THE CAUSES OF 1755 LISBON EARTHQUAKE ON KANT

FILOMENA AMADOR
Universidade Aberta, Lisboa

Abstract

The Lisbon earthquake produced great reactions among some European naturalists and philosophers. Kant wrote several essays about this subject in which he tried to develop a model to account this kind of events. In our opinion, analysing these papers linking them to other two Kant's texts, "Physische Geographie" (1802) and "Allgemein Naturgeschichte und Theorie des Himmels" (1755) could improve the understanding of some Kant's geologic statements.

Introduction

Lisbon's earthquake of 1755 aroused great shock and interest in scientific community of the last eighteenth century. A lot of texts were published about this subject, not only descriptive essays but also interpretative works that sought logical explanations for this kind of phenomena. Kant (1724-1804) wrote several essays about this subject where he tried to explain why this event took place and provided evidence to demonstrate its natural causes. However, he has also gathered some moral conclusions of this sudden and calamitous event: "The contemplation of such dreadful events is edifying [lehrreich]. It humbles a man by showing him that he has no right, or at least that he has lost it, to expect convenient consequences only from the laws of nature, which God has ordered, an he also perhaps learns in this manner to perspect [einsehen]: that this arena [Tummelplatz] of his desires ought not equitably to contain the aim of all his views"[1]

1. Three essays on Lisbon's Earthquake in Kant's writings

The essays (three) about Lisbon Earthquake[2], dated of 1756, can be included in the 'pre-critical' writings, a set of writings preceding his main philosophical texts[3].

[1]This reference is a translation of Stephen Richard Palmquist (revising Richardson, 1799), 1994 (http://www.hkbu.edu.hk/~ppp/fne/essay1.html). All the other references in English are translations of REINHARDT, O. and OLDROYD, D.R., 1983, "Kant's Theory of the Earthquakes and Volcanic Action"*, Annals of Science*, 40, 247-272. In this paper the authors present a full translation of the most important parts of these articles. In the footnotes all the references are in the original languages of the texts consulted.

[2] KANT, I., (1756a) *Von den Ursachen der Erderschutterungen bei Geleggenheit des Unglucks, welches die westliche Lander von Europa gegen das Ende des vorigen Jahres*

In our opinion analysing these papers and linking them to other two Kant's texts, *Physische Geographie* (1802) and *Allgemein Naturgeschichte und Theorie des Himmels* (1755), could improve the understanding of some geologic statements. We begin our analysis putting in relief some particular features of these last texts that justified its use in our commentaries. Regarded as an important text, *Allgemein Naturgeschichte und Theorie des Himmels*, has been fundamentally analysed by authors interested in its philosophical significance. However it hasn't quite often had a similar attention from science historians. The fact that Laplace hasn't cited Kant, probably by unknown, when he presented the nebular hypotheses to explain the development of the universe out of an original chaos, firstly suggested by Kant in this book[4], can probably contribute to a smaller recognition. The fact that this text has been written in the same year of the Lisbon's earthquake essays suggest a conceptual proximity that can help to understand and appreciate some geological statements. On the other hand, *Physische Geographie*, published for the first time in 1802, has a particular situation in Kant's writings. It had written in parallel with the development of critical philosophy. This book was organised to give a global vision of all the things that would exist on the Earth, but it's fundamentally a set of lecture notes that will be enriched during the years[5].

The end of seventeenth century was marked by the decline of the Cartesians cosmologies. In opposition to the vortice models, defended by Fontenelle and Huygens, appeared, at the time, the universe models influenced by Newton's ideas, based on the law of the gravitational pull. Despite the Cartesians criticism that associated this attraction to a distance force, so re-introductory of occult forces in the explanation of natural phenomena, the Newtonians ideas ended to prevail on the European continent in the early/middle eighteenth century. When Kant began his

betroffen hat (*Kant's Werke*. Druck und Verlag von Georg Reimer. Berlin, 1902. 11 Vols. *In*-8º *Vorkritische Schriften* I/1747-1756. Vol. 1).

KANT, I., (1756b), *Geschichte und Naturbeschreibung der merkwurdigsten Vorfalle des Erdbebens welches an dem Ende des 1755sten Jahres einen grossen Theil der Erde erschuttert hat* (*Kant's Werke*. Op. cit. Vol. 1).

KANT, I., (1756c), *Fortgesetzte Betrachtung der seit einiger Zeit wahrgenommenen Erderschutterungen* (*Kant's Werke*. Op. cit. Vol. 1).

[3] The first one was published in the *Königsberger Wöchentlichen Frage – und Anzeigungs - Nachrichten* and the second (a series of short articles) were issued in the form of a forty-page pamphlet in quarto by the Königsberger publisher Hartung. The third essay was published in the Königsberger weekly (REINHARDT and OLDROYD, 1983).

[4] But we could also refer two other reasons to justify this situation: the non continuity given, by Kant, to the " theory of the Earth " and also the fact that he has neglected a fundamental physical principle, the conservation of the kinetic moment.

[5] Kant began his academic activities in 1755 and he lectured in his huge professional life 49 courses of physical geography, what is after logic and metaphysic the discipline more lectured by Kant.

graduate studies (≈ 1740) the Newtonian mechanics had already been imposed, not only in methodological levels but also on conceptual levels. Kant entered the University of Königsberg six years later the creation of the Academy of Berlin (1746) that marked the victory of Newtonian conceptions in Germany and the re-discovery of Leibniz. In spite of the Newton's book importance, *Philosophiae Naturalis Principia Mathematica* (1687) that presents the first axiomatic physical theory and provides a new methodology, the fluxion calculus proposed in it had been surpassed by the infinitesimal calculus created by Leibniz. In practice either the Newtonianism or the Liebnizianism not being philosophically compatible, supplied the necessary instruments to study the nature. Kant's thought was formed in this period of discussion between the Newtonian and Leibnizian ideas (SEIDENGART, 1984).

Kant´s focus on physical forces to explain terrestrial phenomena and his concerns with new research methodologies, also in continuity with Galileu's ideas, are present in these essays: "the natural philosopher's obligation to the public is to give an account of the insights yielded by observation and investigation" (KANT, 1756a). However, he recognized that the inaccessibility of part of study object (the interior of the Earth) limited the methods used.

2. The "old history of the Earth", subterranean cavities and earthquakes

The idea of an outer crust crossed by labirynthic galleries was always present along Kant's essays. He found one prove of the existence of these subterranean passages in the sound that accompanies the earthquakes, similar to the sound produced by heavy carriages over cobble-stones. Besides this, the occurance of an earthquake, in the same day, in places as separated as Lisbon and Island, sign that some thing should connect them internally. In Kant's view these subterraneous galleries that linked all the regions, carried out a great importance in the course of the "old history of the Earth"[6]. In an initial phase the Earth was integrally a mass

[6] "En dépit de ces raisons, je présente cette explication comme une simple conjecture que je n'ose affirmer. Mon opinion véritable est a la suivante: dans l'état originaire de leur première formation, la rotation des planètes autour de leur axe correspondait assez précisément au plan de leur trajectoire annuelle, et des causes se sont présentées qui ont déplacé l'axe de sa première position. Un corps céleste qui passe de son état fluide primitive à l'état solide subit, lorsqu'il se forme complètement de la sorte, une grande transformation dans la régularité de sa surface. Celle-ci devient ferme et dure aussi longtemps que les matières plus profondes ne se sont pas encore sufissamment affaissées à la mesure de leur poids spécifique ; les sortes plus légères qui étaient entremêlées à la mesure de la planète finissent, après s'être séparées des autres, par aller sou l'écorce supérieur devenue solide, et produisent de grandes cavités dont les plus grandes et les plus vastes se trouvent, pour des raisons qu'il serait trop long de développer ici, au-dessous de l'équateur ou dans son voisinage ; l'écorce en question finit par se précipiter dans ces cavités et produit de multiples inégalités, des montagnes et des cavernes" (KANT, 1984, pp. 126/127). Kant argues that doesn't exist a central fire in the Earth, but melting materials, because it doesn't exist the air

fluid, a chaos in which all the elements (air, earth, water, etc.) were mixed and melted. Later the Earth began to cool, starting from the upper crust, and air and water ascended from the centre to the crust. As a result of this process cavities and passages were formed under the crust already solid[7]. Then, many of these structures suddenly collapsed and the upper materials of the crust fell on the floor, creating an irregular terrestrial surface formed by mountains and valleys (basins). These last ones, sometimes, of great dimensions, were swamped by water that also ascended to the surface. In some cases the water submerged into the Earth again, leaving vestiges of its presence in the mountains. In Kant´s view (1984) all these alterations in the terrestrial crust generated discontinuities that caused changes in the axis of rotation of the Earth.

On the other hand, the mountains[8] are more frequent in Ecuador and its proximities because in these places the materials suffer a centrifuge force larger to the suffered for the materials located in the poles (KANT, 1755). Kant, following Newton's[9] ideas, thought that this crust asymmetry was resulted of materials attraction and rotation movement of the Earth. Newton calculated the flattening of the terrestrial ellipsoid considering two liquid columns in balance, communicating in the center of the Earth, driven one to the pole and another to the Equator. The equality of the weights of these two channels implied that the column that went to the Ecuador, in which the weight had decreased due to the centrifugal force, was longer than the column that went to the pole (DEPARIS & LEGROS, 2000).

The mountains were formed by broken terrestrial crust, being that surrounded by fissures. So, the margins that limit the seas today are walls of old galleries that fell

necessary for combustion (KANT, 1999, § 48): “Il est tout à fait vraisembables qu’il reste une masse molle en son milieu. On peut même supposer que si la Terre était totalement dure elle cesserait d’être habitable. Car de l’intérieur montent des vapeurs qui lui donnent sa fertilité" (*ibid.,* § 49).

[7] Later, in *Physische Geographie,* Kant also refers : “Les grottes sont la plupart du temps dês cavités avec ses voûtes et des galeries plus au moins grandes. Leur formation est due tantôt au passage de l’eau, et tantôt à des éruptions de feu souterraines" (KANT, 1999, § 47).

[8] Kant (1999, § 42) classified the mountains in rocky/veined mountains and sandy/layered mountains. The first ones preceded the seconds in time.

[9] Concerning to the form of the Earth Kant follows Newton: the figure of the Earth is determined by gravitational pull and rotation movement. “Si les planettes n’avaient point le mouvement journalier de rotation autour de leur axe, elles doivrent être sphériques à cause de l’égale gravité de leurs parties. Le mouvement de rotation fait que les parties quis’éloignent de l’axe font effort pour monter vers l’équateur. Et par conséquent, si la matiére dont elles sont composées était fluide, son élèvation vers l’équateur augmenteroit le diamétre de ce cercle, & son abaissement vers les Pôles diminueroit l’axe" (*Principia*, Book III, Proposition XVIII). Kant (1999) also refers the works of Huygens, although his preference for Newton's explanations is obvious.

and formed valleys (Fig. 1). These collapses were more frequent in the torrid zones. Kant (1999) supposed that this was the reason to meet the highest mountains and the seas of larger dimensions in these regions.

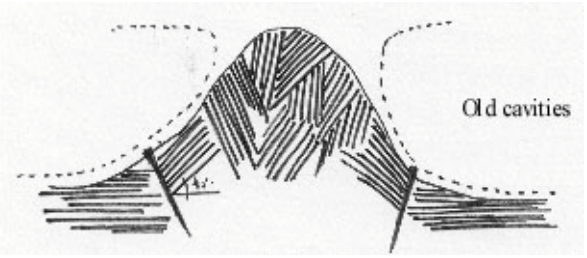


Figure 1 – Mountains and galleries.

KANT (1756a) also refers that the "direction of the caverns is parallel to the direction of mountain ranges, and, by a natural connection, the great rivers also. For these occupy the lowest parts of long valleys contained of the both sides by parallel mountains. This is also precisely the direction in which earthquakes usually extend". Some recommendations result out of this type of statements: "if it is permitted to humans to use foresight in [face of] such terrible catastrophes, if it is not regarded as an audacious and futile effort to oppose general misfortune with some measures suggested by common sense, then should not the unhappy survivors [Überreste] of Lisbon take [due] precaution in rebuilding along the lenght of the same river, which indicates the direction along which earthquakes must naturally occur in that country?". So, "the catastrophe at Lisbon thus seems to have been exarcebated by its position along the banks of the Tagus. And for this reason, any town in a country where earthquakes have been experienced several times, and where their direction can be known from [previous] experiences, should not be planned in a direction that is the same as that of the earthquakes" KANT (1756a). It wasn't possible to establish any causal link between these statements and the project of reconstruction of the city of Lisbon, but it's probable that this type of suggestions, proceeding not just from Kant but also from another authors who have contributed to a reconstruction of the one part of the city according to an axis transverse to the River Tagus (Fig. 2).

Figure 2 – Detail of map of Lisbon showing rebuilt plan on rectangular grid (copper engraving, France, 1785).

But, there are also other characteristics of the galleries that in Kant's view influence the direction of the earthquakes (KANT, 1756b). If the overlying strata are horizontal they will just move on the perpendicular, down and upward. But, if they are inclined towards a side the force of the underground fire will be impelled on the direction of the strata inclination. But actually it would be difficult to predict the direction in which the ground would be shaken by an earthquake because normally we haven't a knowledge of the disposition of these internal layers and yet, due to the fact that they aren't probably plane, they have in its surface several elevations and depressions.

3. Earthquakes: chemical and mechanical causes

In these articles KANT (1756a/b) argued that the subterranean conflagration of some materials is the main cause of the earthquakes[10]. KANT (1756a), following

[10] Later, in *Physische Geographie* (KANT, 1999), he already hasn't a firm opinion about this subject. We think that he changed his opinion. He affirms that the amounts of sulfur that has been found are not enough to explain the chemical phenomenon, it's necessary to think in mechanical causes (*ibid*., § 51). However, these mechanical causes seem to be associated to the pressure exercised by underground gases that behaves as an elastic fluid that seeks an exit for the surface. Kant attributes the origin of these underground gases to the fact of the Earth still not have reached its maturity and continue to exist a movement of the lightest matters towards the surface. But in Kant's view (KANT, 1756b) the earthquakes don't only might arise due to the ignition of subterranean materials but also to the propagation of underground gases.

Nicolas Lémery's[11] ideas, refers, about this subject, two experiences; the first one used iron filings and powdered sulphur. Putting a mixture of these compounds under the ground and by wetting it we can produce chemical actions that simulate volcanic and seismic activity. He doesn't have doubts that these compounds exist inside the Earth. Kant also refers one second experience in which he uses vitriol, iron filings and water. He also hasn't any doubt that the vitriol and the pieces of iron exist inside the Earth. Starting from this type of comments he associates the volcanic phenomena to the earthquakes, asserting that the existence of a volcano helps to free underground gases and to reduce the seismic risks, only " if a volcano were open up in the mountains of Portugal it could become an early indication that the misfortune was gradually going to disappear " (KANT, 1756a).

The combustions ("fermentations") would happen mainly in caverns located in mountainous areas because are larger and this would facilitate the formation and the circulation of gases. It results of the previous argument too (on the location and direction of the galleries) that the earthquakes would be more frequent in mountainous zones and in the great rivers valleys. KANT (1756b) also enhanced other aspects: "the earthquakes are determined by the nature of the subterranean caverns. And these follow the law according to which the collapses of the upper crust must have occurred in the beginning, in such a way that the closer they are to the equator, the deeper and more numerous are the indentations they had made, and as a result of which these mines containing the tinder [*Zunder*] for the earthquakes had become enlarged and consequently better suited to the ignition ".

On the other hand, he supposed that the subterranean caverns under the sea are the more narrowest and lowest, so the melted materials flowed down to these cavities. KANT (1756b) uses this kind of arguments to account the fact of the greater earthquakes have happened in places near the coastline, because the weight of overlying water drives the earthquakes to the nearest adjacent lands. In the case of Lisbon he asserts that the place of the ignition should be the sea floor. Mentioning Pierre Bouguer[12] Kant also agrees with him that the penetration in fissures of the marine water could facilitate and turn the combustions more violent.

In the third essay KANT (1756c) discusses another cause for the earthquakes: this could be due to the influence on the Earth of the particular configurations of the planets, specially the moon[13]. But, Kant strongly disagree with this hypothesis and he stated that these forces would not be enough to cause neither earthquakes nor

[11] French academician that was concerned in found the causes of the earthquakes.
[12] French academician.
[13] "... de um homem de ciência há mais que esperar. Não basta admitir uma causa para um efeito só porque ela costuma ter efeitos parcialmente semelhantes: é necessário que a causa seja proporcional ao efeito" (KANT, 1756c).

great movements of the water, it eventually only could provoke the combustion of materials inside the Earth. Furthermore, Kant argued that the Moon on the 1st November was at the last phase and this is exactly the moment in which the Newtonian theory the experienced teaches that the attraction is smaller.

4. The movement of the water

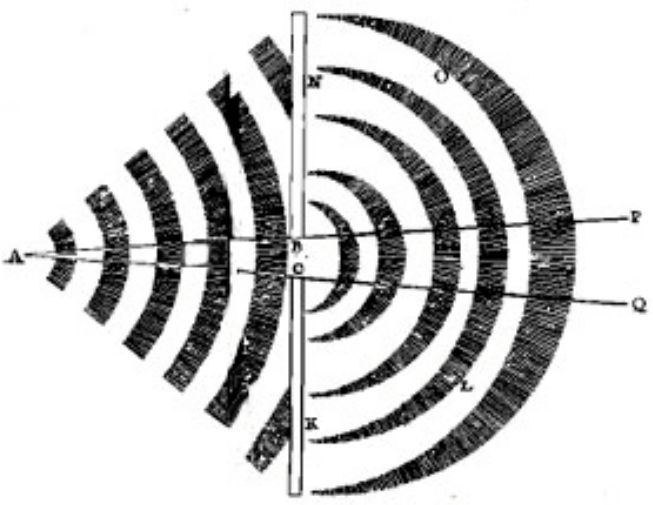
KANT (1756b) reported that "history has no example of a shaking of water over such a large part of the Earth in a few minutes" like this one that hit Lisbon on the morning of 1st November 1755 – All Saints Day. KANT (1756a) gathered that many authors are "inclined to suppose – and not without [good] reason – that the surging of the waters arose from a continued shaking that the sea received on the Portuguese coast, from the direct impact of an earthquake", but he found some difficulties in this explication: "I can understand that in a liquid any pressure must be felt throughout the whole mass, but how could the pressure of the water of the Portuguese sea still arise the water at Glückstadt and Husum by several feet, after spreading for several hundred miles?". He argued that there are two ways in which a liquid might be set in motion (KANT, 1756a), by:

- rising and faling, that is, in a wave-like manner (according to Kant this process insufficient to account for the event);
- a "sudden pressure that gives an impulse to a mass of water in its interior, and drives it away as if it were a solid body without giving it time to escape the pressure by means of a wave-like surges and [thereby] spreads its movement gradually" (in Kant's view is probably what happened).

These statements seem to be strongly influenced by Newton's ideas[14]. Kant thinks that the water was put in movement by a sudden and violent pressure and it

[14] *Principia*, Book I, Proposition XLII, T. XXXIII. "tout le movement qui a passé premierement par l'ouverture BC, commencera à se dilater & à s'éntendre en ligne droite de cette ouverture comme de son origine & comme d'un centre vers toutes les parties".

behaved as a solid body. If we regarded it as being enclosed in a channel with equal openings at each end we could think that its speed would be reduced at the inversely proportional rate to the distance of the beginning (epicentre). Furthermore Kant also argued that the movement spreads in circles in which the "circumferences" increase with the distance from the centre, but at the same time decrease the strength of the movement. The value of the morphology of the coastlines as agent that intensifies the dimension of the movement of the water[15] is a result of this kind of reasoning. The fact of Lisbon be placed near the Atlantic Ocean and the narrow estuary of Tagus River would have increased the strength of the tsunami (Fig. 3). Similar interpretation is used to explain the intensity of the effect observed in Holstein and in Denmark (5 feet a second): the proximity of the French and English coast (Mancha Channel) would have made increase the pressure of the waters that would have compensated the expected diminishing of the effect in these regions.



[15] In the peculiar case of Portugal, KANT (1756a) imagines that “the whole West coast of Portugal and Spain from Cape St. Vincent to Cape Finistere (about 100 German miles) was shaken, and that this quake extended an equal distance westward into the sea, then 10,000 square German miles of the bottom of the sea were raised by a sudden quake whose speed we do not exaggerate if we equate it with that produced by a powder mine which throws a body lying on it 15 feet into the air, and is thus capable (according to the principles of mechanics) of travelling 30 feet per second”.

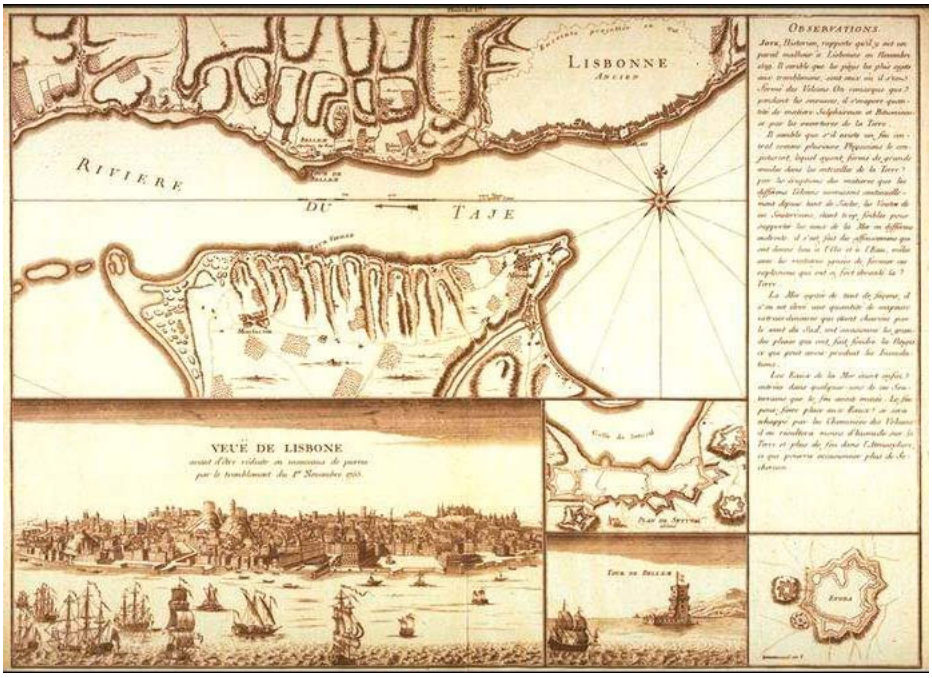


Figure 3 – Map and view of Lisbon before the earthquake (Stadt – und Universitats – bibliothek, Bern, Switzerland. Le Rouge, Georges- Louis, "Carte des environs de Lisbone de la bouche du Tage", Paris, 1756).
http//www.eerc.ber…/kozak_quake ?eq_id=5234&qn=Lisbon,+Portugal+Nov.+1,+175

But it's with perplexity that Kant recognizes that the movement spreads through the sea at larger distances than through earth and that interior lakes, without visible connection with the ocean (Templin in Norway), had been affected by the event. Consequently, in Kant's view this seems to be a strong evidence that exists an underground connection with the waters of the Mediterranean seas and the oceans. But, at the same time, Kant recognized that is difficult to say something with exactitude about a so rare event. It is possible that the movement of the seas comes from another causes.

REINHARDT and OLDROYD (1982) consider that these works were mainly derivative, without original theoretical suggestions and with little influence on subsequent writers, for all that we believe that these texts when analysed in an internal perspective continue to provide a rich material of analysis to the history of science despite the exhaustive work of these two authors.

Bibliography

BRAHIC, A. (2001) *Cinq leçons d'Astronomie. Planétes & Satellites*, Paris, Vuibert.

DEPARIS, V, and LEGROS, H. (2000) *Voyage à l'intérieur de la Terre*, Paris, CNRS Éditions.

KANT, I. (1984) *Histoire Générale de la Nature et Théorie du Ciel*, Librairie Philosophique J. Vrin, Paris. Translated to French by Pierre Kerszberg, Anne-Marie Roviello and Jean Seidengart.

KANT, I. (1756a) "Von den Ursachen der Erderschutterungen bei Geleggenheit des Unglucks, welches die westliche Lander von Europa gegen das Ende des vorigen Jahres betroffen hat" (*Kant's Werke*. Druck und Verlag von Georg Reimer. Berlin, 1902. 11 Vols. In-8º Vorkritische Schriften I/1747-1756. Vol. 1). "On the causes of earthquakes on the occasion of the calamity which befell the western countries of Europe towards the end of the last year", translated to English by Reinhardt, O. and Oldroyd, D.R., 1983.

KANT, I. (1756b) "Geschichte und Naturbeschreibung der merkwurdigsten Vorfalle des Erdbebens welches an dem Ende des 1755sten Jahres einen grossen Theil der Erde erschuttert hat" (Kant's Werke. Op. cit. Vol. 1). "History and natural description of the most noteworthy occurrences to the earthquake, which struck a large part of the Earth at the end of 1755", translated to English by Reinhardt, O. and Oldroyd, D.R., 1983. "Historia e descrição dos acontecimentos mais notáveis do terremoto que no fim do ano de 1755 agitou grande parte da Terra", translated to Portuguese by Luis Silveira.

KANT, I. (1756c) "Fortgesetzte Betrachtung der seit einiger Zeit wahrgenommenen Erderschutterungen" (*Kant's Werke*. Op. cit. Vol. 1). "Novas considerações acerca dos últimos abalos de terra", translated to portuguese by Luis Silveira.

KANT, I. (1955) *Ensaios de Kant a propósito do terremoto de 1755*, Lisboa, Câmara Municipal de Lisboa.

KANT, I. (1999) *Géographie*, Paris, Aubier. Translated to French by Michèle Cohen- Halimi, Max Marcuzzi and Valérie Seroussi.

NEWTON, I. (1966) *Principes mathématiques de la phisolosphie naturelle*, Jacques Gabay, Paris, 2 vol.. Translated to French by Marquise de Châtelet (1759).

REINHARDT, O. and Oldroyd, D.R. (1983) "Kant's Theory of the Earthquakes and Volcanic Action"*, Annals of Science*, 40, 247-272.

SEIDENGART, J. (1984) "Genese et structure de la cosmologie kantienne précritique" in *Introduction to Histoire Générale de la Nature et Théorie du Ciel*, Paris, Librairie Philosophique J. Vrin.