7

THE LISBON EARTHQUAKE OF 1755 *VS.* VOLCANO ERUPTIONS AND DRY FOGS – ARE ITS *"METEORIC"* DESCRIPTIONS RELATED TO THE KATLA ERUPTION OF MID OCTOBER 1755?

Gaston R. Demarée
Øyvind Nordli

There will be famines and earthquakes in various places.
(Matthew 24: 7)

Un jour tout sera bien. Voilà notre espérance. Tout est bien aujourd'hui. Voilà l'illusion.
(Voltaire, Poème sur le désastre de Lisbonne)

ABSTRACT

The authors consider different sources and views related to the *"meteoric"* observations of the Lisbon earthquake. The literature explicitly mentions the appearance of a dark cloud, smell of sulphur and a yellow fog or smoke. It is now well known that such manifestations may be related to large volcano eruptions and consequently the transport of tephra or volcanic ash by atmospheric circulation. However, the accounts of the fatal earthquake of Lisbon containing evidence of *"meteoric"* appearances were steadily interpreted by their authors either as observations in line with Aristotle's *"Meteorologica"* or as prognostications from the Bible. Nevertheless, other accounts testify to the emerging new vision of scientific ideas in the spirit of the Enlightenment.

The *"meteoric"* occurrences fitted well in Aristotle's theory, still the dominant scientific theory on earthquakes at that time. In that view subterranean caverns containing large amounts of gases loaded with sulphur and bitumous matters, are set afire and produce tremors and earthquakes. At the same time, exhalations are freed through cracks and fissures and witnessed as sulphurous gases. Another explanation is taken from the Bible where the wrath of God, punishing the people for their numerous sins and godless lifestyle, is mentioning the same appearances.

However, as Aristotle's view on earthquakes belong now definitely to the history of seismological sciences, a new explanation of these "meteoric" appearances needs to be found. Therefore, the authors of the present paper suggest a possible connection with the Katla eruption of mid October 1755 where large masses of tephra were sent into the atmosphere and possibly transported by atmospheric circulation to the Iberian Peninsula.

Earthquakes, Katla volcano eruption in Iceland and its ensuing tephra fallout in October 1755

Katla volcano, located near the southern end of Iceland's eastern volcanic zone, is hidden beneath the 200-700 m thick Mýrdalsjökull ice cap that fills a caldera of about 70 km^3. It has erupted in historical times, on average, twice a century producing damaging glacier-outburst floods, or jökullhlaups, whose peak volumes can be compared with the River Amazon.

On the 10th September 1755 heavy earthquakes started to occur in northern Iceland, but most violently near Húsavík and on the island Flatey[1]. What follows is taken from the account of several natural scientists who witnessed the earthquakes at the farm Höfði in Skágafjarðarsýsla in northern Iceland[2]. The first shock was noticed at 8 o'clock in the morning as a relatively strong movement of the ground. It was moving five or six times at either side, but without damage. At 9 o'clock another movement occurred much more intense than the previous one and also all later ones. Much noise was also heard. The earthquakes lasted for six days. Before the beginning of these earthquakes there was about 14 days of fair weather without much wind, which is very unusual at this time of the year. This may in a certain way agree with what the old people in Iceland unanimously tell and take for truth, that earthquakes always have brought a "thick" air and mild and fair weather.

The earthquake had its largest effect on the uttermost headlands rather than on the mountains that are situated inland of Iceland. From this the natural scientists concluded that the earthquake's epicentre was situated at sea. They further believed that the earthquakes were connected to the Katla volcanic eruption that was to come.

Katla erupted on 17 October 1755. It started with incessant earthquakes before noon. An enormous jökullhlaup started in the evening and lasted all night. The southeastern part of the Mýrdalssandur outwash plain was flooded. This time, the jökullhlaup seemed to be more devastating than previous ones in 1625, 1660 and 1721. The "Annals of the Katla eruptions" mention that farms were destroyed due to flooding, tephra fallout, sand and pumice stones. Both grass and bush disappeared under ash that led to abandoning about 50 farms, and all farms in western Skaftafellssýsla County were heavily damaged. In the vicinity of the volcano the thickness was four to six feet deep in cavities in the gardens whereas in the farthest areas from the volcano it varied from one or two feet on flat surfaces.

On the 18 October 1755, the earth was like stunned and the sky full of clouds and fog so that one couldn't see the mountains but lightnings flashed through the darkness accompanied by frequent roaring, bangs and earthquakes but not so strong as on the first day.

The eruption produced much ash that was brought over most of the country, and brought also over a long distance at sea. The following wind directions were observed

O Terramoto de 1755_1.pmd 118 03-04-2007, 11:00

that could transport the ash: on the 19th and the 20th October NW (the day became dark to the east of Mýrdalsjökull due to the smoke of the eruption). The 21st October NE, the 22nd was the culmination of ash fallout. On the 23rd – 28th October the wind was northerly and northeasterly so that the dust was blown far to the south. In the period 28th October till 7th November there was low visibility and the eruption was only seldom seen, but could be heard. Both the earthquakes and the downfall of ash diminished during that period. However, on November 17th a strong eruption occurred again with a release of melting water. This was the last large eruption. Now and then until New Year 1756 some fire was observed and a greyish fog. In 1756 there were some weak eruptions but on 12th and 13th August Katla again sent a lot of ash and again covered Skaftártunga. The fire was again seen in fair weather on 25th August.

The lack of visibility is vividly described as follows:

> "Smoke, sand and ash that the mountain throw out fill the air in such a way that the sun's rays and the daylight could not penetrate. Three Danish miles away from the mountain, when there was no wind on the 22nd and 23rd October, it was never more than half illuminated, and on the 24th one had to light the houses from 2 o'clock in the afternoon. Where it was windy, the ash and the sand fell down in streams like the most intense rain, and caused such a darkness that people who went together in the fields were not able to see each other, and had to take hands of each other for not getting separated. […] At some places the darkness was told to have been lasting for 8 days. The strong wind in the mountains had already spread a layer of as far as Mùlasýsla, 50 Danish miles away, so that travellers could not find the road and had to wait, and in the houses at midday they could not see the smallest daylight."

Tephra fallout was noticed on the Shetland Islands as has been reported: *" […]; only on Monday the 20th October last, betwixt the hours three and four in the afternoon, the sky being very hazy, as it uses to be before a storm of thunder and lightning, there fell a black dust over all the country, tho'in greater quantities in some places than in others. It was very much like lampblack; but smelled strongly of sulpher. People in the fields had their faces, hands, and linen, blackened by it. It was followed by rain. Some people assign the cause of it to some extraordinary eruption of Hecla. Several other persons of credit and reputation had seen and observed the same phænomenon in different parts of the country at the time above-mentioned."* The wind direction at the time of the black dust was from the SW[3].

Another letter, dated Edinburgh, 10 Feb. 1756, mentioning black dust comes from a passenger on board of the ship belonging to Mr. David Loch, merchant in Leich, and bound for Charlestown in South-Carolina: *"We are informed, that upon the night of the 23rd or 24th of October last, when the weather was quite calm, a shower of dust fell upon the decks, tops and sails of the ship, so that next morning they were covered thick with it. The ship at this time was betwixt Shetland and Iceland, about 25 leagues distant from the former, and which was the nearest land. The shower was probably owing to the great eruption, which happened to the mountain Hecla in Iceland, in October."*[4]

HISTORICAL BLACK CLOUDS AND DRY FOGS

During historic times Icelandic volcanoes have erupted large volumes of ash, some of its appearances were noticed all over Europe and are known as *"Dry Fogs"*. The dry fogs could have the appearance of dark black clouds providing a most dreadful impres-

O Terramoto de 1755_1.pmd 119 03-04-2007, 11:00

sion[5]. It was quite evident that the appearance of such a cloud was interpreted as an omen of the worst.

The best-known example is given by the Lakagígar eruption of the year 1783[6]. Around Midmorn on Whitsun, June 8th of 1783, in clear and calm weather, a black haze of sand appeared in the Sida area of southern Iceland. The Lakagígar, the Laki fissure or also named the *"Skaftáreldar"* or Skaftá Fires, volcano eruption had begun. Soon after, a haze was spun out like a veil over much of the Northern Hemisphere, persisting for periods up to three months and more.

Jacob Crisóstomo Pretorius, an early Portuguese meteorologist, reported: *"Porém o que faz este anno[1783] mais novatel entre muitos passados, foi o tempo nevoado do veraõ. Desde 22 de Junho até 6 de Julho houve por tempo de 14 dias huma nevoa permanente de dia e de noite, e pouco tempo depois desde 12 de Julho até 20 succedeo o mesmo por espaço de 8 dias: e o que he ainda mais de reparar, o mesmo tempo nevoado reinou na maior parte do nosso Hemisferio Boreal. Mas naõ obstante esta continuada nevoa, e algune nevoeiros, foi/soi todo o Veraõ muito secco: bem se/fe pode chamar extraordinario que por tempo de 70 dias, desde 19 de Junho até 27 de Agosto naõ chovesse, fóra daquella pouca humidade dos ditos nevoeiros: ainda que esta falta de chuva sosse/fosse depois bem compenssada …"*[7]

However, Pretorius did not make any relation to similar occurrences at the occasion of the Lisbon earthquake of November 1755.

Another less known example of dry fog appearing in Western Europe occurred in June 1721. A pale white sun, without rays, looking like the moon, obscured by a transparent fog appeared in Paris on the 1st of June 1721, on Whitsun Day. Cassini saw the same phenomenon in Picardie while Chevalier de Louville (Jacques Eugène D'Allonville, 1671-1732) had heard that it was also seen in Auvergne and in Milan. It was noticed as very singular that the fog that had caused this appearance had to have a large coverage and had to be very uniform[8]. Wiedeburg[9] quotes a German reference of observations of the sky on the 1st June 1721. It is tentative to ascribe this optical phenomenon to the Katla eruption of 11 May 1721; this eruption lasted for more than 100 days.

As the Lisbon earthquake, occurred soon after the large Katla volcanic eruption in Iceland on October 17, 1755, and tephra fallout was demonstrated on the Shetlands and over the Atlantic Ocean, it was suggestive to search for descriptions similar to Pretorius' observations.

The weather conditions at Lisbon

In this section, in line with the 18th century natural scientists, the weather conditions extracted from contemporaneous writings before and on the day of the earthquake are given.

The general weather conditions at the moment of the fatal earthquake are given by Moreira de Mendonça: *"Sábado, primeiro de Novembro, e vigessimo oitavo da Lua, amanheceu o dia sereno, […] Pouco depois das nove horas e meya da manhãa, estando o Barómetro em 27 polegadas, e sete linhas, e o Thermometro de Reaumur em 14 gráos a cima do gelo, correndo hum pequeno vento de Nordeste, começou a terra a abalar*

O Terramoto de 1755_1.pmd 120 03-04-2007, 11:00

com huma pulsaçao do centro para a superficie, e aumentando o impulse, continuou a tremer formando hum balanço para os lados de Norte a Sul."[10]

Richard Wolfall, a surgeon in Lisbon writes: *"Since the beginning of the year 1750, we have had much less rain than has ever been known in the memory of man, excepting the last spring, which gave such a supply of rain, as has produced very plentiful crops: the summer has been cooler than usual, and for the last forty days, fine weather, without being remarkably so. […], for in about two hours after the shock, fires broke out in three different parts of the city, occasioned from the goods and the kitchen-fires being all jumbled together. About this time also the wind, from being perfectly calm, sprung up a fresh gale, which made the fire rage with such a fury, that at the end of three days, all the city was reduced to cinders."*[11]

João Mendes Saccheti, a Portuguese physician, wrote from the fields of Lisbon: *"This year has been with us very rainy and wet, the three preceding ones excessively dry, insomuch that some springs, formerly plentiful of water, were dried, and totally lost; at the same time the predominant winds were east and north-east, accompanied with various, though very small, motions or tremblings of the earth, and, in the year1750, we had a very sensible one. The day before the fatal earthquake the atmosphere, and light of the sun, had the appearance of clouds and notable offuscation, and more strong and visible at the actual time of the great shock, which was by undulation, and lasted from six to eight minutes. The weather was rather warmer than commonly we have it at this time of the year, and had continued so for several days before. In all this time were predominant the east and north-east winds. […] The earth opened in fissures in several parts, but neither fire or visible smoke came out of it."*[12]

Stoqueler, Consul of Hamburg, made the following observations at Colares, a town about twenty miles from Lisbon: *"The 31st of October the weather was clear, and uncommonly warm for the season; the wind north, from which quarter about four o'clock in the afternoon, there arose a fog, which came from the sea, and covered the valies; a thing very common in the summer, but rare in this season of the year. Soon after the wind changing to the east, the fog returned to the sea, collecting itself, and becoming the thickest I ever saw. As the fog retired, the sea rose with a prodigious roaring.*

The 1st of November, the day broke with a serene sky, the wind continuing at east; but about nine o'clock the sun began to grow dim, and about half an hour after we began to hear a rumbling noise, like that of carriages, which increased to such a degree as to equal the noise of the loudest canon, […] I observed from one of the hills called the Fojo, near the beach of Adraga, that there issued a great quantity of smoke, very thick, but not very black; which still increased with the fourth shock, and after continued to issue in a greater or less degree. Just as we heard the subterraneous rumblings, we observed it would burst forth at the Fojo; for the quantity of smoke was always proportioned to the subterraneous noise. This I saw continue till the noon of the 2nd of November, when I retired from the place where I had observed it. It continued to smoke some days longer, more or less, according to the subterraneous rumblings. […]

The 20th in the afternoon, being on the former spot, I saw a small fog coming from the sea (from the same quarter whence the smoke appeared), which smelt of sulphur; and the wind returning to the east, the fog retired to the sea; and in the morning of the 21st, about nine o'clock, we felt two shocks of an earthquake sufficiently violent, but no more smoke was seen. […] I went to examine the place, from whence I saw the smoke arise, but I did not discover from whence it could have issued; nor did I find any signs of fire

O Terramoto de 1755_1.pmd 121 03-04-2007, 11:00

near the place: from whence I infer, either that the smoke exhaled from some eruption or volcano in the sea, which the waters covered, or that, if it issued from some chasm in the land, it closed afterwards."[13]

Stoqueler rather inclined to the former opinion because of the movements of the waters. He observed the same prognostic in the afternoon of the 24th November but the fog wasn't so thick and no earthquake occurred in the following days.

Thomas Heberden (1703-1769), an English physician, writes from Funchal in Madeira: *"The season of the year has been more than ordinarily dry; the rains, which generally begin to fall the beginning of October, not having set in as yet (Nov. 10). The weather for some weeks preceding the earthquake has been very fine and clear, but the day previous thereto (October 31), was very remarkably fair and serene, as was the former part of the day on which it happened: but the afternoon was very dull and dark, the sky being entirely overcast with heavy black clouds: the subsequent day was very fair."*[14]

A letter, dated 19 November 1755, from a merchant of Lisbon to his correspondent at Paris states that: *"The air there had seemed heavy with a reddish and unhealthy fog at sunrise and at sunset in the last days of October. At the eve of All Saints, one noticed some light tremors that were forerunners of the shock that was felt the day afterwards at 10 o'clock in the morning."*[15]

However, most letters from Lisbon or from other places in Portugal and Spain report only the beautiful weather conditions the day of the fatal earthquake.

Mr. Plummer, a merchant in London, reports from Oporto that: *"during the time of the earthquake, and indeed preceding it, was heard a hollow dreadful noise, but I did not observe any disagreeable smell, or alteration in the air, the sky being serene as usual, and the after-part of the day without a breath of air."*[16]

Another author writes similarly: *"The day broke with a clear sky over this immense town … on the 1st of November"*.[17] The Rev. Charles Davy (1722-1797) witnessed the earthquake as follows: *"There was never a finer morning than the 1st of November; the sun shone out in its full luster; the whole face of the sky was perfectly serene and clear; and not the least signal of warning of the approaching event …"*.[18]

Judith Nozes published ten or so British eye-witness accounts, mostly by merchants, of the Lisbon earthquake. The calm weather just before the fatal earthquake is mentioned at several occasions. *"There I was sitting on the first Day of the present Month, about Ten of the Clock in the Morning, (the Weather being serene, and the Sky without a cloud in it), when I felt the House begin gently to shake […]. About Ten O'Clock, after Breakfast, the 1st of November, All-Saint's Day, […] A calm fine Morning; suddenly we found the House shake, and a great Noise like a Coach and Six driving by […]"*.

G. Rapin witnessed the calamities at Lisbon[19]. He published a book in Liège, capital of the Prince-Bishopric of Liège, expressing his ideas on the nature of the earthquakes, his personal account of the event and also a relation on what occurred in Cadiz. The weather on the fatal day is described as follows: *"On the 1st November, All Saints Day, at sunrise a thick fog dominated over the whole town, and apparently over all surroundings, but as the very scorching rays of the sun dispersed it, the air seemed to evaporate, and a great many persons complained and one could only breath with great difficulty, of a kind of exhaustion in which they were dozing despite themselves. The sea seemed itself moved by the great calm that reigned at that moment what seemed all the more so extraordinary to the sailors as they were used to see, especially at daybreak, a land wind that usually favoured the entry or exit of the harbour to the vessels."*

O Terramoto de 1755_1.pmd 122 03-04-2007, 11:00

Mr. Benjamin Bewich, merchant at Cadiz, reports: *"The day of the earthquake the weather was clear and serene as the finest summer-day in England"*.[20] Don Antonio d'Ulloa writes from Cadiz: *"The earthquake happened in very fine weather…"* .[21]

At Cadiz, the weather conditions were as follows: *"In the morning of the 1st November 1755, the horizon was clear and the sky without clouds. The wind not much considerable was at northwest, and remained there, not without one noticed anything else than a heat that wasn't exactly of the season. But as it wasn't very sensitive, one didn't pay too much attention"*.[22]

Rapin continues his description by the account of Gaudin, academician and mathematician at Cadiz, of what has happened in that town: *"On the 1st November at sunrise, the weather was clear and calm, with a moderate north-west wind. One noticed small clouds in the north. The atmosphere was in a good equilibrium through the height of the mercury in the barometer was at 28 "degrees" and 3 inches, and of an irregular behaviour, what could be observed by the 11 ½ degrees of a thermometer exposed outside while another one inside and well regulated showed 15 degrees at the same time"*.[23] Rapin explains in a footnote that these clouds at Cadiz denote the fog that prevailed at Lisbon (at a distance of several hundreds of km!).

Don Fernando Lopez de Amazúa describes the weather at Madrid as follows: *"The first of November, at daybreak, the same [north-west] wind still reigned, although with less violence. The sky was enough clear; the sun was only disturbed by a few clouds which, not covering it entirely, made its light from time to time a little bit pale"*.

How did evolve the weather on the days after the earthquake? Thomas Jacomb, a merchant, mentions that: *"On the 11th November 1755, several accounts of Eruptions in the Earth especially at Cintra near the Rock where much Flames and Sulphur were seen to evaporate"*.[24] From the 18th till the 22nd November 1755, there were some very heavy rains in Lisbon.[25]

Fiery red sunrises and sunsets were reported in various parts of Europe and over the Atlantic from November 1755 to January or February 1756. In Cornwall, England, on 1 November 1755 the sky full of fiery red clouds, in the afternoon becoming 'a very odd coppery colour in places'. Flame-coloured glow was noticed till 2 ½ hours after sunset in western Ireland on 1st November 1755.[26]

Moreira de Mendonça writes in his famous memoir on earthquakes: *"Em diversas terras foi visto hum vapor, como fumo, que sahia da terra, e causava hum grande defeito á luz do Sol, e da Lua. Na vespera do dia do Terremoto pelas cinco horas da tarde vi eu com grande admiração do adro da Igeja de N. Senhora da Graça esta Cidade cuberta de huma especie de fumo amarelo escuro, que me causou algum espanto pela densidade, e côr"*.[27]

The Gazeta de Lisboa of February 5th, 1756, writes*: "Alanquer [Portugal] 11. de Fevereiro. No primeiro dia do mez de Novembro do anno passado, pelas nove horas e meya da manhan, assoprando o vento quasi insensivelmente da parte do Noro-este, e achando-se o Orizonte desta Villa limpo de nuvens, ocupou repentinamente a athmosphera hum tenue, e futil vapor, que fazia parecer o Sol palido, e se percebeu hum calor nam ordinario, na actual estaçam"*.[28]

Sousa Moreira *et al*. mention further *"unusual gas exhalations (a kind of fog)"* at Alcalá, Spain, several days before the earthquake[29].

In the inquiry ordered by the Marquis de Pombal after the catastrophe sulphur or sulphurous gases are mentioned in the district of Aveiro[30]:

"…, ainda que algunz advertidos na primeira revolução do tremor afirmão que sentirão huma respiração Sulfurea, o mineral porem como não há maior evidencia que

O Terramoto de 1755_1.pmd 123 03-04-2007, 11:00

justifique a noticia, nada mais se acrescenta para as relaçois da historia." (Freguesia de Nossa Senhora da Apresentação).

"Apareçeo este memorando dia que suposto na çerenidade do tempo por claro não permitia o infelis suçesso suçeçuto, pois esta mesma quietação servio de emgano q quazi o mundo todo, de repente das 9 para as 10 horas da manhãa se ofuscou o ar com huma cor nunca vista pois nem imitava a tudo sombra, nem por funebre, se ouvio do Norte…" (Freguesia de S. Miguel).

"… – as Alampadas andavão em hum continuo movimento fazendo tudo hum tão formidavel spectacullo que cada hum entendia tinha chegado o fim da sua vida: sentiose hum fedor de Enxofre; porem pella infinita bondade de Deos não cahio caza alguma, …" (Concelho de Vagos, Freguesia de Covão do Lobo).

Similarly, in the aftermath of the 1755 earthquake, King Fernando VI of Spain ordered an enquiry to know the damages due to that earthquake. A large part of the information in Galicia came from the southern part of the region, this is the area adjacent to Portugal. The information from the jurisdiction of Celanova (Orense) contains the following information:

"Durante y pasado el temblor se advertió cubrir la Atmosphera de un bapor denso como humo espeso, que obscureció – estando el cielo claro y sin nubes – a la manera de un casi Central eclipse, la Luz del sol, quedando sus raios bien remisos, y su Luz pálida. Cuios vapores aun duran el día de Oy como una niebla fumosa, que a alguna distancia ocultan o ofuscan los objetos por bien abultados que sean, señal cierta de que la tierra por sus poros y bocas aun Vomita los malinos halitos de las exhalaciones subterráneas, que causan tantos movimientos en su pedado cuerpo, pues después del gran terremoto se han observado unos diez o doce momentáneos…". (11-XI-1755)[31].

More difficult to be related to the Katla volcanic eruption is the snowfall that was mentioned in the same enquiry in three villages of the Orense Province (South of Galicia): *"… la noche del día (18 de Octubre de 1755) con la occasion de caer una copiosa nieve…"* (Jurisdicción de Viana do Bolo. 11-XII-1755), *"Solo sí, cosa de quince días antes del dicho terremoto cayó una nieve en este dicho Valle y agregados tan copiosa, que arruinó la mayor parte de los árboles, …"* (Jurisdicción de Conso y sus cotos. 12--XII-1755), *"…el domingo (20 de Octubre) en que amanecieron desgajados la mayor parte de los árboles fructíferos e infructíferos de todo este país, del que resultó una ruina muy considerable con poca nieve que se vio dicho día veinte de Octubre".* (Villa de Orrios y su Jurisdicción y Partido de Souto Vermud. 5-XII-1755).[32]

It is questioned if this snowfall late October is an exceptional phenomenon or related to disturbances in the atmospheric circulation patterns due to the large amount of tephra in the atmosphere. Is it comparable to the remarkable frost observed in England[33] on the 23rd of June, 1783, a few days after the Lakagígar eruption?

Several optical phenomena indicative of large volcanic eruptions were witnessed in the Iberian Peninsula:

"On the 23rd of October, at Olias (near Malaga, Spain), luminous exhalations.

At the foot of the Pyrenees, one could see a bright reddish light that lasted several hours and that was repeated every night until the 27th.

On the 29th, at Olias, very luminous exhalation in the night.

At Hueva (S.W. Spain), three other luminous exhalations at three different hours and during three different nights.

31st of October and the foregoing night, at Lillo in Spain (Castillo-La Mancha), in clear weather one could smell a bad smell. At Olias, the light of the candles was offus-

O Terramoto de 1755_1.pmd 124 03-04-2007, 11:00

cated by the exhalations.

At Seville, one has seen several times a thick fire-colored cloud in the night in the western part of the horizon and that lasted longer than half-an-hour each time.

On the 1st November, many falling stars were seen in many places in Spain; the sun seemed pale at Almagro, Jaén (Spain); one smelled at Damiel (Ciudad Real, Spain) a smell of sulphur".[34]

Earlier tremors, movements of the water and tsunamis

Apparently, several contemporaneous authors mention earlier tremors in the day before the fatal earthquake. Similar conclusions might be drawn from the unusual state of the River Tagus in the early morning of All-Saint's Day. It might be hypothesized that this unusual state of the river is due to seiches caused by these tremors that were hardly felt by the Lisbon people.

"On the eve of All-Saint's Day, one noticed some light tremors that were precursory to the shock that was felt next day." [35]

"He also said that the Tage has had a considerable rise in the water level that had preceded the earthquake…"[36].

"Yesterday, first day of November, at about nine o'clock in the morning, one came to tell me that the Tagus, prodigiously swollen, attracted the attention of a great number of people. The one that brought me this news, didn't have the time to speak, when I felt the wooden floor of my room tremble under my feet."[37]

Lopez de Amezúa (1756) notes at Madrid: *"In the night of the last day of October, a horrible wind blew from the north-west. Religious figures and some individuals […] assured that they felt some tremors at midnight."*

Moreira de Mendonça writes: *"Na misma noite se ouviu o mar summamente embravecido, postoque o tempo estrava muito sereno. Experimentou-se o ar quente com hum calor, que a estação não permittia. Multiplicárão-se em breves horas os signais da grande fermentação, que se estava fazendo no interior da terra."*[38]

Earthquakes, exhalations and volcanoes[39]

Until the late 18th century Aristotle's *"Meteorologica"* still remained the principal source of meteorology (or what was being considered as meteorology by that time). Indeed all sub-lunar manifestations such as winds, earthquakes, thunder; lightning, exhalations, and even falling stars are considered as "meteors". This term is used in that way here. Vapours, named *exhalations,* occur in the lower stratum of the atmosphere that is the region where meteors defined by the action of the air including winds, earthquakes, thunder, lightning, etc. are taken place.

Under the earth, subterraneous caverns full of inflammable gasses, loaded with sulphurous mixtures, nitrous and bitumous matters, etc. strongly interact and explode. This causes exhalations through the cracks. These exhalations are sometimes witnessed as sulphurous vapours and, are described to condense as falling stars in the higher regions[40].

By the beginning of the 18th century, several physicists started to make observations and asked the question *"whether there follow not great winds, rains, thunder and light-*

O Terramoto de 1755_1.pmd 125 03-04-2007, 11:00

ning after the earthquake is over". For centuries, generations of physicists and meteorologists took this sentence as a working programme. The atmospheric conditions preceding an earthquake could be disputed as it turned out quite naturally, but the question was never abandoned. The latter consequently provided plentiful of weather descriptions[41], data now treasured by the historical climatologists.

It was believed that earthquakes generally begin with calm weather, and a black cloud. And when the air is clear, just before an earthquake, yet there are often signs of plenty of inflammable sulphurous matter in the air[42].

Boni dealing with historical and philosophical account of the doleful events of the year 1755 states that: *"The air then cleared from dimness and fogs, and also anticipates earlier the tremblings many times, and we have the example of this in the earthquake fatal to Lisbon and to the rest of Portugal, and so widely spread over Spain, and over a so large part of Europe…"*[43].

A good example of the description of meteorological conditions accompanying earthquakes is provided by the account of the earthquakes felt in Livorno, Italy, from the 16th to the 27th of January 1742:

"The 16th of January was a very temperate Day, with a gentle Breeze between South and West: […] However, I saw this Cloud, which passed with a bad Smell; […] However, I saw this Cloud, blacker and thicker than the rest, settle within a Foot and an half on the Tops of the Houses, like the Smoke that the Peasants make in an Evening, when they burn their Garden Rubbish, or such-like. […] We may observe here, that some Earthquakes happen in cloudy, some in serene, some in still, and other in quite stormy Weather. The 16th of January [1742] at Night, was Snow and Clouds, as above-noted, with a very Small South Wind from Midnight to Break of Day; the fogginess turned into Clouds, which afterwards became Sleet and Snow. […] There was a strong Smell of Sulpher in the Streets. This Smell was likewise found in the Water of some Wells. The Sea was seen in sundry Situations, now high, and then presently very low again; sometimes strongly agitated, and at others on a sudden calm"[44].

All "meteoric" ingredients are present in this account of the Livorno earthquakes in the year 1742. Again, all these "meteoric" actors were noted at the Lisbon earthquake, true or not true.

Rapin sees the subterraneous fires as the origin of the outbreak of the fires in the destroyed town after the shocks. *"One wasn't able to witness, because of the clearness of the day, that by its openings the earth vomited fires which set afire the combustibles of several houses, […] from where a thick smoke, that could be seen in other places, announced together with the impetuous winds which suddenly arose, the general fire of the whole town"*[45]. However, most probably, the falling of burning candles or kitchen fires under the churches and houses caused these fires. Indeed, a large part of the population was in the churches and monasteries to celebrate the religious festivities of All Saints Day.

Rapin following the scientific theories of his time wrote: " *The Earth that had opened itself under the foundations of the houses of the town, vomited at the same time bituminous and sulphurous matters, which catching fire by syncope, in the openings or otherwise the cracks, exhalations evaporated that weakened the strongest hearts".*

Moreira de Mendonça writes*: "Ventos empetuosos, e continuados:*

Nascem estes das muitas exhalações secas que a terra emana, e estas procedidas do fogo que se acha em movimento, indicão bastantemente a proximidade de algum tremor de terra"[46].

O Terramoto de 1755_1.pmd 126 03-04-2007, 11:00

The last words of this treatise are the following: *"Este signal he equivoco. He verdade, que ao ultimo Terremoto precedêrão grandes ventos no verão antecedente. Estes havia mais de hum anno que se sentião tormentosos por todo o Reino de Portugal, e suas costas. Estes são os signaes que nos apontão varios Authores. Expuz as causas delles segundo o meu systema."*

THE TRADITIONAL RELIGIOUS VIEWS VS. THE ENLIGHTENMENT

The occurrence of some minor earthquakes that struck London in February and March 1750 left a terrorizing effect on the English that until then had considered earthquakes rather as rare and abnormal events[47]. These earthquakes raised their attention and when the Lisbon earthquake took place, it immediately had an immense response in England, the traditional ally of Portugal.

The hypothesis of the wrath of God for the sinful way of living of people was one of the constants in the literature that was occasioned by the dreadful Lisbon earthquake. Of course emphasis and views were different according to the authors whether they were Roman Catholics, Anglicans, Lutherans (in The Netherlands). In non-Roman Catholic media the brutal and bloody actions of the Inquisition in Portugal were denounced as one of the factors of the wrath of God.

One of the key players in the debate was without doubt Voltaire (François-Marie Arouet, 1694-1778) who, shortly after the earthquake, wrote his famous poem in which he expresses his Deist vision on the world and where God is not so much seen as an actor but rather as a spectator on what happens on this earthy floor.

One of the interesting voices was the French jansenist Laurent-Etienne Rondet (1717-1785) who claimed a justification of the Lisbon earthquake as Portugal being one of the countries where the Jesuits were very welcome. As a matter of fact, the Marquis de Pombal, the dictator that emerged from the earthquake shut down the Jesuit order in Portugal in 1762. Rondet wrote a two-volume treatise in which he tries to prove with biblical texts that all meteoric appearances could be seen as prognostications.

Rondet dedicated his work with the quotation *"He (=The Lord) looks at the earth, and it trembles (Psalm 104: 32)"*. The movements of the waters were explained as signs that redemption was near: *"On the earth, nations will be in anguish and perplexity at the roaring and tossing of the sea (Luke 21: 25)"*. According to the bible, the waters represent the people: *"The waters you saw are peoples, multitudes, nations and languages. (Revelation 17: 15)", "He turned rivers into a desert, flowing springs into thirsty ground, and fruitful land into a salt waste, because of the wickedness of those who lived there (Psalm 107: 33-34)".*

It is clear that the traditional views on the causes of the Lisbon earthquake collided directly with those of the Enlightenment. The Enlightenment scientists were putting more stress on "observation", "scientific evidence" and "change". However, the debate was still influenced by the Aristotelian view on earthquakes and one had to wait until new theories emerged. As a matter of fact, the Lisbon earthquake served as a laboratory for new seismological concepts. Authors like Immanuel Kant, Elie Bertrand, John Bevis, John Mitchell, and others, wrote soon on the subject.

O Terramoto de 1755_1.pmd 127 03-04-2007, 11:00

CONCLUSIONS

The Lisbon earthquake of November 1, 1755, is without doubt one of the most important landmarks of the 18th century. Not only, was it one of the earthquakes that has left a very deep impression on the general public in Western Europe by the size of its destructions but also by the blow that the catastrophe caused to the optimism of the Enlightenment philosophy. Immediately, a large number of letters, papers, pamphlets, books dealing with scientific, religious, political, philosophical aspects, or merely of an informative character, were published.

The authors have put together a number of quotations out of these contemporaneous publications of the earthquake related to the *"meteoric"* observations of the Lisbon earthquake. In these quotations, there is several times mention of the appearance of a dark cloud, smell of sulphur and even of a yellow fog or smoke.

In many cases, these mentions are in line with Aristotle's *"Meteorologica"* that was still largely the surviving scientific theory at that time. Another interpretation came from the religious point of view where the appearances dealing with sulphurous events were related to prognostications from the Bible. In this view, the earthquake was often seen as the wrath of God.

All these mentions are rather difficult to interpret and much caution should be given. It is not always clear if the authors write what was consistent with the dominant scientific and philosophical theory of their times or if it corresponds to factual information. However, the authors of the present paper are inclined to accept that part of the information do corresponds to facts. As Aristotle's *"Meteorologica"* belongs itself completely to the reign of the History of Science, another explanation had to be sought. It is suggested that these observations are related to the Katla volcanic eruption in Iceland of mid October 1755. Black dust fallout has been reported in the Shetlands and over the Atlantic Ocean by the late October 1755. Indeed, the time scale of the process of the injection of large amounts of SO_2 gases into the atmosphere, its conversion into sulphate aerosols and the transport of tropospheric aerosols (having a lifetime of 1 to 3 weeks) by the atmospheric circulation patterns is largely consistent with the observations on the Iberian Peninsula.

Furthermore, the quotations are widely consistent with the descriptions of the *"Great Fog of 1783"* corresponding to the Lakagígar eruption in Iceland[48]. Of course, the synoptic weather patterns in the second part of October 1755 could provide valuable additional information.

ACKNOWLEDGEMENTS

The authors express their sincere gratitude to Dr Isabel Maria Coelho de Oliveira Malaquias, Universidade de Aveiro; to Dr Domingo L. González Lopo, Universidade de Santiago de Compostela; Mrs. Maria Justina Correia, Instituto de Meteorologia e Geofisica at Lisbon, Dr Ana-Maria Spanoghe, University of Ghent; Dr Luci Hidalgo Nunes, UNICAMP, Brasil; Mrs. Franca Maria Vacante, Ghent; Dr Magnus Stefansson, Bergen University; Dr Alex Deckmyn, Royal Meteorological Institute of Belgium; Dr Mariano Barriendos Vallvé, Universitat de Barcelona and Mrs. Lina Nordlie, Oslo, for their valuable and precious help in the archival search, translation and editing. Thanks are also due to the Historische Drucke, Preußischer Kulturbesitz, Staatsbibliothek at Berlin and the Biblioteca nacional de España, Madrid.

O Terramoto de 1755_1.pmd 128 03-04-2007, 11:00

NOTAS

[1] Th. Thoroddsen, "Die Geschichte der Isländischen Vulkane (nach einem hinterlassenen Manuskript). Det Kongelige Danske Videnskabernes Selskabs Skrifter, Naturvidensk. og Mathem. Afd. 8", *Rekke*, IX, Kobenhavn, 1925.

[2] "Beskrivelse over det, i Island, den 11 Sept. 1755 paakomne Jordskiælv, og den derpaa, den 17de Octobr. samme Aar, fulgte Ilds-Udbrydelse af den forbrænte Bierg-Kløfte Katlegiaa udi Is-Bierget Myrdals-Jøkel; efter de sammesteds observerende Studenteres indsendte Beretninger. Det Kgl. Danske Videnskab", *Selsk. Skr.*, VII, 1758, pp. 185-196.

[3] A. Mitchell, "An Account of an extraordinary Shower of black Dust, that fell in the Island of Zetland 20th October 1755. In a Letter from Sir Andrew Mitchell of Westshore, Bart. To John Pringle", *Philosophical Transactions*, Vol. L, Part I, For the Year 1757, 1758, pp. 297-299.

[4] R. Whytt, "An Account of the Earthquake felt at Glasgow and Dumbarton; also of a Shower of Dust falling on a Ship between Shetland and Iceland; in a Letter from Dr. Robert Whytt, Professor of Medicine in the University of Edinburgh, to John Pringle, M.D. F.R.S.", *Philosophical Transactions*, Vol. XLIX, Part II, For the Year 1756, 1757, pp. 509-511.

[5] K.E.A. von Hoff, *Geschichte der durch Überlieferung nachgewiesenen natürlichen Veränderungen der Erdoberfläche. I. Theil. Vom Jahre 3460 vor, bis 1759 unserer Zeitrechnung. IV. Theil. Chronik der Erdbeben und Vulcan-Ausbrüche. Mit vorausgehender Abhandlung über die Natur dieser Erscheinungen*, Gotha, J. Perthes, 1840-1841.

[6] J. Grattan and M. Brayshay, "An Amazing and Portentous Summer: Environmental and Social Responses in Britain to the 1783 Eruption of an Iceland Volcano", *The Geographical Journal*, vol. 161 (2), 1995, pp. 125-134; R. B. Stothers, "The Great Dry Fog of 1783", *Climatic Change*, n. 32, 1996, pp. 79-89; G.R. Demarée, A. Ogilvie, Zhang De'er, "Comment on R. B. Stothers «The Great Dry Fog of 1783» (Climatic Change 32, 1996): Further Documentary Evidence of Northern Hemispheric Coverage of the Great Dry Fog of 1783", *Climatic Change*, n. 39, 1998, pp. 727-730; G. R. Demarée & A. Ogilvie, "Bons Baisers d'Islande: Climatic, Environmental and Human Dimensions Impacts of the Lakigígar Eruption (1783-1784) in Iceland", *in*: Jones *et al.* (eds.), *History and Climate: Memories of the Future*, Kluwer Academic / Plenum Publishers, 2001, pp. 219-246.

[7] Jacob Chrysostomo Pretorius, *Extracto Das observações Meteorologicas feitas em Lisboa nos annos 1783, e 1784 por Jacob Chrysostomo Pretorias Socio da Academia Real das Sciencias. Almanach para o anno de MCCCLXXXV*, Lisboa, Oficina Academia Real das Sciencias, 1785, pp. 267-276.

[8] *Histoire de l'Académie royale des Sciences. Année M.DCCXXI. Diverses observations de Physique générale*, 1723, pp. 25-26; G. Lapi, *Sulla caligine del corrente anno 1783. E sulla vigorosa vegetazione e fertilità delle piante del suddetto anno. Congetture di Giovanni Lapi Mugellano già publico lettor di Botanica o Direttore del giardino dei Georgofili di Firenze*, Firenze, 1783.

[9] J. E. B. Wiedeburg, *Ueber die Erdbeben und den allgemeinen Nebel 1783*, Jena, 1784.

[10] J. J. Moreira de Mendonça, *Historia universal dos Terremotos, ... Com huma narraçam individual Do Terremoto do primeiro de Novembro de 1755, (...) E huma dissertaçaõ phisica Sobre as causas geraes dos Terremotos, seus effeitos, differenças, e Prognosticos ; e as particulares do ultimo*, Lisboa, 1758.

[11] Letter II, *Philosophical Transactions of the Royal Society of London*, 1756, pp. 402-407.

[12] Letter IV, *Ibidem*, pp. 409-411.

[13] Letter VI, *Ibidem*, pp. 413-418.

[14] Letter XVII, *Ibidem*, pp. 432-434.

[15] *Recueil Fontanieu*, Bibliothèque Nationale Française, Paris, [Z Fontanieu 347(15)], pp. 341-348.

[16] *Philosophical Transactions (...)*, 1756, pp. 419-420.

[17] *Abregé succinct d'une infinité de maux lamentables & de dégâts déplorables que la violence & la conjuration des quatre elemens ont fait éprouver à la grande ville & à la cour de Lisbonne, le premier novembre de cette année. Traduction littérale de l'imprimé espagnol*, Orléans, 1756.

[18] E. M. Tappan (ed.), *The World's Story: A History of the World in Story, Song and Art*, vol. V, Boston, Houghton Mifflin, 1914, pp. 618-628.

[19] G. Rapin, *Idées générales et physiques Sur la Nature des Tremblemens de Terre, precedées De la Description des Calamités de Lisbonne, Par un Spectateur de ce Désastre avec La Relation exacte de ce qui s'est passé à Cadix le premier 9bre 1755*, Liège, 1757.

[20] Letter XIV, *Philosophical Transactions of the Royal Society of London*, 1756,pp. 425-427.

O Terramoto de 1755_1.pmd 129 03-04-2007, 11:00

[21] Letter XV, *Ibidem*, pp. 427-428.

[22] *Recueil Fontanieu*, *op. cit.*, pp. 366-371.

[23] G. Rapin, *op. cit.*.

[24] R. Macaulay, *They went to Portugal*, London, Jonathan Cape, 1946.

[25] Letter III, *Philosophical Transactions of the Royal Society of London*, 1756, p. 408.

[26] H. H. Lamb, "Volcanic dust in the atmosphere; with a chronology and assessment of its meteorological significance", *Philosophical Transactions of the Royal Society of London*, series A, vol. 266, 1970, pp. 425-533.

[27] J. J. Moreira de Mendonça, *op. cit.*, p. 237.

[28] Courtesy of Isabel Maria Malaquias.

[29] Victor Sousa Moreira *et. al*, "Review of the historical seismicity in the Gulf of Cadiz area before the 1 November 1755 earthquake", *in*: M. Stucchi (ed.), *Historical Investigation of European Earthquakes, Materials of the CEC project Review of Historical Seismicity in Europe*, vol. 1, CNR – Instituto di Ricerca sul Rischio Sismico, 1993, pp. 225-235; see also H. Woerle, "Der Erschutterungsbezirk des grossen Erdbebens zu Lissabon. Ein Beitrag zur Geschichte der Erdbeben von Hans Woerle", *Münchener Geographische Studien*, 8. St., München, Theodor Ackermann, 1900.

[30] See basically E. Costa, *O terramoto de 1755 no distrito de Aveiro*, separata do vol. XXII do *Arquivo do Distrito de Aveiro*, Aveiro, 1956, pp. 5-110 (courtesy Isabel Maria Malaquias); but also L. Runa & A. G. Morais Freire, *The Earthquake of the 1st November 1755 in Portugal - Present Position of the Researches – Transcrições das respostas dos párocos ao inquérito do Marquês de Pombal. O sismo de 1755. Segundo as respostas dos Párocos das sedes dos concelhos dos districtos*, Aveiro, Instituto Nacional de Meteorologia e Geofísica, 1987; and Victor Sousa Moreira *et al*., *op. cit.*.

[31] Archivo Histórico Provincial de Orense, Sección del Archivo Municipal de Orense, Caja n° 291 (courtesy Domingo González Lopo, Universidade de Santiago).

[32] *Ibidem*.

[33] J. Cullum, "An account of a remarkable Frost on the 23d of June, 1783", *Philosophical Transactions*, vol. LXXIV, part II, 1784, pp. 416-418.

[34] G. de Montbeillard, *Liste chronologique des éruptions de Volcans, des tremblements de terre, de quelques faits météorologiques les plus remarquables, des comètes, des maladies pestilentiennes, &c. jusqu'en 1760…*, tome VI, Paris et Dijon, 1761, pp. 488-651.

[35] *Recueil Fontanieu*, *op. cit.*, p. 344.

[36] *Ibidem*, p. 351.

[37] *Lettre d'un officier portugais à un de ses amis à Paris (sur le tremblement de terre de Lisbonne ; ainsi datée: du lieu où a existé Lisbonne ce 2 novembre 1755)*, s.l., s.d..

[38] Moreira de Mendonça, *op. cit.*, p. 237.

[39] The text of this section owes very much to the book of Vladimir Jankoviæ, *Reading the skies – A cultural History of English Weather, 1650-1820*, Manchester, Manchester University Press, 2000.

[40] Ortiz Gallardo de Villarroèl, *Lecciones entretenidas, y curiosas, physico-astrologico-metheorologicas, sobre la generacion, causas, y señales, y varios efectos del sucedido en España en el dia primero de Noviembre del passado de 1755*, Sevilla, Imprenta Real de la Viuda de D. Diego de Haro, s.d.; Vladimir Jankoviæ, *op. cit.*.

[41] See e.g. K. E. A. von Hoff, *op. cit.*.

[42] Cfr. Vladimir Jankoviæ, *op. cit.*, p. 182.

[43] G. Boni, *Delle luttuose vicende dell'Anno MDCCLV. Racconto istorico, e filosofico con una dissertazione sopra il tremuoto*, Milano, Carlo Ghislandi, 1756.

[44] *Philosophical Transactions (…)*, 1744, pp. 77-90.

[45] G. Rapin, *op. cit.*.

[46] Moreira de Mendonça, *op. cit.*,, p. 260.

[47] T. D. Kendrick, *The Lisbon Earthquake*, Philadelphia & New York, Lippincott Company, 1957.

[48] See Demarée and Ogilvie, *op. cit.*.

O Terramoto de 1755_1.pmd 130 03-04-2007, 11:00

Both volcanic eruptions and earthquakes are our planetâ€™s mechanisms to insure a stable equilibrium pressure. By venting excess pressure built up within our planet thru volcanic eruptions , geysers, and earthquakes, the earth insures that it will not explode into total annihilation. Another analogous example would be what happens when holding a lit firecracker. If you hold it on the palm of your open right hand, when it goes off it will sting, you may even get first degree burns.Â When pressure is released,magma explodes to the surface causing an eruption. The lava from the eruption cools to form new crust. Over time, after several eruptions, the rock builds up and a volcano forms. Now how volcanoes erupt. Volcanoes erupt when magma rises to the surface of the volcano. Volcanoes are commonly believed to be the causes of catastrophes and destruction. These fire-breathing dragons of earthly terrain invoke different feelings in people. Thereâ€™s even a number of disaster movies about volcanic eruptions.Â When the chamber is completely filled, the surplus of magma comes up to the surface through the volcano channels. The processes inside the magma chamber. Due to reduction of temperature, the magma inside the reservoir crystallizes gradually, sinks to the bottom, displaces the lighter molten rocks, and forces them out into the upper part of the chamber.Â Its splashes can also cause the volcano eruption. This process is unpredictable and can happen at any time. The processes above the magmatic chamber. The 1755 Lisbon earthquake, also known as the Great Lisbon earthquake, impacted Portugal, moreover the Iberian Peninsula and Northwest Africa on the morning of Saturday, 1 November, Feast of All Saints, at around 09:40 local time. In combination with subsequent fires and a tsunami, the earthquake almost totally destroyed Lisbon and adjoining areas. Seismologists today estimate the Lisbon earthquake had a magnitude of at least 8.4 on the moment magnitude scale, with its epicenter in the Atlantic Ocean... Video: 1755 The Great Lisbon Earthquake. There were three distinct quake shocks over a ten minute period. The first shock was followed by an even more powerful second shock which sent buildings toppling down.Â The eyewitness account of the Lisbon earthquake and its aftermath by Rev. Charles Davy, a survivor of this great Lisbon disaster, makes horrifying reading. Only the 1906 San Francisco earthquake is comparable in its economic and psychic impact. Image: The Ruins of Lisbon.Â The Lisbon earthquake, the first to be studied scientifically for its effects over a large area, can be said to be the slap that led to the birth of modern seismology and earthquake engineering.