Geosistemy perehodnykh zon = Geosystems of Transition Zones / Геосистемы переходных зон

2023, vol. 7, no. 1, pp. 25–53

URL: http://journal.imgg.ru/archive.html ; https://elibrary.ru/title_about.asp?id=64191

https://doi.org/10.30730/gtrz.2023.7.1.025-036.037-053 ; https://www.elibrary.ru/xdworg

On stress drops in the sources of moderate and weak earthquakes: features of distribution in time

Leonid M. Bogomolov[1], https://orcid.org/0000-0002-9124-9797, bleom@mail.ru

Vladimir N. Sychev*[1], https://orcid.org/0000-0001-7508-9087, koitash@mail.ru

Naylya A. Sycheva[2], https://orcid.org/0000-0003-0386-3752, ivtran@mail.ru

[1]*Institute of Marine Geology and Geophysics of the Far Eastern Branch of RAS, Yuzhno-Sakhalinsk, Russia*

[2]*Schmidt Institute of Physics of the Earth of RAS, Moscow, Russia*

Abstract PDF ENG Резюме PDF RUS Full text PDF RUS & ENG

Abstract. An analysis has been performed of the change in stress drops over time during the period of foreshock activity of strong earthquakes for two seismically active regions with different geodynamic settings: the Northern Tien Shan and the Southern Kuril Islands. The catalogs of earthquake dynamic parameters, DP (source ones in English publications), in these regions, with a number of events, were used as initial data. The DP catalog for the Northern Tien Shan includes 183 records of source parameters of earthquakes with magnitudes of 2.6–6.0, and the catalog for the Southern Kurils – 264 records. The stress drop values throughout a general sampling were analyzed as well as that in foreshock periods of 500 days length before the strongest earthquakes. For each region 12 such meaningful events have been specified, the magnitudes were $M > 5$ for the Northern Tien Shan, and $M \geq 6.5$ for the Southern Kurils. The median average values of stress drops during 500-day period have been determined. The temporal variations of stress drops have been compared with changes in the *b*-value parameter (angular coefficient of earthquake recurrence plot) in the same observation periods. The computation of *b*-value for the case of the Northern Tien Shan involved the catalog data of KNET seismological network (1994–2021, more than 10 000 events), and the catalog of International Seismological Center (ISC, 1964–2000) for the Southern Kurils. In both cases, *b*-values were determined in 500-day moving interval with one day step. The computation gave the result that the well-known effect of *b*-value growth before strong earthquakes manifested itself explicitly in the considered regions. It has been established that such increase in *b*-value is accompanied by a decrease in the averaged stress drop values. The obtained results showed that the monitoring of the stress drop values can be used to identify the non stationary stage of the seismic regime.

Keywords:

earthquake, seismicity, foreshocks period, stress drops, *b*-value,

Northern Tien Shan, Southern Kuril Islands

For citation: Bogomolov L.M., Sychev V.N., Sycheva N.A. On stress drops in the sources of moderate and weak earthquakes: features of distribution in time. *Geosistemy perehodnykh zon = Geosystems of Transition Zones*, 2023, vol. 7, no. 1, pp. 25–53. (In Russ. & Engl.). https://doi.org/10.30730/gtrz.2023.7.1.025-036.037-053 ; https://www.elibrary.ru/xdworg

References

1. Sycheva N.A., Bogomolov L.M., Kuzikov S.I. **2020.** *Computational technologies in seismological studies (on the example of KNET, Northern Tian Shan).* Yuzhno-Sakhalinsk: IMGiG DVO RAN, 358 p. (In Russ.). https://dx.doi.org/10.30730/978-5-6040621-6-6.2020-2
2. Kal'met'eva Z.A., Mel'nikova T.A., Musienko E.V., Yudahin F.Ya. **1992.** [Models of source zones of strong earthquakes]. In: [*Typical geological and geophysical models of seismic and aseismic regions*]. Bishkek: Ilim, p. 124–131. (In Russ.).
3. Burymskaya R.N. **2001.** [Radiation spectral content and the source parameters of earthquake in the northwestern Pacific during 1969–1996]. In: A.I. Ivashchenko (ed.) [*Dynamics of source zones and forecast of the strong earthquakes in the Northwestern Pacific*]. Yuzhno-Sakhalinsk: IMGiG DVO RAN, vol. 1: 48–67. (In Russ.).
4. Klyuchevskii A.V., Demjanovich V.M. **2002.** Source amplitude parameters of strong earthquakes in the Baikal seismic zone. *Izv., Physics of the Solid Earth*, 38(2): 139–148. EDN: LHLKPZ
5. Brune J.N. **1970.** Tectonic stress and the spectra of seismic shear waves from earthquakes. *J. of Geophysical Research*, 75(26): 4997–5009. https://doi.org/10.1029/jb075i026p04997
6. Brune J.N. **1971.** Corrections. *J. of Geophysical Research*, 76: 5002.
7. Sycheva N.A., Bogomolov L.M. **2020.** On the stress drop in North Eurasia earthquakes source-sites versus specific seismic energy. *Geosistemy perehodnykh zon = Geosystems of Transition Zones*, 4(4): 393–446. (In Russ. & Engl.). https://doi.org/10.30730/gtrz.2020.4.4.393-416.417-446

8. Dziewonski A.M., Chou T.A., Woodhouse J.H. **1981.** Determination of earthquake source parameters from waveform data for studies of regional and global seismicity. *J. of Geophysical Research*, 86: 2825–2852. https://doi.org/10.1029/jb086ib04p02825
9. Kocharyan G.G. **2012.** About the radiative efficiency of earthquakes (example of geomechanical interpretation of seismological observation results). *Dynamic processes in the geospheres*, 3: 36–47. (In Russ.).
10. Kocharyan G.G. **2014.** Scale effect in seismotectonics. *Geodynamics & Tectonophysics*, 5(2): 353–385. (In Russ.). https://doi.org/10.5800/GT-2014-5-2-0133
11. Kocharyan G.G. **2016.** *Geomechanics of faults*. Moscow: GEOS, 424 p.
12. Kocharyan G.G., Ivanchenko G.N., Kishkina S.B. **2016**. Energy radiated by seismic events of different scales and geneses. *Izv., Physics of the Solid Earth*, 52(4): 606–620. https://doi.org/10.1134/s1069351316040030
13. Bogomolov L.M., Sycheva N.A., Zakupin A.S., Kamenev P.A., Sychev V.N. **2015.** Stress drop distribution in sources of earthquakes and trigger effects manifestation. In: [*Trigger effects in geosystems: Proceedings of the Third All-Russian workshop-meeting (Moscow, 16–19 June, 2015)*, *IDG RAS*]. Moscow: GEOS, p. 48–56. (In Russ.).
14. Sycheva N.A. **2020.** Seismic moment tensor and dynamic parameters of earthquakes in the Central Tien Shan: translation. *Geosistemy perekhodnykh zon* = *Geosystems of Transition Zones*, 4(2): 178–209. (In Russ. & Engl.). https://doi.org/10.30730/gtrz.2020.4.2.178-191.192-209
15. Molnar P., Tapponnier P. **1975**. Cenozoic tectonics of Asia: Effects of a continental collision: features of recent continental tectonics in Asia can be interpreted as results of the India-Eurasia collision. *Science*, 189(4201): 419–426. https://doi.org/10.1126/science.189.4201.419
16. Sycheva N.A. **2022**. Some characteristics of the earthquake catalog and the seismic process according to the KNET network. *Geodynamics & Tectonophysics*, 13(3). (In Russ.) https://doi.org/10.5800/GT-2022-13-3-0640
17. Nusipov E.H., Ospanov A.M., Li A.N., Nysanbaev T.E. **2004.** Lugovskoe earthquake May 23, 2003. In: [*Modern geodynamics and seismic risk in Central Asia: Reports of the Fifth Kazakh-Chinese International Symposium, September 24–27, 2003*]. Almaty: IS MON RK, p. 19–25. (In Russ.).
18. Grebennikova V.V., Frolova A.G., Bagmanova N.H., Beryozina A.V., Pershina E.V., Moldobekova S**. 2018.** Kadji-Say earthquake (November 14, 2014) with K_p=13.7, M_{PVA}=6.2, I_0=7 (Kyrgyzstan – Southern Issyk-Kul). *NNC RK Bulletin*, 2(June): 135–143. (In Russ.). https://doi.org/10.52676/1729-7885-2018-2-135-143
19. Fortuna A.B., Abdieva S.V., Klokov I.A., Korzhenkov A.M., Strel'nikov A.A. **2019.** [Seismicity of Issyk-Kul region]. *Vestnik Instituta sejsmologii NAN KR* [*Bull. of the Institute of Seismology of the National Academy of Sciences of the Kyrgyz Republic*], 2(14): 98–107. (In Russ.). https://journal.seismo.kg/archive/journal_2019-14/article11.pdf
20. Guseva I.S., Arkhipova E.V. **2019.** [Analysis of the system unity of the modern development of the Kuril-Kamchatka Island Arc and Sakhalin Island on the basis of seismological data]. *Uspekhi sovremennogo estestvoznaniya* = *Advances in Current Natural Sciences*, 6: 46–50. (In Russ.).
21. Prytkov A.S., Vasilenko N.F., Frolov D.I. **2017.** Recent geodynamics of the Kuril subduction zone. *Russian J. of Pacific Geology*, 11(1): 19–24.
22. Tihonov I.N., Levin B.V**. 2015.** [Forecast of strong earthquakes in the Sakhalin region: history, results and prospects]. [*Geodynamic processes and natural disasters. Experience of Neftegorsk: Sat. materials of the All-Russian scientific conference with international participation* (ed. by B.V. Levin, O.N. Likhacheva). In 2 vol. Yuzhno-Sahalinsk; Vladivostok: Dal'nauka, vol. 1: 41–45. (In Russ.).
23. Safonov D.A., Konovalov A.V. **2017.** Moment tensor inversion in the Kuril-Okhotsk and Sakhalin regions using ISOLA software*. Tikhookeanskaya Geologiya*, 36(3): 102–112. (In Russ.).
24. *International Seismological Centre ISC-EHB: Event catalogue.* URL: http://www.isc.ac.uk/citations/ (accessed: 02.11.2022).
25. Kostrov B.V. **1975.** *Focal mechanics of a tectonic earthquake*. Moscow: Nauka, 175 p. (In Russ.).
26. Riznichenko Yu.V. **1985.** [*Problems of seismology*]. In: *Izbrannye trudy* [*Selected works*]. Moscow: Nauka, 408 p. (In Russ.).
27. Madariaga R. **1976.** Dynamics of an expanding circular fault. *Bull. of the Seismological Society of America*, 66: 639–666.
28. Madariaga R. **1979.** On the relation between seismic moment and stress drop in the presence of stress and strength heterogeneity*. J. of Geophysical Research*, 84: 2243–2250. https://doi.org/10.1029/jb084ib05p02243
29. Boore D.M. **2003.** Simulation of ground motion using the stochastic method. *Pure and Applied Geophysics*, 160(3): 635–676. https://doi.org/10.1007/pl00012553
30. Abercrombie R.E., Rice J.R. **2005**. Can observations of earthquake scaling constrain slip weakening? *Geophysical J. International*, 162: 406–424. https://doi.org/10.1111/j.1365-246x.2005.02579.x
31. Lancieri M., Madariaga R., Bonilla F. **2012**. Spectral scaling of the aftershocks of the Tocopilla 2007 earthquake in northern Chile. *Geophysical J. International*, 189: 469–480. https://doi.org/10.1111/j.1365-246X.2011.05327.x
32. Kaneko Y., Shearer P.M. **2014**. Seismic source spectra and estimated stress drop derived from cohesive zone models of circular subshear rupture. *Geophysical J. International*, 197(2): 1002–1015. https://doi.org/10.1093/gji/ggu030
33. Gibowicz S.J., Kijko A. (eds) **1994.** *An introduction to mining seismology*. San Diego: Academic Press, 399 p. https://doi.org/10.1016/c2009-0-02348-4
34. Moskvina A.G. **1969.** [The displacement field of elastic waves formed by propagating dislocation]. *Izvestiya AN SSSR. Fizika Zemli*, 6: 3–10. (In Russ.).
35. Moskvina A.G. **1969.** [Studies of the displacement fields of elastic waves depending on characteristics of earthquake source]. *Izvestiya AN SSSR, Fizika Zemli*, 9: 3–16. (In Russ.).
36. Sato T., Hirasawa T. **1973.** Body wave spectra from propagating shear cracks. *J. of Physics of the Earth*, 21: 415–431. https://doi.org/10.4294/jpe1952.21.415
37. Kwiatek G., Ben-Zion Y. **2013.** Assessment of *P* and *S* wave energy radiated from very small shear-tensile seismic events in a deep South African mine. *J. of Geophysical Research: Solid Earth*, 118(7): 3630–3641. https://doi.org/10.1002/jgrb.50274
38. Gutenberg B., Richter C.F. **1944**. Frequency of earthquakes in California. *Bull. of the Seismological Society of America*, 34: 185–188. https://doi.org/10.1785/bssa0340040185

39. Smirnov V.B., Zavyalov A.D. **2012.** Seismic response to electromagnetic sounding of the Earth's lithosphere. *Izv., Physics of the Solid Earth*, 48(7): 615–639. https://doi.org/10.1134/s1069351312070075
40. Smirnov V.B., Ponomaryov A.V. **2020.** *Physics of transitional regimes of seismicity.* Moscow: RAN, 412 p. (In Russ.).
41. Popandopoulos G.A. **2018.** Detailed study of time variations in the Gutenberg–Richter *b*-value based on highly accurate seismic observations at the Garm prognostic site, Tajikistan. *Izv., Physics of the Solid Earth*, 54(4): 612–631. https://doi.org/10.1134/s1069351318040092
42. Lyubushin A.A. **2007.** *Analysis of data from geophysical and environmental monitoring systems*. Moscow: Nauka, 228 p.
43. Shchetnikov N.A **1981.** *Tsunami*. Moscow: Nauka, 88 p. (In Russ.).
44. Tikhonov I.N. **2006.** [*Earthquake catalog analysis methods for medium- and short-term predictions of strong seismic events*]. Vladivostok; Yuzhno-Sakhalinsk: IMGiG DVO RAN, 214 p. (In Russ.).
45. Bogomolov L.M., Sycheva N.A. **2022.** Earthquake predictions in XXI century: prehistory and concepts, precursors and problems. *Geosistemy perehodnykh zon* = *Geosystems of Transition Zones*, 6(3): 145–182. (In Russ. & Engl.). https://doi.org/10.30730/gtrz.2022.6.3.145-164.164-182