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Radiolaria fossils in the surface sediments and sedimentary environment in the Bering Sea

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Abstract Totally 2472 grains of Radiolaria belonging to 36 Genera and 45 species are distinguished from 12 surface sediments in the Bering Sea. The distribution characteristics of Radiolaria fossils in the surface sediments are as follows: (1) From the shelf of shallow water to the upper of continental slope, there are a few Radiolaria fossils and monotonous genus and species; (2) In the lower of continental slope, Radiolaria fossils are poor in the volcanic cinders and turbidite; (3) The abundance and diversity of Radiolaria fossils are high in clay of the basin. The dominant species of Radiolaria is *Spongotrochus glacialis* on the continental shelf. Current, topography, water depth, and temperature etc. are key factors influencing Radiolaria distribution. The sources of sediments mainly are terrigenous, biogenic and volcanic sediments in the survey area and they are mostly from the Kamchatka peninsula in the east of Russia and the Aleutian Islands.

Key words Bering Sea, Radiolaria fossils, sources of sediments.

1 Introduction

From July to September 1999, China made a scientific expedition for the Arctic Ocean and the Bering Sea by R. /V. "Xuelong" under leadership of the Chinese government. Before this cruise, some scientific institutes once cooperated with overseas in different way. Chinese scientists started to study climatic and environmental change in Barrow of Alaska in 1994, and joined the BESIS Plan by IASC in 1996 (Li and Zhang 1996). These works provided good bases to study the Arctic Ocean and the Bering Sea.

The Bering Sea is a marginal sea of the North Pacific Ocean. It is located between the Kamchatka Peninsula of Russia and the Alaska of USA, and it connects with the Chugach Sea of Arctic Ocean through the Bering Strait. The Bering Sea is 230.4 km^2 wide and 1598 m deep on the average with the most depth 4191 m in the southeast; and the salinity of seawater ranges from 28 to 33. Totally 11 surface sediments were obtained in 3 Profiles with only one in the Bering Basin. The surface sediments were dredged mainly by a small newly-produced box-like Sampler in the expedition and occasionally by a multi-barrel corer in stations with especially deep water. All obtained samples were described and analyzed in the field, some of which were taken photos.

2 Distribution characteristics of Radiolaria (genus and species)

Station, depth, sediment characteristic, and Radiolaria abundance of surface samples are illustrated in Fig. 1 and Table 1.

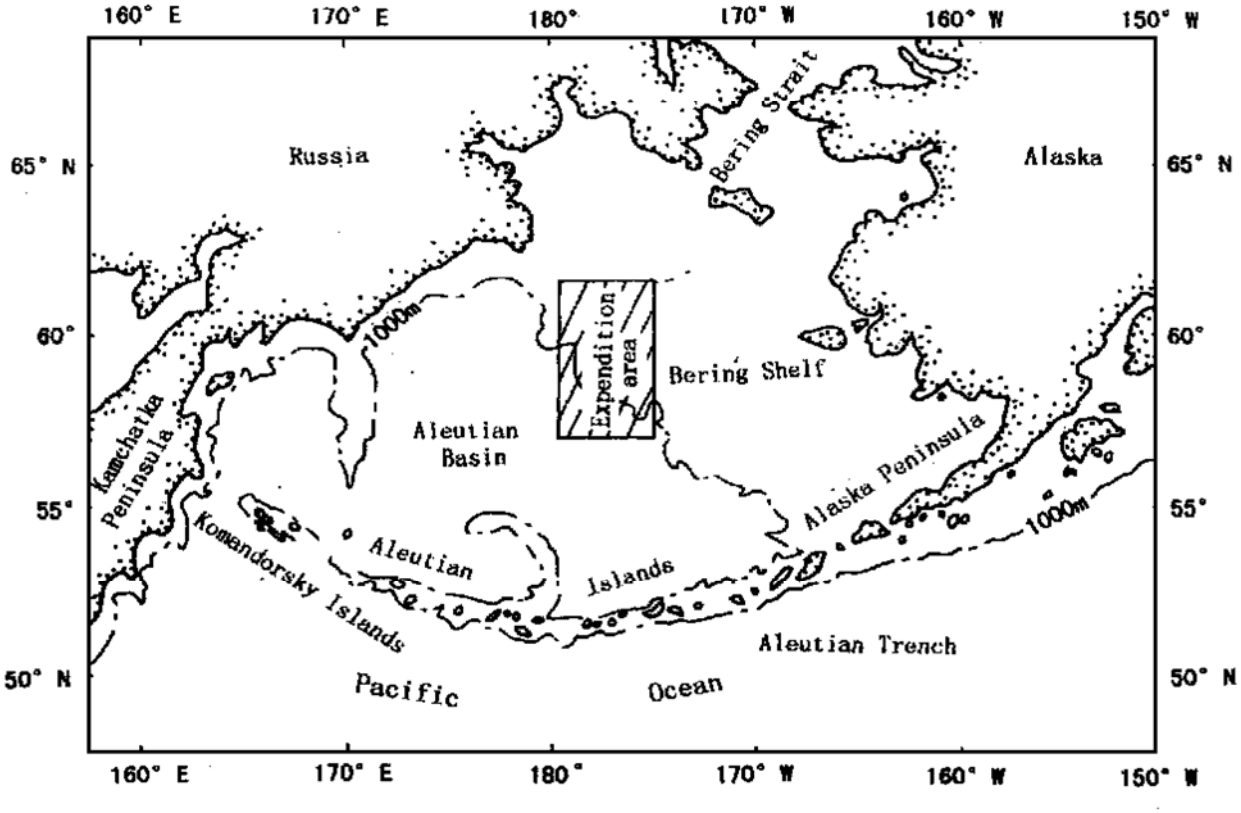

Fig. 1. Map showing the location of the study area.

Table 1. Station, depth, sediment characteristics and Radiolaria abundance of surface sediments in the Bering Sea

Station	Location		Depth /m	Sediments	Radiolaria abundance	Remark
	Latitude	Longitude				
B1–13	60°55′04″N	177°05′44″W	140	Silty mud	F	
B1–12	60°39′51″N	178°18′34″W	165	Muddy silty	C	
B1–11	61°31′40″N	178°44′09″W	235	Muddy silty	M	
B1–10	60°24′59″N	179°03′52″W	516	Fine sand	F	
B1–9	60°15′42″N	179°25′44″W	840	Silty sand	C	
B2–3	57°38′01″N	179°21′22″W	3850	Silty clay	Z	F: < 15/g
B2–9	59°17′32″N	178°41′50″W	2200	Muddy silty	M	C: (15 – 30)/g
B2–10	59°29′00″N	178°27′00″W	420	Muddy silty	M	M: (30– 50)/g
B2–11	59°33′08″N	178°10′50″W	180	Muddy silty	M	A: > 50/g
B2–12	59°42′57″N	177°50′45″W	162	Muddy silty	M	
B5–7	58°26′35″N	176°09′37″W	2440	Silt	M	
B5–9	58°34′13″N	175°58′56″W	180	Fine sand	C	
B5–10	58°39′55″N	175°33′29″W	139	Fine sand	M	

It is easy to find that depth in the expedition area changes from one hundred to thousands of meters in Table 1. The stations are located from continental shelf in the west to continental slope in the east except for station B2–3 in the Bering Basin. The sediments have different types and different Radiolaria numbers with changes in depth and topography.

2.1 *Characteristics of main Radiolaria* (*genus and species*)

Totally 2472 grains of Radiolaria belonging to 36 genus and 45 species are identified in the surface sediments.

It can be seen that Spumallaria is principal species in this area based on results of analysis of Radiolaria fossils in surface sediments; the number of Spumallaria amounts to 97% and Nassallaria only 3% in total. In the other hand, genus and species of Radiolaria are monotonous with low diversity from the shallow continental shelf to the upper of continental slope, for example, *Spongotrochus glacialis* amounts to 76.92% and 76.47% at the stations B1 – B11 and B5 – B9 with diversity (S) of only 1. In the lower of the continental slope and in the basin, Radiolaria have many genera and species or even more than 40 species, and diversity amounts to 3. The abundance of Radiolaria in the surface sediments is shown in Fig. 2, and dominant species of Radiolaria in three profiles are listed in Table 2.

Table 2. Dominant species of Radiolaria fossils in three profiles

Section	Station	Dominant genus
I	B1–13, B1–12, B1–11	*Spongotrochus glacialis* *Thecosphaera grecai*
II	B2–12, B2–11, B2–10	*Spongotrochus glacialis* *Stylodictya* sp. Spongophacus flos
III	*B5–11, B5–9*	Spongotrochus glacialis Streblacantha circumtexta Thecosphaera grecoi

The previous studies showed that *Spongotrochus glacialis* was also an important species in the shallow and intermediate waters in the Weddell Sea in the Antarctic Pole, enrichment of *spongotrochus glacialis* in sediments indicated an environment with shallow water (Joseph and Jeanne 1985). So, it is clear that ecological characteristics of microorganisms in high latitudes of Antarctic and Arctic are similar. The analyzed Radiolaria in surface sediments except for that in the Bering Basin is less in number and lower in diversity (S) than that in the Northeast Pacific Ocean and in the center of Pacific Ocean. A main reason leading to this difference is due to fewer Radiolaria in water.

2.2 *Influence of topography, depth, water temperature on distribution of Radiolaria*

Continental shelf is narrow in the west and in the southwest of the study area. The difference in the distribution of Radiolaria is that due to change of topography and water

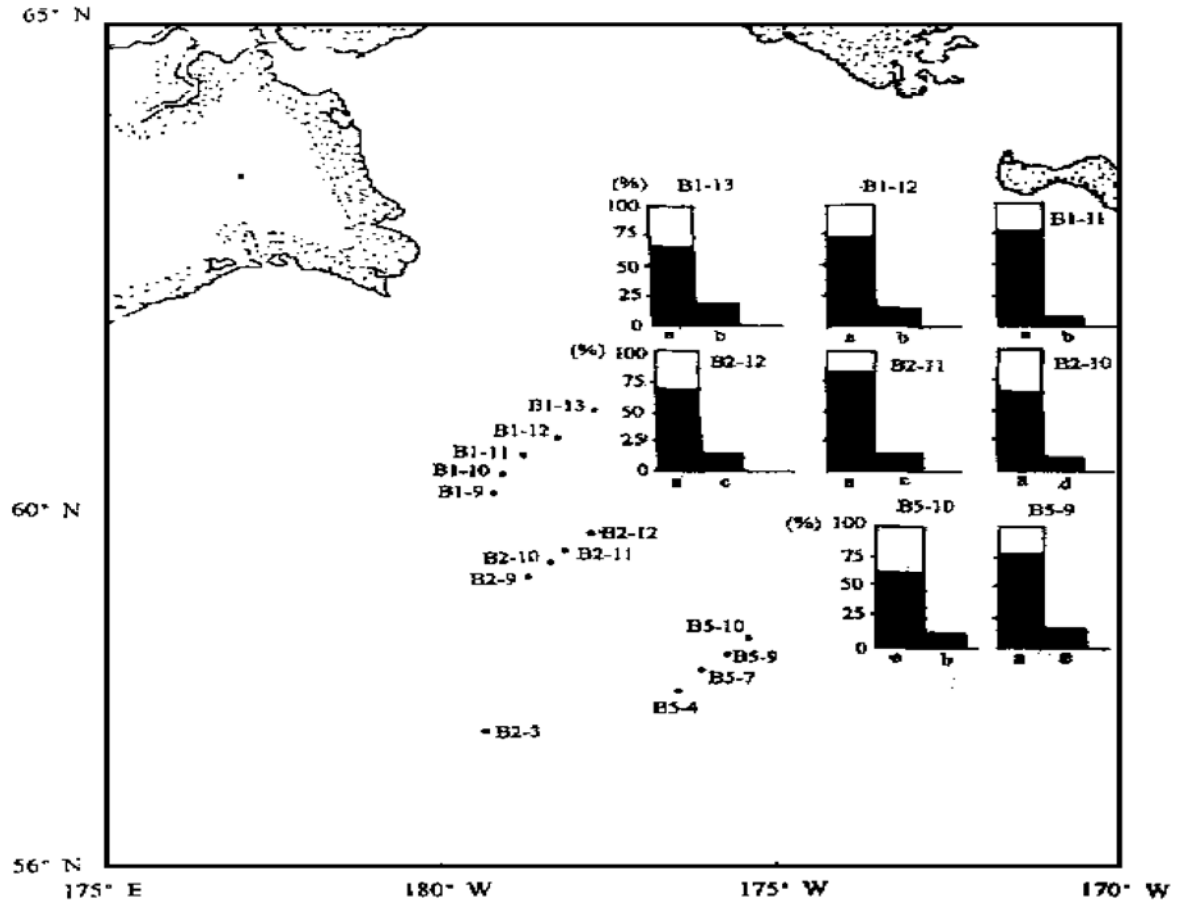

Fig. 2. Percentage of main Radiolaria in the surface sediments. (a) *Spongotrochus glacialis*; (b) *Thecosphaera grecoi*; (c) *Stylodictya* sp.; (d) *Spongophacus flos*; (e) *Streblacantha circumtexta*.

depth from the continental shelf to the slope, and eventually to the basin. On the continental shelf and on the slope, Radiolaria isopleth over 30 n/g almost coincides with 1000 m isobath; while isopleth below 30 n/g is distributed along isobath of 500 m.

Additionally, influence of temperature is also an important factor. It was reported that the near-shore area of the Bering Sea was controlled by polar climate and has average temperature below 10℃; but, sea ice almost covered the whole Bering Sea in winter except for near Kamandorsky and Aleutian Islands and in the Bering Basin (Stabeno and Reed 1994). Because of intrusion of sea ice, the surface temperature further dropped and became unfavorable to existence of Radiolaria that like to live in the water of high temperature and high salinity; So, it is possibly an important factor for which the Radiolaria are lacking in the shallow water area. The near-shore areas are not favorable to the living and breeding of Radiolaria due to the change of salinity caused by fresh water discharge.

2.3 Distribution characteristics of Radiolaria in different surface sediments

It is shown that distribution of Radiolaria fossils has a close relationship with sediment types in the study area. The sediments in the area may be generally divided into 3 types as follows: one is fine sand and silt, and mainly distributed on the shallow water shelf and sometimes on the continental slope where depositional environment is not stable and organic substance, benthic organism and microorganism Radiolaria deplete in

sediments. Secondly, the ooze area with deep water, it has stable sedimentary environment, sediments are composed dominantly of clay or ooze with high abundance of Radiolaria. The number of Radiolaria (n/g dry) is from 100 to several hundred grains. Thirdly, the bedrock area (e.g. B5 – B7) on the continental slope of the Bering Sea, it is covered with pyroclast and turbidite sediments except the exposed bedrock (Lisitzin 1969); the Radiolaria in these sediments are low in diversity and few in abundance.

3 The general situation of current and water mass

The main surficial currents in the Bering Sea and in the Aleutian Trough are illustrated in Fig. 3 (after Arsenev 1967; Lisitzin 1969; Takenouti and Ohtani 1974, Kinder *et al.* 1975; Okkonen 1993). It is well known that migration of living Radiolaria depends on entrain of currents; so, the direction and strength of current directly influences distribution pattern of Radiolaria. The circulation pattern of surface currents in the Bering Sea is a cyclonic gyre with a boundary current (the East Kamchatka Current) at the western margin of the basin. The distribution of Radiolaria is mainly controlled by the western boundary current (the East Kamchatka) on the continental shelf in the west which has slow flow velocity (< 2 cm/s) and low temperature and low salinity. This condition is not favorable for life and migration of Radiolaria, and may be taken as another main reason for the lacking of Radiolaria in the sediments. The genus and species of Radiolaria as well as their combination characteristics in sediments in the Bering basin are similar to those in the North Pacific Ocean. So, it is clear that ecological environment and sedimentary condition of the Radiolaria in the Bering basin has the same characteristics as that in the North Pacific Ocean.

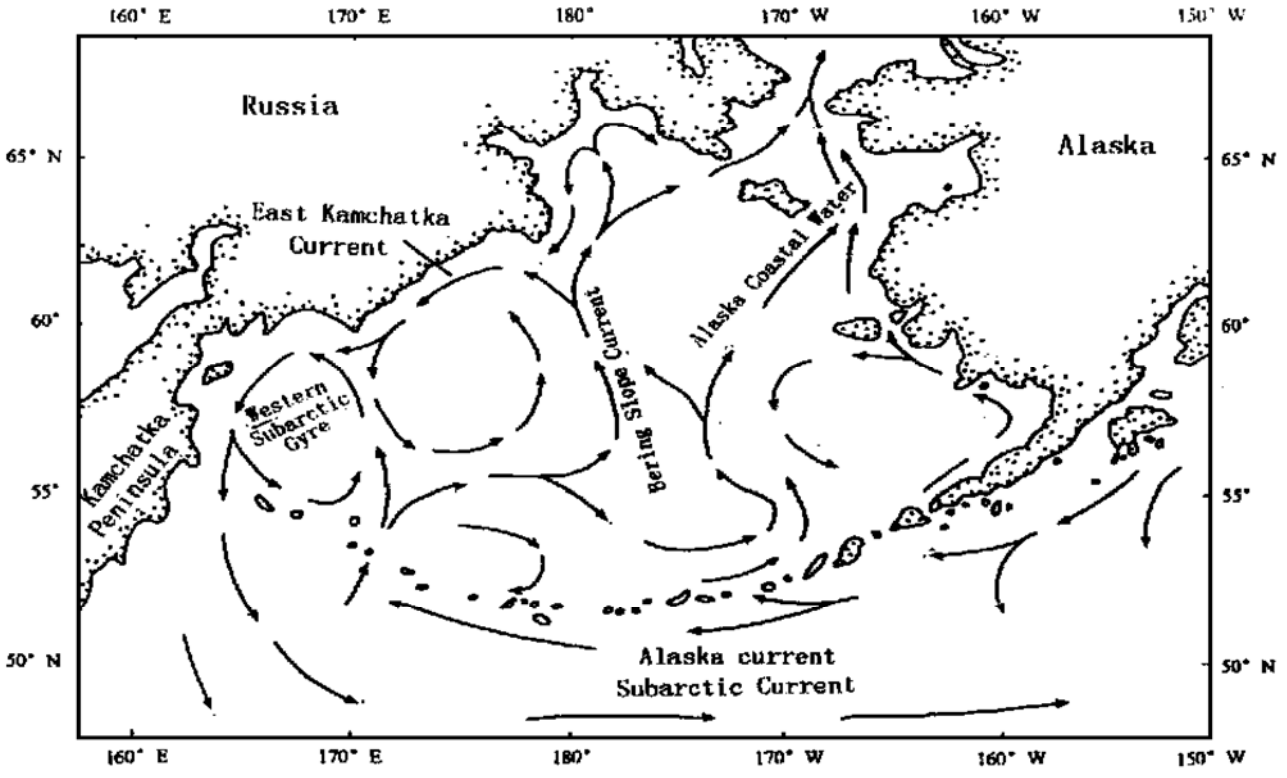

Fig. 3. The currents in the Bering Sea (after Naidu *et al.* 1995).

4 The sedimentary composition and characteristics in sediments of the expedition area

The sources of sediments in the Bering Sea are various including weathered products from the Kamchatka Peninsula, the terrigenous materials from the Alaska Peninsula and the debris of volcanic, sedimentary and metamorphic rocks from the Aleutian Islands.

4.1 Terrigenous materials

It has been found that sediments on the shallow water continental shelf are composed dominantly of terrigenous materials, which contain feldspar, quartz and mica etc. but is depleted of organisms (including microorganism Radiolaria). Most of these materials are products weathered and eroded from the peninsulas in the east of Russia; they are discharged into the sea by rivers and then transported by coastal currents. The analysis of clay mineral further confirmed that most of clay derived from Russia can not reach the Bering Basin and they are trapped on the Bering Sea Shelf, and the fine-grained materials in the basin are derived from the Alaska mainland (Naidu and Mowatt 1983).

Additionally, it was found that there were remains of tillites in the study area, such as at stations of B1 – B12 and B1 – B13. They have common characteristics that these tillites are not equal in size and some of them have abraded indents or holes left during the transportation. The composition of tillite is complex and parts of them were discharged into sea by epicontinental ice, which drifted with currents and deposited after ice melting. Some tillites are detritus of sedimentary, volcanic or metamorphic rocks from the surrounding islands.

4.2 Biognic sediments

Biogenic sediments mean remains and shells reserved in the sediments after living animals and plants died in the water. In the expedition area, analysis of microfossils revealed that calcareous foraminifera and mollusk are distributed mainly in the area from the shallow water shelf to the upper of the continental slope, and many remnants of diatom or Radiolaria occur on the lower section of the continental slope and in the Bering Basin because calcareous fossils will dissolve below CCD.

4.3 Volcanic sediments

There are many active volcanoes in the Aleutian Islands in the south of the Bering Sea. Based on data of stepwise multiple discriminate analysis, there exist evident deplete of kaolinite but enrichment of expandable minerals in the sediments of the Aleutian Trench and the Bering Sea indicating that they are originated from volcanic materials (Naidu *et al.* 1995). The landmasses surrounding the Bering Basin represent three major geologic provinces. The Aleutian Islands in the south are comprised mainly of Cretaceous to recent andesites and basalts (Scholl *et al.* 1970). The kamchatka region is typified by Mesozoic and Cenozoic sedimentary rocks, Neogene ultrabasic rocks, and Quaternary andesite and basalt. The geosynclinal sequences in the Koryak coastal highlands consist of Mesozoic to Cenozoic sedimentary and pyroclastic rock overlying

Proterozoic schist, sandstone and limestone. These rocks have extensive intrusions of andesites, basalts and granitoid (Nalivkin 1960; Zonenshain *et al*. 1990). It is clear that the Bering Sea is influenced by volcanic pyrogenesis in different stages of geologic history, and volcanic sediment is also a main source of materials.

5 Conclusion

(1) The dominant species of Radiolaria fossils in the continental shelf area is *Spongotrochus glacialis* with average content > 50%. And so *Spongotrochus glacialis* can be taken as a characteristic species or representative species.

(2) There are few Radiolaria fossils and monotonous genus and species in the sediments of silt and fine sand. The Radiolaria fossil depletes and diversity is low in the pyroclast and turbidite. The abundance and diversity of Radiolaria fossils are high in the basin clay.

(3) The distribution of Radiolaria fossils is mainly controlled by current, topography, water depth, water temperature etc. in the expedition area of the Bering Sea. The east Kamchatka Current has a great influence on the shallow water shelf; abundance of Radiolaria in the basin is related to the deep currents coming from the North Pacific Ocean.

(4) The material sources of sediments in the area included three types as follows: (a) the terrigenous deposits (including tillite); (b) the biogenic sediments; (c) the volcanic sediments. They mainly come from the Kamchatka Peninsula of the east Russia, the Alaska Peninsula of USA and the Aleutian Archipelago.

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References

Arsenev (1967): Currents and water masses of the Bering Sea (in Russian, English summary). Izd. Nauka, Moscow. (Transl., 1968, Nat. Mar. Fish. Serv., Northwest Fish. Center, Seattle), 135 (as quoted in Takenouti and Ohtani, 1974).

Joseph JM, Jeanne CS (1985): Antarctic Radiolaria in late Winter/early Spring Weddell Sea Waters. Micropaleontology, 31(4): 365 - 371.

Kinder TH, Coachman LK, Galt JA(1975): The Bering Slope current system. J. Phys. Oceanogr., 5: 231 - 244.

Li YF, Zhang QS (1996): Microfossil groups and paleoenvironment significance at core AB-27 in the Barrow of Alaska. Acta Geography Sinica, 51(3): 252 - 259.

Lisitzin AP(1969): Recent sedimentation in the Bering Sea. In: Bezrukov PL, ed. Akademiya Nauk SSSR, Inst. Okeanologii (Transl. Isr. Prog. Sci. Translations. Public., Jerusalem), 614.

Nativkin DV(1960): The Geology of the USSR, A: Short Outline. New York: Pergamon.

Naidu AS, Han MW, Mowatt TC, Wajda W (1995): Clay minerals as indicators of sources of terrigenous sediments, their transportation and deposition: Bering Basin, Russian-Alaskan Arctic. Marine Geology, 127: 87 - 104.

Naidu AS, Mowatt TC (1983): Sources and dispersal patterns of clay minerals in surface sediments from the continental-shelf areas off Alaska. Geol. Soc. Am. Bull., 94: 841 - 854.

Okkonen SR(1993): Circulation variability in the Bering Sea. Ph. D. Thesis, Fairbanks, Univ. Alaska, 126.

Royer TC, Enery WJ(1984): Circulation in the Bering Sea, 1982 - 1983, based on satellit e tracked drifter observation. J. Phys. Oceanogr., 14: 1914 - 1919.

Scholl DW, Buffington EC, Hopkins DM, Alpha TR (1970): The structure and origin of the large submarine canyons of the Bering Sea. Mar. Geol., 8: 187 - 210.

Stabeno PJ, Reed RK(1994): Circulation in the Bering Sea Basin observed by satellite-tracked drifters: 1986 - 1993. J. Phys. Oceanogr., 24: 848 - 854.

Takenouti, Ohtani (1974): Currents and water masses in the Bering Sea: a review of Japanese work. In: Hood DW and Kelley EJ, ed. Oceanography of the Bering Sea. Inst. Marine Sci., Univ. Alaska, Fairbanks, 39 - 58.

Zonnenshain LP, Kuzmin MI, Natapov LM (1990): Koryak-Kamchatka foldbelt. In: Page BM, ed. Geology of the USSR: A Plate-Tectonic synthesis. (Geodynamics Ser., 21.) Am. Geophys. Union, Washington D.C., 149 - 167.