



ISSN 3079-2894 (Online)

ISSN 3079-2886 (Print)

Stratigraphy, petroleum sedimentology, geochemistry

www.isjss.com

International scientific journal

Ministry of Science and Education of Azerbaijan Republic
"Institute of Geology" Public Legal Entity (PLE)

2.2026



**“Stratigrafiya, neft sedimentologiyası,
geokimya” beynəlxalq jurnalının
redaksiya heyəti**

Ak.A. Əlizadə – Baş redaktor
E.H.M. Əliyeva – Baş redaktorun müavini
Q.R. Babayev – Baş redaktorun müavini
S.A. Məlikova – Məsul katib

Redaksiya heyətinin üzvləri

Əkpər Feyzullayev – Azərbaycan
Vasif Babazadə – Azərbaycan
Pərviz Məmmədov – Azərbaycan
Sehrab Şixlinski – Azərbaycan
Orxan Abbasov – Azərbaycan
Şəfəq Bayramova – Azərbaycan
Sergey Popov – Rusiya
Larisa Qolovina – Rusiya
Jon Veber – ABŞ
Əli İsmayıl Əl-Cubouri – İraq
Lev V. Eppelbaum – İsrail
Kristian van Baak – Böyük Britaniya
Frank Vesseling – Niderland

**Editorial board of International Scientific
Journal “Stratigraphy, petroleum
sedimentology, geochemistry”**

Ak.A. Alizadeh – Editor-in-chief
E.H.M. Aliyeva – Deputy Editor-in-chief
G.R. Babayev – Deputy Editor-in-chief
S.A. Malikova – Executive secretary

Editorial board

Akper Feyzullayev – Azerbaijan
Vasif Babazadeh – Azerbaijan
Parviz Mammadov – Azerbaijan
Sehrab Shikhliniski – Azerbaijan
Orhan Abbasov – Azerbaijan
Shafaq Bayramova – Azerbaijan
Sergey Popov – Russia
Larisa Golovina – Russia
John Weber – USA
Ali Ismail Al-Juboury – Iraq
Lev V. Eppelbaum – Israel
Christiaan van Baak – UK
Frank Wesselingh – the Netherlands

**Редколлегия международного журнала
«Стратиграфия, нефтяная
седиментология, геохимия»**

Ак.А. Ализаде – Главный редактор
Э.Г.-М. Алиева – Зам. главного редактора
Г.Р. Бабаев – Зам. главного редактора
С.А. Меликова – Ответственный секретарь

Члены редколлегии

Акпер Фейзуллаев – Азербайджан
Васиф Бабазаде – Азербайджан
Парвиз Мамедов – Азербайджан
Сехраб Шихлинский – Азербайджан
Орхан Аббасов – Азербайджан
Шафаг Байрамова – Азербайджан
Сергей Попов – Россия
Лариса Головина – Россия
Джон Вебер – США
Али Исмаил Аль-Джубоури – Ирак
Лев В. Эппельбаум – Израиль
Кристиан ван Баак – Великобритания
Франк Весселинг – Нидерланды

“Nafta-Press” nəşriyyatı, 2026/2
Çapa imzalandı: 23.10.2026
Sifariş № 4, tirajı 100 nüsxə
Qiyməti müqavilə üzrə

Publishing house “Nafta-Press”, 2026/2
Signed to print: 23.10.2026
Order № 4, circulation – 100 copies
Contract price

Издательство “Nafta-Press”, 2026/2
Подписано к печати: 23.10.2026
Заказ № 4, Тираж – 100 экз.
Цена договорная

MAKHTESH RAMON: A UNIQUE NATURAL-RESOURCE COMPLEX OF STRATEGIC, MULTI-COMPONENT MINERAL RAW MATERIALS IN SOUTHERN ISRAEL**Eppelbaum L.V.^{1,2}**¹*Dept. of Geophysics, Faculty of Exact Sciences, Tel Aviv University, Israel
Ramat Aviv, Tel Aviv, 6997801*²*Azerbaijan State Oil and Industry University, Azerbaijan
20, Azadlig Ave., Baku, AZ1010: levap@tauex.tau.ac.il*

Summary. An integrated analysis of regional geological and geophysical factors led to selecting the Makhtesh Ramon area (northern Negev, Israel) to search for diamondiferous associations. The most important regional factor is the Middle Cretaceous maximum in upper-mantle hot-spot development, which appears prominently in this area. Analysis of magnetic (paleomagnetic), self-potential, and ion-selective data unambiguously indicates the presence of some bodies possibly having kimberlite (lamproite) origin occurring at small depths (8-50 m) in the western Makhtesh Ramon. Repeated erosion in the area removed most of the sedimentary associations and significantly simplified mineral sampling and rock collection for geochemical and petrological analyses. Comprehensive mineralogical analyses enabled the detection of the following minerals-satellites of diamond associations: chrome-diopside, orange garnet, bright-crimson pyrope, picroilmenite, moissanite, corundum, black spinel, olivine, anatase, and tourmaline (including black samples). These minerals are not rolled or oxidized, providing additional evidence of their association with the indigenous rocks. Data from electron microscopy show that the grains of (1) picroilmenite and (2) pyrope contain, respectively: (1) cobalt, chrome, magnesium, and nickel and (2) chrome, magnesium, and aluminum. This indicates that both picroilmenite and pyrope have a hyper-abysal origin, which also indicates the possible occurrence of diamondiferous pipes. Secondary-importance satellite minerals include feldspars, pyroxenes, magnetite, hematite, ilmenite, galena, pyrite, limonite, mica, chromite, leucoxene, zircon, rutile, etc. These minerals (compared with the first group) also indicate diamond-bearing mineralization in the studied area. Small gold and silver plates, along with considerable traces of La, Ce, Th, Nb, and Ta (Rare earth elements), may also be associated with the nearest kimberlite rock occurrence. The total number of recognized microdiamonds exceeds 300; five diamonds (> 1 mm) were identified (the largest crystals are 1.2 and 1.35 mm). Thus, based on a set of geological-geophysical factors and the identification of the mentioned minerals, we estimate that the Makhtesh Ramon area is promising for discovering diamondiferous rocks (kimberlite or lamproite pipes) as well as diamond crystals in loose deposits. The discovered silver-, gold-, and REE-bearing signatures may be important on their own.

Keywords: hot spot, diamonds, satellite minerals, gold, REE, geophysical signatures

© 2026 Earth Science Division, Azerbaijan National Academy of Sciences. All rights reserved.

Introduction

Three tectono-erosional cirques, termed “makhteshim” in Hebrew (sing. “makhtesh”), lie the anticlinal ridges in southern Israel (northern Negev): Makhtesh Ramon (largest), Makhtesh Gadol (intermediate), and Makhtesh Qatan (small). The makhteshim form closed valleys surrounded by steep cliffs 200-400 m high, with outlets carved into the steep southeastern flanks of some of the largest asymmetric folds (Zilberman, 2000).

The Makhtesh Ramon erosional-tectonic depression (canyon), 40 km long and about 8 km wide, lies 65 km southwest of the Dead Sea (Fig. 1).

Its formation ended approximately 132 Ma ago, during the Levantine tectonic phase (Katz, Eppelbaum, 1998; Eppelbaum, Katz, 2015). The subsequent origination of the Levantine marginal volcanic suture (Eppelbaum, Katz, 2012) promoted the accumulation of post-collisional trap rocks (alkaline basaltic, alkaline gabbroic, and kimberlitic associations).

Vent facies of the central-type Mahale Khatmaut depression contain peridotite xenoliths with spinel-bearing lherzolites (Stein et al., 1993). The presence of such rocks indicates significant depths of explosive volcanism. Magmatic rocks of the western Makhtesh Ramon

Canyon are represented by picritic and olivine basalts, basanites, mantle xenoliths, melilites, and alkaline picrites (Shimshilashvili, Yudalevich, 2005; Vapnik, 2005; Eppelbaum et al., 2006; Samoilov, Vapnik, 2007; Sharygin et al., 2011). Itamar (1988) described polymetallic mineralization in Makhtesh Ramon.

Based on integrated geological, geophysical, and geochemical investigations, along with geomorphological reconstructions, we selected western part of the Makhtesh Ramon Canyon (Fig. 1) as the most promising area for discovering microdiamonds. We sampled clastic rocks from both early and late epochs of secondary erosion, represented by Mesozoic (Lower Cretaceous Arod conglomerates) and Cenozoic (Middle Quaternary–recent alluvium) rocks, respectively. Samples from the near-surface layer (depth interval 20–80 cm) were concentrated by conventional tools in the geological base in Mizpe Ramon town and afterward were thoroughly analyzed mainly in the laboratories of

the Moscow State University and Moscow State Geological-Prospecting University (Eppelbaum et al., 2002, 2003, 2006; Samykina et al., 2005; Surkov et al., 2008).

Brief Geological Background

Over 200 basaltic and trachytic dikes intruded the sedimentary rocks in the Makhtesh Ramon area (Bayer, Reches, 1991). Most dikes are arranged in a complex (radial) system, and a smaller number of dikes create two systems of NW-SE and NE-SW trends. The dikes are accompanied by many sills of similar composition. The smaller folds tend to form second-order structures superimposed on the larger folds and flexures (Garfunkel, 1993). The known magmatic outcrops at Makhtesh Ramon, Har Arif, and Qrief en Naqa belong to two different magmatic phases, pre- and post-dating a sub-Cretaceous unconformity (Garfunkel, Katz, 1967; Starinsky et al., 1980; Lang, Steinitz, 1985; Baer et al., 1995; Gvirtzman et al., 1994).

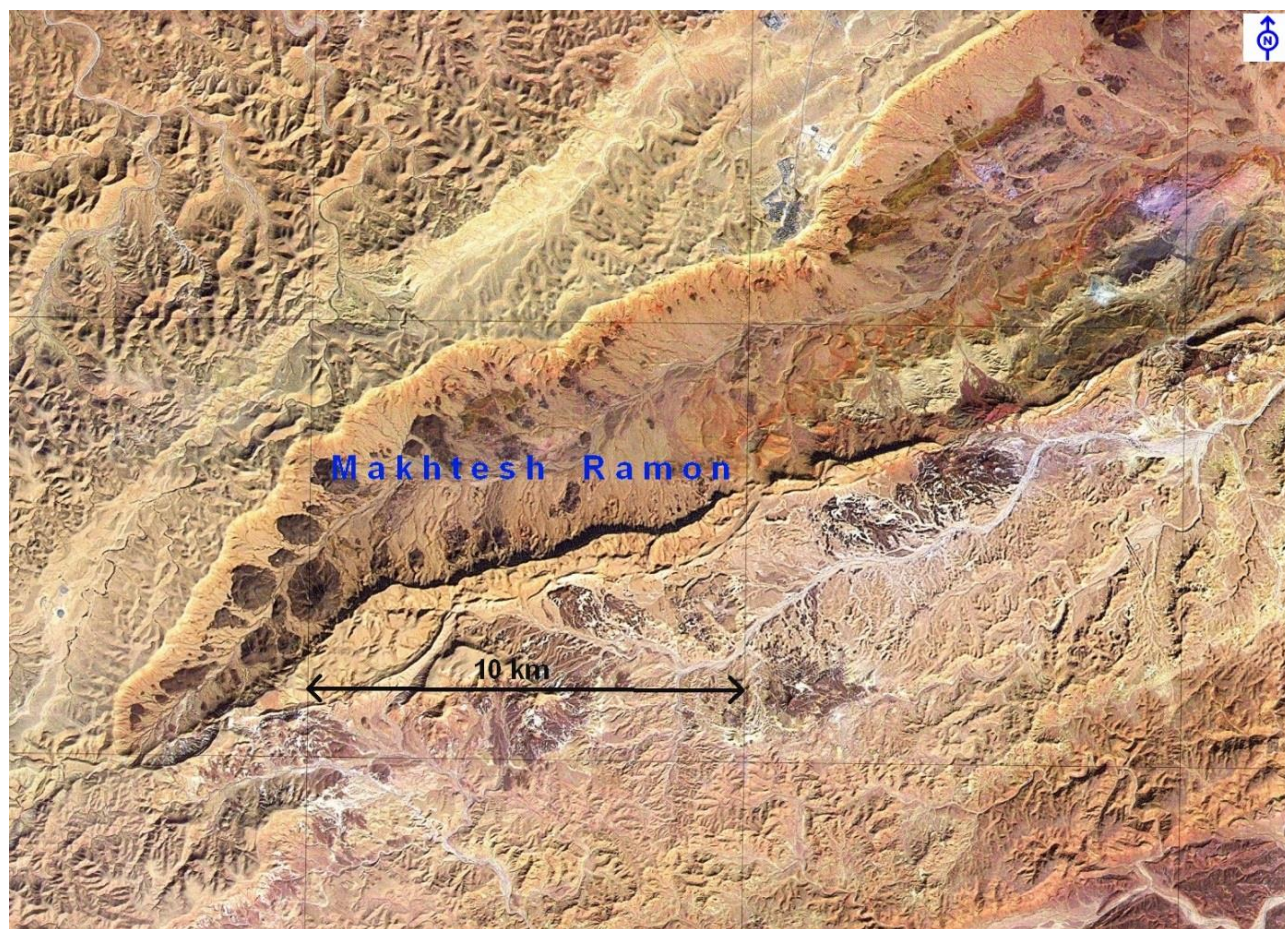


Fig. 1. Makhtesh Ramon (southern Israel): Fragment of “The Holy Land Satellite DataBase Project” (the imagery was made from data obtained from NASA’s Landsat 5 satellite with French SPOT satellite)

Maximal magmatism in the region occurred about 120 Ma ago, corresponding to the epoch of global tectono-thermal activation. Larson (1995) termed this epoch the Middle Cretaceous maximum in the development of upper mantle hot spots and associated it with the high development of diamond-bearing kimberlites during the Mid-Cretaceous. In the Makhtesh Ramon area, this stage is reflected in central-type volcanoes composed of lava flows, eruptive breccia, and tuffs, suggesting widespread explosive volcanism in the Middle Cretaceous (Lang, Steinitz, 1989; Segev et al., 2005).

Chang and Lee (2011) presented a tectonic map with three large mantle plumes in the Near and Middle East, and one of the plumes completely covers the makhteshim family location.

Ben-Avraham et al. (2002) and later Eppelbaum and Katz (2015) have recognized Ab-

delaziz, Negev, Aleppo, Anaximander, Antilebanon, Cyprus, Eratosthenes, Galilee-Lebanon, Heletz, Judea-Samaria, Levant Basin, Palmyrides, and Pleshet terranes in the Easternmost Mediterranean (Fig. 2). It should be noted that Makhteshim occurs at the boundary between the Sinai and Negev terranes, i.e., in the tectonically weakened zone (see Fig. 2).

The geological map of the Makhtesh Ramon area (after Sneh et al., 1998) (Fig. 3) shows a complex, mosaic distribution of sedimentary rocks and magmatic and metamorphic associations. The stratigraphic sequence along the Ramon lineament ranges from the Middle Triassic to the Middle and Late Eocene (Bentor et al., 1965; Benjamini, 1979; Sneh et al., 1998). At the same time, Early Cretaceous igneous rocks play the most significant role.

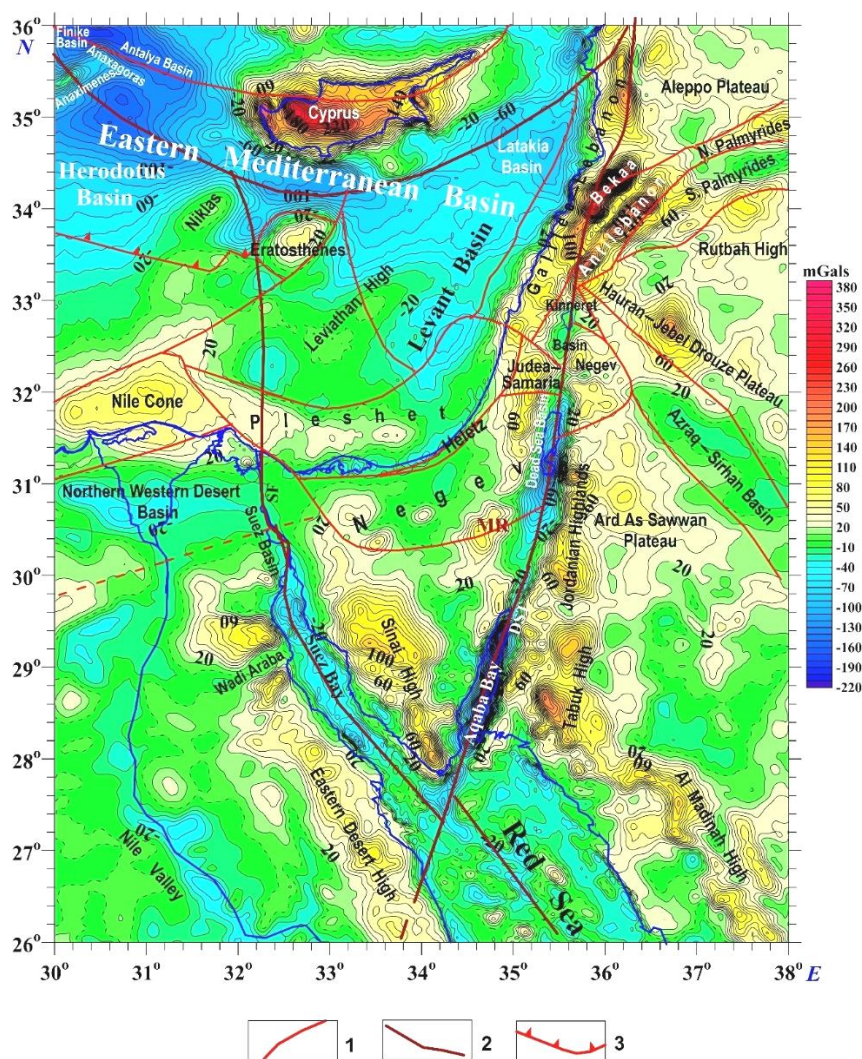


Fig. 2. Areal map of the region under study (supplemented after Eppelbaum et al. (2023)). Satellite-derived gravity map of the study area with the main tectonic features (isoline density is 10 mGals). (1) Intraplate faults, (2) interplate faults, (3) the southern boundary of the Mediterranean accretionary belt. DST, Dead Sea Transform; SF, Sinai Fault. MR, Makhtesh Ramon

that the anticline peak protruded like a continental island above the rest of the anticline, which was still underwater. Because the top of the anticline was worn away, there is no conglomerate rock on the peak.

4. The Ramon anticline continued to rise (60-70 million years ago) along the line of the Ramon fault, with strata of chalk and flint (Senonian formation) and chalk with some clay and phosphates (Maastrichtian formation). Strong erosion washed sands and conglomerates away from the top of the anticline, and they were deposited around the anticline.

5. During the Eocene era (40-50 million years ago), the whole area flooded, including the Ramon anticline and the primary makhtesh. Geologists identified the limestone deposited in this sea in the western part of the Ramon anticline and on the Avdat plateau.

6. The sea level dropped, and the Ramon anticline continued to rise (30 million years ago). The peak of the Ramon anticline was largely eroded, exposing a large sandstone core that precipitated during the early stages of the Makhtesh Ramon formation.

7. The rivers have been developing and creating Makhtesh Ramon (20 million years ago – present). The fact that the Ramon Ridge now stands more than 1,000 meters above sea level is evidence of a marked rise in the ridge. As the ridge rose, it tilted slightly northeast (towards the Arava) as the deep Dead Sea Transform valley developed. The large height difference and the ridge's tilt led to vigorous erosion and undermined the soft sandstone strata, which were carried from the Ramon Ridge to the Arava. Erosion of the ridge's inner parts created Makhtesh Ramon as we observe it today.

Regional Geophysical Data Analysis

It is assumed that events of regional kimberlite magmatism are associated with some parameters of Earth's crust and lithosphere, including some of their physical properties and the presence of linear deformations on the mantle surface and in the Earth's crust (Milashev, 1974; Kaminsky et al., 1995; Mitchell, 1995; Morgan, 1995; Kutinov, Chistova, 2016).

The low heat flow ($\sim 35 \text{ mW/m}^2$) in southern Israel is a positive indicator of potential diamond deposits in the area (Eppelbaum et al.,

2006). Commercial diamond deposits have been found exclusively in regions with heat flow less than 40 mW/m^2 (Kaminsky et al., 1995; Morgan, 1995; Kutinov, Chistova, 2016).

The comparatively deep Moho discontinuity in the Makhtesh Ramon area (38 km) (Fig. 4) (Eppelbaum, Pilchin, 2006) is also a positive signature (Morgan, 1995; Cherepanova et al., 2013; Kutinov, Chistova, 2016).

Another significant geophysical indicator is the large depth of the Curie Point isotherm (Morgan, 1995; Condie, 2001). The calculated Curie Point isotherm for the Makhteshim area location is about 39 km (Eppelbaum, Pilchin, 2006) (Fig. 5), which is also an auspicious indicator (cooling lithosphere).

Finally, the last positive regional geophysical indicator is the relatively shallow depth of the crystalline basement (Morgan, 1995; Nixon, 1995). In the Makhtesh Ramon area, the depth of the crystalline basement, according to Rybakov, Segev (2004), is 3.3-3.5 km.

Taken together, these two indicators suggest that a thick crystalline basement is also favorable. It can also be considered a positive signature (Morgan, 1995; Cherepanova et al., 2013). In the study area, the crystalline basement exceeds 30 km in thickness.

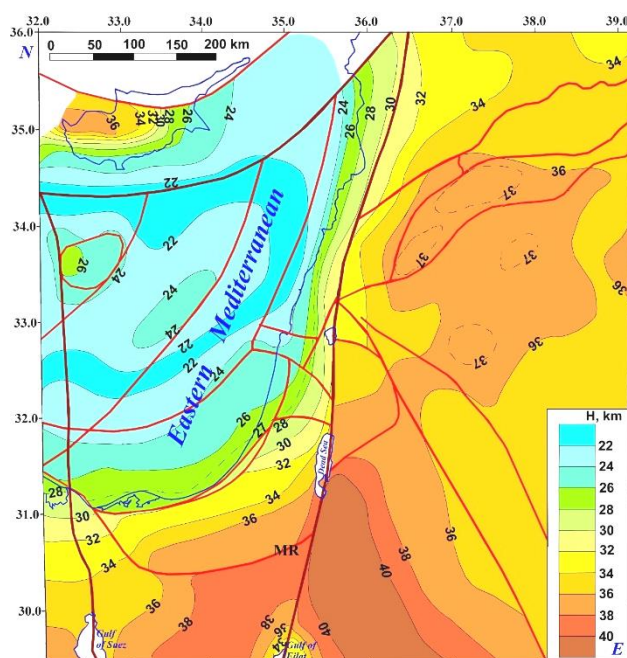


Fig. 4. Map of Moho discontinuity of the Easternmost Mediterranean (after Eppelbaum, Pilchin, 2006, with small modifications). MR, Makhtesh Ramon

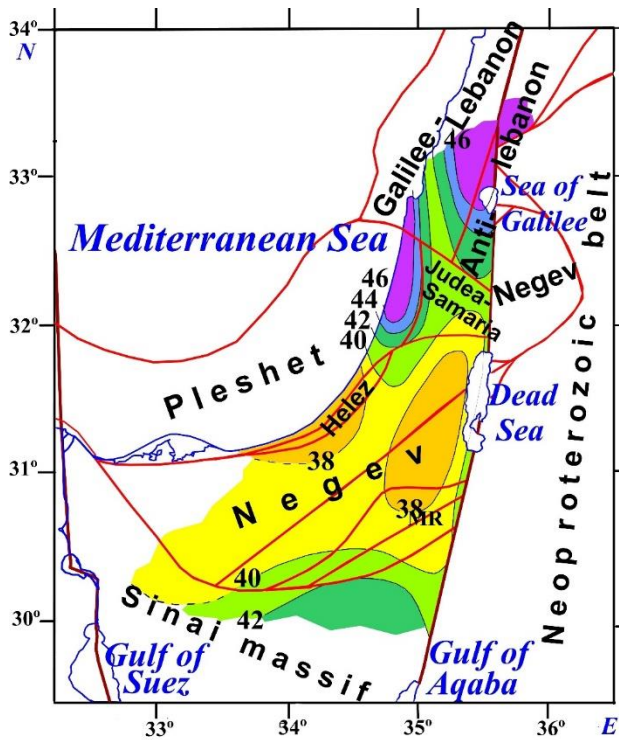


Fig. 5. Curie map of Israel (supplemented after Eppelbaum, Pilchin, 2006). MR, Makhtesh Ramon

Many authors (e.g., Green, Gueguen, 1974; Mitchell, 1986; Griffin, 2008) note a possible major role for mantle diapirism in transporting kimberlite material from depth to the Earth's surface. From this perspective, the greatest magnetic anomaly in Israel, 'Hebron' (~110 km NNE of the Makhtesh Ramon), was interpreted as a mantle diapir (Eppelbaum et al., 2005). This indicates that mantle material is rising in this region.

Figure 6A shows an airborne magnetic map of western Makhtesh Ramon overlaid on a simplified geological map (after Gvirtzman, Weinberger, 1994) and two interpreting magnetic profiles. Results of magnetic field modeling (semi-automatic software developed at the Moscow State University was applied) along profile II – II are presented in Fig. 6B. It should be noted that the airborne magnetic observations (considering the altitude and spacing of the aeromagnetic survey) reflect only large anomalous bodies (at least two buried targets have expressed quasi-kimberlite structure).

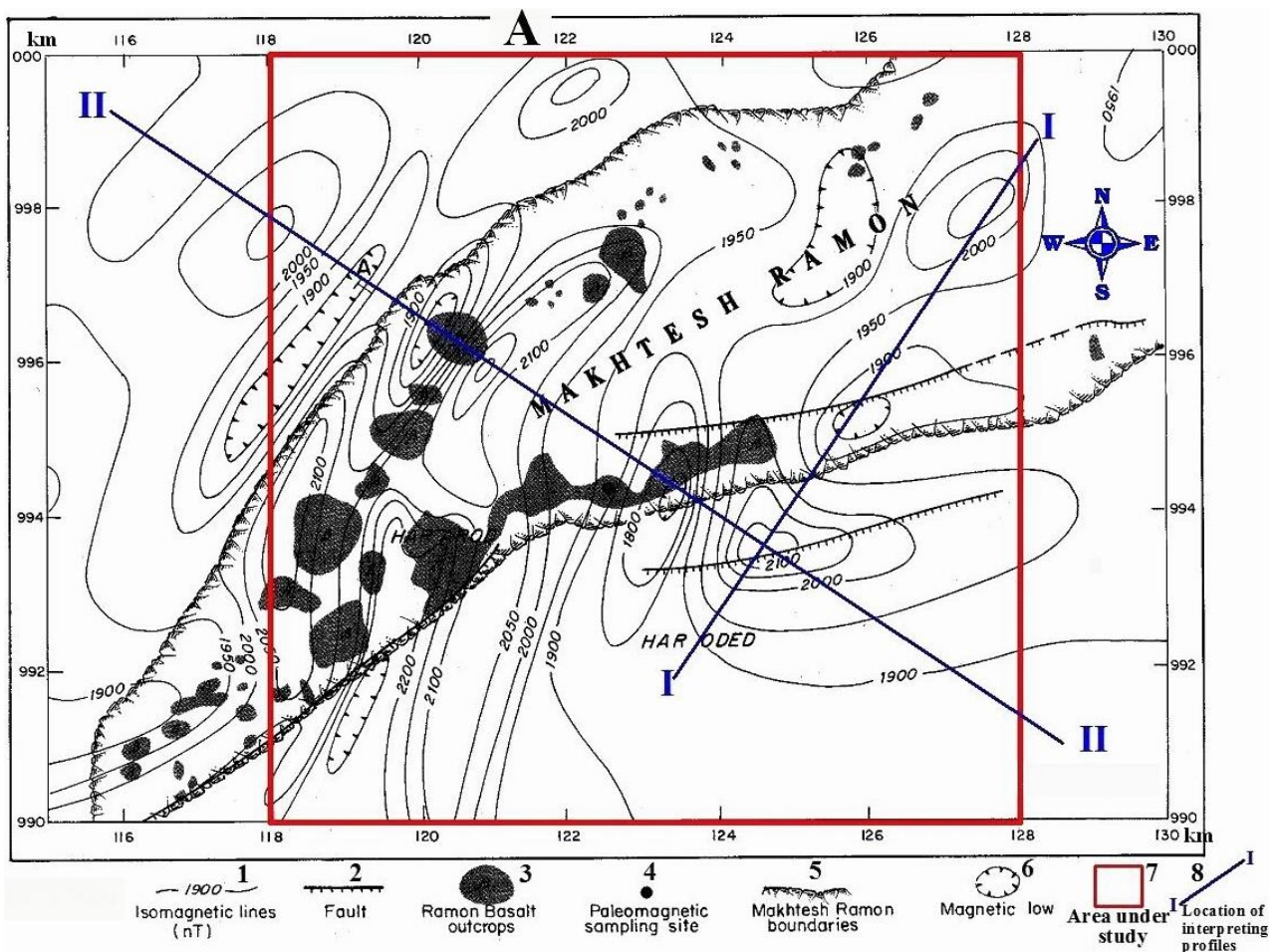


Fig. 6A. The aeromagnetic map (flight altitude: 1000 m, spacing: 2000 m, IGRF removed) of western Makhtesh Ramon overlaid on a geological map (after Gvirtzman, Weinberger, 1994), with the locations of two interpreted profile

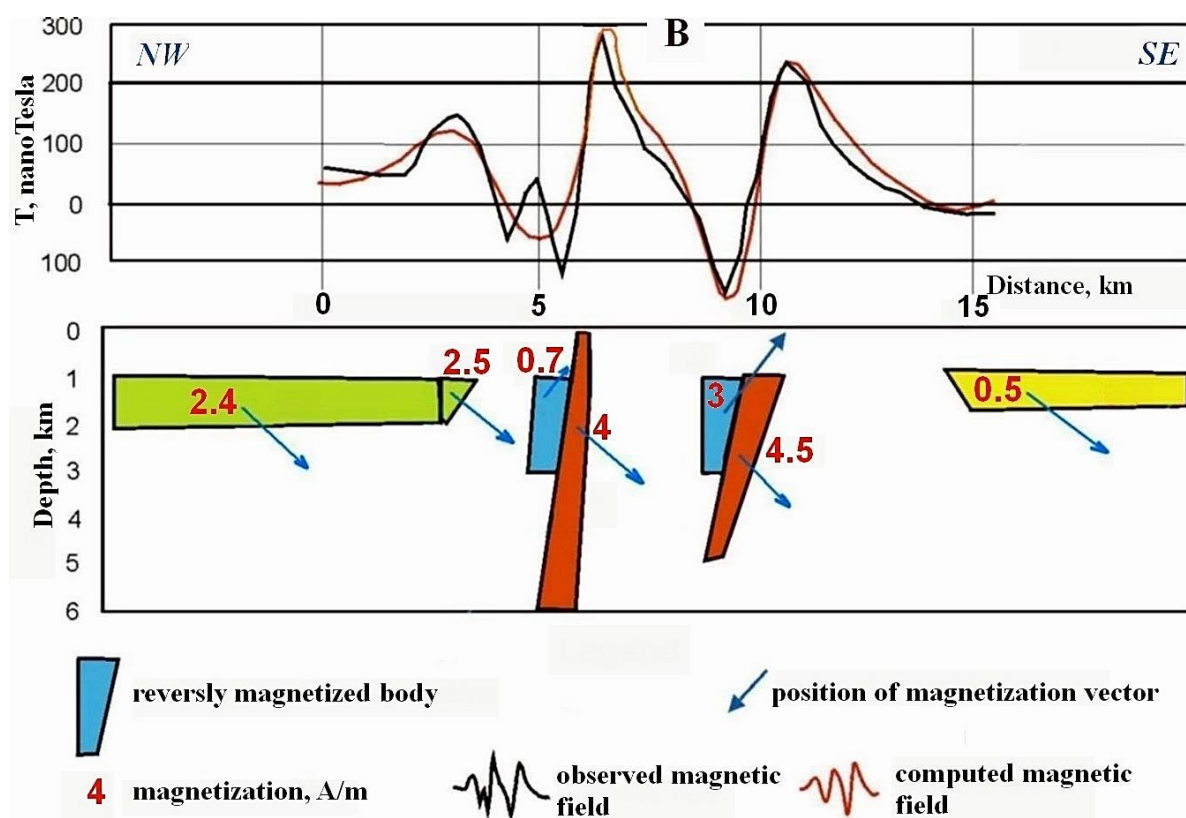


Fig. 6B. Results of magnetic field modeling along profile II – II in Makhtesh-Ramon (location of this profile is shown in Fig. 6A) (after Eppelbaum et al., 2002, with modifications)

Concerning the confinement of the kimberlite magmatism to zones of regional linear deformations. Several investigators (e.g., Ben-David, Mazor, 1988; Zilberman, 1991; Ben-David et al., 2002) have suggested that the makhteshim structures were developed during the Middle to Late Cenozoic in response to the formation of the Dead Sea Transform Zone (see Fig. 2).

Detailed Geophysical Data Analysis

Magnetic data analysis

The magnetic pattern of the Makhtesh Ramon area is very complex (Folkman, Yuval, 1976; Gvirtzman et al., 1994) because magnetized rocks at different depths (tephrites, basanites, olivine basalts, quartz syenites) contribute diverse effects to the observed field.

Detailed analysis of the magnetic data (including the quantitative interpretation and 3D modeling; developed methodologies for complex physical-geological conditions are described in detail in Khesin et al. (1996) and Eppelbaum, Khesin (2012)) indicates the presence of near-surface occurrence (from eight to fifty meters) bodies having the form of thin beds and 'inverse carrot' (Eppelbaum et al., 2003; 2006).

The observed magnetic map of area 'I' is unclear because a strong regional background masks local anomalies. Fig. 7 shows the results of applying the gradient operator to the total magnetic field data in area 'I'. Even a simple visual analysis of this map indicates a series of ring structures at low depths.

Figure 8 shows an interesting example of magnetic data re-interpretation. Initial geological-geophysical data analysis (Baer et al., 1989) proposed that this anomaly originated from a buried sill (Fig. 8). However, re-interpretation of this anomaly (Eppelbaum et al., 2006) allowed us to conclude that a kimberlite pipe (classical kimberlite pipe model presented in Haggerty (1995)) is the most suitable model.

Gvirtzman et al. (1994) analyzed sizable magnetic anomalies in the Makhtesh Ramon area and south of it. The authors associated the examined anomalies with large magmatic bodies of Late Jurassic–Early Cretaceous age and apparently basaltic consistency. Interestingly, models of disturbing bodies developed using 2.5D magnetic field modeling (Gvirtzman et al., 1994) often resemble the classic models of large kimberlite pipes (Haggerty, 1995; Mitchell, 1995).

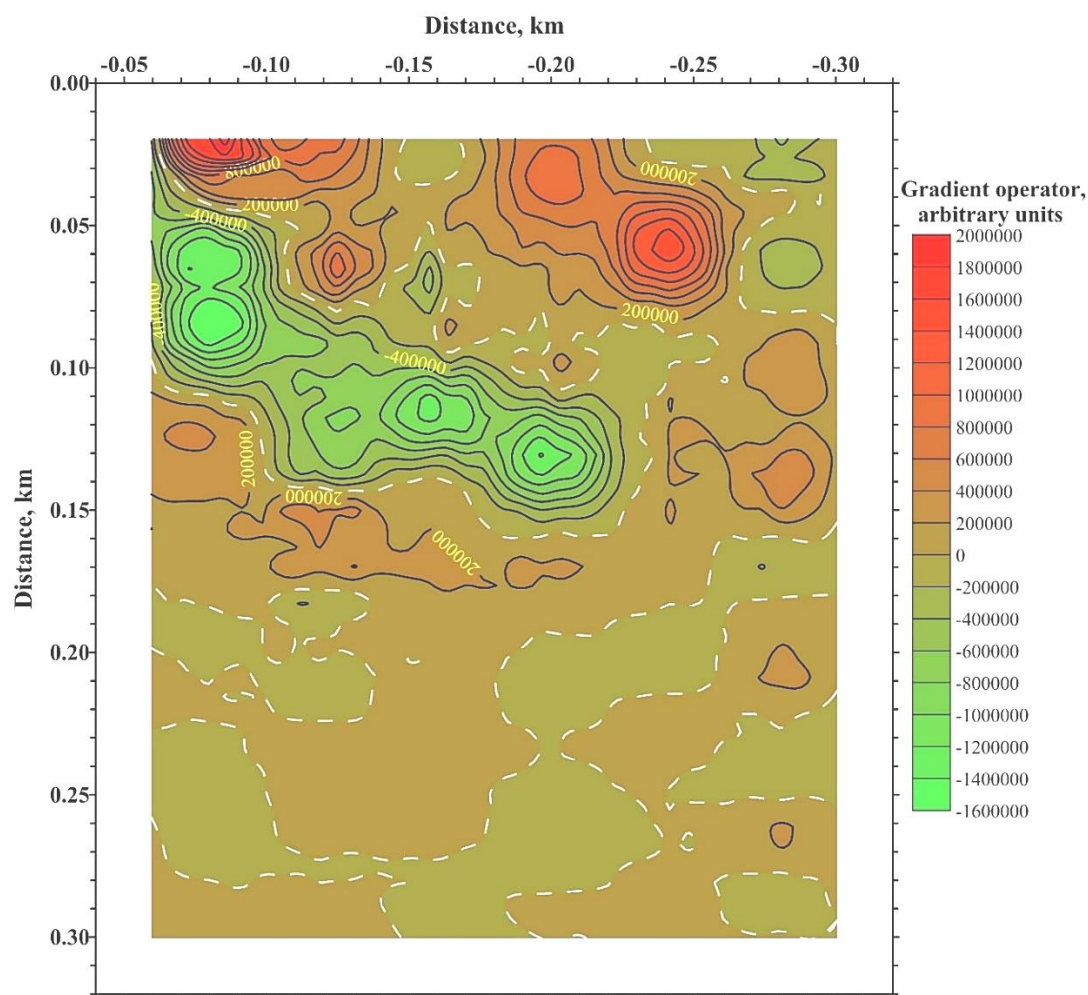


Fig. 7. Results of the total magnetic field processing by the gradient operator in area 'I'

Paleomagnetic map compilation

Paleomagnetic data are sometimes important because they can provide results that other geological and geophysical methods may not (Eppelbaum, 2015). For compiling the first paleomagnetic map of Makhtesh Ramon, the available paleomagnetic, radiometric, and geological data were examined (e.g., Garfunkel, Derin, 1988; Lang, Steinitz, 1989; Baer, Reches, 1991; Baer, 1993; Eyal et al., 1996; Gvirtzman et al., 1996; Segev, 2000; Segev et al., 2005). The oldest preaccretional dikes (Omolon paleomagnetic zone) trend south-north, and the dikes of the accretional stage (upper part of Gissar paleomagnetic zone) trend east-west (Fig. 9A). The eastern margins of preaccretional and accretional dike complexes and other magmatic bodies are older than the western margins. The eastern Omolon zone is 165.7 Ma; the western margin is 151.4 Ma. Within the Gissar zone, ages change from east to west from 142.5 Ma to 126.8 Ma. Various volcanic bodies of the

postaccretional stage (Jalal paleomagnetic zone) are discordant relative to dike orientations in the Omolon and Gissar zones. Most magmatic bodies of the Jalal zone trend from WSW to ENE (Fig. 9A). Paleomagnetic analysis carried out by Gvirtzman et al. (1996) in the SWW part of the Jalal zone (this paleomagnetic zone is characterized by predominant direct polarity) indicates that all magmatic sample determinations show direct polarity except for the Mt. Arod area, where both direct (younger flows) and inverse (older flows) polarities were registered. The Gissar paleomagnetic zone is characterized by numerous approximately equivalent alternations of direct and reverse polarities (this must be considered in the qualitative and quantitative examination of magnetic anomalies). Figure 9B shows the geodynamic rotation of the Makhtesh Ramon block (subterrane) in the Middle Mesozoic. This rotation was primarily counterclockwise, driven by a deep, giant rotating mantle structure (e.g., Eppelbaum et al., 2021, 2025).

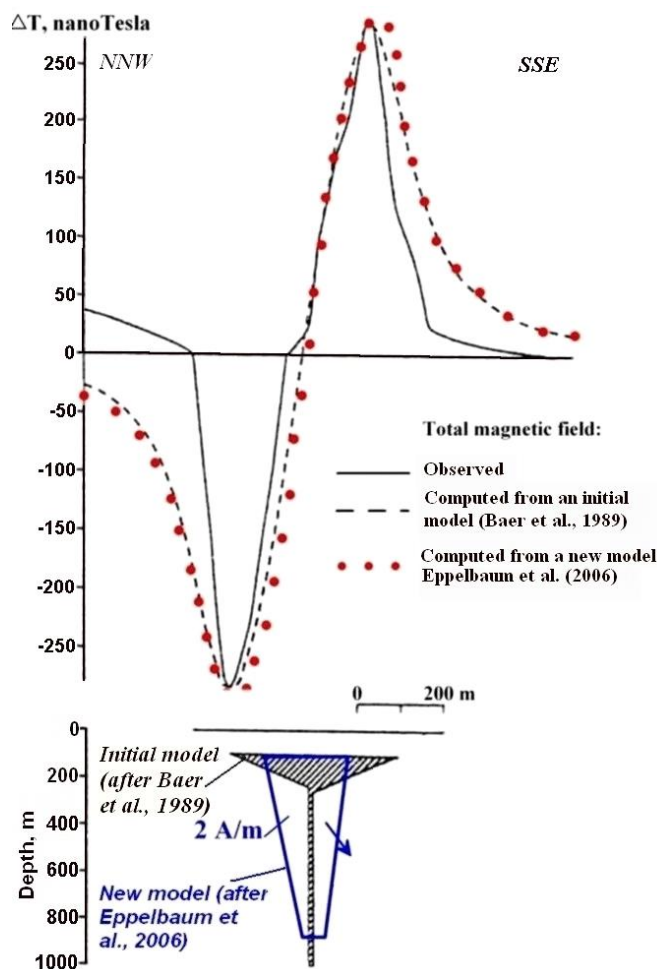


Fig. 8. Results of magnetic data interpretation in the eastern part of the Makhtesh Ramon area (initial data after Baer et al., 1989; revised model – after Eppelbaum et al., 2006)

Self-potential data examination

In the developed self-potential map of area I (Fig. 10), an anomalous zone is contoured (white dashed line), which agrees well with the magnetic susceptibility map examination (Eppelbaum et al., 2003). Quantitative interpretation of the self-potential anomalies performed using advanced methods developed in magnetic prospecting (Eppelbaum et al., 2004; Eppelbaum, 2021) allowed us to estimate a depth of the upper edge of the buried target: $\approx 25\text{--}30$ m.

Application of ion-selective electrodes

An ion-selective electrode method (e.g., Nowak, 2010) is based on applying a set of calibrated ion-selective electrodes (Cl^- , Br^- , I^- , Na^+ , K^+ , NH_4^+ , NO_3^- , NO_2^- , Ag^+ , S^{2-} , Cu^{2+} , Cd^{2+} , Pb^{2+} , Hg^{2+} , Ca^{2+} , Ba^{2+} (SO_4^{2-} , ClO_4^- , ReO_4^- , F^- , AuCl_4^- , CNS^- , $\text{Ca}^{2+}+\text{Mg}^{2+}$, Ph, Ph_{int} , Eh) for

studying soil mixtures (loose deposits) “in situ” or under laboratory conditions. Among these electrodes, we selected parameters associated with kimberlite pipes. We present only Na^+ and Ba^{2+} maps (Figs. 11 and 12, respectively), but other ion-selective electrodes also gave positive results.

Kimberlite rocks, or products of their destruction, contain higher Na^+ contents (Ahrens et al., 1975; Mitchell, 1986, 1995), which may also serve as a search indicator. Measurements using Na^+ electrodes show a direct correlation between ion concentration and the registered potential. The developed Na^+ map (Fig. 11) enabled delineation of a fault-oriented SW–NE across the points 0/150, 50/375, 100/325, 150/300, 200/275, and 300/225. The fault is traced in almost all developed ion-selective maps. The proposed kimberlite pipe location is contoured by elevated Na^+ contents.

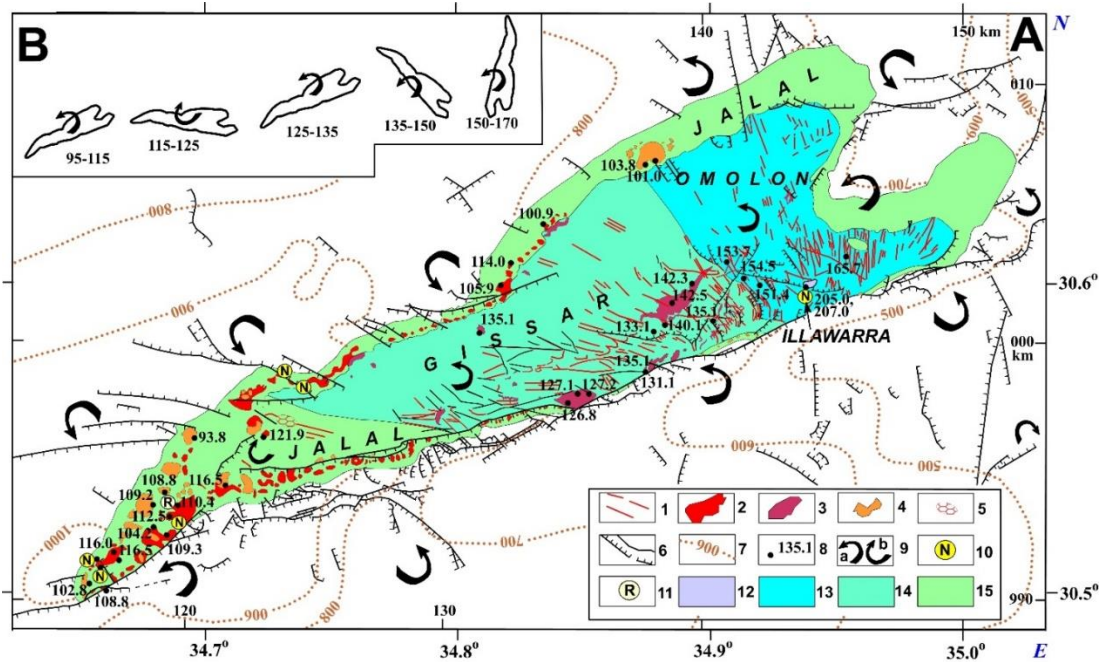


Fig. 9. Makhtesh Ramon geodynamic–paleomagnetic map (modified and supplemented after Eppelbaum et al. (2023)). (A) Geodynamic–paleomagnetic indicators. (B) Geodynamic changes in Makhtesh Ramon subterranean displacement in the Middle Mesozoic. (1) Pre-collisional–collisional basalt dikes, (2) post-collisional alkalic olivine basalt flows and volcanoclastic rocks, (3) pre-collisional association of alkalic olivine gabbro, monzogabbro, and syenites, (4) post-collisional association of basanites and nefelinites, (5) quartzitic hexagonal prisms, (6) faults, (7) hypsometric isolines within the Makhtesh Ramon plateau (1-7) from Garfunkel, Katz, 1967; Zak, 1968; Baer, Reches, 1991; Baer, 1993; Sneh et al., 1998; Avni, 2001b; Zilberman, Avni, 2004; Vapnik et al., 2007; Yudalevich et al., 2014, 2018; Eppelbaum, Katz, 2015; Avni et al., 2017), (8) radiometric age of the magmatic rocks Lang, Steinitz, 1989; Segev, 2000; Segev et al., 2005), (9) counterclockwise (a) and clockwise (b) rotation of the linear structures (faults, dikes, and volcanic ridges), (10)–(11) magmatic rocks with normal (10), and reversal (11) paleomagnetic polarity (from Ron, Baer, 1988; Baer et al., 1995; Gvirtzman et al., 1996; Dembo et al., 2022), (12)–(15) paleomagnetic zonation inside the magmatic complexes: (12) Illawarra, (13) Omolon, (14) Gissar, (15) Jalal

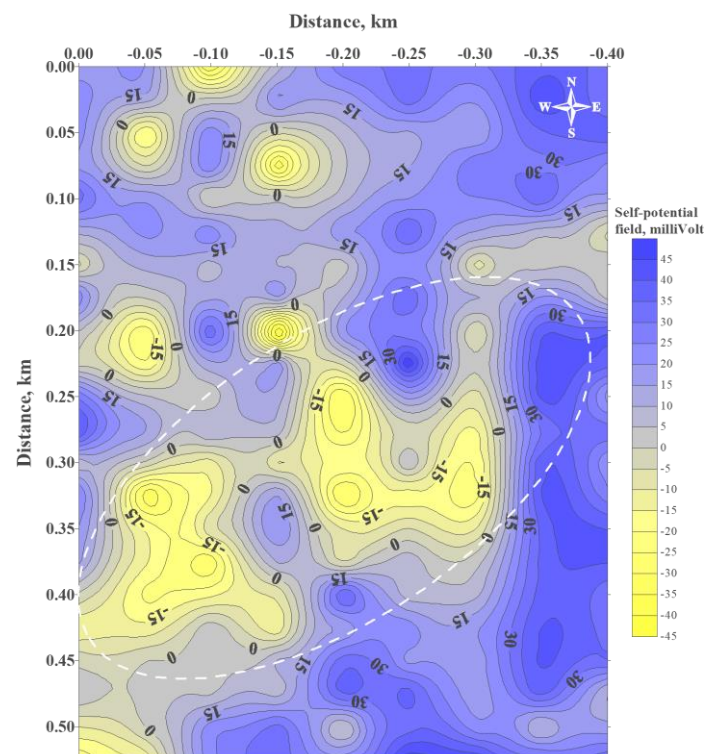


Fig. 10. Results of self-potential method application at the area I of the western Makhtesh Ramon

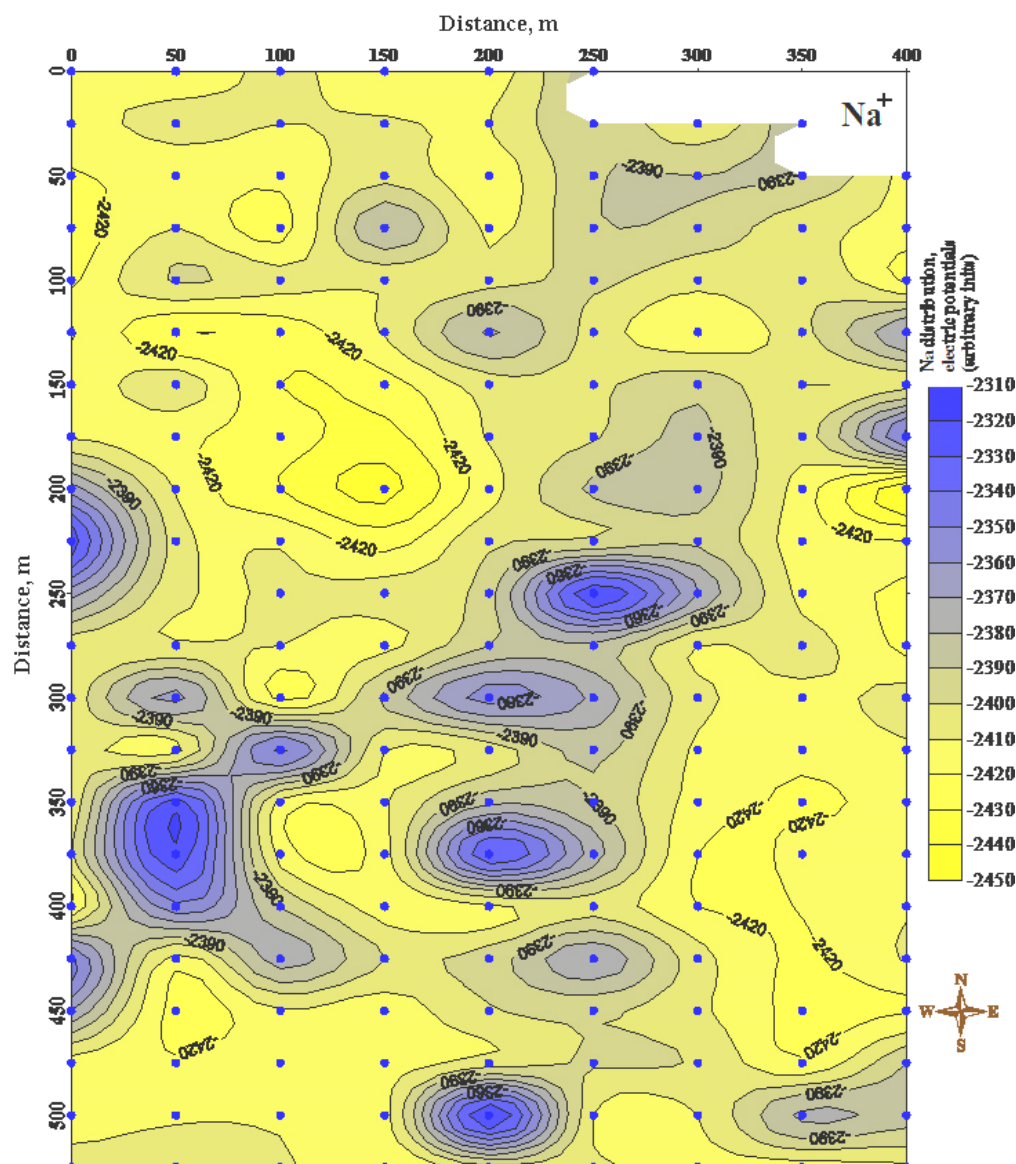


Fig. 11. Map of Na^+ observations in area I of the western Makhtesh Ramon

Barite is a known kimberlite-generative mineral (Bobrievich et al., 1959; Ahrens et al., 1975; Mitchell, 1995). Most of the barite is concentrated in the upper part of the kimberlite pipe (Bobrievich et al., 1959). In the developed map of barite isopotentials (Ba^{2+}) (Fig. 12), a fault is clearly traced. Anomalous zones point out the most prospective areas for near-surface well drilling or bore-pit excavation.

Mineralogical, Petrological and Geochemical Data Analysis

Interestingly, Kaminsky et al. (1995), in the scheme ‘Diamondiferous territories of the World’, distinguished an Eastern Mediterranean diamondiferous province.

The first microdiamond in Israel was discovered in the Negev Desert 30 km north of Makhtesh Ramon (Israel) in the Cretaceous/Paleogene boundary iridium layer and was attributed to a meteorite fall (Flexer et al., 1988b). However, the habit, size, and characteristic impurities in the microcrystal suggest that it was washed out from diamondiferous igneous rocks.

Samples from the near-surface layer were withdrawn in the western Makhtesh Ramon (depth interval 10–80 cm), processed at the temporary base in Mizpe Ramon town, and later thoroughly analyzed in laboratories of the Moscow State University and Moscow State Geological-Prospecting University (Eppelbaum et al., 2002, 2003; Samykina et al., 2005; Surkov et al., 2008).

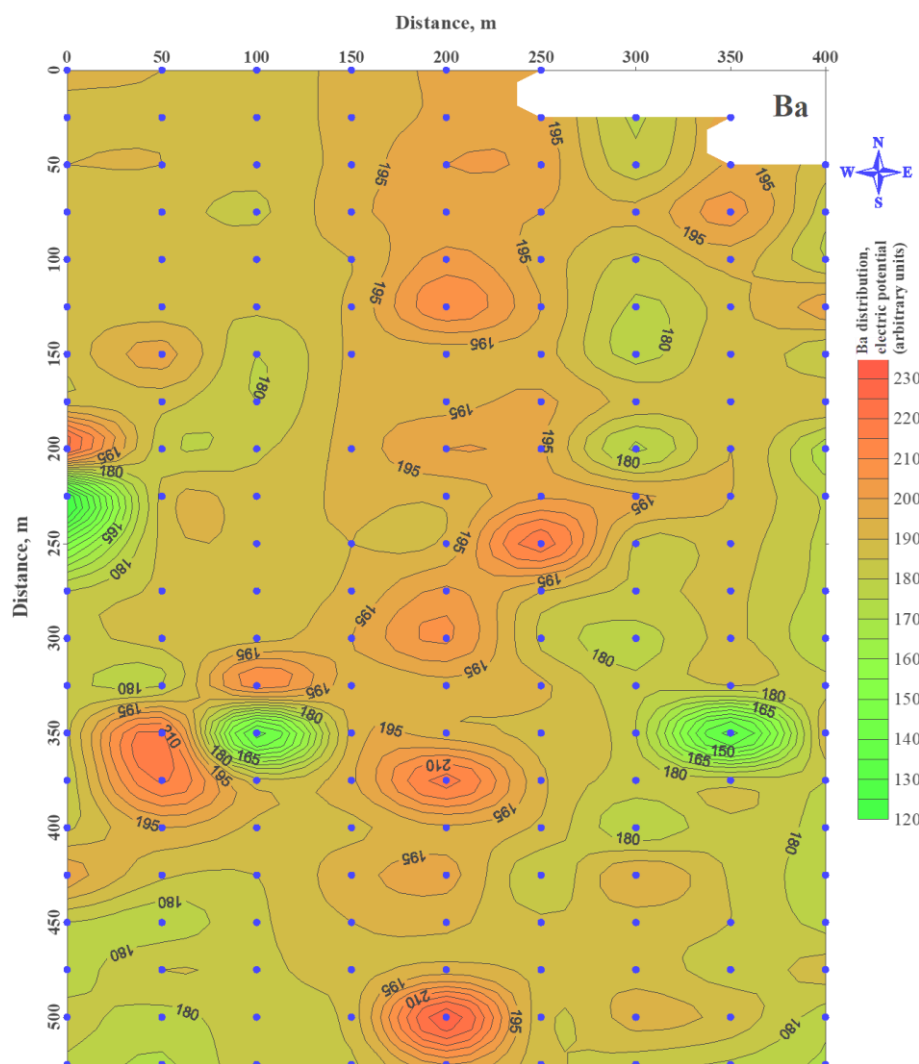


Fig. 12. Map of Ba^{2+} observations in area 'I' of the western Makhtesh Ramon

The minerals of the diamondiferous association in these samples can be divided into two groups. The *first group* includes chromediopside (e.g., Fig. 13a and 13b), orange garnet, bright crimson pyrope (e.g., Fig. 14), picroilmenite, chromspinel (e.g., Fig. 15), olivine, moissanite, perovskite, anatase, corundum, titanomagnetite, and tourmaline (including black species). This mineral list includes almost all the main satellite minerals of diamond. The total content of these minerals is very high (in 150 kg of concentrate, more than 15 000 grains were identified).

Chromediopside is a well-known satellite mineral of diamond. Orange garnets, bright crimson pyropes, and tourmalines also indicate diamondiferous associations in this area. Corundum and moissanite are even better satellite minerals in this regard (Mitchell, 1986; Ilupin et al., 1990; Kharkiv et al., 1997). Most associated mineral grains are not rounded or oxidized, sug-

gesting proximity to diamondiferous bedrock associations. Moissanite (SiC), widely known as a rare high-pressure mineral of mantle origin, offers an important window into oxygen-deficiency processes deep in the Earth. Researchers found moissanite samples in both Makhtesh Ramon (Eppelbaum et al., 2006) and the Qishon Valley (northern Israel) (Eskel et al., 2007; Griffin et al., 2016). For the first time, researchers found the 4H SiC polytype *in situ* in the Qishon Valley (Mukhin et al., 2015). A comprehensive examination of this sample indicates a mantle origin for the 4H SiC polytype and possible redox conditions in a significantly larger volume of the lithosphere in Israel than previously thought. A thick lithosphere is a prominent signature (together with other indicators) for the discovery of diamond-bearing regions (Ilupin et al., 1990; Mitchell, 1995; Morgan, 1995; Kutinov, Chistova, 2016).

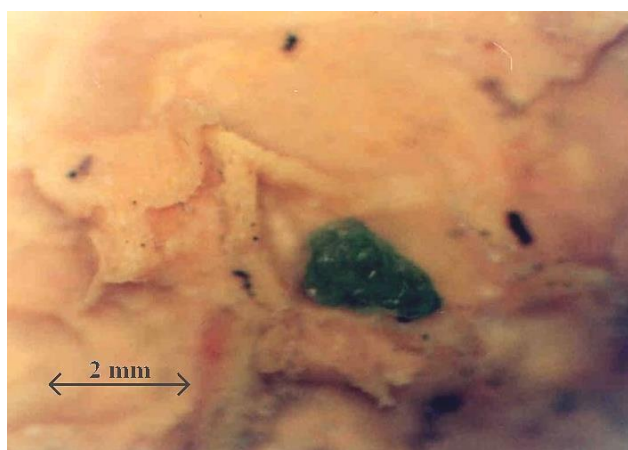


Fig. 13a. Crystal of chromediopside No. 1243 withdrawn in selected geological associations of the Makhtesh Ramon deposit

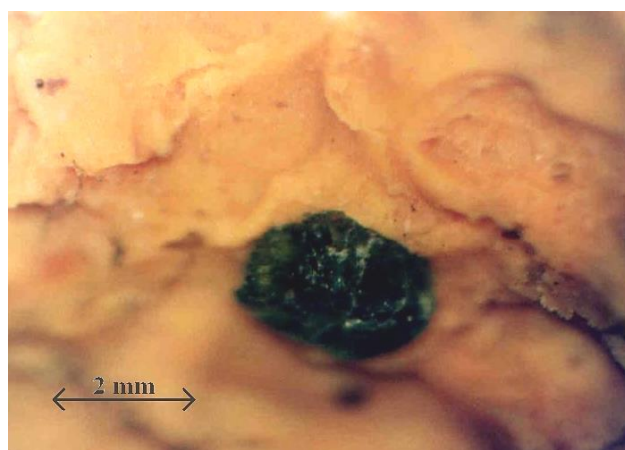


Fig. 13b. Crystal of chromediopside No. 1517 withdrawn in selected geological associations of the Makhtesh Ramon deposit

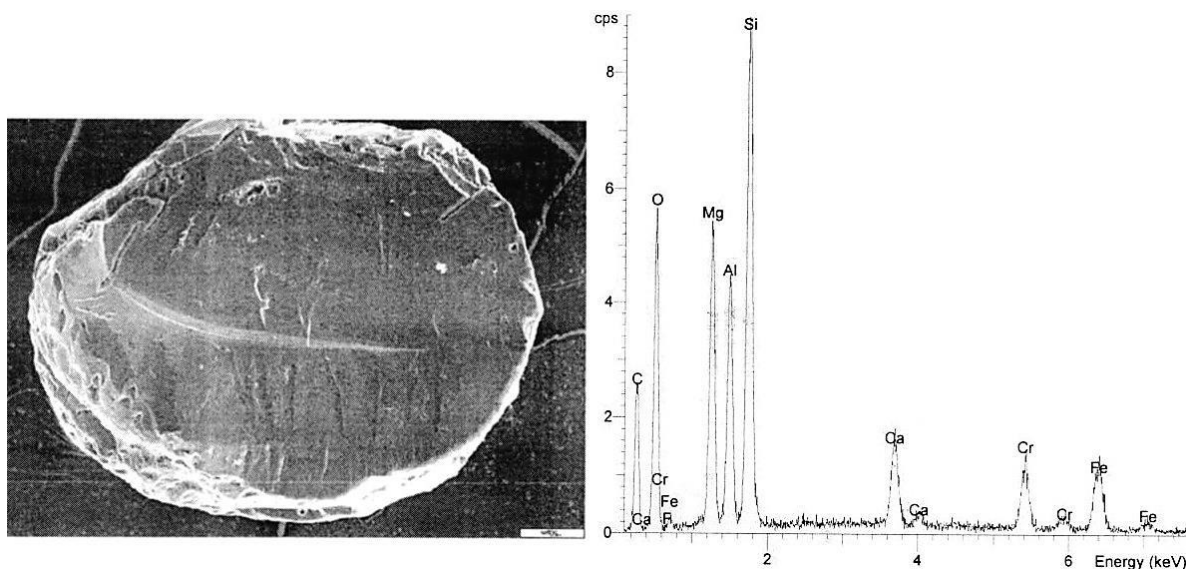


Fig. 14. Pyrope: back-scattered electron image (left) and electrodispersion spectrum (right)

The *second group* includes hexagonal quartz, feldspars, pyroxenes (black, green, dark-green, gray-green, brown-green), magnetite, hematite, ilmenite, galena, pyrite, limonite, small magnetic spheres, mica, hydro-mica, chromite, leucoxene, zircon (Fig. 16), rutile, secondary minerals of cuprum (green and blue), calcite, etc. These minerals, combined with the minerals of the first group, also suggest the diamond potential of this area.

Mineral coesite, identified in large volumes, is an important signature of the deep origin of the investigated rocks, according to Sobolev (2006).

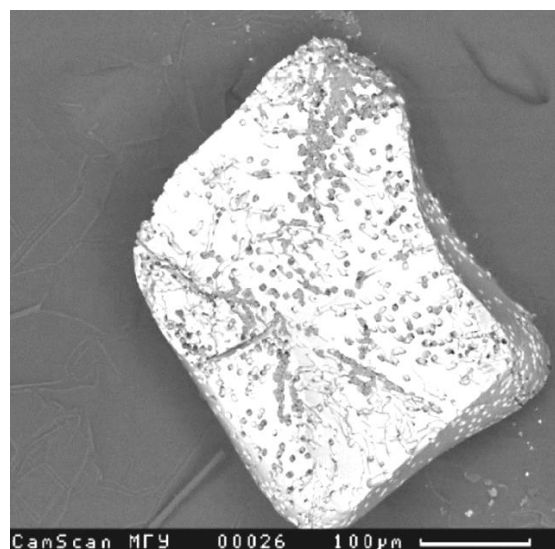


Fig. 15. Chromspinel. Back-scattered electron image

Examining rocks with fluoric and other acids revealed several gold and silver flakes, accompanied by traces of REE: La, Ce, Th, Nb, and Ta. These elements can also indicate proximity to kimberlitic rocks (Kaminsky et al., 1974; Le Roex et al., 2003; Shcheka et al., 2006; Giuliani et al., 2013).

Yttrium phosphate (Figs. 17a and 17b) is usually associated with the nearest kimberlite (Mitchell, 1986; Ilupin et al., 1990).

Experimental testing of detrital sediments from the western Makhtesh Ramon identified a set of minerals typical of an arid climate, multiply re-deposited from older deposits, and rounded in form: quartz, pyroxene, rutile, leucosene, zircon, and tourmaline (Eppelbaum, Vaksman, 2017). However, minerals of a “fresh pattern” are not rounded and are more stable in weathering conditions: green pyroxene, olivine, native silver, gypsum, calcite, barite, and feldspars. From the withdrawn samples, we selected a group of minerals with similar fragment size and weight (Table 1). However, their densities differ. This fact indicates that conventional gravitational concentration in this area may not be effective (Samykina et al., 2005). Therefore, in the Makhtesh Ramon area, an enhanced mineral concentration scheme (Surkov, 2000) was applied.

Due to microscopic analysis, 1459 grains were selected and measured from 8 sites (the results reflect only the preliminary stage of the investigations), among which were identified pyrope, garnet, diopside, chromediopside, ilmenite, tourmaline, spinel, rutile, pyroxenes, zircon (Table 2), as well as galena, pyrite, chalcopyrite, secondary minerals of cuprum, etc. (Eppelbaum et al., 2006). In probes selected from deposits of temporary flows (alluvium) and conglomerates (Table 3), all identified minerals occurred as secondary minerals.

As is noted in Table 3, many samples were collected in the dry channel ('wadi') of Nahal Ramon (Fig. 18).

We should underline the fact that minerals revealed in the possible diamondiferous association: pyrope, garnet, diopside, chromediopside, picroilmenite, ilmenite, and spinel (according to the investigations carried out using an optical microscope MBS-10) have no traces of wear (they are not smoothed), which indicates the occurrence of indigenous sources.

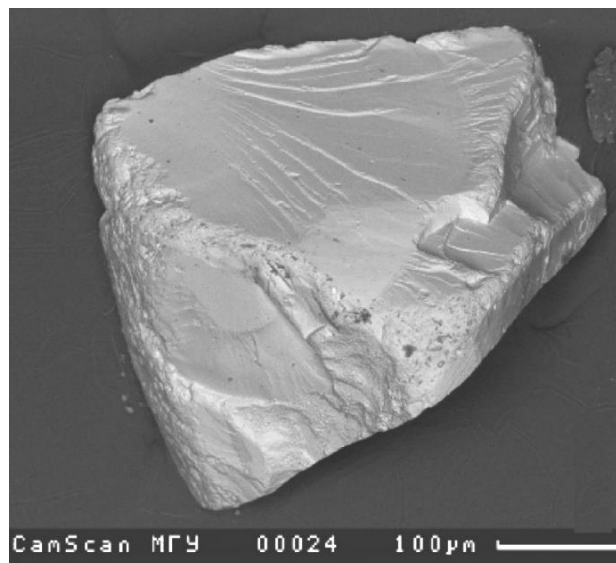


Fig. 16. Zircon. Back-scattered electron image

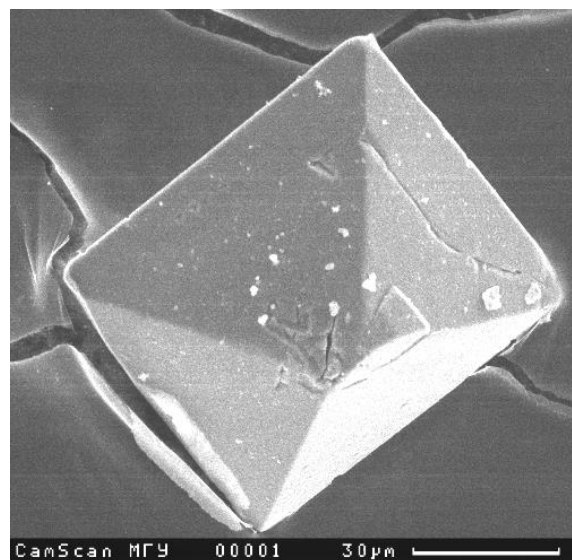


Fig. 17a. Back-scattered image of yttrium phosphate crystal

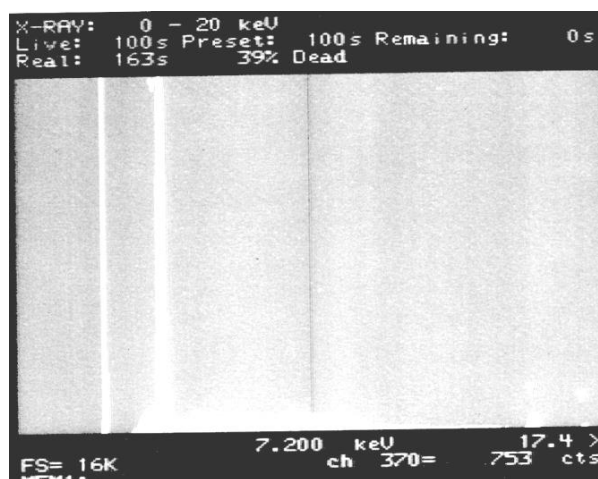


Fig. 17b. Energy dispersion spectrum of the yttrium phosphate crystal

We observed and examined all prerequisites for the presence of the desired diamondiferous associations (volcanism, structural-tectonic environments, and geomorphological conditions) (Eppelbaum et al., 2002, 2003, 2006). We studied the most representative mineral indicators

using the scanning electron microscope JSM-5300, which obtained images in reflected electrons and energy-dispersive spectra reflecting their chemical composition. Altogether, we studied about 100 minerals using the aforementioned methodology (preliminary stage).

Table 1

Results of some mineral investigations in the western Makhtesh Ramon area (southern Israel)
(after Eppelbaum et al., 2002)

N/n	Mineral	Size, mm	Average density, kg/m ³	Weight of crystal, milligrams
1	Olivine	1.36 x 1.20 x 0.72	3500	4.11
2	Diopside	1.34 x 1.19 x 0.79	3300	4.15
3	Diamond	1.35 x 1.15 x 0.75	3510	4.09
4	Ilmenite	1.36 x 1.16 x 0.55	4750	4.13
5	Gold	1.31 x 0.90 x 0.20	1740	4.18
6	Quartz	1.34 x 1.17 x 1.01	2650	4.19

Table 2

Results of detailed granulometric analysis of monofractions of possible genetic and dynamic indicators of diamonds (density of diamond $\rho = 3510 \text{ kg/m}^3$)

$\rho, \text{ kg/m}^3$		3580	3220	4750	3300	3270	3350	4210	4600	Σ
№	№ of sites	garnet	diopside	picroilmenite	spinel	tourmaline	pyroxenes	rutile	zircon	
1	S1	-	-	7	-	1	-	1	-	9
2	S2 III.1	13	12	58	9	80	13	6	23	214
3	S2 congl.	11	24	59	4	75	55	169	95	492
4	S3	44	24	85	-	12	86	21	5	277
5	S3	-	2	5	-	23	-	59	14	103
6	S3	7	22	42	2	45	49	100	19	286
7	S4	2	2	10	-	17	10	12	1	54
8	S7	1	1	2	-	2	-	6	-	12
Σ		78	87	268	15	245	213	374	157	1447

Total number of measurements: **4341**



Fig. 18. Valley of temporary channel ("wadi") Nahal-Ramon (western Makhtesh Ramon)

Table 3

Description of selected samples (western Makhtesh Ramon)

No. of sample	Volume, m ³	Weight, kg	Weight of concentrate, kg	Notes
S1	0.0025	7	0.3	Selected from small bore pit (0.3 m) in dry channel (Nahal Ramon)
S2	0.03	60	3.0	Cut out from the exposed conglomerates and crushed in a mortar till obtaining grain sizes of 1 mm
S2.III1	0.1	50	4.0	Selected from a small-bore pit with dimensions of 0.6 x 0.6 x 0.6 m in a dry channel, with the fraction less than 1.6 mm
S3	1.5	2000	10.0	Composed of four bore pits located at distance of 30 m between themselves in the channel of a dry rivulet, with a removal fraction less than 1.6 mm
S4	0.02	50	2.0	Cut out from the output of indigenous rocks with the following crushing and removing fraction less than 1.6 mm (tuff breccia)
S7	0.04	70	2.0	Cut out from the outputs of acid basaltoids with the following crushing in a mortar and removing the fraction less than 1.6 mm

A short description of the discovered main mineral indicators of diamonds is presented below.

Picroilmenite is a well-known high-pressure mineral of kimberlites (Haggerty, 1995; Nixon, 1995; Kharkiv et al., 1997). The mineral grating is composed of titanium, iron, and oxygen. As admixtures, Mg, Al, and Cr (possibly involved in microphases), and calcium (from calcite) were detected. The detected phase 'calcium-titan' from perovskite is also well-known in kimberlites (Haggerty, 1995; McClenaghan et al., 2000; Nixon, 1995). Such revealed admixtures as cobalt, nickel, and natural Ferrum (reflecting the ultrabasic consistency of magma) are also typical for kimberlites. Manganese reflects the exogenetic hydroxides and carbonaceous dust, increasing conductivity. Thus, the observed picroilmenite crystals correspond to known indicators of diamondiferous associations (Cullers et al., 1996; Griffin, Ryan, 1995; Mitchell, 1986, 1995). Electronic imaging indicates that the studied grains have a complex structure. Their micro-aggregates resemble nodules (micro-nodules) with little transport from the indigenous source (the crystal surface is not rolled).

Pyrope is one of the most important mineral indicators of diamond association (both for kimberlites and lamproites) (Mitchell, 1986; Nixon, 1995; Kharkiv et al., 1997). The studied grains are characterized by a light crimson and

red color with a lilac tint. The crystal surface is not rolled. Electron microscope examination indicates that the main elements are magnesium (magnesia pyrope), aluminum, silicon, and oxygen, confirming the visual diagnosis. Admixtures of chrome and magnesium in pyrope unambiguously indicate that the mineral originated under high pressures (large depths). Calcium clearly reflects the calcite micro-phases and carbon-rich dusting.

Pyroxenes were detected in the various probes selected in the area (from 3-5 up to 15 units of this mineral) (see Table 2). Pyroxenes are dark green, brown, and sometimes black. These minerals are also not eroded. Pyroxenes are essential components of kimberlites, along with products of alteration of ultrabasic and basic rocks. Most of the known diamondiferous associations contain these minerals (Bulanova, 1995; McClenaghan et al., 2000; Kharkiv et al., 1997).

Chromediopside is a well-known mineral associated with diamonds (Mitchell, 1986, 1995; McClenaghan et al., 2000; Nixon, 1995). A key peculiarity of this mineral is that it is unstable under alluvial transport and hypogene weathering (Marshall, Baxter-Brown, 1995; Mitchell, 1995; Kharkiv et al., 1997). This mineral is the generic isomorphic type of diopside-hedenbergite (Mitchell, 1995). Diopside contains mainly calcium, magnesium, silicon, and oxygen. Chrome admixture is rich in 7%

chrome and 18% MgO. The chromediopside samples studied are lighter in color than typical chromediopside grains. Titanium admixture is typical of such titanium varieties of ultrabasic rocks as kimberlites and lamproites. The mineral is hardly eroded, indicating the nearest occurrence of endogenic rocks.

Figure 19 presents the technological scheme for diamond recognition from the withdrawn concentrate. In addition to conventional procedures (grain-size separation, magnetic separation, visual identification, X-ray luminescence, electron microscopy, etc.), we used

concentrated solutions. We used these solutions ($3\text{HCL}+\text{HNO}_3$, HF) with boiling because many desired minerals were redeposited several times under the extremely arid climate of southern Israel (e.g., Bentor, 1969) and were covered by hard shells. Removing these shells was impossible without using these solutions (Eppelbaum et al., 2002). This also explains why diamonds were not found earlier in the area (excluding Flexer et al., 1988b). Applying the mentioned technological scheme at a final stage allowed us to discover numerous microdiamonds and several diamonds.

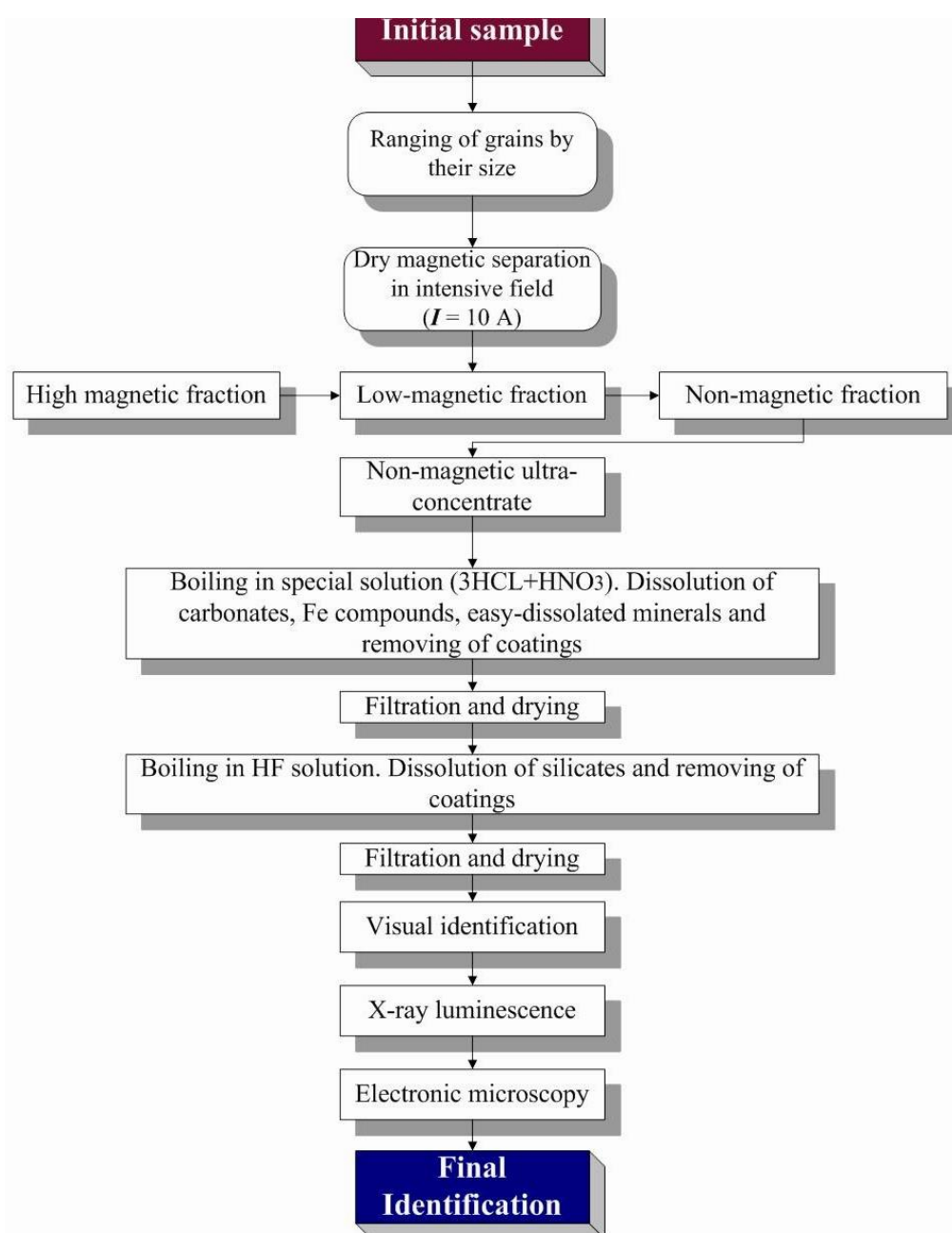


Fig. 19. Fractionation of selected samples of titanomagnetite association: A technological scheme

After conducting visual and qualitative/quantitative analyses using a binocular microscope, we investigated the polyminerals fractions using a Camscan-DV scanning electron microscope equipped with an energy-dispersive Link AN10000 microprobe. The most significant result was the discovery of more than 300 microdiamonds (< 1 mm and << 1 mm) and five

diamonds ranging from 1 to 1.35 mm (along the longest axis). Most of them were characterized by a cubic habit, and hexagonal species were less. Figure 20 shows a microdiamond associated with quartz. Two large discovered diamond crystals (which are fragments of a larger crystal (Surkov et al., 2008)) measured 1.35 mm (Fig. 21) and 1.20 mm.

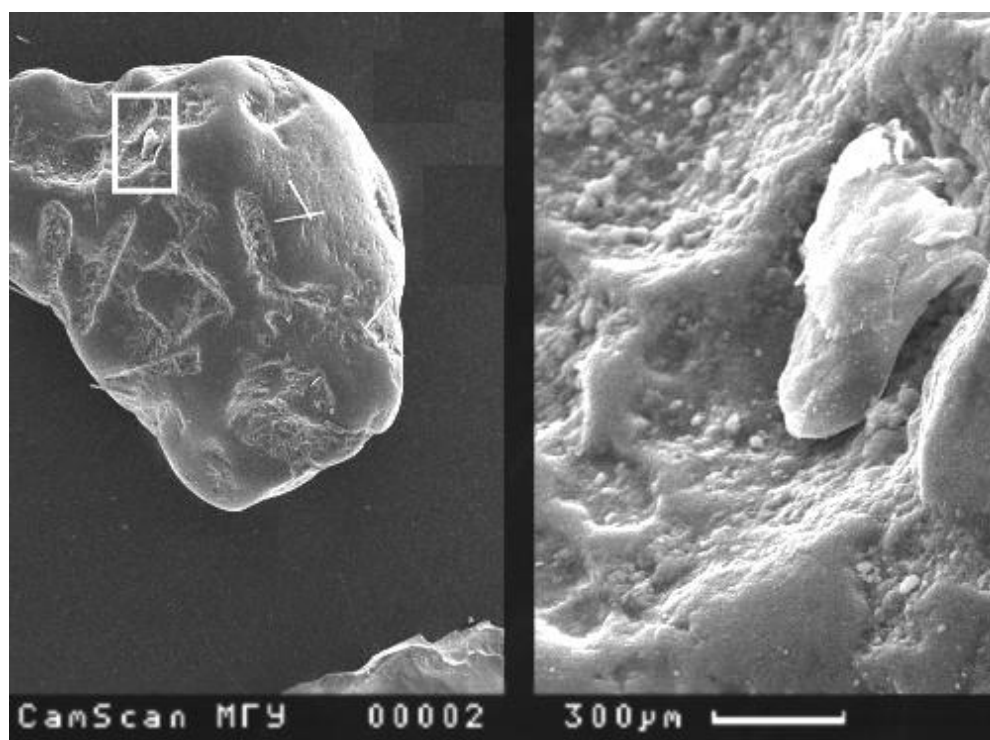


Fig. 20. Left panel: quartz with diamond. Right panel: enlarged image of the diamond. Back-scattered electron images

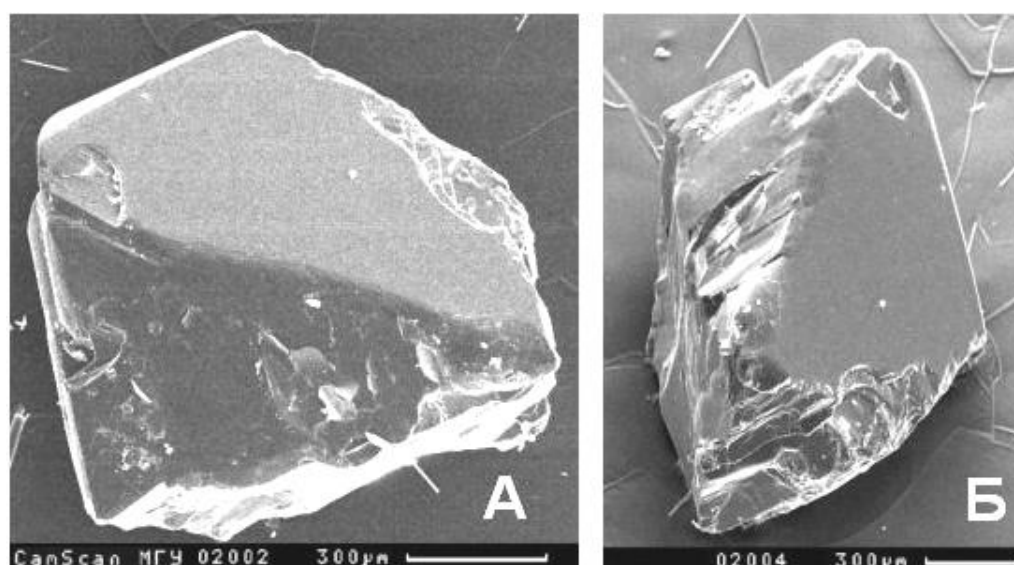


Fig. 21. The largest diamond crystal ever identified (A and B are the back-scattered electron images of the same crystal from different sides)

Figure 22 shows the chemical composition of the identified meimechite rock sample, which is very similar to kimberlite associations (e.g., Arndt et al., 1995; Eppelbaum et al., 2003).

In the western part of the Makhtesh Ramon Canyon, we studied exposed volcanic and volcanic-fragmentary rocks. These outcrops form hills up to 150 m high and, from a geological point of view, represent relics of volcanic flows (Bentor, 1952), for which columnar (prismatic) individuality is often typical. Sometimes small subvolcanic bodies break up these flows. Some outcrops show a typical presence of volcano-genic-fragmental rocks. Magmatic rocks are sometimes covered by Lower Cretaceous deposits that define the upper limit of the area's magmatic activity; at the same time, these rocks intrude rocks older than the Lower Triassic. Thus, geological data indicate that all magmatic activity occurred during the Lower Triassic–Upper Cretaceous (Bentor, 1952). K-Ar isotope dating determined the magmatic rocks' age to be about 125-115 Ma (Lang, Steinitz, 1985, 1989; Lang et al., 1988; Recanati et al., 1989).

We studied about 100 bright, transparent sections using a polarized microscope, an electronic microscope (Camscan 4DV), and an energy-dispersive microprobe analyzer (Link-10000). The effusive rocks were divided by

their composition into (1) plagioclase-containing and (2) not containing plagioclase.

The main volume of samples, withdrawn at point 100 (probes 100-15; 100-15A; 100-16) (Fig. 23) and points 124 and 125, consists of olivine, clinopyroxene, titanomagnetite, nepheline, and glass. Albite and potassic feldspars were sometimes recognized. The content of nepheline reaches 5-10%.

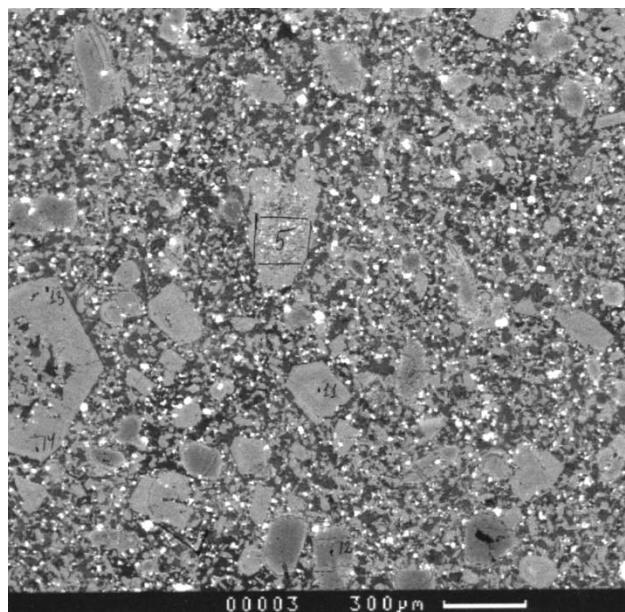


Fig. 22. Sample of meimechite rock. Back-scattered electron image

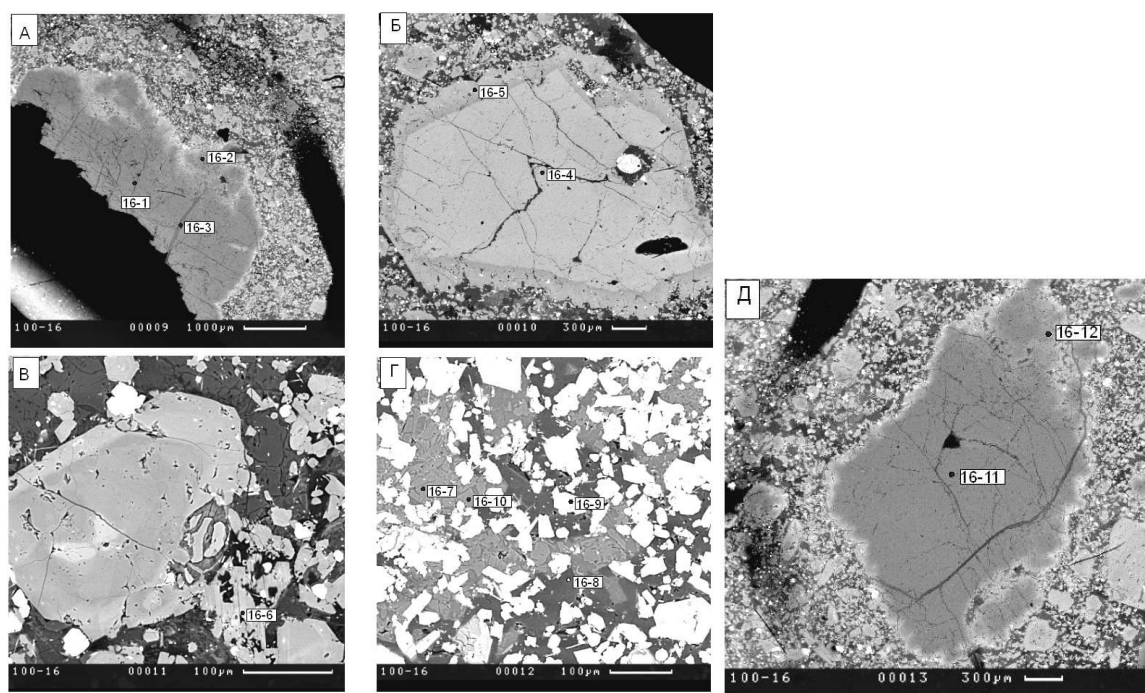


Fig. 23. Samples were withdrawn in probe № 100_16 in Makhtesh Ramon. **А** and **Д** – olivine of I and IV generations, **Б** and **В** – clinopyroxenes, **Г** – main mass presented by nepheline points 16-7 and 16-10), titanomagnetite (point 16-9), and glass (point 16-8)

Contains Cr_2O_3 in clinopyroxenes from the sedimentary deposits of the Makhtesh Ramon range in the range of 0.5-1.2% (Table 4; here only part of the measurements is presented); the content of FeO changes from 2.5 up to 6%, which is typical for chrome diopsides and kimberlites and other associations (deep inclusions, basalts, and carbonates) (Ilupin, 1984). The Al_2O_3 content in the studied clinopyroxenes ranges from 2.3 to 6.6%, and Na_2O from 0.5 to 1.5% (Table 4). The Al_2O_3 – Na_2O diagram of the studied clinopyroxenes (according to Ilupin's (Ilupin, 1984) classification) falls within the domain of chromediopsides in deep inclusions in basalts and kimberlites of North America. Comparison of the studied clinopyroxenes (western Makhtesh Ramon) with the chromediopsides from kimberlites of the "Arkhangelskaya" pipe (Winter Coast, Siberia, Russia) (Kharkiv et al., 1995) indicates that chromediopsides of sedimentary deposits of Makhtesh Ra-

mon are similar to low-baric group of clinopyroxenes generated from the disintegrated spinel peridotites propagating by magmatic melts from the upper mantle (spinel peridotites are a composite part of the deep spinel-pyroxene phase). Comparison of chromediopsides from the sedimentary deposits of Makhtesh Ramon (Eppelbaum et al., 2003) with the clinopyroxenes of the Zolotnitsky field of the Arkhangelsk province (Bogatikov et al., 1999) shows their close relationship to clinopyroxenes in diamondiferous lherzolites and websterites. Thus, chromediopsides of Makhtesh Ramon fall within the high-alumina, low-sodium field in diagrams by various authors. These inclusions may originate from deep basalt xenoliths (Ilupin, 1984), encountered in kimberlite pipes as fragments of spinel peridotites (Kharkiv et al., 1995), peridotites, and pyroxenes (Bogatikov et al., 1999).

Table 4

Composition of chrome clinopyroxenes (chromediopsides) from the sedimentary deposits in the western Makhtesh Ramon

	100/ 1_50	100/ 1_20	100/ 1_21	100/ 1_27	100/ 1_28	100/ 1_29	100/ 1_30	100/ 1_31	100/ 1_32	100/ 1_34	100/ 1_35
SiO_2	52.68	51.32	50.81	53.25	52.67	52.61	52.22	53.36	53.16	53.02	50.19
TiO_2	0.36	0.62	0.54	0.00	0.00	0.32	0.29	0.00	0.24	0.25	1.25
Al_2O_3	2.81	5.38	5.64	4.81	5.01	5.28	5.84	4.21	4.28	2.32	4.38
FeO	4.70	4.35	4.44	2.67	2.69	3.01	2.78	2.77	2.99	3.05	4.55
MnO	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MgO	15.55	16.00	16.35	15.71	15.97	15.77	15.65	16.26	16.13	17.24	14.26
CaO	22.49	20.33	20.19	21.61	21.63	20.70	20.97	21.59	21.70	22.13	23.83
Na_2O	0.56	0.77	0.82	1.17	1.18	1.39	1.13	0.98	0.78	0.98	0.39
K_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cr_2O_3	0.62	0.98	1.22	0.77	0.85	0.93	1.13	0.82	0.73	1.00	1.14
NiO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	114/ 2_3	114/ 2_66	114/ 2_67	114/ 2_68	114/ 2_69	114/ 2_70	114/ 2_71	114/ 2_72	114/ 2_74	114/ 2_75	114/ 2_76
SiO_2	52.34	52.77	47.55	52.83	52.84	52.91	52.43	52.33	52.20	52.83	47.69
TiO_2	0.38	0.42	1.77	0.21	0.00	0.00	0.25	0.25	0.32	0.29	1.88
Al_2O_3	5.22	2.95	6.59	5.55	5.26	4.99	4.90	5.31	5.56	5.01	6.20
FeO	2.98	4.74	6.03	3.18	2.79	2.94	2.67	2.98	3.20	2.76	5.97
MnO	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MgO	15.96	14.68	12.90	15.26	14.92	15.55	15.97	15.82	15.13	15.70	13.06
CaO	20.91	22.94	23.64	20.78	22.40	20.58	20.97	21.06	20.79	21.29	24.05
Na_2O	0.92	0.83	0.60	1.35	1.11	1.71	1.42	1.29	1.66	1.12	0.50
K_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cr_2O_3	1.01	0.46	0.90	0.85	0.68	1.34	1.39	0.94	1.14	0.99	0.65
NiO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Comprehensive mineralogical and geochemical analyses enabled the detection of several native small gold plates (Eppelbaum et al., 2003, 2006). The identified gold plates were investigated using Surkov's (2000) advanced methodology (Fig. 24). Lavi et al. (1988) earlier identified higher concentrations of gold and Rare Earth Elements (REE) in Makhtesh Ramon sediments. Flexer et al. (1988a) and Rosenfeld et al. (1989) have reported detecting some platinum-group elements in the vicinity of the Makhtesh Ramon area. Besides this, Adatte et al. (2005) found Platinum Group Elements in trace quantities in another member of the makhteshim family – Makhtesh Gadol.

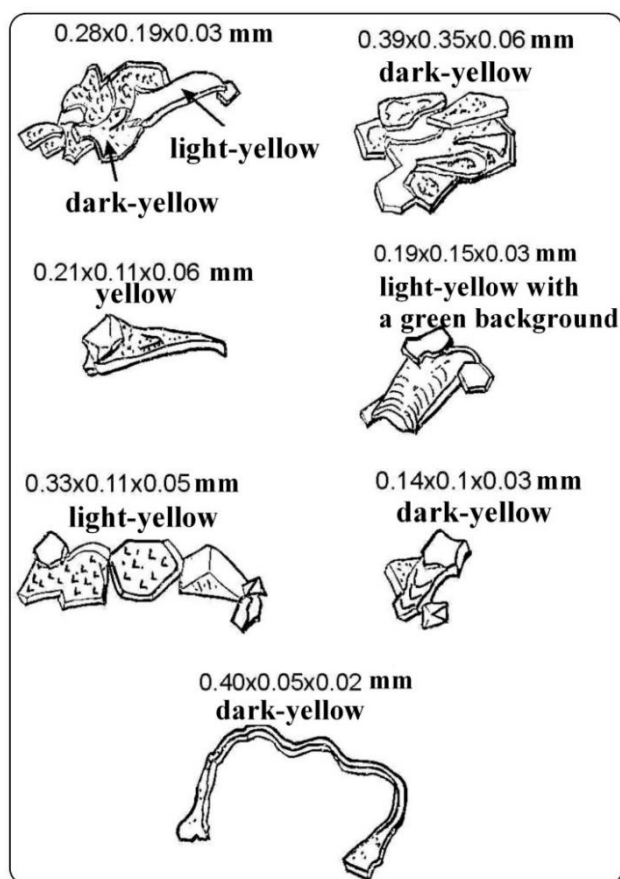


Fig. 24. Forms of native gold plates discovered in the channel deposits of Nahal Ramon in the western Makhtesh Ramon (Eppelbaum et al., 2006)

The presence of gold and platinum-group elements may also testify (Kaminsky et al., 1974; McDonald et al., 1995; Paul et al., 1979) to the nearest occurrence of basic kimberlite pipes. At the same time, gold, platinum, and REE may be important on their own. We propose that Makhtesh Ramon – the window to

Earth's upper mantle – contains a compound commercial ore deposit containing several strategically important elements.

Discussion and conclusions

The maximum number of kimberlite pipes that have been formed in the world (by radiometric data) is in the interval of 125-63.5 Ma (Katz, Eppelbaum, 1998). It coincides with the maximal magmatic activation in the region under study (120 Ma). The geophysical, tectonic, mineralogical, petrological, geochemical, and other factors described in the previous sections indicate the presence of rocks of abyssal origin (including diamondiferous and other economic components) in the Makhtesh Ramon area.

Analyzing the Makhtesh Ramon complex deposit (Eppelbaum et al., 2006) together with the discovery of diamonds and kimberlite indicator minerals in the Qishon Valley (northern Israel) (Eskel et al., 2007; Griffin et al., 2016), NW Syria (Mahfoud, 2002), and Central Eastern Desert, Egypt (Barakat, Kandil, 2019) resulted in a map showing the Eastern Mediterranean–Nubian diamondiferous belt (modified after Eppelbaum, Katz, 2012) (Fig. 25). The developed scheme can be used to predict further diamond discoveries in the region.

Available geological and geophysical data indicate that the Makhtesh Ramon area (southern Israel) is favorable for discovering a diamondiferous deposit (Eppelbaum et al., 2003, 2006). Judging from petrographic, geophysical, and geomorphological data, the diamondiferous sources are situated at shallow depths (Eppelbaum et al., 2002). Unfortunately, further investigations in the Makhtesh Ramon area are hampered because it is a state geological reserve where all mining is prohibited. However, further combined mineralogical, geochemical, and geophysical studies, integrated with mining works, will likely be rewarded with the discovery of diamondiferous rocks and other useful minerals. The presence of useful components such as gold and Rare Earth Elements (especially the latter) may be as significant as diamonds. Undoubtedly, this area may become a center of mining exploration in Israel (a country characterized by the world's most advanced diamond-manufacturing industry).

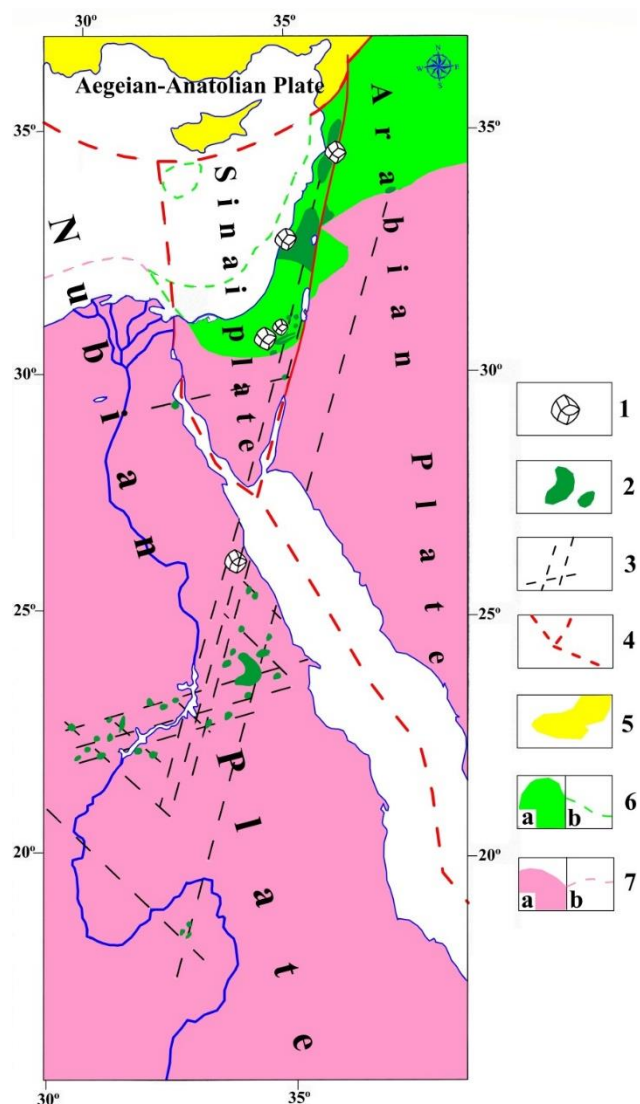


Fig. 25. East Mediterranean–Nubian diamondiferous belt. (1) areas of the diamond discovery (after Mahfoud, 2002; Eskel et al., 2007; Eppelbaum et al., 2006; Griffin et al., 2016; Barakat, Kandil, 2019), (2) Cretaceous magmatic, (3) Levantine–Nubian volcanic fault system, (4) boundaries between the tectonic plates, (5) Aegean–Anatolian plate, (6) province of the terrane belt with a thinned Precambrian crust (a – land, b – marine), (7) province located on the ancient Nubian–Arabian Precambrian platform (a – land, b – marine)

Analysis of the tectonic evolution model indicates that significant erosion processes substantially reduced the thickness of sedimentary deposits in the area studied. This allows the most cost-effective open-cut mining method.

The revealed horizons of technical water of superficial occurrence (e.g., Issar, 1983; Ben-David et al., 2002) are crucial for the process of withdrawn sample enrichment. A mild climate allows us to carry out integrated mining-geological work year-round while minimizing energy costs. Another important factor is the lack of jobs in nearby towns and settlements (creating a mining center may provide several hundred new jobs). Finally, the projected water channel between the Red and Dead Seas (Abu Ghazleh et al., 2009; Fine, 2018) is located near the discovered deposit, which will allow us to connect additional communication (including the channel and railway) and electric (hydroelectric power station) capacities.

A very simplified calculation may be carried out using elementary principles of probability theory. We have six independent indicators (regional tectonics, regional geophysics, local geophysics, mineralogy, petrology, and geochemistry) that positively estimate the diamond bearing of the Makhtesh Ramon area. For simplicity, let's treat these indicators as equivalent and assign each a weight of $\frac{1}{2}$. The significance of mineralogical indicators (revealing diamonds and indicator minerals) is greatly higher than $\frac{1}{2}$. The probability of the random coincidence of these factors (according to the trivial rules of probability theory (e.g., Korolov, Sinai, 2007)) in this case is $(\frac{1}{2})^6 = 0.0156 = 1.56\%$; e.g., the positive assessment of the diamond-bearing potential of the Makhtesh Ramon area is 98.44%. Really, this parameter is higher.

Acknowledgements

The author thanks the staff of Moscow State University and the Moscow Mining Academy for their participation in this research. The author particularly acknowledges the immense contribution of the late Dr. Vladimir Vaksman; without his enthusiasm and support, this research would not have been possible.

REFERENCES

- Abu Ghazleh S., Hartmann J., Jansen N., Kempe S. Water input requirements of the rapidly shrinking Dead Sea. *Naturwissenschaften*, Vol. 96, No. 5, 2009, pp. 637–643, <https://doi.org/10.1007/s00114-009-0514-0>.
- Adate T., Keller G., Stüben D., Harting M., Kramar U., Stinnesbeck W., Abramovich S., Benjamini C. Late Maas-trichtian and K/T paleoenvironment of the eastern Tethys (Israel): mineralogy, trace and platinum group elements, biostratigraphy and faunal turnovers. *Bulletin de la Société Géologique de France*, Vol. 176, No. 1, 2005, pp. 37–55, <https://doi.org/10.2113/176.1.37>.

- Ahrens L.H., Dawson J.B., Duncan A.R., Erlank A.J. (Eds.). *Physics and Chemistry of the Earth*, Vol. 9. Selected Papers presented at the First International Conference on Kimberlites (Cape Town, 1973). Pergamon Press, 1975.
- Arndt N., Lehnert K., Vasil'ev Y. Meimechites: highly magnesian lithosphere-contaminated alkaline magmas from deep subcontinental mantle. *Lithos*, Vol. 34, No. 1-3, 1995, pp. 41-59, [https://doi.org/10.1016/0024-4937\(95\)90009-8](https://doi.org/10.1016/0024-4937(95)90009-8).
- Avni Y. Structure and landscape evolution of the Makhteshim Country – interrelations between monoclines, truncation surfaces and the evolution of the Makhteshim. In: Krasnov B. and Mazor E. (eds.) *The Makhteshim Country: A Laboratory of Nature*. Pensoft, Bulgaria, Sofia, 2001a, pp. 33-58.
- Avni Y. Har Loz, Sheet 21-III. Geological Map of Israel 1:50,000. Geological Survey of Israel, Jerusalem, 2001b.
- Avni Y., Beker A., Zilberman E. Be'erot Oded, Sheet 21-IV. Geological Map of Israel 1:50,000. Geological Survey of Israel, Jerusalem, 2017.
- Baer G. Flow directions in sills and dikes and formation of cauldrons in eastern Makhtesh Ramon. *Israel Journal of Earth Sciences*, Vol. 42, 1993, pp. 133-148.
- Baer G., Heimann A., Eshet Y., Weinberger R., Mussett A., Sherwood G. The Saharonim Basalt: A Late Triassic – Early Jurassic intrusion in southeastern Makhtesh Ramon, Israel. *Israel Journal of Earth Sciences*, Vol. 44, 1995, pp. 1-10.
- Baer G., Frieslander U., Goldman M. The Red Valley – an Early Cretaceous Caldera in eastern Makhtesh Ramon. *Israel Journal of Earth Sciences*, Vol. 38, 1989, pp. 163-172.
- Baer G., Reches Z. Mechanics of emplacement and tectonic implications of the Ramon dike systems, Israel. *Journal of Geophysical Research*, Vol. 96, No. B7, 1991, pp. 11895-11910, <https://doi.org/10.1029/91JB00371>.
- Barakat A.A., Kandil S.M.R. Diamond in the newly discovered kimberlite and related rocks, Central Eastern Desert, Egypt. In: *Magmatism of the Earth and Related Strategic Metal Deposits. Proceedings of XXXVI International Conference*, St. Petersburg University, Russia, May 23-26, 2019, pp. 36-42.
- Ben-Avraham Z., Ginzburg A., Makris J., Eppelbaum L. Crustal structure of the Levant Basin, eastern Mediterranean. *Tectonophysics*, Vol. 346, Issues 1-2, 2002, pp. 23-43, [https://doi.org/10.1016/S0040-1951\(01\)00226-8](https://doi.org/10.1016/S0040-1951(01)00226-8).
- Ben-David R., Eyal Y., Zilberman E., Bowman D. Fluvial systems response to rift margin tectonics: Makhtesh Ramon area, southern Israel. *Geomorphology*, Vol. 45, Issues 1-2, 2002, pp. 147-163, [https://doi.org/10.1016/S0169-555X\(01\)00194-5](https://doi.org/10.1016/S0169-555X(01)00194-5).
- Ben-David R., Mazor E. Stages in the evolution of Makhtesh Ramon and its drainage system. *Israel Journal of Earth Sciences*, Vol. 37, No. 2-3, 1988, pp. 125-135.
- Benjamini C. The geological history of central and southern Israel during the Eocene. Ph.D. Thesis, Hebrew University, Jerusalem, 1979, pp. 1-41.
- Bentor Y.K. Magmatic intrusions and lava sheets in the Ramon area in the Negev (Southern Israel). *Geological Magazine*, Vol. 89, No. 2, 1952, pp. 129-140, <https://doi.org/10.1017/S0016756800067479>.
- Bentor Y.K. On the evolution of subsurface brines in Israel. *Chemical Geology*, Vol. 4, Issues 1-2, 1969, pp. 83-110, [https://doi.org/10.1016/0009-2541\(69\)90041-2](https://doi.org/10.1016/0009-2541(69)90041-2).
- Bentor Y.K., Vroman A., Zak I. The geological map of Israel, scale 1:250,000, southern sheet. Geological Survey of Israel, 1965.
- Bobrievich A.P., Bondarenko M.N., Gnevushev M.A., Krasov L.M., Smirnov G.I., Yurkevich R.K. Diamond deposits of Yakutia. Sobolev V.S. (ed.). *Gosnauchtekhizdat*, Moscow, 1959, 526 p. (in Russian)
- Bogatikov O.A., Vasilyeva E.R., Verzhak V.V., Verichev E.M., Garanin V.K., Kononova V.A., Kudryavtseva G.P., Parsadanyan K.S., Posukhova T.V. Arkhangelsk diamondiferous province (geology, petrography, geochemistry and mineralogy). Bogatikov O.A. (ed.). Moscow State University Press, Moscow, 1999, 524 p. (in Russian)
- Bulanova G.P. The formation of diamond. *Journal of Geochemical Exploration*, Vol. 53, Issues 1-3, 1995, pp. 1-23, [https://doi.org/10.1016/0375-6742\(94\)00016-5](https://doi.org/10.1016/0375-6742(94)00016-5).
- Chang S.-J., van der Lee S. Mantle plumes and associated flow beneath Arabia and East Africa. *Earth and Planetary Science Letters*, Vol. 302, Issues 3-4, 2011, pp. 448-454, <https://doi.org/10.1016/j.epsl.2010.12.050>.
- Cherepanova Y., Artemieva I.M., Thybo H., Chemia Z. Crustal structure of the Siberian craton and the West Siberian basin: An appraisal of existing seismic data. *Tectonophysics*, Vol. 609, 2013, pp. 154-183, <https://doi.org/10.1016/j.tecto.2013.05.004>.
- Condie K.C. *Mantle Plumes and Their Record in Earth History*. Cambridge University Press, Cambridge, 2001, <https://doi.org/10.1017/CBO9780511810589>.
- Cullers R.L., Dorais M.J., Berendsen P., Chaudhuri S. Mineralogy and petrology of Cretaceous lamproite sills, southeastern Kansas, USA. *Lithos*, Vol. 38, Issues 3-4, 1996, pp. 185-206, [https://doi.org/10.1016/0024-4937\(96\)00010-2](https://doi.org/10.1016/0024-4937(96)00010-2).
- Dembo N., Kraus E., Seliverstov I., Weissman G., Granot R. Geomagnetic field behaviour during the early Cretaceous Normal Superchron from palaeomagnetic analysis of the Ramon Volcanics, Israel. *Geophysical Journal International*, Vol. 231, Issue 3, 2022, pp. 1982-1995, <https://doi.org/10.1093/gji/ggac300>.
- Eppelbaum L.V. (Ed.) *New Developments in Paleomagnetism Research. Earth Sciences in the 21st Century*. Nova Science Publishers, New York, 2015, 195 p.
- Eppelbaum L.V. Review of processing and interpretation of self-potential anomalies: Transfer of methodologies developed in magnetic prospecting. *Geosciences*, Vol. 11, Issue 5, 2021, pp. 1-31, <https://doi.org/10.3390/geosciences11050194>.

- Eppelbaum L., Ben-Avraham Z., Katz Y. Does mantle diapir produce Hebron magnetic anomaly? Transactions of the Conference of the Israel Geological Society, Annual Meeting, Moshabim Country Logging (Negev), Israel, 2005, p. 26.
- Eppelbaum L.V., Ben-Avraham Z., Katz Y.I., Cloetingh S., Kaban M.K. Giant quasi-ring mantle structure in the African-Arabian junction: Results derived from the geological-geophysical data integration. *Geotectonics* (Springer), Vol. 55, No. 1, 2021, pp. 58-82, <https://doi.org/10.1134/S0016852121010052>.
- Eppelbaum L.V., Katz Y.I. Mineral deposits in Israel: A contemporary view. In: Ya'ari A. and Zahavi E.D. (eds.) *Israel: Social, Economic and Political Developments*. Nova Science Publishers, Inc. New York, 2012, pp. 1-41.
- Eppelbaum L.V., Katz Y.I. Eastern Mediterranean: Combined geological-geophysical zonation and paleogeodynamics of the Mesozoic and Cenozoic structural-sedimentation stages. *Marine and Petroleum Geology*, Vol. 65, 2015, pp. 198-216, <https://doi.org/10.1016/j.marpetgeo.2015.04.008>.
- Eppelbaum L.V., Katz Y.I., Ben-Avraham Z. Geodynamic aspects of magnetic data analysis and tectonic-paleomagnetic mapping in the Easternmost Mediterranean: A review. *Applied Sciences*, Special Issue "Ground-Based Geomagnetic Observations: Techniques, Instruments and Scientific Outcomes", Vol. 13, No. 18, Article number 10541, 2023, <https://doi.org/10.3390/app131810541>.
- Eppelbaum L.V., Katz Y.I., Ben-Avraham Z. Giant quasi-ring mantle structure beneath the Eastern Mediterranean: Interpretation of new magnetic, paleobiogeographic, and seismic tomography data. *Geotectonics*, Vol. 59 No. 2, 2025, pp. 101-126, <https://doi.org/10.1134/S001685212570013X>.
- Eppelbaum L.V., Khesin B.E. *Geophysical Studies in the Caucasus*. Springer. Heidelberg – N.Y., 2012, 441 p.
- Eppelbaum L.V., Khesin B.E., Itkis S.E., Ben-Avraham Z. Advanced analysis of self-potential data in ore deposits and archaeological sites. In: *Proceeding of the 10th European Meeting of Environmental and Engineering Geophysics*, Utrecht, the Netherlands, 2004, pp. 1-4, <https://doi.org/10.3997/2214-4609-pdb.10.P054>.
- Eppelbaum L., Kouznetsov S., Vaksman V., Klepatch C., Smirnov S., Sazonova L., Korotaeva N., Surkov A., Itkis S., Shemesh M. Results of integrated geological-geophysical examination of Makhtesh Ramon area (southern Israel) on diamond-bearing associations. *Proceedings of SPIE – The International Society for Optical Engineering*, Vol. 5239, Barcelona, Spain, 2003, pp. 109-120, <https://doi.org/10.1117/12.512403>.
- Eppelbaum L.V., Pilchin A.N. Methodology of Curie discontinuity map development for regions with low thermal characteristics: An example from Israel. *Earth and Planetary Science Letters*, Vol. 243, Issues 3-4, 2006, pp. 536-551, <https://doi.org/10.1016/j.epsl.2006.01.003>.
- Eppelbaum L.V., Vaksman V.L. Makhtesh Ramon Complex Deposit (Southern Israel) – A Window to the Upper Mantle. *International Journal of Mining Sciences*, Vol. 3, Issue 1, 2017, pp. 1-28, <https://doi.org/10.20431/2454-9460.0301001>.
- Eppelbaum L.V., Vaksman V.L., Klepatch C.A., Modin I., Kouznetsov S.V., Surkov A.V., Korotaeva N.N., Smirnov S.A., Bezlepkin B.A. Discovering of diamondiferous association in the Makhtesh Ramon area, Negev Desert (Southern Israel). *Romanian Journal of Mineral Deposits*, Vol. 80, 2002, pp. 25-28.
- Eppelbaum L.V., Vaksman V.L., Kouznetsov S.V., Sazonova L.M., Smirnov S.A., Surkov A.V., Bezlepkin B.M., Katz Y.I., Korotaeva N.N., Belovitskaya G.I. Discovering of microdiamonds and minerals-satellites in Canyon Makhtesh Ramon (Negev Desert, Israel). *Doklady Earth Sciences* (Springer), Vol. 407, No. 2, 2006, pp. 202-204, <https://doi.org/10.1134/S1028334X06020097>.
- Eskel M., Kalmanovich E., Roup A. The diamonds and kimberlite indicative minerals within the context of stratigraphy and source in Shefa Yamim drill SY-15, Pliocene-Pleistocene, Qishon River Valley, Israel. Transactions of the Conference of the Israel Geological Society, Annual Meeting, Neve Zohar, Dead Sea, Israel, 2007, p. 29.
- Eyal M., Becker A., Samoylov V. Mt. Arod – an Early Cretaceous basanitic volcano with a fossil lava lake. *Israel Journal of Earth Sciences*, Vol. 45, No. 1, 1996, pp. 31-38.
- Flexer A., Rosenfeld A., Honigstein A. The periodicity of possible extraterrestrial signatures in the Mesozoic-Cenozoic succession of Israel. Transactions of the Conference of the Israel Geological Society Annual Meeting, En Boqeq, 1988a, pp. 27-28.
- Flexer A., Rosenfeld A., Honigstein A., Dvorachek M. A microdiamond additional support for extraterrestrial signatures near the K/T boundary in Israel. *Lunar and Planetary Science Conference*, 19th, Abstracts, Vol. 1, Houston, 1988b, p. 337.
- Folkman Y., Yuval Z. Aeromagnetic map of Israel, 1:250,000. Israel Institute for Petroleum Research and Geophysics, Holon, Israel, 1976.
- Garfunkel Z. The Arod Pass area: structural-stratigraphic relations and their implications for the history of the Ramon lineament. *Israel Journal of Earth Sciences*, Vol. 42, 1993, pp. 165-175.
- Garfunkel Z., Derin B. Reevaluation of the latest Jurassic-Early Cretaceous history of the Negev and the role of magmatic activity. *Israel Journal of Earth Sciences*, Vol. 37, No. 2-3, 1988, pp. 43-52.
- Garfunkel Z., Katz A. New magmatic features in Makhtesh Ramon, southern Israel. *Geological Magazine*, Vol. 104, Issue 6, 1967, pp. 608-629, <https://doi.org/10.1017/S0016756800050275>.
- Giuliani A., Kamenetsky V.S., Kendrick M.A., Phillips D., Wyatt B.A., Maas R. Oxide, sulphide and carbonate minerals in a mantle polymict breccia: metasomatism by proto-kimberlite magmas, and relationship to the kimberlite megacrystic suite. *Chemical Geology*, Vol. 353, 2013, pp. 4-18, <https://doi.org/10.1016/j.chemgeo.2012.09.025>.

- Green H.W. II, Gueguen Y. Origin of kimberlite by diapiric upwelling in the upper mantle. *Nature*, Vol. 249, 1974, pp. 617-620, <https://doi.org/10.1038/249617a0>.
- Griffin W.L. Major transformations reveal Earth's deep secrets. *Geology*, Vol. 36, No. 1, 2008, pp. 95-96, <https://doi.org/10.1130/focus012008.1>.
- Griffin W.L., Gain S.E.M., Adams D.T., Huang J-X., Saunders M., Toledo V., Pearson N.J., O'Reilly S.Y. First terrestrial occurrence of tistarite (Ti₂O₃): Ultra-low oxygen fugacity in the upper mantle beneath Mount Carmel, Israel. *Geology*, Vol. 44 No. 10, 2016, pp. 815-818, <https://doi.org/10.1130/G37910.1>.
- Griffin W.L., Ryan C.G. Trace elements in indicator minerals: area selection and target evaluation in diamond exploration. *Journal of Geochemical Exploration*, Vol. 53, Issue 1-3, 1995, pp. 311-337, [https://doi.org/10.1016/0375-6742\(94\)00015-4](https://doi.org/10.1016/0375-6742(94)00015-4).
- Gvartzman Z., Bartov Y., Garfunkel Z., Rotstein Y. Mesozoic magmatism in the central Negev (southern Israel): implications from magnetic anomalies. *Israel Journal of Earth Sciences*, Vol. 43, Issue 1, 1994, pp. 21-38.
- Gvartzman Z., Weinberger R. Interpretation of Ramon basalt anomalies: Magnetic modeling and a paleomagnetic study. *Israel Journal of Earth Sciences*, Vol. 43, No. 1, 1994, pp. 47-53.
- Gvartzman G., Weissbrod T., Baer G., Brenner J. The age of Aptian stage and its magnetic events: new Ar-Ar ages and paleomagnetic data from the Negev, Israel. *Cretaceous Research*, Vol. 17, Issue 3, 1996, pp. 293-310, <https://doi.org/10.1006/cres.1996.0021>.
- Haggerty S.E. Upper mantle mineralogy. *Journal of Geodynamics*, Vol. 20, Issue 4, 1995, pp. 331-364, [https://doi.org/10.1016/0264-3707\(95\)00016-3](https://doi.org/10.1016/0264-3707(95)00016-3).
- Hall J.K., Krashennnikov V.A., Hirsch F., Benjamini C., Flexer A. (Eds.). *Geological Framework of the Levant*. Vol. II: The Levantine Basin and Israel. Historical Productions-Hall, Jerusalem, 2005, 826 p.
- Ilupin I.P. Discovery of "kimberlite" minerals in non-kimberlite igneous rocks. *Transactions of TsNIGRI*, No. 188, 1984, pp. 46-51. (in Russian)
- Ilupin I.P., Vaganov V.I., Prokopchuk B.I. Kimberlites. Nedra, Moscow, 1990, 248 p. (in Russian)
- Issar A. Emerging groundwater, a triggering factor in the formation of the Makhteshim (erosion cirques) in the Negev and Sinai. *Israel Journal of Earth Sciences*, Vol. 32, Issues 1-2, 1983, pp. 53-61.
- Itamar A. Polymetallic mineralization in Makhtesh Ramon and Har Arif, Central Negev, Israel. *Geological Survey of Israel, Bulletin No. 80*, Jerusalem, 1988, 56 p.
- Fine S.L. Conduit for Peace in the Middle East: An Analysis of the Red Sea-Dead Sea Water Conveyance Project. *Harvard Environment Law Review* (online). March 12, 2018. Conduit for Peace in the Middle East: An Analysis of the Red Sea-Dead Sea Water Conveyance Project – Harvard Environmental Law Review (last visited 11.10.2026).
- Kaminsky F.V., Feldman A.A., Varlamov V.A., Boyko A.N., Olofinsky L.N., Shofman I.L., Vaganov V.I. Prognostication of primary diamond deposits. *Journal of Geochemical Exploration*, Vol. 53, Issues 1-3, 1995, pp. 167-182, [https://doi.org/10.1016/0375-6742\(94\)00019-8](https://doi.org/10.1016/0375-6742(94)00019-8).
- Kaminsky F.V., Frantenson Ye.V., Khvostova V.P. First information on platinum metals (Pt, Pd, Rh, Ir, Ru, Os) in kimberlitic rocks. *Proceedings of the Academy of Sciences of the USSR, Earth Science Sections*, Vol. 219, 1974, pp. 190-193.
- Katz Y.I., Eppelbaum L.V. Larson's Mid-Cretaceous Superplume Effect and a new look to Israeli territory as perspective to kimberlite pipes discovering. *Transactions of the Annual Meeting of the Geological Society of America*, Toronto, Canada, Section: Planetary Geology, Vol. 30, No. 7, 1998, p. A289.
- Kharkiv A.D., Zinchuk N.N., Kruchkov A.I. Geological-Genetical Foundations of Schlich-Mineralogical Method of Searching Diamond Deposits. Nedra Publ., Moscow, 1995, 348 p. (in Russian)
- Kharkiv A.D., Zinchuk N.N., Zuev V.M. The History of Diamond. Nedra, Moscow, 1997, 602 p. (in Russian)
- Khesin B.E., Alexeyev V.V., Eppelbaum L.V. Interpretation of Geophysical Fields in Complicated Environments. *Modern Approaches in Geophysics*, Vol. 14. Springer. Dordrecht, 1996, XII, 353 p., <https://doi.org/10.1007/978-94-015-8613-9>.
- Korolov L., Sinai Y.G. *Theory of Probability and Random Processes*. 2nd Edition, Springer, Berlin-Heidelberg, 2007, XI, 358 p., <https://doi.org/10.1007/978-3-540-68829-7>.
- Kutinov Yu.G., Chistova Z.B. Arkhangelsk diamondiferous province on small-scale geological, tectonic and geophysical maps. *Space and Time*, Vol. 11, No. 1, 2016. (in Russian)
- Lang B., Hebeda E.H., Priem H.N.A., Steinitz G., Verdurmen E.A.Th. K-Ar and Rb-Sr ages of Early Cretaceous magmatic rocks from Makhtesh Ramon, southern Israel. *Israel Journal of Earth Sciences*, Vol. 37, No. 2-3, 1988, pp. 65-72.
- Lang B., Steinitz G. New K-Ar ages of Mesozoic magmatic rocks in Makhtesh Ramon. *Geological Survey of Israel, Jerusalem. Transactions of the Annual Meeting of the Israel Geological Society*, Yotvata, 1985, pp. 56-57.
- Lang B., Steinitz G. K-Ar dating of Mesozoic magmatic rocks in Israel: A review. *Israel Journal of Earth Sciences*, Vol. 38, 1989, pp. 89-103.
- Larson R.L. The Mid-Cretaceous superplume episode. *Scientific American*, Vol. 272, No. 2, 1995, pp. 82-86, <https://doi.org/10.1038/scientificamerican0295-82>.
- Lavi N., Lipshitz G., Neeman E., Itamar A., Baer G. Determination of trace amounts of gold in the presence of rare earth elements in rock samples from Makhtesh Ramon (Southern Israel), by instrumental epithermal neutron activation analysis. *Journal of Radioanalytical and Nuclear Chemistry*, Vol. 120, No. 1, 1988, pp. 105-112, <https://doi.org/10.1007/BF02037856>.

- Le Roex A.P., Bell D.R., Davis P. Petrogenesis of group I kimberlites from Kimberley, South Africa: Evidence from bulk-rock geochemistry. *Journal of Petrology*, Vol. 44, Issue 12, 2003, pp. 2261-2286, <https://doi.org/10.1093/petrology/egg077>.
- Mahfoud R.F. Presence of diamond in the pyrope peridotite, Dreikeesh area, Tartous province, NW Syria: a new theory on the origin of diamond. *Microchemical Journal*, Vol. 73, No. 3, 2002, pp. 265-271, [https://doi.org/10.1016/S0026-265X\(02\)00040-1](https://doi.org/10.1016/S0026-265X(02)00040-1).
- Marshall T.R., Baxter-Brown R. Basic principles of alluvial diamond exploration. *Journal of Geochemical Exploration*, Vol. 53, Issues 1-3, 1995, pp. 277-292, [https://doi.org/10.1016/0375-6742\(94\)00067-L](https://doi.org/10.1016/0375-6742(94)00067-L).
- McClenaghan M.B., Thorleifson L.H., DiLabio R.N.W. Till geochemical and indicator mineral methods in mineral exploration. *Ore Geology Reviews*, Vol. 16, Issues 3-4, 2000, pp. 145-166, [https://doi.org/10.1016/S0169-1368\(99\)00028-1](https://doi.org/10.1016/S0169-1368(99)00028-1).
- McDonald I., de Wit M.J., Smith C.B., Bizzi L.A., Viljoen K.S. The geochemistry of the platinum-group elements in Brazilian and southern African kimberlites. *Geochimica et Cosmochimica Acta*, Vol. 59, Issue 14, 1995, pp. 2883-2903, [https://doi.org/10.1016/0016-7037\(95\)00183-2](https://doi.org/10.1016/0016-7037(95)00183-2).
- Milashev V.A. Kimberlite Provinces. Nedra. Leningrad, 1974, 218 p. (in Russian)
- Mitchell R.H. Kimberlites: Mineralogy, Geochemistry and Petrology. Plenum Press. New York, 1986, 442 p.
- Mitchell R.H. Kimberlites, Orangeites, and Related Rocks. Plenum Press. New York, 1995, 410 p.
- Morgan P. Diamond exploration from the bottom up: regional geophysical signatures of lithosphere conditions favorable for diamond exploration. *Journal of Geochemical Exploration*, Vol. 53, Issues 1-3, 1995, pp. 145-165, [https://doi.org/10.1016/0375-6742\(94\)00072-J](https://doi.org/10.1016/0375-6742(94)00072-J).
- Mukhin P., Eppelbaum L., Wirth R., Schreiber A., Dobrzynetska L. First find of 4H SiC polytype *in situ* in volcanic rocks of northern Israel (Invited Lecture). Transactions of the 25th Goldschmidt Conference, European Association of Geochemistry and the Geochemical Society, Prague, Czech Republic, 2015.
- Nixon P.H. The morphology and nature of primary diamondiferous occurrences. *Journal of Geochemical Exploration*, Vol. 53, Issues 1-3, 1995, pp. 41-71, [https://doi.org/10.1016/0375-6742\(94\)00034-9](https://doi.org/10.1016/0375-6742(94)00034-9).
- Nowak P. Influence of surfactant adsorption on the leaching of copper sulfides. *ECS Transactions*, Vol. 28, No. 6, 2010, pp. 143-153, <https://doi.org/10.1149/1.3367909>.
- Paul D.K., Crockett J.H., Nixon P.H. Abundances of palladium, iridium and gold in kimberlites and associated nodules. In: Boyd F.R. and Meyer H.O.A. (eds.) *Kimberlites, Diatremes and Diamonds: Their Geology, Petrology and Geochemistry* (Proceedings of the 2nd International Kimberlite Conference, Vol. 1. American Geophysical Union, Washington, D.C., 1979, pp. 272-279.
- Recanati P., Steinitz G., Platzner I., Starinsky A. Early Cretaceous igneous activity in the northern Negev: Evidence from K-Ar dating of subsurface cores. *Israel Journal of Earth Sciences*, Vol. 38, 1989, pp. 155-162.
- Ron H., Baer G. Paleomagnetism of Early Cretaceous rocks from southern Israel. *Israel Journal of Earth Sciences*, Vol. 37, 1988, pp. 73-81.
- Rosenfeld A., Flexer A., Honigstein A., Almogi-Labin A., Dvorachek M. First report on a Cretaceous/Tertiary boundary section at Makhtesh Gadol, southern Israel. *Neues Jahrbuch für Geologie und Paläontologie – Monatshefte*, No. 8, 1989, pp. 474-488, <https://doi.org/10.1127/njgpm/1989/1989/474>.
- Rybakov M., Segev A. Top of the crystalline basement in the Levant. *Geochemistry, Geophysics, Geosystems*, Vol. 5, Issue 9, Article number Q09001, 2004, pp. 1-8, <https://doi.org/10.1029/2004GC000690>.
- Samoilov V.S., Vapnik Y. Fractional melting – the determining factor in the origin of the tephrite – basanite – nephelinite rock suite: evidence from western Makhtesh Ramon, Israel. *Neues Jahrbuch für Mineralogie, Abhandlungen*, Vol. 184, No. 2, 2007, pp. 181-195, <https://doi.org/10.1127/0077-7757/2007/0090>.
- Samykin E., Surkov A., Eppelbaum L., Semenov S. Do old spoils contain large amounts of economically valuable minerals? *Minerals Engineering*, Vol. 18, Issue 6, 2005, pp. 643-645, <https://doi.org/10.1016/j.mineng.2004.10.009>.
- Shcheka S.A., Ignat'ev A.V., Nechaev V.P., Zvereva V.P. First diamonds from placers in Primor'e. *Petrology*, Vol. 14, No. 3, 2006, pp. 299-317, <https://doi.org/10.1134/S0869591106030064>.
- Segev A. Synchronous magmatic cycles during the fragmentation of Gondwana: radiometric ages from the Levant and other provinces. *Tectonophysics*, Vol. 325, Issues 3-4, 2000, pp. 257-277, [https://doi.org/10.1016/S0040-1951\(00\)00122-0](https://doi.org/10.1016/S0040-1951(00)00122-0).
- Segev A., Weissbrod T., Lang B. ⁴⁰Ar/³⁹Ar dating of the Aptian-Albian igneous rocks in Makhtesh Ramon (Negev, Israel) and its stratigraphic implications. *Cretaceous Research*, Vol. 26, Issue 4, 2005, pp. 633-656, <https://doi.org/10.1016/j.cretres.2005.03.003>.
- Sharygin V.V., Kóthay K., Szabó Cs., Timina T.Ju., Török K., Vapnik Ye., Kuzmin D.V. Rhönite in alkali basalts: silicate melt inclusions in olivine phenocrysts. *Russian Geology and Geophysics*, Vol. 52, No. 11, 2011, pp. 1334-1352, <https://doi.org/10.1016/j.rgg.2011.10.006>.
- Sneh A., Bartov Y., Rosensaft M. Geological Map of Israel, Scale 1:200,000. Geological Survey of Israel, Ministry of National Infrastructure, Jerusalem, 1998.
- Shimshilashvili E., Yudalevich Z. Mechanism of phenocryst formation in alkaline ultrabasic and basic volcanic rocks: Evidence from Makhtesh Ramon, southern Israel. *Israel Journal of Earth Sciences*, Vol. 54, No. 2, 2005, pp. 113-120, <https://doi.org/10.1560/H09N-F2NT-B9J0-N1G4>.

- Sobolev N.V. Coesite as an indicator of ultrahigh pressures in continental lithosphere. *Russian Geology and Geophysics*, Vol. 47, No. 1, 2006, pp. 94-104.
- Starinsky A., Beilski M., Bonen D., Steinitz G. Rb-Sr whole rock ages of syenitic intrusion (Shen Ramon and Gevanim) in Ramon area, Southern Israel. *Israel Journal of Earth Sciences*, Vol. 29, 1980, pp. 177-181.
- Stein M., Garfunkel Z., Jagoutz E. Chronothermometry of peridotitic and pyroxenitic xenoliths: Implications for the thermal evolution of the Arabian lithosphere. *Geochimica et Cosmochimica Acta*, Vol. 57, Issue 6, 1993, pp. 1325-1337, [https://doi.org/10.1016/0016-7037\(93\)90069-9](https://doi.org/10.1016/0016-7037(93)90069-9).
- Surkov A.V. Atlas of Forms of Native Gold (Sketching and Measurements by Microscope Investigations). Vols. I and II. *Studia Publ.*, Moscow, 2000.
- Surkov A., Samykina E., Eppelbaum L., Semenov S. The Main Reason for Mineral Loss in Gravity Dressing. *The Open Mineral Processing Journal*, Vol. 1, 2008, pp. 37-44, <https://doi.org/10.2174/1874841400801010037>.
- Vapnik E. Melt and fluid inclusions and mineral thermobarometry of mantle xenoliths in Makhtesh Ramon, Israel. *Israel Journal of Earth Sciences*, Vol. 54, No. 1, 2005, pp. 15-28, <https://doi.org/10.1560/LDW9-WU1Q-NTKR-WPQB>.
- Vapnik Y., Sharygin V., Samoilov V., Yudalevich Z. The petrogenesis of basic and ultrabasic alkaline rocks of western Makhtesh Ramon, Israel: geochemistry, melt and fluid inclusion study. *International Journal of Earth Sciences*, Vol. 96, 2007, pp. 663-684, <https://doi.org/10.1007/s00531-006-0131-5>.
- Yudalevich Z.A., Fershtater G.B., Eyal M. Magmatism of Makhtesh-Ramon: Geology, geochemistry, petrogenesis (Conservation area Har Ha-Negev, Israel). *Lithosphere*, No. 3, 2014, pp. 70-92. (in Russian)
- Yudalevich Z., Vapnik E. Xenocrysts and megacrysts of alkali-olivine-basalt-basanite-nephelinite association Makhtesh Ramon (Israel): Interaction with transporting magmas and morphological adjustment. *Lithosphere*, Vol. 18, No. 5, 2018, pp. 718-742, <https://doi.org/10.24930/1681-9004-2018-18-5-718-742>. (in Russian)
- Zak I. Geological Map of Israel (1:20,000). Makhtesh Ramon, Har Gevanim. Israel Geological Survey, 1968.
- Zilberman E. Landscape evolution in the central, northern and northwestern Negev during the Neogene and the Quaternary. *Geological Survey of Israel, Report GSI/45/90*, 1991, 164 p. (in Hebrew, English abstract).
- Zilberman E. Formation of "makhteshim" – unique erosion cirques in the Negev, southern Israel. *Israel Journal of Earth Sciences*, Vol. 49, No. 3, 2000, pp. 127-141, <https://doi.org/10.1560/8C09-4MJ4-RY2P-8K30>.
- Zilberman E., Avni Y. The geological map of Israel, 1: 50,000. Sheet 21-II: Mizpe Ramon. Israel Geological Survey, Jerusalem, 2004.

МАХТЕШ-РАМОН – УНИКАЛЬНЫЙ ПРИРОДНО-РЕСУРСНЫЙ КОМПЛЕКС СТРАТЕГИЧЕСКОГО МНОГОКОМПОНЕНТНОГО СЫРЬЯ НА ЮГЕ ИЗРАИЛЯ

Эппельбаум Л.В.^{1,2}

¹*Кафедра геофизики, факультет точных наук, Тель-Авивский Университет, Израиль
6997801, Тель-Авив, Рамат-Авив*

²*Азербайджанский государственный университет нефти и промышленности, Азербайджан
AZ1010, Баку, просп. Азадлыг, 20: levap@tauex.tau.ac.il*

Резюме. На основе комплексного анализа региональных геолого-геофизических факторов, Махтеш-Рамон (северный Негев, Израиль) был выбран в качестве перспективного участка для поиска алмазоносных комплексов. Важнейшим региональным фактором является максимум активности мантийного горячего пятна в средне-меловую эпоху, отчетливо проявившийся на данной территории. Многократные эрозионные процессы привели к удалению большей части осадочных отложений. Анализ данных магнитометрии, метода естественного электрического поля и результатов ионоселективных измерений однозначно указывает на наличие в западной части Махтеш-Рамона геологических тел, залегающих на небольших глубинах (8-50 м) и, вероятно, имеющих кимберлитовое (лампроитовое) происхождение. Минералогические исследования позволили выявить следующие минералы-спутники алмазов: хромдиопсид, оранжевый гранат, ярко-малиновый пироп, пикроильменит, муассанит, корунд, черную шпинель, оливин, анатаз и турмалин. Отсутствие следов окатанности или окисления служит дополнительным свидетельством их связи с коренными породами. Данные электронной микроскопии показывают, что зерна (1) пикроильменита и (2) пироба содержат соответственно: (1) кобальт, хром, магний и никель, а (2) хром, магний и алюминий. Это указывает на глубинный (гиперабиссальный) генезис данных минералов. К второстепенным минералам-спутникам относятся полевые шпаты, пироксены, магнетит, гематит, ильменит, галенит, пирит, лимонит, слюды, хромит, лейкоксен, циркон, рутил и др. Наличие этих минералов (в дополнение к первой группе) также указывает на алмазоносную минерализацию в исследуемом районе. Обнаружение мелких пластинок золота и серебра, а также значительных концентраций La, Ce, Th, Nb и Ta (редкоземельных элементов), также может быть связано с ближайшими выходами пород глубинного происхождения. Общее количество выявленных микроалмазов превышает 300; также было обнаружено пять алмазов размером более 1 мм (размеры наиболее крупных кристаллов составляют 1,2 и 1,35 мм). Выявленные признаки присутствия серебра, золота и редкоземельных элементов могут представлять самостоятельный интерес.

Ключевые слова: горячая точка, алмазы, минералы-спутники, золото, редкоземельные элементы, геофизические признаки

MAXTEŞ RAMON: CƏNUBİ İSRAİLDƏ STRATEJİ ƏHƏMİYYƏTLİ ÇOXKOMPONENTLİ MİNERAL XAMMALIN UNİKAL TƏBİİ-RESURS KOMPLEKSİ

Eppelbaum L.V.^{1,2}

¹Tel-Əviv Universitetinin dəqiq elmlər fakültəsi, geofizika, İsrail
6997801, Tel-Əviv, Ramat-Əviv

²Azərbaycan Dövlət Neft və Sənaye Uiversiteti, Azərbaycan
AZ1010, Bakı, Azadlıq pr., 20: levap@tauex.tau.ac.il

Xülasə. Regional geoloji-geofiziki amillərin kompleks təhlili əsasında Mahtəş-Ramon (Şimali Neqev, İsrail) ərazisi almazlı assosiasiyaların axtarışı üçün perspektivli sahə kimi seçilmişdir. Bu ərazidə özünü aydın şəkildə büruzə verən Orta Təbaşir dövründə üst mantiyada qaynar nöqtə aktivliyinin maksimumu ən mühüm regional amil hesab olunur. Təkrar eroziya prosesləri çökmə süxurlarının əksəriyyətinin yuyulmasına səbəb olmuşdur. Bu isə geokimyəvi və petroloji analizlər üçün mineral nümunələrinin götürülməsini və süxur materialının toplanmasını əhəmiyyətli dərəcədə asanlaşdırmışdır. Maqnit (paleomaqnit), təbii potensial və ion selektiv məlumatların təhlili Mahtəş-Ramonun qərb hissəsində, az dərinliklərdə (8-50 m) yerləşən və ehtimal ki, kimberlit (lamproit) mənşəli olan geoloji cisimlərin varlığını birmənalı şəkildə göstərir. Mineraloji tədqiqatlar almazın aşağıdakı peyk-minerallarını müəyyən etməyə imkan vermişdir: xromdiopsid, narıncı nar (qranat), parlaq al qırmızı pirop, pikroilmenit, moissanit, korund, qara şpinel, olivin, anataz və turmalin. Bu minerallarda oksidləşmənin və ya yuvarlaqlaşmanın olmaması onların ana süxurlarla əlaqəsinin əlavə sübutudur. Elektron mikroskopu məlumatlarına əsasən, pikroilmenit dənələrinin tərkibində kobalt, xrom, maqnezium və nikel, eləcə də pirop dənələrində isə xrom, maqnezium və alüminium aşkar edilmişdir. Bu isə sözügedən mineralların hiperabissal mənşəli olduğunu göstərir və eyni zamanda almazdaşıyan kimberlit və ya lamproit cisimlərinin mümkün mövcudluğuna işarə edir. İkinci dərəcəli peyk-minerallara isə çöl şpatları, piroksenlər, maqnetit, hematit, ilmenit, qalenit, pirit, limonit, slyudalar, xromit, leykoksen, sirkon, rutil və s. aiddir. Birinci qrup minerallarla yanaşı, bu mineralların da mövcudluğu tədqiq olunan ərazidə almaz mineralaşmasından xəbər verir. Qızıl və gümüşün kiçik lövhəciklərinin, həmçinin La, Ce, Th, Nb və Ta elementlərinin nəzərəcarpan izlərinin müəyyən edilməsi yaxınlıqda yerləşən kimberlit süxurlarının təzahürü ilə də əlaqəli ola bilər. Sahədə aşkar edilmiş mikroalmazların ümumi sayı 300-dən çoxdur; həmçinin ölçüsü 1 mm-dən böyük olan beş almaz dənəsi də tapılmışdır (ən böyük kristalların ölçüləri 1,2 və 1,35 mm-dir). Gümüş, qızıl və nadir torpaq elementləri ilə bağlı müəyyən edilmiş perspektivli geokimyəvi əlamətlər müstəqil maraq doğura bilər. Beləliklə, geoloji və geofiziki amillərin məcmusu və qeyd olunan mineralların aşkarlanması əsasında Mahtəş Ramon ərazisi həm almazlı süxurların, o cümlədən kimberlit və ya lamproit borularının, həm də yumşaq çöküntülərdə almaz kristallarının aşkar edilməsi baxımından perspektivli hesab olunur.

Açar sözlər: qaynar nöqtə, almaz, peyk-mineral, qızıl, nadir torpaq elementləri, geofiziki əlamətlər

COMPARATIVE MINERALOGICAL-GEOCHEMICAL CHARACTERISTICS OF THE OIL-BEARING ROCKS OF EAST AZERBAIJAN WITH ATHABASCA (CANADA)

Mehdiyev O.T.*, Mammadova A.N., Nagizade A.A., Bakhshiyeva F.G.

Ministry of Science and Education of the Republic of Azerbaijan,

Laboratory of Oil and Gas Field Geology,

“Institute of Geology” Public Legal Entity (PLE), Azerbaijan

119, H. Javid Ave., Baku, AZ1073

**Corresponding author: orxan95mehdiyev@gmail.com*

Summary. This research evaluates the oil-bearing rocks of East Azerbaijan exemplified by the Akhtarma-Puta, Cheyildere, and Araliq areas by comparing them with Athabasca, one of the world's best-studied oil sand systems, to determine their mineralogical, major oxide, and organic-geochemical characteristics, as well as their similarities and differences. The study is based on the XRD and WDXRF results of 12 rock samples from the aforementioned areas, along with the determination of moisture content, extractable bitumen, and bitumen fractions in group samples. Compared to Athabasca, the average composition of the East Azerbaijan samples is characterized by lower quartz (28.92% vs. 51.30%), clay minerals (23.42% vs. 40.30%), and SiO₂ (46.29% vs. 78.82%), but higher feldspar (15.83% vs. 3.10%), carbonate (16.08% vs. 4.40%), and CaO (12.19% vs. 3.07%). The average bitumen content is 4.61% in the local samples and 7.15% in Athabasca, while the moisture content is 1.45% and 3.40%, respectively. Within the local areas, Cheyildere is distinguished by being quartz-rich and carbonate-free, whereas Araliq is characterized by bitumen with a high asphaltene content. These results indicate that the investigated oil-bearing rocks of East Azerbaijan possess distinct mineral-matrix and bitumen characteristics compared to Athabasca, alongside significant compositional variability within the local areas.

Keywords: East Azerbaijan, Athabasca, oil-bearing rock, mineralogy, major oxides, moisture content, bitumen

© 2026 Earth Science Division, Azerbaijan National Academy of Sciences. All rights reserved.

Introduction

Azerbaijan has a rich and long-standing history of oil and gas production (Khuduzade et al., 2026). At the same time, the transition of some traditional fields into a mature development stage and the gradual year-on-year decline in national oil production make it urgent to reassess unconventional and secondary hydrocarbon sources alongside remaining reserves (Abbasov et al., 2026). In this regard, oil shales, natural bitumens, and oil-impregnated rocks in East Azerbaijan are of particular interest. In recent years, the distribution, mineralogical-geochemical characteristics, and hydrocarbon potential of Paleogene-Miocene oil shales have been investigated in detail using various approaches (Salaev et al., 1989; Aliyev et al., 2018; Abbasov et al., 2025; Aliyev, Abbasov, 2019a; Aliyev, Abbasov, 2019b; Aliyev et al., 2019). These results indicate that unconventional hydrocarbon systems are broadly repre-

sented in the region and possess prospective potential. In this context, the comparative evaluation of oil-bearing rocks within the same unconventional resource group in Azerbaijan is of special significance.

Worldwide, heavy oil and oil sand reserves constitute a major unconventional hydrocarbon base, the bulk of which is located in Cretaceous and Cenozoic reservoirs (Liu et al., 2019). The Athabasca deposit, located in the province of Alberta, Canada, and primarily associated with the Lower Cretaceous McMurray-Wabiskaw sediments, is one of the most thoroughly studied oil sand systems in terms of its geological structure, mineral matrix, bitumen composition, and extraction technologies (Hein et al., 2006; Osacky et al., 2013; He et al., 2013). Therefore, the Athabasca deposit was chosen as a reference system for comparison not due to superior resource quality, but because of its extensive and systematic database on geological structure,

mineral matrix, and bitumen properties. This approach allows for a clearer determination of the compositional position of the lesser-studied East Azerbaijan occurrences within global oil sand systems.

The aim of the present work is to comparatively evaluate the mineralogical composition, major oxide geochemistry, and organic-geochemical characteristics of the oil-bearing rocks of East Azerbaijan exemplified by the Akhtarma-Puta, Cheyildere, and Araliq areas against Athabasca, to identify their similarities and differences, and to formulate a general compositional picture of the East Azerbaijan oil-bearing rocks within this comparative context.

Geological setting and study objects

The study objects represent three different oil and gas regions of East Azerbaijan (Table 1): Akhtarma-Puta is located in Absheron, Cheyildere in Shamakhi-Gobustan, and Araliq in the Lower Kura depression. All three areas are as-

sociated with structures where mud volcanism is developed (Baldermann et al., 2020). In Akhtarma-Puta and Araliq, the samples are related to the Productive Series, whereas in Cheyildere, they are associated with the Miocene Chokrak regional stage. Since the samples occur in the form of sand and sandstone, both lithological and stratigraphic heterogeneity exist within the local areas.

Materials and Methods

A total of 12 samples were investigated (Table 1). Mineral phases were determined using a MiniFlex 600 X-ray diffractometer (XRD), and major element oxides were analyzed using an S8 TIGER Series 2 WDXRF spectrometer. The quantitative contents of quartz, feldspars, clay minerals, carbonates, and other mineral phases were evaluated from the XRD results, while the distribution of major oxides was assessed from the WDXRF data.

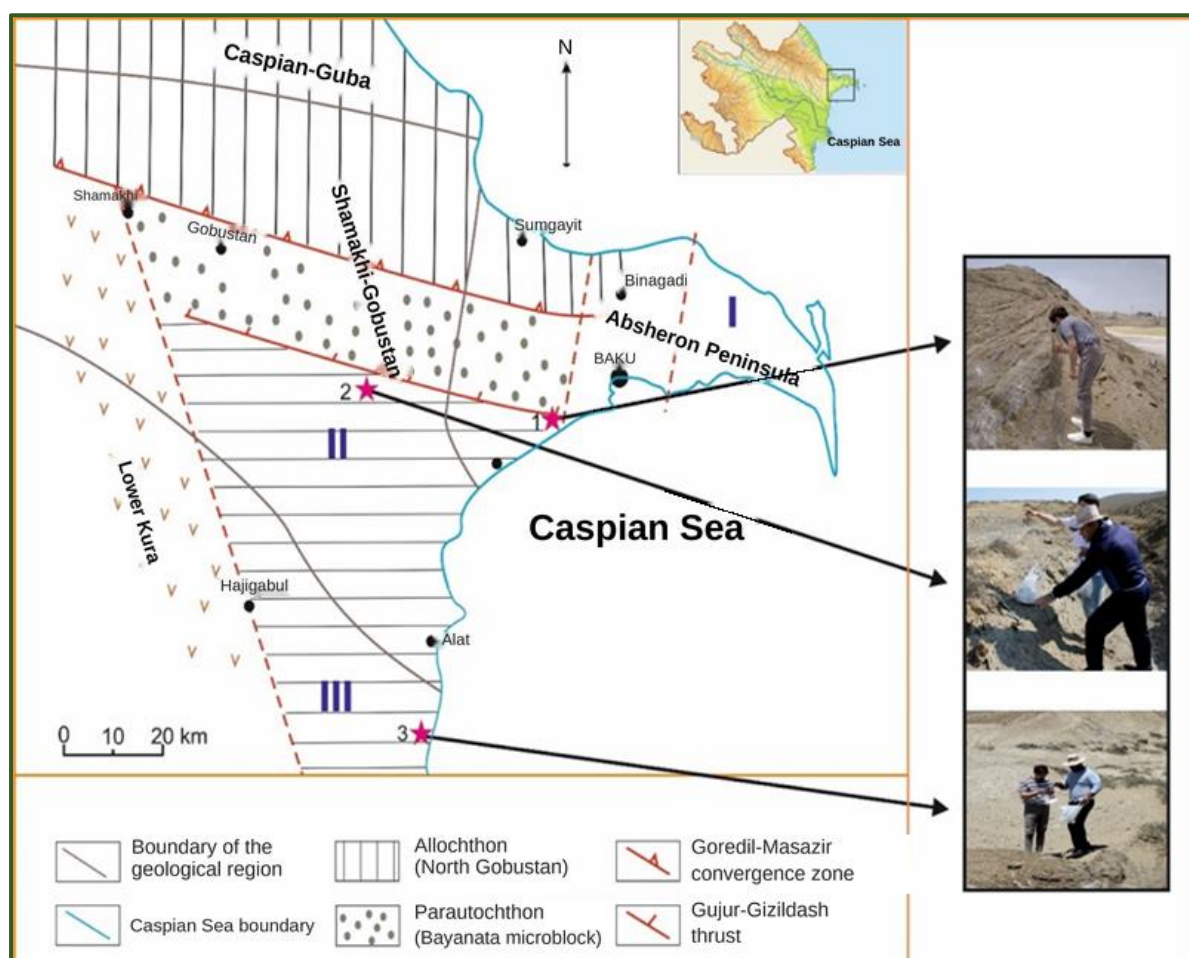


Fig. 1. Regional location of the Akhtarma-Puta (1), Cheyildere (2), and Araliq (3) areas

Table 1

Brief geological characterization of the study objects

Area	Oil and Gas Region	Stratigraphy	Lithology	Number of Samples
Akhtarma-Puta	Absheron	Productive Series	Sand, Sandstone	4
Cheyildere	Shamakhi-Gobustan	Chokrak	Sand, Sandstone	4
Araliq	Lower Kura	Productive series	Sand, Sandstone	4

In the organic-geochemical section, moisture content, extractable bitumen, oil, resin, and asphaltene fractions, as well as hydrocarbon groups, were evaluated across group samples. Indicators carrying identical or similar analytical significance compared to Athabasca were selected. For comparison with Athabasca, data from Osacky et al. (2013) were utilized for mineralogy and major oxides, and data from He et al. (2013) for the fractional composition of bitumen. Organic fractions obtained through different laboratory protocols were not treated as direct equivalents.

Results and Discussion

General mineral-geochemical comparison with Athabasca

The local samples are depleted in quartz and total clay minerals compared to Athabasca, while being richer in feldspars and carbonates (Table 2, Fig. 2). This difference is also reflected in the major oxide composition: the East Azerbaijan samples exhibit lower SiO_2 and Al_2O_3 , but higher CaO and Fe_2O_3 contents. Consequently, the average composition of the local rocks transitions from Athabasca's quartz-clay dominant matrix to a more feldspathic-carbonate matrix.

Table 2

Comparison of the average parameters of East Azerbaijan samples with Athabasca

Parameter	East Azerbaijan, average	Athabasca	Comparative feature
Bitumen, %	4,61	7,15	lower in local samples
Water, %	1,45	3,40	lower in local samples
Mineral fraction, %	93,94	89,40	higher in local samples
Quartz, %	28,92	51,30	lower in local samples
Feldspar, %	15,83	3,10	higher in local samples
Clay minerals, %	23,42	40,30	lower in local samples
Carbonates, %	16,08	4,40	higher in local samples
SiO_2 , %	46,29	78,82	lower in local samples
Al_2O_3 , %	9,54	13,03	lower in local samples
CaO , %	12,19	3,07	higher in local samples
Fe_2O_3 , %	4,98	2,00	higher in local samples

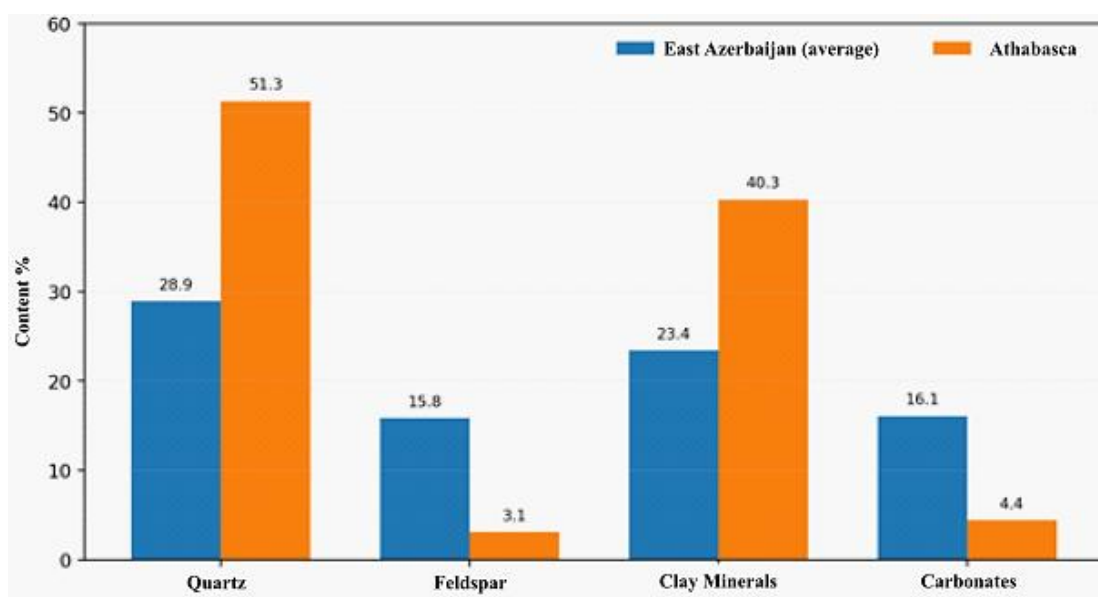


Fig. 2. Comparison of average mineral groups of East Azerbaijan with Athabasca

Differentiating features across local areas

The overall average values do not fully reflect the variability within the three areas. Cheyildere is distinguished by a high quartz and SiO₂ content, the absence of carbonates, and very low CaO (Table 3). In contrast, Akhtarma-Puta and Araliq exhibit lower quartz contents along with higher carbonate and CaO values. Although the total bitumen content is relatively similar across the three areas, their fractional composition is not identical, with Araliq clearly standing out due to its high asphaltene content. These spatial differences indicate that the average values calculated for East Azerbaijan are the generalized result of various local compositions and necessitate considering the intra-system heterogeneity in comparison with Athabasca.

Bitumen content and organic-geochemical characteristics

Although the total bitumen content in the local areas is relatively similar, its fractional and hydrocarbon composition varies noticeably

(Fig. 3). In Akhtarma-Puta and Cheyildere, the oil fraction is predominant, while asphaltene content remains at approximately 11%. In Araliq, against the background of a decreasing oil fraction, the asphaltene content rises to 41.65%. Regarding hydrocarbon groups, Akhtarma-Puta and Cheyildere are distinguished by the dominance of methane-naphthenic components, whereas Araliq is characterized by a high proportion of monocyclic compounds. Data on the SARA composition of Athabasca bitumen also indicate that it is characterized by a complex composition consisting of saturate, aromatic, resin, and asphaltene fractions (Osacky et al., 2013). Furthermore, the mineral and chemical properties of Athabasca oil sands demonstrate that the mineral matrix hosting the bitumen also plays a crucial role in the overall compositional character of the system (He et al., 2013). Consequently, compared to Athabasca, the East Azerbaijan bitumens exhibit distinct compositional characteristics not only in terms of bitumen content, but also regarding fractional properties and their interaction with the mineral matrix.

Table 3

Main differentiating parameters across local areas

Area	Quartz, %	Carbonate, %	SiO ₂ , %	CaO, %	Bitumen, %	Asphaltene, %
Akhtarma-Puta	14,75	22,75	30,42	18,24	4,69	10,74
Cheyildere	50,75	0,00	66,92	0,86	4,67	10,87
Araliq	21,25	25,50	41,53	17,48	4,48	41,65

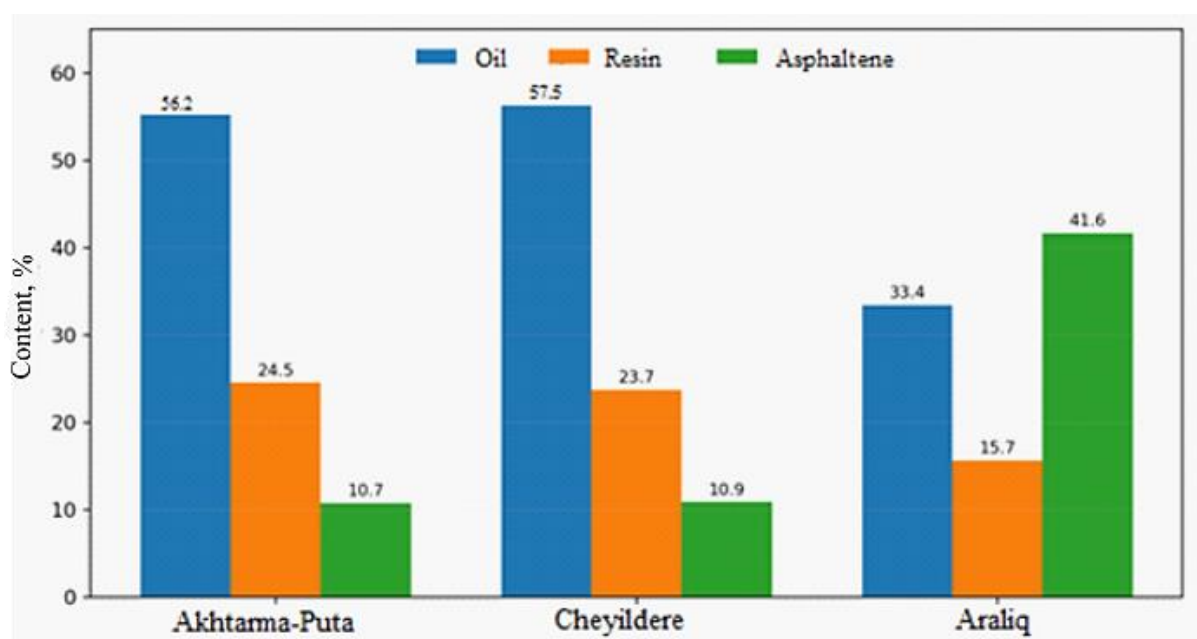


Fig. 3. Distribution of oil, resin, and asphaltene fractions of bitumen across local areas

Conclusion

The comparison with Athabasca demonstrates that the investigated oil-bearing rocks of East Azerbaijan possess a distinct regional compositional profile in terms of their mineral matrix and bitumen characteristics. While the average quartz content in the local samples is 28.92% and carbonate content is 16.08%, these values in Athabasca are 51.30% and 4.40%, respectively. The average bitumen content is 4.61% in the East Azerbaijan samples and 7.15% in Athabasca. These differences indicate that local oil-bearing rocks are distinguished

from Athabasca's quartz-clay-dominated system by a more feldspathic-carbonate mineral matrix and lower bitumen content. Furthermore, the differences identified among Akhtarma-Puta, Cheyildere, and Araliq confirm the existence of significant spatial heterogeneity within the regional profile, where the rise of asphaltenes to 41.65%, particularly in Araliq, shows that the fractional composition of bitumen varies substantially across areas. Therefore, the general comparison of East Azerbaijan's oil-bearing rocks with Athabasca must be complemented by a separate consideration of spatial characteristics.

REFERENCES

- Abbasov O.R., Baloglanov E.E., Yolchuyeva U.J., Khuduzade A.I., Akhundov R.V. Factors controlling the formation and oil-generating potential of the Middle Eocene organic-rich shales of Eastern Azerbaijan. *Boletín de la Sociedad Geológica Mexicana*, Vol. 77, No. 1, Article number A020724, 2025, <https://doi.org/10.18268/bsgm2025v77n1a020724>.
- Abbasov O.R., Mardashov D.V., Gasimov E.E., Guliyev I.S., Aliyarov R.Y., Yolchuyeva U.J., Baloglanov E.E., Akhundov R.V. Prospects of synthetic hydrocarbons in immature Cenozoic onshore shale-bearing strata of Eastern Azerbaijan: geological and geochemical assessment. *Journal of Mining Institute*, Vol. 279, 2026, pp. 112-131.
- Aliyev Ad.A., Abbasov O.R., Ibadzade A.J., Mammadova A.N. Genesis and organic geochemical characteristics of oil shale in Eastern Azerbaijan. *SOCAR Proceedings*, No. 3, 2018, pp. 4-15, <https://doi.org/10.5510/OGP20180300356>.
- Aliyev A.A., Abbasov O.R. Nature of the provenance and tectonic setting of oil shale (Middle Eocene) in the Greater Caucasus southeastern plunge. *Geodynamics*, Vol. 1, No. 26, 2019a, pp. 43-59, <https://doi.org/10.23939/jgd2019.01.043>.
- Aliyev A.A., Abbasov O.R. Mineralogical and geochemical proxies for the Middle Eocene oil shales from the foothills of the Greater Caucasus, Azerbaijan: implications for depositional environments and paleoclimate. *Mineralia Slovaca*, Vol. 51, Issue 2, 2019b, pp. 157-174.
- Aliyev A.A., Abbasov O.R., Agayev A.M. Mineralogy and geochemistry of oil shale in Azerbaijan: Classification, palaeoweathering and maturity features. *Visnyk of V. N. Karazin Kharkiv National University. Series Geology, Geography, Ecology*, No. 50, 2019, pp. 11-26, <https://doi.org/10.26565/2410-7360-2019-50-01>.
- Baldermann A., Abbasov O.R., Bayramova A., Abdullayev E., Dietzel M. New insights into fluid-rock interaction mechanisms at mud volcanoes: Implications for fluid origin and mud provenance at Bahar and Zenbil (Azerbaijan). *Chemical Geology*, Vol. 537, Article number 119479, 2020, <https://doi.org/10.1016/j.chemgeo.2020.119479>.
- He L., Li X., Wu G., Lin F., Sui H. Distribution of saturates, aromatics, resins, and asphaltenes fractions in the bituminous layer of Athabasca oil sands. *Energy & Fuels*, Vol. 27, Issue 8, 2013, pp. 4677-4683, <https://doi.org/10.1021/ef400965m>.
- Hein F.J., Cotterill D.K. The Athabasca Oil Sands – A Regional Geological Perspective, Fort McMurray Area, Alberta, Canada. *Natural Resources Research*, Vol. 15, 2006, pp. 85-102, <https://doi.org/10.1007/s11053-006-9015-4>.
- Khuduzade A.I., Abbasov O.R., Guliyev I.S., Yolchuyeva U.J., Baloglanov E.E., Jafarova R.A., Akhundov R.R., Aliyeva N.M., Bashirov O.K. Geochemical-paleontological study of Mesozoic source rocks, Eurasian–Gondwana junction, Azerbaijan. *Episodes*, 2026, <https://doi.org/10.18814/epiiugs/2026/026002>.
- Liu Z., Wang H., Blackburn G., Ma F., He Z., Wen Z., Wang Z., Yang Z., Luan T., Wu Z. Heavy Oils and Oil Sands: Global distribution and resource assessment. *Acta Geologica Sinica*, Vol. 93, Issue 1, 2019, pp. 199-212, <https://doi.org/10.1111/1755-6724.13778>.
- Osacký M., Geramian M., Ivey D., Liu Q., Etsell T.H. Mineralogical and chemical composition of petrologic end members of Alberta oil sands. *Fuel*, Vol. 113, 2013, pp. 148-157, <https://doi.org/10.1016/j.fuel.2013.05.099>.
- Salaev S.G., Kravchinsky Z.Y., Selimkhanov A.I., Nadirov S.G., Sadikov A.M., Aliyev G.M. Oil Sands and Oil Shale of Azerbaijan. *Elm. Baku*, 1990, 210 p. (in Russian)

СРАВНИТЕЛЬНАЯ МИНЕРАЛОГО-ГЕОХИМИЧЕСКАЯ ХАРАКТЕРИСТИКА НЕФТЕНОСНЫХ ПОРОД ВОСТОЧНОГО АЗЕРБАЙДЖАНА И АТАБАСКИ (КАНАДА)

Мехтиев О.Т.*, Мамедова А.Н., Нагизаде А.А., Бахшиева Ф.Г.
*Министерство науки и образования Азербайджанской Республики,
Лаборатория геологии нефтегазовых месторождений,
“Институт геологии” Публичное юридическое лицо, Азербайджан
AZ1073, Баку, просп. Г. Джавида, 119*

**Автор, отвечающий за переписку: orxan95mehdiyev@gmail.com*

Резюме. В данном исследовании проводится оценка нефтеносных пород Восточного Азербайджана (на примере площадей Ахтарма-Пути, Чейлдере и Аралых) путем их сравнения с Атабаской одной из наиболее изученных в мире систем нефтеносных песков с целью определения их минералогических, петрохимических (основные оксиды) и органико-геохимических характеристик, а также выявления их сходств и различий. Работа основана на результатах рентгенофазового (XRD) и волнодисперсионного рентгенофлуоресцентного (WDXRF) анализов 12 образцов пород из указанных районов, а также на определении влажности, экстрагируемого битума и группового состава битумных фракций. По сравнению с Атабаской, средний состав образцов из Восточного Азербайджана характеризуется более низким содержанием кварца (28,92% против 51,30%), глинистых минералов (23,42% против 40,30%) и SiO_2 (46,29% против 78,82%), но более высоким содержанием полевых шпатов (15,83% против 3,10%), карбонатов (16,08% против 4,40%) и CaO (12,19% против 3,07%). Среднее содержание битума в местных образцах составляет 4,61% (в Атабаске 7,15%), а влажность 1,45% и 3,40% соответственно. Среди исследованных местных площадей Чейлдере выделяется повышенным содержанием кварца и отсутствием карбонатов, в то время как Аралых характеризуется битумом с высоким содержанием асфальтенов. Полученные результаты показывают, что исследованные нефтеносные породы Восточного Азербайджана обладают специфическими минеральной матрицей и характеристиками битума по сравнению с Атабаской, наряду со значительной вариативностью состава внутри самих локальных участков.

Ключевые слова: Восточный Азербайджан, Атабаска, нефтеносная порода, минералогия, основные оксиды, влажность, битум

ŞƏRQİ AZƏRBAYCANIN NEFTLİ SÜXURLARININ ATABASKA (KANADA) İLƏ MÜQAYİSƏLİ MİNERALOLJİ-GEOKİMYƏVİ XÜSUSİYYƏTLƏRİ

Mehdiyev O.T.*, Məmmədova A.N., Nağızadə A.Ə., Baxşıyeva F.Q.
*Azərbaycan Respublikası Elm və Təhsil Nazirliyi,
Neft-qaz-mədən geologiyası laboratoriyası,
“Geologiya İnstitutu” Publik Hüquqi Şəxsi (PHŞ), Azərbaycan
AZ1073, Bakı, H. Cavid pr., 119*

**Yazışmalara məsul: orxan95mehdiyev@gmail.com*

Xülasə. Tədqiqat işi Axtarma-Puta, Çeyildərə və Aralıq sahələrinin təmsalında Şərqi Azərbaycanın neftli süxurlarını dünyanın ən yaxşı öyrənilmiş neftli qum sistemlərindən biri olan Athabasca ilə müqayisə etməklə onların mineraloji, əsas oksid və üzvi-geokimyəvi xüsusiyyətlərini, oxşar və fərqli cəhətlərini müəyyən edir. Tədqiqat adıçəkilən sahələrə aid 12 süxur nümunəsinin XRD və WDXRF nəticələrinə, həmçinin qrup nümunələrində nəmlik, ekstraksiya olunan bitum və bitum fraksiyalarının təyininə əsaslanır. Şərqi Azərbaycan nümunələrinin orta tərkibi Atabaska ilə müqayisədə daha az kvars (28,92 və 51,30%), gil mineralları (23,42 və 40,30%) və SiO_2 (46,29 və 78,82%), lakin daha çox çölşpatı (15,83 və 3,10%), karbonat (16,08 və 4,40%) və CaO (12,19 və 3,07%) ilə səciyyələnir. Orta bitum miqdarı yerli nümunələrdə 4,61%, Atabaskada 7,15%, nəmlik isə müvafiq olaraq 1,45 və 3,40%-dir. Yerli sahələr daxilində Çeyildərə kvars ilə zəngin və karbonatsız, Aralıq isə yüksək asfaltanlı bitumla seçilir. Bu nəticələr Şərqi Azərbaycanın tədqiq olunan neftli süxurlarının Athabasca ilə müqayisədə fərqli mineral-matris və bitum xüsusiyyətlərinə malik olduğunu, yerli sahələr daxilində də əhəmiyyətli kompozisional dəyişkənliyin mövcudluğunu göstərir.

Açar sözlər: Şərqi Azərbaycan, Atabaska, neftli süxur, mineralojiya, əsas oksidlər, nəmlik, bitum

CORRELATION OF MAGNETOSTRATIGRAPHIC SCALES AND PALEOMAGNETIC CHARACTERISTICS OF TRIASSIC DEPOSITS IN THE NAKHCHIVAN AUTONOMOUS REPUBLIC (AZERBAIJAN, PRELIMINARY DATA)

Bagirova A.A.

*Ministry of Sciences and Education of the Republic of Azerbaijan,
“Institute of Geology” Public Legal Entity (PLE), Azerbaijan
119, H. Javid Ave., Baku, AZ1073: arzu-bagirova2013@yandex.ru*

Summary. This article presents the results of investigations of the Mesozoic (Triassic) sedimentary deposits in the Nakhchivan Autonomous Republic, focusing on the horizontal movements of the Earth's crust and approaches to resolving related tectonic problems. Paleomagnetic investigations were carried out on the Akhura and Tananam stratigraphic sections, where Triassic sedimentary rocks were studied in detail. Based on the paleomagnetic data, the kinematic parameters of tectonic blocks and their horizontal displacements were determined. Similar results were obtained from the characterization of lithological components: clays and fine-grained sandstones exhibit the highest magnetic stability, coarse-grained rocks display metastable magnetic behavior, whereas coarse-grained sandstones, dolomites, and related lithologies are characterized by unstable magnetic properties.

During the magnetic cleaning (demagnetization) process, the stable components of remanent magnetization were isolated. On average, their directions coincide with the magnetization directions determined by the fold test. The investigated sections exhibit a regular alternation of rocks with normal and reversed magnetic polarity. Following thermal and stepwise demagnetization, rocks with both normal and reversed magnetization from the Akhura and Tananam sections yielded the same characteristic magnetization direction. This demonstrates the synchronicity of the natural remanent magnetization (J_n) and confirms the absence of the secondary magnetization components after demagnetization.

The objectives of this study were to investigate the paleomagnetic properties of the Triassic sedimentary rocks exposed within the Nakhchivan Autonomous Republic; to determine the position of the Earth's northern geomagnetic pole during the Triassic; to evaluate the horizontal displacements and rotational parameters of tectonic blocks; and to reconstruct the regional geological evolution and paleotectonic development based on paleomagnetic evidence.

The significance of the present paleomagnetic investigation lies in the fact that paleomagnetic methods provide the only quantitative approach for reconstructing paleotectonic settings and assessing the relative rotations of different geological structures.

This study represents the first comprehensive paleomagnetic investigation conducted in the Nakhchivan region (39.5°N, 45.3°E), in which paleomagnetic directions of the Triassic sedimentary rocks were determined using complete demagnetization procedures and Principal Component Analysis (PCA). Nevertheless, the results obtained from the Nakhchivan region are in close agreement with previously published paleomagnetic data from neighboring regions and stratigraphically equivalent Triassic sections, confirming the regional consistency and reliability of the obtained paleomagnetic dataset.

Keywords: *Magnetic susceptibility, stratigraphic division, geological-geophysical analysis, Tananam sections, Trias epoch*

© 2026 Earth Science Division, Azerbaijan National Academy of Sciences. All rights reserved.

Introduction

The territory of the Nakhchivan Autonomous Republic, an integral part of the Republic of Azerbaijan, is distinguished by its complex geological-tectonic structure and a geological section spanning a wide stratigraphic range from the Devonian to the Holocene (Fig. 1).

Tectonically, the geological structure of the sedimentary cover is not homogeneous; it is characterized by the complex interrelationships

of the following structural units (tectonic zones) that differ in lithological-stratigraphic sections, deformation features, and geological history: 1. Sharur-Julfa Uplift Zone; 2. Ordubad Trough Zone; 3. Zangezur Uplift Zone; 4. Nakhchivan Superimposed Basin (Babayev et al., 2016). These zones differ from one another in the composition of their geological formations, the nature of tectonic deformations, age, and thickness; they are, in turn, composed of tectonic blocks of vari-

ous sizes bounded by deep faults. The studied area belongs to the Sharur-Julfa Uplift Zone.

Lower Triassic: Characterized by *Xenodiscus* and *Paratirolites*; *Goniatites adichianus* (Moll) is present at the basal part.

Middle Triassic: Tabular limestones (Muschelkalk) with various greyish-green and pinkish shades containing gastropod and lamelli-branch (bivalve mollusk) fossils.

Upper Triassic: A thick sequence of cavernous dolomite devoid of faunal remains. The observed thickness of the Triassic limestone sequence exceeds 1.5 km.

Geology of the studied area

The Nakhchivan Autonomous Republic (NAR) area consists of sediments from the Paleozoic, Mesozoic, Tertiary, and the Quaternary periods. The geological cross-section (from bottom to top) is shown in Fig. 1.

The Oldest Rocks: The oldest rocks are represented by alternating layers of medium- and thin-bedded gray and black limestones, mica-bearing intermediate layers, quartzites, and schists. The characteristic fauna of the Middle

and Upper Devonian periods has been discovered in the limestones and, to some extent, in the sandstones and schists. The visible thickness of this layer exceeds 1 km.

Carboniferous Rocks: A thick sequence of dark gray, medium- and thick-bedded limestones containing Carboniferous fauna lies directly on top of the alternating sequence of Devonian rocks mentioned above.

Permian Rocks: The Carboniferous limestones transition into reddish-colored limestones with Permian fauna, followed by a sequence of thin limestones (local marls and sandstones).

Triassic Rocks: At higher elevations, the Permian limestones give way to reddish-gray, partially dolomitic, medium-bedded Triassic limestone sequences.

The Triassic period is primarily developed in the southeastern part of the middle stream of the Eastern Arpachay River, within the upper and middle stream basins of the left tributary, Akhurchay (Gabakhlychay). Outside the Eastern Arpachay Basin, the Triassic period is widespread in the Jahrichay region (Subus mountain range) and, finally, in the Julfa depression (Fig. 1).

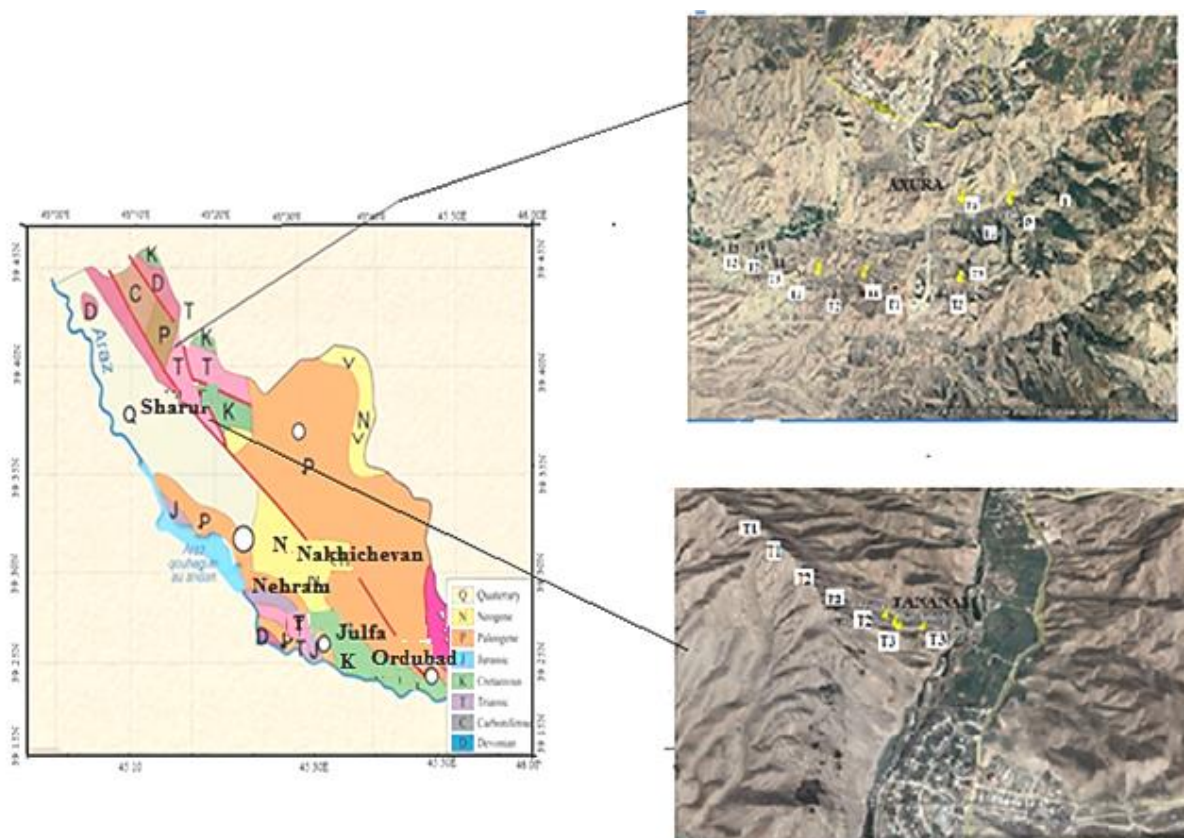


Fig. 1. Geological map of Nakhchivan and the locations of paleomagnetic sampling sites along the Tananam and Akhura sections

Stratigraphy of the Studied Area

The stratotype is located to the northeast of Tananam village, while the parastratotype is situated in the Nehram depression (Ismail-Zade et al., 2005). To the northwest, the major exposures are widespread around the Gabaglychay and Jahrichay basins, in the areas of Chalkhangala, Garabaghlar, Tananam, Akhura, and Havush villages. Additionally, it forms the summits and slopes of the Daralayaz mountain range, including the peaks of Ardaghy, Hinadali, Remlar, Garavultapa, Anabad-Gadik, Garagush, and Bazakli mountains. Smaller exposures are observed at the source of the Lizbirtchay and the upper reaches of the Kichik Davaolandara stream (the south of Ardych Mountain). It also participates in the geological cross-section of the northeastern wing of the eponymous rise in the Julfa depression in the southeast.

The area is represented by gray to dark gray dolomites and dolomitic limestones. The lower and middle Triassic deposits are transgressively deposited, with their weathered top sections unconformably covered by various Jurassic and Cretaceous layers. The discovery

of rare fauna remains at the base of the cross-section allows the upper Triassic deposits to be classified accordingly.

The dolomites are characterized by gray color, medium- to thick-bedded cavernous structures with cracks, which rest unconformably on the rock formations of the Ardaghy layer. Their thickness is around 30 meters (Rustamov, 2023).

The Upper Triassic dolomites, which are gray in color and have medium- to thick-bedded cavernous structures, unconformably rest on the rocks of the Ardaghy layer. The total thickness of the cross-section is 600 meters (the Upper Triassic) (Fig. 2).

The Middle Triassic Layer Sequence: Dark gray, thick-bedded, silicified and iron-rich brecciated dolomites with a thickness of 35 meters. The total thickness is 224 meters.

The Lower Triassic Layer Sequence: The layer consists of gray conglomeratic limestones, thick-bedded marly limestones, clayey limestones, thin-bedded laminated limestones, and thin-layered furoid-bearing limestones. The total thickness is 346 meters.



Fig. 2. Dolomites of the Upper Triassic Tananam Formation

Based on the data from E.A.Molostovski on the South Ural and the central part of the Eastern European Platform, a regional magnetostratigraphic table for the Lower Triassic was prepared (Bazhenova, 1983). The most up-to-date version of the regional magnetostratigraphic table for the Permian and Triassic periods of the Eastern European Platform has been presented by summarizing the works of the aforementioned researchers (Molostovski, 1985). However, most of the data used in its preparation were obtained and verified without meeting the requirements of magnetostratigraphy (Krasa et al., 2007).

Thus, obtaining new paleomagnetic data for the Perm-Triassic boundary interval of the Russian Platform is an urgent task for refining and detailing the regional magnetostratigraphic table and the GPTS (Geologic Time Scale). The study area is located in the western part of the Nakhchivan Autonomous Republic, around the Sharur plain, and includes the villages of Tananam, Nehram, and Akhura. The region has undergone significant deformation due to the Aip orogeny. Given its proximity to an active tectonic zone, weak seismicity is also possible (Fig. 5).

The Upper Triassic section is represented by the Tananam layer formation, a carbonate facies with a maximum thickness of 800 meters, and it is found in the geological structure of the Autonomous Republic, along with the Lower (Carnian) and Middle Norian stages. The rocks of the Carnian stage constitute the main part of the sequence, while the upper part of the cross-section belongs to the Norian stage. The area is tectonically active and rich in faults.

Methodology

The article is focused on the study of the geological structure, formation conditions, and paleotectonic characteristics of Triassic period sedimentary rocks and dolomites in the Nakhchivan region. In the laboratory, samples were subjected to petrographic analysis to study their mineral composition, magnetic susceptibility, and textural and structural characteristics through optical microscopy (Bagirova, Rzayev, 2018).

Geochemical analysis methods were used to determine the chemical composition of the carbonate rocks. In the Dynamic Geology Laboratory, demagnetization measurements of rock

samples were performed using the LDA-5 Demagnetizer, employing alternating and direct magnetic fields.

The remanent magnetization of rock samples, particularly those with strong magnetic properties, was determined using the JR-6A spinner magnetometer. In addition, the phase and amplitude of the induced electromotive force (EMF) in the samples were measured using this instrument.

Rock samples were also subjected to thermal demagnetization using the TD-48-SC thermal demagnetization furnace, which operates over a temperature range of 25-800°C.

Magnetic susceptibility was measured in the selected samples, and stepwise thermal and alternating magnetic field cleaning methods were applied to separate the initial magnetization components within the framework of the paleomagnetic studies. Based on the obtained results, the possible horizontal movements of geological blocks during the Triassic period and the influence of rifting regimes were assessed (Khramov, Sholpo, 1967).

Structural-Geological Analysis: Faults, anticline and syncline structures, as well as tectonic elements related to the rift zone were studied. In particular, the positioning of peridotite intrusions observed in the dolomite layers and their tectonic relationships were analyzed.

All the obtained data were comprehensively summarized, leading to the conclusion that the dolomites in the Nakhchivan region formed in riftogenic-sedimentary conditions during the Triassic period, involving mantle-derived magnesium-carbonate thermal waters.

Paleomagnetic Analysis

Magnetic susceptibility was measured in selected samples, and stepwise thermal and alternating magnetic field cleaning methods were applied to separate the initial magnetization components within the framework of paleomagnetic studies. Based on the obtained results, the possible horizontal movements of geological blocks during the Triassic period and the influence of the rift regime were assessed (Khalafly, 2007).

For paleomagnetic research, materials were collected from Mesozoic-aged sedimentary rocks from three cross-sections in Nakhchivan. This paleopole position is in fairly

good agreement with the mean Triassic pole position of the Turan Plate (149°E longitude; 49°N latitude). Additionally, a Triassic palaeogeographic reconstruction of Iran, Arabia (Gondwana), and the Turan Plate (Eurasia) is also presented (Soffel et al., 1996). To isolate

the characteristic remanent magnetization, both alternating and stable magnetic fields, as well as temperature demagnetization procedures, were used for detailed paleomagnetic analysis. The following results were obtained (Kodama, 2012) (Fig. 3.3).

Table 1

Primary paleomagnetic directions and paleomagnetic poles of the Trias rocks of Nakhchivan, T₁ in (Induan) T₁ ol (Olenekian) T₂ an (Anisian) T₂ ld (Ladinian) T₃ ca (Carnian) T₃ no (Norian) number of samples, D – Declination, Inc – Inclination, K = Fisher K, α_{95} = virtual geomagnetic pole (VGP) 95% cone of confidence

Spesimen	ϕ	λ	Dec	Inc	R	K	α_{95}	ϕ	Λ	Θ_1	Θ_2	Rot
T ₁ in	39.84	45.33	238	39	2.09	10	10	-21	282	11	3	CCW 58
T ₁ ol	39.502	45.334	192.9	8.5	20	21	7	-40	90.8	8	11	CCW 40
T ₂ an	39.503	45.197	207	20.1	31	9	10	-34	192	10	5	CCW 37
T ₂ ld	39.504	45.196	210	7.02	31	9	10	-38.9	185	10	5	CCW 30
T ₃ ca	39.504	45.195	139	13.8	20	21	13.8	-30	274	10	5	CCW 41
T ₃ no	39.500	45.192	148	2.73	21	21	10	-40	269	10	5	CCW 42

Induan: In between 3-7.9

Olenekian: In between 1-4.9

Anisian: In between 1-2.4

Ladinian: In between 1-3.16

Carnian: In between 2-9.3

Norian: In between 1.5-4.75

counterclockwise-CCW

Geodynamic Interpretation

Fisher Mean: Dec = 189.7°

I (Inclination): 15.1°

α_{95} (Confidence Interval): 8.5°

k (Concentration Parameter): 18

This data indicates that Nakhchivan was situated in an **equatorial–subtropical** position along the northern margin of the **Tethys Ocean**.

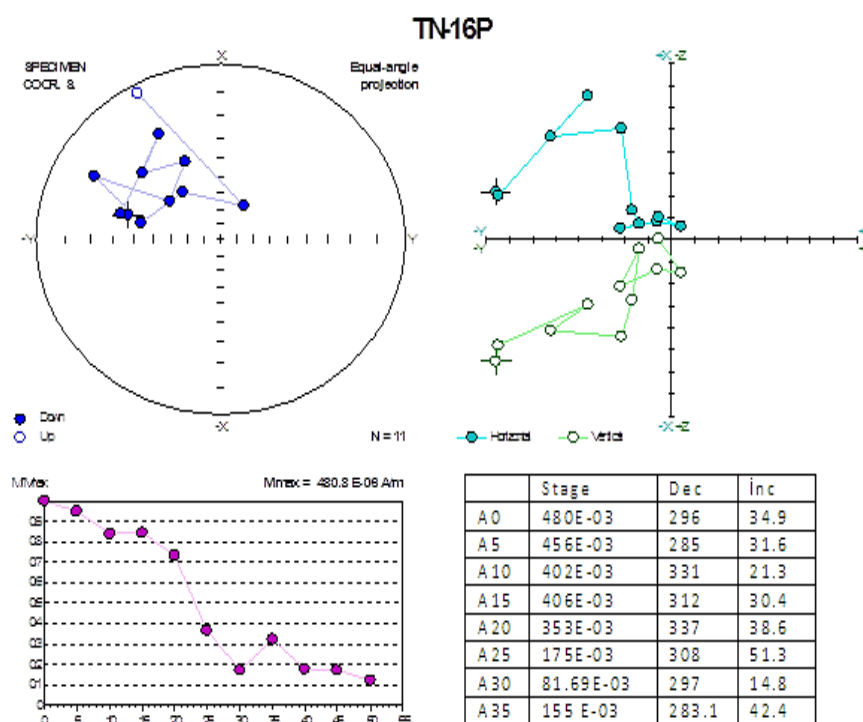


Fig. 3. Stereographic Trajectory of Movement for Sample No. 16 in the Tananam section

In the Tananam Gross-section, the direction during step-by-step demagnetization of sample No. 16 is shown. The (D, J) projections are presented (Fig. 2). In the top-right corner – **Zijderveld Dia-**

gram – shows the directional changes of the vectors during demagnetization (both in the horizontal and vertical planes).

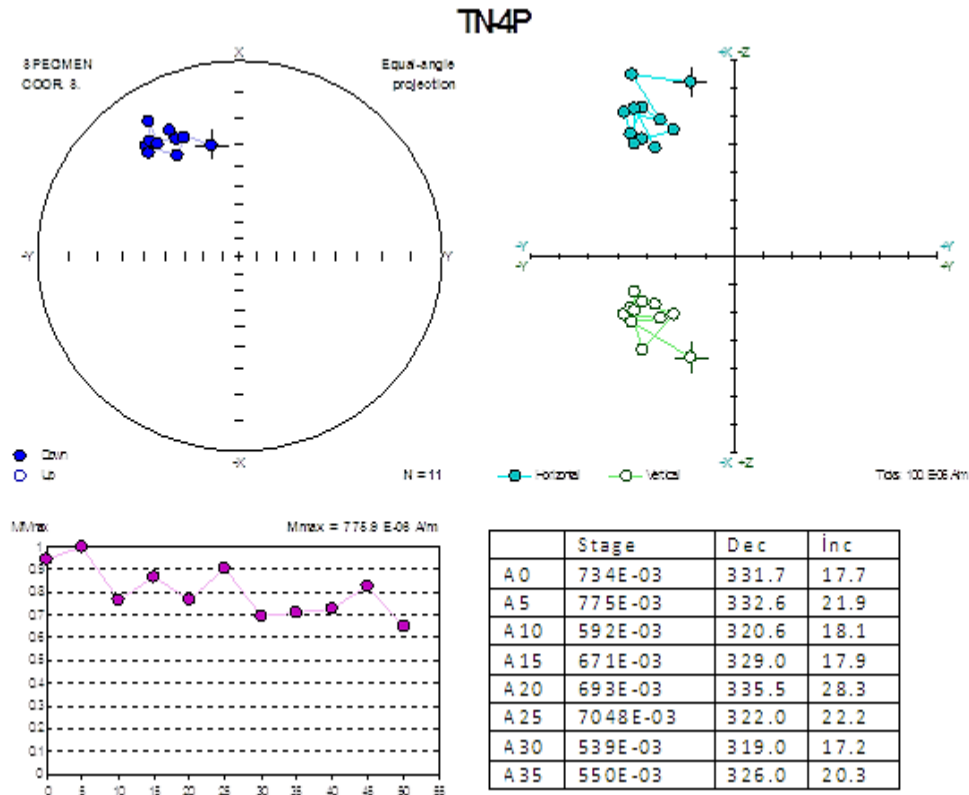


Fig. 3.1. Stereographic Trajectory of Movement for Sample No. 4 in the Tananam-Section

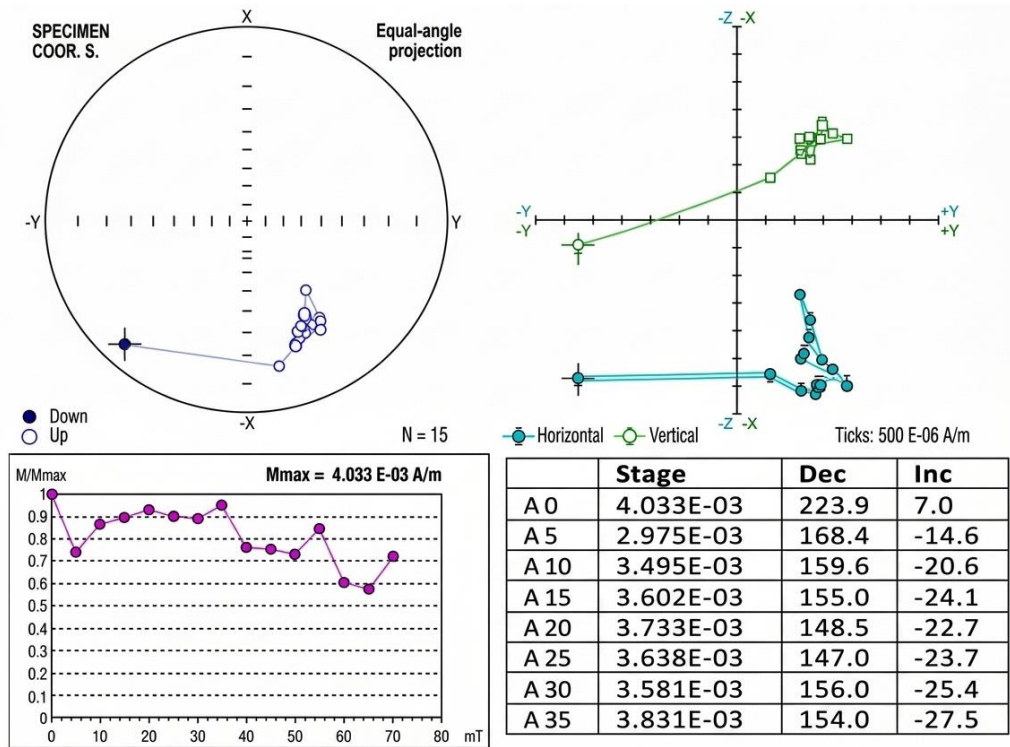


Fig. 3.2. Stereographic Trajectory of Movement for Sample No. 6 in the Nehram-Section (Trias)

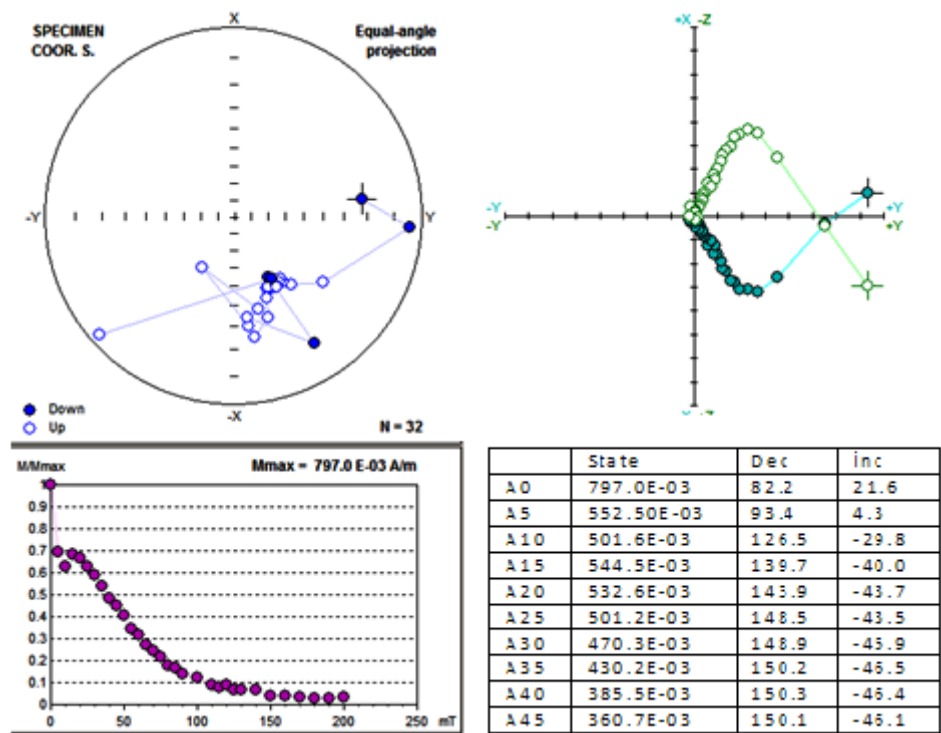


Fig. 3.3. Stereographic Trajectory of Movement for Sample No. 5 in the Nehram-Section (Trias)

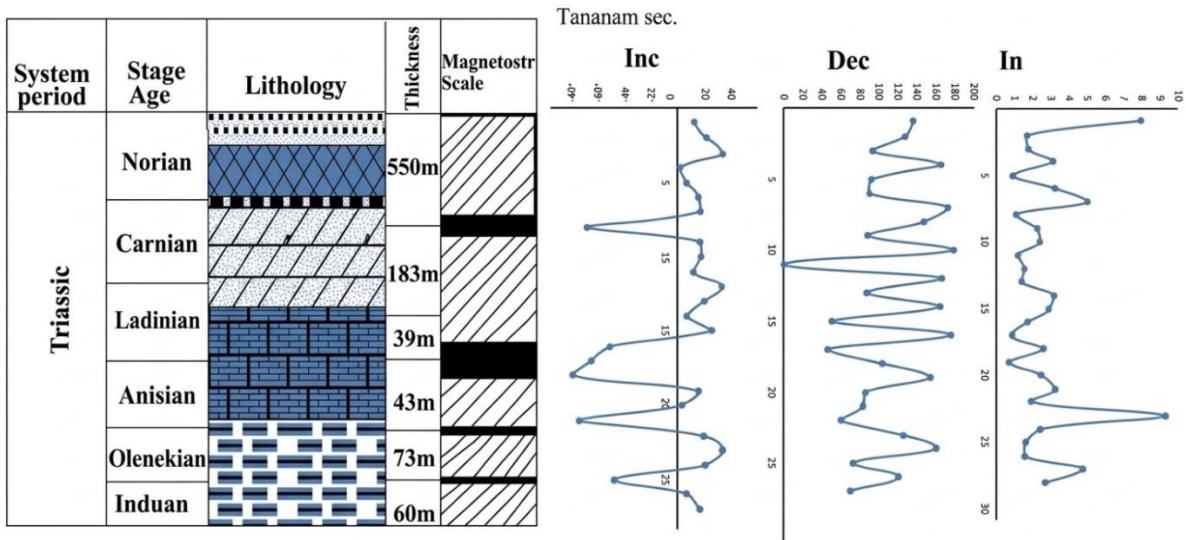


Fig. 4. Paleomagnetic Scale of Triassic-aged Sedimentary Rocks in the Tananam Cross-section

To the north of the Akhura village, the Lower Triassic sediments participate in a small synclinal fold structure and extend in a narrow strip towards the Kyurdkend area. Here, the Lower Triassic is deposited on the Upper Permian sediments and, in some places; it is associated with either the Upper Tabasaran or with the Upper Permian directly. To the north of the Akhura village, the Lower Triassic sediments again participate in a small synclinal fold structure and extend in a narrow strip towards the Kyurdkend area.

To the north of Akhura village, the Lower Triassic sediments participate in a small synclinal fold structure and extend in a narrow strip towards the Kyurdkend area. Here, the Lower Triassic rests on the Upper Permian sediments and, in places; it is associated with either the Upper Tabasaran or Upper Permian. To the north of the Akhura village, the Lower Triassic sediments again participate in a small synclinal fold structure and extend in a narrow strip towards the Kyurdkend area.

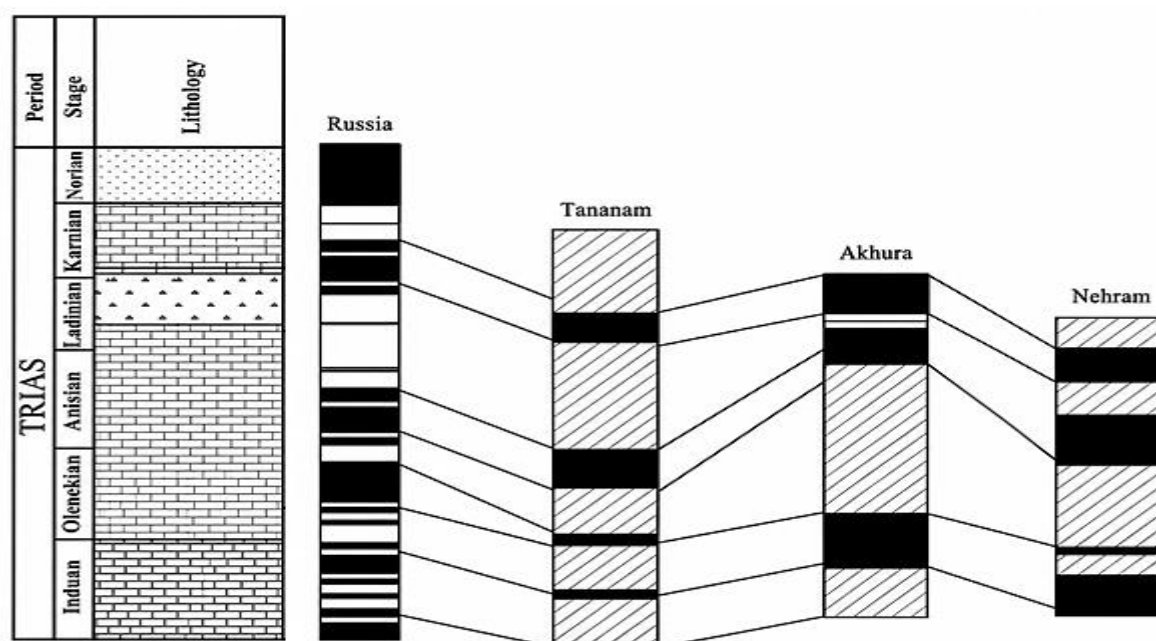


Fig. 5. Correlation of the Triassic-aged Cross-sections

Discussion

Thermal Cleaning Gives Similar Results

The majority of the studied samples demonstrate very simple demagnetization behavior. In some of them, a two-component magnetization is observed. However, in most cases, after the unstable part of the magnetization is removed by heating to 100-150°C, only one component remains (Fig. 3.1). This component corresponds to the high-temperature component observed in the two-component samples. It decreases towards the starting point in orthogonal diagrams and represents the characteristic remanent magnetization (ChRM) in both cases. The maximum blocking temperature of these ChRMs varies depending on the contacts. In samples taken from the Tananam and Akhura cross-sections, the maximum blocking temperature is typically around 600-640°C (Fig. 5), while in samples from the Tananam cross-section, ChRM disappears entirely only around 660-670°C (Fig. 3.2). Based on the maximum blocking temperature values, it can be said that the primary remanent magnetization carrier in the studied rocks is magnetite, which has been oxidized to various degrees. In all of the studied contacts, the average direction of ChRM is characterized by positive inclination and north-northeast declination (Table 1). The average direction obtained in the article for the Tananam–Akhura cross-sections aligns very well with the paleomagnetic direc-

tions presented for those cross-sections (Fig. 3). Since the bedding corrections applied for different outcrops were not significantly different, a reliable “fold test” could not be conducted. Therefore, results obtained by Nguen and Pecherski for the Triassic-aged rocks in neighboring areas are referenced. These results are almost identical to our paleomagnetic directions and confirm the Triassic age of the ChRMs isolated in the Tananam and Akhura cross-sections.

The average direction of ChRM obtained from the Central Iran zones does not statistically differ from the data we acquired. These directions significantly differ from both normal and reverse directions, and do not reflect the actual direction of the ancient geomagnetic field (Salehi et al., 2026). The similar directions of the outer values can be partially explained by the fact that at least five of them were taken from consecutive layers along the cross-section and were likely formed within a short time interval. The primary origin of the ChRM isolated in the Tananam, Akhura, and Central Iran cross-sections indicates that these rocks are suitable for paleointensity studies (Table 1). The double heating process was conducted in at least 16 stages, up to 650°C (Fig. 4). After each stage, TRM checks and magnetic susceptibility measurements were conducted. For each sample in paleointensity determination, 2.5 cm-sized two to four cubic samples were used. Some of the samples were heated in a

furnace with a residual magnetic field of less than 50 nT and processed in a device (LDA-5) that measures both stable and variable magnetic fields (Molostovski, 1985).

The Induan period (252-249 Ma years) forms the beginning of the Triassic period. And from a paleomagnetic point of view, it is considered one of the most complex stages in the history of the Earth.

$D = 238^\circ$ $Inc = 39^\circ$ $K = 10$ $\alpha_{95} = 10^\circ$
 $R = -58^\circ$ counterclockwise

Olenekian period (249-245 Ma) Tananam section:

$D = 192.9^\circ$ $Inc = 8.5^\circ$ $K = 21$ $\alpha_{95} = 7^\circ$
 $R = -40^\circ$

The Nakhchivan block was rotated in the counter-clockwise direction during this period.

Anisian period (Middle Triassic) (245-237 Ma) Paleomagnetic materials for the consist mainly of reddish carbonate and terrigenous sediments.

$D = 207^\circ$ $Inc = 20.1^\circ$ $K = 21$ $\alpha_{95} = 9.8^\circ$
 $R = -37^\circ$

Ladinian (Middle Triassic) (237-228 Ma)

During the Ladinian period of the studied Tananam section:

$D = 210^\circ$ $Inc = 7.02^\circ$ $K = 9$ $\alpha_{95} = 10^\circ$
 $R = -30^\circ$ (turned counter clockwise).

Carnian period (Upper Triassic) (228-216 Ma)

$Dor. = 139^\circ$ $Inc = 13.8^\circ$ $K = 9$ $\alpha_{95} = 13.8^\circ$
 For the Norian floor, the Eurasian ARWP

Dref = 300 is adopted.

Norian period (Upper Triassic) (216-203 Ma)

$D = 148^\circ$ $Inc = 2.73^\circ$ $K = 21$ $\alpha_{95} = 10^\circ$
 $R = Dobs-Dref$
 $R = 42^\circ$

Nakhchivan-Iranian microblocks were moving tectonically. It is widely used in regional studies between 30-90°.

The result we received corresponds to this regional model.

Results

This study is the first work conducted in the Nakhchivan region, at latitude of 39.5°N and 45.3°N, where paleomagnetic directions of the Triassic-aged sedimentary rocks have been obtained using complete demagnetization and principal component analysis (PCA) (Fig. 5). Nevertheless, the results from the Nakhchivan region show a high degree of agreement with neighboring regions and previous studies conducted on cross-sections of the same age.

REFERENCES

- Babayev Sh.A., Kengerli T.N., Mammadov A.B. Stratigraphy of Nakhchivan Autonomous Republic. Baku, 2016. (in Azerbaijani)
- Bagirova A.A., Rzaev A.G. Kinematic parameters of block movements in the Nakhchivan Autonomous Republic based on paleomagnetic data. Seismoprognozis Observation Territories, Vol. 15, No. 1, 2018, pp. 14-18.
- Bazhenova M.L. Relationship between paleomagnetic directions and lithology in Cretaceous and Paleocene sediments of the West Kopet Dag. Izvestiya, Academy of Sciences of the USSR, Physics of the Solid Earth, No. 8, 1983, pp. 67-75. (in Russian)
- Ismail-Zade A.D., Rustamov M.I., Kengerli T.N. Arazian Megazone. Geology of Azerbaijan, Vol. IV, Tectonics. Nafta-Press. Baku, 2005, pp. 338-359. (in Russian)
- Khalafly A.A. Supporting paleomagnetic section of the Middle-Upper Jurassic deposits of the Lesser Caucasus of Azerbaijan. Reports of the Academy of Sciences of Azerbaijan. Tahsil. Baku, 2007, 98 p. (in Russian)
- Khramov A.N., Sholpo L.E. Paleomagnetism. Nedra. Leningrad, 1967, 251 p. (in Russian)
- Kodama K.P. Paleomagnetism of Sedimentary Rocks: Processes and Interpretation. Wiley-Blackwell. Oxford, 2012, 157 p., <https://doi.org/10.1002/9781118384138>.
- Krasa D., Petersen K., Petersen N. Variable field translation balance. In: Gubbins D., Herrero-Bervera E. (eds.) Encyclopedia of Geomagnetism and Paleomagnetism. Springer. Dordrecht, 2007.
- Molostovski E.A. Stratigraphic aspects of paleomagnetism. Bulletin of the Moscow Society of Naturalists, Geological Series, Vol. 60, Issue 5, 1985, pp. 116-127. (in Russian)
- Rustamov M.I. Geology, geodynamics, magmatism and metallogeny of the Nakhchivan Autonomous Republic. Vol. I. Geology, geodynamics, magmatism and metallogeny of Nakhchivan AR. Nafta Press. Baku, 2023, 336 p. (in Russian)
- Salehi A., Wilmsen M., Zamanian E., Heubeck Ch. Cimmerian tectonostratigraphic events in east-central Iran revealed by a long drill core of the Shemshak Group (Upper Triassic–Middle Jurassic). Journal of Asian Earth Sciences, Vol. 297, Article number 106895, 2026, <https://doi.org/10.1016/j.jseaes.2025.106895>.
- Soffel H.C., Schmidt S., Davoudzadeh M., Rolf C. New palaeomagnetic data from Central Iran and a Triassic palaeoreconstruction. Geologische Rundschau, Vol. 85, 1996, pp. 293-302, <https://doi.org/10.1007/BF02422235>.

КОРРЕЛЯЦИЯ МАГНИТОСТРАТИГРАФИЧЕСКИХ ШКАЛ И ПАЛЕОМАГНИТНАЯ ХАРАКТЕРИСТИКА ТРИАСОВЫХ ОТЛОЖЕНИЙ НАХЧЫВАНСКОЙ АВТОНОМНОЙ РЕСПУБЛИКИ (АЗЕРБАЙДЖАН, ПЕРВЫЕ ДАННЫЕ)

Багирова А.А.

*Министерство науки и образования Азербайджанской Республики,
“Институт геологии” Публичное юридическое лицо, Азербайджан
AZ1073, Баку, просп. Г. Джавида, 119: arzu-bagirova2013@yandex.ru*

Резюме. В статье представлены результаты исследования мезозойских (триасовых) осадочных отложений на территории Нахчыванской Автономной Республики, посвящённые изучению горизонтальных движений земной коры и реконструкции, связанных с ними тектонических процессов. Палеомагнитные исследования были проведены на стратиграфических разрезах Ахура и Тананам, где детально изучены триасовые осадочные породы. На основе палеомагнитных данных были определены кинематические параметры тектонических блоков и величины их горизонтальных перемещений. Анализ литологических компонентов показал, что глины и мелкозернистые песчаники характеризуются наиболее устойчивой остаточной намагниченностью, крупнозернистые породы обладают метастабильными магнитными свойствами, тогда как крупнозернистые песчаники, доломиты и другие литологические разновидности отличаются неустойчивым магнитным поведением.

В процессе магнитной очистки (размагничивания) были выделены устойчивые компоненты остаточной намагниченности. В среднем их направления совпадают с направлениями намагниченности, установленными с помощью теста складчатости (fold test). В исследованных разрезах наблюдается закономерное чередование пород с нормальной и обратной магнитной полярностью. После термической и поэтапной магнитной очистки образцы, как с нормальной, так и с обратной полярностью из разрезов Ахура и Тананам приобрели единое характеристическое направление намагниченности. Это свидетельствует о синхронности естественной остаточной намагниченности (J_n) и подтверждает отсутствие вторичных компонентов намагниченности после размагничивания.

Целями настоящего исследования являлись изучение палеомагнитных свойств триасовых осадочных пород, распространённых на территории Нахчыванской Автономной Республики; определение положения северного геомагнитного полюса Земли в триасовый период; оценка горизонтальных перемещений и параметров вращения тектонических блоков; а также реконструкция геологической эволюции региона и его палеотектонического развития на основе палеомагнитных данных. Научная значимость настоящего исследования заключается в том, что палеомагнитные методы являются единственным количественным инструментом, позволяющим реконструировать палеотектоническую обстановку и оценивать относительные вращения различных геологических структур.

Настоящая работа представляет собой первое комплексное палеомагнитное исследование, выполненное в Нахчыванском регионе (39,5° с.ш., 45,3° в.д.), в котором палеомагнитные направления триасовых осадочных пород были определены с использованием полного размагничивания и метода анализа главных компонент (Principal Component Analysis, PCA). Полученные результаты хорошо согласуются с ранее опубликованными палеомагнитными данными из соседних регионов и стратиграфически сопоставимых триасовых разрезов, что подтверждает региональную согласованность и надёжность полученного палеомагнитного материала.

Ключевые слова: магнитная восприимчивость, стратиграфическое деление, геолого-геофизический анализ, разрезы Тананам, триасовый период

NAXÇIVAN MUXTAR RESPUBLİKASININ TRIAS ÇÖKÜNTÜLƏRİNİN MAQNİTOSTRATİQRAFİK ŞKALALARININ KORRELYASIYASI VƏ PALEOMAQNİT XARAKTERİSTİKASI (AZƏRBAYCAN, İLKİN MƏLUMATLAR)

Багирова А.Ә.

*Azərbaycan Respublikası Elm və Təhsil Nazirliyi,
“Geologiya İnstitutu” Publik Hüquqi Şəxsi (PHŞ), Azərbaycan
AZ1073, Bakı, H. Cavid pr., 119: arzu-bagirova2013@yandex.ru*

Xülasə. Məqalədə Naxçıvan Muxtar Respublikası ərazisində Mezozoy (Trias) çöküntülərinin öyrənilməsinin nəticələri, yer qabığının horizontal hərəkətləri və problemin həlli yolları təqdim olunur. Axura və Tənənəm kəsilişlərində paleomaqnit tədqiqatları aparılmış və Trias çöküntüləri öyrənilmişdir. Paleomaqnit məlumatları əsasında ilkin olaraq blokların kinematik parametrləri və onların horizontal yerdəyişmələri müəyyən edilmişdir. Oxşar nəticələr komponentlərin xarakteristikası zamanı da əldə olunmuşdur: gillər və xırdadənəli qumdaşları daha stabil, iri dənəli süxurlar metastabil, iri dənəli qumdaşları, dolomitlər və s. isə qeyri-sabitdir.

Maqnit təmizlənməsi prosesində maqnitlənmənin sabit komponentləri ayrılır. Orta hesabla onların istiqaməti kəskin üsulu ilə müəyyən edilən maqnitlənmə istiqaməti ilə üst-üstə düşür. Kəsilişlərdə düz və tərs maqnitlənməyə malik

süxurların müntəzəm növbələşməsi müşahidə olunur. Zaman və temperatur üzrə təmizlənmədən, həmçinin mərhələli maqnit təmizlənməsindən sonra Axura və Tənənəm kəsilişlərində həm düz, həm də tərs maqnitlənməyə malik süxurlar eyni istiqaməti alır. Bu, Jn-un sinxronluğunu və təmizlənmədən sonra Jn-də ikinci dərəcəli maqnitlənmə komponentlərinin olmadığını göstərir.

Bu tədqiqatın məqsədi Naxçıvan Muxtar Respublikası ərazisində aşkar edilmiş Trias çöküntü süxurlarının paleomaqnit xüsusiyyətlərini öyrənmək; bu geoloji dövrlərdə Yerin şimal geomaqnit qütbünün mövqeyini müəyyənləşdirmək; tektonik blokların üfüqi yerdəyişmələrini və fırlanma parametrlərini qiymətləndirmək; paleomaqnit məlumatlara əsaslanaraq bölgənin təkamülü və paleotektonik proseslərinin yenidən qurulması.

Apardığımız paleomaqnit tədqiqatlarının aktuallığı və əhəmiyyəti ondan ibarətdir ki, yalnız bu üsul vasitəsilə paleotektonik şəraiti müəyyən etmək və müxtəlif geoloji strukturların bir-birinə nisbətən fırlanmasını kəmiyyətcə qiymətləndirmək mümkündür.

Bu tədqiqat, tam demaqnitləşmə (maqnisizləşdirmə) və əsas komponentlərin analizi (PCA) metodlarından istifadə etməklə Trias yaşlı çökmə süxurların paleomaqnit istiqamətlərinin əldə edildiyi, 39.5° şimal enliyi və 45.3° şərq uzunluğunda yerləşən Naxçıvan bölgəsində aparılmış ilk işdir. Bununla belə, Naxçıvan bölgəsindən əldə olunan nəticələr qonşu regionlar və eyni yaşlı kəsilişlər üzərində aparılmış əvvəlki tədqiqatlarla yüksək dərəcədə uyğunluq təşkil edir.

Açar sözlər: maqnit həssaslığı, stratigrafik bölgü, geoloji-geofiziki analiz, Tənənəm kəsilişləri, Trias dövrü

INTEGRATED ANALYSIS OF GEOLOGICAL-GEOCHEMICAL AND
HYDROGEOLOGICAL CONDITIONS AND GIS ASSESSMENT FOR
REGIONAL PLANNING OF ECOLOGICAL INFRASTRUCTURE
IN EASTERN GEORGIA

Giorgadze A.^{1,2*}, Chikviladze Kh.¹, Oboladze S.^{1,3},
Mtchedlishvili G.¹, Buachidze N.⁴, Kavtaradze B.^{1,5}

¹Solid Waste Management Company of Georgia LTD, Georgia

14, A. Politkovskaya Str., Tbilisi, 0186

²G. Tsulukidze Mining Institute, Georgia

7, E. Mindeli Str., Tbilisi, 0186

³I. Javakhishvili Tbilisi State University,

Petre Melikishvili Institute of Physical and Organic Chemistry, Georgia

5, A. Politkovskaya Str., Tbilisi, 0186

⁴Georgian Technical University, Institute of Hydrometeorology, Georgia

150G, D. Agmashenebeli Str., Tbilisi, 0112

⁵I. Javakhishvili Tbilisi State University, Faculty of Exact and Natural Sciences, Georgia

3, I. Chavchavadze Ave., Tbilisi, 0179

*Corresponding author: giorgadze.anzori@gtu.ge

Summary. Safe management and disposal of hazardous waste is a critical environmental and public health priority globally, and an urgent infrastructure need for Georgia. Despite ongoing industrial growth and environmental regulatory approximation with European Union standards, Georgia currently lacks a modern, engineered, compliant facility dedicated to hazardous waste landfilling. As a result, hazardous industrial byproducts are often stockpiled on-site in temporary storage facilities or in unlined municipal dumpsites, threatening regional water resources and public health.

This study presents a GIS-based multi-criteria evaluation for hazardous waste landfill site selection in Eastern Georgia, focusing on the Marneuli, Gardabani, and Tetritskaro municipalities. A multi-layer spatial database was assembled in a GIS environment, incorporating a 20-meter resolution Digital Elevation Model (DEM) and derived hillshade, 1:25,000 topographic map, 1:200,000 geological map, regional seismic hazard model, landslide and mudflow susceptibility maps, hydrological networks, infrastructural layers, and cadastral property boundaries. Adopting the environmental criteria framework developed by the European Bank for Reconstruction and Development, candidate locations were evaluated across 20 social, environmental, technical, and geological parameters. Each parameter was scored on an integer suitability scale from 1 to 5. Spatial screening identified 10 candidate locations. Aggregated multi-criteria scoring revealed three primary candidate sites: Marneuli (73), Tsintskaro (71), and Former Military Site (65).

This research establishes an empirical, objective decision-support baseline to guide the development of Georgia's first hazardous waste disposal facility, and outlines a comprehensive 6-phase GIS workflow for regional environmental infrastructure planning.

Keywords: hazardous waste management, landfill site selection, Geographic Information Systems (GIS), Multi-Criteria Decision Analysis (MCDA), Eastern Georgia, environmental planning

© 2026 Earth Science Division, Azerbaijan National Academy of Sciences. All rights reserved.

Introduction

Rapid industrial expansion, urbanization, and technological modernization have generated substantial volumes of solid and hazardous waste globally (Kaza et al., 2018; Yatoo et al., 2024). While solid waste predominantly comprises biodegradable matter, paper, plastics,

and inert debris, hazardous waste consists of industrial byproducts, toxic chemical residues, heavy metals, medical waste, and flammable, corrosive, or ecotoxic compounds that pose severe risks to public health and ecological equilibrium (Singh, 2022). Mismanagement of such wastes can lead to long-term environmental

degradation, notably the contamination of surface and groundwater resources through toxic leachate percolation, soil salinization, and atmospheric emissions of volatile organic compounds (Kareem et al., 2023).

In Georgia, the transition toward modern environmental governance and industrial alignment with international standards has highlighted hazardous waste management as a critical national issue (Chikhradze et al., 2025). Georgia generates diverse industrial, medical, and agricultural chemical wastes, primarily concentrated along the economic and industrial transport corridors encompassing Tbilisi, Rustavi, and surrounding municipalities (Buachidze et al., 2016; Buachidze et al., 2021).

Despite substantial regulatory progress under the European Union–Georgia association agreement and the adoption of the national Waste Management Code, Georgia does not yet possess a single modern, engineered, compliant facility dedicated to the disposal or long-term containment of hazardous waste. As a consequence of this infrastructure deficit, hazardous industrial residues are frequently stored within aging industrial premises. Moreover, wastes are stockpiled in temporary on-site holding units that lack adequate containment safeguards (Le Pavic et al., 2026).

Establishing a hazardous waste landfill is one of the most contentious and complex spatial planning tasks in environmental engineering. Landfill site selection requires balancing environmental, hydrogeological, engineering, economic, and socio-political constraints.

The integration of Geographic Information Systems (GIS) with Multi-Criteria Decision Analysis (MCDA) has become the gold standard (Vijay et al., 2005). GIS provides capabilities to capture, store, analyze, manipulate, and visually present disparate geospatial layers, ranging from satellite remote sensing data, digital elevation models (DEM), and hydrological streams to infrastructural networks and cadastral layouts (Chalkias, Lasaridi, 2011). Furthermore, MCDA techniques provide structured mathematical and operational frameworks to weight qualitative and quantitative decision parameters, reconcile competing objectives, and rank spatial alternatives (Gorsevski et al., 2012; Singh, 2019; Ali et al., 2023).

While international studies have frequently coupled GIS with the Analytic Hierarchy Process (AHP), Fuzzy AHP, Ordered Weighted Averaging (OWA), and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to allocate municipal solid waste sites, hazardous waste landfill siting requires specialized regulatory, engineering, and geo-hazard considerations (Chang et al., 2008; Wang et al., 2009; Nas et al., 2010; Khorsandi et al., 2019; Elkhachy et al., 2023).

This study presents a GIS-based multi-criteria evaluation for hazardous waste landfill siting in Eastern Georgia, focusing on Marneuli, Gardabani, and Tetrtskaro municipalities. Utilizing the systematic environmental criteria guidelines formulated by the European Bank for Reconstruction and Development, this study integrates 20 social, environmental, technical, and geological criteria across high-resolution spatial datasets.

Through an objective scoring framework, 10 candidate locations (see Fig. 1) are screened and ranked. The ultimate goal of this research is to resolve the infrastructural deficit in Georgia's hazardous waste sector by identifying geologically secure, environmentally robust, and socially acceptable candidate locations for future facility development.

Materials and Methods

Study area description

The study area is located in Eastern Georgia within the Kvemo Kartli region (see Table 1), encompassing sections of the Marneuli, Gardabani, and Tetrtskaro municipalities, situated directly south and southeast of Tbilisi and adjacent to the industrial center of Rustavi. Geographically, this territory serves as a core logistical, industrial, and agricultural center of the South Caucasus.

The terrain ranges from flat alluvial plains and low-elevation semi-arid plateaus along the Mtkvari River basin to hilly terrain and structural cuestas formed by the foothills of the Lesser Caucasus (Tielidze, 2019). The regional climate is predominantly dry semi-arid to temperate continental, characterized by hot summers, moderately cold winters, and mean annual precipitation between 400 and 550 mm (Keggenhoff et al., 2014).

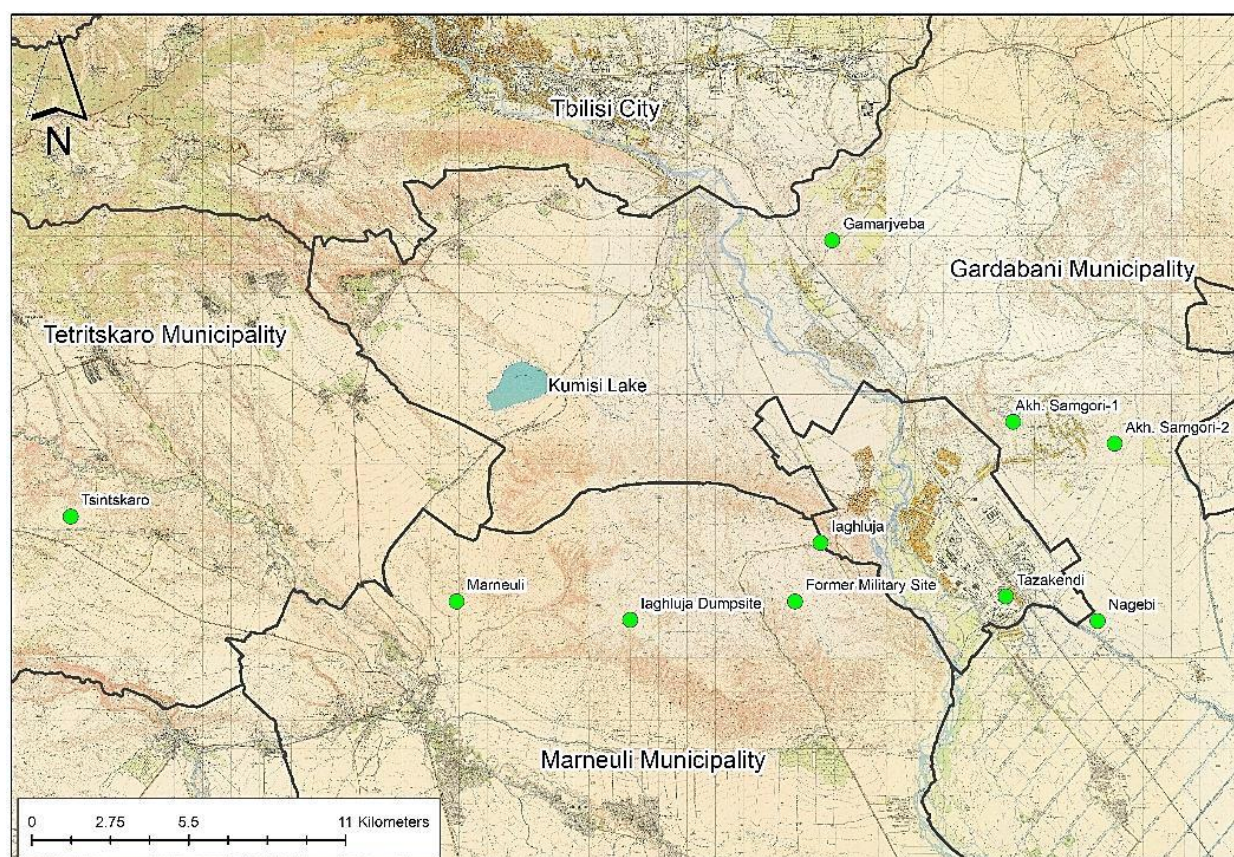


Fig. 1. Candidate sites on a 1:25,000 scale topographic map

The hydrographic network is controlled by the Mtkvari River and its key regional tributaries, including the Khrami and Algeti rivers, alongside enclosed water bodies such as Lake Kumisi. Groundwater configurations vary across the study territory: shallow water tables characterize the river floodplains, while deeper, confined, and semi-confined aquifers underlie

the elevated structural plateaus, all these generalized information about groundwater levels were obtained from state hydrogeological maps. Land use is divided between irrigated agricultural farmlands, dry pastures, expanding suburban agglomerations, transport infrastructure, and heavy industrial installations in Rustavi.

Table 1

Coordinates of candidate sites (UTM -38N Zone)

X Coordinate	Y Coordinate	Location
498002	4608904	Gamarjveba
496697	4596234	Former Military Site
497595	4598289	Iaghluja
504354	4602529	Akhali Samgori-1
507911	4601769	Akhali Samgori-2
504094	4596407	Tazakendi
507314	4595547	Nagebi
471284	4599214	Tsintsikaro
484819	4596234	Marneuli
490913	4595585	Iaghluja Dumpsite

Regional geological, tectonic and geohazard setting

As hazardous waste landfills require isolation from the biosphere across multi-decadal time horizons, the geological barrier represents the single most important safety component. The candidate territories are situated within the Marneuli structural block, which belongs to the weakly folded sedimentary cover of the Bolnisi subzone within the Artvin-Bolnisi tectonic zone of the Lesser Caucasus fold-and-thrust belt system (Adamia et al., 2017; Alania et al., 2026). Stratigraphically, the candidate sites sit atop two primary sedimentary suites: 1. Lower Oligocene Sakaraulo Stage (N_1^{1sk}): Dominated lithologically by thick molassic successions of arkosic and greywacke sandstones intercalated with thick layers of non-carbonate, jarosite-bearing, and gypsiferous clays. These dense clay layers exhibit low hydraulic conductivity and high clay mineral contents, offering natural impermeable containment properties. 2. Lower Miocene Maeotian-Pontian Stages (N_1^{3m-p}): Comprising thick clays and fine sandstones, occasionally interbedded with polymictic conglomerates. The dominant horizons provide natural attenuation barriers that prohibit downward migration of hazardous leachates (Gudjabidze et al., 1977).

Seismic hazards here are governed by the ongoing deformation within the Arabia-Eurasia convergence zone (Alania et al., 2018; Alania et al., 2022). According to the probabilistic seismic hazard and Peak Ground Acceleration (PGA) mapping for Georgia (Onur et al., 2020), the candidate locations fall within a uniform regional seismic zone characterized by a PGA reference value of 0.24 g (with a 10% exceedance probability in 50 years). Exogenous geological hazards, specifically landslide and mudflow susceptibility, were evaluated using regional geohazard inventories and topographic slope gradients. Hilly margins and dissected plateau slopes in Kvemo Kartli display moderate-to-high susceptibility to gravitational mass movements, whereas the low-gradient plateau surfaces and alluvial terraces exhibit low susceptibility.

Geospatial data acquisition and processing

Primary and secondary spatial datasets were processed using GIS software. A 1:25,000-scale topographic map was used to extract administra-

tive boundaries, populated places, transport axes, and spot elevations. Cadastral land-registry polygons were integrated to identify public versus private land ownership boundaries and legal land use categories. A 20-meter spatial resolution Digital Elevation Model (DEM) was used to compute topographic surface metrics, including terrain slope, topographic aspect, and a hillshade model. These layers enabled the identification of low-gradient terrain to minimize excavation volumes and erosion risks. The 1:200,000 Geological Map of Georgia (Gudjabidze et al., 1977) was used to establish surface lithological units. Also, rivers, secondary channels, natural lakes and canals were mapped as polyline and polygon layers. Spatial layers were assembled for airfields/aerodromes, archaeological and cultural monuments, protected conservation territories (e.g. the Gardabani Managed Reserve), railways, and road arteries, while distance buffers of 500 meters were established around preliminary candidate locations to evaluate local isolation margins (See Fig. 4).

Multi-criteria Decision Analysis (MCDA) framework

The initial 10 candidate locations were empirically identified and validated through extensive field campaigns, including site assessments conducted during the EBRD project in 2024. In this study, the constraint and exclusion process is directly embedded within the scoring matrix; sites exhibiting critical environmental or technical deficiencies received minimum scores, effectively excluding them from final consideration and isolating the top-scoring locations. The model evaluates 20 discrete spatial parameters grouped into three main categories: social, environmental, and technical/geological (see Table 2). Candidate sites are assigned suitability rating scores for each parameter on an integer scale from 1 to 5.

Score 1 (poor) means that conditions pose severe environmental risks, direct social conflicts, or insurmountable technical barriers that cannot be mitigated by standard engineering practices. Score 2 (low suitability) represents that conditions are highly unfavorable and would require extensive engineering interventions or complex reclassifications to meet minimum safety standards. Score 3 (moderate) is

acceptable conditions but requires standard engineering adjustments or mitigations. Score 4 (High) means favorable conditions that naturally align with safety and operational requirements, requiring minimal technological intervention, while Score 5 (optimal) is the highest tier of suitability, providing maximum natural environmental containment, optimal logistical efficiency, and zero social or legal conflicts.

Results and Discussion

The scoring results clear distinction between the top three (Marneuli, Tsinskaro, Former Military Base) candidate sites (scores 65-73), while the remaining candidate locations scored 51-64. Akhali Samgori-2 (51 points), Akhali Samgori-1 (56 points), and Tazakendi (63 points) scored poorly across hydrogeologi-

cal criteria. These locations are underlain by shallow water tables, lie close to drainage channels, and feature Quaternary alluvial gravels at the surface rather than impermeable bedrock. These conditions increase the vulnerability of regional aquifers to leachate migration. Nagebi (55 points) suffered from private landownership, inadequate area, irregular boundary geometry, and shallow groundwater conditions. Gamarjveba (56 points) showed limited contiguous area, close proximity to suburban development corridors, and surface exposures of alluvial formations. Iaghluja Dumpsite (64 points) and Iaghluja Plateau (60 points) provide impermeable soils, but scored lower due to poor road access, uneven morphology, complex local topography, and existing dumping operations.

Table 2

Multi-criteria evaluation parameters template for the candidate sites

Parameters	Basis of value selection (Score)		
	1-2	3	4-5
Type of access road	Track	Minor road	Main road
Distance to main road	>10 km	2-10 km	<2 km
Distance to railway sidings	>5 km	2-5 km	<2 km
Railway sidings on site	No	Possibly	Yes
Distance to power supply	>1 km	0.5-1 km	<500 m
Use of site by local population	Often	Moderate	No
Depth to aquifer	<10 m	10-50 m	>50 m
Distance to nearest surface water	<500 m	0.5-1 km	>1 km
Main ownership of land	Private	State	Owned
Current activities on site	Active	Possibly	No
Existing facilities on site	No	Some	Yes
Size (minimum 20 Ha)	Small	Adequate	Large
Topography	Steep	Moderate	Level
Landform	Uneven	Rough	Flat
Shape (length to breadth ratio)	Irregular	>3	1-2
Geological strata at surface	Alluvium	Rock	Clay
Chemically aggressive minerals	High	Moderate	Low
Susceptibility to flooding and erosion	High	Moderate	Low
Mineral resources on site	Definite	Possible	No
Mineral reserves permitted	Definite	Possible	No

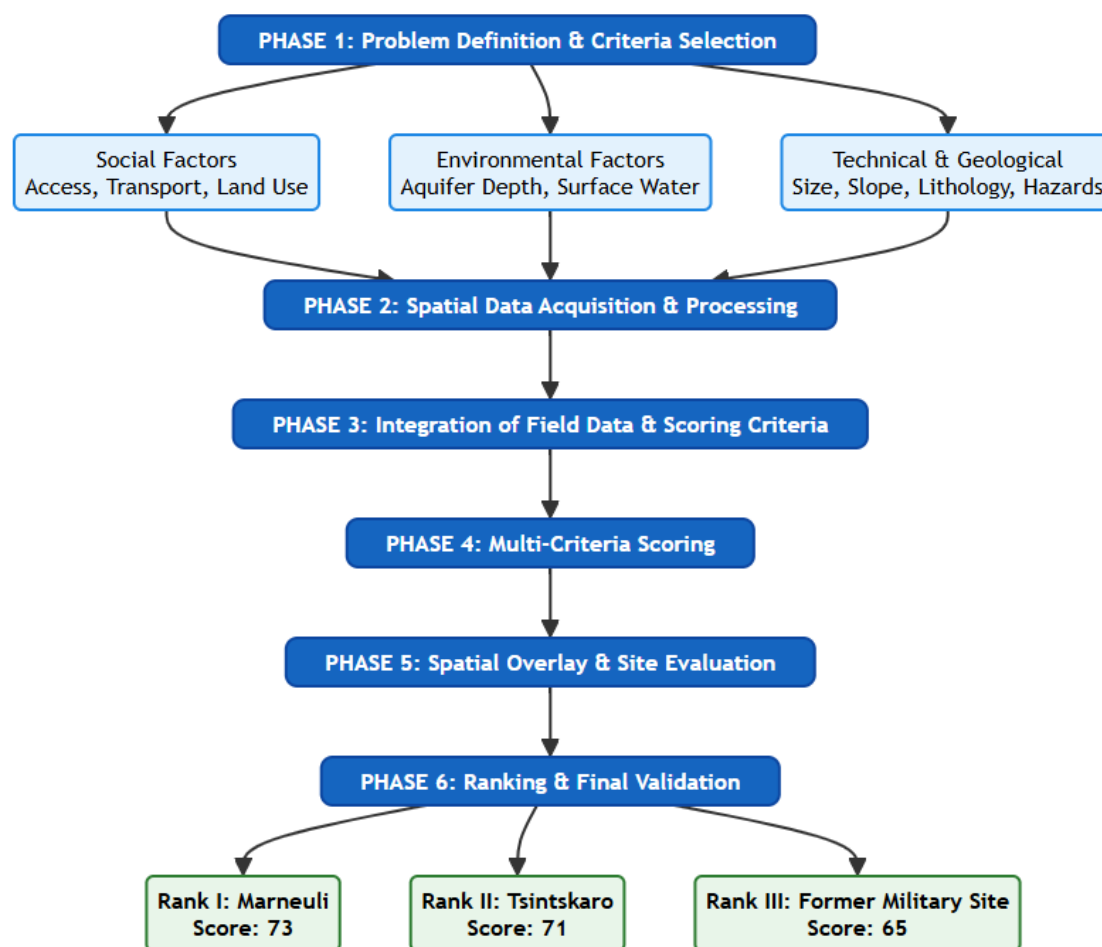


Fig. 2. A 6-phase GIS workflow for hazardous waste landfill siting

In this assessment, an unweighted linear additive scoring model was utilized, assigning equal mathematical weight to all 20 social, environmental, and technical parameters. Each criterion was scored strictly on a 1 to 5 scale, yielding a maximum theoretical site score of 100 (See Fig. 3). This unweighted approach was adopted to establish a transparent, objective screening baseline and to eliminate the subjective biases often associated with expert-assigned weighting frameworks. Consequently, the final rankings exhibit narrow numerical margins, particularly between the top-tier locations: Marneuli (73 points) and Tsintskaro (71 points).

Because of these small score differences, the specific ranking order of the top candidate sites is highly sensitive to minor parameter fluctuations; a 1- or 2-point adjustment in a secondary logistical parameter (such as access road quality or proximity to power supplies) could

alter the sequential ranking of the top two sites. However, despite this mathematical sensitivity at the top of the ranking, the overall screening result remains appropriate. The clear separation between the top three candidate sites (65-73 points) and the lower-tier sites (51-64 points) is driven consistently by critical, high-impact environmental parameters. Sites that scored low were ultimately constrained by fundamental hydrogeological factors - such as shallow aquifers (<10 m) and permeable alluvial geology, which cannot be easily mitigated by engineering interventions. Therefore, while the precise 1st, 2nd, and 3rd place rankings may shift based on future detailed weighting, these three sites are definitively validated as the most secure locations for subsequent on-site geotechnical characterization and Environmental and Social Impact Assessments (ESIAs).

Evaluated Parameter	Marneuli	Tsintskaro	Former Military	Iaghluja Dumpsite	Tazakendi	Iaghluja	Akh. Samgori-1	Gamarjveba	Nagebi	Akh. Samgori-2
1. Access road type	3	3	1	2	5	2	3	3	4	3
2. Dist. to main road	4	4	3	3	5	4	4	4	5	4
3. Dist. to rail sidings	3	3	1	1	4	1	3	3	4	2
4. Rail sidings on site	1	1	1	1	1	1	1	1	1	1
5. Dist. to power supply	4	4	3	4	4	3	4	4	4	4
6. Site use by population	5	3	3	2	3	3	4	4	3	3
7. Depth to aquifer	3	3	3	3	1	3	2	2	1	1
8. Dist. to surface water	4	4	4	4	1	4	1	1	1	1
9. Land ownership	5	3	3	5	3	3	1	3	0	1
10. Current site activities	4	4	3	2	3	3	3	3	3	3
11. Existing facilities	1	1	3	1	1	1	1	1	1	1
12. Size (≥ 20 ha)	5	5	5	3	4	5	5	3	0	2
13. Topography (Slope)	3	5	4	4	4	3	3	3	4	3
14. Geomorphology	3	4	4	4	4	2	2	2	2	3
15. Geometric shape	4	4	4	4	4	2	3	4	0	3
16. Surface geology	4	3	4	4	1	4	1	1	4	1
17. Aggressive minerals	3	3	3	3	3	3	3	3	3	3
18. Flood/erosion risk	4	5	3	4	4	3	4	3	3	4
19. Mineral resources	5	5	5	5	4	5	4	4	5	4
20. Permitted reserves	5	5	5	5	4	5	4	4	5	4
Total Aggregated Score	73	71	65	64	63	60	56	56	55	51

Fig. 3. Full multi-criteria scoring matrix for all candidate locations

Conclusion

Our study applied a GIS-based multicriteria evaluation framework (See Fig. 2) to select suitable landfill sites for hazardous waste disposal in Eastern Georgia, focusing on the Marneuli, Gardabani, and Tetrtskaro municipalities. As mentioned above, by integrating 20 social, environmental, technical, and geological criteria based on the EBRD guidelines, 10 candidate locations were screened and ranked.

Marneuli site (Rank I, Score: 73) is the optimal candidate location. Key advantages include designated non-agricultural land status,

full state ownership, large area, direct access to paved transport arteries, an impermeable substrate of Maeotian-Pontian clays, and compatible land use legal status.

Tsintskaro site (Rank II, Score: 71) is also a strong candidate featuring level terrain, low erosional risks, a deep aquifer, thick impermeable Sakaraulo clay strata, and co-location within an established industrial waste corridor (adjacent to a regional municipal landfill and industrial explosives plant), though it requires agricultural land reclassification.

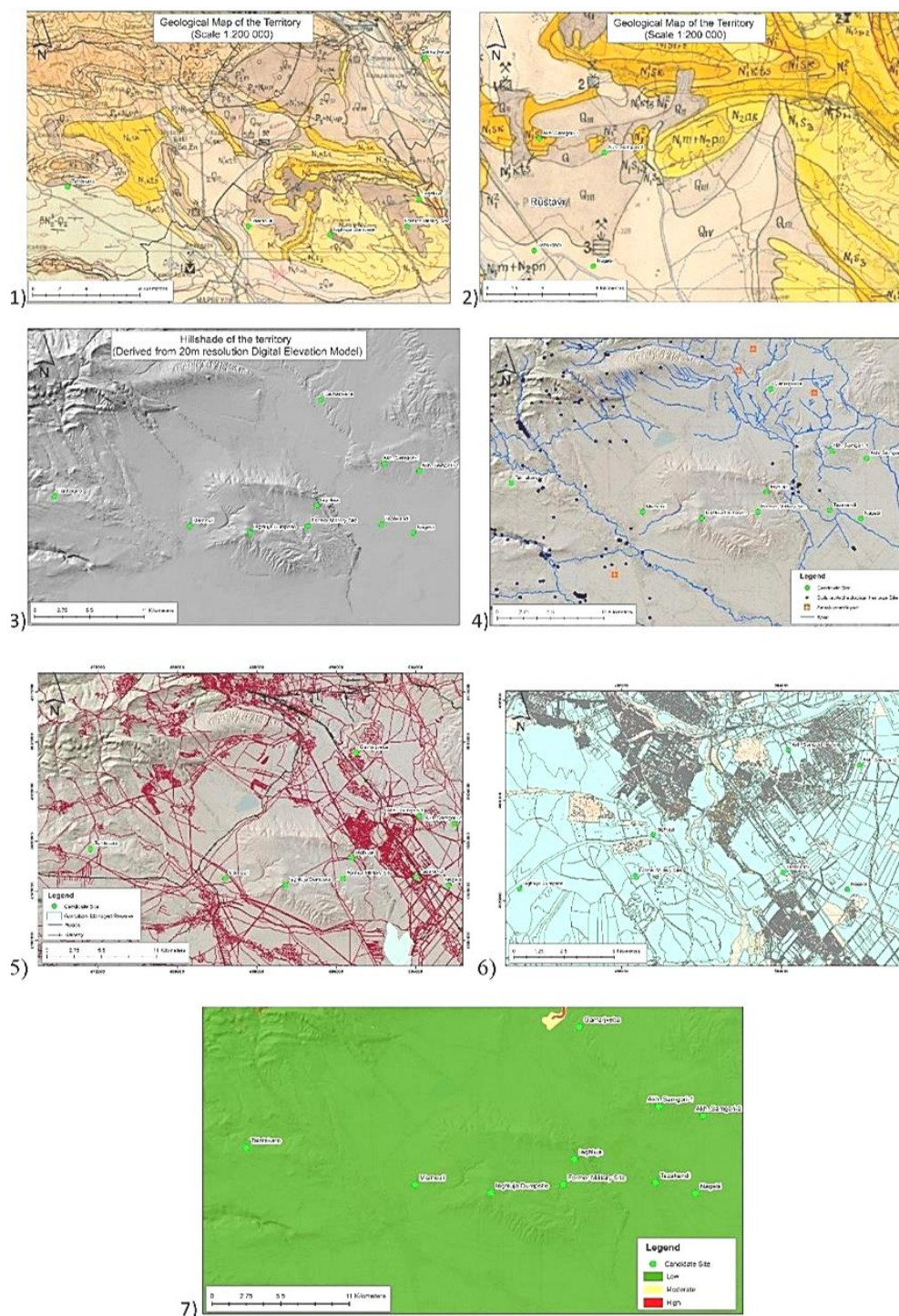


Fig. 4. 1) and 2) 1:200,000 scale geological maps; 3) Hillshade derived from a 20-meter resolution DEM; 4) Airports, cultural heritage sites and hydrographic network; 5) Protected area, road and railway systems; 6) Landownership; 7) Geohazard zoning

Former Military site (Rank III, Score: 65) is a viable candidate offering the largest buffer distance to residential settlements (3.7 km) and direct on-site railway system connections, though it requires road surface upgrades.

These results offer an empirical, scientifically grounded roadmap for policymakers, environmental engineers, and international financial institu-

tions. Prior to final site commissioning, next steps must focus on detailed geotechnical borehole drilling and in-situ hydraulic conductivity testing across the top-ranked candidate locations, comprehensive site-specific Environmental and Social Impact Assessments (ESIAs), structural seismic design of multi-barrier containment cells calibrated to the local (0.24 g) PGA hazard parameter,

and transparent public consultation processes to build community engagement and trust.

Competing interests

The authors declare that they have no competing interests.

Authors' contribution

A.G. and K.C. conceived of the presented idea. A.G. took the lead in writing the manu-

script. K.C. and B.K. reviewed and edited the manuscript. A.G. processed all visual materials. All authors provided critical feedback and helped shape the research, analysis, and manuscript.

Acknowledgement: The authors would like to thank the Editor-in-Chief, the reviewer and Ms. Samira Malikova for their helpful and constructive comments and suggestions throughout the review process.

REFERENCES

- Adamia S., Chabukiani A., Chkhotua T., Enukidze O., Sadradze N., Zakariadze G. Tethyan evolution and continental collision in Georgia. In: Sorkhabi R. (ed.) *Tectonic Evolution, Collision, and Seismicity of Southwest Asia: In Honor of Manuel Berberian's Forty-Five Years of Research Contributions*. The Geological Society of America, Special papers, Vol. 525, 2017, pp. 501-535, [https://doi.org/10.1130/2017.2525\(16\)](https://doi.org/10.1130/2017.2525(16)).
- Alania V., Enukidze O., Glonti N., Razmadze A., Chabukiani A., Giorgadze A., Glonti B.V., Koiava K., Beridze T., Khutsishvili S., Chagelishvili R. Structural architecture of the Kura foreland fold-and-thrust belt using seismic reflection profile, Georgia. *Universal Journal of Geoscience*, Vol. 6, No. 6, 2018, pp. 184-190, <https://doi.org/10.13189/ujg.2018.060602>.
- Alania V., Melikadze G., Pace P., Fórizs I., Beridze T., Enukidze O., Giorgadze A., Razmadze A. Deformation structural style of the Rioni foreland fold-and-thrust belt, western Greater Caucasus: Insight from the balanced cross-section. *Frontiers in Earth Science*, Vol. 10, Article number 968386, 2022, <https://doi.org/10.3389/feart.2022.968386>.
- Alania V., Beridze T., Enukidze O., Gusmeo T., Razmadze A., Tevzadze N., Vashakidze G. Deep Structure and Deformation Structural Style of the Georgian Part of Lesser Caucasus Orogen. In: Mukherjee S. (ed.) *Structural Geology and Tectonics*. Springer Nature Singapore, 2026, pp. 1-14, https://doi.org/10.1007/978-981-95-4743-2_1.
- Ali I., Islam A., Ali S.M., Adnan S. Identification and selection of suitable landfill sites using GIS-based multi-criteria decision analysis in the Peshawar District, Pakistan. *Waste Management & Research*, Vol. 41, Issue 3, 2023, pp. 608-619, <https://doi.org/10.1177/0734242X221124069>.
- Buachidze N., Chikviladze K., Kordzakhia G., Shubladze E., Shavliashvili L. Research of Uncontrolled Landfills Impact on Environment in Georgia. *American Journal of Environmental Protection*, Vol. 5, Issue 3, 2016, pp. 65-70, <https://doi.org/10.11648/j.ajep.20160503.14>.
- Buachidze N., Dzebisashvili N., Gurguliani I., Chikviladze K., Ghosh S.K. Circular Economy of Georgia. In: Ghosh S.K. and Ghosh S.K. (eds.) *Circular Economy: Recent Trends in Global Perspective*. Springer Nature Singapore, Singapore, 2021, pp. 359-382, https://doi.org/10.1007/978-981-16-0913-8_12.
- Chalkias C., Lasaridi K. Benefits from GIS based modelling for municipal solid waste management. *Integrated Waste Management* (Kumar S., ed.), Vol. 1, 2011, pp. 417-436, <https://doi.org/10.5772/17087>.
- Chang N.B., Parvathinathan G., Breeden J.B. Combining GIS with fuzzy multicriteria decision-making for landfill siting in a fast-growing urban region. *Journal of environmental management*, Vol. 87, Issue 1, 2008, pp. 139-153, <https://doi.org/10.1016/j.jenvman.2007.01.011>.
- Chikhradze N., Elizbarashvili M., Dzebisashvili N., Khachidze M., Tsintsadze M., Dvalashvili G., Rikadze Z. Integrating Waste Legislation and Circular Economy Strategies in Climate Policy: International Lessons and Georgia's Experience. *The Journal of Solid Waste Technology and Management*, Vol. 51, No. 4, 2025, pp. 765-776, <https://doi.org/10.5276/jswtm/iswmaw/514-1/2025.765>.
- Elkhrachy I., Alhamami A., Alyami S.H. Landfill site selection using multi-criteria decision analysis, remote sensing data, and geographic information system tools in Najran City, Saudi Arabia. *Remote Sensing*, Vol. 15, Issue 15, Article number 3754, 2023, <https://doi.org/10.3390/rs15153754>.
- Gorsevski P.V., Donevska K.R., Mitrovski C.D., Frizado J.P. Integrating multi-criteria evaluation techniques with geographic information systems for landfill site selection: a case study using ordered weighted average. *Waste management*, Vol. 32, Issue 2, 2012, pp. 287-296, <https://doi.org/10.1016/j.wasman.2011.09.023>.
- Gudjabidze G., Kandelaki D., Geguchadze Sh., Jighauri D., Torozov R., Pruidze M., Adamia Sh., Javakhishvili Sh., Tsagareli A., Buleishvili D., Edilashvili V. *Geological maps of Georgia, scale: 1:200,000*. Ministry of Geology, Tbilisi, 1977.
- Kareem H.A., Riaz S., Sadia H., Mehmood R. Industrial Waste, Types, Sources, Pollution Potential, and Country-Wise Comparisons. In: Riaz U., Iqbal S. and Jamil M. (eds.) *Waste Problems and Management in Developing Countries*. Apple Academic Press, 2023, pp. 169-203, <https://doi.org/10.1201/9781003283621-8>.

- Kaza S., Yao L.C., Bhada-Tata P., Van Woerden F., Levine D. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. Urban Development Series. Washington, DC: World Bank, 2018, <https://doi.org/10.1596/978-1-4648-1329-0>.
- Keggenhoff I., Elizbarashvili M., Amiri-Farahani A., King L. Trends in daily temperature and precipitation extremes over Georgia, 1971-2010. Weather and climate extremes, Vol. 4, 2014, pp. 75-85, <https://doi.org/10.1016/j.wace.2014.05.001>.
- Khorsandi H., Faramarzi A., Aghapour A.A., Jafari S.J. Landfill site selection via integrating multi-criteria decision techniques with geographic information systems: a case study in Naqadeh, Iran. Environmental monitoring and assessment, Vol. 191, No. 12, Article number 730, 2019, <https://doi.org/10.1007/s10661-019-7863-8>.
- Le Pavic G., Bescotti E., Andguladze A., Bachelet A., Buzogány A., Carvell M., Delcour L., Gavrilova S., Gonashvili-Münch I. Forum: Bridging divides—Georgia, the European Union, and the challenges of cooperation amid conflicts. Cooperation and Conflict, 2026, <https://doi.org/10.1177/00108367261432930>.
- Nas B., Cay T., Iscan F., Berktaş A. Selection of MSW landfill site for Konya, Turkey using GIS and multi-criteria evaluation. Environmental monitoring and assessment, Vol. 160, No. 1-4, 2010, pp. 491-500, <https://doi.org/10.1007/s10661-008-0713-8>.
- Onur T., Gök R., Godoladze T., Gunia I., Boichenko G., Buzaladze A., Tumanova N., Dzmanashvili M., Sukhishvili L., Javakishvili Z., Cowgill E., Bondár I., Yetirmishli G. Probabilistic seismic hazard assessment using legacy data in Georgia. Seismological Research Letters, Vol. 91, No. 3, 2020, pp. 1500-1517, <https://doi.org/10.1785/0220190331>.
- Singh A. Remote sensing and GIS applications for municipal waste management. Journal of environmental management, Vol. 243, 2019, pp. 22-29, <https://doi.org/10.1016/j.jenvman.2019.05.017>.
- Singh O. Chapter 19 – Forecasting trends in the generation and management of hazardous waste. In: Yadav D.K., Kumar P., Singh P. and Vallero D.A. (eds.) Hazardous Waste Management: An Overview of Advanced and Cost-Effective Solutions. Elsevier, 2022, pp. 465-489, <https://doi.org/10.1016/B978-0-12-824344-2.00015-X>.
- Tielidze L. (Ed.). Geomorphology of Georgia. Geography of the Physical Environment. Springer International Publishing, Cham, 2019, <https://doi.org/10.1007/978-3-319-77764-1>.
- Vijay R., Gupta A., Kalamdhad A.S., Devotta S. Estimation and allocation of solid waste to bin through geographical information systems. Waste Management & Research, Vol. 23, Issue 5, 2005, pp. 479-484, <https://doi.org/10.1177/0734242X05057763>.
- Wang G., Qin L., Li G., Chen L. Landfill site selection using spatial information technologies and AHP: a case study in Beijing, China. Journal of environmental management, Vol. 90, Issue 8, 2009, pp. 2414-2421, <https://doi.org/10.1016/j.jenvman.2008.12.008>.
- Yatoo A.M., Hamid B., Sheikh T.A., Ali S., Bhat S.A., Ramola S., Ali M.N., Baba Z.A., Kumar S. Global perspective of municipal solid waste and landfill leachate: generation, composition, eco-toxicity, and sustainable management strategies. Environmental Science and Pollution Research, Vol. 31, No. 16, 2024, pp. 23363-23392, <https://doi.org/10.1007/s11356-024-32669-4>.

ИНТЕГРАЛЬНЫЙ АНАЛИЗ ГЕОЛОГО-ГЕОХИМИЧЕСКИХ И ГИДРОГЕОЛОГИЧЕСКИХ УСЛОВИЙ И ГИС-ОЦЕНКА ПРИ РЕГИОНАЛЬНОМ ПЛАНИРОВАНИИ ЭКОЛОГИЧЕСКОЙ ИНФРАСТРУКТУРЫ ВОСТОЧНОЙ ГРУЗИИ

Гиоргадзе А.^{1,2*}, Чиквиладзе Х.¹, Оболадзе С.^{1,3}, Мchedlishvili Г.¹,
Буачидзе Н.⁴, Кавтарадзе Б.^{1,5}

¹ООО “Компания по управлению твёрдыми отходами Грузии”, Грузия
0186, Тбилиси, ул. А. Политковской, 14

²Горный институт им. Г. Цулукидзе, Грузия
0186, Тбилиси, ул. Э. Миндели, 7

³Тбилисский государственный университет им. И. Джавахишвили,
Институт физической и органической химии им. П. Меликишвили, Грузия
0186, Тбилиси, ул. А. Политковской, 5

⁴Грузинский технический университет, Институт гидрометеорологии, Грузия
0112, Тбилиси, просп. Д. Агмашенебели, 150Г

⁵Факультет точных и естественных наук,
Тбилисский государственный университет им. И. Джавахишвили, Грузия
0179, Тбилиси, просп. И. Чавчавадзе, 3

*Автор, отвечающий за переписку: giorgadze.anzori@gtu.ge

Резюме. Безопасное обращение с опасными отходами и их захоронение представляют собой критически важный глобальный приоритет в сфере охраны окружающей среды и общественного здравоохранения, а также острую инфраструктурную потребность для Грузии. Несмотря на продолжающийся промышленный рост и гармонизацию экологического законодательства со стандартами Европейского Союза, в настоящее время в Грузии отсутствует современный, инженерно оборудованный и соответствующий нормативным требованиям

полигон, предназначенный для захоронения опасных отходов. В результате опасные побочные продукты промышленного производства зачастую складываются непосредственно на территориях предприятий во временных хранилищах или на неизолированных муниципальных свалках, что создает угрозу региональным водным ресурсам и здоровью населения.

В исследовании рассматривается комплексный подход с использованием геоинформационных систем (ГИС) для определения оптимального местоположения полигона опасных отходов в восточной части Грузии, уделяя особое внимание муниципалитетам Марнеули, Гардабани и Тетрицкаро. В геоинформационной системе (ГИС) был сформирован комплекс пространственных данных, объединивший цифровую модель рельефа (ЦМР) с разрешением 20 метров и полученную на её основе модель затенения рельефа, топографическую карту масштаба 1:25 000, геологическую карту масштаба 1:200 000, региональную модель сейсмической опасности, карты распространения оползневых и селевых процессов, гидрографическую сеть, данные об инфраструктуре, а также кадастровые границы земельных участков.

С применением системы экологических критериев, разработанной Европейским банком реконструкции и развития (ЕБРР), потенциальные участки были оценены по 20 социальным, экологическим, техническим и геологическим параметрам. Для каждого параметра использовалась пятибалльная система оценки степени пригодности. В результате пространственного анализа было выявлено 10 потенциальных участков. На основе комплексной оценки по совокупности критериев определены три приоритетные площадки: Марнеули (73 балла), Цинцкаро (71 балл) и территория бывшего военного объекта (65 баллов).

Результаты исследования обеспечивают научно обоснованную и объективную информационную базу для принятия решений относительно размещения первого в Грузии объекта захоронения опасных отходов. Кроме того, в работе представлен комплексный пятиэтапный алгоритм на основе ГИС, предназначенный для регионального планирования объектов экологической инфраструктуры.

Ключевые слова: обращение с опасными отходами, определение местоположения полигона захоронения отходов, геоинформационные технологии (ГИС), система критериев выбора оптимального участка, Восточная Грузия, территориальное экологическое планирование

ŞƏRQİ GÜRCÜSTANDA EKOLOJİ İNFRASTRUKTURUN REGIONAL PLANLAŞDIRILMASINDA GEOLOJİ-GEOKİMYƏVİ VƏ HİDROGEOLOJİ ŞƏRAİTİN KOMPLEKS TƏHLİLİ VƏ CİS QIYMƏTLƏNDİRİLMƏSİ

Giorqadze A.^{1,2*}, Çikviladze X.¹, Oboladze S.^{1,3}, Mçedlişvili G.¹, Buaçidze N.⁴, Kavtaradze B.^{1,5}

¹Gürcüstan bərk məişət tullantılarının idarə edilməsi şirkəti MMC, Gürcüstan

0186, Tbilisi, A. Politkovskaya küç., 14

²G. Tsulukidze ad. Dağ-Mədən İnstitutu, Gürcüstan

0186, Tbilisi, E. Mindeli küç., 7

³İ. Cavaxişvili ad. Tbilisi Dövlət Universiteti,

P. Melikşvili ad. Fiziki və Üzvi Kimya İnstitutu, Gürcüstan

0186, Tbilisi, A. Politkovskaya küç., 14

⁴Gürcüstan Texniki Universiteti, Hidrometeorologiya İnstitutu, Gürcüstan

0112, Tbilisi, D. Aqmaşenebeli pr., 150G

⁵Dəqiq və təbiət elmləri fakültəsi,

İ. Cavaxişvili ad. Tbilisi Dövlət Universiteti, Gürcüstan

0179, Tbilisi, İ. Çavçavadze pr., 3

*Yazışmalara məsul: giorqadze.anzori@gtu.ge

Xülasə. Təhlükəli tullantıların etibarlı idarə olunması və utilizasiyası qlobal miqyasda ətraf mühitin və ictimai sağlamlığın qorunması baxımından mühüm prioritet, Gürcüstan üçün isə təxirəsalınmaz infrastruktur ehtiyacıdır. Davam edən sənaye artımına və ekoloji tənzimləmələrin Avropa İttifaqı standartlarına uyğunlaşdırılmasına baxmayaraq, hazırda Gürcüstanda təhlükəli tullantıların basdırılması üçün nəzərdə tutulmuş müasir, mühəndis-texniki cəhətdən təchiz edilmiş və normativ tələblərə cavab verən xüsusi obyekt mövcud deyil. Nəticədə, sənaye məhsəli təhlükəli yan məhsullar çox vaxt müəssisələrin ərazisində müvəqqəti saxlama sahələrində və ya izolyasiyaedici qatı olmayan bələdiyyə tullantı sahələrində toplanır ki, bu da regional su ehtiyatları və ictimai sağlamlıq üçün təhlükə yaradır.

Bu tədqiqat Şərqi Gürcüstanda, Marneuli, Qardabani və Tetritskaro bələdiyyələrini əhatə etməklə, təhlükəli tullantı poliqonu üçün sahə seçiminə dair Coğrafi İnformasiya Sistemlərinə (CİS) əsaslanan çoxmeyarlı qiymətləndirməni təqdim edir. CİS mühitində 20 metr məkan ayırdetməsinə malik Rəqəmsal Yüksəklik Modeli (RYM) və ondan əldə edilmiş kölgələndirilmiş relyef modeli, 1:25 000 miqyaslı topoqrafik xəritə, 1:200 000 miqyaslı geoloji xəritə, regional seysmik təhlükə modeli, sürüşmə və sel hadisələrinə meyllilik xəritələri, hidroloji şəbəkələr, infrastruktur layları və kadastr mülkiyyət sərhədlərini birləşdirən çoxlaylı məkan məlumatları bazası yaradılmışdır. Avropa Yenidənqurma və İnkişaf Bankı tərəfindən hazırlanmış ekoloji meyarlar çərçivəsi əsasında namizəd sahələr 20 sosial, ekoloji, texniki və geoloji parametrlə üzrə qiymətləndirilmişdir. Hər bir parametrlə 1-dən 5-dək tam ədədlərdən ibarət yararlılıq şkalası üzrə

qiymətləndirilmişdir. Məkan skrininqi nəticəsində 10 namizəd sahə müəyyən edilmişdir. Ümumiləşdirilmiş çoxmeyarlı qiymətləndirmə nəticəsində üç əsas namizəd sahə müəyyən olunmuşdur: Marneuli (73), Tsintskaro (71) və Keçmiş Hərbi Sahə (65).

Bu tədqiqat Gürcüstanda təhlükəli tullantıların basdırılması üçün ilk xüsusi obyektin yaradılmasına istiqamət verən qərarların qəbulunu dəstəkləmək məqsədilə empirik və obyektiv baza formalaşdırır və regional ekoloji infrastrukturun planlaşdırılması üçün hərtərəfli 6 mərhələli CİS iş axınını təqdim edir.

Açar sözlər: *təhlükəli tullantıların idarə olunması, tullantıların basdırılması poliqonunun yerləşmə yerinin müəyyən edilməsi, coğrafi informasiya sistemləri (CİS), optimal sahənin seçilməsi meyarları sistemi, Şərqi Gürcüstan, ərazi üzrə ekoloji planlaşdırma*

CONFERENCE INFORMATION

INTERNATIONAL CONFERENCE ON GEOLOGY AND GEOPHYSICS

09-10 November, 2026, Tokyo, Japan

Website: <https://waset.org/geology-and-geophysics-conference-in-november-2026-in-tokyo>

Program: <https://waset.org/conferences-in-november-2026-in-tokyo/program>

**INTERNATIONAL ASSOCIATION FOR GONDWANA RESEARCH (IAGR)
THE 23RD INTERNATIONAL CONFERENCE ON GONDWANA TO ASIA, INTERNATIONAL
CONFERENCE ON TECTONICS OF SOUTH EAST ASIA (ICTSEA 2026)**

11-15 November 2026, Chiang Mai, Thailand

Website: <https://www.iagr2026.science.cmu.ac.th>

E-mail: iagr.ictsea.2026@gmail.com

FIRST EAGE CONFERENCE ON BASIN AND PETROLEUM SYSTEMS MODELING

17-19 November 2026, Houston, USA

Website: <https://eage.eventsair.com/eage-first-conference-on-petroleum-systems-modeling/>

E-mail: abstracts@eage.org

ASIA PACIFIC SUMMIT ON DRONE GEOPHYSICS

30 november – 3 december 2026, virtual

Website: https://seg.org/calendar_events/2026-summits-on-drone-geophysics

E-mail: dmitchell@seg.org

AGU ANNUAL MEETING

7-11 December 2026, San Francisco, CA

Website: <https://www.agu.org/annual-meeting>

XVII CHILEAN GEOLOGICAL CONGRESS

13-18 December 2026, Valdivia, Chile

Website: <https://www.sociedadgeologica.cl>

E-mail: sociedad.geologica.chile@gmail.com

INTERNATIONAL CONFERENCE ON GEOLOGY, GEOPHYSICS AND EARTH SCIENCES

30-31 December, 2026, Karachi, Pakistan

Website: <https://waset.org/geology-geophysics-and-earth-sciences-conference-in-december-2026-in-karachi>

XXII INQUA CONGRESS – QUATERNARY SCIENCE AS SOCIETAL SERVICES

28 January–3 February 2027, Lucknow, India

Website: <https://www.inquaindia2027.in>

E-mail: inqua.india@bsip.res.in

**INTERNATIONAL CONFERENCE ON PHYSICAL GEOLOGY AND
GEOPHYSICS (ICPGG 2027)**

28-29 January 2027, Dubai, UAE

Website: <https://waset.org/physical-geology-and-geophysics-conference-in-january-2027-in-dubai>

INTERNATIONAL CONFERENCE ON GEOLOGY AND GEOPHYSICS (ICGG 2027)

11-12 February 2027 | Dubai, UAE

Website: <https://waset.org/geology-and-geophysics-conference-in-february-2027-in-dubai>

E-mail: info@waset.org

3RD ASIAN PALAEOONTOLOGICAL CONGRESS (APC3)

2-5 March 2027, Bangkok, Thailand

Website: <https://apc3.org>

E-mail: apc3@msu.ac.th

39TH INTERNATIONAL MEETING OF SEDIMENTOLOGY (IMS 2027)

14-16 June 2027, Çeşme, İzmir, Türkiye

Website: <https://ias2027izmir.org>

E-mail: secretariat@ias2027izmir.org

**18TH BATHURST MEETING – INTERNATIONAL MEETING OF
CARBONATE SEDIMENTOLOGISTS**

6-8 July 2027, Marseille, France

Website: <https://premc.org/bathurst2027>

**SECOND EAGE/AAPG CARBONATES AND MIXED
CARBONATE SYSTEMS SYMPOSIUM**

15-17 November 2027, Riyadh, Saudi Arabia

Website: <https://eage.eventsair.com/second-cross-regional-carbonates-and-mixed-carbonate-systems-symposium>

E-mail: middle_east@eage.org

GUIDE FOR AUTHORS

The editorial board of a journal "Stratigraphy, petroleum sedimentology, geochemistry" accepts papers, reviews and brief information. Manuscripts should be submitted in Azerbaijani, Russian and English.

Articles, after publication, are assigned an individual DOI identifier

The title of the manuscript

(font: Times New Roman (TNR) – 12 pt., all letters in the Title capital, bold, should be placed symmetrically relatively the middle of page along the width of text margin (16.5 cm), then – type the author's last name then initials, in one space). Title should be given in the original language of the manuscript in line with Russian and English translation.

Author's names and initials and affiliation

(font: – 11 pt, lower-case letters, should be placed symmetrically relatively the middle of page, text margin. Then, below, type the title of the affiliation, its mail address and after the colon – e-mail address of the corresponding author (for contacts and correspondence at all stages of the review process, publication, and in the period after publication). Font: – 11 pt, italics, letters lower-case, should be placed symmetrically relatively the middle of page along the width of text margin. Email address of the corresponding author indicates that the author will handle correspondence at all stages of refereeing and publication, also post-publication.

Authors should be indicated as follows: first is the last name then initials. If the authors work in different affiliations, after initials should be put superscript. After the authors' last name and initials, in the next line the respective superscript should be placed, corresponding to the affiliation of the authors. For instance, such as below,

Ismail-Zadeh A.J.¹, Musyaev Sh.D.², Veliyev Z.A.¹

*¹Geology and Geophysics Institute, Azerbaijan National Academy of Sciences, Azerbaijan,
119, H. Javid Ave., Baku, AZ1073: arifismail@mail.ru*

*²"AzerGold" CJSC, Azerbaijan
2H, M.Mushfig Str., Baku, AZ1004*

Summary

Please provide Summary of 200 to 250 words describing the objectives of the research, and the rationale and methods (if relevant), should be included. The word "Summary" should be bold. Both the word "Summary" and the text should have font: – 11 pt, lower-case letters. The text in Summary should not contain formula. References should be avoided. Also, non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself. The width of the text should not exceed 13.5 cm and should be placed symmetrically relatively the middle of page. Single space between lines should be considered. Summary should be given in the original language of the manuscript, also in Russian and English and contain 200-250 words.

Keywords

Immediately after the abstract in a single space provide a maximum of 7 keywords, avoiding general and plural terms and multiple concepts (if possible, avoid, for example, 'and', 'of'). The word “Keywords” with colon should be bold and italic. After the colon the keywords should appear italic and separating from each other by comma. The keywords will be used for indexing purposes. After two spaces Introduction should come.

Introduction

State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

Requirement to manuscript design

There are no strict requirements on consequent enumeration of the titles in the manuscript. Authors can put title in any style or format as long as the titles in the manuscript are consistent. Authors can select to either enumerate each title or not to enumerate. Titles and subtitles are indented in the text by separate line on the line with an indentation and are printed by bold font – 14pt (for titles) and 12pt (for subtitles). Their appearance begins on the left margin of the text.

Text of the manuscript

Each paragraph begins with indentation of 1 cm from the left margin of the column. The spaces between lines in the text are 1.5 interval, the text of the paper is printed in the MW. Recommended font: 14pt (Times New Roman). The other fonts (Helvetica, Arial and etc.), should be avoided. The papers are presented in Azerbaijani, Russian, or English languages. However, if presented in Azerbaijani language, please, ensure to provide the Russian version of the manuscript. Overall, the preference will be given to the papers presented in English.

The text of the paper should be formatted (in particular, all lines should be justified from left and right without leaving the margins of the text), should be edited and checked from the spelling viewpoint, special geographical terms and signs (in the international SI system).

Page format

Page format corresponds to A4 format, (21,0×29,7cm). Margins: from left 3 cm, right – 1.5 cm, from top and bottom – 2 cm. Number all manuscript pages consecutively in the lower right corner.

Material and methods

Provide sufficient details to allow the work to be reproduced by an independent researcher. Methods that are already published should be summarized, and indicated by a reference. If quoting directly from a previously published method, use quotation marks and also cite the source. Any modifications to existing methods should also be described.

Theory/calculation

Theory section should extend, not repeat the background to the manuscript already dealt with in the Introduction and lay the foundation for further work. In contrast, a Calculation section represents a practical development from a theoretical basis.

Illustrations, tables, formulas

Each figure (map, diagram, scheme, etc.) should be presented as a separate object in the end of the text or as file in JPEG (*.jpeg, *.jpg). As a rule, their sizes should not exceed 7.75 cm in the width. It should not exceed the width of text margin (16.5 cm) and located symmetrically relatively the middle of page. Picture caption should be carried out by font – 12pt (bold), the caption (deciphering of conditional signs, explanation etc.) font TNR – 12 pt in italics. Each figure and caption should be on one page, and figure caption is under the figure.

For graphical work, you are recommended to use the following guidelines:

- For bitmap images, use the JPG/JPEG, TIF format at 300-dpi resolution, 256 grayscales.
- Vector images must be submitted in CorelDraw, Adobe Photoshop.
- For photographs, use a JPG/JPEG, TIF format at no less than 300 dpi.

Numbers and names of tables are given by font – 12pt (bold) above them. The tables should not be huge and should not be left the boundaries of text margin. The tables should not have continuation from one page to another. The tables should be placed in the text of the paper. Please, number tables consecutively in accordance with their appearance in the text and place any table notes below the table body. Each figure and its caption must be placed on the same page, with the caption directly below the figure. Abbreviations are not allowed in the table.

Formulas are given without intermediate computation, with compulsory deciphering of symbols using in them (immediately after formulas), with a distinct displacement of degrees and footnote indexes, relatively the middle of page, containing this formula. Numbers of formulas are put in round brackets near the right margin of text on one line with formula in case if they are mentioned in text. Microsoft Equation is recommended for formulas. The width of line with formula and number of formula should not exceed 7.75 cm.

Results and/or Discussions

Results should be clear and concise. Discussion should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.

Conclusions

The main conclusions of the study may be presented in a short. **Conclusions** section may stand alone or form a subsection of a **Discussion** or **Results and Discussion** section, depending on the decision of author(s), style of the research in manuscript, obtained results from theory/calculations, etc.

Reference

Please follow the reference style shown in the examples below. References must not be numbered and provided entirely in English, regardless of the original language of the publications. The original language of the source must be indicated in parentheses at the end of the reference, e.g., (in Azerbaijani) or (in Russian).

The names of publishers must remain untranslated and be given in their original form, such as Nauka, Nedra, Nafta-press, Elm, etc.

Example:

Garibov Y.E. Anthropoge-

nous transformation of modern landscapes of the Azerbaijan Republic and their optimization ways. Abstract of PhD dissertation (geography), Baku, Azerbaijan, 2013, 47 p. (in Azerbaijani).

Hasanov T.Ab. Ophiolites of Lesser Caucasus. Nedra. Moscow, 1985, 240 p. (in Russian).

Isachenko A.G. Landscape studies and physico-geographical zoning. Vysshaya shkola. Moscow, 1991, 366 p. (in Russian).

Bortnikov N.S. Geochemistry and origin of ore forming fluids in hydrothermal-magmatic systems in tectonically active zones. Geology of ore fields. Vol. 48, No. 1, 2006, pp. 3-28 (in Russian).

Examples of References for the paper

REFERENCES

- Dearing J. Magnetic susceptibility. In: Walden J., Smith J.P., Oldfield F. (Editors). Environmental Magnetism: a practical guide, Quaternary Research Association. Technical Guide, No. 6, London 1999, pp. 35-62.
- Dodonov A.E., Tchepalyga A.L., Mihailescu C.D., Zhou L.P., Markova A.K., Trubikhin V.M., Simahova A.N., Konikov E.G. Last-interglacial records from central Asia to the northern Black Sea shoreline: stratigraphy correlation. Netherlands Journal of Geosciences, Vol. 79, No. 2/3, 2000, pp. 303-311.
- King J.W., Channell J.E.T. Sedimentary magnetism, environmental magnetism, and magnetostratigraphy. U.S. Nat. Rep. Int. Union Geod. Geophys. Rev. Geophys. 1987-1990, V. 29, 1991, pp. 358-370.
- Lowrie W. Identification of ferromagnetic minerals in a rock by coercivity and unblocking temperature properties. Geophys. Res. Lett., Vol. 17(2), 1990, pp. 159-162.
- Mammadov A.B., Aleskerov B.D. Pleistocene of Azerbaijan. Azerbaijan National Academy of Sciences. Institute of Geography. Baku, 2002, 70 p. (in Russian)
- Pilipenko O.V., Sharonova Z.V., Trubikhin V.M., Novruzov Z., Karyagdy S.K., Abrakhamen N. Study of environmental change of Karaja section rocks formation (Azerbaijan) on results of petromagnetic research. Earth Physics, No. 4, 2009, pp. 85-96. (in Russian)
- Trubikhin V.M. Paleomagnetic method and dating of regional geological events of Pontian-Caspian. New data on geochronology of Quaternary period. Nauka. Moscow, 1987, pp. 150-157. (in Russian)
- Alizade E.K., Tarikhazer S.A. Exomorphodynamics of mountain relief and its estimation. Victory. Baku, 2016, 236 p. (in Russian).
- Budagov B.A. Modern natural landscapes of the Azerbaijan SSR. Elm. Baku, 1988, 135 p. (in Russian)
- Census of the population of the Republic of Azerbaijan, 2009. Vol. 19. Baku, 2011, 820 p. (in Azerbaijani)
- Constructive geography of the Republic of Azerbaijan (B.A.Budagov, ed.). In three volumes. Vol. 3. Avropa. Baku, 2003, 256 p. (in Azerbaijani)
- Garibov Y.A. Anthropogenic transformation of modern landscapes in Azerbaijan Republic. Mars print. Baku, 2011, 299 p. (in Azerbaijani)
- Garibov Y.A. Optimization of natural landscapes in Azerbaijan Republic. Printing house of ATU. Baku, 2012, 216 p. (in Azerbaijani)
- Ibrahimov T.O. Landscape studies and their ecological problems. Elm. Baku, 2015, 384 p. (in Azerbaijani)
- Kazakov L.K. Landscape science (natural and anthropogenic landscapes). Academy MNEPU. Moscow, 2004, 264 p. (in Russian)
- Mammadov G.Sh. Fundamentals of soil science and soil geography. Elm. Baku, 2007, 660 p. (in Azerbaijani)
- Mammadov R.M. Landscape planning in Azerbaijan (first experience and application). Baku, 2009, 142 p. (in Azerbaijani)
- Miller G.P. Landscape studies of the mountain and foothill areas. Vishcha shkola. Lviv, 1974, 202 p. (in Russian)
- Namazova S.N. Assessment of sustainable development and landscape planning of Khyzi administrative district. Proceedings of Pedagogical University, series of natural sciences, No. 4, 2014, pp. 70-72. (in Azerbaijani)
- Suleymanov M.A. Geographical laws of natural and anthropogenic landscapes of Azerbaijan. Abilov, Zeynalov ve ogullari. Baku, 2005, 248 p. (in Azerbaijani)

Please ensure that every reference cited in the text is also present in the reference list (and vice versa). Citation in the text must be given depending on the origin of the manuscript language.

All citations in the text should be in parenthesis and should refer to:

1. Single author: the author's name (without initials) and the year of publication;
2. Two authors: both authors' names and the year of publication;
3. Three or more authors: first author's name followed by 'et al.' and the year of publication.

Groups of references should be listed chronologically. Example: “as evidenced (Bryulov, 1999; McKenzie, 2000)...”. Citation can be also such as follows: “Alizadeh et al. (2016) have recently shown ...”.

List: References should be arranged alphabetically. Font – 12 pt. Family name starts with the capital letter, the rest letters in the family name – in lower-case, no comma after the family name. After author(s) name(s), journal title/book title, chapter title/article title, volume/issue number, book chapter/ journal number, printing house, city, year of publication and pagination must be present. Use of DOI is highly encouraged. More than one reference from the same author(s) in the same year must be identified by the letters 'a', 'b', 'c', etc., placed after the year of publication.

Examples:

Reference to a journal publication:

Ismayil-zadeh A.J. Bipolar conjugation of volcano-plutonic and ophiolitic belts in Caucasus. Proceedings of NAS of Azerbaijan. The Sciences of Earth, No. 1, 2009, pp. 40-53 (in Russian).

Reference to book:

Mustafayev G.V. Mesozoic granitoid formations of Azerbaijan and peculiarities of its metallogeny. Elm. Baku, 1977, 234 p. (in Russian).

Reference to a chapter in an edited book:

Mettam G.R., Adams L.B. How to prepare an electronic version of your article. In: Introduction to the Electronic Age. E-Publishing Inc., New York, 2009, pp. 281–304.

Reference to dissertation and/or Abstract of dissertation (known as Avtoreferat):

Garibov Y.E. Anthropogenous transformation of modern landscapes of the Azerbaijan Republic and their optimization ways. Abstract of PhD dissertation (geography), Baku, Azerbaijan, 2013, 47 p. (in Azerbaijani).

Reference to Conferences and Symposia

Khain V.Ye. Northcaucasian-Turkmeno-Northafganian Late Triassic volcano-plutonic belt and detection of north zone of Tethys. Doklady AS of USSR, Vol. 249, No. 5, 1979, pp. 1190-1192 (in Russian).

Reference to a website:

Cancer Research UK. Cancer statistics reports for the UK. 1975, <http://www.cancerresearchuk.org/aboutcancer/statistics/cancerstatsreport/> (accessed 13 March 2003).

Reference to a dataset (methodological recommendation booklet):

Oguro M., Imahiro S., Saito S., Nakashizuka T. Mortality data for Japanese oak wilt disease and surrounding forest compositions. Mendeley Data, Vol. 1, 2015.

Submission

All submitted papers undergo reviewing and approval by the Editorial Board. Papers which passed this procedure and received a positive review, are published free of charge. Authors should submit their manuscripts online to the Editorial Board via “**Submit the manuscript**”.

The term of the manuscript reviewing takes from **one to two months** since the date of its submission to the Editorial Office. Manuscripts are published in the order of their submission. Help us to make your manuscripts to the highest possible standards – in both paper and electronic formats. Submitting your manuscripts in an electronic format helps us produce your work to the best possible standards, ensuring accuracy, clarity and a high level of detail.

In the case when the manuscript will be returned to the authors for alteration, the revised version should be returned to the editorial office **within two weeks**. If the manuscript is delayed by the authors for **over two weeks**, it will thereafter be considered by the editorial office to be newly received.

When submitting a paper, please, send the scanned electronic version of the cover letter addressed to the Editor-in-Chief with a request to accept the paper for review according to the rules of the Journal and after required procedures, if applicable, to publish it.

MÜƏLLİFLƏR ÜÇÜN QAYDALAR

“Stratigrafiya, neft sedimentologiyası, geokimya” jurnalının redaksiya heyəti məqalələri, icmal xarakterli məlumatları, müzakirələri və qısa məlumatları qəbul edir. Məqalələr İngilis, Rus və Azərbaycan dillərində təqdim edilə bilər.

Nəşr edildikdən sonra məqalələrə fərdi DOI identifikatoru verilir.

Məqalənin adı

Şrift: Times New Roman (TNR) – 12 pt, bütün hərflər böyük, qalın olmalı, səhifənin ortasında tam eninə (16,5 sm) simmetrik yerləşdirilməlidir. Sonra bir interval buraxaraq müəlliflərin soyadı və adının baş hərfləri yazılmalıdır. Məqalənin adı orijinalda rus və ingilis tərcümələrinə uyğun olaraq yazılmalıdır.

Müəlliflərin inisialı və soyadı, işlədikləri təşkilatın adı

Şriftin ölçüsü – 11 pt, kiçik hərflərlə səhifənin mərkəzinə simmetrik yerləşdirilməlidir. Aşağıda təşkilatın adı, poçt ünvanı iki nöqtə ilə – müəllifin e-mail ünvanı (bütün mərhələlərdə, eləcə də nəşrdən sonrakı yazışmalar və müraciətlər üçün). Şrift – 11 pt, kursiv, kiçik hərflərlə, səhifənin tam eninə simmetrik yerləşdirilməlidir.

Müəlliflər aşağıdakı ardıcılıqla qeyd edilməlidir: əvvəlcə soyad, sonra isə inisial. Əgər müəlliflər fərqli təşkilatlarda işləyirlərsə, inisialdan sonra yuxarı indeksdə rəqəm qoyulmalıdır. Soyad və inisialdan sonra, növbəti sətirdə müvafiq yuxarı indeks müəlliflərin işlədiyi təşkilatın adı ilə uyğun olaraq yerləşdirilməlidir. Məsələn, aşağıdakı kimi:

Ismail-Zadeh A.J.¹, Musyaev Sh.D.², Veliyev Z.A.¹

¹*Geology and Geophysics Institute, Azerbaijan National Academy of Sciences, Azerbaijan
119, H. Javid Ave., Baku, AZ1073: arifismail@mail.ru*

²*“AzerGold” CJSC, Azerbaijan
2H, M.Mushfig Str., Baku, AZ1004*

Xülasə

Xülasədə 200-250 söz olmalı və burada tədqiqatın məqsədi, mahiyyəti və lazım gələrsə, metodları (əgər tələb olunursa) izah edilməlidir. “Xülasə” sözü qalın şriftlə çap olunmalıdır. Həm “Xülasə” sözü, həm də mətn 11 pt. şrift ölçüsündə, kiçik hərflərlə yazılmalıdır. Xülasə mətni düsturlardan ibarət olmamalıdır. İstinadlardan istifadə etməyin. Standart olmayan və ya nadir abreviaturalardan çəkinin, lakin lazım gələrsə, onlar ilk dəfə qeyd edildikdə açıq şəkildə göstərilməlidir. Mətnin eni 13,5 sm-dən çox olmamalıdır və səhifəsinin mərkəzində simmetrik yerləşdirilməlidir. Mətnə sətirlər arasındakı məsafə – 1 interval olmalıdır. Xülasə orijinal dildə, rus və ingilis dillərində təqdim olunmalı və həcmi 200-250 söz olmalıdır.

Açar sözlər

Xülasədən sonra 1 interval buraxaraq, maksimum 7 sözdən ibarət açar sözlər yerləşdirilməlidir, bu zaman ümumi və çoxsaylı terminlərdən və anlayışlardan çəkinin (mümkünsə, məsələn, “və” bağlayıcısından istifadə etməyin). “Açar sözlər” iki nöqtə ilə kursiv və qalın şriftlə yazılmalıdır. İki nöqtə işarəsindən sonra açar sözlər kursivlə, vergüllə ayrılaraq yazılmalıdır. Açar sözlər indeksləşdirmə zamanı istifadə olunacaq. Daha sonra 2 intervaldan sonra Giriş yazılmalıdır.

Giriş

İşin məqsədlərini, mövzunun öyrənilməsini göstərin, bu vaxt dərc olunan materialların və ya tədqiqatın nəticələrinin ətraflı icmalından uzaq olun.

Məqalənin tərtibinin tələbləri

Mətnin sərlövhəsinin nömrələnməsi ilə bağlı birbaşa tələblər yoxdur. Müəlliflər sərlövhələri istədikləri stil və formatda çap edə bilərlər. Sərlövhələri nömrələmək və ya nömrələməmək müəlliflərin ixtiyarındadır. Sərlövhələr və yarımşərlövhələr mətndə ayrı bir sətirdə sol tərəfdə ara buraxaraq qalın şriftlə – 14 pt (sərlövhələr üçün) və 12 pt (yarımşərlövhələr üçün) çap olunmalıdır.

Məqalənin mətni

Hər bir abzas səhifənin sol tərəfindən 1 sm aralı başlayır. Mətndə sətirlər arasındakı məsafə – 1,5 interval olmalıdır, məqalə MW formatda çap edilməlidir. Təvsiyə olunan şrift ölçüsü – 14 pt (Times New Roman). Başqa şriftlərdən istifadə etməyin. Məqalələr Azərbaycan, rus və ya ingilis dilində təqdim olunmalıdır. Əgər məqalə azərbaycanca yazılıbsa, xahiş edirik, rus dilində olan versiyasını da əlavə edin. İngiliscə təqdim olunan məqalələrə üstünlük veriləcək.

Məqalənin mətni düzgün formatlanmalı (xüsusilə, bütün sətirlər soldan və sağdan düz olmalı, səhifədən kənara çıxmamalıdır), diqqətlə redaktə olunmalı və coğrafi adların, geoloji terminlərin və beynəlxalq SI sistemindəki simvolların düzgün yazılması baxımından yoxlanılmalıdır.

Səhifənin formatı

Səhifənin formatı A4 ölçüsünə (21,0 x 29,7 sm) uyğun olmalıdır. Kənarlar: soldan – 3 sm, sağdan – 1,5 sm, yuxarıdan və aşağıdan – hər biri 2 sm məsafədə, əlyazmasının səhifələrinin nömrələnməsi – aşağı sağ küncdə olmalıdır.

Material və metodlar

Müstəqil tədqiqatçının işi yenidən çapa edə bilməsi üçün ətraflı məlumat təqdim edin. Bundan əvvəl dərc olunmuş metodları qısa şəkildə izah edin və onlara istinad edin. Əvvəllər dərc olunmuş bir metodu birbaşa sitat gətirəndə onu dırnaq içində yazın və mənbəni göstərin. Mövcud metodların bütün dəyişikliklərini də qeyd etməlisiniz.

Nəzəriyyə və hesablamalar

Nəzəri hissə geniş şəkildə təqdim olunmalı və gələcək işlər üçün əsas yaratmalıdır, girişdə verilmiş məlumatlar təkrarlanmamalıdır. Hesablamalar bölməsi işin praktik hissəsini təsvir edir, bu da işin nəzəri mövqeyini təsdiqləyir.

İllüstrasiyalar, cədvəllər, düsturlar

Hər bir şəkil (xəritə, diaqram, sxem və s.) mətndən sonra ayrı obyekt kimi təqdim olunmalı və ya JPEG (*.jpeg, *.jpg) formatında fayl olaraq göndərilməlidir. Onların ölçüləri, bir qayda olaraq, eni 7,75 sm-i və ya səhifənin kənarlarını (16,5 sm) aşmamalıdır. Şəkillər səhifənin mərkəzində simmetrik yerləşdirilməlidir. Şəkilin altındakı yazıların ölçüsü – 12 pt, şəkildə yazı mətni (şərti işarələrin izahı və s.) – 12 pt; kursivlə yazılmalıdır. Hər bir şəkil və şəkildə yazı mətni eyni səhifədə olmalı, şəkildə yazı mətni şəkilin altında yerləşməlidir.

Qrafik işlər üçün aşağıdakı qaydaları tövsiyə edirik:

- Rastr təsvirlər üçün JPG/JPEG, TIF formatını 300 dpi, boz rəngin 256 qradasiyasında istifadə edin.
- Vektor təsvirlər CorelDraw, Adobe Photoshop formatında təqdim olunmalıdır.
- Fotolar üçün JPG/JPEG, TIF formatını 300 dpi-dən aşağı olmayan rezolyusiyada istifadə edin.

Cədvəllərin nömrələri və adları onların üzərində 12 pt şriftlə göstərilməlidir. Cədvəllər çox mürəkkəb olmamalıdır və səhifədən kənara çıxmamalıdır. Cədvəlin bir səhifədən digərinə keçməsi qadağandır. Cədvəllər məqalənin mətni içində yerləşdirilməlidir. Cədvəlləri mətndəki yerinə uyğun olaraq bir-birinin ardınca nömrələyin, cədvələ aid qeydləri isə cədvəlin altında yerləşdirin. Cədvəldə qısaltmalara icazə verilmir. Düsturlar araşdırmalar olmadan verilməlidir, istifadə olunan simvolların açılışı (düsturdan dərhal sonra) mütləq olmalıdır və dərəcələrin və alt indekslərin mətndəki düsturun ortasında dəqiq şəkildə yerləşdirilməsi tələb olunur. Düsturların nömrələri, əgər onlara istinad olunursa, düsturun sağ tərəfində, düstur ilə eyni xətdə dairəvi mötərizələr içində göstərilməlidir. Düsturların yazılması üçün Microsoft Equation redaktorundan istifadə edilməlidir. Düstur və düstur nömrəsi olan sətirin eni 7,75 sm-dən çox olmamalıdır.

Nəticələr və/və ya Müzakirələr

Nəticələr aydın və qısa şəkildə təqdim edilməlidir. Müzakirələrdə işin nəticələrinin əhəmiyyəti xüsusi qeyd edilməlidir, nəticələri təkrarlamamalı, çoxsaylı sitatlardan və dərc olunmuş ədəbiyyatın müzakirələrindən çəkinilməlidir. Nəticələr və Müzakirələr bölmələrinin birləşdirilməsi mümkündür.

Nəticələr

Tədqiqatın əsas nəticələri qısa şəkildə təqdim oluna bilər. Nəticələr bölməsi ayrıca yerləşdirilə bilər və ya Müzakirələr və ya Nəticələr və Müzakirələr bölmələrinin alt bölməsi kimi müəlliflərin seçiminə uyğun olaraq, eləcə də məqalənin üslubuna, əldə olunan nəzəri nəticələrə, hesablamalara və s. görə yerləşdirilə bilər.

Ədəbiyyat

Ədəbiyyat aşağıda göstərilən tələblərə və nümunələrə uyğun olmalıdır: nömrələnmə aparılmadan və nəşrin orijinal dilindən asılı olmayaraq tamamilə ingilis dilində təqdim edilməlidir. Mənbəyin orijinal dili biblioqrafik istinadın sonunda mötərizə daxilində qeyd olunmalıdır, məsələn: (in Azerbaijani) və ya (in Russian).

Nəşriyyatın adını tərcümə etmədən göstərin, məsələn: Nauka, Nedra, Nafta-Press, Elm və s.

Məsələn:

Garibov Y.E. Anthropogenous transformation of modern landscapes of the Azerbaijan Republic and their optimization ways. Abstract of PhD dissertation (geography), Baku, Azerbaijan, 2013, 47 p. (in Azerbaijani).

Hasanov T.Ab. Ophiolites of Lesser Caucasus. Nedra. Moscow, 1985, 240 p. (in Russian).

Isachenko A.G. Landscape studies and physico-geographical zoning. Vysshaya shkola. Moscow, 1991, 366 p. (in Russian).

Bortnikov N.S. Geochemistry and origin of ore forming fluids in hydrothermal-magmatic systems in tectonically active zones. *Geology of ore fields*. Vol. 48, No. 1, 2006, pp. 3-28 (in Russian).

Məqalə üçün ədəbiyyat siyahısının təqdim olunmuş nümunəsi

REFERENCES

- Dearing J. Magnetic susceptibility. In: Walden J., Smith J.P., Oldfield F. (Eds.). *Environmental Magnetism: a practical guide*, Quaternary Research Association. Technical Guide, No. 6, London 1999, pp. 35-62.
- Dodonov A.E., Tchepalyga A.L., Mihailescu C.D., Zhou L.P., Markova A.K., Trubikhin V.M., Simahova A.N., Konikov E.G. Last-interglacial records from central Asia to the northern Black Sea shoreline: stratigraphy correlation. *Netherlands Journal of Geosciences*, Vol. 79, No. 2/3, 2000, pp. 303-311.
- King J.W., Channell J.E.T. Sedimentary magnetism, environmental magnetism, and magnetostratigraphy. *U.S. Nat. Rep. Int. Union Geod. Geophys. Rev. Geophys.* 1987-1990, V. 29, 1991, pp. 358-370.
- Lowrie W. Identification of ferromagnetic minerals in a rock by coercivity and unblocking temperature properties. *Geophys. Res. Lett.*, Vol. 17(2), 1990, pp. 159-162.
- Mammadov A.B., Aleskerov B.D. Pleistocene of Azerbaijan. *Azerbaijan National Academy of Sciences. Institute of Geography*. Baku, 2002, 70 p. (in Russian)
- Pilipenko O.V., Sharonova Z.V., Trubikhin V.M., Novruzov Z., Karyagdy S.K., Abrakhamson N. Study of environmental change of Karaja section rocks formation (Azerbaijan) on results of petromagnetic research. *Earth Physics*, No. 4, 2009, pp. 85-96 (in Russian)
- Trubikhin V.M. Paleomagnetic method and dating of regional geological events of Pontian-Caspian. *New data on geochronology of Quaternary period*. Nauka. Moscow, 1987, pp. 150-157. (in Russian)
- Alizade E.K., Tarikhazer S.A. Exomorphodynamics of mountain relief and its estimation. *Victory*. Baku, 2016, 236 p. (in Russian)
- Budagov B.A. Modern natural landscapes of the Azerbaijan SSR. *Elm*. Baku, 1988, 135 p. (in Russian)
- Census of the population of the Republic of Azerbaijan, 2009. Vol. 19. Baku, 2011, 820 p. (in Azerbaijani)
- Constructive geography of the Republic of Azerbaijan (edited by B.A.Budagov). In three volumes. Vol. 3. *Avropa*. Baku, 2003, 256 p. (in Azerbaijani)
- Garibov Y.A. Anthropogenic transformation of modern landscapes in Azerbaijan Republic. *Mars print*. Baku, 2011, 299 p. (in Azerbaijani)
- Garibov Y.A. Optimization of natural landscapes in Azerbaijan Republic. *Printing house of ATU*. Baku, 2012, 216 p. (in Azerbaijani)
- Ibrahimov T.O. Landscape studies and their ecological problems. *Elm*. Baku, 2015, 384 p. (in Azerbaijani)
- Kazakov L.K. Landscape science (natural and anthropogenic landscapes). *Academy MNEPU*. Moscow, 2004, 264 p. (in Russian)
- Mammadov G.Sh. Fundamentals of soil science and soil geography. *Elm*. Baku, 2007, 660 p. (in Azerbaijani)
- Mammadov R.M. Landscape planning in Azerbaijan (first experience and application). Baku, 2009, 142 p. (in Azerbaijani)
- Miller G.P. Landscape studies of the mountain and foothill areas. *Vishcha shkola*. Lviv, 1974, 202 p. (in Russian)
- Namazova S.N. Assessment of sustainable development and landscape planning of Khyzi administrative district. *Proceedings of Pedagogical University, series of natural sciences*, No. 4, 2014, pp. 70-72. (in Azerbaijani)
- Suleymanov M.A. Geographical laws of natural and anthropogenic landscapes of Azerbaijan. *Abilov, Zeynalov ve ogullari*. Baku, 2005, 248 p. (in Azerbaijani)

Xahiş edirik, məndə istinad edilən hər bir ədəbiyyat mənbəyinin ədəbiyyat siyahısında olmasına (və əksinə) diqqət yetirin. Məndəki istinadlar original dildə verilməlidir.

Bütün istinadlar məndə mötərizəyə alınmalı və aşağıdakı qaydalara uyğun olmalıdır:

- Bir müəllif: müəllifin soyadı (inisial olmadan), nəşr ili;
- İki müəllif: hər iki müəllifin soyadı, nəşr ili;
- Üç və ya daha çox müəllif: birinci müəllifin soyadı, ardından “et al.” (və s.), nəşr ili.

Bir sıra istinadlar xronoloji ardıcılıqla təqdim olunmalıdır. Məsələn, (Bryulov, 1999; McKenzie, 2000)...”. İstinad həmçinin aşağıdakı formada da ola bilər: “Alizadeh et al. (2016) have recently shown ...”.

Ədəbiyyat siyahısı: İstifadə olunan ədəbiyyat mənbələri əlifba sırasına uyğun olmalıdır. Şriftin ölçüsü – 12 pt. Soyad böyük hərflə başlayır, digər hərflər kiçik olmalıdır, soyaddan sonra vergül olmamalıdır. Soyad(lar)dan sonra jurnalın adı/kitabın adı/ bölmənin adı/məqalənin adı, cild/nömrə, kitabın bölməsi/jurnalın nömrəsi, nəşriyyat, şəhər, nəşr ili və səhifə nömrələri göstərilməlidir. DOI identifikasiya indekslərinin istifadəsi tövsiyə olunur. Eyni müəllifin eyni nəşr ili üçün bir neçə ədəbiyyat mənbəyi varsa, əlavə olaraq “a”, “b”, “c” və s. hərfləri tətbiq olunmalıdır (Aliyev, 2009a).

Nümunələr:

Jurnal məqalələrinə istinadlar:

Ismayil-zadeh A.J. Bipolar conjugation of volcano-plutonic and ophiolitic belts in Caucasus. Proceedings of NAS of Azerbaijan. The Sciences of Earth, No. 1, 2009, pp. 40-53 (in Russian).

Kitablar və monoqrafiyalara istinadlar:

Mustafayev G.V. Mesozoic granitoid formations of Azerbaijan and peculiarities of its metallogeny. Elm. Baku, 1977, 234 p. (in Russian).

Redaktə olunan kitablardakı bölmələrə istinadlar:

Mettam G.R., Adams L.B. How to prepare an electronic version of your article. In: Introduction to the Electronic Age. E-Publishing Inc., New York, 2009, pp. 281-304.

Dissertasiyalar və ya avtoreferatlara istinadlar:

Garibov Y.E. Anthropogenous transformation of modern landscapes of the Azerbaijan Republic and their optimization ways. Abstract of PhD dissertation (geography), Baku, Azerbaijan, 2013, 47 p. (in Azerbaijani).

Konfranslar və simpoziumlara istinadlar:

Khain V.Ye. Northcaucasian-Turkmeno-Northafganian Late Triassic volcano-plutonic belt and detection of north zone of Tethys. Doklady AS of USSR, Vol. 249, No. 5, 1979, pp. 1190-1192 (in Russian).

Veb-saytlara istinadlar:

Cancer Research UK. Cancer statistics reports for the UK. 1975, <http://www.cancerresearchuk.org/aboutcancer/statistics/cancerstatsreport/> (accessed 13 March 2003).

Məlumat bazalarına istinadlar (metodoloji məqalələr, broşürlər):

Oguro M., Imahiro S., Saito S., Nakashizuka T. Mortality data for Japanese oak wilt disease and surrounding forest compositions. Mendeley Data, Vol. 1, 2015.

Məqalələrin təqdim edilməsi

Təqdim olunan bütün məqalələr resenziyalaşdırılma və redaksiya heyəti tərəfindən təsdiqlənməyə göndərilir. Bu prosedurdan keçən və müsbət rəy alan məqalələr pulsuz dərc olunur. Müəlliflər əlyazmalarını **“Məqaləni təqdim et” (Submit the manuscript)** funksiyası vasitəsilə onlayn olaraq Redaksiya Heyətinə təqdim etməlidirlər.

Rəy prosesi məqalənin redaksiyaya təqdim olunmasından etibarən **1-2 ay müddətində** davam edir. Məqalələr qəbul edildikləri ardıcılıqla dərc olunur. Həm kağız, həm də elektron formatda təqdim olunan məqalələrin yüksək peşəkar standartlara uyğun olmasını xahiş edirik. Məqalələrin elektron formatda təqdim edilməsi etibarlılığı, dəqiqliyi və ətraflı məlumatlılığını təmin edərək işinizi yüksək səviyyədə hazırlamağa kömək edəcək.

Məqalə müəlliflərə dəyişikliklər edilməsi üçün qaytarıldıqda, düzəldilmiş variant **iki həftə ərzində** redaksiyaya qaytarılmalıdır. Əgər əlyazma müəllifin günahı üzündən **iki həftədən artıq** gecikərsə, redaksiya tərəfindən məqalə yenidən qəbul olunmuş kimi qiymətləndiriləcək.

Məqaləni təqdim edərkən baş redaktorun adına göndərilən müşayiət məktubunun skan edilmiş elektron versiyasını da göndərməli, məqalənin jurnalın qaydalarına uyğun olaraq baxılması və bütün tələblərə uyğun olduğu halda çap olunması xahiş olunmalıdır.

ПРАВИЛА ДЛЯ АВТОРОВ

Редакционный совет журнала "Stratigraphy, petroleum sedimentology, geochemistry" принимает статьи, обзорную информацию, дискуссии и краткие сообщения. Статьи могут быть представлены на английском, русском и азербайджанском языках.

После публикации, статьям присваивается индивидуальный идентификатор DOI

Название статьи

Шрифт: Times New Roman (TNR) – 12 pt, все буквы заглавные, жирные, следует располагать симметрично относительно середины страницы по всей ширине текстового поля (16,5 см), далее через один интервал печатать фамилии авторов и инициалы. Название печатается на языке оригинала, соответствующего русскому и английскому переводам.

Инициалы и фамилии авторов, название организации, в которой они работают

Размер шрифта – 11 pt, строчные буквы нужно располагать симметрично относительно середины страницы, текстового поля. Далее ниже печатать название организации, ее почтовый адрес и после двоеточия – e-mail автора (для контактов и переписки на всех этапах процесса рецензирования, публикации, а также в период после публикации). Шрифт – 11 pt, курсив, буквы строчные, располагать симметрично относительно середины страницы по всей ширине текстового поля.

Авторов следует указывать в следующем порядке: сначала печатается фамилия, затем инициалы. Если авторы работают в разных организациях, после инициалов следует ставить цифру в надстрочном индексе. После фамилии и инициалов авторов на следующей строке нужно расположить соответствующий надстрочный индекс в соответствии с названием организации авторов. Например, так, как указано ниже:

Ismail-Zadeh A.J.¹, Musyaev Sh.D.², Veliyev Z.A.¹

¹*Geology and Geophysics Institute, Azerbaijan National Academy of Sciences, Azerbaijan
119, H. Javid Ave., Baku, AZ1073: arifismail@mail.ru*

²*"AzerGold" CJSC, Azerbaijan
M.Mushfig Str., 2H, Baku, AZ1004*

Резюме

Следует включить резюме из 200-250 слов, описывающих задачи, суть, а также методы (если необходимо) исследования. Слово «Резюме» печатать жирным шрифтом. Как слово «Резюме», так и текст должны иметь размер шрифта – 11 pt., буквы – строчные. Текст резюме не должен содержать формул. Не используйте ссылки. Избегайте нестандартных или редких аббревиатур, но если они необходимы, то должны быть расшифрованы в самом резюме при первом упоминании. Ширина текста не должна превышать 13,5 см, а текст следует располагать симметрично относительно середины страницы. Расстояние между строками в тексте – 1 интервал. Резюме представляются на языках оригинала, русском и английском и должны содержать 200-250 слов.

Ключевые слова

Сразу после резюме через 1 интервал следует расположить ключевые слова, включающие максимум 7 слов, при этом избегайте общих и множественных терминов и понятий (ес-

ли возможно, не используйте, например, союз «и»). «Ключевые слова» с двоеточием нужно набирать курсивом и жирным шрифтом. После двоеточия сами ключевые слова печатаются курсивом через запятую. Ключевые слова будут использоваться при индексировании. Далее через 2 интервала печатать Введение.

Введение

Укажите цели работы, изученность темы, при этом избегайте подробного обзора публикаций или результатов исследований.

Требования к оформлению статьи

Нет прямых требований к нумерации заголовков рукописи. Авторы могут печатать заголовки в любом стиле и формате. Можно нумеровать и не нумеровать заголовки (на рассмотрение авторов). Заголовки и подзаголовки следует вставлять в текст в левом поле на отдельной строке с отступом и печатать жирным шрифтом – 14 pt (для заголовков) и 12 pt (для подзаголовков).

Текст статьи

Каждый абзац начинается отступом 1 см от левой границы текстового поля. Расстояние между строками в тексте – 1,5 интервала, текст статьи следует печатать в MW. Рекомендуемый размер шрифта – 14 pt (Times New Roman). Другие шрифты просим не использовать. Статьи представляются на азербайджанском, русском или английском языках. Однако, если они на азербайджанском, пожалуйста, приложите русскую версию рукописи. Предпочтение будет отдаваться статьям, представленным на английском языке.

Текст статьи должен быть отформатирован (в частности, все строки должны быть выровнены слева и справа, не выходя за поле текста), тщательно отредактирован и выверен с точки зрения правильности написания географических названий, геологических терминов и обозначений (в международной системе СИ).

Формат страницы

Формат страницы соответствует формату А4 (21,0 x 29,7 см). Поля: слева – 3 см, справа – 1,5 см, снизу и сверху – по 2 см. Нумерация страниц рукописи – в нижнем правом углу.

Материал и методы

Предоставьте детальную информацию, позволяющую воспроизвести работу независимым исследователем. Следует кратко изложить ранее опубликованные методы и указать на них ссылки. При непосредственном цитировании ранее опубликованного метода используйте кавычки и укажите источник. Нужно описывать любые модификации существующих методов.

Теория и расчеты (вычисления)

Теоретическая часть должна излагаться в расширенном виде и создавать основу для дальнейшей работы, а не повторять информацию, приведенную во введении. Раздел Расчеты (вычисления) описывает практическую часть работы, подтверждающую теоретические положения работы.

Иллюстрации, таблицы, формулы

Каждый рисунок (карта, диаграмма, схема и т.д.) представляется в виде отдельного объекта в конце текста или в виде файла в формате JPEG (*.jpeg, *.jpg). Их размеры, как правило, не должны превышать ширины в 7,75 см или текстового поля (16,5 см). Рисунки следует размещать симметрично относительно середины страницы. Размер шрифта подрисуночных подписей – 12 pt, а подрисуночного текста (расшифровка условных обозначений и т.д.) – 12 pt; набирается курсивом. Каждый рисунок и подрисуночный текст должны располагаться на одной странице, причем подрисуночный текст – под рисунком.

Для графической работы рекомендуется использовать следующие правила:

- Для растровых изображений используйте формат JPG/JPEG, TIF при разрешении 300 dpi, 256 градаций серого.
- Векторные изображения следует предоставлять в CorelDraw, Adobe Photoshop.
- Для фотографий применяйте формат JPG/JPEG, TIF при разрешении не менее 300 dpi.

Номера и названия таблиц приводятся шрифтом 12 pt над ними. Таблицы не должны быть громоздкими и выходить за пределы текстового поля. Перенос таблицы с одной страницы на другую не допускается. Таблицы должны быть помещены в текст статьи. Пронумеруйте таблицы одну за другой в соответствии с их местоположением в тексте, а примечания к ним разместите под таблицей. В таблице не допускаются сокращения. Формулы даются без промежуточных выкладок с обязательной расшифровкой используемых в них символов (сразу после формулы) с четким смещением степеней и подстрочных индексов относительно середины строки, содержащей эту формулу. Номера формул, если они упоминаются, указываются в круглых скобках у правой границы текста, на одной линии с формулой. Для набора формул следует использовать редактор Microsoft Equation. Ширина строки с формулой и номером формулы не должна превышать 7,75 см.

Результаты и/или Обсуждения

Результаты должны быть изложены четко и кратко. В Обсуждении следует акцентироваться на значимости результатов работы, а не повторять их, избегая многочисленных цитирований и обсуждений опубликованной литературы. Допускается объединение разделов Результаты и Обсуждение.

Выводы

Основные выводы исследования могут быть изложены кратко. Раздел **Выводы** может располагаться отдельно или образовывать подраздел **Обсуждения** или **Результатов и Обсуждений** по рассмотрению авторов, а также в зависимости от стиля статьи, полученных теоретических результатов, вычислений и т.д.

Литература

Литература должна соответствовать нижеприведённым требованиям и примерам: приводиться без нумерации и полностью на английском языке независимо от языка оригинала публикации. Оригинальный язык источника необходимо указывать в скобках в конце библиографической ссылки, например: (in Azerbaijani) или (in Russian).

Названия издательств следует указывать без перевода, в оригинальном написании, например: Nauka, Nedra, Nafta-Press, Elm и т. д.

Список литературы должен быть упорядочен по алфавиту фамилий первых авторов. Все библиографические сведения должны быть полными и точными. При наличии DOI настоятельно рекомендуется указывать его в библиографической записи.

Например:

Garibov Y.E. Anthropogenous transformation of modern landscapes of the Azerbaijan Republic and their optimization ways. Abstract of PhD dissertation (geography), Baku, Azerbaijan, 2013, 47 p. (in Azerbaijani).

Hasanov T.Ab. Ophiolites of Lesser Caucasus. Nedra. Moscow, 1985, 240 p. (in Russian).

Isachenko A.G. Landscape studies and physico-geographical zoning. Vysshaya shkola. Moscow, 1991, 366 p. (in Russian).

Bortnikov N.S. Geochemistry and origin of ore forming fluids in hydrothermal-magmatic systems in tectonically active zones. Geology of ore fields. Vol. 48, No. 1, 2006, pp. 3-28 (in Russian).

Пример Списка литературы для статьи

REFERENCES

- Dearing J. Magnetic susceptibility. In: Walden J., Smith J.P., Oldfield F. (Eds.). Environmental Magnetism: a practical guide, Quaternary Research Association. Technical Guide, No. 6, London 1999, pp. 35-62.
- Dodonov A.E., Tchepalyga A.L., Mihailescu C.D., Zhou L.P., Markova A.K., Trubikhin V.M., Simahova A.N., Konikov E.G. Last-interglacial records from central Asia to the northern Black Sea shoreline: stratigraphy correlation. Netherlands Journal of Geosciences, Vol. 79, No. 2/3, 2000, pp. 303-311.
- King J.W., Channell J.E.T. Sedimentary magnetism, environmental magnetism, and magnetostratigraphy. U.S. Nat. Rep. Int. Union Geod. Geophys. Rev. Geophys. 1987-1990, V. 29, 1991, pp. 358-370.
- Lowrie W. Identification of ferromagnetic minerals in a rock by coercivity and unblocking temperature properties. Geophys. Res. Lett., Vol. 17(2), 1990, pp. 159-162.
- Mammadov A.B., Aleskerov B.D. Pleistocene of Azerbaijan. Azerbaijan National Academy of Sciences. Institute of Geography. Baku, 2002, 70 p. (in Russian)
- Pilipenko O.V., Sharonova Z.V., Trubikhin V.M., Novruzov Z., Karyagdy S.K., Abrakhamsen N. Study of environmental change of Karaja section rocks formation (Azerbaijan) on results of petromagnetic research. Earth Physics, No. 4, 2009, pp. 85-96 (in Russian)
- Trubikhin V.M. Paleomagnetic method and dating of regional geological events of Pontian-Caspian. New data on geochronology of Quaternary period. Nauka. Moscow, 1987, pp. 150-157. (in Russian)
- Alizade E.K., Tarikhazer S.A. Exomorphodynamics of mountain relief and its estimation. Victory. Baku, 2016, 236 p. (in Russian).
- Budagov B.A. Modern natural landscapes of the Azerbaijan SSR. Elm. Baku, 1988, 135 p. (in Russian)
- Census of the population of the Republic of Azerbaijan, 2009. Vol. 19. Baku, 2011, 820 p. (in Azerbaijani).
- Constructive geography of the Republic of Azerbaijan (edited by B.A.Budagov). In three volumes. Vol. 3. Avropa. Baku, 2003, 256 p. (in Azerbaijani)
- Garibov Y.A. Anthropogenic transformation of modern landscapes in Azerbaijan Republic. Mars print. Baku, 2011, 299 p. (in Azerbaijani)
- Garibov Y.A. Optimization of natural landscapes in Azerbaijan Republic. Printing house of ATU. Baku, 2012, 216 p. (in Azerbaijani).
- Ibrahimov T.O. Landscape studies and their ecological problems. Elm. Baku, 2015, 384 p. (in Azerbaijani)
- Kazakov L.K. Landscape science (natural and anthropogenic landscapes). Academy MNEPU. Moscow, 2004, 264 p. (in Russian)
- Mammadov G.Sh. Fundamentals of soil science and soil geography. Elm. Baku, 2007, 660 p. (in Azerbaijani)
- Mammadov R.M. Landscape planning in Azerbaijan (first experience and application). Baku, 2009, 142 p. (in Azerbaijani)
- Miller G.P. Landscape studies of the mountain and foothill areas. Vishcha shkola. Lviv, 1974, 202 p. (in Russian)
- Namazova S.N. Assessment of sustainable development and landscape planning of Khyzi administrative district. Proceedings of Pedagogical University, series of natural sciences, No. 4, 2014, pp. 70-72. (in Azerbaijani)
- Suleymanov M.A. Geographical laws of natural and anthropogenic landscapes of Azerbaijan. Abilov, Zeynalov ve ogullari. Baku, 2005, 248 p. (in Azerbaijani)

Пожалуйста, удостоверьтесь, что каждый литературный источник, на который ссылались в тексте, имеется в списке литературы (и наоборот). Ссылки в тексте должны даваться на языке оригинала.

Все ссылки в тексте должны быть заключены в скобки и относиться к:

1. Одному автору: фамилия автора (без инициалов), год издания;
2. Двум авторам: фамилии обоих авторов, год издания;
3. Трем и более авторам: фамилия первого автора, далее следует «et al.» (и др.), год издания.

Ряд ссылок следует представить в хронологическом порядке. Например, (Bryulov, 1999; McKenzie, 2000)...". Ссылка также может быть в следующей форме: "Alizadeh et al. (2016) have recently shown ...".

Список литературы: Цитируемые литературные источники должны быть выстроены по алфавиту. Размер шрифта – 12 pt. Фамилия начинается заглавной буквой, остальные буквы строчные без запятой после фамилии. После фамилии(й) автора(ов) указываются название журнала/название книги/название раздела/название статьи, номер тома/ выпуска, глава книги/номер журнала, издательство, город, год издания и номера страниц. Настоятельно рекомендуется использовать идентификационные индексы DOI. В случае нескольких ссылок на литературные источники одного и того же автора и одинакового года издания, следует применить дополнительно буквы "a", "b", "c" и т.д. (Aliyev, 2009a).

Примеры:

Ссылки на журнальные статьи:

Ismayil-zadeh A.J. Bipolar conjugation of volcano-plutonic and ophiolitic belts in Caucasus. Proceedings of NAS of Azerbaijan. The Sciences of Earth, No.1, 2009, pp. 40-53 (in Russian).

Ссылки на книги и монографии:

Mustafayev G.V. Mesozoic granitoid formations of Azerbaijan and peculiarities of its metallogeny. Elm. Baku, 1977, 234 p. (in Russian).

Ссылки на главы в книгах под редакцией:

Mettam G.R., Adams L.B. How to prepare an electronic version of your article. In: Introduction to the Electronic Age. E-Publishing Inc., New York, 2009, pp. 281-304.

Ссылки на диссертации и/или авторефераты:

Garibov Y.E. Anthropogenous transformation of modern landscapes of the Azerbaijan Republic and their optimization ways. Abstract of PhD dissertation (geography), Baku, Azerbaijan, 2013, 47 p. (in Azerbaijani).

Ссылки на конференции и симпозиумы:

Khain V.Ye. Northcaucasian-Turkmeno-Northafganian Late Triassic volcano-plutonic belt and detection of north zone of Tethys. Doklady AS of USSR, Vol. 249, No. 5, 1979, pp. 1190-1192 (in Russian).

Ссылки на вебсайты:

Cancer Research UK. Cancer statistics reports for the UK. 1975, <http://www.cancerresearchuk.org/aboutcancer/statistics/cancerstatsreport/> (accessed 13 March 2003).

Ссылки на базы данных (методологические разработки, буклеты, брошюры):

Oguro M., Imahiro S., Saito S., Nakashizuka T. Mortality data for Japanese oak wilt disease and surrounding forest compositions. Mendeley Data, Vol. 1, 2015.

Представление статей

Все представленные статьи посылаются на рецензирование и одобрение редакционной коллегии. Статьи, которые прошли эту процедуру и получили положительный отзыв, публикуются бесплатно. Авторам следует представлять рукописи в Редакционную Коллегию онлайн посредством функции **“Подать статью (Submit the manuscript)”**.

Рецензирование длится **1-2 месяца** со дня представления статьи в редакцию. Статьи публикуются в порядке поступления (очередности). Будем благодарны, если статьи как в бумажном, так и электронном виде будут соответствовать высоким профессиональным стандартам. Представление статей в электронном виде поможет нам подготовить вашу работу наилучшим образом, обеспечивая достоверность, четкость и подробную информативность.

В случае возврата статьи авторам для внесения изменений доработанный вариант должен быть возвращен в редакцию **в течение двух недель**. Если рукопись будет задержана по вине автора **более двух недель**, она будет рассматриваться редакцией как вновь поступившая.

При представлении статьи необходимо прислать также отсканированную электронную версию сопроводительного письма на имя главного редактора с просьбой принять статью на рассмотрение согласно правилам журнала и в случае соответствия всем требованиям опубликовать ее.

CONTENTS

Eppelbaum L.V.

Makhtesh Ramon: A unique natural-resource complex of strategic, multi-component mineral raw materials in Southern Israel3-30

Mehdiyev O.T., Mammadova A.N., Nagizade A.A., Bakhshiyeva F.G.

Comparative mineralogical-geochemical characteristics of the oil-bearing rocks of East Azerbaijan with Athabasca (Canada)31-36

Bagirova A.A.

Correlation of magnetostratigraphic scales and paleomagnetic characteristics of Triassic deposits in the Nakhchivan Autonomous Republic (Azerbaijan, preliminary data).....37-47

Giorgadze A., Chikviladze Kh., Oboladze S.,

Mtchedlishvili G., Buachidze N., Kavtaradze B.

Integrated analysis of geological-geochemical and hydrogeological conditions and GIS assessment for regional planning of ecological infrastructure in Eastern Georgia.....48-59

Conferences information60-61

Guide for authors in English, Azerbaijani and Russian.....62-79

MÜNDƏRİCAT

Eppelbaum L.V.

Maxteş Ramon: Cənubi İsraildə strateji əhəmiyyətli çoxkomponentli mineral xammalın
unikal təbii-resurs kompleksi3-30

Mehdiyev O.T., Məmmədova A.N., Nağızadə A.Ə., Baxşıyeva F.Q.

Şərqi Azərbaycanın neftli süxurlarının Atabaska (Kanada) ilə müqayisəli mineraloji-
geokimyəvi xüsusiyyətləri31-36

Bağirova A.Ə.

Naxçıvan Muxtar Respublikasının Trias çöküntülərinin maqnitostatigrafik şkalalarının
korrelyasiyası və paleomaqnit xarakteristikası (Azərbaycan, ilkin məlumatlar).....37-47

Giorqadze A., Çikviladze X., Oboladze S., Mçedlişvili G., Buaçidze N., Kavtaradze B.

Şərqi Gürcüstanda ekoloji infrastrukturun regional planlaşdırılmasında geoloji-geokimyəvi
və hidrogeoloji şəraitin kompleks təhlili və CİS qiymətləndirilməsi48-59

Konfranslar barəsində məlumatlar60-61

Müəlliflər üçün qaydalar (ingilis, azərbaycan və rus dillərində).....62-79

ОГЛАВЛЕНИЕ

Эппельбаум Л.В.

Махтеш-Рамон – уникальный природно-ресурсный комплекс стратегического много-компонентного сырья на юге Израиля3-30

Мехтиев О.Т., Мамедова А.Н., Нагизаде А.А., Бахшиева Ф.Г.

Сравнительная минералого-геохимическая характеристика нефтеносных пород Восточного Азербайджана и Атабаски (Канада)31-36

Багирова А.А.

Корреляция магнитостратиграфических шкал и палеомагнитная характеристика триасовых отложений Нахчыванской Автономной Республики (Азербайджан, первые данные)37-47

Гиоргадзе А., Чиквиладзе Х., Оболадзе С.,

Мchedlishvili Г., Буачидзе Н., Кавтарадзе Б.

Интегральный анализ геолого-геохимических и гидрогеологических условий и ГИС-оценка при региональном планировании экологической инфраструктуры Восточной Грузии48-59

Информация о конференциях60-61

Правила для авторов (на английском, азербайджанском и русском языках).....62-79