On the spatial distribution of postseismic activity in the Khibiny Mountains

© 2020 S.V. Baranov[1], A.Yu. Motorin[2], P.N. Shebalin[3]

[1]*KoB GS RAS*, *Apatity*, *Russia*; [2]*KB of Apatit*, *Kirovsk*, *Russia*; [3]*IEPT RAS*, *Moscow*, *Russia*

Abstract Using data on the seismicity of the Khibiny Mountains, it was shown that the distances from seismic events triggered by an earlier seismic event to their triggers obey a power-law distribution with a parameter independent of the magnitude of the trigger event. It was previously shown by Felzer & Brodsky [2006], Richards-Dinger et al. [2010] that the same distribution is appropriate for tectonic seismicity. Additionally, in the present paper, it was shown that in the Khibiny Mountains, the distribution of distances from seismic events to triggering explosions is also power-law. Thus, the power-law character of the spatial distribution of post-seismic activity takes place both for tectonic and mining-induced seismicity. The same type of distribution for postseismic and post blasting activities in Khibiny Mountains gives a reason to suppose that the spatial distribution is determined by the features of the rock and does not depend on the mechanism of its perturbation (seismic event or explosion). The use of these features and the previously established laws of earthquake productivity, verified for mining-induced seismicity, and seismic productivity of explosions, allows evaluating the zone where repeated events are expected with a given probability.

Keywords Khibiny Mountains, seismic events, explosions, aftershocks, spatial distribution.

For citation Baranov, S.V., Motorin, A.Yu., & Shebalin, P.N. (2020). [On the spatial distribution of postseismic activity in the Khibiny Mountains]. *Rossiiskii seismologicheskii zhurnal* [Russian Journal of Seismology], *2*(3), 34-42. (In Russ.). DOI: https://doi.org/10.35540/2686-7907.2020.3.03

References

Adushkin, V.V. (2016). Tectonic earthquakes of anthropogenic origin. *Izvestiya. Physics of the Solid Earth*, *52*(2), 173-194.

Arzamastsev, A.A., Arzamastseva, L.V., Zhirova, A.M., & Glaznev, V.N. (2013). Model of formation of the Khibiny-Lovozero ore-bearing volcanic-plutonic complex. *Geology of Ore Deposits*, *55*(5), 341-356.

Baiesi, M., & Paczuski, M. (2004). Scale-free networks of earthquakes and aftershocks. *Physical Review E*, *69*(6), 066106-1 - 066106-8. doi: 10.1103/PhysRevE.69.066106

Baranov, S.V., Zhukova, S.A., Korchak, P.A., & Shebalin, P.N. (2020). Productivity of Mining-Induced Seismicity. I*zvestiya. Physics of the Solid Earth*, *56*(3), 326-336.

Baranov, S.V., Zhukova, S.A., Shebalin, P.N., & Motorin, A.Yu. (2019). [On the independence of seismic productivity from the mechanism of rock pertrubation]. *Gornyj informacionno-analiticheskij byulleten'* (*nauchno-tekhnicheskij zhurnal*) [Mountain Information and Analytical Bulletin (Scientific and Technical Journal)], *S37*, 333-342. (In Russ.).

Bayliss, K., Naylor, M., & Main, I.G. (2019). Probabilistic identification of earthquake clusters using rescaled nearest neighbor distance networks. *Geophysical Journal International*, *217*(1), 487-503.

Clauset, A., Shalizi, C.R., & Newman, M.E.J. (2009). Power-Law distributions in empirical data. SIAM Review, 51(4), 661-703. Retrieved from: https://arxiv.org/PS_cache/arxiv/pdf/0706/0706.1062v2.pdf

Felzer, K.R., & Brodsky, E.E. (2006). Decay of aftershock density with distance indicates triggering by dynamic stress. *Nature*, *441*(7094), 735-738.

Huc, M., & Main, I.G. (2003). Anomalous Stress Diffusion in Earthquake Triggering: Correlation Length, Time Dependence, and Directionality: Anomalous Stress Diffusion in Earthquake Triggering. *Journal of Geophysical Research: Solid Earth*, *108*(B7). doi: 10.1029/2001JB001645

Korchak, P.A., Zhukova, S.A., & Menshikov, P.Yu. (2014). [Formation and development of a system for monitoring seismic processes in the production area of Apatit JSC]. *Gornyj zhurnal* [Mining Journal], *10*, 42-46. (In Russ.).

Kozyrev, A.A., Semenova, I.E., Rybin, V.V., Panin, V.I., Fedotova, Yu.V., Konstantinov, K.N., Salnikov, I.V., Gadyuchko, A.V., Belousov, V.V., Korchak, P.A., & Streshnev, A.A. (2016). *Ukazaniya po bezopasnomu vedeniyu gornyh rabot na mestorozhdeniyah, sklonnyh i opasnyh po gornym udaram* (*Hibinskie apatit-nefelinovye*

mestorozhdeniya) [Guidelines for the safe conduct of mining operations in deposits prone and dangerous in mountain impacts (Khibiny apatite-nepheline deposits)]. Apatity, Russia: Mining Institute KSC RAS Publ., Apatit JSC Publ., 112 p. (In Russ.).

Kozyrev, A.A., Semenova, I.E., Zhuravleva, O.G., & Panteleev, A.V. (2018). [The hypothesis of the origin of a strong seismic event at the Rasvumchorr mine 01/09/2018]. *Gornyj informacionno-analiticheskij byulleten'* (*nauchno-tekhnicheskij zhurnal*) [Mountain Information and Analytical Bulletin (Scientific and Technical Journal)], *12*, 74-83. (In Russ.).

Onokhin, F.M. (1975). *Osobennosti struktur Hibinskogo massiva* [Features of the structures of the Khibiny mountains]. Leningrad, Russia: Nauka Publ., 105 p. (In Russ.).

Plenkers, K., Kwiatek, G., Nakatani, M., & Dresen, G. (2010). Observation of seismic events with frequencies f>25 kHz at Mponeng deep gold mine, South Africa. *Seismological Research Letters*, *81*(3), 467-479.

Richards-Dinger, K., Stein, R.S., & Toda, S. (2010). Decay of aftershock density with distance does not indicate triggering by dynamic stress. *Nature*, *467*(7315), 583-586.

Shebalin, P.N., Narteau, C., & Baranov, S.V. (2020). Earthquake productivity law. *Geophysical Journal International*, *222*(2), 1264-1269.

Vallejos, J.A., & Estay, R.A. (2018). Seismic parameters of mining-induced aftershock sequences for Re-Entry protocol development. *Pure and Applied Geophysics*, *175*, 793-811. doi: 10.1007/s00024-017-1709-5

Vallejos, J.A., & McKinnon, S.D. (2010). Omori's law applied to mining-induced seismicity and Re-entry protocol development. *Pure and Applied Geophysics*, *167*, 91-106.

Woodward, K., & Wesseloo, J. (2015). Observed spatial and temporal behavior of seismic rock mass response to blasting. *Journal of the Southern African Institute of Mining and Metallurgy*, *115*(11), 1045-1056.

Zaliapin, I., & Ben-Zion, Y. (2016). A global classification and characterization of earthquake clusters. *Geophysical Journal International*, *207*, 608-634.

Information about authors

Baranov Sergey Vladimirovich, Dr., Leading Researcher of the Kola Branch of the Geophysical Survey of the Russian Academy of Sciences (KoB GS RAS), Apatity, Russia. E-mail: bars.vl@gmail.com

Motorin Alexander Yurievich, Leading Geophysicist of the Kirovsk Branch of the Apatit of PhosAgro (KB of Apatit), Kirovsk, Russia. E-mail: AYuMotorin@phosagro.ru

Shebalin Peter Nikolaevich, Corresponding Member of RAS, Dr., Director of the Institute of Earthquake Prediction Theory and Mathematical Geophysics, Russian Academy of Sciences (IEPT RAS), Moscow, Russia. E-mail: p.n.shebalin@gmail.com