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GEOLOGY AND TECHNICAL SCIENCES**

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*The scientific journal News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences has been indexed in the international abstract and citation database Scopus since 2016 and demonstrates stable bibliometric performance.*

*The journal is also included in the Emerging Sources Citation Index (ESCI) of the Web of Science platform (Clarivate Analytics, since 2018).*

*Indexing in ESCI confirms the journal's compliance with international standards of scientific peer review and editorial ethics and is considered by Clarivate Analytics as part of the evaluation process for potential inclusion in the Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI), and Arts & Humanities Citation Index (AHCI).*

*Indexing in Scopus and Web of Science ensures high international visibility of publications, promotes citation growth, and reflects the editorial board's commitment to publishing relevant, original, and scientifically significant research in the fields of geology and technical sciences.*

*«Қазақстан Республикасы Ұлттық ғылым академиясының Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналы 2016 жылдан бастап халықаралық реферативтік және ғылымиметриялық Scopus дерекқорында индекстеледі және тұрақты библиометриялық көрсеткіштерді көрсетіп келеді.*

*Сонымен қатар журнал Web of Science платформасының (Clarivate Analytics, 2018) халықаралық реферативтік және наукометриялық дерекқоры Emerging Sources Citation Index (ESCI) тізіміне енгізілген.*

*ESCI дерекқорында индекстелуі журналдың халықаралық ғылыми рецензиялау талаптары мен редакциялық этика стандарттарына сәйкестігін растайды, сондай-ақ Clarivate Analytics компаниясы тарапынан басылмды Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) және Arts & Humanities Citation Index (AHCI) дерекқорларына енгізу қарастырылуда.*

*Scopus және Web of Science дерекқорларында индекстелуі жарияланымдардың халықаралық деңгейде жоғары сұранысқа ие болуын қамтамасыз етеді, олардың дәйексөз алу көрсеткіштерінің артуына ықпал етеді және редакциялық алқаның геология мен техникалық ғылымдар саласындағы өзекті, бірегей және ғылыми тұрғыдан маңызды зерттеулерді жариялауға ұмтылысын айқындайды.*

*Научный журнал «News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences» с 2016 года индексируется в международной реферативной и наукометрической базе данных Scopus и демонстрирует стабильные библиометрические показатели.*

*Журнал также включён в международную реферативную и наукометрическую базу данных Emerging Sources Citation Index (ESCI) платформы Web of Science (Clarivate Analytics, 2018).*

*Индексирование в ESCI подтверждает соответствие журнала международным стандартам научного рецензирования и редакционной этики, а также рассматривается компанией Clarivate Analytics в рамках дальнейшего включения издания в Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) и Arts & Humanities Citation Index (AHCI).*

*Индексирование в Scopus и Web of Science обеспечивает высокую международную востребованность публикаций, способствует росту цитируемости и подтверждает стремление редакционной коллегии публиковать актуальные, оригинальные и научно значимые исследования в области геологии и технических наук.*

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**МИРЛАС Владимир**, PhD, профессор, Восточный научно-исследовательский центр, Университет Ариэля (Ариэль, Израиль), <https://www.scopus.com/authid/detail.uri?authorId=8610969300>; <https://www.webofscience.com/wos/author/record/53680261>

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## CONTENTS

<b>Abetov A.E., Seitzhanov A.K., Samenov Y.R., Zhassymbek S.A.</b> Machine learning and neural networks for lithofacies mapping and reservoir property evaluation of core samples.....	8
<b>Aitkaliyev A.K., Pak Y.N., Kolmakov Y.V., Pak D.Y., Matishev T.V.</b> Application of the X-Ray radiometric method to improve the operational quality control of copper ores during geological testing.....	26
<b>Altay Y.A., Karymsakova N.T., Fedorov A.V., Absadykov D.B., Ismagul G.K.</b> Predictive control of diagnostically significant parameters of acoustic emission using machine learning: new data.....	41
<b>Astanakulov K.D., Kodirova M.G., Saydumarov B., Nersesyan D.V., Kurashkin S.O.</b> Resource potential of ecological and geological systems of allocated soil masses.....	58
<b>Avazov Sh.B., Yodgorov Sh.I., Mukhammadkulov N.M., Aktamov B.U., Khayriddinov B.B.</b> Instrumental seismometric assessment of the impact of technogenic seismic vibrations on the structural stability of historical objects.....	74
<b>Baskanbayeva D., Kalmaganbetov S., Sabirova L., Zholdybayeva G., Koptleuov K.</b> CFD analysis of screw compressor rotor geometry influence on gas compression efficiency in geology.....	92
<b>Borotov A.N., Karshiev F.U., Igamberdiyev A.A., Grigoryan A.G., Sarigo N.V.</b> Ecological aspects of resource conservation in the development of mineral deposits.....	107
<b>Gerasidi V.V., Lisachenko A.V., Apatenko A.S., Sevryugina N.S., Fomin A.Y.</b> Analysis of the application of non-destructive testing methods for assessing the technical condition of mining equipment motors based on vibration parameters.....	121
<b>Hajiyeva A.Z., Ibrahimova L.P., Humbatova Sh.Y., Jafarova F.M.</b> Ecological processes of vertical landscape transformation and their manifestation in the natural landscapes of Nakhchivan.....	135
<b>Jakiyayev D.K., Nussipali R.K.*, Malibekov A.K., Jakiyayev B.D., Zhashen S.Zh.</b> Statistical model of multi-cycle fatigue of steel structural elements under a complex non-uniform stress state.....	149
<b>Jumatov Y.K., Tashbulatov S.B., Pushanov A.N., Kozenkova G.L., Yarygina I.V.</b> Technological substantiation of sustainable mining reclamation of disturbed lands in open pit operations.....	169
<b>Kainenova T.S., Kosmbaeva G.T., Bissembayeva K.T., Otarbayeva A.T., Orazbek A.A.</b> Effectiveness of measures to regulate the development process at the Alibekmola field.....	185

<b>Koishiyeva G.Zh., Yerimova A.Zh., Kurbaniyazov S.K., Agaidarova K.H., Abdraimova K.T.</b>	
Radiological properties and stratigraphic significance of glauconite-bearing formations: implications for paleoenvironments and geochemical zonation.....	203
<b>Kondratiev V.V., Bryukhanova N.N., Kononenko R.V., Gladkikh V.A., Matasova I.Y.</b>	
Environmental and technological assessment of beneficiation tailings reprocessing based on mechanical activation and non-ferrous metals leaching.....	223
<b>Kuldeyev Ye., Negmatov S., Nurpeissova M., Kirgizbaeva D., Donenbayeva N.</b>	
Geodynamic Polygon of the Zhilandy Ore Field: Results and Prospects.....	237
<b>Madibekov A., Christian Opp., Karimov A., Ismukhanova L., Zhadi A.</b>	
Regularities of distribution and accumulation factors of heavy metals in soils of the Zhetysu region (Kazakhstan).....	253
<b>Malikov G.I., Musayeva S.A., Mammadov K.S., Jabiyeva U.M., Jafarova K.V.</b>	
Effects of hydrocarbon fuel quality fluctuations on energy generation efficiency, economic viability, and environmental footprint.....	272
<b>Narbaev M.T., Ismailova G.K., Narbaeva K.T., Burlibayeva D.M., Groll M.</b>	
Assessment of ecological and water management parameters of the Syrdarya River.....	290
<b>Nurmagambetov A.</b>	
On seismic hazard of Almaty and tectonic faults in the city.....	309
<b>Permana A.P., Kasim M., Hutagalung R., Uno D.A.N., Sandi I.N.</b>	
petrographic, provenance, and tectonic setting of Dolokapa formation sandstone, North Gorontalo.....	319
<b>Ratov B.T., Khomenko V.L., Yavorska O.O., Koroviaka Ye.A., Akhmetova N.S.</b>	
Analytical and structural justification of a wellhead sealing device for large-diameter drilling operations.....	335
<b>Skrobala V.M., Popovych V.V., Kopylov V.P., Popovych N.P.</b>	
Comprehensive assessment of heavy metal pollution of a river within a large city.....	355
<b>Sunakbaeva D.Kh., Yuldashbek D.Kh., Aitekova K., Seitbayev K.Zh.</b>	
Monitoring heavy metals in soils and waters of the City of Turkestan: geoecological aspect.....	371
<b>Zakirov M.M., Agzamova I.A., Ochilov G.E., Gulyamov G.D., Xudayberdiyev T.M.</b>	
Analysis of the results of changes in the gas and isotopic composition of groundwater during the period of earthquake preparation.....	385
<b>Zhanbatyrov A.A., Tukhfatov Zh.K., Bektay E.K., Turisbekova G.S., Zhanbatyrov N.A.</b>	
Current state of potash ore development in the Caspian lowlands of the Republic of Kazakhstan: problems and solutions.....	399

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National Scientific Center for Seismological Observations, Almaty, Kazakhstan.

E-mail: [nalkuat@mail.ru](mailto:nalkuat@mail.ru)

## ON SEISMIC HAZARD OF ALMATY AND ABOUT TECTONIC FAULTS IN THE CITY

**Nurmagambetov Alkuat** — Doctor of Geological and Mineralogical Sciences, Professor, Chief Researcher, National Scientific Center for Seismological Observations, Almaty, Kazakhstan,  
E-mail: [nalkuat@mail.ru](mailto:nalkuat@mail.ru), <https://orcid.org/0009-0004-4379-6608>.

**Abstract. Relevance.** The seismic hazard in Almaty remains a critical issue due to the city's location in an active tectonic zone. The development and continuous updating of seismic microzoning (SMZ) maps are essential for ensuring safe urban planning and construction. The increasing number of identified tectonic faults and expansion of high-intensity seismic zones highlight the need for reassessment of existing approaches. *Goal.* The aim of this study is to analyze the seismic situation in Almaty, review the development stages of seismic microzoning maps, and evaluate the justification for including local tectonic faults and imposing construction restrictions within their zones. *Methods.* The study is based on the analysis of historical and modern SMZ maps, comparison of different mapping stages, and review of existing scientific publications. Instrumental observations, geological and tectonic data, as well as regulatory documents (including SP RK 2.03-30-2021) were used to assess changes in seismic zoning and fault identification. *Conclusions.* The latest SMZ map shows a significant increase in the number of tectonic faults and expansion of high seismic intensity zones. However, the justification for including local faults and restricting construction within their influence zones remains debatable. The author suggests conducting additional studies to specify the position and characteristics of faults, after which a more scientifically grounded decision regarding construction limitations in fault zones can be made. A distinctive feature of the new map compared to the previous one is the increase in its total area due to the addition of new sites, and, accordingly, the area of 9- and 10-point zones, and, most importantly, the increase in the number of tectonic faults. On the map, 27 tectonic faults pass through

Almaty, along which experts have recommended excluding development within 300 meters (the exception is the 500-meter-wide Zailiysky fault zone). The author of this article discusses whether it is worthwhile to show such local faults on the construction and installation work map and restrict development within them. The article analyzes existing publications on this topic and expresses her opinion regarding the questionability of the local faults identified on the map and their zones of influence, within which development is restricted.

It is proposed to conduct additional research to clarify the planned position of the faults, and based on their results, make a decision about the fault zone in the city.

**Key words:** Earthquake, seismic hazard, seismic microzoning, tectonic faults

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Сейсмологиялық байқау және зерттеу ұлттық ғылыми орталығы,

Алматы, Қазақстан.

E-mail: [nalkuat@mail.ru](mailto:nalkuat@mail.ru)

## АЛМАТЫ ҚАЛАСЫНЫҢ СЕЙСМИКАЛЫҚ ҚАУІПТІЛІГІ ЖӘНЕ ҚАЛАДАҒЫ ТЕКТНИКАЛЫҚ ЖАРЫЛЫМДАР ЖАЙЛЫ

**Нұрмағамбетов Әлқуат** — геология-минералогия ғылымдарының докторы, профессор, бас ғылыми қызметкер, Ұлттық сейсмологиялық бақылау және зерттеу ғылыми орталығы, Алматы, Қазақстан,  
E-mail: [nalkuat@mail.ru](mailto:nalkuat@mail.ru), <https://orcid.org/0009-0004-4379-6608>.

**Аннотация.** Мақала Алматы қаласының сейсмикалық жағдайын талдауға арналған. Алматы қаласы үшін әрбір кезеңде жасалған сейсмикалық микроаудандау карталары қарастырылған. Алғаш рет мұндай карталарды жасау жұмыстары 1953 жылдан басталып, Алматы қаласына арналған «Временных указаний по застройке города Алма-Ата» атаулы уақытша ереже жасалған. Алматы қаласының сейсмикалық қауіптілігі жоғары болуына байланысты, қала аумағында сейсмикалық микроаудандау жұмыстары алдағы уақытта арнайы мекемелердің қатысуымен қосымша кешенді зерттеулермен жалғастырылды. Бұл зерттеулер нәтижесінде картаның жаңа варианты жасалып, онда алғаш рет қала аумағында сенімді (бірінші категориялы) және жорамал бөлінген жарылым белдемдері көрсетілген. Айта

кететін жәйт, ол кезде қала аумағы айтарлықтай үлкен емес және де түнгі мезгілде біршама «тыныш» болатын. Сондықтан, түнгі мезгілде жоғары сезімталды геофизикалық аспаптармен жұмыс істеуге мүмкіндік болатын. Картада көрсетілген жарылым белдемдері құрылыс жұмыстарына ешбір шектеу болмайтын яғни құрылыс ережелерінде (РСН) мұндай шектеулер келтірілмеген. Қаланың бүгінгі таңдағы соңғы сейсмикалық микроаудандау картасы 2021 жылы жасалып, іске қосылды (СП РК 2.03-30-2021). Мақалада қала үшін әрбір кезеңде жасалған сейсмикалық микроаудандау карталарының көріністері келтірілген. Қазіргі қолданыстағы сейсмикалық микроаудандау картасының басқа карталарға қарағанда ерекшелігі қала аумағына кейінгі кезде қосылған жаңа учаскелерге байланысты картаның ауданы, әсіресе қала аумағындағы тектоникадық жарылымдар санының өсуі. Картада 27 тектоникалық жарылымдар көрсетіліп және оларды қуалай 300 метр ені аумағында ешбір құрылыс жұмыстарының жүргізуге болмайтыны ұсынылған (бұл ұсыныс Іле атаулы жарылымда 500 метрге тен). Мақала авторы осы барлық жергілікті жарылымды картада көрсетіп, оларды қуалай 300 метр енділікте құрылыс жұмысына тоқтату дұрыспа деген сұраққа жауап іздейді. Ол үшін автор осы тақырыпқа арнаған басқа да мақалаларға сараптау жасап, өз пікірін білдіреді.

Автор мақалада көтерілген сұрақты жан-жақты саралай келіп, қосымша кешенді зерттеулер жүргізіп, жергілікті жарылымдардың қала аумағында орналасуын түбегейлі зерттеп, олардың сейсмикалық қауіптілігін нақты анықтауды ұсынады.

**Түйін сөздер:** жерсілкінісі, сейсмикалық қауіптілік, сейсмикалық микроаудандау, тектоникалық жарылымдар

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Национальный научный центр сейсмологических наблюдений и исследований, Алматы, Казахстан.

E-mail: nalkuat@mail.ru

## О СЕЙСМИЧЕСКОЙ ОПАСНОСТИ ТЕРРИТОРИИ г. АЛМАТЫ И О ТЕКТОНИЧЕСКИХ РАЗЛОМАХ В ГОРОДЕ

**Нурмагамбетов Алкуат** — доктор геолого-минералогических наук, профессор, главный научный сотрудник, Национальный научный центр сейсмологических наблюдений и исследований, Алматы, Казахстан,

E-mail: nalkuat@mail.ru, <https://orcid.org/0009-0004-4379-6608>.

**Аннотация.** *Актуальность.* Статья посвящена анализу сейсмической ситуации на территории города Алматы, характеризующегося высокой степенью сейсмической опасности. В условиях активного градостроительного развития и роста антропогенной нагрузки особую значимость приобретает уточнение параметров сейсмического микрорайонирования (СМР)

и корректная интерпретация тектонических структур, влияющих на безопасность застройки. *Цель исследования* — анализ эволюции карт сейсмического микрорайонирования города Алматы, оценка достоверности выделения тектонических разломов и обоснование необходимости уточнения их пространственного положения для принятия градостроительных решений. *Методы.* Рассмотрены этапы формирования карт СМР, начиная с первых исследований, проведённых в 1953 году, завершившихся разработкой «Временных указаний по застройке города Алма-Аты». В последующие годы исследования были расширены за счёт применения комплексных геофизических, инженерно-геологических и инструментальных методов с привлечением специализированных организаций. Проведён сравнительный анализ карт СМР различных периодов, включая действующую нормативную карту, введённую в эксплуатацию в 2021 году (СП РК 2.03-30-2021). В работе использованы архивные материалы, опубликованные научные исследования и нормативные документы. *Результаты и выводы.* Установлено, что новая карта СМР существенно отличается от предыдущих версий увеличением охвата территории города, расширением зон сейсмичности интенсивностью 9 и 10 баллов, а также значительным ростом количества выявленных тектонических разломов. На современной карте выделено 27 разломов, вдоль которых рекомендовано ограничение застройки в пределах полос шириной до 300 м (для Заилийской зоны - до 500 м). Показано, что в предыдущих нормативных документах ограничения строительства в зонах разломов отсутствовали, несмотря на их наличие. В статье проведён анализ существующих публикаций по данной проблематике и обоснована дискуссионность вопроса о достоверности выделения локальных разломов и ширины зон их влияния. Отмечено, что чрезмерная детализация разломной структуры без достаточного геофизического и геодинамического подтверждения может приводить к необоснованным ограничениям градостроительной деятельности. В связи с этим предлагается проведение дополнительных комплексных исследований, направленных на уточнение планового положения тектонических разломов, после чего следует принимать обоснованные решения относительно установления зон ограничения застройки на территории города.

**Ключевые слова:** землетрясение, сейсмическая опасность, сейсмическое микрорайонирование, тектонические разломы

**Introduction.** According to the official map of seismic zoning of Kazakhstan (Construction Norms and Rules of the Republic of Kazakhstan), the seismic hazard level of Almaty is estimated at 9 points, which is the initial or design seismicity for the city. Then, based on this assessment, the seismic hazard of the city territory is specified by drawing up a seismic microzonation map (SMZ).

In geological and structural terms, the territory of Almaty belongs to different tectonic blocks in terms of structure and history of geological development: the

Almaty Depression, the Boroldai Rise and the elevated stage of the piedmont counters (Geophysical, 1975). The peculiarity of the tectonic position of the city and the high degree of seismic hazard requires special attention to the design and location of housing and industrial construction facilities, for the preparation of the General Plan of the city's development considering seismic hazard.

**Literature Review.** *About the history of research on SMZ.* The history of seismic microzonation mapping of Almaty city territory dates to the early 50s of the last century. For the first time such works in the republic were started in 1953 and ended with the creation of "Temporary guidelines for the development of the city of Alma-Ata".

In 1962, S.V. Medvedev (Professor of the Institute of Physics of the USSR Academy of Sciences, Moscow) made a scheme of seismic microzonation based on engineering and geological data (Figure 1a), where the territory of the city is divided into 9- and 10-point zones (Medvedev, 1962).

In 1958, the Institute of Geological Sciences of the Academy of Sciences of the Kazakh SSR initiated purposeful research on seismic microzonation mapping, which was largely experimental and methodological in nature. Based on the results of these studies, in 1962 the first map of microseismic moray zonation of the territory of Alma-Ata (Kazanli D.N., Antonenko E.M., 1960) was drawn up, which served as a basis for the first normative document approved by the Gosstroy of the KazSSR - Republican Construction Norms (RCN)-10-62. It should be noted that both maps (compiled by S.V. Medvedev and in the IGN of the Academy of Sciences of the KazSSR) practically coincide.

The works on clarification of the map of the SMZ of Alma-Ata continued in 1965-1967 with the involvement of other organisations, and in 1970 a clarified version of the map of the SMZ was published, which was included in RCN-10-70 (Antonenko et al., 1976).

Due to the high degree of seismic hazard of the city territory, further works on seismic microzonation were continued with the application of a wider range of studies and with the involvement of the organisation Ministry of Geology of the KazSSR. The main data on the geological and tectonic structure of Alma-Ata and its surroundings were obtained during geological surveys (Kulikovsky K.T., Chabdarov N.M.). Geophysical works to study the structure of the Earth's crust and identify tectonic fault zones on the territory of the city and suburbs were carried out using aeromagnetic, gravimetric survey, seismic survey by the method of exchange waves, deep seismic sounding, seismological observations with "Earth" equipment (Akishev T.A., Shatsilov V.I., Rosenblat M.M., Popov K.A., Malinin E.G.). It should be noted here that the city was then relatively "small" in area and "quiet" at night, which allowed for instrumental observations with the installation of high sensitivity instruments.

**Materials and Basic Methods.** To clarify the position of tectonic faults, parallel geodetic (levelling) observations were carried out at the Alma-Ata geodynamic polygon created in 1967 (Atrushkevich P.A., Ostropiko P.A., Peredero V.S.). The

levelling tracks were mainly oriented in meridional direction and crossed inferred faults.

Based on the results of these studies, a new version of the seismic microzonation map (RCN 10-70) was drawn up in 1970. It showed, for the first time, fault zones (first-order faults) and zones of inferred faults confidently identified within the city. However, no restrictions on construction in fault zones were introduced in the building code of Republican Construction Norms (RCN) (Figure 1b).

In 1976, the Institute of Seismology was established as part of the Academy of Sciences of the Kazakh SSR, in connection with which research in the field of seismic microzonation was further developed. Given that many issues were not resolved in the previous maps, such as the role and plan position of fault zones, boundaries between zones with different grades, etc., the research was continued with the involvement of new directions: hydrogeological studies on groundwater (V.F. Shlygina), assessment of engineering-geological and seismic characteristics of soils (M.T. Adikov, V.I. Shatsilov, V.V. Podkolzin, V.V. Musin, V.M. Beloslyudtsev), new interpretation of the consequences of the destructive Vernen earthquakes of 1887 and Kemin earthquakes of 1911 (A. Sydykov, A. Nurmagambetov). Methodologically, for the first time, a fundamentally new approach was proposed, the essence of which is to summarise the incremental scores with smoothly decreasing initial scores (Erzhanov et al.,1982).

**Results and Discussion.** As a result of the conducted complex studies, a new map of seismic microzonation of Alma-Ata and its suburbs was drawn up in 1981, which was included in RCN-10-83 (Figure 1c) (Republican, 1983). For the first time, RCN-10-83 introduced a clause prohibiting the placement of new buildings and reconstruction of existing buildings and structures in the zones of possible manifestation of tectonic faults on the daytime surface.

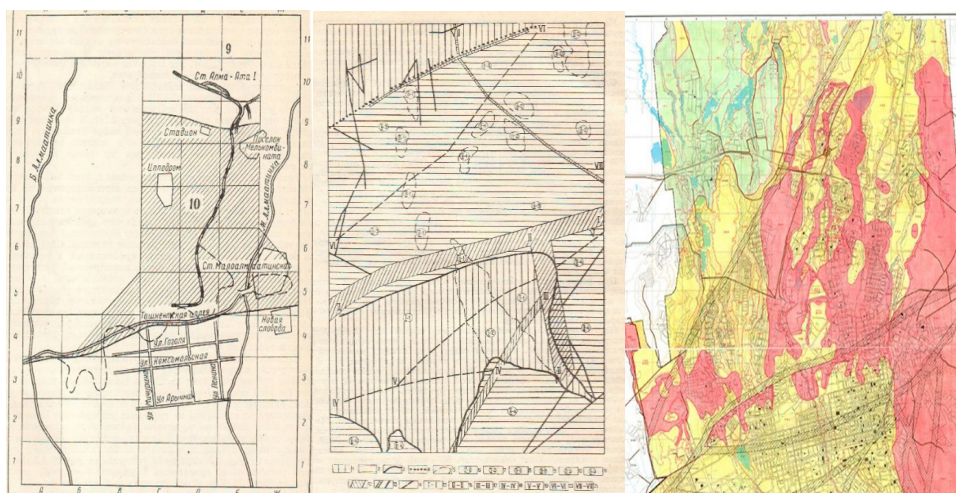


Figure 1 - Fragments of seismic micro zonation maps of Almaty

a - 1953 (Medvedev,1962) ; b – 1970 (Antonenko et al.,1976); c – 1983 (Erzhanov et al.,1982).

*Map of SMR 2021.* After the collapse of the USSR, research on seismic microzonation of Almaty was not developed for some time, although the city continued to be actively constructed. Issues related to the issuance of conclusions on seismic conditions of newly built-up areas were handled by a specialized organization Kazakh State Institute for Engineering Surveys and Land Management (KazGIIZ) (Beloslyudtsev V.M.), which carried out point engineering and survey works at the request of construction companies.

In 1995 the map of seismic microzonation was republished with some additions by KazGIIZ, on the basis of which the building standards Construction Norms of the Republic of Kazakhstan (SN RK) B.2.2-7-95 "Building of Almaty city and adjacent territories taking into account seismic microzonation" were approved (Development, 1995).

Practically since the release of the SMZ map in 1983 up to 2012 the city was built without a new map (only considering point additions of KazGIIZ). An attempt to create a new map was made several times, (in 2012 and 2014), but the work was interrupted due to the lack of full funding for the work. Only in 2018, due to the annexation of new areas to the city, the work on creating a new map was started. For this purpose, the executors involved all available archival and reporting materials, additional engineering and geological surveys were carried out in the newly annexed areas. As the authors write, the map was calculated using a new methodological approach. In 2021, a new seismic microzonation map of Almaty (SP RK 2.03-30-2021) was commissioned to replace the 1983 map (Figure 2a) (Development, 2021).

The SMZ map set includes 14 maps, including a map of active tectonic faults in the territory of Almaty and its vicinity (Figure 2b).

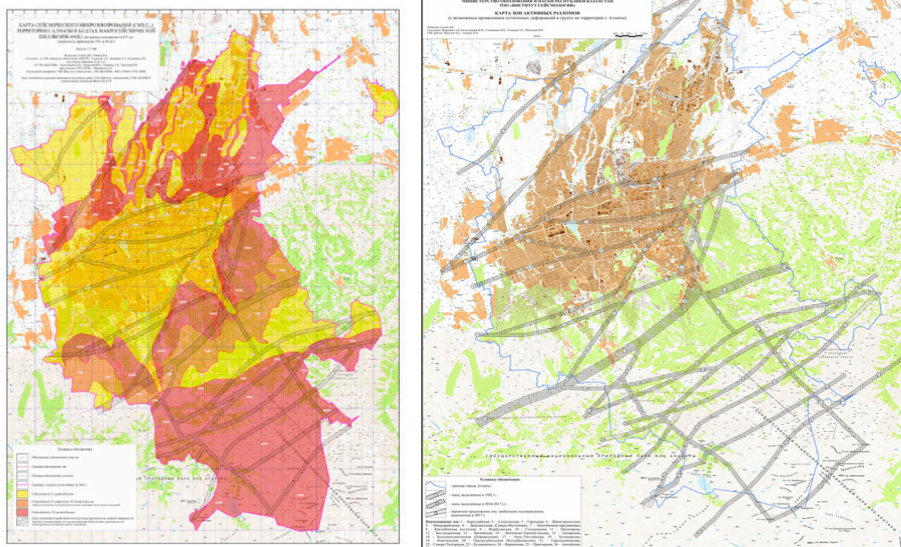


Figure 2a - Map of SMR 2021 (Development...,2021). Figure 2b - Scheme of active tectonic faults

A distinctive feature of the new map compared to the previous one (RCN-10-83) was the growth of the total map area due to the addition of new areas, and accordingly the area of 9- and 10-point zones, and most importantly, the number of tectonic faults increased to 27.

*Tectonic faults on the city map.* On the map, 27 tectonic faults run through Almaty, along which the width of 300 metres experts recommended to exclude development (the exception is the Zaili fault zone with a width of 500 metres).

In classical geological literature, faults (discontinuities) are understood as tectonic disruption of rock continuity with displacement of parts separated by the discontinuity relative to each other (in other words, zones of juxtaposition or boundaries of crustal blocks). They play a crucial role in the geological history not only of a particular region, but of the planet as a whole. Faults are present everywhere and everywhere, the Earth's crust is something like a broken plate.

Faults vary greatly in their size: length, width, penetration depth, and seismic activity. They can be local, regional, and deep. *Local* faults are mostly reflected only in the sedimentary cover and are characterised by shallow depths. *Regional* can be traced many kilometers deep into the Earth's crust down to the basaltic layer, while *deep* faults form a break in rock continuity and extend into the upper mantle (Ibrahimović, 1978).

Seismic activity (seismogenicity) of faults is usually determined by the confinement of earthquake sources to them. Most of these are regional and deep faults, hundreds of kilometres long and tens of kilometres wide, which can serve as seismogenic structures. As for local faults, given their size and shallow depth, they are practically never seismogenic.

How localised faults manifest themselves during earthquakes?

There is very little information about it in the literature. It is known only about the formation of a fault (shear) more than 29 km long, which crossed the post. Kum-Dag (Turkmenistan) during the earthquake in 1983 with magnitude  $M=5.4$ . In homogeneous engineering-geological conditions with intensity on the territory of Kum-Dag settlement equal to 8 MSK in the fault zone (strip with length about 100 m), intensity increased by 0.5 MSK (Rupture, 1985). As for the width of the zones of possible influence of faults, there is also a lack of complete information about this.

The question arises as to whether it is worth showing such localised faults on the SMZ map and restricting development within them. There is no unambiguous answer to this question. Negative attitude to tectonic discontinuities during IDA is reflected in scientific publications, recommendations and normative documents (Influence..., 1973; Recommendations..., 1980). Researchers note that it is important to assess the degree of engineering hazard of each particular rupture (Tectonic, 1982; Nurmagambetov et al., 1981; 2017). Unfortunately, on the ground, especially in built-up areas, this is very difficult, sometimes impossible to assess.

It should be noted that it is very important to study the so-called tectonic

nodes (fault intersections) during SMZ. It is they that have anomalous seismic and engineering-geological properties and can lead to the formation of seismic dislocation and activate processes dangerous for structures. Such phenomena were encountered when studying the consequences of the Verny 1887 and Kemin 1911 earthquakes on the territory of Verny, where the intensity of shaking exceeded 9 on MSK scale, and in some places, water fountained from the cracks (Shatsilov, 1989).

**Conclusion.** 1. The 9- and 10-point zones shown on the latest SMZ map of Almaty (SP RK 2.03-30-2021) are calculated according to the generally accepted methodology using available experimental engineering-geological and seismological data.

2. Most of the tectonic faults shown on the Almaty SMZ map are localized faults and the confinement of weak and micro-earthquake sources to them has not been proven by anyone to date. In addition, there is no reason to believe that in the event of a strong earthquake, they will be subject to large movements.

The exception is the Almaty fault, which crosses the territory of the city in the sublatitudinal direction and is confirmed by a complex of methods, although its seismogenicity is not proved, but it showed itself during the destructive earthquakes of the past years.

The Zailiyskiy fault, limiting the zone of mobile traps, by a few features (length, depth of penetration, confinement to them the sources of weak earthquakes) belong to the regional faults capable of generating strong earthquakes. The origin of the Verny earthquake of 1887 is confined to this zone.

3. Thus, the faults identified on the map and their zones of influence, within which development is restricted, require confirmation. In connection with the instruction of the President of the Republic of Kazakhstan to conduct a "Special seismological study" in Almaty, it is proposed to include a paragraph "On clarification of the provisions of tectonic faults on the territory of the city using modern methods and technology".

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