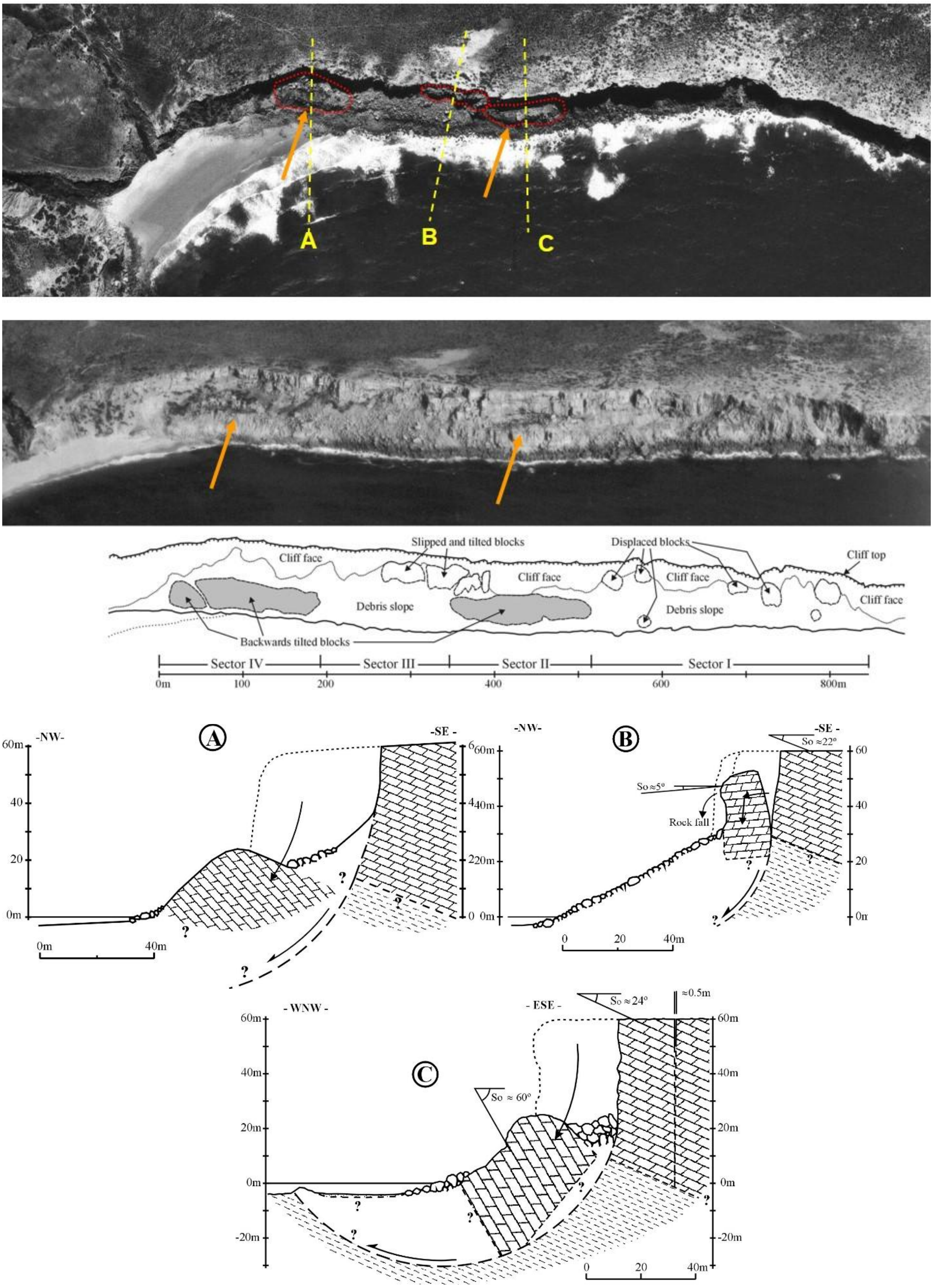
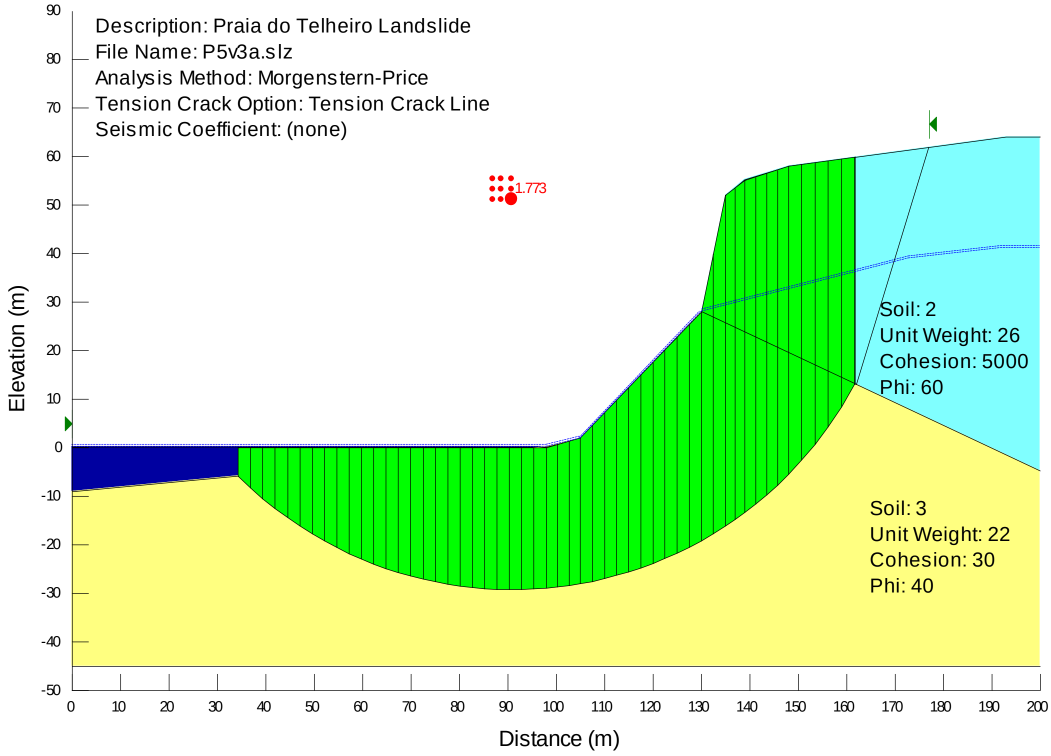


Fig. 4 – From top to bottom: Vertical and oblique aerial views and sketch of the landslide with localization of the cross sections A, B and C (Marques, 2001, 2005).



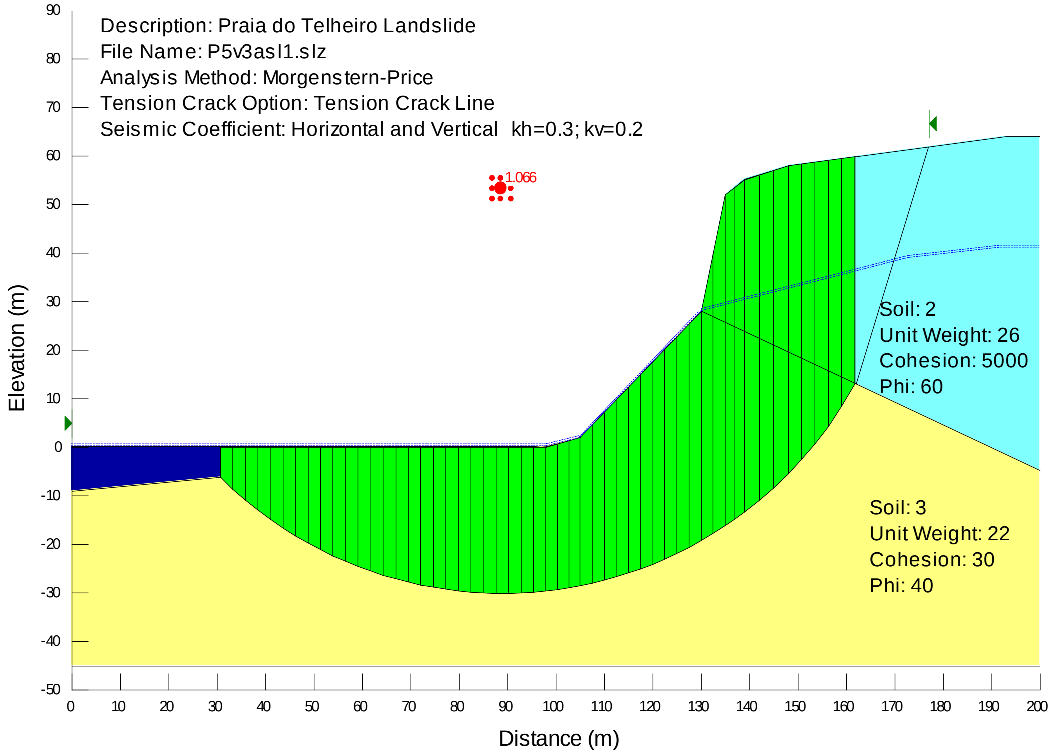


Fig. 5 – Example of backanalysis of the landslide without (top) and with pseudostatic coefficients compatible with the 1755 earthquake of the cross section A in Fig. 4 (Marques, 2005).

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