

New Data on Regularities of Fault Activation in the Baikal Rift System and the Adjacent Territory

S. I. Sherman

Presented by Academician S.V. Gol'din September 18, 2006

Received September 28, 2006

DOI: 10.1134/S1028334X07050303

Possible sources of fault activation in real time are deformation excitation waves generated by evolution of rifting and interplate motions.

In [1], spatial oscillating longitudinal–transverse migration of seismic sources in dynamic influence zones of specific faults is shown on the basis of seismic monitoring. Temporal quasi-periodicity of fault activation in real time is shown in [2, 3]. Based on the major criterion of modern activation of faults, i.e., confinement of seismic sources to them [1–3], and concepts of earthquake generation regions [4], properties of modern active faults unknown previously in the study region were revealed and new data on structural regularities and geodynamic sources of activation of ruptures were obtained.

The reconstructions discussed below are based on the following concept: a new focus of an earthquake reflects a macroscopic change in the inner structure of faults and its corresponding growth; this is accompanied by intensification of fracturing and displacement of limbs in the case of strong events. The frequency of seismic events in the fault zone reflects the intensity of violations of dynamic equilibrium and their probable periodicity. The tendency in the spatial orientation of sources along the fault axis correlates in time with macroscopic changes in the fault zone and the fault growth vector. According to S.V. Gol'din [5], the second mechanism of the development of a major fracture is realized: the fracture continues to develop along a newly formed percolation network of smaller ruptures, and the rate of fracture development (activation) can be extremely low compared to the geological time.

Based on the catalogue of earthquakes in the Baikal rift system (BRS) and the adjacent territory compiled by the Baikal Branch of the Geophysical Survey, Siberian Division, Russian Academy of Sciences, more than

100 faults of different ranks with seismic sources of classes 12–16 in areas of their dynamic influence have been revealed over the last 40 years (Fig. 1). By analogy with [6, 7, and others], we compiled graphs of the relationship between the length of a fault with the corresponding positions of earthquake epicenters (on the abscissa) and the time of events (on the ordinate). On graphs of time–space coordinates, slopes of lines reflect time trends of seismic events on faults, i.e., directions of their additional “ripping” expressed by seismic sources—episodes—in the long-term evolution of faults. Time trends form systems of parallel straight lines as though series of disturbances that initiate seismic events propagated with constant velocity along corresponding faults (Fig. 2). Each straight line corresponds to disturbances in specified faults, the slope of straight lines determines the velocity, and their deviation to the left or right from the vertical position defines the direction of disturbances along the strike of faults.

Based on similar slopes to the abscissa, time trends are systematized into six groups (table). Based on the criterion of similar velocities, i.e., extreme disturbances (activation) of faults, these groups testify to the identity of their activation parameters (Fig. 1). The velocity of fault activation V and the average fault length L show a high nonlinear correlation $r = 0.9$ (Fig. 3). The regression equation describes the correlation by the following interrelations of parameters:

$$V = 7E - 06L^3 - 0.0053L^2 + 1.2098L - 81.725 \text{ (km/year)},$$

where R^2 is approximation reliability. Furthermore, the different spatial direction of the time trend in faults (activation vector) is also recorded.

The revealed properties of faults—different velocity and vector trends of activation most likely related to deformation excitation waves (DEW)—give grounds to analyze thoroughly the structural position of activated faults in the general BRS structure at the boundary between the Siberian and Transbaikalian (Amur) plates [1]. For this purpose, we excluded from each of the six

*Institute of the Earth's Crust, Siberian Division,
Russian Academy of Sciences, ul. Lermontova 128, Irkutsk,
664033 Russia; e-mail: ssherman@crust.irk.ru*

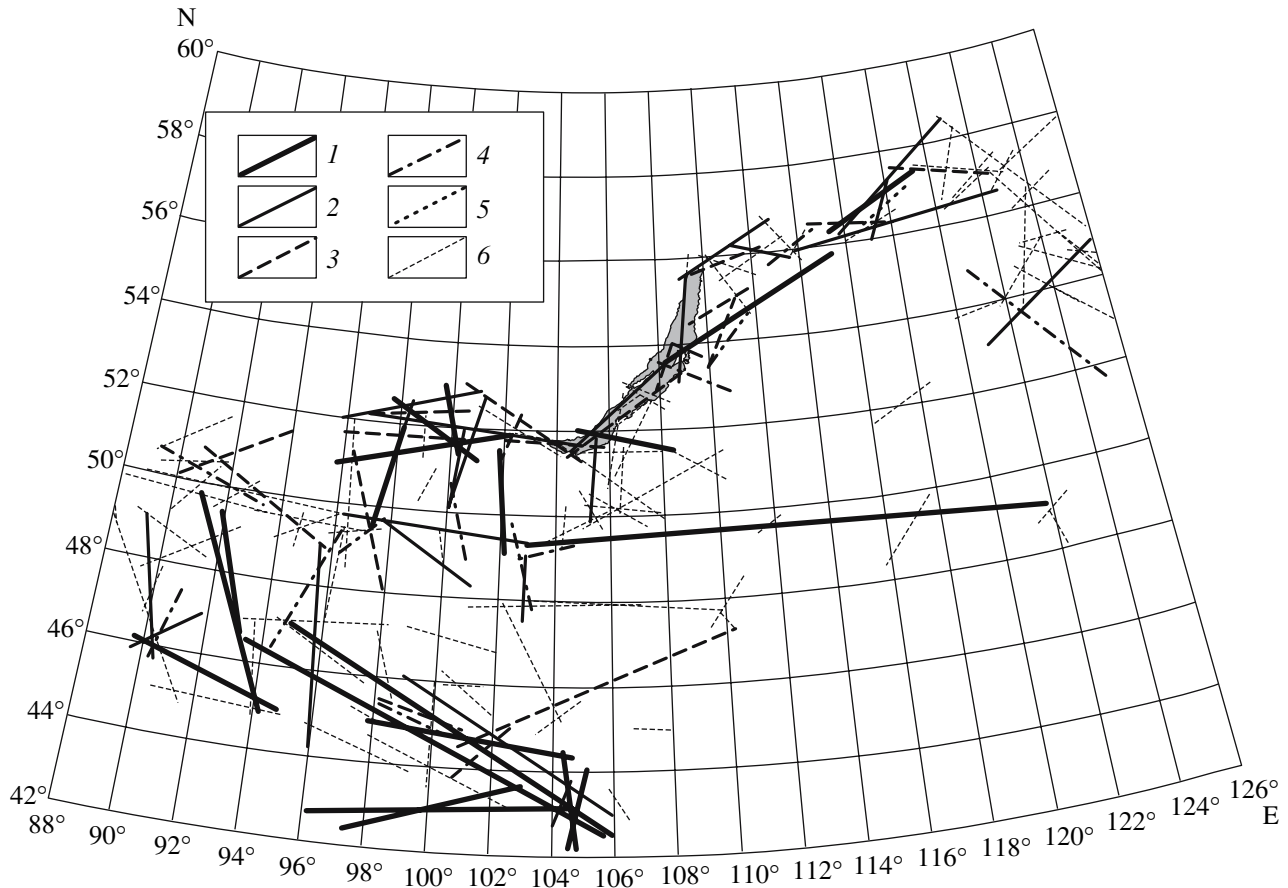


Fig. 1. Map of active faults of the BRS and adjacent territory and their classification by recent activation velocity. Groups of faults and their activation velocity (km/yr): (1) 94; (2) 22; (3) 12; (4) 7; (5) 5; (6) 2.

groups those faults, for which the trend lines were ensured by fewer than three events. The first four groups of faults successively shown in Fig. 4 remain statistically and reliably ensured. Their distinctive properties are the advance propagation of deformation excitation waves and the activation vector trend. The first and fourth groups are sharply distinguished in terms of these parameters. The first group is characterized by the prevalence of the W–E activation vector in the eastern part of the area and the E–W activation vector in the western part. Everything is quite the reverse in the fourth group. The southern part of the territory stands out sharply: all extended faults of the first group are characterized by the E–W activation vector. In the second group, the E–W activation vector prevails; the opposite activation vector of the DEW is recorded only at the southwestern flank. In the third group, practically all faults are characterized by the W–E activation vector of the DEW; the opposite direction is typical only of the southwestern flank. In terms of the parameter described, the second and third groups can be regarded as transitional between the first and fourth groups. The boundary of variation in the DEW vector is established quite undoubtedly for all four groups: the boundary is

submeridional (passes approximately along 105° E); it separates the central part of the BRS and its northeastern flank from the southwestern flank. The generation of wave disturbances resulting in activation of major faults starts in the central part of the zone of the BRS lithosphere extension and extends from it to the east and west. Extension with strike-slip and strike-slip stress fields, which are typical of BRS flanks and the

Parameters of recent activation of faults in the Baikal rift system and adjacent territory

Group/total number of faults/faults involved in the analysis	Average length of faults, km	Tangent of slope of activation time trend, deg	Average velocity of fault activation, km/yr
1/26/19	438 ± 152	89.4 ± 0.24	94 ± 57
2/23/22	321 ± 87	87.44 ± 0.3	22 ± 3
3/23/17	299 ± 94	85.39 ± 0.4	12 ± 1.25
4/15/14	206 ± 62	81.28 ± 0.9	7 ± 0.7
5/5/3	199 ± 269	78.76 ± 1.8	5 ± 1.8
6/5/3	131 ± 84	66.32 ± 5	2 ± 4.9

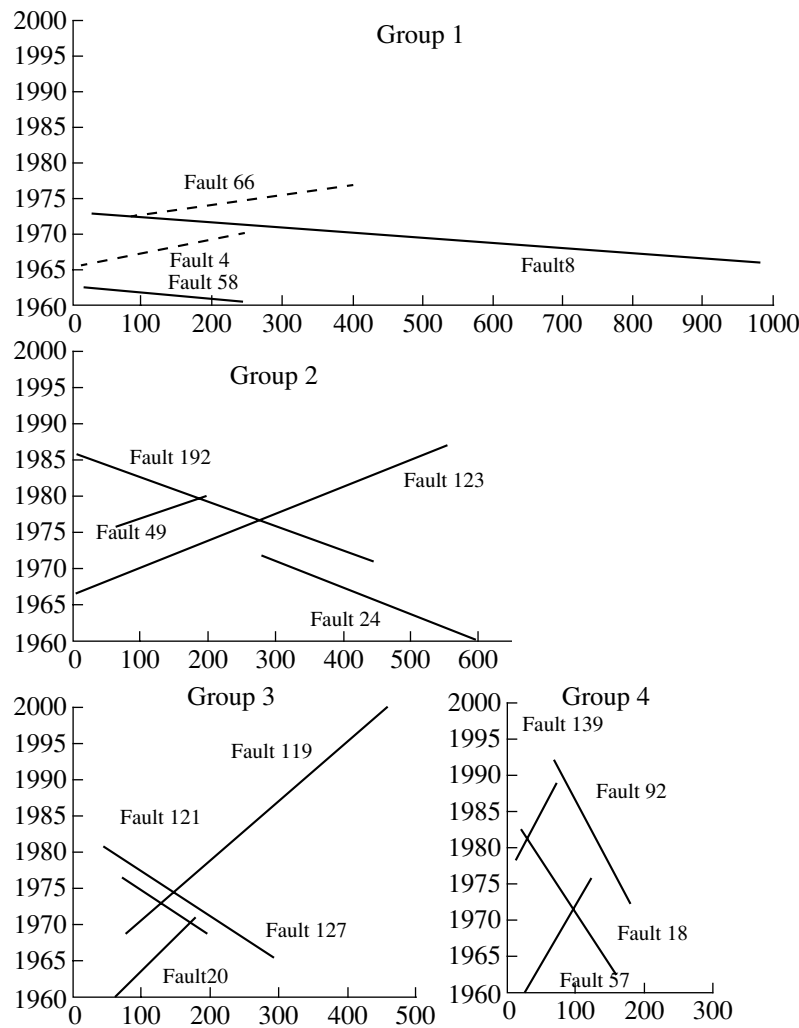


Fig. 2. Representative graphs of time trends of seismic events in the first four groups of faults with different activation velocities. Years of activation and fault length (km) are given along the ordinate and abscissa, respectively.

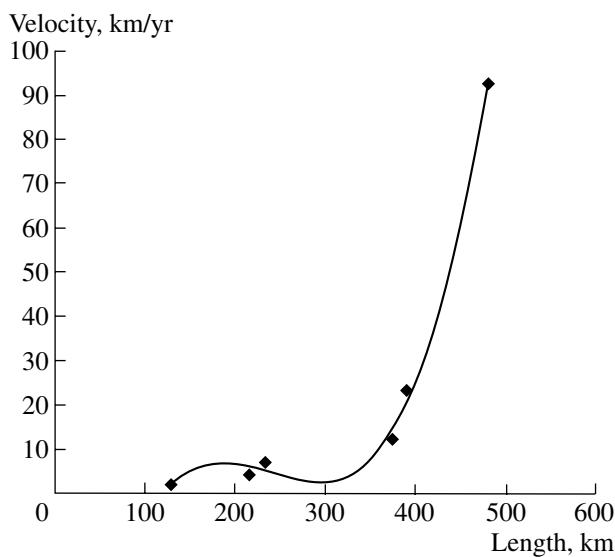


Fig. 3. Interrelation between the average length of faults in the groups and velocities of their activation.

southern part of the study territory [8], favor the activation of faults along the strike from east to west.

A regular coordination in activation of faults, which make up each of the hierarchic rank groups, and persistent directions of fracture ripping indicate that reactivation of faults in the BRS and adjacent territory in real time could be initiated by different-length DEWs, sensitivity to which is variable in the distinguished groups. Sources of such waves could be represented by ongoing processes of active rifting leading to episodic shifts of the whole interblock boundary between the Siberian and Amur (Transbaikalian) plates [9] or more local displacements between blocks of other ranks at the flanks or in the central part of the BRS. The high probability of excitation of waves due to displacements of blocks lying on a viscous base is consistent with calculations [10, 11].

Phenomena of systematic migration in one or various directions were registered for sources of mainly strong earthquakes in many seismic zones (see, for

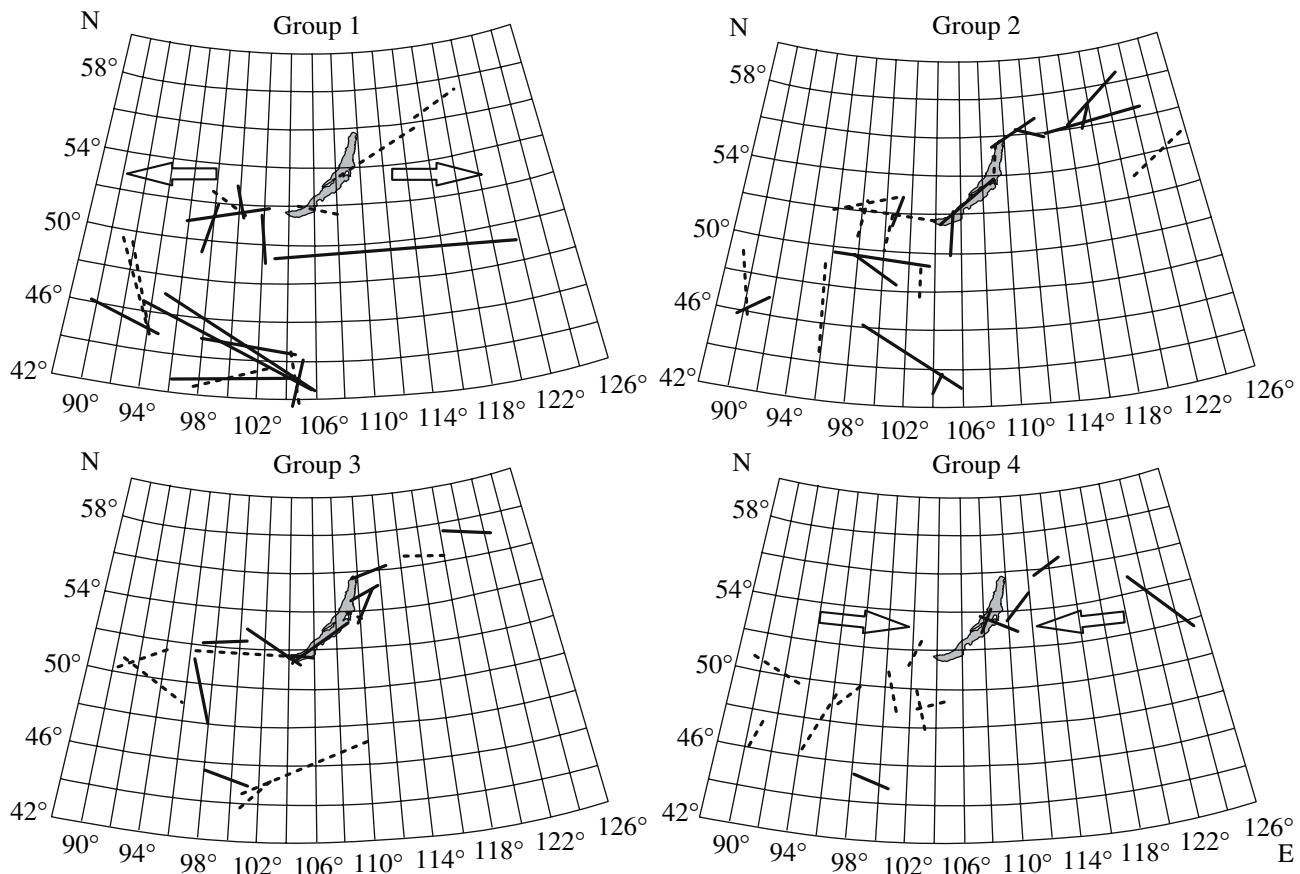


Fig. 4. Location of active faults in the BRS (northern Eurasia) and the adjacent territory with different velocities and vectors of DEWs. Dashed line shows the fault activation vector directed from west to east; solid line, the fault activation vector directed from east to west; and arrows, approximate direction of the front of DEWs of faults.

instance, [7, 12]). The established migration velocity of sources varies from 10 to 100 km/yr. Based on study of the seismoactive regions of Central Asia, Ulomov [13] pointed out the migration of sources in the so-called spatiotemporal channels owing to waves of seismic activation. To date, the fact of the existence of deformation waves is beyond question [14]. They can be regarded as one of the classes of mechanic movements typical of the Earth's crust and the lithosphere as a whole [15].

The facts presented above suggest several conclusions related to the current activation stage of faults in the BRS and adjacent territory. These conclusions supplement the concepts of the author of the present paper concerning the stationary and nonstationary models of faults with new characteristics: activation of faults and its relatively high frequency in real time are caused by slow DEWs, the source of which could be interplate and interblock displacements at the boundary between the Siberian and Transbaikalian (Amur) plates.

In terms of the propagation velocity of DEWs, active faults of the territory are subdivided into six groups, four of which are substantiated by statistically reliable data.

The groups are characterized by the following properties: (i) a clear relationship between the average length of faults and the velocity of the DEW motion; (ii) a definite orientation of the DEW time trend (from west to east or conversely); and (iii) the existence of a spatial boundary separating different trends of DEWs of faults of certain groups.

ACKNOWLEDGMENTS

The author is grateful to Academician S.V. Gol'din for advice taken into consideration during preparation of the manuscript.

This work was supported by the Russian Foundation for Basic Research (project nos. 04-04-64348, 07-05-00251), and the Presidium of the Russian Academy of Sciences (Program 16, Project 3 "Dynamics of Deformation Processes in Seismoactive Regions of Central Asia and in Source Zones of Strong Earthquakes").

REFERENCES

1. S. I. Sherman, V. M. Dem'yanovich, and S. V. Lysak, *Tectonophysics* **380** (3/4), 261 (2004).

2. S. I. Sherman, A. P. Sorokin, and V. A. Savitskii, Dokl. Earth. Sci. **401A**, 413 (2005) [Dokl Akad. Nauk **401**, 395 (2005)].
3. S. I. Sherman and V. A. Savitskii, Dokl. Earth Sci. **408**, 640 (2006) [Dokl. Akad. Nauk **408**, 398 (2006)].
4. S. V. Gol'din, Fiz. Mezomekhanika, No. 1, 5 (2005).
5. S. V. Gol'din, Fiz. Mezomekhanika, No. 5, 5 (2002).
6. E. V. Vil'kovich, Sh. A. Guberman, and V. I. Keilis-Borok, Dokl. Akad. Nauk SSSR **218**, 77 (1974).
7. K. Kasahara, Tectonophysics **52**, 329 (1979).
8. S. I. Sherman and O. V. Lunina, Dokl. Earth Sci. **379**, 553 (2001) [Dokl. Akad. Nauk **378**, 672 (2001)].
9. *Topical Problems of Modern Geodynamics of Central Asia*, Ed. by K. G. Levi and S. I. Sherman (SD RAS, Novosibirsk, 2005) [in Russian].
10. V. N. Nikolaevskii and T. K. Ramazanov, Izv. Akad. Nauk SSSR, Fiz. Zemli, No. 10, 3 (1986).
11. M. V. Nevskii, *Geophysics at the Turn of Centuries. Selected Works of OIFZ RAS* (OIFZ RAS, Moscow, 1999), pp. 124–139 [in Russian].
12. K. Mogi, *Earthquake Prediction* (Academic Press, Tokyo, 1985; Mir, Moscow, 1988).
13. V. I. Ulomov, Fiz. Zemli, No. 4, 43 (1993).
14. V. G. Bykov, Geol. Geofiz. **46**, 1176 (2005).
15. S. V. Gol'din, Fiz. Zemli, No. 10, 37 (2004).