RING-SHAPED SEISMICITY WITHIN VARIOUS DEPTH RANGES IN THE REGION OF KURIL AND KAMCHATKA

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Abstract – We have analyzed characteristics of the seismicity in the region of the central and northern Kuril Islands and Kamchatka within depth ranges of 0-33 and 34-70 km prior to large and great earthquakes that have occurred in 1993-2007 and within seismic gaps. We have identified ring-shaped distributions of seismicity in both depth ranges. It was shown, that epicenters of the major earthquakes were located near areas of intersection or the closest proximity of the ring structures. By analogy with the Sumatra region, and using data on the sizes of such rings, we have obtained prognostic estimates of magnitudes of large earthquakes, which can occur in seismic gap zones. We have identified seismic gaps, where large earthquakes are most probable in the near future. We also compare these data with long-term forecasts of other authors.

Introduction

Earlier we showed that ring-shaped distributions of seismicity form within various depth ranges prior to large and great earthquakes in subduction zones (Kopnichev and Sokolova, 2008a; 2009a; 2009b). We also established that sizes of these structures, as a whole, increase with the magnitude of imminent event. This allows us to use the method of ring-shaped seismicity distributions to identify zones where large earthquakes appear imminent. In this paper we consider seismicity characteristics in the region of Kuril and Kamchatka, where, according to long-term forecast by Fedotov et al. (2007), the probability of earthquakes with M≥7.7 in the near future is relatively high.

Historic seismicity

We consider the region that includes the central and northern Kuril Islands and Kamchatka (between 45.5º and 56.5º N), where a number of large earthquakes, including great earthquakes (Mw≥7.7), have occurred since 1900: particularly, events of 03.02.1923 (Mw 8.5), 04.11.1952 (Mw 9.0), 04.05.1959 (Mw 8.0), 15.11.2006

(Mw 8.3) and 13.01.2007 (Mw 8.1) (see Table 1). The giant Kamchatka earthquake of November 4, 1952 was the forth-largest earthquake of the 20-th century. The length of its rupture zone was ~600-700 km, and it generated Pacific-wide tsunamis. The mean recurrence interval for events with M≥7.7 within the whole Kuril-Kamchatka arc is estimated to be 140±60 years (Fedotov et al., 2007). Note that no earthquakes with Mw>7.7 have occurred in the region of the northern Kurils and Kamchatka during the past 50 years. In contrast, 5 events with Mw≥8.0 took place in the southern and central Kurils between 1963 and 2007.

Table1

Large and great earthquakes in the Kuril-Kamchhatka region since 1900

Date	φº N	λº E	h, km	Mw
05.01.1915	47.50	154.50	35	7.9
30.01.1917	56.50	163.00		7.7
03.02.1923	53.85	160.76	35	8.5
04.11.1952	52.75	159.50		9.0
04.05.1959	53.37	159.66	35	8.0
15.12.1971	56.02	163.17	22	7.8
05.12.1997	54.80	162.00	37	7.8
15.11.2006	46.59	153.27	10	8.3
13.01.2007	46.24	154.52	10	8.1

Method and data used

We have been studying seismicity characteristics in the region of central, northern Kuril and Kamchatka within depth ranges of 0-33 and 34-70 km. We used NEIC earthquake catalogs (since 01.01.1973). We used events that occurred in the environs of rupture zones of subsequent great earthquakes, and specifically we included earthquakes with magnitudes M≥Mt1 and M≥Mt2, for which Mt1 varied from 4.5 to 5.5 for the first depth range and Mt2 from 4.2 to 5.3 for the second (Table 2). We selected time intervals since 01.01.1973 until one day preceding the major event. We have processed data on seismicity prior to five large and great earthquakes with Mw 7.0-8.3 (Table 2). Besides them, we have studied seismicity characteristics in a few seismic gap zones, where no earthquakes with Mw>7.8 have occurred for many decades; for these zones we have considered events until 01.01.2009.

Table 2

Large and great earthquakes in the Kuril-Kamchatka region, for which ring structures were found

Date	φº N	λº E	h, km	Mw
13.11.1993	51.93	158.65	34	7.0
05.12.1997	54.80	162.00	37	7.8
15.11.2006	46.59	153.27	10	8.3
13.01.2007	46.24	154.52	10	8.1
15.01.2009	46.86	155.15	36	7.4

Data analysis

<u>Central Kurils</u>. Three large to great earthquakes with Mw=7.4-8.3 occurred here in 2006-2009. Figure 1 shows seismicity characteristics in the environs of rupture zone of the great earthquake of 15.11.2006 for the interval of 01.01.1973 to 14.11.2006. It follows from the figure, that ring-shaped structures have been revealed prior to this event in the both depth ranges (Mt1=5.0, Mt2=4.7). These structures trend northeast-southwest, and the lengths of major axes are L~120 km and l~70 km, respectively. The epicenter of the major earthquake is located near the northeastern part of where the rings intersect (Δr~ 10 km). Based on our earlier work (Kopnichev, Sokolova, 2009a, 2009b), we will call the rings of the first type "shallow" and second – "deep."

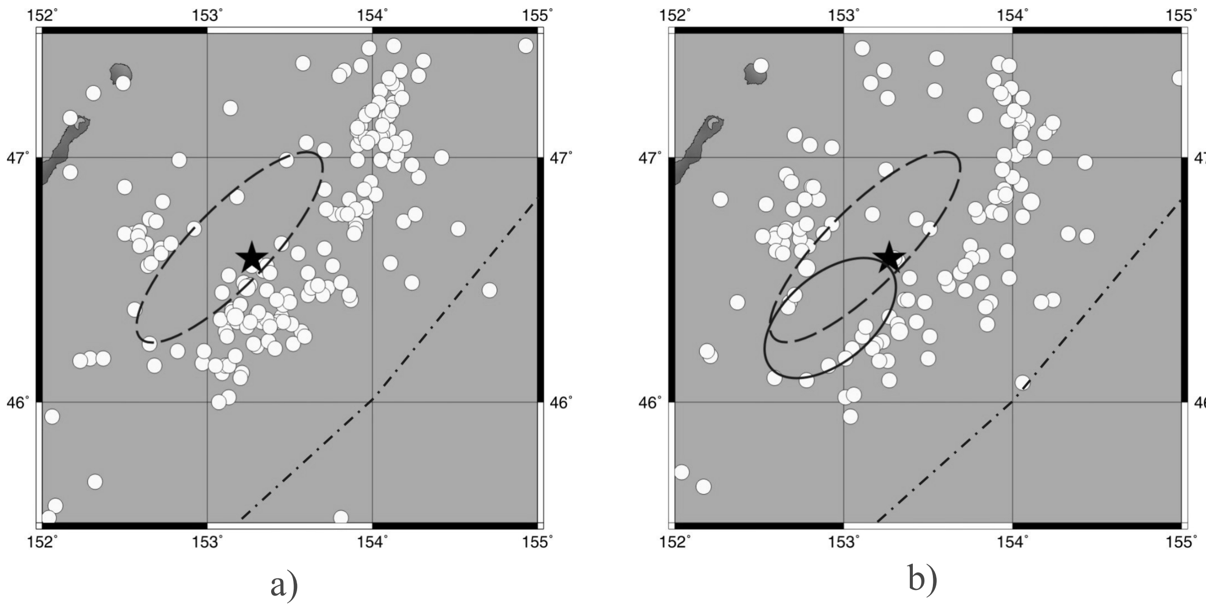


Figure 1

Ring-shaped seismicity prior to the earthquake of 15.11.2006 in the area of central Kuril (Mw 8.3).

(a) Depth of 0-33 km. Epicenters of earthquakes: small circles – 5.0≤M<6.0; big ones - M≥6.0. Dotted ellipse denotes the shallow ring. The star is epicenter of the earthquake of 15.11.2006. A chain line is an axis of the Kuril-Kamchatka trench.

(b) Depth of 34-70 km. Epicenters of earthquakes: small circles – 4.7≤M<6.0; big ones - M≥6.0. A firm ellipse denotes the deep ring. The remaining notation – in Figure 1a.

In Figure 2 analogous data for the rupture zone of great earthquake of 13.01.2007 are shown; this event occurred southeast of the zone of preceding one. In this case the shallow ring structure (Mt1=5.2, L~100 km) extends northeast. The deep ring, revealed less distinctly, is situated at the southern border of the shallow one (Mt2=4.5, l~50 km). The epicenter of the major event was located at a distance of Δr~ 15 km from the eastern area of intersection of the rings.

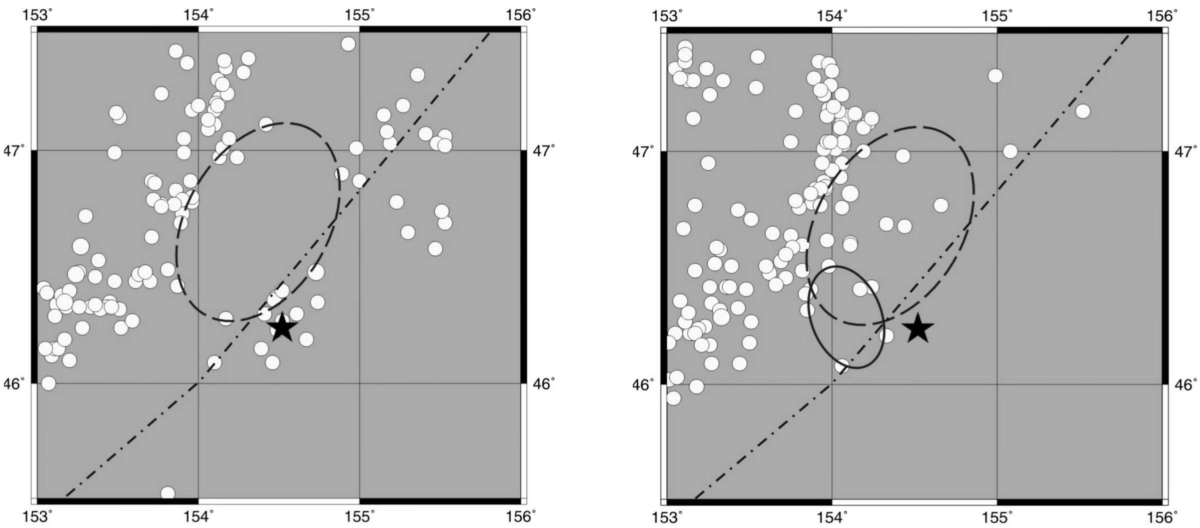


Figure 2

Ring-shaped seismicity prior to the earthquake of 13.01.2007 in the area of central Kuril (Mw 8.1).

(a) Small circles - 5.2≤M<6.5, big ones - M≥6.5. The star is epicenter of the earthquake of 13.01.2007. The remaining notation – in Figure 1a.

(b) Small circles – 4.5≤M<6.0. The remaining notation – in Figure 1b.

Figure 3 illustrates seismicity in the source zone of the large earthquake of 15.01.2009 (Mw=7.4) until 14.01.2009. One can see that ring structures have formed here too: the shallow one (Mt1=4.8, L~95 km) stretches in the meridional direction, and the deep one (Mt2=4.2, l~110 km) is oriented in northwest. The hypocenter of earthquake of 15.01.2009 (h=34 km) was located at the edge of the deep ring, at a distance of ~20 km from the shallow ring and relatively far from southern area of their intersection (Δr~ 40 km). Interestingly, the epicenter of the large earthquake of 15.01.1915 (Mw=7.9) occurred near the northern area of their intersection.

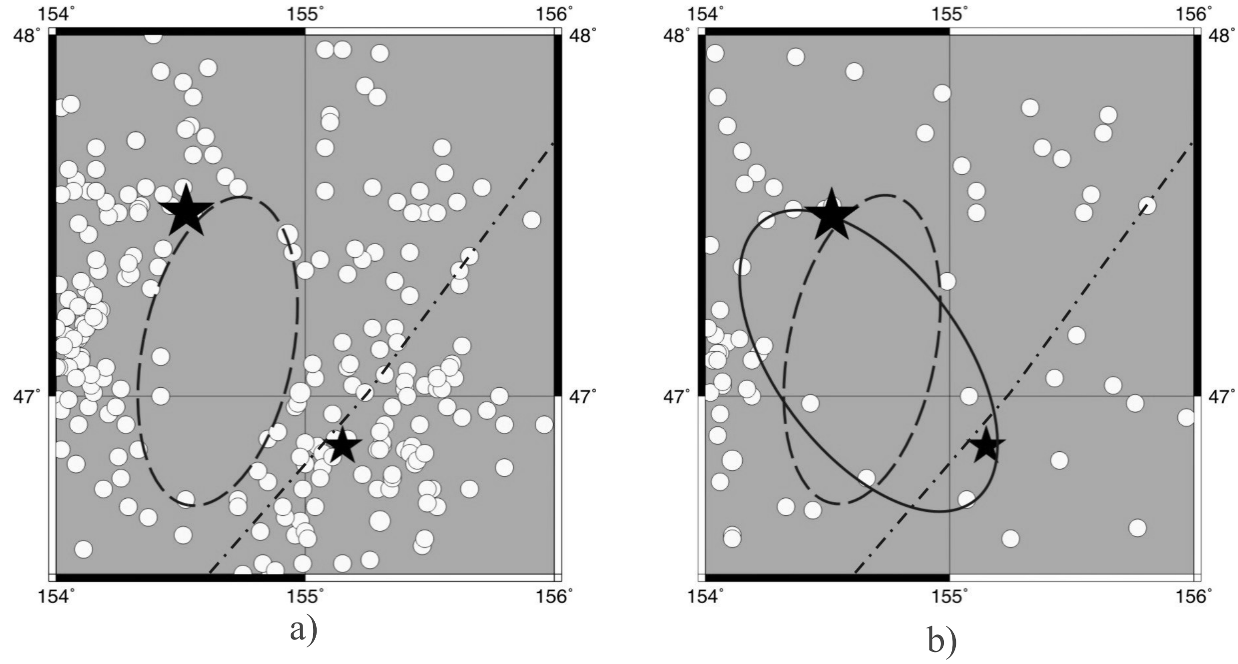


Figure 3

Ring-shaped seismicity prior to the earthquake of 15.01.2009 in the area of central Kuril (Mw 7.4).

(a) Small circles – 4.8≤M<6.0. Small and big stars are epicenters of earthquakes of 15.01.2009 and 05.01.1915 (Mw 7.9) respectively. The remaining notation – in Figure 1a.

(b) Small circles – 4.2≤M<6.0. The remaining notation – in Figures 1b and 3a.

<u>Northern Kuril.</u> Seismicity in a region to the north of rupture zones of the two great earthquakes (15.11.2006 and 13.01.2007) is shown in Figure 4. Here prior to 01.01.2009 shallow (Mt1=5.4, L~140 km) and deep rings (Mt2=5.3, l~50 km), stretch north-northeast and northwest, respectively. The deep ring intersects the northeastern edge of the shallow one.

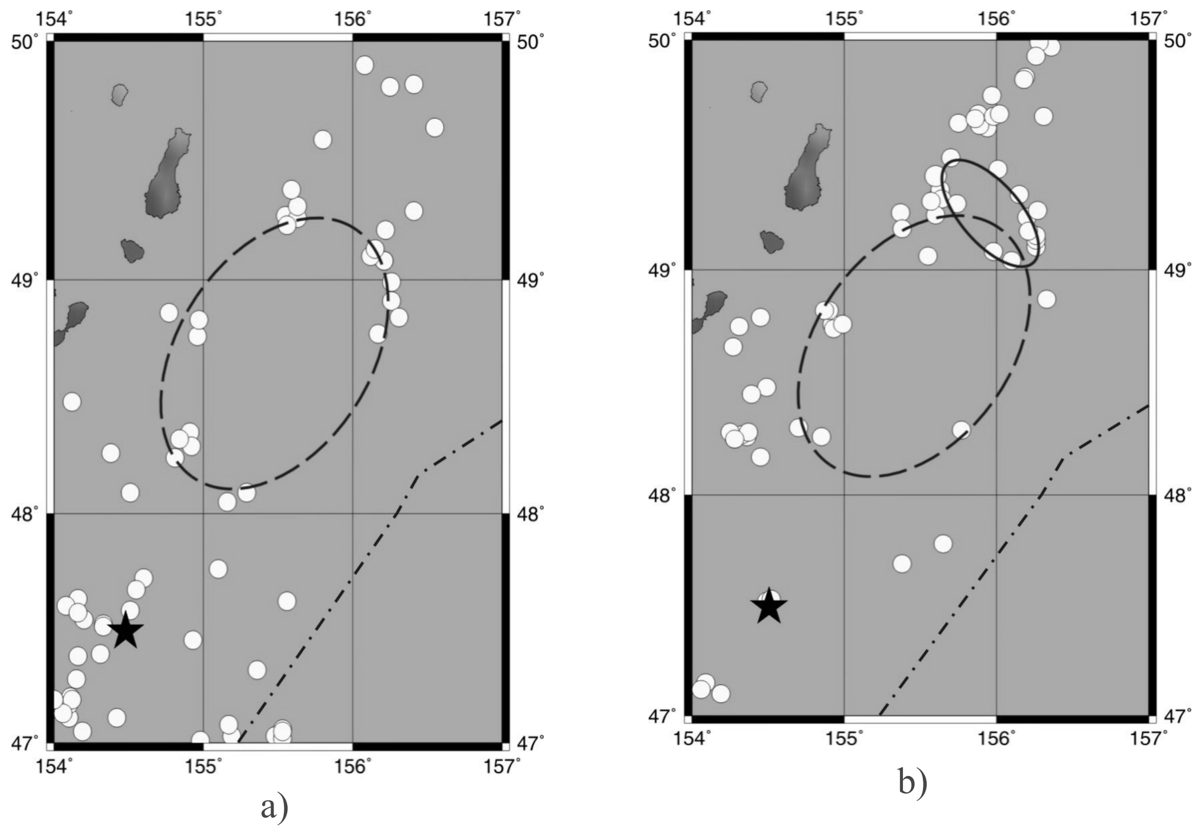


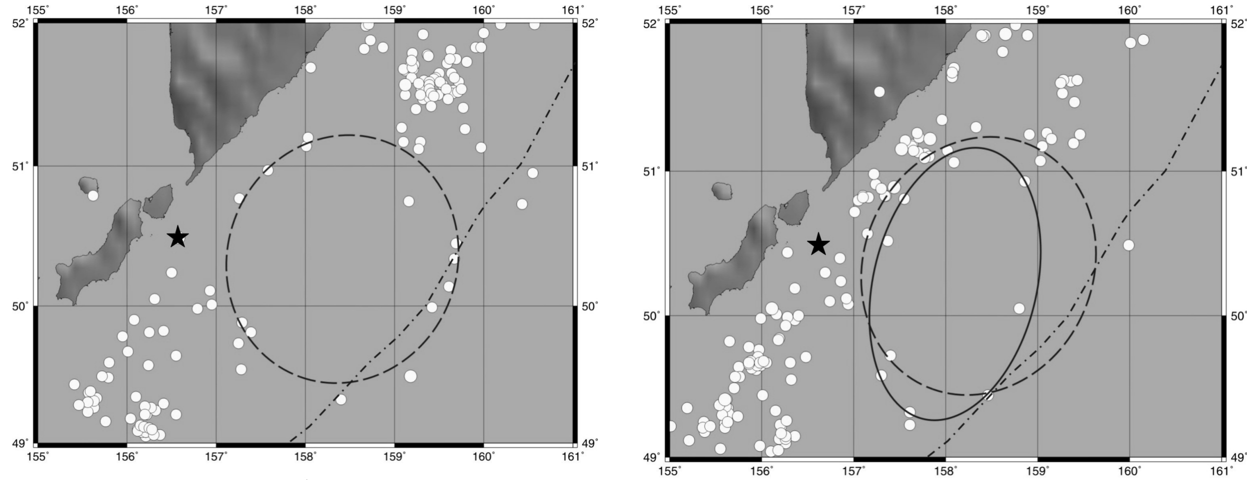
Figure 4

Ring-shaped seismicity in the region of northern Kuril.

(a) Small circles - 5.4≤M<6.5, big ones - M≥6.5. The star is epicenter of the earthquake of 05.01.1915. The remaining notation – in Figure 1a.

(b) Small circles – 5.3≤M<6.5. The remaining notation – in Figure 1b.

In Figure 5 seismicity in the southern part of the rupture zone of the giant Kamchatka earthquake of 04.11.1952 are shown. The aftershock zone of this event was located approximately between 49º and 53º N. It follows from the figure, that until 01.01.2009 a shallow ring of almost circular form (Mt1=5.0, L~200 km) and a deep one, oriented in meridian direction (Mt2=5.0, L~210 km) have formed here. The biggest part of the deep ring lies within the shallow one. Note that the rupture zone of the Paramushir earthquake of 28.02.1973 (Mw 7.1) was located near the western border of the shallow ring.



a) b)

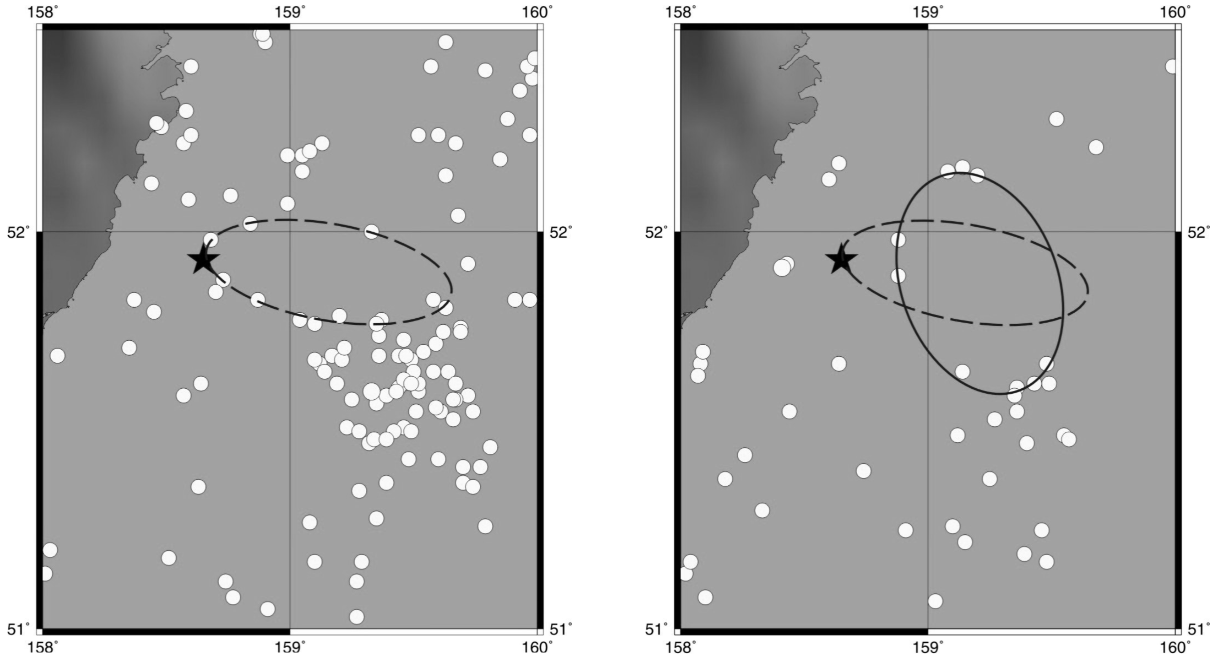
Figure 5

Ring-shaped seismicity in the region of northern Kuril and southern Kamchatka.

(a) The star is epicenter of the Paramushir earthquake of 28.02.1973. The remaining notation – in Figure 1a.

(b) Small circles – 5.0≤M<6.0. The remaining notation – in Figure 1b.

Kamchatka. Figure 6 illustrates seismicity characteristics, revealed in the area of southern Kamchatka, between 51º and 52.5º N in the period of 01.01.1973-12.11.1993, prior to the earthquake of 13.11.1993 (Mw 7.0). A shallow ring (Mt1=4.5, L~70 km) stretches in a latitudinal direction, and is revealed more clearly than the deep one (Mt2=4.6, l~65 km) oriented north-northwest. The epicenter of the large earthquake (13.11.1993) was located at the border of the shallow ring, at a distance of ~20 km from the northwestern area where the rings intersect.



a)

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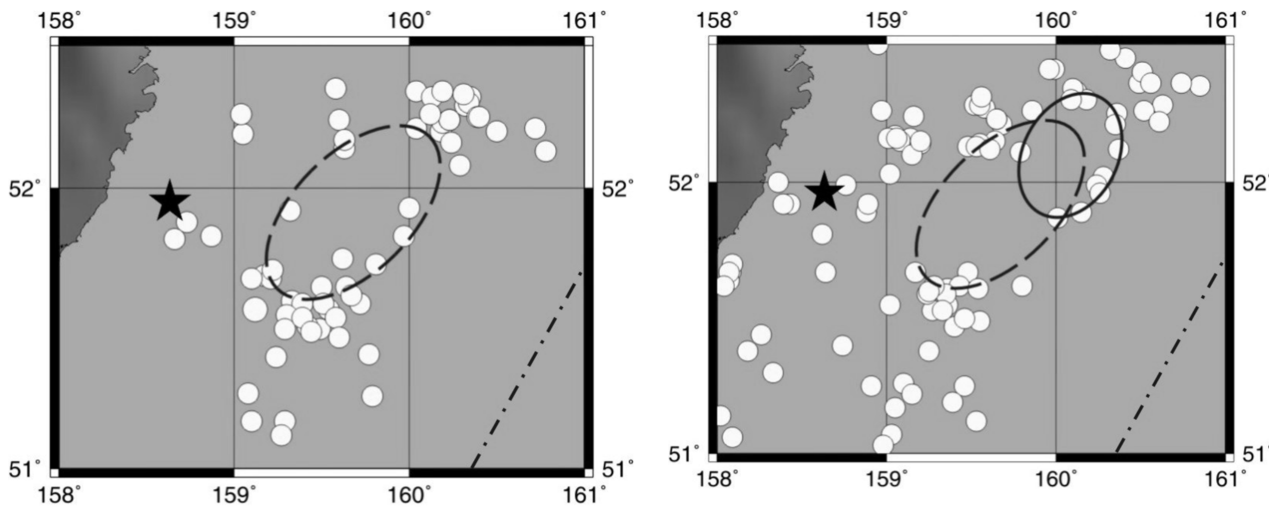
Figure 6

Ring-shaped seismicity prior to the earthquake of 13.11.1993 in the region of southern Kamchatka (Mw 7.0).

(a) Small circles – 4.5≤M<6.0. The star is epicenter of the earthquake of 13.11.1993. The remaining notation – in Figure 1a.

(b) Small circles – 4.6≤M<6.0. The remaining notation – in Figure 1b.

Figure 7 shows seismicity in the region of southern Kamchatka, to the east of the previous zone. Here a shallow ring (Mt1=5.3, L~85 km) is oriented northeast, and a deep one (Mt2=4.8, l~55 km) stretches to north-northeast. The deep ring intersects the northeastern edge of the shallow one.



a) b)

Figure 7

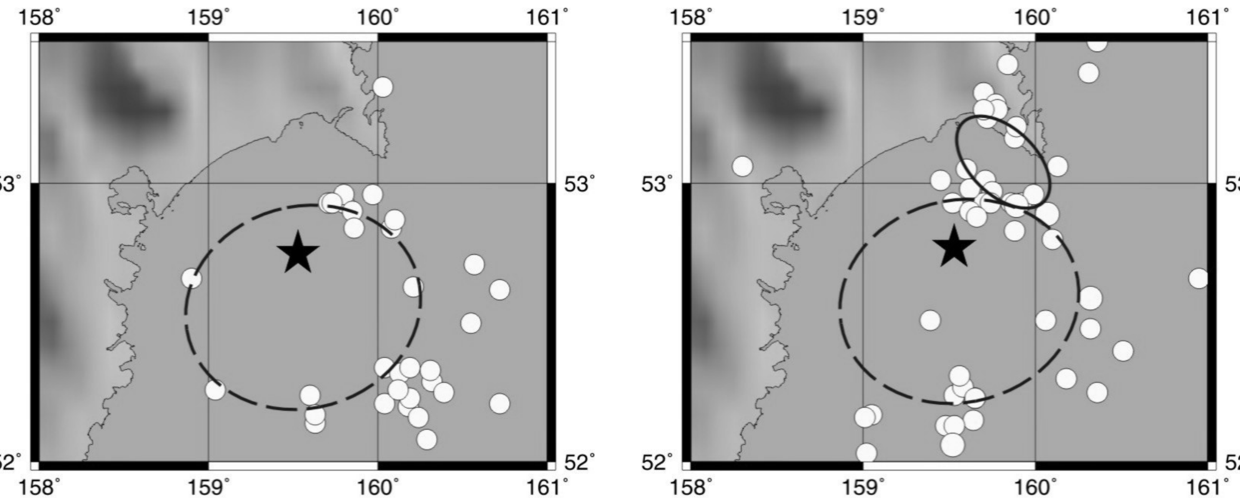
Ring-shaped seismicity in the region of southern Kamchatka.

in the period of 01.01.1973-01.01.2009.

(a) Small circles - 5.3≤M<6.5, big ones - M≥6.5. The star is epicenter of the earthquake of 13.11.1993. The remaining notation – in Figure 1a.

(b) Small circles – 4.8≤M<6.0. The remaining notation – in Figure 1b.

In Figure 8 seismicity in the area between 52º and 53.5º N are presented. Here prior to 01.01.2009 an almost circular shallow ring (Mt1=5.5, L~95 km) and a small deep one (Mt2=5.2, l~45 km) oriented northwest have formed. The rings touch each other near 52.9º N, to the south of the Shipunsky peninsula.



a) b)

Figure 8

Ring-shaped seismicity in the region of southern Kamchatka.

(a) Small circles - 5.5≤M<6.5, big ones - M≥6.5. The star is epicenter of the earthquake of 04.11.1952. The remaining notation – in Figure 1a.

(b) Small circles - 5.5≤M<6.5, big ones - M≥6.5. The remaining notation – in Figure 1b.

Figure 9 illustrates seismicity in an area bounded by coordinates 52-54º N, 159-163º E. Here a relatively large shallow ring (Mt1=5.3, L~150 km) stretching parallel to the Kuril-Kamchatka trench and a deep one (Mt2=5.0, l~80 km) oriented in a latitudinal direction have formed. These structures intersect at the northeastern edge of the shallow ring. Note that in the west the shallow ring also touches the deep one, described earlier (Figure 8).

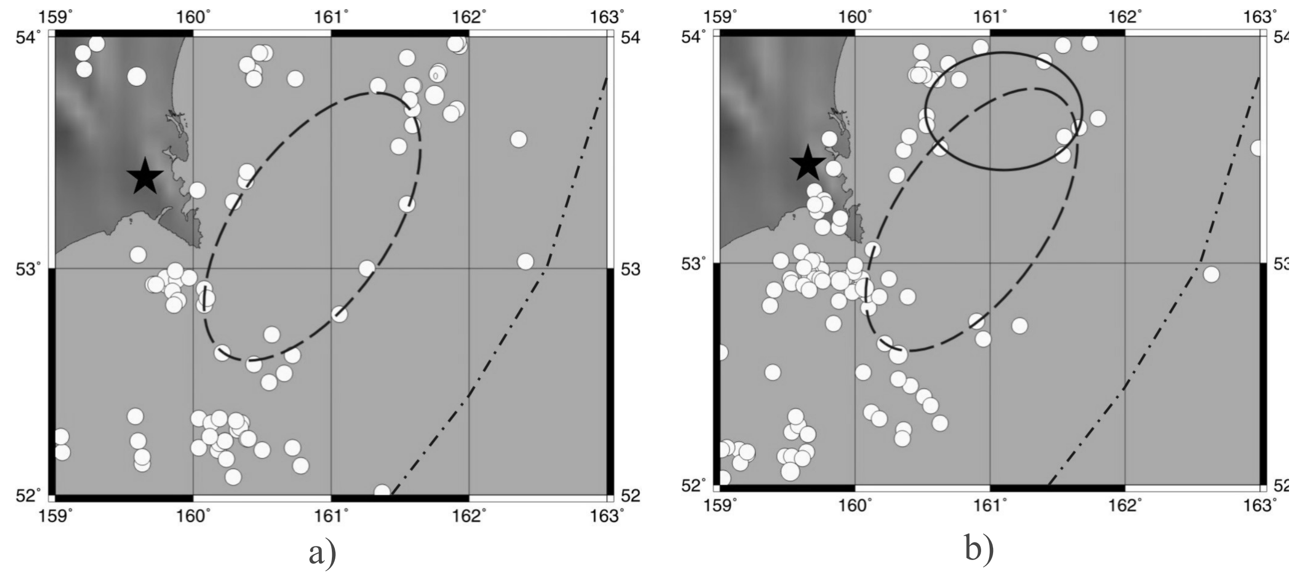


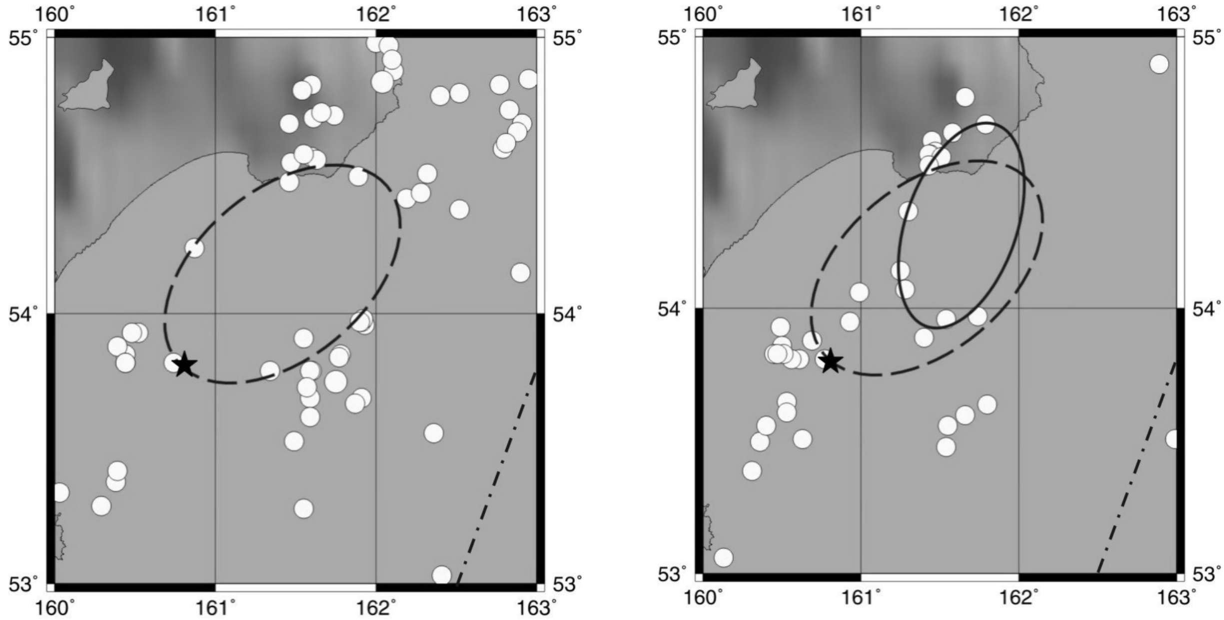
Figure 9

Ring-shaped seismicity in the region of southern Kamchatka.

(a) Small circles - 5.3≤M<6.5, big ones - M≥6.5. The star is epicenter of the earthquake of 04.05.1959. The remaining notation – in Figure 1a.

(b) Small circles - 5.0≤M<6.0. The remaining notation – in Figure 1b.

In Figure 10 seismicity in the region of central Kamchatka between 53º and 55º N are shown. A shallow ring (Mt1=5.3, L~110 km) oriented northeast and a deep one (Mt2=5.0, l~90 km) stretched along a meridian have been identified. Note that the deep ring, up until 01.01.2009, is revealed less distinctly than the shallow one. The rings intersect in the north, in the area of Kronotsky peninsula.



a) b)

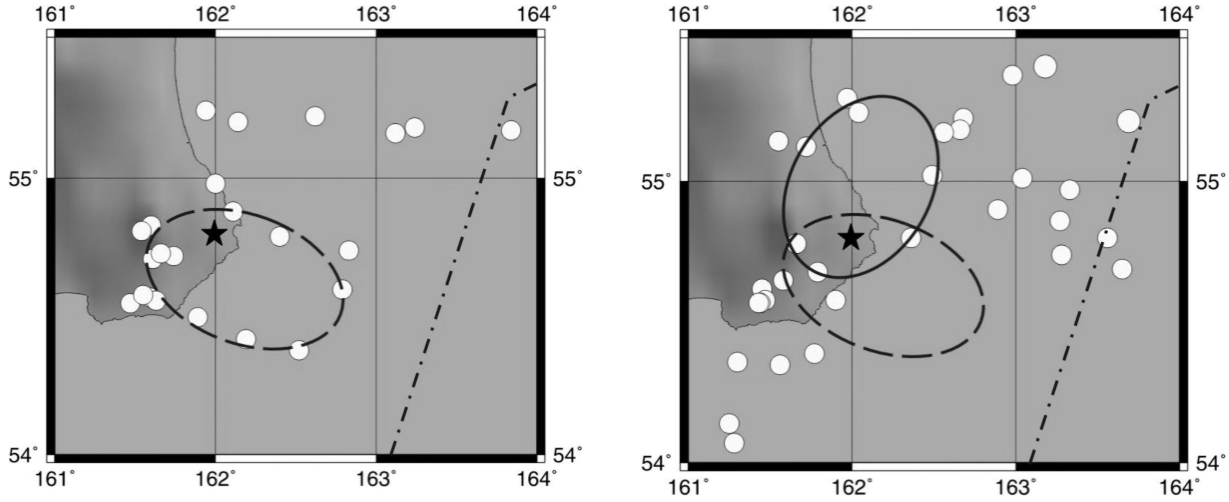
Figure 10

Ring-shaped seismicity in the region of central Kamchatka.

(a) Small circles - 5.3≤M<6.5, big ones - M≥6.5. The star is epicenter of the earthquake of 03.02.1923. The remaining notation – in Figure 1a.

(b) Small circles - 5.0≤M<6.0. The remaining notation – in Figure 1b.

In Figure 11 seismicity in the area between 54º and 55.5º N during interval 01.01.1973 to 04.12.1997, prior to Kronotsky earthquake of 05.12.1997 (Table 1), are presented. In this case a shallow ring (Mt1=5.3, L~85 km) stretches west-northwest and is revealed distinctly. The deep ring (Mt2=4.5, l~75 km) is oriented normal to the shallow one, but is revealed less clearly. These rings also intersect in the area of Kronotsky peninsula. Note that the epicenter of the Kronotsky earthquake was ~25 km from the areas of both pairs of ring intersections.



a) b)

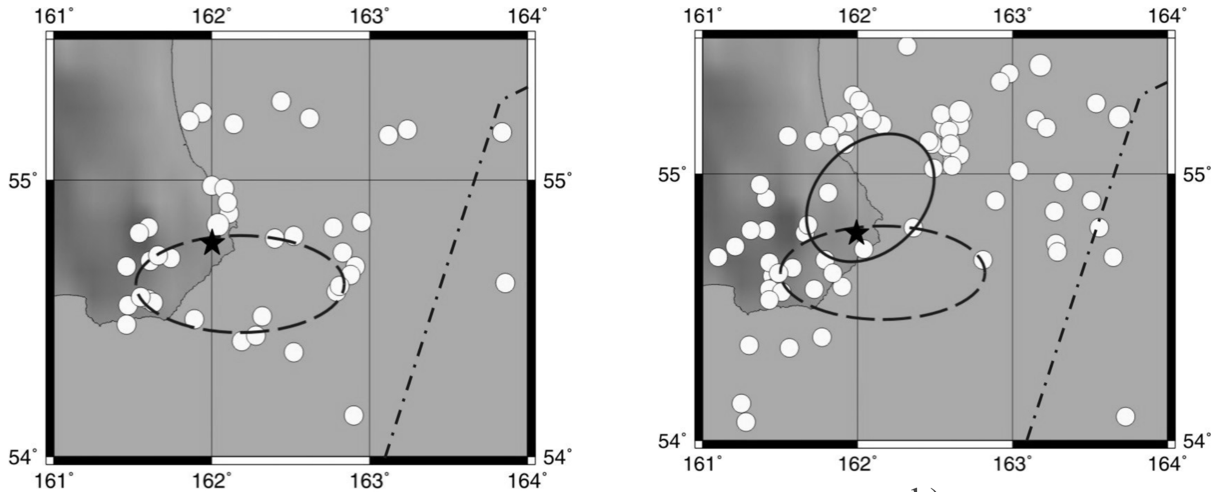
Figure 11

Ring-shaped seismicity prior to the Kronotskiy earthquake of 05.12.1997 in the region of central Kamchatka (Mw 7.8).

(a) Small circles – 5.3≤M<6.5, the big ones - M≥6.5. The star is epicenter of the earthquake of 05.12.1997. The remaining notation – in Figure 1a.

(b) Small circles – 4.5≤M<6.0. The remaining notation – in Figure 1b.

It follows from Figure 12 that in 11 years the distribution of seismicity changed notably. The more clearly expressed shallow ring formed (with practically the same length, but relatively narrow, oriented in latitudinal direction). The epicenter of the Kronotsky earthquake lay at the border of this ring. The deep ring is revealed clearly too (Mt2=4.5, l~60 km). Interestingly, the areas of rings intersection were almost at the same places, as in Figure 11.



b)

a)

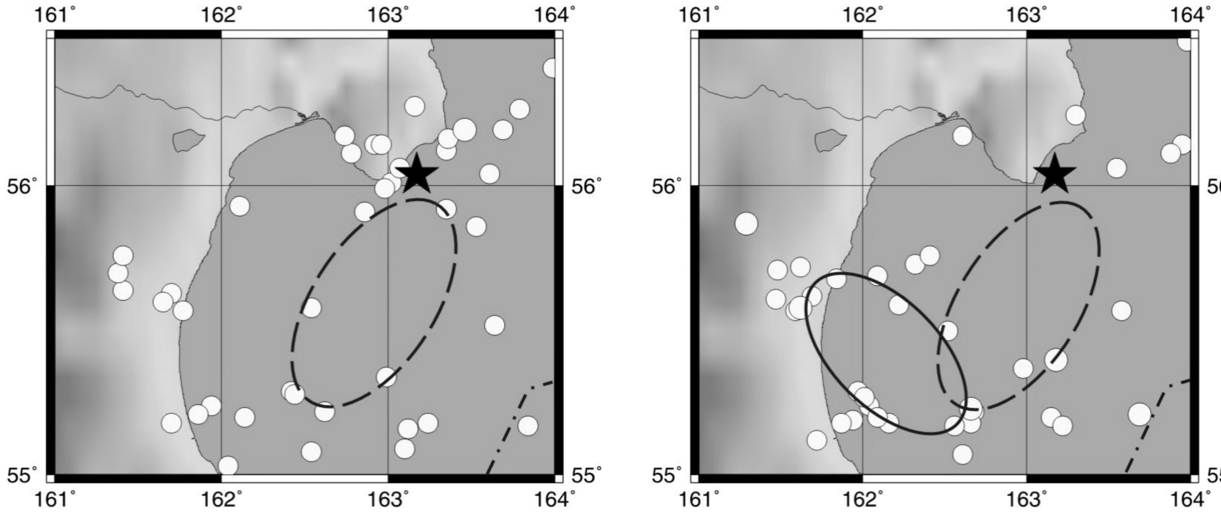
Figure 12

Ring-shaped seismicity in the region of central Kamchatka.

(a) Small circles - 5.3≤M<6.5, big ones - M≥6.5. The star is epicenter of the earthquake of 05.12.1997. The remaining notation – in Figure 1a.

(b) Small circles – 4.5≤M<6.0. The remaining notation – in Figure 1b.

In Figure 13 seismicity to the south of Kamchatka peninsula between 55º and 56.5º N is shown. One can see a shallow ring (Mt1=5.0, L~85 km) oriented northeastern. The epicenter of the Ust'-Kamchatka earthquake of 11.12.1971 (Mw 7.8) was located near the border of this ring. The deep ring, revealed more clearly (Mt2=4.7, l~75 km), stretches northwest. The rings intersect near 162.5º E.



a) b)

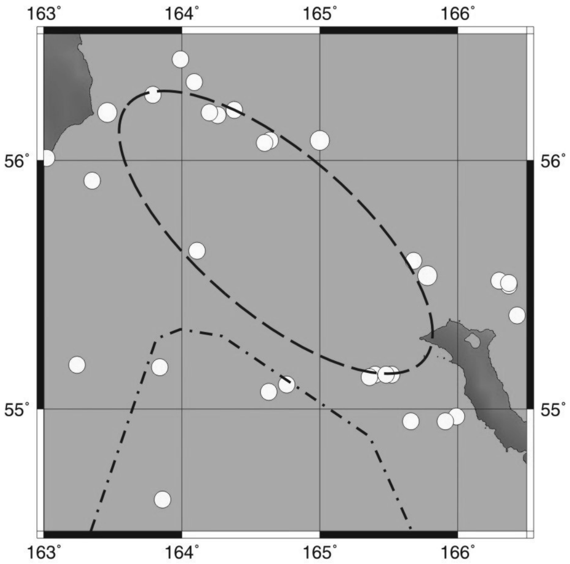
Figure 13

Ring-shaped seismicity in the region of central Kamchatka.

(a) The star is epicenter of the earthquake of 15.12.1971. The remaining notation – in Figure 1a.

(b) The notation is in Figure 1b.

Figure 14 illustrates seismicity at the junction of the Kuril-Kamchatka and Aleutian arcs, between the Kamchatka peninsula and Komandorsky Islands. A long shallow ring (Mt1=5.4, L~180 km) stretches northwest, and a deep one (Mt2=4.7, l~130 km) is oriented north-northwest. Coordinates of ring intersection are ~55.3º and 56.1º N.



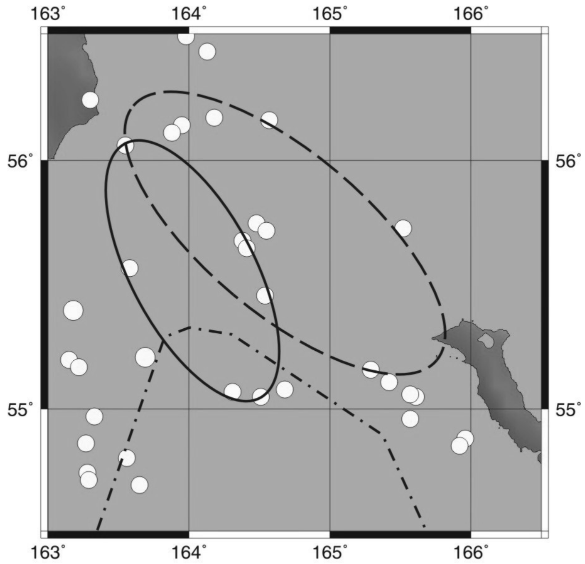


Figure 14

Ring-shaped seismicity at the junction of the Kuril-Kamchatka and Aleutian arcs.

(a) Small circles - 5.4≤M<6.5, big ones - M≥6.5. The remaining notation – in Figure 1a. (b) The notation – in Figure 1b.

Ring structures in the whole region under consideration are shown in Figure 15. It follows from the Figure, that the shallow and deep rings fill the entire strip between 46º and 56.5º N, and intersect or touch each other. Gaps between rings are observed only in the rupture zone of the giant Kamchatka earthquake of 1952, and to the south of it, between 48º and 51.5º N.

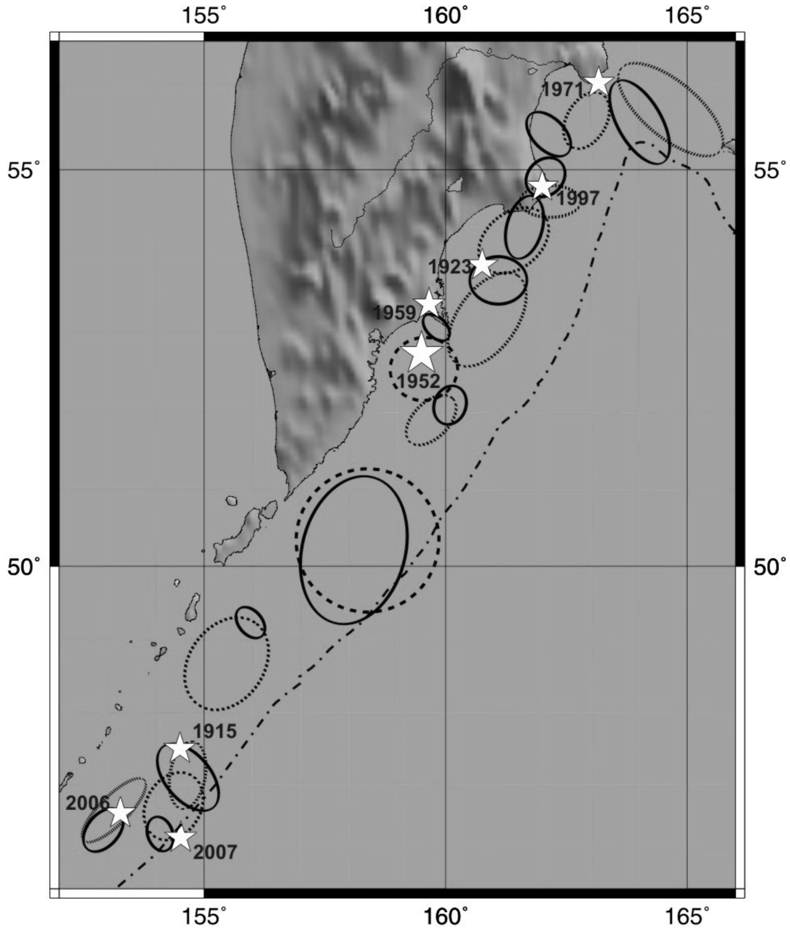


Figure 15

Ring-shaped seismicity in the region of the Kuril-Kamchatka arc. Epicenters of large and great earthquakes: small stars – 7.8≤Mw<8.5; big one – Mw 9.0 (the years of these events are shown). The remaining notation – in Figure 1a.

Estimates of magnitudes of possible earthquakes in the region of Kuril and Kamchatka. To estimate the energy released by earthquakes that can occur in the areas of the ring structures, we use an approach based on a comparison with data obtained for Sumatra region (Kopnichev and Sokolova, 2009b). It was shown in this paper, that the sizes of shallow and deep rings and also the values of Mt1 and Mt2 increase with Mw of the imminent earthquake. For a series of earthquakes that occurred in 2000 to 2008 in the Sumatra region (Mw=7.0-9.0), we obtained the following dependences of L, l, and also Mt1 and Mt2 values on the magnitude of the major events Mw (with high correlation quotients r):

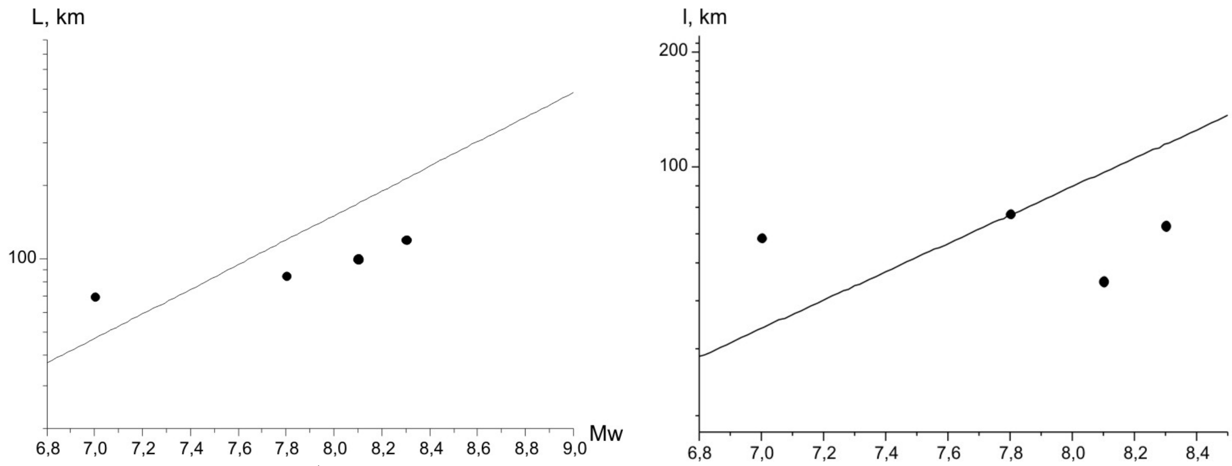
$$\log L \text{ (km)} = 0.51Mw - 1.88, \quad r=0.91, \tag{1}$$

$$\log l\,(km) = 0.37Mw - 1.04, \quad r = 0.86, \tag{2}$$

$$Mt1 = 1.92 + 0.38Mw, \quad r = 0.90, \tag{3}$$

$$Mt2 = -0.02 + 0.60Mw, \quad r = 0.92, \tag{4}$$

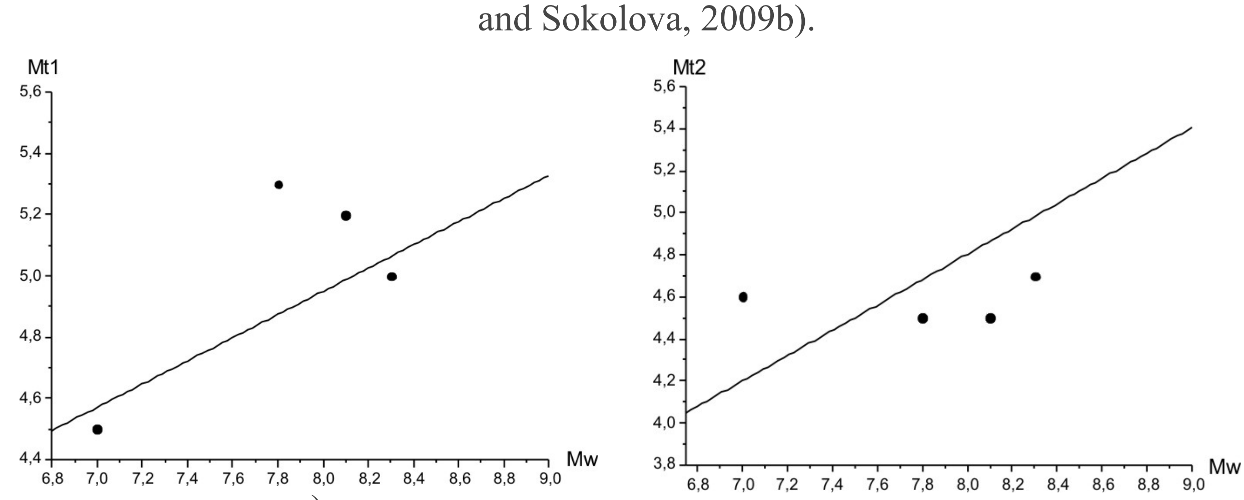
In Figures 16 and 17, values of these parameters for 4 earthquakes from the region of Kuril and Kamchatka that occurred between 1993 and 2007 are presented. It follows from Figures 16 and 17 that the values relating log L and log l to Mw for these events (in a range of Mw=7.0-8.3) differ insignificantly from (1) and (2) (by -0.13±0.17 and by -0.03±0.20). The corresponding values for Mt1 and Mt2 differ from (3) and (4) on average by 0.13±0.20 and by -0.09±0.30.



a) b)

Figure 16

The dependences of L (a) and l (b) on Mw for the region of Kuril-Kamchatka arc. The straight lines are the same dependences for the Sumatra region (Kopnichev and Sokolova, 2009b).



a) b)

Figure 17

The dependences of Mt1 (a) and Mt2 (b) on Mw for the region of Kuril-Kamchatka arc. The straight lines are the same dependences for the Sumatra region (Kopnichev and Sokolova, 2009b).

Taking these data into account, it is possible to use, as a first approximation, the expressions (1) and (2) to estimate values Mw, including the corrections obtained. In Table 3 mean prognostic values Mw are presented for all zones, where ring structures are identified. It follows from the Figure, that mean values Mw vary from 7.7 to 8.9.

Using values Mw, by formulas (3) and (4) it is possible to estimate prognostic values Mt1 and Mt2, including again corrections for these parameters, presented above. In Table 3 prognostic values Mt1 and Mt2, and also deviations of measured values from prognostic ones (ΔMt1 and ΔMt2) are shown. It follows from Table 3 that very high values of ΔMt1 and ΔMt2 are observed for areas 2 and 5 (correspondingly 0.4; 0.7 and 0.6; 0.7). Note that both areas are at the boundaries of the rupture zone of the giant Kamchatka earthquake of 1952 (prognostic values Mw equal 7.9±0.4 and 7.7±0.3 for these areas). Moreover, the northern area corresponds approximately to the rupture zone of the earthquake of 17.05.1841 (M~8.4). One more area (4) with relatively high values of ΔMt1 and ΔMt2 (0.4 and 0.3 correspondingly) is in the southern part of the rupture zone of the earthquake of 1952. At the same time, big negative values of ΔMt1 (-0.3) and ΔMt2 (-0.6) correspond to the southernmost area, at a border of rupture zones of events of 2006 and 2007 (Table 1).

Table 3

Forecast of values Mw, Mt1 and Mt2 for seismic gap zones in the region of Kuril and Kamchatka

Area	φ° N	λ° E	Mw	Mt1	Mt2	ΔMt1	ΔMt2
1	46.5-48	154-156	8.2±0.3	5.1	4.8	-0.3	-0.6

2	48-50	154-157	7.9±0.4	5.0	4.6	0.4	0.7
3	49-52	157-160	8.9±0.4	5.4	5.2	-0.4	-0.2
4	51-52.5	159-161	7.7±0.1	4.9	4.5	0.4	0.3
5	52-53.5	158-161	7.7±0.3	4.9	4.5	0.6	0.7
6	52-54	160-162	8.2±0.1	5.1	4.8	0.2	0.2
7	53-55	160-163	8.1±0.1	5.1	4.7	0.2	-0.2
8	54-55.5	161-163	7.8±0.1	5.0	4.6	0.3	0.1
9	55-56.5	161-164	7.9±0.1	5.0	4.6	0.0	0.1
10	55-56.5	163-166	8.5±0.1	5.3	5.0	0.1	-0.3

Large negative values of threshold magnitudes are observed also for the area 3, which is situated in the central part of the rupture zone of the Kamchatka earthquake of 1952 (-0.4 and -0.2). Of course, the mentioned values should be considered only as a first approximation, because of limited data quantity for the rupture zones of the past large earthquakes in Kuril and Kamchatka region, especially for two areas, where estimates Mw>8.3 are obtained.

Discussion

The data analysis shows that in the region of Kuril and Kamchatka ring-shaped seismicity structures in two depth ranges are widely distributed, as in some other subduction zones (Kopnichev and Sokolova, 2009a; 2009b). In the region under consideration the mean thickness of continental crust is ~30-35 km (Bűrgmann et al., 2005). Thus it is sensible to assume, as a first approximation, that the shallow rings form in the crust, and the deep ones in the uppermost mantle (mainly within the mantle wedge). It is important, that epicenters of large and great earthquakes, as a rule, are in the areas of ring intersections or shortest distances between them (Kopnichev and Sokolova, 2009a; 2009b). The same conclusion could be made for four zones of large and great earthquakes in the region of Kuril and Kamchatka.

It has been shown in (Kopnichev and Sokolova, 2008a; 2008b) that high attenuation of short-period shear waves occurs near the contours of shallow rings. At the same time, relatively weak attenuation is observed inside the shallow rings. The absence of recent volcanism shows, that these rings are not connected with partially molten rocks. For this reason, the most natural explanation of these effects is connected to migration of deep fluids. It's possible to suppose, that the shallow rings form at the borders of relatively rigid blocks, where fluid ascent takes place (Kopnichev and Sokolova, 2008a; 2008b).

We do not yet have detailed information on characteristics of the media within the deep rings, but it is known that mantle wedges, where these rings are mainly located, consist of hydrated rocks with relatively low viscosity (Umeda et al., 2007). It is possible to suggest that seismicity at contours of deep rings is governed by the embrittlement of rock of the oceanic crust and uppermost mantle resulting from dehydration (Yamasaki et al., 2003).

Note that in the case of existing two-phase layers with an interconnected network of fractures and pores, filled by fluid, stress concentration is observed at the top of the layer (Gold and Soter, 1984). Importantly, the value of stress increases with the layer thickness. In the cases under consideration the maximum stress should be observed in areas, where fluid networks, corresponding to the edges of shallow and deep rings, border and the maximum thickness of the two-phase layer takes place. This allows us to explain the locations of epicenters of large and great earthquakes in the areas of shallow and deep rings intersect or approach one another. New data agree with an effect of ascending mantle fluids into the earth's crust after large and great earthquakes (Husen and Kissling, 2001; Kopnichev and Sokolova, 2003; Kopnichev et al., 2009; Ogawa and Heki, 2007).

The biggest data volume on ring-shaped seismicity has been obtained for the Sumatra region, where 10 events with Mw=7.0-9.0 have occurred between 2000 and 2008 (Kopnichev and Sokolova, 2009a; 2009b). Seismicity rings were revealed clearly prior to these earthquakes, the sizes of which varied from 35 to 700 (for shallow ones) and from 30 to 200 (for deep ones). Moreover, in the Sumatra region seismicity rings have been identified in seismic gaps, where no large events (M>7.7) had occurred since 1900.

Our data show that prior to 4 large and great earthquakes that occurred in the region of central Kuril and Kamchatka between 1993 and 2007, ring-shaped seismicity structures have also developed in two depth ranges. Epicenters of large earthquakes in all four cases were located near areas of intersection of the shallow and deep rings. At the same time, the areas of ring intersection prior to the earthquake of 15.01.2009 were quite far from the epicenter of this event. Also, in area I values Mt1 and Mt2 are underestimated strongly relative to the prognostic value Mw (taking into account corrections, presented above). This allows us to suggest, that the event of 15.01.2009 was initiated by stress increase after two great earthquakes with Mw>8.0, similarly to Sumatra region (Sorensen and Atakan, 2008). For this reason the seismicity rings, which possibly reflect the fluid ascent process, did not have time to form here.

Importantly, seismicity rings formed in seismic gaps in the region of northern Kuril and Kamchatka until the beginning of 2009. The values of ΔMt1 and ΔMt2 can be considered as a measure of intensity of mantle fluid ascent in corresponding areas (Kopnichev and Sokolova, 2009a; 2009b). Thus, using data on these values, it is possible to estimate the extent over which the potential for a large earthquake might be developing in a given area. Taking this into account, one can compare our data with long-term forecasts by Fedotov et al. (2007) for the Kuril-Kamchatka region.

The biggest values of ΔMt1 and ΔMt2 were obtained for areas 2 and 5 (prognostic values Mw for them equal 7.9±0.4 and 7.7±0.3, respectively). According to Fedotov et al. (2007), the probability of earthquakes with M≥7.7 in these areas until November, 2011 is rather high. (The data, obtained here and earlier (Kopnichev and Sokolova, 2009a; 2009b), may show that epicenters of large earthquakes should be located near areas of intersection or maximum approach of seismicity rings). At the same time, the highest probability of a large or great earthquake during the period indicated, according to (Fedotov et al., 2007), corresponds to the area 3. For this area we obtained the maximum prognostic value Mw (8.9±0.4) and simultaneously negative values of ΔMt1 and ΔMt2. The data obtained allow us to suggest that a great earthquake is less probable here in the near future, than large events in areas 2 and 5 (and also, to the less extent, in area 4).

From an analysis of GPS and gravimetry data Bürgmann et al. (2005) pointed out areas of maximum coupling of descending Pacific plate in the region of Kamchatka. According to Bürgmann et al. (2005), the strongest coupling, which corresponds usually to areas of future strong earthquakes, is located directly to the south of Shipunskiy peninsula. This zone coincides with area 5, for which, for data on ring structures, we predict the maximum probability of a large earthquakes in the near future. (Note that a section of subduction zone with a width of ~100 km to the south of 53º N corresponds to an area of biggest seismic moment release during the Kamchatka earthquake of 1952 (Johnson and Satake, 1999)).

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