Earthquakes in ancient India

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Strong earthquakes in quick succession in the country have heightened the sensitivity of the common man towards this natural phenomenon. Effects of earthquakes can be so severe as to cause social and political upheavals apart from property damage. Thus mitigation of seismic risk in big cities is a matter of concern to engineers and administrators alike. All the current scientific approaches the world over, depend on historical records for estimating the seismic hazard in a given region. Unfortunately for the Indian subcontinent, reliable data on place and date are available for the past two hundred years only. A recent work undertaken by Iyengar *et al.*[1] has led to a reliable identification of another twenty earthquake occurrences in the medieval period (12–18th century AD). This still leaves the ancient period almost blank except for stray references. However, this does not mean that ancient Indians were not fascinated or not affected by earthquakes. The *Vedas*, *Puranas* and the epics contain many references to earthquakes and allied phenomena. But what may be of interest in the contemporary context, are the writings of persons who were acclaimed scholars of their days. There exist a large number of writings in Sanskrit on natural phenomena. Among these, at least two are available in print namely, *Brihat Samhita* (*B.S.*) of Varaha Mihira[2] (5–6th century AD) and *Adbhuta Sagara* (*A.S.*) of Ballala Sena[3] (10–11th century AD).

Discussion on causes of earthquakes had been a perennial topic in ancient Indian literature. According to *A.S.*, the opinion of Kashyapa was that earthquakes were due to movement of sea creatures, whereas Garga opined that it was due to the sigh of elephants carrying the earth. According to Vasishta, tremors were due to interaction of two strong winds which eventually impacted the oceans and shook the earth. Another opinion was that earthquakes occurred due to chance or unseen forces. Finally, both *B.S.* and *A.S.* give an explanation due to Parashara that once upon a time mountains could fly and move. Thus they were frequently falling on the earth causing earthquakes continuously. At the request of the earth, the Creator ordered *Indra* (thunder) to cut the wings of the mountains so that the earth became stable. Yet, the four elements namely Wind, Fire and Water along with *Indra* cause the earth to shake. This explanation originating from the *Rig Veda* has been given in the two texts as a rudimentary theory on formation of stable continents and not in any religious sense. Ballala Sena quotes another writer Ushanas, who was categorical that the four elements shake the earth in the four quarters east, south, west and north, respectively. From the commentaries on *B.S.*, we find that Parashara was of the opinion that eclipses and planetary aberrations could also cause earthquakes. Over the centuries this idea might have been given up since *A.S.* does not list this reason.

After discussing the causes, both the books turn their attention to classification of earthquakes into four groups, depending on the time of occurrence and the reigning stellar constellation. Thus, an earthquake which occurs from north in the last quarter of the night or in the first quarter of the day under any of the stars *Asvini, Mrigasira, Punarvasu, Hasta, Chitta, Svati* or *Uttarapalguni* belongs to the wind group (*Vayavya*). The directions of occurrence are not explicitly mentioned in *B.S.* These were given by Ushanas as quoted in *A.S.* It is also mentioned that many scholars do not accept the classification based on the time of occurrence. Similarly, earthquakes of the *Agni* (fire), *Indra* and *Varuna* (water) group originate from south, east and west, respectively and are governed by specific star groups. Neither of the books indicate how the directions are to be fixed. It is observed that so far the effort has been only to group the earthquakes after their occurrence, according to some recognizable attributes.

About the effects of earthquakes, Varaha Mihira does not mention about damages to buildings. However other writers are categorical that *Vayu*-type earthquakes lead to extensive destruction of houses, monasteries, temples, palaces, towers and forts. The after-effects mentioned are occurrences of windstorms within a week after such an earthquake. Similarly, the *Agni*-type earthquake induces surface fires engulfing villages and towns. Rivers and water sources dry up. *Indra*-type tremors, lead to rains and elimination of pest colonies. The *Varuna*-type earthquake kills people living along river and sea coasts. Earthquakes were also supposed to be a portent for

impending death of kings, outbreak of wars and epidemics. In *B.S.* the list of regions affected, is short, whereas information given in *A.S.* from various sources including those of *B.S.* is more exhaustive. The geographical regions disturbed by earthquakes according to both the books are as follows.

Vayu-type earthquake

B.S.: Saurashtra, Kuru, Magadha, Dasarna, Matsya; *A.S.*: Yavana, Dandaka, Salva, Sauvardhana, Pulinda, Videha, Nala, Darada, Anga, Vanga, Avanti, Malva, Trigarta, Sauvira, Yaudheya, Ksudraka, Shivika, Madraka, Shaka, Kamboja, Bahlika, Gandhara, Kalinga, Sabara, Mlechha, Tangana.

Agni-type earthquake

B.S.: Ashmaka, Anga, Bahlika, Tangana, Kalinga, Vanga, Dravida, Shabara; *A.S.*: Pulinda, Yavana, Odhra, Avanti, Iksvaku, Kuluta, Tushara, Shivika, Trigarta, Videha, Surastra, Madhyadesh, Dasarna.

Indra-type earthquake

B.S.:Kashi, Yugandhara, Paurava,
Kirata, Kira, Abhisara, Hala, Madra,
Arbuda, Saurastra, Malva; *A.S.*: Kashmira, Dravida, Andhaka, China, Prachya, Shaka,
Pahlava, Dandaka, Kailasa, Malla, Vahala.

Varuna-type earthquake

B.S.: Gonarda, Chedi, Kukkura, Kirata, Videha; *A.S.*: Kashmira, Parata, Vatsa, Abraka, Karusha, Sinhala.

It was recognized by all the authors that earthquakes may occur under any star at any time. Thus, combination-type earthquakes became possible. The places affected by such mixed-type tremors as mentioned by Parashara, are reported in *A.S.*

Vayu–Agni: Kuru, Salva, Matsya, Nishadha, Pundra, Andhra, Kalinga, Vindhya foothills.

Vayu–Indra: Prachya, Shaka, China, Pahlava, Yaudheya, Yavana, Magadha.

Vayu–Varuna: Avantika, Pulinda, Videha, Kashmira, Darada.

Agni–Indra: Ikshvaku, Patachara, Abhira, China, Barukacha.

Agni–Varuna: Gonarda, Anganarajya, Coastal regions.

Indra–Varuna: Kashi, Abhisara, Achyuta, Kachadvipa.

The effects of these earthquakes were supposed to be a combination of the effects of the primary types described earlier. Many of the places in the list given earlier are easily identifiable with their present-day equivalents. Several regions are outside the present-day Indian political boundary. In Figure 1, the regions are marked taking into account the ancient geography of India as described in the works of Kautilya, Varaha Mihira, Bana, Kalhana and others. A question may arise as to how widespread the knowledge was about seismic regions in ancient times, and whether Dravida was in South India. Fortunately, a book in Kannada, *Lokopakarakam*, written in 1025 AD by Chamunda Raya[4] under the patronage of the Chalukyan king Jayasimha is available as a cross-reference. This author

devotes briefly eight stanzas for describing the four types of earthquakes. For the *Vayu*-type earthquake, he indicates the affected places as Kurumagadha, Magadha, Dravida and Kuntala. In his own explanation, Chamunda Raya identifies Dravida *with Tigula Desha*

Figure 1. Possible locations of the seismic regions.

(Tamil country). For *Agni*-type earthquakes he includes in his list Anga, Vanga, Kalinga, Kerala, Bahlika and Dravida. According to this book, *Indra*-type earthquakes affect only Saurashtra and Abhisara; whereas *Varuna*-type earthquakes affect Videha, Govardhana, Nishadha and Vihara.

Interpretation of old texts concerning natural phenomena is difficult. Still, seen critically from the present-day perspective the delineation of the country into four major seismic zones of differing damage types, 1500 years ago is no mean achievement. This indicates some kind of observation and data collection. All the regions listed are presently known to be susceptible to earthquakes. But it is interesting to note that Dravida (Tamil country), Kuntala (North Karnataka), Ashmaka (Maharashtra), Andhra and Odhra (Orissa) were considered to be earthquake prone to varying degrees.

A significantly quantitative approach to earthquakes is reflected in the ancient writings. *Vayu*-type earthquake was unanimously accepted as the most destructive. Opinions differed about the other three. Some held that *Agni-, Varuna-*, and *Indra*-type earthquakes in that order were decreasingly harmful. It was perhaps in this context that the ancient writings introduced the extent of ground shaking as a measure of the four types. Ballala Sena in his *A.S.* first cites the book *Bhargaviya* which perhaps belongs to a period earlier than *B.S.* According to this text, the extent of ground shaking is 200 yojanas during *Vayu*-type earthquake. The corresponding values for *Agni-, Indra*- and *Varuna*-type earthquakes are given as 90, 80 and 70 yojanas, respectively. It may be speculated that this order was a reflection of the descending order of socially harmful effects associated with the four types of tremors. Varaha Mihira agrees with only the first value and for the other three, his values are *Varuna*-type 180, *Indra*-type 160, and *Agni*-type 110. No

information is available on how these were obtained or measured. However, these values are amenable for interpretation from a contemporary perspective. One yojana is equal to 6 miles or 9.6 km as per actual measurements carried out by Stein[5], of distances mentioned by Kalhana in his *Rajatarangini*. Thus, *Vayu*-type earthquakes could have had a radius of area of perceptibility of (100 yojana) 960 km.

This may be compared with some modern values. The mean radius of percep-tibility for the great earthquakes of Assam (1897) and Bihar (1934) were 1440 km and 1280 km, respectively[6]. The level of human perceptibility for ground acceleration is generally accepted as 1 cm/s^2. For this level of acceleration, the attenuation results currently available lead to magnitude estimates of 6–8 for the *Vayu*-type earthquake. It is quite well known that damage to man-made structures generally occurs from shocks of magnitude 5 and above. Thus, the regions said to be affected by *Vayu*-type earthquakes, shown in Figure 1, are the most likely places where damage-causing earthquakes have been felt in the ancient past. About prediction of earthquakes, Varaha Mihira is essentially silent. In chapter 4 of *B.S.* he echoes a previous opinion that when the moon's orb appears like the yoke of a cart stretched south to north, there would be an earthquake. There was also a belief that comets were precursors for earthquakes. Parashara mentions that the comet *chala ketu* which appears once in 5000 years shakes the earth and destroys a populated country in the Madhyadesha. Similarly, he held the opinion that the comet *Dhruva Ketu* which appears at irregular intervals also portends earthquakes.

There was also a strong belief about earthquakes being an omen for further tragedy. Ballala Sena would like us to believe earthquake citations from *Puranas* and *Mahabharatha* as historical evidence to this effect. The great epic cites earthquakes in *Udyoga Parvan*, in *Drona Parvan*, in *Salya Parvan* and three times in *Gada Parvan*. The graphic description in *Salya Parvan* is *Chachala Sabdam Kurvana Saparvatavana Mahi* (The earth moved along with mountains and forests making sound). At other places, the epic does not associate sound with the tremors. If accepted as factual, this would be the main shock accompanied by three aftershocks felt at Kurukshetra during the great war (*circa* 3000 BC). Apart from this speculation nothing more can be gleaned about the dates of earthquakes, from the books under reference.

The belief of linking earthquakes with the demise of important personages, appears to be derived from Buddhist traditions. Narratives[7] about Buddha's life mention that immediately after Buddha attained Nirvana (at Kushinagara in 483 BC), the earth trembled, stars fell down and celestial music was heard. Three months prior to this final act, the traditional texts state that when Buddha was camping in a grove to the north of the village Upabhoga, there was an earthquake. Buddha himself is said to have interpreted the earthquake as the sign that he would soon pass away into Nirvana.

Earthquakes have been occurring from ancient times in India and our ancestors took considerable interest in these as with other unusual phenomena. There has been an effort over centuries, to identify places which suffered from earthquakes. Varaha Mihira's approach of describing earthquakes in terms of the extent of ground shaking is refreshingly scientific. The information available so far though very little, is valuable. It is quite likely that there are Sanskrit manuscripts with scientific information yet to be published. It is hoped that persons responsible for preparing seismic zonation maps of the country, study the relevant literature written prior to the colonial period before drawing conclusions on the subject.

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