P. A. IGNATOV[1], *Leading Researcher, Professor, Doctor of Geologo-Mineralogical Sciences, petrignatov@gmail.com*
S. A. MALYUTIN[1], *Senior Researcher, Associate Professor, Candidate of Geologo-Mineralogical Sciences*
A. A. VERCHEBA[1], *Leading Researcher, Professor, Doctor of Geologo-Mineralogical Sciences*
J. P. MEDINA[1], *Engineer, Candidate for a Master's Degree*

[1]*Sergo Ordzhonikidze Russian State University for Geological Prospecting, Moscow, Russia*

GOLD DEPOSIT TYPES IN THE CRATONS OF AFRICA AND SOUTH AMERICA: IMPLICATIONS FOR THE PROSPECTIVITY OF EASTERN COLOMBIA

The territory of Eastern Colombia occupies the western part of the Amazonian Craton and is composed of Precambrian rocks overlain by a sedimentary cover. This region hosts occurrences of endogenous gold mineralization and numerous placer deposits. Collapsed quartz veins and exposures of gold-bearing conglomerates have been identified. The area is considered promising, although it remains virtually unexplored. No medium- or large-scale geological mapping or exploratory drilling has been conducted there. To determine the potential geological and industrial types of gold deposits, an overview of the main deposit types typical for the cratons of South and West Africa and South America is presented. Analysis of cratonic gold endowment indicates that the most probable types for Eastern Colombia are vein and vein-stockwork gold deposits of the quartz–sulfide type. To a lesser extent, stratiform deposits may occur in areas of banded iron formations, and gold-bearing quartz conglomerate bodies are likely to be present at the base of Paleoproterozoic sequences. The gold potential of this territory is considered to be high, as it lies within the gold-bearing metallogenic zones of the Amazonian Craton.

Keywords: *Eastern Colombia, craton, Archean, Proterozoic, greenstone belt, mobile belt, metallogenic type, gold, exploration criteria*
DOI: *10.17580/em.2025.02.04*

Introduction

The territory of Eastern Colombia is almost entirely covered by a sedimentary sequence of Paleozoic and Cenozoic deposits and, therefore, remains insufficiently studied. It occupies the extreme western part of the Amazonian Craton, whose structure is primarily composed of Archean granite–greenstone and Proterozoic mobile belts, intruded by granitoID complexes of various ages.

Two main structural–substance complexes are distinguished within the territory of Colombia (**Fig. 1**). The first is represented by the Phanerozoic formations of the Andean fold system, which forms part of the planetary East Pacific mobile belt and is located in the western part of the country. The geological structure of this region is relatively well studied. It hosts the main mineral deposits, including gold deposits, among which Gravelot (60 t) and La Coloss (60 t) are the largest.

The second complex, whose rocks are exposed among the cover deposits only in the extreme east of Colombia, is represented by Proterozoic formations of the western part of the Amazonian Craton. Here a large (>100.000 km^2) massif of Paleoproterozoic crystalline rocks is distinguished, together with intrusive bodies of Paleo- and Mesoproterozoic granitoids and small, spatially restricted fields of Neoproterozoic volcaniclastic–sedimentary rocks [1–3].

At various times, the eastern part of Colombia has been covered by geological surveys at scales of 1:1.500.000, 1:1.000.000 and 1:500.000; however, more detailed geological mapping and exploratory drilling have not been carried out.

Although the geological structure of the concealed portion of Eastern Colombia is unknown, there is a high probability that it belongs to the Amazonian Craton. This territory may possess metallogenic characteristics typical of cratons and thus host the gold deposit types characteristic of such shields.

Despite its concealed nature, the area is considered prospective for endogenous gold mineralization because of observed indicators (collapsed quartz veins and outcrops of conglomerates with elevated gold contents) and because active — largely illegal — alluvial gold mining is taking place (**Fig. 2**).

To determine the potential geological–industrial types of gold deposits within this territory, it is advisable to review the main types of gold deposits characteristic of the South African cratons (Kaapvaal and Zimbabwe), the West African Craton, and the South American cratons — Amazonian and São Francisco. It should be noted that after the breakup of Gondwana, the Amazonian and West African cratons formed a single continental nucleus.

On the geological map of Colombia at a scale of 1:1.500.000, several prospective areas for gold mineralization have been identified within the western part of the Amazonian Craton. These areas include auriferous zones in alluvial deposits and Proterozoic rocks. The Precambrian exposures located in the departments of Guainía and Vaupés (on the border with Brazil) — within the Nakén, Karanacoa, and Taraira mountain ranges — are associated with the metaconglomerates and metasandstones of the Amazonian Craton, which apparently possess characteristics comparable to those of the Witwatersrand deposits of the Kaapvaal Craton in South Africa [4].

It is well known that cratons host the world's most significant gold-bearing provinces and districts, containing unique deposits such as Witwatersrand in South Africa, Kolar in India, and Kalgoorlie in Australia [5]. Large gold deposits are also known within the Amazonian Craton beyond the territory of Colombia.

To identify the probable geological–industrial types of gold deposits and their exploration criteria for Eastern Colombia, an analysis of gold-bearing formations from the South American and the South and West African cratons has been carried out.

The boundaries of cratons are defined by the depth of the Moho discontinuity, which on average ranges from 32 to 39 km. The outlines of cratons may include, in addition to Archean rocks, intracratonic sedimentary basins, mobile belts, and zones of tectonomagmatic activation [6].

Results

In the Archean Kaapvaal Craton, which occupies an area of about 0.55 million km², the main gold-bearing units are the Mesoarchean granite–greenstone belts of Barberton (3.28–3.23 Ga) and Murchison (3.09–2.97 Ga), as well as the intracratonic Neoarchean Witwatersrand Basin (3.1–2.7 Ga), which hosts the world-famous polygenetic conglomerate-type gold deposits of the same name. The basin overlies the aforementioned belts, which likely served as partial sources of gold.

The Barberton greenstone belt is characterized by quartz–gold–arsenide–sulfide vein-type deposits hosted within metasedimentary sequences overlying ultramafic volcanic rocks (3.26–3.23 Ga). The deposits are controlled by a regional northeast-trending shear zone and occur within mylonitized rocks [7].

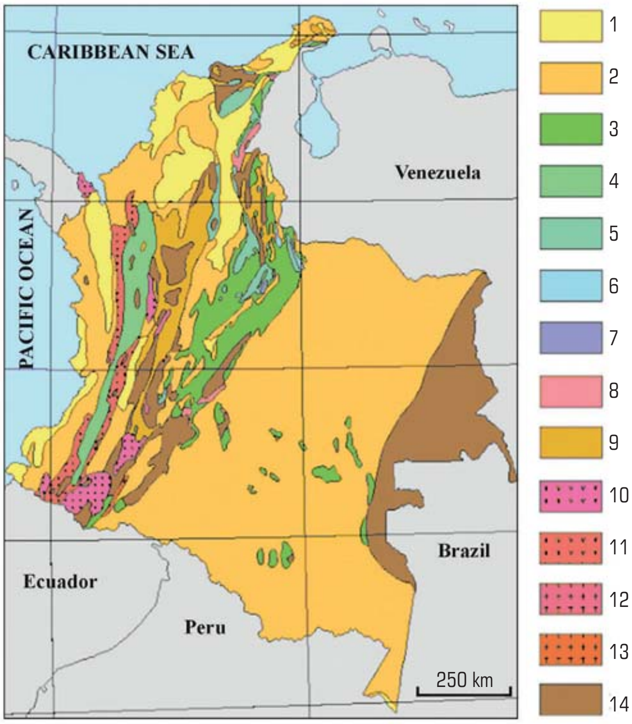

Fig. 1. Schematic geological map of Colombia [1]:
1–9 – sedimentary rocks of different ages: 1 – Quaternary;
2 – Paleogene–Neogene; 3 – Cretaceous; 4 – Jurassic–Cretaceous;
5 – Triassic–Jurassic; 6 – Carboniferous–Permian;
7 – Devonian; 8 – Cambrian–Ordovician; 9 – Precambrian–Paleozoic;
10–11 – volcanic rocks: 10 – Cretaceous and Paleogene–Neogene;
11 – Mesozoic; 12–13 – intrusive rocks: 12 – Mesozoic–Cenozoic;
13 – Paleozoic–Neoproterozoic; 14 – undifferentiated Precambrian formations

Gold mineralization in the Murchison belt is represented by mesothermal and epithermal quartz–gold–stibnite vein-type deposits that are spatially associated with granodioritic intrusions [8].

The Zimbabwe Craton, relatively small in size (0.24 million km^2), is composed of Neoarchean granite–greenstone belts (2.85–2.68 Ga). It hosts more than 5.000 gold deposits, mostly small in size, with medium and large ones being rare. Two principal metallogenic types are recognized: (1) stratiform gold-bearing banded iron formation (BIF)-hosted deposits with pyrite, probably related to volcanic activity within the greenstone belts; and (2) later mesothermal quartz–sulfide–gold vein and stockwork deposits associated with granitic complexes of the Neoarchean Sesombi and Chilimanzi suites.

Gold-bearing quartz veins in the Zimbabwe Craton commonly occupy not only linear but also ring-shaped faults developed around oval granite–gneiss domes, volcanic centers of greenstone belts, and individual isometric granite bodies [9]. It can be inferred that the primary gold source for the Witwatersrand deposits may have been hydrothermal fluids discharged into a marine basin contemporaneously with the development of the Neoarchean granite–greenstone belts of Zimbabwe.

The surrounding Paleoproterozoic mobile belts of Limpopo and Magondi are considerably less gold-bearing. In the Magondi Belt, gold-bearing volcanogenic massive sulfide (VMS) deposits and small gold–quartz vein deposits containing native uranium minerals (e.g., Redwing) occur, associated with Neoproterozoic reactivation processes. In the Limpopo Belt — which separates the Kaapvaal and Zimbabwe cratons and is composed of Mesoarchean rocks that underwent intense Paleoproterozoic metamorphism — only one medium-sized gold deposit, Renco, is known; it belongs to the gold–quartz type.

Of additional interest are gold-bearing Cu–Mo porphyry-type occurrences related to the Mesozoic Mutandahwe ring complex of alkaline rocks located within the Limpopo Belt.

The **West African Craton** occupies an extensive area of about 2.9 million km^2 but remains relatively poorly studied. Within the exposed crystalline basement, several major tectonic blocks are distinguished — of Archean (3.6–2.7 Ga), Eburnean (2.1–2.0 Ga), Kibaran (1.4–1.3 Ga), and Pharusian–Katangan (Pan-African) (0.65–0.62 Ga) consolidation stages. Archean rocks crop out in the north (Reguibat Shield) and in the south (Liberian Shield), separated by the sedimentary Taoudeni Basin, beneath which an Archean basement is inferred.

The western part of the Liberian Shield is composed predominantly of migmatitic orthogneisses (3.5–2.8 Ga), while its eastern part comprises Neoarchean greenstone belts hosting large iron deposits within itabirites. To the east, the Archean block is bounded by the Paleoproterozoic Birimian Mobile Belt, which underwent the Eburnean orogeny (2.10–2.075 Ga) [10].

This belt hosts some of the most important gold deposits in West Africa. The principal lithologic framework of the Birimian Belt is formed by metavolcanic rocks of basic, intermediate, and acidic composition belonging to the Birimian Supergroup, which consists of several subparallel volcanic and sedimentary belts of the second order, separated by granite fields. The total thickness of Birimian strata exceeds 6 km.

Within the Birimian Supergroup, the Tarkwa Group occupies a northeast-trending basin about 25 km wide and over 300 km long. The Tarkwa Group is composed of metaconglomerates, metagravelites, quartz sandstones, and phyllites that unconformably overlie Birimian volcanic rocks. The group's thickness reaches 2 km. The second unit from the base — the Banket Formation — is auriferous, hosting gold-bearing conglomerate deposits that represent the second largest deposit of this type in Africa, after Witwatersrand, with reserves exceeding 250 tonnes of gold.

All Birimian rocks, including the Tarkwa Group, were intruded by granitoID bodies and associated dikes dated at 2180–1980 Ma [11].

Throughout West Africa, Paleoproterozoic volcanic and volcano-sedimentary Birimian belts host numerous gold deposits, including several world-class ones. The most notable are the Ashanti gold–quartz–arsenide deposit (>900 tonnes) in Ghana; the Sigiri and Sankarani vein deposits in Guinea; Sadiola (172 tonnes) in Mali; and Aksiso in Liberia, among others. All of these deposits formed after the emplacement of Paleoproterozoic granitoID magmatism.

During the Neoproterozoic (Late Riphean) period, Pan-African orogenic belts developed, characterized by the emplacement of granitoID plutons, post-tectonic intrusions of increased alkalinity, and diverse, highly productive ore-forming systems. These include diamond-bearing kimberlites, rare-metal and rare-earth carbonatites, polymetallic, cobalt, and other types of deposits. Gold mineralization is scarce, with the most significant occurrence represented by the Tiririne gold–quartz vein deposit in Algeria, with resources estimated at about 50 tonnes.

The **Amazonian Craton**, covering an area of approximately 1.2 million km^2, occupies parts of Colombia, Venezuela, Guyana, French Guiana, Suriname, and Brazil. Archean rocks of the craton are exposed within three major Precambrian shields — the Northern Guiana, Southern Guiana, and Guaporé shields in Brazil. It is generally accepted that prior to the opening of the Atlantic Ocean, the Amazonian Craton represented the continuation of the West African Craton [12–15]. The central portion of the craton is overlain by the Mesoproterozoic sedimentary cover of the Amazon Basin.

The geological structure of the shields is rather complex. Archean metamorphic rocks, represented mainly by granito–gneisses, form the Imataca block (3.7–3.4 Ga) in Venezuela, and the Carajás and Southern Amapá blocks (3.23–2.93 Ga) in Brazil [12]. Within these blocks, Mesoarchean and Neoarchean (2.8–2.6 Ga) greenstone belts are

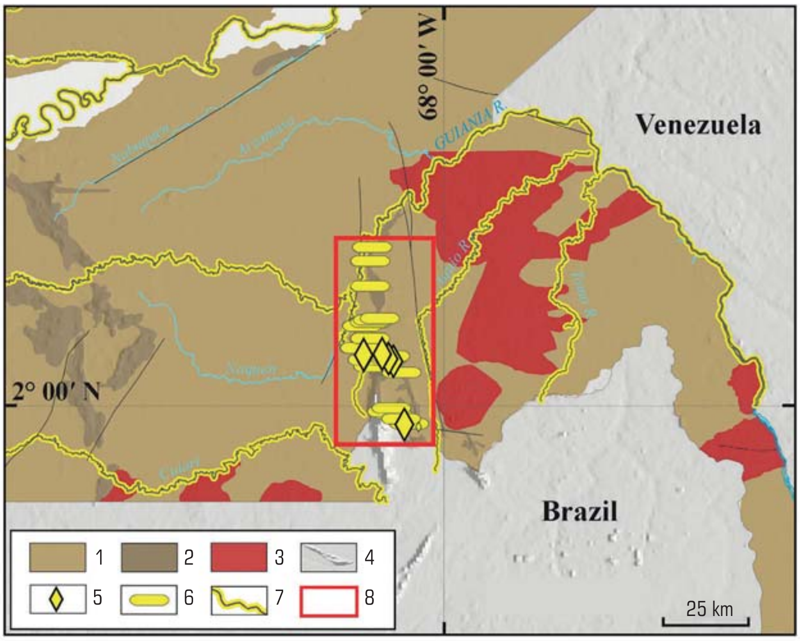

Fig. 2. Fragment of the metallogenic map of Colombia at a scale of 1:1,500,000 [4]:
1 – Paleoproterozoic: gneisses, orthogneisses, migmatites, amphibolites, quartzites, marbles, granites, and alaskites; 2 – Mesoproterozoic: metaconglomerates, metaarenites, quartzites, and metapelites; 3 – Meso– to Neoproterozoic: rapakivi granites, nepheline syenites, and alkaline gabbros; 4 – territory of Brazil and Venezuela; 5 – epithermal gold deposits; 6 – gold placers; 7 – auriferous alluvium; 8 – Nakien ore–placer district

distinguished [16, 17]. These are accompanied by calc-alkaline and granitic plutons emplaced during the Late Archean.

A unique gold–platinum–nickel deposit, Cerro Pelata, occurs within one of these greenstone belts, hosted by carbonaceous metapelites and banded iron formations. The genesis of this deposit and the precise age of its host rocks remain uncertain.

Intensely metamorphosed sedimentary and volcanic rocks of basic to acidic composition belonging to Paleoproterozoic mobile (greenstone) belts (>2.2 Ga) are widespread throughout all three shields, being most prominent in the Northern Guiana Shield. These sequences were intruded by syn- and post-tectonic granitoID complexes (2.2–1.95 Ga). The Southern Guiana Shield is composed almost entirely of Paleoproterozoic granitoids. These rock assemblages are considered equivalent to the Birimian Supergroup of the Paleoproterozoic granite–greenstone belt of West Africa [12].

Mesoproterozoic mobile belt formations, consisting of volcanogenic–sedimentary rocks metamorphosed under amphibolite-facies conditions and crosscut by granitoID complexes, are less extensive. In the Middle Proterozoic, portions of the Amazonian Craton were intruded by anorogenic granitic complexes (including anorthosites and charnockites) and underwent intense metamorphism. Later, during the Neoproterozoic, mobile belts developed in southeastern Brazil. Neoproterozoic sequences, represented by sedimentary and felsic volcanogenic rocks belonging to the proto-cover, are limited in distribution.

During the Neoproterozoic and Mesozoic, the territory underwent tectonomagmatic reactivation. The Neoproterozoic is characterized by nepheline syenite intrusions, while the Mesozoic records andesitic and doleritic lava flows.

The principal gold deposits of the Amazonian Craton belong to the low-sulfide quartz–vein metallogenic type, spatially associated with Early Proterozoic granitoids. Such deposits are known in Guyana, Suriname, French Guiana, Venezuela, and Brazil. In Venezuela, large stratiform Cu–Au deposits such as Cristinas (1.000 t Au) and Brisas occur within Paleoproterozoic volcano-sedimentary sequences and are possibly of volcanogenic massive sulfide (VMS) type.

The **São Francisco Craton**, located in the eastern part of the South American continent, covers an area of approximately 0.7 million km^2. It is generally accepted that prior to the opening of the Atlantic Ocean, this craton represented the continuation of the Congo Craton in southern Africa.

The northern portion of the São Francisco Craton comprises two major blocks — Gavião and Jequié — each with a distinct geological history. The Gavião Block consists of the oldest rocks known in South America, including Lower Archean sequences and greenstone belts (3.4–3.0 Ga). The Jequié Block is mainly composed of charnockites and enderbites (2.9–2.6 Ga).

The southern part of the craton is composed of migmatitic gneisses and greenstone belt rocks (up to 3.4 Ga), intruded by granitoID and mafic bodies (2.8–2.6 Ga). It is probable that the São Francisco Craton also contains formations belonging to Neoarchean greenstone belts.

A major gold deposit, Morro Velho, is hosted in black shale–carbonaceous–carbonate sequences, possibly of Neoarchean age.

A significant part of the craton is overlain by Proterozoic sedimentary rocks [6]. Along the eastern margin of the São Francisco Craton, in Brazil, extensive marine deposits of the Minas Supergroup (2.6–2.12 Ga) are developed, represented by several sedimentary formations. The upper portion is composed of the Caue Formation (2.5 Ga), consisting of banded iron formations (itabirites), which host major iron ore deposits. Some of these deposits also contain gold mineralization (e.g., Paracatu, Passagem, and others).

The youngest strata of the Minas Supergroup, belonging to the Paleoproterozoic, consist of conglomerates and sandstones of the Itacolomi Group (2.1 Ga), which host gold-bearing quartz conglomerate deposits such as Jacobina and others [18].

A summary of the main gold deposits in the discussed cratons is presented in **Table**.

It is advisable to consider the prerequisites for the occurrence of known geological–industrial types of gold deposits in Eastern Colombia.

The territory of Eastern Colombia, which forms part of the Guiana Shield, includes the Paleoproterozoic Ventuari–Tapajós Province and the Paleo–Mesoproterozoic Rio Negro–Juruena Province, which, according to our interpretation, correspond to structural–formational or metallogenic megazones (**Fig. 3**).

The Ventuari–Tapajós megazone is gold-bearing. Within its extent in Brazil (Guaporé Shield), an epithermal gold deposit with estimated resources of 30 tonnes has been identified; it is spatially associated with a caldera filled with hydrothermally altered volcanogenic and clastic rocks. This deposit, characterized by copper–molybdenum–gold mineralization, is genetically related to porphyry dykes.

In the same area of the Guaporé Shield, four additional gold deposits — Luizaio, Serrinha, Juruena, and Pe Quento — are located within the Alta Floresta gold metallogenic zone, situated between the Ventuari–Tapajós and Rio Negro–Juruena megazones. The ore zones of these deposits are represented by metasomatic disseminations of sulfides of iron, lead, zinc, and copper.

Within the same metallogenic megazone of the Guaporé Shield, there are also three quartz–vein gold deposits — Paraíba, Edu, and Piteca. A third

Geological and Industrial Types of Gold Deposits in the Cratons of Southern and Western Africa and South America

Geodynamic Setting, Age (Ga)	Metallogenic Type	Association with Magmatism (Ga)	Ore-controlling Structures	Deposits, Resources / Reserves
Kaapvaal Craton (South Africa)				
Mesoarchean granite–greenstone belt of Barberton (3.23–3.28)	Hypothermal quartz–gold–arsenide–sulfide veins	Possible association with alkaline granites (3.106±0.003)	Mylonitized shear zones separating amphibolites and ultramafic schists	New Consort (55 t), Lily, Sheba (65 t), Fairview, Abbotts, Pioneer, Barberton ore field, Bellevue (South Africa)
Mesoarchean greenstone belt of Murchison (3.09–2.97)	Meso- and epithermal quartz–gold–stibnite veins [19]	Granodiorites (2964 ± 7 and 2970 ± 7 Ma)	Series of steeply dipping fractures	Gravelotte, Weigel, United Jack, Monarch (60 t), Malati Pump and others (South Africa)
Neoarchean intracratonic Witwatersrand Basin (3.1–2.7)	Polygenic stratiform conglomerate–sandstone gold deposits	Not established	Ore-bearing sequence of conglomerates and sandstones up to 8 km thick	Evander, East Rand and others; total resources >40,000 t (South Africa)
Zimbabwe Craton (Southern Africa)				
Neoarchean greenstone belts (Gwanda, Bulawayo, etc.) (2.85–2.68)	Stratiform banded iron–quartzite gold-bearing with pyrite	Andesite–rhyodacite volcaniclastic formation with iron quartzites (2.715±0.012); possible link to Neoarchean granitoids	Horizons of banded iron formations	Vubachikwe (18 t), Blanket (15 t), Fred (17 t) and others (Zimbabwe)
Neoarchean greenstone belts (Midlands, Bulawayo, Shamva, etc.) (2.85–2.68)	Mesothermal vein and stockwork gold–sulfide–quartz type (quartz–gold–stibnite–quartz, gold–bismuth–telluride–sulfide–quartz)	Related to granitoids of Sesombi (2.63–2.66) and Chilimanzi (2.57–2.62) complexes	Shear and ring faults, fracture zones	Globe–Phoenix (120 t), Cam & Motor (150 t), Kadoma, Indorama and others
Paleoproterozoic Magondi Belt (2.07–2.29)	Stratiform Au–Ag-bearing copper–pyrite	Volcaniclastic basalt–rhyolite formation	Fractured zones within favorable horizons and steep faults	Alaska, Shamrock, Mangula, Silverside, Shackleton and others [20]
Neoproterozoic reactivation zones in Magondi Belt (1.0–0.9)	Vein gold–quartz–sulfide with uranium	Neoproterozoic intermediate dikes	Shears and fracture zones	Redwing and others
Mesozoic tectonomagmatic activation zones (Tuli–Mateke–Sabi–Lebombo Rift)	Stockwork Cu–Mo–porphyry with gold	Alkaline granites of ring complexes (Cretaceous)	Fracture zones	Mineralization near Mutandahwe ring complex (Zimbabwe)
West African Craton				
Birimian Paleoproterozoic granite–greenstone belt (2.2–2.0)	Polygenic stratiform conglomerate–sandstone gold deposits	Probable relation to Eburnean granitoID magmatism	Conglomerate, gravelite and sandstone horizons	Tarkwa (250 t), Ghana
Birimian Paleoproterozoic granite–greenstone belt (2.2–2.0)	Vein gold–quartz–sulfide	Eburnean granitoID magmatism (2.18–1.98) [11]	Intersections of shear zones and subsidiary fractures	Ashanti (550 t, Ghana); Lero–Carte–Fayalala (71.5 t, Guinea); Sadiola (73 t, Mali), etc.
Amazonian Craton (South America)				
Neoarchean granite–greenstone belts with carbonaceous metapelites (3.0–2.65)	Polygenic, polychronous gold–platinum highly productive deposits in mineralized zones, altered by hypergene processes	Ultramafic and granitoID magmatism of Neoarchean–Proterozoic age	Mineralized zones of NE trend	Cerro Pelata (>50 t), Brazil [21]
Paleoproterozoic granite–greenstone belt (2.26)	Vein gold–quartz	Paleoproterozoic granitoids (2.14) [22]	Shears and subsidiary fractures	Ipitanga gold district: Divisao, Limão, Novo Esperança, Castanhal, Catarino, Carara, etc. (Brazil)
Paleoproterozoic granite–greenstone belt (1.95–2.2)	Mesothermal vein–stockwork gold–quartz–low-sulfide with tourmaline	Paleoproterozoic granitoID intrusive complexes; possible association with Mesoproterozoic intrusions [12]	Contacts and mineralized zones along shear faults	Omai (170 t), Aurora (218 t), Topo Paru (310 t), Kaburi–Eldorado, Greta Creek, Eagle Mountain and others (Guyana) [8, 12, 23,24]
Paleoproterozoic granite–greenstone belt (2.26–2.07)	Vein gold–quartz	Paleoproterozoic granitoids (2.09–2.1)	Shear and fracture zones	Maria Gealdi ore district, Meriam (Suriname)
Stratiform gold–copper–sulfide	Volcanogenic–sedimentary sequences [25]	Volcanic rock horizons	Cristinas and Brisas (>1000 t), Venezuela [25]	
Mesothermal vein–stringer gold–sulfide–quartz	—	Shears and fracture zones	El Callao, El Manteco, El Dorado, Choco 10 (258 t), Increíble 6 (Venezuela) [25]	
São Francisco Craton (South America)				
Upper horizons of Neoarchean belts with micaceous–carbonate schists	Hypothermal stratiform–vein quartz–gold–sulfide with tourmaline in siderite quartzite horizons	Probable association with Neoproterozoic granitoids and dikes	Horizons and mineralized zones in carbonate schists	Morro Velho (>450 t), Criçum, Urubu, Raposos (Brazil) [26]
Neoarchean–Paleoproterozoic greenstone belt (2.5)	Stratiform gold–iron–quartzite	Possible association with Neoproterozoic granitoID magmatism	Fractures parallel to schistosity within iron quartzite horizons	Paracatu (500 t), Conceição, Passagem (50 t), Rapazas (35 t), etc. (Brazil)
Paleoproterozoic molasse basins (2.08–1.9)	Polygenic stratiform uranium-bearing gold conglomerate	Possible link with Neoproterozoic dike complexes	Conglomerate and sandstone horizons, intersections with mineralized dikes	Jacobina ore field (resources 160–170 t), Brazil [27]

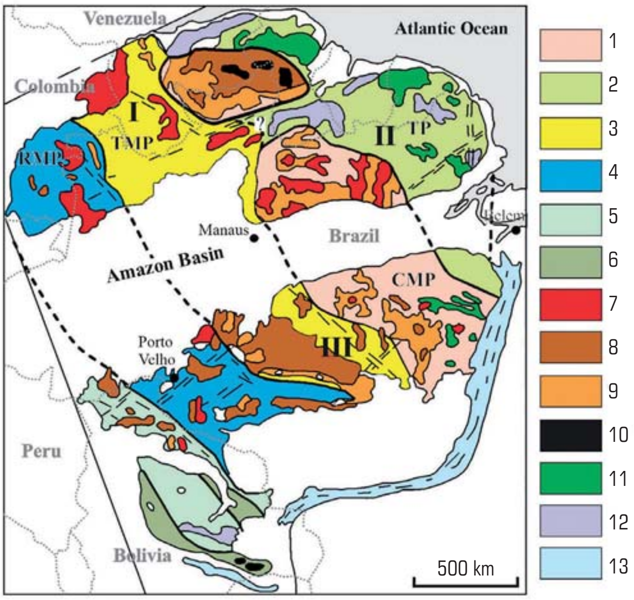

Fig. 3. Geological–structural scheme of the regions of different ages within the Amazonian Craton [19]:
1–6 – structural–formational megazones (domains): 1 – Central Amazonian (CMP), 2.3 Ga; 2 – Maroni–Itacaiunas (TP), 2.3–1.95 Ga; 3 – Ventuari–Tapajys (TMP), 1.95–1.8 Ga; 4 – Rio Negro–Juruena (RMP), 1.8–1.55 Ga; 5 – Rondonian–San Ignacio, 1.55–1.3 Ga; 6 – Sunsas, 1.3–1.0 Ga; 7 – granitoids; 8 – sedimentary sequences; 9 – volcanic rocks of acidic to intermediate composition; 10 – basic volcanic rocks; 11 – greenstone belts; 12 – granulite complex; 13 – Neoproterozoic mobile belt. Amazonian Craton shields: I – Northern Guiana; II – Southern Guiana; III – Guaporй

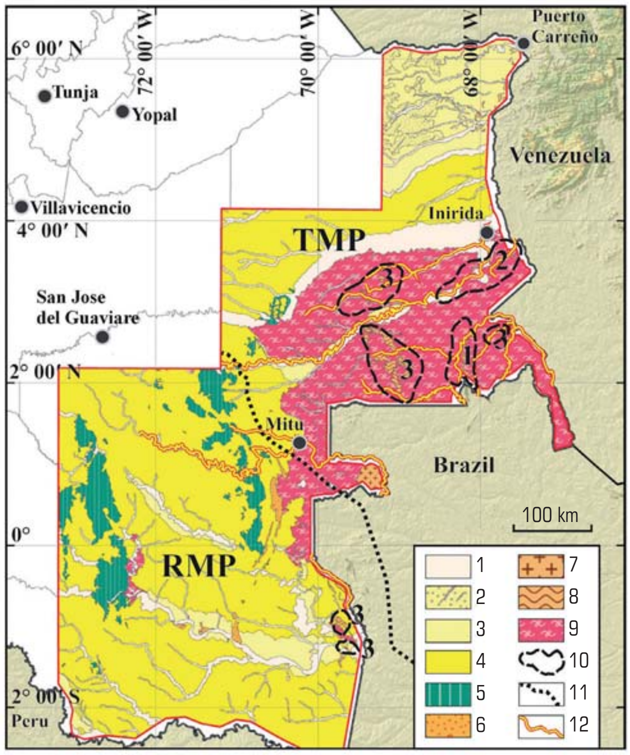

Fig. 4. Prospective areas (dashed lines) for gold mineralization exploration in Eastern Colombia [4]:
1–4 – Quaternary deposits:1 – alluvium; 2 – dunes and loess-like sediments; 3 – alluvial terraces; 4 – Miocene conglomerates and sandstones; 5 – Ordovician dolomites, shales, and feldspathic metapsammites; 6 – Neoproterozoic conglomerates, rhyodacitic tuffs, quartzites, and feldspathic sandstones; 7 – Mesoproterozoic granites and rapakivi granites; 8 – Mesoproterozoic weakly metamorphosed metaconglomerates, metarenites, quartzites, and metapelites; 9 – Paleoproterozoic quartz–feldspathic and quartz gneisses, amphibolites, migmatites, quartzites, granites, and monzonites; 10 – Prospective gold-bearing areas with low (1), medium (2), and high (3) potential; 11 – boundary between the Ventuari–Tapajys and Rio Negro–Juruena structural–formational megazones; 12 – river valleys with alluvial gold placers

mineralization type in this gold-bearing metallogenic zone is represented by vein quartz–sulfide gold deposits such as Francisco, Bigode, and Luiz, which are associated with black porphyries (1.774 ± 7.5 Ga) [28].

The Rio Negro–Juruena and Rondonian–San Ignacio megazones, located west of the Guaporé Shield, are predominantly tin-bearing, although the occurrence of gold mineralization within them cannot be excluded.

The Ventuari–Tapajós gold metallogenic megazone and the Alta Floresta metallogenic zone, extending east–west across the Amazon Basin, continue into the territory of Eastern Colombia, where promising gold exploration areas have been delineated. However, according to recent data, these gold districts in Brazil are now considered part of an independent orogenic belt, since a giant latitudinal gravity anomaly has been identified within the Amazonian Syneclise, separating the Guiana and Guaporé shields [29].

Nevertheless, the gold potential of Eastern Colombia remains significant. Within Paleoproterozoic gneisses, fields of granitic and volcanogenic–sedimentary rocks have been identified (**Fig. 4**).

Discussion of results

The analysis of gold deposits in the considered cratons shows that three main geological–industrial types of deposits are distributed there to varying degrees: (1) stratiform deposits in ancient metalliferous quartz conglomerates;(2) stratoID and vein–stockwork deposits hosted in banded iron formations (BIFs);(3) vein and stockwork plutonogenic–hydrothermal quartz–sulfide and quartz–low-sulfide deposits with tourmaline.

In the Kaapvaal Craton, deposits of the first type — in Late Archean conglomerates — clearly dominate and define the main resource base. In the Zimbabwe Craton, hydrothermal quartz–sulfide deposits are more widespread.Within the West African Craton, deposits hosted in Lower Proterozoic conglomerates and hydrothermal types occur in roughly equal proportions.In the Amazonian Craton, deposits of the third type prevail.

For the latter, several **general ore localization criteria** are known: extensive compression and shear zones; exocontact areas (in a broad sense) of synorogenic granitoids; environments contrasting in physical and mechanical properties, including ultrabasic bodies and dikes of various compositions; and halos of tourmalinites, quartz–sericite metasomatites, and secondary quartzites.

Conclusions

• In eastern Colombia, the most probable deposits are vein and vein–stockwork gold deposits of the quartz–sulfide type, which is indirectly supported by the presence of numerous alluvial gold placers. To a lesser extent, stratoid-type deposits may occur within areas of banded iron formations (BIFs). In addition, at the base of the Paleoproterozoic sequences, bodies of auriferous quartz conglomerates are likely to be present.

• In the known ore–placer and alluvial gold districts located in the southeasternmost part of Colombia, hydrothermal deposits are considered more probable. To forecast their occurrence, it is necessary to analyze known ore-controlling criteria based on geological and geophysical data.

Acknowledgements

The research was supported by Ministry of Education and Science of the Russian Federation, Project No. 075-15-2025-657 «Gold Metallogeny of the Western Colombian Shield and the Development of Digital Predictive Criteria for Concealed Deposits».

References

1. Tewalt S. J., Finkelman R. B., Torres I. E., Simoni F. World Coal Quality Inventory: South America. 2006. Chapter 5. Available at: https://pubs.usgs.gov/of/2006/1241/Chapter%205-Colombia.pdf (accessed: 21.10.2025).

2. Bonilla A., Cramer T., De Grave J. et al. The NW Amazonian Craton in Guainía and Vaupés departments, Colombia: Transition between orogenic to anorogenic environments during the Paleo-Mesoproterozoic. *Precambrian Research*. 2021. Vol. 360. ID 106223.

3. Gómez T. J., Mateus-Zabala D. The Geology of Colombia. Bogota : Servicio Geológico Colombiano, 2020. Vol. 1. DOI: 10.32685/pub.esp.35.2019

4. Prieto R. G., Guatame C. L., Cárdenas S. C. Recursos minerales de Colombia. Bogota : Servicio Geológico Colombiano, 2019. Vol. 2. DOI: 10.32685/9789585246980

5. Kuleshevich L. V. Gold mineralization in Precambrian shields of the Earth (geodynamic position, systematics, and main principles of study). *Proceedings of Petrozavodsk State University*. 2010. No. 8(113). pp. 29–41.

6. Baranov A. A., Bobrov A. M. Crustal structure and properties of archean cratons of gondwanaland: similarity and difference. *Russian Geology and Geophysics*. 2018. Vol. 59, No. 5. pp. 512–524.

7. Otto A., Dziggel A., Kisters A. F. M., Meyer F. M. The New Consort Gold Mine, Barberton Greenstone Belt, South Africa: Orogenic gold mineralization in a condensed metamorphic profile. *Mineralium Deposita*. 2007. Vol. 42. pp. 715–735.

8. Jaguin J., Poujol M., Boulvais P., Robb L. J., Paquette J. L. Metallogeny of precious and base metal mineralization in the Murchison Greenstone Belt, South Africa: Indications from U–Pb and Pb–Pb geochronology. *Mineralium Deposita*. 2012. Vol. 47. pp. 739–747.

9. Ignatov P. A., Malyutin S. A., Tawanda Marimo, Lanchak M. M. The main features of regional metallogeny of the Zimbabwe Craton. *Gornyi Zhurnal*. 2024. No. 5. pp. 28–37.

10. Bering J., Brinckmann J., Camara N'doungou. et al. Evaluation de l'Inventaire des Ressources Minérales de Guinée – Etude. Hannover : Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), 1998. 109 p.

11. Bozhko N. A., Adu T. K., Kravtsova M. Yu. Paleoproterozoic molassoID complexes of southwestern Ghana. *Moscow University Bulletin*. 2016. Vol. 71. pp. 385–394.

12. Rusanov R. V., Bondarenko S. V. Gold ore formations and their geodynamic position in the northern part of the Guiana Shield (Republic of Guyana). *Nedra Povolzhya i Prikaspiya*. 2021. Vol. 104. pp. 52–64.

13. Cordani U. G., Teixeira W., D'Agrella-Filho M. S., Trindade R. I. The position of the Amazonian Craton in supercontinents. *Gondwana Research*. 2009. Vol. 15, Iss. 3–4. pp. 396–407.

14. Kroonenberg S. Geological evolution of the Amazonian Craton: forget about geochronological provinces. *Geological Map of South America Workshop*. 2014.

15. Kroonenberg S. B., de Roever E. W. F., Fraga L. M. et al. Paleoproterozoic evolution of the Guiana Shield in Suriname: A revised model. *Netherlands Journal of Geosciences*. 2016. Vol. 95(2). pp. 491–522.

16. Tassinari C. C. G., Macambira M. J. B. Geochronological provinces of the Amazonian Craton. *Episodes*. 1999. Vol. 22(3). pp. 174–182.

17. Teixeira W., Tassinari C. C. G., Cordani U. G., Kawashita K. A review of the geochronology of the Amazonian Craton: tectonic implications. *Precambrian Research*. 1989. Vol. 42, Iss. 3-4. pp. 213–227.

18. Shumilin M. V. *Historical metallogeny of uranium (experience of global analysis)*. Irkutsk : Reprocenter, 2015. 255 p.

19. Dardenne M. A. Metalogenese do Brasil. Brasília, DF : Editora UnB, CPRM, Servico Geologico do Brasil, 2001. 392 p.

20. Ignatov P. A., Malyutin S. A., Painos Gweme, Lanchak M. M. Geology and metallogeny of the mobile Magondi Belt in the west of the Republic of Zimbabwe. *Eurasian Mining*. 2024. No. 2. pp. 8–13.

21. Milesi J. P., Ledru P., Marcoux E. et al. The Jacobina Paleoproterozoic gold-bearing conglomerates, Bahia, Brazil: a "hydrothermal shear-reservoir" model. *Ore Geology Reviews*. 2002. Vol. 19, No. 1-2. pp. 95–136.

22. Klein E. L., da Rosa-Costa L. T. Geology of quartz-vein gold deposits in the Ipitinga Auriferous District, northern Brazil, southeastern Guiana Shield. *Géologie de la France*. 2003. No. 2–3–4. pp. 231–242.

23. Kotelnikov E. E., Istomin V. A., Sidorenko K. Yu., Vildanov D. I. Guyana: geology and mineral resources. Moscow : TsNIGRI, 2019. 27 p.

24. Maslovsky A. P. Gold deposits of the Guiana Shield. *Ores and Metals*. 2020. No. 4. pp. 4–10.

25. Germakhanov A. A., Chernykh A. I., Girfanov M. M., Istomin V. A., Svatkov A. S. The state and prospects of development of the mineral resource base of solID minerals of the Bolivarian Republic of Venezuela. *Ores and Metals*. 2022. No. 4. pp. 10–30.

26. Konstantinov M. M. Gold ore provinces of the world. Moscow : Nauchny Mir, 2006. 358 p.

27. Bettencourt J. S., Juliani C., Xavier R. P. et al. Metallogenetic systems associated with granitoID magmatism in the Amazonian Craton: An overview of the present level of understanding and exploration significance. *Journal of South American Earth Sciences*. 2016. Vol. 68. pp. 22–49.

28. Juliani C., Rodrigues de Assis R., Monteiro L. V. S. et al. Gold in Paleoproterozoic (2.1–1.77 Ga) continental magmatic arcs at the Tapajós and Juruena Mineral Provinces (Amazonian Craton, Brazil): A new frontier for the exploration of epithermal–porphyry and related deposits. *Minerals*. 2021. Vol. 11, Iss. 7. ID 714.

29. Moyano–Nieto I. E., Cordani R., Cárdenas–Espinosa L. P. et al. Contribution of new airborne geophysical information to the geological knowledge of eastern Colombia. *The Geology of Colombia*. 2020. Vol. 1, Chapter 2. pp. 17–36. EM