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Lithological Features of Precambrian Gold-Bearing Rocks: Evidence from the Ukrainian Shield

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Abstract—Based on traditional petrochemical and nontraditional mineralogical methods (accessory zircon generation analysis), specific features of the primary composition of strongly metamorphosed rocks from some Early Precambrian Au-bearing rocks of the Ukrainian Shield (US) were studied. The confinement of several gold ore occurrences to primarily sedimentary Late Archean rocks of the Ukrainian Shield has been established and the possibility of their chemogenic origin is considered. The joint analysis of plicative tectonics and metamorphism facies in the study area demonstrated that Au-bearing primarily sedimentary (chemogenic) rocks of the Khashchevatoe–Zaval'ev Formation of the Bug Group (AR_2) are confined to amphibolite-facies domains within tectonic (high-order synform) structures with a significant gold potential.

Study of lithological features of Au-rich rocks is gaining an increasing significance in the world practice. In recent years, researchers have established and found new pieces of evidence in favor of the essential role of chemogenic and biochemogenic processes in the formation of gold deposits (Nekrasov, 1991). The role of organic material in gold mineralization of Phanerozoic black shales and certain Precambrian rocks is crucial (Yudovich *et al.*, 1990; Nikeshin and Emel'yanov, 1993). Gold concentration in recent silty sediments (coastal zones of Kamchatka and Oregon, northwestern shelf of the Black Sea, and other areas) has a fundamental significance in this respect (Lepkii and Kolesnikova, 1984; Lebed *et al.*, 1994).

Analysis of data on the Belaya Tserkov–Odessa gneiss–granulite region of the Ukrainian Shield demonstrates a certain relation of Au concentration with ancient conglomerate and strongly metamorphosed Fe-bearing rock sequences. Deciphering of the genetic nature of this relationship is a difficult task unsolved in most cases. Some researchers emphasize the metaterrigenous nature of Au-bearing rock complexes. However, one cannot also rule out their chemogenic origin related to the chemical differentiation of crustal material in the Early Precambrian.

GENERAL ISSUES OF THE DEVELOPMENT OF PALEOLITHOLOGIC MODELS

Application of nontraditional paleoreconstruction methods is essential for deciphering the genesis of thick monotonous rock sequences. The accessory zircon generation analysis developed by researchers in Odessa (Nosyrev, 1990; Nosyrev *et al.*, 1985, 1989) is among such methods. This method is based on the detailed ontogenetic study and quantitative evaluation of relict, synpetrogenic, and superimposed genetic types of accessory zircon.

Zircon grains of relict generation type (hereafter, relict zircons) are used for the paleoreconstruction of granulites (Fig. 1). They predate the major associations of rock-forming minerals and are subdivided into the clastogenic and magmatogenic subtypes based on ontogenetic features. They represent relicts of the primary material of magmatic, sedimentary, and metamorphic rocks.

The shape of relict clastogenic zircon depends on the character of disintegration and differentiation of volcanosedimentary rocks. It is commonly observed as acute-angled clasts in quartzites and metaconglomerates formed after coarse-clastic rocks. Well rounded, sometimes spherical zircon grains (K_{elong} = 1–1.5) are typical of some gneisses and granitoids formed after silts and pelites (Fig. 1).

The relict magmatogenic zircon consists of the internal primary crystal and several regeneration rims. The internal crystal is usually characterized by the absence of any traces of mechanical defects and high grade of preservation ($K_{elong} > 2$). Such zircon is typical of charnockites, amphibolites, pyrope-bearing gneisses, and crystalline schists (Fig. 1).

The clastogenic zircon is never observed in metamagmatic rocks. The simultaneous presence of magmatogenic and clastogenic zircons in rock testifies to its metaterrigenous origin during a weak sedimentary differentiation, e.g., metagraywackes formed after coarse-grained sediments under specific conditions of Early Precambrian (Tables 1, 2). Their genesis is far from clear and may be related to alteration of the primary ultrabasic–basic substrate.

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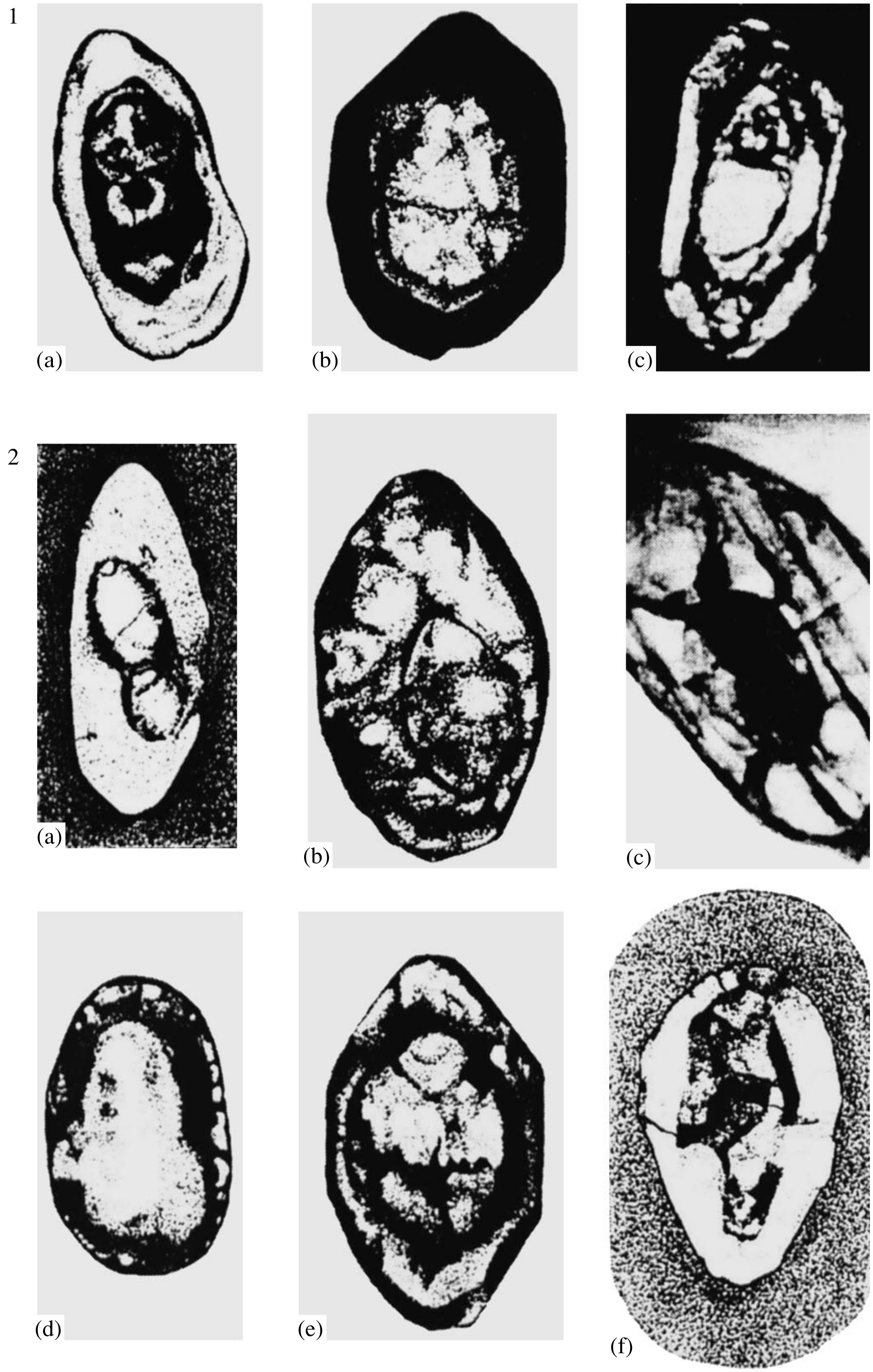

Fig. 1. Relict genetic types of zircon. (1) Magmatic: (a) granites of the Voznesensk Massif, western contact, (b) pyroxene gneisses of the Bug region, (c) charnockites of the Bug region, magn. 700; (2) clastogenic: (a, b) granites of the Voznesensk Massif, eastern contact, (c) Trikrat granites of the central Voznesensk Massif, (d) garnet–biotite gneisses, (e) garnet–pyroxene gneisses, (f) Kirovograd granites, magn. 600.

Table 1. Abundance of genetic zircon types in some granulites of the Ukrainian Shield, %

Sample no.	Rocks	Sampling locality	Genetic zircon types						Composition of primary rocks
			Relict			Superimposed			
			C	EM	LM	PG	PN	HT	
Middle Bug region, Bug Group (AR_2)									
100/13	Crystalline schist	Settlement of Savran	–	5	10	–	3	72	Orthomagmatic rock
556/40			–	–	–	–	–	100	Chemogenic sediment
328/102	Pyroxene gneiss	Settlement of Gvozdavka	20	–	–	55	–	25	Silt
Kirovograd Block, Ingul–Inguletsk Group									
8434	Garnet–biotite gneiss	Bratsk Synclinorium	40	–	–	–	35	25	Sand, silt
8310	Biotite gneiss		89	–	–	–	–	11	Silt, pelite
Koshary–Aleksandrov Formation, Bug Group (AR_2)									
K 1/1	Quartzite	Settlement of Shamarevka	12	–	–	–	26	62	Quartz sand
K 1/2			15	–	–	10	30	45	
K 1/5			12	–	–	–	28	60	
R 1/1		Settlement of Koshary	4	–	–	–	20	76	
Azov region, Temryuk Formation, Central Azon Group (AR_2)									
ZP 9/10	Calciphyre	Settlement of Starchenkovo	–	–	–	–	–	100	Chemogenic sediment
ZP 1/2	Quartzite	Balka Labunova Tract	6	–	–	–	–	94	Quartz sand
ZP 9/3			10	–	–	13	60	17	

Notes: (C) Clastogenic; (EM) early magmatic; (LM) late magmatic; (PG) pegmatitic; (PM) pneumatolytic; (HT) hydrothermal; (–) not detected.

Table 2. Abundance of genetic zircon types in rocks of the Khashchevatoe–Zaval'ev Formation (AR_2) (Middle Bug region, Ukrainian Shield), %

Sample no.	Rocks	Sampling locality	Genetic zircon types						Composition of primary rocks
			Relict				Superimposed		
			C	EM	LM	PG	PN	HT	
1002/3	Pyroxene gneiss	Settlement of Bandurovo	–	12	25	7	–	56	Orthomagmatic rocks
1007/2	Crystalline schist		–	14	24	7	10	45	
1005/1	Amphibolite		–	7	15	3	47	28	
1002/9	Calciphyre		–	10	23	5	23	39	Metasomatite
1014/1		Settlement of Khashchevatoe	–	9	20	2	–	69	Metasomatite after gabbroids
1015/1			–	15	24	3	–	58	
20г/3		Settlement of Troyanka	–	3	2	–	–	95	
556/21		Settlement of Kapustyanka	–	–	–	–	42	58	Chemogenic sediment
556/26			–	–	–	–	13	87	
556/29			–	–	–	–	–	100	
556/59			–	–	–	–	–	100	
550/86	Actinolized amphibolite	Eastern Kapustyanka gold ore occurrence	–	–	–	–	50	50	
550/90			–	–	–	–	10	90	
550/94			36	8	8	28	10	10	Graywacke, sand
552/80	Amphibolite		5	17	18	–	30	30	

Note: See Table 1.

Of particular interest are some crystalline schists, amphibolites, quartzites, and calciphyres (Tables 1, 2). The lack of relict zircon in these rocks suggests their metasomatic formation from chemogenic sediments.

Quartzites are subdivided into three (metaterrigenous, metachemogenic, and metasomatic) groups. Metaterrigenous quartzites are developed after different sandy and sandy–clayey rocks. Metachemogenic rocks include the majority of Fe-bearing quartzites without the relict zircon. Judging from the relict zircon composition, metasomatic quartzites are also developed after different rocks. The abundance of complex zircon crystals suggests that the metasomatic quartzites are occasionally developed after leucocratic ultrametamorphic granitoids. In other cases, garnet–biotite gneisses are metasomatized and a well-rounded internal core is developed in the majority of zircon grains.

Calciphyres have a complex composition. They are subdivided into metachemogenic and metasomatic types. The first type includes calciphyres of the Azov region (Temryuk Formation) and some calciphyres of the Bug region, while the second type includes some calciphyres developed after gabbroids in the Bug region.

Thus, analysis of accessory zircon makes it possible to reconstruct the composition of primary granulite sections and the evolution history of granulite-hosting geological structures.

Study of gold ore occurrences in the Belaya Tserkov–Odessa gneiss–granulite region revealed that almost all of them are confined to Early Precambrian metachemogenic sequences and, therefore, may be considered chemogenic objects.

ISSUE OF THE CHEMOGENIC NATURE OF GOLD

Possibility of the chemogenic formation of gold has been repeatedly discussed in geological literature in connection with the behavior of Au in oceanic water during present-day sedimentation (Kharitonov, 1936; Peshchevitskii *et al.*, 1965; Nekrasov, 1991). Gold occurs in free state as micrometer- and submicrometer-sized suspension in seawater. According to Kharitonov, an active proponent of the chemogenic concept of Au concentration in sediments, salt in the evaporated seawater contains as much as 457 mg/t Au and 54.4 mg/t Ag. Gold is also present in deep-sea sediments recovered by drag samplers from the seafloor (Kharitonov, 1936). The occurrence of Au in present-day sediments has also been reported in later works (Nekrasov, 1991).

Analysis of specific features of the geochemistry of gold made it possible to distinguish its most mobile forms (fine-dispersed, colloidal, and dissolved). Gold mainly migrates in the dissolved form as negatively charged $[AuCl_2]^-$ complexes in lower layers of oceanic water (Peshchevitskii *et al.*, 1965).

However, the diversity of water types results in significant variations of Au concentration and different forms of its occurrence. According to (Roslyakov, 1981; Velyukhanova *et al.*, 1988; Shishkina and Dmitriev, 1991), gold mainly migrates as organic complexes in surficial fresh waters. According to (Goleva, 1977; Pogrebnyak, 1983), inorganic complexes of one-valent Au ($[AuCl_2]^-$, $[Au(OH)_2]^-$, and $[Au(SO_4)_2]^{3-}$) and colloidal forms of elemental Au play the major role. The essential role of fulvic complexes in Au migration is emphasized in all works mentioned above. They agree that the major forms of Au migration in surface waters are hydroxy fulvate complexes of Au (III), hydroxy complexes of Au (III), and colloidal gold, the relationship between them being governed by conditions of their concentration in different types of water. According to (Miller and Fisher, 1974), Au concentration in solution inversely correlates with the thermophile $AuCl_2^-$. According to (Shishkina and Dmitriev, 1991), relationship between oxidized and reduced forms of Au in natural oceanic and fresh waters is governed by the amount of dissolved oxygen. Gold in brines of thermal water is characterized by oxidation degree of +I if organic acids are absent (Shishkina and Dmitriev, 1991).

The formation of colloidal solutions should be taken into consideration in the study of mobile forms of Au. As is well known, transfer of Au into solution is mainly caused by the tendency of its atom to form complex anions. Mobility of these complexes plays a significant role in the transfer and precipitation of Au. This property depends on several parameters of water solutions (pH, Eh, and so on). For example, the mobility of its chloride complexes strongly depends on the pH value of solutions. Gold can precipitate even at room temperature if the pH value increases. The presence of carbon oxide promotes this process. If CN^- ions are present, the process of Au solution becomes particularly intense, resulting in its oxidation and formation of $[Au(CN)_2]^+$ under atmospheric conditions (Sazonov, 1985).

Precipitation of Au directly from seawater is related to three factors (sorption, electrochemical reactions, and vital activity of organisms). The combined impact of these processes results in gold precipitation in the near bottom layer where a potential difference gradient originates near the seafloor during the motion of water and the seafloor is converted into an electrode. If the charge is positive and the milieu is alkaline, negative ions of gold chloride can be reduced and transferred as metacolloidal particles to sediments. Subsequently, the charged colloidal gold particles adsorb positively charged hydrosols of gold oxides. Micelles of colloidal gold are transformed into insoluble micrometer-sized concretions as a result of electrophoresis (Yasyrev and Nikitin, 1972). Such mechanism was probably responsible for the form of gold concretions in fine-dispersed shelf sediments in the Black Sea and Sea of Okhotsk.

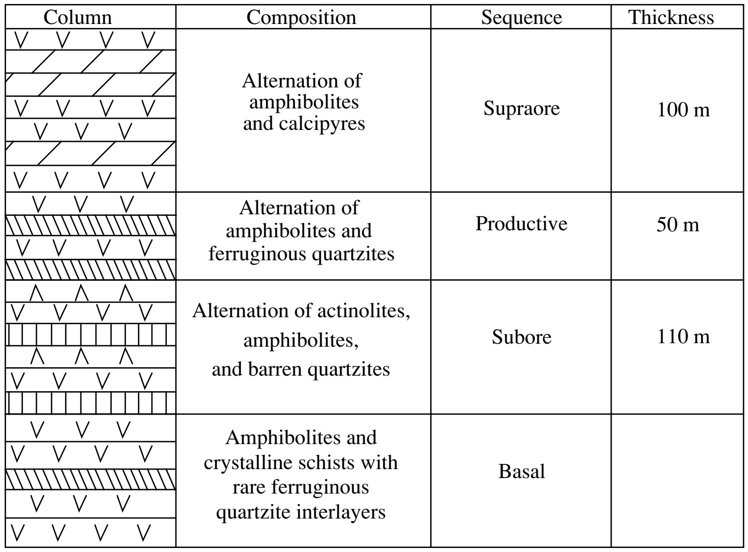

Fig. 2. Cross section of the Eastern Kapustyanka gold ore occurrence.

The phenomenon of electrophoresis can also be used for the extraction of gold from present-day pelitic and silty sediments.

Some researchers attach special attention to the role of organic matter in the precipitation of gold. Gold is concentrated near phosphate bone remains. The Au concentration in the proximal zone (1–2 cm) can be as much as 14 g/t, and small gold nuggets can locally be formed (Yasyrev and Nikitin, 1972).

Gold can also be absorbed from seawater by ferromanganese hydroxides, phosphates, and ferruginous humites.

The average Au content in present-day marine sediments varies from 1.5 to 4.2 mg/t. The Au content is as much as 7.5 mg/t in deep-water sediments of the Black Sea (Nesterenko and Vorotnikov, 1983). The Au enrichment is presumably related to high organic matter content and presence of H_2S-induced reductive barrier in sediments of the Black Sea. Gold concretions are formed with the help of active sorbents, such as metastable iron sulfide (greigite). Based on experimental data, the formation of greigite provides an extremely intense sorption of gold (~100% within the entire pH range). Ageing of the metastable sulfide promotes its breakdown into pyrite-marcasite and fine-dispersed native gold. Moreover, the native gold is partially desorbed. The available data show that sediments of the ancient (7000-yr-old) unit in the Black Sea contain globular pyrite and hydrotroilite that can actively absorb Au from seawater. The high contents (up to 40%) of clay minerals (primarily smectites) promotes this process. The Au content in the ancient sediment unit ranges from 2.0 to 5.2 mg/t. The Au content in the overlying unit of recent (3000-yr-old) sediments increases to 6.5 mg/t (Lepkii and Kolesnikova, 1985).

High Au contents within the northwestern shelf of the Black Sea are associated with poorly sorted sediments mainly represented by varigrained clayey sands (20–46 points per sample) and aleuritic-pelitic muds (1–10 points per sample). Gold is observed as micrometer-sized (occasionally spherical) grains without traces of rolling, suggesting its formation *in situ.* Another type is observed as lumpy grains with an iron hydroxide coating (Lebed *et al.*, 1994). Their formation may be related to chemogenic processes.

Of particular interest are seasonal variations of Au contents in present-day oceanic and marine waters (Okhotsk Sea, coast of Oregon in the United States, and other regions). Such variations are presumably caused by physicochemical transformations in colloidal systems of bottom sediments.

As is well known, the largest gold deposits in the world are genetically associated with Precambrian metasedimentary sequences formed under basically different conditions relative to the present-day environment. Sediments accumulated as a result of weak chemical differentiation in the Early Archean. Reductive conditions of that period were favorable for an intense migration of Fe, Mn, and Au in the form of complex compounds, such as $Fe(HCO_3)_2$ and $Mn(HCO_3)_2$. At the same time, sulfide sulfur was not oxidized. The detection of authigenic pyrite and organic substances in the matrix of Au-bearing conglomerates of Witwatersrand indicates considerable accumulations of sulfurous compounds and organic matter (sulfur bacteria type) and the probability of chemogenic origin of a part of gold (Gor'kovets, 1990). According to (Salop, 1982), a major portion of the gaseous phase of Early Precambrian atmosphere was composed of nitrogen and carbon that migrated under reductive conditions at temperatures of approximately

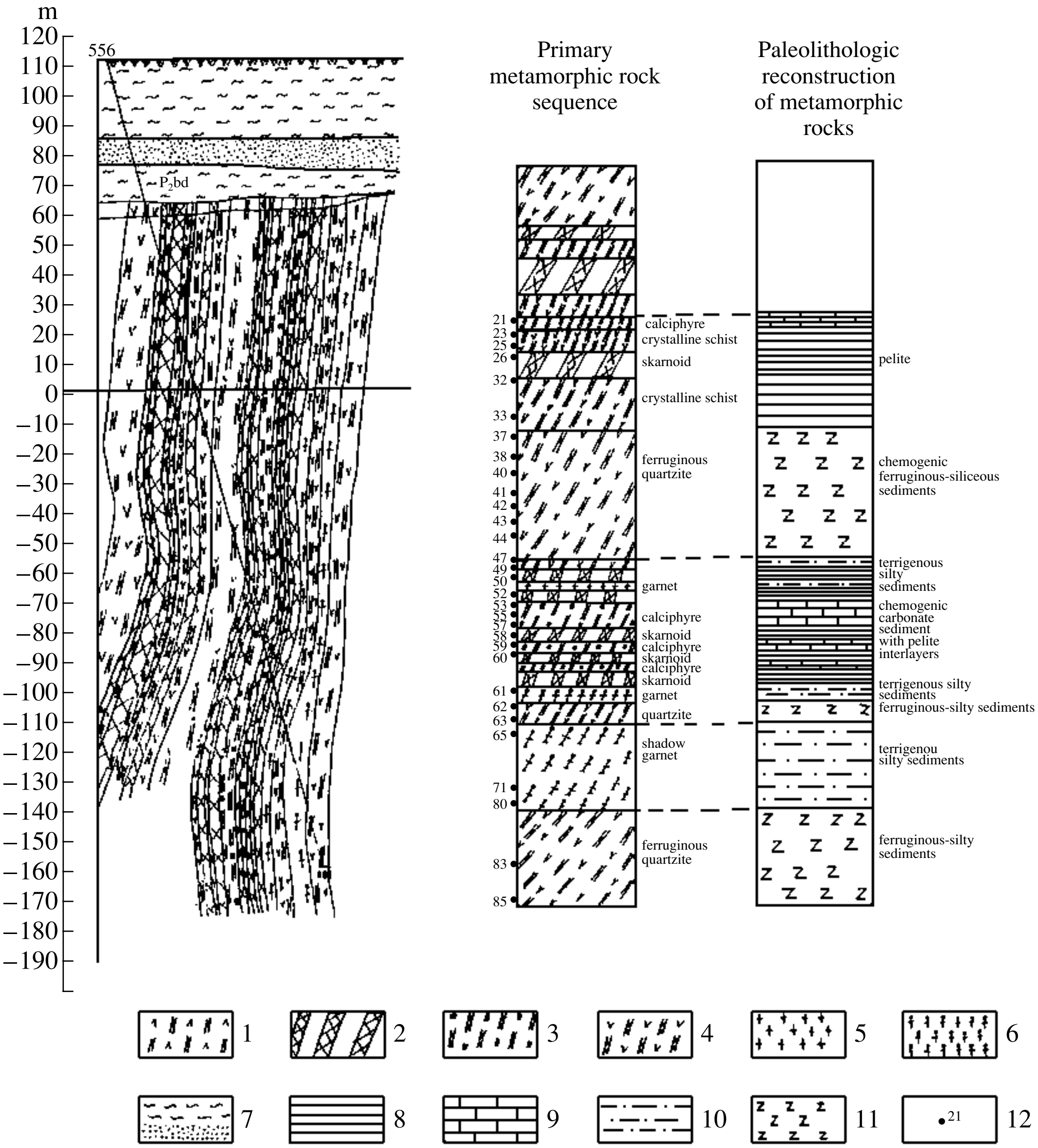

Fig. 3. Reconstruction of the lithological composition of metamorphic rocks of the Savran sector. Crystalline rocks: (1) magnetite–pyroxene quartzite, (2) diopside–magnetite skarn, (3) diopside–magnetite calciphyre, (4) crystalline (magnetite–quartz–pyroxene) schists, (5) pegmatoid garnet, (6) garnet–biotite hypersthene granites; (7) rocks of the sedimentary cover; reconstructed sediments: (8) pelitic, (9) chemogenic ferruginous–magnesian–carbonate, (10) silty, (11) chemogenic ferruginous–silicate; (12) samples donating the accessory zircon crystals and their numbers.

150–370°C. Drastic increase in the fugacity of N and Au under such conditions in the presence of Fe, As, and Zn admixtures inevitably promoted the formation of highly mobile cyanide complexes of the Au[HCN] type and the accumulation of Au in specific chemogenic or volcanogenic–chemogenic sequences.

According to various estimates, the share of chemogenic rocks in the Early Precambrian was very significant and amounted to no less than 25%, ferruginous quartzites accounting for ~5%. Models of the formation of such rocks are insufficiently developed and substantiated (Gor'kovets, 1990). Other metachemogenic sediments consist of calciphyres, barren quartzites, amphibolites, and high-aluminous gneisses. The metachemogenic sediments were supplemented with metagraywackes, i.e., weakly differentiated clastic rocks that represent products of the reworking of a protocrust. Mechanism of the formation and accumulation of metagraywackes is poorly studied. They can be associated with chemical weathering of an ultrabasic–basic substrate under conditions of the primary low-water atmosphere (Dragomiretskii, 1996). Such

Table 3. Chemical composition of rocks of the Khashchevatoe–Zaval'ev Formation, Bug Group (AR_2) within the Eastern Kapustyanka gold ore occurrence (Ukrainian Shield), wt %

Oxides	Metaultrabasic–basic rocks						Amphibolites	
	Sample no.							
	552–13	550–75	550–169	550–79	550–104	550–86	550–74	550–178
SiO_2	45.44	49.56	50.29	46.94	49.93	47.08	48.88	68.29
TiO_2	0.30	0.30	0.24	0.25	0.23	0.42	0.32	0.31
Al_2O_3	11.21	12.89	8.53	9.42	8.01	13.13	11.20	12.10
FeO	5.89	2.73	4.06	4.89	4.56	4.67	5.21	3.99
Fe_2O_3	4.03	7.34	3.57	4.74	5.61	4.50	5.29	1.26
MnO	0.38	0.21	0.39	0.39	0.38	0.18	0.29	0.09
CaO	7.49	5.15	11.97	3.19	3.26	3.08	5.11	1.55
MgO	20.10	16.51	16.16	23.52	25.50	18.19	19.04	5.81
Na_2O	0.96	0.54	0.88	0.50	0.73	0.48	1.00	0.35
K_2O	0.28	1.73	0.62	0.47	0.38	2.83	0.62	2.00
P_2O_5	0.038	0.046	0.046	0.048	0.031	–	0.023	0.053
SO_3	0.81	0.12	0.29	0.11	0.28	0.19	0.66	0.27
L.O.I.	1.70	2.25	2.50	4.98	1.30	14.77	1.62	1.88
Total	98.63	99.38	99.55	99.45	99.20	99.52	99.26	97.92
Coefficients for the ACFM diagram								
A	23.01	28.89	19.26	20.59	17.06	30.18	24.42	48.97
C	15.37	11.54	27.02	6.97	6.95	7.08	11.15	6.27
FM	61.61	59.57	53.72	72.44	75.99	62.74	64.43	44.76
Coefficients for the FAK diagram								
A	–42.1	7.5	150.5	22.5	4.6	–4.7	–4.0	4.2
K	–12.5	9.5	2.1	–3.1	–7.7	2.6	–2.3	15.6
F	0.800	0.597	0.572	0.871	0.897	0.694	0.710	0.182

primarily clastic rocks could also serve as a favorable medium for the accumulation of thiocyanates and metals.

PALEOLITHOLOGIC RECONSTRUCTIONS OF SECTIONS OF THE KHASHCHEVATOE–ZAVAL'EV FORMATION (LATE ARCHEAN BUG GROUP)

Investigation of Au-bearing granulites of the Khashchevatoe–Zaval'ev Formation at the Eastern Kapustyanka ore occurrence in the southern Belaya Tserkov–Odessa gneiss–granulite district was carried out using the proposed reconstruction method based on relict zircon. The Khashchevatoe–Zaval'ev Formation includes marbles and calciphyres (with occasional magnetite), pyroxene–magnetite quartzites, iron ores, skarnoids, graphite–biotite and pyroxene–biotite gneisses, crystalline schists, and amphibolites. The fine-dispersed gold mineralization is confined to ferruginous quartzites and their contacts with thin amphibolite interlayers. The cross section includes the following units (from the top to bottom): supraore orthoamphibolites and chemogenic calciphyres; productive unit of ferruginous quartzites with amphibolite interlayers; and subore unit of actinolized amphibolites with barren quartzite interlayers (Fig. 2).

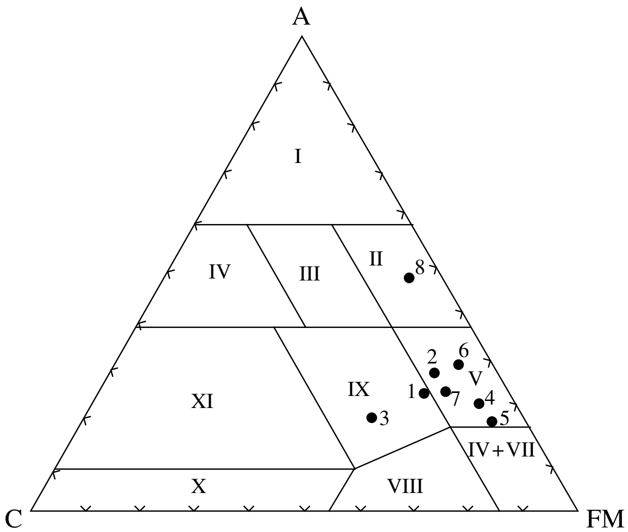

Fig. 4. Petrochemical diagram showing rock compositions of the Khashchevatoe–Zaval'ev Formation, Ukrainian Shield (after N.P. Semenenko). Petrochemical series. Aluminosilicate rocks. Rock subgroups: (I) aluminosilicate, (II) ferruginous–magnesian–aluminosilicate, (III) alkaline earth–aluminosilicate, (IV) calcareous–aluminosilicate. Rock groups: (V) aluminous–magnesian–ferruginous–siliceous, (VI) ferruginous–siliceous, (VII) magnesian ultrabasic, (VIII) alkaline earth–low aluminous ultrabasic, (IX) alkaline earth–aluminous basic. Alkaline earth–calcareous rock subgroups: (X) calcareous–carbonate, (XI) aluminous–calcareous. (1–8) Data points of studied rocks (numbers as in Table 3).

The productive unit (ferruginous quartzites and amphibolites) lacks relict zircons, suggesting its chemogenic origin (Table 2). Thin granitoid bodies in the section contain relict clastogenic zircon grains and, therefore, can be referred to as metaterrigenous formations. Some amphibolites of the subore unit were formed after the graywacke-type coarse-grained sediments.

The composition of granulites from other sections of the Khashchevatoe–Zaval'ev Formation within the studied region also testifies to their metachemogenic origin. Granulites of the Koshary–Aleksandrov Formation (AR_2) and certain sections of the undivided Dniester–Bug Group (AR_1) are metavolcanic–terrigenous rocks. Figure 3 shows results of the paleoreconstruction of metamorphic rock section at the Savran gold ore occurrence located in this region.

Table 3 shows results of petrochemical calculations performed in order to confirm these conclusions and evaluate the primary chemical composition of granulites. The ternary diagram proposed by N.P. Semenenko (*Petrografiya…*, 1956) is appropriate for this purpose.

In Fig. 4, data points of the majority of granulites fall into the domain of aluminous–magnesian–ferruginous–siliceous rocks, suggesting their chemogenic origin.

We also used the binary diagram of Predovskii (1980) for the reconstruction and comparison of primary compositions of silicate granulites of the Khashchevatoe–Zaval'ev Formation.

In Fig. 5, data points of granulites fall into the domain of ultrabasic–basic rocks, tuffites, and products

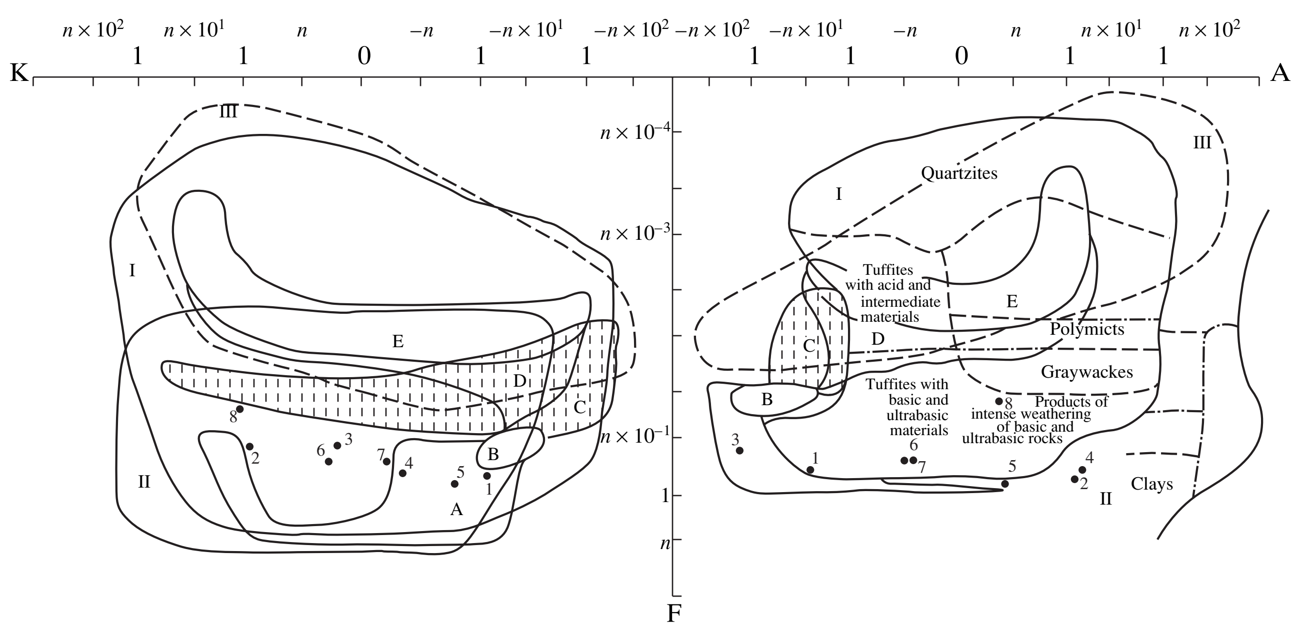

Fig. 5. Petrochemical diagram showing rock compositions of the Khashchevatoe–Zaval'ev Formation, Ukrainian Shield (after A.A. Peredovskii). Compositional fields of sedimentary and volcanosedimentary rocks: (I) granular sedimentary and mixed rocks, (II) pelites, (III) chemogenic silicites. Compositional fields of igneous rocks: (A) ultrabasic rocks, (B) basic rocks, (C) syenites, (D) diorites, plagiogranites, and dacites, (E) granites and rhyolites. (1–8) Data points of the studied rocks (numbers as in Table 3).

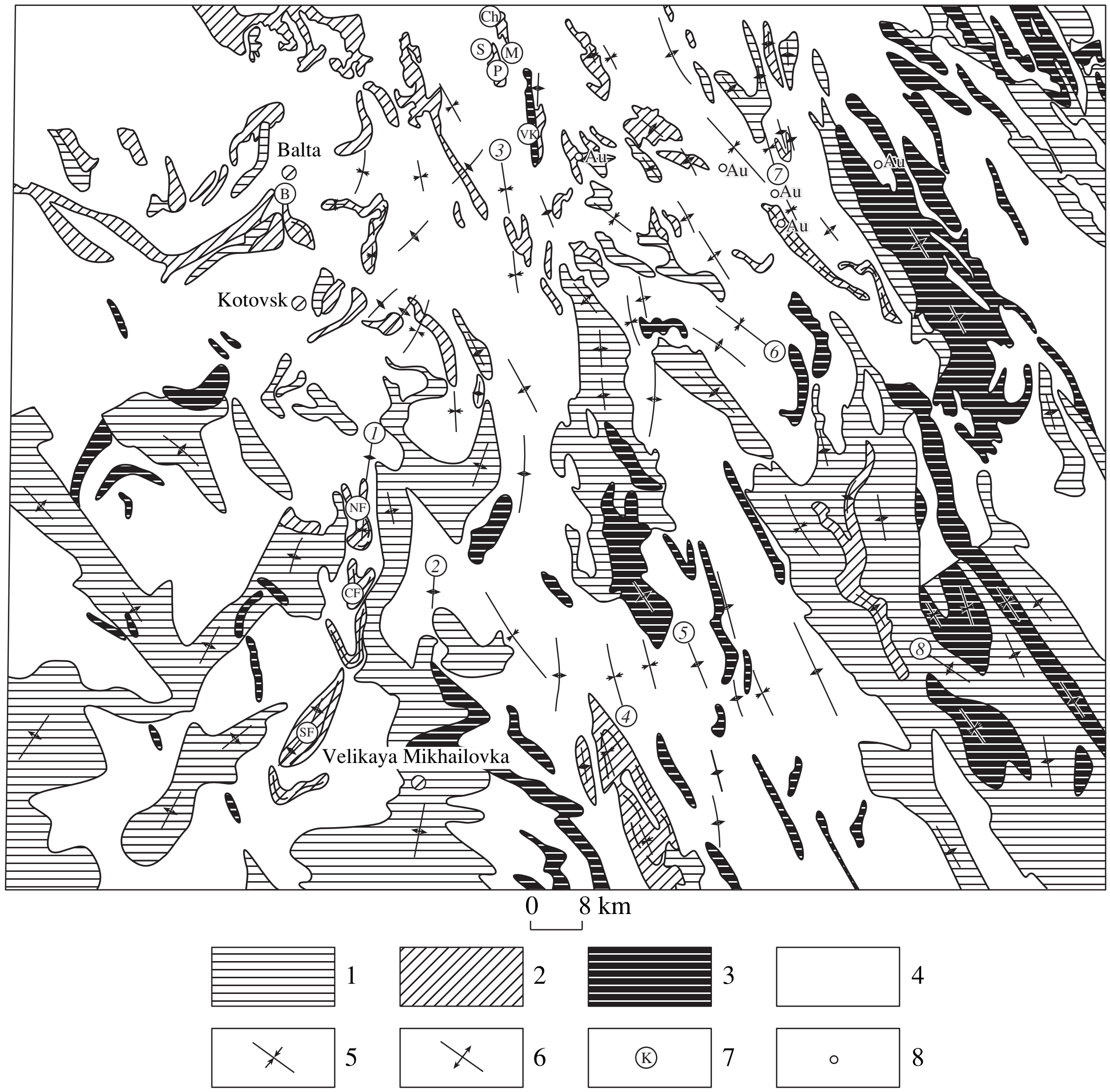

Fig. 6. Major plicative structures and facies in the southwestern sector of the central Ukrainian Shield. Facies of regional metamorphism: (1) greenschist–epidote–amphibolite (Koshary–Aleksandrov Formation, Bug Group, AR$_2$ka), (2) low-grade amphibolite–amphibolite (Khashchevatoe–Zaval'ev Formation, Bug Group Ar$_2$khz), (3) high-grade amphibolite–granulite (Dniester–Bug Group, AR$_1$db); (4) granitoids; (5) large synform structures and their axes: (1) Frunzov, (3) Kapustyanka, (4) Odessa Trough, (6) Krivoe Ozero, (7) Vradiev; (6) large antiform structures and their axes: (2) Velikaya Mikhailovka, (5) Troitskaya, (8) Domanev; (7) gold ore occurrences: (Ch) Chemerpol, (P) Polyanetsk, (S) Savran, (M) Maisk, (B) Balta, (VK) Eastern Kapustyanka, (F) Frunzov; (8) other gold ore occurrences.

of their intense weathering. On the whole, domains outlined in Figs. 4 and 5 correspond to the composition of chemogenic rocks.

Thus, the petrochemical reconstruction of primary compositions of granulites of the Khashchevatoe–Zaval'ev Formation testify to a high convergence of results obtained by the methods mentioned above.

The distribution of gold ore occurrences within the Belaya Tserkov–Odessa gneiss–granulite district demonstrated that practically all these ore occurrences (East Kapustyanka, South Frunzov, Balta, Polyanetsk, and others) are confined to metachemogenic sections of the Khashchevatoe–Zaval'ev Formation and can be considered chemogenic objects.

The ultimate aim of our investigations was to analyze specific features of the distribution and structural localization of Upper Archean Au-bearing metachemogenic sections within the Belaya Tserkov–Odessa gneiss–granulite district. We also reviewed the information concerning the geostructural distribution of Archean rock complexes. Thus, we established the following most essential genetic indicators of Au-bearing sectors: (1) the presence of primarily sedimentary (chemogenic or volcanogenic–chemogenic) rocks of the Khashchevatoe–Zaval'ev Formation of the Late

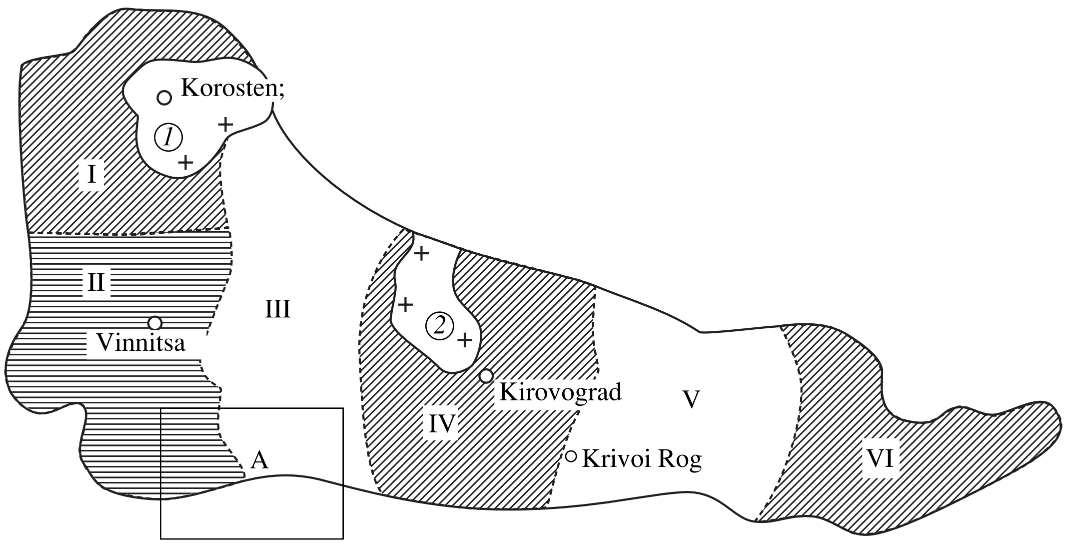

Fig. 7. Tectonic regionalization of the Ukrainian Shield (after Kalyaev *et al.*, 1977). Blocks: (I) Volhynia, (II) Podolsk, (III) Belaya Tserkov–Odessa, (IV) Kirovograd, (V) Middle Dnepr region, (VI) Azov region. Plutons (numbers in circles): (1) Korosten, (2) Korsun–Novomirgorod. (A) Study area.

Archean Bug Group; (2) their abundance within metamorphic rocks of the amphibolite facies; (3) the confinement of amphibolite-facies metamorphic rocks to large Precambrian synform structures.

The results obtained made it possible to reconstruct the model of plicative tectonics, metamorphic facies, and gold ore occurrences in the southern sector of the central Ukrainian Shield (Fig. 6). All Au-bearing metachemogenic sections of the Khashchevatoe–Zaval'ev Formation are generally confined to domains of the amphibolite-facies metamorphic rocks in marginal and central sectors of large synform-type folds, such as the Odessa Trough and the Gvozdav, Vradiev, Kapustyanka, and Frunzov folds (Fig. 7). In contrast, the barren Early Archean metaterrigenous-volcanic (Dniester–Bug Group) and Late Archean metavolcanic–terrigenous (Koshary–Aleksandrov Formation) rocks are confined to large tectonic antiform structures (Troitskaya, Velikaya Mikhailovka, and Domanev).

Results of the paleoreconstruction show that metachemogenic Au-bearing sequences are confined to high-order synform structures. Hence, such structures can be qualified as areas with a gold potential.

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