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GEOPHYSICS

Inhomogeneities in the Attenuation Field of Short-Period *S*-Waves in the Source Zone of the Assam Earthquake on August 15, 1950

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Characteristics of the attenuation field for *S*-waves are studied in the uppermost mantle in the source zone of the Assam earthquake. The method of study is based on the analysis of envelopes of the short-period coda for Lg and Sn waves. It was found that attenuation in the uppermost mantle regularly increases from the central part of the source zone to its periphery and further at distances up to 200 km from the aftershock region. In general, the attenuation in the source zone is significantly weaker than in many regions, where no strong earthquakes have occurred in the last 100 yr with $M \geq 6.5$. The obtained data evidence that mantle fluids ascend to the Earth's crust in the source zone, probably due to a sharp increase in the permeability of the rocks provoked by the strongest earthquake.

The Great Assam earthquake of August 15, 1950, was the strongest tectonic event ($M_w = 8.6$) in the intracontinental regions and the strongest earthquake beyond the subduction zones in the past 105 yr [1, 2]. According to [2], this event is related to a strong change in the seismic regime over the entire Asian continent. In this relation, it is interesting to study the structural features of the lithosphere and asthenosphere, as well as geodynamic processes in the source zone of the Assam earthquake. In this work, we consider heterogeneities of the attenuation field of short-period shear waves in a large region of the Himalayas and Southern Tibet including the source zone of this seismic event.

Digital records of crust earthquakes with $M \sim 4.0$–5.5 obtained at stations LSA and KMI in the years 1987–2004 were processed (Fig. 1). A total of more than 70 seismograms were recorded in the range of epicentral distances ~300–600 km. The heterogeneities in the attenuation field are manifested most clearly at frequencies of approximately 1 Hz [3, 4]. Therefore, a preliminary frequency filtering of the records was carried out (we used a filter with the central frequency equal to 1.25 Hz and bandpass width equal to 2/3 of octave at a level of 0.7 of the maximum).

We used a method related to the analysis of the short-period coda of Lg and Sn waves [5]. Previously, it was shown that the coda is formed at frequencies of approximately ~1 Hz mainly by *S*-waves reflected from subhorizontal boundaries in the upper mantle [3, 4, 6]. As time *t* from the beginning of radiation increases, the waves characterized by greater angles of incidence at the *M* boundary and penetration to deeper depths in the upper mantle arrive at the coda. At distances of ~300–600 km, the initial part of the coda receives waves characterized by a sharp temporal increase in the path length in the uppermost mantle in the epicenter region, where the heterogeneities in the attenuation field are most prominent (at depths up to 200–250 km [5]). Later, the coda receives waves that can propagate to deeper depths in the upper mantle, where the attenuation field is characterized by greater homogeneity [3]. Thus, based on the ratio of effective Q-values determined from the attenuation of amplitudes in the early and late coda, one can judge about the heterogeneities of the attenuation field in the uppermost mantle in the study region. The effective Q-factor over two time intervals—the first interval immediately after the Lg wave (duration 70 s) and the second interval at $t = 250$–400 s—was calculated from the formula

$$Ac(t) \sim \frac{1}{t} \exp\left(-\frac{\pi t}{Q_s T}\right)$$

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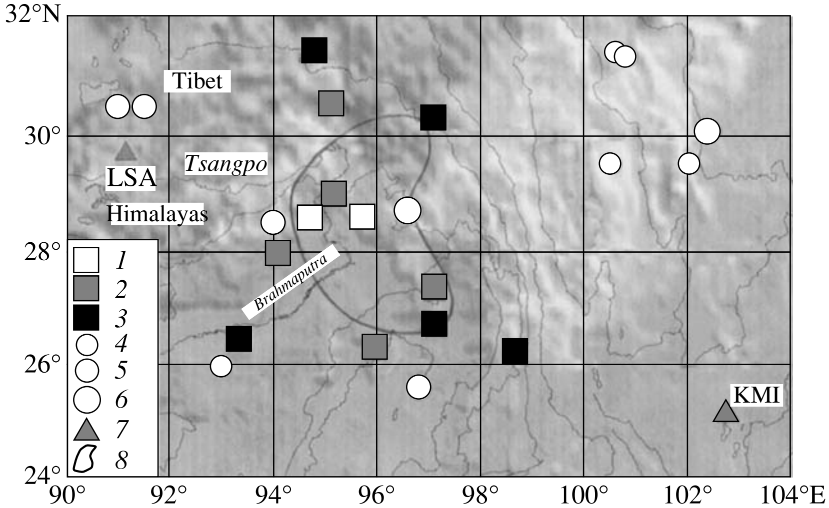

Fig. 1. Chart of the study region. Values of $\frac{Q_1}{Q_2}$: (*1*) >2.00; (*2*) 0.90–1.25; (*3*) 0.50–0.85. Epicenters of strong earthquakes: (*4*) 7.0 ≤ *M* < 7.5; (*5*) 7.5 ≤ *M* ≤ 8.0; (*6*) *M* = 8.6; (*7*) seismic stations; (*8*) region of aftershocks of the Assam earthquake [1].

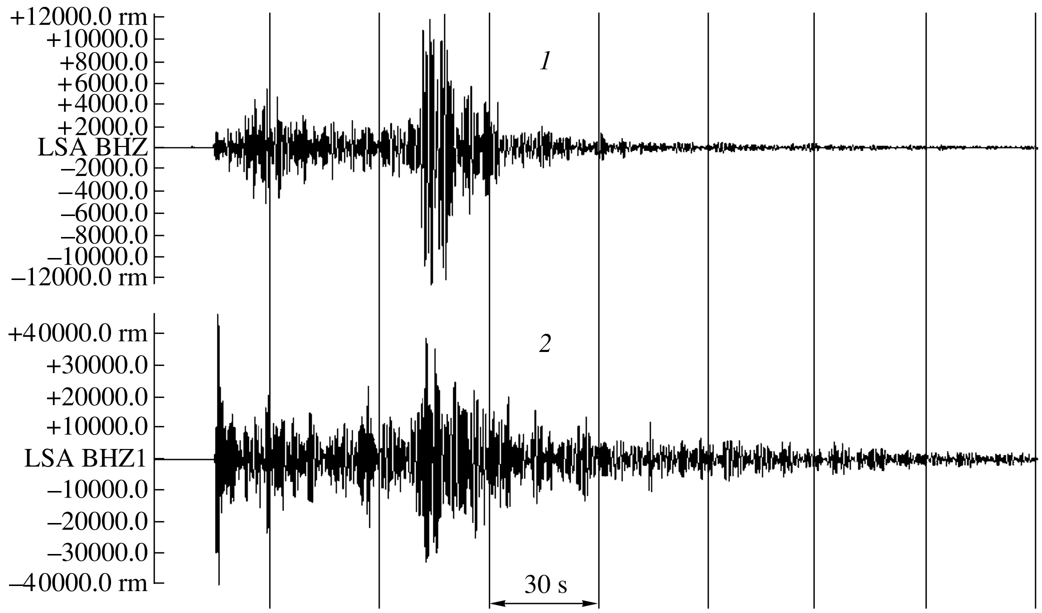

Fig. 2. Examples of seismograms obtained at LSA station (vertical component, filter 1.25 Hz). (*1*) August 5, 2000; 31.85° N, 94.43° E; *h* = 33 km (north of the source zone); (*2*) November 30, 2002; 28.62° N, 95.07° E; *h* = 31 km (central part of the source zone).

(*T* is the oscillation period [3]). We shall denote these intervals as Q_1 and Q_2 for brevity. If 1-Hz group Lg was not found in the records, the measurements were carried out after its arrival based on the travel-time curve.

Figure 2 shows examples of records of two earthquakes: from the source zone and the northern region. The epicenters of both events were located approximately at equal distances from the LSA station (390–400 km). It is seen that the coda attenuates more slowly after the Lg wave than in the source zone during the time interval with a duration of approximately 70 s.

Figure 3 shows the envelope coda of the Lg wave plotted for different areas of the source zone and its nearest environs based on the LSA station data. It is seen that the envelopes differ strongly in shape. In general, the slower attenuation of the Lg coda in the initial part is characteristic of the source zone compared to its environs. Variations in the shape of the envelopes are less notable for the distant coda.

It follows from Table 1 and Fig. 1 that the values of Q_1 and Q_2 vary from 440 to 790 and from 340 to 380, respectively, in the source zone. The corresponding variations in its nearest environs are 190–490 and 320–430, respectively. (We note that region 12 is not related to the source region due to a displacement of the rays in the upper part of the mantle). Parameter $\frac{Q_1}{Q_2}$ varies from 1.12 to 2.32 in the source zone and from 0.50 to 1.21 beyond the zone. We note that the values of $\frac{Q_1}{Q_2}$ in the aftershock region are within (7–19)σ for the mean value and standard deviation σ obtained in the regions with a weak level of seismicity over the last 100 yr (0.45 ± 0.10 [5]). It is interesting that the maximal values of $\frac{Q_1}{Q_2}$ correspond to the inflection region in the source zone, where the extension of the aftershock region changes from northeastern to southeastern. At the same time, significantly greater values of the parameter (0.66–1.21) are also observed near the source zone (at distances approximately up to 100 km from the aftershock region). Furthermore, the values of $\frac{Q_1}{Q_2}$ decrease to a normal level (~0.50) corresponding to weakly seismic regions at ~100–200 km north of this region. At the southeastern boundary of the source (according to the KMI station data), the value of $\frac{Q_1}{Q_2}$ only slightly exceeds the mean level (0.66). It decreases even more (up to 0.53) with increasing distance from the boundary to 150 km. It is worth noting that the greatest values of $\frac{Q_1}{Q_2}$ beyond the source region are observed near the northwestern, western, and southern boundaries of the region. It is interesting that the epicenters of the strongest earthquakes that have occurred since 1900 (M_s = 7.0–8.0, see Fig. 1) at distances approximately equal to 350 km from the boundaries of the region are located to the west and south of the source region.

Thus, the source zone of the Assam earthquake ~40–55 yr after this event is characterized by strong inhomogeneity of the attenuation field. In general, high values of parameters Q_1 and Q_2 are observed in this zone compared to the normal values in the territories with weak seismicity. In addition, the region of increased values of these parameters notably exceeds the size of the source zone.

Comparatively low attenuation of *S*-waves in the source zone of the Assam earthquake evidences that the upper part of the mantle is relatively dry due to the low content of partly molted materials and (or) fluids. The obtained data are consistent with the previous conclusions about the ascent of mantle fluids to the Earth's

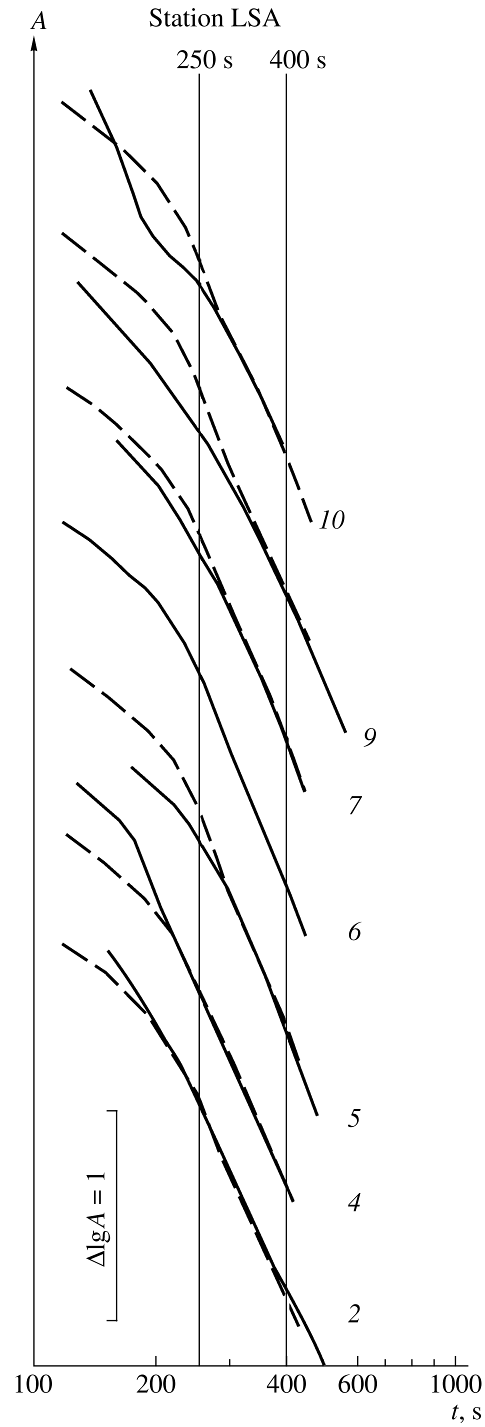

Fig. 3. Envelope coda for different regions of the source zone and its nearest environs (station LSA). Numerals in the figure correspond to the numbers of regions (table). (*5–7*) Data in the source zone; (*2*, *4*, *9*, *10*) data beyond the zone. Envelope for region *6* is shown with a dashed line.

Values of Q_1, Q_2, and $\frac{Q_1}{Q_2}$ in the source zone of the Assam earthquake and its environs

Number of region	φ°, N	λ°, E	Q_1	Q_2	$\frac{Q_1}{Q_2}$	Station
1	25.9–26.7	95.5–96.5	410	340	1.21	LSA
2	26.1–26.8	93.0–93.7	310	370	0.84	″
3	27.1–27.6	96.8–97.4	440	370	1.19	″
4	27.7–28.2	93.3–94.3	340	360	0.94	″
5	28.3–28.9	95.4–96.1	740	340	2.18	″
6	28.2–29.0	94.4–95.1	790	340	2.32	″
7	28.6–29.3	95.0–95.3	470	380	1.24	″
8	30.3–30.5	96.8–97.4	240	350	0.69	″
9	30.3–31.0	94.7–95.5	490	430	1.14	″
10	31.0–31.9	94.1–95.5	210	420	0.50	″
11	26.0–26.1	98.7–98.9	190	360	0.53	KMI
12	26.6–26.9	97.0–97.2	210	320	0.66	″

crust after large and great earthquakes [5, 7, 8]. New data demonstrate that the region characterized by the ascent of mantle fluids can exceed significantly the size of the source zone. This effect may be related to the fact that the fluids can also migrate in the newly formed zone of relative extension in the horizontal direction [9]. In addition, an increase in the permeability of the crust as a result of several strong earthquakes in the years 1931–1952 [10] (Fig. 1) could have stimulate the ascent of fluids in the regions south and west of the source. We can suppose that the maximal values of $\frac{Q_1}{Q_2}$ correspond to the junction of large ruptures of different directions characterized by relatively high permeability of the Earth's crust [11]. We note that very high values of $\frac{Q_1}{Q_2}$ obtained in the source zone do not contradict the conclusion that motion in the source had a strong shear component [1, 12] because pure thrusting and reverse faulting events are usually characterized by significantly lower values of this ratio [5].

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