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Қ. И. Сәтпаев атындағы Қазақ ұлттық техникалық зерттеу университеті

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ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
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Қазақстан Республикасы Ұлттық ғылым академиясы "ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы" ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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RESEARCH OF SOLAR-LITHOSPHERIC RELATIONSHIPS IN NORTH TIAN SHAN ATTRACTING PALOSEISMIC DATA

Abstract. The purpose of the work is to systematize data on strong earthquakes in the Northern Tien Shan, taking into account the results of paleoseismic studies, and to establish patterns in the concomitant variations in solar activity, both during the instrumental period of observations and reconstructed by the radiocarbon ^{14}C method to a depth of ~ 1000 years. It is shown that the dates of the occurrence of strong earthquakes in the study area gravitated to the dates of the extreme state of solar activity - solar grand minimums or grand maximums. So, during the solar grand maximum in 1960 ± 40yrs, such earthquakes occurred: Kemino-Chuisk M6.9 in 1938, Chatkal M7.5 in 1946, Kokshaal M6.6 in 1969, Sary-Kamysh M6.8 in 1970, Zhalanash-Tyup M7.0 in 1978, Baysorun M6.4 in 1990, and Suusamyr M7.5 in 1992. During the solar grand minimum of Dalton (1790-1820), the Almaty M6.7 earthquake occurred in 1807, and during the solar grand minimum of Gleisberg (1880-1915) earthquakes occurred: Belovodsk M6.9 in 1885, Vernensk M7.3 in 1887 , Chilik M8.3 in 1889, and Kemin M8.2 in 2011. The strong earthquakes that occurred in the area of Alakol lake at ~ 910 ± 300yrs [1], in the tectonic zone of the Issyk-Ata fault at ~ 1385 ± 100 [2], in the Chon-Aksu river valley in (1480–1660) [3], in the vicinity of the Balkhash lake at the Lepsinsk Fault in 1715 [4] were accompanied by the solar grand minima of Oort (~ 1040 ± 30), Wolf (~ 1305 ± 35), Sporer (~ 1470 ± 80) and Maunder (~ 1680 ± 40), respectively. It is assumed that with the beginning of the 21st century a new solar grand minimum began to develop [5, 6], and quite strong earthquakes have already occurred in the study area namely: Sarydzha, 2013, M6.8 and Kadzhisay, 2014, M6 .2. Clustering of strong earthquakes in the Northern Tien Shan during periods of extreme solar activity is in line with a similar clustering of strong earthquakes throughout the whole planet [7].

Key words: solar activity, paleoseismicity, clustering of strong earthquakes.

Introduction. The problem of forecasting strong earthquakes is relevant for the entire planet, including the adjacent territories of Kazakhstan and the Kyrgyz Republic, located in seismically active regions of the Northern Tien Shan. To date, it has been established that strong earthquakes tend to temporarily cluster. To date, it has been established that strong earthquakes tend to temporarily cluster. So, at the beginning of the 20th century, the strongest seismic events occurred on the Tien Shan in 1911, M8.2; Alaska in 1899, M 8.0; in Western Turkmenistan in 1895, M 8.0; Kashgariya in 1902, M8.2; Northern Mongolia in 1905, M8.2; California in 1906, M8.3; China in 1906, M8.3; Colombia in 1906, M8.6 [3,8]. After that for about 25 years on the planet there were no earthquakes with a magnitude of 8.5 or more, and only in the middle of the XX century there was a strong earthquake in South Kamchatka - Northern Kuriles in 1952, M9.0; Aleut in 1957, M 8.6; in Chile in 1960, M9.5; in Alaska in 1964, M 9.2 [9-11].

In the first decade of the 21st century, a number of extremely strong earthquakes again appeared in different regions of the Earth: three of them were in Indonesia near the island of. Sumatra 12/26/2004. M9.1, March 28, 2005. M8.5, and 04/11/2012, M8.5; three in Chile 02/27/2010. M8.8; 04/01/2014, M8.2, and 09/16/2015. M8.3; two on the Kuril Islands on 11/15/2006, M8.3, and 01/13/2007, M 8.1; in Japan on 03/11/2011, M9.0; Sea of Okhotsk on May 24, 2013, M8.3; Mexico City 09/08/2017, M8.2 [3,7,8,10-12]. The probability of the effect of clustering strong earthquakes in the middle of the 20th century

(1950-1965) and the beginning of the 21st century (2004-2011) was evaluated in [9,10,13] where it was concluded that the probability of its accident is very small – is no more than 0.5%.

After five strongest earthquakes with magnitudes Mw≥8.5 that occurred at the beginning of the 21st century, and especially after the M9.0 earthquake in Japan, at the meeting of the Seismological Society of America in 2011, a heated debate about whether the observed temporary clusterization of strong earthquakes has some physical cause, as well as the possibility of a strong earthquake in the near future [10,11,14]. The question was posed in [7]: "If global clustering of earthquakes is so important that it should be taken into account when assessing seismic hazard, then seismological data should reject the "null hypothesis" that the temporal distribution of earthquakes on the planet is described by the distribution Poisson (uniform distribution of random independent events that occur at a constant speed).

However, immediately the question arose about the reliability of the results of such testing conducted on a time-limited sample of very rare events (which are the strongest earthquakes). The work [15] evaluated the effectiveness of traditional statistical tests to unambiguously answer the question of the existence or absence of clustering of earthquakes in catalogs with a small number of events. He concluded that when analyzing a fairly short sample with rare events, as in the case of a sample of ~ 110 years for earthquakes with M≥8.0 (95 events), the test results cannot be considered absolutely reliable. The conclusion [15] is consistent with the opinion [7), who noted: "... even if there is a global process leading to the generation and clustering of earthquakes, the length of the instrumental seismological series is currently too small to reliably to discover. This situation may change either with the accumulation of seismological data in the future, or with the advent of the physically justified hypothesis of earthquake generation, which will positively affect the test results." This article develops both of the issues voiced by [7]. Firstly, the clustering of strong earthquakes is analyzed from the perspective of a new hypothesis of their generation associated with variations in solar activity, and secondly, the length of a series of strong earthquakes increases due to the use of paleoseismic data to a depth of ~ 1000 years (for example, the Northern Tien Shan).

Strong earthquakes and solar activity. Figure 1 shows the temporal distribution of earthquakes with magnitudes M≥8.0 that occurred on the planet since 1900 from the work [7], where by ovals 1-3 we designated the periods of their clustering – at the beginning of the XX century, its middle and at the beginning of the XXI century. Figure 2 shows the variations in the annual average sunspot numbers.

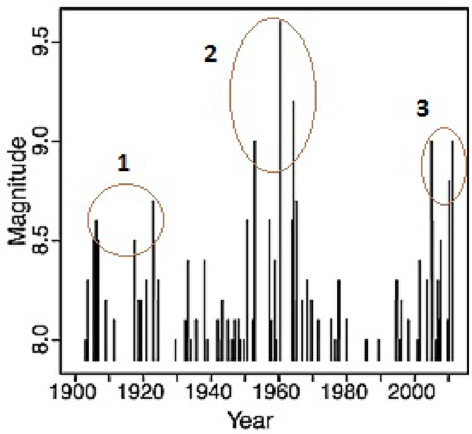

Figure 1 – Time distribution of earthquakes with magnitudes M≥8.0, which occurred on the planet since 1900 from the work [7]; ovals 1-3 mark three time periods for the clustering of strong earthquakes

Figure 2 shows that the intensity of 11 summer solar cycles varies over time. The state of solar activity, in which the intensity of several consecutive 11 year cycles is significantly less than the average value, is characterized as a solar grand minimum, and when it is significantly greater than the average value, it is described as a solar grand maximum. In the 19th – 20th centuries, there was a solar grand minimum in the period 1880–1915, named after the astronomer Gleisberg, and a solar grand maximum in the period 1960 ± 40 years [16], and since the beginning of the 21st century, as suggest [5, 6], a new solar grand minimum began to develop.

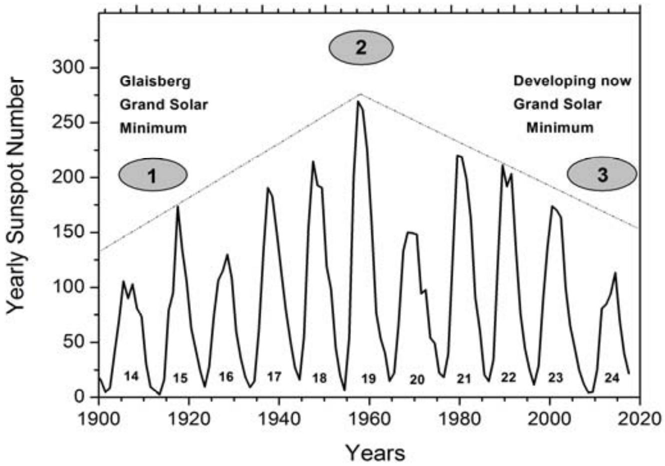

Figure 2 – Yearly mean number of sunspots from 1900 to 2017. The digits indicate sequential numbers of the solar cycles; dark ovals mark the periods of clustering of the strongest earthquakes on the planet in accordance with figure 1

Comparing figures 1 and 2, it is not difficult to see that the global clustering of earthquakes in the early XX and XXI centuries (ovals 1, 3) coincides with periods of Grand minima of solar activity: Gleisberg - at the beginning of the 20th century, and the current one, which began in the 21st century [5,6]. Global clustering of earthquakes in the middle of XX century (oval 2) coincides with the Grand maximum of solar activity centered around 1960 with a range of ± 40 years [16]. It was in 1960 that the planet's greatest earthquake occurred in Chile with M9.5 (figure 1). The previous global solar maximum took place approximately 2500 years earlier and accounted for ~ 445 BC [16]. The tendency of the confinement of strong earthquakes, either to minima or to maxima of solar activity, is also traced in the analysis of seismicity in specific regions of the planet. For example, [17] studied the relationship between solar activity, volcanic eruptions and seismicity in Japan, it was shown that of the 12 major earthquakes (M≥7.5) that occurred in 1700-2010, nine events (75%) occurred in the solar activity minimums, and the dates of the three earthquakes were timed to the time of solar maxima.

Figure 3 shows the strongest earthquakes (magnitude over 7) of the Northern Tien Shan that occurred during the period of the solar grand minimum of Gleisberg (Verny 1887, M7.3; Chilik 1889, M8.3; and Kemin 1911, M8.). Also, we show a strong earthquake in Almaty in 1807, M6.7 [18].

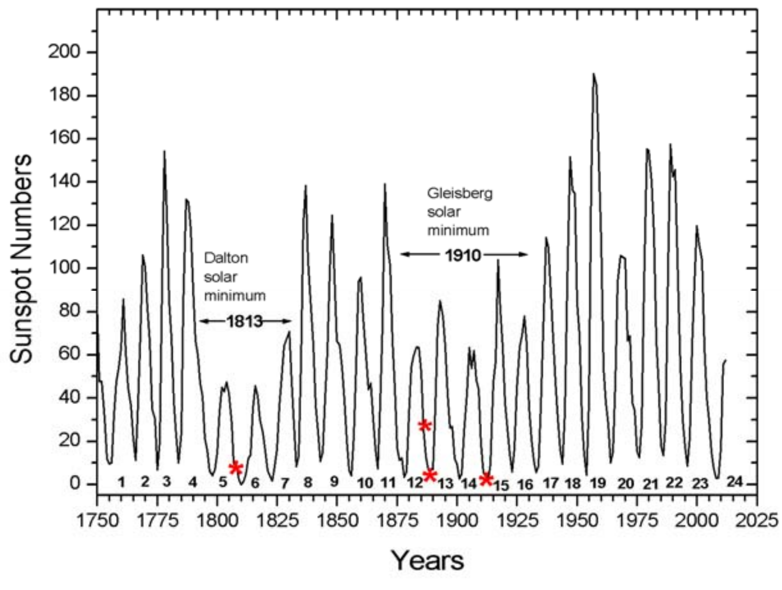

Figure 3 – Yearly mean number of sunspots in 1750-2011 (1-24 solar cycles) http://www.sidc.be/silso/datafiles; red circles - dates of the strongest historical earthquakes in the Northern Tien Shan occurred at solar grand-minimums, namely: Almaty 1807, Verny, 1887, Chilik, 1889, and Kemin 1911, as adapted from [19]

Figure 3 shows that the Almaty earthquake of 1807 occurred during the Dalton solar grand minimum at the completion phase of the low-amplitude 11-year solar cycle at number 5, and the following three events (Vernensk, Chilik and Kemin) occurred during the Gleisberg solar grand minimum at the completion phase of the low-amplitude solar cycles numbered as 12 and 14.

At the middle of the 20th century, the peak of the solar grand maximum occurred in 1960±40 years [16]. According to seismological catalogs, clustering of strong earthquakes also occurred in the Northern Tien Shan during this period of time - such seismic events occurred as: Kemino-Chuisk 1938, M6.9; Chatkal 1946, M7.5; Kokshaal 1969, M6.6; Sary-Kamysh 1970, M6.8; Zhalanash-Tyup 1978 1978, M7.0; Baysorun 1990, M6.4; Suusamyr 1992, M7.5. After the Suusamyr earthquake, for about 15 years there were no strong earthquakes in the region, and only in 2007, with the development of the new solar grand minimum, as suppose [5,6], strong earthquakes Sarydzhas, 2013, M6.8 and Kadzhisay, 2014, M6.2 occurred.

Solar activity and paleo-earthquakes in the Northern Tien Shan. As shown above, the problem of solar-lithospheric relations in the Northern Tien Shan was studied earlier [19,20 and references in herein] on the basis of instrumental series of seismological data, however, their duration in accordance with the conclusions of [7,15] cannot be considered sufficient for reliable conclusions about the nature of long-term variations in seismic activity. To increase the length of seismological series, which is necessary to increase the reliability of conclusions about long-term patterns in the frequency of occurrence of strong earthquakes, as noted in [7], we used for our analysis the data on strong paleo-earthquakes detected in the Northern Tien Shan to a depth of ~ 1000 years.

Thus, in [3], paleoseismological studies were carried out in the Chon-Aksu river valley (42º50'N, 77º21'E). A trench up to 6 m deep with a length of 18-20 m was studied and it was shown that here seismically calm periods alternate for several thousand years with periods when several strong seismic events occur during a period of several hundred years (figure 4). This pattern of alternating calm and disturbed seismic periods is typical for regions of intracontinental seismicity, where the process of stress accumulation is very slow [21]. Figure 4 shows that in the studied region, the last of the discovered earthquakes was the event dated 1480-1660 years, that is, that occurred before the Almaty earthquake in 1807.

Figure 5 shows the variations in solar activity from 900 to 2000 AD, reconstructed by radiocarbon ^{14}C as presented at the web-site https://en.wikipedia.org/wiki/Solar_cycle method. One of the horizontal

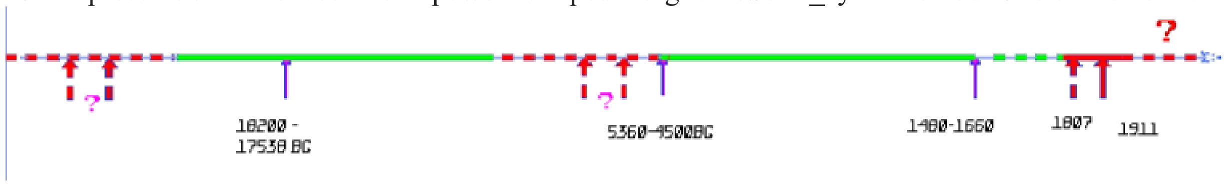

Figure 4 – Periods of seismic activation and calm according to data obtained in the trench in the Chon-Aksu River valley (42º50'N, 77º21'E). Blue arrows - dated events, red arrows are solid - confident data, dotted lines - the alleged events [3]

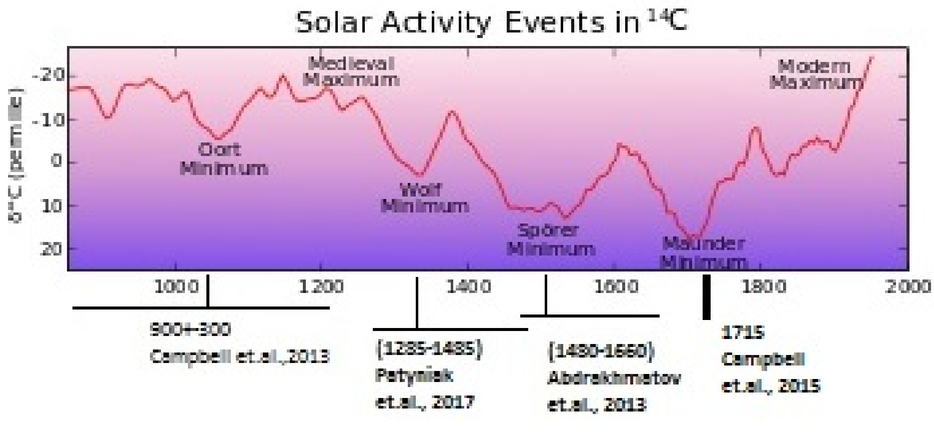

Figure 5 – Variations in solar activity in 900 - 2000 AD reconstructed by the radiocarbon method ^{14}C, with periods of solar grand minimums highlighted: Oort; Wolf, Sperer and Maunder (https://en.wikipedia.org/wiki/Solar_cycle); the horizontal and vertical lines at the bottom of the figure show the degree of confinement of the paleo-earthquakes established in the Northern Tien Shan to the solar grand minimums (see text)

lines at the bottom of the figure marks the time period (1480-1660yrs) when a paleo-earthquake occurred in the Chon-Aksu river valley. A vertical line drawn perpendicular to this segment marks the extremum in the solar grand minimum of Sperer, which occurred in 1470 ± 80 AD [16]. It is seen, the period of paleo-earthquake established in [3] in the Chon-Aksu river valley can be attributed to the Sperer solar grand minimum, of course, with taking into account errors in the paleo data, both for seismic and solar activity.

In [1], paleoseismological studies of the Dzungar fault in the region of Alakol lake. The age of five periods of seismic activation in the region was estimated and it was established that the last of them occurred ~ 1100 ± 300 years ago, i.e., in ~ 910 ± 300 AD. One of the horizontal lines at the bottom of Figure 5 marks the interval 910±300 AD, and the line perpendicular to the segment marks the date of the extremum in the solar Oort grand minimum, which took place at 1040 ± 30 AD [16]. It can be seen that the period of paleo-earthquake established in [1] in the region of Alakol lake can be attributed to the solar grand minimum of Oort.

In [2], paleoseismological studies were carried out in the river valley Dzhelamysh in the tectonic zone of the Issyk-Ata Fault, near Bishkek. The results of the study revealed the consequences of three strong paleo quakes - two in BC and the last one in a new era in ~ 1385 ± 100 AD. One of the horizontal lines in Fig. 5 marks the time period (1285-1485yrs), when a paleo-earthquake occurred in the tectonic Issyk-Ata fault zone, and the line perpendicular to the segment marks the extremum in Wolf's solar grand minimum, which occurred at 1305 ± 35 AD [16]. It is seen that the paleo-earthquake period established in [2] in the zone of the tectonic Issyk-Ata fault can be attributed (with taking into account dating errors) to the solar grand Wolf minimum.

The seismological catalog [18] provides a historical record of an ancient seismic event that occurred on the Northern Tien Shan in the vicinity of Lake Balkhash in 1715. The paper [4] presents the results of detailed field and satellite studies of this region (the Lepsinsky fault extending 120 km east-west from the high-mountain Dzhungar Ala-Too to the Kazakh platform), where about 10 meter vertical shift along the entire length of the fault was discovered. The results of geomorphological analysis, radiocarbon and luminescent dating methods showed that the fault was formed in Holocene as a result of at least two seismic events, the last of which occurred about 400 years ago with a magnitude of Mw 7.5–8.2. The thick vertical line in Figure 5 marks the date of the earthquake in 1715 that occurred in the vicinity of Lake Balkhash at the Lepsinsky Fault. It can be seen that this seismic event occurred during the period of the deepest solar grand minimum of Maunder, which took place in 1680 ± 40 AD [16].

Conclusion. Clustering periods of the planet's strongest earthquakes (magnitude M8 or more) at the beginning of the 20th century, its middle and the beginning of the 21st century [3,7-11,13,14] fell on periods of the extreme state of solar activity – solar grand minimums at the beginning of the 20th and beginning of the 21st centuries, and the solar grand maximum at the middle of the 20th century.

On the territory of the Northern Tien Shan, strong earthquakes also demonstrate the effect of temporary clustering, similar to what is happening for the planet as a whole. The strongest earthquakes of the recent past: Verny 1887 M7.3; Chilik 1889 M8.3; Kemin 1911 M8.2 were confined to the solar grand minimum Gleisberg, which took place in 1880-1915 yrs.

Analysis of paleoseismic data in the Northern Tien Shan to a depth of ~ 1000 years showed that strong earthquakes that occurred during this period in the area of Alakol lake at ~ 910 ± 300, in the tectonic zone of the Issyk-Ata fault at ~ 1385 ± 100, in the valley of the Chon-Aksu River in the period 1480-1660, in the vicinity of Balkhash lake on the Lepsinsky Fault in 1715, also gravitated to the periods of solar grand minimums: Oort, Wolf, Sperer and Maunder, respectively.

The results obtained, firstly, support the idea of the existence of geospace relationships, which is currently being actively developed, including in Kazakhstan [19,20,22], and confirm the existence of solar-lithospheric relationships, which was first drew the attention of the world known astronomer Wolf almost two centuries ago. Secondly, the results speak in favor of the fact that the paleoseismic data currently accumulated for different regions of the planet can increase the length of the series of strong earthquakes, which will reveal more reliable long-term (secular) variations of the Earth's seismic activity.

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ПАЛЕСЕЙЗМИКАЛЫҚ МӘЛІМЕТТЕРДІ ҚАТЫСУЫМЕН СОЛТҮСТІКПЕН ТЯНЬ-ШАНЬДАҒЫ КҮН-ЛИФОФЕРИКАЛЫҚ БАЙЛАНЫСТЫ ЗЕРТТЕУ

Аннотация. Жұмыстың мақсаты – Солтүстік Тянь-Шаньдағы күшті жер сілкінісі туралы мәліметтерді жүйеге келтіру, палеозеологиялық зерттеулердің нәтижелерін ескере отырып, бақылаудың инструменталды кезеңінде және радиокарбон ^{14}C әдісімен ~ 1000 жыл тереңдікке дейін қайта құру арқылы күн белсенділігінің қатар жүретін өзгерулерінің заңдылықтарын анықтау. Зерттеу аймағында күшті жер сілкіністерінің пайда болу күндері күн белсенділігінің төтенше жағдайына – күн гранд-минимумдары немесе грим-максимумдарға сәйкес келетіні көрсетілген. Күннің максималды мөлшері 1960 жылы - 40 гг. жер сілкіністері орын алды: 1938 жылы Кемино-Чуй М6.9, 1946 жылы Чаткал М7.5, 1969 жылы Көкшаал М6.6, 1970 жылы Сары-Камыш М6.8, 1978 жылы Жалаңаш-Түпск М7.0, 1990 жылы Байсорун М6.4. және Суусамыр М7.5 1992 ж. Дальтонның ең үлкен күндік минимумы кезінде (1790-1820 жж.), Алматыда М7.8 жер сілкінісі 1807 жылы болды, ал Глейсбергтің (1880-1915) күндік минималды жер сілкінісі кезінде: 1885 жылы Беловодское М6.9, Верненское М7.3 1887 ж., 1889 жылы Чилик М8.3, 1911 жылы Кемин М8.2. Бұл аймақта қатты жер сілкінісі болды. Алакөл ~ 910 ± 300 г [1], Ыстық-Ата жарылысының тектоникалық аймағында ~ 1385 ± 100 г [2], Чон-Аксу өзенінің алқабында (1480-1660 жж.) [3], шамамен. 1715 жылы Лепсі бұзылуындағы Балқаш [4] Оорт (~ 1040 ± 30), Қасқыр (~ 1305 ± 35), Сперера (~ 1470 ± 80) және Майдер (~ 1680 ± 40) күндік минимумымен бірге жүрді. сәйкесінше. XXI ғасырдың басынан бастап күннің жаңа минимумы дами бастады деп болжануда [5, 6] және зерттеу аймағында қатты күшті жер сілкіністер болды: Сарыжа, 2013 ж., М6.8 және Каджисай, 2014, М6 .2. Күннің төтенше белсенділігі кезеңінде Солтүстік Тянь-Шаньдағы қатты жер сілкіністерінің кластары бүкіл планетаның осы кезеңдерінде күшті жер сілкіністерінің кластеріне сәйкес келеді [7]. Сонымен, XX ғасырдың басында күн гранд-минимумында күшті жер сілкінісі тек Тянь-шанада ғана емес, 1895 ж. М 8.0 Батыс Түрікменияда да болды; 1902 ж. М 8.2 Кашгарияда; 1905 ж. М 8.2 Солтүстік Моңғолияда; 1906 ж. М 8. 3 Калифорнияда; 1906 ж. М 8. 3 Қытайда; 1906 ж. М 8. 3 Колумбияда; 1906 ж. М 8. 6 Колумбияда болды [3, 8]. Осыдан кейін шамамен 25 жыл бойы планетада магнитудасы 8.5 және одан да көп жер сілкінісі болған жоқ, тек XX ғасырдың ортасында күн гранд-максимум кезеңінде Оңтүстік Камчаткада – Солтүстік Курил аралында 1952 ж. М 9.0; Алеутта 1957 ж. М 8.6; Чилиде 1960 ж. М 9. 5; Аляскада 1964 ж. М 9.2 қатты жер сілкінісі болды [9-11]. XXI ғасырдың басында күн гранд-минимумы қайта дами бастады және жердің әр түрлі аймақтарында тағы да бірқатар экстремалды күшті жер сілкіністері пайда болды деп болжайды [5,6], олардың үшеуі Индонезияда маңында болған. Суматрда 26.12.2004 ж. М 9.1, 28.03.2005 ж. М 8.5, және 11.04.2012, 8.5; үшеуі Чилиде 27.02.2010 ж. М 8.8, 01.04.2014 ж. М 8.2, және 16.09.2015 ж. М 8. 3; екеуі Курил аралында 15.11.2006 ж. М 8.3, және 13.01.2007 ж. М 8.1; Жапонияда 11.03.2011 ж.М. 9.0; Охот теңізінде 24.05.2013 ж. М.8.3; Мехикода 08.09.2017 ж. М 8.2 [3, 7, 8, 10-12]. XXI ғасырдың басында, m≥8.5 магнитудасы бар бес күшті жер сілкінісі әсіресе Жапонияда М 9.0 жер сілкінісінен кейін, 2011 жылы Америка Сейсмологиялық қоғамының отырысында қатты жер сілкінісінің байқалып отырған Уақытша кластеризацияլануы кездейсоқ немесе кейбір физикалық себептерге ие екендігі, сондай-ақ жақын болашақта күшті жер сілкінісінің пайда болу мүмкіндігі туралы қызу пікірталас болды [10, 11, 14]. XX ғасырдың ортасында (1950-1965 жж.) және XXI ғасырдың басында (2004-2011 жж.) күшті жер сілкіністерін кластеризациялау әсерінің ықтималдығын бағалау [9, 10, 13] жұмыстарында орындалды және оның кездейсоқ ықтималдығы өте аз - 0.5%-дан аспайды деген қорытынды жасалды. Жұмыста келтірілген нәтижелер күн-литосфералық байланыстардың болуы идеясын қолдайды [17, 19, 20, 22] және қазіргі уақытта планетаның әр түрлі аймақтары үшін жинақталған палеосейсмикалық деректер күшті жер сілкіністері қатарының ұзындығын ұлғайтуы мүмкін, бұл жердің сейсмикалық белсенділігінің ұзақ мерзімді (ғасырлық) вариацияларын анықтауға мүмкіндік береді.

Түйін сөздер: күн белсенділігі, палеозеизм, күшті жер сілкіністерінің кластары.

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ИССЛЕДОВАНИЕ СОЛНЕЧНО-ЛИТОСФЕРНЫХ СВЯЗЕЙ НА СЕВЕРНОМ ТЯНЬ-ШАНЕ С ПРИВЛЕЧЕНИЕМ ПАЛЕОСЕЙСМИЧЕСКИХ ДАННЫХ

Аннотация. Цель работы – систематизировать данные о сильных землетрясениях на территории Северного Тянь-Шаня с учетом результатов палеосейсмических исследований и установить закономерности в сопутствующих вариациях солнечной активности как за инструментальный период наблюдений, так и восстановленных радиоуглеродным ^{14}C методом на глубину ~1000 лет. Показано, что даты возникновения сильных землетрясений на исследуемой территории тяготели к датам экстремального состояния солнечной активности – солнечным гранд-минимумам или гранд-максимумам. Так во время *солнечного гранд-максимума в 1960*±40 гг. произошли землетрясения: *Кемино-Чуйское М6.9 в 1938 г., Чаткальское М7.5 в 1946 г., Кокшаальское М6.6 в 1969 г., Сары-Камышское М6.8 в 1970 г., Жаланаш-Тюпское М7.0 в 1978 г., Байсорунское М6.4 в 1990 г. и Суусамырское М7.5 в 1992 г.* Во время солнечного гранд-минимума Дальтона (1790-1820 гг.) произошло Алматинское М6.8 землетрясение в 1807 г., а во время солнечного гранд-минимума Гляйсберга (1880-1915 гг.) произошли землетрясения: Беловодское М6.9 в 1885 г., Верненское М7.3 в 1887 г., Чиликское М8.3 в 1889 г., и Кеминское М8.2 в 1911 г. Сильным палеоземлетрясениям, произошедшим в районе о. Алаколь в ~910±300 г [1], в зоне тектонического Иссык-Атинского разлома в ~1385±100 г [2], в долине реки Чон-Аксу в (1480-1660 гг.) [3], в окрестности о. Балхаш *на Лепсинском разломе* в 1715г [4], сопутствовали солнечные гранд-минимумы Оорта (~1040±30), Вольфа (~1305±35), Шперера (~1470±80) и Маундера (~1680±40), соответственно. Предполагается, что с началом XXI века начал развиваться новый солнечный гранд-минимум [5,6], и на исследуемой территории в наши дни уже произошли достаточно сильные землетрясения: Сарыджаское, 2013 г., М6.8 и Каджисайское, 2014 г., М6.2. Кластеризация сильных землетрясений на Северном Тянь-Шане в периоды экстремальных состояний солнечной активности находится в соответствии с аналогичной кластеризацией сильных землетрясений на всей планете [7].

Так, в начале XX века при солнечном гранд-минимуме сильные землетрясения произошли не только на Тянь-Шане, но и в Западной Туркмении в 1895 г. М 8.0; Кашгарии в 1902 г. М8.2; Северной Монголии в 1905 г. М8.2; Калифорнии в 1906 г. М8.3; Китае в 1906 г. М8.3; Колумбии в 1906 г. М8.6 [3, 8]. После этого в течение примерно 25 лет на планете не происходило землетрясений с магнитудой 8.5 и более, и только в середине XX века в период солнечного гранд-максимума произошли сильные землетрясения на Южной Камчатке – Северных Курилах в 1952 г., М9.0; Алеутах в 1957 г. М 8.6; в Чили в 1960 г. М9.5; на Аляске в 1964 г. М 9.2 [9-11]. Предполагают [5,6], что с началом XXI века вновь начал развиваться солнечный гранд-минимум, и в разных регионах Земли вновь возник целый ряд экстремально сильных землетрясений: три из них были в Индонезии вблизи о. Суматра 26.12.2004 г. М9.1, 28.03.2005 г. М8.5, и 11.04.2012, М8.5; три в Чили 27.02.2010 г. М8.8, 01.04.2014 г. М8.2, и 16.09.2015 г. М8.3; два на Курилах 15.11.2006 г. М8.3, и 13.01.2007 г. М 8.1; в Японии 11.03.2011 г. М9.0; Охотском море 24.05.2013 г. М8.3; Мехико 08.09.2017 г. М8.2 [3, 7, 8, 10-12]. После пяти сильнейших землетрясений с магнитудами М≥8.5, произошедших в начале XXI века, и особенно после М9.0 землетрясения в Японии, на заседании Сейсмологического Общества Америки в 2011 году разгорелись жаркие дебаты о том, случайна ли наблюдаемая временная кластеризация сильных землетрясений или имеет некоторую физическую причину, а также о возможности возникновения сильного землетрясения в ближайшем будущем [10, 11, 14]. В работах [9, 10, 13] была выполнена оценка вероятности эффекта кластеризации сильных землетрясений в середине XX века (1950-1965 гг.) и начале XXI века (2004-2011 гг.) и сделан вывод, что вероятность его случайности очень мала – составляет не более 0.5%. Приведенные в работе результаты поддерживают идею существования солнечно-литосферных связей [17, 19, 20, 22] и говорят в пользу того, что палеосейсмические данные, накопленные в настоящее время для различных регионов планеты, могут увеличить длину рядов сильных землетрясений, что позволит выявить более надежно долговременные (вековые) вариации сейсмической активности Земли.

Ключевые слова: солнечная активность, палеосейсмичность, кластеризация сильных землетрясений.

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