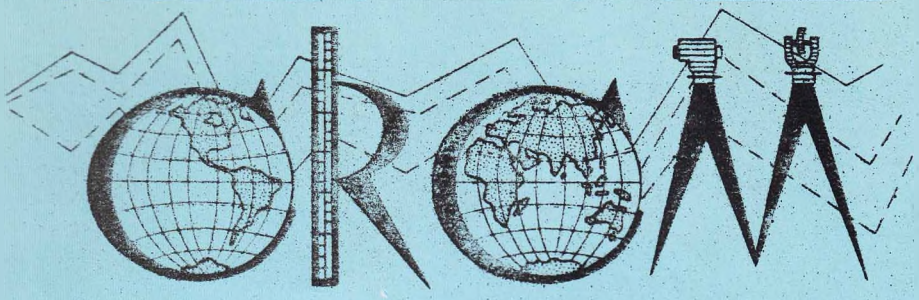
INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS
INTERNATIONAL ASSOCIATION OF GEODESY
COMMISSION ON RECENT CRUSTAL MOVEMENTS



Third Symposium

Leningrad, USSR, 22-29 May 1968

RECENT CATASTROPHIC CRUSTAL MOVEMENTS IN THE MONGOLIA-BAIKAL SEISMIC REGION

ACADEMY OF SCIENCES OF THE USSR

SIBERIAN DEPARTMENT

INSTITUTE FOR RESEARCH OF THE EARTH'S CRUST

IRKUTSK

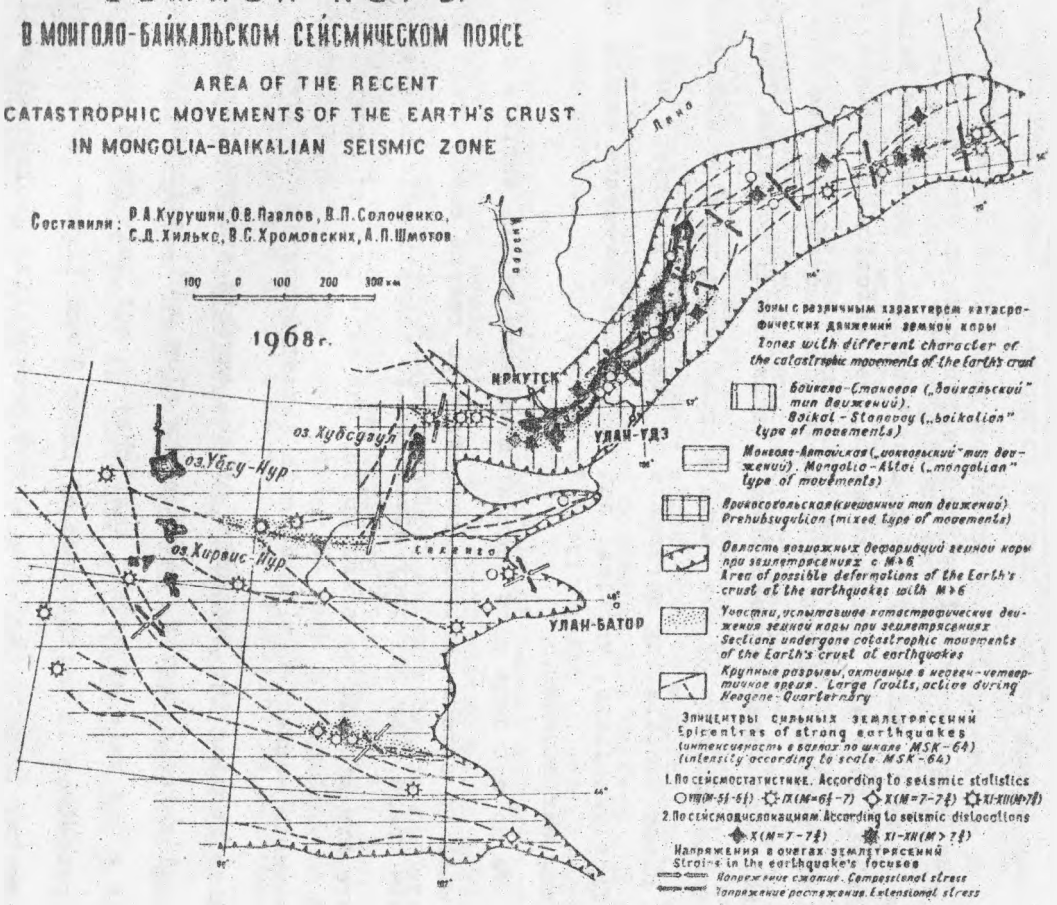
ОБЛАСТЬ СОВРЕМЕННЫХ КАТАСТРОФИЧЕСКИХ ДВИЖЕНИЙ ЗЕМНОЙ КОРЫ В МОНГОЛО-БАЙКАЛЬСКОМ СЕЙСМИЧЕСКОМ ПОЯСЕ

AREA OF THE RECENT CATASTROPHIC MOVEMENTS OF THE EARTH'S CRUST IN MONGOLIA-BAIKALIAN SEISMIC ZONE

Составили: Р.А.Курушин, О.В.Павлов, В.П.Солоненко, С.Д.Хилько, В.С.Хромовских, А.П.Шмотов

100 0 100 200 300 км

1968 г.



V.P.Solonenko, S.D.Milko, V.S.Khromovskih,
R.A.Kurushin, O.V.Pavlov, A.P.Shmotov.

RECENT CATASTROPHIC EARTH-CRUST MOVEMENTS IN THE MONGOLIA-BAIKAL SEISMIC REGION.

The Mongolia-Baikal seismic region with an area of about 2 million sq.km is mainly of two zones: Mongolia-Altaiski and Baikal-Stanovoi. They are different as to the tectonical (strength) field and the rate and direction of neotectonic movements. The Prikosso-golski zone takes between them a transitional position. The stable tectonic activity of the earth's crust shows up slow undulatory and block oscillating movements of the earth's surface and rapid, in fact immediate, vertical and horizontal movements coming up with strong earthquakes.

We do not deny slow secular movements of the earth's crust but we wish to stress that in literature on recent earth-crust movements there they pay poor attention to catastrophic movements. There are grounds to stand up for the main part of crustal block movements connected with seismic catastrophes in the present tectonics forming the sculpture of the earth's surface in the Mongolia-Baikal seismic region, because the slow oscillating motions have such a low rate of spread that they do not only go as seismotectonic processes in earthquakes of force 9 and higher (M>6.5) but also in weaker tremors (M>5.5-6.5) not provocating geological well defined displacements of the earth's surface. Moreover, numerous (1000 - 1500 shocks and more are there yearly alone in the Baikal-Stanovoi zone) weak and moderate earthquakes possibly may put up a much greater summary effect than recent oscillating movements.

The conclusions on recent oscillating movements of the Baikal coasts, put forward by V.V.Lamakin (6,7), are based on an errone-

ous interpretation of geodetic, hydrologic and geomorphologic data. Comparing the results of rerunning of levelling (1906-1907 and 1937-1943), watergauging (from 1869-1957), investigating of Baikal's hydrologic regime and measuring of Cherski's curbs showed that amplitudes of precent oscillating movements do not exceed the accuracy limits of instrumental investigations and that the different levels of wave-cut notches, which are for V.V.Lamakin very important, are due to wind surge in the lake and level variations (1,2,5,8).

Regions with a high seismic activity do hardly show the relief-forming role of recent oscillating movements or, at least, their essential influence on the change ofthe earth's surface: millimetre amplitudes of displacement in these movements are hundred and thousand times covered by amplitudes of displacement in strong earthquakes. To confirm the reliefforming role of recent sudden movements of the earth's crust needs of course data of strong earthquakes. For the territory of the Mongolia-Baikal seismic region we have date of 29 strong and catastrophic earthquakes (forces 9-11)[1] for the period from 1725-1967. The real number of such earthquakes is much greater but there are no data because the territory is deserted and there stand peculiar conditions in the historical development of Mongolia and Buryatia. Then geological visible vertical and horizontal displacements arose in pleistoseistic zones of such earthquakes.

The Tsaganski earthquake, 12 Jan.1862, came up with a clear sinking of the earth's surface on a territory stretch of 36 km and a breadth of 20 km; the earth cracked on a way of up to 125 - 130 km from the epicentre (12). A tectonic block of 260 sq.km sank

---

) The scheme shows epicentres of earthquakes with true coordinates.

for 7-8 m resulting in the Proval bay of a depth of 4-5 m (203 sq. km), where nothern the Middlebaikal earthquake broke cut (1959, force=9, M=6¾, H=18 km) which brought a lowering of the lake bottom of 10-15 m in the pleistoseistic zone and shoves along faults were 35 km from the epicentre (13).

By the Muiski earthquake, 27 June 1957, (force 10, M=7.8, H=22) on the north-west side of the Mongolia-Baikal seismic region there the embryonic basin of the Baikal type sank for 5-6 m and moved to south-west; the Udokan ridge lifted for 1-1.5 m and drew to north-east for 1-1.2 m and simultaneously moved upon the basin using the upthrust-shift. Shoves along the faults were seen in the east at 90 km and in the west at 50 km from the epicentre (19). In the east of the Muiski earthquake there were 2 other in 1958 with force 9 (M=6¾) and one in 1967 with force 9-10 (M=7-7½) going with visible displacements of the earth's crust.

The Gobi-Altai earthquake, 4 Dec. 1957, was teaching a lesson as to the character of catastrophic movements of the earth's crust (force 12, M=8.6, H=25-28 km). During this earthquake there the mountain range of Gobi-Altai with heights of 4,000 m, a length of 275 and breadth of 35 km lifted for 10 m, displaced almost 9m to the east and formed a rupture system with an extent of about 850 km. With the rise of a wedge-shaped tectonic block of the Ikhe-Bogdo mountains of 80 km long and 30 km broad, out of the stretching of the earth's crust, arose the central graben of Ikhe-Bogdo. The pitch of this process framed the gravitational-seismic structure of Bitut, holding elements of tectonic sinking and collapse. Thereby a mountain massif of about 3.5 sq.km subsided for 328 m and moved for some 10 m eastward. Further, in the region of the Bitut structure there 3 mountain caps broke off, 350 m from the top, and went

anticlockwise; the largest one had a basal section of 0.7 x 1.5 km (4,23). Latef on such structures were also found in Pribaikalia (16, 19, 22).

We wish to remind of the Khangaiski earthquakes, 9 and 23 July 1905 (M=8.4 and 8.7), with fault system lengths of 115 and 350 km, and earth-crust movements in an enormous area (4,23); the Mogotski earthquake, 5 Jan.1957 (force 10, M>7.5), came out in a length of 45 km with an amplitude of vertical displacement of up to 4-4.5 m.

So the earthquakes of Mongolia alone, from 1905 - 1967, came up with 8 seismotectonic fracture zones of 15 to 350 km long, where renovated and fresh faults make up over 2,000 km.

We should not slight that all given displacement amplitudes show only visible fault amplitudes; the true amplitude is much greater for unconsidered flexure strains.

Similar catastrophic movements of the earth's crust are not episodic. This is understood through systematic manifestations of remainder strains during recent earthquakes (in our case by M 6) and numerous paleoseismo-dislocations, traces of catastrophic earthquakes of the latest past with an age of ten/hundreds to thousand years. Such structures are ascertained more than 80 in the Mongolia-Baikal seismic region. The epicentres of strong earthquakes and paleoseismo-dislocations are spread all over the active part of the Mongolia-Baikal seismic region. There the odd epicenter concentration in different areas, likely, tells more about the how of study than the different levels of seismic activity.

Here the scales of paleoseismo-dislocations let us know the pass of systematic earthquakes of force 9 to 11-12 in the latest millennium, resulting in seismodislocations from several kilometres to 180 km and amplitudes of vertical displacement from 0.5 -

1.2 m to more than 20-30 m, but with seismogravitational structures of the Bitut type there the displacement crept up to 880 m. (16,20); and shifts, playing a secondary role in the Baikal-Stanovoi zone, are here often noted.

The high seismic activity of the Mongolia-Baikal seismic region comes from early stages of the Neogene-Quarternary activation, and the curve of neotectonic process takes up(21). This said, the problem of the type of recent crustal movements, which tie the keeping of geomorphological contrasts, is very weighty. And so: the size of pleistoseistic regions, the length of renovated faults, morphology and morphometry of rupture strains depend on the rate of recent movements, their energy and trend.

Investigations of the earthquake focus mechanism showed that distinguishing the Baikal-Stanovoi and Mongolia-Altai zones by geologic-structural and seismotectonic peculiarities is quite justified and confirmed there with different characters of crust stress.

The earth's crust of the Baikal-Stanovoi zone is under near-horizontal stretching, orthogonal to neotectonic structures, and steeply inclined (about 70°) compression along the structures. The axes of compressive and tensile stresses in the Mongolia-Altai zone are near-horizontal, compression stresses going across the strike of neotectonic structures. Then the discharge of tectonic stresses of the Baikal-Stanovoi zone is mainly drawing upon faults and shift-faults with a predominant vertical component, but that of the Mongolia-Altai is upon upthrust and upthrust-shifts. By these conditions and the same seismic potential, Mongolia is richer with catastrophic earthquakes than Pribaikalia, where the energy is given away to frequent but weaker ones. This means that the

Mongolian earthquakes with M>8 and epicentral zones of hundred of km are quite the thing while in Pribaikalia for strong earthquakes tens of km are regular and those of M>8 are very rare (15).

Prikossogolye is intermediate. Here across neotectonic structures act compressive stresses; tensile ones are near-vertical and oriented also across those structures or diagonally to them since the superposition of the "Mongolski" stress field on the "Baikalski". So by the earthquakes we may expect a mixed "Mongolia-Baikal" type of tectonic movements of the earth's crust.

In the Mongolia-Altaiski zone there is a process of intensive ridge development going on which is brought up on intermontane basins by drawing them in the pediment formation and also on forming foothills before the main clumpy uplifts of frontal tectonic wedges. The greatest foothills have in their faces tectonic wedges of the second order, going more deeper into the basins. Their bulging up goes oddly and so intensively that the Upper-Quarternary deposits on them incline 30° to the side of the main clumpy mountains and even deposits of the first terrace are found strained. By Gobi-Altaiski earthquakes all foothills were stricken with powerful fractures of upthrust-shifts and upthrusts on which the Pre-quaternary foothills formations was thrusted on recent deposits (14).

But the go of the Baikal-Stanovoi zone is a shortening of ridge areas standing on longitudinal and transversal development of rift structures and young upland basinformations. So there faults come up with all earthquakes by $M>6\frac{1}{2}$ and they are easily distinguished in seismological investigations of pleistoseistic regions. Ascvencive horst movements are more difficult to get at and the want of dead shots proving their activity, let spontaneously thrive the opinion of their present passive development, sticking to energy of flexural strain, inherited from the origin period of the Baikal

dome. Earlier we already doubted about the seismotectonic of these structures (17, 18) and now we have facts to stand up for their activity. They are: concentration of earthquake foci under some ridges; here and there the presence of two parallel faults, one confining the basin bottom and plunging under it, the other lining out on the rear seam of the slanting submontane plane (pediment) and dipping under the ridge; and visual observations in the epicentre of the Muiski earthquake by which the Udokan ridge lifted and moved eastward, the rear seismotectonic fracture having a dip under the ridge with an angle of about 70° 1).

Sudden movements of the earth's crust, naturally, do not go only within the fault field but take a considerable area. By the first approximation for earthquakes with intracrustal foci it goes equal (or a bit less) with the area over the stressed volume of the earth's crust, giving the energy for earthquake, fixed by after - shocks (10, 11, 25).

Though we supposed the strains of the earth's surface by strong earthquakes to hold large areas, observations surpassed our expectations. For instance, the area of sudden tectonic crustal movements (with an amplitudes of up to 4 m vertically and 3 m horizontally) by Alaska earthquake (1964, M>8.3-8.75) turned out to be about 200,000 sq.km (24).

Investigations on seismic regime and traces of heavy earthquakes disclosed this possible occurrence of earthquakes in a rather inquired and seismo-active part of the Baikal rift system of

---

1) All clearly expressed displacements of upthrust-shifts had a dip under the ridge with an angle of 68° (Gobi-Altai earthquake). Such angles have here paleoseismo-dislocations, which is apparently regular.

230,000 sq.km (during 1,000 years): force 8=508, 9=192, 10=68, 11=24, and 12=6.

These data and aftershock areas of the well investigated Kyakhtinski, Muiski, Gobi-Altaiski, East-Sayanski and Middlebaikalski earthquakes let us draw up the correlation dependence between earthquake magnitude and strain area (S km^2):

$$\lg S = (0.99 \pm 0.07)M - 3.6$$

Even by these preliminary calculations the minimum dimension of area suffering from seismotectonic movements wells up as that (1000 sq.km/1,000 years): by earthquakes of force: 8=127, 9=422, 10=[illegible]23, 11=600, 12=240. The total area is greater than 1.8 mill.sq.km, and this means that the earth's crust in the Baikal-Stanovoi zone during 1,000 years could undergo 8 rapid seismic movements. Their results are crying in many regions of the Mongolia-Baikal seismic area, while, alas, almost a century observations on the Baikal coast failed to let out any good data on secular movements there.

Rapid movements of the earth's crust are not characteristic for the Mongolia-Baikal seismic belt alone. Now we hold many data indicating their essential role in the African rift system, in Alaska, California, New Zealand, Japan, Middle Asia, in the Anatolia fault zone, Adriatic Sea and many other highseismic areas of the earth.

REFERENCES.

1. Афанасьев А.Н. Вопросы современной подвижности берегов Байкала. В кн.: "Проблемы неотектоники", М., 1964.

2. Афанасьев А.Н., Гречищев Е.К. Оценка современных тектонических движений на Байкале по данным

наблюдений над его уровнем. Труды Вост.-Сиб.геол.ин-та СО АН СССР, вып. 2. Иркутск, 1959 .

3. В в е д е н с к а я А . В . Особенности напряженного состояния в очагах Прибайкальских землетрясений. Изв. АН СССР, сер. геофиз., № 5, 1961.

4. Гоби-Алтайское землетрясение. Ред.: Н.А.Флоренсов, В.П. Солоненко. М., Изд-во АН СССР, 1963.

5. Г р е ч и ш е в Е . К . Методы оценки современных тектонических движений на Байкале. Бюлл. Совета по сейсмологии АН СССР, М., № 10, 1960.

6. Л а м а к и н В . В . Обручевский сброс на Байкале и Байкало-Селенгинский сдвиг. В кн.: "Идеи академика В.А. Обручева о геологическом строении Северной и Центральной Азии и их дальнейшее развитие". М.- Л., Изд-во АН СССР, 1963.

7. Л а м а к и н В . В . По островам и берегам Байкала. М., Изд-во "Наука", 1965.

8. Л о п а т и н Г . В . Многолетние колебания уровня Байкала. Тр.лимн.станции, т. XУ, М.-Л., 1957.

9. М и ш а р и н а Л . А . Напряжения в земной коре в рифтовых зонах. М., Изд-во "Наука", 1967.

10. П ш е н н и к о в К . В . Некоторые особенности повторных толчков землетрясений Прибайкалья и Монголии. Геология и геофизика, № 4, 1962.

11. П ш е н н и к о в К . В . Механизм возникновения афтершоков и неупругие свойства земной коры. М., Изд-во "Наука", 1965.

12. С г и б н е в А . С . Отчет Императорского Русского географического общества за 1869 год. Отчет о действиях Сибирского отдела ИРГО. Спб., 1864.

13. С о л о н е н к о В . П . , Т р е с к о в А . А . Среднебайкальское землетрясение 29 августа 1959 года. Иркутск,

I959.

I4. С о л о н е н к о В . П . Гоби-Алтайское землетрясение. Геология и геофизика, № 2, I960 .

I5. С о л о н е н к о В . П . Сейсмичность Южного Прибайкалья и опыт сейсмического микрорайонирования конуса выноса на оз. Байкал. Труды Ин-та земной коры СО АН СССР, вып. I8 - Вопросы сейсмичности Сибири. Новосибирск, I964.

I6. С о л о н е н к о В . П . Определение эпицентральных зон землетрясений по геологическим признакам. Изв. АН СССР, сер.геол. № II, I962.

I7. С о л о н е н к о В . П . Сейсмическое районирование Восточной Сибири. Иркутск, I963.

I8. С о л о н е н к о В . П . Сейсмотектоника и современное структурное развитие Байкальской рифтовой зоны. В кн.: Байкальский рифт. М., Изд-во "Наука", I968.

I9. С о л о н е н к о В . П . , Т р е с к о в А . А . и д р . Живая тектоника, вулканы и сейсмичность Станового нагорья. М., Изд-во "Наука", I966.

20. С о л о н е н к о В . П . , Т р е с к о в А . А . и др. Сейсмотектоника и сейсмичность рифтовой системы Прибайкалья. М., Изд-во "Наука", I968.

2I. Ф л о р е н с о в Н . А . Мезозойские и кайнозойские впадины Прибайкалья. М.-Л. , изд-во АН СССР, I960.

22. Х р о м о в с к и х В . С . Сейсмогеология Южного Прибайкалья. М., Изд-во "Наука", I965.

23. B a t h M . , D u d a S . J . Earthquake volume, fault-plane area, seismic energy, strain, deformation and related quantites. Annali de geofisica. Vol.XVII, N 3. Rome, 1964.

24. F l o r e n s o v N . A . , S o l o n e n k o V . P . Ed

The Gobi-Altai earthquake. Jerusalem-Washington, 1965. London, 1966

25. H a n s e n W a l l a c e R . The Alaska earthquake of 1964. "Nature" (Engl.). 215, N 5099, 1967.