ISSN 2518-170X (Online)
ISSN 2224-5278 (Print)

NEWS OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN, SERIES OF GEOLOGY AND TECHNICAL SCIENCES

№3
2026

ISSN 2518-170X (Online)
ISSN 2224-5278 (Print)

CENTRAL ASIAN ACADEMIC
RESEARCH CENTER

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN, SERIES OF GEOLOGY AND TECHNICAL SCIENCES

3 (477)

JUNE – JULY 2026

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, 2026

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

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

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

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

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

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

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

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

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

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

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

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

EDITOR-IN-CHIEF

ZHURINOV Murat Zhurinovich, Doctor of Chemical Sciences, Professor, Academician of IAAS and NAS RK, General Director of the Research Institute of Petroleum Refining and Petrochemicals (Almaty, Kazakhstan), https://www.scopus.com/authid/detail.uri?authorId=6602177960; https://www.webofscience.com/wos/author/record/2017489

DEPUTY EDITOR-IN-CHIEF

ABSADYKOV Bakhyt Narikbayevich, Doctor of Technical Sciences, Professor, Academician of NAS RK, Satbayev University (Almaty, Kazakhstan), https://www.scopus.com/authid/detail.uri?authorId=6504694468; https://www.webofscience.com/wos/author/record/2411827

EDITORIAL BOARD:

ABSAMETOV Malis Kudysovich, Doctor of Geological and Mineralogical Sciences, Professor, Academician of NAS RK, Director of the U.M. Akhmedsafin Institute of Hydrogeology and Geoecology (Almaty, Kazakhstan), https://www.scopus.com/authid/detail.uri?authorId=56955769200; https://www.webofscience.com/wos/author/record/1937883

ZHOLTAEV Geroy Zholtaevich, Doctor of Geological and Mineralogical Sciences, Professor, Honorary Academician of NAS RK (Almaty, Kazakhstan), https://www.scopus.com/authid/detail.uri?authorId=57112610200; https://www.webofscience.com/wos/author/record/1939201

SNOW Daniel, PhD, Associate Professor, Director, Aquatic Sciences Laboratory, University of Nebraska (Nebraska, USA), https://www.scopus.com/authid/detail.uri?authorId=7103259215; https://www.webofscience.com/wos/author/record/1429613

SELTMANN Reimar, PhD, Head of Petrology and Mineral Deposits Research in the Earth Sciences Department, Natural History Museum (London, Great Britain), https://www.scopus.com/authid/detail.uri?authorId=55883084800; https://www.webofscience.com/wos/author/record/1048681

PANFILOV Mikhail Borisovich, Doctor of Technical Sciences, Professor at the University of Nancy (Nancy, France), https://www.scopus.com/authid/detail.uri?authorId=7003436752; https://www.webofscience.com/wos/author/record/1230499

SHEN Ping, PhD, Deputy Director of the Mining Geology Committee of the Chinese Geological Society, Member of the American Association of Economic Geologists (Beijing, China), https://www.scopus.com/authid/detail.uri?authorId=57202873965; https://www.webofscience.com/wos/author/record/1753209

FISCHER Axel, PhD, Associate Professor, Technical University of Dresden (Dresden, Germany), https://www.scopus.com/authid/detail.uri?authorId=35738572100; https://www.webofscience.com/wos/author/record/2085986

AGABEKOV Vladimir Enokovich, Doctor of Chemical Sciences, Academician of NAS of Belarus, Honorary Director of the Institute of Chemistry of New Materials (Minsk, Belarus), https://www.scopus.com/authid/detail.uri?authorId=7004624845

CATALIN Stefan, PhD, Associate Professor, Technical University of Dresden (Dresden, Germany), https://www.scopus.com/authid/detail.uri?authorId=35203904500; https://www.webofscience.com/wos/author/record/1309251

JAY Sagin, PhD, Associate Professor, Nazarbayev University (Astana, Kazakhstan), https://www.scopus.com/authid/detail.uri?authorId=57204467637; https://www.webofscience.com/wos/author/record/907886

FRATTINI Paolo, PhD, Associate Professor, University of Milano - Bicocca (Milan, Italy), https://www.scopus.com/authid/detail.uri?authorId=56538922400

NURPEISOVA Marzhan Baysanovna, Doctor of Technical Sciences, Professor of Satbayev University (Almaty, Kazakhstan), https://www.scopus.com/authid/detail.uri?authorId=57202218883; https://www.webofscience.com/wos/author/record/AAD-1173-2019

RATOV Boranbay Tovbasarovich, Doctor of Technical Sciences, Professor, Head of the Department of Geophysics and Seismology, Satbayev University (Almaty, Kazakhstan), https://www.scopus.com/authid/detail.uri?authorId=55927684100; https://www.webofscience.com/wos/author/record/1993614

RONNY Berndtsson, Professor, Director of the Centre for Advanced Middle Eastern Studies, Lund University (Lund, Sweden), https://www.scopus.com/authid/detail.uri?authorId=7005388716; https://www.webofscience.com/wos/author/record/1324908

MIRLAS Vladimir, PhD, Professor, Eastern R&D Center, Ariel University (Ariel, Israel), https://www.scopus.com/authid/detail.uri?authorId=8610969300; https://www.webofscience.com/wos/author/record/53680261

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Owner: «Central Asian Academic Research Center» LLP (Almaty).
The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Communications of the Republic of Kazakhstan № KZ50VPY00121155, issued on 05.06.2025
Thematic scope: *geology, hydrogeology, geography, mining and chemical technologies of oil, gas and metals*
Periodicity: 6 times a year.
http://www.geolog-technical.kz/index.php/en/

© «Central Asian Academic Research Center» LLP, 2026.

БАС РЕДАКТОР

ЖҰРЫНОВ Мұрат Жұрынұлы, химия ғылымдарының докторы, профессор, ХҒАҚ және ҚР ҰҒА академигі, Мұнай өңдеу және мұнай-химиясы ғылыми-зерттеу институтының бас директоры (Алматы, Қазақстан), https://www.scopus.com/authid/detail.uri?authorId=6602177960; https://www.webofscience.com/wos/author/record/2017489

БАС РЕДАКТОРДЫҢ ОРЫНБАСАРЫ:

АБСАДЫҚОВ Бақыт Нәрікбайұлы, техника ғылымдарының докторы, профессор, ҚР ҰҒА академигі, Қ.И. Сәтбаев атындағы Қазақ ұлттық техникалық зерттеу университеті (Алматы, Қазақстан), https://www.scopus.com/authid/detail.uri?authorId=6504694468; https://www.webofscience.com/wos/author/record/2411827

РЕДАКЦИЯ АЛҚАСЫ:

ӘБСӘМЕТОВ Мәліс Құдысұлы, геология-минералогия ғылымдарының докторы, профессор, ҚР ҰҒА академигі, У.М. Ахмедсафин атындағы Гидрогеология және геоэкология институтының директоры (Алматы, Қазақстан), https://www.scopus.com/authid/detail.uri?authorId=56955769200; https://www.webofscience.com/wos/author/record/1937883

ЖОЛТАЕВ Герой Жолтайұлы, геология-минералогия ғылымдарының докторы, профессор, ҚР ҰҒА құрметті академигі (Алматы, Қазақстан), https://www.scopus.com/authid/detail.uri?authorId=57112610200; https://www.webofscience.com/wos/author/record/1939201

СНОУ Дэниел, PhD, қауымдастырылған профессор, Небраска университетінің Су ғылымдары зертханасының директоры (Небраска, АҚШ), https://www.scopus.com/authid/detail.uri?authorId=7103259215; https://www.webofscience.com/wos/author/record/1429613

ЗЕЛЬТМАНН Раймар, PhD, Жер туралы ғылымдар бөлімінің петрология және пайдалы қазбалар кен орындары саласындағы зерттеулерінің жетекшісі, Табиғи тарих мұражайы (Лондон, Ұлыбритания), https://www.scopus.com/authid/detail.uri?authorId=55883084800; https://www.webofscience.com/wos/author/record/ 1048681

ПАНФИЛОВ Михаил Борисович, техника ғылымдарының докторы, Нанси университетінің профессоры (Нанси, Франция), https://www.scopus.com/authid/detail.uri?authorId=7003436752; https://www.webofscience.com/wos/author/record/1230499

ШЕН Пин, PhD, Қытай геологиялық қоғамының Тау-кен геологиясы комитеті директорының орынбасары, Американдық экономикалық геологтар қауымдастығының мүшесі (Бейжің, Қытай), https://www.scopus.com/authid/detail.uri?authorId=57202873965; https://www.webofscience.com/wos/author/record/ 1753209

ФИШЕР Аксель, PhD, қауымдастырылған профессор, Дрезден техникалық университеті (Дрезден, Германия), https://www.scopus.com/authid/detail.uri?authorId=35738572100; https://www.webofscience.com/wos/author/record/2085986

АГАБЕКОВ Владимир Енокович, химия ғылымдарының докторы, Беларусь ҰҒА академигі, Жаңа материалдар химиясы институтының құрметті директоры (Минск, Беларусь), https://www.scopus.com/authid/detail.uri?authorId=7004624845

КАТАЛИН Стефан, PhD, қауымдастырылған профессор, Дрезден Техникалық университеті (Дрезден, Германия), https://www.scopus.com/authid/detail.uri?authorId=35203904500; https://www.webofscience.com/wos/author/record/1309251

САҒЫНТАЕВ Жанай, PhD, қауымдастырылған профессор, Назарбаев университеті (Астана, Қазақстан), https://www.scopus.com/authid/detail.uri?authorId=57204467637; https://www.webofscience.com/wos/author/record/907886

ФРАТТИНИ Паоло, PhD, қауымдастырылған профессор, Бикокк Милан университеті (Милан, Италия), https://www.scopus.com/authid/detail.uri?authorId=56538922400

НҰРПЕЙІСОВА Маржан Байсанқызы, техника ғылымдарының докторы, Қ.И. Сәтбаев атындағы Қазақ ұлттық техникалық зерттеу университетінің профессоры (Алматы, Қазақстан), https://www.scopus.com/authid/detail.uri?authorId=57202218883; https://www.webofscience.com/wos/author/record/AAD-1173-2019

РАТОВ Боранбай Товбасарович, техника ғылымдарының докторы, профессор, «Геофизика және сейсмология» кафедрасының меңгерушісі, Қ.И. Сәтбаев атындағы Қазақ ұлттық техникалық зерттеу университеті (Алматы, Қазақстан), https://www.scopus.com/authid/detail.uri?authorId=55927684100; https://www.webofscience.com/wos/author/record/1993614

РОННИ Берндтссон, профессор, Таяу Шығысты заманауи зерттеу орталығының директоры, Лунд университеті (Лунд, Швеция), https://www.scopus.com/authid/detail.uri?authorId=7005388716; https://www.webofscience.com/wos/author/record/1324908

МИРЛАС Владимир, PhD, профессор, Ариэль университетінің Шығыс ғылыми-зерттеу орталығы (Ариэль, Израиль), https://www.scopus.com/authid/detail.uri?authorId=8610969300; https://www.webofscience.com/wos/author/record/53680261

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Меншіктеуші: «Орталық Азия академиялық ғылыми орталығы» ЖШС (Алматы қ.).
Қазақстан Республикасының Ақпарат және коммуникациялар министрлігінің Ақпарат комитетінде 05.06.2025 ж. берілген № KZ50VPY00121155 мерзімдік басылым тіркеуіне қойылу туралы куәлік.
Тақырыптық бағыты: *геология, гидрогеология, география, тау-кен ісі, мұнай, газ және металдардың химиялық технологиялары*
Мерзімділігі: жылына 6 рет.
http://www.geolog-technical.kz/index.php/en/

© «Орталық Азия академиялық ғылыми орталығы» ЖШС, 2026,

ГЛАВНЫЙ РЕДАКТОР

ЖУРИНОВ Мурат Журинович, доктор химических наук, профессор, академик МААН и НАН РК, Генеральный директор НИИ нефтепереработки и нефтехимии (Алматы, Казахстан), https://www.scopus.com/authid/detail.uri?authorId=6602177960; https://www.webofscience.com/wos/author/record/2017489

ЗАМЕСТИТЕЛЬ ГЛАВНОГО РЕДАКТОРА

АБСАДЫКОВ Бахыт Нарикбаевич, доктор технических наук, профессор, академик НАН РК, Казахский национальный исследовательский технический университет им. К.И. Сатпаева (Алматы, Казахстан), https://www.scopus.com/authid/detail.uri?authorId=6504694468; https://www.webofscience.com/wos/author/record/2411827

РЕДАКЦИОННАЯ КОЛЛЕГИЯ:

АБСАМЕТОВ Малис Кудысович, доктор геолого-минералогических наук, профессор, академик НАН РК, директор Института гидрогеологии и геоэкологии им. У.М. Ахмедсафина (Алматы, Казахстан), https://www.scopus.com/authid/detail.uri?authorId=56955769200; https://www.webofscience.com/wos/author/record/1937883

ЖОЛТАЕВ Герой Жолтаевич, доктор геолого-минералогических наук, профессор, почетный академик НАН РК (Алматы, Казахстан), https://www.scopus.com/authid/detail.uri?authorId=57112610200; https://www.webofscience.com/wos/author/record/1939201

СНОУ Дэниел, PhD, ассоциированный профессор, директор Лаборатории водных наук Университета Небраски (Небраска, США), https://www.scopus.com/authid/detail.uri?authorId=7103259215; https://www.webofscience.com/wos/author/record/1429613

ЗЕЛЬТМАНН Раймар, PhD, руководитель исследований в области петрологии и месторождений полезных ископаемых в Отделе наук о Земле Музея естественной истории (Лондон, Великобритания), https://www.scopus.com/authid/detail.uri?authorId=55883084800; https://www.webofscience.com/wos/author/record/ 1048681

ПАНФИЛОВ Михаил Борисович, доктор технических наук, профессор Университета Нанси (Нанси, Франция), https://www.scopus.com/authid/detail.uri?authorId=7003436752; https://www.webofscience.com/wos/author/record/1230499

ШЕН Пин, PhD, заместитель директора Комитета по горной геологии Китайского геологического общества, член Американской ассоциации экономических геологов (Пекин, Китай), https://www.scopus.com/authid/detail.uri?authorId=57202873965; https://www.webofscience.com/wos/author/record/1753209

ФИШЕР Аксель, PhD, ассоциированный профессор, Технический университет Дрезден (Дрезден, Берлин), https://www.scopus.com/authid/detail.uri?authorId=35738572100; https://www.webofscience.com/wos/author/record/2085986

АГАБЕКОВ Владимир Енокович, доктор химических наук, академик НАН Беларуси, почетный директор Института химии новых материалов (Минск, Беларусь), https://www.scopus.com/authid/detail.uri?authorId=7004624845

КАТАЛИН Стефан, PhD, ассоциированный профессор, Технический университет Дрезден (Дрезден, Германия), https://www.scopus.com/authid/detail.uri?authorId=35203904500; https://www.webofscience.com/wos/author/record/ 1309251

САГИНТАЕВ Жанай, PhD, ассоциированный профессор, Назарбаев университет (Астана, Казахстан), https://www.scopus.com/authid/detail.uri?authorId=57204467637; https://www.webofscience.com/wos/author/record/907886

ФРАТТИНИ Паоло, PhD, ассоциированный профессор, Миланский университет Бикокк (Милан, Италия), https://www.scopus.com/authid/detail.uri?authorId=56538922400

НУРПЕИСОВА Маржан Байсановна, доктор технических наук, профессор Казахского национального исследовательского технического университета им. К.И. Сатпаева (Алматы, Казахстан), https://www.scopus.com/authid/detail.uri?authorId=57202218883; https://www.webofscience.com/wos/author/record/AAD-1173-2019

РАТОВ Боранбай Товбасарович, доктор технических наук, профессор, заведующий кафедрой «Геофизика и сейсмология», Казахский национальный исследовательский технический университет им. К.И. Сатпаева (Алматы, Казахстан), https://www.scopus.com/authid/detail.uri?authorId=55927684100; https://www.webofscience.com/wos/author/record/1993614

РОННИ Берндтссон, профессор, Директор Центра современных ближневосточных исследований, Лундский университет (Лунд, Швеция), https://www.scopus.com/authid/detail.uri?authorId=7005388716; https://www.webofscience.com/wos/author/record/1324908

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

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.

ISSN 2518-170X (Online),

ISSN 2224-5278 (Print)

Собственник: ТОО «Центрально-Азиатский академический научный центр» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и коммуникаций и Республики Казахстан № KZ50VPY00121155, выданное 05.06.2025 г.

Тематическая направленность: *геология, гидрогеология, география, горное дело и химические технологии нефти, газа и металлов*

Периодичность: 6 раз в год.

http://www.geolog-technical.kz/index.php/en/

© ТОО «Центрально-Азиатский академический научный центр», 2026.

CONTENTS

NEWS OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC
OF KAZAKHSTAN, SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224–5278
Volume 3.
Number 477 (2026), 325–347

https://doi.org/10.32014/2026.2518-170X.656

UDC: 622.271(528.7)
IRSTI: 52.21.23

**©Sayyidqosimov S.S., Qurbonov H.A.*, Nizamova A.T.,
Khakberdiyev M.R., Yakubov T.Sh., 2026.**
Tashkent State Technical University named after Islam Karimov,
Tashkent, Uzbekistan.
*E-mail: kimqx92@gmail.com

EXPERIMENTAL STUDY OF THE ACCURACY OF UNDERGROUND MINE MODELS CONSTRUCTED FROM MOBILE IMAGING DATA

Sayidqosimov Sayidjabbor — Doctor of Technical Sciences, Professor, Tashkent State Technical University, Tashkent, Uzbekistan,
E-mail: sayyidjabbor@yandex.com, https://orcid.org/0000-0002-5954-2790;
Qurbonov Hasan — PhD Student, Tashkent State Technical University, Tashkent, Uzbekistan,
E-mail: kimqx92@gmail.com, https://orcid.org/0009-0004-2077-0798;
Nizamova Albina — PhD, Associate Professor, Tashkent State Technical University, Tashkent, Uzbekistan,
E-mail: at.nizamova@gmail.com https://orcid.org 0000-0001-5606-2030;
Khakberdiyev Muzaffar — PhD, Associate Professor, Tashkent State Technical University named after Islam Karimov, Tashkent, Uzbekistan,
E-mail: zafarzafar2066@gmail.com, https://orcid.org/0000-0002-8386-4036;
Yakubov Tohir — Senior Lecturer, Tashkent State Technical University named after Islam Karimov, Tashkent, Uzbekistan,
E-mail: tohiryakubov1994@gmail.com, https://orcid.org/0009-0006-6612-7858.

Abstract. *Relevance.* In the context of the implementation of digital technologies in mine surveying practice, increasing attention is being paid to methods of spatial documentation of underground mine workings that combine sufficient accuracy, operational efficiency, and affordability. In this regard, the use of photogrammetry based on smartphone cameras is of particular interest under low-light conditions typical of underground mining environments. *Objective.* The aim of this study was to experimentally evaluate the accuracy of photogrammetric reconstruction of underground workings using mid-range smartphones and determine the feasibility of their application in mine surveying operations. *Methods.* A non-operational section of an underground working was selected as the research object. Image acquisition was performed using four smartphones: Redmi Note 13 Pro, Samsung Galaxy A25, Vivo V21, and Infinix Note 30i. Illumination was provided by a

U-600 floodlight with adjustable brightness and color temperature. Photographs were captured in three vertical rows with a spacing of 3 m, ensuring at least 60% longitudinal overlap and 25% transverse overlap. The collected images were processed in the Agisoft Metashape software environment to generate dense point clouds and three-dimensional models. Accuracy assessment was carried out in CloudCompare using the Cloud-to-Cloud Distance method by comparing the resulting point clouds with a reference model obtained through laser scanning. *Results.* The experimental results demonstrated that smartphone-based photogrammetry can provide spatial accuracy sufficient for solving engineering and mine surveying tasks. The highest reconstruction accuracy and point cloud density were achieved using the Vivo V21 and Redmi Note 13 Pro smartphones, whereas the Samsung Galaxy A25 showed the lowest reconstruction stability. *Conclusions.* The obtained results confirm the feasibility of using smartphones for photogrammetric surveying of underground workings, provided that requirements for image acquisition and lighting conditions are satisfied. The study highlights the potential of mobile photogrammetry for improving the digitalization and efficiency of mining operations.

Keywords: mobile photogrammetry, underground mine workings, smartphone, three-dimensional modeling, point cloud, Agisoft Metashape, CloudCompare, spatial reconstruction, accuracy, laser scanning

For citations: *Sayyidqosimov S.S., Qurbonov H.A., Nizamova A.T., Khakberdiyev M.R., Yakubov T.Sh. Experimental Study of the Accuracy of Underground Mine Models Constructed from Mobile Imaging Data. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences. 2026. No.3. Pp. 325–347. DOI: https://doi.org/10.32014/2026.2518-170X.656*

©Сәйітқосымов С.С., Құрбонов Х.А.*, Низамова А.Т., Хакбердиев М.Р., Якубов Т.Ш., 2026.
И.Каримов атындағы Ташкент мемлекеттік техникалық университеті,
Ташкент, Өзбекстан.
*E-mail: kimqx92@gmail.com

ҰЯЛЫ ТҮСІРІЛІМ ДЕРЕКТЕРІ БОЙЫНША ҚҰРЫЛҒАН ЖЕР АСТЫНДАҒЫ ТАУ-КЕН ҚАЗБАЛАРЫ МОДЕЛЬДЕРІНІҢ ДӘЛДІГІН ЭКСПЕРИМЕНТТІК ЗЕРТТЕУ

Сәйітқосымов Сәйітжаббар — техника ғылымдарының докторы, профессор, И. Каримов атындағы Ташкент мемлекеттік техникалық университеті, Ташкент, Өзбекстан,
E-mail: sayyidjabbor@yandex.com, https://orcid.org/0000-0002-5954-2790;
Құрбонов Хасан — PhD докторант, И. Каримов атындағы Ташкент мемлекеттік техникалық университеті, Ташкент, Өзбекстан,
E-mail: kimqx@gmail.com, https://orcid.org/0009-0004-2077-0798;

Низамова Альбина — PhD, доцент, И. Каримов атындағы Ташкент мемлекеттік техникалық университеті, Ташкент, Өзбекстан,
E-mail: at.nizamova@gmail.com, https://orcid.org 0000-0001-5606-2030;
Хакбердиев Музаффар — PhD, доцент, И. Каримов атындағы Ташкент мемлекеттік техникалық университеті, Ташкент, Өзбекстан,
E-mail: zafarzafar2066@gmail.comhttps, https://orcid.org/0000-0002-8386-4036;
Якубов Тохир — аға оқытушы, И. Каримов атындағы Ташкент мемлекеттік техникалық университеті, Ташкент, Өзбекстан,
E-mail: tohiryakubov1994@gmail.com, https://orcid.org/0009-0006-6612-7858.

Аннотация. ***Өзектілігі.*** Маркшейдерлік практикаға цифрлық технологиялардың белсенді енгізілуі жағдайында дәлдігі жеткілікті, жеделдігі жоғары және экономикалық тұрғыдан қолжетімді болып келетін жерасты тау-кен қазбаларын кеңістіктік құжаттаудың әдістерін іздеу ерекше маңызға ие. Осы тұрғыда қазіргі заманғы смартфон камераларына негізделген фотограмметрияны қолдану мүмкіндіктерін, әсіресе жерасты тау-кен қазбаларына тән шектеулі жарықтандыру жағдайларында, бағалау өзекті болып табылады. ***Зерттеу мақсаты***. Орташа баға сегментіндегі смартфон камераларын пайдалану арқылы жерасты тау-кен қазбаларын фотограмметриялық қайта құрудың дәлдігін эксперименттік түрде бағалау және олардың маркшейдерлік жұмыстарда практикалық қолдану мүмкіндігін анықтау. Зерттеу нысаны ретінде пайдаланылмайтын жерасты тау-кен қазбасының учаскесі таңдалды. Түсірілім Redmi Note 13 Pro, Samsung Galaxy A25, Vivo V21 және Infinix Note 30i смартфондарын пайдалана отырып жүргізілді. Жарықтандыру жарықтылығы мен түстік температурасы реттелетін U-600 жарықдиодты прожектормен қамтамасыз етілді. Фототүсірілім 3 м қадаммен үш тік қатарда жүргізіліп, бойлық бағыттағы қабаттасу кемінде 60 %, ал көлденең бағыттағы қабаттасу кемінде 25 % болды. Алынған кескіндерді өңдеу Agisoft Metashape бағдарламалық ортасында жүзеге асырылды. Дәлдікті бағалау CloudCompare бағдарламасында Cloud-to-Cloud Distance (C2C) әдісі арқылы фотограмметриялық нүктелік бұлттарды лазерлік сканерлеу әдісімен алынған эталондық модельмен салыстыру жолымен орындалды. ***Нәтиже.*** Эксперименттік деректер мобильді құрылғыларды пайдалана отырып жүргізілген фотограмметрия инженерлік міндеттерді шешу үшін жеткілікті кеңістіктік дәлдік деңгейін қамтамасыз ететінін көрсетті. Нүктелік бұлттың тығыздығы мен қайта құрудың жалпы дәлдігі бойынша ең жоғары көрсеткіштерді Vivo V21 және Redmi Note 13 Pro смартфондары көрсетті, ал Samsung Galaxy A25 қайта құру нәтижелерінің тұрақтылығы бойынша ең төмен көрсеткіштермен сипатталды. Алынған нәтижелер түсірілім әдістемесіне және жарықтандыру жағдайларына қойылатын талаптар сақталған жағдайда смартфондарды жерасты тау-кен қазбаларын фотограмметриялық түсіруде қолдану мүмкін екенін растайды. Бұл маркшейдерлік қамтамасыз ету саласында мобильді фотограмметрияны кеңінен енгізуге алғышарттар жасайды және өндірістік үдерістердің цифрландыру деңгейі мен экономикалық тиімділігін арттыруға ықпал етеді.

Түйін сөздер: мобильді фотограмметрия, жерасты тау-кен қазбалары, смартфон, үшөлшемді модельдеу, нүктелік бұлт, Agisoft Metashape, CloudCompare, кеңістіктік қайта құру, дәлдік, лазерлік сканерлеу

©Сайййдкосимов С.С., Курбонов Х.А.*, Низамова А.Т., Хакбердиев М.Р., Якубов Т.Ш., 2026.
Ташкентский государственный технический университет имени
И. Каримова, Ташкент, Узбекистан.
*E-mail: kimqx92@gmail.com

ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ ТОЧНОСТИ МОДЕЛЕЙ ПОДЗЕМНЫХ ГОРНЫХ ВЫРАБОТОК, ПОСТРОЕННЫХ ПО ДАННЫМ МОБИЛЬНОЙ СЪЁМКИ

Сайййдкосимов Сайййджаббор — доктор технических наук, профессор, Ташкентский государственный технический университет имени И. Каримова, Ташкент, Узбекистан,
E-mail: sayyidjabbor@yandex.com, https://orcid.org/0000-0002-5954-2790;
Курбонов Хасан — PhD-докторант, Ташкентский государственный технический университет имени И. Каримова, Ташкент, Узбекистан,
E-mail: kimqx@gmail.com, https://orcid.org/0009-0004-2077-0798;
Низамова Альбина — PhD, доцент, Ташкентский государственный технический университет имени И. Каримова, Ташкент, Узбекистан,
E-mail: at.nizamova@gmail.com, https://orcid.org/0000-0001-5606-2030;
Хакбердиев Музаффар — PhD, доцент, Ташкентский государственный технический университет имени И. Каримова, Ташкент, Узбекистан,
E-mail: zafarzafar2066@gmail.com, https://orcid.org/0000-0002-8386-4036;
Якубов Тохир — старший преподаватель, Ташкентский государственный технический университет имени И. Каримова, Ташкент, Узбекистан,
E-mail: tohiryakubov1994@gmail.com, https://orcid.org/0009-0006-6612-7858.

Аннотация. *Актуальность.* В условиях активного внедрения цифровых технологий в маркшейдерскую практику особое значение приобретает поиск методов пространственной документации подземных выработок, сочетающих достаточную точность, оперативность и экономическую доступность. В этой связи актуальной является оценка возможностей применения фотограмметрии на основе камер современных смартфонов, особенно в условиях ограниченного освещения, характерных для подземных горных выработок. *Цель.* Экспериментально оценить точность фотограмметрической реконструкции подземных выработок при использовании камер смартфонов среднего ценового сегмента и определить возможность их практического применения в маркшейдерских работах. *Методы.* В качестве объекта исследования выбран неэксплуатируемый участок подземной выработки. Съемка выполнялась с использованием смартфонов Redmi Note 13 Pro, Samsung Galaxy A25, Vivo V21 и Infinix Note 30i. Освещение обеспечивалось светодиодным прожектором U-600 с регулируемой яркостью и цветовой температурой. Фотографирование проводилось в три вертикальных ряда с шагом 3 м при продольном перекрытии не менее 60% и поперечном - не менее 25%. Обработка изображений осуществлялась в программной среде Agisoft Metashape. Оценка точности выполнялась в CloudCompare методом Cloud-to-Cloud Distance путем сравнения фотограмметрических облаков точек с эталонной моделью, полученной методом лазерного сканирования. *Результаты и выводы*. Экспериментальные данные показали, что фотограмметрия с использованием мобильных устройств обеспечивает уровень пространственной точности, достаточный для решения инженерных задач. Наилучшие показатели плотности облака точек и точности реконструкции продемонстрировали смартфоны Vivo V21 и Redmi Note 13 Pro, тогда как Samsung Galaxy A25 характеризовался наименьшей стабильностью результатов. Полученные результаты подтверждают возможность применения смартфонов в фотограмметрической съемке подземных выработок при соблюдении требований к методике съемки и освещению. Это создает предпосылки для расширения использования мобильной фотограмметрии в маркшейдерском обеспечении горных работ и способствует повышению уровня цифровизации и экономической эффективности производственных процессов.

Ключевые слова: мобильная фотограмметрия, подземные горные выработки, смартфон, трёхмерное моделирование, облако точек, Agisoft Metashape, CloudCompare, пространственная реконструкция, точность, лазерное сканирование

Introduction. Three-dimensional documentation of underground mine workings has advanced rapidly over the past decade. In practice, stationary terrestrial laser scanning and mobile systems based on simultaneous localization and mapping (SLAM) remain the dominant options for spatial capture underground (Dabove et al., 2019; Morelli et al., 2024; Skarlatos et al., 2024; Pukanská et al., 2024), enabling detailed digital models that support excavation-volume estimation, overbreak/underbreak analysis, and compliance checks against design contours. In parallel, image-based modelling via photogrammetry has gained traction as a flexible and cost-effective complement to laser scanning, particularly when professional digital cameras are available.

The fast evolution of mobile hardware now suggests a credible path for smartphone-based photogrammetry (Dabove et al., 2019; An et al., 2022; An et al., 2021; Alijani et al., 2022). Modern handsets combine high-resolution sensors with advanced on-device processing and, in favourable conditions, can approach the output of dedicated cameras. Transferring this promise underground, however, is non-trivial: standardized capture protocols are largely absent; optimal imaging parameters are not well established; and the effects of limited and spatially variable illumination are insufficiently addressed (Burdziakowski, 2024; Morelli et al., 2024; Pukanská et al., 2024). Moreover, most published workflows were designed for well-lit surface environments and are not tailored to underground constraints (Dabove et al., 2019). To the best of our knowledge, the literature still lacks a compact, field-tested protocol for smartphone photogrammetry specifically in low-light underground settings.

Here we do not claim to replace TLS; rather, we ask under what conditions mid-range smartphones can produce geometrically reliable models. Our contributions are deliberately practical: a capture layout with explicit overlaps and spacing, an image-count formulation with ceiling rounding per direction, and a like-for-like accuracy benchmark against a TLS reference using CloudCompare with the Cloud-to-Cloud Distance metric and ground control point (GCP) residuals. All parameters (software versions and CloudCompare settings) are reported for reproducibility, and limitations are discussed upfront (illumination non-uniformity, edge occlusions, and texture scarcity) (Burdziakowski, 2024).

Literary review. Over the past decade, photogrammetry based on the acquisition of metric three-dimensional information from overlapping images has become widely adopted in underground mine workings. A major contribution to its development has been made by advances in Structure from Motion (SfM) algorithms, improvements in digital image processing, and the emergence of high-sensitivity cameras and unmanned platforms, which have enabled effective data acquisition in remote and poorly illuminated underground environments (Benton et al., 2017). Whereas the geometry of mine workings was previously documented mainly using traditional surveying methods or laser scanning, during the period 2015–2025 photogrammetry has been increasingly incorporated into geodetic support practices for mining operations.

In both scientific and applied studies, photogrammetric methods are employed to generate accurate 3D models of underground excavations, assess rock mass deformation, analyze ground support conditions, and perform geometric control of excavation cross-sections. It is noted that, in many cases, the accuracy of photogrammetric data is comparable to that of laser scanning, while offering lower costs and greater operational flexibility. A number of publications emphasize that mobile photogrammetry can effectively complement laser scanning and, under certain conditions, partially replace it.

Recent research links the development of underground photogrammetry to the concept of the “Digital Mine,” which involves integrating spatial data on mine workings, geology, and equipment within a unified geoinformation environment. Photogrammetric 3D models and point clouds are widely integrated into specialized mining GIS and software platforms, where they are used for planning, analysis, and monitoring. According to international reviews, the integration of photogrammetry and GIS enhances the efficiency of spatial data analysis, improves calculation accuracy, and supports more informed engineering decision-making.

The literature also highlights the importance of using photogrammetric data as part of digital twins of underground spaces (Benton et al., 2017; Morelli et al., 2024). Models referenced to the mine coordinate system are combined with attribute information—such as rock mass properties, sensor locations, and equipment routes—providing a comprehensive representation of the state of mine workings. These approaches enable spatial queries, the creation of thematic layers, and the automation of reporting processes, thereby reducing time and labor requirements.

A distinct research direction focuses on the application of photogrammetry for deformation monitoring. Studies demonstrate that photogrammetric measurements of displacements and crack openings can achieve accuracy comparable to that of traditional contact-based methods. This creates opportunities for the partial replacement of physical sensors with remote observation techniques, particularly in hazardous areas. Several works also examine the integration of photogrammetry with seismic monitoring, strain gauge measurements, and thermal imaging data for comprehensive rock mass assessment (Cazes G et al., 2024.).

Prospective research is increasingly oriented toward the automation of data acquisition and processing. The literature describes experiments involving robotic platforms and autonomous drones capable of performing regular photogrammetric surveys of underground workings. Such solutions are regarded as a foundation for transitioning toward near-continuous monitoring and enhancing industrial safety.

Overall, an analysis of published studies indicates that digital photogrammetry has rapidly evolved from an experimental approach into an industrially applied technology. Despite remaining limitations related to lighting conditions and surface texture, ongoing advances in hardware and software continue to expand its range of applications. In the scientific literature, photogrammetry is increasingly regarded as an integral component of digital information systems for mining operations and a promising element of the “smart mine” concept.

Materials and methods. Recent advances in photogrammetry and mobile hardware have opened practical routes to efficient, low-cost three-dimensional modelling of underground structures (Dabove et al., 2019; An et al., 2022; An et al., 2021; Morelli et al., 2024; Cazes et al., 2024; Zhang et al., 2024). While professional digital cameras have been used successfully in several international studies, underground deployment remains challenging: illumination is limited and non-uniform, humidity and airborne dust are common, and space is confined (Morelli et al., 2024; Pukanská et al., 2024).

To address these constraints, we examine the use of mid-range smartphones for underground image capture. Under the tested conditions, contemporary phone cameras can provide imagery of sufficient quality for accurate reconstruction while offering pragmatic advantages—affordability, compact form factor, wireless data transfer, and ease of access. At the same time, underground smartphone photogrammetry is still insufficiently studied and requires purpose-built acquisition protocols and processing guidelines (Cazes et al., 2024; Morelli et al., 2024; Pukanská et al., 2024; Zhang et al., 2024). Details of the devices, imaging modes, and software are provided in Section 1.2 (Equipment and software).

Accordingly, we developed and piloted an experimental protocol under real underground conditions. The primary tasks were: to acquire imagery using four mid-range smartphones; to process the photographs for dense point cloud generation; and to evaluate reconstruction accuracy through comparison with a reference point cloud obtained using a SLAM-based laser scanner. (Morelli et al., 2024).

Field campaign. The trials were conducted in June 2025 at an inactive segment of a hydraulic tunnel near a reservoir in the Kashkadarya Region, Republic of Uzbekistan (Figure 1). Work took place in a vehicle-turning chamber currently used as storage. The surveyed segment measures 8 m in length, 5 m in height, and up to 5.5 m in width—dimensions that reproduce typical underground constraints (confined geometry and limited illumination). Global Navigation Satellite Systems (GNSS) were unavailable, so georeferencing relied on GCPs measured with a total station; the reference dataset was acquired by TLS using an FJdynamics Trion P1 and served as an independent geometric baseline. All trials were conducted by the author (doctoral researcher H. A. Kurbanov) with minimal ancillary equipment—a 1.5 m tripod and a portable LED spotlight (U-600)—to underscore the deployable, low-overhead character of the workflow.

Figure 1. Location of the test site.

Equipment and software. As the imaging platform, we employed four mid-range, consumer-grade smartphones (Table 1). Devices were chosen to reflect realistic cost and logistics constraints in underground work (Dabove et al., 2019; An et al., 2022; An et al., 2021; Alijani et al., 2022). Imaging was performed with manual exposure and white balance, AE/AF lock, and HDR/AI enhancements disabled. RAW capture was not available on the tested handsets; therefore, acquisition used minimally processed JPEG.

Table 1. Technical specifications of the smartphones used in this study.

Smartphone model	Main Camera (MP)	Sensor size	Aperture	Price (USD)
Redmi Note 13 Pro	200	1/1.4»	f/1.65	300 $
Samsung Galaxy A25	50	1/1.56»	f/1.8	300 $
Infinix Note 30i	64	1/2»	f/1.7	200 $
Vivo V21	64	1/1.72»	f/1.8	300 $

To ensure adequate lighting under limited-visibility conditions, we used a portable U-600 LED spotlight with stepless control of luminous output and correlated colour temperature (CCT), adjustable between ~3200 K and ~5600 K (Burdziakowski, 2024). Two illumination regimes were tested: (i) residual ambient light and (ii) directed illumination from the U-600 (Figure 2).

Image processing, point-cloud generation, and 3D reconstruction were performed in Agisoft Metashape Professional v2.2.1. Accuracy assessment and geometric discrepancy analysis were conducted in CloudCompare v2.14 using the C2C tool with Euclidean nearest-neighbour (NN) search. Unless otherwise noted, we restricted the analysis to a shared ROI, applied spatial resampling to uniform spacing, enforced a maximum distance to clip spurious matches, and reported mean, standard deviation, min/max, and histograms. For signed interpretation, normals were estimated on the TLS reference.

Reference data were acquired using an FJDynamics Trion P1 handheld SLAM LiDAR scanner. Public specifications indicate a point rate of ~200 k pts/s, Class 1 (905 nm) laser, internal 512 GB storage, IP54 protection, and relative accuracy up to ~2 cm, with a nominal range up to ~40 m at 10% reflectivity (up to ~70 m at higher reflectivity). These figures are provided for context; in this study, the SLAM-based laser scanning model served as an independent geometric baseline (Stroner et al., 2025; Janiszewski et al., 2022) for smartphone reconstructions.

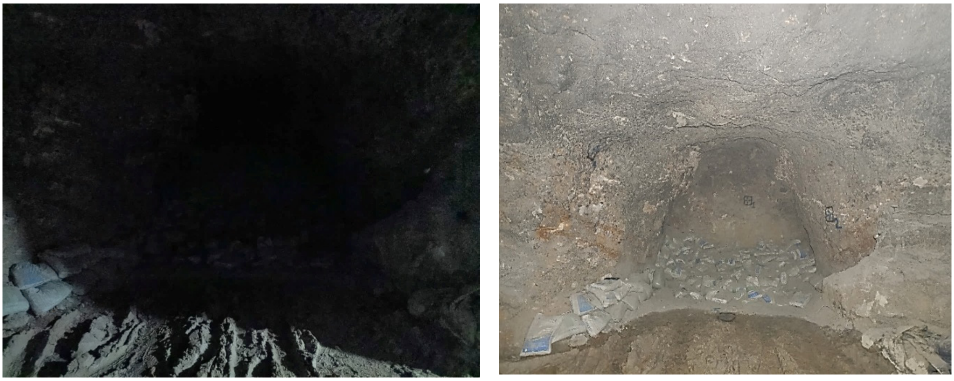


Figure 2. Visual comparison of imaging conditions: left—the tunnel face under residual ambient light; right—the same location under directed illumination using a portable U-600 LED spotlight.

Pre-acquisition setup. Prior to image capture, five ground control points were installed within the test section and distributed across the excavation to span all three axes: at the heading face, on the sidewalls, at the roof (crown), and on the floor (Figure 3). Each target was painted directly on the rock as a matte blue 100 × 100 mm square with a central circular mark (≈ 10 × 10 mm) to facilitate precise centroiding and to suppress specular glare. Because GNSS is unavailable underground, camera centres cannot be determined directly; spatial registration of the photogrammetric models therefore relied on these GCPs.

All GCP coordinates were measured with a South N7 total station; each point was observed three times, and the arithmetic mean was adopted for subsequent processing. The models were oriented in a local right-handed Cartesian datum common to all reconstructions. The heading face was additionally captured by terrestrial laser scanning, which served as an independent geometric reference for validation against the smartphone-derived reconstructions (Morelli et al., 2024).

During bundle adjustment, GCPs were identified on the images and used for exterior orientation. Each control point was captured from multiple stations; even at the most distant stations, a minimum of two images per GCP was ensured to maintain redundancy and stable adjustment.

Figure 3. Placement of ground control points (GCP1–GCP5) at the tunnel heading face.

Image acquisition and data collection. Imagery was captured with a smartphone mounted on a 1.5 m tripod inside a rigid stabilizing cage fitted with an integrated LED spotlight (Burdziakowski, 2024). This arrangement provided stiff camera support and controllable, uniform illumination of the heading—both essential under limited-visibility conditions. The cage suppressed micro-vibrations during longer exposures and enabled repeatable framing along the planned capture path; the directed light minimized motion blur and exposure variability. Where necessary, spotlight output and correlated colour temperature (CCT, ~3200–5600 K) were adjusted to suppress specular glare and enhance surface-texture contrast, improving tie-point detection and the robustness of bundle adjustment. Imaging used manual exposure and white balance with AE/AF lock and HDR/AI enhancements disabled.

Photogrammetric imaging proceeded along three vertical rows with forward overlap ≥60% and side overlap ≥25%, consistent with widely adopted recommendations for accurate Structure-from-Motion reconstruction (Dabove et al., 2019, An et al., 2022; An et al., 2021). Image stations were spaced at approximately 3 m along the tunnel axis. The smartphone and LED spotlight were co-mounted; at each station, the camera was slewed through a modest arc to secure overlap both between adjacent frames and between rows. The heading is approximately 5 m, width of up to 5.5 m, and a length of 8 m. (Figure 4)

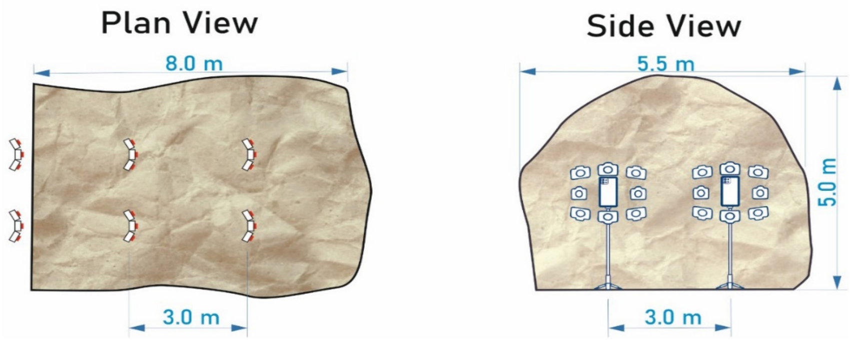


Figure 4. Schematic of camera placement during image capture in the tunnel heading.

The required number of photographs was computed using the relation previously proposed by Prof. S. S. Sayyidqosimov (Qurbonov et al., 2025; Sayyidkosimov et al., 2025), which ties capture density to the excavation geometry and the intended overlaps. In our implementation, the image count N is given by

$$N = \left(\frac{L}{d*(1-\Delta p)} + 1\right) * \left(\frac{W}{h_{cov}*(1-\Delta t)} + 1\right) * \left(\frac{H}{v_{cov}*(1-\Delta v)} + 1\right) \qquad (1)$$

Here, L is the length of the surveyed section (m), W is the the width of the tunnel (m), H the height of the heading (m), d is the along-track station spacing (3 m), Δp, Δt, Δv the forward, side, and vertical overlaps (0.60, 0.25, and 0.60, respectively), and h_{cov} *and* v_{cov} the horizontal and vertical coverage widths of a single frame at a camera-to-surface distance of 3 m. In accordance with established photogrammetric practice, ceiling rounding per direction was applied to ensure complete coverage and sufficient overlap in all dimensions.

This approach enables rational image planning, eliminates potential coverage gaps, and improves the robustness of subsequent SfM–MVS reconstruction.

This target count was implemented for each smartphone during acquisition (Figure 5), providing sufficiently dense, uniform coverage for robust SfM–MVS reconstruction.

All imagery was acquired in fully manual mode, with the phone's built-in post-processing and scene automation disabled. In particular, we switched off HDR/auto-HDR, "AI Camera" scene optimisation, multi-frame night modes, electronic stabilisation, aggressive noise-reduction pipelines, in-app lens-distortion/vignetting correction, exposure bracketing and burst/stacking features. Although such modules can improve visual appeal—by smoothing textures, boosting local contrast, or fusing multiple frames—they compromise metric fidelity.

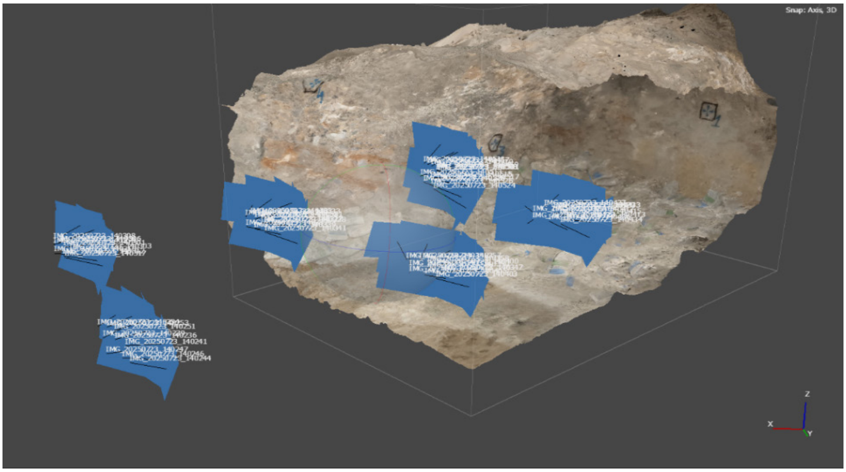


figure 5. camera positions and reconstructed 3d scene in agisoft metashape.

From a photogrammetric standpoint, these algorithms alter pixel statistics in ways that matter: repeatable fine relief is softened; local tone mapping changes micro-contrast; multi-frame fusion can introduce frame-to-frame inconsistencies over the same surface patch; and electronic de-shake/denoise may warp local geometry. The net effect is less stable keypoint detection and matching, reduced tie-point consistency between adjacent images, and, consequently, a higher risk of geometric bias during bundle adjustment and surface reconstruction—especially at the tunnel face under low light.

Accordingly, disabling all auto-enhancers was a necessary condition for obtaining reproducible data in smartphone photogrammetry. In practice, we maintained fixed exposure and white balance across each sequence, captured single frames (no bracketing), and relied on self-calibration in Agisoft Metashape to model lens parameters. As RAW capture was not available on the tested handsets, we used the least-processed JPEG available in the camera app (minimal sharpening and noise reduction where adjustable).

Results and discussions. Photogrammetric processing—including image alignment, dense point-cloud generation, and 3D model reconstruction—was performed in Agisoft Metashape Professional v2.2.1. For cross-validation and point-cloud comparison we used CloudCompare v2.14, where the photogrammetric outputs were evaluated against the TLS reference (see Methods §1.2 for C2C settings).

To keep runtimes reasonable and ensure stable operation under sustained loads, computations were carried out on a Windows 11 (64-bit) laptop (Asus TUF Gaming A15) equipped with an AMD Ryzen 7 7435HS CPU, 16 GB RAM, and an NVIDIA GeForce RTX 3050 GPU. This configuration provided sufficient headroom for the datasets considered and allowed the workflows to run without interruption.

Processing settings. All datasets were processed in Agisoft Metashape Professional v2.2.1 (Windows 11, 64-bit) using the application's factory defaults unless stated otherwise. Photo alignment was run at medium accuracy with Generic pair preselection enabled and reference preselection disabled; the Key point limit remained 40,000 and the Tie point limit 0 (unlimited). Camera calibration relied on Metashape's automatic self-calibration (Brown–Conrady model). After introducing five ground control points, the bundle was re-optimized via Optimize Cameras with the default parameter set (f, cx, cy, k1–k3, p1–p2) left active. No additional outlier pruning of tie points (beyond the software defaults) was applied. Dense reconstruction used the default settings (Quality = Medium, Depth filtering = Mild), and dense point clouds were exported in a local right-handed Cartesian frame (metres).

Geometric comparisons were performed in CloudCompare v2.14 with the Cloud-to-Cloud Distance tool, again using software defaults and exactly the same configuration for each smartphone cloud against the LiDAR reference. Both clouds were imported in the same local datum; no ICP refinement was applied after Metashape. The analysis covered the full overlapping extent, without explicit resampling or edge masking. C2C used octree-based nearest-neighbour (Euclidean NN) search, unsigned distances, no local modelling, and no enforced maximum search distance. We report the standard statistics returned by CloudCompare (mean, standard deviation, min/max) together with default histograms; colour maps in the figures use a fixed range in millimetres to preserve comparability across devices. No additional outlier-rejection options (e.g., "Ignore outliers") were enabled.

Reconstruction quality assessment. Processing was carried out in Agisoft Metashape using a uniform workflow for each smartphone: image alignment and tie-point extraction, bundle adjustment with camera self-calibration, dense point-cloud generation, and estimation of projection parameters. To isolate device effects, all models were reconstructed from the same number of images (96 per dataset) acquired under identical conditions and processed with identical settings. This design enables a like-for-like comparison across devices, minimizing confounding from acquisition geometry or processing choices. Key quality indicators and summary statistics are reported in Table 2.

Table 2. Key metrics of the photogrammetric workflow across devices.

Smartphone model	Images (n)	Tie points (count)	Projections (count)	Dense points (count)	Processing time (min)
Redmi Note 13 Pro	96	109 032	332 323	5 515 978	25
Samsung Galaxy A25	96	68 270	181 589	4 828 593	29
Infinix Note 30i	96	101 013	314 003	4 239 337	32
Vivo V21	96	73 659	203 688	5 889 014	38

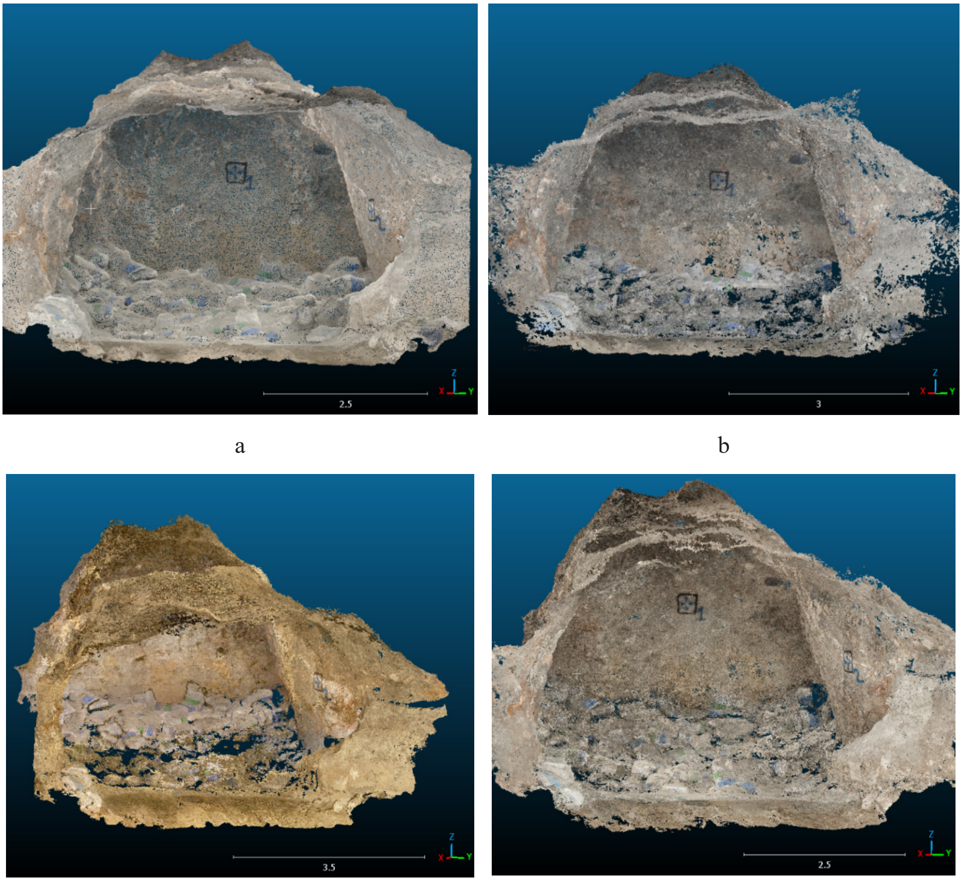
The data in Table 2 indicate that both camera characteristics and capture conditions materially affect reconstruction quality and efficiency. Even with identical acquisition geometry and 96 images per dataset, the devices behaved differently.

- Redmi Note 13 Pro and Infinix Note 30i produced the largest counts of tie points and projections (Redmi: 109,032 / 332,323; Infinix: 101,013 / 314,003), consistent with stable focus, adequate texture, and robust overlap. Despite its very high nominal resolution (200 MP), Redmi yielded a 5.52 M dense cloud with a comparatively short processing time (25 min), suggesting repeatable features under well-controlled lighting.
- Vivo V21 registered fewer tie points (73,659) yet produced the densest cloud (5.89 M). This points to a favourable balance among sensor quality, optical stabilisation, and exposure/sharpness settings—dense-cloud yield is not strictly proportional to tie-point or projection totals.
- Samsung Galaxy A25 recorded the lowest numbers of ties (68,270) and projections (181,589), coinciding with a smaller dense cloud (4.83 M) and 29 min runtime. This pattern is consistent with lower effective sensitivity in low light and less stable autofocus underground.
- Infinix Note 30i shows an instructive divergence: a high projection count (314,003) but the smallest dense cloud (4.24 M) and the longest runtime (32 min), indicative of elevated noise, local misalignments, or stricter depth-map filtering during densification.

Comparison of dense point clouds with the reference model. Following image alignment and tie-point identification, the spatial reconstruction was successfully computed as a dense point cloud representing the geometry of the test scene (Figure 6).

Using CloudCompare v2.14 (C2C tool, Euclidean nearest-neighbour, unsigned absolute distances, shared ROI, other options left at defaults), we compared each photogrammetric cloud with the TLS reference. The behaviour of the distance histograms and the deviation maps is broadly consistent across datasets: a compact centimetric core and a long, low-amplitude right tail driven by edge effects (grazing incidence, partial occlusions, weak texture). The specifics by device are as follows.

- Redmi note 13 pro. The Gaussian fit to the C2C histogram gives a mean ≈ 12.35 mm and SD ≈ 22.36 mm (2,349 bins). Most points lie in the 0–20 mm band; isolated enlargements (colour bar locally up to ~0.37 m) are confined to narrow strips along scene margins and the crown. This aligns with the GCP 3D RMSE ≈ 11.7 mm and a higher reprojection residual (1.45 px): the central corridor is reconstructed stably at engineering accuracy, while the heavy-tail portion reflects peripheral artefacts rather than a global bias. In practice, clipping an outer band (e.g., >50 mm) tightens the spread without changing the conclusion.



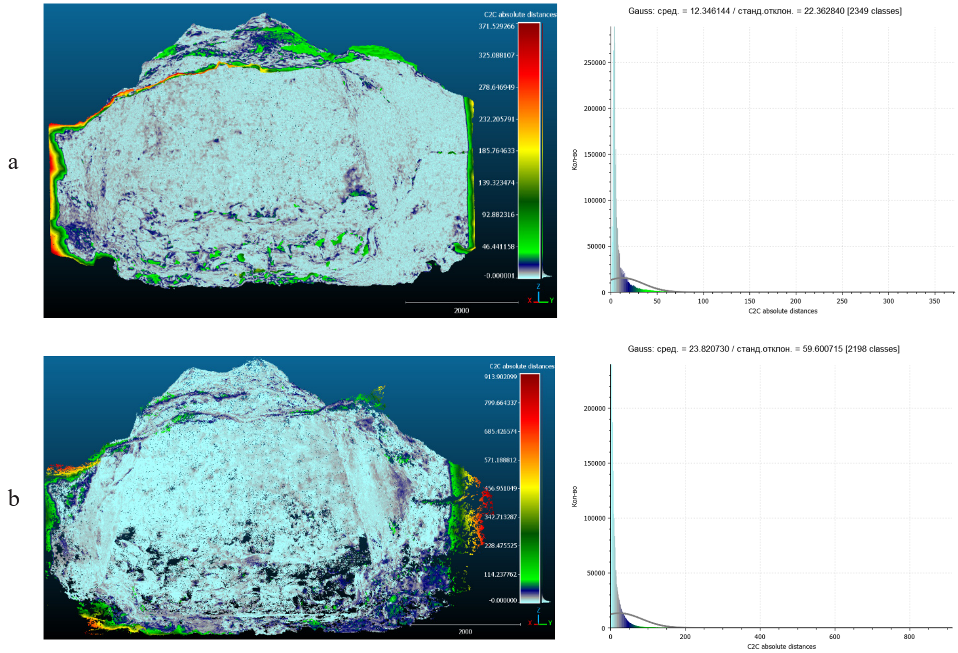
a b

c d

Figure 6. Dense point clouds reconstructed from the smartphone datasets: (a) Redmi Note 13 Pro; (b) Samsung Galaxy A25; (c) Infinix Note 30i; (d) Vivo V21.

- Samsung Galaxy A25. This dataset shows the weakest surface fidelity. The histogram is broad with a pronounced right tail (mean ≈ 23.8 mm, SD ≈ 59.6 mm), and the map reveals clusters of larger misfits at boundaries and the crown, with additional patches in the far field where the cloud thins. Typical symptoms—local warping, thinning, texture dropouts—are consistent with lower effective sensitivity and less reliable AF in low light. Even so, the image network remains internally coherent (GCP 3D RMSE ≈ 10.0 mm, mean reprojection ≈ 1.04 px). The model is serviceable for reconnaissance and bulk estimates, but tight conformity checks would benefit from stronger lighting and higher overlap/baseline.

- Infinix Note 30i. Coverage is broadly continuous, yet noisier than the better performers. The histogram is sharply right-skewed (mean ≈ 15.25 mm, SD ≈ 34.60 mm, 2,059 classes): the bulk sits below ~30–40 mm, with a long tail. Larger deviations concentrate at edges, the crown, and parts of the floor; isolated green–yellow–red patches (hundreds of millimetres) correspond to occlusions or depth-map dropouts. Together with the smallest dense-cloud size and longest runtime reported earlier, this points to optical/AF limits and the absence of robust stabilisation. Denser station spacing, stricter manual focus and more uniform lighting would likely suppress long-tail errors while keeping the core in the ~10–20 mm band.
- Vivo V21. The histogram is tightly concentrated in 0–30 mm; the Gaussian fit reports mean ≈ 15.1 mm, SD ≈ 34.5 mm (2,427 classes). The deviation map is pale-cyan across the central field; higher errors are confined to scene boundaries and crown/bench contacts. This indicates a geometrically stable core, fully consistent with GCP 3D RMSE ≈ 10.5 mm: within the working area, agreement with TLS is close, and discrepancies cluster in low-texture or oblique-view zones.



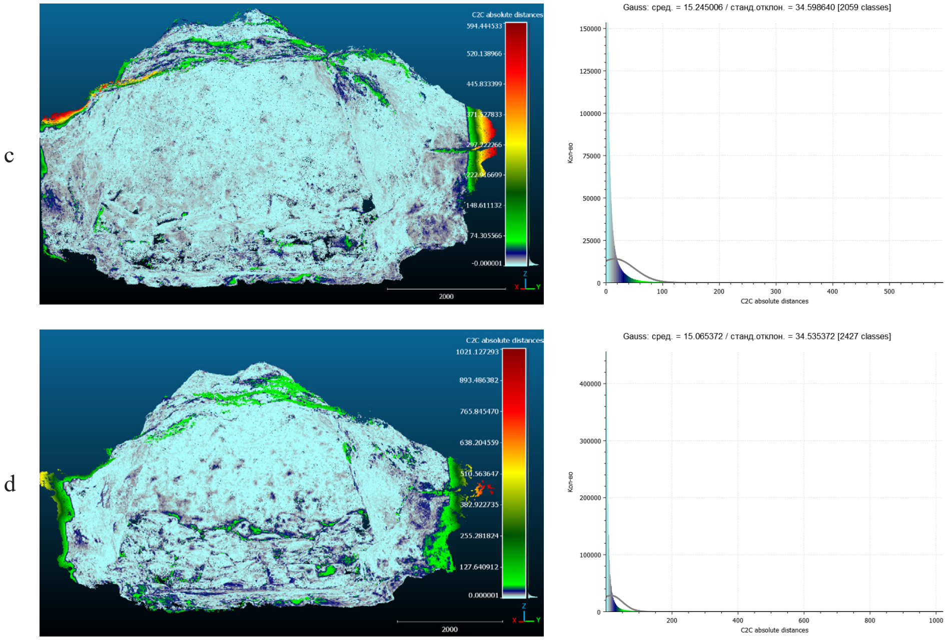
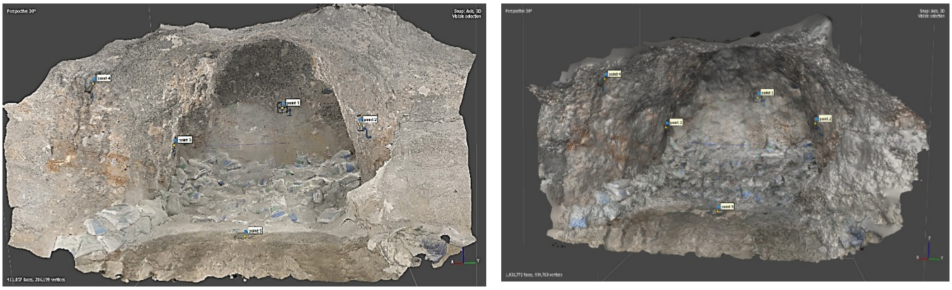


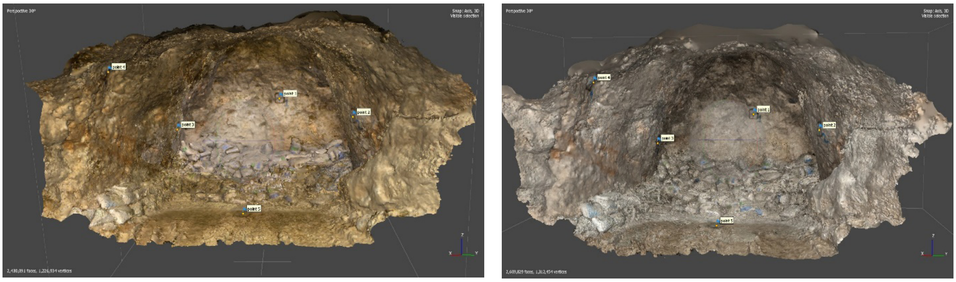
Figure 7. Comparative analysis of dense point clouds from four smartphones against the TLS reference: (a) Redmi Note 13 Pro; (b) Samsung Galaxy A25; (c) Infinix Note 30i; (d) Vivo V21. Left: C2C Cloud-to-Cloud Distance) deviation maps with colour scale. Right: histograms of absolute deviations (mm).

Assessment of spatial positioning accuracy. A 3D model of the underground heading was reconstructed from the dense point cloud (Figure 8), after which the spatial positioning accuracy of the GCPs was quantified. Using total-station coordinates as the reference, we report: (i) axis-wise errors along X, Y, Z (as RMSE, mm), (ii) the combined 3D RMSE of point positions (mm), and (iii) the mean reprojection error (px) of marker coordinates—an indicator of alignment quality. Detailed statistics for each smartphone are provided in Tables 3–6 (units: mm for spatial errors; px for reprojection).



a

b



c d

Figure 8. Reconstructed 3D models of the tunnel heading from the four smartphone datasets: (a) Redmi Note 13 Pro; (b) Samsung Galaxy A25; (c) Infinix Note 30i; (d) Vivo V21.

Samsung Galaxy A25 (Table 3). This dataset shows the lowest geodetic fidelity among the tested phones: 3D RMSE = 9.95 mm, with component errors X = 3.56 mm, Y = 6.58 mm, Z = 6.56 mm. The pattern is consistent with lower effective sensitivity and limited stabilisation under low-light, underground conditions. The mean reprojection error is 1.04 px, illustrating that good 2D fits do not necessarily imply low 3D RMSE.

Table 3. Accuracy of ground control points (Samsung A25).

Point	Error X (mm)	Error Y (mm)	Error Z (mm)	3D RMSE (mm)	Image residual (px) (projections)
point 1	-1.3049	-6.7040	2.4425	7.2534	0.663 (16)
point 2	6.5759	-0.0516	-11.5518	13.2925	0.770 (14)
point 3	-3.2450	-4.3525	2.9222	6.1656	1.108 (5)
point 4 -0.4156		-2.2551	-1.5633	2.7753	1.982 (8)
point 5	-2.7604	12.1551	8.0540	14.8403	0.575 (9)
Total	3.5572	6.5836	6.5614	9.9524	1.037

Vivo V21 (Table 4). Best geodetic accuracy overall: 3D RMSE ≈ 10.5 mm, with well-balanced axis-wise components (each ≤ ~6.5 mm). The mean reprojection error is 1.35 px, indicating a well-constrained bundle and stable alignment—consistent with effective optical stabilisation and a workable sensor–lens trade-off in low light.

Infinix Note 30i (Table 5). Satisfactory result for engineering-visualisation tasks: 3D RMSE ≈ 12.9 mm. A notable feature is high redundancy at control points—on average ~10.08 image observations per GCP—suggesting that strong overlap compensated for lower effective sensor sensitivity. Despite modest optics, the reconstruction shows no obvious systematic bias.

Redmi Note 13 Pro (Table 6). Mid-range performance: 3D RMSE ≈ 11.7 mm. The mean reprojection error is the largest among the tested phones (1.45 px), implying slightly noisier feature localisation (e.g., micro-motion or texture handling in low light), yet the capture geometry and overlap were sufficient to keep spatial accuracy within engineering tolerances.

Table 4. Accuracy of ground control points (Vivo).

Point	Error X (mm)	Error Y (mm)	Error Z (mm)	3D RMSE (mm)	Image residual (px) (projections)
point 1	-1.4186	-5.1704	1.7478	5.6392	0.868 (23)
point 2	12.6742	-1.1111	-8.7170	15.4226	1.369 (19)
point 3	-3.5003	-8.1278	1.5536	8.9849	0.982 (6)
point 4	-2.4309	2.8478	0.5269	3.7811	3.047 (6)
point 5	-5.3083	11.5838	4.8879	13.6475	0.817 (14)
Total	6.4651	6.8749	4.5962	10.4970	1.349

Table 5. Accuracy of ground control points (Infinix Note 30 I).

Point	Error X (mm)	Error Y (mm)	Error Z (mm)	3D RMSE (mm)	Image residual (px) (projections)
point 1	0.0717	-6.9568	-0.0580	6.9574	5.297 (21)
point 2	14.2094	1.8935	-12.1863	18.8148	2.021 (13)
point 3	-1.7438	-4.7888	0.9972	5.1931	26.521 (6)
point 4	1.6036	-1.2866	3.8217	4.3396	1.733 (5)
point 5	-14.1410	11.1388	7.4254	19.4725	0.910 (3)
Total	9.0276	6.3347	6.6218	12.8638	10.083

Table 6. Accuracy of ground control points (Redmi Note 13 Pro).

Point	Error X (mm)	Error Y (mm)	Error Z (mm)	3D RMSE (mm)	Image residual (px) (projections)
point 1	-0.9675	-5.8098	2.7531	6.5015	0.930 (13)
point 2	8.2715	-4.2041	-13.1393	16.0852	1.647 (13)
point 3	-5.2032	-4.0308	4.2791	7.8506	1.388 (12)
point 4	0.6716	-2.1369	-1.0143	2.4589	1.106 (7)
point 5	-2.7724	16.1818	7.1212	17.8955	1.908 (11)
Total	4.5730	08.1742	7.0749	11.7383	1.453

For a direct comparison of spatial positioning accuracy across devices, a comparative histogram was compiled (Figure 9). It summarizes the mean 3D Euclidean positioning error and the mean reprojection error (in pixels) computed from the ground control points.

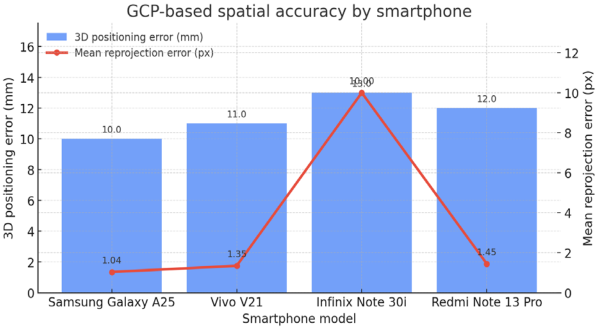


Figure 9. GCP-based accuracy by smartphone: mean 3D Euclidean positioning error (mm) and mean reprojection error (px) (error bars: ±1 SD where applicable).

The experiments indicate that mid-range smartphones can support engineering-grade documentation of underground headings when acquisition protocols are followed with discipline. Across devices, GCP-based 3D RMSE fell in the ~10–13 mm range, which is operationally useful for volumetrics and conformity checks in confined headings.

Device behaviour. Among the tested handsets, Vivo V21 delivered the best overall geodetic performance, combining low 3D RMSE with a uniform point distribution—consistent with effective optical stabilisation and a well-balanced sensor–lens package. Redmi Note 13 Pro produced high-quality reconstructions, especially centrally, but showed greater sensitivity to micro-motion and noise; at very high pixel densities and without stabilisation, small vibrations and texture fluctuations propagate into geometry. Samsung Galaxy A25 was least accurate—plausibly reflecting lower effective sensitivity, fewer manual controls, and lack of OIS—although its moderate mean reprojection error suggests internally coherent image networks. Infinix Note 30i required higher redundancy and longer processing, yet achieved acceptable geometry, illustrating that budget setups can work if overlap and capture discipline compensate optical limits.

Where reconstructions fail. C2C analyses show error concentrations near scene boundaries and in low-texture areas (crown, far-field). These patterns underline the role of stable, uniform illumination and manual exposure/white balance, particularly underground where visibility is intrinsically constrained.

Implications. Reconstruction accuracy is not dictated by nominal resolution alone. Outcomes emerge from the interaction of sensor quality, (opto-)stabilisation, lighting, and processing choices. High resolution without control of capture conditions does not guarantee high accuracy.

Practical recommendations (from this study):

1. Use a rigid stabilising cage on a ~1.5 m tripod; disable HDR/AI/multiframe features.
2. Maintain forward overlap ≥ 60 % and side overlap ≥ 25 %; plan image counts with ceiling rounding per direction.
3. Provide directed LED lighting with adjustable CCT (~3200–5600 K); avoid specular glare; keep exposure constant within a sequence.
4. Enforce GCP coverage across crown, walls, floor; use a local Cartesian datum; validate against an independent TLS reference via C2C.
5. Prefer uniform processing presets across devices; monitor both GCP residuals and C2C distributions.

Limitations and future work. The use of a single underground test site in this study was methodologically justified, since the primary objective was not to demonstrate the universal applicability of smartphone photogrammetry under all mining conditions, but to perform a controlled comparative assessment of different smartphone cameras under identical acquisition parameters. Conducting all experiments within the same tunnel geometry, lighting configuration, imaging distance, overlap conditions, and processing workflow minimized the influence of external variables and ensured that the observed differences in reconstruction accuracy were mainly associated with the imaging performance of the tested devices rather than site-specific geological factors. At the same time, the experiments were conducted at a single underground test site characterized by relatively stable geological and environmental conditions; therefore, the obtained results should not be interpreted as universally applicable to all underground mining environments. Variations in rock texture, moisture, dust concentration, and operational activity may significantly influence photogrammetric reconstruction quality and should be investigated in future studies.

Although a portable U-600 LED floodlight was used to simulate low-light underground conditions, the illumination environment during the experiments remained more stable and controllable than in active mining operations. In real underground environments, non-uniform lighting, moving equipment, airborne dust, and dynamic shadows may reduce reconstruction quality and affect feature-matching stability. Future studies should therefore investigate smartphone photogrammetry under more variable and operational underground lighting conditions.

Results derive from a single site (8 m segment) and four smartphones without RAW capture; findings may not transfer to larger headings, different lithologies, or harsher dust/humidity regimes. The TLS reference is a single platform; cross-instrument validation would strengthen generality. Future work should quantify (i) the effect of station spacing and overlap on accuracy–runtime trade-offs, (ii) illumination strategies for ultra-low-light scenes, and (iii) explicit comparisons of OIS/EIS behaviours and in-app lens corrections versus pure self-calibration. Developing a standardised smartphone protocol for underground photogrammetry is a natural next step.

Conclusion. This study shows that mid-range smartphones can be used for photogrammetric reconstruction of underground workings in low light, provided that capture protocols are applied with care. Despite hardware gaps relative to professional cameras and TLS systems, the tested devices delivered centimetre-scale positioning and geometric fidelity when lighting, overlap, and processing settings were controlled.

Performance varied across handsets. Vivo V21 yielded the most internally consistent reconstructions, with uniformly dense coverage and stable geometry—consistent with effective optical stabilisation and a balanced sensor–lens package. Redmi Note 13 Pro also performed well, especially in the central field, but its very high pixel density made it more sensitive to micro-motion when stabilisation was not available. Samsung Galaxy A25 produced the least reliable geometry, indicating limited suitability without corrective measures, whereas the budget Infinix Note 30i reached acceptable accuracy when supported by high overlap and disciplined capture.

Across datasets, controlling factors were clear: sensor quality and effective sensitivity; the presence of optical image stabilisation; access to manual exposure/

white-balance; and stable, uniform illumination. C2C comparisons against the TLS reference consistently revealed local distortions near scene boundaries and in weakly textured areas, underscoring the role of lighting configuration and camera control underground.

Overall, mobile photogrammetry is a practical option for mine surveying and geometric documentation in constrained headings. Progress will depend on (i) standardised, smartphone-specific acquisition protocols tailored to low-light environments and (ii) continued improvements in embedded cameras and stabilisation. Together, these developments can support wider adoption of smartphones in digital monitoring workflows for underground operations.

AI-assisted tools statement. ChatGPT (OpenAI, GPT-5) was used exclusively for language editing and translation of the manuscript under full author supervision. All scientific content, data analysis, methodological decisions, and conclusions were developed and verified by the authors. The authors take full responsibility for the accuracy, originality, and integrity of the manuscript.

References

Alijani Z., Meloche J., McLaren A., Lindsay J., Roy A., & Berg A. (2022). A comparison of three surface roughness characterization techniques: photogrammetry, pin profiler, and smartphone-based LiDAR. International Journal of Digital Earth. – No. 15(1). – P. 2422-2439. https://doi.org/10.1080/17538947.2022.2160842 (in English).

An P., Fang K., Jiang Q., Zhang H., & Zhang Y. (2021). Measurement of rock joint surfaces by using smartphone Structure from Motion (SfM) photogrammetry. Sensors. – No. 21(3). – P. 922. https://doi.org/10.3390/s21030922 (in English).

An P., Fang K., Zhang Y., Jiang Y., & Yang Y. (2022). Assessment of the trueness and precision of smartphone photogrammetry for rock joint roughness measurement. Measurement. – No. 188. – P. 110598. https://doi.org/10.1016/j.measurement.2021.110598 (in English).

Benton D., Seymour J., Boltz M.S., Raffaldi M., & Finely S. (2017). Photogrammetry in underground mining ground control – Lucky Friday mine case study. In Deep Mining 2017 Proceedings. Perth, Australia. – P. 587-598. https://doi.org/10.36487/ACG_rep/1704_39_Benton (in English).

Burdziakowski P. (2024). The effect of varying the light spectrum of a scene on the localisation of photogrammetric features. Remote Sensing. – No. 16(14). – P. 2644. https://doi.org/10.3390/rs16142644 (in English).

Cazes G., Vernant P., Baleux F., Giuliani C., Brugal J.-P., & Jouves J. (2024). Full size cave 3D modelling using close range photogrammetry and comparison with laser scanning. Research Square. https://doi.org/10.21203/rs.3.rs-4849312/v1 (in English).

Dabove P., Grasso N., & Piras M. (2019). Smartphone-based photogrammetry for the 3D modeling of a geomorphological structure. – Applied Sciences. – No. 9(18). – P. 3884. https://doi.org/10.3390/app9183884 (in English).

DiFrancesco P.-M., Bonneau D., & Hutchinson D.J. (2020). The implications of M3C2 projection diameter on 3D semi-automated rockfall extraction from sequential terrestrial laser scanning point clouds. Remote Sensing. – No. 12(11). – P. 1885. https://doi.org/10.3390/rs12111885 (in English).

Janiszewski M., Torkan M., Uotinen L., & Rinne M. (2022). Rapid photogrammetry with a 360-degree camera for tunnel mapping. Remote Sensing. – No. 14(21). – P. 5494. https://doi.org/10.3390/rs14215494 (in English).

Kazakov A.N., Khakberdiyev M.R., Qurbonov H.A., Turgunov Sh.Sh., & Obidov M.I. (2026). Effect of rock mass discontinuities on underground mine stability (Uzbekistan). News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences. – No. 1(475). – P. 170-181. https://doi.org/10.32014/2026.2518-170X.597 (in English).

Lague D., Brodu N., & Leroux J. (2013). Accurate 3D comparison of complex topography with terrestrial laser scanner data: The M3C2 algorithm. ISPRS Journal of Photogrammetry and Remote Sensing. – No. 82. – P. 39-49. https://doi.org/10.1016/j.isprsjprs.2013.04.009 (in English).

Morelli L, et al. (2024) Accuracy assessment of a canal-tunnel 3D model by comparing photogrammetry and laser scanning. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences (ISPRS Archives). XLVIII-2/W8. – P. 335-342. (in English).

Pukanská K., Bartoš K., Gašinec J., Pašteka R., Zahorec P., Papčo J., Bella P., Andrássy E., Dušeková L., Bobíková D., & Kseňak Ľ. (2024). Methodological approaches to survey complex ice cave environments – the case of Dobšiná (Slovakia). Frontiers in Environmental Science. – No. 12. – P. 1484169. https://doi.org/10.3389/fenvs.2024.1484169 (in English).

Qurbonov H., Kazakov A., Khakberdiyev M., Turgunov Sh., & Xamitov N. (2025). Photogrammetric 3D modeling of underground excavations using smartphones: A cost-effective alternative to LiDAR. E3S Web of Conferences. – No. 646. – P. 00039. https://doi.org/10.1051/e3sconf/202564600039 (in English).

Sayyidkosimov S.S., Nizamova A.T., & Khakimov A.M. (2025). Improving surveying accuracy for shield tunneling at Phase II of the Tashkent Metro. Mining Journal. – No. 11. – P. 14-21. https://doi.org/10.17580/gzh.2025.11.02 (in English).

Skarlatos D., Cuca B., Kafataris G., Previtali M., & Agapiou A. (2024). Low-cost photogrammetry solutions for surveying confined underground spaces: Testing the traditional set-up against a 360° camera on the Tombs of the Kings archaeological site. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLVIII-2/W8-2024. – P. 425-430. https://doi.org/10.5194/isprs-archives-XLVIII-2-W8-2024-425-2024 (in English).

Štroner M., Urban R., Křemen T., Braun J., Michal O., & Jiřikovský T. (2025). Scanning the underground: Comparison of the accuracies of SLAM and static laser scanners in a mine tunnel. Measurement. – No. 242. – P. 115875. https://doi.org/10.1016/j.measurement.2024.115875 (in English).

Winiwarter L., Anders K., Wieser M., & Höfle B. (2021). M3C2-EP: Pushing the limits of 3D point-cloud change detection by error propagation. ISPRS Journal of Photogrammetry and Remote Sensing. – No. 177. – P. 333-352. https://doi.org/10.1016/j.isprsjprs.2021.05.019 (in English).

Zhang C., Chen J., Li P., et al. (2024). Integrated high-precision real-scene 3D modeling of karst cave landscape based on laser scanning and photogrammetry. Scientific Reports. – No. 14. – P. 20485. https://doi.org/10.1038/s41598-024-71113-y (in English).

Publication Ethics and Publication Malpractice in the journals of the Central Asian Academic Research Center LLP

For information on Ethics in publishing and Ethical guidelines for journal publication see http://www.elsevier.com/publishingethics and http://www.elsevier.com/journal-authors/ethics.

Submission of an article to the journals of the Central Asian Academic Research Center LLP implies that the described work has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see http://www.elsevier. com/postingpolicy), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The Central Asian Academic Research Center LLP follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (http://publicationethics. org/files/ u2/New_Code.pdf). To verify originality, your article may be checked by the Cross Check originality detection service http://www.elsevier.com/editors/plagdetect.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/ or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will only accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the Central Asian Academic Research Center LLP.

The Editorial Board of the Central Asian Academic Research Center LLP will monitor and safeguard publishing ethics.

Requirements for articles design for publication in the journal are available on the websites:
www:nauka-nanrk.kz
http://www.geolog-technical.kz/index.php/en/
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Managing Editor: *T. Apendiev*
Editors: *D.S. Alenov, A.Shormakova*
Computer layout: *G.D. Zhadyranova*

Signed for print: July 10, 2026
Format: 70×90 1/16. 26.5 printed sheets. Order No. 3.

«Central Asian Academic Research Center» LLP
Almaty, Shevchenko Street, 28