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Formation of Lower and Middle Jurassic Coaliferous Sequences in the Northern Caucasus

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Abstract—Pliensbachian coaliferous sequences were formed along the southern margin of the Stavropol Uplift in various paleogeographic environments. Therefore, peat bogs are developed in various landscape zones. In the southern Kuban coaliferous district, which adjoins the tectonically active central Caucasus, coaliferous sediments were formed in river valleys, whereas peat bogs were developed in swamped valleys. In the northern Kuban and Baksan coaliferous districts situated away from this region, coaliferous sediments were formed under conditions of alluvial–deltaic and alluvial–lacustrine plains. Peat bogs were localized in the swamped alluvial–deltaic and alluvial–lacustrine plains. In the Laba–Urup and southeastern Baksan coaliferous districts situated far away from the tectonically active central Caucasus and dominated by partly isolated bays and lagoons (or coastal plains), peat bogs were formed in the swamped (partly isolated) bays and lagoons (or coastal plains). Similar environments of sedimentation and peat deposition were typical of the Daghestan coaliferous district in the early Aalenian and Bathonian of Middle Jurassic.

INTRODUCTION

Coaliferous rocks of the northern Caucasus were studied by Mokrinskii (1937, 1940), Kakhadze (1947), Pogrebnov (1956), Frolov (1963, 1965), Polyanskii (1987) and many other researchers. However, there are still many vague points concerning coal deposition in this region, particularly processes controlling the development of various environments of Early–Middle Jurassic sedimentation and peat formation in the Kuban, Baksan, and Daghestan and adjacent coaliferous districts.

This paper is a summary of our long-term studies in the Caucasus. Correlation of lithofacies sections based on the coal deposits and occurrences of the northern Caucasus provided insights into the formation conditions of coaliferous sequences, made it possible to compile paleogeographic schemes for different time intervals, and interpret the peat deposition environments.

Lithofacies sections of Jurassic coal deposits and occurrences on the northern slope of the Caucasus were constructed on the basis of Jurassic correlation scales adopted for the southern Soviet Union.

Rocks of various ages participate in the geological structure of the northern Caucasus. Mesozoic rocks comprise Triassic, Jurassic, and Cretaceous sequences. Jurassic rocks form the southern monocline in the northwestern Caucasus (between Maikop and Nal'chik), but they are severely deformed and transformed into folds broken by faults in the central Caucasus.

Coaliferous sequences of the middle Lias and lower Pliensbachian are generally localized in the northwestern part of the northern Caucasus (from Maikop to Nal'chik) and further exterded toward the central Caucasus. Aalenian coal deposits and occurrences are traced in the southeastern direction from Vladikavkaz to the Caspian Sea.

Previously, Pogrebnov (1963) recognized the Kuban, Baksan, and Daghestan coaliferous districts in the Jurassic region of the northern Caucasus. Taking into account that the coaliferous rocks extend northwestward from the Bol'shoi Zelenchuk River to the Dakho coal occurrence, he additionally delineated the Laba–Urup coaliferous area (Fig. 1). This is substantiated by the fact that formation conditions of coal-hosting rocks in this area differ from those in the Kuban coaliferous district.

Origin of coal deposits in the northern Caucasus is interpreted in different ways. According to Pogrebnev (1956), all coals in the northern Caucasus are humic, paralic, and autochthonous formations; the parental plant material was deposited in basins with unstable sedimentation regime; the Kuban and Baksan districts were situated within a common basin extending from the Bol'shoi Zelenchuk River to the Cherek River in the east at the time of peat formation. The peat was formed in coastal and deltaic zones of the shallow-water basin located between a deeper sea in the east and west and land in the north and south.

Frolov (1965) divided Jurassic coaliferous sequences of Daghestan into formations and subformations. However, boundaries between formations and subformations were conventional. Therefore, correlation of lithostratigraphic units was unreliable and paleogeographic reconstructions were groundless.

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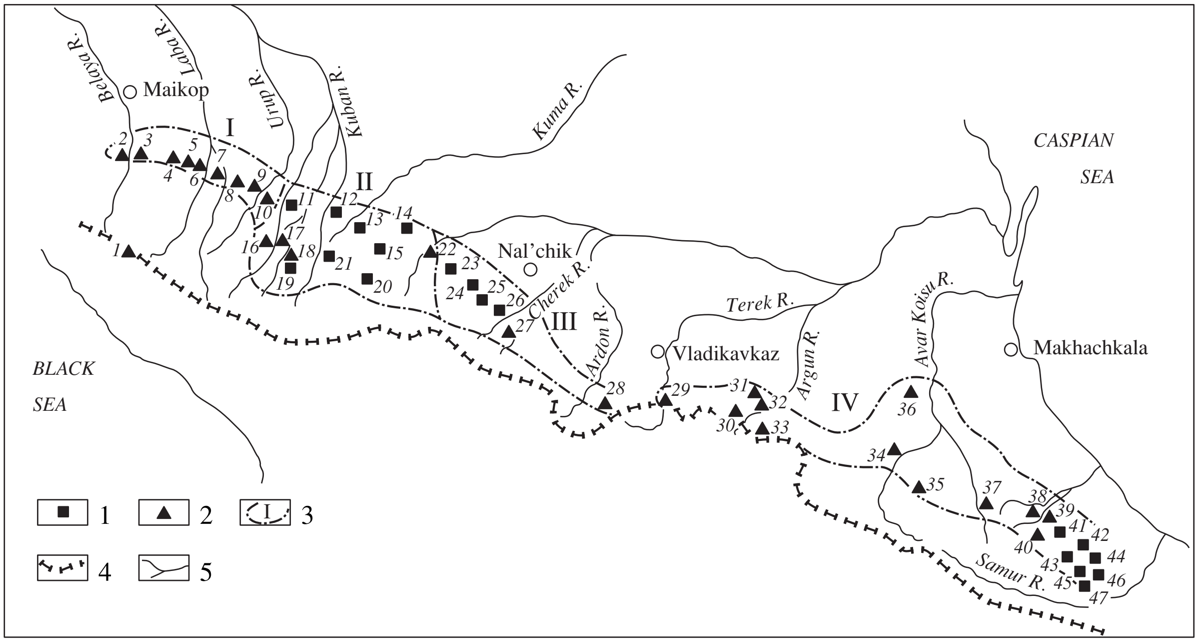


Fig. 1. Schematic index map of Jurassic coal deposits and occurrences in the northern Caucasus. (I) Laba–Urup coaliferous area; coaliferous districts: (II) Kuban, (III) Baksan, and (IV) Daghestan. (1) deposits; (2) occurrences, (3) coaliferous areas and districts; (4) water divide; (5) rivers. Coal deposits and occurrences: (*1*) Adler, (*2*) Dakho, (*3*) Barakaev, (*4*) Beslineev, (*5*) Kizilov, (*6*) Shchedok; (*7*) Laba, (*8*) Akhmetov, (*9*) Urup, (*10*) Balka Nadezhnaya, (*11*) Tishinsk, (*12*) Khumara, (*13*) Podkumok, (*14*) Khasaut, (*15*) Kuban–Malka, (*16*) Uzhum, (*17*) Marukha, (*18*) Ezi-Taukhchi, (*19*) Aksaut–Teberda, (*20*) Kartzhut, (*21*) Ust'-Kal'tyube, (*22*) Musht, (*23*) Tyzyl, (*24*) Bylym, (*25*) Kerdyuk–Bylym, (*26*) Chegem; (*27*) Farankol; (*28*) Gutiatikau, (*29*) Armkha, (*30*) Verkhnii Kii, (*31*) Barskoe, (*32*) Becha, (*33*) Kolkhodai, (*34*) Datun, (*35*) Upkit, (*36*) Chirkhata, (*37*) Akushin, (*38*) Bugunchai, (*39*) Ufek–Afnadag, (*40*) Ulluchai–Kaidagchai, (*41*) Rubaschai and Chirakhchai, (*42*) Gushtil, (*43*) Lak, (*44*) Arkhit, (*45*) Khiva, (*46*) Tsitinsk, (*47*) Fereg.

Panov (2000) suggested the existence of grabenlike (apparently rift) troughs filled with continental sediments.

According to Polyanskii (1987), moderate-sized peat bogs of the Khumara and Baksan coal deposits were situated within a vast coastal alluvial plain up to 50 km wide and mainly deltaic environments were developed in the Daghestan district.

Lack of a common opinion regarding the genesis of coal deposits in the Kuban coaliferous district testifies to the complex paleogeographic environment of coaliferous rock deposition. The present work is devoted to the investigation of this issue.

METHODS OF THE STUDY OF COALIFEROUS ROCKS

The lithofacies analysis of Lower and Middle Jurassic coaliferous sequences of the northern Caucasus was carried out using the methods elaborated by Timofeev (1970, 1994, 1998) and slightly modified by the author of the present work.

Following Timofeev (1994, 1998), we understand the genetic type of sediments as one or several paragenetically associated lithological types (lithotypes) having a set of genetic features indicating common formation conditions.

Timofeev (1969, 1970) defined the facies as a complex of physicogeographic conditions of sedimentation that promote the formation of paragenetically associated genetic types of sediments and primary sediments with a certain combination of genetic types.

In lithological sections, genetic types of sediments systematically replacing one another and grouped into facies are generally regarded as common facies-complexes (Table 1).

Paragenetically associated facies and facies-complexes characterize sedimentation environments (cycles-parageneses) corresponding to the evolution of transgressive–regressive and regressive–transgressive series (Figs. 2, 3). Coal seams in the cycles reflect the stable sedimenation environment and are crucial for the recognition of cycles-parageneses.

The cycles-parageneses were named based on the predominant and most characteristic set of sediment facies types taking into account the rocks underlying and overlying the coal seams.

Cycles-paragenes of continental sediments are subdivided into the alluvial, alluvial–lacustrine, lacustrine, and alluvial-estuarine types.

Table 1. Genetic types, facies, and facies-complexes of coaliferous sediments

Environment	Facies-complex	Facies	Genetic type
A. Continental	1. Channels and floodplains of small river valleys AC	a. Gravel–pebble sediments in small river channels AC_1	Conglomerate with varisized angular rock fragments and charred plant branches
			Poorly sorted conglomerate and coarse-grained gritstone with angular and poorly rounded rock fragments
		b. Sandy–gravel sediments in small river channels AC_2	Fine- and medium-grained (occasionally coarse-grained) gritstones with thick unidirectional cross-bedding and rhythmic sorting of material
			Coarse-grained and less abundant medium-grained sandstones with pebbles and numerous lenses of coal
	2. Channels and floodplains of large river valleys AC^1	a. Sandy sediments of large river channels AC_3	Fine-grained gritstone and coarse-grained sandstone with thick unidirectional cross-bedding, rhythmic sorting and sporadic angular fragments of alien rocks
			Medium-, fine-, and less abundant coarse-grained sandstones with unidirectional cross-bedding
		b. Silty–sandy sediments of near-channel floodplain AC_4	Fine-grained sandstone and siltstone with thin unidirectional convergent cross-bedding or striated bedding
			Siltsone and mudstone with horizontal wavy bedding, numerous plant remains, and siderite nodules
	3. Swamped floodplains in river valleys AP	a. Clayey–silty sediments of stagnant swamped floodplains AP LS_1	Siltstone and mudstone with horizontal discontinuous bedding, thin fine-grained sandstone interlayers, and plant scraps
			Mudstone with interlayers of fine-grained siltstone, occasional intercalation of these rocks with horizontal lenticular bedding, and numerous plant remnants
		b. Sediments of mobile, strongly inundated peat bog PB	Telinite and posttelenite (high- or low-ash) coal and coaly mudstone
	4. Lakes in floodplains of large river valleys L	a. Sandy–silty sediments in running water zones of shallowing lakes L_1	Medium- and fine-grained sandstones and siltstone with horizontal lenticular discontinuous bedding, roiling structures, and abundant plant remains (attritus)
			Vaguely bedded siltstone with numerous plant remains (attritus)
		b. Clayey–silty sediments of lakes L_2	Dark gray siltstone with horizontal bedding, occasionally clotted and intercalating with thin beds of fine-grained sandstone
			Dark gray, vaguely bedded, clotted mudstone, occasionally intercalating with thin siltstone beds; well-preserved plant remains
	5. Swamped alluvial–lacustrine plains L^1	a. Clayey–silty sediments of swamped lakes LS_1	Clotted siltstone with numerous root remains
			Clotted mudstone intercalating with thin lenticular siltstone beds; root remains
		b. Sediments of stable, stagnant, and inundated peat bog SB	Collinite ash and low-ash coals (occasionally precollinite and less often posttelinite)

Table 1. (Contd.)

Environment	Facies-complex	Facies	Genetic type
B. Coastal continental	1. Alluvial–deltaic plain (subaerial delta)	a. Sandy–pebble sediments of estuarine alluvium	Conglomerate and coarse-grained sandstone with relatively good sorting, uni- and multidirectional convergent cross-bedding (attritus)
		AD_1	Medium- and fine-grained sandstones with relatively good sorting, massive structure or unidirectional oblique bedding accented by siltstone laminas with plant remains
	AD	b. Silty–sandy sediments of estuarine alluvium	Fine-grained sandstone with relatively good sorting, uni- and multidirectional convergent cross-bedding, and frequent intercalation with plant remains
		AD_2	Massive siltstone with dark gray mudstone or fine-grained sandstone interlayers emphasizing the multidirectional convergent cross-bedding (attritus)
	2. Swamped estuarine alluvial–deltaic plain	a. Sandy–silty sediments of swamped alluvial–deltaic plain	Fine-grained sandstone with relatively good sorting, massive siltstone with clotted structure and well-preserved plant remains
	AD^1	AD_3	Siltstone with thin lenticular interlayers of fine-grained sandstone containing plant remains
		b. Clayey–silty sediments of swamped alluvial–deltaic plain AD_4	Clotted siltstone and mudstone with well-preserved plant remains
		LS_3	Black coaly mudstone (clotted) with a vague horizontal bedding and well-preserved plant remains
		c. Sediments of relatively mobile and inundated strongly peat bog with a weak water circulation PB	Telinite, posttelinite, and less common parenchyma coals (high- and low-ash); coaly mudstone
C. Shallow-water coastal-marine	1. Shallow-water estuarine zone (submarine delta)	a. Sandy–pebble sediments of submarine delta	Conglomerate, gritstone, and less common coarse-grained sandstone with relatively good sorting, thick multidirectional cross-bedding, and rare plant scraps
		MS_1	Coarse-, medium-, and fine-grained sandstones with thin or thick multidirectional low-angle bedding, good sorting, plant scraps, and fragments of alien rocks
	MS	b. Sandy–silty sediments of submarine delta	Medium- and fine-grained sandstones and siltstone with multidirectional, low-angle cross-bedding, and plant remains
		MS_2	Fine-grained sandstone and massive siltstone with good sorting, pebbles of alien rocks, sporadic interlayers of clotted mudstone; plant remains
	2. Partly isolated bays and lagoons	a. Silty–sandy sediments of coastal parts of bays and lagoons	Medium- and fine-grained sandstones with wavy bedding accented by thin siltstone laminas and clayey–carbonate cement
		MS_3	Clayey siltstone with horizontal-wavy rhythmic bedding accented by laminas of fine-grained sandstone; shell remains
	MS^1	b. Sandy–silty sediments of bays and lagoons	Siltstone and fine-grained sandstone with fine striation, discontinuous wavy cross-bedding, and sporadic interlayers of homogeneous mudstone, limestone, and marlstone; shell remains
		MS_4	Siltstone and mudstone with sporadic interlayers of fine-grained sandstone accenting a discontinuous-wavy cross-bedding; well-preserved shell remains
	3. Swamped bays and lagoons MS^{11}	a. Silty–clayey sediments of swamped isolated bays and lagoon LS_4	Siltstone and mudstone (occasionally black) with horizontal and discontinuous vague, abundant plant remnants, combustible shale interlayers
		b. Sediments of relatively stable and stagnant peat bog SB	Collinite, precollinite, less common posttelinite and liptinite coals, coaly mudstone

Table 1. (Contd.)

Environment	Facies-complex	Facies	Genetic type
D. Shallow-water epicontinental marine basin	1. Open mobile shallow-water shelf	a. Silty–sandy sediments of shallow-water coastal zone	Fine-grained clayey or calcareous sandstone with vague wavy bedding accented by siltstone laminas; shell remains and sporadic interlayers of sandy and clayey marlstone
		M_1	Siltstone with horizontal-wavy bedding accented by laminas of fine-grained sandstone; well-preserved shell remains (occasionally with clayey limestone interlayers)
	M	b. Silty–clayey sediments of shallow-water coastal zone M_2	Siltstone and mudstone with rhythmic horizontal layering, shell remains, and sporadic limestone interlayers; pyroschists
	2. Swamped coastal continental plain	a. Silty–clayey sediments of the swamped coas M_3	Massive siltstone with a vague horizontal bedding or frequent intercalation with fossiliferous mudstone interlayers
		LS_5	Mudstone and less abundant siltstone with clotted structure and plant remains; coaly mudstone
	M^1	b. Sediments of peat bog with a stable water flow SB	Collinite, precollinite (high- and low-ash) coals; coaly mudstone
E. Relatively deep-water marine basin	1. Deep-water shelf at some distance from shore	a. Sandy–silty marine sediments in off-shore zone	Fine-grained sandstone with vague horizontal bedding accented by laminas of darker mudstone
		MR_1	Siltstone and mudstone with calcareous cement and well-reserved marine fossils
	MR	b. Silty–clayey marine sediments in off-shore zone MR_2	Massive (occasionally clayey and sandy) limestone with marine fossil
		c. Carbonate sediments MR_3	Calcareous, homogeneous, and clotted mudstone (less common siltstone)

Cycles-parageneses of continental–marine sediments are subdivided into alluvial–coastal-marine and alluvial–marine types. Marine cycles-parageneses are subdivided into coastal-marine and marine (coaliferous and coal-free) types (Fig. 3).

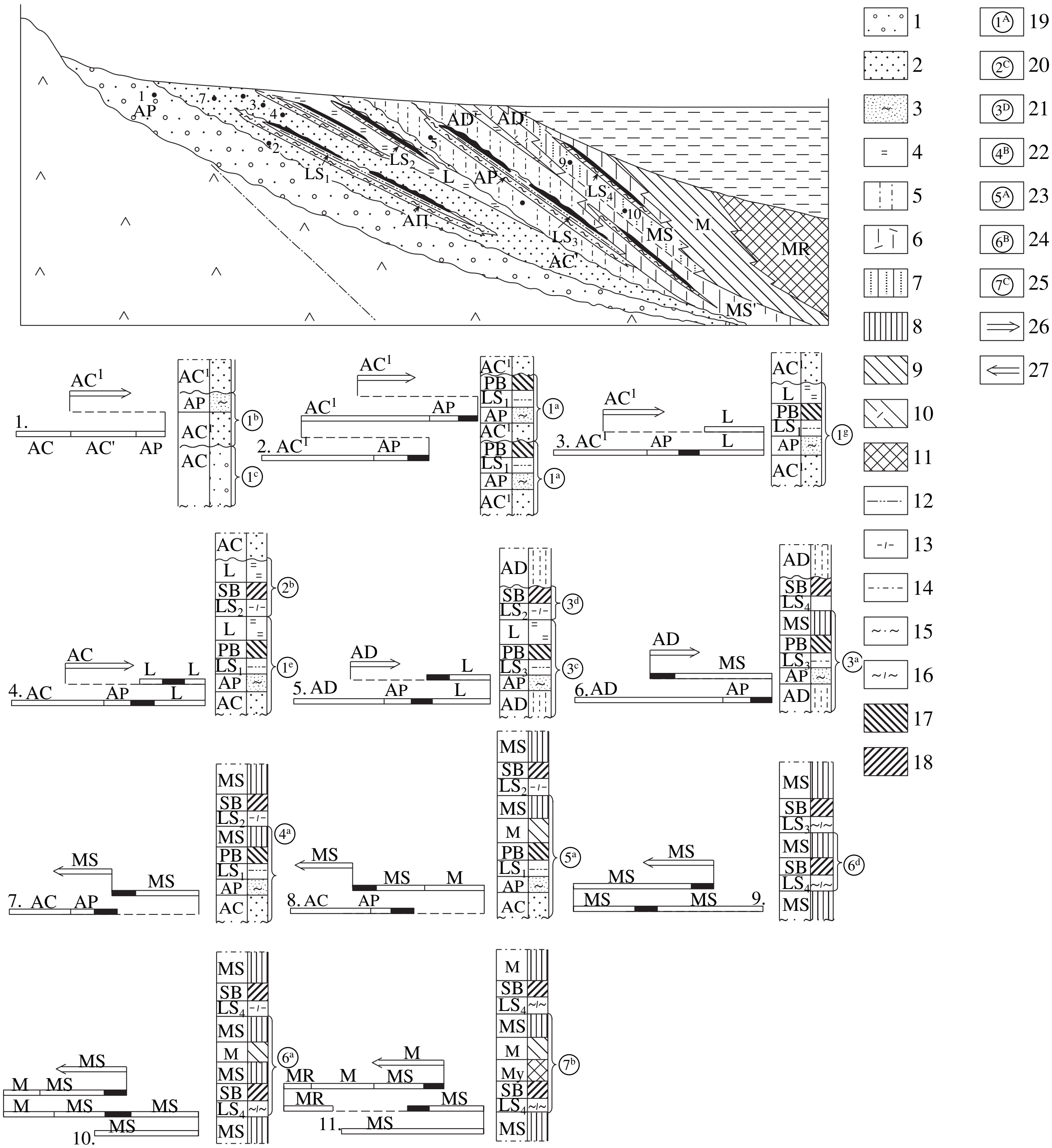
The vertical succession and spatial distribution of cycles-parageneses characterize a general environment of ancient sedimentation and peat formation. This information can be used to reconstruct the paleogeographic setting of coaliferous rocks and evolution of peat bogs in specific landscape zones.

Cycles-parageneses characterizing the evolution of specific landscapes and landscape zones are shown in Table 2.

EARLY JURASSIC COALIFEROUS SEQUENCES

Information on Lower and Middle Jurassic coal deposits and occurrences of the northern Caucasus is given as generalized lithofacies sections (Figs. 4, 5). This work presents averaged sections exhibiting the most typical spatiotemporal sedimentation environments at each deposit or occurrence.

Fig. 2. Sedimentation environments and cycles-parageneses. Continental: (1) channels and floodplains of small river valleys (AC), (2) channels and floodplains of large river valleys (AC^1), (3) (AP^1) swamped river valleys (floodplains), (4) lakes at floodplains of large river valleys (L); coastal continental: (5) alluvial–deltaic plain (subaerial delta) (AD), (6) swamped estuarine alluvial–deltaic plain (subaerial delta) (AD^1); shallow-water coastal-marine: (7) estuarine shallow-water coastal-marine (submarine delta) (MS), (8) partly isolated bays and lagoons (MS^1); shallow-water epicontinental marine basin: (9) open mobile shallow-water shelf (M), (10) swamped coastal continental plain (M^1); (11) relatively deep-water marine basin (MR); (12–16) lacustrine–swamp environments (LS_1–LS_5); (17) (PB) environment of mobile, strongly inundated peat bog; (18) environment of relatively stable inundated stagnant peat-bog (SB); types of cycle-parageneses: (19) alluvial and alluvial–lacustrine, (20) lacustrine, (21) estuarine alluvial, (22) alluvial–coastal-marine, (23) alluvial–marine, (24) coastal-marine, (25) marine; (26) transgressive–regressive cycles-parageneses; (27) regressive–transgressive cycles-parageneses.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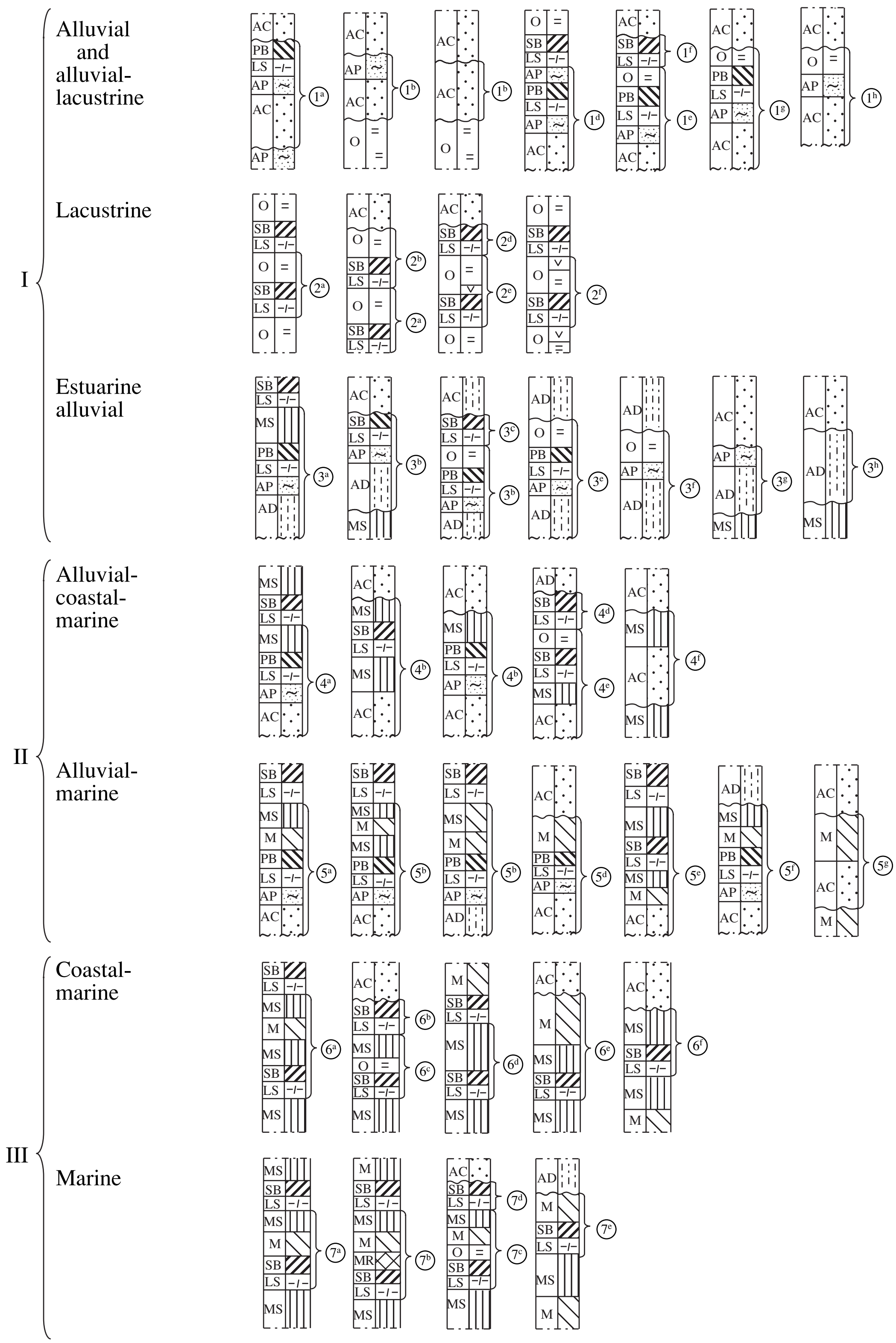

Fig. 3. Types of cycles-parageneses. (I) continental: (1) alluvial and alluvial–lacustrine, (2) lacustrine, (3) estuarine alluvial; (II) continental–marine: (4) alluvial–coastal-marine, (5) alluvial–marine; (III) marine: (6) coastal-marine, (7) marine. See Fig. 2 for legend.

Table 2. Cycles-parageneses of landscapes and landscape zones

Landscape	Landscape zones	Cycle-paragenesis type
River valleys		Mainly incomplete, coal-free, alluvial, and rare alluvial–lacustrine and lacustrine
	Swamped alluvial plains	Complete (occasionally incomplete) alluvial–lacustrine and lacustrine
	Swamped lacustrine plains	Complete and incomplete lacustrine
Alluvial–deltaic plain		Incomplete coal-free estuarine alluvial, alluvial, and less frequent alluvial–lacustrine
	Swamped alluvial–deltaic plains	Complete and incomplete, mainly alluvial, estuarine alluvial–lacustrine, and lacustrine
Partly isolated bays and lagoons		Incomplete coal-free alluvial–coastal-marine and complete alluvial–marine
	Swamped (partly isolated) bays and lagoons	Complete and incomplete alluvial–coastal-marine, alluvial–marine, less frequent lacustrine or alluvial–lacustrine
Coastal continental plains		Coal-free coastal-marine, marine, and less frequent alluvial–marine
	Swamped coastal continental plains	Complete coastal-marine and marine

Sections of the Kizilov (5) and Laba (7) coal occurrences shown in Fig. 4 are similar in facies composition and structure to sections of the Adler (1), Dakho (2), Barakaev (3), Beslineev (4), Shedok (6), Akhmetov (8), Urup (9), and Balka Nadezhnaya (10) coal occurrences and the Tishinsk coal deposit (11) shown in Fig. 1. Within these coal occurrences, Lower Jurassic coaliferous rocks overlie with erosion Triassic marine rocks. Sandy sediments of submarine deltas with sparse marine fossils occur in the basal section. Silty–clayey sediments of the isolated swamped bay and lagoon facies with occasional peat bog sediments predominate upsection (Table 1). The thickness of these lacustrine–swamp units is insignificant. They are locally overlapped by silty–sandy sediments of an open and mobile shallow-water shelf facies with sparse marine fossils and thin limestone interlayers. However, sediments of the estuarine shallow-water marine facies are more typical (Table 1).

Cycles-parageneses of alluvial–coastal-marine and alluvial–marine types lie at the base of these sections. Upsection, they give way to the coastal-marine and marine types, indicating the existence of coastal-marine shallow-water zone and shallow-water epicontinental basin.

Lithofacies sections of the Khumara (12) and Kuban–Malka (15) deposits (Fig. 4) are identical to those of the Podkumok (13), Khasaut (14) deposits, as well as the Uzhum (16), Marukha (17), and Ezi-Taukchi (18) coal occurrences (Fig. 1). The basal unit composed of sediments of channels and floodplain of large river valleys (Table 1) overlies the eroded Upper Paleozoic rocks. Upsection, the sequence consists of intercalation of clayey-silty and sandy-silty sediments (alluvial–deltaic plain facies including sediments of peat bogs) with clayey–silty and sandy–silty sediments of the swamped alluvial–deltaic plain facies (Fig. 4). Silty–sandy sediments of the near-channel floodplain facies are rather often. Sandy sediments (large river channel facies) and clayey–silty sediments (lacustrine basin facies) are less abundant (Table 1).

Cycles-parageneses recognized in the sections (Fig. 4) correspond to the alluvial, alluvial–lacustrine, lacustrine, and estuarine alluvial types that characterize continental environments of sedimentation and peat formation (alluvial–deltaic plains).

The base of the coaliferous sections at the Aksaut–Teberda (19), Kartzhut (20), and Ust'-Kal'tyube (21) coal deposits in the southern Kuban coaliferous district (Fig. 5) consists of gritstone and medium-grained sandstone with thick unidirectional cross-bedding. These sediments of the facies of channels and floodplains of large river valleys overlap the eroded Late Paleozoic rocks. Similar facies and facies-complexes occurring upsection contain sparse lenticular coal seams. Cycles-parageneses in lithological sections are only represented by incomplete alluvial types characterizing environments of swamped river valleys.

Polyanskii (1987) revealed that the terrigenous material was mainly derived from the Stavropol Uplift in the late Early Jurassic.

Denudation areas are shown on the paleogeographic scheme of the central Caucasus as islands and peninsulas slightly emerging above the sea level (Fig. 6).

Relatively coarse-clastic units in the southern Kuban coaliferous district and numerous lava flows in the lower Pliensbachian section indicate that volcanic islands and peninsulas (active uplifts) existed in the early Pliensbachian in the central Caucasus during the

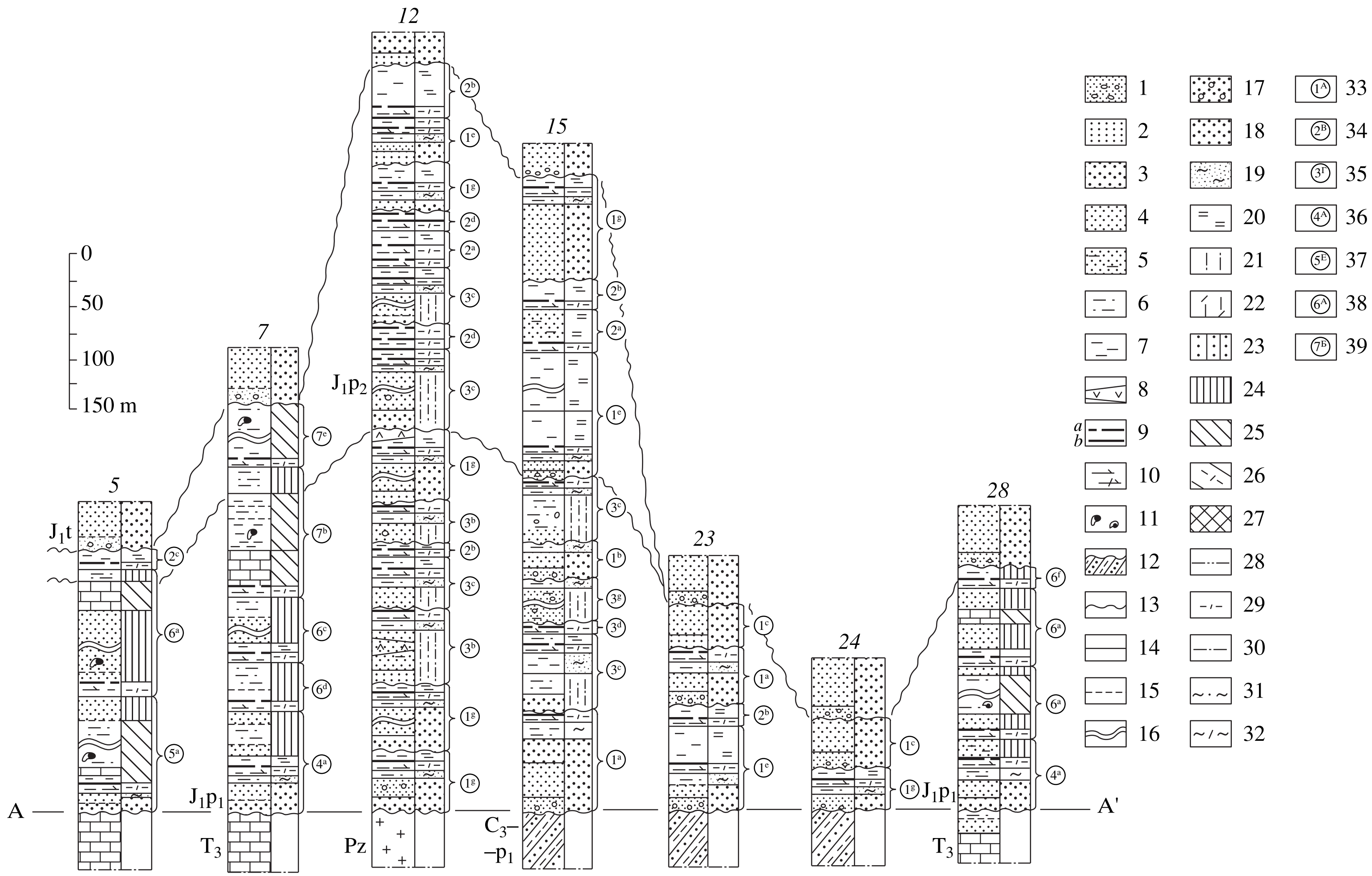

Fig. 4. Lithofacies sections of Early Jurassic coal deposits in the northwestern part of the northern Caucasus along line A–A[1] (see Fig. 6). (1) Conglomerate; sandstones: (2) coarse-grained, (3) medium-grained, (4) fine-grained; (5) clayey; (6) siltstone; (7) mudstone; (8) lava; (9) coal seams: (*a*) <1 m, (*b*) >1 m; (10) plant remains; (11) fossils; (12) unconformity; (13) intraformational erosion; (14) sharp transition; (15) gradual transition; (16) gap in column (out of scale); facies and facies-complexes: (17) channels and flood plains in small river valleys; (18) channels and floodplains in large river valleys; (19) swamped river valleys (floodplains); (20) lakes on floodplains in large river valleys; (21) alluvial–deltaic plain (subaerial delta); (22) swamped alluvial–deltaic plain; (23) shallow-water sea (submarine delta); (24) partly isolated bays and lagoons (shallow-water coastal-marine); (25) open mobile shallow-water shelf; (26) swamped coastal continental plain; (27) relatively remote deep-water shelf; (28) stagnant swamped floodplain; (29) swamped lake; (30) swamped alluvial–deltaic plain; (31) swamped isolated bays and lagoons; (32) swamped coastal zone; types of cycles-parageneses: (33) alluvial and alluvial–lacustrine, (34) lacustrine, (35) estuarine alluvial, (36) alluvial–coastal-marine; (37) alluvial–marine, (38) coastal-marine, (39) marine.

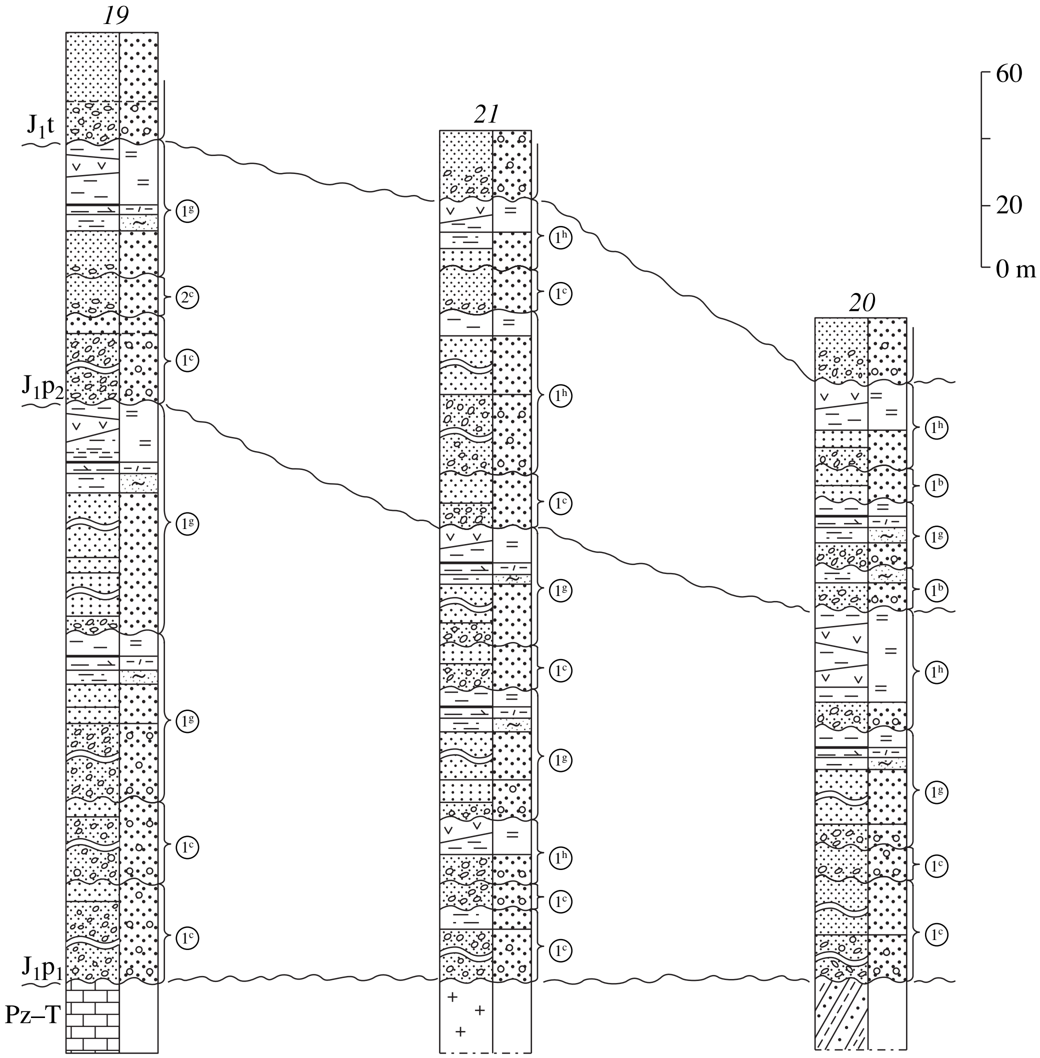

Fig. 5. Lithofacies sections of Early Jurassic coal deposits in the southern Kuban coaliferous district along line B–B_1 (see Fig. 6). See Fig. 4 for legend.

domination of terrigenous material supply from the north (Donets tectonic phase).

The active uplifts developed contemporaneously with sedimentation and could serve as sources of coarse-clastic material and lava flows at the Aksaut–Teberda, Kartzhut, and Ust'-Kal'tyube coal deposits. At the initial stage of coaliferous sediment deposition, the lava flows could occasionally reach the Khumara deposit.

Lithological coaliferous sections of the Tyzyl (23) and Bylym (24) deposits (Fig.4), as well as Musht (22), Kerdyuk–Bylym (25), Chegem (26), and Farankol (27) deposits (Fig. 1) are composed of sandy and silty–sandy sediments (large river channel facies) at the base. Clayey–silty sediments of swamped stagnant floodplains underlie and overlie peat bog sediments in the upper part of the section (Table 1).

Alluvial–lacustrine, lacustrine, and less abundant alluvial cycles-parageneses in sections of the Baksan coaliferous district characterize the continental environment of sedimentation and peat formation largely within the swamped alluvial–lacustrine plains.

The Gutiatikau coal occurrence (28) located south of Vladikavkaz in the southeastern part of the northern Caucasus (Fig. 1) completes the Pliensbachian coaliferous sequence. The lithological section in this area (Fig. 4) consists of intercalating sandy and sandy–silty sediments (submarine delta facies) and sandy–silty–clayey sediments (partly isolated bay and lagoon facies) in combination with silty–sandy sediments (shallow-water coastal zone facies) and silty–clayey sediments (swamped coastal continental plain facies) with sediments of the lacustrine–swamp and peat bog facies (Table 1).

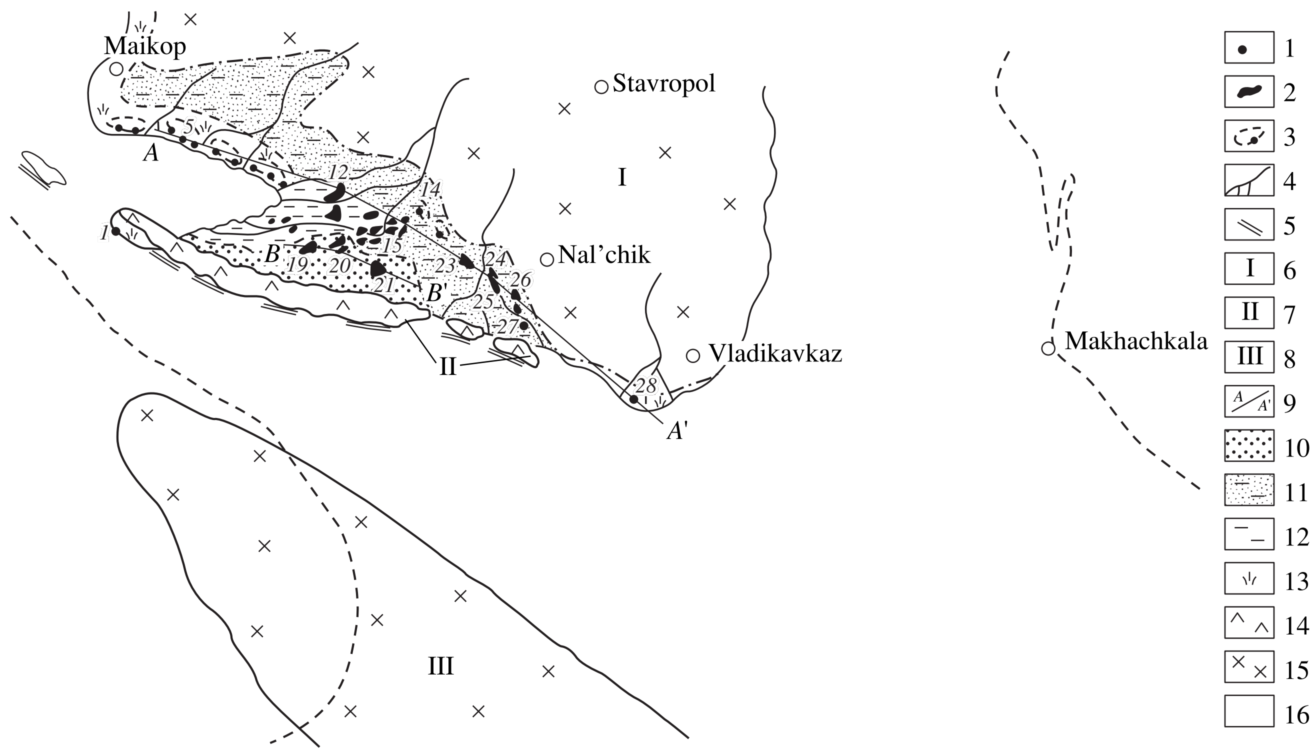

Fig. 6. Paleogeographic scheme of Early Jurassic peat deposition in the northwestern part of the northern Caucasus. (1) Coal occurrence; (2) coal deposit; (3) prospective coaliferous areas; (4) paleostreams; (5) deep faults; (6) Stavropol Uplift; (7) uplifted central zone of the Greater Caucasus; (8) Transcaucasus Median Mass; (9) profiles A–A_1 and B–B_1; landscape zones: (10) swamped alluvial plains, (11) swamped lacustrine plains, (12) swamped alluvial–deltaic plains; (13) swamped coastal continental plains and partly isolated bays and lagoons; (14) active uplifts (land); (15) passive uplifts (land), (16) epicontinental marine basin.

Cycles-parageneses of the coastal-marine and alluvial–coastal-marine types characterize the evolution of shallow-water coastal marine environment, shallow-water epicontinental basin, and swamped coastal continental plains.

A coarse-clastic or inequigranular terrigenous sequence overlies with erosion and unconformity older rocks at the base of all lithofacies sections of early Pliensbachian coal deposits and occurrences. This testifies to a structural rearrangement that predated the deposition of Lower Jurassic coaliferous sequences.

Further active tectonic movements in the central Caucasus changed paleogeographic environments in space and time.

Coaliferous sediments of the southern Kuban coaliferous district (Aksaut–Teberda, Kartzhut, and Ust'-Kal'tyube deposits) confined to tectonically active uplifts of the central Caucasus were deposited in river valleys. The peat bogs were formed in alluvial swamped plains (Fig. 6).

Active uplifts of the central Caucasus are areas subjected to most intense geotectonic movements. In the northern Kuban district situated at some distance from the central Caucasus zone, coaliferous sediments were deposited in estuarine alluvial and deltaic plains. Peat bogs are typical of the swamped estuarine alluvial and deltaic plains.

Cycles-parageneses of lacustrine and alluvial–lacustrine types in the Baksan coaliferous district were formed in alluvial–lacustrine plains, whereas peat bogs were formed in the swamped alluvial–lacustrine plains.

In the Laba–Urup and southeastern Baksan coaliferous districts situated far away from the zone of active tectonic movements of the central Caucasus, coaliferous sediments were deposited in coastal continental plains and partly isolated bays and lagoons. Peat bogs were formed on swamped coastal continental plains and, to a lesser extent, in partly isolated bays and lagoons (Fig. 6).

MIDDLE JURASSIC COALIFEROUS SEQUENCES

Middle Jurassic coaliferous sequences in the southeastern part of the northern Caucasus are confined to the Aalenian Stage. They were formed at the southern and southwestern margins of the Daghestan Uplift that extends along the present-day Caspian Sea coast in southern Daghestan. This area was a slightly elevated land during the Aalenian.

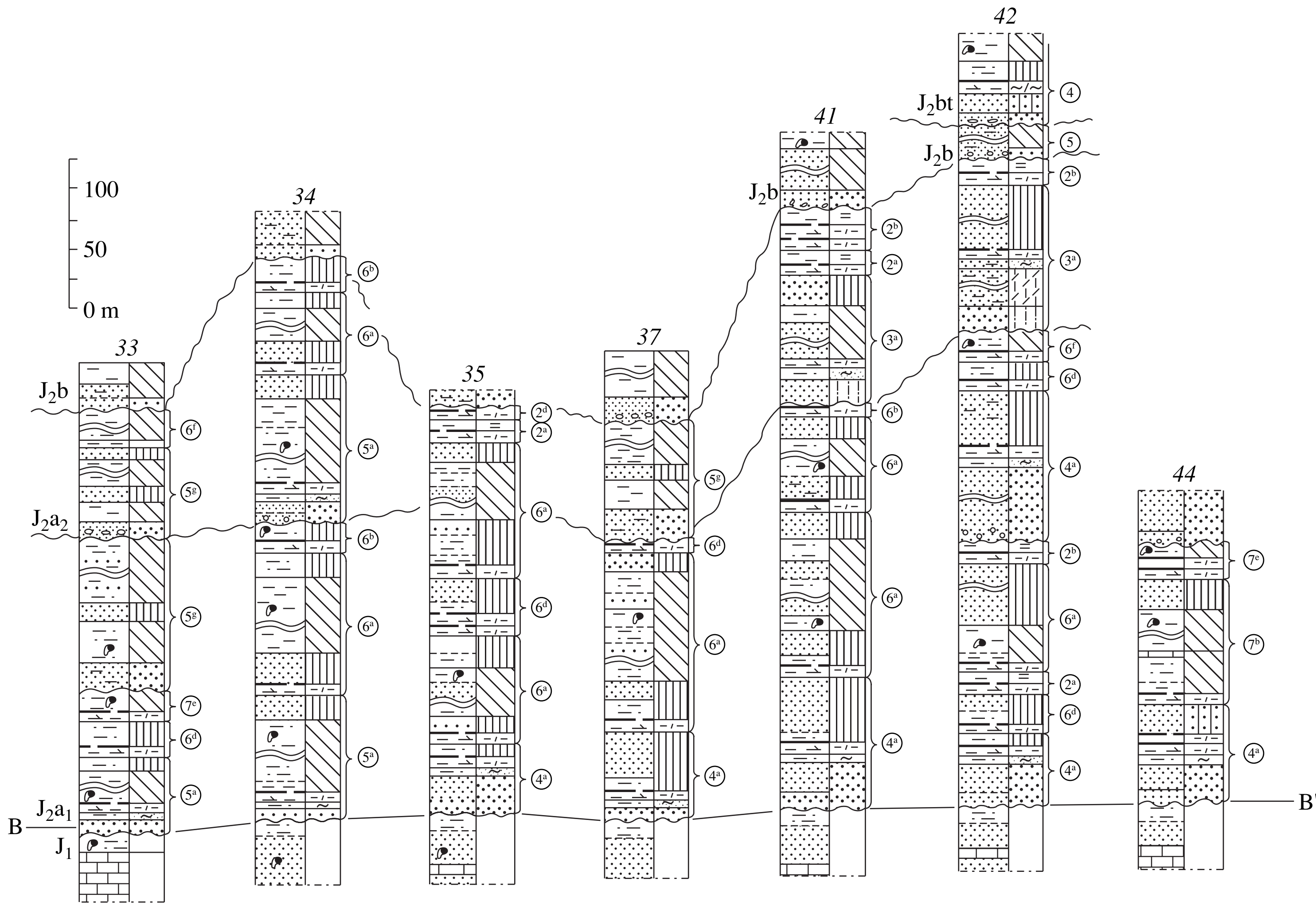

Fig. 7. Lithofacies sections of Middle Jurassic coal deposits in the southeastern part of the northern Caucasus along line B–B' (see Fig. 8). See Fig. 4 for legend.

Polyanskii (1987) stated that the Aalenian peat deposition in the southeastern Fore-Caucasus occurred at a regressive stage of the transgressive deposition of the thick Jurassic sequence. Nevertheless, periods of Aalenian sedimentation under transgressive conditions are not ruled out.

The Kolkhodai coal occurrence (33) is located at the Argun River (Fig. 7). Similar lithological sections are known at the Verkhnii Kii (30), Barskoe (31), and Becha (32) coal occurrences (Fig. 1).

Coarse- and medium-grained sandstones with gritstone interlayers occur at the base of the lower Aalenian section overlying the eroded Toarcian marine sediments. Sandstones with thick unidirectional cross-bedding (up to 10–15 m thick) representing sandy–gravel sediments (small river channel facies) are widespread throughout the Daghestan coaliferous district.

At the aforementioned coal occurrences, thin coal seams intercalate with sediments of the open shallow-water sea (silty-sandy and silty–clayey sediments of the coastal facies) (Table 1).

Cycles-parageneses at the base of the section correspond to alluvial–marine types. Upsection, they are replaced by coastal-marine and less abundant marine types. This implies that peat bogs were initially formed in swamped (partly isolated) bays and lagoons and then at the swamped coastal continental plains.

Shallow-water coastal-marine areas and the subordinate epicontinental shallow-water basins developed in the late Aalenian were unfavorable for peat bog formation (Table 1).

Silty–sandy and silty–clayey sediments (mobile shelf facies) and less abundant sandy sediments (submarine delta facies) (Table 1) are predominant in sections of the Darun (34), Upkid (35), Akusha (37), and Chirkhata (36) coal occurrences (Fig. 7). The basal unit of medium- and coarse-grained sandstones with thin gritstone interlayers (10–20 m thick) overlies the eroded Toarcian marine sediments. Peat bog sediments include simple thin coal seams structure spaced at a considerable distance from one another. Cycles-parageneses of alluvial–coastal-marine, alluvial–marine, coastal-marine, and less frequent marine types indicate that the peat bogs were formed in swamped coastal continental plains and less common partly isolated bays and lagoons.

Middle Jurassic coaliferous sequences at the Rubaschai (41) and Chirakhchai (42) deposits (Fig. 7) are composed of intercalating sandy–silty sediments (submarine delta facies), sandy–silty–clayey sediments (swamped water reservoir facies), and silty–clayey and silty–sandy sediments of the shallow-water coastal zone (Table 1). The basal unit consists of conglomerate, gritstone, and coarse- and medium-grained sandstones with thick unidirecional cross-bedding pertaining to the facies of sandy–gravel sediments of small river channels. These rocks overlie the eroded Toarcian marine sediments.

Like lower Aalenian coal occurrences in the northwestern area of the Daghestan coaliferous district, middle and upper parts of the Rubaschai and Chirakhchai sections include a sedimentary unit typical of channels and floodplains within relatively large river valleys. The thickness of these facies-complexes reaches 40–50 m (occasionally, up to 70 m) and is no more than 5–10 m in the northwest. Cycles-parageneses in these lithofacies sections correspond to the coastal-marine, marine, less common alluvial–coastal-marine and alluvial–marine and rare lacustrine types. Hence, the peat bogs were initially confined to swamped (partly isolated) bays and lagoons. The subsequent peat formation in the Daghestan coaliferous district developed in swamped coastal continental plains.

The deposition of Aalenian coaliferous sediments was promoted by active tectonic movements leading to the emergence of volcanic uplifts in the central Caucasus. The general uplift of the southeastern Daghestan district, including the rector with a favorable environment for the formation of coaliferous sequences and peat bogs was probably also related to the tectonic events. Since the peat deposition area was located at some distance from the tectonically active region, coaliferous sediments were formed during the development of coastal continental plains, whereas peat bogs were formed in swamped coastal continental plains (Fig. 8).

Marine transgression in the Caucasus was maximal during the Bajocian. This transgression also covered a considerable area of the northern Caucasus. However, the central Caucasus uplift continued to exist despite the transgression (Kakhadze, 1947; Mokrinskii, 1965). As was shown by Khalifa-Zade and Magamedov (1982), small uplifts trending along the main Caucasus structure were also formed in the Bajocian at the southeastern termination of the Main Caucasus Range.

The Bathonian orogenic phase, the first manifestation of Late Kimmerian Orogeny, substantially changed paleotectonic and landscape patterns of the eastern and southeastern Caucasus. Tectonic processes of this period promoted the formation of Transcaucasus Median Mass and large longitudinal uplifts in the axial zone of the present-day Greater Caucasus.

The Bathonian coaliferous sediments are virtually lacking on the northern slope of the Caucasus as a result of erosion in the pre-Callovian time. They are only preserved in Daghestan. Their thickness attains 670 m at the Chirakhchai deposit and along the Avar Koisu River.

Alluvial sequences reaching 100–150 m in thickness unconformably overlie the eroded Aalenian rocks at the Bathonian section base of the Rubaschai and Chirakhchai deposits (Fig. 7). The coaliferous sequence was formed at the regressive stage, whereas peat bogs originated during periods of tectonic stabilization. However, the Bathonian peat deposition was not widely developed due to the remote position of the Daghestan

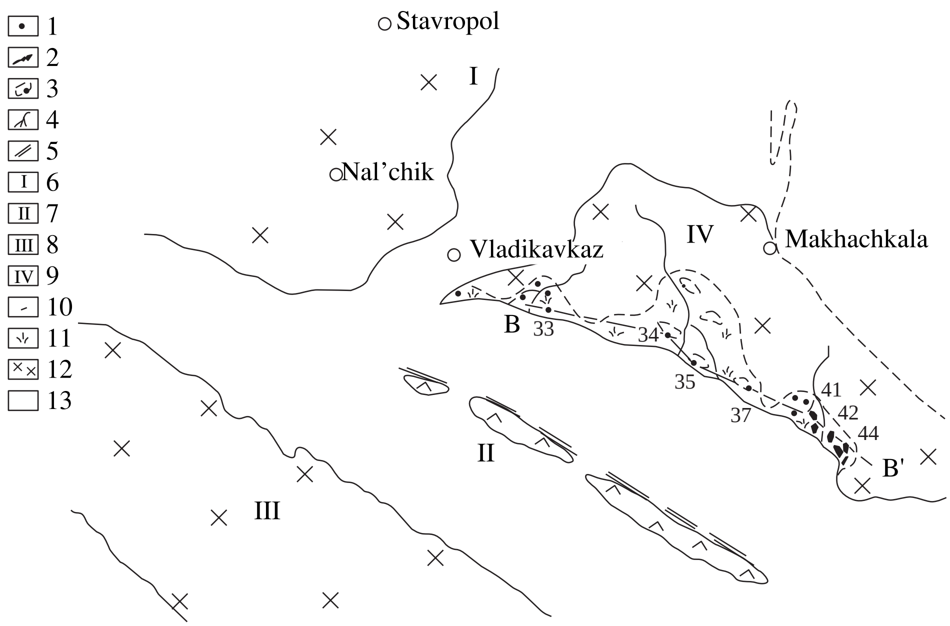

Fig. 8. Paleogeographic scheme of Middle Jurassic peat deposition in the southeastern part of the northern Caucasus. (1) Coal occurrence; (2) coal deposit; (3) prospective coaliferous areas; (4) paleostreams; (5) deep faults; (6) Stavropol Uplift; (7) uplifted central zone of the Greater Caucasus; (8) Transcaucasus Median Mass; (9) Daghestan Uplift; (10) profile B–B_1; (110 landscape zone of swamped coastal continental plains and partly isolated bays and lagooms; (12) passive uplifts (land); (13) epicontinental marine basin.

coaliferous district relative to the tectonically active region. Cycles-parageneses of alluvial–marine type testify that the peat bogs were largely formed in swamped (partly isolated) bays and lagoons. Subaerial deltas with thin peat units were locally formed in the Daghestan coaliferous district during short periods.

PALEOGEOGRAPHIC ENVIRONMENTS OF EARLY AND MIDDLE JURASSIC SEDIMENTATION AND PEAT DEPOSITION

Different landscapes (alluvial valleys, alluvial–deltaic plains, partly isolated bays and lagoons, and peat deposition zones) are recognized within the Early Jurassic coaliferous rock belt of the northern Caucasus that extends along the coast of the Jurassic epicontinental marine basin (Table 2). As follows from the lithofacies analysis, their distribution along the southern margin of the Stavropol Uplift was controlled by various factors.

Partly isolated bays and lagoons including the swamped (partly isolated) bays and lagoons existed in the Pliensbachian (Fig. 6) at the initial stage of coal deposition in the belt of Dakho, Barakaev, Beslineev, Kizilov, Shchedok, Laba, Akhmetov, Urup, Balka Nadezhnaya, and Tishinsk coal occurrences. Swamped coastal continental plains originated at the subsequent stages of this process.

Shoaling zones of shallow-water (partly isolated) bays and lagoons marked by the deposition of peat were readily filled with higher and lower plants. The lowest sites abounded in sphenopsid, lycopod, and small fern bushes. Bush and treelike cycad sphenopsids yielded the main mass of peat. Marine fossils are occasionally found in the underlying sediments. Plant material in peat bogs underwent a slow progressive decomposition. Being gradually overlapped by lacustrine and lacustrine–swamp sediments, the peat was subsequently retained in the hydrous medium. The peat units were also gradually overlain by terrigenous sediments due to the slow subsidence and flooding by seawater. The cyclic sections were formed under conditions of repeated subsidences and uplifts described above, indicating the formation of coaliferous sequences in shallow-water (coastal-marine and epicontinental marine) basins (Table 1).

The bush vegetation and abundant lower plants yielded the main material for peat formation in swamped coastal continental plains where the peat is saturated with water from rivers and floodplain lakes. Mainly thin coal seams and interlayers were formed under these conditions (Timofeev, 1998).

The landscape of estuarine alluvial–deltaic plains is typical of the Mukhara, Kuban–Malka, Podkumok coal deposits and the Uzhum, Marukha, and Ezi-Taukchi coal occurrences. Peat bogs were formed in swamped estuarine alluvial–deltaic plains with the predominance of terrigenous material supplied from the land. Marine sediments are generally lacking in such sections. Diverse sediments of subaerial deltas characterize an unstable dynamic setting at the continent–sea boundary.

Under favorable conditions, the subaerial deltas expanded toward the sea and formed vast alluvial–lacustrine plains with continental conditions of sedimentation and peat deposition. Coaliferous sequences of the Khasaut, Musht, Tyzyl, Bylym, Kerdyuk-Bylym, Chegem, and Farankol deposits were formed in such swamped alluvial–lacustrine plains.

As was mentioned above, coaliferous sediments of the Aksaut–Teberda, Kartzhut, and Ust'-Kal'tyube deposits were formed in river valleys, whereas peat deposits are typical of the swamped valleys. Such sedimentation conditions, promoted the pinchout of coal seams, their erosion, and overlapping by coarse-clastic rocks with lenticular bodies of redeposited charred wood.

The development of river valleys in the coastal zone is related to the existence of volcanic islands and peninsulas in the marine coast front near the Stavropol Uplift in the south. The appearance of islands and peninsulas in the southern Stavropol Uplift changed the direction of terrigenous material transport by paleorivers. Therefore, the terrigenous material was largely supplied into the epicontinental basin in the Early Jurassic from the northeast and the material from the southern area could not reach the land.

Peat bogs in swamped river valleys are characterized by a relatively stable water regime. The fast burial of plant remains prevented the decomposition and partial mechanical disintegration of plant tissue.

Semiisolated bays and lagoons existed in the Early Jurassic at the Gutiatikau coal occurrence southeast of the Farankol deposit. Peat was deposited on coastal continental plains (Fig. 6).

Paleogeography of the northern Caucasus was slightly changed in the early Aalenian when areas favorable for the peat deposition were displaced to the southeast (Fig. 8).

The coaliferous sediments of the Daghestan coaliferous district were formed in shallow-water (coastal-marine and epicontinental marine basin) zones at the Rubaschai and Chirakhchai coal deposits and numerous occurrences at the southwestern margin of the Daghestan Uplift.

Peat was deposited in swamped (partly isolated) bays and lagoons at the initial stage and in swamped coastal continental plains at the later stage.

Bathonian peat units were formed under similar landscape conditions in local areas of the southern Daghestan coaliferous district adjoining the Daghestan Uplift in the south.

CONCLUSIONS

Tectonic uplift of the northwestern part of the northern Caucasus in the early Pliensbachian resulted in the emergence of the Stavropol Uplift above the sea level and provided the growth of volcanic islands and peninsulas at its southern margin. Various paleogeographic environments of coaliferous sedimentation and peat formation were created along the southern margin of the Stavropol Uplift.

Swamped coastal continental plains and partly isolated bays and lagoons were formed in the Laba–Urup coaliferous area and in the southeastern Baksan coaliferous district situated in the distal zone the tectonically active central Caucasus.

Coaliferous sequences of the southern Kuban district were deposited in river valleys near the region of active tectonic movements in the central Caucasus. Peat bogs were confined to swamped river valleys.

In the western and northern Kuban coaliferous areas, peat was deposited in swamped estuarine alluvial–deltaic plains.

Landscapes of alluvial–lacustrine plains were typical of the northwestern and central Baksan coaliferous areas located at some distance from the tectonically active central Caucasus. Peat bogs existed in the landscape zone of alluvial–lacustrine plains.

Tectonic activity of the central Caucasus was shifted in the early Aalenian to the southeast. This promoted the uplift of territories adjoining the Daghestan Uplift in the south and southwest. The peat deposition area was situated at some distance from the tectonically active region. Therefore, coaliferous sequences of the Daghestan district were deposited on coastal continental plains and in partly isolated bays and lagoons. Peat was deposited on swamped coastal continental plains and in partly isolated bays and lagoons.

In the Bathonian, the Daghestan coaliferous district was also situated at some distance from the tectonically active zone of the central Caucasus. Therefore, the coaliferous area was characterized by the predominance of coastal continental plains, the partly swamped zones.

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