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Characteristics of earthquakes in the Mediterranean Sea and their effects, in Arab-Islamic heritage

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Abstract. Historical information on earthquakes is important and useful data in the earthquake prediction process and in determining the seismicity of an area. The Arab-Islamic heritage sources constitute a very important reference for such data.

The seismic events which this article refers to, cover a period from November 885 until January 1409. These events are cited in historical sources covering a period from the first half of the 12 Century to the beginning of the 16th century of the Christian era. The geographic, historical and literary sources, constituting the Arab-Islamic heritage that refers to earthquakes, cover a longer period, ranging from the very beginning of the 8th century, until the end of the 18th century.

In this article, we have focused on a variety of scientific heritage sources (books and letters in the natural sciences, travel books, a number of historical sources), which deal with earthquakes in the Mediterranean basin (especially in its eastern part). In addition to the definition and description of the phenomenon, these sources refer to many features of the earthquakes as their causes, types, intensity, strength, extension, material damage and human casualties; their recurrence and duration; As well as the phenomena associated with them, such as natural effects (such as tidal waves or tsunamis) and impacts on the landform.

Finally, it is important to note, contrary to what many historians of science think, that the Arab-Islamic civilization clearly contributed to the development of seismological thought. Arab-Muslim scholars have defined earthquakes and described them appropriately. They also tried to understand the phenomenon and to offer scientific explanations to it, far from the mysterious and mythical interpretations that prevailed in many parts of the world, in early and high medieval period.

Key words: Earthquakes – Islamic Heritage – Mediterranean – Causes – Genetic classification – impacts.

1; Introduction

Seismology relies heavily on trying to predict, so it needs a series of information and historical data that may help to calculate appropriate indicators of areas of weakness in the Earth's crust. Historical sources, yearbooks, books and letters on the subject can be considered as important sources in monitoring earthquake events. It should be noted that seismic events have received special attention in Arabic writings.¹

2; Earthquakes, description, types and causes of their occurrence

2.1 Description of the earthquake

Earthquakes have been described in traditional Arab-Islamic sources in different ways. The most interesting descriptions liken them to an underground vibratory movement that makes the earth undulate or to the trembling of a feverish body or

¹- Geological Encyclopedia. V: 4. p: 85.

to the movement of a sieve or even to the flapping of a bird's wings. Ibn Al-Aadim says about the earthquakes of the year 1138 (Ibn Al-Aadim, p. 113): «*On Thursday 13 Safar, a strong earthquake occurred, then another followed, and the earthquakes continued, so the people fled Aleppo to the outskirts of the country... and the earth was seen to ripple, and the stones on it were shaking like wheat in a sieve.*».

2.2 Causes of earthquakes

In ancient times, people attributed the occurrence of earthquakes to mythical and legendary causes, such as: the movement of the whale carrying the earth above she or the bull moving the earth he carries, from one horn to the other, after he is tired...

This remained widespread among men at least until the early and high Middle Ages.

The ideas of Greek philosophers represent some of the first scientific attempts to explain the seismic phenomenon. We cite mainly those of Aristotle in his "Meteorologies", in which he presented the ideas of his predecessors, specifying his point of view regarding their ideas.

Aristotle believed that there are two kinds of exhalations: a moist one, called vapor, and a dry one called pneuma. Pneuma is a common element in earthquakes and winds. In fact, the Earth produces a large amount of pneuma, either through its internal fire or externally, when it is heated by the Sun. Sometimes, the pneuma comes out completely and gives rise to the winds; sometimes it heads towards the interior of the Earth, where it accumulates and causes earthquakes; sometimes still, it is shared between the surface and the interior and can produce small earth tremors. This theory was taken up by Lucretius, Seneca, Pliny..., as well as all the encyclopedists of the Middle Ages (Isidore of Seville, Bede the Venerable...) (Poirier, 2008, p. 28).

Earthquakes attracted the attention of several Muslim scholars who attempted to explain the phenomenon scientifically, without simply reproducing the ideas of Aristotle and other Greek philosophers.

The Ikhwan Al-Safa (1995, p. 505) state, «Concerning the movements of the Earth, they come in three forms: some are like flashes of lightning, some are like eclipses, and others are like swaying back and forth. As for the cause of earthquakes, it arises from the repressed vapor within the earth, seeking to escape. It shakes certain parts of the earth, causing them to become agitated and tremble, much like a person with a severe fever trembles. When a fever rages within a body, accidental heat ignites, melting and decomposing it, transforming it into smoke and vapor escaping through the body's pores. The entire body or a part of it vibrates and quakes. The body remains in this state until these vapors and smoke escape, calming and settling. Similarly, parts of the earth move during earthquakes. Perhaps the earth's surface will crack open, and all these winds, smokes, and confined vapors will escape at once. The earth and its surroundings will collapse, falling into this abyss, just as the roof of a house collapses and falls into its foundation. ».

Hammudi Adnan (1986, p. 63) believes that the comparison between Aristotle's interpretation of earthquakes and that of Ikhwan Al-Safa, reveals fundamental differences between the two ideas, notably: the origin of wind (or dry vapor); wind accumulation factors inside the earth; As well as the heat source which transforms surface water into dry steam.

"Al-Shifa" encyclopedia is considered one of the most important sources of Arab-Islamic scientific heritage dealing with earthquakes. Indeed Ibn Sina devoted several paragraphs of the book "Minerals and Meteorologies" to discussing the opinions of the scientists and philosophers who preceded him. He also presented the main ideas and opinions that had been formed on earthquakes up to his time.

Ibn Sina Said (1965, pp. 20-21): «Regarding earthquakes, they are the result of a disturbance that exposes a portion of the Earth's surface as a reaction to what lies beneath it. Undoubtedly, the motion below the surface triggers a corresponding motion on the surface. The causes of this earthly agitation can be attributed to various factors: a potent, smoky vapor rushing like the wind; a liquefied body of water; an aerial force; a fiery presence; or

a terrestrial element. The fiery presence doesn't naturally form beneath the surface as fire, but is, without a doubt, a powerful smoke or a burning wind. Similarly, the terrestrial body doesn't undergo motion unless driven by a cause similar to its basic nature, making it the primary instigator of earthquakes. Concerning the windy element, whether it possesses fire or not, it must emanate from beneath the earth's surface, leading to the undulating movements of the earth in most instances. The aerial force, on the other hand, can only exhibit movement when influenced by external factors, such as the strong flow of water. In such cases, the air's blows it forcefully, as seen in collapses resulting from the erosion of pit and cave corners. These collapses fall downward, disrupting the air and the earth connected to it, and they also reach the surface if they land on a solid foundation. In essence, the primary agents of earthquakes are water and earth's movements, often mediated by the influence of the air. These are the various scenarios in which earthquakes can occur, driven by either strong winds or fiery vapors that set the earth in motion, and this is the most important aspect, either waters that flow at once, and this is the opinion of Democritus, or the collapse of certain pillars inside ».

Ibn Sina stated (1965, p. 21), «A compelling piece of evidence suggesting that engorged winds are a primary cause of earthquakes is observed in regions where earthquakes are frequent. In such areas, if numerous wells and canals are excavated to facilitate the release of accumulated winds and gases, the occurrence of earthquakes diminishes. ».

As for Al-Quazouini (2006, p. 145), he explained that earthquakes and subsidences subjected by the Earth are linked to the accumulation of vapors within its interior, «when these vapors are confined without any means of release, the entire earth's structure begins to tremble and become unsettled, much like a person's body in the grip of a severe fever due to the presence of trapped, decaying moisture within. This moisture ignites the body's natural reactions, causing it to melt and break down, transforming into vapor and smoke that escapes through the body's pores. The heat generated in the process causes the body to shake and quiver. This state persists until these substances find an outlet. In the case of earthq

uakes, the movements within the earth's parts are eventually quelled, and the earth's surface may crack open, allowing these confined materials to be released all at once. ».

These ideas can be considered as an interesting contribution to the development of scientific perception of earthquakes and the internal structure of the Earth. And these texts are of great importance in the history of seismology in particular and in the history of geology in general.

The most important of these ideas can be summarized as follows (Hammudi Aadnan, 1986, pp. 66-70):

- the causes of most earthquakes are found underground;
- the bodies that can move and make the Earth move are either gaseous (vapour), liquid, stone or fire. It is an inference that reflects an evolution of geological thinking regarding the Earth, its nature and what might be happening inside;
- these factors are of unequal strength and influence;
- according to Ibn Sina, the wind (one of the most important causes of earthquakes), is an internal, smoky, ardent and flaming wind that rushes with enormous force from the depths of the earth and does not depend on atmospheric factors; whereas the Aristotelian wind results from the dry vapor which bubbles in the depths, and it is a wind which depends on the atmosphere, the climate, the temperature of the sun, day and night, and the nature of the ground.

The engorged winds or the smoke, considered to be the cause of earthquakes, correspond well to the vapors and gases accompanying volcanic eruptions, as can be deduced from the speeches of Ibn Sina and Al-Quazouini. These would be the first texts relating to "seismic energy" residing inside the Earth.

The fall of meteorites from outside the Earth and their collision with the Earth's surface is considered one of the well-known causes of earthquakes, many of which have occurred in many regions of the Muslim world, have been recorded by many historians, such as: the

earthquake of Qums and Nishapur in the year 855 AD (Al-Yaacoubi², 1995, p. 312); And that of Damascus in the year 1505 AD (Al-Aaydarous³, 2001, p. 28).

Some Muslim naturalists; including Jaber bin Hayyan; believed that earthquakes were linked to astronomical phenomena (IBn Hayyan, 2006, p. 299).

This can be seen as an aspect of the influence of Greek thought on early Muslim scholars. But this decreased considerably with the development of seismic thinking among Muslims. Indeed, for Ibn Sina, astronomical phenomena no longer had any role in earthquakes.

It is clear from what it has been mentioned in the writings of scholars of Islamic civilization, such as: IBn Hayyan (721-813), Al-Kindi (805-873), Al-Farabi (874-950), Al-Hamadani (893-947), Ikhwan Al-Safa (10th century), Al-Biruni (973-1048), Ibn Sina (980-1037), Al-Quazouini (1203-1283), Al-Suyuti (1445-1505) and others, that the most important causes of earthquakes are: earth movements resulting from internal body movements; subsidence; And the impact of meteors against Earth's surface.

Basically, we can say that these reasons are the same as those known to seismologists of our time.

2.3 Types of earthquakes

Hammudi Aadnan (1986) believes that the first classification of earthquakes could be attributed to Ibn Sina (Avicenna). It is based on the criterion of genetic factors. Thus, Ibn Sina divided earthquakes into three categories: Collapse earthquakes; Subsidence earthquakes; and Volcanic earthquakes. In addition, Ibn Sina (1965, p. 22) developed a second classification, based on the nature of the tremor that causes the earthquake, according to which he distinguished: Quiver earthquakes in which the effect of the tremor is essentially vertical and rectilinear; Convulsive earthquakes, in which the effect of the tremor is lateral;

And "ladder earthquakes", in which the effect of tremors is both vertical and lateral.

3; Earthquakes' intensity and material damage

Earthquakes vary in strength and intensity. Historians have used several qualifications to point to this variation. Ibn Al-Atheer (1160-1233) described in *Al-Kamil Fi Al-Tarikh* twenty-nine seismic events, with four different descriptions, depending on the strength and intensity of the earthquake, such as: major (great), intense, big (large) and medium earthquakes.

3.1 Physical damage.

In addition to some imprecise qualifiers (enormous, terrible, major, intense, large...), Muslim historians, geographers and travellers, have described the material damage caused by many earthquakes, that can be taken into consideration to distinguish earthquakes according to their strength and their intensity⁴.

Among the many texts that mention seismic events and the importance of the material damage caused by them, we will content ourselves to the following texts:

- Ibn Al-Aadim (1996, p. 113) said about the Aleppo earthquake of the year 1138: «*Many houses collapsed in Aleppo, the fence was broken and the walls of the citadel shook.* »;
- Abu Yaela (1998, p. 206) says about the earthquake of the year 1157: «*The news came from the north, with what was very bad to hear and what his citation terrifies the souls, so that Hama and its castle collapsed and all its houses and homes...; As for Shayzar, its suburb was unhurt, except what was destroyed first; As for its famous fortress, it was demolished... As for Homs, its people had been evacuated to the outside and they were safe, their homes were destroyed and its castle was destroyed. As for Aleppo, some of its houses were destroyed, and its people left. As for its*

² - 9th Century ; Died after 905.

³ - 1570-1628.

⁴- As currently used in earthquake classification scales, such as the M.S.K scale, based on the nature of the physical damage to determine the intensity of an earthquake.

castles and strongholds that were far from it, to Jableh and Byblos, the horrific ruins affected it, and Salamiyah was destroyed, as well as what connected it to the area of Al-Rahba and its surroundings. »;

- Al-Maqrizi (2001a, p. 310) says about the events of the year 1169: «On Monday, the twelfth of Shawwal, after the sunrise, a huge earthquake occurred in Damascus, from which some of the balconies of the Umayyad Mosque collapsed, and the heads of the eastern and western minarets were cracked. And the northern minaret was shaking as the frond shook in the gale-force wind. ».

From the texts that I have been able to consult, it is possible to deduce some characteristics related to the intensity of earthquakes. The most important features that stand out can be summarized as follows:

- a great diversity in the intensity of earthquakes;
- a variation in earthquake intensity according to time:
- a variation in earthquake intensity according to location.

3.2 Human losses (table 1).

In addition to the material damage caused by earthquakes, we found in these sources, a keen interest in mentioning the figures related to the loss of life, caused by many of the mentioned earthquakes. The numbers of victims vary greatly from one earthquake to another, as the numbers ranged from one victim caused by the earthquake of March 4th 1287 in Cairo, to about 80,000 victims left by the Aleppo earthquakes in the year 1169

Author	Source	Time	Location	Number of Victims
Ibn Al-Atheer (1160-1233)	The Complete in History	November. 885	Cairo	1000 in one Day
Ibn Al-Atheer (1160-1233)	The Complete in History	March 25. 1068	Palestine & Egypt	25000 in Ramlah
Abu Yaala (1071-1160)	History of Abou Yaala			About 100 in Banyas And 100 in Al Kods
Ibn Al-Aadim (1192-1262)	Milk butter in the history of Aleppo	October 26. 1138	Al-Athareb	600
Al-Dhahabi (1274-1348)	History of Islam	1169	Aleppo	80000
Ibn Taghri Bardi (1410-1470)	bright luminous stars	1200	Nablus	30000
Al-Suyuti (1445-1505)	History of the Caliphs	March 4. 1287	Cairo	1 (chief judge)
Al-Maqrizi (1364-1442)	The way to know the Kings' countries	Jaunary 1409	Jableh	15

Table 1: Human losses caused by some of seismic events mentioned in historical sources

4; Earthquake intensity, duration and extension

4.1 Seismicity and its intensity for some regions.

Seismic activity varies in different regions and locations, the highest being found at the boundaries of convergent tectonic plates. It is understood from Al-Massaoudi's (896-957) talk about earthquakes (2006, p. 60.), that the Levant and the countries of eastern Anatolia are characterized by

the abundance of earthquakes and their extreme violence. This is consistent with the current reality and with the conclusions of recent seismic studies: Amos (1998), from Stanford University, compared the locations of 47 destroyed ancient cities of the eastern Mediterranean basin, with the epicentres of earthquakes that occurred in the region between 1900 AD and 1980 AD. It was found that almost all of these cities were located in areas that experienced violent earthquakes during the twentieth century (Fig 1).

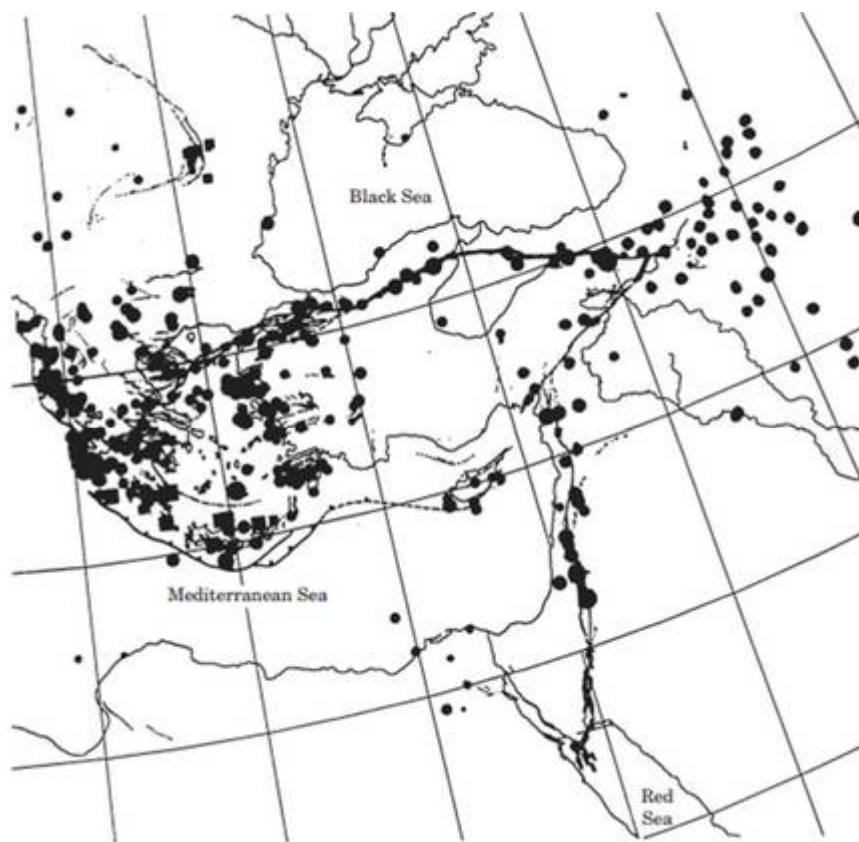


Fig. 1: The Eastern Mediterranean: instrumentally recorded earthquakes of magnitude 6.5 (Intensity VII and larger) in the period c. 1900–1980 (after Armijo, Deschamps & Parter, 1986) (in Amos, 1998).

4.2 Aftershocks and seismic durations.

In addition to documenting the extent of earthquakes, a great interest has been taken to recording information about the number of tremors and the duration of major seismic events and associated aftershocks.

The table 2 summarizes data related to the duration and the number of tremors that characterized a group of earthquakes mentioned in a number of Arab and Islamic heritage sources, and which concerned the Mediterranean basin.

Author	Source	Duration and number of tremors	Location	Time
Abu Yaala (1071-1160)	History of Abou Yaala	80 or 100 times from October 17 to November 05	Damascus	October-November 1138
Ibn Al-Aadim (1192-1262)	Milk butter in the history of Aleppo	80 quakes from October 16 to June	Aleppo	October-June 1138
Ibn Al Jawzi (1160-1201)	The Regular	10 times	Houlwane	December 2. 1149
Al-Maqrizi (1364-1442)	The Honafas' learnings...	From July 05 to August 1st.	Damascus	July-August 1170
Al-Suyuti (1445-1505)	History of the Caliphs	3 hours	Egypt	1247
Al-Suyuti (1445-1505)	History of the Caliphs	An instant	Cairo	March 4. 1287
Al-Dhahabi (1274-1348)	Biographies of the nobles	The time to read the chapter Al-Kahfe	Levant	April-May 1202
Al-Muradi (1760-1791)	Wire of pearls in the notables of 12 th century.	Twice or 3 times a week from October 29 to November 26.	Damascus	October-November. 1759

Table 2: Data on duration and number of tremors for earthquakes cited in Arab-Islamic Heritage sources

4.3 The extent and the superficies of the earthquakes

Among the important information contained in the Arab-Islamic heritage related to seismic events, we find data on the magnitude and on the extent of the earthquakes, so we can cite:

- the events recorded in some cities of the Levant, such as Damascus' earthquakes of the month of March of the year 1157 (Abu Yaela, 1998, p. 202);
- the events which affected most of the cities and regions of the Levant, such as Damascus' earthquake on Monday, the fifth July 1170 (Al-Maqrizi, 2001a, p. 310);
- the events, which were extended from Upper Egypt to the city of Alexandria, covered all the cities of the Egyptian coast and the rest of the Levant, and perhaps even reached Persia, like the earthquake of Monday 04 May 1139 at dawn (Al-Dhahabi, 2003a, p. 4205);

- and those whose extent was much greater, such as the earthquake in 1205, extending from Ceuta on the West Mediterranean coast to Mosul and Iraq. Al-Maqrizi (2018b, p.45) says: «*It was a great earthquake that spread most of the land of Egypt and the Levant, Al jazira, the countries of the Romans, Sicily, Cyprus, Mosul and Iraq, and it reached Ceuta in the countries of the Maghreb.*».

But concerning the area covered by earthquakes, the citations were very rare.

5. Earthquakes: Associated Phenomena and natural impacts

5.1 Phenomena and status associated with earthquakes

Seismic events generate a number of atmospheric and terrestrial phenomena. These phenomena can occur, before the earthquake; during it; or after it ends.

The sources that dated earthquakes did not neglect to talk about this aspect, and the most important of these phenomena and conditions can be summarized as follows:

- the occurrence of thunder and lightning before a great earthquake, which was heard and sensed from half a mile from Aleppo (Al-Maqrizi, 2018b, p.599);
- the eclipse of the sun accompanying a great earthquake that occurred in the land of the Romans (Al-Maqrizi, 2018b, p.1231);
- seeing smoke descending from the sky to the earth between sunset and the night's pray, in Damascus at the land of Qasr Atika, accompanying the earthquake of Karak and Shobak of the year 1212 (Al-Maqrizi, 2018b, p.49);
- a sequence of very loud sounds. The annoying loud thunder sounds that followed the earthquake tremors that took place in Hama in the year 1157, led to a number of deaths (Abu Yaela, 1998, p. 207);
- hot winds (called Samoume) blew with a hurricane. They lasted for three days after the earthquake which occurred in Egypt in the year 1192.

5.2 Effect of earthquakes on landforms

If the devastating earthquakes cause the collapse of many buildings and the death of many people, their effects extend to a range of effects on nature, which can appear quickly and directly (short-term effects) or be delayed for a long period of time (long-term effects). All of this has a clear impact on the outer shape of Earth's surface. We have traced an important number of impacts, mentioned in the sources that dated the most important seismic events, in the Islamic countries in general and in Egypt and the Levant in particular. They are as follows:

- raising/and lowering of areas and formation of hills because of this;
- slidings and horizontal transitions of land;
- cracking of the earth;
- falling rocks and lands' collapse;
- exploding of water springs;

- hiding of rivers and streams and their dispartition inside the earth.

5.3 The tsunamis

The tsunami phenomenon and its linking to earthquakes is very present in the Arab-Islamic heritage, as the texts of Al-Maqrizi (2018b, p. 1101), Al-Suyuti, Ibn Taghri Bardi and others. Al-Maqrizi (2001a, p. 192) says about Egypt's and the Levant's earthquake of the year 1069: «*And in it...the sea in Palestine disappeared from earthquakes, and it moved away from the coast about a day's walk, then returned over many many people who came out to gather from its land.*». Al-Suyuti (1997c, p. 314) also reports that Egypt experienced in August 1303 a great earthquake, «*Its impact in Alexandria was greater than elsewhere, and the sea rose until the half of the country, and the porters and men were taken, and the boats sank.*». It is to point, As Bacha (1997, pp. 60-61) precised, that a re-reading and analysis of these data can be useful in «*Understanding the tectonic state of the Mediterranean region and the potential for coastal areas to be affected by sea seismic waves (tsunami).*».

6. Conclusion

Referring to Western books and articles, which are interested to the history of seismic thought, we generally find an absence of the contribution of Islamic civilization in this field, by jumping centuries from the history of human scientific giving, as is the case with Ben-Menahem (1995) who tried to monitor the most important historical stations of the development of seismic thought until present and with Duncan Carr Agnew (Poirier, 2008, p. 4), who claimed that Muslim scholars during the Middle Ages, were only an echo of the Aristotelian seismic thought.

It must be noted that the Islamic civilization was not absent from this field. By referring to the known current sources, it is confirmed that the imprint of this civilization is very clear, whether it was at the level of theoretical contribution or at the level of historical contribution. El Ghalbi (2018, pp. 48-50) noted that it is possible to summarize the participation of Muslim scholars, like: Al-Hamadhani, Al-Kindi, Ibn Hayyan, Ikhwan Al-Safa and Ibn Sina

and others, in the development of seismic thought, to their contribution to the description and the determination of what earthquakes are, as well as to their contribution to understanding the phenomenon, its interpretation and its scientific explanation.

As for the historical sources and travel stories..., which dated many important seismic events in different regions, they provide many important and varied information and data, concerning the exact date of the seismic event and the hour of its occurrence, the number of its tremors,

the extent of its spread, the number of victims caused by it, its damages, its natural effects, its impact on landforms and the phenomena associated with it. This gives to these sources a great value and importance, as the extrapolation of historical data helps to evaluate the intensity of earthquakes. It also allows -Besides extrapolation of automatic seismic data provided by monitoring devices- the production of the seismic record of a specific region, which purpose is to study the seismic risk in order to reduce it (Fig. 2).



Fig. 2. General plan in seismology and tectonics (from Morabet Azroual, 2005)

In conclusion, it must be emphasized that establishing the origin or the beginning of seismology, allows to stand on the importance of studying heritage sources, in terms of correcting the history

of science and in terms of its role in understanding the nature of natural phenomena, which require accurate and documented facts of its long history (Basha, 1997, p. 61).

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