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Campanian-Maastrichtian Deposits in the Frontal Part of the Olyutor Zone (Southern Koryak Upland)

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Abstract—New dating of volcanogenic-siliceous oceanic (marginal-sea) deposits of the frontal Olyutor zone correlative with rocks of the Vatyna Group indicates that, in addition to Albian-Campanian, they include the younger Campanian-Maastrichtian horizons. The data allow us to contend that the oceanic and/or marginal-sea (Vatyna) and island-arc (Achaivayam) deposits, also dating back to the Campanian-Maastrichtian, were in lateral connections at that time. On the other hand, the analysis of new and published data shows that the Campanian-Maastrichtian island-arc deposits could probably overlap the pre-Campanian oceanic and/or marginal-sea sediments without any apparent disconformity.

INTRODUCTION

The frontal part of the Olyutor zone consists of the Cretaceous volcanogenic-siliceous-terrigenous complexes. Two principal stratigraphic units—the Vatyna Group and Achaivayam Formation—were recognized here by the late 1980s (Lipman, 1959; Zhamoida, 1972; Kazintsova, 1979; Alekseev, 1979). The study of volcanogenic rocks revealed two different genetic types of the Cretaceous deposits: those of oceanic and island-arc series (Bogdanov *et al.*, 1982; *Geologiya yuga...*, 1987; Chekhovich, 1993). In general, the Vatyna Group deposits were considered as similar to oceanic, whereas the Achaivayam Formation was classed with the island-arc one (Alekseev, 1979).

By the late 1980s, deposits of the Vatyna Group have been dated back to the Albian-Campanian, and island-arc deposits of the Achaivayam Formation to the Maastrichtian-Paleocene (Vishenvskaya, 1985; *Geologiya yuga...*, 1987). Data obtained recently indicate that, in addition to the Albian-Campanian, the Vatyna Group comprises younger deposits of the Campanian-Maastrichtian age (Palechek, 1997; Soloviev *et al.*, 1998), whereas the Achaivayam deposits likely accumulated in the Campanian (Palechek, 1997). This suggests some synchronism in the accumulation of oceanic (marginal-sea) and island-arc deposits, at least in the Campanian-Maastrichtian, as well as their lateral connections. Some researchers assume vertical relationships between units and assume that younger deposits of the Achaivayam Formation overlie with the older deposits of the Vatyna Group without an apparent disconformity (Astrakhantsev *et al.*, 1987; Kazimirov *et al.*, 1987; Shapiro, 1995). Our work aims to resolve this contradiction on the basis of new radiolarian dating of the Cretaceous deposits from the frontal part of the Olyutor zone. While simultaneously analyzing the published data on the age of Cretaceous deposits in the Olyutor zone, we took into account the available dating results for siliceous deposits associated with volcanic rocks of a known geochemical affinity, which allowed us to conceive this or that geodynamic environments of sedimentation.

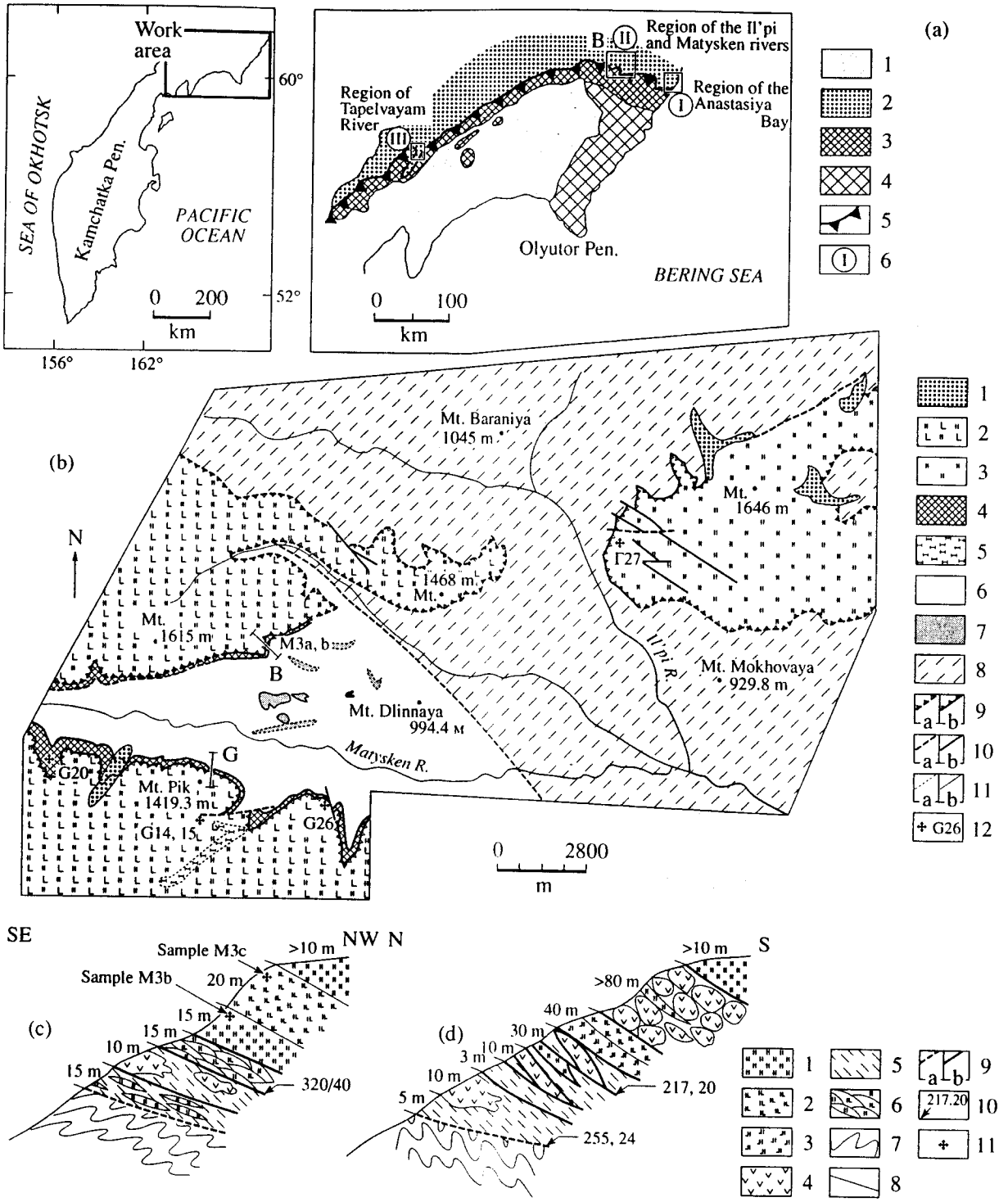
STRUCTURAL POSITION, COMPOSTION, AND AGE OF DEPOSITS IN THE FRONTAL PART OF THE OLYUTOR ZONE

The frontal part of the Olyutor zone extends along its northwestern boundary and is characterized by the imbricated nappe structure and a wide development of the Cretaceous deposits (Bogdanov *et al.*, 1982; Chekhovich, 1993) (Fig. 1a). The structure of the frontal part is defined by the Vatyna-Vyvenka regional thrust fault (Mitrofanov, 1977), more than 500 km long. Structural units strike here conformably with the Vatyna-Vyvenka thrust fault, along which the Olyutor zone deposits are thrust over the deposits of the Ukelayat trough.

The Cretaceous strata make up major subhorizontal slices (Chekhovich, 1993). We studied three regions within the frontal part of the Olyutor zone (Fig. 1a): the area of the Anastasiya Bay (the northern region I), the area of the upper courses of Il'pi and Matysken rivers (the northwestern region II) (Fig. 1b), and the area of the Tapelvayam River basin (the southwestern region III).

The northern region of the Anastasiya Bay. Allochthonous *volcanogenic-siliceous* and *volcanosedimentary* rocks of the northern Olyutor zone occur here in tectonostratigraphic successions consisting of imbricated tectonic slices of different ages (Palechek, 1997; Soloviev *et al.*, 1998).

Volcanogenic-siliceous deposits are exposed at the base of the allochthonous complex being represented



by basaltic pillow lavas, hyaloclastites, jasper with *Inoceramus* fragments, cherts, and aleuropelites. The late Turonian-early Campanian, Coniacian-middle Campanian, and Campanian-Maastrichtian radiolarian assemblages are macerated from siliceous rocks of various slices (Palechek, 1997; Soloviev *et al.*, 1998). Basalts of the volcanogenic-siliceous sequence are medium differentiated rocks (MgO/FeO_{tot} = 0.34–0.76). Judging from the content of TiO_2 (0.83–2.03%), Zr (76–160 ppm), and Y (30–47 ppm), basalts are similar to tholeiites of mid-oceanic ridges (MORB) and marginal seas (Hawkins, 1976; Sun *et al.*, 1979). Basalts show the moderate fractionation of LREE relative to HREE [$(La/Yb)_N$ ratios vary from 2.8 to 3.7] that, along with the behavior of major and other trace elements, allow us to class them with the E-type basalts of marginal sea basins (*Petrologiya i geokhimiya...*, 1987).

Fig. 1a. Distribution of Cretaceous deposits in the Olyutor zone (the study area is shown in the inset map: (1) Cenozoic deposits; (2) Cretaceous-Paleogene deposits of the Ukelayat zone; (3–4) the Cretaceous deposits of the frontal Olyutor zone (3) and the of the Olyutor Range region (4); (5) the Vatyna-Vyvenka thrust fault; (6) studied exposures

Fig 1b. Regional geologic scheme of the of Il'pi and Matysken rivers (compiled in collaboration with M.T. Brandon and G.I. Garver using materials by A.V. Ditmar, K.S. Ageev, A.S. Finogentov, and E.S. Alekseev): (1) Quaternary unconsolidated deposits; (2) aphyric pillow lavas of basaltic composition, cherts, and jaspers; (3) cherts and jaspers; (4) the Vatyna-Vyvenka thrust-fault zone; (5) blocks of dunites, wehrlites, and clinopyroxenites; (6) the tectonic melange zone; (7) basaltic blocks; (8) the Ukelayat flyschoid deposits; (9) thrust faults proved (a) and deciphered in aerial photographs (b); (10) steeply dipping faults proved (a) and hypothetical(b); (11) contacts proved (a) and hypothetical (b); (12) localities and numbers of samples with microfauna.

Figs. 1c–d. Fragments of tectonostratigraphic successions exposed at the left (C) and right (D) slopes of Matysken River: (1) green cherts; (2) black cherts; (3) red-brown jasper; (4) basaltic pillow lavas; (5) cataclastic aleuropelites; (6) siliceous rocks with boudinage; (7) the Ukelayat flyschoid deposits; (8) stratigraphic contacts; (9) tectonic contacts proved (a) and hypothetical (b); (10) bed attitude; (11) localities and number of samples with microfauna.

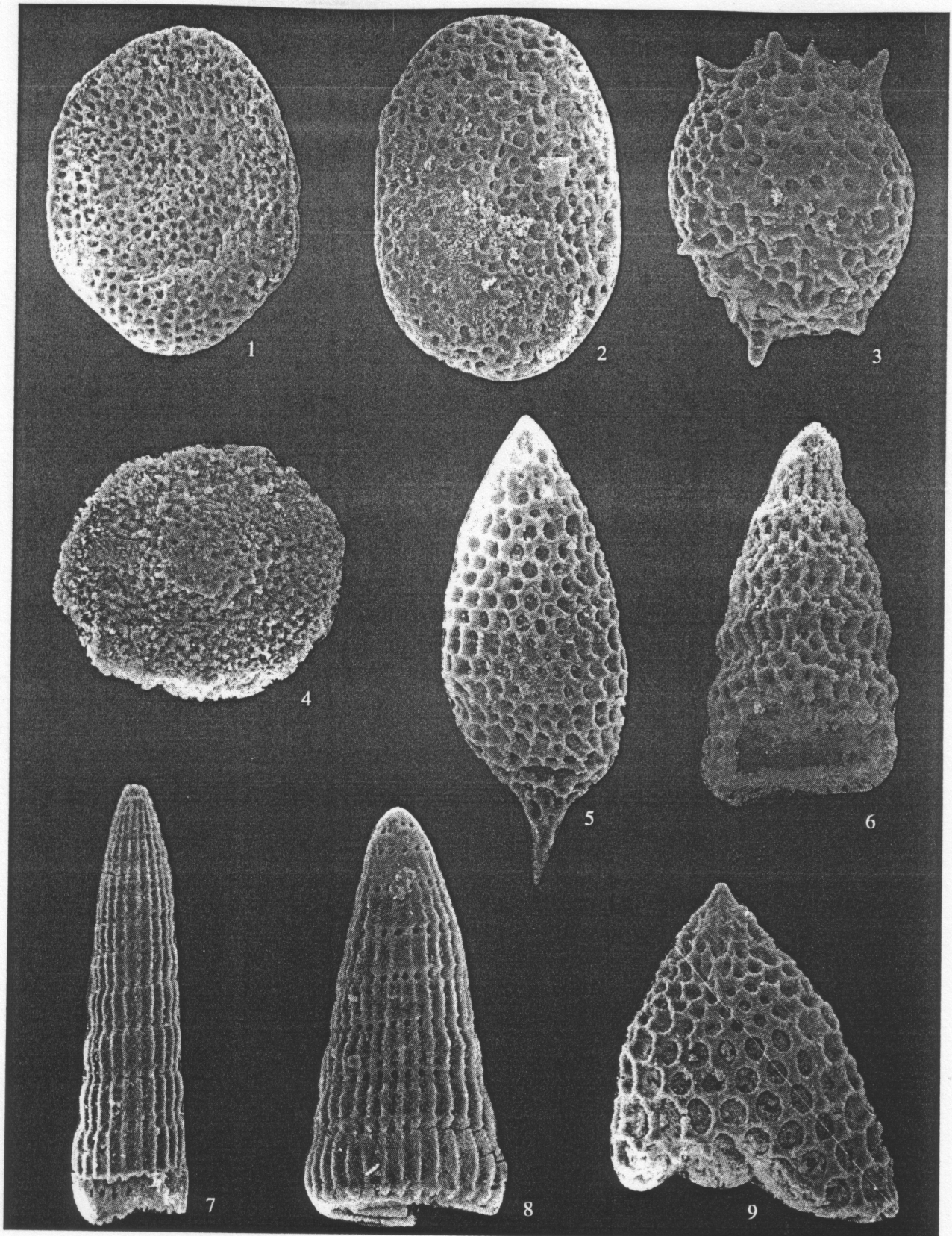
Volcanosedimentary deposits are widespread within the area of Anastasiya Bay. According to our results, basalts are subdivided, with a fair degree of convention, into three sequences: (1) *volcanogenic (lower)*; (2) *volcanogenic-terrigenous (middle or "transitional")*; and (3) *siliceous-terrigenous (upper)*. The lower volcanogenic sequence includes clinopyroxene-phyric amygdaloidal basalts, lava breccia of basaltic composition; lava clastics in a graywacke matrix and lenses of basaltic andesites are rare. The volcanosedimentary sequence overlaps with tectonic contact the volcanogenic-siliceous deposits described above. *The volcanogenic-terrigenous* sequence ("transitional", middle) is characteristic of isolated allochthonous slices. It includes graywacke sandstone beds, monomictic basaltic breccias, basalts, lava breccias, and siliceous rocks with the admixture of terrigenous material. *The siliceous-terrigenous sequence* (upper) is represented by graywacke sandstones, aleuropelites, cherty siltstones, green and black cherts. The sequence overlies deposits of the volcanogenic sequence. Radiolarian assemblages from cherts of the siliceous-terrigenous sequence indicate that volcanosedimentary deposits of the Anastasiya Bay area comprise the Campanian-Maastrichtian horizons (Palechek, 1997; Soloviev *et al.*, 1998). Basalts and lava breccias from volcanosedimentary deposits vary considerably in composition: TiO_2 (0.56–1.16%), Zr (8–82 ppm), Y (4–32 ppm), and MgO/FeO_{tot} = 1.03–1.64. By geochemical parameters, these occupy an intermediate position between typical tholeiitic and calc-alkali series. Basalts exhibit a higher fractionation of LREE relative to HREE [$(La/Yb)_N$ = 3.2–7.7] that is typical of the island-arc rocks. By geochemical characteristics, the basalts are correlative with those calc-alkali series moderately rich in potassium (*Petrologiya i geokhimiya...*, 1987; Frolova *et al.*, 1989).

The northwestern region (upper courses of the Il'pi and Matysken rivers). Several structural elements are distinguished in the upper courses of the Il'pi and Matysken rivers (Fig. 1b; (from the base upward): (1) *autochthon* of flyschoid deposits of the Ukelayat trough; (2) the tectonic melange zone; (3) the Vatyna-Vyvenka thrust fault; and (4) *allochthon* of volcanogenic-siliceous deposits of the Olyutor zone. A similar structure is characteristic of the northern part of the Olyutor zone (Astrakhantsev *et al.*, 1987).

The tectonic melange zone is chaotic in structure. The primary nature of the sequence is undeterminable here, because the rocks are subjected to intense tectonization; it likely was an olistostrome originally. The matrix is composed of black aleuropelites with rare and thin interlayers of fine-grained sandstone. Blocks are represented by phyric and aphyric basalts, lava breccias, and basaltic hyaloclastites, all rarely intercalated with black and green cherts. In the northern slope of Matysken river valley, there are exposed blocks of magmatic rocks: porphyroid melanocratic gabbro, leucocratic gabbro-diorite, and rare ankaramite-like gabbro. Chilled contacts of basaltic flow crosscutting the terrigenous flyschoid rocks of the Ukelayat trough are described at the foot of Mt. Dlinnaya. Near the contact zone, siltstones are transformed into black hornfels, and magnophyric basalts become microphyric to aphyric in the quenching zone. The sequence is of an imbricated structure. Further south, a similar rock sequence of analogous structure was regarded as an olistostrome, whose age was determined on the basis of such benthonic foraminifers as Maastrichtian (Mitrofanov and Sheludchenko, 1981).

The Vatyna-Vyvenka thrust fault zone (from 50 to 150 m thick) is characterized by imbricated structure. Tectonic slices of the zone are composed of rocks of the Olyutor zone and of deposits of the Ukelayat trough. The zone is especially distinct in slopes of the Matysken River valley (Fig. 1b). The slices bordered by subhorizontal thrust-fault planes consist of black and green siliceous rocks displaying boudinage, aphyric basalts, lava breccias, black cataclastic aleuropelites, and more rare sandstone beds. The slices vary in size from a few to dozens of meters.

Volcanogenic-siliceous deposits occupying the highest hypsometric level and often constituting the isolated tectonic slices are represented by basaltic pillow lavas, lava breccias, basaltic hyaloclastites, and siliceous rocks. In the studied region, the latter are diverse and represented by red jasper beds enclosing interlayers with broken *Inoceramus* shells and intercalated with massive black, green and gray cherts. Volcanogenic-siliceous rocks are highly disintegrated, and it is



Radiolarians from volcanogenic-siliceous deposits in upper courses of the Il'pi and Matysken rivers: (1) *Phaseliforma carinata* Pessagno, ×300, Sample G26; (2) *Phaseliforma laxa* Pessagno, ×200, Sample G26; (3) *Lithomespilus mendosa* (Krasheninnikov), ×300, Sample G26; (4) *Pseudoaulophacus* cf. *lenticulatus* (White), ×200, Sample M3/v; (5) *Stichomitra livermorensis* (Campbell & Clark), ×250, Sample G26; (6) *Wildeus punctulatus* (Pessagno), ×300, Sample G14; (7) *Dictyomitra andersoni* (Campbell & Clark), ×200, Sample G26; (8) *Dictyomitra densicostata* Pessagno, ×300, Sample G26; (9) *Clathrocyclas* cf. *hyronia* Foreman, ×200, Sample G26.

Radiolarians from the frontal part of the Olyutor zone

Species	Region of the Anastasiya Bay (Soloviev *et al.*, 1998)			Upper courses of the Il'pi and Matysken rivers			Region of the Tapelvayam River		
	Sample number								
	4	29	A12	M3/v	G26	G27	3T	17T	18T
Phaseliforma carinata Pessagno	*	*	*	*	*				
P. subcarinata Pessagno		*							
P. cf. *laxa* Pessagno					*				
P. cf. *meganosensis* Pessagno		*							
Phaseliforma sp.						*	*		
Orbiculiforma sp.	*			*			*	*	*
Praestylosphaera pusilla (Camp. & Clark)	*	*	*						
P. hastata (Camp. & Clark)		*	*	*					
Praestylosphaera sp.						*			
Lithomespilus mendosa (Krasheninnikov)			*	*	*	*			
Pseudoaulophacus cf. *lenticulatus* (White)							*		*
Pseudoaulophacus sp.				*				*	
Alievium sp.	*								
Prunobrachium sp.									*
Spongurus sp.				*					
Archaeospongoprunum sp.	*							*	
Actinomma sp.	*								
Stichomitra livermorensis (Camp. & Clark)	*	*	*		*		*		
S. cf. *shirshovica* Vishnevskaya		*							
Stichomitra sp.						*			*
Cornutella california Camp. & Clark	*		*				*		*
Amphipyndax stocki (Camp. & Clark)	*	*	*	*	*		*	*	*
A. stocki var. B Vishnevskaya		*							
A. streckta Empson–Morin	*	*	*						
Theocampe? sp.							*	*	
Bathropyramis sp.	*								
Archaeodictyomitra regina (Camp. & Cl.)		*			*				
Dictyomitra andersoni (Camp. & Cl.)					*				
D. densicostata Pessagno	*	*	*		*	*			
D. multicostata Zittel	*		*	*	*				
Dictyomitra sp.								*	
Clathrocyclas hyronia Foreman	*	*	*	*	*				
C. tintinnaeformis Camp. & Clark		*							
Clathrocyclas sp.						*			
Xitus cf. *asymbatos* (Foreman)	*								
Xitus sp.			*						

* Species presence in samples.

impossible to restore the original sequence of their thin and isolated slices (Figs. 1b, c, d). Different horizons of volcanogenic-siliceous deposits occur over the thrust fault zone, for instance, basaltic lavas with chert lenses in the southern and northern slopes of the Matysken River valley and siliceous rock further to the north and east (Fig. 1b).

Radiolarians of different preservation degree were extracted from siliceous rocks of the volcanogenic-sili-

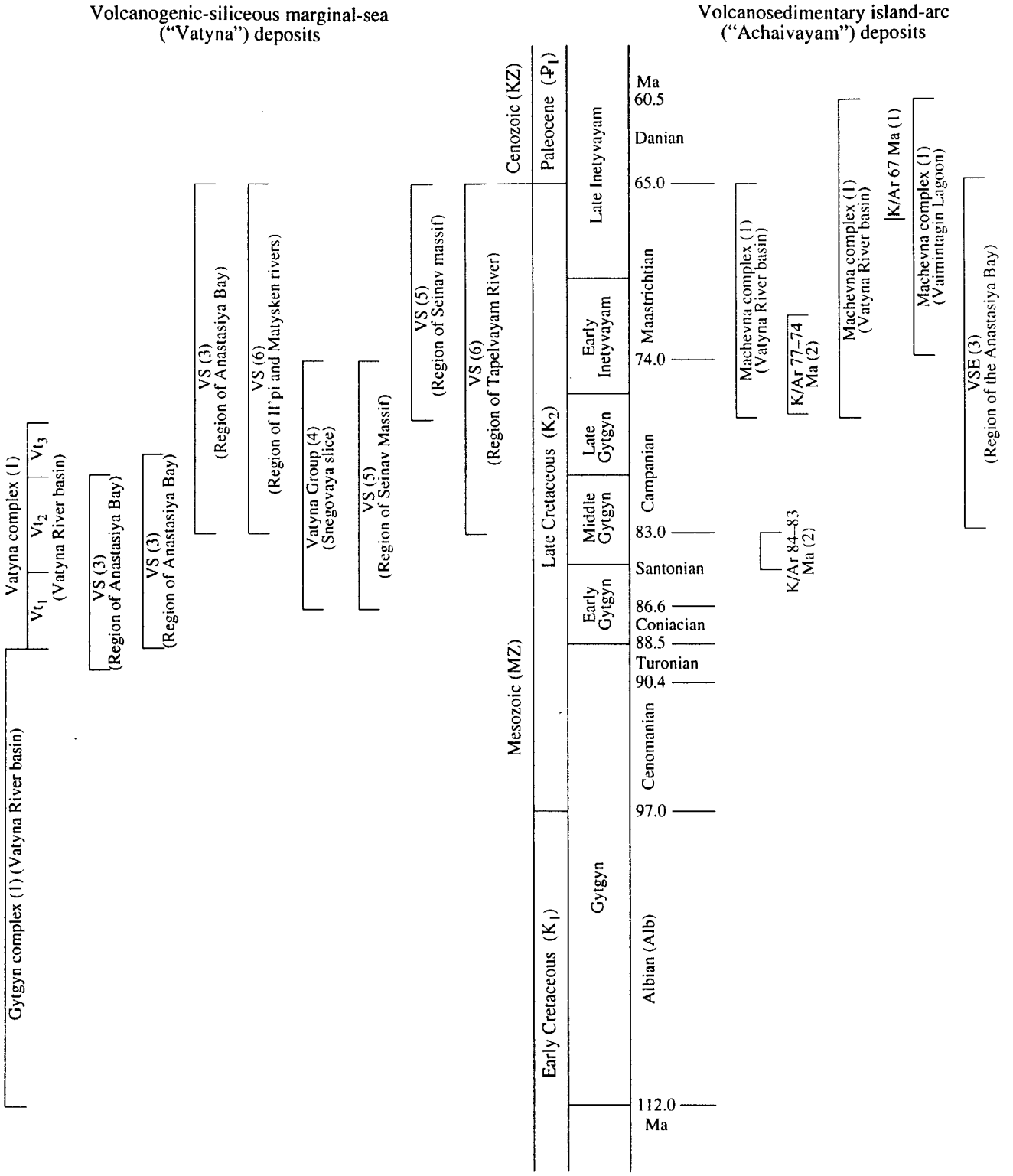


Fig. 2. Correlation scheme of volcanogenic-siliceous marginal-sea ("Vatyna") and volcanosedimentary island-arc ("Achaivayam") deposits. The geochronological scale is calibrated on the basis of radiolarian assemblages identified the Olyutor zone (Vishnevskaya, 1985). Shown in the scheme are time ranges of tectonic slices, where siliceous deposits associate with volcanic rocks of the marginal-sea (on the left) or island-arc (on the right) types: (VS) volcanogenic-siliceous and (VSE) volcanosedimentary sequences (Palechek, 1997, and this work). K/Ar dates are shown for basaltic rocks of the Vatyna River basin. Numbers in parentheses indicate data sources: (1) *Geologiya yuga...*, 1987; (2) Alekseev, 1979; (3) Soloviev *et al.*, 1998; (4) Astrakhantsev *et al.*, 1987; (5) Kravchenko-Berezhnoy *et al.*, 1993; (6) this work.

ceous slices and also from the Vatyna-Vyvenka thrust-fault zone. Radiolarian assemblages are of a low taxonomic diversity and abundance (see the plate and table). Eight radiolarian taxa have been identified in a very representative sample (G26) as being represented by a few dozen specimens. Their assemblage (G26) includes *Phaseliforma carinata* Pessagno, *Ph. laxa* Pessagno, *Lithomespilus mendosa* (Krasheninnikov), *Stichomitra livermorensis* (Campbell & Clark), *Archaeodictyomitra regina* (Campbell & Clark), *Dictyomitra andersoni* (Campbell & Clark), *D. densicostata* Pessagno, *D. multicostata* Zittel, and *Clathrocyclas* cf. *hyronia* Foreman (table and plate). The assemblage suggests that volcanogenic-siliceous deposits in the upper courses of the Il'pi and Matysken rivers comprise the late Campanian-Maastrichtian horizons. We should point to the distinct deformation of some radiolarian skeletons in the assemblage (G26) from the thrust-fault zone. This is most typical of *Phaseliforma carinata* Pessagno and less characteristic of nasselarians *Archaeodictyomitra regina* (Campbell & Clark). The radiolarian assemblage is similar in taxonomic composition, but less diverse than the coeval assemblage from the Anastasiya Bay region (Palechek, 1997; Soloviev *et al.*, 1998). Another radiolarian assemblage of the Campanian and, probably, early Maastrichtian age was identified earlier by Kazintsova (1979) in thin sections of siliceous rocks from the Il'pi River basin. In some features, it is less similar to our assemblage than the late Vatyna radiolarians (Vishnevskaya, 1985) .

The volcanosedimentary deposits characteristic of the Anastasiya Bay region are not found in the region under discussion. These deposits have likely been eroded.

The southwestern region (the Tapelvayam River basin). A large tectonic outlier of the Olyutor zone deposits (Mitrofanov, 1977) is surrounded here by flyschoid deposits of the Late Cretaceous-Paleogene Ukelayat zone representing the autochthon. The paraautochthon is composed of the Maastrichtian "olistostrome" sequence (Mitrofanov and Sheludchenko, 1981). The outlier represents a packet of allochthonous slices of different deposits (Astrakhantsev *et al.*, 1991; Kravchenko-Berezhnoy *et al.*, 1993). The lower slice is composed of volcanogenic-siliceous rocks of the Vatyna Group of the Santonian-Campanian (Astrakhantsev *et al.*, 1991) or Campanian-Maastrichtian age (Kravchenko-Berezhnoy *et al.*, 1993). The middle slice is represented by tuffaceous-siliceous deposits of the Maastrichtian-Paleocene Achaivayam Formation. The upper slice is made up of ultramafic and gabbroid rocks of the Seinav, Galmoenan and Imlan massifs.

We studied *the volcanogenic-siliceous deposits* in the upper courses of the Oginravayam River, where they are thrust over the Ukelayat flysch. Their sequence includes basaltic pillow lavas, hyaloclastites, basic lava breccias, siliceous rocks, and cherty aleuropelites. The radiolarian assemblage of low taxonomic diversity and of a medium preservation degree was detected in siliceous rocks (see table). The assemblage consists of *Stichomitra* cf. *livermorensis* (Campbell & Clark), *Cornutella* cf. *californica* Campbell & Clark, *Ampipyndax stocki* (Campbell & Clark), and *Pseudoaulophacus* cf. *lenticulatus* (White). It suggests the Campanian-Maastrichtian age of enclosing deposits. Radiolarian assemblages similar in taxonomic composition were identified earlier by Vishnevskaya in siliceous deposits of the Seinav Mountain area in the southwestern region (Kravchenko-Berezhnoy *et al.*, 1993).

DISCUSSION

(1) In general, the Campanian-Maastrichtian radiolarian assemblages from volcanogenic-siliceous deposits of different areas of the frontal part of the Olyutor zone are similar in their taxonomic composition and correlate well with one another (table). The studied assemblages are comparable to the late Vatyna and early Inetyvayam radiolarian faunas (Vishnevskaya, 1985). They are also correlative with the radiolarian assemblages from the Upper Cretaceous deposits of California (Campbell and Clark, 1944; Pessagno, 1976), DSDP Site 275 (Pessagno, 1975), and New Zealand (Hollis, 1997).

(2) Volcanogenic-siliceous deposits in all studied areas of the frontal part of the Olyutor zone are similar in the composition and structural position. Along with older beds, they include the Campanian-Maastrichtian horizons, and this allows their correlation within the time interval in question. The rocks are also comparable in composition to oceanic and/or marginal-sea deposits of the "Vatyna Group" (Bogdanov *et al.*, 1982; *Geologiya yuga...*, 1987; Chekhovich, 1993), the formation of which could have lasted correspondingly until the latest Cretaceous. Volcanosedimentary deposits of the northern Anastasiya Bay region comprise the Campanian-Maastrichtian horizons as well (Palechek, 1997; Soloviev *et al.*, 1998), and they are correlative in composition with island-arc deposits of the "Achaivayam Formation" (Chekhovich, 1993) which thus accumulated their beginning from the Campanian.

(3) The correlation scheme for the Cretaceous oceanic (marginal-sea) and island-arc deposits of the Olyutor zone (Fig. 2) is compiled on the basis of new age determinations and published data. The scheme suggests some important consequences. Obviously, the Campanian-Maastrichtian island-arc deposits overlie, most likely without any apparent disconformity, the pre-Campanian oceanic and/or marginal-sea sequences, as it has been reported in a series of publications. Such a situation is likely when an island arc develops on the oceanic crust basement (Astrakhantsev *et al.*, 1987; Kazimirov *et al.*, 1987). On the other hand, simultaneous formation of island-arc and oceanic (marginal-sea) deposits during the Campanian-Maastrichtian (Fig. 2) allows us to suspect the primary lateral connections between them and to interpret their con-

tacts in the modern structure as a result of the later tectonic imbrication.

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